Knowledge web: realising the semantic web... all the way to knowledge-enhanced multimedia documents

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KNOWLEDGE WEB: REALISING THE SEMANTIC WEB… ALL THE WAY TO KNOWLEDGE ENHANCED MULTIMEDIA DOCUMENTS[†]

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The semantic web and semantic web services are major efforts in order to spread and to integrate knowledge technology to the whole web. The Knowledge Web network of excellence aims at supporting their developments at the best and largest European level and supporting industry in adopting them. It especially investigates the solution of scalability, heterogeneity and dynamics obstacles to the full development of the semantic web. We explain how Knowledge Web results should benefit knowledge-enhanced multimedia applications.

1. Introduction

The current World Wide Web (WWW) is, by its function, a syntactic web where the structure of the content has been expressed while the content itself is inaccessible to computers. Although the WWW has resulted in a revolution in information exchange among computer applications, it still cannot provide interoperation among various applications without some pre-existing, human-created agreements outside the web. This applies to multimedia documents as well as classical web documents for two reasons: First because these are easier to produce, compose and exchange each day; but mainly because the conceptual content to be extracted from a multimedia document is not usually expressed in a symbolic language like text is.

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Nowadays, when a user wants to search some information on the web, she receives a huge amount of irrelevant information and faces the task of going through all the results in order to identify what information is useful for her. Finding the cheapest version of a music CD, or finding a hotel in a given city with some price restrictions, implies surfing a big amount of web sites or designing parsers and brokers which are very quickly obsolete. Multimedia documents are even more difficult to find.

The next generation of the web, the semantic web [1, 5], aims to alleviate such problems and provide specific solutions targeting concrete problems. Web resources will be more readily accessible by both human and computers with the added semantic information in a machine-understandable and machine-processable fashion. The degree of formality employed in capturing these descriptions can be quite variable, ranging from natural language to logical formalisms, but increased formality and regularity clearly facilitate machine understanding.

Similarly, web services can significantly increase the potential of the web architecture. However, in their current state of development they fail to fulfil their vision. First, current technology provides limited support in mechanizing service recognition, service configuration and combination (i.e., realizing complex workflows and business logics with web services), service comparison and automated negotiation. All these features are required by e-commerce applications. Second, all the given service descriptions are based on semi-formal descriptions. Therefore, the human programmer needs to be kept in the loop and the scalability as well as economy of web services is limited. Keeping the human in the loop prevents scalability, maturity, and economy in price. Bringing web services to their full potential requires their combination with semantic web technology.

Semantic web services 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 done. The following elements are necessary to enable efficient inter-enterprise execution: Public process description and advertisement; discovery of services; selection of services; composition of services; and delivery, monitoring and contract negotiation.

The semantic web has the potential to significantly change our daily life due to the hidden intelligence provided for accessing services and large volumes of information. By adding explicit and machine-processable semantics, the semantic web will bring the web to a new level. Users will specify their needs in an explicit and machine-understandable manner. *The hidden intelligence of* *the semantic web will help to provide only the results that are relevant to the user*.

The semantic web will have a much higher impact on e-work and e-commerce than the current version of the web. Explicit semantics will enable the automatic and dynamic location, composition and interoperation of web services, *dramatically reducing the cost of e-work and e-commerce solutions and improving their flexibility*.

Nonetheless, there is a long way to go to transform the semantic web from an academic adventure into a technology provided by the software industry. *Supporting this transition process of ontology technology from academia to industry is the main and major goal of Knowledge Web*.

2. Objectives of Knowledge Web

Knowledge Web[c] is a FP6 Network of Excellence which counts with 18 participants including leading partners in semantic web, multimedia, human language technology, workflow and agents.

In a nutshell, the mission of Knowledge Web is to strengthen the European industry and service providers in one of the most important areas of current computer technology: Semantic web enabled e-work and e-commerce. This network of excellence aims at achieving relevant results for the development of semantic web and semantic web services and their transfer to the European industry.

