Community-oriented Course Authoring to Support Topic-based Student Modeling

Sergey Sosnovsky, Michael Yudelson, Peter Brusilovsky
School of Information Sciences, University of Pittsburgh, USA
{sas15, mvy3, peterb}@pitt.edu

Abstract. Content authoring is an important part of adaptive educational system development process. The success of the large-scale transfer of these systems to the real classrooms highly depends on how actively classroom teachers will be involved in the content authoring. This paper suggests an approach to the adaptive content authoring based on the coarse-grained topics. While providing sufficient adaptation to student knowledge topics do not put an additional authoring burden on the classroom teachers. The utilization of common metadata standards and application of semantic web technologies for knowledge description facilitates the sharing and reuse of created models and enables reasoning both within a single model and across related models. On the interface level topic sharing and reuse is supported by the community-oriented learning portal. The learning portal communicates with the user modeling server, which employs newly created topic-based course structures as the basis for automatic overlay student modeling and adaptation to student knowledge.

Keywords. Content Authoring, Learning Portal, Topic, Adaptive Educational System, Content Shareability and Reusability, RDF.

Introduction

Authoring of adaptive content* is one of the most important and labor-intensive activities of content-based adaptive educational system (AES) development workflow. Traditionally it relies on the design of a fine-grained domain model and careful indexing of various learning objects (LO): tutorial pages, problems, test questions, examples, etc. – with multiple domain concepts [1, 2, 3, 4]. Such approach requires from the authors the expertise in both: the domain of discourse and knowledge engineering, as well as a considerable time investment. Naturally, this fact is one of the main reasons why adaptive learning technologies are so slow to transfer from university labs to the education market. The primary author of the learning content – a classroom teacher – does not have a necessary experience in the development of sophisticated domain models and enrichment of learning content with domain knowledge, while the AES developers are physically unable to create sufficient volumes of intelligent content that can suit the needs of multiple teachers.

The complexity of content authoring in modern AES primarily originates in the complexity of the domain models used in these systems. The more detailed and precise the modeling is, the more accurately an AES can assess student knowledge, and

* By adaptive content we understand here the content of adaptive systems, enriched with the domain knowledge components

consequently the more effectively it can potentially adapt its content to the individual student*. However, the important question is: where does the "golden mean" lie, what is the best tradeoff between model precision and model complexity, effectiveness of adaptation and ease of development?

The known approaches to solve the problem of content authoring in AES do not question the need for complex domain models and sophisticated content indexing, but attempt to deal with it. The promising methodology here is to rely on domain models developed by experts and provide teachers with dedicated and friendly authoring tools supporting effective indexing of learning content [5, 6, 7].

In this paper we employ an alternative approach called topic-based knowledge modeling. This approach inspired by the instructional design practice [8] is based on using coarse-grain domain models and simple indexing schemes. Our experience with adaptive hypermedia system QuizGuide [9] based on this approach shows that the domain model does not have to be very detailed to ensure the effective adaptive behavior and usability of the system. The original domain model of QuizGuide consists of only 22 coarse-grained topics describing the domain of C Programming. To compare, the formal ontology we have developed for the same domain, defines 574 fine-grained concepts. Each topic represents a fairly large chunk of knowledge and instead of indexing learning material it is used for aggregation of individual LOs. For example, the left part of figure 1 demonstrates how QuizGuide groups quizzes by topics. From the authoring point of view, the development of the topic structure of a course is a traditional teaching activity. Any classroom teacher subdivides the course curriculum into large categories and assigns to them available LOs. Several classroom studies demonstrated that despite its coarse-grained domain model QuizGuide has been an extremely efficient as an AES. Both, the increase in knowledge gain [9] and the increase in student motivation [10] were significant.

