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SEMANTIC WEB APPLICATIONS: FIELDS AND BUSINESS  
CASES. THE INDUSTRY CHALLENGES THE RESEARCH.

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## Semantic Web Applications: Fields and Business Cases. The Industry Challenges The Research.

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**Abstract.** Semantic Web technology is being increasingly applied in a large spectrum of applications in which domain knowledge is conceptualized and formalized (e.g., by means of an *ontology*) in order to support diversified knowledge processing (e.g., *reasoning*) by machine. Moreover, through the subtle joining of (cognitive) human reasoning and (logical) machine reasoning, it is possible for humans and machines to share complementary tasks. Some examples of application areas where these tasks arise are: corporate portals and knowledge management, e-commerce, e-work, healthcare, e-government, natural language understanding and automated translation, information search, data and services integration, social networks and collaborative filtering, knowledge mining, and so on. From a social and economic perspective, this emerging technology should contribute to growth in economic wealth, but it must also show clear cut value for everyday activities through technological transparency and efficiency. The uptake of Semantic Web technology by industry is progressing slowly. One of the problems is that academia is not always aware of the concrete problems that arise in industry. In contrast, industry is not often well informed about the academic developments that can potentially meet its needs. In this paper we present ongoing work in the cross-fertilization between industry and academy. In particular, we present a collection of application fields and use cases from enterprises which are interested in the promises of Semantic Web technology. We explain our approach by analyzing the industry needs in different application areas. We summarize industrial requirements with respect to Semantic Web technology in the form of a typology of knowledge processing tasks. These results are intended to focus academia on the development of plausible knowledge-based solutions for concrete industrial problems, and therefore, facilitate the industrial uptake of Semantic Web technology.

## 1 Introduction

As a result of the pervasive and user-friendly digital technologies emerging within our information society, web content is increasingly multiform, inconsistent and very dynamic. Such content is unsuitable for machine processing, and necessitates human interpretation and its respective costs in time and money for business. To remedy this, approaches aim at abstracting of this complexity (e.g. by using ontologies) and offering new and enriched services able to process those abstractions (e.g., by mechanized reasoning) in a fully automated way. This abstraction layer is the subject of a very dynamic activity in research, industry and standardization which is usually called "Semantic Web" (see, for example, DARPA, European IST Research Framework Program, W3C initiative). The initial application of Semantic Web technology has focused on Information Retrieval (IR) where access through semantically annotated content, instead of classical (even sophisticated) statistical analysis, aimed to give far better results (in terms of precision and recall indicators). The next natural extension was to apply IR in the integration of enterprise legacy databases in order to leverage existing company information in new ways. Present research has turned to focusing on the *seamless integration* of heterogeneous and distributed applications and services (both intra- and inter-enterprise) through semantic web services, with the expectation of a fast return on investment (ROI) and improved efficiency in E-Work and E-Business.

This new technology takes its roots in the cognitive sciences, machine learning, natural language processing, multi-agents systems, knowledge acquisition, automated reasoning, logics and decision theory. It can be separated into two distinct – but cooperating fields - one adopting a formal and algorithmic approach for common sense automated reasoning (automated Web), and the other one “keeping the human being in the loop” for a socio-cognitive semantic web (automated social Web).

On a large scale, industry awareness of Semantic Web technology has started only recently, e.g., at the EC level with the IST-FP5 thematic network Ontoweb<sup>1</sup> [2001-2004] which brought together around 50 motivated companies worldwide. Based on this experience, within the IST-FP6 network of excellence KnowledgeWeb<sup>2</sup> [2004-2008] an in-depth analysis of the concrete industry needs in the key economic sectors has been identified as one of the next steps towards stimulating the industrial uptake of Semantic Web technology.

The rest of the paper is organized as follows. Three prototypical application fields are presented in Section 2, namely knowledge management (KM), e-commerce and healthcare. A use cases collection methodology from industry and their preliminary analysis leading to the identification of key knowledge processing tasks and components are presented in Section 3. Finally, Section 4 reports some conclusions and discusses the future effort.

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<sup>1</sup> <http://www.ontoweb.org>

<sup>2</sup> <http://knowledgeweb.semanticweb.org>

## 2 Prototypical Application Fields

### 2.1 Knowledge Management

Knowledge is one of the key success factors for enterprises, both today and in the future. Therefore, company knowledge management has been identified as a strategic tool. However, if information technology is one of the foundational elements of KM; KM, in turn, is also interdisciplinary by its nature. In particular, it includes human resource management, enterprise organization and culture<sup>3</sup>. We view KM as the management of the knowledge arising from business activities, aiming at leveraging both the use and the creation of that knowledge for two main objectives: capitalization of corporate knowledge and durable innovation fully aligned with the strategic objectives of the organization.