The project concentrates its efforts around the outreach of this technology to industry. Naturally, this includes education and research efforts to ensure the durability of impact and support of industry. Therefore, Knowledge Web devotes its efforts to the three areas, as can be seen in Figure 1:

[c] http://knowledgeweb.semanticweb.org/

Figure 1. Knowledge Web Areas.

In the following, we summarize the major results expected from the Knowledge Web activities in each of these areas.

2.1. *Outreach to Industry*

The main objective of Knowledge Web's outreach to industry area is to promote greater awareness and faster take-up of semantic web technology within Europe in full synergy with the research activity, in order to reduce time needed to transfer the technology to industry and, therefore, to market.

In the increasingly competitive knowledge-intensive economy, the search for competitive advantage creates a pressing need for evaluating the contribution to value creation of any new technologies and specifically the ones that are potentially disruptive. This is especially true of information technology and knowledge-intensive applications for which this value creation is not always clear and easy to justify. Outreach to industry has the objective of providing awareness, bridge building, cross-fertilization, software framework and industry-enabling services to boost opportunities for market take-up of the key results of semantic web technology. The key focus is on accelerating the rate of the technology transfer from research.

The activities of the industrial area will lead to the recommendation of an ontology language, tool, and methodology set that covers all the major tasks in working with ontologies and to the development of standards that will help to solve the interoperability problem. Benchmarking, compliance testing, usage scenarios, cook-book style textbooks with best practices, and definition of tool environments based on loosely coupled web services will also result from the outreach to industry activities of Knowledge Web.

Contributing to the creation of an Ontology Outreach Authority and the elaboration of a consortium for sharing the tools developed within Knowledge Web is seen as one of the main durable structures that can be proposed to industry. It is also expected that Integrated Projects which may grow out of the network will provide sustainable activity for industry.

2.2. *Outreach to Education*

If the European workforce is to establish and hold a lead in the use of semantic web technologies, it is absolutely vital that the means for educating the next generation of semantic web application developers and researchers are in place. Moreover, since learning can take place in a variety of contexts, training courses for professionals in industry have to be provided. The objective of Knowledge Web is to work towards the establishment of a Virtual Institute for Semantic Web Education (VISWE) which will act as the principal focus for educational activities on semantic web.

The establishment of VISWE will include the provision of up to date learning materials, curricula and, ultimately, new degree programmes, and will provide enhanced delivery of course materials by making use of novel semantic web technologies in combination with more traditional e-learning environments.

VISWE will eventually create a well-trained European workforce, also guaranteeing some homogeneity within this workforce, which will be a benefit, both to research and industry. This will include training with the tools developed in the research and industry activities, spreading methodology and best practices, and establishing teaching standards.

Several high level educational institutions will guarantee that the proposed curriculum persist as long as it is necessary (or necessary at the European level).

2.3. *Coordination of Research*

The leading position of Europe can only be maintained and strengthened by continuing to perform cutting edge research. The objective of Knowledge Web is to ensure that the research as performed by the leading groups in this area will be sufficiently coordinated to avoid both duplication and fragmentation. Such coordination is particularly important for the semantic web: since it is an inter-disciplinary area, joint collaborations among and across various research communities is necessary. The objective of Knowledge Web is to coordinate the European research effort to make semantic web and semantic web services [7] a reality.

The links already established between a wide core of scientific and technological experts in the research and development area of ontologies and the semantic web will be made more explicit and tightened through the Virtual Research Centre and the Joint Programme of Activities of Knowledge Web.

Research is carried out in such a way that a European critical mass will be available for taking advantage of and enhancing the results. The dissemination of research results is achieved through many different instruments, including publications, norms (many Knowledge Web members are members of normative efforts, W3C WebOnt[d], RDFCore[e] and they are in contact with other institutions, e.g. FIPA[f]), the Knowledge Web semantic portal, lectures given to VISWE, and industry seminars and tutorials.