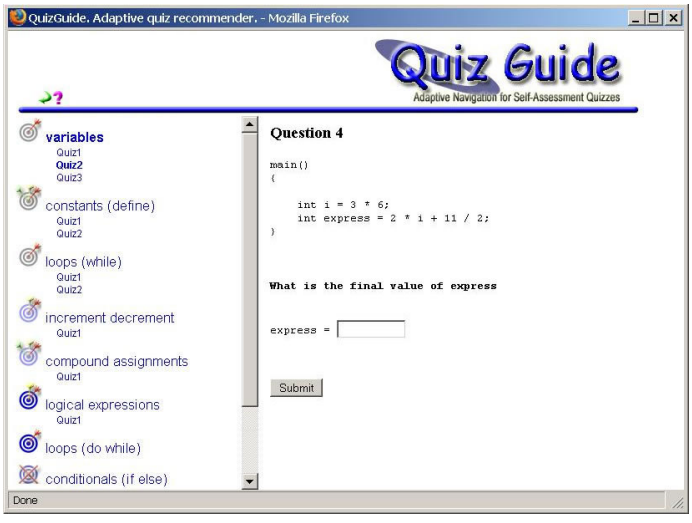

Figure 1. Topic-based Adaptation in QuizGuide

* Of course, the quality of assessment and the quality of adaptation depend on how effective the corresponding components of AES work. The model granularity sets the limit defining the possible accuracy of the system adaptation.

The paper presents our recent work on scaling the topic-based approach from a specific AES to a teacher-oriented authoring framework. The goal has been to develop a tool that allows teachers to develop AES based on their own sets of topics with minimal efforts. Our design is based on three core ideas:

- the natural for teacher hierarchical organization of learning content defined by the topic structure of a course;
- community-driven sharing and reuse of learning content facilitated by semantic web technologies for knowledge representation;
- and the automatic student modeling on the basis of newly created course model to support the immediate topic-based adaptation.

We have developed the authoring framework implementing the above principles, which allows a community of teachers to design topic-based curricula of their courses, associate topics with relevant LOs, share and reuse each other's topics and even entire course structures. This functionality is implemented on the new version of KnowledgeTree learning portal [11].

The rest of the paper has the following structure. Section 1 gives the details of our topic-based authoring approach. Section 2 describes the authoring interface that allows a teacher to design a topic-based course structure and categorize LOs. Sections 3 and 4 explain the internal functionality of the system. Section 3 concentrates on the model representation, while the fourth section talks about the roles of the Ontology Server and the User Model (UM) Server as well as the system communication flow. Finally section 5 discusses the directions of future work and concludes the paper.

1. Topic-based Knowledge Modeling and Adaptation

In a content-based AES the main purpose of a coarse-grained topic is the same as of a traditional fine-grained concept – to represent an element of knowledge in the domain of discourse, to serve as a basis for identification of student understanding of a corresponding part of learning material and to support a proper adaptation. Yet, topic-based approach to knowledge modeling is different in several ways:

- Topics provide a useful way of learning material aggregation, but not indexing. As a result the relationships between topics and LOs are "1-to-many" (1 topic corresponds to many LOs) and topic-based "indexes" do not exceed manually manageable numbers.
- Topics organize a natural approach for a classroom teacher to divide the course into logically separate units and assign to them appropriate pieces of content. Consequently, the authoring of the topic-based domain model can be easily done by a classroom teacher while s/he is developing the course structure.
- In adaptive systems topics can play two roles: as knowledge components for the student modeling and content-based adaptation, and as interface elements for the content structuring and navigation.
- Topics are coarse-grained; therefore, when relying on topic-based knowledge modeling we sacrifice the model precision. The results of our evaluation of the quality of topic-based student modeling in QuizGuide [12] show that the precision and predictive validity of such models are not high. Nevertheless,

several classroom studies have demonstrated that the adaptation stays efficient, and the overall learning impact of the system is significant.

- Topics are subjective. If we compare topic structures of the same course developed by different teacher, with a high degree of certainty we would expect them to be different. The presence or absence of a single topic, the naming labels, the size of particular topics, the inter-topics relations, and the scope of the entire set can vary from one structure to another based on the personal decision made by a teacher.

To summaries, topics are unique knowledge components, which in the framework of adaptive learning have some pros and cons comparing to smaller concepts. However, the main advantage of a topic is that while ensuring sufficient adaptation quality it provides a classroom teacher with a natural approach to adaptive content authoring from the beginning to the end.

2. Community-oriented Authoring of Topic-based Course Models

Virtually in every course management system teachers organize their content hierarchically, by breaking the course material into fairly large chunks (lectures, themes, topics) [13, 14, 15]. Our approach follows this, natural for teachers, procedure; the entire process of learning content authoring revolves around topics. From the point of course structuring topics could be considered as containers for LOs. The interface of the KnowledgeTree learning portal provides necessary functionality for topic creating and editing as well as for categorizing available LOs with the topics (fig. 2).

