Periodic Progress Report N°: 2

Covering period 1/1/2003 – 31/12/2003

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WonderWeb Project

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Contents

Executive summary

The project is proceeding according to plan, and many of its key objectives have already been met, including standardisation of the OWL ontology language, the development of the KAON server and ontology engineering environment (an early prototype of which was demonstrated at the first project review), the development of the WonderWeb ontology library, and the development of an ontology modularisation framework. Significant results above and beyond the stated objectives of the project have also been achieved, e.g., the development of techniques for the semi-automatic annotation of dynamic Web sites and the investigation of alternative reasoning techniques.

Members of the consortium have continued to make a key contribution to the development and standardisation of the OWL web ontology language, which is now a W3C proposed recommendation and is imminently expected to achieve full recommendation status. WonderWeb consortium members have also been central to ongoing language development efforts, including proposals for a rules language extension to OWL (soon to become a W3C Note) and a query language for OWL, as well as being involved in discussions regarding the formation of new working groups to study the development and deployment of ontologies.

As far as tools and services are concerned, this period has seen the completion of the KAON server, and the integration of a wide range of software components (editors, reasoners etc.). A completely new inference engine has also been developed in order to provide improved reasoning services for OWL applications. The result is a powerful and extensible ontology development environment.

Complementing the KAON server and tools is the WonderWeb ontology library, a rich collection of foundational ontologies and domain specific extensions. As well as the DOLCE ontology, the library now includes two more foundational ontologies (OCHRE and BFO), and extensions covering areas such as *web services*, *plans* and *descriptions and situations*. Work is also underway on a review of the current state of the art in ontology design methodologies, with a view to characterising the notion of ontology quality, and to identifying useful design patterns.

Finally, work on ontology engineering methodologies has focused on the extension of previous results on change management, in particular to deal with distributed ontologies, and on web service ontologies. A formal framework for representing and reasoning about modular ontologies has also been developed, and automated methods for splitting up large ontologies into modules are being studied.

Project organisation and management has continued to work well, with regular meetings and exchanges of personnel between sites. A second successful meeting of the Industrial Advisory Board (IAB) was also held in October in conjunction with the International Semantic Web Conference. Numerous papers describing the work carried out in the project have been published, including several joint papers resulting from cooperations between various project partners and IAB members.

The goal of the next period will be to complete the work on language extensions, and on ontology engineering services and methodologies. We are confident that the next six months will also continue to see exciting new developments not envisaged in the technical annex.

Work progress overview

Objectives

The goal of the project is to develop a methodology and toolkit supporting Web based ontological engineering. In the second year, many of the key objectives of the project have been achieved, or even exceeded:

- the OWL language is now a W3C standard, and is already being widely adopted;
- work on language extensions is well underway, with a rules language proposal soon to become a W3C note;
- the KAON server has been completed, along with a range of software components which together provide a complete ontology development environment;
- complementing the KAON server is the WonderWeb ontology library, which by now includes a rich collection of foundational and domain specific ontologies;
- engineering methodologies have been developed to deal with issues such as change management in distributed ontologies, and the modularisation of ontologies;
- the IAB has continued to provide useful feedback and testing of the languages, tools, ontologies and methodologies developed in the project;
- results from the project have been published widely and have had a major impact on the development of web based ontology engineering.

Progress

The project is well on track, and has exceeded expectations in several respects. All deliverables have been produced on time (see Appendix A), and all milestones have been achieved.

Organisation

Project meetings were held in Amsterdam on the 15-17/01/03, in Trento on the 14–15/04/03, in Trento again on the 30/6–1/7/03, in Karlsruhe on the 29–30/09/03 and in Manchester on the 14-15/01/04. The next meeting will be held in Amsterdam on the 1–2/04/04.

The Project Management Board (Ian Horrocks (VUM), Frank van Harmelen (VUA), Steffen Staab (AIFB) and Nicola Guarino (ISTC-CNR)) met regularly at project meetings; these are open meetings, and both minutes and presentation materials are posted on the project web site.[1]

The project web site has proved a valuable resource, both within the project and as means of dissemination; project deliverables, publications and software are all available from the site.