Furthermore, Knowledge Web encourages mobility, which is expected to provide a wider recruitment pool for research institutions.

2.4. *Contribution to Standards*

Knowledge Web continues and extends standardization efforts through the involvement in new W3C activities with respect to semantic web education and outreach (e.g. W3C Semantic Web Best Practices Interest Group), the initiative to develop a UML profile for ontologies from the Object Management Group (OMG), linking between ontologies and topic maps, ontology query and rule languages, web services at W3C, and linking between ontologies and multimedia.

2.5. *European integration*

The integration efforts of Knowledge Web go beyond the partners integrating the Knowledge Web consortium. Knowledge Web is part of the SDK project cluster[g], which counts with two other important EU-funded projects in the areas of semantic web and semantic web services, namely: SEKT[h] and DIP[i].

The SDK cluster has the ultimate goal of providing international standards for semantic web and semantic web services, in cooperation with the US-based DAML[j] initiative. The participation of Knowledge Web in the cluster ensures the cooperation in this area with both European and US efforts.

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[d] http://www.w3.org/2001/sw/WebOnt/
[e] http://www.w3.org/2001/sw/RDFCore/
[f] http://www.fipa.org/
[g] http://www.sdk-cluster.org/
[h] http://sekt.semanticweb.org/
[i] http://dip.semanticweb.org/
[j] http://www.daml.org/

Knowledge Web also develops formal close cooperation with other FP6 projects. It especially has contact with the Rewerse[k] network of excellence dedicated to the development of reasoning languages for the web.

3. A research perspective

Knowledge Web research activities address the major scientific concerns with respect to the implementation of a semantic web and the design of semantic web services. It aims at transforming ontology technology into a mature technology for the semantic web. The emphasis here is on large ontologies with several tens to hundred thousands of definitions; on heterogeneous ontologies with conflicting definitions; and on ontologies that keep changing depending on the underlying reality and design rationales.

We focus on these three main aspects for realizing the semantic web: scalability, heterogeneity, and dynamics. These topics are not the whole semantic web, but deal with serious challenges to its availability that require research by not just one team but a community of European researchers. Knowledge Web has decided to concentrate its attention on these challenges, and to additionally contribute to the development of appropriate rule and query languages for the semantic web. Our goal is to address these issues convincingly so that results can be progressively transferred to the industrial part of the network.

Together with these three areas, our work focuses on applying them to one of the key application domains for semantic web technologies: semantic web services.

3.1. *Scalability*

In order to deal with the envisaged volumes of information, new technologies will be required. We focus on knowledge process and ontology-based tool benchmarking. Related to knowledge process, we explore new techniques for approximation (in order to reduce computational costs) and modularity (in order to reduce the amount of information that must be taken into account). Related to benchmarking, we will compare several types of ontology based tools and tool suites. We will define a methodology, general and specific criteria, test beds, and prototypes of tools to be used on the benchmark.

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[k] http://www.rewerse.net

Approximation: Current proposals for the foundational languages of the semantic web (RDF Schema, DAML+OIL, OWL) are all based on formal logic. This is a strength because of the well-foundedness of the languages. However, the expected size of the future semantic web will be orders of magnitude larger than anything that traditional logical inference mechanisms can deal with. We will provide a set of techniques in order to reconcile the logical foundations of the semantic web with the requirements for robust and scalable reasoning, namely: Knowledge Compilation, Language Weakening and Approximate Deduction. These techniques are studied, implemented, further researched and benchmarked by the evaluation activity in order to retain the most adequate set of techniques in particular contexts.

Modularisation: We are aiming at the development of proper ontological modules, which will provide a mechanism for packaging coherent sets of concepts, relations and axioms, and a means for reusing these sets in new environments. To enable the reuse of such modules, a description of the competence of their components is necessary, e.g., language choices and commitments to paradigms and modelling styles. Modularization also requires the specification of mechanisms to construct new ontologies from modules, e.g., inclusion mechanisms, mapping rules and redefinition methods. As an ontology may be built up from other ontologies written in different representation languages, the characterization of modelling primitives in languages may also be necessary. We will develop mechanisms to define and to describe ontology modules and to construct new ontologies from such modules.

