
HANDBOOK OF RESEARCH ON
Social Dimensions of Semantic Technologies and Web Services
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VOLUME I
REFERENCE
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VOLUME II
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Handbook of Research on Social Dimensions of Semantic Technologies and Web Services

Maria Manuela Cruz-Cunha
Polytechnic Institute of Cavado and Ave, Portugal

Eva F. Oliveira
Polytechnic Institute of Cavado and Ave, Portugal

António José V. Tavares
Polytechnic Institute of Cavado and Ave, Portugal

Luis G. Ferreira
Polytechnic Institute of Cavado and Ave, Portugal

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List of Contributors

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The chapter introduces SWAF, the Semantic Web Accessibility Framework, a base framework for supporting the integration of accessibility services into Web design and development processes. SWAF affords both tailoring accessibility to user needs and specifying the semantic validation of accessibility guidelines in different application situations.

The chapter explores a novel approach to the so-called recommender systems, based on reasoning about the semantics of both the users' preferences and considered items, by resorting to less rigid inference mechanisms borrowed from the Semantic Web.

The chapter introduces the Web Accessibility Knowledge Framework for specifying the relevant information about the accessibility of a Web page. This framework leverages Semantic Web technologies, together with audience modeling and accessibility metrics. Through this framework, the authors envision a set of queries that can help harnessing and inferring this kind of knowledge from Web graphs.

The chapter looks at the impact and opportunities of semantic technologies and Web services to business relationships and how social Semantic Web techniques foster e-business and collaborative networks. It formulates a vision based on three stages developing digital business ecosystems. Semantic Web technologies, mainly modeling business partner profiles with ontology, combined with sound techniques of information retrieval and selected concepts and methods of social network analysis build the conceptual framework.

The chapter presents a Semantic Model for Tourism (SeMoT), designed for building Semantic Web enabled applications for the planning and management of touristic itineraries, taking into account the new requirements of more demanding and culturally evolved tourists.

The chapter attempts to characterize the scenario of cross-language information retrieval as a domain, with special attention to the Web as a resource for multilingual research, suggesting also some major directions for cross-language information retrieval research in the future.

The chapter introduces CRISS (Collaborative Route Information Sharing System) which is a collaborative online environment where visually impaired and sighted people will be able to share and manage route descriptions for indoor and outdoor environments and describes the system's route analysis engine module which takes advantage of information extraction techniques to find landmarks in natural language route descriptions written by independent blind navigators.

Section IV
Applications and Current Developments

Preface

Well… today Web is about communication, about meanings, about socialization, let's say, about semantics, and not mere computer connections and in its previous generation.

Almost everything turns around Web and of what relates with Web: we are meaning the development of applications, business processes, governmental initiatives, research, defense, terrorism, and an interminable set of subjects. And this is why one of the main concerns relies clearly on the way all the information, useful or not, updated or not, should be organized on the Web and made available to the user.

The semantic technologies are the most important contribution to the development of the Web, towards a universally recognized medium of exchanging information, with impact on people, organizations and society. It is becoming a rapidly growing area in IT, with emerging key developments, tools, techniques, that are engineering the Web of the future, and determining a new way of acceding, using and exploring information and creating knowledge.

The impact of IT on the society, on organizations of every stripe and on individuals is growing. Today, key challenges of Semantic Web include, besides the technological dimension, the impact on people and on society, which are revealing increased relevance.

A few years ago it would have appeared impossible to think about a global Web of semantically structured information.

Today, the Web is recognized as a main support of business processes. *Business Process Management Technologies* are progressively gaining its space; legacy systems and multiple databases are surviving through important models of data integration; business processes are re adapting to the emerging business paradigms and different enterprises inter-interact either through their interfaces or through functional integration models. The social aspects, recognized as complex, appear as the most recent aspect, where answers are sought in a *new* Web, called social Web.

ORGANIZATION OF THE HANDBOOK OF RESEARCH

This handbook of research is a compilation of 46 contributions to the discussion of the main issues, challenges, opportunities and developments related with this new technology able to transform the way we use information and knowledge, from the social and technological dimensions, in a very comprehensive way, and to disseminate current achievements and practical solutions and applications.

The 46 chapters are written by a group of 130 authors that includes many internationally renowned and experienced authors in the Semantic technologies field and a set of younger authors, showing a promising potential for research and development. Contributions came from 23 different countries: USA, Latin America, several countries of Eastern and Western Europe, South Africa and several countries of

Asia. At the same time, the handbook integrates contributions from academe, research institutions and industry, representing a good and comprehensive representation of the state-of-the-art approaches and developments that address the several dimensions of this fast evolutionary thematic.

It is organized in four sections:

- **Section I -** Semantic Web Components and Enabling Technologies presents the main infrastructures, frameworks, protocols and components that enable or support the Semantic Web.
- **Section II** – Social Semantic Web introduces the social shaping of Semantic Web, its concerns, potential and challenges.
- **Section III** – Challenges, Opportunities, and Impact discusses new trends and new directions, influences and impact that semantic technologies and Web services are offering.
- And finally **Section IV** – Applications and Current Developments presents recent and state-of-the-art applications and exploitations of semantic technologies and Web services to different sectors of activity.

The first section, "Semantic Web Components and Enabling Technologies" includes 16 chapters that are briefly described.

Chapter I, "Semantic Approach to Knowledge Representation and Processing," proposes a technique for knowledge representation and processing based on the semantic approach - hierarchical semantic form - that uses semantic contexts to implicitly define the meaning, facilitating a large scale processing of semantic knowledge represented in natural language documents.

Chapter II, "Challenges on Semantic Web Services," discusses and suggests insights into new solutions to three main challenges in the area of Semantic Web services: composition, discovery and trust. For the first issue, the authors suggest to use program transformation coupled with services' descriptions; for the second, it is proposed a solution based on a mapping algorithm between ontologies; and finally, for the last problem, a solution based on fuzzy voting model is outlined.

Chapter III, "A Service Oriented Ontological Framework for the Semantic Validation of Web Accessibility," introduces SWAF, the Semantic Web Accessibility Framework, a base framework for supporting the integration of accessibility services into Web design and development processes. SWAF affords both tailoring accessibility to user needs and specifying the semantic validation of accessibility guidelines in different application situations.

In **Chapter IV**, "Semantic Web Technologies in the Service of Personalization Tools," the authors explore a novel approach to the so-called recommender systems, based on reasoning about the semantics of both the users' preferences and considered items, by resorting to less rigid inference mechanisms borrowed from the Semantic Web.

"Querying Web Accessibility Knowledge from Web Graphs", **Chapter V**, introduces the Web Accessibility Knowledge Framework for specifying the relevant information about the accessibility of a Web page. This framework leverages Semantic Web technologies, together with audience modeling and accessibility metrics. Through this framework, the authors envision a set of queries that can help harnessing and inferring this kind of knowledge from Web graphs.

In "Ontology Evolution: A Case Study on Semantic Technology in the Media Domain", **Chapter VI**, the authors introduce a general framework for ontology learning from text, that has been applied in the media domain, in particular to video, music and later on to game search to offer an extended user experience in machine-to machine as well as user-machine interaction.

Chapter VII, "Attempting to Model Sense Division for Word Sense Disambiguation," explores the potential of co-occurrence data for word sense disambiguation; the findings on the robustness of the different distribution of co-occurrence data on the assumption that distinct meanings of the same word attract different co-occurrence data, has taken the authors to experiment (i) on possible grouping of word meanings by means of cluster analysis and (ii) on word sense disambiguation using discriminant function analysis.

Chapter VIII, "Association between Web Semantics and Geographical Locations: Evaluate Internet Information Consistency for Marketing Research," introduces a quantitative metric, Perceived Index on Information (PI), to measure the strength of web content over different search engines, different time intervals, and different topics with respect to geographical locations. Visualizing PI in maps provides an instant and low-cost means for word-of-mouth analysis that brings competitive advantages in business marketing.

Chapter IX, "Visualization in Support of Social Networking on the Web," explores the contribution visualization can make to the new interfaces of the Semantic Web in terms of the quality of presentation of content, discussing some of the underlying technologies enabling the Web and the social forces that are driving the further development of user-manipulable interfaces.

Chapter X, "Tracing the Many Translations of a Web-Based IT Artefact," discusses the centrality of meaning in implementing an Internet-based self-service technology, and uses the actor-network theory (ANT) to describe the complex evolution of a Web-based service at a healthcare insurance firm.

Chapter XI, "Semantic Annotation of Objects," compares various knowledge representation techniques, like frame-based formalisms, RDF(s), and description logics based formalisms from the viewpoint of their appropriateness for resource annotations and their ability to automatically support the semantic annotation process through advanced inference services, like error explanations and expressive construct modeling, namely n-ary relations.

Chapter XII, "Web Services Automation," presents a methodology to support the use of automatic composition of complex Semantic Web services with natural language. Web service semantics are linked with natural language processing capabilities to empower users to write descriptions in their own language and in the sequel to have these descriptions mapped automatically into a well tuned Web service orchestra.

Chapter XIII, "Semantic Web Services: Towards an Appropriate Solution to Application Integration," introduces the different techniques to overcome the application integration challenge, discusses the current trends in Semantic Web services and the most recent R&D projects, presents a selection of available tools and discusses the use of ESB as a suitable mechanism to deploy Semantic Web services.

Chapter XIV, "Semantic Visualization to Support Knowledge Discovery in Multi-Relational Service Communities," describes the approach by Fraunhofer IGD and Siemens AG for multi-relational semantic services selection and semantic visualization, and its application in the project "TEXO" Business Webs in the Internet of Services.

Chapter XV, "Knowledge Protocols," presents a knowledge exchange procedure for creating an integrated intelligent manufacturing system able to cope with changing markets that are unpredictable and diverse; knowledge protocols are presented for easing agent based communication and coordination to provide the development of distributed manufacturing applications.

Finally, **Chapter XVI**, "Multi-Agent Systems for Semantic Web Services Composition," reports the major works and results achieved by multi-agent systems and discuss how their exploitation in the area of service-orientation systems could be very promising in different areas.

The second section of this handbook of research, "Social Semantic Web" includes the seven chapters described below.

Chapter XVII, "On the Social Shaping of the Semantic Web," the author addresses the social shaping of the Semantic Web in the context of moving beyond the workplace application domain that has so dominated the development of both information and communications technologies, and the social shaping of technology perspective.

Chapter XVIII, "Social/Human Dimensions of Web Services: Communication Errors and Cultural Aspects: The Case of VRL-KCiP NoE," presents recent studies of the social and human dimension of Semantic Web services in the era of virtual organizations, analysing the risks arising from the modern communication process and discussing the cultural aspects of managing a virtual organization that determine the efficiency of the knowledge management processes. The authors consider the challenges and the associated effect on developing Web services from the social/human perspective and examine the impact on an organization's cultural dimensions.

In **Chapter XIX**, "Socio-Technical Challenges of Semantic Web: A Culturally Exclusive Proposition?," the authors explore how Semantic Web can disseminate learning and identify the causes of critical socio-technical and cultural challenges, looking at two major styles of learning and Semantic Web structure and giving recommendations for addressing these challenges.

Chapter XX, "Social Networks in Information Systems: Tools and Services," analyses state-of-the-art social networks, explaining how useful social network analysis can be in different contexts and how social networks can be represented, extracted, and analyzed in information systems.

Chapter XXI, "The Generative Potential of Appreciative Inquiry as an Essential Social Dimension of the Semantic Web," presents a framework of ideas concerning the expected form of knowledge sharing over the Semantic Web. Of specific interest is the perspective of appreciative inquiry, which should accommodate the creation of some appreciative knowledge environments based on the peculiar organizational concerns that would encourage or better institutionalize knowledge work among people in an organization.

In **Chapter XXII**, "Online Virtual Communities as a New Form of Social Relations: Elements for the Analysis," the authors analyze the meaning of concepts such as *virtual community*, *cyber culture*, or *contacted individualism*, as well as the meaning and extent of some of the new social and individual behaviors which are maintained in the Net society as a consequence of the new communication technologies scope.

Finally, **Chapter XXIII**, "E-Learning and Solidarity: The Power of Forums," explores solidarity as a social dimension in the context of e-learning and the Semantic Web, based on a study in higher education to identify where the students show more solidarity with each other - in online learning environments or in offline settings.

The third section, "Challenges, Opportunities and Impact," contains the following twelve chapters.

In **Chapter XXIV**, "Applying an Organizational Uncertainty Principle: Semantic Web-Based Metrics," The authors review the traditional theory of the interaction, organizational theory, and the justification for an organizational uncertainty principle. The organizational uncertainty principle predicts counterintuitive effects that can be exploited with the Semantic Web to formulate a set of metrics for organizational performance, which are applied in two case studies.

Chapter XXV, "Security in Semantic Interoperation," investigates the currently used security methods in semantic interoperation, including the security methods employing Semantic Web representation languages such as XML, RDF and ontologies, and their application methods in semantic interoperation such as secure access control and secure knowledge management. It also discusses how to manage privacy, trust and reputation at the same time during semantic interoperation.

Chapter XXVI, "Semantic Discovery of Services in Democratized Grids," presents the motivation and the technologies developed towards a semantic information system in the Grid4All environment, emphasizing on bridging the gap between Semantic Web and conventional Web service technologies, supporting developers and ordinary users to perform resources' and services' manipulation tasks, towards a democratized Grid.

Chapter XXVII, "Semantic Web and Adaptivity: Towards a New Model," proposes a model that gives an abstraction to the functionalities and data involved in adaptive applications for the Semantic Web. As the quantity of provided information on the Web is getting larger, the need for adaptation in software is getting more and more necessary in order to maximize the productivity of individuals. With the Semantic Web, adaptation can be performed autonomously and in runtime, making the whole process transparent to the user.

Chapter XXVIII, "Semantic Technologies and Web Services: A Primer on Legal Issues," aims at offering an overview of the legal framework that supports people's access to Web services, according to the Semantic Web innovations. The basic aspects examined include: delegation, liability, privacy and e-identity, with a special focus on e-business.

Chapter XXIX, "The Influences and Impacts of Societal Factors on the Adoption of Web Services," explores influences and impacts of societal factors on the adoption of Web service technology. Societal factors considered in the study are culture, social structure, geography, ethics, and trust. Common themes identified across these factors are need for mechanisms to support globalization management, to monitor and assess trustworthiness, and relationship management.

Chapter XXX, "The Geospatial Semantic Web: What are its Implications for Geospatial Information Users?," provides a basic understanding of the needs and visions driving the evolution toward the Semantic Web and Geospatial Semantic Web (GSW), the principles and technologies involved in their implementation, the impacts of the GSW on the way we use the Web to discover, evaluate, and integrate geospatial data and services; and the needs for future research and development to make the GSW a reality.

Chapter XXXI, "Enabling Distributed Cognitive Collaborations on the Semantic Web," illustrates and discusses an alternative approach to the development of the agent mediated Semantic Web, based on the premise that enhancing agents cognitive and interactional abilities is the key to make the digital world of agents more flexible and adaptive in its role to facilitate distributed collaboration.

Chapter XXXII, "Social Impact of Collaborative Services to Maintain Electronic Business Relationships," looks at the impact and opportunities of semantic technologies and Web services to business relationships and how social Semantic Web techniques foster e-business and collaborative networks. It formulates a vision based on three stages developing digital business ecosystems. Semantic Web technologies, mainly modeling business partner profiles with ontology, combined with sound techniques of information retrieval and selected concepts and methods of social network analysis build the conceptual framework.

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And the fourth and last section, "Applications and Current Developments," contains eleven chapters.

Chapter XXXVI, "Modeling Objects of Industrial Applications," presents the development and design of an industrial application based on new semantic technologies and explores the technological dimension of data acquisition, storing, access, and use; the data structure and integration and aggregating values from data necessary for the control of production processes.

In **chapter XXXVII**, "The Impacts of Semantic Technologies on Industrial Systems," the authors review the state of the art of the research of ontologies, Semantic Web, and Semantic Web services, together with advances on the usage of semantic technologies in industry. The usage of semantic technologies is illustrated with two applications – semantics in multi-agent manufacturing systems and structural search in industrial data.

Chapter XXXVIII, "Towards Process Mediation in Semantic Service Oriented Architecture (SSOA)," focuses on the public process heterogeneity which describes the behavior of the participants during a conversation, and proposes a solution for dealing with it, explaining the functionality of the process mediator developed as a part of the Web service execution environment and its mediation scenario. This proposed solution is applied on federated enterprise resource planning systems to get the semantic extension from it.

Chapter XXXIX, "Social Networks Applied to E-Gov: An Architecture for Semantic Services", proposes a software architecture, using a social network to map the relationships and interactions between citizens, accounting and storing this knowledge in a government ontological metadata network. It introduces a prototype to manage and handle e-gov-driven social networks, capable of providing graphical display of social networks, enabling the identification of different social links between citizens, creating a tool for government agencies.

Chapter XL, "Ontologies and Law: A Practical Case of the Creation of Ontology for Copyright Law Domain," introduces the specificity of the development of a particular type of legal ontology, that is ontology of copyright law, the ALIS IP ontology, that should be seen as a miniature guide for anyone who will pursue a goal to create an ontology for any sphere of law.

Chapter XLI, "Technology Roadmap for Living Labs," evaluates available ICT for use in a living lab and presents an implementation roadmap taking into account state-of-the-art technology and likely future trends.

Chapter XLII, "Technologies to Support the Market of Resources as an Infrastructure for Agile/Virtual Enterprise Integration," proposes an architecture to support the operation of the market of resources - an environment developed by the authors to cope with the requirements of agile/virtual enterprise integration-, representing a fusion of the peer-to-peer architecture with the client-server architecture, as a variant of P2P architecture.

Chapter XLIII, "KC-PLM: Knowledge Collaborative Product Lifecycle Management," defines a system and a methodology, the knowledge collaborative product lifecycle management (KC-PLM), to better support the complete product lifecycle in the industry, that intends to reduce the lead-time from new product development to production by providing and integrating knowledge platform, based on a semantic information repository, domain ontology, a domain specific language and on the user collaboration.

Chapter XLIV, "PolyOrBAC: An Access Control Model for Inter-Organizational Web Services," proposes a new access control framework for inter-organizational web Services: "PolyOrBAC", extending OrBAC (Organization-Based Access Control Model) to specify rules for intra- as well as inter-organization access control and enforcing these rules by applying access control mechanisms dedicated to Web services; it is also proposes a runtime model checker for the interactions between collaborating organizations, to verify their compliance with previously signed contracts.

Chapter XLV, "Development and Implementation of E-Government Services in Turkey: Towards a More Citizen-Oriented Public Administration System," focuses on e-government applications highlighted to reach a more citizen centric e-government in Turkey, giving particular relevance to two concepts of e-government, content management system and measuring citizens' satisfaction from e-services.

In **Chapter XLVI**, "Technical Outline of a W3 Spatial (Decision Support) Prototype," the authors propose the technical outline of a WWW spatial prototype, SAKWeb©, an Internet application of spatial analysis for geographical information systems users and decision support and discuss future trends for this application.

EXPECTATIONS

The book provides researchers, scholars, and professionals with some of the most advanced research developments, solutions and implementations of Semantic Web. It is expected to provide a better understanding of semantic technologies and Web services developments, applications, trends and solutions. This way, is expected to be read by academics (i.e., teachers, researchers and students), technology solutions developers, and enterprise managers (including top level managers). The book is also expected to help and support teachers of several graduate and postgraduate courses of information technology.

Maria Manuela Cruz-Cunha
Eva Ferreira Oliveira
António José Tavares
Luís Gonzaga Martins Ferreira
Editors
Barcelos, January 2009

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Editing a handbook is a quite hard but compensating and enriching task, as it involves an array of different activities like contacts with authors and reviewers, exchange of ideas and experiences, process management, organization and integration of contents, and many other, with the permanent objective of creating a book that meets the public expectations. And this task cannot be accomplished without a great help and support from many sources. The authors would like to acknowledge the help, support and believe of all who made possible this creation.

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We are also grateful to all who accede to contribute to this book, some of them with high quality chapter proposals, but unfortunately, due to several constraints could not have seen their work published.

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Thank you.

The Editors,

Maria Manuela Cruz-Cunha
Eva Ferreira Oliveira
António José Tavares
Luís Gonzaga Martins Ferreira
Barcelos, January 2009

Section I
Semantic Web Components and Enabling Technologies

Chapter I
Semantic Approach to Knowledge Representation and Processing

Mladen Stanojević
The Mihailo Pupin Institute, Belgrade, Serbia

Sanja Vraneš
The Mihailo Pupin Institute, Belgrade, Serbia

ABSTRACT

In this chapter, several knowledge representation and processing techniques based on a symbolic and semantic approach are briefly described. The majority of present-day techniques, like the relational database model or OWL (Web Ontology Language), is based on the symbolic approach and supports the representation and processing of semantically related knowledge. Although these two techniques have found many successful applications, there are certain limitations in their wider use, stemming from the use of naming in explicit description of the meaning of the represented knowledge. To overcome these limitations, the authors propose a technique based on the semantic approach, Hierarchical Semantic Form (HSF), that uses semantic contexts to implicitly define the meaning. This chapter first provides concise information about the two most popular techniques and their limitations, and then proposes a new technique based on semantic approach, which facilitates a large scale processing of semantic knowledge represented in natural language documents.

INTRODUCTION

Seven years have passed since the idea of Semantic Web was introduced. In the meantime, many ontology and schema languages have been proposed and many Semantic Web and other processing techniques have been introduced, which provide a functionality needed for semantic knowledge representation and processing. Despite all that, a very moderate progress has been recorded in the past period regarding the number of practical applications of these techniques. Truly, these techniques provide the required capacity, but the development of Semantic Web applications is still very expensive, because skilful ontology designers are required to describe the domain and programmers are needed to interpret these descriptions and implement the application at hand.

Although the existing semantic knowledge representation techniques enable the representation of semantic knowledge, they are, in their essence, based on the symbolic approach to knowledge representation. The symbolic approach was introduced with the advent of the first high level programming languages, where symbols (variables), described by their names and values, were used in various calculations to produce the desired results. To facilitate the representation of semantically related information, symbols became more complex, enabling the representation of structure either internally (tables-fields, classes-attributes) or externally (using different relationships). However, the essence of the symbolic approach is preserved, because the names (of tables, fields, relationships, classes, objects, attributes, etc.) are used to define their meaning. Due to the increased complexity, the role of a programmer in symbolic programming has been twofold: the role of an ontology designer responsible for describing the application domain and the role of an application programmer in charge for the processing of the represented knowledge.

Computers are not able to automatically provide domain descriptions, or to interpret automatically the represented knowledge, so the role of highly specialized human experts that will perform these jobs in developing semantic knowledge processing applications is inevitable. As a consequence, the development of such applications is more expensive than in case of symbolic applications, which prevents their use on a large scale. Another consequence of the application of the symbolic approach to semantic knowledge representation is that representational ability of the corresponding knowledge representation techniques is both defined and limited by their design, i.e., these techniques are domain dependent. Each extension of the application domain or merging the knowledge from different domains or even the same domain requires substantial and non-trivial redesigning of the existing ontologies.

Since the symbolic approach to semantic knowledge representation creates the problems mentioned above, the question is - what would be the requirements for the pure semantic approach to knowledge representation that would overcome the spotted problems? The minimum requirements would include the ability to represent the concepts and relationship between these concepts. In the framework of natural language texts, concepts at the lowest level of hierarchy would be letters, at one level higher –syllables, then words, phrases, sentences, paragraphs etc. The relationships between letters are described by the contexts representing syllables, the relationships between syllables – by the context defined by words and so on. The basic semantic knowledge requirements could be defined in terms of two principles: a principle of unique representation and a principle of locality. The principle of unique representation states that all concepts at different levels of hierarchy must be uniquely represented within all contexts they may appear in. The principle of locality states that contexts at different levels of hierarchy are composed of the concepts of the corresponding complexity. The letters are of the atomic nature, while other concepts have a complex structure comprised of sequences of concepts with lower complexity, i.e., syllables are composed of letters, words are composed of syllables, phrases are composed of words etc.

The semantic knowledge representation technique presented in this paper enables automatic translation of texts into a structured form and vice versa, with no loss of information, and with automatic extraction and representation of all concepts and relationships between them. Since knowledge is represented in a structured form, it is readable for computers and also for humans, because it can be translated back to a natural language text, with no loss of information. No naming is used to describe the meaning of the represented knowledge, so no designing process is required. This way, all the limitations of the symbolic approach are overcome: knowledge representation is not domain dependent, because any text (independent of domain) can be automatically represented in a structured form, highly specialized experts will be no longer needed, which will substantially decrease the costs and increase the extendibility of the represented knowledge.

The understanding capability of the new semantic knowledge processing technique is provided using the background knowledge. This knowledge consists of simple and complex semantic categories and patterns. Semantic categories generalize a set of semantic concepts at different levels of hierarchy (words, phrases, sentences, etc.), which have a similar meaning in defined semantic context. Patterns consist of semantic concepts defined by semantic categories and are used to interpret the meaning of commands, questions, answers, etc. Both patterns and semantic categories are expressed in a natural language using examples.

KNOWLEDGE REPRESENTATION AND PROCESSING

Unrelated information is not of much use in any productive application. To be useful, data must be interrelated in a way that is comprehensible to a human user and if data are connected in such a way, they comprise semantically related knowledge.

Human beings are no longer able to process a vast quantity of available data without the help of computers. In an attempt to provide such help, researchers encounter many problems related to knowledge representation (Sowa, 2000), information retrieval (Croft, 2003), data mining (Hand, Manilla, 2001), knowledge management (Liebowitz, 2001), intelligent Web search (Cercone, 2001), Natural Language Processing (Jurafsky & Martin, 2000), machine translation (Hutchins, 1992), etc. However, all of them are related to the problem of determining the meaning of the represented knowledge. Any data processing application that gives a satisfactory answer to a user's request provides some kind of understanding of both represented data and user's request.

There are two possible approaches to determine the meaning of semantically related knowledge - symbolic and semantic. Symbolic techniques, representing the main stream, are successfully applied in many applications to represent semantically related knowledge and include a wide variety of classical (e.g. relational (Date, 2005) and object-oriented (Russel, 2000) databases), AI (Sowa, 2000; Vraneš, 1994) (e.g. logic formalism, semantic nets, conceptual dependencies, frames, scripts, rules, etc.), Semantic Web (Fensel, 2003) (e.g. XOL (Karp, 2005), SHOE (Heflin, 1999), OML (Kent, 2005), RDFS (Brickley, 2005), DAML+OIL (McGuinness, 2002), OWL (McGuinness, 2005)) and distributed approach in connectionist model. These techniques assume that the meaning of knowledge can be described independently and separately from the knowledge itself. They try to represent the meaning explicitly by naming or tagging the representational vehicles. In applications using symbolic techniques, a database (knowledge base, ontology) designer provides the understanding of represented data, while a programmer provides the understanding of user's requests.

On the other side are radical connectionists (O'Brian, 2002), which claim that a natural language (naming) is not used as representational, but rather as communicational medium. In semantic techniques, the meaning is implicitly determined by semantic contexts and matching the parts of these semantic contexts with semantic categories and complex patterns. The localist approach of connectionist model (Hinton, 1990) could be used to implement the ideas of radical connectionism. One implementation of a pure semantic approach to knowledge representation is represented by Hierarchical Temporal Memory (HTM) (Hawkins, 2007), while another solution (Kharlamov, 2004) relies on the Hopfield-like neural networks. In the applications based on semantic techniques, the understanding of represented data and user's requests is not borrowed from database (knowledge base, ontology) designers and programmers, but represents an intrinsic capability of the application provided by the corresponding algorithm, which is used to interpret the meaning of the represented knowledge.

What are the main consequences of the two approaches? The supporters of connectionism claim that symbolic techniques cannot be used for a large-scale, real world modeling. When naming (tagging) is used to define the meaning of representation vehicles, these vehicles inevitably must be specific. The modeling of domain specific knowledge requires a design effort of a highly specialized expert (database or ontology designer), that will identify and name all relevant objects and relations between these objects. These objects and the corresponding relations must be named in advance, hence the developed representational vehicles are limited to represent only these objects and relations. Any extension or merging of existing ontologies (databases, knowledge bases) requires a considerable redesigning effort, which limits their representational capability. The capacity of all techniques based on the symbolic approach to represent semantically related information is both determined and limited by their design.

On the other hand, in the semantic approach the representational vehicles (nodes, units) do not have any predefined meaning, whereby these nodes get the meaning in their matching with semantic categories and complex patterns. The capacity of techniques based on the semantic approach to represent semantically related knowledge is based on learning (not designing), hence they do not post any representational restrictions.

All existing knowledge representation and processing techniques based on symbolic approach are domain-dependent. They define the meaning of represented knowledge by describing the domain of an application. The representational ability of these techniques are both defined and limited by these domain descriptions. The problem with these techniques is that only highly specialized human experts are able to provide these descriptions and to interpret them. Therefore, the development of semantic knowledge representation and processing applications is very expensive, which inevitably severely limits the number of practical application of these techniques. Two other consequences of the symbolic approach to knowledge representation and processing are that it is hard to extend the existing database (knowledge base, ontology) or to merge databases (knowledge bases, ontologies) from different domains of an application.

The situation reminds on the early days of Internet when only highly specialized experts were able to use HTML and design Web pages. The exponential growth of Internet became possible only after the advent of graphical tools for Web page designing, which have hidden the complexities of HTML syntax and enabled a large number of non-experts to design Web pages. However, the problem of using knowledge representation and processing techniques is not related so much to the complexity of syntax (there are already many environments that are hiding these complexities), but rather to the complexity of semantics regarding the representation and processing of semantically related knowledge. The introduction of knowledge representation and processing techniques based on the semantic approach will allow an inclusion of a large number of non-experts therefore facilitating r the use of semantic knowledge on a large scale.

To enable the computer processing of knowledge, information must be represented in structured form. Knowledge representation techniques based on the symbolic approach are not able to translate the knowledge in a plain text form into a structured form without some loss of information. Furthermore, this process cannot be done automatically, hence a substantial expert effort is needed. As a consequence, huge quantities of data represented in a natural language in Web pages and other electronic documents cannot be processed by computers.

To facilitate processing of relevant information contained in natural language documents, information retrieval techniques are used. These techniques use a natural language and knowledge representation techniques to extract relevant information from a natural language document and represent it in a structured form. However, being based on the symbolic approach, they are domain-dependent and very expensive to develop, which limits their practical use.

On the other hand, knowledge representation techniques based on the semantic approach enable an automatic translation of plain texts into a structured form and vice versa with no loss of information. This will facilitate knowledge processing of natural language documents on a large scale and decrease the demand for the information retrieval techniques.

In the field of a natural language understanding, all the existing techniques are based on the symbolic approach. The consequences are similar as in the case of knowledge representation. The applications are domain-limited, very expensive to develop, which hinders a faster take up of these techniques.

The understanding capability of knowledge processing techniques based on the semantic approach is facilitated by the use of background knowledge expressed in a natural language. This background knowledge consists of simple and complex semantic categories and examples, which can be fed to the system in a similar way the children are learning the language. Since semantic categories and examples are defined in a natural language, many non-experts may be involved in providing background knowledge from several domains, thus making the development much cheaper and therefore more feasible. Furthermore, the collected background knowledge can be easily extended or merged with some other background knowledge.

The understanding ability of knowledge processing techniques based on the semantic approach will enable the development of a new class of user interfaces suitable for mobile phones, PDAs and other applications where voice interfaces are preferred.

Moreover, searching Web pages and text documents using various search engines is a very useful feature, although it may be sometimes a frustrating experience. Standard search engines accept the Boolean combinations of keywords and try to find the text documents (Web pages) that contain the pattern. One of the main objectives of the Semantic Web initiative was to provide semantically-based search in contrast to the keywords search provided by the standard search techniques. Semantically-based search in Semantic Web remains limited to only specialization-generalization semantic relations, which represent the backbone of the taxonomies of concepts and terms. In its essence, semantically-based search in Semantic Web is a keywords search enhanced by the filtering power of the underlying ontologies of concepts and terms. However, apart from using specialization-generalization relations, there are numerous other ways how data can be semantically related.

In knowledge representation techniques based on the semantic approach, not only specialization-generalization relations are represented but all types of relationships that can be found in a natural language text. Unlike a standard search engine that implicitly assumes that the search context is at the document level, semantic knowledge processing techniques can define the search context more precisely using semantic contexts, which results in more precise answers.

As search engines are used to search through the unstructured data, question answering systems are used to find the needed information, which is represented in a structured way. If questions are posted in a natural language, then these systems include a natural language understanding technique, query language (e.g. SQL) and the corresponding knowledge representation technique. If these techniques are symbolic-based, we will again meet the known problems: these systems are domain-limited, they are hard to extend and expensive to develop.

Question answering based on the semantic approach remains domain-limited, but the domain extension or merge of domains will be performed easily. Since no designing is required, the development of question answering systems should be relatively cheap and should result in more intelligent Web search, where a user will able to post a natural language query and get a precise answer also in a natural language found on the Web.

In this paper we are proposing the Hierarchical Semantic Form (HSF) and Space Of Universal Links (SOUL) algorithm as the implementation of semantic approach to knowledge representation and processing. HSF resembles the localist approach, where each node uniquely describes the meaning depending on its semantic context. However, HSF overcomes the limitation of the localist approach expressed in the inability to represent the structure (Fodor, 1988) and the context of the node.

The Space Of Universal Links (SOUL) algorithm (Stanojević, 2007) is used to create and maintain HSF, but also to interpret the meaning of the knowledge represented by HSF. The applicability of HSF with SOUL was tested on an example of Semantic Web service prototype (Stanojević, 2005) that provides information about flights from flight timetables defined in a natural language within an ordinary HTML file using natural language queries.

However, HSF represented in (Stanojević, 2007) was a hybrid solution where semantically related knowledge was represented using a semantic approach, while semantic categories were represented using a symbolic approach (naming). In this paper HSF is modified so that both semantically related knowledge and semantic categories are represented using a semantic approach. Modified HSF represents a kind of recurrent neural network (Mandic, 2001), with no fixed topology, where, like in cascading neural networks (Hoehfeld, 1992), new nodes can be added to the network.

Although HSF may look like yet another connectionist approach, there are some important differences. First, in the connectionist approach only one type of nodes is used, while in HSF, four types are used. Second, nodes in connectionist approach can be either in active or inactive state, while in HSF they can be in one of four different states. Third, the output value(s) of nodes in connectionist approach are defined by its inputs and the corresponding transformational function, while in HSF they are dependent on inputs, current state of the node and transitional table representing several transformational functions. Fourth, all outputs of a node are the same in connectionist approach, while in HSF they can be different. Sixth, the outputs in connectionist approach usually take values from the continuous space, while the outputs in HSF can be in one of seven discrete states. Seventh, learning in connectionist approach are usually based on some kind of cost functions and gradient descent, while in SOUL we use learning by repetition to define the context and learning by generalization and by specialization in the interpretation of meaning.

To illustrate the representational abilities of the main stream, symbolic techniques such as relational databases and ontology languages (OWL) and the retrieval abilities of the corresponding query languages on one side, and HSF with SOUL as a representative of semantic approach on the other side, we will use a very simple, but illustrative example.

SYMBOLIC TECHNIQUES

Relational Database Model

A relational database model is the most popular technique for the representation of semantic knowledge. There are several reasons for this popularity:

- A simple and comprehensive data model.
- Efficient knowledge representation supported by the use of primary and foreign keys and by database normalization, which ensures the unique representation of data.
- Use of SQL for retrieving the semantically related information, which is easy to learn and use.
- Use of indexes to speed up the information retrieval.

To be able to represent the needed data we have designed a relational database (Figure 1). We have defined three tables: Student, Car and StudentCar. The table Student contains two fields StudentID and Name corresponding to primary key of the table and student's name. The table Car contains primary key CarID, the plate number of the car (PlateNo) and the color of the car (Color). The table StudentCar represents the relation between students and their cars, where StudentID is a foreign key from Student table and CarID is a foreign key from Car table.

To speed-up search in case we want to find out the color of the car knowing the name of the student, we could define three indexes: NameIndex on the field Name from Student table, and StudentIDIndex and CarIDIndex from the StudentCar table, supposing that indexes are automatically created for all primary keys.

To student cars database the following records can be added (Tables 1, 2, 3).

These records describe the facts that John has a red car, with license plate number "123 ABC", and a green car, with plate number "456 DEF", and that Bill has a black car, with license plate number "789 GHI".

The design process in this simple example is comprised of naming the tables and the corresponding fields, determining data types, pri-

Figure 1. Student cars database

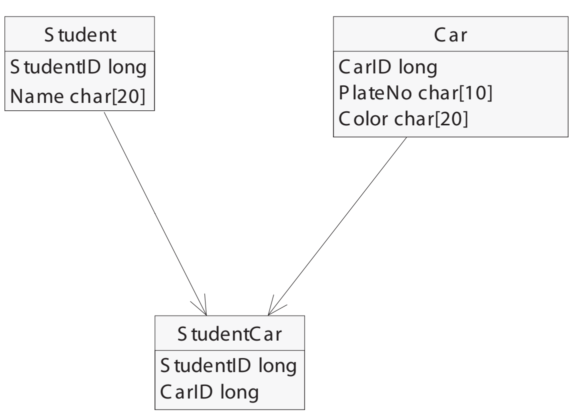


Table 1. Records added to Student table

StudentID	Name
1	John
2	Bill

Table 2. Records added to Car table

CarID	PlateNo	Color
1	123 ABC	red
2	456 DEF	green
3	789 GHI	black

Table 3. Records added to StudentCar table

StudentID	CarID
1	1
1	2
2	3

mary and foreign keys and defining all necessary indexes. Furthermore, in a real-life database design, normalization theory must be applied to avoid undesirable update anomalies. Notice that this small database can be used only to represent the restricted information related to students and their cars and if we want to represent some other data, for instance, a list of exams John and Bill have passed, then this simple database must be redesigned by adding new tables, new fields and new primary and foreign keys.

If we, for example, want to find the color of John's cars, we have to specify an SQL query like:

```
SELECT PlateNo, Color
FROM Student, Car, StudentCar
WHERE Name = 'John' AND Student.StudentID
     = StudentCar.StudentID AND Car.CarID =
     StudentCar.CarID;
```

and after executing this query we will get the results presented in Table 4.

So, if we want to extract some information from a relational database, we must know how to use SQL or some equivalent query design tool and must be familiar with the design of the corresponding database.

OWL: Web Ontology Language

Many ontology and schema languages are used in Semantic Web, OWL being one of the most popular. To illustrate the application of OWL on our simple example, we have used Protégé 3.2 beta (Protégé, 2006). OWL employs classes and individuals to implement object hierarchies and their instances and object properties to represent relationships.

Table 4. Results of the query

PlateNo	Color
123 ABC	red
456 DEF	green

On the top of OWL hierarchy is the Thing class from which all other classes are derived. For the purpose of our example we have defined two classes: Student and Car (Figure 2).

The Student class contains a datatype property name and object property hasCar describing the relationship between a student and his/her car. The Car class has two datatype properties plateNo and color, and one object property, possessedBy, representing the inverse of the hasCar relationship.

We have also defined two instances of the Student class, and three instances of the Car class.

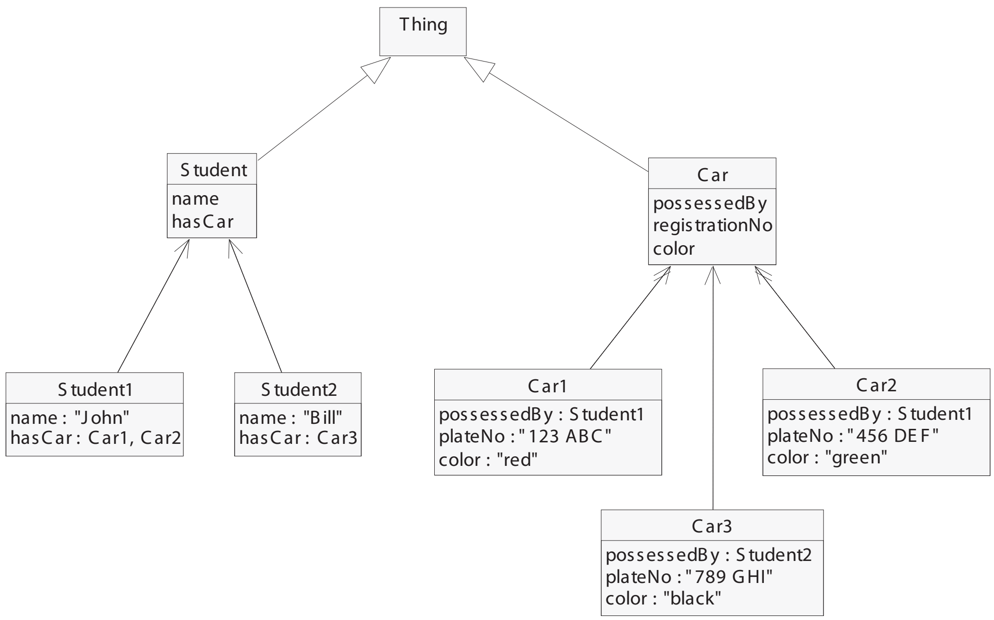
As in the relational database approach to the problem of semantic knowledge representation, naming is also used in ontology languages to give the meaning to classes, instances, properties and relationships. The consequence is the same: an ontology designer must define ontology by extracting semantic information, i.e., classes, instances, properties and relationships from the domain needed in the implementation of a Semantic Web application. To be able to represent additional semantic information the ontology has to be redesigned.

Protégé 3.2 beta supports a dialect of SPARQL query language, which enables retrieval of semantically related information. The following SPARQL query could be used to find the license plate numbers and colors of John's cars:

```
SELECT ?plateNo ?color
WHERE {?student:name ?name .
     ?student:hasCar ?car .
     ?car: plateNo ?plateNo .
     ?car.color ?color .
     FILTER(?name = "John") }
```

The retrieval of semantically related information represented in some ontology language requires the use of specialized query language and understanding of the ontology design.

Figure 2. OWL classes and instances



The advantage of OWL (and other ontology languages) compared to relational databases lies in more comprehensible knowledge representation. However, unlike ontology languages, relational databases provide not only the representational formalism, but also the implementation guidelines, which guarantee for both representational and search efficiency.

SEMANTIC APPROACH TO KNOWLEDGE REPRESENTATION AND PROCESSING

Hierarchical Semantic Form

The Hierarchical Semantic Form (HSF), that we propose here, can be used to represent various kinds of syntax and semantic categories as well as relationships between these categories. The automatic extraction of semantic categories and relations between them is provided by the SOUL (Space Of Universal Links) algorithm, which gives support to the Hierarchical Semantic Form. HSF uses two types of nodes, *groups* and *links*, to build the hierarchy of categories.

Patterns appearing in a natural language sentences are in their essence sequences. Patterns at the lowest level of hierarchy are characters, syllables are sequences of characters, words are sequences of syllables, groups of words are sequences of words, semantic categories are sequences of words and other semantic categories, while complex semantic categories and patterns are sequences of semantic categories. Except at the lowest level of hierarchy, complex patterns represent sequences of simpler patterns.

The group node designates characters, a group of characters, words, a group of words, sentences, etc. Except at the lowest level, where groups represent single characters, this data abstraction is used to represent sequences at different levels of hierarchy (a group points to the first link of a sequence). One group can appear in different contexts, so it can have many associated links (for each context – one link). In this way, a unique representation of a category is provided.

The link node enables the creation of sequences at different hierarchy levels (sequences of characters, words, group of words, sentences, etc.). The main role of links is to represent categories (groups) in different contexts. For each new context where category appears, we need a new link. A link points to a group it represents within the sequence, but also to a predecessing link and all successive links (defining the context of the category). If a link is the last in the sequence of links, instead to successive links it points to a group that represents this sequence.

SOUL Algorithm

Space Of Universal Links (SOUL) algorithm is capable of learning new patterns, new semantic categories and their instances. When we feed plain text to it, SOUL algorithm performs the partial matching using the existing patterns and semantic categories defined in HSF, discovers old patterns in a new text, creates new patterns (if there are any), performs the matching of existing semantic categories and finally creates a HSF representation of a new text consisting of old and new patterns and semantic categories. Unlike other connectionist solutions, which can learn a structure when structures are fed to them, HSF and SOUL algorithm support the unsupervised learning of structures from plain text.

The unique representation of patterns and semantic categories gives rise to the learning capability of SOUL algorithm. SOUL acts as a bottom-up parser, which performs the partial matching able to locate the existing patterns, and discover new patterns if there is a sequence of existing patterns that matches a part of new text.

There are three possible cases when new patterns can be discovered: at the beginning of a sequence, in the middle of a sequence, and at the end of a sequence. When SOUL algorithm discovers a new pattern, a new group, that will uniquely represent this pattern, is created as well as two new links representing this new pattern within two separate contexts. This way SOUL supports a unique pattern representation in all contexts.

Knowledge Representation

The abilities of HSF with SOUL to represent semantically related information will be illustrated using the same simple example of students and their cars, which has been already used for the relational database model and OWL ontology language.

The following statements will be used to describe the semantically related information needed for the example:

1. “John has a car plate number 123 ABC”
2. “John has a car plate number 456 DEF”
3. “Bill has a car plate number 789 GHI”
4. “The color of the car plate number 123 ABC is red”
5. “The color of the car plate number 456 DEF is green”
6. “The color of the car plate number 789 GHI is black”

The representation of these statements in HSF does not require any designing, and is based on learning abilities of the SOUL algorithm. The learning process begins with single words learning. For instance, when we feed words “John”, “has”, “car”, “plate”, “number”, “123ABC”, SOUL will create a HSF representation like the one presented in Figure 3.

If we then enter the whole first statement, SOUL will link single words to represent this statement. When we enter the second statement, SOUL will recognize that the sequence of words “John”, “has”, “a”, “car”, “plate”, “number” repeats and creates a new group (7) that represents this sequence. As we add other statements, SOUL will recognize some new repeated sequences and create new groups for them: “has a car plate number” (8), “car plate number” (9), “the color of

Figure 3. Representation of single words in HSF

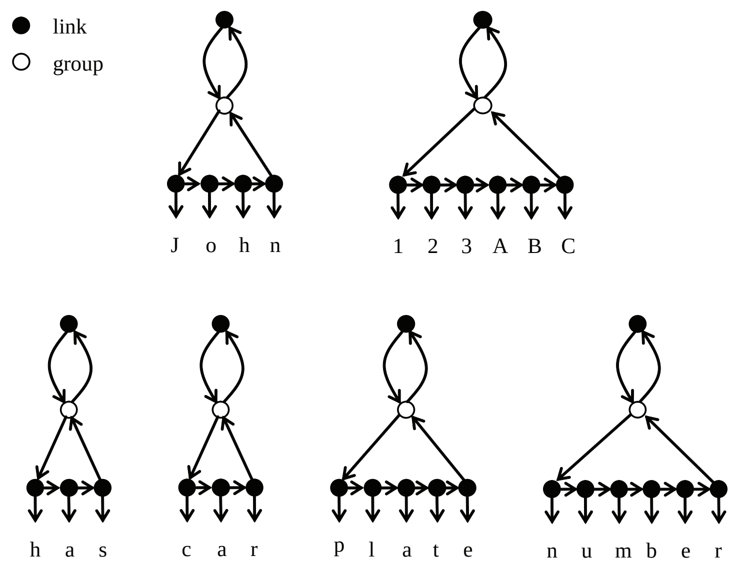
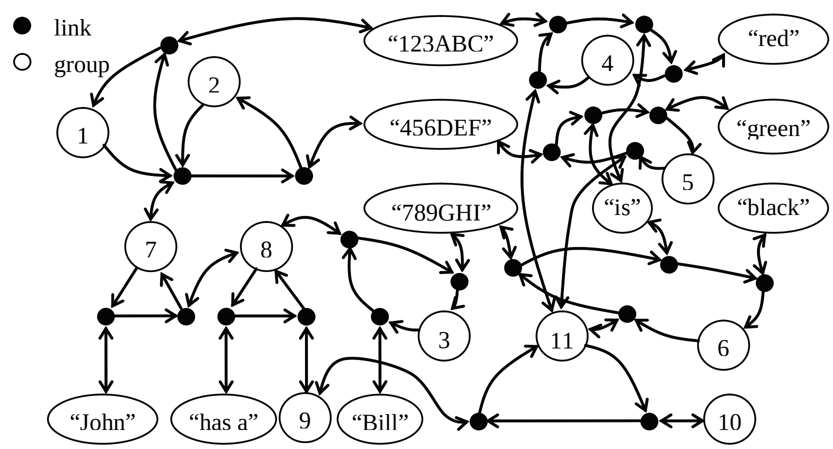


Figure 4. HSF representation of six statements



the" (10), "the color of the car plate number" (11). The final HSF representation of all six statements is presented in Figure 4.

Notice that repeated sequences at all levels of hierarchy (representing words, phrases or statements, Figure 4) are uniquely described by the corresponding groups. In different contexts the same group is represented using separate links (one link for each context in which this group appears). Links describe semantic relationships between groups at the same hierarchical level.

Semantic Categories

The understanding in HSF with SOUL is provided using basic and complex semantic categories. Basic semantic categories represent generalizations of language structures, while complex semantic categories are comprised of basic semantic categories and other complex semantic categories. Semantic categories and patterns constitute the background knowledge, i.e. knowledge about real world, which is not defined in symbolic knowledge representation techniques, and which is provided by a database (knowledge base, ontology) designer. This type of knowledge can be obtained by learning by generalization and learning by specialization.

To provide the understanding functionality, groups in HSF are divided on specific groups (Figure 5.a) corresponding to language structures (words, phrases, sentences, etc) and generic groups (Figure 5.b) representing semantic categories. Specific groups can be permanently linked using specific links with the corresponding generic groups, while generic groups are permanently linked with constituting and encompassing semantic categories and patterns and temporarily linked with the corresponding specific links (Figure 5).

Semantic categories are defined through learning by generalization. Suppose that we have fed the statement to SOUL algorithm:

13. “John is a student”

If we then enter the statement:

14. “Bill is a student”

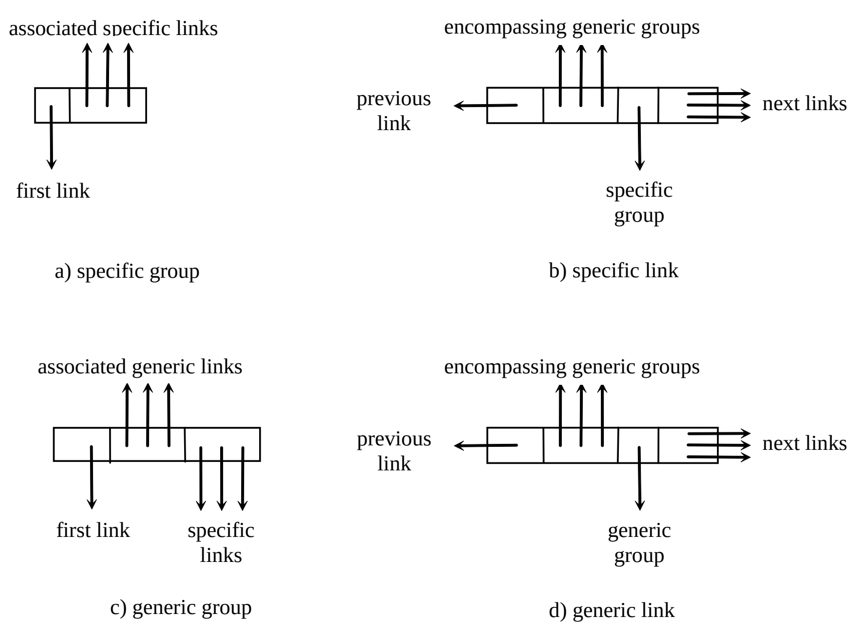
SOUL will discover that groups corresponding to John and Bill appear in the same context and will generalize them by creating a generic group (15) representing <student> semantic category (Figure 6). Although we named the generic group as <student> semantic category, actually no meaning (name) is attached to this group.

Learning by specialization will be illustrated on an example of feeding the statement:

16. “Tom is a student”

SOUL will discover that the group “Tom” appears at the same place in the same context as the groups “John” and “Bill” and since the <student> semantic category (15) is already defined, it will assume that the group “Tom” represents a specialization of this semantic category.

Figure 5. Specific and generic groups and links



In a similar way we can define other semantic categories and their instances needed for our simple example (Table 5).

After we have defined needed semantic categories, we can feed the query to SOUL:

23. "What is the color of John's car?"

SOUL will modify HSF to represent the query in its natural language form and to create the corresponding semantic categories (Figure 7). The complex semantic category (24) is comprised of semantic categories <interrogative-pronoun>, <car-characteristic>, <student> and <vehicle>, which provide the understanding of the corresponding query (23).

If we then feed the question-answer form to SOUL:

27. "What is the color of John's car?
 John has a car plate number 123 ABC
 The color of the car plate number 123 ABC is red"

it will modify HSF correspondingly. While processing statements (1) and (4) of the question-answer dialog. SOUL will create generic groups (25) and (26) representing the meaning of these two statements. Complex semantic category (25)

Figure 6. Learning by generalization

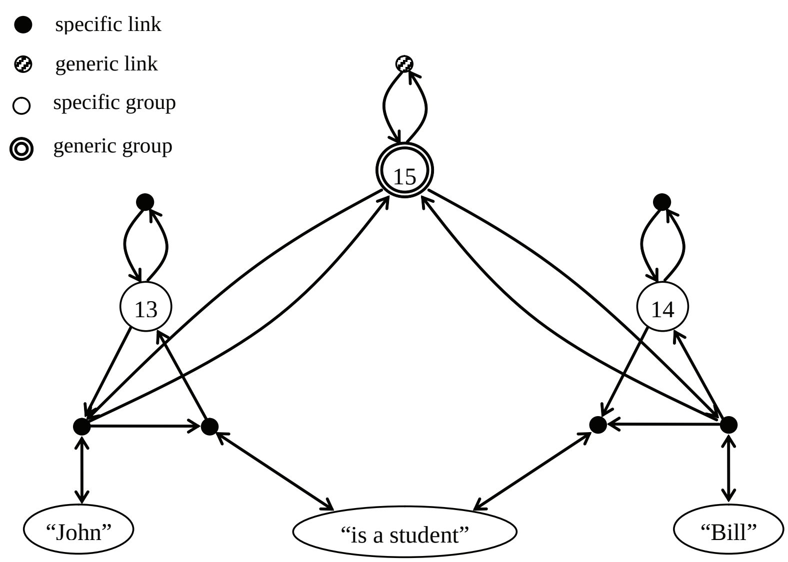
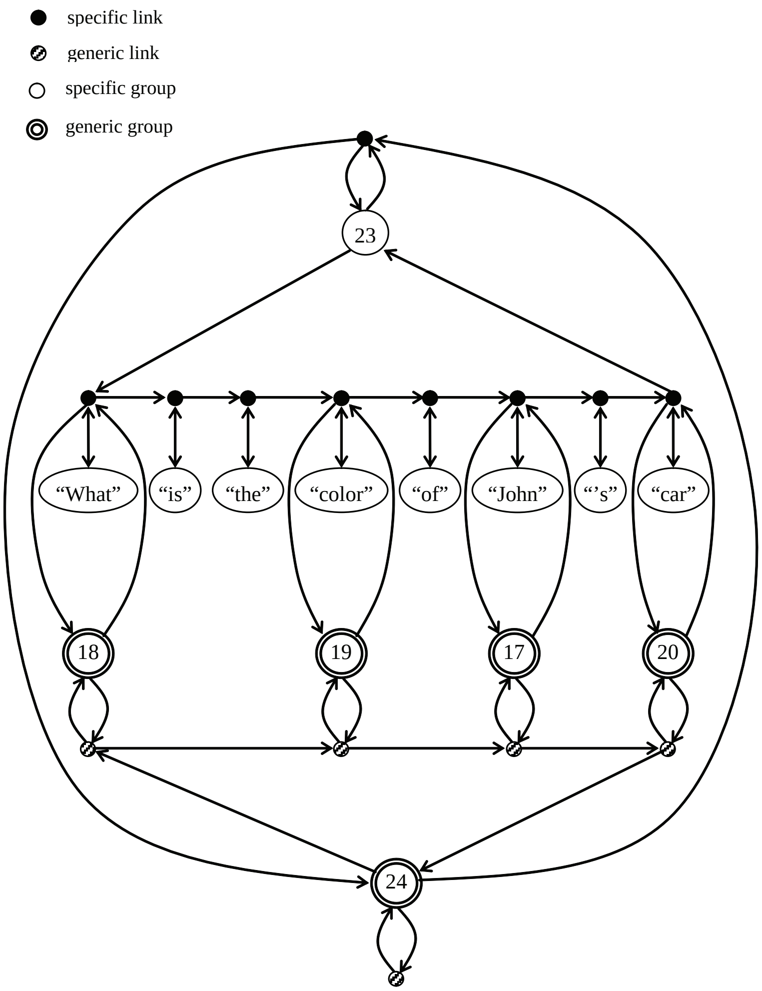


Table 5. Semantic categories and their instances

Semantic category	Group Id	Instances
<student>	17	John, Bill, Tom
<interrogative-pronoun>	18	what, which
<car-characteristic>	19	color, maximum speed
<vehicle>	20	car, truck
<plate-number>	21	123ABC, 456DEF, 789GHI
<color>	22	red, green, black

Figure 7. Query representation in HSF



includes semantic categories <student>, <vehicle> and <plate-number>, while complex semantic category (26) represents semantic categories <car-characteristic>, <vehicle>, <plate-number> and <color>. A group 27 represents the given question-answer form, while complex semantic category 28 represents the understanding of its meaning.

Query Answering

In HSF, each group and link can be in one of the four states (Table 6): inactive, semi-active, excited and active.

There are also seven types of signals that can be exchanged between links and groups (Table 7): reset, relaxed, inhibitory, no signal, semi-active, excited and active.

The query answering process is performed in four phases:

1. **Matching.** In this phase, words and phrases from the query are matched with the corresponding semantic categories. These semantic categories constitute the complex semantic category standing for the general form of the query, but also represent parts of general form of the answer. At the same

Table 6. Types of states

State	Indication
inactive	0
semi-active	½
excited	¾
active	1

Table 7. Types of signals

Signal	Indication
reset	-1
relaxed	-¾
inhibitory	-½
no signal	0
semi-active	½
excited	¾
active	1

time as the query is matched against the complex semantic category representing general query form, statements representing potential answers to this query are also identified. The states of the matched semantic category corresponding to general query form will be set to active and the states of statements representing potential answers will be set to semi-active.

2. **Excitation.** If the complex semantic category representing the general query form is matched against the query, the excitation phase will start. The complex semantic category representing the general answer form is only partially matched and the constituting semantic categories that are still not matched will, in this phase, be matched with words and phrases from the statements identified in the matching phase as potential answers. In the excitation phase the first answer to the query will be selected and the state of statements representing this answer will be set to excited.
3. **Relaxation.** In the relaxation phase statements in the excited state will be relaxed, i.e. their state will be set to inactive. During this phase, statements that are relaxed can be presented as an answer to the query. If there are some other answers, they will be identified in the repeated excitation phase. Excitation and relaxation phases will be repeated as many times as there are valid answers to the query.
4. **Resetting.** If there are no more valid answers, the states of all nodes in HSF will be set to inactive in the resetting phase.

We will illustrate these four phases of query answering process using our simple example. The matching phase begins with feeding the query to SOUL:

23. “What is the color of John’s car?”

After the first word of the query, “What” is processed by SOUL, the state of the corresponding specific group will be set to 1. The input signals for the specific link attached to the “What” group are:

0 – Previous Link
1 – Specific Group (last changed signal)
0 – Generic Group

and the state of link is 0. Looking at the Table 8, we can see that the specific link will change the state from 0 to 1, a signal to Next Link will be ½, and signal to Generic Group will be 1.

When the word “color” is processed, the generic group <car-characteristic> (19, Figure 7) will become active, while specific groups:

4. “The color of the car plate number 123 ABC is red”
5. “The color of the car plate number 456 DEF is green”

6. “The color of the car plate number 789 GHI is black”

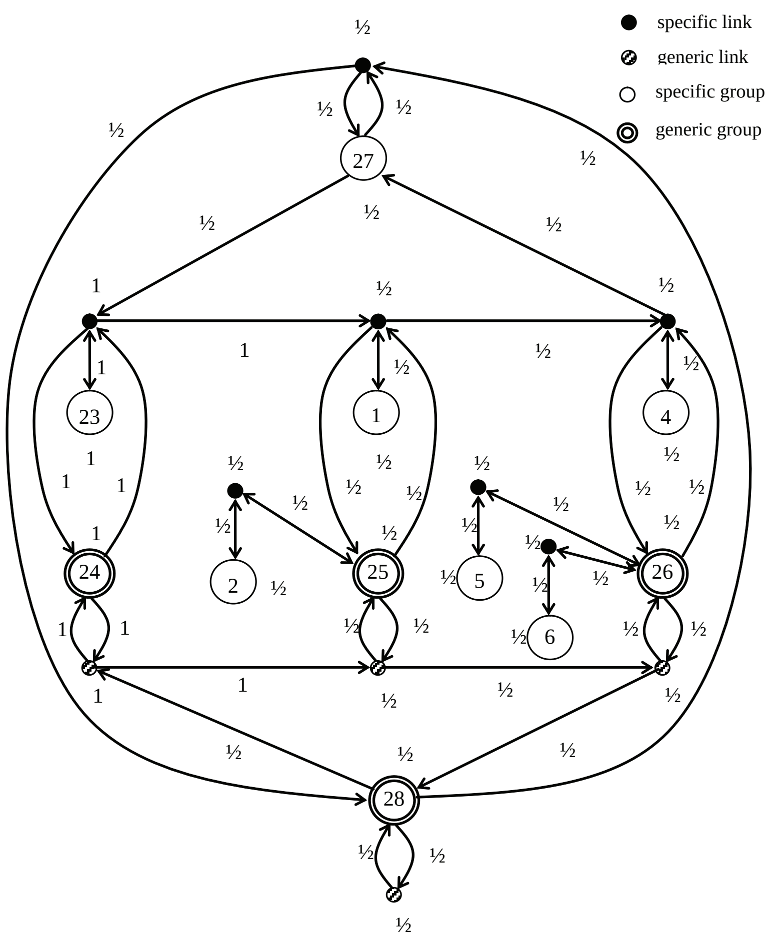
and a complex semantic category (26) corresponding to these specific groups, will become semi-active.

Finally, when the word “car” is processed, <vehicle> semantic category (20) will be matched, a group representing the whole query (23) will become active as well as a semantic category corresponding to this query (24). The state of HSF, after the matching phase is completed, is represented in Figure 8.

After the query has been matched, starts the excitation phase. This phase is initiated by sending the active signal from the generic link attached to the generic group corresponding to the query (24, Figure 8) to the generic link attached to the generic group (25, Figure 8). This generic link is semi-active and according to the Table 9 it will become excited. According to the Table 11 the attached generic group (25, Figure 8) will then also become excited. When the generic group becomes excited, it transfers the excitation signal to one of the attached semi-active specific links. Suppose that the signal is sent to the specific link attached to the specific group (1, Figure 8), corresponding to the statement:

1. “John has a car plate number 123 ABC”

Figure 8. State of HSF after matching phase



When the specific group corresponding to the plate number “123ABC” becomes excited, by the propagation of signals, a specific group representing the statement:

4. “The color of the car plate number 123 ABC is red”

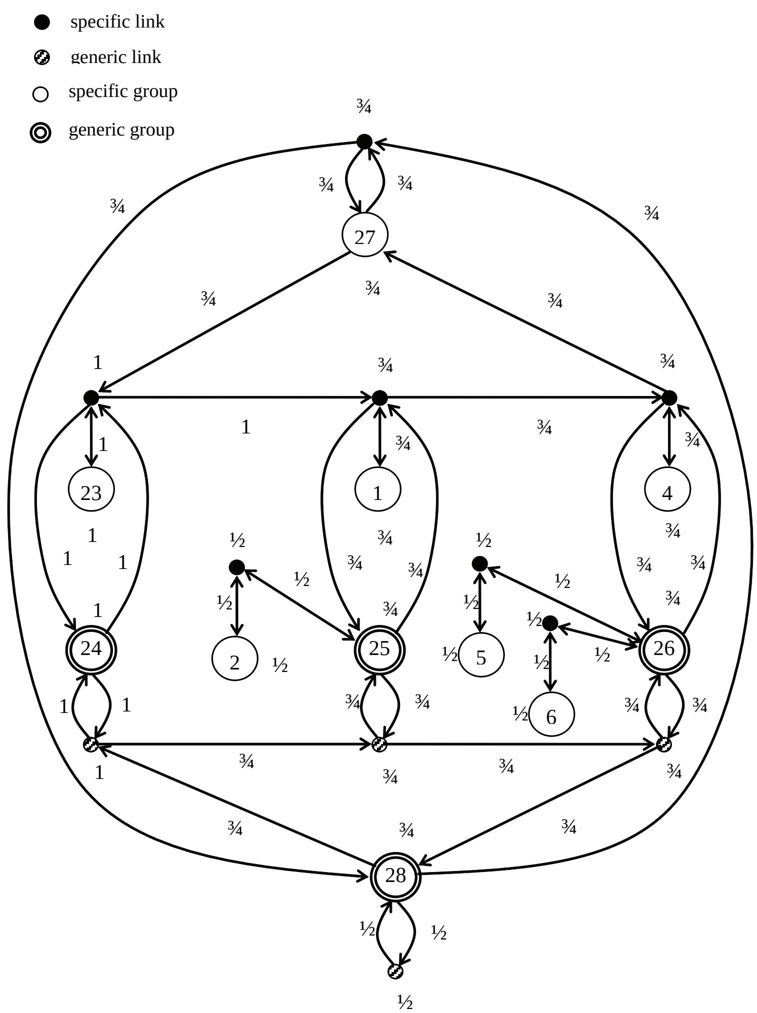
will also become excited.

The state of HSF at the end of the excitation phase is presented in Figure 9.

When the excitation signal reaches the excited generic link attached to the generic group (25, Figure 9), begins the relaxation phase. In the relaxation phase all links and groups in the excited state will transmit relaxation signal and after the signal turns back, they will be set to inactive state. In the relaxation phase, specific groups (1 and 4, Figure 9) in the excited state represent the answer to the query:

1. “John has a car plate number 123 ABC”
4. “The color of the car plate number 123 ABC is red”

Figure 9. State of HSF after excitation phase



After the first answer is provided, HSF will be in the state represented in Figure 10.

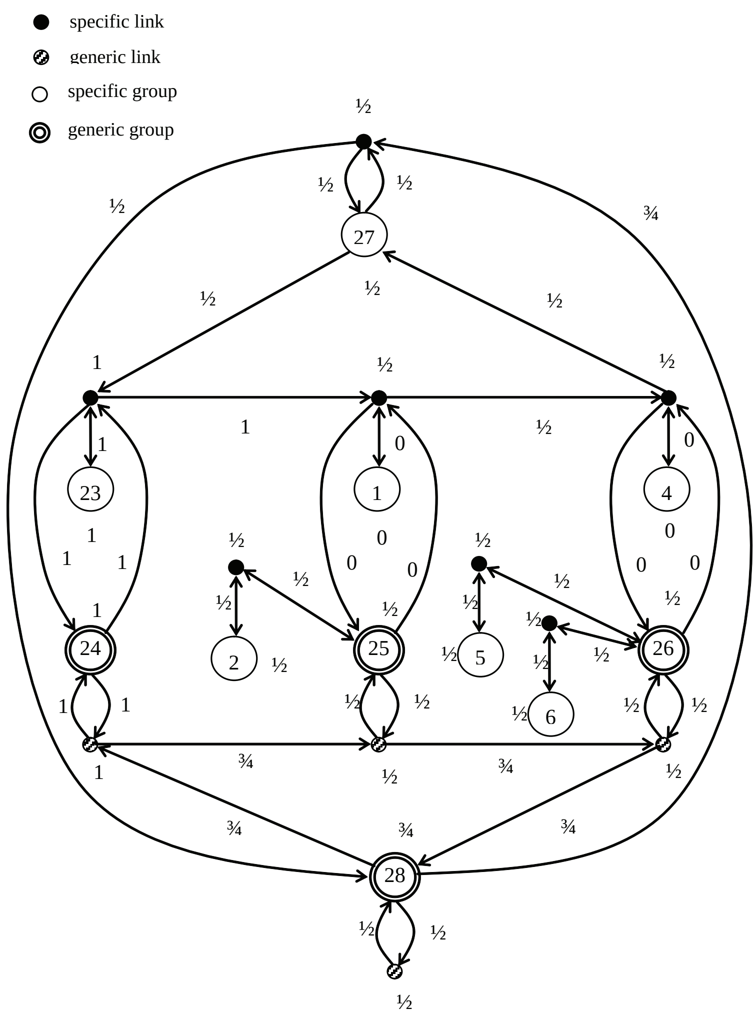
When the relaxation phase is finished, a new excitation phase will begin, resulting in changing the state of specific groups (2 and 4, Figure 10) to the excited state. In a new relaxation state, specific groups (2 and 5, Figure 10) represent another answer:

2. “John has a car plate number 456 DEF”
5. “The color of the car plate number 456 DEF is green”

When the excitation signal reaches generic link attached to the generic group (25) which is in the inactive state, it transmits then a reset signal, which will set the whole HSF to the inactive state.

Note that understanding capability of HSF with SOUL is not limited by the specific form used to define statements and questions. It is defined by used semantic categories and question-answer forms, which provides them a great flexibility in understanding. For instance, information that Tom has bought a new car could be expressed using the following statements:

Figure 10. State of HSF after the first relaxation phase



30. “Tom has recently bought a new car plate number 323 BIL”
31. “Car plate number 323 TOM is painted blue”

Supposing “323 TOM” is defined before as <plate-number> and “blue” as <color>, statement 30 can be matched with complex semantic category comprised of <student>, <vehicle> and <plate-number> semantic categories, while statement 31 can be matched with the complex semantic category consisting of <vehicle>, <plate-number> and <color> semantic categories.

Similarly the question:

32. “Could you please tell me what is the color of Tom’s new car?”

can be matched with the complex semantic category (24) comprised of <interrogative-pronoun>, <car-characteristic>, <student> and <vehicle> semantic categories. If this question is fed to HSF, it will provide statements 30 and 31 as an answer.

HSF can even understand a statement in the form:

33. “Tom has bought a new blue car plate number 323 TOM”

which can be matched simultaneously with both complex semantic categories (25 and 26). If the question 32 is fed to HSF, the single statement 33 will be provided as an answer.

Advantages of HSF with SOUL

The advantages of HSF with SOUL in the representation of semantic knowledge are the following:

- **Representation of knowledge which is not domain specific**. HSF does not use any kind of naming or tagging for groups and links, so knowledge represented using HSF is not domain limited.
- **Automatic semantic knowledge acquisition from plain text**. Semantic knowledge represented in HSF is equivalent to its plain text form. Knowledge in plain text form can be translated by SOUL into Hierarchical Semantic Form and vice versa with no loss of information.
- **Learning of language structures and semantic relationships between these structures**. SOUL algorithm has the ability to recognize and learn repeated sequences at various hierarchical levels (word, groups of words, statements), to identify all semantic relationships between them and to represent them using HSF.
- **Extending the existing HSF semantic knowledge repository is easy**. HSF can be easily extended by simply feeding new statements to SOUL without any need for the knowledge repository redesign. As new statements are fed to SOUL, it reorganizes the existing HSF structures so that each structure is represented uniquely and that all semantic information is preserved.
- **Merging of existing semantic knowledge repositories in HSF can be performed automatically**. When two knowledge repositories in HSF need to be merged, one of them can be transformed into a plain text form and then statements can simply be added to the other one.

The advantages of HSF with SOUL in semantic knowledge processing are the following:

- **Ability to learn to understand statements in natural language**. Instead of defining a fixed grammar for a subset of a natural language, HSF with SOUL is able to learn basic and complex semantic categories defining the meaning of statements and questions.

- **Flexible understanding**. Since understanding in HSF with SOUL is supported using semantic categories, a great flexibility of understanding is achieved, because SOUL can process and understand statements that contain words in an arbitrary order or unknown words, as well as statements that are syntactically incorrect.
- **Efficient information retrieval**. The efficiency of the information retrieval using HSF with SOUL is achieved by the hierarchical representation of knowledge in HSF and neural network capability for parallel processing of semantic categories appearing in question and in potential answers. This means that at the same time the question is processed, some potential answers to this question are also found.

When compared with a relational database model or ontology languages, the main advantage of HSF with SOUL is that, unlike these semantic knowledge representation techniques based on the symbolic approach, they enable knowledge representation that is not domain limited, which means that they do not require designing to describe the meaning of represented knowledge, nor programming to retrieve the needed information. Instead, designing is replaced with unsupervised learning used to organize the represented knowledge, while programming is replaced by supervised learning of basic and complex semantic categories used in question-answer forms.

FUTURE TRENDS

The application of knowledge representation and processing techniques based on semantic approach might have a profound impact on the way we are using computers and other intelligent devices, but also on the increased productivity in processing the information expressed in natural languages.

The use of natural languages in the implementation of user interfaces should enable the inclusion of some social groups (e.g. elderly population and technically illiterate people) that are not able to benefit from the use of computers or Web. Although modern graphical user interfaces are user friendly and easy to use, they still require some training, which the above mentioned social groups are not willing or not able to accept, but they would be probably more open to the possibility to use computers if they could communicate with them in natural language. Natural language based user interfaces could be also used in mobile phones PDAs and other similar intelligent devices thus changing the way of their use and increasing substantially their possible application.

There is still a huge quantity of legacy knowledge expressed in natural languages in various electronic documents and on the Web. This knowledge is not represented in the structured form, hence it cannot be processed automatically. By applying the semantic approach the automatic processing of this knowledge should become possible, which would lead to a tremendous increase in the information processing productivity.

Furthermore, the idea of world knowledge could become a reality, where each person would be able to use it and benefit from it. Unlike standard keyword search engines, which are document oriented, by applying semantic approach a user should be able to make a natural language query and get a precise natural language answer.

Web 2.0 or Social Web applications represent a huge resource of information created by the large number of their users. Usually this information is expressed in natural languages, so a big problem is how to find the needed information. Semantic approach could alleviate this problem by enabling Web 2.0 users to make natural language queries and find the needed answers. It could also provide the intelligence required for the transition from Web 2.0 to Web 3.0.

In the domain of Web services the use of semantic approach should enable the use of natural languages in defining service descriptions and service requests, but also easier service discovery and automatic service composition, which should eliminate the need for highly specialized experts for describing and finding services and help developing the full potential of Service Oriented Architecture (SOA) and applications built on it.

At present several types of services (e.g. eFinance, eCommerce, eTourism, eGovernment, eLearning, etc.) are offered on the Web. Usually the Web sites are offering one service or a group of similar services. However, by applying semantic approach it would be possible to integrate many heterogeneous services within the same Web site, where natural language user interface could provide the needed functionality. Furthermore, mobile phone and PDA users could also benefit from such approach by getting the needed information or service by voice.

Semantic approach could also find its application in several other domains ranging from company knowledge representation, management and processing to providing the needed information in various information, help or support centers.

CONCLUSION

To be able to search through the large quantities of data, different knowledge representation techniques are used. Regarding the way they define the meaning of represented knowledge, they can be classified as techniques based on the symbolic approach, because they use names (of tables, fields, relations, classes, attributes, etc.) to describe the meaning. If naming is not used to describe the meaning, then represented knowledge by itself will not have any explicit meaning. The meaning in the semantic approach is implicitly defined by contexts.

Although symbolic techniques have found many successful applications, they still have some limitations (e.g., domain-dependent knowledge representation, problems with extending and merging of represented knowledge, problems with extracting knowledge from plain text, etc.). These limitations are actually caused by the very essence of these techniques, i.e. use of naming to describe the meaning of represented knowledge.

To describe the knowledge we need an expert to design a database (knowledge base, ontology), and we need a programmer to interpret and use this knowledge in an application. The need for designing – to represent knowledge, and for programming – to interpret this knowledge, posts the applicative limits for techniques based on the symbolic approach. They can be used in domain limited tasks, but many problems emerge in large-scale, real-world modeling.

A relational database model represents the most popular technique based on the symbolic approach used to represent and search large quantities of data stored in computers, while various Semantic Web languages are used to store semantically related information on the Web. In this chapter, a simple example of representing and retrieving semantically related information is used to illustrate the main characteristics of relational database model and OWL as the representative of ontology languages.

The Hierarchical Semantic Form (HSF) may look like a modification of the localist approach of a connectionist model and a kind of recurrent neural network with non-fixed topology. However, HSF has some characteristics (e.g. node and signal types, applied learning techniques, complex transitional tables, etc.) that distinguish this approach from the connectionist approach. HSF powered with SOUL algorithm enables the representation of semantic knowledge and interpretation of its meaning without naming, i.e. it represents a technique based on the semantic approach.

HSF with SOUL provides a unique representation of natural language structures at all levels of hierarchies (words, groups of words, statements), representation of all semantic relations between these structures as well as representation of semantic categories used to interpret the meaning of represented knowledge. Hierarchical Semantic Form represents a hierarchical equivalent of a plain text form, while SOUL algorithm supports translation from one form to the other without loss of information. Furthermore, SOUL algorithm provides unsupervised learning to automatically extract natural language structures (e.g. words, phrases, sentences, etc.) from a plain text and supervised learning to identify semantic categories (semantic generalization) and their instances (semantic specialization).

The query answering process is implemented in HSF with SOUL based on signal propagation. The process is divided into four phases: matching, excitation, relaxation and resetting. In the matching phase a natural language query is matched against semantic categories comprising a general query form and general answer form, in the excitation phase the first answer is selected, while in the relaxation phase the selected answer is presented and then discarded. The excitation and relaxation phases repeat as many times as there are answers to the query. In the resetting phase all HSF nodes that took part in the query answering process are set to inactive state.

HSF with SOUL offers some advantages in the representation of semantic knowledge and retrieving the needed information – the representation of domain independent knowledge, automatic knowledge acquisition from plain text, learning of language structures and semantic relations between them, easy extending and merging of existing HSF knowledge repositories, ability to learn a natural language, flexible understanding, efficient information retrieval, etc., which should initiate an easy application of these techniques in a semantic knowledge representation and processing of various natural language documents (Web pages and other electronic documents).

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KEY TERMS AND DEFINITIONS

Background Knowledge: Knowledge expressed in terms of simple and complex semantic categories, and patterns defined in a natural language used to define the meaning of a word, phrase, statement, query, or answer in the given context.

Information Retrieval: Information retrieval techniques are used to extract the relevant information from the natural language documents and represent it in a structured form suitable for computer processing.

Knowledge Representation: Knowledge representation techniques support the representation of knowledge in a structured form, which is suitable for computer processing.

Natural Language Understanding: Natural language understanding techniques enable computers to understand natural language statements, queries, answers, commands, etc.

Pattern: Patterns are used to generalize natural language statements, queries, answers, commands, etc. They are comprised of simple and complex semantic categories and defined in the form of examples in natural language.

Question Answering: Question answering is supported by a natural language understanding technique and knowledge representation technique. It provides the natural language answers on natural language queries using a knowledge repository.

Semantic Approach: Semantic approach to knowledge representation and processing implicitly define the meaning of represented knowledge using semantic contexts and background knowledge.

Semantic Category: Semantic categories are used to generalize natural language concepts (e.g. words, phrases). Simple semantic categories generalize words, while complex ones generalize phrases.

Semantic Context: Semantic contexts represent the sequences at different hierarchical levels of natural language concepts of various complexities. Phrases represent the semantic contexts for words and simpler phrases, while statements, queries, answers and commands represent the semantic contexts for words and phrases.

Semantic Web: An extension of ordinary Web comprised of various techniques, which should enable both humans and computers to read and process information available on the Web.

Symbolic Approach: Symbolic approach to knowledge representation and processing uses names to explicitly define the meaning of represented knowledge. The represented knowledge is described by names given to tables, fields, classes, attributes, methods, relations, etc.

Chapter II
Challenges on Semantic Web Services

Maria Vargas-Vera
The Open University, UK

Miklos Nagy
The Open University, UK

Dominik Zyskowski
Poznan University of Economics, Poland

Konstanty Haniewicz
Poznan University of Economics, Poland

Witold Abramowicz
Poznan University of Economics, Poland

Monika Kaczmarek
Poznan University of Economics, Poland

ABSTRACT

The promise of being able to support Business-to-Customer applications with a rapidly growing number of heterogeneous services available on the Semantic Web has generated considerable interest in different research communities (e.g., Semantic Web, knowledge representation, software agents). However, in order to overcome the challenges of the current Web services, new level of functionalities is required in order to integrate distributed software components using existing Semantic Web standards. In this chapter, the authors discuss and suggest insights into new solutions to the main challenges in the area of Semantic Web services: composition, discovery and trust. For the first problem they suggest to use program transformation coupled with services' descriptions. For the second problem (discovery of Web services) a solution based on the authors' mapping algorithm between ontologies is suggested. While, for the last problem a solution based on fuzzy voting model is outlined. Through the chapter, the authors work with an investing scenario, in order to illustrate our suggested solutions to these three challenges.

INTRODUCTION

Web services technology has greatly advanced since its first emergence. Although, it has been adopted worldwide and is successfully used in the industry, it is still in the focus of attention of many research communities. The most active research is to automate interactions with and between Web services. One of the methods that may be used to achieve this is taking advantage of the semantic annotation of services and application of Semantic Web technologies, thus using Semantic Web services. A Semantic Web service (SWS) is defined as an extension of Web service description through the Semantic Web annotations, created in order to facilitate the automation of service interactions (McIlraith et al., 2001). These annotations are usually expressed using ontologies.

Ontologies are explicit formal specifications of the terms in the domain and the relations among them (Gruber, 1993). They provide the mechanism to support interoperability at a conceptual level. In a nutshell, the idea of interoperating Semantic Web services, being able to exchange information and carry out complex problem-solving on the Web, is based on the assumption that they share common, explicitly-defined, generic conceptualizations. These are typically models of a particular area, such as product catalogues or taxonomies of medical conditions. However, ontologies can also be used to support the specification of reasoning services (McIlraith et al., 2001; Fensel & Motta, 2001), thus allowing not only "static" interoperability through shared domain conceptualizations, but also "dynamic" interoperability through the explicit publication of competence specifications.

The promise of being able to support Business-to-Customer applications with a rapidly growing number of heterogeneous services available on the Semantic Web has induced a lot of interest within different research communities e.g. Semantic Web, knowledge representation, software agents. However, in order to overcome the challenges of the current Web services, new level of functionalities is required. In addition, although Semantic Web services are perceived as a very promising technology, as in case of any new technology, the problem of its maturity and its impact on the society and the business interactions arises. When it comes to business-to-customer interactions, the very important issues are social aspects connected with automatic transactions, especially the issue of trust within service discovery and composition.

Therefore, within this chapter, we discuss and suggest insights to new solutions to the main challenges in the area of Semantic Web services, namely composition and discovery as well as the issue of trust of Semantic Web services within those interactions. For the first problem we suggest to use program transformation coupled with services' descriptions. For the second problem (discovery of Web services) a solution based on our mapping algorithm between ontologies is suggested. While, for the last problem a solution based on fuzzy voting model that may be used both within discovery as well as composition is outlined. The fuzzy voting model reflects the typical social situation in which one has to decide the opinion of which expert should be finally considered. Through the chapter, we work with an investing scenario, in order to exemplify our suggested solutions to these three challenges.

The main aim of this chapter is to delve into the issue of Semantic Web services and familiarize a reader with the main challenges lying ahead of them. We focus mainly on discovery, composition and trust and then, present possible solutions. In order to fulfil its aims, the chapter is structured as follows. First, we present the idea of Semantic Web services, their interactions as well as the main challenges in this area. Then, the issue of trust of Semantic Web services is discussed and we show the fuzzy voting model and its possible usage. In the next section, a solution to services discovery using Dempster-Shafer theory of evidence is presented. Then, we suggest an alternative solution to the problem of composition of Semantic Web services. Finally, the chapter concludes with a summary and outlook on our future work.

SEMANTIC WEB SERVICES: AN OVERVIEW

A Semantic Web service is defined as an extension of Web service description through the Semantic Web annotations, created in order to facilitate the automation of service interactions (McIlraith et al., 2001). Therefore, from the perspective of the functionality offered, Semantic Web services are still Web services. The only difference lays in their description and the consequent benefits that follow, namely the reduction of human involvement in the performed interactions.

The contribution of the Semantic Web annotations in case of Semantic Web services is twofold. First, it provides ontologies acting like a shared knowledge base and thus providing universal dictionaries. In this way all Web services share the same interpretation of the terms contained in the exchanged messages and provide the bases for the description of capabilities of Web services (Paolucci et al. 2003). Secondly, it provides a logic that allows performing reasoning. Only these two mechanisms (ontologies and reasoning infrastructure) allow to introduce the required level of automation to performed interactions.

Interactions between Web services, and in consequence also Semantic Web services, typically involve three or more parties: a user, one or more providers and a registry that supports the Web services during the transaction and possibly mediates between the user and the provider (Paolucci, Sycara, & Kawamura, 2003). In case of Semantic Web services, a user is represented by an intelligent agent or system acting on the behalf of the user.

Let us consider the typical interactions with and between Web services. First, a provider in order to make his services available needs to advertise their description with the registry (O'Sullivan et al. 2002). Then the process of the provider discovery i.e. Web services discovery follows. This process is composed of at least three main stages. First a user has to compile a request for a service and send it to the registry. Within the next step the registry is to locate an advertisement that matches a request (Paolucci et al. 2003). Matching process is not an easy task, depending on the approach taken. Needless to say, that it should take into account the fact, that different parties with different perspectives may (and in most cases do) provide different description of the same service (not only when it comes to a different terminology used, but also a different level of the granularity of the description). This step should at the end guarantee that the selected Web service produces the effects that the user desires (also when it comes to the social and trust related aspects). The result should be a list (preferably a kind of a ranking) of potential providers among which the requester has to make a selection. It is stated that there is no general rule for the selection of the provider and it is in fact domain specific decision as well as it depends on the trust the user assigned to a particular service or its provider. In the most basic scenario, the provider with the highest score among the matches returned is selected (service that maximizes some utility function) or further negotiations may follow. In general, this step ends with signing the contract that defines the rights and obligations of both parties. Invocation is in fact the call for the execution of a service. Invocation of the contracted service usually entails service execution and finally, the assessment of the delivered results may follow.

Of course, individual services offer only limited capabilities. The real power of Service-Oriented Architecture (SOA) paradigm lies in the possibility to easily create composite applications and reconfigure them on demand. Therefore, in fact two types of Web services may be identified, namely atomic and composite. Atomic services are Internet-based applications that do not rely on other Web services to fulfil consumer requests. A composite service may be defined as an ordered set of outsourced services (atomic as well as composite) working together to offer a value-added service. The composite services may be used as basic services in further compositions or may be utilized directly by end clients.

To summarize, the following interactions may be distinguished:

1. **Publication:** Making the Web service (description) available for use by others.
2. **Discovery:** Web service discovery is the process of locating Web services that can be used to request a service that fulfils some user needs.
3. **Filtering:** Identifying relevant services from the stream of new ones.
4. **Composition:** Creation of applications/business processes out of atomic and composite services.
5. **Negotiation:** Negotiating the terms of service provisioning and its characteristics.
6. **Contracting:** The process of contracting, via a discovered Web service, a concrete service fulfilling such needs.
7. **Invocation:** Call for service execution.
8. **Enactment and monitoring:** The actual provisioning of a service and monitoring its behaviour.

Ideally, we would like Web services to act autonomously and require minimal human intervention. Therefore, software agents or intelligent systems should be able to autonomously register with infrastructure registries and use the registries to discover services that they (or their users) need, and finally, create service compositions. Such automation is of interest of providers as well as customers and the automation of Web service interactions is the ultimate goal of many research projects.

The research conducted in the field of Semantic Web services may be divided into two main areas – SWS description methods and SWS interactions. First of these gathers groups working on languages and formalisms used to describe Web services and their capabilities. A Semantic Web Services representation is currently shaped by three main initiatives – OWL-S (Web Ontology Language for Web Services) (Martin et al. 2004), WSMO (Web Services Modelling Ontology) (Roman et al. 2005) and SAWSDL (Semantic Annotations for WSDL) (Farrell et al. 2007). The two first share a common attitude to a service (in order to automate service interactions define the description of a service with use of standardized language, concepts from the ontology build with the use of this language and providing the ability of being enhanced by its users) and in some sense are interoperable due to the activities of the research communities[1].

The second group focuses on a very wide universe of interactions with and between Web services. The ultimate goal is to automate and simplify the whole process of SWS management. This process includes following activities: SWS description creation and its publication, discovery and filtering, negotiation and contracting, composition, execution and monitoring as well as profiling. Some research projects like ASG (Fahringer et al., 2007), DIP (DIP 2007) or INFRAWEBS (Nern 2006) provided sophisticated platforms that support and automate all abovementioned Semantic Web services interactions. Some of the solutions proposed by these projects were even submitted to standardization bodies as industry standards proposals.

The researchers heavily investigate each of the SWS interactions. And in fact, each interaction is supported in most cases by a number of applicable mechanisms. There are, however, several research problems which still need to be addressed such as a composition and Semantic Web services discovery. Other issues are the social aspects of the desired automation. As the discovery and composition are performed automatically, it is the system or an agent that selects the service, not the user. If an agent is to act on a user's behalf it has to be equipped with the appropriate information on user's preferences and desires. In the real world scenario, users do not only select and use services that are functionally meeting their requirements. Usually they select trusted providers, those were recommended by people their trust or those that were recommended by a big number of other users. This element is somehow ignored within most of current approaches. Within the next sections we present the possible solutions to composition and discovery of services and also show how the problem of trust may be tackled.

SWS USAGE SCENARIO

In order to allow for better understanding of the issues presented in this chapter, please consider a following scenario of Semantic Web services usage in real world. Assuming the significant number of available services, it would be possible to assemble complex applications out of chosen SWS. However, the main issue regarding the choice of appropriate service is the trust user has for a certain service provider. Such a user may also take advantage of opinions of another users that already used services of this particular provider. Second of all, before the creation of complex application out of atomic services user needs to collect candidate services that may be used as a building blocks of his desired application. To perform this task correctly, appropriate techniques of service discovery must be applied in order to assure that only reliable services will be composed. Finally, Semantic Web service composition algorithms should be employed to create an executable chain of services that provide results requested by the user.

Within this chapter we address all three issues (trust, discovery and composition) that we consider crucial for the success of Semantic Web services. An investment scenario which is presented in the section presenting SWS composition is a detailed version of the outlined SWS usage scenario.

TRUST

In the context of Semantic Web services the requestors interact with unknown service providers, therefore they have to determine if they can trust such services or not.

In the context of the Semantic Web services trust can have different meaning therefore before we describe the problem let us define the basic notions of our argument.

- *Trust*: One mapping agent's measurable belief in the competence of the other agents' belief over the established similarities.
- *Content related trust*: Dynamic trust measure that is dependent on the actual vocabulary of the mappings, which has been extracted from the ontologies and can change from mapping to mapping.
- *Belief*: The state in which a software agent holds a proposition or premise over a possible mapping of selected concept pair combination to be true.

Detecting and managing conflicting evidence over the possible meaning of the Semantic Web data is not always obvious. In practice the degree of conflict can differ considerably from case to case.

The problem of trust in this environment has different aspects, which have been investigated by different research communities. Most of the research is inspired by the traditional security problem where in order to secure a communication between two parties, the two parties must exchange security credentials (either directly or indirectly). However, each party needs to determine if they can "trust" the asserted credentials of the other party.

A peer to peer policy based trust approach is presented for establishing trust through iterative negotiation (Olmedilla et al., 2004) where both the service provider and the requestor possess a trust policy which is published either in a centralised registry or in distributed P2P environment. The negotiation is carried out by a matching algorithm which increases trust between the requestor and provider during the iteration revealing more and more information between the parties. Other security related aspects of trust can be represented through access control (Agrawal et al., 2004), which means the users must fulfil certain conditions in order to access certain services which are based on issued trust credentials by each Web service provider. Additionally these credentials are independent of other service providers. A Semantic Web service provider, acting as a verifier, can locally and autonomously decide whether access to his service should be granted or not. These solutions range from authorization based access control to authentication based access control of Web services which can be based either on public keys or identities. Other aspects of trust that focus on the provided answers that was requested from a service are based on the idea that trust in a Semantic Web service should take into account not only the functional suitability of the services but also their prospective quality offered to the end-users. This quality can be expressed directly as a proof for the provided answer using a specific language (Silva et al., 2004) or calculated with ranking algorithms (Vu et al., 2005), trust and reputation evaluation techniques e.g. compare the announced and actual service performance.

After analysing the related work on trust for Semantic Web services the main effort seems to be in security, encryption and authentication. Therefore, in this section we will introduce our proposal to trust.

During the Semantic Web services discovery we assume that different agents considered as different experts from the Dempster-Shafer point of view assess similarities between different services and the request. The application of agent is required because in the context of Semantic Web services it is hardly imaginable that isolated applications will be able to serve successfully the users' ever growing requirements since the information normally available to human decision makers continues to grow beyond human cognitive capabilities. In such an environment a single agent or application limited by its knowledge, perspective and its computational resources cannot cope with the before mentioned scenarios effectively. Further, the combination of individual beliefs into a coherent view works in most of the cases and turns out that an aggregated belief function can provide more reliable mapping than several individual ones. However in certain situations the belief combination may produce an incorrect result even though before the combination a correct mapping could have been derived for the particular case based on individual beliefs. The problem occurs when the different experts' similarity assessments produces conflicting beliefs over the correctness of a particular mapping. A conflict between two beliefs in Dempster-Shafer theory can be interpreted qualitatively as one source strongly supports one hypothesis and the other strongly supports another hypothesis, where the two hypotheses are not compatible. In this scenario applying Dempster's combination rule to conflicting beliefs can lead to an almost impossible choice because the combination rule strongly emphasizes the agreement between multiple sources and ignores all the conflicting evidence through a normalization factor.

The counter-intuitive results that can occur with Dempster's rule of combination are well known and have generated a great deal of debate within the uncertainty reasoning community. Different variants of the combination rule (Sentz, 2002) have been proposed to achieve more realistic combined belief. Instead of proposing an additional combination rule we turned our attention to the root cause of the conflict itself namely how the uncertain information was produced in our model (Nagy et al. 2008).

In order to illustrate the problem let's take the before mentioned scenario where Maria wants to invest money through on-line technologies. Our system has found a Web service which might be useful for converting the investment currency:

- ServiceDescriptor{interchange, foreign exchange, IBAN number}

However once the different experts assess whether the service is relevant or not the following situation occurs before belief combination:

- Expert 1: belief(Request-ServiceDescriptor)=0.05
- Expert 2: belief(Request-ServiceDescriptor)=0.90
- Expert 3: belief(Request-ServiceDescriptor)=0.10
- Expert 4: belief(Request-ServiceDescriptor)=0.92
- Expert n: belief(Request-ServiceDescriptor)=0.93

In this scenario the belief of Expert 1 and Expert 3 is in conflict with the other experts' beliefs and due to the normalization factor the combination would result in an incorrect mapping therefore incorrect service selection. In our mapping framework the belief functions are considered as a method to model an expert's beliefs, therefore the belief function defined by an expert can also be viewed as a way of expressing the expert's preferences over choices, with respect to masses assigned to different hypotheses. The larger the mass assigned to a hypothesis is the more preferred the hypothesis will be. In this context the problem is how we handle the experts' conflicting individual preferences that need to be aggregated in order to form a collective preference. Therefore, instead of modifying the combination rule we need to revise the conflicting information itself since this is what poses the problem and not the combination rule. Additionally, the similarity algorithm hence expert which contributes the conflicting belief can vary from mapping to mapping. In order to resolve the problem of choosing between different propositions for a selected service we propose as a method for assessing trust in Semantic Web services the fuzzy voting model developed by Baldwin (Baldwin, 1999). Fuzzy voting model has been used in fuzzy logic applications. However, to our knowledge has not been introduced in the context of Semantic Web services. In this section, we introduce briefly the fuzzy voting model theory with a simple example of 10 voters (agents) voting against or in favour of a Semantic Web service.

According to Baldwin (Baldwin, 1999) a linguistic variable is a quintuple **(L, T(L),U,G,M)** in which **L** is the name of the variable, **T(L)** is the term set of labels or words (ie. the linguistic values), **U** is a universe of discourse, **G** is a syntactic rule and **M** is a semantic rule or membership function.

We also assume for this work that **G** corresponds to a null syntactic rule so that **T(L)** consists of a finite set of words. A formalization of the fuzzy voting model can be fount in (Lawry 1998).

Let us consider the set of words {Low_trust (L_t), Medium_trust (M_t) and Hight_trust (H_t)} as labels of a linguistic variable **trust** with values in U=[0,1]. Given a set **"m"** of voters where each voter is asked to provide the subset of words from the finite set **T(L)** which are appropriate as labels for the value u. The membership value:

$$X_{M_{(w)(u)}}$$

is taking the proportion of voters who include **w** in their set of labels which is represented by u.

Let us start illustrating previous ideas with a small example - let us define our linguistic variable L as TRUST and **T(L)** the set of linguistic values as T(L)=(Low_trust, Medium_trust, High_trust). The universe of discourse is **U** which is defined as U=[0,1]. Then, we define the fuzzy sets M(Low_trust), M(Medium_trust) and M(High_trust). Consider the following fuzzy sets for "Expert 1":

- M(**Low_trust**) = [10:0, 20:1, 30:1, 40:0]
- M(**Medium_trust**) = [45:0, 50:1, 60:1, 65:0]
- M(**High_trust**) = [65.5:0, 70:1, 80:1, 90:1, 100:1]

We need to introduce more opinions to the system i.e. we need to add the opinion of the other agents in order to vote for the best possible outcome.

Let us assume for the purpose of our example that we have 10 voters (agents), Formally, let us define V={A1,A2,A3,A4,A5,A6,A7,A8,A9,A10},

T(L)={L_t,M_t,H_t} where V represents the voters and T (L) describes the trust levels. The number of voters can differ however assuming 10 voters can ensure that:

1. The overlap between the membership functions can proportionally be distributed on the possible scale of the belief difference [0..1]
2. The work load of the voters does not slow the mapping process down

The random set L=TRUST is defined by the table below. Note that in the table we use a short notation L_t means Low_trust, M_t means Medium_trust and H_t means High_trust.

We need to evaluate the different voting on the selected expert's assessment e.g. for the assessment of "Expert 1" we get the results in Table 1.

Then, we compute the membership value for each of the elements on set T(L):

$$X_{M_{(w)(u)}}$$

$$X_{M_{(Low\_trust)(x)}} = 1$$

$$X_{M_{(Medium\_trust)(x)}} = 0.6$$

$$X_{M_{(High\_trust)(x)}} = 0.3$$

$$T(L) = \frac{Low\_trust}{1} + \frac{Medium\_trust}{0.6} + \frac{High\_trust}{0.3}$$

A value x is presented and voters pick exactly one word from a finite set to label x (Table 2).

This gives a probability distribution on words:

$$\sum \Pr\left(L = Low\_trust \middle| x\right) = 0.3$$
$$\sum \Pr\left(L = Medium\_trust \middle| x\right) = 0.6$$
$$\sum \Pr\left(L = High\_trust \middle| x\right) = 0.1$$

Taken as a function of x these probabilities form probability functions. They should therefore satisfy:

$$\sum \Pr\left(L = w \middle| x\right) = 1$$
$$w \in TL$$

At the end of the process we will have the trust evaluated by different voters. In our example

Table 1.

Voters

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
L_t	L_t	L_t	L_t	L_t	L_t	L_t	L_t	L_t	L_t
M_t	M_t	M_t	M_t	M_t	M_t				
H_t	H_t	H_t							

the voters have produced different probability distributions on the words. In our case the voters have assigned low level of probability to the High_trust quantitatively 0.1 and 0.2. From the other side all other experts have received high level of probability for the High_trust quantitatively 0.7, 0.8, 0.9 for Expert 2, 4, n. Therefore as a result of the voting we can conclude that Expert **1** and Expert **3** assessments cannot be trusted and the service should be selected for the currency conversion task.

As we have seen in the previous sections, the main challenges and our proposed solutions for the fundamental components of the Semantic Web services can be applicable for capturing the data and metadata associated with a service together with specifications of its properties which we believe is a prerequisite for widespread adoption of Semantic Web services. Our solution provides means for agents to populate their local knowledge bases so that they can reason on Web services to perform automatic Web service discovery, and composition even if certain information is missing or ambiguously defined. This allows computer agents to automatically construct and execute Semantic Web service request and potentially respond to the service request.

Validation of the Service Discovery and Trust

For validating our service discovery and trust we have simulated mapping scenarios on the scientific publications domain. The evaluation was measured with recall and precision, which are useful measures that have a fixed range and meaningful from the mapping point of view.

Before we present our evaluation let us discuss what improvements one can expect considering the mapping precision or recall. Most people would expect that if the results can be doubled i.e. increased by 100% then this is a remarkable achievement. This might be the case for anything but ontology mapping. In reality researchers are trying to push the limits of the existing matching algorithms and anything between 10% and 30% is considered a good improvement. The objective is always to make improvement in preferably both in precision and recall

We have carried out evaluation with the benchmark ontologies of the Ontology Alignment Evaluation Initiative (OAEI)[2], which is an international initiative that has been set up for evaluating ontology matching algorithms. The experiments were carried out to assess how trust management influences results of our mapping algorithm. Our main objective was to evaluate the impact of establishing trust before combining beliefs in similarities between concepts and properties in the ontology. The OAEI benchmark contains tests, which were systematically generated starting from some reference ontology and discarding a number of information in order to evaluate how the algorithm behave when this information is lacking. The bibliographic reference ontology (different classifications of publications) contained 33 named classes, 24 object properties, 40 data properties. Further each generated ontology was aligned with the reference ontology.

The benchmark tests were created and grouped by the following criteria:

- **Group 1xx:** Simple tests such as comparing the reference ontology with itself, with

Table 2.

Voters

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
L_t	M_t	L_t	M_t	M_t	M_t	H_t	M_t	M_t	L_t

another irrelevant ontology or the same ontology in its restriction to OWL-Lite.

- **Group 2xx:** Systematic tests that were obtained by discarding some features from some reference ontology e.g. name of entities replaced by random strings or synonyms.
- **Group 3xx:** Four real-life ontologies of bibliographic references that were found on the web e.g. BibTeX/MIT, BibTeX/UMBC.

As a basic comparison we have modified our algorithm (without trust), which does not evaluate trust before conflicting belief combination just combine them using Dempster's combination rule. The recall and precision graphs for the algorithm with trust and without trust over the whole benchmarks are depicted on Figure 1. Experiments have proved that with establishing trust one can reach higher average precision and recall rate.

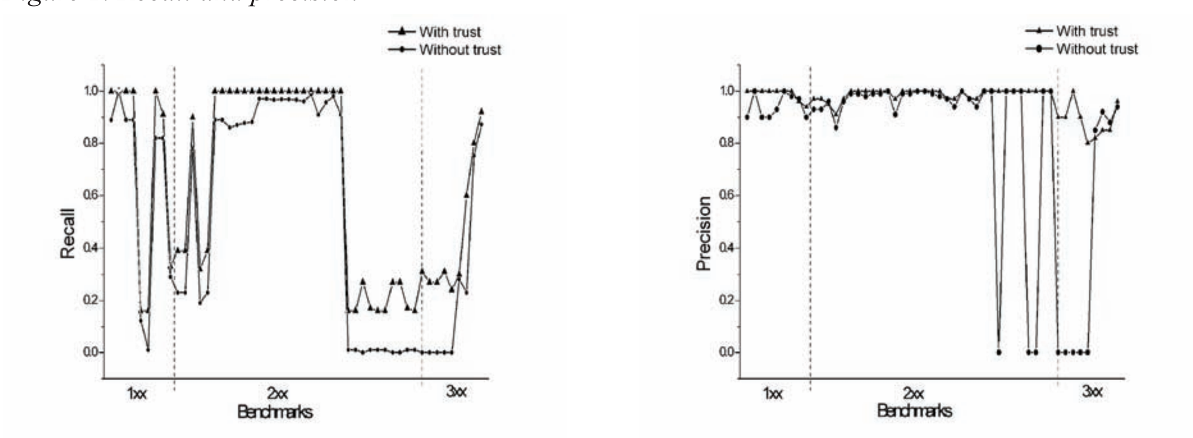
Figure 1 shows the improvement in recall and precision that we have achieved by applying our trust model for combining contradictory evidences. From the precision point of view the increased recall values have not impacted the results significantly, which is good because the objective is always the improvement of both recall and precision together. We have measured the average improvement for the whole benchmark test set that contains 51 ontologies.

Based on the experiments the average recall has increased by 12% and the precision is by 16%. The relative high increase in precision compared to recall is attributed to the fact that in some cases the precision has been increased by 100% as a consequence of a small recall increase of 1%. This is perfectly normal because if the recall increases from 0 to 1% and the returned mappings are all correct (which is possible since the number of mappings are small) then the precision is increases from 0 to 100%. Further the increase in recall and precision greatly varies from test to test. Surprisingly the precisions have decreased in some cases (5 out of 51). The maximum decrease in precision was 7% and maximum increase was 100%. The recalls have never decreased in any of the tests and the minimum increase was 0,02% whereas the maximum increase was 37%.

WEB SERVICES DISCOVERY

Another, yet equally important challenge, which needs to be addressed in the Web services area is the discovery of services. In order to use SWS or compose new applications, the appropriate SWS need to be first discovered. A Semantic Web service discovery may be defined as an automated process of finding appropriate SWS

Figure 1. Recall and precision



(and in consequence also service providers) for the needs of a service requestor through a semantic service matchmaking. The semantic matchmaking process operates on the similarity measure that is defined adequately to the available representation of a service and a user goal definition.

There is a number of different semantic-based algorithms that are used to perform matchmaking between a request and an offer for each of the description initiatives already mentioned. They all were successfully implemented in the various research projects. For example the entire group of OWL-S based matchmaking algorithms may be distinguished. Algorithms falling under this category reason on the OWL-S ontology and OWL domain ontologies used to provide semantics of a service. Four levels of similarity are distinguished: exact, plug-in and subsumes and fail e.g. (Paolucci et al. 2002). Some more sophisticated methods were also defined that e.g. propose a matchmaking technique that goes beyond simple subsumption comparisons between a service request and service advertisements offering even more flexible matching by identifying not exact match but the best cover of the request etc.

From a number of approaches the one which got our attention relates to the case-base reasoning. Case-based reasoning (CBR) is an AI method that relies on a case-base of prior experiences and similarity criteria for comparing two situations and retrieving the cases more relevant to the new situation. Therefore, the problem of discovery of Web services can be seen as a problem of matching two cases in a CBR.

The matching of two Semantic Web services can be done either at syntactic or semantic level. As the syntactic matching is a text processing technique, we concentrate on the semantic matching. If we imagine that each of our services is subscribed to an ontology, then we can use the concepts and properties of the ontology in our algorithm for matching. Therefore, we suggest to use our Dempster-Shafer based Similarity (DS-Sim) framework for the discovery of services, especially for matching concepts and properties between two ontologies. Then, our proposal for service discovery is to use one of the algorithms for matching concepts and properties between two ontologies as described in (Vargas-Vera & Motta, 2004; Nagy et al., 2005, 2006a, 2006b, 2007).

In order to describe and share Semantic Web services, different Semantic Web Markup languages like OWL-S[3] or WSMO[4] have been defined as standard ontologies, consisting of a set of basic classes and properties. Usually a service request which can be considered as a query which needs to be answered from different service descriptions. As these service descriptions are expressed using different concepts from ontology, the problem of matching the query and description concepts, properties and constraints has been in fact in the focus of different research communities for several years.

The matching problem was first investigated by databases community where the issue of how different database schemas can be aligned during database integration was the primary interest of the community. A good survey of automatic schema matching approaches is described in (Rahm & Bernstein, 2001). With the emergence of the Word Wide Web and Semantic Web the matching problem remained the same, although the metadata i.e. ontologies that describes the concepts and properties has evolved considerably. Today these ontologies can easily be converted into logical formulas which can be used for reasoning purposes. In spite of the fact that Semantic Web services and data can be described with rich semantics which is based on sound logic formulas, the problem of matching these ontologies (Kalfoglou & Schorlemmer, 2003) still remains unsolved.

Further, the problem of mapping two ontologies effectively and efficiently is a necessary precondition to discover the Semantic Web services. During recent years different research communities have proposed (Choi et. al, 2006) a wide range of methods for creating ontology mappings on the Semantic Web. The proposed methods usually combine syntactic and semantic measures by introducing different techniques ranging from heuristics to machine learning. While these methods perform well for certain ontologies, the quality of the produced mappings can differ from domain to domain depending on the specific parameters defined in the methods e.g. tuning similarity threshold. These limitations are particularly important for Semantic Web services discovery, since in order to find the correct set of services which corresponds to our needs one usually have to browse through multiple domains or sub-domains. Naturally, one may not expect that any mapping method will provide perfect mappings or perform equally well in each and every context, but we can think of a solution which would perform "well enough" for the users in such situations.

Therefore our objective is to come up with a method that:

1. Performs equally "well enough" in case of a domain changes.
2. Does not depend on any fine tuned internal parameters.

Additionally, in the context of Semantic Web services where the service and its parameters are specifically defined one cannot assume having large amount of data samples a'priori for machine learning. Our hypothesis is that the correctness of different similarity mapping algorithms is always heavily dependent on the actual content and conceptual structure of these ontologies which are different even if two ontologies have been created for the same domain but with different purposes. Therefore, from the mapping point of view these ontologies will always contain inconsistencies, missing or overlapping elements and different conceptualisation of the same terms which introduces a considerable amount of uncertainty into the mapping process. Further, the ontology mapping process can definitely be improved by applying background knowledge. The form of this background knowledge can differ depending on the mapping need and varies from WordNet (Giunchiglia et.al, 2006) based solutions to Semantic Web based (Sabou et. al., 2006) knowledge extraction. The use of any kind of background knowledge, however, does not necessarily increase our certainty of the ontology mapping, but it can also introduce further possibilities that can in fact be irrelevant from the mapping point of view. The question is how one can decide what alternatives for the mapping are worth investigating or select as a possible Web service that would help achieving the users' task. This selection between possible alternatives is therefore based on subjective and uncertain information which is extremely dependent on the context of the mapping. We believe that if we can handle this uncertainty properly during the mapping the service discovery process can provide relatively good alternatives for the Semantic Web service composition.

Our Solution to Mapping Problem

In our ontology mapping framework (Nagy et al., 2005, 2006a, 2006b, 2007) we assume that one have only partial knowledge of the domain and can observe it from its own perspective where available prior knowledge is generally uncertain. Our main argument is that knowledge cannot be viewed as a simple conceptualization of the world, but it has to represent some degree of interpretation. Such interpretation depends on the context of the entities involved in the process. This idea is rooted in the fact the different entities' interpretations are always subjective, since they occur according to an individual schema, which is then communicated to other individuals by a particular language. In order to represent these subjective probabilities in our system we use the Dempster-Shafer theory of evidence (Shafer, 1976), which provides a mechanism for modelling and reasoning uncertain information in a numerical way, particularly when it is not possible to assign belief to a single element of a set of variables. Consequently, the theory allows the user to represent uncertainty for knowledge representation, because the interval between support and plausibility can be easily assessed for a set of hypotheses. Missing data (ignorance) can also be modelled by Dempster-Shafer approach and additionally evidences from two or more sources can be combined using Dempster's rule of combination. The combined support, disbelief and uncertainty can each be separately evaluated. The main advantage of the Dempster-Shafer theory is that it provides a method for combining the effect of different learned evidences to establish a new belief by using Dempster's combination rule. In order to illustrate our algorithm and the elements of the Dempster-Shafer theory take the before mentioned example where the requested service is exchanging currency:

```
convert_currency(2500, EUR, USD, marias_
account_number, USD_account_number)
```

Consulting background knowledge we augment our query for the terms convert, currency and account number. Once our extended query is finalized considering concepts and properties from the query we start extracting Semantic Web service descriptions from the available domain. Based on these descriptions we determine that there is a service which interchanges foreign exchange. Our primary objective is to create hypotheses for the possible mappings. In order to demonstrate our algorithm we show the main steps and associated values for the belief functions. The demonstration of the whole state space is not feasible since the number of subsets for a hypothesis with 8 variables is 2^8.

Definition: *Frame of Discernment (Θ)* is a finite set representing the space of hypotheses. It contains all possible mutually exclusive context events of the same kind:

$$\Theta = \{H_1,..., H_n,...,H_N\}$$

In our system this corresponds to the possible mappings between concepts and properties i.e. the base entities that describe the domain e.g. conversion, exchange, currency, foreign exchange etc. Our algorithm iterates through all items in the Semantic Web services descriptors and creates several hypotheses that must be verified with finding evidences e.g.:

H_1(mapping) Query{convert, currency, account number}
↔ServiceDescriptors{interchange, foreign exchange, IBAN number}

H_2(mapping) Query{convert, currency, account number}
↔ServiceDescriptors{exchange, money, bank account}

Further we try to find supporting evidences for the hypotheses.

Definition: *Evidence* is available certain fact and is usually a result of observation. Used during the reasoning process to choose the best hypothesis in Θ. For finding evidences different syntactic and semantic similarity measures (Nagy et al. 2005) are considered as different experts are used which will determine belief mass functions for the hypothesis. We encounter certain evidence e.g. when we find similarity between term "convert" and exchange.

Definition: *Belief mass function* (m) is a finite amount of support assigned to the subset of Θ. It represents the strength of some evidence and:

$$\sum_{A \subseteq \Theta} m(A) = 1$$

where m(A) is our exact belief in a proposition represented by A. The similarity algorithms itself produce these assignment based on different similarity measures. As an example let us consider the query that contains the concept "convert". Based on background knowledge like WordNet we identify that the concept "exchange" is one of the inherited hypernyms of the “convert” so after similarity assessment our variables will have the following belief mass value for the first hypothesis:

- m_1(*Query{* convert, currency, account number *},ServiceDescriptor{* interchange, foreign exchange, IBAN number *}*) = 0.85
- m_2(*Query{* convert, currency, account number *}, ServiceDescriptor{* interchange, foreign exchange, IBAN number *}*) = 0.91

In practice we assess up to 8 inherited hypernyms similarities using different similarity measures e.g. Jaccard, Jaro-Winkler (considered as experts) which can be combined based on the combination rule in order to create a more reliable mapping. In practice we evaluate similarity with different experts for the whole hypothesis set with the size of 2^8. For our example the main associated belief masses are shown in Table 3.

Definition: *Dempster's rule of combination*. Suppose we have two mass functions $m_i(E_k)$ and $m_j(E_{k'})$ and we want to combine them into a global $m_{ij}(A)$. Following Dempster's combination rule:

$$m_{ij}(A) = m_i \oplus m_j = \sum_{E_k \cap E_{k'}} m_i(E_k) * m_j(E_{k'})$$

An important aspect of the mapping is how one can make a decision over how different similarity measures can be combined and which nodes should be retained as best possible candidates for the match. The combined belief mass function which is based on both qualitative similarity and semantic measures and is a coherent view of different expert's assessment of a hypothesis. Once the combined belief mass functions have been assigned the belief can be derived from the available information. The belief combination is computationally really expensive operations since in our case the number of combination operations is 2^8*2^8.

Definition: *Belief* is the amount of justified support to A that is the lower probability function of Dempster, which accounts for all evidence E_k that supports the given proposition A.

$$belief_i(A) = \sum_{E_k \subseteq A} m_i(E_k)$$

As last step we need to select the hypothesis in which we believe in most i.e. we need to select a Semantic Web service which we believe corresponds to our need. In our example the final beliefs for the different hypotheses are:

H_1(convert, interchange)=0.95
H_2(convert, exchange)=0.45

Therefore, we select the service where the descriptor contained:

```
ServiceDescriptor{interchange, foreign
exchange, IBAN number}
```

The belief value for both H_1 and H_2 has been calculated as a sum of variable subsets where the hypothesis and subset contain common variables. Therefore the demonstrated belief values are derived from the available state spaces and are just values to demonstrate this example.

Based on preliminary experiments we have verified (see section validation of the service discovery and trust) that our mapping approach for Semantic Web service can improve the quality

Table 3.

	Expert1(m_1)	Expert2(m_2)	Expert3(m_3)
H_1	0.85	0.91	0.99
H_2	0.33	0.43	0.45

of the discovery on the Semantic Web. However, it poses numerous challenges as well e.g. if the service is described only with natural language text or the background knowledge cannot describe properly the domain.

Further a problem could arise when two semantic services have the same belief value of **H** then the system should use a heuristic to decide which one can be used. This can be seen as the old problem of conflict resolution in rule based systems. In our view, heuristics is necessary in this case since there is no easy way to create an another method that would provide the better choice then the first one, especially considering the fact that using one kind of calculation we have reached equality between two services. The heuristics has to consider different aspects of the Web service e.g.:

- Who is the publisher?
- When was the service published?
- How well the service is described in its repository?
- What is the difference between some reference rates and the provided service?
- How much do we need to pay for the service offered by the service provider?

Additionally, this heuristics can also be ranked according to their importance. As an example assume that we have found two services for the exchange rate conversion. The first is offered by a bank and the second is by a financial services company. Based on the publisher information we would normally choose the service of the bank because we think is more reliable, however it is really important for us how much we can lose during the conversion. Based on the European Central Bank's reference rate we realise that choosing the financial services company we would be better off after conversion therefore we choose the second service.

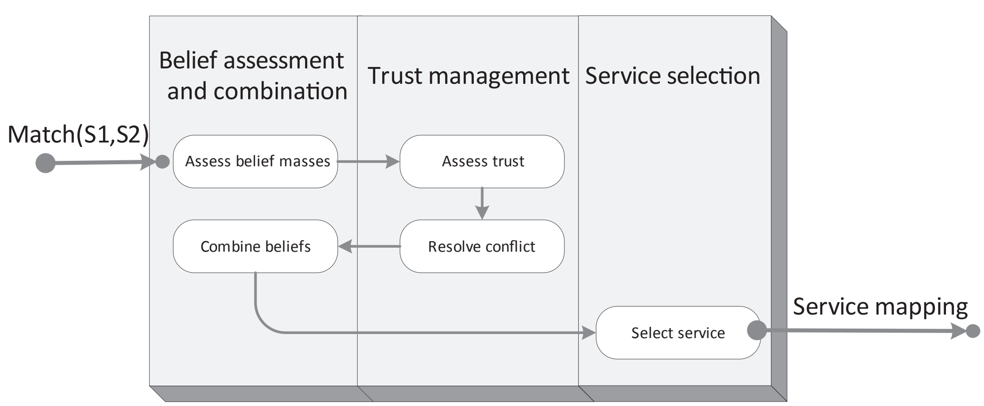
Further there is also the possibility that using our matching algorithm we do not find any service that would match our need. This can happen if the mapping algorithm assigns all belief masses to the empty set therefore, indicating ignorance on the correctness of the mapping. In this case the mapping cannot be carried out and the user needs to indicate his/her choice between the available services.

An algorithm for matching Semantic Web services called Matching-SWS (Figure 2) is outlined below.

Algorithm

Match(S1,S2) where **S_1 and S_2** are Semantic Web service:

Figure 2. Matching SWS



1. Compute masses m_i.
2. If there is conflict between the assessed hypothesises use the voting model to assess trust.
3. Combine masses using Dempster-Shafer theory of combination and obtain H_i.
4. If mappings ($H_i = H_{i+1}$) use heuristic to decide for one H_i.
5. If no matching was found i.e. all variables has been assigned to the ignorance provide the user all the available services so the user can decide which one to choose.
6. Use the selected services as bases and assess trust based on the voting model in order to select the one which needs to be used for the composition.

Finally, to our knowledge Dempster-Shafer has not been used in Semantic Web services as a way to discover Semantic Web services. It has been investigated in the context of information fusion (Yu et al., 2005) where several successful applications have been published. For the ontology mapping problem it has started to be evaluated in different context, but to date Bayesian approaches are dominant for this problem. The main disadvantage of the Dempster Shafer theory is it's the scalability for large domains since the belief combination is computationally expensive operation. Our ongoing research is devoted to this problem since both for ontology and Semantic Web services' mapping this is the key obstacle that needs to be resolved for further applications.

COMPOSITION OF SERVICES

The process of developing a composite service may operate on composite as well as on atomic services. Within the typical process of service composition a composer tries to solve the user requirements by composing the services advertised by the providers. Usually, the composer takes the functionality of service to be composed as an input and as outputs returns the process model describing the composite service. The process model contains a set of selected atomic services, as well as definition of a control and data flow among them.

Although the composition process is quite well supported by a number of different initiatives, the achieved results still leave a space for improvement. The algorithms used to perform automatic composition range from those using workflow techniques, to those taking advantage of the achievements from the AI area such as: situation calculus (e.g. (McIlraith & Son, 2002)), rules (Ponnenkanti & Fox, 2002), theorem proving, HTN (Wu et al. 2003) or STRIPS based solutions (Rao et al. 2004). The algorithms used to perform SWS composition differ in terms of their precision and quality of the returned results, efficiency, complexity, performance as well as the form (e.g. BPEL process description) and the scope of the returned result (whether the generated plan is ready to be deployed on the execution engine and then executed, consists only out of service specifications and service implementations still need to be selected to the plan generated, the control flow is specified but the data flow still needs to be defined etc.).

In our view an elegant solution to the composition of Web services is the one which sees the problem of composition as a planning problem (Drumm et al., 2007; Meyer, 2006). However, it has some important limitations i.e, the complexity of algorithm and there is not guarantee that the result might be found as the approach uses enforced hill climbing algorithm. The second problem of this method is that it is not possible to create intermediate variables.

Therefore, although a number of different approaches exist, the problem of composition has not been solved and more research work on composition of Semantic Web services is needed. Some inspiration may be taken from the program transformation area as is shown further in this section.

The presented idea of composition comes from early days of AI where researchers were interested in combining programs (flows of control) in an integrated manner for functional programming (Burstall & Darlington, 1977) and also for logic programs (Vargas-Vera, 1995; Vargas-Vera and Robertson 1994). Let us define a composition of Semantic Web services in the context of program transformation as a tight integration of the specification/code of services. The composition operator is a binary operator that takes two services at the time and without a lost of generality the composition can be performed number of times.

Web services can be seen as functions in Functional Programming Languages. Complex services can be obtained by combining simple services. In the simplest case, composition can be reduced to compose functions like in mathematics. If we take this perspective, then a semantic service is a function with parameters, preconditions & effects, inputs and outputs. However, the composition of services can be more complex. Semantic services can be described as logic statements. Then the composition problem can be seen as merging logic statements with constraints. The work reported in (Vargas-Vera, 1995) describes an automatic system which combines logic programs using program histories. This approach could be adapted to the composition problem since each service can be seen as a logic program and we also have histories for each service describing its functionality and restrictions imposed by the service creator. The composition problem is explained by means of an example in the following section.

We envision the composition of Semantic Web services which will be generated on the fly using either combining specifications (Fuchs, 1994) or combining the code associated to each service using services' descriptions which guide synchronisation of the flows of control. Our vision of composition system is having a library of simple services and to produce more complex services by program composition or by composing specifications of the services. Then, the synchronization of flows of control is defined in a Joint Specification.

Composition Scenario

Maria has just found a new hobby and decided to start investing money through online channels. During her research on available platforms that could be used to do that she discovered that there is a solution that allows for service composition. In addition, there exists a set of services that support financial domain. These services provide a wide range of granularity and functionality, from the simplest ones such as currency converters and stock quotes tickers to the more advanced such as services providing trend for user investments. Of course, Maria wants to use only trusted services.

Lets us consider an investment scenario where Maria wants to prepare a custom application made out of the available Web services. She is aware that not all of the functionalities she wants to employ are readily available. Nevertheless, services are prepared in a manner that allows for their composition.

Maria tries this solution and starts with a simple task of creating a service that will allow her to invest a spare sum of money. The workflow is composed of the following tasks:

1. Checking the account balance in order to asses whether there is superfluous amount of money available.
2. Checking the currency exchange rates between euro and US dollar in order to establish whether investment in arbitration game is feasible and brings profits.
3. Assessment of the trend of euro and dollar exchange rates.
4. Risk analysis of the investment.
5. Confirmation of the transaction.

This is a simple scenario, which can be split by a broker into several simple Semantic Web services such as check-account-balance, currency-exchange-rate, trend-analysis, risk-analysis, convert-currency, and investment-trigger. A formal specification for Maria's request is shown below. The request is written in Prolog language.

```
request :- check _ account _ balance(marias _ pin _ numer, marias _ account _ number),

currency _ exchange _ rate(EUR, USD, 02-10-2007),trend _ analysis(USD, 02-08-2007, 02-10-2007),

risk _ analysis(USD),

convert _ currency(2500, EUR, USD, marias _ account _ number, USD _ account _ number),
confirm _ investment(marias _ activation _ key)
```

Imagine the idealistic scenario where our library of services contains already two services which can be used to build a new service on the fly. The initial library of services is not meant to be complete.

```
investment _ situation(currency,start _ date,end _ date)
:-
trend _ analysis(currency,start _ date,end _ date),
risk _ analysis(currency).
```

The second service is perform_arbitration_ game defined as follows:

```
perform _ arbitration _ game(PIN, account _ number1, account _ number2, currency1, currency2, date, key) :-

Check _ account _ balance(PIN, account _ number1),

currency _ exchange _ rate(currency1, currency2, date),

convert _ currency(amount, currency1, currency2, account _ number1, account _ number2),

confirm _ investment(key).
```

Please note that variables currency from the first service and currency2 from the second service relate to the same concept.

Combined Service

The composition can be specified by means of a joint specification where the synchronisation of the two flows of control is requested:

$$JS \rightarrow S1 \circ S2$$

where S1 and S2 are services:

```
proceed _ with _ arbitration(currency1, currency2, start _ date, end _ date, date, PIN, account _ number1, account _ number2, key)
→
investment _ situation(currency,start _ date, end _ date) and perform _ arbitration _ game(PIN, account _ number1, account _ number2, currency1, currency2, date, key).
```

The combined program produced by using the above **JS** is shown as follows:

```
proceed _ with _ arbitration(currency1, currency2, start _ date, end _ date, date, PIN, account _ number1, account _ number2, key)
:-
trend _ analysis(currency2, start _ date, end _ date),
risk _ analysis(currency2),
check _ account _ balance(PIN, account _ number1),
```

```
currency _ exchange _ rate(currency1, currency2, date),
convert _ currency(amount, currency1, currency2, account _ number1, account _ number2),
confirm _ investment(key).
```

In our working example, we can observe that we are dealing with a hybrid definition of Semantic Web services. Each service appears to have logic and a numerical component that need to be satisfied. Therefore, we could think in dividing our HKB (Hybrid Knowledge Base) in two components, the first one will contain logical statements and axioms associated to them. In turn, the second one should contain numerical constrains which need to be solved using a constraint solver. A general framework using a several distributed reasoners which merge their results together (Knowledge fusion), like the one presented by Bo Hu (Bo, 2003) on Fusion knowledge, is to be used. Bo Hu's approach divides a HKB into smaller components each containing the homogenous knowledge that can be processed by a different specialized reasoning system. Results of the inferences are then consolidated. This solution should alleviate the problem that reasoning is a time consuming task.

Coming back to our working example, it is worth to note that the description of each service is needed in order to synchronise the control flows. If information in the descriptions of services states that the flows of control cannot be synchronised as requested the composition cannot be performed. A mathematical property that can be guaranteed after the composition is that the meaning is preserved i.e. the solutions generated for each individual service are given to the resulting composed service. This is guaranteed if during the composition process only operations that preserve the meaning are used. Examples of such operations that preserve meaning are for instance fold/unfold (replacement of a procedure call by its definition) operations (Tamaki & Sato, 1984).

Validation of the Composition Services System

Our composition system has been tested on composing logic programs, refers to the work reported in (Vargas-Vera 1995). This composition system was written in Sictus Prolog running in a windows and Unix operating system. The properties observed in the composition system are the following:

The combined services generated automatically are different from the ones that programmers produced. This is because there is an automatic optimization of variables in the code generated automatically and also by transforming the services using the fold/unfold operation the code of the original services looks rather different. However, the solutions generated for each individual service are given to the resulting composed service answers. The latest as we already mentioned is guarantee by the use of operations which preserve meaning for instance, fold/unfold operations.

The specification defined by users is validated automatically by the system using the history of each service in order to ensure that the composition is feasible. If the composition is not feasible then a message is displayed to the user telling that the services cannot be combined.

In our first implementation the join specification needs to be provided in pseudo language (like the one shown in example) and then internally is transformed into First Order Logic expressions. However, in future the request (of the investment scenario) could be submitted by a user in natural language. It could then be processed by a natural language parser that would map it into first order logic predicates.

Finally, a comprehensive use of the composition system and uses of "program history" in applications such reverse engineering and Prolog Explanation system can be found in (Bowles et al. 1994). Furthermore, a program generator for simulation models in Ecology using our composition system is reported in (Castro 1994).

FUTURE WORK

In the future research we would like to investigate how our proposed approach can be applied in the context of Enterprise Application Integration (EAI) which still requires human interaction to a large extent e.g. the human programmers have to manually search for appropriate Web services in order to combine them in a useful manner. This is important since the majority of IT development efforts of different organisations is still focusing on how to find, extract, and interpret information from highly heterogeneous systems. Our long term objective is to provide the possibility of helping people to develop and to manage services more efficiently and effectively on the Semantic Web. Our proposed agent based solution for service discovery is especially promising considering the fact that the Semantic Web is a web of distributed knowledge bases, and agents can read and reason about published knowledge with the guidance of ontologies. Further the reasoning capabilities of these agents are limited by the "lack" of proper information which is an obstacle for creating applications that fulfil their missions autonomously and intelligently.

CONCLUSION

The main contribution of this chapter is to provide new insights to three challenging problems that in our view they still not completely solved in the area of Semantic Web services. Firstly, we suggest a solution to the composition problem. Our method is based on program transformation of specification/code of each of the two services participating in the composition. The composition makes use of services descriptions to guide the whole process. This solution is not expensive in time complexity since we do not need to build the planning graph as in solutions based on planning algorithms. For the discovery of Semantic Web services, a solution based in Dempster-Shafer theory of evidence is suggested. We also, outline a model to assess trust based on fuzzy voting model. To our knowledge the fuzzy voting model has not been used to solve the problem on trust on Semantic Web services. Furthermore, Theory of Evidence has not been applied to the problem of discovery of Web services in the way presented in this chapter. Therefore, we believe that an agent framework (like the one suggested in this chapter) fits nicely with two of the problems in Semantic Web services namely discovery and trust assessment.

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KEY TERMS AND DEFINITONS

Dempster-Shafer Theory of Evidence: A statistical uncertain reasoning model which uses belief functions for combining separate pieces of information (evidence) to calculate the probability of an event.

Fuzzy Voting Model: A model which used different voters for fuzzy sets in order to determine the membership value.

Service Discovery: The capability of automatically identifying a software service in Internet which matches the service request criteria.

Services Composition: In a Service Oriented Architecture (SOA) the operation which aggregates or combines small services into larger services

Trust: The ability to assess the credibility of source information based on different criteria

Unfold and Fold Operations: Techniques for source level program transformation. Those operations allow to transform clear but inefficient programs into more efficient equivalent programs.

ENDNOTES

[1] http://www.daml.org/services/owl-s/1.1/related.html#wsmo

[2] http://oaei.ontologymatching.org/

[3] http://www.ai.sri.com/daml/services/owl-s/1.2/

[4] http://www.wsmo.org/

Chapter III
A Service Oriented Ontological Framework for the Semantic Validation of Web Accessibility

Rui Lopes
LaSIGE, University of Lisbon, Portugal

Konstantinos Votis
Pattern Recognition Laboratory, University of Patras, Greece
Informatics and Telematics Institute, CERTH, Greece

Luís Carriço
LaSIGE, University of Lisbon, Portugal

Spiridon Likothanassis
Pattern Recognition Laboratory, University of Patras, Greece

Dimitrios Tzovaras
Informatics and Telematics Institute, CERTH, Greece

ABSTRACT

The Web serves as the principal mediator for information sharing and communication on a worldwide scale. Its highly decentralized nature affords a scale free growth, where each endpoint (i.e., Web site) is created and maintained independently. Web designers and developers have the onus of making sure that users can interact without accessibility problems. However, coping with users with disabilities poses challenges on how to ensure that a Web site is accessible for any kind of user. When (and if) this is done, designers and developers do it in a post-hoc way, (i.e., verify and tweak Web sites according to guidelines such as WCAG). In this Chapter the authors present SWAF, the Semantic Web Accessibility

Framework, a base framework for supporting the integration of accessibility services into Web design and development processes. SWAF affords both tailoring accessibility to user needs and specifying the semantic validation of accessibility guidelines in different application situations.

INTRODUCTION

The increasing adoption of technologies from users puts the Internet in a central spotlight. The Web, as its major application, is accessed and interacted by users at constantly increasing pace, allowing them to quickly seek information, interact with their peers through social networks, or perform transactions from the comfort of their homes. For this reason, the way information is structured and presented is critical for the success of accessing it.

However, users have their own specific characteristics (e.g., abilities, impairments, preferences, knowledge). Consequently, the accessibility of each piece of information – such as a Web page – can differ significantly from user to user. While often dismissed in the Internet realm and, more specifically, on the Web, people with disabilities are not just a small population minority. If one takes into account people with mild disabilities, the slice of the population that requires some sort of software-based accessibility ramp is of the uttermost importance.

The most important way to mitigate this problem is making sure that information providers (ranging from the individual to large corporations) do not overlook such accessibility issues. Internationally recognized organizations such as the World Wide Web Consortium (W3C, n.d.) play a critical role on helping information providers to cope with accessibility. Traditionally, this goes in the form of specifying accessibility-centric best practices, guidelines, and vocabularies to augment already existing Web languages.

Evangelization of accessibility practices, coped with the progressive intertwining of accessibility features in Web languages has brought Web accessibility more close to information providers. Consequently, each day, Web accessibility is gaining awareness. Guidelines such as WCAG, the Web Content Accessibility Guidelines (Chisholm, Vanderheiden, & Jacobs, 1999), are being followed more often, leading more users with disabilities to have access to information without barriers. In order to be so, these guidelines are presented as straightforward as possible, geared towards the largest set of Web designers and developers. However, mostly due to financial, human resources, and technological expertise problems, several companies (and individuals) totally dismiss the adequacy of Web sites to the different requirements of accessibility-dependent audiences, despite the fact that legislation is being pushed in several countries, in order to promote the rights of people with disabilities.

The dismissal of accessibility from information providers leverages the fact that such guidelines and standards for accessibility have inherent problems. Since they are specified in such a way that they require manual inspection of their conformance, developers have an increased effort on coping with accessibility issues. Furthermore, by being informally described (i.e., in natural language), they tend to lead to different interpretations from developers and accessibility experts and, for this reason, different and incoherent ways to ensure that a given Webpage is accessible.

When Webpages and Websites require an additional effort of supporting more specific and fine-grained audiences, the development of accessibility-centric solutions becomes cumbersome. Guidelines have an implicit assumption of which audiences they target to (and more often than not, in a very informal and loose way). Typically, these are often geared towards people with visually impairments (e.g., different kinds of blindness).

The way users from this audience interact with a webpage is also left implicit, but often assumed to include specific devices (e.g., screen readers). This leads to a lack of understanding what is the role of guideline checkpoints for each user and device characteristic they are tackling, thus posing more difficulties on developers on how to tackle fine-grained accessibility analysis and consequent development of accessible Websites and Webpages. Consequently, software developers need to have a conceptual framework in which to situate disabled-related guidelines, which they often do not have due to lack of experience with disabled people and their technologies.

This Chapter proposes SWAF (Semantic Web Accessibility Framework) as an ontological framework targeted to accessibility-aware Web design and development processes. This will enable large organizations, small enterprises, or even individuals (developers, designers, etc.) to produce Web sites of superior accessibility and usability, accompanied with appropriate measures, technologies and tools that improve their overall quality. This ontological framework can be used to answer questions about common accessibility standards, user abilities and disabilities, as well as about the technical capabilities and constraints of appropriate assistive devices, thus forming the context for semantic validation of Web accessibility. In This Chapter we present the general overview of the framework, and detail it in the context of existing Web accessibility standards, in order to facilitate accessibility assessment of Web sites across different audiences.

BACKGROUND

Designing for people with disabilities is becoming an increasingly important topic for a variety of reasons, but especially due to recent legislation in many countries that aims at promoting and enforcing the rights of people with disabilities. A number of philosophies and methodologies have been developed to support this process.

Firstly there has been the development of the *universal design*, *design for all*, and *universal usability* philosophies, as detailed by Shneiderman (2000). Many developers worry that they will be expected to produce a system that will be usable by every user, regardless of their abilities, and that they might have to seriously compromise their overall design to achieve this aim. Clearly this would be in no-one's interest. With the increasing ability to personalize interfaces to meet the requirements of different users, this is not necessary.

Secondly, there have been numerous sets of guidelines to help developers produce systems that are accessible and usable by people with disabilities. These range from very general guidelines to the very specific guidelines for Web user agents (e.g., Web browser), authoring tools, and content creators. However, it is not clear whether providing guidelines is an effective method for ensuring usable designs, since these might be differently interpreted by developers and designers. Developers need to have a conceptual framework in which to situate disabled-related guidelines, which they often do not have due to lack of experience with people with disabilities and assistive technologies.

Consequently, even if people with disabilities want to be independent and do things for themselves by themselves, unfortunately, most Web sites and Web applications are not fully accessible today. There are a number of reasons for this as explained below:

- The Web has evolved over the latest years, and the importance of accessibility has only begun to be appreciated and encouraged in recent years. Older solutions are unlikely to be fully accessible (or accessible *at all*). Making an existing Web site accessible is often very difficult and expensive, in much the same way as making an existing building wheelchair-friendly can be very difficult, as well as un-aesthetic. Although efforts should be made to improve accessibility, it will be typically easier to do so during a major refurbishment.

- Many developers and, more surprisingly, designers, are not aware of the importance or need for accessibility. Consequently, new developments are being built in blissful ignorance, as many of them do not have the necessary knowledge or skills for building accessible Web sites.
- Some market stakeholders believe that creating accessible solutions will have prohibited costs and, at the same time, make them boring and less attractive to the majority of users (read: the non-impaired).
- Existing design and development tools give little out-of-the-box assistance in most cases or, at worst, make it impossible to develop accessible solutions.

Accessibility Standardization

Up to now, there are several initiatives concerning guidelines, tools and technologies for Web accessibility. The major steering body for accessibility is the World Wide Web Consortium and its Web Accessibility Initiative (WAI, n.d.). WAI has three main tracks: the Web Content Accessibility Guidelines (Chisholm et al., 1999), the Authoring Tool Accessibility Guidelines (Treviranus, Richards, Jacobs, & McCarthieNevile, 1999), and the User Agent Accessibility Guidelines (Jacobs, Gunderson, & Hansen, 2002). The activities of W3C and WAI are the result of collaboration of groups and organizations from different countries, like the TRACE Research and Development Centre (TRACE, n.d.), which is responsible for compiling and publishing the original set of Web accessibility guidelines that provided the backbone of WAI guidelines.

Apart from the guidelines, there are also legislative and standards initiatives for accessibility. Strong governmental support in the Unites States has led to initiatives such as the Americans with Disabilities Act (ADA, 1990). The UK equivalent is the Disability Discrimination Act (DDA, 1995) amended in 1999, and now extended to the Special Educational Needs and Disability Act (SENDA, 2001). The rulings of ADA are also extended to Section 508 of the US Rehabilitation Act (Section 508, 1998). This legislation defines processes and the monitoring role of the US federal government in the procurement of electronic and information technology. Regarding accessibility, it states that regardless of medium, government must ensure that disabled federal employees and members of the public have the same accessibility as non-disabled members. Where accessibility is not present, government is directed to provide alternative means. Although, Section 508 is intended for the US federal government, many organizations and software houses worldwide are making efforts to address its mandate, which puts it as a central destination for Web accessibility verification practices.

Major standards bodies such as the US Human Factors and Ergonomics Society (HFES, n.d.) are engaged in furthering the accessibility drive. Their efforts extend to features and functions of the operating systems, drivers, application services, other software layers upon which the application depends and applications that increase accessibility with a general aim of reducing the need for add-on assistive technologies. The International Standards Organisation ISO/TS 16071:2003 (ISO 16071, 2003), Ergonomics of Human–system Interaction also provides guidance on accessibility for HCI interfaces. The guidelines were designed to complement general design for usability covered by related standards on usability.

As thoroughly discussed in this Section, there exist several initiatives and standardization bodies concerning guidelines, standards and methodologies for accessibility assessment that can be effectively applied in the context of Web technologies. It is also a fact that the existing standards and best practices concerning accessibility are in most cases confusing and incomplete (Lopes & Carriço, 2008). Therefore, developers need to have a conceptual framework in which to situate Web accessibility-related guidelines, which they often do not have, due to lack of experience on technologies for the disabled. The fundamental aspect of pushing forward accessibility on Web site design and development practices is to provide concrete and objective rules and standardized guidelines that homogenize accessibility assessment and quality control procedures. Consequently, existing software that aims at assessing accessibility based on such guidelines (a thorough list of such software packages can be found at http://www.w3.org/WAI/ER/tools/complete) will provide incomplete and overly generalized answers to whether a given Web page or Web site is accessible.

While it is clear that determining what truly represents accessibility in the customer's view can be elusive, it is equally clear that the number and frequency of problems and defects associated with a Web site are inversely proportional to its accessibility. Software problems and defects regarding accessibility are among the few direct measurements of software processes and products. Such measurements allow us to quantitatively describe trends in defect or problem discovery, repairs, process and product imperfections, and responsiveness to customers. Problem and defect measurements also are the basis for quantifying several significant software accessibility attributes, factors, user characteristics and criteria.

Although the advantages of measurement in the Web site design and development process are indisputable, the popularity of measurement methods, within accessibility terms, in practice is rather limited (McGarry, 2002; Varkoi, 1999; SEI, 2006). Very often difficulties arise when trying to focus the measurement. In many cases it is unclear what should be measured and also how the measurement data obtained should be interpreted (Habra, Abran, & Lopez, 2004; Kulik, 2000). Choosing the correct measurement entities and ranking the importance of measurement accessibility indicators is still a challenging task (Neely, 1998). Despite the difficulties, metrics such as those defined by Vigo et al. (2007) provide insightful cues on how to approach the problem of measuring the accessibility of Web sites, based on WCAG standards. This will help designers and developers to have a better (and measurable) understanding of accessibility on Web technologies.

Ontologies for Disability and Accessibility

There are several efforts towards the direction of the definition of ontological concepts and taxonomies for people with disabilities. These efforts try to cover adequately the personal requirements of the end users, including the person's disabilities and individual preferences.

A central reference for classifying disabilities concerns the World Health Organization's International Classification of Functioning, Disability and Health (ICF, n.d.), particularly tailored to impairment qualification on medical diagnosis tasks. Consequently, it stresses just on profound disabilities, leaving out several impairments such as color blindness. Obrenovic, Abascal, & Starcevic (2007) have leveraged ICF concepts into an accessibility description framework to help designers and developers discuss and describe multimodal interaction issues.

Gruber (1993) proposes an ontology architecture that tries to cover comprehensively the situation of persons with special needs for the purpose to utilize this information for customization of their home environment's services is proposed. This approach tries to combine contextual information like personal aspects (e.g., disabilities, preferences), technical aspects (e.g., equipment, services, network) and natural aspects (e.g., location, time) in a way that the smart home environment's services can adapt to the end user more or less automatically while keeping the user in control.

Several pre-existed ontologies for supporting context-aware smart environments, like CoOL (Strang, Linnhoff-Popien, & Fank, 2003), COBRA-ONT (Chen, Finin, & Joshi, 2003), CONON (Wang, Zhang, Gu, & Pung, 2004), SOUPA (Chen, Perich, Finin, & Joshi, 2004), and UbisWorld (Heckmann, 2005). All these ontologies share common concepts and structures. From these, SOUPA incorporates most concepts of previously defined ontologies and seems to be the most elaborated one of the listed ontologies. However, all of them still lack a specific support for persons with special needs towards a comprehensive specification.

A major contribution to the field of ontologies for disabilities was made from EU's FP6 ASK-IT project (ASK-IT, n.d.). Within ASK-IT, ontology modeling and mapping produced a collection of shared sub-ontologies, which reflect mobility impaired people user needs, and relationally map available services to them. These needs were initially specified and afterwards, the ontology authoring procedure was based on content models derived from these specifications. It also defines the interrelationships that may rationally hold between user groups of people with disabilities and various user information needs of different content types, including multi-modal content.

The potential for applying ontologies in end user diverse environments and their potential for promoting a unified methodology is exemplified by the ontology devised by Uschold, King, Moralee, & Zorgios (1998). This ontology includes lexical and relational terms based on the idea of the activity (anything that involves doing) linked to the doer or operative unit which may be a person, organizational-unit or machine said to have capability and on occasion possessing roles in respect of an activity such as activity-owner.

Wooldridge, Jennings, & Kinny (2000) also adopted a role-oriented analysis as a natural step in the Gaia methodology. Another example, the Framework for Distributed organizational Memories (Abecker et al., 2001), describes the various actors in domain ontologies according to their goals, knowledge and competencies. Van Heijst, Schreiber, & Wielinga (2000) also capture the role of an ontology in the accessibility requirements specification process, where they illustrate how a methodology can extract semantics from an ontology at different levels of depth to produce conceptual models.

As stated by Masuwa-Morgana & Burrell (2004), an ontology for accessibility requirements could be centered in a similar fashion, on an activity such as a use case in which there are doers (people and access technologies). The only difference is that in that ontology for accessibility requirements there would be a need to reliably furnish (with clear identities and essence) descriptions of doers-people and patterns of doer-access technology and subsequent competencies and demands on interface design and interaction styles. Abecker et al. (2001) propose "AccessOnto" as an accessibility requirements theoretic ontological framework consisting of four components: a requirements elicitation subsystem, an inference engine, a requirements explanation subsystem and an accessibility knowledge base. It has the intention of extrapolating a requirements specification based on rules extracted from the accessibility knowledge database based on end user traits data elicited by the end user.

The aforementioned ontological frameworks emphasize the fact that there is little coupling between ontologies regarding accessibility and disabilities, and Web accessibility assessment practices (as they tend just to frame different accessibility scenarios). Our proposed ontological framework will be based on existing ontological models, as well as in best practices for ontology engineering, affording the design of a multi-layer knowledge base for accessibility and disability requirements mapping into Web accessibility verification procedures that can provide support for the requirements and needs of different accessibility-centric user groups.

SEMANTIC WEB ACCESSIBILITY FRAMEWORK

For many people, in particular for groups at risk of exclusion, the complexity and lack of accessibility and usability of Web sites is a major barrier to information access. We respond to this challenge by proposing a tailored accessibility assessment ontological framework, the Semantic Web Accessibility Framework (*SWAF*), which affords the specification of user characteristics and their requirements, and associate them to specific accessibility assessment procedures.

The main goal of SWAF is to provide support for the formal and unambiguous definitions of accessibility domains, as well as the possible semantic interactions between them. We have specified SWAF to be integrated into accessibility verification environments (e.g., authoring tools, Web accessibility evaluators, integrated development environment - IDE). This will establish a common vocabulary for exchanging and describing the complex information that is related to accessibility assessment of Web sites. The framework aims to formalize conceptual information about:

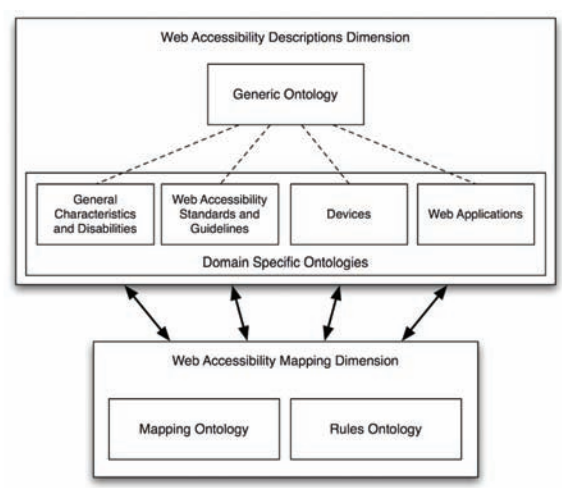
- The *characteristics* of users with disabilities, devices, applications, and other aspects that should be taken into account when describing an audience with disabilities and developing tailored Web sites.
- Web accessibility *standards* and associated checkpoints.
- Semantic *verification rules* to help describing requirements and constraints of audiences, and associating them to accessibility checkpoints.

In order to cope with these goals, the framework must comply with the following requirements:

- To be as *formal* as possible, thus providing all the necessary definitions in a concise, unambiguous, and unified form;
- Provide information that can be *easily processed* by software applications and integrated into accessibility validation processes;
- *Easily implemented* by software developers and other users involved in the software development process of Web accessibility tools.

One of the main issues in designing and developing the proposed framework was to make it maintainable and extensible, while assuring model consistency within the framework. Therefore, we have separated SWAF into two distinct dimensions: *Web Accessibility Descriptions*, and *Web Accessibility Mapping*, as depicted in Figure 1. Each dimension is further explained in the following Sections.

Figure 1. Semantic Web accessibility framework



Web Accessibility Descriptions

The first dimension provides constructs to describe different Web accessibility concepts (WAD). To explore the differences and synergies between Web accessibility fields, and to support the inclusion of external concepts from other domains, the WAD dimension cuts the concept space into a Generic ontology and a set of Domain Specific ontologies, as detailed next.

Generic Ontology

The Generic ontology forms the core ontology and describes top-level entities and concepts that are critical for the semantic validation of Web accessibility. Thus this ontology provides more abstract and generic knowledge such as general characteristics and disabilities of users, devices, Web accessibility standards, and other main aspects that constitute the basis for applying accessibility-based approaches into the accessibility validation field.

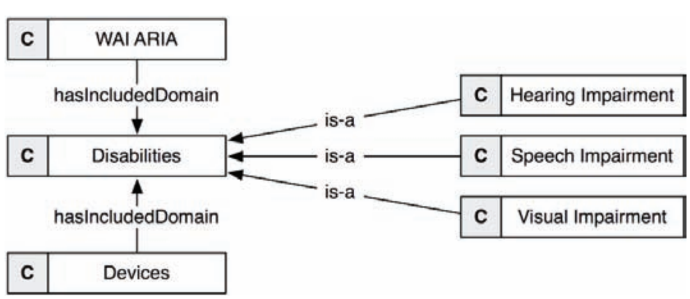
Domains are specified in classes and subclasses providing a hierarchical model representing all the knowledge fields that are necessary for the accessibility validation. There are also a number of properties denoting the relationship between classes. A part of the Generic Ontology is depicted in Figure 2. This partial snapshot of the ontology consists of the main classes *Disabilities*, *WAI_WCAG* and *Devices*. The *Disabilities* class contains three subclasses: *HearingImpairment*, *SpeechImpairment*, and *VisualImpairment*. There is also a property of the type *hasIncludedDomains* denoting that the classes *WAI_WCAG* and *Devices* include disabilities.

Domain Specific Ontologies

To better illustrate how the Generic Ontology can cope with real scenarios within the Web accessibility domain, we defined several domain specific ontologies and integrated them into SWAF. These domain specific ontologies (DSO) cope with the key aspects that are part of the integration of Web accessibility into Web design and development processes. This way, ontologies are able to represent a more detailed description of their corresponding domain, fruitful for extensibility scenarios (e.g., using Web accessibility validation ontologies in Mobile Web tailoring scenarios). The purpose of distinguishing a generic ontology from the domain specific ones is to facilitate the extension of SWAF to different application domains (e.g., outside the scope of Web related accessibility guidelines and applications).

Each DSO uses the basic entities of the Generic Ontology to describe the specific concepts and structures that are needed for the semantic validation of Web accessibility. This ensures that all terms and their relationships utilized by each accessibility approaches separately are included in the generic ontology scheme. To cover every

Figure 2. Excerpt of the generic ontology



spectrum of applicability of accessibility assessment procedures, there should exist a corresponding domain specific ontology. Next, some of these ontologies are described.

General Characteristics and Disabilities Ontology

As discussed previously, validating accessibility is a process that must cope with user's disabilities, as well as with each individual's preferences. Thus it is of great importance to consider the users' personal capabilities determined by her/his impairments. Consequently, different categories of disabilities (based on the ICF categorization) are incorporated within this ontology, such as:

- *Visual impairments.* Disorders in the functions of the eye ranging form reduced capability of sight, color-blindness to total disability to see (e.g., cataracts or retinal detachment).
- *Hearing impairments.* Disorders in perceiving audio, ranging from problems in understanding normal conversations to complete deafness (e.g., high or low tone hearing loss).
- *Specific learning impairments*. Disorders manifested by significant difficulties in the acquisition and use of listening, speaking, writing, reading, reasoning, or mathematical abilities.

The degree of the users' disabilities determines the extent of Web accessibility concepts and guidelines that must be followed by Web sites (e.g., enlarging font sizes) to suit to users' computing environment and usage context.

To afford the specification of such concepts, the General Characteristics and Disabilities Ontology provides a set of supportive constructs at a meta-level (e.g., generalizations). The main concepts are *User* and *Characteristic*. A *hasCharacteristic* property maps characteristics to users, thus affording the description of users. We have further detailed several meta-concepts under the *Characteristic* umbrella. Since this ontology is tailored to accessibility scenarios (in the broad sense of *ability to access*), we introduced a small taxonomy to afford the classification of *Characteristic* instances. This taxonomy distinguishes *Ability*, *Disability*, and *Preferences*, as well as more specific concepts (e.g., *SensorialAbility* or *LearningDisability*). Accordingly, the *hasCharacteristic* property has been refined to cope with the three main domains.

Lastly, to afford a semantic extensibility and proper categorization of user characterization concepts, we defined an *extendsCharacteristic* property that maps between *Characteristic* instances in a taxonomical way.

All of these concepts provided by the ontology strive for a strong and expressive tool for Web designers and developers to describe and characterize their target users in a clean, thorough way, along the line of the descriptive ontologies devised by Obrenovic et al. (2007). Furthermore, by affording an extensible way of organizing user characterization concepts independently from users/audiences, Web designers and developers can build their own taxonomies with respect to their particular needs without being tied to a particular way of thinking and organizing information typical of stricter solutions.

Web Accessibility Standards and Guidelines Ontology

This domain ontology covers the main evaluation guidelines for Web accessibility assessment devised in the Web Accessibility Initiative, such as WCAG. These guidelines are divided into checkpoints and arranged based on their impact and priority. The combination of these factors is given in levels (none, A, AA, or AAA), depending on their evaluation outcomes. For instance, to claim conformance on level A, all the priority one checkpoints must be satisfied.

The table presented in the Appendix of this chapter reproduces the most fundamental Priority 1 checkpoints, which have been incorporated into this ontology. It is important to notice that some of these checkpoints may be irrelevant in different situations. Certain Web site instances might not have markup that can trigger accessibility problems. Furthermore, they might also be irrelevant based in the particular constraints and preferences of a user (from an accessibility point-of-view).

In particular, the checkpoints 1.2 and 9.1 apply (only) if image maps are used, the checkpoints 5.1 and 5.2 apply if tables are used, the checkpoint 12.1 applies if frames are used, the checkpoint 6.3 applies if applets or scripts are used, and finally the checkpoints 1.3 and 1.4 apply if multimedia is used. Most of these checkpoints are just relevant for those with visual impairments.

On the meta-level, this ontology introduces the *Guideline* and *Checkpoint* concepts, which can be mapped through an *includesCheckpoint* property. While Web designers and developers can leverage verification processes with the already supplied instances for WCAG, the extensibility provide by this meta-level affords the addition of new guidelines and checkpoints to their development processes in an effective way. Furthermore, this will allow them to leverage out-of-the-box all domain independent verification rules provided in SWAF's Web Accessibility Mapping Dimension.

Devices Ontology

Owing to the rapid development of electronic technologies, it tends to be common to access Web sites outside the traditional field of a desktop PC and a computer screen (e.g., PDAs, mobile phones, assisting devices, etc.). This has brought more specific assistive technologies to improve interactivity for users with disabilities, as well as broad personal preferences. This includes the ability of coping with diverse input/output modalities combination within interactive scenarios. Since the diversity of these technologies varies along different axes (e.g., display resolution, images coloring, multimedia process, etc.), the way accessibility is assessed for Web pages must also cope with these differences.

This ontology provides a simple set of meta-level concepts to describe devices ecology: a *Device hasFeature DeviceFeature*. Like in the description of users and accessibility scenarios, this ontology affords out-of-the-box instances for common cases of devices and device characteristics without closing the door to extensibility and odd-case scenarios.

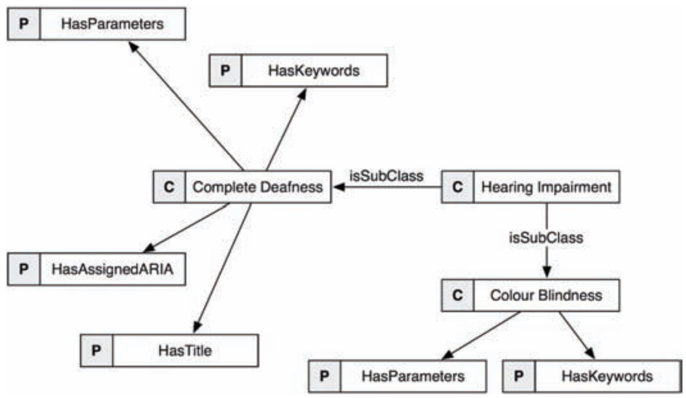
The description of devices can be used at two different fronts within development processes: it can help triggering semantic validation rules on user/device mismatches (e.g., user with total blindness and computer screen), and tying Web accessibility guidelines and checkpoints to particular devices and/or device features.

Web Applications Ontology

Web pages are not the only end for Web technologies. Nowadays, an increasingly number of applications is being ported from "traditional" desktop environments into Rich Internet Applications (RIA), by taking advantage of the richness of Web browsers, thus becoming easily available to any kind of users. However, since these technologies cannot cope with specific semantics of desktop applications widgets, accessibility issues may arise. The proposed domain ontology supports the development of accessible Web applications by affording the inspection of ARIA keywords (Accessible RIA) within Web pages, according to application requirements.

Figure 3 represents a partial snapshot of the ontology describing the knowledge domain of *HearingImpairment*. One of the main classes is the *CompleteDeafness* that consists of four subclasses *Title*, *Parameters*, *Keywords* and *AssignedARIA*. Each of these subclasses is characterized by a

Figure 3. Example of domain description ontology



set of properties that can be either a simple data property or an object property that denotes the relationship between two classes.

This ontology supports both HTML-specific concepts (such as key HTML terms that have influence on accessibility issues), besides Web application domain concepts. This way, Web pages are perceived as a subset of Web applications from the point-of-view of key concepts, thus affording reuse scenarios of the ontology.

For example, the Web Applications Ontology provides the *GUICharacteristic* and *GUITechnology* abstract concepts (coupled with more fine-grained concepts such as *HTML*), to support the description of the Web Applications domain.

Web Accessibility Mapping

Finally, SWAF is completed with the Web Accessibility Mapping (WAM) dimension. This dimension aims to cover the establishment of mapping relationships between the ontologies of the first dimension, and to validate the semantics of these relationships. These relationships can be used, e.g., for efficient navigation and searching inside the ontologies, as well as to afford the creation of semantic rules-based accessibility verification. Two ontology layers are provided in this dimension (as detailed next): *Mapping Ontology,* and *Rules Ontology.*

Mapping Ontology

The WAM dimension provides a mapping ontology comprising of a set of lexical and notational synonyms to express the semantics of the relationships between concepts within the *General Ontology* and *Domain Specific Ontologies*. This mapping is necessary, since each ontology domain represents the semantics of different knowledge domains. It is important to notice that these mapping concepts can be use to tie terms from the General Ontology to any Domain Specific Ontology, as well as between different Domain Specific Ontologies. This way, the Semantic Web Accessibility Framework can support different interdependent relationships between DSOs, thus affording richer Web accessibility validation scenarios.

Since the proposed integration needs require that information be passed seamlessly among the different layers, generic and domain ontology mapping is absolutely necessary. This semantic information stems from the semantic metadata description of the content and has to be mapped to the corresponding classes and properties of the relevant domain description ontology. Therefore, each domain specific ontology will provide a set of concepts to the mapping ontology to support this type of mappings.

For instance, the Web applications ontology provides properties to map *Checkpoint* instances (inherent from the Web Accessibility Standards and Guidelines Ontology) to *Application* instances (described with concepts from the Web Applications Ontology). This mapping property allows the specification of which checkpoints are valid to the particular set of technologies available for the design and development of Web applications. Another set of mapping concepts provide support for bridging *Checkpoint* instances with *Device* instances and *User* instances, thus closing the loop between characterization of devices and audiences and tailored Web accessibility assessment processes.

Rules Ontology

The last piece in the Web Accessibility Mapping dimension of the Semantic Web Accessibility Framework concerns the specification of semantic validation rules for Web accessibility. This ontology will provide the required set of rules that go beyond the syntactic analysis of Web accessibility processes, such as the description of checkpoints, users, etc. The role of this ontology is, therefore, to bridge the semantic verification gap between the Web Accessibility Description domain and the Mapping Ontologies.

We have devised this ontology as a set of rules based on SWRL (Horrocks, Patel-Schneider, Boley, Tabet, Grosof, & Dean, 2004), a rules language that affords the specification Horn-like rules with OWL predicates. The Rules Ontology can be used to reason which concepts from other ontologies (both at the instance and meta levels) and which combinations of them are satisfied by accessibility validation procedures. By setting up these rules within an inference engine, relevant accessibility rules will be reasoned out according to the information residing within the ontologies of the Semantic Web Accessibility Framework's Web Accessibility Domain dimension.

While some rules can be specified with General Ontology concepts, its use is fairly limited, as they are not tied to particular application domains. By using terms originated from Domain Specific Ontologies, and by combining them according to the semantics of existing validation processes, Web design and development processes can be augmented with more interesting verification rules that are triggered according to specific application/audience requirements. It is worth mentioning the fact that this ontology serves as an entry point for semantic validation processes. We devised it as a placeholder upon which the SWAF ontology can (and, in fact, *should*) be enriched with application-specific and technology-specific semantic Web accessibility validation rules.

As a simple example, we present the description of a set of rules for users that have been characterized as having some sort of visual disability, and how to cope with content presentation. This is one of the critical rule types that are to be supported within Web accessibility validation scenarios. User rules are defined as the set *UR* = {*U1*, *U2*, *U3*}, where each one of the rules represents a single semantic validation according to a specific user audience:

U1: if user is color blind then content of black and white images and black text are preferred.
U2: if user is partially sighted then content of audio and appropriate image is preferred.
U3: if user is totally blind then pure audio content is preferred.

The same approach can be used in other domains, e.g., for devices. When verifying if Web sites can cope with device capabilities, one can check if content can be appropriately fit into the constraints imposed by devices. Such rules domain, e.g., DR = {*D1*, *D2*, *D3*} can be defined as:

D1: if device is a mobile phone then image depth must be black and white.

D2: if device is a PDA image color contrast must be high.

D3: if device is a PC then image depth can be of any size.

When defining such semantic rules, the constructs available on the different ontologies can be used to express the concrete situations that help Web designers and developers in the tailored Web accessibility verification processes in an effective, unambiguous way. As an example, we detail how to express the Checkpoint 2.1 from the Web Accessibility Content Guidelines 1.0 (as shown in the Appendix), which state: "Ensure that all information conveyed with color is also available without color, for example from context or mark-up". When targeting to audiences composed by individuals with color blindness, this checkpoint can be expressed in SWRL as (compact syntax):

```
wao:hasGUITechnology(?APP, ?x1) &
wao:HTML(?x1) &
wao:hasGUICharacteristics(?x1, ?x2) &
wao:characteristicName(?x2, "alterna-
tiveNonColoredInformation") &
wao:characteristicValue(?x2, "true") &
gdco:hasDisability(?USER,
Individual("colorBlindness"))
=>
wasgo:isDefiningValidApplication(Individual
("WAI _ checkpoint2.1"), ?APP)
```

Here we are ensuring that conforming to Checkpoint 2.1, only for users (`?USER`) characterized by color blindness (`colorBlindness`), applications (`?APP`) encompassing HTML technologies (`wao:HTML`) must provide alternative non colored information. It is worth mentioning that the constructs provided by the Web Accessibility Ontology (`wao:hasGUITechnology`, `wao:HTML`, `wao:hasGUICharacteristics`, `wao:characteristicName`, and `wao:characteristicValue`) form the core validation rule, since they bind more general concepts (color blindness, WCAG checkpoint) to concrete concepts inherent of the application domain. All of these concepts would have to be substituted, if targeting the specific WCAG rule to other application technology (e.g., outside the scope of Web accessibility). Likewise, this type of rule can be easily adapted to device constraints such as the device domain rules described above, as follows:

```
wao:hasGUITechnology(?APP, ?x1) &
wao:HTML(?x1) &
wao:hasGUICharacteristics(?x1, ?x2) &
wao:characteristicName(?x2, "alterna-
tiveNonColoredInformation") &
wao:characteristicValue(?x2, "true") &
do:hasFeature(?DEV,
Individual("colorDepth1bit"))
=>
wasgo:isDefiningValidApplication(Individu
al("WAI _ checkpoint2.1"), ?APP)
```

Here we attach Checkpoint 2.1 just to those devices (`?DEV`) that are severely constrained by color depth, e.g., just black and white displays (`"colorDepth1bit"`). All other atomic rules can be retained, thus showing that Web accessibility verification semantics are similar between different characterization and verification domains (e.g., color blind vs. color depth). In both rules, the test for `alternativeNonColoredInformation` provides the bridge towards an actual accessibility check. In this case, a software component attached to a SRWL rules processor is triggered and analyses an HTML document accordingly.

More complex rules can be built on simpler rules, thus affording sharing semantics between verification scenarios. This will afford a richer and more complete approach to the implementation and integration of SWAF into Web accessibility aware design and development tools. In the next example we rework the two rules presented above by refactoring the common set of rules in a modular way:

```
wao:hasGUITechnology(?APP, ?x1) &
wao:HTML(?x1) &
wao:hasGUICharacteristics(?x1, ?x2) &
wao:characteristicName(?x2, "alterna-
tiveNonColoredInformation") &
wao:characteristicValue(?x2, "true")
=>
ex:verifyHTMLColor(?APP)

ex:verifyHTMLColor(?APP) &
gdco:hasDisability(?USER,
Individual("colorBlindness"))
=>
wasgo:isDefiningValidApplication(Individu
al("WAI _ checkpoint2.1"), ?APP)

ex:verifyHTMLColor(?APP) &
do:hasFeature(?DEV,
Individual("colorDepth1bit"))
=>
wasgo:isDefiningValidApplication(Individu
al("WAI _ checkpoint2.1"), ?APP)
```

FUTURE TRENDS

As described earlier, Web accessibility is gaining traction as time goes by, and as Web technologies mature. Web designers and developers are becoming more receptive to accessibility and inclusive design practices, to broaden the spectrum of users that can be targeted by a Web site or Web application. Still, they tend to follow blindly guidelines such as WCAG, thus lacking the perception that these do not cope with a high range of accessibility situations that are not taking into account.

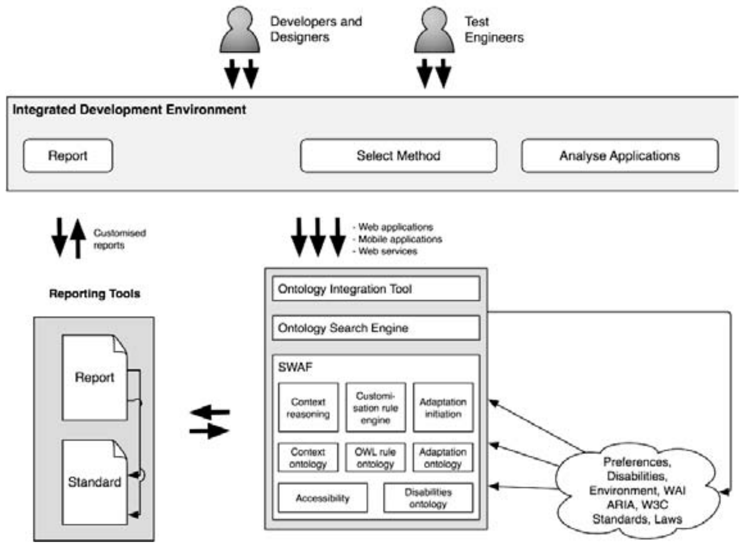
Furthermore, the lack of integration of accessibility tools within the design and development process of Web sites and Web applications tend to leave accessibility assessment procedures to quality assurance tasks or, at best, usability testing tasks. This fact sets Web accessibility assessment as a patch to existing development processes, which has consequences on the adequacy of Web sites and applications.

We believe that the entry point for disrupting how Web accessibility is perceived nowadays must come from proper tool support, e.g., by means of open and free Web accessibility tools that can be plugged into existing Integrated Development Environments (e.g., NetBeans, Visual Studio, etc.) and design tools (e.g., Dreamweaver). This way, Web designers and developers will have an acute sensibility for Web accessibility issues during the design and development processes they are working in.

As an extra point, the Semantic Web Accessibility Framework detailed in this Chapter provides a fine-grained control of audiences and their characteristics, and how these can cope with existing Web accessibility guidelines. We expect that by providing this feature out-of-the-box, Web design and development teams will bring audience-modeling procedures to their development processes. This will give them more control on implementing Web sites and Web applications that are accessible and verifiable during development stages.

Lastly, while Web accessibility is an important issue to take into account, it is just the starting point for providing digital services to end-users that are totally accessible and universally usable. Other domains, such as mobile phones, desktop applications, or even embedded services must also be targeted by accessibility assessment procedures during early design and development stages. The SWAF framework described in this Chapter will be extended in the future to cope with these scenarios in a very effective way, since extensibility is one of the core concerns inherent to it. On Figure 4 we present our vision of the application of SWAF in the context of application development (not just to Web sites and Web applications), and how it can be tied to Integrated Development Environments.

Figure 4. Architecture for accessibility validation services



This architecture builds on the core technologies and concepts defined in SWAF in different fronts. First, different application domains are supported through a plug-in fashion (e.g., Web accessibility would be one of the plug-ins), based on semantic technologies such as the Mapping and Rules ontologies, or the General Characteristics and Disabilities ontology. An inference engine would provide context-reasoning features tied to particular application and technology-dependent ontologies (e.g., Web sites and HTML). We envision three extra components in this architecture that complement SWAF: (1) an ontology-oriented search engine, where developers can search for information residing in SWAF-based knowledge bases, (2) an ontology integration tool, to afford the specification of new domain-specific ontologies, and (3) a set of reporting tools centered on providing concise information about accessibility assessment procedures.

A supportive Integrated Development Environment will tie these technologies to already existing features as a complementary facet of development (e.g., similar to a debugging/helper feature). We believe that enriching IDEs with such features, as well as supportive accessibility simulation and reporting facilities will bring Web accessibility and general accessibility assessment procedures to a wide range of designers and developers, thus lowering the burden of providing accessible applications to all users without any kind of barriers.

CONCLUSION

This chapter presented SWAF, the Semantic Web Accessibility Framework, as the foundation for the semantic description of Web accessibility audiences, concepts and verification rules. This framework provides the basic constructs for the creation of Web accessibility verification engines that are capable of performing assessments tailored to specific user audiences and interaction devices. We have divided SWAF into two dimensions, Web Accessibility Descriptions (which includes general and domain specific concepts) and Web Accessibility Mapping (which affords semantic mapping and rules between concepts from the first dimension), in order to afford the extension of SWAF into different domains in the scope of Web accessibility.

Ongoing work is currently being done in several fronts in the SWAF realm, including: (1) building a comprehensive set of concept instances for user and device feature characterization, (2) providing support for guidelines and standards other than WCAG, (3) improving the Mapping Ontology to cover more situations, (4) implement a robust inference engine supporting SWAF concepts, (5) integrate this inference engine into existing Integrated Development Environments and other Web site development tools, and (6) extend the SWAF ontology to cover other application domains outside the scope of the Web.

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KEY TERMS AND DEFINITIONS

Accessibility: The *ability to access.* Often tied to people with disabilities (e.g., total blindness), accessibility thrives to break the barriers to information access. We follow the strict sense of accessibility by embracing any situation where the ability to access information can be disrupted by device or even surrounding environment constraints.

Accessibility Guidelines: A set of best practices that must be followed by designers and developers when implementing software solutions (e.g., Web site) that will help on providing accessible information. By being guidelines, it should not be assumed that content is accessible just by following them.

Checkpoint: A concrete verification task that materializes a (part of a) guideline. Checkpoints can be fully automated if application technology provides corresponding support (e.g., verifying if all images have associated textual captions).

Integrated Development Environment: A computer application used by developers that provides several features to ease the task of developing applications, such as text editor, compiler, automation features, etc.

Universal Usability: a research field that studies the adequacy of user interfaces and information to all users, regardless of their characteristics, knowledge, or mean of interaction (Shneiderman, 2000).

Usability: A research field that studies how adequate user interfaces are to users, how easily can they learn to perform tasks, and what are their levels of satisfaction when interacting with user interfaces.

User Interface: The "visible" side of an application, where users can acquire and interact with information.

Web Accessibility: The subfield of accessibility that is targeted to the specific technologies and architecture that compose the World Wide Web. This includes technologies such as HTML, CSS and JavaScript, as well as the HTTP protocol.

APPENDIX: WAI WEB CONTENT ACCESSIBILITY PRIORITY 1 CHECKPOINTS

Cp	**Description**
Cp1.1	Provide a text equivalent for every non-text element (e.g., via "alt", "longdesc", or in element content).
Cp2.1	Ensure that all information conveyed with colour is also available without colour, for example from context or mark-up.
Cp4.1	Clearly identify changes in the natural language of a document's text and any text equivalents (e.g., captions).
Cp6.1	Organize documents so they may be read without style sheets.
Cp6.2	Ensure that equivalents for dynamic content are updated when the dynamic con-tent changes.
Cp7.1	Until user agents allow users to control flickering, avoid causing the screen to flicker.
Cp14.1	Use the clearest and simplest language appropriate for a site's content.
Cp1.2	Provide redundant text links for each active region of a server-side image map.
Cp9.1	Provide client-side image maps instead of server-side image maps except where the regions cannot be defined with an available geometric shape.
Cp5.1	For data tables, identify row and column headers.
Cp5.2	For data tables that have two or more logical levels of row or column headers, use mark-up to associate data cells and header cells.
Cp12.1	Title each frame to facilitate frame identification and navigation.
Cp6.3	Ensure that pages are usable when scripts, applets, or other programmatic objects are turned off or not supported. If this is not possible, provide equivalent information on an alternative accessible page.
Cp1.3	Until user agents can automatically read aloud the text equivalent of a visual track, provide an auditory description of the important information of the visual track of a multimedia presentation.
Cp1.4	For any time-based multimedia presentation (e.g., a movie or animation), synchronize equivalent alternatives (e.g., captions or auditory descriptions of the visual track) with the presentation.
Cp11.4	If, after best efforts, you cannot create an accessible page, provide a link to an alternative page that uses W3C technologies, is accessible, has equivalent in-formation (or functionality), and is updated as often as the inaccessible (original) page.

Chapter IV
Semantic Web Technologies in the Service of Personalization Tools[1]

Yolanda Blanco-Fernández
University of Vigo, Spain, and E.T.S.E. de Telecomunicación, Campus Lagoas-Marcosende, Spain

José J. Pazos-Arias
University of Vigo, Spain, and E.T.S.E. de Telecomunicación, Campus Lagoas-Marcosende, Spain

Alberto Gil-Solla
University of Vigo, Spain, and E.T.S.E. de Telecomunicación, Campus Lagoas-Marcosende, Spain

Manuel Ramos-Cabrer
University of Vigo, Spain, and E.T.S.E. de Telecomunicación, Campus Lagoas-Marcosende, Spain

Martín López-Nores
University of Vigo, Spain, and E.T.S.E. de Telecomunicación, Campus Lagoas-Marcosende, Spain

ABSTRACT

The so-called recommender systems have become assistance tools indispensable to the users in domains where the information overload hampers manual search processes. In literature, diverse personalization paradigms have been proposed to match automatically the preferences of each user (which are previously modelled in personal profiles) against the available items. All these paradigms are laid down on a common substratum that uses syntactic matching techniques, which greatly limit the quality of the offered recommendations due to their inflexible nature. To fight these limitations, this chapter explores a novel approach based on reasoning about the semantics of both the users' preferences and considered items, by resorting to less rigid inference mechanisms borrowed from the Semantic Web.

INTRODUCTION

Recommender systems arose around middle of nineties with the aim of facing the excessive overload of information to which users are exposed in numerous domains of application. Fulfilling the personalization requirements of this kind of systems requires to incorporate three crucial components into its architecture: firstly, a domain-dependant *database* which stores the available items (e.g. audiovisual contents in Digital TV, comercial products in e-commerce, and educational courses in e-leaning); secondly, *profiles* where the users' preferences are modeled; lastly, *recommendation strategies* to select automatically the suggestions that best match the likings of each user. In this regard, content-based filtering and collaborative filtering are two of the personalization paradigms most widely used in literature (Adomavicius, 2005; Montaner, 2003). Broadly speaking, a content-based filtering approach recommends items similar to those the user liked in the past, whereas the collaborative approaches select items for a given user that individuals with similar likings also appreciated. Both techniques have a common drawback, due to the fact that the selection of the recommendations is based on purely *syntactic* mechanisms, which dismiss much knowledge about the users' preferences due to their rigid and inflexible nature.

To overcome such limitations, this chapter explores a theoretical approach based on exploiting the *semantics* of the application domain of each recommender system, by harnessing the experience gained in the field of Semantic Web. Specifically, our approach takes advantage of several features elemental in the philosophy of this initiative. Firstly, the provision of annotations (metadata) makes it possible to process the meaning of information, thus enabling interoperability among machines and automation of tasks which could be tedious for users (e.g. personalization processes). Secondly, the use of reasoning processes allow to relate the annotated resources to each other by exploring the knowledge hidden behind their semantics. Specifically, this chapter describes the use of two of these semantic reasoning mechanisms in the field of personalization:

- On the one hand, our approach infers *complex semantic associations* (Anyanwu, 2004) between the items available in the recommender system, which are previously formalized in a domain ontology along with their semantic annotations. We emphasize the use of the semantic associations as reasoning techniques to discover much hidden knowledge about the likings of the users, by exploring the hierarchical relationship and properties formalized in the ontology.
- Besides, we also resort to the so-called *Spreading Activation techniques* (Crestani, 1997), which are computational mechanisms able to: (i) explore efficiently huge generic networks with interconnected nodes (just like the domain ontology), (ii) process the semantic associations inferred from this kind of conceptualization, and (iii) discover concepts (items) strongly related to the users' interests. This new knowledge permits to compare in a more flexible way the user's preferences with the available items, thus leading to more accurate recommendations.

Although the mentioned reasoning mechanisms have been widely adopted in the context of the Semantic Web, their internals must be adapted to deal with the personalization requirements of a recommender system. For that reason, the chapter explores how to extend the existing inference techniques so as to enable: (i) to learn automatically new knowledge about the users' preferences from the feedback provided after recommendations, (ii) to incorporate this knowledge into the subsequent inferential processes, and (iii) to adapt dynamically the reasoning-based recommendations as the users' preferences evolve over time.

In brief, from the general perspective of our approach, it follows that the essential goal of the chapter is to investigate the synergies between Semantic Web technologies and recommendation strategies in the field of personalization. In other words, we emphasize the use of semantic reasoning as an efficient mechanism to mitigate greatly the intrinsic limitations of the traditional (syntactic) personalization paradigms. In order to illustrate the mentioned synergetic effects, we propose two reasoning-enhanced strategies: the first one integrates our semantics-based mechanisms into existing content-based approaches, while the second strategy emerges from mixing the philosophy of collaborative filtering with processes of inference from ontologies. Last but not least, the chapter also reveals the computational feasibility, scalability and flexibility of our personalization approach based on Semantic Web technologies. All these properties make it possible to reuse the resulting reasoning-based strategies in multiple domains and personalization tools.

The chapter is organized as follows. Firstly, the drawbacks of traditional content-based and collaborative filtering paradigms are detailed. Next, we explain how our semantics-based approach overcomes these limitations and describe its main components: firstly, the domain ontology; secondly, the technique employed to model the users' preferences; and lastly, our two reasoning-enhanced recommendation strategies. After describing the experimental evaluation of our approach and before concluding the chapter, we point out some research trends that should be advisable to tackle in the future to continue promoting the field of personalization.

BACKGROUND

In traditional content-based strategies both recommendable items and user profile information are represented in terms of a suitable set of content attributes. In this strategy, the user's profile effectively delimits a region of the item-space from which all future suggestions will be drawn, in such a way that the relevance of a given item to a specific user is proportional to the similarity of this item to those defined in her profile. To measure these similarity values, traditional approaches resort to syntactic metrics that only permit to detect resemblance among items sharing identical attributes, thus leading to *overspecialized* recommendations that suffer from a limited diversity. This is particularly problematic for new users since their recommendations will be based on a reduced set of items represented in their immature profiles. So, items appealing to a user, but bear little or no resemblance to the items in her profile, will never be suggested in the future.

Differently from content-based paradigm, in collaborative filtering approaches the basic idea is to move beyond the experience of an individual user's profile, and instead draw on the experiences of a community of users. Typically, each target user is associated to a set of nearest-neighbour users by comparing their respective profiles. To delimit the user's neighbourhood, collaborative techniques look for correlation between users in terms of the ratings they assigned to the items contained in their profiles, in such a way that two users are neighbours when they have rated common items by assigning them similar ratings. Finally, the items with highest ratings in the neighbours' profiles are suggested to the target user. Two of the most severe drawbacks in traditional collaborative approaches are the so-called *sparsity problem* and *latency concerns.* As for the first limitation, note that as the number of available items increases, it is unlikely that two users rate the same items in their profiles, thus hampering the selection of the user's neighbours. Also, in this scenario the creation of the user's neighborhood (based on computing correlations between vectors of ratings) becomes too demanding in computational terms, leading to severe scalability problems. The second-mentioned limitation is related to the fact that collaborative filtering is not suitable for suggesting new items because only those already rated by other users can be recommended. So, if a new item is added to the database in the recommender system, there can be a significant delay before this item will be considered for recommendation.

At the end of nineties, the so-called hybrid approaches started to gain in popularity. As Burke (2003) explained, these approaches are based on gathering content-based and collaborative filtering with the goal of harnessing their respective strengths and mitigating to a great extent their main drawbacks. The most widely adopted hybrid technique is the so-called "collaboration via content" by Pazzani, where content-based profiles are built to detect similarities among users (Pazzani, 1999). Specifically, Pazzani computes the similarity between two users's preferences by considering both the content descriptions (just like in content-based filtering) and their respective ratings (like in collaborative solutions). This mechanisms makes it possible to fight the *sparsity problem* by detecting that two users have common preferences even when there does not exist overlap between the items contained in their profiles. However, in order to measure similarity in this case, it is necessary that these items have common attributes. For that reason, Pazzani's approach is still limited by the syntactic metrics used in the traditional content-based techniques.

The approach proposed in this chapter aims at fighting this kind of limitations, by defining metrics that compare in a more flexible way the user's preferences against the items available in the recommender system. For that purpose, it is necessary to go beyond the syntax of the compared items, focusing on the semantics or meaning formalized in a domain ontology. In this regard, note that the use of the semantic information in recommender systems has been already proposed in other systems. In the simplest proposals, the semantic descriptions permit to provide the users with additional information about the items they have rated. For instance, in television domain, it is common to find TV recommender systems that resort to semantic annotations to offer data about the programs the users are viewing (e.g. information about places or actors involved in a movie, as shown in (Dimitrova, 2003; Prata, 2004)). On the contrary, some more sophisticated approaches also consider these semantic attributes in the recommendation process, with the goal of enhancing the offered suggestions. Broadly speaking, the main difference between proposals such as those described in (Yu, 2007; Wang, 2007; Liu, 2007; Hsu, 2008) and our approach is related to the richness of the inferential capabilities offered by the recommender system. While the mentioned works only employ the information *explicitly* represented in the domain ontology, we *discover* hidden semantic associations from the ontological model, by exploring its structure and exploiting the formalized knowledge. This kind of enhanced reasoning processes permit the recommender system to learn additional knowledge about the users' preferences, thus improving the accuracy of the final suggestions and overcoming limitations unresolved in literature.

OUR REASONING-BASED PERSONALIZATION APPROACH

Before explaining the internals of our reasoning-based strategies in Sect. 3.2 and Sect. 3.3, we describe the three components required in a personalization approach aimed at inferring knowledge from semantics of users' preferences: the domain ontology, the user modeling technique and the recommendation strategies. Thereupon, we discuss some concerns related to the experimental evaluation, and describe the possible execution environments of our strategies (e.g. centralized servers and consumer devices) by arguing the main benefits of each option.

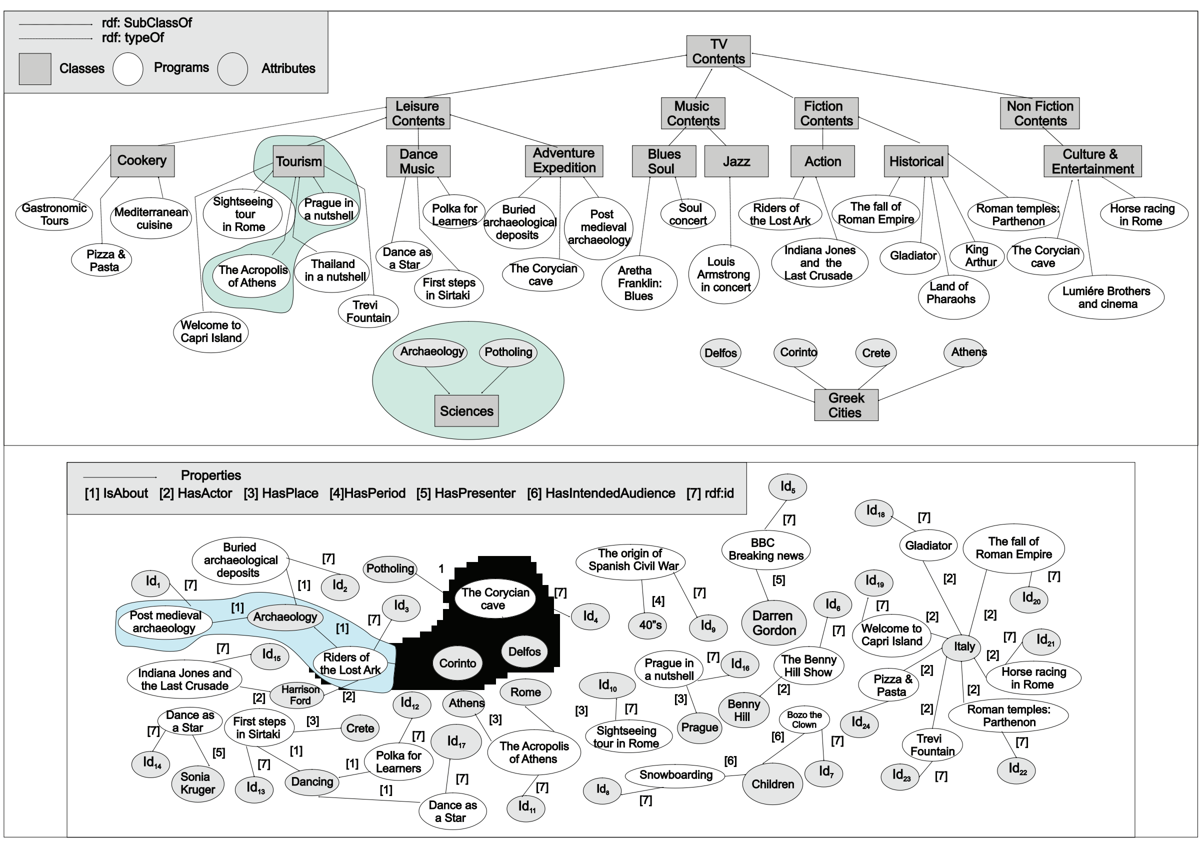
A General View of Resoning-Based Recommender Systems

Ontology. A reasoning-based personalization approach requires an ontology where the knowledge of the specific domain of the recommender system must be formalized. This domain ontology includes the items available in the system along with their main attributes. These attributes are identified by instances of hierarchically organized classes, and are joined to each item by labeled properties. As an example, note the brief excerpt from an ontology adopted in a TV recommender system which has been depicted in Figure 1. Here, we have several instances referred to specific TV programs that belong to a hierarchy of genres, whose root node is *TV Contents* (e.g. *Fiction*, *Non Fiction*, *Music*, *Leisure*). The attributes of these programs (e.g. *cast*, *intented audience*, *topics*) are also identified by hierarchically organized classes, and are related to each program by means of properties (e.g. *hasActor*, *hasIntendedAudience*, *isAbout*).

As we will explain at the end of this section, both the structure and the knowledge formalized in the domain ontology are crucial for reasoning purposes, because they allow to discover semantic associations between the available items by exploring the hierarchical links, siblingness relationships between classes (and instances), and the chains of properties defined in the ontological model.

Ontology-based user modeling technique. The capability of knowledge sharing provided by ontologies is especially benefitial in order

Figure 1. Subset of classes, properties and specific instances defined in a TV ontology



to model the users' preferences in a semantics-enhanced recommender system. In this case, the users' profiles include a list of the items that were appealing or unappealing to them (named *positive* and *negative preferences*, respectively), along with their ratings or levels of interest. Ratings take values in the range [-1,1], with -1 representing the greatest disliking and 1 representing the greatest acceptance. Besides, each item in the user's profile is identified by a unique reference, which allows to use the domain ontology as a common knowledge repository to query its detailed semantic annotations (e.g. the categories under which the item is classified and its attributes). Really, instead of identifying only a flat list of attributes (just like in traditional user modeling proposals), we exploit the structure and relationships represented in the ontology with the goal of discovering additional knowledge about the user's preferences. More precisely, starting from the ratings of the items defined in the user's profile, we infer her interest in: (i) the attributes of these items, and (ii) the hierarchy of classes to which the items belong in the ontology, as explained next:

- Firstly, the interest in an attribute is inferred by averaging the ratings of all the items in the user's profile that are joined to it in the domain ontology.
- Analogously, the level of interest for a class results from averaging the ratings of the items in the user's profile belonging to that class.
- Lastly, the rating of each class is propagated upwards in the hierarchy in order to infer the interest of the user in categories related to her preferences. Specifically, the rating of a superclass is computed by averaging the ratings of its child classes in the ontology. For example, assume a user who has rated the movies *Gladiator* and *King Arthur* depicted in Figure 1. Since both movies belong to *Historical* category, her (level of) interest in this class results from averaging the ratings of both movies. Next, this value is propagated upwards to *Fiction contents* category, whose rating is computed by averaging the levels of its child classes *Action* and *Historical*.

Although other ontology-based proposals have been devised in literature, our user modeling approach differs to a great extent from these existing works. As a proof, note the Quickstep system proposed in (Middleton, 2003), which suggests research papers according to the users' interests. The main difference between our work and Quickstep is related to the knowledge used for modeling purposes. In fact, Quickstep uses a simple taxonomy of research categories for representing the papers each user appreciates, whereas our proposal exploits the whole knowledge formalized in the ontology, permitting to carry out reasoning processes that discover extra information about users' preferences. The same limitation can be identified in the system proposed in (Ziegler, 2004), which recommends books according to the user preferences. There, the knowledge discovery is based on analyzing just only hierarchical relationships, thus hampering more complex inference processes as those pursued in our work. The knowledge inferred by means of these processes is useful in order to fight the intrinsic limitations of traditional personalization paradigms, and to enhance the suggestions selected by our recommendation strategies.

Recommendation strategies. The domain ontology and the user's profile provide the information required by the recommendation techniques to select tailor-made suggestions. Since our goal is to highlight the benefits of reasoning mechanisms borrowed from the Semantic Web to the field of personalization, we will describe along the paper two independent recommendation strategies. However, both strategies could be combined by any of the hybridization techniques proposed by Burke (2002). We do not enforce any particular solution in this regard, since the combination approach must be selected by considering the specific domain of each recommender system.

A Strategy to Improve Traditional Content-Based Filtering

The content-based strategy explored in this chapter aims at alleviating the overspecialized nature of the suggestions offered by traditional techniques, by employing a new similarity metric that reasons about the semantics of the compared items. Thanks to the flexibility enabled by semantics, our metric measures similarity between items that do not share identical attributes, thus endowing the offered recommendation with a rich diversity. Specifically, our content-based strategy consists of two stages –named filtering phase and recommendation phase, respectively– which are sketched below and detailed next:

- **Filtering phase:** Broadly speaking, our content-based strategy selects in the domain ontology instances of classes and properties that are relevant for the user (as per her personal preferences). Next, the strategy infers *semantic associations* among the entities selected identifying specific items. These hidden associations are discovered from the hierarchical links and properties defined in the domain ontology.
- **Recommendation phase:** The knowledge inferred from the ontology is processed in the second phase by employing *Spreading Activation techniques* (henceforth SA techniques), which are intelligent mechanisms able to: (i) explore efficiently the entities and associations discovered during the filtering phase, and (ii) select the items potentially interesting for the user.

Filtering Phase

Firstly, our strategy locates in the domain ontology the items that were (un)appealing to the user, which are defined in her profile. Next, it traverses successively the properties bound to these items until reaching new instances (nodes) in the ontology. In order to guarantee the computational feasibility, we have developed a controlled inference mechanism that works as follows. As new nodes are reached from a given instance, our approach firstly quantifies their relevance for the user. Next, the nodes whose *relevance indexes* are not greater that a specific threshold are disregarded, in such a way that our inference mechanism continues traversing successively only the properties that permit to reach new nodes from those that are relevant for the user. Consequently, our strategy explores only significant nodes and properties, thus filtering those that do not provide useful knowledge for the personalization process.

In our filtering mechanism, the more significant the relationship between a given node and the user's preferences (either positive or negative preferences), the more relevant the node. In order to measure the relevance of this node, we have developed a technique –described in detail in (Blanco, 2008a) and omitted here due to space limitations– that takes into account diverse ontology-dependent parameters, such as the existence of chains of properties joining the user's preferences to the considered node, the ratings of the user in items related to it, and the existence of hierarchical relationships between these preferences and the node:

- First, the longer the chain of properties established between the items included in the user's profile and the considered node, the less relevant this node, as its relationship to the user's preferences is not significant due to the presence of many intermediate nodes.
- Second, the most significant the (lack of) interest of the user in items related to the considered node, the greater its relevance, because the node helps to identify recommendations with a minimum risk of failure

for the system: if the node is strongly related to the user's favourite items, it probably will be interesting for her; if the node is related to the most unappealing items to the user, it probably will be rejected (that is why it will not be suggested) [2].

- Last, the relevance of a node is increased when it is possible to find a common ancestor between it and the user' likings in some hierarchy in the domain ontology, because these hierarchical relationships detect resemblance between the node and the user's positive preferences.

Once the nodes related to the user's preferences (and the properties linking them to each other) have been selected, our strategy infers semantic associations between the instances identifying specific items. Such associations are easily inferred from the chains of properties and hierarchical relationships detected in the filtering process, as we describe next:

- Specifically, two items are associated when they are linked by a chain of properties in the ontology. For instance, the programs *Post medieval archaeology* and *Riders of the Lost Ark* are associated in a sequence of two properties through the *Archaeology* node, as shown in the first shaded area at the bottom of Figure 1.
- A semantic association is established between two items when their attributes are classified under a common category in the domain ontology. For example, the programs *Post medieval archaeology* and *The Corycian Cav*e are related because their respective attributes *Archaeology* and *Potholing* belong to the *Sciences* class, as shown at the top of Figure 1. Analogously, *The Corycian Cav*e and *Riders of the Lost Ark* are associated because both programs are bound to *Greek cities* (*Delfos* and *Corinto*, respectively).
- Last, two items are associated when share a common ancestor in some hierarchy defined in the ontology. As an example, note that *Prague in a nutshell* and *The Acropolis of Athens* are related because both programs belong to the *Tourism* class, under the *Leisure contents* category, as shown at the top of Figure 1.

Thanks to the filtering and knowledge inference processes, our approach builds a network for the user, whose nodes are the instances of classes selected during the filtering phase, and whose links are both the properties defined in the ontology and the semantic associations inferred from it. The knowledge represented in this network is analyzed in the second phase of our content-based strategy.

Recommendation Phase

In order to select the items suggested to the user, we emphasize the use of SA techniques as a computational mechanism to: (i) efficiently explore the relationships among the concepts interconnected in the aforementioned network, and (ii) infer from them knowledge useful for the recommendation process. To begin with, we explain the internals of SA techniques, and next, detail how they are adapted to meet the personalization requirements of our reasoning approach:

- The nodes of the network to be processed have an implicit relevance, named *activation level*. Each link between two nodes has a weight, in such a way that the stronger the relationship between both nodes, the higher the weight. Initially, a set of nodes are selected and their activation levels are spread until reaching the nodes connected to them by links (named neighbour nodes).
- The activation level of a reached node is computed by considering the levels of its neighbours and the weights of links joining

them to each other. Consequently, the more relevant the neighbours of a node (i.e. higher their activation levels) and the stronger the relationships between the node and its neighbours (i.e. higher the weights of the links between them), the more relevant this node in the network.

- This propagation process is repeated successively until reaching all the nodes of the network. Finally, the highest activation levels identify the nodes that are closest related to those initially selected.

In our approach, the proposed strategy activates in the user network the nodes referred to the items defined in her profile, and assigns them an initial activation level equal to their respective ratings. Next, it is necessary to weight conveniently the links of the user network, which represent both the explicit knowledge formalized in the ontology (i.e. properties), and the implicit knowledge discovered from it (i.e. semantic associations). In contrast to the existing approaches based on SA techniques –in which the weights of the links in the network remain static–, our strategy must adjust these values dynamically as the user's preferences evolve over time. For that reason, the weight of a link between two nodes in our user network is computed by considering the relevance indexes measured during the filtering phase: the stronger the relationship among the two linked nodes and the user's preferences, the higher the assigned weight. This way, as these preferences change, the weights of the links in the user network are conveniently modified and, therefore, the recommendations are also updated.

Once the spreading process has reached all the nodes in the user network, the highest activation levels correspond to items satisfying two conditions: (i) their neighbour nodes are also relevant for the user (that is why their high activation levels), and (ii) they are closely related to the user's preferences (that is why the high weight of the links). For that reason, these nodes identify the items finally suggested by our content-based strategy.

To conclude this section, we highlight the main benefits of our reasoning-based spreading process to the personalization field:

- First, our strategy is able to discover that an item is appealing to the user even when it does not share the same attributes defined in her profile. Thanks to the SA techniques, this item is relevant if it is semantically associated with the user's preferences. Consequently, our reasoning-based strategy offers diverse recommendations, beyond the overspecialized suggestions offered by the traditional content-based techniques.
- Second, note that our approach not only favours the knowledge reusing, but it also permits that the user network adapts easily as her preferences evolve. As these interests change, the filtering phase selects new nodes, properties and semantic associations, and it incorporates them into the current user network.
- Lastly, our semantic reasoning processes consider both the positive and negative preferences of the user. Whereas the positive interests help to identify items appealing to the user, the negative preferences decrease the activation levels of the nodes to which are related (either explicitly by means of properties, or implicitly by semantic associations). This way, our strategy prevents from suggesting items associated with those the user did not appreciate in the past.

Some Sample Content-Based Recommendations

Suppose that Mary has enjoyed several of the TV programs depicted in Figure 1. As shown in Table I, Mary liked several *Leisure contents,* such as the adventure documentary *Post medieval archaeology*, and the tourism programs *Prague in* *a nutshell* and *Sightseeing in Rome*. Also, Mary enjoyed *Riders of the Lost Ark*, an action movie set in the Greek city of Corinto where Harrison Ford performs as Indiana Jones. As for negative preferences, note that two TV programs aimed at teaching dance skills were unappealing to this viewer.

Our filtering criteria and the inferred semantic associations lead to the network depicted in Figure 2, where we depict programs and attributes hierarchically related to Mary's preferences, and joined to them by short chains of properties.

After weighting the links of the Mary's network and propagating the activation levels through it, our content-based strategy suggests the following TV programs:

- Firstly, our strategy discovers the interest of Mary in the program *The Corycian Cave* by exploiting the semantic associations existing between it and her preferences (which have been exemplified along Sect. 3.2.1). The links referred to these associations in Figure 2 permit SA techniques to spread the relevance of *Post medieval archaeology* and *Riders of the Lost Ark* until reaching the suggested program.
- Analogously, our strategy also suggests to Mary the program *The Acropolis of Athens* by considering the highly weighted links coming from the nodes *Riders of the Lost Ark*, *Prague in a nutshell* and *Sightseeing tour in Rome*, as shown in Figure 2. These links are due to the fact that all these programs are hierarchically related by the common ancestor *Tourism* in the TV ontology.
- Last, SA techniques also detect programs that should not be suggested to Mary, as they are related to her negative preferences. As shown in Mary's network, *First steps in Sirtaki* receives links from three programs: *Riders of the Lost Ark*, *Dance as a Star* and *Polka for Learners*. As the first movie is very interesting for Mary, the weight of

Figure 2. SA network employed to select content-based recommendations for Mary

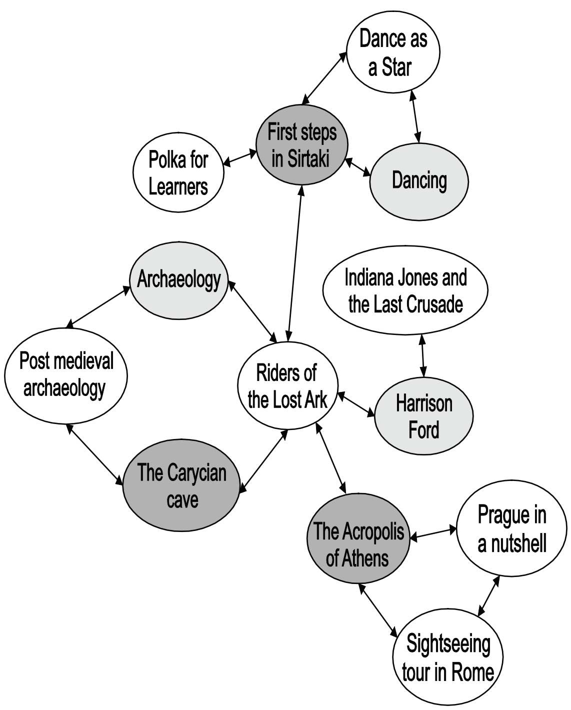


Table 1. Mary's preferences

Classes in the hierarchy of genres		TV programs (and ratings)
Leisure Contents	Adventure & Expedition	*Post medieval archaeology* (1)
	Tourism	*Prague in a nutshell* (0.8) *Sightseeing tour in Rome* (0.85)
	Dance/Music	*Polka for learners* (-1)
Fiction Contents	Action	*Riders of the Lost Ark* (0.9)

its link in the network tend to increase the activation level of the program about sirtaki. However, as *Dance as a Star* and *Polka for Learners* are about a topic unappealing to this viewer (dancing, as shown in Table I), both nodes inject negative weights into *First steps in Sirtaki*. The weights of the three links are finally combined, resulting in a low activation level for *First steps in Sirtaki*, that is why this program is not suggested to Mary.

In sum, the diverse nature of our reasoning-based recommendations is due to the fact that the suggested programs do not share the *same* attributes defined in Mary's profile (e.g. *Archaeology* and *Corinto* bound to the programs *Post medieval archaeology* and *Riders of the Lost Ark* in Figure 1), but they are related to her preferences from a semantic point of view. For that reason, Mary (who liked the archaeology) has received as recommendations programs about potholing –science strongly related to her likings– and about Greece, a country of deep-rooted archaeological tradition.

A Strategy to Improve Traditional Collaborative Filtering

The collaborative strategy we propose in this chapter employes semantic reasoning both in the phase of the user's neighborhood formation, and in the prediction of her level of interest in a generic target item (not necessarily rated in the profiles available in the recommender system).

Neighborhood Formation

In order to form the user's neighborhood, we extend the "*collaboration via content*" paradigm by Pazzani, so that we reason about the semantics of the users' preferences instead of using only their content descriptions. This process is organized as follows. Firstly, we propose a *taxonomy-based approach* to create the user's rating vector. Instead of including the ratings of the available items, our vector contains her ratings in the categories under which these items are classified in the ontology. Actually, the rating vector of a user only includes her level of interest in the categories most significant for the personalization process, that is, the classes which are most appealing and most unappealing to her (identified by ratings close to 1 and to -1, respectively). The hierarchical organization of these categories permit us to fight the sparsity problem present in the traditional collaborative approaches. More precisely, this organization allows to detect that the preferences of two users are similar even when their respective profiles do not contain identical items or attributes. In our approach, it is only necessary that the categories of the considered items share a common ancestor in some hierarchy of the domain ontology.

After creating the user's rating vector, we select those users who have rated items belonging to the most of classes defined in it. Next, we create their respective rating vectors by including their ratings in these classes. Finally, we compare their preferences by computing the Pearson-r correlation between their respective rating vectors, and we select as the user's neighbours the N individuals with the highest correlation.

Prediction of User's Rating in the Target Item

Once the user's neighborhood has been delimited, our collaborative strategy predicts her level of interest in the considered target item. This prediction process consists simply of averaging the levels of interest of each neighbor in the target item, weighted by the correlation values measured between the user and those neighbours. In contrast with current collaborative approaches –which only consider the contribution of the neighbours who have already rated this item– we explore the full neighborhood of the user. This way, if a neighbor has rated the target item, the prediction is based on the rating defined in her profile; otherwise, we predict this level of interest by measuring the matching value between the neighbor and the target item. Specifically, the greater the number of semantic associations inferred between this neighbor's preferences and the target item, the higher the matching level computed. From our explanation, it follows that the rating predicted for the user will be greater when the target item is very appealing to her neighbours, and when their respective preferences are strongly correlated. Finally, the target item is suggested to the user if the predicted rating is greater than a configurable threshold.

Before concluding this section, we highlight the benefits of our *process of neighbours' ratings estimation* to the collaborative strategy. On the one hand, this process enables to suggest (without unnecessary delays) items which are completely novel for all the users in the system. Therefore, it permits to alleviate the *latency problem* of the traditional approaches, in which an item must be rated by many users before it can be suggested. On the other hand, the estimation of neighbours' ratings increases the accuracy of our strategy with regard to traditional approaches, by selecting many items appealing to the user which would go unnoticed in the existing collaborative techniques. Our approach discovers these items because it is able to predict in advance that they are also interesting for the user's neighbours (thanks to our semantic reasoning capabilities).

Some Sample Collaborative Recommendations

In this example we assume the viewer Paul (whose profile is depicted in Table 2) and the target program *The fall of Roman Empire* in Figure 1. In this scenario, our collaborative strategy decides about recommending this program to Paul, by considering the interest of his neighbours in this content.

According to our taxonomy-based approach, the nearest neighbours of Paul are users who have rated programs belonging to the most of classes defined in his profile, such as the viewers Anne and John, whose preferences are depicted in Table 3. As per their profiles, the two neighbours share the interest of Paul in cookery and tourism contents, historical movies and culture documentaries, as well as his lack of interest in diverse music shows.

As *The fall of Roman Empire* has not been rated by none of Paul's neighbours, our collaborative strategy predicts their levels of interest in the target program. As per Table 3, the program about the Roman Empire seems to be appealing to Paul's neighbours, as Anne and John have been interested both in historical programs and in the country of Italy. Specifically, Anne has liked programs about Roman temples and Italian island Capri, while John enjoyed contents related to historical monuments and traditions from Italy (like *Trevi Fountain* and *Horse racing in Rome*).

Table 2. Paul's preferences

Classes in the hierarchy of genres		TV programs (and ratings)
Leisure Contents	Cookery	*Gastronomic tours* (1)
	Tourism	*Thailand in a nutshell* (0.8)
Fiction Contents	Historical	*King Arthur* (0.95)
Non Fiction Contents	Culture & Entertainment	*Lumiére Brothers and the cinema (0.9)*
Music Contents	Jazz	*Louis Armstrong in concert (-1)*

These semantic associations permit us to detect the interest of Paul's neighbours in the target program, leading to significant matching values between the target content and the preferences of Anne and John. For that reason, the program about the Roman Empire is finally suggested to Paul.

EXECUTION ENVIRONMENTS AND EXPERIMENTAL EVALUATION

The recommender systems can be executed either remotely in a centralized server, or locally in a consumer device (e.g. PC, PDA, mobile phone). In a server-based recommender system, ontologies and users' profiles are stored in dedicated servers, and the filtering algorithms run remotely, too. In this scenario, users access the server to provide their personal preferences and to query their recommendations. This execution environment is especially appealing in a personalization scenario due to two reasons:

- Firstly, filtering information at the server side enables to plan better the items offered to the users. In other words, it is possible to harness the recommendation strategy to remove information irrelevant for users, replacing it with items potencially interesting for them. For instance, a TV recommender system could decide the contents to be broadcast at every moment as per the available kind of audience. Analogously, a recommender system for e-commerce could employ recommendation strategies to select the most saleable products, by considering the consumption histories of potential users.
- Second, a centralized server is typically powerful equipped, enabling to run more complex filtering algorithms that lead to more accurate recommendations.

Nonetheless, the server-based approach is not devoid of significant limitations. On the one hand, the users could be unwilling to store their preferences in the server, fearing that details about their personal consumption histories (e.g. viewed TV programs or frequently purchased products) can be revealed. On the other hand, server-based scenario forces the users to have a return channel in order to provide their preferences and relevance feedback about the selected recommendations. Although today this is not a especially critical limitation –suffice it to consider the extended use of xDLS technologies–, the weaknesses of the server-based execution environment can be greatly alleviated by moving the personalization logic to a local consumer device.

This option means to distribute the personalization service between a server and the user device: on the one hand, the user's preferences are modeled in the device, where the recommendation strategies are also locally executed;

Table 3. Preferences of Paul's Neighbours

ANNE's preferences			**JOHN**'s preferences
Leisure Contents	Cookery	*Mediterranean Cuisine* (1)	*Pizza & Pasta* (0.9)
	Tourism	*Welcome to Capri Island* (0.9)	*Trevi Fountain* (1)
Fiction Contents	Historical	*Gladiator* (0.95)	*Land of Pharaohs* (0.95)
Non Fiction Contents	Culture & Entertainment	*Roman Temples: Parthenon* (1)	*Horse racing in Rome* (1)
Music Contents	Blues & Soul	*Aretha Franklin: Blues* (-1)	*Soul concert* (-0.9)

on the other one, the ontologies still have to be kept in the server, because they can be enormous databases, totally unmanageable for limited-resources devices. To bridge the gap between the two sides, we introduce server-side mechanisms for a twofold purpose:

- Firstly, the server makes a pre-selection to deliver only the items which are potentially most interesting for the users. This is indeed a filtering process, although not driven by the profile of an individual viewer, but rather by a set of *stereotypes* that average the preferences and needs of different groups of users.
- Secondly, it is necessary to devise a pruning procedure to reduce the amount of information to be handled by the user local devices. This procedure consists of cutting off metadata from the ontology to leave only the most relevant concepts about the pre-selected items. As a result, we get a partial ontology of a manageable size for the user devices to work with, plus partial stereotypes to support the filtering. When those data have arrived the devices, it is finally possible to run the recommendation strategies to decide what items will be offered to each user. The details of this approach has been described in (López-Nores, 2007), where we highlight its benefits in terms of users privacy and elaboration of recommendations regardless of the return channel availability.

We have experimentally validated both the server-based model and the distributed execution environment in the field of Digital TV, where a significant overload of audiovisual contents and interactive applications is noticeable. Besides, thanks to the flexibility and generality of our reasoning-based approach, we included our reasoning approach in diverse personalization tools:

- First, in (Blanco, 2008b) we incorporated a hybrid strategy –resulting from combining our content-based and collaborative techniques– into a TV recommender system called AVATAR, which selects the programs that best match each viewer's preferences.
- Second, in (Pazos-Arias, 2008), this hybrid strategy was employed in a personalized t-learning platform to identify education courses potencially interesting for each user, by considering the interests defined in her personal profile.
- Lastly, in (López-Nores, 2007), we validated experimentally our reasoning-enhanced strategies involving diverse hanheld devices (such as set-top boxes, PDAs and mobile phones). The goal of our experiments in this execution environment was to measure the personalization quality, taking for granted that it would be lower than in a server-based approach, because we now perform semantic reasoning over a reduced amount of data (i.e. the partial ontology and the stereotypes). Even though our proposal achieved slightly lower personalization quality than existing approaches to server-side semantic reasoning, we could confirm that this reduction does not affect significantly the viewers' positive perception of the services delivered (see details in (López-Nores, 2007)).

In sum, the results obtained from our experimental validation revealed: (i) enhanced accurate recommendations, (ii) significant increments of recall and precision[3] w.r.t. traditional syntactic approaches, which are devoid of our reasoning capabilities, and (iii) computational viability. This last property was achieved thanks to diverse refinements aimed at reducing the cost and improving the scalability of our approach:

- The first of these refinements is related to our technique for creating the users' profiles. This technique permits to model the user's preferences from a common knowledge repository, soothing the required storage capabilities needed for modeling purposes.

- Secondly, the taxonomy-based approach employed to create our rating vectors in the collaborative strategy also brings benefits in terms of scalability. As new items arrive to the existing collaborative systems, the size of users' vectors increases and therefore, the cost of computing correlations greatly rises. In contrast with this, as the number of available items gets higher in our reasoning approach, our rating vectors do not necessarily increase in size. This is due to the fact that many new items can belong to the same hierarchical classes in the ontology, thus reducing the computational complexity of our neighborhood formation process.
- Finally, note that in order to prevent our strategies from becoming too demanding in computational terms, we compute *off-line* many parameters involved in the inference of semantic associations, which can be reused as new users log into the recommender system (e.g. distance between two nodes in a chain of properties, and common ancestors between each pair of classes in the domain ontology).

In conclusion, the adopted measures shape strategies enhanced by reasoning mechanisms, whose flexibility and computational feasibility permit an extended use in multiple recommender systems and diverse execution environments.

FUTURE AND EMERGING TRENDS

Before concluding the chapter, we present some research trends that could harness our reasoning-based approach to continue promoting the field of personalization. The first trend is bound to the so-called Web 2.0. As O'Reilly (2005) described, the Web 2.0 encourages the collaboration and sharing of knowledge among users interacting in the context of a social network. In this scenario, users generate contents and provide tags for them (by informal annotations named *folksomies*) aimed at advanced searching tasks. Besides, users also rate the contents and suggest them to other individuals in the social network, and even, provide reviews and comments for contents generated by other users. The so participative role adopted by the users leads to a noticeable overload of information in the Web 2.0, therefore calling for a recommender system in the context of the social network. The emerging research trends in this field filter information by considering both the users' preferences and the annotations provided by the user-generated folksonomies (Yang, 2007; Yang, 2008). Since folksonomies are defined without consensus, some recent proposals are considering confidence models in order to decide whether the knowledge provided by these informal annotations is trustworthy (Li, 2008; Walter, 2008). These proposals can be greatly improved by incorporating our inference mechanisms, and specifically, enriching a formal domain ontology with the semantics represented in the folksonomies, about which our strategies could reason and select enhanced recommendations.

The second of the personalization trends explored in this section is related to the consumer electronics boom. Nowadays, users access through handheld devices to diverse entertainment and informative services in idle times (e.g. breaks between classes and journeys in public transport). In this scenario, two parameters mus be taken into account: first, the limited time that the users have to access the offered services, and second, the reduced size of displays in some consumer devices (such as PDAs and mobile phones). Both constraints force to personalize the list of items offered to the users, by selecting only those potencially interesting for them, as explained in (Mahmoud, 2007; Mifsud, 2007; Lee, 2007). Besides, since the list shown to the users cannot be very long, the included items must be different from each other; this way, even if an item is not appealing to the user, it is still possible to find successfull recommendations among the remaining items, as described in (Zhang, 2006; Panayiotou, 2006). Our reasoning-based approach could be an interesting starting point in the achievement of the mentioned diversity. As we discussed in the previous section, in this case it is necessary to consider the limited performance of handheld devices, so that our semantics-enhanced strategies can be locally executed in environments devoid of return channel.

Other research trend to be combined with our reasoning approach is the capability to select personalized recommendations for a group of users accessing together the personalization services (Masthoff, 2006). In this scenario, it is necessary to model the preferences of the group as a whole, so that the offered recommendations meet the likings of all the users. A possible reasoning-based approach consists of discovering semantic associations between the (individual) preferences of the members of the group, and employing them to discover patterns of (dis)liking common to all them. The knowledge inferred by this process makes it possible to model an improved *group profile*, which would lead our strategy to selecting only recommendations valid for all the users. As well as modeling the group profile, future research trends should adapt our reasoning-based strategies as the users' preferences evolve over time, considering both the effects of joining new users and leaving members of the group. In this regard, it is necessary to (i) identify the knowledge inferred up to date that our strategy could continue using, and (ii) filter information that is not valid in the new personalization scenario.

The last research trend pointed out in this section consists of incorporating information about the current context of the user into the personalization process. The research advances in contextualization have not yet been fully integrated into working systems. At the most, there are location-aware recommenders that can adapt their outputs depending on the user's spatial location. For the following years, it is expectable that a lot of research efforts will be devoted to other dimensions such as infrastructure (e.g. input devices available or surrounding communication resources), environmental conditions (noise, light, ...), time frames or even the user's feelings (e.g. mood or stress). These advances will boost the personalization quality of the current recommender systems, far beyond the performance achievable by matching descriptions of the available resources against the features defined in the users' profiles. The advances in the identification of context and the subsequent influence on filtering operations bear potential problems of scalability. To begin with, considering many dimensions of context makes it necessary to deploy many types of sensors around the users and their environment. Those sensors may provide an overwhelming amount of information, so it will be computationally very hard to select context-aware recommendations. Making this processing efficient may well require advances from such diverse areas as hardware engineering, algorithmic theory, fuzzy computing, emotion and cognition, as described in (Anand, 2007; González, 2007; Boutemedjet, 2008).

CONCLUSION

In this chapter, we have explored synergies between Semantic Web technologies and recommender systems in the field of personalization. Specifically, we have extended several reasoning mechanisms –mainly semantic associations and Spreading Activation techniques– to meet personalization requirements of a recommender system, with the goal of overcoming unresolved limitations of the traditional recommendation strategies.

Firstly, we have developed a *content-based strategy* aimed at alleviating the overspecialized nature of traditional suggestions, by employing a new similarity metric that reasons about the semantics of the compared items. Specifically, in our approach the resemblance between two items depends on both the semantic associations discovered between them in the domain ontology, and the relevance that Spreading Activation techniques assign to such associations. Thanks to the flexibility enabled by semantics, our metric measures similarity between items that do not share identical attributes, thus endowing the offered recommendation with a rich diversity.

Besides, we have described a novel *collaborative strategy* where our reasoning capabilities are exploited during both the process of neighborhood formation for each user, and the selection of her personalized recommendations. On the one hand, thanks to the knowledge formalized in the domain ontology and to our flexible semantics-based metric, our collaborative strategy detects similarity between the profiles of two users even when they have not rated the same items. On the other hand, it is also possible to suggest items that have not been rated by any user in the system, by predicting their levels of interest by reasoning-based estimation processes. Consequently, our proposal greatly alleviates the adverse effects of both the *sparsity problem* and the *latency concerns* present in current collaborative approaches.

In proof of the flexibility of our domain-independent personalization approach, we have incorporated our reasoning-based strategies into diverse personalization tools in the field of Digital TV, such as a TV recommender system, a t-learning platform, and a tool that delivers personalized advertisements. Our experimental evaluation has revealed both the scalable nature and the computational feasibility of our domain-independent personalization approach based on semantic reasoning, dealing with diverse execution environments (either a dedicated server or a local consumer device). From these results, we conclude that the semantic reasoning is a step forward in the development of enhanced pesonalization services.

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KEY TERMS AND DEFINITIONS

Collaborative Filtering is a recommendation strategy that estimates the relevance of an item to a user by considering the ratings that other individuals with similar preferences have given to that item.

Complex Semantic Associations are semantic relationships inferred from the hierarchical links and properties formalized in an ontology.

Content-Based Filtering is a recommendation strategy that estimates the relevance of an item to a user by matching its content descriptions against the attributes defined in the user's profile.

Hybrid Filtering is a personalization technique that harnesses the synergetic effects derived from the combination of diverse recommendation strategies.

Ontology is a formal specification of a conceptualization, that is, an abstract and simplified view of the world that we wish to represent, described in a language that is equipped with a formal semantics.

Personalization is the capability to select recommendations of items tailor-made for a user by taking into account the preferences or needs previously modeled in a personal profile.

Recommender Systems are personalization tools that select items potencially interesting for the users by employing strategies that filter irrelevant information according to the users' profiles.

Semantic Web is an evolving extension of the World Wide Web in which the semantics of information is defined, making it possible to understand and satisfy the requests of people and machines to use the web content.

Spreading Activation Techniques are computational mechanisms able to explore efficiently huge networks with interconected nodes, and infer knowledge from the relationships represented in such networks. Specifically, Spreading Action techniques detect nodes that are strongly related to others initially identified in the network.

ENDNOTES

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[2] Recall that the most appealing items to the user are identified by ratings close to +1, while the most unappealing ones are identified by ratings close to -1.

[3] In our tests, recall is defined as the percentage of items (TV programs or educational courses) interesting for the user that are suggested by our strategy, and precision is the percentage of suggested items that are appealing to the viewer.

Chapter V
Querying Web Accessibility Knowledge from Web Graphs

Rui Lopes
LaSIGE, University of Lisbon, Portugal

Luís Carriço
LaSIGE, University of Lisbon, Portugal

ABSTRACT

Web Accessibility is a hot topic today. Striving for social inclusion has resulted in the requirement of providing accessible content to all users. However, since each user is unique, and the Web evolves in a decentralized way, little or none is known about the shape of the Web's accessibility on its own at a large scale, as well as from the point-of-view of each user. In this chapter the authors present the Web Accessibility Knowledge Framework as the foundation for specifying the relevant information about the accessibility of a Web page. This framework leverages Semantic Web technologies, side by side with audience modeling and accessibility metrics, as a way to study the Web as an entity with unique accessibility properties dependent from each user's point of view. Through this framework, the authors envision a set of queries that can help harnessing and inferring this kind of knowledge from Web graphs.

INTRODUCTION

Since its inception, the Web has become more and more prolific in people's lives. It is used as an information source, both one-way (e.g., newspapers) and two-way (e.g., blogging, forums, or even instant messaging). New Web sites and new content are produced and published each second by both professionals and amateurs, each one with different usability and accessibility quality marks. This fact, in conjunction with the Web's decentralized, yet highly connected architecture, puts challenges on the user experience when interacting and navigating between Web sites.

At the same time, the attractiveness of the Web brings more users to use it on a regular basis. This means that user diversity will be closer to real life where both unimpaired and impaired users coexist. Since each user has its own specific requirements, (dis)abilities, and preferences, their experience is different for each one, resulting in different satisfaction levels. In the same line of user diversity, device prolificacy and Internet connection ubiquity also contribute to the range of possible user experiences on interacting with the Web and, consequently, also have a stake in accessibility issues.

For all these reasons, the shape of the Web itself deeply influences each user's interactive experience in different ways. Users tend to navigate through the Web by avoiding Web sites that cannot be rendered correctly, which provide poor interactive capabilities for the specificities of the user or the device she/he is using to access the Web, reflecting negatively on users' experience. Therefore, it is required to understand the Web's graph of Web pages at a large scale from the point-of-view of each individual's requirements, constraints and preferences, and grasp this information to devise future advancements on Web standards and accessibility-related best practices. The inability to adapt the Web, its standards, technologies, and best practices will pose severe problems on the society in general, by leaving untouched the barriers towards a proper e-inclusion level that can actually cope with everyone, independently of impairments and related needs.

The main contributions of this Chapter are: (1) the establishment of a Web accessibility framework that can be used to create complex knowledge bases of large scale accessibility assessments; and (2) a set of query patterns to infer critical aspects of the accessibility of Web graphs with a fine-grained control (based on users' requirements and constraints). The proposed framework and the set of query patterns will form a core tool that helps analyzing the semantics of the accessibility of Web graphs. Next, we describe the relevant background work on Web accessibility and knowledge extraction from Web graphs.

BACKGROUND

Two main research topics have influence and contribute to the study of Web accessibility on large scale: the analysis of accessibility compliance of a Web page (or Web site), and the analysis of the Web's graph structure.

The Web Accessibility Initiative (WAI, n.d.) of the World Wide Web Consortium (W3C, n.d.) has strived for setting up the pace of Web Accessibility guidelines and standards, as a way to increase accessibility awareness to Web developers, designers, and usability experts.

The main forces of WAI are the Web Content Accessibility Guidelines, WCAG (Chisholm et al., 1999). WCAG defines a set of checkpoints to verify Web pages for specific issues that have impact on accessibility of contents, such as finding if images have equivalent textual captions. These guidelines have been updated to their second version (Caldwell et al., 2008) to better handle the automation of accessibility assessment procedures, thus dismissing the requirement of manual verification of checkpoint compliance.

Until recently, the results of accessibility assessment were presented in a human-readable format (i.e., Web page). While this is useful for developers and designers in general, this is of limited use for comparison and exchange of assessment results. Therefore, WAI has defined EARL, Evaluation and Report Language (Abou-Zahra, 2007), a standardized way to express evaluation results, including Web accessibility evaluations, in an OWL-based format (Dean & Schreiber, 2004).

EARL affords the full description of Web accessibility assessment scenarios, including the specification of *who* (or *what*) is performing the evaluation, the *resource* that is being evaluated, the *result*, and the *criteria* used in the evaluation.

However, EARL does not provide constructs to support the scenarios envisioned in macro scale Web accessibility assessments. It cannot cope with metrics (thus dismissing quantification of Web accessibility) and with the Web's graph structure. This way, EARL becomes limited to single Web page qualitative evaluations.

Lopes & Carriço (2008a) have shown that current Web accessibility practices are insufficient to cope with the whole spectrum of audiences (both disabled and unimpaired users), and that any user can influence everyone's interactive experience on the Web (especially regarding accessibility issues). As Kelly et al. (2007) have predicted, to cope with every user, holistic approaches to Web accessibility have to be taken into account. This includes tailoring of accessibility assessment procedures to each individual's characteristics, as thoroughly discussed by Vigo et al. (2007b).

Generalizing the concept of accessibility to all users (and not just to those that deeply depend on it – i.e., people with disabilities), the adequacy of user interfaces to each user's requirements, limitations, and preferences is the ultimate goal of *Universal Usability*, as defined by Shneiderman (2000). As detailed by Obrenovic et al. (2007), one has to take into account users, devices, and environmental settings when studying accessibility in a universal way. However, to our knowledge, there is no work on how to measure the universal usability quality of a single Web page, from the perspective of a unique user (*per definition* of universal usability).

When scaling up to the size of the Web, other aspects of analysis have to be taken into account. The characterization of the Web (e.g., its size, analysis metrics, statistics, etc.) is a hot topic today. *Web Science* is emerging as a discipline that studies the Web as a dynamic entity, as described by Berners-Lee et al. (2006). It is centered on how infrastructural requirements, application needs, and social interactions depend and feed each other in the Web ecology (Hendler et al., 2008).

At a more fundamental level, one of the core aspects of studying the Web concerns on how it is universally usable, as hypothesized and defended by Shneiderman (2007). However, since this discipline is fairly new, little is know about the Web from a universal usability point-of-view. It is known that the evolution of Web standards has influence on the way users navigate and interact with the Web (Weinreich et al., 2006), but not to what extent and what is the impact on each individual's characteristics. By having a proper characterization of the Web's graph from each individual's point of view (i.e., requirements, needs, constraints, preferences), more complex studies can be preformed at higher abstraction levels, such as in-depth Social Network Analysis (cf. Berger-Wolf & Saia, 2006) and other types of social studies.

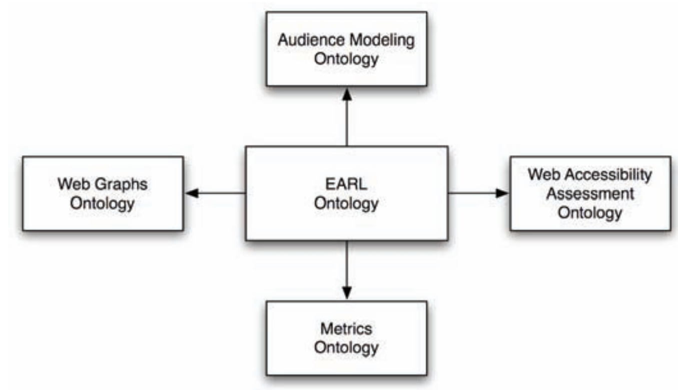
In Lopes & Carriço (2008b) the authors presented a mathematical model to study universal usability on the Web. It supports the analysis of the Web from the point-of-view of each user's characteristics, and explains how the Web's structure influences user experience. While the authors have hypothesized how this model can be used to observe the evolution of the Web, it just provides a theoretical framework for the analysis of accessibility. Nevertheless, this model provides interesting contributions on how the query patterns presented in this Chapter should be formulated.

WEB ACCESSIBILITY KNOWLEDGE FRAMEWORK

In order to open the way to querying different Web accessibility properties from Web graphs, we have defined a supportive knowledge framework. This framework groups four different components, as depicted in Figure 1: *Web Graphs*, *Web Accessibility Assessment*, *Audiences*, and *Metrics*. The framework has been design according to the following requirements:

- *Universal*. The framework should not be limited to "traditional" accessibility audiences (such as people with visual impairments), but cope with different kinds of

Figure 1. Web accessibility knowledge framework



accessibility-prone issues, such as limited interaction devices (e.g., mobile phones), or adversary environment settings (e.g., poor lighting settings). The universality concept can (and, in fact, should) be also extended to all users and usage situations, thus allowing knowing the impact of Web accessibility and similar universal usability issues on any user.

- *Generalized*. The framework must not impose *a priori* any limitation or bias towards particular accessibility assessment concepts. It should define them at a meta-level, in order to be possible to define query patterns that are independent from particular instances (e.g., a query pattern depends on user characteristics, not on *a* user characteristic).
- *Extensible*. Since the accessibility assessment procedures change (mostly to enforce better analyses), the framework should support the application of different procedures.
- *Fine-grained*. As discussed earlier, current accessibility evaluation practices are black-boxed, leading to having just a general view of evaluation results. The framework should support fine-grained analyses, to support studying accessibility from the perspective of different audiences.
- *Scalable*. The framework should not impose limits to the size and complexity of encoded information (i.e., knowledge base).

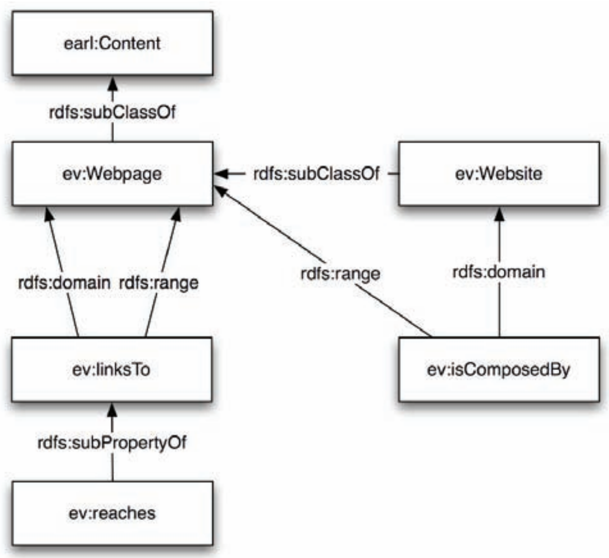
Each component is defined through a specific OWL-based vocabulary, as the inclusion of already existing ontologies (mostly specified in OWL) lowers the burden of defining each component of the framework. Accordingly, we have developed this framework by extending the EARL ontology to support the elicited requirements. Next, each component of the framework is described in more detail. For details about the namespace prefixes used in the next Sections and their corresponding URI mappings, please consult the Appendix. Throughout this Section we will provide examples on how to describe accessibility knowledge based on the Notation 3 (N3) syntax (Berners-Lee, 2006).

Web Graphs

The first component in the framework relates to the specification of Web graphs. The goal of this component is to represent each Web page as a single resource, as well as its corresponding hyperlinking structure. Figure 2 presents the concepts that support the specification of Web graphs.

The main subject of constructing Web graphs is the Web page. Since the EARL specification

Figure 2. Web graphs ontology



only supports the specification of subjects that are available on the Web (*earl:Content* class), we have further refined the concept to limit its scope just to Web pages (the core subject of accessibility assessment procedures), through the *ev:Webpage* class. Other types of content, such as images and CSS stylesheets (Bos, Çelik, Hickson, & Lie, 2007), were considered inherent of each Web page, from the perspective of evaluation procedures.

Two main properties (and their inverse) were defined to specify hyperlinks. The first, *ev:linksTo* (and its corresponding inverse property, *ev:islinkedBy*) establishes the direct relationship between two Web pages. The second property, *ev:reaches* (and its inverse, *ev:isReachedBy*), extends *ev:linksTo* with a transitive characteristic. This way, it becomes possible to query Web graphs from the perspective of reachability between two (or more) Web pages, not just on direct linking properties. This property will only afford knowing whether two Web pages are indirectly connected, leaving outside of the scope the number of links in between them. We have opted to explicitly define inverse properties, to afford the specification of queries that are more expressive and closer to natural language. To complement these constructs, we have specified the *ev:Website* class that, in conjunction with the *ev:isComposedBy* property (and its inverse, *ev:composes*), affords the direct specification of which Web pages belong to the same Website. To support out-of-the-box the specification of hyperlinking structure for Web sites, we have defined that *ev:Website* extends the *ev:Webpage* concept. However, the ontology cannot enforce the semantics that if two Web pages are linked, then their corresponding Web sites are also linked. Hence, we have devised two rules in SWRL (Horrocks et al., 2004) to afford linking scenarios, as presented next:

```
ev:linksTo(?website1, ?website2) =>
    ev:isComposedBy(?website1, ?webpage1) &
    ev:isComposedBy(?website2, ?webpage2) &
    ev:linksTo(?webpage1, ?webpage2)

ev:reaches(?website1, ?website2) =>
    ev:isComposedBy(?website1, ?webpage1) &
    ev:isComposedBy(?website2, ?webpage2) &
    ev:reaches(?webpage1, ?webpage2)
```

Next, we present a small example of how to define Web graphs, formally expressed (in the N3 format):

```
@base <http://example.com/>.

<b.html> a ev:Webpage.
<c.html> a ev:Webpage.
<a.html> a ev:Webpage;
    ev:linksTo <b.html>;
    ev:linksTo <c.html>.

<> a ev:Website.
<> ev:isComposedBy <a.html>;
 ev:isComposedBy <b.html>;
 ev:isComposedBy <c.html>.
```

Web Accessibility Assessment

The essential aspects for accessibility assessment results concern the description of the tests and their resulting outcome of applying them to a Web page. Consequently, the EARL ontology affords an extensible way of describing Web accessibility assessment results, in the form of *earl:Assertion* predicates. This includes, amongst other predicates, the specification of which test is being applied (i.e., *earl:TestCase*) and what is the result of its application to the Web page that its being evaluated (i.e., *earl:TestResult*).

In the second component of our framework, we have extended the EARL predicates for accessibility assessment by refining test cases (i.e., *earl:TestCase*) with appropriate semantics about the nature of the tests, regarding the different technologies used in Web pages. This will afford the fine-grained analysis of Web pages according to technological criteria, as depicted by the concepts in Figure 3.

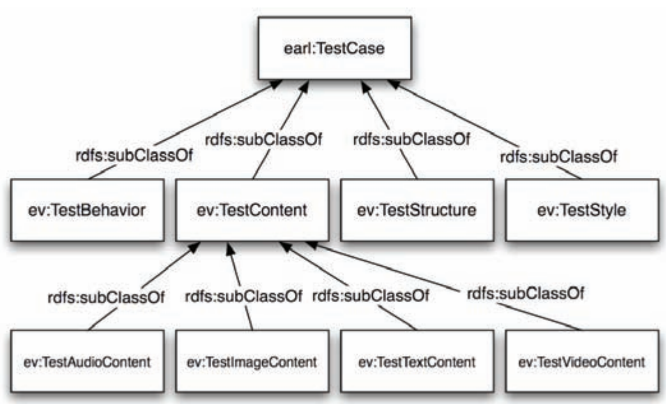
The main predicates for describing the nature of the tests are: *ev:TestContent*, for the specification of tests applied to the actual contents (in different media) of Web pages; *ev:Structure*, for tests applied directly on the HTML structure itself; *ev:Style*, when testing styling properties (such as analyzing CSS); and *ev:Behavior*, to represent tests over scripts (e.g., Javascript).

To better illustrate the usage of this ontology, we present next a classification of some WCAG 1.0 guidelines:

```
@prefix wcag10: <http://www.w3.org/TR/WCAG10/#>.

wcag10:gl-color a ev:TestStyle.
wcag10:gl-structure-presentation a evTest-Structure.
```

Figure 3. Web accessibility assessment ontology



```
wcag10:gl-structure-presentation a evTest-
Style.
```

Audiences

We have defined a third component in our ontological framework to support the specification of audiences. This will ensure that different queries can be performed to a knowledge base of Web accessibility assessment according to the necessities and characteristics of different audiences. We based this support on earlier works on audience modeling, such as those described in Lopes & Carriço (2008a). Figure 4 depicts the complete ontological vocabulary to describe audiences (for simplicity, inverse properties are omitted).

The atomic concept in this vocabulary is *ev:AudienceCharacteristic*. Its purpose is to represent a single concept of an audience (e.g., a specific disability, a device characteristic, etc.). Since characteristics may represent concepts at different abstraction levels, they should be structured taxonomically. We introduce the *ev:refines* property (and its inverse, *ev:isRefinedBy*) to afford this expressivity.

The inherent nature of audiences raises the fact that they are often defined by several characteristics. Accordingly, this vocabulary introduces *ev:AudienceClass* as a way to represent them, along the side of the *ev:audienceClassContains* property (and its inverse, *ev:audienceCharacteristicIsContainedBy*) to map characteristic inclusion by an audience. However, since this association is merely syntactic, incoherent audiences might be described. To mitigate such issues we have introduced two additional concepts in the vocabulary. The first, *ev:dependsOn*, affords mapping dependencies between characteristics (such as total blindness depends on screen reader). The second, *ev:incompatibleWith*, allows the specification of incompatibilities between characteristics (e.g., total blindness is incompatible with screen). With these two properties, the semantics of audiences can be verified automatically. These properties, in conjunction with *ev:refines*, form the set of semantic relations that can be established between characteristics. Therefore, we introduce a generalization concept, *ev:characteristicRelation*, as an abstraction for the three concepts. This term affords inferring, e.g., if two characteristics have any kind of dependency between them.

While analyzing Web graphs from the perspective of a single audience can provide interesting

Figure 4. Audiences ontology

results, the scope of such results is limited. It is often to perform comparative analyses of the results for a set of audiences. To support such scenarios, we have defined an audience aggregation concept, *ev:AudienceDomain*, to represent the domain of audiences that will be analyzed. The inclusion of an audience by a domain is represented through the *ev:audienceDomainContains* property (and corresponding inverse, *ev:audienceClassIsContainedBy*).

Lastly, we introduce in this vocabulary another concept to explore the synergies and differences between audiences, through the *ev:audienceClassExtends* property (and its *ev:audienceClassIsExtendedBy* counterpart). This extension mechanism is based on traditional object oriented modeling practices, i.e., an audience that extends another audience inherits its characteristics, thus creating parent-child relationships between audiences within a domain. Moreover, due to the fact that characteristics are taxonomically organized (through the *ev:refines* property), the characteristics of child audiences can be inferred and generalized to their common parent audience. A simple example follows, where a small taxonomy of characteristics is defined, and used in the definition of an audience domain.

```
@prefix tx: <http://taxonomy.com/>.
@prefix au: <http://audiences.com/>.

tx:characteristic a
ev:AudienceCharacteristic.
tx:disability a ev:AudienceCharacteristic.
tx:blind a ev:AudienceCharacteristic.
tx:totallyBlind a ev:AudienceCharacteristic.
tx:colorBlind a ev:AudienceCharacteristic.
tx:device a ev:AudienceCharacteristic.
tx:screen a ev:AudienceCharacteristic.

tx:disability ev:refines tx:characteristic.
tx:blind ev:refines tx:disability.
tx:totallyBlind ev:refines tx:blind.
tx:colorBlind ev:refines tx:blind.
tx:device ev:refines tx:characteristic.
tx:screen ev:refines tx:device.

tx:totallyBlind ev:incompatibleWith
tx:colorBlind.
tx:totallyBlind ev:incompatibleWith
tx:screen.
tx:colorBlind ev:dependsOn tx:screen.

au:domain1 a ev:AudienceDomain.

au:blind a ev:AudienceClass.
au:blind ev:audienceClassContains tx:blind.
au:domain1 ev:audienceDomainContains
au:blind.

au:totallyBlind a ev:AudienceClass.
au:totallyBlind ev:audienceClassContains
tx:totallyBlind.
au:domain1 ev:audienceDomainContains
au:totallyBlind.

au:colorBlind a ev:AudienceClass.
au:colorBlind a ev:audienceClassContains
tx:colorBlind.
au:colorBlind a ev:audienceClassContains
tx:screen.
au:domain1 ev:audienceDomainContains
au:colorBlind.

au:totallyBlind ev:audienceClassExtends
au:blind.
au:colorBlind ev:audienceClassExtends
au:blind.
```

However, affording the description of audience domains has limited applicability. To ensure that queries on Web graphs can be formulated based on the characteristics of audiences, there must be a mapping between audiences and accessibility assessment tests. Such vocabulary is synthesized in Figure 5.

In this vocabulary we have introduced a single property, *ev:requiresCharacteristic* (and its cor-

Figure 5. Audience/test mapping sub-ontology

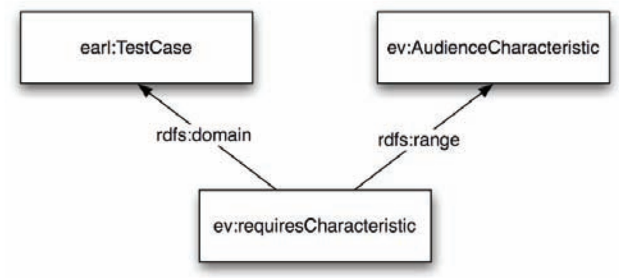
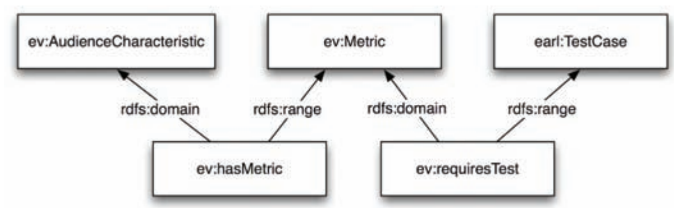


Figure 6. Metrics ontology



responding *ev:isRequiredByTest* counterpart), that maps a characteristic to a particular *earl:TestCase* instance. With this property, any audience or even entire domain can be mapped to the battery of tests that must be performed to a Web page, in order to obtain results tailored to these audiences. Dually, if the entire set of tests is performed over each Web page, their results can be queried from the perspective of different audiences or entire domains. An example follows, where the two previous examples are bound together. More specifically, we map test cases to concrete audience characteristics that have been defined.

```
@prefix wcag10: <http://www.w3.org/TR/WCAG10/#>.
@prefix tx: <http://taxonomy.com/>.

wcag10:gl-color ev:requiresCharacteristic tx:colorBlind.
wcag10:gl-structurePresentation ev:requiresCharacteristic tx:totallyBlind.
```

Metrics

The last component in the framework concerns the specification of Web accessibility metrics, i.e., providing quantitative information about the accessibility of a Web page. Since different metrics can be applied to evaluation results, a supportive vocabulary for the specification of metrics must be extensible. This way, Web graphs can also be analyzed from the perspective of different metrics, thus allowing exploring which metric is better suited to different accessibility scenarios. Figure 6 depicts the vocabulary to support the specification of metrics.

The main concept in the metrics vocabulary is *ev:Metric*. Its purpose is to afford the specification of metrics that are applied to each Web page, based on the results of corresponding tests. While some metrics might be independent from specific tests, more concrete metrics can depend on the application of them. Therefore, we introduce the *ev:requiresTest* property to define dependency binds between metrics and tests (and its counterpart, *ev:isRequiredByMetric*). This property can be used, e.g., to specify consistency verification rules on the application of metrics, based on their semantics. Furthermore, by crossing this property with the *ev:requiresCharacteristic*, metrics can be mapped indirectly to audience characteristics. However, metrics can also be directly related to audience characteristics. This affords tying up specific quantification procedures to characteristics. Hence, we introduce an extra property in the vocabulary, *ev:hasMetric*, in order to support this type of scenarios. Next, we present a simple example on how to bind metrics with tests and characteristics.

```
@prefix wcag10: <http://www.w3.org/TR/WCAG10/#>.
@prefix m: <http://example.com/metrics#>.
@prefix tx: <http://taxonomy.com/>.

m:simpleMetric a ev:Metric;
    ev:requiresTest wcag10:gl-color;
    ev:requiresTest wcag10:gl-structurePresentation.

m:charMetric a ev:Metric.

tx:colorBlind ev:hasMetric m:charMetric.
```

We have introduced another concept on the vocabulary that is crucial to the specification of metrics. Each metric is supposed to have a concrete value, when applied to a Web page. Therefore, the vocabulary provides support to this feature through the *ev:hasMetricValue* datatype property, where metric values can be setup in the [0, 1] range (i.e., percentage). This way, since each metric does not yield an absolute value, Web graphs can be compared in the perspective of different metrics. With these constructs, the framework provides the support for specifying the resulting application of a given metric, in the context of an accessibility evaluation procedure. However, it is out of the scope of this Chapter to describe how these metrics are calculated (cf. Vigo et al., 2007a).

Consequently, since this property is abstract, concrete metrics properties must be derived from *ev:hasMetricValue* through subclassing. This extension to the metrics ontology is depicted in Figure 7.

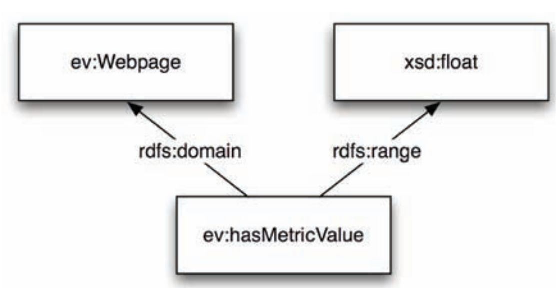
As a simple example, we present how to use this extension to the metrics ontology, by specifying a new datatype property, as well as its application in a concrete set of Web pages.

```
@prefix m: <http://example.com/metrics#>.
@base <http://example.com/>.

m:hasSimpleMetricValue rdfs:subPropertyOf ev:hasMetricValue.
<a.html> m:hasSimpleMetricValue 0.2.
<b.html> m:hasSimpleMetricValue 0.9.
<c.html> m:hasSimpleMetricValue 0.45.
```

However, with these constructs it is impossible to know what are the metric values associated with a specific characteristic or test case, for a given Web page. This happens due to *ev:Metric* instances are not automatically bound to datatype properties derived from *ev:hasMetricValue*. Consequently, query patterns cannot be created to explore complex mining scenarios, as each binding between metrics and datatype properties have to be artificially created on each query, which poses sever limitations on the generalization requirement for querying Web accessibility. In

Figure 7. Metrics ontology extension



order to mitigate this situation, we defined another property, *ev:relatesToMetric* (and its counterpart, *ev:isRelatedToDatatypeProperty*), to draw both concepts together, as depicted in Figure 8.

Since we wanted to bind a datatype property directly to an *ev:Metric* instance, we had to import the OWL schema into our own ontology. This is due to the fact that, per definition, object properties bind class instances. Because *ev:hasMetricValue* (and subclassed datatype properties) are *owl:DatatypeProperty* instances, we circumvented this to afford the specification of richer and more complex query patterns that can remain agnostic to particular concepts or instances.

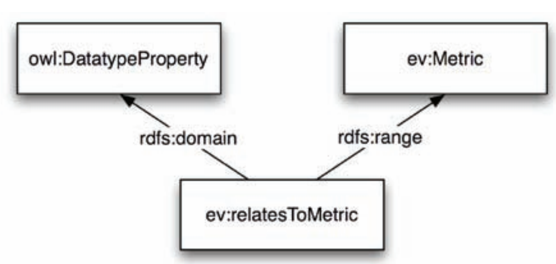
To exemplify the usage of this property, we have bound a metric instance to a particular datatype based on the previous examples, as shown next.

```
@prefix m: <http://example.com/metrics#>.

m:hasSimpleMetricValue  ev:relatesToMetric
m:simpleMetric.
```

However, by setting *ev:relatesToMetric*'s domain to a generic OWL construct, one can bind metrics to any datatype property as there is no formal way to restrict the domain just to datatype properties derived from *ev:hasMetricValue*. To mitigate this issue, there must be an appropriate semantic enforcement through rules. The following SWRL rule affords this scenario:

Figure 8. Metrics binding scheme




```
ev:relatesToMetric(?datatypeProperty, ?met-
ric) =>
   owl:subPropertyOf(?datatypeProperty,
ev:hasMetricValue)
```

QUERY PATTERNS

The extensions to the EARL ontology that we presented in the previous Section provide a comprehensive set of concepts that afford the full description of Web graphs from the perspective of Web accessibility and audience richness. This framework serves as the base ground for setting up Web graph knowledge bases that can be semantically queried in different forms. From the vast range of Semantic Web querying technologies, we opted to specify queries in the SPARQL language (Prud'hommeaux & Seaborne, 2008), as it is the *de facto* querying standard in the Semantic Web stack.

All examples in this Section will be based on the following SPARQL prefixes mapping:

```
PREFIX earl: < http://www.w3.org/ns/earl#>
PREFIX ev: <http://hcim.di.fc.ul.pt/ontolo-
gies/evaluation#>
PREFIX m: <http://example.com/metrics#>
PREFIX tx: <http://taxonomy.com/>
PREFIX au: <http://audiences.com/>
PREFIX  wcag10:  <http://www.w3.org/TR/
WCAG10/#>
```

In this chapter, we have distinguished two different types of query patterns than can be applied to Web graphs: mining properties, and partitions extraction. Next, we describe each one of these pattern types.

Mining Web Site Properties

Web sites on their own can be analyzed from several perspectives. In this Section, we present some query patterns that can extract relevant information about a single Web page, as well as a set of Web pages perceived as one single entity (i.e., Web site). For practical purposes, all SPARQL patterns are applied to a dummy Web page (*http://example.com/a.html*) or Web site (*http://example.com*), whose semantics are marked as *ev:Webpage* and *ev:Website* instances, correspondingly; other instances that appear on queries are based on the examples presented in the previous Sections.

Metric thresholds. One of the simplest ways of verifying the accessibility of a single Web page relates to setting up quality thresholds. We have devised several query patterns for this purpose. The simplest query concerns a strict threshold that yields whether a Web page has a minimum quality level for a specific metric:

```
ASK {
    <http://example.com/a.html>
    m:hasSimpleMetricValue ?v.
    FILTER (?v >= 0.5)
}
```

Based on this pattern, one can generalize it for minimum and maximum boundaries, thus allowing checking if a Web page belongs to a particular quality cluster:

```
ASK {
    <http://example.com/a.html>
    m:hasSimpleMetricValue ?v.
    FILTER(?v >= 0.5 && ?v <= 0.75)
}
```

On the other hand, thresholds can be used to understand what metrics are above a certain value (or between two boundaries). Along these lines, the previous query pattern can be rewritten as:

```
SELECT ?metric
WHERE {
    <http://example.com/a.html> ?metricValue
    ?v.
    ?metricValue ev:relatesToMetric ?metric.
    FILTER (?v >= 0.5 && ?v <= 0.75)
}
```

Content quality. Another aspect that can be explored in a Web page deals with the semantics of the tests applied to it. In conjunction with metric value filtering, one can grasp the quality of a Web page based on the semantic categorization of test cases:

```
ASK {
    <http://example.com/a.html> ?metricValue
    ?v.
    ?metricValue ev:relatesToMetric ?metric.
    ?metric ev:requiresTest ?test.
    ?test rdfs:subClassOf
    ev:TestImageContent.
    FILTER (?v >= 0.5)
}
```

This query pattern can be extended to find out which types of test cases have an inherent quality above a given threshold (the DISTINCT query modifier has been used to remove duplicates):

```
SELECT DISTINCT ?testType
WHERE {
    <http://example.com/a.html> ?metricValue
    ?v.
    ?metricValue ev:relatesToMetric ?metric.
    ?metric ev:requiresTest ?test.
    ?test rdfs:subClassOf ?testType.
    FILTER (?v >= 0.5)
}
```

Characteristic quality. As explained earlier, characteristics can be bound to metrics. This feature of the framework allows the exploration of quality metrics similar to *metric thresholds*, but taking into account characteristics as the main feature to be analyzed:

```
ASK {
    <http://example.com/a.html> ?prop ?v.
```

```
    tx:colorBlind ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?v >= 0.5)
}
```

This pattern can be extended in order to leverage which characteristics have a quality level above a certain threshold:

```
SELECT ?char
WHERE {
    <http://example.com/a.html> ?prop ?v.
    ?char ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?v >= 0.5)
}
```

By having a quality mark associated to characteristics, these can also be compared, to verify which one is better supported in a Web page. This can be directly achieved with the following query pattern:

```
ASK {
    <http://example.com/a.html> ?prop1 ?v1.
    <http://example.com/a.html> ?prop2 ?v2.
    tx:colorBlind ev:hasMetric ?metric1.
    tx:totallyBlind ev:hasMetric ?metric2.
    ?metric1 ev:isRelatedToDatatypeProperty
    ?prop1.
    ?metric2 ev:isRelatedToDatatypeProperty
    ?prop2.
    FILTER (?v1 > ?v2)
}
```

Furthermore, both patterns can be combined to extract which characteristics have a better quality than a predetermined one:

```
SELECT ?char
WHERE {
    <http://example.com/a.html> ?prop1 ?v1.
    <http://example.com/a.html> ?prop2 ?v2.
    tx:colorBlind ev:hasMetric ?metric1.
    ?char ev:hasMetric ?metric2.
    ?metric1 ev:isrelatedToDatatypeProperty
    ?prop1.
    ?metric2 ev:isrelatedToDatatypeProperty
    ?prop2.
    FILTER (?v1 > ?v2)
}
```

Audience quality. One of the important aspects discussed earlier pertains to knowing if a Web page has a certain degree of quality in what respects to a particular audience. The previous query pattern can be adapted to support this feature:

```
ASK {
    <http://example.com/a.html> ?prop ?v.
    au:totallyBlind ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?v >= 0.5)
}
```

While this query pattern affords the explicit verification of the quality of a given audience, it is also relevant to explore and infer which audiences are supported in a Web page, with a given quality level. This pattern can be translated into SPARQL as:

```
SELECT ?audience
WHERE {
    <http://example.com/a.html> ?prop ?v.
    ?audience  ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?v >= 0.5)
}
```

Domain quality. In the same fashion as the previous patterns, one can obtain information about whether a domain is supported by a Web page or not, according to a specific threshold:

```
ASK {
    <http://example.com/a.html> ?prop ?v.
    au:domain1 ev:audienceDomainContains
    ?audience.
    ?audience ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?v >= 0.5)
}
```

In the case where one wants to discover which domains are above a given threshold, the previous query pattern can be adapted in a simple way to cope with this requirement, as follows:

```
SELECT ?domain
WHERE {
    <http://example.com/a.html> ?prop ?v.
    ?domain ev:audienceDomainContains
    ?audience.
    ?audience ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?v >= 0.5)
}
```

Website quality. While all of the previous patterns are targeted just to a single Web page, it is relevant to find out information about the set of Web pages from a unique entity point of view (e.g., a Web site). By exploring the Web graph ontology provided in the framework, Web sites can be analyzed as a single entity:

```
SELECT ?page
WHERE {
    ?page ev:composes <http://example.
    com>.
}
```

More complex patterns can be devised for Web sites, based on this pattern and the set of patterns presented above for Web pages. For instance, combining this pattern with characteristic quality analysis, Web sites can be analyzed to find out which ones are entirely accessible for any audience characteristic above a certain threshold:

```
SELECT ?site
WHERE {
    ?site ev:isComposedBy ?page.
    ?page ?prop ?v.
    ?char ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?v >= 0.5)
}
```

A variant on this query pattern can be defined as verifying if the average metric value is above the threshold, for a given characteristic. This would unify Web pages, thus analyzing a Web site as a single entity. However, SPARQL does not provide aggregation functions out of the box. Therefore, some implementations have circumvented this issue through, e.g., the AVG function. Without this function each metric value should be aggregated outside the query pattern and an average value calculation should be performed, which influences its scalability. Hence, this pattern uses the AVG function accordingly:

```
SELECT AVG(?v)
WHERE {
    <http://example.com> ev:isComposedBy
    ?page.
    ?page ?prop ?v.
    tx:totallyBlind ev:hasMetric ?metric.
```

```
    ?metric:isRelatedToDatatypeProperty
    ?prop.
}
```

Semantically Extracting Web Graph Partitions

While capturing information about the accessibility of single Web pages or Web sites has value, it is more interesting to analyze Web graphs as a whole. The set of query patterns presented in the previous Section can be adapted to grasp new knowledge about entire Web graphs. In this Section we present query patterns that afford the extraction of Web graph partitions according to accessibility criteria. Along the lines of the previous Section, all SPARQL patterns are applied to a set of dummy Web pages (e.g., *http://example.com/a.html*) or Web site (*http://example.com*), with the semantics of *ev:Webpage* and *ev:Website*, correspondingly; other instances that appear on queries are based on the examples presented in the previous Sections.

Reachability. The simplest information that can be obtained about a Web graph concerns its edges, i.e., the link structure. Edges are described through *ev:linksTo* property instances. The transitiveness of the *ev:reaches* property, based on *ev:linksTo*, allows the exploration of connectivity between Web pages (and between Web sites, as well). This query pattern will be used as the base support for extracting Web graph portions according to different accessibility semantics. Reachability can be a property queried between Web pages, e.g.:

```
ASK {
    <http://example.com/a.html>  ev:reaches
    <http://example.com/b.html>.
}
```

This notion can be extended to explore which Web pages can be reached from a starting point:

```
SELECT ?page
WHERE {
    <http://example.com/a.html>  ev:reaches
    ?page.
}
```

The opposite pattern, knowing which Web pages reach a specific ending point, can also be explored similarly:

```
SELECT ?page
WHERE {
    ?page ev:reaches <http://example.com/a.
    html>.
}
```

Lastly, based on these queries, Web graph portions can be extracted according to their linking structures. For these patterns, we use the CONSTRUCT query form provided in SPARQL. The simplest graph portion extraction concerns finding out the linking structure reached from a specific starting Web page:

```
CONSTRUCT {
    ?page ev:linksTo ?otherpage
}
WHERE {
    <http://example.com/a.html>  ev:reaches
    ?page.
    ?page ev:linksTo ?otherPage.
}
```

By generalizing this query pattern, the entire information about a particular Web graph portion can be extracted. While we could use the DESCRIBE query form, we opted to use CONSTRUCT since it is required to be supported in every SPARQL implementation. The query pattern is as follows:

```
CONSTRUCT {
    ?page ?prop ?value
}
```

```
WHERE {
    <http://example.com/a.html>  ev:reaches
    ?page.
    ?page ?prop ?value.
}
```

Lastly, all of these patterns can be further extended towards a macroscopic level, i.e., not centered on Web pages per se, but on Web sites. It is important to understand graph connectivity at this level, e.g. whether a Web site directly links to another one:

```
ASK {
    <http://example.com>  ev:isComposedBy
    ?page.
    <http://example2.com>  ev:isComposedBy
    ?page2.
    ?page ev:linksTo ?page2.
}
```

Based on this pattern, it might be relevant to understand what are the linking sources in such cases:

```
SELECT ?page
WHERE {
    <http://example.com>  ev:isComposedBy
    ?page.
    <http://example2.com>  ev:isComposedBy
    ?page2.
    <page ev:linksTo ?page2.
   }
```

Expanding further, one is able to find out which Web sites link directly to a given Web site:

```
SELECT ?site
WHERE {
    ?site ev:isComposedBy ?page.
    <http://example.com>  ev:isComposedBy
    ?page2.
    ?page ev:linksTo ?page2.
}
```

This type of pattern can be applied to all of the subsequent query patterns accordingly. For simplicity purposes, each one of the next query patterns is applied to Web pages.

Common characteristics. Based on the characteristics quality pattern for Web pages and Web sites, the same type of information can be acquired from entire Web graphs. Here, a quality threshold dictates which characteristics are above it in the entire Web graph:

```
SELECT ?char
WHERE {
    ?page ?prop ?v.
    ?char ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?v >= 0.5)
}
```

Based on this query pattern, Web graphs can be partitioned according to characteristic-oriented quality thresholds, following the same rules presented above:

```
CONSTRUCT {
    ?page ?prop ?value
}
WHERE {
    ?page rdf:type ev:Webpage.
    ?page ?prop ?value.
    ?char ev:hasMetric ?metric.
    ?metric ev:isrelatedToDatatypeProperty
    ?prop.
    FILTER (?value >= 0.5)
}
```

While this last pattern extracts the entire RDF graph, there are cases where just the corresponding Web graph structure (i.e., just the Web pages and linking structure) is extracted. In these cases the pattern can be easily adjusted as follows:

```
CONSTRUCT {
    ?page ev:linksTo ?otherPage.
}
WHERE {
    ?page ev:linksTo ?otherPage.
    ?page ?prop ?value.
    ?char ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?value >= 0.5)
}
```

Common audiences. The same type of query pattern can be applied to find out if a given Web graph is tailored to a specific audience:

```
ASK {
    ?page ?prop ?value.
    au:totallyBlind ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?value >= 0.5)
}
```

Based on this query pattern, the Web graph itself can be partitioned according to this specific semantics:

```
CONSTRUCT {
    ?page ?prop ?value
}
WHERE {
    ?page rdf:type ev:Webpage.
    ?page ?prop ?value.
    au:totallyBlind ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?value >= 0.5)
}
```

Characteristic reachability. This query pattern has been devised to find out which Web pages can be reached from a starting point, while maintaining a quality level above a specific threshold for a given characteristic:

```
SELECT ?page
WHERE {
    <http://example.com/a.html> ev:reaches
    ?page.
    ?page ?prop ?value.
    tx:totallyBlind ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?value >= 0.5)
}
```

However, the way this query pattern has been devised misses the intermediate Web pages that might not have the desired quality level for the selected characteristic. To mitigate this issue, all intermediate Web pages have to be verified accordingly:

```
SELECT ?otherPage
WHERE {
    ?page ev:linksTo ?otherPage.
    <http://example.com/a.html> ev:reaches
    ?page.
    <http://example.com/a.html> ev:reaches
    ?otherPage.
    ?page ?prop ?value.
    ?otherPage ?prop ?value2.
    tx:totallyBlind ev:hasMetric ?metric.
    ?metric ev:relatesToDatatypeProperty
    ?prop.
    FILTER (?value >= 0.5 && ?value2 >=
    0.5)
}
```

Accordingly, this pattern can be adapted to extract the corresponding Web graph portion. This is done by creating an RDF graph consisting of *ev:linksTo* derived triples, where both end-points have to be reached from the starting point, as follows:

```
CONSTRUCT {
    ?page ev:linksTo ?otherPage
}
WHERE {
    ?page ev:linksTo ?otherPage.
    <http://example.com/a.html>  ev:reaches
    ?page.
    <http://example.com/a.html>  ev:reaches
    ?otherPage.
    ?page ?prop ?value.
    ?otherPage ?prop ?value2.
    tx:totallyBlind ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?value >= 0.5 && ?value2 >=
    0.5)
}
```

This last version of the query pattern can be further adapted to find out just whether there are any Web pages that cannot be reached according to the devised semantics:

```
ASK {
    ?page ev:linksTo ?otherPage.
    <http://example.com/a.html>  ev:reaches
    ?page.
    <http://example.com/a.html>  ev:reaches
    ?otherPage.
    ?page ?prop ?value.
    ?otherPage ?prop ?value2.
    tx:totallyBlind ev:hasMetric ?metric.
    ?metric  ev:isRelatedToDatatypePropery
    ?prop.
    FILTER (?value < 0.5 && ?value2 < 0.5)
}
```

If one wants to know what Web pages are not reached through this method, the previous version of the query pattern can be further adapted. Please notice that this version of the pattern simply inverts the filter, in comparison with the second version of this query pattern:

```
SELECT DISTINCT ?page
WHERE {
    ?page ev:linksTo ?otherPage.
    <http://example.com/a.html>  ev:reaches
    ?page.
    <http://example.com/a.html>  ev:reaches
    ?otherPage.
    ?page ?prop ?value.
    ?otherPage ?prop ?value2.
    tx:totallyBlind ev:hasMetric ?metric.
    ?metric  ev:isRelatedToDatatypePropery
    ?prop.
    FILTER (?value < 0.5 && ?value2 < 0.5)
}
```

Audience reachability. As audiences are more closely representative of users (by aggregating characteristics), it is also important to study the graph reachability from this point of view. The simplest query pattern for audience reachability concerns finding out what Web pages are appropriate for a specific audience:

```
SELECT ?page
WHERE {
    <http://example.com/a.html>  ev:reaches
    ?page.
    ?page ?prop ?value.
    au:totallyBlind ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?value >= 0.5)
}
```

Like in characteristics reachability, one has to take into account that all Web pages in between must also have a quality level above the threshold that has been set. Accordingly, this query pattern must cope with this issue:

```
SELECT ?otherPage
WHERE {
    ?page ev:linksTo ?otherPage.
    <http://example.com/a.html> ev:reaches
    ?page.
    <http://example.com/a.html> ev:reaches
    ?otherPage.
    ?page ?prop ?value.
    ?otherPage ?prop ?value2.
    au:totallyBlind ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:relatesToDatatypeProperty
    ?prop.
    FILTER (?value >= 0.5 && ?value2 >=
    0.5)
}
```

This pattern version can be easily adapted towards extracting the corresponding Web graph partition:

```
CONSTRUCT {
    ?page ev:linksTo ?otherPage
}
WHERE {
    ?page ev:linksTo ?otherPage.
    <http://example.com/a.html> ev:reaches
    ?page.
    <http://example.com/a.html> ev:reaches
    ?otherPage.
    ?page ?prop ?value.
    ?otherPage ?prop ?value2.
    au:totallyBlind ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:relatesToDatatypeProperty
    ?prop.
    FILTER (?value >= 0.5 && ?value2 >=
    0.5)
}
```

It is also possible to build on this query pattern version to find out if there is any Web page that cannot be reached with at least the same quality level:

```
ASK {
    ?page ev:linksTo ?otherPage.
    <http://example.com/a.html> ev:reaches
    ?page.
    <http://example.com/a.html> ev:reaches
    ?otherPage.
    ?page ?prop ?value.
    ?otherPage ?prop ?value2.
    au:totallyBlind ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypePropery
    ?prop.
    FILTER (?value < 0.5 && ?value2 < 0.5)
}
```

Likewise, we can also extract from the Web graph the set of Web pages that cannot be reached according to this semantics:

```
SELECT DISTINCT ?page
WHERE {
    ?page ev:linksTo ?otherPage.
    <http://example.com/a.html> ev:reaches
    ?page.
    <http://example.com/a.html> ev:reaches
    ?otherPage.
    ?page ?prop ?value.
    ?otherPage ?prop ?value2.
    au:totallyBlind ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypePropery
    ?prop.
    FILTER (?value < 0.5 && ?value2 < 0.5)
}
```

Domain reachability. Along the lines of the previous two patterns, it is important to find out what partitions of a Web graph are reached from a starting point for all audiences within an audience domain, according to a previously set quality level threshold. The patterns for domain reachability follow closely the ones for characteristic and audience reachability. Therefore, we present a query pattern representative of the specific details for domain reachability. The following pattern affords the extraction of a Web graph partition for all the Web pages that are reachable from a starting point, based on a quality threshold:

```
CONSTRUCT {
    ?page ev:linksTo ?otherPage.
}
WHERE {
    ?page ev:linksTo ?otherPage.
    <http://example.com/a.html> ev:reaches
    ?page.
    <http://example.com/a.html> ev:reaches
    ?otherPage.
    ?page ?prop ?value.
    ?otherPage ?prop ?value2.
    au:domain1 ev:audienceDomainContains
    ?audience.
    ?audience ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:relatesToDatatypeProperty
    ?prop.
    FILTER (?value >= 0.5 && ?value2 >=
    0.5)
}
```

Another interesting pattern for domain reachability concerns finding out whether an audience domain has any audience that limits the reachability property:

```
ASK {
    ?page ev:linksTo ?otherPage.
    <http://example.com/a.html> ev:reaches
    ?page.
    <http://example.com/a.html> ev:reaches
    ?otherPage.
    ?page ?prop ?value.
    ?otherPage ?prop ?value2.
    au:domain1 ev:audienceDomainContains
    ?audience.
    ?audience ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:relatesToDatatypeProperty
    ?prop.
    FILTER (?value < 0.5 && ?value2 < 0.5)
}
```

This query pattern can be further converted to find out what are these audiences. This way, researchers can ask what are the specific audiences that limit reachability. This pattern is as follows:

```
SELECT ?audience
WHERE {
    ?page ev:linksTo ?otherPage.
    <http://example.com/a.html> ev:reaches
    ?page.
    <http://example.com/a.html> ev:reaches
    ?otherPage.
    ?page ?prop ?value.
    ?otherPage ?prop ?value2.
    au:domain1 ev:audienceDomainContains
    ?audience.
    ?audience ev:audienceClassContains
    ?char.
    ?char ev:hasMetric ?metric.
    ?metric ev:relatesToDatatypeProperty
    ?prop.
    FILTER (?value < 0.5 && ?value2 < 0.5)
}
```

Inward linking quality. As explained before, one of the great powers of the Web resides on how its linking structure is perceived and navigated by users. One important aspect of this property concerns the quality of the Web graph from the perspective of how Web sites are linked to each other. This query pattern explores linking to a specific ending point, i.e., all Web pages that link to a target Web page. First, it is important to extract the graph partition composed by the Web pages that point to it:

```
CONSTRUCT {
    ?page ev:linksTo <http://example.com/a.
    html>
}
WHERE {
    ?page ev:linksTo <http://example.com/a.
    html>.
}
```

Based on this simple query, quality thresholds can be set according to one of the query patterns presented in the previous Section (i.e., patterns for Web pages and Web sites), e.g., for characteristics:

```
CONSTRUCT {
    ?page ev:linksTo <http://example.com/a.
    html>
}
WHERE {
    ?page ev:linksTo <http://example.com/a.
    html>.
    ?page ?prop ?v.
    tx:colorBlind ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?v >= 0.5)
}
```

While this pattern query is interesting for extracting the Web graph based on a predetermined threshold, it is more important to extract it based on the quality of the target Web page. This query pattern can be further extended accordingly:

```
CONSTRUCT {
    ?page ev:linksTo <http://example.com/a.
    html>
}
WHERE {
    ?page ev:linksTo <http://example.com/a.
    html>.
    ?page ?prop ?v.
    <http://example.com/a.html> ?prop ?v2.
    tx:colorBlind ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?v >= ?v2)
}
```

Another aspect that can be explored based on this last version of the query pattern concerns knowing whether the target Web page has better quality than the Web pages that point to it. This allows us to understand if the target Web page can be perceived as an accessibility haven on navigation tasks:

```
ASK {
    ?page ev:linksTo <http://example.com/a.
    html>.
    ?page ?prop ?v.
    <http://example.com/a.html> ?prop ?v2.
    tx:colorBlind ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (?v < ?v2)
}
```

Outward linking quality. Dually to the previous query pattern, it is also important to understand the linking quality by setting up an initial starting Web page and explore the Web pages that it links to. The type of queries in this pattern follows closely the previous set of patterns with small changes. For instance, the following query leverages the Web graph partition of the Web pages that are safe to navigate:

```
CONSTRUCT {
    <http://example.com/a.html>  ev:linksTo
    ?page.
}
WHERE {
```

```
    <http://example.com/a.html>  ev:linksTo
    ?page.
    ?page ?prop ?v.
    <http://example.com/a.html> ?prop ?v2.
    tx:colorBlind ev:hasMetric ?metric.
    ?metric ev:isRelatedToDatatypeProperty
    ?prop.
    FILTER (v? >= ?v2)
}
```

Verticality. It is a fact that the Web is partially tailored to specific accessibility situations, e.g., "accessible versions" of a Web site. This property can be explored by studying the verticality of Web graphs. For example, given two different characteristics and a quality threshold, there might be an overlap between which Web pages are accessible to both. The amount of Web pages in this situation is directly related to the verticality of their corresponding partitions. This is done through the following query pattern:

```
SELECT ?page
WHERE {
    ?page ?prop1 ?value1.
    ?page ?prop2 ?value2.
    tx:colorBlind ev:hasMetric ?metric1.
    tx:totallyBlind ev:hasMetric ?metric2.
    ?metric1 ev:isRelatedToDatatypeProperty
    ?prop1.
    ?metric2 ev:isRelatedToDatatypeProperty
    ?prop2.
    FILTER (?value1 >= 0.5 && ?value2 >=
    0.5)
}
```

FUTURE TRENDS

The framework presented in this chapter is just one of the initial steps that can help understanding the impact of Web accessibility and Web standards on users, in a large scale (i.e., the *whole* Web) and with a fine-grained control over what aspects of Web accessibility and users are to be studied. We envision that semantic technologies can disrupt the way Web developers and designers think of accessibility and its social impact in the way users feed and consume information of the Web.

To grasp this knowledge, the framework we presented must be supported by its implementation and use in the analysis of large portions of the Web. Hence, we foresee that the following trends will help in this complex task:

- *Scalable architectures.* Building large scale Web accessibility observatories require scale-free approaches to crawl, store, process, and query the Web. We expect that with ongoing and future developments of scalable architectures that can cope with these type of tasks will help providing further insights on the influence that the Web's structure poses on Web accessibility issues.
- *Graph visualization algorithms.* There is a need for visualize large quantities of data (e.g., billions of metadata of Web pages), to grasp Web accessibility knowledge from semantic queries over Web graphs. Even when intelligent ways of extracting information from Web graph accessibility data, coping with billions of Web pages is not trivial. New graph visualization techniques can help lowering the burden of *finding the needle in the haystack*, i.e., the relevant information about the impact of Web accessibility at a large scale.
- *Automated verification.* Experts verify usability and accessibility problems in a manual/guided fashion. Since this approach is scale-bounded, there is the need for new automated verification procedures. With the advance in this research field (most probably with the aid of semantic technologies), more information can be obtained about usability and accessibility problems of the Web at a large scale. Significant advances to this challenge include understanding better

how humans interact with computers, new models and theories for human psychology, as well as more pragmatic approaches such as statistical content analysis.

- *Metrics.* Accurate metrics provide better answers for finding the impact of Web accessibility implementation for all users. Having a base framework such as the one we presented in this chapter will help comparing metrics (and their corresponding application to Web graphs) and improve their accuracy.
- *Predictive and evolutionary models.* By having available smart models, the Web can be studied from predictive and evolutionary perspectives, opening the way to improving Web standards and Web accessibility assessment tools.

With advancements on these fronts, we foresee that the work described in this chapter can be put together within existing Web crawling, indexing and searching facilities with minor tweaks, forming an architecture for large scale Web accessibility assessments, as presented in Figure 9.

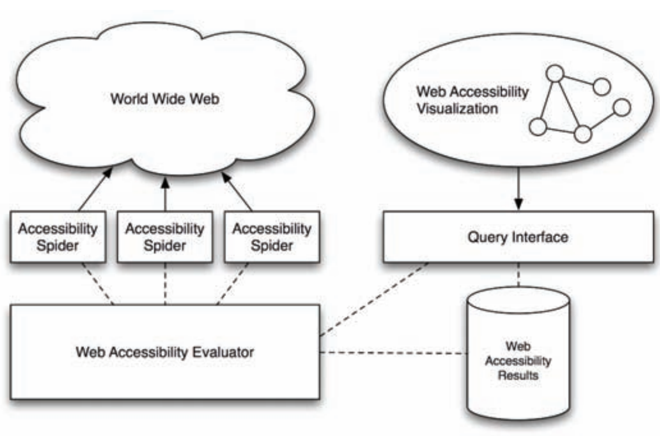
In this architecture the central aspect resides on the *Web accessibility results* repository, which should follow the metadata structures defined in this chapter. This repository holds all information about the accessibility semantics of the Web graph, as grasped by *Accessiblity Spiders* (similar to Web crawler's spiders) and an aggregating *Web accessiblity evaluator* module. Through the *Query Interface*, and the query patterns described in this chapter, we envision that this architecture will facilitate on visualizing Web accessibility at a large scale. We believe that this will provide clues on how Web standards and accessibility recommendations should evolve in the future towards a universally accessible and usable Web.

CONCLUSION

In this chapter we have presented a semantic knowledge framework for Web accessibility. This framework supports the definition of Web graphs and their accessibility properties. Through a set of query patterns, we have described a way to mine Web graphs in order to understand how the Web can cope with end users' intrinsic and transient characteristics, such as disabilities, interactive devices, etc.

We are currently developing ongoing work to implement this framework within the context of the architecture proposed in the previous Section in cooperation with the Portuguese Web Archive (PWA, n.d.) and apply it to study the entire Por-

Figure 9. Architecture for large scale Web accessibility assessments



tuguese Web (around 40 million Web pages). We believe that the set of query patterns presented in this chapter will help us to understand the shape of the Web in what respects to its Web accessibility properties. More specifically, it will allow us discovering which Web sites are more accessible, and to verify if Web sites created by non-experts have significant accessibility problems, in comparison to those created by experts.

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KEY TERMS AND DEFINITIONS

Accessibility: The ability to access. Often tied to people with disabilities (e.g., total blindness), accessibility thrives to break the barriers to information access. We follow the strict sense of accessibility by embracing any situation where the ability to access information can be disrupted by device or even surrounding environment constraints.

Accessibility Guidelines: A set of best practices that must be followed by designers and developers when implementing software solutions (e.g., Web site) that will help on providing accessible information. By being guidelines, it should not be assumed that content is accessible just by following them.

Checkpoint: A concrete verification task that materializes a (part of a) guideline. Checkpoints can be fully automated if application technology provides corresponding support (e.g., verifying if all images have associated textual captions).

Metric: A quantification procedure based on several criteria. In the context of this Chapter, metrics quantify accessibility based on different accessibility checkpoints.

Universal Usability: A research field that studies the adequacy of user interfaces and information to all users, regardless of their characteristics, knowledge, or mean of interaction (Shneiderman, 2000).

Web Accessibility: The subfield of accessibility that is targeted to the specific technologies and architecture that compose the World Wide Web. This includes technologies such as HTML, CSS and JavaScript, as well as the HTTP protocol.

Web Graph: A formal representation of the Web's structure. Web pages are represented as the graph's nodes, whereas hyperlinks are represented as its arcs. By representing the Web as a graph, traditional graph analysis algorithms can be applied.

LIST OF NAMESPACE PREFIX/URI MAPPING

1. **earl:** http://www.w3.org/ns/earl#
2. **ev:** http://hcim.di.fc.ul.pt/ontologies/evaluation#

Chapter VI
Ontology Evolution:
A Case Study on Semantic Technology in the Media Domain

Christian Weiss
T-Systems Enterprise Services GmbH, Germany

Jon Atle Gulla
Norwegian University of Science and Technology, Norway

Jin Liu
T-Systems Enterprise Services GmbH, Germany

Terje Brasethvik
Norwegian University of Science and Technology, Norway

Felix Burkhardt
T-Systems Enterprise Services GmbH, Germany

Jianshen Zhou
T-Systems Enterprise Services GmbH, Germany

ABSTRACT

As semantic web technologies, including semantic search, have matured from visions to practical applications, this chapter describes a case study of (semi-) automatic construction and maintenance of ontologies and their applications to the media domain. A substantial amount of work has been done and will be done to integrate semantic search technologies into all kind of services where the underlying data is crucial for the success of automatic processing. Semantic search technologies should help both the user-to-machine and machine-to-machine communication to understand the meaning behind the data as well as to retrieve information according to user's requests and needs. The crucial question is how *to manage the semantic content (meaning) and how to deliver it in order to increase the value-chain of users' benefits. Ontologies provide the basis for machine-based data understanding and ontology-based semantic search as they play a major role in allowing semantic access to data resources. However, the human effort needed for creating, maintaining and extending ontologies is often unreasonably high. In order to reduce effort for engineering and managing ontologies, the authors have developed a general framework for ontology learning from text. This framework has been applied in the media domain, in particular to video, music and later on to game search to offer an extended user experience in machine-to machine as well as user-machine interaction.*

INTRODUCTION

Semantic technology is based mostly on automatic building of ontologies which is often referred to by the term "ontology learning", originally introduced by Mädche, A. & Staab, S. (2001). It is normally described as the process of (semi-) automatically constructing ontologies on the basis of in-domain texts where a domain can represent a small part of a world-knowledge such as finance, media, or technical or cultural knowledge. The text data for learning is then taken out of this section of world-knowledge. The assumption is that the domain texts reflect the terminology that should go into the ontology, and that appropriate linguistic and statistical methods should be able to extract the appropriate concept candidates and their relationships from these texts. Semantic technology is an application-driven technology. In one of the most recent studies (Mills, D. 2008), more than 100 application categories have been examined, where semantic related technologies can be applied to. Generally speaking, semantics as a leading technology in the evolution of the Internet and the information society, should help to understand and manage the opinions freely expressed by people and make them not only understandable to humans but also to computers. This is the most essential focus in many applications, as machine-to-machine communication will play an increasingly important role in helping people to search, find and evaluate desired information. Most of the applications can be divided into two domains, the enterprise (B2B) domain and the private end consumer (B2C, or C2C) domain. In the enterprise domain, Enterprise Resource Planning (ERP), Enterprise Content Management (ECM), Supply Chain Management (SCM), Finance and Accounting (FA) as well as Project Lifecycle Management (PLM) are among others the applications deployed in mid-sized and large companies. In the consumer domain, topics like customer self-service, customer service automation, media entertainment, directories and information/product portals as well as mobile search profit strongly from semantic search technologies.

Semantically enabled search and management technologies have still been characterized as early *market*. The majority of current investments is rooted in R&D activities and rarely reaches operational deployment. More and more companies, however, are seriously considering the gradual introduction of the new technologies. Similar to classic motivations for investment, there are three basic elements for measuring the business value of semantic technologies:

- **Cost saving:** This is to raise the efficiency. The purpose is to do the same job faster, cheaper and with fewer resources than previously.
- **Return on assets:** This is to increase the effectiveness, doing a better job than you did before, and improving the productivity and performance.

- **Return on investment:** This is to create new and /or value-added services by changing some existing business aspects and/or adding new strategic advantages.

Table 1 shows that semantic technologies can significantly reduce production and operating cost improve service quality and create new business.

In this contribution, we will concentrate on a selected use case with the application of advanced semantic and search technologies in the media entertainment domain which can be placed in the B2C segment but in a broader view it could be extended to B2B and C2C in peer-to-peer environments.

As construction, maintenance and evolution of ontologies to enable semantically data processing is in the focus of applied research since long, numerous ontology learning approaches have been proposed and many toolsets have being developed in recent years. One can say that most of the ontology engineering methodologies follow a common approach. A minimal assembly consists of studying the feasibility, analyzing the requirements, extracting the concepts and deployment. See e.g. (Navigli, R. & Velardi, P., 2004a), (Haase, P., & Völker, J., 2005), (Gulla, J., Borch, H.O. & Ingvaldsen, J.E., 2004) and (Völker, J., Vrandecic, D., Sure, Y. & Hotho, A., 2007), among others as a first insight. Most of the ontology learning approaches combine a certain level of linguistic analysis with machine learning algorithms in order to find potentially interesting concepts and relations between them to interpret the semantics. The conceptualization is a non trivial process and involves the development of the domain model, the formalization of the model and the implementation [PM04]. Ontology learning toolsets may generate candidate concepts and relationships, but human labor is usually needed to verify the suggestions and complete the ontologies. There are still very few ontology learning toolsets in active use in industrial ontology engineering projects. Most ontologies are constructed using traditional modeling approaches with teams of ontology and domain experts working together. This is partly due to the strategic issues involved in ontology engineering, but it also seems that current ontology learning tools do not have the reliability or credibility needed in large-scale ontology engineering projects. In order to get an overview of current technologies in ontology engineering we refer to the comprehensive surveys of ontology learning techniques in (Buitelaar, P., Cimiano, P. & Magnini, B., 2005), (Cimiano, P., 2006), or (Cimiano, P., Völker, J. & Studer, R., 2006). In the following, we briefly discuss some existing ontology learning toolsets that are comparable to our approach.

Text2Onto[1] is a framework for data-driven change discovery by incremental ontology learning. It uses natural language processing and text mining techniques in order to extract an ontology from text and provides support for the adaptation of the ontology over time, e.g. when documents are

Table 1. Impact of semantic technologies on business value (adapted from Mills, D. 2004)

Impact of Semantic Technologies		
Cost Saving	**Return on Assets**	**Return on Investment**
20-80% less labor hours 20-90% less cycle time 30-60% less inventory levels 20-75% less operating costs 25-80% less set-up cost 20-85% less development cost	50-500% quality gain 2-50× productivity gain 2-10× greater number or complexity of concurrent projects, product reales, & units of work handled 2-25× increased return of assets	2-30× revenue growth 20-80% reduction in total cost ownership 3-12 month positive return on investment 3-300× positive ROI over 3-years

added or removed. Text2Onto was developed by the AIFB[2] initially in context with the European SEKT project (Semantically-Enabled Knowledge Technologies) [3] (Cimiano, P. & Völker, J., 2005). Text2Onto makes use of Eclipse, Gate, Kaon, Lucene and Google.

OntoGen[4] is a system for data-driven semi-automatic topic ontology construction. A "topic ontology" is a set of topics connected with different types of relations. Each topic includes a set of related documents. OntoGen was also part of the European-funded project SEKT and developed by the Jožef Stefan Institute, Slovenia[5]. It utilizes some text mining techniques which are based on the Text Garden, a text mining software library [6].

OntoLT[7], developed by the DFKI[8] by (Buitelaar, P., Olejnik, D. & Sintek, M., 2004) etc., is a plug-in for the widely used ontology development tool Protégé. It supports the interactive extraction and/or extension of ontologies (concepts and relations) from a linguistically annotated text collection.

OntoLearn is a system for (semi-)automated ontology learning from domain texts, which has been developed by the Department of Computer Science at the University of Rome "La Sapienza"[9]. The key task performed by OntoLearn is the semantic interpretation or semantic disambiguation of terminology through machine learning and natural language processing. OntoLearn tries to identify the correct sense for each term and the relation between terms by building domain concept trees based on data from the WordNet[10] knowledge base.

UIMA[11] (Unstructured Information Management Architecture) is not an ontology generation tool as such, but a framework for the analysis of unstructured content such as text, audio and video. It is undergoing a standardization effort and might be used in industry very widely in the future. The UIMA SDK implementation of the Search and Index API (SIAPI) is provided by IBM for developing semantic search applications.

All these frameworks apply various ontology learning approaches for the interactive extraction and/or extension of ontologies from unstructured domain texts. However, it has not been so far possible to fully automate the generation of ontologies. An additional challenge is the incremental updating of ontologies, support of splitting and merging of ontologies for collaborative ontology engineering.

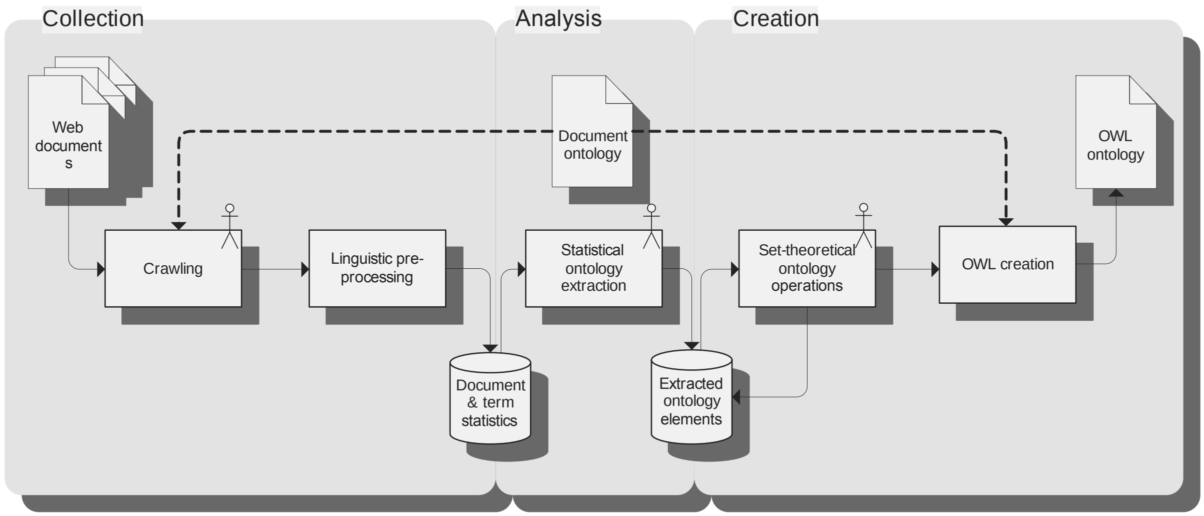
ONTOLOGY ENGINEERING

Most ontology creation workbenches combine a linguistic preprocessing stage with various statistical tests on word frequencies. The linguistic techniques transform the actual tokens found in the domain documents to standardized lexical forms that are potential concepts or instances in the prospective domain ontology. For example, for the sentence "*In rural Texas, welder and hunter Llewelyn Moss discovers the remains of several drug runners*"[12], we may use a parts-of-speech tagger and a lemmatizer to replace the word inflections with their base forms. If we also remove stop-words, i.e. words that are irrelevant to the statistical analysis

later, we end up with the following set of phrases: {*rural texas, welder, hunter, llewelyn moss*, *discover, remain*, *drug dealer*}. Since in ontology learning, we tend to use noun phrases only, we remove adjectives and verbs and keep the set {*texas, welder, hunter, llewelyn moss, remain*, *drug dealer*} for the subsequent statistical analysis of terms.

Most ontology workbenches will then combine all sets of noun phrases extracted from all sentences of the available documents and run a number of pre-specified ontology learning algorithms. Each technique produces lists of ranked terms or term relationships that have to be carefully recreated as ontology structures. Instead, our workbench has a more interactive approach to the statistical extraction of ontology

Figure 1. The ontology engineering process



structures. It consists of three parts, namely collection, analysis and construction, which are used independently of each other, so that the user may use them simultaneously when constructing new ontologies. Since each component also allows the user to manually influence the results, the created ontology will reflect both the quality of the extraction techniques and the contributions of the user. Like this, an iterative collaborative ontology creation process is supported, in which one or more users actively explore the underlying document text and construct ontologies without being bothered by the ontology representations themselves. Figure 1 shows a schematic overview of the ontology engineering process. In the following subsections, we discuss the workbench architecture of Figure 1 and the components in some more detail.

ONTOLOGY LEARNING

Existing ontology development toolkits are most often only modelling editors for dealing with formal ontology languages like OWL and RDF. Some toolkits also have visualization facilities that help users to validate the resulting ontologies, but the editors have normally only limited support for evolutionary aspects or collaborative editing. The following points describe the current situation.

- Several approaches and tools for semi-automatic ontology learning have been proposed. But they are still immature and under continuous development
- So far, it has not been possible to fully automate the generation of ontologies. Ontology learning toolsets may generate candidate concepts and relationships, but human labour is needed to verify the suggestions and complete the ontologies
- Learning an ontology requires techniques that span from extracting terms and their synonyms to formulating rules and restrictions for the ontology. The most mature techniques, which fall within term extraction, are fairly successful in suggesting potential concept candidates and tend to be used by most workbenches.
- Techniques for extracting relationships between concepts are still not very reliable, though there are many different approaches and each tends to display its own strengths

and weaknesses. Separating taxonomic relationships from non-taxonomic relationships is one of the main challenges. Identifying relationship names is usually not possible with current technologies, as well as extracting rules and restrictions.

- Ontology learning tends to be most successful for the construction of lists of concepts and instance candidates, as well as identifying (but not naming) relationships between these elements. This may be sufficient for many search ontologies, but large-scale ontologies for application integration issues tend to need more sophisticated structures.
- There are still very few ontology learning toolsets in active use in industrial ontology engineering projects. Current ontology learning tools seem not to have the reliability or credibility needed in large-scale ontology engineering projects.
- An additional challenge is the incremental update of ontologies and the collaborative support for ontologies (splitting and merging), which has so far not been dealt with properly by current ontology learning toolsets.
- However, using ontology learning approaches can significantly speed up the construction and maintenance of ontologies. Especially the new techniques that utilize the web as an enormous data source for linguistic background models are promising.

COMPONENTS OF THE LEARNING PROCESS

The following describes the individual steps of our proposed ontology workbench. As mentioned above; they can be divided into three distinct tasks: collection, analysis and construction that might be carried out independently of each other (see Fig. 1). We refer in the description to our application in the media domain.

Collection

At the *Collection* stage, there are a number of crawlers that parse HTML pages and transform them into XML documents. A unified document ontology, which is part of the workbench configuration, specifies all important document structures for all data sources and defines a unified ontology format for all of them. This format will form a part of the prospective ontology.

The XML documents generated by the crawler are fed into a linguistic pipeline that carries out the following transformations:

- **Tokenization and transliteration:** Word boundaries are identified, and standardized spelling is introduced.
- **Named entity recognition:** Locations, persons, and organizations are identified and tagged for later indexing.
- **Parts-of-speech tagging:** Parts-of-speech tags are associated with every word in the text.
- **Lemmatization or stemming:** German and English dictionaries are used to lemmatize the text. If the word is not found in the dictionaries, stemming is used instead.
- **Noun phrase recognition:** We recognize and tag noun phrases that consist of one or more adjectives followed by consecutive nouns. In addition, we include complex foreign phrases like *film noir*, assuming that they carry a particular meaning in the domain.
- **Stop word removal:** Words not relevant for ontology creation, like prepositions, conjunctions and determiners, get deleted.

The linguistically pre-processed document text is stored in Lucene[13] indices, corresponding to the structures of the document ontology. For the media domain, this means that there are specific indices for elements like movie titles, actors, and directors, but also noun phrase indices for plots and user reviews.

Analysis

At the *analysis* stage, a battery of ontology creation techniques is applied that uses the indices being generated during the collection stage, in order to extract candidate concepts, candidate instances, and various types of relationships from the indexed text.

