Ontological Hypermedia in Education: A framework for building web-based educational portals.

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Abstract

The World Wide Web offers access to a wealth of educational material; yet these are often weakly interlinked and fail to make explicit any real-world relationships. Ontological engineering support has been identified and stressed as one of the key limitations to overcome in building next generation web-based educational systems enabling knowledge sharing and reuse. In this paper we address this important issue by combining the strengths of hypermedia systems with the benefits of ontology-based systems to provide high quality, semantic-enabled web-based educational portals. We present Ontoportal: an ontological hypertext framework for building generic web-based educational portals. We also describe two simple case studies showing how the framework could be used to create ontology-based metadata and generate educational portals semantically interlinking various web-based educational resources (tutorials, assessments, courses, etc) for learning and teaching.

Keywords: web-based educational portal**,** Ontology, hypertext, ontological hypermedia, navigation, information access.

1 Introduction

The web is a very large scale hypertext information space where different types of users can search and find information in different domains. In the educational/instructional domain there is now access to a wealth of freely accessible online educational materials.

Tutors can use these resources in their teaching, and students can use them to support their learning; for example a student who needs to learn a new programming language or to know more about a W3C standard, is likely to first browse the web looking for relevant open access resources (tutorials, portals, example code, courses, assessments, experts, institutions, etc). This scenario is true across all subject domains, the Internet has become an important tool within education.

But one of the main problems (aside from the variable quality and providence of these resources) is that they are often weakly interlinked, in other words the natural or real-world relationships existing between them are not explicitly exposed to users, meaning that information-finding becomes more difficult. Classical web portals fail to address this shortcoming as they are simple collections of links to web resources. More successful web based portals should therefore weave together resources to provide a coherent view of the domain and enabling knowledge sharing with users [35]. Although the use of ontologies in educational systems is not new [31], they have not been widely used as a domain knowledge modelling technique that can provide navigational support in designing educational systems. The main reason for this is concerned with the methods of instruction or reasoning over the content (for problem solving support) than with content specification and knowledge structure. A major shift in the use of ontologies in web based educational systems is therefore required to enable knowledge sharing and reuse, and new types of interactions with users [27, 28, 29, 30].

In this paper we combine ontological and hypermedia research principles to address this issue by using an ontological hypermedia framework to build new types of web-based educational portals that provide and expose a meta-layer of semantic links over existing Web resources [23], see Figure 1. Ontologies are used as a semantic backbone to improve the navigational capabilities in the portal.

The paper presents two case studies based on simple and slightly different domain ontologies, support slightly different perspectives for learning and teaching. The first one (TPortal) is to help academics to discover resources for teaching a Java programming course. The second one (XPortal) is intended for final-year computer science undergraduate students on an Advanced Web Technologies unit and is populated with material about XML and related standards. However in both cases these portals are reusable as they can easily be populated with different subjects to support teaching and earning areas across the educational domain.

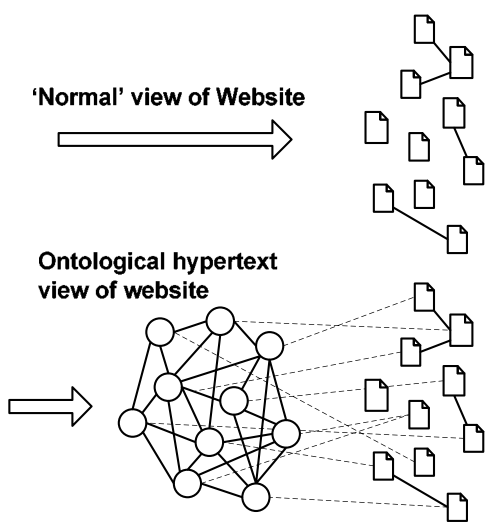

Figure 1 The portal allows a weakly linked web to be enriched through the meta-layer provided by the portal.

In the remaining of the paper, we first give our definition of ontologies and their use in education, then we present the Ontoportal system as a generic application framework along with the two case studies outlined above which illustrate the use and the benefits of the framework. The paper finishes with some discussions and concluding remarks.

