

Authoring Topic Maps-based Digital Course Libraries

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Abstract. Digital course libraries are educational Web applications that contain instructional materials to assist students' learning in a specific discipline (course). To address the critical issues of findability and reusability of learning resources, we propose a general framework for standards-based, ontology-aware course libraries and use it to develop an environment for building, maintaining, and using such libraries. The proposed environment, TM4L (Topic Maps for Learning), is based on the new ISO standard XML Topic Maps that provides a paradigm for organizing and retrieving online information and for interchanging semantic information on the Web. In this paper we present the TM4L authoring tool for creating ontology-aware Topic Maps-based repositories of learning materials (TM4L Editor).

1 Introduction

Digital course libraries are educational Web applications that contain instructional materials to assist students' learning in a specific discipline (course) and support students' course-related work aimed at reinforcing their knowledge. They play a vital role in out-of-class learning, especially in project-based and problem-based learning, as well as in lifelong learning. Digital course libraries are expected, from one side, to provide learners with powerful and intuitive search tools that allow them to efficiently access learning resources, and from another, to support instructors with powerful authoring tools for efficient creation and update of instructional materials. The latter is closely related to the issue of *reusability* and *shareability* of learning content, which in turn is concerned with both the existence of shared agreement on the content and the standards-based representation of the materials.

We address the problems of findability, reusability and shareability of learning materials in digital course libraries by suggesting the use of Semantic Web technologies in creating them. More specifically, we propose a framework for digital course libraries that incorporates a meta-layer – *semantic layer*, based on conceptualization of the course subject domain. The fundamental idea is to build those libraries as both *concept-based* and *ontology-aware* repositories of learning objects [1]. Further on, we propose that the implementation of such libraries is based on the ISO XTM standard - XML Topic Maps [2]. Topic Maps (TM) [3] are an emerging Semantic Web technology, that can be used as a means to organize and retrieve information in e-learning repositories in a more efficient and meaningful way.

The expressive power of Topic Maps, commonly perceived as a method for indexing information resources, places the standard very close to artificial intelligence and knowledge modeling. Topic Maps resemble semantic networks and conceptual graphs, but offer more - a unique, standards-based way of encoding and exchanging knowledge on the Web. Topic Maps provide an external meta-structure (a knowledge navigation layer) in form of a dynamic, semantically based hypertext. As a result, TM-based courseware can offer the following benefits [4]:

- *For learners:* efficient context-based retrieval of learning resources; better awareness in subject-domain browsing; information visualization; customized views, adaptive guidance, and context-based feedback.
- *For instructors:* effective management and maintenance of knowledge and information; personalized courseware presentations; distributed courseware development; reuse and exchange of learning materials, collaborative authoring.

Currently available commercial TM software is mainly aimed at supporting rapid development of TM-based applications (e.g. Ontopia Knowledge Suite [5], Mondeca Intelligent Topic Manager [6], etc.). There are some available TM authoring tools but they are too general and good for experts in knowledge representation, not for end users. We are not aware of existing specialized education-oriented TM tools that can be used to facilitate the creation, maintenance, search, and visualization of Topic Maps-based learning resources. This was our motivation for designing the general framework for ontology-aware digital course libraries and using it to develop a specialized environment for creating, maintaining, and using TM-based learning repositories – TM4L (Topic Maps for Learning). In this paper we discuss briefly the framework and present the authoring tool of TM4L (TM4L Editor).

2 A General Framework for TM-based Course Libraries

The proposed framework is aimed at supporting the development of *ontology-aware* repositories of learning materials. It is focused on enabling authors to capture, share and access knowledge. Subject ontologies aim at capturing domain knowledge in a generic way, and provide a commonly agreed upon representation vocabulary of a subject domain, which may be shared and reused across people and applications. Ontology editing is an essential aspect for all ontology-aware systems. An important issue within ontology editing is the underlying ontology model or “structure” that is to be edited. In our framework for developing repositories of learning resources it is a network of concepts. This involves creating views of a specific domain in terms of domain concepts and relationships among them that suggest the semantics of the resources relevant to that domain. Such a conceptual structure would enhance information retrieval within the repository since the set of concepts, relationships, and inference rules defined by the domain ontology constrain the possible interpretations.