Each technique is specified with a *domain* and a *range* before it is run on the document index. While the domain determines which subset of the index should be used, the range is the type of ontology structures to be extracted. For example, if extracting the most prominent actors that appear in drama movies, the domain would be drama movies and the range would be actors. Also, every technique has a number of configuration parameters that direct the analysis in particular directions.

Currently we support the following ontology extraction techniques:

- **Instance/concept extraction with frequency-based scores:** This technique lists prominent terms and ranks them according to several ranking schemes, among them the tf.idf scores. Terms are individual words, identified entities, or tagged noun phrases.
- **Instance extraction with structure-based techniques:** Instances given by the structure of the documents are extracted directly, using the corresponding XML tags.
- **Relationship extraction with similarity measures:** Relationships between instances are calculated and ranked based on the cosine similarity between their vector representations.
- **Relationship extraction with association rules:** Association rules are based on co-occurrence data and specify which sets of terms tend to imply the presence of another term. Terms involved in an association rule can be assumed to be semantically related.
- **Relationship extraction with clustering:** Suffix tree clustering is used to group terms together in clusters based on common suffixes. The assumption is that there is a relationship between all terms in a particular cluster.

Each technique can be run numerous times with different domains and ranges. They can be used in any order and combined in any possible way to produce the final set of elements which can be transformed into ontology structures. The extracted concepts, instances and relationships—or a selection of them—are then stored in a separate index for the ontology generation.

Creation

All result sets from the analysis phase can get manually modified and stored for later OWL generation. The generation itself is based on the stored result sets and the following sets of operations are used to select the elements that will be included in the final ontology:

- **Union:** a term or term relationship is kept, if it appears in at least one of the selected result sets.
- **Intersection:** a term or term relationships is kept, if it appears in all selected result sets.
- **Difference:** a term or relationship is kept, if it appears in the first result set and not in the other. None of the entries in the second result set are kept.

The OWL creation component turns instances into OWL individuals, concepts into OWL classes, and relationships into OWL data and object properties. The exact nature of the mapping to OWL is defined by the document ontology as well as the ontological definition of each extraction technique. Some structural simplifications are made to make sure that meta-modeling problems are avoided and the constraints of OWL DL get respected.

APPLICATION-DRIVEN ONTOLOGY DEPLOYMENT

There are numerous strategies for mapping document terms into classes, individuals and properties in ontologies. In case of our media domain example, we apply the following overall strategies for the ontology learning process:

- A document ontology is provided from the outset. This model simply reflects the structure of the data sources fed into the learning process. Basically, the document ontology model is specified in OWL DL and consists of two parts: (1) movie concepts, (2) world concepts (topics of the movies). There are no individuals in this ontology, but basic object properties like isActorIn link the various concepts together.
- Normal terms in the documents are interpreted as references to as individuals in the ontology. These individuals carry the same name as the terms themselves. Linguistic variants of the same term and synonyms, like *New York* and *New York City*, are grouped together into the same individual in OWL.
- There are a few terms that refer to concepts in the document ontology (like Movie and Director). These will end up as classes in the generated ontology.
- The terms found in the documents are stored as annotations to the individuals and classes they refer to. This is done with the predefined annotation property *rdfs:label*. This strategy ensures that we maintain the connection between terms and ontology structures, even though the terms themselves are not part of the formal ontology.

OWL Construction Summary

In the following, we describe the single steps that are carried out during ontology creation in detail.

1. Take the given OWL document ontology as the starting point
2. Generate indices as follows based on Movie concepts from the document ontology:
   - **For each non-narrative concept:** Produce one Lucene index for each leaf concept and data type. This results in separate indices for Cast, Director, Writer, etc.
   - **For each Narrative concept:** produce one full index for all terms, one NP index, and one index for stemmed/lemmatized terms for each leaf concept. For the plot description, there will be a full text index, a lemmatized index, and an NP index.
   - Create separate indices for each entity type, i.e. recognized persons, organizations and locations.
3. Extract OWL individuals and object properties for Movie concepts:
   - Generate OWL individuals from each non-Narrative leaf concept from Lucene index. Use Title&Year to name movie individuals.
     - **Example:** *if Brad Pitt is in the Cast index with reference to, a document associated with the movie Seven, Brad Pitt is considered an instance of concept Cast. Seven_1995 is created as an instance of Movie.*
   - For each OWL individual (except Movie instances), use the predefined properties in the document ontology and create the lowest-level object property mapping from the individual to the corresponding Movie individual.
     - **Example:** *Brad Pitt is in the Cast index, and Seven is in the Movie index, and both are associated with the same domain document. The object property isActorIn is then established between Brad Pitt and Seven.*

- For actors playing roles in particular movies, create object property playsRoleOf between the two individuals.
    - **Example:** *Brad Pitt playsRoleOf Jesse James*
4. Learn movie relationships
    - Choose and configure the movie relationship learning algorithm
        - **Example:** *Find similar documents/movies*
    - Flag which relationships to be included in the ontology
        - **Example:** *Choose the two highest ranked relationships for each movie*
    - Repeat steps a. and b. with other algorihms and/or other ranges and domains.
        - **Example:** *We have a set of relationships generated from association rules and another set generated from clustering.*
    - Combine results sets from c. with standard set operations (union, intersection or difference). This gives us a final set of relationships to go into the ontology.
        - **Example:** *Only include relationships that are generated by all techniques used.*
    - For each relationship, insert the object property isSimilarTo between pairs of movies.
        - ***Example:*** *About a boy isSimilarTo SpiderMan*
5. Apply learning techniques to extract new instances:
    - Select the subset of information to be extracted
        - **Example:** *Genre: Drama from IMDB*
    - Select the subset of indices for the analysis:
        - **Example:** *NP index for plot descriptions*
    - Choose and configure certain techniques to run
        - **Example:** *Extract prominent multi-word terms*
    - Flag terms that should be considered synonyms
        - **Example:** *Flag that New York and New York City are synonyms*
    - Flag which terms should be included for later OWL generation
        - **Example:** *Choose the 20 first terms*
    - Repeat steps a. through e. with other techniques or other ranges and domains to produce alternative sets of instances. Store them for later use.
    - Combine result sets from f. with standard set operations (union, intersection and difference) to produce the final list of instances to go into the ontology.
    - Create an individual for each term from the list in g. If the term is in the Person index, it is created as an instance of Person. If it is in the Location index, it is created as an instance of Location. If it is in the Organization index, it is created as an instance of Organizations. Otherwise, it is created as an instance of Concept.
    - The term itself and its flagged synonyms are added as annotations to the created individual with the *rdfs:label* annotation.
    - If a particular movie was selected in step add all individuals as instances of the content of the movie.
        - **Example:** *western and gunfighter are added as instances of the content of the Jesse James movie.*
    - If a particular genre was selected link all individuals to the genre with the object property relatesTo.

6. Learn Relationships between world instances
- Extract pairs and flag pairs to be included in OWL ontology
- Create the object property relatesTo for every flagged term pairs.
    - **Example:** *Young woman relatesTo Love.*

Up to now, no weights or probabilities are represented in the ontology. These measures may be of use to search applications, but are considered not part of the ontology itself.

ONTOLOGY LEARNING INSIDE THE MEDIA DOMAIN

Domain-specific web search solutions can be used to index poorly structured documents that describe knowledge within a domain. There is often some informal document structure for parts of the document text, though most of the text is in unstructured natural language. The IMDB.com database for movies, for example, has a set of standard headings for movie-related data, like actors and directors; whereas the plot of the movie is made up of paragraphs of natural language text. Similar strategies can be used to describe movies on Videoload.de, Wikipedia and many other web sites. Web sites for books, music and other products also tend to mix a semi-structured part for meta-information with an unstructured part for the real content.

This phenomenon can be clearly seen in the web movie domain. Structure-based ontology learning techniques extract movie classes like the ones shown in Figure 2. There are relationships (object properties) between Movie (class) and each of the other classes. These classes are created on the basis of the document structures of IMDB.com, Videoload.de and Wikipedia, and most of the classes correspond to particular layout headings used in the documents.

Because we use OWL to describe the content of, for example, the IMDB database, we need to consider several ontology problems that are linked to both the nature of the documents and the functionality of search applications. In particular we have to deal with multiple domains, meta-levels, term/concept confusion, ontology granularity, and ranking issues that comes up in the rather ill-defined movie domain. One can say that presenting data about movies is rather just like any arbitrary text since besides the structured data the description part of the movie is taken out and could be classified in any domain of our world-knowledge. As we can see in the description of the above movie example "Lost in Translation" the text has no relevant relation to a movie domain. It could be a story written in a magazine in any newspaper or book with emphasis on the country Japan, the city Tokyo, a man called Bob. This phenomenon occurs in almost most of the movie description and can be seen as a complex multi-layered multiple-context related text. As opposed to medical subdisciplines or technology areas, movies can in theory be about anything and are not restricted to a particular terminology. In fact, the terminology will often vary for artistic

Figure 2. (a) Extraction from movie document structure (b) Terms extracted from thriller movies

(a)	(b)
Movie (class):	*Los Angeles*
→ Title (datatype)	*young woman*
→ Year (datatype)	*serial killer*
→ Language (datatype)	*unlikely ally*
→ Running time (datatype)	*FBI agent*
→ Genre (class)	*good friend*
→ Cast (class)	*Jean Gray*
→ Role (class)	*young man*
→ Writer (class)	*DEA agent*
→ Company (class)	*hit man*
→ Production (class)	*Hoover dam*
→ Music (class)	*New York*
→ Editor (class)	*young couple*
→ Soundtrack (class)	*bad guy*
→ Plot (class)	*different man*
→ Review (class)	drug dealer
	drug lord

or stylistic reasons, which makes it difficult to extract a standard vocabulary that describes movies in general. It is of course easier to describe the movie business itself as an ontology, including only meta data about the movies themselves. However, since many people would like to search for movies on the basis of plots and user reviews, important aspects of the movie stories need to be reflected in the ontology as well.

A serious problem faced by movie ontologies as well as many other ontologies is the issue of meta-modelling. Imagine the movie *No Country for Old Men*, in which the figure *Anton Shigurh* is a ruthless murderer tracking down the bag of stolen money. *Anton* can be modeled as an individual, an instance of some *Hit man* class. Now, the ontology may also list a number of illegal professions, like *Hit man*, that come up in movies. We do not want to model *Hit man* as a subclass of some *Illegal profession* class, as that would turn *Anton Shigurh* into an instance of a profession. It is also difficult to model *Hit man* as an individual, as *Anton Shigurh* is supposed to be an instance of *Hit man* again. Most prefer to consider *Illegal profession* as a class of classes to avoid these problems, but the class of class structure is not legal in standard ontology languages. Since Description Logic cannot deal with these structures, it cannot be used in OWL DL or any other language that supports reasoning.

CONCLUSION

A state-of-the-art overview has been compiled for both semantic search and ontology learning with focus on technological algorithms and existing relevant solutions.

In this study, various approaches to semantic search and ontology learning have been described and illustrated with concrete examples. Several existing relevant semantic search solutions, ontology learning workbenches and ontology development toolkits have been also introduced.

The following points deal with the main conclusions and further work.

- Semantic search is of growing importance in the Semantic Web vision. Semantic search applications use different strategies. Semantic may improve search process through effects on the index, the query, the result page and/or the navigation help of the application
- Approaches to semantic search are still under continuous development. Most approaches or algorithms suffer from performance issues and cannot only be applied in restricted domains.
- It is difficult to evaluate the quality of semantic search applications. Many of them focus on providing more navigational help for searching, which can not be simply evaluated by applying traditional measures like precision and recall. The quality of the search application depends on a combination of the adopted semantic strategies and the quality of the underlying ontology. An adequate evaluation of semantic search applications needs to separate these two issues, though it seems difficult to do this with traditional evaluation techniques.
- It seems easier to use semantic search strategies to increase recall than precision. There are some efficient strategies for finding more relevant documents (increasing recall). Increasing precision requires, that the system is able to understand more precisely what the user is looking for, and this is still a very difficult task with current users' preference of short queries. User clustering and contextual search strategies may in the future help us to interpret the users' queries with the accuracy that is needed to increase search precision. Navigational help is also a feature that adds more precision into the search session as a whole, even though it does not affect the set of documents returned.

- Most commercial products for semantic search follow the approach to combine standard index retrieval technology with some ontological knowledge representation and reasoning. Only a few utilize semantic indexing, since this requires an entire new indexing strategy that cannot compete performance-wise with the inverted indices of the vector space model.
- Several corpora support the linguistic preprocessing process ranging from proper names lookup to morphological analysis of the input text, though English is by far the language for which most lexica exist., Gaining access to useful domain data is not trivial for most of the domains, specially as the statistic algorithms need large quantities of data.. Data resources are essential for ontology construction since they provide the underlying basis for the learning algorithms. The text data resources cover training data resources to model a learning process for semi-automatic ontology learning.
- There are several R&D activities related to the areas of semantic search and ontology technologies running in Germany (BMBF or BMW projects) and in Europe (EC projects, in 6 FP „Semantic-based knowledge and content systems"). The large number of projects with partners/experts coming from various fields shows that both semantic search and ontology technology are quite active R&D areas. Advanced technologies have still to be developed. The application potential is huge; this can be gathered from the versatile use cases defined in the projects.
- Query Language for RDF was released by the W3C as a Recommendation in January 2008.

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ENDNOTES

1 Text2Onto - http://www.aifb.de/WBS/jvo/text2onto/
2 AIFB - http://www.AIFB.de/
3 SEKT - http://sekt.semanticweb.org/
4 OntoGen—http://ontogen.ijs.si/
5 Jožef Stefan Institute - http://wordnet.princeton.edu/
6 Text Garden - http://textmining.net/
7 OntoLT - http://olp.dfki.de/OntoLT/OntoLT.htm/
8 DFKI - http://www.DFKI.de/
9 La Sapienza - http://www.uniroma1.it/
10 WordNet - http://wordnet.princeton.edu/
11 UIMA - http://domino.research.ibm.com/comm/research_projects.nsf/pages/uima.index.html
12 From the imdb.com description of the movie ”No country for old men”.
13 Lucene: http://lucene.apache.org

Chapter VII
Attempting to Model Sense Division for Word Sense Disambiguation

Pascual Cantos Gómez
Universidad de Murcia, Spain

ABSTRACT

This chapter starts exploring the potential of co-occurrence data for word sense disambiguation. The findings on the robustness of the different distribution of co-occurrence data on the assumption that distinct meanings of the same word attract different co-occurrence data, has taken the author to experiment (i) on possible grouping of word meanings by means of cluster analysis and (ii) on word sense disambiguation using discriminant function analysis. In addition, two priorities have been pursued: first, find robust statistical techniques, and second, minimize computational costs. Future research aims at the transition from coarse-grained senses to finer-grained ones by means of reiteration of the same model on different levels of contextual differentiation.

INTRODUCTION

The new demands of automatic word sense disambiguation (WSD hereafter) have had a twofold effect on the field of lexicography and semantics. Such demands have widened the applicability domain of lexicographic and semantic works, but at the same time, they have posed new challenges to lexicographers. Experts in WSD have called into question the procedures for deciding where one sense of a word ends and the next begins (Agirre and Edmonds 2006; Ide and Véronis 1998; Kilgarriff 1997, 2006). The question about where the boundaries between senses lie remains unresolved.

This chapter analyses the problems associated with meaning and sense division an issue which troubles WSD researchers, semanticists and lexicographers. First, we shall explain the notion of meaning and its structure in relation to word(s).

Then, we shall explore how context or co-textual elements can help in disambiguating and/or typifying the meaning of words. Next, we shall move one step further and try to find a rationale for sense grouping based on distribution and appearance of co-occurrences. Finally, we shall propose a WSD system that pursues two priorities: first, easy to implement and second, minimize computational costs. Computationally, this model has the advantage of involving relatively low-dimensional feature space, because it runs on raw contextual data. We shall use discriminant function analysis (DFA) as it allows us to compute distances between each occurrence and each semantic class; for each meaning, we shall determine the location of the point (group centroids) that represents the means for all variables (collocational data) and for each case we shall then compute the distances (of the respective case) from each of the group centroids. Then, we shall classify cases as belonging to the group (meaning) to which it is closest. Finally, a proposal will be made concerning questions for future research.

BACKGROUND AND STATE-OF-THE-ART

Word sense disambiguation (WSD) is the problem of determining which sense or meaning of a word is activated by the use of the word in a particular context, a process which appears to be largely unconscious in people. WSD is a natural classification problem: Given a word and its possible meanings, as defined by a dictionary, classify an occurrence of the word in context into one or more of its sense classes. The features of the neighbouring words (Bar-Hillel 1960) provide the evidence for classification.

The 121 most frequent English nouns, which account for about one in five word occurrences in real text, have on average 7.8 meanings each (Miller 1990; Ng and Lee (1996)). But the potential for ambiguous readings tends to go completely unnoticed in normal text and flowing conversation. The effect is so strong that some people will even miss a real ambiguity obvious to others. Words may be polysemous in principle, but in actual text there is very little real ambiguity to a person.

WSD has relationships to other fields such as lexical semantics, whose main endeavour is to “understand” the relationships between “word”, “meaning”, and “context”. But even though word meaning is at the heart of the problem, WSD has never really been a key issue in lexical semantics. It could be that lexical semantics has always been more concerned with representational issues (Lyons 1995) and models of word meaning and polysemy so far too complex for WSD (Cruse 1986; Ravin and Leacock 2000). And so, the obvious procedural or computational nature of WSD paired with its early invocation in the context of machine translation (Weaver 1949/1955) has allied it more closely with language technology and thus computational linguistics. In fact, WSD has more in common with modern lexicography, with its intuitive premise that word uses group into coherent semantic units and its empirical corpus-based approaches, than with lexical semantics (Wilks et al. 1996).

Words do not mean by themselves. Complete meaning is found in the environment of a word, not within its limits (Sinclair 1998; Teubert 2004; Tognini-Bonelli 1996, 2001). Stubbs (1995: 387) states that “single words are only rarely the relevant unit for a semantic analysis. Meaning is distributed across word clusters”. Similarly, Sinclair (1998: 23) expresses that “the word is not the best starting-point for a description of meaning, because meaning arises from words in particular combinations.”

However, current dictionaries describe the meaning of words as isolated units of language (Filip 2005). Dictionaries have been and are most useful for identifying and detecting meaning and are considered powerful tools for learning and transferring meanings from one language to other languages (Nida 1958; Cook 1997; Devapala 2004).

There is an obvious clash between the way dictionaries present words in isolation and other linguistic view, mentioned above, that words do not mean by themselves (Jurus 1994; Almela 2007). This takes us to approach the question of word meaning from a more ample perspective and admit that words are complex from a semantic point of view (Mathieu 2001; Domínguez et al. 2004) and that such complexity ranges from a minimum to a maximum. The minimum is the core meaning, a rather fixed and necessary component which cannot be erased unless the words itself ceased to be used by the users. The maximum, in this meaning scale, includes all variants and additions, which allow for the core meaning to expand and enrich (Almela 2007).

The notion of "shared meaning" (Bublitz 1996; Schulze 1998; Lorenz 1999) accounts for the fact that features of lexical meaning are distributed across word boundaries. Normally, the semantic features that are activated in particular stretches of text are not the exclusive contribution of individual words, although individual words must previously have the necessary semantic potential to bring to the surface and accept features which may only be activated when in contact with specific external elements, i.e. specific words or context.

Besides taxonomies, the phenomenon of shared meaning among lexical collocates can establish other types of semantic bonds. For example, *incidence* and *increase* (as a verb) can hardly be related in any taxonomy. *Incidence* is a noun that is used to describe a state; *increase* is a verb which describes a process. Yet, the semantic feature 'number/amount' in Examples 1 and 2 is arguably distributed across the boundaries between these two words.

Example 1: *The* ***increased*** *rates could not be explained by a higher* ***incidence*** *of sickle-cell disease among African-American children compared to other children.*

Example 2: *In 1998, a large national study showed that tamoxifen cut the* ***incidence*** *of invasive breast cancer by 49 percent in a group of women at moderately* ***increased*** *risk of the disease.*

The meaning of the noun *incidence* is largely represented by its collocational profile. Two defining features of the use of this word are 'amount' and 'harmful event'. The *Collins COBUILD Dictionary* defines *incidence* as follows: 'The **incidence** of something bad, such as a disease, is the frequency with which it occurs, or the occasions when it occurs'; The *Macmillan English Dictionary* distinguishes the main meaning from a sub-sense. The paraphrase to the main meaning is "the number of cases of an illness or a medical condition in a particular, place, group, or situation". The sub-sense is defined in the following words: "the number of times something happens, especially something bad". The paraphrases in the two dictionaries coincide to a large extent. As can be noted, the *definiens* includes words referring to 'quantity' and 'negativity'. Let us turn now to some of the habitual co-occurrences of *incidence*, to check whether and to what extent its meaning is expressed by means of or with the aid of lexical collocation. Almost a fifth (37 out of 194) of the occurrences of the noun *incidence* in the LACELL Corpus[1] is accompanied by some form of the verb or noun *increase* in the same sentence. The figures for co-occurrences with the form *disease(s)* are quite close: the chances that *incidence(s)* occurs in the same sentence than *disease(s)* are as high as 18% (35 out of 194). This proportion adds to the evidence that *incidence* also shares its meaning with other collocates: *decrease*, *cancer*, etc. To which extent does the semantic trait 'amount, number, quantity' ignore the boundaries between words like *incidence* and its co-occurrences *increase*, *decrease*, or *rate*? To which extent is the feature 'harmful' sensitive to the limits between *incidence* and *disease*, *cancer*, or *AIDS*? Arguably, *incidence* does not express any meaning on its own. Its monosemy can thus be seen as a projection of its limited collocability.

The building and expansion of language and semantic relationships is not a logically directed process, but the result of additions and connections triggered by communicative situations which are often not subject to the control of the speakers (Bekke and Bakker 2003; Aberer et al. 2004; Sondel 2008; Almela 2007). Moreover, speakers themselves may be subject to conditions of different nature and demanding contradictory requirements. Ambiguity of language is not a property of the linguistic system per se, it results from the situation and context in which human beings use and build their communicative tools. Context and situation are therefore needed to interpret communicative events (Hymes 1964, 1974, 1989; El-Madkouri 2008).

Ambiguity in daily communication is most of the times positively solved because the situation and context within which it evolves carries with the necessary elements to avoid misinterpretations (Gringas and Carrier 1996; Qi 2006). The case is different when such a context fails in its self-explanatory potential, when one of the speakers is unable to interpret it adequately or when it is not present at all (Fujimoto and Hashimoto 2008).

The processing of human language by computers faces the problem of context in its most crude way. Computers are given the language as if it was a set of isolated words; they lack the ability to interpret co-textual elements and build a larger semantic unit (context) out of them. When faced with multiple meanings, computers are not given the wisdom and knowledge necessary to make the appropriate selection. In fact, they have not been trained to take the right decisions when more than one option (i.e. ambiguity) is offered.

Despite uncertain results on real applications, the effort on WSD has produced a solid legacy of research results, methodology, and insights for computational semantics. For example, local contextual features (i.e., other words near the target word) provide better evidence in general than wider topical features (Yarowsky 2000). Indeed, the role of context in WSD is much better understood. Some words can be disambiguated by a single feature in the right position, benefiting from a "discriminative" method; others require an aggregation of many features.

Approaches to WSD are often classified according to the main source of knowledge used in sense differentiation. Methods that rely primarily on dictionaries, thesauri, and lexical knowledge bases, without using any corpus evidence, are termed *dictionary-based* or *knowledge-based*. Methods that eschew completely external information and work directly from raw unannotated corpora are termed *unsupervised* methods (Schütze 1998; Pedersen and Kulkarni 2007). Finally, *supervised* and *semi-supervised* WSD make use of annotated corpora to train from, or as seed data in a bootstrapping process (Márquez et al. 2007).

In what follows, we will briefly summarize the performance achieved by state-of-the-art WSD systems. First, homographs are often considered to be a solved problem. Accuracy above 95% is routinely achieved using very little input knowledge: for example, Yarowsky (1995) used a semi-supervised approach evaluated on 12 words (96.5%), and Stevenson and Wilks (2001) used part-of-speech data on all words using LDOCE[2] (94.7%). Accurate WSD on general polysemy has been more difficult to achieve, but has improved over time. In 1997, Senseval-1[3] (Kilgarriff and Palmer 2000) found accuracy of 77% on the English lexical sample task[4] just below the 80% level of human performance. In 2001, scores at Senseval-2 (Edmonds and Cotton 2001) appeared to be lower, but the task was more difficult, as it was based on the finer grained senses of WordNet. The best accuracy on the English lexical sample task at Senseval-2 was 64%.

By 2004, the top systems on the English lexical sample task at Senseval-3 (Mihalcea and Edmonds 2004) were performing at human levels. The ten top systems, all supervised, made between 71.8% and 72.9% correct disambiguations compared to an inter-tagger agreement of 67%.6 The best unsupervised system overcame the most-frequent-sense baseline achieving 66% accuracy. The score on the all-words task was lower than for Senseval-2, probably because of a more difficult text. Senseval-3 also brought the complete domination of supervised approaches over pure knowledge-based approaches.

SENSES AND CO-OCCURRENCES

Our attempt here is try to re-explore how context or co-textual elements can help in disambiguating and/or typifying the meaning of words. We therefore need, first, capture the potential context in terms of lexical elements, that is, words that co-occur with the word under investigation. The aim is to find those elements (words) that interact with other elements (words) to construct larger and self-contained meaningful units. This will guide us to investigate if the interaction of a word with other words implies any sharing of meaning. In the literature, these interacting elements or words are known as co-occurrences (Sinclair 1966; Tognini-Bonelli 2001), and more precisely if these co-occurrences are statistically significant, they are addressed to as collocations (Sinclair 1991; Bahns 1993; Clear 1993; Nesselhauf 2005) This, finally, takes us to the analysis of meaning by collocation, which is beckoned by the hypothesis that meaning arises from co-textual environment (Janny 2002). As already stated, research will have to clarify whether the word in collocation should be treated as a constituent of a multi-word structure or whether collocational information should be treated as part of the meaning of a word.

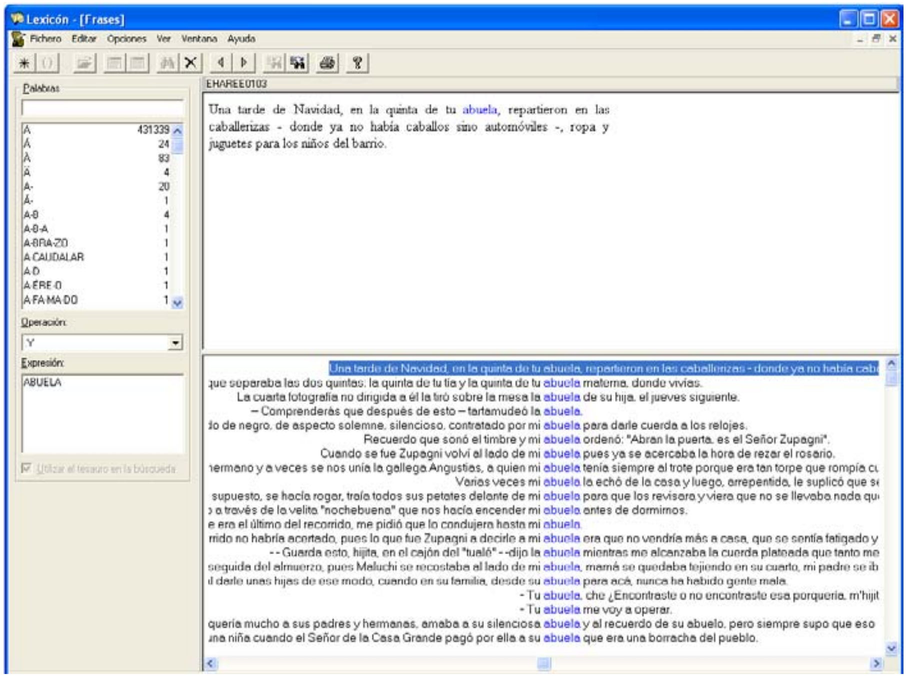
Standard collocation analysis relies basically on statistical measuring of significance (Church et al. 1991; Clear 1993; Sinclair 1991; Stubbs 1995; Barnbrook 1996). That is, each co-occurrence is analysed comparing its "normal" behaviour found in the corpus versus its "specific" behaviour within the concordance lines of the word under investigation. Succinctly, comparing both behaviours we can get three possible outcomes: (1) the "normal" and the "specific" behaviour are the same or very similar, (2) the "normal" behaviour is greater than its counterpart, or (3) the "specific" behaviours release to be greater than the behaviour within the corpus. The first result means that the co-occurrence under investigation is no collocate of the node word, as its behaviour is very much the same as with the rest of the word in the corpus. The second output shows that the co-occurrence is, on average, much more frequent with the rest of the words in the corpus than with the node word we are interested in. Furthermore, this means that this co-occurrence is to some extent repelled or rejected by the node word. And finally, the last possible outcome can be straight forward interpreted as that the co-occurrence is a strong collocation candidate of the node word.

In what follows, we want to go one step further. Our aim is to analyse in depth the distribution of the co-occurrences in order to shed some new light on the semantically relevant co-textual information that "surrounds" the node word.

To avoid any biasing, let's start assuming that no optimal span was taken for granted. This explains why we took the full sentence as the concordance (though important collocates can be missed due to anaphoric reference). In addition, we concentrated on the occurrences of the Spanish noun *abuela*[5] (extracted from the Spanish *CUMBRE Corpus*-20 million tokens).

The total amount of sentence concordances for *abuela* were 1062, and the total co-occurrences of *abuela* 33.947. Next, we excluded closed-class words. That is, articles, prepositions, conjunctions and pronouns, based on the hypothesis that they appear in any context and in any sense definition, and that their presence contributes partially, and not always, if we consider their relative distance with the node. However, in this research and for practical reason, we have deliberately excluded all close-class words, considering only lexical co-occurrences. The co-occurrences left, after

Figure 1. Sample of sentence concordance extract for "abuela"



filtering out all closed-class items were 2208[6] for *abuela*.

To substantiate the fact that the word senses can be determined from the context, we carried out several experiments in which human subjects disambiguated the word *abuela* in the sentence concordances by taking into account the surrounding words only. Subjects were asked to classify the sentences according the following Spanish sense definitions:

1. *La madre del padre o de la madre de una persona*
2. INFML *Mujer anciana o de avanzada edad*
3. INFML *Indica incredulidad o duda por parte del oyente*
4. INFML *Se dice irónicamente de una persona que se alaba a sí misma en exceso*
5. VULG *Indica, irónicamente, el aumento inoportuno de personas o cosas cuando ya hay muchas o demasiadas en un lugar*

Clearly, the most frequent sense for *abuela* was the first one (mother of either of one's parents) with 977 counts with almost 92 %, followed by sense two (45 counts, 4,3 %), sense five (15 counts, 1,1 %), sense four (13 counts, 1,2 %) and sense three (12 counts, 1,4 %).

A look at the co-occurrences of *abuela* (Appendix A) reveals that the most frequent co-occurrence is *casa* (113) and *madre* (108). Curiously, both co-occurrences do only go with sense one (mother of either of one's parents). The amount of distribution of co-occurrences is as follows:

In the noun *abuela*, the distributions (sense and co-occurrence one) are virtually the same, they correlate highly. However, if we examine the co-occurrences we realise the little overlapping or intersection. That is, very few occur in more than one sense or context (see Appendix A). Figure 4[7] below shows graphically how the different co-occurrences are also grouped by senses. Interesting is the fact that those co-occurrences that go with more than one sense *behave* differently depending on the context or sense they appear.

Figure 2. Sense distribution of "abuela"

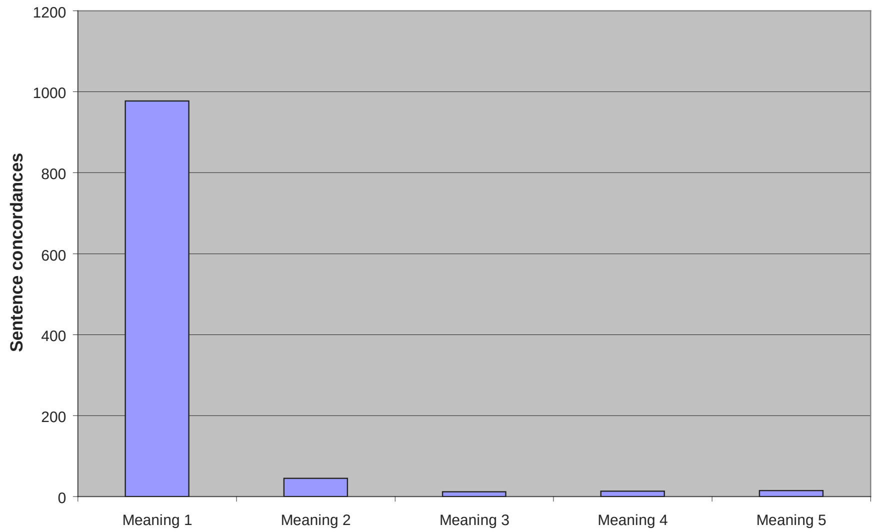
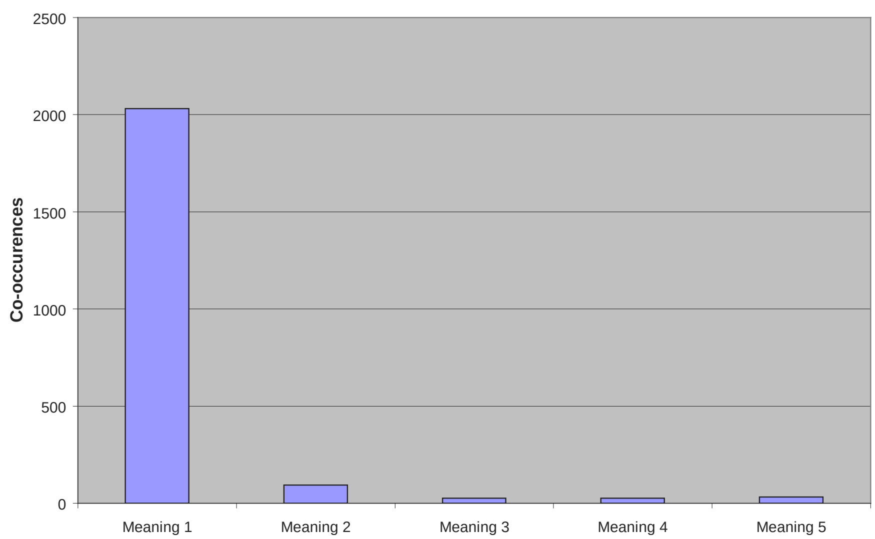


Figure 3. Co-occurrence distribution for ***abuela***

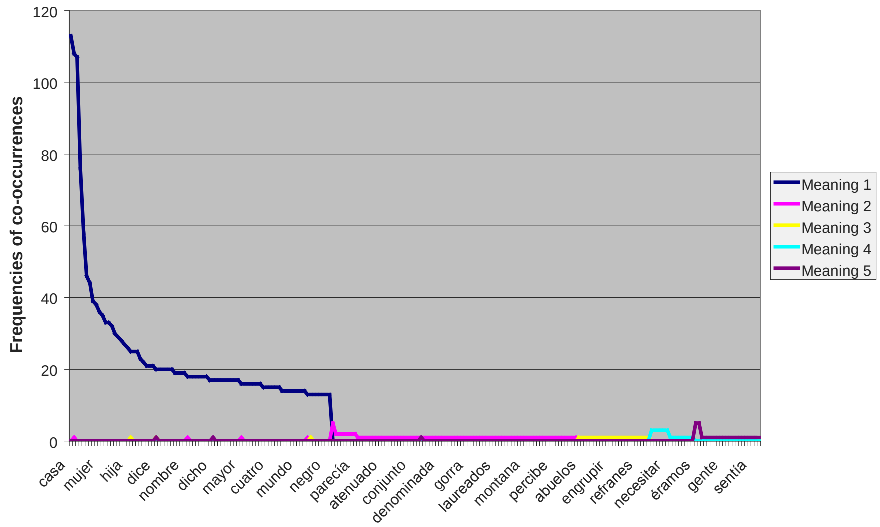


Using relatively simple analytic data (just co-occurrence data), it seems possible to obtain promising sense distribution analysis and consequently positive resolution of lexical ambiguity. The attractiveness of this method relies on its simplicity, effectiveness and transparency. This technique itself seems easy to implement, flexible and can be applied quickly to any word and requires neither special lexical resources, linguistic knowledge nor training data.

Sense Grouping

Though the evidence from the experimental results above is very promising, it is not conclusive, we remain confident that this method can be improved.

Figure 4. Co-occurrence grouping: abuela



We want to go one step further and try to find a rationale for sense grouping based on the findings above: the distribution and appearance of co-occurrences is determined by the meanings they convey in conjunction with the (polysemous) word they occur with.

To avoid any biasing, let's start assuming the following concordance lines of the fictional word "ZZZ". In addition, and for practical reasons, we shall substitute the co-occurrences with senseless letters that should stand for words. Our main focus here is on the structuring of the co-textual information around the node word, not on the optimal span. This explains why the concordance lines have been truncated to a span -5 +5. (see Table 1)

The headline of Table 1 indicates the position of the co-occurrence relative to the node word: negative figures show that the co-occurrence comes before the node word and positive figures indicate post nodal positioning. The first column simple refers to the various concordance lines.

A preliminary analysis shows that the most "influential" co-occurrence is "C" appearing 5 times within the context of "ZZZ".

A more detailed analysis of word "C" reveals however that "C" occurs more frequently before the node word "ZZZ", mostly in position -2 but also in -3. Interesting are in this respect concordances 2 and 3 forming an apparent pre-nodal semantic structure "A B C" ranging from positions -4 to

Table 1. Co-occurrence data of five fictional concordances for the KWIC[8] ***ZZZ***

	-5	**-4**	**-3**	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**+4**	**+5**
1	A	B	C	D	E	ZZZ	F	G	H	I	J
2	Z	A	B	C	E	ZZZ	K	L	M	N	O
3	Y	A	B	C	R	ZZZ	P	O	X	V	Z
4	L	K	J	H	G	ZZZ	F	E	C	D	A
5	K	L	J	H	G	ZZZ	T	H	F	W	C

Table 2. Frequency data

Type	Frequency
C	5
A	4
H	4
B	3
E	3
F	3
G	3
J	3
K	3
L	3
D	2
O	2
Z	2
I	1
M	1
N	1
P	1
R	1
T	1
V	1
W	1
X	1
Y	1

-2, allowing an “intruder” in position -1. This takes us to think that the meaning of “ZZZ” in concordances 2 and 3 is very likely to be the same one. But what happens with “C” in concordances 4 and 5? In these two concordance lines “C” is post-nodal and probably less semantically influenced by the node word “ZZZ”?

The notion of gravity (Mason 1997, 1999) states that the influence of the node word on the co-occurring items fades away with distance. That is, words close to the node word exert a greater influence on the meaning of the node words, whereas more apart words are less influential on the node word. If we assume this analogy: the closer the more influential.

We can move further, weighting the co-occurrences above according to its relative distance to the node word. In addition, the “influence” on the node word can be combined, considering also the frequency on the belief that not only distance but also the number of occurrences is determined; that is,

*Influence = Weight * Frequency*

If a word appears very often next or close to another word, then we might assume that this co-distribution is not due to mere random but due to some “effect”, some attraction any or both words exert on one another to some degree. So, combining both notions: distance and frequency, we get the weighting shown in Table 3 for the co-occurrences[9].

Note that the further apart, less weighting, showing a reverse relationship between distance and weight. In addition and in order to distinguish whether the co-occurrence is pre- or post-nodal, we need to add a plus or minus sign to the weights. (see Table 4)

This distribution of weighting is pretty naïve though effective for our purposes.

Table 3. Weighting

Distance	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
Weight	1	2	3	4	5	0	5	4	3	2	1

Table 4. Weighting considering positioning

Distance	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
Weight	-1	-2	-3	-4	-5	0	+5	+4	+3	+2	+1

Table 5. Influence measures of the co-occurrence data in concordance line 1

Distance	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
Concordance	A	B	C	D	E	ZZZ	**F**	**G**	**H**	**I**	**J**
Weight (W)	-1	-2	-3	-4	-5	0	+5	+4	+3	+2	+1
Freq. (F)	3	3	3	1	2	0	2	1	2	1	1
Influence (W * F)	-3	-6	-9	-4	-10	0	+10	+4	+6	+2	+1

However, by considering the position relative to the node word, we shall consider separately the counts of the pre- and post-nodal co-occurrences. For instance, "A" occurs overall 4 times, yet it only appears 3 times pre-nodal as in the first concordance line. The resulting influence measures for concordance line 1 are shown in Table 5.

A visual display (Figure 5) shows how the most prominent influence on the node word is exerted by the co-occurrences "E" and "F". In addition, the trend line points that the pre-nodal influence is overall greater than its counterpart. More solid evidence to this is the total sum of the pre and post-nodal influences. We just need to maximize both sums, that is, we ignore the minus sign and concentrate on the number with the highest cardinality:

Pre-nodal: max[(-3) + (-6) + (-9) + (-4) + (-10)] = 32

Post-nodal: max[15 + 4 + 6 + 2 + 1] = 28

The pre- and post-nodal influence of all concordance lines are shown in Table 6.

Clearly, the pre-nodal influence (163) is greater than the post-nodal one (128). This again speaks in favour of separating both influences when analysing the semantic structure of words. Consequently, if we assume that the pre-nodal influence is more determined, we could now proceed in grouping the concordances according to their pre-nodal co-occurrences.

A possible method for grouping objects of similar kind (sentences/concordances) into respective categories (meanings/senses) is cluster analysis. A general question facing researchers in many areas of inquiry is how to *organize* observed data into meaningful structures, that is, to develop taxonomies. In other words cluster

Figure 5. Influence of co-occurrences on node word in concordance line 1

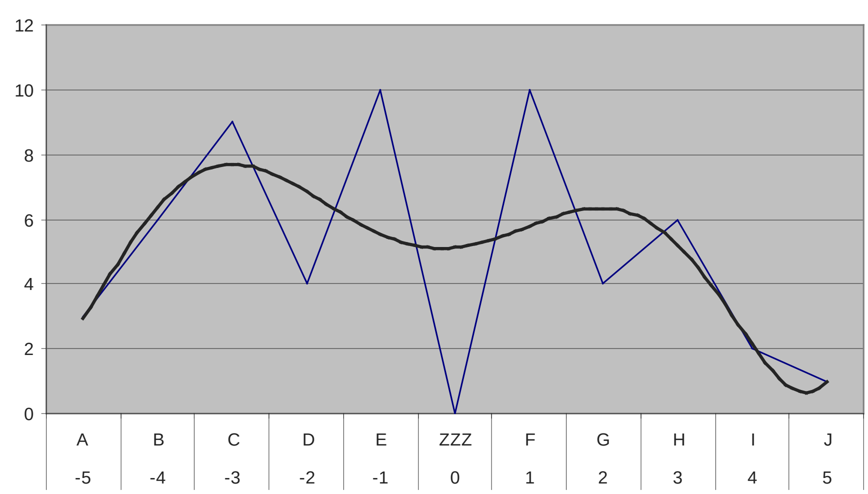


Table 6. Pre- and post-nodal influences

Concordance	Pre-nodal	Post-nodal
1	32	28
2	38	28
3	33	19
4	30	28
5	30	25
Total	163	128

analysis is an exploratory data analysis tool which aims at sorting different objects into groups in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise. Given the above, cluster analysis can be used to discover structures in data without providing an explanation/interpretation. In other words, cluster analysis simply discovers structures in data without explaining why they exist.

A cluster analysis of the pre-nodal data reveals that (i) on the one hand, concordances 2 and 3, and (ii) on the other hand, concordances 4 and 5 are very much similar. Furthermore, as all concordances are extracted using the same node word, we can determine that the word "ZZZ" might have three main behaviours, probably related to three different meanings:

Meaning 1: *expressed by concordances 4 and 5*
Meaning 2: *concordances 2 and 3*
Meaning 3: *concordance 1*

Interesting is also the fact that the potential meaning of concordance 1 is closer related to the meaning of concordances 2 and 3, and not to meaning 1 (concordances 4 and 5). This might take us to, possibly consider, two main meanings:

Meaning 1: *expressed by concordances 4 and 5*
Meaning 2: *concordance 1*

And a sub-meaning of concordance 1, expressed by concordances 2 and 3, getting this final meaning structure:

Meaning 1: *concordances 4 and 5*
Meaning 2: *concordance 1*
Meaning 2.1: *concordances 2 and 3*

Figure 8 only shows the post-nodal occurrences.

Figure 6. Pre and post-nodal influence relative to positions (± 1 to ± 5)

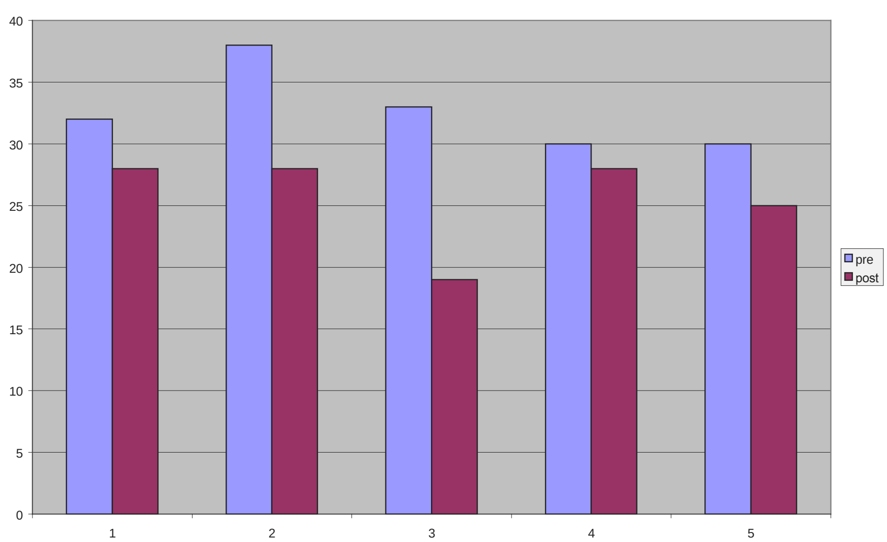


Figure 7. Cluster analysis using pre-nodal data

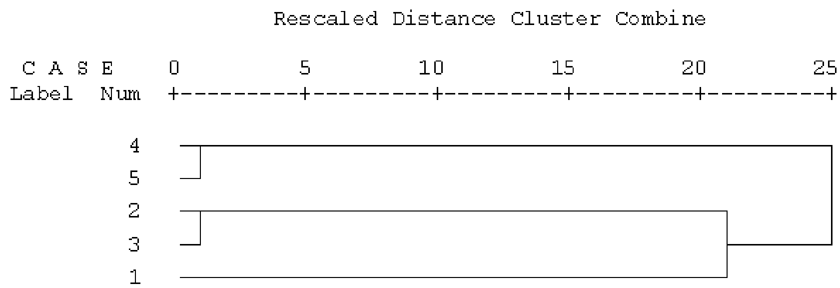


Figure 8. Cluster analysis using post-nodal data

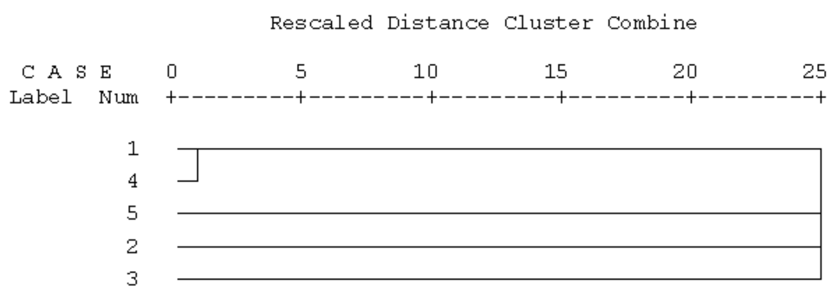
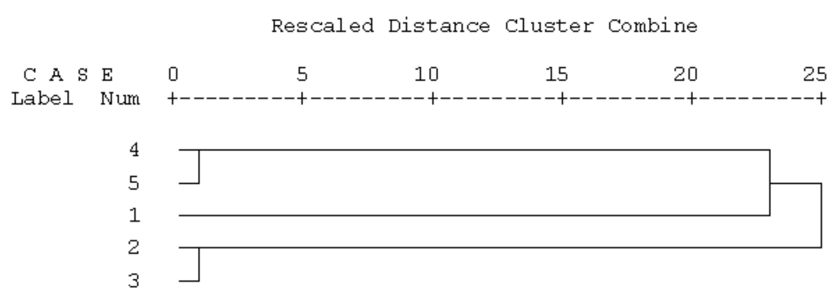


Figure 9. Cluster analysis using pre- and post-nodal data



We find only similarities between concordances 1 and 4. This might be a hint that the pre-nodal structure of the node word "ZZZ" is semantically more determined in order to elucidate possible meanings of "ZZZ".

Finally, considering the whole co-occurrence information (pre- and post-nodal data), we get the results shown in Figure 9.

In principle, the pre- and post-nodal clustering is quite similar to the pre-nodal clustering, except for concordance 1, which is grouped to concordances 4 and 5.

Interesting, however, is the fact that the pre-nodal influence has a greater influence in the sense grouping than the post-nodal one. This points towards important implications: (i) the need to separate pre- and post-nodal data when considering the meaning or semantic clustering of a words or idioms and (ii) the semantic structures that the pre- and post-nodal co-occurrences form have different weight or influence on the meaning of a word, strengthening the notion that a different form necessarily implies a different meaning.

It seems clear, that the idea of using co-occurrence data for sense grouping is a positive contribution. In what follows, we shall experiment in significantly improving this method by means of using Discriminant Function Analysis.

DISCRIMINANT FUNCTION ANALYSIS

Previous research has demonstrated that distinct meanings of the same word attract different co-occurrence data (Almela et al. 2006). Above, we have analysed the distribution of co-occurrences of the node Sp. *abuela* in a sense-tagged sub-corpus. One possible statistical modelling of this data is by means of Discriminant Function Analysis (DFA hereafter).

We applied the DFA to a polysemous word *w* starting from a set of collocational data with *n* entries. The number of entries is determined by the number of sentences containing *w*, that is, as many entries as sentences containing *w*, irrespective of the meaning of *w*. For each of the *n* entries, we extracted *p* numeric independent variables (collocational data), defining the profile of features of each *n.* An additional quantitative dependent variable is considered with as many categories as word senses *w* has. This variable is used to assign group membership (meaning) and to define the group to which each sentence (or item) belongs to. The resulting table is of size table *n*(p+1),* where each case appears with its profile and a group membership assignment.

The discriminant mathematical model will be obtained out of the table *n*(p+1)* and might allow us to examine the profile of new items (sentences containing *w*) and assigned them to the most likely group (meaning).

When the classification of the items is just between two groups of *k* classifying variables, a single discriminant function is required. In general, when the classification of the items is among *G* groups (*G>2*), the number of discriminant axes is given by *min(G-1, p)*. Therefore, we can get up to *G-1* discriminant axes, if the number of explanatory variables *p* is greater or just as *G-1*. Each one of the discriminant functions D_i results into a linear function of the *p* explanatory variable *X*, that is to say:

$$D_i = u_{i1} X_1 + u_{i2} X_2 + \cdots + u_{ik} X_k \text{, con } i=1, 2, \ldots, G-1.$$

The *G-1* discriminant axes are defined by the vectors $u_1, u_2, \ldots, u_{G-1}$ respectively:

$$u_1 = \begin{bmatrix} u_{11} \\ u_{12} \\ \vdots \\ u_{1k} \end{bmatrix} \quad u_2 = \begin{bmatrix} u_{21} \\ u_{22} \\ \vdots \\ u_{2k} \end{bmatrix} \quad \ldots \quad u_{G-1} = \begin{bmatrix} u_{(G-1)1} \\ u_{(G-1)2} \\ \vdots \\ u_{(G-1)k} \end{bmatrix}$$

We can conclude that the discriminant axes are the components of the normalized vectors related to the values of matrix $W^{-1}F$, ordered in decreasing order (the greater the own value, the better the discriminant axis).

As for the contrasts of significance, DFA for multiple groups, that is, when more than one discriminant function is estimated (for example, when there are three groups), calculates specific contrasts to determine whether each one of the values λ_i, obtained from the resolution of the equation $W^{-1}Fu = \lambda u$, is statistically significant or not. That is, DFA determines which variable(s) are the best predictors for the meaning assignment of word *w* in sentence *n*. This is done by means of Wilks' Λ, in conjunction with Bartlett's *V*:

$$-V = -\left\{ n - 1 - \frac{k+G}{2} \right\} Ln(\Lambda) \rightarrow \chi^2_{k(G-1)} \qquad \Lambda = \frac{|W|}{|T|}$$

The null hypothesis of this resistance is H_0: $\mu_1 = \mu_2 = \ldots = \mu_G$, and has to be rejected, as this would indicate that variables used lack of the discrimination power.

DFA AND WORD SENSE DISAMBIGUATION

We shall start by defining the classifying variables used. Each of these variables refers to the word-collocate with respect to position or distance to the word we want to disambiguate. For example, the qualifying variable *pre5* contains the collocate 5 word-positions to the left of the word we want to disambiguate.

Previous analysis and research on the optimal window span for disambiguation purposes revealed that the interval [-5, +5] is more than adequate[10], since it contributes enough information without overloading the volume of the data. This results into 10 classifying variables (5 words before and 5 after the word under investigation).

Due to the nominal nature of the data (words: strings of characters), we converted randomly the nominal variables into discrete ones.

For each polysemous word under investigation, we introduce the data in a matrix with the following features:

Feature 1: **Rows:** the matrix will have as many rows as sentences containing the ambiguous word (with all its meanings): $n = n_1 + n_2 + ... + n_i$, where i is total number of meanings of the word.

Feature 2: **Columns**: the matrix will have 11 columns, corresponding to the 10 classifying variables, plus the discriminant variable, that is, the associated meaning of the word within each sentence.

Previous data preparation of the matrix:

1. Removing repeated items, since they just evidence duplicated sentences without contributing additional information, but increase the volume of the data and slowing down the algorithm performance.
2. Normalizing the data of the classifying variables by means of a logarithmic transformation.
3. Computing the mean of all classifying variables; and in order to relate all means we computed the grand mean. In addition, the value of the grand mean will be negative signed in those instances where no collocate occurs (empty position). This is done as a centralization measure and to diminish the dispersion of the data.
4. Removing outliers from the data set; outliers can be a major source of skewness in the data set. Therefore, it is important to exclude out outliers so that it does not introduce possible bias into our analysis.
5. Inputting the resulting matrix into the statistical package SPSS and computing DFA: the classifying variables ones are the collocational-data [-5, +5], and the discriminant variable is the meaning, with *rank = number of meanings*. Regarding the prior probabilities, we defined all groups equal, since there are major size differences among the meaning sample sentences. We do also save the discriminant scores as well as the probabilities of group membership. Next, we examine and interpret the following output:
   - Wilks' λ tests the null hypothesis: that is, among the sentences (population) the meanings (groups) do not differ from one another on mean for any of the discriminant functions. This Wilks' λ is evaluated with a chi-square approximation (values of λ close to 0 are statistically significant and indicate that the variables discriminate).
   - Eigenvalues: the Eigenvalues reflect how much 'work' each function does in discriminating between groups (meanings), that is, the total among-groups variability. The greater its value, the

more discrimination power the function has.

- Canonical correlations measure the deviations of the discriminant scores between groups with respect to the total deviations without distinguishing groups. If its value is great (close to 1), the dispersion is due to the differences between groups, and consequently the function is a powerful discriminator.
- Cross validation: this technique consists of leaving out an item (sentence) of the sample, re-compute the discriminant function and re-assign the left-out item to any of the existing groups. This reiterative process is performed with all items (sentences). Finally, the total percentage accuracy if calculated.

6. Refining of the discriminant analysis:
   - Analysis of the scatter diagrams: allow a quick visual evaluation of the spatial distribution of each element, as well as of the centroids of each group (meanings). These diagrams might give us valuable information on possible ambiguities of the data or atypical cases.
   - Median line box plot: allows us to refine group assignment by means of analysing the dispersion or concentration of the medians.
   - Box plot of outliers: represents the distribution of the elements of a variable. It is a representative diagram of the dispersion of the elements, and allows us to detect atypical data.
   - The elimination of elements is carried out in order to enhance the discrimination power of the groups, with minimal changes of the original data. Our aim is to delimit the set of items around its own centroids.
7. Re-computing a DFA with the same characteristics in order the improve Wilks' λ index and the cross validation. The process is repeated until the results are accurate and satisfactory, and no further refinement is possible.

THE DFA ALGORITHM

In what follows we shall illustrate the algorithm performance on an example, the Spanish common noun: *abuela.* The five meanings analysed are (see section *Senses and Co-occurrences*):

1. *La madre del padre o de la madre de una persona*
2. INFML *Mujer anciana o de avanzada edad*
3. INFML *Indica incredulidad o duda por parte del oyente*
4. INFML *Se dice irónicamente de una persona que se alaba a sí misma en exceso*
5. VULG *Indica, irónicamente, el aumento inoportuno de personas o cosas cuando ya hay muchas o demasiadas en un lugar*

First, we compute the mean of all classifying variables; and in order to relate all means we compute the grand mean, which is 5.418.

Next, we calculate Wilks' λ, in order to know whether the variables used discriminate positively or not. The significance values of the Wilks' λ obtained (Table 7) reveal that the variables used discriminate positively (all sig. values are ≤ 0,05)

The Eigenvalues (Table 8) are ratios of importance of the dimensions which classify cases of the dependent variable. The higher the values, the more discrimination power the function has. Clearly, Function 1 has the most discrimination power (1,213) and explaining 74,2 % of the whole variance. In addition, The canonical correlations show that all functions discriminate, and reaffirms that Function 1 the most powerful discriminator of all (0,74).

Table 7. Wilks' λ

Test of function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 4	,307	367,165	40	,000
2 through 4	,678	120,521	27	,000
3 through 4	,847	51,516	16	,000
4	,945	17,635	7	,014

Table 8. Eigenvalues and canonical correlation

Function	Eigenvalue	% of Variance	Cumulative %	Canonical correlation
1	1,213	74,2	74,2	,740
2	,249	15,2	89,4	,446
3	,115	7,0	96,4	,322
4	,058	3,6	100,0	,235

Finally the cross validation obtained reveals a high accuracy percentage of the DFA model: 96,9 %.

A most positive contribution of DFA is that once the discriminant functions are known, we can construct a model that allows us prediction of membership (meaning). For instance, one might wish to analyze a new, unknown set of cases in comparison to an existing set of known cases. This is done by means of the resulting discriminant function coefficients.

In addition, for each group (meaning) in our sample, we can determine the location of the point that represents the means for all variables in the multivariate space defined by the variables in the model. These points are called group *centroids* (Table 10 and Figures 10-14). For each case we can then compute the Mahalanobis distances (of the respective case) from each of the group centroids. Again, we would classify the case as belonging to the group to which it is closest, that is, where the Mahalanobis distance is smallest.

Table 9. Discriminant function coefficients

	Function			
	1	2	3	4
pre5log	,033	,023	,040	-,077
pre4log	-,123	,113	,232	,064
pre3log	,028	,068	-,165	,043
pre2log	,036	-,226	-,004	-,137
pre1log	-,118	,258	-,038	,168
pos1log	,070	-,025	,169	,079
pos2log	,181	-,170	,000	,030
pos3log	,126	-,121	-,037	,192
pos4log	,139	,208	,108	,017
pos5log	,242	,131	-,082	-,212
(Constant)	-4,153	-1,114	-,535	-,666

Table 10. Centroids

SIG[1]	Function			
	1	2	3	4
1	,217	,028	-,025	-,016
2	-2,946	,931	1,169	1,118
3	-9,058	1,075	-1,788	-,464
4	-1,592	-5,075	-1,318	1,437
5	-3,697	-2,053	1,829	-1,089

Figure 10. Centroid for meaning 1

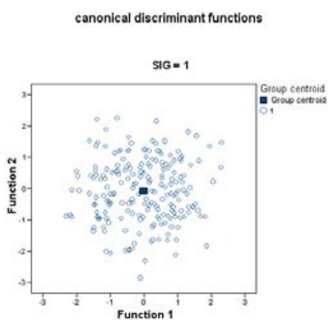


Figure 11. Centroid for meaning 2

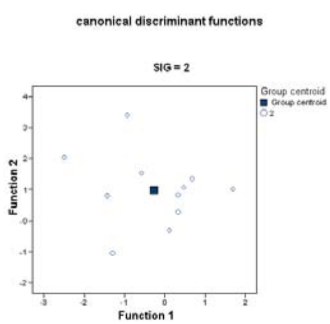


Figure 12. Centroid for meaning 3

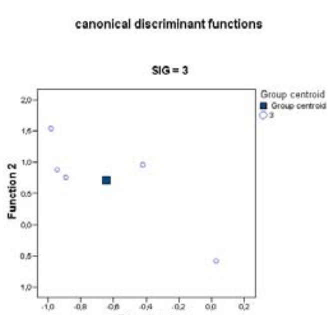


Figure 13. Centroid for meaning 4

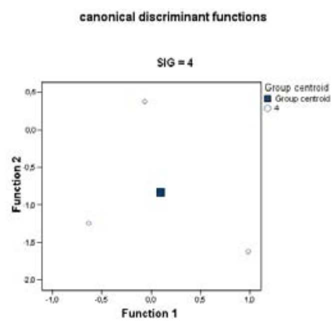


Figure 14. Centroid for meaning 5

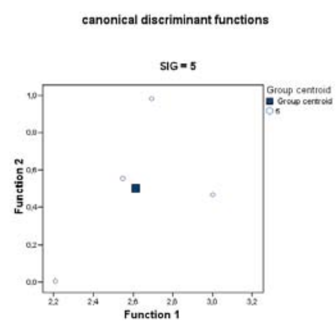


Table 10 shows the centroids of all five meanings relative to the four discriminant functions. Visually this is represented in Figures 10 to 14. The square shows the centroid and the little circles the samples (sentences) that have been grouped to each centroid or meaning. The closer the circles (sentences) are to centroids, the more related they are with that centroid (meaning). In a way, the centroids are the sort of prototypal meaning

Appendix B entails all five centroids (meanings) and cases (sentences) for *abuela*. From the display it becomes clear that (i) meaning 1 dominates the spectrum and overlaps with meanings 2 and 4, (ii) meanings 2 and 3 are very close, although they hardly overlap and (iii) meaning 5 is a clear outsider.

FUTURE TRENDS

One of the revealing findings was the little overlapping of co-occurrences among senses, which is very much in favour for continuing experimenting with Lesk's based algorithms (Lesk 1986, Cowie et al. 1992, Stevenson and Wilks 2001, etc.), using real co-occurrence and/or collocational data extracted from a corpus (Cantos 1996), instead of sets of dictionary entries.

A distinctive characteristic of our research is the potential reiteration of the algorithm at successive levels of sense differentiation. This reiteration is intended to represent various degrees of sense granularity. Each of these levels is represented in terms of a hierarchy of lexical constellations. In the present chapter, we have illustrated the application of the algorithm to obtaining sense classifying information for coarser senses. The next step in our research project is the application of the algorithm to obtaining more specific (refined/granular) levels of sense-meaning correlation. Currently, the lexical sub-entries of each first-level sense are in preparation. Future research aims at the transition from coarse-grained senses to finer-grained ones by means of reiteration of the same WSD model based on DFA on different levels of contextual differentiation.

CONCLUSION

In this chapter, we have approached the analysis of semantic complexity in the word and the problems it poses for linguistic theory as well as for practical implementations, notably lexical disambiguation in natural language processing. We have put forward that collocational patterning explains many aspects of sense-enrichment in the word, and that collocational information is a powerful tool for disambiguation. Word senses spread in networks that roughly coincide with sets of collocates. Therefore, we should be able to predict the sense of the keyword if we have identified the environment.

In order to group word senses of similar kind into respective categories we used cluster analysis. A general question facing researchers in many areas of inquiry is how to *organize* observed data into meaningful structures, that is, to develop taxonomies. In other words cluster analysis is an exploratory data analysis tool which aims at sorting different objects into groups in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise. Given the above, cluster analysis can be used to discover structures in data without providing an explanation/ interpretation. That is, cluster analysis simply discovers structures in data without explaining why they exist. The experiment above on fictional sense clustering using collocational environments seems promising.

It is precisely the initial robustness of the different distribution of co-occurrence data that has taken us to model this behaviour in a most economical way. That is, low computer cost and raw corpus data. The starting point was extracting full concordance sentences, all containing the same ambiguous word and hand-sense-tagged the sentences according to the meaning of that word, according to the sense definitions of a standard paper dictionary. This supervised method gave us valuable data on sense distributions and co-occurrence data around the sense distributions.

All in all, our WSD model based on DFA combines some ideas of the generative lexicon (Pustejovsky and Boguraev 1993; Pustejovsky 1995; Busa 1996; Bouillon 1997) with corpus-based techniques of collocational description (Sinclair 1991; Levow 1997; Gabrielatos and Baker

2006). It is useful to develop actual senses from underspecified semantic representations. The dynamic behaviour of sense extension supersedes the well-known limitations of static enumerative sense inventories (Kilgarriff 1997, 2006). However, the extraction of collocational patterns from surface text facilitates a more realistic method than the formulation of abstract rule sets.

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KEY TERMS AND DEFINITIONS

Cluster Analysis: Cluster analysis encompasses a number of different algorithms and methods for grouping objects of similar kind into respective categories. A general question facing researchers in many areas of inquiry is how to organize observed data into meaningful structures, that is, to develop taxonomies. In other words cluster analysis is an exploratory data analysis tool which aims at sorting different objects into groups in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise.

Co-Occurrence: Co-occurrence is defined as a word/term or sequence of words/terms which simply co-occur with another word or term. For example, consider the following sentence:

Buying her first computer, Heron taught herself to trade online.

If we take the word *computer*, all other words —*buying, her, first, Heron, taught, herself, to, trade*, *online*—are seen as co-occurrences of *computer.*

Collocation: Within the area of corpus linguistics, collocation is defined as a sequence of words or terms which co-occur more often than would be expected by chance within the context of a specific word (node/KWIC). Collocation refers to the restrictions on how words can be used together, for example which prepositions are used with particular verbs, or which verbs and nouns are used together. Collocations are examples of lexical units. Collocations should not be confused with idioms. For example, let us consider the same sentence above:

Buying her first computer, Heron taught herself to trade online.

A statistical analysis reveals that among the co-occurrences only one of them occurs within the context of *computer* more often than would be expected by chance, namely *online*. So we conclude that *online* is a collocation of *computer.*

Concordance: A concordance is a special type of visual display of a sentence or list of sentences which are alingned according to the word under investigation with their immediate contexts. For example:

```
Ken Done had to paint his house of natural tones _ so he
   in your typical suburban house now, this is a middle
  a middle suburban sort of house, there is basically nothing
Lewin are living in a rented house while their own house is
        house while their own house is renovated.
    has to have lungs in the house, space, ability of the outside
       work on the Customs House, for example.
     for us than the Customs House.
```

Discriminant Function Analysis: Discriminant function analysis is used to determine which variables discriminate between two or more naturally occurring groups. For example, a medical researcher may record different variables relating to patients' backgrounds in order to learn which variables best predict whether a patient is likely to recover completely (group 1), partially (group 2), or not at all (group 3). Discriminant function analysis could then be used to determine which variable(s) are the best predictors of patients' subsequent recovery.

Gravity: Gravity represents the extent of influence of the node word (KWIC) on its immediate environment. In other words, gravity shows which co-occurrences/collocations do most contribute to the meaning of the node word. The calculation of gravity is determined by the relative position/ distance of the co-occurrences/collocations with respect to the node word and their frequency.

Lexical Ambiguity: Lexical ambiguity arises when context is insufficient to determine the sense of a single word that has more than one meaning. For example, the word "bank" has several distinct definitions, including "financial institution" and "edge of a river," but if someone says "I deposited €500 in the bank," most people would not think you used a shovel to dig in the mud.

Span: The span or window-size refers to the amount of co-textual data—left and right to the node word—we are considering for our investigation. It is normal use to take a span of -5 +5, that is up to 5 words left to the KWIC and 5 words right to it.

Word Sense Disambiguation: In computational linguistics, word sense disambiguation is the process of identifying which sense of a word—having a number of distinct senses—is used in a given sentence. For example, consider the word *corn*, three distinct senses of which are:

1. Seed of any various grain, chiefly wheat, oats, rye and maize; such plants while growing
2. Music, verse, drama, etc that is banal, sentimental or hackneyed.
3. Small, often painful, area of hardened skin in the foot, esp on the toe

and the sentence:

This romantic ballad is pure corn.

To a human it is obvious that this sentence is using the word *corn* in the second sense above. Although this seems obvious to a human, developing algorithms to replicate this human ability is a difficult task.

ENDNOTES

1 A 20 million-word corpus of contemporary English compiled by the LACELL Research Group at the University of Murcia (Spain).

2 Longman Dictionary of Contemporary English

3 The purpose of Senseval is to evaluate the strengths and weaknesses of computer programs for automatically determining the sense of a word in context with respect to different words, different varieties of language, and different languages.

4 A "lexical sample" task involves tagging a few occurrences of a sample of words for which hand-annotated training data is provided. An "all-words" task involves tagging all words occurring in running text.

5 Grandmother.

6 See Appendix I.

7 For more details see Appendix I.

8 *KWIC* stands for Key Word In Context.

9 Note that we deliberately skip here talking about collocations, we prefer to use the more vague term co-occurrence in order to about the discussion on collocation extraction methods.

10 On optimal spans, see i.e. Jones and Sinclair 1973; Martin et al. 1983; Smadja 1989; or Berber 1997, among others).

11 SIG stands for *meaning.*

APPENDIX A

Co-Occurrences	Meaning 1	Meaning 2	Meaning 3	Meaning 4	Meaning 5	Total
casa	113	0	0	0	0	**113**
madre	108	1	0	0	0	**109**
había	107	0	0	0	0	**107**
años	76	0	0	0	0	**76**
padre	58	0	0	0	0	**58**
tenía	46	0	0	0	0	**46**
tía	44	0	0	0	0	**44**
abuelo	39	0	0	0	0	**39**
día	38	0	0	0	0	**38**
mujer	36	0	0	0	0	**36**
vida	35	0	0	0	0	**35**
decía	33	0	0	0	0	**33**
dijo	33	0	0	0	0	**33**
familia	32	0	0	0	0	**32**
ir	30	0	0	0	0	**30**
tiene	29	0	0	0	0	29
te	28	0	0	0	0	**28**
tiempo	27	0	0	0	0	**27**
hija	26	0	0	0	0	**26**
bien	25	0	1	0	0	**26**
año	25	0	0	0	0	**25**
miedo	25	0	0	0	0	**25**
casi	23	0	0	0	0	**23**
recuerdo	22	0	0	0	0	**22**
ojos	21	0	0	0	0	**21**
parte	21	0	0	0	0	**21**
sé	21	0	0	0	0	**21**
dice	20	0	1	0	1	**22**
iba	20	0	0	0	0	**20**
mamá	20	0	0	0	0	**20**
niños	20	0	0	0	0	**20**
ser	20	0	0	0	0	**20**
tres	20	0	0	0	0	**20**
hacer	19	0	0	0	0	**19**
han	19	0	0	0	0	**19**
murió	19	0	0	0	0	19
nombre	19	0	0	0	0	**19**
pueblo	18	1	0	0	0	**19**
gran	18	0	0	0	0	**18**

continued on following page

APPENDIX A: CONTINUED

hijos	18	0	0	0	0	**18**
marido	18	0	0	0	0	**18**
mire	18	0	0	0	0	**18**
ropa	18	0	0	0	0	**18**
vacaciones	18	0	0	0	0	**18**
cosa	17	0	0	0	0	**17**
dicho	17	0	0	0	1	**18**
habían	17	0	0	0	0	**17**
hijo	17	0	0	0	0	**17**
niño	17	0	0	0	0	**17**
tarde	17	0	0	0	0	**17**
vamos	17	0	0	0	0	**17**
ver	17	0	0	0	0	**17**
vieja	17	0	0	0	0	**17**
voy	17	0	0	0	0	**17**
mayor	16	1	0	0	0	**17**
decir	16	0	0	0	0	16
don	16	0	0	0	0	**16**
hermanas	16	0	0	0	0	**16**
historia	16	0	0	0	0	**16**
niña	16	0	0	0	0	**16**
podía	16	0	0	0	0	**16**
bajo	15	0	0	0	0	**15**
ciudad	15	0	0	0	0	**15**
cuatro	15	0	0	0	0	**15**
hermano	15	0	0	0	0	**15**
hubiera	15	0	0	0	0	**15**
son	15	0	0	0	0	**15**
creo	14	0	0	0	0	**14**
edad	14	0	0	0	0	**14**
hizo	14	0	0	0	0	**14**
joven	14	0	0	0	0	**14**
muerte	14	0	0	0	0	**14**
mundo	14	0	0	0	0	**14**
reina	14	0	0	0	0	**14**
vivir	14	0	0	0	0	**14**
hermana	13	1	0	0	0	14
lado	13	0	1	0	0	**14**
comer	13	0	0	0	0	**13**
hermanos	13	0	0	0	0	**13**

continued on following page

APPENDIX A: CONTINUED

manos	13	0	0	0	0	**13**
momento	13	0	0	0	0	**13**
negro	13	0	0	0	0	**13**
padres	13	0	0	0	0	**13**
super	0	5	0	0	0	**5**
cárcel	0	2	0	0	0	**2**
dejan	0	2	0	0	0	**2**
exposición	0	2	0	0	0	**2**
juez	0	2	0	0	0	**2**
libertad	0	2	0	0	0	**2**
libre	0	2	0	0	0	**2**
parecía	0	2	0	0	0	**2**
actuó	0	1	0	0	0	**1**
anciana	0	1	0	0	0	**1**
anteriores	0	1	0	0	0	**1**
aptitudes	0	1	0	0	0	**1**
arriba	0	1	0	0	0	1
arte	0	1	0	0	0	**1**
asaltante	0	1	0	0	0	**1**
atenazado	0	1	0	0	0	**1**
atenuado	0	1	0	0	0	**1**
benjamines	0	1	0	0	0	**1**
boticario	0	1	0	0	0	**1**
cascarrabias	0	1	0	0	0	**1**
casó	0	1	0	0	0	**1**
chicas	0	1	0	0	0	**1**
comentó	0	1	0	0	0	**1**
componen	0	1	0	0	0	**1**
comunicarle	0	1	0	0	0	**1**
conjunto	0	1	0	0	0	**1**
conocer	0	1	0	0	0	**1**
considerar	0	1	0	0	0	**1**
curiosidad	0	1	0	0	1	**2**
debe	0	1	0	0	0	**1**
defenderme	0	1	0	0	0	**1**
defendí	0	1	0	0	0	**1**
defensa	0	1	0	0	0	1
dejada	0	1	0	0	0	**1**
denominada	0	1	0	0	0	**1**
diseñador	0	1	0	0	0	**1**

continued on following page

APPENDIX A: CONTINUED

eco	0	1	0	0	0	**1**
encerrada	0	1	0	0	0	**1**
escapaba	0	1	0	0	0	**1**
estatales	0	1	0	0	0	**1**
francés	0	1	0	0	0	**1**
generaciones	0	1	0	0	0	**1**
generales	0	1	0	0	0	**1**
gorra	0	1	0	0	0	**1**
grito	0	1	0	0	0	**1**
hallan	0	1	0	0	0	**1**
hombres	0	1	0	0	0	**1**
hondureña	0	1	0	0	0	**1**
honoríficos	0	1	0	0	0	**1**
humillarse	0	1	0	0	0	**1**
iban	0	1	0	0	0	**1**
interés	0	1	0	0	0	**1**
laureados	0	1	0	0	0	1
lesbiana	0	1	0	0	0	**1**
llamado	0	1	0	0	0	**1**
llegó	0	1	0	0	0	**1**
local	0	1	0	0	0	**1**
masa	0	1	0	0	0	**1**
mató	0	1	0	0	0	**1**
médico	0	1	0	0	0	**1**
miércoles	0	1	0	0	0	**1**
montana	0	1	0	0	0	**1**
musa	0	1	0	0	0	**1**
nacieron	0	1	0	0	0	**1**
nixtamal	0	1	0	0	0	**1**
obras	0	1	0	0	0	**1**
obreros	0	1	0	0	0	**1**
olor	0	1	0	0	0	**1**
oro	0	1	0	0	0	**1**
paz	0	1	0	0	0	**1**
percibe	0	1	0	0	0	**1**
perfectos	0	1	0	0	0	**1**
período	0	1	0	0	0	1
pintores	0	1	0	0	0	**1**
premios	0	1	0	0	0	**1**
prensa	0	1	0	0	0	**1**

continued on following page

APPENDIX A: CONTINUED

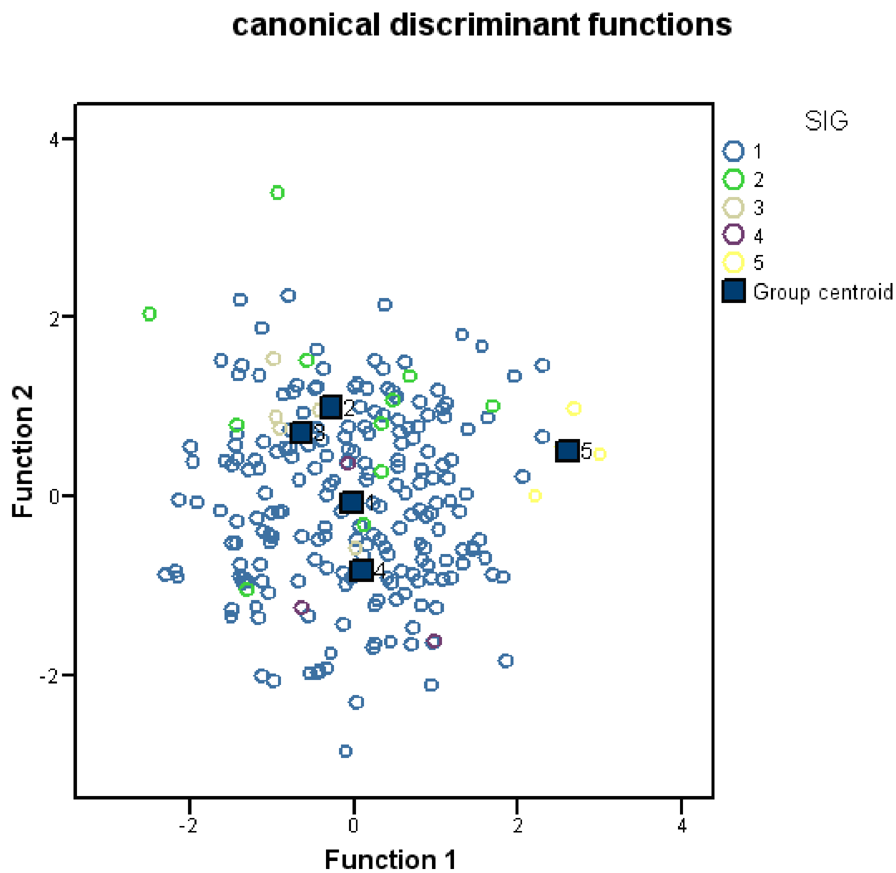
preparó	0	1	0	0	0	**1**
propia	0	1	0	0	0	**1**
abuelas	0	0	1	0	0	**1**
abuelos	0	0	1	0	0	**1**
ándate	0	0	1	0	0	**1**
cagó	0	0	1	0	0	**1**
conocía	0	0	1	0	0	**1**
contárselo	0	0	1	0	0	**1**
cuéntaselo	0	0	1	0	0	**1**
cuente	0	0	1	0	0	**1**
decirse	0	0	1	0	0	**1**
duda	0	0	1	0	0	**1**
engrupir	0	0	1	0	0	**1**
familiar	0	0	1	0	0	**1**
frase	0	0	1	0	0	**1**
hablando	0	0	1	0	0	**1**
haciéndome	0	0	1	0	0	1
mina	0	0	1	0	0	**1**
niega	0	0	1	0	0	**1**
pone	0	0	1	0	0	**1**
refiere	0	0	1	0	0	**1**
refranes	0	0	1	0	0	**1**
risa	0	0	1	0	0	**1**
suele	0	0	1	0	0	**1**
usted	0	0	1	0	0	**1**
alaba	0	0	0	3	0	**3**
critica	0	0	0	3	0	**3**
frases	0	0	0	3	0	**3**
habérsele	0	0	0	3	0	**3**
muerto	0	0	0	3	0	**3**
necesitar	0	0	0	3	0	**3**
detallazo	0	0	0	1	0	**1**
jefe	0	0	0	1	0	**1**
pregunta	0	0	0	1	0	**1**
presidente	0	0	0	1	0	**1**
qué	0	0	0	1	0	**1**
redondearon	0	0	0	1	0	1
Secretaria	0	0	0	1	0	**1**
va	0	0	0	1	0	**1**
éramos	0	0	0	0	5	**5**

continued on following page

APPENDIX A: CONTINUED

parió	0	0	0	0	5	**5**
ama	0	0	0	0	1	**1**
aumenta	0	0	0	0	1	**1**
comezón	0	0	0	0	1	**1**
concurrencia	0	0	0	0	1	**1**
da	0	0	0	0	1	**1**
declaración	0	0	0	0	1	**1**
entender	0	0	0	0	1	**1**
gente	0	0	0	0	1	**1**
habría	0	0	0	0	1	**1**
inoportuno	0	0	0	0	1	**1**
inquietud	0	0	0	0	1	**1**
modo	0	0	0	0	1	**1**
morochos	0	0	0	0	1	**1**
perdón	0	0	0	0	1	**1**
popular	0	0	0	0	1	**1**
refrán	0	0	0	0	1	1
sentía	0	0	0	0	1	**1**
sexual	0	0	0	0	1	**1**
sintió	0	0	0	0	1	**1**
TOTALS	2031	93	26	26	32	2208

APPENDIX B: CENTROIDS FOR MEANING 1-5



Chapter VIII
Association between Web Semantics and Geographical Locations:
Evaluate Internet Information Consistency for Marketing Research

Kimman Lui,
The Hong Kong Polytechnic University, Hong Kong

Keith C. C. Chan,
The Hong Kong Polytechnic University, Hong Kong

Kai-Pan Mark,
City University of Hong Kong, Hong Kong

ABSTRACT

Social software completely revolutionizes the way of information sharing by allowing every individual to read, share and publish online. In terms of marketing, it is an effective way to understand consumers' perceptions and beliefs in different local regions by analyzing and comparing the web content regarding a specific product retrieved on the Internet with respect to different locations. Interestingly, incidents originated from a location may attract more Internet discussions by individuals from remote locations. Therefore, it is difficult to measure the strength of people's perceptions between different locations if we solely rely on the web traffic statistics. Moreover, it is difficult to compare strength of perceptions retrieved by different search engines, at different times, and on different topics. To overcome these inadequacies, the authors introduce a quantitative metric, Perceived Index on Information (PI), to measure the strength of web content over different search engines, different time intervals, and different topics with respect to geographical locations. Further visualizing PI in maps provides an instant and low-cost mean for word-of-mouth analysis that brings competitive advantages in business marketing.

INTRODUCTION

Market research is concerned with identifying the tastes, values, preferences and buying patterns and selection behavior of consumers. Nowadays, there is a considerable amount of such consumer information available on the Internet at public forums such as blogs, internet special interest communities and social networking sites. While these discussions are of interest to marketers in themselves, they are also a source of information about goods and services for consumers who are not active participants in these forums but who use search engines to search for product information and as a result will obtain numerous results of varied provenance and reliability from a large number of sites as a basis for their buying decisions. However, analyzing such consumer information published on the Internet is always challenging because: (1) the geographical origin of an individuals' post in an online community is insufficient for identifying the geographical origin of the event; (2) consumer information is highly dynamic and is changed rapidly; (3) there exists different results when different search engines process the same query; and (4) there is a lack of an empirical way to compare different search results.

Identifying the origin of an event is important for localizing marketing campaigns. Different web content contains rich information for marketing research. Marketing information retrieved from web contents, through either reading manually, or by machine analysis, contains facts and localized peer opinions that are of high value to marketers to launch local marketing campaigns. Further knowing geographically where the peer opinions regarding a specific product are from, marketers can have a picture on the market response from different local markets. Associating different peer opinions with the source of geographical regions allows marketers to launch localized marketing campaigns easily and rapidly.

Understanding the difference in search engines results produced by the same query enables a marketer to know what consumer information are perceived by consumers through different search engines. In addition, it will be a marketer's interest to trace the change in the strength of consumers' perceptions by comparing two sets of search results at different times, or on different topics. The issue to be considered in this chapter is how to determine whether two sets of search results are consistent and to comparing the search results empirically.

The organization of this chapter is as follows. The next section gives the background on different approaches on information analysis research by information systems, computer science and marketing researchers. Next followed by the related works on web browsing and information sharing behaviors on information systems discipline, and on web analysis with the more technical aspect on traffic analysis and web content analysis. Then, we point out the inaccuracy in the existing systems and propose a new algorithm on measuring the strength of perception with respect to topics, time, search engines and geographical locations. Afterwards, we discuss the application and present industry cases on how this algorithm benefits marketers. Finally, we conclude this chapter by pointing out the future directions on this research and the contributions of our chaper.

BACKGROUND

Individual's information sharing behaviors on the Internet is a popular field in information systems research (e.g. Bock et al., 2005; Wasko & Faraj, 2005). Surprisingly, people are motivated intrinsically in sharing their knowledge. Reward by money is not the primarily goal in publishing information on the Web for the public. More and more consumers prefer to publish comments on personal blogs and discussion forums. As a consequence, more and more consumers also search for other consumers' comments in social networking sites before making a buying decision. Influence of online Word of Mouth (WOM) on buying decision has grown significantly over the past years (Riegner, 2007).

Behavior of consumers in online social networks has already caught the attention of marketing researchers (Cooke & Buckley, 2008). Researchers have identified the opportunities in using Web 2.0 for marketing purposes especially in retrieving consumers' perceptions over products systematically. However, analyzing web content with meaningful human semantics is a challenge to both human beings and intelligent systems. Information searching is an everyday activity to support human decision making. In the digital age, information searching in web content is made instant and easy. A piece of information that someone needs is surely available on the web somewhere. Availability of information is no longer a concern to information seekers. Instead, the problem is how to find it and how to integrate different pieces of information retrieved from web contents in a meaningful way (Decker et al., 2003).

Search engine is one of the simplest solutions to address the problems encountered by marketers and consumers. Advancement in search engine technologies brings people together with desired information instantly by a simple query. Faster searching algorithms are proposed by computer scientists. Semantics of web content is being accounted in machine search processes. Still, search engines are not perfect in analyzing people's preferences. It was found that results provided by search engine and the users' own perception are of big difference (Bar-Ilan et al., 2007). Moreover, search engines only provides relevant web pages without authenticate the truth and source of the information on the web.

One limitation of relying on search engines for marketing analysis is that search engines are unable to authenticate the source of information. It is very likely that information containing both facts and rumors are mixed in the search results without identification. Information retrieved by search engines may be facts that are confirmed and with a discernible source or rumors that cannot be confirmed and without a credible source. However, individuals seldom question the authenticity of information on the Internet. In the reality, people make decisions based on what they perceived to be true instead of what is proved to be true. Often, people's perceptions are influenced significantly with information perceived from the Internet even though the information is a rumor because identifying rumors on the web is difficult.

To marketers, a better way to react is first to analyze what information consumers perceive on a product through different search engines no matter the information is factual or is a piece of rumor. As consumers can easily reach information on the web through search engines, often they retrieve rumors that give negative effects to their buying decision. Negative rumors are harmful to business that marketers always try to avoid, control and stop. Negative rumors are spread among consumers in a more negative manner, while positive rumors are spread less favorably (Kamins et al., 1997). Controlling what to be published and proving the authenticity of every piece of information on the Web are absolutely infeasible and violate human rights on freedom of speech. Analyzing contents presented in a web page is theoretically a more practical solution, but the highly dynamic web and infinite number of web pages make it totally impossible. Most likely, consumers rely on the search results supplied by a search engine to perceive information of their interest. It is sufficient to analyze top results from the search engine to get some hints on what the public's voice is over a certain topic of interest. This mechanism is technically feasible as it involves only a finite set of web pages supplied by the search engine.

To analyze the huge volume of information on the Internet, computer scientists have developed the Semantic Web to represent human semantics in standard ways. The Semantic Web has been proposed to assist machines to understand the contents and services provided by a web page. A Resource Description Framework is deployed in the web pages to categorize web content with different human perceptions that can be understood by computer systems. It assembles the semantics in human communications and partly solves the problem of web content analysis. However, web content is updated dynamically, especially in social computing environments. It is unable to define web semantics in such systematic way because the content is updated by users collaboratively and dynamically.

The Semantic Web, however, does not work well when the web page is highly dynamic. It is impossible to code the semantics of every single post in a discussion forum being frequent updated by the online community. With the emergence of social computing technologies, information is diffused rapidly over the Internet. Traditionally, information is diffused in one direction only from the information source to the public. Contemporary Web 2.0 technologies revolute the flow of information by allowing the public to construct information freely in the Internet through blogs, wikis, discussion forums and many other channels. At present, flow of information is multi-directional. Every one is the audience, and at the same time, the source and the contributor of information.

In this chapter, we propose an efficient methodology to evaluate the consistency of online information perceived on the web with different search engines, different topics of interest, and different time intervals with respect to different geographical locations empirically. By defining a Perceived Index (PI, pronounced as “pai”) on information, it gives a quantitative metric on the strength of voice over a topic of interest with respect to different geographical locations, different search engines and different time intervals. Further visualization of PI in a map gives an effective way to trace the change of WOM consistency on the Internet with different search engines, different topics of interest, and different time intervals against different geographical locations. Finally, we conclude that WOM consistency with geographic information is useful to marketers by presenting relevant industrial cases.

RELATED WORKS

In this section, we present the work done on web content and user pattern analysis in behavioral and technical approaches. First, we review the definitions of two categories of information that are influential to buyers’ decisions on the Internet: rumors and Word of Mouth (WOM). Next, we present the literature on people’s information exchange behaviors on the Internet focusing on social computing tools such as blogs and discussion forums. Afterwards, we present the existing literature on analysis on web searching behaviors and patterns. Finally, we introduce some existing tools on web traffic analysis and conclude this chapter by pointing out the weaknesses of the existing solutions in marketing analysis.

Information on the Internet

In this section, we review the different categories of information appearing on the Internet that is of consumers’ and marketers’ interests. The Internet contains rich source of factual and non-factual information for consumers. Consumers are especially interested in seeking product information before making a purchase decision. It is very common for consumers to share their experience on a product on the Internet. Online WOM is formed when consumers gather as a community in a social web site and exchange information on a product. Usually, WOM is subjective and cannot be totally verified. Marketers are willing to understand WOM among different groups of consumers. The Internet is also an efficient channel for marketers to retrieve WOM from the consumer groups. WOM found in blogs and discussion forums gives useful hints for marketers to design new marketing campaigns. The information is also vital in forming new strategy against competitors and rumors.

Rumor

Rumors are classified as unverified "mysterious" or "magical" information that fascinate, overwhelm, entrap and stir up people's minds (Schindler, 2007). Nearly every type of company is affected by unverified stories and questionable information (Kimmel, 2004). Such unverified rumors pose some effects, although not always negative, to the consumers' perceptions as well. In the financial market, it has been proved that takeover rumors posted on Internet Discussion Forums cause abnormal market activities (Clarkson et al., 2006). Griffin et al. (1991) even argued that denial of a negative rumor gives the same impact as ignoring the event entirely. Even worse, when people were told the information was false initially, the more likely they were to believe the information was true (Skurnik, 2005).

Marketers are aware of the power of rumors. Even before the existence of the Internet, effort has been made by different researchers to combat negative rumors. Information Processing Theory was employed to form new strategies in reducing the impact of adverse rumors (Tybout et al., 1981). Nowadays, marketers have realized the importance to identify the source, understand the content, react to the criticisms, and drive the discussions. Crawford (1999) has proposed a four pointer model – "Bone up", "Get the Big Picture", "Keep Cool" and "Drive the Discussion" as the strategy to react to negative rumors on the Internet.

Word of Mouth

WOM is classified as "consumer-to-consumer (C2C)" marketing (Sernovitz, 2006). WOM from friends, relative and experts always influence significantly on buyers' decision. It is no doubt that consumers, even ourselves, seek advice from our family and friends, and perhaps from the Internet sites, before we make a purchase decision. There are many channels for consumers to access information (Kumar & Lang, 2007). Previous research indicated that both specific product information and social influence information contributed to customer's selection (Rosen & Olshavsky, 1987). Consumers actively choose whether to approach a firm's web site in the World Wide Web (Hoffman & Novak, 1996). Among different channels, interpersonal consumer network has significant impact in marketing of new or improved products (Brooks & Robert, 1957).

Perceptions and beliefs, rather than verified facts, build WOM. Rumor, therefore, gives a significant impact on WOM formation. Positive emotions, such as pleasure and arousal on satisfaction, contribute to positive WOM creation (Ladhari, 2007). Positive WOM gives positive influences to other consumers through social interaction known as "informational social influence" (Cohen & Golden, 1972). With Internet and its rich social computing web sites, people begin to search and exchange WOM in different virtual communities. Personal blogs and discussion forums are popular for WOM search and exchange. WOM is also important in online auctions. Consumers engage in virtual communities as they provide an anti-fraud function (Chua et al., 2007) that consumers may search for the reputation of the seller or producer.

WOM gives marketers invaluable hints on developing new strategies. Barton (2006) claimed that online word of mouth provides valuable marketing information for advertisers on customer perceptions. One of the most common social computing tools for marketing to obtain consumers' WOM online is through blogs. Blogs are convenient and easy to use and hence they become a way for advertising and marketing (Dearstyne, 2005). It is easy to obtain feedback instantly and inexpensively from a large community and hence to promote word of mouth (Dellarocas, 2003). People enjoy searching, and also contributing, contents online by blogs. Although blogs are comparatively informal in information distribution, its effect cannot be neglected. The negative feedbacks from blogs can be useful for overcoming negative effects in marketing (Kalyanam et al., 2007). Messages posted in blogs diffuse rapidly through different social network online. Consequently, this negative WOM harms the firm's revenue and stock value (Luo, 2007).

Information Exchange on the Internet

Information sharing has been an interesting topic of research by information systems researchers. Instead of expecting help in return, people contribute information in electronic networks of practice when they perceive that it is enjoyable and would enhance their professional reputation (Wasko & Faraj, 2005). Contemporary tools in Web 2.0 also enhance individuals to publish and share information. Davis (1989) considers usefulness and ease of use as the most important factors in motivating users to use a new technology. This explains why blogs and discussion forums are overwhelmingly used by many consumers to share their perceptions.

Blogs and Discussion Forums

Information contained in blogs is diversified and unstructured. Every one can write every thing in blogs. It is very common for bloggers to write about his own experience as a consumer in his blogs. It is not rare that we can search contradictory views from different blogs. As a promising new media in growth, the impact of blogs can no longer be neglected. Marketers now pay attention to blogs so that they know what consumers are talking about their products. Though efforts are put into blog research, little can be achieved as the numbers of blogs are infinite.

Forums form a virtual community of interest. People with similar interest join as members in a forum. Forum discussion can be open to public or private to members only. People begin discussion by opening a new thread and continuously reply to the thread. There are active members in the discussion as well as "lurkers" who only read the content without any contribution.

Consumer Information Exchange and Marketing

Impact of Internet forums is significant to business that marketers must pay attention to the latest voice from the consumers. There have already been reported disastrous incidents that business was being negatively affected by forum posts.

In May 2008, an individual posted a set of free ice-cream coupons in *forum.hkgolden.com*. People could download, print a hardcopy of coupon and redeem free ice-cream in a convenience store chain. Actually it was a promotion campaign from a beauty product but it was "abused" by forum members. Eventually the campaign was stopped before the deadline. Some people were not satisfied with the beauty product producer as they were unable to redeem ice-cream even though they were eligible to (OK , 2008). Undoubtedly, this event created a popular topic in Hong Kong, but its effect was negative.

In Mainland China, online forums become a source of call for boycott in recent years. For instance, French products and shops were boycotted in China as a response to its Government's attitude towards Beijing Olympics.

Marketers nowadays should realize the impact of posts in forums and blogs as rumors spread fast in forums and blogs. Although the negative impacts cannot be totally eliminated, it is wise to form early marketing strategies to prepare for the worst. Understanding the mechanisms on how individuals perceive WOM on the Internet and individuals' browsing behaviors, therefore, is vital for marketers to measure the information perceived from the Internet from time to time and from different sources

Linking People with Relevant Information

People and information were initially isolated. People nearby spread information about an incident happened nearby. Information was diffused through human interactions within the neighborhood. Identifying the geographical source of the incident was easy by tracing back individuals who have diffused the information because seldom did people talk, and spread, the information regarding to an event happened far away. However, the source of information in virtual communities cannot be identified easily.

Information Source

Identifying the source of information is a challenge in analyzing the consumer information retrieved from the online communities. Instead of diffusion from the source that the incident has happened (i.e. source of happening), all people in the Internet can discuss the incident at the same time. The Internet enables people to exchange information without geographical limitations. Source of information distribution becomes multiple and concurrent although there is only one source of happening. It is no longer possible to identify the source of happening by simply tracing sources of distribution backwards by identifying Internet traffic because people anywhere can talk about any events.

Search Engine

Search engine has a significant impact on influencing what information people perceive from the Internet. Analyzing web contents presented by a search engine would certainly give valuable insights to marketers on how people perceive their products. Understanding people's behavior on web searching also help marketers optimize how people perceive their products' information in a better way.

Web browsing is a major task for people to surf online. In a field study done by Kellar et al. (2007), 20% of activities online was related to browsing the Web, which included browsing different blogs. It is a habit for people to search for topics of interest in search engines to browse. Often, search engine provides too many results that people are unable to browse all of them. Therefore, it is a must to specify explicitly the search keywords in order to find the right information (Heinen, 1996).

Search engine does not always produce what information people want. First, the search result ranking is easily influenced by paid advertisements. It is reported that on average 60% of the search results presented on the first page are paid listings (Nicholosn et al., 2006). It is also possible to "optimize" a web site's search listing rank by using a meaningful domain name with meaningful keywords (Barrett, 2007). Markers have already utilized this "small trick" by search engine optimization and paid placements for several years (Sen, 2005; Sen et al., 2006). Recent research has shown that customers no longer trust the paid placement in the search results, and advertisers tend to optimize the search engine listings by modifying the keywords and code blocks of its own web site (Sen, 2005). Most likely, it is due to the aggressive advertisers who pay to "steal" the traffic of competitive search key terms (Klaassen & Teinowitz, 2007).

Web Analysis

Analyzing Internet users' behavior on information sharing and its impact on buying decision making over different geographical locations is not easy. Technically speaking, it is easy to trace the source of a post but it does not necessarily give an accurate picture on consumers' perceptions in the source's geographical location. Next we present the current work on web analysis by web traffic source, followed by the behavioral analysis on Internet users' browsing behavior. We then figure out how consumers interact with different sources of Internet information and how such behavior helps marketing research.

Technical Analysis on Web Traffic Source

It is always a challenge to analyze web contents. Technically, it is easy to count the occurrence of a pre-defined set of keywords in a given web page. Knowing the semantic meaning, however, remains a complex problem to computer scientists. It requires information retrieval systems to understand, and extract, useful information in the viewpoint of human. Artificial intelligence is deployed in opinion mining systems to classify qualitative contents into both supportive and non-supportive views. The core of opinion mining systems involves opinion extraction, summarization, and tracking (Ku & Chen, 2007). Often, it takes a long time to analyze one document. Once the document is updated, it needs to be analyzed again.

Given that the highly dynamic nature of the Web, it is impossible to perform real-time analysis on every relevant page especially in blogs and forums. Instead of retrieving full-text analysis results on a set of web pages, people are rather interested in the relationship between topics of interest and geographic locations in the web pages. There has already been an existing implementation, BlogScope (http://www.blogscope.net/), available on the World Wide Web. It analyzes and visualizes the popularity of a key term with respect to time and geographical location. It presents search results in a bar chart that users can easily view the intensity of topic popularity against time, as well as intensity with respect to different geographical locations of bloggers. Google Analytics (2007) is another powerful implementation for web site owners to see how visitors actually interact with the web site. It presents graphically where the visitors actually are from. This feature helps marketers provide some localized and optimize marketing strategies for potential market development in a particular geographic area.

Web traffic analysis tools give the latest information on the physical location of potential customers. Sales can be forecasted more accurately based on geographical information. Particularly, instant actions are needed when a competitor launches a marketing campaign in a region. For instance, customer loyalty of fast-moving consumer goods is low (McDonald et. al, 2001). Competitors can take advantages easily by marketing campaigns targeted on the potential customers. It is always too late to locate where potential customers accurately until a marketing research is completed.

Technically, it is possible to trace the geographical location of web sites through its IP address location by protocols such as "whois". There is a severe problem in analyzing geographical source of an Internet user by IP address. IP address analysis only shows the country where the IP address is registered by not where the user actually comes from. Recalling that consumers discuss any topics regardless of location of happening in the Internet, geographic source of IP address is not meaningful as it is not sufficient to understand the strength of perceptions from consumers in the geographic area registered with the IP address. The human semantic meaning of the web site context is much more useful instead.

User Behavior Analysis in Web Searching

Understanding what search engines are popular and people's behavior in retrieving information from search engines can help reducing information marketers need for analysis. A survey conducted in 2005 revealed that the top three search engines that customers would use as their primary search engines were Google, Yahoo and MSN (Abu-Shalback Zid, 2005). Google, Yahoo and MSN even provide user friendly toolbars that can be embedded in the desktop environment. Toolbar allows direct search from the Internet browser without retrieving the search engine's homepage.

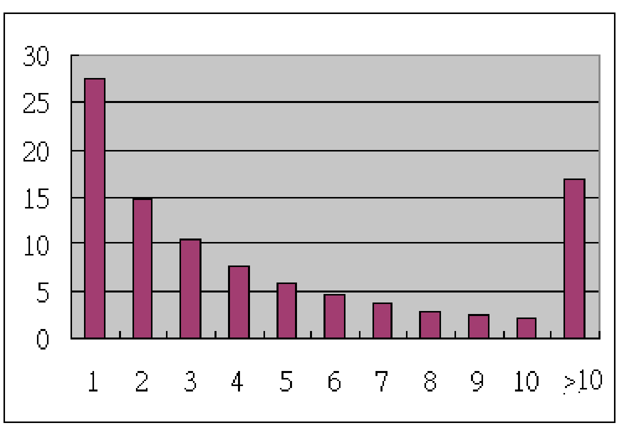
Most of us have used search engines. Very often, a long list of relevant web pages is produced with descending order of relevancy. We always start at the beginning of the list and seldom browse until the last item in the list. Splink & Jansen (2004) have analyzed click-through activities of web users to investigate the effect of search result ranking and user's browsing activities. The results of people's browsing behavior were obtained in Figure 1.

Impact of ranking in search engine result is significant in user's browsing behavior. It can be seen that the effect of ranking is logarithmic in the analysis. The top rank web page always gets the highest attention from users. Web pages outside top ten catch little attention that the browse rate of all pages outside top ten is smaller than that of the top one.

Search Engine and Marketing Research

Marketers make use of search engine in two ways. First, search engines enable consumers to interact with marketers. Through advertising in search engines, we increase the chance for potential customers to reach a product's web site; by optimizing keywords in web page for search engines, we improve the rank listing in search results so that more people are willing to browse a product's web site. The second way of interaction is reversed. Marketers get access to consumers' voices and feedbacks through search engines. A very straightforward way to evaluate a product is searching for the product name in search engines. If the web site or brand is returned in the search listings, it means customers can retrieve it as well. Further, marketers can specify to search discussion forums and blogs to retrieve consumers' WOM. Similar procedures can be used to retrieve

Figure 1. People's browsing behavior vs. search result rank



the latest information on competitors' products. Search engines provide no extra information to the marketers if it is simply used under this way. A proper model with data mining applications (Thelen et al., 2004) such as competitor analysis, geographical analysis and metric for information consistency from the search listings, aids to digest the massive data and extract valuable marketing information from the search results.

RESEARCH PROBLEM IN SEARCH ENGINE MARKETING

Search engines play a dominant role in controlling what information people can access. People perceive information through search engines. They have a great impact on people's preference over which piece of information to access by its search result ranking. Different search engines provide different search results even for the same web site. Comparison between the impacts of the same information source retrieved from different search engines is always difficult due to the variance in ranking. It is always difficult to determine "importance" of a piece of information using quantitative metric.

Search engines only bridge up people and information. Information can be both facts and rumors. In the reality, it is impossible for people to validate every piece of information source over the Internet. Therefore, it would be more valuable to know what information people perceive from the Internet. Analyzing search results from multiple search engines allow marketers to learn what actually people perceive on the product especially with respect to different geographical locations.

In our approach, a Perceived Index (PI) is defined to compare the strength of different voices of a particular issue with respect to different geographic locations, different search engines and different time intervals with respect to different topics of interest. It produces a quantitative index on intensity of people's perceptions by analyzing search results from multiple search engines.

Approach in Measuring Information Perception

It is difficult to measure the impact of Internet information on people with respect to different geographical locations. First, analysis on source of geographical locations should be lexical instead of solely relying on the IP address source of web traffic. To achieve this goal, a set of corpus containing different levels of geographical locations should be installed for analysis. Often, high level of localization is needed in the corpus, which requires high precision and is always time consuming.

Second, the search ranking supplied by a search engine plays a critical role on influencing people's browsing behavior and information perception. Different search engines present different search results to people, and people's browsing activities are further influenced by the rank supplied by respective search engines. The impact of search ranking should be taken into account when we measure the effect on information perception.

Impact of Search Engine on Information Perception

Recalling Spink & Jansen's (2004) findings in Figure 1, it was proved that search ranking dominates people's web browsing behavior. Using the data on click-through activities by Splink & Jansen (2004) again, a regression analysis was performed on the first ten pages retrieved by the search engine. Table 1 shows the variables click-through activities and rank listing further processed with a natural logarithm.

Linear regression analysis was performed with *ln(p)* and *ln(r)*. Regression analysis shows a linear pattern between *ln(p)* and *ln(r)* such that *ln(p)* =

3.465 – 1.123ln(r) with high significance ($R^2 = 0.985$ *and p-value* = *0.000*). It implies that search rank and percentage of web browsing activities are in a non-linear relationship. The percentage of browsing activities decreases logarithmically when the rank decreases. It was found that the top ten pages retrieved by search engines already accounted for 82% of total web browsing activities. The impact of remaining pages is, therefore, trivial enough to be neglected.

Semantic Geographical Content Analysis

Analysis of geographical locations is a complex issue. Occurrence of a geographical location does not simply mean appearance of the exact wording. Higher level of geographical location contains a set of many lower level geographical locations. Take an example of a country-level location “China”. China has many provinces and special administrative regions. The set of descendent geographical locations under China may include Guangdong, Guangxi, Hong Kong, which are provinces and special administrative regions. Hong Kong also has a set of descendent geographical locations such as “Kowloon” and “New Territories”. If semantic content is to be analyzed with province-level of geographical locations, appearance of “Kowloon” must be counted towards “Hong Kong”. Technically, a corpus with a set of different levels of nodes containing geographical locations is installed in the system. Each node should contain the geographical location and its parent geographical location. In the above example, “Kowloon” is a level 3 node pointing to its level 2 parent “Hong Kong”. “Hong Kong” is a level 2 node pointing to its level 1 parent “China”. Depending on the precision required, we may analyze up to the country level or the provincial level, or even the city level. If we analyze the provincial level of geographical locations, “Kowloon” is to be counted as “Hong Kong” by the system automatically. This automatic conversion is vital in our system otherwise much statistical data on geographical locations would be lost if descendent geographical locations are discarded.

In terms of computer data structures, geographical locations are represented in different level of nodes in a tree. The top-level node represents the whole world. Second-level nodes represent different countries under the world. Third-level nodes represent administrative regions such as states, and provinces. Fourth-level nodes represent cities. It is possible to customize the

Table 1. Data on click-through analysis by Splink & Jansen (2004) further processed with a natural logarithm

Rank (r)	Percentage (p %)	ln(p)	ln(r)
1	27.6	3.317816	0.000000
2	14.9	2.701361	0.693147
3	10.2	2.322388	1.098612
4	7.6	2.028148	1.386294
5	5.8	1.757858	1.609438
6	4.6	1.526056	1.791759
7	3.7	1.308333	1.945910
8	2.9	1.064711	2.079442
9	2.5	0.916291	2.197225
10	2.1	0.741937	2.302585

whole tree by further adding lower-level nodes to represent different parts of a city. Depending on the level of geographical locations to be analyzed, more levels can be added to improve granularity. A pre-defined set of geographical locations with a respective level of its nodes is stored statically in the system so that the corresponding upper-level node is traversed automatically by the system.

The algorithm we adopted is based on depth-first search (BFS) with a hierarchy of regions. We begin at the root node and transverse all the neighboring nodes and then the unexplored neighbor nodes and so on until it finds the goal. Figure 2 shows the generic tree structure containing different levels of nodes in the adopted search algorithm.

A node always has a significant impact on its parent, or even the neighboring higher-level node (siblings). The influences by neighboring regions can be imagined easily using real-life examples. Asian stock markets are always influenced by neighboring stock markets. In China, Hong Kong (a special administrative region residing on a third-level node) and Shenzhen (a city under Guangdong province residing on a fourth-level node) stock markets can impact all of China, and even Japan (a sibling note residing on the same level as China). Figure 3 shows the partial tree structure of China, Japan, and Thailand.

The algorithm analyses the occurrence of keywords in a page retrieved by the search engine. Depending on the level of information needed (country, province or city), customization is needed. Note that descendents keywords (i.e. nodes under a parent node) count as a parent. Given a sentence on a webpage as "Hong Kong, Shenzhen and other major cities in stock markets have potential impact on the Pan China, and even Japan economy", the system will count China as 1 and Japan as 1 at the country level (level 1), even though China appears twice and both Hong Kong and Shenzhen are part of China.

Impact of Time on Information Perception

Web pages updates at all times. Search result ranking is updated continuously as well. Information

Figure 2. A generic tree structure

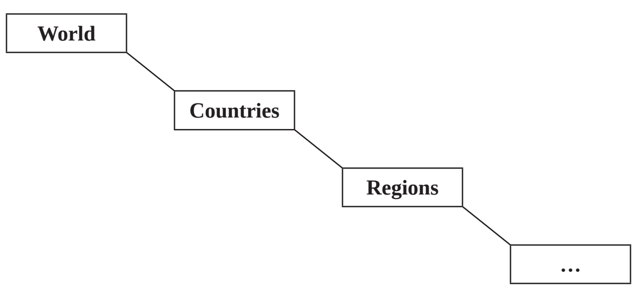
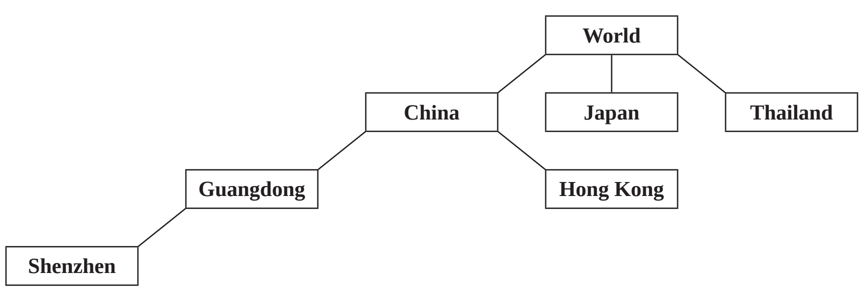


Figure 3. Partial tree structure showing China (4 levels), Japan and Thailand (2 levels)



perceived by people in different countries retrieved at a certain time interval is not identical to that retrieved at different time intervals especially on hot topics. It is because information perception relates to search ranking and geographical location analysis that is refreshed from time to time. An example of search ranking using the same search engine, Google, between two different topics, NASDAQ and AIDS, on six time intervals are recorded and presented in Figure 4 and Figure 5 respectively. The results were obtained at 6 identical consecutive 3-hour intervals between 12 February and 13 February 2008. Content analysis on geographical locations was performed on six regions to analysis the intensity of people's voice over the topics using our algorithm.

The fluctuation of voice over NASDAQ is much higher than that of AIDS. It is because NASDAQ is changing rapidly daily. On the contrary, AIDS is a rather a static issue over the world.

Figure 4. Change of perceived information on NASDAQ with respect to 6 countries recorded on 6 time intervals from 12 February 2008 to 13 February 2008

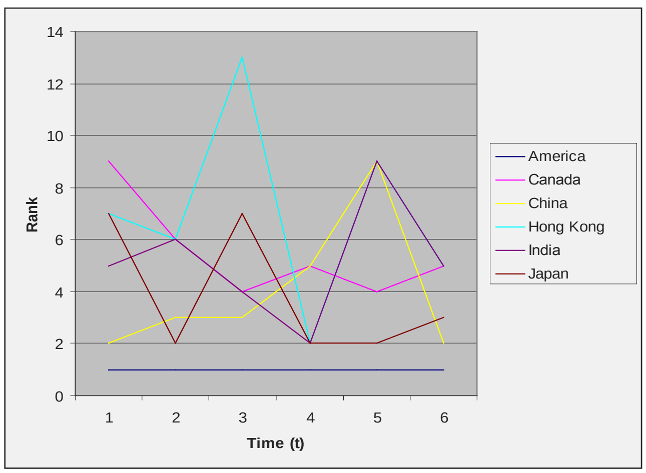
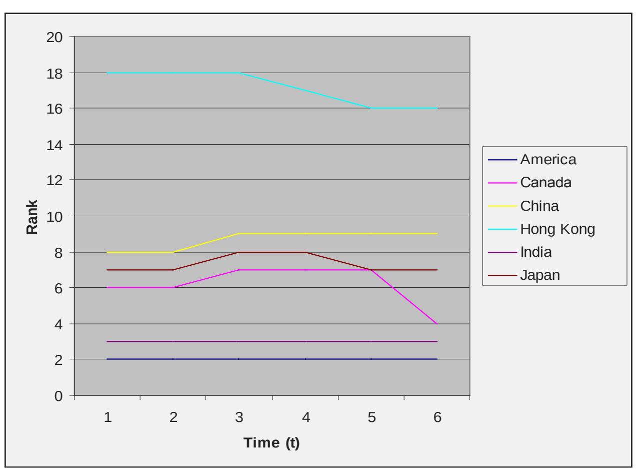


Figure 5. Change of perceived information on AIDS with respect to 6 countries recorded on 6 time intervals on 12 February 2008 to 13 February 2008



Obviously, time is an important element to include in information perception analysis. As seen in the figure, people's voice even changes rapidly in a 3-hour interval. Using the traditional way of web semantic analysis would not be able to produce valuable information to marketers. Once the analysis is ready, it has already been outdated.

MATHEMATICAL REPRESENTATION FOR PERCEIVED INFORMATION

Having all the parameters influencing Perceived Information, we can mathematically formulate Perceived Index on Information (PI) as

$$PI(s_i, g_j, t_k) = \ln(r) \times \ln(100 - p)$$

where s, g, t, r and p represent search engine, geographical location, time, rank and percentage respectively. If we explain how we measure perceived information by text, we can explain it as "Intensity of what people perceive on the specific topic on a region, using a specific search engine, and at the specific time, is given by the product of the natural logarithm of its rank and browse rate."

There are also some observations on PI that helps understanding the word of mouth effectively. A geographical location always has its PI equals to 0 when it is of the highest rank (1).Similarly, the smaller value PI is; the more popular the topic is in the location.

Visualizing PI with a Map

Presenting a list full of numerical PI value is of little value to marketers. Instead of a precise numerical value, it is more meaningful to present people's voice intensity over a large region with respect to specific topics of interest. A prototype, named Geogle, was developed by the authors to produce visual results of this implementation customized for China. It is available for public access on http://geogle.comp.polyu.edu.hk/. Technically, it interacts with different search engines through their APIs to retrieve search results associated with a topic of interest supplied by the user. Web contents in the top 10 are being traversed sequentially by fetching the web pages from the web in real-time basis. The contents on geographical locations are being analyzed lexically and processed with a weighting with its search rank. Afterwards, the PIs of different regions are obtained and presented on the map visually.

Figure 6 shows visualization of the intensity of people's information perceived on AIDS with respect to different provinces in China.

In this example, the topic AIDS was analyzed with respect to different provinces in China. Instead of giving mathematical representations with respect to different geographic locations, the system generates the correlation with different colors representing the popularity. According to our implementation, people in Henan and Yunnan have a relatively stronger voice on AIDS. It is not surprised to have this finding because Henan and Yunnan are the two major sources of confirmed AIDS cases in China. Although people throughout China are talking about AIDS cases, Geo-and-gle can still easily identify the actual geographical source of AIDS cases through its semantic search algorithm.

We have also performed another search in Geo-and-gle with the keyword "Olympic Games". Figure 7 presents the analysis with respect to different parts of China. We can see that Beijing, the host city of Beijing Olympics 2008, has the highest correlation with Olympic Games as reported by the system.

APPLICATION OF PI AND GEO-AND-GLE

Theoretically, PI gives a measure to intensity of people's voice with respect to different geographi-

Figure 6. AIDS's intensity in China presented by Geo-and-gle

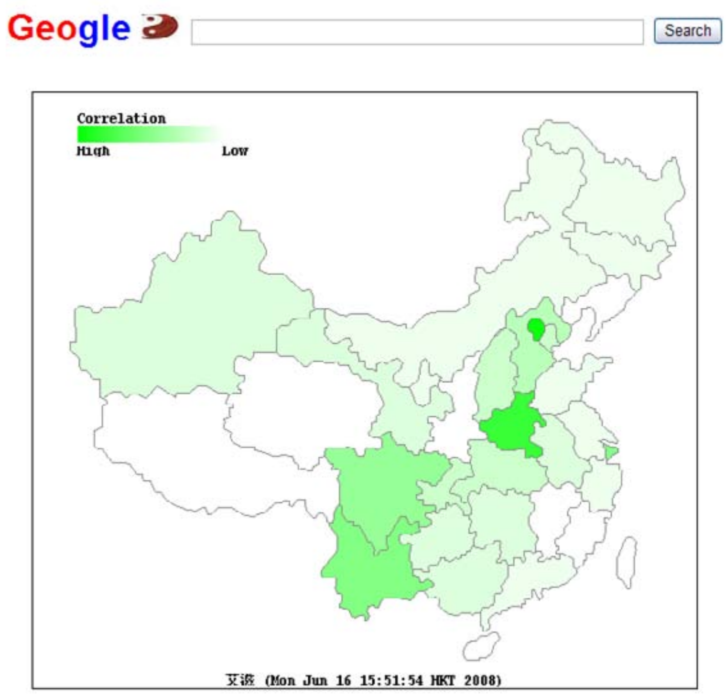


Figure 7. Olympic games presented by Geo-and-gle

cal locations on the Internet at a specific time. Voice refers to topics or incidents that the local community is interested in. Voice, however, does not give any perception on whether the incident gives positive or negative perception to people. Intensity of people's perceived information changes with respect to time and the channel (i.e. search engine) used for information search.

Practically, by analyzing quantitatively the perceived information with respect to geographical locations, we can have an objective metric to easily determine popularity of the topic among people in the region. We can also compare the popularity of topic easily with respect to different locations and different time. In terms of marketing, it let marketers identify the fluctuation of WOM in different time intervals, as well as in different locations. Based on the analysis, marketers are able to form different strategies. For example, marketers can launch aggressive strategies to beat competitors directly, or to open new markets that are without the dominance of potential competitors.

Worldwide Competitor Analysis Using PI

A start-up company needs marketing data before launching its new product. It is impossible to retrieve sensitive business data, such as sales figures and profit, of a competitor. Large scale worldwide marketing research is too costly to a small firm, and it takes too long time to complete. However, it is possible to estimate competitors' dominance in different regions by extracting its WOM in different places. The Internet is a good resource to marketers as it is too easy to retrieve customers' voice in the web, especially in blogs and discussion forums through search engines.

A local Chinese beverage manufacturer has been planning to promote its products to the overseas market. Our system is used to obtain the voices of its major competitors, Coca Cola and Pepsi on the Web with respect to different countries.

In December 2007, data on Coca-Cola and Pepsi were retrieved. PI of different countries with respect to Coca-Cola has been evaluated and further summarized in descending order with respect to different countries. Table 2 shows the intensity of people's voice over Coca-Cola with respect to different potential markets as analyzed by our system. Table 3 shows similar country analysis of Pepsi at the same time.

Full analysis on PI of different countries with respect to Coca-Cola and Pepsi is included in Appendix I and Appendix II respectively.

Upon analysis, two opposite marketing strategies are aggressive direct competition and new marking opening in non-dominated countries. The following conclusions on geographical dominance and corresponding marketing strategies can be drawn:

Geographical Dominance

Coca-Cola dominates the drinks market in America (PI=0), Mexico (PI=8.91) and India (PI=11.44). The dominance is proved by the significant difference with average PI on Coca-Cola (PI=24.04). On the other hand, Pepsi dominates the drinks market in America (PI=0), India (PI=7.31) and Africa (PI=8.25). The dominance is proved by the significant difference with average PI on Pepsi (PI=21.96). This can be explained by the heavy promotion of Coca-Cola and Pepsi in the respective countries.

Corresponding Marketing Strategies

PI values give hints on finding the right countries for product promotion. The most aggressive marketing strategy is to launch a direct competition on countries that are heavily dominated by Coca-Cola and Pepsi. Countries with low PI values (PI<15.00) are classified as heavy dominated markets in this case. For instance, a direct

Table 2. Summary on Coca Cola's voice ranking in different countries on 27 December 2007 (Average PI =24.04)

Rank	Google	Yahoo	MSN	Ask
1	America	America	America	America
2	India	Mexico	Mexico	Russia
3	Mexico	India	India	Africa
4	Canada	Canada	Canada	Mexico
5	UK	France	France	Canada
6	Africa	Japan	Japan	France
7	Australia	Australia	Australia	UK
8	France	Germany	Germany	India
9	Germany	New Zealand	New Zealand	Japan
10	Japan	China	China	China

Table 3. Summary on Pepsi's voice ranking in different countries on 27 December 2007 (Average PI=21.96)

Rank	Google	Yahoo	MSN	Ask
1	America	America	America	America
2	India	India	India	Canada
3	Africa	Africa	Africa	India
4	Canada	Japan	Japan	Africa
5	Japan	Russia	Russia	Japan
6	Russia	Canada	Canada	China
7	Australia	Brazil	Brazil	Russia
8	Brazil	China	China	Mexico
9	Italy	South Korea	South Korea	Brazil
10	UK	Finland	Finland	South Korea

competition may be launched in Africa, America, Canada, France, Japan, India and Mexico against Coca-Cola and Pepsi through extensively heavy advertising campaign.

A less aggressive approach in marketing is opening up new markets that existing competitors do not have dominance. The higher PI value a country has, the more popular that product is in the country. The data above may help to form marketing strategies so to help the drink manufacturer to avoid markets that Coca Cola or Pepsi dominates. For instance, countries with PI values greater than the overall PI value might be good new market for promotion to avoid direct competition with Coca Cola and Pepsi. A good example of such new markets is the Middle East countries, which often have high PI values (PI>30).

In conclusion, the pilot company decided to promote their products in Middle East countries first to avoid risky direct competition with the beverage giants.

Local Market Analysis Using Geo-and-gle

Domestic market, apart from the international market, is also important to a new entrant of business. Local marketers should be able to understand the domestic market deeper, and certainly can do business in the local way. In a large country, like China and Russia, cities are far apart geographically. Different region may even have different cultures. International competitors remain dominant in some parts of the country, but there are still some areas that are less dominant by the giants.

Geo-and-gle's generic BFS algorithm can be localized easily. Instead of using second-level nodes consisting of country names for searching and analysis, third-level nodes consisting of provinces (such as Guangdong, Tibet, Hebei), direct-controlled municipalities (such as Beijing, Shanghai) and special administrative regions (Hong Kong, Macau) are being analyzed as the set of geographical locations.

PI value with respect to different geographical locations does not give much meaningful information. Plotting PI value using different color intensities visualizes the perceived information. Integrating with a geographical map, we can easily see the distribution of perceived information regarding to different regions.

Figure 8 shows people's perceptions on Coca Cola in China, while Figure 9 shows that of Pepsi in China. It is clear from the figures that Coca Cola and Pepsi target on different provinces in China. People's perception on Pepsi is stronger in the Eastern part of China, while Coca Cola's focus is on inner as well as Southeastern China.

We can see clearly from the figures that the central and northwestern regions are not dominated by the beverage giants. As a kick-start for domestic beverage manufacturers, it is wise to avoid direct competitions in regions dominated by Coca Cola and Pepsi. The map also helps new entrants to further avoid neighboring regions of dominance as it is risky that beverage giants can enter those regions with less effort.

Figure 8. PI analysis of Coca Cola in China

Figure 9. PI analysis of Pepsi in China

FUTURE WORK

Assume that as the information will grow and change, we may develop some opinion index similar to traditional option index such as Consumer Sentiment Index. In this case, the work can be to formulate another set of index which is used to confirm those opinion indexes.

CONCLUSION

Relationship between information and people is a two-way interaction. People rely on information to make decision; they also contribute information to other people when they have made a decision. Eventually, different communities are formed to facilitate information exchange. In the Internet, social computing technologies enable information to be constructed, shared, collaborated and diffused easily and rapidly.

Search engine plays an important role in linking people with information. People retrieve topics of interest using search engines. Often, consumers make use of search engines to search for WOM before deciding on what product to purchase. Afterwards, they share their consumer experiences online and become new source of WOM. Marketers also make use of search engines to retrieve consumers' perceptions with respect to their products, as well as what their competitors are doing. As both consumers and marketers rely on search engines to retrieve information on the Internet, the search result, and particularly the rank, is influential to what information people will perceive.

Identifying what people are talking on a region, especially the importance of information people perceive, is a difficult task. It is impossible to analyze every web page on the Web due to the huge content and highly dynamic nature. Instead of analyzing all semantic content on the whole web, people are rather more interested in strength of perceptions by people over different geographical locations.

A quantitative metric, known as the Perceived Index on Information (PI), on discovering associations between topics of interest and geographic semantic information over the Web is proposed to solve the problem. PI can be used in country analysis, as well as customized in domestic analysis using the same generic algorithm. Information diffusion on the virtual communities initiated by search engines can be presented easily with a quantitative metric. Practically, people's perceptions (source of information) and geographic semantics (source of happening) are linked together for decision support.

A visual tool to present relationship of PI and geographical locations, Geo-and-gle, was implemented. It was found that our proposed metric provides fast and reliable information to support marketing decisions. We conclude that information flows in different social networks on the internet can be understood in a quantitative way, which provides an efficient way for decision making.

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KEY TERMS AND DEFINITIONS

Information Consistency: Degree of similarity between perceived information.

Perceived Information: Web content, no matter facts or rumors, that is retrieved by a user from a search engine by querying a set of keywords.

Search Engine: A World Wide Web page that accepts a set of keywords as query and returns web pages that matches to the indexes with ranking.

Social Computing: Web services that facilitate collaborative efforts from users.

Source of Distribution: The physical location where people voice out, or discuss, about a particular event happens. Source of distribution may be, or may not be, the same as source of information.

Source of Information: The physical geographical location where a particular event happens initially.

Word of Mouth: User experience, both positive and negative, that is diffused in an informal way.

APPENDIX I: ANALYSIS OF COCA COLA ON 27 DECEMBER 2007

Keyword (g)	Google PI	Yahoo PI	MSN PI	Ask PI	Mean	Standard Deviation
Africa	16.502	28.87866	22.08495	10.11749	19.39577477	7.99202
America	0	0	0	0	0	0
Australia	16.502	17.92191	16.50218	22.88634	18.45310616	3.030328
Belgium	26.62102	26.09458	22.08495	22.08471	24.22131468	2.476342
Brazil	22.88634	22.08495	22.08495	24.30609	22.84058286	1.047498
Canada	12.76741	12.76755	12.76755	14.82283	13.28133429	1.027662
China	24.94179	17.92191	16.50218	21.2069	20.14319569	3.757177
Denmark	28.04109	28.87866	27.59141	28.87897	28.34753165	0.640349
Finland	29.27096	28.87866	27.59141	28.87897	28.65499904	0.732758
France	16.502	14.82267	12.76755	14.82283	14.72876012	1.52844
Germany	20.23653	17.92191	16.50218	22.88634	19.38673847	2.794981
Greece	29.27096	31.92061	31.01394	28.87897	30.27111862	1.438865
Hong Kong	26.62102	22.08495	22.08495	24.30609	23.77425277	2.167518
India	6.383359	10.11771	10.11793	19.15174	11.44268666	5.43252
Iran	29.27096	28.87866	27.59141	28.87897	28.65499904	0.732758
Iraq	31.62819	31.92061	31.01394	32.47898	31.76042993	0.610111
Israel	23.62354	24.94152	22.08495	28.04109	24.67277649	2.530841
Italy	24.94179	27.59141	27.59141	26.09458	26.55479945	1.286175
Japan	20.23653	16.502	16.50218	19.15174	18.09811053	1.895393
Malaysia	28.04109	22.08495	22.08495	28.04109	25.06301997	3.438777
Mexico	10.11782	6.383428	6.383428	12.76741	8.913022662	3.114779
Netherlands	23.62354	26.09458	22.08495	26.09458	24.47441185	1.973437
New Zealand	20.23653	17.92191	16.50218	27.59141	20.5630073	4.931897
North Korea	31.62819	31.92061	31.01394	31.32619	31.47223114	0.390181
Norway	29.27096	28.87866	27.59141	26.09458	27.95890078	1.43506
Pakistan	31.62819	31.92061	31.01394	33.00543	31.89204204	0.832892
Portugal	31.62819	31.92061	31.01394	33.50341	32.01653642	1.060817
Russia	26.09458	28.87866	27.59141	6.383359	22.23700105	10.63015
Saudi Arabia	31.62819	31.92061	31.01394	33.25778	31.95513051	0.94707
Singapore	29.27096	27.59141	27.59141	28.87897	28.33318877	0.871349
South Korea	29.27096	31.32619	31.01394	31.62819	30.80981869	1.056114
Spain	26.62102	22.08495	22.08495	24.30609	23.77425277	2.167518
Syria	31.62819	31.92061	31.01394	32.74597	31.8271762	0.719688
Taiwan	28.04109	27.59141	27.59141	28.87897	28.02572138	0.607046
Thailand	31.62819	26.09458	31.01394	32.20402	30.23518309	2.80285
Turkey	29.27096	28.87866	27.59141	28.87897	28.65499904	0.732758
UK	14.82267	24.94152	22.08495	14.82283	19.1679919	5.151201
Vietnam	31.62819	31.32619	31.01394	31.92061	31.47223114	0.390181
Mean	24.27176	24.2055	23.20458	24.47904	**Overall PI(g)**	24.04022
Standard Deviation	7.772232	7.83831	7.762488	8.025609		

APPENDIX II: ANALYSIS OF COCA COLA ON 27 DECEMBER 2007

Keyword (g)	Google PI	Yahoo PI	MSN PI	Ask PI	Mean	Standard Deviation
America	0	0	0	0	0	0
India	6.383705	6.38322	6.38322	10.11771	7.316964722	1.867166
Africa	6.383705	10.11738	6.38322	10.11771	8.25050577	2.155876
Canada	6.383705	16.502	16.50236	6.38322	11.44281979	5.842042
Japan	14.82251	12.76727	12.76713	14.82267	13.79489418	1.186676
Russia	16.50182	14.82267	14.82251	17.92172	16.01717646	1.496245
Brazil	19.15195	17.92211	16.50236	20.23697	18.45334418	1.608097
China	27.11899	17.92211	16.50236	14.82267	19.09152964	5.499536
South Korea	27.11899	17.92211	16.50236	20.23697	20.44510475	4.707967
Finland	27.11899	21.20736	16.50236	20.23697	21.2664189	4.397429
Pakistan	27.11899	21.20736	16.50236	20.23697	21.2664189	4.397429
Saudi Arabia	27.11899	21.20736	16.50236	20.23697	21.2664189	4.397429
Mexico	22.08519	24.94206	23.62406	17.92172	22.14325721	3.046904
Australia	17.92191	24.94206	23.62406	24.30662	22.69866198	3.229658
Italy	19.15195	24.94206	23.62406	24.30662	23.00617136	2.62524
France	22.08519	24.30662	23.62406	24.30662	23.58062025	1.04759
Germany	22.08519	24.94206	23.62406	24.30662	23.7394822	1.227171
Hong Kong	22.08519	24.94206	23.62406	24.30662	23.7394822	1.227171
New Zealand	22.08519	24.94206	23.62406	24.30662	23.7394822	1.227171
Spain	22.08519	24.94206	23.62406	24.30662	23.7394822	1.227171
Taiwan	22.08519	24.94206	23.62406	24.30662	23.7394822	1.227171
Thailand	29.27096	21.20736	23.62406	24.30662	24.60224814	3.38459
UK	21.20713	30.00818	23.62406	24.30662	24.78649571	3.726453
Netherlands	22.08519	30.00818	23.62406	24.30662	25.0060107	3.461782
Malaysia	29.27096	24.94206	23.62406	24.30662	25.53592362	2.54752
Singapore	29.27096	24.94206	23.62406	24.30662	25.53592362	2.54752
Vietnam	29.27096	24.94206	23.62406	24.30662	25.53592362	2.54752
Belgium	29.27096	30.00818	23.62406	24.30662	26.80245212	3.301595
Denmark	29.27096	30.00818	23.62406	24.30662	26.80245212	3.301595
Greece	29.27096	30.00818	23.62406	24.30662	26.80245212	3.301595
Iran	29.27096	30.00818	23.62406	24.30662	26.80245212	3.301595
Iraq	29.27096	30.00818	23.62406	24.30662	26.80245212	3.301595
Israel	29.27096	30.00818	23.62406	24.30662	26.80245212	3.301595
North Korea	29.27096	30.00818	23.62406	24.30662	26.80245212	3.301595
Norway	29.27096	30.00818	23.62406	24.30662	26.80245212	3.301595
Portugal	29.27096	30.00818	23.62406	24.30662	26.80245212	3.301595
Syria	29.27096	30.00818	23.62406	24.30662	26.80245212	3.301595
Turkey	29.27096	30.00818	23.62406	24.30662	26.80245212	3.301595
Mean	23.13814	23.36747	20.26574	21.07783	**Overall PI**	21.9623
Standard Deviation	7.720964	7.26272	5.868799	5.842049		

Chapter IX
Visualization in Support of Social Networking on the Web

J. Leng
Visual Conclusions, UK

Wes Sharrock
University of Manchester, UK

ABSTRACT

In this chapter the authors explore the contribution visualization can make to the new interfaces of the Semantic Web in terms of the quality of presentation of content. In doing this they discuss some of the underlying technologies enabling the Web and the social forces that are driving the further development of user-manipulable interfaces.

INTRODUCTION

The internet is a communication device. Its interface consists not just of static text but other static and dynamic constructs e.g., tables, images, animations and customised web applications. Some of these elements hold meaningful content while others are used for graphic reasons[1]. The rise of social networking in the form of Weblogs, discussion boards, wikis, and networking sites allows the general public to share content on the web. Such non-technical users require high level web-apps to help design and deliver their content with as little explicit dependence on the technicalities as possible.

Before talking about social networking on the web it is worth considering what this means. The expression ‘Social Networking Sites’ is used for sites with the primary purpose of supporting or creating sociable relationships, prominently friendships, but we use ‘social networking’ in a more inclusive way to include the formation of all kinds of networks such as those, for example, that form to collaborate on a task (as with an open source development).

The naming conventions used within visualization can confuse, this relates to the difficulty in producing a visualization taxonomy which is discussed later. Visualization is a visual means to analyse data and is cross-disciplinary. The name of the discipline normally identifies a particular theme but where the name of the discipline is also the name of a technique the naming convention lacks clarity. For example social networking visualization could be the use of visual methods to show and analyse social networks or could be the use of visualizations in the support of social networking i.e., as a means to help people form and co-ordinate their activities. This chapter looks at the latter, at how visualization can aid communication on the web. Whilst this can include the visualization of social networks (because users of the web may like to understand the social networks they participate in) that is not the primary focus.

In this chapter we introduce visualization, its history and the two main visual paradigms in use, dividing the visualization community between those concentrating on scientific and information visualizations respectively. We survey the technologies that shape the web and the applications running on it. This allows us to look at how the technology shapes visualization systems (the visualization pipeline and the flow of data) and how these can be distributed to work efficiently in web environments. Finally we review some web applications that support social networking and consider what future trends may be.

WHAT IS VISUALIZATION?

The History of Visualization

There is no accepted definition of visualization but it can be adequately summarized for our purposes as using visual means to aid the communication and understanding of information. Modern visualization increasingly uses computer graphics technology to make information accessible. Visualization's long history predates the origin of computers by at least 8 thousand years. Maps are one of the oldest forms of graphical aid whose continued usefulness is demonstrated by the fact that mapping applications are amongst the most popular web-based applications. Before computers visualizations generally were not interactive, though there are exceptions to this as some scientists developed models and pop ups in books to explain their ideas but these were rare and expensive (Tufte, 1997; Tufte, 2001).

The roots of visualization are tangled into our history; a timeline of visualization is available on the internet (Friendly, 2008). Many historical breakthroughs were made possible through visualization, such as John Snow's use (in London in 1854), of maps to show the distribution of deaths from cholera in relation to the location of public water pumps. Visualization has never been an isolated discipline; it has been an integral element of scientific, intellectual and technical developments.

The timeline of visualization shows that the development of visualization has accelerated since 1975, since when important changes have depended upon advances in computing. Improved computer speed and capacity increasingly allow data to be visualized by increasingly intensive computational methods. Computers make visualizations more interactive and allow direct manipulation of data, e.g. selecting data by linking, brushing or using animation in grand tours. Also driving the development of visualization is the fact that visualization methods are being applied to and developed for an ever-expanding array of problem areas and data structures, including web applications that enable social networking.

Modern Visualization

Modern computer-based visualization developed through the accumulation of three specific areas (Schroeder, 1997). Scientific visualization was the first. It is a discipline stemming from computational science and started as an IT support activity. Computational simulations produced digital data representing natural phenomena, for example the weather forecast. Commonly the data has an inherent geometrical shape and the data represents continuous fields within this geometry. The data were produced as large arrays of values that were difficult to analyse by hand or eye. Instead, computers were used to produce images of the data within its native geometrical shape.

'Scientific visualization' is typically categorised by the dimensionality of the data values (number of dependant variables), and whether the data is scalar, vector, tensor, or multivariate (Brodlie, 1992; Schroeder, 1997). However another taxonomy distinguishes by technique between global, geometric and feature-based techniques (Post, 1999).

Subsequently, it was realised that techniques for scientific visualization could be applied to data from the humanities and social sciences. Since this data commonly looks at geographical distributions of populations this field focuses on statistical graphs and thematic cartography. Gradually, the field of data visualization diverged further and information visualization, the final area of visualization, emerged. This field was primarily aimed at visualizing computerised databases so that relationships could be found; commonly using tables, graphs and maps. Currently visual display and analysis of text in the form of academic papers, web pages, and patient records, are included in information visualization. 'Information visualization' can also be classified by data type, common types being multi-dimensional databases (with more than 3 dimensions), text, graphs and trees (Bohm, 2001; Schneiderman, 1996). Similar to scientific visualization, a technique classification system is based upon display styles which include table, or information landscape (Card, 1997; Chi, 2000). However unlike scientific visualization some classifications also look at tasks, for example gaining an overview or drilling down on detail (Schneiderman, 1996).

Over this period visualization has been transforming into an increasingly independent academic subject within the field of computer graphics and is commonly taught in computer science departments, and is divided between two main specialisms categorised as 'scientific visualization' (developing visualizations for purposes of aiding scientific research) and 'information visualization' (providing ways of communicating information generally e.g. in the design and presentation of charts, diagrams, graphs, tables, guides, instructions, directories and maps which can also be used to aid research whether scientific or not). However this division does not best reflect visualizations true nature, and there are attempts to improve on this classification. Tory (2004), complains that the division between scientific and information visualization encourages segregation of different kinds of activities from one another when many visualization problems cross that divide, proposing instead, a systematic scheme 'based on characteristics of models of the data rather than on characteristics of the data itself'. An easy-to-understand taxonomy would be useful to both users of visualization and researchers into visualization and if it existed it would have been presented here.

The application area of interest in this chapter falls mostly within the information visualization paradigm although map based visualization applications are also important but these techniques are on the border of the 2 paradigms drawing from both scientific and information visualization (Tory, 2004). However visual appearance is not the only theme in visualization research of importance to web 2.0. Visualization system design and the distribution of that system are relevant research themes. The web is a distributed computing environment, with users also distributed and if they are to work together then synchronization of their activities must be facilitated by the visualization system. These themes were originally titled 'remote visualization' and 'collaborative visualization', growing out of scientific visualization. To understand the underlying technology and social forces driving the development of the web it is necessary to understand the position of and the relationship between the information visualization and scientific visualization communities.

A Survey of Information Visualization Techniques

There are hundreds of techniques with thousands of low level elements that could be considered. This chapter is too short to take on this task so we aim to give the reader an idea of where to look for further information and an overview of a few relevant techniques. Many information visualization techniques rely on the use of colour, animation and interactive input from the user but in this book only static grayscale images are possible so where possible we refer the reader to websites for examples.

Visualization is a young subject without a definitive text but the selection of papers, books and websites in the references section should provide a suitable starting point. Friendly's timeline of visualization (Friendly, 2008) presents an online timeline of visualization with static images for each entry in the timeline. This site is a good starting point for examples of visualization techniques developed before 2004. Images and demos of information visualization techniques are on the websites of commercial vendors of general purpose information visualization software (although demos are not always available and users may require registration). There are 5 stable information visualization companies known to the authors: AVS (Advanced Visual Systems) has OpenVis (AVS, 2008); Spotfire focuses on business information (Spotfire, 2008); Tableau is similar to Spotfire (Tableau 2008); Steema has TeeChart and TeeTree (Steema, 2008); and finally aiSee is designed for large data (aiSee 2008).

Some key techniques from information visualization are:

- **Graphs:** a 2D plot showing the relationship between parameters. Typically orthogonal axes show the values of the parameters represented in the plot. Harris (1999) illustrates all the visual elements of graphs, tables and other information plots and recent research is available in the Journal of Graph Algorithms and Applications (Tamassia & Tollis, 2008).
- **Trees and Networks:** nodes are connected by lines showing relationships between nodes. If the nodes represent people then the plot represents a social network. These plots can be difficult to understand if many nodes are used. Networks do not occupy a real geography but are optimized by complex mathematics to look good in a 2D display. In information visualization these are considered to be graphs. Freeman (2000) and Bertini (2008) survey the history and applications in this area, and two case studies of social network visualization applications are in Brandes (2001) and Shen (2008).
- **Multiple Related Views:** a number of 2D plots are viewed in one problem solving environment. If the plots are graphs then the plots tend to be arranged so that the horizontal or vertical axis that relate to the same parameter are aligned and a user selection made in one graph can be seen to relate across to the other plots. The next 4 techniques use multiple related views but relationships are made by different user interactions.
- **Drilling:** if the plots are geographical then they may represent different levels of detail of a region the user selects from the higher resolution plot.
- **Brushing:** if a user is interested in the geographic distribution of different age groups within the US then using the histogram and selecting (brushing) regions from the histogram this selection is displayed on a map.
- **Linking:** many elements are related so colour is used across multiple views to clearly identify each relationship.
- **Grand tours:** an animated tour is given through the data display space so that the user can get an overview of the data.

The Development of Visualization in Relation to Computer Technologies

The development of visualization is driven not only by the development of visualization techniques, but in response to the development of new computer technologies offering new possibilities for visual representation. Changes in computer hardware, graphics hardware, computer display devices, computer input devices, software design, collaborative working environments, remote visualization and visualization services all play an influential part in determining what can be visualized and how the user can manipulate it.

IN TRANSITION FROM WEB PAGES TO WEB APPLICATIONS

The Handbook is about the changes from Web 1.0 to Web 2.0, made possible by a mix of new technologies and approaches. The step changes in technology and user participation are not yet completed. We review the current state of the technology and how it might adapt to provide better graphical tools for the 'semantic web'.

From Static to Dynamic Web Pages

One of the main changes is the development of Content Management Systems (CMS) providing a web page delivery system that replaces static HTML web pages (North 2008). CMS separates two aspects of a web page, the content from the presentation. In CMS the content is separated from the web page as it no longer sits in an HTML file waiting for a user to access it, but is in a database so that the HTML page is dynamically reconstructed for the user when they select that web page.

The change from static to dynamic content has relied on these changes in technology:

1. **Static web pages:** the content and presentation are not only included in the same file but are mixed together throughout the text in the file
2. **Cascading Style Sheet (CSS) web pages:** the content and presentation are separated into separate text files. HTML (Hyper Text Markup Language) is the language encoding the information on a web page. It provides the information as text along with text that defines the style (presentation) of the informational text. The presentation information can be separated from the content information by the use of Cascading Style Sheets. Such CSS enable changes to the look and feel of a whole website through alterations to only one file, rather than requiring the individual rewriting of every page on the site.
3. **Dynamic web pages:** content and web pages are separated.

CMS are powerful because they separate out the responsibility for designing and developing a website from providing the content. CMS[3] build in tools to enable non-technical users to enter and manage their content (which is why CMS are popular for blogging sites). Many social networking websites give the user the option whether to produce their content as text or HTML, which contributes to the control that users now want over web content (manifested by the popularity of open source communities), giving them control over its style. There are in effect two interfaces to a website, one between the site and its non-technical users, the other between the site and those with technical competences. Site providers increasing encourage technically competent users to create and share service specific applications by releasing their API (Application Program Interface) and disseminating technical information which makes the addition of new modules easy.

HTML remains the underlying language that is recognized by web browsers so CMS must reconstruct HTML pages dynamically for the viewer. Even where web delivery technologies, e.g., wikis, have their own markup language or where websites allow plain text entry these inputs are still translated into HTML. Standardising interpretation of HTML across all browsers has taken considerable time and effort, improvements to HTML being coordinated between browser vendors by the World Wide Web Consortium (W3C). It would be too problematic to get the W3C to coordinate this effort and for browser developers to commit the resources for each brand of markup language, so wikis and comparable applications have developed their own markup with special functionality for their relevant formatting and semantic issues. Nonetheless, wiki applications have their own translator to convert that markup into more basic HTML components. HTML has limited functionality with regard to style, so the functionality that handles the graphical content and interactivity important to visualization is provided by supplementing HTML with other languages. These languages commonly provide applications (e.g., web-based games) or structural and navigational tools (e.g., menu systems) for a website. Depending on their specific functionality these languages can create applications that are stored in and served from a database in a CMS site, adding to the CMS functionality or providing style for a static web page. The main languages that contribute to visualization on the web were developed in the 1990's, including Java, JavaScript, VRML (Virtual Reality Modeling Language) and Flash.

The Java programming language was developed by Sun Microsystems (Gosling, 2005; Java Home Page, 2008; Wikipedia, 2008). It is an interpreted language meaning that a program written in Java can run on all the popular computer platforms without any adaption; "Write Once, Run Anywhere". Combined with its other features this makes it ideal for the web so web browsers quickly incorporated small Java programs (called applets) within web pages. Later Java was configured for particular platforms e.g. J2ME (Java 2 Micro Edition) for mobiles. Java Servlets, instead of being embedded in a web page as applets, are used to extend the functionality of the web server, allowing extra content to be added to web pages dynamically from the server. Whilst Applets and Servlets can be used to add important visual content to the web, Java is much more powerful for such a purpose as it has dedicated libraries that handle necessary functionality: the SWING library adds user interface functionality, the Drag and Drop library allows object manipulation by mouse, and the 2D and 3D libraries allow the graphics modeling of 2D and 3D objects.

JavaScript is a scripting language commonly used for client-side web development; the web browsers incorporate the ability to interpret JavaScript programs (W3 Schools, 2008; Wikipedia, 2008). JavaScript was designed to look like Java but has less functionality and is easier for non-programmers to work with. The primary purpose of JavaScript is to embed interactive functionality into web pages, typically to inspect or create content dynamically for that page. For example, a JavaScript may validate input values in a web form, control the opening of pop-up windows or change an image as the mouse passes over it. Because JavaScript code runs locally in a user's browser (rather than on a remote server), it can respond to user actions quickly, making an application feel more responsive. Furthermore, JavaScript code detects user actions which HTML cannot. JavaScript is heavily used in many web-based applications including CMS and those that support social networking through gmail and facebook.

VRML is a standard text file format similar to HTML used to represent 3D interactive objects (W3D Consortium, 2008; Wikipedia, 2008). Developed with the web in mind a browser can interpret VRML by installing the appropriate plug-ins. A number of small geometrical primitives are defined within the format and each of these primitives may have a number of properties that define the visual aspects of the object such as colour or transparency. The shape of large 3D objects are defined by combining the correct geometrical primitives e.g., 3D surfaces are defined as a mesh of triangular primitives. These models are interactive in a number of ways. Web links can be made by clicking with a mouse on a node, timers and external events can trigger changes in the scene and Java or JavaScript can be incorporated into the world (VRML files are called worlds, the term world is used where in other graphical systems the term scene would be used). The VRML format is an open format that has an ISO standard making it suitable for sharing geometrical model data which ensures its popular within academia. Successors to VRML include X3D and 3DMLW (based on XML).

VRML is useful in applications where the 3D shape of an object in important such as teaching anatomical structures to medical students. An early interactive web-based application using VRML was created to teach medical students to perform lumber punctures (John, 2001). A model of the external skin, spinal bones, spinal cord and cerebrospinal fluid (CSF) were combined in one world, enabling the student to manipulate the model in the viewer, viewing it from any angle and altering the transparency of all the elements. The student could then place the puncture needle in the model to simulate taking a sample of CSF. The student would be given feedback on their performance and could alter the transparency to see into the puncture site.

Flash (currently Adobe Flash, previously Shockwave Flash and Macromedia Flash) is a multimedia graphics program used to create interactive animations for web pages (W3 Schools, 2008; Wikipedia, 2008). Its features make it especially suited for a web environment. It uses vector graphics, which means that the graphics can be scaled to any size of display area without losing quality and it supports bi-directional streaming so that it can load into a web page more quickly than animated images. Most web browsers can interpret Flash but the Shockwave Player can be downloaded for free and used as a plug-in. Flash is being ported for use on mobiles and PDA. Flash applications are developed through an authoring tool.

From HTML to XML

HTML provides static content for the web and deals with formatting and style of text. While HTML allows the publisher to present their information in a particular style, Web 2.0 uses XML (Extensible Markup Language) to handle the data that is passed across the internet. XML has a user defined format to handle particular types of data which means that without standardization of XML file formats the variation in XML file content makes them difficult to handle. File formats based on XML and handling data relevant to visualization are developing e.g., the previously mentioned 3DMLW format. While that data does not have to be human-legible both HTML and XML are designed to be human-legible. Currently XML is rendered as raw text in a web browser with no unified display protocol for XML across all web browsers. In order to style the rendering of XML data the XML file must reference a style sheet that can not only give style but can also convert regions of the data into other data formats such as HTML.

Eventually XML may replace HTML and if it does good styling and visual display functionality may be included in the format. However currently the importance of XML is not in how it is rendered but as a way of formatting data to allow machine readable semantic information to be incorporated into the web. The best known function of XML is in price comparison websites, but it could be used to extend content to give information of interest (on when, what and the provenance of information) to social networking sites. Comparisons of large amounts of information where the structure, layout and interaction are important would benefit from visualization techniques.

VISUALIZATION SYSTEMS AND THE DEVELOPMENT OF TECHNIQUES

The Visualization Pipeline

The 'visualization pipeline' (Figure 1, from Haber and McNabb (1990a) gives an abstract presentation of the visualization computational process), indicating how scientific simulations are rendered in computerized form and thus made available to computational scientists. While this abstraction was developed for scientific visualization it can be expanded to encompass visualization more generally, and, some argue, covers computation generally. It shows (Figure 2) which parts of the pipeline are dependent on which computer hardware component. The performance of a pipeline is determined by the component with the worst performance called a "bottleneck". Developments in areas of computer technology on which the pipeline depends alter what is possible in the corresponding part of the visualization process. The graphics hardware and the display device are closely tied because the graphics card produces the images seen on the screen and this stream of images is a heavy load. The short dedicated cable connecting graphics processor and screen in a desktop computer is sufficient to enable the graphics card to service an acceptable refreshment of on-screen images—requiring at least 25 frames per second—but this works less well if the cable is replaced by a shared network for example the internet. While software on the pc comes with advice on minimum hardware requirements web-based applications do not, so users with low performance hardware will either have a poor experience of the application or the application must adapt to the user's system. The development of adaptive systems (Brodlie, Brooke, Chen, Chisnall, Hughes, John, Jones, Riding, Roard, Turner, & Wood, 2007) allows the detection of and adjustment for the nature of display systems and network speeds, allowing tailoring of the output so that, for example, a small mobile device could be fed lower resolution images to those fed into a wired pc or home entertainment system.

Physical interaction with a visualization is by two different types of input (Figure 3). Generally speaking interaction with the graphical object held on the graphics hardware is fast and uses a mouse or other device that feels natural. Interaction with the computation that occurs in the pipeline before the data reaches the graphics hardware tends to use application specific menu systems with mouse and keyboards input separated from the visual scene and disruptive of activity as the user must shift concentration from the graphical objects they are working with. Virtual Reality menu systems (Curington, 2001) appear to lessen disruption to the actions of the user but these can cause clutter in the visual scene and to reduce that clutter these menu systems have limited functionality. A third and dominant, but not physical, interaction is between the functionality of the application and the requirements of the user: if the visualizations do not appropriately represent reality then the user dependent on them may be

Figure 1. An overview for the whole of the visualization pipeline originally given by Haber (1990a) in text and Domik (2008) diagrammatically and refers to computational science. "Computer representation of reality" referred to computer simulation but could refer to a database or any digital data

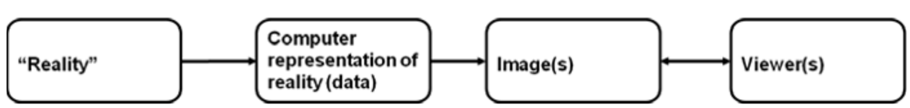


Figure 2. Overview of the whole visualization pipeline in figure 1, but in this case the hardware that each element of the pipeline depends on is identified. Computer and graphics hardware can be part of the same machine but this is not necessarily so, but graphics hardware is normally closely tied to the display device

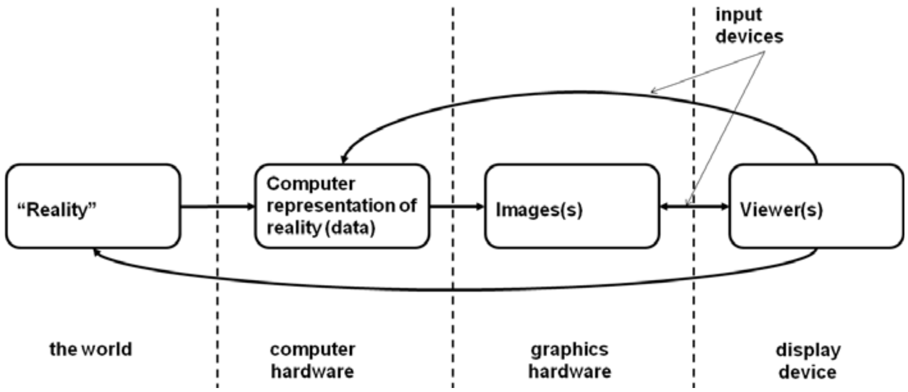


Figure 3. Overview of the whole visualization pipeline in figure 1, but with the 3 main types of user interaction given and numbered to match the order of discussion in the body of the chapter

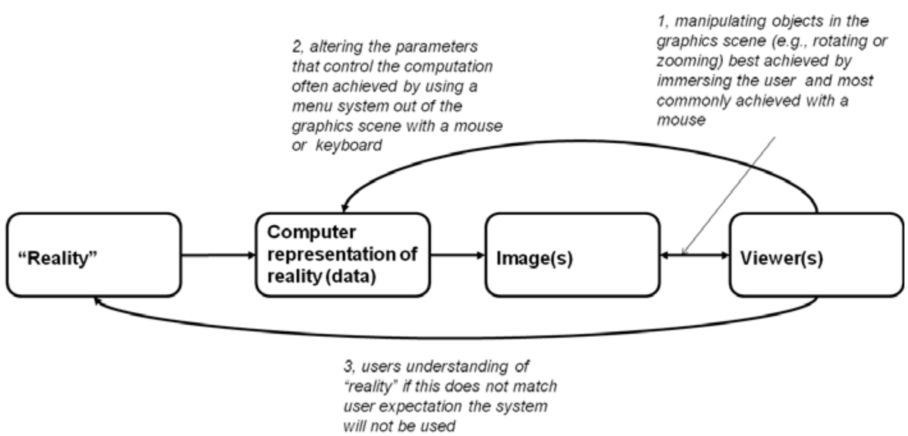
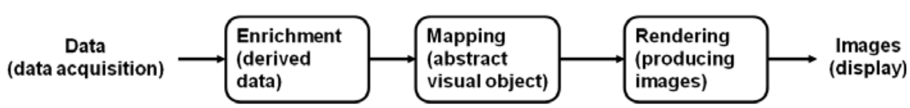


Figure 4. Overview of the visualization pipeline for just the visualization system showing how internally the visualization system handles data-flow (from left to right) and categorises types of interaction by data transformation type



misled when making their decisions, and if they are not confident that the results are useful they will abandon the system.

The visualization pipeline of the visualization system alone was further abstracted to categorise the interaction with the user and so exhibit the data-flow paradigm that is inherent in the software structure of visualization systems (Figure 4). The data is shown as flowing through the system while transformations are performed to deliver the final image. Haber (1990a) identified three types of transformation. The viewer is able to interact with the visualization and so affect each of these transformations, potentially gaining new insight into the data being displayed.

First, raw data is transformed by a data enrichment step into 'derived data'. Raw data can come from any digital source such as simulations, data files and databases. Enrichment fits the data to the desired model perhaps including data manipulations such as smoothing, filtering, interpolating, or even hypothetical alterations. Preparing data for visualization can be time consuming and so deter the first time users.

The second transformation, mapping, converts data into an abstract visual object (AVO). Attributes of the data are converted to corresponding geometric features according to a set of classification rules. By adjusting these rules, the viewer can cause distinctions in the data to become perceptually obvious. This step establishes the representation of the data, but not necessarily the final visual appearance on the screen.

The third transformation, 'rendering', ultimately converts the AVO to a displayable image. This involves computer graphics techniques such as view transformations (rotation, translation, scaling), hidden surface removal, shading, shadowing. The transformations at this stage occur on the graphics hardware and alter the perspective on the display, contribute to the overall appearance and dictate what is or is not visible

This pipeline makes explicit the transformations the data must go through to produce images. These transformations must be performed in this sequence. The concept of the data passing successively through each transformation is built into visualization software as 'data-flow'. This pipeline is drawn to reflect generic features of data transformation but specific ones can be drawn for particular applications and used to optimize and/or split the process. This is a common strategy for complex visualization applications such as Google Earth which branch the pipeline and spread the computation across a number of computational resources in a way invisible to the user but designed to improve the functionality and interactivity for the user.

Interactive Rates

Interactive rates strongly constrain visualization strategies. There is no exact criterion for an appropriate interactive rate. In TV and film production there are three different frame rate standards, the slowest at 25 frames per second. Stereographic systems need at least twice this rate as one frame is produced for each eye. On a single unloaded machine[2] a visualization system will maintain a good frame rate up to a threshold in data size where the threshold is determined by the data's geometric composition, the complexity of the visualization techniques used, and the memory usage rather than by the disc space that the raw data occupies. Higher frame rates improve user satisfaction particularly for stereoscopic projection but in exceptional circumstances a rate may be acceptable down to about 10 frames per second, as when the user has no other way of viewing their data, however below this rate the user will prefer static images or animations produced in batch mode.

These issues affect the interactive rate of transformations occurring in the graphics hardware but changes to parameters in the earlier transformations (enrichment and mapping) alter the representation of the data output from a particular visualization pipeline without affecting the frame rate, so the rate that enrichment and mapping are updated is slower. There is no exact figure, but a lag of more than a few seconds causes delays that may confuse the user, who cannot be sure what transformations have already been applied and which are waiting to fed into the scene currently being viewed.

Visualization Systems

Scientific visualization software was initially developed before the idea of web services had taken hold. It mainly consisted in standalone software taking advantage of specialist graphics hardware and specialist display and interaction devices. This close tying of software to hardware improves performance and made this a suitable setting for the development of virtual environments. Scientific visualization started as a support activity for computational science when simulations were run on supercomputers that were administered in computing centers. The need for the visualization of simulations drove the development of computer graphics hardware and virtual reality environments by Silicon Graphics, a supercomputing vendor. Scientific visualization systems exploited local hardware using many processors and optimization strategies to allow the largest possible datasets to be visualized. Initially the display was to a simple screen but larger display areas were developed using projectors or tiled screens so that a number of users could explore and interact with the visualization scene at the same time. New input devices were needed in these environments such as the space mouse (a mouse designed for manipulating objects in a 3D environment by permitting the simultaneous control of all six degrees of freedom) as the users would walk close to the screen and away from the key board and mouse which were then wired into the computer terminal. The 3D scenes produced by the visualization software seemed flat; meaning that information such as the depth of an object was difficult to interpret so stereoscopic output was integrated into these environments to trick the eye into seeing these objects in their "real" 3D form.

When the visualization systems were physically tied to the hardware, the user needed to be in the computing center to take advantage of them. Thus users did not make intensive use of this specialist and very expensive equipment so the idea of remote visualization developed to allow users to stay in their office and make use of the graphics hardware over a network. The first remote visualization systems were developed before the web and were developed alongside the abstraction of the visualization pipeline (Haber, 1990b). Pioneering visualization web services used scientific visualization software on a supercomputer to produce static 3D images from medical scans served interactively through a web browser to medics (Jackson, 2000). Later more dynamic visualizations dependent on specialist graphics hardware again physically located in the computing centre using a product, Silicon Graphics VizServer were developed. However their use was restricted in practice to projects where the visualizations were produced on a proprietary Silicon Graphics supercomputer and a dedicated high bandwidth network was in place; the images produced on the graphics hardware were compressed before passing down a dedicated network to users who could interact with the objects in the images. The Op3D project delivered and projected3D medical visualizations onto the wall in operating theatres so surgeons could compare the patient to the 3D visualizations side by side (McCloy, 2003). Typically specialized research systems produced their software from scratch, in this case developing a user interface employing a joy stick that was easy to use and suitable for a sterile environment. Collaborative visualization allowed users to share their experience either by sharing the results of the visualization on a large display or by splitting the visualization pipeline at some point and distributing the output across the network where it is rendered and displayed for each collaborator.

Collaborative environments used for teaching, consultations and group discussions enhance how knowledge is learnt and shared. The idea of adaptive visualization has been furthered by the Grid research initiative which aims to provide computer resources and services to academics across the web (Brodlie, et al. 2007). It is not a visualization system but it is a remote service that supplies users with visualization resources intelligently. In principal the user cannot choose which visualization software they use on which machine but instead define the scene that they wish to interact with and their local resources. As all visualization systems produce visually different results even for the same algorithm the user could find results from different softwares were not comparable. Visualization is a diverse and cross-disciplinary field so that the terminology within visualization and its applications is not consistent and this impacts on the ability to create an ontology or taxonomy for visualization making it difficult creating a visualization modeling language standardised across all applications (Brodlie & Mohd Noor, 2007). Technologies developed by the games industry are now the main driver for collaborative synchronous graphics environments.

Information visualization software followed a different path, developing later than scientific visualization software. Some early visualization systems for viewing social networks were adapted from scientific visualization software for molecular visualization using stereographic displays and VRML (Freeman 2000). However dedicated information visualization software was coded in Java rather than C or C++ and was suitable to integrate with web services from the start. Information visualization like scientific visualization displays large quantities of data often using different display techniques requiring less performance from the graphics hardware. Characteristically information visualization applications are more meaningfully displayed in 2D rather than 3D and use multiple related views that are easy to develop as web services. However such applications are computing intensive in the enhancement and mapping transformations rather than the rendering transformation (meaning that demands on the graphics card are contained). ManyEyes, a research application from IBM (Viegas 2007) is a web-based system that allows users to upload and visualize data through their browser. The visualizations are produced by java applets running asynchronously on the user's computer allowing each user to visualize and comment on uploaded datasets in a social networking environment similar to video and photo sharing in flickr or YouTube. Designed for visualization novices the system uses "ShowMe", a special interface to help users select suitable visualization techniques for their data, eliminating the need for a visualization modeling language. Its developers advocate good design web-based because it increases ease-of-use, as the authors of this chapter agree. Java applets are suitable for techniques that are not compute intensive.

Independently of the visualization community the Access Grid, an internet based video conferencing system, has developed. It is superior to video conferencing because the equipment is cheaper, using 'multicasting' technology that allows many sites to participate, facilitating online meetings, seminars and conferences. Access grid works by streaming video and audio over the internet, it is easy to stream visualization scenes across the internet and so include it in a session. This is interactive at the host site but not yet at other sites. Access grid sessions can be recorded and played back using visualization techniques designed to augment the analysis and playback of meetings (Buckingham Shum 2006; Slack 2006).

In Google Earth, a visualization web service combining satellite images, maps and other GIS information, vast amounts of computation are needed to serve the data to the user so that the best results are obtained for each user no matter what their graphics hardware (Jones, 2007). Web services will always be slower than locally run software running on high performance hardware. The distribution of computational resources needs to be balanced between the server and client, which are more noticeable for visualization than for non-graphical and non-interactive web applications. Currently, it is only by providing high performance data serving as in Google Earth that this complex visualization application becomes possible. There are other visualization applications that may be useful to social networking for example the production of large graph trees for particular members of a social networking website, perhaps including a famous politician who has an account on a social networking website. Large graph trees require high computational intensity and a low graphical intensity so the performance of an application aiming to produce such a tree would also require specialist hardware and code optimization, most likely to come from the proprietors of a social networking website rather than the open source community that is extending the functionality of the website. More generally such complex applications are most likely be developed within the commercial sector.

Visualization Design

Understanding visualization techniques is only part of the story. Knowing which techniques to pick, how to combine low level design elements and how to appraise a visualization are also important. Many elements of design are open to debate. Here we give the reader an idea of possible approaches to design and analysis.

The most scientific approach to design comes from psychology. Colin Ware, perceptual psychologist who for a short time worked as an artist before becoming interested in visualization, has studied visualization design from the perspective of the science of perception. His book (Ware, 1999) is the definitive guide to issues such as when to use words and/or images and the possibilities for visual programming languages. Lately techniques from psychology are used to test how "good" a newly developed visualization technique is by a method called 'user assessment'.

Another way to understand visualization design and analysis is through the history of how information has been visually represented. If a number of visual information representations can be understood from throughout history then it may be possible to use that understanding to analyse current visualizations and even to predict future developments (Friendly, 2008; Tufte, 1997; Tufte, 2001; Tufte, 2006; Wainer, 2005). By studying history it is possible to understand better the social context in which the techniques were developed and explain two types of negative outcomes. Firstly, the situation where techniques were developed but at that time it was disregarded only sometime later to become an accepted visual representation. This was the case with William Playfair who in the 16th Century developed the grounding for modern statistical plots 150 years before they were accepted (Playfair, 2005). Secondly, where the poor visual representation of information have contributed to the failure of projects. This approach has been applied to two NASA based projects involving the launch of the space shuttle Challenger and the space flight of the shuttle Columbia in 2003 (Tufte, 1997; Tufte, 2006). To improve his analyses Tufte shares information with a variety of experts who use visual methods to communicate information, creating a moderated web forum for this purpose.

Cross-disciplinary teams can not only be good for analyzing visualizations but also for designing and creating visual representations. The term "renaissance team" was coined in the mid 1980s by an artist, Donna Cox, who worked collaboratively with computer scientists and scientists to find novel visual ways to explore how the universe was formed. Collaborative cross-disciplinary teams including artists trained in design can be used to create novel and visually pleasing techniques. Art criticism is the discussion or evaluation of visual fine arts, and it has been suggested that it be extended for the analyses of the products of visualization i.e., images, animations or virtual environments.

The final approach to visualization design is not a formal design strategy or methodology but is mentioned only because it has the potential to affect the type of visualization applications available on the web. It involves the exploration and testing of technical possibilities for visualization through developing web-based open source applications by experienced graphics programmers who will probably have worked in creative environments reliant on computer graphics who create visualizations for fun, as does Jim Bumgardner who among other things has contributed open source software to flickr, an online photo management and sharing application (Bumgardner, 2008).

A SURVEY OF VISUALIZATION IN USE TO SUPPORT SOCIAL NETWORKING ON THE WEB

The current state of visualization to support social networking is poor. The web pages on social networking sites tend not to be visually novel or pleasing[4]. Good graphic design means some websites have a visually appealing header and menu system though there are arguments that web pages should have little visual clutter and that graphical headers are a distraction. We do not get involved in this argument as it is only how information is structured within the pages and the functionality of web-based applications that is really of relevance.

The layout of the web pages within social networking websites tend to be structured into tabular formats with information structured into long web pages that require scrolling, a typical artifact of CMS. Web pages in a blog style are placed in a list ordered by the date the blog entries were created. In websites primarily handling other types of data relevant to social networking such as images, video, film reviews or web bookmarks, the data are again tabulated but the entities are ranked by some property other than date. Often users of these websites will rate the data or other ways are used to calculate the popularity of the data. One of the features making these websites clumsy for social networking is the way different kinds of data are segregated within them i.e., the separation of images from video and the lack of support for other types of files such as pdf, powerpoint or even applets. While it can make sense to segregate data there are activities such as planning a wedding that require integration of a number of activities which may be carried out through social networking sites. Also, if file formats that can be uploaded and viewed cannot be annotated mean then their features of interest must be described in text that is isolated from the file.

Two web applications offering greater visual diversity are Google Earth/Maps (an online geographical application that combines maps and satellite images) and flickr (an online photo organization application).

Google Earth/Maps have advanced functionality allowing real time manipulation of large amounts of geographical information, with an open API to these applications so that further applications can be developed that extend the functionality for particular sets of users such as recreational runners who may use the MapMyRun website to share routes and to plot graphs of changing elevations over the run. Other information can be added for example 3D models of buildings can be attached to the maps or satellite images or outputs from simulations can be visualized within the Google Earth environment. The API is of commercial value to Google as the professional versions of these applications can be extended further than the non-commercial version.

Flickr also has advanced functionality but it really stands out for its graphical novelty. It has an open API but that is not supported by flickr. There are fewer stand-alone applications extending the functionality of flickr through the API than with Google Earth. One exception is the trip planner, using flickr's mapping functionality to link photos to a geographical location on a map, extended to allow planning trips in a shared environment. Flickr is graphically pleasing and especially within its open source community there is graphical experimentation, perhaps because this community is interested in photography and as such is aesthetically motivated.

FUTURE TRENDS

Though a great deal is happening in the field of Visualization, it is not yet a significant presence in the public life of the internet, though this situation will probably change drastically. With many fundamental problems of making information available over the internet now solved, demand for improvements to both presentational quality of information and to the appearance of websites and stand alone web-based applications will surely increase. This will bring the existing and evolving techniques of visualization to much wider attention. Google Earth and Google Maps, a visualization application, have 'introduced hundreds of millions of users to what have, in the years since Ivan Sutherland's Sketchpad, been concepts at the core of visualization research-projections, 3D user interaction, user feedback, motion models, level of detail, frame-rate management, view-dependent rendering, streamed textures, multimodal data composition, data-driven extensibility, and direct manipulation' (Rhyne, 2007).

Visualization may further facilitate user's access to and control over web content through contribution to the development of code writing. The development of techniques to support this task involves either the use of visualization to aid the writing of textual programs or the development of visual metaphors providing a visual language. In the first case the user must still understand the principals of programming, but techniques from text visualization may be appropriate (Card 2004) or functionality similar to that used in debugging packages could be applied. In the latter case the metaphors will only be helpful if they are apt but harmful if they are not and it is difficult to make them apt (Ware, 1999).

Using the web to aid academic research has been popular from the start but it seems that the semantic web will extend that popularity, aiding researchers in an ever increasing number of ways (Waldrop, 2008). Sharing textual information is the underlying means of communication. However other forms of communication will develop such as the access grid which allows video conference style communication but to multiple users is also popular for the delivery of seminars, conferences and meetings. Visualization could be used to structure information, for disciplines that have a geometrical or geographical dimension (such as engineering, anatomy or archeology) to share shape and location and in fields where there is intense cross-disciplinary activity which is not currently well supported. This trend could result in greater demands for more effective real time display across the internet, involving much greater visual access, and calling for shared visual environments. The semantic web also offers an important means of communication to hobbyists and intelligent lay people requiring similar functionality for different application areas such as football, patchwork quilting and dieting.

Visualization will become more relevant to domestic and leisure uses of the internet as the display and input devices available multiply in form, variety and functionality, with their presentational quality enhanced. With ever larger screens and projection systems used in home entertainment suites social groups and families could benefit from advances made in virtual environments (such as stereographic displays and the space mouse which has similar functionality to the Wii controller) and the access grid allowing groups to socialize through video streaming. Also the increasing array of input devices means that online gaming and training simulators can become more natural.

Comparable opportunities exist with mobile devices, in connection with problems of visualization for small screen spaces, the servicing of touch screens, the development of menu systems and the progressive improvement in interactivity. Google Earth can be accessed on mobile systems and this has the potential to turn any mobile device into a GPS (Global Positioning System).

Visualization can also contribute to the interfaces underlying social networking services. For example, Mayaviz (Roth, 2004) developed a system that uses web-based technology to help synchronize complex logistical efforts similar to planning social events. The ideas used in this product address many of the clunky features noticed in current social networking sites. Work sheet like constructs can be created by users and access can be limited appropriately. Data files of any type can be dragged and dropped anywhere on the sheet (they do not have to be in a tabular layout) and users can make clusters of elements holding related information. Data elements can be drawn on and annotated by the user and changes in data/information can be propagated into other related data without the user having to control these changes. An alternate example is improvements to techniques rather than systems such as to graphical representations of large social networks or to combine both social connectednesses in virtual space with geographic relations on a map.

CONCLUSION

The internet may be on the edge of a golden age for visualization as its techniques find use in many more application areas than those specialized niches within which it has developed. Much of the more complex functionality and varied applications will probably develop commercially but there is still a place for academic research into visualization and for the single open source developer to create interesting visual techniques.

With very powerful levels of functionality now available on the internet, there is the possibility of a rebalancing the emphasis toward more aesthetic and ease-of-use concerns. Future generations of technology will be integrated into the semantic web to provide superior audiovisual experiences. To this end visualization practices themselves will continue to evolve, taking advantage of the new devices and innovative functionality that continues to come on-stream. Not only will visualization become more commercially driven but more frontal emphasis to aesthetic quality is likely as it becomes more intensely cooperative with graphic designers and creative artists in forming the new user interfaces of the semantic web.

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KEY TERMS AND DEFINITIONS

API: (Application Program Interface) contains all the elements that a programmer needs to extend an application.

CMS: (Content Management System) a web delivery system separating content from presentation. These allow users to add content making them popular in social networking sites but the web pages have a tabular form that isolates the elements that make up the content.

Data visualization: The second area of visualization to emerge that focused on statistical plots and thematic cartography has now merged with information visualization.

Flash: is a multimedia web application adding animation and interactivity to web pages by using efficient streaming and vector graphics techniques.

Google Earth: The most popular visualization tool ever. It is a standalone web application combining maps, satellite and GIS information into a meaningful spatial context that gives the user direct manipulation of the applications elements.

Information visualization: The final area of visualization to emerge that aimed to show visually the relationships within databases.

Java: A powerful programming language that adds functionality to the web at the server side and the client (browser) side. Several libraries relevant to visualization are included within Java.

JavaScript: A scripting language that adds interactivity into web pages.

Scientific visualization: The first distinct area of visualization to have developed. Initially computer graphics technology was used to "view" the result of computer simulations which had an inherent geometry e.g., the flow of air over an aircraft.

Visualization: There are many definitions of visualization. In this chapter we use the term to cover the use of computer and computer graphics technology to present data to aid human understanding and communication. Today visualization is somewhat arbitrarily divided into scientific and information visualization.

VRML: is a file format that holds 3D models. Some animation and interactivity is encoded into the file.

ENDNOTES

[1] This does not mean graphic design is unimportant or that the structure and layout of information is not part of the aim of visualization. However the original web language (HTML) made no allowance for design so that constructs such as html tables have been adapted to take on a dual role i.e., one of enforcing a design.

[2] Single machine is stated here because the visualization system could run on a cluster where the process is spit over several machines. The 'unloaded' term is more important. On supercomputers there may be other users taking control of resources such as memory, processing power or I/O systems that affect the visualization system's ability to produce the optimum frame rate. On machines dedicated to the use of a single user this may still be a problem. If a machine is running background processes for example installing updates or if the user is using other software at the same time then there may also be a conflict in the sharing of resources affecting the frame rate.

[3] The authors have worked with three CMS Joomla!, Zope and BSCW.

[4] The authors could not view every possible website however they attempted to view websites that supported as many different activities as possible: YouTube (http://uk.youtube.com/), Flickr (http://www.flickr.com/), Fantasy Football (http://fantasyfootball.metro.co.uk/fantasy-games/), FaceBook (http://www.facebook.com/), LinkedIn (http://www.linkedin.com/), TopCoder (http://www.topcoder.com), ManyEyes (http://services.alphaworks.ibm.com/manyeyes/home), Del.ic.ious (http://delicious.com/), Jango (http://www.jango.com/), Wikipedia (http://www.wikipedia.org/), MapMyRun (http://www.mapmyrun.com/), Fetch Everyone (http://www.fetcheveryone.com/) and Now Public (http://www.nowpublic.com/). A blog was also developed on the blogspot website (https://www.blogger.com/start) that uses Google's blogger interface.

Chapter X
Tracing the Many Translations of a Web-Based IT Artefact

R. Naidoo
University of Pretoria, RSA

A. Leonard
University of Pretoria, RSA

ABSTRACT

This chapter adopts an interpretive, case based research strategy to discuss the centrality of meaning in implementing an Internet-based self-service technology. Actor-Network theory (ANT) is used to describe the complex evolution of a Web-based service at a healthcare insurance firm. Using processes of inscribing, translating and framing, this chapter explores the emergence of the technology from 1999 – 2005 using three technological frames, 'channel of choice', 'dazzle the customer', and 'complementary channel' as episodes of translation. ANT demonstrates that the Internet-based self-service technology at this particular healthcare context emerged out of many unplanned negotiations and mediations with both human and non human actors. Finally, this chapter argues that ANT's socio-technical lens provides a richer understanding of the meaning of Internet-based self-service technology within a multi-channel context.

INTRODUCTION

The rational and conventional view of e-commerce suggests that Internet-based self-service technologies are poised to provide potential added value to a healthcare firm's business goals as well as service delivery to customers (Dabholkar, 1996; Dabholkar and Bagozzi, 2002). After all, such technologies enable healthcare firms to reach beyond traditional boundaries, thus providing myriad administrative and commercial opportunities. However some research suggests that potentially valuable customers may perceive barriers to interaction with technology-enabled service systems (Uzzi, 1999). Advocates of this view argue that the electronic service delivery process often does not address the various needs, capabilities and concerns of the user, as they are designed mainly with the aim of achieving operating efficiencies for the firm. Furthermore, organisations appear to be paying little attention to existing relationships which the technology wishes to replace. In addition, a number of investigations reveal that customers are unwilling to replace face-to-face contact with electronic alternatives. It is not surprising that another stream of research indicates that face-to-face relationships may be more cost effective than virtual relationships (Granovetter, 1985). Clearly, recent studies show that rational and economic models of e-commerce are an oversimplification of what actually happens in the socio-technical environment. It appears that firms tend to ignore important contextual dynamics which may provide a deeper understanding of self-service technology implementation. Therefore the main premise underlying this chapter is to emphasise that the subjective insights of designers and users are crucial if we are to understand human conduct in the use of Web-based IT artefacts.

This chapter presents results from an interpretive case study investigation at a major South African healthcare insurance organisation, focusing on 1999-2005 as the years most crucial to its SST implementation. The chapter is organized as follows: The section on the conceptual framework explores various concepts and theoretical elements from Actor-Network theory (ANT) that suit the exploration of complex IT artefacts. The next section describes the case study approach for understanding the emergent nature of SST implementation. The results lead to an analysis of the SST implementation phenomenon. Finally, the last section discusses the implications of these findings for the study of Web-based IT artefacts and assesses the utility of the ANT approach for understanding the implementation of innovative Web-based self-service technologies.

CONCEPTUAL FRAMEWORK

A conceptual framework can be defined as the structure, the scaffolding, or the frame of a study (Merriam, 1998). Some researchers refer to it as the lens through which we view the world (Walsham, 1995; Orlikowski and Baroudi, 1991) or the territory to be explored (Caroll and Swatman, 2000). As already alluded to, an SST implementation has both technical and social merits and it might be more appropriate to try to overcome the distinction between technical and social to improve our understanding of this phenomenon. Drawing on key concepts and assumptions from the social shaping of technology this chapter draws on the actor-network (ANT) approach to understand the heterogeneous and interrelated character of social and technological components (Callon and Law, 1982). ANT contends that both social and technical determinism are flawed and advocates a socio-technical account in which neither the social nor the technical are privileged. According to ANT, what appears to be social is partly technical and what appears to be technical is partly social (Law, 1992).

In this way, ANT differs sharply with views purporting purely technical or purely social relations. Structuration, another popular social theory used to understand IT artefacts is unable to unpack how technology regulates society and society's reaction to technology with the same level of precision as ANT (Schultze and Orlikowski, 2004). ANT assumes that when humans interact with other humans, these interactions are mediated through non human artefacts of various kinds, and asserts that such interactions are mediated through additional networks of non human artefacts and humans. Hence, if material artefacts in these networks disappear, so to would "social order". ANT also investigates how actors enlist other actors into their world and how they bestow qualities, desires, visions and motivations on these actors (Latour, 1996). Thus ANT offers a unique approach to theorising innovations such as self-service technologies and their implementation; an approach that resists essentialist notions inherent in the conventional treatment of self-service technologies.

Recently, Faraj, Kwon and Watts (2004) built on actor-network theory a basis for studying the complex evolutionary processes of modern information technologies. A particular appeal of this approach is their attempt to to reveal the interdependencies between actors and in particular how processes of inscription, enrolment, and framing dynamically enabled and constrained the implementation of information technology.

Figure 1 demonstrates that the implementation processes consists of recurring operations in which networks of actors continuously act, react and interact, creating a spiral of technology implementation. Pocesses of inscription, enrolment and framing are shown to operate recursively within a social context. It is envisaged that analysing these processes bound in a particular social context will draw greater attention to the dynamics of SST

Table 1. A synthesised analytical framework using actor-network theory

Conceptual Component	Associated Conceptual Elements
Inscribing	Entities that make up a network are often converted into inscriptions of devices such as documents, reports, models and software. This process is concerned with how ideas, values and intentions of social actors become inscribed in technology. Inscriptions prescribe a program of action for other actors, which the latter may or may not follow, depending on the strength of the inscription.
Translating	Translation describes a variety of ways in which actors actively seek to interest others in supporting the construction of a claim, enrolling them directly or indirectly in a coalition dedicated to building a fact or a machine. The process of creating these actor-networks, consists of four major stages: problematisation, interessement, enrolment, and mobilization. Translation processes do not pass through all these stages and may fail and halt at any stage.
Framing	The framing process describes the emergent outcome of technology meeting practice. Key actors engage in actions in support of a certain vision or pattern of design and usage. However unexpected uses are developed leading to a new perspective on what the technology does and is expected to do.

Figure 1. ANT process model for SST Implementation (Adapted from Faraj, Kwon and Watts, 2004, 190)

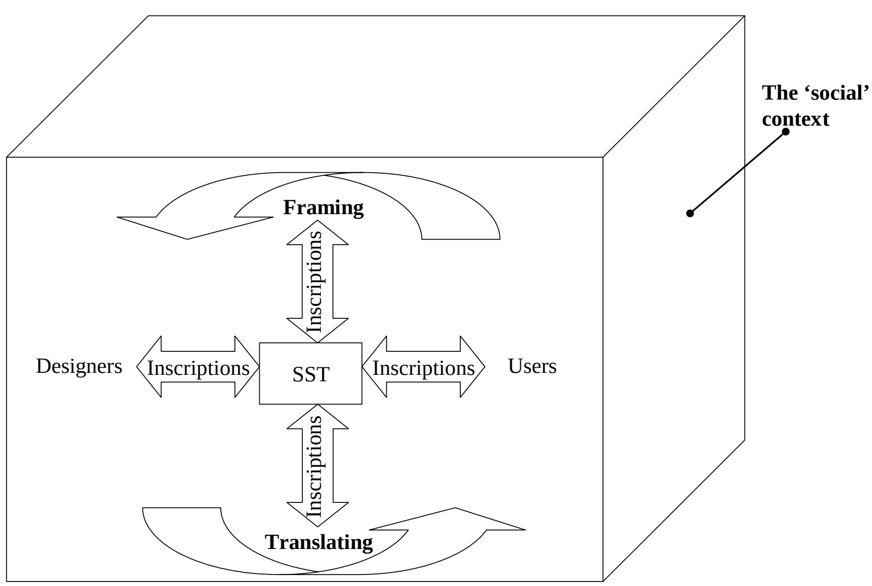


Figure 2. The four moments of SST translation (Adapted from Callon in Law, 1986, p. 196-223)

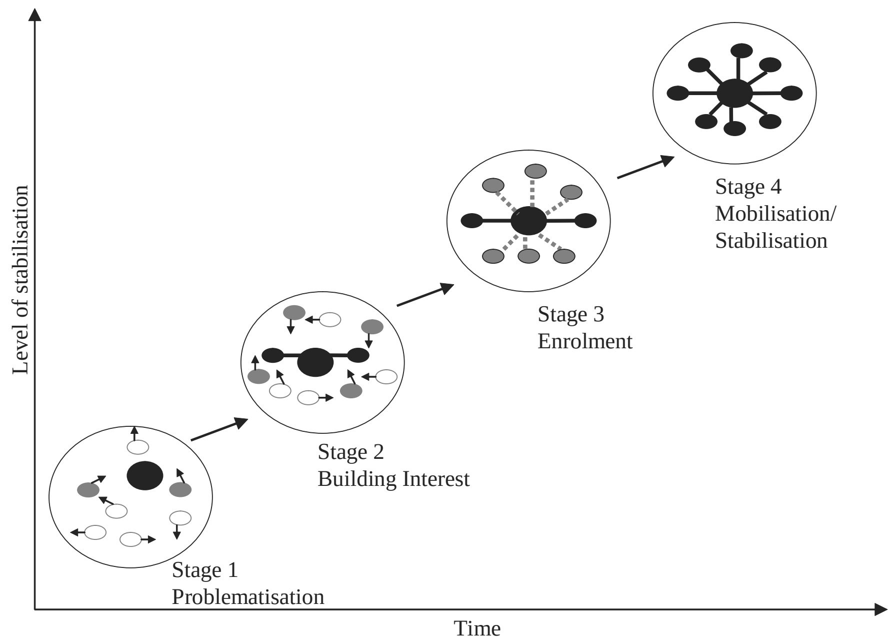


Table 2. The stages of SST translation

Translation Stages	Stage Definitions
Problematisation	In the problematisation stage, a group of one or more key actors define the problem and suggest solutions that make them indispensable to the solution.
Interessement	In this stage, the key actors build interest and lock key allies in, by finding ways to (re)formulate the problem or solution in such a way that key allies will associate their own interest with the formulation
Enrollment	In this stage, the problem or solution is established as an accepted fact, that is the problem or the solution is legitimised, by controlling or influencing the production of facts, by using allies and spokespersons, and by inscribing problem or solutions in the organisational memory (e.g. documented agenda, minutes).
Mobilisation / stabilisation	Finally, during mobilisation, the solution gains wider acceptance. Compliance is ensured by monitoring the network and addressing desent as and when it arises. The key actors use the stability in the network to enact solutions.

implementation and provide rich insights into their emergent consequences. To complement the above ANT process model for SST implementation, Figure 2 will be used to describe the translation sub processes in more detail.

Figure 2 shows that actor-networks are configured by the enrolment of various human and non-human allies, via a series of negotiations where one group of actors attempts to impose definitions and roles on other actors (Callon, 1986). Callon (1986) discerns four 'moments': problematisation; interessement; enrolment; and mobilisation. The model above demonstrates the notion of weak ties (depicted by broken, thinner and disconnected lines) and strong ties (depicted by darker and connected lines). Whereas actors during problematisation are characterised by fragmented alliances and instability (weak ties), through the process of translation, actors are progressively locked into stronger alliances, whereupon they come together and the network stabilises (strong ties). The depiction of the orderly sequence of the translation sub-processes is merely an analytical convenience. It provides us with the ability to construct an understanding of the SST implementation process by focusing on the sequence of events that leads to its outcome.

During the first moment of *problematisation* one actor, the initiator makes an effort to make other actors subscribe to its own conceptions of the solutions or definitions of the problem. Initiators try to demonstrate their quality of being indispensable to the solution of the problem during the initial stage (Bloomfield and Best, 1992). In ANT parlance initiators attempt to establish themselves as an 'obligatory passage point'. Introna (1997) defines an obligatory passage point as a rhetorical device that presents the solution to the problem in terms of the resources of the agency proposing it. To pass through the obligatory passage point, the other actors must accept a set of specific conventions, rules, assumptions and ways of operating laid down by the focal actor (Tatnall, 2000). During the second moment of *interessement*, an attempt is made to impose and stabilise the identities and roles defined in the problematisation on the other actors, thereby locking other actors in the roles proposed for them (Callon, 1986). Gradually existing networks are replaced by the new network (Grint and Woolgar, 1995). The third moment is *enrolment*. Enrolment occurs when a stable network of alliances is formed and the actors yield to their defined roles and definitions. This involves a multilateral political process where the initiator seeks to convince other actors. It is for this reason that Callon (1986: 211) states: "To describe enrolment is thus to describe the group of multilateral negotiations, trials of strength and tricks that accompany the interessements that enable them to succeed". The final moment is *mobilisation*. Mobilisation is a set of methods that initiators employ to ensure that allies do not betray the initiators interests. During mobilisation the proposed solution gains wider acceptance and achieves stability. Stability implies that the technologies content is institutionalised and is no longer controversial. In other words the technology becomes taken-for-granted and is "black-boxed". From an ANT perspective, material artefacts are significant in the structuring of these relations. As Lowe (2001:82) so lucidly puts it: "Objects provide receptacles for human knowledge and vastly enable the process by which facts become accepted".

Following ANT, translation is seen as necessary for stability in these networks since actors from the outset have a diverse set of interests (Monteiro, 2000). Aligning these interests causes a network to become stable and durable. However, according to Mahring, Holmstrom, Keil and Montealegre (2004), the translation processes does not necessarily pass through all the stages described above. It is plausible that the translation processes may fail and halt at any stage, depending on the strength of the network's inscriptions. In contrast to diffusion models which assume technologies to be immutable, actors in ANT not only reshape technologies, but are themselves changed as the changing artefact spreads through the social network.

Besides the four stages of translation, the process of inscription is critical to building and stabilising actor-networks as most material artefacts within a social system embody inscriptions of interests. Inscriptions refer to the way technical artefacts embody certain viewpoints, values, opinions and rhetoric such as reports, documents, scientific papers, software code or computer applications (Bowker and Star, 1994). In other words technological artefacts can also embody a world-view (inscription) that reflects the socio-economic context and rationality in which it is created. For example Chilundo and Aanestad (2005) found that in the implementation of technologies in developing countries, the potential for a clash of rationalities is greater were the values inscribed in Western technologies conflict with values of developing countries. So, inscription implies that a material or technological artefact never begins as a blank slate. In other words artefacts always embodies the designer's beliefs, social and economic relations, previous patterns of use, and assumptions as to what the artefact is about (Akrich, 1992). Since inscription can guide users to behave in a way that forces a definition of the form and function of the technology, many actors actively seek to inscribe their vision and interests into the artefact (Faraj, Kwon, and Watts, 2004). Inscriptions may also lead to irreversibility. Irreversibility refers to the degree to which in certain contexts it is impossible to go back to a point where alternative possibilities exist (Callon, 1991). Irreversibility is often the result of the inscription of interests into technological artefacts that become increasingly difficult to change (Hanseth and Monteiro, 1998; Mahring et al., 2004). As ideas are inscribed in technology artefacts and as they diffuse in their relevant contexts, they help achieve socio-technical stability (Latour, 2005). Walsham (1997) notes that inscriptions developed in software as 'frozen discourse' may resist change and display signs of irreversibility. Hanseth and Monteiro (1997) suggest four notions of inscription and translation that should be emphasised in an ANT study:

- The identification of explicit anticipations or scenarios of use held by the various actors during design;
- How these anticipations are translated and inscribed into materials;
- Who inscribes them; and
- The strength of these inscriptions (i.e. the effort it takes to oppose or work around them).

Another important concept related to translation and inscription is framing. Framing is defined by how key social actors engage in actions in support of a certain vision or pattern of usage. This examination of how social actors frame criteria for selecting and stabilising features is essential to our understanding of the evolution of technology. According to Faraj et al. (2004), inscribed patterns of use can be deemed as unsuccessful when actors do not conform to their assigned program of action. In many new technologies, actors modify and adapt the technology artefact into new forms of use. Based on actual practice, unexpected uses are developed and new functionality is envisioned, leading to a new perspective on what the artefact does or is expected to do. When studying the user of technical artefacts, one also necessarily shifts back and forth between the designer's 'projected user' and the 'real user' in order to describe this dynamic process of negotiating the design (Akrich, 1992). Thus it is crucial to measure which of these superimposed inscriptions actually succeeds in shaping the pattern of use in order to measure the strength of an inscription (Monteiro, 2000).

To summarise, ANT views implementation as an emergent process initiated and guided by actors with specific interests. Their agendas are enacted through processes of inscription, translation, and framing. Inscription and the sub processes of translation are used to enrol dissidents who oppose the new agenda. By inscribing the agenda in material artefacts, actors enable material artefacts like internet-based self-service technologies to assume the role of actors in the network; that is, they stand in for the agenda setters. However, unexpected uses may occur leading to a new perspective on what the technology does and what it is expected to do. The framing process describes the emergent outcome of the technology meeting practice.

METHODOLOGY

The main research strategy selected was an in-depth case study of a single organisation. This research could have been approached using surveys designed to examine changing patterns in the firm and the various stakeholder communities. However this might not have revealed in detail the unique experiences of the individual organisation and other human and non human actors influencing the change. Yin (1999) also endorses the study of single facilities arguing that a single case can often produce a more penetrating study. Semi structured interviews and secondary source analysis were the main data collection mechanisms. Individual interviews carried out on site were the primary technique used to elicit information from the SST's designers. The field research for the case study was carried out in three main periods, consisting of 3 months in mid-2005, 3 months in late-2005, and another month in late-2006 (It should be noted one of the authors also spent three years prior to this actively involved in the SST implementation project). In total a total of 55 formal interviews were conducted during this period (Table A1). All 55 interviews were tape recorded and extensive research notes were taken. This practice ensured that everything said was preserved for analysis.

Data Analysis

Data was systematically coded into as many themes and categories as possible. As the categories emerged and were refined, they were evaluated as to how they related to one another and what the theoretical implications were. This pattern is sometimes called "grounded theory" (Strauss and Corbin, 1998). However unlike grounded theory we used the theoretical framework to guide this process. We also used version 5 of ATLAS.ti to code and store these themes and categories at the textual and conceptual level (See Figure A1) (Muhr and Friese, 2004; Darke, Shanks, and Broadbent, 1998).

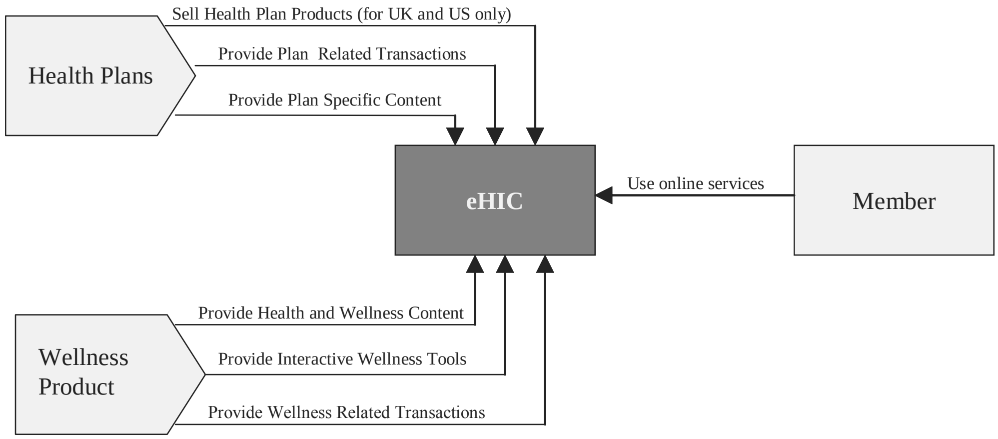
THE HEALTHCARE INSURER CASE STUDY

This section presents the empirical heart of the case study and is presented in historical sequence. It starts with a brief sector background followed by a short description of the demise of a healthcare insurer's information portal and the rise of the e-business. Next, the integration of the e-business into the IT department and the eventual disbanding of the e-business department by integrating it into the various business and system functions, specifically the front-office applications, are discussed. The reflections of the user community are also interwoven into these discussions to describe the complex web of events.

Sector Background

Many healthcare insurance firms are now modelling their business on the so-called "consumer-driven healthcare" concept. These healthcare firms frame this emerging concept as one were the consumer plays a greater role in making decisions on their healthcare, have better access to information to make informed decisions, and share more in the costs (Cannon and Tanner, 2005). Consequently proponents of consumer-driven healthcare view the Internet as a source of information and support that can potentially make a significant contribution to the efficient and effective delivery of healthcare services. A number of these firms are implementing online self-service applications to reduce the cost of servicing customers and to improve customer relationships (Kolsky and Bivin, 2001). These online self-service applications provide consumers with interfaces to access a firm's data, enabling consumers to serve themselves with the information they need or the service they require. During the latter part of the 90's, a major South African health insurer known for reasons of confidentiality as HIC, integrated elements of wellness into their product design and was keen on making these available both through a Web-based portal. This initiative is reviewed in the next section.

Figure 3. eHIC's e-service model for members



The Online Self-Service Project

Phase 1: From Information Portal to E-Business

In 1996, HIC began its use of Internet technologies. The initial solution began with a hosted service delivering static content that was predominantly product focused. It soon emerged that the e-commerce channel could equally provide online services in the form of transactions to customers. As a result a bolder project was conceived during 1997 at a time when many other organisations were exploring the transactional potential of Internet technology. With just over 5% of the member base having registered, the team was facing an uphill battle to justify commercial viability of the technology. However the general optimism of the Internet at the time combined the competitive threat of a pure play dotcom insurer usurping the healthcare insurance market prompted the insurer to radically improve its online offerings. The development of eHIC began in the latter part of 1999, when excitement about dotcoms was at its zenith. As the Head of eHIC put it: "Initially it was just to be part of the space and no one really could draw a more rational reason than that. You have got to be part of this play. The whole world was going to go online". On the 10th of May 2000, HIC formally announced the formation of its e-commerce subsidiary known as eHIC. eHIC was to operate as a separate entity within the HIC stable with the purpose of delivering the e-commerce needs of the firm on the assumption that the e-commerce arm would deliver better solutions more efficiently to its client base.

However from the outset the newly formed e-business team faced a constant struggle for attention from the systems and business areas. The way the online channel wanted to offer services to customers brought in into conflict with the way in which HIC had traditionally architected the same services for the existing service channels. To add to the growing consternation the online SST was slow and difficult to use. At the time business connectivity levels offered by the predominantly state-owned monopoly telecommunications provider were very poor and consumer broadband was almost nonexistent. One user mentioned that the "the site looks great but is painfully slow to use". When dotcoms started to falter worldwide in the middle of 2000, it became increasingly difficult for eHIC to defend its position as an autonomous business unit. Upon losing its credibility, eHIC was struggling to maintain its legitimacy as an appropriate service channel.

Phase 2: From E-Business to E-Department

Shortly after the world was hit by the dot-com crash and Silicon Valley firms came crashing down around the globe, HIC's senior management expediently absorbed eHIC back into the business. eHIC began operating as one of the several functional areas of the IT department. eHIC was still treated as a foreigner. This treatment extended into the business areas. One illustration is the inconsistency in how communication prepared for other mediums or channels were tailored for the online world. In adapting content for the Web, Marketing often accused eHIC of being too techno-centric, while eHIC viewed Marketing as being to territorial about the firm's brand. Staff generally felt that despite the structural change to eHIC, the department still maintained a superior attitude and a dismissive and arrogant culture.

Nevertheless the launch of eHIC was followed by a very effective marketing campaign. The web site was promoted in various mediums from call centre awareness campaigns, e-mail campaigns to magazine articles. During this period, some of the key functionality that were provided online included claims submissions, claims status tracking and viewing health savings account balances to enable consumers to manage their health plan finances. On the wellness and lifestyle segment, there were travel bookings with which users were able to plan and book their hotel accommodation, flights and car hire, online. Furthermore, there was access to health and medical information; accredited information on a vast number of medical conditions and diseases. The site also offered a variety of useful tools and content for members to ensure that they stay healthy.

As opposed to health plan specific transactions, it was the innovation in the wellness program that provided all sorts of opportunities to utilise the online medium. Wellness members had access to selected health and fitness facilities and eHIC offered their customers incentives to use them. Two major tools that were developed during this period were the online nutrition and stress centres. Meanwhile by October 2003, more than 25% of all interactions with HIC were now being achieved via the online channel. The goal was to move the interactions to 51% as this would imply in some circles that the SST was now the dominant channel. Despite this, only 26% of the total membership base had registered to use the online service. And even though there were major site redesigns as part of the valiant effort to move this ratio to 40%, the ratio of active registered members would hover around the 25% mark for the next 2 years. Further analysis revealed that many of the 25% had a higher servicing need than the average consumer. These users either tended to be high claimers or loyal followers of the wellness programme. The loyal user base consisting of 25% represented a minority of the member base.

Of more concern, over time as many as 60% of the users who registered never returned to use the website. This is in stark contrast to the health member base churn or lapse rate of 3 to 4 %. Furthermore the remaining segment of the user base showed only sporadic use. On the other hand, the use of the traditional call centre channel remained relatively high with repeat calls accounting for a significant component of the call volume. Internal statistics showed that 40% of insured customers were phoning more than once during a month. Furthermore only 10% of the registered user base had registered to use wellness applications like the nutrition centre. Given the steep tapering of use among the majority of the users who signed up to join the nutrition centre, there was this impression by the design team that many users were joining merely to obtain the wellness incentives. As the online nutrition expert put it: "The advantages of going to a dietician, you go into a professional environment, you are having that contact with the dietician who can read you and build a relationship with you and become a partner in this process". Meanwhile, another research conducted internally suggested that the electronic service intended to proactively address members' concerns were instead closely associated with calls. It emerged that the call rate increased significantly in the proximity of an eHIC site visit. Not surprisingly the e-department entered another episode of further scrutiny.

Phase 3: From E-Department to Front-End Development Team

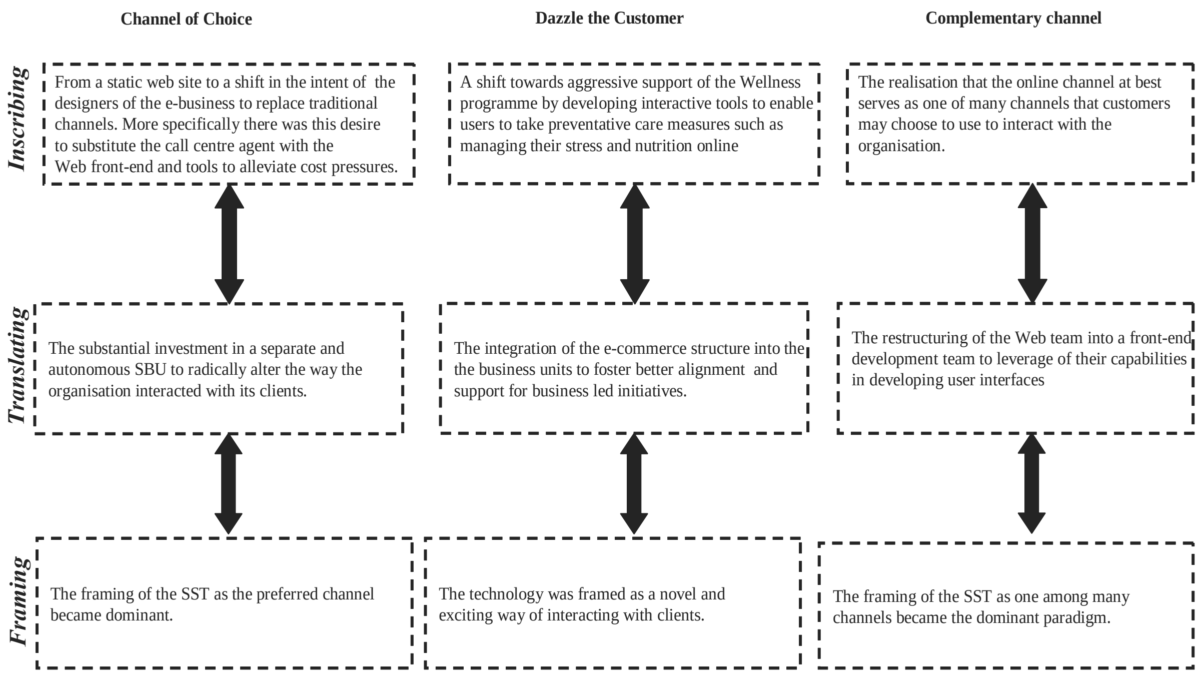
There were a number of further organisational changes within HIC during 2005. Operational efficiency was becoming an important driver of cost savings and profitability for the firm. There was an intensive focus on streamlining the operational aspects of the business specifically in the service and operational infrastructure arena. The aim was to create a platform for ongoing efficiencies and more specifically to provide a framework for HIC's back-office operations. Back office support for the two recent international joint ventures was to operate from South Africa. Similarly the call centre service and Web development projects for the two joint international ventures were to operate locally. Therefore there was a huge drive to restructure the existing IT infrastructure so that it could support the two international expansion initiatives.

Furthermore instead of developing channels that competed with each other the focus now shifted towards integrating the different channels. The firm was attempting to merge these channels in the back-office organisation where the core operational processes were being managed. During this period new technology platforms were touted by various steering mechanisms as being able to provide web services, component based modelling, and communication for implementing a service-oriented architecture (SOA). In other words it was more plausible to achieve this level of channel integration by enrolling other ground-breaking technical allies for the recoding of existing and new functionalities into atomic services that could be reused by other services. Problems relating to front-office and back-office integration were also high on the agenda. There was also an attempt to refocus eHIC's capabilities and competencies related to this. One of the aspects that eHIC had executed particularly well on over the years was the "softer" elements of the online channel. These include "how to position, how to message, and how to design a user interface". There was an increasing need for these skills throughout the firm, including within the traditional systems environment which used to build "unfriendly" user interfaces for the internal users. As part of improving IT's overall performance, there was this notion of separating back-end and front-end development. The IT leadership team viewed this as an avenue to avoid duplication of effort and to facilitate greater alignment and matching of team priorities. In the meantime, there was a general feeling that the SST would play a more prominent role in the UK and the US markets than it had done in South Africa. Moreover, there was greater emphasis on understanding online behaviour using research houses and reporting tools. On reflecting on the evolution of the SST, one of the senior managers told us: "I think, if we look today at where we have come, our initial objective was to convert a channel (call centre) into another channel (online self-service). And lessons are learnt, that you know, this is a social environment, okay. There is no dominant channel. It's apparent to me that the channels are interlinked, merged, and one will use whatever is closest in proximity".

ANALYSIS

Technological frames are used as episodes of translation as suggested by the work of Bijker (1995) as a means for linking the enrolment process of ANT with broader social and cultural processes. The subjective nature of the Internet-based SST in this particular case gave the designers and users room

Figure 4. Self-service technology in practice: Shifting translations



to invoke three particular technological frames, from that of a channel of choice, to a channel that dazzles, to a complementary channel.

Channel of Choice

Inscription

Until 1999, the technological frame of disseminating "static content" dominated HIC's website implementation. A new technological frame for the SST to become the "Channel of Choice" or in other words the preferred channel was emerging at HIC as the ability to transact online became more plausible. At the time a rapidly growing customer base resulted in increasing capital expenditure on call centre technology. Furthermore the call centre high fixed cost base combined with the high labour cost attributed to the growing number of call centre consultants all gave strength to this internal inscription of improving service efficiency through automation. This inscription was also strengthened by the dotcom hype created by various steering mechanisms. An organising vision emerging from a heterogeneous collective consisting of the academic world, media, consultants, software vendors, and dotcom start-ups bestowed a lot of appeal upon the "substitution claim" and other "efficiency" inscriptions (Hannemyr, 2003). Swanson and Ramiller (2004) assert that this "bandwagon" phenomenon is especially prevalent where an innovation achieves a high public profile, as with the Internet and e-commerce. Planned action is typically dismissed by the urgency to join the stampeding herd, despite the high costs and apparent risk. Clearly the larger community's organising vision was the embarking point for HIC's sense making journey with e-commerce. The primary intent of HIC's e-business designers was to replace or substitute traditional channels. More specifically there was this desire to substitute the call centre consultant with the Web front-end (See Figure 3). This major inscription to take on the role of the call centre agent was based on the assumption that the self-service technology would be able to save calls by having answers to key call reasons programmed and made available on the website using the Web and related technologies.

Translating

To show support for the new channel, the leadership of the organisation provided autonomy to the self-service channel to transform the way customers interacted with the organisation and the way customers were to be serviced. Furthermore, the firm invested significantly in hardware and software such as the state-of-the-art technology in the ATG Dynamo suite of applications, which was then the leading and premium Web server technology. Other leading tools such as Documentum for document management and Verity as a search engine also formed part of envisaged solution. The firm also chose Java as the development platform instead of .NET as this was deemed to be the best technology for constructing Web applications at the time.

However there was great resistance by certain Exco members towards any attempt to sell HIC's healthcare products online. The problematisation in this scenario is overtly concerned with the power relationship between brokers and employers in the South African context. In effect, brokers sold health insurance directly to employers and employees had to select from a group of health plans as part of their "employee benefit". So as not to jeopardise the relationships with these powerful intermediaries and hence future sales, the SST initiative had to realign with the interests of these actors. For these reasons, the seduction of the Internet as a direct sales channel could not be used to coax some of the dissidents sitting on the Exco committee. The OPP towards a shared view of a service-centric online channel was established. Furthermore the lack of skills and newness of these technologies impinged on the team's ability to deliver on time, with as few "bugs" as possible and thus contributed to poor translations of eHIC. In addition, political battles being fought at other levels. After all there were fears in other areas that the role of the SST was to squash legacy practices embedded in traditional channels. The predominantly batch mode of processing between internal systems, the use of a non-standard database platform, poor data quality and integration issues also made for weak (ties) inscriptions. The internal system, a robust client-server application used by the internal operational areas for high volume data capture was at odds with the Java based application for developing Web based applications. Furthermore a number of the functionally driven applications were built as one monolithic piece of code and therefore could not be easily adopted for a component-based Web environment. As a result of the conflict between the two technologies and resultant unsteady support from both system and business departments, the implementation of the project was completed much later than envisaged. In addition the frequent system failures created a flood of phone calls to the call centre. These queries to the call centre did not help the reputation of the online service internally.

For users, interessement was positioned in the various promotions by way of convenience, secure and real-time information in various media. However the poor ICT infrastructure supplied by the monopoly telecommunications firm, the speed and cost of bandwidth, the corporate standard to verify user name and password through a call-centre validated process were major barriers to using the new system. For instance, since firms can be held liable for granting consent to users for accessing a customer's information, trust is a concept that applies equally to the firm and the user. In supporting relationships via SSTs the firm delegated trust decisions to verify and authenticate the identity claimed by the user to both human and technical systems. The SST was liable for any breaches of trust or negligence in its use. Therefore a policy for controlling access to the SST via new roles and profiles had to be established. These were stored in a database. Linked to these new identities were a variety of attributes describing specific relationships so that the SST could grant the correct privileges to the user. Many users expressed their frustration that this process was protracted.

Framing

From this discussion, it might be concluded that the translation of the actors in eHIC, the obligatory passage point (OPP), failed to achieve the desired outcome as the preferred channel or the channel of choice. The initial network and its loosely formulated OPP – "to become the channel of choice" – was readily accepted internally by a few of the key senior executives, but remained too weak to mobilise a sufficiently strong enough network to become the dominant channel. One of the reasons for this unintended outcome was that the advocates of sales via an intermediary were aligned to powerful networks inside and outside the organisation so that the vision of direct sales had to be reformulated. The loose formulation of goals such as "the preferred channel" were also naturally not sufficiently convincing for those managers and staff that represented the traditional channels the SST was attempting to substitute. More specifically, the interactions with both human and non human actors supporting the traditional channels would during this long implementation journey be more contentious than collaborative. In this spiralling innovative climate and increasingly demanding service environment as a result of rapid market growth, achieving synergy between departments would prove to be particularly problematic largely due to the various actors having to facilitate multiple and conflicting agendas. As a result negotiations were often beset by 'clashes' of interest and these conflicts often became irresolvable.

Successful translations depend on how faithful key actors are towards their alliances. Certainly, the local ICT infrastructure was not supportive of a self-servicing environment for a majority of the customers. Furthermore standards and security were impeding the Web channel when compared to alternative channels. In addition, the poor interoperability with systems designed to support internal processes and the lack of technical skills of the newly appointed development e-business team translated into unsuccessful and unstable translations between internal actors. Attempts to mobilise, expand and stablise the majority of users also turned out to be complex and frustrating. For the user, the telephone clearly had a better inscription than the web. Allied to telephone was the customer's membership card, inscribed with a membership number and telephone number, which could easily fit into a customer's wallet, as opposed to a user name and password which remained a cognitive challenge. Importantly the evolving consumer-driven healthcare product was becoming laden with jargon. Apart from understanding the Health Savings Account (HSA) mechanism and how it works, customers needed to understand a plethora of unfamiliar concepts related to the mechanics of the HSA. On the other hand a call centre consultant has the ability to retranslate these terminologies based on their impression they formulate of the client. In other words they have the "interpretive flexibility" to retranslate consumer-driven healthcare terminology to facilitate client understanding. This capacity of the human agent in this instance was beyond that of a resource such as an SST. There were simply too many things attached to the use of the call centre channel. The competing call centre channel in alliance with the frozen network element of the telephone was demonstrating features of irreversibility.

Consequently, weak inscriptions demonstrated by the allies of the SST and their inability to act in ways that maintained the network, led to the majority of customers persisting with the use of the traditional call-centre channel. Given the properties of irreversibility demonstrated by the traditional channel, there was this realisation among the senior management team that the "substitution claims" may have been farfetched.

Dazzle the Customer

Inscription

When the dotcom bomb started, the role of e-commerce in the organisation was subject to further internal evaluation. The inability to deliver the initial projects on time and the failure to convert a majority of the customers to the online channel had compromised the SST's intention to substitute the call centre and become the channel of choice. This led to a shift in strategy as well as re-organising the way that e-commerce organisation was structured to improve internal alignment as well as inter-departmental relationships. While there was still a focus on efficient servicing, major emphasis was being placed on a new paradigm that was emerging, one were the organisation sought to "dazzle users" with online tools designed to support its wellness programme. Meanwhile to get acceptance internally and externally a stronger form of enrolment was needed. The e-business was reintegrated into the IT division and was now operating as one of the many systems department. Senior Management were hoping that the closer relationships with rival systems department and a location change will resolve some of the political and alignment issues experienced during the previous phase. The "dazzle" metaphor describes the shift that reveals the second major inscription of the on line self service technology. The role of the self-service technology was fundamentally driven by the firm's new focus on its wellness offering. Within this technology frame the emphasis was on hedonic aspects as opposed to merely health plan transactional features as during the "preferred channel" era. Customers were now being incentivised to stay healthy and the wellness team was interested in establishing whether the Web could be an appropriate mechanism to promote a healthy lifestyle. Loyalty points and other forms of rewards would be offered to customers for following a healthy lifestyle with the aid of online tools.

Translating

Economist, John Kenneth Galbraith (1984) distinguishes between three kinds of power: Coercive power wins submission by inflicting or threatening sanctions; compensatory power by offering incentives and rewards; and conditioned power by changing beliefs through persuasion or education. The firm was attempting to inscribe the right mixture of these forms of power in order to resolve conflicting interests between itself and its customers. At the time, the wellness business unit was powerfully positioned and was becoming a major part of the firms' actor-network. Consequently the online channel was being viewed by business proponents of wellness as an important ally to their success. Both the wellness business unit as well as the e-business department shared similar views on the "cost savings" argument as the rhetorical device to enrol users to self-service using online wellness applications as opposed to using more costly wellness practitioners. With these redefinitions of the SST concept came shifts in the enrolment strategy of eHIC.

Framing

As the SST started to play a major role in the wellness programme it was slowly being validated internally as a novel and exciting way to interact with the clients and promote wellness. However, although HIC is known in the marketplace for offerings that are inventive, attempts to engage customers in managing their health through the online channel when compared to the size of the customer base showed only moderate success. It appears that translating the wellness innovation and engaging style to the online world appealed to only a minority of users than had been envisaged by the designers. The wellness programme itself while proving to be an effective product differentiator for the health insurer and an attractive selling point for brokers, was not effective at enrolling a majority of its customer base and effecting actual behavioural change. Many users used the points for online use in an unanticipated way. Rather than followed the assigned way of using the online channel as an obligatory approach to "improve their health", the anti-program of "points chasers" emerged as a result of the online incentives. Many users appeared to be more interested in moving statuses with minimal behavioural changes to their lifestyles to obtain incentives. The designers had been betrayed by the users they thought they were representing. With the appointment of a new head for the wellness programme, there was a "push" to drive customers towards the organisation's wellness partners. As the majority of customers showed a preference for using the call centre to resolve administrative related queries, similarly of the two networks, face-to-face consultation would prevail over the use of virtual wellness diagnosis and consultations. In the end despite moderate use by end users, the SST was an oversimplification of what wellness practitioners do. It appears for now that only "real world" wellness practitioners can deal with the full complexity of the wellness practice.

The Complementary Channel

Inscription

Eventually there was this realisation that at best the self-service tool was a complementary channel for a small captive audience. This current technological frame emerged as current social, technical and political contexts made the inscriptions for other channels stronger. During this phase there was a notable shift in alliances with the wellness team away from the SST to networks of healthcare professionals. Despite attempts by the self-service's team management to persuade key actors that wellness online "worked", the third major inscription that emerged was one in which the self-service channel was regarded as a complementary channel.

Translation

As was evident in this case the path of translation of technology is seldom smooth. There was a shift towards a physical network of partners for fitness, nutrition and stress. In a sense like the call centre channel, wellness led by health practitioners remained "black boxed". The self-service technology had lost a key ally and had to alter its conception as a key driver in the wellness programme and was now confined to a supporting role. As a result there was a definite shift in how the online wellness tool fitted into the bigger picture of the wellness programme. For one, there was this "figuring out" that the tool could not operate as a "real-world" wellness practitioner. There was still a need for a wellness practitioner-patient interaction even though there were wellness tools available online. There was also a prevailing view that the SST was one of many ways of communicating with customers. Today the wellness programme has a network of practitioners and customers seeking guidance in this area are referred to those practitioners.

Framing

The initial organisational metaphor guiding the development of the self-service channel was a "channel of choice" technological frame. Given the early furore about the Internet, it was conceived that the SST would replace the call centre consultant for a broad population of the firm's customers. When contradictory social facts emerged this frame was retranslated to "Dazzle the Customer" were the technology was used for more hedonistic purposes. Internally the drive had shifted towards novel ways of interacting with customers to promote their well-being. In its most recent translation the SST was framed as a complementary channel. In its mutation as a complementary channel, it became a stock of usability experts that could deliver front-end development expertise for the rest of the organisation including all systems and channels. Eventually the online channel itself was fully integrated in the firm's business functions. Not surprisingly the use of this technological frame evoked a less grand conclusion about the self-service technologies capabilities and led the eHIC team to become anxious about their own roles in the organisation. Many of the experienced team members left to the firm to pursue careers in other organisations.

This case reveals that a seemingly endless improvisation with its role characterises Internet-based self-service technologies. It appears that in this particular case no particular role was permanent specifically in an environment of alternative channels. As such ongoing negotiations characterises SSTs better than the 'black box' metaphor. The most recent translation as a complementary channel is likely to remain an immutable mobile for a while. After all, with this broader conception of a complementary channel, the interests of other actors could fall in with the SST's schemes without too much controversy. However in tracing the various actors it was evident that this "complementary" translation was emergent and not planned. Clearly, becoming the preferred channel and thus reducing administrative costs was the planned perspective, but many actors did not come together to make this possible.

DISCUSSION

The concept of a non-human "actant" (technology), in this case being the self-service technology and related technology allies, influencing the social context and social process on the basis of the interests and assumptions (meaning) inscribed within them, is one of the undeniable appeal for using ANT to understand web-based IT artefacts. Many researchers consider SSTs as neutral objects with no politics. ANT has demonstrated that SSTs are far from neutral or objective. As ANT has illustrated, an SST is a social construction inscribed with many bias assumptions and notions of its designers. In the case study, the designers inscribed the interests of the firm into the technology. The first dominant notion that designers locked into the SST was the notion of substituting the call centre consultant. While the use of the Web site as a replacement channel was in some respect a rational decision based on internal efficiency goals, it neglected the socially rich context of the external user and their already inscribed routines with existing traditional channels. Unlike internal users who are subjects of the governing structures of the organisation, external users appear to possess substantial discretion in their use of channels. This context of substantial "interpretive flexibility" makes the process of attracting, converting and retaining external users a major challenge for firms seeking to implement SSTs. Failing to see the intricacies of interacting with traditional channels as a social construction results in a misconception that an SST can somehow take on the role of traditional channels. Similarly delegating the role of a wellness practitioner to the channel dismissed the interpersonal roles that are so essential in a wellness practitioner-patient interaction. As a result, diversity in interpretation by different social actors and therefore what the SST "is" to these different actors. Therefore although we may talk about self-service as a singular, the identity of the SST itself is dissolved into multiplicity. After all, the SST is performed by multiple objects and subjects. The translations of managers, academics, software vendors, developers, designers, users, analysts, marketing departments, traditional healthcare practitioners, application servers, software programming languages, browser versions, joint venture partners, the health insurance membership card, the telephone, the ICT sector, traditional channels such as call centres, call centre consultants, intermediaries, dieticians, clinicians, incentive schemes all intertwine in translating the emergent outcomes of the SST.

While meaning is often viewed as a cognitive non material phenomenon, ANT asserts that meaning is shaped and inscribed in technology. According to ANT, SSTs are also subject to their social contexts for their continuous adaptations. Designers of SSTs shape SSTs but cannot control them in a deterministic way and SSTs that do not match the demands of their social contexts are unlikely to evolve in ways inscribed by designers. Furthermore SST designers have to face external users as well as internal business and traditional systems staff interests and alignments that are often contingent and unstable. ANT also reveals that the implementation phenomenon is not just socio-political but technical as well. In other words the SST demands or depends on the mobilisation of several technologies. In this case, the SST was consistently reinvented by both designers and users. The different conceptions of the SST emerged as more 'facts' about the SST was produced over time and how actors reflexively altered their stance. In this way ANT was very effective at teasing out those socio-technical relations that we need to explicate to come to terms with the role of self-service technology systems together with human actors in constituting contemporary organisations. Therefore instead of reducing ourselves to notions of success and failure, what we can say is, that the existence of the SST already makes a difference in this particular healthcare insurance context – both in planned but more so in many unplanned and emergent ways. For the SST to carry on its march further translations are needed. One could speculate that as broader social influences such as bandwidth and accessibility become aligned to the interests of the SST, the SST may find it easier to enrol future actors. However these factors alone are insufficient to mobilise users. What these translations will be only time will reveal.

CONCLUSION

This chapter demonstrates the value of ANT concepts as an analytical device to trace the meaning that actors assign and inscribe to Web-based technologies. By using concepts such as inscription, translation and framing, this chapter was able to tease out important insights relevant to the translation of an Internet-based SST. Significantly, the analysis above has demonstrated the powerful role which human and nonhuman elements can play within a long and heterogeneous network implicated in the conflicting meanings attached to an Internet-based SST. From a practical standpoint, many late implementers of SSTs can benefit by considering the use of SSTs within a broader framework that focuses on the convergence of multiple channels. Apart from ensuring closer integration between technologies implicated in the process, a convergence strategy may lead to lower resistance and hence the mobilisation of multiple interest groups within the organisation. More importantly this will enable customer empowerment in the true sense of the word, since the customer can ultimately choose the channel that best suits their circumstance in a particular moment.

Internet-based self-service technologies are beginning to change the way customers interact with firms. The increasing depersonalisation of services through self-service technologies like with all human designs is prone to both opportunities and challenges. Despite the incongruency in meanings inscribed in SSTs as the chapter illustrated, this new channel has showed a high degree of robustness and sustainability. It is rooted in inscriptions and values that is both a fundamental and an alarming feature of our society and economy. The Internet-based SSTs resilience despite its vulnerability is rooted in an interwoven social-technical web of politics and values that are beyond the Internet, designers or the users (Introna and Whitley, 1999). Therefore, instead of trailing in the shadows of superfluous notions such as success or failure, social scientists should pursue those social-technical webs that are often elusive in order to develop a better understanding of technology artefacts such as Internet-based SSTs.

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KEY TERMS AND DEFINITIONS

ANT: Actor-network theory

ATG: Applied Technology Group

eHIC: The e-commerce subsidiary of United Assurance Group

HAS: Health savings account

HIC: Health Insurance Company

ICT: Information and communication technology

IT: Information technology

OPP: Obligatory passage point

SOA: Service-oriented architecture

APPENDIX

A fieldwork design was conducted early in the research process. It was decided to interview as widely as possible among the different stakeholders of the SST project. The table does not account for informal, written or email contact with the design team during the course of the case study.

Figure A1. A snapshot of a conceptual network with nodes of memos and quotes (Note: Coding using ATLAS.ti Version, 5.0)

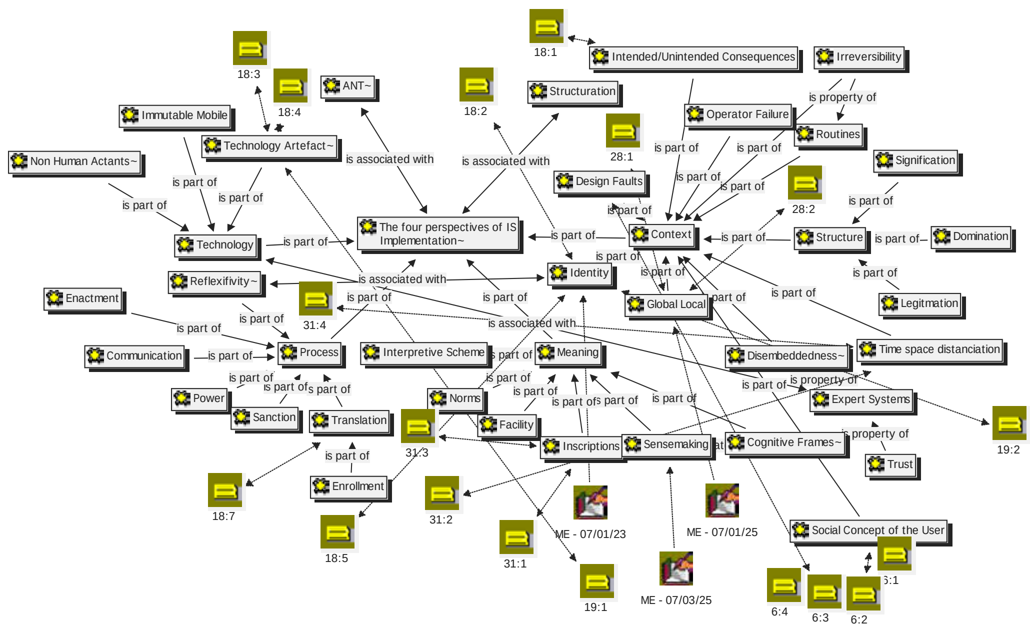


Table A1. Summary of interviews conducted with design team

	Number of Interviews				Totals	
Nature of Group	**Field trip 1**	**Field trip 2**	**Field trip 3**	**Other**	**Number of interviews**	**Number of respondents**
Management Team	1	6	7	2	15	11
Business/Systems Analysts	11		4		15	13
Usability Analysts	1			2	1	1
Java Developer	4	2	1		7	6
System Architects	5		2	1	7	7
Graphic Designers		6			6	6
Subject Matter Experts*		1	1	1	2	2
Marketing	1	1			2	2
Other		1		3	1	1
Total	23	17	15		55	49

Note: The category "other" refers to progress and clarification meetings with key stakeholders. The team responsible for "Customer intelligence" assisted in the co-ordination of the interview process. The Stress and Nutrition Experts were subject matter experts on the implementation team

Chapter XI
Semantic Annotation of Objects

Petr Křemen
Czech Technical University in Prague, Czech Republic

Miroslav Blaško
Czech Technical University in Prague, Czech Republic

Zdeněk Kouba
Czech Technical University in Prague, Czech Republic

ABSTRACT

Compared to traditional ways of annotating multimedia resources (textual documents, photographs, audio/video clips etc.) by keywords in form of text fragments, semantic annotations *are based on tagging such multimedia resources with meaning of objects (like cultural/historical artifacts) the resource is dealing with. The search for multimedia resources stored in a repository enriched with* semantic anno*tations makes use of an appropriate reasoning algorithm. Knowledge management and* Semantic Web *communities have developed a number of relevant formalisms and methods. This chapter is motivated by practical experience with authoring of semantic annotations of cultural heritage related resources/objects. Keeping this experience in mind, the chapter compares various knowledge representation techniques, like frame-based formalisms, RDF(S), and description logics based formalisms from the viewpoint of their appropriateness for resource annotations and their ability to automatically support the semantic annotation process through advanced inference services, like error explanations and expressive construct modeling, namely n-ary relations.*

INTRODUCTION

This paper has been motivated by experience gained by the authors in the course of solving the EU project CIPHER (5^{th} Framework Programme 2001-2004). The main output of the project was the Story Fountain (Mulholland et al., 2004)—a software tool providing intelligent support for story research and exploration. Story Fountain is based on a collection of semantically annotated stories and supports the user in exploring these stories, e.g. looking for similarities, finding a chain of stories, which logically connects two stories etc.

The developed methodology and tools have been tested on two story collections. The first one was devoted to the Bletchley Park. Bletchley Park is located in Bletchley (now integral part of the city of Milton Keynes, UK). It is the place where the British Government's Code and Cipher School was located during the Second World War. Nowadays, it is a museum of the code breaking work done there. The exhibition located in Bletchley Park emphasizes the influence it has had on contemporary communication and computing technology. The collection consisted of several hundreds of stories, mainly interviews with people having worked there. The other collection consisted of about 50 historical stories related to castles in Southern Bohemia, Czech Republic.

Story Fountain accepts semantic annotations expressed in a subset of Operational Conceptual Modeling Language—OCML (Motta, 1999). OCML is a frame based conceptual modeling language. See next chapter for more information on frames. A frame represents basically an n-ary relation between individuals. Hence, the modeling process is more straightforward in comparison with formalism based on description logics including at that time emerging standard OWL (W3C, 2004), which provide only binary relations and the annotation process is thus much more tedious work than in case of using frame based formalisms. This was the main reason, why OWL was not chosen as the formalism for semantic annotations at the beginning of the project.

Nowadays, OWL is a well established standard with a large community of users and developers. There exist a number of public domain reasoners and other supporting tools. For example we were missing a tool for semantic comparison of two ontologies in OCML—a kind of a semantic diff tool. In OWL environment, the availability of reasoners makes the development of such a semantic diff tool much easier. Another big problem in CIPHER was debugging of semantic annotations. If there was an inconsistency in the annotation, discovering its root was a hard problem for the author of the annotation in Story Fountain. On the other hand, description logics provide a well defined mathematical background, which makes possible to develop effective algorithms for detecting the smallest sets of inconsistent axioms.

The restriction to binary relations seems to be the only one important weak point of OWL as a formalism for authoring semantic annotations. Fortunately, there exists decidable description logic with possibility to express n-ary relations called DLR (Calvanese, 1998). DLR motivated the authors of this chapter to explore the possibility of using DLR as a primary formalism for semantic annotations with subsequent translation to OWL—a key opening the doors to the wealth of publicly available semantic web tools. The rest of this chapter deals with basic aspects of a new methodology for authoring semantic annotations using DLR and OWL based semantic web tools.

STATE OF THE ART

Semantic Networks and Frames

One of the well known knowledge representation formalisms are semantic networks. There are many particular implementations with different graphical notations and different semantics. In principal, a semantic network is a directed or undirected graph, where nodes represent concepts or individuals (instances of concepts) and edges represent semantic relations between various concepts (individuals). Typical relations are: (i) A is-a B –concept A is a specialization of concept B or an individual A is an instance of concept B, (ii) A is-part-of B meaning that B has A as part of itself, (iii) various types of associations. An interesting extension to this basic semantic network paradigm are conceptual graphs (Sowa, 1992). A simplified version of conceptual graphs was used as a basis for a graphical tool for semantic annotations (Uhlíř at al., 2005) in the CIPHER project. The user drew a conceptual graph, which was later transferred to the frame based OCML transcription. Experiments have shown that users intuitively understand better conceptual graphs than the structured expressions in a conceptual modeling language even if visualized by means of a form-based editor.

Frame-based conceptual languages mentioned above are based on the concept of frames introduced by Marvin Minsky (Minsky, 1975) as a framework for knowledge representation. According to him, a frame is *" ... a data-structure for representing a stereotyped situation, like being in a certain kind of living room, or going to a child's birthday party. Attached to each frame are several kinds of information. Some of this information is about how to use the frame. Some is about what one can expect to happen next. Some is about what to do if these expectations are not confirmed. We can think of a frame as a network of nodes and relations. The "top levels" of a frame are fixed, and represent things that are always true about the supposed situation. The lower levels have many terminals–"slots" that must be filled by specific instances or data. Each terminal can specify conditions its assignments must meet. ... Simple conditions are specified by markers that might require a terminal assignment to be a person, an object of sufficient value, or a pointer to a sub-frame of a certain type. More complex conditions can specify relations among the things assigned to several terminals.*"

The concept of frames is similar to the object-oriented paradigm. *Frames* correspond to *classes* well-known in the OO world. *Slots* correspond to *properties of classes* (data members in OO programming). *Slots* may contain *values*. The value can be (i) again a frame (corresponds to meta-class—class relationship), (ii) an individual (instance of a class) or (iii) simple data value (non-object data types like integer). The relation of frame *generalization/specialization* corresponds to *class inheritance* forming a subsumption hierarchy.

Very often it is necessary to express restrictions on slots. That is why slots have so called facets (restrictions on slots or properties of slots). Facets determine e.g. (i) type of the slot, (ii) its cardinality, (iii) if the value of this slot is obligatory or not, etc. Type facet restricts the set of all possible values of the slot to the set of values compatible with defined slot type(s). Cardinality facet determines how many values can be filled in the slot simultaneously (typically one or many).

A set of mutually interrelated classes forms a formal explicit representation of concepts in a (specific) domain of discourse. An ontology together with a set of class instances (individuals) is often called a knowledge base.

A number of particular frame representation systems aimed at expressing knowledge bases were developed in recent years like Loom (see http://www.isi.edu/isd/LOOM/LOOM-HOME.html) or **Ontolingua** (see http://www-ksl-svc.stanford.edu:5915/). In order to achieve interoperability of various knowledge representation systems, there were attempts to develop generic protocols allowing portability of application between any particular knowledge representation systems compliant with the particular generic protocol. The most famous generic protocols are GFP (Generic Frame Protocol—see http://www.ai.sri.com/~gfp/) and its successor OKBC (Open Knowledge Base Connectivity—see http://www.ai.sri.com/~okbc/).

There exist a number of tools allowing for ontology authoring. Probably the most famous is the Protégé platform (see http://protege.stanford.edu/overview/index.html) supporting two main formalisms—frames and OWL. Protégé-Frames is an ontology editor aimed at authoring OKBC compliant ontologies. There exist plug-ins for main OKBC compliant knowledge representation systems and it is possible to create own plug-ins for not yet supported OKBC compliant ones.

Logic-Based Languages

During the past decade the attention of knowledge representation community has turned from frame-based systems and semantic networks to logic oriented languages. Simultaneously, introduction of the idea of the semantic web in 2001 by Tim Berners-Lee catalyzed research efforts in the area of semantic annotation and knowledge representation the web. First significant results, Resource Description Framework (RDF) and RDF-Schema (RDFS), have been developed and standardized as a W3C Recommendation in 2004. RDF is essentially a graph representation of some domain knowledge. Figure 1 shows an example graph, each link of which represents one RDF statement in the form (*subject: S, predicate: P, object: O*). Subjects are labeled either by resources (anything that can be identified by an URI), or blank nodes (existentially quantified variables), predicates are labeled by resources and objects are labeled either by resources, blank nodes, or literals. From the RDF point of view, the graph in the Figure 1 is interpreted as 7 statements corresponding to its links, where the links labeled rdf:type have a special meaning. For example the leftmost link represents the triple (*:b* rdf:type *:X*) (all examples of RDF graphs will be given in the N3 notation) and says that a resource *http://example.com/myknowledgebase#b* is an *instance*, or a *realization* of a resource denoted by *http://example.com/myknowledgebase#X*.

RDFS complements RDF with the possibility to model simple statements about the domain structure, like class/property hierarchy and property domains and ranges. The RDF graph representation of RDF+RDFS (denoted as RDF(S)) restricts the form of described structural relations in the domain to just binary ones. Central in RDF(S) is the notion of a *class* (denoting a set of domain objects) and a *property* (denoting a binary relation over domain objects). The graph in Figure 1, viewed as an RDF(S) document, describes *:X* to be a subclass (i.e. subset) of an anonymous class *_:q* and *:q* to be a subproperty (i.e. subrelation) of *:p*. This allows an RDF(S) reasoner to deduce that *:a* is related with :d also through the relation *:p*. In addition to these (rather natural) features, RDF(S) allows to model higher order statements for example by using one resource both as a class and as an instance. Although such modeling constructs might be useful in various applications, they compromise the possibility of translation such an RDF(S) document into the first order predicate calculus. While RDF(S) is a simple language, it is a wide-spread choice for representing simple taxonomies and semantic annotations.

Together with the evolution of the semantic web and of the description logics (Baader, 2003) a family of more expressive logic based languages has been studied. First of them, DAML, was developed by the DARPA project and was subsequently extended to DAML+OIL and to OWL, which became a W3C Recommendation in 2004. The OWL language is layered into three variants according to the expressivity. The OWL-full variant extends RDF(S) with various class/property constructs well-known from description logics. Most important OWL class and property constructors (in N3 notation) involve:

- **intersection, union, complement:** "class of women students" (*Woman* and *Student)*

  _:w owl:intersectionOf (:Woman :Student) .

- **existential/universal quant:** "class of objects that have a son" (*hasChild* some *Man*)

  _:w rdf:type owl:Restriction .

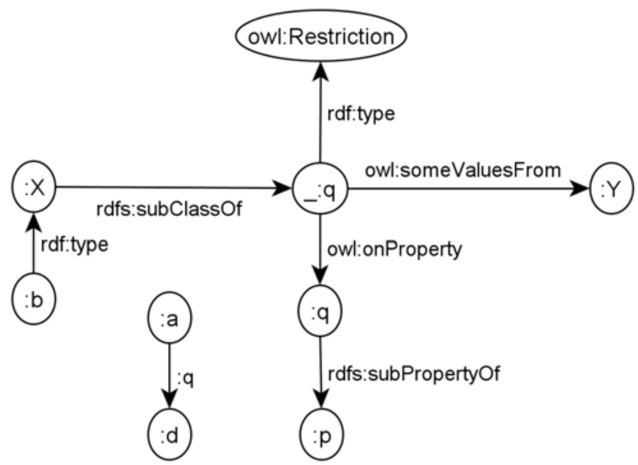
  _:w owl:onProperty :hasChild .

  _:w owl:someValuesFrom :Man .

- **min/max/exact cardinality restrictions:** "class of those objects that have exactly 3 children" (*hasChild* exactly *3*)

  _:w rdf:type owl:Restriction .
  _:w owl:onProperty :hasChild .
  _:w owl:cardinality 3 .

Figure 1. An example RDF graph. URIs in node/link labels are shortened as usual; prefix : corresponds to the namespace http://example.com/myknowledgebase#, prefix rdf: to the RDF vocabulary namespace http://www.w3.org/1999/02/22-rdf-syntax-ns#, prefix rdfs: to the RDF Schema namespace http://www.w3.org/2000/01/rdf-schema#, and prefix owl: to the OWL vocabulary http://www.w3.org/2002/07/owl#



- **nominals:** "class containing exactly two object—*John* and *Paul*" ({John, Paul})

  _:w owl:oneOf (:John :Paul) .

- **inverse properties:** ":*hasChild* is inverse of :*hasParent*". (*hasChild* subPropertyOf *hasParent*)

  :hasChild owl:inverseOf :hasParent .

Due to the correspondence to the logical calculus, each OWL knowledge base *K* consists of *axioms*, some of which are already known from RDF(S). Each axiom is represented as an atomic statement of the following form :

1. **property assertion:** „*:a* is related to *:d* through *:q*" (*q*(*a*,*d*))

   :a :q :d .

- **class assertion:** „*:b* is of type *:X*" (*X*(*b*))

  :b rdf:type :X .

- **class subsumption, equivalence, complement:** „*:X* is subclass of the class of elements that are related with *:q* to some element of *:Y*" (*X* subClassOf *q* some *Y*)

  :X rdfs:subClassOf _:q .
  _:q rdf:type owl:Restriction .
  _:q owl:onProperty :q .
  _:q owl:someValuesFrom :Y .

- **property subsumption:** „*:q* is a subproperty of *:p*". (*q* subPropertyOf *p*)

  :q rdfs:subPropertyOf :p .

- **transitive, functional, inverse functional, symmetric properties:** "property *:hasSpouse* is symmetric". (*hasSpouse* subPropertyOf *hasSpouse* $^{-}$)

  :hasSpouse rdf:type owl:SymmetricProperty .

- property domains/ranges, instance identification, and other, see (McGuinness 2004) for the full description of the OWL language.

The RDF(S) basis of OWL-full causes its undecidability due to possibility to model higher order constructs. To provide a decidable fragment of OWL-full, the OWL-DL variant of OWL language has been introduced. To stay decidable and to allow translation into first order predicate calculus, OWL-DL enforces some syntactic restrictions on an OWL document, like disallowing a resource to be used both as a class and as an instance. OWL-DL has direct correspondence to a subset of first order logic—the description logic *SHOIN(D)*. Evaluating the RDF graph in Figure 1 using the OWL-DL semantics, it can be inferred, in addition to the RDFS inferences mentioned above, that *:b* is related through the property *:q* to some (unspecified) instance of *:X*.

The least expressive variant in the OWL language family is the OWL-Lite, that disallows using some of the above mentioned OWL constructs, like nominals and general form of number restrictions trading them for more efficient reasoning (consistency checking is EXPTime complete vs. NEXPTime complete for OWL-DL). However, optimizations implemented in most state of the art OWL reasoners (see below) seem to narrow the gap between OWL-Lite and OWL-DL for real world ontologies and leave OWL-DL the most popular variant of the OWL language, at present.

Although the expressivity of the OWL language is sufficient for many applications, it still lacks some practically useful constructs that do not compromise decidability and practical tractability, like qualified cardinality restrictions and more expressive role constructors. These extensions will be present in the upcoming extension of the OWL language, called OWL 2. In addition to the enhanced expressivity, several *tractable fragments* are specified within OWL2 to support more efficient, and even polynomial, reasoning for specific applications.

Languages, such as OWL 2, based on traditional DLs do not support modeling relations of arity greater than two. If a need emerges during the domain modeling to express an n-ary relation within OWL 2, it has to be expressed using binary roles. This transformation usually loses significant information about the n-ary relations and overwhelms the semantic annotation author with a bunch of rather unintuitive concepts and relations.

These problems show the importance of the information loss analysis and of finding ways to hide this binary representation from the user as much as possible. An n-ary description logic DLR that allows for expressing relations of arbitrary arity has been introduced in (Calvanese et al., 1998). In addition to its convenience for modeling of n-ary relations in complex domains, the expressive power of DLR allows for establishing a mapping from conceptual modeling languages such as UML, EER, and ORM2 to description logics (Berardi et al., 2005; Calvanese et al., 1998; Keet, 2007).

Basic building blocks of DLR are *atomic concepts*, *atomic relations of arbitrary arity* and *individuals*. Furthermore, there are several constructors (similar to the OWL ones) for creating complex concepts and complex relations. Comparing to the OWL, complex concept/role constructs in DLR it is necessary to point to the *arguments* of an n-ary relation. In the examples below we use binary relations *hasChild*, *hasDaughter* and *hasSon* and a ternary relation *isBetween* with their natural meaning. Since there is no known correspondence between DLR and RDF(S), we provide just the abstract syntax for DLR statements and constructs :

- **class intersection, union, complement:** "class of woman students"

  Woman and Student .
- **existential quantification:** "class of individuals that have a child"

  [*$1*] some *hasChild* .
- **min/max/exact cardinality restrictions:** "class of individuals that are at most between 3 pairs of individuals"

  [*$2*] *max 3 isBetween* .

Relation constructors allow for construct complex relations from simpler ones:

- **intersection, union, complement (all arguments have to be relations of the same arity):** "binary relation of tuples between a parent and a son or daughter"

  hasSon or *hasDaughter* .
- **projection:** "ternary relation of tuples the second argument of which is of type *Person*"

  (*$2/3* : *Person*) .

Similarly to OWL, a DLR knowledge base consists of set of axioms of the following form:

- **concept inclusion axiom:** "class *Man* is a subclass of the class *Person*"

  Man subClassOf *Person* .
- **relation inclusion axiom:** "binary relation *hasSon* is a subrelation of the relation *hasChild*" (both relations have to be of the same arity)

  hasSon subRelationOf *hasChild* .
- **concept assertion:** "John is a *Person*"

  Person(*John*)
- **relation assertion:** "individual y is between individual x1 and individual x2"

  isBetween(*x1, y, x2*)

Use of relation inclusion axiom and relation assertion is restricted to only relations and tuples of the same arity.

Tools for Semantic Annotation Authoring

A number of semantic authoring tool has been developed since the late 90's of the 20th century. First interactive semantic annotation authoring tool, Knowledge Annotator, was developed in 2001 at the University of Maryland. This tool allowed the user to annotate a HTML document using a very simple annotation language SHOE. An extended version of this system , called *SMORE*, allowed more expressive annotation languages, like RDF, RDFS and DAML+OIL. Both the Knowledge Annotator and SMORE system were supposed to support semantic annotations of HTML documents with no support for semi-automatic annotation authoring and inferences. Simultaneously, in 2001, two systems were developed at the University of Karlsruhe: OntoMat-Annotizer and OntoAnnotate**.** Both of these tools allowed to annotate web pages in the DAML+OIL or OWL format and offered to the user simple support for knowledge base consistency checking, without the possibility to explain modeling errors and of (semi-) automatic information extraction. In 2001, several other systems supporting using text-mining and machine learning methods for pattern extraction were introduced. Lockheed Martin Corporation developed the AeroDAML that uses text-mining methods to generate semantic annotations into predefined linguistic DAML+OIL ontologies automatically. Another tool, MnM, was developed at the Knowledge Media Institute, Open University. Comparing to the other mentioned systems, it allows to generate and store semantic annotations directly in the annotated document. Since 2001, a bunch of project emerged, namely WebKB, Annotea, CREAM, OntoBroker and other. For an in-depth survey of semantic annotation tools, see (Gómez-Pérez et al., 2005).

The most wide-spread system for ontology development and semantic annotation authoring is the above mentioned *Protégé* tool (Protégé, 2008). It is available in two versions, a frame-based version, and an OWL version. For both of these variants a bunch of plugins is available, ranging in functionality from inference support to visualization. The OWL version of the Protégé tool can be integrated with an OWL-DL reasoner.

To facilitate inference support for creating annotations many of the semantic annotation tools are backed by an inference engine for the underlying language. We will survey shortly the best known semantic web inference engines used in connection with annotation tools. The Jena system provides an RDF/RDFS/OWL management system, which employs rule-based inference service for reasoning with RDF/RDFS ontologies and for incomplete reasoning with OWL. The most popular systems that provide a complete support for the OWL language *are Fact++, Pellet* and *RacerPro* . They are based on the highly optimized tableau-based decision procedures. Both Fact++ and Pellet could be integrated into the Protégé system, thus providing Protégé users with consistency checking, error explanations, classification and other inference services. An alternative to the tableau reasoning for a subset SHIQ of OWL2 has been introduced by the system *KAON2*, which translates the knowledge base to a disjunctive datalog program.

INFERENCE SUPPORT FOR CREATING SEMANTIC ANNOTATIONS

The problem of creating semantic annotations in any of the languages mentioned in the previous sections is a very tedious and time-consuming task. During the Cipher project (cipher, 2004) several dozens of historical narratives were annotated to facilitate an efficient search through various aspects of the historical domain, like important historical events, actors of these events and their locations. All of these concepts have different granularities (for example, each father is a special kind of man) and different attributes (for example, each historical event has some date).

To navigate the annotation creator through this (rather complex) domain structure, as well as through (typically much larger) set of annotations, it seems crucial to provide some form of automated support. Unfortunately, fully automated creation of semantic annotations of natural language documents and all types of multimedia is a complicated task that requires natural language processing and speech recognition techniques. While both of these areas are rapidly evolving during last years, they are still far from being useful without human interaction. Thus, the natural language processing and speech recognition techniques might be used just as preprocessing of the documents/multimedia resources to produce a start-up knowledge base that has to be reviewed by human. Keeping this in mind, in the rest of the paper we will deal only with semi-automatic annotation creation, i.e. with inference services of the chosen modeling language that provide significant and useful help for manual creation of semantic annotation creation.

Next paragraphs describe several convenient services, each of which addresses a different problem that occurs when creating semantic annotations. First paragraph focuses on the problem of detecting and explaining inconsistencies in the semantic annotation repository. When authoring/managing large annotation knowledge bases it occurs frequently, that some assertions in such a knowledge base are inconsistent. Unfortunately, even if such an inconsistency is detected, the user can hardly get rid of it without knowing what the causes of it are.

As presented in the previous sections modeling language families differ in their expressivity and, in particular, in their support for modeling relations of arbitrary arity—besides binary ones. Unfortunately, current state-of-the-art languages for knowledge representation in the semantic web, like RDFS and OWL, support just binary relations. The second paragraph discusses this problem and proposes several approaches for modeling relations of arbitrary arity in such cases.

Modeling Error Explanations

Informing the author of semantic annotations about inconsistencies and about reasons why these inconsistencies occur in the repository of semantic annotations is of crucial importance, especially for large repositories. Although the notion of inconsistency can be theoretically studied for frame-based systems and other formalisms that do not have foundations in logics, tracking back sources of an inconsistency in these languages is usually rather trivial and thus, we will stick our attention to explaining inconsistencies in logic-based formalisms, although some of the discussed methods will have much broader application area.

Most of the methods that deal with explaining modeling errors in an inconsistent logic knowledge base *K* focus on finding the smallest subset *K'* of *K* that is inconsistent. Providing such *K'* (usually several orders smaller than *K*) to the user helps him/her to localize the problem and solve it, e.g. by removing one of the axioms in *K'* from *K*. In general, there might be more smallest subsets *K'*, *K''*, … of *K* (also known as minimal unsatisfiable subsets, or MUSes). In this case it is necessary to make each of these subsets consistent, e.g. by removing an axiom from all of them.

Nowadays, there are three general approaches to find the subsets *K'*, *K''*, … of *K* that differ in the level of their integration to the underlying consistency checking service. The black-box methods take an arbitrary knowledge base *K* and an arbitrary inference engine for checking consistency of the language under consideration. There is a variety of black box methods, both well-known from other research areas and original ones. Here, we will briefly describe only some of them, referencing interested readers to (Křemen and Kouba, 2008) for more details.

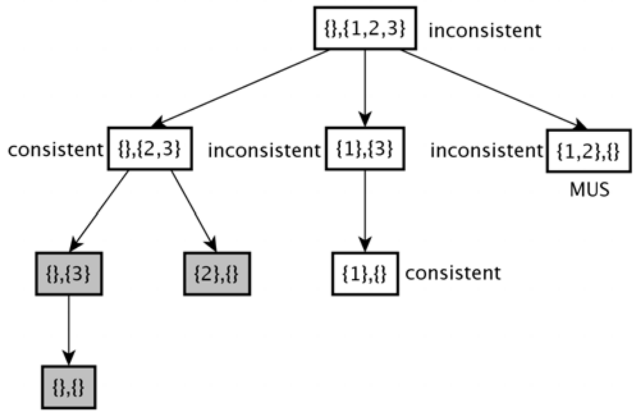
A well-known method (De La Banda, et al. 2003) for error explanations uses the notion of so called CS-tree. A CS-tree represents a search tree of all subsets of a given set of axioms. Each node in a CS-tree is of the form *D, P*, where *D* are axioms that belong to all MUSes represented by the subtree of the current node, and *P* of axioms that might, but need not belong to some of the MUSes. Each of its |*D*|+|*P*| children lacks one axiom from either *D* or *P*. The algorithm starts with all axioms in the P part of the node, leaving D empty. The algorithm traverses the CS-tree in the depth-first manner, performing one consistency check at each explored node. If the explored node is consistent, then all of its children are pruned (consistent knowledge base has only consistent subsets). Whenever an inconsistent node without children (or with only pruned ones) is reached, it corresponds to a MUS and the search backtracks. CS-tree algorithms might be augumented with additional pruning heuristics, constraint set partitioning and eliminating always satisfiable constraints, see (De La Banda et al., 2003) for more details. As an example let's take an OWL-DL knowledge base containing 3 axioms (written in DL-notation):

1. *Car* subClassOf *Vehicle* and *(hasWheel* exactly *4)*
2. *(Car* and *(hasWheel* exactly *3))(myVelorex)*
3. *(Car* and *hasWheel* only *Nothing)(justCar-Body)*

The algorithm to find these MUSes automatically traverses the CS-tree as depicted in Figure 2. The inconsistency of the knowledge base is represented by the root node. Then, 3 possibilities are checked (3 successors of the root): either axiom 1 is certainly not in the MUS (left branch), or axiom 2 certainly does not belong to the MUS, while axiom 1 certainly does (central branch) , or both axioms 1 and 2 certainly belong to the MUS, and axiom 3 certainly does not (right branch). In the right branch ,the set of axioms {2,3} turns out to be consistent and subsequent branches (shown in gray color) need not be tested. In the very same manner the rest of the tree is traversed and the MUS {1, 2} is found (there is one more MUS {2, 3} for this knowledge base).

Although various optimizations and heurstics could be used to prune the search space, the problem of computing all MUSes has exponential complexity, in the worst case.

Figure 2. An example of a conflict set tree



On the other hand, users of annotating tools might not need all MUSes at a moment. Instead, a single MUS, that localizes one of the modeling errors, may be sufficient. The reparation procedure is then incremental—a single MUS is found, the user fixes it and if the resulting KB is still inconsistent, the procedure is repeated. There is a simple method (Schlobach, 2005) for computing a single MUS with polynomial complexity. In the first phase, this algorithm starts with an empty set *S* and fills it with all available axioms one by one until it becomes inconsistent. In the second phase, each axiom is conditionally removed from *S*. If the new *S* turns satisfiable, the axiom is put back. The resulting set of axioms is a MUS. For more details, see (Schlobach and Huang, 2005).

More detailed survey of applications of black-box methods to error explanations is given in (De La Banda et al., 2003). Although their wide reusability, black-box methods typically suffer, especially when used with expensive consistency checking procedures, with poor scalability, see (Křemen and Kouba, 2008) for more details.

While black-box methods do not need to know any details about internals of the underlying consistency checking procedure, *incremental methods for error explanation* additionally need access to the consistency checking algorithm state and restoring the originally saved state. This slightly refined interface to the reasoned allows us to avoid repeated generation of the internal state structure, for example a completion graph in case of a tableau algorithm. An interesting approach to compute all MUSes is presented in (De La Banda et al., 2003). It proposes to search through a tree, that is a generalization of the CS-tree described above. In addition to the D and P sets, each node contains also a set *T* that represents axioms from $D \cup P$, such that D ∪ T is satisfiable, and sD, sT—states of the reasoner corresponding to the sets of axioms D, resp. T. To find all MUSes, this tree is searched in the depth-first manner, performing several incremental tests at each node, stopping whenever an inconsistency occurs. In an analogous way to the black-box methods, (Křemen and Kouba, 2008) presents an optimization of this method and a method for computing a single MUS using the incremental techniques. All incremental methods require, in general, more interactions with the reasoner than the black-box ones, but these interactions/consistency checks are usually much cheaper. Thus, the performance is typically several times better (Křemen and Kouba, 2008) than the performance of black-box methods.

The most efficient type of error explanation techniques are *glass-box methods*, i.e. methods that are fully integrated into the consistency checking service itself. Currently, to the best of authors' knowledge, there is a lack of glass-box techniques for most of the expressive logic-based languages (including OWL). Let's briefly introduce a glass-box technique (Schlobach and Huang, 2005) for the description logic *ALC* (Baader et al., 2003). Consistency of an ALC knowledge base is typically checked with a tableau algorithm implementation. The explanation extension of the consistency checking procedure keeps the history of the generated candidate models (completion graphs) to track dependencies of the generated assertion to the axioms. Whenever a clash occurs in a completion graph, all axioms corresponding to the clashing concepts are output as the explanation for the clash. Direct extension of this idea (Kalyanpur, 2006) to the language OWL-DL is incomplete, due to the interaction of the tracked dependencies with tableau expansion rules for OWL-DL, so that it can be used only as a (usually quite efficient) preprocessing step. After the preprocessing the resulting axioms have to be handled using one of the incremental/black-box techniques mentioned above.

Expressive Modeling Constructs

In July 2004, W3C addressed the OWL shortcoming of expressing relationships of higher arity in a Working Group Note (Noy and Rector, 2006). The document describes two different ontology design patterns to represent n-ary relations in semantic web languages RDF(S) and OWL. First of the techniques is useful in situations where n-ary relations have fixed number of arguments, while the second one describes relations that are much like lists or sequences of arguments. In this paragraph, we will concentrate on the first case - relations of fixed arity. We show that there are cases for which the rather light-weight solution suggested in (Noy and Rector, 2006) is not sufficient and propose a correct solution based on reification of DLR first introduced in (Calvanese, 1998). At the end we show how this transformation can be used in semantic annotation authoring tools.

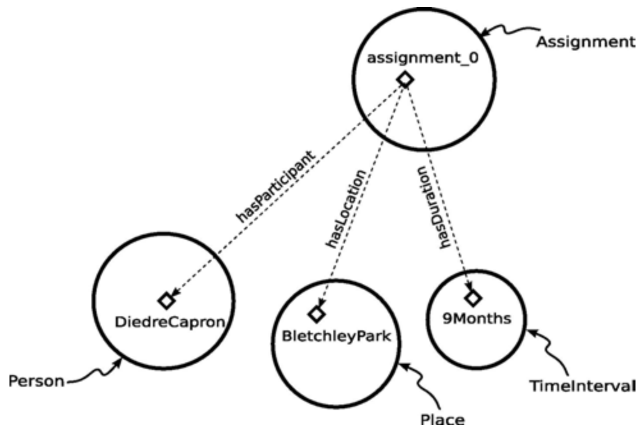
The document proposes to model n-ary relations with fixed number of arguments by so-called *reification*. The main idea behind *reification* is that n-ary relations are represented by fresh atomic concepts and as many roles as is the arity of the relation. A tuple of the relation is represented as an instance of the fresh concept and it is linked via dedicated roles to individuals representing the components of the tuple.

There are three different use cases of the reification pattern defined in the document. Each of them explains how dedicated roles should be connected to reified relation and what additional conditions should be applied along these roles. First two use cases address situations in which there is one argument of the relationship that acts as a subject or an "owner" of the relation. The third use case describes a situation in which all participants of the n-ary relation are equally significant. Let's consider an example about the person Deidre Capron who has worked on an assignment in Bletchley Park for 5 months. Such knowledge can be modeled by introducing a new concept *Assignment* that represents the reified version of the relation *work* and new roles *hasParticipant*, *hasLocation*, and *hasDuration* that connect instances of the *Assignment* concept to the components of the relation, as depicted in the Figure 2. For the sake of this example, we specify that each assignment has exactly one participant, location and duration.

Properties of the reified relation *work* are captured by the definition of concept *Assignment*, i.e. it is stated that each individual of the concept is connected to exactly one individual for each of three roles (e.g. for role *hasLocation* it could be expressed by axioms *Assignment* subClassOf *hasLocation* some *Place*, *Assignment subClassOf hasLocation* max *1*).

In order to complete our goal to represent n-ary relation work correctly, without an in-

Figure 3. Reification of ternary relation work according W3C ontology design pattern. Individuals are represented as diamonds, concepts are represented as circles and roles are represented as dashed lines connecting two individuals with arrow-head pointing to the role second argument



formation loss, there is one missing constraint that concept Assignment has to satisfy. In the Figure 3 individual assignment_0 represents tuple <DeidreCapron, BletchleyPark, 9Months>. However, there is no constraint that would rule out another individual (e.g. assignment_1) different from assignment_0 to represent same tuple. This problem of reified relation is refered to as tuple-admissibility problem. We say that reified relation is tuple-admissible if it is interpreted as set of tuples and thus the reification concept contains only one representative for each instance of a tuple. Solution to tuple-admissibility problem goes beyond the scope of the W3C document for defining n-ary relations.

Another interesting work on reification of n-ary relations can be found in (Calvanese, 1997). In the work, Calvanese used DLR to solve query containment problem (QCP). Part of the solution of QCP was satisfiability problem of DLR which was translated and delegated to satisfiability problem of CIQ DL knowledge base. Since there was no implementation of reasoner based on CIQ DL, Calvanese at al. solution did not lead to practical decidability. To overcome this problem, (Horrocks et al., 2000) introduced slightly different mapping of QCP to DLR and translated it to satisfiability problem of the description logic SHIQ knowledge base that is a strict subset of the OWL 2 language. This tuple-admissible transformation works as follows:

For each arity *i* of relations occuring in original DLR knowledge base (KB), a concept T_i is defined that corresponds to all reified tuples of the arity *i*. T_1 corresponds to concept of all simple individuals. Next, new functional roles f_i are introduced to represent i-th component of reified tuples (f_i functional). The interpretation domain of reified couterpart is defined as a union of all concepts T_i (T subClassOf T_1 or T_2 or … or T_{max}) that are mutually disjoint by its definitions. Each T_i contains only individuals that are connected to exactly *i* individuals (components of a tuple) of concept T_1, each by a dedicated functional role f_i:

T_i equivalentClass f_1 some T_1 and ... and f_i some T_i and f_{i+1} only *Nothing*, f_i only *Nothing* subClassOf f_{i+1} only *Nothing.*

In addition, it is stated that each reified counterpart of an atomic concept and an atomic relation of arity *i* is subconcept of T_1 and T_i respectively.

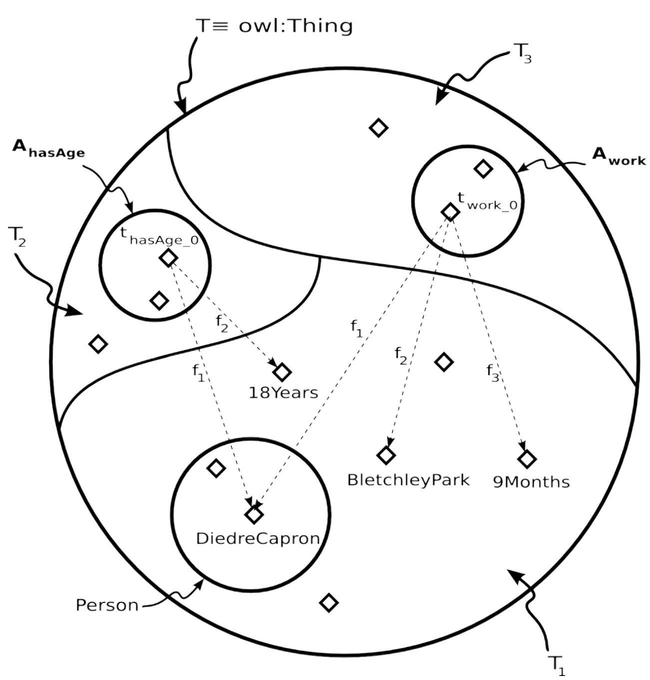
With such a structure of binary knowledge base it is proved that each DLR inclusion axiom can be strightforwardly transformed to equivalent axiom of reified couterpart without compromising tuple-admissibility.

From the semantic annotation point of view, it is interesting to pinpoint, how DLR assertion axioms are transformed to the binary representation. For each asserted tuple occuring in original DLR knowledge base a new individual is introduced along with an axiom that ensures uniqueness of this tuple representative and thus supply tuple-admissibility of reified relation. DLR concept assertions are transformed directly to concept assertions of reified counterpart. DLR relation assertions of arity *i* are transformed to a concept assertion, which states that tuple representative belongs to reified counterpart, and *i* role assertions, which state that tuple representative is connected to its components.

For demonstration of the transformation we extend our example n-ary knowledge base about Deidre Capron to contain binary relation *hasAge* and a fact that Diedre Capron is 18 years old. The structure of reified counterpart according to Horrocks is shown inFigure 4. In the figure, super concept of all concepts (T) is divided into three disjoint subconcepts T_1, T_2, and T_3. DLR relations *hasAge* and *work* are reified to concepts A_{hasAge} and A_{work} that are subconcepts of T_2 and T_3 respectively. For the triple *<DeidreCapron, BletchleyPark, 9Months>* a new individual t_{work_0} is introduced and linked through roles f_1, f_2, f_3 to the corresponding components of the triple. In much the same way a new individual t_{hasAge_0} is linked to *DeidreCapron* and *18Years* by roles f_1 and f_2 respectively.

There is a limited support for expressing n-ary relations in OWL in most semantic annotation tools. The well known ontology editor (Protege, 2008) contains a wizard for creating n-ary relations according to the W3C design patterns. The main benefit of the wizard is that it unifies common tasks in creation of n-ary pattern and helps user to specify similiar names for some components of the pattern by specifying prefixes and suffixes

Figure 4. Reification of DLR knowledge base about Deidre Capron (according to Horrocks et al.)



of new OWL entities. Major disadvantage of this approach is that after completing the wizard, the ontology editor produces the corresponding OWL axioms directly and throws away the information about the correspondence between an n-ary relation and its reified counterpart .

Thus, there is no way to change already created ontology pattern in a systematic manner (e.g. change all prefixes of similiar components without changing each of them separately) or provide other extended functionality to the editor that makes use of the n-ary nature of the knowledge (e.g. in definition of an n-ary relation assertion the ontology editor could provide slots for all individuals of the assertion without having to define tuple representative or its relationships to all individuals of the assertion).

Our current research in n-ary relations focuses on the use of a simplified version of DLR for semantic annotations of documents. Consistency of the annotations can be checked in OWL 2 after performing the reification of n-ary relation assertions, as explaining earlier, which facilitates the use of other, more advanced, inference services that can be reduced to the consistency checking problem of a DL knowledge base.

One of such advanced services is error explanations, as described in the previous section. The explanation of inconsistencies in a DLR knowledge base is a bit more complicated than in the binary case. DLR can be again reified to OWL ontology, however, after finding MUSes in the ontology, we need to transform the result back into DLR to present it to the user. For this purpose we developed transformation from reified OWL ontology back to DLR knowledge base. This can be done thanks to advanced annotation capabilities of OWL2. In OWL2 it is possible to annotate each OWL entity (i.e. class, property or individual) using a rich annotation system. When transforming DLR to OWL, the annotations can be used to keep extra information the reification process that is used back in the reverse transformation. Note that added annotations does not alter semantics of OWL knowledge base and that using the transformation from OWL to DLR it is possible to keep all anotations in the OWL ontology. This technique could also be a direction for future work and integration within ontology editors like Protege.

CONCLUSION AND FUTURE WORK

This chapter discusses some of the most important problems that occur when creating semantic annotations of multimedia/textual resources during the CIPHER project. First, relevant formalisms, like frames, semantic networks and description logics, are introduced. The above discussion shows why the latter is considered the most advantageous choice for creating semantic annotations. In spite of the difficulties of description logics to model n-ary relations, they provide a well-defined semantics that opens the door to advanced and useful services, like modeling error explanations. The subsequent sections present the state of the art in error explanation techniques for OWL Web Ontology Language and the possibility of solving the problems with modeling n-ary relations in OWL.

The problematic of creating semantic annotations is very complex, thus leaving this chapter necessarily incomplete. Practical tools that support creating annotations will certainly exploit the data mining and pattern extraction techniques to guide the user during the annotation process, based on the annotation patterns the user has created so far. Another important point is the support for macros—n-ary relation transformation presented above can be considered as a special case of such macros. Last but not least, it might be useful to preprocess the multimedia resources/documents with some application specific techniques. For example, the natural language processing techniques might provide a first starting set of annotations that is later edited by the user.

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KEY TERMS AND DEFINITIONS

Description Logics: A family of decidable logic based knowledge representation formalisms that is a basis for the current semantic web technologies.

Error Explanation: A complex inference service, that provides the user of a semantic annotation tool with a concise explanation of given modeling problem, like the knowledge base inconsistency.

Frames: A knowledge representation paradigm that allows to group knowledge into logically interrelated pieces—frames. It is close to the object-oriented technology.

Knowledge Base: A common repository of semantic annotations to facilitate a fast and efficient search in the given set of resources. Binding a knowledge base to an ontology gives the semantic meaning to the annotations according to the domain structure described in the ontology.

Ontology: A conceptual model of the domain under consideration. It defines the structure of the domain, by the specification of the relevant concepts and structural relations between them.

Reification: A process of converting an n-ary knowledge into the binary one.

Semantic Annotation of a Resource: The process of enriching a resource (text, multimedia) with tags, the meaning of which is specified in the chosen ontology. The main purpose of this process is to provide a structure to—formerly unstructured or semi-structured date—to enable an efficient searching in the resource repository.

Chapter XII
Web Services Automation

L. Koumakis
Technical University of Crete, Greece
Foundation for Research and Technology–Hellas (FORTH), Greece

V. Moustakis
Technical University of Crete, Greece
Foundation for Research and Technology–Hellas (FORTH), Greece

G. Potamias
Foundation for Research and Technology–Hellas (FORTH), Greece

ABSTRACT

Web services revolutionize use of information systems and to some extent academic research. Put it simply, web services come in small pieces of software, which can be put together to address complex tasks over heterogeneous and distribute data sources. In doing so, services represent an effective solution to isolated software integration. Web services are based on standards; HTML is used as communication protocol layer and XML is used as basic language. Web service composition and orchestration is not trivial. Representation of a human inquiry to an efficient orchestra of services must pass from a translation step, made possible via the use of metadata, which carry real world semantics. To this end, semantic web services denote intention to provide additional information about, and to facilitate, individual service integration and automatic composition. The chapter presents a concrete methodology to support the use of automatic composition of complex semantic web services with natural language. Web service semantics are linked with natural language processing capabilities to empower users to write descriptions in their own language and in the sequel to have these descriptions mapped automatically into a well tuned web service orchestra.

INTRODUCTION

A web service (WS) is defined by the W3C as “a software system designed to support interoperable Machine to Machine interaction over a network Web services add a new chapter to the success story of semantic web standards. Open standards, like XML, foster universal exchange of information over internet. WS technology adds universal interchange ability and thus universal availability of application logic. Web services represent the second generation of internet tools to connect people to things they are dealing with. They are not connecting people with html web pages; they are connecting their business applications with those of their colleagues, customers, partners and suppliers. Web services could in fact revolutionize the way we develop applications like the internet itself changed our life.

The use of standards has come up as essential part from the first steps of WS technology. Standards are pre-requisite for interoperability. Users want their web services to link and interact with those of their partners and colleagues in a standardized way, yet, personalized to their needs and preferences. The launch of XML opens new avenues for a completely new type of interoperability of software across networks. The desire to use each other’s applications in order to develop new ad-hoc services and appliances is within reach.

Unfortunately semantic web standards cannot solve all the problems that appear in web services. Even though they support interoperability, the development of large and complex domain-specific applications still remains complicated and time consuming.

Interchange availability of web services does not signal automatic pathway to new horizons in designing IT-based business processes. Real applications emerge from a complex and dynamic composition of a number of web services. Almost all business processes span beyond the boundaries of single operation and cross over organizational boundaries.

Choreography and orchestration languages come to fill in that gap and to address the middle layer where atomic services are integrated. An orchestration language (such as Business Process Execution Language) specifies an executable process that involves message exchange with other systems, such that the orchestration designer controls the message exchange sequences. Choreography language specifies interactions and message exchanging through web services in a way to support interoperability and defines legal sequences and interactions among them. Choreography gives the flexibility to the user to select from many different interactions that comply with the language definitions.

The orchestration and the choreography distinctions are based on analogies: orchestration refers to the central control (by the conductor) of the behaviour of a distributed system (the orchestra consisting of many players), while choreography refers to a distributed system (the dancing team) without centralized control.

Technologies related to web services such as SOAP, UDDI and WSDL provide limited support to service discovery, service matching, choreography, orchestration and generally in the process of automated service composition. Furthermore the key actors, the experts of these processes, are not IT experts who nonetheless have to be involved in the design of business processes.

Natural language (NL) by itself is not appropriate for programming, but reference to NL is a key factor for the design of program instructions that are both machine-ready for processing and understandable to humans. For information retrieval and speech recognition systems NL reference is essential and aspect-oriented programming shows how powerful program organizations can be realized based on instructions and structures expressed in NL.

In a WS environment, services are propagated and identified through descriptions. To avoid ambiguity the descriptions have to be linked correctly into a coherent context map that allows, at the same time, to locate the required service. Semantic annotations such as domain ontologies or even simple control vocabularies related to a specific category are objects of coordination that can be communicated. The use of information retrieval methods can map the UDDI and WSDL descriptions to domain language objects. From a different angle this solution resembles the current successful application of NL processing in speech recognition systems where command languages are combined with NL processing interfaces to provide for robustness.

The objective of this chapter is to expand semantics used for web services by NL processing capabilities and enable users to write descriptions in their own language which can be transformed automatically into web service semantics. An integrated infrastructure, in a closed word, can give solutions to NL queries using web services.

An integrated environment, in a close world, can translate NL descriptions to specific queries, find relevant web services, orchestrate, choreograph them and return the desired results to the end user. Such a system hides complexity from the end user, for instance the complexity associated with XML, SOAP, UDDI, WSDL, BPEL and gives the opportunity to non IT people to benefit from web services. In the business area enterprises would lease each other's server-side applications over the Internet and would plug into each other and do business over the wire, on the fly. Software companies co-operate on the fly and provide ad-hoc solutions that integrate their customers' business processes.

In the following section we overview the background technologies (section 3) which are essential for the automatic composition of web services. In section 4 we analyse the methodology for a successful automatic web services composition. In section 5 we discuss the related work and conclude the chapter and discuss areas for further work (section 6) on the web services automation.

BACKGROUND

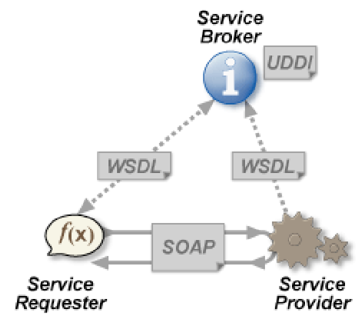
A lot of effort has been done for the standardization of the processes and the messages that enable interoperable integration between heterogeneous IT processes and systems. In next sections we focus on the existing standards about web services, semantics, business process execution language and natural language. In section 3.1 we discuss the service oriented architecture. Section 3.2 and 3.3 focuses on web services standards, and on standards about semantics and ontologies for web services respectively. In section 3.4 we discuss business process execution languages for web services and in section 3.5 we discuss natural language processing.

Service Oriented Architecture (SOA)

SOA (OASIS 2006) is an architectural style whose goal is to achieve loose coupling among interacting software agents. Service is a component which aims to fulfil a specific work for a service consumer. It's an architectural paradigm that can be used to build infrastructures enabling those with needs (consumers) and those with capabilities (providers) to interact via services across disparate domains of technology and ownership.

Services are the core components of software applications which require a good orchestration in order to function properly. Several new trends in the computer industry rely upon SOA as the enabling foundation. Trends include: automation of Business Process Management (BPM), composite applications (applications that aggregate multiple services to function), or new architectural and design patterns generally referred to as Web 2.0.

Figure 1. Web service architecture



Web Services (WS)

WS are frequently just web APIs that can be accessed over a network, and executed on a remote system hosting the requested services.

WS can be used to implement a service-oriented architecture. A major focus of WS is to make functional building blocks accessible over standard internet protocols that are independent from platforms and programming languages, to be self-contained, self-describing, modular applications that can be published, located, and invoked across the web. WS perform functions, which can be anything from simple requests to complicated business processes. An example of the WSs architecture is shown in Figure 1.

WS have showed the way to the formation of numerous standards and of industrial and academic consortia. WS are indeed useful for easier, faster integration, good in terms of return of investment, establishing friction free markets, and rapid value added assembly of services. WS represent an environment in which developers use components with well defined units of business logic and data access that can be assembled, at run time, to enable a business process. However, some of the inherent problems of e-business like scalability and semantic interoperability are not solved by the service-oriented architecture provided by WSs. A WS offers a specific business function to applications provided by another application via standard internet protocols (XML, SOAP, WSDL, and UDDI. In the next sections we describe the SOAP, WSDL and UDDI protocols.

Simple Object Access Protocol (SOAP)

SOAP is an XML protocol for information exchange in a decentralized, distributed way. SOAP consists of three parts: the envelope which defines a framework for describing what is in a message and how to process it, a set of encoding rules for expressing instances of application-defined data types, and a convention for representing remote procedure calls and responses.

Web Services Description Language (WSDL)

The WSDL (WSDL) defines services as collections of network endpoints, or ports. A WSDL specification provides an XML format for documents for this purpose. WSDL handles set of ports, port types, operations and messages. A port is defined by associating a network address with a reusable binding, and a collection of ports define a service. Messages are abstract descriptions of the data being exchanged, and port types are abstract collections of supported operations. The concrete protocol and data format specifications for a particular port type constitute a reusable binding, where the operations and messages are then bound to a concrete network protocol and message format. WSDL describes the application programming interface to a WS.

Most of the times WSDL is used with SOAP and XML schema to publish WSs over the network. A client program connecting to a WS can read the WSDL to determine what functions are available on the server. Any special data types used are embedded in the WSDL file in the form of XML schema. The client can then use SOAP to actually call one of the functions listed in the WSDL.

Universal Description, Discovery and Integration (UDDI)

UDDI (OASIS UDDI, 2002) allows the discovery of potential business partners on the basis of the services they provide. Each business description in UDDI consists of a businessEntity element that describes a business by name, a key value, categorization, services offered (businessServices) and contact information for the business. Each businessService element contains descriptive information such as names and descriptions, and also classification information describing the purpose of the relevant WS. Using UDDI, a WS provider registers its advertisements along with keywords for categorization. The user retrieves advertisements out of the registry based on keyword search. So far, the UDDI search mechanism relied on predefined categorization through keywords, but more recently specifications to use OWL in UDDI are emerging as a uniform way to express business taxonomies.

Semantics and Ontologies for Web Services

Description of metadata is a key to semantic web and pillar technologies, which support description, are RDF and OWL. RDF is a data model for referring to objects ("resources") and how they are related. Such a model is usually represented in XML syntax. RDF Schema is a vocabulary for describing properties and classes of RDF resources, with a semantics for generalization-hierarchies of such properties and classes. OWL adds extra vocabulary to describe properties, classes, and relations between classes.

In the area of the Semantic Web Services (SWS) there are various technologies and standards relevant to the semantic description of WSs like OWL-S (described in 3.3.1), SAWSDL (described in 3.3.2), Dublin core metadata (described in 3.3.3) WSDL-S (described in 3.3.4), SWSF (described in 3.3.5) and WSWO (described in 4.4.6).

Semantic Markup for Web Services (OWL-S)

OWL-S (OWL-S: OWL-based Web Service Ontology), formerly DAML-S, builds on top of OWL and allows for the description of a WS in terms of a Profile, which tells "what the service does/provides", a process model, which tells "how the service works", and a grounding, which tells "how to access the service" (Martin D &, Paolucci M. & McIlraith S. & Burstein M.,2004). The service profile describes what is accomplished by the service, limitations on service applicability and quality of service, and requirements that the service requester must satisfy in order to use the service successfully. The process model gives details about the semantic content of requests, the conditions under which particular outcomes will occur, and, where necessary, the step by step processes leading to those outcomes. In the process model a service can be described as an atomic process that can be executed in a single step or a composite process that, similar to a workflow, can be decomposed in other processes based on control structures like 'if-then-else' and 'repeat-while'. Finally, grounding descriptions supply information about the communication protocol and other transport information (such as port numbers) and the message formats and serialization methods used in contacting the service. The only currently specified grounding mechanism is based on WSDL 1.1 and has been extended to WSDL 2.0.

Semantic Annotations for WSDL

Semantic Annotations for WSDL and XML Schema (Semantic Annotations for WSDL and XML Schema, 2007) define how to add annotations to various parts of a WSDL document such as input and output message structures, interfaces and operations. The extension attributes defined in this specification fit within the WSDL 2, WSDL 1.1 and XML Schema extensibility frameworks.

For example, this specification defines a way to annotate WSDL interfaces and operations with categorization information that can be used to publish a WS in a registry. The annotations on schema types can be used during WS discovery and composition. In addition, SAWSDL defines an annotation mechanism for specifying the data mapping of XML Schema types to and from ontology; such mappings could be used during invocation, particularly when mediation is required. To accomplish semantic annotation, SAWSDL defines extension attributes that can be applied both to WSDL elements and to XML Schema elements. The semantic annotations reference a concept in ontology or a mapping document. SAWSDL is independent of the ontology language and this specification requires and enforces no particular ontology language. It is also independent of mapping languages and does not restrict the possible choices of such languages.

Dublin Core Metadata

The Dublin Core metadata element set (DCMI, 2009) is a standard (NISO Standard Z39.85-2001 and ISO standard 15836:2003) that provides a simple and standardized set of conventions for describing networked "resources" through a set of elements such as 'Creator', 'Subject', 'Title', 'Description', and so on. Dublin Core is widely used to describe digital materials such as video, sound, image, text and composite media like web pages. Implementations of Dublin Core are typically XML and RDF based.

Web Service Semantics (WSDL-S)

WSDL-S is a means to add semantics inline to WSDL. It is actually an extension to WSDL 2.0 but can be used for WSDL 1.1. According to WSDL-S inputs and outputs of WSDL operations are annotated with domain concepts while the operations themselves are annotated with preconditions and effects (post conditions). Also the service's interface is annotated with category information which could be used while publishing services in registries such as UDDI. The semantic domain model used is external to these annotations and could be expressed in OWL or other ontology language of choice.

Semantic Web Services Framework (SWSF)

SWSF (Semantic Web Services Framework), initiated by the semantic WSs initiative (http://www.swsi.org/), includes the Semantic Web Services Language (SWSL) and the Semantic Web Services Ontology (SWSO). SWSL is a logic based language for specifying formal characterizations of WS concepts and descriptions of individual services. SWSO is ontology of service concepts defined using SWSL and incorporates a formal characterization (or the "axiomatic definition") of these concepts in first-order logic.

Web Services Modelling Ontology (WSMO)

WSMO defines the modelling elements for describing several aspects of Semantic Web services. These elements are Ontologies, which provide the formal semantics to the information used by all other elements, Goals which specify objectives that a client might have when consulting a WS, WSs that represent the functional and behavioural aspects which must be semantically described in order to allow semi-automated use, and mediators that are used as connectors and they provide interoperability facilities among the other elements. It also defines the Web Service Modelling Language (WSML) which formalizes WSMO and aims to provide a rule-based language for the Semantic Web.

BPEL for Web Services

The Business Process Execution Language for Web Services (Web Services Business Process Execution Language Version 2.0, 2007) is an XML language for describing business process behaviour based on WSs and business interaction protocols. The BPEL workflow description language supports flow control, variables, concurrent execution, input and output, transaction scoping/compensation, and error handling.

Each BPEL document specifies the behaviour of a business process. BPEL processes often invoke WS to perform functional tasks and can be either abstract or executable.

- Abstract processes describe inputs, outputs and act like application programming interfaces for processes. They also provide a description of what a process does.
- Executable processes do the "heavy weight lifting"—they contain all of the execution steps that represent a cohesive unit of work.

A process consists of activities connected by links. (A process sometimes only contains one activity, which is usually a container for more activities.) The path taken through the activities and their links is determined by many things, including the values of variables and the evaluation of expressions.

The starting points are called start activities. When a start activity is triggered, a new business process instance is created. From then on, the instance is identified by data called correlation sets. These data uniquely identify a process, but they may change over time. For example, the correlation set for a process may begin as a purchase order number retrieved from a customer order. Later, when an invoice is generated, the correlation set may be the invoice number.

BPEL is layered on top of other Web technologies such as WSDL, XML Schema, XPath, XSLT, and WS Addressing.

With the introduction of WS, terms such as "web services composition" and "web services flow" were used to describe the composition of WSs in a process flow. More recently, the terms orchestration and choreography have been used to describe this.

WS orchestration or choreography languages address the middle layer where atomic services (or operations) are integrated for more complex applications. In the following sections (3.4.1 and 3.4.2) we analyse choreography and orchestration of WS.

Choreography

Choreography deals with the message passing and the sequence between customers, suppliers, partners and anybody who is involved with the WSs. Choreography is typically associated with the public message exchanges that occur between multiple WSs, rather than a specific business process that is executed by a single party.

Web Services Choreography Language (Web Services Choreography Description Language) describes collaboration protocols of cooperating WS participants, in which services act as peers, and interactions may be long-lived and stable. WS choreography leverages the power of WSs to allow entities to create business processes that mirror today's dynamic and ever-changing business needs. Organizations can expose their application software and resources as WSs so that others can dynamically find and use them in their business processes. WS-Choreography addresses the vision of true WS coordination and collaboration by providing practical models for dynamic, reusable and scalable process compositions and choreography, addressing technical completeness, correctness, and execution issues, enabling more

Figure 2. Choreography

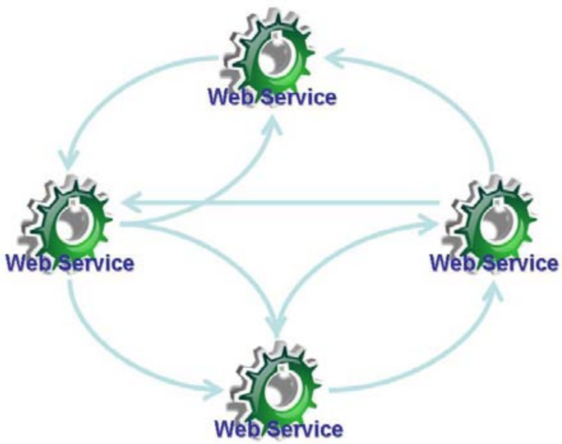


Figure 3. Orchestration

dynamic, semi-automated composed processes and enabling the incorporation of semantics.

Orchestration

Orchestration describes how WSs can interact with each other at the message level, including the business logic and execution order of the interactions. WS orchestration is the success story of SOA applications.

The SOA community has produced various competing specifications for WS orchestration. The Business Process Management Language for Web Services (BPML4WS) was the first mature specification available. BPEL4WS is a specification that models the behaviour of WS in a business process interaction. BPEL4WS is based on XML grammar for describing the control and the logic required to coordinate WSs in a workflow environment. BPEL4WS can be interpreted and executed by an orchestration engine, which is controlled by one of the participating parties. Industry has almost unanimously adopted the BPEL4WS orchestration description. One of the main drawbacks of BPEL4WS is the need for intensive human-tool interaction and in some cases the need for manual programming efforts.

Another promising standard proposal for WSs orchestration is WSCI. WSCI only describes the observable or visible behaviour between WS. In contrast to BPEL4WS WSCI, does not handle the definition of executable business processes. Furthermore, a single WSCI document only describes one partner's participation in a message exchange. As the following illustrates, WSCI choreography would include a set of WSCI documents, one for each partner in the interaction. In WSCI, there is no single controlling process managing the interaction.

In order to cope with such challenges, the use of intelligent and distributed systems implementing peer-to peer interactions has long been proposed.

Choreography vs. Orchestration

There is an important distinction between WS orchestration and choreography. Orchestration refers to an executable business process that may interact with both internal and external WS. For orchestration, the process is always controlled from the perspective of one of the business parties. Choreography is more collaborative in nature, in which each party involved in the process describes the part they play in the interaction. The term WSs orchestration is used here to describe the creation of business processes, either executable or collaborative, that utilize WSs.

Natural Language Processing

It is doubtful whether web standards together with WS orchestration and choreography standards suffice to unleash the full potential of software components that enable rapid development of versatile and highly adaptable applications. Natural language processing (NLP) (J Allen, 1995) can enhance these standards and give the ability to simple users to come closer together in the design of IT-based business processes.

Many NLP techniques, including stemming, part of speech tagging, compound recognition, de-compounding, chunking, word sense disambiguation and others, have been used in Information Retrieval (IR). Typical information retrieval systems search documents/texts in the large data store at either a single word level, or at a term level.

For every document a similarity score is assigned and information retrieval systems reveal subset of the original documents to the user. In most of the cases this subset has a relevancy score which is higher than a given or default score.

Semantic information is used in retrieval techniques to expand knowledge about documents and to foster performance. In one such system, NLP is used to match the semantic content of queries to that of the documents to be searched. Sentences or phrases are then translated to terms for indexing the documents to be searched.

NL can provide us with semantics to write requests in our language, and in a close world to compose and choreograph WSs in the way humans think.

WEB SERVICE AUTOMATION

WS are software systems designed to support interoperable machine-to-machine interaction over a network. They are the preferred standards-based way to realize SOA computing. While there has been a significant progress in this area, there are a number of factors that prevent the wide scale deployment of WS and creation of web processes. A perspective that has seen much interest from the research community is that of automated composition of WS. The most inherent problems for this approach concern discovering and orchestrating WS. The current solutions take a structural approach to describe WS using XML based definitions. The main problem that the community faced and tried to solve it by introduction the semantic WS, is that it's not possible to explicitly define the purpose of the WSs as intended by the WS provider without semantics.

The ultimate goal is to realize WS compositions or web processes by leveraging the functionality of syntactic description of WSs. Most of the composition standards build on top of WS description standards. Hence semantically describing a service could help in composing a process whose individual components are semantically described. Section 4.1 describes the web service automation in a seven layer architecture. Sections 4.2 to 4.6 analyse the layers of the architecture and in section 4.7 we give an example of the system.

Architecture

The objective is to develop a framework that enables experts in business processes rather than IT experts to define business processes. Experts will use just NL for the definition or description of processes. NL descriptions are transformed according to semantic standards into statements which will be enacted by computers. The transformation process, in turn, resorts to semantic web metadata. We focus primarily on coexistence of NL and semantic web standards in a layered architecture for automated enactment of WS.

With the use of semantic WS a service provider can enrich it's applications with semantic descriptions. The OWL-S part of the description describes services in terms of semantics and is used in building the communication operations and an overall WS ontology.

The NL descriptions are matched with semantic representations of services. Input and output parameters of the services have to be considered in order to combine different services and generate a complete workflow. These representations help to identify the relevant services and to address correctly the information required by these services as well as the information produced by them. Matching process, in our point of view, is the key feature for a successful WS composition. Having a powerful service discovery application and semantic description of the corresponding WS, the process of choreography and orchestration become simple and effective.

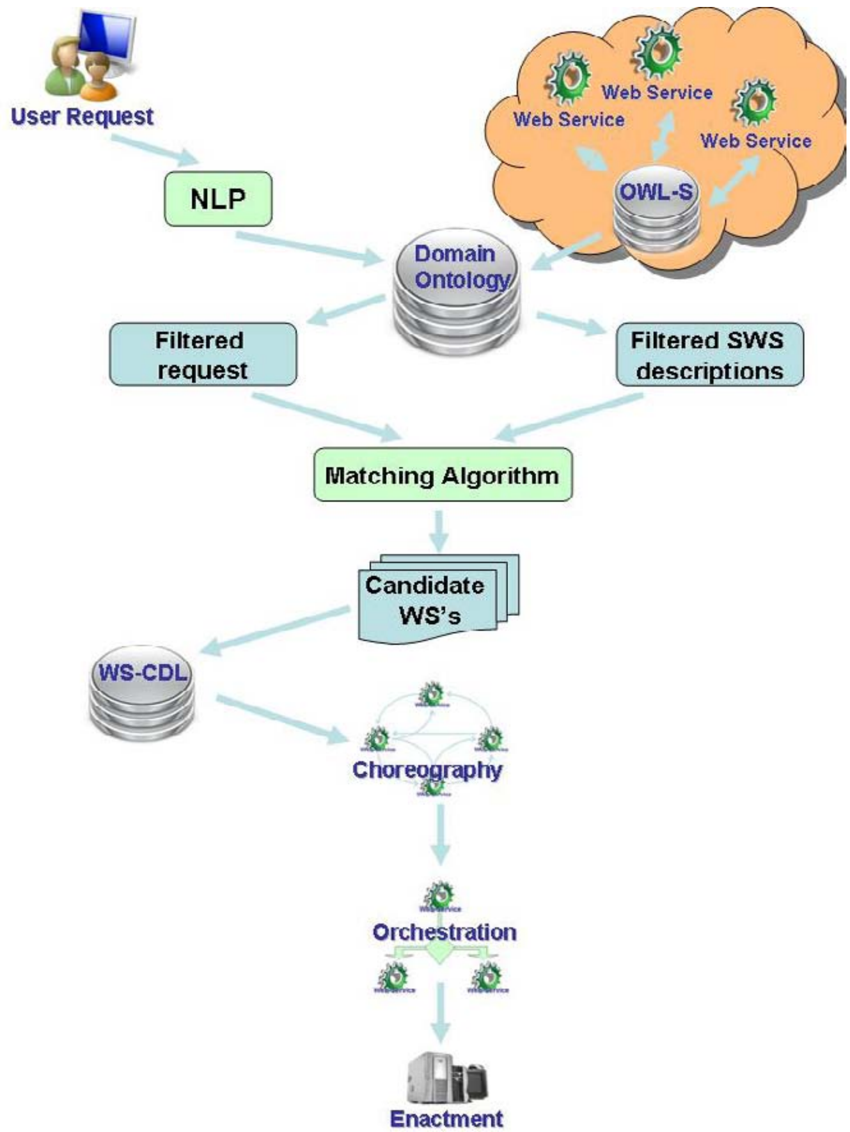
In a fully automated WSs' environment the expert user must only provide a description in NL which can be used to develop the top layer of the architecture and which will have impact on the orchestration layer. Our objective is to make top layer's semantics human-understandable. To achieve this goal we propose a layered architecture as follows:

1. **Natural Language Query:** Expert user posts a request as a description in natural language.
2. **Natural Language Parsing:** A system based on information retrieval and artificial intelligence applications is used to decompose/decrypt the user's request to semantic and syntactic annotations using lexical resources such as WordNet , FrameNet and VerbNet.
3. **From Natural Language to Domain Language:** A domain language is based on a specific ontology for the domain. It is essential to have a specific ontology which will be used to translate NL to semantic description.
4. **Web Services Discovery:** A matching mechanism will trigger in order to find the appropriate services that decompose the user's request. The service's descriptions, semantic (OWL-S) and simple text (UDDI), will be translated to the domain language and with the translated request a simple matching algorithm will propose candidate WSs. In that phase the user can optionally evaluate that services which will participate in the WS orchestration.
5. **Choreography Construction:** With standards like WS-CDL the proposed WSs will be evaluated and the result is an automated composed process. WS-CDL describes interoperable collaborations between services. WS-CDL is like a contract containing the definitions of the constraints and the ordering conditions under which messages are exchanged. This describes the common and complementary observable behaviour of all the services involved from a global viewpoint.
6. **Orchestration Construction:** According to (Mendling & Hafner, 2005) "BPEL process definitions of all parties involved in a choreography can be derived from the global WS-CDL model". Using such a system the orchestration can be generated using only the WS-CDL model.
7. **Enactment:** After a composite process is generated, the composite service is ready to be executed. Execution of a composite WS can be thought as a sequence of message passing according to the process model. The generated executable if it is composed in a BPEL4WS format can be executed in any BPEL execution engine.