[1] http://wonderweb.semanticweb.org/meetings.shtml

Activities

Workpackage 1: Language Architecture

Work on the development of the Ontology Language Layer has culminated in the standardisation (by the W3C) of the OWL ontology language. OWL has now achieved W3C proposed recommendation status, and is expected to become a full recommendation on February 10th, 2004.

Members of the consortium, including Sean Bechhofer (VUM), Frank van Harmelen (VUA), Ian Horrocks (VUM) and Raphael Volz (AIFB), have been active members of the W3C Web Ontology working group,[2] have made crucial contributions to the development of OWL, and have edited/authored several key documents including the Overview,[3] Reference[4] and Semantics and Abstract Syntax.[5] Bechhofer was also asked to produce a guide to parsing the OWL RDF/XML syntax, based on his experience developing (as part of the WonderWeb project) an OWL API [1], and this is now a W3C note.[6] In addition to the OWL language specification itself, this work is described in publications such as [7, 2].

Work on language extensions is now well underway and has resulted in the development of SWRL (a proposed rules language extension to OWL) and DQL (a proposed query language for OWL), with Horrocks (VUM) being a lead author of both proposals. This work is being carried out in cooperation with the DARPA DAML program and the Joint EU/US committee on agent markup languages,[7] of which both van Harmelen and Horrocks are members.

SWRL is soon to become a W3C Note, and will be an important input to a new W3C "Semantic Web Rules" working group that is to be established within the next twelve months. Detailed studies of the relationship between rules and description logics, and possible implementation pathways, have also been carried out. This included studying the possibility of translating a (maximal) fragment of the ontology language into Prolog, and investigating the extent to which the semantics of the ontology can be preserved. Volz (AIFB) has shown, by empirical assessment of available ontologies, that the fragment of the ontology language which can be fully expressed in Prolog is able to capture many realistic ontologies, and that use of rule-based reasoners for implementing reasoning in this fragment is a feasible alternative to native reasoners such as those developed in WP 2.4. The empirical assessment also showed that equality reasoning severely slows down rule-based reasoners, but suggested that the materialisation of entailements and the incremental maintenance thereof might be a possible means by which to regain acceptable performance. This work (which goes well beyond what was envisaged in the technical annex) is described in deliverable D2 and in publications such as [4, 6, 19, 22, 21].

Further language extensions that have been studied within the project include extended support for datatypes and predicates (e.g., arithmetic predicates), a more powerful

[2] http://www.w3.org/2001/sw/WebOnt/
[3] http://www.w3.org/TR/owl-features/
[4] http://www.w3.org/TR/owl-ref/
[5] http://www.w3.org/TR/owl-semantics/
[6] http://www.w3.org/TR/2004/NOTE-owl-parsing-20040121/
[7] http://www.daml.org/committee/

language for describing relationships between properties (e.g., complex role inclusion axioms), and the ability to use data values as database style keys. This work will be described in deliverable D3 (due in Month 30), and has already led to several important publications such as [13, 8, 10].

Workpackage 2: Tools and Services

The last year has seen significant work on the main organisational unit and infrastructure kernel of WonderWeb, i.e., the KAON server (aka. OntoServer). Although its design and development was based on existing Application Servers, we have applied and augmented their underlying concepts for easier use in the Semantic Web, and integrated semantic technology within the server itself in order to improve its flexibility and facilitate its use.

The KAON server's architecture has been extensively revised and improved for the demonstrator, which is described in deliverable D7 and in publications such as [12, 20]. The KAON server is open source, and is available from Sourceforge.[8] Deliverable D7 also includes a user's guide and shows how to start the server, work with the management console, deploy and discover components and how to work with client-side surrogates.

A combination of work on the KAON server, the OilEd editor and a syntax validator for the OWL ontology language has resulted in the development of the WonderWeb OWL API,[9] which provides programmatic access to data structures representing OWL ontologies [2]. The API is open source (it is also available from Sourceforge[10]) and is already seeing widespread adoption by OWL implementors.

In parallel with the work on the KAON server itself, work continued on the integration of software modules providing a variety of services to applications. These included the Sesame RDF store, the OntoEdit and OilEd editors, and the FaCT, Racer and Ontobroker reasoners (see deliverables D8, D9 and D10). The KAON server and the available set of software modules now provide a powerful ontology development environment that is highly flexible (e.g., provides multiple editors and reasoners), and yet at the same time fully integrated.

