Semantic Web Application Areas

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Abstract. Currently, computers are changing from single, isolated devices into entry points to a worldwide network of information exchange and business transactions called the World Wide Web (WWW). However, the success of the WWW has made it increasingly difficult to find, access, present and maintain the information required by a wide variety of users. In response to this problem, many new research initiatives and commercial enterprises have been set up to enrich the available information with machine-processable semantics. This Semantic Web will provide intelligent access to heterogeneous, distributed information, enabling software products (agents) to mediate between user needs and the information sources available. In this paper we describe some areas for application of this new technology. We focus on ongoing work in the fields of knowledge management and electronic commerce. We also take a perspective on the semantic web-enabled web services which will help to bring the semantic web to its full potential

1. Introduction

The World Wide Web (WWW) has drastically changed the availability of electronically accessible information. The WWW currently contains some 3 billion static documents, which are accessed by over 300 million users internationally. However, this enormous amount of data has made it increasingly difficult to find, access, present and maintain the information required by a wide variety of users. This is because information content is presented primarily in natural language. Thus, a wide gap has emerged between the information available for tools aimed at addressing the problems above and the information maintained in human-readable form.

In response to this problem, many new research initiatives and commercial enterprises have been set up to enrich available information with machine-processable semantics. Such support is essential for "bringing the web to its full potential". Tim Berners-Lee, Director of the World Wide Web Consortium, referred to the future of the current WWW as the "*semantic web*" - an extended web of machine-readable information and automated services that extends far beyond current capabilities ([Berners-Lee et al., 2001], [Fensel & Musen, 2001]). The explicit representation of the semantics underlying data, programs, pages, and other web resources, will enable a knowledge-based web that provides a qualitatively new level of service. Automated services will improve in their capacity to assist uses in achieving their goals by "understanding" more of the content on the web and thus providing more accurate filtering, categorization and searching of information sources. This process will ultimately lead to an extremely knowledgeable system that features various specialized reasoning services. These services will support us in nearly all aspects of our daily life - making access to information as pervasive and necessary as access to electricity is today.

This paper does not focus on semantic web technology as such. For a detailed introduction to semantic web technology we refer the reader to [Broekstra et al., 2001], [Ding et al., to appear], [Fensel, 2001], [Fensel et al., 2002a], [Fensel et al., to appear (b)]. Instead it focuses on promising areas for application of semantic web technology. In Section 2, we discuss the application of semantic web technology to knowledge management. We describe the results of a leading IST project called Ontoknowledge[1] [Fensel et al., 2000], and sketch further improvements to this approach in a new IST project called SWAP. In Section 3, we discuss the application of semantic web technology to electronic commerce. Scalable electronic commerce has to overcome a number of obstacles: Ontology Mapping, Ontology Versioning, and massive Ontology Instantiation. In this section, we also discuss the emerging area of web service and outline Semantic Web enabled Web Services as a potential killer application of the new technology. Conclusions are provided in Section 4.

2. Knowledge Management

This section discusses one very promising application area of semantic web technology: knowledge management. We first describe a generic infrastructure developed in the Ontonknowledge project. Then we describe the approach of a recently started project called SWAP that tackles one of the serious bottlenecks of semantic web technology, the large scale generation and use of Ontologies.

2.1 Semantic Web Enabled Knowledge Management

Efficient knowledge management has been identified as key in maintaining the competitiveness of organizations. Traditional knowledge management is now facing new problems triggered by the web; information overload, inefficient keyword searching, heterogeneous information integration and geographically-distributed intranet problems, to name but a few. These problems will be tackled by the modern technology known as Semantic Web Technology ([Fensel, 2001] and [Fensel et al., 2002]). The Ontoknowledge[2] (OTK) project (cf. [Fensel et al., 2000]) is an important player devoting itself to finding content-driven knowledge management solutions through evolving ontologies. It employs the power of the Semantic Web Technology to facilitate knowledge management.

