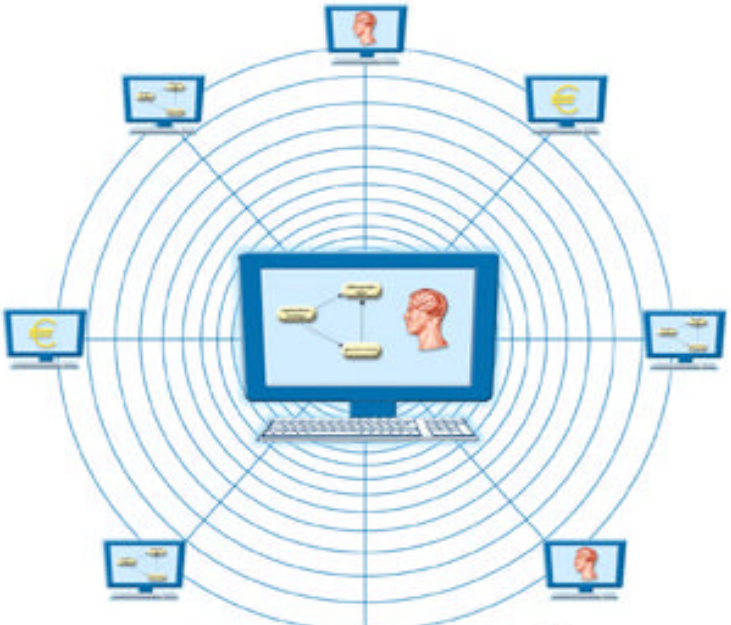

A survey on ontology-based applications.

e-commerce, knowledge management, multimedia, information sharing and educational applications will deserve special attention

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Identifier	Deliverable 1.6
Class	**Deliverable**
Version	**1.0**
Version date	**14/01/04**
Status	**Draft**
Distribution	**Public**
Responsible Partner	**UPM**

OntoWeb Consortium

This document is part of a research project funded by the IST Programme of the Commission of the European Communities as project number IST-2000-29243.

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Revision Information

Revision date	Version	Changes
3-10-2003	0.1	First draft
13-11-2003	0.2	York Sure's comments
22-12-2003	0.3	Ontoprise and OU updates
26-12-2003	0.4	UPM revision
13-1-2004	0.5	UPM updates
14-1-2004	1.0	UPM revision

Contents

Executive summary

This deliverable presents an overview of **ontology-based applications** organized in several groups: Knowledge Management applications, e-Commerve applications, Information Sharing and Retrieval applications and Education application; related to knowledge management, e-commerce, semantic web portals, intelligent integration of information, information retrieval, and education. This list of applications is not exhaustive, but tries to show a broad overview of existing ontology-based applications in different areas of knowledge.

The deliverable is organized as follows:

- Section 1 contains the introduction to this deliverable.
- Section 2 presents **Knowledge Management applications**. It is organized in two subsections: *Knowledge Management applications* and *Semantic Webportals and Web Communities*.
- In Section 3 we present **e-Commerce applications**.
- Section 4 presents **Information Sharing and Retrieval applications**. It contains two subsections that are *Intelligent Integration of Information applications* and *Information Retrieval applications.*
- Section 6 presents an overview of **Education applications**.

Inside each section, contents will be organized in alphabetical order.

1 Ontology-based applications

In this deliverable, we present relevant ontology-based applications from diverse research areas, such as Knowledge Management, e-Commerce, Information Sharing and Retrieval, and Education. However, this distribution of ontology-based applications in research areas should not be considered strict, because some applications combine and solve problems from different groups. In these cases of interdisciplinarity, we have decided to include the application in the most relevant group, and include the other research areas covered as additional topics.

The list of applications presented here does not attempt to be complete. On the contrary, it aims at presenting interesting work in different areas from the different groups involved in the ontology research and development community.

Let us see now a summary of each group of applications described in this deliverable:

Knowledge Management applications.- This group is organized according to two main subtopics: Knowledge Management applications, and Semantic Webportals and Web Communities. With regard to Knowledge Management applications, we describe nine: CoMMA, IBROW3, Marchmont Observatory Semantic Search Service, MGT, MyPlanet, On-To-Knowledge, OntoWeb, PatMan and PlanetOnto. With regard to the second subtopic (Semantic Webportals and Web Communities), we also describe nine: C-WEB, OntoRoadMap, SEAL, ODESeW, Time2Research, KAON Portal, K42, ITM, and RDF Gateway.

e-Commerce applications.- This group of applications (e-commerce platforms) are the result of several R&D projects: Alice, MKBEEM, OBELIX, and SMART-EC. The common characteristic of these e-commerce platforms is that they use ontologies to represent the underlying knowledge of the platform, with different purposes: to build product and service catalogues, to represent e-business scenario analysis, or to help in the natural language processing needed to understand user queries in natural language.

Information Sharing and Retrieval applications.- The first group of applications (those aimed at information sharing) show that ontology technology can be used to share information through its intelligent integration from heterogeneous resources. These applications are especially useful in the Web context, where a huge amount of diverse heterogeneous information is available, and involves many complex tasks: finding information, extracting it, merging it, synthesizing it, etc. We will describe the following applications and approaches: Ariadne, OBSERVER, PICSEL, OntoBroker, V3 Real-Time Integration Platform, Cerebra Platform, and IODE. With regard to information retrieval, ontology technology can be also used: users pose queries to systems and retrieve relevant information from them. We will describe the following applications and approaches: OntoSeek, SemanticMiner, SyDoM, and WebKB-2.

Education applications.- This group contains applications that are explicitly based on ontologies and ontology technology, and those that do not mention ontologies but talk about, for example, structures of concepts and relations. Ontologies (and also these so-called structures) and standards in these applications have an important role in the representation of learning objects and repositories. Besides detailed descriptions and pointers of relevant education applications and approaches (CIPHER, Connexions, Conzilla, Edutella, Elena, EML, Garden of Knowledge, GESTALT, KTH Metadata Tools, Magpie, PADLR, POOL, RichODL, ScholOnto, SCULPTEUR, Stojanovic&Staab&Studer's e-learning scenario, Trellis, and WBES), we provide our own conceptualization of the Semantic Web and Learning Space.

2 Knowledge Management applications

2.1 Knowledge Management applications

In this section, we show approaches to the modelling of corporate knowledge in corporate knowledge management systems. Ontologies play a key role in this framework, as they model the main information used inside the organization, and provide a shared view of it.

2.1.1 CoMMA: Corporate Memory Management through Agents

CoMMA is an IST project (1999-12217) aiming at implementing a corporate memory management framework in the context of two scenarios: insertion of new employees in the company and support of technology monitoring. [CoMMA, 2000]. COMMA studies the corporate memory as a "corporate semantic Web" where the ontology O'CoMMA is the keystone. In [Gandon, 2001] are presented both the approach adopted to build O'CoMMA and the resulting ontology. Adaptation and customization of agents to users, rely on machine learning techniques presented in [Kiss and Quinqueton, 2001]. Finally, CoMMA uses multi-agents systems to deployment of a software architecture above the distributed information landscape of the corporate memory [Gandon et al., 2000]. On the one hand, individual agents locally adapt to users and resources they are dedicated to. On the other hand, thanks to cooperating software agents distributed over the network they capitalize an integrated and global view of the corporate memory.

URL: http://www.si.fr.atosorigin.com/sophia/comma/Htm/HomePage.htm

References:

CoMMA Corporate Memory Management through Agents, In Proc. E-Work & E-Business, Madrid.

F. Gandon, Engineering an Ontology for a Multi-Agents Corporate Memory System, In proceedings of ISMICK 2001 Eighth International Symposium on the Management of Industrial and Corporate Knowledge, 22-24 October 2001, Université de Technologie de Compiègne, France, pp 209-228.

F. Gandon, R. Dieng, O. Corby, A. Giboin, A Multi-Agent System to Support Exploiting an XML-based Corporate Memory, In Proceedings PAKM'00 Basel, Switzerland, October 30-31, 2000, pp 10.1-10.12.

Kiss A., Quinqueton J. Multiagent Cooperative Learning of User Preferences, Proceedings of European Conference on Machine Learning Principles and Practice of Knowledge Discovery in Databases, 2001.

Topics: Agents, Cooperative Knowledge Acquisition, Information Retrieval, Intelligent Information Integration, KA methodologies, Knowledge Elicitation, Knowledge Management, Machine Learning, Ontologies, Semantic Web.

Ontologies used: O'CoMMA.

2.1.2 IBROW3

The objective of IBROW3 is to develop intelligent brokers that are able to distributively configure reusable components into knowledge systems through the World-Wide Web. The WWW is changing the nature of software development to a distributive plug & play process, which requires a new kind of managing software: intelligent software brokers. IBROW3 will integrate research on heterogeneous DB, interoperability and Web technology with knowledge-system technology and ontologies.

URL: http://www.swi.psy.uva.nl/projects/IBROW3/home.html

References: *Not available*.

Topics: Agents, Knowledge Management, Ontologies.

Ontologies used: *Not available*.

2.1.3 Marchmont Observatory Semantic Search Service

In the autumn of 2000 the UK government created the University for Industry (Ufi) whose goal is to provide flexible learning packages in order to improve the quality of life of individuals and to boost

business competitiveness. For the Ufi to be successful associated researchers and policy makers would need to discover and disseminate good practice on lifelong learning. It was decided that the main supporting mechanism for this would be a Web portal, termed the National Observatory. Part of this portal is the Marchmont Observatory Semantic Search Service built on ontologies which focus on the attributes associated with lifelong learning. These ontologies index a 'Good Practice' database which hold several hundred hand-coded summaries of articles describing lifelong learning initiatives.