Natural Language Processing

Having a non-IT expert as user it is essential to distinguish between the external (natural) language and internal (web service) language. NL used by the users to enhance accessibility in the sense that they can express what they want in a relatively easy manner. Internal language is used by the composition process generator, because the process generator requires more formal and

Figure 4. Architecture



precise languages, for example, the logical programming languages.

Semantics' web vision is to give access and knowledge to machines with semantic information which is normally used by humans. On the other hand, it will also revolutionize access to services by adding semantic information to create machine-readable service descriptions. NLP has advanced to the point where it can break the impasse and open up the possibilities of semantic web. NL systems can automatically create annotations from unstructured text. This provides the data that semantic web applications require.

NL search systems, such as Powerset (PowerSet), take advantage of semantic web markup and ontologies to augment their interpretation of underlying textual content. They can also expose SWS directly in response to NL queries using automatic techniques for semantic parsing. Such techniques have been successfully used in information extraction and question answering using a semantic parser.

A semantic parser can "decompose" the linguistic structure to extract meaning. An example of such a parser is XLE (Cahill & King & Maxwell, 2007). XLE consists of cutting-edge algorithms for parsing and generating Lexical Functional Grammars (LFGs). Another robust semantic parser is (Shi & Mihalcea, 2005) that uses a broad knowledge base created by interconnecting three major resources: FrameNet, VerbNet and PropBank. VerbNet lexicon provides the knowledge about the syntactic behaviour of the verbs. FrameNet thesaurus consists of examples annotated with semantic roles.

The linguistic interface layer is the key factor for a fully automated WSs environment. With NLP we ensure that the service proxy "understands" a phrase expressed in a descriptive way. "Understanding" means mapping an information item like a WS request into an appropriate request description. The linguistic layer contains thus features to map a service request or a service description (source language) into the target language generating automatically a request description that contains only terms of the domain ontology.

Domain ontology is a well defined description for the business process world that we focus. The domain ontology acts as a filter in user's requests and in WS's descriptions. Interpretation of NL to linguistic structure becomes feasible with the help of a semantic parser and public available sources like WordNet, FrameNet, VerbNet and PropBank (Giuglea & Moschitti, 2006). But what we finally need is to find services that will solve a specific problem. So the linguistic structure of user's request must be translated to a common language with the WS's descriptions. Domain ontology comes to fill in that gap. Using a filter over the domain ontology linguistic structure of the request and WS's descriptions are translated to a common intermediate and domain specific "language".

Semantic Web Services Discovery

WS selection is a crucial aspect of process composition. Semantic discovery is the process of discovering services based on the semantic metadata attached with the services. The use of ontologies allow richer description of activity requirements and more effective way of locating services to carry out the activities in the executable Web process.

WS described by semantics like OWL-S ontology become SWS, which enable programs to use the explicit semantics to automatically discover, invoke, compose and monitor the associated processes. Automatic discovery is accomplished by semantic matchmaking of a description of a required or sought process with available descriptions of SWS profiles. Because matchmaking is done using inference rather than one-to-one mappings, discovery can be performed based on skill sets rather than on device types.

Finding the right services is easier if service providers categorize services based on the domain with each registry maintaining only the WSs pertaining to that domain (Sivashanmugam & Miller & Sheth & Verma, 2005). If registries are specialized like this, it is possible to use domain specific ontologies. Environment specific information (in our case domain ontology) captures the characteristics of the environment where the universal (generic) processes are implemented. Universally applicable processes require information about the environment in which they are applied. For instance, a service for microarray discovery needs to know about the database where it can retrieve genes.

Furthermore, use of SWS enables working with multiple ontologies and, in particular, reasoning over unknown ontologies in order to identify recognized patterns. Semantic mappings between ontologies, such as term equivalence, enable linking overlapping domains. However, the problem of translating ontologies is nontrivial, as more often than not direct translations are not possible.

Automatic Choreography Construction

Choreography is the abstract level that defines the transaction schema and interaction processes that must hold in order to execute a process through a WS.

A composite service query is generated based on the NLP of user's request. The query profile includes the description of the composite service and the interface of the expected composite service, in which the output parameters, output constraints, input parameters, and their constraints have been extracted. The output constraint specifies the requirements on the outputs by the user.

Given that WSs can provide a suitable infrastructure for interactions and encapsulation of processes and skills and those OWL ontologies can provide the necessary machine-interpretable semantics, an approach that unifies these technologies is required.

WS's ontology describes the interfaces of services and the relationships among them. An abstract service specifies names and types of input and output parameters with no property constraints. Like domain ontologies, a service inherits the properties of its parent service in WSs ontology (Zhang & Arpinar & Aleman-Meza, 2003). This requires capturing user's goals and constraints, and matching them with the best possible composition of existing services. Therefore, inputs and outputs of the composite service should match the user supplied inputs, and expected outputs, respectively. Furthermore, the individual services placed earlier in the composition should supply appropriate outputs to the following services in an orchestrated way similar to an assembly line such as pipe-and-filter in a factory so they can accomplish the user's goals. Finally, the composition should conform to the user specified constraints including time, cost, and user specified quality of composition properties.

Using WSCI or WS-CDL descriptions WSs can be formalized and check whether two or more services are compatible to interoperate or not (Brogi, A., Canal, C., Pimentel, E., Vallecillo, A, 2004). If services are incompatible then specification of adaptors that mediate between them can be automatically generated. In this context, compatibility can be described as the ability of two WS to work properly together, that all exchanged messages between them are understood by each other, and that their communication is deadlock-free.

Automatic Orchestration Construction

A complementary concept to service choreography is service orchestration. The orchestration level is concerned with the workflow-oriented execution and sequencing of atomic processes and it does not take into account the different types of conversation patterns required to invoke the implementing services that are associated with the abstract atomic processes of the workflow. An orchestration engine implements the application logic necessary to orchestrate atomic services, and provides a high-level interface for the composed process.

In order to execute a WS, its preconditions must be satisfied, possibly using information provided by other WSs. Moreover care has to be paid in avoiding the duplication of effects when composing services, which might be due to entailment relationships among different effects provided by services being composed.

Automatic composition is achieved by semantic matchmaking of atomic operations in a complex process orchestration to the skills described in discovered service ontologies (Jammes & Smit & Martinez-Lastra & Delamer, 2005). Enactment engines can thus execute complex processes by composing individual processes, enabling autonomous manufacturing system orchestration. Semantics enable the chain of reasoning to traverse several ontologies in order to match post- and pre-conditions and compose services.

The main goal of transforming WS-CDL to BPEL is to allow the participants a rapid modelling and development process and generate relevant BPEL and WSDL documents which can then be used as a basis to implement the private (non-visible) business logic. According to (Mendling & Hafner, 2006) a dynamic formula can define the basic mapping rules from WS-CDL to BPEL. Using a recursive XSLT based approach we generate the BPEL processes by iterating through each role type of service to check its relevance.

Another approach based on time automata model which is verified and validated for correctness using formal model checking techniques have been proposed by (Diaz & Cambronero & Pardo & Valero & Cuartero, 2006). The key element is the WS-CDL document, in which each participant is represented as well as the time it enters into action. WS-CDL documents are translated into timed automata in a first step, and in a second step they intend to translate the timed automata into WS-BPEL documents.

Enactment

Automatic invocation is accomplished by interpreting the supported conversational semantics for discovered services. Consequently, the framework can select the appropriate choreography for service interactions. After a unique composite process, the services are ready to be executed. Execution of a WS workflow can be thought as a sequence of message passing according to the process model. The dataflow of the services is defined as the actions that the output data of a former executed service transfers to the input of a later executed atomic service.

The generated executable BPEL4WS process can be executed in any BPEL execution engine.

The semantic web 'vision' is one of enhancing the representation of information on the web with the addition of well defined and machine readable semantics, thereby encouraging a greater degree of 'intelligent' automation in interactions with this complex and vast environment. WS composition involves ordering a set of atomic services in the correct order to satisfy a given goal.

EXAMPLE

We illustrate the proposed methodology with a generic procedure for knowledge discovery in the context of clinico-genomic trials. The experiment has been developed within the ACGT infrastructure. ACGT (Tsiknakis & Kafetzopoulos & Potamias & Marias & Analyti & Manganas, 2006) is an integrated project named "Advancing Clinico-Genomic Trials on Cancer: Open Grid Services for Improving Medical Knowledge Discovery". ACGT is the provision of a unified technological infrastructure which will facilitate the seamless and secure access and analysis of multi-level clinico-genomic data enriched with high-performing knowledge discovery operations and services. The main advantage of ACGT infrastructure is that it supports a well defined master ontology (Mathias B. & Gabriele W. & Cristian C. & Holger S & Norbert G. & Martin D. et al., 2008) in the breast cancer domain.

Let's assume that a physician wants to find 'evidential' correlations between patients' gene groups and clinical profiles for a specific dataset. So a possible description from the physician would be "Give me correlations between gene groups and Metastasis for the public dataset Veer".

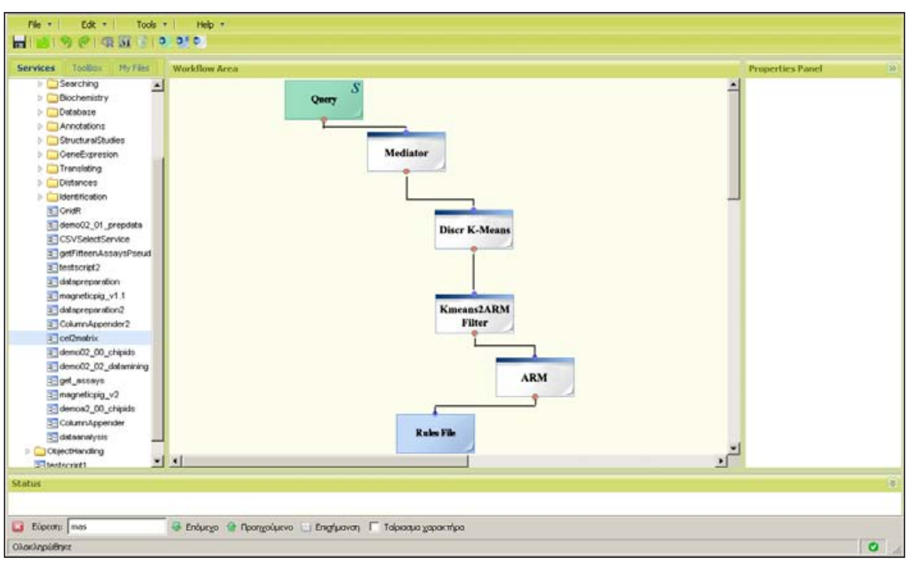
The first step of the process is the linguistic analysis. The physician's description will be enriched with synonyms. Semantics and syntactic decomposition of the phrase will also come up.

At the next step a filtering according to the domain ontology, which in our case is the master ontology of ACGT, will start. The same holds for the descriptions (OWL-S and UDDI) of the WSs in the ACGT infrastructure. Having a common filtering of the NL description and the service's descriptions we create a common language (or simply a vocabulary) for services and people.

Then a matching procedure reveals the candidate services. The semantic WSs within ACGT that reveals in response to the physicians request are three. The mediator service, the association rules service and the discretized k-means service. The mediator is a service which takes as input a query and give as output a zip file with merged data of clinical and genomics for each patient. Mediator has been proposed by the WS discovery service because of the keywords "public" and "dataset". Discritized K-Means is a special implementation of the known algorithm k-means within ACGT. The keyword that revealed this service is "group". This keyword appears in the semantic description of discritized k-means service. Association rules mining service implements a machine learning algorithm called apriory on XML data and gives relations between attributes. Detailed description of the knowledge discovery services is beyond the scope of this chapter and can be found in (Potamias & Koumakis & Kanterakis & Sfakianakis & Analyti & Moustakis et al, 2007). Association rules mining service has been proposed by the WS discovery service because of the keyword correlation which is synonym to association and appears in the description and in the master ontology.

Having these three services the system will try to combine (orchestrate) and generate a complex service which will give the desired output. Based on the WS-CDLs of the services we can see that mediator service need as input a string which is the query and give as output a zip of clinical and genomic data. The discritized k-means need as input a zip file with the clinical and genomic data and give as output a zip file with clinical and clusters of genomic data. Association rules mining service need as input an xml file with clinical and genomic data and give as output a file with associations between clinical and genomics. As we can see the output of mediator can be input at k-means algorithm but the output of k-means is incompatible with the input of association rules mining service. In this case the system will try to automatically find services that act as intermediates (or filters) for data type conversion. This search is based on the data types of input and output services. The search mechanism finds a new

Figure 5. workflow editor and enactment environment (WEEE) of ACGT



service which is called Kmeans2ARMfilter and is a simple transformation of the output zip files of k means service to XML which is the desired input for association rules mining. Have also this service the system can orchestrate the available services in order to generate a workflow.

In the next step the system propose a sequential workflow where the mediator service is the first one to invoke. The input of this service (the query) must be specified by the user. Then the output of mediator goes to discretized k-means service which clusters the genomic data. After the clustering data goes to Kmeans2ARMfilter service which transforms the output of discretized k-means to input for association rules mining service. Finally the association rules mining service generate associations between clinical and genomics data and stores them to the file system. Figure 5 shows the workflow which has been designed with the workflow editor and enactment environment (WEEE) of ACGT.

RELATED WORK

Automatic composition of semantic WSs is one of the most interesting and challenging problem in the field of semantic web. Current trends in industry and in research increase the number and the heterogeneity of WSs making automatic composition harder but also essential in large scale applications.

Benatallah at al (Benatallah & Dumas & Sheng & Ngu, 2002) proposed a platform called SELF-SERV which implements WSs composition using state charts, where the resulting services can be executed in a decentralized way within a dynamic environment. This execution model allows services participating in a composition, to collaborate in a peer-to-peer fashion in order to ensure that the control and data flow dependencies expressed by the schema of a composite service are respected.

METEOR-S (Sivashanmugam, Miller, Sheth, & Verma, 2005) is a project which focuses on applying semantics in annotation, quality of service, discovery, composition and execution of semantic WSs. The project focuses on adding semantics to WSDL and UDDI o BPEL4WS, and proposes a semi-automatic approach for annotating WSs described using WSDL. The METEOR-S WS annotation framework leverages schema matching techniques with a Naïve Bayesian Classifier, for semi-automatic annotation. The composition process involves a functional perspective and an operational perspective. The functional perspective involves WS discovery, addressing semantic heterogeneity handling. The operational perspective takes form of the research on quality of service specification for WSs and processes.

SWORD (Ponnekanti & Fox, 2002) is a set of tools for the composition of a class of WSs including ‘information-providing’ services. SWORD manages service composition as a sequence of operations the compute data. In SWORD, a service is represented by a rule that expresses certain inputs and is capable of producing particular outputs. A rule-based expert system is then used to automatically determine whether a desired composite service can be realized using existing services. If so, this derivation is used to construct a plan that when executed instantiates the composite service. SWORD focuses on the composition of services based on descriptions but it does not address the problem of mismatching inputs/outputs of WSs.

CONCLUSION AND FUTURE WORK

WSs represent the second generation of Internet tools. Standards are undoubtedly important for this technology. In most of the cases, applications emerge from a complex and dynamic composition of a number of WSs. Almost all business processes span beyond the boundaries of single operation and cross over organizational boundaries. Choreography and orchestration languages describe two aspects of emerging standards for creating business processes from multiple WSs. In this chapter we expand semantics used for WSs by NLP capabilities and enable users to write descriptions in their own language which can be transformed automatically into WS semantics. Robust text mining methods that map descriptions into a suitable domain ontology ensure that the descriptions are machine-process useable.

We have shown that it is feasible to create an integrated infrastructure for automatic composition of WSs in a closed world is which will give solutions to NL requests. To serve these requests, we expand semantics for WSs by NLP capabilities. Standards like OWL-S and WS-CDL on semantic WSs give us the ability and flexibility to select appropriate services and orchestrate them in order to answer NL questions automatically. The system is based in a “closed” world which means that the services and the domain are specific. Furthermore domain ontology helps us at the interpretation of requests and at searching over the services in order to have effective and accurate results. In our example we selected the ACGT environment because it has a specific domain (breast cancer) with a well defined domain ontology (ACGT master ontology) and support semantic WSs.

The proposed architecture can be expanded outside the boundaries of a specific domain using statistical and information retrieval techniques for automatic domain ontology generators. Furthermore an ontology evaluator and evolution system based on text analysis algorithms using precision/recall and F-measure methods could support the maintenance of the ontology. Such a method take as input documents selected by the user and update the ontology in real time. The input documents can be also the visited web pages of the user. Having this in mind we can pass to automatic composition of complex WSs from the domain specific world to user specific world.

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KEY TERMS AND DEFINITIONS

NLP: Natural Language Processing

SWS: Semantic Web Services

OWL-S: Web Ontology Language(OWL) based framework of the Semantic Web

WS-CDL: Web Services Choreography Description Language

BPEL4WS: Business Process Execution Language for Web Services

APPENDIX: ACRONYMS

B2B	Business to Business
BPEL	Business Process Executable Language
BPEL4WS	Business Process Execution Language for Web Services
DAML-S	DARPA agent markup language for services
HTML	HyperText Markup Language
IR	Information Retrieval
ISO	International Organization for Standardization
IT	Information Technology
LFG	Lexical Functional Grammars
NL	Natural Language
NLP	Natural Language Processing
OWL	Web Ontology Language
OWL-S	Web Ontology Language(OWL)based framework of the Semantic Web
RDF	Resource Description Framework
SAWSDL	Semantic Annotation of WSDL
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SWS	Semantic Web Services
SWSF	Semantic Web Services Framework
SWSL	Semantic Web Services Language
SWSO	Semantic Web Services Ontology
UDDI	Universal Description, Discovery and Integration
W3C	World Wide Web Consortium
WS	Web Service
WS-CDL	Web Services Choreography Description Language
WSCI	Web Service Choreography
WSDL	Web Service Description Language
WSDL-S	Semantic Web Service Description Language
WSML	Web Service Modelling Language
WSMO	Web Services Modelling Ontology
WSRF	Web Services Resource Framework
XML	Extensible Markup Language
Xpath	XML Path Language
XSLT	Extensible Stylesheet Language Transformations

Chapter XIII
Semantic Web Services:
Towards an Appropriate Solution to Application Integration

Antonio J. Roa-Valverde
University of Málaga, Spain

Ismael Navas-Delgado
University of Málaga, Spain

José F. Aldana-Montes
University of Málaga, Spain

ABSTRACT

The potential growth of applications distributed over a network and the large number of users has created the need for an infrastructure which can support increasing interaction among such users and applications. In this environment a scalable solution is needed. This problem known as application integration *is addressed in this chapter, and it is combined with Semantic Web technology. After introducing the different techniques to overcome the* application integration *challenge current trends in Semantic Web Services are discussed and the most recent R&D projects and a selection of available tools are presented. Also discussed is the use of ESB as a suitable mechanism to deploy Semantic Web Services.*

INTRODUCTION

Nowadays, Web Services technology has become extremely important in the distributed computing field. This technology, based on a set of standards recommended by the W3C, enables applications to communicate and exchange data over the Internet (Deitel, 2003). Web services benefit from object-oriented programming techniques because they allow developers to build applications from existing software components. This feature facilitates integration at the enterprise level which explains why large companies in the ICT (Information and Communication Technologies) sector are involved in its development.

In parallel with the increasing Web services available, the Semantic Web has emerged. The idea of this Web is that machines are not only able to present information but can also "understand" it. It is not however an entirely new Web, rather, it is an extension of the existing one, in which the information has a well-defined meaning thereby enabling computers and people to work in conjunction.

New techniques are being developed to overcome the limitations of traditional Web Services and are brought together in the concept of Semantic Web Services (SWSI, 2002), which are capable of integrating the formalism provided by the Semantic Web to carry out automatic service discovery, composition and execution.

Currently there is a significant effort being made to achieve standardization of the technology behind the Semantic Web Services, which is apparent in the various proposals submitted by different authors to the W3C. The most relevant proposals are WSMO (WSMO, 2005) and OWL-S (OWL-S, 2004) which are reflected in recently developed work.

A prerequisite for the development of a semantic layer to evolve current applications is to know the existing technologies and tools available. An initial analysis is necessary of the features that the existing systems have for annotating Web Services. This analysis will be conducted as a comparison of the different existing technologies with emphasis on the needs we may be particularly interested in. Certain aspects to be taken into account when carrying out this study may be the number of tools available to work with the specific technology, the impact of this technology, which can be seen by the number of related works, and the possibility of it becoming a standard.

Firstly, in section 2 we provide an introduction to distributed computing. We talk about mechanisms such as RPC and related approaches such as CORBA or RMI. After that, we introduce the most important aspects of Service Oriented Architectures (SOA) and the basis of Web Services. We also discuss the application integration problem. We comment on the most important concepts in this area, namely EAI and ESB. So, we explain the existing problem in each approach and a possible solution to it. Secondly, in section 3 we describe the state-of-the-art of Semantic Web Service (SWS) technologies focusing on the current proposals. These approaches enable the life cycle of Semantic Web Services, thus we consider it relevant to describe the current trends in this area and related projects carried out by researchers in this area are discussed. We also show the best known tools for annotation, registering, discovery and composition of Semantic Web Services. In section 4 we present our ongoing work to improve the use of an ESB in application integration. In this way, we will provide a brief description of the ESB concept and how to combine this technology with Semantic Web technologies. In section 5 we discuss future trends in this area and finally, in section 6 our conclusions are presented.

BACKGROUND

With the expansion of the local networks and the Internet in the 90s, a need arose for applications to communicate with each other. This communication consists in exchanging data and computational effort among different processes with the ultimate goal of building a distributed system. Several solutions have been proposed to overcome the problem of communicating different applications across a network and using this network within a global environment. This problem, known as *application integration*, has now become a priority task among system providers.

The application integration problem is closely related to the programming style used. So, the object-oriented paradigm provides a good way to re-use solutions developed in other domains.

Object oriented software architecture is hierarchically structured to build complex and reusable software. On the lowest level, functionalities are encapsulated in an object. A set of interacting software objects is collected into a component, a fact which facilitates the task of integrating different applications in a more complex system. However, it is not enough enough to solve the integration problem and it is also necessary to facilitate the communication among applications. In order to do so, several approaches have been proposed from different providers. These already had at their disposal their own object oriented models, extended to allow communication over the network. The OMG1 established the IIOP (Internet Inter-ORB Protocol) as the standard protocol for network communication in CORBA. Microsoft, on the other hand, introduced DCOM (Distributed COM) and Sun Microsystems proposed Java RMI (Remote Method Invocation) for the Java users. These approaches all use a mechanism called RPC (Remote Procedure Call). RPC is a protocol that one program can use to request a component from a program located in another computer without having to understand the different network details.

The main drawback of the previous approaches is the lack of interoperability among different protocols, i.e., users that use RMI can easily invoke RMI compatible servers, but they encounter difficulties if they want to communicate with DCOM or CORBA. These problems increased with the "explosion" of the Web because applications had to communicate with other ones running on different platforms. So, the question of heterogeneity was added to the communication problem. Furthermore, the protocols described above may have security issues because it is necessary to open ports that usually are unknown, something, system administrators are usually against.

Thus, the use of an owner technology in such a heterogeneous environment makes the standardization process more difficult. This is the main reason for not using the previous protocols. We can conclude then, that in an environment such as the Internet the use of a particular technology cannot be restricted.

A first approach to solve the interchange of data among different applications arrived in the second half of the 90s with the appearance of XML. Developers found the possibility of expressing the information in a descriptive and uniform way. This fact allowed overcoming the heterogeneity among different operating systems and programming languages.

One of the best known protocol implementations using XML is XML-RPC which allows users/programmers to call remote procedures in a platform independent way. XML-RPC is the predecessor of SOAP (Simple Object Access Protocol), which will be described later when we introduce the basics of Web Services.

A World of Services

In the previous section we established that functionalities are encapsulated in an object. Components collect a set of related objects. The Service Oriented Architecture (SOA) consequently extends this hierarchical structure to distributed systems and defines services as a collection of components. From the user's point of view a service can be defined as a set of activities that try to satisfy client necessities and have the following characteristics (Govern, 2003):

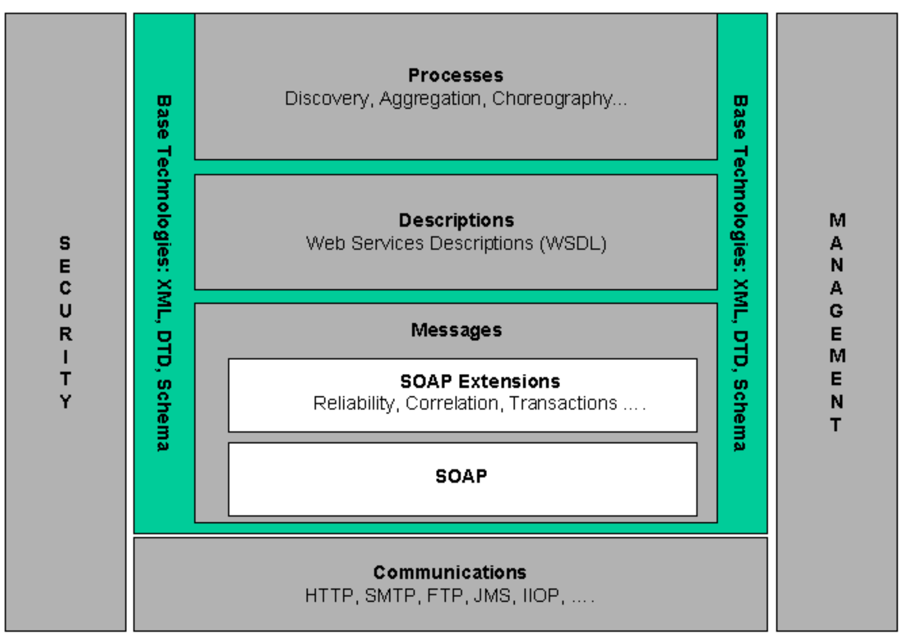
- Services are self contained and modular
- Services are discoverable and dynamically bound
- Services stress interoperability
- Services are loosely coupled, reducing artificial dependencies to their minimum
- Services have a network-addressable interface
- Services have coarse-grained interfaces in comparison to finer-grained interfaces of software components and objects
- Services can be composed

Thus, SOA is an architectural style for achieving loose coupling among interacting software agents, i.e. to minimize their artificial dependencies. Services are only a fragment of the SOA world and Web Services are the interface for interacting with these services. It is necessary therefore to distinguish Web Services from the service implementations. SOA may or may not use Web Services but Web Services provide a simple way towards SOA.

Coming back to the previous section, Web Services achieve high interoperability by using languages based on XML and standard protocols such as HTTP or SMTP. In this sense, Web Services overcome the drawbacks of technologies such as CORBA, DCOM and RMI and allow developers to build modular and auto-descriptive applications that can be published, registered and invoked from anywhere on the Web in a platform independent way. However, Web Services have some drawbacks that were solved in those technologies, i.e., quality of service and security issues. On the one hand, because they rely on the HTTP protocol, many experts have criticized the Web Services performance. This problem is inherent to TCP/IP since upper levels have a higher abstraction level but a lower performance. Experts argue that Web Services are not suitable for example for building applications which rely on high performance computation. Web Services were proposed to overcome communication problems among heterogeneous systems. On the other hand, nowadays researchers spend their efforts on improving the security of the current standards as can be seen in the recent versions. Despite these objections, Web Services have become today a commonly accepted technology among ICT companies.

Now, we are going to describe briefly the three basic concepts around the Web Service technology. Web Services are described using a formal language that is platform independent, WSDL (Web Service Description Language). These descriptions are published to enable the location and understanding of the services. Web Services are accessed through SOAP (Simple Object Access Protocol). In order to enable the location and integration of remote services the service provider

Figure 1. Web Service Stack (extracted from http://www.w3.org/TR/ws-arch/)



can make use of UDDI (Universal Description, Discovery and Integration). Figure 1 depicts the relationship among the standards supported by the W3C.

The way to use Web Services consists in three easy steps that involve each one of the standards presented above: description, discovery and invocation.

Three main actors take part in the Web Service usage process: the Web Service broker, the Web Service requester and the Web Service provider. The Web Service provider is the actor who develops and offers one or more services. To make this possible the provider must describe the offered service in an understandable way using WSDL. These service descriptions in WSDL will be stored in a public registry called UDDI to facilitate the service discovery by other requesters. UDDI acts as a service broker in the sense that it stores the necessary information to allow interaction between the Web Service requester and the Web Service provider. When a requester tries to find a Web Service that satisfies its necessities, it must look up the UDDI to obtain the service description. This service description contains the information required to allow the requester to begin a communication process by exchanging SOAP messages with the Web Service provider. Figure 2 summarizes these ideas.

Trends in Enterprise Integration

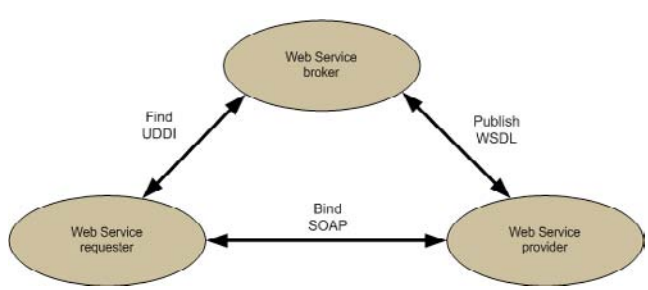
As we have observed previously, application integration has become a challenge for many ICT leaders. In addition to the previously commented distributed models other proposals have emerged to solve the integration problem in business applications. In this section, we will describe the EAI, SOA and ESB concepts in order to clearly distinguish between them. In this section we will also discuss architectural options available for enterprise integration and in which sense these options are suitable for.

Chappell (2004) states that "indications are that only a small percentage of enterprise applications are connected, regardless of the technology being used. According to a research report from Gartner Inc., that number is less than 10%. Another statistic is even more surprising of the applications that are connected, only 15% are using formal integration middleware" (p. 28). The lack of experience and knowledge in the use of these technologies may be a possible explanation for this situation. For this reason, we consider this section a need.

Enterprise Application Integration (EAI)

Enterprise Application Integration is a way of making diverse business applications communicate with each other to achieve a business objective in a seamless and reliable way, irrespective of platform and geographical location. EAI involves methodologies, processes, tools and technologies used to connect systems, data and workflows within one or between several companies. If the connection is about systems, data or processes among different companies it is called Business to Business Integration (B2Bi). In this work we

Figure 2. Web Service usage



focus on the connection of systems and processes, leaving out the data integration or Enterprise Information Integration (EII).

EAI systems have evolved over time and can be classified in the architectures explained below. The first is the point-to-point integration architecture (Figure 3) also known as "accidental architecture" because it is something that nobody actually set out to create, but it is the result of years of accumulating direct connections (Chappell, 2004). This architecture is not easily extensible because for each additional/application system that needs to be integrated, the number of connectors will increase exponentially. This fact makes it very difficult to manage.

The second architecture is known as the hub & spoke integration architecture (Figure 4). This one is a centralized solution that can be managed easily, but it is not easily scalable and was developed to overcome the problems present in the accidental architecture. The hub & spoke approach aims to reduce the number of connections among heterogeneous systems, by relying on the concept of an EAI broker, which is the component that other systems use to connect to the architecture. EAI brokers provide adapters that allow heterogeneous systems built over different platforms and programming languages to communicate in real time.

Figure 3. P2P integration architecture

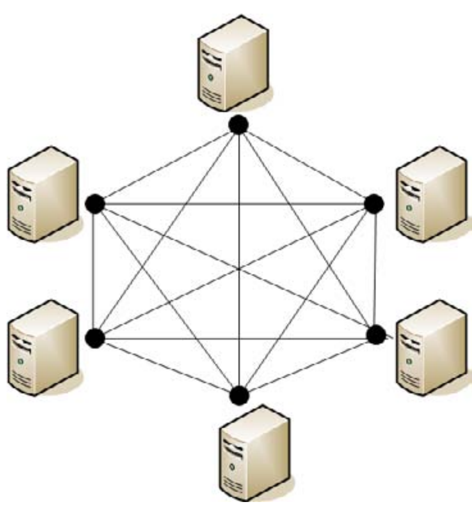
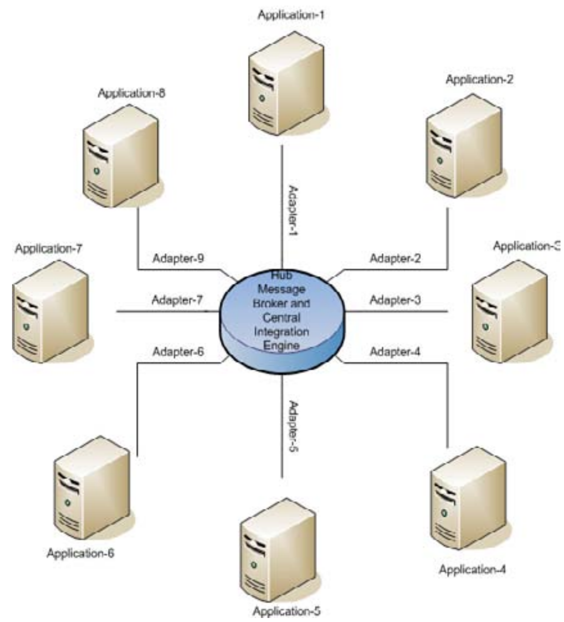


Figure 4. Hub & Spoke topology

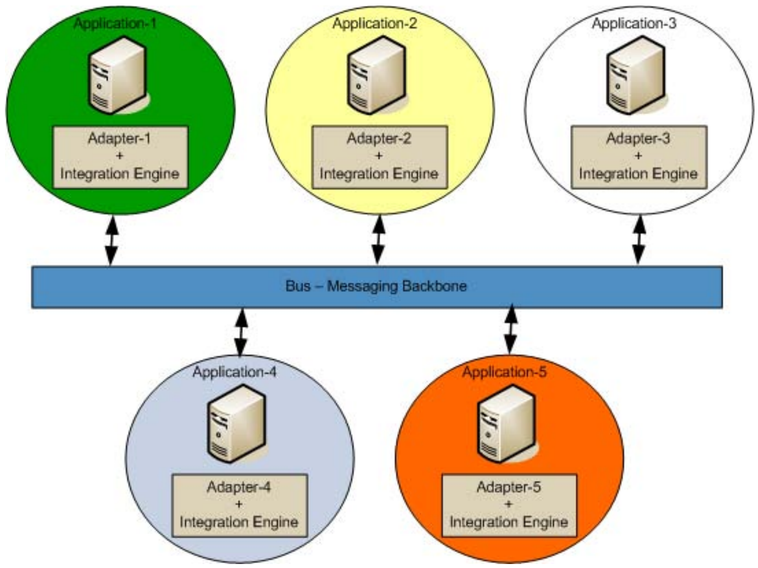


The third architecture is the bus integration architecture (Figure 5). Bus architecture uses a central messaging backbone for message propagation. Each application publishes the required messages in the bus using adapters in the same way as happens with EAI brokers. The difference between bus and EAI broker approaches is in the adapters. While EAI brokers use a centralized solution, in bus topology, adapters are distributed in the application side. This later scales much better but it is more complex to maintain compared to a hub & spoke topology.

Enterprise Service Bus (ESB)

The different EAI topologies have tried to solve the drawbacks of the "accidental architecture", however, they rely on the use of proprietary internal formats. This fact makes application integration specific to each provider. The ESB is based on today's established standards in these areas and has real implementations that are already being

Figure 5. Bus topology



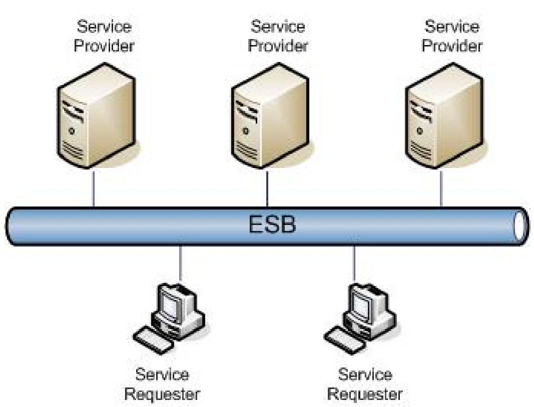
deployed in a number of industries. This is one of the main advantages of ESB over EAI.

An ESB in conjunction with SOA provides the implementation infrastructure to build a highly distributed approach for integration. An ESB provides a container that could alleviate the security and quality of service problems existing in Web Services. In this way, an ESB provides support to extend the use of Web Services.

ESB draws from traditional EAI approaches in that it provides integration services such as data transformation, routing of data, adapters to applications and protocol conversion. However, in an ESB, services can be configured rather than coded. There is nothing wrong with writing code, but there is plenty of code to be written elsewhere that doesn't have to do with interdependencies between applications and services.

The most relevant aspect of using an ESB is that it enables the abstraction of the communication model used by the applications. This fact allows us to work more comfortably without having to worry about low-level details and allows us to focus on the development of the logic that will use semantic technology. Figure 6 depicts a schematic view of an ESB.

Figure 6. ESB integration diagram



FROM SYNTACTIC WEB SERVICES TOWARDS SEMANTIC WEB SERVICES

In the previous section we established that Web Services are a good approach to overcome the heterogeneity which exists among different platforms and languages. We also discussed the main criticisms about technical issues such as security, performance, quality of service and looked at how the use of an ESB can alleviate these problems.

However, we have not treated Web Services from the final user point of view.

Figure 2 shows the process that a Web Service requester should follow to use the required service. This operational policy is somewhat utopic, in the sense that all processes around the Web Service life cycle rely on syntactic descriptions. In a SOA world it is not possible to manually explore a full repository as the available amount of Web Services is constantly increasing. Thus, an automatic way to manage Web Services usage is necessary.

This is the point where Semantic Web technology comes into play. Semantic Web technologies provide the required support to build an information system in a machine understandable way. Just as the Semantic Web is an extension of the World Wide Web, Semantic Web Services (SWS) are an extension of Web Services. The aim of combining both technologies is to provide a full set of mechanisms to obtain a common framework that facilitates the use of the traditional Web Services in a SOA.

A desirable goal would be to stimulate the use of Semantic Web Services among developers without a high effort to migrate from traditional Web Services towards Semantic Web Services. Experience in computer science has shown us that this feature is the key for the success of a new technology.

In this section we talk about the proposals submitted to the W3C in this area, although the different proposals are not explained in detail because we consider that it is outside the scope of this chapter and other authors have already treated this topic in depth. Our aim here is to provide the reader with a general overview that they can understand the rest of the chapter. We discuss the most relevant current R&D projects carried out by important research groups in the Semantic Web Services field, namely DERI2, STI3, KMI4 and LSDIS5. Finally, we present an overview of existing tools which can be used to put into practice these technologies.

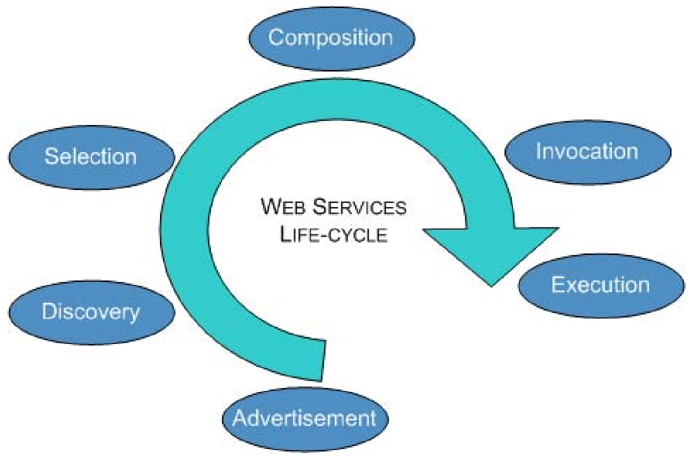
Current Proposals for Semantic Web Services

The aim of the Semantic Web Service is to add meaning to traditional Web Services using semantic annotations. In the Semantic Web field these annotations rely on a stack of accepted standards recommended by the W3C. These standards allow us to conceptualize a particular portion of the world in which we may be interested. This conceptualization is known by the term "ontology" and is responsible for adding meaning to resources, thereby disambiguating the available resources and allowing users to reason about them.

In the case of Semantic Web Services it is necessary to extend this stack with other mechanisms that allow developers to model the relationship between different Web Services. These mechanisms should provide the capability to describe Web Services in order to automate processes such as advertisements, discovery, selection, composition, mediation and invocation. Advertisement refers to the process of publishing the description and endpoints of a Web Service in a service repository. Discovery is the process of locating all Web Services that match the original request. Selection is the process of selecting the most suitable Web Service out of the ones discovered, usually based on application-dependent metrics (e.g., QoS or availabilty). Composition is the process of integrating selected Web Services into a complex process in order to create a complex service. Invocation references the process of invoking a single Web Service or complex process, by providing it with all the necessary inputs for its execution. Figure 7 depicts the relationship among these processes in the Web Service life-cycle.

Many of the related technologies and standards are still under development, but it is important to create an awareness of this technology and to think about it today rather than tomorrow. The technology might not be at an industrial strength maturity yet, but the problems are already (Fensel, 2007).

Figure 7. Web Service life-cycle



Nowadays, technologies that try to overcome the Semantic Web Service challenge can be classified in two different approaches, namely the top-down strategy and the bottom-up strategy. The first steps towards adding semantics to Web Services follow a top-down approach. This approach includes the four mayor works submitted by W3C members in 2004-2005, namely OWL Web Ontology Language for Services (OWL-S)6, Web Service Modeling Ontology (WSMO)7, Semantic Web Services Framework (SWSF)8 and Web Service Semantics (WSDL-S)9.

OWL-S was the first proposal submitted to W3C. It defines a service ontology based on OWL, which is composed of three interlinked models:

- **Service Profile:** provides information about the service and the owner that is used in the discovery phase.
- **Service Model:** provides a detailed description of the service and its behaviour.
- **Service Grounding:** how to interact with the service.

WSMO is a conceptual model that distinguishes between four different concepts to model relationships among Semantic Web Services, namely goals, ontologies, web services and mediators:

- **Goals:** model the requestor point of view about a Web Service. This information is very important in the discovery phase because it determines a correct match.
- **Ontologies:** provide the terminology used by the other concepts in WSMO.
- **Web Services:** consist of a Web Service description about its interfaces, capabilities and grounding.
- **Mediators:** describe elements that try to solve interoperability problems, e.g., ontology alignment and communication among different Web Services.

SWSF is a more recent work in this field. It relies on OWL-S (sharing its three concepts of profile, model and grounding) and the Process Specification Language (PSL), standardized by ISO 18269. SWSF is based on a conceptual model and a language to axiomatize it.

WSDL-S (Sheth, 2005) was created in the project METEOR-S10 with the aim of adding semantic annotations to WSDL and XML Schema. WSDL-S does not provide a specific model for Semantic Web Services like the other proposals because it considers that annotations are sufficient for a conceptual model. WSDL-S was taken as the basis for the Semantic Annotation for WSDL and the XML Schema recommendation (SAWSDL, 2007), the first step towards a bottom-up approach.

Recently, efforts are focused on overcoming the logical separation between traditional and Semantic Web Services. While the previously commented top-down approach is closer to the semantic layer, a bottom-up approach is closer to the syntactic layer. In this sense, SAWSDL can be seen as a first rapprochement among the two approaches.

A recent WSMO-based ongoing work built on top of SAWSDL is known as WSMO-Lite11 (Vitvar, 2008). Authors in this work provide a light ontology based on WSMO to allow a bottom-up modelling of services. On the other hand, a recent work that grounds OWL-S in SAWSDL is described in (Paolucci, 2007). Finally, in (Kourtesis, 2008) authors attempt to build a repository of Semantic Web Services based on UDDI, SAWSDL and OWL-DL.

Related R&D Projects

In this subsection we describe the major projects carried out in recent years in the Semantic Web Services field. Many of these projects have inspired the creation of others projects, working groups and initiatives (e.g. SDK cluster12 or ESSI cluster13) to improve the Semantic Web Service technology.

Adaptive Services Grid (ASG) (http://asg-platform.org) is one of the projects in the 6th Framework Programme whose aim is to build a platform for semantic service provision. ASG provides a platform to enable discovery, composition and enactment of Semantic Web Services. The goal of ASG is related with the INFRAWEBS and METEOR-S projects responsible for the Infraweb Integrated Framework tool and the SAWSDL recommendation, respectively.

Semantic Discovery on Adaptive Services Grid (SemGrid) (http://lsdis.cs.uga.edu/projects/semgrid/) is a project funded by NSF. This project involves collaboration between the LSDIS SemDis and METEOR-S projects, and the European Commission sponsored Adaptive Service Grid (ASG) project. It investigates the use of semantic associations in Web Service discovery and Dynamic Web Process composition, and computing Semantic Associations over the grid.

Intelligent Framework for Generating Open (Adaptable) Development Platforms for Web-Service Enabled Applications using Semantic Web Technologies and Multi-Agent Systems (INFRAWEBS) (http://www.infrawebs.org/) is a European IST Project in the 6th Framework Programme. The main objective of INFRAWEBS is the development of a set of tools which will help users to create, maintain and execute Semantic Web Services. The developed platform known as the Infraweb Integrated Framework (IIF) is WSMO compliant and it relies on the Eclipse IDE.

Each set of tools is deployed within an ESB which is also considered an Infrawebs Unit. The IIF defines two distinctive (but linked) parts: a Design Time Phase and a Runtime Phase. The Design Time Phase consists of the tools involved during the design of Semantic Web Services (using the Eclipse IDE), whereas the Runtime Phase consists of those tools involved during the execution of Semantic Web Services (using the ESB). Some of the tools may of course be involved in both phases. This approach ensures that system users (whether developers or normal end-users) deal with the minimum (but complete) set of tools required. Furthermore, it also provides an environment which is focused on the specific needs of the users.

The METEOR-S project (http://lsdis.cs.uga.edu/projects/meteor-s/) at the LSDIS Lab aims to extend standards such as BPEL4WS, SOAP and WSDL with Semantic Web technologies to achieve greater dynamism and scalability. This project has generated many deliverables related to the SWS life-cycle. We reference the SAWSDL recommendation as the main result of this work.

Data, Information, and Process Integration with Semantic Web Services (DIP) (http://dip.semanticweb.org/) is an Integrated Project supported by the European Union's FP6 programme. The DIP objective has been to develop and extend Semantic Web and Web Service technologies in order to produce a new technology infrastructure for Semantic Web Services; an environment in which different Web Services can discover and cooperate with each other automatically. The long term vision of DIP is to deliver the enormous potential benefits of Semantic Web Services to e-Work and e-Commerce.

The EU IST integrated project Semantic Knowledge Technologies (SEKT) (http://www.sekt-project.com/) developed and exploited semantic knowledge technologies. Core to the SEKT project has been the creation of synergies by combining the three core research areas; ontology management, machine learning and natural language processing.

Semantics Utilised for Process Management within and between enterprises (SUPER) (http://www.ip-super.org/) is another project supported by the European Union's FP6 programme that aims to introduce the use of Semantic Web Services into the Business Process Management (BPM). The main objective of SUPER is to raise BPM to the business level, where it belongs, from the IT level where it mostly resides now. This objective requires that BPM be accessible at the level of semantics of business experts. Semantic Web and, in particular, Semantic Web Services technology offer the promise of integrating applications at the semantic level. By combining SWS and BPM, and developing one consolidated technology SUPER will create horizontal ontologies which describe business processes and vertical telecommunications oriented ontologies to support domain-specific annotation. Therefore this project aims at providing a semantic-based and context-aware framework, based on Semantic Web Services technology that acquires, organizes, shares and uses the knowledge embedded in business processes within existing IT systems and software, and within employees heads, in order to make companies more adaptive.

The Triple Space Communication (TripCom) project is supported by the European Union's FP6 programme (http://www.tripcom.org). The aim of TripCom is to build a coordination infrastructure for machine-to-machine interaction combining Tuple Space technology (Omair Shafiq, 2006), Semantic Web technology and Web Service technology. Moreover, Triple Space computing follows the same goals for the Semantic Web Services as the Web for humans: re-define and expand the current communication paradigm. One of the important goals is to bring Triple Spaces to an Internet-scale level. This means that any number of data providers and readers can write and read communication data over the Internet. As in the case of Web pages, there should be no limitation: the architecture is independent of system properties like response-time and throughput.

Business process fusion based on Semantically-enabled Service-oriented Business Applications (FUSION) is a project funded by the European Commission in the 6th Framework Programme (http://www.fusionweb.org/Fusion/project/project.asp). Special attentention is given to e-Business, as FUSION aims at efficient business collaboration and interconnection between enterprises by developing a framework and innovative technologies for the semantic fusion of service-oriented business applications that exist within the collaborating companies. FUSION aims at the integration of research activities carried out in the areas of Business Process Management, Semantic Web and Web Services.

Other projects related with enterprise interoperability in the same way as FUSION are the following: ABILITIES, ATHENA, GENESIS, IMPORTNET, INTEROP, NO-REST, TRUSTCOM. Information related with these projects is available at http://cordis.europa.eu/ist/ict-ent-net/projects.htm.

The GRISINO research project is funded by the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT) in the FIT-IT programme (http://www.grisino.at/). It combines "Grid computing", "Semantic Web Services" and "intelligent objects" in order to create an example of the future, enhanced infrastructure of the World Wide Web.

The main result of the project will be an experimental software prototype which will demonstrate how this infrastructure should be designed and how it will improve collaboration amongst people and machines over the World Wide Web.

Service Web 3.0 is a project financed by the European Union 7th Framework Programme (http://www.serviceweb30.eu/cms/). The aim of Service Web 3.0 is to support emerging technologies such as the Semantic Web or Web Services that try to transform the Internet from a network of information to a network of knowledge and services. To overcome this challenge, Service Web 3.0 will contribute to the implementation of framework programmes and will support the preparation of future community research and technological development. The main mission of this project is to facilitate Semantic Web Services and Semantic Web technology adoption, in particular for SMEs.

SHAPE is another project in the 7th Framework Programme (http://www.shape-project.eu/). The objective of SHAPE is to support the development and the creation of enterprise systems based on Semantically-enabled Heterogeneous Architectures (SHA). SHA extends SOA with semantics and heterogeneous infrastructures (Web services, agents, Semantic Web Services, P2P and grid) within a unified service oriented approach. SHAPE will develop a model-driven engineering (MDE) tool-supported methodology. SHAPE will take an active role in the standardization of meta models and languages for SHA. The technical results will be compliant with the proposed standards to ensure high industry acceptance. In current SOA approaches, business requirements and technical details are intertwined constraining the evolution of service-oriented business solutions. SHAPE will provide meta models and languages, methods and tools to separate the different viewpoints of SOA for the development of semantically-enabled, flexible and adaptive business services on a rich SHA infrastructure.

Single European Employment Market-Place (SEEMP) is a project supported by the European Union's FP6 programme (http://www.seemp.org/). The mission of SEEMP is to design and implement in a prototypal way an interoperability architecture for public e-Employment services. The architecture will encompass cross-governmental business and decisional processes, interoperability and reconciliation of local professional profiles and taxonomies as well as semantically enabled web services for distributed knowledge access and sharing. In particular, the SEEMP project will develop an EIF-compliant federated architecture and interoperability middleware as well as applicative plug-in services to allow existing National/Local job market places and data warehouses to be interoperable at pan-European level by overcoming state-of-the-art limitations.

SOA4All is endorsed by the NESSI14 and aims to alleviate the problems of current SOA solutions (http://www.soa4all.org/). Its success depends on resolving a number of fundamental challenges that SOA does not address today. SOA4All will help create a world where billions of parties provide and consume services via advanced Web technology.

The outcome of the project will be a comprehensive framework and infrastructure that integrates four complimentary and revolutionary technical advances into a coherent and domain independent service delivery platform, namely Web Services, Web 2.0, semantic and context management.

COllaboration and INteroperability for networked enterprises (COIN) is an integrated project in the European Commission 7th Framework Programme (http://www.coin-ip.eu/). The mission of the COIN IP is to study, design, develop and prototype an open, self-adaptive, generic ICT integrated solution to support the expansion of SOA. The COIN business-pervasive open-source service platform will be able to offer, integrate, compose and mash-up in a secure and adaptive way existing and innovative yet to-be developed Enterprise Interoperability and Enterprise Collaboration services, by applying intelligent maturity models, business rules and self-adaptive decision-support guidelines to guarantee the best combination of the needed services. This will be done independently of the business context, e.g., of the industrial sector and/or domain, the size of the companies involved, or the openness and dynamics of collaboration.

This way, the Information Technology vision of Software as a Service (SaaS) will find its implementation in the field of interoperability among collaborative enterprises, supporting the various collaborative business forms, from supply chains to business ecosystems, and becoming for them like a utility, a commodity, the so-called Interoperability Service Utility (ISU).

The COIN project will finally develop an original business model based on the SaaS-U (Software as a Service-Utility) paradigm where the open-source COIN service platform will be able to integrate both free-of-charge and chargeable, open and proprietary services depending on the case and business policies.

SWING is a project of the Information Society Technologies (IST) Program for Research, Technology Development & Demonstration under the 6th Framework Programme of the European Commission (http://www.swing-project.org/). SWING aims at deploying Semantic Web Service technology in the geospatial domain. In particular, it addresses two major obstacles that must be overcome for Semantic Web Service technology to be generally adopted, i.e. to reduce the complexity of creating semantic descriptions and to increase the number of semantically described services. Today, a comprehensive knowledge of logics, ontologies, metadata and various specification languages is required to describe a service semantically. SWING will develop methods and tools that can hide the complexity - and automate the creation of the necessary semantic descriptions. The objective of SWING is to provide an open, easy-to-use SWS framework of suitable ontologies and inference tools for annotation, discovery, composition, and invocation of geospatial web services. SWING builds on the DIP and SEKT IPs, by adopting, combining and reinforcing their results. A main key to the solution is adapting the SWS technology of DIP to handle geospatial services and content. Another key is utilising and advancing the technology of SEKT to annotate geospatial services with semantic information. A synergy between these two research initiatives is demanded in order to maintain and extend Europe's leading role in SWS. The SWING framework and pilot application will increase the use of distributed and heterogeneous services in geospatial decision making. The results can be reused in other domains and will boost the availability of semantic services and bring the vision of the SWS a great leap forward. Exploitation of SWING's results will provide Europe's decision makers and citizens with a new paradigm of information retrieval and new business opportunities.

Available Tools

The number of tools available for using with a particular technology is a good indicator of the importance of such technology. There are several tools to work with Semantic Web Services that try to put into practice the more important proposals, namely OWL-S, WSMO and SAWSDL. Usually, these tools are distributed under GPL or LGPL license. In the following, we list the tools available for each proposal.

OWL-S Based Tools

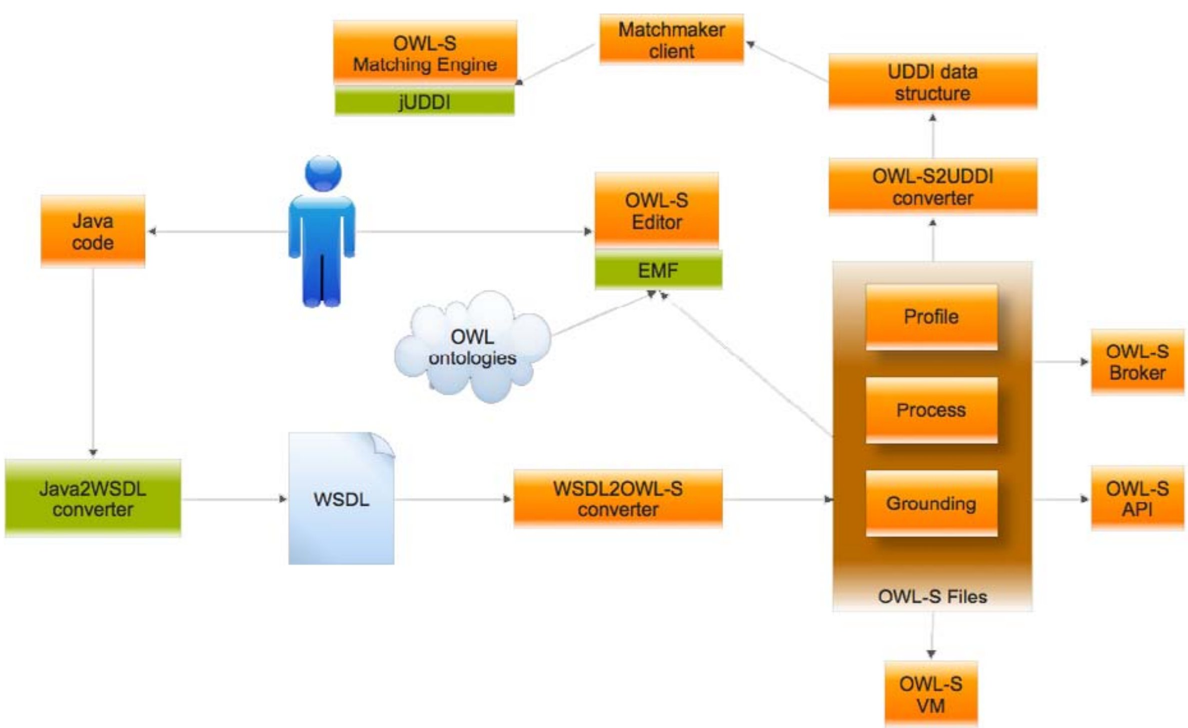
Figure 8 depicts an overview of the existing tools for OWL-S. These tools can be classified into two main groups, namely necessary tools at design time (e.g. editor) and necessary tools at run time (e.g. matchmaker). Generally, these tools are developed for academia and so they are not well known in the business world.

WSDL2OWL-S provides translation between WSDL and OWL-S. The results of this translation are a complete specification of the Grounding and partial specification of the Process Model and Profile. The incompleteness of the specification is due to differences in information contained in OWL-S and WSDL. Specifically WSDL does not provide any process composition information, therefore the result of the translation will also lack process composition information. Furthermore, WSDL does not provide a service capability description. Therefore the OWL-S Profile generated from WSDL is also necessarily sketchy and must be manually completed. Nevertheless the output of WSDL2OWL-S provides the basic structure of an OWL-S description of Web services and saves a great deal of manpower (Paolucci, Srinivasan, Sycara, & Mishimura, 2003).

The Java2OWL-S Converter provides a partial translation between Java and OWL-S 1.1. The results of this translation are a complete specification of the Grounding, partial specification of the Process Model and Profile and an OWL Class file, when at least one of arguments in the java class method is a user defined class. This tool extends the WSDL2OWL-S converter, instead of taking a WSDL file, it takes a java class file as input and converts it into a WSDL file, using apache axis' Java2WSDL converter, and then feeds the generated WSDL file as input to the WSDL2OWL-S converter (Paolucci, Srinivasan, Sycara, & Mishimura, 2003).

OWL-S2UDDI Converter converts the OWL-S profile descriptions to corresponding UDDI advertisements, which can then be published

Figure 8. Interaction schema for OWL-S tools



in any UDDI registry. This converter is part of the OWL-S/UDDI registry. The OWL-S/UDDI registry enhances UDDI registry with OWL-S matchmaking functionalities (Paolucci, 2002a).

The Matchmaker Client can be used to interact with the OWL-S/UDDI matchmaker (Srinivasan, 2002; Paolucci, 2002a), which is responsible for matching OWL-S descriptions with the UDDI information. An online version of the matchmaker client is available at http://www.daml.ri.cmu.edu/matchmaker (Paolucci, Srinivasan, Sycara, & Mishimura, 2003).

OWL-S IDE is a development environment that supports a semantic web service developer through the whole process from the Java generation, to the compilation of OWL-S descriptions, to the deployment and registration with UDDI.

OWL-S VM is an environment developed with the aim of executing Semantic Web Services (Paolucci, Srinivasan, Sycara, & Mishimura, 2003).

OWL-S Broker provides the necessary logic for the discovery process. This component is strongly related with the Matchmaker Client and OWL-S/UDDI matchmaker (Sycara, 2004; Paolucci, 2004).

WSMO Based Tools

The main criticisms received for these tools are to do with the number of them required to cover the SWS life-cycle. Advocates of other proposals, such as WSMO, have tried to collect the implemented tools in a unified environment. Components that have become WSMO in a suitable approach for Semantic Web Services are WSML15 and WSMX16.

The Web Service Modeling Language (WSML) is a language that formalizes the Web Service Modeling Ontology (http://www.wsmo.org/TR/d16/d16.1/v0.21/). It uses well-known logical formalisms in order to enable the description of various aspects related to Semantic Web Services and consists of a number of language variants, namely WSML-Core, WSML-DL, WSML-Flight, WSML-Rule and WSML-Full.

The Web Services Execution Environment (WSMX) is an execution environment for dynamic matchmaking, selection, mediation and invocation of semantic web services based on WSMO. WSMX tries to cover the SWS life-cycle. A downloadable version of WSMX is available at http://sourceforge.net/projects/wsmx/.

The Web Services Modeling Toolkit (WSMT) may be **the best known tool compliant with WSMO. WSMT** is a framework for the rapid deployment of graphical administrative tools, which can be used with WSMO, WSML and WSMX. **WSMT is** built over the Eclipse IDE and it brings together the following components among others.

- **WSML2Reasoner Framework** (http://tools.deri.org/wsml2reasoner/) is a highly modular architecture which combines various validation, normalization, and transformation functionalities essential to the translation of ontology descriptions in WSML with the appropriate syntax of several underlying reasoning engines.
- **WSMO Studio** (http://www.wsmostudio.org/) is a Semantic Web Service editor compliant with WSMO. WSMO Studio is available as a set of Eclipse plug-ins that can be further extended by third parties.
- **WSML Rule Reasoner and WSML DL Reasoner are two** reasoner implementations for WSML available at http://dev1.deri.at/wsml2reasoner/**.**
- **WSML Validator is** a WSML variant validation implemented as part of wsmo4j. An online validation service is available at http://tools.deri.org/wsml/validator/.
- **WSMO4J** is an API and a reference implementation for building Semantic Web Services applications compliant with the Web

Service Modeling Ontology. WSMO4J is compliant with the WSMO v1.2 and WSML 0.2 specifications. A downloadable version is available at http://wsmo4j.sourceforge.net**.**

Other WSMO compliant environments are the Internet Reasoning Service (IRS III) and INFRAWEBS Integrated Framework. The Internet Reasoning Service is a KMi Semantic Web Services framework, which allows applications to semantically describe and execute Web services. The IRS supports the provision of semantic reasoning services within the context of the Semantic Web. The core of IRS III uses the language Common Lisp to build the reasoner component. More information is available at http://kmi.open.ac.uk/projects/irs/**.**

INFRAWEBS Integrated Framework was described in the previous section when we mentioned the European project INFRAWEBS (http://www.iit.bas.bg/InfrawebsDesigner/Index.html). In this section we want to show the INFRAWEBS Designer, a graphical, ontology-based, integrated development environment for designing WSMO-based SWS and goals. The INFRAWEBS Designer does not require any preliminary knowledge of WSML. This issue simplifies the user's effort in a top-down design.

SAWSDL Based Tools

Finally, we look briefly at the available tools to work with SAWSDL. All of these tools have been developed by LSDIS and are available at http://lsdis.cs.uga.edu/projects/meteor-s/SAWSDL/.

The SAWSDL4J API interface is an implementation of the SAWSDL specification. The API would allow developers to create SAWSDL based applications. SAWSDL4J extends the WSDL4J API for WSDL1.1.

Woden4SAWSDL is a WSDL 2.0 parser, based on Apache Woden, with API classes that allow for SAWSDL parsing and creation.

Radiant is an Eclipse plugin that allows creating and publishing SAWSDL and WSDL-S service interfaces. Users can add annotations to existing service descriptions in WSDL using the user friendly graphical interface of Radiant.

Lumina is other Eclipse plugin that allows for discovery of Web services based on semantics. Lumina is a graphical user interface built on top of the METEOR-S Web Services Discovery Infrastructure engine. In the MWSDI engine, a semantically enhanced services registry is created based on UDDI.

APPLYING SEMANTIC TECHNOLOGY TO ENTERPRISE INTEGRATION

In the background to this chapter we established that ESB has become the most promising solution to build a SOA infrastructure from several heterogeneous sources. We also mentioned that there are a lot of projects and work being carried out by researchers in the area of Semantic Web Services. However, many of those works have focused on the search for a suitable technology to model traditional Web Services applying the acquired knowledge in the Semantic Web. Proof of this fact can be seen in a number of proposals submitted to the W3C.

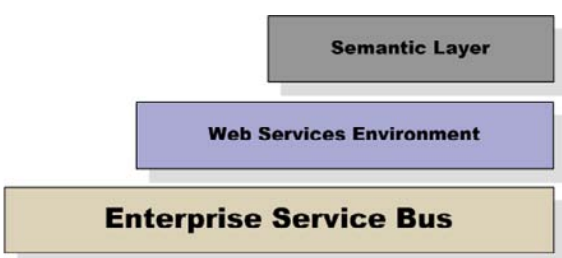
Although there is not an official standard for modelling Semantic Web Services we believe that developed approaches must be put in practice. In this way it is possible to use Semantic Web Services in conjunction with an ESB to overcome the problem of enterprise integration.

The use of the Semantic Web Services technology in enterprise would not be possible without the existence of an infrastructure that allows covering the life cycle of Web Services using semantic annotation techniques. This necessary infrastructure could be an ESB, which would facilitate the integration of various heterogeneous systems. An ESB allows the cooperation and the exchange of data between services. It is a logical architecture based on the principles of SOA, which aims to define services explicitly and independently of the implementation details. It also pays close attention to securing a transparent location and excellent interoperability (Chappell, 2004).

An ESB makes Web Services, XML, and other integration technologies immediately usable with the mature technology that exists today. The core tenets of SOA are vital to the success of a pervasive integration project, and are already implemented quite thoroughly in the ESB. The Web Service standards are heading in the right direction, but remain incomplete with respect to the enterprise-grade capabilities such as security, reliability, transaction management, and business process orchestration. The ESB is based on today's established standards in these areas, and has real implementations that are already being deployed across a number of industries. The ESB is quite capable of keeping in step with the ongoing evolution of the Web Services equivalents of these capabilities as they mature.

It would be interesting to maintain these capabilities over the use of Semantic Web Services. For this reason it has been proposed to construct an infrastructure composed of different layers where the ESB is the foundation on which the others are based. The objective is to define a Semantic Enterprise Service Bus (SESB), providing mechanisms to collect all these technologies together and acting as a layer to access services through the invocation paradigm based on goals. This SESB would therefore be responsible for the process of coordinating individual services available on the Web. Figure 9 shows an overview of the proposed infrastructure.

Figure 9. SESB architecture



The first step towards designing the system is to select a possible implementation of an ESB, which will be built on the remaining layers of the architecture. The fact that this tool is the pillar of the design means that the choice of implementation is of great significance with regard to possible integration with other technologies to be used in the upper layers.

On top of the first layer we can find the Web Services layer, which provides the necessary mechanisms for executing such services. Basically, this is the logic that acts as an intermediary between the lower layer and the semantic layer.

We are now working on developing the semantic layer. Our aim is to introduce semantics into the core of the ESB. This issue provides reasoning capabilities to the artefacts deployed on the ESB. Although we have not obtained experimental results we believe that the ongoing prototype will facilitate the deployment of new (semantic) services.

FUTURE TRENDS

Nowadays, the main challenge among researchers in the Semantic Web Service field lies in overcoming the technological gap between the use of syntactic technology and semantic technology. As we can see, many R&D projects are ongoing with the aim of bringing semantics into SOA. In many cases, the goal of these projects is to build a platform enabling the use of Semantic Web Services (INFRAWEBS, WSMX, IRS-III). These platforms cover the whole Semantic Web Service life-cycle enabling discovery of services based on goals, composition, registry and mediation. The developed tools rely on a top-down design, i.e., they assume that users start with an ontology implementation from which Web Services will be annotated. This way, the first step would be to specify goals, mediators and others semantic restrictions in order to build a semantic layer that Web Services will use.

Despite being the most common way to begin a new project based on Semantic Web Service technology in future, now it is not the most suitable way to evolve current SOA applications towards a Semantic SOA. The reason for this is that with a top-down design it is not possible to take advantage of the existing Web Services. Nowadays, a bottom-up design is necessary, which allows developers to re-use the existing applications and adapt them to the Semantic Web.

At present, some researchers have noticed this necessity and have begun to provide solutions. In this sense, a first approach has been the recent recommendation of SAWSDL by W3C, after developing a mechanism to enable semantic annotation of Web Service descriptions in WSDL 2.0. SAWSDL is independent of the language used for the ontology description. This fact makes SAWSDL suitable for being combined with different approaches such as WSMO or OWL-S as we can see in the recent works in this field (Vitvar, 2008; Paolucci, 2007; Kourtesis, 2008).

Current effort shows that researchers have become aware of the actual technological transition in SOA. In this sense, it is difficult to know when Semantic Web Services may be used among ICT enterprises without any limitation. For the moment, researchers should postpone the development of new platforms that cover the SWS life-cycle focusing their effort on obtaining a solution to overcome the current transition problem between SOA and Semantic SOA.

Therefore we propose the development of adapters or wrappers over existing SOA applications as a future extension of the described work. These adapters will allow the application of a semantic layer over implemented Web Services which will ba reusable in the proposed Semantic ESB. In this work we expect to implement an automatic or semi-automatic tool to annotate Web Services using SAWSDL over concepts in an ontology. This tool will be incorporated into the Semantic ESB to facilitate the deployment of not annotated Web Services.

CONCLUSION

In this chapter we have presented an overview of the topics of application integration and Semantic Web Services. First, we listed the different approaches for solving the application integration problem. Subsequently, we introduced the basis of SOA, Web Services and ESB, and later we described the main ideas in Semantic Web Services. We have commented on the existing proposals and classified them into two groups, namely top-down and bottom-up strategies. We also discussed the available tools for developing Semantic Web Services and provided a set of related projects with this technology.

Later, we briefly described our work on improving the use of an ESB in application integration.

The aim of this chapter has not been to compose a detailed manual in application integration nor Semantic Web Services because these topics have been treated in depth by other authors. However, we provided an overview of the work in this area and many useful references throughout the discussion for the interested reader.

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KEY TERMS AND DEFINITIONS

CORBA: The Common Object Request Broker Architecture (CORBA) is a standard defined by the Object Management Group (OMG) that enables software components written in multiple computer languages and running on multiple computers to work together.

DCOM: Distributed Component Object Model (DCOM) is a proprietary Microsoft technology for communication among software components distributed across networked computers. DCOM extends Microsoft's COM and provides the communication substrate under Microsoft's COM+ application server infrastructure.

EAI: Enterprise application integration (EAI) is the process of linking applications within a single organization together in order to simplify and automate business processes to the greatest extent possible, while at the same time avoiding having to make sweeping changes to the existing applications or data structures.

ESB: Enterprise Service Bus (ESB) provides an abstraction layer on top of an implementation of an enterprise messaging system, which allows integration architects to exploit the value of messaging without writing code. Contrary to the more classical enterprise application integration (EAI) approach the foundation of an enterprise service bus is built of base functions broken up into their constituent parts, with distributed deployment where needed, working in harmony as necessary.

GIOP: General Inter-ORB Protocol (GIOP) is the abstract protocol by which object request brokers (ORBs) communicate. Standards associated with the protocol are maintained by the Object Management Group (OMG).

IIOP: Internet Inter-Orb Protocol (IIOP) is the implementation of GIOP for TCP/IP. It is a concrete realization of the abstract GIOP definitions.

OMG: The Object Management Group, Inc. (OMG) is an international organization supported by over 600 members, including information system vendors, software developers and users. Founded in 1989, the OMG promotes the theory and practice of object-oriented technology in software development. Primary goals are the reusability, portability, and interoperability of object-based software in distributed, heterogeneous environments. OMG Task Forces develop enterprise integration standards for a wide range of technologies, and an even wider range of industries. OMG's modeling standards enable powerful visual design, execution and maintenance of software and other processes. OMG's middleware standards and profiles are based on the Common Object Request Broker Architecture (CORBA) and support a wide variety of industries.

ORB: An object request broker (ORB) is a middleware technology that manages communication and data exchange between objects. ORBs promote interoperability of distributed object systems because they enable users to build systems by piecing together objects- from different vendors- that communicate with each other via the ORB (Wade, 1994). The developers are only concerned with the object interface details. This form of information hiding enhances system maintainability since the object communication details are hidden from the developers and isolated in the ORB (Cobb, 1995).

RMI: Remote Method Invocation is the Java implementation for performing the object equivalent of remote procedure calls. The Java Remote Method Invocation system allows an object running in one Java virtual machine to invoke methods on an object running in another Java virtual machine. RMI provides for remote communication between programs written in the Java programming language.

RPC: Remote procedure call (RPC) is an inter-process communication technology that allows a computer program to communicate with a procedure running in another address space (commonly on another computer on a shared network) without the programmer explicitly coding the details for this remote interaction.

SAWSDL: The Semantic Annotations for WSDL and XML Schema (SAWSDL) W3C Recommendation defines mechanisms using which semantic annotations can be added to WSDL components. SAWSDL does not specify a language for representing the semantic models, e.g. ontologies. Instead, it provides mechanisms by which concepts from the semantic models that are defined either within or outside the WSDL document can be referenced from within WSDL components as annotations.

SOA: Service Oriented Architecture (SOA) is a software architecture where functionality is grouped around business processes and packaged as interoperable services. SOA also describes IT infrastructure which allows different applications to exchange data with one another as they participate in business processes. The aim is a loose coupling of services with operating systems, programming languages and other technologies which underly applications.

SOAP: SOAP is a simple and lightweight XML-based mechanism for creating structured data packages that can exchanged between network applications. SOAP consists of four fundamental components: an envelope that defines a framework for describing message structure, a set of encoding rules for expressing instances of application-defined data types, a convention for representing remote procedure calls (RPC) and responses, and a set of rules for using SOAP with HTTP. SOAP can be used in combination with a variety of network protocols; such as HTTP, SMTP, FTP, RMI/IIOP, or a proprietary messaging protocol.

UDDI: Universal Description, Discovery and Integration (UDDI) is a platform-independent, XML-based registry for businesses worldwide to list themselves on the Internet. UDDI is an open industry initiative, sponsored by OASIS, enabling businesses to publish service listings and discover each other and define how the services or software applications interact over the Internet.

WSDL: The Web Services Description Language (WSDL) is an XML-based language that provides a model for describing

ENDNOTES

1 Object Management Group

2 http://www.deri.org/

3 http://www.sti2.org/

4 http://kmi.open.ac.uk/

5 http://lsdis.cs.uga.edu/

6 http://www.w3.org/Submission/2004/07/

7 http://www.w3.org/Submission/2005/06/

8 http://www.w3.org/Submission/2005/07/

9 http://www.w3.org/Submission/2005/10/

10 http://lsdis.cs.uga.edu/projects/meteor-s/

11 http://www.wsmo.org/TR/d11/v0.2/20080304/

12 http://sdk.semanticweb.org/

13 http://www.essi-cluster.org/

14 NESSI Open Framework is one of the main challenges of the European Platform on Software and Services. It has a consortium of 16 partners and is led by Atos Origin. More information is available at http://www.nessi-europe.com/Nessi/.

15 http://www.wsmo.org/wsml/

16 http://www.wsmx.org/

Chapter XIV
Semantic Visualization to Support Knowledge Discovery in Multi-Relational Service Communities

Nadeem Bhatti
Fraunhofer IGD, Germany

Stefan Hagen Weber
Siemens AG, Germany

ABSTRACT

Services provided through the Internet serve a dual purpose. They are used by consumers and by technical systems to access business functionality, which is provided remotely by business partners. The semantics of services, multi-relational networked data and knowledge discovery in multi-relational service communities (e.g., service providers, service consumers, and service brokers, etc.) become an area of increasing interest. The complex multi-dimensional semantic relationship between services demands innovative and intuitive visualization techniques to present knowledge in a personalized manner, where community members can interact with knowledge assets and navigate through the network of Semantic Web services. In this chapter, the authors introduce Semantic Visualization approach (SemaVis) to support knowledge discovery by using hybrid recommender system (HYRES). It makes use of the semantic descriptions of the Web services, and also exploits the dynamic evolving relationships between services, service providers and service consumers. The authors introduce a sample scenario from a research project TEXO, within the THESEUS research program initiated by the German Federal Ministry of Economy and Technology (BMWi). It aims to supply a service-oriented architecture for the integration of Web-based services in the next generation of Business Value Networks. The authors present as well the application of their approaches SemaVis and HYRES to support knowledge discovery in multi-relational service communities of future Business Value Networks.

INTRODUCTION

In recent years there has been an enormous increase in interest in novel collaborative web sites on the one hand and semantically annotated content on the other hand. The fusion of collaborative and semantic data leads to complex scenarios with multi-relational data that contain several entity classes and multiple interactions. As an example consider some of the recent developments in the Web 2.0 that have resulted in novel types of social network communities represented as multi-relational data. Similarly, it is expected that the emergent Semantic Web will produce an enormous amount of structured relational data. Another example is B2B and B2C transaction data that is collected and analyzed to better serve the customers. Yet another example is enterprise applications based on service oriented architectures (SOA), containing a network of semantic Web services. Multi-relational networked data are now easily accessible and knowledge discovery in multi-relational domains has become an area of increasing interest. As a sample scenario, a platform for dealing with semantic Web services will be described. Providers as well as consumers are part of a service community realizing future business value networks.

The success of Web applications and platforms increases proportional with the amount of high quality content provided and collected from all customers. Supporting customers as most valuable assets therefore is a crucial aspect of a flourishing web business. Additionally, exploiting all existing data with leading technology to the customer's benefit is one of the most important tasks to address. The main driving force for a satisfied customer in his community is uniqueness. The customer has to be given the feeling of being perceived as an individual rather than let him drown in the pool of anonymity. This can only be achieved by understanding dynamic social network structures, the customers themselves as well as their relations. Existing approaches from social network analysis or machine learning concentrate on one single relation type that exists between two entity types. In practice, however, entity types are arranged in multi-relational networks and the involved relation types are usually highly correlated. Using all correlated relation types simultaneously will improve the performance of the relation prediction. Siemens AG developed HYRES (HYbrid REcommender System), an easy to apply, scalable and multi-relational matrix factorization model able to deal with any number of entity types and relation types.

Knowledge discovery in multi-relational service communities is a great challenge. However, the best technological background processes will be in vain if the knowledge presentation cannot be accomplished in an intuitive and user-friendly way. The complex multi-dimensional semantic relationship between knowledge assets (e.g. services and related recommended services) demands innovative visualization techniques to present knowledge in a personalized manner, where community members can interact with knowledge assets and navigate through the network of semantic Web services. The semantic visualization techniques offer a very promising solution to support knowledge discovery in service communities.

Fraunhofer IGD and Siemens AG have developed an approach of how semantic visualization can support knowledge discovery in multi-relational service communities. According to this approach, when a knowledge worker searches for a service he starts a query. As a result, the knowledge discovery system delivers a list of services which then are presented within knowledge spaces or clusters, e.g. services for automotive industry or services for the entertainment industry. In order to distinguish services and related recommended services, different graphical metaphors within knowledge spaces or clusters will be applied. These recommendations are based on HYRES that predicts a collaborative ranking of services according to the user's profile and favoured services (preferred by other community members with similar behavioural patterns).

Innovative service bundles[1] and their (semantic-) relationships will be visualized within clusters (knowledge spaces). Personalized graphical metaphors are exploited on the base of collaborative exchange of the data (knowledge sharing) to increase the service usage or generate new business models for customers and complete the value network. Furthermore, the semantic visualization allows knowledge workers to navigate through knowledge spaces or clusters to explore through automatic generated intelligent, dynamic hierarchical cluster of like-minded customers. This approach allows them to recommend suitable groups where the user's participation is most valuable and makes the customers feel unique and perceived.

The following subchapters describe our approaches for multi-relational semantic services selection and semantic visualization. Furthermore the deployment of this approach in the project "TEXO" Business Webs in the Internet of Services (IoS) as case study will also be presented.

SEMANTIC VISUALIZATION

It is not surprising that the field of Human Computer Interaction (HCI) has been closely bound to Moore's law[2]. At its inception, HCI was concerned primarily with the only large group of people who had access to the technology: office workers. This type of user had very clearly defined tasks and goals that they tried to achieve on fairly limited hardware. As Moore's law resulted in computer technology leaking out of corporations, HCI morphed to accommodate home usage and to look at how people set about completing less well-defined tasks. Currently, HCI has expanded to look at social and even whimsical application of technology (Marsden, G, 2008)). In the same way, semantic technologies are not limited to scientific community or companies any more. The semantic technologies are becoming part of daily life, that is why different user friendly and easy to use HCI techniques have to be introduced to improve acceptance of users.

According to (Gruber, T. R., 1993), an ontology is an explicit specification of a conceptualization. The term "Conceptualization" is defined as an abstract, simplified view of the world that needs to be represented for some purpose. It contains the objects concepts and other entities that rare presumed to exist in some area of interest and the relations that hold between them. The term "Ontology" is borrowed from philosophy, where ontology is a systematic account of existence. For knowledge-based system what "exists" is exactly that which can be (and has been) represented.

Therefore, as defined in Noy, N. F., & Mcguiness D. L. (2001), an ontology is a formal explicit description of concepts, or classes in a domain of discourse. Properties –or slots- of each class describe various features and attributes of the class, and restrictions on slots (called facets or role descriptions) state conditions that must always hold to guarantee the semantic integrity of the ontology. Each slot has a type and could have a restricted number of allowed values. Allowed classes for slots of type instance are often called arrange of slot. An ontology along with a set of individual instances of classes constitutes a knowledge base.

An ontology is more than just a hierarchy of concepts. It is enriched with role relations among concepts and each concept has various attributes related to it. Furthermore, every concept most probably has instances attached to it, which could range from one or two to thousands. Therefore, it is not simple to create a visualization that will display effectively all this information and allows the user to easily perform various operations on the ontology at the same time (Katifori, A. & Halatsis, C., 2007).

The following section describes the semantic visualization fundamentals (e.g. Human Visual Perception and graphical metaphor) which play a key role for the semantic visualization approach.

Human Visual Perception

According to Ware, C. (2004) a simplified information-processing model of human visual perception consists of three stages. In Stage 1, information is processed in parallel to extract basic features from the environment. In Stage 2, active processes of pattern perception pull out structures and segment the visual scene into regions of different colour, texture and motion pattern. In Stage 3, the information is reduced to only a few objects held in visual working memory by the active mechanism of attention to form the basis of visual thinking.

In Stage 1 processing, billions of neurons work in parallel, extracting features from every part of the visual field simultaneously. This parallel processing proceeds whether we like it or not, and it is largely independent of what we choose to attend to (although not of where we look). It is also extremely fast. If we want people to understand information quickly, we should present it in such a way that it could easily be detected by these large, fast computational systems in the brain. Important characteristics of Stage 1 processing include:

- Fast parallel processing
- Extraction of features, orientation, colour, texture, and movement patterns
- Transitory nature of information, which is briefly held in an iconic store
- Bottom-up, data-driven model of processing

At the second stage, rapid active processes divide the visual filed into regions and simple patterns, such as continuous contours, regions of the same colour, and regions of the same textures. Patterns of motion are also extremely important, although the use o motion as an information code is relative neglected in visualization. The pattern-finding stage of visual processing is extremely flexible, influence both by the massive amount of information available from Stage 1 (parallel processing) and by the top-down action of attention driven by visual queries. Important characteristics of Stage 2 processing include:

- Slow serial processing
- Involvement of both working memory and long-term memory
- More emphasis on arbitrary aspects of symbols
- In state of flux, a combination of bottom-up feature processing and top –down attention mechanisms
- Different pathways for object recognition and visually guided motion

At the highest level of perception, the objects are held in visual working memory by the demands of active attention. In order to use an external visualization, we construct a sequence of visual queries that are answered through visual search strategies. At this level, only a few objects can be held at a time, they are constructed from the available patterns providing answers to the visual queries. For example, if we use a road map to look for route, the visual query will trigger a search for connected red contours (representing major highways) between two visual symbols (representing cities).

Visual Information Seeking Mantra

There are many visual design guidelines but the basic principle might be summarized as the Visual Information Seeking Mantra “Overview first, zoom and filter, then details-on-demand” (Shneiderman, B., 1996). Based on ontology visualization characteristics, this section attempts an analysis of tasks related to ontologies. The categorization of tasks is based on the tasks analysis proposed by Shneiderman (Shneiderman, B., 1996), who presents high-level tasks that an information visualization application should support.

1. **Overview:** Gain an overview of the entire collection.
2. **Zoom:** Zoom in on items of interest
3. **Filter:** Filter out uninteresting items.
4. **Details-on-demand:** Select an item or group and get details when needed.
5. **Relate:** View relations hips among items.
6. **History:** Keep a history of actions to support undo, replay, and progressive refinement.
7. **Extract:** Allow extraction of sub-collections and of the query parameters.

Overview strategies include zoomed out views of each data type to see the entire collection plus an adjoining detail view. The overview contains a movable field-of-view box to control the contents of the detail view, allowing zoom factors of 3 to 30. Replication of this strategy with intermediate views enables users to reach larger zoom factors.

Users typically have an interest in some portion of a collection, and they need tools to enable them to control the zoom focus and the *zoom* factor. Smooth zooming helps users preserve their sense of position and context. Zooming could be on one dimension at a time by moving the zoom bar controls or by adjusting the size of the field-of -view box. Dynamic queries applied to the items in the collection to *filter* out uninteresting items are one of the key ideas in information visualization. Filtering allows users to quickly focus on their interests by eliminating unwanted items. *Details-on-demand* allows users to get detailed information on a selected item or group of items. The usual approach is to simply click on an item to get a pop-up window with values of each of the attributes. Viewing *relationships* among items (e.g. "book written by an author") as detail-on-demand allows users to understand different interaction patterns.

Keep a *history* of actions to support undo, replay, and progressive refinement. It is rare that a single user action produces the desired outcome. Information exploration is inherently a process with many steps, so keeping the history of actions and allowing users to retrace their steps is important. Allow extraction of sub-collections and of the query parameters: Once users have obtained the item or set of items they desire, it would be useful to be able to *extract* that set and save it to a file in a format that would facilitate other uses, such as sending by email, printing, graphing, or insertion into a statistical or presentation package.

Graphical Metaphors

User interface design requires designing metaphors, the essential terms, concepts, and images representing data, functions, tasks, roles, organizations, and people. Advanced user interfaces require consideration of new metaphors and repurposing of older ones. Awareness of semiotics principles, in particular the use of metaphors, can assist researchers and developers in achieving more efficient ways to communicate to more diverse user communities (Marsden, G., 2008).

Since Visicalc's metaphorical ledger and the Xerox Star's desktop metaphor[3], interface designers have been incorporating metaphors into user interfaces. User interface guidelines for most of the popular operating systems encourage the use of metaphors in interface design. They suggest that applications should build on the user's real-world experience by exploiting concrete metaphors thereby making applications easier to use. Surprisingly little research supports the popular belief that metaphors in user interfaces facilitate performance, e.g. productivity.

The motivations for using metaphors in the design of user interfaces are similar to the reasons metaphors have long been popular in education. Many educators have observed that giving students comparisons can help them learn. For example, an analogy commonly used in teaching about electricity is "Electricity is like water". Imagine electricity flowing as water does. You can then imagine the wires as pipes carrying water (electrons). It follows that your wall plug can be thought of as a high-pressure source which can be tapped by inserting a plug. These types of comparisons are also used in teaching in the domain of human-computer interaction. For example, a physical metaphor for electronic storage is to think of "storage locations as buckets." Experimental studies of the effectiveness of metaphor in teaching programming concepts have been conducted. Mayer showed that many programming constructs in BASIC (i.e., memory locations) could be learned more easily when they were presented in the context of a concrete metaphor. Thus, educators in many domains believe that students can import conceptual relations and operations from one domain to another.

SEMAVIZ: A SEMANTIC VISUALIZATION TOOL

"SemaViz" (Semantic Visualization), developed by Fraunhofer IGD, is a tool for ontology visualization, supporting different aspects, such as thematic co-occurrences, clusters, configurable domain-specific representations, and others. This section describes the semantic visualization approach of SemaViz, based on the semantic visualization fundamentals described in section 2. It also shows how the human visual perception and "visual information seeking mantra" were considered during the conceptualization of SemaViz and how they are supported by the use of various graphical metaphors.

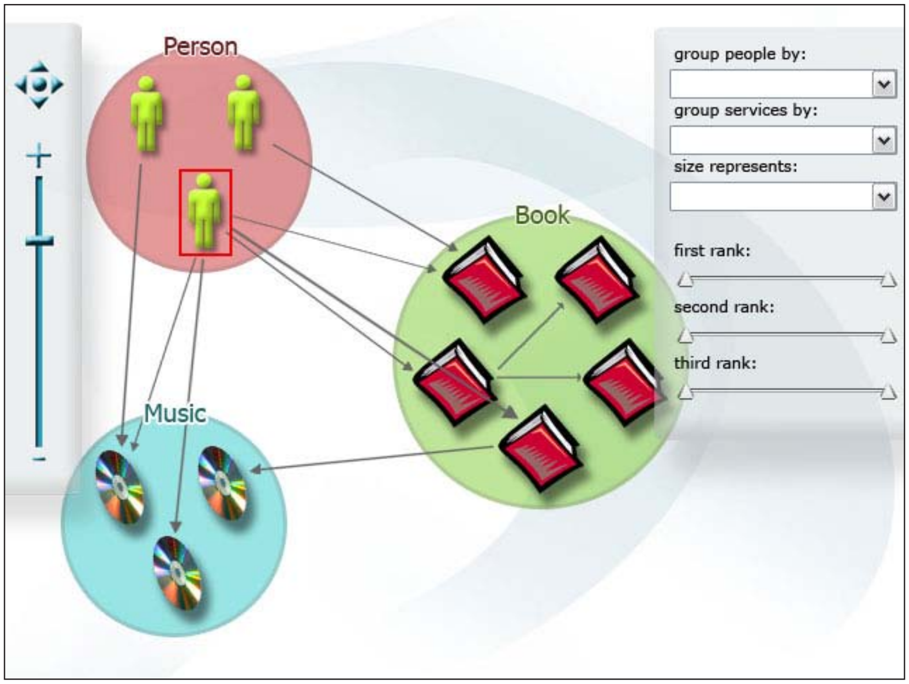
Some suggested approaches by Colin Ware (Ware, C., 2004), which improve effectiveness of information visualization for users, are listed below:

- In any case where it is necessary to reveal fine detail, luminance contrast is essential.
- Low-level channels tell us about coding dimensions. It means that we can usefully consider colour, elements of form (orientation, size), position, simple motion, and stereoscopic depth as separate channels.
- For clearly related information, the visual structure should reflect relationships between data entities. Placing data glyphs (graphical object) in spatial proximity, linking them with lines. Or enclosing them within a contour will provide the necessary visual structure to make them seem related. In terms of seeing patterns in rather abstract data displays, perception of contours is likely to be especially important.

As described in section 2, ontology is more than just a hierarchy of concepts. The concepts contain role relationships, attributes, and most probably have instances attached to them.. This means that instances are related to concepts and have relationships between them. According to the approaches suggested by Colin Ware, to use visual structure to reflect relationships, SemaViz has chosen circles as visual structure to represent concepts and graphical objects within circles to represent instances. The graphical objects enclosed within a circle provide a visual structure to show that an instance is related to concepts. The lines between instances represent the relationships between them. For example, Figure 1 shows three concepts (person, book and music) as circles, and instances as graphical objects within the circles. The relationships between instances are represented as directed edges. Furthermore, the colour coding represents different concepts and the size of circles represents the number of instance within one circle, respectively one concept.

According to the visual information seeking mantra, SemaViz is able to show all semantic

Figure 1. Overview in SemaViz

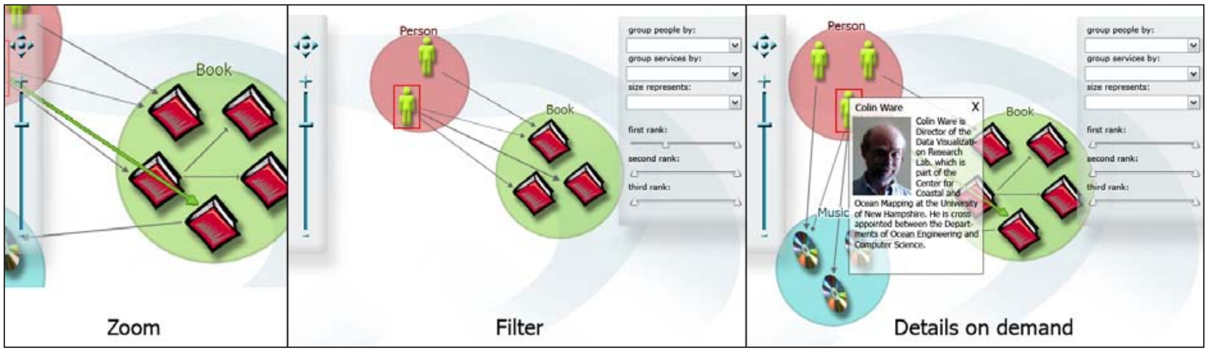


information as *Overview*, as shown in Figure 1. The semantic overview contains all concepts, instances and relationships. For example when users seek for a book "Information Visualization", then SemaViz shows all concepts and instances directly (first order siblings) or indirectly (second order sibling) related to the book. Additionally, users have the possibility to navigate through the semantic network by clicking on instances. With this approach, users can start querying the system and explore through the semantic network representing the query results. The *relationships* between instances can also be coded with colour or thickness to represent different types or attributes of relationships. For example, the relationship *isSimilar* might have the attribute *similarityValue* indicating the degree of similarity between two instances. In Figure 1, Colin Ware is marked and an arrow clarifies that the person "Colin Ware" *has written* the book "Information Visualization".

SemaViz offers *zoom* in and zoom out capabilities, enabling users to focus on specific semantic information, as shown in Figure 2. If a user is just interested in two concepts, e.g. book and person, then he can zoom in until the view is only focused on the desired semantic information. The control panel allows users to *filter* the visible information, and thus reduce the displayed semantic information, as shown in Figure 2. If a user wants to see just the books published in 2008, he can use a filter to do this, and to fade out all other books. Following another of Shneiderman's suggestions, SemaViz allows users to get *Details-on-demand* by selecting (clicking) one instance, as shown in Figure 2. The popup window shows detailed information, e.g. description, picture or video.

Graphical metaphors can assist researchers and developers to achieve more efficient ways to communicate to more diverse user communities, as described in section 2.3. SemaViz uses the cluster metaphor (circle) to represent the concepts

Figure 2. Zoom, Filter and Details-on-demand in SemaViz



of an ontology, graphical objects within clusters to represent instances, and arrows to represent relationships between instances. This metaphor should help users to easily understand complex ontology terms, such as concepts, instances, properties and relations. Furthermore, the use of icons for instances should help users distinguish different instances of different concepts. For example, abstract icons for books and persons make it easier for users to understand the semantic of an instance, as shown in Figure 1. The usage of individual book covers and person pictures, instead of abstract icons, will help users additionally to understand individual semantic relationships with respect to his/her environment, but also increases the amount of information in the overview.

MULTI-RELATIONAL SEMANTIC SERVICE SELECTION

This section focuses on the domain of personalized service selection, in an environment where users are offered a multitude of services, from which they must choose the best fitting ones. We also consider in which way services can be semantically described, and what relations exists between them. Furthermore, it is pointed out that service selection based solely on semantic annotation is usually not sufficient. The addition of an improved recommender system and the description of the additional relational concepts complete the service selection approach.

Semantic Service Description

The well established usage of Service Oriented Architectures (SOA) (Erl, T., 2005;Newcomer, E., & Lomow, G., 2005) in B2C and B2B applications is rapidly expanding the focus of Internet. These days the Internet provides not only textual and multimedia information, but also thousands of Web Services (Booth, D., Haas, H. & McCabe, F., 2004). A challenging task is the discovery and selection of yet unknown services in the huge space of the WWW, fitting to user requirements (Verma, K., Sivashanmugam, K., & Sheth, A., 2005; Sreenath, R. & Singh, M., 2004). Universal Description, Discovery and Integration (UDDI) (Bellwood, T., Capell, S., & Clement, L., 2004) repositories were a first and important step towards the registration and discovery of Web services. However several problems could not be solved by this approach: Web Services are described via the Web Service Description Language WSDL (Christensen, E., Curbera, F., & Meredith, G., 2001) only syntactically and not semantically, UDDI allows only keyword and taxonomy based searches, multiple categorizations and identification schemas are used and no search for unknown services is provided.

Hence the semantic description of Web Services has been the logical extension to the existing standards (Sheth, A., & Meersman, R., 2002). Domain independent ontologies for flexible modelling of the web service capability descriptions are defined by upper level ontologies, including OWL-S (David, M., Burstein, M., & Hobbs, J., 2004), WSDL-S (Akkiraju, R., Farrell, J., & Miller, J., 2005) and WSMO (De Bruijn, J., Bussler J., & Domingue, J.,, 2006). All models provide terms, concepts, and relationships to describe various service properties like inputs, outputs, preconditions and effects (IOPE).

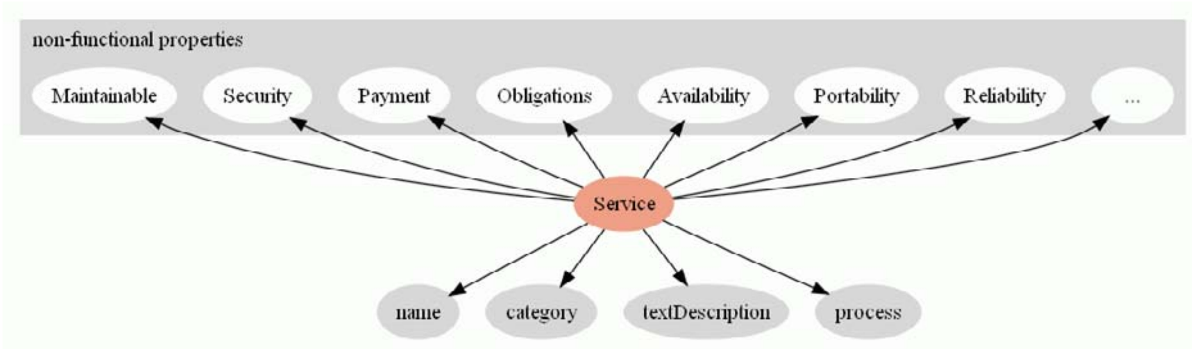
Based on such models, semantic matching algorithms can be applied to discover fitting services (Smeaton, A., & Quigley I., 1996); Klein, M., & Bernstein, A. (2003); Rodriguez, M., & Egenhofer, M., 2003) and to rank the results (Cardoso, J., & Sheth A., 2003). Several ranking methods can be used to calculate the degree of match. The logic-based approach uses description logics and first order logic reasoning to match semantic capabilities (Paolucci, M., Kawamura, T., & Payne, T. R., 2002). Similarity-based methods apply information retrieval techniques like linguistic similarity or term frequency for match making (Wu, J., & Wu, Z., 2005). Graph matching calculates a structural match where two service descriptions match if they have the same structure and the corresponding nodes match (Bellur, U., & Kulkarni, R., 2007).

However the IOPE properties of services are not sufficient to carry out efficient service discovery. Non-functional properties define what the service is about. They describe the service in terms of its descriptive metadata, such as a reference to a classification type, or characteristics that are not directly related to the functional description of the service. O'Sullivan, J., Edmond, D., & ter Hofstede, A. H. M., (2005) gives a detailed formal description for non-functional service properties. They introduce complexity to the description of services but their inclusion is crucial to the automation of service discovery, comparison and substitution. The OWL Web service ontology offers "placeholders" for the description of non-functional service properties, along with a minimal number of specific non-functional properties. In the context of the OWL-S profile, the non-functional properties of services are considered to be almost entirely domain specific. The Web Services Modeling Ontology (WSMO) uses Dublin Core metadata[4] as the core properties, and then extends these to include some Web service properties. The non-functional properties outlined thus far are more indicative of the categories of non-functional properties than a specific non-functional property set. The model is extensible and aims at domain-specific inclusions. The Web services Description Language (WSDL) presents an entirely functional view of services and was not intended to attempt the description of the non-functional properties of services. Non-functional properties in OWL-S and WSMO are an initial set that can be expanded.

Examples of non-functional properties resulting from the Dublin Core Metadata Ontology are: name, contributor, coverage, creator, description, date, format, identifier, language, publisher, relation, rights, source, subject, title or type. Examples of non-functional properties regarding Quality of Service (Toma, I., Foxvog, D., Jaeger, M.,, 2006; KangChan, L., JongHong, J., WonSeok, L., 2003; Maximilien, E. M., & Singh, M. P., 2004) include: accuracy, network related QoS, performance, reliability, robustness, scalability, security and trust. Other non-functional properties mentioned by O'Sullivan, J., Edmond, D., & ter Hofstede, A. H. M., (2005) are: availability, maintainability, portability, payment, price, discounts, obligations, penalties, quality, location of provisioning, version, delivery terms, benefits, supported languages, delivery unit, owner, type of match or category.

Figure 3 depicts a semantically described Web service (OWL-S) with examples of non-functional properties.

Figure 3. Semantic Web service description (OWL-S)



Personalized Service Recommendation

The semantic discovery and ranking of services in the worst case still leads to an impersonalized list of hundreds of services. The personalized service selection is yet unaddressed. Web services can be traded as virtual products via the WWW. In the majority of cases product selection is done using a recommender system. Recommender systems are computer programs which attempt to predict items (movies, music, books, news, web pages or services) that a user may be interested in, given some information about the item or the user's profile. Content based algorithms only use item information whereas collaborative filtering makes use of personal preferences and information of the user. Various recommender solutions can be applied to the service selection problem (Karta, K., 2005; Balke, W., & Wagner, M. 2003; Manikrao, U. S., & Prabhakar, T. V. 2005).

A pure content based recommender system takes the described functional and non-functional properties of a Web service as input to calculate a recommendation. Approaches using collaborative filtering make use of relations between the entities (Herlocker, J. L., Konstan, J. A., & Terveen, L. G.,, 2004). Hybrid solutions combine both methods resulting in improved prediction accuracy. The identified entities are users, services and actors. Obvious relations in a service ecosystem are listed in Table 1.

Service Ratings

The relation consumes could be used as an implicit feedback and interpreted as a user's positive attitude towards the service. However, this behaviour

Table 1. Relations between users, services and actors

Entity 1	Relation name	Entity 2	Description
User	`Consumes`	Service	The user takes the role of a requester. A requester entity is a person or organization that wishes to make use of a provider entity's Web service. It will use a requester agent to exchange messages with the provider entity's provider agent.
User	`Provides`	Service	Here the user takes the role of a provider. The provider entity is the person or organization that provides an appropriate agent to implement a particular service.
Service	`Orchestrates`	Service	An orchestration defines the sequence and conditions in which one Web service invokes other Web services in order to realize some useful function.

Service	`contactInfo`
	`contributor`
	`creator`
		User/
		Actor
			Provides a mechanism of referring to individuals responsible for the service (or some aspect of the service). The range of this property is unspecified within OWL-S, but can be restricted to some other ontology, such as FOAF, VCard, or the now deprecated Actor class provided in previous versions of OWL-S

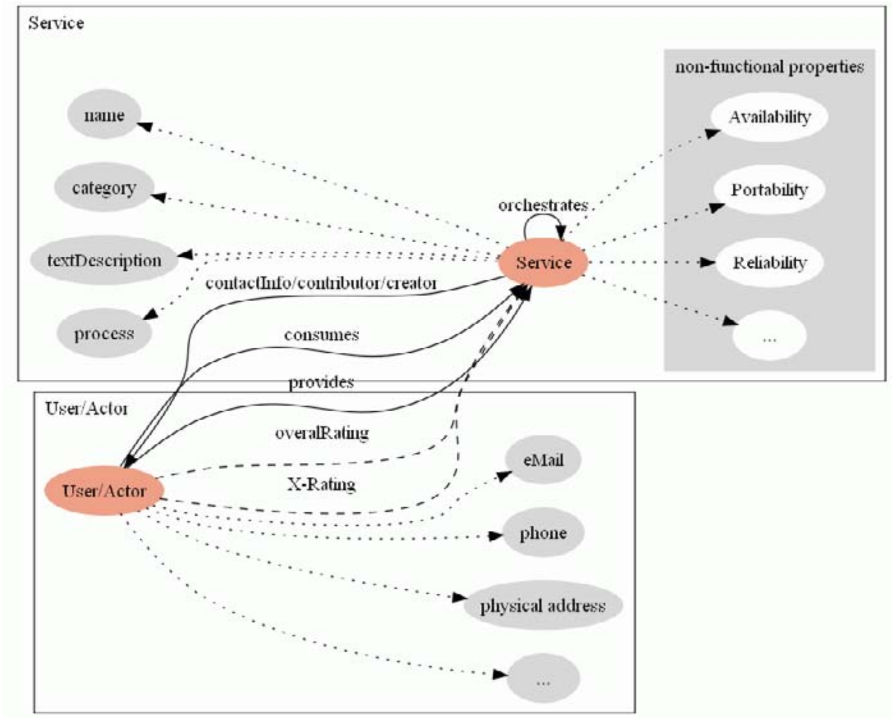
data does not necessarily accurately represent the user's true opinion of a service. The implicit data collection does not demand any direct input of the user regarding his opinion. Instead, his actions are monitored and used as an indicator of his attitude towards the product. The implicit data collection can lead to a huge amount of data. Explicit data collection requires the user to rate content with an ordinal value. The users therefore are aware of the importance of their opinion which might lead to a more accurate feedback but less data available. Furthermore, the preferences can be divided into different aspects of the service to achieve a better understanding of the individual service consumers and their prioritization of certain aspects of the service itself. For example, one consumer might appreciate the performance of a certain service, while disapproving the availability and the security aspects. Since he puts more emphasis on performance, his overall opinion of the service still tends to be good. The above mentioned quality of service aspects are already described as non-functional properties of the service. The values of the non-functional properties only reflect the opinion of the service provider or an impartial partner. They cannot reflect the individual taste and rating of all the service consumers. Therefore, the preferences for these aspects have to be explicitly collected as *ratings.* Since there may be a large number of non-functional properties, a subset might be defined that is to be rated by the service consumers. In addition, it is not reasonable to rate all non-functional properties, e.g. for a service it makes no sense to rate Dublin Core properties like contributor, coverage, creator, date, format, identifier, language, publisher, source or subject. Note that the rating of all the different sub-aspects should be optional, as the user might be indifferent in his opinion towards some of them. Furthermore, the user should get the opportunity to describe his experience with a consumed service and his opinion about it in detail. This can be accomplished by offering a free text input field. Free text will not be further evaluated here since we focus rather on structured rating data than on unstructured data. Feature extraction algorithms, however, can be used to derive structured information from free text. Examples of additional relations resulting from non-functional properties are listed in Table 2.

Figure 4 depicts the described entities with their various interrelations. Each arrow symbolizes one relation type. To keep the figure layout clear, all the non-functional rating relations are subsumed in one relation called "X-Rating". Dotted edges indicate attribute relations, dashed edges refer to rating relations and solid edges describe transactional relations.

Table 2. Examples for non-functional rating relations between user and services

Entity 1	**Relation name**	**Entity 2**	**Description**
User	`overallRating`	Service	overall impression of the service
User	`accuracyRating`	Service	precision and exactness of service results
User	`performanceRating`	Service	manner or quality of functioning
User	`reliabilityRating`	Service	worthy of reliance or trust
User	`availabilityRating`	Service	degree of being present and ready for use; at hand; accessible
User	`priceRating`	Service	cost/performance ratio
User	`paymentRating`	Service	quality and quantity of types of payment services offered
User	`robustnessRating`	Service	ability to operate despite abnormalities in input, calculations, etc.
User	`scalabilityRating`	Service	ability to either handle growing amounts of work in a graceful manner, or to be readily enlarged

Figure 4. Semantic Web service descriptions and interrelations to service provider, consumer and actors



Semantic Rating Description

The rating relation is not binary, but ternary. In Semantic Web languages, e.g. RDF and OWL, we have only binary relations (properties) between individuals, such as a property P between an individual A and individual B, more precisely, P is the property of A with the value B. However, every rating from the user to a service also has a rating value attached or an additional timestamp. Noy, N., & Rector, A., (2004) describe a solution to represent properties of a relation, such as rating value as follows: P becomes a relation among user, service, and rating. A common solution to representing n-ary relations such as these is to create an individual which stands for an instance of the relation and relates the entities that are involved in that instance of the relation. The original relation then becomes a class of all these relation instances.

OverallRating_1 is an individual instance of the OverallRating class representing a relation:

```
:OverallRating_1
 a      :OverallRating ;
 :user :Tom ;
 :service :Ecocalculator ;
 :ratingValue :4.
```

The following figure shows the corresponding classes and properties. Each rating has exactly one rating person, exactly one rated service and exactly one rating.

All other rating relations can be modelled as sub-classes of the OverallRating class. They inherit all the properties of the super class. Figure 7 shows the RDFS schema with three sample ranking instances: user Tom rates the service “EcoCalculator” in three different ways: the overall rating is 4, the performance rating is only 1, whereas the accuracy rating is 5.

Figure 5. N-ary rating relation

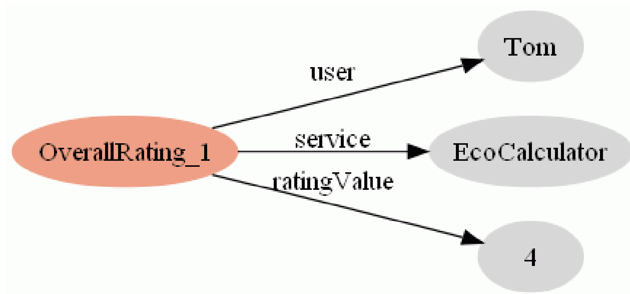


Figure 6. Classes and Properties of N-ary rating relation

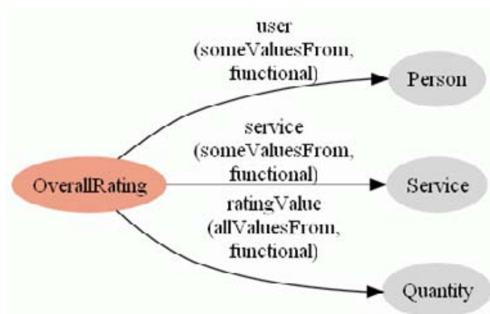
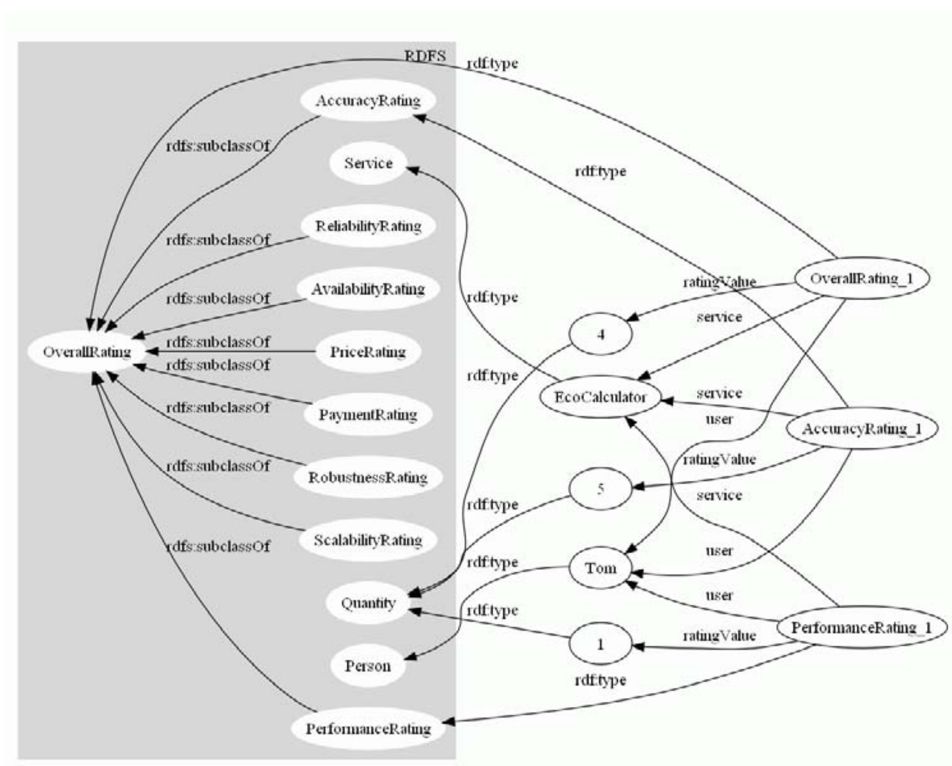


Figure 7. RDFS-Rating hierarchy with sample instances



HYRES: A Multi-relational HYbrid REcommender System

Recommender Systems traditionally focus on a two dimensional model, usually recommending items to users or vice versa. However it has been argued that this approach based on singular rating values is not sufficient in the context of semantic Web services. Multidimensional recommender systems provide a solution to this problem.

Siemens implemented a hybrid recommender system (HYRES) that makes use of the semantic descriptions of the Web services, and also exploits the dynamic evolving relationships between services, service providers and service consumers. HYRES is based on a novel algorithm called multi-relational matrix factorization (MRMF) presented in (Lippert, C., Weber, S., Huang, Y., 2008). Established matrix factorization models are focused on a single relation class connecting two entity classes. MRMF can handle an arbitrary number of entity types and relation types in a given domain and exploits multiple relation types simultaneously. The approach picks up the idea from (Yu, K., Yu, S., & Tresp, V., 2005) of combining more than a single matrix factorization in a single optimization criterion and generalizes it to an arbitrary number of matrix factorizations. By applying a gradient descent algorithm similar to (Takacs, G., Pilaszy, I., & Nemeth, B., 2007), (Rennie J., Srebro, N., & Jaakkola, 2005) and (Funk, S.,, 2006) the approach can handle sparsely observed input matrices and is highly scalable.

SEMANTIC VISUALIZATION FOR MULTI-RELATIONAL SEMANTIC SERVICE SELECTION

HYRES exploits semantic features of the Web services together with the interactions between services, service providers and service consumers, as described in Section 4 The basic idea is to combine the power of semantics and recommender systems to support semantic service selection. This approach will help users easily identify useful services, as well as interesting sub-communities. The advantages of this approach can only be achieved if the results of a semantic search and personalized recommendations are presented in an intuitive and user friendly way.

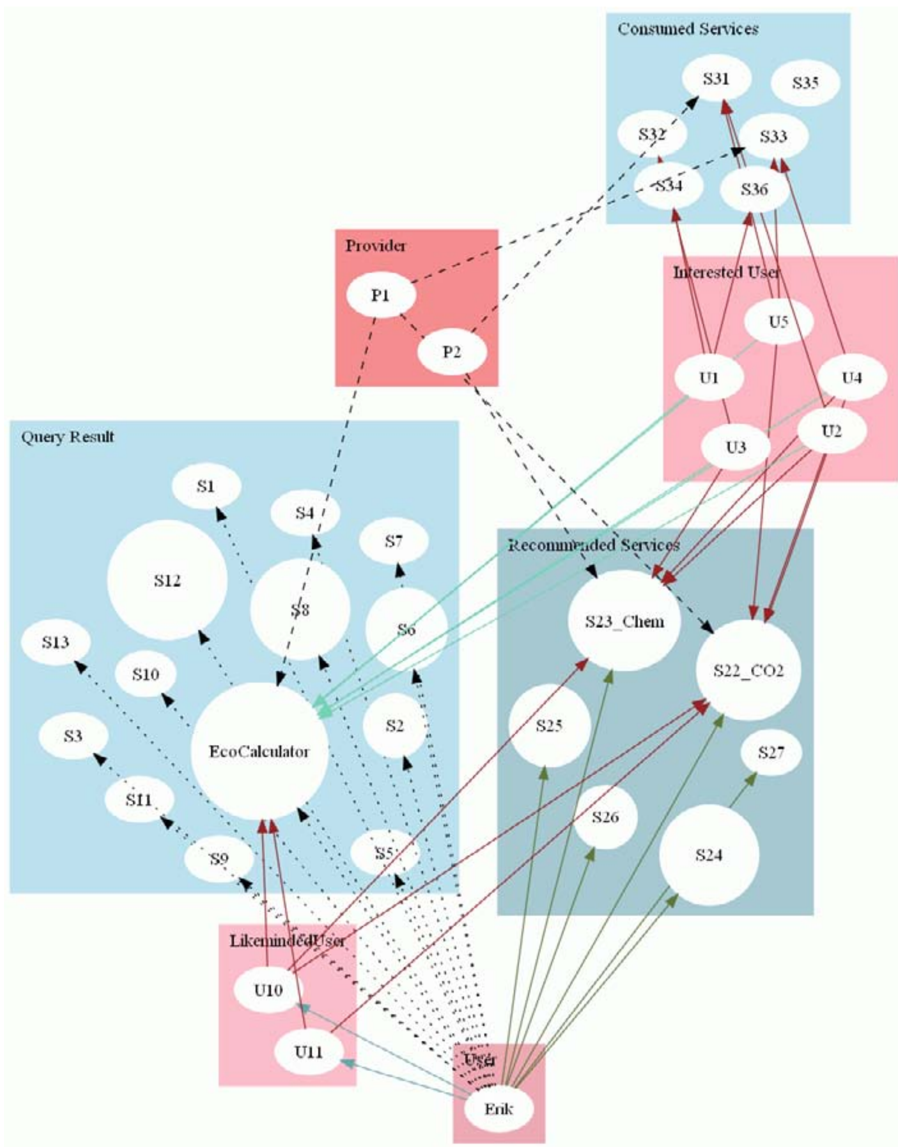
Different and partially concurrent aspects and roles have to be visualized coherently. The ontology concept of a person can take one or more of the following roles. Each role has to be clearly visualized to the knowledge worker.

- **Initial service searching consumer:** The knowledge worker himself should play a central role in the visualization. He is connected through various relations to services and other users in their particular roles, e.g. he might have relations to the discovered services, to recommended services, to self-provided services or to a recommended sub-community of likeminded users to ease valuable intercommunication.
- **Service provider:** A person who provides his own services also has to be reflected in the visualization. His relations are e.g. to his service consuming customers, to recommended potential customers, to competitors or to recommended value chain completing services.
- **Recommended similar user:** this relation shows users with similar service usage behaviour - be it as provider or consumer or a combination of both.
- **User interested in service:** The interest can be derived from two different sources. First the user shows his interest by using the service directly and rating it. Second a collaborative recommendation to the user can identify a potential interest.

Accordingly, the roles of a service can be defined as services retrieved by a semantic search, by a collaborative recommendation or by similarity to other services. Furthermore users and services might be distinguished by a category, e.g. their industry sector. Figure 8 shows an example of a user Eric who has relations to services retrieved by his query, to recommended services and to likeminded users. Furthermore, service providers, interested users and consumed services are shown.

The combination of all the different roles leads to complicated scenarios to be visualized in an acceptable manner. On the one hand, ontologies have to reflect the actual roles of all participants or the ontology has to be enhanced with these concepts during the visualization process. On the other hand, sophisticated relations have to be simplified without any information loss. One example is the visualization of ratings which are

Figure 8. Example of user and service roles



described in Section 4.3. Ratings as n-ary relations are modelled as ontology concepts themselves. It is not worthwhile and neither catchy to visualize ratings as entities. Users will still want to perceive ratings as relations notwithstanding the ontological model.

Semantic visualization concepts, as described in chapter 2, have to be extended to meet the needs of recommender systems like HYRES. After a semantic search the results of the query will be presented according to the semantic visualization approach. For example, industry sectors are concepts of the ontology in use and services within an industry sector are ontology's instances. In a second step SemaViz visualizes recommendations of HYRES (Multirelational HYbrid REcommender System) as additional information. This can be one or a combination of the following aspects:

- Historical ratings about used services of the current user can be shown. The relation can be labelled as "rates" and includes the rating value as an attribute of the relation. The ratings could further be split in two relations. One reflects the ratings with very high values and therefore describes the relation likes. The opposite relation dislikes consists of all the ratings with very low values. Mostly only the relation likes will be of interest to the user.
- Personalized recommended services are predicted by HYRES based on the historical service usage of the user. The recommendation is a prediction of the rating value the user would give to a service if he would consume it. This relation can be labelled as recommendedService. Again this relation could be split in "highly recommended" for high predicted rating values and "avoid" for low predicted rating values. We focus only on recommended services with high predicted rating values.
- The reverse relation to recommendedService is the relation potentialUser which is of interest for service providers. This relation is also predicted by HYRES.
- Similar services are predicted by HYRES based on the historical service usage of the services themselves, and on their semantic description. The recommendation is a prediction of the similarity between services. The relation is labelled similarService.
- Similar users are predicted by HYRES based on their historical service usage and their semantic description. The recommendation is a prediction of the similarity between users. The relation is labelled similarUser.

These new recommender system specific relations have to be added to SemaViz. The following table represents all additional relations.

To visualize the HYRES specific relations, a colour coding as shown in Table 3 is used. Since the knowledge worker is only interested in a subset of all available information, there has to be a way to dynamically arrange the desired visualisation. Depending on the user's objectives the visualization has to be interactively adapted: relations and roles are shown or (partially) hidden and the level of abstraction can be zoomed as described in section 3.

CASE STUDY: TEXO, A SERVICE BROWSER FOR SERVICE COMMUNITIES IN INTERNET OF SERVICES (IOS)

TEXO[5] is a research project, within the THESEUS research program initiated by the Federal Ministry of Economy and Technology (BMWi). It aims to supply a service-oriented architecture for the integration of web-based services in the next generation of Business Value Networks. The research focus of TEXO addresses the full lifecycle ("from innovation to consumption") of business

Table 3. Additional recommender system specific relations in SemaViz

From	Relation	To	Source	Colour coding	Description
User	`rates`	Service	Ontology Management System		Historical ratings from users about used services. This relation could be split is “likes” and “dislikes”.
User	`Recommended Service`	Service	HYRES		Predicted rating values based on historical service usage of the user
Service	`Potential User`	User	HYRES		Users that would give a high rating value to the service with a high probability.
Service	`Similar Service`	Service	HYRES		Similar services, based on service usage as well as service description
User	`SimilarUser`	User	HYRES		Likeminded users, based on service usage as well as user description

services via intuitive interfaces and technical systems, and aims to provide a new Internet-based infrastructure to support the development, the use, the retrieval, and the access of services, and to improve their value of knowledge.

Services provided through the Internet serve a dual purpose: they are used by consumers and by technical systems to access business functionality which is provided remotely by business partners. The goal of TEXO is to provide a platform which makes services tradable on the internet, compose able into value-added services, and allows the integration of customized services into the environment of service consumers. An example for such a service is described in the next chapter: the certified calculation of a product’s eco-value to guarantee compliance with new laws.

TEXO takes advantage of semantics and web 2.0 technologies like Community and Mashups to support the search and the use of services in the web. In collaboration with Siemens AG, Fraunhofer Institute for Computer Graphics (IGD) has developed the semantic visualization tool SemaViz for the service discovery and selection. The following section describes a TEXO scenario and application of SemaViz in the TEXO project.

TEXO Sample Scenario: Eco Calculator

The European Union has recently introduced a voluntary scheme to encourage businesses to market products and services that are environmentally-friendly and for European consumers - including public and private purchasers - to easily identify them with an Eco-label. The EU Eco-label has a clear objective of encouraging business to market greener products. With growing concern for the environment, consumers are becoming more aware of the need to consume eco-friendly products. This market dynamics puts pressure on manufacturers and producers. The EU has published a list of products that have eco-friendly labels. It initially started with simple products such as laundry detergent. However, recent additions include personal computers, televisions, and washing machines. So far, there is no mention of any automotive product. While the EU Eco-label is a voluntary scheme, increasing market pressure from consumers with environmental concerns has made many manufacturers and producers realize that eco-labelling their products makes good business sense.

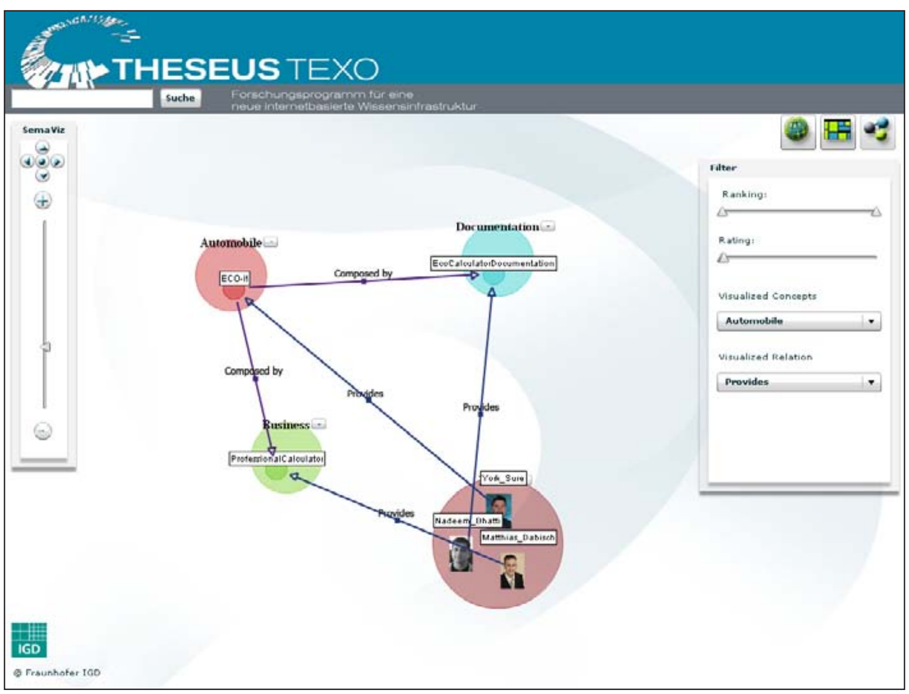
The use case plays in the automotive manufacturing industry. A seat manufacturer has been asked by a car manufacturer, to offer and adapt one of their seat models for the new Eco-label. This sets prescriptive limits for e.g. recyclable material and environmentally friendly manufacturing processes. The seat manufacturer is already aware of the advantages of TEXO Business Web and has registered their company profile.

Service providers also notice the recent increase of queries for Eco-label services. First basic versions of this new service are offered by several providers who compose and orchestrate several existing services. Some even add newly developed own services. The resulting new service only fulfils the basic demand for calculating an Eco value and issue a certificate.

The seat manufacturer figures out they have to calculate and proof that the eco balance for the seat is above 85%. Since his software environment does not offer such calculations he drags and drops the whole government requirement text on the TEXO icon in the taskbar. The visual service discovery SemaViz is started as front end to all background processes that are retrieving the results to the user query. Figure 9 depicts the visualization of the query results. A service "Eco it" is found. Additional semantical information is displayed indicating that the service is provided by "York_Sure" and that the service itself is composed of two other services "EcoCalculator-Documentation" and "ProfessionalCalculator". Their providers are also displayed, e.g. the service "EcoCalculatorDocumentation" is provided by "Nadeem Bhatti".

In order to better visualize the presented results, services can be ranked by several methods: by level of ability to be automatically integrated in the software and the system environment of the seat manufacturer, the purchasing conditions, the pricing model and by a personalized ranking factor indicating how well the new service would fit to the historical service usage behaviour pattern of the seat manufacturer. The last ranking method, calculated by HYRES, is one of the most important since it covers the actual hidden preferences of the company. For example, if several Romanian colleagues work in the software-lab, support from a Romanian speaking helpdesk is generally preferred. This information is not explicitly modelled anywhere. However there exists a fraction of likeminded users from the TEXO environment that already made their decision and experiences. They prefer a certain service that now gets a higher ranking for the seat manufacturer as a

Figure 9. SemaViz visualizes the query results

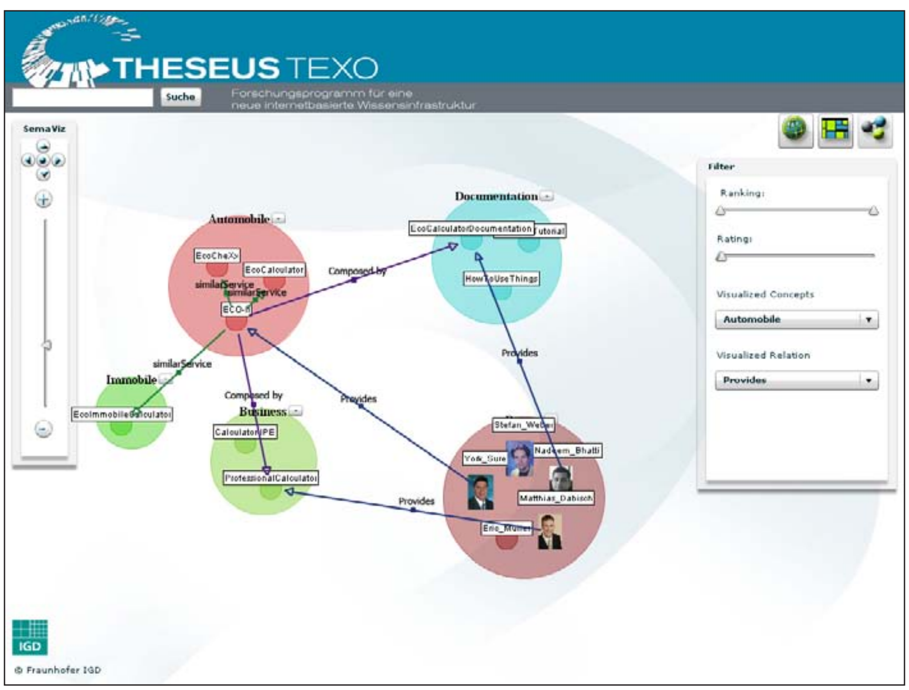


consequence. Since in the above example only one service was found by the semantic query, the seat manufacturer would like to have a more diversified choice of services. One way to expand the list of services is to display all services that are used in the same way as the "ECO-it"-service. HYRES recommends some services that feature similar behavioural patterns as the "ECO-it"-service and therefore are highly correlated to it.

Now the seat manufacturer has a better overview and decides to use one of the recommended services. To use it, the user accepts the displayed conditions and the software is automatically integrated in his working environment; in this case, extending the parts list table with a column for the "eco value", displaying a button "eco calculator" in the navigation bar and a button "calculate eco balance" in the product & design tool. After running the calculator, the parts list table shows that the overall eco value is shortly under the required value of 85%, barely missing the norm.

At this point the manufacturer would like to know some more details about the root causes of the bad "eco value". Therefore he needs some more services that complete the Eco Calculator service in its complexity. Initially he has no further keywords to query for. Again, likeminded users might have solved this problem for him. So the seat manufactured uses SemaViz to explore various semantic relationships. First he requests a set of top ten recommended services. Furthermore SemaViz displays all other consumers of the Eco Calculator service along with their used services. Immediately, the manufacturer notices that two of the recommended services are also broadly used by other consumers using the Eco Calculator. One delivers information about the amount of carbon dioxide released during the production process of polymethane cellular plastics used in the seats. Another service gets the detailed chemical composition of the used type of polymethane cellular plastics and the environmental compatibility of each component. Now the seat manufacturer has all information in his hands to start the improvement of his product. In the end the certificate

Figure 10. Similar services calculated by HYRES



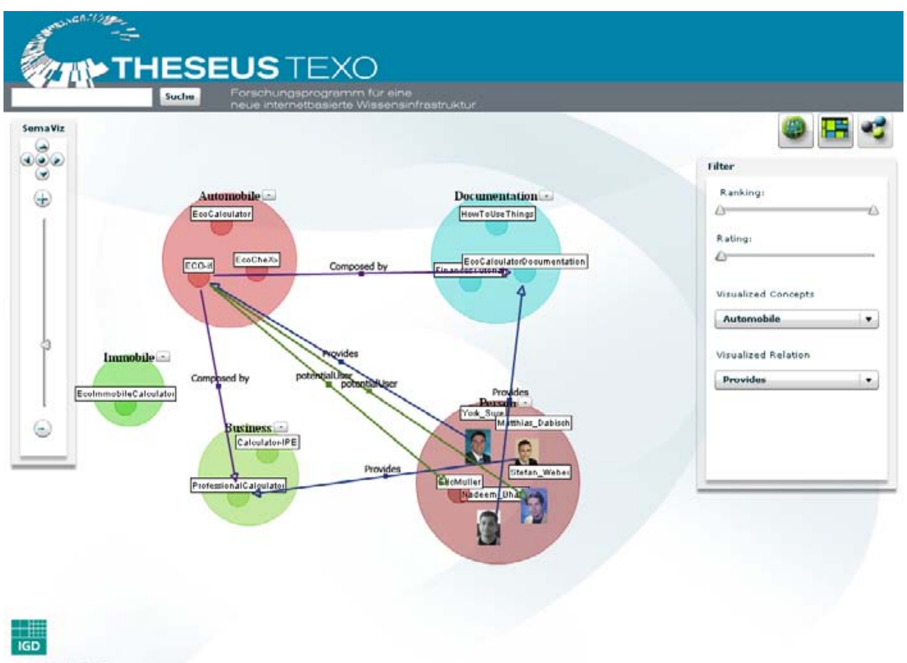
can be downloaded and the service usage can be stopped via TEXO Business Web.

It may be that at some point the seat manufacturer still has some open questions regarding the new law concerning the eco-value regulations. There is no service that will answer his demand. However, a dynamic and agile community is available and ready to answer. HYRES finds a sub-cluster of service community members fitting to the seat manufacturer's service usage profile and recommends the found users the manufacturer. Now he has all information on his fingertips.

The service provider at the other side is aware that the Eco Calculator offered by him is completed by other services on the customer side. Now he has several alternatives to explore service usage relations. First he requests a list of all recommended services for him as service provider. Second he shows all service consumers of these recommended services together with the services they are already consuming from his offered services. This combination clearly shows up what services really have the potential to complete his value chain of offered services. He updates his offer range and now can cover a broader bandwidth of his customer's demands. To increase his customer base with his now completed value chain he decides for letting TEXO search for potential customers. Again HYRES predicts a list of service consumers that would need the offered services with a high probability. He can also get an overview about what his competitors offer. Other service providers however might only be displayed anonymized. Figure 11 shows a possible display of potentialUsers. The provider can now make a dedicated offer to e.g. "Stefan Weber".

SemaViz harmonizes all these interactive service browsing activities in one easy to use graphical interface. It allowed users also to filter the services according to their system ranking and user rating with the filter panel as shown Figure 11. Users can also decide which concepts and relationships have to be visualized to reduce information and cognitive overload. Furthermore, details on demand about services will be offered

Figure 11. Recommended Customers are displayed for campaign management



by double click on services or by using different levels of zoom.

CONCLUSION AND FUTURE WORK

A number of important challenges for visualization and service selection research have been answered. Given an increasing quantity of available relational information, it is essential to use powerful tools for discovering and visualizing accurate information from semantic service communities. We have designed and implemented a graphical tool for the visualization of semantic metadata for the use of multi-relational service selection. SemaViz is capable of visualizing multi-relational data in an interactive and user-friendly way. The interactivity and appropriate visualization greatly helps the user to analyze relationships in service communities and browse complex semantic descriptions. The recommendation system HYRES enriches knowledge discovery in service communities by personalized recommendations of services and sub-communities. Recommendations based on machine learning methods help selecting services and open up business opportunities.

Other challenges still have to be approached. Among them is the inclusion of additional relations and other views like cushion trees and geographical visualization (e.g. via Google maps). Although scalability has been proven for the recommendation system (Lippert, C., Weber, S., Huang, Y., 2008) it has to be shown that the visualization approach is scalable for thousands of instances. Furthermore, similarities of services/users might be displayed using graphical means by displaying more similar entities nearer to each other. This will be a significant improvement of visual cognition. Extensions to SemaViz to enhance the ease of use include the dynamic personalized view adaption, e.g. the interactive selection of relation types and the possibility to define dynamic fading in and out of relations over a defined number of edges. This can be done by more than one instance (e.g. two users simultaneously).

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ENDNOTES

1. These bundles consist of various services of different kind that are orchestrated together in an innovative way.
2. http://www.intel.com/technology/mooreslaw/
3. http://www.baddesigns.com/mswebcnf.htm
4. http://dublincore.org/
5. URL: http://theseus-programm.de/scenarios/en/texo

Chapter XV
Knowledge Protocols

Ercan Oztemel
Marmara University, Goztepe Campus, Turkey

Esra Kurt Tekez
Sakarya University, Esentepe Campus, Turkey

ABSTRACT

Manufacturing enterprises continuously have to cope with changing markets that are unpredictable and diverse; manufacturing industry is facing international competitiveness and globalization. This obviously requires industrial organizations to manage different components of their organizations by integrating and coordinating them into a highly efficient, effective, and responsive system in order to maintain and improve their competitiveness. This chapter presents a knowledge exchange procedure for creating an integrated intelligent manufacturing system. The basic features of proposed scheme are introduced and the approach is supported through a case study.

INTRODUCTION

Manufacturing enterprises continuously have to cope with changing markets that are unpredictable and diverse; manufacturing industry is facing international competitiveness and globalization. In order to succeed in this dynamic environment, integrated manufacturing systems ensure compact information and material flow between the manufacturing components. It also provides facilities for manufacturers to respond to the manufacturing changes in an effective manner. In order to manage integrated manufacturing systems, the right knowledge needs to be provided to the right place at the right time. Therefore, integrated manufacturing entails effective information and knowledge systems.

The rapidly changing needs require interoperability to be integrated in different a manufacturing functions in order to share knowledge and sustain collaboration among organizations. It is now obvious that the enterprises have to manage the different components of their manufacturing environment through efficient integration and coordination of knowledge and technology. In other words; manufacturing systems require a lot of interdepartmental relationship among different departments such as design, process control, production, storage, etc. Since these departments could be located at different places, management of distributed manufacturing environment with integrated manufacturing functions is highly demanded. The processes of distributed systems are in general characterized as follows (Kim et al., 2001):

- Participants of the processes are often geographically distributed.
- The computing environments they use are mostly heterogeneous.
- Individual tasks are usually carried out independently.
- Collaboration of the participants is critical to the success of product development.

The traditional approaches confine the expandability and reconfiguration capabilities of the manufacturing systems. Traditional manufacturing facilities have shortcomings that affect their ability to compete in today's constantly changing marketplace (Odell, 2002; Leitao et al., 2001). Some of those are as the following.

- They do not have mechanisms in place to accommodate rapid changes in business conditions caused by global competition and changing demands.
- They do not have mechanisms in place to modify systems while they are executing.
- They are rigid and slow to make significant organizational or functional changes.
- They do not have a mechanism to recover gracefully from partial failures on the factory floor. They are hard in order to optimize their execution and to manage the disturbances and warnings.
- They are unable to form or to participate in virtual enterprises.
- They are not scalable for changes in the market.
- The business model and the operational philosophy are not customer driven.
- They don't support efficiently the distribution and decentralization of functions and entities.
- The development of this type of applications based on this traditional approach has the advantage of its simplicity when compared with other advanced approaches; but the code developed cannot be re-used.

These shortcomings may bring about problems like reduced productivity and quality, increased costs, and missed market opportunities.

The main problems of traditional approaches are the distribution of functions, cooperation among distributed modules, reaction to the disturbances, and adaptation to changing environments. The main requirements for next generation of manufacturing systems should therefore be comprised as (Shen and Norrie, 1999):

- **Enterprise Integration:** In order to support global competitiveness and rapid market responsiveness, an individual or collective manufacturing enterprise will have to be integrated with its related management systems (e.g. purchasing, orders, design, production, planning, scheduling, control, transport, resources, personel, materials, quality, etc.) and its partners via networks.
- **Distributed Organization:** For effective enterprise integration across distributed organizations, distributed knowledge-based systems will be needed so as to link demand management directly to resource and capacity planning and scheduling.
- **Heterogeneous Environments:** Such manufacturing systems will need to accommodate heterogeneous software and hardware in both their manufacturing and information environments.
- **Interoperability:** Heterogeneous information environments may use different

programming languages, represent data with different representation languages and models, and operate in different computing platforms. The sub-systems and components in such heterogeneous environments should interoperate in an efficient manner. Translation and other capabilities will be needed to enable such interoperation or interaction.

- **Open and Dynamic Structure:** It must be possible to dynamically integrate new subsystems (software, hardware, or manufacturing devices) into or remove existing ones without stopping and reinitializing the working environment. This will require open and dynamic system architecture.
- **Cooperation:** Manufacturing enterprises will have to fully cooperate with their suppliers, partners, and customers for material supply, parts fabrication, final product commercialization, and so on. Such cooperation should be in an efficient and quick-response manner.
- **Integration of humans with software and hardware:** People and computers need to be integrated to work collectively at various stages of the product development and even the whole product life cycle, with rapid access to required knowledge and information.
- **Agility:** Considerable attention must be given to reduce product cycle time to be able to respond to customer desires more quickly. Agile manufacturing is the ability to adapt quickly in a manufacturing environment of continuous and unanticipated change and thus is a key component in manufacturing strategies for global competition. To achieve agility, manufacturing facilities must be able to rapidly reconfigure and interact with heterogeneous systems and partners.
- **Scalability:** Scalability means that additional resources can be incorporated into the organization as required. This capability should be available at any working unit and at any level within those.
- **Fault Tolerance:** The system should be fault tolerant both at the system level and at the subsystem level so as to detect and recover from system failures at any level and minimize their impacts on the working environment.

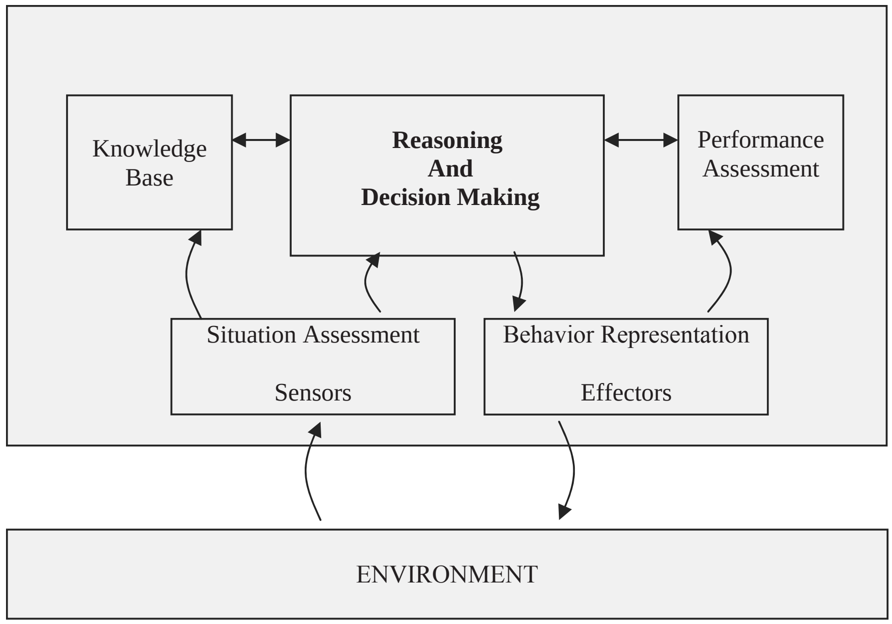
Intelligent manufacturing systems are introduced in order to cover some or all of these requirements. By definition, multi-agent systems are suitable for distributed manufacturing environments, since the manufacturing applications presents characteristics like modular, decentralized, changeable, ill-structured and complex, for what the agents are best suited to solve (Parunak, 1998).

There are many definitions about agents. The key feature would appear to be “autonomy”, which is the ability of the agent to formulate its own goals and to act in order to satisfy those (Anumba et al., 2002). Russell and Norvig (1995) state general concept of agent as in Figure 1 indicating that agents interact with environments through sensors and effectors. Similar architecture is provided by several other studies (Hao et al., 2005; Monostori et al., 2006; Chang, 2008).

Wooldridge and Jennings (1995) define the term agent, which is used to denote a hardware or (more usually) software-based computer system that enjoys the following properties:

- **Autonomy:** Agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state;
- **Social ability:** Agents interact with other agents (and possibly humans) via some kind of agent-communication language;
- **Reactivity:** Agents perceive their environment, (which may be the physical world, a user via a graphical user interface, a collection of the other agents, the internet, or perhaps all of these combined), and respond in a timely fashion to changes that occur in it;

Figure 1. General concept of an agent



- **Pro-activeness:** Agents do not simply act in response to their environment, they are able to exhibit goal-directed behaviour by taking the initiative.

Valderrama et al. (2005), Shen et al. (2007) and Montano et al. (2008) added collaboration, interoperability, reusability and learning characteristics on top of these.

This chapter is structured as follows: Section 2 narrates literature survey on integrated intelligent manufacturing systems and clearly indicate that decision making and automation capabilities of intelligent agent technology; Section 3 presents brief introduction to reference model developed for intelligent integrated manufacturing systems; Section 4 focuses on importance of knowledge sharing among manufacturing agents; Section 5 defines knowledge protocols for creating integrated intelligent manufacturing systems; Section 6 proposes a case study and the chapter concludes after a discussion future trends in this area provided in Section 7.

BACKGROUND

Multi-agent systems, when their agents work together, give rise to better task sharing and problem solving mechanisms than centrally dictated schemes (Leong et al., 2002). Hence, multi-agent systems overcome several disadvantages of centrally controlled systems by distributing the decision making capability over several autonomous agents. A distributed system consists of independent entities, which act to exchange information and knowledge among themselves to improve performance. However, the integration and coordination as well as communication of these agents still need more attention and research. The respective literature survey is summarized here indicating the possible research areas and thereafter a proposed solution for knowledge exchange is provided.

Chu et al. (1997) explain the importance of integrated manufacturing through introducing a process so called CIIMPLEX. Their approach does not clearly seem to include full manufacturing cycle starting from design to product shipment.

Besides, their study rather seems to concentrate on the software development aspects rather than manufacturing functionalities. Note that they used a well known KQML protocol as an agent communication language (see Finin et al., 1994, for more information).

Similarly Shen et al. (1997) developed a system called Agent-Based Manufacturing Enterprise Infrastructure (ABMEI). This system is reported to use a network of mediators whose main aim is to resolve heterogeneity between manufacturing sub-systems. Note that, although this approach narrates a negotiation protocol for knowledge exchange, the encoding scheme implemented is not explained in the paper. Following this study, Maturana et al. (1999) proposed a similar approach called *MetaMorph.* In that, a mediator-centric federation approach was developed for creating intelligent manufacturing systems. The following high-level mediators are taken into account:

- Enterprise Mediator,
- Design Mediator (CAD Mediator),
- Resource Mediators and
- Simulation/Execution Mediator (AGV Mediator).

Adaptation of the manufacturing system in this approach is facilitated through structural change of organization as well as with two learning mechanisms as "learning from past experiences" and "learning future agent interactions". Note that learning is achieved by simulating future dynamic and emergent behavior of manufacturing systems. Shen et al. (2000) extended this study to *MetaMorph II* concentrating on a wider manufacturing cycle from design to execution. It looks like "quality" and "R&D issues" are still missing. Additionally, this approach rather seems to focus on design of mediator agents and internal agent structures. Similar to ABMEI, the encoding scheme implemented in this approach is not clearly introduced in their paper.

Similarly, Frey et al. (2003) proposed a multi-agent based integrated supply chain management system focusing on the integration of supply chain, scheduling, shop floor production planning as well as control and proactive tracking and tracing services. This system is tested by a case study for the proof of concept. They proposed to use another famous agent communication language called FIPA for which the detail explanation is given by Chaib-Draa and Dignum (2002).

Furthermore, Lim and Zhang (2004) introduce a multi-agent-based framework in which process planning and production scheduling are integrated. In this study, the idea of integration is driven by the need to increase the flexibility and agility of manufacturing systems within the competitive market.

Moreover, Kishore et al. (2006) proposed a conceptual framework for MIBIS which is a Multi-agent-based Integrative Business Information System. They emphasize that multi agent systems could be considered as an appropriate approach for modeling and implementing as well as executing an integrated business information system. They formulated the integration process using eight components such as "agent", "role", "goal", "interaction", "task", "resource", "information" and "knowledge".

Delen and Pratt (2006) developed an integrated software environment for intelligent decision support system capable of providing help to managers throughout the decision making life-cycle. The system works in 5 stages as (1) structuring a problem from a given set of symptoms, (2) once the problems is structured, determining the best analysis tool (i.e. model type) to address to problem, (3) automatically generating the executable models specific to the structured problem, (4) conducting the analysis, and (5) providing the results back to the decision maker in an easily understandable format.

Based on the concept of the integration of overall enterprise, Chen et al. (2006) developed an integrated supply chain management approach so called "X" model. This model integrates six different manufacturing system approaches including:

- Material Requirement Planning (MRP) and Just In Time (JIT) module,
- Computer Aided Design (CAD) and Computer Aided Process Planning (CAPP) module,
- Optimized Production Technology (OPT) module,
- Supply Management module,
- Distribution Management module,
- Control module

Although X Model emphasizes the cooperation of multi-agents, there is no suggestion regarding how the proposed agents will interact and negotiate with each other.

Furthermore, semantic web technology is also utilized in multi-agent systems (see for example Debenham and Sierra, 2008). It should be clearly noted that semantic web is rather a data sharing technology which could support communication languages and information processing methodologies. Increasing the complexity of information to be shared in various dimensions makes it difficult to effectively utilize semantic nets for knowledge processing especially in autonomous agent interactions with ill-defined knowledge structures requiring knowledge integrated solutions. Although semantic web services act as autonomous software entities that discover, compose, invoke and monitor services without human intervention and they are very capable of carrying out arduous and time consuming tasks as well as being able to adapt themselves into changing situations they require semantically set environments (Garcia-Sanchez et al., 2008). Dependency upon domain ontology through semantic descriptions provides no action on the control of redundancy and inconsistency as the entire knowledge of the world is assumed to be known or to be predicted. However semantic web technology can still be a systematic base line for agent based communication schemes which are even able to handle knowledge inconstancies and dynamicity of domain knowledge which could not be pre-determined or provisionally predicted.

Carrascosa et al. (2008) presented a flexible and efficient integration of high level, multi-agent architecture with real time behaviours in a complex and dynamic environment. A multi-agent system that includes deliberative and pure reactive processes has been implemented using FIPA ACL as a communication language. This approach has been tested in automated management simulation of internal and external mail in a department. It looks like; this study is not focused on manufacturing functions.

The literature survey on the integrated multi-agent systems as some examples are given above clearly indicates that the integration of business units requires handling very complex knowledge exchange procedures as efficient and effective as possible. Traditional methods may not also be sufficient to deal with the level of complexity associated with the manufacturing processes and products. To remain competitive in such a complex and rapidly changing environment, flexibility, responsiveness, agility, concurrency etc. are crucial for shorter delivery times, better quality and wider variety of products. This obviously points out the importance of automated knowledge exchange between manufacturing units. In other words, to create an interoperable system, enterprises have to share their knowledge and available information in real time. Taking the advantages of all others, a general framework and a reference model for intelligent integrated manufacturing system called REMIMS is developed. A brief summary of the description of REMIMS is given below (see the details in Tekez, 2006). Note that, this chapter explains the knowledge exchange procedure of REMIMS which is so called "*knowledge protocol*".

BRIEF INTRODUCTION TO REMIMS

REMIMS is a multi-agent framework designed to achieve manufacturing system integration. It consists of a hierarchically nested architecture and is intended to provide a general framework for dynamic integration and standard knowledge exchange infrastructure in distributed manufacturing environments. It requires a manufacturing enterprise to be organized into management units (modules) each of which consists of a group of intelligent agents. Each of these particular agents should possess a combination of manufacturing knowledge as well as related skills and abilities. REMIMS is designed in three different aspects including:

- management of processes and workload (system view),
- logical inferences and intelligent capabilities (reasoning view) and,
- knowledge and information flow (knowledge view).

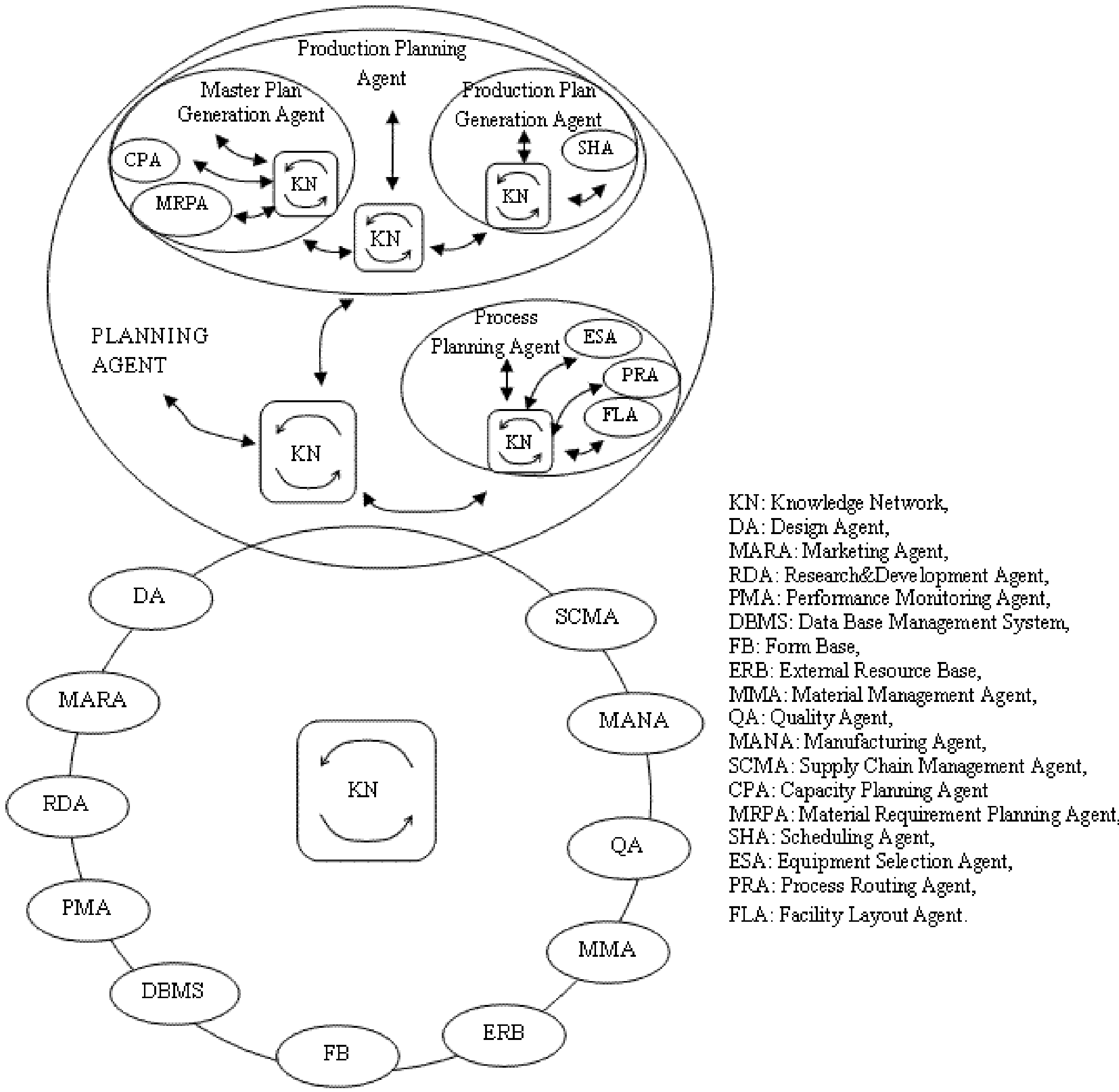
System view includes the description of the overall manufacturing system and concentrates on system functionalities in order to set up smooth interrelations between different manufacturing functionalities which were handled by agents. REMIMS includes mainly design, marketing, planning, supply chain management, manufacturing, quality, material management, and research and development systems. From the system point of view, REMIMS is based on a hierarchically nested architecture as depicted in Figure 2. Note that Figure 2 indicates second and third level agents for production planning including production planning agent and process planning agent at the second level whereas master plan generation, production plan generation, equipment selection, process routing and facility layout agents at the third level.

Reasoning view of REMIMS highlights the basic capabilities of decision making, problem solving and reasoning capabilities of each agent which is responsible to carry out a certain manufacturing function. As indicated in Figure 2, REMIMS is composed of a set of intelligent agents each of which is responsible for performing a different manufacturing activity. As the reasoning view provides a framework for distributed multi-agent manufacturing environment, REMIMS can be considered as general framework for automated distributed manufacturing. Note that each agent within this reference model can be created in a general agent architecture and works as receiving information from the environment, reasoning about them and responding accordingly.

Similar to other aspects, the knowledge view points out the capabilities of knowledge and information flow among the manufacturing agents. Agents which are equipped with certain manufacturing knowledge should be able to perform their actions as effectively as possible and communicate the results of its actions to the respective agents. REMIMS provides a certain standard for the agents to communicate their outputs to the respective agents through a Knowledge Network (KN) as indicated in Figure 2. Due to its distributed architecture, REMIMS proposes a distributed knowledge flow which can allow a certain agent responsible for a certain manufacturing activity to communicate directly with all other agents responsible for related activities.

The integration clearly requires that the agents should communicate their knowledge to each other in order to have operational effectiveness within the integrated manufacturing environment. It should be noted that an agent may produce certain knowledge which would be a strict requirement by other agents. Similarly it may need some inputs which could be produced by other agents. A standard knowledge exchange procedures could therefore be extremely useful to handle automated exchange of information as well as knowledge. Moreover, using this standard procedure is a crucial point for the successful development of a new generation of agile control and integration

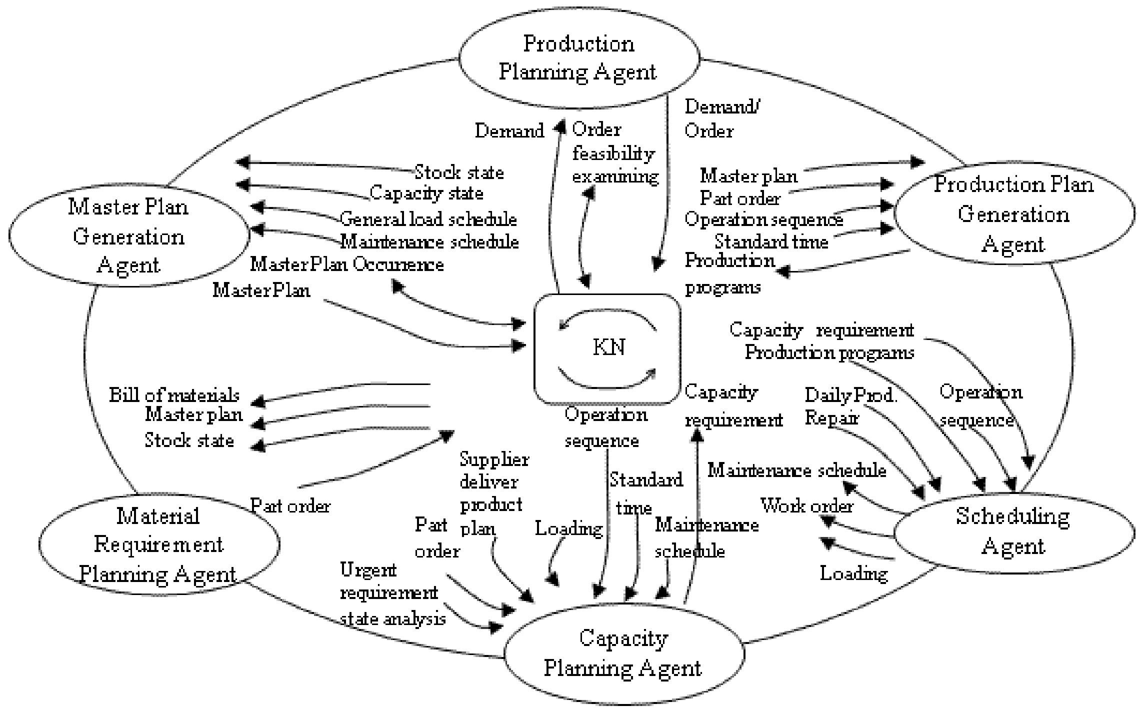
Figure 2. Nested architecture of REMIMS



applications. Due to this fact, REMIMS provides a standard knowledge exchange capability so called ***"knowledge protocol"*** in order to facilitate efficient communication and knowledge sharing between manufacturing agents.

The tree-view aspects of REMIMS as explained above are utilized with a formal structure of agents and their relationships. This structure is also called as a "reference model". In this model, an ideal manufacturing environment is defined. The user or system developers can tailor this model to create a more specific manufacturing system for their own purposes and based on their requirements. The reference model can be considered as an umbrella model indicating manufacturing functions and their interrelationships. Each manufacturing function is detailed in such a way that all aspects of an ideal manufacturing system are covered. The relationship can be provided from more abstract level to the most detailed description level of a manufacturing system. Since the aim of this chapter is to describe knowledge exchange

Figure 3. An example of several knowledge exchanges between agents



capabilities of REMIMS, the other features are omitted here and detail information can be found in Oztemel and Tekez (2004), Tekez (2006).

As mention earlier the knowledge flow between REMIMS agents is carried out on a Knowledge Network (see Figure 3). Each agent is responsible for performing its own tasks and provides the required information to the integrated system over the network. The Knowledge Network therefore can be considered as distributed information system providing ways of interactions by several means, in this case *"knowledge protocols*" and *"knowledge forms".*

IMPORTANCE OF KNOWLEDGE SHARING AMONG MANUFACTURING AGENTS

In order to manage the enterprise-wide knowledge, it is necessary to share a common area of expertise among manufacturing facilities. Manufacturing functions interact with each other in a highly coordinated manner to achieve their own and shared goals, thereby contributing to overall enterprise goals. Furthermore, manufacturing functions in an integrated enterprise need to be coordinated to be able to managed and interdependencies between tasks they perform and resources they use to be resolved.

In order to facilitate knowledge sharing, details of agent communication; learning, knowledge usage and transferring knowledge across regions need to be studied carefully. Capturing the knowledge and delivering the powerful knowledge message throughout manufacturing units is very essential in order to define inter-agent knowledge sharing procedures. Successful knowledge sharing within an organization may produce synergetic learning (Loebbecke and Angehrn, 2004) which in turn increases competitive advantages as well as manufacturing stability.

Looking at the literature, several systems even languages are developed for information and message exchange between agents. Among them are KQML, FIPA as mentioned above. These languages seems to be rather complex and require extra efforts to be spent for achieving required exchangeability. For example, when an agent sends a message it should receive a confirmation signal making sure that the requested action will be performed. However, this still does not guarantee that the action requested to be performed is carried out or not. This, obviously, makes it too hard to understand how a multi agent system could work robustly. Moreover, these communication protocols works using a set specific commands so called *performative*s. It is possible to use only a single *performative* within a message which could not be sufficient in most of the manufacturing environments. This clearly limits sharing different attributes of manufacturing knowledge at a time in contrast, REMIMS provides a standard knowledge sharing scheme to overcome the above problems.

KNOWLEDGE PROTOCOLS DEFINED BY REMIMS

As mentioned before, REMIMS proposes a general framework for knowledge sharing and information transfer among the agents. Two ways of knowledge exchange capability so called knowledge protocol is introduced. These are:

- Utilizing a knowledge exchange scheme
- Using knowledge forms furnished with manufacturing knowledge

Knowledge Exchange Scheme

Knowledge exchange scheme is a specific format for handling inter-agent communication. This is to use a four-layer protocol including an identity layer, a query layer, a response layer, and a remark layer as shown in Figure 4.

Identity layer indicates the owner of the knowledge (sender) and the receiving agents. Each agent is represented with a certain identifier code as shown in Table 1. As seen in Table 1, the code of planning agent, the code of production planning agent, the code of master plan generation agent, and the code of material requirement planning agent are 03000000, 03010000, 03010100, and 03010101 respectively. This table also shows that the nested architecture of the reference model can be extended in both vertically and horizontally in order to update the model for the industry specific needs. This capability is considered as one of the promoting features of REMIMS.

Based on this coding, Figure 5 indicates that Material Requirement Planning Agent (MRPA) coded as 03010101 is receiving some information from Master Plan Generation Agent (MPGA) as identified with the code of 03010100. The knowledge to be utilized is stored in so called the knowledge form named as MPF (Master Plan Form) which is also coded as F0301010002001000. The knowledge forms are explained later in this chapter.

Figure 4. Format of inter-agent knowledge exchange

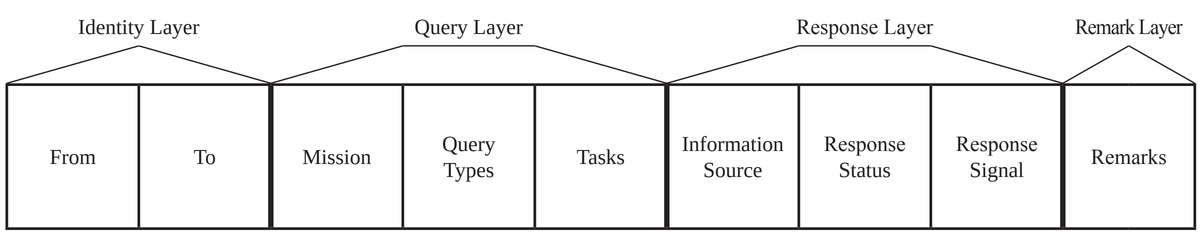


Table 1. An example of agent code system

Manufacturing Function				
1. Level	2. Level	3. Level	4. Level	
03. Planning Agent	03.01. Production Planning Agent	03.01.01. Master Plan Generation Agent	03.01.01.01. Material Requirement Planning Agent	
			03.01.01.02. Capacity Planning Agent	
		03.01.02. Production Plan Generation Agent	03.01.02.01. Scheduling Agent	
	03.02. Process Planning Agent	03.02.01. Process Routing Agent		***Horizontal Extension***
		03.02.02. Equipment Selection Agent		
		03.02.03. Facility Layout Agent	**Vertical Extension**	

Figure 5. An example message for notifying an agent

03010100 From MPGA	05000000 to MANA	0 Query	001 Ask	001 Approve	F0301010001001000 Use form MPOF	00 Wait	00 Wait	000 Remark

Query layer is designed to perform queries which is represented by several aspects including the "mission" part (taking the values of "query", "response", "notify" etc.) content of the "query" (such as "ask", "when", "where", "how many", "how much", "information", and "do action" etc.) and the requested "tasks" to be performed (for instance, "calculate", "cancel", "check", "comment", "inspect", "update", etc). The query layer representation as given Figure 5 can be commented that the MPGA notifies the MRPA on the updated information.

Response layer includes the response against the requested queries. For each query type several responses can be generated and coded. The response layer has different sections such as information source, response status and response signal. The information source includes the code of related knowledge form which stores related manufacturing knowledge. The response status indicates whether required query is accepted, rejected or waiting for response generation (coded as 01, 02 and 00, respectively). Similarly the response signal produces the code of 01 or 02 indicating whether required changes are performed or not. Similarly, Figure 5 indicates that the MPGA is to wait for necessary actions to be taken by MRPA.

Remark layer includes explanation for mission, query type, and tasks. Each possible explanation

Table 2. Some examples of explanations in the "remark layer"

Remark Code	Explanation
000	It is expected explanation
001	Plan generation
014	Results of evaluation

can also be coded in order to provide standardization. Although it seems difficult to do so, the coding scheme allows billions of explanations to be stored and the similar type of messages could be stored with the same code. Table 2 shows some examples of remarks which were generated during the case study performed and explained in the latter section. Note that, there is no limitation on adding new comments with new codes.

Knowledge Forms

Second aspect of the knowledge protocol proposed in this paper is the definition of ***"Knowledge Forms***". Every type of manufacturing related information and knowledge can be stored in standard knowledge forms. Each form has its own architecture based on the content and context of knowledge itself. Handling the knowledge forms is not difficult by the agents as the knowledge forms can be stored using a well known formats such as XML. REMIMS does not put any constraint on the format of the representation of knowledge forms as long as the used format is well recognized by computing society. Similar to the knowledge exchange scheme, each form is identified through a specific identifier code which is formatted as shown in Table 3.

As can be realized from Table 3, it was assumed that the reference model can handle maximum 99 main agents with 99 sub agents each of which can in turn having 99 sub-sub agents. Similarly each agent could have maximum 99 different types of forms with each having 999 sub forms. Note that, version number could be used if different agents need to respond to the same query.

Table 3 also indicates that F0301010002001000 is the code for *"Master Plan Form"*. This form is generated by MPGA and has to utilize the plan numbered as 001. Similar to knowledge base of expert systems, the knowledge forms could be stored in a Knowledge Form Base. The Knowledge Form Base should also include "Knowledge Library" and "Priority Relation Matrix" which indicates the priorities of working agents making sure that requested knowledge is provided on time and requested action to be performed before declaring the knowledge produced. This is another important feature of REMIMS. Because, an agent with a priority performs and updates its Knowledge Forms before the other agents can use the related content. Note that, the content of each form can only be changed by the authorized agents identified by REMIMS. The information regarding the ownership of the knowledge forms is stored in a so called knowledge library. However the forms could be available to all respective agents within the integrated framework and could be utilized. The content of knowledge form of Master Plan is provided in the Table 4.

Table 3. An example of code for a knowledge form

Form Identifier	Main Agent	Sub Agent	Sub Agent	Sub Agent	Form Id	Form Number	Version Number
F	03 Planning Agent	01 Production Planning Agent	01 Master Plan Generation Agent	00	02 Master Plan Form	001 Plan number	000 Version

Table 4. The content of the "Master Plan Form"

MASTER PLAN FORM : F0301010002001000										
Form No: 001				**Version No:** 000				**Date:** 30.04.2008		
Model No	**TIME / QUANTITY**									
	30/06	01/07	02/07	03/07	04/07	07/07	08/07	09/07	10/07	11/07
BC60	4	4	5	6	6	5	5	4	6	5

CASE STUDY

The case study is carried out in one of the automobile producing company, mainly in the department of production planning control. This department is responsible for the production planning of the vehicle and all its components in house. The case study is only limited to production planning activities for the proof concept of knowledge exchange capability of REMIMS as explained above. Thirteen agents as listed below are required to perform respective planning processes.

- Planning Agent (PA),
- Marketing Agent (MARA),
- Scheduling Agent (SHA),
- Material Management Agent (MMA),
- Supply Chain Management Agent (SCMA),
- Master Plan Generation Agent (MPGA),
- Manufacturing Agent (MANA),
- Material Requirement Planning Agent (MRPA),
- Generation of Bill of Material Agent (GBMA),
- Capacity Planning Agent (CPA),
- Production Plan Generation Agent (PPGA),
- Product Audit Agent (PDA),
- Purchasing Agent (PUMA)

These agents are supposed to communicate with each other using the proposed knowledge protocol. Within the current manufacturing environment, the agents should perform their activities as in the following manner.

PA is responsible for transforming demand generated by MARA into manufacturing orders. This agent expects the message of updated information of demand from MARA according to the information of priority relation matrix in order to perform its function. When PA takes this message, it investigates the order feasibility with respect to customer demand. The investigation done through communicating with scheduling, material management, and supply chain management agents to make sure that the demand can be met or not. Note that each agent responds to this query by creating the same form with a new version number. PA evaluates answers coming from these agents together with bill of material and standard time information. It then makes a decision and notifies the related agents.

When the PA approves the manufacturing of the demand, MPGA works to transform the demand into manufacturing plans. It takes stock state, shop floor capacity state, assembly capacity state, general load schedule, maintenance schedule into account in order to create master plan using "master plan occurrence form". MPGA asks to approve this plan to MANA in order to provide effectiveness of master plan in the manufacturing environment as depicted in Figure 6. The knowledge to be utilized is stored in the knowledge form named as MPOF (Master Plan Occurrence Form) and coded as F0301010001**001**000. MANA fills in the related information into MPOF and also conveys this information to the MPGA using standard format as depicted in Figure 7 indicating that the evaluation of plan is performed and the result is stored in the knowledge form.

Figure 6. The example of query message

03010100 From MPGA	05000000 to MANA	0 Query	001 Ask	001 Approve	F0301010001001000 Use form MPOF	00 Wait	00 Wait	000 Remark

Figure 7. The example of response message

05000000 to MANA	03010100 From MPGA	1 Resp.	006 Information	001 Approve	F0301010001002000 Use form MPOF	01 Accepted	01 Done	014 Remark

MPGA then creates master plan evaluating response taken from MANA and notifies the knowledge to the material requirement planning (see Figure 5), production plan generation and product audit agents using “master plan form”. Information about the relevant agents is stored in the knowledge library, an example of which is given in Table 5. Knowledge library does not only contain the file identifiers and related agent names but also location of the knowledge within form to be assessed. An example of indicating the location of respective knowledge fields of “master plan form” of Table 4 is shown in Table 6.

Following this, MRPA uses bill of materials that is created by the help of GBMA as well as the master plan. MRPA also takes inventory information from MMA. Table 7 indicates that, MRPA should receive information from MPGA, GBMA, and MMA beforehand. As it can be seen, REMIMS is designed on a strict requirement of the agent’s precedence relationships. Each agent can only perform its activities if the other agents which should create the required information have finished their actions. The precedence relations and working priorities are managed through a priority relation matrix as shown in Table 7. Based on the available knowledge, MRPA determines how many of each item must be manufactured and /or purchased and when, and then notifies the part orders to the relative agents including Capacity Planning, Production Plan Generation and Purchasing. Note that the purchasing agent then orders the required items from the suppliers.

CPA is concerned with ensuring the feasibility of material requirement plans. To develop an executable manufacturing plan, it is essential to establish the feasibility of the planned order releases obtained from MRPA. This agent use part order knowledge, loading information for machines and assemble lines and schedules, supplier product deliver plan, operation sequence, part operation standard time and maintanence schedules in order to generate “capacity state form” and “requirement report form” for shop floors and assemble line.

Integrated manufacturing planning system works based upon real time data from other agents. When the capacity plannning agent receives message of update of the form called “urgent requirement state analysis” from MMA, it works and generates capacity state and requirement reports and notifies capacity requirement knowledge to SHA.

PPGA is responsible for creating production programs utilizing “master plan”, “part order”, “operation sequence” and “part operation standart time” forms. SHA allocates workloads to shop floors and assemble line and determines the sequence in which operations are to be performed. The information going into scheduling are capacity requirement, loading information for machines and assemble lines and maintanence schedules, operation sequence information, production programs, and repair information and actual production progress (daily production registra-

Table 5. An example of a Knowledge Library

Knowledge	**Knowledge location within knowledge form**	**Knowledge producing agents**	**Knowledge Forms which utilized to produce the knowledge**	**Knowledge form**	**Knowledge utiliz-ing agent**
Form No	01	03010100 Master Plan Generation Agent (MPGA)	F0301010001001000 Master Plan Occurrence Form (MPOF)	F0301010002001000 Master Plan Form (MPF)	03010101 Material Requirement Plan-ning Agent (MRPA) 03010200 Production Plan Generation Agent (PPGA) 06010400 Product Audit Agent (PDA)
Version No	02				
Date	03				
Model No	04				
Time/Quantity	05a 05b 05c 05d 05e 05f 05g 05h 05i 05j				

Table 6. Data block which indicate location region of knowledge in the Master Plan Form

Locate:01	**Locate:02**	**Locate:03**	**Locate:04**	**Locate:05a**	**Locate:05b**	**Locate:05c**
Form No	Version No	Date	Model No	Time/Quantity 30/06	Time/Quantity 01/07	Time/Quantity 02/07
Locate:05d	**Locate:05e**	**Locate:05f**	**Locate:05g**	**Locate:05h**	**Locate:05i**	**Locate:05dj**
Time/Quantity 03/07	Time/Quantity 04/07	Time/Quantity 07/07	Time/Quantity 08/07	Time/Quantity 09/07	Time/Quantity 10/07	Time/Quantity 11/07

Table 7. An example of a Priority Relation Matrix

Agent	**Agents should work beforehand**					**Form**
03010101 Material Requirement Plan-ning A. (MRPA)	03010100 Master Plan Generation Agent (MPGA)	02020200 Generation of Bill of Material A. (GBMA)	07000000 Material Manag. Agent (MMA)			F0301010101001000 Weekly Requirement Plan Form

tion knowledges) for dynamic scheduling. SHA can adapt to internal changes such as machine breakdown, scrap and external changes such as postpone of supplier dispatching. If there is machine breakdown, when SHA received message of update of repair registration form, it updates schedules including in work orders and maintenance sechedules. If there is scrap or postpone of supplier dispatching, “urgent requirement state analysis” form is updated by MMA and notified to the relative agents. SHA takes the knowledge of this changes from CPA. SHA is also responsible for pursuiting schedulues with daily production registration forms which are utilized as knowledge of actual production progress in which loading diagrams for machines and assemble lines. In addition to this tasks, SHA is responsible for deciding if the customer demand is to be accepted or not through interacting with the planning agent as explained above.

As a result of this simple case study, it was realized that, thirteen agents would cooperate with each other without any problem and share their knowledge in order to enable effective production planning. The information and knowledge flow presented in this case study is an actual instance of production planning activities in the respective company.

FUTURE TRENDS

Multi-agent systems are now being proven to be very beneficial for handling manufacturing activities. In the manufacturing environment, there are extremely variable requirements for customization. Moreover, manufacturing functions are distributed and composed of system components that need to interact with each other to resolve inconsistencies and dependencies to accomplish goals. Hence, agents represented manufacturing functions should interact with each other and coordinate their actions derived from their knowledge. Agent-based approaches emphasize the importance of knowledge because of interdependencies among the agents. They have to utilize their knowledge in integrated fashion in order to link the respective tasks carried out by different agents. Interoperability and interactions between agents can be effectively achieved through knowledge protocols proposed in this chapter. The trend towards the adaption of collaborative and concurrent engineering practices within the manufacturing functions needs to be supported by agent communications techniques. In addition to this, it is expected that technological ways in the future focus on the following areas:

- The development of a common ontology for shared domain concepts, agent communication needs to be elaborated. Because, ontology is an important concept for knowledge integration.
- Standardization of internal architecture of agents in order to carry out given tasks should be investigated.
- Mobile code which is important paradigm in an open and dynamically changing environment can pervade for distributed application frameworks.
- Scalability can become key issues due to the fact that additional resources can be incorporated into the organization as required.

This study will continue to include the following:

- developing also systematic mechanism to easy horizontal and vertical extension of the reference model embracing, for example, business specific needs,
- providing automated process improvements or related recommendations,
- improving self agent performance monitoring capability,
- creating agent satisfaction methodology among agents,
- enriching the model with risk management functionalities.

CONCLUSION

This chapter reflects the research that is being done in the area of distributed and cooperative automation and manufacturing systems through the use of multi-agent technology. In this chapter, knowledge protocols are presented for easing agent based communication and coordination to provide the development of distributed manufacturing applications. This chapter is intended to indicate that this technology can be used for generating automated integrated manufacturing environments. Note that the proposed architecture reflects two aspects: the standardized structure for knowledge sharing and interactions of agent based modeling. The knowledge protocol as proposed has been tested on a case study. The results were encouraging in developing a reference model for an integrated fully automated manufacturing environment. In the case study only production planning procedures are handled by thirteen different manufacturing agents. The proposed model contributes to the productivity of manufacturing environment and eliminates some of shortcomings within the manufacturing area as described below.

- REMIMS can reduce production cycle time and delivery time providing required level of efficiency which is one of the predominant requirements of current manufacturing systems.
- As opposed to traditional manufacturing systems which are not capable of handling rapid changes, REMIMS enables a general architecture that manufacturers can adapt to their systems easily without violating their own manufacturing objectives. It is mainly based on cooperation and coordination capabilities of intelligent agents. This provides open and dynamic structure.
- Although some of the existing models are reported to be capable of handling real time knowledge, but real time modification is still a problem. In contrast, REMIMS has a robust structure so called priority matrix to make sure that timely and most recent knowledge is used. This model can response dynamic environment which changes circumstances continuously indicating that the priorities of working agents which is necessary to provide requested knowledge on time and perform requested action before declaring the knowledge produced. Hence, the agents are sure that their used information is updated information.
- Most of the existing manufacturing systems are based on data-driven models. Whereas REMIMS enriches manufacturing systems with knowledge-driven facilities which is particularly built upon knowledge networks. This surely facilitates interoperability of heterogeneous environments in an efficient manner.
- Most of the existing manufacturing systems lack complete integration of all manufacturing functions with respective interactions. REMIMS provides full set of manufacturing functions to be integrated as intensively required in real life applications. The reference model described in the chapter can be as flexible as handling all kinds of manufacturing activities.
- REMIMS increases responsiveness of manufacturing systems which is one of the most important problems of today’s manufacturing environments. The agents can respond timely to the quick changes.
- Through implementing REMIMS, changes in production plans and schedules can be handled easily without stopping the production providing practical suggestions regarding on how the proposed agents will interact and negotiate with each other. This facilitates enabling the sustainable manufacturing.
- REMIMS generates a distributed knowledge management mechanism preventing information exchange problems in respective manufacturing systems. It handles control requirements and manages resources distributed distance apart.

In addition to above characteristics REMIMS also possesses the following capabilities.

- REMIMS can support any methodological and technological changes such as e-business activities.
- The existing models rather focus on either agent internal architecture or respective information systems. REMIMS, on the other hand, concentrates manufacturing functions in an integrated manner.

- REMIMS provides autonom structure in order to prevent information and knowledge exchange bottleneck which is prone to happen with centralized approach as appeared in some of the existing models.
- As mentioned above the existing communication languages seems to be rather complex and require extra effort to achieve required exchangeability. In a language such as KQML and FIPA, there is no indication of whether the requested action will actually be carried out or not. REMIMS provides a rather simple communication scheme making sure that all actions are completed.
- The structure of existing communication languages limits sharing different attributes of manufacturing knowledge at a time. In the proposed model, the knowledge utilized by the agents are stored in so called *knowledge forms* and updated by the respective agents.

The social dimensions of REMIMS in comparison to the traditional manufacturing processes are also analyzed as the following:

- Automation and autonomous systems is becoming the fact of life in manufacturing society. Establishing robust systems such as REMIMS will gain the trust of manufacturing people as well as managers providing that they can reduce cost and create new opportunities.
- Autonomous and automated systems supported by REMIMS-like architecture will prevent staff to be employed in dangerous and hazardous situations as well as unhealthy environments.
- New areas of implementation such as REMIMS create new areas of employment the staff need to be employed in information technology, agent technology, distributed manufacturing modeling etc.
- As a consequence there will be a need for training and development programs for new skills and capabilities which seems to be inevitable.

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KEY TERMS AND DEFINITIONS

Form Base includes in knowledge forms, knowledge library and priority-relation matrix.

Knowledge Form is source of knowledge stored in computer with specified formats

Knowledge Library stores information regarding the ownership of the knowledge forms, related agent names, and the location of the knowledge within form to be assessed.

Knowledge Network can be considered as distributed knowledge flow system which provides ways for interactions through knowledge protocols.

Knowledge Protocol is a means providing knowledge exchange capability between agent of REMIMS in order to facilitate efficient communication and knowledge sharing.

Priority Relation Matrix indicates the priorities of working agents which is necessary to provide requested knowledge on time.

REMIMS is reference model for intelligent integrated manufacturing system.

Chapter XVI
Multi-Agent Systems for Semantic Web Services Composition

Agostino Poggi
Università degli Studi di Parma, Italy

Paola Turci
Università degli Studi di Parma, Italy

ABSTRACT

The vision which is making its way in information technology is to encapsulate organizations' functionalities within appropriate interfaces and advertise them as one or more Web services, which could be integrated, when brought into play, in workflows. This innovative idea brings with it new outstanding opportunities but also new great issues, related mainly to the ability to automatically discover and compose Web services. Several researchers belonging to the agent community are convinced that this technical area is a natural environment in which the agent technology features can be leveraged to obtain significant advantages. This chapter is aimed at briefly recalling the major results achieved by agent community and showing how their exploitation in the area of service-orientation systems could be very promising.

INTRODUCTION

Industry has been and still, more than ever, is interested in executing business functions that span multiple applications. This demands high-levels of interoperability and a more flexible and adaptive business process management. Most of the technology and market research companies, which provide their clients with advice about technology impact on business and consumers, agree on the fact that the adoption of a SOA paradigm is strategic and should be part of the most forward-looking software projects. Nevertheless the paradigm shift is still quite challenging.

Many researchers belonging to the agent community are convinced that this technical area appears to be a natural environment in which the agent technology features can be leveraged to obtain significant advantages. Multi-agent systems, in fact, can play an important role in a service-oriented scenario, by efficiently supporting distributed computing and the dynamic composition of Web services. It is plain, in fact, that service-oriented technologies cannot provide by themselves the autonomy and social and proactive capabilities of agents. Agents, taking advantage of their social ability, exhibit a flexible coordination that makes them able to both cooperate in the achievement of a global goal and compete in the distribution of resources and tasks. However, what comes out is that the agent technology has to be appropriately engineered and integrated with other key technologies in order to provide a real powerful approach, combining ubiquity, context-awareness and intelligence. Driven by such motivations, a number of research works have been undertaken with the aim of tackling the problem of integrating service-oriented technologies with multi-agent systems.

This chapter has the goal of reporting a synopsis of these works and providing evidence of why multi-agent systems may be considered one of the most promising technologies for semantic Web services composition.

BACKGROUND

The first subsection includes a brief survey of the literature in the areas of standard Web services, workflow and semantic Web services technologies with the objective of showing the scenario in which the agent possibly contribution should be set and at the same time to give a short preamble acting as a motivation and rationale of the research work done by the agent community.

There are plenty of papers on the subject of agent and multi-agent system definition. The purpose of the second subsection is not to be comprehensive but simply to establish some basic concepts.

Service-Oriented Applications: State of the Art

The new vision of a Web constituted by dynamically interoperating nodes and the ever increasing demand for high-levels of interoperability by organizations that want applications to have broader reach, have stimulated the rapid growth of novel standards, technologies and paradigms with the aim of giving an answer to such problems The most appropriate response to this need seems to be a service-oriented architecture (SOA), i.e. a system assembled from a loosely coupled collection of services and in particular of Web services—the integration technology preferred by organizations implementing SOA,

The basic specifications of Web services provide the infrastructure that supports the fundamental operations of a SOA. They are based on XML and define layers of abstraction including the message format description and communication protocol (SOAP), the operations performed by Web services and the related messages exchanged (WSDL), publishing and discovery capabilities (UDDI). This allows accomplishing an explicit agreement on the way Web services interact, providing a basic service-oriented middleware which can be exploited by possible higher layers enabling the realization of an effective SOA.

While Web services may be used in an isolated way to accomplish a specific business task, the need to aggregate multiple services in a new single meaningful composite service or to integrate them as part of workflow processes is more and more felt. During the last years a lot of research works have been undertaken, ranging from theoretical foundations, standardization efforts to concrete tools, technologies and real-world application case studies (Alonso et al. 2005; Dietrich et al., 2007; Dustdar & Schreiner, 2005; WS-Coordination, 2007). However, a still open problem is that the information and the research activities in this area are quite fragmented (Papazoglou et al., 2006).

Restricting the ambit of investigation and focusing mainly on the standardization efforts related to service composition based on workflow patterns for the business process management, a prominent standard that provides for explicit process modeling and execution, based on Web services, is particularly interesting, i.e. the business process execution language for Web services (WS-BPEL).

The WS-BPEL (WS-BPEL, 2007) specification defines an XML-based language for the formal description of a business process based on Web services orchestration. It is an open standard approved as an OASIS standard. A WS-BPEL workflow is a structured XML document composed of three main parts: (i) the definition of the process attributes; (ii) the definition of the execution context, and (iii) the activities to be executed. Due to industry's increased interest on business process management and the wide acceptance of WS-BPEL as the language to use in the workflow definition, several vendors are producing software tools for workflow design, specification and enactment.

WS-BPEL is particular significant if used in combination with another W3C candidate recommendation: i.e. the Web service choreography description language (WS-CDL, 2005). As a matter of fact, the two specifications are complementary: WS-BPEL is about orchestration, it is based on a central coordinator that is responsible for invoking and combining the single sub-activities, while WS-CDL is about the modelling and execution of cross-organizational business processes, specifying the common observable behaviour of all participants engaged in business collaboration.

The main drawback of these standards, specifications and also of other work based on XML is that they only support static service composition. The composition takes place during design-time when the architecture and the design of the software system are planned, in other words they do not provide support for dynamically discovering new Web services or exploiting new of them in case of unpredictable events. This may be suitable on condition that business partners and service components do not or only rarely change, but in a dynamic environment characterized by continuous evolution where companies need a business process that is capable of ongoing modifications, this often represents an undesirable limit.

Relying, indeed, exclusively on XML one can reach only a syntactic interoperability. Expressing message content in XML does not make possible semantic "understanding" of the message contents and as a consequence programmers have to reach explicit agreement on both the format of the messages exchanged and the way Web services interact.

On the one hand the syntactic description is essential since it provides information about the structure of input and output messages of a service and how to invoke the service itself, but on the other hand semantics is needed to describe what a service really does.

On the research front, in response to these limitations several proposals have been submitted to W3C in order to make Web services semantically described and thus make the description of Web service interfaces unambiguous, paving the way for semi-automatic or even automatic discovery and composition of services. From an analysis of such submissions, in our opinion the most prominent are: OWL-S (OWL-S, 2004) and SAWSDL (SAWSDL, 2007). Both approaches are based on the reference to one or more domain ontologies, in which the concepts, referred in the semantic part of the service description, are defined.

OWL-S, a proposal submitted to the W3C by a community of researchers, is characterized by a quite comprehensive approach to the semantic orientation of the Web service description. It defines an OWL-based service ontology (domain-independent), to which one has to refer for a semantic description of a service. Such a description keeps the semantic information into a separate file, but has a clearly defined grounding to the WSDL document of the real service. To facilitate the adoption of OWL-S specifications the OWL-S researchers developed an OWL-S integrated development environment, called OWL-S IDE (Srinivasan et al., 2006). OWL-S IDE is a framework with the aim of supporting the complete lifecycle of semantic web services: that is the development of OWL-S descriptions, the advertisement, discovery and the execution of OWL-S web services. The most significant and central feature of that work is represented by the support to semantic Web service discovery, achieved by extending the standard UDDI registry specification incorporating OWL-S semantics.

SAWSDL, which became a recommendation of the W3C last year, follows a lightweight, incremental approach. It proposes a small set of extensions to WSDL in order to associate semantic annotation, called model reference, to the WSDL document itself. These annotations relate elements belonging to the WSDL service descriptions with domain-specific semantic elements, e.g. concepts belonging to domain ontologies, but, as opposed to OWL-S, being agnostic to the semantic representation language. Besides semantic annotations, SAWSDL also introduces schema mapping annotations, to be added to XML Schema element declarations and type definitions, with the aim of specifying mappings between semantic data and XML. Such mappings could be used during the invocation phase, particularly when a software agent or more in general a software application playing the role of mediator is used. In fact, model references could be used to determine if a service match client requirements, during the discovery phase, but can also be used during the invocation phase. In a likely scenario, an agent invokes a Web service referring to a high level description of the service itself, based on ontological concepts. In view of the fact that there may be mismatches between the semantic description of the service and its real invocation, the lowering schema mapping is used to obtain the concrete data required to invoke the service; vice versa, in the case of the lifting schema mapping. At the moment, both mappings rely solely on XSLT transformations between RDF/XML, which is a tedious and often an error-prone task. Since it is quite a novel W3C recommendation, the open source tools (e.g. API for handling SAWSDL documents and tools for annotating WSDL services to produce SAWSDL documents) realized by the research community are still in a preliminary phase.

To improve the service discovery phase, Web services registries represent an important component of the semantic Web service infrastructure. As a matter of fact, the need for a dynamic composition of services requires the identification of services based on their capabilities in order to recognize those services that can be combined together. As stated before, the UDDI standard for Web services registries provides publishing and inquiry functionalities, but since it does not make use of semantic information, it fails to address such issue. OWLS-UDDI matchmaker (Srinivasan et al., 2005) and the hybrid matchmaker, called OWLS-MX (Klusch et al., 2006), are at present the most visible of a few semantic Web service matchmakers which have been developed in the last years. Both are based on a matching algorithm which gives as a result a list of suitable services associated with a degree of match, giving the information of how much an advertisement and a query are semantically compatible. They perform service I/O based profile matching, exploiting ontological concepts as values of service input and output parameters. The peculiarity of OWLS-MX is that it is based on a hybrid matching algorithm, which utilizes both logic based reasoning and information retrieval techniques for semantic service discovery, outperforming the previous approaches based only on logic reasoning. The main drawback of both approaches is that they do not consider in their matching algorithm advance reasoning on logically defined preconditions and effects and additional filtering on non functional requirements.

Agents and Multi-Agent Systems

Agent, software agent and multi-agent system are terms that have found their way into a number of technologies and have been largely used, for example, in artificial intelligence, databases, operating systems and computer networks literature. Although there is no single definition of an agent (Genesereth & Ketchpel, 1994; Wooldridge & Jennings, 1995; Russell & Norvig, 2003), all definitions agree that an agent is essentially a special software component that has autonomy that provides an interoperable interface to an arbitrary system and/or behaves like a human agent, working for some clients in pursuit of its own agenda. Even if an agent system can be based on a solitary agent working within an environment and if necessary interacting with its users, usually they are based on multiple agents and so they are called multi-agent systems. These multi-agent systems are suitable for modelling complex systems, introducing the possibility of agents having common or conflicting goals. Agents may interact with each other both indirectly (by acting on the environment) or directly (with communication and negotiation among them). Moreover, agents may decide to cooperate for mutual benefit, or may compete to serve their own interests.

There is no universally accepted definition of the term agent, however, the different definitions allow distinguishing between the features that all the agents should own and the features that some special kinds of agents should provide. In particular, an agent should be autonomous, because it should operate without the direct intervention of humans or others and should have control over its actions and internal state, should be social, because it should cooperate with humans or other agents in order to achieve its tasks, should be reactive, because it should perceive its environment and respond in a timely fashion to changes that occur in the environment, should be pro-active, because it should not simply act in response to its environment, but should be able to exhibit goal-directed behaviour by taking the initiative. Moreover, if necessary an agent can be mobile, showing the ability to travel between different nodes in a computer network, it can be truthful, providing the certainty that it will not deliberately communicate false information, it can be benevolent, always trying to perform what is asked to it, it can be rational, always acting in order to achieve its goals, and never to prevent its goals being achieved, and it can learn, adapting itself to fit its environment and to the desires of its users.

From the technological point of view, a lot of work has been done in the last decade for spreading the use of agents for the realization of software applications. Several software systems and technological specifications are the results of such work. Among them the main results are the definition of FIPA specifications (FIPA, 2000), a set of specifications oriented to support the interoperability between heterogeneous agent systems, and an agent development framework, called JADE (Bellifemine et al., 2008, JADE, 2008), that implements such specifications and supports the interoperability between agents and the most common technologies currently used for realizing software applications.

AGENTS CAPABILITIES FOR WEB SERVICES COMPOSITION

The purpose of this section is to provide a summary of the achievements by the agent community, without aiming at being exhaustive, bearing in mind the great amount of work done, but purely highlighting what we consider relevant because their particular advantages when applied to the specific field of service-oriented applications.

Agents are designed to operate in dynamic and uncertain environments, making decisions at run-time. Moreover, agents take advantage of their social ability to exhibit a flexible coordination that makes them able to both cooperate in the achievement of a global goal and compete in the distribution of resources and tasks. Therefore, agent technology may be considered an interesting means for the enhancement of the current Web services composition solutions and even more for the realization of more effective and reliable Web services composition solutions.

In fact, the agents ability of operating in dynamic and uncertain environments allows coping with the usual problems of failures or unavailability of services and the consequent need of finding substitute services and/or back tracking the system in a state where execute an alternative workflow. Moreover, the capabilities of some kinds of agent of learning from their experience make them able to improve their performance over the time avoiding untrusted and unreliable providers and reusing successful solutions.

Even more important it is the agents' ability in coordinating themselves, because it can be the main ingredient for the development of flexible, intelligent and automatic Web services composition solutions. Coordination among agents can be handled with a variety of approaches including, negotiation, contracting, organizational structuring and multi-agent planning, and all these approaches can be used to cope with some problems of Web services composition.

Negotiation is the communication process of a group of agents in order to reach a mutually accepted agreement on some matter (Jennings, 2001). Negotiation can be competitive or cooperative depending on the behaviour of the agents involved. Competitive negotiation is used in situations where agents have independent goals that interact with each other. They are not a priori cooperative, share information or willing to back down for the greater good, namely they are competitive. Cooperative negotiation is used in situations where agents have a common goal to achieve or a single task to execute. Negotiation can be used with success for automating some operations both in the design and the execution phases of the provision of a composite service. In fact, while in the design phase, negotiation techniques help customers in selecting the most appropriate component services and in reaching an agreement about all the issues charactering the provision of such services, in the execution phase, negotiation can be useful for the redistribution of the component services among both the different servers of a provider and even among different providers.

Among the negotiation techniques, contracting is probably the best way for searching the most appropriate services that satisfy a specific contract. Contracting is a negotiation technique based on a decentralized market structure where agents can take on two roles, a manager and contractor and where managers tries to assign tasks to the most appropriate contractors (Smith & Davis, 1980). The basic premise of this form of coordination is that, if an agent cannot solve an assigned problem using local resources/expertise, it will decompose the problem into sub-problems and try to find other willing agents with the necessary resources/expertise to solve these sub-problems. The problem of assigning the sub-problems is solved by a contracting mechanism consisting of: 1) contract announcement by the manager agent, 2) submission of bids by contracting agents in response to the announcement, and 3) the evaluation of the submitted bids by the contractor, which leads to awarding a sub-problem contract to the contractor(s) with the most appropriate bids.

Contracting solves the problems of searching and selecting the services that can be used in the realization of a composite service, but does not give any help in identifying the contracts that the different component services must satisfy and in defining the way in which they are executed to obtain the composite service. To cope with these two issues, agent can take advantage of multi-agent planning techniques. Multi-agent techniques enable agents to allow the realization of plans that move agents towards their common/individual goal preventing any possible interference among the actions of the different agents (Tonino et al., 2002). In order to avoid inconsistent or conflicting actions and interactions, agents build a multi-agent plan that details all the future actions and interactions required to achieve their goals, and interleave execution with more planning and re-planning. Multi-agent planning can be either centralized or distributed (Rosenschein, 1982; Durfee, 1999). In centralized multi-agent planning, there is usually a coordinating agent which, on receipt of all partial or local plans from individual agents, analyses them in order to identify potential inconsistencies and conflicting interactions (e.g., conflicts between agents over limited resources). The coordinating agent then attempts to modify these partial plans and combines them into a multi-agent plan where conflicting interactions are eliminated. In distributed multi-agent planning, the idea is to provide each agent with a model of other agents plans. Agents communicate in order to build and update their individual plans and the models of other agents until all conflicts are removed.

Multi-agent planning techniques are useful to identify the contracts that the component services must satisfy and to design the composite service, but cannot be used for identifying the providers offering the needed component services; therefore, it must be applied in conjunction with a means able to identify such set of components and, of course, contracting is the most appropriate one. Moreover, multi-agent planning can be used together with contracting during the execution of a composite service when there are one or more malfunctioned component service and for each of these service there is not another available service able to replace it. In these cases, multi-agent planning is able to redesign part of the composite service either replacing a component service with a set of component services realizing together the task assigned to the single service or replacing a set of component services with another set of services that execute the same task that have been assigned to the initial set of services.

Organizational structuring are some coordination techniques that are complementary to both contracting and multi-agent planning techniques. Organizational structuring techniques allow defining the organization that govern the interaction among the agents of a system, i.e., define the information, communication, and control relationships among the agents of a system (Horling & Lesser, 2005). Therefore, the use of such techniques together with contracting and multi-agent planning ones can be useful to guarantee a higher reliable and efficient provision of services by defining the most appropriate organization to manage and monitoring the distributed execution of a composite service and to localize the work needed to be done to cope with some component services.

MULTI-AGENT SYSTEMS FOR WEB SERVICES COMPOSITION

From the above considerations, it clearly emerges that the subject of service composition turns out to be vast and enormously complex and more work needs to be done in order to realize real flexible, adaptive intelligent service-oriented systems. As a matter of fact, current SOA implementations are still restricted in their application context to being an in-house solution for companies.

In the attempt to delineate an effective solution, some researchers have envisaged as strategic the integration of SOA with both semantic and Web technologies (Vitvar et al., 2007). Others have turned their attention towards the agent technology, integrated with semantic and Web technologies, as an interesting means for the realization of more effective and reliable service-oriented systems and for SOA to be successful on a worldwide scale (Huhns et al., 2005).

Integrating Software Agents and Web Services

The problem of composing Web services exploiting agent technology can be reduced to three fundamental problems: (i) the management of the interactions between agents and Web services; (ii) the execution of a workflow or more in general of a plan that describes how Web services interact; (iii) the discovery of the Web services that perform the tasks required in the plan.

The first issue that the agent community has had to cope with has been the integration of the two technologies, which has implied a mapping between the different semantic levels of the two paradigms or patterns of communication. Before analyzing the approaches to the problem it is useful to point out the issues connected. In analyzing and comparing the two technologies, as far as the agent community is concerned, we have referred to the FIPA specifications, since its crucial role in the development of agent technology.

As regards to FIPA, we can assert that the inter-agent communication is dealt with in several documents and definitely represents an important part of the overall specifications. In our attempt to be concise and rigorous, we can state that FIPA specifications target autonomous agents expected to communicate at a high level of discourse, whose contents are meaningful statements about agents' knowledge and environment. The FIPA Agent Communication Language is based on the speech act theory; messages are communicative acts that, by virtue of being sent, have effects on the knowledge and environment of the receiver as well as the sender agent. Furthermore, the language is described using formal semantics based on the modal logic. From this it clearly emerges the communication complexity which characterizes multi-agent systems compared to the very simple conversation patterns of the Web services.

For the sake of clarity, it is fair to reiterate that Web services are also suitable for high-level communication patterns and that in the last years several efforts have been carried out in order to provide description languages enabling service orchestration and choreography and moreover to make Web services semantically described, as already mentioned in the "background" section. Nevertheless, the main goal is still to improve interoperability between entities that are not necessarily characterized by sophisticated reasoning capabilities.

To sum up, the two entities, Web services on the one hand and agents on the other hand, and the corresponding communication patterns are quite different from a semantic point of view. That raises problems about the mapping between the two worlds, essentially because differences between the two communication patterns could lead to a loss of descriptive power in the mapping.

Several researchers belonging to the agent community have dealt with the issues concerning the interconnection of agent systems with W3C compliant Web services, with the aim of allowing each technology to discover and invoke instances of the other.

The proposed integration approaches (Greenwood & Calisti, 2004; Nguyen, 2005; Shafiq et al., 2005) denote different shades of meaning of the same idea, i.e. a wrapper or an adapter module playing the role of mediator between the two technologies. Most of them have adopted the gateway approach, providing a translation of WSDL descriptions and UDDI entries to and from FIPA specifications, thereby limiting the communication to simple request-response interactions. One approach (Soto, 2006), which differentiates quite substantially from the others, realizes a FIPA compliant JADE Message Transport System for Web Services enabling agents to interact through the Web with Web services preserving the FIPA compliant communication framework. It only provides a solution for an integration at a low level, leaving a number of issues at higher levels still unresolved.

The most significant of these approaches is WSIGS (Web Services Integration Gateway

Service), a stand alone, encapsulated application that provides transparent, bidirectional transformations between JADE agent services and Web services (JADE Board, 2005). Through the use of the WSIG JADE add-on, JADE agents are able to expose their services, published in the JADE DF, as web services.

The WSIG supports registration and discovery of JADE Agents and agent services by Web service clients, automatic cross-translation of DF directory entries into UDDI directory entries and invocation of JADE Agent services by Web services. Two main processes are continuously active in the WSIG application: (i) the one responsible for intercepting DF registrations/deregistrations, converting them into suitable WSDLs and registering these information with a UDDI registry as tmodels; (ii) the process responsible for serving incoming web service requests, which consists of retrieving the appropriate tModel from the UDDI repository, translating the invocation message into ACL and sending it to the target agent. Any response from the agent will be translated back into SOAP and sent to the requesting Web service.

When an agent needs to invoke a Web service it directly creates the SOAP message and sends it to the provider, e.g. exploited AXIS2 API. In this case no particular support is needed possibly except for a framework that decouples the agent from the API used to invoke Web services.

To date, WSIG supports only simple WSDL description of Web services, without taking into account emerging technologies related to the semantic Web. Another limit of this integration service is that it does not provide any means that agents can use to automatically or even semi-automatically compose Web services.

Agent-Based Workflow Management Systems

Once the infrastructure, enabling a bi-directional connectivity between the two technologies, is in place an agent can play the role of the orchestrator of dynamic Web service compositions. This is also in line with what is reported in the Web Services Architecture specification (WSA, 2004), which introduces a set of concepts and abstractions for Web architectures, ”… software agents are the running programs that drive Web services—both to implement them and to access them …”; and furthermore, “A choreography defines the sequence and conditions under which multiple cooperating independent agents exchange messages in order to perform a task to achieve a goal state”.

The current multi-agent solutions, aiming at realizing an effective agent-based service composition, are still in a preliminary phase and certainly need to be improved (Buhler & Vidal, 2005; Savarimuthu et al., 2005). However a lot of researchers and software developers are really interested in giving a significant contribution in this direction.

What clearly emerges is that to be successful, in a first phase it is crucial to appropriately engineer and integrate agent technology with other technologies, in addition to Web services, that have found and will find a purpose in this area, in particular semantic Web. In this scenario agents could represent the “glue” that hold these technologies together, leveraging them and making them perform properly.

Assuming to adopt an agent-based approach, a typical scenario of a service-oriented application would be characterized mainly by three actors: service providers, brokers and users, playing roles which would be allocated to different concrete agents. The system architecture would likely be organized in communities constituted by different kinds of agents: service providers, personal assistants and middle agents (e.g. service brokers, user profile managers, workflow managers, etc). In order to achieve their goals (semantic matching, service contracting and so on) these autonomous agents should be able to perform their tasks in cooperation or competition with other agents and to interoperate with external entities (e.g., legacy software systems). Moreover they should show reasoning capabilities and should have a support for dynamic behaviour modification based on business rules. Finally they should be able to build workflows, compose the external Web services and monitor their execution. The entire process should be supported by a distributed trust management.

Clearly the researchers are well aware that such a scenario is quite ambitious and the outlined objectives difficult to achieve in a short period. Nevertheless the realizations of prototype systems centred on the underlying infrastructure can be of great help in order to raise awareness of these issues, to delineate possible solutions and therefore to make progress in the development of service-oriented multi-agent systems.

It is in this ambit that our research work (Negri et al., 2006) is situated. During the last years, we have been implementing prototypes of agent based frameworks that cope with the static and dynamic composition of Web services through the use of workflow technologies. The transition from a prototype to another has been due to the evolution of the standards related to semantic Web service composition. What characterizes the prototypes is the architecture, while what differentiates them is the referenced standards for the description of semantic Web services.

The architecture is based on a heterogeneous society of agents, where different members have different internal complexity. In such a heterogeneous society, hierarchical collaboration between reasoning capable agents is achieved mainly through goal delegation. From the point of view of this dissertation, the most interesting types of agents, which compose the society, are: the component manager agent and the workflow manager agent. Each component manager agent is associated to one or more Web services and is responsible for the interaction with them. Workflow managers have the goal of supporting users in the process of building the workflows, composing external Web services and monitoring their execution. The workflow manager agent assumes the role of the delegate agent in a goal delegation protocol (Bergenti et al., 2003), subdivides its goal in sub-goals, generates a utility function from each sub-goal and sets up a negotiation process with the component manager agents.

To accomplish its activity in the most appropriate way the workflow manager provides the users with two alternative automatic procedures:

1. Predefined workflow; the workflow is extracted from a repository of standard and common templates, e.g. templates used in previous computations. The workflow manager is responsible for supporting the user in the choice of the most appropriate Web services for the execution of the various workflow tasks. The workflow manager is able to select a matching service thanks to the exploitation of a shared ontology. Even though we were aware that Web services supplied by different providers usually have individual and unique semantics, described by independently developed ontologies, in our attempt towards a semantic support, we considered the simplified, but still significant, case of a shared ontology that gives a common knowledge background to the entities in the system. In order to facilitate the resolution of structural and semantic heterogeneities, semantic Web services have their interfaces semantically described by ontological concepts belonging from this shared ontology.
2. Dynamic workflow; the workflow manager, according to the user's requirements, creates a new workflow, composing the atomic services available in the system. This is done by applying a planner, which we have realized extending the Sensory Graphplan planner (SGP, 2000), that works on the ontological concepts related to the semantic service descriptions provided by component managers. After the composition of the final

workflow, the workflow manager is able to update it and possibly replace those Web services that are failed or no more available during the enactment phase.

In addition, the users have been offered the possibility of manually building workflows. In this case, a personal assistant (i.e. an agent, associated with each user active in the system, responsible for the interactions between the user and the other parts of the system) helps its user presenting her/him the tasks (Web services) that can be composed and possibly informing her/him when the realized workflow does not satisfy the composition rules, deduced from the service descriptions. When a complete workflow is realized, the user can ask its personal assistant to delegate its execution to a workflow manager. The enactment is clearly a problematic phase. When a workflow is going to be executed, a Web service could be no more available due to the expiration of a timeout, a failure of a resource or other unpredictable problems. In this case the workflow manager helps the user finding a new solution, creating a new contract phase with all the component managers that are able to satisfy the task and suggesting to the user the replacement of the failed service with the new one.

As far as the semantic aspects are concerned, we have coped with the issue of supporting agents both in the action of looking for a service on the basis of the requirements to be met by the service itself and during the service invocation phase, handling the mapping between the semantic description of the service and its real invocation. In the latter, the agent is therefore asked to provide the semantic input parameters, which for instance refer to ontological concepts, irrespective of the concrete data format required to invoke the real service.

When we started our research work, SAWSDL was not a recommendation yet and OWL-S was the most visible of the several proposals. Our initial choice fell down on OWL-S. We developed a framework enabling agents to invoke Web services on the basis of the ontological concepts belonging to OWL-S documents describing the services and we exploited OWLS-UDDI matchmaker for supporting the discovery phase. Now we are extending the unifying application model in order to include a support for the SAWSDL specification and at the same time we are working on a semantic UDDI registry based on the SAWSDL specification.

In a very early phase workflows were described by using the XPDL workflow language, an XML-based language defined by the Workflow Management Coalition. The manually building workflows were generated using JaWE, a graphical XPDL editor. An XPDL workflow is composed of a set of linked activities. The 'activity' element in the XPDL language is the basic building block of a workflow process definition. In our domain each activity corresponded to a Web service and could be linked to other elements of the workflow through a set of 'transitions'. XPDL supports hierarchical decomposition of activities as the execution of a sub-flow: in this specific case an activity is a link to another XPDL file and workflow. This functionality was used to realize some required loops and to delegate the execution of a specific part of a workflow to another workflow manager agent.

Afterwards, we have moved to WS-BPEL specification. On the one hand WS-BPEL has a better support for Web service, actually its focus is on Web services, but on the other hand it does not support the definition of sub-workflow so far.

In the attempt to give an answer to such problem, we have realized a framework for the distributed execution of a BPEL process. The BPEL process execution is constituted of three phases: (i) interpretation of the BPEL document, (ii) creation of an internal process model, aiming at describing in a consistent way the business process characteristics and at the same time to make easy and efficient the execution of the business process itself, (iii) preparation of the execution context and distributed execution, possibly providing for the exploitation of new Web services.

The main engine, part of the workflow manager agent, is responsible for initiating and coordinating the entire execution process. It creates the execution context, which represents the reference context during the execution process. Next, it identifies those parts of the workflow (e.g. scope activities, sub-activities of the flow activities, single activities and so on), that if delegated to other agents of the systems (component manager agents but also other workflow manager agents) would positively affect the performance of the system.

Finally, in order to allow agents to be able to produce and consume semantically annotated information and services, it is necessary to provide them with an ontology management support. An interesting approach is characterized by the definition of a meta-model that closely reflects the OWL syntax and semantics. The best effort in this field is represented by the modelling APIs of Jena, an open source semantic Web framework for Java, which is the most famous and widely used tool in the sphere of the semantic web and recently also in the context of multi-agent systems. Initially we used the Jena toolkit to load, maintain and reasoning about OWL DL ontologies, while agents necessitating simple artefacts to access structured information were provided with a light ontology support, called OWLbeans (Tomaiuolo et al., 2006). To date an implementation of a full OWL DL support through a home-made framework supplying ontology management and reasoning functionalities is under development, with the main purpose of reducing the amount of computational resources and time required (compared to the Jena engine).

An interesting real-world agent-based application in the area of business process management is reported in (Greenwood & Rimassa, 2007). The paper describes a system consisting of several integrated components for modeling, executing and administering business processes using a goal-oriented and autonomic approach. A real and current customer case in the domain of Engineering Change Management, from Daimler AG, is used to explore the approach. The authors make a comparison against traditional workflow engines. In particular, as far as the BPEL standard language is concerned, they highlight how it is a rather static language and it does not offer the major advantage of goal-oriented autonomic business process management such as the superior flexibility and dynamic self-management. The infrastructure is not based on a service-oriented architecture but since using a goal-oriented approach separates the statement of what the desired system behavior is, from the possible ways to perform such behavior, in a future it will be possible and probably fundamental to adopt such architecture.

Distributed Collaboration and Coordination

The agents' ability of operating in dynamic and uncertain environments and the capability of learning from experience have mainly driven the research activities of the agent community in the area of service-oriented computing so far.

Other interesting features, which can be the main ingredients for automatic cooperation between enterprise services, are the agents' capabilities of collaborating and coordinating themselves. In a business environment, an example would be a broker that has frequently to seek providers as well as buyers dynamically, to collaborate with them and finally to coordinate the interactions with and between them in order to achieve its goals. An intelligent service-oriented infrastructure could do it automatically or semi-automatically, within the defined constraints.

As far as the automatic cooperation between enterprise services is concerned, to the best of the authors' knowledge, there are very few ongoing studies. The most significant is the one reported in (Paschke et al, 2007). In this work, the authors combine the ideas of multi-agent systems, distributed rule management systems and service-oriented and event-driven architectures. The work is mainly focused on the design and implementation of a pragmatic layer above the syntactic and semantic layers. Taking advantage of this layer, individual agents can form virtual organizations with common negotiation and coordination patterns. An enterprise service bus is integrated as a communication middleware platform and provides a highly scalable and flexible application messaging framework to communicate synchronously and also asynchronously with external services and internal agents. To date, the authors have developed an interesting methodology and an architectural design but they have only outlined a possible implementation of the system.

FUTURE TRENDS

Multi-agent systems, semantic Web and Web services are still evolving towards a complete maturity. In particular, the evolution and the strengthening of the semantic Web technologies and of the related technologies for providing semantic Web services should influence the evolution of multi-agent technologies given that, on the one hand, the use of agents for the composition of Web services is considered one of the most promising area where applying agents and, on the other hand, one of the requirements for the success of multi-agent systems is that they have to guarantee an easy integration with other widely used industrial technologies as Web services already are and semantic Web ones have a lot of chances to become.

Moreover, multi-agent systems will be able to become the most important mean for Web services composition if the current studies on coordination, knowledge management, distributed planning and learning will have as one of their results the definition of a set of techniques able to simplify and at the same time to enhance the realization of systems where parties have multiple, perhaps competing, objectives and services have to be provided satisfying the required quality of service and coping with the possible failures due to either the unavailability or the malfunctioning of some components of the system.

CONCLUSION

In this chapter we have tried to show how the agent technology together with Web service and semantic Web technologies allow the conception and realization of an advanced solution to Web service composition, paving the way for real flexible, adaptive intelligent service-oriented systems.

The research in distributed artificial intelligence has been addressing for several years the problem of designing and building coordinated and collaborative intelligent multi-agent systems. This interesting and advanced work can be fruitfully exploited in the area of service-oriented computing if agent technology is appropriately engineered and integrated with the other key technologies. To support this claim, we have addressed the benefits in applying multi-agent systems and we have shortly introduced the solutions that multi-agent systems can provide trying to show how the powerful synergism between these technologies could be very promising.

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KEY TERMS AND DEFINITIONS

Autonomic Computing: It is an initiative started by IBM in 2001 and it is about an approach for realizing self-managing systems, i.e. systems characterized by self-configuration, self-healing, self-optimization and self-protection properties.

Coordination: Coordination is a process in which a group of agents engages in order to ensure that each of them acts in a coherent manner.

Contracting: A process where agents can assume the role of manager and contractor and where managers tries to assign tasks to the most appropriate contractors.

Goal Delegation Protocol: An interaction protocol allowing an agent to delegate a goal to another agent in the form of a proposition that the delegating agent intends its delegate to bring about.

Multi-Agent Planning: A process that can involve agents plan for a common goal, agents coordinating the plan of others, or agents refining their own plans while negotiating over tasks or resources.

Multi-Agent System: A multi-agent system (MAS) is a loosely coupled network of software agents that interact to solve problems that are beyond the individual capacities or knowledge of each software agent.

Negotiation: A process by which a group of agents come to a mutually acceptable agreement on some matter.

Organizational Structuring: A process for defining the organizational structure of a multi-agent system, i.e., the information, communication, and control relationships among the agents of the system.

Software Agent: A software agent is a computer program that is situated in some environment and capable of autonomous action in order to meet its design objectives.

Section II
Social Semantic Web

Chapter XVII
On the Social Shaping of the Semantic Web

Paul T. Kidd
Cheshire Henbury, UK

ABSTRACT

Addressed in this chapter is the Social Shaping of the Semantic Web in the context of moving beyond the workplace application domain that has so dominated the development of both Information and Communications Technologies (ICTs), and the Social Shaping of Technology perspective. The importance of paradigms and the values that shape technology are considered along with the utility value of ICT, this latter issue being somewhat central in the development of these technologies. The new circumstances of ubiquity and of uses of ICT beyond mere utility, as a means of having fun for example, are considered leading to a notion of the Semantic Web, not just as a tool for more effective Web searches, but also as a means of having fun. Given this possibility of the Semantic Web serving two very different audiences and purposes, the matter of how to achieve this is considered, but without resorting to the obvious and rather simple conceptual formulation of the Semantic Web as either A or B. The relevance of existing Social Shaping of Technology perspectives is addressed. New thoughts are presented on what needs to be central to the development of a Semantic Web that is both A and B. Key here is an intelligent relationship between the Semantic Web and those that use it. Central to achieving this are the notions of the value of people, control over technology, and non-utility as a dominant design principle (the idea of things that do not necessarily serve a specific purpose).

INTRODUCTION

When computing and communications technologies merged and moved from the industrial, commercial, academic and government settings in which the technologies initially developed, into society at large, something fundamental and quite profound happened. On achieving ubiquity, Information and Communications Technologies (ICTs) ceased to be the primary preserve of the professional developer and the work-based user, and became, in effect, public property. No more can the use of ICT be perceived as the domain of a select few. And the World Wide Web is the quintessential embodiment of this new circumstance. But it is not just the user community that has changed, for it is also the case that professional software developers also now operate in a world where anyone, potentially, can become a software or applications developer.

However, with the movement of ICT out from, and beyond, the workplace, into society at large, there is a need to look beyond traditional concerns with problem-solving, efficiency, utility, and usability. These are the criteria of the business world, of government departments, and the like, who are single-mindedly focused on delivering against targets set from high above. To these types of organization, computers, software, the Internet, and the World Wide Web are but functional utilitarian tools deployed in the service of profit, in the case of business, or policy as the embodiment of high political principles, in the case of governments.

Step beyond this well ordered world, into the life of an everyday citizen in modern society–the information society–and all these conventional concerns with problem-solving, efficiency, utility and the like, sit side-by-side, often uncomfortably, or are often substituted by, a second dimension representing a whole spectrum of other interests. The defining characteristics of this second dimension to the Web are typically: fun, enjoyment, happiness, fulfillment, excitement, creativity, experimentation, risk, etc. These in turn raise a much wider range of values and motivations than those of business, and embody notions such as freedom, individuality, equality, the human right to express oneself, and so forth. Moreover, these lead to a World Wide Web as a place, not of order, but of chaos, anarchy, subversion, and sometimes, even the criminal. And into this world moves the notion of semantic technologies, potentially transforming this chaotic and unpredictable environment into a place of order and meaning, taming this wild frontier, making it more *effective* and *useful*. But order, meaning, effectiveness, and usefulness for whom?

This paper addresses this rather simple, yet profound question. It is argued that the Semantic Web, as originally conceived, is not, as has been claimed, an improvement upon the first generation of the World Wide Web, but potentially a destructive force. What the Semantic Web may end up destroying is the unpredictability of interactions with the Web. This unpredictability, it is argued, is one of the Web's most appealing characteristics, at least to those who are *not* seeking to be more efficiency, or effective, and the like. And with the loss of unpredictability goes serendipity, which is something that has a value beyond quantification, for both the workplace user and the non-workplace user.

However, this outcome is not inevitable: there is no immutable law which states that the Semantic Web has to be such that all unpredictability in encounters with the Web has to be eliminated. The Semantic Web, like all technologies, can be shaped to produce outcomes (MacKenzie & Wajcman, 1985), and these do not have to be dominated by the need for efficiency and utility. In other words, insights form the social sciences can be used to design a technology that is different from one where purely technical and business considerations dominate.

To understand this perspective it is first necessary to understand how design paradigms influence the development of technology, and how these paradigms have failed to adapt to the age of computers and the information society (Kidd, 2007a). These paradigms, it is argued, are still predominately locked into a world dominated by inflexible electro-mechanical systems, these being technologies which severely limit design freedom and which do not allow designers to accommodate individualism. This, it is further argued, has implications, not just for social users of the Web, but also for business users.

Consideration is also given to values underlying science and technology, which still seem to embody Newton's Clockwork universe, with its belief in predictability and absoluteness, a perspective which sits in sharp contrast to the modern world view of a chaotic and relative universe. The journey will also consider notions of happiness and how this is connected to the concept of *meaning.* Meaning here does not refer to that which is commonly understood in the context of the Semantic Web. What *meaning* implies in this context is something that is strongly linked to the subjective, and key among this is emotions, which are a human trait that surpasses the domains of usability and conventional human factors. Emotions and meaning however are not well understood by software developers, but it has been argued that these are the very things that underlie the success of many of the modern world's most successful products (mobile phones being the classic example). Finally, the discourse will consider the concept of Ludic Systems, Ludic (Huizinga, 1970) being an obscure word meaning playful, but in a very wide sense, including learning, exploration, etc. This perspective does not just characterized people by thinking or achievements, but also by their *ludic* engagement with the world: their curiosity, their love of diversion, their explorations, inventions and wonder. Play is therefore not just perceived as mindless entertainment, but an essential way of engaging with and learning about the world and the people in it.

Bringing these perspectives together, the contribution will then consider the Social Shaping of the Semantic Web, namely the conscious design of the Web such that it accommodates the two very different, but important dimensions of the Web discussed in the chapter. It will be argued that the appropriate perspective is not to view these as competing and opposing views, a case of the Web as *A or B*, but rather the Web as *A and B*, in effect, order co-existing with chaos. And the key to achieving this lies in the development of a different sort of Semantic Web, one with different aims, and this in turn involves adopting a new design paradigm. This new perspective needs to explicitly acknowledge that usefulness, as defined in the classic sense, is not the beginning and end of matters, and that, it is legitimate to design the Web taking into account that not everything has to have a particular purpose. Put another way, as Gaver (2008a) has noted, some artifacts can just simply be *curious things for curious people*. The elements of such an approach will be described, including links to another Web development that goes under the label of *Web 2.0*; specifically context awareness.

BACKGROUND

The Semantic Web can be viewed as a business engendered ICT, that is to say, driven by and shaped by the needs of business. The promise is of a structured information resource from which information and knowledge can be more easily discovered than is the case with the first generation of the World Wide Web. A key requirement for creating the Semantic Web is the organization and classification of web content. In support of this requirement, knowledge-based technologies are needed that will provide a means of structuring this content, adding meaning to it, and automating the collection and extraction of information and knowledge.

Ultimately the goal appears to be transforming the World Wide Web from a chaotic and disorganized place, into an efficient information and knowledge source, providing a basis for the development of value added services based on this Semantic Web. One of the key elements in achieving this goal is the creation of ontologies (Benjamins *et.al.*, 2003), which are in effect agreed and shared vocabularies and definitions, that provide a basis for adding meaning to web content. These ontologies should provide a common understanding of the meaning of words used in different circumstances. One of the essential tasks in the development of the Semantic Web, is to research and define ontologies for specific applications. Another key research topic is that of content quality assurance, for without this there can be no trust that the data, information and knowledge derived are of any value.

There are of course other challenges of a technical nature, including scalability, multilingualism, visualization to reduce information overload, and stability of Semantic Web languages (Benjamins *et.al.*, 2003).

All these issues are recognized as being central to the successful development of the Semantic Web. However there is one more element, perhaps less well appreciated, that is also central to the success of the Semantic Web. This additional factor is the human and social dimension. It can be argued that the handling of this particular area could significantly affect, for better of worse, both the usefulness and the acceptability of the Semantic Web. To understand why this is so, it is necessary to understand something of the bigger picture that provides a contextual background to the development of the Semantic Web. This reflection begins with consideration of the future development of ICTs in general.

Future visions for ICTs are characterized by a belief in the ubiquity of these technologies (e.g. see Wiser (1991), Ductal *et.al.* (2001), Aarts & Marzano (2003)). Phrases such as *ubiquitous computing*, *pervasive computing*, and *Ambient Intelligence* represent visions of computing devices embedded into everyday things, thus transforming these items into intelligent and informative devices, capable of communicating with other intelligent objects. These intelligent and networked artefacts will assist people in their daily activities, whether these are associated with work, travel, shopping, leisure, entertainment, etc.

The prospect of embedded intelligence transforming the nature of everyday objects builds upon the already widespread use of ICTs in society at large. Personal computers, mobile telephones, laptop computers, personal digital assistants, MP3 players, games' consoles, and such forth are ubiquitous in society. And applications such as the Internet and the World Wide Web have provided a new access channel to existing services, and also opened up new activities, like social networking, blogs, instant messaging, personal web sites, and so forth, that were previously unforeseen and infeasible. Moreover, the ubiquity of computing and communication devices along with cheap (some times free) software downloadable from the Internet, has transformed the non-workplace user environment, for those with the inclination, into a *do-it-yourself* development environment. Many of the these developments in ICT can be described as socially engendered ICTs and applications, that is to say, driven by and shaped by social interests.

This is a very new circumstance and not surprisingly this has raised some concerns about the social effects of all this new and networked technology.

These concerns are wide ranging (Kidd, 2007b). They include worries over security, loss of privacy, and the rise of a surveillance society where the state, as well as some rich and powerful corporations, take on the features of the all seeing and all knowing *Big Brother* central to George Orwell's novel *Nineteen Eighty Four*. Other concerns include the fear that society is becoming too dependent upon computers, to the point where the computer becomes the defining feature of reality, and, if the computer says something is so, or not so, then this must be true, even if it is not. There are also worries about peoples' behavior. These range from increased detachment from the real world as people are increasingly drawn into the artificial world of cyberspace, through to concerns about lack of consideration for others, for example, by those using mobile telephones in public spaces without any regard for the affect on those around them (referred to as increasing civil inattention (Khattab & Love, 2008)).

In Europe there is also a worry that citizens will not accept the offered vision of *ubiquitous computing.* As a result of these concerns a different vision has been formulated for *ubiquitous computing*, one that goes by the name of *Ambient Intelligence*. Specifically, the concept of *Ambient Intelligence* offers a vision of the information society where the emphasis is on greater user-friendliness, more efficient services support, user-empowerment, and support for human interactions (Ductal *et. al.,* 2001). People will be surrounded by intelligent intuitive interfaces that are embedded in all kinds of objects, and their environment will be capable of recognizing and responding to the presence of different individuals in a seamless, unobtrusive and often invisible way. This particular perspective is founded, at least in principle, on the notion of humans at the centre of all this technology, of the technologies serving people, of a human-centered information society.

But even the acceptance of this more human-centered vision by society at large is perceived to be a problem. This has led some senior representatives of the European ICT industry to propose that ordinary citizens become involved in the research, development and design processes that lead to the creation of so called intelligent everyday objects (ISTAG, 2004). This approach, as presented by ISTAG, is quite radical as it advocates design by, with, and for users, seeing these people not just as subjects for experiments, but also as a source of ideas for the development of new technologies and products.

In the USA there is also an appreciation of the importance of the human dimension with respect to ubiquitous computing (Abowd & Sterbenz, 2000). Key among the topics raised with respect to what are called *human-centered research issues,* is that of control. Control in this case means considering circumstances when an intelligent environment should initiate an interaction with a human, and vice versa, or when sharing of control is necessary between users and the system, and also flexibility in the level of control. Other issues raised are deciding which activities should be supported by these intelligent environments, what new capabilities they enable which go beyond current capabilities and activities, and support for task resumption following an interruption.

There is a danger however, that such matters might be seen as either usability issues or those relating to traditional human factors or ergonomics. And Abowd and Sterbenz (2000) do in fact raise matters that are very much in the sphere of traditional human factors. However there is more to *human-centred research issues* than these more traditional concerns. To understand why this is so, it is necessary to consider technologists' and engineers' perceptions of human-centredness.

Isomäki (2007) reports on a study of information systems designers' conceptions of human users. Of note is the observation that these designers occupy a continuum of perceptions. At one end there are those with very limited conceptions, right though to the other end where designers have more holistic and comprehensive perspectives. This tends to support the conclusion that different forms of responses are possible when taking into account people, ranging from ergonomics of human-computer interfaces, right through to designing technologies so that users have full control over the way that the technologies work and the way that they are used.

With different conceptions of human issues, it follows that designers will have different perceptions of the problems that need to be addressed. To those with limited conceptions, traditional ergonomics and human factors is all that is needed to address the human dimension. However, for those with more developed perceptions of the human dimension, of what human centeredness might imply, the scope of designing for the human, has, potentially, much greater scope.

These designer conception issues therefore raise matters of values and design paradigms concerning technologies and the relationships with people, and more broadly with society.

This then leads to the familiar ground of technological determinism (MacKenzie & Wajcman, 1985, page 4), where technology is perceived to lie outside of society, having effects upon society, but being neutral in the sense that the technology is not influenced by subjective elements within society (e.g. such as values). If there is a choice in relation to technology, then it is one of choice between competing inventions, and by virtue of rational assessment and judgments, the best technology can be selected. This chosen technology then has some effect upon society, and matters of human issues just reduce to finding the most appropriate way to interact with the technology.

An alternative view is to consider technology as the product of society, a result of the prevailing economic, political, social and value systems. Technology therefore is not neutral and independent of society, but is shaped by society and its dominant values. And if this is so, then it is possible to shape technology in different ways, depending upon the values that are dominant, which opens up the possibility for the *Social Shaping of Technology*, using insights from the social and psychological sciences to produce different technologies to those that would normally be produced when technologists are left to themselves.

This discussion about the factors that shape technology leads to considerations of design paradigms. Paradigms are comprised of core beliefs, shared values, assumptions, and accepted ways of working and behaving (Johnson, 1988). Technological determinism is part of the framework of beliefs that are held by technologists, and is therefore part of the paradigm of technology development.

It has been argued (Kidd, 2007a) that the shift to the knowledge age, to a world where Ambient Intelligent systems predominate, involves a paradigm shift, not just in technology, but also in terms of the values that technologists bring to the process of designing these technologies. The knowledge era is heralded as a new age for humankind, implying some sort of transition from the past, to a new and different future, one based on the value of information and knowledge. The old age that is being left behind, the industrial era, was, to a large extent, based on subjugation of human skills, knowledge, expertise, and purpose to the demands of a resource-intensive economic system based on mass production. This led to a relationship between people and machines, where the needs of machines were predominant, and technology was designed to, as far as possible, eliminate the need for human intelligence, or to move this need to a select group of people within organizations, such as engineers and managers.

In other ways also, technology design practices have been shaped by the limitations of past technologies. The age in which technology development and design practices emerged and were refined, was primarily characterized by rather inflexible electrical, mechanical, or (a combination) electro-mechanical systems, which severely limited what was possible. In many respects the advent of relative cheap and highly flexible computers, which are in effect universal machines, has done very little to change these established practices, especially when it comes to considering the human dimension. This is the power that paradigms hold over people, trapping them into avenues of thought and practice that no longer have relevance.

But the industrial age view of technology and machine, also reflected the dominant world view of the time, where the universe was seen as a machine, a majestic clockwork (Bronowski, 1973, pages 221-256) and where its workings are defined by causal laws (Newton's), and where, by using reductionist scientific methods, all in time could be understood and be known. Of course, the universe turned out to be a much stranger place than Newton imagined, a place of relativity, chaotic behavior within what were once perceived as predictable systems, and of the quirky behavior of matter at the quantum level.

But in many respects this clockwork view of the world still prevails in the world of technology, for it is far easier to conceive of people as being components of machines, since the alternative is to consider humans in their true light, with all their quirkiness, likes and dislikes, interests, emotions, wants, and so forth. Yet the advent of the information society, the knowledge era, the age of *Ambient Intelligence*, demands just such as shift, for no more can ICT be perceived primarily as technologies for the workplace, where the employees can be subjugated to the needs of employers and the purposes of the employing organization.

And the primary reason for this is the change, is that of a different context for the use of ICT, which is now just as much focused on the world outside of the familiar workplace environment, as it is on the workplace. But this not only has implications for technology and technology design practices, it also has implications for the social sciences. Traditionally, those concerned with the *Social Shaping of Technology* have developed their theories and concepts based on the use of ICTs, as well as early generations of automation technologies, in the context of workplace environments. In other words they have been motivated by business engendered ICTs. This is no longer the prevailing circumstance. ICTs now need to be designed for both the workplace user and the non-workplace user. Business engendered ICTs and socially engendered ICTs have to be accommodated, with an ill-defined boundary between the two, and this provides the *Social Shaping of Technology* perspective with new challenges.

MAIN FOCUS OF THE CHAPTER

Relevance of Existing Social Shaping of Technology Theories and Concepts

To begin to address the Social Shaping of the Semantic Web, it is first necessary to make a detour to consider some key theories and concepts of the *Social Shaping of Technology*, and then to address their potential relevance to the Social Shaping of the Semantic Web.

The *Social Shaping of Technology* has it roots in the understanding that technology is not neutral, and that technology is *shaped* by the values and beliefs of those that influence its development, these being mostly engineers, technologists, and scientists. Change these values and a different technology will result.

While the scientific and technical community tend (and like) to believe that technology is neutral and is not determined by values, many social scientists think differently. As a result there is a body of thought and knowledge in the social sciences, that provides a theoretical and conceptual basis for the *Social Shaping of Technology*. Key among the existing body of knowledge is *socio-technical design*. Another important perspective is *interfacing in depth*.

For completeness, some of the key features of both will first be described. Then, the relevance of these to the Social Shaping of the Semantic Web will be addressed.

The Sociotechnical School developed in the United Kingdom shortly after World War II, in response to the introduction of new technology into the British coal mining industry. Its central tenant is that surrounding technology, which can be regarded as a sub-system, there is also a social sub-system. These two sub-systems can be designed to be compatible, either by changing the technology to match the social sub-system, or modifying the social sub-system to match the technology, or a mixture of both.

The Sociotechnical School of thought has been articulated in the form of principles, (Cherns, 1976, 1987) that embody the values and key features of sociotechnical design. These principles, of which there are 11, are: *Compatibility*; *Minimum Critical Specification*; *Variance Control*; *The Multifunctional Principle–Organism vs. Mechanism*; *Boundary Location*; *Information Flow*; *Support Congruence*; *Design and Human Values*; *Incompletion*; *Power and Authority*; and *Transitional Organization*.

Among the above there is a sub-set of principles that are primarily organizational in nature. These are: *The Multifunctional Principle–Organism vs. Mechanism*; *Boundary Location*; *Information Flow*; *Support Congruence*; and *Power and Authority.*

The *Multifunctional Principle–Organism vs. Mechanism* refers to traditional organizations which are often based on a high level of specialization and fragmentation of work, which reduces flexibility. When a complex array of responses is required, it becomes easier to achieve this variety if the system elements are capable of undertaking or performing several functions. *Boundary Location* is a principle that relates to a tendency in traditional hierarchical organizations to organize work around fragmented functions. This often leads to barriers that impede the sharing of data, information, knowledge and experience. Boundaries therefore should be designed around a complete flow of information, or knowledge, or materials, to enable the sharing of all relevant data, information, knowledge and experience. The *Information Flow* principle addresses the provision of information at the place where decisions and actions will be taken based on the information. *Support Congruence* relates to the design of reward systems, performance measurement systems, etc., and their alignment with the behaviors that are sought from people. For example, individual reward for individual effort, is not appropriate if team behavior is required. *Power and Authority* is concerned with responsibilities for tasks, and making available the resources that are needed to fulfill these responsibilities, which involves giving people the power and authority to secure these resources.

There is also another sub-set of principles that largely relate to the process by which technology is designed. These are: *The Compatibility Principle*; *The Incompletion Principle*; and *The Transitional Organization Principle*.

The *Compatibility Principle* states that the process by which technology is designed needs to be compatible with the objectives being pursued, implying that technologies designed without the involvement of users, would not be compatible with the aim of developing a participatory form of work organization where employees are involved in internal decision making. *Incompletion* addresses the fact that when workplace systems are designed, the design is in fact never finished. As soon implementation is completed, its consequences become more evident, possibly indicating the need for a redesign. The *Transitional Organization* principle addresses two quite distinct problems when creating new organizations: one is the design and start-up of new (greenfield) workplaces, the other relates to existing (brownfield) workplaces. The second is much more difficult than the first. In both situations the design team, and the processes it uses, are potentially a tool to support the start-up and any required transitions.

What remain from Cherns' set of 11 sociotechnical design principles, is a sub-set that is significantly technology oriented, although the principles also have organizational implications. The principles in question are: *Minimum Critical Specification*; *Variance Control*; *Design and Human Values.*

The principle of *Minimum Critical Specification* states that only what is absolutely necessary should be specified, and no more than this, and that this applies to all aspects of the system: tasks, jobs, roles, etc. Whilst this is organizational in nature, it impacts technology as well. It implies that what has to be done needs to be defined, but how it should be done should be left open. In terms of features and functions of technology, the technology should not be over determined, but should leave room for different approaches. It implies a degree of flexibility and openness in the technologies. Turning now to *Variance Control*, this is a principle that, as its name suggests, is focused on handling variances, these being events that are unexpected or unprogrammed. Variances that cannot be eliminated should be controlled as near to the point of origin of the variance as possible. Some of these variances may be critical, in that they have an important affect on results. It is important to control variances at source, because not to do so often introduces time delays. Next on the list of principles is that of *Design and Human Values*. This is concerned with quality of working life. In the context of the working environment it manifests itself in issues such as stress, motivation, personal development, etc. This principle has both a social sub-system dimension and a technology sub-system dimension, in that both can be designed to reduce stress, and to enhance motivation and personal development.

The second approach mentioned as being of relevance to the Social Shaping of the Semantic Web, known as *interfacing in depth*, has its roots in technology design, specifically the design of computer-aided manufacturing systems.

This perspective on the *Social Shaping of Technology* rests on the observation (Kidd, 1992) of the importance of technology in influencing organizational choice and job design. There is a perspective (e.g. see Clegg, 1984) that suggests that technology is of secondary importance with respect to job design and organizational choice. However, as noted by Kidd (1992), technology is clearly not neutral and can close off options and choice in the design of organizations and jobs. Technology for example can be used to closely circumscribe working methods, to limit freedom of action and autonomy, and to determine the degree of control that users have over the work process.

This viewpoint, of technology shaping organizations, roles, and working methods, led to the notion of *interfacing in depth*. So, rather than just applying ergonomic and usability considerations to the design of human-computer interfaces, it was proposed that there is also a need to apply psychological and organizational science insights to the design of the technology behind the interface.

Kidd (1988) for example, describes a decision support system that was designed using this broader perspective. A key point about this decision support system is that the system characteristics were not achieved through the application of ergonomics or usability considerations to the design of the human-computer interface. Rather the characteristics arose from the technology behind the human-computer interface, where the technology refers to the algorithms, data models, architectures, and the dependency upon human judgment and skills that were built into the operational details of the software.

Kidd (1988) also points out that it is necessary to make a distinction between the surface characteristics of a system, as determined by the human-computer interface, and the deeper characteristics of a system, as determined by the actual technology. The surface characteristics are strongly related to ergonomics and usability, while the deeper characteristics relate more to the view of the user held by the designer, in that if values are driven by a desire to reduce user autonomy, this will be reflected in the details of the underlying technology. Likewise if values are such that autonomy is valued, then this will lead to a different type of underlying technology.

Consequently, good human-computer interface (surface) characteristics are necessary, but not sufficient. Attention must also be paid to the deep system characteristics, that is, the technology behind the human-computer interface. This is called *interfacing in depth*.

The relevance of both *sociotechnical design* and *interfacing in depth* to the *Social Shaping of the Semantic Web* has been addressed by Kidd (2008a). A key point in this consideration is the relevance of both approaches to non-workplace environments, for socially engendered ICTs, given that both the sociotechnical approach and *interfacing in depth* were developed in the context of workplace environments.

Kidd (2008a) specifically addresses the relevance of sociotechnical principles and *interfacing in depth* for the case of the Semantic Web, not just as a technology for the workplace, but in the context of the non-workplace user environment, for example in the home.

A key feature of any web technologies is that the outcome of the use of this type of technology is not known in advance. Consequently, to over determine how the technology is used, to over limit results based on semantics, could be incompatible with the purpose of the technology, as perceived by some people, and its value to users.

This implies that the sociotechnical variance control principle could potentially be very important in the design and development of the Semantic Web. One of the potential downsides of the Semantic Web is that it eliminates variances in web search results, thus destroying some of the value of the Web (the experience of discovering the unexpected). Consequently, enabling the user to decide how much variance to tolerate, in other words to place control of variances in the hands of users, could be an important attribute that needs to be designed into the Semantic Web, and for this reason therefore, variance control is potentially an important principle for the non-workplace environment. But it could also be an important principle in the workplace environment as well. The reason for this primarily lies in the competitive imperative for innovation, and in the need to be adaptive and responsive, especially in the face of structural changes in the business environment; changes that require agility, and corresponding organizational designs and operating principles that are open to bottom-up adaptation (Kidd, 2008b).

Control therefore is potentially important because not to have control over technology such as the Semantic Web, for users not to be able to decide which features of the technology should be employed, reduces the role of the Semantic Web to that of a vending machine for search results. This could be highly de-motivating to users of the Semantic Web.

This observation also arises from the *interfacing in depth* perspective. The whole philosophy of *interfacing in depth* is based on design of technologies where there is uncertainty and unpredictability in terms of outcomes. This approach provides a framework to counter the tendency to reduce human-computer encounters to circumstances where there is no uncertainty and unpredictability in outcomes. This theory is highly relevant to the Semantic Web, for this approach would seek to allow user autonomy and control to flourish, thus maintaining the potentially chaotic and serendipitous nature of the World Wide Web, but at the choice of the user.

Moving Towards the Social Shaping of the Semantic Web

Summarizing the central argument, the key issue is to shape the Semantic Web so that it does not reduce interactions with the Web to the circumstance where the Web becomes like a vending machine. But there is more involved here than a simple on-off switch that disables or enables, at will, the semantic features of the Web, although such as approach could be used. Ideally a circumstance should be created where the technology provides a more sophisticated approach. But the question remains how to do this? A key issue here relates to avoiding a circumstance where the Web is viewed in polar terms. The appropriate perspective therefore is not to see two competing possibility, two extremes, a case of the Web as semantic or the Web as non-semantic, but as a combination of both, as a continuum of infinite possibilities.

Such a perspective has been advanced before in connection with other technologies (Kidd, 1994, pages 301-303), but also more recently in relation to Ambient Intelligent Systems (Kidd, 2007a). The conceptual basis lies with *interfacing in depth* and variance control, and has been referred to as user defined human-computer relationships. This word *relationship* is important here as it implies more than just an interaction between person and machine. There has to be intelligence in this relationship, something that is often overlooked when the word intelligence is used in the context of computers. It is not, for example, very intelligent for a so-called *intelligent everyday artifact* to enforce a given way of working on users. An intelligent relationship with a semantically based World Wide Web would be built on control and understanding. Control comes from providing the technologies that will allow users to specify in some way, how semantic based searches operate, perhaps for example by including some form of *control knob* that would tone down the strength of the semantic dimension. But more than this, the Semantic Web needs to understand something of the context of the user.

This then touches upon a sensitive area, that of context awareness (Braun & Schmidt, 2006), which is a matter that arises in another area of World Wide Web development often referred to as *Web 2.0*. The sensitivity hinted at here relates to privacy, for to understand a user's context it is necessary to capture information, some of which may be of a personal nature, including patterns of usage and the like, much of which people may not want to have stored within a computer system. The information is also of the sort that commercial organizations, interested in marketing products and services, might be all too keen to lay their hands on.

However, putting aside for the moment these very serious issues, understanding the context under which users come to the Web, knowing something of their likes and dislikes, whether their are interests are broad or narrow, how much they value serendipity and how often they follow-up seemingly random and unrelated search results, could be a key factor in enabling the development of a more adaptive and responsive Semantic Web.

But this only defines the relationship. What about user motivation? Why should technology developers bother with such sophistication? This returns the discussion to the matter of paradigms and technologists' conceptions of the human dimension of the Semantic Web. Here, looking beyond utility, a factor that is such a dominant feature of the workplace, is critical. This involves addressing the non-utilitarian perspective, something that is perhaps an alien concept to the technologist. Put simply, not everything has to have utility.

Technologists need to understand that what makes people happy is not always something that is useful. Sometimes happiness comes from meaning, from emotional connection. This, it has been argued, is central to understanding why certain technologies are so successful, while others are less so (Lyngsø & Nielsen, 2007). For example, text messaging on mobile phones seems very much to be an example of a very useful tool, and it certainly has a very obvious utility. But text messaging is not just used for utilitarian purposes. Many young people use text messages to communicate with each other. But to adults the messages may seem to be pointless, like "where are you?" or "what are you doing?" or "I'm bored" and so forth. This is just chatter, which is meaningful to the younger generation, but not to adults. And the word *meaningful* is key here. It is the meaningfulness of the text messaging system that makes it so popular. And the same can be said for instant messaging, blogs, and social networking sites. They have very little in the way of utility. They are in fact just an extension of the face to face discussions that take place when people meet. But this point is important, because their motivation is not oriented to fulfilling a task, but to other more human inclinations, like for example, *having a good time*. These applications and many more, are examples of socially engendered ICT.

Socially engendered ICT points to a different type of driver for the development of the Semantic Web. The Semantic Web is not just a tool to undertake more efficient and effective searches of Web content, but can also be a means for people to *have a good time*. This is therefore links to the concept of Ludic Systems.

Ludic is something of an obscure word; it means playful (Huizinga, 1970), but in a very wide sense. Included are activities such as learning, exploration, etc. The Ludic perspective does not just characterized people by thinking or achievements, but also by their *ludic* engagement with the world: their curiosity, their love of diversion, their explorations, inventions and wonder. Play is therefore not just perceived as mindless entertainment, but an essential way of engaging with and learning about the world and the people in it (see Gaver (2008b) for an example).

Consequently, the Social Shaping of the Semantic Web needs to incorporate this perspective, which explicitly acknowledges that usefulness, as defined in the classic sense, is not the beginning and end of matters, and that, it is legitimate to design the Web taking into account that not everything has to have a particular purpose. Put another way, some artifacts can just simply be *curious things for curious people* (Gaver, 2008a). This could be of key importance in reshaping design paradigms, introducing a different dimension that explicitly recognizes that there is *life beyond mere utility*.

With this view in mind, Kidd (2008a) has proposed an additional sociotechnical design criteria to add to the 11 proposed by Cherns (1976,1987). This new criteria takes sociotechnical design out beyond the workplace environment, into the world of ubiquitous computing, of Ambient Intelligent systems, a world of the Web as used by a vast network of people seeking to *have a good time*, of a world of socially engendered ICT. The new principle embodies the mood of the age, as manifested in social networking Web sites, blogs, instant messaging, and so forth. The principle, referred to as the *Non-utility Principle*, is articulated as:

Non-utility Principle: *ICT in non-workplace contexts serve purposes beyond mere utility, and ICTs should therefore be designed to enable users to achieve emotional fulfillment through play, exploration, and several other dimensions, that are not traditionally associated with workplace environments.*

FUTURE TRENDS

Clearly during the early years of the 21st century there has been an emergence of, as well as a significant growth in, ICTs that are predominately focused on the world outside work. Many of these systems, while they also provide the workplace with useful tools that serve the utility oriented perspective of the working environment, were not conceived with this outcome in mind. It is more the case that they serve a purpose that is related to people as social creatures with a need to find meaning. Often these systems are used in what might be seen, when judged by the rational standards of work, as being nothing more than frivolous time wasting activities. But when looked at from a broader perspective, they seem to embody life, for life is made up of many activities such as enjoying oneself, socializing through small talk and casual chat, etc.

Further development and growth in these types of ICTs seems set to continue as social scientists and technologist begin to collaborate on the design and development of technologies that will make the experience of using these socially engendered systems, even better.

This collaboration between the social sciences and technologists is key to creating technologies that are better suited to the new circumstances of ICT and their use. With time, as technologists begin to realize that the value of technology does not just lie with utility, with making things more efficient, and so forth, and that it is quite legitimate to design technologies that will help people to find meaning through whatever activities (within reason) that they want to undertake, there should emerge a very different sort of technology to that which has already been developed.

What new delights lie ahead for the users of these systems is hard to foretell. What needs to be done to bring about these systems is however a little more predictable. Central will be the development of interdisciplinary design, and even the emergence of a new breed of technologist, with knowledge in social sciences as well as in technology subjects. Based upon this, the notion of a new breed of professional can be suggested, involving people who can operate in the spaces between the social sciences on one side, and engineering and technology on the other. Such people would be capable of taking into account both perspectives and would use their knowledge to design technologies more acceptable to society than those that might emerge from a more technology-oriented approach.

This in turn would lead to new research agenda, and in effect the implementation of *Social Shaping of Technology* in a world where technology is no longer perceived to lie outside of society, but to be an integral part of it. This development will in part be aided by research that is already underway looking at the development of complex systems science (European Commission, 2007) and its relevance and application in areas where ICT and society have already merged (social networking Web sites for example).

CONCLUSION

ICTs are beginning to develop along new paths, socially engendered and shaped to a significant extent by such concepts as instant messaging, chat rooms, social networking, and the like. These developments come from the world outside of work and are not based upon the notion of utility, but more on meaning, of doing things for fun, of explorations, etc. The Semantic Web on the other hand largely comes from business engendered thinking, from a world where the primary concerns are utility, effectiveness, efficiency, and usefulness.

These two worlds in many ways seem to clash, to be polar opposites. But this does not have to be so. The Semantic Web can be shaped in entirely new directions and does not have to become a tool for business, but could also be another means of having fun. To this end the paper has mapped out some preliminary possibilities, provided a conceptual basis for development, and highlighted a key guiding design principle. The challenge for the future is to take what is emerging from the domain of socially engendered ICT, and bring this to the area of business engendered ICT, to the benefit of both domains. For to do so would provide a means of preserving what is good about the Web, that is to say its unpredictability, providing a means by which meaning is found, while also delivering a Web that is also more useful for those with a more serious purpose. This new notion for the Semantic Web would provide a place for both work and play, adapting as required to the needs of users at specific moments in time.

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KEY TERMS AND DEFINITIONS

Ambient Intelligence: A human-centered vision of the information society where the emphasis is on greater user-friendliness, more efficient services support, user-empowerment, and support for human interactions with respect to intelligent everyday objects and other ICT systems.

Business Engendered ICT: Information and Communications Technology, the development and use of which is driven and shaped by the needs of business.

Interfacing in Depth: Shaping the characteristics of a technology by considering the details of the technologies that lie behind the human-computer interface, where technology refers to the algorithms, data models, architectures, and the dependency upon human judgment and skills that are built into the operational details of the software.

Ludic Systems: Ludic refers to the play element of culture. Ludic systems are based on a philosophy of understanding the world through play, of play being primary to and a necessary condition for the generation of culture. Such systems therefore do not necessarily fulfill any particular purpose in the sense that most technological systems usually exist to fulfil a need, or have some useful function, or are a utility.

Non-Utility Principle: ICT in non-workplace contexts serve purposes beyond mere utility, and ICTs should therefore be designed to enable users to achieve emotional fulfillment through play, exploration, and several other dimensions, that are not traditionally associated with workplace environments.

Social Shaping of Technology: The philosophy that technology is not neutral and is shaped by the dominant social, political and economic values of society. As a result therefore, changes in values lead to different technological outcomes, and as a result, social science considerations can be used to shape technologies.

Socially Engendered ICT: Information and Communications Technology, the development and use of which is driven and shaped by social interests.

Chapter XVIII
Social/Human Dimensions of Web Services: Communication Errors and Cultural Aspects. The Case of VRL-KCiP NoE

Anca Draghici
Politehnica University of Timisoara, Romania

Diana Barglazan
Politehnica University of Timisoara, Romania

Myriam Lewkowicz
Université de Technologie de Troyes, France

Gila Molcho
Israel Institute of Technology, Technion, Israel

ABSTRACT

This chapter presents some recent studies of the social and human dimension of Semantic Web services in the era of virtual organizations, focusing on the challenges, effects, and implications. The issues and results presented refer to the virtual organization known as the Virtual Research Laboratory for a Knowledge Community in Production (VRL-KCiP), Network of Excellence (NoE). In this chapter the authors analyze the risks arising from the modern communication process in this new form of organization, focusing in particular on the knowledge sharing process. Furthermore, they discuss the cultural aspects of managing a virtual organization that determine the efficiency of the knowledge management processes. The aim is to consider the challenges and the associated effect on developing Web services from the social/human perspective and to examine the impact on an organization's cultural dimensions.

INTRODUCTION

Semantic technologies are "meaning-centered." They include tools for auto-recognition of topics and concepts, information and meaning extraction, and categorization. Semantic technology software encodes meanings separately from data and content files, and separately from application code. The objective is to enable machines and people to share understanding and reason while programs are being executed. Semantic technologies then provide an abstraction layer above existing information technologies in order to bridge and interconnect data, content, and processes. Using semantic technologies, the process of adding, changing and implementing new relationships or interconnecting programs is relatively straightforward. From the portal perspective, semantic technologies can be thought of as a new level of depth that provides an improved, intelligent, relevant, and responsive interaction compared to that available with "classical" information technologies alone.

Hence, these technologies seem to hold the promise for improving communication and collaboration among dispersed organizations worldwide. This chapter discusses how such technologies functioned in a virtual organization involving numerous partners.

After describing the operations of the VRL-KCiP Network of Excellence (NoE) over the past three years, we briefly review the promising challenges of Web services. We then describe the Web services implemented and provided to VRL members. We show that even if these services are necessary for common and distributed work among the various partners, they alone cannot solve communication problems arising from misunderstandings. Based on the results of a previous study, we describe these misunderstandings and then examine cultural aspects of communication within the NoE which were determined to be critical factors in misunderstandings. These cultural dimensions cannot be handled technically but must be taken into account for Web services to be efficient.

THE CASE OF VRL-KCIP NOE

The Virtual Research Laboratory for a Knowledge Community in Production (VRL-KCiP) is a Network of Excellence (NoE) established in 2004 as part of the EC Sixth Framework Programme (Contract no. FP6-507487). The 27 member teams from 16 different countries (see Table 1) sought to create a new delocalized research structure at the European level, in which they would share research strategies, knowledge and resources, responsibilities, rights, and duties, as well as industrial contacts and contracts.

The idea behind the network (virtual organization) was to overcome fragmentation by applying the network principle to research. The NoE applied a multicultural approach both to the integration of modeling and simulation of knowledge-based production processes and to the relations among the joint partners. The objective of the VRL-KCiP was to support dynamic organizations, inter-enterprise operability, and necessary standardization. The network was driven by advances in virtual production, supply chain and life-cycle management, interactive decision-aid systems, development and rapid manufacturing. Incorporating these factors necessitated bi-directional relationships with industry. The virtual organization also aimed to benefit from the different approaches of the multicultural teams in treating common manufacturing problems and in promoting successful technology transfer. This would be achieved by incorporating emerging technologies driving new production paradigms in all phases of the complete/extended value-chain (design, production, distribution, use and end-of-life phases, including recycling) to allow development of new knowledge-based, added value and quality products and services in traditional sectors (Tichkiewitch, 2005).

Table 1. The list of the partners in the VRL-KCiP NoE

Role*	Partic. No	Participant name	Participant short name	Country
CO	1	Caisse des dépôts et Consignations	CDC	F
CR	2	Institut National Polytechnique de Grenoble	INPG	F
CR	3	University of Twente	UT CIPV	NL
CR	4	University of Berlin	FhG/IPK	G
CR	5	ITIA CNR	ITIA	I
CR	6	University of Bath	Bath	UK
CR	7	Fundation TEKNIKER	TEKNIKER	E
CR	8	University of Patras	UPATRAS	GR
CR	9	Kungliga Tekniska Högskolan	KTH	S
CR	10	Hungarian Academy of Sciences	MTA SZTAKI	HU
CR	11	University of Ljubljana	UNI LJ	SL
CR	12	Universitaet Stuttgart	USTUTT	G
CR	13	Israel Institute of Technology	TECHNION	IL
CR	14	Ecole Centrale de Nantes	ECN	F
CR	15	Université Technologique de Troyes	UTT	F
CR	16	Politechnica University of Timisoara	UPT	RO
CR	17	Ecole Polytechnique Fédérale de Lausanne	EPFL	CH
CR	18	University of Durham	UoD	UK
CR	19	Delft University of Technology	TU Delft	NL
CR	20	Eindhoven University of Technology	TUE	NL
CR	21	Politechnica Poznanska	PUT	PL
CR	25	Pôle Productique Rhône Alpes	PPRA	F
CR	26	University of Stellenbosch	US	SA
CR	27	Politecnico di Milano	Poli-Milano	I

**CO = Coordinator; CR = Contractor*

The network attained industrial involvement and commitment by incorporating selected European industries to play a key role in providing industrial viewpoints on research relevance, research directions and awareness of integration activities and research topics related to production. Moreover, the joint research outcomes were publicized to attract and recruit new members.

Obviously, such a network is not primarily hierarchical in nature, and co-operation cannot be dictated from above. The research topics are extremely diverse and evolve significantly, which may appear to some extent uncontrolled. Thus we can assume that networks of excellence are adaptive and flexible but hard to manage and coordinate (Shpitalni, Guttman, Bossin, 2005).

The main activities of research in the VRL-KCiP NoE were as follows:

1. **Integrating activities:** The goal of these activities was to create the integrated infrastructure (processes, tools, and procedures) required to establish a sustainable, integrated, European level virtual research laboratory.
2. **Joint research activities:** These research activities were designed to evaluate the joint research capability of the network,

improving constantly as the infrastructure developed as part of the *"integrating activities"* evolved. These research topics were determined both by the ongoing research in the different labs and by the research directions determined together with large EU industrial members. The research teams were determined by taking into account actual member competencies, in order to reduce research fragmentation in Europe and to create the best complementary activities between the actors.

3. **Spreading excellence activities:** These activities were directed at extending the scientific benefits of the network to academia and industry and, disseminating new knowledge by means of training sessions, scientific journals, web sites, and conferences.

The large number of network participants together with the network's multicultural, multidisciplinary, multilingual inherent characteristics require advanced knowledge and information sharing services, which may be facilitated by implementing Semantic Web services. The following overview discusses the promising challenges of available Web services, and describes those implemented in the VRL.

THE PROMISING CHALLENGES OF WEB SERVICES

A Web service is a set of related application functions that can be invoked over the Internet as an integrated part of any program code. Businesses can dynamically mix and match Web services to perform complex transactions with minimal programming. Web services allow buyers and sellers worldwide to discover each other, connect dynamically, execute transactions, and share information (data, knowledge) in real time with minimal human interaction.

Web services are self-contained, self-describing modular applications that can be published, located, and invoked across the Web:

- **Web services are self-contained:** On the client side, no additional software is required. A programming language with XML and HTTP client support is sufficient to get started. On the server side, a Web server and servlet engine are required. The client and server can be implemented in different environments. It is possible to turn an existing application into a Web service without writing a single line of code.
- **Web services are self-descriptive:** The client and server need to recognize only the format and content of request and response messages. The definition of the message format travels with the message; no external metadata repositories or code generation tools are required.
- **Web services are modular:** Simple Web services can be aggregated to form more complex Web services either by using workflow techniques or by calling lower layer Web services from a Web service implementation.
- **Web services are platform independent:** Web services are based on a concise set of open, XML-based standards designed to promote interoperability between a Web service and clients across a variety of computing platforms and programming languages.

Examples of Web services may include applications used for theatre reviews, weather reports, credit checks, stock quotations, travel advisories, or airline travel reservation processes. Each of these self-contained business services is an application that can easily integrate with other services, from the same or different companies, to create a complete business process. This interoperability allows human activities, interactions and/

Table 2. Categories of Web services (Source: www.service-architecture.com/web-services/index.html)

No.	Category	Description
1	**Business information**	A business shares information with consumers or other businesses. In this case, the business is using Web services to expand its scope. Examples of business informational Web services are news streams, weather reports, or stock quotations
2	**Business integration**	A business provides transactional, "for fee" services to its customers. In this case, the business becomes part of a global network of value-added suppliers that can be used to conduct commerce. Examples of business integration Web services include bid and auction e-marketplaces, reservation systems, and credit checking
3	**Business process externalization**	A business differentiates itself from its competition through the creation of a global value chain. In this case, the business uses Web services to dynamically integrate its processes. An example of business process externalization Web services is the associations between different companies to combine manufacturing, assembly, wholesale distribution, and retail sales of a particular product.

or collaboration to dynamically publish, discover, and bind a range of Web services through the Internet. Table 2 presents the main categories of Web services.

Web services make up a connection technology, providing ways to connect services together into a service-oriented architecture. A network component in Web services architecture can play one or more fundamental roles: service provider, service broker, and service client.

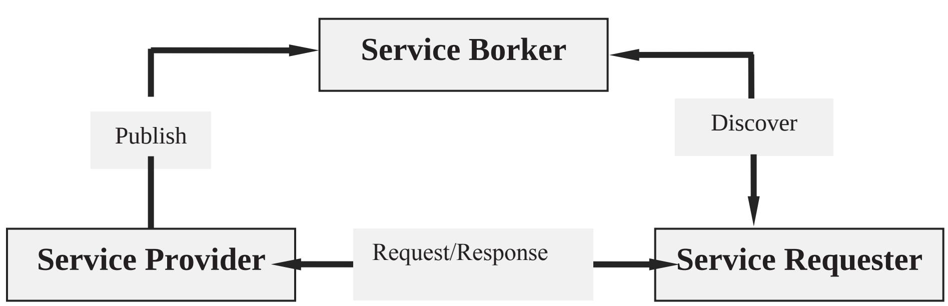
Services providers create and deploy their Web services and can publish the availability of their WSDL-described services (Web Services Definition Language) through a service registry, such as a Universal Description, Discovery, and Integration (UDDI) Business Registry.

Services brokers register and categorize published services and provide search services. For example, UDDI acts as a service broker for WSDL-described Web services.

Services clients use broker services such as the UDDI Business Registry to discover a needed WSDL-described service and then to bind to and call the service provider. Binding involves establishing all environmental prerequisites necessary to successfully complete the services. Examples of environmental prerequisites include security, transaction monitoring, and HTTP availability. The relationships between these roles are described in Figure 1.

In this chapter, the term Web services refers to technologies that allow connections via the web. A service is the endpoint of a connection. Moreover, a service has some type of underlying computer system that supports the connection offered. The combination of services—internal and external to an organization—makes up a Service-Oriented Architecture (SOA), which is essentially a collection of services that communicate with each other. This communication can

Figure 1. Service roles and interactions



involve either simple data transfer or two or more services coordinating some activity. Some means of connecting services to each other are needed (www.service-architecture.com).

WEB SERVICES FACILITIES IN THE VRL-KCIP NOE

The following Web service facilities were used for internal and external communication between the partners of the Virtual Research Laboratory for a Knowledge Community in Production (VRL-KCiP) Network of Excellence (NoE). The main achievements to support internal communication included:

1. Registration and administration of the VRL-KCiP Internet domain, and installation of a DNS server for the domains vrl-kcip.org and vrl-kcip.com;
2. Implementation of an internal website for NoE members with access control;
3. Provision of the project partners' contact data, CV, areas of research, collaborations, and publications;
4. Specification and development of a tool for central administration of contact data and task allocation (the VRL Shepherd);
5. Installation and maintenance of a central contacts database;
6. Development of a communication handbook (*The Hitchhiker's Guide to VRL-KCiP*);
7. Installation and administration of a mail server for mailing lists (Sympa);
8. Issuance of document templates for all kinds of documents needed within the project (e. g. for presentations, poster, reports) to ensure a unified appearance and facilitate management and assignment of documents to different operations;
9. Implementation of knowledge management capabilities and file sharing among members of the NoE using the SmarTeam tool.
10. Implementation of a common calendar for publishing important events.
11. Implementation of a common topic based forum capability.
12. Implementation of an expertise mapping capability

After communication and groupware services were initially installed on numerous PCs at the beginning of the project, it became evident that a more stable server platform was needed to deliver stable and reliable services to network members. To this end, in early 2005 Fraunhofer IPK began planning an adequate IT infrastructure. After analysis, it was decided to implement the new infrastructure using only two servers and a client PC for administration, made possible by utilizing virtual machine technology with multiple virtual PCs / servers running on a single computer (Figure 2). The implemented environment is described below in further detail.

Experience from past project coordination showed delivering reliable Web services requires that the corresponding server applications run on separate server machines. Moreover, some of the utilized services require different operating systems. An analysis of the required services for the IT infrastructure of VRL-KCiP internal and external communication indicated that a reliable implementation would need a total of eight machines. During a test phase these services were installed on eight physical test machines. This infrastructure had suitable performance but maintenance of the hardware turned out to be rather difficult. Also, running eight physical machines seemed to be unreliable since the malfunction of one machine could paralyze all services. Therefore, after an analysis of how to improve the infrastructure, a server was specified to run virtual machines, each hosting a separate PC, and a backup server was specified as well.

The IT infrastructure for VRL-KCiP internal communication is now based on two Dell servers

Figure 2. Web service facilities: Intranet services

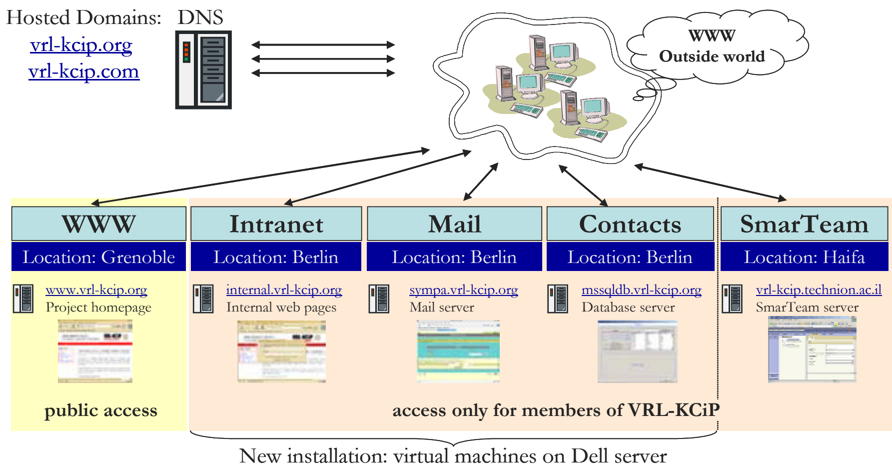


Table 3. Hardware specifications

Hardware	Parameters / Specifications
Server 1	Dell Server Power Edge 2800: Dual P4 Xeon 3,0 GHZ; 3 GB Ram; Hard drives: 450 GB Raid 5, 73 GB Raid 1
Server 2	Dell Server Power Edge 2800: single P4 Xeon 3,0 GHZ; 1 GB Ram; Hard drives: 73 GB Raid 1
Workstation	Single P4 3,0 GHZ; 1 GB Ram; Hard drives: 80 GB Raid 1

and a virtual environment containing eight virtual machines, replacing eight physical PCs (Figure 3). This virtualization technology has enabled the organization management to reduce cost and optimize redundancy for the whole infrastructure. A Dell workstation is used in addition for administration and development tasks. The hardware specifications are presented in Table 3.

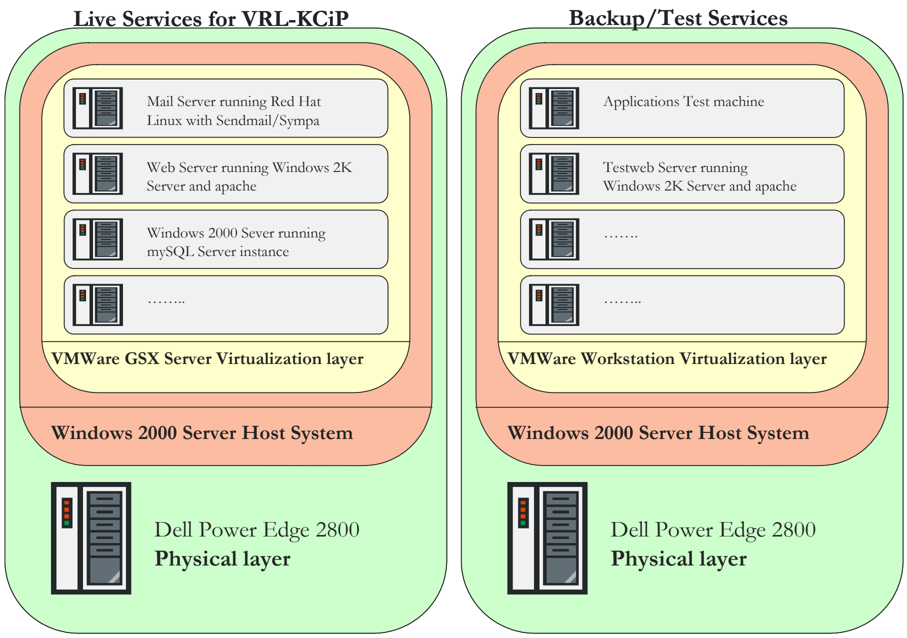
The virtualization of the information technology infrastructure for VRL-KCiP internal communication is based on VMware Server Software. VMware provides a virtual layer residing on a Windows 2000 Server local host system. The virtual server farm is divided into two virtual segments:

- A live segment hosting all live virtual servers with their services;
- A backup/test segment hosting all tests, daily backups for the live-Segment.

Based on the described virtual platform, servers have been set up to provide all VRL-KCiP partner services, as follows:

- **Mail Server:** running Red Hat Linux with sendmail and Sympa;
- **Web Server:** running MS Windows 2000 server with Apache as web server software;
- **Database Server:** running Windows 2000 server and a mySQL server instance holding all the data for the VRL-Shepherd client;
- **Database Server:** running Windows 2000 server and a mySQL server instance. This server will provide a centralized login data for web and forum services;
- **Backup Server:** running Windows 2000 for disc-to-disc backup of all live virtual servers from segment 1 to segment 2;
- **Web Server:** a mirror of the web server mentioned above acting as a test platform for all releases before going live;

Figure 3. VRL-KCiP virtual segments



- **Application Server:** a standard client machine for testing purposes of the VRL Shepherd client;
- **Forum Server:** running windows 2000 server with apache and forum software.

For effective communication and project management a number of groupware services needed to be implemented and deployed. These "VRL-KCiP member services" include Web-based Intranet as a hub for information distribution, management of contact data information, document management and e-mail exchange. All of these VRL-KCiP member services have been set up and are widely used by network members. Access to the services is available via the network's public web site (www.vrl-kcip.org) or via a direct URL at http://internal.vrl-kcip.org/. Access to member services requires a login with username and password on the VRL-KCiP Intranet section of the virtual organization's Web page (Table 4).

The Web service facilities define the "**VRL world**". These facilities supported the development of human relations among the laboratories and universities involved in the partnership. They served as the foundation of building the knowledge community in the field of manufacturing, the project's main objective. Despite communication problems and cultural differences, the members met the challenges of working together. They succeeded in creating a unified integrated world that can be easily navigated and that presents the network's members, research areas, publications and collaborations all in context over the web.

SOCIAL / HUMAN CHALLENGES AND IMPACT ASSOCIATED WITH WEB SERVICES IN THE VRL-KCIP NETWORK OF EXCELLENCE

The Web service facilities in the VRL-KCiP have some unique features:

- The service providers and service clients are members of the same knowledge community. They work together to enrich the knowledge base system;

Table 4. The VRL-KCiP Intranet: Web services for the virtual organization members

Network organization	
Hitchhiker's Guide	Hitchhiker's Guide is the project management handbook for VRL-KCiP. It provides information about who's who in the network and about the different internal communication facilities
Who's who	Who´s Who in VRL-KCiP: 1. Organigram; 2. Contact data of all members of the network; 3. Registration process.
Mailing	All mailing lists are displayed and can be downloaded as .xls file.
Templates	Templates for all documents which are needed within the network, e. g. posters, presentations, deliverables.
Deliverables	All Deliverables for VRL-KCiP can be downloaded from the Intranet.
Registration process	New members of the project have to be registered by the main representative of the laboratory they belong. This will ensure consistency and avoid non-project partners attaining project internal information. The new member has to give information about personal data and membership to organizational units (categories) within the NoE to the main contact.
Logos	The logos of all organizations within the VRL-KCiP network and the VRL-KCiP logo can be downloaded in different files formats.
VRL shepherd reader	VRLshepherd. It can be used to view partner and organization data.
VRL Web shepherd reader	Test version of the new web based VRL Web Shepherd.
Member Services	
SmarTeam	The SmarTeam Knowledge Management System is used for asynchronous data exchange
CDC tool	Tool for financial management of the NoE is located at CDC, Paris
Discussion Forum	Forum for discussion of relevant network themes
Calendar	All project internal dates, meetings, deadlines etc.
Video conferencing support	Instructions for use of VRL-KCiP video conferencing system
News section	Actual news concerning VRL-KCiP are presented for members only
Software Demonstration and Exchange Platform	The platform gives an overview on software tools developed by NoE partners
Key Performance Indicators	Input platform for indicators to evaluate VRL-KCiP performance

- The management team (which acts as broker) supports both the service providers and the clients, piloting the virtual organization's activities with respect to European Commission "rules" and performance indicators for the 6th Framework Program.

The VRL Web service facilities must support the *virtual knowledge work* of different researchers working in distributed laboratories in different countries (see Table 2). The heterogeneous backgrounds of the participating professionals, the diverse professional interactions (among the team members and with industries), and the challenges to be met can generate various kinds of misunderstandings, leading to errors and conflicts. Our experience with the VRL NoE showed that despite innovative Web services, the problem of misunderstandings still remains. These misunderstandings can interrupt activities and lead to decisions that are later regretted. In other words, the NoE, assumed to provide a creative forum in which researchers and companies can interact and share knowledge, often must face major complexities due to accumulated misunderstandings. Experience has shown that to manage the risks linked to such misunderstandings, we must focus on communication errors. In this context, we propose general guidelines for cross-cultural communications and discuss the potential role of

IT-based tools in solving misunderstandings in virtual engineering teams.

Misunderstandings in the VRL-KCiP Communication Process

According to the Free Dictionary (http://www.thefreedictionary.com/misunderstandings), the term "misunderstanding" can be explained in two ways:

1. Putting the wrong interpretation on;
2. An understanding of something that is not correct;

Another related word in this context of explanations is misconception, which is an incorrect conception.

These definitions underline the causes and effects of misunderstanding. The consequences of misunderstandings must be avoided.

According to international standard ISO/IEC 11179-4, misunderstanding in information technology must be avoided: "Precise and unambiguous data element definitions are one of the most critical aspects of ensuring data shareability. When two or more parties exchange data, it is essential that all are in explicit agreement on the meaning of that data. One of the primary vehicles for carrying the data's meaning is the data element definition. Therefore, it is mandatory that every data element have a well-formed definition; one that is clearly understood by every user. Poorly formulated data element definitions foster *misunderstandings and ambiguities* and often inhibit successful communication".

All these definitions and contextual explanations of misunderstandings are linked with communication and human perception of concrete terms, concepts, information or knowledge.

Communication is not only a necessary process for solving technical problems. It is also a very important tool to manage a team, both to motivate people and also facilitate knowledge transfer between team members. Misunderstandings and errors can occur during the communication process, as outlined below (Paek & Horvitz, 2000):

- Channel failure, overhearing (Paek & Horvitz, 2000);
- "Non-understanding" (Hirst et. al., 1994); "Problematic reference" (Schegloff, 1987); "Communication breakdown" by cochlear-implant user (Tye-Murray & Witt, 1996); Jargon (Ahlsen, 1993);
- Misunderstanding by abduction (McRoy & Hirst, 1995), by coherence (Ardissono et. al., 1998); "Negotiated misunderstanding" (Blum-Kulka & Weizman, 1998); Conventional breakdown in cross-cultural interaction (Ulichny, 1997); Input failure (Ringle & Bruce, 1981); Underspecification (Deemter & Peters, 1996);
- Misconception (McCoy, 1989); Breakdown by unshared conventions (Gumperz, 1995); Co-membership differences (Schegloff, 1987); Problematic sequential implicativeness (Schegloff, 1987); Pracmatic infelicities (Marcu & Hirst, 1996); Model failure (Rigle & Bruce, 1981);
- Contribution (Clark, 1996).

This interdisciplinary taxonomy of communication errors is not meant to be a complete or exhaustive review of the research literature. Rather, it serves as a preliminary attempt to correlate different types of communication errors. All the definitions of misunderstandings, groundings, and mentioned causes can be integrated in the six semiotic layers mentioned by Stamper (1973 & 1996).

The most relevant sources of communication errors in the VRL-KCiP virtual organization are explained below (Lewkowicz , Wijnhoven & Draghici, 2008):

- **Video conference:** Video conferences are marked by a time lag between when a question is asked and when the other party perceives the question. For example, three seconds can elapse between the time you ask a question and the time your question is perceived at the other end. That's a long silence to tolerate. Many conferences fell apart because someone repeated a question while the person on the other end was trying to answer, resulting in a waste of time. Functional errors of the video conference system that can induce misunderstandings are as follows:
  - Delays between a speaker's explanations and presentation image reconstruction;
  - Echoes causing voice distortions and missing information;
  - People who do not take system delays into consideration and therefore speak too quickly. Misunderstanding is generated because slow voice refreshing can affect the duration of the meeting.
- **Language:** Misunderstandings are often generated because English words and phrases are mispronounced and/or used incorrectly by people whose native language is not English (i.e., Romanian, Hebrew, French, Greek, Hungarian, Spanish, Swedish etc.). While people seem to have accepted each other's pronunciation styles, sometimes English-speaking partners speak too quickly and are misunderstood. Such misunderstandings can be avoided by e-mail communication.
- **Cultural gap (communication gap):** Due to differing perceptions (or prejudice) about the work process and possible work solutions (cultural influences, education in national systems, experiences in national companies), misunderstanding in cooperation can occur. Most of the researchers, task and work package leaders believed in the importance of the following:
  - Face-to-face meetings and early involvement of all key players;
  - Common objectives, commitment, clear roles and responsibilities, rules and practices Team research and goal setting theory has demonstrated the importance of establishing a common purpose among team members and then working towards this purpose to increase team effectiveness (Hacker & Lang, 2000).;
  - Ongoing follow-up video conference meetings and
  - Well established standard tools and good systems that are compatible in terms of software, hardware, electronic communication / data transfer.
- **Cultural differences, cross-culture communication:** Cultural issues and poor leadership lead to misunderstandings and conflict that are not easily resolved. Cultural differences must be acknowledged and carefully handled. Communication feedback (even in the case of e-mail communication) is necessary to avoid misunderstandings.
- **Knowledge Management Systems:** The main drivers for implementing KM initiatives are as follows: dissemination of best practice to a key set of employees; retention of the tacit knowledge of key employees; promoting continuous improvement; responding to customers more quickly; and reducing rework. The VRL-KCiP Knowledge Management System (KMS) was developed using the SmarTeam application. The most frequent misunderstandings with the KMS were generated by difficulties connecting with the server, which did not allow data saving and forced people to input the information again. Moreover, access to specific items in the KMS was very difficult

for most people in the beginning because of problems using the SmarTeam interface. These problems have been partially solved by enabling external data input possibilities, and by publishing the knowledge from within the SmarTeam system on regular web pages.

- **Annual evaluation / motivation / recognition:** The VRL management team agreed that these practices definitely helped motivate the network members. However, it was mentioned by some that this could be further amplified by developing a complementary incentive program celebrating the achievement of key project goals. Such measures quantify network achievements and the contribution of each separate team in achieving network goals. The idea was to develop common goals and agreed upon measurements that were known to all teams in order to reduce misunderstandings of the aims and the means required to achieve them.
- **Experience:** As project managers gain experience in global virtual team projects, they learn how to overcome the challenges and drastically improve project performance metrics, among them engineering cost, construction cost, engineering time, overall project delivery time, engineering quality, and construction quality. Figure 4 shows the semiotic layers of misunderstanding together with human guidelines for improving cross-cultural communication skills. Improving knowledge sharing and communication in virtual engineering teams could be an important management tool (Lewkowicz, Wijnhoven & Draghici, 2008). This improvement can, for example, help detect and diagnose non-functioning design teams, advance understanding of how design teams acquire and maintain their collective identity, and help serve as a means for understanding the evolution of information needs in design teams.

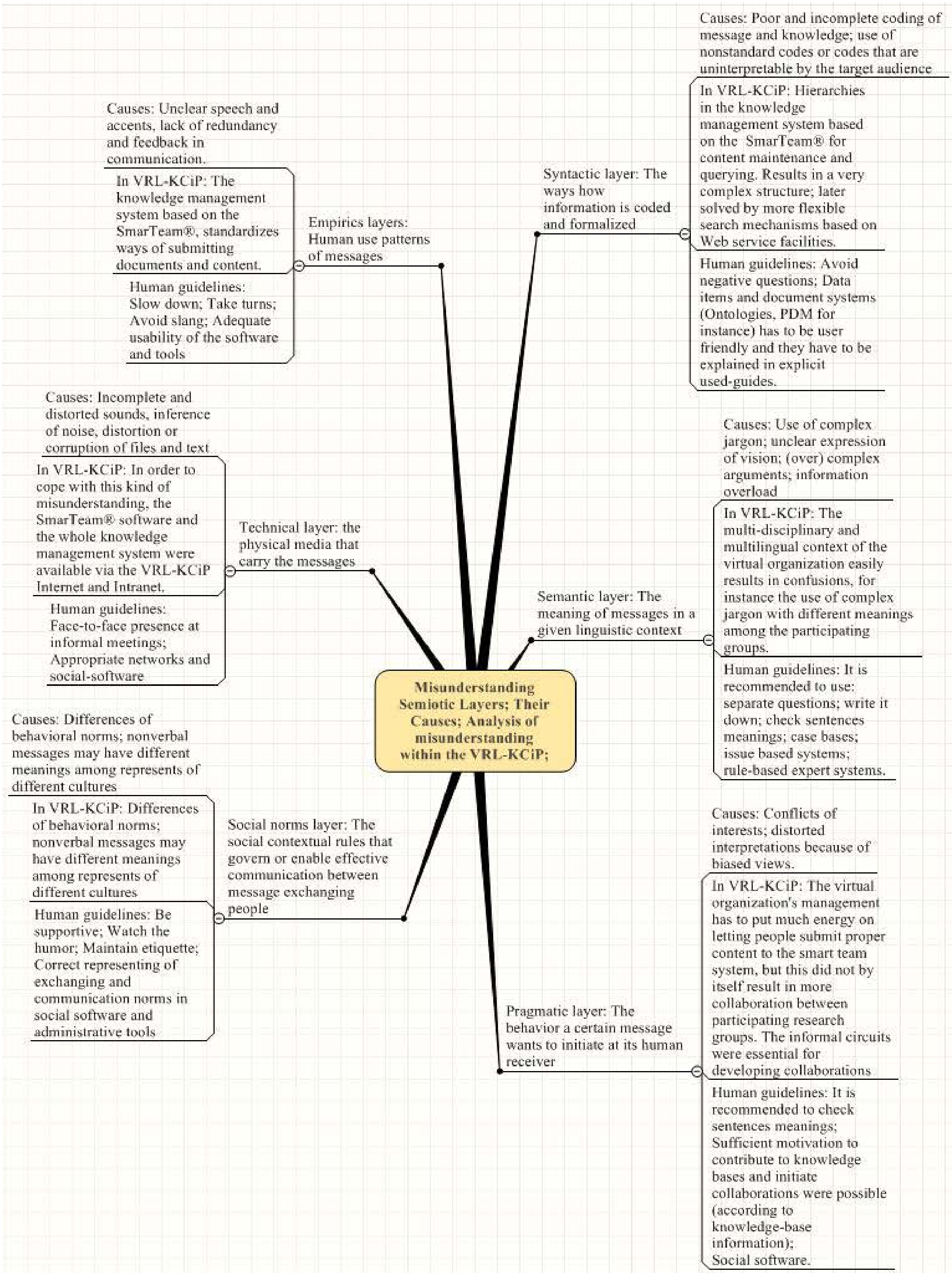
Currently, no well developed tool exists for identifying level of understanding, and especially for detecting potential misunderstandings in a global virtual engineering team. As indicated above, such a tool is urgently needed. It can be built by means of further literature research, survey studies (to learn the business magnitude of this problem more precisely), possible tests of such tools, and making these tools part of common project management practices for virtual teams. Some initial attempts at such research have already been made in the field of off-shore information technology development (Kernkamp, 2007), and the field of manufacturing and product engineering must soon follow.

The above review of the literature combined with our experience in the VRL-KCiP NoE has led to the synthesized presentation in Figure 4. The figure shows the misunderstanding semiotic layers together with their causes, an analysis of the communication errors in the VRL-KCiP organization and some human guidelines (Lewkowicz, Wijnhoven & Draghici, 2008). Even though the word *virtual* is found in global virtual engineering teams, some element of face-to-face interaction is critical and cannot be avoided. One of the most crucial failure factors was a lack of understanding of local work practices, cultural differences, and language issues.

Organizational Culture Assessment and Study

Another aspect of social/human impact associated with Web service creation and use in the VRL-KCiP is multi-cultural synergy. This synergy had an impact upon organization management, approaches to knowledge management and, in particular, knowledge sharing. The debate started from the potential advantages of virtual communities, which can create culturally synergistic

Figure 4. Synthetic presentation of the misunderstanding semiotic layers



solutions, enhance creativity and cohesiveness among team members, promote greater acceptance of new ideas and provide a competitive advantage for the whole organization. Yet, culture is not a sure or stand-alone remedy for improving organizational performance, which is complex, multileveled and deeply rooted. Culture must be observed and analyzed at every level before it can be fully understood or successfully changed and managed.

In this context, a study of organizational culture research was carried out within the VRL-KCiP NoE. The questionnaire was inspired by the survey presented by Anawati and Craig (2006). The main ideas in building the questionnaire were:

1. **General overview** of the virtual team: awareness of cultural differences; accepting cultural differences; allowing team socializing/informal chat; rewarding good behavior in culturally appropriate manner.
2. **Spoken and written** characteristics for communication and inter-relation development. The general overview takes the following into consideration: avoid slang, colloquialisms, jargon, acronyms; use simple language; avoid metaphors; avoid humor; keep to the point; confirm understanding by asking open-ended questions; reiterate key points; use follow-up emails for feedback; formulate criticism/ praise carefully. In addition, **spoken language** is linked with verbal dialogue, so the following aspects are relevant: speak slowly/clearly; acknowledge/invite each individual to speak; allow for "think time" between responses; alter tone of voice (do not be too abrupt); supplement discussions with written text or visual. Some important aspects regarding **written** communication are: write from the receiver's point of view; be more descriptive; use lists/points; vary between formal and informal writing.
3. **Religious belief** is important for scheduling meetings and deadlines (religious holidays or celebrations must be considered).
4. **Time zone** is linked with time organization: allow extra time for time zone differences; attempt to schedule meetings during work hours; rotate meeting times to share the burden of after-hours work.
5. **Face-to-face** meetings are the most relevant way to build trust in the organization and should be encouraged: initiate team face-to-face meeting if possible; initiate team video conferences; put team member photographs on a website; rotate face-to-face meetings in different locations.

This research underlines that cultural aspects have had an important influence on the VRL-KCiP network. The organizational culture emphasizes the individual teams'/partners' culture, and this culture is in a state of transition. In the following, the research results are examined by analyzing the answers given by each thematic group to each question (122 respondents). The nationalities of the participants involved in the research were: Spanish, Hungarian, German, Colombian, Japanese, Slovene, South Korean, British, Romanian, Dutch, Greek, Israeli, Italian, French and Swedish. For analysis purposes, the participants were divided into four groups: Northern Europe (British, Dutch and Swedish), Central Europe (Hungarian, German, Slovene and Romanian), Southern Europe (Spanish, Greek, Israeli, Italian and French) and East Asia (Japanese and South Korean). The participants' average age was 37.07 years. This low average isan advantage for the VRL-KCiP organization, as the population of Europe, and particularly the research community, tends to be older. The youngest participant was 24 years old, while the oldest was 62; 24 % of the participants were female, and 76 % were male. Table 5 presents the most relevant research results.

In our study, we focused on discovering and describing the impact of multi-culturally in virtual teams, and in particular in the VRL-KCiP Network of Excellence. The potential advantages of global virtual teams are that they can create

Table 5. Relevant research results

<table>
<tr><th>Question</th><th>Comments</th></tr>
<tr><td colspan="2">1. Inter-relationship development inside the organization</td></tr>
<tr><td>How do you rate the importance of socializing (e.g. informal chat, subjects out of work, jokes)?</td><td>The participants mainly rated the importance of socializing as very high or high; no one rated it as rather or completely unimportant.</td></tr>
<tr><td>Do you tolerate the religious beliefs of others (e.g. prayer time, religious holidays)?</td><td>The results do not show a significant tendency. While most of the participants pay attention to this topic, others consider it less important. Possible causes for this could be either that religion is not of great importance for them, or they think that religion is a private matter that should be kept out of work.</td></tr>
<tr><td>Should the other team members be aware of your culture?</td><td>According to Anawati and Craig (2006) this should be the case. For 31% of the participants it is very important that others are aware of their culture, and for 45 % this is sometimes the case; 24 % of the participants think that culture should not be of importance.</td></tr>
<tr><td colspan="2">2. General differences</td></tr>
<tr><td>Have other team members sometimes behaved in a way that bothered you?</td><td>
<table>
<tr><th></th><th>North Europe</th><th>Central Europe</th><th>South Europe</th><th>East Asia</th><th>?</th></tr>
<tr><td>Lack of Participation</td><td>15.7</td><td>18</td><td>6</td><td>5</td><td>44.7</td></tr>
<tr><td>Too much participation</td><td>0</td><td>10</td><td>0</td><td>0</td><td>10</td></tr>
<tr><td>Prejudices</td><td>5.7</td><td>9</td><td>1</td><td>15</td><td>30.7</td></tr>
<tr><td>Harsh criticism</td><td>5.7</td><td>4</td><td>2</td><td>5</td><td>16.7</td></tr>
<tr><td>False praise</td><td>7.1</td><td>7</td><td>2</td><td>5</td><td>21.1</td></tr>
<tr><td>Lack of team commitment due to other work</td><td>21.4</td><td>17</td><td>6</td><td>15</td><td>59.4</td></tr>
<tr><td>Bad humor</td><td>5.7</td><td>4</td><td>4</td><td>0</td><td>13.7</td></tr>
<tr><td>Too direct</td><td>1.4</td><td>6</td><td>3</td><td>0</td><td>10.4</td></tr>
<tr><td>Too shy</td><td>12.9</td><td>7</td><td>1</td><td>5</td><td>25.9</td></tr>
<tr><td>Speaking too fast</td><td>2.9</td><td>10</td><td>3</td><td>0</td><td>15.9</td></tr>
<tr><td>Speaking too slow</td><td>4.3</td><td>9</td><td>1</td><td>0</td><td>14.3</td></tr>
<tr><td>Language accent makes understanding difficult</td><td>10</td><td>15</td><td>3</td><td>15</td><td>43</td></tr>
</table>
To obtain the answers to this question, comparable answers were assigned with a value (3/often, 1/sometimes, 0/never) and then scaled relative to the number of each group’s participants. The following hypotheses were assumed, based on culture (discussed in the answers to the next question):
Hypothesis 1: The environment of Northern Europe is informal;
Hypothesis 2: The environment of Central Europe is hierarchical;
Hypothesis 3: The environment of Southern Europe is informal;
Hypothesis 4: The environment of East Asia is hierarchical.
</td></tr>
<tr><td>Is your environment rather hierarchical or informal? Is this due to your culture, workplace, religion or others (please specify)?</td><td>In general, the participants consider their environment as rather informal. The research results validated hypothesis 1 and 3; hypothesis 2 could not be validated because of the distribution of the answers, and hypothesis 4 was not admissible. For 76 % of the participants, workplace relations were the decisive factor in this estimation; 31% mentioned culture, while religion did not play a decisive role in human relations. In this context, it must be considered that workplace relations will, in most cases, be influenced by the culture of the surrounding environment.</td></tr>
</table>

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Table 5. continued

Question	Comments
Do you prefer: • Criticizing directly or indirectly? • Praising directly or indirectly? • Being criticized directly or indirectly? • Being praised directly or indirectly?	The initially formulated research hypotheses, correlated with hypotheses 1, 2, 3 and 4, were: **Hypothesis 5:** *Members of the North European group prefer to criticize directly;* **Hypothesis 6:** *Members of the Central European group prefer to criticize directly;* **Hypothesis 7:** *Members of the South European group prefer to criticize indirectly;* **Hypothesis 8:** *Members of the East Asian group prefer to criticize indirectly.* As expected in hypotheses 1 and 2, in North and Central Europe direct criticizing is preferred while East Asians criticize indirectly (hypothesis 4). Contrarily to hypothesis 3, the South Europeans do not necessarily criticize indirectly. The preferred direct criticizing in North Europe and indirect criticizing in South Europe and Asia may be linked with the answers to question 9 of the North Europe group when they stated that other participants tend to be too shy. As a consequence, the following hypotheses were formulated: **Hypothesis 9:** *Members of the North European group prefer direct praising;* **Hypothesis 10:** *Members of the Central European group prefer direct praising;* **Hypothesis 11:** *Members of the South European group prefer direct praising;* **Hypothesis 12:** *Members of the East Asian group prefer direct praising.* Hypotheses 9, 10 and 12 were admissible, while hypothesis 11 could not be validated as the answers from the South Europe group show no preference regarding this behavior. Regarding being criticized, the working hypotheses were: **Hypothesis 13:** *Members of the North European group prefer being criticized directly;* **Hypothesis 14:** *Members of the Central European group prefer being criticized directly;* **Hypothesis 15:** *Members of the South European group prefer being criticized indirectly;* **Hypothesis 16:** *Members of the East Asian group prefer being criticized indirectly.* The answers showed that only the North and Central Europeans are convinced they should be criticized directly, as expected in hypotheses 13 and 14, but the South Europeans and East Asians were not as opposed to this as expected (hypotheses 15 and 16 cannot be validated). Regarding being praised, the working hypothesis were: **Hypothesis 17:** *Members of the North European group prefer being praised directly;* **Hypothesis 18:** *Members of the Central European group prefer being praised directly;* **Hypothesis 19:** *Members of the South European group prefer being praised directly;* **Hypothesis 20:** *Members of the East Asian group prefer being praised directly.* The research results show that hypotheses 17, 18 and 20 were admissible, but a proportion of South Europeans like to be praised indirectly (hypothesis 19 was not validated).
3. Behavioral Adaptation (**Hypothesis 21:** *The behavior within a team should be adapted to the recipient.*)	
If the behavior within a team should be adapted, to whom should it be adapted?	We expected that most of the participants would choose the recipient, but in fact it seems that the VRL-KCiP participants are oriented primarily to industry, as many of them chose the answer “enterprise”. The answer “team manager” was the second choice, perhaps caused by the wish for efficient recipient.

