Building a distributed system for dynamic information search, organization and classification for educational purposes

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Abstract. Our focus is on a Web-based Knowledge Portal for educational purposes. We consider a distributed system for information retrieval and document collection, which will enable different forms of knowledge construction. Also accessing information from multiple information systems and integrating them into a knowledge portal are key issues in developing our system. Some tools are considered to be used namely ontologies, concept maps and software agents to deal with semantic issues.

Previous related initiatives are described and tools for dealing with semantics are also present. A comprehensive section on syntactic and semantic interoperability is described in detail.

A very high-level architecture is drafted along with ideas to deal with its implementation

Introduction

Currently we are designing a scaffold for learning with semantic interoperability, with two issues. One aspect is considering web search for information retrieval. Other is using reusability of learning contents available in autonomous and heterogeneous information systems.

Despite the technological aspects, conceptual and pedagogical issues arise when we develop a framework for being used by learners. All the design and system architecture are based on the social constructivist theory that sees learning as a participation in social processes of knowledge construction.

This knowledge portal is intended to be a reference place for students of an undergraduate or graduated course where all members (tutors, teachers, content producers) will have an active role in achieving good educational results. It is intended as a reinforcement in their study of a real subject, where they can revise subjects, understand their basics, other fields of interest some how related and even go deep in the subjects of their course.

We have been studying Knowledge Management Systems (KMS) and B2B application integration to draw our framework. Both refer semantic, which is intended to be the core issue of our system. To deal with it we intend to use some available technologies, namely software agents, ontologies and Concept maps.

One might say that our approach of reusability tends to follow a method-oriented B2B application integration, but for us the trading partners are schools or education institutions. A common set of objects, that for us are content usable in disciplines, invites reusability and significantly reduces the need of redundant methods and applications. By defining methods these can be shared and integrated, in inter application trough distributed objects.

In this article we first focus KMS, B2B, semantic and syntactic interoperability and then analyze some architecture platforms with semantic support and some integration in data or logic level. We also present some considerations about semantic desktop. Finally a comprehensive framework is proposed to provide semantic interoperability among different systems web supported. Finally future work is referenced, namely building the system, evaluating its effectiveness and usefulness.

KMS

Knowledge management systems aren't a new idea. In fact in 1997 University of California, Berkeley [15] have already implemented a KIE (Knowledge Integration Environment) which is a learning environment that uses Internet to help middle and high school students develop an integrated understanding of science and a critical eye toward the complex resources found on the Web. The KIE combines network resources and software with sound pedagogical principles to improve science learning. KIE networking tools allow students to use scientific evidence in activities that foster knowledge integration. [4]

This project continued in the Web-based Inquiry Science Environment (WISE), which is a free on-line science learning environment for students in grades. [16]

Knowledge management systems (KMS) are also emerging applications that require mechanisms for dealing more explicitly with the meaning and use of the data with semantics.

B2B

After having studied some aspects related to data-oriented B2B application integration data movement, transforming tools and technologies we thought in applying these same concepts into a web portal which will provide a working place for students to deal with their school matters.

In an B2B application integration may occur at the data level or logic level. Also integration can occur in the B2B oriented application interface. In this layer we take into account the usefulness of APIs (Application Programming Interfaces) because we will be able to communicate to applications that use a proprietary interface with a standard interface. APIs developers may invoke the services of the entities evolved in order to obtain some value of them. For example the Google search engine provides its APIs for search and manipulates information on the web. In this particular case applications connect remotely the APIs threw the SOAP protocol, a mechanism based on XML format, which uses HTTP. [17]

Before implementing an application method-oriented one must decompose it to its scenarios or types. In a B2B application these can be rules, logic, data and objects.

Rules are defined as a set of conditions and are used to control the flow of information between partners.

Logic differs from rules in that way it is simply a sequence of instructions in a program. There are three classes of logic: sequential processing, selection and iteration. Sequential processing is related to a series of steps in data processing, while selection is the decision making dynamic within the program. Iteration can be seen as the repetition of a series of steps.

Data is sharing information between trading applications, computers and humans.

Objects are simply data and business services bound as objects. In fact they are bundles of data encapsulated inside an object and surrounded by methods that act upon that data. [24]

Process B2B integration can be defined as the ability to define a common business process model that defines the sequence, hierarchy, events, execution logic, and information movement between systems residing in multiple organizations.