A recent CEN/ISSS<sup>4</sup> project has issued a finalized proposal on good practices in KM. The project began in October 2002 on KnowledgeBoard<sup>5</sup>, which is the European Commission public KM portal, and was closed with a final set of CEN recommendations in the fall of 2003 entitled "European guide to Good Practice in Knowledge Management".

The European KM Framework is designed to support a common European understanding of KM, to show the value of this emerging approach and help organizations towards its successful implementation. The Framework is based on empirical research and practical experience in this field from all over Europe and the rest of the world. The European KM Framework addresses all of the relevant elements of a KM solution and serves as a reference basis for all types of organizations, which aim to improve their performance by handling knowledge in a better way.

#### 2.1.1 Where should knowledge-based KM benefit?

In the past, information technology for knowledge management has focused on the management of knowledge containers using text documents as the main repository and source of knowledge. In the future, Semantic Web technology, especially ontologies and machine-interpretable metadata will pave the way to KM solutions that are

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<sup>3</sup> Some of the well-known definitions of KM include:

(Wiig 1997) " Knowledge management is the systematic, explicit, and deliberate building, renewal and application of knowledge to maximize an enterprise's knowledge related effectiveness and returns from its knowledge assets" [1]

(Hibbard 1997) "Knowledge management is the process of capturing a company's collective expertise wherever it resides in databases, on paper, or in people's heads and distributing it to wherever it can help produce the biggest payoff" [2]

(Pettrash 1996) "KM is getting the right knowledge to the right people at the right time so they can make the best decision" [3]

<sup>4</sup> <http://www.cenorm.be/cenorm/index.htm>

<sup>5</sup> <http://www.knowledgeboard.com>

based on semantically related pieces of knowledge. The knowledge backbone is made up of ontologies that define a shared conceptualization of an application domain and provide the basis for defining metadata that have precisely defined semantics, and are therefore machine-interpretable. Although the first KM approaches and solutions have shown the benefits of ontologies and related methods, a large number of open research issues still exist that have to be addressed in order to make Semantic Web technology a complete success for KM solutions:

- Industrial KM applications have to avoid any kind of overhead as far as possible. A *seamless integration* of knowledge creation (e.g. content and metadata specification) and knowledge access (e.g. querying or browsing) into the working environment is required. Strategies and methods are needed to support the creation of knowledge, as side effects of activities that are carried out anyway. These requirements mean *emergent semantics*, e.g. through *ontology learning*, are needed, which reduce the current time consuming task of building-up and maintaining ontologies.
- Access to as well as presentation of knowledge has to be *context-dependent*. Since the context is setup by the current business task, and thus by the business process being handled, a tight integration of business process management and knowledge management is required. KM approaches can provide a promising starting point for *smart push services* that will proactively *deliver relevant knowledge* for carrying out the task at hand more effectively.
- *Conceptualization* has to be supplemented by *personalization*. On the one hand, taking into account the experience of the user and his/her personal needs is a prerequisite in order to avoid information overload, and on the other hand, *to deliver knowledge at the right level of granularity and from the right perspective*.

The development of knowledge portals serving the needs of companies or communities is still a manual process. Ontologies and related metadata provide a promising conceptual basis for generating parts of such knowledge portals. Obviously, among others, conceptual models of the domain, of the users and of the tasks are needed. The *generation of knowledge portals* has to be supplemented with the (semi-) automated evolution of portals. As business environments and strategies change rather rapidly, *KM portals have to be kept up-to-date in this fast changing environment*. Evolution of portals should also include some mechanisms *to 'forget' outdated knowledge*.

KM solutions will be based on a combination of intranet-based functionalities and mobile functionalities in the very near future. Semantic Web technology is a promising approach to meet the needs of mobile environments, like location-aware personalization and adaptation of the presentation to the specific needs of mobile devices, i.e. the presentation of the required information at an appropriate level of granularity. In essence, employees should have access to the KM application *anywhere* and *anytime*.

*Peer-to-Peer computing (P2P)*, combined with Semantic Web technology, will be a strong move towards getting rid of the more centralized KM approaches that are currently used in ontology-based solutions. P2P scenarios open up the way to derive consensual conceptualizations among employees within an enterprise in a bottom-up manner.

*Virtual organizations* are becoming more and more important in business scenarios, mainly due to decentralization and globalization. Obviously, semantic interoperability between different knowledge sources, as well as trust, is necessary in inter-organizational KM applications.

The integration of KM applications (e.g. skill management) with *e-learning* is an important field that enables a lot of synergy between these two areas. KM solutions and e-learning must be integrated from both an organizational and an IT point of view. Clearly, interoperability and integration of (metadata) standards are needed to realize such integration.

Knowledge Management is obviously a very promising area for exploiting Semantic Web technology. Document-based KM solutions have already reached their limits, whereas semantic technology opens the way to meet KM requirements in the future.