2 Ontologies and Their Use

Ontologies aim at modelling and capturing domain knowledge, and providing a shared and commonly agreed understanding of a particular domain which may be communicated between people and across application systems [26, 35]. A real-world domain is modelled by explicitly declaring its key concepts, the relations between them and the rules which constrain them. By providing an explicit conceptualisation of a domain, ontologies facilitate complex reasoning over concepts and relationships (model of knowledge) and this can contributes to improve communication in any circumstance where a shared understanding is important --- between people in business arrangements, software agents in negotiation environments or interactive linking services in hypertext systems. Ontologies can also be seen as large taxonomies defining an agreed vocabulary [14] using five main components: classes or concepts, their instances, relations between them, functions and axioms [15].

In terms of typology ontologies can be classified by level of formality in the specification: ranging from highly informal (expressed in natural languages); semi-informal (structured natural language); semi-formal (in formal language) through to the rigorously formal (language with formal semantics, theorems, proofs, etc.) [13]. A number of methods have evolved for building ontologies depending on the types of ontologies being built and whether they are created from scratch, reengineered or cooperatively specified. Two methodologies are of particularly significant. The first, Methontology [19] is considered by Corcho et al [14] as the most mature method because it can be used for construction from scratch, by reengineering, or the reuse of existing ontologies. Its proposed steps are 'specification', 'conceptualisation', 'formalisation', 'implementation' and 'maintenance'. This methodology is supported by the WebODE (Ontology Development Environment) tool and has been used to restructure the (KA)2 ontology [20]. The second, the Ontolingua's methodology [12] is useful for defining new ontologies and has the following main steps: 'Identification of purpose', 'Ontology capture' (identification and definition of key concepts), 'Ontology coding' (representation), 'Integration of existing ontologies' and the 'evaluation and documentation' [13, 21].

Ontologies have a significance to hypermedia because hypermedia is "the practice of what can be said using computer media, databases and links" [23, 24] and ontologies are "models of things that exist". "What can be said" (hypermedia) is derived from "things that exist" (ontologies) and so ontological hypertext is about using ontologies and the real-world relationships that they model to improve navigational facilities in hypertext systems. Resources are represented by concepts in a defined ontology and their natural relationships are used to create new sets of links: ontological or 'conceptual' links. The resulting hypertext using not only the classical linking but also conceptual linking is more profitable to the users. It allows reasoning over resources by issuing new types of queries such as "what resources are related to *some extent* to this one". Examples of ontological hypertext systems include COHSE [2] which combines a web-based open hypermedia link service and an ontological reasoning service to enable conceptual linking of hyper documents based on their contents. The aim of this combination of services is to improve the quality and consistency of links in hyper documents at both retrieval and authoring times.

In brief the main purpose of ontologies is to explicitly specify domain (i.e. resources) knowledge for sharing, reuse and reasoning. The main purpose of hypertext is the efficient linking of resources. Thus a key purpose of 'ontological hypertext' is to practise knowledge sharing, reuse and reasoning and to embody it in enhanced linking.

The use of ontologies in building educational systems is not a new concept in education and has always been implicitly used to specify educational goals and explicitly represent different concepts or subject matters to be taught in a course [31]. Most of the ontological research in IES are concerned with Teaching and/or learning strategies ontologies, or in general task ontologies [17]. However, their use as a knowledge modelling technique to address domain and content modelling issues, and improve navigational capabilities in designing educational system is a relatively new research activity. Issues that can be addressed by ontology-based conceptual modelling include the sharing and reuse of educational resources, design reuse of educational systems, web-based resource annotation for easier access, and high level interaction with users. The main interest has been more on the "form" (with methods of instruction or reasoning over the content) than with content specification and knowledge structure [32]. It is argued that although many IES exist, knowledge reuse from one system to another is almost non-existent, therefore a more content-oriented view over the IES will facilitate knowledge sharing and reuse..

3 The Ontoportal framework

The Ontoportal framework was initially developed in the Ontoportal project [33], and was used to build a web portal for the metadata research community, Metaportal [11]. It has now been extended to a generic application framework for building web portal applications based on domain ontologies. The Ontoportal system is the result of integrating ontologies as conceptual models of knowledge with hypertext to provide a powerful application environment taking advantage of the various benefits of ontological hypertext which also augments the breadth of hypertext with more meaningful links. Such advantages can be summarised as mentioned above as knowledge sharing, reuse and reasoning for high quality linking.