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Table 5. continued

Question	Comments
In which way do you adapt your behavior when working in a cross-cultural team?	The results obtained by interpretation of the answers showed that the participants are already aligned to the Anawati and Craig (2006) dimensions and their description. They did not have the opinion that avoiding humor is very important. They think that humor is an important part of socializing, and as high importance has been attributed to socializing this would be the reason of this attitude.
4. English Communication Skills (**Hypothesis 22:** *Members of the North European group have mainly native speaker/excellent English communication skills;* **Hypothesis 23:** *Members of the Central European group have mainly excellent/good English communication skills;* **Hypothesis 24:** *Members of the South European group have mainly good/adequate English communication skills;* **Hypothesis 25:** *Members of the East Asian group have mainly good/sufficient English communication skills.*)	
How do you rate your English communication skills?	The answers showed that North Europeans' English skills are quite varied, so that hypothesis 22 cannot be validated. In this group there are naturally some native speakers as the researchers from the United Kingdom contribute to this result. The Central Europeans have rather good or excellent skills, as predicted (hypothesis 23 validated). The hypothesis 24 and 25 can be validated, but there are some South Europeans that have advanced English communication skills. Even native English speakers from North Europe frequently have difficulty understanding everything during the working sections in VRL-KCiP, due to accents, pronunciation, word use, etc.
What do you do if you have (spoken) English understanding difficulties?	The research results show that the participants prefer to solve the problem as quickly as possible by asking for a repetition or consulting a colleague. Consulting a dictionary book is not a popular option, whereas online or software alternatives are sometimes used
5. Advanced language skills: We tried to analyze if the researchers who speak many languages (polyglot) have marked advantages over the rest (non-polyglot).	
How many additional languages apart from English do you speak?	Someone who speaks two or more additional languages was considered a polyglot. 69 % of the participants were polyglot, compared to 31 % non-polyglot. In this context we formulated the working hypothesis for the next question: *Hypothesis 25:* In the presence of others, polyglot persons avoid using languages that others do not understand more often than do non-polyglot persons.
Do you sometimes use your own language during a virtual meeting so that/although some of the others can't understand you?	45 % of all participants said they "never" use their own language in front of others with the purpose of not being understood, 38% answered "rarely" and 10% answered "sometimes". The non-polyglot participants use their own language less often, contrary to hypothesis 25.
Are you bothered by others using their own languages that you don't understand?	**Hypothesis 26:** *Polyglot persons are less bothered by others using their own languages than are non-polyglot persons.* Only 17 % of all participants said they are "never" bothered and 38% are "rarely" bothered; 34% are "sometimes" bothered, 7% are "regularly" bothered and 3% are even "very often" bothered. Also, it is possible that participants are not always aware they are bothering or disturbing (embarrassing) others by using their own language.
6. Information about culture	
Would you be interested in short culture summaries for a better understanding of other team members?	In this context we discovered that giving some basic information to sensitize participants to specific issues of different cultures would be very much appreciated by 28% of the participants; 52 % stated "slightly" and only 17 % "no".

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Table 5. continued

Question	Comments
7. The preferred communication environment	
Which is for you the preferred communication/collaboration environment for technical discussion?	The most preferred means of communication between the VRL-KCiP members was e-mail (65%), followed by the video-conference system (37%).
8. Face-to-face meetings	
Would you prefer to have more face-to-face meetings with other virtual team members?	**Hypothesis 27:** *The VRL-KCiP researchers would like to have more face-to-face meetings.* 7% answered this question with "much more" and 66 % with "some more," while only 10% said "less". It can therefore be assumed that face-to-face meetings still have high importance, even though 3% thought no face-to-face meetings were necessary. Hypothesis 27 was validated.
If there was more than one face-to-face meeting, where should such meetings take place?	**Hypothesis 28:** *The preferred face-to-face meeting venues were the different countries of the team members.* 83% thought the meetings should take place in the different countries of the team members, while the rest preferred always the same place. No one wanted to hold the meetings in a neutral place. Hypothesis 28 was therefore confirmed.
9. Final questions	
Do you think there is a benefit from cross-cultural work? (i.e. higher creativity, higher knowledge synergy)	The research results showed that most of the participants were convinced that there is a benefit from cross-cultural work. Only 3% thought there was no benefit.
Do you have any additional comments about this topic?	"Generally very interesting topic. I wonder what the results of your questionnaire will be, in particular concerning the VRL-KCiP project. May the results (or parts of them) be published via the network homepage?" (participant 8); "Many obstacles stand in the way of achieving our goals in the VRL. It is extremely important to have face-to-face meetings which then enable the virtual collaborations due to the informal connections since all members of the labs are multi-tasking units that need to make time to achieve the VRL goals alongside their own. These informal connections speed up the work and aid in creating real collaboration" (participant 16).

culturally synergistic solutions, enhance creativity and cohesiveness among team members, promote a greater acceptance of new ideas and, hence, provide a competitive advantage for multinational corporations.

We were interested in describing and characterizing the human/social aspects and relational dynamics generated by modern information and communication technology methods and tools implemented in a virtual organization (and/or the impact of creating Web service facilities), in particular for the VRL-KCiP NoE.

We have presented the results of the research conducted within the setting of VRL-KCiP and based on the topics presented by Anawati and Craig (2006). The results show that it is very difficult to formalize cultural issues, as every individual ultimately acts differently. But when the virtual team members behave in a tolerant and endeavoring way they can overcome culture-related difficulties. If the commitment to the common task is granted to the required extent, the task will be accomplished successfully.

Desktop conferencing/collaboration tools can provide very good support for intercultural collaboration as they offer many possibilities to express and explain even complex matters and can be therefore recommended as useful investments.

Finally, even if today's technology provides possibilities for cross-cultural virtual teams, the classic face-to-face meeting remains indispensable as a decisive part of effective team building.

The research, statements and observations regarding the VRL-KCiP organizational culture point out two largely shared perspectives: (1) the culture emphasizes the individual teams' (partners) culture, and (2) the culture is in a state of transition. It seems that organizational culture and Web service facilities are connected in their evolution.

FUTURE RESEARCH AND TRENDS

Our research approach will be repeated in the future because the VRL-KCiP has been extended to become EMIRAcle – European Manufacturing and Innovation Research Association, a cluster leading experience, whose aim is to valorize the results of VRL-KCiP as a legal entity in the form of an international non-profit association according to Belgium Law (AISBL). Until the end of June 2008, the NoE and the association co-existed in order to guarantee a seamless transition between the two organizations. EMIRAcle is an important element of the common marketing and dissemination strategy created by VRL-KCiP members.

The present and future trends of real organizations are focused on encouraging the development and implementation of virtual teamwork. As organizations worry about their bottom lines and reduce travel, they will begin to more strongly support virtual teams. They will also begin to focus on increasing the productivity of those teams. In the new millennium, the competence of most organizations will depend on innovative deployment of new technologies for effectively managing knowledge networks for organizational performance (Tapscott & Williams, 2006). Many such "virtual" organizations using information and knowledge as their fundamental bases are redefining the "reality" of their traditional environment. In the process, they are also posing challenges and opportunities by redefining traditional thinking about industries, organizations, competition, products, services, technologies, people and economy (Draghici & Draghici, 2006).

CONCLUSION

This chapter has presented some of the human dimensions of a virtual organization (in particular the VRL-KCiP NoE). In our approach, the Web services term/concept refers to the technologies that allow connections, and a service is the endpoint of a connection. For effective communication and project management, a number of groupware services were implemented and deployed in the "virtual space" of the NoE. These "VRL-KCiP member services" include: Web-based Intranet as a hub for information distribution; management of contact data information; document management; e-mail exchange. All of these VRL-KCiP member services have been set-up and are widely used by network members. Access to the services is available on the network's public web site (www.vrl-kcip.org) or via a direct URL at http://internal.vrl-kcip.org/. Despite all of these services, misunderstandings still remain. We then focused on discussing the challenges and impact associated with web services development, from the social/human perspective and its impact on the organizational culture dimensions of VRL-KCiP NoE.

The potential advantages of virtual teams are that they can create culturally synergistic solutions, enhance creativity and cohesiveness among team members, promote greater acceptance of new ideas and provide a competitive advantage for the whole organization. Yet, culture is not a sure or stand-alone remedy for improved organizational performance. Culture is complex, multileveled and deeply rooted, and must be observed and analyzed at every level before it can be fully understood or successfully changed and managed.

The theoretical aspects are verified through the results of organizational culture research within the VRL-KCiP. The questionnaire used in the research was inspired by the survey presented by Anawati and Craig (2006). These researchers proposed a framework of behavioral adaptations in order to give an orientation for cross-cultural virtual team members by considering the following items: general overview of the virtual team; spoken and written characteristics for communication; religious belief importance for scheduling meetings and deadlines; time zone linked with the time organization; face-to-face meetings, which are the most relevant ways for building trust in the organization. The research underlines that cultural aspects have had an important impact on the VRL-KCiP network. The organization's culture emphasizes the individual teams'/partners culture, and this culture is in a state of transition.

Future studies will be developed in the context of VRL dynamics and its transformation into the EMIRAcle association.

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KEY WORDS AND DEFINITIONS

Ad-Hoc or Virtual Team is a recombinant structure for work that pulls people and resources together quickly to solve a particular problem or client issue (Koulopoulos & Frappaolo, 1999).

Core Competency represents the overriding value statement of an organization. Core competency need not be narrow (Kotler, 2000). Hindle (2000) identifies three essential elements of a core competency: (1) provide potential access to a wide variety of markets; (2) make a significant contribution to the perceived customer benefits of the end product; and (3) be difficult for competitors to imitate.

Expertise is the property of a person (that is, expert) or of a system that delivers a desired result, such as pertinent information or skills.

Expertise generally implies providing useful and large amounts of knowledge and action quickly (fluency). In general, expertise has several synonyms, among them know-how, skill, knowledge, competence, or excellence.

Knowledge Community is a community of people, groups or teams that share competencies, information and knowledge (in a specific field of activity) based on a specific knowledge management system defined in the context of a knowledge sharing culture with a proper ICT system. Web services support knowledge communities.

Misunderstanding: Can be explained in two ways: putting the wrong interpretation on; b. an understanding of something that is not correct. Another related word in this context of explanations is misconception, which is an incorrect conception (according to the Free Dictionary http://www.thefreedictionary.com/misunderstandings). In information technology must be avoided: "Precise and unambiguous data element definitions are one of the most critical aspects of ensuring data shareability. When two or more parties exchange data, it is essential that all are in explicit agreement on the meaning of that data. One of the primary vehicles for carrying the data's meaning is the data element definition. Therefore, it is mandatory that every data element have a well-formed definition; one that is clearly understood by every user. Poorly formulated data element definitions foster *misunderstandings and ambiguities* and often inhibit successful communication" (according to international standard ISO/IEC 11179-4)

Organizational Culture is a concept in the field of Organizational studies and management which describes the attitudes, experiences, beliefs and values of an organization. It has been defined as "the specific collection of values and norms that are shared by people and groups in an organization and that control the way they interact with each other and with stakeholders outside the organization." (Charles & Gareth, 2001).

Semantic Technologies provide an abstraction layer above existing information technologies in order to bridge and interconnect data, content, and processes. Using semantic technologies, the process of adding, changing and implementing new relationships or interconnecting programs is relatively straightforward. From the portal perspective, semantic technologies can be thought of as a new level of depth that provides an improved, intelligent, relevant, and responsive interaction compared to that available with "classical" information technologies alone.

Virtual Research Laboratory for a Knowledge Community in Production (acronym VRL-KCiP) is a virtual Network of Excellence (NoE) established in June 2004, consisting of 27 partners (more than 200 researchers) from 16 different countries that decided to work together and build a knowledge community in the field of design and manufacturing research (www.vrl-kcip.org). VRL-KCiP is financed by the European Commission in the 6^{th} Framework Programme.

Web Service is a set of related application functions that can be invoked over the Internet as an integrated part of any program code. Businesses can dynamically mix and match Web services to perform complex transactions with minimal programming. Web services allow buyers and sellers worldwide to discover each other, connect dynamically, execute transactions, and share information (data, knowledge) in real time with minimal human interaction.

Chapter XIX
Socio-Technical Challenges of Semantic Web:
A Culturally Exclusive Proposition?

Bolanle A. Olaniran
Texas Tech University, USA

Hansel E. Burley
Texas Tech University, USA

Maiga Chang
Athabasca University, Canada

Rita Kuo
Ming Dao University, Taiwan

MaryFrances Agnello
Texas Tech University, USA

ABSTRACT

The Semantic Web holds significant implications for learning, culture, and non-native speakers, with culture and non-native speakers rarely being addressed in the literature. In that light this chapter goal explores how Semantic Web disseminates learning, and it addresses critical socio-technical and cultural challenges facing semantic web, potential users, and learners using it. The chapter identifies some of the causes of the socio-technical challenges, looking at two major styles of learning and the position of Semantic Web structure in them. The chapter also offers recommendations for addressing selected challenges facing the Semantic Web.

INTRODUCTION

In general, the Web holds a special place in information communication technologies (ICT) for information sharing among people globally. As a concept, Semantic Web implies and focuses on the new generations of World Wide Web (W3) architecture platforms that use formal semantics to enhance content delivery. According to Stojanovic, Staab, and Studer (2001), Semantic Web implies that designers create content that best suits machine consumption rather than content for human consumption. However, from the standpoint of Berners-Lee (2000), Semantic Web provides an environment in which both human and machine agents communicate on a semantic basis. The Semantic Web can also be viewed from the standpoint of ontology, the organization of learning and services around a small domain of semantically enriched objects. From this standpoint, Semantic Web can partition and organize information and materials into customized learning, then deliver this information to end users on demand, according to users' preferred needs (Stojanovic, et al., 2001).

BACKGROUND

As a basis for intelligent applications, the Semantic Web is integral to achieving the goals of e-learning, distance, and global education. These intelligent applications will enable more efficient information use by drawing upon deep collections of repository knowledge (Schoop, deMoor, & Dietz, 2006). Beyond the internal world of web architecture paradigms, the organization of Semantic Web and its approach to learning holds significant implications for learning—in general, culture, and non-native speakers that are rarely addressed in the literature, however. This chapter addresses the Semantic Web's socio-technical and cultural challenges that are presented to users, learners, and the Semantic Web itself, while it disseminates learning.

The chapter accomplishes this by identifying selected causes of the socio-technical challenges, focusing on two major styles of learning and the Semantic Web structure position in them. Furthermore, to illustrate the nature of the challenges, the authors explore the foundation of knowledge acquisition tracing it as far back to the idea to Plato and Aristotle's positions on universalism and particularism ideologies. These two foundations help to illuminate the importance of culture and the challenges culture poses in Semantic Web deployment as a learning platform. The idea of cultural variation will be provided as a way to illustrate a key pitfall of Semantic Web which revolves around amplification of digital divide when taken together. For instance, human computer interaction (HCI) model of interaction in the Semantic Web environment and for enhancing communication between users and the computer occur at conceptual, semantic, syntactic, and lexical levels (Patil, Maetzel, & Neuhold, 2003). However, there are key discrepancies and mismatches between technology, and user needs and requirements, some of which are attributable to knowledge, general illiteracy, and information communication technology (ICT) illiteracy and different cultural demands. The chapter also addresses some key implications for Semantic Web regarding design, use, and general effectiveness or lack thereof. A call to action for policy makers, IT designers, and Users would also be made. First, however, is the need to offer a general background on the Semantic Web.

Semantic Web

The rise of the World Wide Web (W3) has significantly influenced the way people conduct research, education, commerce, and politics in the global world. Access to Internet and the W3 allows users to search information on billions of topics in infinite ways. However, the impact is not restricted to mere information searches, but the Internet has evolved as a means for bringing about political reforms and socio-cultural changes in societies. McLaughlin (2003) points to the significant role Web sites play in less than democratic countries to bring about political reforms and change. However, in spite of the great positives the Internet brings, a serious consequence of Web assessable information is information overload. It is not uncommon for one query to produce hits ranging from hundreds to millions of data when searching for information online (de Moor, 2005). For users, challenge shifts from finding information to deciphering the usefulness and relevance of information. Therefore, for Semantic Web to have the intended impact on learning and continued relevance for all world cultures, much needs to be done regarding its complex, changing and imperfect sources of meaning. Great confusion and debate remains about how to model context in Semantic Web in order to achieve it's pragmatic component (de Moor, 2005; Stojanovic, et al., 2001; Mey, 2003).

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According to Berners-Lee, Hendler, and Lassila (2001), the Semantic Web makes its most contribution by making the W3 more relevant by adding structure and logic. In essence, Semantic Web creates structure by establishing rules for reasoning and organizing data before they can be shared and used by distributing agents. As indicated earlier, the key to Semantic Web is ontology (i.e., shared meanings and services), which can be used to improve accuracies of Web searches and service discovery and delivery. The claim or the underlying assumption of ontology is that by selecting the right concept for a given task or shared knowledge, in theory should become more effective and efficient. However, that is precisely the challenge, in theory, it ought to work, but in reality, there are several factors that hinder the accuracy and performance of ontology in Semantic Web. For instance, scholars allude to the fact that in practice, the Semantic Web needs to take into account the issue of semantic and pragmatics of the Web (e.g., de Moor, 2005, Kim & Dong, 2002; Reppenning & Sullivan, 2003; Singh, 2002a; Spyns & Meersman, 2003; Stojanovic et al., 2001). The next section examines some technical challenges with the Semantic Web.

Technical Challenges

In an attempt to make Semantic Web a reality, one begins with extensible markup language (XML) which provides the structure and syntax rules. In addition to the XML, challenges remain with the notion of resource description framework (RDF) which addresses the actual semantics or meaning. However, problems exist in deciding how much XML would accomplish and to what degree functionalities of the Semantic Web must be relegated to RDF (Stojanovic, et al., 2001; Veltman, 2004). At the same time the details of what RDF content looks like in Semantic Web is always in question, thus, adding to the mystery. One of the primary challenges with the Semantic Web is that the platform or architecture layer is always changing. For instance, Veltman (2004) notes that the fundamentals shifted from standard generalized markup language (SGML) to XML, to Unicode plus uniform resource identifiers (URI). Without getting overly technical, *ontology* enters the picture to speak to the difficulties in sense-making (i.e., shared meanings and services). Among these different types of platforms, the issue of meaning was never really addressed by an ontological perspective. As a matter of fact platform designers have relegated ontology to the idea of logic, that is, the most common meaning associated with a given idea or concept, to the extent that all other forms of meaning are deemed subjective and perceived as non important. Therefore, the limitation put on meaning by reducing it to logic creates pragmatic and contextual difficulties. Sowa (2000) refers to this problem as *semantic primitives.*

However, different fields, communities, and cultures have different terminologies and meanings for similar words (Olaniran, 2007a, & 2007b). Furthermore, while it is true that logic may be ideal and perhaps solve some of the challenges with computer-to-computer communication and interactions, and may even offer solutions to science and technology, there remains the challenge with the needs of *culture* where human-human, human-computer, and other instances of human-computer-human interactions (i.e., Veltman, 2004) are the norms remain unaddressed. Therefore, this paper shares some of Veltman's concern about Semantic Web as presented below.

The issue of culture is especially problematic to Semantic Web and is, in essence, an Achilles' heel that IT designers and theorists fail to consider thoroughly in the development of the Semantic Web. Culture however, is the essence of human existence and development. Significant body of literature has identified the need for understanding culture and its implications in knowledge based learning and in the world of globalization and technologies (Hofstede, 1980, 1991; Gudykunst & Kim, 1997; Olaniran, 2004, 2007a, 2007b). Veltman (2004) concurs that "since every culture focuses on some aspects of knowledge and ignores others, history is essential to understand both the sources of our views and the limitations of the frameworks or worldviews with which we present them" (p. 9). The idea of culture can be traced as far back to Plato and Aristotle who were the foundational figures of Western philosophy using the ideas of *universals* and *particulars.* Plato emphasized the importance of universals while Aristotle focused on the particulars. More importantly, is the globalization and technological trends demanding increase need to digitize information in an attempt to make it more widely available and assessable. According to Veltman (2004) the ideas of universals and particulars came to the fore fold when oral knowledge is shifting to hand-written knowledge.

Thus, the shift from oral to written, print, digital, multimedia, and multi-modal knowledge is creating new possibilities in knowledge domain and dissemination. An example of such a new possibility is e-learning. In the context of universals and particulars are logical rules, particularly, the notion of relations. Logical rules like "relations with," "relations to," and "in comparison to," allow one to develop an understanding and definition of a concept. However, outside the context of universals and particulars, a logical but rather imperfect what of understating a concept is to define it in terms of what it is (Lytras & Naeve, 2006; Veltman, 2004). Dahlberg (1995) on the other hand, offer four categories of definition including: 1. Abstraction (e.g., something is a), 2. Partition (something a part of), 3. Opposition (something is not), and 4. function (something is about). Unfortunately, no one particular dictionary that offers comprehensive definition at these four levels of distinctions. Thus, the problem of acceptable definition persists and is germane to the Semantic Web. Assuming that "context-free" facts and logical rules are adequate is problematic because of the impossibility of describing data enough for use in "arbitrary applications" or technology (Braun, & Schmidt, 2006; McCool, 2005; Singh, 2002a).

The universal is considered static (Veltman, 2004) and can easily be incorporated into machine language or metaphors. On the other hand, the particular is constantly changing, and thus, termed organic metaphors. Thus, when considering services or knowledge dissemination via electronic platforms, it makes sense, and it is easier to separate the changing from the static. More importantly, the universals or the unchanging aspects are more amenable to program into machine as objective elements that can be easily assessed than the particulars or subjective components. This problem creates challenge in the sense that by separating or not accounting for the different particulars, the target audience for whom

Semantic Web is designed becomes limited at best or are removed altogether (Olaniran, 2007a; Veltman, 2004). Although, a suggestion might be why don't we come up with new sets of particulars that all cultures can relate? Unfortunately, this approach is not feasible; simply because it will be impossible to understand and preserve past classification from different cultures. On the other hand, creating a new classification schemes is believed to be insufficient to understand *how* and *why* earlier cultures use different ways of organizing knowledge (Veltman, 2004).

From another perspective, the shift from oral to written results in what has been viewed as a decline of dialogue (Ong, 1958). This is true as some cultures and societies, such as those found in Somalia, did not have any written form of language until after World War II, though the society existed millennia prior to that time. At the same time, the shift from written to print or digital culture is putting tremendous emphasis on linear and analytic thinking (McLuhan, 1962) which characterize the tenet of most e-learning and other human–computer interactions. The challenge, in essence, is in how to use the digital media content in a way that preserves and keep alive the awareness of different historical and cultural modes of perception. More importantly, how to use the new technology (i.e., Semantic Web) to address different ways of thinking that is not limited to mere access to information, but rather relate to different belief systems and different way of knowing including mindsets and varieties of world views. After all, information cannot be understood unless the historical content and the dialectic that creates it is understood (Lytras & Naeve, 2006; Stutt & Motta, 2004).

The quest for meaning is an age old idea and began prior to the development of Semantic Web itself. It has been argued that without meaning, there can be no shared understanding or communication (Veltman, 2004). Thus, meaning is important, the challenge however, is that the process of meaning is problematic in machine contexts when considering different elements that are involved, specifically, the idea of culture. Berners-Lee (1997) was on the right track when he outlines the need for Semantic Web to go beyond access to information to one that accesses different methods of knowledge. However, the implementation of Berner-Lee idea varies from technologists or artificial intelligence narrow view of definition to humanists' ideology of inculcating all human knowledge and experiences (see also Veltman, 2004).

Socio Cultural Challenges

More specific to issue of e-learning is the need to explore how culture influences learning such that mere access, which has a challenge of it own as far as Semantic Web is concern, influences content and learning as whole. For instance, Olaniran (2007a) illustrate the effect of culture on e-learning using the Hofstede's dimensions of cultural variability (see also Van Dam & Rogers, 2002). In particular, the uncertainty avoidance dimension and e-learning identifies security and risk as a primary concern in some cultures. For instance, while e-learning is expected to be seen in high-risk or innovative culture as something intriguing and potentially fun, motivational, and interesting; in a low risk cultural environment, the same technology can be perceived as dangerous or counter culture (Olaniran, 2007; Van Dam & Rogers, 2002). From another standpoint, certain cultures view authority or power differently (Hall, 1976; Hofstede, 1980). For instance, in a power distance culture (i.e., a measure of inequality in a culture), contrary to high equality culture where the expectation, is that knowledge is shared equally across the society and people; high power distance culture, recognizes the uneven distribution of power in the society.

The different approach to power, in essence, becomes contradictory to the aim of e-learning and the Semantic Web technologies that power it. For instance, different learning styles surface within different cultures. In particular, technology architecture such as Semantic Web is seen as convenient way to accomplish the aim of constructivist idea (e.g., Weigel, 2003) of making learning fun, easy, and for giving greater control to students about learning. However, in a power distant culture, such approach is counter to cultural demands of the culture and at times confusing and often frowned upon. Thus, "*telling*" or learning style that emphasizes hierarchical transfer of skills from authoritative teachers to students is the norm in power distant cultures (Olaniran, 2007a; Richards & Nair, 2007).

Furthermore, it has been suggested that it might be difficult to get people to use certain technology in power distant cultures where status dictates every aspect of interpersonal communication (e.g., Devereaux and Johansen, 1994; Olaniran, 2007b). For instance, in African culture, where significant emphasis is put on relationships, it was found that when e-mail was used for communication and interactions, people follow through in person or other communication media such as telephone to make sure that messages were indeed received (McConnell, 1998), and had the desired effect (Olaniran, 2001). Although, following through with more traditional medium may be less cultural than McConnell suggests, it has been shown that culture influences how communication medium or technology is used. For instance, Japanese designers consider cultural factor by acknowledging that not all types of communication can be supported by communication technology systems (e.g., internet or Semantic Web). Furthermore, the use of technology for supporting group project or collaborative work in Japan demands that, groups must first meet physically to establish a trust environment before interacting via technology medium (see also Barron, 2000; Olaniran, 2007a).

The role of culture on e-learning and Semantic Web can be drawn from explanation provided by Paul Kawachi. Kawachi (1999) argues that the Japanese lags and do not embrace e-learning as a result of their language structure. Specifically he indicates that Japanese language, developed early in life, is more susceptible to right brain learning mode (i.e., visual and memorization skills) when compare to left brain (i.e., analytic and argumentation skills). As a result, the W3 is primarily used for searching and printing-out information for reading or translating and secondarily for entertainment and games (Kawachi, 1999).

In summary, when there is no fit between technology and culture the diffusion and eventual acceptance of the technology will be seriously handicapped regardless of whether its Semantic Web or not (e.g., Green and Ruhledder, 1995, Mesdag, 2000; Olaniran, 2007a, 2007b). From transitioning Semantic Web within the context of globalization and ensuing e-learning, significant emphasis must be put on remediation of the challenges of Semantic Web identified above such that content must match the needs of users (in both learning styles and cultural preferences). Thus, the key to resolving cultural problems is to recognize cultural differences and associate technology use with the prevailing cultural values, structures, and activities within these different environments. As is, the Semantic Web is designed with the goal of one size fits all and for content to be applied universally such that individuals irrespective of cultures or unique preferences are able to use it. However, different societies have developed their own vocabularies to meet their unique needs. The different vocabulary, however lack formal semantics. Stojanovic et al (2001) contend that regardless of the time and money put into creating training material (e-learning content) the content is useless if it cannot be indexed or searched with ease. At the same time, content in Semantic Web is only as good as users' parameter or query. For instance, simple keyword search are only useful when users have a clear idea of what they are looking for and the information fits into generally accepted definition (a precisely defined semantic).

Technology access is another factor contributing to adoption and acceptance for eLeaning (Olaniran, 1993, 2007; Vaughan & McVicar, 2004; Wahid, 2007). The level of access to technology especially in less economically developed countries (LEDCs) has been written about extensively and it reinforces the digital divide between economically developed countries (EDCs) and the LEDCs. An erroneous assumption that is often made about technology especially by designers and programmers is the fact that individuals around the world have similar and easy access to technology and internet. Consequently, content providers create content for e-learning in particular, without regards to the issue of bandwidth (Olaniran, 2004, 2007a; Wahid, 2007). Along the same line of reasoning is the fact that Internet access cost a lot more in the developing countries when considered in proportion to income. Individuals or users may have to travel several miles to access required e-learning curriculum, which does not bold well in motivating potential users to adopt the technology. Also, the lack of proficiency in English, creates hindrance to internet adoption in certain countries (Olaniran, 2007b; Wahid, 2007). Furthermore, the patterns of technology adoption differ between men and women. For example, Wahid (2007) using the technology acceptance model in a study among Indonesians found that adoption of technology among men is affected by the *perceived usefulness* while women's adoption is based on *ease of use*. Access problems also impede the frequency of use and lack of comprehension of basic commands and protocols to be successful and to facilitate adoption that results in continue usage of technologies (Olaniran, 1993, 2001).

Along with general access, culture plays a significant role in how people perceive technology (as indicated earlier in this study). For instance, the challenge in what a new technology innovation such as e-learning can offer and the hindrance by traditional (local cultural) approach is not to be taken lightly. People fear new things despite the fact that change itself is a constant in human life. However, in high power distance culture, people tend to see technology system as threatening to their traditional learning methods. The perceived threat creates anxiety about technologies and consequently the ensuing negative reactions in using them.

Other social problems exist with semantic problems that transcend culture. With the transitioning from print to digital media comes information overload. Information overload addresses the issue of navigating the Web through enormous archives of data from books, newspapers, films or videos among others. Google for instance currently, index more than three billion Web pages (Stutt & Motta, 2004). Learners have always been faced with the challenge of having to sort through array of material and to evaluate information. But the advent of digital information creates exponential leap in the amount of information that learners and users must work with. Though the need to sort through massive information led to the development of most visited search engines and Semantic Web tools such as Google and ontology based search (Stutt & Motta, 2004).

Information authentication, the difficulty sorting good information from bad, increases in complexity in lockstep with web growth. Outside of traditional or conventional indexing facilities such as librarians and information archivists, there are many Web sites where information can be gathered. Although, some digital archivists maintain objective standards, there are several however with ulterior motives. Stutt and Motta (2004) puts it more succinctly when they argue that some of this archivist have "axe to grind." Some sites provide themselves as valid and impartial research data sources, but they are funded by other commercial interests to perpetuate their causes and goals (Stutt & Motta, 2004). For example, a website purportedly about Martin Luther King is actually sponsored by a white supremacist group.

Based on the amount of information, it is often problematic to match learners with material that is relevant to their needs at a given point especially when attempting to customize course content or information delivery. At the same time, efficiency is lost in the amount of time spent on the matching process. Semantic Web and e-learning also face challenge with the need to provide support for learners (formal or informal). For example in the traditional classroom, students know to go to the instructor or a designated person who is more experienced than the learners to obtain answers to questions. Whereas, in online forum, learners may have to rely on technology or large informal groups of users (Stutt & Motta, 2004) that may or may not have the correct answers or at times offer conflicting information that must be sought through.

FUTURE TRENDS AND IMPLICATIONS

The Semantic Web and technologies at large need to be pragmatic to be effective and useful. Specifically, the Semantic Web must be sophisticated enough to address how different cultures categorize, classify, organize their worlds and interactions that exist within them. The globalization trend or the idea of one world is not helping the situation much; as we live in a world where developed countries with population less than one third of the world controls resources and are transplanting their cultural ideals to the rest of the world as the norm via technologies. Consequently, traditional distinctions are constantly being eroded (Hovy, 2002)

One way, by which Semantic Web is attempting to resolve the challenge of the distinctions is ontology. Ontology usually is attributed to generic meaning and knowledge that can be used in different applications. Ontologies contain semantic networks of concepts, relations, and rules that define the meaning of particular information resources (de Moor, 2005; Lytras & Naeve, 2006). However, to be effective, it is argued that ontology needs not be too restrictive or tightly linked to a particular purpose or user group (Spyns, Meersman, & Jarrar, 2002). The challenge, however, is that ontology is not an end itself, because one of the major purpose of the Semantic Web is to provide access to Web services, but semantic approach for describing, discovering, and composing Web services is not adequate. Services or contents can not be described without paying attention to how it will be used (i.e., pragmatics) because a “community of service” almost always use services in novel and unintended ways. To this end, de Moor (2005) argues that social mechanisms are needed for evaluating and discovering trustworthy providers and consumers of services by taking into account the contexts and interactions in the composition of service applications (Kim & Dong, 2002; Lytras & Naeve, 2006; Mey, 2003; Singh, 2002a; Singh, 2002b). The usefulness of ontology is in the eye of the users or what de Moor calls the “eyes of multiple beholders”—the communities and individuals within them using ontology for a specific and collaborative purposes.

Furthermore, human communication is important in meaning negotiation that characterizes Pragmatic Web. Conceptual approaches discussed in this paper can be use to augment but not necessarily automate human meaning interpretation and negotiation processes. De Moor (2005) offer Language/Action Perspective as a way forward in modeling more complex and realistic communicative interactions by stressing the coordinating role of language. This perspective, in particular has led to various proposals for human/agent communication-based collaborative models and systems (e.g., Harper & Delugach, 2004; McCarthy, 1996; McLaughlin, 2003; Weigand, & de Moor, 2003). While ontologies are important for the semantic and Pragmatic Web development, much of the research addresses representation and reasoning. However, there is the need to also address ontology methodology issues in an attempt to bring Semantic Web to a pragmatic level. According to de Moor (2005), the process will include the human process of modeling, selecting, using, and changing meanings for collaborative projects. At the same time, e-learning and the educational sector, along with other public agencies and industrial sectors have similar needs for a common competency ontology that can be used for developing customizable training pathways. The Pragmatic Web, therefore, becomes an extension of Semantic Web in the next phase and evolution of W3. It is true that for the Semantic Web to accomplish its claim and potentials, more work must be done on its pragmatics. For instance, simple keyword queries maybe problematic in e-learning forum where it is noted that the viewpoints and the knowledge levels of the author and users of learning content may be completely different (Stojanovic et al., 2001). Specifically simple keyword queries do not always pick up synonyms, abbreviations, different languages (e.g., house & haus) or morpohological variations and the query context. The context of use for extracting meanings stored in ontology should be better understood. After all, the central component of the Pragmatic Web is meaning and the process of negotiation that it entails and thus, it should be connected to the Semantic Web in terms of selection and representation. One way of addressing such challenges is to establish and define corresponding relations in keywords in the *domain ontology* (Stojanovic et al., 2001*).* Also, finding out how meaning negotiation process works is helpful to pragmatics of the Web and for creating automated or support systems for meaning negotiation (de Moor, 2005). The attempt to move research from meaning representation to meaning application and usage should be given considerable focus (i.e., from semantics to pragmatics). This approach would help in network applications where individuals or communities of users are able to immerse themselves by tapping to their full collaborative potential. For example, the idea of multiple knowledge neighborhoods (i.e., locations in cyberspace) where learners and groups can meet with goal of learning about certain topic is suggested (Stutt & Motta, 2004). In essence, members can belong to more than one community or groups. The Semantic Web can be aimed at supporting the different communities by providing specific ontologies for them either through topics, tasks, practices and others, the Web can aim at providing an acceptable *"lingua franca"* for each community. Consequently, the targeted ontologies could result in fewer problems in developing, negotiating, and shared understanding than when attempted to offer global ontologies (Stutt & Motta, 2004). The key to its potential effectiveness lies in the fact that each knowledge neighborhood will address its own specific needs; however, the option for sharing content with other communities can still be maintained. Communicating across boundaries of different communities cannot solve the cultural and cross-cultural challenges; however, it can offer a buffer where members from different communities may help synthesize and translates information or concepts to other community members. In other words, membership in different communities can allow learning objects or ontologies to be flexible in addressing local and outside community needs. The key is that the learning objects is able to take on different meanings in different domains and social worlds (Star & Griesemer, 1989; Stutt & Motta, 2004).

Furthermore, there is need for knowledge charts—which are constructed using ontologies but geared towards graphical representation of content summaries and interpretations, Due to several possible meta learning in any course structure, it is suggested that there needs to be a way to automate knowledge chart construction (Stutt & Motta, 2004). As work in human language technology continues, emphasis on supporting extraction of argument structures from text is paramount (Sereno, 2003; Kurtz & Snowden, 2003; Stutt, & Motta, 2004; Vergas-Vera & Moreale, 2003) along with a new form of browsers to search the Web. Vergas-Vera and Moreale (2003) conducted and reported on a study about extracting arguments from students essays, and there is ongoing work "ClaimSpotter"—for automatic extraction of scholarly claims among other ScholOnto project. Increase use of RSS feed for extraction of content and documents are also gaining popularity. At the same time, there is ongoing work in Semantic Web browsers to augment successful knowledge navigation. A case in point is the "Magpie" semantic browser which originated as a means of assisting in sense-making for users and to provide access via contextual menu for complementary database or sources of knowledge that can be used in contextualizing and interpreting information on Web pages. However, Stutt & Motta (2004) warns about limitation of magpie that it is limited to instances of knowledge contained in its database, such that there needs to be a way to extend its concept recognition abilities. Development and extension of semantic browser's concept recognition abilities would allow phrases referencing a project and those of texts in different languages can be identified together as concept instances while given a broader concept domain.

In essence, the Semantic and Pragmatic Webs relate to each other on broad array of socio-technical dimensions. We call this relationship onto-covariation, the usability and relevance of the Semantic Web to users in diverse contexts. Like that of the mathematical correlation, no relationship between the semantic and pragmatic would equal zero, while a perfect relationship between these two entities would be 1. So defined, one can theorize about causes of phenomena (like those mentioned above), measure the relational aspects among components of the Semantic and Pragmatic Webs, and test usability models. Once successfully modeled, remedial efforts can be efficiently targeted to either the semantic or Pragmatic Webs with greater probability of effective improvements. Finally, onto-covariation pushes the Semantic and Pragmatic Webs even further—to the practical. Understanding how the partitioning and organization of information covaries with the semantic biases of diverse cultures will no doubt drive future development and usability of the Semantic Web.

CONCLUSION

Significant challenges exist within Semantic Web to be used for e-learning and service provision. Some of these challenges are technical and some are social. Thus, this paper alluded at some of the social technical challenges facing effectiveness of the Semantic Web. Ontology issues within Semantic Web and the pragmatics of Semantic Web were addressed as well. In addition, effort is made to offer few approaches that can be used to alleviate some of the problem especially in the light of some cross-cultural challenges that may continue to persist even with the best of intention from technology capabilities.

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KEY TERMS AND DEFINITIONS

Culture: Consists of different value preferences that influence communication interaction and how people create meaning.

E-Learning: Involves the process of knowledge dissemination and acquisition taken place over electronic networks

Globalization: Involves economic and socio-cultural ideas where organizations are able transcend national geographic and cultural boundaries through convergence of space and time in attempt to accomplish goals.

Ontology: Represents the organization of learning or course materials and services around small domain of semantically enriched objects Semantics

Pragmatic Web: Focuses on meaning and the process of negotiating meaning.

Semantic Browser: Search browser for determining the contextual use of concepts.

Semantic Web: Implies the process or idea where content is made suitable for machine consumption rather than content that is only fit for human consumption.

Chapter XX
Social Networks in Information Systems:
Tools and Services

Hernâni Borges de Freitas,
IST/INESC-ID, Portugal

Alexandre Barão,
IST/INESC-ID, Portugal

Alberto Rodrigues da Silva
IST/INESC-ID, Portugal

ABSTRACT

A social network represents a set of social entities that interact through relationships like friendship, co-working, or information exchange. Social Network Analysis studies the patterns of relationships among social entities and can be used to understand and improve group processes. The arrival of new communication tools and networking platforms, especially the Web 2.0 Social Networking Services, opened new opportunities to explore the power of social networks inside and outside organizations. This chapter surveys the basic concepts of social networks methods, approaches, tools, and services. In particular, this chapter analyzes state-of-the-art social networks, explaining how useful Social Network Analysis can be in different contexts and how social networks can be represented, extracted, and analyzed in information systems.

INTRODUCTION

The notion of a social network and the methods of social network analysis (SNA) have attracted considerable interest and curiosity from the social and behavioral science communities in recent decades (Wasserman and Faust 1994). Social Network Analysis (SNA) has been used as a powerful tool in organizations to understand the connections and influences both inside and outside the organization as well as how these connections affect the performance of core processes.

A social network is generally defined as a set(s) of actors and the relationship(s) defined among them. Actors, also defined as social entities, can be individual or collective social units that are connected by links. Links constituting a social network may be directed or undirected, but they can be categorized as confirmed or unconfirmed based on the confirmation of the relationship by both actors (Cross and Parker 2004). The relationships between actors can be also classified based on cardinality: a dyad is a linkage or relationship between two actors and a triad involves a triple of actors and associated ties.

In structural terms, there are different kinds of social networks: one-mode networks study just a single set of actors, whereas two-mode networks focus on sets of actors and one set of events. Dyadic networks and affiliation networks are examples of two-mode networks (Wasserman and Faust 1994). An ego-centered network is an example of a one-mode network and consists of a local actor (termed ego), a set of alters who have ties to ego, and measurements of the ties among these alters (Wasserman and Faust 1994). Subsets or subgroups can be identified and studied separately in the network. A clique designates a subset of a network in which the actors are more closely tied to one another than they are to other members of the network (Jamali and Abolhassani 2006).

Both social actors and links may have additional attributes that express additional information about them. Such attributes include the relationship role played by the entity (Masolo, Vieu et al. 2004), more information about the entity, or the relationship between nodes.

The introduction of computational methods opened new opportunities for the use of social networks by allowing the analysis of larger datasets. This analysis facilitates the addition of social networks as well as their automatic extraction from existing information repositories.

Web 2.0 popularized the concept of the semantic web. Several social communities permitting users to connect and share information and knowledge with their friends or the whole community appeared.

This chapter presents the tools and methods for correctly extracting a social network and representing it in a form that can be later analyzed. After that, different software tools for performing SNA are analyzed. With regard to the organizational context, the Web 2.0 social networking services phenomenon is developed. Several examples of known worldwide platforms are presented and compared, and we show how organizations are using these tools to improve connections and knowledge sharing inside organizations. We discuss also our vision about what the future can bring to this field with the integration of different platforms and methodologies. Finally, we present SNARE (Social Networking Analysis and Reengineering Environment), a system we are currently developing that proposes to integrate Organization Network Analysis and Social Networking Services with different approaches and techniques. We conclude with our vision of the major concerns in these topics and how they are related to the general topic of the book.

BACKGROUND

Social Network Analysis represents a method for achieving analytical results about almost any group interaction in which social entities are present. This section introduces SNA and its most common measures and explains its use in the organizational context.

Social Network Analysis

The roots of SNA techniques were affected by three main influences beginning in 1930s. The most notable influence was Jacob Moreno, who investigated how an individual's group relationships affected his own actions and development. Moreno was credited of devising a sociogram as a way to depict such social relationships (Fredericks and Durland 2005). Most of the concepts and techniques were introduced in the 1950s by work done in the fields of sociology, anthropology, mathematics, networks, and graph theory. Even, if it was not always considered a theoretical field, the arrival of computer methods and the automatic analysis of large quantities of data gave SNA new importance. Since then, it has been the subject of studies and applications from widely diverse fields of study (Borgatti and Foster 2003).

In the 1990s, network theories emerged in virtually every traditional area of organizational scholarship (e.g. leadership, power, turnover, job satisfaction, job performance, entrepreneurship, stakeholder relations, knowledge utilization, innovation, and profit maximization) (Borgatti and Foster 2003).

SNA is now used wherever a social network is present, and its study can be interesting for understanding and improving any group process. Recent projects applied the same methods in the following totally different social network contexts:

- Economy (the analysis of economic relationships between countries (Krempel and Plümper 2002))
- Health (the analysis of social networks in epidemiology studies (Chen, Tseng et al. 2007; Rubeis, Wylie et al. 2007))
- Politics (the analysis of the political relationships in a congress (Fowler 2006))
- Academic research (the analysis the research network on a continent (Besussi 2006))
- Leisure and sport (the analysis of all the actions performed among all players on a football team during a game (Bundio and Conde 2004))
- Organization improvement (the identification of tacit knowledge in enterprises (ZHU, SHAO et al. 2007))
- Marketing (the analysis of customer preferences for buying certain items (Kappe 2006))
- Fight against crime and terrorism (Tsvetovat and Carley 2005).

Social Network Analysis is also the focus of associations (INSNA, INSNAE), conferences (SUNBELT), and journals (JOSS , Social Networks and Redes).

SNA Measures

To perform SNA, it is necessary to define measures that can be compared between actors or networks. Measures in SNA can be distinguished as those that evaluate the entire network and those that evaluate only a specific node (Wasserman and Faust 1994).

At the individual level, the most frequently analyzed measure is *centrality*. This measure evaluates an actor's position in the network and can be interpreted as the prominence of an actor in the social group. It can be measured using: (1) *nodal degree* (number of nodes adjacent to a node, with ties from it, or with ties to it), (2) *betweeness* (the number of times a person lies along the shortest path between two others), and (3) *closeness* (how far a person is from all others in the network). Other important concepts are the *geodesic distance* (the shortest distance between one node and another in the graph) and the *structural equivalence* (the extent to which an actor shares the same set of links with another).

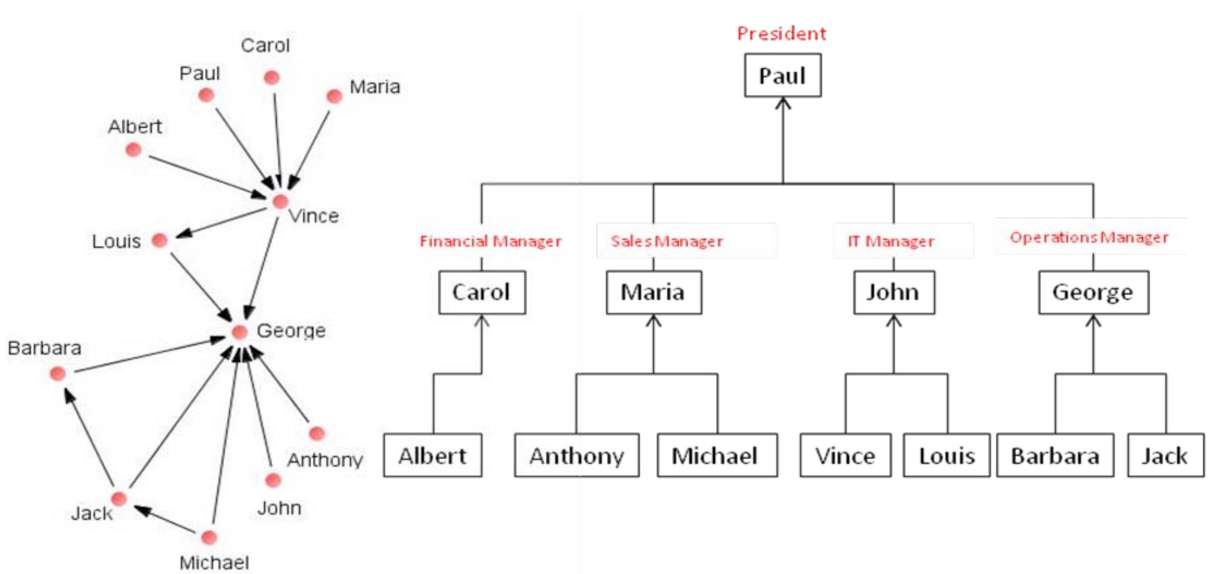
At the network level, it is important to understand how the network is structured. *Clustering* measures the ease of partitioning the graph into a finite number of subsets: a higher clustering coefficient indicates greater separation between the groups in a network. *Centralization* is directly connected with the notion of central nodes: a more centralized network indicates that most of the ties are dispersed around one or a few nodes. *Path Length* is defined as the average of the distance between all pairs of nodes. *Cohesion* measures the percentage of actors directly connected to each other by cohesive ties. Directly linked with this concept are the members who would disconnect the group if they were removed. These kinds of nodes are called *cutpoints*. Ties that disconnect parts of the graph when removed are called *bridges*.

Organizational Network Analysis

The need for more agile, flexible, dynamic, and polyvalent organizations and employees in locations where organizational change is a daily routine, and the rise of new ways of working, collaborating and interacting has caused Social Network Analysis to become a "must-have" tool for analyzing communities and groups. Management consultants use this methodology with business clients and refer to it as Organizational Network Analysis (ONA). As Rob Cross states in his book, real organizations are typically different from those expressed in organizational charts (Cross and Parker 2004). A company's hierarchy topology is represented in Figure 1 along with the relationships extracted by internal questionnaires. Looking to the sociogram, we can understand that actors in lower hierarchical positions can have great importance inside the organization due to their knowledge, role, or personal relationships with other peers.

Factors like gender, age, ethnicity, and education can drive people to communicate primarily with peers who do not have relationships with them in the organizational chart or are not connected to their organizational role. The same reasons, when introduced into department and project separation, can produce a lack of communication, lack of awareness of resources, and lack of collaboration between actors within a company. Conversely, the excess of importance of an actor can bottleneck the entire organization. SNA is a powerful managerial tool because it makes

Figure 1. Example of differences between an organizational chart and real relations (adapted from Cross and Parker, 2004)



visible the patterns of relationships within and across strategically important networks (Cross and Parker 2004).

Social network analysis can be used in an organization to better understand the social capital (connections within and between the network) (Borgatti and Foster 2003), support partnerships and alliances (Cross and Parker 2004), measure the degree of embeddedness of the actors as well as actors' importance in the network, support knowledge management policies, identify who really knows what in the company (Helms and Buijsrogge 2005), integrate networks across core processes, promote innovation, integrate new members or organizational changes, support the development of informal communities of practice, improve leadership effectiveness, replicate high performance throughout an organization, and understand and improve the disconnects between groups in the organization or between groups and the outside world (Cross and Parker 2004).

TOOLS AND SERVICES

Several software packages that support Social Networks Communities or perform SNA are available. The packages can range from complete software to analyze and visualize social networks to systems that permit the design and execution of surveys and then use the data obtained to perform a full network analysis. Other systems allow the automatic discovery of network information via mining a data repository or communications gateway. As depictured in Figure 2, this section surveys approaches and formats for representing Social Networks as well as approaches, tools, and services supporting Social Network Analysis.

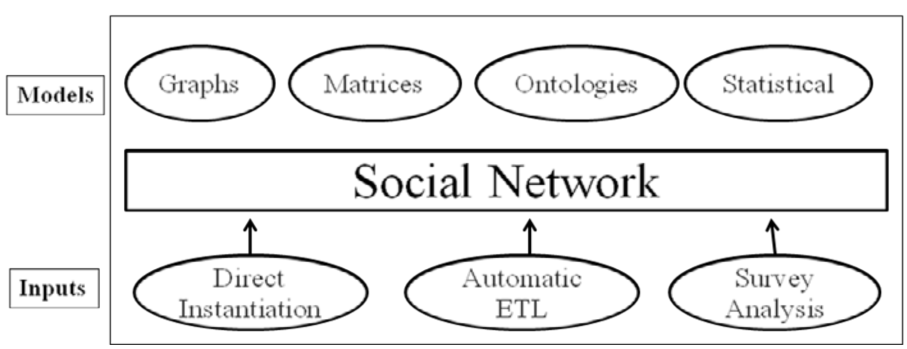
Representations

Most common forms of representing and analyzing social networks work through (1) descriptive methods (e.g. text or graphs), (2) analysis procedures based on matrix operations presented in data files with proper formats or ontological representations, and (3) statistical models based on probability distributions. One reason for the use of mathematical and graphical techniques in SNA is their ability to represent the descriptions of networks compactly and systematically (Jamali and Abolhassani 2006).

Graphs

Graph theory provides a vocabulary that can be used to label social structural properties: points called nodes are used to represent actors, and lines or arrows connecting the points are used to represent links. A graph is called directed when its edges have a direction, and it is called undirected when they do not. Visual representation of graphs can be used to center in the screen the most connected actors in the network, isolate in

Figure 2. Different approaches for capturing and representing a social network



the periphery the less connected, and alter the actor and tie sizes in order to represent more or less importance in the network. It thus offers a powerful tool for uncovering patterns in the network (Cross and Parker 2004).

Matrices

Matrices contain the same information as graphs but are more suitable for calculation in the analysis. The adjacency list is the primary matrix used in SNA and is usually referred as the sociomatrix. Actors occupy the first line and first column of a matrix composed of as many rows and columns as there are actors in the dataset, and cells have a positive value when relations are present.

Ontologies

Conceiving ontologies (explicit specifications of the conceptualization of a domain) as engineering artifacts permits their objectification, separation from their original social context of creation, transferation across the domain (Mika 2005), and export to other sources. GraphML (Brandes, Eiglsperger et al. 2002) is a language for modeling graphs that can be adapted to represent social networks. FOAF (Miller and Brickley 2000) is a machine-readable ontology describing people, their activities, and their relationships to other people and objects. hCard (Çelik and Suda 2004) is a format for publishing contact details of people, companies, organizations, and places that is used to import and export data in social networking websites. DyNetML is a universal data interchange format that enables the exchange of rich social network data and improves the compatibility of analysis and visualization tools (Tsvetovat and Carley 2003; Diesner and Carley 2005).

Statistical Models

Statistics models enthusiasts argue that it is most fruitful to consider models where network evolution is represented as the result of many (usually unobserved) small changes made at discrete times occurring between consecutively observed networks (Carrington, Scott et al. 2005). That kind of model describes the evolution of local structure, global connectivity, search ability, and highly skewed degree distributions as mathematical formulae that can be predicted and analyzed. Recently, there has been a growing interest in exponential random graph models (ERGMs) (Robins, Pattison et al. 2007) that describe a general probability distribution of graphs on n nodes and consider the possible ties among nodes of a network as random variables.

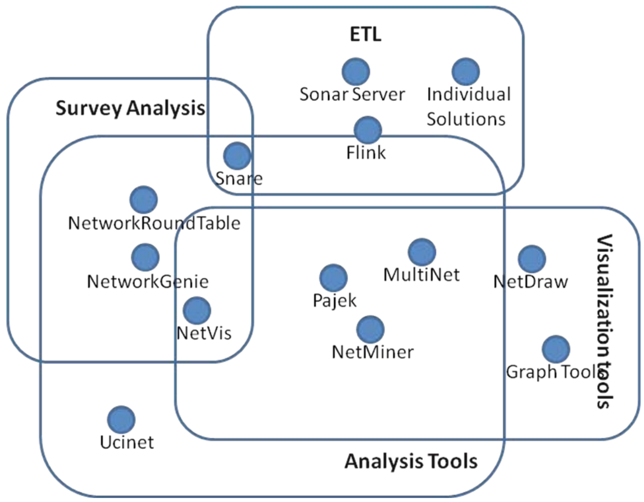
Social Networks Tools

The common way to extract a social network is by instantiating it directly through SNA software packages. However, it is also possible to automatically extract Social Networks from information gateways or through automatic survey analysis. Figure 4 represents the most important tools organized by their main scope of application. Most of the software packages analyzed share common features to extract, analyze, and visualize social networks.

Visualization and Analysis Software

Ucinet (Borgatti 2002) is probably the best-known and most frequently used software package for the analysis of social network data (Wasserman and Faust 1994). It is a commercial product developed by Steve Borgatti's team, but an evaluation version is available for 30 days. Ucinet uses datasets as collections of matrices, can import data in various formats, and has a spreadsheet editor to permit data manipulation. Ucinet works as a graphical application and is distributed with a user manual and reference guide for social network analysis. It contains a large number of network analysis methods, such as analysis procedures for computing centrality degree, ego network analysis, and

Figure 3. Main scope of Social Network Software



the detection of subgroups and structural holes in both the entire and parts of the network. It includes statistical procedures and can handle two-mode network transformations and analysis. Ucinet does not contain graphic procedures or visualization techniques, but it can export directly to NetDraw (developed by the same team and included in its package) or other formats.

Pajek is a free software developed by the University of Ljubljana and is designed to handle large data sets (Batagelj and Mrvar 2008). It is distributed with a reference manual containing a list of commands and operations, but there is also a textbook about SNA theory, applications, and the use of Pajek in network analysis (Nooy, Mrvar et al. 2005). Data can be entered directly into the program by 1) importing ASCII network data from network files, 2) importing data with other formats (e.g. UCINET), or 3) opening a Pajek project file (.paj) that combines all the data structures supported in one file. Pajek permits the manipulation of all of its structures (e.g. of the transposition of networks, change of directionality in graphs, or extraction of networks). Advanced visualization techniques are present in Pajek: network drawing is based on the principle that distances between nodes should reveal the structural pattern of the network. Pajek uses spring-embedding algorithms that seek a configuration of the bodies with locally minimal energy; they seek a position for each body such that the sum of the forces on each body is zero (Eades, Battista et al. 1999). The algorithms from Kamada-Kawai (Kamada and Kawai 1988) and Freuchterman-Reingold (Fruchterman and Reingold 1991) are good examples of this kind of technique. Graph images can be exported to traditional image formats. In Pajek, descriptive methods are also present and include: the computation of degrees, depths, and cores; centrality (closeness, betweeness); the detection of components, paths, structural holes, and some binary operations in twomode networks (Carrington, Scott et al. 2005). Unlike Ucinet, Pajek has no direct procedures for detecting cliques due to the difficulty of this procedure for large networks. However, it contains a p-cliques procedure that partitions the network nodes into clusters such that the nodes within one cluster have at least a proportion of p neighbors inside the cluster. Some statistical procedures are also available, and Pajek can invoke directly statistical software.

Netminer is a commercial product developed by Cyram and contains analysis and visualization techniques (Cyram 2007). NetMiner has an innovative data model composed of a dataset of various unit data designed to represent almost every feature of network data. NetMiner has the easiest and simplest user interface of all of the software in this category, and almost all of its results are presented both textually and graphically. Constructing new datasets out of nodes and links on a visualized network map for subgroup analysis can be easily achieved by mouse-dragging on the network map without time-consuming main menu navigation. Network-drawing can be based on spring-embedding algorithms, multidimensional scaling, analysis procedures (e.g. centrality), and simple procedures (circle, random). Built-in standard statistical procedures and charts are also integrated in NetMiner.

Survey Analysis Platforms

The problem present for software introduced in the last section is that this software requires the analyst to insert data gathered through other means (e.g. interviews, surveys, or observation) into specific formats. Other kinds of tools, including initial surveys to infer relationships in a network, have appeared to aid SNA.

Netvis is a web-based tool distributed as an open-source program to analyze and visualize social networks using data from comma-separated value files (csv) and surveys (Cummings 2008). The software permits the registration of actors present in the network, and then it allows users to define a survey and use the data received from the answers to perform a social network analysis. Although the software itself has standard procedures to analyze and visualize networks, it can also export data to most common formats.

A team at University of Virginia's McIntire School of Commerce headed by Research Director Rob Cross developed an application called Network Round Table. Most of the content and documentation is not public and is only available to clients who subscribe by paying an annual fee; however its features, steps, and procedures are available on the website. Based on an organizational perspective, the software permits an analyst to register or import all of the actors into the system, join them into teams or groups, and assign them roles. After that, the analyst can create a survey with questions to infer all of the social relationships in the network as well as their strength or frequency. The software is powerful enough to direct specific questions and answers to specific actors or groups, and questions can be open-ended, rating scale type, multiple-choice, order importance choice, or nested in groups. The analyst can explain how each question is important and what he wants to infer from the analysis of the answers. After the survey's activation, the users registered receive an email directing them to visit a web address and properly complete the survey. The analyst can check the status of the survey; when he gets a satisfactory amount of answers, he can close it. After closing the survey, an individual action plan is available to all actors with the analysis of their own answers. The analyst can view and analyze the results of the complete network. There are options available to export the data to the most common formats, but simple direct analyses are also present in the software. The analyst can also view, edit, annotate, or delete individual answers and filter them by parameters. The team states that the personal network feedback enables by itself each actor to assess his connectivity within the network and improve it by planning changes. The feedback is delivered either on paper that can be analyzed in group meetings or in an online action plan that allows actors to annotate and plan actions to increase connectivity.

Network genie is an online application developed by Tanglewood Research for designing and managing social network projects. It includes the design of surveys and survey questions, the management of social network projects, the collection of social network survey data, and the import/export of data to SNA software.

The main objective of this kind of software is to gather information from surveys and automatically export data to the most common software applications for SNA.

Platforms to Social Networks Extraction, Transformation and Load

More recently, the use of electronic data extraction became popular in the study of social networks. While traditional survey or interview methods are limited by the size of networks and the number of measurements (time-points), gathering electronic data enables large scale, longitudinal studies of networks (Mika, Elfring et al. 2006). Automatic detection of relationships is possible from various sources of information, such as e-mail archives, schedule data, and web citation information (Matsuo, Mori et al. 2006). What this kind of systems proposes is to 1) gather information from a large collection of data, 2) identify and disambiguate social entities, and 3) understand both the links between them as well as their strength, periodicity, and probability.

The SONAR platform developed by Trampoline Systems proposes to plug into a corporate network and connect to existing systems like email servers, contact databases, and document archives to extract and analyze data to build a map of social networks, information flow, expertise, and individual interests throughout the enterprise (TrampolyneSystems 2008). The platform consists of several functional modules that can be combined as required by each customer; all information is available to managers, and personal data is available to users.

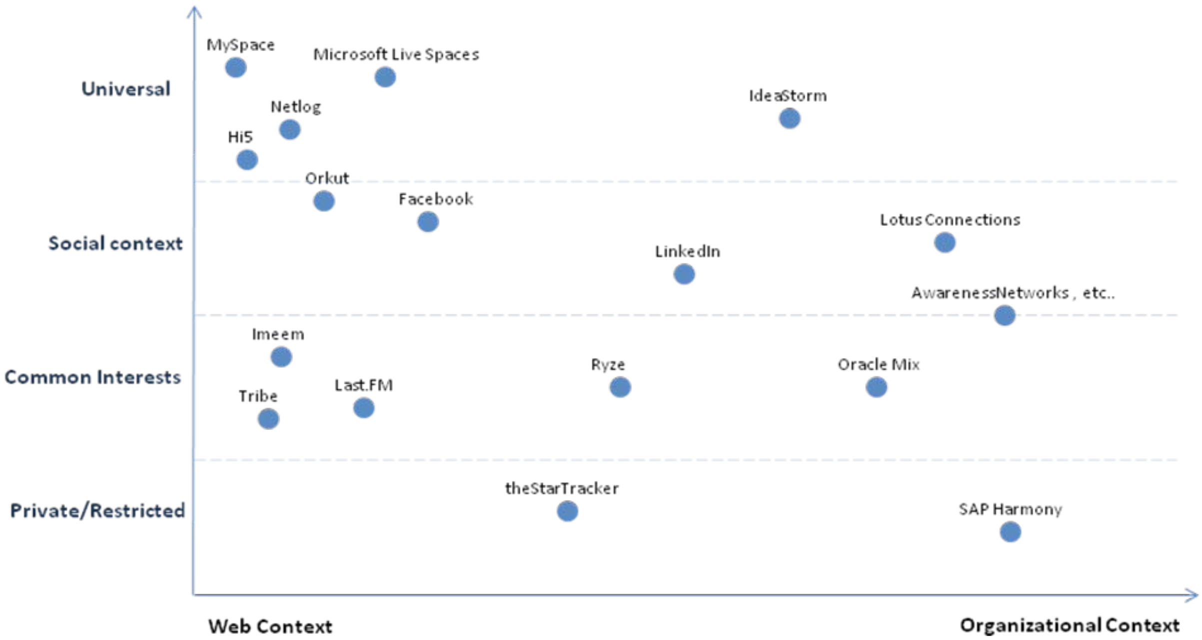
Flink, the best semantic web application at the semantic Web Challenge of 2004 in ISWC2004, was developed by Peter Mika's team and supports the complete process of data collection, storage, and visualization of social networks based on heterogeneous sources of electronic data (Mika, Elfring et al. 2006).

Data comprising social networks tend to be heterogeneous, multirelational, and semi-structured (Han and Kamber 2006). Link mining is an emergent field of research with contributions from many areas that can help in social network mining. It can be used to classify entities based on their links, predict the type or even the existence of links and their evolution, and detect subgroups and properties common to some group (Han and Kamber 2006). Polyphonet (Matsuo, Mori et al. 2006) is a social network mining system that has been used at four academic conferences in Japan to infer the relationships between authors, reviewers, and participants. It is a good example of the use of link mining, because it uses web search engines to understand and measure the connections between people via balanced coefficient that define relationships.

SOCIAL NETWORKING SERVICES

Although the Web itself is an example of a social network and the formation of communities is one of its most important achievements, the Web 2.0 boom brought the possibility of group information sharing to users via the spread of wikis, forums, blogs, and social networking communities. Although these websites feature much of the same content that appears on personal Web pages, they provide a central point of access and bring structure in the process of personal information sharing and online socialization (Jamali and Abolhassani 2006). People can register or be invited to these websites. After uploading information about themselves, they can upload photos, join groups of people, and connect to other friends or people with similar interests. People become organized in networks or groups and can see each other's profiles, relationships, and actions in the network. Most of these websites allow people to upload and tag photos, share files, post in blogs, and interact in other ways with their peers.

Figure 4. Social networking services scope



Community-Wide Services

According to web statistics (HitWise.com), Myspace is still the dominant social networking service and has more than 200 million users registered (Alexa.com 2008). It is also the sixth most popular website in the world. Founded in 1999, MySpace offers to its users features like profile customization, comments, and the ability to post videos and music and participate in groups and bulletins. Apart from these functions, MySpace offers users an instant message service, a classified ads system, news, and a video sharing system.

Founded in February 2004, Facebook.com was initially open only to college students; today, it has more than 70 million active users and 55,000 networks. The website permits people to register and join a university, workplace, or village network, upload information and photos, tag photos, organize and join events in the network, and exchange messages and other content with friends' networks. Facebook's Platform API enables anyone to build complete applications that users can join and use with their profiles and friends network, opening new opportunities for development of new concepts using the social network. To date, 12000 applications have been built on Facebook platform. Other facts about Facebook are impressive: the number of active users doubles every 6 months; more than half of the active users return daily; people spend an average of 20 minutes on the site daily.

Friendster.com, with almost 50 million registered users, is a very important website in Asia and has recently developed a public API as Facebook that permits the growth of the community. In Europe, Netlog.com has more than 32 million registered users and Hi5.com has 50 million users.

Big enterprises are also already in this market: Microsoft has Live Spaces, Google has Orkut.com, and Yahoo has Yahoo 360º .

Specific networks oriented to people with similar interests (e.g. Tribe.net, iMeem, Last.fm), people who want to find old friends (e.g. classmates.com, graduates.com), people who want to share photos with friends (Flickr.com), or people who want to join in charity projects (SixDegree.org) also exist.

Table 1. Most popular social networking services

	Users (Millions)	Notes
Myspace	200	Oldest and most famous SNS. Sixth most visited website in the world.
Facebook	70	Has the most rapid current growth. The number of users doubles every six months.
Friendster	50	Used particularly in Asia.
Hi5	50	Most visited website in Portugal in 2007.
Netlog	32	Used particularly in Europe.

According to Hitwise.com, 6.5 percent of all Internet traffic in February 2007 in the world was generated by this kind of social networking website. According to Nielsen/NetRatings (another web statistics website), social networking sites are the reality television of the Internet. In Portugal, the most frequently used social networking website is Hi5; this was the most frequently visited website in Portugal in 2007 according to Alexa.

Even if few social networks currently charge money for membership, the fact that these kinds of communities are constantly renewed by their members and organized in networks by interests, location, or situation means that these websites can sell specific ads to specific groups. This is quite appealing for investors and can extend the context of these communities even further in the future. There is also a tendency to define a standard way to exchange data between these services. Google OpenSocial (Google 2008) provides a common set of APIs for social applications across multiple websites and is supported by some social networking websites. It is composed of three APIs that permit programmers to access core functions and social network information like profiles, friends' information, and activities.

Some concerns are being raised due to the success of these communities. These include concerns about users giving out too much personal information, lack of privacy, and fake content and profiles. Information posted on sites like MySpace, Hi5, and Facebook has been used by the police to prosecute users.

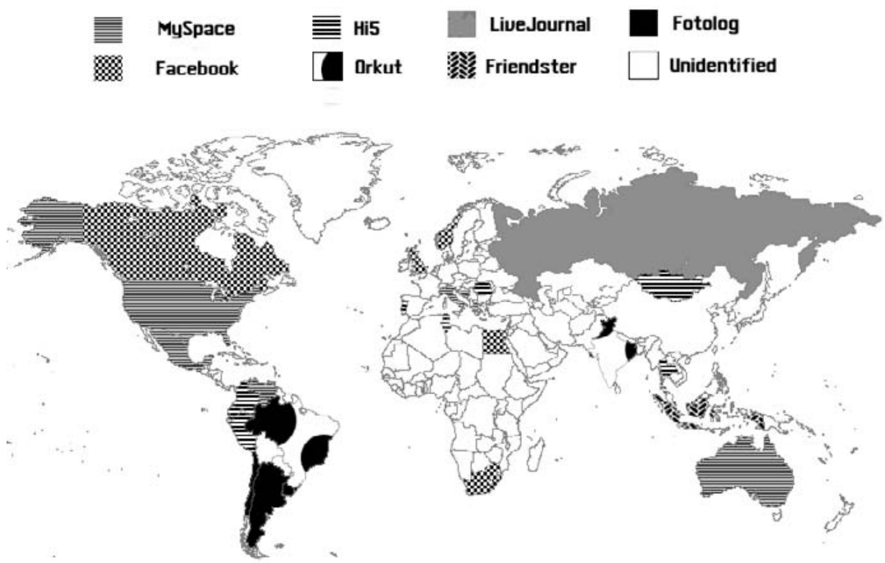
Social networking services can be also used in a more oriented professional context. LinkedIn is a website where people can post their professional experience as well as share and connect with others with the same interests, professional background, or company. Ryze is designed to link business professionals, particularly new entrepreneurs. The site claims to have over 250,000 members in 200 countries, with over 1,000 external organizations hosting subnetworks on the site. The Portuguese website theStarTracker allow its members to join communities of Portuguese people working abroad and understand what they are doing.

It is not easy to explain why different services have different popularities in different countries and cultures. Each service is mainly used by a certain type of community or culture. ValleyWag published in 2007 a world map of social networks according to their use in different countries. Even though MySpace is still the global leader, different websites are more popular SNSs in different regions.

Organization-Wide Services

Big companies have begun to understand the power behind this kind of system for sharing knowledge, experience, and practices inside and outside their companies. In November 2007, a team in Oracle launched Oracle Mix (Oracle 2007). Oracle Mix is a social network for oracle developers, partners, employees, and customers that allows them to share the best practices, experiences, and ideas. Dell also developed a similar

Figure 5. The world map of social networks (Adapted from Valleywag, http://valleywag.gawker.com/tech/notag/the-world-map-of-social-networks-273201.php, published June 27th, 2007 © Gawker Media 2007. All rights reserved. Used with permission.)



system called IdeaStorm (Dell 2007), which is used by customers to share ideas with the company and receive feedback from the community. Sap developed an internal system called Harmony that is already being used by SAP Labs users behind the firewall. IBM went further, introducing in July 2007 the Lotus Connections Suite. This software suite permits a company's employees and partners to register profiles, share ideas, experiences, activities, and resources about company products as well as what they are doing in the company, and create new communities. IBM uses this suite inside the company as the company yellow pages. Even SharePoint 2007, a collaboration suite from Microsoft, already has some business social networking capabilities like user profiles, people search facilities, and tools like wikis and blogs; it is expected to be expanded by a social networking driver. Other firms like AwarenessNetworks and HiveLive are also developing this kind of social networking applications for enterprises.

FUTURE TRENDS

The integration of social network-based platforms is already a reality, and their use should prove effective to organizations that adopt them. Platforms that gather social communities, social network analysis, and knowledge management features would be an amazing information broker inside the organization. They would offer a powerful directory in which knowledge and expertise is easy to find, and they would centralize information and reduce the distance between departments and groups inside the organization. Additionally, these platforms would also be a powerful decision tool to help managers understand the real connections and daily activities developed by their employees. By joining the best of these two worlds, organizations would gain a real notion of what is going on inside and outside their walls; employees would have access to a new tool to increase their productivity and provide precious information that would be covered in other ways.

However, copying or adapting existing social networking services is not sufficient. These kind of joined platforms that can be referred to as Social Networking Services for Enterprises (SNES) have different requirements than normal social networking systems do. They need to be used in an organizational context, and they should be used to increase productivity. They should be extremely secure, and privacy should be a major concern. Users should be able to feel secure and in total control of the information they share.

Organizations already have their own information systems, and SNES should plug into them to make sure that information is automatically and constantly retrieved. This represents a huge challenge because of the heterogeneity of tools, servers, technologies, and software present inside organizations. SNES should plug into mail servers, workflow applications, client relation management systems, phone logs, or other information systems that employees or customers use to communicate or work.

Systems should adapt to an organization's characteristics and workflow processes to provide increased value to employees and departments instead of creating unnecessary entropy inside an organization's walls. Employees should recognize a system's value before they begin using that system. These systems should contain important information even without the contribution of organizational actors. However, actor contribution is fundamental for success, so different modules should be present in order to promote strong connections among actors. These modules could include bulletin boards, profile pages, groups and communities of practice, messaging, the ability to find people based on their interests, departments, or related work, easy content sharing using wikis or blogs, and other popular Web 2.0 tools.

Following these concerns, we are currently working on the SNARE project (Barão and Silva 2008) to design and develop a suite of software tools to be used in organizations to analyze and capture social networks. The SNARE system provides social network features in information systems not originally designed for this effect. SNARE is also able to capture existing social networks by analyzing answers to surveys and inferring relationships and properties. These questions focus mainly on how people trust, rely, and work in the organization; they can thus be useful for analyzing the way people understand each other in the organization.

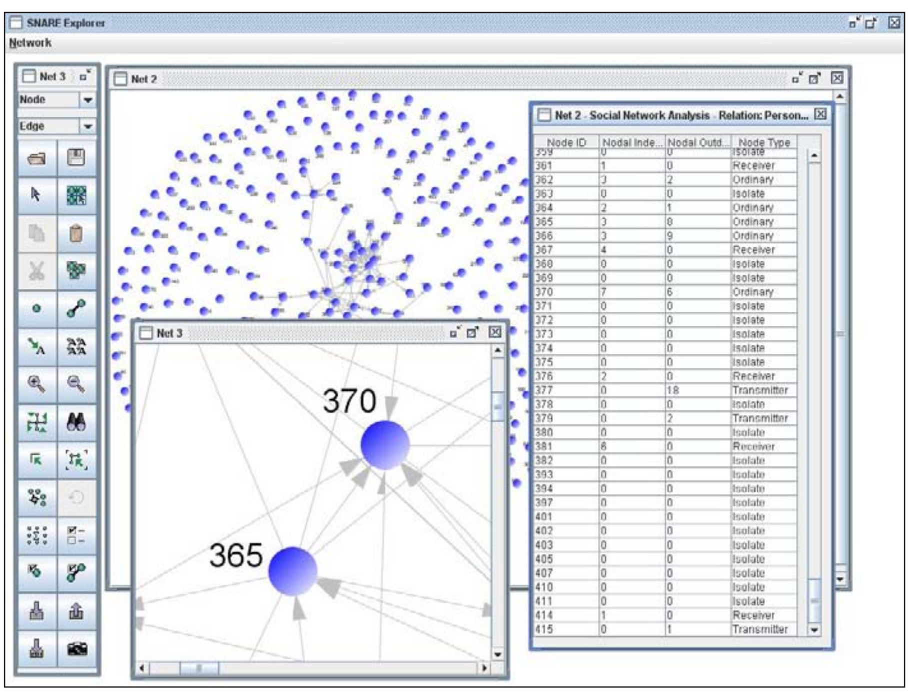
SNARE architecture is composed of a core application in which other applications can connect through web services. WebSNARE is a web application designed to help managers and consultants construct social communities, define social entities (persons, groups, and external entities), define the type of relationships and their instances, and enrich relationships and social entities with customized properties. Managers can also define surveys to apply to the network in order to infer relationships from the answers given. Every social entity can have a unique system login, so users can update their personal data or answers to surveys after seeing after their personal results. In addition to these functions, SNARE can be used like the usual Social Networking Systems: social entities can connect to each other and define what they do together. Each user is able to search in the organization by some context or name and retrieve the content required. Users can also organize and join groups (e.g. groups based on interest or communities of practice inside the organization). Users are able to publish and retrieve content in their profiles or network pages.

In addition to the ability to promote networking and knowledge sharing inside the organization, SNARE can also perform Social Network Analysis on relationships defined by users or extracted from surveys. Managers can identify bottlenecks inside organizations or specific groups, highlight social entities with specific properties, and use SNA measures to analyze different domains or enterprises processes. SnareExplorer is a stand-alone application that is used to visualize and analyze social networks and can import and export data directly to SNARE.

SNARE ETL Services provide a technical interface-to-Desktop ETL Tool. This desktop application defines and controls ETL actions and has a required interface for executing SNARE Service methods. The aim of this component is to extract relevant social network data through ETL mechanisms. This tool allows users to specify transformations through a graphical user interface. Data transformation can involve the following: (1) smoothing, which works to remove noise from data, (2) aggregation, which involves summary operations applied to the data and is typically used in constructing a data cube for the analysis of data at multiple granularities, (3) generalization of the data, where low-level data are replaced by higher-level concepts through the use of concept hierarchies, (4) normalization, where attribute data are scaled so as to fall within a small specified range, and (5) attribute construction, where new attributes are constructed and added from the given set of attributes to help the mining process (Han and Kamber 2006). This module can be used to plug SNARE into different existing systems and constantly update data that can be analyzed. Future work will be done in this field, and different modules will be developed in order to achieve integration with common systems.

SNARE is already being applied in some projects and tested in different contexts and with different goals. The SNARE model is able to represent relationships in almost any context and enrich them by populating relationships and entities with customized properties. The ability to join entities and relationships with temporal or contextual similarity is a powerful advantage and will be fundamental for achieving the richest analysis. It will better support reengineering in organizational contexts while it promotes networking and information sharing inside organizations.

Figure 6. Snare Snapshot



CONCLUSION

Social Networks are not a new or recent concept. However, Web 2.0 evidence suggests that they now constitute an emergent field of study. The way people connect and work in enterprises brought a new drive SNA and changed its main goals. Using traditional concepts, studies conducted in many subjects and areas uncovered interesting aspects. Now, the challenge is to create systems that are able to represent, extract, and analyze social networks in the context of enterprise information systems.

There is not a perfect way to take a snapshot of social relationships, and all methods present some problems and limitations. Surveys can be manipulated by who is answering. Direct observation does not permit understanding of all relationships present in a group, and the most important relationships cannot be extracted from information gateways like email servers. The combined application of these techniques can, however, provide the best approach to represent and analyze a social network.

Social Networking Services are also a key player in this field. They began as just a new way of connecting people but are already being used in organizations. Companies who use them understand that injecting trust into the equation lowers the barrier to entry and sharing ideas. Employees and customers find these systems useful and fun to use, and that permits a new way to connect inside and outside the company. The future will show what benefits social networking tools and services provide when they care connected with HR (Human Resources) systems, ERP (Enterprise Resource Planning), CRM (Customer Relationship Management) software packages, and different SNA tools.

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KEYS TERMS AND DEFINITIONS

Organizational Network Analysis: Organizational Network Analysis (ONA) involves the use of Social Network Analysis in organizational contexts in order to help managers to better understand the relationships present inside and outside the organization. It can be used in an organization to better understand the social capital, support partnerships and alliances (Cross and Parker 2004), measure the degree of embeddedness of the actors and define their importance in the network, support knowledge management policy and reveal who really knows what in the company, integrate networks across core processes, promote innovation, integrate new members or organizational changes, support the development of informal communities of practice, improve leadership effectiveness, replicate high performance throughout an organization, and understand and improve both the disconnects between groups in the organization as well as connections to the outside world.

Social Network: A social network is generally defined as a set(s) of actors and the relation(s) defined for them. Actors, also defined as social entities, can be individual or collective social units that are connected by links. Links constituting a social network may be directed, undirected, or mixed. Social Networks can be analyzed using defined measures, and their results can be compared with those from similar networks. Each actor's position and connections can also be individually analyzed and compared with those of other actors in order to understand their relative importance in the network and highlight network bottlenecks and cutpoints as well as isolated and equivalent actors.

Social Network Analysis Measures: Measures in SNA are the metrics through which networks and social actors can be evaluated and compared. SNA measures can be distinguished into those evaluate the entire network and those that evaluate only a specific node. At the individual level, the most frequently analyzed measure is *centrality;* this can be measured using *nodal degree, betweeness,* and *closeness.* At the network level, is important to understand how the network is structured; it is therefore important to measure network *cohesion, centralization, and clustering* and identify important nodes like *cutpoints.*

Social Network Tools: Social Network Tools are software tools that can be used to represent, visualize, and analyze social networks. These tools can usually read and write in common formats and use matrices to compute social networks and graphs called sociograms to represent them. Other platforms have other important characteristics like the ability to convert answers from internal surveys to social network data or extract social network information from existing systems using ETL techniques. Some graph software or general network analysis software can also be used to identify key aspects in social networks.

Social Network ETL: Social Network Extraction, Transform, and Load designates the set of techniques used to map existing information system data into social network models. Entities present in the systems should be normalized and resolved, and the selected interactions between them are transformed into relationships. After extraction and transformation, data can be loaded in the usual SNA tools. Good examples of social network ETL use arise from community boards, server communication logs, knowledge repositories, and wikis.

Social Networking Services: Social Networking Services (SNS) are websites where people can register their personal profiles and connect with others to share information based on interest, upload photos, or join groups. This kind of website is a popular Web 2.0 phenomenon; millions of people are currently registered, and SNS websites are some of the most visited websites on the internet. SNS represent a new way to connect to collaborators, and they permit the sharing of information and breaking of common barriers. Although concerns regarding privacy issues arise, restricting information to only those users people trust circumvents the problems of sharing it with no restrictions in the network.

Social Networking Services for Enterprises: Social Networking Services for Enterprises are internal information systems used by organizations to increase connections and information sharing among their collaborators. These systems share the same features as social networking services but are used to low barriers inside organizations. They are intended to promote productivity by increasing information sharing. Usually, they are platforms that try to join features of Social Networking Services and knowledge repositories with Social Network Analysis. They give the managers and consultants the ability to access existing organization networks and hidden relationships and make decisions for reorganization based on what is really happening in the organization.

Chapter XXI
The Generative Potential of Appreciative Inquiry as an Essential Social Dimension of the Semantic Web

Kam Hou Vat
Faculty of Science and Technology, University of Macau, Macau

ABSTRACT

The mission of this chapter is to present a framework of ideas concerning the expected form of knowledge sharing over the emerging Semantic Web. Of specific interest is the perspective of appreciative inquiry, which should accommodate the creation of some appreciative knowledge environments (AKE) based on the peculiar organizational concerns that would encourage or better institutionalize knowledge work among people of interest in an organization. The AKE idea is extensible to the building of virtual communities of practice (CoP) whose meta-data requirements have been so much facilitated in today's Web technologies including the ideas of data ownership, software as services, and the socialization and co-creation of content, and it is increasingly visible that the AKE model of knowledge sharing is compatible for the need of virtual collaboration in today's knowledge-centric organizations. The author's investigation should provide a basis to think about the social dimension of today's Semantic Web, in view of the generative potential of various appreciative processes of knowledge sharing among communities of practice distributed throughout an organization.

INTRODUCTION

In the late 20th century, Tim Berners-Lee (1999) had the idea of providing rapid, electronic access to the online technical documents created by the world's high-energy physics laboratories. He sought to make it easier for physicists to access their distributed literature from a range of research centers scattered around the world. In the process, he laid the foundation for the World Wide Web. Berners-Lee has a two-part vision for the working of the World Wide Web (http://public.web.cern.ch/Public/Welcome.html). The first is to make the Web a more collaborative medium. The second is to make the Web understandable and thus serviceable by machines. Yet, it was not his intention that someday his idea to link technical reports via hypertext then has actually revolutionized essential aspects of human communication and social interaction. Today, the Web provides a dazzling array of information services designed for use by human, and has become an ingrained part of our lives. There is another Web coming, however, where online information will be accessed by intelligent agents that will be able to reason about that information and communicate their conclusions in ways that we can only begin to dream about. This is the Semantic Web (Berners-Lee, Hendler, & Lassila, 2001; Berners-Lee, 1998a, 1998b, 1998c; http://www.SemanticWeb.org), representing the next stage in the evolution of communication of human knowledge. The developers of this new technology have no way of envisioning the ultimate ramifications of their work. Still, they are convinced that "creating the ability to capture knowledge in machine understandable form, to publish that knowledge online, to develop agents that can integrate that knowledge and reason about it, and to communicate the results both to people and to other agents, will do nothing short of revolutionize the way people disseminate and utilize information" (Musen, 2006, pp. xii). This article is meant to provide a strategic view and understanding of the Semantic Web, including its attendant technologies. In particular, our discussion situates on an organization's concerns as to how to take advantages of the Semantic Web technologies, by focusing on such specific areas as: diagnosing the problems of information management, providing an architectural vision for the organization, and steering an organization to reap the rewards of the Semantic Web technologies. Of interest here is the introduction of the appreciative context of organizational systems development based on the philosophy of appreciative inquiry (Cooperrider, 1986; Gregen, 1990), a methodology that takes the idea of social construction of reality to its positive extreme especially with its relational ways of knowing.

THE TECHNOLOGICAL BACKGROUND OF SEMANTIC WEB

Most of today's Web content is suitable for human understanding. Typical uses of the Web involve people's seeking and making use of information, searching for and getting in touch with other people, reviewing catalogs of online stores and ordering products by filling out forms, as well as viewing the confirmation. The main tool of concerns is the search engine (Belew, 2000), with its key-word search capability. Interestingly, despite much improvement in search engine technology, the difficulty remains; namely, it is the person who must browse selected documents to extract the information he or she is looking for. That is, there is not much support for retrieving the information, which is a very time-consuming activity. The main obstacle to providing better support to Web users is the non-machine-serviceable nature of Web content (Antoniou & van Harmelen, 2004); namely, when it comes to interpreting sentences and extracting useful information for users, the capabilities of current software are still very limited. One possible solution to this problem is to represent Web content in a form that is more readily machine-processable and to use intelligent techniques (Hendler, 2001) to take advantage of these representations. In other words, it is not necessary for intelligent agents to understand information; it is sufficient for them to process information effectively. This plan of Web revolution is exactly the initiative behind the Semantic Web, recommended by Tim Berners-Lee (1999), the very person who invented the World Wide Web in the late 1980s. Tim expects from this initiative the realization of his original vision of the Web, i.e. the meaning of information should play a far more important role than it does in today's Web. Still, how do we create a Web of data that machines can process? According to Daconta and others (2003), the first step is a paradigm shift in the way we think about data. Traditionally, data has been locked away in proprietary applications, and it was seen as secondary to the act of processing data. The path to machine-processable data is to make the data progressively smarter, through explicit metadata support (Tozer, 1999). Roughly, there are four stages in this smart data continuum (Daconta, Obrst, & Smith, 2003), comprising the pre-XML stage, the XML stage, the taxonomies stage, and the ontologies stage. In the pre-XML stage where most data in the form of texts and databases, is often proprietary to an application, there is not much smartness that can be added to the data. In the XML stage where data is enabled to be application independent in a specific domain, we start to see data moving smartly between applications. In the third stage, data expected to be composed from multiple domains is classified in a hierarchical taxonomy. Simple relationships between categories in the taxonomy can be used to relate and combine data, which can then be discovered and sensibly combined with other data. In the fourth stage based on ontologies which mean some explicit and formal specifications of a conceptualization (Gruber, 1993), new data can be inferred from existing data by following logical rules. This should allow combination and recombination of data at a more atomic level and very fine-grained analysis of the same. In this stage, data no longer exists as a blob but as a part of a sophisticated microcosm. Thereby, a Semantic Web implies a machine-processable Web of smart data, which refers to the data that is application-independent, composable, classified, and part of a larger information ecosystem (ontology).

Understanding Semantic Web Technologies

Today, XML (extensible markup language; http://www.xml.com) is the syntactic foundation of the Semantic Web. It is derived from SGML (standard generalized markup language), an international standard (ISO8879) for the definition of device- and system-independent methods of representing information, both human- and machine-readable. The development of XML is driven by the shortcomings of HTML (hypertext markup language), the standard language also derived from SGML, in which Web pages are written. XML is equipped with explicit metadata support to identify and extract information from Web sources. Currently, many other technologies providing features for the Semantic Web are built on top of XML, to guarantee a base level of interoperability, which is important to enable effective communication, thus supporting technological progress and business collaboration. For brevity, the technologies that XML is built upon are Unicode characters and Uniform Resource Identifiers (URI). The former allows XML to be authored using international characters, whereas the URI's are used as unique identifiers for concepts in the Semantic Web. Essentially, at the heart of all Semantic Web applications is the use of ontologies. An ontology is often considered as an explicit and formal specification of a conceptualization of a domain of interest (Gruber, 1993). This definition stresses two key points: that the conceptualization is formal and hence permits reasoning by computer; and that a practical ontology is designed for some particular domain of interest. In general, an ontology describes formally a domain of discourse. It consists of a finite list of terms and the relationships between these terms. The terms denote important concepts (classes of objects) of the domain. The relationships include hierarchies of classes. In the context of the Web, ontologies provide a shared understanding of a domain, which is necessary to overcome differences in terminology. The search engine can look for pages that refer to a precise concept in an ontology instead of collecting all pages in which certain, generally ambiguous, keywords occur. Hence, differences in terminology between Web pages and the queries can be overcome. At present, the most important ontology languages for the Web include (Antoniou & Harmelen, 2004): XML (http://www.w3.org/XML/), which provides a surface syntax for structured documents but imposes no semantic constraints on the meaning of these documents; XML Schema (http://www.w3.org/XML/Schema), which is a language for restricting the structure of XML documents; RDF (Resource Description Framework) (http://www.w3.org/RDF/), which is a data model for objects ("resources") and relations between them; it provides a simple semantics for this data model; and these data models can be represented in an XML syntax; RDF Schema, (http://www.w3.org/TR/rdf-schema/) which is a vocabulary description language for describing properties and classes of RDF resources, with a semantics for generalization hierarchies of such properties and classes; OWL (http://www.w3.org/TR/owl-guide/), which is a richer vocabulary description language for describing properties and classes, such as relations between classes, cardinality, equality, richer typing of properties, characteristics of properties, and enumerated classes.

Clarifying the Meta-Data Context of Semantic Web

It is hard to deny the profound impact that the Internet has had on the world of information over the last decade. The ability to access data on a variety of subjects has clearly been improved by the resources of the Web. However, as more data becomes available, the process of finding specific information becomes more complex. The sheer amount of data available to the Web user is seen as both the happy strength and also the pity weakness of the World Wide Web. Undoubtedly, the single feature that has transformed the Web into a common, universal medium for information exchange is this: using standard search engines, anyone can search through a vast number of Web pages and obtain listings of relevant sources of information. Still, we have all experienced such irritation (Tozer, 1999; Belew, 2000) as: the search results returned are incomplete, owing to the inability of the search engine to interpret the match criteria in a context sensitive fashion; too much information is returned; lack of intelligence exists in the search engine in constructing the criteria for selection. Likewise, what is the Semantic Web good for? Perhaps, a simple example in the area of knowledge management could help clarify the situation. The field of organizational knowledge management typically concerns itself with acquiring, accessing, and maintaining knowledge as the key activity of large businesses (Liebowitz, 2000; Liebowitz & Beckman, 1998). However, the internal knowledge from which many businesses today presumably can draw greater productivity, create new value, and increase their competitiveness, is available in a weakly structured form, say, text, audio and video, owing to some limitations of current technology (Antoniou & Harmelen, 2004, p.4) in such areas as: *searching information*, where companies usually depend on keyword-based search engines, the limitation of which is that even though a search is successful, it is the person who must browse selected documents to extract the information he or she is looking for; *extracting information*, where human time and effort are required to browse the retrieved documents for relevant information, and current intelligent agents are unable to carry out this task in a satisfactory manner; *maintaining information*, where there are current problems such as inconsistencies in terminology and failure to remove outdated information; *uncovering information*, where new knowledge implicitly existing in corporate databases is extracted using data mining, but this task is still difficult for distributed, weakly structured collections of documents; and *viewing information*, where it is often desirable to restrict access to certain information to certain groups of employees, and views which hide certain information, are known from the area of databases but are hard to realize over an intranet or the Web. The aim of the Semantic Web is to allow much more adaptable technologies in handling the scattered knowledge of an organization (Swartz & Hendler, 2001) such as: knowledge will be organized in conceptual spaces according to its intended meaning; automated tools will support maintenance by checking for inconsistencies and extracting new knowledge; keyword-based search will be replaced by query answering—requested knowledge being retrieved, extracted, and presented in a human-friendly manner; query over several documents will be supported; and defining who may view certain parts of information will also be made possible.

CRAFTING THE KNOWLEDGE-CENTRIC ORGANIZATION

It is not uncommon to hear any Chief Executive Officer (CEO) respond to the question, "What distinguishes your company from its competitors?" with the emphatic "Our knowledge." Yet, it is also not surprised to see the same CEO become somewhat puzzled when the follow-up question, "What comprises your knowledge assets and value on this knowledge?" is presented. Many leading organizations nowadays are discovering they need to do a better job of capturing, distributing, sharing, preserving, securing, and valuing their precious knowledge in order to stay ahead of their competition, or at least survive (Liebowitz, 1999). By the term knowledge-centric (Daconta, Obrst, & Smith, 2003; Liebowitz & Beckman, 1998), we mean the process of managing knowledge in organizations with the focus to provide mechanisms for building the knowledge base of the firm to better apply, share, and manage knowledge across various components in the company. The use of Semantic Web technologies is a means to achieving the knowledge-centric organization by weaving the underlying technologies into every part of the organization's work life cycle, including production, presentation, analysis, dissemination, archiving, reuse, annotation, searches, and versioning of the knowledge work. To situate our discussion on the Semantic Web context, it is helpful to investigate what a typical non-knowledge-centric organization scenario is like in its daily operations.

Making Sense of Information Overload

To remain competitive, many an enterprise today accrue numerous information resources to use in their problem solving, decision making and creative thinking for improving products, processes, and services. Yet, the critical problem for the typical organization is the sheer volume of information coming in, from a wide variety of sources, in various formats (papers, emails, and different electronic media), and it is difficult to manage such resources and turn them into knowledge, which according to Tom Davenport (1997), is a synthesis of information. The knowledge process in a non-knowledge-centric organization typically comprises five stages of information management. The first stage is often characterized by a capture process, in which a human being in the organization takes information from somewhere (newspaper, radio, Internet, database, phone call, or email), and brings it to the organization, via some means such as vocally by mentioning the information to someone, or electronically by sending it through email to someone. If the data is not lost in the process, the recipient writes a paper or presentation, or even a status report. The second stage is often characterized by a securing process, in which the data is put into a database, recorded to a digital file, or indexed into a search engine. Now that entering information is always the first step, but the potential problem is this: each division, group, or project in the organization may enter the information into different systems. Assuming there is only one database per project, and assuming a division has only ten projects, there may be ten different databases containing data in a division. What if there is a different database system for each project? There then will be ten different software systems containing data. What if there are five divisions in the company, with similar systems in use? We now have many data sources that might be individual stovepipes in the organization, each of which perform a specific task at the expense of trapping the data and robbing the organization of business agility in adapting such data to new systems of interest. The third stage in the knowledge process is often characterized by integration, depending on the complexity of the organization's information architecture, a blueprint based on which different information systems services are rendered. Perhaps, since most of the information systems are stove-piped (namely, information cannot be shared by other systems that need it), there is usually no good way to combine different information systems into a coherent picture. In other words, any attempt to combine the information must involve data conversions across incompatible software systems, in which each database and software system is designed differently and has different interfaces to talk to them. As a result, there is usually little or no integration of these databases, because it is prohibitively difficult and expensive. Even if there is an integration solution, the result is often another stove-piped system. The fourth stage of the knowledge process is often characterized by searching, or discovery of an organization's internal resources. This is a haphazard and time-consuming activity because it involves so many different systems. Imagine we have to login to different databases and search engines, and manually compare and contrast the information we find into a coherent picture or thought. This is the most wasteful part of the knowledge process in person-hours. Finally, the fifth stage is concerned with the application of the search results (if we succeed in the last stage). After the tedious search process, the result is usually a presentation or paper report. Many times, this process of creating the report involves several people. The approval process is done by manual reviews and is often slow. After the new product is created, the information is supposed to be filed, say, onto a Web server that may or may not be indexed by one of the organization's search engines. The issues with this approach of knowledge process are many: How are we to know what version of the document we have? There is no way to tell if the information has been superseded once this new document is integrated into one of the organization's stove-piped databases. How are we to reuse the information, in terms of the ability to discover, refine, annotate, and incorporate past knowledge?

Making Use of Semantic Web Technologies

The knowledge process in a knowledge-centric organization starts with the discovery and production phase where an individual member of the organization receives an information item and would like to turn that into a knowledge item. It is intended as a process that could be repeated by many others in the same organization. With Semantic Web technologies, any new piece of information must be marked up with XML using a relevant organizational schema. Once this is done, the individual should digitally sign the XML document using the XML signature specification to provide strong assurance that the individual verified the validity of the information. The next step is the annotation process, in which the individual may want to use RDF to annotate the new information with his or her notes or comments, adding to the XML document, but without breaking the digital signature seal of the original material. At the end of the annotation process, the author should digitally sign the annotation with XML signature. Then, the annotated information must be mapped to topics in the taxonomy and entities in the corporate ontology so that pieces of the information can be compared to other pieces of information in the organization's knowledge base. Example annotations include: Who is the person that authored this document? What department does he or she work in? Is the individual an expert on this topic? Is this topic in the organization's taxonomy? Once this is completed, it is time to store the information in an application with a Web service interface. If that is a new Web service, the Web service should be registered in the organization's registry, along with its taxonomic classifications. The result of the discovery and production process is that the information coming into the organization has been marked up with standard XML, digitally signed to show assurance of trust, annotated with an author's comments, mapped to the organization's ontology, and published to a Web service and registered in a Web service registry. Consequently, because the Web service is registered in a registry, people and programs in the organization can discover the Web service based on its name or taxonomic classification. Besides, now that any incoming information is stored in an easily accessible format (Web services) and is associated with the organization's ontology and taxonomy, retrieval of information is much facilitated.

Preparing for Change via the Semantic Web

It follows from our previous discussion that in order to take advantage of Semantic Web technologies, most organizations need to change the way they manage information resources (Van den Hoven, 2001) such as: encouraging the sharing of information resources by using common terminology, definitions, and identifiers across the enterprise; establishing an enterprise-wide information architecture, which show the relationships between information held in various parts of the enterprise; ensuring information integrity through procedures to ensure accuracy and consistency; improving information accessibility and usability by putting it in useful formats to make it accessible in any way that makes business sense; and enforcing security to protect the information resources from accidental or deliberate modification, destruction, or unauthorized access. Fortunately, these changes can mostly be implemented evolutionarily over time so as to realize the vision of a knowledge-centric organization. In fact, the most challenging aspect may not be the technology, but the cultural transformation of the mind-set of employees because the use of Semantic Web represents a whole system change of the behavior in accessing, integrating, and leveraging knowledge throughout the organization. So, how do we get started? Our learning indicates that the IDEAL model (Gremba & Myers, 1997) originally conceived as a life cycle model for software process improvement based on the capability maturity model (CMM) for software at the CMU-SEI (Paulk, Weber, Curtis & Chrissis, 1994), has been found helpful in the change management process. IDEAL suggests a useable and understandable approach to continuous improvement by outlining the steps required to establish a sustainable improvement program, through five different stages of work. Initiating (I) is to lay the groundwork for a workable improvement effort. Diagnosing (D) is to determine where we are relative to where we want to be. Establishing (E) is to plan the specifics of how we will reach our destination. Activating (A) is to do the work according to the plan. Learning (L) is to learn from the experience and improve our ability to adopt new technologies in the immediate future. In the context of the knowledge-centric organization using Semantic Web, *Initiating* involves developing a clear vision for changing the information management process in the organization. What is the clear and compelling business case for change? How will the Semantic Web technologies enable the organization to achieve its business goal? How does this change link to other, broader corporate goals? If these issues are not well elaborated, it is very hard for members of the organization to buy into the change. A clear, concise, and simple mission statement may help. *Diagnosing* involves setting clear goals and milestones specific to the organization, based on the vision (or mission) communicated in the Initiating stage. Often, visionary goals (not technical goals) are what are needed. An example is: "Be able to look up all project information across the organization by spring 2009." *Establishing* involves identifying critical stakeholders who will be impacted by the change. Oftentimes, it helps to divide stakeholders into different groups to assess the unique impact on each group and develop targeted plans to help them work through change. For example, what kind of resources or tools can help each group manage the change? It might also help if some change facilitators are made available to address the cultural and organizational change issues identified in the process. *Activating* involves picking a core team to spread the vision throughout the organization. This team preferably composed of both technical and management people, is charged with the mission to mobilize the change efforts among members of the organization. It is also important to identify a change champion to help lead the effort of organizational and cultural transformation to ensure that the company embraces the new technology. At this point, *learning* is the most important because the core team will need to understand the high-level concepts of the Semantic Web, the purpose behind it, and the core business benefits it brings. Once the management and the technical staff are on board the core team, it is time to determine the technical goals to implement the plan. Example technical goals could include (Daconta, Obrst, & Smith, 2003, pp. 252-254): *Mark up documents in XML*—After this step, all new document development in the organization should have XML formats, to enable data content to be separate from presentation, and style sheets can be used to add different presentations to content later. *Expose applications as Web services*—so as to publish the application's interfaces as self-describing knowledge objects, with a goal of delivering small, modular building blocks that can be assembled by the intended users. *Establish an organizational registry*—so as to register different applications and provide query for Web services. *Build ontologies*—so as to overlay higher-level semantic constructs on the documents marked up with XML which provides facilities and syntax for specifying a data structure that can be semantically processed. *Integrate search tools*—so as to allow members of the organization to do searches of documents based on specific ontology. *Provide an enterprise portal*—so as to provide some aggregation points to integrate knowledge management into the organization through specific user-interfaces of search engines.

ORGANIZATIONAL CHALLENGES FACING THE SEMANTIC WEB

Based on our earlier discussion, it is not difficult to see that in an organization with Semantic Web technologies, because any incoming information has been marked up with XML, standard techniques and technologies can be used to store it and style its presentation. Still, because the information has been mapped to the organization's ontology, any new information can be easily associated and compared with other information in the organization. Also, because the original information has been digitally signed, anyone looking at the information will have assurance of its validity. Besides, because author annotations are added and also digitally signed, there is convenient tracking of who found the information and their comments. Furthermore, because it is stored in a Web service, any software program can communicate with it using open standards. Nonetheless, what do all these technology-made conveniences mean for the social dimension of the Semantic Web installed inside an organization? It is no denial that organizational knowledge synthesis (or creation and transfer) is a social as well as an individual process (Nonaka, 2002). Sharing tacit knowledge requires individuals to share their personal beliefs about a situation with others. At that point of sharing, justification often becomes public. Each individual is faced with the tremendous challenge of justifying his or her beliefs in front of others—and it is this need for justification, explanation, persuasion and human connection that makes knowledge synthesis a highly dynamic as well as fragile process (Markova & Foppa, 1990; Vat, 2003). To bring personal knowledge into an organization, within which it can be amplified or further synthesized, it is necessary to have a field (Ichijo & Nonaka, 2007; Von Krogh, Ichijo, & Nonaka, 2000; Nonaka & Takeuchi, 1995) that provides a place in which individual perspectives are articulated, and conflicts are resolved in the formation of higher-level concepts. In the specific context of Semantic Web, this field of interaction is yet to be defined and engineered by the organization architect of the company, or of the organizational change management behind the Semantic Web. Principally, this field should facilitate the building of mutual trust among members of the organization, and accelerate the creation of some implicit perspective shared by members as a form of tacit knowledge. Then, this shared implicit perspective is conceptualized through continuous dialogue among members. It is a process in which one builds concepts in cooperation with others. It provides the opportunity for one's hypothesis or assumption to be tested. Typically, one has to justify the truthfulness of his or her beliefs based on his or her unique viewpoint, personal sensibility, and individual experience, sized up from the observations of any situation of interest. In fact, the creation of knowledge, from this angle, is not simply a compilation of facts but a uniquely human process that can hardly be reduced or easily replicated. Yet, justification must involve the evaluation standards for judging truthfulness, and there might also be value premises that transcend factual or pragmatic considerations before we arrive at the stage of cross-leveling any knowledge (Von Krogh, Ichijo, & Nonaka, 2000); namely, the concept that has been created and justified is integrated into the knowledge base of the organization. The key to understand the social dimension of the Semantic Web is to ask how it could support or facilitate knowledge sharing among individuals. Putting knowledge sharing (or rather conversation among individuals) to work means bringing the right people with the requisite knowledge together and motivating their online interaction. That way, they could work collaboratively to solve real and immediate problems for the organization. To reach that level of practical impact, there must be trust and commitment among the participants apart from software and online connectivity. In light of our discussion, that means leading and fostering the kind of organizational culture that motivates people to share what they know with their peers (co-workers) without a fear of being questioned, critiqued or put on the defense. In the specific context of this article, this culture of knowledge sharing which should be in the driver's seat for selecting and configuring the Semantic Web technologies for an organization, could be developed from the idea of appreciative inquiry (AI) (Cooperrider & Whitney, 2005).

THE GENERATIVE POTENTIAL OF APPRECIATIVE INQUIRY

The contributions behind the work of appreciative inquiry (AI), is mainly attributed to David L. Cooperrider's (1986) doctoral research at Case Western Reserve University. The context of AI is about the co-evolutionary search for the best in people, their organizations, and the relevant world around them. In its broadest focus, it involves systematic discovery of what gives life to a living system when it is most alive, most effective, and most constructively capable in economic, ecological, and human terms. Principally, AI involves the art and practice of asking questions that strengthen a system's capacity to apprehend, anticipate, and heighten positive potential. AI has been described in different ways since its publication: as a paradigm of conscious evolution geared for the realities of the new century (Hubbard, 1998); as a methodology that takes the idea of the social construction of reality to its positive extreme especially with its relational ways of knowing (Gergen, 1990); as the most important advance in action research in the last decade of the 20th century (Bushe, 1995); as offspring to Abraham Maslow's vision of a positive social science (Chin, 1998; Curran, 1991); as a powerful second generation practice of organizational development (Watkins & Cooperrider, 1996); as model of a much needed participatory science (Harman, 1990); as a radically affirmative approach to change which completely lets go of problem solving mode of management (White, 1996), and others as an approach to leadership and human development (Cooperrider & Whitney, 2005). In essence, AI is an attempt to determine the organization's core values (or life giving forces). It seeks to generate a collective image of a future by exploring the best of what is in order to provide an impetus for imagining what might be (Cooperrider & Srivastva, 1987). Positively, Thatchenkery and Chowdhry (2007, p.33) says it well, "To be appreciative, we must experience a situation, accept the situation, make sense of the situation (pros/cons), and do a bit of mental gymnastics to understand the situation, with an appreciative lens. Not only that, the appreciative lens that we put on the situation impacts our next experience as well." Indeed, the interpretive scheme we bring to a situation significantly influences what we will find. Seeing the world is always an act of judgment. We can take an appreciative judgment or a critical or deficit oriented judgment. AI takes the former. Geoffrey Vickers (1965, 1968, 1972), a professional manager turned social scientist, was the first to talk about appreciation in a systematic way. Vickers' main contribution is that of appreciation and the appreciative process which constitutes a system. An appreciative system may be that of an individual, group, or an organization. In explaining appreciation, Vickers used systems thinking (Checkland & Casar, 1986), which provided basic concepts to describe the circular human processes of perceiving, judging, and acting. Specifically, Vickers focused on five key elements of appreciation, including respectively: the experience of day-to-day life as a flux of interacting events and ideas; reality judgments about what goes in the present or moment and a value judgment about what ought to be good or bad, both of which are historically influenced; an insistence on relationship maintaining (or norm seeking) as a richer concept of human action than the popular notion of goal seeking; a concept of action judgments stemming from both reality and value judgments; and action, as a result of appreciation, contributing to the flux of events and ideas, as does the mental act of appreciation itself. This leads to the notion that the cycle of judgments and actions is organized as a system. Simply put, as humans, we are in a state of flux. We judge the events we experience based on our individual history. We make meaning based on the interactions with other humans to enrich our lives. Our judgments, relationships, and values dictate how we act in subsequent events. By framing our perceptions and judgments on appreciation, we can change our behavior. In the context of fostering a knowledge-centric culture for an organization including possibly various communities of practice (Wenger, 1998), we can change the way we hoard knowledge to a philosophy of sharing knowledge. Indeed, the basic rationale of AI is to begin with a grounded observation of the best of what is, articulate what might be, ensure the consent of those in the system to what should be, and collectively experiment with what can be.

VIRTUAL ORGANIZING IN SUPPORT OF APPRECIATIVE INQUIRY

The idea of virtual organizing, attributed to Venkatraman and Henderson (1998), can be considered as a method to operationalize the context of appreciative inquiry, dynamically assembling and disassembling nodes on a network of people or groups of people in an organization, to meet the demands of a particular business context. This term emerged in response to the concept of *virtual organization*, which appeared in the literature around the late twentieth century (Byrne, Brandt, & Port 1993; Cheng 1996; Davidow, & Malone 1992; Goldman, Nagel, & Preiss 1995; Hedberg, Dahlgren, Hansson, & Olve 1997; Mowshowitz, 1997). There are two main assertions associated with virtual organizing. First, virtual organization should not be considered as a distinct structure such as a network organization in an extreme and far-reaching form (Jagers, Jansen, & Steenbakkers 1998), but virtuality is a strategic characteristic applicable to every organization. Second, information technology (IT) (not excluding Semantic Web technologies) is a powerful enabler of the critical requirements for effective virtual organizing. In practice, virtual organizing helps emphasize the ongoing process nature of the organization, and it presents a framework of achieving virtuality in terms of three distinct yet interdependent vectors: virtual encounter for organization-wide interactions, virtual sourcing for asset configuration, and virtual expertise for knowledge leverage. The challenge of virtual organizing is to integrate the three hitherto separate vectors into an interoperable IT platform that supports and shapes any new organizational initiative, paying attention to the internal consistency across the three vectors.

Understanding the Three-Vector Framework

The first of the three vectors of virtual organizing deals with the new challenges and opportunities for interacting with the members of an organization. The second focuses on the organization's requirements to be virtually integrated in a network of interdependent (business) partners, so as to manage a dynamic portfolio of relationships to assemble and coordinate the necessary assets for delivering value for the organization. The third is concerned with the opportunities for leveraging diverse sources of expertise within and across organizational boundaries to become drivers of value creation and organizational effectiveness. All these three vectors are accomplished by the provision of suitable information system (IS) support, whose ongoing design represents the IS challenge of every organization in the Internet age.

- **Virtual Encounter:** This idea of providing remote interaction with the organization is not new, but has indeed been redefined since the introduction of the Internet, and particularly, the World Wide Web. Many an organization feels compelled to assess how its products and services can be experienced virtually in the new medium of the Internet. The issue of customization is important. It requires a continuous information exchange with parties of interest, which in turn requires an organizational design that is fundamentally committed to operating in this direction. Practically, organizations need to change from an inside-out perspective to an outside-in perspective. This is often characterized by the emergence of online customer communities, with the capacity to influence the organization's directions with a distinct focus. It is believed that with virtual organizing becoming widespread, organizations are increasingly recognizing communities as part of their value system and must respond appropriately in their strategies.
- **Virtual Sourcing:** This vector focuses on creating and deploying intellectual and

intangible assets for the organization in the form of a continuous reconfiguration of critical capabilities assembled through different relationships in the business network. The mission is to set up a resource network, in which the organization is part of a vibrant, dynamic network of complementary capabilities. The strategic leadership challenge is to orchestrate an organization's position in a dynamic, fast-changing resource network where the organization can carefully analyze her relative dependence on other players in the resource coalition and ensure her unique capabilities.

- **Virtual Expertise:** This vector focuses on the possibilities for leveraging expertise at different levels of the organization. In today's organizations, many tasks are being redefined and decomposed so that they can be done at different locations and time periods. However, the real challenge in maximizing work-unit expertise often rests not so much in designing the technological platform to support group work but in designing the organization structure and processes. The message is clear: knowledge lives in the human act of knowing, and it is an accumulation of experience that is more a living process than a static body of information; so, knowledge must be systematically nurtured and managed. In effect, organizations are increasingly leveraging the expertise not only from the domain of a local organization but also from the extended network (Figallo & Rhine, 2002) of broader professional community.

Adapting the Three-Vectors to an Appreciative Knowledge Environment

What makes managing knowledge through the Semantic Web a challenge is that knowledge comes often not as an object that can be stored, owned, and moved around like a piece of equipment or a document. It resides in the skills, understanding, and relationships of its members as well as in the tools and processes that embody aspects of this knowledge. In order for knowledge sharing within an organization to be successful, it is convinced that the people involved must be excited about the process of sharing knowledge. For many people, the primary reason for knowledge sharing is not that they expect to be repaid in the form of other knowledge, but the conviction that their individual knowledge is worth knowing, and that sharing this knowledge with others will be beneficial to their reputation (van den Hoof et al., 2004, p.1). There is some psychological benefit to sharing knowledge as the sharer may be held in higher esteem by the receiver(s) of the knowledge and may gain status as a result. Thereby, an appreciative sharing of knowledge must be viewed as the non-threatening and accepting approach that makes people realize what they do can make a difference. One common example is the communities of practice (CoP) (Wenger, McDermott, & Snyder, 2002) (be it physical or online) mentioned earlier. Many organizations today are comprised of a network of interconnected communities of practice each dealing with specific aspects such as the uniqueness of a long-standing client, or technical inventions. Knowledge is created, shared, organized, revised, and passed on within and among these communities. In a deep sense, it is by these communities that knowledge is owned in practice. Yet, knowledge exists not just at the core of an organization, but on its peripheries as well (as part of the knowledge network) (Tsoukas, 1996; Figallo & Rhine, 2002). So, communities of practice truly become organizational assets when their core and their boundaries are active in complementary ways, to generate an intentionally appreciative climate for organizational knowledge synthesis. In response to the knowledge challenge in a knowledge-centric organization, it is useful to conceive of an appreciative knowledge environment (AKE) based on virtual organizing, and experiment with how the ideas of its three vectors can be applied to nurture online the growth of different communities of practice (Wenger, 1998) scattered throughout an organization.

- **Virtual Encountering the AKE:** From a management perspective, it is important to identify what CoP's currently exist in the organization, and how, if they are not already online, to enable them to be online in order to provide more chances of virtual encounter of such communities, to the organizational members. For those communities already online, it is also important to design opportunities of interaction among different online communities, to activate their knowledge sharing. Since it is not a CoP's practice to reduce knowledge to an object, what counts as knowledge is often produced through a process of communal involvement, which includes all the controversies, debate and accommodations. This collective character of knowledge construction is best supported online with individuals given suitable IS support to participate and contribute their own ideas. An IS subsystem, operated through virtual encounter, must help achieve many of the primary tasks of a community of practice, such as establishing a common baseline of knowledge and standardizing what is well understood so that people in a specific community can focus their creative energies on the more advanced issues.
- **Virtual Sourcing the AKE:** From the discussion built up in the first vector, it is not difficult to visualize the importance of identifying the specific expertise of each potential CoP in the organization, and if not yet available, planning for its acquisition through a purposeful nurture of expertise in various specific CoP's. In order to enable an organization to be part of a vibrant, dynamic network of complementary capabilities, in which the same organization could claim others' dependence and ensure her unique capabilities, an IS subsystem, operated through virtual sourcing, must help the organization understand precisely what knowledge will give it the competitive edge. The organization then needs to acquire this knowledge, keep it on the cutting edge, deploy it, leverage it in operations, and steward it across the organization.
- **Virtual Expertizing the AKE:** It is important to understand that not everything we know can be codified as documents and tools. Sharing tacit knowledge requires interaction and informal learning processes such as storytelling, conversation, coaching, and apprenticeship. The tacit aspects of knowledge often consist of embodied expertise—a deep understanding of complex, interdependent elements that enables dynamic responses to context-specific problems. This type of knowledge is very difficult to replicate. In order to leverage such knowledge, an IS subsystem, operated through virtual expertise, must help hooking people with related expertise into various networks of specialists, to facilitate stewarding such knowledge to the rest of the organization.

FUTURE TREND OF THE SEMANTIC WEB

The future of the Semantic Web must not be seen only from its technological possibilities, but also from its social dimension to operationalize knowledge sharing among members of the organization (Argyris, 1993). In order to facilitate the stewarding of knowledge through the various online communities of practice in an organization, it is important to have a vision that orients the kind of knowledge an organization must acquire, and wins spontaneous commitment by the individuals and groups involved in knowledge creation (Dierkes, Marz, and Teele, 2001; Kim, 1993; Stopford, 2001). This knowledge vision should not only define what kind of knowledge the organization should create in what domains, but also help determine how an organization and its knowledge base will evolve in the long run (Leonard-Barton, 1995; Nonaka & Takeuchi, 1995). The central requirement for organizational knowledge synthesis (or sharing) is to provide the organization with a strategic ability to acquire, create, exploit, and accumulate new knowledge continuously and repeatedly. To meet this requirement, we need an interpretation framework, which could facilitate the development of this strategic ability through the various communities. It is believed that there are at least three major appreciative processes constituting the interpretation framework of a knowledge-centric organization, including the personal process, the social process, and the organizational process. What follows is our appreciation of these three important processes (Checkland & Holwell, 1998, pp.98-109; Checkland, & Casar, 1986) considered as indispensable in the daily operations of the organization with the Semantic Web capability. Of particular interest here is the idea of providing meta-data support for various appreciative settings, which according to Vickers (1972, p.98), refer to the body of linked connotations of personal interest, discrimination and valuation which we bring to the exercise of judgment and which tacitly determine what we shall notice, how we shall discriminate situations from the general confusion of ongoing event, and how we shall regard them.

- **The Personal Process:** Consider us as individuals each conscious of the world outside our physical boundaries. This consciousness means that we can think about the world in different ways, relate these concepts to our experience of the world and so form judgments which can affect our intentions and, ultimately, our actions. This line of thought suggests a basic model for the active human agent in the world. In this model we are able to perceive parts of the world, attribute meanings to what we perceive, make judgments about our perceptions, form intentions to take particular actions, and carry out those actions. These change the perceived world, however slightly, so that the process begins again, becoming a cycle. In fact, this simple model requires some elaborations. First, we always selectively perceive parts of the world, as a result of our interests and previous history. Secondly, the act of attributing meaning and making judgments implies the existence of standards against which comparisons can be made. Thirdly, the source of standards, for which there is normally no ultimate authority, can only be the previous history of the very process we are describing, and the standards will themselves often change over time as new experience accumulates. This is the process model for the active human agents in the world of individual learning, through their individual appreciative settings. This model has to allow for the visions and actions, which ultimately belong to an autonomous individual, even though there may be great pressure to conform to the perceptions, meaning attributions and judgments, which belong to the social environment, which, in our discussion, is the community of practice.
- **The Social Process:** Although each human being retains at least the potential selectively to perceive and interpret the world in their own unique way, the norm for a social being is that our perceptions of the world, our meaning attributions and our judgments of it will all be strongly conditioned by our exchanges with others. The most obvious characteristic of group life is the never-ending dialogue, discussion, debate and discourse in which we all try to affect one another's perceptions, judgments, intentions and actions. This means that we can assume that while the personal process model continues to apply to the individual, the social situation will be that much of the process will be carried

out inter-subjectively in discourse among individuals, the purpose of which is to affect the thinking and actions of at least one other party. As a result of the discourse that ensues, accommodations may be reached which lead to action being taken. Consequently, this model of the social process which leads to purposeful or intentional action, then, is one in which appreciative settings lead to particular features of situations as well as the situations themselves, being noticed and judged in specific ways by standards built up from previous experience. Meanwhile, the standards by which judgments are made may well be changed through time as our personal and social history unfolds. There is no permanent social reality except at the broadest possible level, immune from the events and ideas, which, in the normal social process, continually change it.

- **The Organizational Process:** Our personal appreciative settings may well be unique since we all have a unique experience of the world, but oftentimes these settings will overlap with those of people with whom we are closely associated or who have had similar experiences. Tellingly, appreciative settings may be attributed to a group of people, including members of a community, or the larger organization as a whole, even though we must remember that there will hardly be complete congruence between the individual and the group settings. It would also be naïve to assume that all members of an organization share the same settings, those that lead them unambiguously to collaborate together in pursuit of collective goals. The reality is that though the idea of the attributed appreciative settings of an organization as a whole is a usable concept, the content of those settings, whatever attributions are made, will never be completely static. Changes both internal and external to the organization will change individual and group perceptions and judgments, leading to new accommodations related to evolving intentions and purposes. Subsequently, the organizational process will be one in which the data-rich world outside is perceived selectively by individuals and by groups of individuals. The selectivity will be the result of our predispositions to "select, amplify, reject, attenuate or distort" (Land, 1985, p.212) because of previous experience, and individuals will interact with the world not only as individuals but also through their simultaneous membership of multiple groups, some formally organized, some informal. Perceptions will be exchanged, shared, challenged, and argued over, in a discourse, which will consist of the inter-subjective creation of selected data and meanings. Those meanings will create information and knowledge which will lead to accommodations being made, intentions being formed and purposeful action undertaken. Both the thinking and the action will change the perceived world, and may change the appreciative settings that filter our perceptions. This organizational process is a cyclic one and it is a process of continuous learning, and should be richer if more people take part in it. And it should fit into the context of the appreciative knowledge environment scenario.

REMARKS OF CHALLENGE FOR KNOWLEDGE-CENTRIC ORGANIZATIONS

Earlier in the manuscript, we have associated the social context of Semantic Web to that of a knowledge-centric organization, and the appreciative importance of communities of practice (CoP) online. In this regard, there is an active role such communities can play in enabling the organization to learn from the experience of its members. Traditional organization (hierarchical) structures are designed to control activities and often discourage the easy sharing of knowledge and learning. Communities, nonetheless, help to foster relationships based on mutual trust, which are the unspoken and often unrecognized channels through which knowledge is shared. In fact, CoPs have profound implications for the management of knowledge work. They highlight the limits of management control in that CoPs are voluntary entities, depending entirely on the interest and commitment of their members. They cannot be designed or imposed in a top-down manner. Knowledge does not circulate through them in any officially prescribed form or procedures. Rather knowledge exchange through suitable means such as stories, jokes and anecdotes which serve to enliven and enhance a shared learning experience, has become important under the following contexts:

- **Perceiving the importance of story-telling:** It is not difficult to understand why story-telling has become a more important way of communicating knowledge than codifying it using specific IS/IT systems (Brown & Duguid, 1991): Firstly, stories present information in an interesting way with a beginning, a body, and an end, as well as people behaving goodly or badly. Secondly, stories present information in a way people can empathize with—recounting a situation which each of us might face, so it has greater perceived relevance. Thirdly, stories personalize the information—instead of talking about the situations in the abstract, we hear about the doings of individuals whom we might know or have heard of. Fourthly, stories bring people together, emphasizing a shared social identity and interests—we share knowledge rather than transfer it. More, stories express values—they often contain a moral about certain kinds of behavior leading to either positive or negative outcomes. In this way, stories link information with interest, values and relevance, giving us a sense of the context in which experience has been developed and helping us to grasp the tacit nature of some of the knowledge being communicated.
- **Understanding the nature of community knowing:** Perceptively, the importance of story-telling also provides an insight into the limits of technology for managing knowledge. Often, the design of IS/IT systems is based on a cognitive model of seeing knowledge as a "thing" (Malhortra, 2000) which is possessed by individuals, whereas the CoPs see it as the product of social interaction and learning among members of the same. By being a member of a community, individuals are able to develop their practice, sharing experience and ideas with others involved in the same pursuit. In light of this, the essence of understanding the social dimensions of managing knowledge work through the Semantic Web comes down to a few key points about the nature of knowing (Nonaka and Takeuchi, 1995; O'Leary, 1998; Wenger, 1998; Wenger et al., 2002):
    - **Knowledge lives in the human act of knowing:** In many instances of our daily living, our knowledge can hardly be reduced to an object that can be packaged for storage and retrieval. Our knowledge is often an accumulation of experience—a kind of residue of our actions, thinking, and conversations—that remains a dynamic part of our ongoing experience. This type of knowledge is much more a living process than a static body of information.
    - **Knowledge is tacit as well as explicit:** Not everything we know can be codified as explicit knowledge such as documents or tools. Sharing tacit knowledge requires interaction and informal learning processes which often involve a deep understanding of complex, interdependent elements that enables dynamic responses to context-specific

problems, even though it is very difficult to document such knowledge in whatever manner serves the needs of practitioners.

- **Knowledge is dynamic, social as well as individual:** It is important to accept that though our experience of knowing is individual, knowledge is not. Appreciating the collective nature of knowledge is especially important in an age when almost every field changes too much, too fast for individuals to master. Today's complex problems solving requires multiple perspectives. We need others to complement and develop our own expertise. In fact, our collective knowledge of any field is changing at an accelerating rate. What was true yesterday must be adapted to accommodate new factors, new data, new inventions, and new problems.

- **Positioning an appropriate appreciation for the Semantic Web:** The move to Semantic Web has been developing rapidly over the last decade, and has attracted a lot of attention in the development of different demonstration projects (Davies, Studer, & Warren, 2006) that can serve as reference implementations for future developers. Yet, what makes managing knowledge work through the Semantic Web a challenge is that today many an organization has come to the realization that unless knowledge is owned by people to whom it matters, it will not be developed, used, and kept up to date optimally. Knowledge is not a thing that can be managed at a distance like in an inventory. It is part of the shared practice of communities that need it, create it, use it, debate it, distribute it, adapt it, and transform it. As the property of a community, knowledge is not static; it involves interactions, conversations, actions, and inventions. Thereby, networking knowledge in a virtual community of practice is not primarily a technological challenge, but one of community development. Addressing the kind of dynamic knowing that makes a difference in practice requires the participation of people who are fully engaged in the process of creating, refining, communicating, and using knowledge. The thrust to develop, organize, and communicate knowledge must come from those who will use it. What matters is not how much knowledge can be captured, but how documenting can support people's abilities to know and to learn when the community itself becomes the living repository of people's knowledge. The Semantic Web works best when it is used to connect communities, not just to capture or transfer knowledge. Because much knowledge is embedded in particular communities, developing a shared understanding and a degree of trust is often the most critical step towards knowledge sharing in an organization. The use of Semantic Web technologies can complement but not replace the importance of social networks in this aspect (DiSessa & Minstrell, 1998). Indeed, the Semantic Web can support the development of new communities of practice through problem-solving interactions that allow individuals to appreciate the different perspectives which others bring to their work. Specifically, the Semantic Web can sustain the development of communities by allowing them to develop and exchange shared cultural objects of interest, such as texts, stories, and images, which help reinforce the meaning and purpose of the communities (Bodker, 1991). From a knowledge-building perspective (Bajjaly, 1999; Cohill & Kavanaugh, 1997), the design of Semantic Web must be based on understanding such concerns as: communities must be viewed as supporting networks of personal relationships in which people can collaboratively construct understanding to enable the exchange of resources and the development of a common framework for the analysis and evaluation of such resources.

Thereby, it is important to consider how different strategies of the Semantic Web implementation can progressively involve individual members by helping them become resources for other community members.

- **Managing the knowledge-centric resources:** In 1969, Peter Drucker emphasized that knowledge had become the crucial resource of the economy. He claims the credit for coining the notion of 'knowledge work', which he contrasted with more traditional forms of work such as service work and manual work. Today, the term 'knowledge work' tends to refer to specific occupations which are "characterized by an emphasis on theoretical knowledge, creativity and use of analytical and social skills" (Frenkel et al., 1995, p.773). Knowledge work, interpreted this way, encompasses both what is traditionally referred to as professional work, such as accountancy, scientific and legal work, and more contemporary types of work, such as consultancy, software development, advertising and public relations. Understandably, these types of knowledge work are not susceptible to be easily imitated because there is a significant application of both tacit and explicit knowledge (Nonaka, 1994). Those engaged in these types of work are often individuals with high levels of education and specialist skills, who demand autonomy over their work processes to get the job done; namely, to demonstrate their ability to apply those skills to identify and solve problems. What is significant about these types of knowledge workers is that they own the organization's primary means of production—that is, knowledge. Nowadays, with the advent of the Semantic Web, we are ready to construct knowledge portfolio (Birchall & Tovstiga, 2002; Dove, 1999) for the organization, to track the knowledge contributions of individual knowledge workers, and different grouping of the same in the form of group-based project work. The management of knowledge workers assumes greater importance for sustaining productivity than the management of machines, technologies, or work processes. Like musicians, Drucker (1988) sees such employees exploring outlets for their creative abilities, seeking interesting challenges, enjoying the stimulation of working with other specialists. This, he argues, poses new management challenges in knowledge-centric organizations: developing rewards, recognition and career opportunities; giving an organization of specialists a common vision; devising a management structure for coordinating tasks and task teams; and ensuring the supply and skills of top management people.

CONCLUSION

Finally, in closing our discussion, it is essential to articulate the promise of appreciative inquiry (AI) (Reed, 2007; Lewis, Passmore, & Cantore, 2008) for a knowledge-centric organization. In the broadest sense, the major theme of appreciative knowledge sharing in and among virtual communities of practice (Hoadley & Pea, 2002) could be understood from the perspective of effectively applying information and communications technologies, ICT (including the Semantic Web technologies) to improve the lives of people (organizational members), in terms of getting knowledge to those of a community who need it in the right time. Of much concern here is an effort to theorize the social dimensions of this ICT-based knowledge sharing. In the words of David Hakken (2002, p.362), we have to ask "what kinds of theorizations make sense in analyzing what happens when a concerted effort is made to introduce a technology supportive of knowledge sharing in a 'holistic' way—that is, to try to anticipate and address the social context/consequences of the interventions." In simpler terms, we can describe

AI as an exciting philosophy for change. The major assumption of AI is that in every organization something works and change can be managed through the identification of what works, and the analysis of how to do more of what works. A key characteristic of AI is that it is a generative process. That means it is a moving target, and is created and constantly re-created by the people who use it. While the electronic stewarding of knowledge in an online community is based upon the Semantic Web technologies, its success rests with its people (Linn, 2000)—organizers, information and knowledge providers, sponsors, users, volunteers—who support the organization (comprising various CoPs) in a variety of ways. Therefore, when attempting to design technology in support of a knowledge-centric organization, it is important to remember "what is working around here?" in the organization. The tangible result of the appreciative inquiry process should be a series of vision statements that describe where the organization wants to be, based on the high moments of where they have been. Because the statements are grounded in real experience and history, it is convinced that people in the organization know how to repeat their success. In retrospect, think about a time when you shared something that you knew that enabled you or your company to do something better or achieve success. What happened? Share your story. Such activities include not only information capture and transmission, but also the establishment of social relationships in which people can collaboratively construct understanding. It is this energy that distinguishes AI's generative potential that presumably has no end because it is a living process. And it is quite promising for any knowledge-centric organization pursing the Semantic Web technologies.

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KEY TERMS AND DEFINITIONS

Appreciative Inquiry (AI): Appreciative Inquiry is about the co-evolutionary search for the best in people, their organizations, and the relevant world around them. In its broadest focus, it involves systematic discovery of what gives "life" to a living system when it is most alive, most effective, and most constructively capable in economic, ecological, and human terms.

Appreciative Processes: These are processes to leverage the collective individual learning of an organization such as a group of people, to produce a higher-level organization-wide intellectual asset. This is supposed to be a continuous process of creating, acquiring, and transferring knowledge accompanied by a possible modification of behavior to reflect new knowledge and insight, and to produce a higher-level intellectual content.

Appreciative Settings: A body of linked connotations of personal or collective interest, discrimination and valuation which we bring to the exercise of judgment and which tacitly determine what we shall notice, how we shall discriminate situations of concern from the general confusion of ongoing event, and how we shall regard them.

Appreciative Knowledge Environment (AKE): A work, research or learning environment to incorporate the philosophy of appreciative inquiry in support of a cultural practice of knowledge sharing among organizational members.

Community of Practice (CoP): These are people who come together around common interests and expertise. They create, share, and apply knowledge within and across the boundaries of teams, business units, and even entire organizations—providing a concrete path toward creating a true knowledge organization.

Knowledge-Centric Organization: Any organization whose knowledge focus is to provide mechanisms for building the knowledge base of the firm to better apply, share, and manage knowledge resources across various components in the company.

Semantic Web: The Semantic Web is an evolving extension of the World Wide Web in which the semantics of information and services on the web is defined, making it possible for the web to understand and satisfy the requests of people and machines to use the Web content. It derives from W3C director Tim Berners-Lee's vision of the Web as a universal medium for data, information, and knowledge exchange.

Virtual Organizing: A method to operationlize the context of appreciative inquiry, with the technology-enabled capability to assemble and disassemble nodes on a network of people or groups of people in an organization, to meet the demands of a particular business context. In virtual organizing, virtuality is a strategic characteristic applicable to every organization.

Chapter XXII
Online Virtual Communities as a New Form of Social Relations:
Elements for the Analysis

Almudena Moreno Mínguez
Universidad de Valladolid, Spain

Carolina Suárez Hernán
IE Universidad, Spain

ABSTRACT

The generalization of the new information technologies has favored the transformation of social structures and the way of relating to others. In this changing process, the logic of the social relationships is characterized by the fragility and the temporality of the communicative systems reciprocity which are established "online" in a new cybernetic culture. "Virtual communities" are created in which the interaction systems established by individuals exceed the traditional categories of time and space. In this manner the individuals create online social webs where they connect and disconnect themselves based on their needs or wishes. The new online communication technologies favor the rigid norms of the "solid society" that dilute in flexible referential contexts and reversible in the context of the "global and liquid society" to which the sociologists Bauman or Beck have referred to. Therefore the objective that the authors propose in this chapter is to try new theoretic tools, from the paradigms of the new sociology of technology, which let them analyze the new relational and cultural processes which are being generated in the cultural context of the information global society, as a consequence of the new communication technologies scope. Definitely the authors propose to analyze the meaning of concepts such as "virtual community", "cyber culture", or "contacted individualism", as well as the meaning and extent of some of the new social and individual behaviors which are maintained in the Net society.

TOWARDS A MEANING OF "VIRTUAL COMMUNITY": A NEW STUDY OBJECT IN THE INFORMATION SOCIETY

The social dimension is one of the natural attributes of the human being, which must be understood as an individual person in interaction with a relational environment. Group, communities and culture are concepts which approach us to the man study in its complex network of social interaction as a social system. In this sense the plural evolution and interaction of the communities and the institutions as well as the forms of social relations and communication have shaped the history of humanity.

The community has been defined as a study object and subject from varied approaches, which comprise from the primitive forms of social association to the complex relationships of the post-industrial society in which the concept "virtual community" has emerged.

From the sociological point of view, community is a concept with a polysemous value, but as a global idea it responds to the anthropologic imperative of the social encounter and the need to create a sense and give shape to the human society. A possession feeling consolidates in it, understood as a psychological community feeling, in which one feels oneself as an active group member, which is decisive for the individuals own identity. Likewise, the feeling of a participation conscience and the link to a common territory are fundamental aspects (Gurrutxaga, 1991) (Pons Díez, J.; Gil Lacruz, M; Grande Gascón, J.M., 1996). The community is a network of social links, that can be based on a territory (a city), on common interests (associations, clubs) on similar characteristics of the individuals (Bar Association) or on an online platform (blogs, etc). Definitely, the community is an analytical category which defines human interaction as a constituent of the social reality, redimensioning the individual as a socialized person in a specific group, with social and symbolic representations and cultural values. Besides a social and anthropological approximation, we can consider the community as a context of action which contributes to the generation of realities based on symbolic truss.

The globalization and informationalization process has generated the transformation of our societies, including the space dimension. In such transformation the new space logic is characterized by the domination of a flow space, structured in electronic circuits that link themselves in the strategic nodes of production and management, which exceeds a space of places locally fragmented and the territorial structure as a way of daily organization. This new dimension takes us towards a Global City, understood as a "net of urban nodes of different levels and different functions, spreading all over the planet and that functions as the nervous center of Informational Economy. It is an interactive system to which companies, citizens and cities have to adapt themselves constantly. "(Castells, 1997: 2).

The Information Technologies are the fundamental instrument that allows the new logic of the social relationships to demonstrate themselves in reality. In them, Internet constitutes one of the most outstanding cases of the growing technological environment whose result has been the step from the Industrial Society to the Information Society (Cornella, 1997).

In the full expansion of Internet, the virtual communities are becoming a new social relationship format where the different communities turn to it to satisfy expectations and needs, to contribute its collaboration and to feel themselves as part of a great community. Unlike the Traditional Community, these impersonal spaces are characterized by the anonymity and the lack of human contact. These new relationship forms are giving way to a media society produced by a change of the social rules, by the capacity of transmitting ideology or by inducing behavior; definitely, by the generalization of a mass culture extensible to all social classes and communities. This turned Internet into a virtual community as means to unify the communications (Sánchez Noriega, 1997).

The first Virtual Communities were based mainly on the simple commerce or the sale of products through the Network, or on a web site where the users could place their personal webs freely. The current Virtual Community was born in this way, whose philosophy is based mainly on the leisure and recreation field, though it houses cultural societies or with certain scientific level: *Geocities*[1]. But the origin of these cyberspace centers is determined by the scientific communities that before the beginning of Internet formed a group and interchanged information (Cantolla, 2000). In 1985, the first Virtual Community of the history arose, *The Well*[2], created by a group of ecologists that "met" to debate about their issues.

Within the Network, new communication forms appear promoted by the use of the electronic mail, but the information exchange among the members was not immediate (deferred communication). Later, with the arrival of the World Wide Web as a hypermedia system that works on Internet, the communication is produced in real time, coming up the interactivity.

This new communication form obliges to distinguish between the Traditional Real Community and the Virtual Community (Iparraguirre, 1998).

Traditional Real Community

- Physical and temporal space for everyone.
- It is developed in the Real Society where the space-time nations and physical encounter determine its behavior and is limited by the territory.
- It is the material support of the Virtual Community.

Online Virtual Community

- The physical and temporal space is not a limitation any more.
- It is developed in the Virtual Society, the cyberspace territory, where there are no frontiers and is planetary.
- It appears when a Real Community uses the telematics to keep and widen the communication.

The breakage of the space-time barriers through the use of the new technologies allowed the development of numerous Virtual Communities. The permanence on the Network depends on basic elements such as the interactivity time and the emotional component among the members that form part of it, what refers us to the traditional sociability forms.

In order to understand the concept of "virtual community" properly one has to get back to the original concept of "community". For the sociologist Tönnies (1986:97-98), the concept of community (Gemeinschaft) (Community) is the stage on which the modern industrial society settles down (Gesellschaft) (Society). The community is characterized by the sort of relationships that prevail in it (based on the family, the homeland and the blood). He defines the community as a sort of social interaction in the emotional identification: he refers to the reciprocity that arises from sharing bonds based on the family, race or blood. The communication will is in the basis of this relationship which gives place to the social action. Therefore, for Tönnies, the community has its original root in the feelings. This definition is useful to refer to the community as a space of feelings and communication. Likewise, the members of a group share specific meanings and a collective vision that come forth from the shared experiences and that generates an own jargon at the end. (Prat, 2006: 29).

The sociological tradition considered the community as a group of persons who, besides exhibiting the social groups characteristics, has a territorial basis or a geographic territory that serves as seat. The first conceptualizations about the communities were carried out on the basis of territorial communities where a person could spend the whole life, as they were relatively self-sufficient. A city, a town, a village, a neighborhood constitute examples regarding this community concept. Under this concept it is present the idea that considers that the community implies more close bonds among the members that the ones existing among the members of a larger society (Gesellschaft) (Society). A so called "communitarian feeling" exists among the members of a community.

However, nowadays, the use of the community concept is quite different according to the contexts and is used at present in a more varied and wide form. It is even tended to name community to groups that are not but conglomerates or social categories. Due to the urban sprawl, the social groups, the communities among them, went beyond the territorial frontiers. Those who emphasized the non territorial nature of the modern communities were the sociologists specialized in the analysis of the socials networks. (Scott, 1994; Wasserman and Faust, 1995). Besides studying the attributes of the group members, the sociologists of social networks analyze the relationships that are produced among them, their objective, intensity, quality as well as the structure and dynamic that arise from them. Wellman and Gulia, for example, have studied communities whose relations network goes beyond their geographic frontiers. Besides, these relationships tend to specialize being contextualized and not globalized at the same time; i.e. a person is related to other persons not in a total and integral manner but in certain specific contexts and will establish relationships with other persons if the context and objective of said relationship are different. According to Wellman and Gulia, the relationship network in which a person takes part might comprise a group of persons that are very far away in the geographic space and besides show time variations. This tendency is confirmed even more now in the cyberspace, where the sociability capacity of the persons is strengthened and creates the possibility of a new sociability manner among them. Wellman and Gulia have demonstrated that the virtual communities are also communities, although their members might not have physical nearness, similar bonds to the ones of the territorial communities are developed among them (Wellman, 1999). Definitely, the concept of virtual community seems to have its origin in the traditional concept of community and is clearly linked with the concepts of communication and socialization.

In fact, the Web allows now to integrate also communication functions and so the virtual communities arose which have a web site as coordination centre both of information and communication reservoirs. The web site became the "territory" of a virtual community. A non geographic territory as the communities studied by the sociologists during a social development stage, but an electronic territory, distributed in the new space that we call "cyberspace". Likewise, there are computer programs specialized in the construction and management of virtual communities, but, what is really a virtual community?

Howard Rheingold, to whom the term "virtual community" has been attributed, in his book, *The Virtual Community*, which became a classic work of literature about the cyberspace, defines the virtual communities as "… social aggregations that arise from the network when a sufficient quantity of persons enter into public discussions during a long enough period of time, with sufficient human feeling, to form networks of personal relationships in the cyberspace" (Rheingold, 1993: 5). We find three basic elements under this definition: the interactivity, the emotional component and the interactivity time, as conditions for a virtual community to exist and they are related to some of the characteristics of the communities in general.

According to Michael Powers, a virtual community is "an electronic place where a group of persons meet to interchange ideas in a regular manner … It is an extension of our daily life where we meet our friends, work mates and neighbors, at the park, at work or at the communitarian center". A more technical definition would be: "... a group of persons that communicate through a network of distributed computers, … (the group) meets at an electronic locality, usually defined by a server software, while the customer software manages the information interchanges among the group members. All the members know the addresses of said localities and invest sufficient time in them in order to be considered a virtual community" (Powers, 1998: 3). The sociological concept of community as inclusive social group, with a territorial basis, is recreated in the virtual community, but the territory of the later is virtual and not geographic. The community does not occupy a space in the physical world but in cyberspace.

However, the essence of all these communities does not lie in the nature of the CMC (computer-mediated communication) that structures them, but in the fact that they are integrated by real individuals, flesh and blood and who for the sake to be included in the community, adopt a form of "online person"; a virtual identity that represents the self of the individual before the other, the totality of the social environment in which the individual is immersed (Turkle, 1995). Therefore, in order to understand the phenomenon reality it will always be necessary to take into account the dialectic of the self/other (identity/otherness), as the description of the virtual communities will always be connected to the recognition that they only exist when several individuals experience it as such, which refers us to the traditional concept of socialization once more.

Definitely, the social investigation about the virtual communities poses several serious queries on its relationship with the "real life" communities. Among them: what is lacking from the real communities for the human being to satisfy the social needs "virtually" through Internet? Do the virtual communities represent the beginning of the real communities' deterioration? Or simply, do they represent a new way of understanding and living the social relationships?

The theoretical and empirical works performed by the science and technology sociology have not been able so far to give an answer to said queries. During the last years, these studies became an alternative and useful theoretical, conceptual and methodological framework, in order to think about the analysis of the technical innovations and the incidence in the relationships and social behaviors, though the CMC technologies, or Internet itself, have not become yet a widely extended focus of attention among these investigators. In fact, it deals with the everlasting forgotten of the social sciences.

In order to reply to these queries in a general manner, we will adopt the theoretical paradigms of authors like Bauman, Beck or Castells to seize how the human needs of belonging to a community enlarge and adapt themselves in a relational and cultural environment, much more flexible with the advent of the new communication technologies. However, this interactive process that suggests new socialization and endoculturation forms is not exempt of contradictions, as the freedom and autonomy that allow the online communications generate certain frustrations regarding that innate human wish of belonging to an everlasting relational community. This has been named as the ambivalence of the new "connected individualism".

THE NEW SOCIAL/RELATIONAL AND CULTURAL DIMENSION OF THE "VIRTUAL COMMUNITIES"

The itinerary of the new communication technologies is closely entwined with the social and cultural changes as well as with the languages and narrative transformation. New concepts arise in order to seize new relational models as result of the convergence of these changes. One of these concepts that define the "information society", "network society" or the "connected society" is the "cyber-culture".

The investigation about the cyber-cultures started recently due to the accelerated advent process of the technological society. Bauman had already warned in the 90´ that it was necessary to break the individual-technology dichotomy and work on the reality/virtuality ambivalence as human product (Bauman, 1990). Therefore, it is essential to integrate the technology to the social and cultural environment (Feenberg, 1999), with the aim of knowing the dimensions plurality that characterize our existence in the information society.

In fact, the cyber-culture, understood as a set of social-technical-cultural systems that take place at the cyberspace (Lévy, 2007: XV), starts transforming the beliefs and speeches of the cybernauts through constant leaps and interactions between the "interface" and the "real world". The online practices start in this way to overwhelm the virtuality and to burst in the reality of the individuals beyond what has been imagined.

The transformations that we are witnessing in these stages of *attitudinal zapping* between the virtual and the real are configuring new ideas of the "being" and new expressions and representation manners of the individual and the community online.

Internet, more than a communication technology, constitutes itself in a par excellence representation technology of the new century. The initial fictional construction of the self is being replaced there by the reconstruction and recognition of the individual in the virtual practices.

The new forms of symbolical representation that are emerging from the Internet virtual space are giving place to new ways of privacy, personal and collective identity and, in brief, to new social relationships as manifests the use of spaces or virtual communities such as Youtube, Myspace, Hi5 or Facebook. Therefore the virtual and the real should not be understood as two opposed categories as the digital culture is, to a great extent, an extension of the culture concept, where the virtual really suggests "another" experience and another analysis of the real that compels us to a better understanding of the bonds and cores that link the realities and the appearances, the illusions and the symptoms, the images and the models. The virtual does not replace the real but it represents it; it is a laboratory of ontological experimentation that compels us to give up the support of the appearances and turns us hunters of the real in forests of symbols (Quéau, 1995: 79).

Therefore, we consider that it is not possible to separate technology, culture and society as autonomous and independent actors, as this would mean to understand the human independently from the material environment and the signs and images that give sense to life and world. "Therefore, the material world and less its artificial part of the ideas cannot be separated through the ideas with which the technical objects are harbored and used, nor from the human beings that invent them, produce them and use them" (Lévy, 2007: 6). The line that divides the real worlds from the virtual realities tends to blur with the progress of the simulation capacities that offer us the technology and its corresponding appropriation by the individuals, provoking new ideas and offering spaces to new experiences that would not be possible without the technological progress. In this sense to define the so called "cyber-culture" implies to understand how certain practices have been naturalized in the popular culture through the symbolic representation and the new communication forms that the individuals experience through the "virtual communities". Indeed and as Turkle points out, the computers by themselves would not have any value without the cultural representations and relationships which take place with the use the individuals make of them: "The computers would not be turning into powerful cultural objects if the people would not fall in love with his machines and with the ideas that the machines entail" (Turkle, 1997: 63).

One of the features that define the new social and communicative relationships that take place in the cyberspace cyber-culture is the simulation and the anonymity. Not everything in the cyberspace is simulation; however, the interfaces have caused the anonymity adoption from the beginning and the possibilities of constructing fictional personalities. The level of anonymity has a very important influence on our behavior as it leads to the lack of inhibitions or relaxation of the normal limits that the society imposes on us. Likewise, the anonymity becomes vital at the moment of experiencing on Internet with our personality; the falseness sensation gets lost and the adventure and exploration sensation is acquired. Therefore, it is interested to know what one feels while playing with the identity, experience different roles and see how the others react. This process changes the traditional sense of "role", "community" or "group" concepts defined by Durkheim, Weber or Mead in the classical sociology. In fact, the physical distance and the few social presence existing in the "virtual communities" make us feel less inhibited, safe from being discovered and less subdued to the command of our superego and the social structures.

Goffman referred to this process with the denomination "game information". From this definition we could say that the relationships in the network constitute a potentially infinite cycle of occultations, discoveries, false disclosures and rediscoveries through which we devote great efforts to produce and sophisticate the image we want to give to others without them knowing how much effort it requires (Goffman, 1959). On the Internet, the game information is much more flexible due to the opacity of the environment and due to the possibility of changing the interface if the game does not run well. The chats and forums offered the first experimentation windows at the beginning of the Network. Nowadays, with the development of the web 2.0, the new MUD as Second Life became the benchmarks in the role games and, therefore, the anonymity in the cyberspace.

This game information that enables Internet generated a new communitarian social idea through the socialization processes that are produced in the "cyber-culture". In fact, nowadays, the communitarian social idea is placed in the center of the theoretical debate: "The technological determinism is not any more a simple concept of intermittent appearance throughout the political thought of the XX century, to become, in fact, part of the communitarian idea about the technology. And it remains continuously corroborated when, curiously, both from technophobes and technophile positions; it is insisted on the inexorability of the technological development" (Aibar, 2002: 38).

The communitarian social idea of Internet, as a set of meanings and symbols, acts in the practice and in the everyday life contributing sense to the human behavior, to the social relationships and the human relationships with the objects, independently of its existence for the "conscious" of this society. According to Vayreda (2004), the technologies of the Computer-mediated Communication (CMC) are a component of the idea instituted of Internet that acquires sense in the daily practices of the individuals. The idea of the CMC is not a scheme of senses, even, without ruptures and fissures. On the contrary, its strength lies precisely in its capacity to adapt the diversity, and, even, the contradiction of the individual behavior of the persons who interact through these platforms (Vayreda, 2004). This is another example of the contradictions that characterize the liquid, individualized and globalized society referred to by Bauman, Beck and Giddens.

The new communication technologies offer us the possibility of connecting and disconnecting ourselves to the social relationships according to our will in the ontological need that the human being has to find protection in the community, either a real or virtual community. But for the communitarian idea that Internet recreates, new contradictions and relational uncertainties are generated that the citizens are not always able to distinguish. It has to do with the dichotomy between the community and the freedom, two opposed forces and equally powerful, two essential values, apparently incompatible and subject to a strain difficult to be placated, according to Bauman (2003).

The key to solve this contradiction is in what Castells calls "directed interconnection"; i.e., "the capacity of anyone to find the own destiny in the network, and in case of not finding it, create the own information arising the appearance of a new network" (Castells: 2001: 67). The electronic inter-connectivity, feature of the CMC technologies, becomes a customized connectivity, turns to be a self-management promise, of individual freedom. The only condition is not to switch off the computer, not to leave the network. According to Vayreda´s words (2004) the idea is to "change from forum, construct a new one, and invent an issue .... but never to switch off". This process responds to a new form of socialization in which the individual decides freely when to connect himself and how to manage the interaction with another individual, without anything being predetermined and defined beforehand as in the traditional socialization forms.

VIRTUAL COMMUNITY, "LIQUID SOCIETY" AND CONNECTED INDIVIDUALISM

The new context of a global society based on interactive communication favored by the information technologies boom is generating what we could call a "cyber cultural revolution". In the XVIII century series of phenomena converged which came to be called "industrial revolution" which meant a transformation of the social and production relationships with the market boom as a way of global interchange of material and cultural goods. Today we can talk about the "cyber cultural revolution" as a transformation process in which the new information technologies are transforming the social structures, the relational forms as well as the own cultural context in which those new forms which individuals adopt to relate to one another and with the environment acquire sense. It has to do with the new "online" environment in which social relationships are separated from the traditional time and space categories. The question one must pose is in what way are the social structures changing? The contemporary sociology does not have any answers to these new phenomena. The time of solid modernity certainties is giving place to another liquid modernity of uncertainties. Solid becomes liquid and with regard to the enigma of "social reality effect" as the one of "network effect" or the "Crowds" (Negri) and "Smart Mobs" (Rheingold, 2004), we only know that they exist but at the moment there is no paradigm that has the key to seize them in its totality. The only thing we can do so far is to learn to coexist and to know how to be in this new "liquid" context full of uncertainties, until we rebuild the concepts of these two basic categories (time and space) for any type of society.

In this interpretation line, one of the greatest descriptions about this new technologized age is given by the Polish sociologist Zygmunt Bauman, who in Liquid Love (2005) talks about a society that moves at a great speed through "liquid" individuals; in other words, people without lasting bonds who have the need to develop and establish ephemeral contact types based on the Internet connection, from Bauman´s point of view, implies an exercise of continuous connection and disconnection; in a virtual relationships network which have an easy access and output. Any resemblance with cinematographic Matrix is not pure coincidence.

In the passage from the solid world to the liquid phase of modernity captured by Bauman there is a fight between the globalizing power of Internet, based on the connection, and the local problematic of each individual or community. It is obvious that Internet is a global environment, but most of the investigators emphasize that the practices acquire a meaning in the local framework. The sites with most traffic in Europe and the United States are the search engines like Google, Yahoo or Windows Live), which are to access door to the navigation of individual and collective interests, big compartments of multiformat content (Fotolog and YouTube). Those are spaces of local information's (digital newspapers) and spaces to buy and sell products (e-Bay) whose usefulness only acquires meaning in the products and services exchange of local scope. Many talk about the kingdom of the "glob quality" in other words global sites due to its scope but with local focus to capture the attention of a specific audience.

The Internet revolution does not limit itself exclusively to the cyber space. In the "network society" (a definition of the Spanish sociologist Manuel Castells) converge the Web (the great generator of a paradigm change that allows, at least in papers, to overcome the temporal-space barriers of people who live in the planet), the globalization, and the institutions crisis in a new relational context that could be denominated as "connected individualism". In this context of the contemporary society, people live in networks not in groups. The groups assume that all the participants know and trust each other, while the essence of the networks is a set of interactions and exchange of information. Of course, this does not mean that groups do not exist, but rather that the life of an individual cannot be reduced nor to a concrete group, nor a fixed place, many times it is the blending of both interaction ways.

The new possibilities that the online interaction technological systems offer are not the reason of the transformation on the ways we connect ourselves. The technologies mainly are developed as an answer to the needs that we have to interact with others. Therefore, the social organization type and the technology that we use influence each other and start giving form to a social contemporary life.

The relationships which we create do not belong to a specific place but are at the same time local and global, product of the communication technologies development. In general, the traditional communities based on a concrete unit lose importance due to the relationships that we maintain with people who are physically in different places and in that way we participate of multiple social networks. The characteristics of modern life, more and more privatized and customized, are reflected in our ways of generating relationships which are more selective and voluntary than in the past. Although our contacts are global; that is to say, scattered in different areas, we continue connecting ourselves from some place, could be our house or our work, which means that we have globalized our relational network always having as reference a local context. (Ninova, 2008).

The new information technologies are changing the way in which we connect ourselves, as we do not necessarily have to be in a place to communicate with others. In fact the physical context becomes less important. The connections are among individuals and not among places, in that way technology offers a change: connects individuals wherever they are. The people become portable; they can be located for interaction through technology in wherever. In this way, the communication person to person becomes central and it supports the defragmentation of the groups and the communities turning them into "liquids". The individuals can "connect" and "disconnect" them to the social structures which even though they continue defining the social behaviors, they do so with more flexibility and liberty than in the past. They are the new "liquid times" the ones Bauman talks about, where the new technologies allow flexibility and fragmentation of the social relationships. Therefore the transition towards a customized world provides the connected individualism[3] where each person changes fast among bonds and networks. It is the person who defines how to operate to obtain information, support or collaborate in some project. We become more flexible when interacting in different spaces.

CONCLUSION

In this chapter it has been pointed out how the new information technologies are changing the traditional ways of communication and of relating with the immediate social environment. In fact in the "network society" or also called "information society" new concepts arise like the f "virtual community" or "cyber culture" associated with new social behaviors which are generated by the online communication programs. As a consequence of this, the traditional analytical categories used by the sociology to study the new social interaction systems generated in the information society are becoming obsolete. So, in this chapter the concepts used in sociology to explain the meaning and the scope of the new "online" communication cultural devices and its incidence in social relationships, in communication and definitely in the social and symbolic structure of the social groups have been checked and widened

Definitely, the virtual mobility that is being practiced in the last decades and which already forms part of our daily life demands a change in our ideas about the influence which the new technologies have, and at the same time, they make us assume that the online/offline dichotomy is a myth. The communication mediated by the computer offers flexibility and autonomy, and in no case, does it substitute the face to face communication but it supplements it and enlarges it. The online relationships fill in the empty spaces in our lives many times.. The proximity does not matter anymore; the communities and the groups are more disperse in time and space.

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KEY TERMS AND DEFINITIONS

Connected Individualism: It is about a term coined by Wellmann (2002) in which the individual operator of his/her network is important, rather than the household or work unit. It is called network individualism—where technology users are less tied to local groups and are increasingly part of more geographical scattered networks. From the sociology point of view it is an expression about the "new liquid and individualized society" referred to by Bauman and Beck, according to which the individuals are more and more determined for the great social structures and therefore they are more owners of their individual destinies thanks to the communication possibility and customized relationship that facilitates the new information technologies.

Cyber Culture: Is a new culture form (symbolic group of values, beliefs and rules that give sense to the social action) that is emerging, due to the use of the new communication technologies. Therefore, the cyber culture is an extension of the traditional concept of culture that brings together the set of human relationships mediated by the information control mechanisms through the different technological communication systems. This turns the communicative process into more fluid and flexible social relationships and in many cases distant from the traditional space-temporal categories.

Cyber Cultural Revolution: It is the social and cultural transformation process generated by the use of new communication technologies. The multimedia revolution has several ramifications in which Internet has a central place, but where other digital networks coexists. Under sociological terms it is about the coexistence and slow displacement of the Homo sapiens, product of the written culture, to the digital homo, who worships the new communication technologies. Definitely, it is about a transformation process of the social and communicative structures through which the daily consumption habits and the human relationships moved about gradually from the daily spaces of the social interaction to the virtual spaces of social relationships created by the new information technologies.

Smart Mobs: It is a collaborative social dynamics made up of persons able to act jointly in order to achieve common objectives when they even know each other. The persons who perform these strategies called Smart Mobs, collaborate in a new context and under circumstances where the collective action was not possible before, thanks to the use of new communication tools and data development.

Society Network: It is a sort of advanced social organization based on technological communication networks. The networks are made up of nodes and links that use a plurality of paths to distribute the information from one link to another. This society auto regulates itself through even governance hierarchies and power distribution. In this sense, Castells states that "we are passing from the information society to the networks society", where each one of the users is a node of different networks that exchange by means of the use of the information technology.

Online Socialization: It is the process through which the individuals internalize and learn the rules and values of a specific social and cultural context through the virtual relational spaces that are created on the online network. This concept is displacing the former socialization concept, as the new technologies create new virtual socialization spaces beyond the family, the educational system and the labor market. These new online socialization contexts do not refer to a specific space and time but in many cases they are created spontaneously and overlapped on the network arising virtual learning and socialization communities.

Virtual Communities: Virtual community is a community whose bonds, interactions and social relationships are not produced in a physical space but in a virtual one as Internet. Investigators like Rheingold define the virtual communities as social groups that emerge from the Network [Internet] when sufficient people establish social communication and interchange networks characterized by the relative space stay and based in a feeling of belonging to a group, to form links of personal relationships in the cyberspace. Three main elements of the social and communication relationships converge under this definition: the reciprocity, the relational affective component and the interactivity time.

ENDNOTES

1 See: www.geocities.com

2 See: www.well.com. The experience of this Virtual Community is gathered in Rheingold´s book. The author describes in a practical way, how this VC was formed, which was its development, etc., becoming one more member of it. We can point out a fragment in which it is described what the persons can do both on this VC and on others: "people who form part the VCs use the words that appear on the screen to interchange courtesies and to discuss, carry out commercial transactions, interchange information, supply emotional support, plan, have great ideas, fall in love, meet friends, etc.

3 "networked individualism" (Wellman, 2002)

Chapter XXIII
E-Learning and Solidarity:
The Power of Forums

Rui Alberto Ferreira Jesus
Centro de Investigação em Tecnologias da Saúde, IPSN, CESPU, Portugal

Fernando Joaquim Lopes Moreira
Universidade Portucalense Infante D. Henrique, Portugal

ABSTRACT

This chapter explores solidarity as a social dimension in the context of e-learning and the Semantic Web. Its aim is to explore where the students show more solidarity with each other—in online learning environments or in offline settings? In the context of this chapter, the term "solidarity between students" means the sharing of useful resources between group members. Online forums are the major Web service that we shall use to support solidarity online. In online forums, we can ask complex semantic questions knowing that someone will understand the meaning of the question and hopefully will give us a good answer to it. Add to forums the possibility of annotation with metadata and we can also depend on them to retrieve meaning rich historical information. The research is based on case studies with focus groups conducted with Portuguese higher education health students.

INTRODUCTION

The Semantic Web is a very promising project to add computer-processable meaning to World Wide Web's documents. In its higher ambition, Semantic Technology would enable computers to process the meaning of things without human intervention (Berners-Lee, Hendler, & Lassila, 2001), besides the initial question or search query. For instance, a person might ask the computer to find in the Web, the contacts of all (amateur) tennis players from his/her own town, in order to find a playmate. With nowadays Web technology, it would be very difficult to solve this search query, although it makes perfect sense to a human being. That is, if we ask a question like that to a person—particularly a tennis player—probably we would get a complete answer. Why is that? Because that person knows descriptions and relationships of things, like “plays tennis”, “lives in town A” and “has the phone number B”. The Semantic Web project intends to annotate information with those kinds of descriptions and relationships.

In learning contexts, the Semantic Web’s benefits are even more valuable, because they will help to achieve one of the main goals of learning—to perceive the meaning of educational subject matters (Devedzic, 2006). For instance, an undergraduate student might want to find out if there are any papers of descriptive nature in a certain research domain. If the answer is ‘yes’, he/she can gain access to the concepts’ descriptions in order to conduct his/her study at a higher level of research knowledge (correlational or experimental). If the answer is ‘no’, he/she knows that his/her research study must be conducted at an exploratory level of knowledge.

These kinds of meaning rich queries are still far from being adequately answered by computers alone, not only because the annotation process is very time consuming (imagine the entire Web scale), but also—and mostly—because there are different and conflicting approaches to implement the Semantic Web (Iskold, 2007a). At the present time, it is much easier to ask complex semantic questions in online forums. This is because we know that our post will be read by a large number of interested persons in that subject—the members of the forum—and that someone might know the meaning and the answer to our specific question.

So, this chapter will emphasize the power of forums in the promotion of a very important social dimension in the Web-enabled learning process—solidarity. In other words, this chapter will explore the extent of solidarity that students tend to share with each other, when using electronic learning (e-learning), in our case, in higher education. Although e-learning environments include several interactive activities, such as blogs, chat rooms and wikis, we shall focus the discussion on online forums, due to its flexibility of use and natural sharing characteristic, which makes them ideal for supporting solidarity.

In a nutshell, the purpose of this chapter is to discuss the presence or absence of solidarity in e-learning environments. In other words, where can we see more solidarity between students, in online learning environments or in traditional education? In the context of this chapter, the term “solidarity between students” means the exchange of information among fellow colleagues or sharing useful resources for the learning experience of other classmates. The analysis has focused on undergraduate health students, which have initiated their first year of higher education in the 2007/2008 academic year, from a Portuguese private polytechnic school.

Chapter’s Organization

This chapter starts by describing the dichotomy machines vs. humans of semantic technologies, in order to set the reference for the rest of the chapter, in the human-based Semantic Web.

After that, we depict the historical evolution of e-learning as a successor of distance education and we describe the various types of interaction that were identified during that process of evolution. In the end, emphasis is given to the learner-learner interaction, without which the solidarity between students cannot take place.

Following, we focus our attention on online forums as one of the most widely spread solutions to support interactivity in online learning environments. We describe the various types of forums and which ones stimulate increased participation from students.

Then, we move on to explore the concept of solidarity and its implications for the field of education, to end up the background section of this chapter.

In the main focus of the chapter, we present an exploratory research study which recently has opened the discussion about e-learning and solidarity. This study has presented a list of myths and realities to whether solidarity between students was more frequent in e-learning environments or in traditional education. Following, we describe the steps of a case study with focus groups as our methodology to confirm the results of that previous exploratory research in the field, and we present our findings relative to the forums' ability to increase solidarity in e-learning.

In the end of the chapter, we discuss future and emerging trends of Semantic Web with relation to e-learning and solidarity; and we end up with the overall conclusion of the topic.

SEMANTIC TECHNOLOGIES: MACHINES VS. HUMANS

The majority of information currently available on the Web is very difficult to process automatically. This is because Web content was mostly aimed to be interpreted by human beings (is represented in natural-language that computers cannot understand nor interpret its meaning). Hence, Web pages up until now tend to focus primarily on document structure and document presentation. Little or no attention is given to the representation of the semantics of the content itself, i.e. the (domain-specific) representation of the subject of the document (Ossenbruggen, Hardman, & Rutledge, 2002).

The main objective of the Semantic Web is to produce documents with content that is processable by both humans and machines (Berners-Lee et al., 2001). Despite the progress made, there are a few important issues that need to be put in place in order to achieve that goal. Devedzic (2004) groups them in four categories: languages for the Semantic Web, ontologies, semantic markup of pages on the Semantic Web, and services that the Semantic Web is supposed to provide. Some—if not all—of these items were covered in previous chapters of this book. So, this chapter will skip the technical details and will concentrate in the dichotomy machines vs. humans of semantic technologies.

With respect to the semantic markup of pages, that is, annotating Web information with descriptions and relationships of entities in order to add computer-processable meaning to the Web, there are two main approaches to the Semantic Web—the classic bottom-up approach and the new top-down one (Iskold, 2008).

The bottom-up approach is focused on annotating information in pages, using languages for the Semantic Web such as RDF (Resource Definition Framework), and ontologies to define the relations among terms. It consists of including tags in Web pages that reflect the meaning of the page content. These hidden labels (tags) can be generated in two possible ways. One is having an algorithm that automatically produces RDF descriptions from the page content (for instance, its text). The other way is for people to annotate existing documents with the help of visual applications that then generate RDF from those annotations. Both ways are questionable. If there is already an algorithm capable of annotating the Web, semantically and automatically, why worry about semantic languages and ontologies? Because that algorithm is still fiction, the annotation process of the bottom-up approach must be done by people. But the task of manually and coherently annotate the entire Web is overwhelming (Iskold, 2007a).

The top-down approach takes current unstructured information in existing Web pages, as it is, and tries to derive meaning automatically. To do that, vertical semantic services focus on specific subjects, like people, books and lessons, and fetch current documents on the Web in search for that particular type of information. For instance, Spock (URL: http://www.spock.com/) is a vertical search engine which scans the Web for information about people. It knows how to recognize names in Web pages and can also identify people's attributes like birthdays, locations, and even relationships (e.g., Clinton as a predecessor of Bush). These vertical semantic services rely on algorithms just like the one mentioned in the bottom-up approach as being fiction. The difference is the much smaller scope of this top-down algorithm—it is specific of a single subject and thus feasible. However, there are also problems with this top-down approach. To start with, it is not the semantic Web envisioned by Tim Berners-Lee. Instead it is a collection of Web services that deliver added-value specific information based on simple semantic recognition. Another limitation is that the vertical service's algorithm does not always get semantics right because of ambiguities. That is, because there is no underlying RDF representation to resolve ambiguities, the top-down approach is not perfect (Iskold, 2007b).

Although both of the above approaches are making good progress, it is hard to say at the present, how long it might take before their full scenarios becomes viable (Devedzic, 2004). Ultimately, the Semantic Web will be composed by a large-scale interoperation of Web services to create a Web of machine-understandable and interoperable services that intelligent agents can discover, execute, and compose automatically (McIlraith, Son, & Zeng, 2001). But there is still a competition between Semantic Web languages and other technical aspects, and there is no guarantee about which one will prevail. In other words, there are many things in the development of Semantic Web that are only at the beginning. (Devedzic, 2004).

Summarizing this section, semantic technologies seek to be machine-dependable in a great extent, but the reality shows that there is still the need for human intervention both to include (annotate) and to extract the meaning of information on the Web. On the other hand, humans themselves can only process a small fraction of information available on the Web, and would benefit enormously if they could rely on machines to analyse and understand Web contents (Noy et al., 2001). It is this uncertain machines vs. humans dichotomy that leads us to explore a more human-based Web service such as the online forum. And that is because online forums have an inherent annotation process (the Usenet hierarchy of subjects, for instance), but its richest meaning characteristic is the human supported interaction, that is capable of answering complex semantic questions.

INTERACTION IN E-LEARNING

According to Keegan (1996), distance education is any instructional activity in which the instructor and the learner are separated by space or time. This definition requires the use of some type of medium to deliver the instructional material to the learners, as well as to support communication between the participants (Holmberg, 1995). Another complementary definition, from the UK Quality Assurance Agency for Higher Education (QAA, 2006) defines distance learning (or distance education) as "a way of providing higher education that involves the transfer to the student's location of the materials that form the main basis of study, rather than the student moving to the location of the resource provider". This definition is not restricted to higher education—QAA's sphere of action—but is applicable to all kinds of education. In both definitions of distance education we can easily include a variety of delivery modes according to the technologies and mediums used. That is the case of correspondence courses, audio and video technologies such as the audiotape or videoconferencing, and computer-mediated learning (Curran, 2006).

The same author has stated that the terminology which is often used to refer to computer-mediated learning varies. Computer-assisted learning (CAL) or instruction (CAI) can be defined as "any learning that is mediated by a computer and which requires no direct interaction between the user and a human instructor in order to run". Computer applications in distance education have also been referred to as computer-managed instruction (CMI), computer-based training (CBT) and more recently online, Web-based or e-learning. These last ones are greatly enriched by interaction functionalities as we shall see. Some examples of e-learning technologies are: the Internet and World Wide Web, email, synchronous and asynchronous computer-mediated communication applications (such as online forums or chats), and interactive multimedia applications on CD or DVD-ROM.

In terms of interaction between the participants, the historical evolution of distance education from correspondence courses to e-learning has shown a remarkable progress in terms of interpersonal interaction. As stated by Woods & Baker (2004), early correspondence courses have enabled the interaction between learners and instructors, although with a significant delay between message production and reception. Videoconferencing made it possible for learners to interact with each other and with instructors, but the high cost of the required equipment often made this technology prohibitive to support distance education. It was only with the emergence of the Internet, and particularly due to the widespread of cost-effective technologies such as email and the World Wide Web, that interpersonal interaction became a reality in distance education.

Why, in general terms, is interpersonal interaction important to the success of distance education and to the success of e-learning in particular? The answer is that learning and teaching are primarily about interaction: interaction between learners and instructors, between learners themselves and between learners and the course material (Moore, 1989). That is, high levels of interaction, particularly those which promote social engagement, can have positive effects on the learning experience (Harasim, 1995; Rovai, 2002).

But let us return to Moore's categorization of interaction in distance education: learner-content, learner-instructor, and learner-learner.

Through learner-content interaction, the student processes the course material, in order to assimilate the knowledge and practices that are being transmitted during the educational experience. This implies that each learner may interact very differently with the same course material, because he/she has to construct his/her knowledge through a process of personally accommodating information into previously existing cognitive structures. In a great extent, that construction of knowledge happens by interacting with content (Moore, 1989). Translated into e-learning, this first type of interaction has been addressed (to a certain extent) by the development of interactive courseware, such as interactive multimedia applications on CD-ROM or simulation programs that are available on the World Wide Web.

Through learner-instructor interaction, the instructor and students communicate with each other, not only in formal instructional discourse, but also in informal dialogues or in offline communication that occurs during the educational experience (Woods & Baker, 2004). Adapted to e-learning, this second type of interaction usually occurs via synchronous and asynchronous computer-mediated communication, such as email, online discussion forums or chat rooms.

Through learner-learner interaction, students communicate with each other, either on an individual basis or on a group basis, and with or without the real-time presence of an instructor (Moore, 1989). Usually, this inter-learner interaction is an extremely valuable or even essential resource for learning, depending on some factors such as age, experience, and level of learner autonomy. For example, younger learners will benefit from peer-group interaction, in terms of stimulation and motivation to study, although this is not so important for most adult and advanced learners, who tend to be self-motivated (Moore, 1989). In the field of e-learning, this third type of interaction is supported by the same applications that were mentioned in the learner-instructor interaction. We must, however, keep in mind that in both types of interaction involving persons in both ends, there may be offline forms of communicating besides computer-mediated communication. That is the case of telephone and face-to-face conversations among members of a class or other group that occur during the progress of a course.

The learner-content, learner-instructor, and learner-learner are the three traditional categories of interaction in distance education. However, as Moore & Kearsley (2005) have stated, e-learning is a changing paradigm, that is perpetually evolving, non-static, and dynamic. Hence, as an outcome of subsequent research in the area, other types of interaction have emerged, such as learner-interface, learner-environment, teacher-teacher, teacher-content, content-content, and learner-context. These six issues are beyond the scope of this chapter but we redirect the interested reader to Woods & Baker's (2004) article about interaction and immediacy in online learning.

In this chapter, we are particularly interested in the last of Moore's categories of interaction—the learner-learner interaction—because the two-way communication between students themselves is a pre-requisite for the existence of solidarity between them, as we shall see in the Solidarity section.

ONLINE FORUMS

There are several alternatives to support interaction in online learning contexts (Woods & Baker, 2004). Blogs, chats, wikis and forums, to name just a few, are examples of common tools to develop learner-learner interaction or learner-instructor interaction. This section describes the most popular online interaction tools, giving emphasis to forums due to its flexibility of use and natural sharing characteristic, which makes them ideal for supporting solidarity.

Known as "the new age diaries", Web logs—or blogs by contraction of those two words—are a form of online journal with one or many contributors (Duffy & Bruns, 2006). Unlike traditional diaries, which are of a personal nature, blogs are a very accessible and intuitive way of publishing content online. Even though they can also be private, the majority of blogs is used to share content with some community (e.g. of students). Ideas, discussions, trends and learning materials, are some of the content that can be published on a blog, knowing that interactivity between sender and receiver is guaranteed to be very intuitive.

A chat is an activity that is used to establish a written conversation in real time. It is a synchronous communication tool, i.e. it allows an immediate exchange of messages between several participants. A chat application can be the basis of a virtual classroom if the access to the chat room is limited to the students enrolled in a class (Peters, 2008).

According to Tonkin (2005), a wiki is an activity that is used by several participants in order to collaboratively create an electronic document about a certain subject. Wikis have the following characteristics:

- All the pages are connected by links and each page can contain several links to other pages;
- All participants can edit existing pages as well as add new pages to the wiki;
- When a participant edits a wiki page, a new version of it is created and old versions are not eliminated, allowing its retrieval at any time.

An online discussion forum is a powerful communication tool in the context of e-learning. A forum is a sort of online messages board where teachers and students can post new messages and respond to existing ones. Being an asynchronous communication tool, students can take all the time they want preparing a new message or an answer before posting it to the forum (Thomas, 2002). This is why online forums are one of the most widely spread solutions to support interactivity in online learning environments, and also the reason why there are so many research studies (Cavallaro & Tan, 2006; Freiermuth, 2002; Warschauer, 1996) which have concluded that students are more likely to participate in an online discussion forum than in a classroom discussion (face-to-face).

Forums are quite simple to set up and operate in online learning platforms, and the communication occurs at the students' convenience. That is, they can access and contribute to the forum literally anytime and from anywhere there is a computer with an Internet connection (Cavallaro & Tan, 2006). However, this ease of use is not sufficient to assure student's participation. As Dool (2007) states, "not all online discussions are created equally", and he identifies three types of online discussion forums: the "Question & Answer (Q&A)" model, the "1-plus" model, and the "dialogue intensive" model.

The "Q&A" model is the most common type of forum. Typically, the teacher posts a specific question that is related to the unit's topic and the students are required to post an answer to that question (Dool, 2007). Usually, the forum can be configured to show all the answers to each student only after he/she submits his/her response to the forum. In this way the teacher increases the critical thinking of the students and at the same time, allows the sharing of their approaches and perspectives in response to the specific question. However, interaction between students and with the teacher is very limited, as there is only one question and several «isolated» answers to that question. The primary value of this "Q&A" model is not to promote the discussion but to encourage the sharing of ideas among the classmates.

In the "1-plus" model, each student not only has to answer to the specific unit's question that was posted by the teacher (like in the "Q&A" model), but he/she must also post at least one comment to his/her peer's postings. In this way, the teacher also promotes the learner-learner interaction (besides the sharing spirit), but normally, the majority of students tend to post the mandatory one response to a peer's posting, so the discussion energy tends to dissipate (Dool, 2007).

The model which promotes the most of interaction, both learner-learner and learner-instructor, is the "dialogue intensive" model. In general, the teacher posts an initial discussion question that is related to the unit's topic and asks the students to share their own experiences, personal opinions, as well as other documented source materials that are related to that question. The teacher himself must also engage in the discussion in order to extend the contributions, not only by challenging students to clarify their points of view, but also to set the quality and quantity method of discussion grading (Dool, 2007). If well set and understood by students, a good discussion grading method will encourage active participation in the forum (e.g. 10+ quality posts to get an A).

Although the "dialogue intensive" model contributes to the most interactive forums, all three models aim to empower the sharing spirit among a learning community. This was the purpose of our case study, to leverage on the power of forums to promote solidarity in e-learning. And as we shall see in the next section, solidarity is mostly about sharing, and all three models, including the "Q&A" which was implemented in our case study, have a natural sharing characteristic, ideal for supporting solidarity.

SOLIDARITY

Maybe due to the Latin origin of the word (Wiktionary, 2007), 'solidarity' is rarely seen in English texts. Writers tend to use other words like 'sympathy' instead. But 'sympathy' is not quite the same as 'solidarity' and therefore this introduction will help understand the following citation. "No one can be sympathetic alone. Solidarity is a social fact." (Perrenoud, 2003). This sentence has several implications to this chapter. Firstly, we must study the concept of solidarity to the light of sociology, hence the reference to Perrenoud, a renowned sociologist in the field of education. Secondly, we must have learner-learner interaction (two students at least) in order to support any kind of solidarity that may exist between them. Finally, the third implication is more semantic in the sense that, from now on, we shall use the term 'sympathetic' with the meaning "characterized by solidarity".

Perrenoud (2003) defines solidarity primarily as a human value, a value that each and every person can achieve in his growing process as a human being and that tends to influence his behaviour towards the others and the surrounding community. Behaviours like sharing, helping and supporting other people, accepting the difference of others, integrating, protecting, taking care of, concern, and so one, are the reflections of that value into concrete actions. But "neither these practices, nor the values that underlie them occur naturally in the development of the human being. Solidarity is not spontaneous, it is a victory against egocentrism and selfishness that characterizes a young child, but also against the ethnocentrism of every human group and the priority it gives to its own interests. Solidarity is a social and cultural construction, a fragile achievement of civilization." (Perrenoud, 2003).

In other words, if we first assume that the typical human being is selfish and just cares about himself, it becomes clear that many people will only form or join a group for something which they cannot get (as easily) by themselves. This is the basis of group solidarity as it was defined by Hechter (1988), and it measures the group's capacity to influence its members' behaviour. The more solidarity there is in a group, the greater the influence it casts upon its members. Groups influence their members by subjecting them to a variety of obligations to act in the corporate interest and by ensuring that these obligations will be fulfilled.

So even being unnatural to the human nature, solidarity can be established, especially in small groups (like a school class), where the students share common individual interests (inter-dependence) and there is no need for controlling the solidarity compliance as in larger groups. This way, greater commonality of individual interest, results in more solidarity within the group. And when a group member gets from the group more than he has expected, then the solidarity will also be larger. That results in the most stable (or solidarity) groups, which can satisfy its members' needs (Hechter, 1988).

From what has been said, Hechter (1988) adds that pro-social behaviour—such as altruism and helping behaviour—is likely to emerge in the absence of any controls at all, based on the selection mechanism or repeated exchange. But he admits that the common knowledge basis that is needed to sustain the cooperation is unlikely to be available in large groups. For instance, in a large corporation, some agency of the group must have the ability to monitor the members' behaviour and to provide sanctions to reward the compliant and punish the noncompliant to the group's solidarity. So, formal controls are necessary for the attainment of solidarity in large groups.

Because solidarity is unlikely to happen spontaneously (particularly in large groups) but at the same time it is possible, there must be some conditions for the development of solidarity in a society. Perrenoud (2003) has presented three conditions that must be continuously met:

1. The principle of solidarity should be part of the ideas and core values of most individuals;
2. There must be some form of reciprocity, at least in the medium term;
3. Solidarity is not always given in advance; it is achieved at the expense of individual and social struggles.

Let us now translate the above three conditions to the field of education, knowing that formal education itself, in our schools, can play an important role in the promotion of solidarity.

The first one—basing solidarity as a value and ethical principle in our society—makes perfect sense although it is hard to measure such a subjective concept as a human value. Even so, school can contribute to the development of solidarity as a value by teaching it as a value, not in the abstract, but through examples drawn from human history, from current news and events, and from literature. But even more important, showing and promoting solidarity through practices: between students, between teachers and students, between parents, between teachers, or between the school and its surrounding community. In other words, school can contribute to create a moral conscience in the students that makes them think twice before doing some selfish—and hence, not sympathetic—act (just like the environmental awareness has already produced some effects in the waste recycle and reduction) (Perrenoud, 2003).

The second one—understanding solidarity as a social contract—is needed to justify why we should be sympathetic when it seems that solidarity «does not pay». No human being can live alone, outside of any community. Belonging to social groups, from family to the global society, is a principle not only for our material survival, but also for our identity, intellectual development and emotional balance. Thus, the symbol of the contract helps us to clarify the roles of education: 1) lead a person to understand that he/she is part of a team and that he/she cannot leave the game without weakening his/her own interests; and 2) encouraging to conceive solidarity not only as a humanistic value, but mainly as a practical condition for the survival of a society (Perrenoud, 2003). Instinctively, each student in a class (traditional or virtual) has the expectation of receiving back, even after some time, the benefits of a contribution that he/she makes to the class today (for example, some useful resource). The instructors can play an important role by "encouraging and modelling this behaviour from the beginning of a course, thereby creating a safe learning environment of acceptance and trust. Activities that enhance sharing and cooperation can further develop openness and solidarity within groups." (McDonald & Gibson, 1998)

The third one—learning to fight to increase solidarity—derives from the fact that solidarity is not spontaneous in any society. Therefore it must be continuously nurtured by the people who have already understood and internalized the two previous conditions. Those persons are the same ones, who fight for more democracy, more equality, more respect for the human rights and differences, and so on. By fighting those battles they are preparing the ground for the development of solidarity. So, training for solidarity is preparing critical individuals who are willing and able to become actors, to defend their interests, and to explain and control the mechanisms that cause violence, poverty, and exclusion. This requires not only economic, legal, technological, scientific, and sociological knowledge, but also analysis, negotiation, coordination, tactical and strategic skills. Once again the education system plays an important role in providing those skills and knowledge (Perrenoud, 2003). In our opinion, teachers should be the main actors in the battle for solidarity in the classroom. Not only by teaching the above information but also by setting the example and showing the way to their students, emphasizing the fact that solidarity is worthwhile for the entire group. For instance, a teacher who posts useful articles in a class forum or who makes encouraging comments to the progress of his/her students is setting the pace in a sharing spirit and partnership among the class members (Carvalho, 2007).

Now that we have more deeply analysed the concept of solidarity in general terms, it is easy to accept the definition of "solidarity between students" as the exchange of information among fellow colleagues or sharing useful resources for the learning experience of other classmates, in order to help and support the group. As examples we may refer to: helping a classmate to complete an assignment, posting an article of interest to the group, answering a question or doubt of a colleague, and so on.

E-LEARNING AND SOLIDARITY: MYTHS AND REALITIES

In a recent research study, we have found out that students tended to express more solidarity with each other in online learning environments than in the classroom (Jesus & Moreira, 2008b). For conducting that study, we have made available for higher education students, a course that was delivered in a blended-learning configuration. Blended-learning (or b-learning) is the use of more than one strategy or delivery system for learning (Shoniregun & Gray, 2003).

In our case and through a cross group experimental design (Jesus & Moreira, 2008a), students had access to:

- traditional classes (2 hours once a week);
- paper-based support material;
- the lessons recorded in electronic media (a CD-Rom with screencasts); and
- an online learning environment (based on a Moodle platform).

A screencast is a digital recording of computer screen output, including mouse movements and clicks. Also known as a video screen capture, screencasts can include audio narration to explain the process that is being documented by the screencast (Peterson, 2007).

Although the term *screencast* is relatively new (2004), products like Lotus ScreenCam were already available in 1993 (Kumar & Govindaraju, 2007). However, the first screencasting applications generated very large files and were limited in their functionalities. More recent applications, like Camtasia Studio (http://www.techsmith.com/camtasia.asp) already support more compact file formats like Macromedia Flash, and have lots of functionalities allowing the video sequence editing, the audio editing (both a human voice and the internal computer sound), and the mouse movements editing.

Screencasts are typically suitable to demonstrate “how to do” computer tasks, because unlike traditional classes which can be taped with a regular video camera, or even an audiotape, classes which focus on computer screen data require a better recording quality in order to clearly visualize and listen to the computer output. Usually, regular video cameras cannot achieve that quality.

Due to the large size in bytes, the screencasts with the lessons were distributed to the students in a CD-Rom, instead of being delivered over the Internet. The students’ reactions to those screencasts were very encouraging as well as productive in terms of learning outcomes (Jesus & Moreira, 2008c).

According to Cole & Foster (2005), Moodle is an open source learning management system (LMS) that is used by all kinds of schools and training companies to add web technology to their courses. Moodle is currently used by more than 10,000 educational organizations around the world to deliver online courses and to supplement traditional face-to-face courses. Moodle is available for free on the Web (http://moodle.org), so anyone can download and install it.

A LMS includes several e-learning tools, both to deliver content materials and to support communication among users. The former can be achieved by interactive lessons, simulations or static documents (e.g. in PDF format). The later can be supported by forums, chats and instant messaging, among others.

In the market there are several LMS to choose from, both commercial and open source. Figure 1 shows some examples of LMS implemented in Portuguese organizations. As we can see, Moodle, which is an international open source project, is responsible for 57% of all platforms installed in Portugal. Following Moodle in the chart, we can see two commercial LMS developed in Portugal—Teleformar.net and Formare—and another international open source project called Dokeos, with around 5% of market share each. The remaining solutions included in the chart are all commercial LMS available internationally.

The reason for the success of Moodle in Portugal is due to the initiative of a public state foundation—FCCN (Scientific Computing National Foundation)—who gave training and technical support to several school IT staff and teachers, to operate with Moodle, particularly in the primary and secondary levels of education.

In the context of Higher Education in Portugal (see Figure 2), Moodle is still the leader in LMS installations, and with a tendency to grow, but with only 32% of market share. This reduction in comparison with the previous chart, is due not only to the inflated contribution of primary and secondary education to the Moodle dominance in Figure 1, but also to the widespread of solutions implemented by universities, the earlier adopters of LMS.

In the Moodle platform used in our research study we were particularly interested in three types of solidarity expressions exchanged between students: 1) the number of supportive forum posts; 2) the number of one-to-one help messages in the instant messaging system, and 3) the number of help messages in chat sessions. To examine those online solidarity expressions we have used log file analysis, whereas to examine the students' sympa-

Figure 1. Percentage of market by LMS in Portugal (adapted from (DeltaConsultores, 2007))

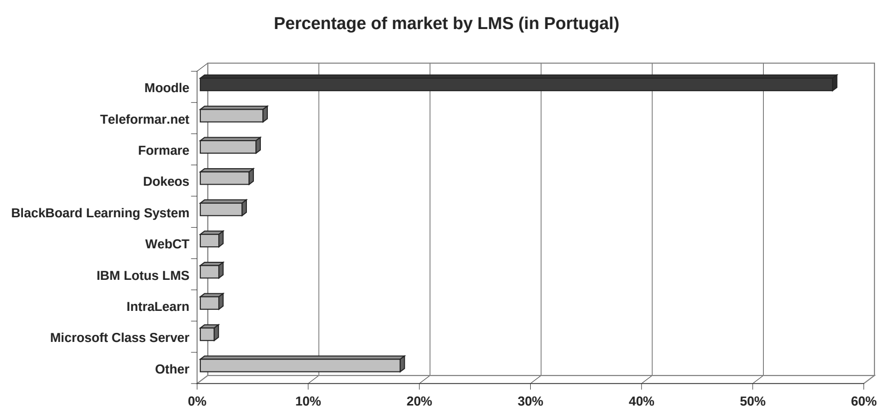
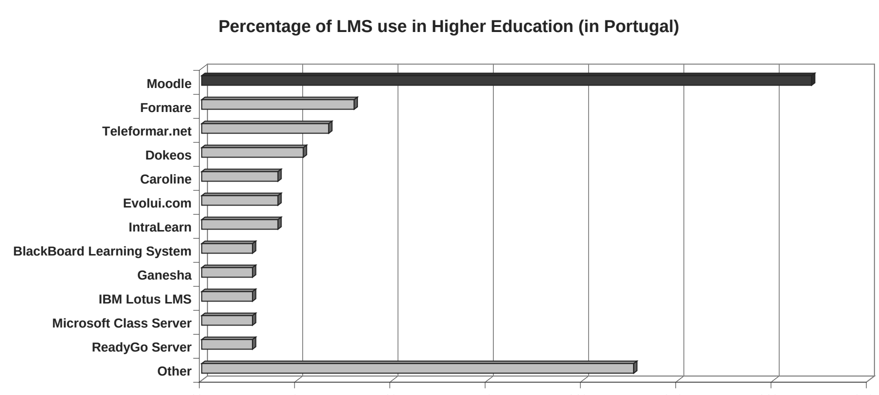


Figure 2. Percentage of LMS use in Portuguese HE Institutions (adapted from (DeltaConsultores, 2007))



thetic behaviours in the classroom we have used the researcher's participant observation, which has consisted of note taking whenever he has perceived that a student was helping a classmate to complete a requested task or assignment.

In a nutshell, in that study (Jesus & Moreira, 2008b), we have seen more than twice as much students' sympathetic behaviours in the online environment than during the classroom sessions, for what have contributed the online forums that were set in the Moodle platform. In order to justify the study's findings, we have presented a list of reasons which we have called realities and myths, as shown in Table 1 and Table 2, respectively.

Table 1 summarizes a set of issues that really justify why there is a tendency to exist more solidarity in online learning environments than in traditional classes. The first two of them are of social or behavioural nature, in the sense that e-learning environments promote different social behaviours among students, when comparing with face-to-face classes. The last two of them are of technical nature, in the sense that e-learning environments make it easier to share resources online than offline, by not having so many technical constraints.

Table 2 goes over a number of topics that mistakenly lead us to believe that solidarity is more

Table 1. Realities of increased solidarity online

Traditional Education	e-learning
More outspoken students tend to participate more, including sharing resources with their peers.	Students feel more protected by the online learning environment, which also leads usually reserved students to share resources with their peers.
Students socialize face-to-face to help each other.	Students do not socialize face-to-face, and this leads them to develop compensatory ways to help each other, such as sharing resources online.
Resource sharing is limited to the periods when students are physically together (is not continuous in time).	Resource sharing can happen on an ongoing basis (including during school holidays).
Resource sharing is not so simple: the resource's owner has to lend it over to a classmate for a period of time, normally to photocopy it.	The growing virtualization of knowledge, makes it very convenient and fast (and also ecological), to share resources online (e.g. via copy/paste).

Table 2. Myths of increased solidarity online

Traditional Education	e-learning
Students share resources, primarily, outside the classroom and there are no logs.	There are logs to register the exchanges of resources.
Therefore, maybe it is a myth to consider solidarity more frequent online than offline, simply because it is easier to keep track of it online.	
There is an atmosphere of competition among students (Who participates more? Who is more popular?).	As the name of its author is registered, the sharing of resources is a similar way to gain notoriety in the group.
So, the motive behind the contribution is not solidarity but recognition and popularity.	
A student cannot as easily (nor at once) reach all his classmates.	There is a tendency to ask for help even before exploring the solutions to a problem.
So, maybe there are more expressions of solidarity online simply because there are more requests for that to happen than in traditional classes.	
Students already know traditional classes for years.	For the majority of students, online learning environments are a novelty and it is natural that they want to explore all the functionalities of the platform.
Thus, some of the sympathetic messages and posts are written not only to help other classmates, but also to try out the forum, the chat room or the messaging system.	

frequent online than face-to-face. All these myths but the second are of technical nature, in the sense that e-learning environments make it easier to keep track of things and to share resources online than offline, by not having so many technical constraints. The second myth reflects an existing social behaviour (in traditional education) that is still maintained by the students in online learning environments, but in an adapted and more disguised way.

In summary and although the above findings are of exploratory nature, they have contributed to a better understanding of the relations between e-learning and solidarity. In the next section, we shall describe a new case study as our methodology to confirm the results of that previous research in the field. In this case, emphasis will be given to the forums' ability to increase solidarity in e-learning.

FORUMS AND SOLIDARITY: A CASE STUDY

In order to confirm the tendency for increased solidarity expressions in online learning environments, we have conducted a case study during the second semester of the 2007/2008 academic year. According to Yin (2003), a case study is an empirical inquiry which investigates a specific phenomenon, in a specific group, in order to answer specific questions holistically.

One of the researchers and author of this chapter is the professor of a health research course whose participants are first year students from the Instituto Politécnico de Saúde do Norte (IPSN, a Portuguese private higher education school; URL: http://www.cespu.pt/pt-PT/ensino/ensino_politecnico/). The course aims to prepare students from several educational areas—Pathological Anatomy, Podiatry and Dental Prosthesis—to conduct research projects in their fields. With a conventional 2-hour lecture per week and a course management system (an online learning environment) to support the course during and between classes, the unit of Health Research takes place in a fully equipped classroom with personal computers and broadband Internet connection.

In this case study have participated 158 students—Pathological Anatomy (n=62), Podiatry (n=42) and Dental Prosthesis (n=54)—that were split into several groups so that each class had an average of 26 students. The students were faced with the following scenario, which was created by their professor:

Let's help our fellow Brazilians!

I have a friend who teaches at a high school in Brazil. His students are about to choose their higher education areas and many of them would like to follow health courses. So he wants to do a project with those students, to help them decide which health areas to follow. In order to do that he asked me for help, because he knows that I am already a lecturer of health students. I thought it would be a good idea to involve you in helping out those young Brazilians.

The idea is to collect as much information as possible about the health area, to compile a thematic dossier. I shall deliver that dossier to my Brazilian friend in the first weekend of May, when he comes to Portugal. Therefore, I ask you to bring me, until the end of April, some of the following materials:

- *Health website addresses,*
- *References on the subject,*
- *Notes (may be photocopies),*
- *Health glossary terms,*
- *Leaflets or brochures,*
- *Magazines or journals,*
- *Etc.*

You can deliver the material, both in paper-based documents (in my school postal box or personally in class), or in electronic format (by posting the *information on the forum that I have set for this purpose in the Moodle platform).*

On my behalf and on behalf of the young Brazilians which we are helping, I thank you in advance, for all your cooperation!

The students were given 10 days to contribute to this “solidarity campaign”, but only if they wished to do so. The professor has explicitly informed the students that there was no obligation to contribute, and that the task was not included in the unit’s assessment plan. Also, the forum that was set up for collecting the students’ contributions was of the Q&A type. Hence, it was not of the type which stimulates the higher participation from students. This was intentional. We wanted to distinguish the authentic sympathetic behaviours from the ones that were identified in Table 2, as mistakenly leading us to believe that solidarity is more frequent online than face-to-face.

On the other hand, the very same students who were invited to contribute to this “solidarity campaign” had already to accomplish a similar task in the beginning of the semester. That is, each student had a week to post in a Q&A online forum, the research objective of his/her project for the semester, but that time, the task was part of the unit’s assessment plan. So, this scenario was mainly set up with the goal of comparing the number of sympathetic contributions in the online forum and in the offline alternatives. But we also wanted to compare the number of contributions in the not assessed online forum vs. the assessed one.

The findings of the case study are based in the online learning environment’s log files—number of forum posts—and in the counting of paper-based documents delivered to the professor.

The online learning environment’s log files were stored and utilised for analysis after removing all individual identification data in order to protect the research subjects’ privacy. The participants were informed of that practice prior to the beginning of the study, and signed a consent form approving that method.

Table 3 summarizes the number of students’ sympathetic contributions by the end of the “solidarity campaign” both online and offline. As we can see, there was nearly half sympathetic contributions offline in comparison with the ones that were made online. These results confirm the findings of the exploratory case study that we have discussed in the previous section. That is, students tend to express more solidarity in online mediums than in offline ones. Also, as we have expected, there were more contributions in the assessed online forum than in the solidarity forum (not assessed). But the difference between both forums is relatively small, which allows us to conclude that: 1) we are in the presence of a truly sympathetic group of students; and 2) forums are really very easy to operate and, hence, have the ability to promote sympathetic behaviours.

The next step of the case study was to confirm the myths and realities that were identified in the previous section. To do that, this research utilised focus groups as a method to collect the opinions of the students who have participated in the “solidarity campaign”. A focus group is an interview with a group of persons in order to capitalize on the synergy of the group interactions. But it is not a freewheeling conversation among group members; it has focus and a clearly identifiable agenda moderated by the interviewer. Its main purpose is understanding and interpreting group members’ experience (Stewart, Shamdasani, & Rook, 2006).

In this case study, focus groups were conducted in the week immediately after the solidarity campaign’s deadline. This timing was chosen in order

Table 3. Number of students’ sympathetic contributions

Paper-based documents delivered	47
Posts in online forum (not assessed)	99
Posts in previous online forum (assessed)	149

to minimize the problem of the students forgetting the experience that was being discussed in the focus group. Also, we have decided to conduct three focus groups: one with three students who have only contributed to the online forum (called 'OF3' from now on); another with three students who have contributed both online and offline (OFPB3); and a final one with two students who have only delivered paper-based contributions (PB2; only these two students did that).

Each focus group's agenda had three main questions:

1. Why have you contributed to the "solidarity campaign"?
2. Why did you opt to contribute with posts in the online forum or with paper-based documents?
3. Do you identify yourself with some of the following myths and realities about e-learning and solidarity? [see Table 1 and Table 2 above]

Focus Groups' Results

The responses of the interviewed students to the focus group's questions were basically the following (the order is just for later reference):

1. Why have you contributed to the "solidarity campaign"?
   - 1.1. "*Because I have identified myself with the young Brazilians' situation. A year ago, I would also appreciate this kind of help.*"
   - 1.2. "*Because I already had the material to hand over without much effort.*"
   - 1.3. "*Because you* [the professor] *asked us to do so.*"
   - 1.4. "*Because I thought it was a good way to complete my daily 'good deed' (sort of).*"
   - 1.5. "*Because I would like that some of the young Brazilians will follow the same health area as I did.*"
2. Why did you opt to contribute with posts in the online forum (OF) or with paper-based documents (PBD)?
   - 2.1. OF: "*Because it was easier to find online materials than paper-based ones and I find it easy to post in forums.*"
   - 2.2. OF: "*Because my paper-based documents were at my parent's house and I only went there last weekend [after the campaign's deadline].*"
   - 2.3. OF: "*Because I did not want to loose my paper-based documents.*"
   - 2.4. PBD: "*Because we went to a congress recently and had lots of leaflets and brochures to hand out.*"
   - 2.5. PBD: "*Because it was easier to make copies of my notes than to scan and post them to the forum.*"
3. Do you identify yourself with some of the following myths and realities about e-learning and solidarity? [see Table 1 and Table 2 above]
   - 3.1 In general, all the groups have agreed with the four realities of Table 1. However, they have disagreed with the last myth of Table 2 (stating that the use of e-learning tools was not so difficult) and had some reluctance in agreeing with the third myth (stating that they are not lazy to find the answers to their questions). More details in the next four paragraphs.

It is not surprising that responses 1.2 and 2.4 were given only by the PB2 group. These students have identified themselves right away with the last reality of Table 1. They have delivered the paper-based materials due to a coincidence—they went to a congress a few days earlier and the materials they have collected there were still in the bags to organize later. They have also pointed out the first myth of Table 2 as the one that they agreed most.

Responses 1.1 and 1.4 (or similar) were cited by all three groups of students. Response 1.5 was given by the groups OF3 and OFPB3, which have also identified themselves right away with the last reality of Table 1. As a matter of fact, they have stated that the contributions they have posted to the forum were made via copy/paste of their own course materials. These two groups have identified themselves equally with the first two myths of Table 2.

Responses 1.3 and 2.5 were given by the OFPB3 group of students, which agreed right away with the first reality of Table 1, and with the second myth of Table 2 (not so right away, but in the end they have admitted that recognition played its part in their sympathetic contribution).

Finally, responses 2.1, 2.2 and 2.3 were cited by the OF3 group, which identified themselves equally with the last two realities of Table 1 and with myths no. 1 and no. 3 of Table 2. As an example, a student from this group has stated that she had some very good paper-based materials at home, but that her parent's home was too far away from school to go there just for that. Another student said that she wanted to help the young Brazilians but was not in the mood to spend some money in order to make copies of her paper-based materials.

In a nutshell, and with regard to the realities of Table 1, although the focus groups have agreed with all of them, they have confirmed very explicitly the last one: "The growing virtualization of knowledge makes it very convenient and fast to share resources online". As to the myths of Table 2, focus groups have only agreed with the first three of them—leaving out the fourth one: "Some of the sympathetic messages and posts are written not only to help other classmates, but also to try out the forum, the chat room or the messaging system."—and they have confirmed very explicitly the first myth: "Maybe it is a myth to consider solidarity more frequent online than offline, simply because it is easier to keep track of it online."

The focus groups have also referred a few times that the forum was an inviting and easy way for them to contribute to the "solidarity campaign". They have found very useful to witness the materials that other students were posting, in order to guide them in their contributions and to avoid repetitions. Also, they have stated that this campaign was useful not only to the Brazilian students, but to enrich themselves with new and varied knowledge. More than simple information, they have considered that some of the posts—that they have called "experts-type"—included very useful and to the point knowledge, difficult to collect just by doing a Web search.

FUTURE TRENDS

After analysing the current state of the art of the Semantic Web it becomes clear that there is still the need for human intervention to derive knowledge—or information with meaning—from the Web. That was the reason that led us to explore a more human-based Web service such as the online forum. Although some online forums—the newsgroups—have an inherent annotation process—the Usenet hierarchy of subjects—online forums would gain much more meaning, if we could include additional metadata in order to improve searches and other information retrieval techniques.

The idea of annotating messages with RDF descriptions is not new. Quan, Bakshi & Karger (2003) have already proposed the development of a well-defined ontology for messaging based on the RDF. Those authors have proposed ontological specifications of how to represent messages, conversations, and people (senders and recipients) using RDF Schema. Their goal was to support for unified messaging in the context of the Semantic Web. That is, to assemble as conversations with meaning, the messages exchanged regardless of the communication channel: e-mail, Internet relay chat (IRC), newsgroups, instant messaging (IM), and news feeds.

We agree with that proposition and envision the annotation of online forums (newsgroups and others) as a major development to amplify the importance of forums in the Semantic Web's era. With metadata attached to the forum posts and the ability to rely on human supported interaction, not only online forums could be used to ask new complex semantic questions, but also we could depend on them to retrieve meaning rich historical information.

With respect to solidarity in e-learning environments, in general terms, and the forum's contribution to amplify it, in particular, we foresee a major increase in the use of dialogue intensive forums. In its essence, this type of forums can stimulate increased participation from students, by encouraging the exchange of personal experiences and meaning rich information. Dialogue intensive forums provide the perfect environment to achieve socially constructed knowledge and the exchange of sympathetic behaviours, but there is a lack of empirical studies to confirm that.

At the same time, our past research studies regarding e-learning and solidarity, have indicated that blended-learning seems to be the best modality of e-learning in order to increase the sharing spirit and partnership among the class members. And that is because blended-learning tends to maximize the benefits of both arguments while minimizing their disadvantages. For instance, reality no. 1 of Table 1 applied to a blended-learning situation, allows the more outspoken students to participate mostly in the classroom, and the more reserved students to participate mostly in the online environment. In addition, students who feel respected and understood tend to be more open, cooperative, constructive, acceptant and responsible. Therefore, the normally quieter students that gain recognition by sharing resources online probably also tend to gradually participate more in the classroom.

Another reason that leads us to consider blended-learning as an ideal solution to promote solidarity between students is that the sharing of written resources is best suited for online environments, but the sharing of some "how to do" practices is best suited to be conducted in face-to-face environments. So, further research is necessary.

CONCLUSION

This chapter has explored a very important social dimension in the context of two overlapping areas for our study: e-learning and the Semantic Web. That social dimension was the extent of solidarity that students tend to share with each other in Web-based learning, in our case, in higher education.

We saw that semantic technologies lack substantial developments in order to support an automated exchange of sympathetic behaviours among humans. That is because solidarity is a human value which makes it very difficult to be processed automatically by machines. As of that, we have turned on to a more human-based Web service, as is the online forum.

In online forums, we can ask complex semantic questions, i.e. we can post to a large number of interested persons in our subject—the members of the forum—knowing that someone will understand the meaning of the question and hopefully will give us a good answer to it. Add to forums the possibility of annotation with metadata and we can also depend on them to retrieve meaning rich historical information.

With regard to e-learning and solidarity, in both studies that we have conducted we found out that students tended to be more sympathetic with each other in online learning environments than in offline settings. In other words, we have seen more sharing of useful resources between group members in online environments than in offline ones. For that increased solidarity online have contributed, in a great extent, online forums that were set to support the students' sympathetic contributions. Forums are really very easy to operate and, hence, have the ability to promote sympathetic behaviours. But that was not the only conclusion of our second study. We have also concluded that our cohort is a truly sympathetic group of students. This and a good discussion question with which students identify themselves (as was the case), justifies the generous contributions, both online and offline.

This second study has also confirmed the majority of reasons that have justified the increased solidarity online in the first study. That is, the realities and myths about e-learning and solidarity. More specifically and in the students' opinion, the findings of the second study have emphasized one reality and one myth as being more important than the others. The former is: "The growing virtualization of knowledge makes it very convenient and fast to share resources online". The later is: "Maybe it is a myth to consider solidarity more frequent online than offline, simply because it is easier to keep track of it online." Although this myth is believed to be true, we still think that it is not enough to level things. That is, we have evidence which lead us to believe that solidarity is more frequent online than offline, even though it is harder to keep track of things in the offline world.

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KEY TERMS AND DEFINITIONS

Blended-Learning: Blended-learning (or b-learning) is the use of more than one strategy or delivery system for learning.

Complex Semantic Questions: Search queries that require the understanding of descriptions and relationships of things in order to be answered.

Dialogue Intensive Forum: A forum where the moderator posts an initial discussion question that is related to a certain topic and asks the users to share their own experiences, personal opinions, as well as other documented source materials that are related to that question. In the context of e-learning, the moderator is the teacher that sets a minimum of participation from the users, which are the students, in order to promote an intensive interaction.

E-Learning: Any learning that is mediated by a computer and which requires no direct interaction between the user and a human instructor in order to run.

Learner-Learner Interaction: Two-way communication between students, either on an individual basis or on a group basis, and with or without the real-time presence of an instructor.

Online Forum: A forum is a sort of online messages board where users can post new messages and respond to existing ones. Being an asynchronous communication tool, users can take all the time they want preparing a new message or an answer before posting it to the forum.

Solidarity: Solidarity is as a human value that every person can achieve in his growing process as a human being and that tends to influence his behaviour towards the others (e.g. sharing, helping and supporting other people, integrating, protecting, etc.).

Solidarity Between Students: The exchange of information among fellow colleagues or sharing useful resources for the learning experience of other classmates, in order to help and support the group.

Section III
Challenges, Opportunities, and Impact

Chapter XXIV
Applying an Organizational Uncertainty Principle:
Semantic Web-Based Metrics

Joseph Wood, LTC
US Army, USA

James Grayson
Augusta State University, USA

Hui-Lien Tung
Paine College, USA

Margo Bergman
Northwest Health Services Research & Development (HSR&D), USA

Tina Marshall-Bradley
Paine College, USA

W.F. Lawless
Paine College, USA

Donald A. Sofge
Naval Research Laboratory, USA

ABSTRACT

The theory of bistable perceptions in the interaction indicates the existence of an uncertainty principle with effects amplified at the organizational level. Traditional theory of the interaction, organizational theory, and the justification for an organizational uncertainty principle are reviewed. The organizational uncertainty principle predicts counterintuitive effects that can be exploited with the Semantic Web to formulate a set of metrics for organizational performance. As a preliminary test of the principle, metrics derived from it are applied to two case studies, both works in progress, with the first as an ongoing large system-wide application of web-based metrics for organizational performance and the second as a case study of a small college where web-based metrics are being considered and constructed. In preparation for the possibility of machine-based real-time metrics afforded by the Semantic Web, the results demonstrate a successful theory and application in the field of an uncertainty principle for organizations.

INTRODUCTION

Overview. No theory of organizations is widely accepted today (Pfeffer & Fing, 2005). In this chapter, we provide a brief discussion of the problems with traditional organizational theory and, focusing on fundamentals, a classical (quantum) alternative model that accounts for predictions from traditional theory and at the same time its supposedly spurious but ultimately disconfirming findings. With its focus on the individual, traditional theory, also known as methodological individualism, encompasses social learning theory (SLT) and game theory. SLT includes classical or Pavlovian conditioning, operant or Skinnerian reinforcement, and modeling (for a revised version and summary, see Bandura, 1989). In contrast to SLT, game theory focuses on the interaction between two or more individuals (Von Neuman & Morgenstern, 1953), but like SLT, it is static; an attempt to make game theory dynamic employs repeated presentations of static game matrices. But the need for the classical (quantum) alternative is inherently based on the fundamental questions raised by the traditional focus on the individual.

In addition to theory, we review field data and the application of the organizational uncertainty principle in the form of performance metrics to two case studies, one of an ongoing, long-term nature and the other incipient. Both case studies are web-based. We include a review of the future semantic web and its implications for the two case studies. Finally, we discuss future prospects with the semantic web for theory, tests and computational models of the organizational uncertainty principle, and a path forward for the two case studies.

From the perspective of the Semantic web, our objectives are to review traditional social learning and game theory for organizations and the alternative organizational uncertainty principle. Our objective for the organizational uncertainty principle is to justify its formulation based on evidence and to review two case studies that use metrics to exploit the organizational uncertainty principle. Our final objective is to provide a path forward with automatic machine-based data generating real-time online metrics for future research with the semantic web.

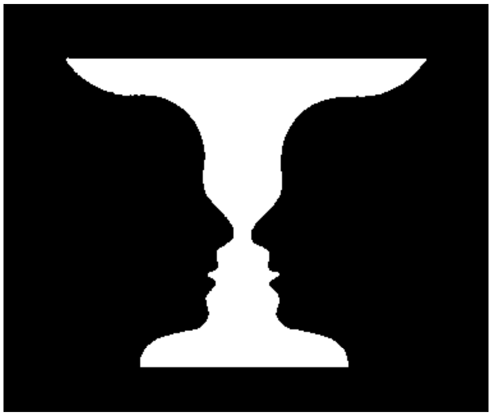
BACKGROUND

Definitions

In the Background, we define bistability, the organizational uncertainty principle, SLT, game theory, organizational theory, and Semantic web. In addition, after each term is defined, we provide a brief literature review for each term. At the end of the references, we summarize these key terms.

Bistability. Bistability is best explained with an example of an illusion (see Figure 1). It occurs when one data set can produce two mutually exclusive interpretations. While the entire data set is processed cognitively by an individual, both interpretations of a bistable illusion cannot be held in awareness simultaneously (Cacioppo et al., 1996). According to Bohr (1955), multiple interpretations support the existence of different cultures. Further, given the importance of feedback to social dynamics (Lawless et al., 2007), the possibility of rapid shifts ($j\omega$, where j is the imaginary number $\sqrt{-1}$ and ω is the discrete frequency in radians per second) between each bistable interpretation increases uncertainty in the non-observed interpretation which not only can create social problems between different groups, but also support the existence of an uncertainty principle, characterized as tradeoffs between incommensurable views (e.g., the rapid shifts in the interpretations presented to a neutral jury during the cross-fires of courtroom debates). We propose that measurements of bistable phenomena collapse interdependence, decreasing uncertainty in observed aspects of a bistable phenomenon while increasing uncertainty in non-observed

Figure 1. An example of bistability



In this very simple two-faces vase illusion, an observer is incapable of observing both aspects of this single picture at the same time.

aspects; e.g., questionnaires of interdependent cognitive-behavior states.

Organizational uncertainty principle. The organizational uncertainty principle acts as a tradeoff in attention directed at reducing the uncertainty in one factor, such as a worldview or business model, with the result that the uncertainty in a second, interdependent factor is inversely increased, such as the execution of a business model. It is based on Bohr's (1955) famous notion that the quantum uncertainty principle applied to social situations is captured by the bistability of action and observation. That is, the more focused a collective of individuals are on acting out a series of steps, the less observant they become of their actions. Applied to societies, clusters of action-observation uncertainty couples form a causal path for different cultures based on multiple interpretations of the same business model or worldview (e.g., religion, liberalism, conservatism). The organizational uncertainty principle we have proposed links uncertainty between planning and execution as well as between resource availability and duration for plan execution (Lawless et al., 2006).

Social learning theory. SLT is a term coined by Bandura (1977) to include the three different schools of thoughts that accounted for learning by organisms, but particularly apt for humans. These three schools were classical conditioning (associations), operant conditioning (rewards and punishments), and modeling, Bandura's own school of thought. According to Bandura, modeling subsumed the other schools of learning. SLT works well in changing behavior at the individual level, irrespective of an individual's cognitive contributions or willingness to change. However, it offers little in the way of insight into organizational dynamics or organizational change, such as mergers and acquisitions (M&A), restructuring, or solving ill-posed cultural problems. More relevant to our thesis, SLT has been adapted to cognitive behaviors, which are dependent on surveys of interdependent physical behaviors. The critical assumption usually made for SLT is that self-reports of the cognitive perceptions of behavior match the behaviors that actually occur, an assumption not supported empirically.

Game theory. Game theory was invented in the 1940's by Von Neuman & Morgenstern (1953). It is a one-shot game, or a series of repeated games, played by two or more agents. In its most basic form, the game configuration presents two static, arbitrary choices for payoffs to each player. Payoffs are interdependent. For example, in the well-known and well-studied Prisoner's Dilemma Game, two players (prisoners) who cannot communicate to each other must decide whether to cooperate with each other, thereby gaining the most points for their dyad, or to compete against each other, producing the least total points for their dyad (Nash equilibrium). However, the best individual payoff occurs if one player competes under the condition that the other player cooperates. Although no communication occurs between the two "prisoners" undergoing simulated interrogation "by the police" in two isolated rooms, the feedback afforded by repeated games from observing prior partner choices affects future choices, leading to Axelrod's (1984) "evolution" of cooperation.

One of the problems with game theory is that it is normative (Körding, 2007). The results from playing these games follow the prevailing social norms independently of fundamental human behavior. That is, the value of the choices available to be made by the participants are not based on empirical support on improving social welfare, but on society's worldview of the ideal social behavior that promotes social welfare; viz., cooperation is superior to competition (this arbitrary choice by scientists is analogous to choosing market winners by authoritarian or command decision-making governments). Second, game theory inverts the assumption made by SLT about behavior. Game theory assumes that a static configuration imposed on cognition generates the desired (normative) behavior exactly. As a consequence, although providing very clear predictions, the results from games do not predict human behavior (Sanfey, 2007).

In sum, when considering the two prevailing models in the social sciences, game theory and social learning theory, these two models of methodological individualism do not focus on improving social welfare, generating creativity, or solving social problems; however, they expect to derive these benefits secondarily. Further, both theories assume the existence of a 1:1 mapping between interdependent states of cognition and behavior, leaving no room for the collapse of interdependence; e.g., by measurements or decision-making. This situation places social scientists in a box—they recognize that restrictions for self-reports are necessary in at least the case where extreme claims made about behavior cannot equal actual behavior (for hypochondria and alcoholic denial, one over states self-reported behavior and the other under states self-reported behavior).

Organizations. Organizations are social groups that perform a function which often cannot be done by an individual alone. Organizations do this by assigning interdependent roles to a set of independent individuals, which requires information coordination and blocking to form them into a working collective, but which consequently amplifies the capabilities of an individual (Ambrose, 2001). An organization arises to serve a function when its operational costs are less than the benefits it accrues and provides to its members (Coase, 1937). It is likely constructed around a geographical centroid (x) about which its business attributes are centered, planned and modeled (i.e., BM_x; derived from Sukthankar, 2008). But multiple theories of organizations exist (Weick & Quinn, 1999). Pfeffer and Fong (2005) concluded that one of the problems is the lack of a foundational theory for organizations; consequently, they proposed the need to incorporate illusions into basic organizational theory. Although "illusions" could be metaphorical, imaginary factors are instrumental in engineering to model oscillations ($j\omega$). We propose that active illusions bruited about during an open discussion interact with real world feedback to generate discussion oscillations ($j\omega$) until interdependence collapses.

Semantic Web. The Semantic web is an ongoing project to extend the World Wide Web (WWW) to permit humans and machines to collaborate efficiently. As envisioned by Berners-Lee (2007), inventor of WWW (and web languages URI, HTTP, and HTML), the future Web should evolve into a universal exchange for data, information and knowledge. Without a universal standard for machine access, HTML data is difficult to use on a large scale. The Semantic web solves this problem with an efficient global mesh for information access by both humans and machines.

The Semantic web includes a Health Care and Life Sciences Interest Group (HCLSIG, 2008) to establish interoperable data standards for "connected knowledge" to improve collaboration across the health care and life sciences, in our case, military medical research training services. The goal for HCLSIG is to reduce medical errors, increase physician efficiency and advance patient care and satisfaction. It includes document annotation and rule processing (with XML formats, OWL ontologies and SWRL rule processors).

A future option for the Semantic web, but one we pursue now in Case Study 1, may be electronic dashboards to link scientific publications and electronic medical records to associate disease, drug compounds, biology and pathway knowledge between R&D groups. As a final concern for HCL-SIG, there is today no widely recognized machine accessible semantic differentiation between a manuscript and publication; illustration and experimental image data; or between an experiment, data, interpretations, and the hypothesis that an experiment was designed to validate. Initially, our first web-based study in Case Study 1 addresses only parts of these problems with an adaptive electronic Institutional Review Board (eIRB) for research protocols rather than medical records; but associated with the eIRB, we are considering business intelligence for individual organization and system-wide performance metrics, and linking scientific publications from multiple military R&D groups to improve patient care.

Brief Literature Review

In addition to the literature reviewed in the background, an additional but brief review is provided here to place our work in a historical context. On its face, Durkheim's (1893) "social facts" stand against Weber's (1958) methodological individualism, today ingrained in game theory, where the choices available to those playing games are influenced by the social and religious norms existing within a culture (Körding, 2007). As an example, the choice to cooperate with a partner in the Prisoner's Dilemma Game is configured with a higher value than the choice to defect from a partner, even though from an information theory perspective, society often gains significantly more social benefits from competition than cooperation (Lawless & Grayson, 2004). While social norms should not be disparaged but studied, neither should scientists favor the norm of cooperation by configuring it with a higher social welfare value, similar to an industrial policy that chooses the winners for its society. But there are limitations to Durkehim's view, too. If reality is bi-stable, social facts are open to multiple interpretations.

Parsons and Luhman contributed to cybernetics and control theory as an information approach to controlling and modeling society. Parsons (1966) developed a systems approach as a grand theory of society. He used systems as a tool to analyze the function of society, concluding the systems that adapt to their environment had evolved into more efficient systems; however, in that the environment is ever changing, adaptation is not an optimal control strategy (Conant & Ashby, 1970). Parsons influenced Luhmann's (1984) theory of autopoietic, or self-organizing, systems. Luhman believed that autopoietic systems filtered information from the environment, independently of other systems, making them autonomous, but also apart from society. Elias (1969) contributed to cybernetics with his ideas on figurational, networked or interconnected structures as the source of power over other systems. Crozier and Friedberg (1981) used game structures to explicitly analyze power and strategy between organizations and their members as interdependent actors. But the limitations remain for game theory from the influence of social norms and the lack of a theory of uncertainty.

Finally, and contrary to Weber's view of different beliefs producing structural differences in a society, Montesquieu (1949) suggested that checks and balances contribute to society by limiting power. Madison applied Montesquieu's idea by building a constitutional government based on checks and balances (Hamilton, Madison, & Jay, 1787-1788), concluding that social structure controls and stabilizes government independently of the social norms in existence. Further, not only do checks and balances recognize the limits of situational awareness, motivated by the search for meaning at the individual level (Carley, 2002); but also, consensus rules and compromise dilute the added information provided to society by checks and balances, their strength. However, compromise leads to an "action consensus" based on a concrete plan of action, compared to the unified worldview of consensus seeking, which reduces the likelihood of action (Lawless et al., 2008b). This is not to conclude that Weber's ideas missed the mark. Just the opposite. Weber understood that the tradeoffs between the incommensurable beliefs of Confucianism and Puritanism produced profound differences in the control of and social welfare benefits for two social systems, which agrees with the uncertainty relations presented below.

MAIN FOCUS OF THE CHAPTER

In general, most of social science is predicated on the assumption that observations of behavior, especially the self-observations made in response to questionnaires, provide perfect or near perfect information about a target behavior, thereby leaving no room for an uncertainty principle. However, striking problems exist with asking agents about the causes of their behavior (self-reports, surveys, structured interviews, case studies). Baumeister et al. (2005) found that a 30-year meta-analysis of survey data on self-esteem correlated poorly with academic and work performance, casting doubt on one of the most studied phenomena in psychology and also on the ability of self-reports to capture targeted phenomena. Similarly, in an attempt to prove the value of air combat maneuvering for Air Force educators, Lawless and his colleagues (2000) found no association between air combat outcomes (wins-losses) and examination scores on air-combat knowledge. And at the end of his distinguished career in testing game matrices, Kelley (1992) found no association between the preferences as measured by surveys before games were played and the choices actually made during games. Along the same line, Axsom and Lawless (1992) found that scientists easily misinterpreted the causes of behavior measured in effort justification experiments designed to reduce public speaking anxiety even when the scientists observed the changes directly.

In their review of decision theory, Shafir and LeBoef (2002) concluded that justifications of actions already taken were not consistent with the actions taken, including for expert judges. In addition, they found that the widely held belief by theoreticians that expectations of well-being lead to well-being was systematically violated, even for experts. But even though the evidence in support of widespread claims based on self-reports does not exist, many social models continue to endorse the belief that cooperation enhances the value of social welfare more than competition. In agreement with Pfeffer and Fong, the lack of fundamentals has produced a subjective social science. In response, we take a more theoretical approach based on the impact that cooperation and dissonance have on the diminution or generation of information (Lawless & Grayson, 2004).

To summarize, metrics must not interfere with the process of measurement; doing so collapses interdependence and invokes the organizational uncertainty principle (e.g, surveys of self-esteem at the individual level by Baumeister et al., 2004; decision-making at the organizational level; Lawless & Grayson, 2004). Perceptions are integral to behavior, as the Coca-Cola Company discovered when it decided to close out its traditional Coca-Cola brand due to its inability to best Pepsi-Cola in internal taste tests (en.wikipedia.org/wiki/New_Coke). But following considerable public criticism, the firm brought back its traditional cola and re-branded it "Classic Coke". As Baumeister has re-discovered, the measurement of perceptions in interdependent states with behavior collapses the interdependence, producing static information.

We plan to study organizations with computational models. However, Bankes (2002) and Conzelmann and his colleagues (2004) have both concluded that current computational models of organizations are not predictive, principally with Agent-Based Models (ABMs). We plan two correctives: first, to test models using social configurations addressed by our organizational uncertainty model to reproduce the results of collapsed interdependent states that we have predicted and found in the field and laboratory; and second, to build bistable organizations constituted with bistable artificial agents.

Organizational Theory and Uncertainty Principle

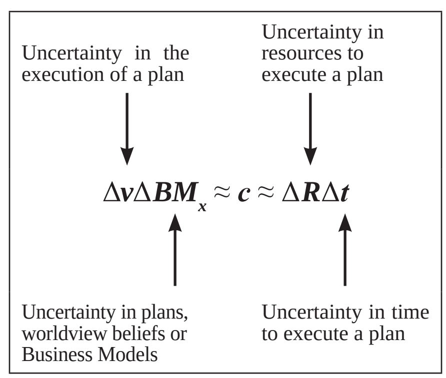
In contrast to traditional social science, we have attempted to combine individuals with organizations and systems, statics with dynamics, and empirical approaches with theory. We incorporate dynamics in our model with the effects of feedback on oscillations within an organization, but as a metric for its performance. We incorporate organizations in our model by introducing control as organizations seek to improve in performing or revising their mission (Mattick & Gagen, 2005; also, May, 1973). Finally, in our approach, an empirical approach alone precludes formal approaches and optimal solutions; our immediate goal, then, is to build and be guided by theory and empirical findings.

To implement control theory (Csete & Doyle, 2002), we need to quantify an organizational or system's level model. In line with earlier arguments, an organization controls at least four aspects of the decision-making process. First, by helping to set or choose its reference or threshold set-points (e.g., culture, decision processes, expectations, planning; and in Case Study 1, mission and vision). Second, by damping unexpected disturbances. Third, by filtering and transforming incoming information about system internal states, inputs, and responses to form patterns and decisions. Finally, by taking actions then collecting feedback to revise decisions. However, Conant and Ashby (1970) concluded that feedback to minimize errors is not an optimal solution for control, that the optimum solution avoided errors (e.g, with a plan that produces the most efficient operation possible).

As metrics for our control theory, we have proposed inverting the organizational uncertainty principle in Figure 2 to link uncertainty between planning and execution as well as between resource availability and the duration of plan execution.

In Figure 2, uncertainty in the social interaction is represented by an interdependence between business models, strategy, plans, or knowledge uncertainty (ΔBM_x, where the knowledge or business model is a function of the social location where it was learned; from Latané, 1981 and Sukthankar, 2008) and uncertainty in the rate of change in knowledge or its execution as $\Delta v = \Delta (\Delta BM/\Delta t)$. This relationship agrees with Levine and Moreland (2004) that as consensus for a concrete plan increases (ΔBM_x reduces), the ability to execute

Figure 2. Measurement problem



The measurement problem occurs as the result of the organizational uncertainty principle. The measurement problem arises from the interdependence between the two factors on each side of the equation. It states that both factors on either side of the equation cannot simultaneously be known exactly. For example, a decrease in the uncertainty in the strategy for an organization results in an increase in uncertainty for the execution of that strategy. In practice, decreasing strategic uncertainty increases action; increasing strategic uncertainty slows action (Busemeyer, 2008). At the same time, the uncertainty principle informs us that only one of the factors on either side of the equation can be known with certainty (Lawless et al., 2007).

the plan increases (Δv increases). By extension, interdependence also exists in the uncertainty in the resources expended to gain knowledge, ΔR, and by uncertainty in the time it takes to enact knowledge, Δt. That these two sets of bistable factors are interdependent means that a simultaneous exact knowledge of the two factors in either set is precluded, due to a collapse of interdependence. However, a partial or proportional collapse is not ruled out (i.e., tradeoffs).

We have used the model in Figure 2 to study human organizations making decisions under uncertainty by addressing complex situations like the environmental cleanup of its nuclear facilities undertaken by the Department of Energy, or mergers and acquisitions. The primary characteristic of this interdependence is reflected in tradeoffs between coordinating social objects communicating to solve problems while in states of uncertainty (Lawless & Grayson, 2004). In Case Study 1, we apply Organizational Uncertainty theory to a system of seven MDRCs (Medical Department Research Training Center). Our goal is to help those MDRCs become more productive in meeting their assigned mission. This means that the MDRC system would shift from a fragmented to a more ordered group of organizations, thereby increasing productivity. In the future, to exploit the power of the semantic web, we propose to use a rate equation to measure in real-time with machines the system performance, thus offering management insight as to the factors to change in a tradeoff that enhances organizational performance.

In addition, we have proposed that alignment of humans and thinking machines (agents) in an organization ranges from disordered in the lowest energy or individual state to one focused on the mission (Lawless et al., 2007). But, by focusing on the mission exclusively as in the latter case, organizations become vulnerable to change. Therefore, it is important to use feedback not only to fine tune an organization's effectiveness over the short term, but to restructure by revising its mission over the long term (Smith & Tushman, 2005). We propose that the tension can be best constructed, maintained and controlled over time by using semantic web-based metrics.

Evidence: Field

Department of Energy Citizen Advisory Boards

In our search for a classical organizational uncertainty principle, we have found in the field and confirmed in the laboratory a planning cognitive-execution tradeoff between consensus-seeking and majority rule decision-making as citizen groups made decisions over complex issues like nuclear waste management (Lawless et al., 2005). Two forms of consensus were found to exist: Worldview consensus and action consensus. The former is more likely to be derived from cooperative processes and the latter from competitive processes (Wood et al., 2008). In the first field study, we looked at the decisions of all nine of the Department of Energy's Citizen Advisory Boards as they responded to DOE's formal request to support DOE's plans to speed the shipments of transuranic wastes to its repository in New Mexico (i.e., the WIPP facility; see www.wipp.energy.gov) as part of its mission to accelerate the cleanup of DOE facilities across the U.S. These nine DOE Boards were geographically separated and located at the DOE sites where the transuranic wastes were being removed and shipped to WIPP. DOE's plans were entailed in 13 concrete recommendations and explained to the various Boards by DOE engineers (e.g., recommendation #8: "DOE in consultation with stakeholders and regulators initiate action to assure that WIPP has the capacity to accommodate all of the above listed TRU waste"). As predicted, four-fifths of DOE's majority-rule boards endorsed these recommendations, while three-fourths of its consensus-ruled boards rejected them. In addition, the time spent in deciding for majority-ruled boards was about one-fourth of the amount of time taken by the consensus-ruled boards.

In a follow-on field study of consensus decisions by the Hanford Board in Washington State and majority rule decisions at the Savannah River Site Board in South Carolina, Boards located at the two DOE sites with the largest cleanup budgets, we found that consensus rule decisions produced a cognitive congestion that resulted in behavioral "gridlock" when the single worldview of the Board conflicted with DOE's vision, increasing social volatility (Lawless & Whitton, 2007). We have found that cognitive congestion is more likely under cooperative decision making because of the inability to accept challenges to illusions (Lawless et al., 2008b). In contrast, we have found that the cognitive disambiguation from competition improves social welfare with practical decisions that feedback amplifies or accelerates.

Relative to the SRS-CAB, Bradbury and her colleagues (2003) analyzed interviews and other self-reported measures to conclude that Hanford CAB members felt very positive about their consensus-seeking process, that they very much wanted a cleaned-up environment, and they felt that DOE at its Hanford site was very responsive to their demands. However, the results from field metrics at DOE Hanford and DOE Savannah River Site (SRS) across three measures of cleanup (high-level radioactive wastes, transuranic wastes, and the environmental remediation of contaminated sites) indicated the opposite (e.g., Lawless et al., 2005). Compared to the SRS CAB and the SRS site, this difference between perceptions at the Hanford CAB and the results in the field represented an increase in risk perceptions (i.e, an unchecked increase in the number of illusions) among the Hanford CAB members that had kept them from making concrete recommendations to accelerate the environmental cleanup at Hanford.

Evidence: Laboratory

Preliminary data from a laboratory experiment nearing completion with college students making recommendations to improve their college experiences appears to have fully replicated the DOE CAB study. In this study, we asked college students in 3-person groups (N = 53 groups) at a Historically Black College and a nearby University to proposed open-ended recommendations to improve operations affecting them at their schools (e.g., with cafeteria food, library, student government, etc.). Students were randomly assigned to three-person groups who made recommendations either under consensus (CR) or majority rules (MR). Time for both types of groups was held constant. Tentatively, we predicted and found that while CR produces significantly more discussions (oscillations or $j\omega$), indicating less time available to craft recommendations, MR produces significantly more total recommendations (our analyses are ongoing).

Evidence: Case Study 1: Military Medical Department Research Training Centers (MDRCs)

Guided by our theoretical and field results in applying the organizational uncertainty principle, we have been assisting a system of seven military MDRCs (Wood et al., 2008) to become more productive; e.g., produce more research with greater scientific impact; improve patient care; and reduce the costs of care. Specifically, when we began this case study, we found little knowledge existed at the organizational level that directly linked each research product (publications, presentations, workshops) with MDRCs assigned mission. Instead, MDRC collected basic citations for each publication; not all publications were captured in its data-base; nor were all conferences attended captured in their data base.

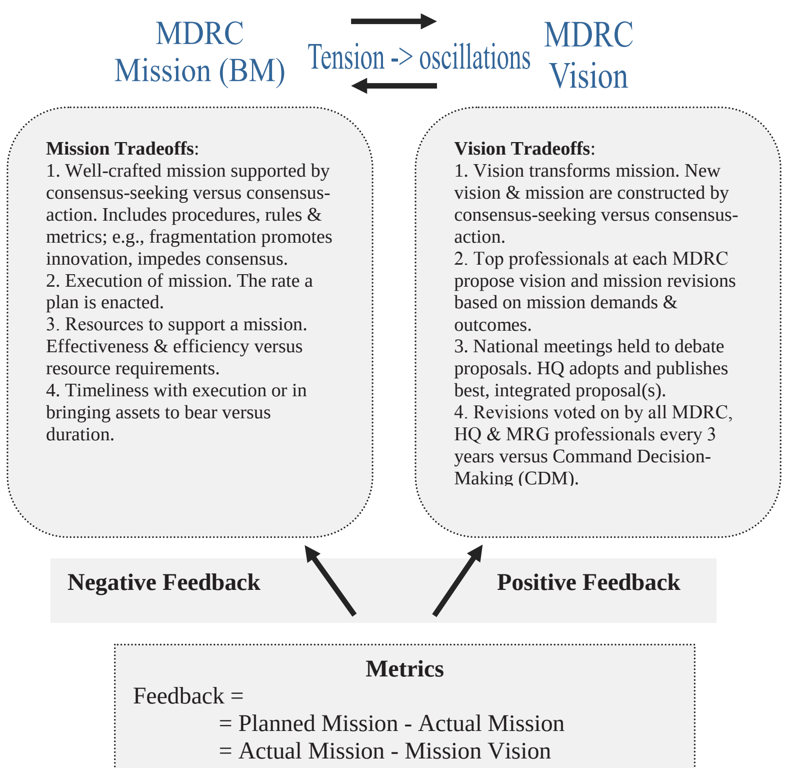
We began with a preliminary set of metrics that indicated the efficiency in meeting MDRCs mission per research protocol across the factors of scholarly activity, personnel availability, space, and funding. But at the same time, these Centers wanted to be able to transform their mission as necessary. These two goals are contradictory. But Smith and Tushman (2005) concluded that satisfying contradictory goals like these could make an organization more productive now, and more transformative in the future (see Figure 3).

Based on feedback from metrics of organizational performance linked to eIRB's, administrators have the ability to execute their mission effectively and efficiently; e.g., with Lean Six Sigma processes. But efficiency alone reduces adaptability to uncertain future missions (Smith & Tushman, 2005). Thus, concomitantly, a group internal to each MDRC and a national group of elite professionals from all MDRC units could gather annually to transform its mission, goals, and rules guided by the same feedback and metrics. As these two systems compete in a bistable relationship to control the Mission, the two systems operate in tension (interdependence), producing a natural evolution of the system.

Evidence: Case Study 1: Application of the Theoretical Model

The military (Wood, 2007) has funded a secure web-based system for one MDRC for the submission of IRB research protocols by its investigators (viz., human and animal research Institutional

Figure 3. Future proposal for a semantic-web based system of seven MDRCs



The initial guidance based on theory were: Mission success makes a lean organization more efficient but also more vulnerable to change; change in a business model or its execution in reaction to environmental change was not optimum (Conant & Ashby, 1970); and a sweet spot exists where mission performance is optimum, errors are at a minimum, and at the same time the mission and the organizations it guides are modernized.

Review Boards). The other MDRCs are included in the product evaluation selection process in the hope that the benefits of the funded eIRB will secure funding for the other sites. The first eIRB includes routing of submissions to IRB members; receipt of comments from IRB reviewers; transmission of modification requests to investigators; development of IRB meeting minutes; tracking of protocol status; automatic notification of investigators of continuing review deadlines; and tracking metrics. The technology provides a platform for collaboration across the organization between Principal Investigators and team members when drafting protocol proposals. It provides feedback among IRB reviewers, the PI and study team, and Administrators. It tracks Adverse Events (medical and drugs); provides guided electronic input and assistance and error checking and reporting to PI's and Administrators; but more importantly, it is a platform for integrated management and reporting.

The vision for this eIRB project is to achieve an end state to:

allow all research proposals, supporting documents, and scholarly products to be submitted and managed by a secured web based electronic system that allows for the real time calculation of research metrics of workload, productivity and quality. Additionally, this kind of system will allow for better management of the necessary documentation for human research protection and ensure a better environment of operational security oversight for potentially actionable medical information. This will be developed with joint execution in mind and have input from our DoD counterparts. A system that effectively captures all aspects of the research process, from protocol submission and processing to publication of scholarly products or novel therapeutics will generate the highest quality data for productivity analysis and metric development. We believe this can best be achieved by development of an electronic protocol submission and management system with the capacity to generate real time metrics of productivity and quality. (Wood, 2007, pp. 4-5)

In installing the eIRB, MDRC will be better positioned to leverage business intelligence (BI) tools that automatically pull together data for metrics with machines from this new electronic system and from other disparate database systems already in place (e.g., electronic medical records). However, only until MDRC has database systems across all aspects of biomedical research and medical care delivery and the BI tools to link these often incongruent systems together will it be able to generate real time data for semantic-web machines to study, define and improve their processes. Once in place, MDRC can make decisions in real-time rather than with data many months old thereby closing the gap between the mission and the vision and pushing the organization faster towards innovation. The natural tension and gap between the mission and vision, as it closes, will decrease the cycle time between these two perspectives propelling MDRC along the pathway of necessary transformation. We believe the ability to quickly and effectively manage knowledge is the key to organizational change.

Knowledge management is one of the fastest growing sectors in the business community. In parallel with the rapid growth of knowledge generated by automation systems, organizations having the capability and diversity of BI tools to analyze their performance against their own chosen metrics should help to accelerate system-wide transformation. These tools can afford a seamless reach across different platforms to easily allow for the automatic generation of dashboards that can visually depict metrics of organizational importance in a manner not previously available. As the present web evolves into the Semantic web, so will the capability of knowledge management with BI tools.

Current Status. A case in point to demonstrate the power of web-based technology and knowledge management has been the virtual collaboration systems used by the MDRC working group planning for an eIRB. Leaders geographically separated were able to meet approximately thirty times over almost two years and work together to solve common problems in a manner that would have been cost-prohibitive in the past. MDRC leaders from Hawaii, Washington State, Texas, Washington DC, and Georgia worked as a networked virtual organization for approximately 60 hours using web-based collaboration technology with visual and audio communication that lead ultimately to the successful funding of the eIRB system (for a review of Networked and Virtual Organizations, see Lawless et al., 2008a). Members simply logged onto the web from the convenience of their own office to participate in problem solving and closing the gap of tension between their mission and vision. Using this virtual collaboration in conjunction with a mind-mapping program (similar to a semantic network) for more effective brainstorming allowed the saving of thousands of dollars in travel and personnel time.

Assessment of Case Study One. We began Case Study 1 by contrasting the organizational performance of MDRC against the specifics listed in its assigned mission: improving patient care in the field; reducing the costs of care; and increasing the impact of research products. We found no clear link between research products and the mission; no measure of publication impacts; and no direct way to measure organizational productivity against its peers (reduced or negligible states of interdependence). In general, the organizations in the MDRC network appeared to be fragmented, with each pursuing its own path to mission success. No overarching measure of system performance existed for the MDRCs that the separate organizations could follow to guide their collective behavior. As a consequence, long-term work practices and cultural differences predominated. Subsequently, the move to adopt a web-based eIRB has set the stage to turn around the lack of organizational and system-wide knowledge. MDRC is prepared for real-time organizational and system-wide based metrics, improvements and future transformations (based on maintaining interdependent states). We believe that the semantic web can enhance these metrics by operating in real-time with data collected by machines to distinguish between classes of data sources (using OWL's vocabulary to label separately a site's physician students, physician scientists and medical scientists across the different sites, etc.). At the same time, we will be diligent in preventing web machines from either the inadvertent disclosure of patient records or the premature release, identity and location of researcher data.

Evidence: Case Study 2: Application of Theoretical Model to a College

After developing and applying metrics for a government organization whose primary mission is training military physicians in medical research practices, it was helpful to apply similar web-based metrics to an organization with a very different purpose. The subject of Case Study 2 is an organization whose primary function is higher education. Although all institutions of higher education are tasked with the production of new knowledge within fields where it offers degrees, this organization's primary purpose is to train the next generation of citizens through the use of a liberal arts curriculum. In its Vision statement, technology is highlighted and indicates that the institution "provides information technologies that link its students' total academic and social experiences to the global world." (Bradley, 2008)

Today's institutions of higher education are faced with an interesting dilemma with faculty members who have come of age during a period of tremendous technological upheaval. During the last twenty years, institutions of higher education have started making significant investments in administrative information systems. Higher education institutions are being asked by policy makers, accrediting bodies, the business community and the public for evidence that college graduates have a demonstrated knowledge base predicated on their degree. With the mounting cost of higher education, consumers are asking for accountability from colleges and universities (Bradley, 2008). Institutions of higher education as well as most organizations must focus on systems that must be in place to ensure that the decisions made in the future take advantage of the best data possible.

Institutions are engaged in a delicate dance of remaining true to their purpose in society while responding to calls for accountability for their actions. Laws such as the Family Education Rights and Privacy Act (FERPA) caused some campus officials to develop extremely strict policies regarding information about student records. These policies were strictly enforced even when it was known that the aggregation and analysis of data from student records would provide the institution with invaluable information for making informed decisions about ways to improve academic programs, increase retention, and address issues being raised by outside entities. Institutional research projects were strangled by the fear of litigation regarding the privacy of student information (Green, 2007).

According to Green (2007) "institutions of higher education have seen an emergence of a wide, rich, and mission-critical array of student and institutional services that are directly linked to core campus information services (or Enterprise Resource Planning (ERP) functions). Yet these new functions and services—alumni services, course/learning management systems, digital content, e-portfolios, e-services (online registration, fee payment), and portals—are all firmly dependent not only on the Web but also on real-time interaction with the core elements of the "old" management information system (MIS), particularly students records and institutional finances." Many of these functions at institutions, particularly small institutions are informal and units within the organization form their own fiefdoms many times as a way of managing the complexity of a system that is governed by external policies and procedures as well as the end users of the services. In an earlier age when students walked from one office to another to engage personnel in the business of enrolling in courses, acquiring financial aid, paying their bills, and obtaining housing, these systems worked. However, in an age where information drives decisions for the organization as well as the consumer, the earlier model is no longer feasible.

The organization employs approximately 200 individuals with the majority of individuals serving as instructional personnel providing instruction for a student body of less than 1,000 individuals studying at the undergraduate level. Besides instructional staff (faculty), there are administrative staff members, staff who provide support services to students, a unit that manages the fiscal enterprise of the organization, and a unit responsible for external partnerships and fund raising. All units of the institution rely on the efficient function of the other areas but are limited in the operational knowledge generated by these other units from the lack of technological (web-based) interconnectivity.

Current Status

Computing and technology support in an academic environment provide the technology infrastructure for academic and administrative activities that have become essential for the operational effectiveness of institutions of higher education. There is a need to analyze the current technology infrastructure due to the present isolation between subsystems and organizational operations. Multiple systems exist but each organizational unit works with its own "preferred" one, producing fragmentation. The different systems are not integrated causing record sharing and management problems. Currently, information technology (IT) support is being done by two staff members, one deals with hardware issues and the other with support software plus the network as part of the college's infrastructure. There is no system request form or work-list. Priority is given to network issues and calls from very important persons (VIPs) within the organization, likely impeding performance.

With a new administration, this organization has realized the need to evaluate the current IT infrastructure and the need for changes to fulfill its vision and mission. After the preliminary investigation, the first need identified was to overhaul and redesign the website. The previous version did not represent the academic organization due to its commercial feel. Then an IT inventory survey was conducted to find out what systems are available, which system is being utilized by which unit (or not at all), the merit of these choices, and the costs associated with each system. To find an enterprise-wide solution, the institution is considering having an IT-consultant company to evaluate the current infrastructure (conceptual model), and suggest the best solution. The institution also needs a chief information officer (CIO) (or MIS director) who is capable of implementing the plan.

All institutional areas that are impacted by or use technology should be evaluated. Either after purchasing an enterprise information system (EIS) or after choosing from currently available systems for a single "main" system that supports most unit functions plus a Transaction Process System (TPS) for business/financial unit online transactions, performance measurement should be enacted. Focus, however, would not be placed on the network *per se*, but on the organization's performance as measured with its EIS. Critical Success Factors for an EIS in a higher education institute like this one which should be measured are:

- Instructional support, as measured by the number of courses offered or supported via the Internet or other electronic methods, number of instructional classrooms supported, number of student computer labs, student accounts, technology in residence halls and shared spaces (i.e. campus center) or other means
- Research support, as measured by access to research databases, high speed network connectivity, other data collection and analysis mechanisms, and specialized research functions
- Cost of services, either measured in the aggregate, or on a per-student full-time equivalent (FTE) or per-faculty FTE basis, including comparisons with peer institutions
- Number of graduates compared with admission
- Student learning outcomes: assessments support

Assessment of Case Study Two

While it is too early in the process to assess this college, and while a measurable semantic-web based baseline is being built, certain areas to measure performance are already obvious. For example, after implementation of the EIS, do faculty publication numbers and the impact of research (quantity and quality) improve? Does the new IT web system improve or assist the College in its assessment processes? After the EIS system is operational, we plan to review its performance as well as the College's.

FUTURE TRENDS

The most important future trend is the use of agent-based models (ABM's) to model social and organizational effects to measure their effectiveness with the semantic web. Agent based systems have been endowed with auction based mechanisms for distributing their resources (Gibson and Troxell, 2007). In this scenario, the various entities would "bid" for the information they require, ensuring that the entity that valued the information the most would receive it in the timeliest manner for their decision making. Double auctions have been used for similar analyses with genetic algorithms (Choi, Ahn and Han, 2008).

Working with mathematics, ABM's, and artificial intelligence, the organizational uncertainty principle can be generalized to interdependent probability distribution functions with the standard deviation of Fourier transform pairs (i.e., the standard deviations from a Gaussian distribution and its Fourier transform form a "Fourier pair"; in Cohen, 1995; Rieffel, 2007). Next, we construct circuits to provide a basic model of social decision making (Yu & Efstathiou, 2002). Circuits can be modeled using virtual natural selection processes (e.g., machine learning, natural computation). Rate equations would then provide a detailed prediction of outcomes that we plan to estimate with Monte Carlo simulations. Completing the process, sensitivity analyses with the rate equation parameters provides a direct link back to the organizational uncertainty principle.

Circuits

Based on entropy measures, Yu and Efstathiou (2002) found that series network circuits underperformed parallel circuits. We expect to find that group decision-making, especially around a table, is similar to a series circuit, with subgroups or subcommittees acting like parallel circuits. However, we also expect that consensus rules (CR) will be serial and sequential, producing the time lags observed in the field and laboratory, but that majority rules (MR) with discussion drivers will act like a parallelization of neutrals, producing the time speedup also observed.

Natural Computation

Natural computation models will permit us to test field data and model the organizations that produce this data, especially the MDRC system in Case Study 1 and later the college in Case Study 2. We propose to test the data and organizational models with artificial agents evolved using biologically inspired natural selection (De Jong, 2008) and social methods of decision-making (e.g. "voting" mechanisms, ensembles). Based on our field research, we predict longer decision times and more oscillations under consensus rule (CR) than majority rule (MR). That is, we expect CR to model serial sequential individual decision processes. Surowiecki (2004) presented evidence and case studies of why agent ensembles often outperform individual experts. Earlier, Opitz and Maclin (1999) empirically showed that ensembles often outperform individuals, with theoretical support provided by Brown (2005) and Tang (2006).

Monte Carlo Simulations

Monte Carlo simulation is a technique that allows the simultaneous iteration of many uncertain variables to understand the impact of input uncertainties on one or more outcome variables. Developed during the 1940s as part of the Manhattan Project, and named after the famous casino in Monaco, Monte Carlo techniques are used today in fields ranging from manufacturing to finance, engineering and life sciences.

The basic concept in Monte Carlo simulation is that each uncertain variable, which we call a random variable, is simulated by a probability distribution. For each trial of a simulation, each random variable is sampled from its corresponding probability distribution and the sampled value is used to compute the output variable(s) for the model. Many such trials are conducted and a value is collected for each outcome variable for each simulation trial. At the conclusion of all trials a distribution of outcomes can be constructed to better understand the distribution of uncertainties for an outcome given the uncertainties in the input variables.

Rate Equation

Lawless and his colleagues (2007) devised a mathematical model of social interaction rates (this approach will allow future tests of this model constructed with machine learning using recombination operators; De Jong, 2008). We propose to adapt this model to guide our future research on organizations, e.g., training MDRC physicians with the experimental method or educating students unprepared for college courses with enhancement classes. In the latter case, the model becomes,

$$\Gamma = N_1 N_2 v_{12} \sigma_{12} \, exp \, (-\Delta A/<A>), \quad (1)$$

where Γ is the college graduation rate; N_1 the population in the group of those who have learned; N_2 those in the population who have not yet learned; v_{12} represents the velocity of knowledge passed between them, with the minimum effect occurring under censorship; σ_{12} represents how well the two groups match their beliefs, with the maximum effect occurring under social agreement (resonance); and $exp\ (-\Delta A/<A>)$ represents the probability of graduation or knowledge exchanges, where ΔA represents the energy or effort required for the knowledge to be acquired, and $<A>$ represents the average amount of effort being expended by the targeted HBCU, its professors and support staff, and its fellow students. Before we address the implications of equation (1), let's rearrange it. If χ represents the knowledge required before a student can be declared to become a graduate, then $\Gamma = \partial\chi/\partial t \approx \Delta\chi/\Delta t$, and

$$\Delta\chi = \Delta t \, N_1 N_2 v_{12} \sigma_{12} \, exp \, (-\Delta A/<A>). \quad (2)$$

From equation (2), given an average time to matriculate from the target HBCU, various opportunities exist as tradeoffs for it as an organization to improve the probability that one of its students will graduate (Δχ) from this college. Increasing the numbers of those who actively support the student increases the occurrence of teacher-support group (N_1) to student (N_2) speech acts. Increasing the velocity (v_{12}) of knowledge passed between the two groups improves the acquisition of knowledge. Increasing the match (σ_{12}) between faculty-support groups and student groups can dramatically increase the knowledge gained (e.g., study groups; student focus groups; faculty-student focus groups; *enhancement* groups). But also the probability of graduation can be increased by reducing barriers for students ($-\Delta A$; e.g., either lowering requirements, choosing better qualified entrants, or *enhancing* the skills of the weaker entrants). Finally, by increasing the overall average effort or excitement by the HBCU directed toward learning and graduation ($<A>$), a college can strongly improve the odds that its students will graduate. Inversely, changing these factors can also decrease or adversely increase the time required for graduation.

Using the equations that we have laid out, with machines automatically collecting the data over the semantic web, we believe that real-time metrics will become possible. This information will not only be able to inform colleges or MDRCs whether they are on-target to achieve their mission as they themselves have defined it, but whether they are making progress evolving into the vision that they themselves have also proposed. With machine readable data feeding real-time metrics, organizations like MDRC will also be able to tune their performance. For the first time, we will know the actual cost of controlling their organizations to realize their benefits.

CONCLUSION

A preliminary web-based metric modeled after the plans for the new semantic web Health Care and Life Sciences Interest Group (HCL SIG) using electronic spreadsheets indicates that researcher protocol effectiveness can be established and measured as part of an organization's mission. In the metric, for theoretical reasons we have chosen the interdependent factors of planning-execution and resources-timing. As a result, the organizational uncertainty principle has proven to be a fertile source for theory and a tool to guide a system of military units in the field as they move into a new web-based collaboration system, and for a college as it begins to establish a web-based EIS system with real-time metrics. Future trends and our next steps along the path forward with natural computation, Monte Carlo simulation and Agent-Based Models (ABM's) were also reviewed. Finally, we will assure that semantic web machines do not inadvertently disclose patient records nor prematurely release data from researchers.

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KEY TERMS AND DEFINITIONS

Bistability: Bistability occurs when one data set produces two mutually exclusive interpretations that cannot be held in awareness simultaneously (Cacioppo et al., 1996). Bohr (1955) concluded that multiple interpretations support the existence of different cultures. Further, given the importance of feedback to social dynamics (Lawless et al., 2007), rapid shifts between bistable perceptions increase uncertainty in the non-observed perception which not only underwrites social problems between different groups, but also supports the existence of an uncertainty principle.

Game Theory: Game theory was invented in the 1940's by Von Neuman & Morgenstern (1953). It is a one-shot game, or repeated games, played by 2 or more agents. In its most basic form, the game configuration presents two choices for payoffs to each player. Payoffs are interdependent. The values in the configuration of choices offered to participants are arbitrary and normative.

Health Care and Life Sciences Interest Group: The Semantic Web includes a Health Care and Life Sciences Interest Group (HCLSIG, 2008) to establish interoperable data standards for "connected knowledge" to improve collaboration across the health care and life sciences. The goal for HCLSIG is to reduce medical errors, increase physician efficiency and advance patient care and satisfaction. It includes document annotation and rule processing (with XML formats, OWL ontologies and SWRL rule processors).

Organizations: Organizations are social collectives performing a function that often cannot be done by an individual alone. Organizations do this by assigning interdependent roles to individuals, which requires coordinating the output of individuals, but also amplifies the capabilities of the individual working alone (Ambrose, 2001).

Organizational Uncertainty Principle: The organizational uncertainty principle acts as a tradeoff in attention directed at reducing the uncertainty in one factor, such as a worldview, with the result that the uncertainty in a second interdependent factor is increased inversely. It is based on Bohr's (1955) famous notion that the uncertainty principle at the atomic level applied to social situations is captured by human action and observation. That is, the more focused individuals are on acting out a series of steps, the less observant they become of their action. Applied to societies, action-observation uncertainty couples that open the path to multiple interpretations of the same social behavior lie at the root of different cultures.

Semantic Web: The Semantic Web is an on-going project to extend the World Wide Web (WWW) to permit humans and machines to collaborate efficiently. As envisioned by Berners-Lee (2007), inventor of WWW (and web languages URI, HTTP, and HTML), the future Web should evolve into a universal exchange for data, information and knowledge. Without a universal standard for machine access, HTML data is difficult to use on a large scale. The Semantic Web solves this problem with an efficient global mesh for information access by humans and machines.

Social Learning Theory: SLT is a term coined by Bandura (1977) that includes the three different schools of ideas that accounted for learning by organisms, but with a primary focus on humans. These three schools were classical conditioning (Pavlovian associations), operant conditioning (Skinnerian rewards and punishments), and modeling, Bandura's own school of thought.

Chapter XXV
Security in Semantic Interoperation

Yi Zhao
FernUniversitaet, Germany

Xia Wang
FernUniversitaet, Germany

Wolfgang A. Halang
FernUniversitaet, Germany

ABSTRACT

With the increasing interest in Semantic Web-based applications, researchers have started to build tools enabling organisations to share information. An important aspect in maintaining the Semantic Web is, however, to preserve security during semantic interoperation of different entities. Security and privacy are indispensable to the success of Semantic Web services. Hence, this chapter aims to investigate the currently used security methods in semantic interoperation, including the security methods employing Semantic Web representation languages such as XML, RDF and ontologies, and their application methods in semantic interoperation such as secure access control and secure knowledge management. How to manage privacy, trust and reputation at the same time during semantic interoperation will also be discussed in this chapter. Finally, some directions for our further research will be presented.

INTRODUCTION

With the increasing interest in semantic web-based applications, tools for semantic interoperation have to be built to enable different organisations to share information. The emerging semantic web integrates logical inference, knowledge representation, and technologies of intelligent software agents. Annotation of web resources with machine-processable metadata and ontologies are employed as means to conceptualise and structure knowledge in order to realise the vision of the semantic web. As the semantic web is composed of web entities like web services, agents and human users, an important aspect in maintaining the semantic web is to preserve security during semantic interoperation of different entities. Hence, for the semantic web to succeed it is essential to maintain the security of the organisations involved and the confidentiality of the data handled, in particular during semantic interoperation of different entities.

The requirements of successful semantic interoperation are arising from three kinds of policies: security policies, privacy policies, and trust and reputation based policies. According to this, this chapter aims to investigate the currently used security methods in semantic interoperation, including the security methods employing semantic web representation languages such as XML, RDF and ontologies, and their application methods in semantic interoperation such as secure access control, secure knowledge management, and secure agent communication. How to manage privacy, trust and reputation during semantic interoperation will also be discussed in this chapter.

The main body of the chapter is organised as follows. The backgrounds and concepts of security and privacy in semantic integration will be introduced in the next section. Then, a comprehensive treatment of different security-preserving methods and architectures will be given. Closely related aspects are XML, RDF security, and security ontology. Secure semantic interoperation architecture and methods such as access control, knowledge management, and agent communication will be addressed, too. Privacy-preserving, trust and reputation-enhanced semantic interoperation will be discussed, since they are closely related to the security requirements. Finally, directions for further research will be indicated.

BACKGROUND

The semantic web (Berners-Lee, 2001) is a universal medium to exchange data, information and knowledge. It suggests annotating web resources with machine-processable metadata. The emerging semantic web integrates logical inference, knowledge representation, and technologies of intelligent software agents. With the increasing interest in web-based applications such as electronic commerce, researchers have started to build tools enabling organisations to share information. Most of these tools have not taken into account, however, the important aspect of maintaining the security of the organisations involved and the confidentiality and privacy of data. Therefore, for the semantic web to succeed it is essential to preserve security and privacy during semantic interoperation of different entities.

Semantic Web Services and Semantic Interoperation

Web services are defined as small units of functionality, which are made available by service providers for use in larger applications. The intention to develop web services was to reduce the overhead needed to integrate functionality from multiple providers. Communication with web services is usually achieved using the SOAP protocol (Gudgin, 2003). SOAP is an XML-based protocol for communication between distributed environments. Descriptions of the interfaces of the web services are formulated using the Web Service Description Language (WSDL) [CCMW01]. WSDL documents are generally stored in a Universal Description Discovery and Integration (UDDI) repository where services can be discovered by end-users.

While web services have indeed reduced the overhead needed to integrate functionality from multiple providers, extensive human interaction is still required in the process. Semantically enabled web services are forming the research area known as semantic web services (SWS). Semantic web services (Payne, 2004) can be defined as web services whose descriptions are annotated by machine-interpretable ontologies, so that other software agents can use them without having any prior 'built-in' knowledge about how to invoke them. Semantic web services complement standards around WSDL, SOAP and UDDI which aim to enable total or partial automation of tasks such as discovery, selection, composition, mediation, invocation, and monitoring of services. The research on semantic web services addresses definition and development of concepts, ontologies, languages, and technologies for SWSs. With the development of the semantic web and semantic web services, interoperation and service sharing are widely adopted to support collaboration across different enterprise systems (Park, 2001). Semantic interoperation and service sharing have been accepted as efficient means to facilitate collaboration among heterogonous system applications.

Ontologies and Their Representation Languages

As an important technique to represent knowledge and information, so-called ontologies allow to incorporate semantics into data to drastically enhance information exchange. The term ontology is borrowed from philosophy, where it refers to a systematic account of what can exist or 'be' in the world. In the fields of artificial intelligence and knowledge representation, ontologies are used to construct knowledge models that specify sets of concepts, their attributes, and the relationships between them. Ontologies are defined as "explicit conceptualisation(s) of a domain" (Gruber, 1993), and are seen as a key to realise the vision of the semantic web.

Ontologies play a prominent role in the concept of the semantic web to provide semantic information in assisting communication among heterogeneous information repositories (Fonseca, 2001). There are many formal languages proposed to represent ontologies, such as XML (eXtensible Markup Language), RDF (Resource Description Framework), and OWL (Web Ontology Language) (Dean, 2002).

As stated by Fensel (Fensel, 2000), XML can be used to define arbitrary domain- and task-specific extensions. RDF took the first step towards defining the web in XML terms. It does so by a syntactical convention and a simple data model for representing machine-processable semantics of data. The RDF metadata model is based upon the idea of making statements about web resources in the form of subject-predicate-object expressions, called *triples* in RDF terminology. The subject denotes the resource, and the predicate denotes traits or aspects of the resource expressing a relationship between the subject and the object.

OWL (Web Ontology Language) (Dean, 2002) has been developed inspired by description logics. It builds upon the Resource Description Framework. An OWL ontology consists of a set of axioms which place constraints on sets of individuals (classes) and the types of relationships permitted between them. These axioms provide semantics by allowing systems to infer additional information based on the data explicitly provided.

Security Requirements

To guarantee semantic interoperation, security measures must be considered to protect against unauthorised disclosure, transfer, modification, or destruction, whether accidental or intentional. To realise them, proper identity must reliably be established by employing authentication techniques, and confidential data must be encrypted during semantic interoperation. The requirements of security include authentication, authorisation, integrity, confidentiality, privacy, trust and reputation. Some of the security requirements are briefly summarised below:

- **Authentication** determines the identity or role of a party attempting to perform some action such as accessing a resource or participating in a transaction.
- **Confidentiality** is generally associated with encryption technologies. It ensures shared content to be viewed by legitimate parties, only.
- **Privacy** is closely related to security. Some portions of a document (XML, RDF, or ontology) may set to be private, so that they are invisible during interoperation, while certain other portions may set to be public or semi-private, which causes a question, that is how one can take advantage of the semantic web and still maintain privacy at the same time?
- **Trust and reputation** are also related to security. Trust exerts an enormous impact on decisions whether to believe or disbelieve information asserted by peers (Ziegler, 2004). Trust and reputation are defined as the "subjective expectation an agent has about another's future behavior based on the history of their encounters" (Mui, 2002).

MAIN FOCUS OF THE CHAPTER

As stated in (Thuraisingham, 2003), to secure the semantic web we must protect all its layers, including XML, RDF, ontologies, and information interoperation processes. In this section, we aim to investigate the security, privacy, and trust-preserving methods in semantic interoperation of semantic web services.

By combining conventional security technologies with semantic web technologies, we may be able to provide network security. Some currently used security-preserving methods are classified into:

- XML and RDF security
- Ontological security
- Secure access control
- Privacy-preservation in semantic interoperation
- Trust- and reputation-enhanced semantic interoperation

XML and RDF Security

In the case of XML and RDF representation languages, the security challenges include specifying security policies with XML and RDF, ensuring access control for XML and RDF documents, and investigating the secure interoperability of resources and services on the web. Access control policies are rules regulating how access control should take place.

The XML Encryption Working Group of the World Wide Web Consortium (W3C) (http://www.w3.org/Encryption/2001/) has proposed as W3C Recommendations an XML encryption syntax, processing specification, and the decryption transform for encrypting or decrypting digital content in XML documents. Though there are technologies that allow people to secure a data object, only W3C XML Signature, when paired with the W3C XML Encryption Recommendation, permits users to sign and encrypt portions of XML data.

Another XML-based security method is proposed in (Lee, 2002). Here, an agent can dynamically exchange its authentication and authorisation information using SAML (Security Assertion Markup Language, based on XML) during the interoperation process. As SAML does not need to share the same security infrastructure and allows applications to exchange authentication and authorisation information, the agent can play various roles in heterogeneous platforms, can dynamically change their requirements and, finally, act on behalf of users with diverse permissions to access the semantic web.

Giereth (Giereth, 2005) has studied hiding a fragment of an RDF document by encrypting it while the rest of the document remains publically readable. The encrypted fragments are included as XML literals which are represented using the XML-Encryption and XML-Signature Recommendations. The access control policies and encryption techniques either allow or prohibit access to sensitive information: They do not allow the use of private knowledge to answer queries that can safely be answered using private knowledge without revealing it.

Jain et al. (Jain, 2006) have proposed an RDF authorisation model based on RDF-patterns. An RDF-pattern is associated with an RDF instance, schema, and a security classification. RDF-patterns are mapped to the statements in RDF-instances and schemas to determine security classifications for the statements. The method can selectively control access to stored RDF triples, assign security classification to inferred RDF triples, and check for unauthorised inferences. The focus of the design is to allow the use of hidden knowledge to answer queries without revealing hidden knowledge.

In (Kagal, 2003), a security framework for the semantic web employing the distributed policy language based on Resource Description Framework Schema (RDF-S) has been proposed to mark up security information, since it is important for web entities to be able to express their security information in a clear and concise manner for its meaning not to be ambiguous. The policy language is modeled on concepts of rights, prohibitions, obligations, and dispensations.

Ontological Security

Ontological security means to formulate security information based on ontology representation. In the current applications of semantic web services, some efforts have been made to facilitate ontological security:

An ontology-based rights expression language (OREL) (Qu, 2004) built on top of OWL has been presented to express access rights to resources. OWL ontologies can be imported by OREL users to write their own licenses by using instantiation or inheritance to fulfill their application-specific requirements. Qin and Atluri (Qin, 2003) have introduced concept-level security polices represented in an OWL-based access control language. This access control model is to specify access authorisations based on concepts and the relationships between these concepts, and to enforce these authorisations upon the data annotated by these concepts. Each concept is defined in an OWL ontology. This work deals with how terms naming resources (whose access is being controlled) can be re-written using other terms subject to logical rules expressed in the Web Ontology Language (OWL).

A fine-grain security mark-up of semantic web service parameters in OWL-S (Kagal, 2004) has been proposed to enforce the privacy and authorisation constraints that cryptographic techniques (using encryption and digital signatures) can implement. It aims to provide security and policy annotations for OWL-S service descriptions and enforcements by extending the OWL-S Matchmaker for policy matching and the OWL-S Virtual Machine (VM) with policy enforcement and security mechanisms. By using the security mechanisms proposed, web services implementing the OWL-S VM are guaranteed to maintain secure communication with their partners.

Secure Access Control

To make semantic interoperation secure, secure access control policies must be established. Security and confidentiality are the key points for the success of electronic commerce. Suppose two organisations want to carry out a transaction, they may both log into their semantic webs and use a variety of information interoperation tools to exchange data and information. Various access control and usage control policies must be applied to ensure that the users can carry out the operations and access the data. Safeguarding multiagent systems also requires the development of access control models for agents.

Access control is the mechanism that allows resource owners to define, manage, and enforce the access conditions for each resource (Samarati, 2001). The Role-Based Access Control model (RBAC), the mediator-based access control model, and the dynamic access control model are considered as the most appropriate paradigms for access control in complex scenarios. In RBAC (Sandhu, 1996), role is an abstract description of behaviour and collaborative relation with others in an organisation, and permission is an access authorisation to an object, which is assigned to role instead as to an individual user to simplify security administration. In the mediator-based model, the mediator performs access control checks to early reject the queries that should be denied access. In dynamic access control, there is neither role nor mediator to assist in the process of access control.

Role-Based Access Control

The Semantic Access Control model (SAC) (Yague, 2005) extends RBAC by considering the semantics of objects and associating permission with concepts instead of objects. It is built on the basis of separating the responsibilities for authorisation and access control management, and provides adequate solutions to the problems of access control in distributed and dynamic systems with heterogeneous security requirements. SAC is characterised by its flexibility for accommodating dissimilar security policies, but also by the ease of management and control over a large number of distributed elements and the support for interoperability of authorisation mechanisms.

Another modified RBAC model, Ontology-based Hybrid Access Control (OHAC) (Sun, 2007) is designed based on a coalition, which stands for an association of representative enterprises in a specific application domain. By defining a common ontology of the domain, the coalition provides a platform for members to share, federate, and collaborate with each other, as well as serves as a portal to provide common services for the public. The authors declare that by mapping local authorisations to the common ontology. Enterprises can efficiently support automatic interoperation across heterogonous member systems in the coalition, as well as general requests from dynamically changing exterior collaborators not belonging to the coalition.

Secure e-business between multiple organisations requires intra-organisational and inter-organisational perspectives on security and access control issues. There is paucity in research on information assurance of distributed inter-organisational e-business processes from a business process perspective. Some security measures for e-business applications have been reported in (Hassler, 2000). The challenges of secure electronic commerce (Thuraisingham, 2005) include identifying and authenticating consumers as well as businesses, and tracing all transactions and purchases. The proposed solution is for consumers and businesses to have some credentials when they execute transactions. These credentials, which may be some random numbers, could vary with any transaction. This way a malicious process that pretends to be a business may not have the correct credentials. Moreover, there will be a problem if the credentials are stolen.

Mediator-Based Access Control

The mediator in the model performs access control checks to reject as early as possible the queries that should be denied. Agarwal (Agarwal, 2004) has introduced policy algebras as a means to specify and handle complex access control policies, and has shown how Access Control Lists (ACLs) and certificates generated by the credential-based public key infrastructure resulting from the merge of the Simple Distributed Security Infrastructure (SDSI) with the Simple Public Key Infrastructure (SPKI) can be integrated with DAML-S to specify access control policies of web services, where DAML-S is a DAML+OIL ontology for web service descriptions aiming to make web services interpretable and to enable tasks like discovery, composition, and interoperation of web services.

In the ARTEMIS project (Boniface, 2005) a semantic web service-based Peer-to-Peer interoperability infrastructure has been developed for healthcare information systems. The ARTEMIS mediator uses the semantic web service descriptions as broker between organisational policies by reasoning about security and clinical concept ontologies. Each health information system is represented as an ARTEMIS Peer node that communicates directly with an ARTEMIS Mediator. The web service descriptions are held at the mediator using standard web service repositories. The service descriptions are annotated with semantics so that service operation, meaning of data, and non-functional requirements can be understood by the infrastructure. In detail, when a web service is invoked, the ARTEMIS mediators act as brokers between requester and provider. ARTEMIS allows requester and provider to support different encryption mechanisms by allowing compatibility between algorithms to be expressed using ontologies. When a web service is invoked, the mediator translates the role of the healthcare professional in the requesting organisation to the equivalent role in the providing organisation.

As the mediator-based access control has the disadvantage that the mediator has to obtain the access control tables of the participating information sources, a modified model called Semantic Access Control Toolkit (SACE) (Pan, 2006) has been proposed to interoperate among semantically heterogeneous information sources, and to handle the corresponding confidentiality concerns of the organisations involved in information sharing. The objective of SACE is to enable users of organisation A to access organisation B's data using queries written against A's database schema without violating any security policy. The architecture of the SACE model has two aspects: the on-line aspect shows how an inter-organisation query is processed at run-time, and the off-line aspect shows how the initial processing is prepared for the on-line processes.

Dynamic Access Control

The Semantic Mapping Framework Security Policy (SPDM) proposed in (Muthaiyah, 2006) aims to dynamically map security policies of real organisations (RO) and virtual organisations (VO), and to update a global policy stored in a knowledge base for future use. Dynamic mappings of local and global policies help to maintain the consistency of mapped global policies in the knowledge base storage. The model functions in five steps: (1) security policy ontologies RO and VO are created and exported to OWL; (2) a reasoning process is carried out to check for consistency, classify the taxonomy, and compute the inferences; (3) consistency checks on RO and VO are performed; (4) the SPDM and via merging a global security policy are generated, and similar instances are merged; and (5) output results are generated and the mapping process is completed.

Privacy Preserving in Semantic Interoperation

Although many tools have been developed to enable different organisations to share information, most of these tools have not taken into account the necessity of maintaining the privacy and confidentiality of the organisations' data and metadata. Actually, some organisations do not want to publish their metadata or even share them with external users. At the same time, however, they want to enable interoperation. Therefore, the privacy of the metadata (the ontologies of information sources or the schemas of databases) must be preserved.

The semantic web has brought about new challenges for privacy management. The privacy-preserving semantic web allows users to employ agents to carry out sophisticated tasks while being confident that personal information is being managed in the fashion desired. Most semantic interoperation approaches rely on the fact that both schemas and ontologies are completely visible by both parties. Clearly, this approach disregards security and privacy considerations. Even within the same organisation, different users have access to different database views.

In this section, the currently used technologies to preserve privacy by ontology representation, by mediators, or just automatically are discussed.

Privacy by an Ontology

Currently proposed policy languages (Tonti, 2003) for information hiding on the semantic web rely on complete denial of access to the hidden parts of an ontology. Such approaches are overly restrictive in that they prohibit the use of hidden knowledge in answering queries where it is possible to do so without disclosing the hidden knowledge. In (Kim, 2002), the idea of a privacy ontology has been proposed to enable agents to exchange privacy-related information using a common language. The privacy ontology should be able to clearly define the various dimensions of privacy (e.g., privacy of personal behaviour vs. privacy of communications), and contain sufficient parameters and index terms to enable specification of a privacy policy in a standard machine-understandable format. It should be descriptive enough to specify the highest known standards of data protection and privacy. It should not only allow specification of a user's privacy preferences to a web-site, but also allow users to collect and store certain information about web-sites and other agents they interact with.

Privacy by a Mediator

Clifton et al. (Clifton, 2004) have discussed issues and identified research directions in privacy-preserving data integration, including those that arise in schema-matching. In their approach, terms in the ontologies and in the matching rules (which define the mappings) are encrypted, so that the mediator does not see the actual terms. During the process of ontology interoperation, however, a human expert has access to both ontologies in clear text with a session key.

Two frameworks (automatic and semi-automatic) for privacy-preserving interoperation have been presented in (Mitra, 2005), especially highlighting their privacy-preserving ontology matching components. These frameworks achieve ontology matching with minimum "privacy leak" of the ontologies being matched. The interoperation system does not assume a trusted mediator. Ideally, organisations want a mediator to gain minimum information about the data and the metadata stored in their information sources. In this system, the mediator operates over encrypted queries, encrypted ontologies, and encrypted data.

Automatic Privacy-Preserving Technologies

The Privacy-preserving Access Control Toolkit (PACT) has been put forward in (Mitra, 2006) to enable privacy-preserving secure semantic access control, and to allow sharing of data among heterogeneous databases without having to share metadata. PACT uses encrypted ontologies, encrypted ontology mapping tables as well as conversion functions, encrypted role hierarchies, and encrypted queries. The encrypted results of queries are sent directly from the responding system to the requesting one, bypassing the mediator to further improve system security. PACT provides semantic access control using ontologies and semantically expanded authorisation tables at the mediator. One of the distinguishing features of PACT is that it requires very little changes to underlying databases.

An automatic privacy-preserving protocol for schema matching using mutual information of pair-wise attributes has been proposed in (Cruz, 2007). The protocol is executed by two entities, each having a private schema. The output of the protocol is a set of mappings between the matching attributes of the two schemas. This privacy-preserving schema matching protocol is proved secure against malicious adversaries for all mapping types, the authors argue.

In (Bao, 2007), a framework has been designed for privacy-preserving reasoning, in which an agent can safely answer queries against its knowledge base using inferences based on both the hidden and the visible part of the knowledge base, without revealing the hidden knowledge.

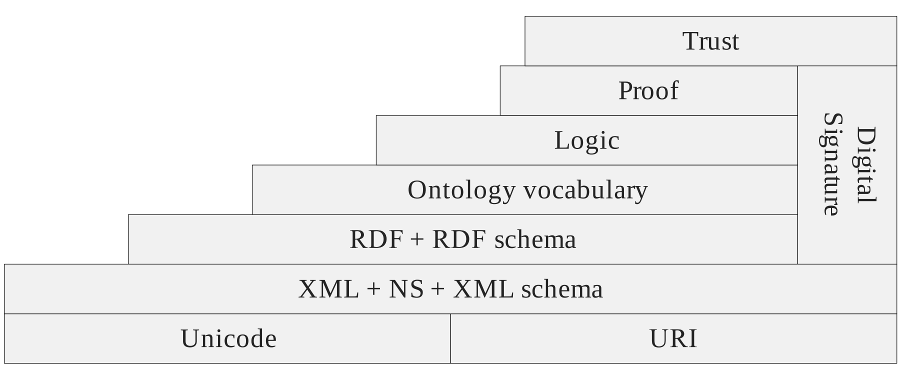
Trust- and Reputation-Enhanced Semantic Interoperation

Trust is a type of social knowledge and encodes evaluations about which agents can be taken as reliable sources of information or services (Ding, 2003). It is an important aspect of social interaction in human society and potentially in agent societies as well. Trust management and negotiations play an important role in semantic security. The semantic web has created new opportunities and challenges to trust: on one hand, the machine-understandable knowledge resources freely available on the semantic web make it easy to build trust relationships, on the other hand, the vast amount of information, including inconsistent and contradictory information, demands trust in managing the interoperation problem. As shown in Figure 1, trust is an integral part of the semantic web architecture.

Reputation-based trust management (Resnick, 2000) has been identified as a viable solution to the problem of trust in multiagent systems and peer-to-peer networks as well. The main goal of a reputation mechanism is to take the reputation information that is locally generated as a result of an interaction between agents, and spread it throughout the network to produce a global reputation.

Problems of trust and reputation on the web in general, and the semantic web in particular, are topics of significant interest. A satisfactory and robust trust model is important in a situation of information overload, and to help users to collect reliable information in on-line communities. The currently used trust measures can be classified as follows:

Figure 1. Architecture of the Semantic Web



(1) Trust is built on an agent's direct experience with an interaction partner. Current research on trust prediction strongly relies on a web of trust, which is directly collected from users based on previous experience. However, the web of trust is not always available in on-line communities, and even when it is available, it is often too sparse to predict the trust value between two unacquainted people with high accuracy (Kim, 2008). In order to overcome the sparseness of a web of trust, another trust measurement has been proposed (Kim, 2008) (Figure 2) to consider a user's reputation (i.e., expertise) and affiliation with contexts as main factors to derive trust connectivity and the degree of trust value. The main idea is that a user would trust an expert in the area of interest that matters greatly to her/him.

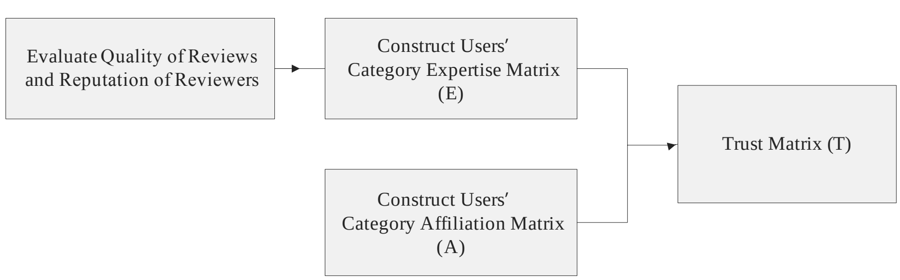
(2) Trust information is provided by other agents. Agents should be able to reliably acquire and reason about the transmitted information. Sabater (Sabater, 2003) has proposed a decentralised trust model called Regret. It uses an evaluation technique not only based on an agent's direct experience of its partners' reliability, but also on a witness reputation component. In addition, trust values (called ratings) are dealt with according to their recent relevance. Regret does not deal, however, with the possibility that an agent may lie about its rating of another agent. Since the ratings are simply equally summed, the technique can be sensitive to noise. The approach in (Venkatraman, 2000) uses a social network to enable a user to leverage the knowledge of several users and their personal agents to find services of the desired type and of high quality without causing excessive communication. A social network (Freeman, 2006) is a social structure made of nodes (which are generally individuals or organisations) that are tied by one or more specific types of interdependency, such as values, visions, or friends.

In a service-oriented environment, trust can be visualised in at least three domains (Hussain, 2006), namely, agent trust, service trust, and product trust. The agent trust ontology is defined as the conceptualisation of agent trust. The interoperation is measured by criteria that are mutually agreed by both the trusting agent and the trusted agent during the negotiation phase.

In (Bentaha, 2007) an agent-based securing system has been developed, where agents are equipped with reasoning capabilities to interact with each other. The agents can reason about the reputation of each other using their argumentation systems. Reputation is computed using a set of parameters based on the interaction histories and the notion of social networks. The model has gathered four most important factors: the reputation of confidence agents; the target's reputation according to the point of view of confidence agents; the number of interactions between confidence agents and the target agent; and the timely relevance of information transmitted by confidence agents. The author claims that this model can produce a comprehensive assessment of the agents' credibility.

(3) Certified trust information is provided by

Figure 2. A framework for deriving degrees of trust



referees. Agents should provide third-party referees to witness about their previous performance. In (Yu, 2003) an approach based on social networks has been proposed, where agents can transmit information as witnesses using referrals. Referrals are pointers to other sources of information similar to links that a search engine would plough through to obtain a web page. In this model, agents do not use any particular reasoning, however, and all witnesses are assumed to be totally honest. Timely relevance information is not treated and all ratings are dealt with equally. Consequently, this approach cannot manage the situation where the agents' behaviour changes.

The trust value of an agent is assessed by collecting the required information of its target agents assuming that they are willing to share their experiences. For this reason, an approach called certified reputation has been put forward in (Huynh, 2006), based not only on direct and indirect experiences, but also on third-party references provided by the target agent itself. The idea is that the target agent can present arguments about its reputation. These arguments are references produced by the agents that have interacted with the target agent certifying its credibility. This approach has the advantage of quickly producing an assessment of the target's trust, because it only needs a small number of interactions and it does not require the construction of a trust graph. However, this approach has some serious limitations. As the referees are proposed by the target agent, this agent can provide only referees that will give positive ratings about it and avoid other referees, probably more credible than the provided ones. Even if the provided agents are credible, their witnesses could not reflect the real picture of the target's honesty. This approach can privilege opportunistic agents, which are agents only credible with potential referees.

(4) Trust information is obtained based on semantic similarity between agents. Jiang et al. (Jiang, 2005) have presented a trust construction model to achieve autonomy of trust management in multiagent systems. The presented model adopts graphs to describe trust information, and uses graph combination and path searching to construct trust relations. Any agent can implement trust management autonomously. An agent system can construct a global trust concept by combining trust information among agents. An agent can achieve a trust relation with another agent by trust path searching or trust negotiation.

Gupta et al. (Gupta, 2003) have designed a partially centralised mechanism using reputation computation agents and a public-key-based mechanism that periodically updates peer reputations in a secure and light-weight manner. The PeerTrust (Xiong, 2002) reputation mechanism has been presented to evaluate the trustworthiness of peers by incorporating feedback context such as the total number of transactions and the credibility of feedback sources, where a scalar trust value for a peer is computed based on a figure of the satisfaction received by other peers. A reputation multiagent system, SemTrust, (Wang, 2006) has been introduced to enable the semantic web to utilise reputation mechanisms based on semantic similarity between agents. The main component in Figure 3 is the trust management with the support of the reputation database which stores the agents' reputation data. The main goal of the reputation

Figure 3. Architectural model of SemTrust Agent

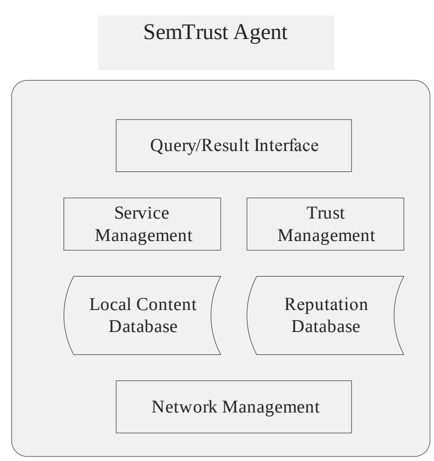
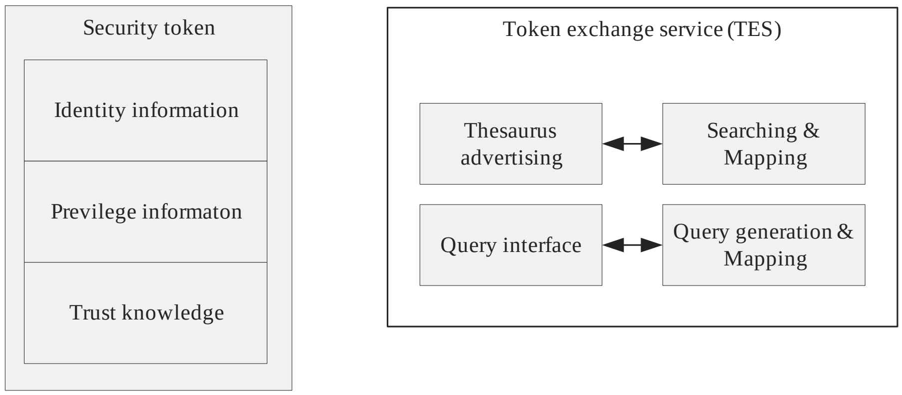


Figure 4. Architecture of a security token (left) and token exchange service (right)



mechanism is to take the reputation information that is locally generated as result of interactions between agents, and to spread it throughout the network to produce a global reputation rating for the network nodes.

(5) Trust information is exchanged using security tokens. In (Wu, 2007), security tokens have been designed to convey various types of trust information exchanged in federated systems. A security token includes claims representing a name, password, identity, key, certificate, group, privilege, and so on. The authors have introduced a hybrid approach (Figure 4) with intermediary- and query-based mechanisms to resolve semantic gaps and incompatibilities for different types of trust information exchanged by security tokens, and then have proposed different exchange models for different types of information.

FUTURE TRENDS

The above overview of the security measures in semantic interoperation shows that there is still a lot of research work to be done. New security levels must be attached to ontologies: certain parts of ontologies could be secret while certain other parts may be open. So, the coming challenge is the interoperation of these ontologies with different security levels, which is the key problem in the application areas of semantic web services.

Current work on ontology security aims to describe security information based on a specified ontology representation language, whereas there are only few papers on how to deal with the security problem of ontologies themselves. This is also worth studying to maintain security and confidentiality of different enterprise ontologies.

Up to now, security research has been separated from trust and reputation. Attention must be given to both security research and privacy research, i.e., we need to protect the privacy of individuals and, at the same time, ensure that they have the information needed to carry out their functions. The adoption of security tokens makes identity, privileges, and trust-related knowledge interoperable across security domains, which eliminates a barrier to inter-domain business transactions, collaborations, and trust-knowledge management. Our future work will focus on managing privacy, trust, and reputation simultaneously during semantic interoperation.

CONCLUSION

This chapter has given a snapshot of the security issues in the semantic web and of web services. After reviewing the background of the security problem in the semantic web, we have provided details of various security methods in semantic interoperation like XML security, RDF security, ontology security, security and privacy in semantic interoperation, and trust (including reputation) enhanced semantic interoperation, where secure access control policies and secure knowledge management techniques have been addressed. Various methods of security, privacy, and trust management during semantic interoperation have been mentioned in the chapter. Significant work is still required, however, to focus on security, privacy, and trust at the same time.

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KEY TERMS AND DEFINITIONS

Access Control: Access control is a mechanism that allows resource owners to define, manage, and enforce the access conditions for any resource.

Ontology: Ontologies are defined as "explicit conceptualisation(s) of a domain" (Gruber, 1993), and are seen as a key to realise the vision of the semantic web.

Privacy: Portions of a document can be set to private, so that they are invisible during the interoperation process.

Security: Syntax for encrypting or decrypting digital content in XML documents, in RDF triples, or in ontology representation languages.

Semantic Interoperation: Semantic interoperation and service sharing are used to support collaboration across different enterprise systems.

Semantic Web: Envisioned by Tim Berners-Lee, the semantic web is a universal medium for data, information, and knowledge exchange. It suggests to annotate web resources with machine-processable metadata.

Semantic Web Services: Semantic Web services can be defined as web services whose descriptions are annotated by machine-interpretable ontologies so that other software agents can use them without having any prior 'built-in' knowledge about how to invoke them.

Trust and Reputation: Trust and reputation is defined as the "subjective expectation an agent has about another's future behavior based on the history of their encounters".

Chapter XXVI
Semantic Discovery of Services in Democratized Grids

George A. Vouros
University of the Aegean, Greece

Andreas Papasalouros
University of the Aegean, Greece

Konstantinos Kotis
University of the Aegean, Greece

Alexandros Valarakos
University of the Aegean, Greece

Konstantinos Tzonas
University of the Aegean, Greece

Symeon Retalis
University of Piraeus, Greece

Ruby Krishnaswamy
France Telecom R&D, France

ABSTRACT

This chapter aims at discussing issues concerning the advertisement and semantic discovery of Web services in a democratized Grid environment: an environment in which users are agnostic of the low-level details for managing the services offered and requested. This type of environment poses new requirements, and thus, it affects the functionality of a service advertisement/discovery system. In the context of this aim, the chapter presents the motivation and the technologies developed towards a semantic information system in the Grid4All environment. The chapter emphasizes on bridging the gap between Semantic Web and conventional Web service technologies, supporting developers and ordinary users to perform resources' and services' manipulation tasks, towards a democratized Grid.

INTRODUCTION

Web services, as a distributed computation paradigm, raise a number of issues in order for their benefits to reach their potential. Semantic descriptions of Web services have emerged due to their prospective to support the automation of service discovery, invocation, composition and monitoring tasks by providing machine-exploitable meaningful declarative descriptions of service characteristics. Despite the benefits of semantic Web services, there is a gap between Semantic Web and conventional Web service technologies, which impedes the semantic manipulation of services' registries, providing limitations for the adequate, flexible and seamless treatment of services. Ordinary Web users, software developers and service providers, as well as users of service registries must be supported to perform their tasks more effectively in such a machine-oriented (semantic) environment. This is particularly true for services or domains that change frequently: Stakeholders must be supported to perform their tasks in effective and adequate ways.

This chapter aims at presenting issues and solutions proposed for dealing with the problems of semantic web service advertisement, discovery and selection in a democratized grid environment: An environment that provides opportunities for (a) users that are agnostic of the low-level details required for managing services offered and requested, and for (b) service providers that need to make the best of their offered services. This type of environment poses new requirements, and thus, affects the functionality of a service advertisement/discovery system. In the context of these issues, the chapter presents specific technologies developed for realizing a Semantic Information System of a grid environment. The developed system supports the Grid4All approach for service discovery and selection in a democratized grid, in the context of the Grid4All European IST project[1].

The Grid4All project aims at developing a self-managed, autonomous, fault tolerant, and easy to use infrastructure that will enable ordinary users and small organizations such as schools and small/medium enterprises to share their computing resources. In this way, a 'democratized' grid is envisaged, which is accessible to organizations that lack the human and computation resources so as to participate in existing grids. In this context, Grid4All resources (traded in markets realized as specific types of services) and application-specific services are being advertised in the Grid4All Semantic Information System (G4A-SIS). The G4A-SIS provides a portal where semantically described grid services are advertised and discovered by (software and human) peers. Peers may pose to the G4A-SIS orders (i.e. requests and offers) concerning (a) specific resources that are being traded in markets, satisfying specific criteria/preferences/constraints concerning resources' configuration, market and order-related properties, or (b) application-specific services' profile specifications. These are further detailed in the sections that follow.

This chapter presents the technologies developed for the G4A-SIS to provide semantically-enriched functionalities for the resources/services' advertisement and discovery tasks, towards a democratized grid environment. Special emphasis is given to the semantic specification of services' profiles, supporting the effective discovery of advertised services.

The structure of the chapter is the following: in the next section, an overview of grid environments and web services is presented. Next, the Grid4All framework is presented, together with the need for an information system which promotes democratization. Next, the features of the Grid4All SIS are discussed, followed by a review of the state of the art in relevant approaches. The chapter ends with some conclusions.