For creating a portal with a web browser interface one must first design the portal application, including the users interface and application behaviour, as well as determine which information contained within the back systems. The portal application needs a traditional analysis-and-design life cycle , as well as a local database. Also a portal architecture is based in web clients, web servers, database servers, back-end applications as application servers. [24]

An architecture diagram (fig. 1) of a general portal, with its evident business logic layer, is called a three layer which enhances scability. Also we can see different types of usages made from different users. The technology involved to integrate different systems can be XML, RDF [22] or even OWL based. [23] In fact these three types distinguish different levels of semantic.

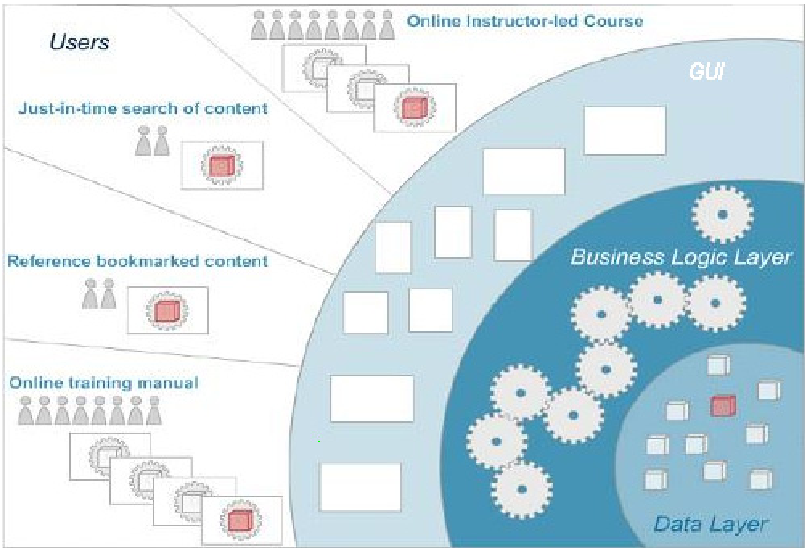

Fig. 1. Architecture diagram

XML provides a surface syntax for structured documents, but imposes no semantic constraints on the meaning of these documents and its associated XML Schema. A XML Schema is considered a language for restricting the structure of XML documents.

RDF [22] is a relation model for objects (”resources”) and relations between them. Provides simple semantics for this model, and these models can be represented in an XML syntax. In this case RDF Schema is a vocabulary for describing properties and classes of RDF resources, with a semantics for generalization-hierarchies of such properties and classes.

Going a step further there's OWL [23] which adds more vocabulary for describing properties and classes: among others, relations between classes (e.g. disjoint ness), cardinality (e.g. ”exactly one”), equality, richer typing of properties, characteristics of properties (e.g. symmetry), and enumerated classes.

Syntactic and semantic interoperability

Integration with interoperability brings a semantic problem as well as syntactic problem among heterogeneous and distributed information systems.

According to [2] semantic interoperability is the knowledge-level interoperability that provides cooperation between businesses. With the ability to bridge semantic conflicts, which arise from differences in implicit meanings, perspectives, and assumptions, we create a semantically compatible information environment based on the agreed concepts between different business entities.

Syntactic interoperability is the application-level that allows multiple software components to cooperate even though their implementation languages, interfaces, and execution platforms are different. [16]

Some available emerging standards such as XML and Web Services based on SOAP (*Simple Object Access Protocol*), UDDI (*Universal, Description, Discovery, and Integration*), and WSDL (*Web Service Description Language*), can resolve many application-level interoperability problems and give a technology solution. But semantic interoperability assumes its solutions in semiotic, linguistic, philosophical, or social environments.

Integration in Data level requires managing the differences in metadata and application semantics. Semantic conflicts might be resolved at the data level, or achieve interoperability resolving schema-level conflicts, that is, structural differences.

The design of a semantically interoperable system environment should provide the capability of detecting and resolving incompatibilities in data semantics and structures, as well as a standard query language for accessing information on a global basis. At the same time, it should involve minimal or no changes to existing systems to preserve the local autonomy of the participating systems. The environment must be flexible enough to permit adding or removing individual systems from the integrated structure without major modifications. [16]

Previous research in semantic interoperability can be categorized into three broad areas: mapping-based, intermediary-based, and query-oriented approaches.