### **2.1.2 Knowledge-based KM applications<sup>6</sup>**

In the context of geographical team dispersion, multilingualism and business unit autonomy, usually a company wants a solution allowing for the identification of strategic information, the secured distribution of this information and the creation of transverse working groups. Some applicative solutions allowed for the deployment of an Intranet intended for all the marketing departments of the company worldwide, allowing for a better division of and a greater accessibility to information, but also capitalisation on the total knowledge. There are three crucial points that aim at easing the work of the various marketing teams in a company: (i) the automatic competitive intelligence of the Web, (ii) skill management and (iii) document management.

Thus, a system connects the "strategic ontologies" of the company group (brands, competitors, geographical areas, etc.) with the users, via the automation of related processes (research, classification, distribution, knowledge representation). The result is a dynamic "Semantic Web" system of navigation (research, classification) and collaborative features.

From a functional point of view, a KM system organises skill and knowledge management within a company, in order to improve interactivity, collaboration and information sharing. This constitutes a virtual workspace which facilitates work between employees that speak different languages, automates the creation of work groups, organises and capitalises structured and unstructured, explicit or tacit data of the company, and offers advanced features of capitalisation. Finally, the semantic backbone makes possible to cross a qualitative gap by providing cross-lingual data.

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<sup>6</sup> <http://www.arisem.com>  
<http://www.mondeca.com>  
<http://www.ontoknowledge.com>  
<http://www.distributedthinking.com>  
<http://www.ontoknowledge.com>  
<http://www.si.fr.atosorigin.com/sophia/comma/Htm/HomePage.htm>

### 2.1.3 Some lessons learnt<sup>7</sup>:

- *The main strong benefits* for the enterprise are high productivity gains and operational valorisation of legacy knowledge;
- *Productivity*: automation of maintenance of the knowledge bases, automation of content indexing, augmented productivity in the publication cycle (commercial proposals, reports), search efficiency (a reduction factor on search time of the order, e.g., 1000 to 1, is claimed to be possible by the use of "semantic search")
- *Quality and operational valorisation of knowledge legacy*: unified management of heterogeneous resources, information relevance, capacity to represent complex knowledge, gains in development and maintenance of knowledge and content management solution, generic and evolvable solution;
- Human factors prove to be the key difficulty in reaching a KM solution with full groupware functionality for company employees, so adopt a step-by-step approach;
- *Access to the information portal* must be well designed and must be supported by a group of people dedicated to information filtering and qualifying (P2P is possible).

## 2.2 E-Commerce

Electronic commerce is mainly based on the exchange of information between involved stakeholders using a telecommunication infrastructure. There are two main scenarios: Business-to-Customer (B2C) and Business-to-Business (B2B).

*B2C applications* enable service providers to promote their offers, and for customers to find offers which match their demands. By providing unified access to a large collection of frequently updated offers and customers, an electronic marketplace can match the demand and supply processes within a commercial mediation environment.

*B2B applications* have a long history of using electronic messaging to exchange information related to services previously agreed among two or more businesses. Early plain-text telex communication systems were followed by electronic data interchange (EDI) systems based on terse, highly codified, well structured, messages. A new generation of B2B systems is being developed under the ebXML (electronic business in XML) heading. These will use classification schemes to identify the context in which messages have been, or should be, exchanged. They will also introduce new techniques for the formal recording of business processes, and for the linking of business processes through the exchange of well-structured business messages. ebXML will also develop techniques that will allow businesses to identify new suppliers through the use of registries that allow users to identify which services a supplier can offer. ebXML needs to include well managed multilingual ontologies that can be used to help users to match needs expressed in their own language with those expressed in the service providers language(s).

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<sup>7</sup> Le Monde Informatique 11 July 2003 and <http://www.mondeca.com>



### 2.2.1 Where is the value of knowledge-based E-Commerce?

At present, ontology and more generally knowledge-based systems, appear as a *central issue* for the development of *efficient and profitable* e-commerce solutions. However, because of an actual lack of standardization for business models, processes, and knowledge architectures, it is currently difficult for companies to achieve the promised ROI from knowledge-based e-commerce.

Moreover, a technical barrier exists that is delaying the emergence of e-commerce, lying in the need for applications to *meaningfully share information*, taking into account the lack of reliability and security of the Internet. This fact may be explained by the variety of enterprise and e-commerce systems employed by businesses and the various ways these systems are configured and used. As an important remark, such *interoperability problems* become particularly severe when a large number of trading partners attempt to agree and define the standards for interoperation, which is precisely a main condition for maximizing the ROI indicator.

Although it is useful to strive for the adoption of a single common domain-specific standard for content and transactions, such a task is often difficult to achieve, particularly in cross-industry initiatives, where companies co-operate and compete with one another. Some examples of the difficulties are:

- *Commercial practices* may vary widely, and consequently, cannot always be aligned for a variety of technical, practical, organizational and political reasons.
- *The complexity of a global description* of the organizations themselves: their products and services (independently or in combination), and the *interactions* between them remain a formidable task.
- It is usually very difficult to establish a priori rules (technical or procedural) governing participation in an electronic marketplace.
- Adoption of a *single common standard may limit business models* which could be adopted by trading partners, and therefore potentially reduce their ability to fully participate in e-commerce.