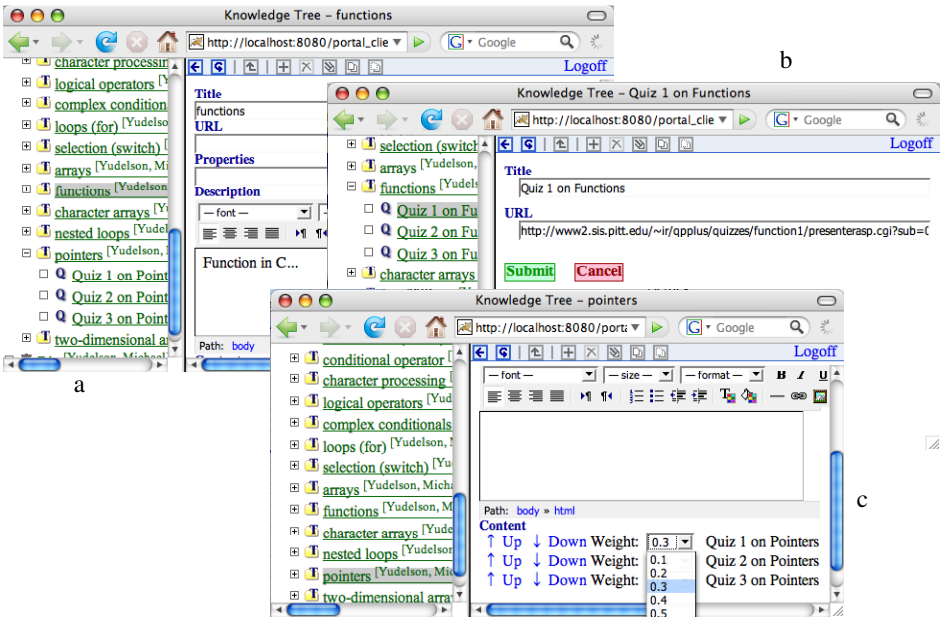

Figure 2. Adding/Editing Topic (a),
Adding/Editing LO – Quiz (b),
and Specifying Degree of Contribution of LOs to a Topic (c)

When adding a new topic to his/her course structure a teacher needs to specify the topic title and description. Both of these could be altered later using identical interface (fig. 5a). When associating a LO with a particular topic a teacher enters its title and the URL where the LO is deployed (fig. 5b). If a teacher wants, he/she also specify a degree of the contribution made by the particular LO to a topic (fig. 5c); otherwise all LOs associated with a topic will have equal weights. Essentially, a weight designates the percentage of work towards mastering a topic that students perform while completing a LO. The topic-based adaptation will depend on these weights. The bigger the weight is the stronger would be the influence of the student activity with a particular LO on this student's knowledge model for the topic.

We try to minimize the intervention of the administrators of the adaptive systems and services. Teacher performs the bulk of the authoring activities. A typical course-authoring scenario on KnowledgeTree learning portal consists of the following steps:

1. Portal administrator initializes a course. A new course node is assigned to a designated teacher that would author the course.
2. A teacher authors the course. He/she can choose to create the course from scratch or to reuse the content and structures the courses already created by the community. The course can be replicated entirely and modified afterwards if needed by adding, removing and editing topics, or the teacher might just copy some of the existing topics to his course.

At the stage of course initialization on the portal the administrator specifies the course name (that can be changed by the course author later) and a URL of the course RDF model (fig. 3).