GRID ENVIRONMENTS AND WEB SERVICES

Grid Environments

A grid provides the infrastructure for sharing and reusing entities by multiple users. These entities are referred to as 'resources'. A grid is a collection of interconnected machines, sometimes referred to as "nodes," "resources", "members", "donors", "clients", "hosts", or "engines". They all contribute any combination of resources to the grid as a whole. There are various other kinds of resources such as computational, storage, network resources, code repositories and catalogs (Foster et al., 2001).

Grid computing may be seen as a step towards integrating various technologies and solutions that move us closer to the goal of making use of heterogeneous resources (exposed, marketed, offered and managed through services), with little or no knowledge of where these resources are located, or what are the underlying technologies. The grid is a distributed computing infrastructure, initially for high performance computing usage in the fields of science and engineering. Grid has emerged as a means of reusing existing infrastructure, that is, computers and storage media, either within, or through different organization boundaries or hosting environments (Foster et al., 2002). Grid systems are built mainly to facilitate a) application performance improvement, b) data storage and management, and c) enhanced access to different types of services (Krauter et al., 2002). Enhanced access to services refers mainly to the facilitation for collaborative and multimedia systems (Krauter et al., 2002; Bote-Lorenzo et al., 2003). Grids support the interoperation of applications in collaborative systems, thus, also enhancing human to human interaction, as in the case of Computer Supported Collaborative Work or Computer Supported Collaborative Learning systems where heterogeneous groupware or multi-conference applications interact (Bote-Lorenzo et al., 2003). In multimedia systems, grid technologies facilitate enhanced QoS in multimedia applications with real-time constraints, such as videoconference applications (Krauter et al., 2002).

Grid4All: Grid Democratization and Social Implications

The Grid4All project aims at developing a grid infrastructure so as to enable domestic users, non-profit organizations such as schools and small/medium enterprises, to share their resources and to access massive grid resources when needed, envisioning a future in which access to resources is democratised, readily available, cooperative, and inexpensive. In other words, Grid4All envisions a "democratic" grid as a ubiquitous utility whereby domestic users, small organizations, and small-medium enterprises may draw on services on the Internet without having to individually invest and manage them. It aims to hide the complexity of grid-based systems, empowering individuals and organizations to create, provide access to, and use a variety of services, anywhere, anytime, in a transparent and cost-effective way, realising the vision of a knowledge-based and ubiquitous utility. Such a transparency is achieved through technologies based on new paradigms concerning self-managed systems, market-orientation, and the Semantic Web.

On the economic front, the community-inspired scenarios motivating Grid4All can create new kinds of micro-economic opportunities: Providing incentives to resource/service owners to share their resources/services raises the possibility to create and generate local, dynamic micro-economies where local enterprises and providers can trade resources/services with the local residents in return for micro-payments. These payments are intended to compensate the overhead of maintenance, administration and complexity of usage space weighs on small enterprises who may offer some of their ICT resources on a service-oriented basis. Grid4All tackles this issue through technical components for resources/services' discovery, brokering and trading.

Small organizations such as schools, community centres and individuals at their homes may benefit from the Grid4All infrastructure by means of discovering, negotiating and accessing services (resource trading services, i.e. markets, and application-specific services) at times of accrued local needs with respect to their specific needs, preferences and budget-related constraints.

Grid4All Economy and Market Model

Grid4All peers participate in either non-profit or for-profit basis in order to acquire, provide or share resources and services. For supporting the for-profit case, Grid4All proposes a market model and a specific market-oriented architecture.

In a market-based environment as envisaged by the Grid4All project, grid resources and services can be made available through peer-initiated markets in a distributed manner. Grid4all adopts a distributed market model where (resource) consumers and providers negotiate on certain traded entities in auctions initiated by providers, consumers or by third party entities. The market place can be considered to be populated by multiple, simultaneous and independently executing trading instances (markets).

Traded goods in grid markets are being allocated to peers based on the supply and demand law. This architecture reduces the computational complexity of centralized auctions that accrues with the number of offers and bids and ensures scalability. In such a distributed market-oriented environment, the discovery of markets with efficiency, precision and scalability is a challenging necessity.

Services Within Grid4All

In order to facilitate uniform access to grid resources, especially in heterogeneous environments, grids exploit service oriented architecture (SOA) approaches (Papazoglou & Georgakopoulos, 2003). That is, each resource in a grid is exposed by a service, thus, facilitating location transparency, uniform semantics and platform independence, as well as virtualization, that is, “encapsulation of various implementations behind a common interface” (Foster et al., 2002). OGSA, a prominent architecture for grid systems (Foster et al., 2002), aims at exposing resources, both computational and storage, through web services. Web services are described by their WSDL[2] descriptions, while other specifications have been proposed so as to capture the *stateful* nature of grid services, such as WSRF[3].

Grid4All, following the generic trend of grid computing, has adopted the Web Services standards to align with existing languages, programming models, tools, and technology directions in Web services and systems management.

Concluding the above, the following are types of discoverable services within Grid4All:

- Market services (i.e. services for trading resources)
- Services that expose computational and storage resources
- Application-specific services

The service discovery component that has been developed within Grid4All aims at the discovery of the above kinds of services. In its current state, the Grid4All Semantic Information System (G4A-SIS) endorses semantic web technologies in order to facilitate the advertisement and querying of available markets and application-specific services.

THE GRID4ALL SEMANTIC INFORMATION SYSTEM (G4A-SIS)

Overall Description of G4A-SIS

G4A-SIS provides a matching and ranking service for peers willing to offer or request resources and services.

Concerning resources, G4A-SIS aims to discover market services (trading instances) that trade resources satisfying specific requirements. Towards this target G4A-SIS exploits resources’ offers and requests (detailed in the sections that follow), in conjunction to resources’ characteristics and market-related properties, to satisfy peers’ intentions and preferences. Resource retrieval in this context extends the notion of resource matchmaking to the process of discovering those markets (trading instances), each with its own auction mechanism, which trade resources matching the requests of buyers and the offers of sellers. To satisfy the requirements of resource retrieval in this context, a specific ontology (Grid4All ontology) has been developed which is being exploited by the Semantic Information System (Vouros et al., in press). The ontology describes resources, markets, offers and requests, peers and their relations in a formal way.

As far as application-services are concerned, to support the democratization of grid, G4A-SIS supports the automatic semantic annotation of these services, and thus their automatic advertisement in the semantic registry, as well as their retrieval via semantic matchmaking techniques. This is important in the deployment of G4A-SIS in the democratic grid, since it alleviates users from possessing detailed knowledge on the semantic specifications of services involved, while facilitating adaptation in evolving ontologies and changing service specifications.

It must be emphasized that although markets are a specific type of services and are been treated in a semantic way (by exploiting the Grid4All ontology), they are treated differently from application-specific services. This shall be made clear in the next sections.

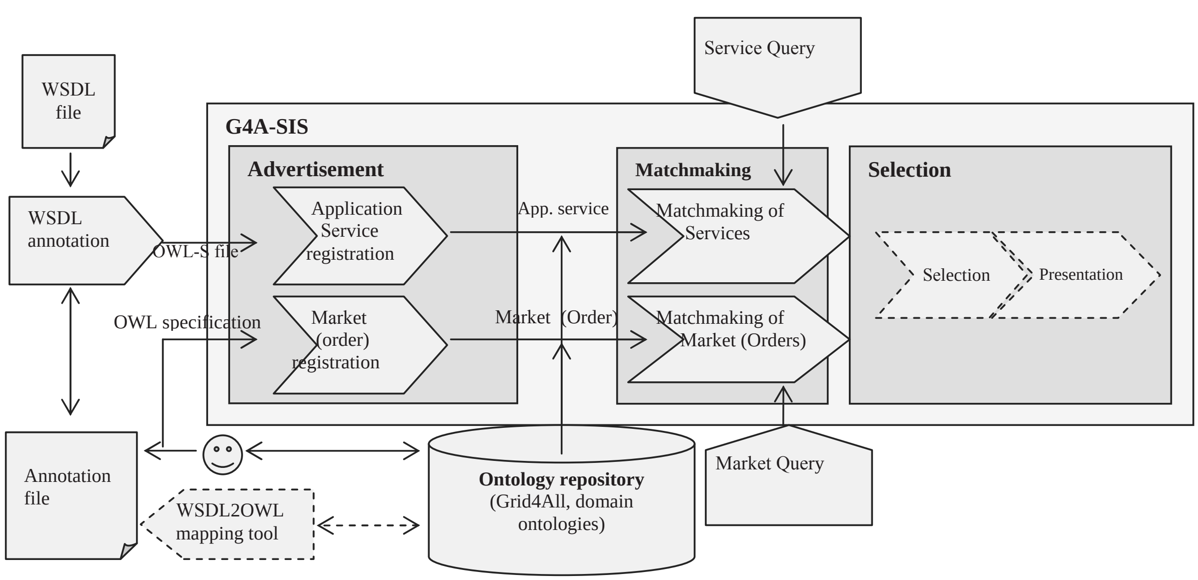
G4A-SIS Workflow

The Semantic Information System (G4A-SIS) provides a matching and selection service for peers to offer or request resources and services within grid environments.

The G4A-SIS may be queried by software agents, as well as by human users to select advertised markets (trading resources) and services: Matchmaking happens through different criteria concerning markets and application-specific services: For application services, matchmaking is based on services' profiles, while for markets this is done by exploiting resources' configuration, markets' characteristics and order-related attributes, as these are being specified in the Grid4All ontology. However, in both cases, query results are ranked according to resources/services matching characteristics and providers'/consumers' features.

The overall workflow of the G4A-SIS is illustrated in Figure 1. The G4A-SIS contains a regis-

Figure 1. G4A-SIS workflow



try in which market and application services are advertised by the agents. Application services are advertised by a specific process named WSDL annotation. The discovery of services and resources is performed by submitting queries for market and application services. Services that fulfill querying criteria are retrieved by means of a matchmaking process involving semantic technologies, while the ranking of results is performed by a selection process. The matchmaking and selection features are discussed in next section.

Functionality of the G4A-SIS

As mentioned earlier, the main functionalities of the G4A-SIS are the discovery of market services (trading instances), and the discovery of application-specific services (e.g. of a collaboration tool with specific data semantics). Despite the fact that markets that trade resources (resource markets) are services themselves, as shown in Figure 1 and pointed out, these two types of services are handled by G4A-SIS in different ways.

Market Advertisement

The purpose of market advertisement is the insertion into the G4A-SIS registry of descriptions of markets that are related to offers or requests made by providers or consumers, correspondingly. Both offers and requests are specific kinds of *orders*. Descriptions of orders (offers and requests) contain information about the entities that are been traded by the associated markets (i.e. resources' configuration), the associated markets, the participants (providers and prospective consumers), as well as attributes of the orders themselves. Such descriptions are formed as classes and instances of the Grid4All ontology classes, stored in OWL format[4]. Markets can be either forward or reverse.

Concerning forward markets, orders concern resources offered to potential customers. Providers are able to advertise a list of offerings combined via XOR or AND connectives, specifying either alternative service/resource configurations at different prices, availability times etc, or conjunctive offers, as a bundle offer. Descriptions of available tradable resources as well as of the related markets are aggregated to *Offers*.

Consumers, acting as provisional buyers, initiate reverse markets in which they call for resources of intended characteristics, thus forming requests. Descriptions of intended resource characteristics associated with reverse markets are aggregated to *Requests*. Similarly to offers, requests may concern a single trading resource, or a "complex" one, concerning a bundle of resources: Multiple, alternative (respectively, conjunctive) requests may be connected using an XOR (respectively, AND) connective.

Summarizing the above:

- A Request describes the resource needs of a consumer (quantity of requested resources and time intervals of their allocation) and the price the consumer is willing to pay for those resources within a specific Market;
- An Offer specifies the exact resources (quantity of offered resources) that a provider trades in specific time intervals and prices: This is in contrast to the specification of requested resources, where the consumers may request a *class* of resources. Offers specify the exact individual resources that providers sell.

Beyond the above information, market orders, that is, offers and requests contain the following information:

- **Market related information:** The description of a market where the resource/service is going to be traded. This includes location of market, start and closing time of market.
- **Offer/request related information:** The description of pricing policy (type of related market auction), initial price (minimum price

for a forward auction and maximum for a reverse auction).

- **Contact information:** Information about the provider or consumer.

Orders deal with two types of grid resources: Computational and Storage resources. Not all resources are tradable. For instance, one may not trade a CPU or a Hard Disk, as such. Tradable resources include Compute Nodes and Clusters.

- A Compute Node is a type of Composite Resource that comprises exactly one Computational Resource and any number of Storage Resources.
- A Cluster is an Aggregated Resource comprising a set of Compute Nodes.

A market is to be advertised directly by its initiator, either provider or consumer, or through the market factory which instantiates this market. The advertisement of markets is supported by an appropriate API (to be used by software agents) as well as by a web-based user interface (to be used by humans). No authoring of formal descriptions of the input information is required from the peers in order to make any advertisement.

Market Discovery

The aim of the market query feature of the G4A-SIS is to provide to prospective providers/consumers an ordered list of available markets, already been advertised to G4A-SIS, that satisfy certain criteria concerning their own characteristics, as well as the characteristics of the traded goods: Performance and QoS characteristics of resources, the configuration of resources, pricing and order-related criteria.

Specifically, peers may query the G4A-SIS for orders (i.e. requests and offers) that match certain attributes and criteria, locating orders that are related to matching resources (i.e. resources satisfying the ordered configuration requirements), traded in forthcoming (initiated but not yet started), or ongoing markets. As it will be explained, the results of queries are ranked according to the preferences and intentions of providers and consumers, as well as according to the characteristics of resources and markets.

Application-Specific Service Discovery

Besides markets, the G4A-SIS provides application-specific services discovery functionalities. Application services are considered to be available for free, that is, they are not traded through markets (although G4A-SIS can support traded services as well). Currently, we have considered that services' semantic descriptions of profiles suffice for their semantic discovery. Therefore, service profile descriptions are being registered in the Semantic Information System as OWL-S[5] specifications. Queries for services are submitted to the G4A-SIS as lists of input/output types. We make the assumption that the I/O types in a submitted OWL-S profile document are already known, i.e. they are references to existent ontology classes/individuals.

The matching of service advertisements to a submitted service query is divided in two main stages: a) matching of inputs, and b) matching of outputs. For the matching of inputs and outputs, the direction of the subsumption relation is important for (a) the input types to ensure proper execution of the service and for (b) the output types to fulfil the demands of the service requester. The types of service matching supported by G4A-SIS are:

- **Exact match:** For every input type of the advertised service, one equivalent input type of the required service is found. Also, for each output type of the required service one equivalent output type of the advertised service is found. The service I/O signature perfectly matches with the request with respect to their formal semantics.

- **"Subsumes" match:** For each input type of the advertised service exactly one input type of the required service has been found, which is at least subsumed by the input type of the advertised service. This means that the advertised service might be invoked with a more specific input than expected. The output types of the required service subsume the output types of the advertised service or are equivalent to them. This means that the required service might receive a more specific output type than expected. Additionally, for all output types of the required service a successfully matching counterpart of the advertised service is identified.
- **Fail:** Service S fails to match with request R in any of the ways described above. This means that one of the following holds: a) at least one input type of the advertised service has not been successfully matched with one input type of the advertised service, and so the service cannot be executed properly, or b) at least one output of the required service has not successfully been matched with an input of the advertised service.

Application-Specific Service Advertisement

An agent offering a service, that is, a provider, submits a service description in WSDL, and a respective annotation document named External Annotation File (EAF). The EAF is an XML document that provides entries ("slots") for the (semantic) annotation of WSDL elements. The EAF annotations are aligned with the WSDL specifications via XPATH[6] expressions. EAF provides elements for "comments", "description", as well as "type reference" to ontology classes, for each of the WSDL elements. Each "type reference" specification maps each WSDL input/output part element to an ontology class, and hence, it semantically annotates the WSDL element. Having the mappings between service I/O types and concepts in OWL ontologies, an *OWL-S profile* specification is automatically generated and inserted in the G4A-SIS registry.

Specifically, during service advertisement, the annotation document of each service is prepared by using the annotation tool described in the next paragraph.

WSDL Annotation Tool

WSDL annotation is an important part of the overall advertisement and thus, matchmaking and selection process, since its purpose is to explicate the data semantics of WSDL specifications, generating the semantic description of services' signatures (profiles). Annotation can be performed either in interaction with humans or automatically, given that sufficient descriptions of WSDL parts to be annotated are provided. Performed interactively, humans provide the mappings between WSDL Input/Output (I/O) messages' part names (WSDL input/ouput parts) and ontology classes (we call this mapping process *semantic annotation*). Done automatically, we have devised a mapping mechanism that computes mappings between WSDL input/ouput parts and OWL classes: To support the automatic semantic annotation of WSDL specifications, humans have to provide descriptions and comments concerning the intended meaning/use of input/output parts and of the types used (in contrast to *semantic annotation*, we call this process *text annotation*). These annotations may also be fetched by documentation and comments associated with the service code.

This Annotation Tool (WSDL-AT) supports a) the manual text annotation of WSDL elements with comments and descriptions in natural language, b) the automatic semantic annotation of WSDL elements with references to classes of domain ontologies, and c) the validation of semantic annotations produced. The results of (semantic) annotation are encoded in the annotation file (EAF).

Creating and authoring the EAFs for WSDL files. Specifically, concerning this task, by using the WSDL-AT, users are able to create a new EAF when the annotation process of a WSDL file starts. However, if an EAF already exists, the WSDL-AT imports and shows the existing annotations, providing appropriate editing facilities to the users. During the annotation procedure, the WSDL-AT provides a set of ontologies from various application domains, among which the user may choose the "appropriate" ontology for performing the semantic annotation. The same ontology shall be used for the validation of the semantic annotation of the WSDL elements.

Providing mappings of WSDL I/O parts to the classes of a given ontology. Concerning this second task, WSDL-AT initiates a WSDL-to-OWL mapping process. Having the textual an-

Figure 2. "Proposed Annotations" tab and domain ontology hierarchy

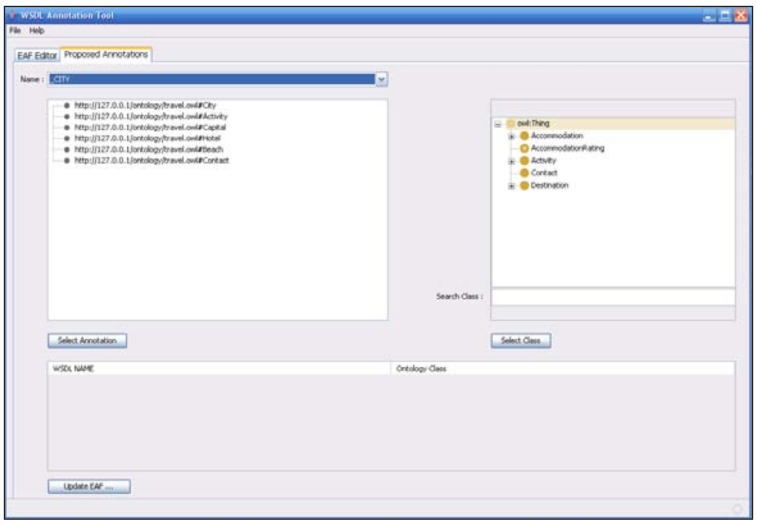
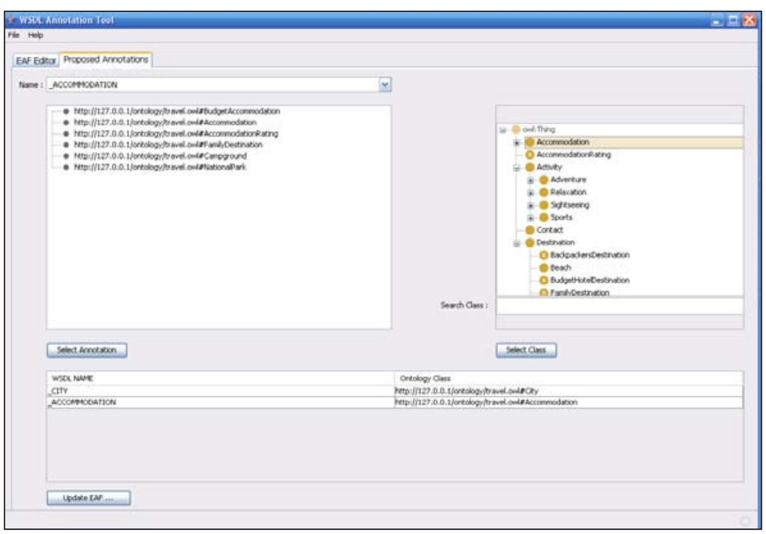


Figure 3. Mapping WSDL elements and ontology classes



notations (provided in natural language within the "descriptions" and "comments" elements of EAF) of WSDL input/output part elements, WSDL-AT automatically computes the OWL classes (from the domain ontology chosen) that are being assessed to correspond to the WSDL input/output part elements (i.e. the semantic annotations of WSDL input/output part elements). This computation is performed using algorithms from the ontology alignment paradigm. The assessed ontology classes for each WSDL input/output part element are returned in a ranked list, as illustrated in Figure 2; the higher position in this list implies a stronger matching proposition between the WSDL part element and an ontology class. Human annotators are able to inspect the domain ontology and the suggested mappings produced by WSDL-AT. However, as Figure 3 shows, the human annotator is able to change the semantic annotation of a WSDL part element by selecting an alternative ontology class (from the domain ontology hierarchy).

WSDL-AT is a platform-independent stand-alone application, with a graphical user interface (GUI).

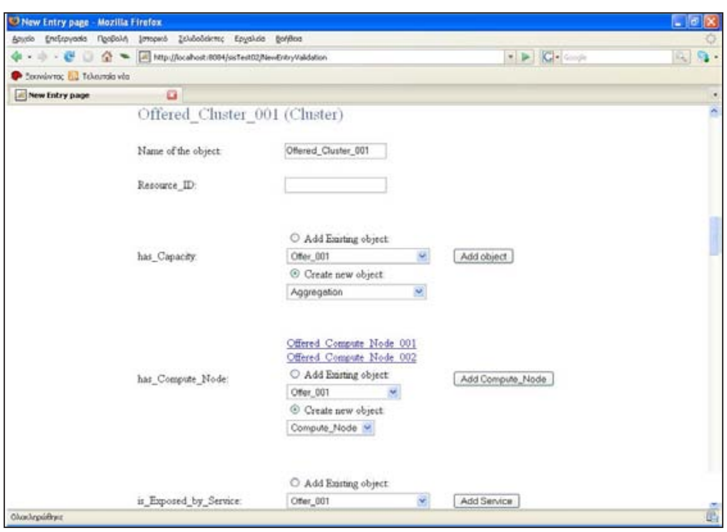
Application-Specific Services' Querying

Prospective clients submit queries to discover services that are already been advertised in the G4A-SIS registry. An application-specific service query is specified by a list of input and output types for the services that the client intends to invoke. These types are OWL classes defined in domain ontologies that are stored in the G4A-SIS. The output of a service query is a ranked list of endpoint references of services, which match the query criteria. A match exists between an advertised and a required service if their input and output types satisfy the conditions described as *exact* or "*subsumes*" matching, described previously. By using the endpoint references of the matching services, a prospective client can invoke any of the discovered services.

Selection Module

The Selection Module (SM) of the G4A-SIS is used for the ranking and selection of services and markets. SM allows ranking and narrowing down the relevant peers' (buyers or sellers) list found by the Matchmaking Service (i.e. those that may provide the ordered service). The SM module

Figure 4. The web user interface of the G4A-SIS



ranks (or narrows down) the list of these peers according to (i) the preferences that providers/consumers have towards consumers/providers, respectively (regarding providers' reputation, for example), (ii) the preferences that providers/consumers have towards queries (regarding which data or service is concerned by the query), and (iii) the query load of providers/consumers. With this aim, it is assumed that consumers and providers declare at any time their preferences to G4A-SIS so as to get the most preferred results. Any peer can define default preferences for those peers it does not know.

Overall, SM aims at satisfying buyers and sellers so that they have the same chances of doing business and getting interesting resources or services in the long-run. Satisfaction, in our context means, how well preferences are met by queries a seller gets and by resources/services a buyer gets. More details and validation results on selection mechanism are provided in (Quiané-Ruiz et al., 2007).

G4A-SIS Implementation

The G4A-SIS exposes its functionality as a specialized portal. It provides a web-based interface as well as an API in order to be accessed by human users and software agents. In both cases, no knowledge of the internal semantic representation of resources and services is required. With regards to human users, appropriate web forms for the submission of both requests and offers are provided. These forms are automatically generated from the underlying Grid4All ontology. Furthermore, market orders' matchmaking is performed internally by a) the automatic classification of individual orders with the computation of their inferred types (by means of the Pellet reasoner[7]), and by generated b) SPARQL[8] queries for filtering the matching individuals according to market-related properties and orders' constraints. Both functionalities are transparent to the human user, as well to the software agent who performs advertisements and queries. A snapshot of the G4A-SIS user interface is shown in Figure 4.

STATE OF THE ART

Semantic Information Systems for the Grid

The following paragraphs describe systems and software frameworks that provide matching of resources and services in grid environments. The provided descriptions focus on the requirements and features provided by these systems and frameworks as well as on the use of semantic technologies in order to meet these requirements. These approaches can be classified in two categories. The first category contains systems that facilitate the discovery of services in a domain-independent way, while the second category contains systems that support the discovery of services in particular application domains such as e-learning and biomedicine.

Harth et al. (2004) present a system for matching resources to requests (applications) of users and agents in a grid environment. The OMMS (Ontology-based Matchmaker System) adopts an extensible approach for performing grid resource selection that uses separate ontologies to describe resources and job requests. Thus, the matching between job requests and available resources is performed in a semantic rather than in syntactical level. Matched resources are ranked according to user preference using a ranking function, which is an arithmetic expression expressed in terms of resource properties. Ludwig & Reyhiani (2006) define a matchmaking framework for semantic service discovery in grid environments and a portal which implements this framework. The aim of the framework is to provide matches between applications and available services. Semantic matchmaking is based on reasoning using structured information about available services and applications, rather than mere syntactic matching based on service/application attribute name comparison. The framework fulfils a number of requirements such as high degree of flexibility and expressiveness, supporting “subsumes” service matching type, compliance with existing grid technologies and capability of lookup and invocation of matched services. The proposed matchmaking mechanism is based on a shared ontology and is defined in three stages: Context selection, where the appropriate context ontology is chosen, semantic selection, where requests are matched to services according to the metadata descriptions of services, and registry selection, where services are looked up in a UDDI registry. Service descriptions are defined in the DAML+OIL ontology language. A service discovery portal implements the framework, supporting the advertising, viewing and searching of services. The framework provides a similarity metric for avoiding the exploitation of the matching mechanism by too generic advertisements or requests that attempt to maximize the likelihood of matching and for facilitating ranking of selected services.

In (Paolucci et al., 2002) a solution for web service advertisement and matching based on a semantic description of web services is described. This description consists of a combination of DAML-S and UDDI standards. The requirements for matching services are flexibility, minimization of false positive and negative matches, and efficiency. DAML-S descriptions are used for formalizing the functionality of the advertised web services using service profiles, while UDDI is used for syntactic keyword-based matching. An implementation, of a DAML-S/UDDI Matchmaker is provided. An algorithm for matching of DAML-S descriptions of services is proposed and implemented.

A number of systems have also been developed for the discovery of domain-specific grid resources and services based on semantic descriptions for specific application domains such as Computer-supported Collaborative Learning (Vega-Gorhojo et al., 2006), Bioinformatics (Wroe et al., 2003) and Meteorology (Ren et al., 2006; Kaijun et al., 2006). These systems are based on Semantic Web formalisms for the annotation of resources and services such as OWL-S and DAML+OIL. The ontologies on which they are based are domain specific, that is, they define concepts that have a specific meaning in the specific context of the application, and thus support refined queries, meaningful for experts in the specific field.

Ontologies for Trading Resource/ Services in Grid E-Marketplaces

In this section, approaches for the allocation of resources within grid computing environments based on economic models that provide algorithms/policies and tools for effective and dynamic resource sharing/allocation are described. Like Grid4All, in these cases, resources are traded within markets following price-based models (as opposed to bartering/exchange-based models), based on demand, supply, value, and the wealth of economic systems. Furthermore, end users may want to negotiate prices based on demand, value, preferences, and available budget (Buyya et al., 2005; Buyya et al., 2001).

Traditional resource descriptions’ matchmaking approaches are mostly based on syntax, and/ or attributes of resource descriptions (Veit et al., 2001). These approaches are difficult to be extended in order to handle partial or incomplete specifications of market orders (resources’ offers/requests), or to support flexible retrieval processes based on the semantics of the specifications of peers’, markets’ and resources’ characteristics. Recent approaches (e.g. Colucci et al., 2005; Li & Horrocks, 2003; Sycara et al., 2003) suggest adopting semantic service/resource descriptions for matchmaking, by means of ontologies, featuring logic-based representation languages. However, these approaches propose the use of centralized matching components paying little or no attention to market-related properties and peers' features.

Lamparter & Schnizler (2006) present an architecture of an ontology-driven market for trading Semantic Web Services. They report on an auction schema which is enriched by a set of components enabling semantics-based matching as well as price-based allocations. The key issue of this work is the merging of classical auction algorithms with the semantic matching capabilities. They propose a communication language which defines how orders (requests and offers) and agreements concerning web services can be formalized. This work contributes towards the grid economy dealing with a single type of auctions concerning Semantic Web Services: It does not deal with multiple types of markets and their distinguishing features. Preferences of providers and consumers are not taken into account during the matchmaking process.

Closely to our approach, the work reported in (Ragone et al., 2007), aims to semantic matchmaking in P2P e-marketplaces. This approach mixes in a formal and principled way the semantic expressiveness of DLR-Lite logic programs, fuzzy logic and utility theory to find the most promising partners in a peer-to-peer e-marketplace. Following the economical model to negotiation, this approach considers peers' preferences and utilities in the matchmaking process. A major issue concerns the modelling of logical specifications as soft-constraints (requirements and preferences on the peers' orders) using fuzzy logic. Focusing on knowledge representation, the framework proposed offers an alternative to our work on formalizing the retrieval of resources in a grid-related market-oriented environment: However the proposed framework is under implementation. Concerning the conceptualization proposed, although the matchmaking approach is market-oriented, it seems that the focus, as far as markets are concerned, is only on pricing (value of goods), i.e. on the process of retrieving resources based on price negotiations between peers. As a consequence, there is lack of information concerning market and order related properties that a peer may consider in order to trade a resource.

Concluding the above, to the best of our knowledge, recent approaches provide effective semantic matchmaking services for discovering and selecting peers that satisfy requests/offers in an e-marketplace. However, there is a lack of a formal conceptualization of all the types of elements involved in a grid market-oriented computing environment: a) The types and characteristics of the resources, b) the properties and constraints related to the specific offers and requests, c) the specific properties of the markets to which the specific orders are placed, and d) the preferences and characteristics of the providers and consumers that participate in these markets. In the approach presented in this chapter we have dealt with the first three types of elements.

CONCLUSION

The Grid4All project aims at developing a self-managed, autonomous, fault tolerant, and easy to use infrastructure that will enable ordinary users and small organisations such as schools and small/medium enterprises to share their computing resources. In this way, a 'democratized' grid is envisaged, which is accessible to organizations that lack the human and computation resources so as to participate in existing grids.

Towards this target, as far as resources and services are concerned, the Grid4All project adopts a market-oriented model, so as to give opportunities to resources' and services' providers and consumers to satisfy their needs at the lowest cost. In such a setting, where multiple markets operate and multiple application-specific services are being offered, it is a necessity for peers to manipulate effectively three types of services identified: (a) market services (i.e. trading instances), (b) services exposing resources, and (c) application specific services. Manipulation of these services entails at least their advertisement and effective discovery. Furthermore, peers must be facilitated to the manipulation of services, since ordinary users and small/medium organizations, which are the main stakeholders of the Grid4All framework, are agnostic of the low-level details required for managing services offered and requested. Also, service providers need to make the best of their offered services. This type of environment poses new requirements, and thus, affects the functionality of a service advertisement/discovery system. In the context of these issues, the chapter presents specific technologies developed for realizing a Semantic Information System of a grid environment. The developed system supports the Grid4All approach for service discovery and selection in a democratized grid.

In this context, Grid4All resources (traded in markets realized as specific types of services) and application-specific services are being advertised in the Grid4All Semantic Information System (G4A-SIS). The G4A-SIS provides a portal where semantically described grid services are advertised and discovered by (software and human) peers. Peers may pose to the G4A-SIS orders (i.e. requests and offers) concerning (a) specific resources that are being traded in markets, satisfying specific criteria/preferences/constraints concerning resources' configuration, market and order-related properties, or (b) application-specific services' profile specifications.

This chapter presented the technologies developed for the G4A-SIS to provide semantically-enriched functionalities for the resources/services' advertisement and discovery tasks, towards a democratized grid environment. Special emphasis is given to the semantic specification of services' profiles, supporting the effective discovery of advertised services.

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KEY TERMS

Web Service Discovery: The process of retrieving specific service information from a service registry by submitting appropriate queries.

Web Service Annotation: The process of attaching metadata to a web service. These metadata typically carry information about service-related data types and execution semantics.

Services' Semantic Information System: A system for the advertisement and discovery of web services and markets in the grid environments based on ontology descriptions.

Semantic Matchmaking of Services: The identification of a set of semantic descriptions of markets and services that fulfill the criteria imposed by a query for market/service discovery.

Services' Selection: The process of ranking and narrowing down the list of market/query results within a services' semantic information system based on user preferences.

Grid Resources: Computation and storage facilities to be discovered and used in a grid environment. These facilities are accessed as web services.

Market Request: In a Grid4All market, a request is a description of the resource needs of a consumer, together with the price the consumer is willing to pay for those resources within a specific market, as well as request-specific properties, such as the time interval that resources need to be allocated.

Market Offer: In a Grid4All market, an offer is an exact description of the resources that a provider trades in specific time intervals and price.

ENDNOTES

1 The authors acknowledge the European Commission for funding Grid4All under grant number FP6, project IST-Grid-4All-2006-034567.

2 http://www.w3.org/TR/wsdl

3 http://www.globus.org/wsrf/

4 http://www.w3.org/TR/owl-ref/

5 http://www.daml.org/services/owl-s/1.0/

6 http://www.w3.org/TR/xpath

7 http://pellet.owldl.com/

8 http://www.w3.org/TR/rdf-sparql-query/

Chapter XXVII
Semantic Web and Adaptivity:
Towards a New Model

Jorge Marx Gómez
Carl von Ossietzky University of Oldenburg, Germany

Ammar Memari
Carl von Ossietzky University of Oldenburg, Germany

ABSTRACT

The chapter aims at proposing a model that gives an abstraction to the functionalities and data involved in adaptive applications for the Semantic Web. As the quantity of provided information on the Web is getting larger, the need for adaptation in software is getting more and more necessary in order to maximize the productivity of individuals, and more issues are emerging that have to be considered in the new generation of hypertext systems. With the advent of Semantic Web, adaptation can be performed autonomously and in runtime, making the whole process of information adapting transparent to the user.

INTRODUCTION AND MOTIVATION

Recent development within the Semantic Web community suggests that the Internet, or the WWW, as we know it is about to change; the content and the services will be annotated with meta data which can describe and define them.

Traditionally, the Web is seen as a collection of linked nodes, as entailed by the specification of the reference model for hypertext applications, the Dexter Model (Halasz & Schwartz, 1994). This model has long been successful in abstracting the applications that could deliver resources to the Web for human users to use.

However, the supply of information is steadily increasing, and today's Web is the place for expressing ideas, telling stories, blogging, sharing movies photos and sound clips…, anything that anybody ever wanted to say, so the huge amount of knowledge available to any one person is far more than they can possibly absorb (Bailey, 2002) and exposing the human brain to such a big pile of information will cause the "Lost in the Hyperspace" problem, when the useful information remains unfound because it is hidden under a huge amount of useless and irrelevant data.

Fortunately as this supply of information increases, so does also the automatic information processing capabilities. So, there is and will be great potentials to make use of these automation capabilities in order to extract from the overflow of the Web the information and services relevant to the user on an ad-hoc basis, and deliver them over a standardized user interface. The retrieval of data in this adaptive manner gains more and more importance as the mass of provided information grow larger.

We can notice that the portion of the information accessed by any individual on the internet, no matter how large it is, is so small and nearly negligible when compared to the full amount of information available. What if we were able to define this portion of information? Or draw the border of it?

The process of moving from the information domain to the interest domain is similar to moving from the time domain to the frequency domain through Fourier transformation.

Efforts to abstract the functionality and data representation of hypermedia systems in a model, or furthermore a reference model, were conducted. Two of them are mostly used, The Dexter Hypertext Reference model, and the model of the World Wide Web, which is slightly different from Dexter.

These Models can no longer abstract the functionalities and data required for adaptive applications for the Semantic Web. Many efforts were made to come up with a model that extends the Dexter model with adaptive functionalities but most of them carried along some of the limitations of Dexter, and some others concentrated on the static structure of the Semantic Web not on the wider spectrum of both static and dynamic relations between the knowledge and the consumer (see (Memari & Marx-Gomez, 2008)). In fact even the Dexter Model had some aspects of adaptivity, but it had them unintentionally, and they are definitely not enough (Dodd, 2008).

BACKGROUND INFORMATION

Dexter Hypertext Reference Model

"The Dexter model is an attempt to capture, both formally and informally, the important abstractions found in a wide range of existing and future hypertext systems." (Halasz & Schwartz, 1994). The Dexter model is an abstraction of existing hypertext systems -till the day it was presented- and was meant to be an abstraction of future hypertext systems as well. It was created as an answer to the question : what do hypertext systems such as NoteCard, Neptune, KMS, Intermedia, and Augment have in common?. So the model had a goal to collect the common properties and specifications of such systems in order to create a standardized model capable of drawing the border between the hypertext systems and other types of systems , as well as helping to develop interchangability and interoperability standards.

The idea of the model was developed during a series of workshops that took place in the years 1988 and 1989 to develop consensus framework specifications for hypertext systems (Iverson, 2003). Started by the "call to arms" issued by Norm Meyrowitz (Meyrowitz, 1989) and ended up by the formulation and presentation of the Dexter Hypertext Reference Model by Frank G. Halasz and Mayer Schwartz in 1990.

The model divides the hypertext system into three layers: Runtime layer, Storage layer and Within-component layer (Iverson, 2003).

1. **Runtime layer**: The active part of the hypertext structure, that allows for interaction and manipulation of the structure as well as

notification of changes and maintenance of link structures.

2. **Storage layer:** This is the place where the hypertext system stores components and links; no structure within the component is modeled, components are treated as generic containers of data.
3. **Within-component layer:** This layer (undefined in Dexter) manages the internal structure of the hypertext objects. It is assumed that this covers all types of data, including text, graphics, audio, video and all the other aspects of the hypermedia archive.
4. **Presentation specifications:** A critical aspect of the Dexter model. Mechanism for encoding presentation or viewing specifications into the hypertext network. Thus we can infer that the way a component is presented is a function of:
    - The specific runtime layer and
    - A property of the component itself which is the presentation specification.
5. **Anchoring:** An extremely critical piece of the Dexter model. The mechanism for addressing (refering to) locations or items within the content of an individual component (Halasz & Schwartz, 1994). This interface provides the clean separation between the storage layer and the within-component layer.

The main focus of the model is on the storage layer and on its adjacent two layers, while the other two layers are not as focused; the within-component layer is purposefully not elaborated within the Dexter model. And concerning the runtime layer the source states: the range of possible tools for accessing, viewing and manipulating hypertext networks is far too broad and too diverse to allow a simple, generic model (Halasz & Schwartz, 1994).

The model defines all of its terms and leaves the important design decisions open, so every hypertext system has the freedom in implementation, and that fits the goal of making a "reference model".

Semantic Web

Semantic Web is about making the Web more understandable by machines (Jeff Heflin & Hendler, 2001). Semantic Web is about building an appropriate infrastructure for intelligent agents to run around the Web performing complex actions for their users (Jeffrey Douglas Heflin, 2001).

Semantic Web is about explicitly declaring the knowledge embedded in many Web-based applications, integrating information in an intelligent way, providing semantic-based access to the internet and extracting information from texts (Gómez-Pérez & Corcho, 2002).

Semantic Web is about how to implement reliable, large-scale interoperation of Web services, to make such services computer-interpretable, create a Web of machine-understandable and interoperable services that intelligent agents can discover, execute and compose automatically (Devedzic, 2006).

Semantic Web is the natural solution for the problems of the current Web, and is the inevitable way to make the huge supply of information that lie within the Web useful and responsive to humans; we can no longer expose the human brain to this massive amount of data and expect it to cope with it and to analyze, extract and compose knowledge out of it. Instead, we must be able to process information automatically and present them to the user, formed and arranged for a particular purpose. No matter how simple the task might seem, it is not that simple; computers have a big advantage over humans concerning the processing capabilities, nonetheless there are many issues to be addressed before we can make any use of this advantage. For example what exists on the current Web is information, and computers are used presently as carriers of this information, so a program does not have a real understanding of the content of them.

The two most essential questions to be answered are:

- How do we represent the knowledge in such a way that it can be understood and processed automatically by a computer.
- Once we have this information, how can we use it effectively in real applications (Walton, 2006).

As an answer to the first question, we must think of a way to represent the knowledge so that it can be interpreted and reasoned about by both the producers and the consumers of it. We must take into consideration what we are going to represent, what we actually represent is a conceptualization, which is a simplified view of the world (Walton, 2006).

The proposed answer to this question is the concept called ontologies, it is a term borrowed from philosophy, and refers in our case to a specification of a conceptualization (Walton, 2006) ; an ontology may include a description of classes, properties and their instances ("OWL Web Ontology Language Guide", 2004); so ontologies are meant to represent a set of concepts within a domain, and different kinds of relationships between those concepts. In addition to the well-known relationships among classes and objects in the object-oriented languages e.g. generalization, composition, aggregation and association, ontologies represent some more relationships and addresses interrelationships between classes properties and instances (individuals) . Some examples of languages used to describe ontologies are : RDF, RDFS and OWL.

In fact ontologies must be designed for reusability, and they will have big portions of intersection, so an ontology can be a part of other ones, and ontologies can share classes, relationships and individuals.

Ontologies have given us a clue about solving the first problem of representing the knowledge in a way readable by machines; this is required, but it isn't enough. To make a real use of this represented knowledge, we need to design a software that can understand , reason about, collect, summarize adapt to this knowledge, and be able to represent it back as a human-friendly knowledge. The Semantic Web vision promotes the concept of agents as the primary consumers of knowledge (Walton, 2006).

Agents and Adaptivity

Agents are programs that act on behalf of the user, they are not executed or invoked for a specific task, rather they are autonomous and activate themselves, they collect Web contents from different sources, process the information, and contact each other to exchange results, experiences and trustworthiness degrees of the knowledge sources… etc.

we can define an agent with the intention to obtain some useful piece of information, e.g. a list of banks in our area. The agent can then be let loose onto the Web and will attempt to find this information for us by utilizing a variety of knowledge sources, and performing inference on this knowledge. (Walton, 2006, p. 11)

Since agent are going to act on behalf of humans, studies are conducted to give them the human logic, and that was approached in many ways, the most popular of these ways is the Believe-Desire-Intention model (Bratman, 1999).

Agents are sensitive to the changes of their environment, the changes in the environment can have a wide range of variety. According to this event the agent has to decide the way it should act, it will interpret the input considering its intentions. Intentions are the driving force of the BDI model as they determine the actions of the agent (Walton, 2006). In addition to intentions the agent has also its beliefs that correspond to knowledge that the agent has accumulated about the outside environment which can be built by own experience or by others, and can be shared among agents; has its desires which is the state of affairs that the agent would (ideally) like to bring about (Walton, 2006) and has its goals which is a subset of desires that do not conflict between each other.

The vision of the Semantic Web goes beyond the view of agents working in isolation, it goes to considering all the agents as a society of communicative individuals. An agent in such a society can act in a social way by interacting with other agents in order to cooperate, coordinate, negotiate, advise and ask for advice… etc. and this kind of system is called a Multi-Agent System (MAS). If we want to consider the ways of inter-agent communication, we must think beyond the standard ways ; an agent must be able to express its beliefs to another agent (Walton, 2006), so each agent may have its own way of storing and understanding these beliefs, but there must be a common language among agents to express them; and this study is inspired by the philosophical "human dialog" study.

As defined in biology: Adaptation is the change in organisms that allow them to live successfully in an environment (Freeman & Herron, 2003). Adaptation allows the living organism to cope with environmental stress and pressure. The environment around the applications of the Semantic Web is in constant variation, and in order for a system to perform a good and suitable action in such a dynamic environment, it has to adapt to the new circumstances. That has to be done dynamically, autonomously and in runtime; today's accurate decision might be inaccurate tomorrow, the system must be capable of "learning from" and "adapting to" changes in the environment.

The relation between adaptation and agents has two different dimensions:

- The adaptive agent dimension: From this point of view, agents react on changes in the environment, and in other words they adapt to it. We look at the agent itself as an adaptive application, since the features of the way that agents work can be easily mapped into performing tasks that are adaptivity-related; e.g. agents use knowledge bases and rules to govern their actions and that can easily be mapped into the use of rules to personalize information according to a user model. An adaptive agent is an agent with actions that are flexible and may be learnt through interaction (Walton, 2006).
- Using agents for building adaptive applications dimension: Looking at the relation from this point of view leads us to considering a higher level of adaptivity, where a Multi-Agent System (MAS) can compose a layer or a module in the application which will be responsible for giving the application an adaptive property, in a way that this MAS is used for filtering, rating and optimizing the information according to the preferences of a user (or a set of users). Such a use of MAS can be found in a semantic search engine that constitutes a part of a Web portal, or for a semantic Web Service discovery component as the one proposed in this chapter. For another example of a multi-agent framework for personalized information filtering see (Lommatzsch, Mehlitz, & Kunegis, 2007).

In our proposed model, the agents concept will be utilized in the form of a layer, which has standardized interfaces with adjacent layers. This agency layer is a subset of a MAS that will be shared among agency layers of other applications.

WHY DEXTER MODEL

The WWW was a success in itself, but can we build another success on top of it?

Even though we can't consider the model that the WWW was built upon as a separate model, we can't say that the WWW conforms one hundred percent to the Dexter Model.

If we try to make a mapping between the WWW and Dexter model, we can easily consider the Web page as the basic composite component in the WWW, this page is composed of other "Atom" components like text, images, videos, etc. and might also be composed of other "composite" components like the case of framed Web pages or the Ajax-based Web pages.

In addition to that, a Web page contains both "Anchors" and "Links" to other anchors (the <a> and <area> tags), we can here detect a difference between the model and the WWW, since the links and anchors are embedded within the page instead of being separated into independent components. That will blur the position of the Web page in the Dexter model layers because it has also elements from the "Anchoring" layer which cannot be separated. This fact will also make it more difficult to work on the hypermedia structure separately in order to add flexible behavior to the system such as the dynamic adaptive navigation, thus confining the system and preventing the WWW from having an adaptive feature that exist in Dexter (discussed later) and in Open Hypermedia Systems in which "information contents are usually stored apart from hypermedia structures" (Grønbæk, Bouvin, & Sloth, 1997). and makes the WWW "completely lack the editability and link maintenance requirements that Dexter imposes." (Iverson, 2003). Despite the advantages of reduced complexity of embedded links, for the Semantic Web the Open Hypermedia approach seems more realistic. Keeping in mind that annotation of others' work has always been an important feature, and the importance of it gets even bigger in Semantic Web, we can notice that the embedding of links inside the documents is as a big obstacle in front of this feature, because the user who wants to annotate a document must have in this case the write access to it.

Links in WWW are uni-directional, this fact can decrease interconnectivity of the system, whereas links in Dexter model have a richer and wider meaning. Although Web browsers provide "back" button depending on session history, and this button can be thought of as a second direction of a link, some transactions (using scripts for example) are not recorded in the that history so they are not traceable. To cover the limitation of uni-directional links in the WWW, Google had to implement a part of the PageRank™ algorithm (Brin & Page, 1998) that takes a given page and calculates all the links that refer to it, in a manner that is similar to a reverse-direction link.

Semantic relationships are more complex than simple HTML uni-directional links. Embedded encoding of such information will increase the complexity of authoring Web content and raise maintenance costs. Since the navigation through semantically annotated resources will involve inferring and reasoning, it is more likely for that to be accomplished on the server side rather than implementing such a linking functionality within the browser, especially if we take into consideration that the reasoning process itself might have aspects which belong to the specific domain of the knowledge.

According to Lee Iverson, the Hypertext systems that existed before the Web were far more capable than the Web and far more sophisticated, and yet they seem to have been swept aside for a much less capable and sophisticated option (Iverson, 2003).

So before jumping to the new era of Semantic Web, let's stop and take a look around.

RELATED WORK AND POSITION OF EFFORT CONCENTRATION

Models Extending Dexter

Since the Dexter model was announced in 1990 and until now, a lot of research was conducted to modify the model in order to make it include some emerging techniques, or to make it adapt to some new standards, most of the modifications tried to be conservative i.e. to keep the old systems included under the new model and come up with a solution that includes the new systems in an extension-like manner. The list includes:

- **Amsterdam Model of Hypermedia (Hardman, Bulterman, & Rossum, 1993)** Amsterdam model came to support some aspects of time and synchronization that Dexter model lacks, since Dexter model does not have these concepts (Dodd, 2008) and this can lead to problems for multimedia applications.
- **Adaptive Hypermedia Application Model (AHAM) (De Bra, Houben, & Wu, 1999) (Figure 3 a)** One of the well-known adaptive hypermedia models. It is an extension of the Dexter model which focuses on the storage layer, anchoring and presentation specification as well. AHAM divides the storage layer into three models:
  - The domain model contains a conceptual representation of the application domain. In the Dexter model the storage layer only contained what AHAM calls the domain model.
  - The user model contains a conceptual representation of all the aspects of the user that are relevant for the adaptive hypermedia application. This includes an overlay model of the domain, the user's background, experience, preferences or anything else that contributes towards the adaptation.
  - The adaptation model describes how an event, such as the user following a link, results in a presentation, by combining elements from the domain model and the user model.

- **Munich Reference Model (Koch & Wirsing, 2002)** As an object-oriented version of the AHAM came the Munich Reference Model which is described using the Unified Modeling Language (UML).

Models for Adaptivity

- **Fundamental Open Hypermedia Model (FOHM) (Millard, Moreau, Davis, & Reich, 2000)** FOHM was presented through an approach towards an Agent-based framework to support adaptive hypermedia. It provides the facility to attach context and behavior objects to the model at various locations. A contextual open hypermedia FOHM server was developed called Auld Linky to instantiate and process the model which belongs to the Open Hypermedia family.
- **Goldsmiths Adaptive Hypermedia Model (GAHM) (Ohene-Djan, 2002)** This is an abstract model that consists of three groups of functions: the H-Region functions model non-personalizable hypermedia-based interaction , the P-Region functions model user-initiated tailoring and the A-Region functions model the system initiated tailoring of hypermedia content.
- **Generic Adaptivity Model (GAM) (Vrieze, Bommel, & Weide, 2004)** GAM is not restricted to hypermedia only , but it is a more generic model. This state-machine-based model can be used as the basis for adaptation in all kinds of applications. To use this model for adaptive hypermedia, another model must be built on top of it, and

then GAM can provide functionality that extends the AHAM model's functionality.

Efforts that Cosider the Semantic Web

- **Enhanced Adaptive Hypermedia Application Model (Kravčík & Gašević, 2006) (Figure .3 b)** The model deals with issues related to design and implementation of personalized and adaptive systems, considering the Semantic Web technologies as a means to achieve certain progress in this field. The model aims at the ways that Semantic Web can solve the demands of interoperability between various systems and between formal models. The effort is oriented towards filling the gap in the harmonization of the different standards through a Semantic Web approach.

This model extends the AHAM (which in turn extends Dexter) by adding other divisions to the storage layer.

Towards more efficient Generic Semantic Authoring for Adaptive Hypermedia (Saksena & Cristea, 2006): This effort is a description of steps taken towards creating more efficient generic semantic authoring for adaptive hypermedia, so it focuses on using the semantic methodology in creating content for educational usage that can be reused in many applications, starting from an existing framework, LAOS, an existing system, MOT, and evaluating results thereof. This system is to make use of existing appropriate Semantic Web techniques (Cristea, Stewart, & Sirmakessis, 2006). The effort concentrates on concrete examples (existing systems) but addresses some important general issues.

As illustrated in Figure 1, we can see that our approach is located in the intersection between Semantic Web applications, Adaptive Applications and Hypermedia applications.

EXPLOITABLE ASPECTS OF ADAPTIVITY

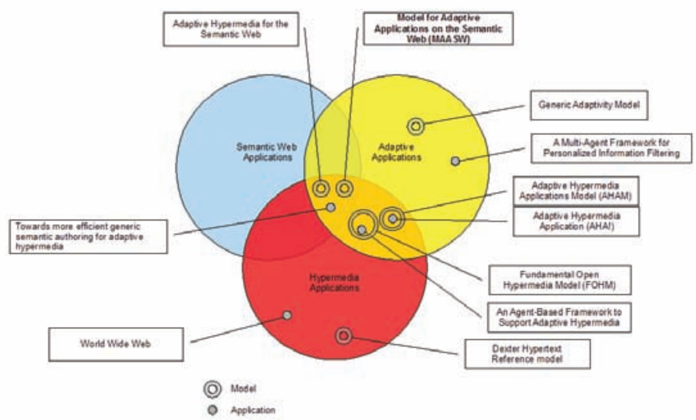
As we can conclude from the motivation, the urgency of the need for adaptation is a current issue. Adaptation is necessary nowadays and in the future systems mainly due to the overflow of available data, thus we can excuse old systems for not concentrating on the adaptation aspects.

Nevertheless, we can still find some handy adaptation-usable features, even in the 20-years old Dexter model:

Dexter model provides the concept of the "Session", which represents a single user interacting with the content and includes a history of user interaction during a session. Although this history was not meant to be used this way, it can be used to help in decisions of selecting among different competing Presentation Specifications, for example if the user was navigating his way through Web pages concerning ancient civilizations and reached our Website which talks about Origami, then there is a better way to present the content of our Website to this specific user, concentrating in the first page on the history of this art. For another user who made his way here through Web pages concerning kids creative games, a different way of presenting our content might sound better to him. All in all, when you see where the man is coming from, you can more easily predict where he is going to.

Dexter model allows to leave the selection of which subset of components to show and which to hide to be made at runtime, which allows for a comprehensive collection of components. Selection can be based on Presentation Specifications, Session history, and component attributes (name/value pairs that help describe the component). Leaving such decision to the runtime gives adaptivity-enabled applications the possibility to make a resource adapt to some needs of the user. Keeping in mind that links according to Dexter are also components and they have their own Presentation Specifications, we can make it possible

Figure 1. Location of different models within the space of the Semantic Web, Adaptive



for example to decide during runtime where to navigate the user when he clicks a specific link. (Note that it is harder to do that in the case of embedded links).

PAVING THE WAY FOR A NEW MODEL

The effect of incorporating the Semantic Web as the platform upon which the new generation of applications will be built is vast, and it is not limited to the static structure of the Web, rather it will also affect the ways of information storing, retrieving, interpreting and presenting.

When we want to think about the next generation of hypermedia systems that resides on top of the Semantic Web, we have to consider the following issues (Ossenbruggen, Hardman, & Rutledge, 2001) and (Halasz, 1988):

1. The environment of the Semantic Web is highly decentralized, distributed and heterogeneous, and when we import technologies like ontologies and knowledge bases from the field of Artificial Intelligence, we have to keep in mind that these technologies focused originally on representing centralized, localized, consistent and trustworthy knowledge. The concept of adaptivity is strongly connected to filtering, which will remove the redundant, irrelevant and inappropriate information from the available heap, providing transparently a stable foundation of information to the upper layers.
2. As mentioned before concerning the multi-directional links, we also have to keep that in mind concerning the URIs inside the RDF annotation. Given an RDF annotation, we can easily resolve the resources using URIs, given a resource, it is hard to resolve all the RDF notations that refer to it without using crawlers (as in the aforementioned Google approach). Learning from the lessons of Open Hypermedia, we should consider having link services in order to separate the structure of the hypermedia from the content. but that will compromise the acentricity of

the system by making it depending on the providers of such services.

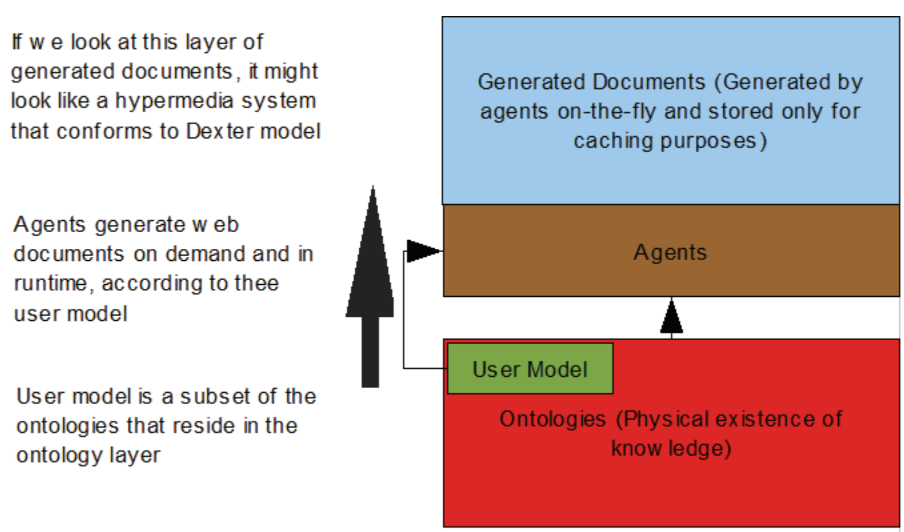
3. Considering binary-encoded data formats in terms of indexing, annotating, recognizing and management. Such formats include images, video files and audio files. None of the already existing systems (which are metadata-management based) is able to define a strong image or A/V semantics derived from the image or A/V structure only. In order to give the knowledge management systems the ability to manage these data types like other contents (text files ...), new languages need to be developed to be able to point into these time-variant and compressed data; enabling for example the search by audio, video, location, image, on-screen text, face, pattern and concept. These formats are common in the multimedia domain. This domain with advances in computer graphics is suggested to play a key role in the evolution of the World Wide Web composing the (other) way leading to Web 3.0.
4. Computer Supported Cooperative Work (CSCW): We are witnessing a steady rise in B2B transactions, enabled by the intercompany exchange of data over a mutually agreed format and recently, the story even goes further, when a few companies make use of the internet platform to move forward towards a across-company integration of their entire information system so as to achieve strategic alliances. CSCW should be considered in the next generation of hypertext systems, since the entire information infrastructure of the company is moving towards the Web platform, offering a unified and standardized access for customers, suppliers and employees to the information and services the companies offer. Making use of applications offered over the employees portal, for instance groupware, staff members can meet, cooperate, and coordinate their work over the internet. Even with the infrastructure of the Semantic Web, many of the features which are main aspects of the cooperative work such as authentication, access control, concurrency control and version control are not yet fully integrated in the Web's infrastructure. We can solve the technical part of this problem by providing extensions which realize these features, but the social and dynamic aspects of the collaboration problem will remain unsolved. It is only because of the Web's initial focus on "read-only'' browsing that these features hardly received any attention. A notable exception is the joint IETF/W3C work on WebDAV (Whitehead Jr. & Wiggins, 1998). While WebDAV predates RDF, it has a similar property-based model for Web resources. In addition to that, it is important to provide means to enable users to annotate the work of others as mentioned earlier in "Why Dexter Model" section, it is an important feature that has been realized in previous efforts namely Stanford ComMentor (Röscheisen, Mogensen, & Winograd, 1995) and others, but disappeared over time due to lack of interoperability, so the annotations could not be shared across applications in the same way as other Web resources.
5. Conceptual Hypertext introduces two layered approach, the bottom layer consists of interconnected "concepts" whereas the upper one contains documents that are presented to the users, separating knowledge representation from document representation as shown in Figure 2. Using the full power of ontologies to improve hypertext linking based on the semantic relations among the associated concepts is a promising methodology that found its implementation in (Carr, Wendy Hall, Bechhofer, & Goble, 2001). Using agents to mediate between the two layers is an approach that adds much

flexibility to the manner of generation by making the processes of adding, deleting and modifying the methodologies of generation as simple as adding, deleting or modifying agents, which can be done in runtime and on the fly.

6. Is the basic model of node, link and anchor (Dexter) still the best way to present information to humans ? (Rouet, 1992) has conducted a study concerning cognitive processing of hyper documents, it includes different experiments that were done to compare linear presentation formats (normal text) to hypertext and has got by then some results, and discussed some ideas. Online definition of of unfamiliar words can improve comprehension only if the defined words are important to the meaning of the text. computerized assistance has to do more than providing additional information, this information must be of correct type and trigger effective comprehension process. Moreover it should be clearly signaled, immediately accessible, and unambiguous. Thus the hypertext in itself should not be thought of as the final answer for information representation, more semantic layers should be involved in the authoring phase. The semantic structure of the domain should also be reflected in the content map of the hypertext in order to facilitate the process of reviewing the document, according to (Rouet, 1992).

Rouet also came to the conclusion that some of the users who were the subject of the experiments were unable to take advantage of the ability to self-organize the content (provided by the hypertext), and they had better results with the linear pre-organized texts, because they didn't build meaningful navigational strategies and they lack the "cognitive monitoring". Since that time and until now, the familiarity of the hypertext to the people has increased significantly, but we still can't say that all the people are able to organize their own learning activity. Furthermore when we consider that the user has to find his way through this huge pile of available information, we can say that all the users are lacking these organizational skills to some extent. Nevertheless, with the progress of personalization and adaptation

Figure 2. Conceptual Hypertext Layers (simplified)



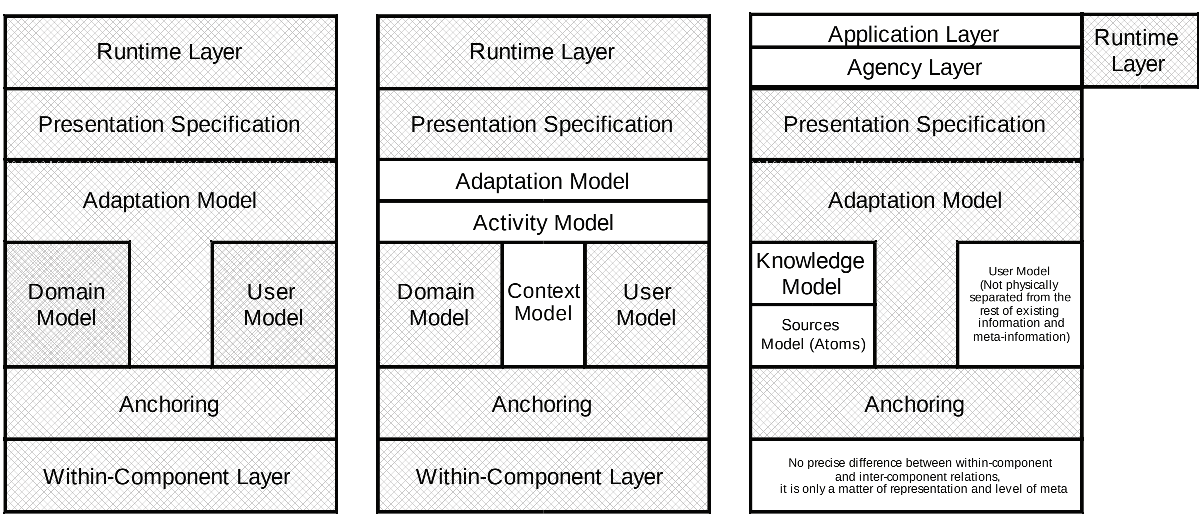
techniques and technologies, we can safely assume that the Semantic Web can compensate this lack of reasoning skills by building user models which can by continuous learning be able to "know" the user more than he knows himself, and thus agents using this model can play the role of the tutor.

7. Different approaches for linking across documents exist on the current Web, they can range from the simple embedded links found in HTML to the conceptual, more advanced linking as what we can find in the RDF family. We are also able to conclude something from examining that the last version of the XML Linking Language (Xlink) (DeRose, Maler, & Orchad, 2001) was released in 2001 and no further development took place, a fact that can support the idea of (Ossenbruggen et al., 2001) that taxonomic hypertext systems might benefit more from ontology-oriented languages than from languages oriented towards navigational hyperlinks such as Xlink. Runtime computation of links and anchors is an appealing idea, using that in addition to statically defined links and anchors that are defined at authoring time can add much flexibility and self-stabilizing ability to hypertexts systems and enhance their infrastructure required to become adaptive systems. They can enjoy the benefits of ontology driven linking that allows documents to be linked via metadata describing their contents and hence improving the consistency and breadth of linking at retrieval time and authoring time (Carr et al., 2001). In addition to the agent-based navigation assistance (El-Beltagy, DeRoure, & W. Hall, 1999).
8. RDF-enabled search engines have the potential to provide a significant improvement over the current keyword-based engines, especially when it comes to metadata and structure-based searching. An example of such a system, albeit not using RDF for encoding its semantic annotation, is the Ontobroker system (Decker, Erdmann, Fensel, & Studer, 1998) which has matured and went commercial, available under Ontoprise (http://www.ontoprise.de/).
9. Beyond the classic user interfaces: what was really special and original, is what Nintendo did by releasing its fifth home video game console known as Wii (Wii: The Total Story, n.d.), Wii didn't introduce the tremendous cutting-edge graphics, nor the market-braking High Definition audio and video, but it introduced a revolutionary controller nicknamed "Wiimote", this wireless pointing and movement detecting device had simply provided a new way of interaction between humans and games, opening new dimensions and exploring new areas that were ignored before in the development of home video games console. The domain of human machine interaction was also ignored in the various existing hypertext models, we can safely say that about Dexter model since it had abstracted away from the user interface details, also Open Hypermedia research considered the user interface as part of the application's functionality and it was more or less ignored. However in adaptive hypermedia the presentation and interactive behavior of hypermedia structures is more complex than the typical button-like behavior of navigational links, and is often tightly intertwined with the underlying semantics of these structures (Ossenbruggen et al., 2001). The ability of the Semantic Web to model the semantics of hypermedia structures explicitly provides new opportunities to improve the hypermedia user interface.

When we take these points in consideration and try to reflect them on a piece of clay in order to get a model that can contain all these aspects, we will find that it is not as easy as it sounds. Nevertheless we still can define the broad strokes that form the clay into the desired adaptive hypermedia model (Figure 3c) and shake the thrones of existing models. Basing on the Enhanced AHAM (Kravčík & Gašević, 2006) which in turn is based on the Dexter-based AHAM (De Bra et al., 1999) the main effects on the different layers of the model are:

- **Within-component layer:** Most of what we used to call a component will be composed in runtime, by the accessing agents for instance. Composite components (e.g. a Web page) will not exist as physical stand-alone components anymore (except for caching purposes) and the pages that the user will see are composed by the system (agents) according to his preferences (Figure 2). Even the so-called atom component are not an exception, e.g. the system can autonomously compose a video out of a collection of images, video clips and audio clips, the same can be easily said about texts, images, audio content that used to be called atom components in Dexter. Of course there will be atom components in the system, components that cannot be divided anymore, but these ones will have more granularity, and they don't have to comply with the definition of atom components that comes from the human point of view. A different way for representing knowledge will be used especially when we consider the conceptual hypertext, and by using ontologies there can be no clear borders between components since ontologies can intersect, one can be part of another and some sources can belong to more than one ontology. Thus no precise differentiation between within-component and inter-component relations, it is only a matter of presentation and level of abstraction.
- **Domain model:** The Enhanced AHAM (Kravčík & Gašević, 2006) divided this model into two interconnected networks of objects, complying with the conceptual hypertext approach mentioned earlier. With different kinds of semantic relations between the concepts in the knowledge space in addition to the relationship between the

Figure 3. Three models in comparison



a - Adaptive Hypertext Applications Model(AHAM)

b- Enhanced Adaptive Hypertext Applications Model

c - The proposed model

hyperdocuments in the hyperspace which have different standards, such can be found for example in the Dublin Core Metadata Initiative ("dublincore.org"). The third kind of relationships is the one that interconnects the two networks, this kind can be thought of as the relationship between sources that "glues" a Web page together, it isn't the semantic relationship that we can find in the knowledge space, rather it is presentation specific, user specific, and is the core of the adaptiveness. So considering that the third kind of relationships belongs only to the domain model can be mistakable, these relations are the ones which will be constructed by the agents in order to "weave" the user-adapted Web.

- **User model:** Is the model that will define what the application should adapt to. It will exist as an ontology and thus it will not be physically separated from the rest of the existing information and meta information only loosely defined. This model can also contain fuzzy information in addition to the normal discrete ones. Different approaches to combine the user model and the domain model also exist such as Probabilistic Latent Semantic Models (PLSA) which is such a concept that integrates information about the domain with user data. A framework based on that concept is (Jin, Mobasher, & Zhou, 2004).
- **Adaptation model:** This model used to represent pairs or multi-end relations between the subjects of adaptation (Domain Model) and the specifications that the subjects must adapt to (User Model), these relations will still exist but not as a separate package, and not limited to any type or group of relations.
- **Presentation specifications:** This layer will remain and will have a similar role to its previous role, will also be connected to both the sources (components) and the agents accessing them, the presentation specifications will be a part of the meta data that is describing the information, and will not constitute a certain group as the group of presentation specifications of a component. The way the information is presented to the user is now a function of much more parameters, which may include a bigger portion of the properties of the information to be presented, and the preferences of the user (both in the storage layer) in addition to the specifications of the accessing agent (in the Agency layer).
- **Runtime layer:** This layer will be divided into two layers:
    - *Application layer:* Has the same role as what used to be called "Runtime Layer" and it has open-ended possibilities that it is hard and unworthy trying to have a model that abstracts all of them. Going beyond the classic user interface can be implemented in lower abstraction levels.
    - *Agency layer:* This is the layer that will contain the activities of different kinds of software agents, the features of agents are needed, The features of the way that agents work can be easily mapped into performing tasks that are adaptivity-related (Memari & Marx-Gomez, 2008). The results that are generated for humans may follow the Dexter model. but the way that these "pages" are generated is the task of agents and it is the part that will hold the adaptiveness. So they will take into consideration:
        - Individual user preferences (user model),
        - Knowledge about sources and other users that can be collected by acting as a Multi- Agent System (MAS).

The layer can have different kinds of agents each with different tasks and algorithm implementations e.g. rating agents, meta data agents, resolver agents (which will perform the "resolve" function described in Dexter), accessor agents, search agents and every other functionality imaginable can be assigned to different kinds of agents. This kind of task assignment can give the system a great amount of flexibility, responsiveness and self-* features; adding, removing and modifying functionalities can be a straight forward process, enhancing a specific feature can be thought of as increasing the number of agents assigned to it, all that can be done in runtime without having to stop the system or recompile from source. That can greatly help breaking down complex and heavy-data-requiring problems. This layer will have a standardized interface with the application layer, application layer will have access to the user model only through the agency layer, this will facilitate the content adaptation but may make the presentation adaptation a little harder.

AN APPLICATION ACTIVITY

In order to get a clearer picture about the role of agents in the process of adaptivity, we can consider the following scenario: let's assume that we have an SOA-Enabled Application, based on a Service Oriented Architecture (SOA), see (Newcomer & Lomow, 2004). That means that the user who will be using this system, will be dealing with it as a service, and this system in turn will be composed of and using other services. This architecture is based on the component-based architecture which has the benefit of simplifying the design of the software, and increasing the reusability of sections of code (components) by making each component appear as a black box with inputs and outputs, so the software designer doesn't have to worry about what's inside or how tasks inside are done. Services in SOA have taken the place of normal software components. The advantage of such an approach is to further simplify the application design and to maximize reusability through letting each component run on a different machine, so it is a total black box to the designer, in a way that he doesn't have to care even about the requirements that a component needs to run properly (because that will be the task of the service provider).

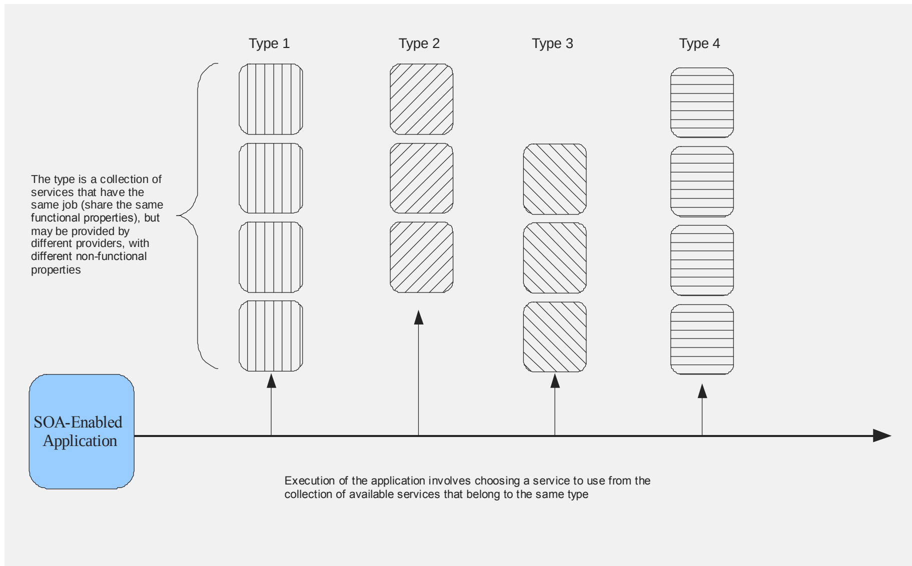
As illustrated in Figure 4 we can see that there are different possibilities for using the available services. Throughout the execution of the application, it will utilize different types of services along the way.

For each type of these services, there is a variety of implementations provided by different vendors, and running on different hardware, that will make them vary in price of use, delay of execution, accuracy of the results etc. which are machine-measurable attributes, additionally they will vary in some attributes that are unmeasurable by machines, like the way a picture looks, or the way a diagram is shown...

Here we can detect two visible problems, the first is that with the huge amount of available services, we are facing the problem of categorizing these services into the appropriate types, since the point of view of the user is always different from the point of view of the programmer, and the essence of reusability is in using the component (service) in different ways, the programmer can only partially categorize his service, and the main burden of this is on the user.

The second problem comes after the categorization, because in each category, there will be a big amount of available services that vary in lots of machine-measurable and machine-unmeasurable attributes as mentioned above, on top of that the sea of provided services is restless, they may change in number, availability, price, quality etc. every minute. That will make the process of taking a

Figure 4. Execution process of an SOA-enabled application



decision about which service of each type to use, too complex for any human mind to solve.

Now let's assume that our application complies to the aforementioned model, that means that the underlying platform is the Semantic Web (or a semantic represented knowledge), also means that we have an agency layer in our application which will be responsible of adaptivity.

In the light of that, let's have a spotlight on the two aforementioned problems, which are summerizable to: a representation problem and an effective usage problem, see (Walton, 2006, p. 3).

The problem of categorization will be solved by representing the service semantically using ontologies as denoted in the vision of the Semantic Web, which means declaring the "What exactly this service does" in a way that is understandable by machines, the process might sound like flipping the service inside out, or penetrating the black box but that's not the case, because we are not declaring how this service works but only what. By using ontologies to describe that, we can guarantee that through the generalization relations within the ontologies, these services are easily categorizable.

The second problem is solved by the agency layer since agents have more processing power than human brains, and they are also in a restless condition and in a constant motion towards better adaptation with the environment, choosing autonomously and in runtime the best possible path among all the available paths, according to certain desires and criteria of the user, in order to accomplish the goals (functionality) of the application.

Now let's have a more concrete example, a simple application that calculates distance between cities, and shows a map to display the shortest path.

A quick look at this application will suggest that we use three types of services: a service that calculates the shortest path between two given cities, another service that calculates the length of a given path, and a third one that displays a map with a given path on it. Assuming that the services are semantically described, the agents will try to find and categorize the relevant services, let's suppose an agent finds a service that does "cartography" and draws "tracks", the agent can reason about that service using relations in the describing ontology that connect “cartography” to “map” and “track” to “path” and conclude that it is relevant and we need it to fill the third position. In the same way the agent can determine that a service that calculates the shortest path between metropolises is relevant because there is an “is a” relation that connects a city to a metropolis.

After getting the results and categorizing them the agent has to choose an appropriate service from each category, according to the preferences of the user.

The preferences of the user are described in the user model which can be modified manually or by learning as mentioned before. The manual modification interface can look like an audio mixer, with different qualifications displayed as trackbars, and the mission of the agent is to find the possible mixture, that best satisfies the given criteria. These criteria in addition to the precise values can have also fuzzy values, so the “price of use” attribute can have values like “0.5”, “< 0.2”, “0.3 - 0.6” as well as values like “reasonable”, “expensive”, “cheap”...

After deciding about the best combination of services (which is the first stage of adaptation), it’s time to get feedback from the user about the final result. The user might dislike some measurable aspects of the results, like the price or speed or resolution of the displayed map or the accuracy of the resulting distances... in this case, the agent can easily detect the responsible service and try to find other alternative for it.

But sometimes the user might give unmeasurable impressions like: he doesn’t like the result, or the result is ambiguous or the result is not worth the price paid for it, in this case a combination of services as a whole is responsible rather than one service, so the agent has to find a better combination to better suit the user. That calls to mind the genetic algorithms, that might be one good solution to use in such case.

The most important issue at this stage, which will draw the border between the agent and the Decision Support Systems (DSS) is that instead of suggesting a possible solution to the user, our agent will act by itself trying to reform the combination of services in order to have a result that conforms more to the needs and preferences specified. In order to do this, the agent must have a margin of freedom, which is be specified by the user through the “audio mixer” interface, the width of this margin reflects the trust that the user gives to the agent.

CONCLUSION

We have presented here the reasons behind the emergency of adaptiveness and personalization in current environments. The example above goes about a simple problem from the usefulness point of view, but real world business problems are more complex and complicated, most of them cannot even have a solution on current hardware within a reasonable time span using conventional methods. The physical limits in front of increasing the hardware resources are another reason for us to think about alternative ways of getting problems solved, and among them: adaptation.

Adaptation has been thought about a long time ago, however it has not been as necessary and urgent as it is today. Models and reference models were conducted in order to capture the abstractions of existing and future systems; we have briefly presented some of them and spotted the light on a few points to be considered for the upcoming hypermedia research.

Finally we tried to look at the Enhanced AHAM model through the eyes of these nine points, taking the Semantic Web as the platform, giving a rough sketch of a new model that tries to abstract the functionality and structure of emerging adaptive hypermedia systems.

No matter whether we use SOAP & WSDL or the simpler alternative REST, whether we use RDF & OWL or the user-friendly XHTML &

Microformats, the Web is definitely going smarter, and that's the future of it: the Semantic Web.

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KEY TERMS AND DEFINITIONS

Adaptation: A process that includes in general the selection of relevant items from a set of items in a way suitable for given requirements or environment conditions.

Agency Layer: Is a layer in our proposed model which has standardized interfaces with the upper and lower layers and contains the activities of a wide variety of software agents.

Hypermedia: Is a term used for hypertext which is not constrained to be text, it can include graphics, video and sound.

Hypertext: Is a concept that is basically a text which contains links to other text.

Multi-Agent System (MAS): Is a system composed of multiple interacting intelligent agents, such a system can be used to solve problems that are impossible for any agent solely to solve.

Reference Model: An abstract representation of the entities and relations within a problem space; it forms the conceptual basis to derive more concrete models from which an implementation can be developed.

Semantic Web: An extension of the World Wide Web in which the semantics of the offered informational and transactional resources are provided and represented in a machine-understandable manner.

Chapter XXVIII
Semantic Technologies and Web Services:
A Primer on Legal Issues

Claudia Cevenini
CIRSFID University of Bologna, Italy

Gianluigi Fioriglio
CIRSFID University of Bologna, Italy

Migle Laukyte
CIRSFID University of Bologna, Italy

Alessandro Rocchi
CIRSFID University of Bologna, Italy

Giuseppe Contissa
CIRSFID University of Bologna, Italy

ABSTRACT

This chapter adds a further dimension to interdisciplinary research on Semantic Web and Web Services: ICT is undergoing a strong and constant regulatory phenomenon at national, European and international level and needs to be constantly monitored. This makes it possible to develop and use technologies in a law-abiding manner and to be aware of the legal position (rights and duties) of oneself and third parties. This chapter aims at offering an overview of the legal framework that supports people's access to Web Services, according to the Semantic Web innovations. The basic aspects examined include: delegation, liability, privacy and e-identity. Finally, a specific section dedicated to e-business will give a dynamic approach to the analysis, so as to consent further developments on the other issues that Semantic Web implies.

INTRODUCTION

The Semantic Web is opening new opportunities for users to access the Web and enhancing the objectives that may be pursued in the Internet environment. The basic reason for this extension is a radical change of the Web's nature. If we consider that until today the world wide Web, based on visual mark-up languages (HTML) has been designed for humans, then we should admit that the Semantic Web, based on machine-processable languages (RDF(S), DAML+OIL, and OWL), is going to see a relevant role of software agents. The Semantic Web for agents, however, is not meant as a replacement of our current Web but only as an extension of it. Along with this extension comes an enlargement in the spectrum of "people" populating the Web, in that agents and humans share a common space through semantic-dynamic data elaboration.

According to these considerations, the first step of a legal analysis of the Semantic Web should start from the relationship between human users and electronic agents to which goals and tasks are delegated and should be followed by the related liability aspects.

Afterwards, other crucial themes are privacy, data protection and e-identity, which analyse the consequences of a Web enabled to collect and process personal data with high usage opportunities and high risks at the same time.

A final survey on improved e-business' services will confirm the opportunity of such investigation, highlighting further ideas for future studies.

SECTION 1. DELEGATION

1.1 Semantic Web: A New Concept of the Web Leads to a New Concept of Delegation

One of the most relevant innovations of the Semantic Web is represented by the possibility to achieve goals through an improved approach to software agents, instead of using mere tools unable of autonomous action[1].

Since ever, autonomy and pro-activity are basic qualities recognized upon software agents (Wooldridge, 1999): they summarize the capability of agents to inter-act in their environment and meet designed tasks, performing non-deterministic repertoires of actions[2].

Despite this potential, the implementation of such agents in the reality is still to come, owing to the necessity to preserve users from failures and mismatches resulting from the actions entrusted to the agent-delegate.

An additional concern is about the loss of autonomy for human users that may follow from the increasing autonomy of agents (Friedman, Nissenbaum, 1997): if agents had power to gain knowledge and self-organize it, according to the task delegated, users may lose control over the acts performed by agents.

However this is exactly the matter of fact which the Semantic Web is entitled to cope with: as authoritatively stated (Berners-Lee, Hendler & Lassila, 2001), the Semantic Web may enhance agents to be not merely tools designed for limited tasks, but tools able *"to assist the evolution of human knowledge as a whole";* this is, in turn, due to the fact that Semantic Technologies may *"enable machines to comprehend semantic documents and data,* - even if - *not human speech and writings"*[3].

The knowledge improvement of software agents increases the goals those agents may accomplish and also the possible way to achieve them.

This implies more opportunities and more risks at the same time for users, when they choose to delegate tasks to autonomous agents.

In its common meaning, delegation is intended as "the action of delegating or fact of being delegated, the appointment or commission of a person[4] as a delegate or representative, the entrusting of authority to a delegate".

The purpose of this section is to analyse the evolution of the legal framework that lies behind "delegation" as a matter of fact, which defines the relationship established between humans and software agents.

The basic components of this relationship are:

- The assignment of a goal to be pursued by the agent on behalf of the user;
- The transfer of the knowledge necessary to the agent to perform its task;
- The degree of autonomy granted to the agent, (i.e. the possibility to assume other information, the assessment of relevance of that information and the power to self-determine the best strategy to pursue the goal).

The innovation, offered by the Semantic Web, is based on knowledge transfer, but is suitable to modify the trade-off between all elements of delegation.

In particular, while the goal's assignment to a software agent is directly related to the technological possibility for the agent to perform the requested action and the user's convenience about it, the other two components are strictly connected to the legal aspects of delegation.

Delegation "as a fact" has found different possible translations in legal terms, according to the regulation set in every State and in each different legal order (i.e. civil of common law orders)[5]: this represents one of the principal causes that limit the usage of (really) autonomous software agents.

Exploiting the current theorizations about delegation, in legal terms, it is important to understand the possible contribution that may enhance software agents' autonomy: people should be safe from unwanted legal consequences due to an excess of delegation on software agents.

1.2 Delegation and Autonomy: Agents as Mere Tools

The basic problem of delegation is to set up a legal framework eligible to ensure the attribution of liability for all actions performed by software agents.

The debate on the legal aspects of delegation has oscillated between two main theories: the possibility to consider agents as mere electronic devices or the establishment of specific legal personhood upon them.

Considering software agents as mere tools attributes all the actions performed by the agent to the user and so the related liability; in some cases, the user will recover his loss suing the creator of the agent, (according also to possible agreements occurred between these parties).

This theory is highly considered in Common Law orders and corresponds to the theory of "agents as simple messengers", which is the same rule applied in Civil Law orders when is not possible to consider agency law (Wettig & Zehendner, 2004).

Particular instances of these doctrines are discussed in the United States, where two potential solutions for delegation are represented by the "unilateral offer doctrine" and the "objective theory of contractual intention" (Chopra & White, 2004).

In the first theory, agents are equal to "vending machines" and the agreement enforced through them is based on public offers whose terms and conditions are deemed as implicitly set by the user.

This theory still considers software agents as mere objects, but implies little changes as concerns liability.

The second theory considers the assent of the user party to the action made by his agent as unnecessary: the action should be attributed to the user according to an objective judgment of reasonableness about his intention (that is to say that the fact implies the intention).

In this theory, software agents role is enhanced, with the sole limit of unpredictability: if the action of the agent appears as it was unpredictable by the user, the latter will not be liable for the consequences.

Both these theorizations – which we exposed just to introduce the variety of possible legal solutions existing under the same concept – are unfit to improve software agents' efficiency in the Semantic Web context: in fact, they consider *knowledge* only as a prerogative of the user's autonomy, instead of evaluating agents as entities able to manage it.

1.3 Delegation and Autonomy: Law of Agency and Legal Personhood

The most important legal scheme used to conceptualize the actions performed by software agents on behalf of their users, considering their capacity to cope with knowledge management, is the so called "agency paradigm" (Andrade, Novais & Neves, 2004)[6].

This legal scheme attributes to software agents the authority to represent their user, according to a specific declaration made by the delegator, which states the content of such delegation and defines the goal to be pursued. This declaration is also important to manage the relationship with counter-parties and thus distribute liability in case of necessity.

This scheme has two main practical accomplishment worldwide, which are the Civil Law model which comprehends French and German versions, (Ferreri, 2002) and the Common Law model.

The French and German models are based on the concept of representation intended as the transfer of authority from the delegator to the delegate, made through a specific entrusting act (procuration).

Two different notions of representation are considered in this case: direct representation (where the actions performed by the agent are directly referred to the delegator) and indirect representation (where the delegate act on his own, but is obliged to attribute the actions' consequences to the delegator with separate act).

These models, moreover, distinguish delegation enacted using the representation legal scheme from delegation accomplished on the basis of a contractual agreement, (like, for instance, the mandate contract under Italian Law).

However, while representation is the unilateral expression of the intention to delegate someone, the contractual scheme naturally implies the exchange of assent between two persons: considering this aspect, the possibility to apply a contractual scheme to software agents seems complicated.

In Common Law systems, such as the United States, the Agency Law does not provide any distinction between direct and indirect representation, but the most relevant thing is that an expression of assent is required also to the agent (as set by the US Restatement of Agency). This is a reason why the agency scheme is not the preferred one by Anglo-American doctrine[7].

The agency paradigm, anyway, embraces more aspects of delegation: for instance, under Italian Agency Law, if the agent reached a goal different from the assigned one or acted in lack of the conferred powers, the delegator may "ratify" anyway the agent's result after done.[8]

If no ratification occurs, a case of "apparent agency" poses (De Miglio, Onida, Romano & Santoro, 2003): here the user will not be liable for actions performed by the agent and the third parties will suffer all damages,.

In the end, the application of agency and representation law has been preferred to the establishment of legal personhood by the main part of the doctrine (Sartor, 2002) and (Andrade, Novais, Machado & Neves, 2007).

The acknowledgment of legal personhood to software agents would require the issue of special laws in each State[9] and would frustrate the doctrinal effort to solve the problem using enforcing laws.

In fact, the attribution of legal personhood to software agents is deemed to be unnecessary in the current context, according to the above mentioned authors: the reason is twofold.

First of all, users need to realize their own goals: the establishment of a legal personhood is connected by legal doctrine to a wider concept of autonomy, which is aimed at determining life in all its aspects (which are not only patrimonial ones, but also moral and social, for instance).

Otherwise, agency law is the most common legal paradigm, present both in civil and common law systems: even if there are relevant distances, the application of this paradigm through analogy, to delegation, is considered the most practicable one.

To enhance an advanced usage of software agents, avoiding legal personhood establishment, (Sartor, 2002) suggested the creation of companies, which would use agents in their business. This idea would cover the risk of contractual liability assignment: the will of the software agent would be replaced by the will of the companies, those grant economically and patrimonial actions made by their agents.

1.4 Delegation and Knowledge Attribution

An interesting approach to enhance Semantic opportunities could be found in the legal doctrine of "attributed knowledge", which is complementary to the agency paradigm and diffuse worldwide (Chopra & White, 2005).

This theory enhances the role of knowledge in delegation, because it considers not only the information already owned by the delegator, but also the additional one that could be retrieved by autonomous agents in their performances.

In this case, the agency paradigm would impute the agent's knowledge to the user when that knowledge is acquired acting within the scope of its powers.

This would be a very pervasive approach, eligible to accomplish Semantic Web opportunities, but would also pose a problem related to unfair information collection by agents or other possible mismatches.

The relevant issue of this theory is that knowledge attribution is focused on the possibility for the user to access the information acquired by the agent.

In other words, the knowledge retrieved by the agent-delegate, during its activity, will be imputed to the user only if the delegator has the concrete possibility to access in each moment the agent's knowledge, i.e. to know what information is in the agent's domain.

The user will be liable in case of no timely check about agent's knowledge; otherwise, the liability of the agent's designer could be considered, if the user is prevented to access available information.

1.5 Conclusions and Perspectives

The reasons against the establishment of a specific legal personhood for software agents still appear acceptable in the Semantic Web context. However, some additional problems are posed: how to ensure an advanced usage of software agents, according to their enhanced knowledge management capabilities?

How could we overcome the problem due to the different theorizations of different legal systems in order to establish a common legal framework for users in the worldwide open environment of the Internet?

The first question seems to find interesting developments under the latest theories exposed (Sartor, 2002; Chopra & White, 2005), while the second problem needs further analysis.

It could be interesting to assume an international comparative law position in evaluating delegation.

The Authors mentioned above focused the possibility to apply agency as the legal scheme suitable of common application, according to limits and adaptations required in each legal order.

However, in Common Law orders agency is not the basic scheme for delegation: trust has an exclusive role as it is based on the concept of *fiducia romana*, where the delegator transfers not only his authority but even the right that he wants to manage, directly upon the agent. This is the so called *equitable property*, which does not have any correspondent in Civil Law basic schemes.

Trust is a legal scheme that relies on the unilateral appointment made by a settlor who entrusts his property to someone (trustee) for the benefit of a beneficiary (that could be also the same person of the settlor).

Therefore, considering the possibility to appoint agents as trustees able to manage delegator rights for a set task would be a relevant occasion to upgrade theories about software agents' delegation, with the enviable advantage of real common legislation basis: in fact, Trust Law is ever diffused over Civil Law contexts[10], even if there is a lack of aptitude to make use of it.

The legal mechanism for applying such an innovative legal scheme could be both the one proposed by (Sartor, 2002) or the legal personhood establishment at all.

In any case this may be a concrete attempt to enhance software agents usage, at least with reference to identified fields of application, such as the finance sector (to which trust already applies in the reality).

SECTION 2. LIABILITY

Introduction

The present legal framework denies that liability for a software agent's actions can fall on the agent itself. From the legal point of view, liability must always be linked to a person, whether natural or legal. In this chapter we consider the view that liability for the agent's actions can be ascribed to its user and its developer, claiming that it is the former and not the latter that should most often be held liable.

Software engineers define the Semantic Web as the world of ontologies, reasoning mechanisms, and software agents (Payne, 2005, p. 191). As highlighted in the previous section, agents have been a focus of interest from part of the legal community, which has increasingly turned its attention to ICT-related issues. Indeed, the regulation of the Web has been engaging legal and philosophical communities in a debate about whether the fast-changing phenomena of the Web and related technologies need to be regulated by new legal forms or whether the forms we already have suffice for the purpose. In case we do need new legal forms, these should be forged on both a national and an international basis. And where we decide to use existing forms, an effort will then have to be made to adapt them to the new phenomena, because the old ones are vague and laden with connotations (Sartor, 2003).[11] What direction the law should take is still an open question and a great challenge for the legal community (Vaciago, 2002). But at least some proposals in this regard have already been made. Thus, Sartor, for example, proposes a "cautious trait-based approach" (Sartor, 2003) which asks us to look closely at the agents' properties and develop on that basis a legal framework that takes such properties into account and is appropriate for them.

Our focus will be on the legal issue of liability. The question is how liability might or should be handled in light of the Semantic Web and its new "dwellers," namely, software agents, asking who is liable for their actions. Why do we address this theme?

Liability is of key importance if we want the Semantic Web technologies to settle definitely. Liability is a part of a bigger issue concerning the general governance of agents and our purpose is to give our contribution in clearing this issue. The chapter is organized as follows: Section 1 briefly introduces the concept of liability; Section 2 deals with the liability ascribable the users of software agents, arguing that these users should have a considerably larger share of liability than that which might be ascribed to the agent's developer, which is the subject of Section 3. Section 4 illustrates some proposals for future research, offering the solutions for the problems pointed out in the preceding sections. There are, finally, a few closing remarks in Section 5.

2.1 The Concept of Liability

What is liability? In everyday language, liability might be defined as one's duty to restore someone to a previous condition once I have damaged them (or their things), whether accidentally or on purpose. Thus, for example, if I bump my car into your car and break your taillight, I should pay the amount it takes to repair the damage. The Italian Civil Code defines liability as "any intentional or culpable act which wrongfully injures someone, and in consequence of which the person who committed the act comes under an obligation to pay damages."[12] This is primary liability. There are also indirect or secondary forms of liability—such as strict liability, or liability without fault—which can attach to someone even through the actions of others. The Italian Civil Code provides for several situations in which this may happen, examples being the liability of someone acting as the guardian of a mentally ill person or the liability of parents to their children, of teachers to their students, or of employers to their employees. In a related class fall all those situations in which the loss or injury can be imputed not to natural persons but to things or activities: one example is when dangerous activities are involved,[13] in which case liability will fall on the person engaged in these activities, and another example is that of damage caused by the things or animals in one's custody, in which case the custodian is held liable.

But what happens when the injury is caused by a software agent? This question is taken up in the following sections.

2.2 The Liability of a Software Agent's User

Clearly, there is no way under current law that a software agent can be held liable as such: liability attaches to the person and not to the tool the person uses. That is why when we discuss the liability of software agents, we have to frame the discussion in terms of strict liability (or liability without a fault), this being the liability of the agent's user or developer.

In this section we will discuss the user's liability. We briefly considered in the last section a few cases in which strict liability arises, so we can consider now where liability for a software agent's actions should be made to fall. The rationale involved in attributing liability to a software agent's user is that when you empower someone to do something, you will be responsible for the consequences that follow from the actions this person does, even if this person is not strictly a person but an artifact. From a legal point of view, this reasoning can be famed within the concept of vicarious or imputed liability, under which a person becomes responsible for harm caused through the fault of another person, the paradigmatic example being an employer becoming liable for damage an employee causes through activities carried out under the scope of employment.[14] Under this analogy, the software agent is its user's employee, and the user (as employer) is liable for anything the agent (as employee) will do. Outside the analogy, the rule is called *respondeat superior*, which is Latin for *let the superior answer for his (or her) subordinate*.[15]

There are at least four considerations under which an employer can be held to be liable for the actions of his or her employee. We will look at these briefly in such a way as to bring out the analogy with the liability of a software agent's user and see if it all makes sense. In the first place, of all employers are supposed to exercise some degree of control or oversight over their employees, and in cases where this does not happen, the employers will be deemed responsible: there is an element of fault that may be imputed to them, because the point of the oversight is to prevent negligence or the consequent damage. Similarly, users should control the software agents they use, and in cases where the agent causes damage and where inadequate control was exercised, the user will be deemed liable. This analogy, however, holds up only to the extent that control over a person can be compared to the kind of control an agent is amenable to—and since an agent is not a person but an artefact, and so cannot be controlled as easily as a person (at least theoretically), it can safely be concluded that a user under this analogy is penalized.

In the second place, the employer (especially if it is a legal person, such as a corporation) has more financial resources than an employee. This puts the employer in a better position than the employee to rehabilitate the injured person: it thus happens that the employer pays damages up front and then seeks reimbursement from the employee. The same reasoning applies to injury caused by a software agent: since an agent cannot pay damages, it falls to the user to do so.

In the third place, the doctrine of *respondeat superior* makes it in the employer's best interest to exercise care in selecting candidates for employment. The same kind of care should be exercised by user selecting a software agent for some purpose, as the user knows he or she will be liable for any injury the agent may cause.

And, finally, employers may not use their employees as proxies if it means delegating to them tasks figuring that this will make it possible to escape personal liability. In the same way, users may not task their agents with activities that are clearly illegal or could end up damaging someone.

We have seen, then, four points of analogy under which the relation between a user and a software agent can be compared to the relation between an employer and an employee, and since an employer may be deemed vicariously liable for damage caused by an employee, the same can be said of a user with respect to a software agent. Still, the user is not the only human agent to whom responsibility may be imputed for damage arising out of an agent's activities, for the agent is, after all, the creation of a software developer, and it is to this developer that we will now turn in connection with the issue of liability.

2.3 The Liability of a Software Agent's Developer

It seems only natural that when the problem is to identify someone responsible for damages caused by a software agent, the first person we should think of is the agent's user: after all, is it not the driver (user) who is held responsible for driving a car (agent) into someone's lawn and knocking over the mailbox, whether intentionally or through negligence? And we have seen some of the reasons supporting such an argument. Still, it is equally fair to ask who the software agent was designed by, and this opens up the possibility of imposing liability on its maker, this being the software developer. Indeed, it is not inconceivable that a user should sue a developer for damage caused by an agent the developer has designed[16].

But, as it turns out, it is not such an easy case that the user has in such a circumstance against the developer: the user must prove either negligence or intent on the developer's part, neither of which is easy to prove. Indeed, only a user whose expertise is in software engineering will be able to prove that the developer was negligent in designing a software agent, and that its architecture was therefore faulty, or that such a defect was intentional. And if the user is in fact a specialist and correctly determines that a software agent is faulty, why did he or she go ahead and use such an agent? So it seems that the only way a user injured by the actions of a software agent could claim damages is if (a) the user has access to the expert knowledge needed to prove intent or negligence, and (b) he or she was unaware of such intent or negligence and had no way of predicting the damage, in that there was no "warning sign" or any indication suggesting that anything might have gone wrong. Clearly, this is far from a simple task, and in most cases the claim is simply impossible to prove.

Another consideration working in favour of the developer is that developers cannot reasonably be expected to know ahead of time what other programs and software agents the agents they design will end up interacting with or what environments these agents will be operating in, which makes it impossible to foresee the way in which these agents might alter their behaviour. The developer can be held liable for negligence, then, only on the ground that the software agent's architecture was faulty in its original design, meaning the defect was present at the time of purchase or the agent was prone to develop this defect right from the start. In all other cases the developer cannot be held liable, and this includes the case of defects arising out of the agent's use or owed to the agent's performance of tasks entrusted to it by the user.

Software developers usually package a liability-limitation clause into the terms under which they sell their agents, and users are therefore advised to pay close attention to these clauses when they make a purchase.

The software developer's liability is covered by the European Union's directive on liability for defective goods (85/374/EEC).[17] This directive states that producers (here, the software developers) are liable for damage caused by defects in their products, but in order for this liability to stand, the injured person must prove the damage, the defect, and the causal relationship between them. This is quite a tough spot to be in, considering that there is a double burden of proof on the injured person, who must show that (a) the software agent was defective and (b) the defect is to account for the damage. Proof poses a big problem in cases involving the use of Web technologies, and this is just an example. The EU directive also sets limitations for the producer's liability. Here are the three main limitations as they apply to a software agent's developer.

First, developers are not liable if they prove that the defect which caused the damage (a) *probably* did not exist at the time when the agent was sold or (b) did not come about until later. Thus, a user who can prove damages, a defect in the agent, and a causal relationship between the two may still not be able to hold the developer liable if the latter proves there was even only a *probability* of the defect being absent at the time the sale was made to the user.

Second, software developers are not liable if, at the time an agent was first marketed, there was not enough scientific and technical knowledge to enable them to discover the defect at issue[18]. This too is a condition that works in favour of the developer while penalizing the user if we only consider that software engineering is constantly advancing, which makes it easier for developers to be excused for not knowing something at some point in the past, all the while making it hard on users to stay up on the latest developments in order to prove their case.

Third, if a software agent forms part of a larger agent-based system that includes other components, and the developer only designed the software agent, he or she could claim that the defect should properly be ascribed to (a) the whole system rather than to a single component within the system or (b) to the instructions provided by the end product's manufacturer. In this case, the user would have to redirect his or her liability claim against the manufacturer of the whole product, thus setting out once more to prove damages, a defect, and a causal relationship (this time in connection not with the software component but with the product the component is part of).

We can see from the above that the user seems to always be at a disadvantage if he or she is damaged by the activity of a software agent and wants to have the developer take responsibility.

2.4 Some Proposals for Future Research

It is obvious that the liability issue is of crucial importance to the implementation of the Semantic Web. The juridical certainty on software agents' liability is the force that could help to launch this technology and contribute to more positive and less suspicious approaches some persons still nurture for it.

Unfortunately it is not easy to work out who should be held liable for the actions of a software agent—its user or its developer—because there is a whole complex of issues involved and many considerations to be taken into account. What, then, could be done to make the situation more manageable?

One solution might be to make it mandatory for the user or the developer to take out an insurance policy, acting as a necessary condition failing which no contract for the sale or purchase of agent-based technology would be valid. Such insurance would spare the user from having to prove that the developer should be held accountable in a case where damage is caused by an agent, and it would generally enable both user and developer to save time, money, and resources whenever an issue comes up that would otherwise resolve itself in a lawsuit. The question is whether insurance companies are willing to insure the software agents and how all the liability issues discussed can be worked out in the contract. How should the insurance premium be made to reflect the unpredictable behaviour of software agents? How should the kind of use the agent is put to be worked into this cost? There are many such practical questions to be answered before seriously taking up the idea of having insurance against damage caused by a software agent. Still, it might be worth a try.

Another idea is to set up a compensation fund between users and developers. There are numerous funds of this kind, an example being the International Oil Pollution Compensation Fund,[19] which was set up to compensate those who are financially damaged by an oil spill. This could serve as a model for future initiatives when software agents (and related technologies) might play an increasingly significant role in our lives.

Finally, a third proposal is to work out a scheme under which to *channel* liability. The rationale here is to find a way by which to deal with complexity of today's multi-agent systems, meaning by this that there are many people involved in their operation, with a consequent spreading out of liability among them all. This dispersion of liability could even be much greater than one might imagine, and it may encourage a wild-goose chase for a "guilty" party. Hence the idea of working out in advance who is responsible for what in different types of circumstances. Such a channelling of liability would benefit of both user and developer: for the user, it would mean that once a software agent has caused damage, it will be clear whom compensation is to be sought from; for the developer—as, indeed, for any other engineer involved—it would mean being able to know in advance, before setting out to design a software agent, what liabilities he or she will incur and under what circumstances.

2.5 Conclusions

It has been suggested in the foregoing that it is impossible to construct around the Web an ethereal world conceived as existing apart from the real world that you and I live in: these two worlds are tied by many threads, and one of them is the thread of the law. We briefly discussed only one filament of it, which is the issue of liability, and the discussion is still very much open-ended.

The real problem of Web technologies is not that there is no law governing the liability issues these technologies give rise to. The real problems lie elsewhere, and there are two main ones, the first having to do with jurisdiction (who is competent to settle liability disputes) and the second with the practical application of norms. Is there anything that can be done to help solve these two problems? The European Union has taken initiatives to clarify the issue of jurisdiction across Europe—unfortunately, however, the borders of the EU are not the same as those of the Web.

We cannot foresee what directions technological development will take: there are many scenarios that we can envision and just as many that we cannot. One such scenario is that presented by Kurzweil, who predicts that in the year 2029 we will see a movement for "robot rights" (Kurzweil, 1999), a movement that will spark a public debate over the legal status of machines: should we attribute rights to them and, if so, what rights should these be? It is this commentator's view that in 2099 machines will attain equal legal status with humans—which would mean that we will then be able to sue agents, on the reasoning that their liability will be no different from the kind of liabilities we humans incur today. But until then, there will be no one that can be held liable aside from the software agent's user, in the first place, and its developer, in the second.

SECTION 3. PRIVACY AND DATA PROTECTION

3.1. The Legal Framework

The right to privacy was initially conceived as the "right to be let alone" (Warren & Brandeis, 1890), but the growing use of computers in the second half of the XX century has led to its consideration mainly as the right to protect and control personal information. Since the 70s many lawmakers have enforced laws to regulate data protection and the processing of personal information in public and private databases. In fact, information relating to individuals is collected and used in many aspects of everyday life; moreover, advancements in Information and Communications Technologies (ICT) allow personal data to travel across borders with greater ease.

While in many fields the law has lagged behind reality, data protection laws have been developed "from a principles basis, in foresight of the power of the technology, rather as a response to perceived problems" (Jay & Hamilton 2003).

While a sector by sector regulation has been adopted in the United States, a different approach has been chosen in the European Union. Here data protection is strongly regulated since the approval of Directive 95/46/EC and is commonly considered a fundamental right. It is technologically neutral and aims at ensuring the free movement of personal data and guaranteeing a high level of protection for data subjects. Furthermore, it develops data protection principles to achieve the harmonisation of Member States legislations. The European Commission maintains a Web site which shows the status of implementation of Directive 95/46/EC[20].

In addition, Directive 2002/58/EC regulates the processing of personal data in the electronic communications sector; it has been amended by Directive 2006/24/EC on the retention of data generated or processed in connection with the provision of publicly available electronic communications services or of public communications networks.

3.2. Key Rules and Principles of Directive 95/46/EC

It is not the aim of this contribution to analyse neither the Directive 95/46/EC (see, among others, Carey, 2006) nor the European or other state laws that regulate data protection (see, among others, Klosek, 2000; Solove, Rotenberg & Schwartz, 2006).

However, it is useful to highlight some provisions of Directive 95/46/EC in order to understand the common approach of the European lawmakers in this field and evaluating relevant profiles in the Semantic Web context.

The legal notions of both personal data and their processing are wide: the former is any information relating to an identified or identifiable natural person ("data subject"). An identifiable person is one who can be identified, directly or indirectly, in particular by reference to an identification number or to one or more factors specific to his physical, physiological, mental, economic, cultural or social identity (art. 2, par. 1, a, Directive 95/46/EC); the latter is any operation or set of operations which is performed upon personal data, whether or not by automatic means (e.g. collection, recording, organization, storage, adaptation, retrieval, consultation, use, disclosure, combination, blocking, etc.; art. 2, par. 1, b, Directive 95/46/EC).

The processing of personal data revealing racial or ethnic origin, political opinions, religious or philosophical beliefs, trade-union membership, or concerning health or sex life (sensitive data) is forbidden unless some requirements are fulfilled, (e.g., explicit consent, public data, etc.).

The Semantic Web enables the inference of personal and even sensitive data, on the mere connection of apparently unrelated information. This poses relevant problem about data management practices, particularly in case of automation.

Legal rules demand good data management practices on the entities who process data, called "data controllers" (the natural or legal person, public authority, agency or any other body which alone or jointly with others determines the purposes and means of the processing of personal data). Thus, several principles are outlined by Directive 95/46/EC, such as fairness and lawfulness of the processing of personal data, which can be conducted only for explicit and legitimate purposes (see art. 6, par. 1, Directive 95/46/EC).

The data subject has several rights which express the control on his or her personal information. For instance, the data subject has the right to know if, how and why his or personal data are processed and to have the same data amended or deleted.

The European regulation is based on the respect of several key principles, among which information and consent have to be mentioned. Without a correct information, the consent is not correctly formed because the data subject has to know the consequences of his or her choice. Data processors and data controllers are required to inform the data subject on several aspects of the data processing, such as its purposes and the rights of the data subject.

Sometimes an explicit consent is not required by the law (e.g., particular types of data processing by public entities) or is impossible (e.g., emergencies) thus it can be obtained after the execution of the processing.

It is also important to mention the retention principle, according to which personal data may be kept for no longer than what is necessary for the purpose for which the data were originally collected or further processed.

The fact that the right to privacy is a fundamental right has led many European States to sanction the violations of data protection laws even with criminal provisions.

Moreover, Data Protection authorities have been set up to ensure the compliance with data protection rules. They have powers of investigation, intervention and prosecution either on their own initiative or following a complaint by a data subject.

3.3. The Right to Privacy in a Global Society

The European legal framework seems still valid, thanks to the comprehensive notion of personal data adopted and to the wide spectrum of the legal remedies foreseen.

However, even if only thirteen years have passed since the approval of Directive 95/46/EC, more and more challenges concerning its practical implementation emerge.

In principle, its application requires to strike a reasonable balance between the right to privacy and other rights. In fact, the former may conflict with other rights, in particular those related to the freedom of expression.

However, the Information Society is now global and computerized. Data are transferred and diffused not only through the traditional mass media, but also through Web sites, email, social networks and so on. The same right may be regulated by each state in a different way so even if the regulation of the right to privacy is quite similar among the European countries, other rights may differ and the above-said balance can dramatically vary.

Moreover, the global society poses the problem to ensure really usable legal remedies to data subjects even if their right to privacy is violated in other countries.

To partially solve this problem, the European lawmakers have stated that for transfers of data to countries outside the European Union special precautions should be taken if the level of data protection in the third country is inconsistent with that provided by European Law. In fact, personal data should only be transferred to countries outside the EU that guarantee an adequate level of protection.

3.4. Emerging Problems and Online Privacy

The Semantic Web could change the shape of the Information Society. Computing is now pervasive and ubiquitous, but this constitutes a real challenge for contemporary lawmakers who have to ensure a rapid flow of information protecting at the same time data subjects' rights.

It is necessary to make each data subject really in control of his or her personal information. Today this is especially true, since Web and social Web Services are more and more used; moreover, they are easily accessible not only through "traditional" computers but also through mobile phones and PDAs (personal digital assistants).

Both private and public entities acquire large amounts of personal data through Web sites and services. Even criminal investigations are conducted looking at the digital life of the involved subject.

Moreover, many people lose the control on their personal information because they care about it only after something occurs. Social networks are widely used, but they include a lot of private information easily accessible and reusable by everyone, even if this is against the law[21].

Much personal information is also shared through file sharing networks (such as eDonkey and BitTorrent); sometimes, the sharer is unconscious of which folders are shared and thus the content of these folders may be accessible by every user of the network.

All these cases show an important profile: once acquired by a third party, personal information is not in control of the data subject any longer. Legal remedies are mostly useless because the illegal acts of data processing may be conducted by many third parties (potentially foreign), thus it can be practically impossible to stop the flow of personal information and the violation of the right to privacy.

3.5. Metadata

Metadata can pose delicate legal problems, since much information may be easily and automatically acquired and processed.

For instance, the large availability of systems able to locate a person or a thing could lead to a diffuse surveillance. Several mobile phones include a GPS and are able non only to assist a driver, but also to automatically insert geo-location data into photos which can be easily shared with others and on the Web. Since one of the key points of the so-called "Web 2.0" is cooperation and sharing, many Web Services are using these data, which could be very useful in several fields (e.g., e-commerce and tourism).

Moreover, the use of FOAF files can lead to the sharing of personal information, which can refer both to one person and to third parties. For instance, information stored in an address book could be acquired by others. In this case, the data controller may be liable for the illegal diffusion of personal data.

3.6. Health Data

The health care sector may benefit from a fast flow of data more than any other sector. In fact, the chance to quickly know the clinical history of a patient can save his or her life in emergency situations. Moreover, the electronic transmissions of medical data can save several hours of human work.

Nevertheless, many problems concerning data protection may arise, with particular reference to the Semantic elaboration of such information. The challenge for the next health information systems is to allow access to personal health information only when it is needed and only from legitimate subjects so as to protect the confidentiality of data.

The possibility to infer sensitive data in medical context, using semantic technologies, could emphasize the risk of incorrect medical treatments or illegitimate data usage.

For instance, many people are concerned about the possibility that their medical data may be accessed by employers and insurances and so they decide not to undergo genetic tests (Article 29 Data Protection Working Party 2004). Obviously, such people will never give their consent to data processing until they are certain that this information will be known only to legitimate subjects.

The diffusion of e-health initiatives can lead to several legal issues: liability, jurisdiction, e-pharmacies diffusion, intellectual property and so on. However, data protection is one of the most delicate ones, since an Electronic Health Record (EHR) usually includes highly sensitive data. According to Article 29 Data Protection Working Party, the self-determination of the patient must be respected: he or she should decide when and how his data are used.

4. E-IDENTITY

Introduction

By building on widely accepted standards, Web Services enable easier connectivity between applications, but at the same time do not allow for in-person identification and thus specific ICT tools are needed. The rules on personal identification, user id and passwords, digital signatures, biometric devices will be taken as a reference and analysed. The law usually regulates the identification of persons; in this section attention will also be paid to the identification of machines interacting through networks.

4.2. The Concept of Personal Identity

Although the concept of personal identity appears quite clear in the mind of everyone of us, we are still confronted with the lack of a clear definition by the legislator. If we need to understand its meaning from the legal perspective, we must therefore resort to doctrinal contributions and Court decisions.

The European Data Protection Directive[22] mentions the term "identity" in the definition of "personal data". These are intended as "any information relating to an identified or identifiable natural person ('data subject'); an identifiable person is one who can be identified, directly or indirectly, in particular by reference to an identification number or to one or more factors specific to his physical, physiological, mental, economic, cultural or social identity".

In general, it may be said that identity in a legal sense may take up two main meanings: on the one side, it may be intended as the set of data which identify a person – whether natural or legal (i.e. name, place and date of birth, address, head office, etc.), that is what may be found on an identity card or passport; on the other side, a more complex and articulated set of information, which makes up a sort of "short biography" of the subject (Resta, 2007).

With reference to this latter meaning, the Italian Cassation Court has defined the right to personal identity as the "value-good which consists in the social projection of the individual's personality", which is correlated to an interest of the individual to be represented, in social life, with its real identity, and not to see a misinterpretation of its intellectual, ideological, ethical, religious, professional legacy[23].

Personal identity is something invaluable for any person: investigating how it can enjoy legal protection is of the utmost importance, especially in the light of the management of identity supported by the use of advanced technologies and in the context of the Semantic Web.

4.3. E-Identity

The passing from the traditional paper-based management of personal identity to the ICT-based one, especially in the context of the Web, has added a dimension of extreme complexity and has raised issues which need a special attention from the legal standpoint. Compared with a traditional concept of identity in the pre-Internet era, it can be said that today identity can no longer be conceived as a pre-existing, static datum, but rather it should be seen as a dynamic, ongoing process of manifestation of the self, in multiple transactions, interactions, and exchanges of data. The right to e-identity thus implies the "correct representation in each context" and the "integral representation of the person" (Rodotà, 1997).

If we think of identity as a set of personal data (according to the first definition), it may be endangered because of the nature of the Web, which allows for the potential epidemic spread of information outside the control of those authorised to data processing, either as a consequence of a technological bug or of a human error/voluntary misbehaviour. This also affects Semantic Web interactions, which although mediated through machines and agents are ultimately reconnected to humans. To understand the delicacy of personal data management, let us imagine the case of a database with genetic data stored and processed for scientific and/or medical purposes. Should the data from this database fall into the hands of businesses, they might be used to complete the profile of job applicants.

If we refer to identity as the social projection of a person, a basic fact needs to be highlighted: while in "offline life" one person may have only one identity, in the online world he/she may take up several different identities, whether voluntarily or non-voluntarily. Information is scattered in a potentially unlimited number of different databases, each one of which records and processes a special set of data for a specific purpose. The same person may thus have a different electronic identity for home banking, for the tax authorities, his/her employer, his/her friends and hobbies, etc. Each database provides a partial image of the person, which does not provide his/her whole picture, but may be understood as "identity". Besides, when not confidential, much of this information may be taken and combined to form more complex, albeit always partial identities. This may provide a picture of a person which reduces it to the sum of its electronic projections (Rodotà, 2004).

The situation worsens with the advent of the Web 2.0: people upload information, often sensitive, about themselves, which allows for the building of precise profiles, which may be used, in certain cases, against them (e.g. by businesses when making decisions on hiring).

With the Semantic Web, information making up one's identity may be automatically gathered and combined in a potentially uncontrollable way. The main problem is that bits and pieces of information spread in an open network, where opportunely combined, can provide a detailed picture of a person, a picture which he/she may wish to keep private. Besides, how can we be sure that this picture will be complete and/or correct?

The possibility to achieve new contacts through social networking platforms, besides, has led users to accept a level of risk concerning the management of their own data which is much higher than the one they would be ready to accept in their offline identity.

4.4. Identification on the Internet: Techno-Legal Issues

Digital identity can be conceived as the set of information and resources of the user of an information system and the techniques for the identification of a person (identification tools). The identification on the Internet can be carried out with several different technical tools, according to the contingent needs. At the same time, a person may have multiple digital identities for different goals and in different contexts.

Each technology, thus, serves a specific purpose. implies different identifying data and offers a different level of security. A fundamental, traditional distinction distinguishes identification methods between: (a) what you know, (b) what you have, (c) what you are.

a. The easiest level may be provided by the knowledge of alphanumeric sequences, such as user id (e.g. PIN) and passwords. Although relatively insecure and not guaranteeing the certain direct connection with a person's identity, these are granted legal value by the E-Signature Directive[24] and can be regarded to as an electronic signature. This can be defined as "data in electronic form which are attached to or logically associated with other electronic data and which serve as a method of authentication". An electronic signature cannot be denied legal effectiveness and admissibility as evidence in legal proceedings "solely on the grounds that it is in electronic form, or not based upon a qualified certificate, or not based upon a qualified certificate issued by an accredited certification-service-provider, or not created by a secure signature-creation device".
b. At a higher level, identification can be performed through a token, such as a smart card for digital signature. From the legal viewpoint, a digital signature is regarded to as a special kind of advanced electronic signature. For the legislator, if an electronic signature possesses further requirements, such as a unique link with the signatory, the capability of identifying the signatory, the creation through means that the signatory can have under his/her sole control and makes it possible to detect any subsequent change to the signed data, it will constitute an "advanced electronic signature". From the legal viewpoint, whenever this latter is based on a qualified certificate and created by a secure-signature-creation device, being more secure, it enjoys a higher protection: it is legally recognised as equal to a handwritten signature with reference to the electronic data to which it is affixed and is admitted as evidence before court in legal proceedings.
c. As concerns the identification with a personal feature, different kinds of biometric devices make it possible to identify a person through a unique characteristic of a his/her body (e.g. fingerprints, retina scan, etc.). Considering the above-mentioned qualities of e-signatures, it may be regarded to

> as a particular kind of advanced electronic signature. However, it shall not meet the requirements for the recognition as hand-written signature.

The Semantic Web context requires not only the identification of persons but the identification of machines, or of persons made through a machine. Different identification procedures should thus be carried out without the need for the intervention of a human being. Let us think, for example, of the identification of software agents on the Web. This may reasonably be made by way of the exchange of time-stamped encrypted certified keys. The use of a public-key infrastructure would make the case fall within the legal concept of digital signature, which – if compliant with all the above-mentioned requirements set by the law – would equal a hand-written signature. The problem can be that – taking as an example the Italian legislation – the use of the private key should be directly made by the same signatory. Would the agent-mediated use be considered the same as the direct use? It could be said that the agent would perform certain actions as would any other machine used by the signatory (as happens with a computer and smart card reader, which are also technological tools used to perform a legally relevant action); however, the difference is that agents may act autonomously and with intelligence and the signatory may not even be aware that he/she has signed something on line at a certain moment in time[25]. Can the signature be deemed valid? A reference in this sense can be found in the context of agent-based contracting. The Uniform Computer Interaction Transaction Act (UCITA) recognises the legal value of on-line contracts made through agents without the direct intervention of the parties. Besides underlining – as in the E-Signature Directive - that a record or authentication may not be denied legal effect, validity or enforceability only because it is electronic, Section 107 of UCITA affirms that the user shall be legally bound by the operations performed by the agent he/she is using. This happens also in case no person knows or can control the agent's actions or results thereof. On the issue, also the UNCITRAL Working Group on E-Commerce[26] has affirmed that a new convention on electronic contracts should expressly acknowledge the validity of contracts made through automatic agents, also in the absence of human control. By analogy, it can be affirmed that the validity of identification procedures carried out by machines in the absence of direct intervention by the users may be recognised and an express affirmation by the legislator in this sense would further clarify the issue.

4.5. Law and Identity in the Semantic Web

From the legal viewpoint, the kind of identity which has been referred to as a set of basic identification data poses the problems of the correct processing of personal data in compliance with Directive 95/46/EC on data protection. This implies, for instance, the prior provision of information by the data controller to the data subject, the obtaining of consent, the processing strictly limited to the purposes for which the consent has been given, the implementation of security measures, etc.[27]

In the Semantic Web, these actions may need to be performed directly in a machine-to-machine interaction. Whenever a machine has access to and needs to start processing identification data, it should be able to understand also that these data fall within the scope of application of data protection legislation, whether they belong to a special category (e.g. sensitive, judicial data) and should be able to implement a way to adopt law-abiding procedures.

The second type of identity intended as the social projection of a person certainly implies the above-mentioned considerations; however, it also requires further attention, owing to its higher level of complexity. Let us think, in particular, of

Web 2.0 platforms and applications. As observed above, the scattering of information in different databases together with the careless sharing of data – often of a sensitive nature (e.g. political and religious opinions, sexual orientation, etc.) – in social networks may endanger a person's online identity or possibly distort it.

Identity may actually be under-represented, over-represented, otherwise represented, presented out of context, stolen or concealed. Semantic Web technologies may enhance these possible distortions, with the support of autonomous machines which understand the meaning of the information they process. On the other side, the legislator sets precise limits on these activities, allowing to process only certain specific kinds of information within limited environments and for specific, express purposes. Automated systems processing such information should be able to 'read' not only the meaning of the same information but also the rules for its legitimate processing. For example: if the user 'anonymous' posts a message in a social network affirming that he/she is a racist, this is not in itself a sensitive datum. If, however, 'anonymous' can be linked to an IP, which can in turn be linked to a nickname, which is in turn linked to a specific identity, the machine would have built sensitive information which may only be processed: a) after providing the data subject with an information with a specific content; b) after obtaining the specific consent by the data subject; c) after obtaining the authorisation by the competent data protection authority[28].

Although the provisions set by the law may be respected, attention should be paid to the fact that sensitive information may be uploaded on line (for example in a social network) and be stored for an extremely long period of time, although it may no longer reflect the position of the person at a later moment in life. Much relevance should be thus given to data retention and the right to oblivion. On the one side, awareness should be raised among Internet users that anything they post may eventually be someday used against them, or to provide a distorted picture/identity of them. They should become aware of their rights according to data protection legislation, such as the right, for example, to have the same information cancelled upon their request. Besides, the fundamental principle of necessity only allows for data processing when it is strictly needed. Once the contingent goal has been achieved, data have to be cancelled or made anonymous.

Another issue is not linked with the mere on line presence of certain data and information—whether sensitive or not—but with the way and the context in which the same data and information are presented. Let us think, for example, of information of a public nature, such as a Court decision. Everyone has the right to have access to it, as there is a public interest in knowing the outcome of judicial proceedings. On the other side, if a sanction deriving from a decision reached years before still appears between the first hits of a general search engine while a user is looking for information on a specific company, this may endanger the company's image (and thus affect its identity), even if after suffering the sanction it has always acted in a law-abiding way[29].

4.6 Open Issues

Despite a consolidated legal framework on identity and the management of identification data and information at European, national and international level, some issues still remain open. Let us think of the balancing of on-line identity rights and the respect of other constitutionally protected or lower level rights. It is the case, for example, of balancing interests between on-line data protection and copyright protection. Do intellectual property rightholders have the right to engage in monitoring activities to identify users who share music files or games on line via peer-to-peer platforms? As concerns labour law and family law, can a judge respectively order the termination of a contract or make a decision in a separation case on the basis of electronic information unduly obtained from non-public sources?

These and other similar issues may be the subject of future research and require the attention of the legislator in future regulatory developments.

5. E-BUSINESS

5.1 E-Business and the Semantic Web

Combining the benefits of Semantic Web Services and associated technologies (like software agents and business registries) with the field of electronic business presents several promising outcomes. By exploiting Semantic Web service capabilities, on-line organisations can advertise their activities by describing the provisions of their underlying software services. Using associated technologies, external consumer-based and business-based entities can connect to and execute these services, which may facilitate e-business transactions.

The issues related to the use of software agents in Semantic Web applications have been discussed in the previous sections; here we will focus on some aspects related to the use of Semantic Web Services in e-business and business registries, these latter being a particular kind of Semantic Web application used in e-business scenarios.

5.2 Interoperability

A key concept in e-business applications based on Semantic Web Services is interoperability: integration is a very important issue in this field, standards and standardization efforts play important roles to improve integration, especially in the areas of data interchange and shared repositories. In fact, we can look at interoperability under three different perspectives:

- **Product data interoperability:** That is to establish methods to share product data, in an environment where product structures and contents in each enterprise collaborating in the context of Semantic Web may be different;
- **System application interoperability:** That is to find solution to problems affecting the integration of business-to-business applications;
- **Process interoperability** as related to business process, when each business partner has its own private process, which should interact with others to collaborate in a public process.

The implementation of interoperability solutions for information sharing is of particular relevance from a legal point of view. An analysis of the main issues is provided below.

a. Ontology development and management. The implementation of interoperability solutions is based on the use of ontologies to build a common ground for representing the knowledge inherent data on products, processes, roles, etc. to be shared between the actors involved in the e-business scenario.

A major problem in providing Semantic Web Services consists in describing ontology concepts in a way that is understandable in the same manner to all systems (such as agents or business registries) that make use of them: commonsense knowledge and primitive concepts (e.g. time, roles, space, actions) often poses relevant theoretical and practical problems in the representation.

Besides, e-business applications are always founded on the representation of several legal concepts in the ontology (e.g. concepts coming from contract law, international law, IPR law, etc.), and very often need a complete formalisation of a legal domain, thus creating a “legal ontology”: here the representation of the “open-texture” legal language is even more problematic, since often legal concepts and definitions have an elastic meaning that is subject to the interpretation of judges. Besides, since e-business applications are usually implemented at international level, also the legal concepts and ontologies should be developed taking in consideration different legal systems – especially with reference to civil law and common law systems - the same concept may have different meanings in each national legal system, and sometimes there are some concepts peculiar to a legal system which have no corresponding meaning in other legal systems.

This set of issues may cause errors in contract negotiation and conclusion.

b. Integrity and security issues. In the Information Society era, e-business actors must necessarily interact to meet the needs of an ever more competitive and ICT-based global market. E-business actors should collaborate with each other in order to provide the services which consumers, professionals and other businesses require, and should protect their infrastructures and applications. These three dimensions are based on information's communication through networks[30]. In the field of network security issues we mention the Network Security Standard (ISO 18028-2[31]) approved by International Standard Organisation (ISO). This standard defines a security architecture and provides the framework for the creation of secure and interoperable end-to-end communications network. This standard is based on three areas: security dimensions, security layers (infrastructure/ services/applications) and security plans (management/control/ end-user). Another issue of great importance in security and integrity matters is digital signature. Network integrity and security is fundamental when providing the legally relevant information and protecting privacy of the contractual parties, who use an interoperable platform.

c. Trust and IPR issues. E-Business Semantic Web applications usually consist of decentralized authorities with quite a large number of actors/ users. As semantic descriptions of content may be subject to unauthorized modifications or vandalism, there need to be ways to guarantee the validity of the descriptions and to secure access to them. Furthermore, the experience coming from popular portals like Flickr or YouTube shows that even copyright protected content is annotated without any previous consent by the rightholder. From the legal standpoint, instead, an express authorisation would be required. This shows that copyright protection is a critical issue when dealing with IPR protected content (such as text, images, multimedia works) and its semantic description.

5.3 Business Registry

An electronic business registry (e-business registry) is composed of a software system and an infrastructure that act as an organizing focal point for the wealth of information and interactions that e-business requires. E-business registries are composed of two main parts:

- **Repository:** File system (database) which rallies the registered objects,
- **Registry:** The part of the information system that supports the metadata for the registered objects.

Business registries make it possible to register, manage and discovery items which are of crucial importance for e-business. A registry is therefore an ideal "middleman" for brokering e-business relationships and transactions. Buyers and sellers need such middlemen to find each other and conduct business.

Business registries serve various purposes, which include:

- Enabling the discovery of trading partners, services, documents and business processes;
- Classification, association of e-business artefacts such as XML schemas, Document Type definitions (DTDs), and trading partner profiles;
- Registration and discovery of Web Services descriptions, such as Web Services Description Language (WSDL) documents.

Registers are made up of several entries which point to an object, that is an entity which may be relevant for a business (e.g. a product or service). There are metadata associated to each one of these entries that help categorize the data, and one or more formal indexes used to retrieve registry information.

Besides all the general problems shared by all interoperability solutions, business registries pose further peculiar legal issues:

E-business registry as information service provider in information society (Directive on electronic commerce). The e-business registry may be considered as an information service provider under the norms established by Directive 2000/31/EC ("Directive on electronic commerce"), in particular for what concerns the information that the service provider shall render easily, directly and permanently accessible to the recipients of the service and competent authorities (Article 5), the information to be provided in the contract (Article 10), the liability and exemptions from liability for the activities of the information society service provider, covering in particular the issues regarding the activities of hosting, caching and mere conduit (Section 4: Liability of intermediary service providers, Articles 12, 13, 14, 15). Consequently, the normative requirements, which are applicable to the information service providers in e-commerce in the EU, should also be applied to e-business registries. For example, information that e-business registry should provide about itself, the duty to inform the users about the codes of conduct, the issues of liability concerning the activities of "mere conduit" and "catching", etc. Thus, attention should be paid not only to national norms but also to the norms of European Community in order to integrate e-business registries in the field of information society services.

IDM (Identity Management). Identity management issues comprise the set of technologies, laws, policies which are adopted in order to manage the identity (in this particular case of e-business registries) of businesses from different e-business registries. In practice, once a business entity has signed in into one registry, it should be identified and authorized for all the actions of all the registries, instead of identifying itself for any action repeatedly. The e-business registry should also adopt the methods of CRM (Customer Relationship Management) and adopt a risk assessment methodology. In implementing IDM systems of e-business registries, one should have in mind the global character of possible users that might have access to the register and adopt corresponding standards, which should be unanimous in an international context also beyond the EU.

Legal relevance of information stored in Business Registry. Assessing the legal relevance of the information provided by an e-business registry may in some cases be practically vital, let us think for example of trade registers, which are more and more set up and managed only through electronic means. A simplified scenario of the issue could be the following: if an individual bases his/her actions on the information taken from an official e-business registry, he/she presumes that this information is relevant, updated and trustworthy. If not, and the actions based on such information cause damage to the same individual, he/she will have the right to sue the e-business registry. The content of the contract between user and business registry also plays a role in this context: often they include clauses of limitation or denial of responsibility which, however, may be in contrast with the applicable law. These contracts may not address this issue: for example, the TelemacoPay[32] contract only states that the data provided by the Telemaco service are the ones possessed by the Chamber of Commerce system.

Privacy and data protection. The main legal issues of business registries in this area are related to the compliance with the rules established by Directive 95/46/EC on data protection and Directive 97/66/EC on personal data protection in the telecommunications sector. Problems concerning the protection of the privacy may emerge when a business entity makes a contract with an e-business registry. Always taking as an example the contract TelemacoPay, it requires personal data such as name, surname and fiscal code. The contractual clauses provide for such data to be utilized only for the provision of the service or provided to judicial authorities upon their request. The user's authorisation is not necessary for the processing of his/her personal data in the cases of direct sale of goods, provision of analogical services, or presentations of the activities of the Chamber of Commerce or other entities which belong to the system of Chambers. Nevertheless, particular attention should be paid to the issues of privacy protection, with specific attention to the security of communications networks and the whole system of registries.

CONCLUSION

The state of the art of scientific research on Semantic Web and Web Services shows an increased interest on this area, however the legal studies still appear scarce. Many businesses have kept away from these technologies because of the fear of unknown legal consequences linked to a still uncertain legal framework.

Another relevant problem is represented by the difficulty to conciliate different legal systems, such as Common Law and Civil Law: the impossibility to apply worldwide acknowledged juridical schemes implies an effort from legal experts to avoid additional risks for users, due to the heterogeneous application of norms.

Considering this, a legal study in this field does not just add a further extraneous element but can act as a real enabler towards future developments of technologies and networks which are of basic importance for the Web. Creating intrinsically law-abiding and secure platforms would paradoxically be the best way to avoid legal conflicts and pathological situations in the implementation of Semantic Web technologies.

Future research would therefore draw a significant advantage from a higher level of interdisciplinarity and also from deeper studies on the legal side.

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KEY TERMS AND DEFINITIONS

Delegation: The fact of entitle someone to achieve a goal on behalf of himself.

Knowledge Attribution: The juridical imputation of the information used by an agent to perform the goal delegated by someone else. This imputation could generate liability if such data are unfairly collected or improperly used.

Software Agent's Developer: The legal or natural person who manages a software agent's development process and places the end product on the market.

Software Agent's User: The natural or legal person under whose name the software agent was purchased. The natural person may be an employee of the legal person, and in this case liability will fall on the latter if the software agent causes damage.

Strict (or indirect) Liability: Liability without fault.

Vicarious Liability: A person's liability for the conduct of another, based on a relationship between these two persons.

ENDNOTES

1 There are several notions of Software Agents, each remarkable on its own, but what is relevant is the difference between software agents and mere objects: "*The fact that software agents have own cognitive states and perform cognitive processes non attributable to the user (and so the fact that this is known both from the user and the agent's counter-parties) is what distinguishes software agents from objects or other tools, under the law perspective*" (Sartor, G. (2002)).

2 This concept is also included in the so called "weak notion" of software agents, as stated by (Wooldridge, M.J., & Jennings, 1995), that also consider reactivity and social ability as basic characteristics of agents, while the "strong notion" is referred to computer systems those are "*conceptualized or implemented using concepts that are more usually applied to humans*".

3 This theme has been analysed with specific reference to the Google-mail case by (Chopra, S. & White, L. (2007)).

4 Oxford English Dictionary Online, second edition, entry "delegation", Retrieved 12, June, 2008, from http://dictionary.oed.com. This basic notion explains that delegation is a concept which is naturally conceptualized from to human to human agents, not to artificial ones. However, software agents are created by humans to perform actions that are usually delegated to other people: this fact suggests the usage of this expression also for this particular type of agents.

5 It is necessary also to consider that, even if the term "delegation" in the acceptation here used has a common sense in every State, thins are different when approaching each legal context: for instance, in common law systems delegation is mainly used to indicate "political representation" (Lindseth, P. (2004)); otherwise, in certain civil law orders, "delegation" rules specific situation of the relationship between a debtor and his creditor: in Italian Civil Law order, in fact, Delegation is intended as the assignment of a debtor by his creditor to a creditor of the delegator, to act as debtor in his place and discharge his debt.

6 The Authors introduce also the nomenclature problem: in civil law orders, instead of common law ones, the name of this legal paradigm is usually "representation", while the term "Agency" is used to identify another type of agreement.

7 This consideration is amplified by the theory of "undisclosed principal": according to this theory if the agent does not disclose the existence of the agency and of the related procuration, then he will be liable to the counter-party and even the later discloser of such delegation will not relieve him from liability.

8 According to Article 1393 of Civil Code, *"the agreement may be ratified by the person concerned, according to the form requirement prescribed for that contract. The Ratification has retro-active effects"*.

9 Currently, the most relevant attribution made by law to Software Agents is contained in the United States Computer Information Transaction Act (UCITA) which (in section 107 (d)) affirms that "a person that uses an electronic agent that it has selected for making an authentication, performance or agreement, including manifestation of assent, is bound by the operations of the electronic agent, even if no individual was aware or reviewed the agent's operations or the results of the operations."

10 The international acknowledgement of Trust Law is due to the Convention of Trust of Aja of 1985. For instance, in Italy it the has been ratifies since 1989, nevertheless it is almost unknown and the first relevant Courts' decision are begin from 1997.

11 Lawyers tend to favor a classificatory approach—based on the idea that classification is the way to go about finding appropriate legal discipline—which Sartor rejects as "completely inappropriate when one wants to develop a coherent framework for approaching a new phenomenon (as is the case of software agents)": his view is that "it is […] risky to rely on classification when we deal with new entities, which under certain regards are similar to the known prototypes and under certain regards are not" (Sartor, 2003, p. 4–5).

12 The original text: *Qualunque fatto doloso o colposo che cagiona ad altri un danno ingiusto, obbliga colui che ha commesso il fatto a risarcire il danno* (Art. 2043 of the Italian Civil Code). The same logic is adopted in almost all civil codes. Here are three examples. The French Civil Code: *Any human act whatever that causes damage to another, obliges the one responsible for it to provide for compensation* (art. 1382). The German Civil Code: *Whoever knowingly or negligently unlawfully injures another person's life, body, health, liberty, or property, or infringes on any right of this person, is liable for the injury* (Section 823). And the Québec Civil Code: *Every person has a duty to abide by the rules of conduct which lie upon him, according to the circumstances, usage or law, so as not to cause injury to another. Where he is endowed with reason and fails in this duty, he is responsible for any injury he causes to another person by such fault and is liable to reparation for the injury, whether is to be bodily, moral or material in nature. He is also liable, in certain cases, to reparation for injury caused to another by the act or fault of another person or by the act of things in his custody* (art. 1457).

13 Examples are the use of poisons, the transportation of hazardous materials, and crop dusting in which there is a risk of contaminating the crops of adjoining fields. Some authors propose to include the software agents to this category, but we are not of the same opinion.

14 A number of considerations are taken into account in deciding whether the damage caused falls under the employer/employee relationship: chief among them are the time and place of the act that caused the damage and the employee's job description.

15 This doctrine is part of the law of master and servant and applies not only to the relationship of an employer to an employee but also to the broader agency relationship (between an agent and his or her principal), but this is not a matter that will be taken up here. See Owen, R.D. (1955). Tort Liability in German School Law. *Law and Contemporary Problems, 1*(20), 72–79.

16 We will not discuss the situation when the developer is working under the instructions of other persons (natural or legal): this issue will be the object of the further research on these issues.

17 The Anglo-American system of jurisprudence distinguishes three types of defective

goods: mis-manufactured, mis-designed, and mis-marketed products. It is therefore useful to analyze software agents from these three points of view, in which regard see Cantu, C.E. (2003). Distinguishing the Concept of Strict Liability in Tort from Strict Product Liability: Medusa Unveiled. *University of Memphis Law Review*, 4(19). Retrieved June 6, 2008 from http://findarticles.com/p/articles/mi_qa3843/is_200307/ai_n9252419. The full name of the EU directive is Council Directive 85/374/EEC of 25 July 1985 on the Approximation of the Laws, Regulations and Administrative Provisions of the Member States concerning Liability for Defective Products. Retrieved June 6, 2008, from http://europa.eu.int/eur-lex/lex/LexUriServ/LexUriServ.do?uri=CELEX:31985L0374:EN:HTML. For more information, see http:// www.iopcfund.org.

18 In this case we could talk about the implicit obligation of developers to keep themselves abreast of technical developments: the discussion is complex, as term "technical development" is obscure and could be easily circumvented.

19 For more information, see http:// www.iopcfund.org.

20 See http://ec.europa.eu/justice_home/fsj/privacy/law/implementation_en.htm.

21 Personal data in social networks as building blocks of a person's identity will be the object of analysis of Section 4.

22 Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data, article 2 "Definitions".

23 As expressed by the Italian Cassation Court, in Decision, 7 February 1996, n. 978.

24 Directive 1999/93/EC of the European Parliament and of the Council on a Community framework for electronic signatures.

25 For a thorough analysis of delegation, see Section 1.

26 Legal aspects of economic commerce, electronic contracting: Provisions for a draft convention", Uncitral Working Group IV, New York, 11-15 March 2002.

27 For further details on this point, see Section 3 on Privacy and Data Protection.

28 The authorisation can be provided by the data protection authority for categories of processing in the form of "General authorisation".

29 On the point, see the Decision of the Italian data protection authority of 10 November 2004. A company has obtained the right to see the outcome of a decision of the antitrust authority which sanctioned it for deceitful advertising only by having access to the specific search engine of the same authority and not from general search engines.

30 According to Rati Thanalawala, vice president of "Bell Labs" network planning, performance and economic analysis division, *"the threats in communications network are five: destruction of the information, corruption of the information, removing of the information, disclosure of the information and interruption of the information*". For more information, see D.Sarkar "International body adopts network security standard", 2006, available at http://www.fcw.com/article92696-03-22-06-Web;

31 The whole ISO 18028 set is composed of 1. Network Security Management; 2. Network Security Architecture; 4. Securing Remote Access; 5. Securing Communications Across Networks Using VPN.

32 TelemacoPay is an Italian business registry portal application. See http://www.infocamere.it/telepay.htm.

Chapter XXIX
The Influences and Impacts of Societal Factors on the Adoption of Web Services

Karthikeyan Umapathy
University of North Florida, USA

ABSTRACT

The objective of this chapter is to identify and analyze implications of social factors on the adoption of Web services technology. Web services allow organizations to streamline their business process applications and expand their market boundaries to global level. Currently, adoption of Web service technology is in the early phase, as organizations are experimenting with it behind secured firewall. Technological immaturity and cost of adoption are considered as primary factors for slow adoption of Web services technology. However, global reach of Web services allows it to be used in different cultural, geopolitical, and infrastructural conditions. Therefore, this chapter explores influences and impacts of societal factors on the adoption of Web service technology. Societal factors considered in this study are culture, social structure, geography, ethics, and trust. Common themes identified across these factors are need for mechanisms to support globalization management, to monitor and assess trustworthiness, and relationship management.

INTRODUCTION

Over the years, the Internet infrastructure has emerged as a technological platform for enterprise applications to access and share information (Alonso, Casati, Kuno, & Machiraju, 2004). The growth of Internet with technologies such as eXtensible Markup Language (XML) has changed the way business collaboration are supported (Benatallah, Dumas, Fauvet, & Rabhi, 2003). In particular, Web service, which is built on top of existing Internet infrastructure, provides an open and XML-based standardized framework for application-to-application interaction.

Web service, following Service-Oriented Computing (SOC) paradigm, promises to solve problems of application integration. The SOC paradigm provides characteristics of loose coupling and dynamic binding by positioning its basic essence of computing as a "service" (Curbera, Khalaf, Mukhi, Tai, & Weerawarana, 2003). Software application (service) developed following SOC paradigm defines their functional requirements and capabilities in standardized machine-readable format. Services represent the basic building blocks, which can be combined in particular ways to achieve business goals. Moreover, Web service is a collage of standards and technologies (Sleeper & Robins, 2001), which allows applications to communicate with each other, regardless of language or platform it was developed and location of the application on the Internet (Manes, 2003). Thereby, solving problems of tight coupling, hard-coding, and heavy-handed implementation of application integration.

Web services technology has received significant amount of attention from both academicians and practitioners. Despite growing interest and recent efforts, Web services is confronted with several critical problems that severely undermines usability of Web services and therefore hindering widespread adoption (Ran, 2003; Umapathy & Purao, 2007b). In organizational context, adoption of new technologies such as Web services can be described as commitment to invest resources towards implementing and using a technology to support core business functionalities (Magnusson, 2004; Rogers, 1995).

There are few research articles that provide analysis on factors affecting the adoption of Web services technology in organizations. There have been some research works on understanding technical factors that affect development of Web services (Gottschalk, Graham, Kreger, & Snell, 2002; Papazoglou, 2003; Tsalgatidou & Pilioura, 2002). There also have been some research works to understand Web service adoption from the business and industrial perspectives (M. Chen, 2003; Ciganek, Haines, & Haseman, 2006; Haines, 2004; Tilley et al., 2002). Primary factors for slow adoption of Web services technology are considered to be technological immaturity and cost of adoption (A. N. K. Chen, Sen, & Shao, 2006; Ciganek et al., 2006).

Web services not only changes the way of conducting business for organizations; it also helps them to streamline business process applications and expand their market boundary to global level. Even though strategic driver for Web services has been organizational needs, the adoption of Web services has social implications. Global reach of Web services allows it to be used in different cultural and infrastructural conditions. Therefore, adoption of Web services technology impacts software development, nature of enterprise systems jobs, and how businesses operate (Ciganek et al., 2006). Therefore consideration of social factors is very important while developing and adopting Web services technology.

Whenever the meaning of context has moved beyond organizational level to include societal and global level, the information systems discipline has been confronted with significant challenges (Walsham, 2000). As Web services technology allows organizations to collaborate with global partners, understanding implications of societal factors are highly important before the heavy investments of resources are made for developing and implementing Web services. However, implications of social factors on Web services are severely under-researched.

The objective of this study is to identify social factors that can influence and impact on the adoption of Web services technology. Walsham (Walsham, 2000) suggests that study of use of information systems in different cultural contexts will be social level of analysis. Therefore, this study would be conducted at the societal level of analysis and utilize the influence/ impact framework (Trauth, 2000) to understand the societal implications of the adoption of Web services technology.

SOCIETAL FACTORS CONSIDERED FOR ANALYSIS

Pouloudi and Vassilopoulou (N. Pouloudi & Vassilopoulou, 2002), drawing upon several social and cultural theories has identified following factors to have social implications on the adoption of electronic business models: culture, legal/regulatory/policy, economic/ethical/professional, and region/geography. Even though Web services is about conducting business electronically, analysis on electronic business models are not applicable to Web services, because it uses service-oriented architecture which is not tailored towards any specific business models. However, these factors are still good starting point for understanding implications of societal factors on the adoption of Web service technology. Therefore, factors considered for this study are: culture, social structure, ethics, region/ geography, and trust.

The influence/impact framework (Trauth, 2000) is used to understand the societal implications of the adoption of the Web services. According to the influence/impact framework, there are two forms of interaction between society and information sector. First, societal factors exert an influence on the way in which the information sector develops and behaves. Second, there is a subsequent impact that the information sector has on the society, in our case, Web service community. In this study, influence/ impact framework will be used to understand interaction between social factors and the adoption of Web services technology. Above listed factors are analyzed to investigate the influences of the social factors on the adoption of Web service technology and subsequent impacts for Web service community to facilitate the adoption of Web services. Below, a brief overview of the culture, social structure, ethics, region/geography, and trust factors are provided.

Culture

Increasing maturity of Internet-based technologies is enabling organizations to redesign their information systems to support business activities over the Internet (Straub, 2004). Organizations can utilize Web service technology platform to assemble individual applications into a value-added services. These individual applications can be developed by globally distributed developers, who may have diverse cultural backgrounds. Therefore is it necessary to understand the influences and impacts of the culture before developing and adopting Web service technologies.

Hofstede (Hofstede, 1980) defines culture as, “the collective programming of the mind which distinguishes the members of one human group from another”. Hofstede (Hofstede, 1991) has proposed five dimensions of national culture; these five dimensions will be analyzed in this chapter:

- **Power distance:** Is the extent to which a society accepts unequal distribution of power in institutions and organizations. Power distance represents the extent of adherence to formal authority channels and is the degree to which the lesser powerful accept the prevailing distribution of power. High power distance cultures have members who are much more comfortable with centralized power than members of low power distance cultures.
- **Individualism vs. collectivism:** Refers to the basic level of behavior regulation, whether by individuals or groups. People high on individualism view self and immediate family as relatively more important than the collectivism. Individualism is the extent to which an individual in society looks after own interest rather than the group.

- **Masculinity vs. femininity:** Masculine culture is assertive, tough, and concentrates on material success while feminine culture is modest, tender, concentrate on quality of life, and human relationships at the forefront.
- **Uncertainty avoidance:** Is the extent to which a member in the society feels threatened by uncertain or unknown situations, as well as feels the importance of rules and standards. People with an orientation low on uncertainty avoidance prefer situations that are free and not bound by rules and regulations.
- **Short-term vs. long-term time orientation:** Is the extent to which society members give value to fostering virtues oriented towards future rewards. Short-term vs. long-term orientation is people's basic reference period. Short-term orientation involves tendencies towards consumption and maintaining materialistic status, while long-term orientation suggests thrift, perseverance, following tradition, and deferred satisfaction.

Social Structure

Giddens (Giddens, 1984) developed theory of structuration in where he suggests that human agency and social structure are related to each other. According to the theory of structuration, the social structure is the basis for individual actions and the actions of individual agents reproduces the social structure. The social structure is defined as patterns of actions, that is., virtual order of actions and modalities (i.e., rules and resources). Actions take place in structural areas, which are formally described as: signification, domination, and legitimation. These three factors will be analyzed in this study. Signification refers to structural features of social systems, drawn upon, and reproduced by actors in the form of interpretive schemes. Signification is a constitutive feature of the context of communication itself. Domination is facilities like authoritative resources, which extends over people and allocative resources, which extends over objects or material phenomena. Legitimation is the norms and/ or rules that individuals draw on for justifying their own actions and that of others. Detailed summary of the theory of structuration can be found at (Rose, 1998).

Ethics

Ethics are defined as a set of standards, or value system by which free, human actions are ultimately determined as right or wrong, and good or evil (White & Wooten, 1986). During targeted market expansions, developers tend to put business-ethics consideration on back burner in order to avoid unduly limitations (Rebne, Ng-Kruelle, Swatman, & Hampe, 2002). Increasing usage of the Internet-based applications makes it difficult to differentiate business actions performed within an organization context and outside; therefore, ownership of business actions performed should be identified (Card, 2005). In the Internet-based markets, organizations have expectation on their partners to provide fair conditions such as fair price, and fair market value (Askland, 2000). Organizations must provide secured means to their partners and employees to access confidential information (Seo & Sycara, 2006). Therefore, factors that will be analyzed in this paper are ownership, fairness, and use of confidential information.

Region/ Geography

Geography can be defined as "a large land area that has particular geographic, political, or cultural characteristics that distinguishes it from others whether existing within one country or extending over several" (N. Pouloudi & Vassilopoulou, 2002). In the organizational context, region/geography refers to issues that are related to specific geographic areas such as linguistic singularities of specific regions and environmental issues such as rules ranging from legal mandates to industry best practices (Kotok, 2001). Therefore, factors that will be analyzed in this paper are language (vocabulary) and environmental issues (country laws, policies, and regulations).

Trust

With the accelerated adoption of electronic collaboration and commerce, organizations can now outsource their information technologies, rather than owning and maintaining their own systems (Ratnasingam, 2002). The geographical dispersion of outsourcing partners, introduces challenge of building a degree of trust needed for effective collaboration (Lederer-Antonucci, Greenberg, Muehlen, & Greenberg, 2003). It is highly necessary to have some notions of trustworthiness of the partners, before they are allocated to perform a selected task in the business process. In the context of Web services, applications developed by globally dispersed partners can be used to support business processes, therefore, trustworthiness of such partners must be managed to permit quicker development Web service applications.

Trust can be defined as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party" (Mayer, Davis, & Schoorman, 1995). Trust is an important component that determines the nature of interactions and people's expectations in social and business environments (Gefen, 2002). Trustworthiness of network systems is multi dimensional issue involving technology and people. A trustworthy system performs its expected tasks irrespective of environmental disruption, human user and operator errors, and hostile attacks (Schneider, 1999). Trustworthiness of network systems encompasses reliability, security, privacy, safety, survivability and prior experience, thus, these are factors that will be analyzed.

- **Reliability:** Is the capability of system, to perform consistently and precisely according to its design with high confidence.
- **Security:** Is capability of a system to ensure that it can resist potentially correlated attacks. Security generally refers to a collection of safeguards that ensure confidentiality of information, protect system(s) or network(s) that process information, and controlling access to information. Security typically encompasses secrecy, confidentiality, integrity, and availability.
- **Privacy:** Ensures freedom from unauthorized intrusion.
- **Safety:** Is a characteristic of trustworthiness asserting that a system will not be cause of physical harm to people or property.
- **Survivability:** Is the capability to provide a certain level of service in adverse or hostile conditions
- **Prior experience:** Refers to experience with the particular market space, with the particular participant, with particular technology and/or with the particular tradable item.

INFLUENCE/ IMPACT ANALYSIS

Culture

Power distance represents the degree to which less powerful accept prevailing power distribution and extent to which they adhere to formal authority channels (Pavlou & Chai, 2002). Members with low power distance would prefer decentralized environment while members with high power distance would prefer centralized environment. In the context of Web services, services (i.e., software applications) are distributed and easily accessible via Internet protocols. Web service composition allows invocation of individual services to be arranged in specific order to achieve a business goal. In regards to executing such composite services, members of high power distance would prefer a centralized mechanism, i.e., they would like to be aware of what ordered tasks need to be executed and required peer-to-peer interactions to accomplish each task. While members of low power distance might prefer to receive information on only ordered tasks that needs to be completed and manage coordination required to achieve the task on their own. In the context of composite services, orchestration standards such as WS-BPEL (WS-BPEL, 2007) is used for describing sequence of tasks that must be performed by participating services in order to achieve the business goals; and choreography standards such as WS-CDL (WS-CDL, 2005) is used for describing peer-to-peer collaborations between multiple participants required to achieve the business goals (Umapathy, 2006). Thus adoption of Web service, pertaining to composite services could be influenced by power distance of service providers, i.e., members of high power distance might prefer using both orchestration and choreography mechanisms while members of low power distance might prefer using only orchestration mechanism. Therefore, during development of composite services, high and low power distance culture characteristics needs to observed and appropriately balanced.

With respect to individualism and collectivism culture, members of individualism generally are not affiliated towards maintaining a long-term relationship. On contrary, member of collectivist are focused on maintaining harmony in the group by going along with common goal of the group. Collectivist, thus are geared towards having a long-term business relationships, while individualism do not seek it purposely (Pavlou & Chai, 2002). Members of individualism cultures would be more interested in dynamic Web service composition, where composer assembles unknown services on the fly to provide value-added composite services. In order to facilitate dynamic Web service composition, individualism members would seek means to evaluate trustworthiness of the service providers, rather establishing a relationship and maintaining it. On the other hand, members of collectivist cultures would depend on their existing business relationship to construct composite services, therefore, they would seek for relationship management that will allow them to establish and maintain long-term relationship.

With respect to masculine and feminine cultures, members of masculine cultures emphasize work and material accomplishments while members of feminine cultures put human relationships at the forefront (Pavlou & Chai, 2002). Members of masculine cultures, thus, would expect clear separation between roles of the partners in composite services; while members of feminine cultures generally would not seek such a clear separation. These cultural differences affect the design and execution of composite services, therefore, roles and actions performed by partners should be made explicit. PartnerLink element in the WS-BPEL specification is tailored towards addressing this issue (WS-BPEL, 2007).

Uncertainty avoidance represents extent to which people feel threatened by ambiguity (Davis & Ruhe, 2003). Members of high uncertainty avoidance orientation would prefer situations where there exist standards and rules of engagement, while members of low uncertainty avoidance orientation would prefer situations that are free and not bound by rules and regulations (Pavlou & Chai, 2002). Web service utilizes Internet infrastructure, which has high degree of uncertainty, to conduct business transactions (Tsygankov, 2004). Members of high uncertainty avoidance orientation would seek for adequate standards and protocols that can provide means to conduct secured and reliable transactions. On other hand, members of low uncertainty avoidance orientation would seek for flexibility on manner which transactions are carried out using such standards and protocols.

Short-term and long-term orientation represents people's basic reference period. Members of short-term orientation would have tendency towards consuming resources and maintaining materialistic status, on contrary, members of long-term orientation would have tendency to follow tradition, defer satisfaction, and have perseverance to be thrifty (Pavlou & Chai, 2002). Members of short-term orientation would take risk of utilizing immature technology like Web services to conduct business; therefore, there is high likelihood that members of short-term orientation would be the first adopters of the Web services technology. Members of short-term orientation would desire for immediate results and achievement of goals, therefore, would risk to use certain aspects of Web service technology that provide reliable and superior mechanisms. Members of long-term orientation would focus on practical value of the system for organizations and be patience in achieving results, therefore, would be late adopters of the Web service technology and prefer all critical aspects of Web service technology to provide reliable and superior mechanisms. Figure 1 provides summary of influence/ impact analysis for cultural factors on the adoption of Web service technology.

Social Structure

In organizational context, participant's actions are constraint by his/her role within the organization. Actions performed by participants in a particular

Figure 1. Influence / impact framework analysis for cultural factors

Influences of cultural factors on the adoption of web services technology

- Members of high power distance might prefer to use both orchestration and choreography mechanisms
- Members of low power distance might prefer to use only orchestration mechanism
- Need to support both ability to make short-term and built long-term relationship
- Need explicitly specific roles of partnering services
- Need regulations to conduct secured transactions over Internet
- Short-term oriented culture might be early adopters
- Long-term oriented culture might be late adopters

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Subsequent impacts on the adoption of web services technology

- Balance cultures with low and high power distance while composing services by using orchestration and choreography mechanisms appropriately
- Develop mechanisms to evaluate trustworthiness of services
- Develop mechanisms to manage relationships
- Develop mechanisms to specific roles and actions performed by partnering services
- Develop standards and protocols for web services transactions
- Develop mechanisms to ensure secured and faster interactions
- Ensure all aspects of web service technology provide reliable and superior mechanisms
- Develop design principles to ensure web services development provides practical value of the system to organizations

circumstance are not under control of organizations (Hassall, 2000). Thus, participants, systems, and organizations with which a person interacts should be considered holistically (Hassall, 2000). In the development of theory of structuration (Giddens, 1984), Giddens insists upon an action/ structure duality, i.e., having balance between participants and organization structure, because by virtue of interacting with the organization, participant's action are being constrained and at same time creating the structure(s) of the organization.

Signification deals with communication of knowledge and meaning which is achieved through stocks of knowledge that participants draw on, in the production and reproduction of action (Orlikowski & Robey, 1991). Through the use of modality of an interpretative scheme, signification can affect ways in which interactions are performed. Forms of significations can be changed via communicative actions performed through interpretative schemes (Hassall, 2000). Web service, therefore, should support different forms of exchanging messages among services. There must be multiple protocols through which services can receive and send messages. However, creation of multiple forms of communication protocols would lead to multiple schemes to interpret the message. Therefore, in the context of Web services, it is critical to develop standardized protocols to exchange and interpret messages unambiguously as well as maintain conversation context among all participants involved. Simple Object Access Protocol (SOAP) standard is tailored towards solving the issue of common protocol to exchange messages (SOAP, 2003). Service conversation specifications such as Web Services Choreography Description Language (WS-CDL) (WS-CDL, 2005) address the issue of maintaining context among participants (Umapathy, 2006).

Allocation of facilities, which enable participants to achieve specific outcomes, typically, depends on participants' power. These facilities represent resources which comprise structures of domination (Nandan, 1996). Resources are means through which intentions are realized, goals are accomplished, and power is exercised (Orlikowski & Robey, 1991). Participants who has authoritative power for a specific resource/ facility would act as coordinators and have power to reward or punish other participants, who are in need of that resource (Sarker & Sahay, 2003). In the context of Web services, composer of a composite service would act as coordinator who co-ordinates interactions and resources utilized by the participants of the composite service. In order to achieve business goal, composer would require co-ordination protocols for managing and monitoring usage of resources by participants. Web Services Business Process Execution Language (WS-BPEL) specification provides means for composers to coordinate usage of resources by their partners (WS-BPEL, 2005).

Participants draw on rules of legitimation for interpreting their actions as well as other participants' actions. Legitimacy of an interaction defines rules governing appropriate conduct within an organizational setting (Orlikowski & Robey, 1991). In the context of Web services, a composite service must describe rules associated for sequence of actions performed by participating services in order to achieve a goal. Web service conversation specifications such as WS-CDL (WS-CDL, 2005) and service composition process specification such as WS-BPEL (WS-BPEL, 2007) are tailored towards this need.

When the signification, domination and legitimation dimensions interplay with each other, they create and reproduce social structure causing relationship management issues (Sydow, 1998). In context of Web services, to manage interplay of these dimensions would require relationship management mechanisms. However, in the context of Web services, there is lack of well established mechanisms to manage relationships. Figure 2 provides summary of influence/ impact analysis for social structure factors on the adoption of Web service technology.

Figure 2. Influence / impact framework analysis for social structure factors

Influences of social structure factors on the adoption of web services technology

- Different forms to communicate
- Maintaining context of interaction
- Need of coordinator to manage and allocate resources
- Need of describe interaction sequence and other associate rules to perform actions
- Create and manage relationships

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Subsequent impacts on the adoption of web services technology

- Develop standardized means to exchange messages over different communication protocols
- Provide protocol to maintain conversational contexts to co-ordination interactions among services
- Provide protocols to describe rules, resources to be used, and sequences of actions to performed by participating services
- Develop mechanisms to manage relationships

Ethics

The Internet infrastructure represents a cyberspace where there seems to be no limit on what is or what will be out there (Halbert & Ingulli, 2002). The growing number of well developed Internet-based technologies has revolutionized the way data is gathered, stored, manipulated, and communicated. Along with its development, this revolution is creating new ethical dilemmas. The speed and efficiency of these Internet-based technologies have forced people to confront new rights, responsibilities, and reconsider current ethical standards that were created before advent of this revolution. As in other new technological arenas, legal decisions lag behind technical developments, therefore, new ethical standards are required to fill the gap on how electronic information should be used via Internet-based technologies (Lynch, 2000).

Mason (Mason, 1986) suggests that there four key ethical issues in the information age, which are: accuracy, property, privacy, and accessibility. Property and accuracy raises the issues of ownership, such as who has information ownership and control, as well as the quality and accuracy of information held. With respect to property, the increasing use of Internet-based resources has created new contexts for the terms piracy and plagiarism (Barroso, 2001). Internet-based resources can be easily copied, altered, and transferred across borders. Therefore, the piracy of intellectual property is a major social problem in this context (Bynum, 2002). In the context of Web services, non-functional characteristics of services such as ownership, quality of services, and copyright of associated services should be shared by service providers with service consumers.

Privacy is concerned with capability of a people or system to keeping personal information confidential (Mason, 1986). There are many efforts from various societies around the world to design and implement national level schemes for Privacy and Data Protection (PDP) (Howley, 2002). Ethical decisions concerned with privacy of information are made in the context of complex relationships (A. Pouloudi, 1999). Therefore the use of confidential information impacts on interpersonal relations (in particular trust) with the stakeholders. In the context of Web services, service providers should provide machine readable descriptions of their privacy policies along with details of how privacy concerns are controlled and enforced. Platform for Privacy Preferences (P3P) developed to tackle privacy concerns in Web environment can be further extended to support Web services environment (Carminati, Ferrari, & Hung, 2005).

Fairness is considered as a justice concept, where in, it can be described as an act of giving a person what s/he deserves (Britz & Zyl, 2004). The concept of justice can be categorized into four kinds: commutative justice, distributive justice, contributive justice, and retributive justice. Commutative justice is about fundamental fairness with regards to all agreements and exchanges among individuals or social groups (Nitsch, 2005). In the context of Web services, service consumers are free to select a service that provides competitive deal. Service providers, therefore, need to have fair and competitive pricing systems for their services. There should also be appropriate regulation to ensure that service consumers make required payments. Contributive justice refers to moral obligations of individuals to society for the common good (Britz & Lipinski, 2001). Contributive justice is about having accessible information infrastructure for all. In context of Web services, services are made accessible for everyone as they are provided via Internet protocols. Distributive justice refers to obligations of society to its individual members (Britz & Lipinski, 2001). Distributive justice can be considered as a norm with regards to fair distribution of resources required to satisfy basic human needs. Retributive justice concerns with punishing those who have violated laws devised to protect social order (Britz & Lipinski, 2001). These norms implies importance for service provider to have fairness in pricing their services, making services accessible by all, and ensure that services as well as providers and consumers are not violating any laws or regulations. Figure 3 provides summary of influence/ impact analysis for ethics factors on the adoption of Web service technology.

Region/ Geography

Internet-based technologies and digitization of information have enabled organizations to operate across national borders with minimal constraints (Straub, 2004). Web, the fastest growing segment of the Internet infrastructure, provides most cost-effective medium for organizations to transfer customized and personalized information beyond geographical boundaries (Bakos, 1998). However, in order to effectively collaborate with global partners, organizations must overcome following challenges: developing trust and relationships with partners beyond geographical boundaries, understanding cross-cultural differences, developing intercultural communication competence, processing multilingual data, and presenting culturally correct information (Zakaria, Amelinckx, & Wilemon, 2004; Zhu, 2003). In the context of Web services, this calls for development of globalization management support mechanisms. Any such mechanisms should include critical features like building and maintaining relationships beyond geographical barriers, ontologies describing language, culture, regional and local contexts, multilingual data processing, localization of business model, and translation services. Currently, mechanisms to support globalization management of Web services are severely under-research.

While organizations are adapting their businesses to exchange information and perform transactions over the Internet infrastructure; Governments and the International bodies are creating new (or extending old) laws and regulations to protect their sovereignty. The growth of

Figure 3. Influence / impact framework analysis for ethics factors

Influences of ethics factors on the adoption of web services technology

- Ethical dilemmas on usage of electronic information
- Protecting from plagiarism of intellectual property
- Protecting personal information
- Fair pricing of services
- Services should be easily accessible by anyone
- Regulations to ensure providers and consumers not violating any laws

Subsequent impacts on the adoption of web services technology

- Develop specifications to describe non-functional properties of service
- Develop mechanism to verify ownership and copyright details of a service
- Develop mechanisms to specify privacy policies
- Develop mechanisms to enforce privacy and control access to confidential information
- Provide appropriate models to set fair pricing for services
- Provide automated means to ensure providers and consumers are not violating laws and regulations

these new laws and regulations presents political and legal challenges for organizations to collaborate with global partners. Some of the challenges faced by organizations are: protecting intellectual property rights, ensuring legally valid electronic contracts and transactions, understanding and incorporating changes in taxation (both in home and partner countries), understanding legal liability on information obtained from global partners, and understanding geo-political and legal business environments in the partners countries. In the context of Web services, the above challenges shows the importance of understanding global laws and regulations before using services provided by global partners. Organization adopting Web service technology to conduct their business with global partners must develop ontologies describing geopolitical and legal business environments of their partners' countries, to address above challenges. Figure 4 provides summary of influence/ impact analysis for region/ geography factors on the adoption of Web service technology.

Trust

The influence of consumer's trust on online transaction activities is fundamental in predicting e-commerce adoption (Pavlou & Chai, 2002). Trust is an important element in influencing consumer behavior; hence, developing service consumer's trust is critical for adoption of Web services. The openness and easiness of conducting transactions over the Internet infrastructure have increased concerns on privacy and security underscoring the importance of trust. In the context of Web services, because services are made accessible over the Internet infrastructure, they are prone for problems of accessibility, reliability, convenience, accuracy, and security (Tsygankov, 2004). Therefore it is highly necessary to have

Figure 4. Influence / impact framework analysis for region/ geography factors

Influences of region/ geography factors on the adoption of web services technology

- Understanding cross-cultural differences and local contexts
- Overcoming linguistic barriers
- Maintain relationships with partners across globe
- Understand laws and regulations in partner countries
- Ensure electronic transactions follows regulations in both home and partner countries

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Subsequent impacts on the adoption of web services technology

- Provide ability to process and present multilingual data
- Develop mechanisms to support globalization management
- Provide ontologies defining vocabulary of multi-linguistic and cross-cultural context information
- Regulations to ensure that global laws and regulations are followed during electronic transactions
- Provide ontologies describing geopolitics guidelines
- Develop mechanisms to manage relationships

some notion of trustworthiness of a service and its service provider, before a particular service is selected to perform a specific task. Evaluating trustworthiness of available services is important, in order to avoid services that provide poor quality of services, create runtime exceptions, or behave erratically. Evaluation of trustworthiness of a Web service essentially means purging services who behave badly, giving low reputation for lower quality of services, and increasing reputation if service behaves correctly (Maximilien & Singh, 2004). Developing trustworthiness of Web services is still under researched and currently there are no well-developed means to evaluate trustworthiness of a service.

Trustworthiness of systems accessed over Internet infrastructure is influenced, in large part, by people's prior experience in using that system (Schneider, 1999). Perceived usefulness and perceived ease of use would influences intention of the consumer to use an information system and also impact on the attitude of consumer towards usage of an information system (Pavlou & Chai, 2002). Experts on perceived trust by consumers argue that consumers spend too little on trustworthiness because of imperfect information (Schneider, 1999). As decision on trustworthiness obtained within the context of imperfect information, it creates a disincentive to invest for both consumers and producers, leading to a market failure. Therefore initiatives to mitigate this problem are highly critical for successful adoption of Web services technology. The absence of standardized metrics or a recognized organization to conduct assessments for trustworthiness is an important contributing factor to the imperfect information problem.

A trustworthy system is the one which users can completely rely on, fulfill requirements, and does not behave erratically (Banerjee, Mattmann, Medvidovic, & Golubchik, 2005). Trust in most disciplines is studied at individual level and is measured as perceived probability of single unit less criteria (Msanjila & Afsarrnanesh, 2006). In the context of Web services, trust is at organization level and is perceived probability of events within service and of the service provider; therefore, trustworthiness of a Web service should be measured as multi-dimension criteria. Trustworthiness of systems accessed over Internet infrastructure can be evaluated based on criteria such as software safety (when software failure would have severe consequences (Leveson, 1986)), availability of the system, reliability of the system, timeliness on responses, integrity of message delivery, survivability from security threat, and fault-tolerance (Voas & Ghosh, 2000; Wei, Zhongwei, & Zhitang, 2005). In context of Web services, there are security related standards such as WS-Security (WS-Security, 2006), WS-Trust (WS-Trust, 2007), WS-Federation (WS-Federation, 2008), and WS-Policy (WS-Policy, 2007); however, these standards address only security issues of Web service technology (Zhang, 2005). As described above, trustworthiness of a Web service includes issue beyond security such as safety, survivability, reputation, performance measure, availability, and fault-tolerance which are not addressed. Thus, in order to obtain favorable attitude from organizations to adopt Web service technology, there is need of well-developed framework to measure, monitor, and mange trustworthiness of services and its provider. Figure 5 provides summary of influence/ impact analysis for trust factors on the adoption of Web service technology.

Figure 5. Influence / impact framework analysis for trust factors

Influences of trust factors on the adoption of web services technology

- Perceived usefulness and ease of use of the service by the customer
- Need of customer reports for trustworthiness of services and providers
- Need for to make trustworthiness judgments on multi-dimension criteria which include issues beyond security
- Need for standardized metrics to assess trustworthiness on real-time basis
- Imperfect information about services

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Subsequent impacts on the adoption of web services technology

- Develop mechanisms to measure, monitor, and mange trustworthiness of services and its provider
- Mitigate imperfect information related to trustworthiness of services to create favorable attitude from customers
- Develop multi-dimensional criteria that includes measures for safety, survivability, reputation, performance measure, availability, and fault-tolerance
- Develop standardized means to exchange secured and reliable messages among services
- Develop standardized means to measure quality of services

DISCUSSION

There is growing interest among researchers to use semantic and Web service technologies to interconnect people and machines; however, there is lack of understanding on influences of social dimensions and their subsequent impacts on these technologies. Understanding implications of societal factors are highly important before heavy investments of resources are made for developing and implementing these technologies. This chapter provides understanding on how societal factors are affecting adoption of Web service technology. Societal factors considered in this study are culture, social structures, geography, ethics, and trust.

Influence/ impact framework analysis of these social factors revealed following common themes across factors: need of mechanisms to assess trustworthiness of services and its provider, need of mechanisms to manage relationships, need of mechanisms to enforce privacy and control access to confidential information, and need of mechanisms to support globalization management. Well-developed mechanisms for the above needs would create favorable conditions for organizations to adopt and conduct their business using Web services technology, thereby, increasing the rate at which Web services technology is adopted.

Culture in itself is not a fixed entity to explain what is happening, but conditions produced and used by the people in and out of activities (Liu & Westrup, 2003). Hofstede's five cultural dimensions were considered as cultural factors for analysis on their implications on the adoption of Web service technology. However, Web service adoption could be cross-organizational and cross-national. Hofstede's five dimensions are for categorizing national culture not for cross-national interactions; therefore other appropriate additional cultural factors such as situation culture should be considered for future work. Situation culture, contrasts views of culture as fixed and immutable, and instead suggests culture as a locally-based phenomenon grounded in the everyday practices and behaviors of particular groups of people in particular settings (Weisinger & Trauth, 2002).

Three modalities (signification, domination and legitimation) from Gidden's theory of structuration were used as social structure factors for analysis on their implications on the adoption of Web service technology. One of the critique on Gidden's theory is that it focuses on categorization of social structure, thus, offering only conceptual model for explaining reproduction of social structure but does not provide methodological approach to understand and reflect back into the world of practice (Rose, 1998). Rose and Scheepers (Rose & Scheepers, 2001) illustrates how the basic concepts of theory of structuration can be adapted by including a more familiar mode of practice (models, frameworks, vocabulary, and tools) to provide framework for understanding discourse style of information systems. Web service technology follows discourse style of information systems, because supporting communication among services is it core characteristic (Umapathy & Purao, 2007a). Therefore, framework provided by Rose and Scheepers for social practice should be considered for future work.

The reach of Internet is beyond geographical boundaries, which forces us to deal with different interpretations of ethics when using the Internet-based technologies (Gattiker, 2001). This chapter tries to answer the question "what are the ethical implications of creating and using Web services?", but questions like "How can we ethically integrate Web services into society?" and "What are the specific social and ethical responsibilities of Web services developers?" are still unanswered.

Societal factors considered in this study are same for both Business-to-Business (B2B) and Business-to-Consumer (B2C) markets, but a study by Gibbs and et al. (Gibbs, Kraemer, & Dedrick, 2003) shows that B2B market seems to be driven by global forces whereas B2C market seems to be driven by local forces. Thus, appropriate global and national policies needs to be considered before adopting Web service technology in either markets.

One of the key factors for successful adoption of Web service technology would be creation of trusted environment for conducting business through Internet protocols. Trustworthiness is multi-dimensional concept; this chapter provides assessment from social dimension. However, necessary technologies have to be constructed that would help organizations to estimate and manage trust among business partners and their services in real-time basis. Such technologies would enable organization reap significant benefits when they adopt Web service technologies as they can use third party resources in a trusted environment.

In this chapter I have considered culture, social structure, ethics, region/ geography, and trust as social factors, and using influence/ impact framework I have shown how these factors influences and subsequently impacts on the adoption of Web service technology. In this section I have critically analyzed societal factors considered in this study and also indicated future direction for this study. In this chapter, I have considered only societal level of analysis, but the adoption of Web service technology would involve both societal and organizational level of analysis. Next ideal step would be to conduct similar study as a multiple level analysis, including both organizational and societal factors.

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KEY TERMS AND DEFINITIONS

Culture: Is a collective mindset of members of a community that distinguishes from members of other communities.

Ethics: Is a normative value system that dictates whether a human action is right or wrong.

Geography: A large land area with particular geographic, political, or cultural characteristics that distinguishes it from other land areas.

Globalization: Can be characterized as exchanges such as capital, goods, ideologies, information, and technology among people across the globe.

Social Structure: Is the basis on which individuals perform their actions depending on associated rules and resources.

Technology Adoption: In organizational context, can be defined as commitment to invest towards implementing and using a technology to support core business functionalities.

Trust: Is willingness of a party to be vulnerable to unmonitored actions of another party.

Web Services: A software system that provides set of standards to support communication and coordination among services over a network, such as Internet, to achieve their goals.

Chapter XXX
The Geospatial Semantic Web: What are its Implications for Geospatial Information Users?

Rafael Moreno-Sanchez
University of Colorado Denver, USA

ABSTRACT

The Semantic Web (SW) and Geospatial Semantic Web (GSW) are considered the next step in the evolution of the Web. For most non-Web specialists, geospatial information professionals, and non-computer-science students these concepts and their impacts on the way we use the Web are not clearly understood. The purpose of this chapter is to provide this broad audience of non-specialists with a basic understanding of: the needs and visions driving the evolution toward the SW and GSW; the principles and technologies involved in their implementation; the state of the art in the efforts to create the GSW; the impacts of the GSW on the way we use the Web to discover, evaluate, and integrate geospatial data and services; and the needs for future research and development to make the GSW a reality. A background on the SW is first presented to serve as a basis for more specific discussions on the GSW.

INTRODUCTION

The Semantic Web (SW) and its corresponding Geospatial Semantic Web (GSW) in the area of geospatial information have been hailed as the next big thing in the evolution of the World Wide Web (WWW or the Web) and how it is used to accomplish useful tasks. However, for most non-Web specialists, geospatial information professionals, and non-computer-science students, these concepts and their implications are not clearly understood. Even less understood are the principles and technologies underpinning their implementation, how they relate to each other, and the current state of the art of the efforts to make these concepts a reality. This is not surprising given that the SW and the GSW are relatively new concepts that are fluid, evolving, and approached in different ways depending on the perspective that is taken to analyze them or to try to implement them. However, it is important to disseminate among non-Web specialists and students a basic understanding of the needs and visions driving the evolution toward the SW and the GSW, and what the most important principles and technologies involved in the creation of these visions are. This knowledge will allow them to better participate in this evolution and will facilitate the eventual uptake and dissemination of the principles, technologies, and standards that are fundamental for the emergence of the SW and GSW.

This chapter provides an overview of the GSW and shows how it relates to the general idea of the SW. The purpose of the chapter is to provide a broad audience of non-Web specialists with a basic understanding of: the needs and visions driving the evolution of the SW and GSW; some of the most important principles and promising technologies involved in the creation of these visions; how these principles and technologies are related to each other and are integrated into current attempts to develop the SW and the GSW; and through examples illustrate some of the possible implications and impacts of the GSW on the way we use the Web to search for information and integrate sources of information and services. The chapter also points to the latest literature and Web resources to expand the basic understanding here provided.

The rest of the chapter is organized as follows. Section two presents a brief background on the SW and a scenario of how it could be used to address information needs. Section three concentrates on the GSW, first it presents an overview of some of the most promising efforts for the implementation of this vision; later an example scenario illustrates how the most promising principles, technologies, and standards are being integrated in the latest efforts to implement the GSW; at the end of this section there is a presentation of the potential impacts of the GSW on the way we search for, discover, and integrate geospatial data and services. Finally, section four presents a series of conclusions and needs for further research and development to achieve the full potential of the SW and GSW.

BACKGROUND ON THE CHARACTERISTICS OF AND THE NEED FOR THE SEMANTIC WEB (SW)

There are numerous definitions of the SW. Yu (2007) reports that there are 290 websites containing the term SW and providing some sort of definition of it; a search in Google for the "Semantic Web" term in Web documents and scholarly works returns 15,300,000 pages (Hepp, 2006). Passin (2004 pp. 3-4) provides several definitions that vary based on the approach taken to analyze or implement the SW. Instead of providing another definition, let's first consider the current limitations of the WWW and why we need an evolution toward the SW and the GSW.

The original intent of the Web was to create a system where information could be linked. The idea was to define a few basic, common rules or protocols that would allow one computer to talk to another located anywhere. For the Web, those elements were (in decreasing order of importance): Universal Resource Identifiers (URIs), the Hypertext Transfer Protocol (HTTP), and the Hypertext Markup Language (HTML) (Berners-Lee, 2000). After going through several evolution stages the Web has evolved into a complex knowledge space where service agents (software that automates processes, acts independently on behalf of the user and has some decision making capabilities) and Web 2.0 technologies help humans to search and organize information (Ding & Xu, 2007).

What are the most common uses of the Web today? The basic functions from a user perspective are (Yu, 2007): search for information; integrate sources of information and services (Web Services); and data mining (i.e. use of software agents to search and retrieve information of particular interest in a particular domain). These activities are carried out in many different contexts and for different purposes (e.g. casual browsing, e-business, emergency response, security and intelligence).

What allows us to carry out these functions on the Web? Many principles and technologies, but most important among them are the interoperability of information and applications created by the agreement on the use of standards and open specifications such as HTTP (for communication) and HTML (for encoding and display of information).

What are the limitations of the Web as we know it today and hence the need for a SW? The main limitation of the current Web is that it was designed to store and display information meant to be read and interpreted by humans (Yu, 2007; Kuhn, 2005; Passin, 2004). Computers or software agents don't understand the intended meaning (semantics) of a piece of information found on the Web. Hence, the most common activities we carry out on the Web (searches, integration of information and services, and data mining) are not as efficient or automated as they could be. For example, today a search for "agent" will return web pages related to a sports or talent agent, agent orange, and software agent.

The lack of understanding of the meaning (semantics) of terms and concepts by computers creates the following problems (Yu, 2007): First, the result of most Web searches is the retrieval and presentation to the user of a large amount of information that is irrelevant to the intended purpose of the search. The user has to scan through all the returned pieces of information to extract the ones that are relevant for the task at hand. In the SW computers are aware of the meaning and context of terms used in searches and hence they retrieve and present to the user only results relevant to the intended purpose of the search, thus human intervention is minimized in finding appropriate pieces of information (e.g. Ding et al., 2005; Seth et al., 2005; Heflin & Hendler, 2001).

Second, today the integration of information sources and services (Web Services) requires too much manual work. Web services are self-contained, self-describing, modular applications that can be published, located, and dynamically invoked across the Web. Once a Web service is deployed, other applications (and other Web Services) can discover and invoke the deployed service (Di, 2004). The first step in the process of integration is to discover the information sources or services required to achieve the task at hand. Currently this step requires a lot of human intervention (Yu, 2007; Passin, 2004). Although the components needed to complete a task might exist on the Web, today's Web is not capable of storing, making available, and processing the meaning of any of these components. Therefore, an agent (a piece of software that automates processes, acts independently on behalf of the user, and has some degree of intelligence) is extremely limited in its capabilities to automate the discovery and integration of information sources and services. This means that today fully automated discovery, composition, and orchestration of Web Services are not possible. The SW promises to facilitate these activities by enabling the storage, exposure, and processing of the meaning and context of the terms and Web services found on the SW (e.g. Klusch et al., 2006; Burstein et al., 2005; Rao & Su, 2005; Medhajed et al., 2003: Sycara et al., 2003; Hendler, 2001).

Third, in the current Web environment data mining is inefficient and expensive because a specialized data mining program has to be developed for each particular application context, and it is very hard to reuse any of these case specific data mining programs (Yu, 2007). Only the developer of the data mining program knows the meaning of each data element in the data source, and how these data elements should interact to present useful information. These meanings have to be integrated without flexibility (hard wired) into the mining software before setting it to work. There is no way for the mining agent to understand, learn, and adapt to these meanings as it works through a task (Yu, 2007). In the SW generic intelligent data mining agents could be built for specific domains and reuse them when data mining is required in that domain (e.g. Berendt et al., 2002; Payne et al., 2002; Hendler, 2001).

With this basic understanding of the limitations of the current Web and why an evolution toward the SW is required, it will be easier now to explore a definition of what the SW is. The SW refers to the vision of having data on the Web defined and linked in a way that it can be used by machines not just for display purposes, but for automation, integration, and reuse of data across application, enterprise, and information community boundaries (http://www.w3.org/2001/sw/SW-FAQ).

What will the SW allow us to do? The following scenario presented by Berners-Lee et al. (2001) illustrates the capabilities envisioned for the SW. Two SW users (Lucy and Pete) in different locations are involved in trying to achieve the following task: find a physical therapist **within a *20-mile radius*** of their Mom's *home* that is covered in her health insurance plan and with a *rating of excellent or very good on trusted rating services*; once a suitable therapy provider is found they want to set up an appointment for their Mom. Both Pete and Lucy make use of software agents that are part of their mobile communication devices (cell phone or Personal Digital Assistant PDA) to search for information on the SW. Lucy's agent retrieves information about her Mom's prescribed treatment from her doctor's agent. Then Lucy's *agent looks up in the SW several lists of physical therapy providers* checking for the desired criteria mentioned above. Once Lucy's agent identifies a suitable list of potential physical therapy providers, it initiates *interactions with each of the physical therapy service provider's agents to try to arrange an appointment* that matches available appointments and available times in Lucy's and Pete's personal agendas.

A potential appointment with a physical therapy provider that matches the criteria specified in Lucy's search is returned to Lucy's mobile device. Lucy forwards it to Pete. Pete doesn't like it. He set his own agent to redo the search with stricter preferences about ***location*** and *time*. Lucy's agent, having *complete trust* in Pete's agent in the context of the present task, automatically assisted by supplying access certificates and shortcuts to the data it had already sorted through. Almost instantly the new plan was presented: a much closer clinic and earlier times—but there were two warning notes. First, Pete would have to reschedule a couple of his *less important* appointments (they are stored in his PDA). He checked what they were—not a problem. The other was something about the insurance company's list failing to include this provider under physical therapists, the agent reports: "Service type and insurance plan status securely verified by other means", the agent offers the alternative "Explain" to provide more details regarding this issue.

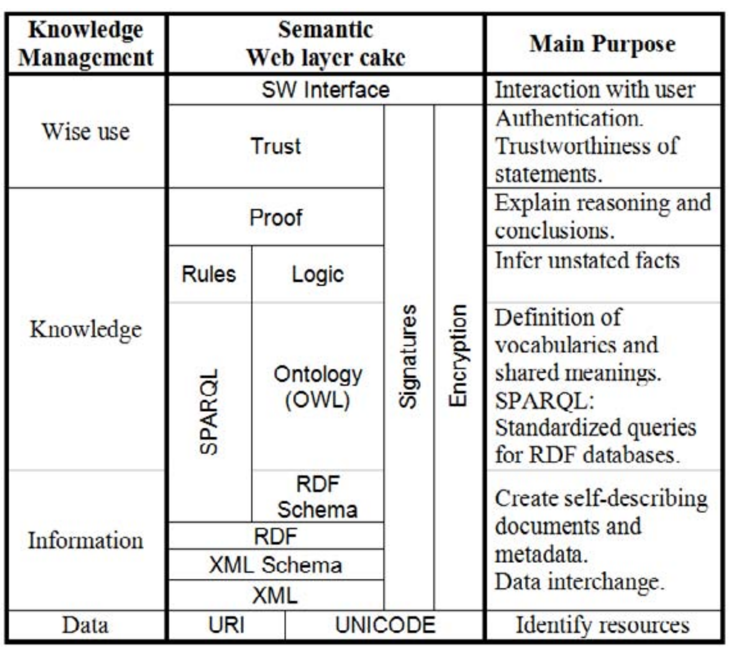
As noted by Berners-Lee et al. (2001), the text emphasized in italics in this scenario indicate terms whose semantics (meaning) were defined for the agent through the SW. It is worth noting that even in this early vision of the use and potential of the SW there are elements that require the participation of the Geospatial Semantic Web (GSW). Here they are emphasized with bold font; they have to do with spatial relations and concepts (e.g. distance and location). After reading the rest of this chapter, the reader should return to this initial scenario and be able to identify the SW and GSW components that make possible the behaviors and capabilities described in the scenario.

What are the principles and technologies involved in making this vision a reality? Figure 1 (second column from left) presents what is known as the SW layer cake. This is a very simplified representation of the principles and technologies involved in implementing the vision of the SW. Each layer is seen as building on (and requiring) the ones below it. In what follows, we will very briefly explain this SW layer cake. While reading the explanation of each layer of the cake, the reader should relate the principles and technologies presented with the functionality described in the scenario above. It is important to note here, however, that the principles and technologies involved in creating the SW are numerous and rapidly evolving, the space provided here is not enough to present them or discuss them beyond this extremely elementary level. For more extensive discussions of these points, the following two books are very accessible to non-Web specialists Yu (2007) and Passin (2004).

At the base of the cake, UNICODE allows computers to consistently represent and manipulate text in most of the world's writing systems, while URI (Uniform Resource Identifier) is used to identify or name resources on the Web. Moving up through the layers, XML (Extensible Markup Language) and XML Schemas are used to facilitate the sharing of structure data across different systems on the Web. RDF (Resource Description Language) is to the SW what HTML has been to the Web. It is the basic building block to support the SW (Yu, 2007, pp. 39-69). RDF is an XML-based language for describing (through metadata) information contained in a Web resource. It is machine understandable. It allows interoperability among applications exchanging machine-understandable information on the Web (see Decker et al., 2000). RDF Schema or (RDFS) is an extensible knowledge representation language that provides basic elements for the description of ontologies (or RDF vocabularies).

An ontology defines the terms used to describe and represent an area of knowledge. An ontology is domain specific (e.g. medicine, education, geography). It contains terms and a hierarchical

Figure 1. The Semantic Web layer cake



representation (superclasses, classes, subclasses) of the relationship between these terms (Yu, 2007). Besides these hierarchical relationships between terms, other relationships between classes and subclasses can be expressed by using a special kind of term: properties. Properties describe various features and attributes of the concepts. By clearly defining terms and the relationships among them, an ontology encodes the knowledge of a domain in such a way that it can be understood by a computer (which is a key feature of the SW). OWL (Web Ontology Language) is the most popular language for creating ontologies. OWL and RDF Schema have the same purpose: define classes, properties, and their relationships. However, OWL is capable of expressing much more complex and richer relationships. With this added capability, software agents or tools can be constructed with greatly enhanced reasoning (or intelligence) ability. See Passin (2004 chapter 2) and Yu (2007 chapter 5) for examples of how RDF and OWL can be used to describe data and their relationships. SPARQL is an RDF query language (http://www.w3.org/TR/rdf-sparql-query/). SPARQL defines a standard way in which to communicate with RDF-based services on the Web, and in this way creating interoperability between different RDF tools and services.

Continuing up the SW layers, logic is the study of correct reasoning used as a means to make correct conclusions. In the SW, logic is used to: infer facts that have not been explicitly stated; explain why a particular conclusion has been reached; detect contradictory statements and claims; and combine information from distributed sources in a coherent way (Passin, 2004). The use of rules to prescribe the behavior of software is one of the oldest practices in the field of computing. They are commonly used in expert systems. Rules can be used in combination with ontologies, or as a means to specify ontologies. In particular, simple rules and axioms can be applied via ontology languages, either in conjunction with or as an alternative to description logics. Rules can also be applied over ontologies, so as to draw inferences, express constraints, specify policies, react to events/changes, discover new knowledge, or transform data (e.g. RuleML see Boley, 2006; www.ruleml.org).

On the upper end of the SW layers, is the issue of trust. People won't use the SW unless they can trust the answers it gives. Information processors on the SW will use logical operations to prove a range of assertions. Having done so, they can (if asked) explain to human users how they came to any particular conclusion (e.g Pinheiro da Silva et al., 2006). Furthermore, once a proof has been carried out, it can be posted on the Web for the benefit of other agents. Still, proofs are not enough for people to believe an answer obtained from the SW. Proofs depend on statements originating on computers distributed all over the SW. The truth of these statements cannot be safely assumed. So proof must be augmented by trust. Digital signatures and encryption are tools used to established trust (Passin, 2004; Richardson et al., 2003). The idea is that documents in the SW will be digitally signed (and/or encrypted) by their authors. So will RDF statements. This will provide a universal basis for deciding how a SW user (and his/her agents) should trust a given document, RDF assertion, or Web service (e.g. Oldemilla et al., 2005; O'Hara et al., 2004). As time goes by, it is expected that a "Web of trust" will come into existence by propagating trust (or conversely distrust) transitively (A trusts B, B trusts C and D, then A can trust C and D) (Welsh, 2003). The following website provides numerous up-to-date resources regarding the issues of trust and security on the SW: http://www4.wiwiss.fu-berlin.de/bizer/SWTSGuide/.

Finally, at the top of SW layer cake is the issue of interfaces to interact with the SW. Several efforts and research projects are on their way in this area, for example the Tabulator project (Berners-Lee et al., 2006; http://www.w3.org/2005/ajar/tab) and Swoogle (Ding et al., 2004; http://swoogle.umbc.edu/).

To make the full functionality of the SW a reality, not only must data be made machine-understandable, but also computers and software agents must be able to understand and work with Web Services (see Hepp, 2006). Specifically this means that computers and software agents must be able to find the service, describe the service and the procedures to invoke it, invoke the service, and exchange data with the service (see Benatallah & Motahari Nezhad, 2005; Cardoso & Sheth, 2005; Yu et al., 2005; Cabral et al., 2004). Currently the Semantic Web Services research community is much smaller than the general SW research community and more work is necessary in the area of SW services (Hepp, 2006). Several technologies not listed in the SW layer cake come into play in the area of SW services. For example, OWL-S (formerly DAML-S) (http://www.w3.org/Submission/OWL-S/) is an upper ontology for services that can be used to describe what a service can do, how it works, and how to invoke it (see Martin et al., 2005). OWL-S enables the automatic, discovery, invocation, composition, and monitoring of Web services. UDDI (Universal Description, Discovery and Integration) and WSDL (Web Services Description Language) are light weight alternatives to OWL-S to add semantics to Web services and enable automatic service discovery. Semantics are added to Web services by inserting annotations into the current Web service standards (Yu, 2007; Rao & Su, 2005). WSDL is an XML-based language that describes key technical data needed for connecting to a service (http://www.w3schools.com/wsdl/wsdl_intro.asp). UDDI is being developed to play the role of a directory service where businesses can register and search for Web services (Passin, 2004, pp. 194-196; http://www.w3schools.com/WSDL/wsdl_uddi.asp).

The following websites present useful up-to-date information on SW applications and case studies (http://www.w3.org/2001/sw/sweo/public/UseCases/), SW tools (http://www.mkbergman.com/?page_id=325), and SW resources on the Web (http://www.iturls.com/English/TechHotspot/TH_SemanticWeb.asp).

THE GEOSPATIAL SEMANTIC WEB (GSW)

The GSW can be viewed as an augmentation to the SW that adds geospatial abstractions, as well as related reasoning, representation and query mechanisms (Brodaric, 2007; O'Dea et al., 2005; Fonseca and Sheth, 2003; Egenhofer, 2002).

Why do we need the GSW? In addition to the needs previously describe for the SW, we need the GSW because access to and use of geospatial information have radically changed in the last decade. The pattern of geographic information utilization has shifted from monolithic local systems (i.e. GIS) towards distributed computing environments (e.g. Spatial Data Infrastructures). Two implications arise from this shift toward distributed environments (Klein, 2006): 1) The number of users with access to geographic information has increased as well as the variation in the users' experiences, viewpoints, and information needs; and 2) geographic datasets that were once produced for a specific purpose and used only within the same organization or information community, are now accessible to a broad and heterogeneous user community.

Previously, the data processed by a GIS system as well the methods used to create it had resided locally and contained information that was sufficiently unambiguous in the respective information community (e.g. transportation). Now both data and methods might be retrieved and combined in an ad hoc way from anywhere in the world, escaping their local contexts. They contain attributes, data types, and operations with meanings that differ from those implied by locally-held catalogues and manuals (i.e. there is semantic heterogeneity). Furthermore, the semantics specified by these local resources is not machine-readable, and hence cannot be shared with other systems (Kuhn, 2005). In this context, currently available methods for finding and integrating geospatial information and services are often insufficient and inefficient (Fonseca & Sheth, 2003; Egenhofer, 2002; Bishr, 1998).

Also, it is important to consider that there are three basic types of geographic information that must be handled to make the GSW a reality (Fonseca & Seth, 2003): (a) *Professional*, that is to say structured geographic information stored in geographic databases (e.g. information in GML format that is part of Spatial Data Infrastructures) which are indexed or described in Web pages; (b) *Naïve*, composed of unstructured, subjacent, informal geographic information in Web pages (e.g. references to places in Web pages); and (c) *Scientific*, i.e. geographic information in scientific papers, models, and theories.

The heterogeneity in geospatial information that exists in today's distributed environments may be classified into (Gosh & Paul, 2006; Nikolaos et al., 2005; Bishr, 1998): syntactic heterogeneity (i.e. various data models are used for data storage and access); schematic heterogeneity (i.e. use of different generalizations and hierarchies); and semantic heterogeneity (i.e. non-uniformity in naming and the meaning of entities, attributes, and relations).

Semantic heterogeneity causes serious problems and resolving it is the key to resolving the other types of information heterogeneity. Data from one source is useless if other sources of data, and geoprocessing services can't understand it properly. The existence of semantic heterogeneity is to be expected because organizations have created information independently of each other, and they use terminology and concepts that are specific to their respective fields of expertise and information communities. Resolving the schematic or the syntactic heterogeneity could not be achieved without knowledge of the mental models of the underlying disciplines. This means that resolving the semantic heterogeneity is the key to resolving schematic and syntactic heterogeneity (Bishr, 1998).

What is required to create the GSW? Numerous things, but most important among them are: (1) Creating semantic interoperability among heterogonous geospatial data and services; and (2) making geospatial data and services machine-understandable. More specifically, semantic heterogeneity issues need to be resolved to enable software agents to perform:(a) Data discovery and evaluation; (b) service discovery and evaluation; and (c) service composition (Kunh, 2005).

How can semantic interoperability and machine-interpretable geospatial data and services be achieved? In a nutshell, through the creation of geo-ontologies and their use for the semantic enrichment of geospatial data and geospatial Web services descriptions. The task of assigning machine-recognizable meaning to terms and relationships includes identifying classes (e.g. a county class), taxonomic hierarchies (e.g. counties subdivide states, which in turn subdivide countries), and relationships (e.g. a county "contains" cities). The formalization of these categorizations and relationships into standard structures creates ontologies (Lowe, 2005). More formally, an ontology is a representation of a set of concepts within a domain and the relationships between those concepts. In other words, an ontology defines the vocabulary of a domain (e.g. transportation). It provides precise definitions that can be linked to different contexts so that the terms used (e.g. highway or secondary road) have precise meanings that can be handled by software agents (Fonseca & Rodriguez, 2007; Arpinar et al., 2006).

By using ontologies to enrich the descriptions of geospatial data and services, the semantics of data content or service functionality become machine-interpretable, and users are enabled to pose concise and expressive queries. Furthermore, logical reasoning can be used to discover implicit relationships between search terms and service descriptions as well as to flexibly construct taxonomies for classifying advertisements in catalogues (Lutz & Klein, 2006; Lutz, 2005). Equally important is the use of ontologies to achieve shared understanding.

Ontologies are evolving as the basis for improving data usage, achieving semantic interoperability, developing advanced methods for representing and using complex metadata, correlating information, knowledge sharing and discovery (Fonseca & Sheth, 2003; Rodriguez & Egenhofer, 2003). For all the reasons previously mentioned, the creation of geo-ontologies and their use in the semantic annotation of geospatial data and services is a fundamental area of research and development for the realization of the GSW (Fonseca & Rodriguez, 2007; Kolas et al., 2005; Fonseca & Sheth, 2003). Several conferences (e.g. Fonseca et al., 2007) and special issues of leading GIScience journals (e.g. *Transactions in GIS* volume 11, number 3, 2007) have been fully dedicated to the subject of geo-ontologies.

Efforts to Create the GSW

Several technologies and approaches are being tried to solve semantic heterogeneity issues to enable agents to perform: a) geospatial data discovery and evaluation (i.e. matching an information offer with an information request); b) geospatial service discovery and evaluation (i.e. matching requests for specific functionality with functionality offerings); and c) geospatial service composition (i.e. matching services to form a combined service, and match the combined service with a request for functionality) (see Kunh, 2005).

Regarding the task of geospatial data discovery and evaluation, semantic interoperability is crucial for automating the searching of data sources and evaluating their content for their appropriateness to respond to a search (Halevy et al., 2003). To address this issue, Klein (2007) proposes a rule-based approach for the automatic semantic annotation of data sources that are part of Spatial Data Infrastructures (SDI) that are available through the Web. The proposed approach adopts developments from the general Semantic Web (such as OWL-DL and Semantic Web Rule Language SWRL) and developments in the area of open specifications for geospatial information (such as Geographic Markup Language GML and Web Feature Services WFS from the OGC. See the technology reference list at the end of the chapter for sources of more information). This work builds on previous efforts described in Klein (2006) and Klein & Lutz (2005). In contrast with the work presented in Klein (2007), which considers only structured geospatial data (i.e. *Professional* geospatial information) contained in SDI's, Arpinar et al. (2006) attempt to address the need to handle *Professional* as well as *Naïve* geospatial information. The framework proposed by this research incorporates the ability to automatically track metadata from syntactically (i.e. with different data models) and semantically (i.e. with different meanings) heterogeneous and multimodal (e.g. text information; images) data from diverse sources.

Next we present some recent research efforts that are attempting to enable the automatic discovery, evaluation, and composition of geospatial Web services. Just as in the case of the SW (see Hepp, 2006), the fulfillment of the vision of the GSW requires going beyond resolving the semantic heterogeneity existing in distributed geospatial data, and getting into solving the semantic issues that will allow the discovery, evaluation, and composition of geospatial Web services by software agents. The latter tasks are more difficult than the first (Kuhn, 2005).

The Open Geospatial Consortium (OGC, www.opengeospatial.org) is leading a Geospatial Semantic Web Interoperability Experiment (GSW.IE, http://www.opengeospatial.org/projects/initiatives/gswie). Two test demonstrations have been carried out as part of this experiment, one led by a group mostly based in the USA (see Lieberman 2006; related work is presented in Kolas et al., 2005), and the other led by a group based in the Institute for Geoinformatics at Munster University, Germany (ifgi http://ifgi.uni-muenster.de/english/ and http://musil.uni-muenster.de/; related work is presented in Lutz, 2005 and 2007; Klein et al., 2006; and Lutz & Klein, 2006).

The GSW.IE makes use of the OGC's Web Feature Service (WFS) and Catalogue Service/Web service specifications, as well as the GML and Filter Encoding (FE) specifications. The information communities considered in the GSW.IE were geospatial intelligence and aeronautical navigation (Lieberman, 2006). Both of the test demonstrations mentioned above worked on an end-to-end semantic geospatial query case, where WFS/FE data and services relevant to a query are discovered through knowledgebase reasoning. Several of the technologies described in the previous SW section were involved or tested: RDF, RDFS, OWL, OWL-S, SPARQL, SWRL; and others not mentioned before such as SESAME (http://www.openrdf.org/), and SESAME-HTTP (http://www.openrdf.org/doc/sesame2/system/ch08.html). Also several OGC specifications were involved: Web Map Services (WMS), WFS, GML, and Catalogue. Lieberman (2006) describes in detailed the processes and methods involved in the GSW.IE.

As part of the ifgi effort, Lutz (2007 and 2005) (with related work presented in Klein et al., 2006 and 2004; Lutz, 2004; Lutz & Klein, 2006; and Lutz & Klein, 2006) worked on the application of an ontology-based methodology for the discovery, access, and composition of geospatial Web services that provide geospatial data and geoprocessing functionality (e.g. creation of buffers, or calculating distance) on the provided data. These research efforts develop on several OGC's specifications (e.g WFS, Catalogue, and Web Processing Services WPS), and standards from International Standards Organization ISO (e.g. ISO 19115 and ISO 19119 metadata standards for geospatial data and geospatial services respectively).

A different attempt for the creation of the GSW is the SWING (Semantic Web Services Interoperability for Geospatial Decision Making, http://www.swing-project.org/index.html) project. This is a European initiative for the deployment of Semantic Web Services technology in the geospatial domain (Andrei et al., 2008; Roman & Klein, 2007). The SWING project aims to create an environment that supports the entire life-cycle of geospatial Semantic Web Services. It integrates an end-user tool, a tool for development of new geospatial Web services, a commercial services Catalogue, the Web Services Execution Environment, and an annotation tool. Demonstrations have been carried out where the environment is used for: The semantic annotation of a legacy Web service; the semantic discovery of a geospatial Semantic Web Service; and the composition of a new geospatial Semantic Web Service. This project also builds on OGC's specifications such as WFS, WMS, and WPS, and on W3C specifications such as WSML (Web Service Modeling Language) (see technologies reference list at the end of the chapter).

Besides the projects here presented, other research efforts exist for attempting to implement the envisioned GSW features and functionality (e.g. Di et al., 2008; Gone & Schade, 2007; Aktas et al., 2006). Each of these approaches addresses specific GSW components or functionality and rests in a series of assumptions and restrictions. At this point in time there is no single or clearly superior path toward the realization of the GSW. Much research is still necessary on their full deployment, and on the evaluation of their advantages and shortcomings.

GSW Usage Scenario

This section contains a simplied scenario of the use of the GSW. The aim of this scenario is to provide a basic understanding of the capabilities and functionality envisioned for the GSW. Also, the scenario is used as a medium to present how some of the technologies and open specifications by the OGC and the World Wide Web Consortium (W3C) relate to each other and fall in place in the flow of processes that take place when using the envisioned GSW. We keep technical details to a minimum and some times we use non-technical language to facilitate ease of reading. As mentioned above, a technology reference list is provided at the end of the chapter to facilitate accessing more information about each of the technologies or specifications mentioned in this section.

The presentation of the inner workings of the GSW described in this section follows the GSW. IE approach. The principles and technologies used in this approach are explained in more detail in Lutz (2007 and 2005), Lutz & Klein (2006), Klein et al. (2006), and Lieberman (2006). These authors present examples of the use of the envisioned GSW in finding a restaurant, retrieving hydrological information, disaster management, and finding airports with specific characteristics respectively.

Scenario: Mary's car breaks down in the early evening. Fortunately, she has her location-aware cell phone which has an integrated Global Positioning System (GPS) and is capable of accessing the GSW. Her cell phone reports her current location in UTM coordinates (in meters). *The request:* She uses her GSW agent through a GSW interface to specify the following search: *"Find a garage or gas station within 5 kilometers from my current location that is currently open and that has a traveling mechanic and/or a tow truck"*.

The GSW infrastructure required: To fulfill Mary's request her agent needs to first find and then evaluate the suitability and compatibility of two types of geospatial Web services: (a) Those providing geospatial data (offering location of gas stations and garages in the city and characteristics of their services including opening times); and (b) geospatial Web services offering geoprocessing of geospatial data (capable of calculating the distance from Mary's location to the gas stations or garages to be able to select the ones closer than 5 miles). After the appropriate data and geoprocessing services have been discovered, Mary's agent needs to be able to compose (or create a chain) of the geospatial Web services identified as the best suited to respond to her query.

Let's consider first the task of finding and evaluating geospatial Web services offering data or geoprocessing functionality. *How is Mary's agent capable of performing this task?* Two methods make this possible: the semantic enrichment of metadata describing geospatial data and geospatial Web services; and the use of Web services catalogues or directories (see Figure 2).

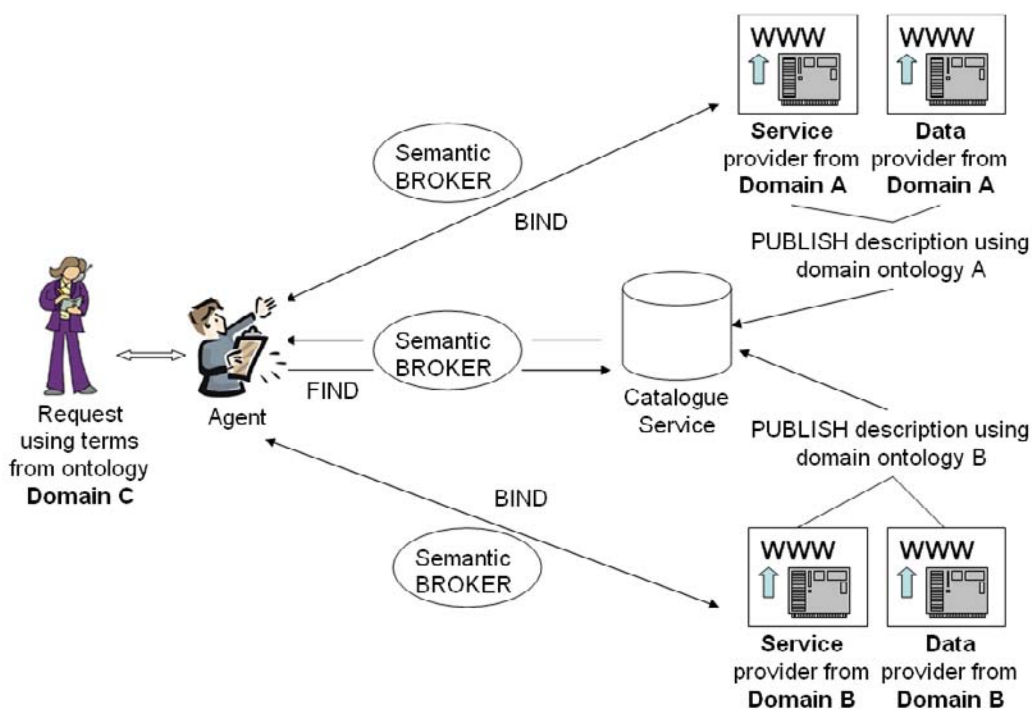
First, in the GSW the metadata describing each geospatial Web service (e.g. following the ISO 19119 specification), and the metadata describing the data offered by a geospatial data service (e.g. following the ISO 19115 specification) have been enriched using ontologies (which would have been created using OWL-S for services and OWL-DL for data). Hence, the semantics of data content or service functionality become machine-interpretable, and users are enabled to pose concise and expressive queries (such as: "garage" "*within*" 5 miles from my "*current location*" "with" "traveling mechanic"). Furthermore, the semantic annotation of data and geoprocessing resources makes logical reasoning possible. This feature can be used to discover implicit relationships between search terms and service or data descriptions, as well as to flexibly construct taxonomies for classifying advertisements in catalogues (Web sites listing services). These capabilities greatly improve on current (keyword-based) approaches to service discovery which are inherently restricted by the ambiguities of natural language, and can lead to low precision (i.e. too many useless resources retrieved) and/or recall (i.e. not all the good resources retrieved).

Second, the discovery of geospatial data and geoprocessing Web services is facilitated by the existence of Web service catalogues or directories (see Figure 2). This type of Web sites exist because service providers (e.g. government agencies or companies that offer geospatial data or geoprocessing functionality) register (publish) their services with a catalogue of services (e.g. using OGC's Catalogue Service technology).

Data service providers can make their data collections available through the Web using one or more of the interoperable interfaces suggested by the OCG for distribution of geospatial data on the Web (e.g. WMS, WFS, or WCS). Let's assume they all use WFS (this assumption is necessary in our scenario because only WFS's provide access to the geospatial feature level with attributes, such as garage location and opening hours). Clients (such as an agent) find resources in these catalogues, and then bind directly to a particular service (this is known as the "publish-find-bind" process; see Figure 2). In the case of GSW this process might require an additional step of translation through a semantic broker function from their native knowledge domain into a knowledge domain accessible to the retrieving client. *Why?* Because in heterogeneous and distributed environments, it has to be assumed that many diverse descriptions of feature types and geoprocessing operations are produced for the registration and discovery of geographic information services in catalogues. To keep these descriptions comparable it is crucial that they be based on a shared vocabulary (or domain ontology).

In the process of discovering and evaluating data and geoprocessing services Mary's agent made use of a semantics broker to be able to match the vocabulary (or ontology) used in Mary's

Figure 2. Use of OGC catalogues and the publish-find-bind arrangement for the discovery of geospatial data and services



request and the vocabulary used by each of the data and geoprocessing service providers found on the GSW (see Figure 2). These vocabularies have to match in two different aspects: a) in the semantics of the operation (or functionality); and b) in the semantics of the interfaces of adjacent services. The first ensures that the service actually does what the client expects it to do; the second ensures that the service correctly interprets the data it receives as input from the preceding service when services are chained.

How is this matching of ontologies done? An OWL-DL reasoning engine such as RACER (http://www.sts.tu-harburg.de/~r.f.moeller/racer/), Pellet (http://pellet.owldl.com/), or FaCT++ (http://owl.man.ac.uk/factplusplus/) could be used to find out which of the service providers' terms equal or are encompassed by the term used in the GSW user's request. All terms for which this is the case are considered to be a match for the request.

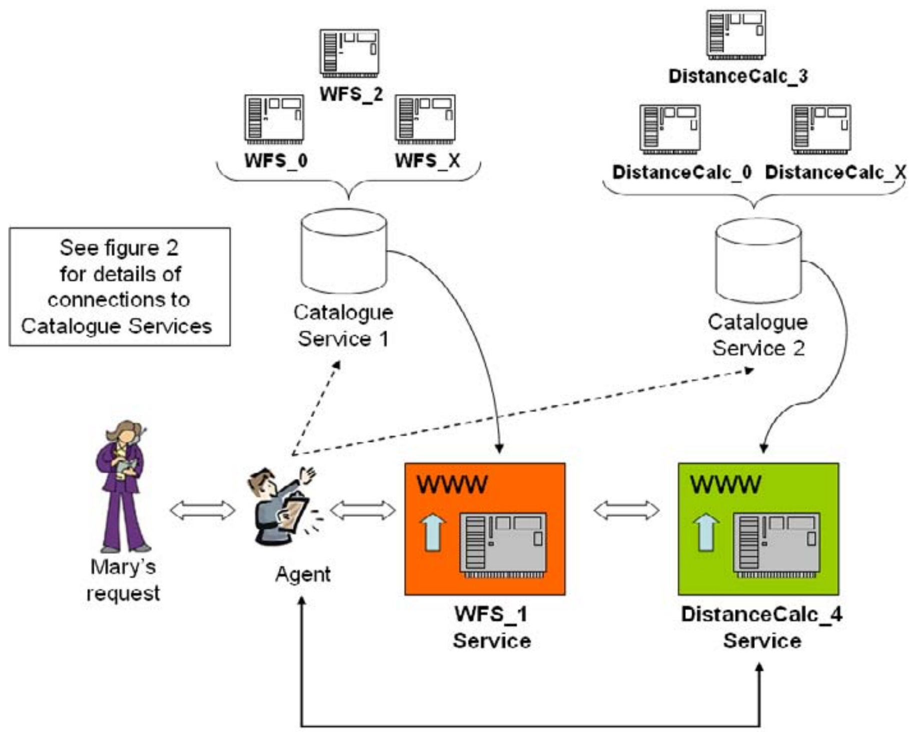
After its search in the GSW, Mary's agent has determined that a combination (a composition or service chain) of the data offered by data provider called "WFS_1" with the spatial analysis functionality provided by the geoprocessing service called "DistanceCalc_4" will best respond to Mary's query. *How did the agent make these selections?* The WFS_1 data service provides locations (as points in UTM coordinates, in meters) of "car repair business" with several attributes including opening hours and services offered (such as tow truck). In the domain ontology of the WFS_1 service "gas station with mechanic service", "garage", and "car dealership with service department" are all subclasses of "car repair business". Other data providers were deemed inferior by Mary's agent because they offered more restrictive listings of potentially useful car repair services (e.g. listed only "garages"), or they were less compatible with the DistanceCalc_4 service (e.g. they report locations of car repair businesses only as addresses). The inferior service providers that were not selected are represented by small service icons in Figure 3.

Service discovery is a very important part of service composition, but service composition also imposes some constraints on service discovery. The component services of the service chain that have already been discovered (such as WFS_1) have to be taken into account during the subsequent discovery steps (in our case finding the best distances calculator service). In other words: a) The outputs of preceding and the inputs of succeeding services have to be considered in order to ensure that the data exchanged between services in a chain are interpreted correctly; and b) the operation (or geoprocessing functionality) provided by each of the services already discovered have to be considered in order to derive which part of the required overall functionality is still missing (see thick arrow connectors in figure 3).

In our scenario the DistanceCalc_4 geoprocessing service was selected because it does what is required to answer Mary's request, and it takes as input the outputs of the previous service WFS_1 that has been already selected. DistanceCalc_4 is capable of taking as input point locations (identifying source and destinations) in UTM coordinates (the output of WFS_1), and calculating the straight line distance between these locations in meters (see Figure 3).

Notice how in the discovery and evaluation processes Mary's agent is showing some degree of logical reasoning that is enabled in part by the semantic interoperability created as explained before. The agent was able to identify WFS_1 as a superior data source option because after matching the domain ontology of Mary's request with the domain ontology used by WFS_1, it realized that this service listed more car repair options than others. Then, in the process of selecting the next Web service required to answer Mary's request, the agent took into account the characteristics of WFS_1 (e.g. it reports locations in UTM coordinates) that had already been selected as part of the criteria for selecting a distance-calculation

Figure 3. Composition of the chain of SW and GSW services required to answer Mary's query



service. These reasoning capabilities enable another feature of the envisioned GSW: agents will be capable of explaining the reasoning that led them to a conclusion or answer. For example, after Mary receives an answer in her cell phone she can push the button "Explain" in her GSW interface and receive a presentation of the chain of logic that lead to the answer received.

Once the best suited services have been discovered and evaluated based on their compatibility, ability to provide the required data, and ability to perform the required analyses, they need to be composed (or chained) to respond to Mary's request. The output of one service (WFS_1) is passed as input to the next service (DistanceCalc_4) where it is processed. The output of Distance_4 (distance from Mary to all car repair businesses) can be passed to another Web service (e.g. a service called "MathLogic_13") capable of performing simple logical mathematical operations to select all points less than 5 kilometers from Mary's location. The list of these points is then formatted using for example XLST for display on Mary's cell phone as a table or a map.

The vision of the GSW and the principles and technologies that will make it a reality are works in progress. Usage scenarios like the one here presented help to convey the importance and value of the GSW vision. Other examples of applications of the GSW in military intelligence (O'Dea et al., 2005), fire alerts (McFarren et al., 2006), and sustainable management of natural resources (MiMS part of the SWING project http://www.swing-project.org/demos.html), as well as the short videos explaining the functionality and operation of the components that integrate the SWING framework (http://www.swing-project.org/demos.html) are valuable resources to complement the basic understanding of the GSW vision provided in this section.

Impacts of the GSW

Addressing some of the most important challenges of the 21st century will require access, fusion, and analysis of large quantities of diverse and heterogeneous data sets that originate from distinct information communities. Geographic information will play a major role as the spatial and temporal dimensions of social, economic, and environmental activities and phenomena are fundamental considerations in decision making. The understanding of the functioning and interactions of natural and man-made systems across multiple spatial and temporal scales will be fundamental to advance all scientific, resources management, and policy-making endeavors. Achieving this understanding will require efficient data and information integration, accessibility, and distribution.

Geographic information and geoprocessing services are becoming more readily available through distributed computing environments. Not only professional structured geographic information stored in geospatial databases is more available, but also unstructured, subjacent, information geographic information in Web pages, and geographic information contained in scientific papers, models and theories. This increased information availability is positive. However, it also makes its discovery and evaluation more complicated and time consuming. On one hand, it can lead to information overload with searches that retrieve too many useless resources. On the other, it can lead to low recall where not all the valuable resources are retrieved.

The emergence of the GSW promises to help in addressing these challenges by delivering the following features. It will improve the discovery and evaluation of geospatial data and geoprocessing services, and it will facilitate their composition into service chains capable of responding to complex queries. The GSW will also reduce human involvement in carrying on these tasks by delegating several steps to software agents. The interoperability present in the GSW will allow joining professional structured geospatial data contained in online databases with informal unstructured geographic information contained in Web pages originally not intended for geospatial processing. Geospatial data and geoprocessing services will become more accessible and usable beyond what have been so far their traditional professional and casual user communities. Finally, the evolution toward the GSW will make legacy geospatial data more available as data collections are eventually semantically annotated for their incorporation into the GSW. These capabilities will enhance the productivity of public and private organizations, professionals in diverse disciplines, and casual users of geospatial data and services with the potential resulting social, economic, and environmental benefits.

CONCLUSION

Are the SW and the GSW pipe dreams, or can they really be created and deliver their full potential? This is a question that can't be answered with any confidence; however the opinions of leaders in industry and academia favor the latter (e.g. Serial No. 110-10, 2007; Shadbolt et. al., 2006; Passin, 2004 pp. 237-255). Much progress has been made in the theories, technologies, and adoption of standards that will facilitate the evolution toward a fully functional SW and GSW. There are already several early examples of applications of the SW. The GSW efforts are following closely behind.

Currently several approaches exist for the creation of the SW and GSW, each addresses specific components or functionality of the SW or GSW and rests in a series of assumptions and restrictions. At this point in time there is no single or clearly superior path toward the realization of these visions. Much research is still necessary on the full deployment and on the evaluation of the advantages and shortcomings of each of the proposed approaches for the implementation of the SW and GSW.

The following challenges will need to be overcome to realize the visions of the SW and the GSW (see Passin 2004; Benjamins et. al., 2002). It will be necessary to upgrade currently available Web content (e.g. Web pages), geospatial data repositories, catalogues, and geoprocessing services to the SW and GSW (e.g. through semantic annotation). Ontologies in general, and geo-ontologies in particular, will have to be created, developed, and adopted; also mappings between diverse ontologies will have to be created. Principles and technologies that are successful in the early stages of the GSW and that work with relatively small amounts of data and services will have to prove that they are scalable to be able to work with larger amounts of information and services as the GSW grows. The issue of multilinguality will have to be addressed to allow the creation and access to semantic content, data, and services independently of the native language of providers and users. New techniques for user interfaces and visualization that go beyond the usual hypertext currently used in the Web will have to be explored. Semantic Web languages will have to become stable to allow the creation of the necessary infrastructure that supports the SW and the GSW. Finally, we will have to deal with the issue of trust and provenance (i.e. the when, where, and conditions under which information originated) of data, services, and content.

It is important to continue work on the cutting edge of Web science and technology using focus incubator communities with a pressing technology need (Shadbolt et. al., 2006). At the same time, it is equally important to disseminate among non-Web specialists and a broader community of potential users a basic understanding of the needs and visions driving the evolution toward the SW and the GSW, as well as of the significance and value of the principles, technologies, and standards involved in their creation. Such knowledge will allow this community to better participate in the SW and GSW evolution and will facilitate the eventual uptake and dissemination of the principles, technologies, and standards that are fundamental for the emergence of the SW and GSW.

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KEY TERMS AND DEFINITIONS

Geoprocessing: Is the manipulation of geospatial data and the analysis of these data to derive information. Geoprocessing is used to generate high-quality data, perform quality control checks on data, and undertake modeling and analysis.

Geospatial Data and Information: Are data and information that identify the geographic location (using precise scientific coordinates), and the characteristics of natural or constructed features and boundaries on the Earth.

Geospatial Semantic Web: Is an augmentation to the Semantic Web that adds geospatial abstractions, as well as related reasoning, representation and query mechanisms.

Interoperability: Is the ability for a system or components of a system to provide information portability and interapplication cooperative process control. This means software components operating reciprocally to overcome tedious batch conversion tasks, import/export obstacles, and distributed resource access barriers imposed by heterogeneous processing environments and heterogeneous data.

Ontology: Is a representation of a set of concepts within a domain and the relationships between those concepts. In other words, an ontology defines the vocabulary of a domain.

Semantic Web: is an extension of the current Web in which data and information on the Web are defined and linked in a way that it can be used by computers not only for display purposes, but for automation, integration, and reuse of data across various applications. The Semantic Web allows computers to make more sense of the information on the Web with the result of facilitating better cooperation between computers and people.

Web Services: Are self-contained, self-describing, modular applications that can be published, located, and dynamically invoked across the Web.

Chapter XXXI
Enabling Distributed Cognitive Collaborations on the Semantic Web

Amna Basharat
National University of Computer and Emerging Sciences, Pakistan

Gabriella Spinelli
Brunel University, UK

ABSTRACT

To date research on improving the state of multi-agent collaboration has only focused on the provision of grounding tools, technologies, protocols, standards and infrastructures that drive the Semantic Web and agent architectures. The basic cognitive and interactional requirements of agents have been neglected leading to the current state-of-the-art development of the Semantic Web whereby its full potential is constrained by the rigid state of multi-agent collaboration. This chapter illustrates and discusses an alternative approach to the development of the agent mediated Semantic Web. The fundamental premise of our approach is that enhancing agents cognitive and interactional abilities is the key to make the digital world of agents more flexible and adaptive in its role to facilitate distributed collaboration. The novelty of this research is that it adapts cognitive models from HCI to develop a heuristic framework called Cognitive Modelling of Multi-Agent Action (COMMAA) for modeling agents' actions in an attempt to provide an architecture that improves the flexibility of Multi-agent interaction by promoting cognitive awareness. The results of the evaluation show an improved flexibility, interoperability and reusability of agents' collective behaviours and goals.

INTRODUCTION

Agents may be autonomous and intelligent entities which typically operate in distributed collaborative environments called Multi-Agent Systems (MAS) which allows multiple heterogenous agents to collaborate by engaging in flexible, high-level interactions (Wooldridge, 2002; Jennings 2000).

Presently, the usability of agent-based applications in a Semantic Web environment is limited due to lack of flexibility in agent's collaboration with multiple agents including humans. This imposes constraints on the interoperability and reusability of agents' behaviour that operate in MAS environment. In addition, the inflexibility of the agents' behaviour does not provide direct mapping to the end user since the end user cannot predict how the agent will behave, thus generating cognitive overload on humans. To date, research on improving the state of multi-agent collaboration has only focused on the provision of grounding tools, technologies, protocols, standards and infrastructures that drive the Semantic Web and agent architectures. Neglect of basic cognitive and interactional requirements are discovered to be the basic reasons for the rigid state of multi-agent collaboration constraining its full potential.

This research presented in this chapter adapts a distributed cognitive view of the agent mediated Semantic Web and argues that enhancing cognition is the key to make the digital world of agents more flexible and adaptive in its role to facilitate distributed collaboration. To this end, work on imparting cognition to improve interaction between multiple agents has been limited. The novelty of this research is that it adapts cognitive models from HCI to develop a heuristic modelling framework for COgnitive Modelling of Multi-Agent Actions (COMMAA) in an attempt to provide an architecture that improves the flexibility of Multi-agent interaction by promoting cognitive awareness. The highlight of the framework is that it identifies architectural and knowledge-based requirements for agents to structure ontological models for cognitive profiling in order to increase cognitive awareness between themselves, which in turn promotes flexibility, reusability and predictability of agent behaviour. The ultimate aim is towards applications which advocate user-centeredness such that as little cognitive overload is incurred on humans. The Semantic Web is used as an action mediating space, where shared knowledge base in the form of ontological models provides affordances for improving cognitive awareness.

Based on the rationale and concerns described above, the objectives and a brief outline of the chapter presented in the next section.

OBJECTIVES OF THE CHAPTER

The following chapter will serve the following aims and objectives:

- Delineate upon the current limitations in the state of multi-agent collaboration in order to elaborate the rationale, need and the synergistic role of cognitive dimension to the Semantic Web with particular regard to distributed collaborations amongst agents
- Describe the conceptual constituents of a theoretical framework called Cognitive Model of Multi-Agent Action (COMMAA) derived from cognitive models in HCI to improve the state of multi-agent collaboration
- Detail upon the Design and Implementation of Semantic Representational and Ontological Models based on the theoretical principles of COMMAA that allow cognitive processing of an agents action using state of the art Semantic Web technologies
- Describe heuristic reasoning mechanisms that can be derived from cognitive models to enhance the cognition of Semantic Web agents
- Analyze and discuss the impact of using COMMAA to model multi-agent collaborative applications on the Semantic Web

BACKGROUND

The Semantic Web vision of Berners Lee (2001) has enabled the Web applications to move from a purely human user community towards a mixed user community consisting of humans as well as of software agents. This imposes certain challenges and brings new requirements towards models for modelling Semantic Web-based systems (Scott et al. 2005; Klein et al. 2004; Neuhold 2003). The foremost issue is that of adaptive collaborative coordination and cooperation for utilizing services and Web information and imposes challenges from the perspective of interaction as well as interoperability amongst both agents and humans (Arai & Ishida 2004). As software agents become more capable and more prevalent, they must be able to interact with a heterogenous collection of both humans and software agents, which can play diverse roles in a system, with varying degrees of autonomy, initiative, and authority across different tasks (Schreckenghost et al. 2002). However, research supporting such interaction with these types of agents has received relatively little attention (Martin et al. 2003a; 2003b).

Limitations in the State of Multi-Agent Interaction

While there has been a significant proliferation of agent architectures and applications in the Semantic Web domain, there is significant separation of concerns from the principles that ensure flexibility of distributed interaction between heterogenous agents. Recently, much effort has been expended on making agents interoperate in the emerging open environments and standards. The Foundation for Intelligent Physical Agents (FIPA), an IEEE Computer Society standards organization, has attempted to facilitate the interoperation and inter-working between agents across multiple, heterogenous agent systems (FIPA, 2007). A variety of FIPA-Compliant platforms have emerged (Luck et. al (2005) provide a review). Despite this effort, this goal has still not yet been achieved as Louis and Martinez (2005a) point out. In addition, the Agentcities European project (Willmott, 2003) which resulted in the deployment of a worldwide open testbed environment, underlined the lack of 'spontaneous' exchanges between agents running in this environment. In almost all cases, agents can only interact with agents they have been designed to interact with. One reason is that agents are implemented using mechanisms such that they conform to only a limited set of interaction protocols generally resulting in inflexible or rigid agents. It is reported in research and learnt from previous experience (Ahmad et al. 2005, Shafiq et al. 2005, Tariq et al. 2005a, Tariq et al. 2005b) that the agents show unyielding behaviour to messages not specified by the protocol. Efforts such as Louis and Martinez (2005a;2005b) have attempted to address the issues but the focus has been largely to provide semantic handling of messages.

It is therefore believed that there is still a long way to go before true homogenisation of agent communities can be achieved. This is because the variance of agent communication and functional pragmatics introduces a certain level of mismatch and the need of flexible and adaptive interactions that promote interoperation becomes imperative. This is particularly essential when the agents from diverse platforms intend to co-exist and cooperate in mutual. In addition, most agent-based applications assume pre-defined knowledge of agents' capabilities and/or neglect basic cognitive and interactional requirements in multi-agent collaboration. Thus the research community is faced with the challenges of improving the limited visibility of agent's processing ability and behaviours that may be a result of possible mismatches between the agents' mental and implementation models. In addition, it is claimed that inadequate adjustability of the agent's autonomy and a basic lack of compatibility between the required capabilities and those provided by an agent impose further research challenges (Martin et al. 2003a; 2003b).

Potential of Cognitive Models to Improve the State of Multi-Agent Interaction

Some interdisciplinary research has stressed the potential of cognitive models studied in cognitive science as substantial means of better probing multi-agent issues, by taking into account essential characteristics of cognitive agents and their various capacities (Sun 2001). The term cognitive models has traditionally been associated with humans as cognition is essentially a human characteristic. Cognition can be thought of as a modelling process which creates a model from which deductions can be drawn (Meredith 1970). Humans are known to continually create and access internal representations of their current situation - referred to as their cognitive model (Saja 1985). It is said that the state of interaction with a system can be greatly improved by design activities that account for and support the emergence of a user's cognitive model. These models are referred to as mental models in human-computer interaction (Norman 1986; 1988).

Inspired by the potential of cognitive models, the research presented in this chapter investigates the possibility of meeting the above mentioned challenges by bringing cognitive models and theories in the Semantic Web to achieve more robust and effective architectures for agents that facilitate distributed collaboration– be it amongst agents or between agents and humans or vice versa. The premise of the research is based on the hypothesis that if artificial (or software) agents were to be designed to emulate the interactional and cognitive properties of humans in a complementary way, such that they interact with each other and their environment in the manner that humans do, it would increase their functional capability to serve humans. Additionally it would also reduce the cognitive load that humans require in distributed collaborations while viewing it from a distributed cognitive perspective.

RESEARCH MOTIVATION AND CONTEXT: DISTRIBUTED COGNITIVE VIEW OF THE AGENT MEDIATED SEMANTIC WEB

The view adapted for Semantic Web is that of a world-mediating system as it mediates between users and a part of the world, often by manipulating machine representations of the world (Clark, 2001). At the basis of this research is the idea to view the Semantic Web as a distributed cognitive system, a basic unit of analysis, composed of human and machine agents in a work domain that is delineated by roles, work and communication norms, artefacts, and procedures (Zhang et al, 2002).

According to (Lu, Dong & Fotouhi 2002) the Semantic Web uses ontologies to describe various Web resources, hence, knowledge on the Web is represented in a structured, logical, and semantic way allowing agents to navigate, harvest and utilise this information (Payne, et al., 2002a;2002b). Agents can also read and reason about published knowledge with the guidance of ontologies. Also the collection of Web-services described by ontologies like OWL-S (Ankolekar et al. 2001; Martin et al. 2005;2007) will facilitate dynamic matchmaking among heterogenous agents: service provider agents can advertise their capabilities to middle agents; middle agents store these advertisements; a service requester agent can ask a middle agent whether it knows of some provider agents with desired capabilities; and the middle agent matches the request against the stored advertisements and returns the result, a subset of the stored advertisements (Sycara et al. 2002;1999).

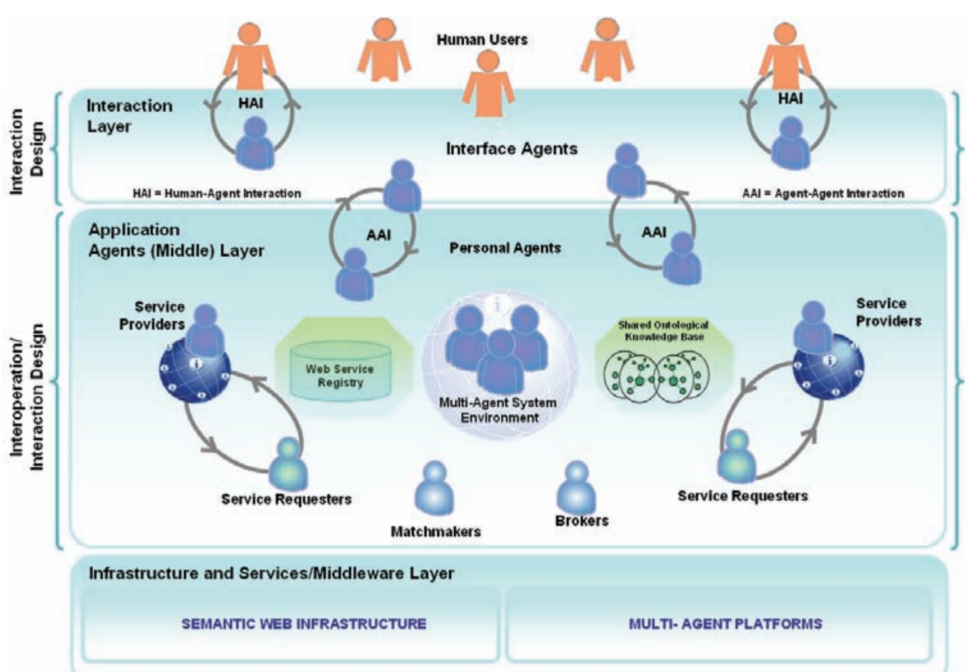
Based on the analysis of literature and state of the art, agent-mediated distributed computing paradigm for the Semantic Web is viewed as a layered abstract architecture shown in Figure 1 -a lens through which multi-agent collaboration can be viewed. Applying the distributed cognitive view of Semantic Web, the abstract layered model revises the traditional view of the Semantic Web by adding cognitively modelled interactions.

The above abstract model of the Semantic Web and agent characteristics requires multi-agent interaction which can consist of three interaction levels: human-human, human-agent, and agent-agent. In each interaction level, both interaction design and interoperability are necessary for mutual accessibility and understanding among them as has also been highlighted by Arai & Ishida (2004). The chapter extends the vision for the need and requirements for modelling these interactions from a distributed cognitive perspective (Basharat and Spinelli, 2008a). By applying the Distributed Cognition perspective Chandrasekharan (2004) this model considers the importance of studying interaction and interoperation amongst multi-agents not in isolation but within the environment agents inhabit. The combination of the Semantic Web inspired by cognitive model can generate a framework where agents and application can better cooperate.

After a review of the available cognitive approaches that model human activities in interaction with any system (artefacts and the environment), the Action Cycle (AC) (Norman 1986; 1992) has been selected as the most promising approach for this research. The aim is to unfold the potential of the AC in an attempt to identify the design and interactional gaps between heterogenous agents on the Semantic Web. The resulting contribution lies in the adoption of the AC to develop a heuristic modelling framework called COgnitive Model of Multi-Agent Actions (COMMAA).

The framework is proposed to model multi-agent actions in a collaborative MAS environment from a cognitive perspective. The framework is intended to aid the designer in modelling the agent behaviour and action through a cognitive cycle. Using the principles of the proposed

Figure 1. Layered Abstract Model for illustrating various levels of Cognitive Collaborations in Agent Mediated Semantic Web



framework designers can define both functional and non functional aspects of the design of an agent's interactive role in a collaborative scenario, especially focusing on the concepts of semantic and articulatory distances, as derived from AC, as mismatch between agents' goals and its functional capabilities.

Not only this research proposes the theoretical guidelines for cognitive modelling of agents, it also provides design illustration for the architectural elements necessary for realizing these principles in the Semantic Web context. Thus the framework identifies architectural and knowledge-based requirements for agents to structure ontological models for cognitive profiling in order to increase cognitive awareness amongst agents. By cognitive awareness, a term coined within this research, it is intended the ability of the Web agents to diagnose their processing limitations and to establish interactions with the external environment (in the form of other agents including humans and software agents) using the principles derived from the framework for COMMAA. This is with the aim to support users' goals in a more direct manner by providing agents that can share, discover and access each other's capabilities in a collaborative manner and are able to function dynamically and adaptively without continuous human intervention.

This brings about a more effective MAS environment; where agents may delegate each other tasks and goals based on each other's awareness of abilities, behaviours and affordances. The ultimate aim is towards applications which advocate user-centeredness such that as little cognitive overload is incurred on humans. The strength of this framework lies in its robust theoretical foundation that has found validation in a developmental infrastructure that helps realise the theoretical principles.

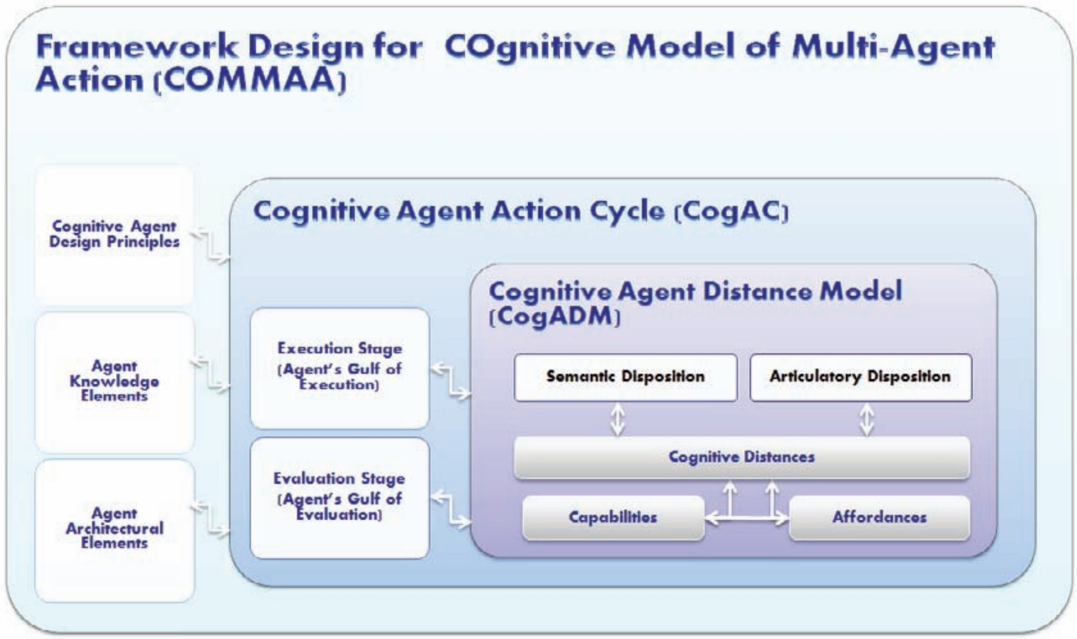
THEORETICAL FRAMEWORK AND CONCEPTUAL CONSTITUENTS FOR COGNITIVE MODEL OF MULTI-AGENT ACTIONS (COMMAA)

The framework developed in this work and presented below is based on these fundamental principles of Agents' action, borrowed and modified from the Human Action Cycle (Norman 1986) and its elaboration for Direct Manipulation Interfaces by Hutchins et al. (1986). The framework of COgnitive Model of Multi-Agent Actions (COMMAA) is shown in the Figure 2. The primary aim of the framework is to cognitively model the agent's action in a collaborative MAS environment situated in the Semantic Web such that the limitations in the state of Multi-Agent Interaction can be overcome.

The conceptual constituents of the framework of COMMAA include:

- **Cognitive agent Action Cycle (CogAC):** COMMAA is based on Cognitive agent Action Cycle (CogAC) which serves as the fundamental core of the framework, and is designed to aid the designer elaborate the agent's functional behaviour using two stages namely Execution and Evaluation, each with its respective steps. The CogAC views agent as the primary entity that interacts and functions in a MAS environment. The stages of an agent interacting with a MAS environment are described such that in order to accomplish a goal, which is in turn delegated to it by a human user, the following steps are traversed by an agent: Goal Formation, Intention formation, Action specification, Execution, Perception, Interpretation and Evaluation.
- **Cognitive Distance Model (CogDM):** The further elaboration of the steps of CogAC leads to the formulation of agent's semantic and articulatory disposition in each stage of execution and evaluation, described and

Figure 2. Conceptual design of Theoretical Framework / Conceptual Constructs of COMMAA – Cognitive Model of Multi-Agent Action



illustrated by the Cognitive Agent Distance Model CogADM. These dispositions also help to identify the agent's Gulf of Execution and Evaluation. These two are discussed in the subsections to follow.

- **Cognitive Agent Design Principles:** The principles are derived using the Action Cycle mapped for agents. The principles may serve as heuristic for evaluating the design of agent-based applications. They help to identify the significant mismatches, constraints and affordances. The framework defines CogADPs only at abstract level. These serve as blueprints which may be specialised to a domain specific context by the designer to derive a context specific cognitive profile for an agent. These may be specialised according to the domain knowledge and the specific contexts of application the agent may be operating in. The design principles aid in Cognitive Mismatch (Distance) Analysis, that allow at design time to be made known the possible stages where distance of execution or evaluation may occur. The designer by analyzing whether provision for these principles in made in the agent's infrastructure can help develop the cognitive profile of the agents, alternatively agents may have the dynamic capability of identifying these distances at runtime and may change, update their profile dynamically.
- **Agent Architectural Elements:** As each sub-stage of agent's execution and evaluation stages are elaborated, and as distances are identified, it helps in identifying the architectural needs and components required for successful completion of agent action cycle. As these are identified by the designer, they may be cross checked against the environment that the agent in being built using. In other words, it may also be said that provision

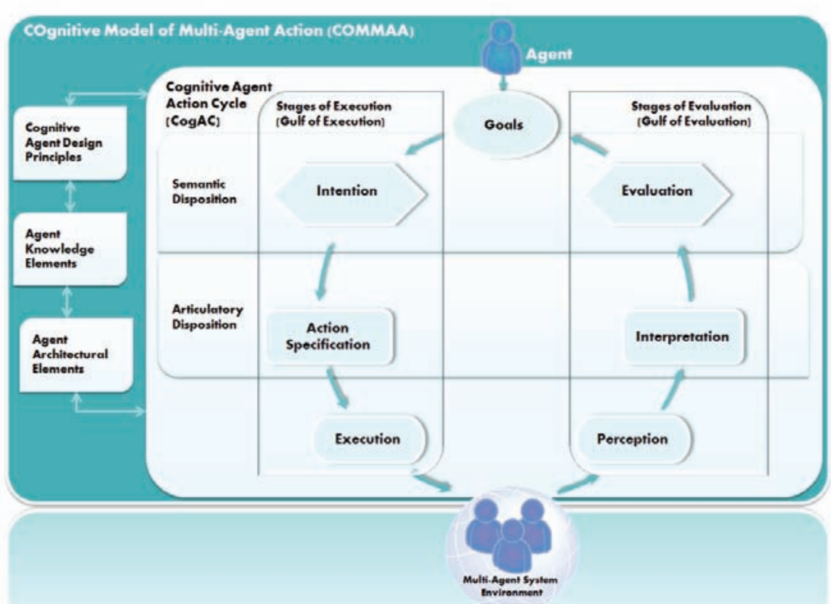
of these capabilities ensure that the agent's Cognitive Design Principles will be met to some extent. The availability of these elements would ensure that the agent is Cognitively Directed, or Cognitive Directness is exhibited in agent's action with respect to its interaction with the environment. The Architectural elements identified ensure the minimal design requirements that must be met in order to bridge the agent's gulfs of execution and evaluation.

- **Agent Knowledge Elements:** The knowledge requirements are identified by the designer such that at each stage of agent's execution and evaluation, these are the elements that the agent must possess or must be provided with in order to achieve the successful realisation of the respective stage.

Cognitive Agent Action Cycle (CogAC)

Agents are designed to continually act upon and monitoring the MAS Environment, interacting with it and collaborating with other agents and entities, evaluating its state, and executing actions. The system is a closed loop: when agents act, it is usually done so in response to some prior evaluation of its perceptions or as a result of some goal delegated to it by a human. After an agent acts, it evaluates the impact of the executed act, often modifying the action as it carries it out. In MAS environment the fundamental unit of agent's social ability is its interaction with other agents using messages in Agent Communication Language (ACL). Agent's Interaction is modelled to have two stages as shown in Figure 3. The Interaction will have some Goal i.e. the objective that needs to be achieved using the interaction. In order to achieve this goal, agent will need to go through the two stages namely Execution and Evaluation

Figure 3. High-level conceptual design of CogAC in relation to other constructs of COMMAA



in order to successfully achieve the goals of the interaction respectively.

The stages of an agent interacting with a MAS environment are described such that in order to accomplish a goal, which is in turn delegated to it by a human user, the following steps are traversed by an agent: Goal Formation, Intention formation, Action specification, Execution, Perception, Interpretation and Evaluation (as shown in Figure 3.). The essential concepts are the Gulfs of Evaluation and Execution, each arising as a result of semantic and articulatory distances (cognitive distances in general). The relevance of these concepts to the agent domain is formally described in the next sections in the form of Cognitive Agent Distance Model, which are detailed further.

The inter-relationship between the CogAC, its stages of execution and evaluation, the semantic and articulatory dispositions and other elements of COMMAA is schematically shown in Figure 3. In Table 1 and Table 2 these stages are elaborated. In addition, a generic view of the corresponding CADPs, Knowledge Requirements and architectural needs are also identified. Together with these main components, the three additional components are identified to help the designer model agents' behaviour in a more robust manner. Cognitive Agent Design Principles, Agent Architectural Elements and Agent Knowledge Elements are all identified, as each stage of the agent's execution and evaluation are elaborated upon.

Cognitive Agent Distance Model (CogADM)

On the Semantic Web, Knowledge is invisible and intangible. While meanings are essential to knowledge, they cannot get across to an agent without some kind of representational form. Knowledge representation has two aspects: the meaning of the information, named semantics, and the physical form or appearance, named syntax.

Table 1. Steps of CogAC in Execution Stage (Agent's Gulf of Execution) cross referenced with design principles, Knowledge elements and Architectural requirements

Steps of CogAC	Description	Cognitive Agent Design Principle (CADP)	Agent Knowledge Elements	Agent Architectural Elements
Execution Stage (Agent's Gulf of Execution)				
Step 1: **Form Goal**	•An Agent's Goal is the state the agent wishes to achieve	•Compatible goal formation •Intention formation •Agent must have the capability to express goals to desired intentions •Semantic Distance Occurs if the capability is not provided to the agent. •Agent is being required to work at lower level of detail, resulting in greater semantic distance	•Task Knowledge Domain knowledge: Appropriate Situation •Affordance for Goal Representation and Formation •Affordance for Expressive Power and Communication	•Goal Representation •Goal to Intention Formulator •Task Representation •Domain Knowledge Representation •Intention Representation
Step 2: Form/ Specify Intentions	•An intention is the decision to act so as to achieve the goal	•Exhibits Semantic Directness of Interaction with the Environment (Disposition of Agent is Semantically Direct wrt its execution of its interactions in the given environment) •Functional Capability for Intention Formation	•Task Knowledge : Intention details	•Content Representing the intentions, as rules or some construct •Heuristic Reasoning needed for Analysis of Functional Capabilities and Semantic Directedness
Step 3: **Action Specification**	•The process (mental) of determining the logical representation of the actions that are to be executed by the agent on the mechanisms of the system (MAS environment) •Action must be taken with respect to the environment the agent is operating in	•Constraints imposed by the environment or the world of the agent must be taken into account •Articulatory Directedness (Disposition of Agent is does not posses any Articulatory distance wrt to execution of its actions in the given environment) •Affordance for Action	•Task Knowledge : Action Details •Domain •Environment Knowledge: Constraints (e.g. Representational)	•Actions Represented as some protocol e.g. Conversation Protocol or Interaction/Negotiation Mechanism •Heuristic Reasoning needed for Analysis of Affordances available and determining the Articulatory directedness
Step 4: **Execution**	•Agent executes the tasks formulated as a result of action specification	• Using the MAS Environment and the middleware to execute its actions	• Knowledge of Execution Mechanisms	•MAS Middleware, Execution Framework, Control Mechanism for Agent's Execution

Table 2. Steps of CogAC in Evaluation Stage (Agent's Gulf of Evaluation) cross referenced with design principles, Knowledge elements and Architectural requirements

Steps of CogAC	Description	Cognitive Agent Design Principle (CADP)	Agent Knowledge Elements	Agent Architectural Elements
Evaluation Stage (Agent's Gulf of Evaluation)				
Step 5: Perception	•Perceive the output, response of an event, a trigger or a message	• Affordance for perceiving the state of the environment	•MAS/Platform Knowledge: •Constructs, Content, Protocols	•Means of Feedback Specification •Means of Perception
Step 6: Interpretation	•The relationship between the state of the MAS environment and the goals of the agent can only be determined by first translating the environment state into psychological states for the agent then interpreting the perceived environment state in terms of agent's variables of interest.	•Articulatory Directedness (Disposition of Agent does not exhibit Articulatory distance wrt to evaluation of its actions and the response of the environment) •Affordance for Reasoning •Affordance for extracting the required meaning from interaction output •Affordance for interpretation of Feedback of the interaction	•Domain Knowledge : Expected effects	•Means of Interpretation •Reasoning Mechanism for Interpretation •Logic Mechanism •Feedback Means •Means to Recognize and Interpret Feedback •Interpretable effects
Step 7: Evaluation	•Evaluation of the environment state requires comparing the interpretation of the environment state with the desired goals. This often leads to a set of new goals and intentions.	•Agent's Functional Capability for Evaluating the Outcome to determine if the goal has been achieved and to determine if it possesses the means to predict the outcome •Semantic Directedness (Disposition of Agent is Semantically Direct wrt to evaluation of its actions and the response of the environment	•Task Knowledge : expected effects •Expected Feedback	•Logics based on which Evaluation is to be carried out •Heuristic Logics •Representational Logics •Expectation Means •Predictability

When an agent interacts with a knowledge representation, it interacts with both the semantics and the syntax.

There is often, however, a gap, known as Cognitive Distance, between the knowledge an agent needs and the manner in which this is represented in its environment, as shown in Figure 4. This manner of representation also includes the mechanisms with which the knowledge is accessed and reasoned about.

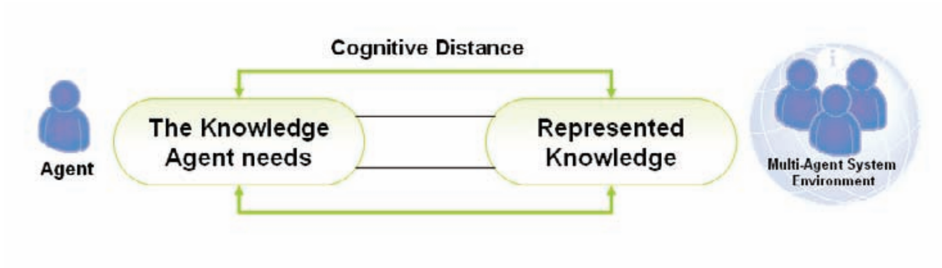
The prospective relevance of the cognitive distances is highly relevant to Communication, collaboration and interactions taking place between agent application residing on the Semantic Web - since the basis of interaction is the communication language and its vocabulary represented as knowledge on the Semantic Web.

Cognitive Distance in this context is taken to be a measure of the gulfs of execution and evaluation

—the conceptual gap, or mismatch between the agent's goals and intentions, and the way in which they are in cohesion to, or represented by, the multi-agent system environment. A large distance is representative of a large gulf in the execution or evaluation stages, signifying that a lot of cognitive load is incurred in translating the agent's intentions into the system's representations, or vice versa.

That is, a large distance of execution means it is relatively difficult or not possible for the agents to express their query or desires to the system, and

Figure 4. Cognitive Knowledge Gap between agent and multi-agent system environment



a large distance of evaluation indicates mismatch of some form within the agent's infrastructure to interpret or evaluate the system's output or response as a result of some interaction with it.

Directness of Agent's Interaction with MAS Environment

Using the directness of interactions as usability measures would involve understanding the agent's problem solving strategies, approaches and intentions as now well the MAS environment supports the agent's functional needs. A design and evaluation methodology that assesses directness requires cognitive basis because understanding the user's mental processes is key to assessment. The concept of directness as suggested by (Hutchins et.al, 1986), and later by (Cuomo 1993) is adapted here to refer to the degree of capacity of an agent to bridge the Gulfs of Execution and Evaluation.

The concept of multi-agent interaction is virtually an unexplored area in terms of operationally defining and assessing the directness of interactions an agent engages in with its MAS environment to a degree that can be applied in practice and measured using qualitative or quantitative tools. Directness of an Agent's Interaction with its environment may be used as a qualitative indicator of the amount of cognitive processing needed to carry out a successful interaction. Directness is inversely proportional to the amount of cognitive processing it takes to manipulate and evaluate the results of agents' interaction with its MAS environment. Moreover the cognitive processing required for an agent is a direct result of the gulfs of execution and evaluation the agent has to deal with. The better the agent's architecture, the less cognitive processing needed and the more direct the resulting interaction between agents.

Thus Distances are complementary to Directness; the lower the distances, the greater the directness, and vice-versa. The two terms distance and directness may be alternatively used, depending on the nature of mismatch or the extent of gulf in the stages of agent action. It would be subsequently shown in the later sections how these concepts are encoded into the profile of agents and how the concepts are important to derive heuristic mechanisms for agents' reasoning.

Applying the Gulfs of Execution and Evaluation in Multi-Agent Environment

In order to identify gaps that separate agents mental states from execution ones, the agent's gulfs of execution and evaluation must be detailed as below:

Agent's Gulfs of Execution: The gulf of execution arises as a result of cognitive distances of execution between the agent and its interaction with the environment (multi-agent, open). The gulf can be identified by elaborating the cognitive distances of execution – which result due to the difference or mismatch between the intentions and the allowable, available actions, capabilities and affordances in its environment. One indicator representing this gulf is to determine how well the agent is able to do the intended actions directly, without extra effort: is the agent able to fulfil its goals delegated to it by humans? Do the actions provided by the agent match those intended by the person? Does the environment/infrastructure (internal infrastructure and/or external environment) provide affordances that allow for the intentions of the agent? If there is a limitation, then there is a gulf of execution in the state of agent's interaction which must be bridged, either with collaborative effort with other agents in the environment or eventually by the human, who would incur cognitive overload or processing. The ultimate aim is to design agents that are able to readily identify and bridge/overcome such a gulf to efficiently achieve the goals set up for them.

Agent's Gulfs of Evaluation: The gulf of evaluation arises as a result of cognitive distances of evaluation between the agent and its interaction with the environment (multi-agent, open); the possible mismatches between agents reasoning capabilities and its representation mechanisms. The Gulf of Evaluation reflects the amount of effort that the agent must exert to interpret the state of its interaction with the system and to determine how well the expectations and intentions have been met. The gulf is smaller when the system provides information about its state in a form that is easy to get, is easy to interpret and matches the manner in which agents' affordances allows these to be perceived.

Bridging the Gulfs and the Cognitive Distances

Directness is inversely proportional to the amount of cognitive effort/processing it takes to manipulate and evaluate the state of interaction with MAS Environment and, moreover, the cognitive effort is a direct result of the gulfs of execution and evaluation. The better the architecture and the environment of the agent helps the agent bridge the gulfs, the less cognitive processing needed and the more directed the resulting interaction. For this, the architecture should facilitate some means of identify, through some indicators, the possible distances and also identify the capabilities and affordances available and not-available corresponding to these indicators.

Agents' Capabilities and Affordances

The concept of affordance is here explored and exploited. It is believed that an affordance inspired agent architecture and environment will help to bridge the gulfs of execution and evaluation. By interfacing perception and action in terms of capabilities and affordances for agents, the aim is to provide a new way for reasoning about agent's capacities and bring about cognitive awareness amongst the agents about each others capacities and constraints, when interacting in a collaborative environment. In Cognitive Science, an affordance is a resource or support that the environment offers an agent for action, and that the agent can directly perceive and employ (Gibson, 1979). Although, this concept has only rarely been used in Semantic Web agent architectures, it offers an original perspective on coupling perception, action and reasoning, differing notably from standard reactive and hybrid architectures. Taking it literally as a means or a metaphor for coupling perception and action directly, the potential that affordances offer for designing new powerful and intuitive agent-based Semantic Web architectures is obvious (Vugt et al. 2006).

The term affordance is adapted for COMMAA to refer to the agent's capacity of action. At each stage of the agent action cycle the agent's corresponding affordance is determined and accounted for. Any constraint in any of the agent's capacities, being the ability to achieve the goal, to formulate the intention or to interpret the consequences of its action, may result in a cognitive distance being introduced. Usually the term affordance is linked to a machine or an application (Norman 1992). In the context of this research affordance is the ability of one agent (the sender) to behave in a way that the other agents in the MAS environment(the receiver) can understand, such that they both have a shared mental model and can trigger, complement or facilitate each other's action/behaviour; therefore these affordances need to be ensured. The affordances are provided by the cognitive artefacts that form part of the agent's internal infrastructure/architecture and its external environment.

Affordances are the opposite concept to distances, so they are complimentary. For instance, an agent's affordance for intention formation will ensure there is no semantic distance of execution and a semantic distance of execution will mean that agent has no affordance for forming an intention. The psychologist Gibson was the first to frame affordances as unified relations between the environment and an actor (Gibson, 1979, p. 127). Affordances can be explained as action possibilities that actors have in the environment. That is, an affordance exists relative to (1) properties of the environment and (2) the action capabilities of an actor (McGrenere and Ho, 2000). For example, a chair has the affordance of 'sitting', because of its shape, height and carrying capacity and because of the humans' ability to sit, the length of their legs, and their weight. The concept of affordances is of particular interest in the field of HCI, which primarily concerned is studying how properties of computers (the environment) and humans (actors) influence their interaction with each other.

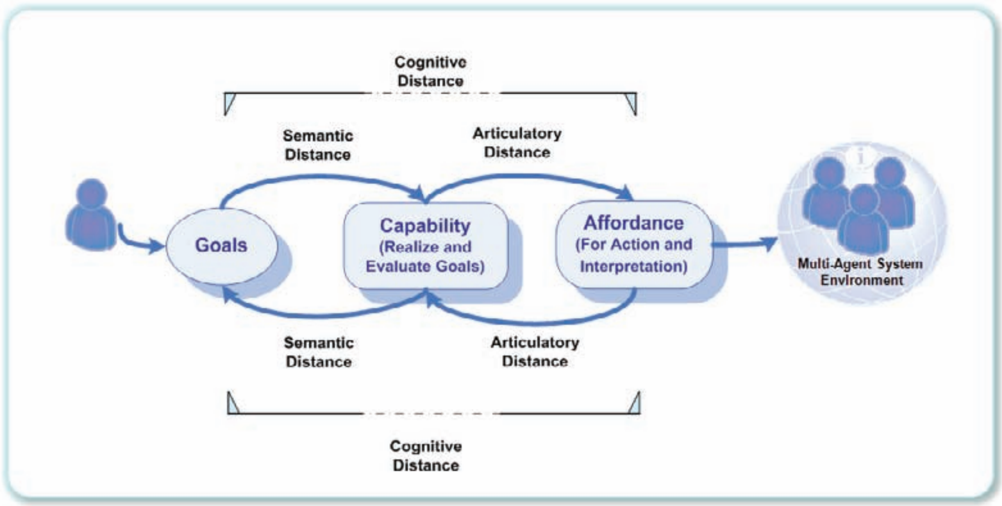
Extending the affordance concept to the Semantic Web, it is believed that by semantically identifying and encoding the affordances of an agent will help achieve cognitive directness of interactions amongst the agents. This will contribute to making agents more interoperable in open and heterogenous environments. Some considerations that must be taken into account include the relationship of goals with respect to agents. Goals are central in affordance evaluations. It is important to understand that an affordance does not change as the needs and goals of the person change (McGrenere & Ho, 2000 interpreting Gibson, 1979). Similarly, for an agent, an affordance must be identified irrespective of what the agent's eventual goals are. E.g. ff an agent affords Message translation from FIPA-ACL into FIPA-SL, it is independent of whether another agent will eventually participate in such interaction where this translation is required. However, agent's actions do depend on the goal context. Agents will typically need to act within the environment (they use an affordance) because of a goal they want to achieve for example, performing a task (Vugt et al. 2006, Kakazu & Hakura 1996).

Semantic and Articulatory Distances in Multi-Agent Interaction Model

Following is a detailed account of how may the components of cognitive distance namely: the Semantic and the Articulatory distances occur in the execution and the evaluation cycles. It is also important to illustrate how the cognitive distances are identified with the help of agents' capabilities and affordances. A conceptual high-level view is shown in Figure 5. Identifying these distances, along with agents' capabilities and affordances is of primary importance in highlighting the possible gulfs of evaluation and execution.

- **Semantic distance:** The degree to which the semantic concepts used by the agent are (1) compatible with those of the other agents (including humans if the interaction is being carried out with a human) and, (2) can be used to easily accomplish the agent's goals
- **Articulatory distance:** The degree to which the form of communication between an agent and its environment reflects the application objects and tasks involved

Figure 5. Components of cognitive distances in multi-agent collaboration



Articulatory distance concerns the actual form that communication takes between say two agents; for example, the choice of Message Encoding, Message Content, Content Type, Interaction Protocol used/employed for the communication. A small articulatory distance results when the input techniques and output representations used are well suited to conveying the required information. Articulatory distance is also decreased when the form of inputs and outputs relate to the semantic concepts used of the underlying conceptual model.

Semantic distance involves the capability of agents required to express desired actions within the concepts of the system. It deals with the possibility to express the concepts of interest concisely using the available capabilities. Semantic distance also involves a measure of how closely the agent's conception of the task domain matches that of the environment. The two distances that compose the Cognitive Distance in Agent's Behaviour are the Semantic Distance and Articulatory Distance. These can be considered as subsets of each of the gulfs, but in reference to input behaviour (initiator's behaviour in communication/interaction) and output behaviour (Respondent's behaviour in communication/Interaction). These are illustrated and discussed in depth below.

An Illustration of Semantic Distance of Execution

Semantic Distance relates to the relationship between an agents intentions and the meaning of expressions, required to convey the agents' intention such that its meaning is interpretable by the intended recipients in the environment. Semantic distance is related to the 'nouns' and 'verbs' or 'objects' and 'actions' provided by an agent's infrastructure and its environment. For execution, forming an intention is the activity that spans semantic distance. The intention specifies the meaning of the input expression that is to satisfy or reach the' agents goal or sub-goal.

If *semantic* indirectness of *execution* existed, agents would not be able to express their intentions directly, or at all in order to achieve the goal delegated to them. Lack of capabilities or affordances would be indicators of this condition. Agent is programmed at lower level of functionality then desired by the human user. The agent or the human may need to carry out more actions then would be expected to accomplish the same goal or intention. E.g. Agent may need to collaborate or request another agent to achieve the goal on its behalf. This requires agent to have desired affordances and capabilities defined. The semantic distance of execution is illustrated in more detail in Figure 6.

An Illustration of Articulatory Distance of Execution

Whereas semantic distance relates to relationships between Agents' formulated intentions and the meanings of expressions/functional capabilities available, articulatory distance in an agent context is defined to relate to relationships between the meanings of expressions/capability and the agent has the affordance to realise the capability in action, or whether agent affords the actions that are essential in achieving the desired intentions. A mismatch of such a form will cause an articulatory distance of execution to exist. The articulatory distance of execution is illustrated in more detail in Figure 7.

An Illustration of Semantic Distance of Evaluation

Semantic distance also occurs on the evaluation side of the interaction cycle. Semantic distance of evaluation is proportional to the amount of processing required by the agent to determine whether the goal has been achieved. The semantic distance of evaluation is illustrated in more detail in Figure 8.

An Illustration of Articulatory Distance of Evaluation

Articulatory distance or indirectness of evaluation would be indicated by errors in interpretation and having to take extra actions to correctly interpret the state of communication or the result of interaction. An agent's inherent articulateness is closely tied to its level of technology. The articulatory distance of evaluation is illustrated in more detail in Figure 9.

Figure 6. An illustration of agent's semantic distance of execution

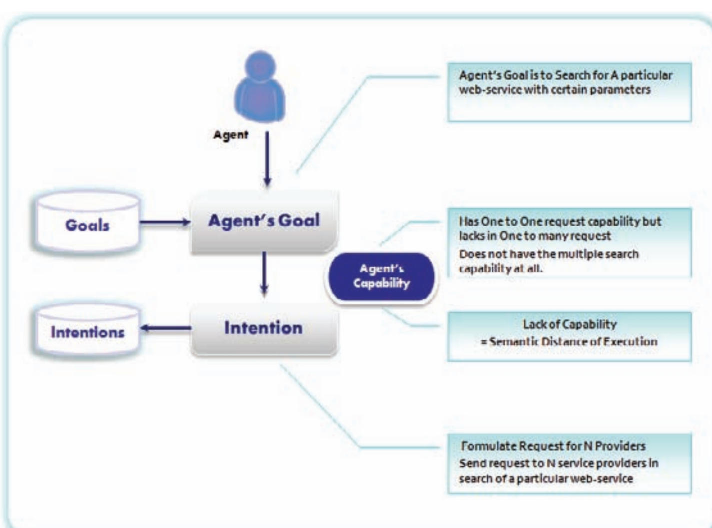


Figure 7. An illustration of agent's articulatory distance of execution

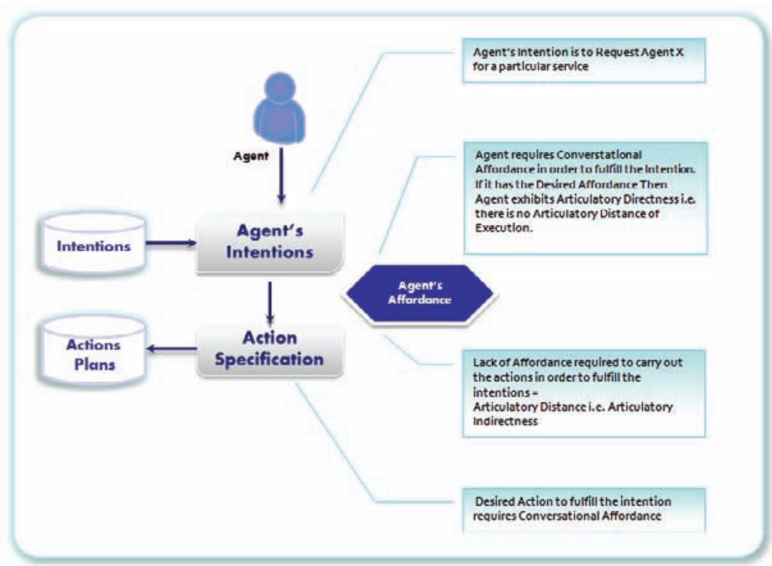


Figure 8. An illustration of agent's semantic distance of evaluation

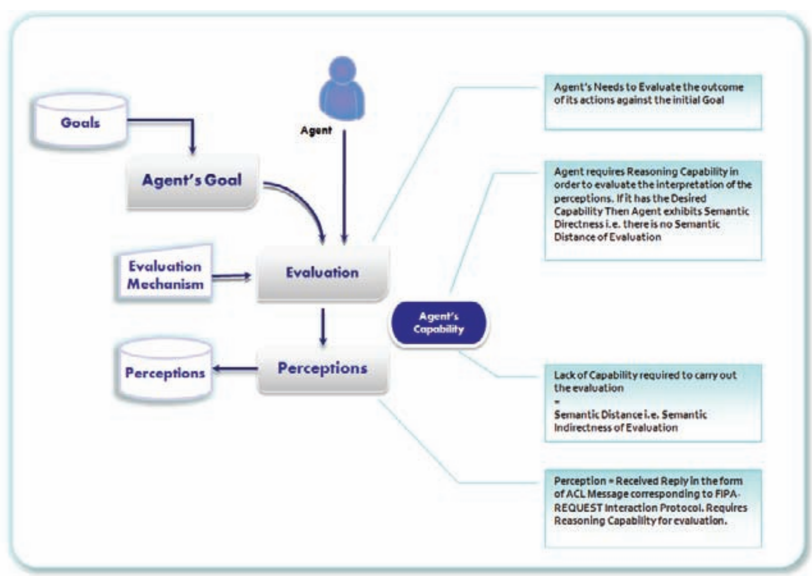
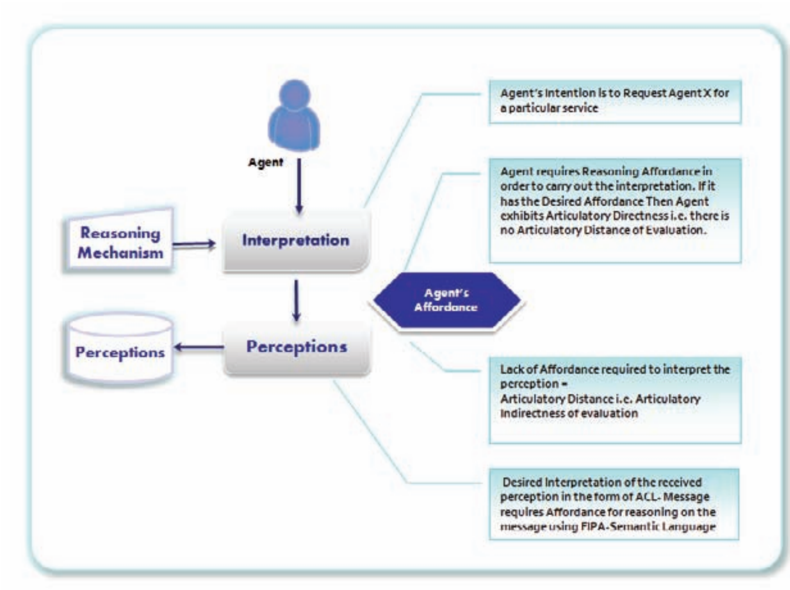


Figure 9. An illustration of agent's articulatory distance of evaluation



DESIGN AND IMPLEMENTATION OF COMMAA INSPIRED AGENT ARCHITECTURE

Design Goals for Cognitive Profiling of Agents

The theoretical foundations of Cognitive Models such as the Action Cycle (AC) bring about important implications in the current Semantic Web architectures. Traditional Web-service agent architectures only allow agents to discover about each others services. However this research claims that an architecture that is inspired from cognitive models would allow the agents to develop a cognitive awareness about each other which could bring to a more effective MAS environment. To validate this claim, a lower-level classification of design goals which provide the basis upon which the Cognitive Profiling Architecture is devised upon includes: (a) Enhanced Negotiation and Collaboration based on Cognitive Awareness (b) Flexibility and Reusability (c)Adaptive Interaction and Interoperability (d)Discovery based on Heuristic reasoning and (e) Minimization of cognitive load on humans.

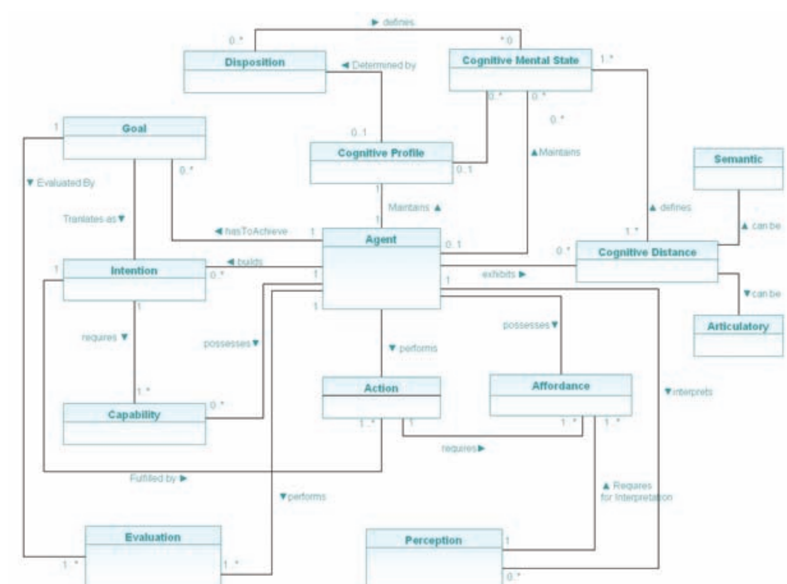
In an attempt to realise the above design goals, which are direct implications of COMMAA, some important considerations are taken into account. Firstly, some mechanism is needed that enables the agents to discover and find out about each others cognitive distances, semantic and articulatory dispositions, capabilities, affordances and constraints. Secondly, dynamic and built in mechanisms are needed for heuristic reasoning and invoking/developing learning, adaptive measures for these constraints and distances to be bridged. These considerations are considered rudimentary to enable agents to be aware of these limitations and Gulfs that may limit their functionality or the extent of services they can provide. As minimal architectural consequences, the elements necessary in COMMAA inspired semantic-Web agent architecture are implemented in a cognitive profiling architecture described in Basharat and Spinelli, (2008b.). The Cognitive Profile of Agents is detailed next.

A Semantic Representation Model for Cognitive Profile of Agents

A possible way of implementing the cognitive profile is by associating an ontology with an agent i.e. agent is given knowledge about its constraints and affordances, its semantic and articulatory disposition. At the heart of the framework is the adoption of ontology to drive the cognitive profile of agents. From a philosophical perspective ontology can be defined as a set of things whose existence is acknowledged by a particular theory or system (Honderich, 1995 cited in Bell et al. 2007). Such 'things' include both types (such as the class of Agents) and individual elements (such as the agent TravelAgent). The adoption of such a definition is important because, when compared with more computationally orientated definitions of ontology (for example, (Gruber 1993); p.1) states that "an ontology is a specification of a conceptualisation"), there is an explicit reference to a system's ontic commitment (i.e., things whose existence is acknowledged or recognised). This leads to representations that are more closely mapped to real world objects.

The use of ontology is also prospective in the Semantic Web action space, since the emerging standards enable reasoning to be carried out effectively on such models. An ontology based reasoner could be invoked on the ontology to carryout reasoning using the heuristic reasoning rules defined; agent could then be made to reason about its state of processing according to CogAC. Architectures that facilitate the sharing of ontologies would enable the agents to discover each other cognitive dispositions thus improving the manner in which they interact. The issue at stake is to be able to represent the cognitive profile adequately and in a manner that can be shared among agents. The Cognitive profile is therefore implemented as an Ontology in OWL, with OWL-DL (Description Logics) as basis of representation of the profile parameters and properties. Being an emergent standard, OWL-DL ensures that the model caters for a more open community. Ontologies have been recognised by the research community as a – model of expressing the knowledge model for agents e.g. by the recent research of (Laclavík et al. 2006).

Figure 10. Conceptual Model of Ontological Knowledge Model for Cognitive Profile of Agents



Conceptual Model for Agents' Cognitive Profile Ontological Model

Figure 10 shows a generic conceptual model, with objects and properties (shown by labels on associations between concepts) of the ontological model to be implemented in order to enable shared cognitive profiling of agents.

Cognitive Profile of Agent

The framework's correct implementation calls for maintaining a cognitive profile of Semantic Web agent. Following are the elements to be maintained in the cognitive profile:

- Agents Cognitive Mental States
- Capabilities
- Affordances
- Semantic Disposition (Semantic Distances of Evaluation and Execution)
- Articulatory Disposition (Articulatory Distances of Evaluation and Execution)
- Goals, Intentions, Perceptions, Evaluations

Cognitive Mental State of an Agent

An agent modelled along the lines of the CogAC requires various cognitive mental states corresponding to the various steps in the execution and evaluation stages of the action cycle. These mental states of the agent facilitate the agent's behaviour in both its execution and evaluation cycles. It provides provision for state modelling, representation and tracking an agent's state of execution. In addition representing these states agents may have the dynamic capability of identifying these distances at runtime and may change and update their profile dynamically. The conceptual model is developed using the Protégé Ontology editor to generate OWL Ontology.

Figure 11. Conceptual Flow of Activities to develop an application according to the guidelines of COMMAA

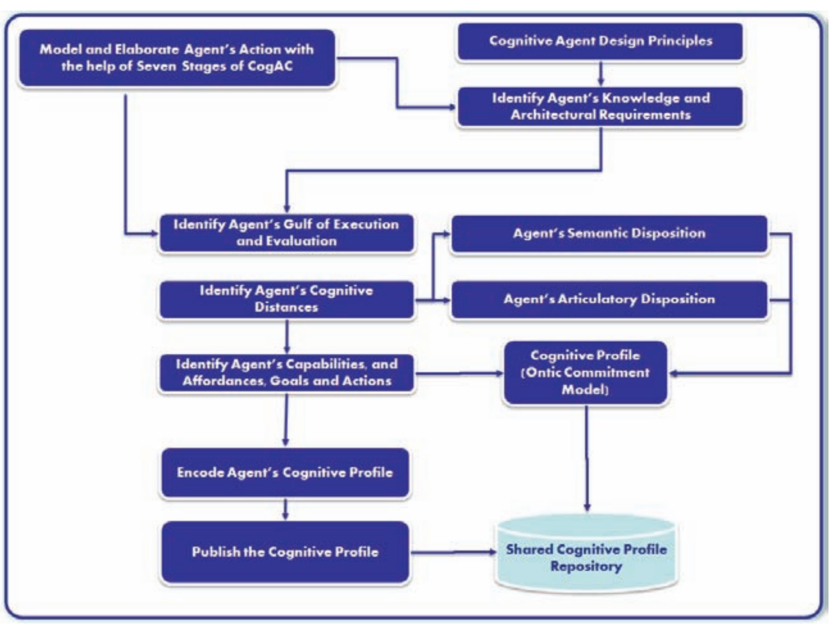


Table 3 . Description of Activities in processing agents' action through COMMAA with input and output artefacts

Activities	Description	Input Artefact	Output Artefacts
Cognitive Modeling of Agent Behaviour	▪ Model Agent's Action using the CogAC ▪ The agent's behaviour is programmed according to the stages described in the CogAC ▪ Elaborate Agent's Action with the help of Seven Stages of CogAC ▪ Identify agent's knowledge requirements and elements ▪ As the knowledge elements needed by the agent are identified, it is ensured that the architecture of the agent provides for these knowledge elements to ensure a successful completion of the CogAC ▪ Program agent's behaviour according to available architecture	▪ Agents Functional Requirements ▪ Agents Knowledge and Representational Constraints ▪ Cognitive Agent Design Principles. The CADPs are used as heuristics to evaluate the design at each stage	▪ Knowledge Requirements
Scoping the Agent's Cognitive Profile	▪ Identify Agents capabilities capacities and affordances ▪ Identify agents cognitive distances ▪ Identify known possible agent's gulf of execution and evaluation ▪ Each of the components of the Agent Profile are interpreted such that they represent its Ontic Committment	▪ Knowledge Requirements ▪ Agents Functional Requirements ▪ Agents Knowledge and Representational Constraints	▪ Individual Agent Cognitive Profile (Ontic Commitment Model)
Encoding of Cognitive Profile	▪ Encode Agent's Cognitive Profile parameters in the ontology ▪ The Disposition of Agent (Semantic and Articulatory) in both stages of execution and evaluation is encoded at design time	▪ Profile Parameters ▪ Agents Semantic Disposition ▪ Agent's Articulatory Disposition	▪ Cognitive Profile ▪ (Ontic Commitment Model)
Sharing the Cognitive Profile	▪ Registering or Publishing the profile	▪ Cognitive Profile	▪ Shared Cognitive Profile Repository populated with Cognitive Profile of Agent

Modelling Agents Using COMMAA

In order to utilise COMMAA in practice to process and analyse the interactions and tasks of an agent, the process shown in Figure 11 is used during the design and development process of an agent-based application. The figure also summarises the components and principles that contribute to the agents state modelling, based on the principles of COMMAA. The process is described in detail in Table 3.

Abstract Heuristic Reasoning Mechanism for Agents

To bridge the gulfs of execution and evaluation, agent must have some heuristic reasoning mechanism built into its architecture, such that given a shared cognitive profile is available, it should be able to reason on the knowledge present in it to aid the agent's processing and help bridge the gulfs of execution and evaluation through collaboration or other means. The important considerations are with regards to the representation, discovery and reasoning of the cognitive distances. Rules generate advice by defining the combination of agent knowledge, action stages, distances, abilities/capabilities, and affordances, typically with the generic format shown in Figure 12.

Heuristic Reasoning Mechanism for Agents Execution Stage

The encoding of agents cognitive distances requires a reasoning mechanism. The reasoning is carried out based on the Semantic and Articulatory disposition of agents encoded in their Cognitive Profile. A reasoning mechanism for the execution stage in the form of pseudo-code is given in Figure 13. This is generic given that the action

Figure 12. Generic Format for Rule-based reasoning of agents' cognitive mental states

```
At Interaction Stage (Execution of Evaluation)
Manipulate Cognitive Profile
If Agent capability and Affordance leads to Directness of Execution
                {
                Action will proceed //i.e. No Gulf Exists
                }
Else Cognitive Distance //i.e. Gulf Exists which needs to be bridged
                {
                Goal Revised
                New Interaction needs to begin
                }
```

Figure 13. Abstract Mechanism for Heuristic Reasoning of the Cognitive Profile Model (Execution Stages)

```
startCogAC(Goal goal){
While (!goalFulfilled)
            {
             - Assert Cognitive Profile
            - Reason
            //Analyze semantic profile
            if (hasSemanticDistance)
            {
            reviseGoal(g);
            startCogAC(g);
            }
            else {
                        IntentionSet  is = getIntentionFromGoal(Goal g);
                        //Analyze Articulatory Dispostion of Execution
                        if(hasArticulatoryDistance)
                        {
                        attempt to overcome/bridge using available affordances
                                    else
                        search Shared CognitiveModel
                        }
            }
}
```

Recursive nature of Cognitive Agent Action Cycle
CogAC, when applied in practice is essentially recursive in nature. A high level Goal can be functionally decomposed into sub-goals. Or, an action specification as a result of intention formation to achieve a certain goal may in turn specify other sub-goals to be achieved, for which the CogAC may be recursively invoked.The same recursive behaviour is also true in the evaluation stages. The desired interpretation of the received perception or evaluation may in turn require some internal goals to be achieve.

cycle is applied in a generic context. It may be specialised according to the agent application being developed.

Heuristic Reasoning Mechanism for Agent Evaluation Stage

A reasoning mechanism for the evaluation stage in the form of pseudo-code is given in Figure 14.

DEMONSTRATION OF AGENTS' ENHANCED COGNITIVE CAPABILITIES

In order to give a flavour of how the framework presented above enhances the agents' cognitive capabilities by imparting improved cognition, the framework was applied to a simulated multi-agent based distributed collaborative application with the aim of testing, improving and evaluating the framework. The purpose of this distributed collaborative multi-agent application is as follows:

- To show how the framework is applied to design of MAS based applications operable on the Semantic Web
- To show how application of COMMAA helps build the cognitive profile of the Agent
- Show how sharing the cognitive Profile improves the collaboration between Agents

High-Level Architecture of Distributed Collaborative Multi-Agent Application

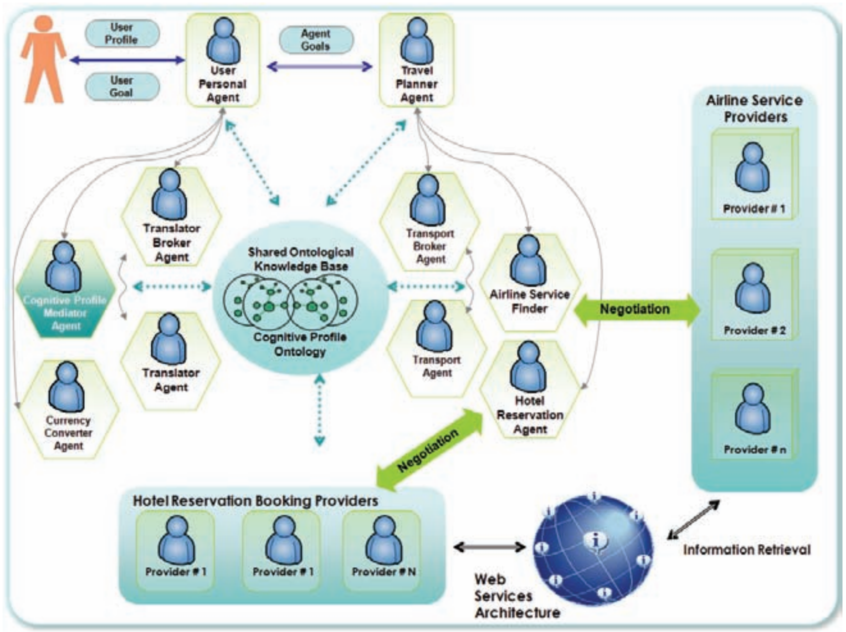
Travel Planning Scenario

The high-level architecture of the travel planning scenario developed to demonstrate the enhanced cognitive abilities of agents is shown in Figure 15) is a customised adaptation from the vision of travel planning agents presented by Hendler (1999).

Figure 14. Abstract Mechanism for Heuristic Reasoning of the Cognitive Profile Model (Evaluation-Sub Stages)

```
Response r = getSystemResponse();
PerceptionSet P = convertResponseToPerceptions();
//assert Perceptions
//Perform Cognitive Profile Check;
If(hasArticulatoryDistance)
        {
        attempBridgeGulfEvaluation (P);
        }
        Else{
                interpretPerception(P);
                if(hasSemanticDistance){
                Goal g = reviseGoal(P);
                g.start();
                } else
                evaluateGoal(G);
        }
```

Figure 15. Cognitively Modelled Agent-based Travel Planning Scenario Modelled according to COM-MAA



The top level functional goals of the demonstration application are as follows: The Multi-Agent based application is aimed to use cognitively modelled agents to solve travel problems given by a user. The user can propose to the user Agent his desired travel, and it will obtain a complete plan that inclu des information about transport, lodging, etc. The agents will Extract, filter and store information automatically from the Semantic Web using other agents. The system aims to use the same information that the user could find if he wish planning the travel himself. Cognitive Sharing of different kinds of abilities is to be demonstrated to gain efficiency in the problem solving task. The agents are simulated to reuse each others capacities, behaviours and offer affordances to each other. Agents closely work according to the user's characteristics, and functions based on the ultimate goals obtained from the user profile and adapt their functional behaviour according to the learned user preferences.

Roles Defined for Agents

Table 4 shows the Roles and Responsibilities defined for Agents involved in Travel Planning Collaboration Scenario. The Collaborative scenario aims integrate the abilities of a set of heterogenous agents. The system is made by a set of agents that can communicate and cooperate among them to reach the problem solution. All the agents in the application use FIPA Based Agent Communication Language for standardization purposes.

Cognitive Profiles of Agents in TPA

The cognitive profile ontology is central to representing the knowledge for agents. The elements of the cognitive profile ontology serve to represent the shared knowledge base of agents through which agents' cognitive awareness will be enhanced. The cognitive profiles are designed to simulate an environment such that some agents are limited in certain capabilities, while others are equipped

Table 4. Roles and Responsibilities defined for Agents involved in Travel Planning Collaboration Scenario

Agent	Functional Role of Agent in the Application
UserAgent	• This agent handles a user query and shows him the solution. To do so, it analyzes the problem and obtains an abstract representation. Subsequently it requests a Travel Planner Agent solutions to that problem. The User Agent has different skills like communication with Travel Planner Agents and users, or learning the user's profiles necessary to customize the system answer. The User Agent has a set of interfaces to allow input and output information and the user evaluation of the solutions found.
Travel Planner Agent	• The main Travel Planner Agent's goal is reason about User Agents and other Travel Planner Agents problems, and find out a set of possible solutions. Travel Planner Agents have different skills like communication (with different agents in the system), planning (its main reasoning module) and learning.
Transport Broker Agent	• This is a mediator agent, who has the ability of directly communicating with a transport agent and may provide services to some other agent which may not be able to directly communicate with a transport agent thus acting as an intermediary.
Transport Agent	• This agent has the capability of finding desired transport options from the web service providers and provides this information to other agents.
Translator Broker Agent	• This is a mediator agent, who has the ability of directly communicating with a translator agent and may provide services to some other agent which may not be able to directly communicate with a translator agent thus acting as an intermediary.
Translator Agent	• This agent simulates a functionally computational agent on the semantic web which has the capability of performing translation services upon request from one language to another e.g. English to Italian.
Currency Converter Agent	• The role of this agent is to retrieve up to date currency conversion rates from the web and provide currency conversion services to other agents upon request.
Airline Service Providers	• Airline Service Provider is responsible for finding information relation to airline reservations.
Accommodation Service Providers	• These are agents belonging to organization such as Hotels etc. which maintain up to date information about the accommodation availability, rates etc. and can carry out automated bookings on behalf of their owners.
Cognitive Broker Agent	• This agent also plays are central role in the collaboration scenario by acting as an indexer of facilitator for other agents to access other agent's cognitive profile.

Table 5. Capabilities and affordances defined for agents in the Travel Planner Application

Agent	Goals and Capabilities	Behaviours (Actions)	Affordances
UserAgent/ TravelPlanner Agent	•CommunicationCapability •CollaborationCapability •ConversationalCapability •**canAchieveGoal (GetTravelDetails)**	•SendMessage/ReceiveMessage •RequestInteractionProtocol •InteractionProtocol-FIPA-Request •InteractionProtocol-FIPA-ContractNet	•**hasNO OntologicalAffordance** •**hasNO ComputationalAffordance** •**hasNO CognitiveProfileAffordance**
TranslatorBroker Agent	•ConversationalCapability •**canAchieveGoal (BrokerageTranslation)**	•InteractionProtocol - BrokerageProtocol	•ComputationalAffordance •CognitiveProfileAffordance
CognitiveMediator Agent	• ConversationalCapability •**canAchieveGoal** •**(SearchCognitiveProfile)**	•InteractionProtocol-FIPA-Request(Responder)	•ComputationalAffordance •CognitiveProfileAffordance
TransportBroker Agent	•BrokerageCapability •**canAchieveGoal (BrokerageTransport)**	•InteractionProtocol - BrokerageProtocol	•ComputationalAffordance •CognitiveProfileAffordance
TranslatorAgent	•ComputationalCapability •**canAchieveGoal (TranslateEnglishToFrench)**	•InteractionProtocol-FIPA-Request(Responder)	•ComputationalAffordance •CognitiveProfileAffordance
Currency ConvertorAgent	•ComputationalCapability •ConversationalCapability • **canAchieveGoal (ConvertPoundToDollar)**	•InteractionProtocol-FIPA-Request(Responder)	•ComputationalAffordance •CognitiveProfileAffordance
TransportAgent	•ComputationalCapability •ConversationalCapability •**canAchieveGoal (TranslateEnglishToFrench)**	•InteractionProtocol-FIPA-Request(Responder)	•ComputationalAffordance •CognitiveProfileAffordance
Airline/Hotel Service Provider Agent	•ConversationalCapability •**canAchieveGoal(ProvideService)**	•InteractionProtocol-FIPA-ContractNet (Initiator)	•ComputationalAffordance •CognitiveProfileAffordance
Airline/Hotel Service Finder Agent	•ComputationalCapability •ConversationalCapability •**canAchieveGoal(FindService)**	•InteractionProtocol-FIPA-ContractNet (Responder)	•ComputationalAffordance •CognitiveProfileAffordance

with them in a complementary manner to facilitate interoperability, resuse and adaptive collaboration based on enhanced cognitive awareness. The cognitive profiles of the agents in the prototype application are shown in Table 5.

Reuse Mechanisms Employed

The Behaviour API and Interaction Protocol API of JADE (Bellifemine et. Al, 2001; 1999; JADE 2004) are used to model the Agent's Actions, or an action Plan. ACL Messages are used as representations for Intentions and perception. An agent is simulated in such a way that it is given runtime capability to change its behaviour, and dynamically change profile so as to demonstrate the power and potential of the Ontological Model.

Cognitive Modelling of Agent Interactions and Communication Scenarios Through CogAC

Table 6 shows an example of how the agents collaboration is modelled through the CogAC.

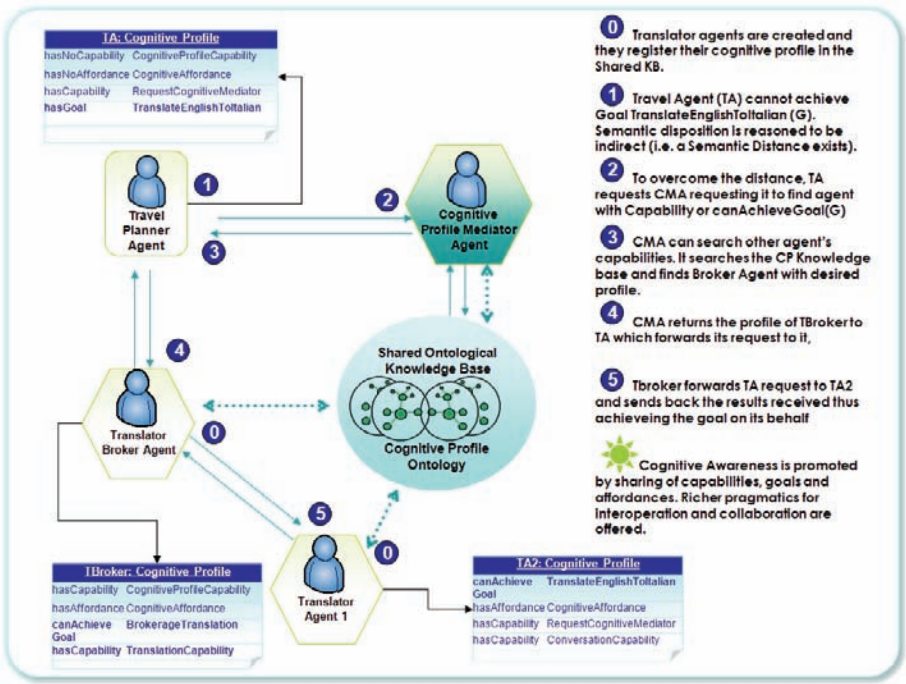
Illustration of Improved Cognitive Awareness

The provision of cognitive profile as shared knowledge base serves as means to increase the cognitive awareness for agents since they can not only reason about their own cognitive distances, they can also access and query other agents' cognitive profiles allowing them to adaptively refine their interactions in attempt to achieve their goals in a collaborative manner. An illustration of how this proves so is shown in Figure 16.