Thus the proposed general framework of ontology-aware discipline-specific repositories is based on building a conceptual structure that represents the subject domain ontology and using it for structuring and classification of learning content. The classification involves linking learning objects (content) to the relevant ontology terms (concepts), i.e. using the ontological structure to *index* the repository content.

This will allow applications and users to understand the relationships between the resources and insure efficient topical access to them. By providing shared agreement on the subjects meaning, ontologies can serve as a means of establishing a conceptually concise basis for communicating knowledge for many purposes, for example, in ontology-based merging of digital repositories. The framework utilizes the advantages of concept-based and standards-based content organization to benefit both learners and authors. For learners it supports efficient contextual retrieval of information relevant to their needs and for authors - the reusability, shareability, and exchangeability of created instructional materials.

We have proposed a layered information structure of the learning material repository consisting of three layers, each of which captures a different aspect of the library information space - conceptual, resource-related, and contextual:

- *Semantic layer*: contains a conceptual model of the knowledge domain in terms of *key concepts* and *relationships* among them.
- *Resource layer*: contains a collection of diverse information resources associated with the specific knowledge domain.
- *Context layer*: contains specifications of different views (contexts) on the library resources depending on a particular goal, type of users, etc., by dynamically associating components from the other two layers.

The developed framework for ontology-aware digital course libraries is described in detail in [1]. This general framework requires using Semantic Web technologies that support efficient organization, retrieval, and interchange of information on the Web. We chose to use the ISO 13250 XTM standard - XML Topic Maps (www.y12.doe.gov/sgml/sc34/document/0323.htm) to implement the developed framework. In the next section we discuss our implementation - the Topic Maps-based environment TM4L - and specifically its authoring tool, the TM4L Editor.

3 The TM4L Editor

Ontology-aware e-learning applications must provide support for both ontology development and ontology usage. In the last decade a number of tools for ontology construction have emerged (see [7]); however, they are not particularly appropriate for use in a TM-based environment. Although some currently available ontology editors such as Protégé-2000 [8] have plug-ins, which allow exporting ontologies to Topic Maps, they do not support essential TM features that can be of significant importance for reusability and sharability of e-learning content and interoperability of e-learning applications, in particular:

- *published subjects* (can provide a platform for interoperability),
- *merge* of topic maps (can support individual or collaborative authoring),
- *scope* (can be used to implement adaptivity through defining contexts).

Thus our goal was to develop an authoring environment guided by two considerations: conformance to the TM standard coupled with facilitating the task of e-learning content authoring. Taking into account these considerations, we have designed an environment, TM4L, which enables the creation, maintenance, and use of ontology-aware courseware based on the ISO standard – Topic Maps. Ontologies and Topic

Maps are complementary tools that aim at giving a more global vision than terminologies, thesauri and concepts systems. While ontologies provide semantic interoperability, the Topic Maps specification ensures syntactic interoperability.

The TM4L environment consists of a TM Editor and a TM Viewer. We have currently completed the TM4L Editor, which is an ontology editor allowing the user to build ontology-driven learning repositories using Topic Maps. It provides ontology and metadata engineering capabilities coupled with basic document management facilities. The TM4L Editor benefits from the Topic Maps' fundamental feature to support easy and effective merge of existing information resources while maintaining their meaningful structure. This allows for flexibility and expediency in re-using and extending existing repositories.

The learning content created by the Editor is fully compliant with the XML Topic Maps (XTM) standard and thus interchangeable and interoperable with any standard TM tools. The Editor can read/open external XTM files directly, i.e. without any *import* pre-processing.

The TM4L Editor is Topic Maps-based, thus the main objects that it manipulates are topics (representing domain ontology concepts), relationships between them (corresponding to the TM associations), resources, and contexts (implementing the TM scoping feature). It includes four different sections (views): *Topic Map*, *Topics*, *Relationships*, and *Views*. A screenshot of the TM4L Editor interface (the Topics section) is shown on Figure 1.