Technically, the observatory interface is a flash™ movie which links to the WebOnto server on which the observatory libraries are stored.

URL: http://kmi.open.ac.uk/observatory/

References:

Domingue, J, Motta. E., Buckingham Shum, S, Vargas-Vera, M. , Kalfoglou, Y. and Farnes, N. (2001) Supporting Ontology Driven Document Enrichment within Communities of Practice. K-CAP'01, The First International Conference on Knowledge Capture. Victoria, British Columbia, Canada, October 21-23, 2001 (available at http://kmi.open.ac.uk/projects/akt/kcap01_john_final.pdf).

Topics: Knowledge Management, Ontologies.

Ontologies used: *Not available*.

2.1.4 MGT

The MGT decision-support tool is a web-based system for supporting guideline-centred healthcare. It is available in both a desk-top and a hand-held portable version (which can also be used "off-line"). It is built upon a hierarchy of both medical and supporting non-medical ontologies and can be integrated with a patient database. Having selected a patient from the database, a physician can view the medical history, add new data and based on such data, directly access the most relevant portion of the guidelines, within a web-based discussion-space.

URL: http://kronsteen.open.ac.uk/mgt/

References: *Not available*.

Topics: Medical guidelines, knowledge representation, ontologies

Ontologies used: *Not available*.

2.1.5 MyPlanet

MyPlanet is an ontology-driven personalised Web-based service. Users submit an email story (e-Story) about a potentially interesting theme in the context of a research lab. We then annotate the e-Story with knowledge structures drawn from the underlying ontology, render the e-Story to produce a high quality Web page to display it, and alert users who might be interested in this e-Story. We also populate our ontology with information extracted from the e-Story, which allow us to provide reasoning services that go beyond traditional keyword-based searches. A designated front-end allow the users to browse the e-Stories archive by specifying their preferences with respect to e-Story's contents.

URL: http://eldora.open.ac.uk/my-planet/

References:

Kalfoglou, Y., Domingue, J., Motta, E., Vargas-Vera, M., Buckingham-Shum, S. MyPlanet: an ontology-driven Web-based personalised news service. IJCAI'01 workshop on Ontologies and Information Sharing. Seattle, USA. August, 2001.

Topics: Knowledge Management, Ontologies, Semantic Web.

Ontologies used: kmi-planet ontology.

2.1.6 The On-To-Knowledge project

The On-To-Knowledge (OKT) project developed methods and tools and employed the full power of the ontological approach to facilitate knowledge management. The On-To-Knowledge tools helps knowledge workers who are not IT specialists to access company-wide information repositories in an efficient, natural and intuitive way. The OTK project applies ontologies to electronically available information to improve the quality of knowledge management in large and distributed organisations.

URL: http://www.ontoknowledge.org/

References:

S. Staab, H.-P. Schnurr, R. Studer, and Y. Sure: Knowledge Processes and Ontologies, IEEE Intelligent Systems, 16(1), January/February 2001.

J. Davies, D. Fensel, F. van Harmelen (eds.). On-To-Knowledge: Semantic Web enabled Knowledge Management. Wiley, 2002, pages 33-46.

Y. Sure. Methodology, Tools and Case Studies for Ontology based Knowledge Management. [online], PhD Thesis, University of Karlsruhe, Department of Economics and Business Engineering, 2003.

Topics: Knowledge Management, Ontologies, Methodologies, Tools.

Ontologies used: AIFB, ProPer.

2.1.7 OntoWeb

In the use of ontologies in the semantic Web, still the different communities are scattered and have not yet found enough interactions to fully employ the potential of this new technology. It is the delighted goal of the OntoWeb network to bypass communication bottlenecks between these various and heterogeneous interest groups. As first steps into this direction, we set up a homepage (url), a mailing list (url), and organised an European workshop coordinating projects proposals for the next open calls of the European Union IST funding. We have also developed the OntoRoadMap application (see section 2.2.2), which allows different research groups register their ontologies, methodologies, languages, applications, important events, etc.

URL: http://www.ontoweb.org

References:

J. Hartmann and Y. Sure. Scalable and Reliable Semantic Portals (SEAL) in Practice. In: Proceedings of the Confederated International Conferences CoopIS, DOA and ODBASE 2003, 3-7 November 2003, Catania, Sicily, Italy, Springer, LNCS.

P. Spyns, D. Oberle, R. Volz, J. Zheng, M. Jarrar, Y. Sure, R. Studer, and R. Meersman. OntoWeb - a Semantic Web Community Portal. In: Proceedings of the Fourth International Conference on Practical Aspects of Knowledge Management PAKM 2002, December 2nd-3rd, 2002,Vienna, Austria, Springer, LNAI 2569, pages 189-200.

Topics: Knowledge Management, Ontologies, Semantic Web.

Ontologies used: reference ontology, SWRC Semantic Web Researcher Community.

2.1.8 PatMan

The PATMAN project is concerned with the provision of integrated support for tackling medical and organisational issues during patient management. The PatMan discussion forum integrates the D3E technology for discussion and debate with an ontology-driven query answering engine, which makes it possible to retrieve knowledge about a particular medical guideline. The integration of these tools provides a powerful solution to support the interpretation process of a medical guideline by a community of healthcare providers. D3E supports a web-based set of discussion spaces centred around the various sections of the guideline, while the ontology-driven query answering system makes it possible to retrieve background domain knowledge and to perform semantic search.

URL: http://kmi.open.ac.uk/projects/patman/

References:

Motta E., Buckingham-Shum, S. and Domingue, J. (2000). Ontology-Driven Document Enrichment: Principles, Tools and Applications. International Journal of Human-Computer Studies, 52(6), pp. 1071-1109.

Topics: Electronic Publishing, Knowledge Management, Ontologies, Semantic Web.

Ontologies used: Medical Guidelines ontology, Pressure Ulcer Ontology, Generic Medical Ontology.

2.1.9 PlanetOnto

KMi Planet is a web based news server which facilitates communication within an organization, by supporting web-based electronic publishing and the automatic generation of a 'front page' from the news items received by a server. It has been in daily use at the Knowledge Media Institute for a number of years and several versions have been customised for corporate organizations, local schools and academic centres. As an archive of news grows, a number of knowledge management problems arise: how to provide semantic search and knowledge retrieval facilities in an effective and sustainable way; how best to provide individualized presentations and news alerts; how best to emulate the behaviour of a newsroom team. To address these challenges we have developed an integrated suite of tools, which is called PlanetOnto. These tools allow ontology-driven document formalization and augment standard browsing and search facilities with deductive knowledge retrieval. In addition, the PlanetOnto architecture includes specialized agents, which provide personalized news feeds and alerts and can proactively identify potentially interesting news items.

URL: http://kmi.open.ac.uk/projects/planetonto/

References:

Domingue, J. B. and Motta, E. (2000). Planet-Onto: From News Publishing to Integrated Knowledge Management Support. IEEE Intelligent Systems, 15(3), May-June 2000, pp. 26-32.

Topics: Electronic Publishing, Knowledge Management, Ontologies, Semantic Web.

Ontologies used: KMi Planet ontology

2.2 Semantic Webportals and Web Communities

These applications aim not only at presenting a web site to users, but also at adding semantics to web sites, providing thus an integrated access to the various information resources of a community or organization.

2.2.1 C-WEB

C-WEB (Community-Web) intends to support specific communities on the Web. These communities have in common some identified and formalized knowledge that they use and make evolve in their joint activities, along with a variety of information resources. In this context, the main challenge is to provide a single point of useful, ubiquitous comprehensive and integrated access to the various information resources of a community.

URL: http://cweb.inria.fr/

References:

Managing RDF Metadata for Community Webs, S. Alexaki, V. Christophides, G. Karvounarakis, D. Plexousakis, K. Tolle, Bernd Amann, Irini Fundulaki, Michel Scholl, Anne-Marie Vercoustre, 2nd International Workshop on the World Wide Web and Conceptual Modeling (2000), pp. 140-151.

Topics: Semantic Web, Semantic Portals, Knowledge Management.

Ontologies used: physics (mechanics) and biology (genome). *Under development*.

2.2.2 OntoRoadMap

This application is being developed inside the OntoWeb project. It is used so that people can register the descriptions of their ontologies, applications, languages, methodologies, etc. OntoRoadMap can generate documents from the inserted information, in fact, this deliverable has been made using this application. It is being a very useful way to manage the knowledge distributed in many research groups.

Concerning the architecture of the system, it is based in the Reference Ontology, which models knowledge about ontologies.

URL: http://babage.dia.fi.upm.es/ontoweb/wp1/OntoRoadMap/index.html

References: *Not available*.

Topics: ontologies, semantic web, methodologies, languages, events, tools, applications, knowledge management, ontology learning.

Ontologies used: Reference Ontology.

2.2.3 SEAL

SEAL (SEmantic portAL) is a generic ontology-based approach for developing semantic portals. It exploits the semantics for providing and accessing information at a portal as well as constructing and maintaining it. This approach has already been used inside AIFB at Karlsruhe University to generate their own web pages on a semantic basis.

URL: http://ontobroker.semanticweb.org/ontos/aifb.html

References:

Alexander Maedche, Steffen Staab, Nenad Stojanovic, Rudi Studer, and York Sure. SEmantic portAL - The SEAL approach. In: Creating the Semantic Web. D. Fensel, J. Hendler, H. Lieberman, W. Wahlster (eds.) MIT Press, Cambridge, MA., 2001.