Once a domain ontology has been created, specific *ontoportals* are generated by populating the knowledge base with specific metadata relating to specific collections of Web-accessible resources, this process is referred to as instantiation of the ontology. That is, the resources have been identified as belonging to one or more of the concepts within the ontology. New *portals*, each representing a different view on the same set of resources, are generated by the Ontoportal framework from the instantiated domain ontology.
These different *ontoportals* are seen as instantiations of the ontology, therefore enable *design reuse*. Figure 2 is the architectural overview diagram of the Ontoportal system and illustrates its main features, which include knowledge capturing, thread discussion and searching [11].

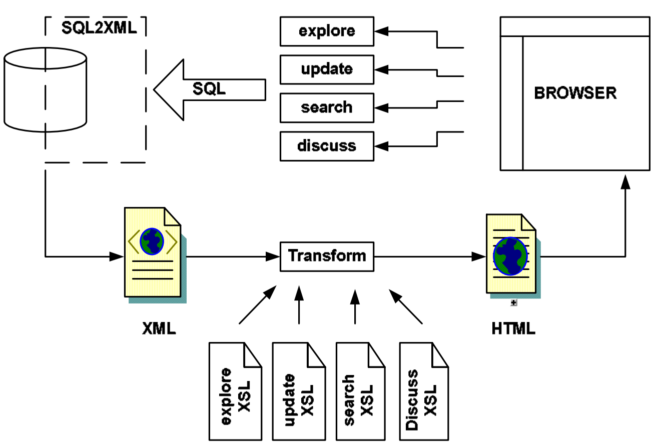

Figure 2 ***The Ontoportal architecture.***

The system provides four interfaces (explore, update, search, and discuss) to handle user requests that are passed to the database via the SQL2XML module. Any resulting XML document is transformed into HTML for the user's browser using a set of style sheets matching different interfaces.

3.1 Building new domain application

The process of building a new *ontoportal* consists of two steps: creating the ontology and populating the knowledge base.

The ontology creation process partially follows previously guidelines suggest by Uschold *et al.* [13], which and can be a time consuming task, however, the effort required can be reduced by the use of simple domain ontologies, as demonstrated in our case studies. The ontology creation process instantiates the Ontoportal architectural diagram shown in Figure 2, for a specific domain application and involves identifying key concepts (or classes) with the domain and their properties, and defining the terms used. This result in a simple domain ontology.

Once the simple domain ontology has been defined and imported into Ontoportal, the next step is to populate the knowledge base by adding content to the database --- in Metaportal [11], for example, content was added by identifying useful online materials (articles, personal home pages, product sites and discussion groups relating to *metadata research*) and dragging and dropping suitable metadata from those resources into the database.

The domain ontology is then used to produce a web-based application in Ontoportal. The ontology is represented in a machine readable format using XML. The Ontoportal systems will import the XML version of the ontology and translate the relationships defined within the ontology into an XML database and create the physical database storing the relationships.

4 Case studies: Ontology-based Teaching and Learning portals

This section describes the two educational portals for cataloguing learning (XPortal) and teaching (TPortal) resources built using the Ontoportal framework. The special feature of the resulting ontology-based web portals is that they take advantage of ontological hypermedia principles to link different teaching and learning concepts according to the relationships existing between them. This conceptual linking in an educational context has a number of advantages such as:

- increasing the "thoroughness" or coverage
- directing the author to enter relevant information
- improving the effectiveness of retrieval in the system (less time needed to find the desired information)
- providing additional facilities (search and discussion)
- enabling easier of access to information needed by the user
- improvement of the teaching and/or learning experience of the user
- enabling query-by-linking defined as the "ability to respond to queries by following links" [11]. Examples of such queries are: Which expert has created such a good tutorial? What institution is he working in? What are the other teaching material from the same expert? …
- While browsing resources, the system allows the user to display the conceptual navigational graph and see the other related concepts, thus knowing what conceptual link can be followed.
- at design level, enable knowledge reuse and sharing in building educational portals

4.1 TPortal: Teaching Portal (for Java)

TPortal is an educational domain application of Ontoportal, designed mainly for lecturers and teachers of Java programming. It allows users to benefit from web-based teaching and learning resources (full courses, syllabus, lecture notes, tutorials, exercises and quizzes, experts, etc.) by linking related but not previously linked resources.