An important strand of the work in this workpackage has been the development of the new FaCT++ inference engine to support the OWL ontology language. A prototype of FaCT++ has now been completed (see deliverable D13). Compared to existing DL reasoners, the new engine employs a completely new architecture (it does not use the standard depth first tableau construction) that is better suited to more expressive languages, incorporates many new optimisations, supports integer and string datatypes (as specified in the OWL standard), and is written in C++ in order to combine efficiency with portability. The FaCT++ engine also has a DIG standard interface,[11] which makes it plug compatible with existing reasoners such as FaCT and Racer.

Further work on the OntoLift prototype has proceeded to an integrated scenario for bootstrapping ontologies that now includes a means to exploit the bootstrapping process for the semi-automatic annotation of dynamic Web sites, i.e., Web sites where Web

[8] http://sourceforge.net/projects/kaon-ext/
[9] http://owl.man.ac.uk/api.shtml
[10] http://sourceforge.net/projects/owlapi
[11] http://dl.kr.org/dig/

pages are generated from a database. This results in the so-called *deep annotation* of the database—either directly by annotation of the logical database schema, or indirectly by annotation of the Web presentation generated from the database contents. From this annotation, the OntoLift data mapping and/or migration steps can be executed, preparing the data for use in the Semantic Web.

Deep annotation will be important given that dynamic Web pages generated from databases outnumber static Web pages; it may also provide a very intuitive way to create semantic data from a database. This data can then be queried directly or materialised as RDF files. This work will be described in deliverable D12 (due in Month 30), and has already led to several important publications such as [18, 5]

Workpackage 3: Foundational Ontologies

The work in this workpackage consists of three main strands. The first of these is the review of current state of the art of ontology design methodologies. Particular attention has been given to two key problems: the problem of characterizing the notion of ontology quality and more specifically the problem of introducing formal frameworks for evaluating and comparing ontologies; and the problem of defining—on the basis of the primitives offered by the foundational ontologies and some additional "application oriented" extensions—ontology design patterns that are useful in specific "clusters" of applications. The result of this work will be presented in deliverable D16 (due in Month 27).

The second strand of work has been the development of the WonderWeb Foundational Ontology Library (WFOL). The final version of the library (described in deliverable D18) includes:

- The first order axiomatic characterization of three reference modules (called visions): OCHRE, BFO and a slightly improved version of DOLCE. These visions have been informally compared to each other on the basis of the major ontological design options discussed in the Ontology Roadmap deliverable (D15).
- Two new extensions of DOLCE: the ontology of "Descriptions and Situations" (D&S), and a minimal ontology of plans (PO).
- An ontology of web services (WSO) based on D&S and PO.
- Machine-readable encodings of several library modules, including KIF versions of DOLCE, D&S, PO and OCHRE, and OWL versions of DOLCE, D&S, PO and WSO.
- An example illustrating the importance and complexity of formal "semantic links" ("semantic mappings") between modules: a part of DOLCE has been formally translated into OCHRE.
- A mapping between DOLCE+D&S+PO and the English version of WordNet. This is particularly relevant for two reasons: it provides a bridge between ontologies and natural languages which is particularly useful in applications, and it contributes to the improvement of the ontological structure of lexical resources.

The final strand of work has been involvement in standardisation efforts. ISTC-CNR have closely monitored discussions on the IEEE-SUO mailing list, where work from the WonderWeb project has been mentioned many times. The DOLCE ontology, together with other foundational ontologies, is also being officially considered among the input resources for a proposed W3C "Semantic-Web Best Practices and Deployment" (SWBPD) Working Group. Work in this area is ongoing.

Workpackage 4: Ontology Engineering

In the last year, work has focussed on the extension of previous results on change management for ontologies and on the acquisition, representation and use of web service semantics. While the first topic covers the proposed work in WP 4, the work on web service semantics goes beyond what is envisaged in the technical annex, addressing some new challenges identified in the course of the project.