J. Hartmann and Y. Sure. Scalable and Reliable Semantic Portals (SEAL) in Practice. In: Proceedings of the Confederated International Conferences CoopIS, DOA and ODBASE 2003, 3-7 November 2003, Catania, Sicily, Italy, Springer, LNCS.

A. Maedche, S. Staab, R. Studer, Y. Sure and R. Volz. SEAL - Tying Up Information Integration and Web Site Management by Ontologies. In: IEEE Computer Society Data Engineering Bulletin, Special issue on "Organizing and Discovering the Semantic Web", Vol. 25, No.1, pp. 10-17, March 2002.

Topics: Semantic Web, Semantic Portals, Knowledge Management.

Ontologies used: AIFB.

2.2.4 ODESeW

The ODESeW (Semantic Web) portal is an ontology-based Web portal built using the WebODE ontology engineering workbench. The contents of this Web portal are automatically generated from a set of ontologies stored in the WebODE platform. The ontologies used to build the portal can be navigated and searched, and the instances of concepts and relations can be viewed, searched and updated. Any update in the ontology is automatically updated in the ODESeW portal with no need for the intervention of the ontology developer. Different levels of reading and updating permissions can be established for the instances stored in the ODESeW portal, which makes it usable for the Internet and for Intranets.

The ODESeW portal has been used for creating the Esperonto project web site.

URL: http://www.esperonto.net/

References:

ODESeW. Automatic Generation of Knowledge Portals for Intranets and Extranets O. Corcho, A. Gómez-Pérez, A. López-Cima, V. López-García, M.C. Suárez-Figueroa Laboratorio de Inteligencia Artificial Facultad de Informática Universidad Politécnica de Madrid Campus de Montegancedo sn. Boadilla del Monte, 28660. Madrid, Spain

Topics: Knowledge Portal, Knowledge Management, Semantic Web portal.

Ontologies used: Any set of WebODE ontologies and ontologies in RDF(S), DAML+OIL and OWL wich are imported in WebODE. In the Esperonto Semantic Web portal (they model an IST project): Person, Meeting, Project, Documentation and Organization.

2.2.5 Time2Research Portal

To support analysts in their daily work, the TIME2RESEARCH-Portal helps to investigate potential investments, to generate reports and let take direct profit from its underlying knowledge. By intelligent semantic technologies the portal delivers exactly the answers an analyst needs for his decisions in a specific stage of investigation.

URL: http://141.41.1.131/t2r

References: *Not available.*

Topics: Knowledge Management, Knowledge Portal, Semantic Web.

Ontologies used: time2research.

2.2.6 KAON PORTAL

KAON PORTAL is an ontology-based portal generator which is also capable of automatically providing metadata-driven services. The KAON PORTAL may then be used to provide default visualization and navigation through ontologies. Multi-Lingual Ontologies are also supported. As it is part of KAON it focus on integrating traditional technologies for ontology management with those used in business applications, and it benefits from all the features that the KAON framework gathers. The most important features are: syndication (RDF Crawler), which allows the collection of metadata located in external web pages, ontology management, evolution and change from heterogeneous sources (RDF API), ontology query answering (KAON Query), ontologies mapping management, and many other features. From a technological point of view, KAON PORTAL uses RDFS with KAON proprietary extensions as description language, any SQL2 compatible database or file for persistent storage and JBoss and Tomcat application servers for deployment.

URL: http://km.aifb.uni-karlsruhe.de/kaon/Members/rvo/kaon_portal.htm

References:

Alexander Maedche, Boris Motik, Ljiljana Stojanovic, Rudi Studer and Raphael Volz. Ontologies for Enterprise Knowledge Management. IEEE Intelligent Systems, Volume 18, Number 2, pp. 26-33, March/April 2003

Topics: Knowledge Management, Knowledge Portal, Semantic Web, Syndication.

References: *Not available*.

Ontologies used: Any KAON ontology.

2.2.7 K42

K42 Knowledge Server provides a new paradigm for organising , maintaining and navigating information, because its information models stores are independent of the physical domain in which the information resides. This feature allows the information deployment in different environments with different requirements. Its knowledge base it's built with the XTM and ISO standard Topic Maps, which are published by means of XSL transformations. It can also be deployed in a distributed enterprise applications, owing that it fully supports both Jini and RMI.

URL: http://www.empolis.com/products/prod_k42.asp

References: *Not available*.

Topics: Semantic Web, Semantic Portals, Knowledge Management, Topics Maps

Ontologies used: *Not available*.

2.2.8 ITM

Developed by the French company Mondeca, ITM (Intelligent Topic Manager) makes use of the topic maps standard, allowing the creation of models of organization, achieving intelligent access to the information through multiple views and along multiple pathways. Around these knowledge bases three main functionalities of ITM are grouped: administration of knowledge bases, editing and consulting of knowledge bases and publication. ITM is a heterogeneous platform. It can use different knowledge bases types, access to several content formats (Microsoft Word, RDFS, relational databases, etc.) an is also capable of handling various publication formats, such as HTML, PDF, XML, RDF, etc. Its architecture also allows multiple possible implementations, ranging over different application server, databases, etc…

URL: http://www.mondeca.com

References: *Not available*.

Topics: Semantic Web, Semantic Portals, Knowledge Management, Topics Maps, Heterogeneity.

Ontologies used: *Not available*.

2.2.9 RDF Gateway

RDFS Gateway is the web portal developed by the company Intellidemension. It is a high performance server that gathers the querying, transformation and delivery of information. The querying is obtained by

means of a rich server side scripting language, RDFQL, a RDFQL processor and RDF deductive database engine. Using them it allows making complex queries across multiple data sources. The transformation of information is achieved using RDF Server Pages (RSP), a Microsoft ASP look-alike technology that smoothly integrates web technologies such us HTML, XML, RDF/XML with the deductive database engine. Information delivery and includes HTTP, a proprietary TCP/IP based protocol and a well defined data service interface. Other RDF Gateway features also include as an authentication and security model based on rights, session management, application packages, applications deployment and new components integration management.

URL: http://www.intellidimension.com

References: *Not available*.

Topics: Semantic Web, Semantic Portals, Knowledge Management, RDF Deductive Data Base, RDFQL

Ontologies used: *Not available*.

3 e-Commerce applications

This section presents to ongoing projects in the application of ontologies to e-commerce. Their aim is the development of e-commerce platforms where underlying knowledge is codified by means of ontologies, which are also used (in the case of MKBEEM) for natural language processing (understanding user queries, translating products in catalogues and generating natural language text).

3.1 Alice Project

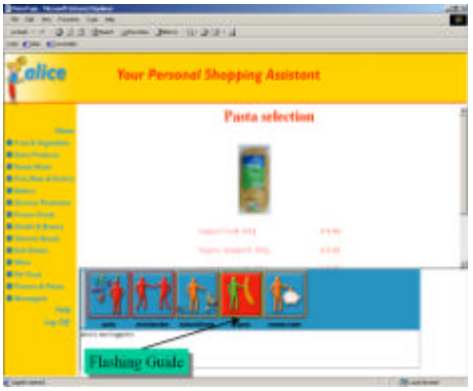
Currently shopping on the internet is not always a pleasant experience. Navigating websites with thousands of products by browsing virtual aisles or by keyword search is time consuming and often frustrating. Contrast the above with the local 'corner shop' which was prevalent in villages in England in the 1950s. We believe that one of the key differences to the customer's shopping experience was due to the fact that the shop had a human agent, the shopkeeper, who used his or her knowledge to personalise the interaction. The overall goal of the Alice project is to make the experience of online shopping seem more like visiting a local corner shop than browsing or searching long lists.

3.1.1 The Alice Approach

The Alice approach is based on the use of ontologies for representing knowledge related to online shopping. Within Alice we use five ontologies to create a personalised online shopping experience.

- *Products* – this ontology describes the main attributes of products, for example, how a product is used, its components, complementary products and a product's geographic origin.
- *Shopping Tasks* – this ontology represents typical shopping tasks, for example a monthly shop for household essentials and shopping for an evening meal.
- *External Context* – For example, relevant local social events, groups, and small businesses. It is common nowadays for supermarkets to have a message board for clients to publish messages (small ads, invitations, etc.)
- *Customer* – this ontology represents the main attributes of a customer including his or her shopping and browsing histories. Note that a customer's interactions can also be recorded anonymously.
- *Alice Media* – this ontology maps between the other four ontologies and relevant web resources.

3.1.2 The Alice System

<table>
<tr><td colspan="2">The shopper is browsing the pasta section of the online store. The Organic Guide indicates that it has something to contribute by blinking red a number of times. The shopper is free to ignore the Guide and to carry on browsing but she elects to see what the Guide has to say and selects the Organic Guide icon. The key design feature of the Alice Guides is that the customer selects them. This means that they reflect the customer's own perspective of themselves (e.g. rich, poor or ethical) and therefore there is a greater likelihood that appropriate suggestions will be made. Also, depending on the current situation the customer can chose to de-select or ignore certain Guides, for example, the Money Saver Guide when shopping for a specific luxurious item.</td><td>Alice interface
 
</td></tr>
<tr><td>  </td><td>Party Guide – this Guide assumes that the task for the session is to buy products for a party (e.g. the free loan of wine glasses), recipes and local services (e.g. marquee hires).</td></tr>
<tr><td>  </td><td>(Product)Matchmaker Guide – this Guide matches products that are purchased to similar or complementary products. For example, it would match pasta with bottled pesto sauce.</td></tr>
<tr><td>  </td><td>Missing Items Guide – When the customer goes to the checkout this Guide collects a list of items that the customer browsed in detail but did not add to his or her basket.</td></tr>
</table>

	*Organic Guide* – when appropriate this Guide recommends organic versions of goods that are being viewed.
	*Money Saver Guide* – this Guide informs the shopper of any offers or promotional items which are related to the currently viewed item.