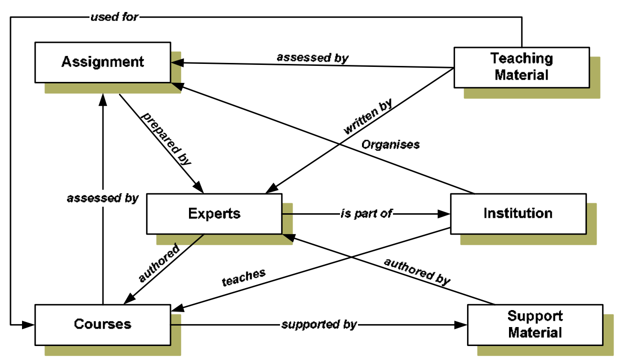

Figure 3 TPortal ontology

To build the ontology, we have followed the Ontolingua's methodology described above [12]. In the ontology capture phase, the preliminary work involved searching and browsing the web and categorizing the materials found, then we proceeded with the identification and definition of the main concepts and the metadata elements (concepts/objects names and properties). This resulted in the following categories which represent the key concepts for the TPortal ontology:

- **Courses:** This concept identifies a course with syllabus, notes, course works, etc.

- **Teaching material:** Tutorials (Articles explaining in detail how to do particular tasks), Lectures (lecture notes or slides in various formats), Labs materials, Books (Online books and books extracts), Tools (Various Java software tools, ready to use, Code samples, Worked examples, White papers.
- **Assessments:** Quizzes (Short questions with short answers, Multiple Choice Questions (MCQ), etc), Exams tests with open questions, MCQ, Other test resources
- **Support Materials:** Collections (containing various resources, such as the Sun's Java home page and other portals) Background readings (resources on prerequisites knowledge such as Object Oriented programming, etc.), Frequently Asked Question (FAQ), Java FAQs, Other resources supporting the teaching of Java
- **Experts:** - This concept identifies the relevant community of Java teaching expertise. These are University lecturers, authors and FAQ maintainers.
- **Institutions:** - Include organization distributing online Java teaching resources directly or through their experts. These include Universities/Colleges/schools and teaching companies.

The aim of the ontology is to represent the domain of Java educators: so that experts are not just Java experts, nor simply Java lecturers, but Java experts who provide educational materials. They may have written some of the courses described in the portal, or they may have created a set of MCQs for a particular programming theme.

4.2 XPortal: Learning Portal (for XML)

XPortal is a web–based learning portal intended for students and learners of XML and related Web technologies. It allows its users to gain access to various online learning resources (tutorials, full courses, test material, etc.), using the underlying ontological hypermedia principles to discover relevant materials and answer various queries on relations between resources.

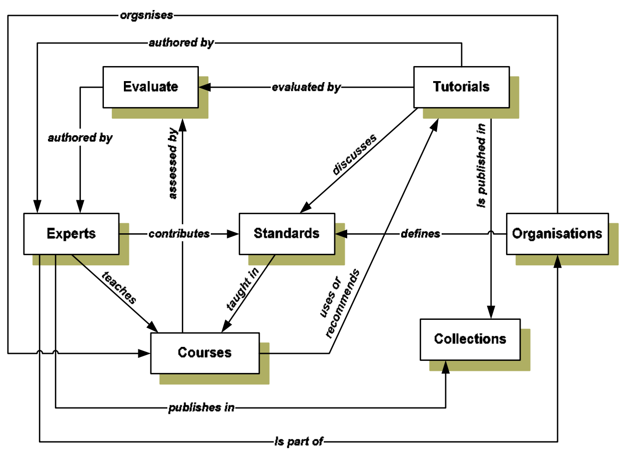

Figure 4: XPortal ontology

By following the same methodology as described above in TPortal, the following key concepts have been identified in the capture process:

- **Tutorials**: online articles explaining and guiding the learner on how to perform a specific task.
- **Courses**: as defined for TPortal above
- **Evaluation Material**: Testing material as described above for assessments.
- **Standards**, Universally defined references and recommendations such as those from W3C (XML, XSL, RDF, XLink, etc.), Other universal references
- **Experts**: as defined for TPortal above
- **Organisations or Institutions**: as defined for TPortal above
- **Collections**: Portals to other resources, Resources treating many themes.