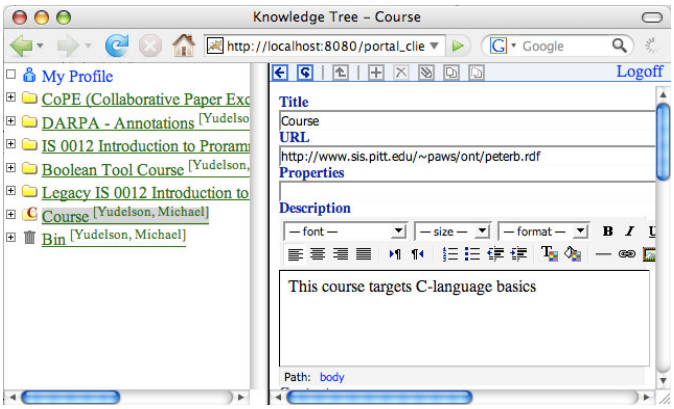

Figure 3. Course Initialization on the Portal

Once the course entity has been created and necessary access rights granted to the author s/he could start working on the course structure. KnowledgeTree provides teachers with the possibility to reuse the material of existing courses. The learning portal will become a sharing point, where multiple teachers giving the same course over the years accumulate solid amount of learning content that could be reused for future iterations of the course. Besides, many courses share parts of the material. For example, courses on C and C++ are likely to have similar topics on Loops and Conditions. The LOs from such topics could be used in both courses. A teacher creating a course on KnowledgeTree can take a previously authored course as a starting point and replicate its entire structure or borrow only some of its topics with their LOs (fig. 4). If the teacher is fully satisfied with the pieces s/he has copied from pre-authored courses; that is all s/he has to do. However, if

there are topics and subsequent LOs the teacher wants to add, change or remove, s/he can use portal tools to do that. Such functionality allows any new teacher entering the portal to have an access to the "community wisdom" and reuse learning content provided by multiple authors on the desired level of granularity.

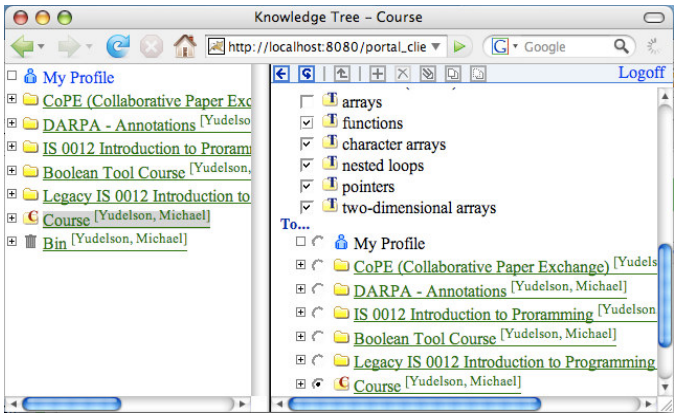

Figure 4. Replicating a Previously Authored Course

3. Portable Representation of Content Models

KnowledgeTree supports sharing and reuse of created models not only on the level of interface. To ensure potential portability beyond the system and to facilitate the import of foreign models to the portal, for knowledge representation we use RDF [16] along with the common metadata standards, such as Dublin Core [17] and IEEE LOM [18]. RDF has been chosen for its wide spread in the framework of semantic web initiative. It has become a "de-facto" standard for knowledge description on the Web. One more argument in its favor is the availability of tools for design of RDF documents (such as Protégé [19] and Altova SemanticWorks [20]) and for implementing inference on RDF graphs (such as Jena).

When a teacher authors a course, s/he does not have to understand the internal representation of underlying models. Copying or creation of a topic, binding of a new LO, even adjustment of weights between a topic and corresponding LOs do not require specific skills beyond traditional Web-based Course Management. On the system level any authoring activity in KnowledgeTree utilizes three models: domain model, LO model, and course model.

3.1 Domain Model

As mentioned in section 1, from the point of context-based knowledge modeling the main purpose of a topic is to represent a chunk of the domain. When a teacher structuring a course defines a topic, he/she categorizes not only some amount of learning material, but also a coherent piece of domain knowledge. As a result during course authoring the teacher indirectly specifies the domain model adjusted for his/her course. This model is used automatically by the UM server as a basis for overlay student modeling and topic-based adaptation. Figure 5 demonstrates an example of topic-based domain model for C programming, which is, essentially, a set of *rdfs:Class*'s. Sometimes the author of the

course might want to specify relations between topics. For example, on fig. 5 topics *IfElse* and *ComplexIfs* are connected with the prerequisite-outcome relation.