URL: http://kmi.open.ac.uk/projects/alice/

References

Domingue, J et al. (2003) Supporting Online Shopping through a Combination of Ontologies and Interface Metaphors, International Journal of HCS, Volume 59, Issue 5 , November 2003.

Topics: *Not available*.

Ontologies used: *Not available*.

3.2 MKBEEM

The MKBEEM platform focuses on adding multilinguality to the following stages of the information cycle for multilingual B2C portal services: products or services content and catalogue semi-automated maintenance; automated translation and interpretation of natural language user requests, and natural dialogue interactivity and usability of the service making use of combined navigation and natural language inputs.

The main overall goals of MKBEEM are to: develop intelligent knowledge-based multilingual key components (NLP and KRR) for applications in a multilingual electronic commerce platform; validate and assess the prototypes on a pan-European scale (France and Finland) with three basic languages (Finnish, English and French) and two optional languages.

URL: http://www.mkbeem.com/

References:

Leger, A. and others. *Ontology domain modeling support for multilingual services in e-Commerce: MKBEEM*. ECAI'00 Workshop on Applications of Ontologies and PSMs. Berlin. Germany. August, 2000.

Topics: e-commerce, ontologies, NL processing, NL generation.

Ontologies used: SNCF services, ELLOS metamodel.

3.3 OBELIX Ontology-Based ELectronic Integration of compleX products and value chains

OBELIX aims to develop an e-business ontology tool suite and library to support smart collaborative e-business and the realization of innovative applications. The OBELIX tool suite consists of an ontology server providing facilities for editing, component brokering, ontology management, and Web language import and export, plus a number of ontology-based tools including an e-business scenario analysis and simulation tool for DVC models and strategies, an automatic product classifier to speed up application of content management standards, and a multi-product configuration tool for online collaborative design scenarios. In addition, OBELIX will deliver a modular e-business ontology library. The tools will be validated through three e-business applications: e-markets for energy trading and servicing, new digital music value chains, and online design of events. Project in the Information Society Technologies (IST) Programme for Research, Technology Development & Demonstration under the 5th Framework Programme. Key action II. 2001-2004. The project partners are: Vrije Universiteit Amsterdam, SENA, Ontoprise GmbH, Germany, SINTEF, PTSS, Melhus Energy.

URL: http://www.cs.vu.nl/%7Ezykov/imse/projects/projects.html

References: *Not available*

Topics: e-commerce, ontologies, automated product classification.

Ontologies used: *Not available*.

3.4 SMART-EC

The SMART-EC platform is an ontology-based intermediation platform for the provision of complex services on Internet. It is being developed in the context of the IST project SMART EC. The following services are provided by this platform:

- Brokering of services between individual service providers and final users requesting complex services.
- Definition and implementation of the life cycle of a complex service, include the required steps for the service provision and the transactional properties of the service.
- One stop shopping, for multi-items purchases giving access to multiple e-commerce sites.

URL: http://www.telecom.ntua.gr/smartec/

References: *Not available.*

Topics: e-commerce, ontologies.

Ontologies used: *Not available.*

4 Information Sharing and Retrieval applications

This section presents ongoing work in the application of ontologies to information sharing and information retrieval tasks. Ontology-based Intelligent Information Integration from heterogeneous resources has proven to be a good approach for the sharing of information, especially in the Web context. It involves complex tasks of finding and extracting information, and merging and synthesizing it. With regard to information retrieval, we will show how ontology technology has been used for these kinds of applications, where users pose queries to systems and retrieve relevant information from them.

4.1 Intelligent Integration of Information applications

The growth of the Internet and other on-line information repositories has greatly simplified the access to numerous sources of information. But this growth has vastly complicated tasks involving finding, extracting, merging or synthesizing such information. In this section, we present some approaches that use ontologies for the tasks of performing an intelligent integration of information from several heterogeneous sources.

4.1.1 Ariadne

The Ariadne project aims at the development of technology and tools for rapidly constructing intelligent agents to extract, query, and integrate data from web sources. It is being developed in the Information Sciences Institute (ISI) at the University of Southern California, with the support of DARPA. This project tries to improve SIMS, allowing the management of semi-structured sources such as Web pages.

The application can access to the different sources via an Ariadne information mediator, which uses ontologies codified in LOOM. This mediator has mappings between the ontologies and the information sources.

URL: http://www.isi.edu/info-agents/ariadne/index.html

References:

Arens, Y., Knoblock, C.A., Shen, W-M. “Query reformulation for dynamic information integration”. Journal of Intelligent Information Systems, Special Issue on Intelligent Information Integration, 6(2/3). 1996. Pp. 99-130.

Barish, G., Knoblock, C.A., Chen, Y-S; Minton, S., Philpot, A., Shahabi, C. “The theaterloc virtual application”. Twelfth Annual Conference on Innovative Applications of Artificial Intelligence (IAAI-2000). Austin, Texas, 2000.

Topics: Intelligent Integration of Information, Agents.

Ontologies used: *Not available.*

4.1.2 OBSERVER

OBSERVER is being developed by Universidad del País Vasco, MCC, and the University of Georgia. It uses different ontologies (implemented in CLASSIC) to represent the different information sources, and a set of mappings between the different ontologies. When a user poses a query, the first answer is given using just an ontology. If the user is not satisfied, he can choose other one to extend the result. Given that the correspondence between the concepts of an ontology with the concepts of the other one is not exact, the system provides the estimated loss of information. That is, it estimates how many items are not proper answers, and how many items should appear, and they do not appear.

URL: http://siul02.si.ehu.es/~jirgbdat/OBSERVER/

References:

Mena, E., Illarramendi, A., Kashyap, V., Sheth, A.P. "OBSERVER: An Approach for Query Processing in Global Information Systems based on Interoperation across Pre-existing Ontologies", In the international journal Distributed and Parallel Databases (DAPD), Volume 8, Number 2, ISSN 0926-8782, April 2000. Pp. 223-271.

Topics: Intelligent Integration of Information.

Ontologies used: *Not available.*

4.1.3 PICSEL

PICSEL is an information integration system over sources that are distributed and possibly heterogeneous. It has been developed by LRI (France). The approach which has been chosen is to define an information server as a knowledge-based mediator between users and several existing information sources relative to a same application domain. The mediator gives its users the illusion of a centralized and homogeneous information system. It allows them to ask domain-level queries and takes in charge in their place the access to the relevant sources in order to obtain the answers to the queries.

URL: http://www.lri.fr/~picsel/

References:

François Goasdoué, Véronique Lattes and Marie-Christine Rousset, The Use of CARIN Language and Algorithms for Information Integration: The PICSEL Project, International Journal of Cooperative Information Systems (IJCIS), 1999.

François Goasdoué, A Knowledge Based Approach for Information Integration: The PICSEL System, In Nicolas Spyratos, K. Vidyasankar and Gottfried Vossen Eds, Declarative Data Access on the Web, Dagstuhl-Seminar-Report 251, p. 7, Dagstuhl Castle, Germany, September 12-17 , 1999.

Topics: Intelligent Integration of Information.

Ontologies used: *Not available*

4.1.4 OntoBroker™

OntoBroker™ is a reasoning engine with semantic information integration capabilities from ontoprise GmbH (www.ontoprise.com, Germany). Data integration is done via several connectors, import and export formats and built-ins, e.g. importing data schemas from existing databases and mapping to ontologies, connectors to search engines and applications. These mappings are translated into F-Logic statements, a frame-based language for logics, so that OntoBroker can reason over the combined ontology results in data references in the original data sources. OntoBroker™ comes along with several optional performance optimization strategies like distributed inferencing, genetic query optimizer, materialization, etc. Representation of the ontology can be done in F-Logic, RDF/S, DAML+OIL. OWL support is under construction.

URL: http://www.ontoprise.de/products/ontobroker_en

References:

Maier, A. et al: Integration with Ontologies, Conference Paper WM2003, Luzern, 2003. http://www.ontoprise.de/documents/integration_with_ontologies.pdf

Angele, J. et al.: On2broker: Semantic-Based Access to Information Sources at the WWW. In: Proceedings of the World Conference on the WWW and Internet (WebNet 99), Honolulu, Hawai, USA, October 25-30, 1999

Tutorial: How to use OntoBroker, ontoprise GmbH, 2003. http://www.ontoprise.de/documents/tutorial_ontobroker.pdf

Topics: Intelligent Integration of Information and Knowledge Representation and Reasoning.

Ontologies used: *Not available.*

4.1.5 . V3 Real-Time Integration Platform

The enLeague V3 Integration Platform™'s goal is to overcome differences in business vocabularies, data definitions and Web services by translating and mapping internally and externally developed data and services to business concepts. Product focus is on creating a scaleable run time environment integrated with popular web application servers. It is a standards-based platform to access, integrate, and extend data usage across organizations. The Platform is founded on an adaptive and reusable model-driven architecture. Its management tool uses model-driven description logics to enable meta-data management. It provides interfaces to portal, business intelligence and external systems. It is compliant with RDF/S, DAML+OIL and OWL.