2.1.1 Tool Structure

On-To-Knowledge supports efficient and effective knowledge management by providing a tool environment powered by Semantic Web Technology. It focuses on *acquiring, maintaining and accessing* weakly structured information sources:

- *Acquiring*: Text mining and extraction techniques are applied to extract semantic information from textual information (i.e., to acquire information). Tool support includes ontology extraction from text (OntoExtract and OntoWrapper).
- *Maintaining:* RDF, XML and OIL are used for describing the syntax and semantics of semi-structured information sources. Tool support includes ontology editor (OntoEdit), and ontology storage and retrieval (Sesame), so as to enable automatic maintenance and view definitions of knowledge.

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[1] http://www.ontoknowledge.org/
[2] www.ontoknowledge.org

- *Accessing*: Push-services and agent technology support users in accessing the information. Tool support includes ontology-based information navigation and querying (RDF_{Ferret}), and ontology-based visualization of information (Spectacle).

In a nutshell, the complete layered tool environment of Ontoknowledge operates as follows (see Figure 1): OntoExtract and OntoWrapper extract unstructured and structured textual information sources from specified domains on the Internet or Intranet. The extracted information is pumped into the RDF-DB (Sesame), where it can be edited with the OntoEdit tool. Finally, the RQL (RDF querying language) reasoning engine allows for the querying of this database and delivers results to a user through RDF_{Ferret} which may be visualized by Spectacle.

2.1.2 Real-Life Applications

Several real-life applications have been conducted during the course of the OTK project to fulfil two requirements: to identify the real-life requirement for the design of the tools and another way around to secure the usability of the tools for tackling problems.