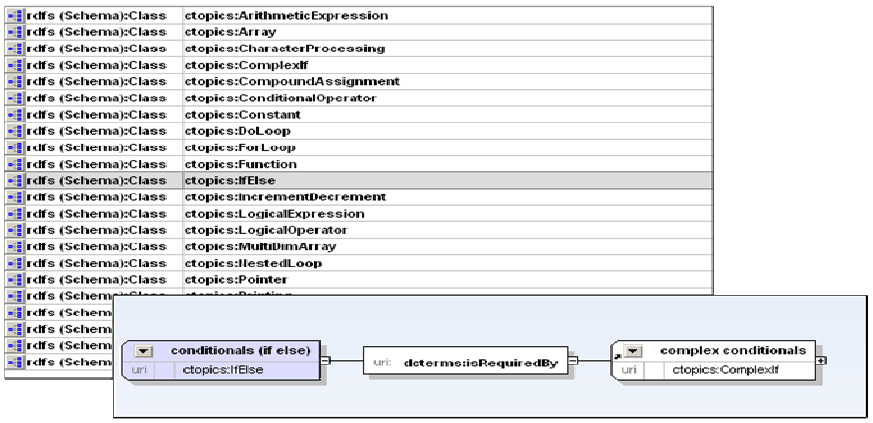

Figure 5. Topic-based Domain Model (C Programming)

3.2 LO Model

KnowledgeTree portal is not used for authoring any type of LOs, hence it does not need to modify the LO description model. However, it is capable of interpreting certain information about LOs represented using standard RDF vocabularies. For example, fig. 6 visualizes the model of a quiz (*lom-edu:Exercise*). It specifies the author of the quiz (*dc:creator*), its url (*dc:identifier*), the quiz metadata document (*rdfs:isDefinedBy*). It also shows that the quiz consists of 4 questions ordered linearly.

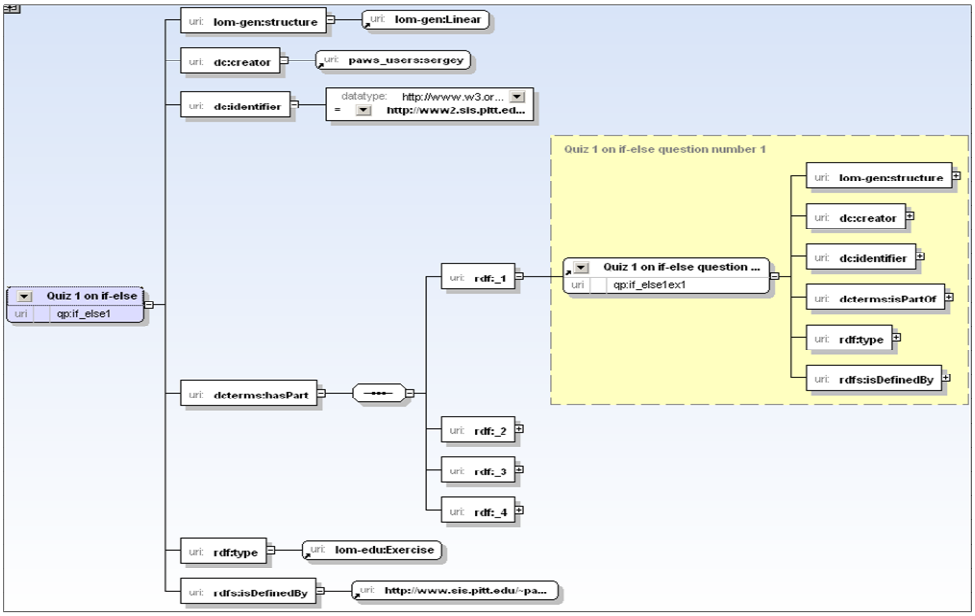

Figure 6. LO Metadata

3.3 Course Model

The main model behind the course authoring is the course model. It utilizes topics from the domain model and LO descriptions from the LO metadata. The primary purpose of the course model is to specify the schedule of topics and association between topics and LOs. Figure 7 visualizes a fragment of the C Programming course model demonstrating such associations. Here topic *IfElse* includes two quizzes; contribution of quizzes to the topic is specified as well.

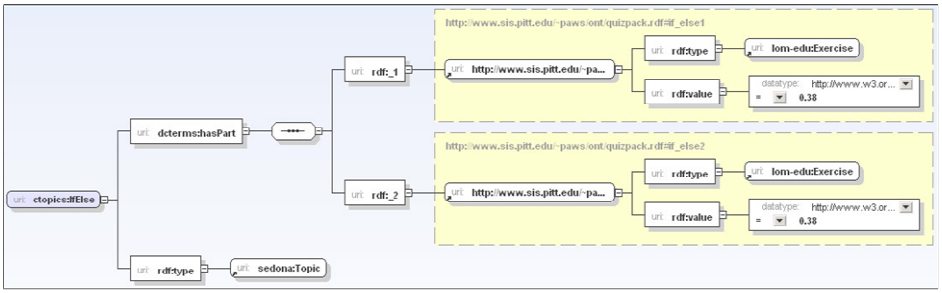

Figure 7. Topic and Associated LOs

From the point of content-based modeling these three models provide traditional representation of the adaptive content: the domain model specifies knowledge elements, the LO metadata describes available learning material, and the course model supplies the "index" of pieces of learning material in terms of domain knowledge.