Table 6. Cognitively Modelled Agent Communication Scenario for Travel Planner Agent

User Profile and Travel Planner Agent			
Stage	**Description**	**Capabilities/ Affordances/Behaviours**	**Inferred Distances Rules for Inference**
Goal	• **hasGoal Convert Currency Pounds to Dollars (G)**	• G requires Capability**(C)** • **C1=ConversationalCapability** • **C2=ComputationalCapability** • G requires Affordance **(A)**	**If (canAchieveGoal (G))** - No Cognitive Distance
Agent's Gulf of Execution			
Intention	• If (hasNoSemanticDistance Stage(Execution)) Proceed (Go to Next Step) • Else ReviseGoal **FindAgent (canAchieveGoal, G)**	• **hasNoCapability(C)**	• **Semantic Distance** G requiresCapability C Agent hasNoCapability C Therefore hasSemanticDistance
Action Specification	• If (hasNoArticulatoryDistance & Stage(Execution)) Proceed (Go to Next Step) • Else ReviseGoal **FindAgent (canAchieveGoal, G)**	• **hasNoAffordance(A)**	• **Articulatory Distance** G requiresAffordance A Agent hasNoAffordance A Therefore hasArticulatoryDistance
Execution	• Performing the actions • Send the Request , Wait for Response		•
Agent's Gulf of Evaluation			
Perception	• Noticing that feedback occurs, if any e.g. Reply Message		
Interpretation	• If (hasNoArticulatoryDistance & Stage(Execution)) Proceed (Go to Next Step) • Else ReviseGoal **FindAgent (canAchieveGoal, G)**	• **hasNoAffordance(A)**	• **Articulatory Distance** G requiresAffordance A Agent hasNoAffordance A Therefore hasArticulatoryDistance
Evaluation	• If (hasNoSemanticDistance & Stage(Execution)) Proceed (Go to Next Step) • Else ReviseGoal **FindAgent (canAchieveGoal, G)**	• **hasNoCapability(C)**	• **Semantic Distance** G requiresCapability C Agent hasNoCapability C Therefore hasSemanticDistance

Figure 16. Agent Collaboration Scenario to Illustrate Improved Cognitive Awareness



Cognitive Profile as an Affordance

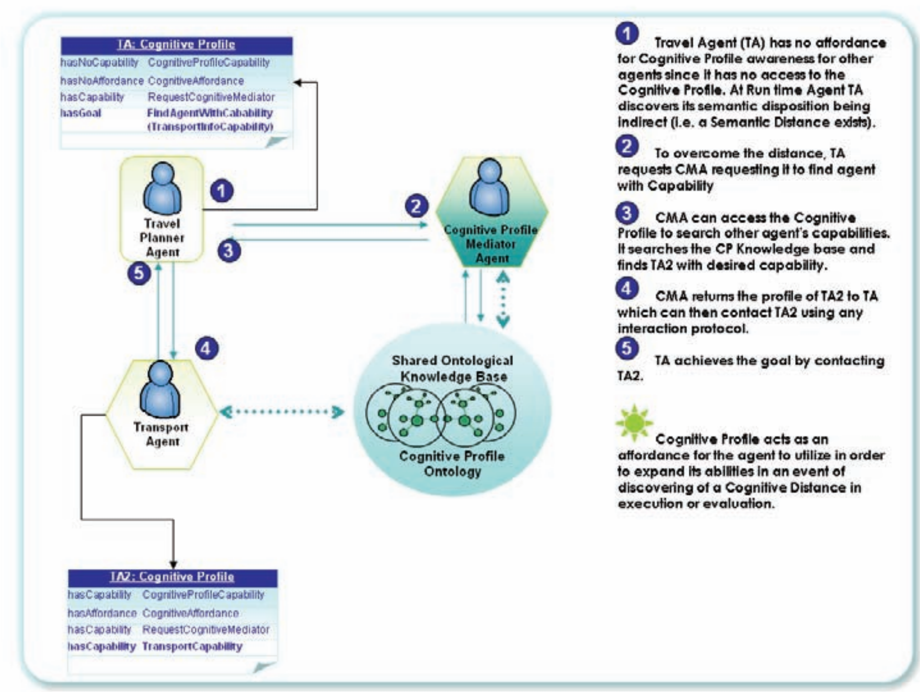
The cognitive profile in the form of ontology serves as an affordance for the agent to be cognitively aware of its environment and make adaptive decisions about it. Following is a scenario in Figure 17 that illustrates how this proves so.

EVALUATION AND FUTURE TRENDS

The application of the COMMAA to the application was found very useful in structuring the agents' interaction and collaborations in an MAS environment. An attempt to assess the directness of engagement using the distances in the multi-agent interaction scenario offered useful results. As shown by the demonstration that the Cognitive Modelling of agents give a powerful boost and shows great potential in the manner that agent utilise each other's capabilities to support each other functional execution and in return facilitate and reduce cognitive overload of humans. The increased cognitive awareness promotes interoperation amongst agents and results in behaviour sharing and reuse. The high visibility into each other's mental models increases the mapping of agent's functional and execution models. The 7 stages of CogAC ensure that enough feedback is received to ensure successful fulfilment of goals through multi-agent collaboration. The Cognitive Profile Ontological Model serves as an essential artefact for agents which, continually provides for both sides of the CogAC: execution and evaluation.

Based on the above evaluation of the application, The CogAC can come to be considered as a fundamental part of the functioning of agent's actions in interaction with its MAS environment. Thus agent modelled along lines of COMMAA exhibit strong principles of user-centred design

Figure 17. Multi-Agent Collaboration Scenario to illustrate the use of Cognitive Profile as an affordance



**Further implementation details are beyond the scope of this chapter*

and advocate ease of use, efficiency and reuse and interoperation. Although, the model is used to model software agents, similar model can be used for classifying user roles and capabilities and for maintaining and sharing user profiles and roles. The proof-of-concept application has also demonstrated the feasibility of implementing the constructs of COMMAA using the combination of Multi-Agent Platform and the Semantic Web middleware.

In addition, the COMMAA takes a holistic view of agent's action and its processing in the stages of execution and evaluation. It increases the cognitive awareness amongst agents by elaborating the action infrastructure, its limitations, constraints (Distances) and its capabilities and affordances. In this way it facilitates the architecture for the agents that are designed to work or be programmed to work more adaptively on the Semantic Web. This was made sufficiently evident using the implementation of the Travel Planning scenario. Similarly, agents can use the semantic information, share it, yet can communicate using ACL languages, programmed according to the Agent principles and do not need to rely on the Web service interfaces and profiles.

The results of the application are validated against the design goals presented earlier in Table 7.

Future Directions

The abstract architecture opens new doors of research. With the core framework in place the natural next step in its expansion is the specialised enhancement towards a more rigorous definition of different levels and variations of cognitive profile

Table 7. Improvements achieved as a result of application of COMMAA

Design Goals	Evaluation
Cognitive Awareness:	▪ Agents profile has shown to be encoded using OWL ontology and published. Thus Agents are able to cognitively describe, publish and access each others capabilities, affordances and distances/constraints by Quering the ontology using SPARQL based mechanism. More dynamic and adaptive behaviour of agents has been shown. Thus the implementation shows cognitively aware modelling agents interaction. ▪ Agents can carry out cognitively aware communication and collaboration with each other ▪ Through Cognitive awareness, agents help each other identify and bridge the gulfs of execution and evaluation
Enhanced Negotiation and Collaboration	▪ As shown by the collaboration scenarios, agents negotiation abilities are enhanced as a result of improved cognitive awareness
Flexibility and Reusability:	▪ As shown, through cognitive profiling, JADE Behaviour API and Interaction protocols have been used with much more flexibility and their reuse is promoted by agents sharing cognitively their goals and abilities. ▪ Agents are equipped with reasoning mechanism to dynamically reason about their semantic and articulatory disposition. This allows them to adapt to the required interaction scenario, thus providing intrinsic support for more flexible interaction.
Adaptive Interaction and Interoperability:	▪ Heterogenous agents in different roles including Transport Agents, Transport and Translator Brokers, Currency Convertors etc. have been shown to participate in adaptive collaborative scenarios through dynamic sharing of their cognitive profiles in order to help each other bridge cognitive distances of execution and evaluation. In doing so, they help each other achieve their goals. ▪ Interoperability is promoted through the sharing of cognitive profiles, dynamic publish and access mechanisms. ▪ Reasoning through SWRLJess based rules enhances cognitive awareness, thus improving interoperability.
Discovery based on Heuristic reasoning:	▪ Agents dynamically reason about their profiles using SWRL Rules and DIG reasoners that classify ontology. This allows dynamic discovery of cognitive distances and other agents' profiles improving agents cognitive awareness of itself and the environment.
Minimisation of cognitive load:	▪ User has been shown to be relieved of much cognitive overload since agent through all of the above functionalities is able to perform much more. It is able to meet all the preferences in the user profile. If the case was otherwise, the distribution of tasks would shift from the agent to the user. E.g. if the agent was unable to meet the goal of converting dollar to pound, given it was not able to find any other agent to achieve the goal, the user would have the added cognitive overload of meeting the desired goal on its own. ▪ Thus human information processing has shown to be reduced as a result of increased cognitive awareness and improvement in the flexibility and adaptability of agents' collaborative abilities.

and its parameters. Identifying the best level of detail for functionally decomposing each task or intention and applying it consistently is difficult. The application highlights that in order to make this model fully implementable or workable in the real world, there needs to be taxonomy of distances, directness measures, capabilities and affordances defined. This study initiates this activity by identifying the rudimentary picture of the basic Cognitive profile of agents e.g. at present the capabilities were identified as high level constructs. They can be made much more elaborate e.g. that of OWL-S. However to make it reach such a state of maturity where it could be utilised in practice will take some more effort. A taxonomy could be appealing because it would allow a generic to specific discussion of cognitive distances across different agent applications. Although some subset of cognitive distances will always be generic, it can be suspected that a fairly large subset will need to be specialised across limited applications.

Ontology Learning, Alignment and Mapping: A serious issue in making this model work on a larger scale will be ensuring the standardization for the interoperability. Issues of Ontology learning (Maedche & Staab 2001), Ontology alignment and mapping (as highlighted in works by Laera et al. 2006, Mocan, Cimpian & Kerrigan 2006; Sampson & Lanzenberger 2006) also become important for standardization and homogenization purposes. Standardization of cognitive profile for agents will be another issue foreseen if this model were to work successfully, but with rich semantic model of OWL and RDF will allow for standardization to be achieved. However it provides substantial stimulus for future research.

Enhanced Learning and Reasoning Mechanisms: Furthermore, an idea that will add immense value to the further development of agents' cognitive model is enhanced Reasoning and learning mechanisms. It would also be worth investigating how the principles of COMMAA plays a useful role in Interface characteristics i.e. investigation into role of cognitive models applied to model interface agents and their activities and management of user profiles. Another issue is with respect to the extent to which agent's knowledge model or cognitive profile is to be shared. The notion of Public, Private profile could be considered. The extent of autonomy given to the agent moving towards Autonomous Semantic Web services (Paolucci & Sycara 2003) is also highly relevant.

CONCLUSION

The Semantic Web community has recognised the advantages of an agent-based approach to building deployable solutions in a number of application domains comprising complex, distributed systems. The chapter targeted some of the key challenges faced when developing autonomic and autonomous entities in the domain of Multi-Agent Collaborations. By applying cognitive models to model agents' behaviour on the Semantic Web, a reasonably successful attempt has been made at coupling cognitive science principles of user-centred design with features of agent base systems and architectures.

This research took into account the emergent standards in both agents and Semantic Web in order to render the framework principles presented. The principles and design of COMMAA have also been used to demonstrate agents' improved capabilities through an evaluation of a multi-agent collaborative scenario to illustrate the adaptive coordination of different agents acting as owners in heterogenous and dynamically changing environments. The results of the evaluation show an improved flexibility, interoperability and reusability of agents' collective behaviours and goals. Thus, it establishes COMMAA as a step forward in providing the next generation of Semantic Web, a successful framework of multi-agent collaboration, which is inevitably required for generating robustly engineered agents able to carry out spontaneous and adaptive collaboration based on cognitive awareness of their environment and infrastructure.

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KEY TERMS AND DEFINITIONS

Affordance: An affordance is a resource or support that the environment offers an agent for action, and that the agent can directly perceive and employ**.**

Agent: Agents are defined as autonomous, problem-solving computational entities capable of effective operation in dynamic and open environments.

Capability: The functional ability possessed by an agent to achieve some given goal or requirement.

Cognitive Awareness: It refers to the ability of the Web agents to diagnose their processing limitations and to establish interactions with the external environment (in the form of other agents including humans and software agents).

Cognitive Model: Internal representations of the current situation created by either a human and agent to assess their state with respect to the environment.

Cognitive Profile: It is a semantic representation model which includes information about the cognitive states of an agent, its functional capacities and affordances.

COMMAA (Cognitive Model of Multi-Agent Action): A framework for modeling agents' actions and interactions in its environment in an attempt to provide an architecture that improves the flexibility of Multi-agent interaction by promoting cognitive awareness .

Multi-Agent System: Multi-Agent System (MAS) is a distributed collaborative environment which allows a number of agents to cooperate and interact with other agents (including both people and software) that have possibly conflicting aims, in a complex environment.

Chapter XXXII
Social Impact of Collaborative Services to Maintain Electronic Business Relationships

Stefan Klink
Universität Karlsruhe (TH) – Research University, Germany

Peter Weiß
FZI Research Center for Information Technology, Germany

ABSTRACT

This chapter looks at the impact and opportunities of semantic technologies and Web services to business relationships and how social Semantic Web techniques foster e-business and collaborative networks in many dimensions. For this the authors follow the vision to support collaborative services for business relationship management within semantic services. Based on a newly approach for business partner management with ontologies in large business communities, the chapter elaborates the conceptual framework for the design and implementation of collaborative services. The often postulated adaptiveness and intelligence of novel collaborative structures, foremost collaborative networks, require new approaches to deal with the increasing difficulty to cope with the resulting complexity of relational ties in communities and business networks. This research strives to leverage the capabilities to deal with large number of business relationships. The chapter formulates a vision based on three stages developing digital business ecosystems. Semantic Web technologies, mainly modelling business partner profiles (BPP) with ontology, combined with sound techniques of information retrieval and selected concepts and methods of social network analysis build the conceptual framework. On this basis, a newly approach is elaborated which offers support for communication processes and complex interactions of business entities in collaborative spaces.

INTRODUCTION

During the last decade, along with growing interest and increasing use of electronic networks, society, science and business have been affected by remarkable changes. Electronically networks have had a tremendous impact on the every day and working life changing the way people interact, live and work. In our economy today, networking plays a crucial role in various application domains. Services are designed to support collaboration and networking among agents, whether humans or machines, in electronic networks.

Services are designed to overcome identified boundaries for Collaborative Networks (Martin-Flatin et al., 2006). The focus of this research is social ties between network entities. In electronic networks the linkages of entities (e.g., business partners, employees, experts, etc.) have to be supported by electronic services. Semantics, self-organization, security, trust and privacy, awareness and incentives are variables influencing the relational ties between units. However, linkages between agents require the right climate and conditions of a collaboration environment. This environment should provide opportunities for or constraints on individual action in a specific given context. These horizontal dimensions facilitate and catalyze the emergence of relational processes and structures to evolve.

This chapter claims that organisational structures with the asked abilities to self-manage, self-configure and self-optimise require besides the necessary culture, and "[…] semantic-informed self-organizing structures […]" (Camarinha-Matos et al., 2003, p. 8). Culture and structure are constituted in the collaboration and innovation environment and provides the "breeding environment" for establishing relational ties between agents (e.g., units, actors, etc.).

In this environment relational ties are to emerge between agents (e.g., units, actors, etc.). From a network perspective, linkages and related relational processes and structures are subject of analysis. The status of relational ties is either latent (passive) or evident (active). If made evident in a specific context given, they offer the channels for transfer or "flow" of resources (either material or nonmaterial). Our research aims at provisioning of a framework allowing to analyse and to conceptualise structures in form of models as lasting patterns of emerging relationships among agents. Again the conditions and environment catalysing the emergence of relational processes and structures in the context of collaboration and innovation processes are looked into. The goal is to analyse related interactions at the level of individuals, teams (or groups), organisations, networks and communities (see Figure 2).

The concept of semantically enriched business partner profiles and sound, proven techniques of information retrieval, data mining, and machine learning, respectively, are combined together to develop a collaborative service environment. Discovery, matching and trust services provide the field for further enhanced services and functionality in collaborative networks.

One of the challenging tasks analysing business networks is to propose the clearest possible view of network characteristics. The concept of network suggests the existence of nodes, which interplay in different patterns according to the network structure. In the future networks will be characterised by the ability to self-organise their shape and to adapt rapidly to changes in their direct environment as e.g. the change of market conditions or new developments in technology. In this chapter we look at the fundamental basis for the design, development and implementation of collaborative services for the efficient partner relationship management in dynamic business ecosystems.

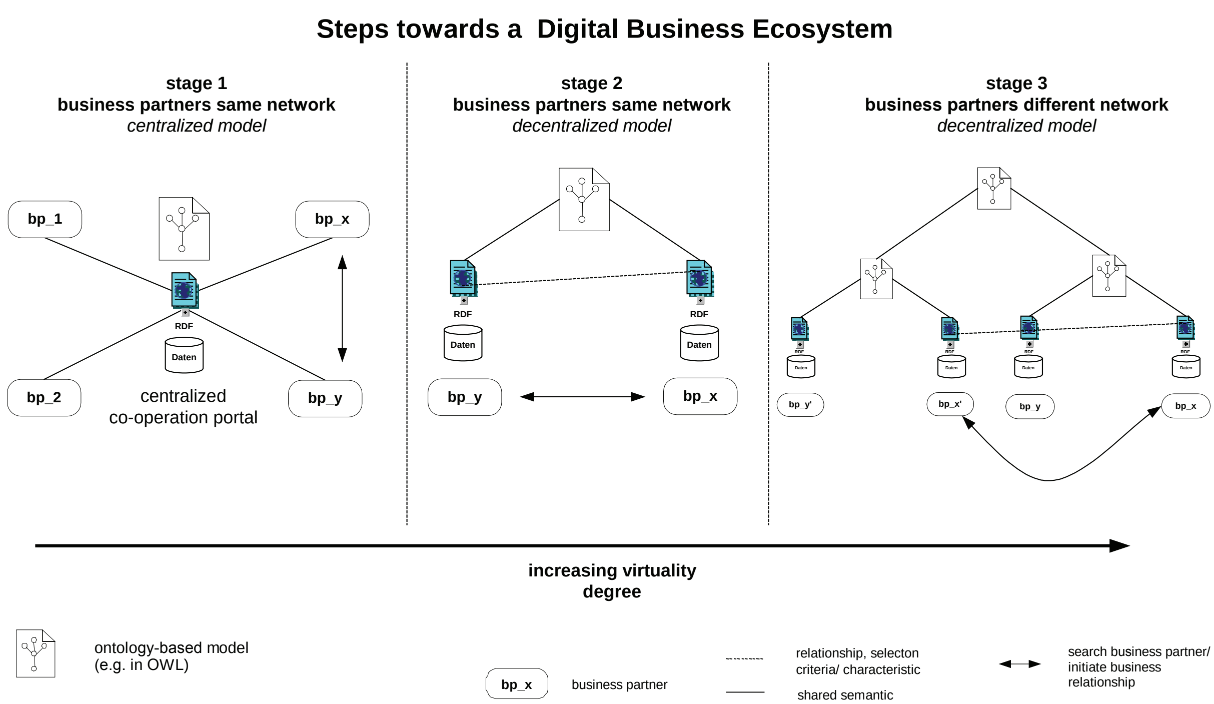
The approach aims to extent existing b2b integration technology architectures. For this, Weiß (2005, 2007) developed a methodology ODAMY[1] transforming the metrics of an empirical model into an ontology based model. The conceptual framework is based on the KAON tool set and infrastructure (KAON 2003). KAON tool set allows iteratively checking at this early stage of development how the conceptual framework shall be used and implemented.

Our research concentrates on the extension of the centralised approach presented by Weiß (2005, 2007) by using a decentralized model for the fingerprints. It focuses on dynamic integration of business partners in the light of emerging digital business ecosystems. The work followed the approach to assess decision criteria in order to support the self-formation and self-organisation of adaptive business networks. Business partner profiles are build based on a shared explicit data model. An ontology-based model describes underlying data structures and concepts which have been taken from an empirical model. The empirical model encompasses important dimensions for the configuration and analysis of business relationships. Weiß (2005, 2007) discussed and overlooked the future and emerging trends.

In Figure 1 the three stages towards a digital business ecosystem are illustrated. Research described in (Weiß 2005) addressed foremost the scenario at stage 1 (left side in Figure 1). At this stage a centralised model for the business partner profiles is applied. Business partners that can be accessed through the ICT infrastructure are limited to information stored and accessible through the registry in form of an Enterprise Portal of the domain network. Related work can be found in the area of business registries for Web services, e.g., UDDI[2] and ebXML[3].

Our research gravitates around the realisation of the scenario shown at stage 2 (middle in Figure 1). At this stage, a decentralised model is developed which is analogous to peer2peer networks. Business Partner Profiles are no longer stored in a central information portal. Instead, they are stored decentralised but are created on basis of a shared conceptual model in form of a domain ontology. Business partners maintain latent busi-

Figure 1. Steps towards a Digital Business Ecosystem (Weiß 2005)



ness relationships solely within the boundaries of the business network they have registered. Boundaries of this network are defined by the number of registered users.

At stage 3 (left side of Figure 1) the approach strives for an advanced decentralised model that allows contacting and querying business partners not limited to any boundaries of the defined network. The information desired for discovery and selection of business partners is retrieved beforehand through machines in form of agents or Web crawlers.

The semantics of data in profiles has to be made explicit and has to be stored in a machine-processable form. The described approach fulfils the needs of the described scenario but has to be further elaborated and developed. Especially, retrieval of collaborative information and data stored in business partner profiles poses interesting questions for future research endeavours. Future developments in adaptive business networks will be driven and dominated by current paradigms of service oriented architecture (SOA) and technologies related to Web services (Weiß, 2007), (Klink and Weiß, 2007).

STATE-OF-THE-ART/BACKGROUND

In the past, network perspective has proved fruitful in a wide range of social and behavioural science disciplines. Today, network perspective noticeably impacts other research disciplines, namely informatics, economics, engineering, law, etc. Network concepts are conceived increasingly as fundamental components for research activities in the field of virtual organisation (Sydow 1992), (Krystek et al. 1997), (Ritter 1998), (Picot et al. 2003), (Weiß 2005).

In today's b2b (business-to-business) integration concepts, strategic aspects are mostly not addressed adequately. In this context Bussler (2003) discusses the problem of integrating business partners into an existing information and communication technology (ICT) infrastructure depicting options by looking into types of b2b integration concepts and scenarios. Current b2b integration concepts are focused merely on technical needs and aspects as definition of interfaces for information exchange, remote invocation of applications or formalisation of business transactions and processes as well as business semantics (Weiß and Stucky 2004). Most influential initiatives to be mentioned here are EDI[4]-based and/or XML[5]-based (Weiß 2005).

New business patterns are characterised by diminishing geographical and time boundaries, globalisation of the labour market, increased connectivity, extended or virtual enterprises, new forms of customer management, and individualised marketing (Lengrand and Chatrie 2000). Beyond doubt, the relevance of networked co-operations in business can be expected to increase strongly in future. Delic and Dayal (2003) discuss and describe future enterprises that will transform themselves into better forms by becoming "more intelligent".

"Intelligent" in this context is perceived as the capability of a business entity to exploit emerging business opportunities and to adapt its operations to changing market conditions. It is also perceived as the capability of a business entity to sense its environment, to understand the situation, and to adapt its business objectives and behaviour accordingly. Enterprises form strategic partnerships with other enterprises "[…] to create dynamic business ecosystems" (Delic and Dayal 2002), that will be self-managed, self-configured and self-optimized. Adaptation can be identified as a key behaviour derived from the behaviour of natural systems. Both systems, natural and business systems, share the same ultimate objective: to survive in an evolving environment and changing circumstances (Delic and Dayal 2002).

Survival in an evolving environment is also a question of how far away is the actual business reality today from the future dynamic business ecosystem. Currently, new efficiencies can be mainly achieved through automation of core business processes, and exploitation of knowledge. In this connexion popular concepts are customer relationship management (CRM), enterprise resource planning (ERP), enterprise application integration (EAI), and enterprise knowledge management (EKM). In essence they encompass enterprise activities aimed at improving efficiency or injecting intelligence into operations (Delic and Dayal 2002). The mission is offering interfaces for integrating proprietary information systems from both internal perspective and external perspective encompassing integration of respective business partners, suppliers, and customers into the enterprise's own operations. In consequence, enterprise's borders are blurring, turning into fuzzy and dynamic borders.

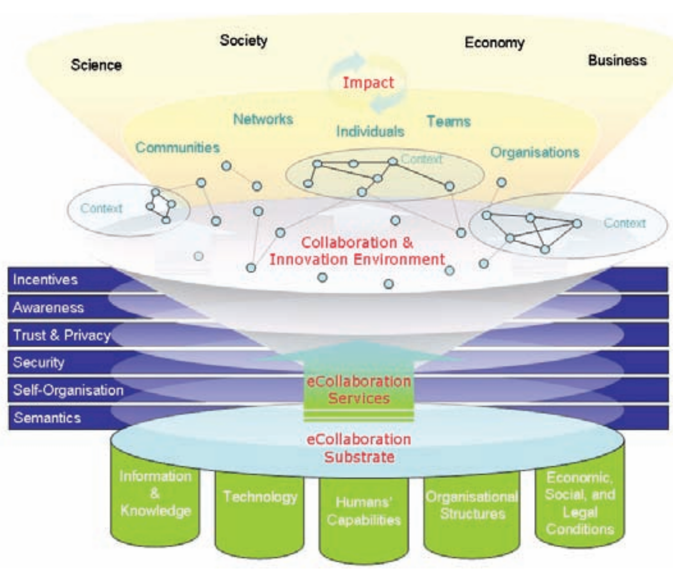
Today, many research endeavours noticeably gravitate around the realisation and problems related to the implementation of concepts mentioned above. Common denominator and underlying problem of many business endeavours can be summarised in the appropriate combination of two extremes: self-organisation versus extrinsic organisation; or more general evolution versus organisation.

This vision sets clear targets for our research endeavour. After having motivated the background of our research, actual needs and aims of this research are further elicited in the following.

Collaborative Networks

Further flexibility and interoperability of the underlying ICT infrastructure is expected to have a tremendous impact on the ways business is conducted. Semantics and related technologies are expected to be of growing importance and are an important enabler for the scenario described above. Enterprise modelling has to respond to these developments through the development and take up of appropriate technologies, methods and tools. Subsequently, we look at important characteristics and show possible ways forward for the development of intelligence of and emergence of structures in business networks.

Figure 2. Framework of collaborative networks' infrastructure (Klink and Weiß 2007)



Collaborative Networks as research discipline are facing noticeably a renewal of interest due to newly emerging trends such as Web2.0 and other emerging paradigms of future applications and software architectures. Strong communities emerged which address in particular research topics and questions related to collaborative networks. (Camarinha-Matos et al., 2002 - 2006). From a network perspective, linkages and related relational processes and structures are subject of analysis. The need of a comprehensive scientific framework of collaborative networks (see Figure 2) is argued facilitating to structure interdisciplinary research activities towards common goals and visions. Subject of analysis are related interactions at the level of individuals, teams (or groups), organisations, networks and communities. It supports evolution of dynamic networks and self-organisation of network entities. The required emergence of relational structures re-quires specific services within collaborative networks.

Conceptual Model of Digital Business Ecosystems

Three stages towards a digital business ecosystem as already highlighted can be realized in literature (see Figure 1). Research described so far addressed foremost the scenario at stage 1. At this stage a centralised model for the business partner profiles (BPPs) is applied. These profiles represent information required to discover, select, and integrate business partners preferably dynamic, on demand into emerging or existing value chains. Business partners that can be accessed through the ICT infrastructure are limited to information stored and accessible through the registry in form of an Enterprise Portal of the domain network.

Current research gravitates around the realisation of the scenario shown at stage 2. At this stage, a decentralised model is developed. BPPs are no longer stored centrally in an information portal. These profiles are stored decentralised but are created on basis of a shared conceptual model in form of a domain ontology. Business partners maintain latent business relationships solely within the boundaries of business network they have registered to. Boundaries of this network are defined by the number of registered users.

At stage 3, the approach strives for an advanced decentralised model that allows to contact and query business partners not limited to the boundaries of the defined network. Information desired for discovery and selection of business partners is retrieved beforehand through machines in form of agents or Web crawlers. The semantics of data in profiles has to be made explicit and has to be stored in a machine-processable form.

Conceptual Framework

Our work follows the approach to assess decision criteria in order to support the self-formation and self-organisation of adaptive business networks. Based on a centralized approach with a shared explicit data model for the BPPs as “fingerprints”, it is looked at further development of this approach to fulfil the envisioned scenario and requirement at stage two and three of our model. Thus, profiles are again regarded as a major concept which we will uptake. Profiles as a concept to store collaborative data will be the major approach we follow. Profiles are based on an ontology-based model (based on an ontology structure) which has been developed on basis of an empirical model encompassing important dimensions for configuration and analysis of business relationships (Weiß 2007).

BPPs are stored either in a central or a distributed database for retrieval and for further analysis. Klink (2006) investigated how information retrieval query techniques can be used to extract concepts from various information resources. Thus, the results of this research flow into our conceptual framework. As shown in Figure 1, we have to deal with some difficult questions and challenges for realising the scenario described at stage 2 and stage 3. Information retrieval as a core discipline seems to have some answers to these questions. Mainly, these questions relate how to deal with different semantics of semi-structured (Web) resources.

There are "[…] *multiple theoretical mechanisms that contribute to the emergence of organizational networks*" (Huang et al., 2008). Huang et al. (2008) discuss *[…] multi-theoretical, multilevel (MTML) hypotheses about the structural tendencies of networks. The study suggests that the social drivers for organizing networks in communities have diverse goals such as exploring new ideas and resource, exploiting existing resources and capabilities, social bonding, mobilizing for action, and rapid response (or "swarming"). These drivers have different levels of impact within and across communities and hence change the mechanisms of recommender systems. For example, looking for a quick solution and producing innovative ideas will result in completely different recommendation systems*" (Huang et al., 2008).

Figure 3 shows three perspectives or levels to analyse business communities. It can be assumed that the rapid emergence and growing popularity of online communities to initiate, manage and maintain business relationships will have tremendous impact on the way business is conducted in the future. The astonishing success of online community portals as Xing[6], LinkedIn[7], Plaxo[8], etc. underline these developments and further motivate the vision of collaborative networks which are self-managed, self-configured and self-organised – a behaviour that can be summarised as a sort of "intelligence".

This relates to the ability to create structures in a self-organised way. This behaviour is often characterised as "emergence"[9]. Looking at concepts and ideas that stand behind emergence would be interesting but shall and can not be covered in the given scope of this chapter. We stress that the basic understanding of self-organising processes is required to come up with any solutions and thus need to be analysed in detail to be clearly understood. Network abilities as "self-reference" and "emergence" are key concepts to be primarily looked into.

Organisation research has identified this as an interesting topic since decades (see for example (Sydow, 1992), (Krystek, 1997)). With the emergence of new ICT technologies and new trends and developments, e.g., concepts discussed as SOA and Web 2.0, bring this fundamental research work back again into the foreground and many technical and conceptual elements can be derived. This applies as well to the fields of information retrieval and social network analysis.

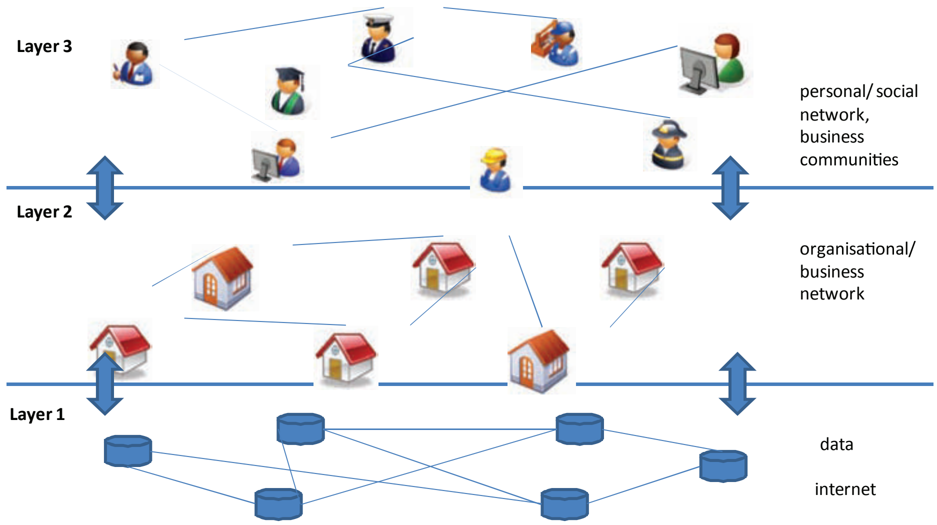
"*Social Network Analysis has emerged as a key paradigm in modern sociology, technology, and information sciences. The paradigm stems from the view that the attributes of an individual in a network are less important than their ties (relationships) with other individuals in the network. Exploring the nature and strength of these ties can help understand the structure and dynamics of social networks and explain real-world phenomena, ranging from organizational efficiency to the spread of information and disease*" (Dasgupta et al., 2008).

Let us come back to central question which we already posed previously in this chapter: how far are future dynamic business ecosystems from real business reality?

For answering this difficult question, let us have a look at current developments, in particular in the field of online communities and social network analysis. The latter has gained tremendous popularity and revival due to growing importance of collaborative networks.

The selection of business partners is to be seen as key to success for the realisation of dynamic business ecosystems in near future. Therefore, business relationships need to be conceived increasingly as intangible asset of an enterprise

Figure 3. Electronic business relationships



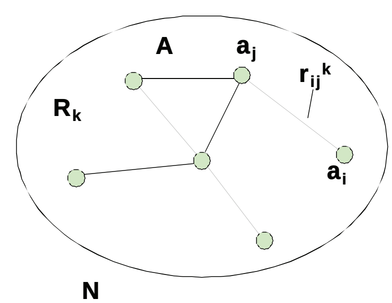
that needs special care. Namely, they have to be maintained continuously through an adequate management. Thus, the areas under investigation are relational ties and enabling organisational structures and cultures in the light of aspired intelligence and ability of systems to self-organise (Weiß, 2007).

There is an obvious need to construct complex data structures to express the complexity of business related information. Besides, there is a need to be able to access these complex data structures and extract relevant information from them within a specification of requirements (Field and Hoffner, 2003).

Figure 4 depicts the core of the research approach. The configuration of business relationships takes place primarily on the organisational layer. To involve the ICT infrastructure collaborative data has to be represented in machine-processable form. This can be realised using ontology for structuring and modelling of the BPP. Profiles are a prominent concept also used by Web services to store service descriptions.

Therefore, this is seen as an appropriate way to approach the problem at hand. BPP are anticipated to bridge the existing barrier between the organisational and ICT infrastructure layer. Through the application of ontology, collaborative services as, e.g., for discovery and/or matching of BPP can be used to support the self-reference and emergence of collaborative structure and cultures. Especially zones of trust can be established with filtering collaborative information and an intensified interaction and information exchange of business entities in advance of concrete business endeavours (Weiß 2007).

For analysing a social network of business partners and their relationships we use the following basic definitions based on typical concepts used in social network analysis:



N

a_i: actor, network entity
A: set of entities
r_k: type of relationship
R_k: set of all identifiable relationships of type k
$N = (A\ ;\ R_k)$: network
X_k: socio matrice
$x_{ijk} = 1$, in case r_m existing;
0, else

Figure 4. Design of approach for business partner relationship management with ontology (Weiß, 2007)

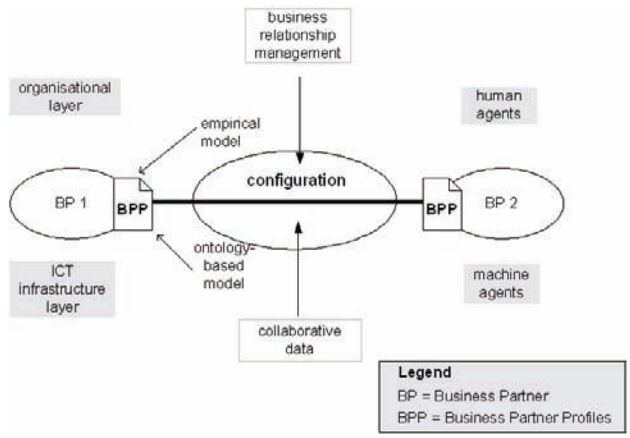
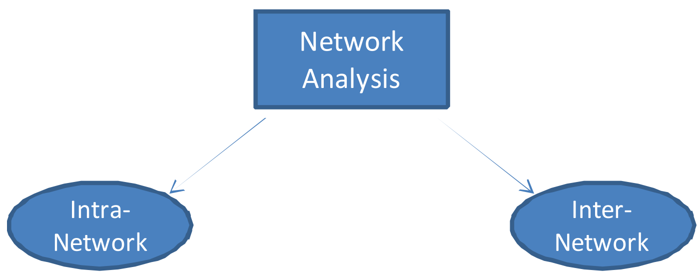


Figure 5. Empirical model for network analysis



More concrete, in contrast to classical network analysis our approach is to introduce different types of relationships r_k. In this way we describe business relationships using a multi-dimensional model. In case a relationship type is existing x_{ijk} has the value 1 in the socio matrice, else 0 indicates that this type of relationship does not exist (Weiß 2005, 2007). Various other types of matrices are used to display interactions and connectivity of network nodes (see e.g., Musolesi et al. 2007; Wassermann and Faust 1994; Scott 2000).

Measurement

The measurement is realised on basis of an empirical model which lays the foundations for later configuration of business relationship. In the following we look at the empirical model which aims analysing the network structure. The network structure encompasses network entities and relational ties between them.

The analysis framework distincts two views: intra- and inter-network view. The intra-network analysis looks at entities inside the network. One particular challenge in analysing business networks is to define boundaries of a network. For this purpose social network analysis offers various techniques how this information can be extracted from business cases.

Network analysis looks at the network itself without describing the quality of the relationships between entities. Presented model delivers additional dimensions which allow analysing business relationships in more detail.

Inter-Network Analysis

The inter-network analysis looks at characteristics of relationships between companies. The perspective is not restricted to boundaries of a network. The measurement assess collaborative about preferences and behaviour of companies (in retrospect). The analysis framework delivers information concerning the configuration of business relationships. Based on this profile the entity is able to find business partners in the network corresponding to their collaboration requirements.

Figure 6 displays in a diagram the seven areas or dimensions that are analysed: flexibility, time horizon (th), network structure (ns), intensity of linkage (il), market (m), trust level (tl), integration effort (ie). Each dimension is supported by a hypothesis which expresses the assumptions made.

The aim of this analysis is to classify network entities according to the given seven dimensions. Quantitative values are aggregated to qualitative values in the range of low, medium and high. How this information is processed will be looked at later on in more detail. Table 1 describes three types of "idealised" network types which span a "continuum of virtuality" according to which cases can be classified and positioned. For more details about development and information about the empirical model readers are recommended to consult (Weiß 2005).

Intra-Network Analysis

Inter-network analysis mainly can be seen as "external" perspective having the network company or entity in focus and its cooperation behaviour

Figure 6. Dimensions of inter-network analysis (Weiß 2007, 2005)

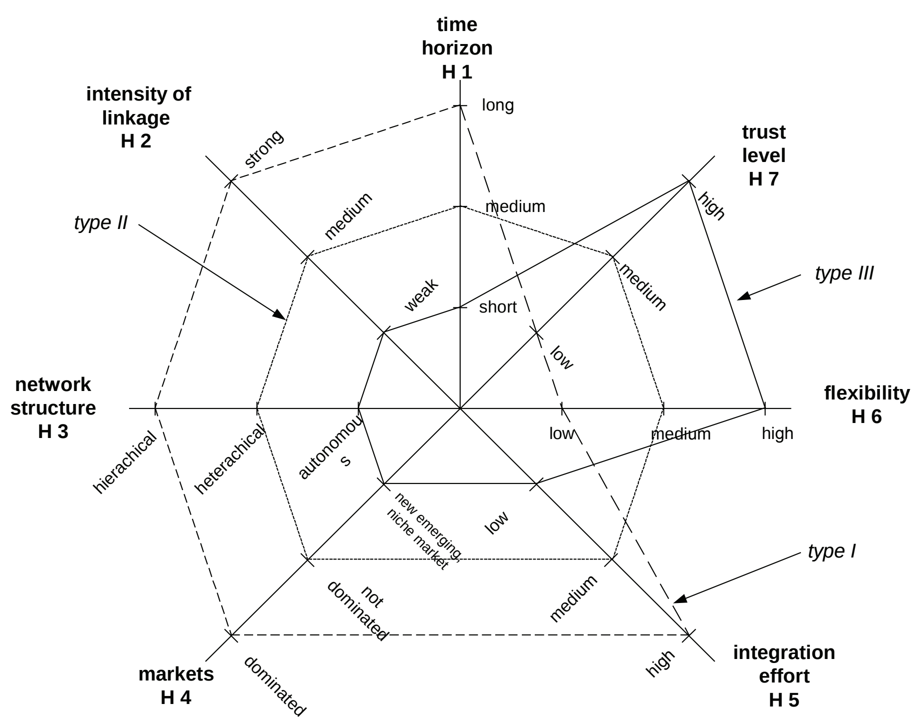


Table 1. Types of network partnerships, based on (Weiß, 2005)

Type	Description
Type I	▪ long term oriented partnerships ▪ focal partners dominate (contracts) ▪ optimisation of the supply or value chain ▪ high intensity of linkage (contracts) ▪ high level of integration ▪ centralised network structure ▪ main objective: efficiency
Type II	▪ dynamic project oriented partnerships ▪ heterarchical network structure ▪ latent business relationships ▪ loosely coupled partnerships ▪ main objective: efficiency and flexibility ▪ Web-based portals and collaborative solutions ▪ democratic structures (code of conducts, constitutions)
Type III	▪ spontaneous, temporary partnerships ▪ main objective: flexibility ▪ business opportunities at short term ▪ Service-oriented architectures ▪ win-win-driven

and preferences. Whereas, intra-network analysis complements our measurement with an additional "internal" view. From this perspective, we are interested to analyse existing network ties within boundaries of an identified business network within its boundaries. But, defining boundaries of a network is a difficult task (Scott 2000), (Wassermann and Faust 1994). While the inter-network perspective determines the co-operation behaviour in retrospect, the intra-network perspective aims analysing the degree of strategic fitness between network partners. Dimensions for the analysis are: roles in network, information exchange performance, co-operation, goal definition, profit share, success, goal binding. Again, quantitative values of variables are aggregated to qualitative values in the range of low, medium, and high. Later on, we will primarily look at the seven dimensions of the inter-network analysis. Nevertheless, implementing the intra-network analysis follows the same principles.

Ontology-Based Model

"*Ontologies are a formal conceptualization of a particular domain that is shared by a group of people*" (Maedche, 2002). Social network analysis combined with ontologies offer new ways to analyse and to deal with collaborative information of networks. Available methods, techniques and tools have considerably improved during the last years, namely KAON[10] and Protégé[11]. In the following, the empirical model presented above is transformed step by step into an ontology structure.

An ontology structure *O* is defined is a tuple $O = \{C, R, H^C, rel, A^O\}$, where (Maedche 2002):

1. *C* is a set whose elements are called concepts.
2. $R \subseteq C \times C$ is a set whose elements are called relations.
   For $r = (c_1, c_2) \in R$ one may write $r(c_1) = c_2$. *C* and *R* are two disjoint sets.
3. $H^C \subseteq C \times C$ is a concept hierarchy in form of directed relationship $H^C \subseteq C \times C$ also called taxonomy. $H^C(C_1 \times C_2)$ means C_1 is subconcept of C_2.
4. *rel*: function $rel: R \rightarrow C \times C$ which sets to concepts in non-taxonomic relationship
5. A^O is a set of axioms on *O* expressed in an appropriate logical language, e.g., FOL.

To cope with the lexical level, the notion of a lexicon is introduced. For an ontology structure $O = \{C, R, A^O\}$ a lexicon L is defined as $L = \{L^C, L^R, F, G\}$, where:

1. L^C is a set whose elements are called lexical entries for concepts.
2. L^R is a set whose elements are called lexical entries for relations.
3. $F \subseteq L^C \times C$ is a reference for concepts such that
   $F(l_C)\ \{c \in C: : (l_C,c) \in F\}$ for all $l_C \in L$
   $F^{-1}(c) = \{l_C \in L^C : (l_C,c) \in F\}$ for all $c \in C$.
4. $G \subseteq L^R \times R$ is a reference for relations such that
   $G(l_R) = \{r \in R : (l_R, r) \in G\}$ for all $l_R \in L^R$,
   $G^{-1}(r) = \{l_R \in L^R : (l_R, r) \in G\}$ for all $r \in R$.

In summary, ontology can be formally defined to be a structure *O*. Whereas, *L* is a corresponding lexicon. Ontology structure *O* represents an explicit specification of a conceptualisation of some domain. Agreed vocabulary is delivered through lexicon *L* and allows communicating about this formal conceptualization.

Collaborative data stored in BPP builds the knowledge base of the network about characteristics of network entities, available capabilities. It is important to understand the relations between ontology and knowledge-base. Ontology aims to capture the *conceptual structures* of a domain consisting of intentional logical definitions (characteristics that distinguish concepts). Whereas, a *knowledge-base* aims to specify a concrete state of the domain comprising of extensional parts (entity instances).

At this stage of development, the resulting model does not intend to fulfil the criteria of the formalism presented above. We derive a full-fledged ontology-based model with maximum of expressivity. Aim is to realise a complete transformation of the empirical model into an ontology-based structure. We do not claim at this stage to fulfil all requirements of above defined ontology structure. Thus, the model processed maximum semantics and expressivity during modelling process without considering requirements of information processing through machines. At this stage of development human agents are in the foreground.

Ontology-based model includes concepts of ontology structure. The model does not fulfil formal requirements of ontology. Requirements for reasoning and inference have to be considered. This requires a further step of transformations so that these models fulfil requirements imposed such as OWL-DL, OWL-Lite and OWL-Full.

OWL is a family of richer ontology languages that enhance RDF schema. The simplest language is OWL-Lite, a limited version of OWL-Full that enables simple and efficient implementation. Finally, OWL-DL is a more simple subset for which reasoning is known to be decidable so that complete reasoners can be constructed on this basis, even if less efficient than OWL-Lite reasoners. OWL-Full is the full ontology language which is in theory undecidable, but in practice useful reasoners can be constructed (Motik et al., 2003), (Weiß, 2005). In order to achieve a better understanding of the measurement we describe the seven dimensions of the inter-network analysis (see Table 2).

The example following shows the dimensions of the inter-network analysis in OWL-notation. In the domain of network-company and typology we see the corresponding concepts subsumed under the object property typology is of the empirical dimensions or areas of measurement.

Example:

```
<owl:ObjectProperty rdf:ID="include">
   <rdfs:label xml:lang="en">typology is</
     rdfs:label>
```

Table 2. Measurement – description of dimensions (Weiß, 2005)

no.	concept *network-company*	description/ measured as
1	time horizon	• time frame or duration of co-operation (depends on co-operation objectives)
2	trust level	• degree of information filtering (exchange of data/ information) • degree of trust compensating/ substituting measures (such as control structures, contracts, formal agreements, etc.)
3	flexibility	• ability to adapt to/ to react on external developments • openness of the network (barriers for entering and leaving the network)
4	integration effort	• system interfaces (data formats, standards, soft- and hardware, structure and business processes) • case/ work item: complexity, variability, structuredness
5	markets	• market structure and constellation in branches (culture: code of conducts, established structures, etc.) strongly influence the emerging structures of collaborative networks • Characteristics of markets are maturity (stage of development), intensity of technology, discontinuities, intensity of competition, etc. o emerging markets (such as bio-technology, nano-technology, etc.) o dominated markets (dominated by multi-national companies, e.g. chemical and automotive industry, etc.) o heterarchical markets (no dominating actor)
6	network structure	• management of network • way decisions are taken in the network o hierarchical (focal partner) o heterachical (democratic) o autonomous (self-organisation)
7	intensity of linkage	• measures/ means to control the network (such as contracts, financial and structural dependencies and influence, etc.)

```
   <rdfs:domain rdf:resource="#
     network-company"/>
   <rdfs:domain rdf:resource="#typology"/>
    <rdfs:range rdf:resource="#
      time-horizon"/>
   <rdfs:range
     rdf:resource="#Flexibility"/>
   <rdfs:range rdf:resource="#
     network-structure"/>
   <rdfs:range rdf:resource="#
     intensity-of-linkage"/>
   <rdfs:range rdf:resource="#
     Trust-level"/>
   <rdfs:range rdf:resource="#market"/>
   <rdfs:range rdf:resource="#
     integration-effort"/>
</owl:ObjectProperty>
```

Excerpt of BPP: network typology in OWL

Next, we continue looking at the structure of business partner profiles.

Business Partner Profile

Business partner profiles (BPP) may differ concerning their structure based on probably varying requirements resulting from type of network, type of involved organisations in a network and as well the objectives and last but not least the branch regarded.

The typical structure of a BPP looks as follows (see Table 3).

In this chapter we concentrate on descriptions about requirements concerning strategy, structure (organisational) and culture.

Table 3. Business partner profiles (BPP)

topic/ area	description
drivers business relationship	strategy: strategic factors to configure business relationship
	process:b2b-integration concepts and -standards
	information system: description of interfaces, data formats, standards, etc.
output	standardised output of business relationships
partner-specific requirements	needs and preferences concerning strategically, structural, cultural configuration of the business relationship
specific set of co-operation requirements	information concerning implementation of collaborative business processes and collaborative information systems

Network entities are characterised within the object property "characteristic-is" with the following attributes:

```
<owl:ObjectProperty rdf:ID=
   "characteristic-is">
  <rdfs:label xml:lang=
    "en">characteristic is</rdfs:label>
  <rdfs:domain rdf:resource=
    "#characteristic"/>
  <rdfs:domain rdf:resource=
   "#network-company"/>
  <rdfs:range rdf:resource=
   "#contact-person"/>
  <rdfs:range rdf:resource="#branch"/>
  <rdfs:range rdf:resource="#employee"/>
  <rdfs:range rdf:resource="#address"/>
  <rdfs:range rdf:resource=
   "#performance"/>
</owl:ObjectProperty>
```

Excerpt BPP of property "characteristics-is" in the domain of concept "network company" in OWL

Figure 7 shows in a diagram the realisation of the transformation of measurement metrics (empirical model). Despite the fact, that the perspective of intra- and inter-network perspective is illustrated, we focus on inter-network analysis (see right part of the figure).

As described in the previous section, the Semantic Web technology stack was applied for modelling. Figure 8 shows an excerpt of a business partner profile represented in RDF(S). Again, concepts "network company" and "strategic fit" are marked and information of business partners is stored in RDF. Now, that the BPPs containing meta data has been explained, we are looking next at some concrete examples. In this way, underlying principles of the approach chosen are pointed out (Weiß 2007).

At the beginning of the chapter we have described the scenario of digital business ecosystems providing context and background of this research. Figure 1 displays three development stages on the way to electronic networks in the sense of digital business ecosystems. Today, the challenge for electronic networks exists in dealing with resulting complexity of a multitude of social ties, explicit or implicit, latent or activated linking the network nodes.

Weiß (2005, 2007) presents a solution for the scenario illustrated at stage 1. In this scenario a centralised repository or data base is used to store the collaborative data. Despite the fact, that BPP are build as "fingerprint" of network entities, semantics of data relies on a shared data structure or model. On stage 2 collaborative data is no longer stored in a central repository but decentral in BPPs which are possibly part of company's Web site, or any other location on the

Figure 7. Business partner profiles

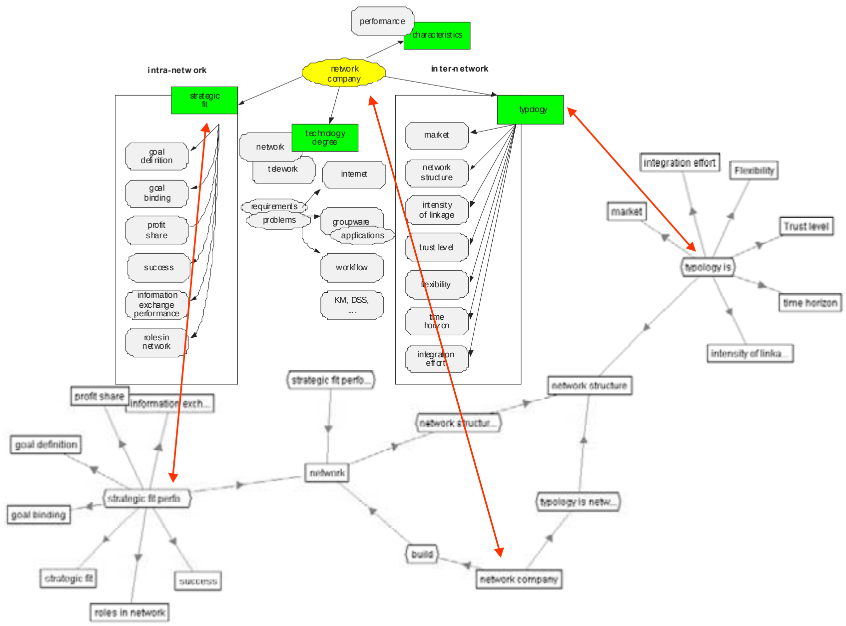
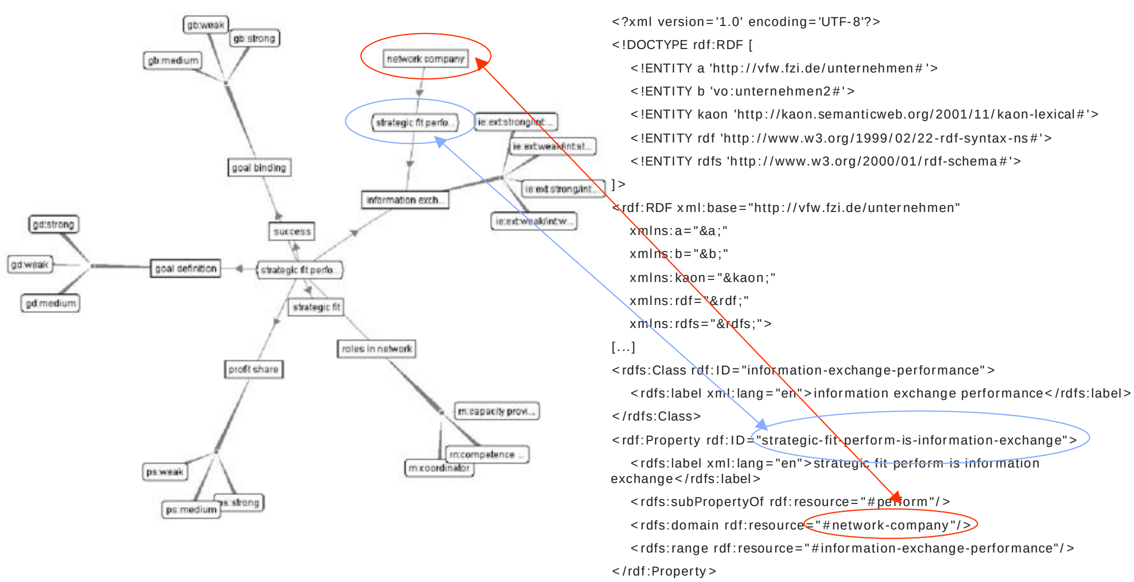
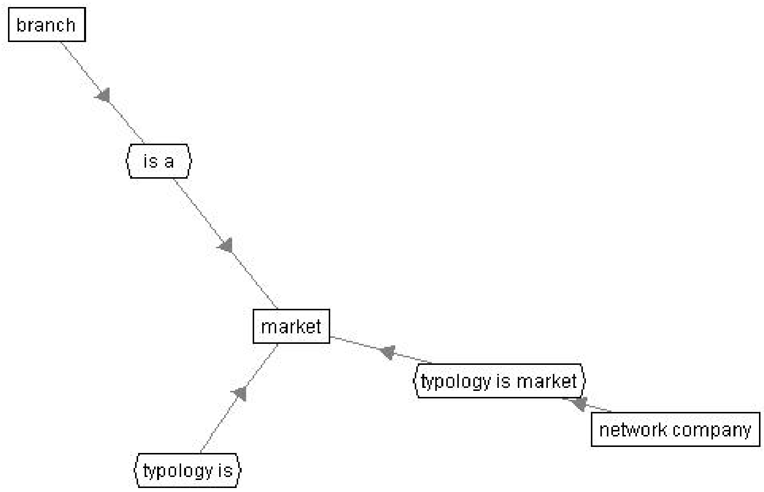


Figure 8. Business partner profiles



Web such as portals of online communities, etc. In this scenario which is already far more challenging with regard to processing of collaborative data we still use a common conceptualisation or data model for describing data stored in BPPs. At stage 3 which constitutes from our point of view the most challenging scenario, we have to deal in contrast with different semantics and data structures. Thus, collaborative data stored in BPPs can be retrieved but not interpreted without semantic annotations or meta data describing the retrieved data entries.

Figure 9. Concept „network company" and concept „market"



Whereas, scenario one can be solved with classic data base techniques, the latter scenario requires explicit semantics at stage of processing of retrieved collaborative data. We envision that this meta data is stored in ontologies which describe the data structure and data stored in BPPs. Techniques of information retrieval are therefore analysed as this discipline has already methods and techniques which fulfil our requirements.

The values of variables before stored are aggregated to factors as e.g. trust level according to predefined rules that are as well stored in the ontology-based model. Questionnaire is as well modelled as ontology structure with the subconcepts questions, answers and code. The latter concept contains the appropriate rules how the answers of respondents that are stored as values of variables are to be aggregated to qualitative values (low, medium, high). To determine the degree of similarity of two different profiles relative distances of values are computed. In order to achieve best possible results the stored original values of respondents are applied.

Figure 10 depicts the reference ontology. Company profiles are assessed using a Web-based questionnaire. Profiles are stored as instances of the reference ontology.

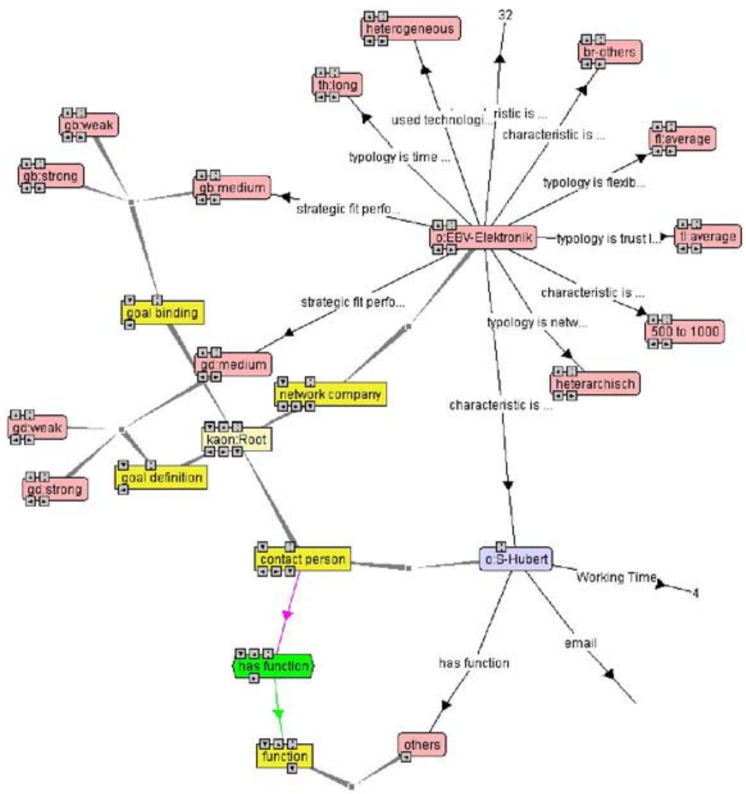
Figure 10 shows a contact person "Hubert" with contact details. "Hubert" is working for a network company "EBV-Elektronik" has a function "others". The strategic fit of the company is medium with regard to the defined criteria. The ICT infrastructure is heterogeneous. The goal binding (gb) with the virtual organisations is medium. The company intends to cooperate in long term with business partners.

Use Case

Nowadays, cluster management gains momentum and turns out to become an important capability for economic development and management of regions. Following case shall underline the relevance of this research on basis of a concrete use case. Therefore, we describe subsequently cluster management as one possible application scenario to which presented conceptual can be applied to.

Today, cluster management is discussed in the light of regional development and building clusters of excellence and innovation. One important ele-

Figure 10. Reference ontology (Maedche and Weiß 2003)



ment of cluster management is to set up a central portal which collects and provides information about capabilities, competences, technologies, contacts, etc. in a particular region. Aim is establishing an infrastructure (according to what we have shown in the figure at the beginning: network layers, services, etc.) which supports the interaction of organisations and fosters development of a digital business ecosystem.

In Figure 3 we have already shown the three different layers (personal/ social network (1), organisational network (2) and data sources/ Internet (3)). Following use case describes a real life application scenario in the technology region Karlsruhe. In our region, social networking amongst companies is supported with various organisations. Industry and education, but as well governmental bodies build relational ties. However, what we find are rather small sub-communities which emerge on basis of personal networks and regular physical meetings. It was decided to support the "networking" and interaction of companies electronically with collaborative services. A research group has been established which is currently looking at the design of such collaborative services. Aim is to set up an infrastructure which allows relational ties to emerge. In total, four collaborative services have been considered to be crucial: (1) search for new business partners with required competences, (2) interact with business partners to plan future activities on basis of collaboration scenario, (3) skill/ competences database (in the form of an inventory what is available in the region, (4) classification of network entities by means of standard classification frameworks so that companies can be found in and beyond boundaries of the region or network. Figure 2 presented a possible framework for collaborative network's infrastructure.

The following questions occurred in the process of project planning: *How and who collects collaborative data required? How will it be stored? Shall information be stored in a central repository (data base)? How can this information be explored? Who keeps this data up to date? How can networking be catalysed relational ties to emerge?* Most of these questions are related to designing collaborative services which access and process the collaborate data. In the following, we look in particular at discovery and matchmaking of business partners which shall be seen as basic concepts for design and implementation. We describe how a possible solution and process shall look like. First, we will present the conceptual base on which base we can achieve required services. Then, we sketch how the solution can be implemented and provide an outlook about next steps and future work.

Looking at the scenario shown in Figure 1, we envision a solution fulfilling the requirements at stage 3. This means that collaborative data is stored decentral in profiles. The profiling process is realised using a self-auditing tool, which supports companies to assess necessary data and to build a BPP. Companies which have no BPP can not be searched and consequently, not processed by collaborative services, because no data is provided to feed discovery and matchmaking services. Profile of a company contains ideally information as shown in Table 3.

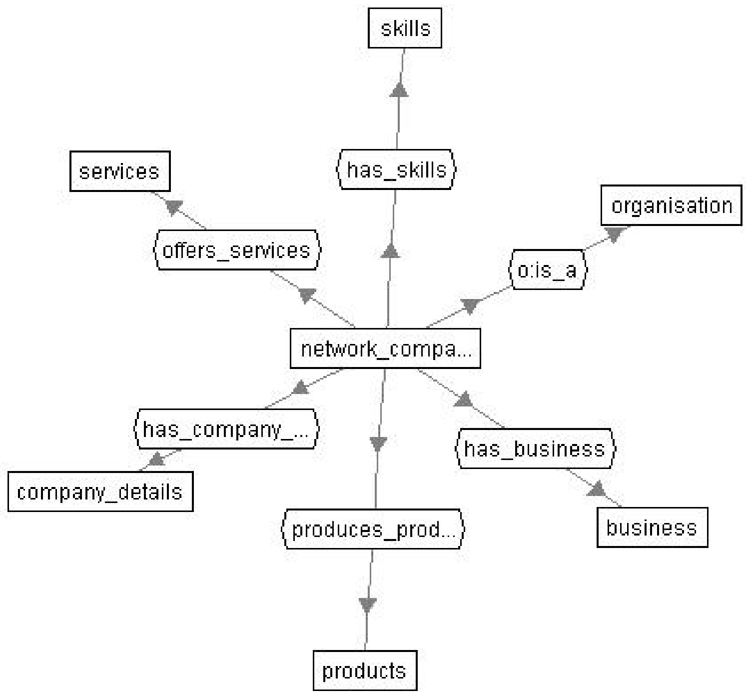
BPPs are stored on the Web site of a network company. Thus, collaborative data is kept up to date by the companies itself. Furthermore, this reduces the amount of data to be stored in a central data base. Boundaries of digital business ecosystem are then determined by the reach of their collaborative services and their ability to interpret collected data. Semantic Web technologies, namely ontology, are able to overcome existing barriers by combining with retrieval techniques all over the world. The Internet provides the required infrastructure and new possibilities. Figure 11 shows the ontology as OI-Model with its sub-concepts and related properties.

Primary information to be retrieved is data about location and capabilities of a company. This comprises as well offers of companies which can be imagined to be accessed automatically through respective Web services.

Table 4. Example BPPs for cluster management

no.	**company details** *(set of attributes: name, location, address, contact, Web site, etc.)*	**branch** *(branch code based on international classification systems, such as NACE)*	**business** *free key words or reference to classification system*	**products/ skills** *classification system such as* ***eCl@ss****, UNSPSC, ETIM, etc.*
1	company a	J62.0.1	software, data base, data warehouse management software	19-21-02-11[1] 19-21-02-90 19-23-20-02
2	company b	J62.0.2	systems analysis (IT consulting), software consulting	25-26-12-01 25-26-12-03
3	company c	C33.1.3	industrial maintenance, facility management, equipment f. NF metal production (maintenance, service, unclassified)	25-04-90-90 18-03-98-90

Figure 11. Descriptors of concept "network company" in OI-Modeller



"Company_details" encompass attributes describing the company such as name of company, contact details, etc. Branch of company is described through an international branch encoding system. Business area can be either described by free key words or a key word system such as a classification system. Products and skills are characterised through descriptors taken from product and service classification systems such as eCl@ss[12], ETIM[13], NACE[14] and UNSPSC[15] or skills/ competences frameworks (such as European e-Competences Framework[16]). Alternatively, e-catalogue systems can be considered to offer more detailed product descriptions and pricing.

Example:

```
<rdf:Description rdf:ID="i-1215196224343-14
  37321528">
  <rdfs:label xml:lang="en">&lt;250</
     rdfs:label>
  <rdf:type rdf:resource="#i-1215195995953-
    804103291"/>
</rdf:Description>
<rdf:Description  rdf:ID="i-1215195733390-18
51815013">
  <rdfs:label xml:lang="en">software</
     rdfs:label>
  <rdf:type rdf:resource=
     "#i-1215195709953-1675840637"/>
</rdf:Description>
<rdf:Description rdf:ID=
  "i-1215195749093-1608225750">
  <rdfs:label xml:lang="en">industrial
     maintenance</rdfs:label>
   <rdf:type rdf:resource=
      "#i-1215195709953-1675840637"/>
</rdf:Description>
<rdf:Description rdf:ID=
  "i-1215196111906-834053317">
    <rdfs:label xml:lang=
```

```
      ”en”>www.company _ b.com</rdfs:label>
    <rdf:type rdf:resource=
      “#i-1215196009640-1874633493“/>
</rdf:Description>
<rdf:Description rdf:ID=
  “i-1215195764203-541590209“>
   <rdfs:label xml:lang=
      “en“>IT consulting</rdfs:label>
   <rdf:type rdf:resource=
      “#i-1215195709953-1675840637“/>
</rdf:Description>
<rdf:Description rdf:ID=
    “i-1215196087062-279141706“>
    <rdfs:label xml:lang=
      ”en”>www.company _ a.com</rdfs:label>
    <rdf:type rdf:resource=
      “#i-1215196009640-1874633493“/>
</rdf:Description>
```

Excerpt of BPP of concept “network company”: Instances of concepts

The example illustrates in which way data and information is accessible for collaborative services. Each concept, property and instance can be located with a unique identifier (URI).

RESULTS/RESEARCH

In this section we will discuss the elements of our conceptual framework. First, trust in electronic networks is looked at, before two collaborative services are regarded in more detail, namely discovery and matchmaking. Those kinds of services support business partners to search for business partners in a pool of potential business partners. Matchmaking services support the decision making process through comparing the profiles of the querying company with profiles of other companies. The collaborative data is processed and the degree of similarity expressed as “strategic fit” is determined.

Trust in Electronic Business Networks

Giving a comprehensive explanation and a discussion of trust in electronic business networks is far beyond the scope of this chapter. But nevertheless, it is required to highlight how essential trust is for the success of “networking”. Many authors believe that trust can replace contractual agreements and obligations between the network partners. However, business realities show us that most business partners still co-operate on legal basis and a normative document in form of a contract which regulates objectives, purpose, scope and rights and obligations in a co-operation of business partners.

The results yielded from empirical analysis have sustained that information, communication and trust are strongly correlated and inter-dependent (for example see (Jung 1999), (Bienert 2002)). Trust per se requires interaction of business partner over a longer period of time. Thus, some authors argue that relationships in a network are either latent or evident (activated). Latent relationships help to build required trust in business networks.

Commitment is another concept typically referred to in context of business relationships. Commitment expresses the degree of personal bonding, in the sense of the willingness of a network partner to invest in a business relationship in long term. This implies that drawbacks in the co-operation are eventually overlooked for the sake of a prosperous long term business relationship. Thus, commitment of a business partner expresses even stronger ties between network partners that those based on trust. Nevertheless, both terms are strongly interdependent and it is difficult to distinct them. Commitment requires trust that a business partner behaves in the expected way and in the interest of common objectives.

Against this background it becomes clearer that communication and interaction of business entities is vital for the process of trust building.

They have to be supported already at early stage of co-operation. Networks rely per se on the personal ties between its members. They are essential for emergence of relational ties within a collaborative and innovation environment. Obviously, increasing dynamics in the interaction of business partners combined with shortening life-cycle of co-operations contradict the nature and actual needs of business relationships regarding trust and commitment. Both concepts occur over a longer period of time and necessitate stable relationships. Once trust is established it reduces opportunistic behaviour. This is substantiated by existing organisation theories as, e.g., transaction cost, principal-agent and property-rights (Picot et al. 2003, pp. 45; Sydow 1992, pp. 130).

Goal is to ease fast and easy docking and quick formation of network entities or new business partners. Whereby, evaluation criteria applied in discovery and selection process have been identified as main study area. Prior criterion to be applied in connexion with selection of business partners is offered business value and ability to complement knowledge, skills and competencies of the network. Aim is to enhance quality and to add value to existing or new products and/or services. As already been pointed out besides these “harder” facts, however, in particular “softer” aspects need to flow into the decision making process.

The proposed ontology-based framework for partner integration aims at developing and supporting trust building mechanisms. Trust building is, beyond any question, a complex issue that offers and necessitates different research perspectives and therefore has been subject to many investigations through different scientific disciplines (Weiß 2005, pp. 81). However, trust building evidently depends on the quality and intensity of communication and information exchange in a collaborative environment. This could be shown by empirical studies (e.g., Jung 1999, p.180; Bienert 2002, p.102). An ontology-based methodology is outlined that facilitates harmonisation and parallelizing of different cultures. In this way, a breeding environment comes into existence from which relational ties and organisational structures are likely to emerge. Moreover, the required characteristic and ability to self-organise are facilitated with self-reference and an initiated learning curve. In this way, a kind of “fingerprint” represents network entities by describing their co-operation ability and requirements. In a process of self-reflection and self-reference relational structures and cultures are then supposed to emerge (Weiß 2007).

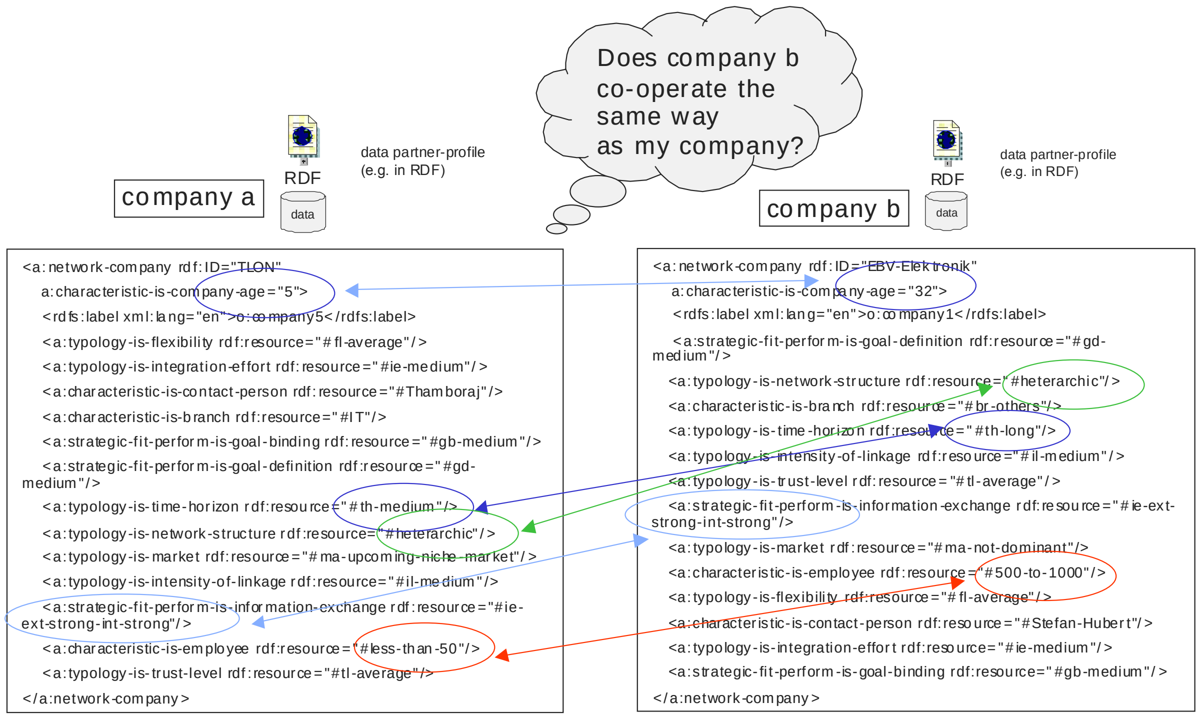
Discovery and Matchmaking

Network companies search for potential business partners using the query user interface of the demonstrator. As an advantage of using an explicit information model in form of an ontology based model, ODAMY is able to use semantic discovery to identify the best fitting partners based on the selected search criteria and applied weightings. Use of ontology brings service provider and service requestor to a common conceptual space and helps in semantic matching of requirements and specifications.

The fingerprint of a network company is produced using a formal explicit ontology-based model structuring criteria for measuring strategic partner fit. In this way, the underlying ICT infrastructure is capable for example to infer that a network company “has” a typology based on ‘time horizon’, ‘integration effort’, ‘intensity of linkage’, etc (Weiß and Maedche 2002).

In Figure 12 an excerpt of fingerprints of two network companies are shown and compared. Company **a** for example is looking for a co-operation with medium time horizon, whereas the network company **b** prefers to co-operate in long-term. The companies share the same conceptual model therefore the values are comparable. A matchmaking environment of a b2b integration technology architecture can process this information and may have discovered and selected business partners **b**. The iep of both

Figure 12. Excerpt business partner profile (BPP) as "fingerprint" of a network company



companies is 'strong', the preferred network structure is 'heterarchical' and the trust-level is 'average', intensity of linkage rated as 'medium' (see Figure 12).

Matching component shall retrieve those cases which show highest similarity with values of the profile of the querying organisation. In the following we look at the matchmaking component. Looking at the vision shown in Figure 1 (stages on the way to the digital business ecosystem) a possible solution retrieves data from BPPs centrally stored. On the advanced stage 2 and 3 we intend to expand the existing boundaries through application of information retrieval techniques.

As an advantage of using an explicit information model in form of ontology based model, it proposed approach enables using semantic discovery to identify best fitting partners based on the selected search criteria and applied weightings. Use of ontology brings service provider and service requestor to a common conceptual space and supports to realise semantic matching of collaborative information stored in the BPP.

Currently, we are investigating the application of different available semantic discovery mechanisms. Particularly, the matchmaking module still requires specifically further investigations and research efforts. However, researchers of different disciplines especially those working in the fields of SOA, electronic markets as well as Web services and business process modelling and management are currently looking into the possibilities to determine the degree of similarity of applied meta models. Therefore, it can be likely taken for granted that a variety of approaches and solutions will emerge soon and will add enhanced functionalities to an adequate matchmaking environment. The task is to search for an existing offer or offers that match each received search query. A central element of a matchmaking environment is the aspect of symmetry (Field and Hoffner 2003). Both sides send a profile that contains relevant data concerning description of the own entity and requirements that the other party must satisfy. According to Field and Hoffner (2003) the customisation of a related service of the ICT infrastructure results from coupling the availability of information from both parties with the ability to update some service properties dynamically.

In the current version of the demonstrator the similarity of profiles A and B is measured as sum of the distances measured of the normed values a_i and b_i of a specific theme i. For each query, themes can be selected from a list of available concepts that can be queried. Each theme i can be weighted in the range of 1 to 5 to enrich the query with individual preferences of the searching entity. The computation of similarity of profiles is described in detail in (Weiß, 2005, pp. 242). Related work of interest is the current developments in the field of Semantic Web services and matchmaking on electronic markets (Veit 2003).

Information Retrieval

As mentioned before, information retrieval techniques offer a huge field for analysing social networks (Klink et al. 2006) and for managing business information (Klink 2006) (Klink et al 2007). Discussing all bits would blast the scope of this chapter. But in particular, the fields of gathering and storing all kind of information and retrieving relevant information are still interesting topics in research which are discussed in various journals (e.g., IJDAR, *Journal of the American Society for Information Science*, etc.) and conferences (e.g., SIGIR, ECIR, ECML, CSCW etc.) and will be touched in the following.

Before a system is able to retrieve relevant information and thus becoming useful, specific information must be gathered from various sources. Especially in business environments collecting information/data and delivering relevant task- and context-specific information is vital (Holz 2005).

In our scenario of b2b environments the collected data is stored and distributed in BPPs. In the case of structured information with known semantic model, BPPs are created using a questionnaire and with the help of a Web-based self-auditing component. This case is described in paragraph 3.4.

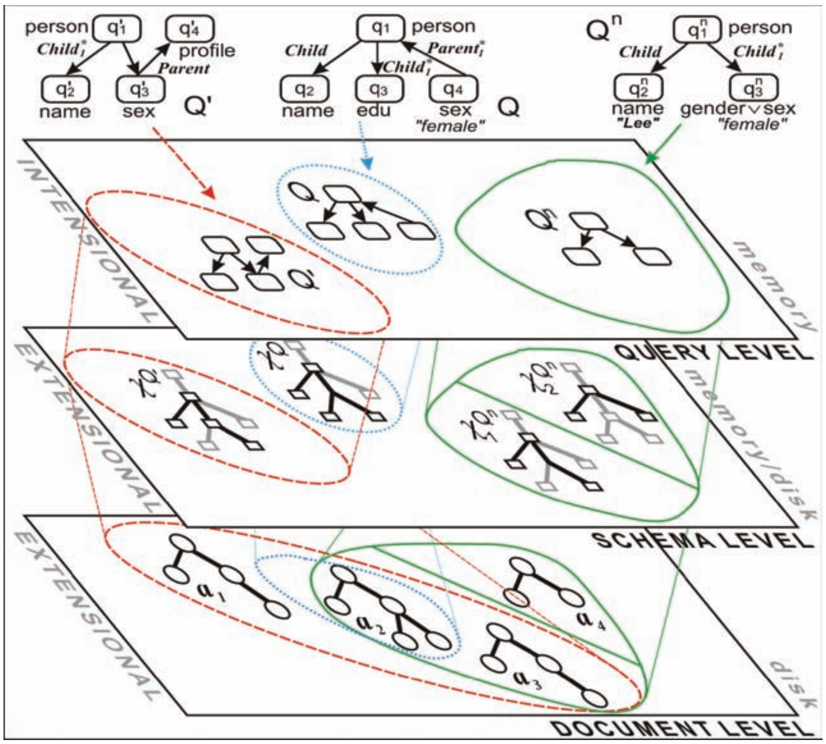
In the case of unstructured information and unknown semantic model, BPPs have to be of such expressiveness that information retrieval techniques allow to gather information from unknown network entities (Klink 2006). In this way, network boundaries are expanded and we are able to establish business relationships with new business partners. Recently, business partners are hosting illustrative and informative Web-sites and it becomes a popular way to use Internet search engines for gathering information of potential business partners (Bergman 2000). But also for creating BPPs this is an elegantly way.

Using business Web-sites for gathering information has the advantage that these Web pages contain recent information because business Web pages are updated regularly. But the disadvantage is that Web pages contain unstructured and much information – mostly in textual form. Thus, the problem of information overflow arises (Klink 2004).

An interesting approach for handling the information overflow problem is summarisation. The huge amount of text is shortened and summarised to some paragraphs or some pages, respectively. Summarisation is one of the emerging fields of information retrieval and is a helpful tool for indexing huge amount of data in Internet search engines (Larsen and Aone 1999). In classical information retrieval summarisation is based on full-text data but recently research is more and more based on structured information and is using XML.

Weigel (2006) presents new structural summaries that enable highly efficient and scalable XML retrieval in native, relational and hybrid

Figure 13. +Three-Level Model of XML Retrieval relates queries (top level) to their matches in the document tree (bottom level) and the corresponding hits in the schema tree (intermediate level) (Weigel, 2006)



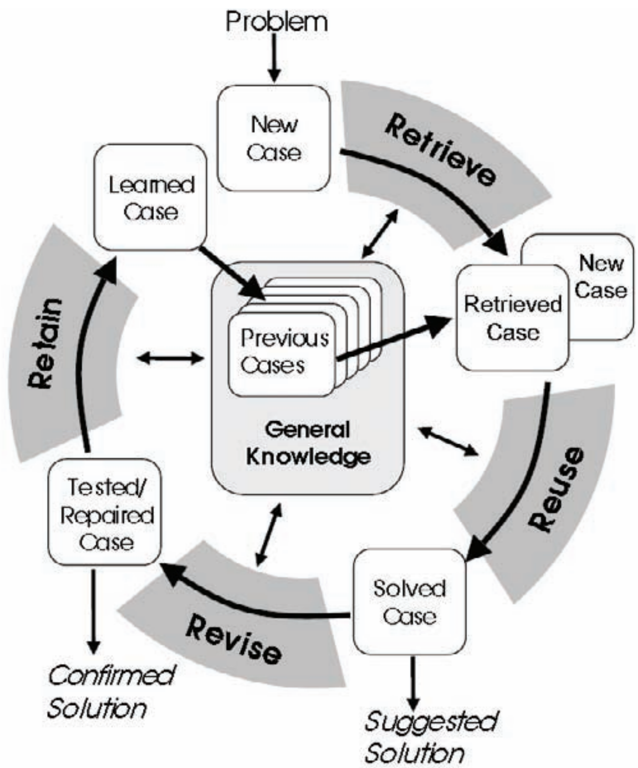
systems. The work shows that structural summaries significantly improve the efficiency and scalability of XML retrieval systems in several ways. Former relational approaches have largely ignored structural summaries. The results show that these native indexing techniques are equally effective for XML retrieval in relational database systems. Unlike some other labelling schemes, this system achieves high retrieval performance with a fairly modest storage overhead (see Figure 13).

Another interesting retrieval technique which is relevant to our approach using BPPs is called Case-Based Reasoning (Bergmann and Stahl 1998), (Bergmann et al. 2003). Case-based reasoning (CBR), as a sub-area of the field of knowledge-based systems, focuses primarily on problem solving by experience. It provides techniques for representing, storing, indexing, and adapting experience. CBR contributes a rich set of techniques which are highly relevant for experience management, particularly for the activities modelling, storing, reusing, and evaluating (Bergmann 2002).

The general procedure when applying CBR, is commonly described by the classical Case-Based Reasoning cycle introduced by (Aamodt and Plaza 1994) (see Figure 14).

The starting point of a new problem solving-process is a given problem for which a solution is required. This problem can be characterised as a new case for which the solution part is still unknown. This new case—often also called query—is then processed in four consecutive steps: retrieve, reuse, revise, and retain. The advantage of using CBR technologies is the learning ability of the system. The more the system is

Figure 14. The Case-Based Reasoning Cycle by Aamodt & Plaza



running and the more BPPs and ties to partners are created, the better and the more "intelligent" the system becomes.

Using CBR vocabulary, the cases in our scenario are the BPPs, the problem is finding an appropriate business partner and the solution is the best fitting business partner. More precisely, if some business is searching for appropriate partners then the BPP of this business is used as the new case. In the retrieve phase, previous cases (in our scenario similar BPPs) are searched in the (general) knowledge database. In the reuse phase, the solutions of retrieved cases are used, i.e. each stored appropriate partner is given as a suggested solution. If the solution is confirmed, then these partners are stored as the solution of the new case and the new (learned) case incl. the solution is stored as an additional previous case in the knowledge database.

Implementation

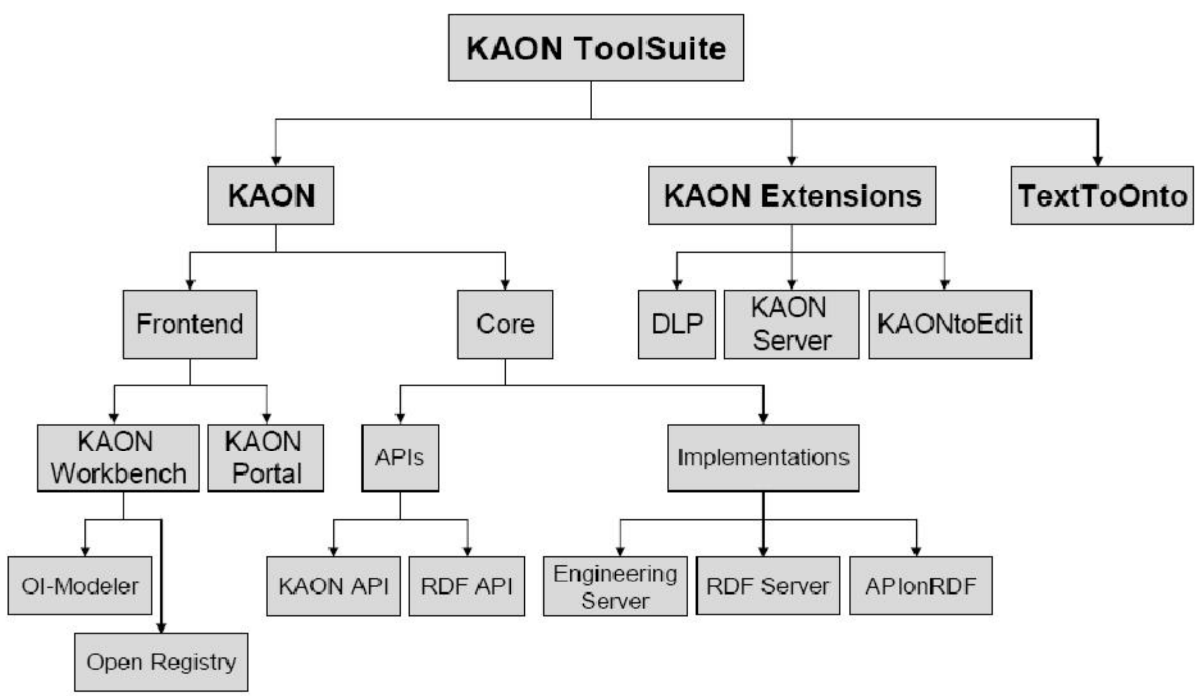
ODAMY is implemented using KAON infrastructure (KAON Dev. Guide 2003). KAON is an open-source ontology management infrastructure targeted for semantics-driven business applications. It includes a comprehensive tool suite allowing easy ontology management and application. Important focus of KAON is on integrating traditional technologies for ontology management and application with those used typically in business applications, such as relational databases. KAON consists of a number of different modules providing a broad bandwidth of functionalities centred around creation, storage, retrieval, maintenance and application of ontologies (Gabel et al. 2004). Typical model elements of KAON OI-Model are concepts, properties, property ranges (property-centric, several ranges), attributes (of type string). Min-max cardinalities are a feature but are depending on API implementation. In the following, we do not consider cardinalities for the modelling. Further features are lexical layer, modularization, evolution and meta-modelling. Main feature used for conceptual modelling is OI-Modeller (ontology editor). For implementing the self-auditing tool KAON portal is used. Figure 15 shows diagrammatically the KAON toolsuite.

BPP are created using a questionnaire which assesses the entry values for different variables. The value of these variables are then computed and aggregated according to predefined rules to values for the aggregated factor values. Figure 16 shows diagrammatically the three subconcepts which shall store assessed data set for each network entity. Concept "Answers" stores the response value for each question (variable). "Questions" contains the questions of the questionnaire. Concept "Code" assigns each value entry a classification code as class identifier.

Figure 16 shows parts of the ontology-based model: the concept "Questionnaire" and its subconcepts "Answers", "Code" and "Questions". This part of the model stores important information to deal with the life-cycle of a BPP. Entering the inter-organisational network corresponds to filling in the questionnaire and producing a BPP. Entities which do not possess a profile are not seen as part of the (electronic) network consisting of latent and activated network relationships. Once a BPP is created collaborative services can be used to establish and maintain business relationship management electronically. In the light of steady increasing number of network nodes humans are no longer able to deal with resulting complexity. We see future networks according to (Krystek et al. 1997) as open, many inter-organisational relationships and of high reciprocity.

Referring to concept "Questionnaire", dealing with dynamics is an important feature in the given context. As already mentioned our work aims

Figure 15. KAON tool overview (Gabler et al. 2004)



to develop a conceptual model which allows to design and develop collaborative services which are able to process the collaborative data stored in the BPPs.

In the following we explain how the model stores assessed collaborative data, and how this information shall be processed through services.

A Web-based self-auditing component supports a network entity in describing its profile. The auditing component consists of a questionnaire. The component has been realized using Java Server Pages and tag libraries which are directly connecting to the API of the KAON-Toolset. The created profile is directly stored as a set of instances into the ontology structuring the network (case base).

Having a look at following example which displays a typical data entry taken from the questionnaire. As shown, the topic is "intensity-of-linkage" as already described in previous section. "102053" documents the origin of the data entry and is stored as cross-reference of the questionnaire.

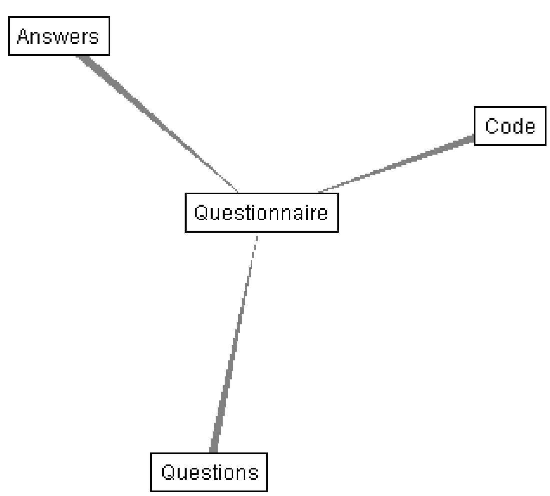
For each data entry (answers of respondent) an instance is produced in concept "Code" and stored in the ontology structure. For the instance a link or relationship is established with the concept "Answers" (number of the question within a topic in the concept and the concept "Questions". The stored answer is referencing to the respondent (in our case the network entity). In addition we have a concept "Rule" which stores information how the stored qualitative data has to be processed in order to achieve "qualitative" values. Typically, these values have the range low, medium or high (see Figure 6).

As our implementation is realised with KAON-Toolset, each data entry has a URI which provides the object with a unique identifier. As we have as well defined a respective namespace, the discovery of data entries is not restricted to borders of the regarded network.

Example:

```
<rdf:Description rdf:ID=”102053”>
 <rdfs:label xml:lang=
    ”en”>102053</rdfs:label>
 <rdf:type rdf:resource=“#Code“/>
 <entry-with rdf:resource=“#3“/>
```

Figure 16. Concept "Questionnaire" and its subconcepts in OI Modeler



```
 <entry-in-topic rdf:resource=
    "#intensity-of-linkage"/>
 <entry-in-question rdf:resource=
    "#Question5"/>
 <entry-in-complex
    rdf:resource="#typology"/>
</rdf:Description>
```

Excerpt BPP of concept "intensity-of-linkage" in OWL: value entry of question 5 of the inter-network analysis

CONCLUSION AND OUTLOOK

In this chapter we elaborated the conceptual basis for establishing and maintaining electronic business relationships. We overlooked current state-of-the-art of business networks and motivated future scenarios of digital business ecosystems. Growing popularity of business communities indicates a noticeable change and openness of business partners to publish information and data (far more than just contact details, comprising career steps, competences, and business interests).

Prominent communities are, e.g., LinkedIn, Plaxo or Xing, the latter with daily up to 30,000 users online. We highlighted that collaborative services supporting business networking and the management of business communities and networks, respectively, are demanded and are expected to have tremendous social impact on how electronic business will be conducted in the future.

The chapter motivated a development path towards digital business ecosystems comprising three distinct development stages. In particular, the scenario shown at stage 3 imposes interesting questions and challenges such as gathering unstructured and textual information from business Web sites.

Furthermore, we introduced business partner profiles (BPP) as an appropriate concept to overcome existing barriers of electronic networks. Limitations currently exist primarily with problems related to gathering and storing of all kinds of business and collaborative information. With the emergence and fast growing of business communities on the Internet, available amount of collaborative information is exploding and challenges current retrieval and analysis techniques. We highlighted some of these challenges and looked at how networks can be analysed from an inter-network perspective.

Additionally, we looked at information retrieval techniques, namely case-based reasoning and gathering of unstructured information. Ontologies are able to describe underlying data structures and semantics of data stored in BPP. Retrieval techniques allow gathering and storing information from unknown network entities and in this way enable supportive collaborative services to maintain electronic business relationships.

We presented a use case which highlighted a possible application scenario in the context of cluster management. Finding business partners and gathering information from business partners is an important task.

Business Web-sites are used for gathering information as they contain relevant business data in unstructured or textual form (typically in HTML or XML-format) but are updated regularly. However, businesses are hosting informative Web-sites containing plenty of information about competences, offerings, products and capabilities of a company. Thus, search engines have become a popular way to use the Internet as an infrastructure to maintain business relationships and to collect information about potential business partners. Ontologies provide required meta data to make information stored on business Web-sites more expressive and self-descriptive. Nevertheless, standards (such as NACE, UNSPSC, eCl@ss, etc.) and reference models (e.g., competence grids such as the European e-Competence Framework) shall be used to structure and reference contents of profiles. Besides, frameworks should be transformed by means of XML-based ontology languages as, e.g., OWL ontologies to serve the needs of our application scenario.

The use case at hand used existing classification systems for structuring and describing this information and data. Besides classification systems we used an empirical model to assess collaborative information from business partners. This information is stored in BPP to support emergence and postulated ability of business networks to be self-descriptive in order to distinct themselves from their environment (an ability called "self-referencing"). Both characteristics are foundations for self-organised systems. Collaborative services primarily aim at supporting self-organisation as it can be seen as one of the key drivers of digital business ecosystems.

Another strand we looked at is case-based reasoning. Case-based reasoning provides techniques required for implementing our collaborative services. It provides the ability to learn from daily experience and to induce intelligence in collaborative services not exclusively related to business relationship management by building required knowledge-bases.

The chapter provided answers primarily on conceptual basis but was at this stage not yet able to provide a proof of concept. For implementation of the presented approach we use KAON infrastructure. Ontology development tool sets have matured during the last years. KAON tool set is used to build BPP by means of a self-auditing tool which uses a standardised questionnaire. With regard to implementation of a software prototype, we envision in a next step further implementing the use case "cluster management" referred. For this purpose BPP profiles have to be build and implemented in a lab environment to apply state-of-the-art query and retrieval techniques. State-of-the-art techniques of information retrieval and Semantic Web have to be combined with methods of social network analysis.

The chapter described and discussed necessary foundations for discovery and matchmaking services. Fast growing acceptance and maturing of business communities will offer interesting use cases for analysis and further research activities. One of the biggest challenges ahead is to learn and to substrate necessary theories and methods from real life cases.

At the beginning of the chapter we have introduced a framework structuring the research area. The framework highlights required interdisciplinary nature of our future research design. Next step to be done is to use the self-auditing tool to build BPP. This will allow working with real life data and to set up a lab environment to analyse, explore, and validate presented concepts.

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ENDNOTES

1 Ontology-based Business Partner Relationship Management Methodology

2 Universal Description, Discovery and Integration

3 Electronic Business XML

4 EDI = Electronic Data Interchange.

5 XML = Extensible Markup Language; see http://www.w3.org/XML/.

6 See http://www.xing.com [last visit 28 July 2008].

7 See http://www.linkedin.com/ [last visit 30 July 2008].

8 See http://www.plaxo.com/ [last visit 30 July 2008].

9 See (Weiß, 2005) for the conceptualisation of self-organisation: major concepts are autonomy, self-reference, complexity, redundancy, adaptivity.

10 KAON is an open-source ontology management infrastructure targeted for semantics-driven business applications. See http://kaon.semanticWeb.org/documentation [last visit, 30 July 2008].

11 Protégé is a free, open source ontology editor and knowledge-base framework. See http://protege.stanford.edu/ [last visit, 30 July 2008].

12 See http://www.eclass.eu [last visit 30.07.2008].

13 See http://www.etim.de/ [last visit 30.07.2008].

14 Statistical Classification of Economic Activities, see http://ec.europa.eu/comm/competition/mergers/cases/index/nace_all.html [last visit 30.07.2008].

15 See http://www.unspsc.org/ [last visit 30.07.2008].

16 See http://www.ecompetences.eu [last visit 30.07.2008].

Chapter XXXIII
The Semantic Web in Tourism

Salvador Miranda Lima
Escola Superior de Tecnologia e Gestão, Instituto Politécnico de Viana do Castelo, Portugal

José Moreira
IEETA / DETI, Universidade de Aveiro, Portugal

ABSTRACT

The emergence of the World Wide Web made available massive amounts of data. This data, created and disseminated from many different sources, is prepared and linked in a way that is well-suited for display purposes, but automation, integration, interoperability or context-oriented search can hardly be implemented. Hence, the Semantic Web aims at promoting global information integration and semantic interoperability, through the use of metadata, ontologies and inference mechanisms. This chapter presents a Semantic Model for Tourism (SeMoT), designed for building Semantic Web enabled applications for the planning and management of touristic itineraries, taking into account the new requirements of more demanding and culturally evolved tourists. It includes an introduction to relevant tourism concepts, an overview of current trends in Web Semantics research and a presentation of the architecture, main features and a selection of representative ontologies that compose the SeMoT.

INTRODUCTION

The concept of tourism emerged in the geographic area which is currently known as the European Union, and came out as a strongly European phenomenon in such a way that Europe is still the prime touristic destination as well as a spinning platform for intercontinental tourist flows, as confirmed by the statistics of the World Tourism Organization. In fact, tourism is the economical and social activity with the biggest impact and significance within the European Union, in such a way that it constitutes a strategic activity for sustained development that ensures the current patterns of living in countries like Portugal, Spain, Austria or Greece.

Tourism demand in the following years or decades will be regulated by the a new social paradigm (considered in the current developments of Alvin Toffer's "third wave" (Toffler, 1980)) centred in the multiplicity of "selves"; in other words, the new consumer will be profiled as having a great diversity of information which will be used as an instrument of demand, agile in the use of intelligent technologies and caring for environmental, cultural and ethnic problems.

In order to face the sustainability demands of European tourism development, as well as the new wave of more demanding and culturally evolved tourists, the development of models of touristic information in the light of the Semantic Web paradigm may play an important role.

Over more than a decade and a half after Tim Berners-Lee presented his original proposal for creating a universal platform of access and dissemination of information between the European Organisation for Nuclear Research (CERN) researchers, the Web became one of the artefacts that have metamorphosed all dimensions of society in an extraordinarily decisive, powerful and fast way. Such an artefact has also limitations that can be numbered as follows:

i. **Information search:** Current search engines ignore the context of the terms (restaurant, museum, handicraft, etc.) or the connections between them (a museum has a restaurant, a restaurant is classified as a space for smokers, etc.);
ii. **Extraction of information:** Obtaining decisive and influential information demands relying on human interpretation both for selection and filtering ("Margarida da Praça" can be both a restaurant or a cod-fish specialty);
iii. **Management:** Website content management can be complex, despite the simplicity of the documents' organisation structure; in this way, the application of appropriate Web Engineering practices will play an important role in both the organisation and classification of touristic information in the Web;
iv. **Automatic document generation:** The inclusion of adaptability mechanisms will reduce the level of user dissatisfaction regarding Webpages which are adaptable to their profiles (museums with the most favourite painters, traditional fish-based gastronomies, etc.).

A touristic itinerary, in its essence, is an aggregator of touristic objects which semiotically have a significant and a meaning given by the resident communities, associating sufficiently attractive eclectic and singular values which promote or stimulate tourism. In this chapter, we contextualise such touristic objects in three kinds of information: spatial information (particularly, the geographical location defined by geographical coordinates and the type of location), temporal information (such as the working schedule and the duration of an event) and thematic information (such as intrinsic and extrinsic values of attractions and touristic descriptors).

Webpages contextualized to the touristic domain, in the current or syntactic Web, are prepared to be interpreted by humans and are, therefore, inadequate for "intelligent" processing by computing agents. Let us consider the example of a search for the restaurant "Margarida da Praça" in the Web. Current search engines are unable to differentiate our object of interest from other homonyms that occur in the Webpages retrieved by the search engines. This means that for the same object of interest we can identify the name of the restaurant, as well as a person's name or a gastronomic specialty. To improve the effectiveness of search engines in what concerns our object of interest, we insert into the Webpages, besides the syntactic reference, the information of what "Margarida da Praça" means (metadata). So, we need semantic structures that represent the knowledge that a restaurant has a name, a geographic location, a phone number and so on. Each Webpage is tagged with metadata based on the referred semantic structures called ontologies and the Web-users will be able to ask questions based on those ontologies.

This chapter covers the following topics: (*i*) the concept of tourism (a brief approach on the touristic phenomenon and its role in the mosaic society; (*ii*) the Semantic Web evolution, inter-layer architecture and Web-socialisation; (*iii*) a conceptualisation of a touristic object and its framing in the touristic destination, through touristic itineraries and a semantic model for the touristic domain and its semantic dimensions “what”, “when” and “where”.

THE CONCEPT OF TOURISM

Touristic Phenomenon

The first scientific studies on tourism appeared a century ago but the lack of consensus around the concept of tourism remains until today. One of the definitions that most influenced subsequent studies was presented by Walter Hunziker and Kurt Kraft (quoted by Lickorish & Jenkins, 1997, p. 34):

Tourism is the sum of the phenomena and relationships arising from the travel and stay of non-residents, in so far as they do not lead to permanent residence and are not connected with any earning activity.

According to the definition proposed by Walter Hunziker and Kurt Kraft we can consider the concept of tourism in four perspectives:

i. **The movement of tourists:** “a movement of persons who temporarily leave their permanent place of residence for any reason related to the spirit, body or job” (Schwink, quoted by Barretto, 1999, p. 10);
ii. **Services, equipments and resources:** “tourism is an identifiable nationally important industry and involves a wide cross section of component activities including the provision of transportation, accommodation, recreation, food and the related services” (Australian Department of Tourism and Recreation, quoted by Leiper, 1979, p. 392);
iii. **Social relation:** “tourism is a social phenomenon consisting of voluntary and temporary movement of individuals or groups of people who, mainly for recreation, rest, culture or health purposes, leave their usual place of residence for another place, where they perform no paid activity, generating multiple inter-relations of social, economic and cultural importance” (Oscar De La Torre, quoted by Ignarra, 2003, p. 13); and
iv. **Area of study:** “tourism[1] is the study of man away from his place of residence, of the industry which satisfies his needs, and of the impacts that both he and the industry generate over the physical, economic and social-cultural environments of the receiving area” (Jafar Jafari, quoted by Ignarra, 2003, p. 12).

Being a complex phenomenon, the search for a more complete and thorough definition of tourism and tourist should include the geographical aspect assumed by the travel or movement, the temporary aspect of the permanence outside the place of residence, as well as the polymorphic aspect associated to:

i. **The touristic subject:** The tourist may perform a diversity of roles, such as a guest for the hotelier, a traveller for the transport industry, a customer for the itinerant traders, a client for the touristic operators or other commercial agents;
ii. **The touristic object:** Aggregating three inter-related components:

a. Business or thematic, as an element of consumption, in which the tourist uses any equipment of touristic service such as accommodation services, food services, recreation and leisure services, etc.;
b. Geographical or spatial, as a location element, in which the tourist consumes a given touristic service; and
c. Temporary, as a duration element, in which the tourist has some time to engage in recreational activities at a given place.

The act of travelling, triggered by the touristic subject (the tourist), takes place with the interaction of the objects joined in the touristic object, that is, the act of moving from one place to another, for a given period of time, and always with the return to the place-of-origin, in order to resume the non-leisure activities.

The Tourists and the Mosaic Society

Nowadays we observe an increasingly larger number of citizens in conditions of enjoying, although in a limited and geographically restricted way, of mass tourism. However, the novelty emerges precisely with more demanding and higher-quality tourism levels. In order to achieve higher-quality touristic services, a certain financial availability is needed, and a substantial reduction of the work time and correlating increase of free time, is important as well. There also exists a larger valorisation of individuality, to which, in normatively desirable situations, is added a bigger concern towards environmental, cultural and ethnic problems. That is to say, it is another type of individuals who set themselves aside from their fellow citizens in this and other spheres (education, work, contacts and sociability), and may even break with the lifestyles of the "mass society", assuming, copying or creating, in reality or appearance, new behaviour patterns expressed in more individualistic ways of life. These become possible due to economic resources, the diversity of social connections on an atomistic or dual basis and to a larger geo-social mobility – which, ultimately, allows for a higher degree of freedom and of choice from the range of leisure and recreation supply and, obviously, of tourism. In this perspective, we will have a new concept for the individuals of the "mosaic society": the "multividual", that is, the individuals who allow themselves to multiply, to metamorphose in the most varied situations, enjoying leisure and material well-being situations (Society of Evaluation of Enterprises and Risk, 2005, p. 578).

The study "*Reinventing Tourism in Portugal: A Strategy for the Portuguese Touristic Development in the 1st Quarter of the 21st Century*", requested by the Confederation of Portuguese Tourism to the Society for the Evaluation of Enterprises and Risk, reveals the future of tourism in the context of the "mosaic society", in which the tourist as a "multividual" will be a consumer with "a more individualistic profile, informed, sophisticated, multi-cultural and multi-ethnical, demanding, […], but with more money, with environmental concerns and a user of new technologies" (Society for the Evaluation of Enterprises and Risk, 2005, p. 590). These new tourists, carrying new patterns of behaviours, attitudes and consumption, will have their behaviours, their attitudes and their decisions constantly changing during their life, and therefore different profiles of the same individual will arise, without excluding different chameleon nuances of different, exotic or even bizarre behaviours. That multifaceted characteristic of the new tourists will require the re-design of their free time available for travel and leisure, inviting to the consumption of "touristic experiences", according to their preferences and motivations.

THE (SYNTACTIC AND SEMANTIC) WEB AND ITS EVOLUTION

An Approach to the Semantic Web

A few years after it came into being, the Web started showing its limitations in sustained development, notwithstanding its extraordinary success in society. Several researchers involved in the On-To-Knowledge Project (On-To-Knowledge, no date; Sure et al., 2003) list the fragilities of the current Web structure in four groups:

i. **Search for information:** The current search engines usually find non desired information, and in addition they ignore the context of the terms or the connection between them;
ii. **Extraction of information:** Obtaining information can hardly be automated, as it requires human interpretation for selection and filtering;
iii. **Management:** Website content management can be complex, despite the simplicity of the document organisation structure; and
iv. **Automatic document generation:** The automatic generation may help in the maintenance of Websites which are adaptable to their dynamics and that may reshape according to different users' profiles.

A typical example of such limitations concerns the information search through search engines (Osti, 2004, pp. 267-272; Salazar, 2005, pp. 47-62):

i. When we ask the search engine for information on a search object (e.g. handicraft and tourism) we obtain information that requires an increased effort and patience to filter and assess the contents of the Webpages retrieved, by applying possibly fallible criteria of relevance;
ii. The search engine does not find Webpages according to our expectations (e.g. classifications on handicraft); and
iii. Current search engines do not include "enough skills" to adequately answer questions such as "in which restaurant can one eat fish?"; we will have to extract the relevant information ourselves, often by performing several searches and examinations of many Webpages to reach the desired results.

Currently, a search in the Web only retrieves Webpages containing terms which, in a given language, may have multiple meanings, among which we may find the ones we are interested in. Such a search mechanism, in which the result of the search is a set of Web-documents which contains the terms introduced in a search (search objects), is called syntactic search. This requires significant users' effort to classify and select the Webpages retrieved from a multitude of documents which compose the current Web, also called, by several researchers (Cardoso, 2006, pp. 3-5; Breitman, Casanova & Truszkowski, 2007, p. 4; Cardoso, 2007), the syntactic Web.

If the Webpages included formal annotations (metadata) identifying unambiguously the concepts and the relevant entities present in the pages (knowledge), the search engines (in this case, a semantic search engine) would be able to deal with polysemous, synonymic or multi-linguistic nature issues. In this way, it would be possible to retrieve only Web-documents related with what we are really interested in when performing a Web search. This is a vision of tomorrows' Web where the information, besides being understood by human beings, is also formally available for intelligent systems. Such a future vision is called the Semantic Web, in which Webpages should include (within the Webpages themselves or in other pages) metadata (also called annotations) which formally describe the information (knowledge) contained in them. In this way, the new Webware[2] applications may explore such a knowledge in order to help the human agents in the automation of the Web-tasks that are currently performed, as we have seen, based on user interaction (following the hyper-links, filling in forms, combining data obtained from several sources, deciding the next step, making searches, etc.).

The meaning of the Semantic Web and its adoption in people's daily life is explained by the World Wide Web Consortium (W3C), through the W3C Semantic Web Activity Statement (quoted by Uschold, 2003), in the following terms:

The Semantic Web is a vision: the idea of having data on the Web defined and linked in a way that it can be used by machines not just for display purposes, but for automation, integration and reuse of data across various applications.

In order to materialize the ideas of the Semantic Web maintained by Tim Berners-Lee, James Hendler and Ora Lassila (Berners-Lee, Hendler & Lassila, 2001) and revisited by Nigel Shadbolt, Wendy Hall and Tim Berners-Lee (Shadbolt, Hall & Berners-Lee, 2006), the W3C adopted a stratified structure, called the "W3C *Semantic Web Layer Cake*" or "*The Semantic Web Stack*", revised from the original "*Semantic Web Road Map*" proposed by Tim Berners-Lee (Berners-Lee, 1998b), which is a sequence of layers with increasing paradigms and their mechanisms and technologies that lead us, layer by layer, towards the reasoning of the computing agents. These, in turn, interact with the human agents through user-centred interfaces or other computing agents (of a higher level).

Figure 1 represents the stratified structure (Berners-Lee, 2006), which we can classify in three basic Web semantic macro-strata, which identify and compose the state of the art:

i. **Metadata:** This stratum aims to structure data and to define their meaning through a set of technological standards defined by the W3C, and which is subdivided in: (*1*) Unicode and URI layer; (*2*) XML layer and its family (XML *Namespaces*, XML *Schema*, XML *Query,* …); and (*3*) RDF and RDF *Schema* layer;
ii. **Ontology:** This stratum aims to form the common understanding and sharing of a specific domain under study by definition of the relations between Web-resources, using another set of technological standards (*Web Ontology Language* (OWL), for instance) and a set of technologies awaiting standardization (SPARQL *Protocol and RDF Query Language*, simply, SPARQL, for instance); and
iii. **Inference:** Finally, it is aimed to define inference mechanisms on the Web-resources through a set of inference rules that computing agents may use to relate and process information; the technologies associated to this macro-stratum are being scientifically studied, that is, they await standardization; the remaining layers are included in this stratum: the rules layer, the logic layer, the demonstration layer and the trust layer.

Metadata

When we are performing a search in a touristic Website and find out that our search object is not considered relevant in the portfolio of the analysed Website or we notice that the Website uses another word with the same meaning as our search object (that is, synonymic words)—which does not allow us to obtain contents retrieved through our search object—, a cycle of attempts in order to locate the desired information is started. However, time is being spent and often the content is not handled with the desired accuracy and rigour.

In order to deal with the scenario described above, Tim Berners-Lee (Berners-Lee, 1997) and the W3C consortium answer by structuring the metadata allowing us to represent and socialize the contents from a given strategic vision of knowledge management. That is, contents should be classified and organized in such a way that it should be possible to answer human agents' information requests, by creating conditions for the Webpages to include their own metadata.

Towards the Semantic Web, the referred metadata structuring enables Web-resources to be available not only for human agents, but also prepared and accessible to computing agents. For that purpose, data on the Web should be defined and linked in such a way that their meanings are explicitly interpreted by agents, instead of being implicitly interpreted by human agents. Thus, the annotation of the Web-resources through metadata with semantics is a key requirement, as a way to provide structured information (identification, location, description and use) about the content of a Web-resource (Rodríguez & Vega, 2000; Rocha, 2004).

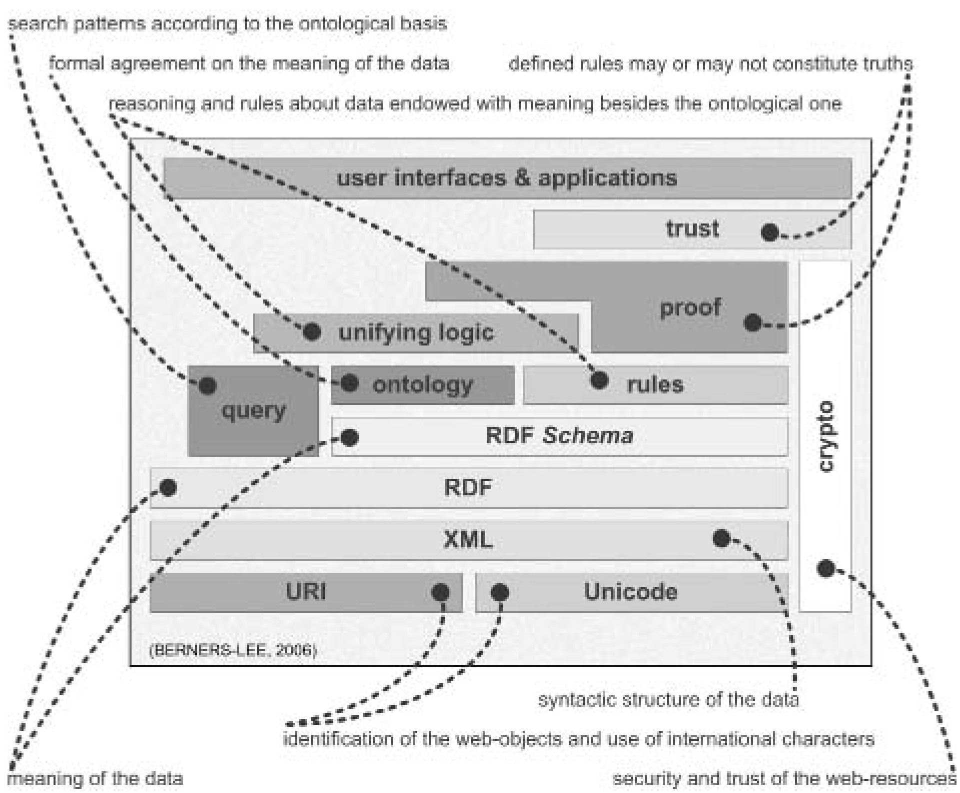
Ontology

Nowadays, there is a growing interest in ontologies as artefacts for the representation of knowledge and, on the other hand, as critical components in knowledge management: the Semantic Web, electronic commerce and other software infrastructures that generate knowledge (Brewster et al., 2004).

Etymologically, the term ontology derives from the Greek *ontos* (being) and *logos* (word, reason, treaty) and describes the "science of being *qua* being", that is, the science of the being as being or which regards the being (Corazzon, 2000).

One of the most referenced definitions in technical-scientific bibliography and, consequently, one of the most consensual, suggested by Rudi

Figure 1. Stratification of the Semantic Web (Adapted from Berners-Lee, 2006)



Studer, Vítor Benjamins and Dieter Fensel (1998) results from the fusion of two definitions of ontology: (*i*) "explicit specification of a conceptualization" (Gruber, 1993); and (*ii*) "formal specification of a shared conceptualization" (Borst, 1997, p. 12). Figure 2 shows the meaning achieved by the fusion of the two definitions referred above, stressing that an ontology is a description of concepts and relations that may exist for an agent (human or Webware) or a community of agents.

From an engineering point of view (Software Engineering (Calero, Ruiz & Piattini, 2006), Web Engineering (Behrendt & Arora, 2006) and Knowledge Engineering (Studer, Benjamins & Fensel, 1998) or Ontology Engineering (Gómez-Pérez, Fernández-López & Corcho, 2004)), an ontology is an artefact composed of a specific vocabulary used to describe a given part of the real world, the meaning of the vocabulary being ensured by a set of suppositions. An ontology is thus formalized, by means of several types of components, whose use varies according to the domain of interest: class hierarchy with attributes and relations; semantic net (set of inter-related instances); logic (set of axioms about classes and instances) and a series of inference mechanisms.

Therefore, the infra-structure needed to create, install and maintain ontologies as high quality Webware artefacts is the one that includes Web Engineering (WebE) practices, as an evolving and incremental process of development, and human resources from different areas of knowledge: (*i*) methodologies (systematic methods for the construction and handling of ontologies), (*ii*) tools (being complex and expensive artefacts, tools guarantee significant gains in the development of ontologies), (*iii*) languages (tools use different languages of ontology construction) and (*iv*) assessment (methods of assessing ontologies as a final product).

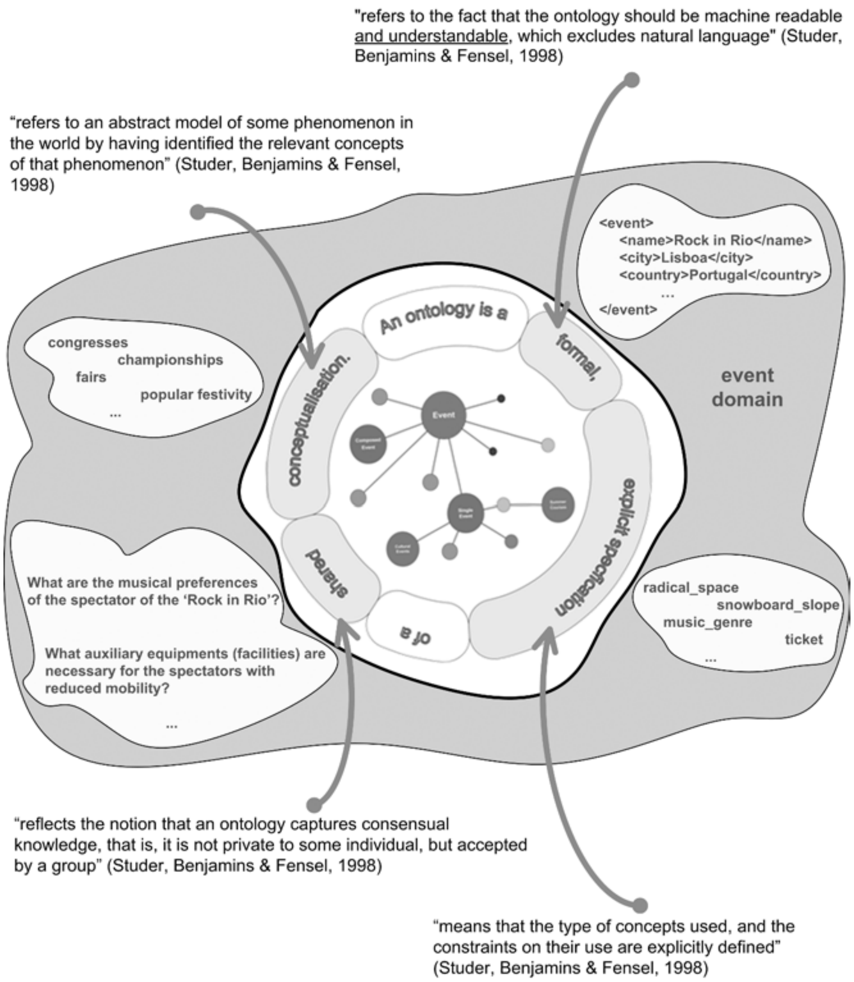
On the other hand, the process of projecting an ontology, that is, the phases constituting the life cycle of an ontology, does not differ much, in general terms, from the one used to build Webware: methodologies, tools and languages for building ontologies (Corcho, Fernández-López & Gómez-Pérez, 2003), ontological engineering with examples (Gómez-Pérez, Fernández-López & Corcho, 2004, pp. 107-197) and ontology tools (Corcho, Fernández-López & Gómez-Pérez, 2007).

Inference

With the previous macro-strata (metadata and ontology) of the Semantic Web stratified structure (Figure 1), the organization of Web-contents regarding the semantic aspect for representation of knowledge is ensured. However, representing knowledge is not yet a sufficient condition to promote the "functional usability" of the Semantic Web aspired by human agents. It is also necessary to look for a mechanism that contributes to that "functional usability" based on inference applied to the tasks or services carried out by the lower layers in the stratified structure, extracting information according to the requests of the human agents. With that inference mechanism the human agent may query the Web using well-defined rules and thus obtain the required information within the context of his search object.

A mechanism is therefore required to perform an inference about data or ontological representations that is able to extract implicit knowledge from the Web-resources and from the descriptions attached to the Web-resources, converting them into explicit knowledge. That is, it is necessary to develop inference engines combining the ontology semantics (ontology macro-stratum) and the used metadata (metadata macro-stratum), in order to create a synergy between the reasoning ability (predicate logic or description logic or rules) and the scalable functioning. In other words, with a set of axioms and inference rules, the inference engines will deduct new facts from data and structures described on the metadata macro-stratum and the relations between those data and structures defined in the ontology macro-stratum.

Figure 2. Consensual definition of the concept of ontology



A CONCEPTUALIZATION OF THE TOURISTIC OBJECT

The Touristic Object and its Semiotics

Herbert Simon defined an object as a "meeting point—an 'interface' in today's terms–between an 'inner' environment, the substance and organization of the object itself, and an 'outer' environment, the surroundings in which it operates" (Simon, 1981, p. 9), and adds "if the inner environment is appropriate to the outer environment, or vice-versa, the object will serve its intended purpose".

Contextualizing the concept of object defined by Herbert Simon for tourism, we can refer to a touristic object as a variability holding many representations, resulting in its possible appearances regarding its touristic resource actually existing in the place and not over itself. According to Maria Almeida (Almeida, 1998), touristic objects are "a human invention by and for tourism", whose identity is imposed by social groups, that is, touristic objects are the result of the social construction of their respective places, according to the interests of the local communities and their traditions and cultures. Within this perspective, touristic objects become new spatiotemporal business structures for tourism, and they may be institutionalized by competent bodies and even imposed by or for local communities.

Before effectively going to a touristic destination, the touristic object is already consumed and analysed through conveyed complementary images and information (for instance, through organizations' Webpages, namely municipal halls', state organizations', touristic companies', among others', or through touristic virtual communities). The travel is, therefore, a search for the conceived image of the touristic objects and their existence is confirmed by the fact that tourists have actually been there and, thus, transform the places into something which is desired and expected by the tourists themselves.

We may say that the touristic object is a construction of a place's sign (from the tourist's point of view) which becomes a conception of representations that, by aggregating a social, natural, cultural and symbolic value of the place, turns into an artefact *sine qua non* of tourism. It is also a memory object which, when returning from travelling, contributes to the structuring of a memory of the actual travel.

With the increase in society's globalizing process, started in the 20th century, touristic objects have very rapidly become known and accessible, due to the diffusion of information through electronic fluxes (Almeida, 1998). With the "mosaic society", touristic objects tend to go from the homogeneity of their construction to the construction of their personalization. Figure 3 dissects the framing, observation and understanding of the touristic object in its different levels of abstraction according to semiotics:

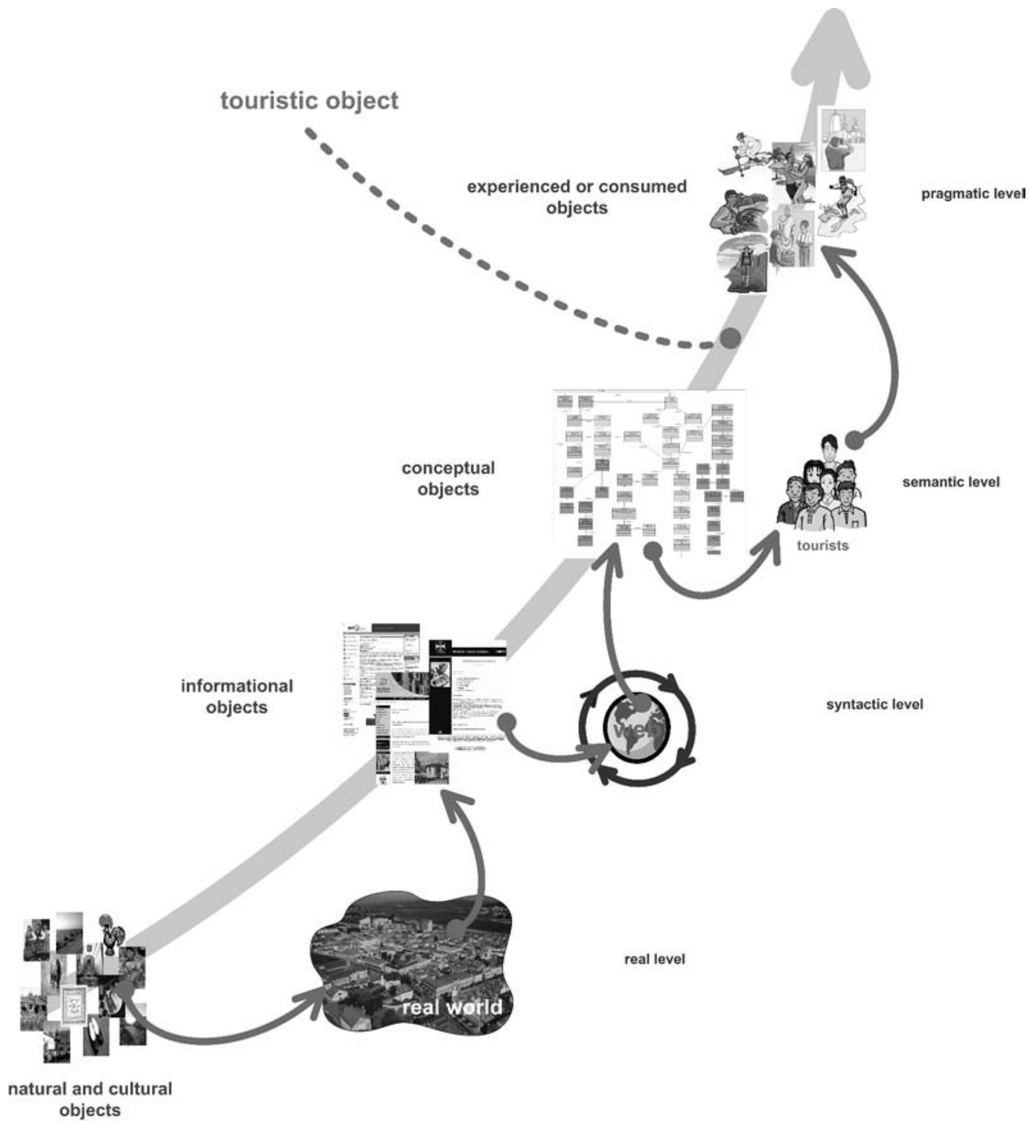
i. The touristic object begins as a real object – a set of symbols inscribed in an attraction place, that is to say, the attraction place is the domain of the symbols to be used or explored in the transformation of the real object into its touristic function;
ii. The Web has the responsibility of syntactically preparing the real object so that it may be adequately presented and acknowledged (informational or syntactic object) by its human receivers (potential tourists);
iii. The image (semantic content) built or formed in the mind of the potential tourists, forms the conceptual or semantic object, which is configured in representative or conceptual shapes that exist in the real world, triggering on tourists the search for new meanings or for post-experience feelings; and
iv. Each tourist will make an individualized interpretation of the received object, finding the meanings in its visibility in the form of a consumed or experienced object.

In short, Figure 3 constitutes the chain of interpretation that triggers the deciphering and perception of the touristic object from its real level up to the experienced level. It also shows the evolution of the touristic object's reception mechanism by the tourist.

Consequently, it is essential to have a set of guidelines oriented towards the process of development (specification, modelling and structuring) of the context-Webware, namely the agreed ontologies for tourism, based on the use of five semantic dimensions (Truong, Abowd & Brotherton, 2001), known as the W4H (*Who-What-When-Where-How*):

i. **Who:** To meet and to categorize touristic needs and preferences, as well as the restrictions or handicaps of the Web-users (tourists or potential tourists) and to register the Web-users' identity (name, age, job, address, among other social-demographic elements); this aims at specifying and modelling the tourist's profile;
ii. **What:** To obtain the touristic objects that satisfy the Web-users' thematic and touristic preferences and needs, to suggest touristic objects as alternatives to unpredictable

Figure 3. The touristic object and its abstraction levels



situations when the objects initially defined on the touristic itinerary are not available (for instance, when a museum is closed for conservation repairs), in order to maintain a satisfactory and desirable level of tourists' expectations; to try, on the other hand, to thematically contextualize the touristic objects according to the Web-users' motivations for travelling to a given destination; this is the semantic dimension in the sense of satisfying, in a maximized way, from the touristic travel point of view, the Web-users' needs and preferences, and of keeping their high motivational conditions for travelling to the chosen touristic destination; "What can a tourist see, visit and what can he do while staying at a tourism destination?" (Cardoso, 2006);

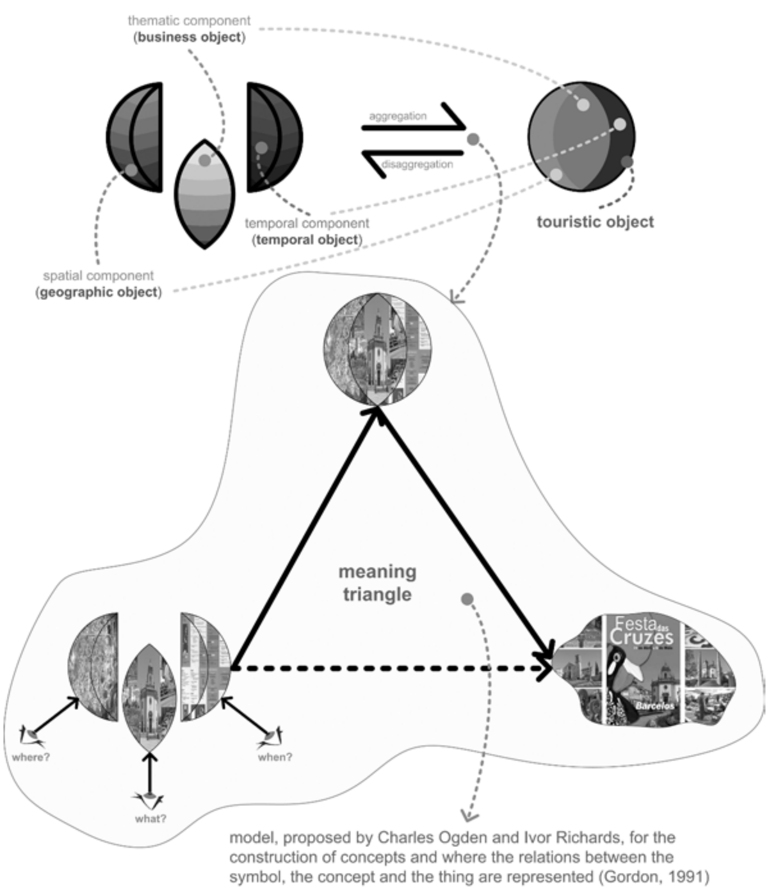
iii. **When:** To temporally delimit the touristic objects, such as events and restaurants, means to set up their temporal features (instants and time intervals) and to deal with temporal conflicts among the Web-users' preferred touristic objects; when a given touristic object is closed for reasons unrelated to tourists, there is a need to re-define the chronology with new alternative touristic objects for the same period of time defined on the touristic itinerary; "When can the tourist visit a particular place? This includes not only the day of the week and the hours of the day, but also the atmospheric conditions of the weather. Some activities cannot be undertaken if it is raining for example." (Cardoso, 2006);

iv. **Where:** To locate the touristic objects according to the Web-users' preferences; in some cases, we may associate the dimension "when" to this semantic dimension "where": by combining these two dimensions in touristic objects, their location is explored (latitude, longitude and place's typology), as well as their working hours (opening and closing time and closing week days); and

v. **How:** To make available devices, particularly mobile ones, to access descriptive information of the touristic objects which are "adapted and adaptable" to the Web-users' touristic preferences, and to check the personalized touristic itinerary at any moment and place in the chosen touristic destination.

In this chapter, we restrict the W4H approach regarding the building, planning and management of touristic itineraries, to three out of the five semantic dimensions: the touristic values embedded in the touristic objects (the "what" dimension), the

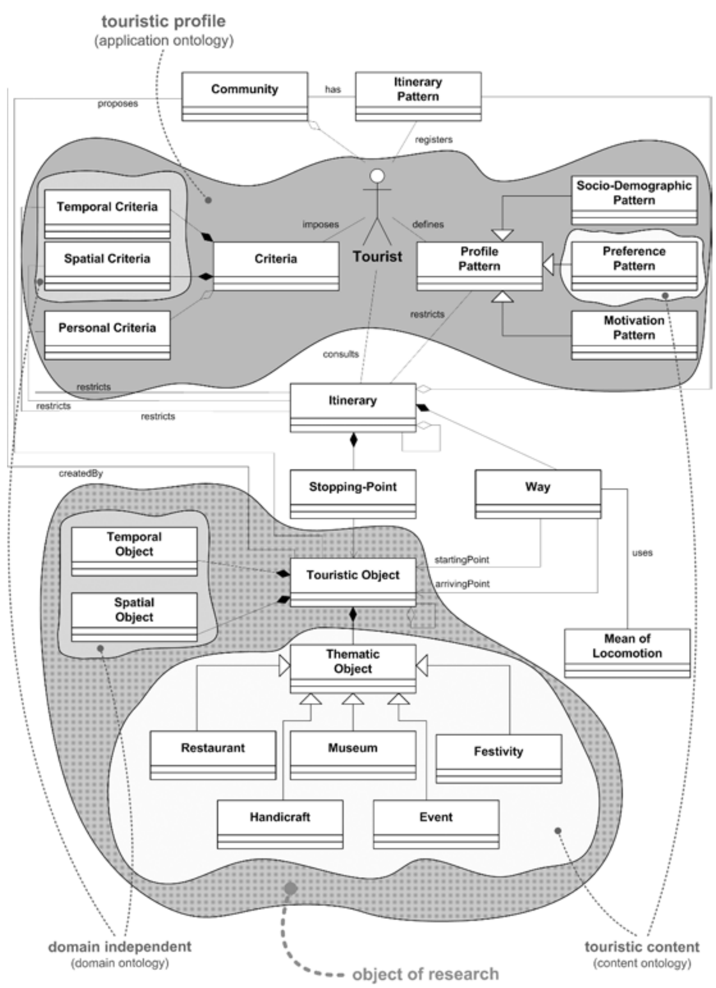
Figure 4. The touristic object and its semiotics



places where such touristic objects are located (the “where” dimension) and the visiting availability of those objects (the “when” dimension) (Figure 4). Nowadays, tourists aim at combining the intensity and extensibility of touristic itineraries, concerning either time (shorter travels), or space (visiting less places), and the touristic objects may assume the role of “advisors” in the construction and planning of the touristic itinerary’s meaning (Figure 5) in order to fulfil the “desire for learning, nostalgia, authenticity, heritage, make-believe, tranquillity, a pollution free environment, action, and/or a closer look at the Other” (Boissevain, 2000, p. 735).

Figure 5 shows that the creation of touristic itineraries is guided by two main factors: the profile of the tourist and the kind of travel. The former includes socio-economic features (age or education), psycho-cognitive elements (such as social interaction), preferences (golf, Celtic monuments and so on), temporal restrictions (for instance, the date chosen for travelling), spatial restrictions (the country or the region to visit) and personal constraints (for instance, persons with motion disabilities). The latter is concerned with issues such as the means of transportation, the visiting locations or the distance between those locations.

Figure 5. Touristic itineraries and their modelling



It is also relevant to point out the important contribution of virtual communities in the construction, planning and management of touristic itineraries. Each community has to make an inventory, to catalogue, preserve and activate the heritage (touristic objects). This decision depends exclusively on the members of each group, but it may look for the support of other communities (Figure 5). Touristic objects carry a significant and a meaning which is attributed by the social group that creates or re-creates them, aggregating eclectic and singular values which are attractive and competitive enough and stimulate the tourists' or tourism's attention.

The Semantic Model for the Touristic Domain

According to Figure 4, the touristic object has embedded in it its touristic value (the business component), the place (the geographical component) and, possibly, the availability restrictions (the temporal component). We use the infrastructure of the Semantic Web to represent the touristic objects' semantic dimensions ("what", "where" and "when") in models that represent the knowledge with explicit meaning, in order to enable sharing and re-use between applications, and automated processing. Such models and ontologies within the context of the Semantic Web should evince ontological characteristics of formality (models should have their concepts formally defined), explicit semantics (models should consist of a set of concepts, distinct and orthogonal in their meaning, likely to be clearly interpreted) and implementation abstraction (models should express a language that allows several types of data, relations and restrictions to be distinguished), which will enable Webware, not only in the sense of inferring new information from the information modelled by ontologies (that is, explicit information), but also to share information.

Figure 6 shows the infrastructure of the Semantic Web on the touristic context. The Webpages contextualized to the touristic domain, existing on the current or syntactic Web, are prepared to be interpreted by humans and, therefore, inadequate to "intelligent" processing by computing agents. Consider, for instance, a search for the restaurant "Margarida da Praça" on the Web. Current search engines are unable to distinguish our search object from other homonyms existing on the retrieved Webpages, that is, for the same search object we can identify, besides the name of the restaurant, the name of a person or a gastronomic specialty. In order to enhance the effectiveness of the search engines regarding our search object, it is necessary to add into the Webpages the information of what "Margarida da Praça" means (metadata), and we hence need semantic structures that represent the knowledge that a restaurant has a name, a geographical position, a telephone number and so forth. Each Webpage is annotated with metadata based on the mentioned semantic structures, named ontologies, and the Web-users may ask questions based on those ontologies. By looking at Figure 6, we can observe a relation between the contents (XML), metadata (RDF) and ontologies (OWL):

i. Ontologies explicitly and formally describe semantic structures through classes and properties: ***Restaurant***, ***Location***, ***Place***, ***OperatingHours***, ***Instant***, ***Facilities***, among others, are classes, and ***hasLocation***, ***hasSpecialities***, ***hasHoursOfOperation*** and ***hasFacilities***, among others, are properties.
ii. Classes are characterized by their properties: ***Restaurant hasLocation***, ***hasSpecialities*** and ***hasHoursOfOperation*** and the value, for instance, of the property ***hasHoursOfOperation*** is found in the class ***OperatingHours***.
iii. Contents are annotated with metadata based on ontologies: the Webpage "Margarida da Praça Restaurant" includes metadata in its RDF layer (RDF document),

Figure 6. Data flow

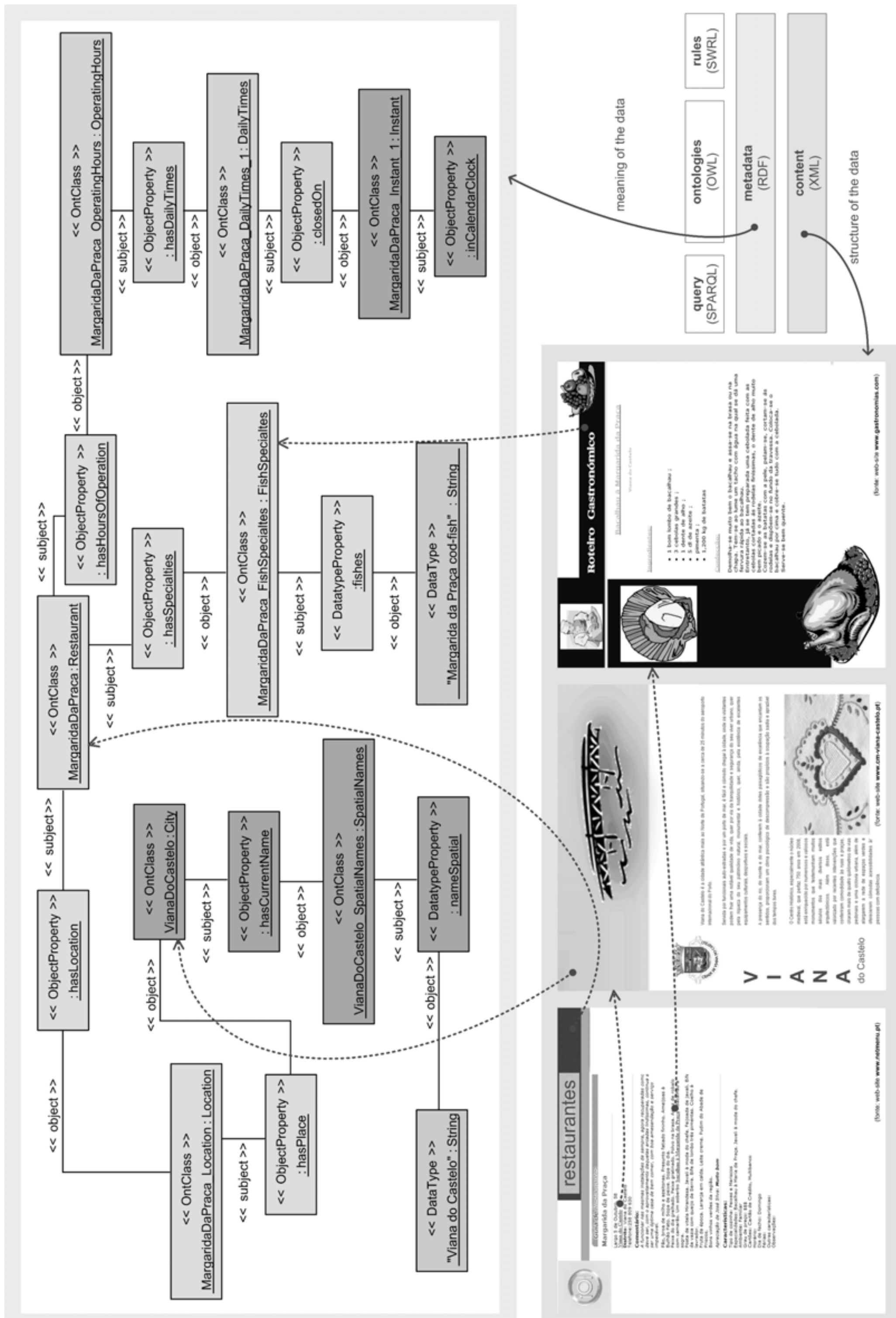
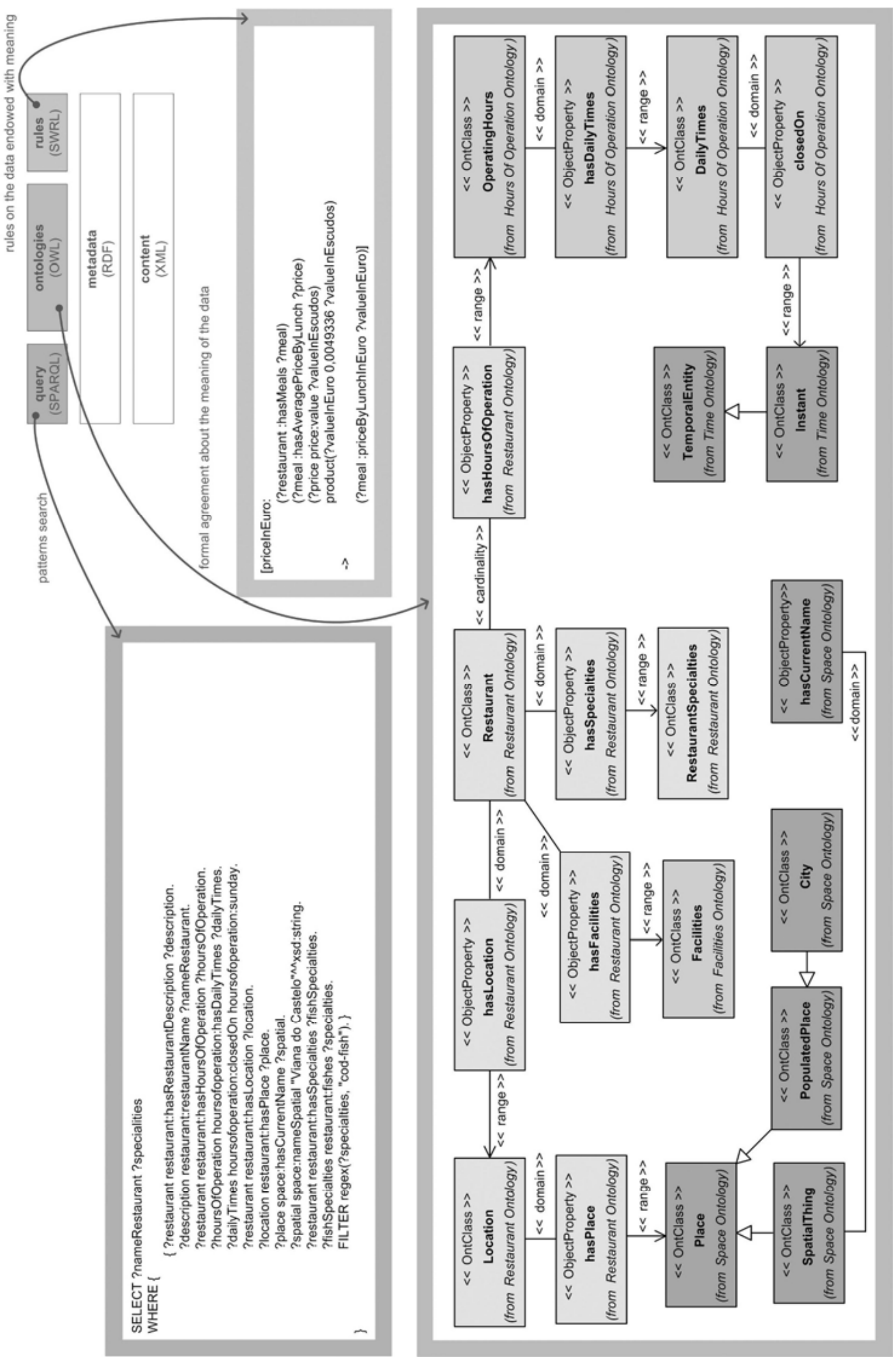


Figure 6. Data flow continued



which, for instance, index "Margarida da Praça" as an instance of ***Restaurant*** (**MargaridaDaPraca:Restaurant**), having properties such as its gastronomic specialty (**Margarida da Praça cod-fish:String**), its geographical location (**Viana do Castelo:City** and **Portugal:Country**), its weekly closing day (**sunday:DayOfWeek**), its telephone number (**258 80 96 30:String**), among other property values.

iv. Finally, Web-users can carry out interrogative searches (SPARQL) about "Margarida da Praça" as a restaurant on the search engines that will use metadata and ontologies in order to produce more efficient and accurate results.

When we use the current search engines in the search for our touristic objects, we usually follow an iterative strategy of collecting, analysing and filtering information contained in the Webpages retrieved, establishing a hierarchy according to their relative importance, that is, we spend too much time finding, extracting and classifying the Webpages that comply with our expectations.

On the scenario of the Semantic Web, the Webpage syntactically described above will also include a new set of information on its own content (named metadata), so that the agents, when accessing the Webpage, will be able to recognize, without human intervention, the concept of restaurant and its relations (***hasLocation***, ***hasSpecialities***, ***hasHoursOfOperation*** and ***hasFacilities***), assembled in an RDF format, as shown in Figure 7: in this case, the browser will continue to highlight the content of the Webpage and the agents will semantically recognize that "Margarida da Praça"

Figure 7. Syntactic description (HTML) and semantic description (RDF) of the Webpage

HTML

```
<html>

<head>
        <title>Guia de Restaurantes</title>
</head>

<body>
        <p> The restaurant "Margarida da Praça", located in "Largo 5 de Outubro" in "Viana do Castelo", Portugal, is classified as a
traditional cuisine restaurant, has "Sundays" as its day off and presents as its fish specialty a superb "<b>Margarida da Praça cod-
fish</b>"</p>
</body>

</html>
```

RDF

```
<rdf:RDF

  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:restaurant="http://www.restaurant.com/restaurant_ont.owl#"
  xmlns:space="http://www.space.com/space_ont.owl#"
  xmlns:time="http://www.time.com/time_ont.owl#"
  xmlns:hoursofoperation="http://www.hoursofoperation.com/hoursofoperation_ont.owl#">

  <rdf:Description rdf:about="http://www.netmenu.pt#margarida_da_praca">

   <restaurant:Restaurant rdf:ID="MargaridaDaPraca">
    <restaurant:hasSpecialties rdf:resource="#MargaridaDaPraca_FishSpecialties"/>
    <restaurant:hasHoursOfOperation>
     <hoursofoperation:HoursOfOperation rdf:ID="MargaridaDaPraca_OperatingHours">
      <hoursofoperation:hasDailyTimes rdf:resource="#MargaridaDaPraca_DailyTimes_1"/>
        </hoursofoperation:HoursOfOperation>
    </restaurant:hasHoursOfOperation>
    <restaurant:hasLocation rdf:resource="#MargaridaDaPraca_Location"/>
   </restaurant:Restaurant>

   <restaurant:FishSpecialties rdf:ID="MargaridaDaPraca_FishSpecialties">
    <restaurant:fishes rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Margarida da Praça cod-fish</restaurant:fishes>
   </restaurant:FishSpecialties>

   <hoursofoperation:DailyTimes rdf:ID="MargaridaDaPraca_DailyTimes_1">
    <hoursofoperation:closedOn>
     <time:Instant rdf:ID="MargaridaDaPraca_Instant_1">
      <time:inCalendarClock>
       <time:CalendarClockDescription rdf:ID="MargaridaDaPraca_CalendarClockDescrition_1">
        <time:dayOfWeek rdf:resource="http://www.time.com/time_ont.owl#sunday"/>
       </time:CalendarClockDescription>
      </time:inCalendarClock>
     </time:Instant>
    </hoursofoperation:closedOn>
   </hoursofoperation:DailyTimes>

   <restaurant:Location rdf:ID="MargaridaDaPraca_Location">
    <restaurant:hasPlace>
     <space:City rdf:ID="VianaDoCastelo">
      <space:hasCurrentName>
       <space:SpatialNames rdf:ID="VianaDoCastelo_SpatialNames">
        <space:nameSpatial rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Viana do Castelo</space:nameSpatial>
       </space:SpatialNames>
      </space:hasCurrentName>
     </space:City>
   </restaurant:Location>

  </rdf:Description>

</rdf:RDF>
```

is a restaurant located in "Viana do Castelo", Portugal, where you can savour a "Margarida da Praça cod-fish" as its gastronomic specialty, and that it is closed on "Sundays".

To sum up, the insertion of semantic information into syntactically structured contents opens up a new impulse in the development of Webware which is based, not only on the syntactic interoperability, but also on the semantic interoperability.

Figure 8 shows our ontological model for the touristic context. This model is formally represented using standard specifications of the Semantic Web defined by the W3C consortium, but it also considers other features which are equally important, and which will make it easy, through the application of Web Engineering and Ontologies Engineering principles such as modularity and extensibility, to respond to other Webware needs or requests. The semantic model written in OWL, includes statements to represent the touristic objects according to the temporal dimension (for instance, the opening hours of a museum), the spatial dimension (the location of the museum) and thematic dimension (a temporary exhibition of ethnographic costumes). The model is composed by two sets of ontologies: (*i*) the ontological core defining a common vocabulary for touristic, temporal and spatial domains, to assist in the creation of general purpose touristic itineraries and *(ii)* ontological extensions to define special purpose vocabularies for the creation specialized itineraries.

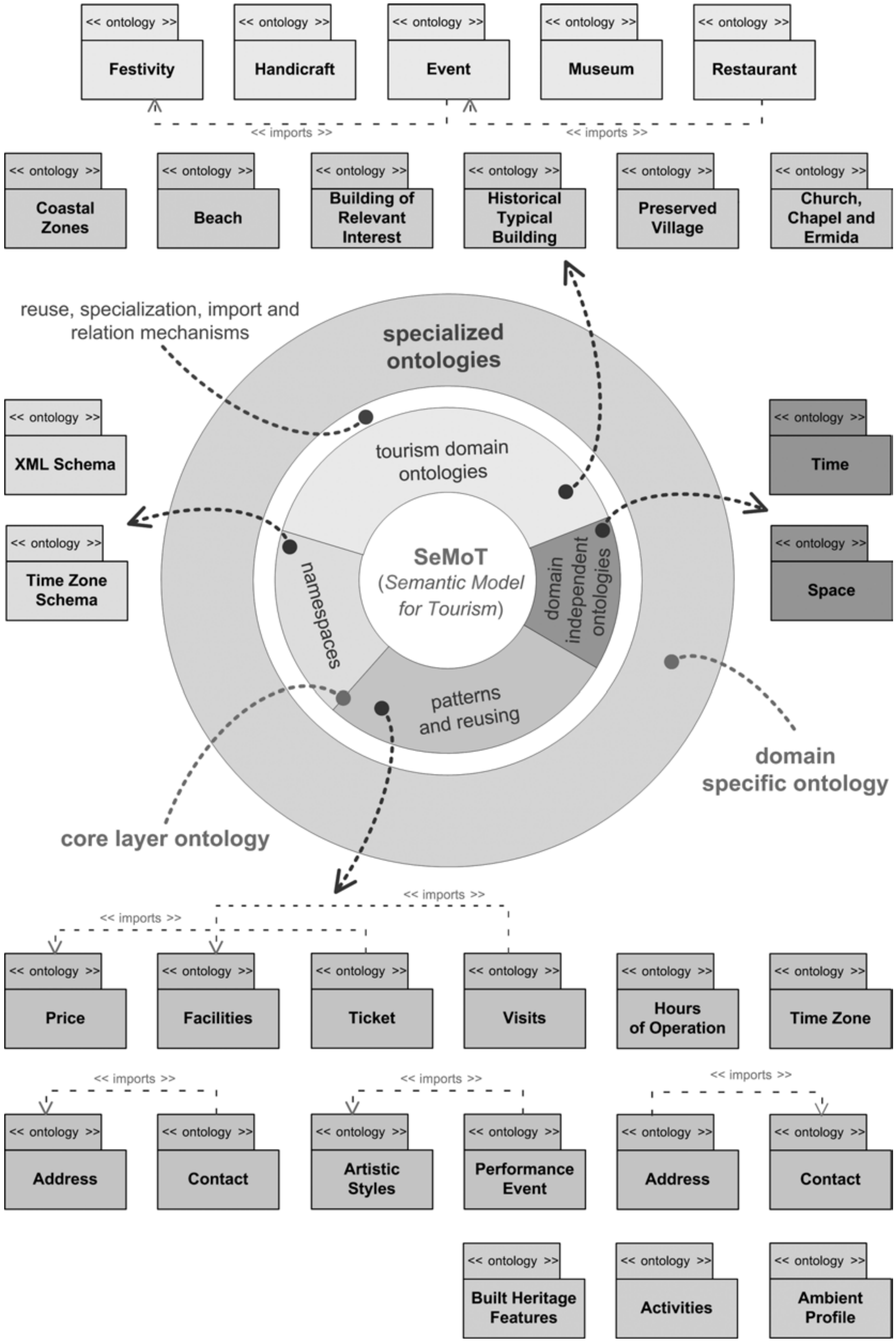
Bearing in mind that the semantic model for the touristic domain presented in this chapter, named *Semantic Model for Tourism* (SeMoT), represents concepts, relations and restrictions of touristic objects, according to its theme ("what"), temporal ("when") and spatial ("where") perspectives, in the following sections we will present some of the ontologies that compose the SeMoT model, where, besides its semantics, issues related to its ontological development are described, as well as the justification for its construction (Lima & Moreira, 2007).

Temporal Domain

One of the possibilities for the abstract representation or description of temporal information consists on specifying an ontology describing its characteristics, namely its ontological, its relational and its logic dimensions. That is to say, the representation includes the definition of a temporal ontology describing primitive entities, and includes the relationships between those entities and the application of restrictions. Therefore, considering the contributions of researchers such as Jerry Hobbs with the collaboration of George Ferguson, James Allen, Richard Fikes, Pat Hayes, Drew McDermott, Ian Niles, Adam Pease, Austin Tate, Mabry Tyson, and Richard Waldinger (Hobbs et al., 2002), Jerry Hobbs and Feng Pan (Hobbs & Pan, 2004), the *Time Ontology* defines instants and time intervals as temporal entities and their algebraic relations, of which we would highlight:

i. The ***TemporalThing*** class describes any type of temporal entity (instant and time interval) and results from the union («*unionOf*») of both the ***InstantThing*** and ***IntervalThing*** classes;
ii. The time interval (individuals from the ***IntervalThing*** class) is limited in its extremities by two properties («*ObjectProperty*») of the ***TemporalThing*** class: ***begins*** («*equivalentProperty*» to ***from***) and ***ends*** («*equivalentProperty*» to **to**); the values that such properties assume are individuals belonging to the ***InstantThing*** class;
iii. According to the intervals algebra proposed by James Allen (Allen, 1983), we have thirteen temporal relations applicable to the individuals of the ***IntervalThing*** class:
    - the ***intBefore*** relation (individual I_1 occurs before individual I_2 and they do not overlap);
    - the ***intMeets*** relation (individual I_1 occurs before I_2 which, in turn, initiates

Figure 8. The Semantic Model for Tourism



immediately after the conclusion of I_1);

- the ***intOverlaps*** relation (individual I_1 initiates before I_2, which, in turn, initiates before I_1 ends);
- the ***intStarts*** relation (individuals I_1 and I_2 initiate simultaneously, but I_1 ends before I_2);
- the ***intDuring*** relation (individual I_1 is completely contained in individual I_2);
- the ***intFinishes*** relation (individuals I_1 and I_2 end simultaneously, but I_1 starts after I_2);
- the ***intEquals*** relation (individuals I_1 e I_2 are the same time interval);
- the ***intOverlaps*** relation (individual I_1 initiates before I_2, which, in turn, initiates before I_1 ends); and
- the ***intFinishedBy***, ***intContains***, ***intStartedBy***, ***intOverlapedBy***, ***intMetBy*** and ***intAfter*** relations are, respectively, the inverse relations of the above numbered relations, from the ***intFinishes*** relation to the ***intBefore*** relation (that is, in a reversed order), except for the ***intEquals*** relation, which does not have a corresponding reversed relation.

Spatial Domain

Bearing in mind our perceptions of the real world concerning space, the spatial model should focus on four dimensions: (*i*) the ontological dimension (which entities are considered relevant to describe the space independently from the application context); (*ii*) the structural dimension (which types of data describe the entities); (*iii*) the relational dimension (which relations exist between the abstracted entities and their algebras); and (*iv*) logic (which restrictions and rules are applied). Some researchers, such as Christopher Jones, Harith Alani and Douglas Tudhope (Jones, Alani & Tudhope, 2001), Alia Abdelmoty, Philip Smart, Christopher Jones, Gaihua Fu and David Finch (Abdelmoty et. al., 2005), Farshad Hakimpour, Boanerges Aleman-Meza, Matthew Perry and Amit Sheth (Hakimpour, ALeman-Meza, Perry & Sheth, 2007), among others, have developed spatial ontologies, some which are specified in languages not standardized by the W3C consortium, namely the DAML language, and some others which are inadequate for the current state of the Semantic Web. Therefore, we find the Space Ontology has classes, properties and relations which describe the location and classification of the spatial entities' place over the face of the earth and its topological and mereological relations:

i. The ***SpatialThing*** class is the main class that describes any entity with a space dimension and is the result of the union («*unionOf*») of the ***GeoSpatialThing*** and ***NoGeoSpatialThing*** classes, that is, the ***SpatialThing*** class represents any entity, either in the geographical space, or in the non-geographical space;
   individuals from the ***SpatialThing*** class have the property («*ObjectProperty*») ***hasCurrentName*** and the property («*ObjectProperty*») ***hasAlternativeName*** which, respectively, associate to them a descriptive name, which is officially registered or known, and an alternative name as a synonym, whose assumed values follow the notation of the ***String*** («*DataType*») type of data of the XML *Schema*;
ii. The spatial relations between individuals of the ***SpatialThing*** class are classified in:
   a. Topological relations (***TopologicalRelation*** class), which describe the concepts of:
      - Adjacency, when individual I_1 touches individual I_2 and they do not overlap, we have the property («*ObjectProperty*») ***touch***; while the property («*ObjectProperty*») ***near*** represents the topological

situation in which individual I_1 almost touches individual I_2;

- ➢ Overlapping or intersection, the property («*ObjectProperty*») ***overlap*** indicates that individual I_1 is over individual I_2 by intersection;
- ➢ Incidence, the property («*ObjectProperty*») ***cross*** specifies that individual I_1 crosses with individual I_2;
- ➢ Equality, individual I_1 occupies the same space as individual I_2, evincing the property («*ObjectProperty*») ***equal***;
- ➢ Inclusion, the property («*ObjectProperty*») ***contains*** considers that individual I_1 contains individual I_2 but they do not touch;
- ➢ Disjunction (the property («*ObjectProperty*») ***disjoint*** considers, topologically, that individual I_1 does not intersect individual I_2; and

b. Mereological relations (***MereologicalRelation*** class), which evince the concept of composition or aggregation in which individual I_1 is a part of I_2 through the property («*ObjectProperty*») ***partOf***; conversely, individual I_2 is a whole of I_1, and hence the inverse of the *partOf* relation is designated by the property («*ObjectProperty*») ***wholeOf***;

the topological relations ***contains*** and ***equal*** and the mereological relation ***partOf*** and its inverse («*inverseOf*») ***wholeOf*** are considered transitive («*TransitiveProperty*»), that is, in the case of the topological relation ***contains***, if individual I_1 contains individual I_2 which, in turn, contains individual I_3, then it may be concluded that individual I_1 contains individual I_3; the same applies to the other transitive relations;

the topological relations ***touch***, ***near***, ***equal*** and ***disjoint*** are considered symmetric («*SymmetricProperty*»), that is, for instance, in a topological relation ***touch***, if individual I_1 touches individual I_2 without overlapping, then individual I_2 also touches individual I_1 without overlapping; the same holds for ***near***, ***equal*** and ***disjoint***;

in addition, the topological relation ***equal*** is also defined as functional («*FunctionalProperty*»), that is, the ***equal*** property is functional because it allows assigning at the most one value to each individual of the ***SpatialThing*** class;

iii. The ***Place*** class defines the type of feature (*feature type*) of a place and may include distinct categories of the place, namely:

a. The ***AdministrativeRegion*** class which represents geographical spaces according to the administrative divisions such as ***Country*** («*OntClass*»), ***Municipality*** («*OntClass*»), ***Parish*** («*OntClass*»), among other divisions;

b. The ***SpotFeature*** class which represents geographical spaces according to more generic features of places, such as ***Beerhouse:BeverageBuilding:Buildings*** («*OntClass*»), ***Monument*** («*OntClass*»), ***Airport*** («*OntClass*»), ***RecreationalFacility:Facilities:Buildings*** («*OntClass*»), among other features;

c. The ***Hydrographic*** class which represents geographical spaces according to hydrographical features, such as ***River:Stream*** («*OntClass*»), among other categories of the place.

Thematic Domain

The notion of theme involves a set of basic definitions for the construction of a thematic model. Its ontological structure describes the knowledge about a theme as an aggregated discourse, which is orchestrated by related entities, around the considered observable object. Among the ontologies developed for the touristic domain, we can point out the following ones:

i. The ***handicraft ontology***: handicraft is an important promoter of the touristic activity, along with the countless festivities that take place in different places. There, craftsmen show, before the observant eyes of tourists, their peculiar abilities in the traditional and manual conception of their compositions as signs that hold surprising meanings;
   in the *Handicraft Ontology*, the concept of handicraft (***Handicraft*** class) is a triangle and its edges denote the ethno-cultural object (***CraftArtefact*** class), the craftsman (***Craftsman*** class) that shapes and models the handicraft artefact, and the production unit (***CraftProductionUnit*** class);
   the artefact is prepared, developed and concluded with the materials which are abundant in the neighbourhoods;
   the handicraft artefact (***CraftArtefact*** class) is classified, according to its raw material, in several categories (***Ceramics*** class, ***Wood*** class, ***Metal*** class, among other categories) gathered around the ***ArtsAndCraftsArtefacts*** class;

ii. The ***event ontology***: the events – created and planned to take place in a given site during a pre-determined period of time – have an attraction effect over a given public (touristic or professional), gathering it in a place (with a given environment and time to occur), where tourists or professionals socialize around the same interests;
   the events take place where there are complex clusters of touristic objects (restaurants, museums, beaches, camping sites, hotels, traditional arts, among other resources), through which tourists or professionals may enjoy (new) leisure pleasures, extending their touristic or professional visiting in order to generate more and newer experiences resulting from their interactions with the places (touristic objects);
   among the classes, properties and relations defined in the *Event Ontology* the following should be highlighted:

   a. Each individual of the ***Event*** class may refer to a single event as a strictly homogenous thematic manifestation (***SingleEvent*** class) or to an aggregated set of simple events (***ComposedEvent*** class), each event related to a thematic supply aimed at a given visiting public;
      also, the events' thematic proposals have their own territorial and communitarian dimension, that is, the territorial and communitarian scope of the events ranges from ***local:EventScope*** to ***international:EventScope***, including the ***municipal:EventScope***, ***regionalAutonomic:EventScope*** and ***national:EventScope***;
   b. The property («*ObjectProperty*») ***hasOrganizer*** identifies the organizer of an event (***EventOrganizer*** class) through the property («*DatatypeProperty*») ***organizerName***;
      in order to specify the place where the event will take place, we have the property («*ObjectProperty*») ***hasLocation***, the date when the event is to take place being defined through the property («*ObjectProperty*») ***hasDate,*** which may be an instant in time (***Instant:Time Ontology*** class) in case the event happens in a calendar day or a time interval (***Interval:Time Ontology*** class) if the event is longer than a calendar day;
   c. The ***SingleEvent*** class classifies several events, according to the thematic focus, such as, ***ReligiousEvents*** («*Ont-*

Class»), ***SportiveEvents*** («OntClass»), ***LeisureAndRecreationEvents*** («*OntClass*»), ***CulturalEvents*** («*OntClass*»), ***PoliticalEvents*** («*OntClass*»), ***ArtisticAndEntretainmentEvents*** («*OntClass*»), among other events disconnected from each other);

iii. The ***festivity ontology***: festivities are the intangible expressions through which the local communities may reveal their peculiar and unique culture, through the way they socialise, what they produce, what they build, what they live on and what they preserve in their traditions and habits;
therefore, festivities are distinct and differentiated looks upon the heritage of the visited sites and their communities that tourists have at their disposal when they include them in their personalized touristic itineraries; among the classes, properties and relations defined in the *Festivity Ontology* the following should be highlighted:
   a. The ***CivicFestivities***, ***CyclicFestivities*** and ***LaicPopularFestivities*** classes are types of festivities (***Festivity*** class);
   b. The property («*ObjectProperty*») ***hasFestivityDescription***, describes the beliefs and values of the rejoicing historical events or the season events of the peasant life or of the religious events of the patron saints, or also, the magical and pagan events that congregate the local communities for the festivities (***festivityDescription*** property) and the name of the festivity (***festivityName*** property);
   c. The property («ObjectProperty») ***hasGeographicRange*** specifies the geographical range of the festivity from the ***local:GeographicRange*** to the ***national:GeographicRange***, including the ***municipal: GeographicRange*** and the ***regionalAutonomic:GeographicRange***.

EVALUATION AND TREND ANALYSIS

With the SeMoT model we have the potential to elaborate specific and personalized touristic itineraries, by importing concepts which reside on the model's core layer, originating more specialized ontologies of touristic interest (for instance, ontologies on migrations of birds with an impact on biodiversity, ontologies on Celtic culture in Southwest European sites, etc.).

For instance, in the case of an ontology for the Celtic culture (***celtic ontology***), the modelling may involve:

i. The ***restaurant ontology***: which may include a subclass of the Celtic cuisine (**CelticCuisine*:Cuisine:Restaurant Ontology***), in other words, the new class CelticCuisine of the domain Celtic culture is a subclass of the class Cuisine of the domain Restaurant) that includes the "rose pudding", the "Celtic eggs", etc.);
ii. The ***historical typical building ontology***: which may portrait the characteristics of the Celtic housing heritage (**CelticArchitecture** «*OntClass*»);
iii. The ***festivity ontology***: a subclass of laic popular festivities of Celtic origins (**CelticFestivity** «*OntClass*»), in other words, the class **CelticFestivity** of the domain Celtic culture represents festivities like "Samhain Festivity" and is a subclass of the class **LaicPopularFestivities** of the domain Festivity;
iv. The ***event ontology***: countless song festivals of Celtic heritage, using dances and musical instruments such as the "bagpipes", are represented by the class **CelticDancingCompany** of the domain Celtic culture that is a subclass of the class **ArtisticGroup of** the domain event.

The ***celtic ontology*** example helps evincing the principles that have guided the creation of the SeMoT: completeness (is the model modular and flexible enough to create new special purpose ontologies for a touristic context?), complexity (does it requires a significant effort for the Webengineers to model and implement extensions to the basic model?), performance (is it difficult to maintain and how will future changes in the basic model influence the robustness of the SeMoT?) and usefulness (is the documentation adequate?).

This research project has focused so far on the modeling of ontologies for the touristic context and the major concerns were expressiveness (the semantics for representing concepts from the touristic domain) and formality (the language constructs used in SeMoT). The next step is to design and implement inference mechanisms from semantically annotated sources, such as annotated Webpages or databases currently in use to maintain information about touristic resources. The latter implies converting the databases information into RDF and OWL. These mechanisms may constitute an important tool to deduce valuable information to assist tourists in performing semantic queries for the planning of touristic itineraries. We may consider two types of inference: the inference based on the semantics of SeMoT and the one based on rules. With such a tool it would be possible to deduce that the Samhain Festivity is a laic popular festivity of the domain of the Celtic culture that occurs at a certain time and place, and that it may be a good choice for tourists interested in ethnographic dances or music, or in Northwestern European gastronomy.

CONCLUSION

Before the Web paradigm, the main technological applications were designed for suppliers (airway companies, hotel companies, rent-a-car companies and others) and intermediaries (travel agencies), and the consumers of touristic products (touristic packages) had only to accept the information supplied by the travel agencies.

Afterwards, with the technological evolution (Web paradigm), the consumers of touristic products have earned a higher decision-making ability in the search for their preferred touristic objects (attraction sites, leisure activities, gastronomic places, among others) at lower expenses (minimizing the costs of transportation, accommodation and other services). Both suppliers and touristic intermediaries resort to applications with low levels of adaptability, which are designed according to the paradigm of the Web-user oriented interaction, evincing the weaknesses and barriers of interoperating data between the computing agents on the Web, in a transparent way. That is to say that, in today’s Web (the syntactic Web), computing agents are unable to solve the problems of interoperability because, on the one hand, the HTML technology is inflexible in displaying a set of tags which promotes data exchange (syntactic interoperability) and, on the other hand, the absence of a basic data model that specifies distinct types and possible values of the countless representations (resources) existing on the Web (structural interoperability).

In the Semantic Web, more usable, more adaptable and more Web-user centred applications are sought, and hence the computing agents must be capable of approaching their results (touristic objects) to the Web-users’ expectations, needs and motivations (theme, location and time criteria). That is, the Semantic Web tries to add meanings to the Web, by transforming syntactic Websites (for instance, Websites as catalogues of touristic destinations) into Semantic Websites (for instance, Websites as “intelligent” touristic guides) that may promote the interaction of their contents with the Web-users’ expectations in a more productive, more usable and more intelligent way.

Touristic itineraries occupy one of the European Union’s most promising strategies for recovering rural economies, by stimulating their development, putting into relief the local communities, handicraft and popular art, river beaches, traditional life-styles, the autochthonous species of fauna and flora, among other specificities of the sites. Hence, the itineraries are built, planned and managed based on the acceptance and the search for touristic objects of a natural singularity (biological, pedological, hydric, geological, climate and landscape), as well as of a cultural one (historical, popular, architectonical, gastronomical, among other cultural modes). In order to answer that challenge, we have proposed the semantic model for the touristic domain, called the Semantic Model for Tourism (SeMoT), grounded on three semantic dimensions, "what", "where" and "when", and which is based on two requirements: (*i*) specifications (which identify the mechanisms that specify or consider the semantics of the touristic objects, describing the concepts' structure and semantics); and (*ii*) interpretation (which identifies the mechanisms that interpret the semantic of the touristic objects). With these requirements, it is possible to improve the mechanisms that support inference, search and recovery of information about touristic objects.

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KEY TERMS AND DEFINITIONS

OWL (*Web Ontology Language*) is a language developed by the W3C which allows, by using its sets of syntactic constructors based on RDF, to represent ontologies which are understandable by machines, hence providing, apart from the mechanisms for creating concepts, instances, proprieties and axioms, three levels of expressivity: OWL Lite, OWL Description Logics (OWL DL) and OWL Full.

RDF (*Resource Description Framework*) is a conceptual model for the description of the content of the Web-resources, sustained by a syntax based on XML, and which is guided by three concepts: resources, proprieties and statements.

RDF-Schema (*Resource Description Framework-Schema*) is a defined structure, using the inheritance and instantiation mechanisms, of the resources in classes, including the restrictions on the objects in the relations existing in an RDF model.

SPARQL (*SPARQL Protocol and RDF Query Language*) is a language developed by the W3C to support queries, handling the knowledge represented in ontologies in RDF, that is, it allows the handling of specific information extracted from the ontologies.

SWRL (*Semantic Web Rule Language*) is a rules language, based on the combination of OWL DL and OWL Lite languages (OWL sub-languages) with *Rule Markup Language* (RuleML) which, through an abstract syntax, allows Horn clauses to be defined that represent rules in ontologies and, on the other hand, the treatment of the rules as *antecedent* → *consequent* axioms to be assumed.

Tourism "can be defined as the theories and practices for being a tourist. This involves travelling and visiting places for leisure-related purposes. Tourism comprises the ideas and opinions people hold which shape their decisions about going on trips, about where to go (and where not to go) and what to do or not do, about how to relate to other tourists, locals and service personnel. And it is all the behavioural manifestations of those ideas" (Leiper, 2004, p. 44).

Tourist "can be defined as a person who travels away from their normal residential region for a temporary period of at least one night, to the extent that their behaviour involves a search for leisure experiences from interactions with features or characteristics of places he chooses to visit" (Leiper, 2004, p. 35).

URI (*Uniform Resource Identifier*) is a unique identifier-address for Web-resources that identifies, either its concrete content (for instance, servers or Webpages), or its abstract content (for instance, concepts or conceptual relations).

Webware is an "artefact with a set of functionalities and components which are adequate to the Web context" (Lima, 2003, p. 10), that is, it is a software with specific proprieties which are inseparable from the Web environment and that we do not find in traditional software products. Therefore, it may be considered an information system in which a great amount of volatile data – highly semi-structured and structured, semantically enriched and located in Web-servers – are consulted, processed and updated by information navigators which are designed according to patterns of usability, adaptability, ergonomics, accessibility and autonomy.

XML (*eXtensible Markup Language*) is a language developed by W3C as a universal format for structured data on the Web, overcoming the *Hypertext Markup Language* (HTML) limitations, by defining rules that allow Webpages to be written in such a way that they are adequately visible to the computing machine.

ENDNOTES

[1] The authors of the chapter are responsible for the underlined words.

[2] Concept developed by Salvador Lima in the monograph *"Webware crisis? – The new werewolves are also slaughtered"* (Lima, 2003).

Chapter XXXIV
Cross-Language Information Retrieval on the Web

María-Dolores Olvera-Lobo
CSIC, Unidad Asociada Grupo SCImago, Spain & University of Granada, Spain

ABSTRACT

The Web stands today as the world´s largest source of public information. Its magnitude can also be perceived as a drawback in a certain sense, however: nowadays there is a generalized problem in retrieving documents that may be written in any language, but through queries expressed in a single source language. And although Information Retrieval (IR) depends on the availability of digital collections, this key aspect is no longer the only concern. It is time for the multicultural society of Internet to make use of new technologies such as Cross-Language Information Retrieval (CLIR). Whereas classical IR is a field that embraces retrieval models, evaluation, query languages and document indexing involving "small" collections of documents, modern IR tends to focus on Internet search engines, mark-up languages, multimedia contents, the distribution of collections, user interaction and multilingual systems. Thus, CLIR may border on work in the following fields: information retrieval, natural language processing, machine translation and abstracting, speech processing, the interpretation of document images, and human-computer interaction. "Given a query in any medium and any language, select relevant items from a multilingual multimedia collection which can be in any medium and any language, and present them in the style or order most likely to be useful to the querier, with identical or near identical objects in different media or languages appropriately identified" (Hull & Oard, 1997). This sentence sums up the main objective of CLIR, acknowledged as an independent research subfield roughly a decade ago, so that at present a number of international CLIR conferences take place in the world. The most important of these are TREC (Text REtrieval Conference) in the US; NTCIR (NII-NACSIS Test Collection for IR Systems) in Asia; and CLEF (Cross-Language Evaluation Forum) in Europe. This chapter attempts to *characterize the scenario of Cross-Language Information Retrieval as a domain, with special attention to the Web as a resource for multilingual research. The authors also manifest their point of view about some major directions for CLIR research in the future.*

INTRODUCTION

The development of the semantic Web requires great economic and human effort. Consequently, it is very useful to create mechanisms and tools that facilitate its expansion. From the standpoint of information retrieval, access to the contents of the semantic Web can be favoured by the use of natural language, as it is much simpler and faster for the user to engage in his habitual form of expression.

The discipline known as Natural Language Processing (NLP)—a subarea of Artificial Intelligence and Computational Linguistics—proves particularly useful in this context. NLP looks at the problems deriving from the automatic comprehension of natural language. It also focuses on the design of systems and efficient mechanisms that allow for communication between people and machines. Among the diverse spheres of application of NLP we have automatic translating and information retrieval, two of the specific areas that later gave rise to cross-language information retrieval.

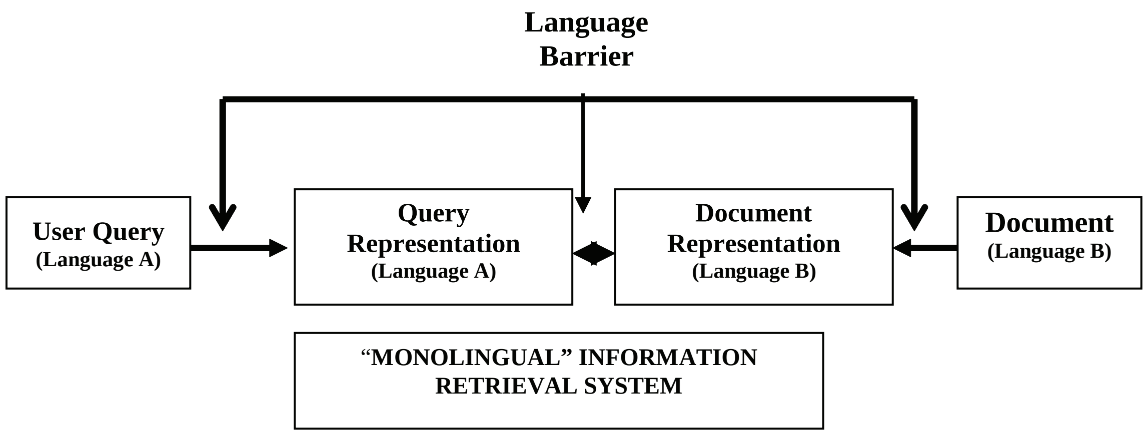
The growing popularity of Internet and the wide availability of Webinformative resources for general audiences are a fairly recent phenomenon, although man´s need to hurdle the language barrier and communicate with others is as old as the history of mankind. The World Wide Web, together with the growing globalization of companies and organizations, and the increase of the non-English speaking audience, entails the demand for tools allowing users to secure information from a wide range of resources. Yet the underlying linguistic restrictions are often overlooked by researchers and designers. Against this background, a key characteristic to be evaluated in terms of the efficiency of IR systems is its capacity to allow users to look up a corpus of documents in different languages, and to facilitate the relevant information despite limited linguistic competence regarding the target language. This may call for resorting to translations of the texts involved.

More generally, information retrieval has been known as the automated process by which a user makes a query expressing information needs, and the system responds by providing a specific list of the most relevant documents related to the query. The traditional model assumes that the process of information retrieval always goes through the same series of tasks: (1) the user has an information need, (2) he/she enters a query into an IR system, (3) the system compares the specific query with the representations of the documents stored in the databases, (4) it presents the users the text or those texts of possible interest, and (5) finally, the user examines them and determines the relevance of the retrieved results. Ideally, some or all of the retrieved documents will solve —totally or partially— the need for information. A good IR system should retrieve *all* the relevant documents (meaning complex coverage), and *only* the documents that are relevant (precision).

This information retrieval model has some implicit restrictions, however, such as the notion that query and document are written in the same language. In a multilingual environment like the Web, most IR systems or Websearch engines can only locate documents written in the same language as the query word(s), although there are some exceptions. Sometimes these systems feature machine translation (MT) devices that go to work when the documents have already been located, but they do not break the language barrier in the searching process.

While the traditional model is rooted in the approach of monolingual retrieval, it can be

Figure 1. The problem of the language barrier in information retrieval



broadened to encompass other perspectives: the terms "cross-language information retrieval" or "cross-lingual information retrieval" draw in (at least) two languages. Both entail specific systems that carry out bilingual information retrieval, also known as translingual information retrieval. In them, the query is made in a source language that is different than the language of the corpus of documents, written in a single target language. Moreover, CLIR can be used to refer to multilingual information retrieval where the system, from a query expressed in a specific language and some documents belonging to a multilingual corpus, offers a ranking or a unique list of documents written in different languages, shown depending on their relevance (López-Ostenero, Gonzalo & Verdejo, 2004).

In this chapter we review the main facets of CLIR and our current knowledge of its implications, especially with regard to the World Wide Web. First of all, we outline the state-of-the-art of the main campaign of evaluation carried out to date, and look at the recent research developments involving CLIR. Our aim is to show what the basic architecture of a CLIR system is, what the main components are, how the information retrieval processes take place, and which main mechanisms and techniques direct the process. Finally, we discuss promising lines of study for the future, as well as future challenges surrounding this area.

EVALUATION CAMPAIGNS

Although Salton (1970) is considered the "father" of the earliest research initiatives concerning CLIR, the first Workshop geared specifically to CLIR topics was celebrated in Zurich and it was organized by the Association for Computing Machinery (ACM) during the SIGIR-96 conference. Nowadays, there are three important international forums about the evaluation of IR systems focusing on techniques and proceedings related with CLIR: TREC, NTCIR and CLEF.

Over the past twenty years, the evaluation of the systems and techniques that participate in information retrieval has incorporated different perspectives, innovative contributions and rigorous research. If we were to trace these new projects, prototypes and research on evaluation back to their beginnings, we would end up in the 1950´s or 60´s, where Lesk (1995) situates the childhood and school age, respectively, of the seven ages of information retrieval. Since then, several new approaches to the problem have been elaborated.

The true importance of the evaluation of IR systems lies in the guarantee of correct performance, including the retrieval of relevant information, adequately adapted to user needs, which in turn include usefulness, speed, low cost, and so on (Salton and McGill, 1983). Previous or classical approaches of evaluation of IR systems, also known as the traditional or algorithmic perspective, stem from 1953, when the Astia-Uniterm test of the Armed Services Technical Information Agency of USA, and the Uniterm test from the College of Aeronautics in Cranfield (United Kingdom) were developed simultaneously. However, this trend was not fully inaugurated until the Cranfield project (Cleverdon, 1997) was conducted at the University of Cranfield by Cyril Cleverdon, beginning in 1957. With collaborative support from the American National Science Foundation (NSF) and the British Association for Information Management (ASLIB), the project consisted of two phases: Cranfield I and II, of lasting significance and repercussions. They led to the creation of a model, a methodology and guidelines for the evaluation of information retrieval systems that are still valid today (Olvera-Lobo, 1999).

Although the Cranfield projects were criticized —according to some authors, they were lab experiments whose results could not be extrapolated to information retrieval systems operating in a real setting (Harter, 1971; Swanson, 1965; 1971)—the main components used in these experiments did indeed set forth the bases of later evaluations: a set of documents, a set of information needs and a set of relevance judgments, with the use of recall and precision measures. The Cranfield test meant advancing from a speculative approach in the design of IR systems to an empiric or experimental perspective. These tools have since been used extensively in studies, such as in TREC (Text Retrieval Conference). In addition, they offer a theoretical framework from which Information Retrieval developed as a subdiscipline of Information Science); and the procedures adopted in these tests were the first ingredients of a tradition marking research, its design, and evaluation.

TREC (Text Retrieval Conference)

A turning point came in November of 1992, with the first TREC conference. It was co-sponsored by the US National Institute of Standards and Technology (NIST) and the Advanced Research Projects Agency (ARPA) and gathered together researchers of information retrieval so that they could discuss the results obtained from their respective systems, using a large new collection of evaluation resources (Harman, 1993). Twenty-two universities and companies from the US, the UK, Germany and Australia took part in this first conference. It stands as an unprecedented initiative that passed along the Cranfield policy, and as a most significant contribution to IR evaluation in a number of ways.

The annual TREC conference plays a vital role in terms of offering a referential paradigm for information retrieval research. Another significant aspect is the global philosophy (Ellis 1996) lending "realism" to the approach of evaluation. Furthermore, although the "TREC concept" is based on an optimal collection and applies different statistic and probabilistic approaches, the range of techniques studied is very wide, reflecting the growing heterogeneous perspectives and numerous approaches that may be used for researching IR.

In successive TRECs, the additional task of merging documents from multiple languages was addressed—for example, one might start with a topic in English and seek to retrieve a ranked list of documents in English, French, German, and Italian. TRECs 7 and 8 were run in cooperation with four European institutions (Harman & Voorhees, 2007): the University of Zurich, Switzerland (working on the French portion); the Social Science Information Centre, Bonn, and the University of Koblenz (working on the German portion); and the Consiglio Nazionale delle Ricerche, Pisa, Italy (a new Italian section). There were 25 new topics put forth in TREC-7, with an additional 28 topics for TREC-8.

During the three years that TREC adopted European CLIR, four core approaches were addressed (Harman & Voorhees, 2007): machine translation (where either the topics or the documents were translated into the target language); the use of machine-readable bilingual dictionaries or other existing linguistic resources; the use of n-gram techniques; and the use of corpus resources to train or otherwise capacitate the cross-language retrieval mechanism. Overall, the best cross-language performance was seen to be between 50 percent and 75 percent as effective as a high-quality monolingual run in TREC-6.

The success of such collaborative partnerships inspired a new European evaluation effort, and in 2000 the European CLIR component moved to the CLEF workshop. But the CLIR task realm remained at TREC for three more years. TREC-9, held in 2000, included a CLIR task that placed 25 English topics against 126 megabytes of Chinese documents from Hong Kong newspapers. Since Chinese CLIR had also been introduced in Asia through the new NTCIR workshop, the TREC CLIR task switched to English/Arabic. TRECs 2001 and 2002 used a total of 75 English topics against 896 megabytes of Arabic from the Agence France Press Arabic newspaper. TREC 2002 represented the final run of the CLIR task in TREC itself. The results of nine years of monolingual and cross-lingual evaluation have altogether shown that information retrieval methods used in English work surprisingly well for other languages. Yet we should also underline that monolingual and cross-lingual efforts are being evaluated elsewhere, and the needless duplication of effort should be avoided (Harman & Voorhees, 2007).

TREC continues its successful progress at the head of textual retrieval because it offers a forum for analysis of the systems, it uses common data and methods, and it serves as the principal point of reference for discussion about methodological issues within IR evaluation. For example, the tracks of TREC-2008 include: Blog Track—to explore information-seeking behaviour in the blogosphere; Enterprise Track—to study enterprise search (satisfying a user who is searching for organizational data to complete a task); Legal Track—to develop search technology that meets the needs of lawyers, to engage in effective use of digital document collections; Million Query Track—to test the hypothesis that a test collection built from very many incompletely judged topics is still a better tool than a collection built using traditional TREC pooling; and the Relevance Feedback Track—to provide a framework for exploring the effects of different factors on the success of relevance in feedback.

TREC has given rise to a wide network of collaboration, designed for constant evolution, where numerous research groups and organizations can compare the results of their systems. It also allows for the rapid diffusion of results and intensified research, offering an important collection of data, uniform procedures and measures of evaluation. At present, TREC can be considered, together with CLEF, as the predominating experimental effort in the realm of information retrieval.

Cross-Language Evaluation Forum (CLEF)

The Cross-Language Evaluation Forum (CLEF) was launched when it was decided to move the coordination of the CLIR track at TREC to Europe. Thus, in 2002, CLEF resulted from the split of TREC. CLEF is the first forum dedicated solely to multilingual IR in the different European languages, amounting to 13 in its report from 2007 (Peters, 2007). CLEF promotes research and development in multilingual information access by (i) developing an infrastructure for the testing, tuning and evaluation of information retrieval systems operating with European languages in both monolingual and cross-language contexts, and (ii) creating test-suites of reusable data to be employed by system developers for benchmarking purposes.

A total of 81 groups participated in CLEF 2007 (in CLEF 2006, 90 groups participated), and different document collections were used in CLEF 2007 to build the test collections (Peters, 2007). Of quite diverse nature, these included: the CLEF multilingual comparable corpus, consisting of more than three million news documents in 13 languages; the GIRT-4 social science database, in English and German (over 300,000 documents), plus two Russian databases (approximately 240,000 documents) used in the domain-specific track; collections for both general photographic and medical image retrieval (ImageCLEF track); the Malach collection of spontaneous conversational speech derived from the Shoah archives in English (over 750 hours) and Czech (some 500 hours) for use in the speech retrieval track; and EuroGOV, a multilingual collection of about 3.5M Webpages, containing documents in many languages and crawled from European governmental sites, to be used in the so-called WebCLEF track.

Seven main tracks for evaluation are suggested in CLEF´s 2008 edition: (1) Multilingual Document Retrieval, (2) Scientific Data Retrieval, (3) Interactive Cross-Language Retrieval, (4) Multiple Language Question Answering, (5) Cross-Language Image Retrieval, (6) CLEF Web Track, and (7) Cross-Language Geographical Information Retrieval. Additionally, two new tracks are offered as pilot tasks: Cross-Language Video Retrieval and Multilingual Information Filtering.

Thus we see that, over the years, the attention of the CLEF campaigns has gradually shifted from text retrieval systems *per se* and the measurement of document rankings toward the provision of a wider range of tasks, including issues of greater interest to the end users in terms of their interaction with the system. Present or future evaluation tracks will account for assessment systems for multilingual question answering, for cross-language image retrieval, and for cross-language spoken document retrieval. The goal is to offer a comprehensive set of tasks covering all major aspects of multilingual multimedia system performance, with particular attention to the needs of the end-user (Gey et al. 2005).

National Institute for Informatics Test Collection for IR (NTCIR)

NTCIR (National Institute for Informatics Test Collection for IR), held since 1999 and co-sponsored by the Japan Society for Promotion of Science (JSPS) and the National Centre for Science Information Systems (NACSIS), is a workshop geared to evaluate translingual systems between the English and some Asiatic languages. The main aims are: (i) to encourage research in information access technologies by providing large-scale test collections that are reusable for experiments and a common evaluation infrastructure allowing cross-system comparisons; (ii) to provide a forum for research groups interested in cross-system comparison and exchanging research ideas in an informal atmosphere; and (iii) to investigate means of evaluation of information access techniques and methods, and to construct a large-scale and reusable data set for experimentation.

During the NTCIR-6, held in 2007, a set of English documents were removed from a collection of the NTCIR test in order to center the research on Asian languages. In total, search results were submitted by 22 groups from ten countries (the major representatives being six groups from Japan and five from Taiwan) (Kishida, et al., 2007). The sub-tasks developed were:

- **Multilingual IR:** The document set of this task consists of two or more languages. For the NTCIR-6 CLIR task, the multilingual search is limited to using the CJK collection, which consists of Chinese (C), Japanese (J), and Korean (K) documents;
- **Bilingual IR:** The document set in a single language is viewed, in search of a topic in a

different language, e.g., searching Japanese documents for Korean topics (K-J run);

- **Single language IR:** The topic set and document sets of this task are written in one same language.

For the 7th NTCIR Evaluation Workshop (held in Tokyo, Japan, December 2008), the array of tasks deals with: (a) Advanced Cross-Lingual Information Access (Complex Cross-Lingual Question Answering and Information Retrieval for Query Answering); (b) Information Access to User Generated Contents (Multi-Lingual Opinion Analysis Task and Cross-Lingual Information Retrieval over Blog data); and (c) Information Access to Focused Domains (Patent Mining Task and Patent Translation Task).

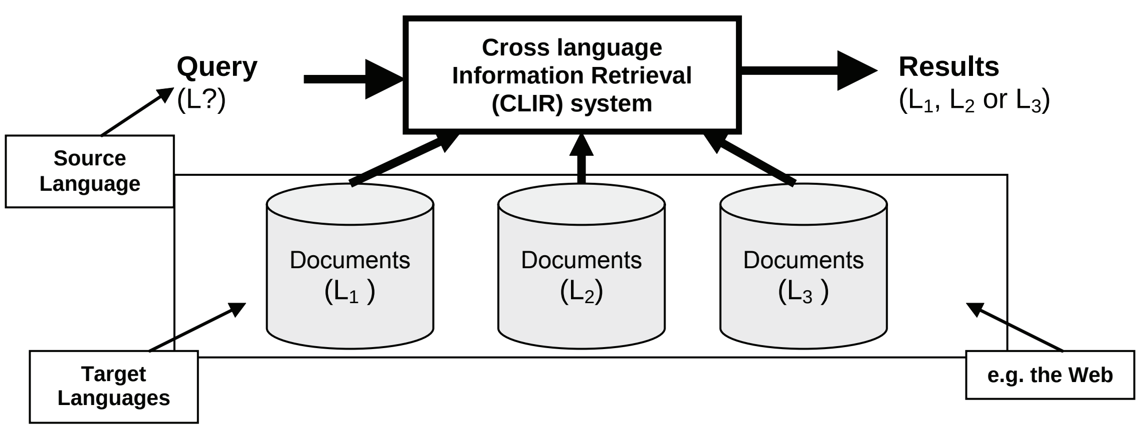
Again according to Gey et al. (2005), the effort invested in evaluation campaigns had an important impact in that it configures a technical and experimental infrastructure for researchers and designers of CLIR systems, as well as a prestigious international framework of reference, to review and compare ideas and approaches. The result can be seen as landmark progress in the design of CLIR systems and in the development of a corresponding research community.

CLIR APPROACHES

We encounter different proposals for crossing that linguistic barrier arising from the fact that queries and documents can be written in different languages. Although the usual process is translation, some researchers describe new approaches that can be used regardless of the language, concentrating instead on a facet known as *cognate matching* (Kishida, 2005).

Cognates are words in different languages with the same root, which therefore share phonetic and lexical aspects (a good example being *noche*, *night*, *nuit*, *nacht*, and *notte*). CLIR implements this method by means of: (i) query terms (untranslatable terms) to find the multilingual documents, such as technical terminology and proper name, which are normally common for all languages; (ii) different methods based on measures like edit distance, to measure the minimum number of operations (insertion, elimination or substitution of a characters) needed to change one complete character chain into another one (using phonetic transliteration when the languages are very different); and (iii) n-gram comparison, a method consisting of breaking up the words of the queries and the documents into a sequence of n-gram characters, for their subsequent comparison.

Figure 2. Cross-Language Information Retrieval (CLIR) system



System architecture for CLIR can generally be classified as query translation, document translation, or interlingual methods (Oard & Diekema, 1998). Query translation is the most frequent option, because the texts are shorter than the documents, and the computational cost of the translation is lower (Hull & Grefenstette, 1996). However, a high number of researchers claim it is particularly difficult to solve problems of ambiguity during the translation process, because the queries are too short and do not offer a relevant context, although user interaction might enhance results (Oard, He & Wang, 2008).

Different linguistic resources are used in this translation process, such as bilingual dictionaries, text corpora, machine translation, thesauruses, etc. (Abusalah, Tait & Oakes, 2005; López-Ostenero, Gonzalo & Verdejo, 2004). In addition, some procedures may be introduced to disambiguate and select the most appropriate translation among all the different possibilities (Kishida, 2005).

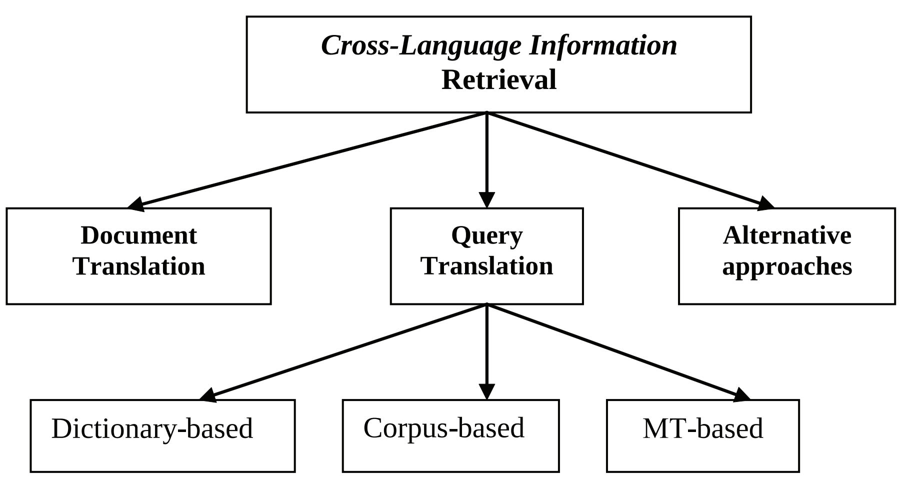
The main strategies for query translation are dictionary-based methods, corpus-based methods, and machine translation.

Dictionary-Based CLIR

Choosing the adequate lexical resources to introduce in the architecture of a defined CLIR system has an important impact on their performance (Xu & Weischedel, 2005). The dictionary-based CLIR approach incorporates all those techniques linked to the use of machine-readable bilingual dictionaries, thereby allowing us to transform a user query into its semantically equivalent representation in the language of the document collection.

Although many elements and techniques form part of the architecture of a dictionary-based CLIR system (Levow, Oard & Resnik, 2005), the processes actually taking place can be summed up in four basic stages (Gearailt, 2005): (a) a pre-translation query modification, with the addition or deletion of source-language query terms, or the application of additional query term weights; (b) the dictionary lookup, invoked to obtain a set of equivalent terms for each source-language query term; (c) the equivalent (candidate translation) selection and weighting of each source-language query term, this implying the selection of some or all of the equivalents obtained during dictionary lookup for that term for possible inclusion in the query translation, and/or calculation of

Figure 3. CLIR approaches



additional weights; and (d) a post-translation query modification, in light of all additions or deletions of equivalents in the query translation that are carried out after completion of all the explicit translation-related operations.

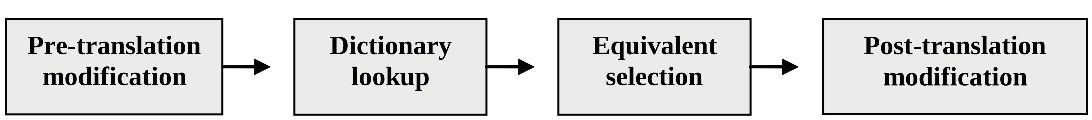
The main problems associated with dictionary-based CLIR reside in: (1) out-of-vocabulary (OOV) words, meaning words that are not found in the translation dictionaries; (2) inflection treatment; (3) the identification and translation of complete sentences; and (4) lexical ambiguity in the source and/or target language. Indeed, the direct use of a dictionary does not guarantee finding translations of terms, for reasons expounded by previous authors (Lopez-Ostenero, Gonzalo & Verdejo, 2004):

- The dictionary does not normally offer a full range of terms. Technical terms often go untranslated, and so it is impossible to find specialized terminology of some specific domain in general dictionaries. For this reason, CLIR should introduce specialized dictionaries.
- Dictionaries do not usually show all the possible morphological variants of a word. This problem can be reduced through *stemming*, a technique that serves to obtain the root of the words to be dealt with.
- It may be necessary to translate proper (personal) and geographical names in order to avoid misunderstandings among languages, the problem at the root of "entity recognition".
- The correct translation of terms always depends upon context. Polysemy complicates translation, and we do not dispose of automatic methods to solve this hindrance.
- The erroneous or improper translation of some terms can really pose a problem when we are dealing with terms included in multiword expressions ("trade agreement", "heavy construction industry").

The techniques that attempt to handle translation ambiguity in dictionary-based CLIR revolve around (Abusalah, Tait & Oakes, 2005): (a) part-of-speech tagging (an automatic linguistic method for identifying a word within its given context); (b) various corpus-based disambiguation methods (such as query expansion to reduce the effects of poor translation equivalents, word co-occurrence statistics for selecting the best translations, or the selection of equivalents on the basis of aligned sentences); (c) query structuring (that is, synonym-based structuring, compound-based structuring, or phrase-based structuring); and finally, (d) use of "the most probable translation strategy", which implies that a single translation for each query term can be chosen on the basis of the number of occurrences of that translation in the dictionary.

In order to choose a sound dictionary for translating queries, we should judge important characteristics such as the average number of distinct equivalents in each dictionary entry (*dictionary scale*), the overall coverage rate (*coverage*) and how a dictionary entry is defined

Figure 4. The four stages of dictionary-based query translation



(*entry definition*), and the retrieval performance of query translations, among others (Gearailt, 2005). In addition, some studies indicate that when query translation uses the information of parallel corpora, greater precision is achieved than through query translations obtained using bilingual dictionaries (López-Ostenero, Gonzalo & Verdejo, 2004; Talvensaari et al., 2007).

Corpus-Based CLIR

In corpus-based methods, the fundamental knowledge for query translation is obtained from collections of multilingual texts using various statistical methods. The collections may be aligned or unaligned; and the alignment can be at the lexical, syntagma, paragraph or document level. In such aligned multilingual collections, each source language document is assigned to a target language document, and when the paired documents are exact translations of each other, the collection is a *parallel corpus*. *Comparable corpora* consist of document pairs that are not translations of each other, yet share similar topics.

As one might imagine, the World Wide Web is also an interesting source for the automatic creation of parallel (Yang & Li, 2004) and comparable corpora (Talvensaari et al., 2008). However, these resources are poorly suited to some pairs of languages and topics. Resnik & Smith (2003: 350), on the optimistic side, claim that *"As computational linguists working on multilingual issues, we view the Web as a great big body of text waiting to be mined, a huge fabric of linguistic data often interwoven with parallel threads*".

There are many freely available parallel corpora on the Web. Perhaps the most comprehensive parallel corpus available is JRC-Acquis, a collection of parallel texts in all 22 official EU languages excepting Irish Gaelic: Bulgarian, Czech, Danish, Dutch, English, Estonian, Finnish, French, German, Greek, Hungarian, Italian, Latvian, Lithuanian, Maltese, Polish, Portuguese, Romanian, Slovak, Slovene, Spanish and Swedish.

The construction of parallel corpora often entails a pre-processing stage and sentence alignment. In the pre-processing stage, sentence and paragraph boundaries are detected and marked, and punctuation is removed. The detection of sentence boundaries is a relatively easy task when the language expression provides a sentence ending mark. In sentence alignment then, the participant sentences are arranged by pairs. This calls for the corresponding sentences to be recognized first, establishing the sentence length. Complementary linguistic information (e.g. parts of speech), and dictionaries can also be utilized in alignment. Moreover, inflected word forms can be normalized into base forms. Departing from the bilingual parallel corpus where sentences are aligned, translation equivalents between the two languages are extracted in view of the co-occurrence statistics of words in the aligned sentences. The drawbacks associated with the extraction of translation equivalents tend to involve multiword expressions and infrequent words.

Generally speaking, this parallel corpus approach has other inherent disadvantages: parallel corpora are not readily available for certain languages, the approach is typically domain specific, and the construction of parallel corpora is time-consuming and expensive.

In some CLIR methods that rely on parallel corpora, no query translation is needed. For example, Latent Semantic Indexing is a vector space IR model in which documents are represented in a multilingual semantic space where monolingual documents are then mapped. Indexing is based on the fact that words occurring in similar contexts are likewise semantically close to each other. In LSI no sentence alignment is needed; alignment is done on the document level.

With the understanding and use of Web capacities as a plentiful spring of resources for CLIR tasks, we may create aligned comparable corpora at the document level. The use of such corpora would not be as immediate as the employment of parallel corpora, but once they are elaborated they can be conformed to create a similarity thesaurus including query language words related to the document language words (Martinez Santiago & Ureña Lopez, 2003). Queries were translated and expanded using the similarity thesaurus.

Machine Translation-Based CLIR

Another resource clearly deserving mention here, widely used to translate queries in CLIR systems, is that of commercial software for machine translation… but only if software is available for the pair of languages precisely under consideration (Lopez-Ostenero, Gonzalo & Verdejo, 2004). The MT-based query translation is possibly the most direct approximation, and offers optimal results, as it involves the use of linguistic analysis tools that improve translation accuracy.

The combined use of MT and machine-readable dictionaries further enhances the results that these methods provide separately. For example, if the translation is made using an MT system, it can be extended with the two or three most frequent translations of each term found in dictionaries. Both these linguistic tools are scarcely found, however, if we are dealing with language pairs that do not include English.

Indeed, MT commercial software is now available for just a number of language pairs, and developing new systems or adding modules for new pairs of languages is an expensive and slow process (Gearailt, 2005). It is nonetheless true that, over recent years, great efforts have been invested in this option. Furthermore, even if one has the MT system needed for a particular CLIR application, the quality of the results will depend to a great extent on the source and target languages involved in the information retrieval process at hand. Therefore, the use of MT systems is hampered by disadvantages (Zhu & Wang, 2006) such as the scarce number of high quality MT systems, the availability of MT systems for only some language pairs, or for use with only very short queries (sometimes consisting of only one term), which limit the effectiveness of MT-based methods in general.

At the same time, however, machine translation is taking on novel aspects and approaches. The common feature among the different MT systems available to date is the requirement of a translation, made automatically by software, from the (natural) source language of a text to a target language. The quality of the translation can vary considerably, but even the most sophisticated MT systems still cannot produce translations without any human revision or assessment. MT systems also have restrictions regarding the nature of texts that can be translated well. Literary prose remains beyond their reach; yet simpler and well organized texts (for example, user guides, news, or weather reports) are suitable for MT processing. In short, the more restricted the topic and vocabulary of the text, the better the resulting translation. By the end of the 1990's, MT was available to all Web users, and dozens of languages can currently be translated on the Internet. The quality of translations may of course be poor, but demand is so great that these services, with their implicit deficiencies, must be considered necessary.

Three different MT approaches have been used in the relatively short history of our field: direct translation, interlinguistic translation, and transfer-based translation. Approaches gradually introduced in the 80's and early 90's stemmed from direct translation was the first of these. An MT system using direct translation generally incorporated the following features: analyzing the text only at a morphological level; translation based on great dictionaries and formed word by word, with some minor grammatical adjustments; an MT system designed for a particular pair of source and target languages; the unit of translation usually being the word.

At the beginning of the 90's, the statistical approach of MT became more popular. In its pure form, statistical MT does not use any traditional linguistic data. The basic idea is that the translation is based on a calculation of the probability of correspondence between one word and another word (or group of words) situated in the aligned sentences. For this reason it requires the same text in two languages (parallel corpora). On the basis of probabilities, the system "learns to translate". It has a variant form known as example-based MT, which consists of reusing finished translations as a foundation upon which a new translation can be done. While these systems have their differences, all of them rely on the existence of vast bilingual or multilingual corpora.

FUTURE TRENDS

As is usual in other scientific fields, in the information retrieval field, and more specifically in the sphere of CLIR, research and industry take roads that never seem to converge. Indeed, many questions already resolved by researchers have not yet found applications in the real world. Advances may spread, but do not necessarily reach the market. And so it is that despite the many achievements of research into different aspects of CLIR, most notably since 1996, commercial interest has been limited until now.

Although this situation can be attributed to various and complex reasons, one is clearly related to the fact that the most important evaluation campaigns (TREC, CLEF and NTCIR) tend to focus on those aspects of system operation that can be easily measured in an objective way (e.g. precision and recall) while ignoring others of equal or even greater importance for system development overall (Braschler et. al., 2007). Characteristics such as speed or the stability of the system (that is, effectiveness criteria) have been repeatedly ignored.

Meanwhile, we can also point to the shortage of user studies in this area of research. This oversight gains increased significance if we consider how crucial certain aspects such as usability can prove to be for the users of multilingual systems. In this sense, users might need some orientation for the process of effective query formulation and assistance in the interpretation of results. In other words, the success of these systems depends largely on how friendly the user interfaces are, and how adequately they answer the needs of different types of users. The findings of research in this direction must provide comprehensible and useful feedback.

In order to achieve a better connection between research and development, an activity named TrebleCLEF was introduced in 2008, to eventually stimulate the development of operational multilingual information access systems instead of focusing on developing research prototypes. TrebleCLEF supports the development and consolidation of expertise in the multidisciplinary research area of multilingual information access (MLIA), and disseminates this know-how toward application communities through a set of complementary activities, with the following objectives:

- To promote high standards of evaluation in MLIA systems using three approaches: test collections; user evaluation; and log file analysis.
- To sustain a MLIA evaluation community by organizing annual evaluation campaigns and providing high quality access to past evaluation results.
- To disseminate know-how, tools, resources and best practice guidelines, enabling system developers to make contents and knowledge accessible, usable and exploitable over time, over media and over language boundaries.

An additional factor impeding the widespread application of advances related to CLIR is the scarce impact that these techniques have had on the World Wide Web. Search engines are the primary means of looking for information on Internet. Yet despite the vast quantity and variety of Websearch engines in existence, access to information from a multilingual viewpoint is still an unresolved issue. Possibly, the Internet multilingual capacity is not being fully taken advantage of. The fact that multiple language support mechanisms for use with search engines have not been incorporated means that access to resources in different languages is not being done in an effective way. Authors Zhang & Lin (2007), who analyzed a total of 82 search engines, 21 of them featuring multiple language support, found that only three search engines (Google, EZ2Find and AltaVista) could handle automatic language translation; and furthermore, the translation obtained was done at a lexical level. It is therefore easy to infer that the search engines must add techniques of machine translation and cross-language information retrieval that allow them to translate at a semantic level, and hence improve their results.

CONCLUSION

The need to embark on translingual searches is becoming an everyday event, the demand for this kind of search being linked to the surge of the Web. Experimental research has recently shown that bilingual or translingual retrieval is not only feasible but is also nearly as effective as monolingual searching (Lopez-Ostenero, Gonzalo & Verdejo, 2004).

Key issues such as the improvement of linguistic tools and of user interaction hold the answers we need to optimize CLIR systems. Improving the quality of translations will call for the development of MT software, bilingual (or multilingual) automated dictionaries, or other more sophisticated techniques for machine translation. Meanwhile, authors such as Kishida (2008) suggest the adoption of a semi-automatic approach, incorporating certain human capacities. For example, an interactive CLIR system that allows users to select the correct or best translation might increase the effectiveness of retrieval.

And so there are two different approaches, both deserving attention, which may well lead to improved CLIR systems: the automatic approach, and the proposal of active participation on the part of the user. Yet we lack adequate methodology for the evaluation of interactive tasks. Current parameters for assessment, designed with automatic systems in mind, do not shed light on the specifically interactive aspects that are also at the root of this kind of task. It is necessary to take into account both the searches and the reasoning process carried out by the user, instead of merely considering the final response of the system and the document that supports it (Lopez-Ostenero et al. 2008).

On occasions CLIR has been described as "the problem of finding documents that you cannot read", or the means to an end of questionable value. Debate is always healthy, but it should not be limited to the issue of the readability or indigestion of what is obtained. Rather, we must ask whether we can afford the luxury of not knowing what exists out there in other languages. While this question may have had a simple affirmative answer in the past, it is acknowledged as a less tolerable fault for the 21st century (Oard, He & Wang, 2008).

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WEB RESOURCES

AltaVista. http://www.altavista.com

CLEF: Cross-Language Evaluation Forum. http://www.clef-campaign.org

DARPA: Defense Advance Research Projects Agency. http://www.darpa.mil

European Commission Joint Research Center. *The JRC-Acquis Multilingual Parallel Corpus,* http://langtech.jrc.it/JRC-Acquis.html

EZ2Find. http://ez2find.com/

Flick. http://www.flickr.com

Google. http://www.google.com

NIST: National Institute of Standards and Technology. http://www.nist.gov

NTCIR: NII-NACSIS Text Collection for Information Retrieval Systems. http://research.nii.ac.jp/ntcir/index-en.html.

SIGIR: Special Interest Group on Information Retrieval. http://www.acm.org/sigir/

TREC: Text REtrieval Conference http://trec.nist.gov

KEY TERMS AND DEFINITIONS

Corpus-Based CLIR: The knowledge basis for query translation is obtained from collections of multilingual texts, using various statistical methods.

Cross-Language Evaluation Forum (CLEF): It runs a series of evaluation campaigns testing monolingual and cross-language information retrieval systems.

Cross-Language Information Retrieval (CLIR): A subfield of information retrieval dealing with retrieving information written in a language different from the language of the user's query.

Dictionary-Based CLIR*:* Incorporating all the techniques related to the use of machine-readable bilingual dictionaries in order to transform the user query in a semantic equivalent to be represented in the language of the document collection.

Information Retrieval: The process by which a user may access relevant information in a timely and effective manner.

Information Retrieval System: Basically consisting of a database, one or more indexes of its content, a search engine and a user interface.

Machine Translation-Based CLIR*:* Machine translation software is used in order to translate queries in CLIR systems.

Text REtrieval Conference (TREC): An annual information retrieval conference entailing competition, its purpose being to support and further research within the information retrieval.

Chapter XXXV
CRISS:
A Collaborative Route Information Sharing System for Visually Impaired Travelers

John Nicholson
Computer Science Assistive Technology Laboratory, Utah State University, USA

Vladimir Kulyukin
Computer Science Assistive Technology Laboratory, Utah State University, USA

ABSTRACT

Limited sensory information about a new environment often requires people with a visual impairment to rely on sighted guides for showing or describing routes around the environment. However, route descriptions provided by other blind independent navigators, (e.g., over a cell phone), can also be used to guide a traveler along a previously unknown route. A visually impaired guide can often describe a route as well or better than a sighted person since the guide is familiar with the issues of blind navigation. This chapter introduces a Collaborative Route Information Sharing System (CRISS). CRISS is a collaborative online environment where visually impaired and sighted people will be able to share and manage route descriptions for indoor and outdoor environments. It then describes the system's Route Analysis Engine module which takes advantage of information extraction techniques to find landmarks in natural language route descriptions written by independent blind navigators.

1. INTRODUCTION

For a person who has a visual impairment, having the ability to be mobile without the aid of another person is a sign of personal independence. It is important enough that a lack of mobile independence can affect an individual's mental health. Someone just beginning to adjust to a new visual impairment may find a decrease in the ability to travel independently, which can lead to depression (Blasch, Wiener, & Welsh, 1992). The ability to travel independently is also a quality of life issue. A 1991 survey in Britain of almost six hundred adults with visual impairments found that only 51% of those surveyed under the age of 60 had left their house alone and on foot in the week prior to the interview (Bruce, Mckennell, & Walker, 1991).

In order to address the need for indoor and outdoor navigation assistance in unfamiliar environments, both commercial and research systems have been developed using various technologies such as GPS (Ran, Helal, & Moore 2004; Sendero, 2008), Wi-Fi-based localization (LaMarca, et al, 2005), and infrared beacons (Crandall, Bentzen, Myers, & Brabyn, 2001). Unfortunately, the adoption rate for these devices in the blind community remains low. There are multiple reasons for this lack of adoption. First, the commercial devices tend to be expensive. For example, the software and GPS-based guidance system Sendero GPS (Sendero, 2008), intended to be used by an individual, costs $1,495, a price which does not include the mobile computer on which to run the software. Other navigation systems do not achieve localization accuracies which would be useful for a blind person in many situations. Place Lab (LaMarca, et al, 2005), for example, achieves a median location error of 15 to 20 meters. Other systems (Crandall, Bentzen, Myers, & Brabyn, 2001; Talking Lights, 2008; Priyantha, Chakraborty, & Balakrishnan, 2000) require a device or sensor to be installed in the environment. The problems are that each device must often have a power source, or the systems must be calibrated and maintained. These systems do not scale to large-scale environments, such as college campuses, where navigational assistance would be needed over a large area. A final issue is that most systems only address either indoor or outdoor navigation, but not both. A navigational assistance device should ideally address both environments.

Almost all navigation devices take the "trust me - you are here" approach. In general, they take a reading from their sensor set, compute a location on a map, and, based on the user's destination, instruct the user where to move next. Unfortunately, due to noise in the environment, signals can be noisy or missing resulting in incorrect location computation. Garmin (2008), for example, reports that its GPS units are accurate to within 15 meters. This amount of error may be acceptable for a sighted person who can make a visual distinction between where the device says he is standing and where he is actually standing. For a person who is visually impaired, especially those who have complete vision loss, an error of this amount reduces the usefulness of the device. If a person who is visually impaired is continually given an inaccurate location, they may at best simply stop using the navigation device or at worst become disoriented and lost.

One sensor that previous systems have not taken into account is the navigator himself. Many people who have a visual impairment receive extensive orientation and mobility (O&M) training. During training, individuals learn valuable skills which enable them to safely and successfully navigate many environments independently, both indoors and outdoors (Blasch, Wiener, & Welsh, 1997). They learn, for example, to perform actions such as following sidewalks, detecting obstacles and landmarks, and crossing streets. They also learn techniques for remaining oriented as they move around inside buildings or outside on sidewalks and streets. Experienced travelers can even handle some unfamiliar environments when given sufficient verbal assistance. There is some research evidence (Gaunet & Briffault, 2005; Kulyukin, Nicholson, Ross, Marston, & Gaunet, 2008) that people with visual impairments share route descriptions and can verbally guide each other over cell phones. In these situations, only verbal route descriptions are used to guide the traveler from one location to another location; the only technology used is the cell phone which simply maintains an audio connection between the two individuals.

Inspired by the possibility of the navigator being an active part of the navigation system, we developed ShopTalk, a wearable device for helping the visually impaired shop for shelved items in a modern grocery store (Kulyukin, Nicholson, & Coster, 2008a; Kulyukin, Nicholson, & Coster, 2008b; Nicholson & Kulyukin, 2007). When guiding shoppers who are visually through large-scale areas of the grocery store – store entrance to aisle, aisle to aisle, aisle to the checkout lane – ShopTalk uses no external sensors. Instead, it makes the assumption that a shopper who is visually impaired and can travel independently has the sufficient navigation skills to follow verbal instructions which describe routes through the store. In two experiments, a single participant pilot study (Nicholson & Kulyukin, 2007) and larger ten participant study (Kulyukin, Nicholson, & Coster, 2008a; Kulyukin, Nicholson, & Coster, 2008b), participants successfully navigated the store despite the lack of a "you are here" sensor in the system.

Encouraged by the success with ShopTalk experiments, we have begun asking how far can the verbal route description only approach be taken. Can it only work indoors, or can it work outdoors as well? Is there some sort of limit to the size and structure of an environment for this type of approach to be feasible? What is a "good" route description? In looking at these and other related questions, we are also taking into consideration research (Passini & Proulx, 1988) which shows that people who have visual impairments prepare more for travel, make more decisions, and use more information than sighted travelers. Instead of designing another "you are here" type of route guidance system, we are designing a new system which takes a different approach.

The Community Route Information Sharing System (CRISS) is a system currently in development which is intended provide more detailed and user appropriate levels of information to enable independent blind navigators to follow routes in unfamiliar indoor and outdoor environments with the need for external sensors such as those based around GPS, RFID, infrared, etc. The reason that CRISS is able to present route descriptions with a level of detail specifically targeted towards blind navigators is that the route descriptions are written by other members of the CRISS community who also have visual impairments and are familiar with the routes. Because the users themselves all have visual impairments and many are familiar with the geographic area, and have traveled the routes themselves many times, the users can describe routes with a level detail appropriate for other blind navigators. Our conjecture is that if a route is described with sufficient and appropriate amount of detail, a visually impaired person who is unfamiliar with the route can use his or her everyday navigation skills and abilities to successfully follow the route. As CRISS becomes operational and is used to gather real-world route descriptions, we will be able to formally define, test, and evaluate this conjecture in large-scale indoor and outdoor settings.

The remainder of the chapter is organized as follows. In Section 2, CRISS is introduced and its basic data structures are described. Section 3 describes the Route Analysis Engine module of CRISS that uses information extraction techniques to find landmarks mentioned in natural language route descriptions and generates new route descriptions via a process known as path inference. In Section 4, related work is presented in order to ground our work in a broader research context.

2. CRISS: A VGI WEBSITE FOR THE BLIND

Volunteered geographic information (VGI), as discussed in Goodchild (2007), consists of user and community generated geographic information system (GIS) tools, data, and Websites. VGI Websites and communities encourage interested volunteers, rather than GIS professionals, to provide the data used to build maps or other GIS services. For example, OpenStreetMap (http://www.openstreetmap.com) allows users to upload

GPS data, gradually resulting in an accurate street level map which covers entire cities and large parts of some countries. Another example is Wikimapia (http://wikimapia.org) where users annotate maps from Google Maps (http://maps.google.com) with information such as building names, descriptions and photos. While these Websites are useful, people with visual impairments are unable to use the sites because the presented information is primarily visual.

A person with a visual impairment, when he or she is familiar with a given geographic area, often has a wealth of spatial information about that area, particular the routes. Consider a student who has spent four years attending a university and navigating its campus. The student has learned and traveled multiple routes around and across the campus - classroom to classroom, building to building, from home to campus and back. If the experienced student could document and share descriptions of the routes with which he is familiar and could make the descriptions available to new students who are also visually impaired, the new students would have an easier time learning the new routes around the campus. With this in mind, we are designing CRISS as a VGI Website for people with visual impairments. Unlike the other current VGI services that rely on visual data, the intention of CRISS is to allow users to collaboratively create a map consisting of natural language route descriptions.

CRISS will allow communities of independent blind navigators to come together and work collaboratively, learning and sharing route descriptions for large geographic areas such as college campuses or even towns and cities. The spirit of the Website is similar to community-based Websites such as Wikipedia (http://www.wikipedia.org) which allows users to add, create, and edit data, resulting in a large and dynamic user-managed collection of knowledge. In CRISS, the community-managed knowledge consists of a large collection of route descriptions, pieces of natural language text that describe how to get from location to location. The route descriptions can cover routes which are entirely indoors, entirely outdoors, or a mixture of both. As the collection of route descriptions for a geographic area grows, the user community will end up creating a route-based map for use by independent visually impaired travelers who are unfamiliar with the area and the route they wish to take. The travelers, instead of relying solely on sighted guides to introduce them to the new area or to assist them in learning an unfamiliar route, will be able to download user created and approved routes from CRISS. Using their everyday navigation skills and abilities, they will be able to travel the unknown route independently. Another advantage of CRISS is that special purpose hardware will not be required. Since route descriptions are text-based, exported routes will be available in simple, standard formats such as plain text, computer generated text-to-speech mp3, and the DAISY Standard for Digital Talking Books (Daisy Consortium, 2008) allowing users to use their everyday technology tools such as smartphones, mp3 players as route guidance tools.

CRISS is intended to become a full-scale VGI service where the community-managed map is not visual and based on vectors and shape data, but on route descriptions. Route descriptions are written by knowledgeable users. However, any user can view and download them. If a route description is found to be inadequate, e.g., insufficiently detailed or unsafe for some people, other users will be able to edit it or replace it with an updated description. Traditional GIS data, such as GPS and compass fixes, may be incorporated in the future, but currently the system is designed to use only natural language route descriptions.

In order to model the environment as a set of route descriptions, CRISS has two main data structures. The first data structure is a hierarchical set of landmarks. A landmark is defined as any useful location or object in the environment that a person who is visually impaired may mention in a route description and which a person can detect using whatever sensory information available to them. Landmarks obviously include both the starting locations and the ending locations of routes. Indoor examples of landmarks include rooms, doors, and hallway intersections. Outdoor landmark examples include entire buildings, sidewalks, and streets. Landmarks can be detected by various human senses and may include landmarks not typically mentioned by sighted travelers in their route descriptions, e.g., "when you smell bread baking" or "where you feel the carpet change to tile."

The landmark hierarchy is a tree representing *part-of* relationships. Larger and more general landmarks are stored higher up in the hierarchy, and more specific landmarks are stored lower in the hierarchy. The larger landmarks contain the more specific landmarks creating the part-of relationship. As shown in the example hierarchy in Figure 1, as one moves down the hierarchy, the landmarks move from large areas, such as the entire university, down to a landmark marking the equivalent of a specific location, e.g. a water fountain on a specific floor of a specific building. The concept of hierarchical landmarks in CRISS is related to regions in the topological level of the spatial semantic hierarchy (SSH) (Kuipers, 2000). Regions in the SSH are areas that can contain smaller regions or be part of larger regions, while landmarks in CRISS can have sets of landmarks as children or be a child of a larger landmark. In other words, *part-of* is the only relationship in the hierarchy.

Landmarks have a unique id allowing CRISS to differentiate between multiple landmarks with the same name, e.g., having multiple landmarks named *SECOND FLOOR* as part of any building with two or more floors. Landmarks may also have a list of zero or more alternative names (strings). This allows a landmark to be referred to in mul-

Figure 1. A partial landmark hierarchy for Utah State University.

```
Utah State University
     Taggart Student Center Building
          First Floor
               Dining Area
               Post Office
          Second Floor
               Registrar Office
     Old Main Building
          First Floor
               Elevator door
          Fourth Floor
               Main Hall
                    CSATL Lab
                    Water Fountain
                    Computer Science Front Office
               Back Hall
                    Room 401E
                    Room 401D
               Elevator Door
```

tiple ways. For example, the landmark *ROOM 414* representing room 414 in the Old Main building could have the alternative names *COMPUTER SCIENCE FRONT OFFICE*, *CS FRONT OFFICE*, and *CS DEPARTMENT HEAD'S OFFICE*. Finally, a landmark has a free text description which allows users to describe the landmark. The description allows knowledgeable users to provide information about the landmark that they feel people who are unfamiliar with the landmark may want to know.

Although the landmark hierarchy can be preloaded with an initial set of landmarks - building names, department names, key rooms and offices, etc - the majority of the landmarks are edited and maintained over time by the user community. When a new landmark is mentioned in a route description, users have the capability to add it to the landmark hierarchy if it has not been previously added. Users can also remove unnecessary landmarks if the landmark is determined not to be needed. If a landmark is not needed for a route description or is never deemed a starting or ending location for any route, then the user community is free to never include it in the hierarchy. Users also have the capability of changing a landmark's position in the landmark hierarchy, ensuring the landmarks are arranged in the most appropriate order.

CRISS's second data structure used to model the environment is a set of user-provided free text route descriptions. A route description is the description of how to travel from one location to another location. Users describe routes using free text as this is a natural way for people to think about routes. It also allows a user to describe routes in terms that are appropriate for other visually impaired travelers. When users download a route description, they receive a natural language description in a form which is exactly the same as if they had received the route description from a friend via email or if they used an audio recorder to save a friend's verbal route description given over the telephone.

A route description has three properties: a starting location, an ending location, and a natural language description which guides a person from the starting location to the ending location. In CRISS, the starting and ending locations reference landmarks in the landmark hierarchy. The natural language description is stored as a list of *route statements*. A route statement is an individual sentence from the user created route description. Route descriptions are broken into route statements in order to associate landmarks mentioned in the descriptions with the normalized set of landmarks in the landmark hierarchy.

A landmark from the landmark hierarchy associated with a route statement is considered a type of tag, or metadata. Tags are data that give meaning to other pieces of data (Mathes, 2004) and are in widespread use today. Flickr (http://www.flickr.com) and YouTube (http://www.youtube.com), for example, have user-created tags which describe the content of the images and videos respectively. One of the advantages of tags is that they allow users on these sites to find related content easily, e.g., find all images which have the associated tag "museum".

One problem with Flickr and YouTube's tagging systems is that there is no consistent naming structure and the namespaces are flat (Mathes, 2004) which results in little semantic meaning associated with the tags. The tag "doors," for example, could be associated with a picture containing multiple wooden doors in a hall as well as a photo of the members of the classic rock band The Doors. In the Semantic Web, the goal is to provide well-defined meaning which both computers and humans can use (Berners-Lee, Hendler, Lassila, 2001). In line with this goal, CRISS only allows users to tag individual route statements with landmarks from the landmark hierarchy.

The advantage of this type of tagging is that a normalized uniform landmark set is associated with the data, in this case, a route statement. As a result, the system ensures that multiple route statements containing phrases with different names or abbreviations for one landmark, e.g., "Computer Science", "CS Dept", "cs department", would all be tagged with a single,standard landmark tag, e.g., *COMPUTER SCIENCE DEPARTMENT.* Users can also tag a route statement with landmarks not explicitly mentioned in the route statement. For example, one user may add a route description with the following route statement: "Turn right when you detect the intersection with the main hall." Another user may choose to tag this route statement with the tag *WATER FOUNTAIN* since that user has found that performing the action in the route statement causes them to pass by a water fountain located at that particular hall intersection.

Tagging route statements with landmarks serves several purposes. First, a traveler, when exporting a route, can optionally choose to export the landmark tags along with the natural language route description. For users who have little knowledge of the area through which the route description will guide them, the extra description provided by the landmark tags will give a better idea of what to expect. Second, tags provide a uniform way of marking landmarks in natural language statements. Multiple landmarks, even those not explicitly mentioned, can be associated with a route. Another benefit is that computer algorithms can be developed to process the routes in terms of landmarks rather than in terms of natural language.

One example of route processing in terms of landmarks is path inference. Path inference is the process of inferring a new route description from existing route descriptions by determining where existing routes intersect. For example, suppose there is a route from A to B and another route from C to D. If the two routes share a common landmark E in the middle, then it may be possible to infer a new route from A to D by way of E. There are two reasons to add this support to CRISS. First, it will reduce the amount of data entry for users. If parts of route descriptions can be reused due to a path inference process, the amount of time users spend entering routes will be reduced. Second, new routes of which no user is yet aware may be discovered. According to Golledge's survey of how the disabled deal the geography (Golledge, 1993), the visually impaired understand the world in terms of routes but sometimes miss relationships between routes. CRISS, with path inference functionality, is intended to assist users in discovering the spatial relationships among routes.

3. ROUTE ANALYSIS ENGINE

Although users will be able to manually tag a route description with landmarks, we have been developing the Route Analysis Engine (RAE) to automate much of the tagging process. This process, called autotagging, uses information extraction techniques (IE) to process free text route descriptions written by users, first breaking each description into a list of route statements and then extracting landmarks explicitly mentioned in each route statement. RAE is intended to provide functionality to automate path inference. RAE is the intelligence behind CRISS with the overall goal of simplifying CRISS's user interface and reducing the amount of data user's need to enter.

Information Extraction and Landmark Autotagging

The route descriptions created by users are natural language texts. Although this is the preferred format for humans, natural language, or unstructured free text, is not handled efficiently by computers. Computers work better when data is presented in a structured format. One set of techniques which is used to extract information from unstructured text into structured formats is Information Extraction (IE) (Cowie & Lehnert, 1996). IE is one solution for automating the annotation of text and documents for use in the Semantic Web (Ciravegna

& Wilk, 2003; Popov, Kiryakov, Manov, Kirilov, Ognyanoff, & Goranov, 2003). Over time, IE techniques have been subdivided and classified into five subtasks of techniques as listed in Cunningham (2005):

- **Named entity recognition (NE):** Finds and classifies entities such as names, places, etc.
- **Co-reference resolution (CO):** Identifies identity relations between entities.
- **Template element construction (TE):** Adds descriptive information to NE results using CO.
- **Template relation construction (TR):** Finds relations between TE entities.
- **Scenario template production (ST):** Fits TE and TR results into specified event scenarios.

Because IE and its subtasks have been researched for over a decade, it is no longer necessary for the researcher or practitioner to implement the general techniques from scratch. There are now tools available that provide IE frameworks allowing developers and researchers to concentrate on developing IE tools for specific domains. One such framework is the General Architecture for Text Engineering (GATE) system from the University of Sheffield (Cunningham, Maynard, Bontcheva, & Tablan, 2002). GATE is a Java-based, general purpose natural language processing (NLP) system and includes various components for different types of NLP tasks. GATE contains an IE component called ANNIE (A Nearly-New IE system). In order to perform many of its tasks, ANNIE uses the pattern matching language Java Annotations Pattern Engine (JAPE) (Cunningham, et al., 2007) that allows an IE developer to write patterns, which, when run against natural language text, allow matching information to be extracted. JAPE is a written using Java and is based on the Common Pattern Specification Language (CPSL) (Appelt & Onyshkevyc, 1996), a language whose purpose was to replace structures like regular expressions or system-specific formalisms for performing IE with a common formalism capable of being used in many systems. A brief overview of ANNIE and JAPE is provided here. An interested reader should refer to Cunningham, et al. (2007) for complete details of GATE, ANNIE, and JAPE.

ANNIE consists of several processing resources (PR). Each PR is responsible for a specific IE task and typical ANNIE usage will chain the PRs together so that the output of one PR is fed into the next PR in the chain. The default ANNIE PRs are:

1. Tokenizer
2. Gazetteer
3. Sentence splitter
4. Part-of-speech (POS) tagger
5. NE Transducer
6. Orthomatcher

The tokenizer splits a natural language text into basic tokens such as numbers, words, and punctuation. After the tokenizer, the text is passed to the gazetteer. The gazetteer is used to find entities which are well-known and capable of being listed, for example, the names of all the employees in a company. After the gazetteer, the text is passed to the sentence splitter. As its name implies, the sentence splitter marks where sentences begin and end. Once the sentences are located, the text is passed to the POS tagger. The tagger assigns a part of speech to each token. Parts of speech include nouns, verbs, etc. Most parts of speech have been subdivided into more specific types for greater control. For example, a noun could be classified as a singular noun, a plural noun, a singular proper noun, or a plural proper noun. The text is then passed to the NE Transducer which is responsible for running JAPE rules which identify entities in the text. Finally, the text is passed to the orthomatcher which finds references in the text which refer to one another.

For example, if a piece of text includes the strings "George Bush" and "President Bush", these two strings should be marked as coreferences since they both refer to the same person.

One of RAE's primary responsibilities is to extract landmarks. Landmarks can be thought of as a type of entity that fall into two basic categories: known entities and unknown entities. Known entities consist of landmarks such as building names. Known entities that are not landmarks can be used to identify landmarks in the text. For example, if Vladimir Kulyukin is a professor at the university, then his name can be used to identify a landmark such as a room with phrases such as "Kulyukin's office." Unknown landmarks are landmarks which are not previously known and cannot be derived from a simple list.

Finding known entities is straightforward and maps directly into ANNIE's gazetteer task. A file is created listing each possible entity for a given type. When the IE task is run the text is annotated with the type of match. For example, if one gazetteer list contains building names and another lists employee names, then the sentence "Kulyukin's office is on the fourth floor of Old Main" is annotated with *employee:Kulyukin* and *building:Old Main*.

Extracting unknown entities requires more processing. ANNIE's NE Transducer is used to find and annotate more complex landmarks and unknown landmarks in the natural language route instructions. The transducer relies on rules written in the JAPE language. An interested reader is referred to Cunningham, et al. (2007) for complete details.

JAPE is a pattern matching language that uses regular expressions to match patterns found in natural language text. A JAPE rule consists of a left hand side (LHS) and a right hand side (RHS) separated by an arrow "-->" . The LHS consists of patterns to look for in the text and the RHS consists of statements which manipulate and create annotations. An annotation describes what a piece of extracted text represents, e.g., a building name or an employee's name. The LHS of a JAPE rule uses the regular expression operators to provide regular expression pattern mapping. These operators include an asterisk (*) for 0 or more matches, the plus sign (+) for 1 or more matches, a question mark (?) for 0 or 1 match, and the pipe symbol (|) representing an OR. Matches can be performed three ways by specifying a specific string of text, a previously assigned annotation, or a test on an annotation's attributes. JAPE also includes the ability to define macros which allow for common patterns to be used in multiple rules. The RHS of a JAPE rule is used to create annotations and manipulate the annotation's attributes. This can be done one of two ways. The simple method involves creating an annotation and then setting the available attributes and each attribute's value. Although sufficient in many cases, the JAPE syntax cannot handle complex annotation manipulations. For more complex manipulations, Java code may be used on the RHS.

Here we provide an example of JAPE rules used for landmark extraction. One type of indoor landmark that has been identified in a set of route descriptions collected from blind individuals is rooms. Rooms serve as starting locations and ending locations of routes as well as landmarks to be noticed while traveling routes. Therefore, rooms are a desirable landmark to extract from route directions. One pattern for identifying rooms that regularly appear in the texts we collected is the string "room" followed by a number, e.g., "room 405". In our department, we also have rooms in the form of a number, then a dash, and then a letter, e.g., "room 401-E". To extract this we first want to identify the string "room." A macro is a convenient way to do this:

```
Macro: ROOM
(
    {Token.string == "Room"} |
    {Token.string == "room"}
)
```

This a macro named *ROOM* which matches a *Token* with the *string* attribute equal to "room" or "Room". This macro can then used in a rule such as:

```
Rule: NumberedRoom
(
    ROOM
    {Token.kind == number}
    (
      {Token.string == "-"}
      {Token.orth == upperInitial,
           Token.length == "1"}
    )?
):numberedroom
-->
:numberedroom.Room =
 {rule="NumberedRoom", kind=room,
                        type=numbered}
```

This will match the string "room" or "Room," as defined in the macro ROOM, followed by a number. It will also match an optional dash followed by a upper case letter string of length one. Any text that matches this rule will cause an annotation named *Room* to be created with the attributes *rule*, *kind*, and *type*. The attribute names are not predefined by JAPE, but instead are defined and set by a knowledge engineer, allowing for domain dependent annotations and attributes.

Of course, there are other types of rooms in buildings. For example, the pattern of a person's name followed by the string "office" is common as in "Vladimir Kulyukin's office". The following JAPE rule can be used to detect this type of natural language pattern:

```
Rule: OfficeRoom
Priority: 10
(
    {Person}
    {Token.category == POS}
    {Token.string == "office"}
):officeroom
-->
:officeroom.Room = {rule="OfficeRoom",
kind=room,
                       type=office}
```

This rule matches any *Person*, found by a previously defined rule or gazetteer entry for matching a person's name. The person annotation must be followed by a token with the category *POS*, which identifies the possessive string "'s". Finally, the pattern ends with the string "office." When matched, a *Room* annotation is created with attributes *rule*, *kind*, and *type*. Although there are two annotation rules for *Room*, the annotation's attributes can be used to determine which rule caused which annotation to be created.

When run against the following natural language text:

Room 402 is to your right and room 401-F is to your left. Dr Kulyukin's office is next to room 402.

The previous JAPE rules would find and create the following four annotations:

- *Room {kind=room, rule=NumberedRoom, type=numbered}* for the text "Room 402"
- *Room {kind=room, rule=NumberedRoom, type=numbered}* for the text "room 401-F"
- *Room {kind=room, rule=OfficeRoom, type=office}* for the text "Dr Kulyukin's office"
- *Room {kind=room, rule=NumberedRoom, type=numbered}* for the text "room 402"

Although it is possible to automate rule development and entity extraction using machine learning techniques (Li, Bontcheva, & Cunningham, 2005), successful training requires a large training corpus. Currently, we have a small corpus of route directions (65 indoor route descriptions and 65 outdoor route descriptions). Thus, JAPE rules have been developed manually with the hope that, over time, as our corpus grows we may be able to investigate machine learning techniques for rule creation.

Landmark extraction and annotation via ANNIE's processes and the custom NE JAPE rules is the first step in RAE's landmark autotagging process. Once a route description's landmarks have been marked, RAE runs the second phase of the process that maps extracted landmarks to landmarks in CRISS's landmark hierarchy. The goal of the second phase is to match extracted landmarks to landmarks in the landmark hierarchy or to insert new landmarks into the hierarchy.

Some landmarks found in the route description are already present in the landmark hierarchy. There are two cases that RAE must handle when a landmark already exists in the hierarchy. In the first case, there is exactly one landmark in the landmark hierarchy that matches the extracted landmark. In this case, the appropriate route statement is simply tagged with the reference to the landmark in the landmark hierarchy. The second case arises when an extracted landmark matches multiple landmarks in the hierarchy. For example, most buildings have a FIRST FLOOR. In this case, RAE attempts to reduce heuristically the set of matches to find the most likely matching landmark. RAE accomplishes this by looking at the route description's starting landmark, ending landmark, and other landmarks extracted from the route description. If the starting landmarks and ending landmarks are limited to one building, for example, then RAE can make a reasonable

Figure 2. Example route description provided by a USU visually impaired student. The Quick Stop is a convenience store, and the Hub is the area where food is sold. Both are located in the USU's student center.

Start: `Quick Stop`

End: `Hub`

Description: `You are standing with your back to the south entrance to the Quick Stop. Turn left so you are walking east. On your left you will pass the ATM machines which make distinctive sounds, and the campus post office and mailbox. You will pass the entrance to the financial aid office on your right and several bulletin boards. Continue walking east and passing offices, the barber shop, and the copy center as you walk down this long hall. Towards the eastern end of the building, you will come to a wide open area on your left. Turn left and walk a little north. Pass Taco Time on your left, and look for a small opening on your lift. This opening will have a cashier counter on your right. Turn left and enter the world of the Hub. You will find a wide variety of food stations around a semicircle.`

assumption to limit its search in the hierarchy for landmarks within that same building. If the locations are limited to the same floor, the search is further constrained. Landmarks that are unknown and for which no exact matches can be found in the landmark hierarchy are inserted into the hierarchy at the most appropriate level possible. The insertion level heuristically determined using logic similar to the logic used for resolving multiple matches of known landmarks described above.

When the landmark hierarchy is sparse, landmark extraction is likely to be error prone: landmarks may be matched incorrectly and new landmarks may be inserted at incorrect positions in the landmark hierarchy. From the system's point of view, this is not a major issue since CRISS's users can resolve these problems by manual editing. After RAE's autotagging process is run, the user who submitted the route description is always given the opportunity to update or delete the landmark tags created by RAE as well as adding any extra landmark tags they may deem necessary. The result will be that over time the number of landmarks in the landmark hierarchy will grow causing RAE's performance for matching and inserting landmarks to improve.

As mentioned above, a route description is stored as a list of route statements. A route statement maps directly to the sentences created by ANNIE's sentence splitter. When the autotagging process is complete, each route statement is tagged with landmarks found during the extraction process. Since some route statements may not contain a landmark, a route statement can have zero or more tags. As an example of the input and output of the autotagging process, Figure 2 shows a natural language route description contributed by a visually impaired USU student, and Figure 3 shows a portion of the structure created when the description is run through RAE's autotagging process.

Path Inference

As more routes are entered, RAE continues to extract landmarks and tag route statements while users continue to refine route descriptions and the landmark hierarchy. Eventually, routes which intersect increasingly appear in the system. Because all route statements are tagged with the appropriate landmarks from the landmark hierarchy, RAE is able to use the structured metadata to perform path inference. Path inference, as mentioned earlier, is the process of determining that two route descriptions describe routes which intersect at a common landmark and then using this information to infer a third route description consisting of the first part of one route description and the second part of the other route description.

For example, suppose one user enters the following route description, route A, which describes how to get from the entrance of the Old Main building to the Library entrance:

Exit Old Main walking east. When you detect the grass, turn left facing north. Walk north for a few steps until you detect a sidewalk intersection on your right. Turn right, walking east. You will walk through the Quad, passing the intersection. Keep walking straight until you run into grass. Turn left, walking north. Walk until you detect the bike racks on your right and then turn right. Walk east until you find the library doors.

In the above description, the Quad refers to a large grassy area on the USU campus with two sidewalks, one running north/south and the other - east/west. The two sidewalks intersect in the middle of the Quad.

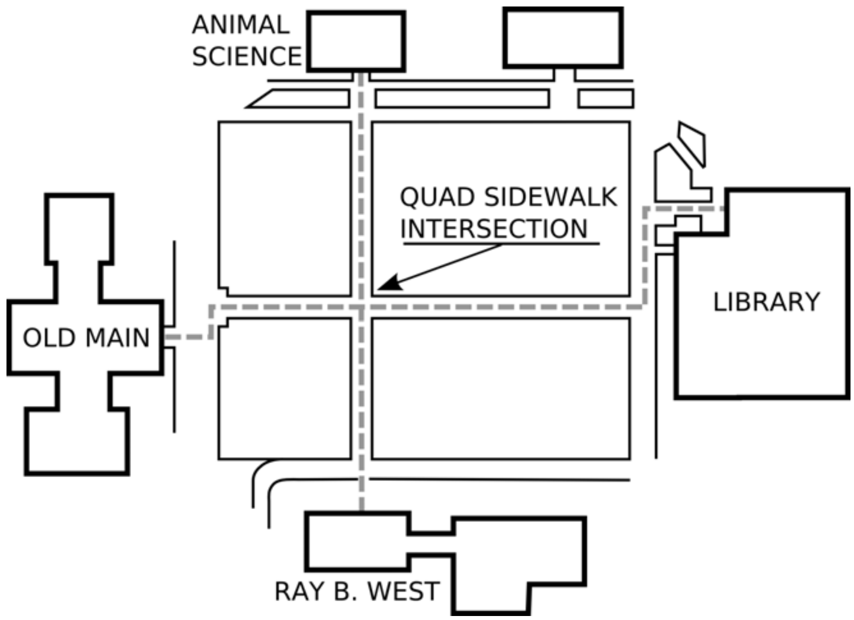
At a later date, another user enters a new route description, call it route B, that describes how to get from the entrance of the Animal Science building to the entrance of the Ray B. West building:

Exit the Animal Science building doors on the south side. Walk straight until you find the sidewalk entrance to the Quad's sidewalk. Walk

Figure 3. Partial example of a tagged route statement

```
<route>
   <route-id>R-35</route-id>
   <start>
     <landmark>
         <id>L-500</id><name>QUICK STOP</name>
     </landmark>
   </start>
   <end>
     <landmark>
         <id>L-789</id><name>HUB</name>
     </landmark>
   </end>
   <statements>
      <statement>
         <id>S-1</id>
         <description>
            You are standing with your back to
            the south entrance to the Quick Stop.
         </description>
         <tags>
            <landmark>
                 <id>L-501</id>
                 <name>SOUTH ENTRANCE</name>
            </landmark>
         </tags>
      </statement>
      <statement>
         <id>S-2</id>
         <description>
            Turn left so you are walking east.
         </description>
      </statement>
      <statement>
         <id>S-3</id>
         <description>
            On your left you will pass the
            ATM machines which make distinctive
            sounds, and the campus post office and
            mailbox.
         </description>
         <tags>
            <landmark>
                <id>L-550</id><name>ATM</name>
            </landmark>
            <landmark>
                <id>L-551</id><name>POST OFFICE</name>
            </landmark>
```

Figure 4. A map showing the intersection of two route descriptions



south until you detect a road. Carefully cross the street. Continue to walk south until you find the doors to the Ray B. West building.

As can be seen in the map in Figure 4, routes A and B intersect. These two routes are next broken into route statements and autotagged by RAE. Let us assume, for the sake of simplicity, that the tagged route descriptions have been approved and modified as necessary by the users who entered the route descriptions.

Route A contains the route statement *You will walk through the Quad, passing the intersection*. This statement is tagged with the landmark QUAD SIDEWALK INTERSECTION. Route B contains the route statement *Walk south until you detect a road*. This statement is tagged with the landmark QUAD SIDEWALK INTERSECTION because, even though it is not explicitly mentioned, performing the action in this route statement causes a traveler to pass though the sidewalk intersection. Because both routes A and B contain route statements sharing a common landmark, a new route description is inferred to guide the user from the entrance of the Old Main building to the entrance of the Ray B. West building. The new route description contains route statements from the first part of route A, taking the traveler from the entrance of Old Main to the center of the quad. The second half of the route description consists of the route statements from route B which take the traveler along the southbound sidewalk of the quad to Ray B. West. The new route description built by RAE would be:

Exit Old Main walking east. When you detect the grass, turn left facing north. Walk north for a few steps until you detect a sidewalk intersection on your right. Turn right, walking east. You will walk through the Quad, passing the intersection.

Walk south until you detect a road. Carefully cross the street. Continue to walk south until you find the doors to the Ray B. West building.

CRISS makes no guarantees as to the understandability of the new route description. As explained below, it performs a digraph-based inference algorithm to build the new route description. Before the new route description is available to all users, it must be *admitted* into the system, i.e., checked by a user familiar with the area to ensure that the description is both understandable and can be used to safely guide a person. In this case, the user, for example, may delete the "passing the intersection" phrase and add a turn directive to ensure that someone who is following the route would make the necessary turn at the sidewalk intersection:

Exit Old Main walking east. When you detect the grass, turn left facing north. Walk north for a few steps until you detect a sidewalk intersection on your right. Turn right, walking east. You will walk through the Quad.

Turn south when you detect the sidewalk intersection in the middle of the quad.

Walk south until you detect a road. Carefully cross the street. Continue to walk south until you find the doors to the Ray B. West building.

The landmark tags associated with the old routes will continue to be used in the route statements in the new route description. This preserves both the landmark tags created thorough RAE's autotagging process as well as user created landmark tags.

In more formal terms, the path inference process is accomplished through a transformation of the tagged route statements into a single, directed graph. The digraph consists of two types of nodes, statement nodes and landmark nodes, and all edges are directed edges. During the transformation, every route description in CRISS's collection is added to the digraph through a process which maps every route statement and its associated landmark tags to nodes and edges of the digraph. The graph is a directed graph because there is no guarantee that the same landmarks and statements would be used when describing a route from A to B as when describing a route from B to A.

Each route statement is represented by a statement node. A route statement that does not have a landmark tag associated with it is connected by an edge to the next statement node in the graph. This connection represents a *precedence* relationship between the two route statements signifying that the action in a route statement cannot be performed before the actions in the preceding route statements are performed. If a route statement has been associated with one or more landmarks, each landmark is represented in the digraph by a landmark node. The statement node and its landmark nodes are connected by edges representing an *association* relationship signifying that the route statement was tagged with the landmarks. A precedence edge from the landmark node then connects the landmark node to the next statement node in the description. This

Figure 5. The partial result of converting the tagged route in Figure 3 into a digraph

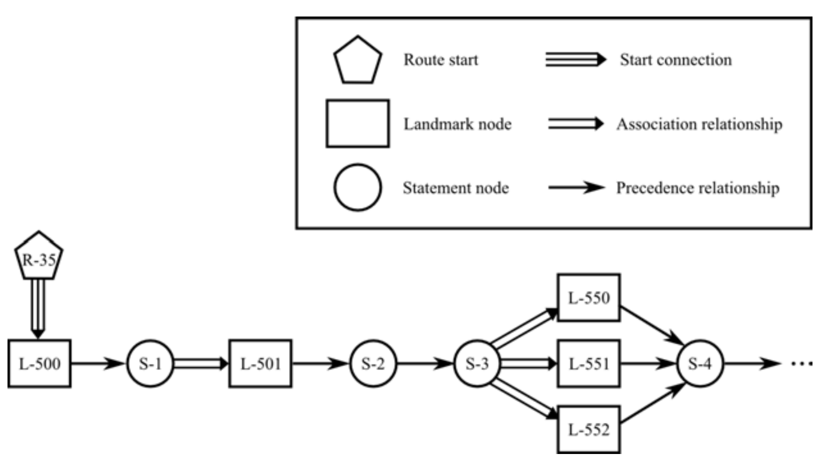
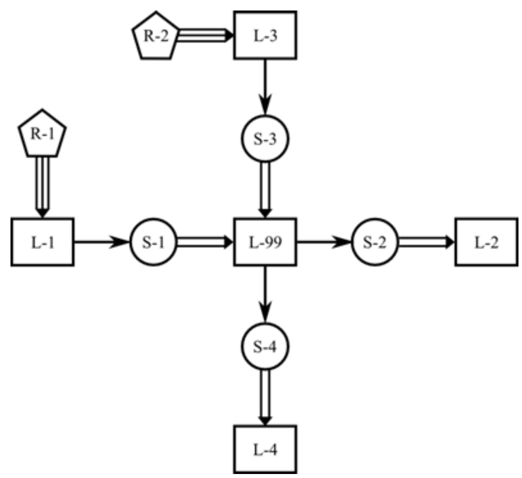


Figure 6. Two route descriptions intersecting. Route description R-1 starts at landmark L-1 and ends at L-2. Route description R-2 starts at L-3 and ends at L-4. The statements S-1 and S-3 are both associated with landmark L-99. Because of this common landmark, a new route description can be inferred starting at L-3 and ending at L-2. The new route description would consist of statements S-3 and S-2.



connection continues to signify the ordering of the route statements in a route description even when route statements have been tagged. Figure 5 shows the example autotagged route from Figure 3 converted into a digraph.

Route intersections are defined in terms of graph algorithms with route description intersecting at the landmark nodes of the digraphs. Figure 6 shows two route descriptions, R-1 and R-2, intersecting and explains how another route descriptions can be inferred from this intersection. When a new route is found in the digraph representation, it must be transformed back into the route structure. To build the new route description, the route statements nodes along the new path will be collected into the new natural language description. This is the level of functionality which RAE provides when inferring a new route description. As mentioned before, the new route description will need to be vetted by users to ensure the route description's clarity and that the new route can be followed safely.

Because many paths may be found between two nodes when inferring a new route, RAE applies heuristics during its search in order to score each route description according to its expected usefulness. Examples of potential heuristics include:

- Preferring new route descriptions that merge fewer older route descriptions. For example, a route description built from two exiting descriptions would be preferred over a route that was built from four existing descriptions.
- Preferring new routes with fewer statements. More statements may signal more complicated routes. Since routes with more segments or actions are harder for the visually impaired to follow and remember (Golledge, 1993), shorter and simpler route descriptions would be preferred.
- Preferring new routes with landmarks that share common parent landmarks in the landmark hierarchy. For example, if the starting and ending landmarks are within the same building, new routes which stay inside the building would be preferred over those which leave the building and then return.

The advantage of the path inference process is that new routes will be added to CRISS at a faster rate. Users will be able to quickly combine existing routes without having to rewrite and re-(NE) common segments of routes. The other advantage of this process is that new routes which no user is currently aware may be discovered, enriching every traveler's spatial knowledge of the area.

4. RELATED WORK

Many navigation aids using various technologies have been and continue to be developed for people who are visually impaired. Technologies are typically divided between indoor and outdoor applications. For outdoors navigation, GPS is the most common technology used due to its ubiquitousness; its primary disadvantage is that it cannot work indoors. Sendero GPS (Sendero, 2008) and Trekker (HumanWare, 2008) are both commercial GPS products specifically designed for independent navigators with visual impairments. Drishti (Ran, Helal, & Moore 2004), an indoor and outdoor navigation system for the blind, uses GPS for its outdoor navigation guidance.

For indoor wayfinding, the selection of technologies is much greater. For indoor environments, Drishti integrated an ultrasonic localization system from the Australian company Hexamite (http://www.hexamite.com). Talking Lights (2008) works with existing light fixtures, modulating lights at different frequencies to enable data transmission, has been used to encode route descriptions to aid in wayfinding within buildings (Leeb, et al., 2000). Talking Signs (Crandall, Bentzen, Myers, & Brabyn, 2001) places infrared transmitters in the environment and then the user carries a receiver. The RadioVirgilio / SesamoNet (D'Atri, Medaglia, Serbanati, & Ceipidor, 2007) places a matrix of small, cheap, passive RFID tags in a carpet and then a user carries a cane with an RFID reader embedded in the tip. Wi-Fi has been used in systems such as the one mentioned in Hub, Diepstraten, and Ertl (2005) in which the received signal strength from standard Wi-Fi access points is measured and then used to localize the user to a point inside a building. Coughlan, Manduchi, and Shen (2006) attach simple, colorful signs with large barcodes to indoor locations and then use computer vision applications running on a cell phone to locate the signs and guide the navigator.

Some navigation tools provide mechanisms which allow users to share navigation and localization data. For example, Loadstone GPS (Loadstone GPS, 2008) is a GPS-based, open source, navigation tool for cell phones. The developers also maintain the Website Loadstone PointShare (http://www.csy.ca/~shane/gps) which allows users to upload the name, latitude, and longitude of new points of interest, as well as download data previously uploaded by other users. Wayfinder Access (Wayfinder, 2008) is a commercial GPS cellphone product which provides text-to-speech navigation for the visually impaired. An extra feature of Wayfinder Access is that it provides access to the website MyWayfinder (http://eu.mywayfinder.com/index.us.php) which allows users to download and share trips, routes, and destinations. Sendero GPS (Sendero, 2008) also allows users to share waypoints through the Sendero website.

Research methods for extracting and evaluating landmarks mentioned in texts has taken various approaches. Loos and Biemann (2007) extract address information for places like restaurants, cinemas and shops from Google query result sets. Instead, of building IE patterns by hand, they use a manually tagged set of sample pages to train their system using a Conditional Random Field algorithm. Another group (Tokuda, et al., 1999) extracted Japanese style addresses from Web pages. They created a dictionary of terms related to addresses from the Japanese Ministry of Postal Services. Addresses from Web pages were extracted when chunks in Web pages contained terms in the dictionary and matched address pattern expressions. Winter and Tomko (2006) extract information about Australian addresses from Web pages and then use this information to find more detailed information about each address from another layer of Web searches, extracting information such as place names, location descriptions. Manov, et al. (2003) bootstrap the IE task of extracting geographic locations using a knowledge base of location data. The InfoXtract system (Li, Srihari, Niu, & Li, 2003) addresses resolving ambiguity in city names found during information extraction, addressing such situation as where there are 23 cities in the United States with the name Buffalo. Silva, Martinsa, Chavesa, Afonsoa, and Cardosoa (2006) developed a NE system specifically addressing multilingual geographic extraction Webpages. The system also includes a disambiguation step which attempts to resolve possible conflicts. In all cases, these systems focus on extracting much larger landmarks than those that RAE extracts.

Other systems have also developed methods for autotagging various pieces of text. AutoTag (Mishne, 2006) suggest tags for blog posts based on tags found in similar blog postings. Fujimura, Fujimura, and Okuda (2007) describe a k-nearest neighbor approach to recommending tags for blog entries. Brooks and Montanez (2006) extract the three words with the top TDIDF (term frequency, inverse document frequency) score in blog entries; the top three words become the document's autotags. Although extracted automatically, the tags generated by these system are similar to Flickr and YouTube type tags in that no structure is imposed on the tags. The lack of structure in the tag names would not meet CRISS's needs.

5. CONCLUSION

We hope that CRISS will be a useful tool for assisting independent visually impaired navigators in learning unfamiliar areas and routes within those areas. It will encourage groups of experienced travelers to document their spatial knowledge by building large, route-based maps. Because the people writing the route descriptions will be members of the target user group, the route descriptions will be written in a manner which is appropriate for other travelers with the same visual impairments.

In order to both simplify the user interface and give additional route analysis capability to the system, CRISS contains the intelligent component RAE which takes advantage of information extraction technologies that have been developed over the last decade. As a result, RAE is able to perform the tasks of autotagging of route descriptions, automatically extracting important navigation landmarks from natural language route descriptions. Users can provide additional tags as well further enhancing the data available in the descriptions. The tags provide additional information to users about landmarks, in particular consistent names and descriptions. The landmark tags also enable RAE to automatically locate and create new route descriptions via the path inference process.

One advantage of CRISS is that it does not replace existing navigation and wayfinding tools, but complements them. CRISS is designed to not only guide travelers and build maps targeted towards people who have visual impairments but also to help provide a better understanding of the types of route directions used and needed by travelers with visual impairments. With a better understanding of route descriptions produced by the people with visual impairments, all navigation assistance tools will be improved.

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KEY TERMS AND DEFINITIONS

Autotagging: The process of using a computer to automatically determine which tags should be associated with a piece of data.

Information Extraction (IE): A technology for extracting structured information from unstructured and natural language text.

Java Annotation Patterns Engine (JAPE): A pattern matching language in which regular expression-type patterns are used to process natural language text, allow matching information to be extracted and then used in more structured formats.

Named Entity (NE) Recognition: A subtask of information extraction which is focused on finding and classifying entities such as names and addresses.

Path Inference: The process of building a new and valid, yet previously unknown, route description from two or more known route descriptions that intersect when followed. The new route description begins at a landmark in one of the known route descriptions and ends at a landmark in another route description.

Route Description: A natural language description of how to follow a route including details such as decision points and landmark descriptions.

Spatial Semantic Hierarchy (SSH): A model of knowledge of large-scale space inspired by the human cognitive map.

Tag: A piece of metadata associated with a larger piece of data.

Volunteered Geographic Information (VGI): Spatial data, tools, and Websites provided by volunteers rather than geographic information system companies and professionals.

Section IV
Applications and Current Developments

Chapter XXXVI
Modeling Objects of Industrial Applications

Lenka Landryová
VŠB – Technical University Ostrava, Czech Republic

Marek Babiuch
VŠB – Technical University Ostrava, Czech Republic

ABSTRACT

This chapter presents the development and design of an industrial application based on new technologies and explores the technological dimension of data acquisition, storing, access, and use; the data structure and integration and aggregating values from data necessary for the control of production processes. The demo application presented here was designed according to the Enterprise-Control System Integration Standard (ISA-95) with the goal of maintaining a standard that defines the interface between control functions and other enterprise management and business functions. The component-based object-oriented development concept was implemented in order to utilize advantages provided by creating a complete plant equipment model. The value of semantics was rediscovered in applications, which communicate among their system modules on Simple Object Access Protocol (SOAP), the standard defined by W3C, whose initiative has provided standard semantics markup languages based on XML as well. The data format and the format of standard XML messages that are used in industrial applications are defined by Business To Manufacturing Markup Language (B2MML) as W3C XML Schema for implementation of ISA-95, while offering the framework for project integration, the separation of business processes from manufacturing processes and focusing on functions instead of systems, organizations or individuals themselves.

INTRODUCTION

Each production is organized in hierarchical levels and for its control and management uses control and information systems. Enterprises name their departments, activities and production functions differently. Communicated information varies depending on every company and its implemented control systems. Even within one company the terminology used for control systems and for management may vary, it is, however, very necessary to be able to communicate efficiently.

The progress and development of new technologies enable the information flow and make it more sophisticated and even easier. Interfaces between enterprise and production systems make important information accessible at the requested time and in a proper place to the appointed competent person. This is possible because of the tools, environments and standards introduced into the design and development of processes, which will be further described.

BACKGROUND: THE TECHNOLOGY WHICH IS HERE FOR US TO BE USED

XML Documents and Their Components

XML is the technology available here for us for sharing information easily based on a format of documents designed for reading over the Internet. XML is made for everybody and to be used by everybody and for almost anything by being easy to understand, easy to use, and easy to implement (Ortiz, 2002). This is one of the many reasons why it has become the universal standard and has faced and met the challenges of convincing us - the development and user community.

When the creators of XML were working out their design, their goals set for an XML document, among others factors, were defined by directions as to how XML is to be used:

- XML documents shall be easy to create, legible to read and reasonably clear, it should be easy to write programs that process XML documents,
- XML design should be prepared quickly, it should also be formal and concise,
- XML shall be straightforwardly usable over the Internet,
- XML shall support a variety of applications.

As referred to sources (Ortiz, 2002), XML offers a simple solution to a complex problem, a standard format for structuring data or information in a self-defined document format. This way, the data can be independent of the processes that will consume the data. But this concept behind XML is not new. It is a subset of a huge amount of specifications and conditions declared and developed by the World Wide Web Consortium (W3C) in 1986. The W3C began to develop the standard for XML in 1996. Since then, many software vendors have implemented various features of XML technologies.

An XML document contains a variety of constructs, also referred to as *elements*. Some of the frequently used ones include:

- **Declaration:** Each XML document can have the optional entry <?xml version="1.0"?>. This standard entry is used to identify the document as an XML document conforming to the W3C recommendation for version 1.0.
- **Comment:** An XML document can contain HTML-style comments such as <!--Equipment data -->.
- **Schema or Document Type Definition (DTD):** In certain situations, a schema or DTD might precede the XML document. A schema or DTD contains the rules about

the elements of the document. For example, we can specify a rule like “An equipment element must have EquipmentName, but AliasName is optional.” .NET uses these schemas exclusively.

- **Elements:** An XML document is mostly comprised of elements. An element has a start-tag and an end-tag, for example *Equipment Requirement*. In between the start-tag and end-tag, we include the content of the element. An element might contain a piece of data, or it might contain other elements, such as EQUIPMENT. For example:

```
<Equipment Requirement>
  <Property List/>
  &lt;Segment Requirement&gt;
    <EQUIPMENT>
       <Property List/>
    </EQUIPMENT>
  &lt;/Segment Requirement&gt;
</Equipment Requirement>
```

- **Root element:** In an XML document, one single main element must contain all other elements inside it. This specific element is often called the *root element.*
- **Attributes:** Since an element can contain other elements or data or both, an element can also contain zero or more so-called attributes. An attribute is just an additional way to attach a piece of data to an element. An attribute is always placed inside the start-tag of an element, and we specify its value using the “name=value” pair protocol. For example: *<RollMill_Diameter ID=”3501” EquipmentName=”RM_Diameter” Alias=”RM_Diameter” Description=”Roll Diameter” />*

There is a more complete list of XML’s constructs at www.w3c.org/xml.

In an XML document, the data are stored in a hierarchical structure. This hierarchy is also referred to as a data structures tree. That suits very well to the purpose of using it by system clients in our system architectures (Babiuch, 2007).

Available Tools to Create XML Documents

When XML has emerged as the web standard for representing and sending data over the Internet, the W3C worked out and established a series of standards for XML and related technologies, including XPath, XSL, and XML schemas. VS.NET provides a number of tools to work on XML documents (Viscom .NET Team, 2007):

- XPath is a query language for XML documents. XPath queries are executed on data items. Search results are returned as a list of items. Each XPath expression may specify both the location and a pattern to match. Boolean operators, string functions, and/or arithmetic operators can be applied to XPath expressions in order to build quite complex queries against an XML document. Furthermore, XPath provides functions to evaluate numeric expressions such as summations and rounding. The full W3C XPath specification can be found at www.w3.org/TR/xpath (Ortiz, 2002).
- XSL translates XML documents from one format to another. The *Extensible Stylesheet Language Transformation* (XSLT) is the transformation component of the XSL specification by the W3C (www.w3.org/Style/XSL). It is basically a template-based declarative language that can be used to transform an XML document to another XML document or to other types of documents, for example HTML and/or text. Various XSLT templates can be developed and applied to select, filter, and process various parts of an XML document.
- XML schemas define the structure and data types of the nodes in an XML document,

such as the 95 Equipment XML Schema, and other schemas developed and available from the (World Batch Forum, 2003).

These technologies are industry standards backed up by the W3C. All of these standards were taken and packaged into the .NET architecture which we are working with now.

Industrial Standard ISA-95 and Models Description

ISA-95 is the international standard for integration of control systems into management systems. It was written for common production environments and can be applied to any industrial area and for continuous, discrete and/or batch type of processes. The main objective was to create a framework for a project integration, to help to separate business processes from production, and to focus on production functions instead of functions of organizations or individuals.

ISA-95 standard divides companies from the control point of view into five levels, Level 0 – Level 4:

- Levels 0, 1, 2 – are process control levels, whose objective is equipment and process control (equipment, tools, units, cells) so that the production process is performed and a product is produced.
- Level 3 – is the MES (Manufacturing Execution System) control level. It consists of several activities, which must be performed for production preparation, monitoring and completion executed at lower levels of a plant, for example detailed planning, scheduling, maintenance and production monitoring.
- Level 4 – is the top control level. Systems at this level are the Enterprise Resource Planning systems (ERP). Logistics and financial issues and activities of a plant, which correlate with production directly or indirectly, are carried over, for example long term planning, marketing, sale, and supply.

Standard ISA-95 consists of five main parts:

- Describes terminology and object models.
- Deals with object attributes.
- Focuses on functionalities and activities of higher control levels.
- Deals with object models and attributes of production operation management.
- Describes transactions between sales and production.

We will describe ISA-95 standard implementation and the use of definitions for the Level 3 – MES. Furthermore, we will focus on object modeling for the component-based development of an application for a rolling mill supervisory control and visualization.

ISA-95 Standard Implementation

ISA-95 standard implementation provides models and information in multiple levels of detail and abstraction. Each model increases the level of detail defined in the previous model, however, they all come from the ISA-95 major object model, which is structured into:

- The basic resources models – such as equipment and material used in a process;
- A model for a product definition and product production rules, such as the business view of production on how to make a product and what is needed to make a product.

Definition of an Object Model

An object model can be described in ISA-95 standard by the relationship of 95.01 and 95.02 parts of the standard:

- ISA-95.01 defines object models

- ISA-95.02 describes attributes for the object models

An example of such a definition is demonstrated for models of equipment and equipment class in Figure 1, Figure 2, and Table 1.

Object-Based Modeling and Development of an Industrial Application

Software environments based on .NET platform have brought a new approach to SCADA/HMI

Figure 1. Definition of the equipment model and its attributes

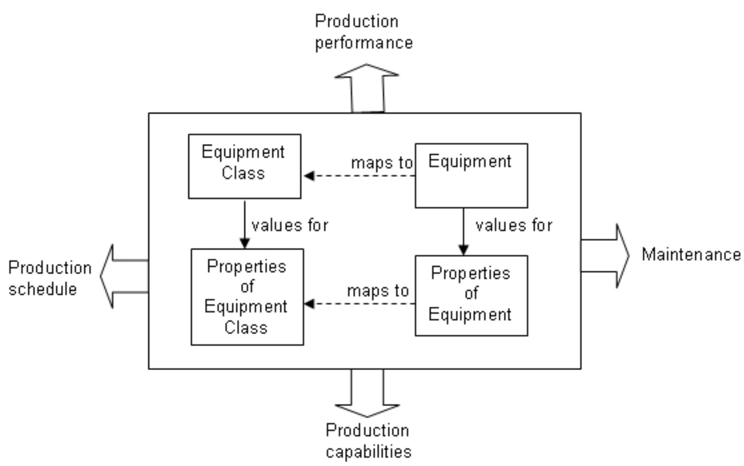


Figure 2. Equipment and equipment class

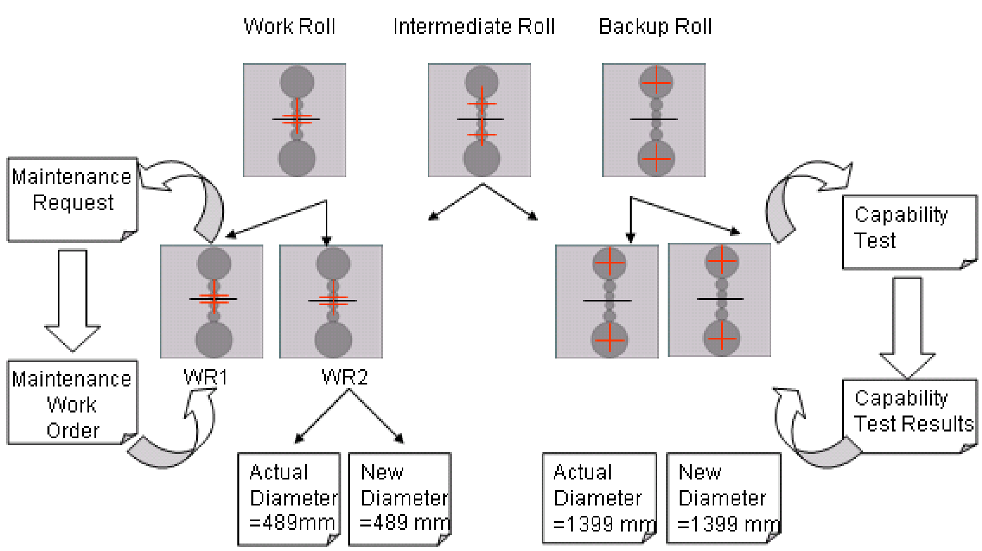


Table 1. Definition of the equipment attributes

Attribute	Description of an attribute	Examples
ID	A unique identification of a piece of equipment within the information exchanged	• Motor 101 • Rolls WR 2 • Coil C1003 • Panel 1
Description	Additional information about the equipment	• a power unit ensuring movement of rolls and a coil together with material • all rolls (work, intermediate, backup,…) appearing in a rolling mill and their hydraulics • produced material through the rolling process • represents the control and supervisory panel
Run	Boolean, direction of rotation, operated by the end-user-supervisor.	Run of a motor
Diameter	Analogue real value, actual or newly set by a supervisor	Diameter for roll
Bent	Analogue real value, bent of working rolls in axes against the strip, operated by a supervisor	Work roll bent

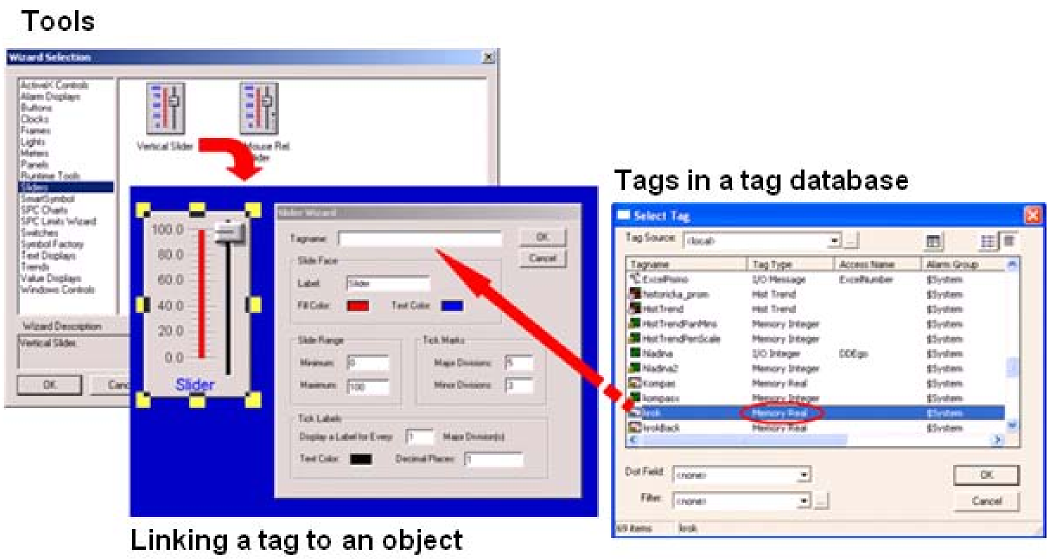
(Supervisory Control and Data Acquisition/ Human Machine Interface) and MES application development enabling developers the use of *development screens* and end-users the use of the *runtime screens* to create and run an application for a complete plant model. The developers are able to concentrate on modeling how the production facility is designed and the end users are dealing with plant-wide supervisory control of processes which comprise the various manufacturing units and cells. After the plant model is ready, supervisory control functions (Landryova, 2004) can be implemented.

Tag- vs. Component-Based Development

A *development environment* of SCADA/HMI software has functions required for creating animations and touch sensitive objects displayed on runtime application screens (Zolotová, I. 2004). In this *development environment* the tools are available for introducing logics through common graphics containing scripts, and for monitoring the alarm states of variables and their trends with the help of created tags and their database, see Figure 3. This *tag database* connects each application screen directly to industrial controllers, I/O systems or other MS Windows applications while switching the tags in *runtime*. However, each change in the database or change of a tag in the system must be analyzed for the effects on the rest of the application.

In SCADA/HMI applications developed with a component-based concept, the application objects contain attributes or parameters, which are directly associated with equipment they are representing. For example, a work roll or a motor object contains its own event triggers, alarm message and alarm limit definitions, access rights and security attributes, other communications and scripting associated with the equipment. The concept of a component-based object-oriented development enables us to select objects already defined in software or to define our own *template* for a new object, see Figure 4. Then the object's properties are shared and used with their attributes in efficient ways releasing the developers from

Figure 3. An object being defined in a tag based development environment



repetitive programming tasks and, at the same time, making use of parent-child relationships, re-application and change propagation features throughout the development of an application.

Creating Object Templates

As mentioned before, manufacturing operation or a process consists of resources, such as equipment, energy, and material used for production. These can represent the physical model view of a production and can be further developed as individual models, while similar equipment or material item properties can be shared, inherited, and defined into one of their classes.

The shared properties then may be defined for one template, on which the modeled object will be built in a *development environment* for the application. The model created in the *development environment* of one computer is then deployed to all computers that will work with the application (Garbrecht, 2006).

Configurable Objects

Each device or a component of the modeled production system is then configurable by the *object template* it has been derived from. The configuration process complies with the standards set for each supervisory application and for any future application as well. Once the application is developed, system maintenance is easy. Changes made to object templates during configuration are then being propagated to their child objects (Landryova, Osadnik, 2008).

The configurable attributes of an *object template* are represented with real I/O variables available in the PLC or a control system, linked to the I/O through device-integration objects.

Components of a system, which were modeled in an application, are assigned to groups according to their security rights as well. The application is visualized in the SCADA/HMI software, see Figure 5.

Figure 4. An object being defined in a component-based development environment

Rolling_Mill

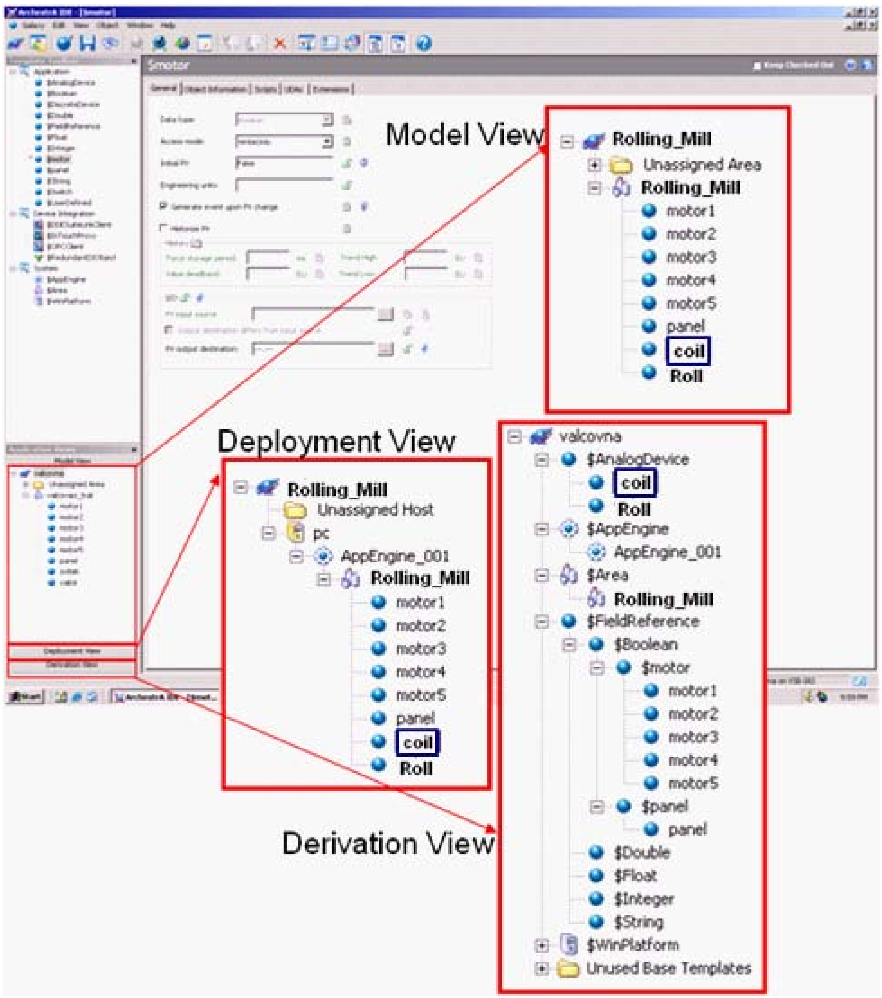
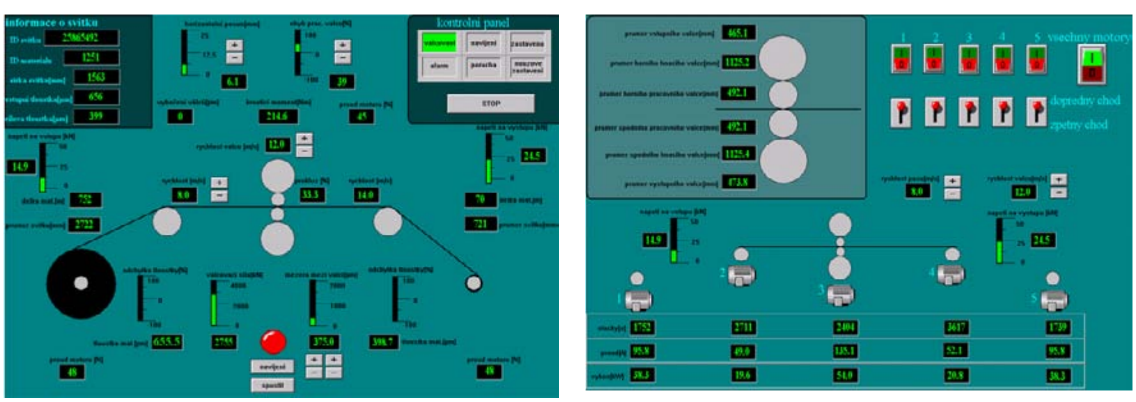


Figure 5. Runtime screens of the supervisory control system application using object model



Event Notifications and Messages on Runtime Screens

Industrial applications collect huge amounts of data, which is required by more and more users at different levels of production or administration (Levine, 1996). Some of these users need effective means that are easy to operate in order to monitor and control processes. Others do not require data continuously, but are interested in data summaries, production results, the quality and history of data. These users only need simple interfaces to access, inspect and analyze the data, such as *internet browsers.* The internet has changed communication within control systems into an interactive and graphically very powerful tool, which is now closer to visualization systems than that of the *human-machine interface* category, because it is able to bring data to the end users. Data is transferred between web clients and servers, where the client is the computer requesting documents, and the server is a computer that is able to send them, because it is equipped with specific software. In the case the server sends files written in some of the standard supported formats, like HTML or XML, the client only needs a browser to view them, and is then called a *thin client.* The web server is able to send data in other formats as well, but the client then needs specific software, in order to be able to read, process and display the data. In such case the client is called a *fat client.*

Browser-Based Interface

Industries require the capability to handle events and display them to the end-users, supervisors, with the help of control system's *thin-clients.* Messages are defined for data being updated in the background of a manufacturing process. But the HTML protocol is *request-response based.* The *thin-client* browser must trigger "a new page" request. There is no default mechanism for event notifications without a trigger. So, the behavior of *browser-based* user interfaces of *thin-client* applications is that they can not automatically react to external events.

Services provided via web service interface allow industrial applications to access available data from the process. Web services here represent a layer between an industrial application and a *thin client.* They are the interface to the industrial application (API) developed according to a concept based on standard internet technologies (Avery J. (2004), Babiuch, M.2004).

Simple Object Access Protocol (SOAP) used for this communication refers to the XML-based, extensible message envelope format enabling message transfer. SOAP consists of an *envelope*, a set of rule codes, and convention for *remote procedure calls* (RPC).

Web Service Description Language (WSDL) refers to the XML format allowing service interfaces to be described. WSDL file with service interface definition is an XML document using interface methods and their parameters.

Event Notification Services

Event notification is a type of service, which provides the mechanism to dispatch events to one or several supervisory stations. Events can be generated within the industrial application through:

Business logic (BL) executed in an application server (AS), which provides services such as data consolidation, user authorization, client data access and scheduled report generation. The services are implemented as a set of objects and server processes.

Custom scripting written in computer language, such as C#. The scripting environment provides an application programming interface (API) (Turtschi, Werry, Hack, Albahari, Nandu, Lee, 2003).

By communication with external applications.

The requests for data update can be generated by different event sources:

- Messages are the input for updating requests data, which can be generated upon, for example, a manual data correction by the end-user, supervisor.
- The communication between the different tiers of a system may also be based on the asynchronous publish-subscribe message pattern.
- The messages must include a topic. The receivers subscribe only for the topics they are interested in. The sender then publishes these messages.

Presenting Runtime Information

With the legacy GUI and information technology, meanings and relationships are predefined and written into data formats and the application program code during their development phase. This means that when two programs need to interact in a new way or when something changes during runtime and previously not communicated information needs to be exchanged, the developers are back to their work and must get involved. Then off-line, they must define and communicate the knowledge needed to make the change, recode the data structures and program logic to accommodate it, then apply these changes to the database and the application. And then, the end-users can implement the changes into a process (Lee, 2004).

It is possible now to modify the display presentation of some GUI controls based on runtime information. We are now working in environments and with software, which encodes meanings separately from data and content files, and separately from the application code. This enables end-users, operators to understand the runtime screens, share knowledge and reason experience at execution time. With this type of software, adding, changing and implementing new relationships or interconnecting programs in a different way can be done as simply as changing and deploying the external model that these programs share. This gives the end-users the required flexibility in data manipulation before display in the GUI (Landryova, Valas, & Winkler, 2008).

To see the idea and how it works, simple examples will be presented, such as style modifications of text and numerical messages depending on runtime information presented to end-users and operators on runtime screen panels, and the manual entry fields requiring supervision of operators when entering set points and command, and data format changes made independently from the required database data type.

Scripting for Runtime Screens

Using XPath expressions (previously described in the section *Available tools to create XML documents*), simple calculations can be made in a runtime software environment. Therefore, the read-only types of properties whose values come from an associated calculation and not from the database are allowed and the calculation is configurable for runtime screens. The property, whose value is calculated, is then associated to an object. The object may, for example, change the color of

Figure 6. Alarm and event display in the supervisory control system application

Event Time	Object Na	Object Description	Condition	Message Description
21/09/07 12:05:42:675	Presetting	Presetting 6 High	CoilIDAlarm	Error sending telegram CoilID to level 2
21/09/07 12:05:42:675	Presetting	Presetting 6 High	L1AliveAlarm	Error sending telegram L1Alive to level 2
21/09/07 12:05:42:675	Presetting	Presetting 6 High	StandStillAlarm	Error sending telegram StandStill to level 2

Figure 7. Information and manual entry fields presented to the end-users on a legacy runtime screen panel

Figure 8. Conditions for displays required by the end-user and the result from XPath implications on displayed values

<Format Condition>
Low pressure $\geq$ 300 display field: red
High pressure < 700 display row: orange

Media	Low Pressure	High Pressure
Hydraulics	100	600
Gear	200	800
Rolling Oil Pumps	300	1000

its displayed background or of a text linked to it depending on some condition of its properties defined from specifications of the end-user.

Figure 8 shows such an example. In a runtime screen monitoring a production process, if the value of the monitored property *low pressure* is larger or equal than a limit set by a manual entry, the background of one display field goes red, or if the value of the property *high pressure* is lower than a limit set, the entire display row's background goes orange. The monitored properties become a part of the XML document of the object and are available for other runtime screen displays, for other scripting, and for a web service and publishing or copying data to periodical history.

Some issues coming from such end-user requirements, however, must be dealt with. For example, the value of a property can be set as the result of a calculation by scripting, but it must also be saved in a property database. The calculations are done only when the property's value is accessed by the end-user. It is also a good idea to set a time-out for all scripting, if a calculation script is hanging in an infinite loop and has to be stopped. The calculation itself may have to throw out an exception, if it cannot be done, so the problem can be logged and presented in order to notify the end-user, and similar cases.

Table 2 describes the idea behind the runtime data manipulation by the end-user, if it is more

Table 2. Flexibility given to the end-user for a comfortable data manipulation during process runtime

<table>
<tr><th>Describing the runtime manipulation step</th><th>Result in the runtime environment</th></tr>
<tr><td>There is a “numeric” data type set in a database for the *Priority* property of a displayed object:</td><td>Priority
3
3
2
1
4
4</td></tr>
<tr><td>The scripting code can change the displayed data type from “numeric” to “text”, for example, if the end-user prefers semantic information to figures:</td><td><pre>
// define user readable texts
string[] texts = new string[]{"Not Set", "Low", "Medium", "High", "Urgent"};

if ((data.Value == null) || (data.Value.ToString().Length < 1))
{
formater.EncodedValue = texts[0];
}
else
{
// preset to 'Not Set'
formater.EncodedValue = texts[0];
int prio = 0;
if (int.TryParse(data.Value.ToString(), out prio) && (prio >= 1) && (prio <= 4))
formater.EncodedValue = texts[prio];
}

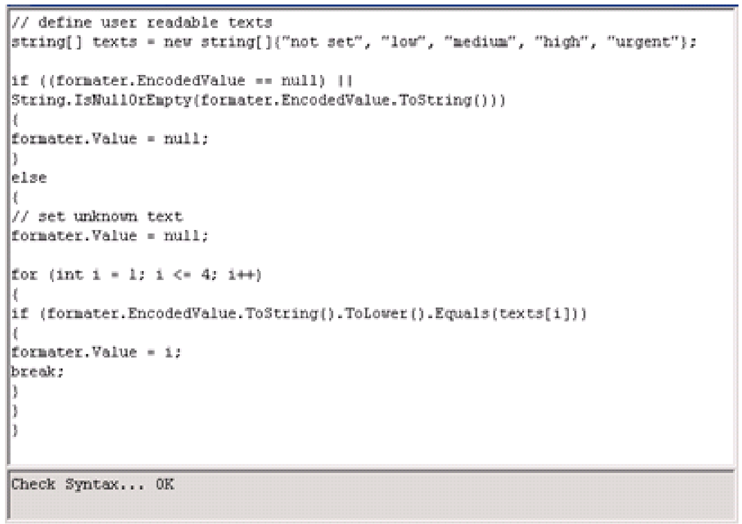
Check Syntax... OK
</pre></td></tr>
<tr><td>The result after applying scripting for changing data type from “numeric” to “text” is:</td><td>Priority
High
High
Medium
Low
Urgent
Urgent</td></tr>
</table>

comfortable to work with a different data type than was defined for a database.

FUTURE TRENDS

Industrial automation in process industries has increased its significance in recent years. Process automation serves to enhance product quality, improves functionalities of the whole range of products, improves process safety and plant availability, and efficiently utilizes resources and lowers emissions. The greatest requirement for process automation is the fastest growing demand for hardware, standard software and services of process automation. The traditional barrier between information and automation technology is gone. The latest technologies, including XPath, XSL, and XML schemas, help to improve the communication of process system modules.

Table 2. continued

<table>
<tr><th>Describing the runtime manipulation step</th><th>Result in the runtime environment</th></tr>
<tr><td>Another scripting then allows to decode the text values and save them in a “numeric” data type into a database even if values were previously set in the “text” data type by the end-user:</td><td>
</td></tr>
<tr><td>But, if the supervisor changed a value of the Priority property in a manual entry field from “High” to “Low” (on the first row of a runtime display), the Priority value is saved in a database in the “numeric” data type although it was written by the end-user as a text.</td><td>
</td></tr>
</table>

Using the *development environment* of the industrial application server helped us to demonstrate a scalable and flexible supervisory control system process development based on a distributed and object-oriented technology. During the application development we used “roll”, “coil”, “motor” object templates representing the technology, equipment, their I/O references, scripts, alarm state definitions, security and data history implemented within. From objects prepared in such a way other „child“ objects could be derived, deployed and repeatedly used within our system to built a hierarchical model of a production control technology. Further development of the application is therefore expected. The equipment model and equipment class model will be extended, models for material (consumed, produced) will be added in order to demonstrate the complexity of a production process and interaction with supervisory functions being modeled based on industrial standards applied.

CONCLUSION

A demo application was designed using new technologies to demonstrate an object-based modeling enabling easier automation of information flow, given the interfaces available for an enterprise and a production system.

The application developers create these new manufacturing execution system solutions (MES solutions) using services for communicating via messages from different sources on the web.

Web services as a new class of applications were developed to serve multiple computer architectures, operating systems, and languages, enabling documents to be readable and to be exposed in a standard way. ISA-95 standard, which was produced in cooperation of ISA and WBF, now provides the tools for implementation. B2MML provides the XML schema implementation of ISA-95. ISA-95 standard is in use today. It is gaining more acceptance driven by operating companies, and provides the framework for further information and process integration. This assures planning for material, equipment and human resources to be ready for production processes controlled by a manufacturing execution system based on new approaches towards collaborative production management.

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KEY TERMS AND DEFINITIONS

Application Programming Interface (API): A set of declarations of the functions (or procedures) that an operating system, library or service provides to support requests made by computer programs.

Application Server (AS): Executes applications for end users and controls networking, is usually between a database and a client application presenting data, application logics, controls data saving into a database and provides data to client applications.

Business Logic (BL): A term generally used to describe the functional algorithms, which handle information exchange between a database and a user interface. It is distinguished from input/output data validation and product logic.

Component: In object-oriented programming and distributed-object technology, a component is a re-usable program building block that can be combined with other components in the same or other computers in a distributed network to form an application. Components can be deployed on different servers within a network and can communicate with each other to perform services. Examples include a single button in a graphical user interface, a small interest calculator and an interface to a database. [Garbrecht, S. D., 2006]

Data Acquisition (DA): The detection and collection of data from processes and systems external to the computer system.

Graphical User Interface (GUI): The display presentation of some GUI controls based on runtime information, for example, to change the style of data presented when entered into a software and data format changes independent from the required database data type.