URL: http://www.enleague.com/products_v3.html

References: *Not available*

Topics: Intelligent Integration of Information and Web Services.

Ontologies used: *Not available.*

4.1.6 . Cerebra Platform

Network Inference's Cerebra Server™ technology provides an implementation of the DL algorithms that use OWL documents in their native form. These algorithms are encapsulated into a run-time engine that is provided as a service to other applications or services and can respond to queries about ontologies from those applications. Cerebra Server™ provides linkages and techniques to reason about data and information not held within a given ontology, by accessing relational data structures or meta-data. Cerebra Server™ is based on FACT from University of Manchester, UK. The intent of Cerebra Server™ is to simplify the use of OWL documents for systems architects and integrators. Cerebra Server™ is compliant to RDF, DAML+OIL and OWL.

URL: http://www.enleague.com/products_v3.html

References:

Berkowitz, Jack: Network Inference Technology Whitepaper. Network Inference, 2003. http://www.networkinference.com/Products/asset_upload_file365_1360.pdf

Horrocks I. The FaCT system. In H. de Swart, editor, *Automated Reasoning with Analytic Tableaux and Related Methods: International Conference Tableaux'98*, number 1397 in Lecture Notes in Artificial Intelligence, pages 307-312. Springer-Verlag, May 1998.

Topics: Intelligent Integration of Information.

Ontologies used: *Not available.*

4.1.7 . IODE

IODE from Ontology Works utilizes a central description of enterprise data to determine answers to complex queries. Each link in the enterprise ontology is mapped to a query in the "ontology database"; this can either be a warehoused database created as part of the ontology engineering process, or a mediated connection to a legacy database. Solutions to queries in the ontology are build using the rules and relations in the ontology, so that the "proof" of the result can be translated in a simple fashion into a program that runs over the databases, to determine the correct answer. Modeling can be done using UML tools, translated into a proprietary Ontology Works Language.

URL: http://www.ontologyworks.com/products.htm

References:

Berkowitz, Jack: Network Inference Technology Whitepaper. Network Inference, 2003. http://www.ontologyworks.com/docs/whitepaper.pdf

William Andersen, Brian Peterson: An Ontology of Modern Military Organizations and their Structure. Conference Paper IJCAI 2001 Workshop on the IEEE Standard Upper Ontology, 2001. reliant.teknowledge.com/IJCAI01/Andersen.ps

Topics: Intelligent Integration of Information.

Ontologies used: *Not available.*

4.2 Information Retrieval applications

In this section, we review some applications of ontology-driven information retrieval, in which users can pose queries to the systems and it retrieves relevant information for them.

4.2.1 OntoSeek

Ontoseek is a system of cooperating intelligent agents. A first prototype of the system has been developed in a co-operative project between the COnsorzio di RIcerca Nazionale Tecnologia Oggetti (CORINTO), a partnership of IBM Semea, Apple Italia and Selfin SpA, and LADSEB-CNR, as part of a project on retrieval and reuse of object-oriented software components.

OntoSeek is designed for content-based information retrieval from online yellow pages and product catalogs. It combines an ontology-driven content-matching mechanism with a moderately expressive

representation formalism. Differently from most of current systems, the user is not assumed to have familiarity with the vocabulary used for component encoding, but the system relies on a large linguistic ontology called Sensus to perform the match between queries and data. It assumes that the information encoding and retrieval processes will involve a degree of interactivity with a human user.

URL: *No URL available*

References:

Borgo, S., Guarino, N., Masolo, C., and Vetere, G. (1997). Using a Large Linguistic Ontology for Internet-Based Retrieval of Object-Oriented Components. In Proceedings of 1997.

Conference on Software Engineering and Knowledge Engineering. Madrid, Knowledge Systems Institute, Snokie, IL, USA: 528-534.

Guarino, N., Masolo, C., Vetere, G. (1999). OntoSeek: content-based access to the Web. IEEE Intell. Syst. (USA), 70-80, vol.14, no.3, May-June 1999

Topics: Agents, Information Retrieval.

Ontologies used: SENSUS.

4.2.2 SemanticMiner

SemanticMiner [Moench 03b],[Moench 03] is a Knowledge Retrieval platform that combines semantic technologies with conventional retrieval approaches. The improved navigation enables the user to easily define semantic queries to all kinds of information sources – especially unstructured documents. Semantic information integration allows for different views and deep analysis of hidden knowledge by the externalization of implicit knowledge. SemanticMiner is designed in client-server architecture. It provides information retrieval in various data sources (e.g. files indexed with an index-server, hypertext-pages reached with a WWW search-engine, and data stored in a database via any DBMS). The SemanticMiner-Server (SMS), which is a specialized OntoBroker-system, provides the interface to the data sources as well as the inference engine to retrieve and present implicit knowledge.

Zope serves as web server to provide the client-side web-interface and as application server to query the SMS. This flexible middleware architecture allows the SemanticMiner to become easily configurable through one central interface [Sure 02].

URL: http://www.ontoprise.de/products/semanticminer_en

References:

- [Moench 03b] E. Moench, M. Ullrich, H.-P. Schnurr, and J. Angele. SemanticMiner - Ontology-Based Knowledge Retrieval. In *Journal of Universal Computer Science*, 9(7):682–696, July2003
- [Moench 03] E. Moench "Semantic Miner: Ein integratives Ontologie-basiertes Knowledge Retrieval System". In *Proceedings of the 2nd Conference on Professional Knowledge Management – Experiences and Visions (WM2003)*, April 2003, Lucerne, Switzerland.
- [Sure 02] Y. Sure, E. Moench: "SemanticMiner: Smarter Knowledge Retrieval". Poster Session at: First International Semantic Web Conference 2002 (ISWC 2002), June 9-12 2002, Sardinia, Italia.

Topics: Information Retrieval, Knowledge Management, Semantic Web.

Ontologies used: *Not available*.

4.2.3 SyDoM

SyDoM is a multilingual Information retrieval system based on a manual indexing. SyDoM proposes a semantic indexing method for XML-encoded documents based on knowledge describing the document content. Two types of knowledge are defined in a semantic thesaurus (an ontology used as a documentary language).

- Domain knowledge composes of concept types and relation types. These types defined a pivot language used to compare document and query representation.

- Terminological knowledge, which is organized in several vocabularies (one per language). Terminological knowledge is related to domain knowledge and constitutes some presentation languages used to visualize the domain knowledge in several languages.

In order to manipulate our indices, we define our own knowledge representation model entitled the semantic graphs. This model is an enrichment of the Sowa model of conceptual graphs by differentiating domain knowledge from terminological knowledge.

URL: http://lisisun1.insa-lyon.fr/

References:

Roussey C., Calabretto S., Pinon J-M. "Multilingual information system based on knowledge representation". Actes de la 5ème Conférence internationale Advances in Databases and Information Systems (ADBIS'2001); Vilnius, Lithuania, 25-28 septembre 2001. Berlin : Springer, 2001, Lectures Notes In Computer Science, Vol. 2151, p98-111.

Roussey C., Calabretto S., Pinon J-M. " A new Conceptual Graph Formalism Adapted for Multilingual Information Retrieval Purposes". Actes de la 12eme Conférence Internationale Database and Expert Systems Applications (DEXA'2001); Munich, Germany, 3-7 septembre 2001. Berlin : Springer, 2001, Lectures Notes in Computer Science, Vol. 2113, p92-101.

Roussey C., Calabretto S., Pinon J-M. "SyDoM: A Multilingual Information Retrieval System for Digital Libraries ". Actes de la 5eme Conférence Internationale ICCC/IFIP On Electronic Publishing (ELPUB'2001);Canterbury, UK, 5-7 juillet 2001, p 150-164.

Topics: *Not available*.

Ontologies used: *Not available*.

4.2.4 WebKB-2

WebKB-2 is a knowledge server that permits Web users to retrieve and add knowledge in a shared knowledge base. The following features distinguish WebKB-2 from other ontology servers or KBMSs: (i) the ontology is large (at present, 69,000 categories and 87,800 links mostly coming from WordNet) and extendible at any time by any user, (ii) asynchronous cooperation between users is supported and encouraged while the knowledge base is kept unique to maximize knowledge interconnection, retrieval and inconsistency detection, (iii) the proposed knowledge representation languages are designed to be both expressive and readable to permit and encourage the users to enter all the knowledge they want (though that still requires motivation).

WebKB-2 is ultimately intended to permit cooperatively-built Yellow-Page like catalogs, that is, permit Web users to publish their information in a way that is automatically retrievable and comparable with other users' knowledge.

URL: http://www.webkb.org/

References:

Martin Ph. & Eklund P. (2001). Large-scale cooperatively-built heterogeneous KBs. ICCS'01, 9th International Conference on Conceptual Structures (Springer Verlag, LNAI 2120, pp. 231-244), Stanford University, California, USA. July-August, 2001.

Martin Ph. & Eklund P. (2000). Knowledge Indexation and Retrieval and the Word Wide Web. IEEE Intelligent Systems, special issue "Knowledge Management and Knowledge Distribution over the Internet", May/June 2000.

Martin Ph. (1997). The WebKB set of tools: a common scheme for shared WWW Annotations, shared knowledge bases and information retrieval. Proceedings of ICCS'97, 5th International Conference on Conceptual Structures (Springer Verlag, LNAI 1257, pp. 585-588), Seattle, USA, August 4-8, 1997.

Topics: Information Retrieval, Knowledge Management, NL processing, Ontologies.