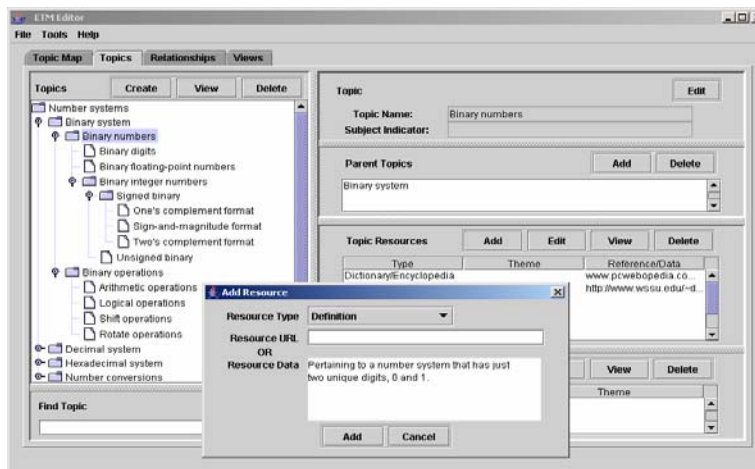


Fig. 1. A screenshot from the TM4L Editor interface.

Topic Map. In the Topic Map section the author defines metadata (Dublin Core [9] and LOM [10] compliant) for the newly created topic map. This includes: TM Title, Creator, Subject / Main Topic (keywords), Description, Publisher, Contributor, Creation Date, Last Modification Date, Location, Source TM (in case of merging TM), Relation, Coverage, IPR / Copyright. Additionally, a Topic Map Subject Indicator is specified. Some LOM tags are automatically included in the TM metadata with

pre-specified values, e.g. LOM 4.1 Resource Format (“text/html”), LOM: 5.1 Interactivity Type (“expositive document”), LOM: 5.3 Interactivity Level (“high”).

Topics. In the Topics section the author defines, edits, and deletes topics. Each topic definition includes the following information: *subject indicator*, *names*, *types*, and related *resources*. For each new topic an ID is automatically generated.

Topic categories. Our major concern in designing the Topic Maps Editor was related to the fact that in the TM standard every subject is a topic, which is a powerful idea but will not make much sense to the uninitiated authors. Different kinds of topics are expected to be used in an educational topic map: ‘concept’ topics needed to build the ontological representation of the subject domain, ‘utility’ topics needed as meta-data fillers in the topic map, for example, to specify the different types of educational resources, and ‘system’ topics needed to represent associations, roles in associations, and other entities required by the TM model.

In TM4L we support two distinct categories of topics: *domain ontology topics* and *utility topics*. The former are defined by and visible to the user; the latter are automatically defined by the editor when a specific authoring activity takes place (such as defining a new relationship between topics) and are invisible to the author. We use the following utility topics categories: association types, association role types, associations, occurrence types, occurrences, and themes (for scoping). The category of a topic depends on where it was created by the user, for example, if it was created as a result of user input in the ‘Create Relationship Type’ dialog, it is an association type.

Topic names. TM4L allows multiple topic names: one *primary* and possibly some *alternative* names. Each name can have alternate names (TM name variants) to be used for special purposes. In this application we have constrained the number of alternate names to four, corresponding to four different purposes of usage of the name: *sort*, *search*, *display*, and *draw*.

Topic Types. In compliance with the TM standard, multiple topic types are allowed. The user is given two ways to declare a topic type (or *parent topic*): either automatically by selecting an existing topic prior to the creation of the new topic, or manually in the ‘Parent Topic Panel’.

Resources. Resources can be internal and external. Internal resources are short pieces of information about a concept, such as definition, short description, some characterizations, etc., stored locally in the course library. External resources can be any addressable learning objects on the Web referenced by their URI. For authors’ convenience, resource types are pre-defined however the author is allowed to define their own types. We have predefined the LOM 5.2. Learning Resource Types: exercise, simulation, questionnaire, diagram, figure, graph, index, slide, table, narrative text, exam, experiment, problem statement, self assessment, and lecture. In addition, we have predefined types of learning resources relevant to characterizing subject domain concepts: definition, example, graphical representation, and simulation.