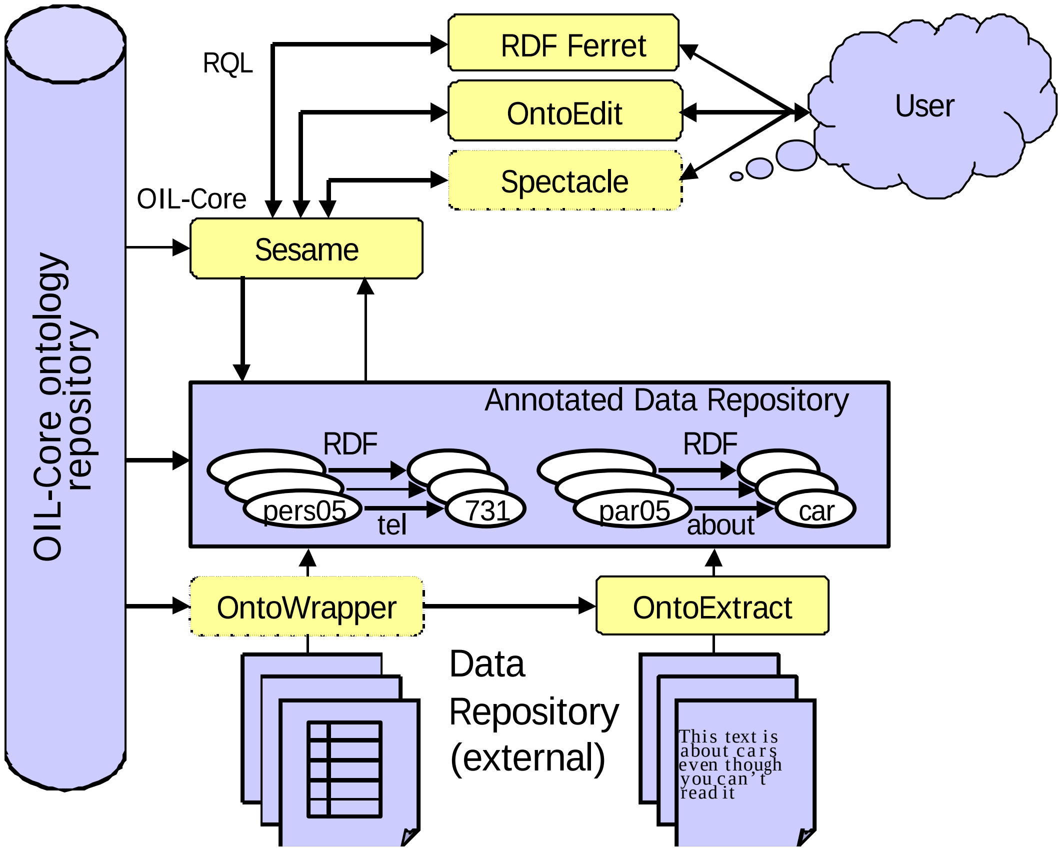

Figure 1. The layered tool environment of the OnToKnowledge

British Telecom Call Center: Call centers are the platform for companies to communicate with their customers and the market is growing by 20% each year, with millions being spent on improving customer relationships. Current call center technology lacks the support of the operator in solving incoming requests. The investment in call center technology can offer great rewards including better customer service, lower overheads, lower operational costs and increased staff profitability. In the BT case study, a system for supporting intranet-based virtual communities of practice is being developed, allowing the automatic sharing of information. The system, *OntoShare*, allows the storage of best practice information in an ontology and the automatic dissemination of new best practice information to relevant call center agents. In addition, call center agents can browse or search the ontology to find the information of most relevance to the problem they are dealing with at any given time. The ontology helps orientate new agents and acts as a store for key learnings and best practices accumulated through experience. It provides a sharable structure for the knowledge base and a common language for communication between call center agents.

Swiss Life Applications: Two of the case studies were carried out by Swiss Life. One of these approached the problem of finding relevant information in a very large document about the International Accounting Standard (IAS) on the Intranet. With the help of the ontology extraction tool, *OntoExtract*, an ontology was automatically learned from the document, which significantly supports a user in reformulating an initial query when it does not deliver the intended results. The second case study made by Swiss Life involves a skills management application that uses manually constructed ontologies about skills, job functions and education. This enables an employee to create in a simple way a personal home page on the company's Intranet that includes information about personal skills, job functions and education. Using the ontology allows a comparison of skills descriptions among employees and makes it possible to automatically extend a query with more general, or more specialized, or semantically associated concepts.

EnerSearch Applications: The case study made by EnerSearch AB focused on validating the industrial value of the project results with respect to the needs of a virtual organization. The main difficulty with the current website is that it is rather hard to find information on certain topics because the current search engine supports free text search rather than content-based information retrieval. To improve this, the whole website is annotated by concepts from an ontology which was developed using a semi-automatic extraction from the documents on the existing EnerSearch web site. The RDF_{Ferret} search engine is used to extend the free text search to a search of the annotations as well. Alternatively, with the Spectacle tool a user is able to get a search result arranged into a topic hierarchy.

2.2. Ontologies and P2P

The recently started IST project SWAP is about demonstrating that the power of Peer-to-Peer computing and the Semantic Web can actually be combined to support decentralized environments where participants can maintain individual views of the world, while sharing knowledge in ways such that administration efforts are low but knowledge sharing and finding is easy. Key to the success of combining Peer-to-Peer solutions with Semantic Web technologies is the use of *Emergent Semantics*. Emergent Semantics builds on lightweight and/or heavyweight ontologies that different individuals, departments or organizations have created. It considers the overlap between ontology definitions and the use of concepts and relations with actual data in order to extract shared ontologies for sets of individuals or groups of people. Intelligent tools will use such definitions to ensure that knowledge will be appropriately structured, so that it can be easily refound. Knowledge Management can occur in a distributed fashion without the overheads of central administration.

Tasks of SWAP will, in particular, account for four challenges that can be derived from some of the major differences between ontologies in a P2P environment and from ontologies in a centralized client-server environment, which is the usual setting in current applications, *viz.*:

- *Peer selection service*: In order to receive the right answers without flooding the peer network with queries, one must ask the "right" peers. Ontology-based peer selection mechanisms will exploit similarity of ontologies for this purpose.
- *Variation of ontologies*: Different peers will use different, though overlapping, ontologies. *Alignment, mapping* and *visualization tools* will have to cope with different ontologies, even though no alignments are explicitly specified. Some of the alignments and the mappings may be found by analysis of peer knowledge using methods in the just emerging field of *Emergent Semantics* (e.g. the same file categorized to different concepts indicates alignment). Another tool will scrape ontologies from legacy information (e.g. folder structures).
- *Lack of ontological precision*: Ontologies will be produced from various user interactions, like classifications into folders or usage of metadata. Ontology definitions will be imprecise and "sloppy" ontologies will be the norm rather than the exception. An inference engine for these ontologies must be able to ask and answer queries from peers in a robust, scalable and often locally contained manner.
- *Ontological drift*: In a P2P environment, one cannot expect *any* maintenance to happen to the ontologies (in fact, users will often not know what is in the ontologies on their machine). As a result, we must design mechanisms that allow the ontologies to update themselves, in order to cope with ontological drift. Based on the queries and answers elsewhere in the P2P network, ontologies will have to adjust their own definitions accordingly.

SWAP aims at resulting systems and experiences that can be seen as a giant leap towards the Semantic Web where both structure and content are truly distributed and (semi-) automatically administered. The research groups and companies in SWAP are pioneers in the research, development and commercialization of ontologies and semantic web solutions. They have all the capabilities needed to combine the Semantic Web and P2P – adding a distinctive dimension to efforts like Gnutella, Napster, or Jxta.

3. Electronic Commerce

Bringing Electronic Commerce to its full potential requires a *Peer-to-Peer (P2P)* approach. Anybody must be able to trade and negotiate with anybody else. However, such an open and flexible method for electronic commerce has to deal with many obstacles before it becomes a reality.

- Mechanized support is needed in finding and comparing vendors and their offers. Currently, nearly all of this work is done manually which seriously hampers the scalability of electronic commerce. Semantic Web Technology can make it a different story: machine-processable semantics of information allow the mechanization of these tasks.
- Mechanized support is needed in dealing with numerous and heterogeneous data formats. Various "standards" exist on how to describe products and services, product catalogues and business documents. Ontology technology is required to define such standards better and to map between them. Efficient bridges between different terminologies are essential for openness and scalability.
- Mechanized support is needed in dealing with numerous and heterogeneous business logics. Again, various "standards" exist that define the business logic of a trading

partner.[3] Mediation is needed to compensate for these differences, allowing partners to cooperate properly.

In this section, we will discuss the three main challenges in applying semantic web technology to Electronic commerce: Efficient Alignment of Ontologies, Versioning of Ontologies, and population Ontologies.

3.1 Ontology Mappings: Integrating Business Documents

Modern document integration tasks impose a number of requirements on the integration technology such as the following:

- The technology must transform the documents with a speed compatible with the databases producing the documents. This limits the usage of logic-based transformation techniques.
- It must allow fast plugging-in of new documents without programming effort that indicates that XSLT[4] alone cannot satisfy the business integration tasks.
- Different documents and vocabularies must be aligned via their mediating conceptual models that capture semantic relations between vocabulary concepts and document elements, i.e., the hierarchy of terms and their equivalence.
- The integration model must be driven by a common process modeling ontology and a shared business integration ontology.

Accordingly, to perform the integration we need to develop ontological models for the following integration sub-tasks:

- Vocabularies that mostly represent sets of terms, sometimes enriched with topology.
- Business documents that mostly represent part-breakdown of documents into elements and their ontological models that contain a shallow concept hierarchy but a number of constraints on element values.
- Processes ontologies that contain a limited number of terms corresponding to timepoints, activities, objects etc., but a rich set of temporal axioms.

All the individual ontologies must be mapped to the mediating ontology that specifies the shared semantics of the concepts used by the integration service.

The business integration technology proposed in [Omelayenko & Fensel, 2001] assumes that XML documents might first be 'lifted up' to their RDF data models (the process known in the Semantic Web area as document annotation). Then different private RDF data models are mapped to the shared mediating data model enriched with different constraints and formal specification of shared semantics of the concepts.

An RDF mapping technology RDFT is now being developed to represent, reuse and execute these mappings [Omelayenko et al, 2002]. Specifically, RDFT provides an integration architecture, a mapping meta-ontology that specifies the mapping constructs called bridges, and the technology for map interpretation and translation to XSLT.

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[3] A simple example: A trading agent using RosettaNet expects an acknowledgement after issuing a purchase order, however, an agent using EDI will never send such an acknowledgement.