In the area of evolution management, foundational work has been carried out to extending the results on change management to distributed ontologies. The methods reported in deliverable D20 have been extended into a general methodology for change management [9], which has been adapted to the Protégé Knowledge Model and integrated into the Protégé Ontology Editor. The Protégé group has also independently developed a special plugin for the OntoClean methodology, developed at ISTC-CNR before the beginning of the project and integrated with the general methodology to be presented in Deliverable D26. A similar plugin has also been incorporated in the WebOde tool, developed at the Technical University of Madrid.

As a response to the weaknesses of the modularization and import mechanisms provided by OWL, a formal framework for representing and reasoning about modular ontologies has been developed based on the notion of distributed description logics. It has also been shown that the change management framework can be used to check the integrity of distributed modules in the presence of change. The framework has been applied in the setting of the case study presented at the last review meeting. This work is described in deliverable D21 and publications such as [15, 16].

Current work addresses the development of automatic methods for splitting up large ontologies into a set of modules. This work will be continued in the remainder of the project, and the potential use of ontological principles in the design of DOLCE will be investigated in cooperation between VUA and ISTC-CNR.

In the area of Web Service Semantics, the use of semantic web technology for modelling the functionality of semantic web tools has been investigated in a cooperation between VUA and AIFB. The use case presented at the first review meeting has been used as a scenario for this investigation. The resulting component ontology has been integrated into the KAON server where it is used to support the automatic selection of components.

Further investigations concerned the use of the DAML-S (recently renamed OWL-S) services ontology[12] for representing the functionality of semantic web tools. First experiments revealed shortcomings in DAML-S w.r.t. capturing some system features. Beyond that, the conceptual design of DAML-S has been analyzed by aligning it to DOLCE,

[12] http://www.daml.org/services/owl-s/1.0/

revealing conceptual problems as well. As a result of this work, members of the WonderWeb consortium are now active in the DAML-S standardization committee.

Current work addresses semi automatic methods for extracting service semantics from software design documents and software libraries. First promising experiments have been carried out on the use of text mining techniques to extract key functionalities from JAVAdoc. This work will be continued and extended in the remainder of the project. In particular the extraction of service semantics from UML diagrams will be addressed.

The work on Web Services has benefited from strong collaborations between VUA, AIFB and ISTC-CNR, which is described in a number of joint publications such as [3, 14, 11].

Workpackage 5: Assessment, Dissemination and Evaluation

A second workshop for members of the IAB was held on 20/10/2003 in conjunction with the International Semantic Web Conference in Florida, USA. At this workshop the latest results of the project were presented, and there was an extended technical discussion and feedback from the IAB. This was particularly useful given that several members of the IAB, including, e.g., Boeing, IBM and SUN, are evaluating the languages, tools, ontologies and methodologies developed in the project by using them in internal R&D projects.

Most of the software developed in the project is open source and can be downloaded from the project website or/and Sourceforge. Sourceforge reports that the KAON server has had more than 9,000 downloads and that the OWL API has had nearly 1,000 downloads.

The ontologies and methodologies developed in WP3 have also been adopted by numerous institutions, research projects and companies, including, e.g., the Dept. of Zoology, University of Oxford, UK; the UN/FAO Agricultural Ontology Service; IBM Watson Research Center, USA; and Nomos SpA, Milano, Italy.

Numerous papers describing the work carried out in the project have been published in journals and in conference and workshop proceedings. Particularly noteworthy has been the number of joint papers resulting from cooperations between various project partners and members of the IAB, e.g., [11, 3, 2, 14, 4, 17]. A complete list of publications is available from the project web site.

Members of the consortium have given numerous invited talks and tutorials on ontology languages, infrastructure and engineering, e.g., at the 2003 International Semantic Web Conference (ISWC), at the Semantic Web Summer School, at the 2003 ACM Symposium on Applied Computing, at the 2003 International Joint Conference on Artificial Intelligence (IJCAI), at the 2003 IFIP Conference on E-Commerce, E-Government and E-business, and at Hewlett-Packard Laboratories in Bristol, UK. They are also heavily involved in the organisation of relevant conferences and journals such as ISWC, the Semantic Web track of the World Wide Web conference, the Journal of Web Semantics and the Journal on Data Semantics.