Benchmarking: Benchmarking of tools and systems is used to compare systems and to measure the progress of research on an objective basis. We will benchmark different types of ontology-based tools and tool suites to be used on the semantic web. We focus on ontology development platforms, annotation tools and the querying and inference engines attached to them.

3.2. *Heterogeneity*

Business integration and web services collaboration (and more generally the semantic web) require the use of heterogeneous ontologies, which, in turn, describe heterogeneous data. There are many sources of heterogeneity: differences of terminology (the same concept can be given different names in two ontologies), differences of modelling (the same concept can be defined in different ways), or differences of knowledge representation languages (a concept cannot be defined as precisely in a language as in another). Semantic interoperability can be grounded in ontology reconciliation: finding relationships between concepts belonging to different ontologies (alignment) and implementing the operator (transformation or merge). We thus focus on the development of these two aspects.

Alignment of ontologies: Be it for ontologies defined over the same language or not, finding correspondence between ontologies, i.e., aligning ontologies is a major task. We are developing a framework for integrating and comparing research results on the many existing alignment efforts with different techniques. This common framework enables the comparison between the various efforts, cooperation between these efforts (i.e., interoperability of the tools), and standardized exploitation of the results in tools for transforming and merging. Current efforts are based on terminological, structural, statistic and model-theoretic techniques that we want to collaborate in order to improve alignment results. These techniques will be implemented into tools for diagnosing misalignments and expected mismatch; creating the alignment data, e.g., for quickly integrating a new resource in an application; and documenting the alignment in order to be used by agents (e.g., for negotiating content, see Dynamics). Once the alignment has been performed, it can be operated as a transformation or as a merging operator.

Transformation and merging: Merging ontologies, transforming messages or mediating queries are very important for interoperability. All these actions can be based on an underlying alignment. Instead of directly producing one of these operators, we have defined a format for expressing the alignment [3] from which it is be possible to produce either a set of transformation rules or a bridging theory. This is be useful for comparing the output of alignment algorithms and benefit all these techniques by offering them the opportunity to be used in all the applications. Last, there is a need for tools that can support semantic web development by providing transformation and merging processing. There are several ways to produce this from providing a transformation language and processing model for RDF (what XSLT is for XML) or using a rule language (such as those developed by Language extensions). Once such a language is defined, the proponents will be able to provide interpreters or compilers for these languages that can be used in the semantic web framework.

3.3. *Dynamics*

Today, ontologies are used as a means of exchanging meaning between different agents. They can only provide this if they reflect an inter-subject consensus and if their content is right. By definition, they can only be the result of a social process. This gives ontologies a dual status for the exchange of meaning. Ontologies are thus as much a pre-requisite for consensus and information sharing, as they are the results of them. For this reason, we need protocols for dealing with evolving ontologies. This is studied under the light of evolution and meaning negotiation.

Evolution: Large ontologies are often developed by several persons and continue to evolve over time. Both the development and the maintenance of ontologies require advanced versioning methods and guidelines for cooperative development. We develop a versioning and development framework for ontologies. The framework will provide methods to disambiguate the interpretation of concepts for users of ontology revisions, and it will make explicit the compatibility of various revisions and their impact on conforming data.

Meaning Negotiation: Another aspect of dynamic ontologies relates to the fact that agents will inevitably encounter agents with a different ontological history. Successfully interacting with such agents requires the ability to reach a dynamic consensus on a shared ontology while maintaining the integrity of the agent's original ontology base, and while extending capabilities to adapt to new concepts, facts, and protocols. For that purpose we will present protocols able to take advantage of alignments provided by Heterogeneity.