[4] www.w3c.org/xslt

Concisely, the RDFT architecture assumes that three tasks (vocabulary, document and process integration) are processed separately. Each specific enterprise must separately align the vocabularies, document formats and processes with the mediating ontology. The mediating process model guides the whole integration process. Process, document and especially vocabulary maps can be frequently reused, which increases the overall efficiency of the integration. Accordingly, the whole transformation chain, from the source XML serialization and RDF model via the mediating format to the target data model and XML serialization, can be represented as a graph allowing backward-chain processing and efficient compilation to XSLT.

Although the RDFT technology was developed to solve quite a specific task, it is easy to see that basically the same tasks frequently reoccur in other Semantic Web applications. To implement the main idea of the Semantic Web of enriching Web data with machine-processable semantics, we need to create conceptual models of the documents and then link them to shared domain theories (ontologies) and process these documents according to them. Hence, the business integration technology provides a solution to a typical Semantic Web task and it might be reused for other applications.

3.2 Ontology Versioning: Content Standards

Content standards form an important enabler for electronic commerce. They specify a standard hierarchy of products and services which can be used by companies to classify their actual products. This hierarchy can be considered as a simple ontology that specifies a consensus on the products that exist. Different companies that use the same content standard can easily communicate with respect to their products. There are several standard classifications in use, e.g. UNSPSC[5], which addresses a general and broad domain of products and services, RosettaNet[6], which is targeted at the IT industry, and e@Class[7], another broad standard that originates from Germany.

A serious threat for electronic commerce is the high change rate of the classification hierarchies and the way in which those changes are handled. For example, when we take a look at UNSPSC, we see the following:

- there were 16 updates between 31 January 2001 and 14 September 2001,
- each update contained between 50 and 600 changes,
- in 7.5 months, more than 20% of the current standard has changed!

Although some parts of the UNSPSC schema might be more stable than other parts, it is clear that this amount of changing cannot be ignored. Such a high change rate can quickly invalidate a lot of the actual classifications of products. For example, the product “Binding elements” in version 8.0 is removed from the standard and three new products are added in version 8.1 (“Binding spines or snaps”, “Binding coils or wire loops”, and “Binding combs or strips”). This means that all products that were classified as “Binding elements” are unclassified under the new version. This is a serious problem because of the high cost of producing the right classifications for products. Moreover, if companies use local extensions of the standard, they have to adapt those extensions to new versions too. A versioning mechanism that allows partly automatic transformation of data between content standard versions is essential.

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[5] http://eccma.org/unspsc/
[6] http://www.rosettanet.org/
[7] http://www.eclass.de/

An effective versioning methodology should take care of the different *types* of changes in ontologies, as these might have different effects on the compatibility of data that is described by them [Klein & Fensel, 2001]. An analysis of differences between several versions of content standards has yielded the following list of typical changes: class title changes, additions of classes, relocations of classes in the hierarchy (by moving them up or down in the hierarchy, or horizontally), relocation of a whole sub-tree in the hierarchy, merging of two classes (in two variants: two classes become one new class, or one class is appended to the other class), splits in classes, and pure deletions. However, current versioning techniques for content standards are often quite simple. In UNSPSC, for example, all changes are encoded as either additions, deletions or edits (title changes). This means that the relocation of a sub-tree is specified as a sequence of "delete a list of classes" and "add a list of classes".

Semantic Web techniques can help to cope with these versioning problems. Current work on ontology versioning builds upon earlier work in database schema versioning [Roddick, 1995]. Although these two are similar to some extent, ontology versioning has some characteristics that make it more complex than database schema versioning [Noy & Klein, submitted]. For example, the distributed and decentralized nature of ontologies makes every coordination of changes impossible. On the other hand, the richness of the data model and the semantics that are often incorporated in ontologies, might help to find and resolve conflicts between versions. An important ontology versioning technique is the ability to compare versions of ontologies and highlight the differences. This allows changes in ontologies to be found, even if they have occurred in an uncontrolled way, i.e., possibly generated by different people in an unknown order. Another technique for ontology versioning is the specification of the *intention and semantics* of changes. For example, some changes are corrections of mistakes, while others represent a change in the world. Different intentions have different consequences for the interpretation of the effects of changes. Semantics of changes specify the intended logical consequences of each change, for example that a new version of a class is a more specific than another version.