A knowledge-based approach has the potential to significantly accelerate the penetration of electronic commerce within vertical industry sectors, by *enabling interoperability at the business level*, and reducing the need for standardisation at the technical level. This will enable services to adapt to the rapidly changing online environment.

The following uses for ontologies and classification schemes that could be defined using ontologies have been noted within electronic commerce applications:

- Categorization of products within catalogues;
- Categorization of services (including web services);
- Production of yellow page classifications of companies providing services;
- Identification of countries, regions and currencies;
- Identification of organizations, persons and legal entities;
- Identification of unique products and saleable packages of products;
- Identification of transport containers, their type, location, routes and contents;
- Classification of industrial output statistics.

### 2.2.2 Knowledge-based E-Commerce applications

According to [4], applications of this kind use one or more shared ontologies to integrate heterogeneous information systems and allow common access for humans and computers. This enforces the shared ontology as the standard ontology for all participating systems, thereby removing the semantic heterogeneity from the information system. The heterogeneity is a problem because the systems to be integrated are already operational and it is too costly to redevelop them. A linguistic ontology is sometimes used to assist in the generation of the shared ontology or is used as a top-level ontology, describing very general concepts like space, time, matter, object, event, action, etc, which the shared ontologies can inherit from. Benefits are the integration of heterogeneous information sources, which can improve interoperability, and more effective use and reuse of knowledge resources<sup>8</sup>.

Yellow pages and product catalogs are direct benefactors of a well structured representation which, coupled to a multilingual ontology, enhance clearly the precision / recall of products or services in a search engine. The ONTOSEEK system (1996-1998) was the first prototype which operates by associating a domain ontology (encoded in a conceptual graph (CG) knowledge representation (KR) formalism with very limited expressiveness) to a large multilingual linguistic ontology (SENSUS – WORDNET) for natural language search of products [5]. ONTOSEEK searches products by mapping natural human language requests to entities of the domain ontology. Unlike traditional e-commerce portal search functions the user is not supposed to know the vocabulary used for describing the products and thanks to the SENSUS ontology (s)he is able to express the query using his or her own vocabulary. The main functional architectural choices of ONTOSEEK were:

- Use of a general linguistic ontology to describe products;
- A high flexibility in expressing the request thanks to the semantic mapping offered between the request and the offers;
- Interactive guided request formulation through generalisation and specialisation links.

A conceptual graph KR is used internally to represent *requests* and *products*. The semantic matching algorithm is based on simple subsumption on the ontology graph and does not make use of a complex graph endomorphism. ONTOSEEK has not been deployed commercially but through its trial period has fully demonstrated the potential benefits of making use of preliminary semantic web tools.

The MKBEEM [6] prototype and technology (Multilingual Knowledge Based European Electronic Marketplace - IST-1999-10589, 2000 – 2003) concentrated on written language technologies and their use in e-commerce. Within the global and multilingual Internet trading environment, there is an increasing pressure on e-content publishers of all types to adapt content for international markets. Localization – trans-

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<sup>8</sup> <http://www.chemdex.com>  
<http://kmi.open.ac.uk/projects/alice/>  
<http://www.telecom.ntua.gr/smartec/>  
<http://www.mkbeem.com/>

lation and cultural adaptation for local markets – is proving to be a key driving factor in the expansion of business on the web. In particular, MKBEEM focused on adding multilingualism to all stages of the information cycle, including multilingual content generation and maintenance, automated translation and interpretation, and enhancing the natural interactivity and usability of the service with unconstrained language input. On the knowledge technology side, the MKBEEM ontologies provide a consensual representation of the electronic commerce field in two typical domains, such as B2C Tourism and B2C Mail orders, allowing for the commercial exchanges to be transparent in the language of the end user, of the service, or of the product provider. Ontologies are used for classifying and indexing catalogues for filtering user's queries, for selecting relevant products and providers, for facilitating multilingual human-machine dialogues and for inferring information that is relevant to the user's requests and trading needs. The key innovative approach is based on the combined use of human language processing and knowledge-based reasoning.

The effectiveness of the developed generic solutions has been tested in Finnish, French, Spanish and English, in the domains of travel booking services (SNCF French Rail services) and mail order sales (La Redoute - Ellos).

## **2.3 Biosciences and Medical Applications**

The medical domain is a favourite target for Semantic Web applications just as the expert system was for Artificial Intelligence applications 20 years ago. The medical domain is very complex: medical knowledge is difficult to represent in a computer format, making the sharing of information even more difficult. Semantic Web solutions become very promising in this context.