3.4. *Semantic web services*

Web services have added a new level of functionality to the current web, making the first step to achieve seamless integration of distributed components. Nevertheless, current web service technologies only describe the syntactical aspects of a web service and, therefore, only provide a set of rigid services that cannot adapt to a changing environment without human intervention. The human programmer has to be kept in the loop and scalability as well as economy of web services are limited [4]. The vision of semantic web services is to describe the various aspects of a web service using explicit, machine-understandable semantics, enabling the automatic location, combination and use of web services. The work in the area of semantic web is being applied to web services in order to keep the intervention of the human user to the minimum. Semantic mark-up is exploited to automate the tasks of discovering services, executing them, composing them and enabling seamless interoperation between them [2], thus providing what are also called intelligent web services. The description of web services in a machine-understandable fashion is expected to have a great impact in areas of e-commerce and enterprise application integration, as it can enable dynamic, scalable and reusable cooperation between different systems and organizations.

For these reasons, we place a special emphasis on semantic web services, because they encompass a number of strategic problems. All of these problems

are also relevant for other areas (knowledge management, e-commerce, mobile information, etc.), but placing all research topics around a common joint focus helps to foster joint work, and ensure the building of momentum towards a virtual cross-Europe research centre, much more so than with each group investigating these problems in a different setting.
Additionally, within this activity we develop techniques permitting the integration of agent-based services as semantic web services. Specific services include intelligent middle agents/broker services and semantic routers, argumentation/negotiation services, dynamic coordination, and the dynamic reconfiguration of software organizations and services.

3.5. *Languages*

A layered language architecture has always been envisaged for the semantic web, and although the ontology language layer will be sufficient for some applications, extensions to the language will certainly be required by other applications. The objectives of Knowledge Web in the languages area are to identify precise requirements for new languages and language extensions, and to represent the interests of the Knowledge Web network in the development and standardization of such languages. We work within Knowledge Web and with other relevant networks, in order to identify precise requirements for new languages and language extensions, and to represent the interests of the Knowledge Web network in the development and standardisation of such languages and language extensions. In particular, we currently focus on two aspects:
Rule Languages: The requirement for rule languages has long since been identified. We work with groups involved in the development and standardization of semantic web rule languages (e.g., the RuleML Mark-up Initiative and the REWERSE network of excellence). One such cooperation has already been initiated within the Joint US/EU ad hoc Agent Mark-up Language Committee, and it is anticipated that this work will lead in due course to the establishment of a W3C standardization working group.
Query Language: The requirement for a query language has also been recognized, and work in this area has also begun within the Joint US/EU ad hoc Agent Mark-up Language Committee. This has resulted in a preliminary proposal for a language and protocol supporting agent to agent query answering dialogues using knowledge represented in OWL.

4. Integration of knowledge into multimedia objects

While Knowledge Web focuses on semantic web and services, the developed technologies are available for the semantic web as a whole and should apply to Knowledge enhanced multimedia applications [10].

On the semantic web side, tools are being built, and some standards are in place and others are being developed, to which Knowledge Web will actively contribute. However, there is an obvious need these days for models (ontologies) and, above all, data. On the multimedia side, one of the key challenges is to facilitate content search. This need is increasing because the production of digital content, mono or multimedia is becoming easier and, therefore, increasing each day. This applies to digital pictures or music as well as to administrative documents.

From that situation, the important point is to be able to produce content with knowledge and knowledge with content and deal with it. This highly relevant issue can be considered on the research aspect:

— how to articulate knowledge and content so that none is a burden for the other. This raises issues like the format and ontologies for multimedia documents.
— how to compose and correctly analyze content with knowledge. For example, while it is easy to include a movie in a multimedia presentation, the question of how to capture and exploit the knowledge contained in it arises.

These issues are considered by many different projects (e.g. AceMedia[1]). Our point here is to present how the achievements of a project like Knowledge Web (as well as the already available technology for the semantic web) could be used for achieving the goals of multimedia projects and for integrating their results within a wider semantic web (as well as any individual's device or merchant's business). For each Knowledge Web research direction, we mention its relevance to knowledge-enhanced multimedia documents.