4. The Back-End Communication Mechanisms

The topic-structure of a course plays several roles in our approach. The learning portal uses it to categorizes the content, however it also serves as a representation of the domain model and, hence, as the basis for student knowledge modeling and adaptation. UM server is responsible for inference, representation and reporting of student knowledge of the specified topics. The models described in the previous section are stored separately on the ontology server. This section explains how separate models are processed and how different systems communicate to each other to ensure the immediate plugging-in of a created topic structure and modeling of student knowledge in terms of newly created topics.

4.1 Communication with SEDONA Ontology Server

While the course authoring interface is served by the learning portal, the underlying processing of created models is mostly done on the ontology server. SEDONA, which stays for Server of EDucation ONtologies for Adaptation [21], communicates with KnowledgeTree learning portal via HTTP protocol. When a teacher designs the course structure, SEDONA discovers necessary models, merges them together and sends the enhanced course model to the portal. Whenever the teacher creates a new topic or adjusts an existing one, the course model and domain model are modified on the ontology server.

The sharing and reuse of topics is handled by SEDONA as well. If an author of a course wills to use an existing topic, SEDONA does not create a duplicate of this topic in

the domain model corresponding to the course. It simply uses the topic URI from the donor model. However, if any modification has been performed, a new version of the topic will be created.

4.2 Modeling of Student Knowledge

The course structure that has been authored via portal interface and is stored on SEDONA is reused for modeling student knowledge. Our user modeling server CUMULATE [22] is aware of the courses authored on KnowledgeTree and stored on SEDONA. Whenever a KnowledgeTree course is created or modified, CUMULATE replicates its topic structure as a domain model. It also retrieves from SEDONA associations (possibly weighted) between topics and LOs and processes them as an index.

This information is enough for CUMLATE to populate overlay topic-based models of student knowledge. Whenever a student works with a LO associated with a topic, her/his knowledge level for this topic is updated and can be reported by CUMULATE upon request from the learning portal or other interested certified applications. Hence, the entire process of adaptive content development for a teacher is now performed during structuring of the course on the learning portal. Once a topic is created it automatically becomes available for knowledge assessment and adaptation.

5. Conclusions and Future Work

In this paper we have described an approach to effective authoring of adaptive content for AES, based on three principles:

- a teacher-friendly approach to authoring of adaptive topic-based learning content;
- a community-oriented framework allowing topic sharing and reuse enhanced with semantic web technologies for knowledge representation;
- automatic modeling of student knowledge and adaptation on-he-fly based on newly created course structures.

One of the prospective work directions is to implement a mechanism allowing a user modeling facility to benefit of topics sharing. While on the level of interface, course authors can use each other's topics, CUMULATE is not aware that two topics from different courses are actually the same. By implementing the inter-model inference of student knowledge we will allow the reuse of modeling information for similar topics, so that the work of a student in one course could be taken into account in the relevant course for the topics shared by the courses.

References

[1] Brusilovsky, P. Developing Adaptive Educational Hypermedia Systems: From Design Models to Authoring Tools. In: T. Murray, S. Blessing and S. Ainsworth (eds.): Authoring Tools for Advanced Technology Learning Environments: Toward cost-effective adaptive, interactive, and intelligent educational software. Kluwer: Dordrecht, pp. 377-409.

[2] Vassileva, J. and Deters, R. (1998) Dynamic courseware generation on the WWW. British Journal of Educational Technology 29 (1), 5-14.