Ontologies used: Wordnet.

5 Education applications

The role of ontologies and/or the Semantic Web in educational or learning systems is discussed in this section.

Although our list is not meant to be exhaustive we aim to include representative examples of applications or projects which make use of ontologies or the Semantic Web. We have also included systems which make no mention of ontologies but which talk about, for example, structures of concepts and relations, others which call themselves semantic but confine this to the use of metadata schemes or XML and yet others which are more concerned with the infrastructure for accessing distributed resources. We hope that we have included all the important ontological oriented/semantic web based applications in the strict sense of the term. At the same time many of our examples would not be accepted as such by purists. Indeed our criteria are lax enough to allow the inclusion of any of the many Learning Object repositories or retrieval systems. In our defence any of these distributed systems could easily make use of a more strictly defined ontology or ontologies which would make them acceptable even to the strictest ontologist.

We can describe current research on learning and the (semantic) web as being centrally concerned with so-called *learning objects*—or separable units of instruction which can be combined and reused in a variety of educational contexts. Central to their reusability are the descriptions which their designers provide using a variety of metadata schemes. Currently there are a number of standards (e.g., IEEE-LOM, IMS, SCORM, CanCore) but it is likely that this number will be reduced with some standards combining and others being discarded as commercial and other pressures come into play. Anido et al. (see below under GESTALT) provide a good overview here.

URL: http://www.imsglobal.org/

URL: http://www.imsproject.org/

URL: http://ltsc.ieee.org/

URL: http://www.adlnet.org/

URL: http://www.cancore.ca/

For more recent standards such as the IMS Learning Design Specifications see http://www.imsglobal.org/learningdesign/index.cfm. Other sites such as CETIS (the UK's Centre for Educational Technology Interoperability Standards - http://www.cetis.ac.uk/) can provide up to date information. The page http://www.cetis.ac.uk/encyclopedia helps newcomers to navigate through the sea of acronyms.

Another development has been the growth of educational repositories (such as MERLOT and MIT OpenCourseWare) and peer to peer networks for sharing these. One example here is the Edutella network.

URL: http://www.merlot.org/Home.po

URL: http://ocw.mit.edu/index.html

URL: http://www.smete.org/smete/

URL: http://www.edna.edu.au/edna/page1.html

At the same time as the means of sharing these objects has developed, work has also proceeded on adding detail to the metadata schemes to ensure that learning objects can be re-used in a variety of specifiable learning contexts. Work on the Educational Modelling Language (EML) is key here.

Most of these developments have been accomplished without the use of explicitly semantic technologies (although as we said above we will often find metadata referred to as 'semantic'). However, a natural development of the repositories and networks is the notion of brokerages which match learners with learning materials (GESTALT) and course construction tools (see Stojanovic et al.'s scenario below) which attempt to automatically combine learning objects into 'courses' or sequences of objects. Finally, more recently, we have seen the development of educational semantic web services. An example here is the Smart Space for Learning approach using the Elena mediation infrastructure. The services here range from assessment, to short lectures, courses and degree programmes.

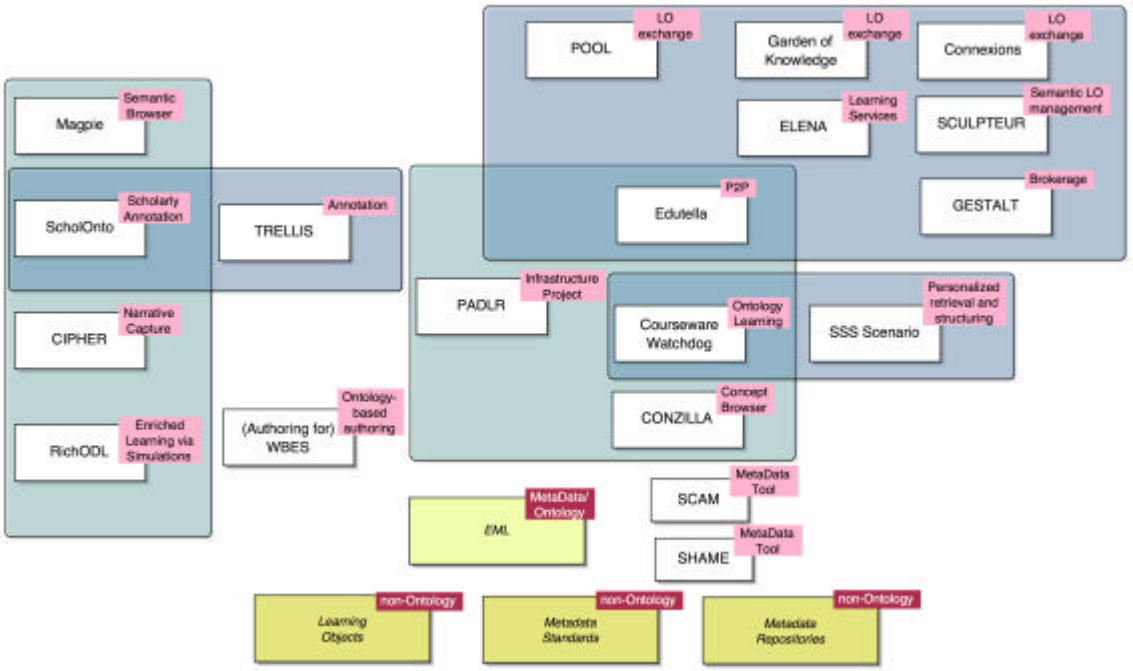


Figure 1: Our conceptualization of the Semantic Web and Learning space. The items are clustered in terms of their similarity, because they are part of a project or because they come from a particular research lab. The pink annotation boxes represent an embryonic ontology for describing research projects in this area.

Figure 1 attempts to cover the space of use of the semantic web or ontologies for education or learning. Note that the description of learning objects, their repositories and the competing standards used to describe them (apart from EML) is outside the scope of this report.

5.1 *CIPHER Project*

The CIPHER project aims to support the exploration of national and regional heritage. This is accomplished by supporting online *Cultural Heritage Forums* (CHFs) where a community focussed on a specific theme or interest can browse or construct narratives relating to the theme or interest. For example, a CHF supports a community interested in communicating/recording narrative accounts of relevant experiences at Bletchley Park in Milton Keynes UK where the Enigma encryption machine was deciphered during the second World War.

Tools associated with the project include the Apollo Knowledge editor, and the RAT Resource Annotation Tool.

URL: http://www.cipherweb.org

URL: http://rat.open.ac.uk

URL: http://apollo.open.ac.uk

References:

Mulholland, P., Zdrahal, Z. and Collins, T. (2002). CIPHER: Enabling Communities of Interest to Promote Heritage of European Regions. Cultivate Interactive, issue 8, 15 November 2002. Available from: http://www.cultivate-int.org/issue8/cipher/

Wolff, A., Zdrahal, Z. and Kouba, Z. (2002) Tools for Personalised Annotation and Organisation of Diverse Web Resources. In The Proceedings of the IEEE International workshop on Presenting and Exploring Heritage on the Web (PEH'02) in conjunction with the 13th International Conference and Workshop on Database and Expert Systems Applications (DEXA 2002). Aix-En-Provence, France. September, 2002.

Mulholland, P. and Collins, T.D. (2002) Using Digital Narratives to Support the Collaborative Learning and Exploration of Cultural Heritage. In The Proceedings of the IEEE International workshop on Presenting and Exploring Heritage on the Web (PEH'02) in conjunction with the 13th International

Conference and Workshop on Database and Expert Systems Applications (DEXA 2002). Aix-En-Provence, France. September, 2002.

Collins, T.D. and Mulholland, P. (2002) A Cultural Heritage Forum Celebrating Technological Innovation at Station X. In The Proceedings of the IEEE International workshop on Presenting and Exploring Heritage on the Web (PEH'02) in conjunction with the 13th International Conference and Workshop on Database and Expert Systems Applications (DEXA 2002). Aix-En-Provence, France. September, 2002.

Topics: Ontologies, Narrative, Learning, Heritage.

Ontologies used: Narrative, Domain

5.2 *Connexions*

Connexions is an open source project which provides *modules* (equivalent to learning objects), a repository, a markup language, and a set of tools for authoring, composing modules into courses and navigating through these courses. Special emphasis is placed on the community of authors. The markup language — cnxML — captures essential aspects of modules such as type (e.g., example, proof, problem, solution) and metadata (such as author, maintainer, abstract, objectives). XML Crosswalks (or mappings) will be provided to provide access to material marked up with other standard schemes such as MathML, IMS, SCORM.

URL: http://cnx.rice.edu/

URL: http://cnx.rice.edu/technology/cnxml/0.5/spec/

References:

Connexions Project (2003) Connexions: The White Paper Sharing knowledge and building communities with the Connexions approach to authoring, teaching, and learning. Revised November 10, 2003.

Henry, G. Baraniuk, R.G. and Kelty. C. (2003) The Connexions Project: Promoting Open Sharing of Knowledge for Education, Syllabus, July 2003.

Baraniuk, R.G. et al. (2002) Connexions: Education for a Networked World. IEEE International Conference on Acoustics, Speech and Signal Processing -- ICASSP'02, Orlando, May 2002.

All available from http://cnx.rice.edu/aboutus/publications/

Topics: XML, Authoring Tools, Course Navigation

Ontologies used: cxnML

5.3 *Conzilla*

A group at the Royal Institute for Technology (KTH) in Sweden is working towards the creation of the *Conceptual Web* —a layer above the Semantic Web intended to make it more accessible to humans using graphical *context maps*. These include concepts and relations among concepts. Conzilla is a concept browser which allows the user to navigate through a space of context maps to access associated content.