The mapping-based approach attempts to construct mappings between semantically related information sources. It is usually accomplished by constructing a global schema and by establishing mappings between the global schema and the participating local. Mappings are not limited to schema components (i.e., entity classes, relationships, and attributes), but may be established between domains and schema. The drawback of the global schema approach is that it is not designed to be independent of particular schemas and applications. Explicit representations of semantics of information sources can help resolve the problems associated with interoperability when constructing mappings between them.

Another promising approach is the intermediary-based approach, which depends on the use of intermediary mechanisms (e.g., mediators, agents, ontologies, etc.). These intermediaries may have domain-specific knowledge, mapping knowledge, or rules specifically developed for coordinating various autonomous information sources. In most cases, such intermediaries use ontologies to share standardized vocabulary or protocols to communicate with each other. The advantage of using ontologies is its ability to capture the tacit knowledge within a certain domain in great detail in order to provide a rich conceptualization of data objects and their relationships. Its knowledge is domain-specific, but independent of particular schemas and applications. Even though such an approach may be theoretically valid, the inherent complexities of the knowledge domain bring enormous difficulties to develop and maintain ontology in autonomous, dynamic, and heterogeneous databases. Therefore, this approach is typically applied only to a restricted application domain, which limits its general applicability in practice.

The third approach, query-oriented approach, is based on interoperable languages, most of which are either declarative logic-based languages or extended SQL. They are capable of formulating queries spanning several databases. In order to resolve semantic conflicts over data structure and data semantics, it is desirable to have high-order expressions that can range over both data and metadata. One of the main drawbacks of this approach is that it places too heavy a burden on users by requiring them to understand each of the underlying local databases. This approach typically requires users to engage in the detection and resolution of semantic conflicts, since it provides little or no support for identifying semantic. Consequently, users are also responsible for semantic conflict resolution.

These research approaches classified into these three categories may not be mutually exclusive. For example, the intermediary-based approach may not necessarily be achieved only through intermediaries. Some approaches based on intermediaries also rely on mapping knowledge established between a common ontology and local schemas. It is also often the case that mapping and intermediaries are involved in query-oriented approaches.

In B2B application integration, semantic conflict analysis can occur at the data level and at the schema level. Data-level conflicts are differences in data domains caused by the multiple representations and interpretations of similar data. Examples of data-level conflicts are data-value conflicts, data representation conflicts, data-unit conflicts and data precision conflicts. Data-level conflicts can be further classified into two different levels depending on the granularity of the information unit (IU). Semantic conflicts can occur at the level of objects' properties and their values (attributes as IU) or at the level of the objects themselves (entities as IU), but not necessarily try to resolve structural differences.

Schema-level conflicts are characterized by differences in logical structures with inconsistencies in metadata of the same application domain. Examples can be found in: naming conflicts, entity-identifier conflicts, schema-isomorphism conflicts, generalization conflicts, aggregation conflicts and schematic discrepancies.

Naming conflicts arise when labels of schema elements (i.e., entity classes, relationships, and attributes) are somewhat arbitrarily assigned by different database designers.

Entity-identifier conflicts are often caused by assigning different identifiers (primary keys) to the same concept in different databases.

Schema-isomorphism conflicts occur when the same concept is described by a dissimilar set of attributes, that is, the same concept is represented by a number of different attributes and, therefore, the sets of entities are not set operation-compatible. Generalization conflicts result from different design choices for modelling related entity classes.

Aggregation conflicts arise when an aggregation is used in one database to identify a set of entities in another database. Therefore, the properties and their values in one database may aggregate corresponding Properties and values of the set of entities of another database schematic discrepancies can occur when the logical structure of a set of attributes and their values belonging to an entity class in one database are organized to form a different structure in another database. The pure schema-level approach, without data-level interoperability, however, may result in achieving interoperability between different schemas that may be semantically different but structurally similar. It is, therefore, desirable to achieve interoperability at both levels. [24]

Some architecture platforms with semantic support

We tried to analyse some architecture platforms which integrate knowledge and have information visualization methods, as the one we intend to build. We divided our analysis in two kinds of approaches:

The first considers *visualizing knowledge and information* for fostering learning and instruction.

They are mainly based on concept mapping technology. Information is conceived as a knowledge resource and is represented in the map. The map is functioning as a personal repository that has been constructed for facilitating visual search and access to knowledge elements and associated resources.