One of the main mechanisms of the Semantic Web - resource description using annotation principles - is of major importance in the medical informatics (or sometimes called bioinformatics) domain, especially as regards the sharing of these resources (e.g. medical knowledge in the Web or genomic database). Through the years, the IR area has been developed by medicine: medical thesauri are enormous (e.g., 1,000,000 terms in Unified Medical Language System, UMLS) and are principally used for bibliographic indexation. Nevertheless, the MeSh thesaurus (Medical Subject Heading) or UMLS<sup>9</sup> have been used to provide data semantics with varying degrees of difficulty. Finally, the web services technology allows us to imagine some solutions to the interoperability problem, which is substantial in medical informatics. Below, we will describe current research, results and expected perspectives in these biomedical informatics topics in the context of Semantic Web.

### **2.3.1 Biosciences resources sharing**

In the functional genomics domain, it is necessary to have access to several data bases and knowledge bases which are accessible via the web but are heterogeneous in their structure as well as in their terminology. Among such resources, we can mention

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<sup>9</sup> <http://www.nlm.nih.gov/research/umls/umlsmain.html>

SWISSPROT<sup>10</sup> where the gene products are annotated by the Gene Ontology<sup>11</sup>, GenBank<sup>12</sup>, etc. When comparing these resources it is easy to see that they propose the same information in different formats. The XML language, which acts as a common data structure for the different knowledge bases, provides at the most a syntactic Document Type Definition (DTD) which does not resolve the semantic interoperability problem.

One of the solutions comes from the Semantic Web with a mediator approach [7] which allows for the accessing of different resources with an ontology used as the Interlingua pivot. For example and in another domain than that of genomics, the NEUROBASE project [8] attempts to federate different neuro-imagery information bases situated in different clinical or research areas. The proposal consists of defining an architecture that allows the access to and the sharing of experimental results or data treatment methodologies. It would be possible to search in the various data bases for similar results or for images with peculiarities or to perform data mining analysis between several data bases. The mediator of NEUROBASE has been tested on decision support systems in epilepsy surgery.

### 2.3.2 Web services for interoperability

The web services technology can propose some solutions to the interoperability problematic. We describe now a new approach based on a “patient envelope” and we conclude with the implementation of this envelope based on the web services technology.

The patient envelope is a proposition of the Electronic Data Interchange for Healthcare group (EDI-Santé<sup>13</sup>) with an active contribution from the ETIAM society<sup>14</sup>. The objective of the work is on filling the gap between “free” communication, using standard and generic Internet tools, and “totally structured” communication as promoted by CEN<sup>15</sup> or HL7<sup>16</sup>. After the worldwide analysis of existing standards, the proposal consists of an “intermediate” structure of information, related to one patient, and storing the minimum amount of data (i.e. exclusively useful data) to facilitate the interoperability between communicating peers. The “free” or the “structured” information is grouped into a folder and transmitted in a secure way over the existing communication networks [9]. This proposal has reached widespread adoption with the distribution by Cegetel.rss of a new medical messaging service, called “Sentinelle”, fully supporting the patient envelope protocol and adapted tools.

After this milestone, EDI-Santé is promoting further developments based on ebXML and SOAP (Simple Object Access Protocol) in specifying exchange (see, items 1 and 2 below) and medical (see, items 3 and 4 below) properties:

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<sup>10</sup> <http://us.expasy.org/sprot/>

<sup>11</sup> <http://obo.sourceforge.net/main.html>

<sup>12</sup> <http://www.ncbi.nlm.nih.gov/Genbank/index.html>

<sup>13</sup> <http://www.edisante.org/>

<sup>14</sup> <http://www.etiam.com/>

<sup>15</sup> <http://www.cen251.org/>

<sup>16</sup> <http://www.hl7.org/>

1. Separate what is mandatory to the transport and the good management of the message (e.g., patient identification from what constitutes the “job” part of the message).
2. Provide a “container” for the message, collecting the different elements, texts, pictures, videos, etc.
3. Consider the patient as the unique object of the transaction. Such an exchange cannot be anonymous. It concerns a sender and an addressee who are involved in the exchange and who are responsible. A patient can demand to know the content of the exchange in which (s)he is the object, which implies a data structure which is unique in the form of a triple {sender, addressee, patient}.
4. The conservation of the exchange semantics. The information about a patient is multiple in the sense that it comes from multiple sources and has multiple forms and supporting data (e.g., data base, free textual document, semi-structured textual document, pictures). It can be fundamental to maintain the existing links between elements, to transmit them together, e.g. a scanner and the associated report, and to be able to prove it.

The interest of such an approach is that it prepares the evolution of the transmitted document from a free form document (from proprietary ones to normalized as XML) to elements respecting HL7v3 or EHRCOM data types.

### **2.3.3 What is next in the healthcare domain?**

These different projects and applications highlight the main consequence of the Semantic Web being expected by the medical communities: the sharing and integration of heterogeneous information or knowledge. The answers to the different issues are the use of mediators, a knowledge-based system, and ontologies, which are all based on normalized languages such as RDF, OWL, and so on. The work of the Semantic Web community must take into account these expectations, see for example the FP6 projects<sup>17-18-19</sup>. Finally, it is interesting to note that the Semantic Web is an integrated vision of the medical community’s problems (thesauri, ontologies, indexation, inference) and provides a real opportunity to synthesize and reactivate some research [10].