Work plan

In the next period, work will continue on the development of language architectures that support web based applications; on the extension of the KAON server based ontology development environment, both by integrating existing components and by developing new ones; on the development of ontology engineering methodologies; and on the study of techniques for refining and reusing ontologies. We will also continue to work with members of the IAB in order to evaluate and exploit the results of the project, and to disseminate our results widely via publications and via open source software.

Project management and co-ordination

On the management side, we should remark that more effort went in to WP 3.2 than originally foreseen. This has, however, produced results considerably exceeding those envisaged in the technical annex.

Coordination of activities was facilitated by the important collaborations that have been established between various partners, by visits between partner sites, and by regular meetings at conferences and workshops in addition to the project meetings.

Project meetings

Regular project meetings have been held, each of which included a meeting of the Project Management Board (see the "Organisation" section on page 2 for more details).

Cooperation and co-ordination

As well as the regular face to face meetings, telephone conferences have been used to facilitate close co-ordination between the various work packages. Visits and exchanges have also played a key role in cementing cooperations and producing important results. These included a 3 month visit to VUM by Raphael Volz (AIFB), a visit to ISTC-CNR from Peter Mika (VUA) and a visit to AIFB from Marta Sabou (VUA). Various other technical meetings were also organised around project meetings, conferences and workshops. As already mentioned, these cooperations have led to a number of joint publications such as [11, 3, 2, 14, 4].

Industrial advisory board

Members of the IAB have been kept informed about the progress of the project via the web site and mailing list. The mailing list has also enabled more active members of the IAB to participate in technical discussions (see list archive[13]). A second very successful IAB workshop was held in conjunction with ISWC (see "Dissemination" section on Page 7).

External co-ordination and cooperation

Members of the consortium are active in the IST OntoWeb Network:[14] Nicola Guarino (ISTC-CNR) chairs the Special Interest Group on Content Standards, Ian Horrocks (VUM) and Frank van Harmelen (VUA) chair the Special Interest Group on Ontology Language Standards, and Andreas Persidis (IAB) and Alain Léger (IAB) chair the Special Interest Group on Industrial Applications. They will also be active in the new networks Knowledge Web[15], REWERSE[16] and Semantic Mining.[17] Clustering is further

[13] http://lists.man.ac.uk/mailman/listinfo/wonderweb
[14] http://ontoweb.aifb.uni-karlsruhe.de/
[15] http://knowledgeweb.semanticweb.org/
[16] http://www.learninglab.de/deutsch/projekte/rewerse.html
[17] http://www.imt.liu.se/mi/semanticmining/

facilitated by members' participation in numerous related projects such as Harmonise, MetoKIS, MONET, Ontologging, SWWS, VICODI and Vision.

Members of the consortium are also very active in international cooperation and standardisation efforts. Both VUM and AIFB are involved in the DARPA DAML program,[18] and several members of the consortium are on the Joint EU/US Committee on Agent Markup Languages,[19] which has developed the SWRL rules language and DQL query language proposals. VUA have also been working with the Protégé development team at Stanford University, helping them to extend their versioning tools to use the framework developed in WP4. VUM, VUA and AIFB have been active in the W3C Web Ontology language standardisation working group,[20] and ISTC-CNR have been active in the IEEE SUO Standard Upper Ontology (SUO) Working Group.[21] VUM is a founder member of the Description logic Interface Group (DIG),[22] whose objective is to develop a standard interface for description logic reasoners.

Effort and Cost breakdown

Effort in person months and costs for the reporting period are shown in Appendix B and Appendix C respectively.

Information dissemination and exploitation of results

The project web site and various mailing lists have been used to publicise the project and facilitate the dissemination of results. Other dissemination activities, including publications, are described under WP5 on Page 7.

Exploitation opportunities look promising, with results of the project already being used by members of the IAB such as Boeing, IBM and SUN, as well as by other research groups and projects. Close cooperations have been established with HP Labs in Bristol, UK (see, e.g., [1]), where a 4 day invited visit was made by Sabou (VUA). Standard APIs such as DIG and the OWL API are being widely adopted, and SME members of the IAB, such as aidministrator, Network Inference and ontoprise have expressed interest in the commercial exploitation of tools developed in the project.