The later is a *knowledge-oriented information organization.*

They may serve as a developmental aid for course designers or as an information basis for students engaged in self-regulated learning in a resource-based learning environment. Concept maps functioning as organizational tools may also be used as navigational aids for fostering knowledge, providing facilities for the visual search of documents in broad information repositories, for example, the World Wide Web, digital libraries, or hypermedia environments. [5]

Both scenarios can be interested to cope in our system. The first scenario can be seen when the learner uses the portal for learning around a particular concept. He has multiple sources to understand it. On the second scenario one might consider the tutor to navigate throw the concept map to populate it with new repositories to be used by the learner. Or even the learner can navigate throw the concept map to visualize the entire subject.

In a first approach Tergan [6] recently brought a new perspective of using concept maps in educational scenarios. The potential of digital concept maps for supporting processes of individual knowledge management is analyzed. The author suggests digital concept mapping as a visual-spatial strategy for supporting externalized cognition in resource-based learning and problem solving scenarios. In fact many authors dealing with cognitive demands inherent in a variety of educational, social, and workplace scenarios, refer explicitly to concept maps as a means for bridging the gap between knowledge visualization and information visualization.

Also Canãs [5] outline a conceptual knowledge represented in a Concept map, which may be linked with content knowledge and information resources coded as text, images, sound clips, or videos accessible in personal or public repositories. In CmapTools, the use of concept maps has been extended beyond knowledge representation to serve as a browsing interface to a domain of knowledge and associated information. The authors outline special features of the approach for integrating, making accessible, and using knowledge and information.

Other important platform, by Neumann [8] called ParIS, which is a learning environment that aims at fostering the development of competencies for self-regulated learning and media competencies as central components of scientific literacy. In ParIS, students solve everyday authentic problems by using Mind Mapping, a visual-spatial strategy to assist planning, gathering, generating, organizing, and using knowledge and knowledge resources. The presented instructional design approach transforms ideas of supporting resource-based learning by helping students visualize their knowledge and relate it to information associated with it.

On the second approach, Coffey [11] describes a learning environment organizer (LEO) that provides students and instructors with information and knowledge visualization capabilities. LEO serves as a meta-cognitive tool for course designers and an advanced organizer for students. It is an extension of the CmapTools developed by Cañas and associates. LEO helps to visualize and plan a course organization by using a concept map. The concept map itself is used as knowledge based visualization of the structure of course components and provides interactive access to the materials. It presents an interesting approach, doable to follow, by integrating both fields of research knowledge and information visualization.

Also Fiedler [12] develop the tool "Weblog authoring”, which enables the user to represent information spontaneously and to maintain it in personal repositories, as well as to generate a social network and collective information filtering and routing. Weblog authoring supports the construction of a personal repository of information, as well as the ability to engage in shared dialogue about artefacts, with the possibility and the benefits of using concept mapping to make sense of the Weblog representations.

Even Lee [13] focuses on design rationales and implementations of an alternative Web search environment called "VisSearch". It has some advantages, particularly with regard to cognitive processes, in dealing with ill structured, open-ended research questions, as compared to conventional Web-search environments. The VisSearch environment facilitates information searching in dealing with such problematic search questions by means of visualizing the knowledge and associated Web resources of both the user and other users looking for useful Web based information on the same or similar topics. VisSearch employs a single, reusable concept map-like knowledge network, called search-graph for a variety of purposes, for example, visualizing Web search results, the history of Web search engine hits of a variety of iterative Web searches of different users, as well as user comments to Web sites and search queries.

The search-graph provides interactive access to all Web resources linked with the elements in the graph.

Going a step further we analysed Frank [14] which gives a strictly application-oriented approach. It focuses on the visualization of knowledge and information management activities underlying the development of the Management Information System (MIS) at DaimlerChrysler. The MIS is for the leaders of the department of research and technology, the central department for technical innovations and the management of technology. It is used not only as a tool with a controlling function, but as a general homogenous information and dialogue platform of high actuality and flexibility, serving as a knowledge and information space. The aim for developing the system was to match the user's needs, processes and visions as closely as possible. The authors show how complex processes and problem solutions in the development and maintenance of a MIS may be visualized and used for facilitating dialogue and for working with a large number of content elements, highly complex information structures and large knowledge networks.

This contribution opens up a perspective of how visualizations may be used on a large-scale basis for knowledge and information visualization in the application context.

Semantic Desktop

Semantic desktop for personal information management and collaboration intends to enable the integration of desktop applications, with the use of ontologies, metadata annotations and semantic web protocols on desktop computers with an integrated personal information management focusing information distribution and collaboration on the Web. This issue is not new. The Semantic Web effort (W3C-SW) [21] provides standards and technologies for the definition and exchange of metadata and ontologies.