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<sup>17</sup> <http://www.cocoon-health.com>

<sup>18</sup> <http://www.srdc.metu.edu.tr/webpage/projects/artemis/index.html>

<sup>19</sup> <http://www.simdat.org>

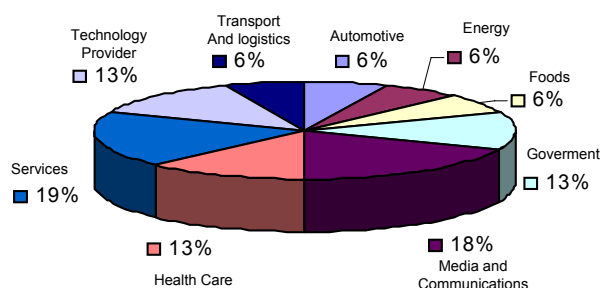
### 3 What is beyond those prototypical applications? Overall business needs and key knowledge processing requirements

#### 3.1 Use Case Collection and Analysis

In order to support a large spectrum of application fields, the EU FP6 Network of Excellence KnowledgeWeb is tasked with promoting transfer of emerging knowledge-based technology from academia to industry. The network is made up of leading European Semantic Web research institutions and co-ordinates their research efforts while parallel efforts are made in Semantic Web education and Outreach to Industry<sup>20</sup>.

In the Outreach to Industry activities, we have formed a group of companies interested in Semantic Web technology. By the end of 2004, this group consisted of 34 members (e.g., France Telecom, IFP, Illy Caffè, Trenitalia, Daimler Chrysler) from across 12 economic sectors (e.g., telecoms, energy, food, logistics, automotive).

The companies were requested to provide illustrative examples of actual or hypothetical deployment of Semantic Web technology in their business settings. This was followed up with face-to-face meetings between researchers and industry experts from the companies to gain additional information about the provided use cases. Thus, in 2004, we collected a total of 16 use cases from 12 companies as shown below in Figure 1.



**Figure 1:** Breakdown of use cases by industry sectors

In particular, it represents (the most active) 9 sectors, with the highest number of the use cases coming from the service industry (19%) and media & communications (18%) respectively. The entire collection of use cases can be found in [11], or on the Outreach to Industry portal<sup>21</sup>.

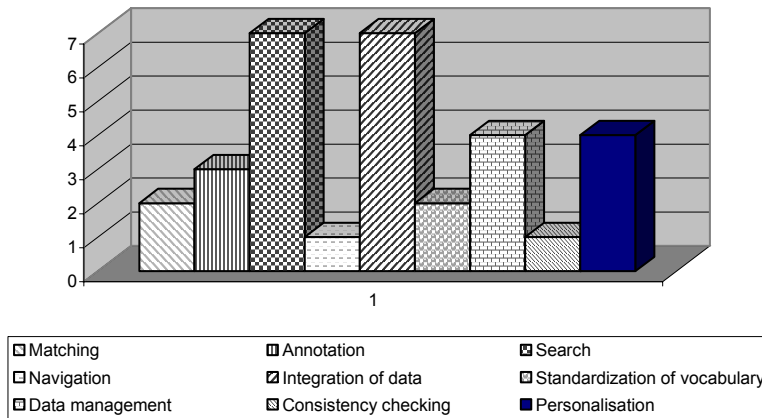
<sup>20</sup> More about all aspects of KnowledgeWeb can be found at <http://knowledgeweb.semanticweb.org>

<sup>21</sup> <http://knowledgeweb.semanticweb.org/o2i/>

### 3.2 Analysis of Use Cases by Expert Estimations

A preliminary analysis of the use cases has been carried out in order to obtain a first vision of the current industrial needs and to estimate the expectations from knowledge based technology with respect to those needs. The industry experts were asked to indicate the existing legacy solutions in their use cases, the service functionalities they would be offered and the technological locks they encountered, and eventually how they expected that Semantic Web technology could resolve those locks. As a result, we have gained an overview of:

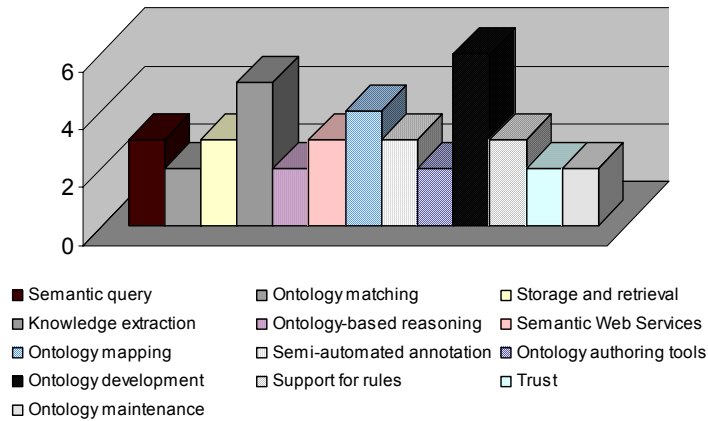
- Types of business or service problems where the knowledge-based technology is considered to bring a plausible solution;
- Types of technological issues (and *the corresponding research challenges*) which knowledge based technology is expected to overcome.