Languages and ontologies in multimedia objects: Raw media use various techniques for attaching metadata (e.g., ID3 tags in MP3 audio, EXIF/ICPT tags in pictures). Composite multimedia descriptions like MPEG-7 [8] do provide an extensible framework for defining descriptors. However, none of these do really integrate within the semantic web. One important property of a format like RDF is its openness: the possibility of always better qualifying knowledge and of freely merging two descriptions for obtaining a new valid description. Recent work has been produced for integrating the two words in a

[1] http://www.acemedia.org

coherent way [6, 9]. This work should be consolidated in order to take advantage of tools developed for the semantic web with knowledge-enhanced multimedia documents.

Moreover, the language extensions proposed in knowledge web (queries and rules over languages like OWL) can greatly benefit multimedia projects. Queries will be useful for searching multimedia databases on knowledge-based criterion. Rules will certainly be a key feature for expressing knowledge composition associated to multimedia documents composition (see below).

Scalability of knowledge based multimedia: Work on multimedia is ahead in dealing with scalability through compression, progressive rendering and adaptation of multimedia documents. All these techniques could be sources of inspiration on the front of scalability.

Enhancing multimedia objects with knowledge will also require the help of techniques for dealing with scalability developed for knowledge based systems. Indeed, knowledge never comes in isolation. The answer to a query can require a vast amount of background knowledge. Methods will be needed to deal with them efficiently (for instance, by progressively filtering results based on the more delicate parts of the query or by providing first the easy answers while digging in the background).

Overcoming heterogeneity: Of course, no one will pretend that the work mentioned above will provide the unique and definitive ontology for dealing with multimedia elements. Hence, composing multimedia documents or consolidating a document base from various sources will require dealing with heterogeneity of knowledge description. Knowledge Web will provide tools for ontology reconciliation that can be used for overcoming the heterogeneity of annotations.

Dynamics: One thing is to annotate raw documents, another is to compose these annotations when more elaborate documents are designed. For instance, does the concurrent display of two series of still images or movies of animals from one continent yield a document about animals from one continent? Not in general. Composition rules on knowledge can be expressed as they are expressed from raw data, but they are domain dependent. This requires a language for expressing the dynamic composition of documents. The extension of ontology languages to rules seems to be a good candidate for such a task.

Knowledge can also be used for generating a multimedia description from raw data depending on the annotations they carry. Here again, deductive capabilities (rules and/or queries) can be used.

Moreover, the ability of some multimedia objects (e.g., pictures) to be covered by several concepts can be used for meaning negotiation between agents, and especially humans in order to make ontologies evolve with their understanding. In this case the negotiation can be either driven by media or by knowledge.

Multimedia objects in semantic web services The achievement of these research trends will enable viable semantic web services. Having knowledge enhanced multimedia objects based on the same technology will help them being integrated within the future semantic web applications. Of course, these multimedia objects could be more relevantly retrieved on the base of their content and thus then will be sold more easily. Moreover, the multimedia composition mechanism could be embedded in the semantic web service infrastructure and the answer to a service invocation could be a multimedia document generated on the fly.

5. Conclusions

We have presented Knowledge Web, a network of excellence whose goal is to realise the semantic web and semantic web services and to facilitate their transfer to industry. Knowledge Web aims at steering the efforts towards helping Europe to keep its leading position in knowledge-based networked solutions that should lead us towards a semantic web.

The exiting perspective of having knowledge embedded within multimedia objects extends the possible reach of the semantic web inside multimedia documents. It should help the semantic web to improve its precision and presentation and help multimedia management to be more relevant. However, knowledge-enhanced multimedia objects raise new challenges tied to knowledge manipulation and joint knowledge and media manipulation.

We have presented how the research coordinated by Knowledge Web is also relevant to knowledge-enhanced multimedia objects as well as essential to their integration in the future applications of the web.

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