Use open-source software with reusability and create, on top of existing sophisticated system, an open personal information management system and collaborative infrastructure based on Semantic Web. *Collaboration, acquisition and dissemination infrastructures* like Wikis and Blogs are providing the foundation for joint collaborative knowledge creation and are essentially simplified knowledge acquisition tools.

Social Software maps the social connections between different people into the technical infrastructure. Online Social Networking enables collaboration relationships as first class citizens, and allows exploiting these relationships for automated information distribution and classification.

P2P and Grid computing, especially in combination with the Semantic Web field, develops technology to interconnect large communities without centralized infrastructures for data and computation sharing, which is necessary to build heterogeneous, multi-organizational collaboration networks.

Several systems have been created already to explore this field, e.g., the Haystack [18] system at MIT, the Gnowsis [19] system at DFKI, or the Chandler [20] system by the OSA foundation. Each of these systems only addresses some parts of the picture.

Proposal of architecture for a Web Portal on a distributed platform of documents

Our framework for the Portal is a multitier architecture which supports various levels of user activities in managing the semantically interoperable environment. Bearing in mind that the Knowledge Portal is based for information finding, classification and even organizing the retrieval of courseware material by users. We are presenting its system architecture as well as its technologic architecture.

System Architecture

The Knowledge Portal comprises three layers: *Information Access* from the user's perspective, *Information Processing* features of the portal and the *Grounding Technologies*. [9]

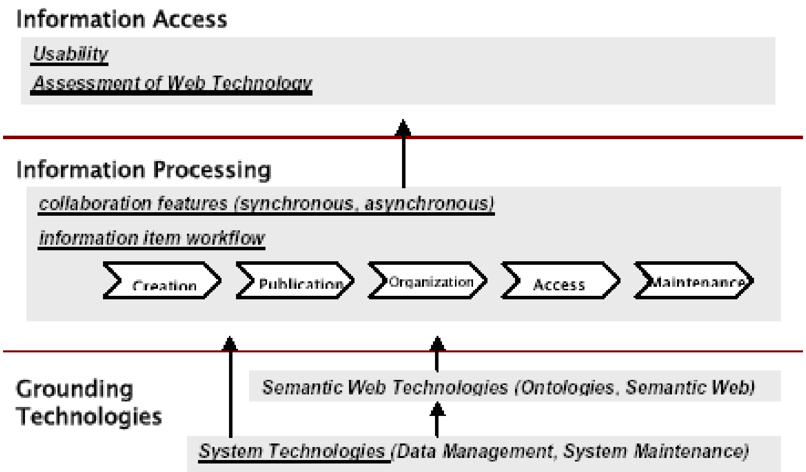

Fig. 2. Layer Architecture

Information Access layer comprises the usability and Assessment of Web Technology. In other words this layer is the front-end of our Knowledge portal for a virtual community, with semantic capabilities.

In detail we are building a knowledge portal in a collaborative perspective with different classes of users. In a brief discussion there are learners, visitors, tutors and administrators. Each member of a class can add new members, which will inherit its privileges.

Some considerations have been taken to the navigation structure. Also we must consider some usage and navigation rules in this layer.

In Information processing layer we are mainly concerned with collaboration features (synchronous, asynchronous) and information item workflow.

Some issues related to document management systems from creation, Publication, organization, access and destruction / maintenance have not yet been considered, but for us collaboration features enabling virtual groups of different domain of interest, such us different courses, must be taken in consideration with synchronous, such as forums and asynchronous features.

The layer grounding Technologies we should consider two aspects. In one hand System Technologies, such as Data Management and System Maintenance. In other hand Semantic Web Technologies namely Ontologies and Topic Maps.

For the former we have not yet decided which Data Management and Data Storage we should consider. But we bear in mind that the success depends upon the System Maintenance and System Administration. Especially the ontologies applied in the system as well as different levels of access with password-protection.

For the later we should consider ontologies based in RDF [22] or OWL [23] with agents to interact with portal members.

This layer is the core of the system, in an innovative perspective, because ontologies are the central components of the portal. Ontology provides term definitions of the domain of interest and it can be applied in different ways to enable Semantic Web enhanced functionalities. Two types of ontologies should be considered, domain ontologies and application ontologies. Also for a knowledge portal based semantic web there must exist some tools for Ontology Management and Editing capabilities using an ontology editor like PROTÉGÉ , OntoEdit, or an editor facility integrated in the portal.