As mentioned above, the ontologies and methodologies developed in WP3 have been widely adopted. DOLCE and the WFOL have also been successfully used by ISTC-CNR in a number of application projects, especially for the development of so-called core ontologies of application domains, e.g., in the Fishery Ontology Service project with UN-FAO, and in several use cases from the Intelligent Knowledge Fusion EUREKA project.

[18] http://www.daml.org/
[19] http://www.daml.org/committee/
[20] http://www.w3.org/2001/sw/WebOnt/
[21] http://ltsc.ieee.org/suo/
[22] http://dl.kr.org/dig/

A Deliverables

Del. No.	Rev.	Title	Type[1]	Class.[2]	Due Date	Issue Date
2	1.0	Rule Language	R	Pub.	30/06/03	30/06/03
7	1.0	OntoServer Demonstrator	D	Pub.	31/12/03	15/12/03
8	1.0	Triple Client	D	Pub.	30/06/03	30/06/03
9	1.0	OntoBroker and OntoEdit Adaption	D	Pub.	31/08/03	29/07/03
10	1.0	FaCT and OilEd Clients	D	Pub.	31/08/03	28/08/03
13	1.0	Reasoner Prototype	P	Pub.	30/09/03	25/09/03
18	1.0	Ontology Library (final)	D	Pub.	31/12/03	31/12/03
21	1.0	Modularisation Mechanisms	R	Pub.	30/06/03	26/06/03
24	1.0	International Conference	D	Pub.	31/12/03	19/12/03

[1] R: Report; P: Prototype; D: Demonstrator

[2] Int.: Internal circulation within project (plus Commission Project Officer and reviewers if requested)
Rest.: Restricted circulation list (specify in footnote) plus Commission SO and reviewers only
IST: Circulation within IST Programme participants
FP5: Circulation within Framework Programme participants
Pub.: Public document

B Effort in person months for reporting period 1/1/2003 – 31/12/2003

	VUM				VUA				ISTC-CNR				AIFB				Total			
	Period		Total		Period		Total		Period		Total		Period		Total		Period		Total	
WP/Task	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.
WP1																				
D 1	0.0	0.0	7.0	4.0	0.0	0.0	1.0	1.5					0.0	0.0	1.0	2.0	0.0	0.0	9.0	7.5
D 2	3.5	3.5	4.5	4.0	1.5	2.5	2.0	3.0					2.0	2.0	2.5	3.5	7.0	8.0	9.0	10.5
D 3	1.5	2.0	2.5	2.0	1.0	1.5	1.5	2.0					0.5	0.5	1.0	2.0	3.0	4.0	5.0	6.0
D 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WP2																				
D 5	0.0	0.0	0.5	0.5									0.0	0.0	2.5	5.5	0.0	0.0	3.0	6.0
D 6	0.0	0.0	0.0	0.0									0.0	0.0	3.0	6.0	0.0	0.0	3.0	6.0
D 7	0.0	0.0	0.0	0.0									6.0	6.0	6.0	7.0	6.0	6.0	6.0	7.0
D 8	0.0	0.0	0.0	0.0									6.0	6.0	9.5	10.0	6.0	6.0	9.5	10.0
D 9	0.0	0.0	0.0	0.0									9.0	9.0	13.0	9.0	9.0	9.0	13.0	9.0
D 10	3.5	3.5	6.0	5.0									0.0	0.0	0.0	0.0	3.5	3.5	6.0	5.0
D 11	0.0	0.0	0.0	0.0									0.0	0.0	3.0	4.5	0.0	0.0	3.0	4.5
D 12	0.0	0.0	0.0	0.0									0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D 13	6.0	7.0	9.0	8.5									0.0	0.0	0.0	0.0	6.0	7.0	9.0	8.5
D 14	3.0	4.0	3.0	4.0									0.0	0.0	0.0	0.0	3.0	4.0	3.0	4.0

Period: Est.: estimated effort in contract for period Act.: actual effort in period
Total: Est.: estimated cumulative effort to date in contract Act.: cumulative actual effort to date