While the context maps are not referred to as ontologies by the authors of Conzilla, they may be regarded as equivalent.

While Conzilla has applications in areas such as e-commerce and administration it is also being developed as part of the PADLR project as a means of accessing and annotating learning objects.

URL: http://www.conzilla.org/

References:

Naeve, A., Nilsson, M. And Palmér, M. (2001) ELearning in the Semantic Age. Proc. 2nd European Web-based Learning Environments Conference (WBLE 2001), Lund, Sweden.

Naeve, A. (2001) The Concept Browser – a New Form of Knowledge Management Tool. Proc. 2nd European Web-based Learning Environments Conference (WBLE 2001), Lund, Sweden.

Naeve, A. (1999) Conceptual Navigation and Multiple Scale Narration in a Knowledge Manifold. CID-52, TRITA-NA-D9910, Dept Numerical Analysis and Computer Science, KTH, Stockholm.

All available from http://kmr.nada.kth.se/papers/index.htm

Topics: Knowledge Management, Concepts, Relations, Context maps, Semantic Web.

Ontologies used: Domain

5.4 Edutella

Edutella provides an infrastructure for Peer-to-Peer systems for exchanging educational resources. Edutella uses metadata based on standards such as IEEE-LOM to describe resources. Edutella provides a query service and a range of services for dealing with different meta-data sources and vocabularies.

Querying in Edutella is via the Conzilla query interface. Semantics is captured using a mixture of RDFS, DAML+OIL and Datalog rules.

URL: http://edutella.jxta.org/

References:

Nejdl, W., Wolf, B. Qu, C., Decker, S.. Sintek, M., Naeve, A., Nilsson, M., Palmér, M, and Risch, T. (2002) 11th Int. World Wide Web Conf. (WWW 2002), May, 2002, Hawaii.

Topics: Semantic Web, E-Learning, P2P, Query Languages

Ontologies used: Based on metadata standards for educational material such as IEE-LOM/IMS, and SCORM.

5.5 Elena

This project aims to create *Smart Spaces for Learning* which are defined as "educational service mediators, which allow the consumption of heterogeneous learning services via assessment tools, learning management systems, educational (meta) repositories and live delivery systems such as video conferencing systems" (from Web site). Since the project aims to provide the infrastructure which will make it possible to match learner needs with available resources and services, personalization is a central concern. The sorts of educational web services which can be accessed via Elena are primarily *learning services* which range from assessment, to short lectures, courses and degree programmes. They also include supplementary services such as brokering services, learner assessment services, service evaluation services and learning service provider reputation services.

Elena comprises the Edutella peer-to-peer infrastructure, a Learning Management Network (which includes the learning service providers and reputation services) and a Smart Space for Learning which includes a number of Personal Learning Assistants (which use learner profiles to search for, select and negotiate with suitable learning services).

URL: http://www.elena-project.org/

References:

Simon, B., Miklós, Z., Nejdl, W., Sintek, M. and Salvachua, J. (2003) Smart Space for Learning: A Mediation Infrastructure for Learning Services. Proceedings of the 12th World Wide Web Conference, May, 2003. Available from: http://nm.wu-wien.ac.at/research/publications/b164.pdf

Dolog, P. and Nejdl, W. (2003) Personalisation in Elena: How to cope with personalisation in distributed eLearning Networks. Proc of International Conference on Worldwide Coherent Workforce, Satisfied Users - New Services For Scientific Information. September 2003, Oldenburg, Germany.

Topics: Semantic Web, E-Learning, P2P, Web services, Educational Services, Learning Services, Personalization, User Profiles

Ontologies used: Educational Services, Educational Resources, Domain, Learner Profiles — based on standards such as Dublin Core, IEEE LOM, WSDL, DAML-S

5.6 EML

Educational Modelling Language (EML) is a notational system developed at the Open University of the Netherlands as a means of representing (a) the content of a unit of study (e.g., texts, tasks, assignments) and (b) "the roles, relations, interactions and activities of students and teachers". Thus EML goes beyond standards such as IEE LOM to model the social context of education. It is intended to capture any type of pedagogic strategy including, for example, competence based approaches and problem based learning. It now forms the basis for the IMS Learning Design Specification.

As with many XML based approaches ontologies are not mentioned. However the learning, unit of study, domain, and learning theory models which form the pedagogic meta-model can be construed as a set of ontologies.

URL: http://eml.ou.nl/introduction/explanation.htm

URL: http://imsproject.org/learningdesign/

URL: http://ltsc.ieee.org/

References:

Koper, R. (2000) From Change to Renewal: Educational Technology Foundations of Electronic Environments. Educational Technology Expertise Center, Open University of the Netherlands. Available from: eml.ou.nl/introduction/docs/ koper-inaugural-address.pdf

Koper, R. (2001) Modeling Units of Study from a Pedagogical Perspective: The Pedagogical Meta-Model Behind EML. Educational Technology Expertise Center, Open University of the Netherlands. Available from: eml.ou.nl/introduction/docs/ped-metamodel.pdf

Topics: Learning Objects, Metadata, Pedagogies

Ontologies used: Units of Study, Learning Theories, Model of Learning

5.7 Garden of Knowledge

Developed at the Royal Institute for Technology (KTH) in Sweden, the Garden of Knowledge is a learning environment "for keeping track of the interrelated structure of ideas, designed to support the expression of their relations to other ideas as well as their evolution over time and culture". Underlying the project is the notion of a *Knowledge Manifold* or collection of personal idea spaces (*Knowledge Patches)* through which individuals experience the world. Learners can add content in the form of *knowledge components* (units conforming to international standards such as IMS) which can be downloaded into knowledge patches. The conceptual structures (*context maps*) of knowledge in these patches/components are represented in ULM (Unified Language Modelling, a notation based on the Unified Modelling Language).

URL: http://kmr.nada.kth.se/gok/

URL: http://kmr.nada.kth.se/cm/

URL: http://www.omg.org/uml/

References:

Naeve, A. (1997), The Garden of Knowledge as a Knowledge Manifold - a Conceptual Framework for Computer Supported Subjective Education, CID-17, TRITA-NA-D9708, Department of Numerical Analysis and Computer Science, KTH, Stockholm.

Topics: Knowledge Manifolds, Knowledge Patches, Conceptual Modelling, UML

Ontologies used: Units of Study, Learning Theories, Model of Learning

5.8 GESTALT

The GESTALT project provides a Resource Discovery Service (RDS) which provides access for learners to educational resources. This takes places as a three-step process: (a) the broker accepts a query, (b) searches for resources using metadata (and optionally learner profiles) and (c) delivers these to the user.

URL: http://www.fdgroup.co.uk/gestalt/

References:

Anido, L. E., Fernández, M.J., Caeiro, M., Santos, J.M., Rodríguez, J.S. and Llamas, M. (2002) Educational metadata and brokerage for learning resources. Computers & Education Volume 38, Issue 4, 351-374.

Topics: Semantic Web, E-Learning, Brokerage

Ontologies used: Educational Services, Educational Resources, Domain, Learner Profiles — based on standards such as Dublin Core, IEEE LOM, WSDL, DAML-S

5.9 KTH Metadata Tools

SCAM is a content archive management system which uses RDF for its metadata which supports standards such as Dublin Core, IEEE LOM and IMS. SHAME is a framework for building metadata editors. There are demonstration editors for LOM and Dublin Core. It can also be used to build query systems for RDF metadata.

URL: http://kmr.nada.kth.se/scam/

URL: http://scam.sourceforge.net/

URL: http://kmr.nada.kth.se/shame/

URL: http://sourceforge.net/projects/shame

References:

Paulsson, F., Naeve, A. (2003), Standardized Content Archive Management – SCAM, IEEE Learning Technology newsletter (ISSN 1438-0625), Vol 5, Issue 1, pp 40-42, Jan 2003. Available from: http://lttf.ieee.org/learn_tech/issues/january2003/learn_tech_january2003.pdf

Topics: Content Management, Metadata, RDF

Ontologies used: Dublin Core, IEEE LOM

5.10 Magpie

While Magpie can be used as a generic semantic web browser, it originated. in part, as a means of assisting in sense-making for participants in the Climateprediction.net experiment. This experiment, like the Seti@home project, makes use of the distributed computing resources of thousands of home computers, in this case, to run different versions of a climate model. Magpie provides access (via a contextual menu) to complementary sources of knowledge which can be used in contextualizing and interpreting the knowledge in a Web page. This is done by automatically associating a semantic layer to a Web page. This layer depends on one of a number of ontologies which the user can select. When an ontology is selected, the user can also decide which classes are to be highlighted on the Web page. Clicking on a highlighted item (i.e., an instance of a class from the selected ontology) gives access to a number of semantic services. For instance the ontology could contain the class 'Project'. Clicking on an instance of this class would provide access to Project details, Research Areas, Publications, Resulting Technologies, Members, Shared Research Areas and project Web Page. In the Climateprediction.net project access is to material which will help to make sense of statistical analyses of complex climate models as well as to the rich literature on climate modelling and climate change.