Both techniques are useful for content standard versioning. Ontology comparison techniques can help companies to find and describe the differences between new versions of the standards and the old versions that were used to classify data. Descriptions of the semantics of discovered changes can facilitate the transformation of data classification. For example, in the most trivial case they can specify that a new version is a combination of two other classes; all products that were classified under the old classes can then be classified under the new class. More complicated specifications of the logical consequences, possibly with approximations, will further decrease the negative effects of the evolution of content standards.

3.3 Ontology Instantiation: GoldenBullet

Finding the right place for a product description in a standard classification system such as UNSPSC is not at all a trivial task. Each product must be mapped to the corresponding product category in UNSPSC to create the product catalog. Product classification schemes contain huge number of categories with far from sufficient definitions (e.g. over 15,000 classes for UNSPSC) and millions of products must be classified according to them. This requires tremendous labor effort and the product classification stage takes altogether up to 25% of the time spent for content management. Because product classification is so expensive, complicated, time-consuming and error-prone, Content Management needs support in automation of the product classification process and the automatic creation of product classification rules.

GoldenBullet is a software environment targeted at supporting product classification according to certain content standards ([Ding et al., 2002a], [Ding et al., 2002b]). It is currently designed to automatically classify products based on their original descriptions and existing classification standards (such as UNSPSC). It integrates different classification algorithms from the information retrieval and machine learning areas and some natural language processing techniques to pre-process data and index UNSPSC so as to improve the classification accuracy.

Cataloguing product descriptions according to UNSPSC is a big burden carried by B2B marketplace vendors. At the moment it is mainly done manually. Achieving semi-automatic or automatic support in cataloguing product descriptions is a significant breakthrough. **GoldenBullet** is a prototype for deploying information retrieval and machine learning methods to classify product descriptions semi-automatically or automatically: data input and export facilities; text processing techniques; classification of product data; and learning and enrichment of product classification information (see Figure 2).

A **wrapper factory** gathers various wrappers to convert raw data description from external formats (Database, Excel, XML-like, formatted plain text,...) to internal formats, and final results to preferable output formats or user-designed formats. Besides the automatic importing and exporting of data, **GoldenBullet** also provides the editor for manually inputting data, which is well suited to small and medium-sized vendors.

The validated product data will be pre-processed before the classification has been performed. Some **Natural Language Processing** algorithms have been implemented in **GoldenBullet**. The product data will be stemmed (grouping different words with the same stems) and tagged (extracting noun-phrases). A stop word list has been generated, updated and extended during the whole process. Currently, **GoldenBullet** can handle English and French product data.

Figure 2 shows the user interface of the classifier. The imported UNSPSC is browsable from the screen, which directs the end-user to the right location of UNSPSC. The classifier classifies the pre-processed product data and proposes the ranked solutions based on various weighting algorithms. The end-user can pull down the proposed list and make the final choice. But when he highlights one of the proposed solutions, the above-mentioned UNSPSC browse window will show the exact location of it in UNSPSC with the details of each level.

Performing the classification task is viewed as an information retrieval. The problem of finding the right class is viewed as the problem of finding the right document as an answer to a query:

- A product description is viewed as a query and UNSPSC is viewed as a document collection.
- Each of the commodities in UNSPSC is treated as a document, where each commodity description forms the text of the document.
- Assigning a proper category for a product is achieved by retrieving a corresponding UNSPSC commodity description.

The performance of such an approach is rather basic (see the next sub-section for more details). Directly using UNSPSC for document collection fails in this respect because the class descriptions are very short (i.e., we deal with very short documents) and the product descriptions are often very short too and use very specific vocabulary that cannot directly be matched with more generic terms in UNSPSC. Therefore, we employed various strategies to achieve a more reasonable and workable result. Basically we employed different retrieval strategies and we made use of large volumes of manually classified data to improve the performance.