We intend to use a dynamic ontology, tracking the changes with consistency.

The KAON (Karlsruhe Ontology and Semantic Web Framework) Framework disposes an ontology tool. KAON offers abstractions for ontologies and text corpora, an ontology editor and application framework, inferencing, and persistence mechanisms, etc. [10] .

Furthermore Semantic Web Services will add a new level of functionality to allow automatic content search, content publication, import and export documents in a distributed environment.

Technological Architecture

Agents are to some degree knowledgeable about the subject matter being learned and are also programmed to have some knowledge about how to find and filter information from available resources in the Internet.

Our portal will have some agents with precise roles. The *Pedagogical Agent* will interact to the user helping in his path. The *Search Agent* will help the tutor to find related documents to attach to the Portal. The *Ontology Agent* to maintain the Ontologies coherent during the dynamic changes made by tutors. Finally the Monitor Agent which will track user actions, activity levels, to facilitate the collaboration process in accordance by urging users to thoroughly discuss concepts, try to initiate discussions and encourage users to reach common ground when negotiations fail.

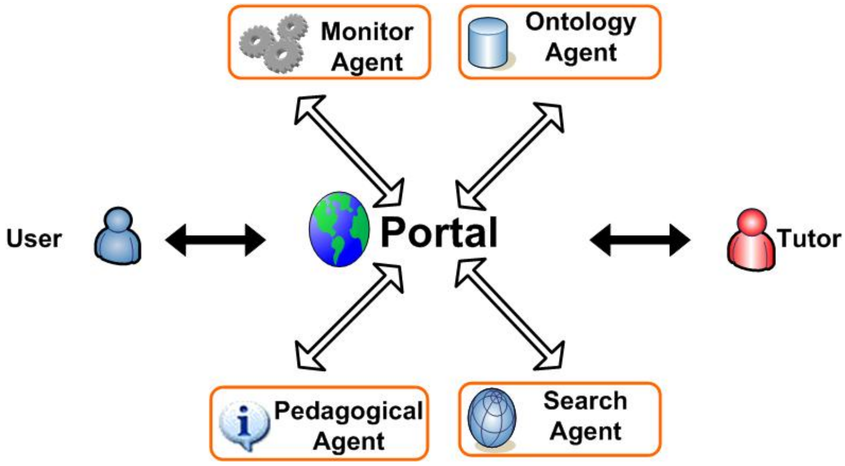

Fig. 3. System Architecture

Ontology Evolution

The Knowledge Portal as presented in this paper must not only have a proper ontology that reflects what the user is interested in, but also future interests which will change together with the teaching/learning subject itself. Therefore, the ontology and the topics represented therein need to be updated. One must deal with several requirements incorporated in such updates:

Modifying the ontology: The ontology must remain consistent at all times. We intend to use the evolution functionalities of the KAON API, which ensure that changes to the ontology will not corrupt it.

Introducing new concepts: First recognizing that a new concept (e. g. a new topic) has appeared in the course material available in the network or on the Web, then inserting this concept into the right place of the taxonomy, and finally linking it via further relations to other concepts.

Implementation Details

The technical implementation of the evolution component uses the functionalities of the KAON API to guarantee the coherence of the ontology. In the KAON API, a special care has been taken to make sure changes to the ontology reflect user changes while preserving the logical coherence of the ontology level.

The evolution component integrates the use of TextToOnto, a KAON component designed to help users in creating ontologies out of texts.

Overall, the Knowledge Portal is expected to indicate how a Semantic Web based approach increases the support of retrieval and management of remote (learning) resources, by providing tools for discovering and organizing them.

Conclusions and next steps

Our purpose his to achieve a portal with the right approach both in terms of technology and cognitive perspective. By analysing the problem approach presented here it seems an interesting approach, up to some extent original. Our main question is if we are in danger of the resulting Portal will not reach critical mass and thus will not be able to penetrate the user space wide enough to result in mass adoption. How to organize information in a user perspective and knowledge or matter perspective is a question to future resolution. Maybe using trees to connect and relate information should be a good idea.

One think is certain, we must use an ontological approach with software agents to interact with learners if we want to exchange information and enable automated processing of information items. With ontologies becoming an integral part of many academic applications, support for ontology evolution and versioning is important.

Next step should be a deep analysis to the framework presented, maybe in a single study, designing and deploying pedagogical agents in a distributed collaborative learning environment and finally have some results to give some test support to the Portal.

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