URL: http://kmi.open.ac.uk/projects/magpie/

URL: http://www.climateprediction.net

References:

Dzbor, M., Domingue, J. and Motta, E. (2003) Magpie – Towards a Semantic Web Browser. ISWC-2003

5.11 PADLR

The Personalized Access to Distributed Learning Repositories project aims to produce a distributed learning web infrastructure. This involves Peer-to-Peer learning resource networks (Edutella is used here), learning environments and personalized *courselets*. Apart from Edutella, another module in the project is the Courseware Watchdog which crawls the web for resources. Courseware Watchdog is also able to cluster resources and provides browsing and visualization tools for the resources it finds and clusters it creates. Finally, it has a mechanism for updating its ontology as new resources (and possibly new trends) become available.

URL: http://www.learninglab.de/english/projects/padlr.html

URL: http://www.learninglab.de/padlr/index.html

URL: http://kmr.nada.kth.se/proj/padlr.html

References:

Nejdl, W., et al (2001), Personalized Access to Distributed Learning Resources (PADLR), WGLN project proposal 2001.

Schmitz, C., Staab, S, Studer, R., Stumme, G. and Tane, J. Accessing Distributed Learning Repositories through a Courseware Watchdog. E-Learn-2002 - Proc. of the World Conference on E-Learning in Corporate Government, Health Care, & Higher Education. Montreal, CA, October 15-19, 2002. AACE.

Topics: P2P, Learning environments, Learning Web, Personalization

Ontologies used: Course materials, Educational/academic

5.12 POOL

The Portal for Online Objects in Learning (POOL) Project is a Canadian project using the CanCore metadata scheme to produce learning object repositories. SPLASH is an application for creating metadata for learning objects, as well as storing and accessing these. PONDS are larger repositories associated with communities. An important aspect of this project is its recognition that there should be two levels of metadata: one of these is generic but with fewer fields than standards such as IEEE LOM, the other is constructed by communities to meet community needs.

URL: http://www.edusplash.net/

References:

Hatala, M. and Richards, G. Global vs. Community Metadata Standards: Empowering Users for Knowledge Exchange, in: I.Horrocks and J.Hendler (Eds.): International Semantic Web Conference 2002, Springer, LNCS 2342, pp. 292-306, 2002.

Hatala, M. and Richards, G. Making A Splash: A Heteregeneous Peer-To-Peer Learning Object Repository, In Proceedings of 12th International Conference of The World Wide Web Consortium (WWW2003), Budapest, May 20-24, 2003

Topics: Metadata, CanCore, Learning Repositories, Semantic Web, Ontologies, Community/Generic Ontologies

Ontologies used: Standard metadata, Local ontologies

5.13 RichODL

RichODL is a learning Web-based environment developed at the Knowledge Media Institute (KMi) at the UK's Open University. It is intended for the training of students and practitioners in the modelling and simulation of dynamic systems. RichODL makes use of KMi knowledge technologies to provide a means of indexing and searching for solved examples with accompanying text. It incorporates a discussion space system — D3E. Ontologies are used to describe the physical domain of the modelled systems.

URL: http://rich-odl.open.ac.uk/

URL: http://d3e.sourceforge.net/

References:

Zdrahal Z., Mulholland P., Domingue J. Hatala M. (2000). Sharing engineering design knowledge in a distributed environment. Behaviour and Information Technology. Vol. 19, No. 3. pp. 189-200.

Topics: Individual and Group Learning, Simulation, Dynamic-Systems Models, Ontologies

Ontologies used: Domain

5.14 ScholOnto (Scholarly Ontologies Project)

In order to support disagreement and conflicting perspectives in academic research fields, we need tools which support the user in making sense of the relations among documents. The ScholOnto project is developing an ontology-based digital library server to support scholarly interpretation and discourse. Researchers can articulate their view of where a document fits in the ongoing academic conversation thus creating a semantic network of scholarly discourse.

A tool — ClaiMaker — has been developed to model the rhetorical relations (proves, refutes, is consistent with, is analogous to, and so on) among claims in research papers, publish these on a server and make queries about the relations and the documents containing them.

While not intended primarily as a learning tool, both the access to a web of inter-related scholarly papers and the opportunity to add further annotations (i.e., extend the research paper semantic web) have educational and well as research applications.

URL: http://kmi.open.ac.uk/projects/scholonto/

URL: http://claimaker.open.ac.uk/

References:

S. Buckingham Shum, E. Motta, J. Domingue ScholOnto: An Ontology-Based Digital Library Server for Research Documents and Discourse. International Journal on Digital Libraries (2000), 3 (3), 237-248.

Li, G., Uren, V., Motta, E., Buckingham Shum, S., and Domingue, J. (2002) ClaiMaker: Weaving a Semantic Web of Research Papers. 1st Int. Semantic web Conference (ISWC 2002), Sardinia.

Topics: Scholarly/Scientific Publishing, Argumentation, Knowledge Management, Ontologies, Semantic Web.

Ontologies used: ScholOnto academic discourse ontology.

5.15 SCULPTEUR

SCULPTEUR is a project which aims to provide the tools for creating, managing, visualizing and learning from, cultural heritage collections. It uses semantic web technologies to query and navigate cultural objects by creating a semantic layer which integrates metadata. *Cultural Learning Objects* comprising 3D models of cultural objects, and other learning material, can be created and displayed using Web browsers and stored using LOM and SCORM in a repository. The project is considering the use of the CIDOC Conceptual Reference Model (CRM) as its main ontology.

URL: http://www.sculpteurweb.org/

URL: http://cidoc.ics.forth.gr/

References:

Giorgini, F. and Cardinali, F. (2003) From Cultural Learning Objects To Virtual Learning Environments For Cultural Heritage Education: The Importance Of Using Standards, Digicult Thematic Issue 4: Learning Objects from Cultural and Scientific Heritage Resources. Available from: http://www.digicult.info/pages/index.php

Topics: Cultural Heritage, Learning Objects

Ontologies used: CIDOC

5.16 Stojanovic, Staab, and Studer's E-learning and the Semantic Web Scenario

In this important paper, Stojanovic, Staab and Studer illustrate how the Semantic web could be used to implement an E-learning scenario. Ontologies can be use to describe (a) the *content* of learning materials, (b) the pedagogical *context* (such as introduction, analysis, discussion), and (c) the *structure* (the overall set of relations among parts of a course such as previous, next, is-part-of, references and so on). This three-fold ontology can be used to personalize access to learning materials.

URL: http://www.aifb.uni-karlsruhe.de/WBS/sst/Research/Publications/Publications.htm

References:

Stojanovic, L., Staab, S and Studer, R. (2001) ELearning Based on the Semantic Web. Proceedings WebNet2001 - World Conference on the WWW and Internet, Orlando, Florida, USA, 2001.

Topics: Semantic Web, Ontologies, E-Learning

Ontologies used: Course ontology, Content/Context/Structure Ontologies

5.17 Trellis

Trellis is an environment which allows user to record/annotate relationships among document fragments. For instance the *statement* "The average water temperature in March is 63 degrees" may have been taken from a complete *document* (web page or other resource). Statements can also be conclusions,

observations, summaries or hypotheses created by the user. *Units* are several statements related by *constructs.* Thus a unit could be the argument that the water is unsustainable for divers *because* the water temperature is 65 degrees and a minimum temperature of 65 degrees is needed. All of these statements may be associated with URIs. Thus Trellis provides a means of adding user-oriented structure to the Web.

The vocabulary for annotation represents a statement or discourse ontology which can be extended by the user. While Trellis is not intended for learning, it is described as a knowledge acquisition tool which allows users to add knowledge (the structures) as they analyze something. Browsing these analyses would be useful for learners as would the construction of units.

URL: http://trellis.semanticweb.org/

URL: http://www.isi.edu/ikcap/trellis/

References:

Gil, Y. and Ratnakar, V. (2002) Trusting Information Sources One Citizen at a Time. Proceedings of the First International Semantic Web Conference (ISWC), Sardinia, Italy, June 9 -12, 2002. Available from: http://trellis.semanticweb.org/expect/web/semanticweb/iswc02_trellis.pdf

Gil, Y. and Ratnakar, V. (2002) TRELLIS: An Interactive Tool for Capturing Information Analysis and Decision Making. In Proceedings of the 13th International Conference on Knowledge Engineering and Knowledge Management, Siguenza, Spain, October 1-4, 2002. Available from http://www.isi.edu/~gil/papers/trellis-ekaw02.pdf

Topics: Semantic Web, Analysis, Statement ontology

Ontologies used: Annotation/Statement ontology

5.18 (Authoring for) WBES

Aroyo and Mizoguchi propose the use of an Authoring Task Ontology as a means of simplifying the authoring of material for Web-based Educational Systems (their examples of WBESs are SmartTrainer and AIMS). Their ATO defines the main authoring activities and sub-activities as well as stages and goals. It includes *nouns* (or objects to be manipulated) such as course, student, text; *verbs* (or authoring activities) such as modify, assign, select; *adjectives* (the modifications of the objects) such as finished, in-use, updated.

URL: http://wwwis.win.tue.nl/~laroyo/

URL: http://www.ei.sanken.osaka-u.ac.jp/members/miz/overview.html

References:

Aroyo, L. & Mizoguchi, R. (2003). Process-aware Authoring of Web-based Educational Systems First International Workshop on Semantic Web for Web-based Learning (SW-WL'03), Workshop at CAISE'03 (The 15th Conference on Advanced Information Systems Engineering, Klagenfurt/Velden, Autria, June 2003. Available from http://www.swwl03.bessag.net/images/Papiers/SW-WL03-Paper%201.pdf

Topics: Web-Based Educational Systems, Authoring, Ontologies.

Ontologies used: Authoring Task Ontology

6 References

The main references for this section have been already provided in each subsection.