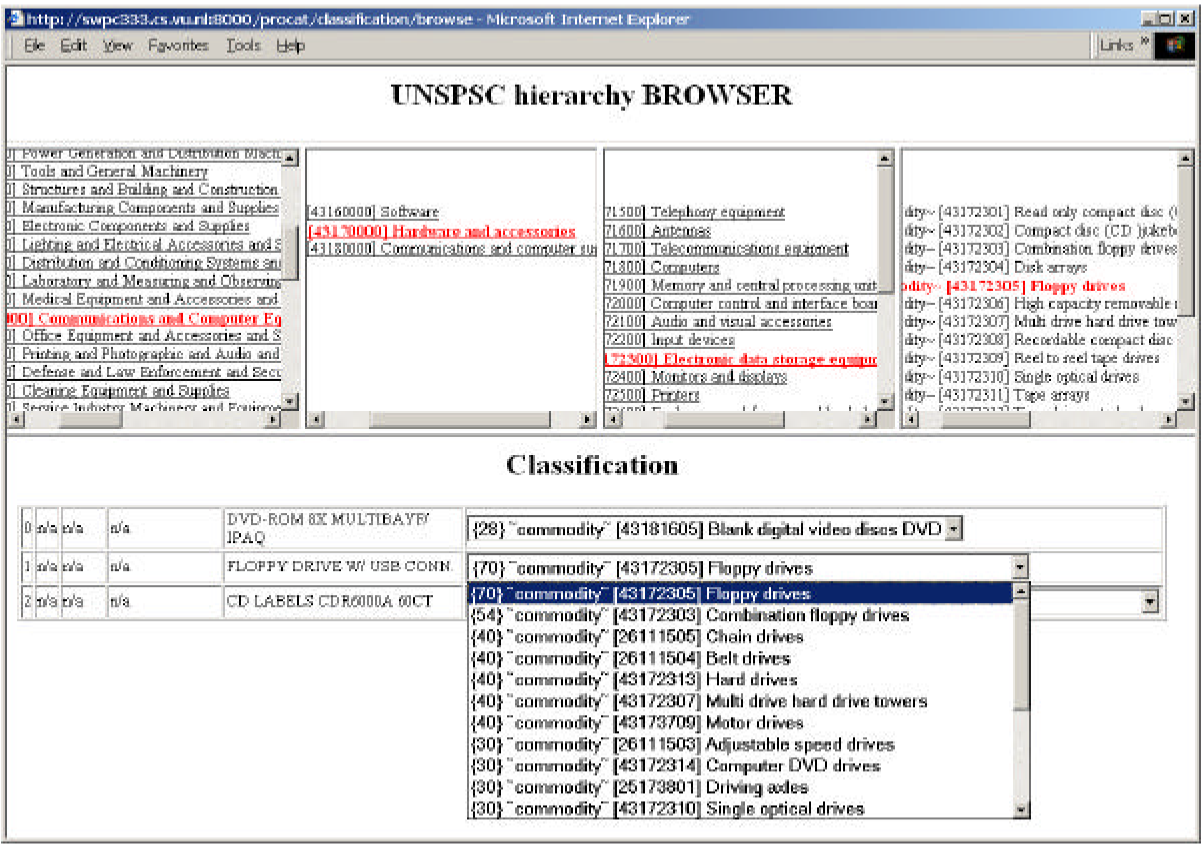

Figure 2. A screenshot of **GoldenBullet**.

3.4 Web Services

Semantic Web technology is still in its early stages. We are focusing on building its basic - and mostly static - infrastructure. The next step will be to produce active components that use this infrastructure to offer users intelligent services. Web services aim to support information access and e-business. Examples include UDDI[8], a repository for describing vendors, products and services. It uses WSDL[9] to describe its entries, and SOAP[10] as a