[3] Henze, N. Open Adaptive Hypermedia: An approach to adaptive information presentation on the Web. First International Conference on Universal Access in Human-Computer Interaction, held jointly with HCI International 2001, 5-10 August 2001, New Orleans, Louisiana, USA.
[4] Carmona, C., Bueno, D., Guzman, E., and Conejo, R. SIGUE: Making Web Courses Adaptive. In: Proceedings of International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH'2002) Malaga, Spain, May 29-31, 2002, Springer-Verlag, pp. 376-379.
[5] Ritter, S., Anderson, J., Cytrynowicz, M., and Medvedeva, O. Authoring Content in the PAT Algebra Tutor. In Journal of Interactive Media in Education 98 (9), Special Issue on Educational Authoring Tools and the Educational Object Economy.
[6] Arroyo, I., Schapira, A., and Woolf, B. P., Authoring and sharing word problems with AWE. In Proceedings of Artificial Intelligence in Education (AI-ED'2001) Amsterdam: IOS Press, pp. 527-529.
[7] Brusilovsky, P., Sosnovsky, S., Yudelson, M., and Chavan, G. (2005) Interactive Authoring Support for Adaptive Educational Systems. In: C.-K. Looi, G. McCalla, B. Bredeweg and J. Breuker (eds.) Proceedings of 12th International Conference on Artificial Intelligence in Education, AIED'2005, Amsterdam, July 18-22, 2005, Amsterdam: IOS Press, pp. 96-103.
[8] Lundgren-Cayrol, K., Paquette, G., Miara, A., Bergeron, F., Rivard, J., and Rosca, I. (2001) Explor@ Advisory Agent: Tracing the Student's Trail. In: W. Fowler and J. Hasebrook (eds.) Proceedings of WebNet'2001, World Conference of the WWW and Internet, Orlando, FL, October 23-27, 2001, AACE, pp. 802-808.
[9] Peter Brusilovsky, Sergey Sosnovsky, Olena Shcherbinina, QuizGuide: Increasing the Educational Value of Individualized Self-Assessment Quizzes with Adaptive Navigation Support. In Janice Nall and Robby Robson (eds.) Proceedings of E-Learn 2004, (pp. 1806-1813). Washington, DC, USA: AACE.
[10] Brusilovsky, P., Sosnovsky, S., and Yudelson, M. (2006) Addictive links: The motivational value of adaptive link annotation in educational hypermedia. In Proceedings of 4th International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH'2006), Dublin, Ireland, June 21-23, 2006, Springer Verlag, pp. 51-60.
[11] Brusilovsky, P. (2004) KnowledgeTree: A distributed architecture for adaptive e-learning. In: Proceedings of The Thirteenth International World Wide Web Conference, WWW 2004, New York, NY, 17-22 May, 2004, ACM Press, pp. 104-113.
[12] Sosnovsky, S. and Brusilovsky, P. Layered Evaluation of Topic-Based Adaptation to Student Knowledge. In: Proceedings of Fourth Workshop on the Evaluation of Adaptive Systems at 10th International User Modeling Conference, UM 2005, July 26, 2005, pp. 47-56.
[13] Blackboard Inc. (2002) Blackboard Course Management System 5.1, Blackboard Inc. http://www.blackboard.com/ (Accessed 21 January, 2002)
[14] WebCT (2002) WebCT Course Management System 3.8, WebCT, Inc., Lynnfield, MA. http://www.webct.com (Accessed 2 July, 2002)
[15] WBT Systems TopClass 3.0, WBT Systems, Dublin, Ireland. http://www.wbtsystems.com/
[16] W3C. Resource Description Framework (RDF). Available at http://www.w3.org/RDF/
[17] Dublin Core Metadata Initiative. Available at http://dublincore.org
[18] IEEE Learning Object Metadata. Available at http://ltsc.ieee.org/wg12/ joint LOM-DCMI specification and LOM-RDF binding available at http://dublincore.org/educationwiki/DCMIIEEELTSCTaskforce
[19] The Protégé ontology editor and knowledge engineering system. Available at http://protege.stanford.edu/
[20] SemanticWorks - visual Semantic Web design tool for RDF and OWL. Available at http://www.altova.com/products/semanticworks/semantic_web_rdf_owl_editor.html
[21] Brusilovsky, P., Sosnovsky, S., and Yudelson, M. Ontology-based framework for user model interoperability in distributed learning environments. In Proceedings of E-Learn 2005, Vancouver, Canada, October 24-28, 2005, AACE, pp. 2851-2855.
[22] Brusilovsky, P., Sosnovsky, S., and Shcherbinina, O. User Modeling in a Distributed E-Learning Architecture. In Proceedings of 10th International User Modeling Conference (Edinburgh, UK, July 24-29, 2005). Berlin: Springer Verlag, pp. 387-391.