Manufacturing Execution System (MES): A system that companies use to measure and control critical performance and production activities.

Service Oriented Architecture (SOA): The software architecture for production control and information management systems that uses software services independent of the underlying platform and programming language.

Supervisory Control (SC): Control where one or more human operators are continually programming and receiving information from a computer that interconnects through sensors to the controlled process or task environment.

XML document: A textual representation of hierarchical data structures. XML documents are case sensitive. XML schema specifies the XML structure of the document made up of XML elements.

XPath: A query language for XML documents. Search results in these documents are returned as a list of items.

Chapter XXXVII
The Impacts of Semantic Technologies on Industrial Systems

Marek Obitko
Rockwell Automation Research Center, Prague, Czech Republic &
Czech Technical University in Prague, Czech Republic

Pavel Vrba
Rockwell Automation Research Center, Prague, Czech Republic

Vladimír Mařík
Rockwell Automation Research Center, Prague, Czech Republic &
Czech Technical University in Prague, Czech Republic

Miloslav Radakovič
Rockwell Automation Research Center, Prague, Czech Republic &
Czech Technical University in Prague, Czech Republic

ABSTRACT

Industrial systems face the challenges of robust and flexible control of industrial processes while satisfying the demand of mass customization and reduced time to market. To meet these requirements, systems need to work in a distributed manner, because the traditional centralized approaches are not sufficient. To achieve automated cooperation and coordination of distributed components at a larger scale, semantic technologies are necessary to enable truly open systems. The authors review state of the art of the research of ontologies, Semantic Web and Semantic Web services, together with advances of usage of semantic technologies in industry. The usage of semantic technologies is illustrated on two applications – semantics in multi-agent manufacturing systems and structural search in industrial data.

THE IMPACTS OF SEMANTIC TECHNOLOGIES ON INDUSTRIAL SYSTEMS

Industrial systems face the challenges of robust and flexible control of industrial processes while satisfying the demand of mass customization and reduced time to market. To meet these requirements, systems need to work in a distributed manner, because the traditional centralized approaches are not sufficient. However, the distributed architectures used in industrial control systems are still tightly coupled from the point of view of system integration. To achieve automated cooperation and coordination of distributed components at a larger scale, semantic technologies are necessary to enable truly open systems that can communicate while the configuration of the system is dynamically changing.

Today, the systems used in manufacturing industry are programmed with the focus on performing particular tasks rather than on interoperability in a dynamic environment. This is understandable, but in order to achieve better integration from the shop floor level up to the level of virtual enterprises, these systems have to use explicit semantics to describe the interpretation of the data they provide. So far, the interoperability has been resolved mainly at the physical and syntactical level. We can see the parallel with the World Wide Web (WWW), where the level of exchanging and interpreting documents is resolved, but the semantical level is being investigated within Semantic Web research. As the networked and distributed industrial systems have been influenced by the traditional WWW, they are apparently going to be influenced by Semantic Web as well.

In this chapter, we review state of the art of the research of ontologies, Semantic Web and Semantic Web services as the most relevant technologies enabling proliferation of semantics in industrial systems. We pay special attention to possible applications in distributed industrial systems and show how semantics can be applied to such systems. We focus on the multi-agent and holonic techniques that provide suitable paradigm for such systems and provide clear modeling framework for introducing semantics. We also review the ongoing efforts to create general purpose reusable ontologies for the industrial domain.

We discuss specific characteristics and requirements of industrial automation domain in contrast to the common issues of Semantic Web. The Web technologies have to handle the problems of semantical heterogeneity, inconsistency and uncontrolled behavior of individual sites. In the industrial domain, this can be avoided to some degree. The impact of discrepancies is also different – for instance inaccurate search result is acceptable, but inaccuracy in industrial domain may lead to potential damage of equipment, unnecessary material consumption, or delays in delivery of the manufactured product. The important difference is that we are dealing directly with the physical components in a real-world environment.

The applications of semantic technologies in industrial domain are illustrated on two research projects of Rockwell Automation: (i) semantics-enhanced agent-based material handling control system and (ii) structural search.

The first project aims at adding semantics to a multi-agent control system for material handling tasks, like for example transportation of materials and semi-products within an assembly line. We show how semantics can be utilized for reasoning in agent's knowledge base. The choreography and orchestration of Semantic Web services provide important inspiration – in reconfigurable industrial systems, it is needed to discover suitable service providers, negotiate the contract, monitor task execution and resolve potential runtime problems.

The latter project focuses on structural search. One of the core applications of the Semantic Web is semantic search, i.e., search within semantically enriched data. The design, operation and maintenance of a manufacturing system is very knowledge intensive task and involves handling of information stored in different forms – for example function blocks or ladder diagrams describing the real-time control system, SCADA (Supervisory Control And Data Acquisition) and HMI (Human Machine Interface) views, collected historical events, etc. We show the advantages of the usage of Semantic Web technologies for enabling search within structured and integrated data. The result helps humans to express queries that involve not only looking for keywords, but also structural relations between pieces of information.

Another potential application of semantic-based systems in manufacturing is the area of human-machine interfaces. They could serve for visualization and further analysis of information where the direct linkage of the manufacturing-oriented semantic systems with the Semantic Web might be required.

As we show, the manufacturing domain is being influenced by the semantic technologies, especially those from the Semantic Web. For distributed reconfigurable industrial systems the vision of the Semantic Web and Semantic Web services is an important inspiration, and despite some differences, much of the research is directly applicable to the manufacturing domain.

SEMANTIC TECHNOLOGIES AND ONTOLOGIES

To allow communication, communicating systems must be able to understand exchanged messages. This is usually guaranteed in closed homogeneous systems by design. However, in heterogeneous environments where systems were not preprogrammed to communicate together, the issue of understanding of messages may arise. After ensuring message delivery, we can distinguish two levels of understanding of messages or other types of interaction – syntactical and semantical. The syntax defines the structure of a language, i.e., a grammar typically in a form of rules that express how symbols may be structured to form sentences. Semantics expresses the aspects of meaning of a sentence, i.e., the sense of symbols as language elements and their combination, including the relation of these elements to the real world.

The semantics may be expressed in an ontology. The term ontology as clarified by Guarino and Giaretta (1995) comes from philosophy, where it refers to the study of being or existence. Originally, ontology in philosophy attempts to describe categories and relationships of all existing things, to describe what properties are common to all existing things. In computer science and engineering applications, the usage of ontologies is reduced to describe only a part of a selected domain. The goal is not to describe the whole world, but rather to have an approximate model that is formal enough to be processable by a machine and that is appropriate for a specific application. A popular definition in this context is that ontology is a formal explicit specification of a shared conceptualization. A conceptualization is a shared view of how to represent the domain of interest. Usually this view is influenced by intended application. The formal and explicit description of such conceptualization is then the ontology. In practice, ontology usually consists of concepts, relations and restrictions expressed in some logical language such as first order predicate logic.

Ontology is used as a base for expressing particular state of affairs in the domain. For example, material handling ontology states that there are conveyor belts and diverters that can be connected together. The ontology describes principles of the domain that do not change. Particular domain state is then captured in a knowledge base. To continue with our example, knowledge base describing particular plant may state that the diverter D_{25} is connected to the conveyor belt B_6.

Semantic Web

Semantic Web is an extension of the current hypertext based World Wide Web in which the content of documents is described in a form processable by software agents. The goal is that the software agents would be able to find, integrate and process information more precisely than on hypertext Web. For this purpose, semantics processable by machines is needed. The Semantic Web aims to provide a common framework for sharing and reusing data together with expressing their semantics. For this purpose, two languages, Resource Description Format (RDF) and Web Ontology Language (OWL), are proposed. These technologies were primarily designed for the World Wide Web; nevertheless, they are suitable for applications running outside the Web as well, including industrial domain (Obitko et al., 2008).

The RDF is a framework for storing data in a graph in a form of triples (Manola and Miller, 2004). The triples have form of subject-predicate-object. A triple is a simple statement about relation (the predicate) of resources (subject and object); these statements together form a graph as same subjects as well as objects appear in different relations. Each resource in an RDF triple is a Web resource identified by a Unified Resource Identifier (URI). In addition, a literal such as string or number can be used in the place of object. RDF statements are stored in RDF documents distributed in the WWW, and can be linked together using URIs. In this way, RDF offer simple but powerful means for integrating data.

RDF itself does not standardize vocabularies for expressing ontological relations. The Web Ontology Language (OWL) was created based on description logics to support expressing ontologies (Dean and Schreiber, 2004). Description logics describe concepts and roles, called classes and properties in the Semantic Web. These entities form a terminology and are described in so called T-Box. T-Box corresponds to the ontology, i.e., general knowledge that is not changing. The other part of a description logic system is an A-box that holds assertions about the current state of affairs that is changing often. The properties of description logic chosen as a base of OWL are sound and complete reasoning in practically usable time. OWL ontology describes taxonomy of classes and properties together with constraints of the use of these classes and properties. In this way, OWL forms a vocabulary describing the world state that can be employed by pure RDF description.

For searching within an RDF graph, the Simple Protocol and RDF Query Language (SPARQL) is available to specify required graph pattern for a query. It should be noted that since OWL is based on RDF, the SPARQL can be used to query OWL statements or to query knowledge bases built on OWL.

Semantic Web Services

Web service specifications are standards for syntactic interoperability and include protocols for calling a service and returning the result, for describing a service interface, and for publishing and discovering metadata about services. Web Services are in fact Web Application programming interface (API) that can be accessed over the internet. The WWW infrastructure is used not only for downloading documents to be displayed in a Web browser, but also for invoking more complex services and for returning results in a standardized form.

Semantic Web Services are not replacement of Web Services, but are rather semantic enrichment of them. The semantic enrichment has a goal of allowing automated discovery, composition and execution of services. Special ontologies were developed for the purpose of describing services in an automatically processable form. Two well-known ontologies are OWL-S (The OWL Services Coalition, 2004) and Web Service Modeling Ontology WSMO (Lausen et al., 2005). As an example, OWL-S at its top level describes a service using ServiceProfile (what the service does), ServiceModel (how it works) and ServiceGrounding (how to access it). The description of a service can be used for both specifying the service offerings and for specifying service requests. Requests are then matched against specifications to find appropriate services. This approach goes towards truly open architecture that would be able to integrate new services. In the internet environment such a vision is often referred to as Internet of Services (Schroth and Janner, 2007).

SEMANTICS IN INDUSTRIAL DOMAIN

Semantics and ontologies can be used in industrial domain in many applications, especially in distributed systems. We pay special attention to semantic search and semantic enrichment of multi-agent industrial control systems. The obvious advantage of using ontologies is that the assumptions about the domain become explicit and are not hidden in the code of systems where it is not easily usable for integration. These explicit assumptions facilitate communication in distributed systems because the communication vocabulary becomes unambiguous. Also, the formal ontology allows reasoning over acquired knowledge, including validity and consistency checking and deducting new facts from known information.

Semantic Search

One of the core applications of the Semantic Web is a semantic search, which includes gathering data from various heterogeneous sources, integrating them together, reasoning over them, and so providing meaningful answer to a query. Such a search is useful also outside the WWW – for example looking for information in a distributed system is very similar. On WWW the document delivery as well as document interpretation is more or less resolved. In industrial systems we usually have to preprocess the data and to convert them to common format to be able to use the data together for answering a query.

An example of search application in industrial domain is the search within data produced during design of an assembly line. These data are usually distributed in many formats accessible by various applications. Translation of these formats to a common form is required to allow answering complex queries.

Once the data are accessible in any of the formats designed for Semantic Web, the Semantic Web technologies can be used to perform the search. Also, once the data are converted, the integration with other Semantic Web based applications is possible. We discuss application of this approach later in this chapter.

Semantics Utilization for Reasoning

Formal ontologies are logic theories that can be used for reasoning in a used logic. The reasoning may seem trivial in many cases, but it is important to note that for this reasoning no additional program code is needed. Let us illustrate the usage of reasoning on a simple example from a transportation domain (Obitko and Mařík, 2003).

Let us suppose that transportation devices, such as conveyor belts, are described using properties such as `targetNode`, `defaultCost`, and `connectedTo`. The ontology states that targetNode is `rdfs:subPropertyOf` of `connectedTo` and the `connectedTo` property is `owl:SymetricProperty`. Then, when it is known that a transportation node is a target node for a transportation edge, it can be derived that not only the node is connected to the edge, but also that the edge is connected to the node.

To show a bit more complex example, let us suppose that it is stated in the ontology that the transportation edge properties – `targetNode` and `defaultCost` – are of type `owl:FunctionalProperty`, which means that there exists at most one value for that property. Let us suppose that there are several different kinds of identifications of a particular transportation node – one is by its purchase identification number from a commercial department and another one is the address used among transportation agents. When an agent gets information from two sources that these two transportation nodes are target nodes of the same transportation edge, it can derive from the functional property type that these two nodes are the same individuals that just have different identifications for different communities.

This kind of reasoning is available just by using the specified ontology. If this ontology is shared among agents, these agents are able to find the same consequences from the information that they exchange about the environment.

SEMANTICS IN HOLONIC AND AGENT BASED INDUSTRIAL CONTROL SYSTEMS

Holonic and multi-agent systems have been widely recognized as enabling technologies for designing and implementing next-generation of distributed and intelligent industrial automation systems (Bussmann et al., 2004). These systems are characterized by high complexity and requirements for dynamic reconfiguration capabilities to fulfill demands for mass customization, yet low-volume orders with reduced time-to-market. Self-diagnostics and robustness that allow efficient continuing in operation even if the part of the system is down are other important properties.

The trend of deployment of multi-agent techniques is obvious at all levels of the manufacturing business. At the lowest, real-time control level, so called holons or holonic agents are deployed. They are usually tightly coupled with the hardware via interacting with the real time control programs, implemented in standards such as IEC 61131-3 (Programmable Logic Controllers (PLC) programming languages such as ladder diagrams) or IEC 61499 (function blocks). Through these interactions, usually carried out by reading and writing shared values in a memory of industrial controllers, agents can directly observe and actuate the physical manufacturing equipment (Vrba, 2006). Intelligent agents are also used for production planning and scheduling tasks both on the workshop and factory levels. More generic visions of intensive cooperation among enterprises connected via communication networks have led to the ideas of virtual enterprises (Camarinha-Matos, 2002).

The common principle in industrial deployment of the agent technology is the distribution of decision-making and control processes among a community of autonomously acting and mutually cooperating units – agents. At the shop floor level, for instance, an agent supervises and independently controls particular physical equipment, such as buffer station, milling machine, conveyor belt, etc. The important characteristic is the mutual collaboration among the agents as they try to pursue their individual goals as well as the common overall goals. The inter-agent interactions vary from simple exchanges of information, as for example one agent notifies the other one that the operation has finished, through requests to perform a particular operation, for example requesting a shuttle in a conveyor network to transport a product to a particular work station, to complex negotiations based on contract-net protocol or different auction mechanisms.

As the information representation and exchange is the essence of such systems, the existence of explicitly defined and shared ontologies becomes crucial. The exploitation of semantics and ontologies has recently gained an increased attention in the agent-based manufacturing control research community. The researches apparently realized that the syntactical interoperability, predominantly ensured by the Extensible Markup Language (XML) based messaging, will not be able to keep up with the trend towards semantically interoperable knowledge based systems. Thus, the use of Semantic Web technologies has accelerated largely over the past few years in this area.

Domain-Specific Ontologies for Agent-Based Manufacturing Control Systems

The number of deployments of ontologies in multi-agent industrial control systems is steadily increasing. However, the usual case is that a small, domain-specific ontology, that covers only a subset of the manufacturing area of interest, for instance assembly, is designed and utilized only for the purposes of the developed agent-based control application.

Cândido and Barata (2007) present the ontology for shop floor assembly. Two basic categories of concepts are proposed: modules and skills. Modules represent physical processing units or their aggregation: the workcell concept is defined as composition of workstations (typical `composedOf` relation is used), where workstation is a composition of units. The examples of units are the transforming unit that has further subclasses pick&place unit and milling machine, the flow unit and the verification unit. To express the inheritance (relation between class and its subclasses), typical `isA` relation is used. Skills represent abilities to execute manufacturing operations, as for instance MoveLinear. More complex skills can be represented as an aggregation of other skills, either basic or complex. The manufacturing resource agent, for instance robot, searches the ontology after its instantiation for skills it supports using its serial number and type of equipment and then registers these skills (MoveLinear) in the Directory Facilitator (DF) agent, which maintains a list of services provided by all individual agents. The equipment can be aggregated into group of equipment by forming a coalition of agents. The coalition leader agent that is in charge of forming such a group gathers coalition members' basic skills and searches the ontology to find out what complex skills could be supported by the coalition. If there are some found, those complex skills are also registered in the DF (with the description of how the coalitions are formed without identifying its members). Each skills description is supplemented with the message template for corresponding inter-agent negotiations. The proposed solution has been deployed in the NovaFlex shop floor environment installed at the Intelligent Robotic Center at UNINOVA that is composed of two assembly robots (each with four different grippers), automatic warehouse and a transportation system connecting all the modules. The solution proved increased plug-and-play, dynamic reconfiguration and interoperability capabilities provided by the multi-agent techniques.

Al-Safi and Vyatkin (2007) report on the development of an OWL-based ontology designed for agent-based reconfiguration purposes. The ontology application is demonstrated on a laboratory manufacturing environment consisting of two machines used for processing and handling of work pieces. The machines are equipped with different mechatronic devices such as rotating indexing table, plunger, drill, picker, etc. The basic ontology concepts, similarly to previous case just using different vocabulary, are resource and operation. The resource can be machine or tool with corresponding subclasses like handling machine and processing machine as well as rotary indexing table, drill, kicker, etc. The operations are subdivided divided into manufacturing operation and logistic operation with further classification on sorting, hole testing, drilling and picking, kicking and rotating, respectively. The fact that a machine enables execution of an operation is captured by relations between the machine concept and the operation concept. These general concepts from the ontology are then instantiated to capture the real environment, such as the particular machines and their relations. Such a dynamic part of the ontology is also expressed in OWL allowing the agents to reason about the available machines and operations, however still in the semantic context.

Magenta Technology provides another example of active investigation into exploration of ontologies in agent-based applications. Rzevski et al. (2007) report on a set of multi-agent tools and describe details of the Ontology Management Toolset. This tool enables users to design and edit both the static and dynamic (called scenes here) aspects of an ontology. The ontology developed by this toolset for supply chain and logistic planning is then presented (Andreev et al., 2007). The examples of concepts are factory, cross-dock, truck, etc., and relations like `isBookedForADemand`. Although it is not explicitly mentioned in the last two cited papers, the Magenta's multi-agent engine provides a mechanism of updating the agent's behavior (i.e., program code) dynamically as the ontology is being extended or modified. The corresponding piece of code providing an agent with an algorithmical description of its behavior associated with a particular new ontology concept is sent to the agent so that it can subsequently execute the code to react appropriately (our similar architecture is described in section Semantics Enabled Agent-Based Material Handling System).

General-Purpose Ontologies for Manufacturing Domain

Previous section documented that even though there are many efforts towards designing ontologies for manufacturing domain, different developers use slightly different vocabularies for describing similar concepts. Moreover, in the majority of cases there is a focus just on a narrow domain of interest. However, there are also activities towards developing generic ontologies for the manufacturing industry.

Very promising standardization effort seems to be concentrated around the OOONEIDA (Open Object-Oriented kNowledge Economy for Intelligent inDustrial Automation) consortium that aims on creating of the technological infrastructure for a new, open-knowledge economy for automation components and automated industrial products (Vyatkin et al., 2005). The objective is to design a framework for both the hardware and the software interoperability at all levels of the automation components market, i.e., from device vendors and machine vendors to system integrators and up to the industrial enterprises. The set of searchable repositories of so-called Automation Objects is envisioned, where each player deposits its encapsulated intellectual property along with appropriate semantic information to facilitate searching by intelligent repository agents. The use of semantic languages for knowledge repositories (mainly OWL) is promoted.

A complementary work to OOONEIDA initiative presented by Lopez and Lastra (2006) aims at semantic extension of automation objects by applying the Semantic Web technologies. Two separate ontologies for mechatronic devices reference model (covering both the hardware and the software features) and the IEC 61499 reference model respectively are proposed and merged into an ontology for Automation Objects reference model (proposed by IEC-TC65 group). The basic concepts designed for the lowest level include function blocks, events, I/Os, etc. The device/machine level part of ontology provides concepts like function block application, resource, etc. Two examples of semantic description of automation objects – Conveyor and Lifter – are sketched. As argued by Lastra and Delamer (2006), the Semantic Web services are generally suitable for rapidly reconfigurable factory automation systems.

National Institute of Standards and Technology (NIST) devotes considerable standardization effort to manufacturing domain. For instance, shop data model is described using UML diagrams and XML serialization examples (McLean et al., 2005). The model includes description of organization, bill of materials, process plans, resources, schedules, etc. Although it is not a formal ontology in the sense described earlier in this chapter, such standards are important as a base for ontologies that would be widely accepted. Another example of NIST activities is the Process Specification Language PSL (Grüninger and Kopena, 2005) that is a logical theory that covers generic process representation, which is common to all manufacturing applications. The PSL ontology contains axioms grouped to theories describing aspects such as complex activities and can serve as a solid base or upper ontology for representing processes.

MASON (MAnufacturing's Semantic ONtology) presented by Lemaignan et al. (2006) represents another contribution in this area. The goal is to develop an upper ontology that would allow seamless integration of more specific ontologies using the common cognitive architecture. The ontology is based on OWL and describes the taxonomy of concepts such as entities, operations and resources and their relations like associating a tool with an operation (property `requiresTool` with the domain `ManufacturingOperation` and a range `Tool`). It is reported that currently the ontology, which is available on-line, constitutes of more than 270 base concepts and 50 properties. Moreover, a mapper has been developed between OWL ontologies and the internal ontology model used by the popular Java Agent DEvelopment Framework (JADE) agent platform (http://jade.tilab.com/). Although some of the constructs in the ontology seem to be application specific, for example restricting previous operation in the definition of operation concepts, this work can be seen as an important step towards formalizing the vocabularies used to describe manufacturing domain.

When building the general-purpose manufacturing ontologies it is obviously necessary to have solid basis in form of well developed foundational (upper) ontologies incorporating for example spatial or time theories. Unfortunately, the direct utilization for manufacturing purposes is limited because these foundational ontologies are often created in very expressive languages without taking care of computability. The formalization of ADACOR ontology (ADAptive holonic COntrol aRchitecture for distributed manufacturing systems) using the DOLCE methodology (Descriptive Ontology for Linguistic and Cognitive Engineering) is outlined by Borgo and Leitão (2004). ADACOR is originally described using Unified Modeling Language (UML) diagrams and natural language descriptions, while DOLCE uses first order modal logic and aims at capturing the ontological categories underlying natural language and human commonsense, such as physical or abstract objects, events and qualities. The alignment of ADACOR to DOLCE yields well formalized and well founded ontology. The ontology described in ISO 15926 "Industrial automation systems and integration" also uses well founded principles of temporal and spatial representation of objects in a form of four dimensional approach to simplify reasoning in the process engineering domain (Batres et al., 2005).

Interoperability of Manufacturing Ontologies

A widely accepted, consistent and comprehensive general-purpose upper level ontology for manufacturing domain and supplementary coherent set of standardized domain-specific ontologies is needed to ensure reusability and interoperability. In the manufacturing domain, standardization plays more important role than in case of a general Web search. However, when describing the same thing from different point of views, such as the view of accounting department and of assembly line designer, there is a need to integrate these different views. In other words, the ontologies in open distributed systems are inherently different, and there is a need to exchange information in this environment.

Similar threats of ontology standardization are pointed out by Lastra and Delamer (2006). As illustrated in Obitko and Mařík (2005), this problem can be solved by translation of messages between ontologies – one agent prepares a message in its ontology, and the message is then translated into the ontology used by the receiving agent while preserving the meaning of the message. The details on the translation using Semantic Web technologies and OWL reasoning are described using transportation domain examples by Obitko (2007).

Common Properties of Ontologies Deployment in Agent-Based Manufacturing Systems

Let us summarize and discuss the typical attributes of the applications of semantics in the agent-based distributed industrial control systems.

Static & dynamic aspects of semantics – as discussed earlier, OWL provides means for expressing static, invariant concepts or facts (T-box) as well as the dynamic model of the real world (A-box) created as particular instances of T-box terms. Machine provides an operation is an example of the former one while machine M34 provides cutting is the example of the latter one. It is questionable how to call these two aspects – the former one could be simply referred to as ontology while the latter one could be referenced as a knowledge base, scene or world model. While ontology can be seen as a semantic network of classes (concepts), their relations, attributes and restrictions, the scene created using concepts from ontology, represents the current situation in the corresponding part of the real world (Andreev et al., 2007). While the ontology is designed a priori, the knowledge base is built by the agents dynamically as they perceive the real world by means of sensors, communication (sharing their knowledge bases) or possibly through user interaction (in case of combined human-machine systems).

Self awareness and localization – essential part of the agent's knowledge base is the information about its localization in the real-world together with the perception of its presence and the results of own actuation in the real world. Sensing, tracking and tracing technologies will play an increasingly important role in providing the real-world acting agents most accurate information about the surrounding environment. We can see a significant potential in the RFID (Radio Frequency Identification) technology as presented in a pilot application where the RFID technology is integrated with agents used for manufacturing control (Vrba et al., 2006).

Reactivity – imagine a situation when an agent notes a particular event in the real world, for instance detects a failure of the controlled machine. It creates a corresponding fact consistent with the ontology (describing relation between a machine and failure concepts) and stores this information into its knowledge base. The agent's inference engine can then possibly deduce other new facts, but this still does not directly lead to reaction. But often, particularly in agents acting in real world, some action or reaction is needed – for instance sending command to hardware (stop the drive) or informing the other agents. So the meaning of the particular concept from the ontology is not only knowledge-based but also "algorithm-based". The ontology should provide the agent also with the explicitly defined rules (or directly a program code) to be executed by the agent to react appropriately. Magenta agent runtime environment (Rzevski et al., 2007) provides such feature – program code is sent to the agent to modify or extend its behavior. In the effort to deploy ontologies in the MAST system (Vrba, 2006), we have recently also implemented such a feature (see next section). In the area of Semantic Web technologies, various rule languages are being developed. Using these languages allows direct exploitation of the relevant RDF-based tools and also easier interoperability outside of the manufacturing domain.

Ontology-based service matchmaking: One of the basic concepts of multi-agent systems is the advertisement of agents' skills and services in the Directory Facilitator (DF). Other agent can then search the DF to find out particular service providers. The information registered in the DF is however in majority of agent platforms available today (JADE or Cougaar) in a very simple form. It usually contains just the type of the service (for instance `Drill`) but it cannot be further parameterized (`Diameter: 10-100 mm`, `Hole depth: 5-20 mm`). Obviously, to fully explore the potential of semantics in agent-based systems, ontologies must be deployed for service registration and lookup through DF as well. Within the registration the agent sends the corresponding part of its ontology (services it offers) to the DF. DF can be then queried for finding particular service providers using more complex queries ("find all machines that can drill a hole of 50 mm diameter and 15 mm depth"). The result sent back by DF to the requester (also in form of ontology) might be with convenience supplemented by the message template and protocol to be used in the corresponding inter-agent negotiations, as discussed by Cândido and Barata (2007). Services provided by agents can be described using OWL-S in a similar way as Semantic Web services. Matchmaking of services can be then made using OWL reasoning.

Orchestration of manufacturing processes: Service integration and composition becomes very attractive topic in the Service-Oriented Architecture (SOA) domain. Hahn and Fisher (2007) describe a solution based on multi-agent and holonic techniques. Community of interacting holons, representing service providers and requestors, can be nested so that requested complex service is automatically orchestrated as a composition of basic services. An important function of a reconfigurable distributed manufacturing system is the distribution of tasks over multiple agents or holons. This goes beyond the simple service matchmaking – the whole process must be composed, executed and problems occurring during the runtime must be resolved. For that, manufacturing processes should be also specified in ontologies (Lastra and Delamer, 2006). We envision the ontology-based recipes compiled as a sequence of elementary operations described in a suitable ontology to allow automatic discovery of equipment that can perform requested operations (see next section for more detail).

Interoperability: Property required within a manufacturing system as well as between other systems on MES (Manufacturing Execution System) or ERP (Enterprise Resource Planning) levels. Translation between ontologies is a way of integrating systems that use different ontologies. The architecture of integrating systems has to be considered as well – the low level control devices would be hardly able to do such translation themselves, and so they need to ask a special service to provide translation for them or the translation has to be made automatically in the message transportation layer (Obitko, 2006).

SEMANTICS ENABLED AGENT-BASED MATERIAL HANDLING SYSTEM

As discussed in Domain-Specific Ontologies for Agent-Based Manufacturing Control Systems section, the integration of semantics in multi-agent based industrial control systems is gaining increasing attention in research community. Providing the agents with the explicitly defined semantics of knowledge about the manufacturing environment that they manage and share with each other as part of the cooperation is essential for such kinds of distributed solutions. Semantics provides the agent control system with increased level of maintainability, interoperability and reconfigurability as the knowledge representation and processing is maintained explicitly instead of implicit and firm insertion of ontology-related functionality in agent code as it is usual in today solutions.

Within the context of work presented by Vrba et al. (2006) there are currently ongoing activities towards deployment of ontologies in the agent-based solution developed for the manufacturing domain. The Manufacturing Agent Simulation Tool (MAST) has been introduced by Rockwell

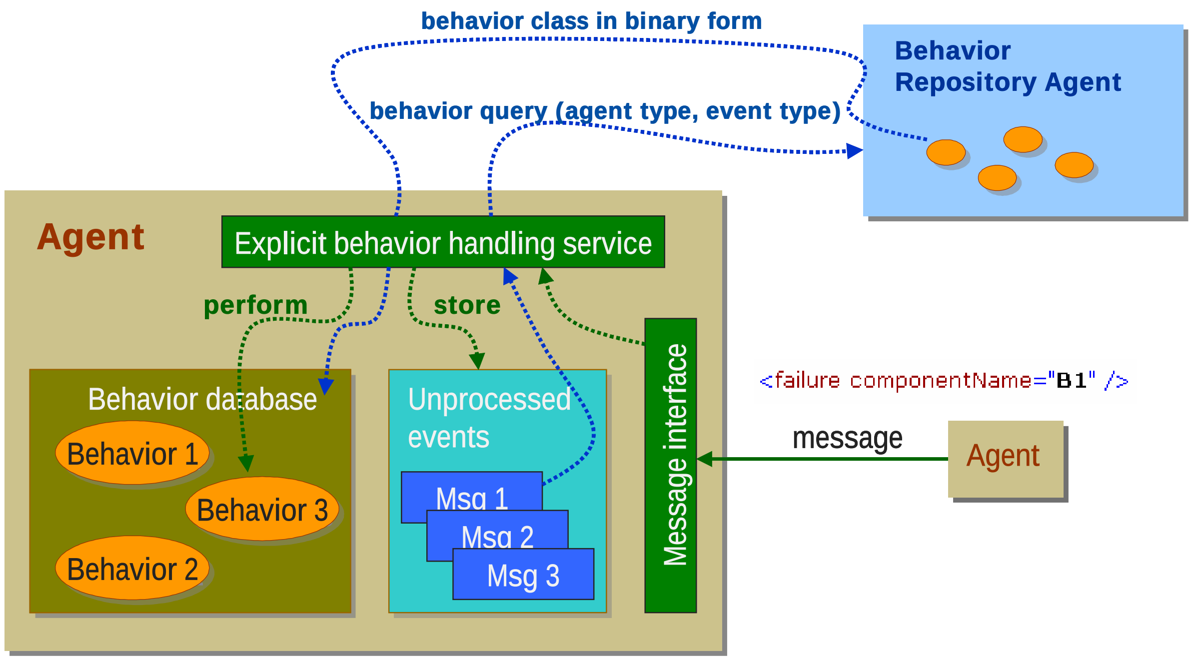
Automation with the intent to provide a simulation tool transparently demonstrating the advantages of application of multi-agent systems techniques in the industrial control domain. Particular attention has been paid to the material handling tasks where the redundant transportation paths and machines with overlapping capabilities represent a perfect fit for the agent technology. From the initial prototype MAST matured into a comprehensive agent based simulation and control solution providing a Programmable Logic Controller (PLC) based interface for actual control of the real physical equipment.

The key part of the referred solution is the library of agent classes representing various manufacturing components like a conveyor belt, diverter, storage, docking station, sensor, etc. The behavior of each agent is aimed at the local control of the supervised manufacturing equipment and concurrently on the collaboration with the other usually neighboring agents in order to fulfill the overall goals of the manufacturing plant. One of the tasks that the agents are mutually capable of solving is the transportation of products (referred to as work pieces) between work cells through a complex and redundant network of conveyor lanes. The work cell, diverter and conveyor agents work together on searching for optimal transportation routes. The optimality criteria is a cost of transportation from a source to a destination work cell computed as a sum of predefined costs of conveyors leading from source to destination. The path searching algorithm is dynamically carried out by the agents in conjunction with the creation or modification of the social knowledge about agents' interconnections. The information about found paths is exchanged between the agents via messages in a back propagation manner and is being refreshed whenever any local update occurs. It is used particularly by the diverter agents to create local routing tables containing the information of what all destination work cells can be reached from the diverter's location and which output conveyor to use to direct the work piece to its desired destination at the lowest cost (Vrba et al., 2006).

The current agent architecture from the viewpoint of knowledge handling and exchange could be characterized as implicit and rigid without a notion of semantics being applied. The agent's representation of the surrounding world is held in local variables of the agent class and the content of exchanged messages is encoded in XML with no explicit definition (using Document Type Definition (DTD) or XML Schema Definition (XSD)) being used. In other words, the meaning of the received message is interpreted directly in the agent code. An example of such a message could be: `<failure componentName="B1" />` that is sent by the conveyor belt agent B1 to a connected diverter agent to inform it that the conveyor has failed. The diverter agent stores the information in a corresponding local variable indicating a failure of its output conveyor and subsequently performs embedded behavior that is associated with the name of the topmost XML tag from the message (`failure`). The reaction to change in the agent's knowledge caused for instance by a change in a real world (I/O values) is carried out similarly by selecting corresponding behavior that is hard coded in the agent class.

In the ontology-related extensions of the presented agent-based manufacturing control architecture the first step taken has been the separation of agent behaviors from the agent core. The reactions to particular events or messages are then handled in more general and extensible way. Each behavior is now held in a separate class while the agent is given a set of "default" behaviors when instantiated. When a message from other agent is received (see Figure 1), the explicit behavior handling service searches agent's internal behavior database for appropriate behavior on the basis of the message content's XML tag name. If the behavior is found, it is performed. If not found, the message is stored in the unprocessed events container. Concurrently, the agent contacts the Directory Facilitator to obtain contact on

Figure 1. Explicit behavior handling



special Behavior Repository Agent(s). This agent is designed to maintain and on request provide uncommon or special behaviors for various agent types. When asked for the behavior of a particular agent type and particular event type, the behavior (if present) is sent back to the requesting agent in a binary form where it is performed on all corresponding unprocessed events.

Such architecture provides a convenient way of managing the agent behaviors. When an update of particular behavior is needed, it is not necessary to change and recompile the whole agent code. Just the particular behavior class is updated in the behavior repository agent (sent for instance by a message from the user) and then, even at runtime without interrupting the targeted agent execution, distributed to the corresponding agents. Other advantage is that tailored behavior packages can be deployed in order to minimize the memory consumption on the targeted devices with constrained resources. Agents running on those devices are equipped just with behaviors needed for everyday operation and receive specialized behavior only when necessary.

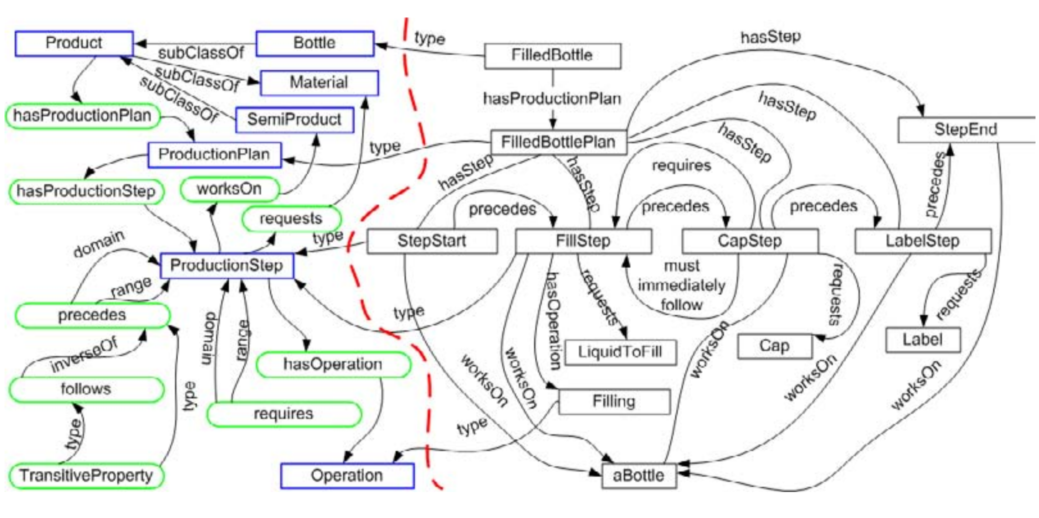
More important part of the semantic enrichment of referred agent-based manufacturing solution is the design of an ontology for selected part of manufacturing domain and deployment of this ontology for knowledge representation, reasoning and information exchange in the MAST system. Trying to take the best from existing approaches, like ANSI/ISA 88 (ANSI, 1995), OOONEIDA (Vyatkin et al., 2005), MASON (Lemaignan et al., 2006) and others, the proposed ontology prototype covers general aspects of a manufacturing process from customer order, through production process description to actual production scheduling and material routing. It is general enough so that it can be extended to describe various discrete manufacturing processes. Yet, it tries to reduce the complexity seen in similar efforts (like MASON ontology) so that the integration with agents is as easy and smooth as possible.

Figure 2 provides an illustration of the ontology part related to the general description of the production process (left-hand side of the picture) with a particular example showing the production of a filled bottle (right-hand side). As seen, the production process consists of particular production steps with defined execution order. Each step (e.g., `FillStep`) has an operation (`Filling`) and material (`LiquidToFill`) associated with it. The type of the product (`FilledBottle`) as well as its parameters (like `type` and `amount` of liquid) are captured in the part of the ontology related to the customer order and are interlinked to the production process description. In fact, the left-hand side of the picture represents the static ontology with its concepts and relations while the right-hand side represents a knowledge base describing a particular instance of the production plan for the particular product.

It is suggested that such a production plan knowledge base is automatically processed by a general Product agent. It receives this plan from the Order agent that is responsible for processing the customer orders. The Product agent takes care of scheduling the execution of production steps by negotiating with the Manufacturing Resource agents as well as with the transportation system agents. The concept of a work station has been devised as a composition of manufacturing resources that, as a whole, provides operations listed in the production plan. Usually, there is for instance a docking station in the transportation system holding a palette carrying a product; robot or other manipulator that moves the product from and to a palette; and a machine performing actual operation. The associated work station agent bids on requests from product agents while internally ensures proper execution of the requested operation by coordinating the subordinate equipment agents. As presented by Lastra and Delamer (2006), the Semantic Web services technology is a suitable candidate for advertising and discovery of services provided by work stations.

For matchmaking of services, OWL-S together with description logic reasoner can be used. Matchmaking using reasoning over inputs and outputs of services is described by Li and Horrocks (2003). The inputs and outputs are described in the OWL-S manner, and the request for service is then compared to advertisements to get one of the levels of the match – exact, plugin (advertisement is more general), subsume (request is more general), intersection (partially satisfiable request), and disjoint. The matchmaking of

Figure 2. Ontology for description of a production process



preconditions and effects is described by Wang and Li (2006). The preconditions and effects are described using OWL knowledge base for each advertisement and request. An algorithm is then proposed that verifies entailment relationship between advertisements and request with the following possible results: exact match, perfect match (better than requested), side-effect match (additional side effects), and common match (more preconditions than requested). These approaches can be used for matchmaking in a manufacturing system in the same manner.

The major advantage of the proposed solution compared to other non-ontology based approaches is the openness and the capabilities of dynamic reconfiguration of the production process. If the production plan for a particular product needs to be changed or a new kind of product is to be introduced, the related ontology is just updated or created and sent to the respective agents. Neither the modification of the agent program code nor any other complicated reconfiguration of the control system is needed. The installation of a new equipment on the factory floor or replacement of the old one is also feasible. The new work station agent instance is created with the installation of a new equipment while registering its services in a service directory. In such a way, it is going to be discovered by product agents in the subsequent negotiations on the production steps scheduling.

STRUCTURAL SEARCH

One of the core applications of the Semantic Web is semantic search, i.e., search within semantically enriched data. The design, operation and maintenance of a manufacturing system is a very knowledge intensive task and involves handling information stored in different forms - for example function blocks or ladder logic code describing a control system. The ladder logic was originally invented to describe logic made from relays and it is still useful in the manufacturing area because engineers and technicians can understand and use it without much additional training. Another information sources are Supervisory Control And Data Acquisition (SCADA) systems that are used to monitor and control automated processes. Part of these systems is Human-Machine Interface (HMI) serving for visualization as well as getting feedback from human. The last notable information source is the data collected during system operation, such as events or data measured by sensors.

These data come in various formats and it is not possible to use even keyword based search known from the hypertext Web without converting data to a searchable form. The Semantic Web technologies provide a format that allows storing structurally related data: RDF. After converting the data to this format, structural queries can be made using SPARQL language (Obitko, 2007). An example of a structural query into the ladder logic is "Find all XIO instructions that use tag StartCell and show names of routines where these instructions appear".

The Semantic Web is designed to resolve integration problems. The integration is simple in this case – all the data are merged in one RDF graph. In this way, different type of information is connected. The result is that we can ask queries that involve data from more sources. An example of a structural query that combines ladder logic code and HMI is to "Find ladder code projects that have a tag used in a gauge control on any HMI display". The SPARQL formulation of this query is illustrated in the Figure 3.

Generally, the semantic search within files used to design and operate manufacturing system is close to the idea of semantic desktop (Deskcer et al., 2006) that enables annotating files or other items such as e-mails for further search. However, we are primarily interested in solutions that do not require manual annotations from users. We can get the structural and context information directly from data so the search service is run-

Figure 3. Query "Find ladder code projects that have a tag used in a gauge control on any HMI display" formulated in SPARQL

```
     SELECT ?exp ?hmicomputer ?hmifile ?ladcomputer ?ladfile
     WHERE
     {
         ?g   a hmi:Gauge; #find gauge
              gen:contains ?conn.
         ?conn hmi:hasExpression ?exp. #and the tag
         ?hmi a gen:File;
              gen:contains ?g; #the file it is in
              gen:hasComputerName ?hmicomputer;
              gen:hasFileName ?hmifile.
         ?tag a lad:Tag; #now try to find match in ladder code
              lad:hasName ?exp. #is there tag with this name?
         ?lad a gen:File; # if so, which file it is in?
              gen:contains ?tag;
              gen:hasComputerName ?ladcomputer;
              gen:hasFileName ?ladfile.
}
```

ning in background without annoying users with entering additional data.

An important part of this solution is the OWL ontology developed to provide background knowledge. For example, the OWL ontology may state, that `contains` relation is transitive, and then the reasoning is used to obtain transitive closure for answering queries.

Data and Query Visualization

The specialized language SPARQL can be used to formulate structural queries. Once user knows this language, he can ask the queries and obtain the results in a tabular form. This approach may be fast for experienced users, but may also mean barrier to use by users that are experts in industrial domain but are not familiar with Semantic Web technologies.

To overcome this barrier, more intuitive ways of formulating queries and reporting results are needed. The basic visualization techniques proposed for the Semantic Web are summarized by Geroimenko and Chen, 2003. They are focused on visualization of large volume of data, for example in a form of linked data clusters or nested groups of items. User interfaces usually allow rotating the views, zooming, selecting groups of objects or relations. These interfaces are useful for analyzing clouds of data, but are not appropriate for formulating structural queries mentioned above. These methods are very suitable for analyzing dependencies and relations in data, and can be used to analyze data obtained from a structural query.

A very popular form of querying RDF data are so called facets. The facet is a common parameter of all objects that are subject to querying. For example, the facet corresponds to material, and the facet values examples are zinc or silver. The selection of objects is then made by selecting possible values in all facets and so constraining the set of objects. The assumption for this approach is that we have objects with common properties. This is not the case when objects are coming from more sources. For example, the ladder logic rungs and HMI displays have almost no common properties. Another assumption is that the query is made by constraining possible values, but there is no way to include structural relations between multiple objects.

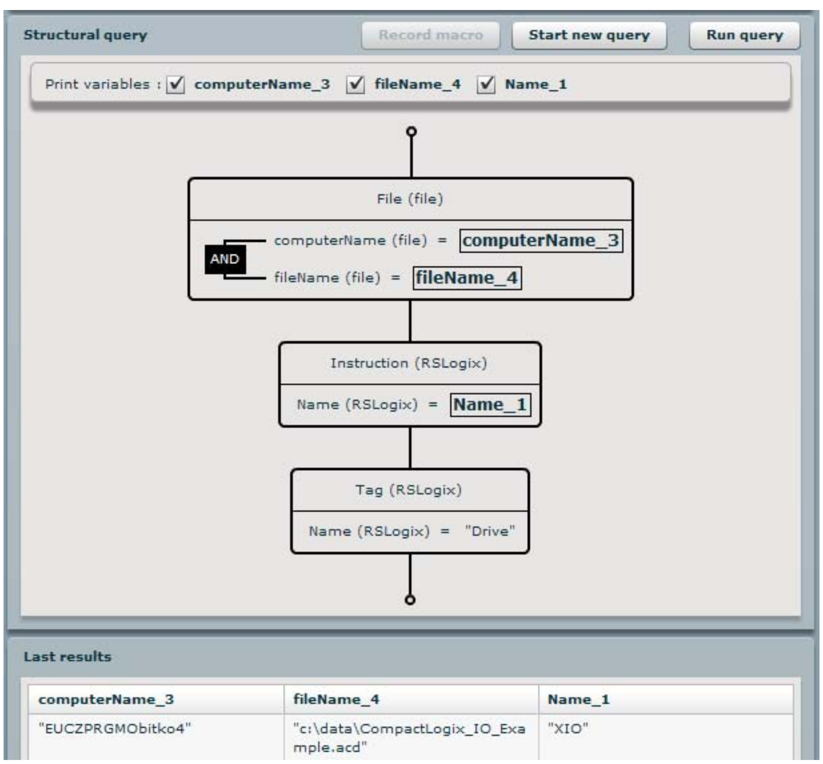
Since we did not find suitable approach to build structural queries as outlined above, we have created an interface allowing to formulate restrictions on classes of objects and to formulate dependencies between them. Sample structural query is illustrated in the Figure 4. As we can see, the approach is influenced by facets – for each object type it is allowed to specify possible values for selected attribute. In addition, multiple object types can be included, and it is possible to include relation between them in the query. One of the notable advantages of the faceted search is the instant evaluation of results – in every moment the user sees results together with changing possible values in facets. In our approach, the same is true – after each change, results are shown, and when making additional constrains, only those attributes and values that appear in objects selected so far are offered.

DIFFERENCES BETWEEN INDUSTRIAL AND WWW-BASED SYSTEMS

Based on our experience with the prototypes described earlier, we can identify areas where the Semantic Web problems are very similar to the problems in industrial systems; however, we can also notice some important differences.

The first difference is that an industrial system is usually designed and described even before the first testing has started, so we are working in much more controlled environment. On the Web, one has to deal with inherent semantical heterogene-

Figure 4. Visualization of query "Find files with instructions that use tag named 'Drive' and show names of the instructions."



ity without any control. In an industrial system, only what the engineers decide to connect is really connected and provides data – there is no such freedom as on the Web where anyone may add and claim anything. This means that the logical models of data are more under control and that there is no need for devices to cheat about their data as the Web pages cheat about their content on the Web to get better ranks in search engines.

On the Web, there are generally no problems with approximate results. The industrial systems often require exact results to exact queries. Based on our experience with structural search it is beneficial to add semantics to data using ontologies defined for specific projects. These ontologies are then used to construct exact structural queries that return results with exact precision and recall. The challenge is to provide simple user interfaces for construction of complex queries, instead of requiring users to learn special query languages such as SPARQL. As we have shown, some of the visualization and query building techniques from WWW environment provide important inspiration for industrial domain applications. The situation is easier for the industrial domain, because the number of ontologies and their size is smaller than on the Semantic Web.

Standardization of ontologies is not generally possible for everything on the Semantic Web. Such effort would even go against basic principles of the Web. However, such standardization makes much more sense in limited industrial systems, at least to some degree. Standardization of ontologies is possible among different vendors; however, there will still be a need for interoperability with unanticipated ontologies – the number of ontologies may be low in an assembly line, however, when systems are connected to MES systems or to other companies to form virtual enterprises, the problem of interoperability will arise. Well founded ontologies and ontologies founded on common upper ontologies will be easier to integrate without significant human intervention. Proper ontology design and interoperability could be achieved more likely in the manufacturing industry than on the general Semantic Web.

The important difference between industrial and Web applications is that industry systems are dealing directly with the physical world. The components and processes to be connected together are physical devices that exist in a physical environment and are bounded by their physical properties. This means that the mistakes in communication or interpretation may be very costly – because of the potential damage of equipment, unnecessary material consumption, or because of delays in delivery of the manufactured product. That is why exact and computationally tractable semantics is needed so that proper results can be guaranteed. This is different from the text search, but similar threats exist in e-commerce or other business applications. Again, we are able to achieve better standardization and to form well founded ontologies, so the task is in this regard easier than in the case of the Web. However, since we know about these constraints, we are forced to prepare for it and in this sense the physical world connection can mean advantage over unprepared and changing WWW.

Despite the differences, we can see both the world of the industrial systems and the world of the Semantic Web have much in common and that the Semantic Web technologies are very well suitable even for applications of semantics in industrial systems.

CONCLUSION

We have summarized state of the art of using ontologies and semantics in industrial domains. We have shown that the Semantic Web research including Semantic Web technologies is directly applicable to industrial domain. We have shown two applications – semantics in multi-agent control system and structural search – that the usage of semantics has impact on industrial systems in a very positive way. In fact, employing semantics and Semantic Web technologies is very beneficial to manufacturing systems and in many cases, straightforward application of WWW technologies to a problem in industrial problem often leads to desired result.

For distributed reconfigurable industrial systems the vision of the Semantic Web services is an important inspiration, and despite some differences, much of the research is directly applicable to manufacturing domain. We have shown how semantics can be exploited from the low level control interoperability through shop floor integration up to the connection to SCADA/MES systems and later to the level of truly computer driven virtual enterprises. As we can see, the internet and WWW technologies are important in the larger control systems particularly when connecting them with human user interfaces or with systems ensuring higher level integration, such as Manufacturing Execution Systems (MES) or Enterprise Resource Planning (ERP) systems.

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KEY TERMS AND DEFINITIONS

Agent-Based Manufacturing Control: Highly distributed and flexible manufacturing control system based on autonomous, intelligent and cooperative entities – agents.

Ladder Logic: The ladder logic was originally invented to describe logic made from relays and is still useful in manufacturing area because engineers and technicians can understand and use it without much additional training.

Material Handling: Equipment used for movement and storage of material, parts and products within a facility or warehouse.

Ontology: Formal explicit specification of conceptualization, in a form of description of concepts and relations existing in a domain of interest, including restrictions, in form that allows automated processing including reasoning.

Programmable Logic Controller (PLC): Special computer with extensive input/output arrangements dedicated to industrial control purposes, such as assembly line machinery control

SCADA/HMI: The Supervisory Control And Data Acquisition (SCADA) systems are used to monitor and control automated processes; part of these systems is Human-Machine Interface (HMI) serving for visualization as well as getting feedback from human.

Semantic Search: Search that uses semantic description of data to disambiguate terms used in queries to return only highly relevant results even for queries that are not stated precisely.

Semantic Web: Extension of the hypertext World Wide Web in which the semantics of information is provided to allow automated searching, understanding and processing of the content.

Semantic Web Services: Semantic enrichment of current Web Services allowing automated discovery, composition and execution of services.

Structural Search : Search that allows utilization of structural relations in data for query building, query evaluation and automated reasoning, but does not offer semantic disambiguation.

Chapter XXXVIII
Towards Process Mediation in Semantic Service Oriented Architecture (SSOA)

Tariq Mahmoud
Carl von Ossietzky University Oldenburg, Germany

Jorge Marx Gómez
Carl von Ossietzky University Oldenburg, Germany

ABSTRACT

Nowadays, it becomes very hard for anybody in the digital world to search and find suitable Web Services fit into his/her needs, since there is a huge amount of data on the Web caused by the enormous increasing of the Web providers and Web Services widespread in this digital community, and one of the most difficulties Web Services have to overcome, in the attempt to use the contents of the World Wide Web, is heterogeneity which is caused by the nature of the Web itself, and has two origins: data or public process heterogeneity. So it is highly required in such environment to have an intelligent mechanism in which every user can search according to his/her needs and later on can fulfill it in a semantic way. The authors will focus in this chapter on the public process heterogeneity which describes the behavior of the participants during a conversation, and propose a solution for dealing with it, explaining the functionality of the process mediator developed as a part of the Web Service Execution Environment (WSMX) and its mediation scenario, and will also apply this proposed solution on Federated Enterprise Resource Planning (FERP) system to get the semantic extension from it.

1. INTRODUCTION

Web Development

The World Wide Web (Web) (Berners-Lee & Calliau, 1990) is a system of interlinked hypertext documents accessed via the internet. With a Web browser, user can view Web pages that may contain text, images, videos, and other multimedia and navigates between them using hyperlinks; the World Wide Web was created in 1989 by Tim Berners-Lee.

According to the extreme growth of information available over the Web, and the powerful development achieved on the basis of World Wide Web, the Web 2.0 was born.

In this new version of interlinked hypertext network, it becomes possible that somebody can have the benefit from the experiments of the others in the same domain, which means that in such an environment like Web 2.0 there is a huge network of information which has the responsibility of enhancing creativity, information sharing capabilities, and most notably, the collaboration among users. These concepts have led to the development and evolution of Web-based communities and hosted services, such as social-networking sites, wikis, blogs, and folksonomies.

Some technology experts, like Berners-Lee, had a lot of reservations on the phrase Web 2.0; Lee had an interview with IBM developerWorks about the differences between the conventional Web (World Wide Web) and Web 2.0, and the discussion was like follows: "Web 1.0 was about connecting computers and making information available, and Web 2.0 is about connecting people and facilitating new kinds of collaboration. Is that how you see Web 2.0?" his point of view was fairly described as follows: "Web 1.0 was all about connecting people. It was an interactive space, and I think Web 2.0 is of course a piece of jargon, nobody even knows what it means. If Web 2.0 for you is blogs and wikis, then that is people to people. But that was what the Web was supposed to be all along. And in fact this 'Web 2.0,' it means using the standards which have been produced by all these people working on Web 1.0" (Berners-Lee, 2006).

And according to that, digital world needs a new way in which the people can interact in a semantic manner, to involve machines support side by side to the human interactions, and this is the main objective of the Semantic Web.

Semantic Web is an evolving extension of the existing Web in a way that the semantics of information and services on the Web must be defined, making it possible for the Web to understand and satisfy the requests of people and machines to use the Web content (Berners-Lee, Hendler, Lassila, 2001).

We are trying to describe in this chapter how we can involve semantic process mediation between machines and humans in order to have benefits from this knowledge in a semantic way by using Semantic Web Services as part of Semantic Web.

The Need of Process Mediation in Semantic Web

If we generally consider that the market is an institution where demands and offerings are coming together, markets also can be seen as a channel to manage the problems of the negotiation between required and available software components (as services) in a very large information system landscapes inside one enterprise or among enterprises.

One of the most significant factors in Enterprise Application Integration (EAI) within the information system world is enterprise integration. This integration can be applied in various management systems like: Enterprise Resource Planning (ERP), Customer Relationship Management (CRM) and Supply Chain Management (SCM).

Service-Oriented Architecture (SOA) is one of the concepts involved in EAI, and this means that there must be a human interaction in order to use Web Services, whereas, if machines have to be involved in this scenario, Semantic SOA (SSOA) will be one of the best solutions.

SSOA is the concept that supports the use of Semantic Web Services, one of its duties is to overcome Web resources heterogeneity problems, since in such digital environment there is a need to deal with the differences in both ways; the way in which the requester wants to consume the functionality of a Web Service, and the way in which this functionality is made available by the Web Service back to the requester, in this chapter we will propose a solution handles these issues.

One of SSOA frameworks is the Web Service Modeling Ontology (WSMO) (Bussler et al., 2004) which initiated the standards related to Semantic Web Services. The objective of this framework is to define a consistent technology for the Semantic Web Services by providing means for (semi-) automatic discovery, composition and execution of Web Services based on logical inference mechanisms.

Web Service Execution Environment (WSMX) (Cimpian et al., 2005), the reference implementation of WSMO, is aiming to provide reference implementations for the main tasks related to Semantic Web Services as suggested by WSMO.

WSMO choreography (Fensel & Stollberg, 2005) will help us to describe the expected behavior of the two parties during a conversation, and it is in fact a formalization of their public business processes. By using these descriptions we will be able to introduce the process mediator, and apply this proposed mediator to the FERP system (one of the Web-Service-enabled Service-Oriented Architecture (SOA) solutions) (Brehm & Marx-Gómez, 2005) to make it possible to adjust the two parties' behavior and to make the communication between them more autonomous, and later on to apply the necessary data mediation scenarios on the system (in our future work). However, the major focus in this chapter is to point out the potentials which process mediator solution offers to enterprise architectures, and to demonstrate the applicability of it inside FERP system to exemplify the activities within the lifecycle of such architecture, and to make the first step towards Semantic FERP (SFERP).

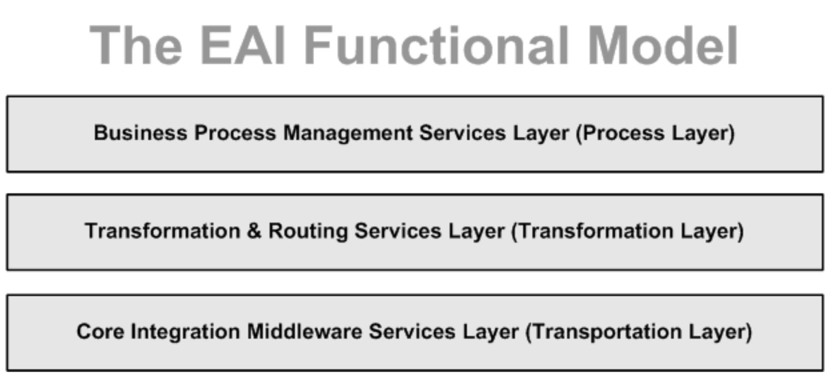
2. BACKGROUND INFORMATION

Enterprise Application Integration (EAI)

In EAI, there are two types of integration: internal and external integration. Internal integration, often referred as intra-EAI, specifies the automated and event-driven exchange of information between various systems within a company, another commonly used term for it is "Application to Application"-Integration (A2A). External integration, referred as inter-EAI, specifies the automated and event-driven information exchange of various systems between companies, it is commonly referred to as "Business to Business"-Integration (B2B) (Bussler, 2003).

EAI solutions can be categorized into three basic layers that make up the majority of technologies common in today's integration solutions:

Figure 1. EAI Architecture layers



Process, Transformation, and Transportation Layers, and Figure 1 illustrates these main layers within EAI.

We can summarize and put some characteristics for each layer mentioned in Figure 1, as follows (Brown, Maginnis, Ruh, 2000):

1. **Business Process Management Services Layer (Process Layer):** It contains tools and components that allow the modeling of discrete business processes across multiple applications. Within this layer there are components for process modeling and process representation support. The purpose of process modeling component is to produce an abstraction of a process model called workflow type that can be either used for improved human understanding of operations within a specific domain or to serve as the basis for automated process representation (Bussler & Jablonski, 1996), in the case of EAI it is used for the latter. Process support refers to the proactive control of the entire process from instancing a predefined workflow type, all the way, to its completion. And when we are talking about process models in EAI, there is a need to make a clear separation between private and public processes, because this separation has the significant role to support the necessary isolation and abstraction between the internal processes within enterprise and processes across enterprises.

2. **Transformation & Routing Services Layer (Transformation Layer):** It includes tools to manipulate data contained in messages between applications. As an application generates a message, components in the transformation layer receive, review, revise, and reroute the message based on a set of rules predefined within the environment. By providing these services, applications do not need to include message queuing, data type matching, and application routing functionality. Instead, application developers can use the same mechanisms across all applications through the use of solutions that fall within the transformation layer. Also this layer addresses the data mismatch either at the lower-level of data type representation or at the higher-level of mismatched data structures. Mismatched data types may arise when two services for example use different binary representation for some data type. Dissimilar data structures on the other hand involve two different structures to represent the same body of data.

3. **Core Integration Middleware Services Layer (Transportation Layer):** It represents the scenarios that allow multiple methods of application-to-application communications. Core middleware techniques and methods can be incorporated directly into the applications that need to communicate with each other. Core middleware, as the name implies, makes up the foundation of most EAI solutions, and it includes database access routines, message-oriented-middleware (MOM), transaction processing middleware (TP), remote procedure calls, and distributed objects. This layer is also responsible for the system- and platform- independent communication between the integration tool and the involved applications, it consists of a common protocol layer and adapters that transform external events in messages and vice versa.

Service Oriented Architecture (SOA)

A Web Service as defined by the W3C consortium is "a software system designed to support interoperable machine to machine interaction over a network" (Booth et al., 2004) and it is the main unit inside SOA.

In concept, there are three main components in SOA architecture (Mahmoud & Marx-Gómez, 2008a):

- **Web service provider:** It creates a Web Service and possibly publishes its interface and access information to the service registry.
- **UDDI-registry:** Also known as service broker, it is responsible for making the access information of both Web Service interface and implementation available to any potential service consumer, and categorizing the results in taxonomies. The Universal Description Discovery and Integration (UDDI) registry, defines the way to publish and discover information about Web Services.
- **Web service consumer:** The service consumer (requester) or Web Service client locates entries in the UDDI registry using various searching operations and then binds to the service provider in order to invoke one of its Web Services.

And Figure 2 illustrates the mechanism of publishing, discovering and binding Web Services in the SOA environment:

So, the role of SOA is to provide a specific Web Service through the internet and make it accessible from a client interface. And a typical example for this scenario is a booking system that uses SOA architecture in order to book a room in a hotel, to buy a flight ticket from an airline company, and to rent a car from a car rental agency…

By extending the concept of SOA with semantics, a formal description of the Web Service functionality will be provided in order to make it understandable by all the involved entities (both humans and machines).

Towards Semantic Service Oriented Architecture (SSOA)

Web Service Modeling Ontology (WSMO)

Web Service Modeling Framework (WSMF) (Bussler & Fensel, 2002) consists of four different main elements for describing Semantic Web Services (see Fig. 3): ontologies that provide the terminology used by other elements, goals that define the problems which should be solved by Web Services, Web Services descriptions that define various aspects of a Web Service, and mediators that bypass interpretability problems.

WSMO is a formal model for describing various aspects related to the world if Semantic Web Services. And it is based on the WSMF concepts. WSMO applies Web Service Modeling Language

Figure 2. The activities within SOA

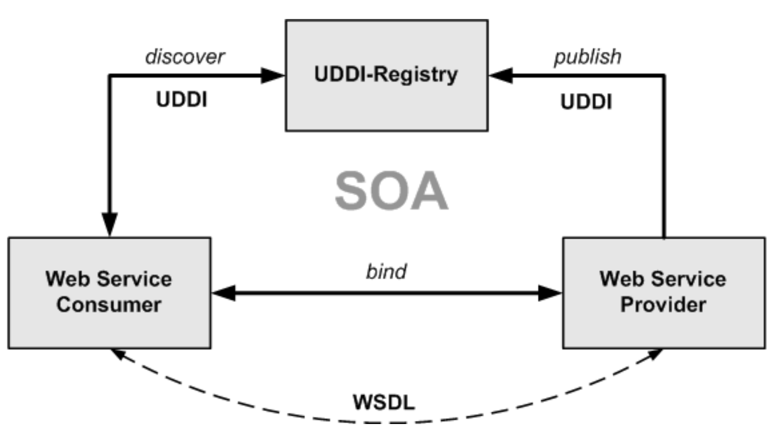
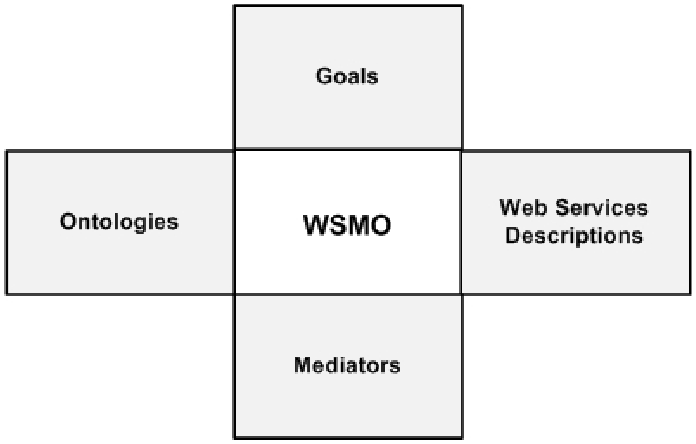


Figure 3. The main elements of WSMF



(WSML), based on different logical formalisms, as the underlying language (Bruijn et al., 2005). Like we mentioned above about WSMF, WSMO defines four main modeling elements to describe several aspects of Semantic Web Services (Bruijn et al., 2007):

- **Ontologies:** Ontology is a formal explicit specification of a shared conceptualization (Gruber, 1993), WSMO ontologies give meaning to the other elements (Web Services, goals and mediators), and provide common semantics, understandable by all the involved entities (both humans and machines).
- **Goals:** They represent the objectives of the service requester that have to be accomplished when consulting a Web Service. They provide the means to express a high level description of a concrete task. A goal can import existing ontologies to make use of concepts and relations defined somewhere else, either by extending or simply by reusing them. The main advantage of using goals is that requesters only have to provide declarative specifications of what they want in order to find the services that providing the appropriate functionality suit into their requirements.
- **Web services descriptions:** Similar to the way that the requester declares his goals, every Web Service capability can be declared. Additionally non functional properties must be defined, and the interface used mediators. Only if the service requester and provider use the same ontology in their respective service description, the matching between the goal and the capability can be directly established. Unfortunately, in most cases the ontologies will differ and the equivalence between a goal and a capability can only be determined if a third party is consulted for determining the similarities between the two ontologies. For this, WSMO introduces the fourth modeling element: the mediator.
- **Mediators:** There are four different types of mediators: ooMediators, ggMediators, wwMediators and wgMediators.
    - **ooMediators:** mediators that have the role of resolving possible representation mismatches between ontologies.
    - **ggMediators** mediators that have the role of linking two goals. This link represents the refinement of the source goal into the target goal or states equivalence if both goals are substitutable.

- ○ **wgMediators** mediators that link Web Services to goals, meaning that the Web Service can fulfill the goal to which it is linked.
- ○ **wwMediators** mediators that are used for linking two Web Services in the context of automatic composition of Web Services.

And as a result, in SSOA there is a need to redefine the three main concepts of the traditional SOA as follows:

- **Service provider:** In it, WSDL can still be in use as a universally accepted interface language, but additionally there is a need to provide another Web Service description like: WSMO, OWL-S or WSDL-S… compliant service description. By doing so Web Service requester will be able to discover services based on formally-defined goals instead of searching only through the directory service and later on selecting the suitable service.
- **Service registry:** The functionality of the service registry (broker) remains the same. The only difference between it and traditional SOA service registry is that it stores semantic service description instead of WSDL description.
- **Service requester:** Service requesters have to publish their desired functionality as semantic goals instead of the traditional way in SOA.

Web Service Modeling eXecution Environment (WSMX)

WSMX is the reference implementation of WSMO and it is an execution environment for dynamic discovery, mediation and invocation of Web Services, it offers also a complete support for interacting with Semantic Web Services. WSMX supports the interaction with non-WSMO Web Services (classical ones), ensuring that the interaction with existing Web Services is totally possible.

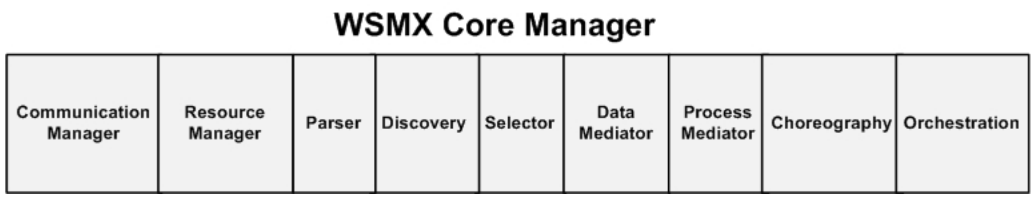
The internal language used within WSMX is WSML, where the capabilities of the Web Services can be described semantically and the Web Service requesters can invoke these capabilities based on semantic goals described also with WSML, and the role of WSMX is to make a matchmaking between semantic capabilities/goals, show the most related Web Services, mediate between Web Service's and requester's ontologies heterogeneity, and invoke the selected Web Service.

And the main components are depicted in Figure 4 that shows the WSMX core manager inside WSMX architecture.

In WSMX core manager there are the following component interfaces (Han et al., 2005):

- **Communication manager:** It has to handle the various invocations that may come from requesters and also to invoke Web Services and retrieves the results of these invocations back to WSMX.
- **Resource manager:** It manages the repositories to store definitions of any WSMO and non-WSMO related objects.
- **Parser:** It checks if the syntax of received WSML descriptions is correct.
- **Discovery:** It has the role of matching the service requester's goal with a service capability stored in any known repository.
- **Selector:** It provides a dynamic selection of the discovered Web Services in the matchmaking process. The selection process is currently based on a limited set of non-functional properties based on the user needs.
- **Data mediator:** It transforms the incoming data from the means of the requester's conceptualization (source ontology) into the means of the provider's conceptualization (target ontology) (Cimpian & Mocan, 2005a).

Figure 4. WSMX Core Manager Components



- **Process mediator:** The role of the process mediator (Cimpian & Mocan, 2005b) is to make the necessary runtime analyses of two given choreography instances and to solve the problem of the possible mismatches that may appear; taking into consideration that we will use a similar process mediator in our new proposed SFERP system.
- **Choreography:** WSMO choreography describes the expected behaviour of the Web Service, and it is in fact a formalization of its public business processes, we will also use WSMX choreography in the proposed SFERP system.
- **Orchestration:** It specifies what each Web Service will actually do during a conversation.

In discovery, selection and invocation functionalities offered by WSMX, mediation can be needed at both data and process level. In this chapter we will focus only on the process mediation.

Abstract State Machine (ASM) and WSMX Choreographies

Yuri Gurevich proposed in the mid-1980s the concept of ASMs, and according to him, ASM consists of states and guarded transition rules. In definition: a state *S* of a Vocabulary (signature) V, defined as a finite collection of function names, is a non-empty set X together with the interpretations of these function names in V on *X* (Gurevich, 1995). So ASM states are not only mere points within the state space, but more precisely an ASM state is a structure in the sense of mathematical logic and is a nonempty set together with a number of functions (operations over the set) and relations.

Related to ASM, we have to make close look at "ground" and "unground" terms in order to have better understanding about ASM concepts. In general, if we take a mathematical term which does not contain any variable symbol, then we can call it "ground term", otherwise we called it "unground term" (Gurevich, 1995).

Also Egon Börger denoted that [we used the term ground model (primary model) for such formulations of "the conceptual construct" or "blueprints" of the to-be-implemented piece of "real world" which "ground the design in the reality"] (Börger, 2003).

Based on ASM methodology, WSMX choreography (Haller & Haselwanter, 2005) interface specification in concept is composed of *state signature*s and *guarded transition*s. Generally, the signature in WSMX is defined by an ontological schema of the information interchanged in choreography interface by specifying the used concepts, relations and functions of it. Conceptually, a *state signature* in WSMX choreography is defined also by its attribute *role,* and there are two types of *roles: grounded* and *ungrounded roles.* Also *role* is defined by an attribute called *mode* which determines whether it is grounded or not depending on the mode that it performs. Within the choreography only an abstract grounding is referenced (the actual physical grounding is resolved in the grounding specification of a Web Service (Kopecký et al., 2007)).

Since choreography interface specification describes the dynamic behavior of the Semantic Web Service, *state signature* can be described using WSMO ontology. And by checking the *mode* attribute of *state signature*'s *role*, the process of who has the right to modify the instances of the concept (the service or the environment) can be controlled. And the *mode* attribute can take these following values (Fensel, 2006):

- **In:** The extension of the concept, relation, or function can only be changed by the environment. And it represents a grounded *role* which has to reference a mechanism that implements write access for the environment.
- **Out**: The extension of the concept, relation, or function can only be changed by the service's owner. It also represents a grounded *role* which has to reference a mechanism that implements read access for the environment.
- **Static:** The extension of the concept, relation, or function cannot be changed. Static modes can only be ungrounded since neither the service nor the environment can change any of the ontology elements.
- **Controlled:** The extension of the concept, relation, or function can only be changed by the service's owner. The difference to the ***out*** *mode* is that it represents an ungrounded *role*.

In the other hand, *guarded transitions* are used to express the changes of states by means of *rules*; and it can be expressed in the following form:

If condition then rules

Where condition is an arbitrary WSML axiom, refers to the state changes regarding to the information space evolution throughout the consuming of Web Service functionality.

And the *rules* actually represent a set of transition rules, consist of arbitrary WSMO ontology instances (*add, delete, update*).

In SSOA spectrum, each action can be represented as one or more transitions, and by using ontologies to model the concepts we can handle the state of the Semantic Web Service. This assumption leads to the issue that we can control the runtime exchanging process schema by using the WSMX choreographies within the process mediator component as a first step towards implementing the SFERP environment.

Federated Enterprise Resource Planning (FERP) System

FERP System Virtues over Conventional ERP System Problems

Before defining FERP system, there is a need to describe the conventional ERP system functionality, list its disadvantages that led to the idea of FERP system.

An *ERP* system is a standard software system which provides functionality to integrate and automate the business practices associated with the operations or production aspects of a company. The integration is based on a common data model for all system components and extents to more than one enterprise sectors (Boudreau, Robey, Ross, 2002) (Rautenstrauch & Schulze, 2003). The main disadvantages of conventional ERP systems are that: in most cases not all of the installed components are needed; and high-end computer hardware is required and the customizing of such systems is very expensive which means that only huge enterprises can apply such complex ERP system to provide business logic of all its sectors.

According to these problems, there is a need to a dedicated system in which the enterprise can fulfill its requirements, and one of these systems is FERP. It allows the separation of local and remote functions whereby no local resources are wasted for unnecessary components. Furthermore, in FERP, single components are executable on small computers which subsides the installation and maintenance costs by decreasing the degree of local system complexity (Brehm, Lübke, Marx-Gómez, 2007).

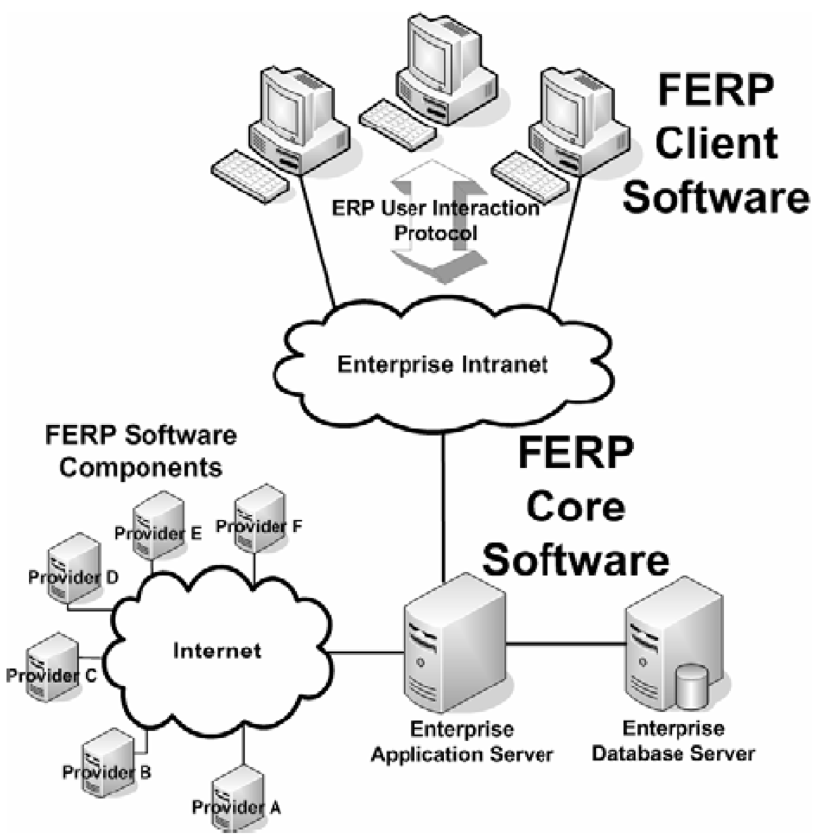
Based to this brief comparison we can notice that the FERP overall functionality is provided by an ensemble of allied network nodes that all together appear as a single ERP system to the user. Different ERP system components can be developed by different vendors (Brehm, Marx-Gómez, Strack, 2007) (Brehm & Marx-Gómez, 2005).

Figure 5 shows how ERP system is supplied by a network of FERP business logic components to provide the needed business functionality.

FERP Reference Architecture

FERP architecture is based on the concepts of SOA, and it is an execution environment for discovery and invocation of enterprise Web Services, it offers also a complete support for interacting with Web Services within the enterprise space or among enterprises. The architecture consists of several subsystems which are interconnected.

Figure 5. Vision of a FERP system landscape where ERP software components can be developed and provided by different software vendors



Because one of the main objectives of the FERP system is to integrate business components of different vendors, all components have to comply with standards which are described as XML schema documents (Brehm & Marx-Gómez, 2007).

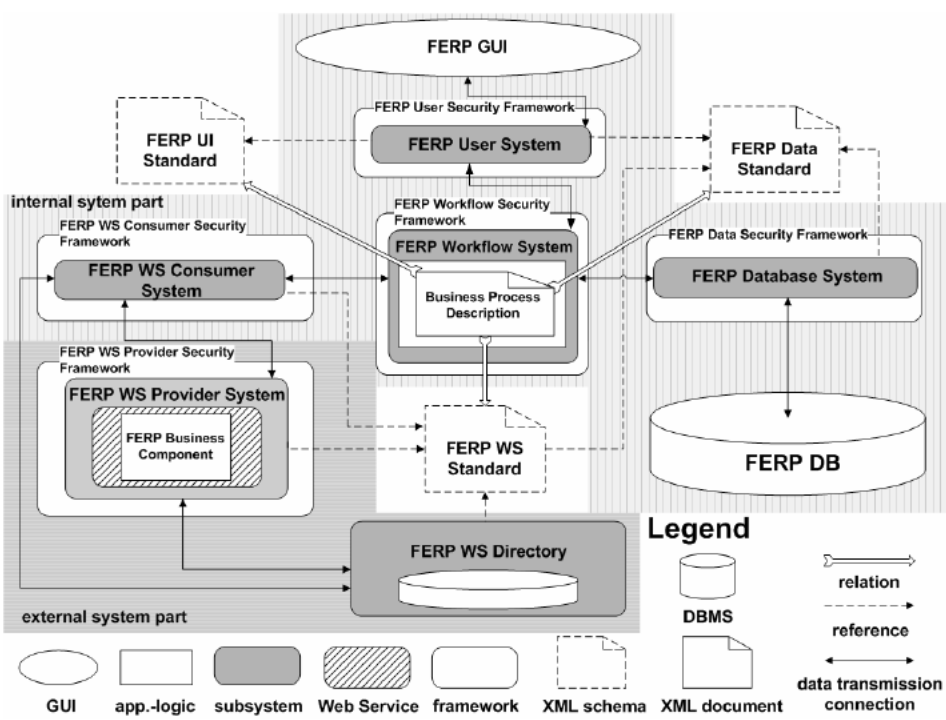
Figure 6 illustrates the reference architecture of FERP system.

And the main subsystems in the FERP architectures are:

- **FERP database system:** Includes the required functions to interact with FERP relational database by exchanging XML messages.
- **FERP Web service consumer system:** Contains XML schema definitions and functions needed for the processes of Web Services discovery and invocation provided by different service providers.
- **FERP Web service provider system**: Contains functions required for providing Web Services compatible with FERP Web Service standard and dealing with HTTP incoming and outgoing user's requests, and has a connection to FERP Web Service directory in order to allow the publication of Web Services.
- **FERP Web service directory:** Its interface has the responsibility of the publication and searching for FERP Web Services based on UDDI standard.

In the SFERP system, Semantic Web Services will be involved within it and the system will be responsible of the matchmaking, filtering results

Figure 6. Reference architecture of FERP System



processes; furthermore it will enable dynamic Web Service composition process by including several Web Services at runtime, and there are two possible scenarios to achieve this: locally inside the enterprise domain by receiving this process from public Web Services directories and implement it inside, or by implementing this process remotely on those directories.

And our focus in this chapter will be on the process mediating issues that deal with the differences in the client and Web Services communication patterns in order to have an equivalent public processes inside the system.

3. PROBLEM DEFINITION

SSOA Advantages over SOA Problems

SOA Service Discovery and Invocation Problems

Within traditional SOA, the problems in discovery and invocation phases can be described as follows:

Since Web Services appear to be more widely adopted, allowing much broader intra- and inter-enterprise integration, the developers will require automated systems for service discovery, enabling further Web Services interaction with even less human effort (UDDI exists precisely for this reason). However, unless the service requester knows the exact form and meaning of a service's WSDL in advance, the combination of UDDI with WSDL and coarse-grained business descriptions is not enough to allow fully automated service discovery and usage.

The public business difference between the requester and the provider processes might arise in the invocation phase of traditional SOA, and there is a need to transformation mechanism between both entities at runtime binding to enable fully dynamic scenario (Brehm et al., 2008).

SSOA Service Discovery and Invocation Advantages

Within SSOA, the discovery and invocation phases can be described as follows:

As we mentioned earlier, the main components in SOA architecture are: provider, registry, and requester, in order to add semantics to these components' interactions, (Li, Lin, Qiu, 2007) proposed a scenario to add semantic matchmaker system to existing UDDI registry, in the other hand, the service provider will add semantics to the descriptions of his Web Services; as well as, the requester will send his request as a semantic goal, and this will be done by using ontologies. In this way, the UDDI will receive a semantic goal and make a matchmaking process with the available Web Services to send the most related results back to the requester based on his needs in semantic and autonomous manner.

In the other hand, using a powerful process mediator between requester and provider at runtime will solve the heterogeneity problems which might arise between their public processes at the invocation phase in order to have a unique and identical public process in the both entities business logic (Brehm et al., 2008).

Definition of a Process, and Process Types

The standard definition of a process is: collection of activities designed to produce specific output for a particular customer, based on specific inputs (Bussler & Fensel, 2002); an activity could be a function, or a task that occurs over time and has recognizable results.

Dealing with business processes, and depending on considered level of granularity, we can consider that each process can be seen as a composition of different transitions or activities.

Also we can differ between two types of processes: private processes and public processes. Private processes, which an organization can execute them internally, and they are used only inside its domain and are not visible to any other entities. While public processes are the processes that represent the behaviour of the organization in collaboration with other entities. In this chapter we are interested only in the public processes; the private processes are used only within the enterprise and nobody has to do with them except enterprise's developers.

Process Heterogeneity Problem

In FERP, every Web Service can be seen as a set of processes and these processes composed of actions. By applying semantic framework like WSMX on it, Semantic Web Services will be involved, and therefore we can use WSMX choreography to represent the public business processes of these services in a way that its actions can be represented as state signatures controlled by guarded transitions rules.

In this new system, WSMX choreography determines the constraints on the ordering of messages sent between service consumer and service provider systems. However, the constraints alone are not enough to determine exactly which message is sent when, this is the role of an orchestration. An orchestration is a specification of which message should be sent when. Hence, the choreography specifies what is permitted for both parties, while an orchestration specifies what each party will actually do (Mahmoud & Marx-Gómez, 2008b); we will use WSMX choreography to apply the mediation algorithm because it describes the behaviour of each partner within a conversation.

In process mediation, behind any interaction, each party has some internal process which manages the resources necessary to perform it (in many domains of application, this will correspond to a business process). In some cases, even though the two parties are able to interact via some protocol, there might be some differences between their processes which mean that this interaction will not succeed. And since the choreographies are built on the scenario of ordering the messages, the process mediator functionalities can be categorized as follows (Cimpian & Mocan, 2005b):

- **Stop an unexpected message:** One of the partners sends a message that the other one does not intend to receive, the mediator should just retain and store it. And it can be sent later, if needed, or it will just be deleted after the communication ends.
- **Inverse the order of messages:** One of the partners sends messages in a different order that the other partner expects them. The messages which are not yet expected will be stored and sent, when it will be needed, in a correct order.
- **Split a message:** One of the partners sends much information in a single message that the other one expects to receive in different messages.
- **Single message**, containing information sent by the other one in multiple messages.
- **Send a dummy acknowledgement:** One of the partners expects an acknowledgement for a certain message, and the other partner does not want to send it, even if he receives the message.

4. TOWARDS PROCESS MEDIATION IN SEMANTIC FERP

Process Mediation Functionality within SFERP

If we take a look on the FERP system architecture, we can notice that it relied on standards in the business process level, and to make the system functionality more extensible and semantic to the consuming system (in addition to keep the conventional behaviour), we will suggest the mechanism of applying WSMX concepts on it through the SOA main phases: discovery, selection, mediation and invocation. We will also apply WSMX process mediator (PM) as a solution to the problem of business process heterogeneity described in the previous paragraph.

WSMX process mediation will deal with the case of how two public processes can be combined in order to provide certain functionality (how two business partners can communicate, considering their public processes), and in the case of FERP, the partners are: FERP Web Service consumer and FERP Web Service provider systems.

The mediation transactions can be described as follows: when WSMX Core Manager receives a message, either from the consumer or from the Web Service, it has to check if it is the first message in the conversation. If it is the first, copies (instances) of both the sender and the targeted business partner choreographies will be created, and stored in a repository, together with the id of the conversation. Otherwise, the conversation id must be determined (in case that it isn't the first message). These computations performed on the message are done by two WSMX core manager components: Communication Manager and Choreography Engine.

After the conversation id had been obtained, the PM receives it, together with the message which consists of concepts' instances from the sender's ontology. Based on the id, the PM loads the two choreography instances from the WSMX Repository, by invoking the Resource Manager component. All the transformations performed by the PM will be done on these instances. In the case that different ontologies formulations have been used for modeling the two choreographies, PM must invoke an external data mediator for transforming the message in terms of the target ontology and this is done by checking value of the attribute *mode*, if it is set to ***in***, for a certain concept, this means that the instance of this concept maybe needed in a future transaction, and all the instances that expected by the targeted partner will be stored in an internal repository (Cimpian & Mocan, 2005c).

PM has to check if these instances (obtained from internal repository) are needed at any part of communication by evaluating the *transitions rules* using *conditions.* The evaluation procedure will check if the instances for that *rule* are expected (an instance is expected when it can trigger an action by changing a *state* or eliminating one *condition* for changing a *state*), only the instances which return a *condition* that cannot be fulfilled are unexpected by the targeted partner. For the expected instances (it is also possible that set of instances can compose a single instance expected by the targeted business partner), the PM sends the instance (message), deletes it from the repository, and updates the targeted business partner choreography instances; and then revaluates all the *rules*, until no further updates are needed. Also one of the PM responsibilities is to check if the sender business partner expects an acknowledgement which the other partner does not intend to send, if so it generates a dummy acknowledgement and sends it back to him.

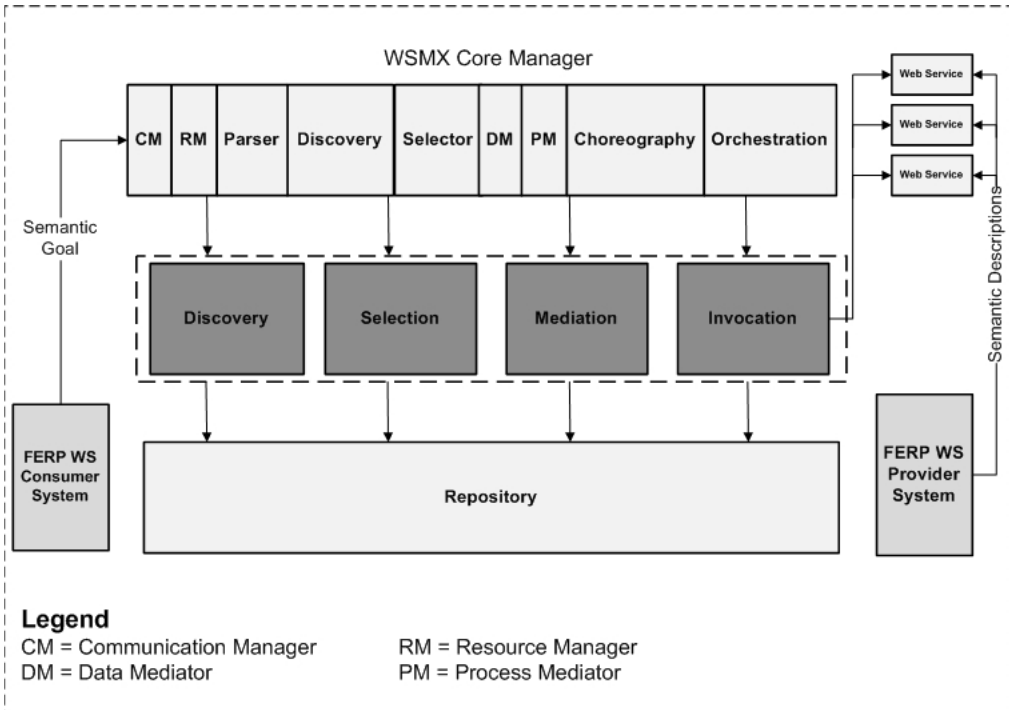
And for better understanding to these transactions, Figure 7 illustrates the overall functionality in the SFERP system and shows how the process mediation takes place between FERP WS consumer and FERP WS provider systems.

Example

In this paragraph and in order to illustrate our idea well, we will give a general example about using choreographies within SFERP, a concrete ERP example will be implemented in our future work, so in this section we will consider some FERP Web Services involved in an electronic shop in order to purchase mobile phones, those Web Services are able to afford mobile phone by providing the name of manufacturing company, model, main specification and price; also the client who wants to invoke such those service.

To keep the example as simple as possible, we will present only some parts of the proposed consumer's and provider Web Service's choreog-

Figure 7. Semantic FERP Overall Functionality



raphies we think that it will be enough to clarify well the functionality of the process mediator. Also, we will consider that some concepts have exactly the same semantic for both the Web Service and the consumer.

In the following paragraphs we will explain firstly the structure of the proposed choreographies and secondly the step by step process mediation scenario that takes place during the conversation between partners, taking into consideration that all the concepts and axioms used in this example are written using WSML language.

FERP WS Consumer and Provider's Choreographies

We will consider that the both parties have the following concepts in their internal ontologies:

- *manufacturingCompany*: The instance of this concept represents the manufacturing company name of a specific mobile phone;
- *modelNumber*: The instance of this concept represents the model number of a specific mobile phone;
- *actualSpecifications*: The instance of this concept represents the manufacturing company's main specifications of a specific

mobile phone like camera, internet connectivity, video, music etc;

- *userSpecifications:* The instance of this concept is very similar to the one in the previous concept, but the difference is that the specifications here are represented from the user's point of view (he can make mixture of specifications) while the previous specifications represent the actual specifications of a certain mobile phone.
- *price***:** The instance of this concept represents the price of a specific mobile phone.

The FERP WS consumer's ontology contains the concept *myMobilePhone*, which has the following state signature:

concept *myMobilePhone*
nonFunctionalProperties
dc#description hasValue "concept of a mobile phone requested by the user, containing the manufacturing company's name, model number, and main specifications of the mobile phone"
mode **hasValue** ***out***
endNonFunctionalProperties
xCompany **ofType** *manufacturingCompany*
nNumber **ofType** *modelNumber*
ySpecifications **ofType** *userSpecifications*

Actually, the *mode* attribute within the FERP WS consumer's choreography has the value ***out*** for the concept *myMobilePhone*, which means that an instance from this concept will be sent to the environment by the consumer. Whereas, for the concepts: *actualSpecifications* and *price*, the *mode* attribute has the value ***in*** since the client expect that he will receive information from the Web Service about the phone specifications with its price. And the *mode* attribute for the concepts: *manufacturingCompany*, *modelNumber* and *userSpecifications* has the value ***controlled*** because only the consumer can take the decision regarding these information about the mobile phone.

The FERP WS consumer choreography (*ferpcc*) has the following *rules*:

?x **[** *xCompany* **hasValue** ?*xCompany_*, *nNumber* **hasValue** *?nNumber_*,
ySpecifications **hasValue** ?*ySpecifications_* **]**
memberOf *myMobilePhone***<-**
?*xCompany* **memberOf** *ferpcc#manufacturingCompany* **and**
?*nNumber* **memberOf** *ferpcc#modelNumber* **and**
?*ySpecifications* **memberOf** *ferpcc#userSpecifications*.

The previous *rule* creates an instance of *myMobilePhone* when the instances from *manufacturingCompany, modelNumber* and *userSpecifications* are created. And the consumer does not expect any input to create an instance of *myMobilePhone* because the *mode* attribute of the concepts: *manufacturingCompany, modelNumber* and *userSpecifications* have been set into ***controlled***.

When the *myMobilePhone* instance had created and sent to the service, instances of *actualSpecifications* and *price* have been expected by consumer, and the following *rules* describe that:

?x **memberOf** *actualSpecifications* **<-**
?*myMobilePhone* **memberOf** *ferpcc#myMobilePhone*.

?x **memberOf** *price* **<-**
? *myMobilePhone* **memberOf** *ferpcc#myMobilePhone***.**

So, and as an overall scenario, the consumer will firstly send an instance of the concept *myMobilePhone* to the service, and expect instances of *actualSpecifications* and *price*, regardless the order of receiving them from it.

And as a response from the service, there are two concepts in the service choreography expected from the FERP WS consumer system which are: *mobilePhone* and *phoneOnUserSpecifications*, and they have the following state signatures:

concept *mobilePhone*
  nonFunctionalProperties
    dc#description hasValue "concept of a mobile phone, having two attributes of type manufacturing company's name and its model number which contains the company name and the mobile phone model"
  mode **hasValue** ***out***
  endNonFunctionalProperties
  xCompany **ofType** *manufacturingCompany*
  nNumber **ofType** *modelNumber*

concept *phoneOnUserSpecifications*
  nonFunctionalProperties
    dc#description hasValue "concept of mobile phone based on the user specifications, containing information about mobile phone, user specifications, actual specifications and price of the mobile"
  mode **hasValue** ***out***
  endNonFunctionalProperties
  forMobilePhone **ofType** *mobilePhone*
  ySpecifications **ofType** *userSpecifications*
  zSpecifications **ofType** *actualSpecifications*
  forPrice **ofType** *price*

Within FERP Web Service choreography, the previous concepts have different values for their *mode* attribute; it takes the value ***in*** for *manufacturingCompany* and *modelNumber* concepts, and the value ***out*** for *mobilePhone* and *phoneOnUserSpecifications* concepts, while it takes the value ***static*** for the other concepts because their instances' values can not be changed within the communication process.

The service choreography (*ferpsc*) has the following *rules*:

?x **[** *xCompany* **hasValue** *?xCompany_, nNumber* **hasValue** *?nNumber_* **]**
  memberOf *mobilePhone* **<-**
  *?xCompany_* **memberOf** *ferpsc#manufacturingCompany* **and**
  *?nNumber_* **memberOf** *ferpsc#modelNumber.*

The previous *rule* creates an instance of *mobilePhone* only when the instances from *manufacturingCompany*, *modelNumber* already exist. The service expects that an input (company's name, model's number) has to be provided by the environment in order to create an instance of *mobilePhone*, because the *mode* attribute of the concepts: *manufacturingCompany, modelNumber* have been set into ***in***, so it sends an instance of *mobilePhone* to the consumer to fulfill his request and send it back to the service.

Another *rule* states that an instance of *phoneOnUserSpecifications* can be created only when the instances from *mobilePhone, userSpecifications, actualSpecifications,* and *price* are already exist. The service expects that only one input (*userSpecifications*) has to be provided by the environment in order to create that instance, because the *mode* attribute of the concept *userSpecifications* has been set to ***in***, while the instances of the other concepts have been already exist and none of them is expected from the environment. This *rule* is described as follows:

?x **[** *forMobilePhone* **hasValue** *?forMobilePhone_,*
  ySpecifications **hasValue** *? ySpecifications_,*
  zSpecifications **hasValue** *? zSpecifications_,*
  forPrice **hasValue** *?forPrice_* **]**
  memberOf *phoneOnUserSpecifications* **<-**
  *?forMobilePhone_* **memberOf** *ferpsc#mobilePhone* **and**

*?ySpecifications_* **memberOf** *ferpsc#userSpecifications* **and**
*?zSpecifications_* **memberOf** *ferpsc#actualSpecifications* **and**
*?forPrice_* **memberOf** *ferpsc#price.*

Later on, as an extension of this example, and according to his agreement, the consumer wants to purchase the selected mobile phone, so he will send an instance of the concept *creditCard* and receive an instance of the concept *creditCard-Verification*, and then he will send an instance of the concept *person* (containing only the name of the person) to receive an instance of the concept *purchaseDone.*

In the other hand, the service will receive an instance of *creditCard* and an instance of *person* (the distinction between the credit card owner and the person who makes the reservation is made internally, and there is no need to publish it in the choreography file) and then it will send an instance of *purchaseDone* to the consumer.

In the previous example we tried to show parts of service and consumer choreographies, where the keywords within the code lines were bold, and the concepts were italic, and the value of mode attribute was bold italic.

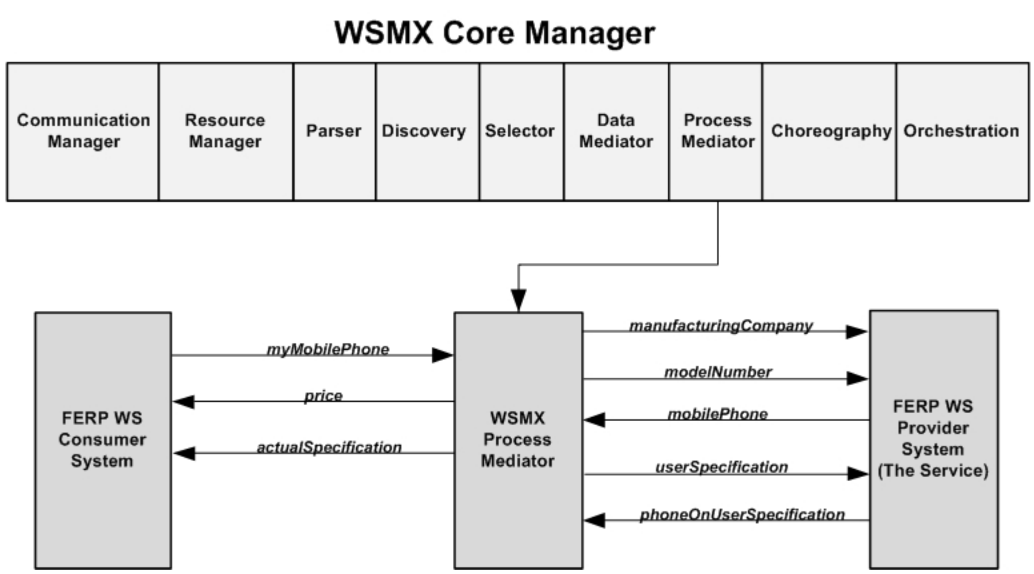
Step by Step Mediation Scenario

We explained in the previous example how the FERP Web Service and FERP WS consumer choreographies have different *mode* attribute values for the same concepts inside. To understand the whole scenario in that example, Figure 8 illustrates the overall interactions between the Web Service and the consumer.

In this Figure the communication process between the FERP WS provider and consumer systems can be explained as follows:

- The consumer starts the conversation by sending an instance of *myMobilePhone.*
- WSMX process mediator (PM) receives this instance and interprets it in terms of

Figure 8. Example about Process Mediation within SFERP



the Web Service ontology, acquiring one instance of *manufacturingCompany*, one of *modelNumber* and one of *userSpecifications*; and stores them in its internal repository.

- According to the FERP Web Service's choreography, all these three instances are expected, but the guarded transitions show that only two of them (instances of *manufacturingCompany, modelNumber*) are expected at this phase of communication. PM randomly sends one of them to the service (since the targeted choreography does not specify which one of these instances are expected), and then deletes it from the repository. Then the second instance is sent and then deleted from the repository.
- Based on the two instances that had been received, service creates an instance of *mobilePhone* concept and sends it to the PM.
- After translating this instance in terms of the FERP WS consumer's ontology, and analyzing both choreographies, the PM discards the instance of *mobilePhone* because nobody is expecting any information from that instance. By evaluating the instances in the repository, PM decides that the provider system expects the previously stored instance of *userSpecifications*; so it sends it to him and then deletes it from the repository.
- PM marks the first rule from the service's choreography and marks the first rule from the consumer's choreography (which means that these rules will not be reevaluated at further iterations). And if there are still unmarked rules, the communication is not over yet.
- The provider system creates an instance of *phoneOnUserSpecifications* and sends it to PM which interprets it in terms of the consumer's ontology obtaining one instance of following concepts: *manufacturingCompany, modelNumber, mobilePhone, price userSpecifications,* and *actualSpecifications*. *manufacturingCompany, modelNumber, mobilePhone* instances will be deleted since nobody expects them anymore, the *price* and *actualSpecifications* instances are then sent to the consumer; the order of sending them is not specified in the requester's choreography, so the PM randomly selects one of them, sends and deletes it from its repository; and then the corresponding rule had been marked.
- The second instance is sent and deleted at the second evaluation of the instances stored in the repository. By sending this instance the rule had been marked.
- PM checks if all rules are marked; since they are, the communication is over.
- PM the deletes both choreography instances from the repository.

5. CONCLUSION AND OUTLOOK

In this chapter the main focus was to show how we applied WSMX process mediator to FERP system to get the new SFERP, and we showed how the heterogeneity problem at the public business process level can be solved by using WSMX choreographies, which represents the behaviors of the participants within a conversation. And as a conclusion the communication scenario between FERP consumer and FERP provider systems, by applying that kind of semantic process mediation, is represented in autonomous and semantic way in order to involve humans and machines side by side.

Our further research will focus on the development of the data mediation scenarios inside such system, and also a concrete example inside the ERP world has to be implemented after finishing some theoretical researches regarding semantic SOA.

Prototype implementations of the future will have to show the practicability of those concepts.

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KEY TERMS AND DEFINITIONS

ASM: A state-based architecture that represents state by algebra as a non empty set together with number of functions and relations changing their values by guarded transition rules which ultimately model the changes of the state.

ERP System: An ERP system is a highly integrated software system representing different types of business application systems.

FERP System: A federated ERP system is an ERP system which consists of system components that are distributed within a computer network, and it is Web-Service-enabled SOA solution.

Ontologies: Represent the key element in WSMO, firstly to define the information's formal semantics and secondly to link machine and human terminologies.

Process Mediation: Is the mediation scenario for solving the problems of heterogeneity between two participants' business processes during a conversation.

Semantic SOA: An architectural style that enables the use of Semantic Web Services and within it data structures are expressed in ontologies in order to create a distributed knowledge base.

SOA: An architectural style that guides all aspects of creating and using business processes, packaged as services, as well as provisioning the IT infrastructure that allows different applications to exchange data from the operating systems and programming languages underlying those applications.

WSMO Choreography: Web Service choreography defines actually its usage interface; choreographies in general define how several Web Services interact in order to perform a unified business goal.

Chapter XXXIX
Social Networks Applied to E-Gov: An Architecture for Semantic Services

Leandro Pupo Natale
Universidade Presbiteriana Mackenzie, Brasil

Ismar Frango Silveira
Universidade Presbiteriana Mackenzie, Brasil

Wagner Luiz Zucchi
Universidade de São Paulo, Brasil

Pollyana Notargiacomo Mustaro
Universidade Presbiteriana Mackenzie, Brasil

ABSTRACT

The technological advances establish new communication forms between people and have also reached the government sphere and its activities, improving access to information and allowing greater interaction between citizens through C2C (Citizen to Citizen) Services. Based on these aspects, this chapter presents a proposal for software architecture, using a social network to map the relationships and interactions between citizens, accounting and storing this knowledge in a government ontological metadata network. Using UML notation (Unified Modeling Language) for Software Engineering process and Java platform for development, a software prototype was modeled and developed in order to manage and handle e-Gov-driven social networks, using ontological metadata to computationally represent the social ties. This prototype is also capable of providing graphical display of social networks, enabling the identification of different social links between citizens, creating a tool intended for government agencies, since it allows a quantitative analysis of information in the social network.

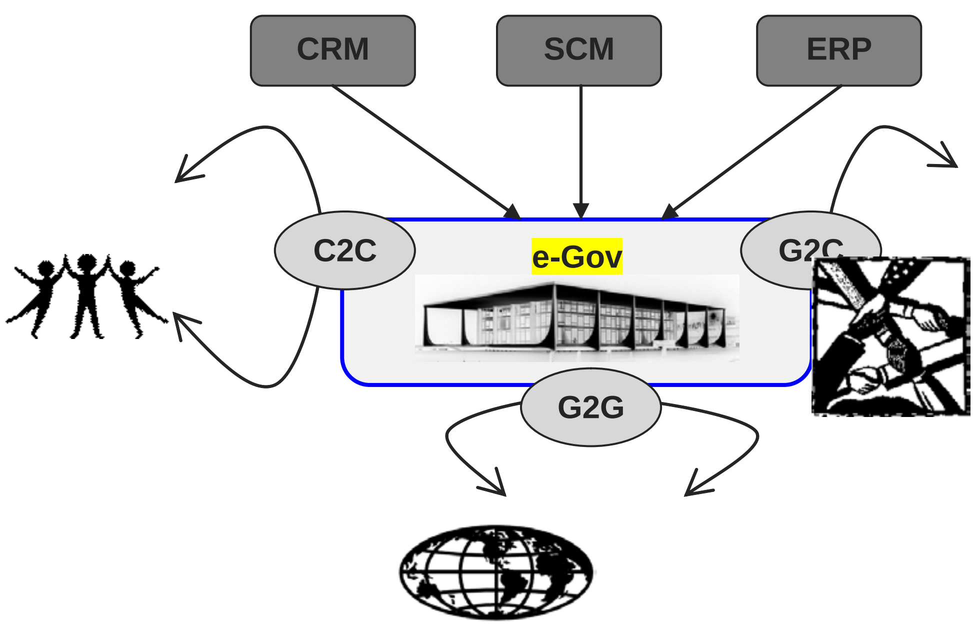
INTRODUCTION

The accelerated advances of Information and Communication Technologies (ICT) have facilitated information exchange among people, geographically separated or not. The availability of faster, computer-mediated interaction devices and technologies enabled the emergence of new kinds of relationships among people, establishing the concept of virtual communities (Rheingold, 2000).

Similarly, governments have been following the above mentioned technological trends, as a way to improve the services they are meant to make available to their citizens, or even for training civil servants in order to improve the decision-making process. This progress enabled the emergence of a new concept for such strategies of computer-mediated governance, often called e-Government (briefly, e-Gov).

These new strategies of using computer-based solutions for improvement of governmental actions have led governments to look for digital convergence through the integration of different systems (G2G), providing faster and clearer information to citizens (G2C), creating solutions to a more participatory politics with the community (C2G) and promoting interaction and integration among citizens (C2C). The development of such structures should take into account the ability to provide high-quality services, besides facilitating an efficient integration between citizens and government agencies, thus making them each time more similar to CRM (Customer Relationship Management)-based systems (Sang et al., 2005). Such e-Gov systems must also handle massive volumes of data, a considerable number of actors, as well as the multiple variables involved in procurement and financial transactions in a similar way to SCM (Supply Chain Management) systems. Another aspect that must be implemented efficiently is the standardization and management of operations and processes, similarly to the functionalities normally found in an ERP

Figure 1. e-Gov as a merge of CRM, SCM and ERP systems



(Enterprise Resource Planning). Figure 1 shows how the merging of such different systems could result in more efficient e-Gov systems.

E-Gov systems that are targeted directly to citizens must promote social integration and must also have tools to help people to meet their needs. A possible way to achieve this goal is through the implementation of adaptive systems that are able to modify themselves according to each information and data inserted into them. Through the use of technical analysis (Hanneman, 2005), each citizen could be represented as an actor in a network; interactions and relationships among them could be represented as relational ties, thus forming an one-mode network.

Knowledge distributed among citizens of a network could also be classified and categorized through metadata, and stored into ontological databases. Thus, ontology-driven computational agents would be able to make inferences about such data and, with this kind of semantic analysis, dynamically expand the social network, consequently extending the relationships of each actor.

Based on the information available through the network, each citizen connected to the system will be able to search and find people which have common needs and interests to discuss possible solutions for individual or common problems. In this context, a social network could be easily viewed in its graphical form, making easier the task of creating groups of citizens, which would be a useful tool for governments to examine the issues discussed in society, and to assist in the creation of more effective public policies.

In this sense, this chapter is organized as follows: first section presents the concept of electronic government, as well as the related stages, platforms and services. Second item deals with definitions, organization and usage of Social networks in the context of electronic government. In the third section it is presented a proposal of an ontology-driven representation and extraction of knowledge in social networks. Fourth item details the development and application of a methodology to implement the previously proposed architecture, showing some tests and results. Finally, last section presents some final comments and indications of future work.

STAGES AND SERVICES IN E-GOV PLATFORMS

As previously stated, ICTs provide new tools and solutions that are changing the processes of governing. Through these innovations, governments are able to create ways to reduce bureaucracy in their processes, modernizing legislation and making faster and clearer the actions of executive, legislative and judiciary branches. These strategies, investments and concepts are commonly grouped under the name of e-Government (e-Gov), as before mentioned. Analyzing the presence and development of e-Gov in several countries, it is possible to identify four main stages, commonly numbered from 1st to 4th (Layne & Lee, 2001)

The first stage, called *Presence* or *Cataloguing*, is characterized by the assembly of electronic information in an unstructured way, with no interactive elements. Each government agency publishes the information on web sites, forming a sort of online catalog. There is no integration among such information, which often leads to the problems of misinformation or, at least, information replication.

In the second stage, named *Interaction* or *Transaction*, information is presented better integrated and organized. In this stage, it is possible to download forms and other types of documents, access links to related pages, among other common functionalities. Citizens are also able to submit suggestions and questions to the responsible for the information, creating a bidirectional way of communication.

The third stage, *Exchange of Values* (*Information*) or *Vertical Integration*, is characterized by a set of processes that can be performed completely online. This is available to citizens in online systems, which enable, for instance, the payment of accounts, taxes, electronic registration in public education systems and some sort of tools for distance learning. Due to the volume of information system' processes required by this stage, these are also elements that promote the integration of different databases, as database management systems that are optimized to operate with distributed databases, components and distributed objects, among others technologies.

In the last stage of development of e-Gov, *Integrated Services* or *Horizontal Integration*, the changes are increasingly more visible and more complex. The government has usually many portals organized by functions or themes. In this stage all governmental bases are integrated and each change in a system must be propagated to other systems.

To achieve each one of these stages of development in the e-Gov-platform, it is necessary to achieve different service' levels in order to update governmental actions, leading to more effective participation of citizens and corporations.

Sang et al. (2005) divide e-Gov systems into six major areas of focus:

- **Government to Citizen (G2C):** Addresses on-line services provided by the government with the aim of providing to citizens pieces of information on procedures for legal proceedings, request and make requests for documents, among others.
- **Citizen to Government (C2G):** Refers to the provision, by the government, of services that enable citizens to introduce a flow of information from them to govern agencies.
- **Citizen to Citizen (C2C):** In this kind of service, the government acts as a provider of integration and interaction between citizens, this occurs through the provision of services and systems that facilitate the exchange of information and interaction.
- **Government to Business (G2B):** Relies on the provision of business services that usually are focused on facilitating and expedition and shipments of documents and information labor and tax, thus promoting more transparent, agile processes.
- **Government to Government (G2G):** It is intended for integration of governmental agencies, thus unifying and facilitating data transfer and internal processes between them. This sort of service could be also be used to promote cross-country integration, for instance, in common market-based economies or political block, as European Union or Unasul, in South America.
- **Government to employer (G2E):** Involves features intended to facilitate the work and enable public services to dialogue with employers, in order to expand the job offers, discuss labor taxes and so on.

In general, the organization of governments is often based on a hierarchical structure, with subdivisions, agencies, ministries and departments. All this structure is barely conducive to solve the real needs citizens have in a timely fashion. One possible solution to this problem is to provide citizens the necessary tools, based on C2C services, so they could establish relationships, though virtual, with other citizens. Through this integration, it is possible to create social networks of cooperation, thus facilitating each citizen to find other people who have, or already have had, the same needs and so being able to collaborate with them.

Next section will explain this kind of collaboration.

SOCIAL NETWORKS OF CITIZENS

By considering the relationships and interactions between people, organizations, groups, institutions, etc., besides establishing a parallel with methods, theories, models and applications normally used for networks analysis, it was coined the term Social networks (Wasserman, 1994). These networks have nodes (or "actors") and specific types of connections. Actors can represent citizens (or social groups), and the relationships between each of these elements may be represented by the connections or relational ties. These social ties between actors could symbolize different kinds of relationships or even the flow of information and resources. Thus, individuals connected to the network could gain and provide access to information or other resources, expanding the opportunities for interact, share or learn (Knoke, 1982).

In order to conduct a more detailed analysis (and at different levels), some key concepts of social networks must be observed: actors, relational ties, dyads (a pair of actors and their relational ties), subgroups, groups, relationships and the network itself (Wasserman, 1994).

Actors refer to any social entities tied together through social relationships and could represent citizens, social groups, cities, countries, government agencies, and so on. This definition allows the grouping of actors into clusters in order to facilitate the study and use of specific analyses. **Relational ties** represent the connections and relationships between the actors of a social network. With the definition of the characteristics of each link, it is possible to define the types of relationships between actors, such as the feelings one person has about another (such as affection, friendship, etc.), or the flow of resources between actors (economic transactions, information exchange, etc.). Physical connections between individuals, cities, states or countries (streets, roads, bridges, etc.) could also be represented by these ties.

Dyads are considered the fundamental social networks' units, formed by two actors and the ties between them. Its study is of utmost importance in the context of the relational aspects in social networks. Through the study of the links and dyads it is possible to identify and classify the relationships of actors in a network, describing them sometimes as central actors, who are involved in many relations with other actors. These central actors are more visible to others, and thus have a higher degree of prestige, identified through the number of links that arrive on and depart from it.

In this context, social networks can be categorized into two groups: Whole and Ego-centered networks. Whole networks can be studied in accordance to the actors involved and the nature of the relationships that they have: one-mode networks or two-mode network.

One-mode networks are formed by a number of actors of the same type, as individuals, organizations, communities, nations, countries, etc. The relational ties among these networks are commonly represented by an index of relationships between dyads of different network levels.

On the other hand, two-mode networks have the focus of study in the relationship between two different types of actors, or between one set of actors with a type of event. The first performs an analysis of links between actors of different types. The types of actors studied in these networks may be the same ones described in one-mode networks.

By analyzing actors and their relations, it can be observed that there is a flow of information and knowledge in the social network. Actors that are part of more than one community could have a continuous learning and benefits from all these communities (Hannerman, 2005), creating a continuous information flow between them.

The knowledge inherently present in social networks can be organized and stored through ontological metadata. By structuring this knowledge in an ontology-driven manner, it would be possible to provide members of a social network different ways of solving problems more effectively, using only the information already made available by other members, and semantic processing to refine that knowledge.

ONTOLOGY: PROPOSAL OF KNOWLEDGE REPRESENTATION FOR E-GOV PLATFORM

The term Ontology has been used in Computer Science from the beginning of the 1990's (Russell & Norvig, 2004) in Artificial Intelligence area, for computational knowledge representation, knowledge engineering and natural language processing. More recently, the notion of ontology has been expanded to the areas of information retrieval on the Internet (as Semantic Web, for instance), knowledge management and development of intelligent educational systems. Therefore, it is computationally possible to represent a particular area through ontological databases, so that communication between people and computers could take place automatically (Swartout, 1999). In this sense, computational agents can share knowledge increasing the relationship that they might have.

To better understand the Ontology concept, several researchers have made their contribution in order to improve this definition, describing concepts and creating new categories to facilitate the construction and use of ontologies. Gruber (1993, p. 3) says that "an ontology is a explicit specification of a conceptualization"; Swartout (1999) also refers to ontology as a shared concept and explicit phenomenon of some thing in the world, described by relevant concepts. Thus it is understood that an ontology describes a field of knowledge in an explicit way, using the relationships that exist between the concepts.

Similarly, an ontology can also be a specialized vocabulary in any field (Chandrasekaran, 1990). However, these vocabularies qualify only the concepts present in a given ontology, which means that this definition makes clear that an ontology is independent of the language in which it was modeled, so that you can translate the concepts of an ontology from English to Portuguese, for example, without changing its essence. In another sense, the ontologies refer to the knowledge base that describes a field.

Besides, according to Berners-Lee (2001), to have a proper knowledge representation, it is necessary to achieve three types of interoperability:

- *Structural interoperability*: Provides the representation for different data types, allowing specify types and possible values for each form of representation;
- *Syntactic interoperability*: Provides precise rules to promote the exchange of data on the Web;
- *Semantic interoperability*: Enables the understanding of data and their associations with other data.

In that sense, it is also possible to classify an ontology in different ways and classifying it in different levels in order to refine the analysis and enable the acquisition of knowledge in a more precise way (Araújo, 2003), as shown below:

- **Generic or top-level ontologies:** Describe general concepts such as space, time, matter, object, event, action, etc., which are independent of a particular area or problem;
- **Field ontologies:** Express conceptualizations of particular fields, describing the vocabulary related to a generic field such as medicine and law.
- **Task ontologies:** Express conceptualizations on the resolution problems regardless of the area where they occur, that is, describe the vocabulary related to an activity or generic task, as diagnose or sales;
- **Application ontologies:** Describe concepts dependent on the field and the particular task. These concepts are often the roles played by entities in the field when carrying out certain activities;

- **Representation ontologies:** Explain the underlying conceptualizations of the formal representation of knowledge.

Complementing this classification, it is also possible to identify five basic elements that define ontology (Perez, 2002): concepts, relationships, functions, axioms and instances.

The wider use of ontologies has made it possible to address different types of problems in various areas of knowledge as Semantic Web, data mining and e-Government systems (Natale, 2008). The e-Government applications that are from the second stage of development have repositories of data and data-processing capacity with volume of information and knowledge in proportion to the size of the population that uses these services.

An example of these applications is the internationally recognized and rewarded Brazilian system of income tax collection. This system has about 600 million records, powerful security features, tools for decision making, identification of fraud and access of approximately two million users. According to the Coordination of Technology-General of Revenue, it is considered the largest database of the world (Receita, 2006).

The development of ontologies for governmental area must produce shareable structures and must provide interoperability in the semantic level. For this, it is necessary to create metadata with vocabularies specific to the context, structuring the field, to allow computational agents to infer new facts and enlarge the knowledge base.

As governments' computational systems will be reaching higher levels of development, complexity and an on-growing base of knowledge, a fertile field for new technology projects appears, including those ones that rely on semantics to perform their tasks. One example is the use of an ontology field of e-Government to store and represent knowledge in a social network formed by citizens. A computational agent committed to this ontology could, through semantic analysis, help citizens to find other citizens in the social network that could, in a collaborative manner, assist to the solution of various issues.

A related work can be found on the OntoGov project, which specifies a platform composed of meta-ontologies with the objective of promoting the development of systems for e-Government services (Ontogov, 2007). In this platform, the domain ontologies consider a high-level ontology, building, in this way, meta-ontologies. From that basic meta-ontological base, it is possible to define information ontologies to represent the knowledge related to flows in services that provide pieces of information to citizens.

It is also possible to use ontologies to establish interoperability between different systems, processes and services. This is the proposal of another related work, the SmartGov platform (2007). In this platform, it is possible to achieve the integration of various areas and government departments, through a knowledge-based system available on,Internet, and directed to the public as end user (Smartgov, 2007).

This type of semantical analysis of knowledge in the social network can work to identify central citizens in a network. This identification can still identify and define characteristics such as degree of influence and importance of each citizen in a social network, creating a tool of social analysis to recognize the leaders of a city, state or country.

Based on theoretical references and on this overview on the use of computational tools in e-Gov, the next item describes a proposal for a system based on C2C social networks and ontology.

DEVELOPMENT OF ADAPTIVE SYSTEMS FOR C2C BASED IN NETWORKS AND ONTOLOGY

Solutions developed for C2C services must manage a large set of variables, besides every information from every citizen. With that, databases are expected to be each time more complex, making harder the task of extracting and handling, in a optimized way, the knowledge inside. Such a context encourages the use of ontologies and different ways to represent knowledge, as a manner to process such data efficiently.

Tools Used

This section shows the possibility of developing an e-Gov low-cost, design pattern-based, scalable, easily maintainable system which would be able to communicate to others systems. In this sense, a technology-independent architecture was modeled, according to UML (*Unified Modeling Language*), looking for plataform-independence, programming language-independence, easy customization to different requirements from each government, besides being easily expandable.

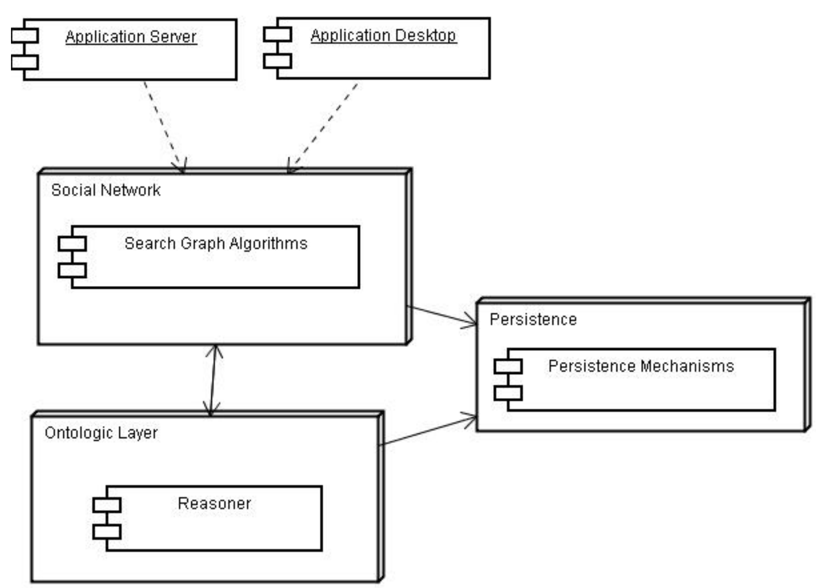
The diagram shown in Figure 2 presents the proposed architecture for a C2C services-based system. Such architecture is composed by three tiers, allowing the development and integration to diverse platforms, making easier the component reuse.

All parts of the system were developed on the Java platform. Such a platform provides a layer between application and operating system, named Java Virtual Machine (JVM). JVM is responsible by interpret the pre-compiled source code, manage memory and threads, intermediate communication and system calls, so providing platform-independence for applications.

Java platform also specifies Java programming language, which follows the object-oriented paradigm, thus allowing faster actualizations, motivating programming practices with high levels of reusability, promoting the use of design patterns and offering a large amount of APIs with diverse functionalities (SUN 2008).

Regarding to Figure 2, Ontologic Layer defines a metadata base and mechanisms used to knowledge representation, providing methods and inference logic that could be used by any computational agents. This data repository stores metadata using a set of OWL namespaces (used

Figure 2. Proposed architecture



to facilitate the properties description), based in XML-Schema (W3C, 2004). With this structure, it is possible to represent explicitly vocabulary terms and semantic relationships among them.

In order to obtain a better expressivity of metadata, while keeping integrity and computational decidability, it was used the OWL-DL sub-language, which has all characteristics refered above. Due to the strategies of modularization used, based on design patterns, it is possible to implement the application in any other language or tools that are metadata-aware.

This layer also has a module responsible for semantic analysis, using Jena API. This API has a handler for RDF triples: (subject, predicate, object), as well as a processor for ontological information expressed in RDF-Schema and OWL. With the use of inference mechanisms, as well as tools for metadata creation, representation and handling that are provided by Jena API, knowledge present in the network is meant to be represented by syntactical, structural and semantical interoperability, allowing the reuse of resources and semantical properties, making easier the sharing of information among computational agents that are committed to the ontology.

Utility algorithms are implemented in Social network layer as tree search algorithms, as well as structures responsible to stores and handle the social network, the citizens and their relationships. This layer allows the implementation of various algorithms, as graph search and minimal path generators, for instance, in a easy and quick way, depending on the specific necessities of each government.

Persistence layer uses different strategies and APIs to store data from other layers, as utilities for creating image files, specialized libraries for XML files and so on. Through a unique interface, it is provided a transparent access to the other layers, in order to store and retrieve necessary data to the system.

By keeping a consistent encapsulation, Presentation layer defines strategies and access interfaces, allowing different system and client applications to have access to specific system's modules, in a platform-independent way.

With this architecture, citizens and governments would have access to social tools provided by the system, through different applications.

Description of Application Operation

Based on typical characteristics and services of an e-Gov platform, this section shows an implementation of a C2C service, aiming to exemplify a real-world application.

The application uses information as addresses, professional activity, marital status, language, educational level, family income, and so on, which are provided by a citizen when he/she logs in the system. Such data are dealt as ontological elements, used to build an ontological database. After the building of this metadata repository, it is possible to dynamically expand a social network.

Figures 3 and 4 shows the dynamics of a social network when a new citizen logs in the system.

Figure 3 exemplifies in detail a particular example geographically located in São Paulo, Brazil, where it is possible to observe a citizen named 'Leandro' that lives in 'Casa Verde' neighborhood. This neighborhood is located in a region named 'Zona Norte' (north zone). The relationships among neighborhoods and zones of the city are stored in an e-Gov domain ontology. In this way, it is possible to assign proximity levels among different regions and neighborhoods of a city.

In Figure 4, when the citizen 'Diego' logs in, informing that he lives in 'Santana' neighborhood, the system, through the domain ontology, identifies that 'Santana' is part of 'Zona Norte' in São Paulo city. After this semantic processing, the social network is augmented, with the creation of a link of 'interacting' type among 'Leandro' and 'Diego', due to the fact of living in the same region of the city.

Figure 3.Social network, before including a new actor (NATALE, 2008)

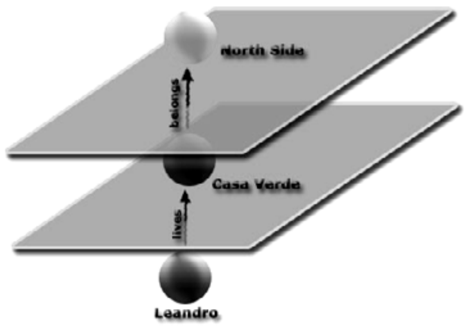
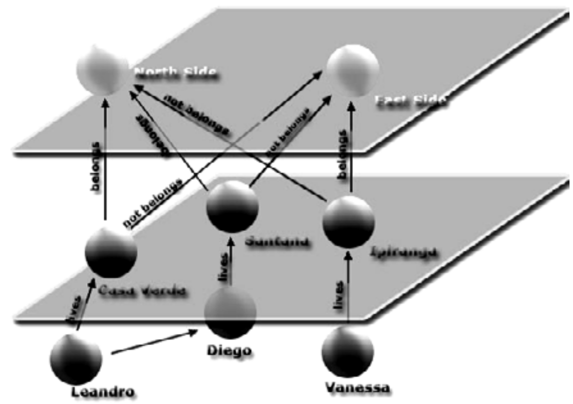


Figure 4. Social network, after including a new actor (NATALE, 2008)



Still in Figure 4, citizen 'Vanessa' logs in the system informing that she lives in 'Ipiranga' neighborhood. By a semantic search on the ontological base, the system identifies that such neighborhood is part of the region known as 'Zona Sul' (south zone). Figure 5 shows a map of São Paulo city's neighborhoods, in order to clarify this example.

Since 'Vanessa' does not live in a neighborhood in the same region as to other registered actors, the social network controller, after using the information provided by ontological layer, don't create an 'interacting' relational tie among 'Vanessa' and the other citizens presents in the network. Nonetheless, this does not forbid that other information provided by citizen 'Vanessa' would allow her to establish other types of connection to other citizens.

This example also shows the multi-dimensionality of the social network graph. Looking in a dimension, there are actors of the same type (citizens), and their relationships, thus forming an one-modal social network. In a second dimension, there are actors from different types (citizens and neighborhoods) and their relationships, thus forming a bi-modal network.

Exemplification of Results Obtained

In order to exemplify the usage and flexibility of the system, it was created an Web-based interface, as seen in Figure 6, which shows the form for citizens' registering. Data obtained after the fulfilling of this form are refined by ontological layer, and afterwards the citizen in inserted in the social network and connected to other citizens according to the information provided.

Only after registering, citizens have access to search functionality (Figure 7), developed in order to allow him/her to perform a search for information in the social network. System is meant to refine the information given by a semantic search in ontological database, looking for citizens that have in their records some information that have some semantical kinship.

With target citizens identified, social network layer, by using Dijsktra's algorithm (Cormen et al., 2001), looks to find the shortest path among these target citizens and the citizen that realized the search. This algorithm was adapted to find the shortest path from only one origin and equally-

Figure 5. Map of São Paulo city showing geographic proximity among actors

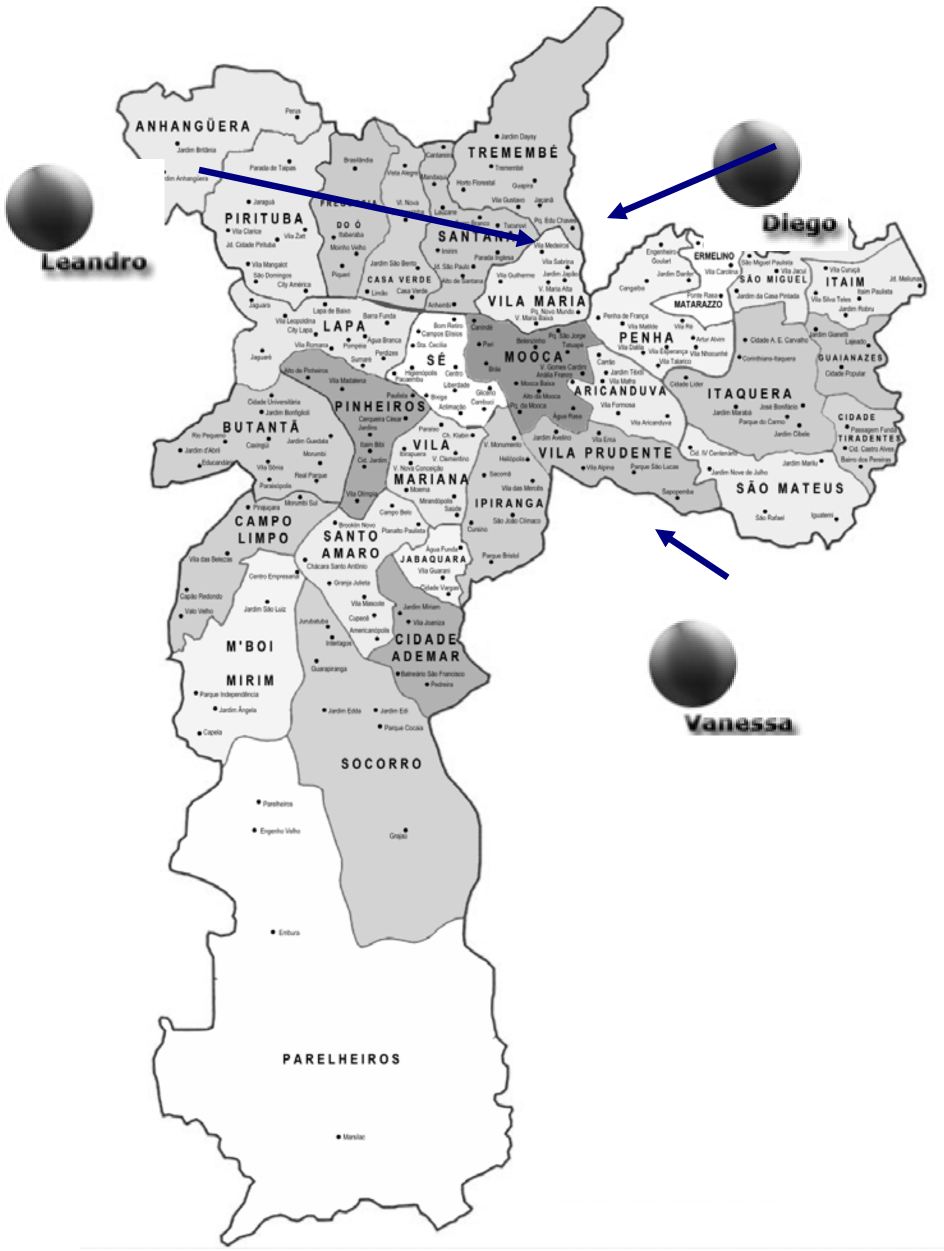
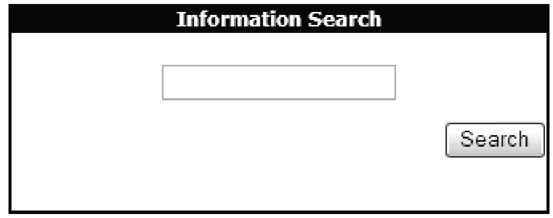


Figure 6. Citizen's sign-in interface (Natale, 2008)

Figure 7. Simple Interface for Information Search. (Natale, 2008)



weighted edges. JUNG (2007) – a Java-based API made to deal with graphs and social networks, is used to generate an applet that exhibits the path to be taken by the citizen to those citizens that could be collaborating to solve his/her questions.

The developed system has also functionalities directed to public administrators, providing different views for the same social network, which was implemented by the before mentioned applet. A JPEG image can also be generated.

Figure 8 shows an example of a complete social network, with different links established, categorized by different labels to make visualization easier.

Figures 9 and 10 shows different kinds of views a government agent could have over a social network, being able to select only the social links of interest. With these specific views, the public administration is able to perform more precise analyzes, by observing social network from the viewpoint of a specific social link. With this, it is possible to observe different social groups presents in different regions of a city, state or country, which could be used to assist in the planning of more effective public policies.

In order to simulate the execution of the system, some tests were performed with fake and real data. In the first experiment, the system was made available in a Web-based environment, running under a servlet container (Tomcat 5). All the system was packed in a single *.war* file. Fifty citizens registered themselves with their own information. None of the pieces of information was mandatory, and the time spent for each citizen to register was stored.

With semantic refining of each piece of information, a search for citizens with semantic proximity was performed each time a new citizen signed in, in order to find citizens to be connected to him/her. Figure 11 shows the time spent for each registering process (average time was 59 sec).

In a second experiment, other fifty records were fulfilled, but in this time all fields of information were required. This was done in order to simulate a more complex scenario for the social network layer, as well as for ontology layer. This experiment produced a complete graph, with every citizen connected to all others. In a similar way, the total time spent for each citizen registering was calculated, with average time of 85 sec. Figure 11 shows the results.

After these experiments, the ontological module was disconnected from the rest of the system and a new experiment was realized with

Figura 8. Complete Social network (Natale, 2008)

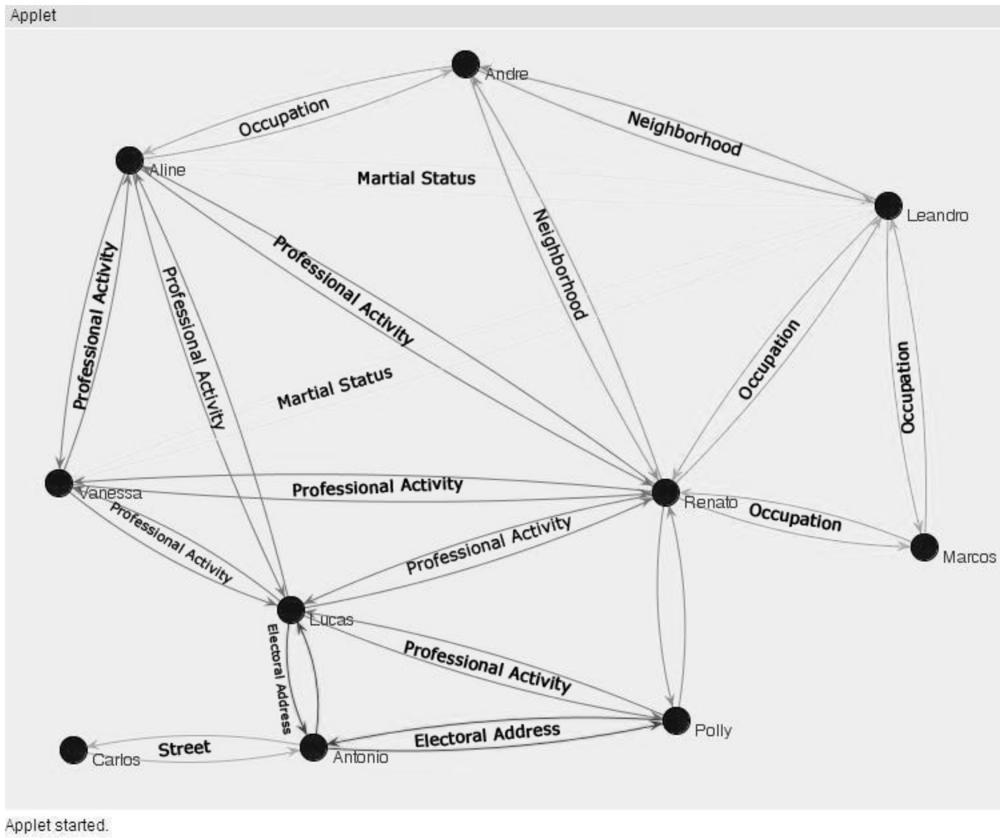


Figure 9. Social network with Professional Activity ('Atividade Profissional') ties (Natale, 2008)

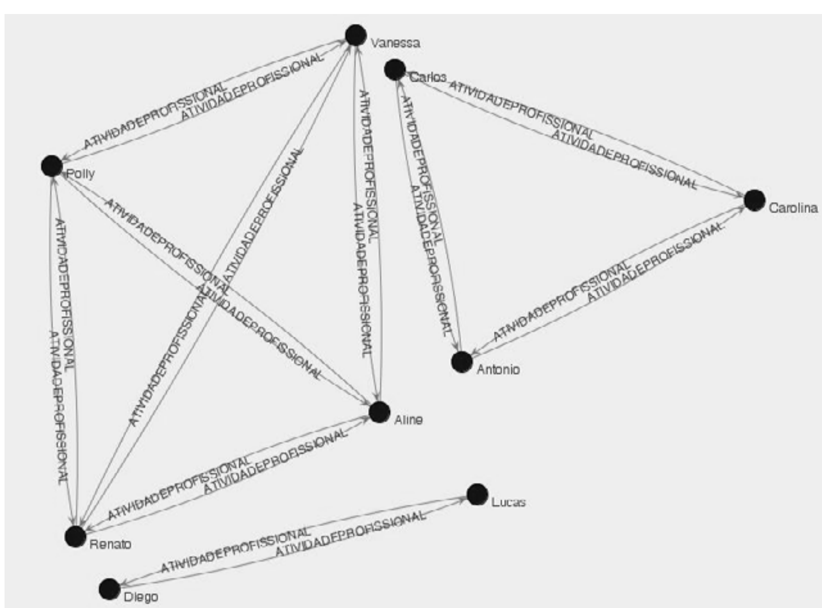


Figure 10. Social network with Electoral Address ('Domicílio Eleitoral') ties (Natale, 2008)

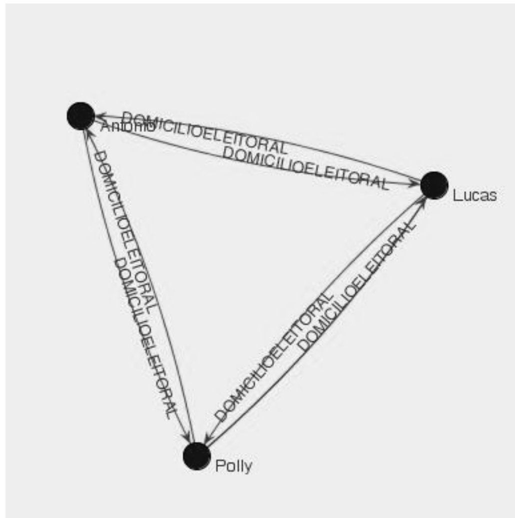
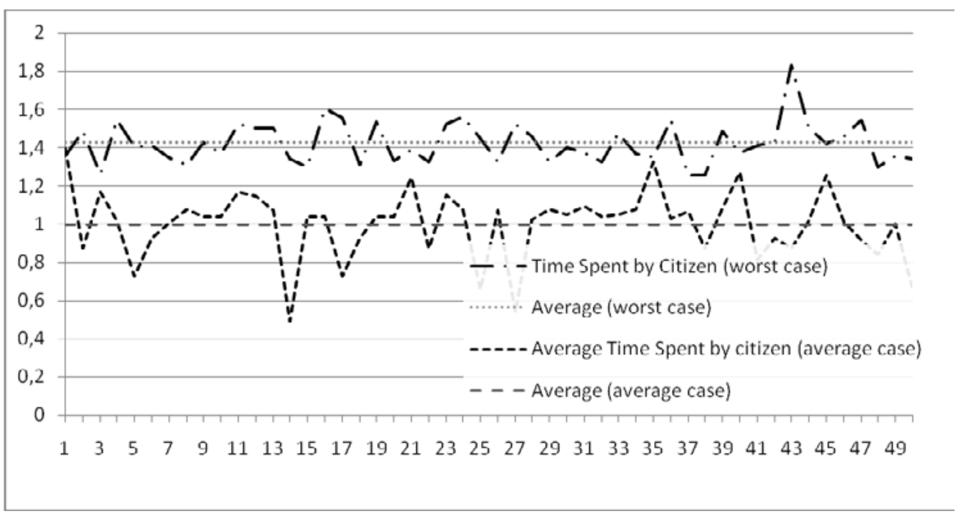


Figure 11. Performance of the experiments (Natale, 2008)



the same amount of data, but with no semantical refining. Average time in this case was 10 ms for each record, showing the huge amount of time that is needed for semantic establishment of the social network.

Finally, the last experiment consisted in performing a search for information in a real-world social network, created by real citizens. In this experiment, the system validated the provided information and refined them using the methods available in the ontological layer, which allowed the performing of a breadth search in the social network in order to find the citizens that had some desired information. After their identification, Dijkstraís algorithm, provided by social network layer, was applied, generating the path a citizen must follow in the network.

FUTURE TRENDS, FINAL CONSIDERATIONS AND FURTHER WORK

E-Gov future trends related to C2C services involve the improvement of ontological databases techniques. In the same way, with Web 2.0 development, it is relevant to point out the need for proposals that adhere to this concept. Regarding to the expansion and easiness of access by multiple platforms, as mobile and desktop, it is necessary also taking into account different ways to present information, according to the device being used. Another trend that must be noted is the dynamic refreshing of information in a way that they could be easily geo-referenced, making easier the integration with GPS systems, for instance. Finally, there is the important necessity of security policies regarding to citizensí information, avoiding information replication or leaking.

Through the studies and comparisons that were shown, it is possible to identify citizens as the main interested in governmental technological advances. Thus, it is extremely relevant to develop e-Gov solutions that follow a service-oriented model. In the case of the present chapter, it was focused the development of a C2C architecture driven to citizen dwelling in a certain area, providing low-cost, easy-maintaining tools to help quotidian information search and problem solving.

In e-Gov context, this work presents the possibility of creating a social network that was built and is able to be expanded using a domain-oriented governmental ontology.

Such structure asserted the possibility of building robust low-cost systems that are able to help citizens to reduce bureaucracy in electronic environments. The governmental strategies used to e-Gov system development must be evaluated and carefully implemented ñ since they are meant to deal with people’s lives ñ and thus reaching a meaningful social effect.

Academically, the present work contributes in the sense that it presents solutions and analysis that are based in a social-governmental context. It dealt with social network analysis, computer-based knowledge representation and retrieval, as well as software design patterns.

As a recommendation for further works, there is need of deeper analyses of the previously mentioned social networks, as well as new implementations based on these new analyses. Such implementations could present some improvements by optimizing the ontology-based mechanisms through multi-thesaurus structures or parallel or distributed engines for inference. These engines could also be internationalized, being language-sensitive. Analyzing the interfaces made to citizens, it is necessary to look for elements that make them more user-friendly, thus improving the access and straightforwardly the utilization of the system.

Another issue to be pointed out is the fact of handling and storing private information, which is meant to be kept in a secure way. Security solutions must be discussed, including basic cryptography, in order to guarantee the privacy and safety of this information in governmental platforms, improving systems’ reliability. Other possibility is to apply techniques related to distributed agents to manage the information traffic on the digital e-Gov social network and analyze package exchanges.

Furthermore only authorized users can perform searches by the system. The data of users should also be stored on servers protected by the guidelines of network security organizations, with access only released to authorized analysts.

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KEY TERMS AND DEFINITIONS

Adaptive Systems: Systems characterized by the possibility of adapting themselves according to the behavior of user or some other environmental changes.

Graphs: Structures formed by nodes and edges that connect pairs of vertices, allowing the study of relations between elements belonging to determinate data set.

Knowledge Representation: Abstract model of a knowledge domain that permits the construction of computer-based systems, knowledge databases or expert systems.

Metadata: Characterization/description or information about data. It is commonly used to describe, manage, and localize some data in a data store.

Ontology: Formal specification of entities' representation (as objects, concepts and so on), making possible to establish relationships among terms and attributes through the use of semantic approaches.

Social Networks Analysis: Interdisciplinary area that combines Math, Computer Science and Sociology, among other aspects (as psychological, geographical, and so on) to determinate kinds of relationship between actors – like people, groups, communities and organizations.

Virtual Communities: Groups of people determined by similar interests that establish contact and interact through use of online communications tools and/or virtual environments.

Chapter XL
Ontologies and Law:
A Practical Case of the Creation of Ontology for Copyright Law Domain[1]

Claudia Cevenini
CIRSFID, University of Bologna, Italy

Giuseppe Contissa
CIRSFID, University of Bologna, Italy

Migle Laukyte
CIRSFID, University of Bologna, Italy

Régis Riveret
CIRSFID, University of Bologna, Italy

ABSTRACT

This chapter introduces the reader with the specificity of the development of a particular type of legal ontology, that is ontology of copyright law. The process of the development of this ontology (ALIS IP Ontology) should be seen as a miniature guide for anyone who will pursuit a goal to create an ontology for any sphere of law. In this chapter the development of the copyright ontology is not addressed separately as such, but in vaster perspective, analyzing not only particular problems that the development of the legal ontology implies, but also looking at the ontology development issues in the light of the general relation that the law (and intellectual property law in particular) has with the IT domain.

1. INTRODUCTION

Where does the term "ontology" come from? This term was introduced by metaphysics[2], which, according to Aristotle, is divided into two directions of study: studies of existence as such and studies of eternal and immaterial entities. For the latter studies the term "rational theology" was applied, while for the former, the term "ontology" was introduced in XVII century: the illuminist philosopher D'Alembert (1717-1783) defines ontology as the branch of philosophy that studies the general properties (like possibility, existence or duration), shared by both spiritual and material entities (Rossi, 1996, p. 240).

This Handbook is dedicated not to the philosophical ontologies though. In this chapter we present the reader with the different kind of ontologies: the ontologies that enable the functioning of the Semantic Web. This chapter focuses on the ontologies developed for a particular domain, that is a legal domain. We describe the legal ontology dedicated to the intellectual property (IP) law, that is ALIS IP Ontology, on which our research group is still working on.

This chapter is organized as follows: Section 2 describes the role the Semantic Web plays in solving the problems of legal domain, with the emphasis on the legal ontologies that provide a big help in this problem solution (section 2.1). Section 3 is dedicated to the particularity of the domain our ontology is addressing, that is intellectual property law. Section 4 introduces the ALIS project to the reader in order to explain what is the purpose and the role of the ALIS IP Ontology. Section 5 is entirely dedicated to explain ALIS IP Ontology: we confront it with other ontologies of IP law domain, such as IPROnto and ICLOnto. The chapter ends up with the conclusions.

2. LAW AND THE SEMANTIC WEB

Law has two major problems today: "handling the complexity and types of legal knowledge, and having reasonable ways to store, retrieve and structure a great amount of legal information" (Benjamins, 2005, p.1). These problems are much more evident in the light of technological development. Naturally, information is a key to success everywhere, not only in legal campus. Nevertheless, law is also the field that has a direct and powerful influence in society: from the citizens to the organizations, from the families to the public administrations. All the lawyers have to know a lot of information, to choose the right resources for retrieving it, to manage it, to know how to apply it and so on. The technological explosion does not cease to make more and more information available. The problem now is not to get the information, but to manage it. And in law this problem is quite an urgent one, considering the quantity of norms, regulations, directives, rulings, codes, statutes, acts, decisions that are created, emanated, abolished, changed, updated, delivered every day.

What are the risks of this situation? The main risk is the so called Information Overload (IO) phenomenon. This situation happens when the lawyer is unable to handle the information to make a decision. In such case he gets overloaded: unable to process the information, to decide, to remember, to link the data and to react to the information he already has. In such a state, the errors usually occur and the price for such errors could be very high.

Furthermore, the legal information should be known not only to the lawyer, Everyone who is retained to be a person (legal or natural) under the law has to have a basic knowledge about the legal framework, or, at least, be able to orientate himself in it. Some specific professionals such as doctors or civil engineers should know further specific norms, which regulate their procession campuses. Of course, it does not mean the we are all supposed to know the law at the level the lawyers know it. Not at all. It simply means that we have to have a certain common knowledge about the laws. This is an endless legal cobweb which winds us round and we cannot do anything.

So what can be done to help the lawyer to manage the legal information and to avoid an IO? (Noyes, 1995, p. 1) claims that we have to cure ourselves with what made us ill, that is IT.

A helping hand is the one of Semantic Web also known as machine-readable world wide web (WWW), which will enable the automatic extraction of the necessary information (from a monstrous quantity of the unnecessary one). In the Semantic Web the research bases not on the keywords but on the content, which is automatically understandable and processable (thanks to the www documents' annotation with meta-information) by the computer.

The Semantic Web today is concentrated in several areas (like data-integration, convergence with Semantic Grid and knowledge management) but very few applications are destined to the areas of mobility, context awareness, and large scale semantic search: as (Van Harmelen, 2006, p.5) puts it, the Semantic Web applications are concentrated on closed communities (mostly companies, among which Vodafone, Amazon.com and Google), while the general public is left apart. Such situation is explained by (Cardoso, 2008, p.6): in order to be adopted, Semantic Web needs to promote its unique value proposition for specific target groups, such as industrial enterprises and other companies. Thus, the logic is that in order to win general community's favour, the Semantic Web has first of all to win the one of economic community. Perhaps, it would be right to say that the conquest of the legal community could be called the second step towards the general success of the Semantic Web. In other words, the Latin saying *divide et impera* is quite at home here: the Semantic Web divides the community into a legal, economic, etc. and conquers one community at a time. We could say that the legal ontologies are the right weapon in order to make lawyers accept the Semantic Web.

2.1 Ontologies in Legal Domain

Ontological problem is simple and, according to (Quine, 1953, p. 1) could be expressed in three words: "What is there?" The answer is "Everything", or "There is what there is". For example, scientific ontologies ask what should, in the light of the current science, be considered as existing. More specifically the scientific ontologies are based on the accepted scientific theories, each of which is made of specific technical terminology (such as "ionic bond" in chemistry or "atomic lattice" in physics). This terminology implies further ontological questions on whether accepting the certain theories means also accepting the terminology and believing that it has references in the real world, that is the ontological question is: "Does atomic lattice exist?"[3] or "Do the entities introduced by the scientific theories are real?"[4]

Could we claim that the same logic applies to the legal ontologies? The answer is no. Legal ontology, as the scientific ontology, is made of specific terminology but here the similarities run out. Following the thought of Quine, we should admit that in law we do not have to ask whether the contract exist, as we know that it exists. The law addresses not the nature, but the entities we, humans, created. Thus we know that these entities exist[5]. Furthermore, ontological engineering is concerned with knowledge capturing, thus, in legal domain, the ontological engineering is concentrated on capturing the legal knowledge.

Other point of view on how legal ontology distinguishes from the other ontologies, is offered by (Benjamins, 2005, p. 10): the legal ontologies are different because they have to cover a lot of common sense physical, mental, social concepts. Indeed, legal ontology on the one hand includes "responsibility", "duty" and "right", on the other, it deals with "article", "judge" and "fine"[6]. As (Benjamins, 2005, p. 10) puts it "in its normative view, law is concerned with overt behaviour, but in assigning responsibility to individuals, mental concepts like intention and predictability play a crucial role".

Whatever view we will prefer, the main problem is the same: to clarify legal concepts and their relationships and find their place in a big puzzle that the legal framework is. For this purpose the computer science offers the best tool, and ontology engineering is a discipline which directly addresses the problems of ontology building. In fact, (Guarino, 2005, p. 1) explains how the views towards ontologies have changed in the last decade: "ontology is no longer perceived as an arcane branch of metaphysics, the province only of philosophers; the study of ontology now fits squarely into the study of modern computer science and informatics. Building ontologies is now an essential activity that underlies nearly everything we do in the development of computational systems".

Unfortunately, the computer scientists do not agree among themselves what the ontologies stand for. We propose two (one laconic and one more detailed) definitions. First one is "Specification of conceptualisation" which could be called the most famous definition of ontology proposed by (Gruber, 1993, p. 199). The conceptualization is intended as the simplification of the world. The second definition is "a set of terms of interest in a particular information domain and the relationships among them" (Mena, 2001, p.5). Substantially it is possible to draw a parallel with the philosophical point of view on ontologies. From a more technological point of view, however the ontologies are defined as "semantically rich metadata capturing the information content of the underlying data repositories"(Mena, 2001, p.5).

But what do the ontologies do practically? The functions of ontology are defined in (Hanh, 2006, p. 4) and are the following: first of all, the ontologies provide a predefined set of terms for exchanging information between users and systems. Secondly, they provide knowledge for systems to infer information which is relevant to user's requests. Thirdly, the ontologies work out information classifying, filtering and ordering it and fourthly, the ontologies work on the arranged information through the indexing. Generally the ontologies contribute to elevate the level of application domain's completeness. The specifications of these four functions are peculiar to each domain, and the legal one is no exception. The survey (Cardoso, 2007, p. 28) presents with the most popular practical purposes that the ontologies are used for: in almost 70% of cases, the ontologies are applied to share common understanding of the structure of information among humans and computers, while 56,3% use the ontologies for the reuse of the domain knowledge. Both of these purposes are easily applicable to the legal domain ontologies.

But how do we decide that the legal ontology is valid? A part from quite general criteria of parsimony in use of primitive terms and transparency, (Valente, 1995, p. 42) proposes to adopt the same criterion that we use to value legal theory, that is to analyze the existing legislation and to confront it with the position of the theory: if the legislation and this position correspond to each other, the theory is valid, if not, the theory is not valid.

Other criterion of the legal ontology's validity is its capability to clarify ontological assumptions of the law: the ontology is valid as much as it is able to represent the legal knowledge both from the epistemological and pragmatic points of view.

Further criteria for the valid legal ontology are comprehensiveness and correctness. The latter criterion implies the relation many-to-many, that is that each term in law can correspond to many terms in ontology and vice-versa. What is the sense of this relation? This relation enables to express the meaning of the legal term on the basis of a certain case, use or situation. This means that the legal term will not have one and only one corresponding term in the ontology, but will have many, each of which will depend on the context where the legal term needs to be used.

Proceeding with the analysis of the role of ontologies in legal domain, we cannot avoid mentioning that the ontologies in legal domain could be also seen as a tool which helps to solve one of the problems concerning the creation of legal knowledge base systems (LKBS): the problem of the open texture. Open texture is a characteristic applicable to any general term of natural language: according to (Hart,1965, p.149) such concepts have a central "core" of meaning and "penumbral" meanings around it. The example of Hart is a term "vehicle": its "core" meaning includes the automobiles, while the "penumbra" includes bicycles, because it is not clear whether the bicycles are really vehicles or not. The decision whether to include a a term among "core" meanings of more general term is done by judges.

(Valente, 1995, p. 59) claims that there are two types of open texture concepts: first type is called *incomplete definition* (also called *world knowledge concept*) , which means that the concept provides with some but not all necessary conditions to apply it (the bicycle satisfies some but not all conditions to be vehicle). In the copyright law domain, such concept is a concept of copyright work[7]. Usually the copyright law does not provide with the clear and exact definition of what the copyright work really is. The list of copyright works is usually indication of what is for sure a copyrightable work, but this list is not an exhaustive one (we will turn back to the problem of exhaustiveness of this list later), so we know that a book is copyrightable work, but this does not enable us to affirm what the copyright work really is. The *incomplete definition* concepts thus are placed in the domain ontologies and not in the upper ones. The second type is called *primitive concept* (also called *common sense concept*) which does not have the definition and whose application depends on the person who applies it (such as time, space, consciousness). These concepts are usually placed in the upper ontologies and not in the domain ones. In copyright law domain, the primitive concept could be the concept of property: usually we define this term using the common sense: for example, we could define "property" as an abstract something that someone possesses and this concept of property is placed not in the copyright law domain ontology but in an upper legal ontology[8].

(Valente, 1995, p. 60) claims that the treatment of open textured terms should be divided between the computer and the humans: a system should be able to recognize and distinguish these two types of open texted concepts, while their classification and interpretation should be done mainly by the users of the system. Thus, from the ontological point of view, the problem of such terms has to be solved, even if "ontology can never substitute a description of the conceptualization in a natural language, but only support it, or add to it, be working as a device in which some of the ideas are verified for completeness and perhaps coherence" (Valente,1995, p.79).

The question is whether the problem of open textured concepts could be solved with the help of ontologies? The problem is quite a hard one, but nevertheless some possible solutions are already elaborated: for example, (van Kralingen, 1995, p.112) solves this problem introducing the concepts of *definition, deeming provision* and *factor*: each of these terms can define a open textured concept, while (Quast, 1996, p. 43) proposes a generic model for abstract representation of collective knowledge (and the open textured concepts are the concepts of collective knowledge), which is called *qualification model.*

3. SPECIFIC LEGAL DOMAIN: INTELLECTUAL PROPERTY LAW

This paper addresses the specific domain of law, that is Intellectual Property (IP) law, which is sometimes defined as "law governing rights in information" (McJohn, 2006, p. 6) What is so special about it?

First of all, some clarifications are necessary. IP law is divided into several sub-branches as copyright, patent law and trademark law. Our focus falls upon the first of these sub-branches, the copyright law[9]. Copyright is defined as "a legal device that provides the creator of a work of art or literature, or a work that conveys information or ideas, the right to control how the work is used" (Fishman, 2006, p. 6). This sub-branch of IP law is also sometimes called the law which protects "the beautiful" (in the contrast with the patent law, which protects "the useful"). To tell the truth, the "beauty" of copyright and the "utility" of patent law is not that simple to distinguish today: the software is a good example of this[10].

What about the copyright and the ICT? The European Commission has hinted different times and in different occasions the importance of healthy interaction between the intellectual property rights and innovation[11]. Indeed, the technological impact asked the copyright for the fast re-estimation of its concepts introducing new ones (such as multimedia creations) and abandoning the old ones (such as restriction of circulation of the physical objects which incorporate the creations). ICT opens new ways of communication and divulgation of the copyrightable works, underlines new dangers for the legitimate use of them, proposes innovative ways to express one's creativity, enables more people to learn about human creative potentials and gives rise to numerous problems[12]. The copyright is undergoing the transformation process, which is a direct result of the new phenomenon that is called information society. The biggest challenge for the lawyers from this point of view, is to set down the regulative framework which enables the copyright owners to maintain the rights they possess without any alterations or losses.

Some authors think that whatever changes ICT brings to the copyright domain, it will never change one aspect of it, that is the creation. This aspect is intrinsically linked to the person, who cannot be substituted with the machine (Cardia, 1996, p. 9). Some computer scientists do not agree on this and propose quite a different scenario[13].

The fear of copyright is to remain motionless in front of the technological tsunami as mere principles which are known (or at least suspected by) to (almost) everyone but followed by no one. They might remain such if the copyright will fight the technology rather than use it. It is true that all branches of law undergo the effects of ICT, nevertheless there is no other branch of law that would be so deeply impacted by those effects: in fact in other branches of law the ICT might cause new procedural solutions, new measures or new tools to facilitate the work, but only the intellectual property law is thrown into confusion and needs to revise its conceptual basis.

The ICT challenges and at the same time offers new opportunities both to the community and to the single authors of works of mind. The challenges have to be overcome and the opportunities have to be exploited. The studies dedicated to the legal (IP included) ontologies are one of the ways to face the challenges. In this context, we present computer system called ALIS to solve problems in different contexts like conflict prevention, alternative dispute resolution, law making or regulatory compliance in the domain of intellectual property law.

4. ALIS: THE GENERAL OVERVIEW OF THE SYSTEM AND THE ROLE OF ONTOLOGIES IN IT

Our ontology makes part of the group of ontologies foreseen by the ALIS (Automated Legal Intelligent System[14]) project.

What is this project about? From the general perspective, this is the alliance of two worlds, the legal and the computer science ones. The outcome of this alliance will be a further proof of the benefits that law gains welcoming technological innovations which come from such scientific fields as game theory, knowledge representation and legal reasoning. From more specific perspective, ALIS is not aiming to address the law in general, but

IP law specifically. The importance of this legal domain has already been addressed above.

ALIS system is the system which aims at facilitating the access to and the use of legal IP law systems in the broadest sense of this term. Such access and use will lend a hand in improving normative compliance with laws and regulations and will assist the evolutionary process of the legal systems.

ALIS addresses four legal contexts: regulatory compliance, conflict prevention, alternative dispute resolution (ADR), law making. What are these contexts about?

Regulatory compliance means ensuring that the public administrations (including governmental institutions), citizens and private companies comply with the legal framework: not only with the laws as such, but also with institutional regulations and public policies and other specific norms that regulate the public and private interests. Regulatory compliance means also the compliance between different sets of law and regulations and ALIS aims not only at ensuring the impossibility to public and private entities to contradict legal framework (external contradictions) but also to avoid the internal ones. For example if the governing party wants to introduce a specific regulation, first of all it should get ensured that such regulation will not contradict the existing legal body. ALIS would be such a consultant in campus of IP law. What is gained eliminating the possibility that legal initiatives contradict the normative framework of the country? First of all, the legal risk is minimized with positive costs reduction effects on the judicial system. Secondly the governance is improved as a consistent legal framework is assumed for good governance. Thirdly, the best practices are shared at the European level disseminating the benefits to the whole European community.

Conflict prevention aims at forestalling the legal disputes between the parties (both public and private). How? By proposing early solutions to come to the agreement acceptable by all the parties involved. In order to do this, ALIS will apply the Game Theory tools. The benefits are both material and immaterial, as the conflict prevention enables not only to save financial and time resources, but also safeguard the relationship between the parties, which could otherwise be damaged if the disagreements would lead to disputes and judicial procedures. If two parties cannot agree on some IP issue (like authorship of the work of mind or the exploitation rights or any other issue pertaining to the campus of IP law), they could consult ALIS and get the proposal of how to organize their issue in a way that no one could lose and both parties could be satisfied.

ADR is a further alternative (next to conflict prevention) to avoid the judicial procedures in order to resolve the disputes among the parties. Substantially ADR is composed of two mechanisms, that is arbitration and mediation. In arbitration process, the role of judge is assigned to the arbitrator, whose decision is binding to the parties. The mediation process differs from the one of arbitration in the non-abidingness of the mediator's decision. For this reason, the mediation process is less formal than the one of arbitration and the role of mediator is more oriented to help the parties to find the solution by their own initiative, than to propose his own. In this context, ALIS will play the role of dispute resolver who will propose the possible solutions to the parties and will underline the outcomes of any decision they will want to take.

Law making refers to the complicated process of the creation of norms. The legislative body always needs to get ensured about the relevance of new legislative proposals, their role in the actual legal framework, and evaluate the implementation assessment. ALIS could lead this process from the proposal of the new law, passing through the elaboration of the *corpus* of law and finishing with the implementation procedure evaluation, including the analysis whether the new law contradicts the existing one(s).

In other words, ALIS is absolutely in line with the previsions of the future some lawyers already made several years ago: “Indeed I believe that the practice of law and the administration of justice will be more radically affected in the coming 50 years by IT than by any other single factor of which we can be aware today” (Susskind, 2000, p.79).

In order to achieve its objectives, ALIS involves four ontologies: IP Ontology[15], Named Entities (NE) Ontology, Game Theory Ontology (GTOnto), and Legal Reasoning Engine (LRE) Ontology. All these ontologies are written in the Web Ontology Language (OWL) (defined as “the language with the strongest impact in the Semantic Web” (Cardoso, 2007, p. 25) using PROTÉGÉ tool.

ALIS IP Ontology is created in order to perform the four main functions. The first is that this ontology should enable the improvements of the management of legal documents repositories. Secondly, the IP ontology should also favour the versatility of the legal document retrieval system. Thirdly, the ontology is used to create a “common” language for the information exchange between the modules and the Web services of ALIS architecture[16].

The GTOnto conceptually describes Game Theory methods, parameters and tools. The construction of this ontology is based on three dimensional ontological approach: the issues related to this ontology were classified in “definitions”, “properties” and “inclusion relations”. The aim of this ontology is help ALIS system to select and use GT tools for solving the users’ cases. For this reason, the GTOnto developers have abandoned the idea to try to cover comprehensively the GT campus, but to select the categories of games and hence the properties attached to these games with specific goal to chose the ones that could improve the functioning of the system. The macro-classes in this ontology are limited to five:

1. **Game:** This class comprises all elements which can be considered as instantiations of a game where the term “game” is interpreted in the game theoretic sense;
2. **Game parameters:** Describes the characteristics of the game rules with respect to cooperation, utility, symmetry, simultaneity, qualitative nature, strategic sets, dynamics, equilibrium, information, and players;
3. **Game object:** These are *alternative dispute resolution, bargaining, compliance, coordination, deterrence, non bargaining or cooperative personal utility maximization, screening, signalling*;
4. **Game process:** This class deals with subclasses related to tools which are used to solve a game and to properties of the game stemming from its analysis.
5. **Game metaphors:** This class comprises best known metaphors of Game Theory in order to represent core issues.

The LRE Ontology is based on conceptual representation of the tools and methods of legal reasoning, such as module specifications, formalization languages, etc. The aim of this ontology is the categorisation and structure of the information related to the characterisation of the different reasoning modules. This ontology is based on three main classes:

1. **LRE modules:** This class describes the implementations;
2. **Formalization languages:** This class lists the general set of possible representational formalisms;
3. **Module specifications:** This class contains the different ways to specify key conceptual and relational aspects of the cases such as social constrains, social states and role.

The NE Ontology is dedicated to the concepts of standard meta data information (for example, location or data) extracted from documents. The aim of this ontology is to provide an extraction information framework to enrich ALIS documents with useful meta data like locations, monetary quantities, etc. The main classes are *Person* (datatype properties are *Title*, *FirstName*, *Surname*), *Organization* (*OrgName*,*OrgType*), *Numex (NumexUnity* like kg, and *NumexValue* like 130), *Timex* (*TimexDate*, *TimexTime*), *Location* (*Address*, *Country*, *City*), and *Event* (that is text references to social, cultural or historical actions like 1st of May or European Football Championship).

How are these ontologies linked among them? The core ontology of ALIS is ALIS IP ontology, as it facilitates the information exchange between different modules. The ontologies in ALIS complement each other and there is a linear conceptual continuity among the ontologies in ALIS: the class *Person* in the ALIS IP Ontology is related the class *Person* in NE Ontology (in this case, these two concepts are the same), *to* class *Player* in GT Ontology and to the class *Roles* in LRE Ontology. If we define properties of the form *Is_A*, it is possible to define relations between these classes in all the ontologies involved.

5. ALIS IP ONTOLOGY

For this ontology we used the bottom-up approach. The ALIS IP Ontology is based on tripartite of key terms in French IP law: the *work of mind*, the *author* and *intellectual property rights.*

The core term in ALIS IP Ontology is *work of mind*, as a expression of intellectual human efforts. This work of mind may be of different types. French IP law defines the following types of works of mind: *abstract authorship, address, applied art work, architectural work, artistic writing, audiovisual work, book, choreographic work, cinematographic work, circus act, collection of miscellaneous works or data, dramatic musical work, dramatic work, drawing work, dumb-show work, engraving work, fashion work, feat, geographical map work, graphical work, illustration work, lecture, literary writing, lithography work, musical composition with words, musical composition without words, painting work, pamphlet, photographic work, photography analogous work, plan work, pleading, scientific writing, sculpture work, sermon, single work, sketch work, software work, three dimensional work, typographical work.*

From the legal point of view however this list is not peremptory, that is this list is not enumerating all the works that can be protected by copyright law. On the contrary, this list is indicative and illustrates explicitly the works which are surely protected by law but does not exclude the enlargement of the list, leaving a space for a free judicial interpretation on case-by-case basis: for example, Italian[17] Court of Cassation recognized that even if not included in the list of works of mind, the calendars, catalogues of goods and other lists might be protected by the copyright law[18]. Obviously, from a legal point of view this is justifiable and logic as the legislator could not foresee all the possible expressions of the human intelligence and creativity. This would be impossible and limitative. Nevertheless from the ontological point of view, this logic complicates the construction of ontology, because the concepts which are not explicative in the law, are not included into ALIS IP Ontology. Consequently, from this latter view, the concepts which are not included into ontology, do not exist. And if they do not exist, they are not considered as the works of mind and consequently are not protected, even if legally they could. The solution for this discrepancy could be updating the ontology. The updating should imply that the updater of the ontology follows the national case law and according to the judicial decisions updates the ontology.

The problem exposed above has certain traits in common with the certain problems we faced concerning the features of the logic underlying OWL ontologies, namely Description Logic (Baader, 2003, pp. 349-369) with respect to the dynamic nature of the legal domain, and the use of ontologies to emulate legal reasoning.

Regarding the dynamic nature of the legal domain, new legal concepts may appear while others disappear, and thus, the ontology has to be updated over time. However, description logic is monotonic, and thus the addition of new concepts to the ontology cannot invalidate previously possible derived conclusions.

An obvious possibility to tackle this issue is to change the axioms constituting the ontology, by making use of belief revision techniques for example. However, despite the declarative nature of ontologies aimed among others to facilitate systems' maintenance, the necessity to change axioms in order to up-date the ontology can be rather time consuming for the human operator up-dating it (e.g. the up-dater may accidentally cause inconsistencies which might not be easily identified and removed).

More generally, it is arguable that ontologies based on a monotonic logic as Description Logic are inappropriate when it is not possible to have a complete knowledge of the domain on which we wish to reason.

Another issue regarding the dynamic nature of the legal domain, is temporal validity of legal concepts. Indeed, a legal concept may be valid for a specific period of time, for example, the period staring at the publication of the regulation introducing the concept and ending at its abrogation. Thus, some temporal information associated with concepts included in legal ontologies may be useful to take into account, but such temporal information cannot be specified using present-day OWL ontologies.

Besides the problems caused by the dynamic nature of legal domain, other issues arise if it is attempted to use ontologies to emulate legal reasoning. Of course, anyone attempting to formalize legal reasoning via logic tools has to face many issues, but a major one comes in mind in the case of Description Logic (beside its low expressiveness).

The issue concerns the monotonicity property of Description Logic. Indeed, legal reasoning is defeasible by nature because legal conclusions can be invalidated in light of further information. On the contrary, in Description Logic, conclusions cannot be invalidated in light of new information. For example, a work of collaboration is a work in the creation of which more than one natural person has participated, but if the work is created at the initiative of a person who edits it, publishes it and discloses it under hid direction and name, and the personal contributions of the various authors who participated in its production are merged in the overall work for which they were conceived, without it being possible to attribute to each author a separate right in the work as created, then the work is a collective work (instead of being a work of collaboration). An OWL ontology reasoner may derive that a work of mind is both a work of collaboration and a collective work, and this would be an incoherency.

In this view, the use of Description Logic to account for legal reasoning can be seen as a step backward with respect to the many efforts of the artificial intelligence and law community. We bring this aside to close and return to the main subject, that is triplet on which ALIS IP Ontology is based conceptually. As we have already seen, the first concept of this triplet is *Work of Mind*, while the second is that of *author*. A work of mind is created by an *author*, who may be a *natural* or *legal* person, and who may also be anonymous or pseudonymous. Hence, a work of mind may itself be *anonymous* or *pseudonymous*. From a legal point of view, it is difficult to imagine situation in which the anonymous work of mind could be created by the legal person though. Nevertheless, we could not exclude such possibility.

The third main concept in the ontology is that of *intellectual property rights*, which every author is entitled to, and which may also be referred to as *incorporeal property rights*. French IP law distinguishes between moral and economic rights. *Moral rights* protect an author's personality and reputation. *Economic rights* enable the copyright owner to benefit economically from the work's exploitation, and they may be transferred to an *economic right holder* (*publisher, editor, producer*) either in part or in full.

French IP Law identifies nine types of moral rights as follows: *right of disclose under the name, right of disclose under to direction, right of divulge work, right of make a collection, right of reconsider assignment of exploitation, right of respect for authorship, right of respect for name, right of respect for work, right of withdraw assignment of exploitation*.

Economic rights are in turn divided in two groups of rights: *right of performance* and *right of reproduction*. The former is the right to communicate the work to the public by any process whatsoever (*perform dramas or lyrics, present or project or recite publicly, telediffuse or transmit also through satellite*). The latter is the right to fix a work into a physical medium by any process enabling it to be indirectly communicated to the public (*publication, cast, draw, engrave, execute, make photos, print, use graphic or mechanical process*).

All italicized concepts in this section are represented as OWL classes connected by datatype or object properties.

The design of this ontology gave rise to the problem of inclusion as a tool of classification. In particular, we have designed two orthogonal categorizations: authorship (*SingleWork, CollaborativeWork, CompositeWork, CollectiveWork*) and type of work (*Book, Sermon, Feat, Geographical Map Work, Graphical Work, Illustration Work, Lecture*,etc.). It seemed to be logic to apply hierarchical structure: for instance, *Graphical Work* is a sub-class to each of the classes of authorship, as such kind of works could be done by more than one person. Nevertheless, the problem arises that now every graphical work is automatically each of authorship classes, that is *Graphical Work* is *SingleWork*, a *CollectiveWork*, a *CollaborativeWork* and a *CompositeWork*. This is not real though. The solution to this illogical outcome of the design was found in the inclusion of Exclusion relations among the entities and in putting these entities at the same level. The negative part of this solution is that every new instance we want to include into ontology has to belong to two categories: authorship and type, and we are not sure this will function in practice.

ALIS IP Ontology, as a domain ontology, needs to rely conceptually on a upper ontology. Such upper ontology is LKIF-Core Ontology[19]: as we have already mentioned, there are concepts which could not be included into domain ontology as they are *primitive* (see part 2.1 of this chapter) and thus belong to the upper ontology. In copyright law domain one of such terms is *property*.

The top level of LKIF-Core Ontology in its own turn is based upon LRI-Core Ontology. The latter ontology provides with the primitive concepts such as *location, time, places* and *change*, which are indispensable for description of any legal reality.

Further level (going from the "top" to the "bottom") of LKIF-Core Ontology is the intentional level, which includes concepts and relations necessary for the description of the intelligent behaviour of the agents. This level also describes mental state of the agent such as *beliefs* or *expression*.

The third level is the legal one: here the set of legal agents, actions, powers, rights, roles is introduced. This set enables the expression of the normative statements.

5.1 ALIS IP Ontology: IPROnto

The creation of ALIS IP ontology was strongly influenced by the other ontology dedicated to the same legal domain, that is IPROnto, described by (but not only) (Delgado, 2003, p. 621-634). Unfortunately the lack of ontologies of IP law is obvious and this provokes the lack of confrontation and discussions. There is no sharing of good-practice or know-how on these issues, which could help the developers of the IP ontologies to solve the problems or to share the knowledge.

Notwithstanding this lack of IP ontologies, IPROnto is an interesting ontological proposal to face the IP domain. IPROnto is addressing enormous domain if we confront it with the one of ALIS IP Ontology. In fact, IPROnto is destined to e-commerce and digital rights management (DRM).

We did not build our IP ontology on IPROnto for several reasons, the main of which is that the IPROnto is much more general and consequently abstract, while the ALIS IP Ontology, based on specific legal framework (that is French Copyright Law), is more definite and precise conceptually. Indeed, ALIS IP Ontology does not share the abstract terminology of the IPROnto. ALIS IP Ontology, on the contrary, follows precisely and almost literally the words of French legislator, avoiding any interpretations or paraphrasing. The precision might also be a limit we have to bear in mind, as the strict and literal linearity with the normative dispositions makes the ALIS IP Ontology less rich every time the French IP law refers to any other law (like it does with Act No. 85-98 of January 25, 1985, on the Judicial Rehabilitation and Liquidation of Enterprises). However the precision in following the French IP law was not total: we excluded certain terms which we retained to be useless and conceptually mistaken, such as "contract for hire"[20].

The developers of IPROnto admit this feature of their ontology, but justify it by the goal of IPROnto to cover the entire IP domain and sustain that it would not be difficult to produce versions of IPROnto following specific laws (Delgado, 2003, p. 622). The domain that IPROnto addresses is based on the World Intellectual Property Organization's (WIPO)[21] Copyright Treaty and Berne Convention. These international agreements oblige the states that signed these agreements to respect certain abstract legal principles regarding the intellectual property. This abstractness is obvious if confronted with concrete IP laws of separate states, which consequently are inspired by WIPO Copyright Treaty and Berne Convention but, again, in general position and not in specific norms.

IPROnto presents also a problem of determination of the boundaries of ontology: IPROnto incudes the concept *Consumer*, while ALIS IP Ontology does not, as the IPROnto covers the wider domain than that of the copyright law as such: indeed, it is oriented toward electronic commerce and digital rights management (DRM).

Which is better: abstract or specific? What ontology should we adopt? We could paraphrase (Quine, 1953, p. 19) who proposes to use "tolerance and experimental spirit" and base our decision on the needs we have: in case we are interested in the whole IP domain covering ontology, the right ontology to chose would be IPROnto, if we are interested in specific proposal on the ontological solution for the particular domain – ALIS IP Ontology could be if not the right answer, at least an interesting direction to have in mind. For the purposes of the ALIS project, we needed an ontology which could ensure that the templates which serve as user interfaces were consistent with the information required by ALIS. This goal could not be achieved by IPROnto which is dedicated to interoperability and automation of different IP frameworks.

5.2 ALIS IP Ontology: ICLOnto

Unfortunately we could not begin the development of ALIS IP Ontology with the inspiration of ICLOnto as we got to know about it afterwards when our ontology was already built. Nevertheless this does not obstacle us to confront these two ontologies and see where they differ and where they are similar.

ICLOnto is an ontology created by Japanese colleagues as a part of The International Copyright Law Articles Consulting System: this ontology aims at overcoming differences in national copyright laws (for today the Japanese and Chinese copyright laws) and is used as "a fundamental conceptual framework to maintain consistency among diverse legal representations for a certain legal phenomenon" (Lu, 2008, p.94), that is copyright. This is done through the intention-oriented Legal Knowledge Model (iLKM) that enables to grasp the intention that is "behind" the certain regulation: in other words, the same concept can be expressed differently in articles of law in two different countries. The iLKM model should be able to capture the intention that two (apparently) different articles share: for example, if one article states that "it is prohibited to copy someone's work without the author's permission" and the other affirms that "the rights of copy belong to the author", the intention in both of these articles is to ensure the author's monopoly of control over her work of mind. The iLKM is supposed to be "an independent "thing" which works as a desirable pivot amongst different laws representations" (Lu, 2008, p.97), which uses two separate models: *Law Article Model* and *Intention Model*.

Consequently, the concepts in this ontology are attributed with the intention of the legal article they represent. This is a huge difference from ALIS IP Onto: to grasp the implicit common legal intention is not the goal of ALIS IP Onto which we worked to make as linear with the legal articles as possible. In other words we adopt only *Law Article Model* but not *Intention Model*. The decision to reveal intention has sense in case of ICLOnto because this ontology addresses the two copyright laws of two different countries. So, the intention is sort of a leading wire between the Japanese and Chinese legal normative visions on copyright.

Differently from ALIS IP Onto, ICLOnto has only one main class *Rights*, while such classes as *Person* and *Work* (which as we have already mentioned, constitute the key triplet in ALIS IP Ontology) are related classes. *Rights* then are divided into *Copyright* and *UsageRights*.

Copyright is based on WIPO: this is the link between IPROnto and ICLOnto. The difference is that only the class *Copyright* follows the recommendations of WIPO, while in IPROnto this international agreement plays much more important role. Being guided by the goal of intention grasping, ICLOnto respectively divided the class of *UsageRights* in rights for general usage and rights of exemptible usage. The rights of general usage involve the person guided by *PrivateInterests*, while right of exemptible usage represents the person with *PublicInterests*. These classes represent in fact the intention underneath the actions performed by the persons.

What ICLOnto shares with ALIS IP Ontology is the granularity that IPROnto lacks. From this point of view, ICLOnto and ALIS IP Ontology are fine granularity ontologies, while IPROnto is a coarse granularity ontology: in fact, while ICLOnto and ALIS IP Ontologies specify the legal properties, classes and their relations, in IPROnto prevails the general representation of concepts.

This ontology is a powerful tool for the comparative legal studies. If further developed, this ontology could help us to grasp the essence of different copyright laws all over the world and deepen the studies on the matter. This is also an important point in the light of globalization the web has introduced: indeed, (Lu, 2008, p. 96) indicates four functions that the application of such ontology-based systems could provide us with: first, the browsing of copyright laws of different countries would be provided, secondly, the matching of articles content would be enabled if that article's intentional orientation is made explicit. Thirdly, due to the matching possibility, the correlative articles are retrieved. Fourthly, through the article information, the user would be helped in clarifying and solving his problems. This last function links ICLOnto to the ALIS IP Ontology which also makes part of the system that aims, among other things, to help the user to understand what her problem is and to resolve it in the best possible way.

There are some sides of this ontology that we were not able to clarify and this is why also our research on this ontology will proceed. We have not found any references to the upper ontology of ICLOnto and the question is whether such exists.

5.3 ALIS IP Ontology: OCATU Model

A particularity of the ALIS IP ontology is the use of a life cycle model called OCATU, which represents and illustrates five stages of whole process of the lifecycle of work of mind in the IP domain. These stages are:

First stage is called "**O**rganize the work of mind". This stage includes all the activities that are being performed before the work of mind is created: these actions might be numerous and of a very different kind, such as negotiations or project preparation, the organization of the team of work which will create the work of mind and other preparatory tasks.

Second stage "**C**reate the work of mind" involves the work that directly produces the work of mind. These actions might include writing, drawing, programming, composing, hollowing, painting, making movie or photos, etc. From a legal point of view though, the "organize" stage is strictly linked to the stage of "transfer", because this "organize" stage involves also the decisions on the distribution of economic rights of the work of mind among the parties who are going to take part in its creation directly or indirectly (for example, one party might organize the premises for the creation of the work of mind, which will be done by the other person. The two persons have to decide before the creation of work of mind how do they divide the economic rights of the work of mind).

Third stage "**A**ssert rights on the work of mind", concerns the affirmation of the rights. This means

Table 1. ALIS IP Onto, IPROnto and ICLOnto compared

	IPROnto	ICLOnto	ALIS IP Ontology
Field	Electronic commercialization of the multimedia domain (with the emphasis of Digital Rights Management(DRM)).	International copyright laws[22] as the part of the E-learning development and also the basis for the international copyright law articles consulting system.	Intelligent legal system in copyright law domain.
Purpose	To facilitate the implementation of applications dedicated to the protection, distribution and control multimedia content (that is applications of DRM).	1) To represent models of typical intentions that stand behind the copyright law articles; 2) To enable the users to understand what are the differences and the similarities among the different copyright law articles in different countries with the help of the models as corresponding pivot	1) to improve the legal document repository management; 2) to create a common layer between GT and legal concepts; 3) to enable the versatility of the document-retrieval system; 4) to develop a common language for the information exchange[23].
Upper Ontology	SUMO	Unknown	LKIF-core
WIPO	Yes	In part	No
Life Cycle	Yes	No	Yes
Granularity	No	Yes	Yes
Editor	Protégé	Hozo	Protégé and TopBrain Composer

that after the work is created, and it does not involve only the one person, the status of rights should be clear (as usually before performing the works that include numerous authors, the latter put clearly down in the contract what and how they are going to solve the question of economic exploitation of their work of mind). In this stage, the work of mind might be registered, the authorship declared and other claims on the authorship/ownership of the work of mind claimed.

Fourth stage "**T**ransfer rights to the work of mind" is the stage in which the author of the work of mind can (but is not obliged to if not on contractual basis) transfer his economic rights to someone else. The moral rights (such as right to proclaim or disclaim authorship, to object any modification of the work of mind that the author retains to damage his reputation, to decide when to publish the work of mind or to withdraw the work of mind from the commercial circulation) cannot be transferred.

Fifth and the final stage "**U**se the work of mind" is the stage in which the owner of the copyright of the work of mind is using his economic rights. The work of mind may be published, translated, distributed, rented, etc. This final stage is particular because it might generate another work of mind, and the process (life cycle) of IP will begin again.

These stages are not explicit sometimes: for example, if the author created a work of mind, he is not obliged to transfer his rights or assert them. The stages represent only the "fullest" possible scenario of the lifecycle of work of mind, but naturally, it might be different.

6. CONCLUSION

We adopted a sort of bottom-up approach in order to illustrate the development of ALIS IP ontology, starting with the general hints on relationship between law and the Semantic Web, then passing to the specificity of the copyright law domain and finishing with the presentation of the project dedicated to copyright law, that is ALIS. Within this project that ALIS IP Ontology is created, developed and applied and with the detailed overview of which we close this Chapter.

We confronted ALIS IP Ontology with two other ontologies that address the IP law domain, that is IPROnto and ICLOnto underlining the differences and similarities. These are the IP law ontologies that we are aware of and in case there were other such ontologies, the further confrontations will be made. All three ontologies address the IP domain with the different linguistic approach. Only the IPROnto in fact is based on the original English text of international agreements, while both the ALIS IP Ontology and ICLOnto are based on English translations of respectively French copyright law and Japanese and Chinese copyright laws.

The acceptance of ontology is the adoption of "the simplest conceptual scheme into which the

disordered fragments of raw experience can be fitted and arranged" (Quine, 1953, p. 16). Paraphrasing this thought, we hope that we succeeded in ordering a piece of IP law domain into a scheme. There is still much work left to do and we hope that the ALIS IP Ontology is only a beginning of a larger legal ontology building initiative we hope to take part in.

In this Chapter we presented only a little piece of a general ontology-related problem the implementation of the Semantic Web has to do with. Indeed, the Semantic Web is based on ontologies, and not only legal. Thus, the issue of legal ontologies is only a little part of the semantic-ontological debate, where copyright ontologies are like grains of sand. Nevertheless, this is how the whole project of the Semantic Web is carried out: putting together small pieces into a big picture of the Semantic Web puzzle.

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KEY TERMS AND DEFINITIONS

Author: The creator of any work, be it written, painted, sculpted, music, a photograph or a film or whatever other type of work of mind.

Copyright: Protects expression of authorship or artistic interpretation, but not the idea upon which such expression is based.

Description Logic: Logic formalism that enables to represent the knowledge in a structured and well-defined way

Intellectual Property (IP): Means intangible property rights which are created by a person's intellectual creative efforts. The results of these efforts enable the creator or owner to control and profit exclusively from them.

IP Law: A branch of law that defines intellectual creations and deals with obtaining, loosing, using, profiting, defending the intellectual property rights. IP law includes trademarks, copyrights, patents and trade secrets. In a more complete vision, it also includes the issues of rights of ideas, unfair competition and rights of publicity.

IP Rights: A whole of moral and economic rights (generally: exclusive right of possessing, enjoying, and disposing of a work of mind).

OCATU Model : Model which is used in ALIS IP Ontology to represent and illustrate five stages (*Organize*, *Create*, *Assert*, *Transfer*, *Use* stages) of whole process of the lifecycle of work of mind in the IP domain.

Ontology: A specification of a conceptualization, which is the set of ideas, concepts, and relationships of a certain domain.

Work of Mind: Creative expression of intellectual work, which may be of different types: literature, music, figurative arts, architecture, etc.

ENDNOTES

1 This chapter is partly supported by the Specific Targeted Research or Innovation Project "Automated Legal Intelligent System" (ALIS), VI Framework Programme of the European Commission, Priority 2, Information Society Technologies.

2 Metaphysics generally means the study of reality. The term comes from the 14 Aristotelian books which appeared after (*metà*) the books on physics (*tà physikà*). These 14 books were dedicated to the prime philosophy, which was called metaphysics.

3 More on this see Worrall J.(ed.) (1994), "Ontology of Science", Dartmouth, UK, 1994.

4 Quine's answer to this question was that we should not consider these entities as the real ones. These entities are "posits" which aim to simplify the collection of our experiences. So we should not consider them in

terms of "real/unreal", but in terms of "best/worse" at effecting such simplification. For more details, see Quine W.V.O. (1953) "Two Dogmas of Empiricism", in *From a Logical Point of View*, Cambridge Mass: Harvard University Press

5 In case of legal ontologies, there is a question which is much harder to respond than in case of say scientific ontology: this question is "what is law?". This is a core question in philosophy of law and it is not answered yet.

6 The same author proposes a list of the core notions of legal ontologies. These notions are: norm, case, contract, institution, person, agent, role, status, normative position (duties, rights), responsibility, property, crime, provision, interpretation, sanction, delegation, legal document. For more details, see (Benjamins, 2005, p. 10).

7 In ALIS IP Onto we do not use the term *copyright work*, but the term *work of mind*, because we decided to keep to terminology of French IP law.

8 In fact while building ALIS IP Ontology we used the concept of property from the upper ontology: LKIF-Core Ontology.

9 You will see later that we have called our ontology with the name of ALIS IP ontology, making reference to the IP and not to the copyright law, even if the ontology (for today) deals exclusively only with the French copyright law. The name indicates the possible expansion of this ontology to the remaining sub-branches of IP law, that is patent law and trademark law.

10 In fact, software is protected by copyright law and considered as the literary work under the Berne Convention for the Protection of Literary and Artistic Works (first signed in 1886). Nevertheless, it might also be protected by patent law. The distinction is made according to what exactly is protected, as the copyright protects the form of program's expression (if it is original though) and the patent law protects the principles and ideas that are the basis of the software (only in the case when this software satisfies the other requirements of the patentability). It is not impossible that these two kinds of legal protection cumulate in one software, and in such case the different aspects of it are protected by different legal institutions, that is copyright and patent law.

11 See for example, C.McCreevy's (European Commissioner for Internal Market and Services) speech during EABC/BSA (European-American Business Council/Business Software Alliance) Conference on Digital Rights' Management, (Brussels, October 12, 2005). Retrieved on June 13, 2008 from http://ec.europa.eu/commission_barroso/mccreevy/docs/speeches/2005-10-12/euam_en.pdf.

12 Just to cite one, but a very big problem: what law is applicable for the works of mind distributed on-line? This problem involves different aspects of the copyright protection, such as the terms of protection, duration of protection, enforcement of legal norms, etc.

13 See for example, Kurzweil, who prophesizes that by 2019 the computers will become virtual artists, which will create their own art and music. For more information, see Kurzweil, R. (1999). The Age of Spiritual Machines. Orion.

14 EU project funded under the 6th Framework Program IST-2004-2.4.9

15 Also called ALIS domain ontology

16 For example, GUI module is "ontology-based", that is it connects the user's input with a specific norm. It is possible that this norm will be obligatory (that is will create an obligation to the user). Game Theory context will take into account this obligation of the user, who in this latter context has a role of a player.

[17] We refer to Italian case law even if the list of works of mind is based on French copyright law: we do this because the Italian and French lists of works of mind are very similar.

[18] Cass.civ.Sez.I, 19-07-1990, n. 7397. Retrieved on June 14, 2008 from http://bd46.leggiditalia.it/cgi-bin/FulShow?NAVIPOS=1&DS_POS=0&KEY=46SE1000209808&FT_CID=408782&OPERA=46.

[19] The LKIF Core ontology is available at http://www.estrellaproject.org/lkif-core.

[20] Art. L111-1, 3rd paragraph: *The existence of conclusion of contract for hire or of service by the author of a work of the mind shall in no way derogate from the enjoyment of the right afforded by the first paragraph above*.

[21] World Intellectual Property Organization. Retrieved on June 10, 2008 from http://www.wipo.org.

[22] International copyright law should not be intended in the sense of the International copyright agreements, treaties or conventions, but in the sense of the copyright laws of the different countries.

[23] The illustration of this information exchange could be ontology-based GUI module that connects every input of the user with appropriate normative regulation, which might establish a certain duty for that user. The latter is also a *Player* in GT and the strategy of the *Player* will automatically take into account the presence of such duty for that *Player* and will modify the strategy correspondingly.

Chapter XLI
Technology Roadmap for Living Labs

Jens Schumacher
Fachhochschule Vorarlberg, Austria

Karin Feurstein
Fachhochschule Vorarlberg, Austria

Manfred Gschweidl
Fachhochschule Vorarlberg, Austria

ABSTRACT

The concept of "Living Labs" in general is not completely new in R&D. Available publications focused on local requirements and targeted on business specific needs. In this chapter available ICT for use in a Living Lab are assessed and an implementation roadmap on behalf of ICT is presented. Besides buzzwords like Web 2.0 and Triple Play, ICT enables fast and substantial advancements. To bring a clear view into the range of solutions the authors orient on an ICT layering-architecture and the client/server nature of today's Web-technology. The roadmap takes into account currently applicable technologies and likely future trends. Technological maturity, social compliance, consumer acceptance and politics & market-regulation are considered in the critique. The breakdown shows that a few core technologies are not only sufficient for the skeletal structure, but also from the main bulk of a Living Lab infrastructure. Thus the technology for most of the desirable features of a Living Lab is on-hand, future functional extensions can be provided by open interfaces and a modular architecture of the system.

INTRODUCTION AND BACKGROUND

70-95% of private and public investments in research and development of ICT-based products and services fail to produce market valid value. One major type of deficiency observed is that traditional ICT R&D projects are initiated and executed in a closed and/or artificial laboratory environment with too limited and too late interaction with, and understanding of the potential market and its users.

Industrial bench-marks [CoreLabs IST-035065 (2008)] indicate that large open user communities outperform very significant in-house industrial efforts, when it comes to produce high quality results over time. However, there are several ways to further develop and improve open user-driven innovation. When open user-driven innovation is improved to empower innovation in **real-world** (not virtual) contexts and when it is based on broad private-public-person partnerships (PPPP - no single vendor) systems we call this ***Living Lab.***

The Living Lab concept was developed by Prof William Mitchell (MIT MediaLab and School of Architecture and city planning). Living Labs represents a research methodology for sensing, validating and refining complex solutions in multiple and evolving real life contexts. Here, innovations, such as new services, products or application enhancements, are validated in empirical environments within specific regional contexts. The individual in focus is in the role of a citizen, user, consumer, or worker. The user experience focus involves areas of user interface design and ergonomics as well as user acceptance, extending to user co-design process, finally leading to service or product creation.

The concept of Living Labs is relevant to the necessities of evaluating e.g. the mass deployment potential of ICT enabled solutions. Living Labs represent regional innovation environments focusing on user communities embedded within "real life". Besides technological aspects Living Labs allow insight on to the human dimension of technology, which is of paramount importance for a successful societal deployment of new technologies.

However, from the industrial perspective there is still a need for clarifying the field of activities needed for the Living Labs approach and a necessity to support industry to start and adopt new user-driven innovation practices. Industry wants to know how to take advantage of these new user-driven innovation and opportunities in their innovation processes. The demonstration of what "Living Labs" is and how it could be used by industry and public sector in their user-driven innovation process is essential.

A first step in this direction was made with the project "Living Lab Vorarlberg" which was funded by the Austrian research foundation FFG. The goal of this basic research study is to apply the Living Lab approach to the requirements of the industry. The project is situated in Austria (Vorarlberg) but the outcome is relevant for all Living Labs related research in Europe and even globally.

As stated in a questionnaire prepared for the local Living Lab: From a business perspective a Living Lab is an innovation enterprise (big enterprise, SME). This enterprise operates either in the business-to-business or in the business-to-consumer area. Thus the customers of a Living Lab are on the one hand professional customers (B2B) or private consumers (B2C). These customers are integrated with methods for customer involvement in the innovation process of the enterprise and to find out the needs. In this document especially methods taken from real life and supported through new technologies and the user as co-creator approach are taken into account. *The technological infrastructure is responsible for supporting these methods.*

Other studies present a "systematic analysis and comparative study of the methods and tools currently employed at both the individual sites and at a multi-stakeholder infrastructure level". *While* *that work focuses on Living Lab methods, this description aims at an implementation roadmap of technologies to support widespread methods.*

This chapter will outline the technological aspects of Living Labs with a special focus on the user as co-creator approach by using different communication channels and technologies. The result will be a technology roadmap relevant for the setup of a Living Lab with State-of-the-Art technology. The authors devise an implementation roadmap for a Living Lab focussed on local sustainable production and describe relevant technologies. In particular the technologies and questions should be aligned to the ICT (Information and Communication Technology) layer-structure and surveys of technologies done, and the performed analysis about existing and future ICT will be included in this technology roadmap.

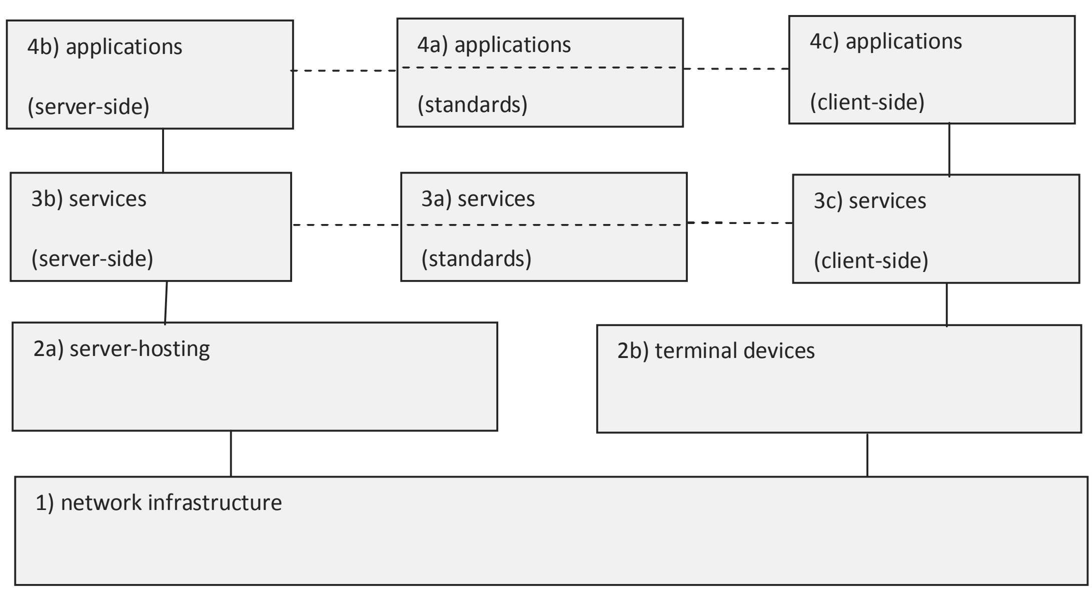
This Living Lab technology roadmap is based on involving the user as co-creator by using modern State-of-the-Art technologies for communication and information exchange with focus on utilizing the internet and client-server-communication. Taking this into account a layering-architecture for ICT in client-server-communication was developed. The developed appropriate layering-architecture is shown in Figure 1.

In the ICT layering architecture shown in figure 1, different parts relevant for communication between a server and different clients can be identified and classified for performing an analysis of *technologies supporting Living Lab methods* for the setup of a local Living Lab.

The following requirements concerning the technologies could be distinguished by subdividing available *methods relevant for Living Labs* into the following topics:

- Representation
- Interactivity
- Management
- Analysis
- Collaboration
- Tracking
- Dialog

Figure 1. ICT Layering-Architecture



Due to the complexity of ICT and software structures - neither these requirement-areas on its own permit a clear structuring of the subject nor the functional blocks of the ICT-layer-structure do so. Taken this into account and combining these two relevant aspects for the creation of a technology roadmap a division into themes was worked out. The themes shall serve as a guide for the analysis of the future impact of the technologies and as a topology for the implementation roadmap of **Living Labs** targeted on sustainable production:

1. Content provision
2. Presentation, content-types
3. Interactivity and dialog
4. Management, administration, storage
5. Transport and cross-section-technologies for communication
6. Analysis
7. Collaboration
8. User Tracking
9. Transformation
10. Terminal devices
11. Network access

When considering a technology roadmap for a Living Lab, no single technology can be accounted and no decision can be made for a single technology in each case of the 11 themes. Only with the orientation of the Living Lab to concrete products the technological arrangement of the Living Lab services can be concretized. The implementation of the services based on ICT will lead in any event to a composition of heterogeneous technologies connected in an open framework.

MAIN FOCUS OF THE CHAPTER

We will examine the above mentioned 11 areas of ICT functionality and develop a roadmap of technologies for the implementation of a Living Lab, dividing the technologies in a base set for a Living Lab with two extensions. The raw partitioning is done in a starting set and two extension stages with classification of these technologies. In addition each concrete implementation stage will represent a functional platform with interoperable interfaces to all desired and necessary technologies.

It will not be possible to give a detailed description of a Living Lab, as this will always depend on the focus of the Living Lab, the already available equipment and the current State-of-the-Art technology, which changes very fast in the ICT sector. Nevertheless, possible technologies for “start-sets” will be outlined and it will be shown which aspects have to be considered when planning and setting up a Living Lab.

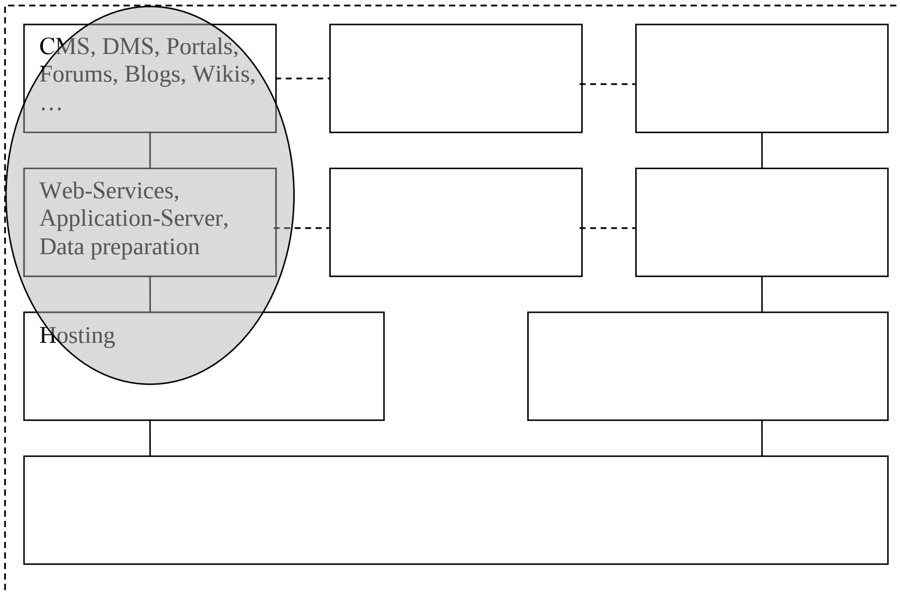
Content Provision

Ordinary State-of-the-Art *multi-tier-server-applications* organize their components within layers. They offer some services over well defined interfaces. Client-applications using these interfaces normally strongly depend on the technologies used on the server-side.

Ordinary server applications try to minimize the number of different technologies used on the server-side. To connect client applications with the services of a server-application, there is a need for a stable and highly integrated binding-technology. Today there are a lot of different tools, libraries and frameworks available and they all propagate server-side programming. But the large number of different implementations available makes server-side programming a challenge. The technologies are complex but they do not seem to be complete which complicates the decision about system layout.

Flexibility is one of the most often mentioned requirements when using tools or frameworks within a software-project. Although the experience showed us that nearly every project has to

Figure 2. Content provision



deal with changing requirements, it still seems that nobody wants to invest some money into the flexibility of software libraries.

Other requirements for technologies used within a software project are:

- **Complexity:** Is it possible to develop complex applications with the chosen technology?
- **Portability:** How difficult is it to adopt the developed application to other platforms?
- **Architecture:** How flexible and mature is the general composition and structure of the framework and is avoiding of redundancy in the development process supported?
- **Performance:** What is the overall performance of applications developed with the technology in a production environment?
- **Integration:** Are there interfaces for further integration of other services and technologies?
- **Deployment:** What are the requirements for the deployment of the technologies and are they available?

Another problem of having a server infrastructure is the *energy consumption* which can produce an exorbitant financial burden. Technologies like *virtualization* and *load balancing* can help to offer reliable and efficient high-performance-services.

To offer some Living-Labs-services can mean to just have some single Web servers but also to have complex computer- or application-networks. Especially the following types of services could be fixed parts of Living-Labs-Web-services:

- **Portal:** Portals consist of some coherent contents offered to some users. The main part of the framework for Living-Lab-Services will consist of portals connected to Content Management Systems (CMS). Many Portals offer the possibility for users to customize the content for registered and logged in users to their needs.
- **Content management system (CMS):** Content Management Systems are widely used by organizations. They can be easily used by members of the Living-Lab to produce some basic content. For a large user base

the CMS should also have some workflow mechanism for releasing the content to the public. Fortunately most available CMS implement such functionality.

- **Document Management System (DMS):** Document Management Systems administer all documents on one server. Documents can be digital ones, online information and scanned documents or pictures. One of the biggest advantages of using a DMS is that all the documents used within an organization are stored using a uniform media. Another benefit could be the very comfortable way of searching for some documents by combining different search-criteria. For the purposes of Living Labs, using an Online-DMS would be the right choice. Some popular CMS also provide basic DMS functionality and if required a detailed analysis of the tools for such functionality should be done.
- **Wiki:** Wikis offer a barrier-free way to easily contribute to online platforms. Users can join the Living-Lab-Dialog by submitting articles. If a wiki is used, it is important to check and observe the provided content in order to avoid misuse of such tools.
- **Forum:** Forums contain posts organized within threads. A thread covers a specific topic. Blogs in contrast consist of articles of a single user. Forums convey a discussion of several participants where they can share their ideas. Forums normally are moderated for observing posts and to keep discussions going.
- **Blog:** With the help of Blogs, users can easily organize his or her articles in a chronological order. Experiences and ideas can be written as you would write it into your diary. Readers can read and comment on each single entry.

Portals can be the central contact-point of developers and customers of the Living Lab. The portal itself offers links and descriptions to several sub-systems of the Living-Lab. Also other, more specialized living-labs can be mentioned and integrated in the portal. It remains to be seen if a CMS, a DMS or a Knowledge Management System (KMS) will be used to create some content.

There are several products available the cover all the mentioned types of Web-services:

- **Web-frameworks:** Ruby on Rails, Grails, Zope, Spring, …
- **Open-source CMS:** AWF, Joomla, Typo3, Plone, OpenCMS …
- **Commercial CMS**
- **Specialized CMS** for Forums or Blogging…
- **Portals:** Liferay (open source), Commercial Portals (Oracle, Microsoft, etc)

Expected development: Continuous enhancements in technologies can be anticipated for content provisioning and new tools may become available. The current development shows that it is important to display information from different sources within a single application. Therefore portals will play an important role in the future as they can be customized by each individual user for displaying the information they are interested in.

Roadmap: For the adoption of the concept of a Living Lab a future-oriented systems-decision is necessary, which relies on the requirements for the technologies used for and by user interaction within a Living Lab and provides possibilities for further content integration.

Technology starting set:

- Portal
- Wikis with moderators (everyone can contribute to it but only the moderator is allowed to change contents provided by others)
- Blogs
- Forums

PRESENTATION, CONTENT-TYPES

According to the ISO/OSI-layering architecture the presentation layer on the top is responsible for displaying the content. The different types of **presentation** are commonly known by the designations of "content types" and "media types". For the display of Living Lab contents it is recommended to use open standard APIs and formats for the possibility of integrating different presentation types.

By taking into account the mentioned aspects, the following exemplary technologies can be distinguished:

- APIs:
- OpenGL
- DirectX
- Java2D / Java3D

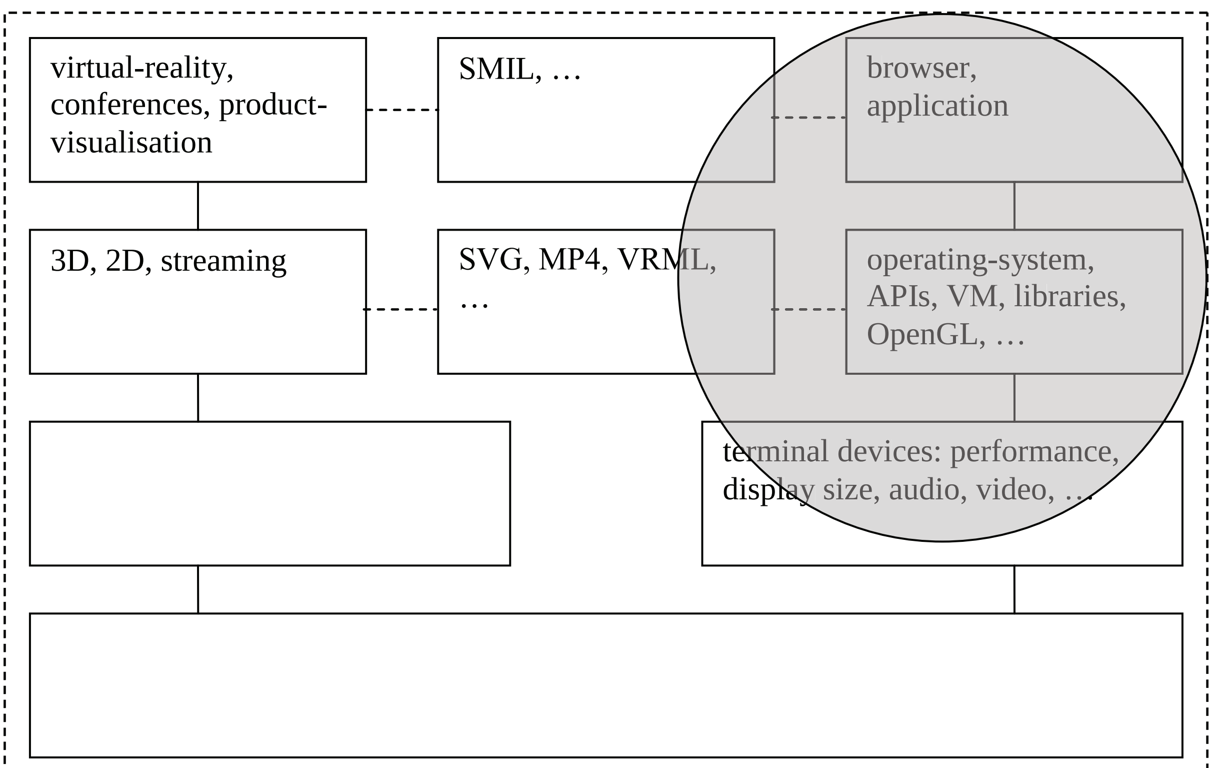
Content formats:

- SVG
- DXF, CGM, …
- Flash, Microsoft Silverlight
- VRML an similar formats

Developments in different areas:

- **Text (with additional pixel images):** Only minor further developments
- **Streaming media:** Formats, protocols, viewer
- **Static vector graphics:** Freely available viewer

Figure 3. Presentation



- **Dynamic vector graphics:** Formats and viewer

Streaming media contents can be useful for the visualization of new ideas and approaches. Considering the role of streaming media in today's online communities, it is important to keep an eye on it, for the integration of streaming media contents in the future if it is necessary.

Streaming media has particular relevance in a Living Lab for the development and implementation of:

- **Video conferencing systems:** Facilitate and support communication
- **VoIP:** Enhance availability in mobile working environments and reduce costs; also telephone conferences are easy to establish without the need of additional tools (e.g. Skype)

Expected development: The competition between different formats and APIs will continue. The effort spent on tools and licenses will decrease, as more of the tools and viewers will become available. Interactive content formats will be an important presentation form of information.

Roadmap: It can be assumed that it will be necessary to support different media types and formats per media type, therefore decisions done for presentation should be future-proof.

Technology starting set:

- OpenGL
- SVG
- Flash
- VRML
- Text (with pixel images)

INTERACTIVITY AND DIALOG

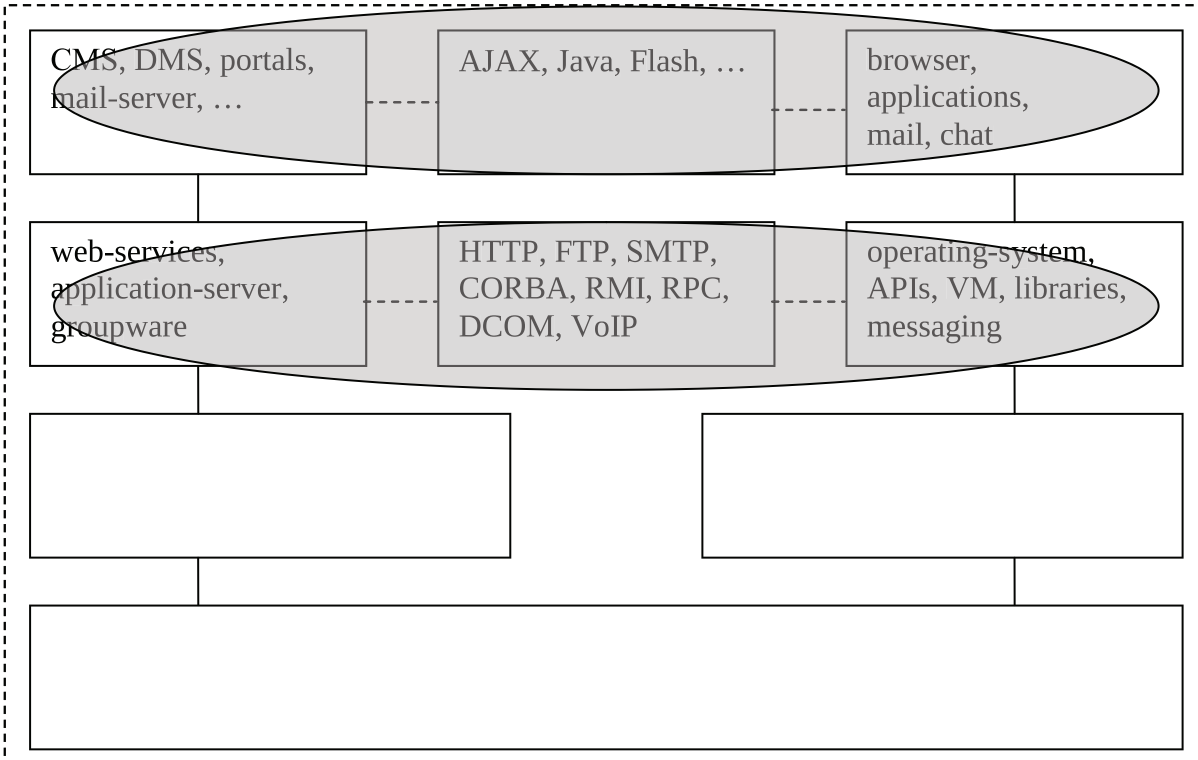
Interactivity is the possibility to affect presented information in its visible view, sequence and content. The degree of interactivity is usually orthogonal to the notation. For example text and video content can be available either statically (static HTML, video-cassette) or dynamically (search-results, interactive BluRay Disc).

The term dialog stands for interpersonal communication. In this context the dialog is transmitted via modern technologies and particularly by ICT. The term "dialog" was selected, because the term "communication" is too abstract. Also the term "information" is too general, because every bit of data carries information and moreover because of the fact that information can be gathered and offered just by one side. The human factor is crucial for a dialog, but missing in a virtual communication. Therefore it is important to simulate at least the appearance of a face to face communication. If a person has a dialog in context of his/her occupation, good moderation skills should be ensured.

To provide interactivity several cross-section-technologies are crucial which will be discussed later.

The access to a Living-Lab should be as easy as possible to achieve that the users can participate in all everyday situations. For this there should be only a few access restrictions for the users and technical barriers should be avoided or at least minimized. That means that the dialog and the interaction between the users and the system should be provided from the Living-Lab for the users independent of their situation. This allows a user to access the Living-Lab with a stationary device as well as with a mobile device. The offered applications and their underlying technologies should work with the most common internet browsers like Microsoft Internet Explorer 6 and 7 and Firefox 2 and 3.The roadmap should have an eye on this market to ensure that all common internet browsers will be supported.

Figure 4. Interactivity and dialog



Functionality of Web2.0: Web applications become more and more like a standard desktop application with the help of technologies and frameworks like AJAX, Flash, JavaScript, etc. All this technologies and frameworks have an intermediate layer between the user interface and the network interface which handles the communication. This allows the user to communicate with the server asynchronous, which means that the user does not have to wait for every communication with the server to complete, but can go on working uninterrupted, while parts of the screen content is being updated.

In an analysis there should be differentiated on:

- **AJAX:** It is based substantially on client-side scripting with JavaScript and XML, performing asynchronous communication with the Web server and dynamically updates only parts of the displayed content modifying the DOM (Document Object Model) structure of the Web page.
- **Java applet, J2SE, Java Web start:** All these technologies require a client-side Java-VM and use different concepts for user interaction provided by Java technology.
- **Flash:** Flash has its own proprietary representation format with own (client-side) scripting-language "ActionScript" developed by Adobe and requires the installation of a proprietary but free available Web browser plugin. It was introduced for providing rich user interfaces and user interaction through the internet based on available technology.
- **Silverlight:** This technology is based on the same concepts as Flash but developed

by Microsoft.

- **ActiveX:** This is an older technology by Microsoft and based on COM/DCOM for Windows and thus only available for MS Internet Explorer.

Expected development: With the availability of new internet technologies (Web 2.0) the possibilities for user interaction are rising but the availability and business models of solutions represent a certain limit concerning universal applicableness. The different technologies will still compete in the future but standards and technologies like AJAX should ease interoperability.

Roadmap: The latest technologies should be used but the choice of the technologies is related to the choice of the system for content provision.

Technology starting set:

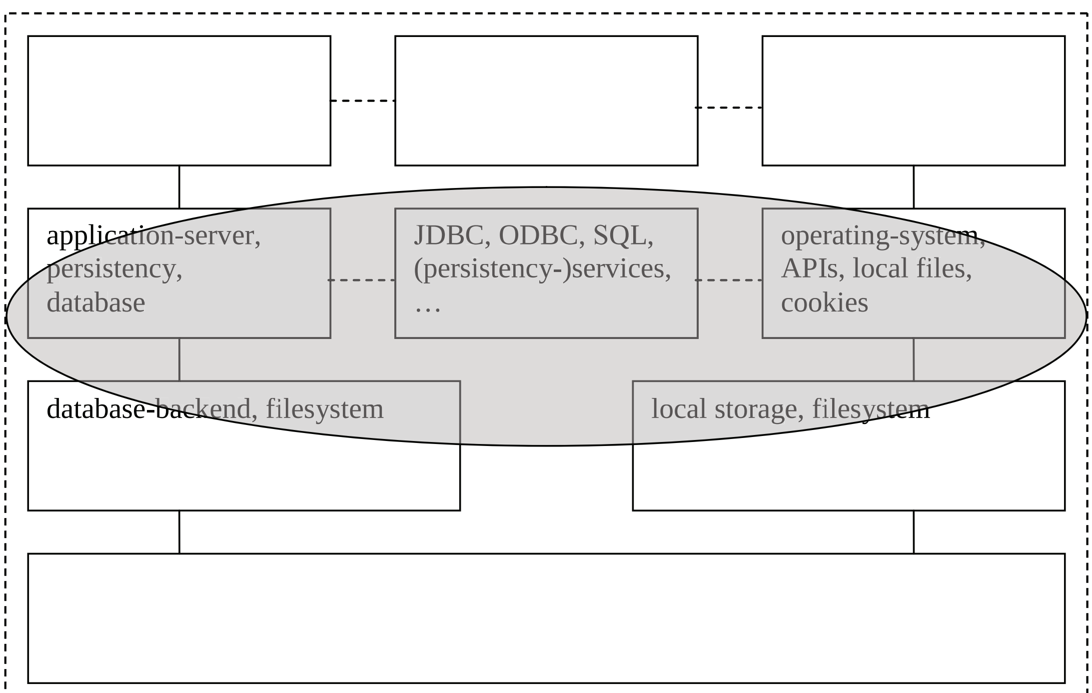
- AJAX
- Flash
- Java-Applets, Java-Web-Start

MANAGEMENT, ADMINISTRATION AND STORAGE

Information management (data management), in particular permanent storage, the structured access and the further processing and rendering at another time and / or at another place is a key issue for each information technology.

Besides the classic relational databases (RDB) also object orientated (ODB) and XML databases are used in different scopes of application, whereas RDBs are most commonly used because of performance issues and already available information stored in them. Furthermore there is the approach of the multi(-model) databases (MDB), hybrids between RDB and ODB (ORDB), widespread

Figure 5. Management, administration and storage



integration of XML as data type into relational databases as well as solutions to (automatic) mapping between object-oriented and relational modelling (ORM; e.g. Hibernate).

As there are different technologies available for information storage and management it is possible to use different but also combined systems for the management and permanent storage of Living Lab data. Typical scenarios could be:

- Central management and storage on one server (or cluster) with advantages in administration and easy backup
- Peer2Peer networks, data replication without a central instance. Advantages: It is a very robust against system failures because normally only a part of the system fails and the rest is still available without any significant reduction in performance. Also the bandwidth is no problem, because access is spread within in the network.
- Hybrid storage on server and terminal equipment. Advantages: It is possible to process the data locally without the need of a central server and bottlenecks in bandwidth utilization can be avoided. Also processing of local data provides advantages in speed because there is no need to always access data on the server.
- Only backups are stored on the server and the used data is on the terminal device.

In a Living Lab it is desired to work in a creative collaboration environment therefore storing data locally with only a central backup on a server is disadvantageous in the scope of its application. The central and hybrid storage are favourable solutions for Living Labs, whereas Peer2Peer networks should be avoided in terms of technical maturity and the administrative organisation.

At least a part of the data should be stored in a classical relational database because of speed advantages. Open source databases like MySQL and PostgreSQL are similar in performance and stability as commercial databases (DB2, Oracle, MS SQL). It belongs to the experience of the developers and administrators which database will be used. Through the availability of ODBC and JDBC every commonly used databases can be accessed. Also most Web applications and frameworks allow the usage of different data storage engines out of the box with minimal configuration needs.

Expected development: The competition between different approaches and providers of database technology will persist and because of the heterogeneous scenarios for application no approach will disappear completely. As decentralized systems evolve, hybrid technology and mapping solutions will be increasingly used for information storage and management.

Roadmap: The used system is dependent on decisions done in content provision. The persistent storage system should be flexible, powerful and future-proof. Mapping solutions between relational, object orientated and XML formats should be available for data (information) exchange.

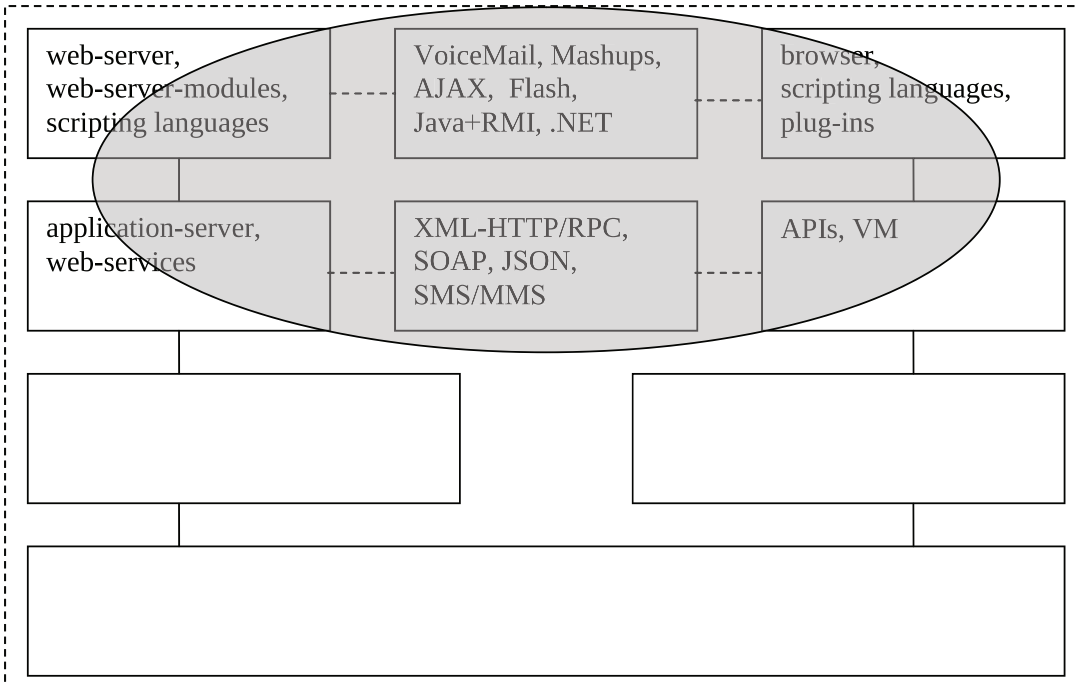
Technology starting set:

- Central administration and storage on a server
- Exchange of structured data using XML
- Database system: MySQL or PostgreSQL
- JDBC / ODBC and possible use of ORM-Mapper (e.g. Hibernate)

TRANSPORT AND CROSS-SECTION-TECHNOLOGIES FOR COMMUNICATION

Communication is a vital part within a Living Lab, because if heavily relies on user interaction combining different methods. The potential benefit depends highly on the consistency and

Figure 6. Transport and cross-section-technologies



interoperability of the methods implemented within the used software system. The technological requirements can of course be derived from the benefits and the types of methods used.

The primary goal of using a software system within Living Labs is to uniform all the methodologies used. It is not always the best idea to use the most popular product for every single method because this can lead to a technological disorder. It is quite important to keep up a certain type of harmony throughout the whole software system. It is mandatory to avoid situations like using high-end OpenGL 3D-applications combined with simple Web forms for configuration purposes. Also the technological usage should follow some kind of consistency.

For the combination of different software systems every programming language providing appropriate APIs can be used but available standards and technologies should be preferred for integration purposes.

Usually a browser uses a standard called HTTP to communicate with a Web-Server. To enlarge the flexibility and interactivity, there are more specialized communication-technologies and standards available which can be used to adapt the software system to the Living-Lab's needs:

- **XML:** XML has proved its value as a data format for information exchange based on standards and used for message exchange format by different communication protocols. There are a lot of different tools and APIs available which make the integration of XML into a software-system quite easy. Alternatively JSON could be used because of its more compact and more readable format which produces less overhead than XML and implementations for every commonly used programming language exist, but a disadvantage is less flexibility in use.

- **AJAX:** Ajax makes the quite static HTTP-protocol more flexible and interactive as it provides asynchronous communication with the Web server and only parts of a Web page in the browser can be updated by manipulating the DOM and is based on JavaScript and XML.
- **SOAP, RPC (remote procedure call):** SOAP and RPCs technologies can be used to couple different Software-Systems by using different approaches for invocation of operations on different software systems and platforms.
- **Mobile communication technologies:** In mobile device communication scenarios standards can be adopted like SMS and MMS for static information exchange and GRPS and UMTS for dynamic communication.
- **Security:** All aspects of security need to be looked at in order to define whether it is necessary to encrypt data sent to client applications or not. Sometimes it would be enough to use just a simple SSL-encryption, but sometimes a stronger encryption would be appropriate.

Expected development: Future software products will not be standardized in a way that it is possible to plug them just together, but there are ambitious efforts in creating bridging technologies (e.g.: converter, gateways) and standardized interfaces for communication and application interoperability.

Roadmap: The used transport and cross-section-technologies should be really powerful, flexible and open (standards) for integration. Ideally the used technologies should not specify the implementation-technology, but use some kind of abstraction layer for underlying technologies.

Technology starting set:

- HTTP
- AJAX
- E-Mail, Messaging, POP3, IMAP, SMTP
- SSL

ANALYSIS

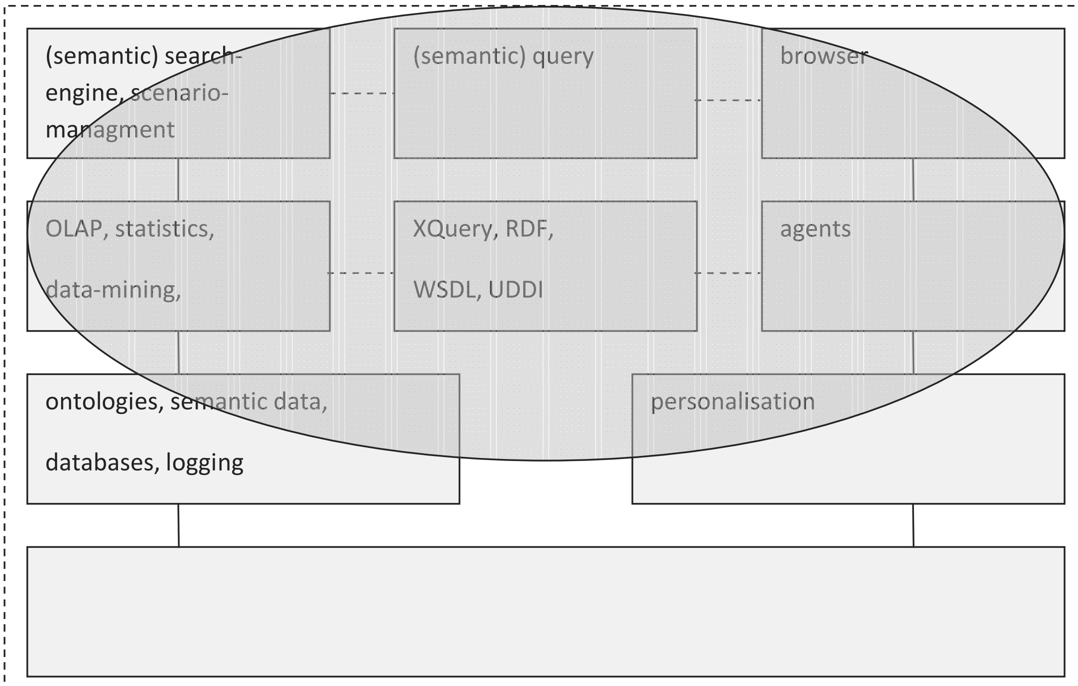
Analysis is required if data is needed, which is not explicitly available or can be received from a partner, but can be obtained through processing of available data. Filtering, aggregation, statistic, time series, etc. are methods for data analysis. In the simplest form the required data can be extracted through a database query (most data is stored in databases) filtering out the desired information from a bigger amount of stored entries or by connecting the data across relational tables. If the analysis can be performed while the system is still active and running the method is called OLAP (Online Analytical Processing) and belongs to the broader sector of business intelligence, which also includes relational reporting (performed on an offline system). Information retrieval out of apparent unstructured data is a goal from data mining (applied to textual content like forums, blogs, etc.) and semantic analysis (applied to semantic commented documents).

Immense challenges for technologies used by a Living Lab are analysis and examination of unstructured data gathered from different sources like blogs, wikis, video and tracking recordings. In many cases it is necessary to manually assess the collected data.

Especially an integrated search on and examination of data from different applications like databases, CMS, DMS, Knowledge Management Systems, etc. complicate the process of information retrieval. Also often different user types use different terms for the expression of the same thing. If there is no common vocabulary defined between the participating users the task of analyzing gets even more complicated.

Some technologies which support the analysis:

Figure 7. Analysis



- **Adoption of ontologies for data lookup:** In information science ontologies are used for formal representation of a set of concepts within a domain and also the relationships between them.
- **OWL:** The Web Ontology Language (OWL) is a specification from the W3C for defining, publishing and distributing ontologies by using a formal description language. OWL is used for the formal description of terms in a domain and the relationships between them, therefore software (e.g. agents) can process ("understand") the meaning of them.
- **Semantic nets including thesaurus, taxonomies and word nets:** This technology is often used for knowledge representation by using a directed or undirected graph where vertices represent concepts and edges represent semantic relations between the concepts.
- **Techniques of data mining** (cluster analysis, principal components analysis, classification methods, artificial neuronal nets, etc)
- **Tagging-techniques:** Users mark unstructured data; for example video-information is marked with tags and these can be searched and processed then as meta-data for the videos automatically.

This area is very complex and not always satisfying answers can be found. To avoid data graveyards rules should be applied for gathering data systematically, which is known in advance to be necessary or important for evaluation.

Expected development: Data-mining and semantic-content-analysis will become more important for the serious investigation of problems with lots of stakeholders and for the determination of potentials of innovation. However, fast availability of economical standards and solutions in this area cannot be expected.

Roadmap: The system should be open and prepared for an extension of the analysis functions, therefore existing standards and architectures should be used instead of proprietary formats; periodic synchronization with projects in the field of semantic-content-analysis (e.g. GridMiner) appears to be beneficial.

Technology starting set:

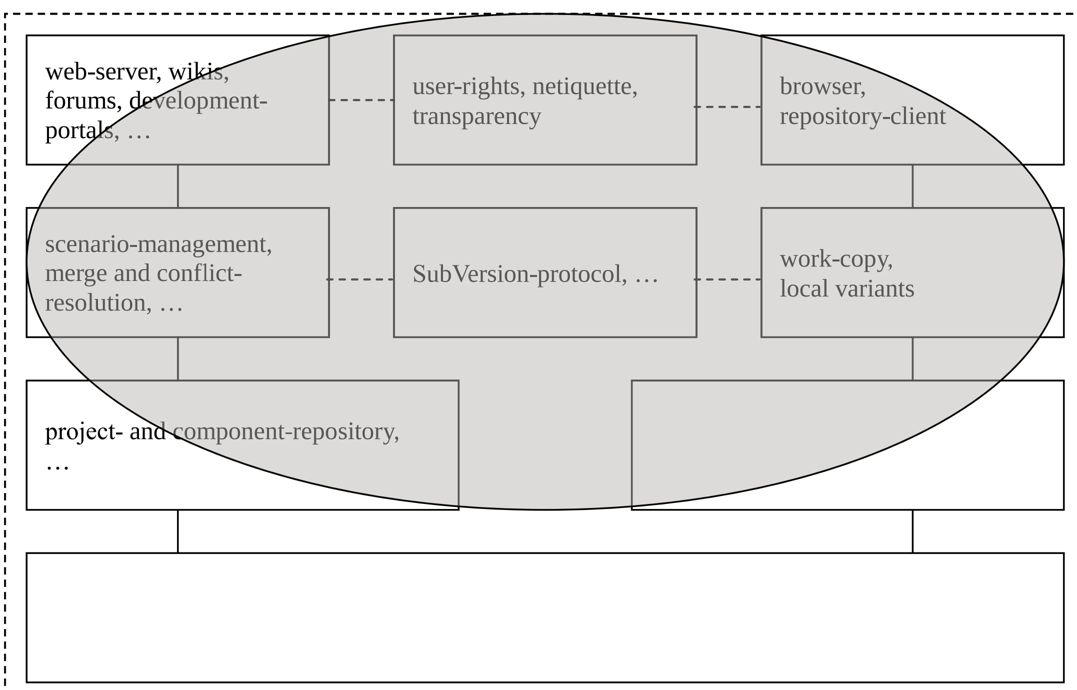
- Statistics
- OLAP
- Data-mining
- Taxonomies, OWL

COLLABORATION

The major task of the Living Lab is to enable smooth communication and **collaboration** between the developers of the enterprise and the users. All parties should be able to communicate their ideas, suggestions and experiences as easy as possible.

There are not many implementations available to solve such tasks. Tools, which support collaborative knowledge work, are quite rare. Groupware like common appointment calendars and project-planning-tools are among as basis, but in open online-communities physical meetings, direct communication and concurrent times of presence are of minor prominence. Common efforts of a community may not be managed by classical project-planning, in order to avoid gross endangerment of the reliability of the voluntary commitment and the sympathetic disposition of the users. Collaboration is not only a technical

Figure 8. Collaboration



topic, but has organizational, group dynamics, legal and ethical aspects.

Topics and special focus of tools within this area can be:

- Concurrent-Engineering-Environments
- Stable, manipulation-resistant systems of evaluation
- Identity- and Rights-Management
- Online-Creativity-Tools
- Merging of parallel development steps
- Social learning and adaptability of the tools to the evolution of the group
- Sharing of Intellectual-Property-Rights

A lot of systems handling concurrent engineering are not suitable for admission into the technology starting set because of lacking of technical maturity and flexibility.

The starting set should be chosen in a way that it can be extended on a concrete need immediately. The selection of tools depends strongly on the requirements of the application.

Expected development: In this relative young area new commercial and free developments can be anticipated, which compete with each other. As collaboration is an important factor in global business and knowledge sharing a great amount of effort is spent in research for the development of new methods and technologies for online collaboration.

*Roadmap:*Existing solutions for branches of the topic (Wikis, version control, etc.) should be integrated most early into the overall system.

Technology starting set:

- Classical groupware functionality
- Ticketing System (systematic pursuit of errors, ideas, occurrences…)
- Version control with merging
- Wikis
- Common directory of addresses, for example for Mail and VoIP (e.g. LDAP)
- Instant-Messaging (e.g. contained in Skype)
- Whiteboards
- Stable, manipulation-resistant evaluation- and survey-systems
- Identity- and Rights-Management (often already integrated in portal software)

USER TRACKING

The term tracking is used for all technologies, which permit the observation of the interaction between a user and a new development (innovation) – **user tracking**. The utilisation of tracking should evidently reveal how the innovation is handled and accepted by the end user, and it should also be observed if it is possible for him to utilize all functions without problems (show satisfaction, according to the expectations of the user, developers or both). If functions are not utilized they should be reconsidered or they should be revealed to the user.

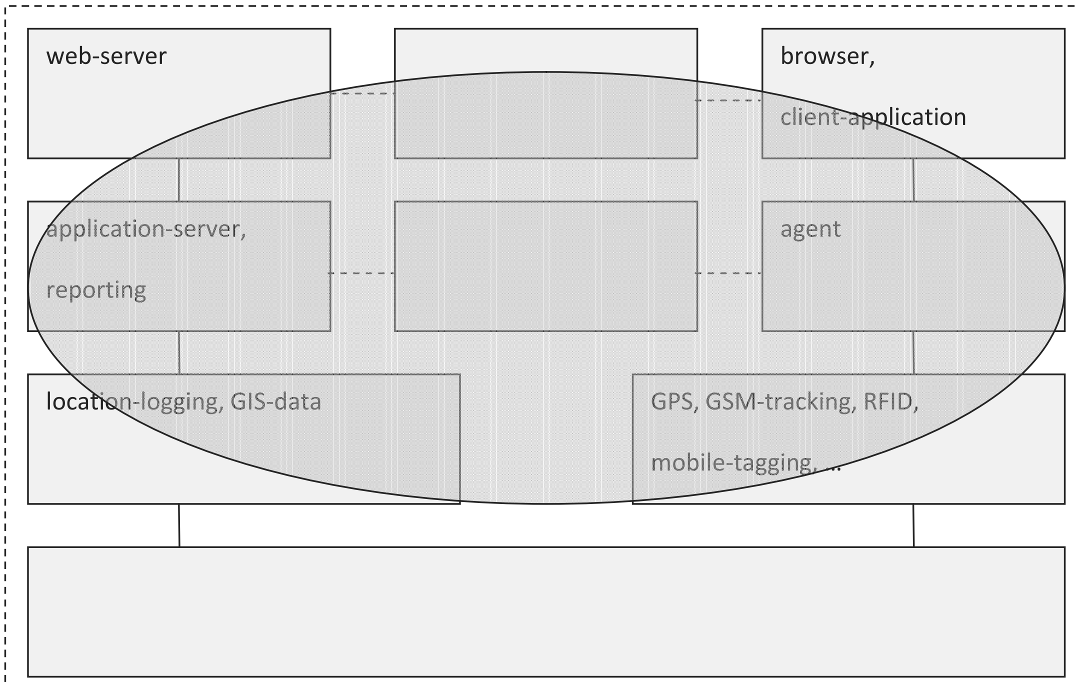
Three established variants of data collection for tracking user movements and behaviour are:

- Eye-Tracking (by high-speed-cameras)
- Motion-Tracking (by camera-system and markers at the body)
- GPS-Tracking (of trucks, containers, bicycles...)

Further possible implementations for tracking systems are:

- Tracing of the location of persons in the dwelling by cameras in the corridor and in the stairway
- User tracing by video-recording using monitoring-cameras installed in the public area and appropriate software for person identification

Figure 9. Tracking



- Logging of the keyboard- and mouse-interaction during the operation of a software product
- Movement tracking by detection of passing at predetermined RFID-tags

By adoption of tracking technologies data-security is a sensitive topic, because with dissemination of modern technologies data can be collected and users can be observed without their knowledge, therefore privacy and informational self-determination can be violated. As a consequence technologies for anonymisation and for secure ciphering play an important role.

Expected development: Projects by enterprises or communities will continue to have individual approaches, but standards could be established by the engagement of a mobile-telephone- or an RFID-manufacturer. Clarification of sensible questions related to broad dissemination of tracking solutions will best be solved by multi-stakeholder research projects.

Roadmap: The development of a mass-consumer tracking-technology would go beyond the scope of a single Living Lab. It should be aimed at a co-ordination with other appropriate research projects, nevertheless the system should be modularly expandable for different topics including tracking.

Technology starting set (only if necessary in a specific case):

- Eye-Tracking
- Motion-Tracking
- GPS-Tracking

TRANSFORMATION

By means of **transformations** structured data can be processed automatically according to given rules as for example filter, aggregation, scaling. These tasks are sometimes necessary, in order to make data comparable and evaluable. Data processing in the form of filtering and linkage of data occur in many places of the ICT layering-architecture and the information-flow, in particular within the large treated topic of the analysis, but also when presenting some information at the client side.

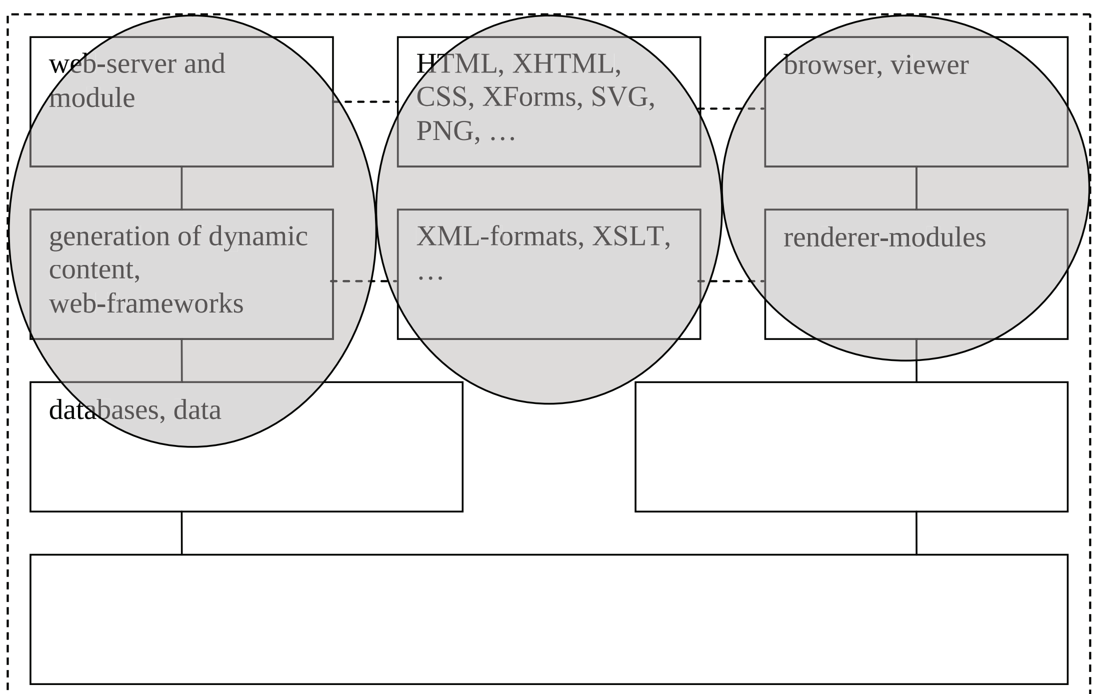
Transformation on server-side is primary used to adapt the data to the context of the data query, whereas the client side transformation takes device-specific aspects and user needs into account (customized layout).

When XML became a wide used standard, XML-transformation technologies like XSLT established. XSLT contains some very interesting new technologies like XPath and XQuery as they offer a quite easy way to query in large XML-data-sets. Furthermore XQuery, which implements the FLWOR-principals (For-Let-Where-Order by-Return), promises to be more type-safe, to have a higher performance and to be more intuitive.

There are controversial discussions going on about the practical usage of XSLT concerning productivity, performance, maintainability and stability. Alternatives like the APIs SAX and DOM and a lot of different (free and open) tools can be used as a fundament to work with XML data.

Expected development: It is not that clear which of the XML-Technologies (SAX/DOM within traditional applications, XSLT with XPath/XQuery) will establish as a method to describe transformations but it seems to be clear that it is a good idea to perform such transformations to generate content (e.g.: using templates) on a higher level of application.

Figure 10. Transformation



Roadmap: It is recommended to evaluate two or three of the mentioned implementations. The transformation layer should be exchangeable.

Technology starting set:

- XSLT
- Explicit transformation in JAVA (SAX, DOM), JavaScript or other programming languages
- Template based solutions like „Apache Velocity" (based on JAVA an permits easy integration with Web applications and frameworks)

TERMINAL DEVICES

There is a multiplicity of different **terminal devices**, which can be used on user side in a Living Lab. These can be roughly grouped as follows:

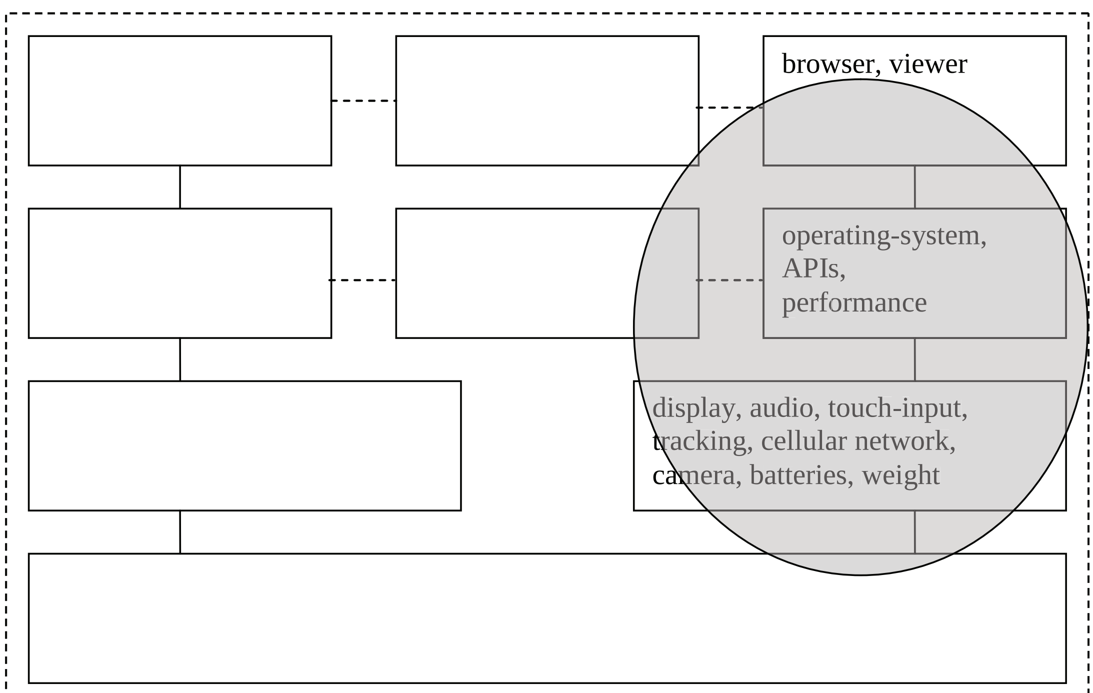
1. Stationary devices with operation interfaces
2. Stationary devices in autonomous operation
3. Mobile devices with operation interfaces
4. Mobile devices in autonomous operation

1. Stationary devices with operation interfaces: To this area belong all classical PCs with display, keyboard and mouse, but also notebooks, although they can be used "nomadic". Peripheral devices like laser-printers and tray-scanners are also belonging to this group of devices as they mostly can only be used stationary.

2. Stationary devices in autonomous operation: Devices in this area are fixed Webcams, RFID-tags and all other stations for data collection.

3. Mobile devices with operation interfaces: All mobile used notebooks, PDAs and smartphones

Figure 11. Terminal devices



are belonging to this group of devices. In addition new developments like wearable-computers, which can be integrated in working clothes (helmet, eyeglasses, waistcoat, and gloves), should also be mentioned here. Mobile devices can be equipped with special functions such as bar-code-scanners, RFID-readers and GPS-receivers.

4. Mobile devices in autonomous operation: Classical devices in this area are end devices for autonomous tracking and tracing of things and individuals in adoption of GPS and radio communication for transfer of geo-coordinates and possible other operational data. If the application is not time critical, the radio connection can be omitted and all data is stored local on the end device and will be transferred later on if it has contact to a service point.

Due to the design (light, small, battery-operated, rugged) of mobile devices a smaller computing- and graphics-performance and reduced ergonomics have to be accepted. As Berger (2006) points out:

Portables are also far more likely than desktop devices to be dropped, rained on, or exposed to temperature extremes. Even a user's pocket can be a harsh environment, subjecting its contents to motion, shock, the salty steam of perspiration, and scratches from such common items as house keys. PIDs [portable information devices] connectors must be smaller than those of desktops, yet they also have to tolerate frequent connection and disconnection.
. . .
A cell phone is no longer just a phone. It can be a camera, a PDA, an e-mail reader, a video display, and a navigation system all integrated into one. Yet PIDs—and their control surfaces—keep shrinking.

Regarding sustainability it has to be pointed out that mobile devices are designed energy-efficiently for long disconnected use from power-supply, however batteries only store a certain amount of energy and therefore they need to be charged or replaced in fixed intervals. For some activities mobile devices with a thumb-keyboard or touch-screen may be suitable, but for active consumer contribution into product development this device class seems to be negligible (up to revocation). A renewed view of the possibilities of mobile devices is however appropriate, if special requirements or new aspects give cause to it.

The interaction with handheld devices changes highly in short intervals. Classical interaction is done by a stylus or a small keyboard. New are gestures as a possibility for the operation of devices. The Apple "iPhone" reacts to its position and images rotate with the device to be viewed normally. The spreading of fingers on the touch screen causes the zooming of the displayed content.

Mobile devices and mobile internet access are mostly useful for continuous online operation and interaction.

Expected development: Innovation speed of the hardware manufacturers will remain at the current level and constantly new mobile devices and device classes (UMPC/MID, iPhone, Blackberry...) will appear on the market. Possibilities and conditions concerning handling and costs will change with the availability of new device classes.

Roadmap: To force hardware developments by oneself or to bind stakeholders and users to a certain hardware manufacturer could cause risks and potential disadvantages for a local Living Lab. The system should although offer possibilities for integration of mobile users (or users of other non-PC devices) in the future.

Technology starting set:

- Classical PCs with display, keyboard and mouse; Notebooks
- PDAs (consider J2ME availability)
- Smartphones (mobile telephones with

extended functionality and programming possibilities)
- Web-cams (as already mounted in factory-buildings, for observation of experimental setups and practice tests, etc.)

NETWORK ACCESS

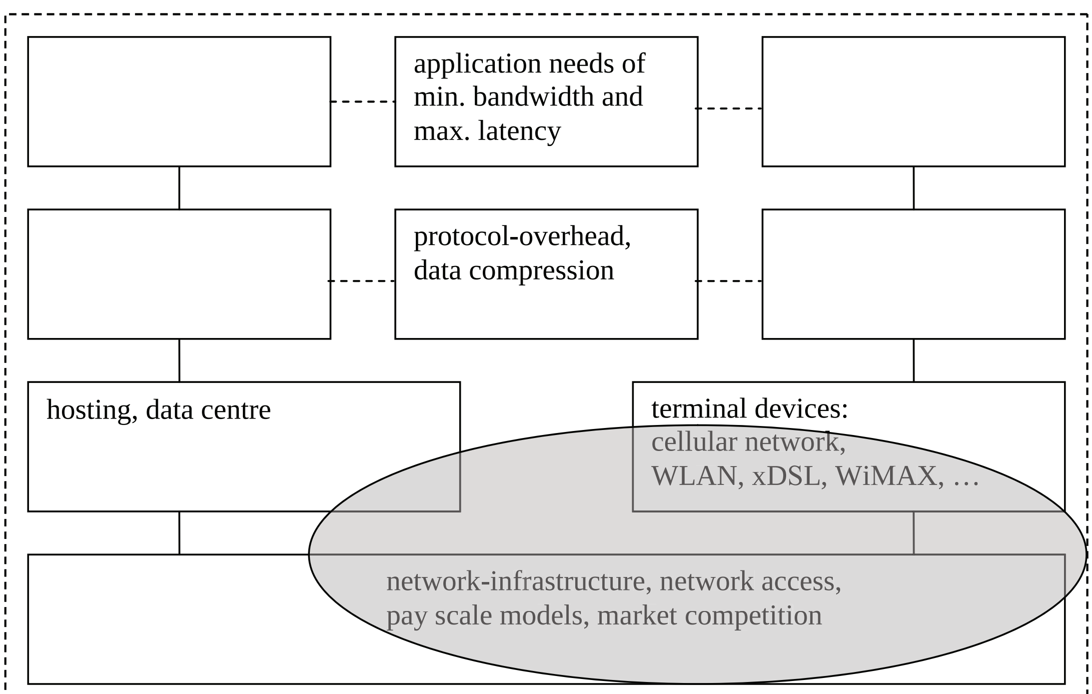
Usually the connection of host-machines (servers) of a Living Lab to the internet is established through conventional IP-internet-access. Therefore the presented Living Lab Roadmap focuses on the end-user part of the connectivity.

The question of the availability of networks, devices and their capabilities of running applications and to display the contents appropriately is a quite important one. It has a big impact on the customer relationships of Living Labs. The increasing number of households with a broadband internet access in Europe is a positive aspect which can be exploited by the Living Lab methods. An increasing number of households with a broadband-internet access leads to the (mostly subjective) appearance of more high performance Web applications and some types of Web based applications experience a higher acceptance (VoIP, Video streaming).

Usually an end-user will consume the offered Living Lab services via a cable-based Web-access. Those users have a sufficient bandwidth, the connections are quite cheap and already available (e.g.: DSL, DSL 2.0). Nevertheless there are several other network technologies which can be used to access the Living Lab Web-services:

- **Satellite Web-access:** Download-links via satellite have been available since several years (e.g.: Astra). Relatively new is the offer of a cost-effective satellite uplink. There are

Figure 12. Network access



several interesting areas of application of a satellite Web-access like at a construction site, remote locations, valleys without Web-access, etc.

- **Mobile Web-access:** Mobile Web-access can be handled via GPRS, UMTS, HSDPA, EDGE, etc. The areas of applications are mostly the same as the ones of using a satellite connection, but additionally the area of moving objects like trucks, transport vehicles, business trips, etc.
- **Wireless LAN (WLAN):** WLAN covers quite small areas. Within this area a connected user can move around freely. This is also an interesting alternative for fixed desktop computers. There is no need for additional wiring. A single WLAN-Access-point usually has a range of about 100 meters and good environmental conditions. By linking several WLAN-Access-points the covered area can be extremely extended (e.g.: a whole university campus, premises, etc.).
- **WiMAX:** WiMAX is similar to WLAN but it has a higher range. WiMAX can bridge distances up to 2 – 3 kilometres. With the help of bean-antennas, WiMAX networks can connect two nodes over a distance of up to 50 kilometres. The WiMAX Telecom (Austrian and Swiss company) for example built WiMAX networks in Austria for field tests in Burgenland, in the Vienna basin and in the eastern part of Styria in 2005 and 2006. The current state of distribution of WiMAX technology in Europe does mostly not exceed the utilization for field tests.

Expected development: The number of households with an internet-access and high speed internet access will continue to increase. Also mobile Web access will become more important in the future with the availability of supporting devices, higher transfer rates and cost reduction in transfer fees.

Roadmap: It does not seem to make sense to force the usage of one special type of network technology. The performance of the implemented services should comply with the limitations of DSL and mobile-phone-access.

Technology starting set:

- DSL
- Mobile 3G-access (UMTS, HSDPA), Mobile 2G-access (GPRS/EDGE)
- Internet-access over Cable-TV
- WLAN

TECHNOLOGIES TO BE OBSERVED

As technology in all areas of ICT advances fast and new developments come available, it is important to keep an eye on R&D for interesting and suitable technologies to be integrated in a Living Labs infrastructure. As it is not possible to predict new developments for ICT, Table 1 summarizes technologies to be observed in future progress of development to be integrated in the different before discussed topics.

Technologies which should be observed, including new developments or technologies with room for improvements, are listed in Table 1

ROADMAP STARTING SET AND EXTENSIONS

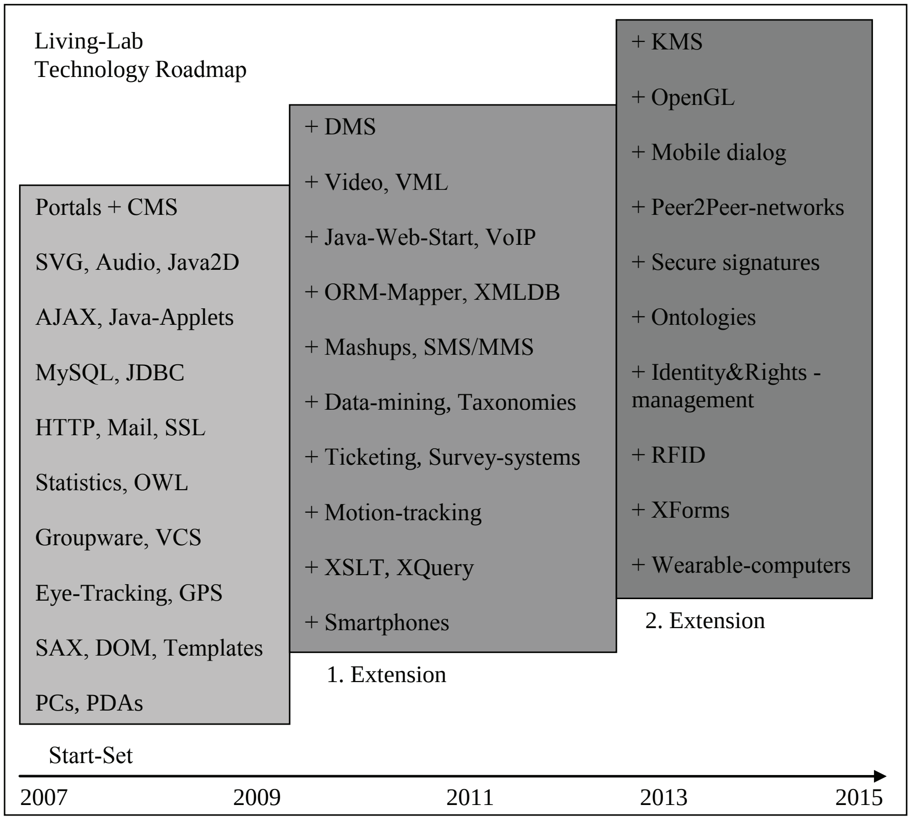
We identified and examined eleven areas of ICT functionality between server and client communication and drafted a roadmap of technologies for the implementation of a local **Living Lab** platform. The compiled roadmap is shown in the diagram in **Figure 13: Roadmap starting set and extensions**Figure 13.

The rough partitioning in a starting set and two extension stages and also the classification of

Table 1. Summary of technologies to be observed

Topic	Concerning technological maturity	Concerning social compliance	Concerning consumer acceptance	Concerning politics and market regulation
Content provision	Web-frameworks e.g. based on new programming-languages	blogs, forums	wikis, forums, CMS, DMS, KMS, Portals	wikis concerning copyright
Presentation	streaming-media, SVG, VRML	availability of free viewers, video concerning stalking …	DirectX, OpenGL, Java2D, Java3D, Microsoft Silverlight	media-player and media-viewer concerning competition
Interactivity and Dialog	AJAX-frameworks, mobile-solutions	chat concerning child-welfare and workplace agreements	VoIP, mobile-solutions, video-conference-systems, gesture input	VoIP
Management, Administration and Storage	Peer2Peer-networks, ORM, XMLDB, ORDB	any keeping of data concerning protection of privacy	Peer2Peer-networks	Peer2Peer-networks
Transport and Cross-Section Technologies	Mashups, secure and comfortable ciphering	platform-independence and availability of terminal devices	SMS and MMS (direct usage)	signatures (personal smartcards), bans on ciphering
Analysis	Semantic Web, semantic analysis	tagging, data-mining/ logging	XQuery, tagging, Semantic Web	ontologies
Collaboration	Mockup-simulation, Webwalls, online-creativity-tools, concurrent-engineering	models for sharing of intellectual property rights, social learning and adaptability to the evolution of the group	Tracing&Tracking, SMS / MMS	alternative models for intellectual property rights (e.g. „Creative Commons“)
Tracking	RFID	any form of data storage and transmission concerning privacy and data protection, GPS-tracking of individuals, RFID	anonymisation, GPS-based-tracking of motion and transportation, GPS-tracking of individuals	availability of GIS-data, general legal conditions for RFID-usage
Transformation	XSLT, XQuery, other approaches for transformation and transf.-languages	availability of terminal devices with high performance for XML-usage	XSLT, XQuery, XHTML and CSS	standardisation by W3C (XForms, …)
Terminal Devices	wearable-computers, GPS-applications, RFID-reader	RFID, Web-cams in public area	wearable-computers, PushEmail-reception, PDAs	
Network-Access	UPnP, Wibree	NFC, Bluetooth	NFC, Zigbee, DVB-H	Cable-TV, WiMAX, Fiber, Satellite-internet-access

Figure 13. Roadmap starting set and extensions



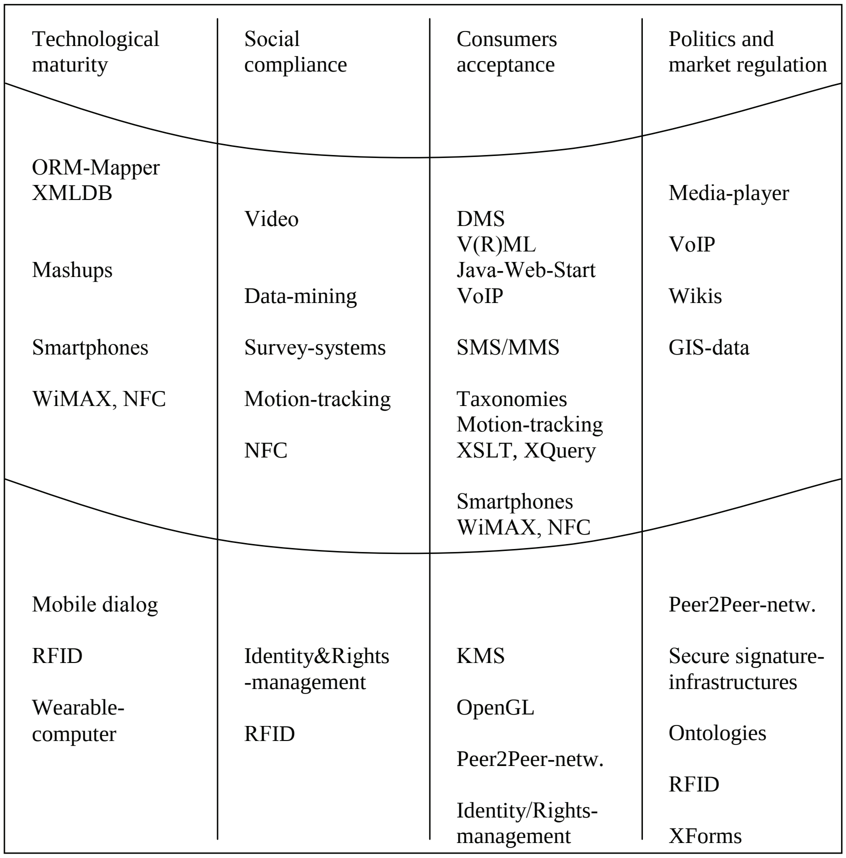
the technologies should be refined by observation of the market and results in R&D with methods like "technology radar". In addition each concrete implementation stage must represent a functional platform with interoperability interfaces to all desired and necessary technologies. The detailed extent and the structure of a Living Lab platform in a certain stage of development or at a certain time cannot be forecasted due to unknown basic conditions of the surrounding field (participating enterprises, motivation and commitment of the consumers, progress of development of some technologies and availability of interfaces, etc.).

A Breakdown of the most-promising technologies with regards to the aspects of observation and timeframe is shown in Figure 14.

Also for this representation it applies that only a periodic observation by a technology radar allows the identification of "fast advancing" (in foreseeable time usable) and "sufficiently mature" (immediately usable) technologies. Moreover the technology radar may emerge new technologies, which overhaul, displace or supplement other technologies.

While the usefulness of some hyped approaches and new proposals are questionable, a practicable starting set of technologies for the implementation of a Living Lab infrastructure can be found. The named technologies are immediately on-hand and by careful design of an open, modular architecture future extensions can be integrated smoothly.

Figure 14. Roadmap aspects overview



CONCLUSION

The concept of a Living Lab for involvement of users and customers in innovation processes is relatively new in the economy and R&D. The need of closer integration of user needs in innovation arises from the fact of shorter product cycles, to avoid over engineering, tailor the products to the customers' needs and therefore to enhance product acceptance by the market. As a significant risk could be the involvement of inadequate customers and users, a market analysis still needs to be performed for the identification of the target groups of products and services.

By applying the concept of Living Labs in the own innovation and / or production process, companies and institutions can easily apply agile methods (e.g. Scrum, Lean Development, eXtreme Programming, Rational Unified Process, etc.) applicable for in in-house development and production cycles, as one requirement for this is the gathering of feedback from customers and users in short iteration cycles. Living Labs and the available methods support information exchange and customer involvement.

The assignment of this work was to show technological aspects for the setup of a Living Lab environment with State-of-the-Art technology and possible future developments and therefore to develop a technology roadmap for tight user integration in the innovation process. As technology changes fast, this roadmap is possible to change in short time by new outcomes from innovation and R&D projects, but it is a good starting point for the setup of a technical Living Labs infrastructure.

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KEY TERMS AND DEFINITIONS

Consumer Contributed Product Innovation: Living Labs provide methods for active consumer contribution to product innovation, life cycles and product iterations.

Consumer Integration: In today's business world consumer integration in innovation processes is an important key factor for market success, because of shorter product cycles and specific user needs.

ICT (Information Communication Technology): All technologies for the communication of information are belonging to this sector including recording and broadcasting technologies.

Living Lab: Living Labs represents a research methodology for sensing, validating and refining complex solutions in multiple and evolving real life contexts.

Technology Radar: A technology radar is a way of observing the market for new innovations and technologies and gather information about them in a consistent style, relate and evaluate them on behalf of the own business.

Technology Roadmap: A technology roadmap outlines a possible implementation of a concept / product on behalf of available technologies.

Technology Starting Set: A technology starting set defines a bulk of technologies, which are required for minimal implementation purposes of concept.

Chapter XLII
Technologies to Support the Market of Resources as an Infrastructure for Agile/Virtual Enterprise Integration

Maria Manuela Cunha
Polytechnic Institute of Cávado and Ave, Portugal

Goran D. Putnik
University of Minho, Portugal

Joaquim Pereira da Silva
Polytechnic Institute of Cávado and Ave, Portugal

José Paulo Oliveira Santos
University of Aveiro, Portugal

ABSTRACT

The agile/virtual enterprise (A/V E) model is considered a highly dynamic version of the virtual enterprise (VE) model, and its implementation presents several requirements in order to keep the VE partnership aligned with the market, that is, with business. Such requirements include (1) the reduction of reconfiguration costs and effort, and (2) the capability to preserve the firms' private knowledge on products or processes. These must be assured by a specific environment, or, in other words, by organizational infrastructures as a meta-organizational structure for VE design (or integration) and operation, such as the Market of Resources—an environment developed by the authors to cope with the highlighted requirements, and assuring a better performance than the traditional environments such as the Internet search engines or the electronic marketplaces. The chapter describes the functionalities of the Market of Resources and explains how does it supports A/V E integration, and addresses some technologies that could support A/V E integration within the Market of Resources, namely XML/ebXML and Webservices. The chapter *proposes an architecture to support the operation of the Market of Resources, representing a fusion of the peer-to-peer (P2P) architecture with the client-server architecture, as a variant of P2P architecture. Also, a laboratory implementation of the Web services for manufacturing is presented too.*

INTRODUCTION

Most definitions of virtual enterprise (VE) incorporate the idea of extended and collaborative outsourcing to suppliers and subcontractors, in order to achieve a competitive response to market demands (Webster, Sugden, & Tayles, 2004). As suggested by several authors (Browne & Zhang, 1999; Byrne, 1993; Camarinha-Matos & Afsarmanesh, 1999; Cunha, Putnik, & Ávila, 2000; Davidow & Malone, 1992; Preiss, Goldman & Nagel, 1996), a VE consists of a network of independent enterprises (resource providers) with reconfiguration capability in useful time (or, in other words: in real-time), permanently aligned with the market requirements, created to take profit from a specific market opportunity, and where each participant contributes with its best practices and core competencies to the success and competitiveness of the structure as a whole. Even during the operation phase of the VE, the configuration can change, to assure business alignment with the market demands, traduced by the identification of reconfiguration opportunities and a continuous readjustment or reconfiguration of the VE network, to meet unexpected situations or to keep permanent competitiveness and maximum performance (Cunha & Putnik, 2002, 2005a, 2005b).

A particular model characterized by a high reconfiguration dynamics capability is the agile/virtual enterprise (A/V E) model (Cunha & Putnik, 2005b; Cunha & Putnik, 2006a, 2006b; Putnik, 2001; Putnik, Cunha, Sousa, & Ávila, 2005).

The implementation of the VE model should assure the required reconfiguration dynamics, which, as we will see in the chapter, is dependent on (1) the reduction of reconfiguration ("transaction") costs and effort, that is, requires a balancing between reconfiguration dynamics and reconfiguration time and costs and (2) the capability to preserve the firms' private knowledge on products or processes.

The formation, integration and operation of A/V E relies on the existence of an adequate platform of information and communication technologies. The environment for creation, integration, operation, reconfiguration and dissolution can be implemented under the format of a Market of Resources, an entity conceived to cover the whole A/V E life cycle (Cunha & Putnik, 2005d; Cunha, Putnik, & Ávila, 2004; Cunha, Putnik, Gunasekaran, & Ávila, 2005). The market offers several business models that already provide a reasonable part of the characteristics of the A/V E model and of the Market of Resources. The electronic marketplaces implement several functionalities identified in the Market of Resources, and the emergent technologies that tend to be consolidated in the implementation of electronic marketplaces can be fundamental also in the implementation of the Market of Resources.

In the first part of the chapter we discuss the VE reconfiguration dynamics requirements and present the Market of Resources as the indispensable environment for enabling VE reconfiguration dynamics, that is, as a tool for managing, controlling and enabling networking and dynamics in VE integration, and the related supporting IT platform architecture.

Based on the organization of the Market of Resources, that is, in its general principles, processes, procedures and operation rules, as well as on the current state-of-the-art of electronic marketplaces, an information technologies (IT) architecture to support the Market of Resources was developed. This architecture defines the integration platform for the operation of the Market of Resources in all the phases of the A/VE life cycle. One of the most important elements of the proposed IT architecture is the *middleware* level supporting *Web services*. The supporting IT and the related architecture are presented in the second and third part of the chapter.

In the second part, the chapter addresses some technologies that could support A/V E integration based on the Market of Resources, namely XML/ebXML and *Webservices*, in the integration and automation of processes and services, that is, in the automatic integration of interenterprise business processes and coordination of business transactions.

In the third part, it is proposed a hybrid peer-to-peer (P2P) architecture model to support the Market of Resources, that results of the fusion of the peer-to-peer (P2P) architecture with the client-server architecture, where the characteristics of the first are remarked as a variant of the P2P architecture.

REQUIREMENTS FOR VIRTUAL ENTERPRISE INTEGRATION

A few important trends have been identified in the strongly competitive business environment, which according to several experts will lead to dramatic changes in present and future productivity and approaches. Altogether, the combination of the shorter life span of new products, increasing product diversity over time, rapid technological developments, increased technological complexity, market globalization, frequent changes in demand, uncertainty, strong competition, are the main trends of the actual worldwide economic context.

For the last years, global competition has strengthened the significance of a company's ability to introduce new products, while responding to increasingly dynamic markets with customers rapidly changing needs, and thus claiming for shortening the time required to design, develop and manufacture, as well as for cost reduction and quality improvement. In the past a product could exist without great changes (adaptations, redesigns). Faced with the challenges of today, a product suffers several redesigns in order to be competitive, that is, aligned with the market demands, besides the shorter duration of a product.

These trends requires enterprises the capability to incorporate in their products or processes the best resources available in the market, and to dynamically adjust its interorganizational structure to keep its maximum alignment with the business opportunity.

But the changing business environment requires also the permanent adaptation of the partner organizations (VE), that is, alignment with business opportunities. By alignment, in this context, we mean the actions to be undertaken to gain synergy between business, that is, between a market opportunity, and the delivery of the required product, with the required specifications, at the required time, with the lowest cost and with the best possible return (Cunha & Putnik, 2005a).

Reconfigurability, that is, the ability of fast change of the VE organization (structure) face to the unpredictable changes in the environment (market), is a requirement of the VE to keep the partnership aligned with business requirements and is a consequence of product life cycle dynamics, that is, business and market dynamics. This requirement implies the ability of:

1. Flexible and almost instantaneous access to the optimal *resources* to integrate in the enterprise
2. Design, negotiation, business management and manufacturing management functions independently from the physical barrier of space

3. Minimization of the reconfiguration or integration time

A VE is defined as a reconfigurable network of independent enterprise, that are partners of the VE, to assure permanent business alignment, in transition between states or instantiations (VE network, or partnership, configurations) along time, as represented symbolically in Figure 1. VE dynamics considers a succession of network's states (physical configurations of the VE) along the time, that is, the network reconfiguration dynamics. Dynamics means precisely the intensity of change the VE is subject of.

MARKET OF RESOURCES: AN ENVIRONMENT FOR VIRTUAL ENTERPRISE INTEGRATION

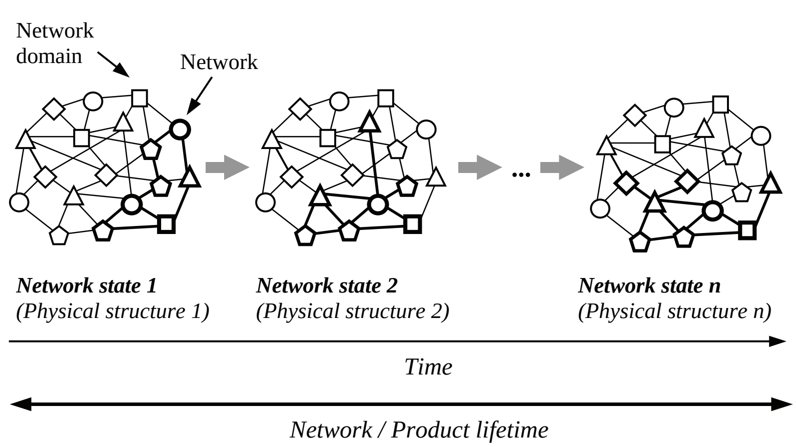
Value chains have been supported by a wide variety of technologies to communicate, but the pace of competition requires more intelligent and effective information and communication systems and technologies. Literature suggests that "traditional" Internet-based tools (such as WWW search engines, directories, e-mail, electronic marketplaces, etc.), can support some activities of VE integration, helping from procurement processes to the search of partners for a partnership, including electronic automated negotiation, electronic contracting and market brokerage (Cunha & Putnik, 2003a; Dai & Kauffman, 2001; Dogac, 1998; Hands, Bessonov, Blinov, Patel, & Smith, 2000; O'Sullivan, 1998; Wang, 2001).

Khalil and Wang (2002) have proposed ways for information technology to enable the VE model, by providing:

1. Web-based information systems, supporting B2B and B2C applications
2. Sophisticated customer databases, supporting data mining, enhancing business intelligence and decision support
3. Support for organizational learning
4. Groupware supported coordination and decision-making

Several authors (Carlsson, 2002; Martin, 1999) refer that the new VE paradigm requires intelligent support for transactions, new effective methods for finding partners, intelligent support

Figure 1. Networking dynamics considers a succession of network's states along the time (Cunha & Putnik, 2005b)



to virtual teams, knowledge management support systems, reliable decision support in VE/network design/configuring, effective tools for information filtering and knowledge acquisition, support in the identification of the best alternatives to keep the network aligned with the market, that is, competitive.

Several supporting organizational infrastructures[1] and supporting applications must exist before we can take advantage of the VE organizational model, such as: electronic markets of resources providers, legal platforms, brokerage services, efficient and reliable global and intelligent information systems, electronic contractualisation and electronic negotiation systems and decision support systems and tools.

The Market of resources, is a solution proposed by the authors, to fully support VE implementation, operation and management, which is in details documented in Cunha and Putnik (2005c, 2005d), Cunha and Putnik (2006a, 2006b), Cunha et al. (2000), and Cunha, Putnik, and Gunasekaran (2003).

Virtual Enterprise Integration Using the Market of Resources

The section explains the main activities involved in the VE creation or VE reconfiguration using the Market of Resources. The activities to perform in order to create or reconfigure a VE are the following:

- **VE request:** Request involves the negotiation with the Market of Resources, broker allocation and VE Design. The VE design complexity is function of product complexity and requires time to answer (by the market). There is an amount of resources needed to completely define the VE (creation or reconfiguration) Project. These resources are broker time, knowledge and effort (human and computational). This VE project consists on a number of instructions and specifications that will drive the search, negotiation and integration, and is associated with a degree of complexity. VE Design is an activity to be undertaken by the client and after validated by the Market of Resources (broker), or in alternative, undertaken interactively by the client (the owner of the VE) and the broker, depending of the request complexity, or of the client ability / knowledge to define the VE project.
- **Resources search, selection and negotiation:** Search, negotiation and selection consists of several steps: the identification of potential resources, separation of eligible resources, negotiation within these to the identification of candidate resources, and finally the selection among these and find the best combination for integration. The identification of the potential resources and, within this set, the separation of the eligible ones is made automatically by the market from its knowledge base, and without intervention of the client (VE owner). In the market, the negotiation can be done using different approaches (automated, reverse auction and direct negotiation). The final selection is a computer-aided activity, controlled by the broker, with an eventual intervention of the VE owner, if necessary.
- **VE integration:** In this activity we will consider only the contractualization aspect. The Market of Resources assures an automated contractualization.

These activities are systematized in Table 1.

The Market of Resources Structure

The Market of Resources is an institutionalized organizational framework and service assuring the accomplishment of the competitiveness requirements for VE dynamic integration an-business alignment (Cunha & Putnik, 2005d; Cunha, Putnik, & Gunasekaran, 2002; Cunha et

Table 1. Description of VE creation/reconfiguration activities

Activity	Activity Description
A/VE Request	
- *Request negotiation*	- Registration of the A/VE owner, specification of the request, broker allocation and contractualization with the Market.
- *A/VE design*	- Computer-aided A/VE design, with specification of the resources requirements and of negotiation parameters; - The selected broker will validate the A/VE Design, or will support the Design, in complex products or when complex negotiation methods are required.
Resources Search and Selection	
- *Eligible resources Identification*	- Identification of the subset of the Market of Resources knowledge base where it is intended to perform the search (Focused domain); - Focused domain filtering – automatically, from the requirements of the VE Design to identify Eligible Resources (eligibility is automatically driven from the catalogues / resources database)
- *Negotiation*	- Computer aided (more or less automated) negotiation with the eligible resources providers, to identify the candidate resources for integration; we distinguish between automatic search, inverse auction and direct negotiation.
- *Selection*	- Computer-aided and broker mediated decision-making for final selection of resources to integrate; sorting of the negotiation results and identification of the best combination of resources providers, followed by confirmation with the selected ones. Depending on the complexity, it involves more or less Broker dedication.
A/VE Integration	
- *Contractualization*	- Automatically, when a selected resources provider confirms its participation; - Selection of the adequate contract from a standardized collection (for request formalization, integration, …); - The Market also offers integration procedures, not considered here.

al., 2005). The operational aspect of the Market of Resources consists on an Internet-based intermediation service, mediating offer and demand of resources to dynamically integrate in an VE, assuring low transaction costs (as demonstrated in (Cunha & Putnik, 2003b, 2003c)) and the partners' knowledge preservation.

The services provided by the Market of Resources are supported by (Cunha & Putnik, 2005d; Cunha et al., 2003; Cunha et al., 2005):

- A knowledge base of resources providers and results of their participation in previous VE (historic information)
- A normalized representation of information
- Computer aided tools and algorithms
- A brokerage service
- Regulation, that is, management of negotiation and integration processes, as well as contract enforcement mechanisms (i.e., the services to carry on the judicial processes when needed)

The Market of Resources is able to offer (Cunha & Putnik, 2005d; Cunha et al., 2003):

- Knowledge for VE selection of resources, negotiation and its integration
- Specific functions of VE operation management
- Contracts and formalizing procedures to assure the accomplishment of commitments, responsibility, trust, and deontological aspects, envisaging that the integrated VE accomplishes its objectives of answering to a market opportunity

The overall functioning of the Market of Resources is represented by an IDEF0 diagram[2] in Figure 2. It consists of the creation and management of the Market of Resources itself (process A.1.), as the environment to support the design and integration of the VE (process A.2.) that, under the coordination of the environment, operates to produce a product to answer to a market opportunity (process A.3.). The market offers technical and procedural support for the activities of identifying potential partners, qualifying partners and integrating the VE, as well as coordination and performance evaluation mechanisms. Process A.2. (VE design and integration) is detailed in Figure 3.

This operation is one of the most effort consuming for the user in its interface with the market. The request for VE creation (or reconfiguration or dissolution) is composed by request negotiation, VE design and request formalization.

Figure 2. IDEF0 representation of the global process for the creation of a Market of Resources and for VE design, integration and operation (Cunha et al., 2003; Cunha et al., 2005)

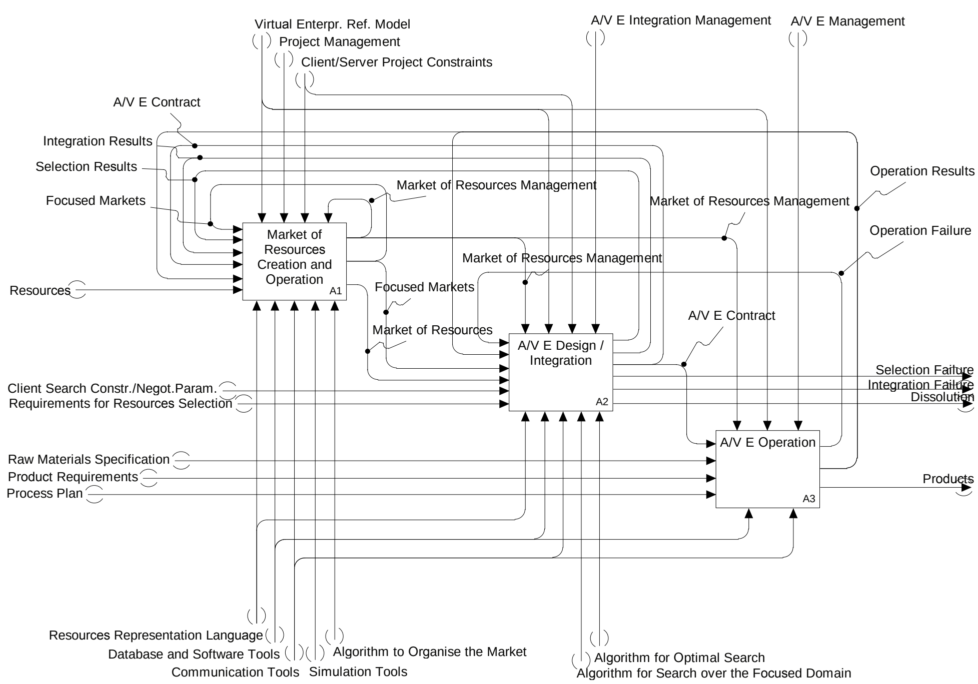
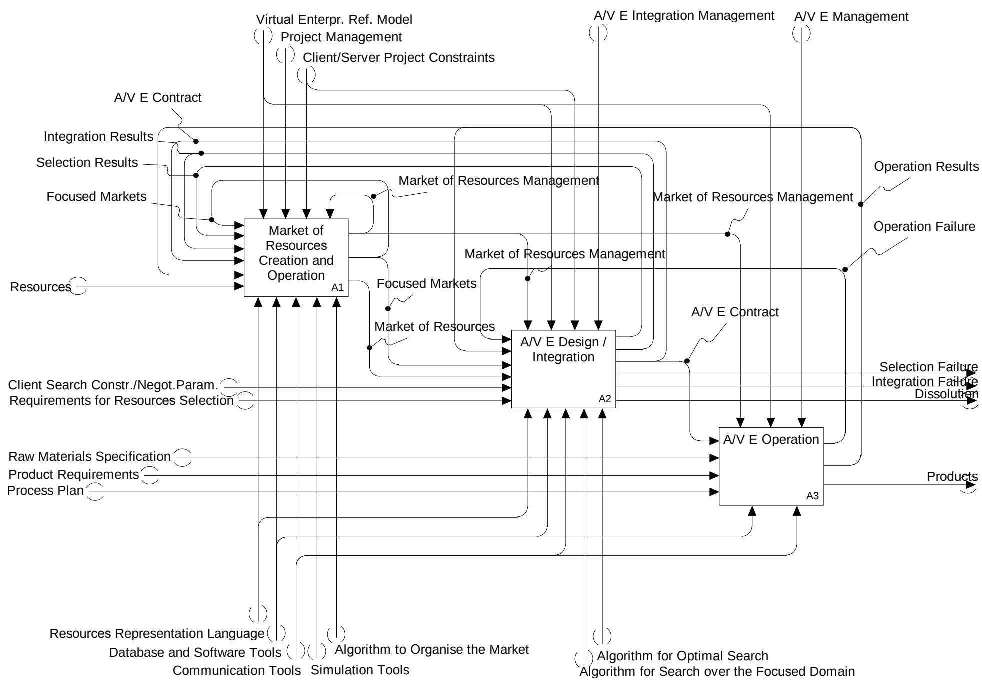


Figure 3. IDEF0 representation of process A.2.—VE design and integration



TECHNOLOGIES TO SUPPORT THE IMPLEMENTATION OF THE MARKET OF RESOURCES

Table 2 lists the main families of technologies to support the main components or processes of the Market of Resources. Virtual enterprise integration is based on the development of technologies able to effective and efficiently handle information complexity. Several technologies (besides the so-called traditional technologies), such as software agents and Web services are living a period of fast expansion and will impact considerably the way resources providers and virtual enterprises interact and perform.

Web services are the main technology that will support cooperation and integrability. In order to look inside each resources provider, a look inward at their own internal systems, applications and processes is necessary. Several business processes that span across multiple internal applications must be able to communicate dynamically in real-time so that it can communicate with the outside world.

The use of standard XML protocols makes Web services platform, language and vendor independent, and an ideal candidate for use in enterprise application integration solutions and as such, a basis for the Market of Resources. By eliminating the interoperability issues of existing solutions (e.g., CORBA and DCOM), and leveraging open Internet standards, Web services description language (WSDL)—to describe, universal description, discovery and integration (UDDI)—to advertise, simple object access protocol (SOAP)—to communicate and Web services flow language (WSFL)—to define work flows.

But several improvements are to come, with the next generation of functionally and technologically advanced Web services, but this concerns are at moment out of our discussion, as we want to highlight the potential of this universal

Table 2. Technologies to support the main components/processes of the Market of Resources (Cunha & Putnik, 2006a)

Market of resources components /processes	Support technologies and tools
- Market contents: user/buyer profile, catalogs, historic, database of resources	- Database management systems - Distributed database management systems - E-Business development platforms - Portals
- Negotiation: request for quotes, auction/reverse auction, optimal selection	- Web services - Software agents - Electronic negotiation tools - Algorithms or protocols - Regulation of negotiation - Intelligent decision making systems - Workflow management
- Transactions: payment, contractualization	- Web services - Electronic payment - Digital signature - Certification - Other security mechanisms
- Management: monitoring, performance evaluation, analysis of operation results, decision making, security	- Web services - Simulation tools - Workflow technology and collaboration techniques - Regulation - Data analysis and decision support systems - Security systems, digital certification, …
- Brokerage: expert advise, monitoring and coordination	- Messaging and conferencing - Database management systems, data analysis and decision support systems - Selection algorithms - Management procedures
- Resources providers integration: file translation, collaboration,	- Web services - Standards for product/services description - Collaboration tools, - Data translation standards and tools - Communication protocols
- Resources final selection (optimal combination)	- Algorithms, heuristics and computer aided tools - Intelligent decision making systems - Artificial intelligence - Data analysis and decision support systems

language and framework to the implementation of an environment to support virtual enterprise integration.

Web services are the most promising technology for business processes integration (webMethods Inc., 2002). The automation of processes, the automatic integration of interenterprise business processes and the coordination of complex business transactions are determinant for obtain high productivity from technology usage and for the creation of dynamic collaboration environment. Several specifications were developed to meet that purpose, like business process execution language for Web services (BPEL4WS), electronic business using extensible markup language (ebXML), and business process management language

(BPML). BPEL4WS and ebXML are more likely to survive and coexist for the foreseeable future; ebXML will probably dominate a regulated B2B scenario and BPEL4WS is more compliant than a nonregulated B2B/B2C scenario. RosettaNet is the first integration processes standard implemented worldwide in industry, by more then 400 of the world's leading information technology and electronic components companies.

Besides SSL and PKI, supported by all the software platforms, it is required more high level security mechanisms for business processes interenterprise integration, like security assertion markup language (SAML) or XML key management specification (XKMS) for Web services security and management, as well as other basic services to supporting the platform, that is, the WS-security stack of services is required.

INFORMATION TECHNOLOGY ARCHITECTURE AND THE MARKET OF RESOURCES

The organization of the Market of Resources is supported by a communications infrastructure where the electronic processes of business transactions among partners take place. Faced with a plethora of solutions and the permanent development of new technologies, we introduce an IT architecture for the Market of Resources, to guide the selection of the most adequate technologies as well as the development of an integration platform to support the organizational model of the Market of Resources.

There is not yet such architecture. Even SOA architecture when implemented with Web services is distributed, open and presents dynamic characteristics (WSDL and UDDI), which raises its flexibility, lacks an organizational view. The higher layers, such as transactions management, choreography, security or authentication are not yet well established. However, there have been launched recently several specifications by standardization consortia, of which we highlight BPMI and ebXML, to overcome these insufficiencies. The corresponding specifications—*Business Process Modeling Language* (BPML) and *electronic business* XML (ebXML)—focus aspects complementary to the management of electronic commerce processes.

The IT infrastructure must support the functionalities required by the processes list at the first column of Table 2.

Face to the constraints invoked, it is proposed a model of an architecture according to a physical and a logical perspectives.

- **Physical architecture:** Describes the interconnection between the several elements of the system
- **Logical architecture:** Shows the structural composition of the software layers that constitute the system

The Physical Architecture

During the 1970s, the computer was an element of support to enterprise management. At that time, most of the systems were not interconnected and were constituted by one central unit with several terminals for access. Later, at the beginning of the 1980s, the personal computer and Ethernet emerged. Networks within enterprises became common and the hybrid systems emerged, constituted by multi-user systems and personal computers connected in networks. Between the mid-1980s and beginning of the 1990s, it was the apogee of the client/server systems, and the organizations' internal networks were consolidated.

With the World Wide Web explosion in the 1990's, the client/server concept was widened from the organizations' limited universe to the global network.

The recent P2P architecture provides a totally decentralized computation environment. However, functionalities continue to exist that justify the existence of dedicated servers, like for example the management of directories with information about the localization of each node/pair and the services it provides.

The architecture proposed to the support to the Market of Resources operation results from the fusion of the P2P architecture with the client/server architecture[3], where the characteristics of the first are remarked. This way it is classified by many as a variant of P2P architecture. By its intrinsic characteristics, the hybrid P2P architecture presented in Figure 4 is the one that is best suited to the operation of the Market of Resources, as it offers as key characteristics interoperability and distributivity, fundamental requisites of the A/V E model and its underlying BM_virtual enterprise architecture reference model (BM_VEARM) (Putnik, 2001). P2P platforms have usually objectives of distributed computation, contents sharing and collaboration, which are also the support to the market operation.

The hybrid P2P architecture is based upon two basic entities:

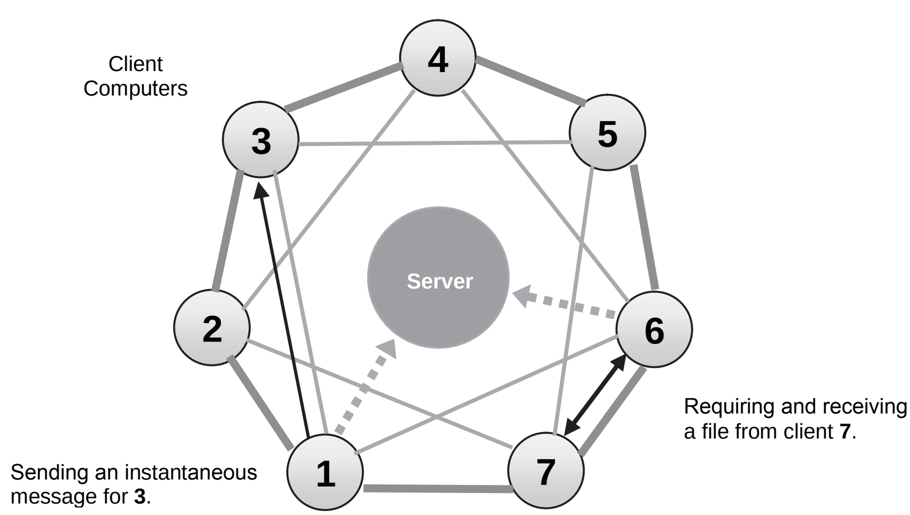
- **Client computers:** The nodes of the network and concern to all the computers that can be clients and suppliers of services/applications of the network
- **Servers:** The computers dedicated to a particular service that perform certain operations of support to the operation of P2P applications

A P2P network can have one or more dedicated servers that support the functions of management and coordination of the network or fundamental services, such as directory of the computers of the network, security and accreditation, business processes management, application server and so forth.