WP3																			
D 15					0.0	0.0	0.0	0.0	0.0	0.0	6.0	5.0					0.0	0.0	6.0	5.0
D 16					0.0	0.0	0.0	0.0	3.5	4.5	3.5	4.5					3.5	4.5	3.5	4.5
D 17					0.0	0.0	0.0	0.0	0.0	0.0	6.0	7.0					0.0	0.0	6.0	7.0
D 18					1.0	1.5	2.0	2.5	9.0	12.5	12.0	16.0					10.0	14.0	14.0	18.5
D 19					0.0	0.0	0.0	0.0	0.0		0.0	0.0					0.0	0.0	0.0	0.0
WP4																			
D 20					0.0	0.0	7.0	9.0	0.0	0.0	0.0	0.0					0.0	0.0	7.0	9.0
D 21					4.5	7.5	9.0	13.5	1.0	1.0	1.0	1.0					5.5	8.5	10.0	14.5
D 22					5.5	9.0	5.5	10.0	1.0	1.0	1.0	1.0					6.5	10.0	6.5	11.0
WP5																			
D 23	1.5	1.5	2.5	2.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0					1.5	1.5	3.0	2.5
D 24	2.5	2.5	2.5	2.5	1.5	2.5	1.5	2.5	0.0	0.0	0.0	0.0					4.0	5.0	4.0	5.0
D 25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0.0	0.0	0.0	0.0
WP6																			
D 26	0.0	0.0	2.0	2.0													0.0	0.0	2.0	2.0
D 27	0.0	0.0	2.0	2.0													0.0	0.0	2.0	2.0
D 28	1.0	1.5	1.0	1.5													1.0	1.5	1.0	1.5
D 29	1.0	1.5	1.0	1.5													1.0	1.5	1.0	1.5
Mgmt	2.0	4.5	3.5	4.5	0.5	0.5	1.0	0.5	0.5	0.5	1.0	0.5	0.5	0.5	1.0	0.5	3.5	6.0	6.5	6.0
Total	25.5	31.5	47.0	44.0	15.5	25.0	31.0	45.0	15.0	19.5	30.5	35.0	24.0	24.0	42.5	50.0	80.0	100.0	151.0	174.0

Notes:

1. Effort exceeded estimate, but total costs are still within budget.

C Costs in keuro for reporting period 1/1/2003 -31/12/2003

	VUM				VUA				ISTC-CNR				AIFB				Total			
	Period		Total		Period		Total		Period		Total		Period		Total		Period		Total	
Cost category	Est.	Act.	Est.	Act.	Est.	Act.*	Est.	Act.*	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.*	Est.	Act.*
Direct costs																				
1. Personnel	147	104	285	165	71	91	139	164	67	81	134	147	115	102	200	197	400	378	758	673
2. Durable equipment	0	0	0	0	0	2	9	9	0	4	12	12	0	2	5	4	0	8	26	25
3. Subcontracting	45	0	45	0	0	0	0	0	0	0	0	0	0	0	0	0	45	0	45	0
4. Travel and subsistence	15	26	30	40	12	16	24	26	9	2	18	13	12	24	24	26	48	68	96	105
5. Consumables	2	3	9	6	1	0	2	1	1	0	3	1	1	0	2	1	5	3	16	9
6. Computing	13	11	26	17	0	0	0	0	0	0	0	0	0	0	0	0	13	11	26	17
7. Protection of knowledge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8. Other specific costs	18	3	18	3	0	2	0	2	0	0	0	0	0	0	0	0	18	5	18	5
Subtotal	240	147	413	231	84	111	174	202	77	87	167	173	128	128	231	228	529	473	985	834
Indirect costs																				
9. Overheads	39	29	74	46	17	22	35	40	54	65	108	118	26	26	47	46	136	142	264	250
Total	**279**	**176**	**487**	**277**	**101**	**133**	**209**	**242**	**131**	**152**	**275**	**291**	**154**	**154**	**278**	**274**	**665**	**615**	**1249**	**1084**

Period: Est.: estimated costs in contract for period Act.: actual costs in period
Total: Est.: estimated cumulative costs to date in contract Act.: cumulative actual costs to date

Selected Publications

[1] Sean Bechhofer and Jeremy J. Carroll. OWL DL: Trees or triples? In *Proc. of the Thirteenth International World Wide Web Conference (WWW 2004)*. ACM, 2004. To appear.