**Figure 2:** Preliminary vision for solutions sought in use cases

Figure 2 shows a breakdown of the areas in which the industry experts thought Semantic Web technology could provide a solution. For example, for nearly half of the collected use cases data integration and semantic search were areas where industry was looking for knowledge-based solutions. Other areas mentioned, in a quarter of use cases, were solutions to data management and personalization.

Figure 3 shows a breakdown of the technology locks identified in the use cases. There are three technology locks which occur the most often in the collected use cases. These are: *ontology development*, i.e., modeling of a business domain, authoring, reusing existing ontologies; *knowledge extraction*, i.e., populating ontologies by extracting data from legacy systems; and *ontology matching*, i.e., resolving semantic heterogeneity among multiple ontologies.



**Figure 3:** Preliminary vision of technology locks in use cases

Below, we illustrate, with the help of a use case from our collection, how a concrete business problem can also be used to indicate the technology locks for which knowledge-based solutions potentially might be useful. This use case addresses the problem of an intelligent search of documents in the corporate data of a coffee company.

The company generates a large amount of internal data and its employees encounter difficulties in finding the data they need for the research and development of new solutions. The aim is to improve the quality of the document retrieval and to enable personalization services for individual users when searching or viewing the corporate data. As technology locks, the expert mentioned here the corporate domain *ontology development* and *maintenance*, and *semantic querying*.

Eventually, this analysis (by experts estimations) provides us with a preliminary understanding of scope of the current industrial needs and concrete technology locks where knowledge-based technology is expected to provide a plausible solution. However, to be able to answer specific industrial requirements, we need to conduct further a detailed technical analysis of the use cases, thereby associating to each technology lock a concrete knowledge processing task and a component realizing its functionalities.

### 3.3 Knowledge Processing Tasks and Components

Based on the knowledge processing needs identified during the technical use cases analysis [12], we built a typology of knowledge processing tasks and a library of high level components for realizing those tasks, see Table 1.

Our first tentative typology includes 12 knowledge processing tasks. Let us discuss knowledge processing tasks and components of Table 1 in more detail.



N°	Knowledge processing tasks	Components
1	Ontology Management	Ontology Manager
2	Matching	Match Manager
3	Matching results Analysis	Match Manager
4	Data Translation	Wrapper
5	Results Reconciliation	Results Reconciler
6	Composition of Web Services	Planner
7	Content Annotation	Annotation manager
8	Reasoning	Reasoner
9	Semantic Query Processing	Query Processor
10	Schema/Ontology Merging	Ontology Manager
11	Producing explanations	Match Manager
12	Personalization	Profiler

**Table 1.** Typology of knowledge processing tasks & components

**Ontology Management, Schema/Ontology Merging and Ontology Manager.**

These tasks and components are in charge of ontology maintenance (e.g., reorganizing taxonomies, resolving name conflicts, browsing ontologies, editing concepts) and merging multiple ontologies (e.g., by taking the union of the axioms) with respect to evolving business case requirements, see [13, 14, 15].

**Matching, Matching Results Analysis, Producing Explanations and Match Manager.** These tasks and components are in charge of (on-the-fly and semi-automatic) determining semantic mappings between the entities of multiple schemas, classifications, and ontologies, see [16, 17]. Mappings are typically specified with the help of a similarity relation which can be either in the form of a coefficient rating match quality in the [0,1] range (i.e., the higher the coefficient, the higher the similarity between the entities, see [18,19,20,21,22]) or in the form of a logical relation (e.g., equivalence, subsumption), see [23, 24]. The mappings might need to be ordered according to some criteria, see [25, 21].

Finally, explanations of the mappings might be also required, see [26, 27]. Matching systems may produce mappings that may not be intuitively obvious to human users. In order for users to trust the mappings (and thus use them), they need information about them. They need access to the sources that were used to determine semantic correspondences between terms and potentially they need to understand how deductions/ manipulations are performed. The issue here is to present explanations in a simple and clear way to the user.

**Data Translation and Wrapper.** This task and component is in charge of automatic manipulation (e.g., translation, exchange) of instances between heterogeneous information sources storing their data in different formats (e.g., RDF, SQL DDL, XML), see [28, 29]. Here, mappings are taken as input (for example, from the match manager component) and are analyzed in order to generate query expressions that perform the required manipulations with data instances.