Although this ontology looks similar to the TPortal ontology described above (and indeed shares many of its concepts), its purpose is different as it is intended to model a domain of study (XML standards, the people who are involved in their creation, the organisations which control them) in which the courses and evaluation materials are of interest as mechanisms to further the understanding of the domain.

5 Discussion

The use of ontological hypermedia as the backbone for our framework allows the building of educational web portals that provide effective ways of navigating existing resources. Pre-existing weakly linked collection of web resources are augmented with dynamically generated conceptual links that enable among others more sophisticated queries on resources to be answered by simply following links (query-by-linking). The ability to see instantly the other tutorials/tests which an expert has created, or the other specialists at an institution, or the other standards addressed by an article provide a richer experience of the domain, as it more completely reflects the various aspects of which it is composed. The discipline imposed on the author/editor who creates the metadata used to instantiate the ontology also encourages a more complete construction of the underlying domain, providing a focused set of questions to elaborate (what else is relevant about this standard? What other significant contribution has this expert made?) Dillon and Gabbard describe hypermedia as a major technology for modern educational systems precisely because of this ability to enable 'rapid, nonlinear access to multiple forms of information' [34]. IOntological hypermedia provides a principled approach to controlling the multiple dimensions of its non-linearity.

Classical web portals are generally simple collections of links to distributed web resources allowing users to access a wide range of information in a given topic. These resources have real-world relationships between them that can be used to augment the navigational facilities in hypermedia systems. In XPortal and TPortal, the online teaching and learning resources are modelled by concepts, and the ontological relationships between concepts are used to create a new layer of meaningful links over these resources. This layer is made of "natural links" based on "natural relations" existing in the real-world. The resulting web portals with their enriched linking facilities therefore provide an improved environment to enhance the overall teaching and/or learning experience for the users.

The Ontological or Conceptual hypermedia uses ontologies as models to enable knowledge sharing and reuse, and improve the breadth of linking in hypermedia systems. Being based on a conceptual hypermedia system (Ontoportal), the two portals built use the underlying principles to provide users with more effective learning/teaching web portals.

6 Conclusion

Classical web-based educational portals are usually simple collections of links to distributed web resources allowing users to access a wide range of teaching and/or learning information in a given topic. These resources have unexploited real-world relationships between them that can be used to facilitate the learning/teaching process of the user (for example by augmenting the navigational facilities in hypermedia systems). In this paper, we have presented an ontological hypertext framework for building educational web portals based on simple domain ontologies. The links derived from the ontology help to transform a weakly linked collection of educational materials and sites into a richly and semantically interconnected collection.

In XPortal and TPortal, the online teaching and learning resources are modelled by concepts, and the ontologies' relationships between concepts are used to create a new layer of meaningful links over these resources. This layer is made of "natural links" based on "natural relations" existing in the real-world. The resulting web portals with enriched linking facilities improves the overall teaching and/or learning experience of its users.

The Ontological or Conceptual hypermedia uses ontologies as models to improve the breadth of linking in hypermedia systems. Being based on a conceptual hypermedia system (Ontoportal), the two portals built use the underlying principles to provide users with more effective learning/teaching web portals.

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The Ontoportal framework was initially developed in the Ontoportal project more information available at http://www.ontoportal.org.uk. The IAM group' for providing servers, the TPortal is available online: http://pip.ecs.soton.ac.uk/tportal/cgi-bin/explore.cgi, Similarly the XPortal with the Java theme, the portal is is available online at http://pip.ecs.soton.ac.uk/xportal/cgi-bin/explore.cgi.

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