[2] Sean Bechhofer, Raphael Volz, and Phillip Lord. Cooking the semantic web with the OWL API. In Dieter Fensel, Katia Sycara, and John Mylopoulos, editors, *Proc. of the 2003 International Semantic Web Conference (ISWC 2003)*, number 2870 in Lecture Notes in Computer Science. Springer, 2003.

[3] Aldo Gangemi and Peter Mika. Understanding the semantic web through descriptions and situation. In *Proceedings of the International Conference on Ontologies, Databases and Applications of Semantics (ODBASE 2003)*, number 2519 in LNCS. SV, 2003.

[4] Benjamin N. Grosof, Ian Horrocks, Raphael Volz, and Stefan Decker. Description logic programs: Combining logic programs with description logic. In *Proc. of the Twelfth International World Wide Web Conference (WWW 2003)*, pages 48–57. ACM, 2003.

[5] Siegfried Handschuh, Steffen Staab, and Raphael Volz. On deep annotation. In *Proc. of the Twelfth International World Wide Web Conference (WWW 2003)*, pages 431–438, Budapest, Hungary, 2003.

[6] Ian Horrocks and Peter F. Patel-Schneider. A proposal for an owl rules language. In *Proc. of the Thirteenth International World Wide Web Conference (WWW 2004)*. ACM, 2004. To appear.

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[8] Ian Horrocks and Ulrike Sattler. The effect of adding complex role inclusion axioms in description logics. In *Proc. of the 18th Int. Joint Conf. on Artificial Intelligence (IJCAI 2003)*, pages 343–348. Morgan Kaufmann, Los Altos, 2003.

[9] Michel Klein. *Change Management for Distributed Ontologies*. PhD thesis, Vrije Universiteit Amsterdam, 2004.

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[12] Daniel Oberle, Steffen Staab, Rudi Studer, and Raphael Volz. Supporting application development in the semantic web. *ACM Transactions on Internet Technology*, To appear.

[13] Jeff Pan and Ian Horrocks. Web ontology reasoning with datatype groups. In Dieter Fensel, Katia Sycara, and John Mylopoulos, editors, *Proc. of the 2003 International Semantic Web Conference (ISWC 2003)*, number 2870 in Lecture Notes in Computer Science, pages 47–63. Springer, 2003.

[14] D. Richards and Marta Sabou. Semantic markup for semantic web tools: A daml-s description of an rdf-store. In *Proc. of the 2003 International Semantic Web Conference (ISWC 2003)*, number 2870 in Lecture Notes in Computer Science. Springer, 2003.

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[16] Heiner Stuckenschmidt and Frank van Harmelen. *Information Sharing on the Semantic Web*. Springer Verlag, 2004. To appear.

[17] Michael Uschold, Peter Clark, Fred Dickey, Casey Fung, Sonia Smith, Stephen Uczekaj Michael Wilke, Sean Bechhofer, and Ian Horrocks. A semantic infosphere. In Dieter Fensel, Katia Sycara, and John Mylopoulos, editors, *Proc. of the 2003 International Semantic Web Conference (ISWC 2003)*, number 2870 in Lecture Notes in Computer Science, pages 882–896. Springer, 2003.

[18] R. Volz, S. Handschuh, S. Staab, L. Stojanovic, and N. Stojanovic. Unveiling the hidden bride: Deep Annotation for Mapping and Migrating Legacy Data to the Semantic Web. *Journal of Web Semantics*, 2004.

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[20] Raphael Volz, Daniel Oberle, Steffen Staab, and Boris Motik. KAON SERVER—A Semantic Web Management System. In *Proc. of the Twelfth International World Wide Web Conference (WWW 2003)*, Budapest, Hungary, 2003.

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[22] Raphael Volz, Steffen Staab, and Boris Motik. Incremental Maintenance of Materialized Ontologies. In R. Meersman, Z. Tari, D. C. Schmidt, B. Kraemer, M. van Steen, S. Vinoski, R. King, M. Orlowska, R. Studer, E. Bertino, and D. McLeod, editors, *Proc. of CoopIS/DOA/ODBASE 2003*, volume 2888 of *Lecture Notes in Computer Science*, pages 707–724, 2003.