It is a scalable and flexible architecture that allows a fast evolution to be adapted to new requirements. It accomplishes the requisites for the integration infrastructure according to Linthicum (2001):

- Real time answer, which implies the existence of messaging systems and processes automation
- Support to processes and data interconnection, implying the interoperability of processes (BPML, ebXML) and the utilization of open standards for data registry (XML)
- Share of information relevant to all the participating systems

Figura 4. The P2P hybrid network proposed to support the operation of the Market of Resources



The Logical Architecture

With the introduction of database management systems (DBMS) during the 1970s, business applications focused on the execution of processes and the interface with the users, and laid the functions of data storage and access to the DBMS. This evolution represented an enormous advance towards the easier development and maintenance of applications, as well as in the data security. In the decade of the 1990s, appeared a new paradigm of software applications development with the creation of a third layer referring to the user interface allowing an application of support of a given process that could evolve from one technology to another, or could simultaneously have different interfaces, and only by change of the last layer, the user interface.

We presently assist to a new paradigm, consequence of the need of supporting new processes or to change the processes currently supported by applications, in a short time. Contrarily to the concept prevailing up to now, where the applications were designed according to requisites identified at a given time, being the identified processes integrated in the application structure, the applications to support an A/V E should be independent from the processes. It should exist as a layer of management of business processes, where the active business processes are dynamically configured.

Besides the services of monitoring, management and optimization of interenterprises business processes, it is needed configuration and installation tools. Before being possible the execution of processes in a virtual enterprise, it is needed to specify the relations among the several partners. It is about services of management of extended relationships (XRM—eXtended Relationship Management) that can be configured by the partners themselves to cover the whole virtual enterprise. In this aspect, the concepts of the P2P model inherent to the proposed architecture can perform an important role. Once configured or reconfigured, the A/VE operation can be supported by the execution of processes at the superior layer.

The proposed architecture is centered on the interoperability offered by the *middleware* layer of support to *Web services*, as presented in Figure 5.

The architecture of the proposed platform of integration to the implementation of the Market of Resources consists of six layers: (1) business processes, (2) brokerage services, (3) middleware, (4) applicational platform, (5) data repository and (6) physical infrastructure; to assure the necessary interoperability, distributivity and flexibility of the infrastructure to adapt to the A/V E dynamic integration needs.

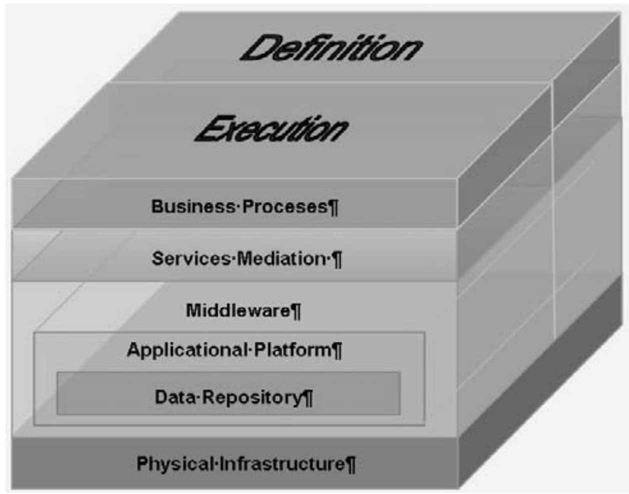
The processes automation supported by the business processes management allows a high level of flexibility that allows the fast A/V E reconfiguration. The principles of the model driven architecture, rapid development and continuous actualization of applications based on the creation and modification of high level functionalities (UML) are applied in the environments of definition and execution of business processes (BPM).

The layer of business processes (BPM) must contain, besides the current processes definition, a block that stores the business rules (the regulation of the Market of Resources), that the processes must verify and that constitutes a validation tool and the more stable part of the system.

Several types of mediators or brokers exist, supported by adequate servers, responsible by several aspects of the quality of the service: location, availability, performance, capacFity, security, confidentiality, integrity, scalability and maintainability.

The architecture of the integration platform to the implementation of the Market of Resources already introduced consists of six layers that assure the interoperability, distributivity and flexibility of the infrastructure in order to fast adapt itself to changes.

Figure 5. Integration platform for the implementation of the Market of Resources (logical architecture).



- **Business processes:** This layer defines the management processes of the Market of Resources and of all the processes of the A/V E life cycle. This layer corresponds to the BPM, in which the business processes are defined and executed, assuring traceability of all the processes and defining personalized access to services and contents. The definition of processes is independent of the applications, so it becomes easy to adjust the processes to the requisites of the market.
- **Services brokerage:** The operation of the Market of Resources is based on a set of services provided by this layer, which include the directory of resources, search tools, selection tools, simulation, artificial intelligence, messaging systems, electronic negotiation, security and authentication services, and so forth. In this frame, we can also include the services made available by providers of specific applications or application service providers (ASP), which can include financial management, sourcing and selling management, customers and suppliers relationship management, CAD systems and so forth. This layer allows the available services to locate and know that they are executed by the applicational platform.
- **Middleware:** The protocols, software and interfaces that interconnect BPM systems to applications; it can also be the way of connecting different applications or to allow the access of applications to data. There are included description protocols (UDDI) and execution of *Web services* (SOAP), as well as protocols and application program interface (APIs) to the execution of P2P applications. Besides allowing the operationality between different environments, this layer also assures distributivity and access to resources independently of their geographical location.
- **Applicational platform:** Corresponds to the set of applications available in the Market of Resources environment, which can be accessed through middleware in the execution of BPM processes or by other applications, local or remote; it includes proprietary applications, legacy systems, P2P applications and ASP applications (applications that can

be remotely accessed by accredited users that pay for the service, in alternative to install the applications in a own system). This layer contains the execution of the services indicated in the brokerage layer.

- **Data repository:** The data repository can correspond to different scenarios, from specific of a given application (and only that application can manipulate them), databases (accessible through the respective database management systems) or as data files in standard formats (accessible directly by the file management system). In any case, data can be local, remote or distributed.
- **Physical infrastructure:** Corresponds to computers, networks, operating systems, communications and basic services that assure the operation of all the superior layers; to assure a broader participation of resources providers, this layer must correspond to the Internet.

In each layer there exist two environments: *definition* and *execution*. The *execution* environment is necessary to the operation of processes and application run. It is in the *definition* environment where are defined processes, the available services, the interface with applications and data syntax and structure (metadata); this environment assures interoperability and adaptation to change.

When separating processes from applications, the BPM layer allows an increased agility and fast response to market changes, by an easy processes redefinition. In case of interorganizational processes; it is necessary that the BPM systems verify the WfMC standards to assure its interoperability. However, it is not enough that the process definition is understood by the partner; it is necessary to negotiate among the diverse partners the process itself and, once accepted a common definition the process should be integrated with other processes active in each organization.

Web services are the other pillar of the proposed architecture. They allow the construction of brokerage and middleware layers, which, under some points of view, can be seen as only one layer. This technology allows to support the interorganizational and distributed business processes, to implement atomic transactions or complete business processes, interconnect heterogeneous applications and to support the operation of P2P applications. They can also be used in interactive applications (standards WSIA e WSRP).

Besides the generalized acceptance of a data representation standard (XML), data are still intrinsically connected to applications, that know their syntax and semantic, which limits interoperability and flexibility. There still exist many problems to overcome in this area, such as data authentication services, product/services description standards, direct access to unknown data (content automatic interpretation, semantics and syntax), management of private and public data, and management of historical data. With the alteration of processes it is also performed the alteration of the data that support them, what poses several difficulties to the storage and interpretation of data concerning processes that are no more supported.

XML is easy and platform independent, but problems remain to be solved, such as storage and management of XML databases. It is missing the implementation of a new database paradigm: a semistructured model, in opposition to the relational model, and object oriented, which are themselves strongly structured (lack of flexibility), that perfectly combines data and metadata, in a way to develop adaptability and perfectly manage historical data.

Supporting Tools and Mechanisms

Table 3 illustrates as an example some of the supporting tools and mechanisms proposed for each layer (column 2 of Table 3), as well as several supporting standards and technologies—protocolar and technological support (column 3).

The proposed model of architecture focused important functionalities not currently implemented in the electronic marketplaces, such as interoperability, sharing of dedicated applications (P2P) such as CAD systems and artificial intelligence tools, collaboration in processes (P2) and flexibility in business processes (BPM).

AN IMPLEMENTATION

In this section, an example of a laboratory installation that has been implemented at the University of Aveiro (Alvarinhas, 2006) is presented. The example shows how the Web services can be used for the manufacturing services solving real problems.

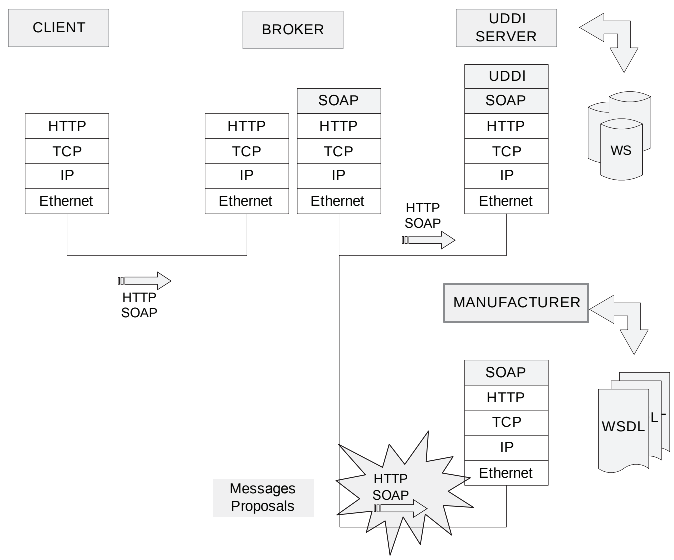
Figure 6 presents the implementation architecture. This architecture encompasses: the client, the broker, the manufacturer and the UDDI servers. This is a typical "three-level" hierarchy architecture, and the basic architectural pattern as a building block for more complex manufacturing system structures, oriented to the dynamically reconfigurable MS and service architectures (see Putnik, 2001; Putnik & Sluga, 2006; Putnik, Sluga, & Butala, 2006) where Broker (also, resource manager or mediator) is an agent of the reconfiguration dynamics. This architecture implements the market mechanisms as one of the mechanisms for developing an adequate structure that would be the most competitive (for the order considered).

A manufacturer can provide Web services to remotely accept and manufacture client orders in

Table 3. Tools and mechanisms (column 2) and supporting technologies and standards (column 3) proposed for each layer of the architecture

Platform	**Supporting Tools and Mechanisms**	**Supporting Technologies and Standards**
Business Processes	- BPM engine, definition and processes interchange	- BPML, ebXML, Wf-XML, BPQL, WSEL
Services brokerage	- Services brokerage, registry and services management, Access control	- UDDI
Middleware – *web services*	- Access to applications and support to services of localization, availability, performance, capacity, security, confidentiality, integrity, reliability, scalability and maintainability, etc.	- SOAP, WSDL, JXTA
Applications	- Electronic catalogues and directories, electronic commerce platforms, tools for resources search and selection, management applications, CAD systems, tools for collaborative development, etc.	- .Net, Java
Data	- Database management systems (DBMS), Distributed DBMS, DOM, etc..	- EDI, XML, cXML, xCBL, STEP
Infrastructure	- Network management and IT infrastructure management	- TCP/IP, http, https, SSL, digital certificates, etc.

Figure 6. Implementation of the inter-enterprise distributed and agile manufacturing system without Market of Resources as an operating environment–basic architectural pattern as a building block for more complex manufacturing system structures (Alvarinhas, 2006)



real time. To do so, the manufacturer has to implement Web services on its server. This server interacts with the manufacturer's shop floor machines and with the brokers, around the world, as the intermediators with clients. The manufacturer's server must implement several Web services, for example, to automatically generate budgets and accept contracts through the WEB.

The client, using a usual browser Web, interacts with the broker to define the product specification and the budget criteria sort (by price, by delivery date or others).

The broker automatically will find all manufacturers available in the world, asking for all manufacturers previously registered in UDDI servers (e.g., the IBM or Microsoft UDDI servers).

Using the manufacturer URLs provided by the UDDI servers, the broker automatically asks to all manufacturers their own WSDL files (Web services description language files) where their Web services are described.

Knowing the Web services provided by each manufacturer, the broker is now able to require budgets to all these manufacturers. When the broker receives the manufacturer's responses, with for example the price and the delivery date of the product intended, the broker sorts these responses/budgets and sends a sorted list of budgets, with prices and delivery dates, to the Client. The client chooses one of the budgets and submits them to the broker that in turn sends an order to the chosen manufacturer.

Once ordered and manufactured the products will be sent to the client by regular mail.

Without using the Market of Resources as the environment for these kinds of services, the architecture is typical, so-called, remote inter-enterprise[4] manufacturing, or, (geographically) distributed manufacturing services.

However, using the Market of Resources, as an indispensable environment for enabling the highest degrees of the interenterprise MS, as well as other types of enterprises, reconfiguration dynamics, the services are monitoring by the Market of Resources. Therefore, all communication has to pass through the Market of Resources.

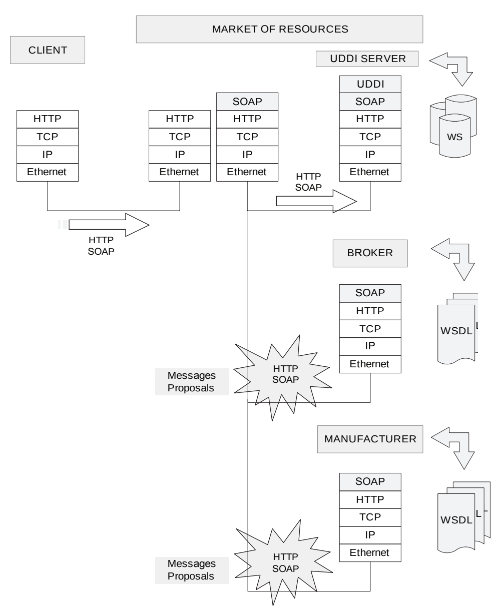
Further, the Broker is now looking not on all manufacturers available in the world, but on all manufacturers available on the Market of Resources, that is, on the manufacturers that are the members of the Market of Resources. (Of course, they are distributed geographically, around the world). This is shown in Figure 7.

The experimental implementation described above, when performed within the Market of Resources, corresponds to the market of Resources's management process and service: monitoring—which could includes also the performance evaluation, analysis of operation results, decision making, security and others, implemented as Web services (see Table 2, row 4).

The experimental implementation described previously, actually has been tested, or validated. Only the technological aspect of the model through the development and implementation of one particular service and, therefore, only some aspects of the architecture of the Integration platform for the implementation of the Market of Resources. However, further validation should address a more complete set of services, in order to fully validate the architecture and the Integration platform for the implementation of the Market of Resources, as well as other aspects: the organizational aspects, which are in fact the critical ones concerning the application of Web services for the Market of Resources, and integration with other technologies as, for example multi-agent systems (MAS) and grids.

Thus, we could say that the implementation, realized until now and presented earlier, represents the first phase of the model implementation and validation. In the future, the second and the third phases will follow. For these (the second and the third) phases, more complex experimental conditions are necessary that implies establishment of a user network (in order to simulate a VE dynamics and use of the more complete set of services, similar to "real life" conditions). In the second

Figure 7. Implementation of the inter-enterprise agile/virtual manufacturing system with Market of Resources as an operating environment



phase, in the future, the "user network" will be constituted of the academic partners and in the third phase industrial partners will be involved. The second phase is already planned for the near future.

CONCLUSION

The proposed information technology architecture model is presented under two specific perspectives (physical and logical). The architecture model works as a guide to the development of architectures with the characteristics intrinsic to the model.

The IT architecture is one of the components of the architecture of an organization. An architecture framework allows developing several architectures in an integrated way and according to objectives of the framework itself. In this chapter we have proposed a model of architecture, with the objective of giving the resultant architectures the ability to support the operation of the Market of Resources as an infrastructure for agile/virtual enterprise integration.

The integration models and the architectures developed are normally based on cutting edge existing technologies. The model presented does not refer technologies in particular, but some technologies are fundamental to the implementation of this model:

- The definition of business processes in high level languages, in a layer above the platform of applications, is the support of adaptability (BPM).
- P2P will be essential to collaboration, from the design to logistics, in particular in the development of new products.
- Web services are the present technology that allows the implementation of this concept and the characteristics of interoperability and distributivity.

The proposed model of architecture promotes interorganizational integration, betting on interoperability, which is a main requisite of market and of organizations. In the same way, it incorporates the identified requisites of the platform of interapplicational integration to support the Market of Resources, and enables interoperability, distributivity, agility and virtuality.

Concerning the model validation, at the moment it is validated only in the technological aspect of the model through the development and implementation of one particular service and, therefore, only some aspects of the architecture of the integration platform for the implementation of the market of resource, described in the section "An Implementation". However, besides the technology, the organizational aspect is critical, too. Future validation will address a more complete set of services, in order to fully validate the architecture and the integration platform for the implementation of the Market of Resources, as well as other aspects: the organizational aspects, which are in fact the critical ones concerning the application of Web services for the Market of Resources, and integration with other technologies as, for example multi-agent systems (MAS) and grids. If the implementation realized could be called the first phase of the model validation, then the future validation will be carried on through the second and the third phase that will involve the network of academic partners and of the industrial partners respectively. The second phase of the validation and development of other Web services, for the network of academic partners, will start in the near future.

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ENDNOTES

1. The infrastructures referred are not information but organizational, meaning that there is a need for a super-, or meta-organizations that enable higher performances of the business processes. Exactly, the Market of resources is one of these meta-organizational infrastructures for the dynamic reconfigurable VE. In fact, this Chapter is about web services as supporting technology for functioning of the Market of resources, i.e. of these meta-organizational infrastructures in general.
2. IDEF stands for ICAM DEFinition methodology (ICAM—Integrated Computer-Aided Manufacturing). IDEF diagrams illustrate the structural relations between two processes and the entities present in the system. The processes (represented as boxes) transform the *inputs* into *outputs* (respectively the left and the right arrows of a process), using the *mechanisms* for the transformation (the bottom arrows of a process) and constrained by *control information or conditions* under which the transformation occurs (the top arrows).
3. Other solutions may be adequate too. E.g., it is suggested that SOA could solve the problem too. Concerning a detailed evaluation of a particular approach, at the moment it would is considered as an issue of the future research.
4. In the case of the interenterprise environment, the Broker wouldn't be necessary (as, in reality, the Brokers do not exist within a "traditional" "monolithic" enterprise).

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Chapter XLIII
KC–PLM:
Knowledge Collaborative Product Lifecycle Management

João Carlos Amaro Ferreira
ISEL – Instituto Superior de Engenharia de Lisboa, Portugal &
GuIAA – Grupo de Investigação em Ambientes Autónomos, Portugal

ABSTRACT

This chapter defines a system and a methodology, the Knowledge Collaborative Product Lifecycle Management (KC-PLM) to better support the complete product lifecycle in the industry. The KC-PLM system intends to reduce the lead-time from new product development to production by providing and integrating knowledge platform, based on a semantic information repository, domain ontology, a domain specific language and on the user collaboration. These characteristics differentiate the KC-PLM system from others PLM systems, because it supports an intelligent rules engine, to extrapolate and make inference with historical solutions that allow the generation of new solutions. A real case study in automobile business shows the current proposal application and its benefits in a product concept phase.

1 INTRODUCTION

The industry is growing rapidly. Globalization continues to introduce new opportunities and increases competition. Manufacturers are faced each day with a rapid globalization of markets and delocalization of suppliers; in this context, companies show a change of capital concerns: not more only physical capital (plants and equipments), but also intellectual capital (global knowledge of products and processes). Companies are trying, globally, to secure the best talent available at the most reasonable cost to serve world-wide markets and are demanding more innovations from suppliers while cutting their prices. Suppliers are asking for better working relationships and more guarantees to justify their higher R&D expenses. Dealers want better and more extended (options) products range to sell to their customers and better training and tools for their technicians. In this increasing complexity also the expectations of customers have increased, forcing manufacturers and suppliers to develop new products frequently and each new product must be more technological and complex, but also more reliable and safer than the previous product, personalized with high quality and reasonable / low costs (i.e., value for money). As a result, new organizational approaches and new business models are required to handle the increased complexity of simultaneously managing knowledge, products, geographies and customers. Traditional bureaucratic designs that are built around vertical control and lateral segmentation are being replaced by organizational models admitting work to occur through cross-cutting processes that run across the organization. In a transnational company, dynamic configurations of teams carry out the development of products and processes, while lateral linkages coordinate and integrate diverse knowledge across dispersed knowledge centers. In other words, global new product development and production is a complex system, not simply the aggregation of multiple virtual and co-located teams. Besides, another consideration is the accelerating technology development. The rapid evolution of computing technologies has changed the automotive product development process to a "digital business" where many digital information formats, internet, pervasive computing and wireless communication are shaping the business landscape.

The companies are also stating that they need to re-evaluate their value propositions and how they differentiate themselves from competitors. They are focusing resources on their core capabilities to realize their competitive advantage, and leveraging business partners to do the rest. Areas in which companies are striving to differentiate themselves include product development, innovation and cycle time. This involves the processes associated with the research and design of products and services that are sold to the customer. Innovation, fast-time-to-market and development of desirable products are key business goals. This entails the integration and collaboration of business partners to respond to an emerging opportunity, customer need or competitive threat. Goals include developing collaborative working relationships across the value net, integrated processes and systems, dynamic linkages to engage and disengage members of the value net, and to formalize the knowledge.

In this industrial and technological scenario, decreasing product development times and costs while working in collaborative real time virtual environments, fast and smart retrieval and manipulation of past programs knowledge and increasing full product lifecycle managements are a must for industrial companies. This chapter idea appears from the collaboration of CEIIA <www.ceiia.com> and Pininfarina both design companies, Portuguese and Italian. Development time must be reduced, by using automatic validation actions and optimization of knowledge acquisition and transfer flows, because Pininfarina plays a coacher role over CEIIA young engineers. My University is experienced in UML, Information Retrieval and IMATI-CNR <http://www.imati.cnr.it/> from Pininfarina side with the experience gained on ontology development conducted to FP7 project KREATE CAR. Also my background experience in AutoEuropa and the nightmare of data integration among development, planning and production raised the idea of exploring current advances in Semantic Web, Social networks and UML modeling to produce tools and create a methodology to handle the complete product life cycle.

These considerations already motivated some previous work on the scientific community as a collaborative, or a knowledge system or even in a Web system (Chiu, 2002; Hai-yue, 2004; Rose, 2005; Rosenman, 1999; Shem, 2007). Also the main Software development entities are looking on this subjects and current advances in Semantic Web. In 2008, following the revolution around Web 2.0, one of the key commercial players in PLM introduced the notion of PLM 2.0 <http://www.cbronline.com/article_news.asp?guid=C472DDF6-3DA7-458A-B077-8FCC73A96CE5>, which encompasses a social community approach to PLM.

In this work is proposed a system KC-PLM to reach the goals above described based on an integrated software framework that supports all product lifecycle in a collaborative environment, knowledge reuse oriented, with a special emphasis on the product design, phase that OEMs can we have great savings potential (time and costs). KC-PLM supports the validation and set up of the initial mock-up of a new product at the Kick-off, which is the feasibility phase of a new product development activity. This is achieved by developing tools for creating, modeling and preserving the knowledge deriving from information available in digital format. The knowledge base will also in a standard and manageable format incorporate ergonomics and homologation rules, technological database (with design, manufacturing and production information) and past design experiences. This environment relies on the formalization (through ontology) of the relationships existing among the product requirements, their application on the corresponding product components and the related rules that must be followed. The abstraction of the component information, required to perform any specific analysis, will be also provided; the ontology and data mining techniques are then used to drive the retrieval of the necessary information from existing data bases of both past project parts and rules existing for homologation and ergonomics. Retrievals of information from the repository based on domain ontology will help users to cooperate in a knowledge environment.

One of the KC-PLM objectives is to create new skills and maintain the knowledge; individuals undertaking a new project for an organization might access information resources in KC-PLM to learn best practices and lessons learned for similar projects undertaken previously, access relevant information again during the project implementation to seek advice for issues encountered, and access relevant information afterwards for advice on after-project actions and review activities. KC-PLM offers systems, repositories, and corporate processes to encourage and formalize these activities. Similarly, knowledge may be captured and recorded when the project team learns lessons during the project and, after-action reviews, may lead to further insights and lessons being recorded for future access. KC-PLM will lead to competitive advantage that comes with improved or faster learning and new knowledge creation and to greater innovation, better customer experiences, consistency in industry practices and knowledge access across a global organization. Considerations driving the KC-PLM might include: (1) making available increased knowledge content in the product lifecycle; (2) achieving shorter new product development cycles; (3) facilitating and managing organizational innovation; (4) leverage the expertise of people across the organization; (5) benefiting from “network effects” as the number of productive connections between employees in the organization increases and the quality of shared information increases; (6) managing the proliferation of data and information in complex business environments and allowing employees rapidly to access useful and relevant knowledge resources and best practice guidelines; (7) facilitate organizational learning; (8) managing intellectual capital and intellectual assets in the workforce (such as the expertise and know-how possessed by key individuals) as individuals retire and new workers are hired; (9) increasing the role of SME in projects with OEM; and (10) ensuring high customers satisfaction with high quality transport products.

This chapter is divided in the follow sections: section two describes the main approach guidelines taken based on the best practices of Software Engineering, Semantic Web and Social Networks.

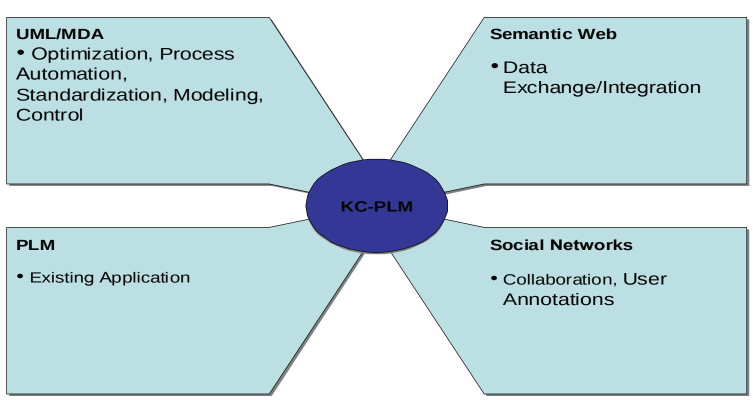
Section three describes KC-PLM main modules; section four is dedicated to PLM lifecycle and the identification of main stakeholders; section five presents a real case study application on product development at Pininfarina and finally in section six the project conclusions are present and the future work.

MAIN APROACHES

Our research proposal is based on using synergies between four main areas: (1) **Semantic Web**, the development started this century around the efforts on the organization of semantic knowledge, based on the use of descriptive technologies such as Resource Description Framework (RDF) and Ontology Web Language (OWL), as well as the data-centric, customizable Extensible Markup Language (XML); (2) **Social Networks**, with user collaboration efforts in terms of semantic annotation used for knowledge reuse; (3) **UML** with a domain specific language (DSL) based on UML2 and follow **MDA** (Model Driven Architecture) approach. We took the most important methodologies from Software Engineering, for the software development, to control and optimize processes and also to automate some semi-automatic routine/standards; (4) PLM, existing PLM through their API will integrate current proposals with a CMS (Content Management System).

Our approach methodology is illustrated on Figure 2 and is based on a domain specific ontology (DSO) that we called Vehicle Corporate Ontology (VCO) (Ferreira, 2007a) DSL based on UML2 called Vehicle Development Modeling Language (VDML) (Ferreira, 2007b) are proposed. Modeling activity processes is performed through VDML in a MDA approach and for a complete description see (Ferreira 2007c; Ferreira, 2007d; Ferreira, 2007e). The output of this modeling activity (models) is used to understand and improve the process and also from predefined templates we can generate digital artifacts (automatic or semi-automatic) to integrate user's applications. This approach is complemented with a VCO which will provide a standard terminology used for data integration and knowledge reuse. Since VCO follows MDA approach, we can perform mapping between different ontology created based on the same approach (Ferreira, 2007a). VCO will benefit of UML classes and visual modeling will decrease syntactic and semantic errors and increases readability. UML itself does not satisfy the needs of the representation of ontology concepts that are imported from descriptive logic and that are in-

Figure 1. Main approaches for the KC-PLM system

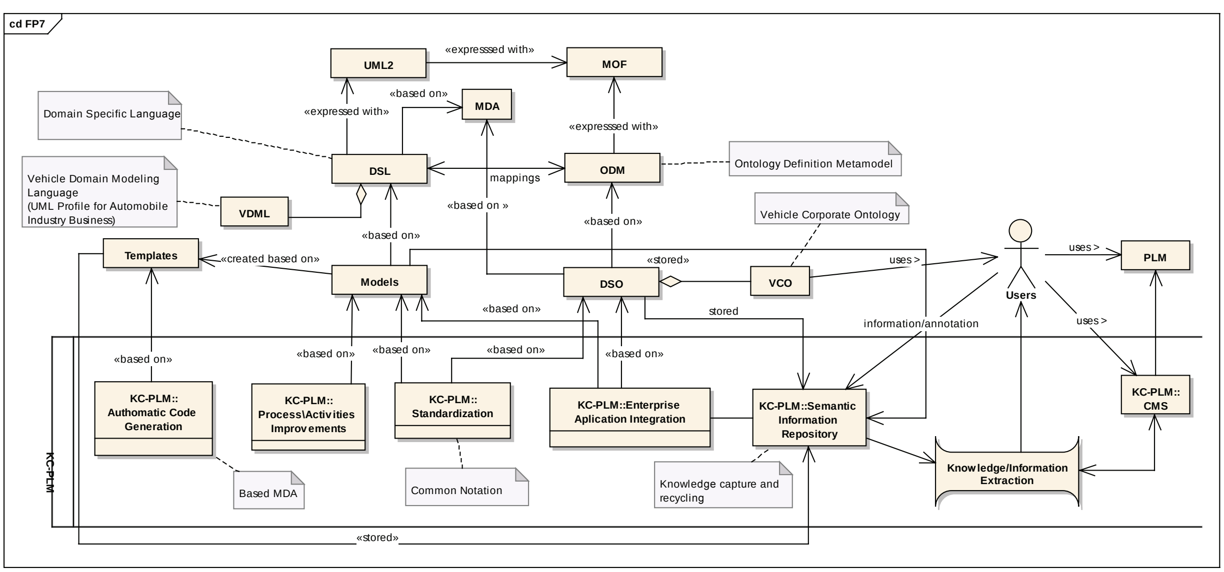


clude in Semantic Web Ontology Language (e.g. OWL, RDF, RDF Schema, …). The OMG's MDA concept has the ability to create, using appropriate family of languages, a metamodel defined by MOF (Meta-Object Facility) and based on OWL. Since industry application uses different terminology systems, database information exchange is achieved whose semantics are specifying using logic based ontologies. A broader terminology is specified by VCO, and is used as reference terminologies. Relations among terminology are indirect, once each terminology can be mapped into other using DSO. A collaborative annotation process will use VCO and will enrich information repository with new content and relations.

UML/MDA Approach

UML has emerged as the software industry's dominant language and is already an Object Management Group (OMG) standard. It represents a collection of the best engineering practices that have been proved successful in the modeling of large and complex systems. OMG is proposing the UML specification for international standardization for information technology. Wide recognition and acceptance, which typically enlarge the market for products based on it, will be the major benefit. Therefore specific subjects (e.g. PLM) require making UML models more specific and thus more precise. This in turn can be done by using stereotypes (since they are an extension mechanism inherent in second version of UML) as means of adding necessary information to existing model elements. Stereotypes have been given a special attention together with the idea of the Model Driven Architecture (MDA) UML profiles are UML packages of the stereotype «profile». A profile can extend a metamodel or another profile (Kobryn, 1999) while preserving the syntax and semantic of existing UML elements. It adds elements which extend existing metaclasses. UML profiles consist of stereotypes, constraints and tagged values. A stereotype is a model element defined by its name and by the base class(es) to which it is assigned. Base classes are usually metaclasses from the UML metamodel, for instance the metaclass «Class», but can also

Figure 2. Main approach methodology for KC-PLM system



be stereotypes from another profile. A stereotype can have its own notation, e.g. a special icon. Constraints are applied to stereotypes in order to indicate restrictions. They specify pre- or post conditions, invariants, etc., and must comply with the restrictions of the base class (Kobryn, 1999). Constraints can be expressed in any language, such as programming languages or natural language. We use the Object Constraint Language (OCL) (OMG, 2001) in our profile, as it is more precise than natural language or pseudo code, and widely used in UML profiles. Tagged values are additional meta attributes assigned to a stereotype, specified as name-value pairs.

MDA (Model Driven Architecture) is a new paradigm in the systems specification (MDA, 2003). MDA can specify systems at all levels, including middleware levels. This new model of systems architecture, offers us a group of very important advantages for distributed environments: (1) supports the whole development life cycle with more precision; (2) decreases development costs; (3) applicable to all languages, platforms, operating systems, networks and middleware; (4) most of the MDA patterns is already available: UML, MOF, XMI, CWM (new metadata standard for data warehousing and business intelligence); (5) a powerful middleware infrastructure: CORBA, IDL and services; built on a success OMG platform technologies OMG, like CORBA and UML; (6) rigorous mapping in the future for another infrastructures as: XML, SOAP, Java, .NET; (7) MDA being independent of middleware, languages or systems (language -, vendor - and middleware-neutral) guarantees that following its requirements and good development practices will have an application with scalability and migration potential.

Semantic Web Approach

The idea of the Semantic Web is to extend unstructured information with machine processable descriptions of the meaning (semantics) of information and to provide missing background knowledge when required. The key challenge of the Semantic Web is to ensure a shared interpretation of information in different information repositories. Related information sources should use the same concepts to reference the same real world entities or at least there should be a way to determine if two sources refer to the same entities, but possibly using different vocabularies. Ontologies and ontology languages are the key enabling technology in this respect. An ontology, by its most cited definition in Artificial Intelligent (AI), is a shared, formal conceptualization of a domain, i.e. a description of concepts and their relationships (Borst, 1997; Gruber, 1993). Ontologies are domain models with two special characteristics, which lead to the notion of shared meaning or semantics: (1) Ontologies are expressed in formal languages with a well-defined semantics; (2) Ontologies build upon a shared understanding within a community. This understanding represents an agreement among members of the community over the concepts and relationships that are present in a domain and their usage. The first point underlines that ontology needs to be modeled using languages with a formal semantics. RDF and OWL are the languages most commonly used on the Semantic Web, and in fact when using the term ontology many practitioners refer to domain models described in one of these two languages.

An ontology specifies a rich description of the: (1) Terminology, concepts, nomenclature; (2) Properties explicitly defining the terms, concepts; (3) Relations among concepts (hierarchical and lattice); (4) Rules distinguishing concepts, refining definitions and relations (constraints, restrictions, regular expressions) relevant to a particular domain or area of interest. Ontology can be used for: (1) independently developed services; (2) agreements among companies, organizations to share common services and information; (3) applications and services can work together to share information and processes consistently, accurately, and completely; (4) improves search accuracy by enabling contextual search using concept definitions and relations among them. The Semantic Web project is the main direction of the future Web development. Domain ontologies are the most important part of Semantic Web applications. AI techniques are used for ontology creation, but those techniques are more related to research laboratories. Recently, there are many proposals to use software engineering techniques, especially the UML since it is the most accepted software engineering standard, in order to bring ontology development process closer to wider practitioners' population. However, UML is based on object oriented paradigm, and has some limitation regarding ontology development. These limitations can be overcome using UML's extensions (i.e. UML profiles), as well as other OMG's standards (i.e. Model Driven Architecture - MDA). Currently, there is an initiative (i.e. RFP) within the OMG aiming to define a suitable language for modeling Semantic Web ontology languages in the context of the MDA.

Social Network Approach

Social Network approach in literature is usually connected to Web 2.0 and deal mainly with users' Web interaction, how they are prepared to provide content as well as metadata, while the Semantic Web opens new technological opportunities for Web developers in combining data and services from different sources. Frequently the combination of Web2.0 and Semantic Web is called Web3.0. This collaborative approach appears in several systems, like: (1) articles and facts organized in tables and categories in Wikipedia; (2) photos organized in sets and according to tags in Flickr; (3) del.icio.us with bookmarks in digital objects of classification; (4) scientific publications are tagged in CiteULike; and (5) 43Things allows users to share their goals and plans (e.g. to travel or loose weight) by annotating their descriptions with keywords and connecting users with similar pursuits. The idea appears in the scientific literature with the name of folksonomy and is based on user's digital objects description (collaborative annotation) to describe a set of shared objects with a set of keywords of their own choice. So we will extend the traditional bipartite model of ontologies (concepts and instances) by incorporating actors in the model, giving a representation as a tripartite graph with hyperedges. The set of vertices is partitioned into the three (possibly empty) disjoint sets A = {a1, . . . , ak}, C = {c1, . . . , cl}, I = {i1, . . . , im} corresponding the set of actors (users), the set of concepts (tags, keywords, most of then taken from the VCO ontology) and the set of objects annotated (bookmarks, drawing, process information etc.). Thus the folksonomy is defined by a set of annotations $T \subseteq A \times C \times I$. Such a network is most naturally represented as hypergraph with ternary edges, where each edge represents the fact that a given actor associates a certain instance with a certain concept.

This approach will win from specialized domain users (e.g designers, production/product engineers, logistics and others) with less predisposition to SPAM and non-collaborative tendencies that sometimes reflects Web users. Users can be rewarded regarding their collaboration based on credit mechanisms latter converted in money or other assets (Ferreira, 2008), but we did not implemented this approach yet.

KC-PLM ARCHITECTURE

As illustrated in Figure 3 the KC-PLM system consists of the following main artifacts: the PLM tool, the K-CMS Web-based system, and the common semantic information repository (SIR).

The SIR is a heterogeneous digital information repository with domain ontology. Available Information types are drawings, normative and ergonomics rules, manufacturing, suppliers, production, technological and molding issues and job templates for automatic retrieval information;

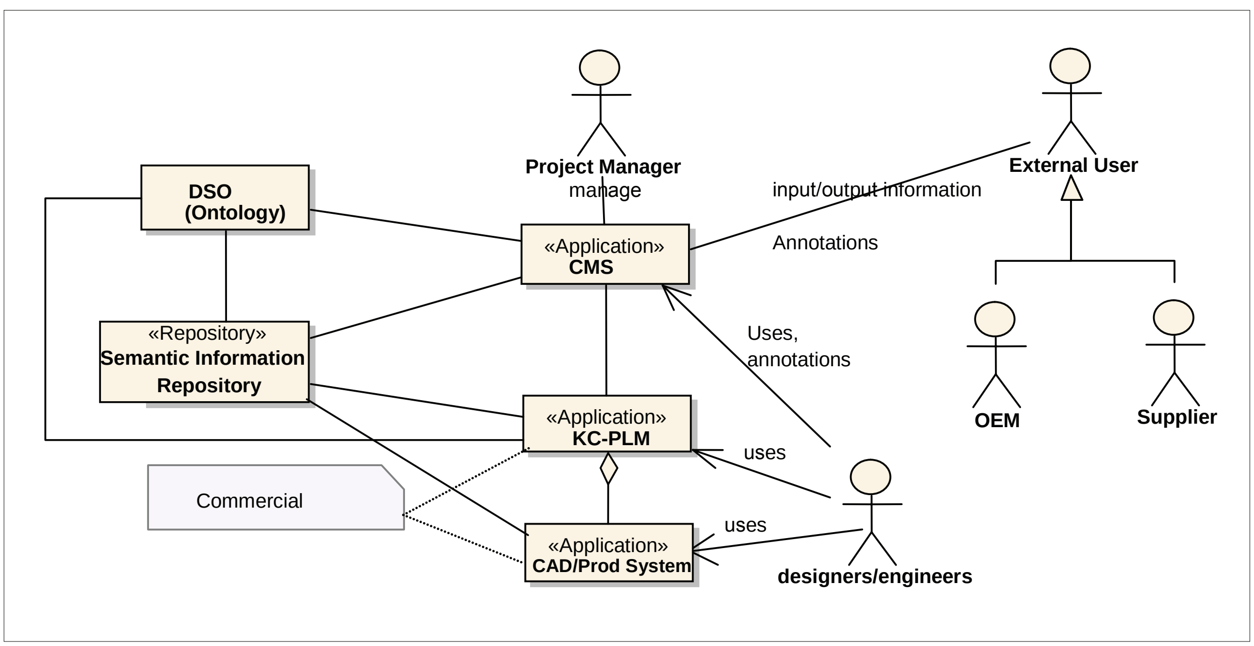
The PLM tool is a desktop application based on a PLM commercial application, with a proper interface to suit the knowledge repository. There is a retrieval engine facility and modules for knowledge acquisition and process and design optimization. Process smart solution selection and retrieval and design optimization are based on evolutionary algorithms. There is also connection to other commercial specific application in CAD, Production areas or other specific systems related with product lifecycle;

The CMS (Content Management System) is a Web-based Content Management System that provides controlled access to the knowledge repository and project management features. The CMS system provides a knowledge and collaboration work environment with some automatic actions based on the job profile description.

As seen in the Figure 3, the KC-PLM system can be used by designers, engineers, production, dealers, project managers, external users (like OEM) and suppliers. This system will serve mainly the project working engineers, but the Web interface will provide access to external users in a controlled access environment, and it will also help project manager to follow and control the related project.

SIR: The main source of information are: (1) collection of information related to CAD/CAS drawings in different formats or other product data (e.g production. Logistics, manufacturing); (2) collection and digital conversion of ergonomics and national homologation rules (which are also the ‘objective functions’ for process and design optimization); (3) collection of information regarding past experiences, common mistakes, changes performed in the different phases of vehicle design and production; (4) Technology Data Base (DB) In order to deal with complex rules requiring verification on different process steps (from conception to production), a specialized module related with an experience database as well as with specific domain ontology will be integrated into final solution; (5) supplier database information; (6) production, logistics database. For this task an experience database

Figure 3. KC-PLM system main modules



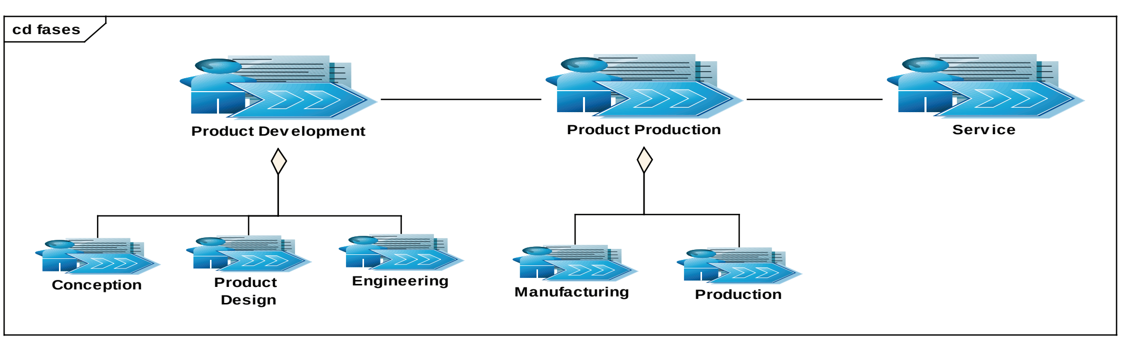
will be used and this will permit to fast define a database structure starting from the ontology definition – automatic import of classes. Because a normal relational database will not fulfill the existing needs, a CBR [Case Base Reasoning] tool and Rule Based databases will be used. These two parts will form the database experience module that will capture the past experience and allow experience to be reused during different processes. CBR is a problem solving paradigm that differs from other major AI approaches, in fact, instead of relying solely on general knowledge of a problem domain, or making associations along generalized relationships between problem descriptors and conclusions, CBR is able to utilize the specific knowledge of previously experienced, concrete problem situations (cases). A new problem is solved by finding a similar past case, and reusing it in the new problem situation. A second important difference is that CBR also is an approach to incremental, sustained learning, since a new experience is retained each time a problem has been solved, making it immediately available for future problems. Regarding user collaboration and annotation process a semi-structure information is created based on the Semantic Web languages such as RDF and OWL.

CMS, for detailed information see (Ferreira, 2008)**.** This a Web-based platform that supports the creation, management, distribution, publication and search of the information kept by the knowledge repository. The CMS will handle information from the knowledge repository, control users access to project information, provide tools for project managements (e.g Project Workflow Management) and also for domain ontology editing and browsing. The CMS is responsible for the Web site's contents life cycle management, providing tools for new content creation and edition, oriented by a content creation/edition workflow. Further on, the CMS will also enable complete site structure and visual appearance management, while delivering automatically generated and completely integrated Web site navigation. Main system features are: (1) **User management**; (2) **Permission Management**; (3) **Content Creation and SIR access**; (4) **Visual style management**; (5) **Multi-Language Support**; (6) **Integrated Content Search Engine and inference rule based knowledge extraction**; (7) **Viewer for CAD file**; (8) **Web based Tool for Ontology Browsing and Editing**; and (9) **Project Workflow Management**.

PLM LIFECYCLE AND MAIN SKATEHOLDERS

Product Lifecycle Management (PLM) involves three main phases, as illustrated in Figure 4: (1) **Product Development**: Conception based users needs and Innovation concepts, market research,

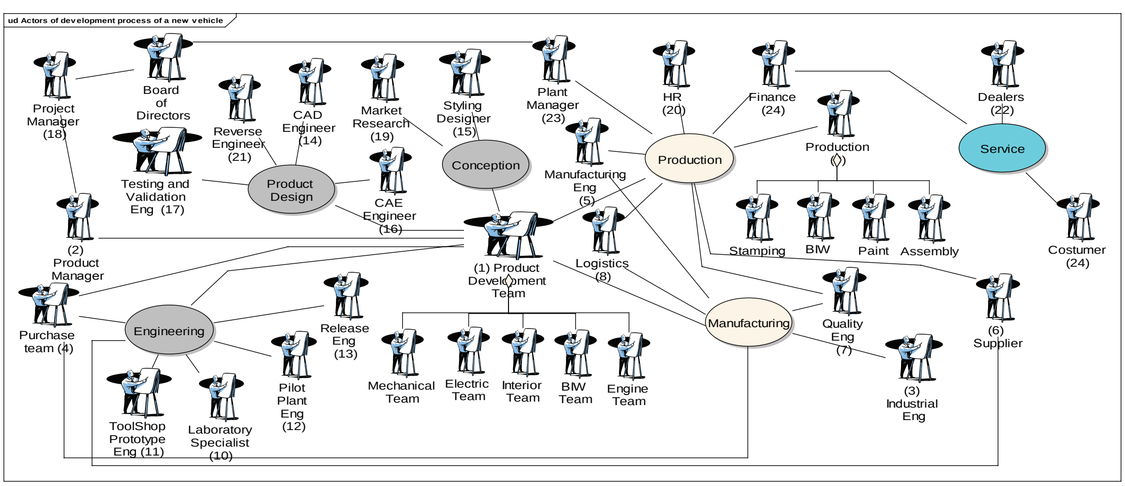
Figure 4. PLM main phases



styling, product guidelines design, test, analyze, product engineer and validation; (2) **Product Production**, which includes manufacturing planning, manufacture; (3) **Service**, which includes use, deliver operate, maintain, support, sustain, phase-out, retire, recycle and disposal.

Main actors of complete PLM cycle is illustrated in Figure 5 are: **(1) Product Development Team**, has the responsibility of development and integration of a certain area of the vehicle as well as its compatibility with the adjacent development teams; **(2) Product Manager**, has the overview of all product development related activities progress and controls the achievement of the various milestones. Identifies, and submits to the project manager approval, special plans for timing achievement if required based on the recommendations of the product development teams; **(3) Industrial Engineer**, concentrates on plant layout, including the arrangement of assembly line stations, material-moving equipment, work standards, and other production matters; **(4) Purchasing Team**, is responsible to find and negotiate the price with supplier for all the outsourced parts identified in a new product; **(5) Manufacturing Engineer**, is responsible to specify and follow up with equipment suppliers the development and installation of all the machinery necessary to produce the defined product; **(6) Supplier** is responsible for the construction of the tool and production of the parts respecting the automotive quality standard. Before delivering to serial production they have to submit master samples for approval and obtain the production release; **(7) Quality Engineer** is trained in various quality tools, including advanced problem solving techniques, to assist in Functional Tests activity. Evaluates several parameters like time, quality and performance (e.g. investigation into water leaks, rattles and squeaks, interior trim, closures, electrical and powertrain, etc) and is responsible for quality assurance at all stages of the process, from an individual part until the release of the final vehicle; **(8) Logistics Planning (part of Manufacturing Activity)** is responsible for planning, implementing an efficient and effective forward and reverse flow and storage of goods and related information between the point of origin and the point of consumption in order to meet customers requirements. Logistics is an integrating function, which coordinates and optimizes all material flow activities, as well as integrates logistics activities with other functions including marketing, sales manufacturing, finance and information technology; **(9) Production Engineer** leads through the productive process and establishes feedback cycles allowing fast detection and correction of repetitive failures avoiding them to reach a further step in the production system or even final customer; **(10) Laboratory Specialist** is responsible for the part material definition taking in account pre-defined targets, homologation rules; **(11) Toolshop Prototype Engineer** is responsible for the construction of the first part taking in account the part definition made by product engineer and laboratory specialist; **(12) Pilot Plant Engineer** is responsible for all validations and test of parts assembled; **(13) Release Engineer** is responsible after the correct validation of part for their release in appropriate system; (14) **CAD Engineers**, demonstrate the ability to interpret and develop a model from a 2D picture or instructions, such as Design Objectives into a 3D model using appropriate techniques to ensure a feasible, proportionally balanced model which meets the design requirements, work with little or no direction to develop a surface displaying an appreciation of shapes, proportions and perception of the final outcome of the 3D model, develop both intricate and surface model surfaces to within 0.2mm of engineering feasibility data, within the required time frame perform feasibility and packaging studies and verify solutions to be in compliance with regulations; (**15**) **Styling and CAS Engineers** produces sketches to invoke the feeling of acceleration or tension, sharpness or softness according emotional and creative passions and the market segment of a car .Define stylistic properties and then creating computer-aided styling (CAS) tools that can capture and produce emotions. The aesthetic shape properties produced, will concur to generate time, energy, and money throughout the design process: from creating and modifying models, to the disconnects in concurrent aesthetic and engineering design, to the broken feedback loop from downstream design/engineering processes; (16) **CAE Engineers** are responsible for predict product performance, drive design, and minimize cost and weight. CAE is also involved in most of the customer functional attributes: durability, NVH, safety, vehicle dynamics, thermal management, aerodynamics, fuel economy and performance, package, weight, electrical systems and electronics; (17) **Testing and Validation Engineers** are responsible, within the Product Development Teams, to identify, perform, and follow up all the tests and validations required to a certain area of the vehicle. Their feed back is essential to the approval of the work produced by the engineers and can originate severe corrections and changes to their work; (18) **Project Manager** has the overall control of the project for timing and costs targets achievement, regarding product development, purchasing, quality and manufacturing activities. Analysis critical situations coming from the various teams and submits recovery plans for approval of the board of management; (19) **Market Researchers** are responsible to collect information about clients' needs and future tendencies and features for a new car. Provide data that is used to support critical technical and financial decisions during all the product life cycle; (20) **Human Resources,** must prepare recruitment (if applicable) training on new technologies and training on the job actions according to the different areas requirements to the various phases of the project; (21) **Reverse Engineer** is responsible for the production of electronic 3D solid product models from captured surface geometry data for use in CAD/CAM/CAE/CAV environments using Reverse Engineering techniques and processes; (22) **Distribution and Importers/Dealers,** are responsible to make sure that the launch timing is the appropriate one taking into consideration the markets and the time of the year and the presentation of a given model in the international main exhibitions worldwide; (23) **Plant Manager**, is the entity that must be informed about the achievement, or not of all milestones in order to activate recovery plans when ever it is necessary making sure that the launch timing will be achieved with the right

Figure 5. Main actors in PLM lifecycle



quantity and quality levels and **(24) Finance,** must install a system that ensures that all the costs are reported in time and are according to the approved budget and the profitability margins are achieved according to the project assumptions.

A description and activity modeling involving all PLM phases can be found at (Ferreira, 2007c; Ferreira, 2007d; Ferreira, 2007e).

The knowledge collaborative system can be defined using a role/task-oriented perspective, in which a set of tasks is performed by different role players: Architect, Requirements Engineer, Designer, Programmer, Tester and Integrator.

CASE STUDY

A complete PLM life cycle case study is complex and difficult to perform due multidisciplinary tasks/process involved and the companies. The most important phase to reduce costs is the design/conception phase, we will conduct a case study in a design company (Pininfarina) in automobile business, mainly in CAD design system and for a detailed view see (Ferreira, 2008). Pininfarina will test in the KC-PLM in a Product Design conception phase in a full one-shot vehicle model frame, applying all of their checking procedures on surfaces in ergonomics, stamping and normative issues. Some of the checking procedures in vehicle ergonomics issues are: Seating Ground Reference Point, A-pillar Obstruction, Windshield Header Sections and Wiper Sweep Design, Manufacturing Feasibility, I/P Hardpoints and Mirror Visibility. For exterior/interior main components the stamping feasibility will be assured by the fulfillment of design rules strictly linked to manufacturing process, like forming axes, flanging appendixes and stamping parameter for major frame components. These smart verification tests on the computer model prevent costly mistakes, since they are taking place already in the planning phase of the car body components, and they are also making the work for the designers easier by reducing the spent time for computing model changes. Another interesting feature is that with the new software it will be possible to test new vehicle architectures against either new CAS definitions or existing models, and with the documented know-how it is possible to achieve component standardization with further benefits in terms of costs and time. In reality, every time that CAS surfaces are changed from the style department, and this may happen many times in a product development of a vehicle, just the feasibility check in ergonomics takes normally one week of work by a design expert. The KC-PLM environment will shorten the time spent for the design process from days to hours, without keeping into account that the CAD-system will use and evaluate at the same time corporate, legal and international rules. This is a validation of the research program more connected to a typical OEM point of view. A general description of the process is the following: The marketing department acquires and aggregates customer needs data and supplies them to the style department that sketches in class B surfaces all the new ideas for the one-shot vehicle production.

The reduction of product development time and costs will be quantified for specified tasks based on the comparison between the classical product development techniques and the new developed KC-PLM based features. The great improvements in manufacturing and quality with strong reduction of technological stamping problems and of customer penalty points will also be localized and quantified compared with classical product development strategy. This increase dramatically the competitiveness of the enterprise: convert the process so it starts out with correct or near correct knowledge-based information, avoiding re-engineering vehicle components near job1-gate, and therefore avoiding wasting money on tooling modifications. Also, the attained quality improvement will avoid producing low quality products. The relevant manufacturing information stored within the database will provide the developed system with the ability to verify and highlight any case were the technological rules have been violated: the database will provide constraints to the product, for example if the base justify that a radius of curvature is too small to allow the component to be manufactured it will be detected immediately. Another possibility achieved from the time reduction is that engineer now can investigate more "what if" packaging scenarios and ergonomic cases than traditionally would be possible due to the time constraints.

The key to sustaining innovation on new products is thus related to the information management and knowledge sharing activities of the multidisciplinary design teams involved in the KC-PLM environment. Concept designers and product engineers need active support to understand each other and to share their knowledge when resolving design issues and problems: this support could be the KC-PLM environment.

A fast visualization helps the user to locate certain parts in the drawing to modify or add elements from a rendered view; the novel aspect in this case is the exploitation of semantic aspects to generate simplified versions of the model according to certain stages in the design process, enhancing specific parts (e.g. coloring) and adapting the camera position. Experts from each automotive discipline involved use shared information to conduct specialized test analysis with the goal of setting a working methodology to reduce development time by using an iterative model that can perform many key analyses.

CONCLUSION

In this chapter was proposed a methodology and a software framework aimed at supporting the complete cycle of a product. Developing tools for capturing, modelling and preserving the knowledge deriving from past design experiences, based on collaboration processes among users, exploring synergies between current approaches of Web 2.0 (Semantic Web) and Social Networks (user collaboration) for knowledge extraction and reuse. This environment relies on the formalization (through ontology) of the relationships existing among the product requirements as well as their application on the corresponding parts/components and the related rules that must be accomplished. The abstraction of the component information, required to perform any specific analysis, will be also provided; the ontology is then used to drive the retrieval of the necessary information from existing data bases of both past project parts and homologation and ergonomic rules. The modeling process activity through VDML can be used for process improvements and the MDA approach embedded permits the conversion of this process activity description to digital artifacts (e.g code pieces to interact with specific program API, for example macro style to integrate in CAD) in a semi-automatic process. An example of this methodology has been applied in the modeling of ergonomic activities in the product design phase. Based on this approach a complete set of Catia V macro was created to perform automatic ergonomics checks during the product design phase. This approach saves considerable amount of time in product development bringing to an earlier stage ergonomics and homologation rules (usually performed in a late project stage), the usage of past experiences and automatic actions will reduce user's working time. Reducing working time will conduct to total cost reduction.

This PLM environment is complemented with a Web based interface to access information in a controlled way and these systems will contribute to the development of a collaborative environment among users in the design phase and subsequent phases like engineering and production. Central and flexible data base will give the opportunity of accessing and sharing information among different development and production phases. SIR permits knowledge reuse and the integration of data application among different applications.

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KEY TERMS AND DEFINITIONS

CMS (Content Management System) is a Web-based Content Management System that provides controlled access to the knowledge repository and project management features. The CMS system provides a knowledge and collaboration work environment with some automatic actions based on the description of the job profile.

Folksonomy, is an collaborative annotation process performed by the users. Users read internet content and associated metadata chosen from a controlled vocabulary or free chosen terms. This metadata is used for retrieval purposes and mainly created by the producers and the consumers of the information.

Knowledge Retrieval is a process of returning (delivering) information in a structured form, consistent with human cognitive processes as opposed to simple lists of data items. Knowledge capture and recycling (Retrieval) is very important is today's organizations, improves the conditions for training/tutoring young technical staff and engineers and is a key point on organization development and evolution.

Ontology is a shared, formal conceptualization of a domain, i.e. a description of concepts and their relationships. This set of concepts is connected in a network or graph and used to described specific knowledge areas and can represent knowledge.

Product Lifecycle Management (PLM) is the process of managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal. Associated to this process there is specific software to help the users to handle and control the different product stages.

Semantic Information Repository, is an information or data collection that links concepts and names together, based on descriptive technologies such as Resource Description Framework (RDF), Web Ontology Language (OWL) and XML. This repository integrates structured, semi-structured and unstructured data in a manageable format.

Unified Modeling Language (UML) has emerged as the software industry's dominant language and is already an Object Management Group (OMG) standard. It represents a collection of the best engineering practices that have been proved successful in the modeling of large and complex systems.

Chapter XLIV
PolyOrBAC:
An Access Control Model for Inter-Organizational Web Services

Yves Deswarte
Université de Toulouse, LAAS-CNRS, France

Anas Abou El Kalam
Université de Toulouse, IRIT, INPT-ENSEEIHT, France

ABSTRACT

With the emergence of Web Services-based collaborative systems, new issues arise, in particular those related to security. In this context, Web Service access control should be studied, specified and enforced. This work proposes a new access control framework for Inter-Organizational Web Services: "PolyOrBAC". On the one hand, the authors extend OrBAC (Organization-Based Access Control Model) to specify rules for intra- as well as inter-organization access control; on the other hand, they enforce these rules by applying access control mechanisms dedicated to Web Services. Furthermore, the authors propose a runtime model checker for the interactions between collaborating organizations, to verify their compliance with previously signed contracts. In this respect, not only their security framework handles secure local and remote accesses, but also deals with competition and mutual suspicion between organizations, controls the Web Service workflows and audits the different interactions. In particular, every deviation from the signed contracts triggers an alarm, the concerned parties are notified, and audits can be used as evidence for a judge to sanction the party responsible for the deviation.

1. INTRODUCTION

Web Services (WS) are increasingly gaining acceptance as a framework for facilitating application-to-application interactions within and across enterprises. In fact, WS facilitate the interoperability by providing abstractions as well as technologies for exposing enterprise applications as services and make them accessible through standardized interfaces (XML (World Wide Web

Consortium [W3C], 2004), WSDL (W3C, 2006b), SOAP (W3C,2003)).

However, while much progress has been made toward providing interoperability, there is still a lot to do at the security level. In particular, a well-founded security study should identify who has access to what, when and in which conditions. The Common Criteria define an "*organizational security policy*" as: *a set of security rules, procedures, or guidelines imposed (or presumed to be imposed) now and/or in the future by an actual or hypothetical organization in the operational environment* (Common Criteria for Information Technology Security Evaluation, 2006a). Such an organizational security policy usually relies on an *access control policy* (Common Criteria for Information Technology Security Evaluation, 2006b). An access control model is often used to rigorously specify and reason on the access control policy (e.g., to verify its consistency). However, the model does not specify *how* the security policy is enforced. The enforcement is realized by technical security mechanisms, such as credentials, cryptographic transformations (e.g., signature, encryption), access control lists (ACL), firewall rules, etc.

Moreover, in the context of an *AAA* architecture, not only it is important to specify and enforce *Authentication* and *Authorization,* but it is also necessary to achieve an efficient *Accounting.* This is extremely important in the WS context, in particular to prove infractions and to clearly identify the responsibilities in case of dispute or abuses.

Our major aim in this chapter is to define a global framework (*access control model and mechanisms*) for secure WS. In our study, we give a major attention and we progressively try to satisfy the following requirements:

- **Secure cooperation** between different organizations / users offering or using WS, but possibly mutually suspicious, with different services, features, functioning rules and security policies.
- **Loosely coupled organizations:** Each organization controls (and is responsible for) its own security policy, resources, applications, etc.
- **Decentralized** enforcement and administration of the security policies: each organization should enforce its own security policy with its own mechanisms.
- **Heterogeneity and self-determination:** As each organization is free to have its own WS, structure, OS, and local objects, it is the matter with heterogeneous systems where organizations keep some local self-determination. Actually, implementation details as well as private information should be managed by each organization, while remote accesses should be carried out through WS interfaces.
- **Fine-grained access control:** Access control decisions should take the context (e.g., specific situations, time and location constraints) into account. Moreover, as the context may change often and as certain reactivity is required in WS, organizations should support dynamic access rights.
- **Enforcement of permissions, explicit prohibitions as well as obligations.** In fact, explicit prohibitions can be particularly useful as we can have composite WS with decentralized policies where each administrator does not have details about the other parts of the system. Moreover, explicit prohibitions can also specify exceptions or limits the propagation of permissions in case of hierarchies. Similarly, obligations can be useful to impose some internal / external, manual / automatic actions that should be carried out by users or automatically performed by the system itself.
- **The security policy must be vendor- and manufacturer-independent.** Each time the

vendor- or technology-specific statements are used, the maintenance burden for the policy increases, especially in this domain where technologies change and new acquisitions often occur. If the security policy is not updated, it becomes obsolete, which would not be acceptable in such systems. The policy must thus remain effective and as abstract as possible.

- **Audit and assessment:** Audit determines if the protections which are defined in the policy are correctly enforced; it also checks if the contracts / agreements established by the partner organizations and users are well-respected.

To satisfy these requirements, we suggest using the PolyOrBAC framework. The latter combines the OrBAC (*Organization-Based Access Control*) model (Abou El Kalam et al., 2003) with WS mechanisms. However, PolyOrBAC (enforced by traditional security mechanisms) is not completely efficient in our context. In fact, while these mechanisms are able to enforce permissions, they do not efficiently enforce obligations and explicit prohibitions, and these kinds of rules are very important for WS. Moreover, in such architectures, it is crucial to audit the different actions and interactions. As stated above, not only we should be able to keep an audit trail, but we also should precisely identify if organizations and users respect their obligations and comply with their expected behaviors. For these reasons, we present a runtime model checker (based on timed automata) that is able to verify if the different interactions are in accordance with the WS protocols.

The remainder of this chapter is organized as follows: Section 2 presents the necessary background to understand this topic as well as some important existing strategies used to secure collaborative systems. Then, the PolyOrBAC access control framework is presented in Section 3. Afterwards, Section 4 discusses our runtime model checker. Finally, in Section 5, we draw out conclusions and perspectives.

2. BACKGROUND

2.1. Standards for WS Security

In some WS implementations, security is delegated at the application level to the security mechanisms of the Web server, which acts as an application server. For example, the Tomcat Web server (Apache 2007) provides a security manager for the administration of users, groups, roles, and permissions.

On the other side, the W3C and OASIS have proposed several interesting standards for Web Services security. Let us present the most relevant ones.

The Organization for the Advancement of Structured Information Standards [OASIS] (2006) defines the Web Services Security (WSS) specification. The latter describes a mechanism for securely (by encryption and digital signature) exchanging SOAP messages (e.g., security tokens such as user name and certificates).

In 2006, the World Wide Web Consortium defines WS-Policy (W3C, 2006a) as a specification that provides a grammar for expressing the capabilities, requirements, and general characteristics of entities in an XML WS-based systems. Note that WS-Policy does not specify how policies are discovered or attached to a Web service. Other specifications are free to define technology-specific mechanisms for associating policy with various entities and resources.

In 2003, OASIS defines the eXtensible Access Control Markup Language (XACML) and in 2005 it proposes the Security Assertion Markup Language (SAML). SAML is an XML-based framework for exchanging authentication data (authentication and attribute assertions) between security domains (OASIS, 2005a), while XACML is a declarative access control policy language implemented in XML (OASIS, 2003). XACML provides a vocabulary to specify subjects, rights, objects and conditions. Implementations of the SAML and XACML standard already exist, for example the IBM implementation (IBM, 2004), the Sun's XACML implementation (SUN, 2005) written in Java, or the Jiffy Software (Jiffy, 2003). SAML and XACML can be used conjointly to provide interoperable policy-based access control: SAML for secure credentials exchange, and XACML for the access control policy definition.

2.2. Traditional Access Control Models for WS

Classical access control models (discretionary "DAC" and mandatory access control "MAC" (Bell & LaPadula, 1976)) are not really adapted to WS. For instance, the HRU model, defined by Harrison, Ruzzo and Ullman in 1976, represents the relationships between the subjects, the objects and the actions by a matrix *M*. *M*(*s*, *o*) represents the "actions" that subject *s* is allowed to carry out on object *o*. It is thus necessary to enumerate all the triples (*s*, *o*, *a*) that correspond to permissions defined by the security policy. Moreover, when new entities are added to or removed from the system, it is necessary to update the policy.

Role Based-Access Control (RBAC) is more flexible. Roles are assigned to users, permissions are assigned to roles and users acquire permissions by playing roles (Sandhu et al., 1996; Ferraiolo et al., 2001). Hierarchical RBAC (Ahn & Sandhu, 2000) adds a requirement for supporting the role hierarchies, while Constrained RBAC enforces the separation of duties. RBAC is unquestionably suitable for a large range of organizations. Indeed, if users are added to the system, only the instances of the relationship between the users and the roles are updated.

To benefit from the advantages of RBAC, several works tried to apply it to WS. In 1991, Beznosov & Deng presented a framework for implementing Role-Based Access Control Using CORBA security service. In 2001, Vuong, Smith & Deng proposed an XML-Based approach to specify enterprise R-BAC policies; in 2004, Feng, Guoyuan & Xuzhou suggested SRBAC, a Service-oriented Role-Based Access Control model and security architecture model for Web Services; and in 2002, Leune, Van & Heuvel presented RBAC4WS, a methodology for designing and developing a Role-Based Access Control model for Web Services. Focusing at Service invocation, this methodology adopts a symmetric perspective considering both the supplier and the customer.

Besides, some other works tried to couple XACML with RBAC. For example, in 2004 , OASIS adopted an XACML profile for Role Based Access Control, whine in 2005, Crampton proposed an RBAC policy using an XACML formulation.

In our recent works, we enhanced the RBAC by proposing the OrBAC (*Organization-based Access Control*) model (Abou El Kalam et al., 2003). Basically, OrBAC is an extension of RBAC that details permissions while remaining implementation independent. The main idea is to express the security policy with abstract entities only, and thus to separate the representation of the security policy from its implementation. Indeed, OrBAC is based on roles, views, activities (introduced in RBAC, VBAC, TBAC (Sandhu et al., 1996; Brose, 1999; Thomas & Sandhu, 1997) to structure subjects, objects and actions.

In the next section, we first summarize OrBAC features and we discuss the limits of this model regarding WS requirements (Abou El Klalam et al. 2007a).

2.3. OrBAC (Organization-Based Access Control)

In OrBAC, an organization is a structured group of active entities, in which subjects play specific roles. An activity is a group of one or more actions, a view is a group of one or more objects, and a

Figure 1. Abstracting subjects

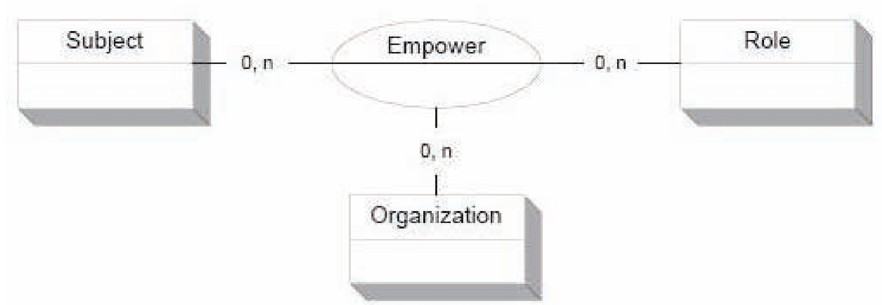
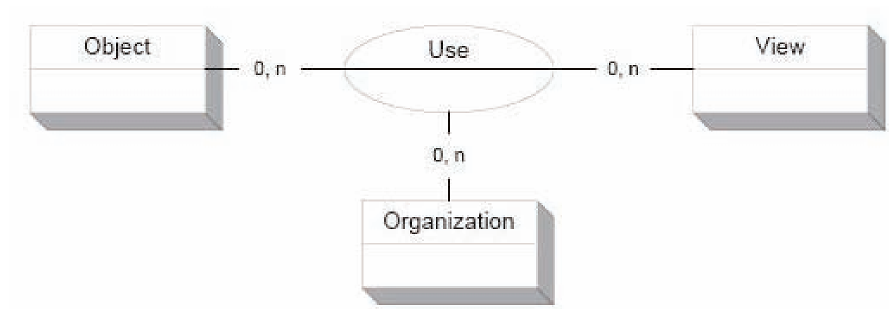


Figure 2. Abstracting objects



context is a specific situation that conditions the validity of a rule.

Actually, the Role entity is used to structure the link between the subjects and the organizations (Fig. 1). The relationship Empower (org, r, s) means that org employs subject s in role r. In the same way, the objects that satisfy a common property are specified through views (Fig. 2), and activities are used to abstract actions.

In security rules, permissions are expressed as *Permission* (*org; r; v; a; c*); obligations and prohibitions are defined similarly. Such an expression is interpreted as: in the context *c*, organization *org* grants role *r* the permission to perform activity *a* on view *v.*

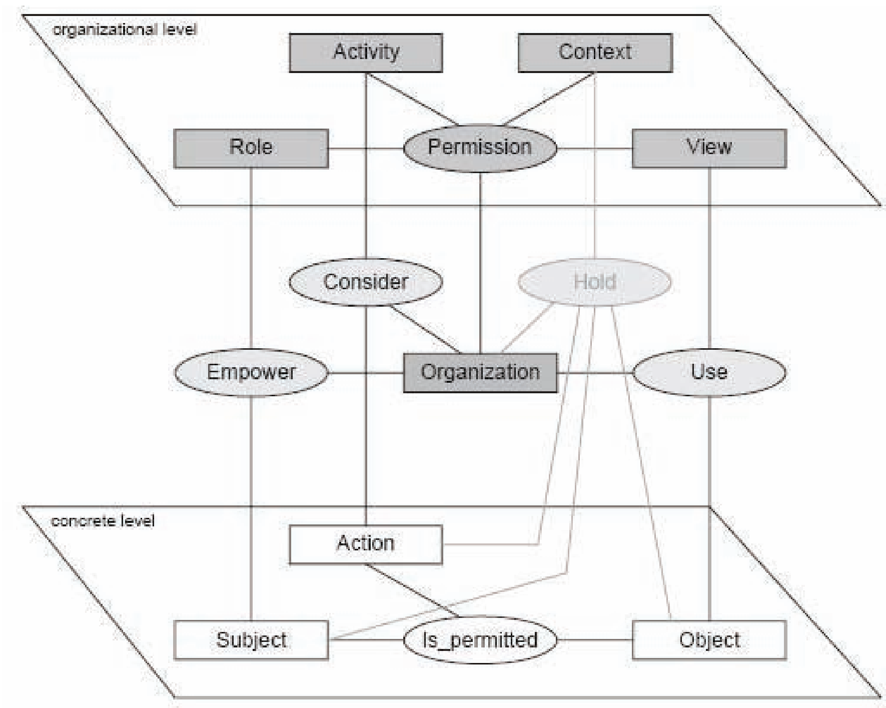
As rules are expressed only through abstract entities, OrBAC is able to specify the security policies of several collaborating and heterogeneous organizations.

In fact, the same role, e.g., "operator" can be played by several users belonging to different organizations; the same view e.g., "*TechnicalFile*" can designate different objects, say TF-Table or TF1.xml, in different organizations; and the same activity "read" could correspond in a particular organization to a "SELECT" action (if the organization has a database system) while in another organization it may specify an OpenXMLfile() action.

Two security levels can be distinguished in OrBAC (Fig. 3):

- **Abstract level:** The security administrator defines security rules through abstract entities (roles, activities, views) without worrying about how each organization implements these entities.

Figure 3. The OrBAC model



- **Concrete level:** When a user requests an access, concrete authorizations are granted (or not) to him according to the concerned rules, the organization, the played role, the instantiated view / activity, and the current parameters.

The derivation of permissions (i.e., instantiation of security rules) can be formally expressed as follows:

$\forall org \in Org, \forall s \in S, \forall \alpha \in A, \forall o \in O, \forall r \in R,$
$\forall a \in A, \forall v \in V, \forall c \in C,$
Permission (org, r, v, a, c) $\wedge$
Empower (org, s, r) $\wedge$
Consider (org, α, a) $\wedge$
Use (org, o, v) $\wedge$
Hold (org, s, α, o, c)
$\rightarrow$ Is permitted(s, α, o)

This rule means:

If a security rule specifies that "in *org*, role *r* can carry out the activity *a* on the *v* when the context *c* is True"; if "in org, r is assigned to subject s"; if "in org, action α is a part of activity a"; if "in org object o is part of view v"; and if "the context c is True for the triple (org, s, α, o)"; then *s* is allowed to carry out *α* on *o*.

In our context, OrBAC presents several benefits:

- **Rules expressiveness:** OrBAC defines permissions, interdictions and obligations.
- *Abstraction of the security policy*: OrBAC has a structured and an abstracted expression of the policy; it also separates the specification from the implementation of the policy.
- **Scalability:** OrBAC has no limitation in size or capacity. It can define an extensible

policy. It is then easily applicable to large-scale environments.

- **Loose coupling:** Each organization is responsible for its assets and entities. Implementation details as well as private information are managed separately by each organization.
- **Evolvability:** A policy in OrBAC is evolvable. It easily handles changes in organizations.
- **User-friendliness:** Specifying and updating an OrBAC security policy are rather intuitive.
- **Popularity:** OrBAC has a growing community. Many research studies are being conducted, based on OrBAC.

However, even if OrBAC has several advantages, is not completely adapted to WS. First, OrBAC is not able to manage collaboration-related aspects. In fact, as OrBAC security rules have the *Permission*(*org, r, v, a, c*) form, it is not possible to represent rules that involve several independent organizations, or even, autonomous sub-organizations of a particular collaborative system. Moreover, it is impossible (for the same reason) to associate permissions to users belonging to other partner-organizations (or to sub-organizations). As a result, if we can assume that OrBAC provides a framework for expressing the security policies of several organizations, it is unfortunately only adapted to centralized structures and does not cover the distribution, collaboration and interoperability needs, while these aspects are very important in the WS context.

Secondly, the translation of the security policy into access control mechanisms is not treated in OrBAC. It is thus necessary to describe suitable architecture, scenario and implementation of the WS security.

To cover these limitations, we propose the PolyOrBAC framework.

3. POLYORBAC

In this section, we suggest adapting OrBAC as well as WS mechanisms to specify and enforce secure collaboration (Abou El Kalam et al., 2007a), in particular in the WS context. The global framework is called PolyOrBAC. The main idea is:

Extending OrBAC to be able to express collaboration rules concerning remote accesses.

Using existing WS standards to enforce the collaboration at service and resource levels.

3.1. Scenario of Execution

Let us develop a simplified (but representative) scenario illustrating collaborative systems in general and WS in particular. We distinguish two global phases.

First phase: *Publication and negotiation of collaboration rules as well as the corresponding access control rules.*

First, each organization determines which resources it will offer to external partners. Web services are then developed on application servers, and referenced on the Web Interface (in UDDI (OASIS, 2005b)) to be accessible to external users. At this stage, we find in organization *B* security rules such as: *Permission*(*B, Accountant*, *Account*, *Consulting*, *Urgency*) and instances (of relations) such as:

- *Empower*(*B, Bob, Accountant*),
- *Consider*(*B*, *OpenXMLFile*(), *Consulting*), and
- *Use*(*B*, *WS*1, *Account*).

Second, when an organization publishes its WS at the UDDI registry, the other organizations can contact it to express their intent to collaborate and use the published services under an agreed access control policy. In the example below, organization

B offers WS1, and organization A is interested in using WS1.

Third, organizations A and B negotiate and come to an agreement concerning the use of WS1.

Fourth, A and B establish a contract and jointly define security rules concerning the access to WS1, These security rules are registered – according to an OrBAC format – in a database containing the policy. The steps of this phase are given in Figure 4.

For example, if the agreement between A and B is "users from A have the permission to consult B's accounts", B should add the Empower(B, PartnerA, Accountant) association to its base. In this notation, PartnerA means any user from A.

We assume that the security policy database already contains the rule Permission(B, Accountant, Account, Consulting, Urgency).

The derivation of the permission (i.e., instantiation of security rules) mentioned above can be formally expressed as shown(Fig. 5).

Second phase: Access to remote services.
At runtime, if a user wants to carry out an activity, the security-related services check the requestor/request authentication, verify its credentials, make an authorization decision based on the security policy, and finally, deny or authorize the access (in some cases, this access is accompanied with some obligations or recommendations). In this

Figure 4. Mutual negotiation of access rules for distant services

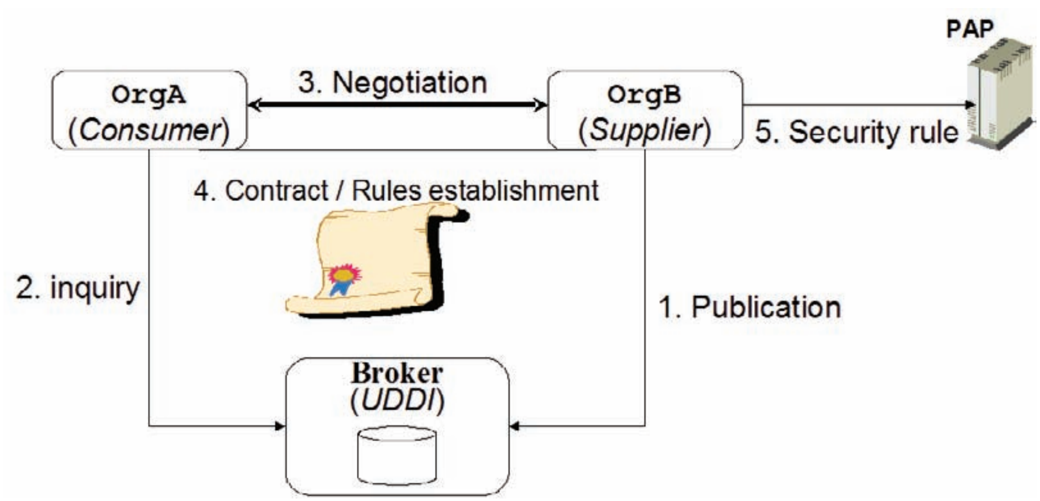


Figure 5. Derivation of permissions in PolyOrBAC

Permission(*B*, *Accountant*, *Account*, *Consulting*, *Urgency*) ∧
Empower(*B*, *Bob*, *Accountant*). ∧
Consider(*B*, *OpenXMLFile*(), *Consulting*) ∧
Use(*B*, *WS*1, *Account*) ∧
Hold (*B*, *PartnerA*, *OpenXMLFile*(),*WS*1, *Urgency*)
→ *Is permitted*(*PartnerA*, *OpenXMLFile*(), *WS*1)

vision, it is important to separate authentication from authorization, and access control decision from access control enforcement.

In our study, we use an *AAA (Authentication, Authorization and Accounting)* architecture: the authorization decision is asked for by a requestor (user) or a resource service; if the security policy allows this access, an authorization ticket is delivered to the requestor; the latter presents the ticket with the authorization context to the resource or service, which enforces the decision, i.e., grants or denies the access. More precisely, if a user from "*A*" (let us note it *Alice*) wants to carry out an activity, *Alice* is first authenticated. Then, the access control decision function of organization *A* checks if the OrBAC security policy of *A* allows this activity. We suppose that this activity contains local as well as external accesses. Local accesses should be controlled according to *A*'s security policy, while external accesses should respect the agreements established between organization "*A*" and the other organizations (providing the requested services).

If, for example, Alice's activity invokes (among others) *B*'s Web service *WS1*, the access to *WS*1 should be controlled by *B*'s Policy Decision Point "PDP", according to: (1) The OrBAC policy of *B*, and (2) the agreement established between *A* and *B* about *WS*1.

It is important to note that the same (abstract) rule, e.g., *Permission*(*B, Accountant, Account, Consulting, Urgency*), can correspond to local as well as collaborative (remote) accesses. The decision corresponding to local access can be done according to:

Permission(*B, Accountant, Account, Consulting, Urgency*) ∧
Empower(*B, Bob, Accountant*) ∧
Consider(*B, SELECT, Consulting*) ∧
Use(*B, Table*1*, Account*) ∧
Hold (*B, Bob, SELECT, Table*1*, Urgency*)
→ *Is permitted*(*Bob, SELECT, Table*1),

while the decision corresponding to remote access can be done according to the rule presented in Figure 5.

Let us also remind that the decision of "Which user from A is associated to *PartnerA*, and so, authorized to access to *WS*1" is done according to *A*'s security policy. In other words, *A* defines internally instances such as (*Alice, PartnerA*), (*Jean, PartnerA*).

In this way, when Alice is authenticated and authorized (by *A*'s policy) to play the role *PartnerA*, an XML-based authorization ticket "*T*1" is generated (based on the positive decision) and granted to *Alice*.

*T*1 contains the following elements:

- The virtual user played by *Alice*: "*PartnerA*",
- *Alice*'s organization: "*A*",
- The agreement's (between *A* and *B*) ID,
- The requested service: "*WS*1",
- The invocated method, e.g., "*OpenXMLFile*()",
- And, a timestamp to prevent reply attacks.

Note that *T*1 is delivered to any user (from *A*) allowed to access to *WS1* (e.g., *Jean*). When *Alice* presents its request as well as *T*1 (as a proof) to *B*, *B* extracts the *T1*'s parameters, and processes the request. By consulting its security rules, *B* associates the role Accountant to the virtual user "*PartnerA*" (representing *Alice* in *B*) according to *Empower*(*B, PartnerA, Accountant*). The access decision is then done according to the rule presented in Figure 5.

3.2. WS Mechanisms in PolyOrBAC

In our implementation, as we use a WS-based architecture, messages exchanged (e.g., services) between A and B are XML files that obey SOAP protocols. Moreover, PolyOrBAC could be integrated perfectly into XACML architecture (Figure 6).

In this architecture, an access request arrives at the Policy Enforcement Point (PEP), the PEP creates an XACML request and sends it to the Policy Decision Point (PDP), which evaluates the request and sends back a response. The response can be either access permitted or denied, with the appropriate obligations. The PDP comes to a decision after evaluating the relevant policies. To get the policies, the PDP uses the PAP to extract the security rules (e.g., Permission(Organization, Role, View, Activity, Context)). The PDP may also invoke the Policy Information Point (PIP) service to retrieve the attribute values related to the organization, the subject, the Web service (resource), or the environment (the context). This consists in evaluating the associations Empower (org, s, r), Consider (org, α, a), Use (org, o, v) and Hold (org, s, α, o, c). The authorization decision arrived at by the PDP is sent to the PEP. The PEP:

- Fulfills the obligations and/or informs the subject about the recommendations, and,
- Based on the authorization decision sent by PDP, either permits or denies access.

Figure 7 describes the components of a PolyOrBAC implementation based on XACML (the target contains instances of (Organization, Role, View, Activity).

Our work can perfectly be coupled with other interesting XML-based standards such as SAML, and WS-Security.

SAML could be used for authentication. It allows a user to log-on once when accessing to different sites (e.g., single sign on). SAML handles the exchanges of requests and responses containing authentication, authorization, and non-repudiation data. Those exchanges are done between the authority asserting that a certain user can use a specific WS, the user that wants to use the WS, and the entity that offers the WS.

3.3. Discussion

PolyOrBAC offers several benefits:

- **Peer to peer approach:** We use a decentralized architecture where organizations and users mutually negotiate their common rules; each organization is responsible for its user's authentication and is liable for their use of other organizations' services; it also controls the access to its own resources and services.

Figure 6. The XACML architecture

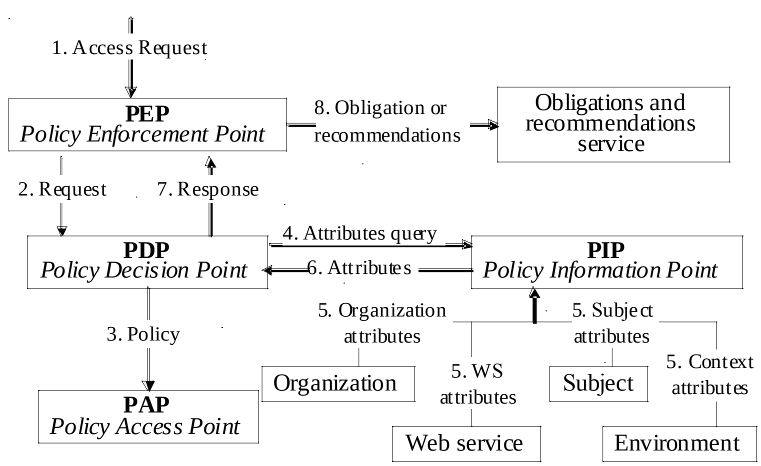
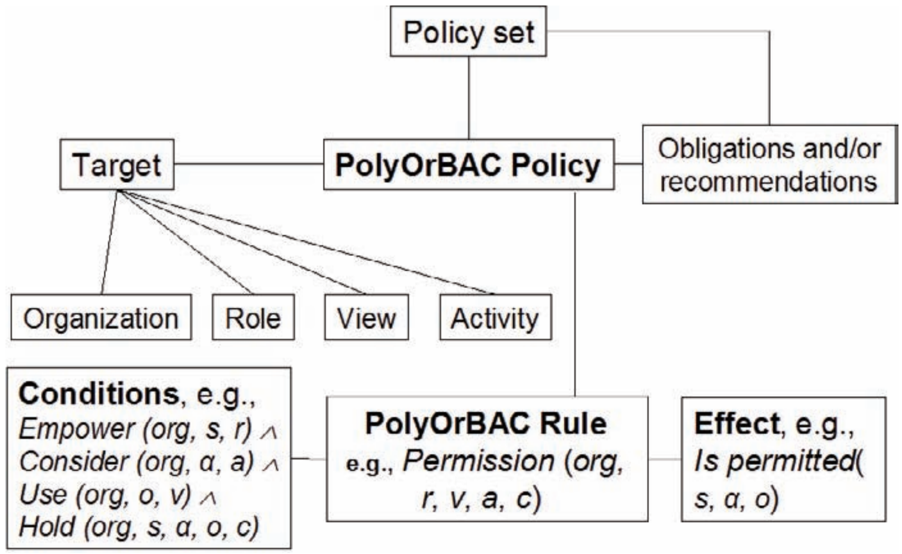


Figure 7. PolyOrBAC-architecture based on XACML



- **Independence:** Even if all PolyOrBAC rules are specified according to OrBAC, organizations are loosely coupled, e.g., each organization keeps its specific security policy, security objectives, services, applications, operating system, etc.
- **Information confidentiality:** Accesses are only possible through the WS interface; in this way communications are possible without intimate knowledge of the organization's IT systems. Such information is usually considered as confidential by organizations.
- **Extensible structure:** The OrBAC extensibility and the WS standards facilitate the management and the integration of new organizations (with their users, data, services, policy, etc.).

However, PolyOrBAC has some limitations, essentially related to the last requirement identified in the introduction. In fact, PolyOrBAC:

- Offers the possibility to grant local accesses to other organizations' users that play certain roles (in their organizations), without having any information about who plays these roles and how the (*user, role*) association is managed by these organizations;
- Supports access control enforcement and real time checking of contracts established between different organizations and users; in fact, the system must be able to check the well-respect of the signed contracts, according to the WS exchange protocol;
- Supports audit logging and assessment of the different actions; every deviation from the signed contracts should trigger an alarm and notify the concerned parties.

Actually, as stated above, when an organization publishes its WS at the UDDI registry, the other organizations can contact it to express their intent to use the published services under an agreed access control policy. This policy is translated into an e-contract; the latter will handle the use of this WS.

In this work we extend timed automata, initially defined in 1994 by Dill & Alur, to capture e-contracts security requirements and to verify some security properties by using a runtime model checking of the WS exchange protocol (Abou El Kalam & Deswarte, 2008).

4. RUNTIME MODEL CHECKING OF WS EXCHANGED MESSAGES

4.1. General Security Requirements

Let us start this section by presenting an example of a WS contract that stipulates the interactions between a buyer and a seller for the purchase of goods. The contract contains clauses of the following form:

- At his discretion, the buyer *may* send a purchase order to the seller.
- The seller is *obliged* to confirm acceptance/rejection of the purchase order *within 24 hrs.*
- The seller is obliged to send an invoice to the buyer within 7 days of accepting the purchase order.
- The buyer and the seller are *forbidden* to send invalid messages.
- *Failures* to honor obligations and prohibitions will result in *financial compensations* equal to 20% of the value of the item.

If one of the contractual parties detects a technical failure that prevents them from continuing the normal course of a transaction, this party is obliged to *send a failure notification message* to the other party as well as to the administrator / third party.

In case of failure, the e-contract is *terminated* and the involved parties are informed.

As we can see in this example, a WS contract should model the following requirements and entities (at least):

- **Actors:** Who are the actors (organizations, roles) involved in the contract? Who can carry out actions according to the contract clauses?
- **Heterogeneity:** *WS* contracts may have complex structures based on bilateral (e.g., buyer-seller), or multiparty (e.g., house building contract) interactions; this naturally implies different views, structures, and implementations.
- **Actions / workflows:** As the contract should identify the activities (tasks/e-services to be executed during the WS protocol), the e-contract security policy should handle the concepts of actions and workflows (sequential, cyclic, ordered, …).
- **Deontic modalities:** A WS contract can be seen as a legally enforceable *agreement* in which two or more parties commit to certain *obligations.* Consequently, classical deontic concepts, such as obligations, permissions and prohibitions are important in modeling the contract security policy.
- **Temporal modalities:** Temporal constraints are rules that regulate the order, timing and duration of actions. It is thus obvious that WS contracts should identify the duration (e.g., number of days / hours) of certain actions, the synchronization requirements as well as when (at, before, after, during …) an action can/must/cannot be carried out.
- **Context:** In order to provide fine-grained access control, it is necessary to take the context into account, e.g., the requestor/resource location, the separation of duty, delegations, exceptions.
- **Sanctions:** As WS contracts contain deontic modalities (e.g., obligations, prohibitions), it is necessary to handle the cases where these modalities are not respected. In particular, a failure to execute an obligation and an attempt to execute a prohibition are considered as contract violations and the offending actor may be subject to sanctions.
- **Auditing:** When implementing an e-contract tool, it is necessary to keep an audit log that

can be analyzed at runtime and/or be used later as evidence in case of disputes.

4.2. A Security Model for a WS Contracts

The previous section presented the most relevant entities and requirements (mainly related to temporal constraints, actions / workflows, deontic modalities and sanctions) that should be handled by an e-contract security policy. The challenge now is to find a convenient framework that captures all these aspects. Actually, we believe that most of these requirements (except deontic modalities) can be specified by timed automata. Our choice is also motivated by the possibility of checking the correctness of the automata behavior and by the availability of several tools dedicated to this issue.

In this context, our methodology consists in: (1) showing how timed automata can capture some WS contract security requirements; (2) trying to homogeneously extend timed automata to capture the deontic modalities (Abou El Kalam & Deswarte, 2008). But before explaining these steps, let us first present the most relevant notions (regarding our study) of timed automata.

4.2.1. Timed Automata

Timed automata have been proposed by Alur and Dill to describe systems behavior with time (Alur 1994). Basically, a timed automaton is a finite automaton with a set of *clocks, i.e.*, real and positive variables increasing uniformly with time. Transition labels are: a guard, *i.e*., a condition on clock values, actions and updates, which assign new values to clocks.

Composition of timed automata is obtained by synchronous product: each action *a* executed by a timed automaton corresponds to an action with the same name *a* executed in parallel by a second timed automaton. In other words, a transition that executes the action *a* can only be triggered in one automaton if the transition labeled *a* can also be triggered in the other automaton. The two transitions are preformed simultaneously and communications use the rendez-vous mechanism. Note that performing transitions is instantaneous; conversely, time can be consumed in nodes.

Besides, each node is labeled by an invariant, that is a Boolean condition on clocks. Node occupation is invariant-dependent. The node is occupied if the invariant is true.

Finally, it is important to note that a system modeled with timed automata can be verified using model-checking. In particular, a reachability analysis can be performed by model-checking. It consists in encoding a certain property in terms of reachability of a given node (of one of the automata). In this respect, the property is verified by a node reachability if and only if the node is reachable from an initial configuration.

In the following subsections, we model the different requirements. The properties will be verified using the UPPAAL model-checker (UPPAAL 2006; Larsen and Pettersson, 1997).

4.2.2. Modeling Permissions

Permissions mean actions that are allowed by the contract' clauses. In our timed automata model, permitted actions are actually specified by transitions. For instance, in Figure 8, the system *can* execute the action *a* at any time and then, behaves like the automaton *A*.

4.2.3. Modeling Prohibitions

We distinguish two kinds of prohibitions:

- **Implicit prohibitions:** The idea is to only specify permissions, which means that prohibited actions (*i.e*., actions that are not in accordance with the contract clauses) do not need to be specified explicitly in the automata. The states, actions and transitions not represented in the automata are

Figure 8. Permissions modeling

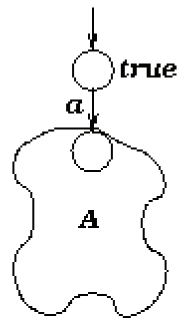
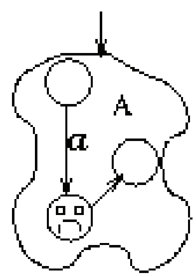


Figure 9. Modeling prohibitions



by essence not possible because the system will not recognize them. This policy is actually similar to "by default-policies" used in some firewall configurations (*i.e.*, in the context of such firewalls, actions that are not explicitly specified as permitted are actually prohibited).

- **Explicit prohibitions:** Explicit prohibitions can be particularity useful in the management of decentralized policies / contracts where each administrator does not have details about the other parts of the system. Moreover, explicit prohibitions can also specify exceptions or limit the propagation of permissions in case of hierarchies. In our model, we specify explicit prohibitions by adding a "*failure state*" where the user will be (automatically) leaded if he/she misuses the system (Figure 2).

In Figure 9, as the *a* action is forbidden, its execution automatically leads to the failure state described by an unhappy face.

4.2.4. Modeling Obligations

Obligations are actions that *must* be carried out; otherwise the concerned entity will be subject to sanctions. In particular, obligations can be useful to impose some internal or external, manual or automatic actions.

In this work, we distinguish two kinds of obligations: *internal* obligations and *external* obligations.

- An *internal obligation* is a set of mandatory actions that must be performed *by local entities* (possibly constrained by a maximum delay). An obligation is automatically triggered by an event such as a change in the context or a particular message exchanged between the contractual entities (e.g., the buyer and the seller).

- An *external obligation* is a set of mandatory actions that *must be performed by remote entities*, but *are checked by local entities.*

Note that the difference between these two kind of obligations is related to the target of the action (*i.e.*, the entity subject to the obligation), not to the way the action is carried out.

This distinction is important in the context of e-contracts as each contractual party has its own automaton, which checks / verifies if the behavior of the other party respects the contract clauses. In fact, in each automaton, it would be important to distinguish between actions that must be done internally and those that must be performed by the other party.

After defining obligations, let us now explain how we model these notions with timed automata. First, as every obligation is also a permission (Obligation $\rightarrow$ Permission), obligations will be specified by particular transitions (in the same way as permissions); however, as obligations are stronger than permissions, we should add other symbols to capture this semantic and to distinguish between what is mandatory and what is permitted but not mandatory.

Actually, to model obligations, we use transition time-outs and invariants.

In this respect, an internal obligation is considered as a simple transition, and if a maximum delay is assigned to the obligation, a time-out (noted by *d* in Figure 10) is set for the delay. When the obligation is fulfilled b*y local entities*, this event resets the time-out and the system behaves like A_1. On the contrary, if the time-out expires, an exception is raised, which is another internal obligation, and the system behaves like A_2 (which can be considered as an exception).

Besides, external obligations are represented by a transition with a time-out (an alternative timed transition). When the remote entity has fulfilled its obligation, it sends a message carrying a proof of obligation completion, which resets the time-out. Alternatively, if the time-out expires, an internal obligation is triggered, corresponding to an exception processing that must be performed by local entities.

In Figure 11, the two automata are running in parallel and should be synchronized on the *a* action. Actually, *a* is an external obligation that must be carried out by the right hand automaton of Figure 4. Besides, the left hand automaton should receive a signal proving the correct-execution of *a*

Figure 10. Modeling internal obligations

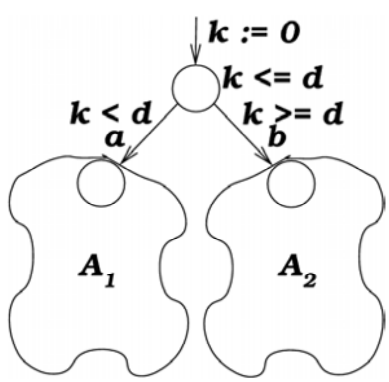


Figure 11. Modeling external obligations

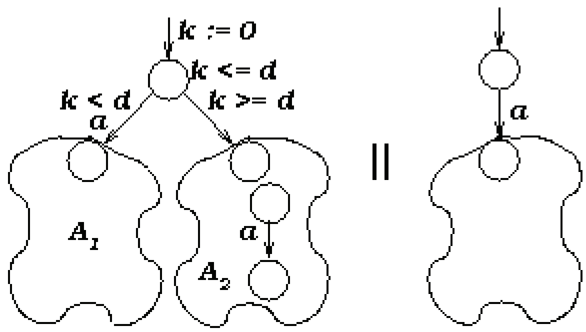
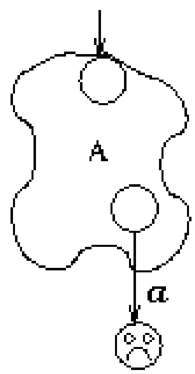


Figure 12. Modeling dispute situations



by the other automaton on the expected delay (*d*). Otherwise the external obligation is not fulfilled (by the right hand party).

4.2.5. Representing Disputes in Our Model

Naturally, a conflicting situation may arise if one of the contract parties does not comply with the contract clauses (e.g., fails to fulfill one of its obligations, or performs a prohibited action). Of course, these dispute situations should be described in the e-contract in order to rigorously state how to solve them and which sanctions to apply. Moreover, each contractual party should maintain an audit log in order to be able to present evidences to a judge in case of dispute. According to these evidences and to the contract clauses, the judge will decide and enforce the corresponding / suitable sanctions.

To model these notions, we use two notions: a dispute state (noted by unhappy face state an in Fig. 12) and variables. Basically, when the conflicting situation is detected by one of the contracting parties, the automata automatically makes a transition to a dispute situation (i.e., to the unhappy state). Contrarily to prohibitions, disputes are stronger (more sensitive) and automatically lead to the end of the contract.

Moreover, as disputes have different severities / sensitivities and as they are not all subject to the same sanctions, we use variables (i.e., labels on the unhappy state) to distinguish the different kinds of disputes as well as the corresponding sanctions.

In this section, we have presented an homogeneous model to specify the most relevant security requirements for e-contracts (workflows, actions, permissions, prohibitions, obligations, time constraints, disputes and sanctions).

In the next section, we present our implementation as well as the mechanisms we use to verify properties such as reachability and correctness.

4.3. The Verification Process

Once we have defined the timed automata of our contract, it would be interesting to check its correct-execution.

Actually, the idea is to verify that the automata will never reach the dispute state. In timed automata, the reachability analysis can be carried out by model-checking. Basically, we should first specify the reachability property (e.g., reaching the unhappy state); then, we can verify if from the initial configuration, there exists a possible execution of the system that leads to a node where this property is verified (i.e., reaching the unhappy state). In this respect, the contract is satisfied if none of the possible executions of the system will lead to the unhappy state (specified through the reachability property).

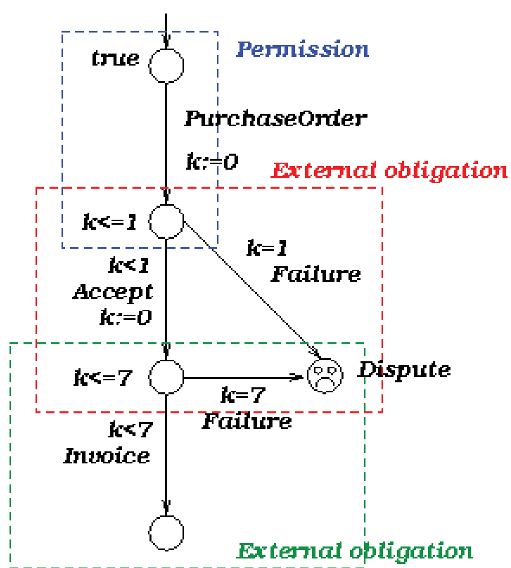
Note that the reachability problem is decidable and that the reachability properties are generally simple to verify by model checkers (Bérard 2001).

4.4. Example of Contract Modeled by Timed Automata-Based Model

After defining our templates as well as our verification process, let us apply our model to the use case presented in Section 4.1.

In the timed automaton of Figure 13, the first transition specifies that the buyer may (*has the permission to*) send a purchase order to the seller. When he does it, he reaches a state where he is waiting for the accept signal from the buyer. Actually this signal corresponds to an external obligation that must be fulfilled by the seller and checked by the buyer automaton. Consequently, we represent it by a transition with a time-out initialized to 1 (1 day = 24 hours) as the seller is obliged to confirm

Figure 13. The buyer e-contract model



the acceptance / rejection within 1 day. When the remote entity (seller) has fulfilled its obligation (sending the acceptance within 1 day), it sends a message carrying a proof of obligation completion, which resets the time-out. Alternatively, if the time-out expires, an exception is triggered, leading to the dispute state.

Similarly, an external obligation for the remote entity (i.e., the seller) to send an invoice within 7 days (after a confirmed order) can be represented by a time-out (set for a 7 day duration). If the message corresponding to the invoice is received, the time-out is reset. On the contrary, if the time-out expires, it triggers an exception (dispute state: the e-contract is canceled, and the buyer informs a judge).

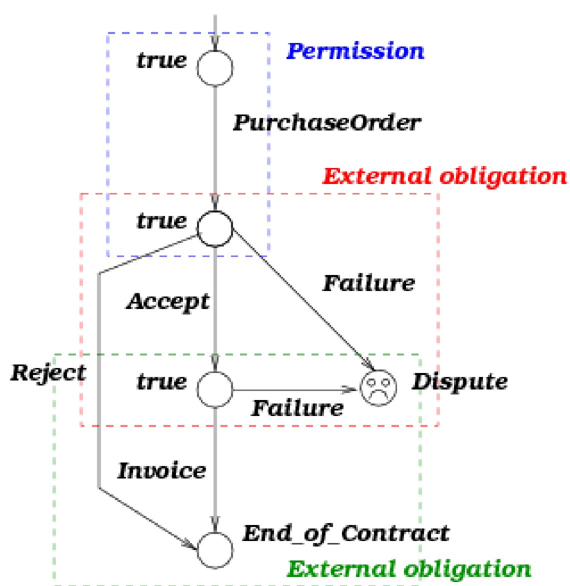
Beside that, in the timed automaton of Figure 14, the seller receives the purchase order from the buyer. Actually, it is the matter of a synchronization action (see also Figure 13). After receiving this signal it reaches a state with a "true" invariant. This means that it can reach and stay in this state without condition. From this state, three transitions are possible. If he/she accepts it within 1 day, or if he/she rejects it within 1 day, he/she fulfills its obligation. Else, he/she will receive a signal (non conformance to the obligation) from the buyer, leading the system to the dispute state.

The same reasoning goes for the rest of the automaton (the obligation to send an invoice within 7 days).

Now, once we have modeled the contractual parties' behavior, we can verify if the system can reach a dispute state. In fact, proving that all the possible executions of the system will never lead to a conflicting situation is equivalent to prove that the exchange protocol can be run according to the contract clauses.

In our implementation, the automata are modeled by the UPPAAL model checker (UPPAAL 2008; Larsen and Pettersson, 1997). The reachability properties are modeled by a subset of the Computational Tree Logic (CTL). For example, to identify the possible executions of the system where the buyer will reach a dispute state (at list once), we can specify and trace the following property:

Figure 14. The seller e-contract model



```
E<>Buyer.Dispute
```

In this property, "E" stands for *it exists* and "<>" means *at least one execution*. Thanks to the model checker (UPPAAL in our case), we have obtained two possible executions:

- The seller does not respect the acceptance delay (1 day);
- The seller does not respect the invoice delay (7 days);

Inversely, the following property means that none of the possible executions will lead the buyer to a dispute state.

```
A[] not Buyer.Dispute
```

4.5. Related Works

Several works have been devoted to logics and theories for e-contracts. The most relevant ones are based on predicate logic, first order logic and speech act theory, deontic logic, model action logic, temporal logic, Petri nets and event calculus.

In the SeCo project, Gisler et al. have presented secure e-contracts based on three levels: logic, information and communication levels (Gisler et al., 1999).

Jimenez et al. have defined a method for specifying contract mediated interactions (Jimenez et al., 2005). Their model is based on deontic modalities. The general form of a contract is: $ns_i : \delta \rightarrow \theta_{s,b} (\alpha<\psi)$, where ns_i (i >= 1) is a label that identifies the i^{th} normative statement of the contract; δ stands for a *condition* that might eventually become true; θ stands for *permission*, *obligation* or *prohibition*; *s* and *b* are the *subject* and *beneficiary* of θ, respectively; α is an *action* to be performed by *s* for the benefit of *b*; ψ is a *deadline*.

O.Perrin and . Godard presented in (Perrin and Godard, 2004) an approach (somewhat similar to (Jimenez et al., 2005)) where permissions, obligations and prohibitions are mapped into ECA (even-condition-actions). An executable contract becomes a set of ECA rules deployed within a trusted third party and placed between two business partners to drive their interactions.

Kumar et al. (2007) proposed an interesting work that couple RBAC (Role-Based Access Control) with TBAC (Task-Based Access Control) and enforces sequential and temporal constraints over them so that process participants get only "Need to know information" with less administrative overhead.

Another interesting work is described by Marjanovic and Milosevic (2001). They *present a specification of deontic constraints and verification of deontic consistency associated with roles in a contract. Their model defines also temporal constraints. In their model, a duration constraint has the Duration(ai, <=, d, h) form:* action *ai must* be completed in no more than *d* time. Concerning the deontic modalities, they give examples such as $O(R_1, ai, e, <=, Date_l, -, t_1, t_2)$: role $\mathbf{R}_1$ is obliged to finish action *ai* no later than $Date_l$. This obligation is valid from time t_1 to t_2.

However, up to our knowledge, most of these works have combined several logics to gain in the expressiveness, while these logics / models are not necessarily homogeneous. As a result, the verification mechanisms are either rarely presented or often too complex.

Moreover, several other works based on deontic logic are not expressive enough to describe situations where neither actions are assigned to specific agents ("*it ought to be that the payment is sent by Alice*"), nor permissions, obligations and prohibitions that become and cease to be in effect depending on the occurrence of time and other events (deontic logic is actually static).

To overcome these limits, some works mix deontic logic with constructs from Modal Logic, Temporal Logic, Logic of Action or from their combinations. Such hybrid logic systems can certainly express complex situations; however such systems have not yet been thoroughly studied and understood. Moreover, the logical rigor of a contract expressed in such notations is questionable; and generally, the resulting language is not really able to automatically verify the correctness of his notation by proof-theoretical means or model checking.

In our work, we based our model on well-known mechanisms ans and tools: timed automata, CTL and UPPAAL. To be as rich as possible while remaining verification-homogeneous, we gave a precise semantic to specify and distinguish between the different deontic modalities (permissions, obligations, prohibitions), the dispute situations and sanctions.

CONCLUSION AND PERSPECTIVES

This chapter presented an access control framework for WS. We first identified the most relevant security-related requirements of WS. Then, according to these requirements, we discussed related works as well as existing WS security-related standards. Afterwards, we proposed the PolyOrBAC access control model and we emphasized its benefits and limits. In particular, PolyOrBAC offers a decentralized management of the access control policies and an architecture where organizations are independent and maintain independently their specific security policy, security objectives, services, applications, operating system, etc.; rights / permissions are defined and enforced by each organization security mechanisms; accesses are only possible through the WS interface and internal details of each organization are not visible to external users.

Then, we enhanced PolyOrBAC by a runtime model checking framework that captures the security requirements of WS contracts and that can be instantiated according to the actual context of a given WS. Our model checker is also used to monitor the well execution of the WS contracts and to verify some security properties.

Currently, we are looking for enhancing our model to take into account other interesting requirements such as delegations. Furthermore, liability as well as privacy issues are also serious challenges that need to be addressed in this field.

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KEY TERMS AND DEFINITIONS

Availability is the readiness for correct service when needed by authorized users.

Collaboration refers to all processes wherein people (or machines, or applications) work together - applying both to the work of individuals as well as larger collectives and societies.

Confidentiality is the absence of unauthorized disclosure of information or functions. It implies that information is readable only to authorized users.

Integrity is the absence of improper system state alterations. It implies that data is modified only by authorized users and only in an authorized manner.

Interoperability is the ability of products, systems, or business processes to work together to accomplish a common task.

Model Checking is a formal verification technique that compares the implementation of a design to a set of user-specified properties. It determines whether a set of properties hold true for the given implementation of a design.

Security studies problems, methods and solutions related to the three security properties: availability, confidentiality, and integrity.

Security Mechanisms are techniques used to implement the authentication and authorization, e.g., credentials, capacities, cryptographic transformations such as signature and encryption, access control lists (ACL).

Security Model rigorously defines a security policy. Generally, a security model is a "formal system" used to specify and reason on the security policy (i.e., it is used as a basis for formal specification proofs). It is thus intended to abstract the security policy and handle its complexity; represent the secure states of a system as well as the way in which the system may evolve, verify the consistency of the security policy, detect and resolve possible conflicts.

Security Policy is the set of laws, rules, and practices that regulate how an organization manages, protects, and distributes sensitive information. Basically, a security policy is specified through: the *security objectives* that must be satisfied (expressed in terms of confidentiality, integrity and availability) and the *security rules* expressing how the system may evolve in a secure way (who has access to what and in which conditions).

Chapter XLV
Development and Implementation of E-Government Services in Turkey:
Towards a More Citizen-Oriented Public Administration System

Asım Balcı
Turksat - International Satellite and Cable Operator, Turkey
& Selçuk University, Turkey

Erhan Kumaş
Turksat - International Satellite and Cable Operator, Turkey

Tunç D. Medeni
Turksat - International Satellite and Cable Operator, Turkey

Tolga Medeni
Turksat - International Satellite and Cable Operator, Turkey

ABSTRACT

Development and extensive use of information and communication technologies has led to important implications for public sectors throughout the world. As a result, in governmental services, citizens have been enjoying better quality services, in an efficient and effective manner. e-government, however, is more related to "government" rather than the "e" as the technical and technological one. The challenge is to use technologies to improve the capacities of government institutions, while improving the quality of life of citizens by redefining the relationship between citizens and their government. Accordingly, this chapter focuses on e-government applications highlighted to reach a more citizen centric e-government in Turkey. Especially, two concepts of e-government, content management system and measuring citizens' satisfaction from e-services are underlined. Therefore, after giving a theoretical background first on e-government, content management and then measuring e-services satisfaction, new developments towards these concepts are accounted.

INTRODUCTION

Extensive use of information and communication technologies (ICTs) has serious implications for all sectors throughout the world. This is especially true for the public sectors of almost every country. With the use of ICTs in governmental services, citizens have been enjoying better quality services, in an efficient and effective manner, through connection to the internet, anywhere and anytime.

Most western governments have been focusing on "citizen centric delivery of public services" for more than a decade. Movements to reform government put citizens first, raise accountability issues, apply performance management techniques, and launch quality-awareness-raising campaigns for making governments more citizen-centric. Electronic government (e-government) applications can be seen from the same perspective as well. The potential of ICTs to provide citizen-centered public services and to yield citizen satisfaction have great importance here. With the use of ICTs in the government sector, and by putting citizens in a central place in the delivery of public services, there is a high potential for transforming the relationship between citizens and government (Information Society Commission, 2003).

These developments have considerable impact on the government sector in terms of its operation and functionality. This impact has reached a point where the major or driving philosophy and the rules of the public sector need to change accordingly as well. However, without making government citizen centric, one cannot talk about citizen-centric e-government applications (Junge et al, 2006). Therefore, a more holistic approach should be taken towards the public sector, if one wants to succeed in making government more citizen-centered.

Despite the ever-increasing expansion and use of ICTs in the government sector, there does not seem to be sufficient literature on the topic focusing on citizen perspectives. As discussed by Wang et al, (2005) "little effort has been placed in evaluation of government service provided through the Web". Moreover, assessing the needs of citizens regarding e-government, and measuring their satisfaction regarding electronic services do not seem to be receiving great consideration from researchers.

Mostly, current research emphasizes frameworks or models that explain the development and advancement of e-government systems according to certain maturation or sophistication stages. Accordingly, generally, e-government systems follow a maturation and sophistication path that starts with basic information-provision and improves with the incorporation of more interactive services into the system. On this sophistication path, content management of the information as well as evaluation of the user satisfaction regarding service quality holds a profound place.

Therefore, citizen-centered e-government applications, where a system of content management is in place, and satisfaction from e- services are measured to reflect anticipated needs of citizens, should be the center of attention in e-government applications. Accordingly, this chapter focuses on e-government applications and their relations to citizen-centric public service provision taking place. Especially, two concepts of e-government, content management system and measuring citizens' satisfaction from e-services, are underlined to achieve more citizen-centric e-government.

The issues covered are especially crucial for Turkey, a country where the needs and expectations of the citizens must be addressed satisfactorily in its administrative system. This situation makes a reform or a major restructuring effort a requirement in Turkey, where ICT use by public organizations has reached a high level. Therefore, after giving a theoretical background first on e-government, and content management, and then measuring e-service satisfaction, new developments regarding these concepts are discussed. By relating these experiences and information, it is hoped that in e-government applications a more general and a broader view is taken to reflect the needs and expectations of citizens seriously.

BACKGROUND: CONCEPTUAL FRAMEWORK OF E-GOVERNMENT

Latest Trends

The latest developments in ICTs and the emergence of the Internet provided easy access to information, everywhere. ICT became a philosophy for governments worldwide, and after the 1990s the term "e-government" has been used commonly to underline the use of ICTs by government agencies. Today, most modern countries focus on e-government projects to reach their citizens, and to better meet with their needs and expectations. Europe, the USA, Canada, South Korea, and Singapore have all been following the same path. To increase the efficiency of governmental services, to reach users easily and quickly, to solve the problems of citizens, and to modernize public services, all developed countries have been realizing new projects in e-government.

E-government is more related to "government", rather than the "e" (OECD, 2003), which is the technical side. As discussed by Kumar et al. (2007) "e-government challenge is not a technological one. Rather, the challenge is to use technologies to improve the capacities of government institutions, while improving the quality of life of citizens by redefining the relationship between citizens and their government." Technical parts of e-government operations can be handled adequately by technical specialists. However, when it comes to applying these new technologies and methodologies to existing troubled and inefficient public administration systems, it is not easy solving new problems. Like pushing an elephant up the stairs, the public sector all over the world has been experiencing important obstacles to the spread of e-government. Since bureaucratic systems are created for preserving the status quo, adjusting them according to the needs of the information society is an enormous task. Moreover, it is not sufficient just to change the hardware and software systems which are used in public organizations. The underlying philosophy, operation styles and cultural aspects must change as well in the public sector.

As argued by Junge et al. (2006), the application of citizen-centric e-government requires a significant and challenging organisational effort by the public sector. And this issue has not been receiving sufficient attention. Despite the positive outcomes of e-government in general, there are some cases in which the expected results were not achieved. In some instances, use of information technology merely improves technical efficiency, without leading to significant organizational changes. And, in some cases, the current organizational inclinations and structures are strengthened (Wong and Welch, 2004: 276). One of the main reasons for this failure is that the e-government applications in general "focus on purely technological issues rather than on the profound organisational and cultural challenges that need to be addressed to make (citizen-centric) e-government a truly successful venture both internally and externally" (Junge et al., 2006).[1]

According to a research finding focusing on e-government and accountability relationships in some countries, Wong and Welch (2004: 289) note "e-government accountability is more about nations and bureaucracies than simply about technology per se." The relationship between e-government and accountability is affected by general characteristics of the civil service and specific features of agency. As a result, in implementing e-government there does not exist an easy and quick solution; a broader perspective is needed, including the needs and expectations of the citizens to make government services more user-friendly. As put forward by Torres et al. (2005) "One main challenge for governments is to identify user needs and to design e-government projects according to the identified target users."

Therefore, without taking citizens' perspectives into account, e-government efforts will yield more bureaucracy, and less public trust.

As indicated by Bekkers and Zouridis, ICTs have a communication potential that facilitates interaction both within and between public organizations and the citizens. This possibility has also potential for integration of public services, and the elimination of the administrative barriers inherent in bureaucratic organizations (Bekkers and Zouridis, 1999). Facilitating communication and improving coordination at different levels of public institutions, e-government can contribute significantly to the transformation into a leaner, more cost-effective government. The "real benefit of e-government lies not in the use of technology per se, but in its application to processes of transformation" (United Nations, 2008, xii). With respect to this, the UN identifies the following stages of e-government evolution and sophistication.

- **Stage I - Emerging:** E-government is mainly comprised of a Web page, much of the information is static, and there is little interaction with citizens.
- **Stage II - Enhanced:** More online information on public policy and governance, with easy access to archived information such as documents, forms, reports, laws and regulations, and newsletters are provided.
- **Stage III - Interactive:** Electronic convenience services such as downloadable forms for tax payments and applications for license renewals are delivered with the initiation of an interactive Website/portal.
- **Stage IV - Transactional:** Two-way interactions between 'citizen and government', such as paying taxes, and applying for ID cards, birth certificates, and passports, allow citizens to access services online 24/7, initiating the transformation of the government.
- **Stage V - Connected:** Developing an integrated back office infrastructure, government transforms itself into a connected entity that responds to the needs of its citizens. e-Participation and citizen engagement in the decision-making process are encouraged.

These connected e-government initiatives can be characterized by 1. Horizontal connections (among government agencies), 2. Vertical connections (central and local government agencies), 3. Infrastructure connections (interoperability issues), 4. Connections between governments and citizens, and 5. Connections among stakeholders (government, private sector, academic institutions, NGOs and civil society) (United Nations, 2008, 16)

Capgemini (2007) also analyzes the sophistication of online services according to the following stages: 1. Information, 2. One way interaction (downloadable forms), 3. Two way interaction (electronic forms), 4. Transaction (full electronic case handling), and as the most sophisticated, 5. Personalization (pro-active, automated).

Benefiting from similar understandings of the stages of e-government services (such as Layne and Lee 2001), Fraser et. al.[2] then applies a perspective of knowledge into these common stages. (p.14)

1. **Publishing — one-way communication:** Knowledge is needed of how to present information clearly online and manage its publication, and how citizens, businesses or government agencies can use the information. Knowledge may be needed for the design, completion and processing of forms. Thus, for instance, if a template is offered for use, then knowledge about how to guide and constrain its usage is needed.
2. **Interacting — two-way communication:** Knowledge is needed of how to react "electronically" to requests from citizens. For instance knowledge may be needed

regarding how information can be searched and received, how user information can be accepted and maintained, and how information security can be established.

3. **Transaction — exchange of resources of nominally higher value than information:** Knowledge is needed of how to ensure secure online exchange of items other than information, such as taxes, registration fees and licenses, as well as how to efficiently and smoothly interface the online system with back-office processing systems. Awareness is raised on issues of trust and details of engaged processes.
4. **Integration — all aspects:** Knowledge is needed of how to streamline and coordinate the design and delivery of services with the attributes from the previous stages. This integration blurs the distinctions such as which unit provides a particular service or holds particular data, where one service ends and another begins, in the eyes of the user.

Accordingly, knowledge units can be directly or indirectly associated with service components. The structure of these associations can then define the basic concepts and relationships of a domain map, or ontology. In addition to these sophisticated stages that requires different knowledge, responsiveness and agility are also important issues for e-government systems.

Responsiveness and Agility of E-Government Systems

For the electronic transformation of government in the UK, Irani and Elliman (2007) point out the central role of flexible and change-receptive e-government information systems, underlining also the importance of standardization and integration of e-government information. SAKE project[3] also emphasizes that changes in the political, economical and ecological environment have impact on government regulations, public administration systems, and processes. A change in one activity in a process or in one part of an e-government system (front and back office) may cause many problems in other parts of the same process or system. Furthermore, these changes impose the need to update the knowledge needed to perform the administrative process or use the e-government system, which is heterogeneous and fragmented.

Therefore, there is a need to resolve changes in a systematic manner, ensuring overall consistency and agile response. This need is specifically important for countries such as Turkey whose membership and integration to the EU depend on adapting its public administration to the existing regulations in a short time. Brewer, Neubauer and Geiselhart (2006) also emphasize this need of agility in changing environments by underlining the consequences of lack of requisite agility within government agencies.

- In dynamic environments characterized by rapid and relatively predictable changes, citizens could challenge public employees, and seek alternative delivery systems
- In turbulent environments characterized by increasingly rapid and relatively unpredictable changes, agencies could increasingly get disintermediated as they cannot adapt quickly enough to changing conditions to regulate or meaningfully participate, and citizens find alternative service delivery systems
- In chaotic environments that are characterized by very rapid and unpredictable changes, agencies lose the ability to monitor and anticipate, whereas agency officials are overwhelmed and unable to influence citizens or other actors.

As a consequence as well as a cause, information and communication technologies present both challenges and opportunities for the provision of public services. These challenges and opportunities regarding electronic government services can also be explained from the perspective of knowledge (management). For instance, Omay (2007) questions the public-politic meaning of knowledge with respect to a SWOT-PEST analysis.

- **Strengths:** All the governments accept knowledge as a necessary target, and show willingness to achieve this target.
- **Weaknesses:** Within the government applications, the information aspect of knowledge is emphasized.
- **Opportunities:** Understanding how public support can be established at the political level can initiate supportive measures for the information aspect of knowledge.
- **Threats:** The information aspect of knowledge can turn into a propaganda tool, while multinational institutions can become more dominant than governments regarding knowledge.

These analyses underline the importance of knowledge and its management for the new economy and society. Stiglitz (1999) also point outs that knowledge creation and information imperfections should not be neglected by socio-economic models, since most institutions can be understood as adaptive responses to informational problems. While "the information or ICT revolution is pushing to eliminate the effects of 'weight' and distance" in the world (p.25), social contributions of ICT and e-government become increasingly important.

These cases above are significant examples and best practices from different parts of the world. (UN 2008) The report (ibid.) then underlines connected governance from the perspective of how governments manage and how they should manage their back office processes. The back office processes are important for realizing the benefits of Knowledge Management (KM) that is at the core of government tasks. Inseparable from strategy, planning, consultation and implementation, KM is based upon the idea that the knowledge of its people is the most valuable resource of an institution. For the institution, KM can enable improvement in performance through increased efficiency and innovation. For citizens, better government services, more choices, more personalization and greater accountability of how their money is spent can be included among the benefits KM can provide.

E-Government: A Citizen Perspective

The growth of citizens' expectations and needs all over the world has led to newer approaches in theory and practice in order to better address these growing demands of the citizens. Citizens are the end users of public services, thus, their perceptions about the quality of governmental services are crucial. And, public trust in government and specifically in bureaucracy is another important concept, because public servants, creating and implementing policies, can use their skills effectively if citizens fully support them. Nevertheless, more and more it has become common among businesses, politicians, and the public in general to feel alike, to criticize governments for waste, inefficiency, inflexibility, and unresponsiveness. In a nutshell, the citizens in general think that overall bureaucracy is not serving their needs and expectations.

There are important developments taking place in theory and practice to address the needs of citizens and to increase public trust in government. To improve the relationships between governments and citizens, many countries have taken a number of different approaches which include customer/citizen relationships, administrative innovation, improving citizen's quality of life, implementation of modern managerial methods, simplification of administrative procedures, the introduction of e-government, and the delivery of high standards of services, with the goal of making the administration more efficient, results oriented, customer oriented, and of ensuring transparency and accessibility for the citizens (Torres et al. 2005). Here, e-government projects can play an important role in coping with these problems, restoring public trust in governments, and creating a new kind of respected relationship between governments and citizens.

Taking a citizen-centered approach in e-government applications is also in the agenda of the EU. The provision of high quality public services is one of the keystones of the i2010 programme of achieving a European Information Society. Public services play an important role in the route to an inclusive European society. According to a latest report, "The e-government policy environment has evolved from 'bringing public services online' to a concept of effective and user-centric service delivery in an inclusive and competitive European society". Based on this idea, i2010 e-government Action Plan underlines five priorities on this topic (Capgemini, 2007):

1. **No citizen left behind:** Promoting inclusion with e-government efforts so that all citizens can benefit from trusted, innovative and accessible services for all.
2. **Making efficiency and effectiveness a reality:** Significantly contributing to high user satisfaction, transparency and accountability, and a lighter administrative burden.
3. **Implementing high-impact key services for citizens and businesses:** By 2010, 100% electronic availability of public procurement with 50% actual usage, and commitments on cooperation to increase high-impact online citizen services.
4. **Putting key enablers in place:** *C*itizens and businesses can benefit from easy-to-use, secure and interoperable authenticated public services across Europe.
5. **Strengthening participation and democratic decision-making:** By employing effective tools, democratic decision-making is fostered in the European countries.

By not only addressing the technical issues and needs of public agencies, but also, redesigning the processes, rules and operations of bureaucracy, e-government applications could address those issues.

However, as discussed by Torres et al. (2005) "some of the benefits promised by e-government can only bear fruit if the content of Web sites is citizen centric and designed specifically for the Internet." Taking this statement as a starting point, there are two important concepts that can play important roles in addressing the citizens perspectives in e-government:

1. Creating and providing citizen centred content which was published in e-government services, especially in e-government gateways,
2. Searching and then increasing the level of citizen satisfaction from e-services that are provided by public agencies.

This chapter specifically focuses on these two issues in creating a citizen centered public administration system. In Turkey, these two concepts have been taken seriously in e-government initiatives. The following section focuses on how these two concepts have been addressed, underlying some of their implications and prospects, as well.

MAIN FOCUS: CONTENT MANAGEMENT AND CITIZEN SATISFACTION IN E-GOVERNMENT

Content Management and E-Government

As a worldwide movement, countries have been taking significant steps to make their services and information available on line. A variety of e-government initiatives have been developed to improve the efficiency and effectiveness of public services, communications with citizens, and transactions with both individuals and organisations (Warkentin et al., 2002). As indicated by Kumar et al. (2007), government Websites are mainly being used to obtain information, therefore, the quality of information is essential to satisfy citizen needs and expectations. It is also important to make progress and go on to the next stages of e-government, such as interaction, transaction and integration. Without getting sufficient, satisfactory, and citizen-oriented information, it will be difficult for citizens to experience new levels of e-government stages.

As stated by West (2001), “what is available online provides important clues in terms of how much progress governments have made harnessing at the interactive potential of Internet and using it as a tool for improved service delivery.” Managing content is an important part of most e-government initiatives. When content is not effectively managed, all the technical work completed, amount of time allocated and monetary resources spent for e-government projects are in danger of being wasted. Because, when the content information provided is not accurate, easy to understand and use, and up-to-date, the users will opt not to use the services. Therefore, proper attention should be paid to content management.

Content management can be defined in a variety of ways. According to the Wikipedia, online encyclopedia, (accessed 20/07/2008), content management refers to “a set of processes and technologies that support the evolutionary life cycle of digital information.” And, content management should be practiced in a systematic way. Mechanisms such as creating, maintaining, and updating of content should be clearly defined in this system. Content management Systems (CMS) are of great importance for e-government gateways as well. In this process it is important to gather information which is useful and important for citizens. Therefore, information which is unnecessary and useless for the citizens should be neglected. In practice there are hundreds of public agencies created for various purposes, but the information provided to e-government services by those agencies may not be of any use for ordinary citizens. Therefore, these kinds of information should be omitted in designing e-government systems.

With application of a CMS, the clarity of information is guaranteed, and the philosophy of citizen-centered public administration is served as well. Meanwhile, it is important to note that whatever information is provided in e-government gateways will directly effect the perceptions of the citizens about the public organizations and the government as a whole. Thus, the information provided by the public agencies should be satisfactory, easy to use, accessible and sufficiently detailed. Shortly, it should be citizen-centered. With the attempts to put a CMS in place, including training sessions, collaborative works, and awareness-raising efforts, the mindsets of public servants and the way of doing business in public organizations are expected to change. As a result, effective provision and delivery of public information is assured in e-government services with the help of a CMS.

As Robertson discusses[4] content management responds not only to the technical necessities for maintaining a large corporate Website or institutional portal, but also addresses organizational goals such as to

- Increase adaptability and agility of the site, support Website growth, and increase Website audience
- Improve accuracy of information with more accurate, up-to-date, comprehensive information, reduce information duplication, and streamline information updates
- Support marketing or public relations, and reduce legal exposure
- Improve customer-citizen experience, business responsiveness, and staff efficiency
- Improve the publishing process

- Reduce costs of Website maintenance, customer support, and publishing
- Capture business knowledge, support knowledge discovery, and improve knowledge sharing

Therefore, content management should not be seen as a simple issue, because it has a variety of implications. These implications are especially important for e-government gateway systems where many public organizations provide information for one portal.

In general, Content management Systems aim to improve the flow of knowledge and information through an institution[5]. As discussed by Robertson[6], the knowledge in a content management system is gained via the processes and opportunities used to capture organisational knowledge. The content provided on the pages, otherwise, cannot be considered as knowledge; it is just information, which does not guarantee the meaning, value and use of the content. People are the source and users of knowledge. Technology should support these people-oriented aspects via search and knowledge discovery, use of metadata, and deployment of effective navigation. For instance,

- By providing an easy-to-use interface for writing new material, many of the barriers to disseminating information can be removed.
- By simplifying the capture and manipulation of metadata ("information about information"), knowledge relationships can then be manipulated.
- By tracking content owners for pages via metadata, it then becomes possible to automatically route feedback directly to the author. By implementing feedback mechanisms, it becomes possible to capture considerable knowledge.
- By identifying content owners for all information stored, a knowledge map that shows which staff (along with contact details) are the holders of specialist knowledge is provided. As a result, content remains up-to-date, and knowledge sharing is supported
- By implementing automated navigation aids, "findability" can be met. (ibid.)

Content management is important in public organizations for several reasons:

- Creating user friendly and accessible public Web sites,
- Taking into account preferences of users,
- Guaranteeing the accuracy of information provided,
- Giving the latest and updated information about government services to the public,
- Easy management of the public Web sites,
- Defining the update mechanisms for content,
- Differentiating the information that is important for the public, from that which isn't,
- Diffusing the idea of citizen-centered public administration in public organizations, promoting a much wider objective.

These points are also true for the e-government Gateway in Turkey. One of the major components of the e-government Gateway project, under the responsibility and mediatory role of Türksat, is the content management system for public institutions. Different solutions for content management have been considered in parallel with the progress of the project. Currently, a new CMS has been prepared and is about to be publicized in Turkey. The new system is tailored according to specific national and institutional characteristics and conditions. In comparison to a standard international system, the specially-tailored national-institutional system is in accordance with an emphasis on reducing over-reliance on external knowledge for ICT solutions.

The new system is about to be introduced to public institutions that are involved in the publication process. Currently, while the general coordination and collaboration between Türksat and public institutions has been established after various presentations and meetings for awareness, information and updating, there are still some difficulties with some institutions that are worth noting, as below:

- Unwillingness to give content due to concerns, such as "I have it on my site, why do I have to give it to you again", and "such information of an institution such as mine should not be given", among others.
- Not taking the content management system seriously, as a result of by not realizing what difference it makes or what value it adds.
- Adding content that has no meaning or use to citizens (or enterprises) such as detailed technical information about rules, regulations and laws.
- Adding content late, or without notice.

These specific difficulties can be addressed significantly with the introduction of a new content management system, accompanied by proper training and development of public institutions. Such training and development activities can also provide an educational platform for the learning of important general issues regarding content management, knowledge management, and transformation of public service processes. During these training sessions, as in the past cases, the centrality of citizens in providing information is underlined.

With the use of a new CMS, "putting citizens first," the underlying philosophy of the e-government Gateway in Turkey, will be better served. Instead of starting with the public organizations' needs, the main priority is given to the needs and expectations of citizens.

The philosophy of "putting citizens first", for instance, currently, is mostly visible in the categorization of content. In the e-government Gateway, content categorization is designed with respect to public services, rather than public institutions. The content is given on the basis of life events, in which the content is categorized under some headings from birth to death, so that citizens can easily find specific information and access public services that they can benefit from. In some cases, the same content has been placed under different headings to make it easier for citizens to find necessary information. For example, "getting a birth certificate" could be found under the "birth" heading, and under "citizenship", as well as "health" headings. Since different citizens can search the same content from different places and headings, this could be seen as a user-friendly approach to locate the necessary information. Search function also supports easy-access to any requested information.

At the same time, we are aware of the fact that these are alone not enough for the fulfillment of such philosophy for e-government Gateway, which new CMS will be an integrated part of. Asking directly to the citizens themselves which public information and services they request to be provided at the e-government Gateway, or, as discussed below, measuring service quality and citizen satisfaction are among the future improvements we will undertake for coming closer to such fulfillment.

However, such an approach requires a new kind of thinking and recognition in provision of public services. Public servants are expected to organize these contents from a citizen's viewpoint, which necessitates a new form of comprehension and a change of mindsets of bureaucrats. It is also necessary for public organizations to remove departmental boundaries, to reflect and recognize citizens' needs. This may not be achieved easily, since the bureaucracy as a whole was created on the basis of departmentalization. However, there are some mechanisms to be used to facilitate this transformation process, such as the use of ICTs, organization of some training sessions across agencies, leadership of some high level bureaucrats and politicians, etc. As a result of such efforts, in the long run the cultural change will take place and the expected result of citizen-centric government will be a reality.

As discussed previously, knowledge in content management can be gained via processes and occasions used to capture organisational knowledge that can be significantly improved with integration and transformation of public services. The difficulty experienced with the content management system is a symptom of a main problem rooted deep in the public administration system, which necessitates transformation of existing processes as well as habitual behaviors and attitude types. Improving the situation regarding content management can then have a positive effect to solve the problem of public institutions' neglecting citizens' perspectives and needs at the root. Improved content management at public Websites can further the positive perception of the state services by citizens, contributing to citizen satisfaction as well as public transformation.

To sum up, CMS could be seen as an opportunity or a driving force for public organizations to become more citizen-centered. However, this force should diffuse throughout the public organization. Otherwise, producing minimal results, it will stay at a very marginal level, and most parts of the public organization will remain as before. As a consequence, our discussion also moves from content provision and management to e-government and citizen satisfaction for citizen-oriented services. Existing frameworks in the world and ongoing work in Turkey for improved service quality and citizen satisfaction are discussed in the following section.

Measuring Service Quality and Citizen Satisfaction

Since the idea of providing citizen-centered e-government services has become a common issue among researchers and practitioners, a variety of approaches has been proposed to put it in place. One of the recent concepts on this issue is finding a mechanism or method to measure the degree of citizen satisfaction level from e-government services. Many governments have put this issue into their agenda. Here, the starting point for service delivery is the citizens' needs and preferences, instead of those of bureaucracy (Bekkers and Zouridis, 1999). In order to put citizens first, it is compulsory to assess the needs and expectations of citizens using a statistical method. There is a limited amount of research to approach this issue. Therefore, it is worth exploring this issue and investigating the latest state-of-the-art.

In the past, citizens were visiting public agencies to receive a special public service, and here there was face-to-face communication. The specific features of citizen-centered public service were somewhat different in this setting. Providing comfortable work places, the organizational climate of a public agency, the behavior of public servants, and the amount of time spent to complete transactions, etc., all affected citizen satisfaction in this setting. However, with the advent of ICTs, this context has changed to include (digital) technological aspects of public service. With e-government applications, a kind of "buffer" (Arif, 2008) is created between the agency and the citizen. This buffer is the Web interface that is seen by the citizen when receiving public services online. Now, citizen satisfaction measurements should be included with different features to assess satisfaction.

According to Arif (2008), "e-government applications need to be citizen-oriented for the government agencies and the end users". And, this orientation could mean "an effective mechanism in order to ensure that development processes incorporate customer needs, an emphasis on usability, the incorporation of accessibility, the effective use of cultural markers", each of which, according to him, could require separate research.

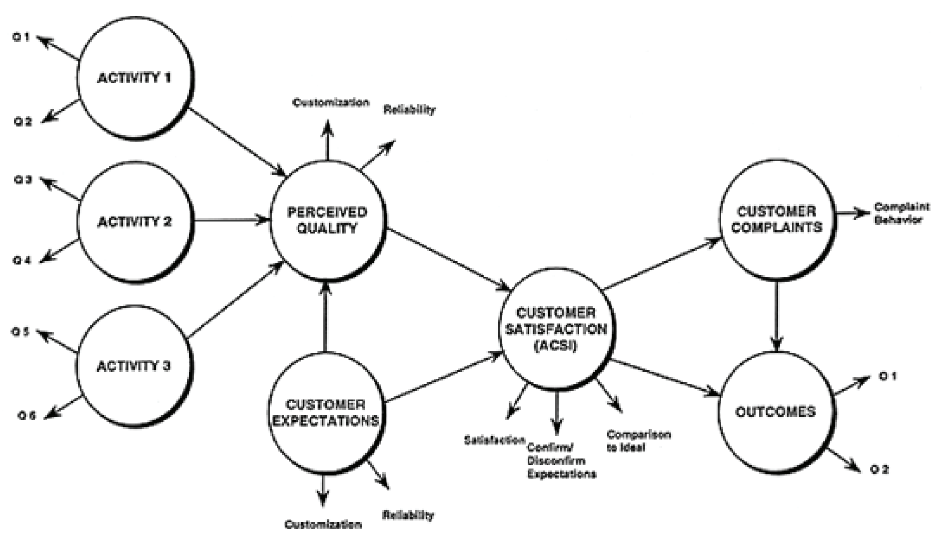
In general terms, research for measuring citizen satisfaction is neither old nor easy. In addition to the usual issues related to eliciting and quantifying intangible service provision and its quality, e-government service provision and its quality can have its own particular characteristics. Currently Web services and mobile services are generally understood as e-government services. Then, for instance, Web-service quality needs to be distinguished from Web service effectiveness. Finally, e-government service, or e-service quality, needs to be considered with respect to how it contributes to general service quality of public services. (Welch & Pandey 2007, and Medina-Borja & Triantis 2007) Still, there are available frameworks that are worth noting for measuring citizen satisfaction, some of which are described below.

Existing Frameworks to Measure (e-) Service Quality for Citizen Satisfaction

The European Customer Satisfaction Index collects data concerning customer satisfaction and loyalty, as well as their influencing factors. Organized by the European Organization for Quality (EOQ) and the European Foundation for Quality Management (EFQM), the first ECSI measurement took place in 12 European countries in 1999[7]. Another well-known CSI is the American Customer Satisfaction Index developed in 1994 and onward.

The American Customer Satisfaction Index uses customer interviews as input to a multi-equation econometric cause-and-effect model with indices for drivers of satisfaction on the left side such as customer expectations, perceived quality (and perceived value); satisfaction (ACSI) in the center; and outcomes of satisfaction on the right side such as customer complaints and outcomes (and customer loyalty). According to the ACSI model, several weighted questions measure the multivariable components that constitute the indices, assessing customer evaluations of the determinants of each index. The strength of the effect of the left index on the item to which the "impact" arrow points on the right is quantified.[8] An adjusted model is used to measure citizen satisfaction with government agencies for the public sector. (Figure 1) For public institutions, the measure of satisfaction is user trust, which is

Figure 1. ACSI for public sector[9]



mostly assessed by 1) user's recommendation of the institution service to other users, and 2) user's trust regarding the improvement of institutional service in the future (Uygur 2006)

The existing CSI models are further developed by various authors in their research. For instance, adapting the ASCI model, Turel and Serenko (2006) investigate the satisfaction with mobile services in Canada. To improve the previous CSI models, Liu et al. (2008) also propose to use fuzzy logic, due to uncertain information in the evaluation of customer satisfaction. Moreover, following the approach used for ACSI, Sohn and Moon (2003) use a structural equation model (SEM) to find the technology commercialization success index.

In addition to citizen satisfaction frameworks like ACSI, service quality frameworks such as quality function deployment (QFD) or SERVQUAL are also applied to the measurement and assessment of public and e-government services. For instance, Barnes and Vidgen (2002) use WebQual instrument based on QFD (QFD Institute) for assessing the quality of a cross-national e-government Web site. With respect to this work, aspects of Web site usability, information quality, and service interaction quality constitute a rounded framework for assessing e-government (and e-commerce) services. Some of the quality constructs measured by SERVQUAL (Parasuraman, Zeithaml and Berry) are also used to develop formulations for evaluating performance of non-profit public service organisations that include government agencies, in the ongoing research of Medina-Borja & Triantis. Medina-Borja & Triantis (2007) further their work by providing an integrative conceptual framework consistent with the way non-profit public organisations operate, which contains four main dimensions of performance, *i. e.*, revenue generation, capacity creation, customer satisfaction and outcome achievement *(i.e.*, effectiveness).

Furthermore, Medina-Borja & Triantis (2007) suggest using Data Envelopment Analysis (DEA) (Charnes *et at.*, 1978) as an analytical approach to compute performance measures of public services. DEA is a linear programming technique that can be used to answer questions of whether inputs are being translated into outputs in the most efficient way in an organizational system, comparing the performance of similarly operating units (Decision Making Units (DMUs). The DMUs, such as firms, agencies, program sites, or any other systems or sub-systems, use the same inputs and transform them into the same outputs, leading to outcomes under similar operating conditions. Comparing each DMU to all other DMUs, DEA uses a set of DMUs to construct a production efficiency frontier or hull consisting of all 'efficient' DMUs in the sample. According to Medina-Borja & Triantis (2007), some benefits of benchmarking or comparative performance techniques such as DEA are explained below:

- DEA does not require that the production function have a specific functional form.
- Input or output prices that are not available in most non-profit settings are not required.
- Inputs and outputs can be of any form and dimensional units.
- DEA can account for multiple influential socio-economic factors (exogenous and endogenous to the organisation).
- In the DEA evaluation non-traditional performance measures of effectiveness and service quality related to public services can be included (p.156).

With respect to these benefits and advantages, Wen, Lim and Huang (2003, 704) also underline that DEA "does not require assigned numeric weights or modeling preferences for analysis". In addition to its multiple advantages, DEA has certain disadvantages:

- There is a requirement that there be an adequate number of decision-making units, so that the approach can discriminate between

the efficient and underperforming decision-making units.
- The decision-making units that are selected as peers need to be validated, in the sense that the model may select benchmark decision-making units that are not realistic.
- The use of the approach by decision-makers has not become common, since it is based on an optimisation approach that is not easily understood by managers not well versed in mathematics. (p.156)

Finally, to sum up the discussion so far, Horan, Abhichandani and Rayalu (2006, 3-4) discuss that according to the existing literature, online quality can be assessed from different perspectives.

- **Quality in use:** Quality is measured by the extent to which the software meets the needs of a user based on context of usage. It is the user's opinion regarding quality. Quality in use measures the extent of effectiveness of a software product, productivity of that product, its safety in use and the satisfaction derived by users. These elements are measured based on contexts in which the product is used.
- **Internal and external quality:** The internal quality metrics are used to ensure that the online service developed is technically sound from a software development and reliability perspective. Measures of external quality metrics are collected by testing, operating, and observing the executable software or system. Software developers and clients of systems often use these measures of internal and external quality, with which ISO standards related with software engineering can be associated.

In addition to the above-mentioned works on measuring CSI, Varavithya and Esichaikul (2004) discuss the design of a citizen advisory service (CAS) to support citizens in accessing e-government services. The design of the CAS aims to advise citizens in selecting an appropriate e-government service, and consists of 1) the e-government advisory interface, 2) backward-chaining rule-based systems, and 3) the governance rule repository. Such design provides not only front-office interactive advisory services to citizens, but also back-office controls and verifications for the accuracy of knowledge. Varavithya and Esichaikul (2004) assert that the lack of knowledge regarding rights and duties makes citizens underprivileged users of e-government knowledge management. Seamlessly browsing through a myriad of e-government services should not be expected unless customized support that is tailored towards an individual's situation and competence is provided.

The discussion in this section has provided so far a brief account of the existing literature and ongoing practices in the world. Next, there will be an application of this account to the specific Turkish case.

According to Information Society Strategy Action Plan (DPT 2006) Action # 28 refers to the applications for citizen-focused service provision. The two specific actions with respect to this action plan are as below (DPT 2006, 17):

- Citizen expectations and needs will be identified at agencies, and integrated service provision will be guaranteed in line with these needs during the development, provision and improvement processes of electronic services in the public; e-consulting functions by which public institutions will be able to gather citizen views on electronic media will be activated.
- A "user satisfaction index" for e-services will be defined and measured regularly.

In accordance with this action plan, a collaboration between Türksat and Kahramanmaraş Sütçü İmam Üniversitesi has been initiated, in order to develop a methodology for measuring citizen satisfaction from e-government services in particular. Based upon the current literature, a draft model underlining some variables such as trust, Website quality and citizen services is proposed. A multi-equation cause-and-effect model and Structural Equation Modelling will be used for data analysis of the relations among the variables. Regarding the Structural Equation Modelling , "Path Analysis with Observed/Latent Variables", and "Confirmatory Factor Analysis" will be applied to the specific Turkish case, for developing indices at three different levels (e-service, e-institution, e-government).

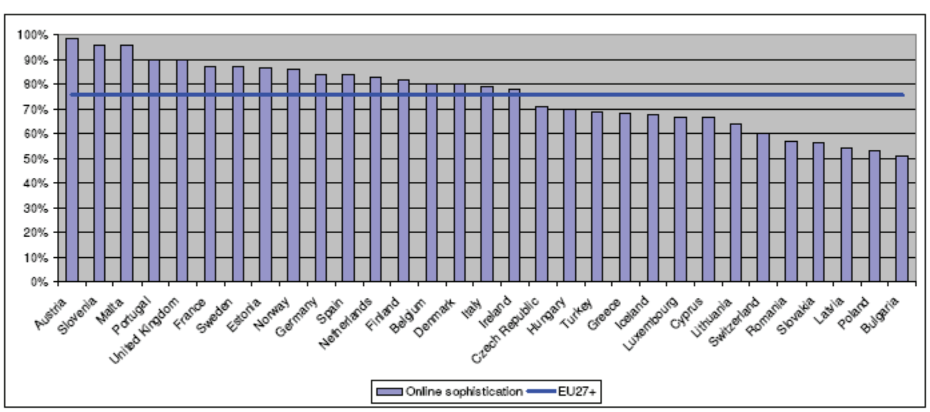
In addition to this national project, an international project for citizen-oriented evaluation of e-government services has been developed in collaboration with Brunel University, UK and American University of Beirut, Lebanon (2008). Well received by the EU MARIE CURIE ACTIONS, PEOPLE, Industry Academia Partnerships and Pathways (IAPP) Program (FP7-PEOPLE-IAPP-2008), the project will be initiated in 2009, after the completion of the final negotiation stage. As a result of the project, by using DEA framework, a reference process model that will be applicable not only to Turkey but also to other EU countries will be developed.

There are other ongoing and future projects, such as development of e-consulting services or disseminating e-government services for citizen satisfaction in Turkey. However, rather than discussing such works, at this point our discussion draws a framework that show the latest situation of e-government in Turkey.

A Framework of Web-Service-Oriented Computing in Turkey

According to the recent report of Brown University, U.S.A., the e-government services provided in Turkey are considered to be in the top ten among the 198 countries of the world. However, according to other reports disseminated by the UN, OECD or EU, the performance of Turkey in e-government can be considered to be about average. For instance, according to the latest report of the UN (2008), Turkey has the ranking of 76 among 182 countries in the world in terms of e-government readiness. Evaluating for the EU, Capgemini (2007) reaches similar conclusions for Turkey with a 70% performance ranking in general. (Figure 2).[13]

Figure 2. Country ranking regarding online sophistication maturity (Capgemini, 2007,15)



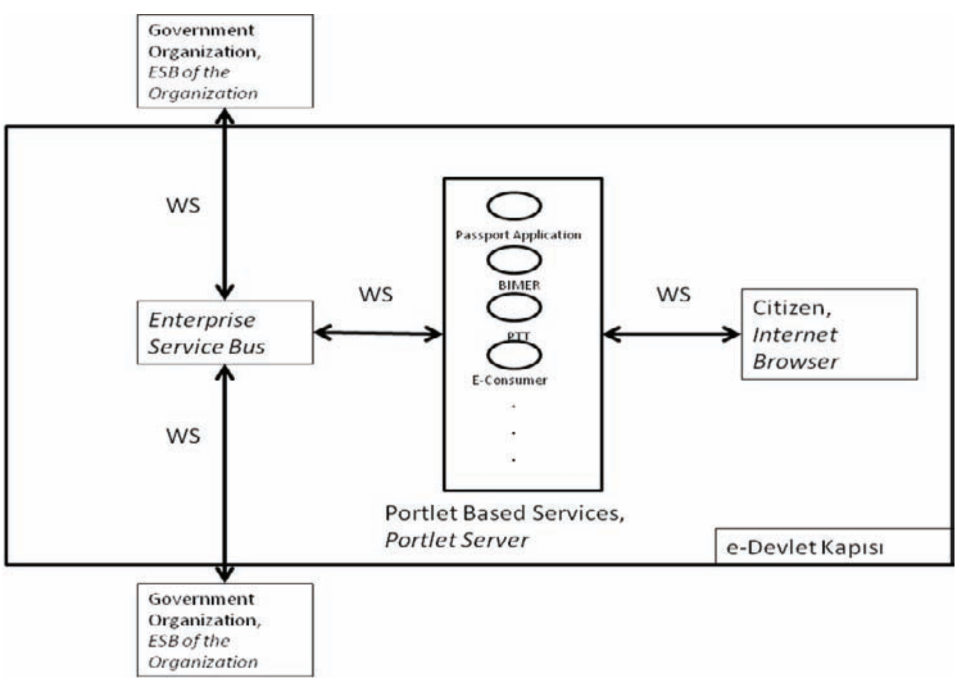
Service-oriented development and programming is an emerging software engineering paradigm that utilizes services as the constructs to support the development of rapid, low-cost composition of distributed applications. Government and country oriented organizations serve to the citizens without considering low cost constraints and profit gains. At this point, an approach originally developed to help companies for profit, finds a new usage inside government transactions.

In the service-oriented development approach, there are different kinds of technologies that can be considered. Web services are the most fashioned ones among these technologies. "Web services is a self-describing, self-contained software modules available via a network, such as Internet, which completes tasks, solves problems, or conducts transactions on behalf of a user or application" (Papazoglu, 2008). Another important point is that, Web services (WS) can establish synergy between other technologies, even if these technologies are based on .Net and Java. Even if an application is created with .Net of Java, it can also be applicable and usable in different platforms via WS.

In Turkey, e-government Gateway infrastructure has been developed as in Figure 3, to support high transactional ratios of Web service usage. A basic representation of the Turkish e-government Gateway architecture can be found in this Figure 3.

According to this figure, one side can be considered as the citizen side. Citizens can reach the services they desire via internet browsers. In the e-government portal called e-Devlet Kapısı, the services are published via a portlet server. This portlet server is directly connected to the Enterprise Service Bus (ESB) of e-Devlet Kapısı, which orchestrates the connections and transactions between e-Devlet Kapısı and Web service publishers or Web service clients. On the other side, are government organizations. To establish interoperability between different government organizations, e-Devlet Kapısı functions in the middle to establish communication lines. For

Figure 3. Summarized Web Service Architecture of e-government Gateway (e-Devlet Kapısı)



transactions and processes concerning WS usage, ESB offers services like those it offers to citizens.

While technology independence is an important factor for global markets as in Turkey, Java-and .Net-based technologies are the most dominant ones in the Turkish market, and this dominance is also reflected in government organizations' technology usage habits. WS and e-Devlet Kapısı thus have an important role to provide interoperability not only for intra-government but also inter-government operations (government-to-government).

The discussion in this section draws a picture about the current situation in Turkey, as well as gives an idea about the future directions of Turkey. Future trends for citizen-oriented e-government services in Turkey are elaborated further in the next section.

FUTURE TRENDS: INTEGRATION AND INTEROPERABILITY FRAMEWORK FOR CITIZEN-ORIENTED E-GOVERNMENT SERVICES IN TURKEY

Increased integration in service delivery based on commonality of infrastructures, data, and business processes, and service innovation achieved by multi-channel service delivery and *smaller and smarter* use of back-end processes and systems to support *bigger and better* front-end operations encourage more collaborative models of service delivery (UN 2008). These models of "connected or networked government" request government agencies rethink their operations, to move towards a chain-oriented paradigm with respect to structure, culture, knowledge and management, and to look towards technology as a strategic tool and an enabler for public service innovation and productivity growth. (ibid.)

According to the same UN report (2008), following a systemic approach to collection, reuse, and sharing of data and information, networked government is based upon interoperability as the ability of government organizations to share and integrate information by using common standards. Potential common standards, policies, and frameworks should be flexible enough to respond to changing conditions and varying requirements. Networked governance encourages creative and collective societal action to advance the public good, influencing and incorporating the strategic actions of multi-stakeholders regionally and internationally.

In recent years e-government services have brought about a more collaborative mindset, owing to the tremendous opportunities for sharing information and aligning (if not integrating) service offerings across different providers. Then, a core challenge for e-government's enterprise architecture is that a more seamless governance be nurtured through collaborative opportunities between units (i.e. departments and agencies), or more aggressively pursued through a single, central service provider. One centralizing force is the pursuit of greater interoperability across enterprise-wide architectures (important elements of a platform for service delivery) for the public sector as a whole. Yet the manner in which centralization and collaboration are viewed as complementary is a significant novelty in this digital environment.

In Turkey, in order to facilitate access to electronic public services by citizens (and enterprises), these e-government services should be reached from a single portal and via multiple channels. Users will be able to access the system with smart cards or imprinted digital certificates for secure transactions. Finally, "integration standards" will be adapted to the establishment of an interoperability framework. For interoperable cross-border interactions, ubiquity, "the possibility to send and receive data anytime and anywhere, and thus eliminate any spatiotemporal restriction", is also a key concept, that paves the way toward mobile government services. Among ongoing interoperability projects, for instance, a document management system and enterprise service bus have been developed. Built upon "xml", "bpel", and "wsdl" are in use for the flow of documents and definition of processes, and for the definition of services, respectively.

In general in Turkey, for integration and interoperability, database management and online accessibility for the following issues are necessary (Altınok, 2008[10]; Acar & Kumaş, 2008)

- Real Person Entities
- Legal Institutional Entities
- Address Information
- Movable Tangible Assets
- Land register and real estate
- Geographic Information System (GIS)

In Turkey, objectives for the Real Person Entities are mostly accomplished by MERNIS (Central Population Affairs System). For the other items, some more work needs to be done, in order to achieve integration and interoperability of e-government services in Turkey. As one step forward, conferences and workshops to be held in the near future will highlight integration and interoperability at interorganizational, intraorganizational and technical levels.

One of the next steps for integration and interoperability is the development of the legal entity system. Currently there is a searchable online company registration database, and a single application form, from which information is distributed by post/courier. The process provides a one-stop shop for registration with trade registry, tax, labour and insurance authorities.[11]

However, there are still unsettled political, administrative and legal issues regarding the improvement and implementation of the project. For instance, for registration of a new company, the responsibility currently belongs to the Union of Chambers and Commodity Exchanges, and Trade Registry Offices of the Chamber of Commerce. Delegation of responsibility over business registration, however, was transferred from the Ministry of Trade and Industry to the Trade Registry Office.[12] Such unsettled issues with respect to authority and responsibility have an inevitable influence on targets and projects such as the development of a Knowledge System for Legal Entities on the way to become an Information Society. In general, in 2011, 70% of all the e-government services will be ready according to the Information Society Strategy in Turkey. In the 2008 progress report, it is noted that among the 111 actions defined in the strategy document, 3 are concluded, 51 are work-in-progress, and 34 are at the beginning stage. When these targets are met, the available services could be very significant for the transformation of not only state institutions but also the society and citizens.

In addition to these issues discussed with respect to content management, citizen satisfaction, integration and interoperability, there are some other embedded aspects, such as, metadata, mobility or ongoing projects on, such as security, standardization and inclusion. In addition, there are potential projects such as a work on the government services network that interlinks any change in services and the institutions and laws that this change will have impact on.

CONCLUSION

This chapter has aimed to provide an overview of the main issues and trends in e-government that will be interesting to the reader of the Handbook, underlying state-of-art issues and sources about e-government concepts and applications such as content management and measurement of citizen satisfaction. We hope the readers would find particularly interesting the focus on citizen satisfaction and measurement of service quality.

In early stages of their development e-government services basically provides information to users as administrators, citizens and businesses. For the information provision, control of content, and accessing, exchanging and understanding content is important. In later stages, more interactive services are incorporated and integrated into the system, enabling further uses for democratization processes, exploitation of public sector information, and citizen competencies. Assessing quality and citizen satisfaction is significant for the service provision. In the future, technologies for personal monitoring, smart security, digital homes, and social software, among others will be in use more and more. (Wilson, 2006)

In general, one of the main objectives of e-government services is satisfying citizen needs by addressing specific issues such as content management and measuring e-services satisfaction levels. Of course, there are other important reasons for adoption of e-government. In order to improve the level of e-government adoption in countries, citizen orientation should always be kept in mind. Without getting proper, sufficient and high quality information, citizens are unlikely to engage different stages of e-government, such as interaction and transaction.

After identifying citizen needs, providing citizen-centric content in e-government, and measuring the level of satisfaction from e-services, the relationship between governments and citizens could become a more trusting one. However, it always should be kept in mind that e-government should be seen as a means, not an end in itself. These efforts must be integrated into broader societal goals, and broader reform processes, specifically to better serve the citizens' needs.

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KEY TERMS AND DEFINITIONS

Content Management: From a specific process perspective; creation, collection, control, management, maintenance, publication, use and improvement of data, information and knowledge in the forms and modes of text, image or sound on the Web sites or other institutions mediums. Here content can be basically understood as information tagged with data, and used as knowledge.

E-Government Gateway (e-Devlet Kapısı, e-kapı): The platform where public services are provided in a simple, understandable way at a single Webpage to citizens and businesses in Turkey. At this platform, information pages, service-oriented applications for citizens and businesses, as well as cross-institutional transactions among public institutions are provided.

E-Government Services: Public services provided via technologies of information, communication and knowledge in a more effective way that are normally provided via conventional methods and methodologies. Thus, the provision of these services also necessitates a thorough revision of the existing methods and methodologies, which can also be expected to initiate a major transformation within the public sector.

User Satisfaction Index for E-Government Services: Application of statistical methodologies to measure how citizens (, as well as businesses or public administrators) evaluate the quality received from the use of e-government services

ENDNOTES

1 From a similar view point, Heeks (2006: 4) indicates that e-government systems can be seen as 'socio-technical systems', therefore neither aspect should be neglected; social – that is, people – and technical aspects are both important in implementing e-government. There is also the institutional environment, consisting of laws and values, economic systems and technological innovations that needs to be addressed (Heeks 2006: 5).

2 http://www.accessegov.org/acegov/uploadedFiles/Webfiles/cffile_3_24_06_3_08_35_PM.pdf last access 20.06.2008

3 SAKE (Semantic-enabled Agile Knowledge-based eGovernment) http://www.sake-project.org/ (last access 16.06.2008)

4 http://www.steptwo.com.au/papers/kmc_goals/index.html

5 http://www.earley.com/CMKM.asp

6 http://www.steptwo.com.au/papers/kmc_wherek/index

7 http://www.fbinnovation.de/en/glossary/ecsi.php

8 ACSI 2008 http://www.theacsi.org/index.php?option=com_content&task=view&id=48&Itemid=41

9 http://www.theacsi.org/index.php?option=com_content&task=view&id=30&Itemid=150

10 Prime Ministry, Meeting in June 2008.

11 (eupractice Website factsheet)

12 (eupractice Website)

13 Further information for this international project can be found in Lee et al. (2008) reference.

Chapter XLVI
Technical Outline of a W3 Spatial (Decision Support) Prototype

João Negreiros
ISEGI-Universidade Nova de Lisboa, Portugal

Marco Painho
ISEGI-Universidade Nova de Lisboa, Portugal

Fernando J. Aguilar
Universidad de Almeria, La Canãda de San Urbano, Almeria, Spain

Manuel A. Aguilar
Universidad de Almeria, La Canãda de San Urbano, Almeria, Spain

ABSTRACT

The present research focuses on the first software to offer spatial autocorrelation and association measures, spatial exploratory tools, variography and Ordinary Kriging spatial interpolation in the World Wide Web. Exploiting IE® (Internet Explorer), ASP® (Active Server Pages), PHP® (Hypertext Preprocessor) and IIS® (Internet Information Server) capabilities, SAKWeb© (Spatial Autocorrelation and Kriging Web) was designed in an attractive and straightforward way for any GIS user. Hence, this chapter concentrates on the technical development and design of this Internet application. The differences between server and client side techniques are emphasized in the preamble section while the following one discusses the controversial debate between GIS (Geographical Information System) and SDSS (Spatial Decision Support System) concepts. The opening prospect given by the Internet platform is presented in section three. The next section fully reviews the main technological software used for its construction. References are made to their use within SAKWeb©. Some particular capabilities as an end-user were not forgotten, as well. The conclusion section leads to some future hints regarding its potential.

PREAMBLE

The death of specialized software is often cited as one of the main reasons for the lack of acceptance of spatial data analysis by empirical analysts (Anselin, 1992). Although this situation has much improved in the last fifteen years, SAKWeb© is the first Web prototype in operation that provides access to an E-Learning audience for geostatisticians at New University of Lisbon, Portugal. SAKWeb© version 2.0 is not a comprehensive statistical package in the tradition of solving everyone's problems. Written for the Internet Information Server® (IIS) environment, it was developed with the philosophy that spatial autocorrelation and Kriging interpolation software is needed as an E-Learning tool by individuals with limited geostatistical knowledge. The incorporation of statistics to explain Earth processes (spatial statistics) has been developed furiously in the last two decades. Interpolation Kriging, the best linear unbiased estimator (BLUE) for spatial domains, is a good example. Using a LaGrangean system of linear equations where the error of prediction should be minimized in some sense, Kriging uses the covariance to measure the spatial autocorrelation among samples (including anisotropy and quadrant search) in order to estimate the value of an unknown site given the values of some other known points. In an elegant matrix layout (cf. Figure 1), each interpolated value is calculated as the sum of weighted known points whose weights are calculated from the (n+1) simultaneous linear equations set: $\mathbf{A}\times\mathbf{W}=\mathbf{B}$ or $\mathbf{W}=\mathbf{A}^{-1}\times\mathbf{B}$. The statistical distance between sample points and distances from each sample to the grid point are used to compute the model variance reproduced on matrices **A** (between samples) and **B** (between each sample and the estimated location). While $\mathbf{A}^{-1}$ underlies the declustering factor, **B** represents the structural distance between the estimation and all samples. In addition, the product of $\mathbf{A}^{-1}$ by **B** adjusts the raw inverse statistical distance weights in matrix **B** to account for possible redundancies between samples. As expected, if no spatial autocorrelation is found among the available samples then the Kriging estimator equals the sample average. This technique has been used in mining, hydrogeology, natural resources, remote sensing and environmental issues (Goovaerts, 1997, Zimmerman, D. *et al.*, 1998).

In addition, it can satisfy the needs of individuals with more training. SAKWeb© deals with deterministic and stochastic interpolation in conjunction with spatial association and autocorrelation measures in a Web continuum process instead of a loose local spatial function. From this view point, an element of its originality and innovation can, thus, be appreciated.

To make this project come to life, several WWW technologies were used. Active Server Pages® (ASP®), PHP® and Dreamweaver® were the main development framework in an Internet application context. WebChart®, ActiveBar®, FrontPage® Server Extensions, Flash® and JavaScript® were the other components required to accomplish this project.

Figure 1. Cov(x1,y1) represent the variance of sample 1, Cov(x1,yn) equals the covariance between sample 1 and sample n, Cov(x1,x0) is the covariance between sample 1 and the estimated unknown site x0, W1 denotes the first weight while Ψ stands for the LaGrange multiplier as a result of the constraint of the weights sum to one.

$$\mathbf{A}=\begin{vmatrix} \text{Cov}(x1,y1) & \dots & \text{Cov}(x1,yn) & 1 \\ \dots & \dots & \dots & \dots \\ \text{Cov}(xn,y1) & & \text{Cov}(xn,yn) & 1 \\ 1 & \dots & 1 & 0 \end{vmatrix} \quad \mathbf{B}=\begin{vmatrix} \text{Cov}(x1,x0) \\ \dots \\ \text{Cov}(xn,x0) \\ 1 \end{vmatrix} \quad \mathbf{W}=\begin{vmatrix} w1 \\ \dots \\ wn \\ Ø \end{vmatrix}$$

At present, there are two cores Web modus operandi to build dynamic applications: client-side and server-side. The aim of any Web server is to publish HTML contents in order to reply to any request through port 80 (443, if SSL protocol is used). This type of solution is the client-side strategy where the HTML code is interpreted by the browser (cf. Figure 2). JavaScript®, Java Applets® and ActiveX® are included in this category.

If the browser contents are dynamically generated by the Web server through local executables and run-time scripts then the server-side technique was chosen (cf. Figure 3). In this domain, the use of the Common Gateway Interface (mainly written on Perl®, script shell or C language) was the first standard communication available. The most widely known CGI program regards the linkage between the submission of an HTML form (using the Get and Post methods) and a database server to save user results. Note, however, that CGI is not a language. Nor is it a program. CGI is a process, an interface which provides well-defined rules for creating partnerships (Abreu, Carreiro, 2007). The benefit is that if everyone respects the rules of this interface then everyone can talk to each other. One alternative, especially for Netscape® servers such as iPlanet®, is Livewire®, a development environment that allows the use of JavaScript® on the server-side (Coelho, 2002).

In this new era, the present development is the server-side script languages that allow the generation of dynamic contents such as PHP®, Java Server Pages (JSP®), Java Servlets® (a server-side version of Java Applets®) and ASPs®. As expected, the use of this server-side scripting has its pros and cons, e.g.: (1) Due to every client has no processing to do, the loading of any page requires less time for the browser of the user. Yet, the responsibility of the Web server to generate the HTML must be taken into account and, hence, robust hardware for the server is mandatory. (2) Because the client only receives HTML, there are no special requirements and plug-ins for the browser. (3) The server script code cannot be viewed by the user, a situation not considered by most client-side technologies. (4) More complex solutions can be built on account of ActiveX® components, for instance.

For the majority of Web applications, the server-side versus client-side issue does not make much sense because both methods have specific

Figure 2. The client-side technology (Adaptation from http://www.homebizpal.com/technical/understanding-Web-technologies/, 2008)

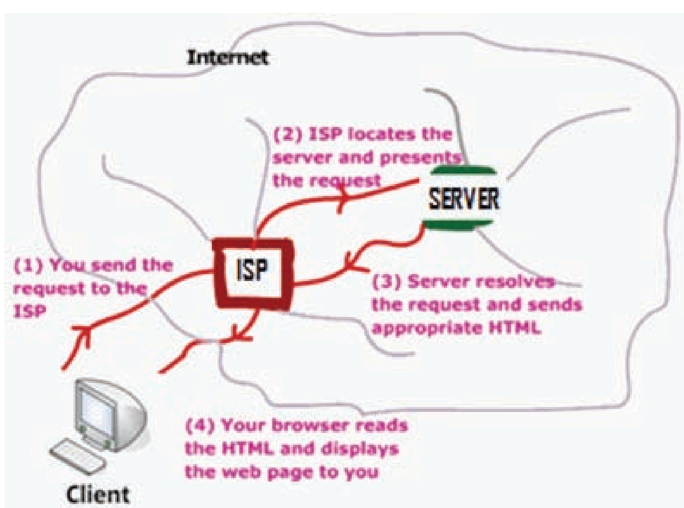
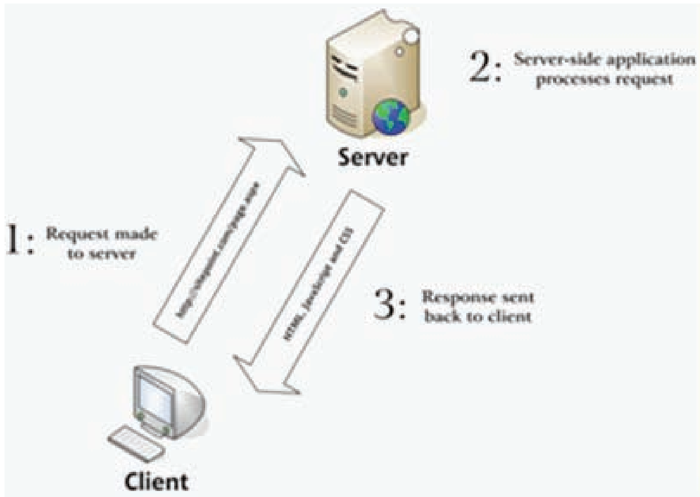


Figure 3. The server-side technology (Adaptation from http://emptyminds.blogsome.com/2008/05/11/what-is-aspnet-part-1/, 2008)



and defined goals. The client-side components are used to validate and process local pages while the server-side is used to produce dynamic contents. SAKWeb© follows both trends because both technologies were applied with both purposes.

This chapter reviews these components without focusing on their integration within SAKWeb©, an Internet application of spatial analysis for GIS users. Section 2 focuses on the conceptual difference between a GIS and a SDSS (Spatial Decision Support System). Under the developer approach, major technical innovations and some functionalities regarding SAKWeb© are discussed in the following sections. The concluding section summarizes future trend of this W3 application.

SAKWEB©: SPATIAL DECISION SUPPORT SYSTEM OR GIS?

GIS is a system of hardware, software and liveware implemented with the aim of storing, processing, visualizing and analyzing data of a spatial nature (Painho, 1999). Pertinent data would include spatial information, such as regions location and their connectivity. Certainly, GIS directly supports the intelligence phase of spatial decision making (Ali, Sato, 2001). Three frameworks have been developed to describe this spatial decision making process: GIS software, spatial extensions of commercial statistical products and independent research applications. Unexpectedly, the Internet choice was almost never undertaken.

Globally, GIS holds two major components: data and model. The first element contains all spatial and non-spatial attributes. The model holds spatial analysis processes and other specific tools, reporting maps, particular guidance for selecting decision alternatives, problem relationships and advice in interpreting possible outcomes. What-if, goal-seeking and other types of sensitivity analyses can also be used to extend or modify the original analyses and evaluations (Guisseppi, 2003). Certainly, it is this feedback loop founded on spatial maps that increases users confidence recommendations and enable the decision maker to better explain, justify and communicate its decisions during implementation.

If a GIS holds this distinct contribution to handle spatial data, what is, then, the difference between a GIS and a Spatial Decision Support System (SDSS)? No direct answer can be given.

The simplest perspective is that a GIS is implicitly a Decision Support System (DSS) since it can be used to support decision making (Keenan, 2002). Mennecke (1997) sees SDSS as an easy-to-use subset of GIS, which incorporates facilities for manipulating and analyzing spatial data. Confirmed by Armstrong and Densham (1990), any GIS lack the modeling component needed to be accepted as a DSS. However, GIS might be regarded as a form of DSS generator (Sprague, 1980) to which models can be added to make a specific DSS (Keenan, 1996).

Clark and Hosking (1986) see spatial analysis as spatial modeling of a decision support such as GADS (Geodata Analysis and Display System) for solid waste spatial planning. In conjunction with the network and spatial analysis of GIS modules, the Decision Support System Location Planner© analyzes market saturation, retail facilities accessibility, population mobility and demand-supply prediction based on demographic and socio-economic attributes, warehouse locations, distance or travel time between sites and expenditure flows between demand and supply chains (Arentze *et al.*, 1997). Still, according to Openshaw (1998), an emphasis of SDSS is a convenient distraction to hide a lack of the relevant GIS technology.

According to Guisseppi (2003), if GIS becomes a major input player required for some other type of information decision maker then the GIS might be said to be acting directly as a SDSS. Yet, if the GIS focus on a specific problem with the complete interest lack of GIS features outside that domain, GIS cannot be regarded as a SDSS. Under both visions, SAKWeb© belongs to the second one.

THE INTERNET GATEWAY

During the last decade, there have been great developments with the Internet. From a technological standpoint, cooperative work, computation distribution and networking have contributed to the widespread dissemination of geographical knowledge with more intuitive, more analytical and more diverse embedding technologies (Weiss, Indurkhya 1998). From the commercial perspective, the Internet can be viewed as an extension of the traditional competitive marketplace. In effect, the Internet is capable of dramatically lowering the transaction and agency costs facing most organizations (cf. Table 1).

Equally important, Internet technology is providing the infrastructure for electronic business because its technology can also be used to make information flow seamlessly from one part of the organization to another. For instance, Internet standards can be used to link disparate systems, such as ordering and logistics tracking that previously could not communicate with each other.

In the past, the cost of comparison shopping procedure was very high, because people had to physically travel from store to store. Internet has

Table 1. Internet technology can radically reduce transaction costs in many industries (Laudon, Laudon, 2006)

E-GOODS	Traditional System	Internet	Percent Savings
Airline Tickets	$8	$1	87%
Banking	$1.08	$0.13	89%
Bill Payment	$2.22 to $3.32	$0.65 to $1.1	71% to 67%
Term Life Insurance Policy	$400 to $700	$200 to $350	50%
Software	$15	$0.2 to $0.5	97% to 99%

changed this relationship. Once everyone is connected electronically, information about products and services can flow on its own directly and instantly to consumers (Laudon, Laudon, 2003), although this situation might create a channel conflict with the firm's traditional channels. Thus, Internet shrinks information asymmetry. In the same way, using hypermedia capabilities, companies can quickly and inexpensively provide detailed product information specific to each customer to a very large numbers of people simultaneously (Evans, Wurster, 2000), the richness-reach concept.

Similarly, Internet might help business-to-consumer (B2C) companies by providing original products and services such as people making online bids for rock concert tickets, the pure-play business model. This includes m-commerce, electronic payment and customer support via e-mail. Another current trend is Web personalization, the capability to present to each customer a modified Web page based on that person's purchase history.

Business-to-business (B2B) generates efficiencies by enabling companies to electronically locate suppliers, solicit bids, place orders and track shipments in transit (Laudon, Laudon, 2006). That is, trading partners can directly communicate with each other, bypassing intermediaries and inefficient multilayered procedures. This means simpler business processes, fewer employees and much flatter organizations than in the past in a redesigned integrated framework.

From the science point of view, the synergy effect of the online educational material (bibliographies, electronic newsgroups, W3 sites and E-Learning software) in which the overall information may be greater than the sum of its parts is a conviction. Under the GIS view, one of the greatest WWW impact is to close the software access gap among users ("from the privilege of the few to the right of the many") with free and direct retrieval of spatial analysis tools. Technically, this implementation model is divided into three layers (the three-tier model): interface, application and data access (Abreu, 2006). Compared with the conventional stand-alone and distributed two-tier structure, Web applications emerge as a new paradigm by integrating complex and boundless technologies such as CGI, ISAPI (Internet Server Application Programming Interface), Coldfusion® (based on a set of tags, the ColdFusion Markup Language, instead of a scripting language), PHP®, JSP® (Java Server Pages), ASP® and ASP.Net®. To introduce the technical infrastructure of SAKWeb© becomes, then, the issue of the following section.

SAKWEB© TECHNOLOGIES

Internet Information Server®

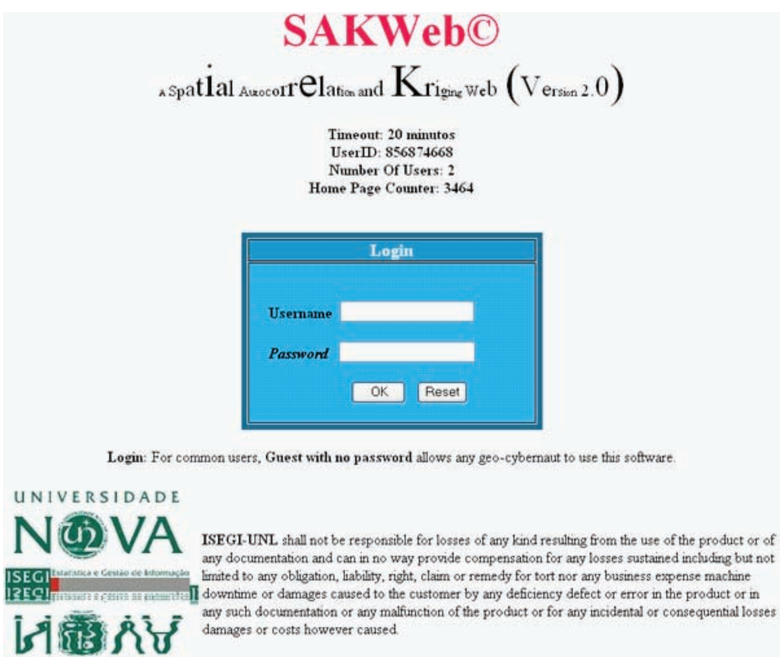
At the heart of any Web application, a Web server is a requirement that might includes FTP (File Transfer Protocol), IRC (Inter Relay Chat), Mail, News, Telnet and Proxy servers (Baptista, 2002). IIS® was SAKWeb© choice. First and foremost, IIS® is a protocol server that implements the Internet protocol HTTP (Hyper Text Transfer Protocol), among others. It also offers standard Application Program Interfaces (APIs) for extending and customizing its server's capabilities. Under Windows® environment, its management console can be found in the Administration Tools (Serrão, Marques, 2007). Regarding its architecture, it is based on WAM (Web Application Manager) technology with COM (Component Object Model) and ISAPI functionalities. When IIS® receives an HTTP request its job is to return the request resource such as a static or dynamic page. Depending on the resource extension name, it loads the appropriate ISAPI extension, forwards the request, receives a return call and returns that data stream to the requesting user's browser. Specifically, when an ASP® page request is received, IIS® forwards the request to the ASP.DLL (the ASP® parser), processes the page and sends the return data to the Inetinfo executable process which simply returns the data to the user.

With regard to SAKWeb©, the next five items depicts setup major steps: (1) The home directory is c:\inetpub\wwwroot; (2) An IP/Port address was required with a DNS (Domain Name Server) name; (3) Login.asp is its default home page; (4) The Executables folder holds execute permission while the Data folder retains write authorization; (5) All other folders hold the default right permissions for read and run scripts. Concerning these last three issues, they are quite critical because implementing security and privacy at IIS® can never be overstated. Basically, this Web server provides four types of authentication:

1. **Basic:** The logon name and password specified by the user
2. **Digest:** This sends the user's credentials for validation in an encrypted form
3. **Integrated windows:** It uses the account credentials of the Windows® domain to authenticate the user
4. **Anonymous:** This type uses a built-in user account to request resources from the Web server. Option one was SAKWeb© choice

To secure a virtual directory, the Web manager needs to invoke the Internet Services Manager and, after the directory in question is selected, the Security tab allows permissions to specific computers to be granted or restricted (Alonso *et al.*, 2004). Another option is the Directory tab that allows selection of the appropriate permissions for the Web application such as Read, Write, Script source access, Directory browsing and Log visits. With regard to this last issue, IIS® provides a number of formats for the Web server log files (Stanek, 2003): (1) Microsoft® IIS® log – It records basic information about Web requests, including IP address, date, time and the number of bytes exchanged while processing the request; (2) NCSA common log – This option records fewer details of requests than the previous one; (3) W3C extend log – This format saves the most detailed

Figure 4. The home and authentication page that includes the keywords Meta tag for search engines robots



description available of a Web request. Option one was SAKWeb© choice. At last, SAKWeb© implements its own authentication mechanism based on the default authentication form (cf. Figure 4). If the user is not authorized, the Web application directs the user to a pre-defined logon refused page. Otherwise, he or she is redirected to the main Web page.

From CGI to ASP® and PHP®

With the wish to create more than just a static display for the Web, Web developers turned to CGIs and Perl® language to introduce some sort of interaction. Since CGI programs are executable applications, it is the equivalent of letting the world run a program on the system, which is not the safest thing to do (Negreiros, Ferreira, 1999). Certain security precautions are, thus, needed: CGIs need to reside in a special directory so that the Web server knows where to execute programs rather than just display it to the browser. If the Web server has an NCSA HTTPd server distribution version, for instance, then the /cgi-bin directory is the chosen one. According to Caphart (2003), this directory is usually under direct control of the Webmaster, prohibiting the average user from creating them.

With CGI applications, the client request is first sent to the server over the Internet via HTTP. The server receives it, determines which program needs to be run and writes the information to an input file. Then, the server launches the CGI program. This program reads the input file, writes the output to another one and terminates itself. The Web server process, which has been waiting for the previous steps, reads the output file and finally sends it back to the client via HTTP (Loureiro, 2005).

CGI applications are easy to write but scale very poorly within Windows® (Microsoft Learning, retrieved from http://www.microsoft.com/mspress/books/sampchap/1394a.aspx, 2008). Because a separate process is spawned for each client request, hundreds of clients create hundreds of instances of the same CGI, each requiring its own memory space and system resources. This is not such a bad thing on Unix®, which is designed to handle multiple processes with very little overhead (Morgan, 1996). However, Windows® expends more system resources when creating and destroying application instances. One way to get around this problem is to embed this processing into the Web server itself by adding logical and processing power (eXtropia, retrieved from http://www.extropia.com/tutorials/devenv/middleware.html, 2008).

Another earliest technology to take advantage of this idea was SSI (Server Side Includes). The concept of SSI is simple. Special tags that are inserted into the HTML document, understood by the Web server and translated on-the-fly by the Web server as the HTML document passes to the browser (eXtropia, retrieved from http://www.extropia.com/tutorials/devenv/middleware.html, 2008).

ISAPI (requires all the programming and layout to be contained in a .dll file) came and went primarily because it required more knowledge to create a dynamic filter than Web programmers were prepared to learn (Pandey, 2002). Finally, Web scripting languages emerged including Microsoft ASP®s, a server-side scripting technology for building Web pages that are both dynamic and interactive, a major demand for SAKWeb project©.

This new technology shifted the focus from desktop to distributed computing where a number of applications are integrated to provide a mechanism solution (Mendes *et al.*, 2004). Thus, resources at remote locations can be integrated with Exchange Server®, Internet Security® and SQL Server®. In addition, PHP® and ASP® offers an open server-application environment where the user combines HTML, server-side scripts and reusable COM server components to create a dynamic and powerful Web-based business solution (Microsoft TechNet, retrieved from http://

www.microsoft.com/technet/ prodtechnol/windows2000serv/reskit/iisbook/c01_active_server_pages.mspx?mfr=true, 2008). At last, after the server-side script runs, the results are returned to the client browser in the form of a standard HTML document.

This server-client framework holds remarkable programming features: (1) Response, Request, Server, Scripting, Application and Session objects that allow dynamic information access to the ASP® Object Model hierarchy. (2) The capability of including standard COM objects (.dll or .exe files) from third party companies. (3) The faculty to access internal objects such as the Dictionary (a collection of miscellaneous key/value pairs that the programmer may use within any page).

A Web application becomes, thus, a collection of ASP® pages, server components and a Website where its distinction among all applications is made by the root directory within the site. Therefore, all content within each directory structure is considered part of the scope of the same application. Moreover, each application has its own set of variables and attributes that define its current state. These are maintained throughout the application lifetime. This time concern with Web based applications is due to the fact that HTTP has no memory and retains no information from one client request to the next (Coelho, 2000). ASP® gets around this issue by using Application and Session objects to store information during a user's session. In a further technical detail, both application and session are initialized and destroyed by the global.asa file found in the root directory of any Web application. Internally, this global.asa is an optional file that might contain declarations of objects, variables, events, library declarations and inclusion files directives (Scribd, retrieved from http://www.scribd.com/doc/98067/asp, 2008).

Regarding SAKWeb©, its code was achieved with this technology in accordance with to the following hierarchical folder structure:

- **/Chat :** This directory contains all files that allow users to meet in a virtual room. It uses cookies and twelve session's variables although its home is an HTML file.
- **/Common:** This folder includes three important scripts: (1) Lib_data_to_array.asp reads Excel® and ASCII input data to an internal dynamic array for post-processing; (2) Menudynamic.asp redirects the user to the home page or to the main menu; (3) Menudynamic.htm includes VBScript® code for the call of a third party component named ActiveBar®.
- **/Content:** This folder consists of several types of files whose aims are Excel® management, variogram fitness procedure, Flash® executables, statistical descriptive measures, indicator mapping for samples, bivariate data posting, image mapping, local interactive statistics and nearest neighborhood analysis.
- **/SK:** This folder contains all files that are responsible for Simple Kriging interpolation.
- **/Data:** It holds all background text files that are created during any SAKWeb© interpolation process by any GIS user.
- **/Executable:** It contains the gamv.for, varmap.for, kt3d.for and kb2d.for files and their GSLib® (a set of geostatistical Fortran routines developed at Stanford university) executable versions.
- **/Kriging:** The twenty-five files existing in it computes Ordinary Kriging interpolation.
- **/Moran:** This folder includes seven ASP® files responsible for dealing with the Moran I correlogram and Moran scatterplot, two spatial autocorrelation measures and particularly appreciated by any GIS user.
- **/Olectra:** It encloses seven definition files (3dconst.inc, 3dgentag.inc, 2dconst.inc, binstream.asp, error.inc, color.inc and 2dgentag.inc) that are required for any Web map displayed by this software.

- /HelpSAKWeb: As expected, this directory is responsible for handling all images, Flash® and Java® Applets files need it for SAKWeb© Help, SAKWeb© News, SAKWeb© Email and other E-Learning features.

SAKWeb© also includes two other tools that use PHP® server-side technology:

- The PHP Configuration option displays SAKWeb© parameters of PHP® variables status.
- The DOS Commands (cf. Figure 5) allows the user entering any MS-DOS® instruction while the results are shown in the browser itself.

JavaScript®

JavaScript® is executed when a document is loaded by the client. Often used to create dynamic HTML documents, JavaScript® increases the aesthetics and friendliness of Websites by adding events to static pages, referenced by the HTML tag <script language="JavaScript" src="corefunctions.js"></script>. Checking input forms and computing client-side mathematical calculus are two critical capabilities of this language. Another potential of JavaScript® (used within SAKWeb®) is the possibility to control the browser itself through the following objects and methods:

The history object allows the local accesses accomplished by the user. For instance, history.go(-1); is equivalent to pressing the Back button of the browser while history.toString(); displays an HTML table with the history of the browser links.

The document object allows access to the properties of the Web page when it is loaded. For instance, document.bgColor="FF0000"; sets up the background color to red while document.clear(); clears the content of the active Web page.

The location object provides information regarding the current URL. For instance, loca-

Figure 5. Snapshot of the DOS Commands option

Type a DOS command: [ ]

Submit | Reset

ATTRIB filename	Displays or changes file attributes.
CHCP	Displays or sets the active code page number.
CHKDSK drive	Checks a disk and displays a status report.
CHKNTFS drive	Displays or modifies the checking of disk at boot time.
COPY file1 file2	Copies one or more files to another location.
DEL file1	Deletes one or more files.
DIR drive:\directory	Displays a list of files and subdirectories in a directory.
FIND "string" filename	Searches for a text string in a file or files.
HELP command	Provides Help information for Windows commands.
MKDIR new_dir	Creates a directory.
PATH	Displays or sets a search path for executable files.
PRINT filename	Prints a text file.
REN file1 file2	Renames a file or files.
RMDIR directory	Removes a directory.
SET	Displays, sets, or removes Windows environment variable
START	Starts a separate window to run a specified program or comm
TREE drive:\directory	Graphically displays the directory structure of a drive or path.
TYPE filename	Displays the contents of a text file.
VER	Displays the Windows version.
VERIFY ON or OFF	Tells Windows whether to verify that your files are written correctly
VOL drive:	Displays a disk volume label and serial number.

tion.reload(); refreshes the current document while location.hostname; displays the name of the remote host.

The window object includes the document and other objects that handle any Internet page internal structure. For instance, window.open ("http://www.nasa.gov") loads the home page of NASA into a new window while window.alert("Your input value is out of range!"); generates a pop-up alert message whose content is its input parameter.

JavaScript® 1.2 also introduces two new functions that are very useful for any programmer, concerning debugging and error corrections. The watch() method is applied to a certain variable and, if something has changed, a particular procedure can be triggered. For instance, if the instruction watch('x',change_var); is setup then an alert message will be displayed every time the x variable changes its content. As expected, the unwatch() method turns off this debugging effect. It is essential to state that JavaScript® cannot create files or establish network connections with other remote hosts.

As a live example of this technology use within SAKWeb©, the following code illustrates how JavaScript® modifies the browser status bar (cf. Figure 6). At first, the Javascript function Date() retrieves from the client the date and time to hoje variable, whose content is displayed on the left bottom of the browser. This process continuous indefinitely due to the setTimeout() procedure that calls the function relogio() recursively every second.

WebChart® and ActiveBar® ActiveX Components

ActiveX® (formerly known as OLE Controls or OCXs) is a reusable software module based on Microsoft's Component Object Model (COM) architecture and providing similar functions (animations, spreadsheet emulation, graphics generation…) to Java Applets. This is the technology used by SAKWeb© to display all graphics and maps. Over the Internet, ActiveX® controls can be linked to a Web page and downloaded by a compliant Web browser as if the program were launched from a Web server (cf. Figure 7). Still, like any executable program running in the computer, ActiveX® controls can perform any operation on your data. This is why the default configuration in most Web browsers is to prompt the user, if an ActiveX® control is being requested, so he/she can decide to download it or not (PC Magazine, retrieved from http://www.pcmag.com/encyclopedia_term/0,2542,t=ActiveX+control&i=37472,00.asp, 2008).

VBScript® allows developers to include ActiveX® controls that are then loaded and registered

Figure 6. The JavaScript® clock output

```
<HTML><head><title>Status Clock</title></head>
<body>
<script>
function relogio(){
    var hoje = new Date();
    window.status = hoje.toString();
    setTimeout("relogio()",1000); }
    relogio();
</script>
</body></HTML>
```

into the user's system. Yet, browser compatibility is an issue: ActiveX® technology is not currently supported by some browsers such as Firefox® or Safari®. Therefore, SAKWeb© requires IE®.

With SAKWeb© hosting system, two ActiveX® names were registered from ComponentOne®. The following HTML page (cf. Table 2) includes an ActiveBar® ActiveX® interface that communicates with the local user by exposing properties and methods to fire events. This also includes an assigned CLSID for an entry into the Windows® registry that allows the client browser to obtain, register and load the control.

Glancing at previous code, the client-side ActiveBar® interface was included to layout the output presented in Figure 8 which has a unique identifier, the 128-bit CLSID. It is the use of this CLSID that avoids the possibility of name collisions among Windows classes because CLSIDs are in no way connected to the names used in the underlying implementation. Hence, no two components with the same interface can be mistakenly used for each other (Powers, 2001).

The 2D/3D WebChart® ActiveX® gives power to this ASP® environment by generating different graphic charts. Internally, the server-side component shares a common API with the client-side that generates an .OC2 or .OC3 control to be passed to the client with the appropriate HTML tags. If the client does not hold the olch2x8.cab and olch3x8.cab files, the Web server generates a runtime-only copy of WebChart® on the client's machine. As expected, a runtime license for the client's computer is created if and only if there is a registered version on the developer's computer (Côrtes, 2000). The generation of the HTML tags that supports this Web functionality is contained in two routines under the scope of 2dgentag.inc and 3dgentag.inc files: OlectraChart2D_GenerateTag_Control() and OlectraChart3D_GenerateTag_ Control(). These are the procedures that allow developers to customize the way that all tags will be generated.

The next ASP® code introduces the generation of the linear trend surface (cf. figure 9), generated from a set of (x,y,z) observations, with the following features: (1) Data values are stored in d(30,30) array; (2) The chart size was setup to 400×300 pixels; (3) The chart type is a 3D bar type; (4) The background color is white while the chart axis becomes blue; (5) The shading surface and zone colors are also included; (6) The IsBatched=true property does not allow changes to the chart while other calculations are being executed; (7) No captions are shown; (8) The Call OlectraChart3D_GenerateTag_JPEG (Chart3D,"Chart3D") instruction is responsible to spawn the chart image to the client.

DISTINCT FUNCTIONALITIES OF SAKWEB©

SAKWeb© is not a full geostatistical, autoregressive regression and simulation software package, yet. Its present functionality was depicted in

Figure 7. ActiveX® controls are stored remotely but they are run locally (Adaptation from PC Magazine, http://www.pcmag.com/encyclopedia_term/0,2542,t=ActiveX+control&i=37472,00.asp, 2008)

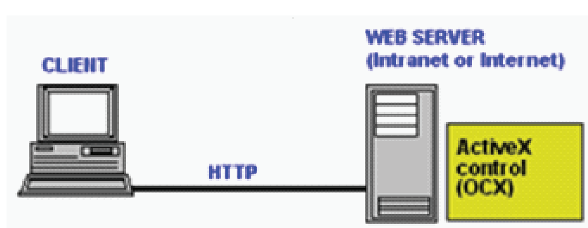
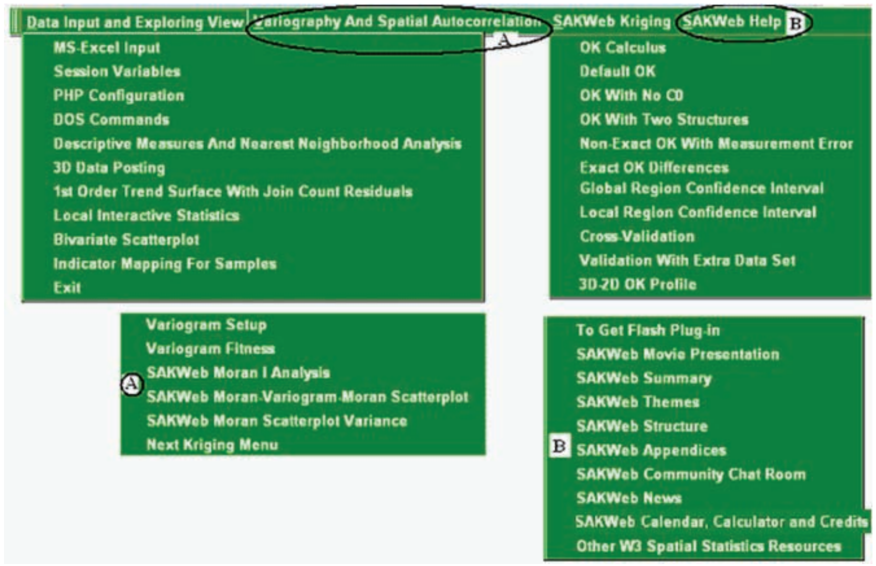


Table 2. Snapshot code of the ActiveBar® inclusion within VBScript®

```
<HTML><head><title>Main Menu</title></head>
<OBJECT classid="CLSID:5220CB21-C88D-11CF-B347-00AA00A28331" VIEWASTEXT><PARAM
NAME="LPKPath" VALUE="ActiveBar.lpk"></OBJECT>
<OBJECT classid="CLSID:E4F874A0-56ED-11D0-9C43-00A0C90F29FC" codeBase=actbar.cab#Version=
1,0,6,5 id=ActiveBar1 style="LEFT: 0px; TOP: 0px" width=32 height=32 VIEWASTEXT> <param
name="_ExtentX" value="847"><param name="_ExtentY" value="847"></OBJECT>
<body><script language="VBScript">
<!--
Sub window_onLoad()
        ActiveBar1.Attach
        Create_Tools
        Create_Bands
end sub
Sub Create_Tools()
        iCat = 100
        Set Tool = ActiveBar1.Tools.Add(iCat + 1, "mnu1")
        Tool.Caption = "&Data View and Tools"
        ...
end sub
Sub Create_Bands()
        Set b = ActiveBar1.Bands.Add("mnu1")
        b.Type = 2 ' ddBTPopup
        b.Tools.Insert b.Tools.Count, ActiveBar1.Tools("descriptivemeasures")
        …
        ActiveBar1.Bands("mnuMain").GrabHandleStyle = 0
        ActiveBar1.BackColor = 33792
        ActiveBar1.ForeColor = 16777215
        ActiveBar1.MenuFontStyle = 1 ' ddMSCustom
        ActiveBar1.Font.Name = "Arial"
        ActiveBar1.Font.Bold = True
        ActiveBar1.Font.Size = 10
        ActiveBar1.RecalcLayout
        ActiveBar1.Refresh
End Sub
Sub ActiveBar1_DataReady()
        ActiveBar1.RecalcLayout
end sub
…
-->
</script></body></HTML>
```

Figure 10. Still, some distinct capabilities will be reviewed here while major features, under the interaction scenario view point of the end-user, can be appraised in Negreiros *et al.* (2006, 2008). The control management of the site itself by the local administrator can be achieved by means of three options: (1) DOS Commands - The capability to browse the contents of MS-DOS® commands. (2) PHP Configuration - The ability to display all PHP® configuration of SAKWeb©. (3) Session Variables – It gives the CGI parameters and the contents of the session variables created by the current user session (a useful tool for the developer to control the application flowchart). As well, SAKWeb© may plot a horizontal 3D graphic with the visitor distribution to the site throughout the day by dividing it into six groups of hours (cf. Figure 10). Its aim is to give clues to geostatiticians to what is the best time to connect SAKWeb©.

Figure 8. The SAKWeb© main menu, partially generated by the previous code presented in Table 2



When spatial analysis is at stake, the possibility for sampling location is achieved with the 3D Data Posting (cf. Figure 11). This tridimensional view includes drop lines and X-Y-Z axis grid lines options. Further, according to samples values, data observations are plotted with three different colors: below 25% of the average, between 25% and 75% and above 75%.

Ordinary Kriging (OK) was the stochastic interpolation method chosen by SAKWeb©. This probabilistic approach tries to find the weighted average estimator that provides an unbiased estimator with the smallest estimation error variance using the LaGrange multiplier and the weights sum to one constraint. That is the reason why Kriging is BLUE (best linear unbiased estimator) and BUE (best unbiased estimator if input data respects the Normal curve). Still, it is the variogram (cf. Figure 12) that underpins Kriging by summarizing the degree of similarity between values for all possible pairs as a distance function. Four major factors embody this spatial autocorrelation measure: (1) Sill – The variogram value that implies no spatial dependence between data points because all variances are invariant with the sample separation distance; (2) Range – The separation distance at which samples are spatially autocorrelated; (3) Anisotropy – It represents the spatial autocorrelation behavior of the variogram according to several directions; (4) Nugget-effect – It embodies the measurement error variance and the spatial variation at distances much shorter than sample spacing, which cannot be resolved (Liebhold, 1995).

According to Armstrong (1998), the nugget-effect (C0) is the most significant and difficult issue to setup the variogram. Hence, three OK approaches are computed by emphasizing this factor: OK with C0, OK without C0 and OK with C0 plus two structures. The capability to rotate, to zoom, to reset and to join the 2D and 3D surfaces together in a W3 environment is a remarkable step for future spatial data analysis software, as well. This advent is a result of the kb2d.exe GSLib® routine that assesses these three OK versions through a PHP® file that uses cookies technology. Cookies are small text files saved by the user browser through the header of

Figure 9. The SAKWeb© trend surface analysis generated by the previous code

```
  Set Chart3D = Server.CreateObject("C1Chart3D8.ASPComponent")
  With Chart3D.ChartGroups(1)
    With .ElevationData
      .ColumnCount = 30
      .RowCount = 30
      For i = 1 To 30
        For j = 1 To 30
          .Value(i, j) = d(i,j)
        Next
      Next
    End With
  End With
  With Chart3D
    .Width = 400
    .Height = 300
    .IsBatched = True
    .ChartGroups(1).ChartType = oc3dTypeBar
    .Interior.BackgroundColor = ocColorWhite
    .Interior.ForegroundColor = ocColorBlue
    With .ChartGroups(1)
             .Styles(1).Symbol.Size = 2
       With .Contour
         .Levels.NumLevels = 20
         .IsZoned = True
       End With
       .Elevation.IsShaded = True
   End With
   .Legend.IsShowing = False
   .IsBatched = False
End With
With Chart3D
      Response.Write("<p align=center>")
      dispChart = Session("DispChart")
      If dispChart = "Jpeg" Then
        Call OlectraChart3D_GenerateTag_JPEG(Chart3D,"Chart3D")
      ElseIf dispChart = "Png" Then
        Call OlectraChart3D_GenerateTag_PNG(Chart3D,"Chart3D")
             ElseIf dispChart = "Png-BinaryWrite" Then
        Call OlectraChart3D_GenerateTag_PNG_BinaryWrite(Chart3D,"Chart3D")
             ElseIf dispChart = "Jpeg-BinaryWrite" Then
        Call OlectraChart3D_GenerateTag_JPEG_BinaryWrite(Chart3D,"Chart3D")
      Else
        Call OlectraChart3D_GenerateTag(Chart3D,"Chart3D")
      End If
      Response.Write("</p>")
End With
Set Chart3D = Nothing
```

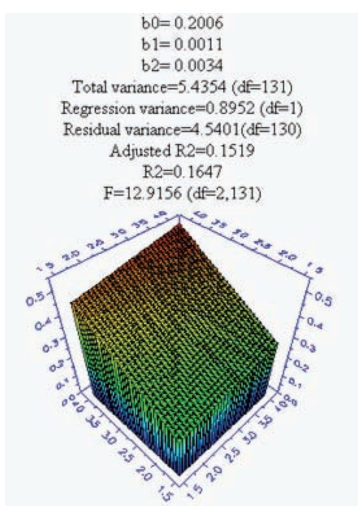


Figure 10. The visitor distribution graphic of SAKWeb©

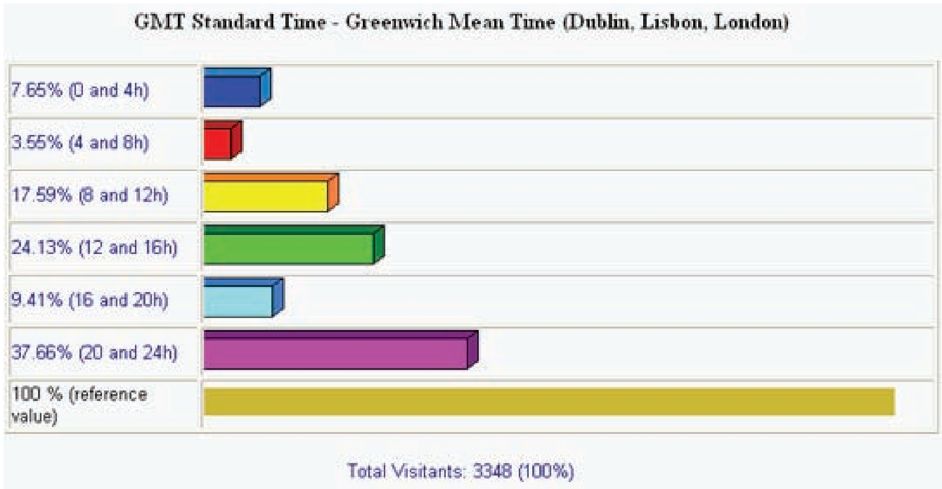
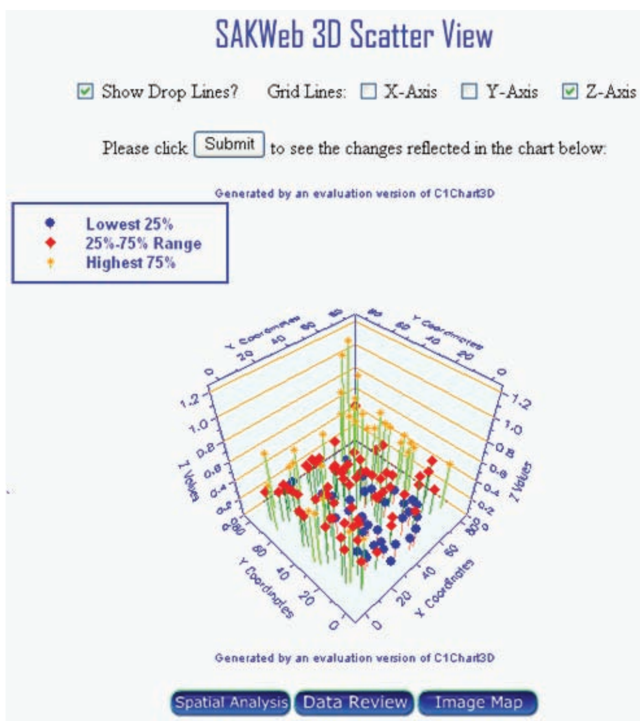


Figure 11. The 3D scatter view of SAKWeb©



an HTML file. Since ASP® and PHP® are able to write (response.write("sakWebsessionid")) and read ($_cookie["sakWebsessionid"]) them, SAKWeb© creates a cookie called sakWebsessionid which contains the user session identification (response.cookies ("sakWebsessionid")). Therefore, the possibility of sharing this crucial information between both scripting technologies becomes real and central for this intercommunication process.

Another motivating option for any geostatistician is the Exact OK Differences option that displays the interpolation differences among the three previous nugget-effect approaches (cf. Figure 13). This includes the computation of the following statistics: average difference, maximum and minimum disparity between approaches and average OK variance.

A weighted average of the previous three models (cf. Figure 14) is also a possibility with this software whose weights are based on the variance of the Kriged estimates (more weight is given to those values with smaller estimation variance).

Flash® MX is the SAKWeb© Help standard authoring tool. One of its achievements relies on its success in capturing the feel of a living, thinking and interactive solution without being distracting, confusing and gimmicky. Distinctive animation for each section has also been created. For instance, the navigation system is focused in a sensitive way, with every button having a normal, rollover and active state. In fact, any interaction model should pursue a consistent navigation scheme that allows users to understand what a button is without having to think about it. With yahoo.com, for example, its common interaction model is represented by underlined text links (Street, 2002). With SAKWeb© help, text link buttons are angular and highlighted when the cursor rolls over them. Color consistency and acid audio in a loop context completes this environment.

FINAL THOUGHTS

There is an increased demand for systems that do more than display spatial data (Ebdon, 1998). Spatial data holds special features to the researcher: Where does this occur? How does this pattern vary across the study area? How does an event at this location affect surrounding locations? Do areas with high rates of one variable also have high

Figure 12. The typical variogram shape with its main parameters (Ouyang, Zhang, Ou, 2005)

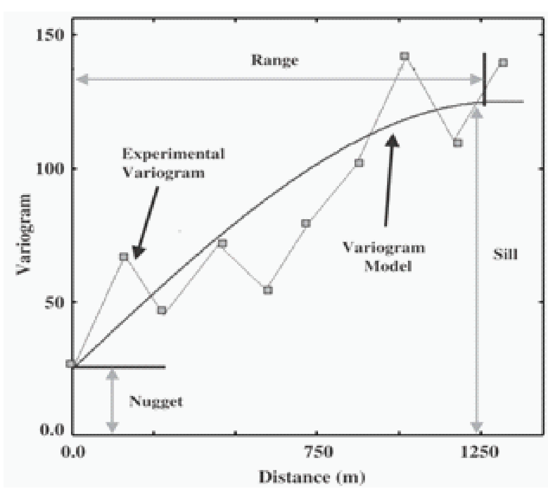


Figure 13. The faculty to compare on-the-fly three nugget-effect approaches is a welcome possibility

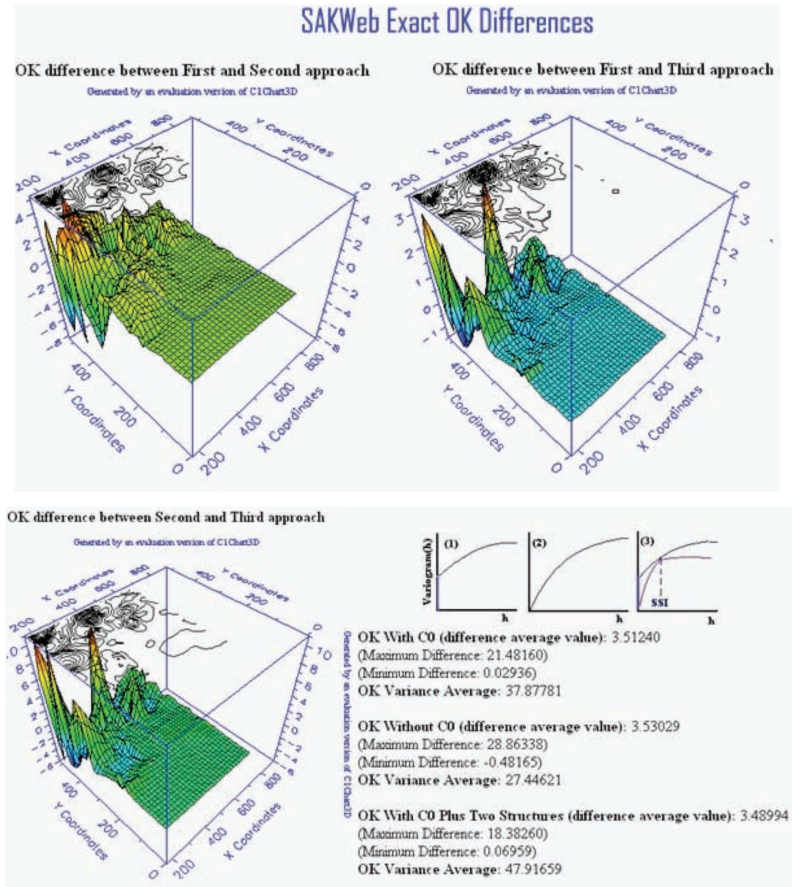
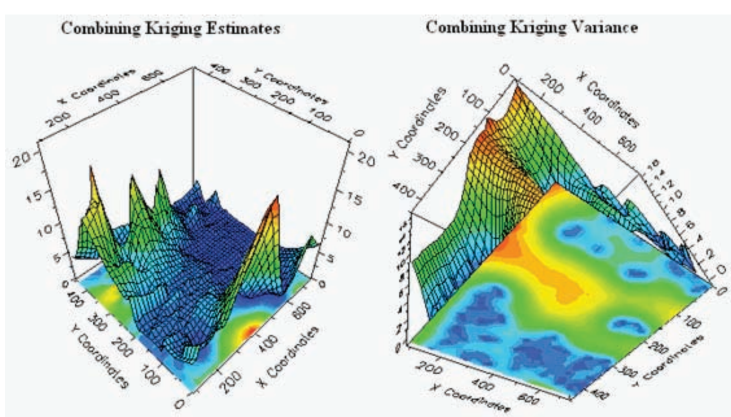


Figure 14 . Combination of Kriging estimates from OK with C0 (model 1), OK without C0 (model 2) and with two structures (model 3)



rates of another? Traditional statistical techniques tend to produce a summary statistic that quantifies the strength of a relationship within a dataset, for example. This approach is undesirable, from a GIS perspective, because it ignores the impact of space. It is important that spatial methods should explicitly incorporate the spatial component to develop a more sophisticated understanding from our data (Negreiros, Painho, Aguilar, 2008).

With the advent of Web technology and modern wireless computing, it has also become necessary to develop a WWW service for GIS interpolation in order to understand the often complex spatial autocorrelation that exist among observations collected in space. The inclusion of both topics in an E-Learning context provided major inspirations for SAKWeb©. Quite often, common users request spatial analysis knowledge in a self-learning view because of global cost reduction, both time and money. In addition, implementing the technological structure that supports E-learning platform is a scalable solution (Painho *et al.*, 2002). Spatial analysis wizards, multimedia tools (including animation and hyperlinks), on-line help, software courses, videos, E-Learning and M-Learning with WML technology are ingredients of this demand. CRM of the Universidade Autónoma de Lisboa and GIS&Sc Master of ISEGI, certified by UNIGIS, are some examples of the Learning Space strategy (Semana Informática, 2002). The International Center for Distance Learning (http://www-icdl.open.ac.uk), the AT&T Learning Network Virtual Academy (http://www.att.com/learningnetwork/virtualacademy), La Escuela de Negocios a Distancia de la Universidade Politecnica de Madrid (http://www.cepade.es), Le Centre National d'Enseignement à Distance (http://www.cned.fr) and the Universidade Aberta (http://www.univ-ab.pt) are others fine examples of this trend (Negreiros and Painho, 2006).

Although this project is still a work in progress, the future of SAKWeb© can be bright. It is expected to be launched in 2009 as myGeooffice.org. Its infrastructure can be applied easily as a WWW interface with GSLib® routines to avoid the reinvention of the wheel for other geostatistical algorithms. This includes UK (Universal Kriging), IK (Indicator Kriging), CK (CoKriging) and Monte Carlo simulation. Morphological geostatistics, cost environmental analysis, K-means clustering, autoregressive regressions and Geary C computation will not be forgotten, as well. Adapting Anselin (1992) software contemplation, all academic research implementation should be a reality in a W3 environment.

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KEY TERMS AND DEFINITIONS

E-Learning: A broad set of applications and processes which include Web-based and computer-based learning, virtual classrooms and digital information. In companies, it refers to the strategies that use the company network to deliver training courses to employees. Lately in most Universities, it is used to define a specific mode to attend a course of study where the students rarely attend the face-to-face traditional classes room because they study online.

Geographical Information Systems (GIS): System of hardware and software used for storage, retrieval, mapping and analysis of geographic data. In its strictest sense, it is any information system capable of integrating, storing, editing, analyzing, sharing and displaying geographically referenced information. In a more generic sense, GIS applications are tools that allow users to create interactive queries, analyze spatial information and present the results of all these operations in maps.

Kriging: A form of statistical modeling that interpolates data from a known set of sample points to a continuous surface. It is the best linear unbiased predictor whether or not data are normally distributed. It is linear since estimations are a weighted linear combination of the available data. It is unbiased because the error mean is zero (no over or under-estimates). It is best since its goal is to minimize error variance.

myGeooffice©: The future marketable name of SAKWeb© that includes other forms of Kriging and spatial autocorrelation measures such as Geary index. Geostatistical simulation, cost analysis and morphological issues will be also covered.

SAKWeb©: It focuses on the first software to offer spatial autocorrelation and association measures, spatial exploratory tools, variography and Ordinary Kriging (OK) in the World Wide Web. In terms of implementation technologies, several different software were used: ASP®, IIS® with Server Extensions, PHP®, FrontPage®, VBScript®, ActiveX®, Dreamweaver®, Ultradev®, Flash®, Director®, Fireworks®, WebChart®, ActiveBar®, Java Applets®, JavaScript®, HTML, DHTML, Fortran and C language.

Spatial Autocorrelation: The degree to which a set of features tend to be clustered together (positive spatial autocorrelation) or be evenly dispersed (negative spatial autocorrelation) over the Earth's surface. As in the data mining process of finding attribute anomalies, spatial autocorrelation measurements look for patterns and relationships within vast spatial digital archives. These indices are categorized into two groups: Distance view and neighboring view.

Spatial Decision Support System: A customized computer-based information system that utilizes decision rules and models and incorporates spatial data. It is designed to assist the spatial planner with guidance in making land use decisions, for instance.

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About the Contributors

Maria Manuela Cruz-Cunha is currently an associate professor in the School of Technology at the Polytechnic Institute of Cavado and Ave, Portugal. She holds a Dipl. Eng. in the field of systems and informatics engineering, an MSci in the field of information society and a DrSci in the field of virtual enterprises, all from the University of Minho (Portugal). She teaches subjects related with information systems, information technologies and organizational models to undergraduated and post-graduated studies. She supervises several PhD projects in the domain of virtual enterprises and information systems and technologies. She regularly publishes in international peer-reviewed journals and participates on international scientific conferences. She serves as a member of editorial board for several international journals and several scientific committees of international conferences.

Luís Ferreira is currently a lecturer in the School of Technology at the Polytechnic Institute of Cavado and Ave, Portugal. He holds a Dipl. in the field of mathematics and computer science and a MSci in the field of informatics, area of distributed systems, computer architectures and computer communications, all from the University of Minho (Portugal). He teaches subjects related with computer science and programming paradigms, information systems integration and Web programming to undergraduate studies. He supervises several software development projects and participates in several consulting and analyzes commissions.

Eva Ferreira de Oliveira is currently is a lecturer in the School Technology at the Polytechnic Institute of Cávado and Ave, Portugal. She holds a Dipl. Eng. in the field of information systems and information technologies and a MSci in the field of systems and informatics engineering both from University Of Minho - Portugal. Actually she teaches multimedia and interactive systems, human computer interaction to undergraduated studies and coordinates an especialized course on development of multimedia products. Her scientific and research interest are related with new ways visualizing and interacting with videos exploring affective dimensions.

António José Videira Tavares is currently an assistant professor in the School of Technology at the Polytechnic Institute of Cávado and Ave, Portugal. He holds a Dipl. Eng. in the field of systems and informatics engineering and a MSci in the field of computer science. He teaches subjects related with programming, information systems and information technologies to undergraduated studies. His scientific and engineering interests include collaborative technologies, peer-to-peer systems and applications and technology management and adoption.

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Anas Abou El Kalam is an assistant professor of network security at the "Institut National Polytechnique", Toulouse, France. He is in charge of the security option. He had several responsibilities as the head of the Computer Science Department at ENSIB. He is / was member of the program committees of several conferences such as IEEE ACSAC08 (24th Annual Security Application Conference), IFIP SEC (International Information Security Conference), ESORICS (European Symposium on Research in Computer Security), IEEE CRiSIS (International Conference on Risks and Security of Internet and Systems), etc. His current research interests concern security policies and models, network security, privacy,security & QoS of embedded systems and intrusion detection systems.

Witold Abramowicz (http://www.kie.ae.poznan.pl/members/wabramowicz) is the chair of Department of Information Systems at The Poznan University of Economics, Poland. His particular areas of interest are information retrieval and filtering, knowledge management in MIS. He received his MSc from The Technical University of Poznan, Poland, PhD from The Wroclaw Technical University, Poland, and habilitation from The Humboldt University Berlin, Germany. He worked for three universities in the Switzerland and Germany for twelve years. He is an editor or co-author of twenty six books and over 150 articles in various journals and conference proceedings. He chaired 17 scientific international conferences and was a member of the program committees of over 200 other conferences. He is member of the editorial boards in some international journals like *Wirtschaftsinformatik* (A list), *Comparative Technology Transfer, International Journal of Web Services Practices, International Journal of Web-Based Learning and Teaching Technology.* Currently professor Abramowicz is involved in 7 research projects in the 6th Framework Program EU. Professor Abramowicz is vice president of the Polish Association of Management Information Systems.

Mary Frances Agnello is an associate professor in the College of Education at Texas Tech University. She completed her undergraduate work at The University of Texas at Austin and obtained her graduate degrees at Texas A & M University. She has taught French, Spanish, and language arts in Texas urban and public schools and teacher education foundations and methods classes at The University of Texas at San Antonio. An associate professor at Texas Tech University, she teaches diversity, curriculum development, and action research and pursues research in diversity, technology, and literacy. Her book, *A Postmodern Literacy Policy Analysis* and subsequent journal articles trace the history of literacy discourses, including technological literacy, in educational policy.

Fernando J. Aguilar received his PhD degree from Cordoba University, Spain, in 1997. He is currently a senior lecturer of the Almería Polytechnic High School at Almería University, Spain, working with the Department of Agricultural Engineering and being the leader of several modules like computer aided design, industrial graphical design and computer aided engineering.

Manuel A. Aguilar received his PhD degree from Cordoba University, Spain, in 2001. He is currently a senior lecturer of the Almería Polytechnic High School at Almería University, Spain, working with the Department of Agricultural Engineering. His fields of interest are close-range, satellite and classic digital photogrammetry, as well as generation and quality control of DEMs.

José F. Aldana Montes became a Member of the University of Málaga in 1990, and is full time professor since 1994. He was born in 20st November 1965 in Málaga, studied computer science at the

University of Málaga. This author has published a lot of papers in the field of data bases, reasoners and Semantic Web.

José Juan Pazos Arias was born in Bayona, Spain in 1964. He received his degree in telecommunications engineering from the Polytechnic University of Madrid in 1987, and his PhD degree in computer science from the Department of Telematics Engineering at the same University in 1995. He is the director of the Interactive Digital Television Laboratory in the University of Vigo, which is currently involved with projects on middleware and personalization applications for Interactive Digital TV, receiving funds from both public institutions and industry.

Marek Babiuch graduated MSc (1998) - graduation thesis: Debuggers and Compilers Implementation, VSB -Technical University Ostrava - Faculty of Electrical Engineering and Informatics. PhD dissertation (2004), thesis: Programming Support of Standalone Microcontrollers, VSB - Technical University Ostrava, Department of Control Systems and Instrumentation of the Mechanical Engineering Faculty 2003 - 2004 working at University Research Centre. The research work focuses on microcontroller's support of measurement and control systems, C#, VB and ASP .NET application, XML Web services. 2004 - till now working as an lecturer at the Department of Control Systems and Instrumentation of the Mechanical Engineering Faculty at VŠB - Technical University of Ostrava. Received certificates: 2007 - Cisco Networking Academy CCNA1 - Networking , 2008 - Cisco Networking Academy CCNA2 - routing protocols and concepts.

Asim Balci is the manager of e-Government Corporate Communication Department at Ttirksat, Turkey. He also holds the position of assistant professor in Department of Public Administration, University of Selcuk, Turkey. Prof. Balci is an expert in public administration and modern managerial approaches such as total quality management (TQM), strategic management, and business process reengineering. He has numerous project experiences funded by World Bank and European Union. Prof. Balci has given not only lectures in Turkish administrative system, economics, constitutional law, (comparative) public administration, but also seminars in TQM, leadership skills and human resource development. He has published numerous books and contributed to various joumal publications and conference proceedings in the fields of public administration, as well as TQM and e-Govermnent.

Alexandre Barão is teacher in Lisbon and PhD student of information systems and computer engineering at Instituto Superior Técnico, Technical University of Lisbon. At INESC-ID, as a member of the Information Systems Group, he is developing the visual tool SnareExplorer. He has professional and research interests in areas like social networks, object oriented programming and graphics computation. He is member of ACM.

Diana Barglazan is lecturer at Politehnica University of Timisoara - Romania, Management Faculty, Department of Economical and Social-Humanities Sciences. Her teaching subjects are economics and culture and civilization. She has obtained the PhD. degree under collaboration between UPT and Poitiers University in France (in the field of international economy). Her research fields of interest are: European integration, economics and organization dynamics (including their financial evolution and competitiveness). She regularly publishes and participates on international scientific conferences.

Amna Basharat (MSc) is a lecturer in the Dept. of Computer Science at FAST National University of Computer and Emerging Sciences, Islamabad, Pakistan. Her research interests include Semantic Web technologies, e-science, distributed information systems and collaborative computing, multi-agent systems and user-centered design. She received her MSc in distributed information systems and computing from Brunel University, West London, UK. Prior to that, she has also been a research associate in Multi Agent Systems Research Group at NUST Institute of Information Technology (NIIT) Pakistan, where she worked as key member for collaborative research work on agent architectures with communication technologies (Comtec), Japan. She was amongst the pioneering design and development team for one of the first open-source FIPA-compliant multi-agent system and agent architecture, SAGE (Scalable, fault Tolerant Agent Grooming Environment). She is currently also pursuing collaborative research in human cognitive models and Semantic Web with Brunel University. She has received various awards and accolades for her contributions in research, amongst which forth mentioning is the Pakistan's National Graduate Engineer of the Year Award (2005), granted by Pakistan Engineering Council.

Terje Brasethvik holds the degree of DrIng from the Department of Computer and Information Sciences, Norwegian University of Science and Technology (NTNU) in 2004. His primary subjects of interest are ontology based information retrieval and computational linguistic support for ontology construction. Since his degree, he has completed a post-doc in health informatics at the Norwegian centre for electronic health records (NSEP) and participated as a researcher in several semantic search related projects at NTNU.

Margo Bergman, PhD Margo is a behavioral economist currently working at the Michael E. Debakey Veteran's Administration Medical Center in Houston, TX. She is also an instructor of medicine, Health Services division at the Baylor College of Medicine. Her main research interests are decision making under conditions of uncertainty, with a recent emphasis on decisions involving information gained from genetic testing.

Nadeem Bhatti studied computer engineering in the technical university of Darmstadt, Germany. He is since October 2002 at Fraunhofer institute for computer graphics. He is responsible for semantic visualization and evolution techniques and application of semantic visualization techniques for different artifacts like digital born artifacts, knowledge artifacts and collective intelligence based artifacts (intelligent content, business ontology and community information). Nadeem Bhatti has worked on different projects knowledge asset management to assist business consultants in order to assess the knowledge assets of companies (KAM-SYS) and best practice based knowledge management at work (ALF). He is now project mangers for the projects THESUES, TEXO and SAP-Topicmap-Viewer at Fraunhofer institute for computer graphics.

Yolanda Blanco-Fernández was born in Orense, Spain in 1980. She is an assistant professor in the Department of Telematics Engineering at the University of Vigo, and a member of the Interactive Digital Television Laboratory. She received the telecommunications engineering degree from the University of Vigo in 2003 and her PhD degree in computer science from the same University in 2007. Her major research interests are the design and implementation of personalization services based on technologies borrowed from the Semantic Web.

Miroslav Blaško obtained his MSc degree from the Faculty of Mathematics and Physics of the Charles University in 2008 in the field of artificial intelligence. At present, he is a PhD student in the Knowledge Based and Software Systems Group at the Department of Cybernetics, Faculty of Electrical Engineering, Czech Technical University in Prague. His research topics include social aspects of semantic technologies, description logics, ontology engineering and design and the OWL language. He is involved in the EU project Netcarity, with a focus on the privacy protection on the Web using semantic technologies.

Felix Burkhardt has a longstanding background in language technology. Originally an expert of Speech Synthesis at the Teclmical University of Berlin, he has been working for the DTAG since 2000. He does tutoring, consulting, research and development in the working fields VoiceXML based voice-portal architectures, text-to-speech synthesis, speaker classification, Semantic Web technologies and emotional human-machine interfaces.

Hansel Burley is an associate professor of educational psychology at Texas Tech University, Lubbock, Texas. Dr. Burley has had extensive experience working with large data bases in the study of minority issues in education, college preparation, remediation and academic success.

Manuel Ramos Cabrer was born in Lugo, Spain in 1966. He received his degree in telecommunications engineering from Polytechnic University of Madrid, Spain in 1991, and his PhD degree in telematics from the University of Vigo, Spain in 2000. Since 2001, he is an associate professor in telematics engineering at the University of Vigo. His research topics are interactive digital TV concentrating on recommender systems, integration with smart home environments and interactive applications design and development.

Luís M. Carriço holds a PhD (2000) and an MSc degree in electronic and computers engineering, from the Instituto Superior Técnico (IST), Technical University of Lisbon. He is currently a professor at the Department of Informatics, Faculty of Sciences of the University of Lisbon and a senior researcher at LaSIGE, and a member of the HCIM Group. His main research areas include human computer interaction, usability and accessibility, intelligent, multimodal and mobile user-interfaces, visual languages, cognition-based systems and health informatics. He has published over 100 refereed technical/scientific papers and book chapters, and supervised several undergraduate projects and master dissertations. He is a member of several program committees for international conferences and a reviewer of international conferences and journals. He participated in several research projects, European (e.g. SOMIW, COMANDOS, FAST, ORCHESTRA), and national ones, some of them as coordinator, and he was involved and lead various technology transfer projects.

Claudia Cevenini is currently qualified at public competition as associate professor in legal informatics and is contract professor of new technologies and law at the ICT Engineering Faculty, Bologna University. She is also university assistant in legal informatics and legal philosophy. She has a PhD in legal informatics and computer law, a Master degree in comparative German-Italian law, a Bachelor degree *cum laude* in business and a Diploma as interpreter-translator. She co-ordinates the artificial intelligence and law research area at CIRSFID, is a lecturer at PhD and Master courses, national and international conferences, member of scientific committees on computers and law, member of the

Italian Societies of legal philosophy and legal informatics and the European Association of Law and Economics. She is author of 50+ national and international publications. She works as consultant for private businesses and public agencies. She is involved in scientific publishing initiatives and formerly assistant editor of the *Artificial Intelligence and Law* journal.

Keith C.C. Chan received the BMath degree in computer science and statistics and the MASc and PhD degrees in systems design engineering from the University of Waterloo, Waterloo, Ontario, Canada. For a number of years, he was with the IBM Canada Laboratory, Toronto, Ontario, working on the development of software engineering tools. In 1993, he joined the Department of Electrical and Computer Engineering at Ryerson University, Toronto, as an associate professor. In 1994, he joined the Department of Computing at the Hong Kong Polytechnic University, Hong Kong, where he is currently a professor and the head of the department. He is a codirector of the Joint Software Engineering Laboratory formed by the Institute of Software, Chinese Academy of Sciences, and the Hong Kong Polytechnic University. He is also a guest professor at the Graduate University of the Chinese Academy of Sciences, Beijing. He is active in consultancy and has served as a consultant to government agencies and various companies in Hong Kong, China, Singapore, Malaysia, and Canada. His research interests include software engineering, data mining, and pervasive computing.

Maiga Chang is assistant professor in the School of Computing Information and Systems, Athabasca University (AU), Athabasca, Alberta, Canada. His researches mainly focus on mobile learning and ubiquitous learning, museum e-learning, game-based learning, educational robots, learning behavior analysis, and data mining in e-learning. He serves several peer-reviewed journals, including AU Press and Springer's Transaction on Edutainment, as editorial board members. He has participated in 67 international conferences/workshops as a program committee member and has (co-)authored more than 91 book chapters, journal and international conference papers. He has been a member of the International Who's Who of Professionals since 2000. In September 2004, he received the 2004 Young Researcher Award in Advanced Learning Technologies from the IEEE Technical Committee on Learning Technology (IEEE TCLT). He is a valued IEEE member for twelve years and also a member of ACM, AAAI, INNS, and Phi Tau Phi Scholastic Honor Society.

Giuseppe Contissa has recently won the fellowship at Stanford University (USA) and is currently a contract professor in artificial intelligence and expert systems at Law faculty (Bologna University) and tutor of the course in legal informatics. He is also university assistant in legal informatics, He got his PhD in legal informatics and computer law and Master degree in legal informatics and computer law. His Bachelor degree in law was obtained from Bologna University. Giuseppe Contissa is also scientific collaborator at CIRSFID for the European project research area. Formerly he participated as knowledge engineer in the development of rule-based systems for the legal domain at RULEBURST (UK). Author of numerous national and international publications.

Yves Deswarte is currently a research director of CNRS, member of the "Dependable Computing and Fault Tolerance" research group at LAAS- CNRS in Toulouse, France. Successively at CII, CIMSA, INRIA and LAAS, his research work has dealt mainly with fault-tolerance and security in distributed computing systems. Recently, his main research interests were in intrusion tolerance, quantitative security evaluation, dependability evaluation criteria, protection of safety critical systems with multiple levels of integrity, flexible security policies, and privacy-preserving authorization schemes. He is the author or co-author of more than 100 international publications in these areas. He is a senior member of SEE, a member of the IEEE TC on Security and Privacy and a member of the ACM SIGSAC. He is representing the IEEE Computer Society at IFIP TC-11 (Technical Committee on Security and Protection in Information Processing Systems).

Anca Draghici is professor at Politehnica University of Timisoara (UPT) - Romania, Management Faculty, Department of Economical and Social-Humanities Sciences. Her teaching subjects are ergonomics, human resources management and knowledge management. Her research field of interest is linked with the impact of the knowledge based society upon the social / human dynamics / evolution and the organizational behavior. She regularly publishes and participates on international scientific conferences. She was member of the UPT team in the Virtual Research Laboratory for a knowledge community in production a network of excellence financed by the European Commission in the context of the 6th Framework Program (VRL-KCiP NoE, FP6-507487-2) that has become the EMIRAcle association in Europe.

João Carlos Amaro Ferreira was born in Angola, June 1967. He is professor of mathematics on informatics and telecommunication degree courses in Polytechnic Institute of Lisbon (IPL/ISEL). He is also consultant with different companies and Portuguese institutions. He graduated in physics at Technical University of Lisbon (UTL/IST), Portugal, received an MSC in telecommunication and a PhD degree in computer science engineering from UTL/IST. Currently, he teaches subjects in the area of mathematics and information systems and he supervises several year end, MSc and PhD students. His professional and research interests are in information retrieval, geographic and multimedia retrieval, semantic web, intelligent transportation (ITS) and sustainable mobility systems. As well as UML, MDE approach, automobile business process improvements and CAD systems. He is author or co-author of more than 50 peer-reviewed scientific papers of several international conferences and workshops in different areas of computer science.

Mag. (FH) **Karin Feurstein** received her degree in process and project management in 2003 at the University of Applied Sciences Vorarlberg (FHV). In 2004 she has started as a research assistant at the research centre for process- and product-engineering at FHV. She has worked on several national projects with the focus on organizational aspects of innovation management. Currently she is working as a senior researcher in several national and EU funded projects: (eten Programme) Tell-Me – "TransEuropean Living Labs for an iMproved E-participation" (EP# 046319); (Competitive and Innovation Programme) CO-LLABS – "Community-Based Living labs to Enhance SMEs Innovation in Europe" (EP# 224979); (Sixth Framework Programme) CoreLabs – "Co-Creative Living Labs" (EP# 35065)

Gianluigi Fioriglio, contract researcher (Faculty of Law, Bologna University), holds a PhD (bioethics and law, University of Lecce). Teaching assistant of legal informatics at the Universities of Bologna and Rome "Sapienza". Former visiting scientist at MIT – CSAIL, he received grants from the Universities of Bologna, Teramo, Lecce and Rome "S. Pio V". Former contract professor in the Universities of Rome "Sapienza" and Teramo. Professor in Master and PhD courses (Superior School of the Ministry of Interior, Universities of Teramo, Pavia and Salento) and author of 2 books and 20+ scientific publications. Lawyer. Scientific collaborator at CIRSFID for the European project research area.

Hernâni Rosado Borges de Freitas is a Master student of information systems and computer engineering at Instituto Superior Técnico, Technical University of Lisbon and was an Erasmus student in Universiteit Utrecht in spring term 2007. He is a trainee at Inesc-id, as a member of the Information Systems Group, where develops SNARE. He has professional and research interests in areas like social networks, virtual communities, knowledge management and Web 2.0 platforms development.

Jorge Marx Gómez studied computer engineering and industrial engineering at the University of Applied Science of Berlin (Germany). He was a lecturer and researcher at the Otto-von-Guericke-University Magdeburg where he also obtained PhD degree in business information systems with the work "Computer-Based Approaches to Forecast Returns of Scrapped Products to Recycling". In 2004, he received his habilitation for the work "Automated Environmental Reporting through Material Flow Networks" at the Otto-von-Guericke-University Magdeburg. From 2002-2003, he was a visiting professor for business informatics at the Technical University of Clausthal (Germany). In October 2005, he became a full professor of business information systems at the Oldenburg University (Germany). Professor Marx Gómez's research interests include business information systems, business intelligence, e-commerce, Web intelligence, material flow management systems, life cycle assessment, eco-balancing, environmental reporting, recycling program planning, disassembly planning and control, simulation, and neuro-fuzzy-systems.

Pascual Cantos Gómez received his BA (1988) and PhD (1993) degrees in English language and literature from the University of Murcia (Spain), his MA in computational linguistics (1995) from Essex University (UK) and a Postgraduate Diploma in multivariate statistics (2000) from the UNED (Spain). He is a senior lecturer in the Department of English Language and Literature, University of Murcia, Spain, since 1990, where he lectures English grammar, corpus and computational linguistics. His main research interests are in corpus linguistics, quantitative linguistics, computational lexicography and computer assisted language learning. He has published extensively in the fields of computer assisted language learning, corpus linguistics and computational lexicography.

James M. Grayson, PhD, is a tenured associate professor of management science and operations at the Hull College of Business Administration at Augusta State University. He received a Bachelor of Science degree from the United States Military Academy at West Point, an MBA with a marketing emphasis from the University of North Texas, and then a PhD in management science with an information systems minor also from the University of North Texas. He brings to his research considerable industry experience including about twelve years at Texas Instruments contributing in quality engineering, quality and reliability assurance management, supplier management, subcontractor management, software quality engineering management, statistical consulting, total quality management and a joint venture management (Ti - Martin Marietta). His research interests are diverse and range from unique approaches to organizational structure to applying management science methods to financial planning to operations management.

Manfred Gschweidl, BSc, has a degree in electrical engineering and received his bachelor degree in computer science in 2008 at the University of Applied Sciences Vorarlberg (FHV). Before starting his studies he has worked as software engineer for several years. In 2008 he has started as a research assistant at the research centre for process- and product-engineering at FHV. Currently he is studying in the Master's degree programme for business process engineering extra occupational and is working as a research assistant mainly in a national and EU funded project: (Seventh Framework Programme) EURIDICE – "European Inter-Disciplinary Research on Intelligent Cargo for Efficient, Safe and Environment-friendly Logistics" (ICT 2007-216271).

Jon Atle Gulla is a member of Qi and J on Atle Gulla is professor of Information Systems at the Norwegian University of Science and Technology since 2002. He received his MSc in 1988 and his PhD in 1993, both in Information Systems, at the Norwegian Institute of Technology. Gulla also has a MSc in Linguistics from the University of Trondheim and a MSc of Management (Sloan fellow) from London Business School. He has previously worked as a manager in Fast Search & Transfer in Munich and as a proj ect leader for Norsk Hydro in Brussels. Gulla's research interests include text mining, semantic search, ontologies, and large-scale enterprise systems. He is currently involved in several national and international projects on ontology engineering and search.

Wolfgang A. Halang, born 1951 in Essen, Germany, received a Doctorate in mathematics from Ruhr-Universität Bochum in 1976, and a second one in computer science from Universität Dortmund in 1980. He worked both in industry (Coca-Cola GmbH and Bayer AG) and academia (University of Petroleum and Minerals, Saudi Arabia, and University of Illinois at Urbana-Champaign), before he was appointed to the chair of applications-oriented computing science and head of the Department of Computing Science at the University of Groningen in the Netherlands. Since 1992 he holds the chair of computer engineering in the Faculty of Electrical and Computer Engineering at Fernuniversität in Hagen, Germany, whose dean he was from 2002 to 2006. He was a visiting professor at the University of Maribor, Slovenia, 1997, and the University of Rome II in 1999. His research interests comprise all major areas of hard real-time computing with special emphasis on safety-related systems. He is the founder and was European editor-in-chief of the journal *Real-Time Systems*, member of the editorial boards of 4 further journals, co-director of the 1992 NATO Advanced Study Institute on Real-Time Computing, has authored 10 books and over 350 refereed book chapters, journal publications and conference contributions, has edited 16 books, holds 12 patents, has given some 80 guest lectures in more than 20 countries, and is active and held offices in various professional organisations and technical committees as well as involved in the programme committees of almost 200 conferences. Contact him at wolfgang.halang@fernuni-hagen.de

Konstanty Haniewicz (http://www.kie.ae.poznan.pl/members/khaniewicz) is a PhD student at Department of Information Systems at Poznan University of Economics, Poland. He received his MSc (with honors) from Poznan University of Economics. His areas of interest include Web services discovery and clustering, Semantic Web services markets and Business Process Management. He is an author or co-author of several conference papers, journal articles and two book chapters. His paper was awarded with "Best Paper Award" (ICIW 2007). He is involved in EU-funded project SUPER. In 2006 he spent three months working in SAP Research Centre in Dresden, Germany.

Carolina Suárez Hernán holds a Bachelor in Hispanic Philology from Madrid's Universidad Autónoma. She has been teaching since 2001 at SEk University and IE University in Segovia. She has taught diverse subjects in Journalism and Audiovisual Communication, such as Communication Theory, Spanish Grammar or Language; she has an ample experience in teaching Spanish as a Foreign Language and, besides teaching language, she teaches Composition and Writing Techniques. She has also taught diverse subjects on Spanish Literature.

Rui Jesus graduated in Systems and Informatics Engineer (1993), MSc in eCommerce (1998), currently is PhD student in Education, researching eLearning tools and learning effectiveness with higher education health students. He has worked at Texas Instruments, Portuguese Society of Innovation (SPI, S.A.), Escola Superior de Enfermagem do Porto, and currently is with the Centro de Investigação em Tecnologias da Saúde, IPSN, CESPU. He is also professor of research and programming subjects at Instituto Politécnico de Saúde do Norte. He is a (co-)author of more than 10 scientific publications with peer-review on national and international conferences, including a book: Comércio Electrónico – Conceitos e Aplicações (eCommerce – Concepts and Applications). His current research interests are in the domains of eLearning and Health.

Monika Kaczmarek (http://www.kie.ae.poznan.pl/members/mkaczmarek) is a PhD student at Department of Information Systems at Poznan University of Economics, Poland and at Macquarie University, Sydney, Australia. She received her M.Sc (Summa Cum Laude) from Poznan University of Economics. Her areas of interest include Web services interactions, Quality of Service and Semantic Business Process Management. She is an author or co-author of several conference papers, journal articles and three book chapters. She was involved in three EU projects: ASG, Knowledge Web and SUPER.

Paul Kidd is an engineer by training, but has spent the majority of his career working on the application of social sciences to technology design, and the development of interdisciplinary design methods. He has published many papers concerned with theories and concepts, as well as applications. Paul has also been involved with the development of technology implementation methods that integrate strategy, technology and organisational design. He has also participated in many research projects that have involved collaboration between social scientists and technologists. For the past 20 years Paul has worked as an independent researcher, writer and consultant, and has had a long running involvement with European Commission supported research programmes. He has also delivered consulting services to many businesses, both large and small, worldwide. He is regularly involved with government agencies, both national and international, in supporting the development, operation and review of various research programmes.

Stefan Klink studied computer science and electrical engineering at University of Kaiserslautern and received the German Diploma (Dipl.-Inform.) in 1998. Since then, he was working as a software engineer at Research Centre for Artificial Intelligence (DFKI GmbH) Kaiserslautern. From 2003 to 2005, Stefan Klink worked as a research scientist and in the research department for databases and information systems (DBIS) at the University of Trier. Within the SemIPort project, his focus lay in developing semantic-based browsing, intelligent information retrieval and visualisation approaches for the manifold awarded DBLP bibliography server. After finishing his Doctoral Thesis in Computer Science (Dr. rer. nat.) Stefan Klink has joint the Institute AIFB and is currently working within the INCOME2010 project where he is responsible for the matching and similarity module as well as for the interoperability and collaborative modeling of distributed business processes. Additionally, he is a lecturer at the Universität Karlsruhe (TH), at the University of Trier, and at the Universidad de La Laguna (Spain).

Konstantinos Kotis holds a BSc in Computation from the University of Manchester, UK and a PhD in Information Management from the Department of Information and Communication Systems Engineering, University of the Aegean, Greece. Currently, he is a senior researcher in the AI Lab of the Department of Information and Communication Systems Engineering, University of the Aegean, Greece. His research and published work concerns Ontology Engineering and Semantic Web. His published scientific work includes more than 25 peer reviewed published papers. He also serves as a member of program committees of international conferences and as a reviewer in international journals.

Zdeněk Kouba received his MSc. degree from Czech Technical University in Prague, Czech Republic in 1983. After graduation he started his research career in the General Computing Centre of the Czechoslovak Academy of Sciences. He received his PhD degree from Czech Technical University in Prague. Currently, he is an associate professor at the Department of Cybernetics at the Faculty of Electrical Engineering of Czech Technical University in Prague. He leads the Knowledge Based and Software Systems research group of the Gerstner laboratory of intelligent decision making and control at the same university. He reads lectures on decision support systems and information systems design. His research interests include formal design of software systems, knowledge management and semantic technologies. His team is involved in several national and international research projects.

Lefteris Koumakis is MSc Software Engineer at the Foundation for Research and Technology – Hellas (FORTH), Institute of Computer Science, Biomedical Informatics Laboratory. He received the BSc and MSc degrees in Computer Science from the University of Crete-Greece in 2001 and 2004 respectively. He is a PhD candidate at the Department of Production Engineering and Management, Technical University of Crete, Chania. His research interests focus in Web Services and Scientific Workflows, and on intelligent data-analysis and mining of clinical and genomics data. He has participated in various international and national R&D projects including, IRAIA, SAFE, WS-Talk, INFOBIOMED, ACGT, GEN2PHEN.

Petr Křemen received his MSc in 2005 from the Czech Technical University in the field of Technical Cybernetics. Currently, he is a research fellow and a PhD student in the Knowledge Based and Software Systems group at the Department of Cybernetics, Faculty of Electrical Engineering, Czech Technical University in Prague. His research topics include mainly semantic web, automated reasoning, description logics and ontologies, namely ontology querying (SPARQL-DL design and implementation in the Pellet reasoner for OWL), ontology design, inference support for creating semantic annotations (DNA tool) and versioning for OWL ontologies (OWLDiff tool). He has been contributing to the following EU projects: CiPHER, SevenPro and Netcarity.

Ruby Krishnaswamy is an architect for innovative services in the Middleware and Advanced Platforms Lab within Orange Labs in France. Her interests include operating systems and wide-area distributed systems. Prior to joining Orange Labs she has worked at Sun Microsystems and Chorus Systems.

Vladimir Kulyukin is an associate professor of computer science at Utah State University. He holds a PhD in computer science from the University of Chicago. His research focuses on assisted navigation solutions for people with visual impairments.

Erhan Kumas is project manager at Tiirk Telekom, Turkey, Previously, he worked on e-Govermnent Gateway Project and information security management systems installation at Ttlrksat, Turkey. Before Turksat, Mr Kumas, worked on ISO standards (9001 :2000, l4001:2005, 16949, 18001, 22000) and "CE marking" as a consultant for approximately 20 companies in the sectors, for instance; construction, mining, health, education, automotive As a lead auditor for ISO 27001:2005, which is about "Information Security Management Systems", Mr. Kumas has also certificate from Carnegie Mellon University about CMMI (Capability Maturity Model Integration). Currently pursuing a master degree on information security and risk management in Industrial Engineering faculty in Kinkkale University, he has approximately 10 publications about e-Government Concepts, Information Security and Risk Management.

Rita Kuo is an assistant professor at Ming Dao University in Taiwan. Rita Kuo received the BS and MS degrees in information and computer engineering and the Ph. D degree in electronic engineering from Chung-Yuan Christian University, Chung Li, Taiwan, R.O.C., in 2000, 2002, and 2007, respectively. She is now an assistant professor in the department of digital design, MingDao University, ChangHua, Taiwan, R.O.C. Her research interests include e-learning, adaptive test, cogitive theory, intelligent agent technology, and mobile learning. She currently is the publication chair of the 4th International Conference on E-Learning and Games (Edutainment 2009) and the editorial advisory board of the Handbook of Research on Learning Culture and Language via ICTs: Methods for Enhanced Instruction. She has participated in 4 international conferences as a Program Committee Member and has authored 29 book chapters, journal and international/national conference papers.

Lenka Landryová graduated MSc (1987) and concluded PhD dissertation (1992) from VSB - Technical University Ostrava, Czech Republic, in Control Systems of Technological Processes. During 1991 worked as a research worker on the project of Diagnostics of Mechanical Systems. 1992 - till now working as an associate professor at the Department of Control Systems and Instrumentation of the Mechanical Engineering Faculty at VŠB - Technical University of Ostrava. The research work focuses on supervisory control systems with knowledge based support. Certificates received within the National Centre of Distance Learning, Prague, CZ (No.2001/049)2001) for tutoring -organizing-administrating distance learning, and for the European Masters Degree in University Management and Administration (2001) awarded in collaboration with EU universities within the framework of the Tempus - Phare Programmme of the European Commission. From 2002-5 cooperating with AppTima, software development group, Ostrava. From 2005 till now working for ABB CZ Operation Centre in a software documentation team. Member of IFIP WG5.7.

Migle Laukyte is currently an University assistant in Legal Informatics in Law faculty, at Bologna University and 2nd year PhD student in Legal informatics and Computer law at CIRSFID (Bologna University). She gained her first Master degree in Legal Informatics at Mykolas Romeris University (Lituania), where she previously earned her bachelor degree in law. Her second Master degree was received in IT Law and Legal Informatics at Bologna University. She is also an author of several publications which were presented in international conferences, such as WCC-CAI 2008, PRO-VE'07, eChallenges2006, etc. Her research interests include artificial intelligence & law, software agents, intellectual property law, philosophy of computer science.

William F. Lawless is a professor of Mathematics and Psychology. He has a PhD in Social Psychology that was granted in 1992 from Virginia Tech, and a Masters Degree in Mechanical Engineering (LSU, 1977). He is a Professional Engineer with a rating in Nuclear Waste Management and he is a Senior member of IEEE. His research interests are in organizational theory, organizational performance and metrics, and in mathematical models of organizations. He has published over 30 articles and book chapters, over 95 peer-reviewed proceedings and abstracts, and over $1 million in research grants. He was a founding member of Department of Energy's Savannah River Site Citizens Advisory Board (1994-2000; 2003-2007) where he authored or coauthored over 100 sets of recommendations. He is also a past member of the European Trustnet hazardous decisions group.

Joanna Leng is a senior high performance computing and visualization expert. She has worked at the University of Manchester (UK) for 12 years where she has specialised in working collaboratively with users and potential users of visualization to help them explore and understand their data. This has involved working with many different application areas and computing environments, often resulting in cross-disciplinary collaborative papers. She contributed to 'The Visualization Handbook', co-authoring the chapter 'Visualization with AVS', published by Elsevier Inc in 2005. She has an interest in understanding the technological and sociological factors that affect use and transfer of visualization technologies. Recently she set up her own consultancy business called Visual Conclusions.

Awie Leonard was born in South Africa. He obtained the degrees BSc, majoring in Computer Science and Mathematics, in 1974 and BSc (Hons) in 1975, both at the Potchefstroom University for Christian Higher Education. He obtained the degree MSc Information Systems at the University of South Africa in 1981. Having spent a few years in the private sector as systems analyst and designer and project leader, he joined the Department of Informatics at the University of Pretoria as senior lecturer in 1992, where he also obtained the degree Dcom (Informatics) in 1998. He has been promoted to the level of associate professor in 2007. His research focus is on service management and he has published several articles and book chapters in this field.

Myriam Lewkowicz is associate professor at the Universite de Technologie de Troyes (UTT) **-** France. She has obtained the PhD degree in computer science. Her current fields of interest are: Distributed Collective Practices, Communities and Technologies, Groupware Evaluation, Knowledge Management and Collective Process Modeling. She regularly publishes and participates on international scientific conferences. She is part of several scientific committees of international scientific conferences in the field of CSCW. She is member of the ACM and IEEE association and board member of the GRACQ (French Association on Knowledge Engineering). She was member of the UTT team in the Virtual Research Laboratory for a Knowledge Community in Production a Network of Excellence financed by the European Commission in the context of the 6^{th} Framework Program (VRL-KCiP NoE, FP6-507487-2) that has become the EMIRAcle association in Europe.

Spiridon Likothanassis received the diploma degree in electrical engineering from the National Technical University, Athens, Greece, in 1980 and the Ph. D. degree in stochastic adaptive control from the Department of Computer Engineering and Informatics, University of Patras, Patras, Greece, in 1986. He is currently Professor and Director of the Pattern Recognition Laboratory, Department of Computer Engineering and Informatics, University of Patras. He is also member of the Managing Committee of the Artificial Intelligence Research Center, University of Patras and Senior Researcher of the Computer Technology Institute (C.T.I.), Patras, Greece. He has been Project Manager and Technical Manager in a number of R&D projects funded by the Greek Government (18) and the European Union (12). He is author of 12 book chapters and more than 175 research papers. His research interests include Intelligent Signal Processing and Control, Computational Intelligence (algorithms and systems and applications) and Intelligent Tutoring Systems.

Salvador Miranda Lima earned his MSc in Computer Science from the Universidade Nova de Lisboa (Portugal) in 1995 and is a candidate for a doctor's degree in Computer Science. He is a professor adjunto in the Escola Superior de Tecnologia e Gestão of the Instituto Politécnico de Viana do Castelo, having taught several disciplines in the area of Software Engineering, namely algorithms, data structure, programming languages and modeling. His interest areas lie in Software Engineering, Web Engineering, Semantic Web, Ontological Engineering, Semantic Technologies in Tourism and Social Sciences in the context of new technologies.

Jin Liu (PhD '89) had been worked in the Heinrich-Hertz-Institute Berlin, Germany as a scientist for ten years and more and has been involved in a number of national and international research projects related to 3D techniques for television and video communications, interactive multimedia services and advanced interactive user interfaces. She joint the T-Systems, a division of Deutsche Telekom in year 2001. Since then, she has been working there as a project manager and senior consultant in various R&D projects. Her current research work focuses on the Human-Machine Interaction, technologies related to Semantic Web and content annotation as well as modelling of domain knowledge. She is author of scientific books, a number of journal papers and inventor of patents.

Kim Man Lui received the bachelor's degree from Tamkang University, Taiwan, the master's degree from the University of Witwatersrand, Johannesburg, South Africa, and the doctoral degree from the Hong Kong Polytechnic University, Hong Kong. He has held a number of IT positions in the commercial sector in Hong Kong and China. With funding support provided by the City Government, he is involved in the set up of a software center that adopts agile development in China. His research interests include software engineering and emarketing. He is the lead author of CMM and SPI (Tsinghua University Press, Beijing, 2002), eXtreme Programming (Publishing House of Electronics Industry, Beijing, 2005), and Software Development Rhythms: Harmonizing Agile Practices for Synergy (John Wiley and Sons, 2008).

Rui Lopes graduated in Computer Science (2004), has a post-graduation on Computer Engineering (2005), and is an MSc (2006), by the University of Lisbon. He is currently doing a PhD in Computer Science on accessibility and Interaction Environments. He is a researcher of the LaSIGE Research Lab with more than five years of experience working within the HCIM Group. His research interests include Web Science, User Experience, Accessibility, Usability, and Interaction Environments modelling. He is a member of ACM SIGWEB, SIGACCESS, SIGCHI and SIGAPP, as well as an Invited Expert on the XProc Working Group of the World Wide Web Consortium (W3C).

Tariq Mahmoud studied Information Engineering at Al-Baath University (Syria) and is currently a research assistant at the working group of business information systems at the Carl von Ossietzky

University of Oldenburg (Germany). He is working on his PhD thesis at the Department of Computer Science in Oldenburg. His research work focuses on applying semantics on SOA-enabled ERP solutions, information security, and Semantic Web.

Vladimír Mařík received both the engineering and the PhD degrees in Control Engineering from the Czech Technical University in Prague, Czech Republic, in 1975 and 1979, respectively. In 1990 he was appointed a full professor of control engineering at the Czech Technical University where he founded the Gerstner Lab in 1996. In 1999, Vladimir Marik founded the Department of Cybernetics, which has been recognized as an EU Center of Excellence in 2000. He acts as the Head of this Department. Besides this, he helped to establish the Rockwell Automation Research Center Prague as a part of the Rockwell Automation Advanced Technology organization and he acts as its Managing Director since 1993. His main fields of interests are agent-based and multi-agent and holonic systems, planning and scheduling, and knowledge representation and management. He acts as the Editor-in-Chief of the IEEE Trans. on SMC, part C since 2005.

Kai-Pan Mark received his Master of Science degree in Information Engineering from The Chinese University of Hong Kong in 2007, Bachelor of Science degree with Upper Second Class Honours and Associate of Science degree with Distinction, both in Computer Studies, from City University of Hong Kong in 2005 and 2002 respectively. He is currently a local MPhil student in the Department of Information Systems, City University of Hong Kong. He is particularly interested in Information and Communications Technologies in Education. He is now serving as the Vice Chairman of IEEE Education Society Hong Kong Chapter.

Tina Marshall-Bradley is Special Assistant to the Provost and professor of education at Paine College in Augusta, Georgia. She is the former Dean of the School of Education at Claflin University and has also worked in the Office of Teacher Education, with the Division of Teacher Quality at the South Carolina State Department of Education. She is a graduate of the College of Charleston and completed her graduate studies at Iowa State University. She has held faculty and research posts at Benedict College, the Citadel, South Carolina State University, and Norfolk State University. She engages in research related to comparative education systems, education reform and information technology in education environments.

Ammar Memari studied Information Engineering at Al-Baath University (Syria) and is currently a research assistant at the working group of business information systems at the University of Oldenburg. He is working on his PhD thesis at the Department of Computer Science in Oldenburg. His research work focuses on adaptation and user modeling, multi-agent systems, and Semantic Web.

Tolga Medeni is working with Tiirksat as an analyst and software engineer. Also he is a part time instructor in Baskent University in Knowledge Management Department. Before Turksat he worked in Sirius Consulting company. Mr. Medeni started his academic career in Ankara University as a research assistant in Computer Engineering. Recently he eamed his MSc degree from Computer Engineering Department, Cankaya University. Also he is holding two Bachelor degrees from ~ Computer Engineering and Management from the same university. He graduated from Business and Administrative Sciences Faculty as in the first place in 2004. His interest areas are software, business processes analysis and design, knowledge science.

Tunc Medeni works as an expert in e—Government Corporate Communication Directory at Tiirksat. He has also been affiliated with Japan Advanced Institute of Science and Technology (JAIST), Japan, and Baskent University, Turkey as a PhD candidate and part-time staff His academic and professional work has been in the fields of knowledge management, knowledge economy and society, currently focusing on e-govemment initiatives, and knowledge mapping as well as practitioner leaming, edutainment, technical communication and cross—cultural management. Mr. Medeni has contributed to various (close to 50 in number) conference presentations, book chapters andjoumal articles in his interest areas. He has been awarded scholarships and fundings from Nakayama Hayao Foundation, JAIST, Japanese State (Mombukagakusho), in Japan, Lancaster University in U.K., and Bilkent University in Turkey for his education, and research activities.

Almudena Moreno Mingués took a PhD in Sociology from the Universitat Autònoma de Barcelona in 2004 and is professor in sociology at the University of Valladolid. She specialised in family issues, welfare state, public policy and comparative research on gender. She has been visiting researcher at the universities of Oxford (United Kingdom), McGill (Canada), Göteborg (Sweden), Stirling (United Kingdom), Turin (Italy) and Chicago (EE.UU). Currently she is taking part in two European projects on equality policies on gender and youth. She is also a member in AREA, where she is developing her work as researcher in different European projects. Her research work has been recognized with the International Award for Young Sociologists, given by the International Sociological Association in 1998; an award of research given by the Fundación Acción Familiar, in 2004 and the extraordinary award of PhD in 2006.

Gila Molcho has obtained the PhD degree in Industrial Engineering and Management and she joins the research team of the Department of Mechanical Engineering, Technion Israel Institute of Technology in Haifa. Her current fields of interest are: the holistic product and services life cycle approach and its influence on modern manufacturing paradigm; intelligent management of product lifecycle knowledge with industrial applications; incorporating business process models with JIT knowledge management capabilities. She was member of the Technion team (and member of the Integrative Management Team) in the Virtual Research Laboratory for a Knowledge Community in Production a Network of Excellence financed by the European Commission in the context of the 6^{th} Framework Program (VRL-KCiP NoE, FP6-507487-2) that has become the EMIRAcle association in Europe.

Fernando Moreira graduated in Computer Science (1992), MSc in Electronic Engineering (1997) and PhD in Electronic Engineering (2003), both at the Faculdade de Engenharia da Universidade do Porto. He is a member of the Dep. Informatics at Universidade Portucalense since 1992, currently as Assistant Professor. He is a (co-)author of more than 10 scientific publications with peer-review on national and international conferences. He has already regularly serves as a member of the Programme and Organizing Committees of national and international workshops and conferences, namely CAPSI, ISEIS, CISTI and CISCI. He conducts his research activities in Communication Networks, Quality of Services, eLearning and mLearning. He is the coordinator of the 3-year degree of Informatics – Software Engineering and the MSc of Informatics. He is associated with NSTICC, ACM and IEEE.

José Moreira received his PhD in Computer Science and Networks from the École Nationale Supérieure des Télécommunications de Paris (France) and the Faculdade de Engenharia da Universidade do

Porto (Portugal) in 2001. He is currently an Invited Assistant Professor at the Department of Electronics, Telecommunications and Informatics of the Universidade de Aveiro and a researcher at IEETA, a non-profit R&D institute affiliated to the same university. His background includes programming languages, data structures and databases. His main research interests cover spatiotemporal database systems and Geographical Information Systems. He is also interested on web semantics and text mining.

Rafael Moreno-Sanchez has a bachelor degree in forestry from the Chapingo Autonomous University in Mexico. He received his PhD in Natural Resources Administration from Colorado State University in the USA. He has research, teaching and administrative experience including: Researcher for the National Institute for Forest, Livestock, and Agriculture Research (INIFAP) in Mexico; Director of the National Center for Disciplinary Research in Conservation and Improvement of Forest Ecosystems INIFAP (Mexico); Post Doctoral Fellow with the Organization of American States—SEMARNAP in collaboration with the University of Western Ontario (Canada). He has twelve years of experience as a fulltime professor teaching natural resources management, sustainable development, and geographic information science and technology including Web-Geographic Information Systems. He is currently teaching and doing research in the Department of Geography and Environmental Sciences at the University of Colorado Denver.

Vassilis Moustakis is an associate professor at the Department of Production Engineering and Management, Technical University of Crete (TUC), Chania, Greece, Director of the Management Systems Laboratory at TUC (www.logistics.tuc.gr) and Affiliated Research Scientist at the Institute of Computer Science, Foundation for Research and Technology – Hellas (FORTH), Heraklion, Greece (www.ics.forth.gr). Dr. Moustakis specializes in management and data mining. He has authored numerous articles, has consulted companies and government agencies in Europe and the USA, and managed numerous R&D projects in information and knowledge based systems. He holds a DSc in Engineering from the George Washington University and a Diploma in Mechanical Engineering from the University of Patras, Greece. Vassilis can be reached at: moustaki@dpem.tuc.gr

Pollyana Notargiacomo Mustaro obtained her PhD in Education (Universidade de São Paulo, 2003), specializing in Internet hackers' Knowledge Building Process. Nowadays, she is a teacher at Universidade Presbiteriana Mackenzie (São Paulo, Brazil). Her research areas include Learning Objects Theory, Learning Styles, Instructional Design, Distance Learning, Social Network Analysis, Hypertext Theory, Game Culture Studies and Knowledge Representation.

Miklos Nagy is part-time PhD student at the Open University's Knowledge Media Institute. His research interests are Uncertain Reasoning, Ontology Mapping, Multi-agent systems and Information Integration using Semantic Web Technologies. His current research focuses on the development of intelligent multi agent systems that can exploit the emerging Semantic Web's large-scale data. Miklos Nagy received his MSc in Information Engineering from the University of Miskolc, Hungary.

Thavandren Ramsamy Naidoo obtained a Bachelor of Commerce from the University of Natal Durban in 1992, a Honours degree in Business Management from the University of South Africa in 1996, a Honours in Information Systems in 1999 as well as a Masters degree in Information Systems from the University of Witwatersrand, in 2003. He completed his PhD in Information Technology in 2008. His main research focus is Self-service technologies.

Leandro Pupo Natale defended his Masters' thesis in the use of the Ontological Database and citizens' social networks analysis of electronic government systems in February 2008, in Universidade Presbiteriana Mackenzie (São Paulo, Brazil). He is currently a teacher at Impacta Tecnologia and develops the role of systems' analyst at UOL (Universo Online). His research areas include Representation, Extraction and Knowledge Manipulation through Ontological Database and Semantics Search, Applications and Software Architectures for e-gov and Social Network Analysis.

Ismael Navas-Delgado became a Member of the University of Málaga in 2002. He was born in 21st November 1977 in Málaga, studied Computer Science at the University of Málaga and is member of this University since the end of his degree. Ismael has got a lot of publications in the topic of Bioinformatics, Semantic Web and Data Bases.

João Negreiros received his PhD degree from ISEGI-New University of Lisbon, Portugal, in 2004. For several years, he taught several computers matters at ISIG, ISEGI-UNL, Lusófona and ISLA such as Operating Systems, Hypermedia and Information Systems. Currently, he is taking a Post-Doc in Web programming for geostaticians applications at Almeria University, Spain.

John Nicholson received a BS in Computer Science from Purdue University, and a MS in Computer Science from DePaul University. After working as an Internet consultant for a number of years, he returned to school in 2003 as a PhD student at Utah State University where he currently researches assistive technology for the visually impaired.

Martín López Nores was born in Pontevedra, Spain in 1980. He is an assistant professor in the Department of Telematics Engineering at the University of Vigo, and a member of the Interactive Digital Television Laboratory. He received the Telecommunications Engineering Degree from the University of Vigo in 2003, and his PhD degree in Computer Science from the same University in 2006. His major research interests are the design and development of interactive services for personalized advertising material for Digital TV.

Marek Obitko received the Master's degree in Computer Science in 2000 and the PhD degree in Artificial Intelligence and Biocybernetics in 2007, both from the Czech Technical University in Prague, Czech Republic. His research interests include knowledge representation and knowledge management, ontologies, semantic web technologies, search, and distributed systems, all with the focus on applications in industrial systems. Since 2000 he is working in Rockwell Automation Research Center in Prague, at first in the area of higher level description of automated systems and its use for Human-Machine Interface and later in the area of structural and semantic search and applying semantics to agent-based industrial control systems.

Bolanle A. Olaniran (Ph. D) is a professor in the Department of Communication Studies at Texas Tech University. His research includes: Communication technologies and Computer-Mediated Communication, Organization communication, Cross-cultural communication, and Crisis Management and Communication. He has authored several articles in discipline focus and interdisciplinary focus Journals (i.e., Regional, National, and International) and edited book chapters in each of these areas. He has served as consultant to organizations at local, national and government level. His works have gained recognition such as the American Communication Association's "Outstanding Scholarship in Communication field," Who is who among College Teachers. He is also the recipient of TTU 2006 Office of the President's Diversity, 2007 President's Excellence in Teaching Awards and nominated for 2007 TTU Chancellor's Distinguished Teaching Award. His recent international invited lecture was a lecture series in Knowledge Learning, Information & Technology (KLIT) Workshop organized by Taiwan Normal University and the National Christian University in Taiwan.

María-Dolores Olvera-Lobo is an associate professor of the Library and Information Science Department in the Faculty of Communication and Information Science, and in the Faculty of Translation and Interpreting at the University of Granada. She is a member of the Grupo SCImago, Associated Unit of Consejo Superior de Investigaciones Científicas, Madrid, Spain. PhD in Documentation, she has interest in New Trends in Information Retrieval and Natural Language Processing. She is involved in several research projects and is the author of books and scholarly articles.

Ercan Oztemel was born in Turkey in 1962. He was graduated from Istanbul Technical University and had a master degree from Bosphorous University in Istanbul. He received his Ph.D degree from the university of Wales College of Cardiff in UK. His PhD study was also supported by SERC (Science and Engineering Research Council of UK) and a company called Seal Technology Systems (STS) in Cardiff/UK. He is the co author of the book called "intelligent quality systems" published by Springer Verlag. Currently he is doing active research in Marmara Research Center of Turkish Science and Technology Research Council and also teaches artificial intelligence and intelligent manufacturing related topics as well as traditional ones in Marmara University. His main areas of interest include artificial intelligence, simulation and modelling, knowledge based systems, strategic planning, quality engineering, decision support systems etc. He has being doing research in these areas and participates several international projects, already completed 8 big scale projects along this line. Currently he is running four international and one national projects. He has been also actively involved in NATO studies as well taking part in 2 projects. He has many publications (including 3 books) in his areas of interest. He is married with 4 children.

Marco Painho received his PhD degree from University of Santa Barbara, USA, in 1992. At present, he is the president of ISEGI-UNL. His main lines of investigation include Geographical Information Systems (GIS), Spatial Decision Support Systems and E-learning. Author of several Portuguese and international publications, he is also a peer-review of main GIS journals and magazines all over the world.

Andreas Papasalouros is a lecturer at the Mathematics Department, University of the Aegean, Greece. He holds a PhD in Electrical and Computer Engineering from the National Technical University of Athens. His research interests include e-Learning, hypermedia design and web engineering. He has a degree in Physics from the University of Athens and a degree in Electrical and Computer Engineering from the National Technical University of Athens. He has participated in several research and development European and national projects and is a co-author of a number of articles published in scientific journals and conference proceedings.

José Juan Pazos Arias was born in Bayona, Spain in 1964. He received his degree in Telecommunications Engineering from the Polytechnic University of Madrid in 1987, and his PhD degree in Computer Science from the Department of Telematics Engineering at the same University in 1995. He is the director of the Interactive Digital Television Laboratory in the University of Vigo, which is currently involved with projects on middleware and personalization applications for Interactive Digital TV, receiving funds from both public institutions and industry.

Agostino Poggi is full professor of Computer Engineering at the Faculty of Engineering of the University of Parma. He coordinates the Agent and Object Technology Lab and his research focuses on agent and object-oriented technologies and their use to develop distributed and complex systems. He is author of more than a hundred of technical papers in refereed journals and conferences and his scientific contribution has been recognized through the "System Research Foundation Outstanding Scholarly Contribution Award" and the "System Innovation Award". Moreover, he is in the editorial board of the following scientific journals: Software Practice & Experience, International Journal of Hybrid Intelligent Systems, International Journal of Agent-Oriented Software Engineering, International Journal of Multiagent and Grid Systems e International Journal of Software Architecture.

George Potamias holds a principal researcher position at FORTH's Institute of Computer Science. For a number of years he was adjunct professor at the Dept. of Computer Science, University of Crete, Greece. He has been working in the field of machine learning and data-mining for over 15 years, with a number of publications to his credit. His current R&D interests focus on semantic Grid-enabled integration of multi-level biomedical information, Web Services and Scientific Workflows, and on intelligent data-analysis and mining related biomedical data and information sources. Dr. Potamias, has contributed to several R&D projects including, INFOBIOMED, ACGT, LOCCANDIA, GEN2PHEN and ACTION-Grid. He is an affiliate member of IEEE.

Goran. D. Putnik received his DiplEng, MSci and DrSci from Belgrade University, both MSci and DrSci in the area of intelligent manufacturing systems (IMS). His current position is aggregated professor, Department of Production and Systems Engineering, University of Minho, Portugal. He served as director of the Centre for Production Systems Engineering (CESP) and as director of the Master and Postgraduate Course on CIM. His scientific and engineering interests are production systems and enterprises design and control theory and implementations, design theory, design engineering, information systems management, formal theory of production systems and enterprises, and distributed, agile and virtual enterprises, and supervises a number of PhD projects as well. He serves as a reviewer and a member of editorial boards for several international journals.

Miloslav Radakovič received the engineering degree in Automation with specialization in robotics and discrete processes from Slovak University of Technology in Bratislava, in 2006. He is currently a PhD student at the Department of Cybernetics of the Faculty of Electrical Engineering, Czech Technical University in Prague, in the study branch Artificial Intelligence and Biocybernetics, and he is working in the Rockwell Automation Research Center Prague focusing on the influence of semantics and ontologies, and their impact on distributed industrial control systems based on multi-agent technologies. His main research interests are focused on distributed control, holonic systems, multi-agent systems and its application in the manufacturing area, artificial life, and semantics and ontologies.

Manuel Ramos-Cabrer was born in Lugo, Spain in 1966. He received his degree in Telecommunications Engineering from Polytechnic University of Madrid, Spain in 1991, and his PhD degree in Telematics from the University of Vigo, Spain in 2000. Since 2001, he is an associate professor in Telematics Engineering at the University of Vigo. His research topics are Interactive Digital TV concentrating on recommender systems, integration with smart home environments and interactive applications design and development.

Symeon Retalis is associate professor at the Department of Technology Education & Digital Systems, University of Piraeus. He holds a diploma of Electrical and Computer Engineer from the Department of Electrical and Computer Engineering studies, National Technical University of Athens, Greece, an MSc degree in Information Technology-Knowledge Based Systems from the Department of Artificial Intelligence, University of Edinburgh, Scotland, and a PhD diploma from the Department of Electrical and Computer Engineering, National Technical University of Athens, Greece. His research interests lie on the development of web-based learning systems, design of adaptive hypermedia systems, web engineering, and human computer interaction. He has coordinates and participated in various European R & D projects such as WEENET, MAUSE, TELL, ELEN, UNIVERSAL, etc. He serves in the editorial board of international journals such as Computers in Human Behavior, IEEE Journal of Educational Technology and Society, ACM Computing Reviews, Journal of Information Technology Education. He participates to the ACM Web Engineering special interest group, to the CEN/ISSS learning technologies workshop. He is also director of the CoSy LLab (Computer Supported Learning Engineering Laboratory)[http://cosy.ted.unipi.gr]. His publication list contains more than 70 items.

Régis Riveret is currently a research Assistant in the Department of Computer Science at the University of Aberdeen (Scotland). He has got his Phd in Computer Science & Law from the Bologna University after being graduated in Physics from University of Caen and a degree in Telecomunication Engineering from the Grande École Telecom Bretagne (France). His fields of research include Artificial Intelligence & Law and Multi-Agent Systems, and in particular formal models of the interactions between normative systems and cognitive agents. This involves the development of defeasible formalisms for the integration of normative notions in agents' epistemic and practical reasoning.

Antonio J. Roa-Valverde became a member of the University of Málaga in 2007. He was born in 28st April 1984 in Puente Genil (Córdoba), studied Computer Science at the University of Málaga and is member of this University since the end of his degree. During this time he has been working in SOA, EAI and Semantic Web Services.

Alessandro Rocchi, contract professor of Fundamentals of Legal informatics, Law Faculty, Bologna University; university assistant in Legal Informatics, Law faculty, Bologna University; scientific collaborator at CIRSFID for the European project research area. Former Business Lawyer at PRAMAC S.p.A. (ITA) and Grant Researcher at Chamber of Commerce of Florence, on the legal aspects of business registry. Master in Legal informatics and Computer law; Master in Business Law; holder of PhD grant in Legal Informatics; degree in Law *cum laude*, Pisa University; university assistant in Civil Proceeding Law at University of Pisa. Author of several national and international publications.

José Paulo Oliveira Santos received his DiplEng of Electronics and Telecommunications of University of Aveiro, the MSci of University of Coimbra in Information systems, branch of Computer Data Networks and the DrSci from University of Aveiro in Automation /Industrial Informatics. Is currently professor at Mechanical Department of University of Aveiro. He is responsible for the CIM laboratory, teaches several classes related with automation, Industrial Informatics, Integrated Production Systems.

Jens Schumacher, JSch (Dr.-Ing., Production Technologies), is a research professor at the University of Applied Sciences Vorarlberg where one of his research focus is the support of innovation through new technologies and methodologies. He is the founder and manager of the Living Lab Vorarlberg and co-editor of the book "European Living Labs - a New Approach for Human Centric Innovation". He is one of the founding members of the European Network of Living Labs and is involved in several European projects that support the development of this network. As such he is active in various EU projects that deal with the development and support of innovation in Living Labs: (eten Programme) Tell-Me – "TransEuropean Living Labs for an iMproved E-participation" (EP# 046319); (Competitive and Innovation Programme) CO-LLABS – "Community-Based Living labs to Enhance SMEs Innovation in Europe" (EP# 224979); (Sixth Framework Programme) CoreLabs – "Co-Creative Living Labs" (EP# 35065); (Competitive and Innovation Programme) Den4Dek – "Digital Ecosystems Network of regions for (4) DissEmination and Knowledge Deployment" (EP# 224976).

Wes Sharrock is professor of Sociology at the University of Manchester (UK) where he has been since 1965. His main interests are in issues in the philosophy of social science, social theory and method, and studies of work. He has authored and co-authored books and papers in these areas. Amongst the most recent publications are *Theory and Methods in Sociology,* Palgrave Macmillan, 2007, (with J. A. Hughes), *Brain, Mind and Human Behaviour in Contemporary Cognitive Science*, Edwin Mellen Press, 2007 (with J. Coulter) and *There is No Such Thing as Social Science,* Ashgate, 2008 (with R. Read and P. Hutchinson).

Alberto Manuel Rodrigues da Silva is professor of Information Systems at the Computer and Information Systems Department at the Technical University of Lisbon (Instituto Superior Técnico - IST/UTL) Lisboa, Portugal. He is also a senior researcher at INESC-ID Lisboa, and a partner at the SIQuant – Engenharia do Território e Sistemas de Informação company. He has professional and research interests in the following areas: Modeling and Metamodeling, MDE (Model driven Engineering), RE (Requirement Engineering), Enterprise knowledge-based platforms, and CSCW and CASE Tools. Complementary, he has also interests in Enterprise Architectures, Software Project Management, Geographic Information Systems, and Social Networks. He is author or co-author of 3 technical books and more than 140 peer-reviewed scientific communications, and he has served on the program committees of several international conferences and workshops in different areas of computer science. He is member of the ACM and the Portuguese Ordem dos Engenheiros.

Joaquim Pereira da Silva is currently an assistant professor in the School of Management at the Polytechnic Institute of Cávado and Ave, Portugal. He holds a Dipl. Eng. in the field of Systems and Informatics Engineering and an MSci in the field of Virtual Enterprises, both from the University of Minho. He teaches in the domain of Software Engineering and Enterprise Information Systems, and his scientific interests are information and communication technologies, virtual enterprises, and systems interoperability.

Ismar Frango Silveira defended his PhD thesis in Distributed Objects applied to Virtual Reality-based Learning Environments in May 2003, at Universidade de São Paulo, Brazil. Currently, he is involved with research in Semantics applied to e-Gov, Game-based Learning and Adaptive Learning Objects. He presently teaches at Universidade Presbiteriana Mackenzie and Universidade Cruzeiro do Sul, both in São Paulo, Brazil.

Donald Sofge co-leads the Natural Computation Group within the Navy Center for Applied Research in Artificial Intelligence (NCARAI) at the United States Naval Research Laboratory (NRL), and has 20 years of experience in applying computational intelligence to real-world systems. He is an acknowledged expert in several scientific disciplines including robotics, machine learning, quantum computing, artificial intelligence, and control systems. He has served as technical panel reviewer for NSF, NASA, and DARPA, and has served as an area expert for new technology evaluation for DARPA and ONR. He has served as peer reviewer for several journals in robotics and computational intelligence, as well as numerous conferences, symposia, and workshops in these and other related areas. He has over 40 peer reviewed technical publications. Educational background includes B.S. in Computer Science, MSEE, currently pursuing PhD in Evolutionary Computation.

Alberto Gil Solla was born in Domayo, Spain in 1968. He is an associate professor in the Department of Telematics Engineering at the University of Vigo, and a member of the Interactive Digital Television Laboratory. He received the PhD degree in Computer Science from the same University in 2000. Nowadays, he is involved with different aspects of middleware design and interactive multimedia services.

Gabriella Spinelli (PhD) is a Senior Lecturer in Information System Management and Deputy Head of School responsible for the Teaching, Learning and the Accreditations of Brunel Business School, West London, UK. Her research interests include User-centred designed systems, Usability, e-government and Information Systems Management and Evaluation, and have attracted external funds from the Engineering and Physical Sciences Research Council (EPSRC), the National Police Improvements Agency (NPIA) and the Department of Trade and Industry (DTI). Prior to her academic career Gabriella has worked on the design and evaluation of interactive systems for Eastman Kodak Usability lab (NY), at Domus Academy (Milan, Italy) and acted as consultant for the Appliance Studio (UK).

Mladen Stanojević is a Senior Researcher at the Mihailo Pupin Institute. He received his MSc degree in the field of belief revision/truth maintenance and PhD in the area of natural language processing, both from the University of Belgrade. He has been working on applying techniques from artificial intelligence and natural language processing in real-world decision support systems, intelligent web applications, complex business web applications, etc. His research interests include semantic knowledge representation and processing techniques, natural language processing techniques, information retrieval, data mining, machine learning, semantic web, web services, expert systems, decision support systems, multicriteria analysis algorithms, etc. In these areas he published over 80 scientific papers. He is a member of IEEE.

Esra Kurt Tekez was born in Turkey in 1974. She was graduated from Istanbul Technical University and had a master degree from Sakarya University. She also received her Ph.D degree from the same university. She has done her PhD on multi agent systems and developed a general framework and a reference model for intelligent integrated manufacturing system so called REMIMS. She especially developed knowledge protocols allowing the agents to exchange their knowledge as much effectively as possible. She is currently working at Sakarya University as an assistant professor. Her areas of interest include intelligent manufacturing systems, strategy and knowledge management, total quality control, supply chain management and lean production systems.

Hui Lien Tung is an assistant professor of Mathematics and Computer Science at Paine College. She has a Masters Degree in Information Science (State University of New York-Albany, 2000) and a Masters Degree in Education (National-Louis University, IL, 1990). Her research interests are in MIS, metrics of organizational information systems and performance, e-Government, Systems Analysis and Design and database. She has published several Journal articles, book chapters and peer-reviewed proceedings.

Paola Turci is currently a contract researcher at the Department of Information Engineering of the University of Parma. Her primary research activities are in the areas of multi-agent systems, knowledge management, software engineering and business process management. She has worked both on the design and development of agent applications employing object-oriented technologies and languages. Since 2001 she has been involving both in national and international projects concerning industrial exploitation of agent technology and of knowledge management techniques in the internet, network management and enterprise application integration fields. She is author of about forty technical papers in refereed journals and conferences.

Konstantinos Tzonas obtained a diploma in Information and Communication Systems Engineering in 2006, and is now working towards the Master's degree in Technologies and Management of Information and Communication Systems at the University of the Aegean in 2008. His research interests include Semantic Web technologies, peer-to-peer systems and Web Services.

Dimitrios Tzovaras is a senior researcher (Grade B') in the Informatics and Telematics Institute. He received the Diploma in Electrical Engineering and the PhD in 2D and 3D Image Compression from Aristotle University of Thessaloniki, Greece in 1992 and 1997, respectively. Prior to his current position, he was a leading researcher on 3D Imaging at the Aristotle University of Thessaloniki. His main research interests include knowledge management, multimodal interfaces, virtual reality, 3D content-based search and retrieval, multimedia knowledge extraction, and biometrics in security. His involvement with those research areas has led to the co-authoring of over 40 articles in refereed journals and more than 120 papers in international conferences. He has served as a regular reviewer for a number of international journals and conferences. Since 1992, Dr Tzovaras has been involved in more than 40 projects, funded by the EC and the Greek Ministry of Research and Technology. He is the coordinator of the FP6 IST projects HUMABIO, Good Route, VICTORY, ACTIBIO and the FP7 ICT project ACCESSIBLE.

Karthikeyan Umapathy is currently working as assistant professor of Information Systems at the School of Computing, University of North Florida. He received his PhD in Information Sciences and Technology from the Pennsylvania State University. His research interests are interoperability among information systems, service-oriented computing, web services, systems integration, and IT standardization. His research works are published in various conferences such as Americas Conference on

Information Systems (AMCIS), Conceptual Modeling (ER), Hawaii International Conference on System Sciences (HICSS), International Conference on Web Services (ICWS), Service Computing Conference (SCC), and Workshop on Information Technologies and Systems (WITS); and journals such as European Journal of Information Systems (EJIS), Information Systems Frontier (ISF), and Journal of Computing and Information Science in Engineering (JCISE).

Alexandros Valarakos is currently a PhD candidate at the Department of Information and Communication Systems Engineering, University of the Aegean, Greece, and Research Fellow at the Software and Knowledge Engineering Laboratory of the Institute of Informatics and Telecommunications at NCSR "Demokritos". He graduated in Mathematics (2000) from the University of the Aegean and received his MSc in Artificial Intelligence (2001) from the University of Edinburgh, UK. His research interests orbit around: Ontology Engineering, Ontology Learning, Knowledge Acquisition, Semantic Interoperability, Web Content Analysis, Machine Learning, Knowledge-based Systems and BioMedical Informatics.

Maria Vargas-Vera is a lecturer in Computing at the Open University, England UK. Dr Vargas-Vera obtained her PhD from the Artificial Intelligence Department at Edinburgh University in 1995. Her current research focuses on Automatic Construction of Ontologies from Text, Ontology Mapping and E-Learning Applications using Semantic Web Technologies. Dr Vargas-Vera has published research papers in international conferences and journals and she is also a member of program committees of international conferences and workshops. Dr Vargas-Vera is an Associated Editor of the Revista Iberoamericana "Computacion y Sistemas" and the "International Journal of Knowledge and Learning (IJKL)".

Kam Hou Vat is currently a lecturer in the Department of Computer and Information Science, under the Faculty of Science and Technology, at the University of Macau, Macau SAR, China. His current research interests include learner-centered design with constructivism in Software Engineering education, architected applications developments for Internet software systems, information systems for learning organization, information technology for knowledge synthesis, and collaborative technologies for electronic organizations.

Konstantinos Votis was born in Ioannina, Greece, in 1978. He received the Dipl. Eng. degree in Computer Engineering and Informatics (2002) and the MSc in Computer Science and Engineering (2004) from the Department of Computer Engineering and Informatics of the University of Patras, Greece. He also received an MBA from the Department of Business Administration, University of Patras (2007). He is now a PhD candidate at the Pattern Recognition Laboratory of Department of Computer Engineering and Informatics, University of Patras. His research is related with Service Oriented Architecture in public administration, Semantic Web, Computational and Artificial Intelligence and Intelligent Agents applications in the fields of enterprise and industrial integration, health, e-learning, digital culture and information retrieval in the WWW. He has authored numerous technical publications for international journals and international conferences and events. Since 2001, Mr. Votis has been involved in many projects, funded by the EC and the Greek Ministry of Research and Technology.

George A. Vouros (BSc, PhD) holds a BSc in Mathematics, and a PhD in Artificial Intelligence all from the University of Athens, Greece. Currently he is Professor and Dean of the School of Sciences, University of the Aegean, Greece, Director of the MSc Program on Information and Communication Technologies and President of the Hellenic Society of Artificial Intelligence. He has done research in the areas of Expert Systems, Knowledge management, Ontologies, and Agents. His published scientific work includes more than one hundred book chapters, journal and national and international conference papers. He has served as program chair and chair and member of organizing committees of national and international conferences on related topics

Sanja Vranes, PhD, is jointly appointed as a Scientific Director of the Mihailo Pupin Institute and as a Professor of Computer Science at the University of Belgrade. She is in charge for Fraunhofer-Pupin Joint Project Office, established in 2003. From 1999 she has also been engaged as a United Nations Expert for information technologies. She received Dipl. Eng. Degree in Electrical Engineering and MSc and PhD in Computer Science all from the University of Belgrade. Her research interests include semantic web, intelligent agents, decision support systems, multicriteria analysis algorithms, etc. In these areas she published over 140 scientific papers. Currently, she coordinates one EC Sixth Framework project and serves as a team leader in two FP7 projects and two Interreg/CADSES projects. She is a member of IEEE, ACM and AAAI. She is a member of Serbian Academy of Engineering Science and National Science Council.

Pavel Vrba received his PhD degree in Cybernetics from the University of West Bohemia, Czech Republic in 2001. In 2000 he joined Rockwell Automation Research Center in Prague. Since September 2005 he is a lead of the Agent Technologies lab with research targets on: (i) the design and implementation of the agent-based manufacturing control solutions integrated with the classical PLC-based architectures, (ii) the agent-based simulation, (iii) application of semantics in agent-based industrial control solutions and (iv) the RFID technology. Dr. Pavel Vrba is an author or co-author of numerous conference papers, journal articles and book chapters related to his research area and co-author of seven pending/filed U.S. patents. He serves as a referee for many conferences (CEEMAS, HoloMAS, IEEE SMC, IFAC) and journals (IEEE Intelligent Systems, IEEE SMC Part C, IJMTM). He is a member of IEEE and member of Technical Committee on Industrial Agents within IEEE IES.

Xia Wang is a PhD candidate working at Digital Enterprise Research Institute (DERI), Galway, Ireland. She received her BEng degree from North-China Electric Power University in 1999, and her MEng degree in Computer Science from East-China Institute of Computer Technology, Shanghai in 2002. Her research interests span a range of aspects of knowledge represention and discovery, information retrieval and artificial intelligence. In particular, her work focuses on semantic web and semantic web services, web service qualities especially on security, ontology building and merging, and social networks. Contact her at xia.wang@deri.org

Stefan Hagen Weber is a researcher in the department "Learning Systems" at Siemens AG, Munich, Germany. In this capacity he is responsible for several Siemens AG work packages of the project THESEUS TEXO funded by the German Federal Ministry of Economy and Technology. His major research interests include collaborative filtering, multi-relational machine learning, data mining, social network analysis, Semantic Web and Web2.0. He filed several patents, including patents on collaborative learning algorithms for SPIT avoidance as well as multi-relational recommender systems. He graduated from Mannheim University in 1998 with an outstanding diploma in Business Informatics. The University of

Mannheim is one of the few institutes selected to be part of the initiative of excellence by the German Federal Ministry of Education and Research.

Christian A. Weiss received his PhD in 2006 from the Department of Communication Research and Phonetics at University of Bonn, Germany. He received a Master in Computational Linguistics from University of Heidelberg. Since 2008 he is working for Deutsche Telekom Laboratories. Previous he worked for T-Systems Enterprise Services GmbH, IBM European Speech Research as well as in a German Research Foundation granted project and was a DAAD/JSPS Fellow in 2005 at the Nagoya Institute of Technology, Japan. He is a member of GI and ISCA.

Peter Weiß is department manager and team leader in the research group Software Engineering at the Research Center for Information Technology (FZI) in Karlsruhe, Germany. He is a member of the research group of Prof. Dr. Wolffried Stucky at the Institute of Applied Informatics (AIFB) at the University of Karlsruhe (TH). Peter received his doctorate in Applied Informatics from the University of Karlsruhe (TH) in 2005. Prior to joining AIFB he was leading the International Relations Office at FZI. His educational and professional background includes a diploma degree in business engineering from the University of Karlsruhe (TH) (1999) and a certificate of apprenticeship as industrial clerk (1992) from a leading manufacturer of diesel engines and drive systems in Germany.

Joseph C. Wood is the chief of a research department at an Army Medical Center. He is a physician and is board certified in Internal Medicine, Endocrine, Diabetes and Metabolism. He has a PhD in Endocrinology that was granted in 1991 from the Medical College of Georgia, and a Doctor of Medicine from the George Washington University School of Medicine in 1995. He is an academic clinician and is on the teaching staff at his institution. His research interests are experimental therapeutics in bone and soft tissue wound healing, thyroid cancer and in organizational theory, organizational performance and metrics. He has published over 8 articles and book chapters, over 38 peer-reviewed proceedings and abstracts, and he has received about $750,000 in research grants. He is a fellow in the American College of Physicians and a Fellow in the American Association of Clinical Endocrinologists.

Yi Zhao received her BEng degree in Computer Software Engineering in 1995, and her MEng degree in Image Processing and Pattern Recognition in 1998 both from Northwestern Polytechnic University, Xi'an, China, and her PhD degree in Pattern Recognition and Intelligent System from Shanghai Jiaotong University in 2001. In the same year she moved to Germany, where she is working with the Chair of Computer Engineering at Fernuniversität in Hagen. Her research interests include semantic web mining, security in semantic web services, knowledge discovery and data mining. Contact her at yi.zhao@fernuni-hagen.de

Jianshen Zhou received her PhD from the Department of Electrical Engineering at the Technical University of Berlin in 1993. She has been working for Deutsche Telekom since 1996. During this time she has been involved in a number of projects in the areas of Advanced Voice Solutions and Semantic Web technologies. As developer, researcher and consultant she concentrates on Data Modelling, Database Specification & Implementation, Service Oriented Architecture and Semantic Web technologies including Semantic Web Services, Semantic Search, Free Question & Answering System and Information Retrieval.

Wagner Luiz Zucchi obtained his PhD in Electrical Engineering at Universidade de São Paulo in 1993. His field of research focuses in Computer Networks and its impacts on society and culture, with published works in information security, management and wireless networks. He presently teaches at Universidade de São Paulo and at Institute of Technological Research - IPT, both in São Paulo, Brazil.

Dominik Zyskowski (http://www.kie.ae.poznan.pl/members/dzyskowski) is a PhD student at Department of Information Systems at Poznan University of Economics, Poland. He received his M.Sc (with honors) from Poznan University of Economics. His areas of interest include Semantic Web services, Quality of Service and service e-marketplaces. He is an author or co-author of several conference papers, journal articles and three book chapters. His papers were awarded with “Best Paper Award” (ICIW 2007) and “Certificate of Merit” (IMECS 2008). He was involved in three EU projects (ASG, Knowledge Web, SUPER). In 2008 he was a visiting fellow in Asian Institute of Technology (Bangkok, Thailand). Dominik is a member of Services and Architectures Working Group of the Future Internet Assembly.

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