Relationships. As we already mentioned, relationships in our model are represented by TM associations. Each relationship has a type (e.g. is-component-of) and one or more *members* (concrete topics) along with the *roles* they play in the relationship. There is a pool of pre-defined relationship types (such as class-subclass) that the authors can use. In the ‘Relationships’ section of the Editor the author can define relationship types and roles; create relationships by specifying their types, roles, and

role players; and edit and delete relationships. When defining relationships the author selects all involved entities – relationship type, members, and roles, from presented lists, so that input errors are minimized. The scope (context) within which the assertion made by a relationship is valid can be defined in the ‘View’ section. If none such is present, the scope is unconstrained and the relation is always valid.

Contexts (Views). Context can be described as the circumstances in which an event occurs; a setting. It can be defined as a collection of *perspectives* (or view-points). In our model, authors use TM scopes and relations to define *contexts*. A scope is a set of *themes of validity* or simply *themes* that describe perspectives. Themes can be defined and applied to objects, thus scopes don’t have their own definitions. In relation to scopes we follow the TM standard and allow scoping of topic names, resources, and associations. Authors define their own theme types and scope objects using them. The standard and application provided scopes are used in the ETM Viewer for information filtering.

In summary, the TM4L Editor’s functionality includes the following capabilities:

- Creating and maintaining concepts.
- Creating and maintaining relationships between concepts: adding and deleting relationship types, member roles (there is no constraint on the number of members in a relationship), and relationship instances.
- Creating resources: defining resource types, adding, deleting, modifying, and merging resources.
- Creating contexts (organizing learning objects): defining different views on a Topic Map including selected topics, relationships, and/or resources.
- Storing Topic Maps persistently either in standard XTM files or in an Ozone database.
- Merging Topic Maps.
- Checking a Topic Map for broken links to external Web resources.
- Importing/exporting Topic Maps.
- External searches on the Web (through Google).

The TM4L Editor is implemented as a client-server application developed in Java and using the TM4J Topic Map Engine [11], which is an open source providing a comprehensive API that allows creating and modifying Topic Map structures stored either in-memory or persistently in a database. The Editor has open modular architecture that allows easy extension of its functionality.

Conclusion

In this paper we present work in progress that is aimed at contributing to the development of efficiently searchable, reusable, and interchangeable discipline-specific repositories of learning objects on the Web. We propose an authoring environment for supporting the development of standards-based ontology-aware online learning materials. The next step in our agenda is the design and development of a browser for Topic Maps-based learning materials. It will support learners to efficiently navigate educational Topic Maps and search for useful resources. The latter is crucial in pro-

ject-based and self-directed learning where the learners are actively engaged in retrieval of trusted relevant information.

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References

1. Dicheva, D., & Dichev, C. A Framework for Concept-Based Digital Course Libraries. *Journal of Interactive Learning Research* (in press, 2004)
2. Biezunski, M., Bryan, M., & Newcomb, S., ISO/IEC 13250:2000 Topic Maps: Information Technology, www.y12.doe.gov/sgml/sc34/document/0129.pdf
3. Park, J. & Hunting, S. XML Topic Maps: Creating and Using Topic Maps for the Web, Addison-Wesley (2002)
4. Dichev C., Dicheva D., & Aroyo L. Using Topic Maps for Web-based Education, *Advanced Technology for Learning* **1** (2004) 1-9
5. Ontopia Knowledge Suite, <http://www.ontopia.net/solutions/products.html>
6. Mondeca Intelligent Topic Manager, <http://www.mondeca.com/english/technologie.htm>
7. Denny, M. Ontology Building: A Survey of Editing Tools, O'Reilly XML.COM (2002) <http://www.xml.com/pub/a/2002/11/06/ontologies.html>
8. McGuinness, D. Ontologies Come of Age. In Fensel, D. Hendler, Lieberman, H. & Wahlster, W. (Eds) *Spinning the Semantic Web: Bringing the World Wide Web to Its Full Potential*. MIT Press (2002)
9. Dublin Core Metadata Initiative 2003. <http://www.dublincore.org>
10. IEEE Standard 1484.12.1-2002, Learning Object Metadata (LOM), <http://ltsc.ieee.org/wg12>
11. TM4J: Topic Maps for Java, <http://tm4j.org/dg-d0e35.html>