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[8]http://www.uddi.org

[9]http://www.wsdl.org

[10]http://www.soap.org

protocol to define how they can be accessed. At present, none of these service description elements are based on semantic web technology. As a result, it requires tremendous human effort to perform such tasks as: searching for vendors, products and services; comparing and combining products; forming coalitions of vendors, etc. Semantic web-enabled services can provide a higher level of service by mechanizing many of these aspects. Steps in this direction are being taken by projects such as DAML[11] and Ibrow[12]. Within DAML, a service description language called DAML-S [Ankolenkar et al., 2001] has been developed. This language allows formal competence descriptions that enable automatic inference as a means of selecting and combining services. Ibrow developed a language called UPML that can be used to describe static and dynamic aspects of a semantic web. [Fensel et al., to appear (a)] offer features that describe Ontologies, heuristic reasoners (called problem-solving methods) and methods to interweave them. Based on these descriptions, an automated broker provides support in component selection, combination and execution.

Web services described by WSDL are individual message exchanges. They can be synchronous or asynchronous one-way messages between a sender and a receiver or a pair of messages following a request/reply pattern between a sender and a receiver.

While these two patterns are sufficient in many cases, they are insufficient for more complex message exchange patterns (called public processes) like a purchase order (PO) and purchase order acknowledgment (POA) exchange whereby the PO message as well as the POA message are acknowledged individually by low-level message acknowledgements confirming the receipt of the message. WSDL is not able to define these public processes and languages like XLANG [Thatte, 2001], WSFL [Leymann, 2001], WSCL [Banerji et al., 2001], BPML [Arkin, 2001] and BPSS [Business Process Project Team, 2001] are proposed for their definition. RosettaNet[13] provides many domain-specific public processes (called Partner Interface Processes) as standard.

If trading partners try to match their complex public processes in order to conduct business with each other they might encounter a mismatch of their public processes. For example, one trading partner expects message acknowledgments but the other trading partner does not provide them. The above-mentioned languages do not support any compensation at all for these public process mismatches.

In a peer-to-peer environment no third party mediator can be asked to compensate for the process mismatches. The trading partners have to do the compensation themselves in their environments. [Bussler, 2001] presents initial work on public process mismatch compensation through the concept of process binding. Through process binding it is possible to generate additional messages, consume superfluous messages as well as change the message exchange order. Through these possibilities the mismatches can be compensated for. Presently, the process binding compensating the mismatches has to be done manually. To implement the vision of mechanized support of public process integration, the appropriate concepts as well as an approach have to be developed.

4. Conclusions

The easy information access based on the success of the web has made it increasingly difficult to find, present and maintain the information required by a wide variety of users.

[11] http://www.daml.org

[12] http:// www.swi.psy.uva.nl/projects/ibrow/home.html

[13] http.//www.rosettanet.org

In response to this problem, many new research initiatives and commercial enterprises have been set up to enrich available information with machine-understandable semantics. This **Semantic Web** will provide intelligent access to heterogeneous, distributed information, enabling software products to mediate between user needs and the information sources available. In this paper, we outlined various applications in areas such as knowledge management and electronic commerce. **Web Services** deal with an orthogonal limitation of the current web. Currently, the web is mainly a collection of information but does not yet provide support in processing this information, i.e., in using the computer as a computational device. Web services can be accessed and executed via the web. However, all these service descriptions are based on semi-formal natural language descriptions. Therefore, the human programmer needs to be kept in the loop and the scalability as well as economy of web services are limited. Bringing them to their full potential requires their combination with semantic web technology. This technology will provide mechanization in service identification, configuration, comparison and combination. **Semantic Web enabled Web Services** have the potential to change our life to a much higher degree than the current web already has. [Bussler, 2001] identifies the following elements necessary to enable efficient inter-enterprise execution: public process description and advertisement; discovery of services; selection of services; composition of services; delivery, monitoring and contract negotiation. Without mechanization of these processes, internet-based e-commerce will not be able to provide its full potential in economic extensions of trading relationships. Initial attempts to apply semantic web technology to web services have already been made.[14] [Trastour et al., 2001] examine the problem of matchmaking, highlighting the features that a matchmaking service should exhibit and deriving requirements on metadata for description of services from a matchmaking point of view. [Hendler, 2001] provides a look at some potential applications of web semantics and consider some challenges the research community should be attacking. In particular, he takes a look at how information agents and ontologies can together provide breakthrough technologies for web applications.

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