**Results Reconciliation and Results Reconciler.** This task and component is in charge of determining an optimal solution, in terms of contents (no information duplication, etc.) and routing performance, for returning results from the queried information sources, see [30].

**Composition of Web Services and Planner.** This task and component is in charge of automated composition of web services into executable processes, see [31]. Composed web services perform new functionalities by interacting with pre-existing services that are published on the Web.

**Content Annotation and Annotation Manager.** This task and component is in charge of automatic production of metadata for the contents, see [32]. Annotation manager takes as input the (pre-processed) contents and domain knowledge and produces as output a database of content annotations. In addition to the automatic production of content metadata, prompt mechanisms should enable the user with a possibility to enrich the content annotation by adding some extra information (e.g., title, name of a location, title of an event, names of people) that could not be automatically detected.

**Reasoning and Reasoner.** This task and component is in charge of providing logical reasoning services (e.g., subsumption, concept satisfiability, instance checking tests), see [33]. For example, when dealing with multimedia annotations, logical reasoning can be exploited in order to check consistency of the annotations against the set of spatial (e.g., left, right, above, adjacent, overlaps) and temporal (e.g., before, after, during, co-start, co-end) constraints. Thus, this must certify that the objects detected in the multimedia content correspond semantically to the concepts defined in the domain ontology. For example, in the racing domain, the automated analyzer should check whether a car is located above a road or whether the grass and sand are adjacent to the road.

**Semantic Query Processing and Query Processor.** This task and component is in charge of rewriting a query by using terms which are explicitly specified in the model of domain knowledge in order to provide a semantics-preserving query answering, see [32, 34]. Examples of queries are “Give me all the games played on grass” or “Give me all the games of double players”, in the tennis domain. Finally, users should be able to query by a sample image. In this case, the system should perform an intelligent search of images and videos (e.g., by using semantic annotations) where, for example, the same event or type of activity takes place.

**Personalization and Profiler.** This task and component is in charge of tailoring services available from the system to the specificity of each user, see [35]. For example, generation and updating of user profiles, recommendation generation, inferring user preferences, and so on. For example users might want to share annotations within trusted user networks, thus having services of personal metadata management and contact’s recommender. Also, a particular form of personalization, which is media adaptation, requires knowledge-based technology for a suitable delivery of the contents to the user’s terminal (e.g., palm, mobile phone, portable PC).

## 4. Conclusions and future work

The most relevant former initiative to our efforts is IST-FP5 Ontoweb (2001-2004). It formed a special interest group (SIG) on Industrial Applications<sup>22</sup> which collected over 50 use cases. However, the majority of those use cases dealt with technology and solution producers rather than potential adopters of the technology. Ontoweb achieved a good overview of the main roadblocks on the way towards a successful transfer of knowledge-based technology to industry and namely on two key business areas: KM and E-Commerce. Based on those foundations, the subsequent IST-FP6 Network of Excellence KnowledgeWeb (2004-2007), has continued the Ontoweb initiative with the inclusion of client industry partners organized in economical sectors (Automotive, Energy, Healthcare, etc.) and by going into the detail of each particular business case, targeting at (i) collecting industry needs from potential client industry with a specific focus on a few most promising sectors; (ii) identifying the key processing components emerging from the concrete needs analysis; (iii) evaluating research and technology for answering industry needs; (iv) making recommendations through best-of-class guidelines; (v) providing education for practitioners via competence centers, thereby enabling the transfer of a technology know-how.

In this paper we have reported in a first part of the paper on our main conclusions from the past Ontoweb initiative and in a second part on some current results on the first two topics as addressed by the Industry area of the running NoE Knowledge Web initiative. By a preliminary analysis of the collected use cases we categorized the types of solutions being sought for, and the types of technological locks which arise when realizing those solutions. By a detailed technical analysis of the selected use cases we identified precisely where in the business processes the technology locks occur, described the requirements for technological solutions that overcome those locks, and argued for the appropriateness of knowledge-based solutions. Moreover, a quick analysis of the other business cases of [11] have shown that most of the knowledge processing tasks of Table 1 repeat with some variations/specificity from use case to use case. This observation suggests that the constructed typology is stable, i.e., it contains (most of) the core knowledge processing tasks stipulated by the current industry needs. By identifying concrete industry needs through tasks and components, we link them to specific research challenges which we expect the Semantic Web researchers to focus on. As such components are made available from the research, it is possible to evaluate them in different industry-strength settings, and therefore, estimate their practical impact and a contribution to the industrial uptake of Semantic Web technology.

With the emergence of new business cases it is likely that new knowledge processing tasks will appear. For example, web service discovery, orchestration, and so on. Thus, future work includes continuing to collect business cases and to carry out their technical analysis until the saturation is reached.

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<sup>22</sup> <http://ago.sig4.fr>

Although pursuing the collection of use cases and so the understanding of the business needs we are now focusing our effort on the following domains: healthcare, cultural heritage, KM and Human Resources.

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