

Ontologies for authoring of intelligent educational systems

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Ontologies for Authoring of Intelligent Educational Systems

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Abstract

The goal of this paper is to illustrate the beneficial role of ontologies in achieving efficient authoring support for Intelligent Educational Systems (IES). We present our ideas within an ontology-driven framework EASE offering power with respect to the functionality, generic approach for its support of instructional strategies and user-friendliness in its interaction with the author. A central function in it has an authoring task ontology that at a meta-level defines and controls the configuration and tuning of an authoring tool for a specific authoring process. In this way we achieve more control over the evolution of the intelligence in IES and reach a computational formalization of IES engineering.

1 Introduction

For many years now, various types of Intelligent Educational Systems (IES) have proven to be well accepted and have gained a prominent place in the field of courseware [Murray, 2003b]. IES also have proven [Brusilovsky, 2003; Murray, 2003a] that they are rather difficult to build and maintain, which became, and still is, a prime obstacle for their wide spread popularization. The dynamic user demands in many aspects of software production are influencing research in the field of intelligent educational software as well [Ainsworth et al, 2003]. Problems are related to keeping up with the constant requirements for flexibility and adaptability of content and for reusability and sharing of learning objects [Devedzic et al, 2000].

Thus, the IES engineering is a complex process, which could benefit from a systematic approach, based on a com-

mon models and a specification framework. This will offer a common framework, to identify general design and development phases, to modularize the system components, to separate the modeling of various types of knowledge, to define interoperability points with other applications, to reuse subject domains, tutoring and application independent knowledge structures, and finally to achieve more flexibility and consistency within the entire authoring process. Beyond the point of creation of IES, such a common engineering framework will allow for structured analysis and comparison of IES and their easy maintainability.

Currently, a lot of effort is focused on improving of IES authoring tools to simplify the process and allow time-efficient creation of IES [Murray, 2003a; Redfield, 1997; Vassileva, 1995]. Despite this massive effort, there is still no complete integrated methodology that allows to distinguish between the various stages of IES design, and also to (semi-)automate the modeling and engineering of IES components, as well as providing structured guidance and feedback to the author. There are efforts to decrease the level of complexity of ITS building by narrowing down the focus to a set of programming tasks and tools to support them [Anderson et al, 1995], and by limiting the view to only correct or incorrect ‘solutions to a set of tasks’ [Ritter et al, 2003]. As a way to overcome the complexity without decreasing the level of ‘intelligence’ in IES, [Ritter et al, 2003] proposes an approach for separation of authoring components, and [Murray, 2003a] offers a KBT-MM a reference model for authoring system of a knowledge-based tutor, which is storing the domain and tutoring knowledge in “modular components that can be combined, visualized and edited in the process of tutor creation”.

A considerable amount of the research on knowledge-based and intelligent systems moves towards concepts and ontologies [Mizoguchi et al, 2000] and focuses on knowledge sharing and reusability [Chen et al, 1998; Ikeda et al,

1997]. Ontologies allow the definition of an infrastructure for integrating IES at the knowledge level, independent of particular implementations, thus enabling knowledge sharing [Breuker et al, 1999]. Ontologies can be used as a basis for development of libraries of shareable and reusable knowledge modules [Aroyo et al, 2002b] and help IES authoring tools to move towards semantics-aware environments.

In compliance with the principles given by [Murray, 2003a] we present an integrated framework that allows for a structured approach to IES authoring, as well as for automation of authoring activities. Characteristic aspect of our approach is the definition of different ontology-based IES intelligence components and the definition of their interaction. We finally aim in obtaining an evolutionary (self-evolving) authoring system, which will be able to reason over its own behavior and subsequently change it if is necessary. In Section 2 we illustrate the aspects of the IES authoring process. In Section 3 we shortly present the main points of the authoring task ontology, and in Section 4 the architectural considerations of the EASE framework are sketched. Finally, we present our conclusions and intentions for future work.

2 Authoring Support Approach

The approach we take follows up on the efforts to elicit requirements for IES authoring, define a reference model and modularize the architecture of IES authoring tools [Aroyo et al, 2004]. We describe a model-driven design and specification framework that provides functionality to bridge the gap between the author and the authoring system by managing the increased intelligence. It accentuates the separation of concerns between subject domain, user aspects, application and the final presentation of the educational content. It allows to overcome inconsistencies and to automate the authoring tasks. We show how the scheme from [Murray, 2003a] can be filled with the ‘entire intelligence of IES’, split into collaborative knowledge components.

First, we look at the increased intelligence. Authoring of IES is a process with an exponentially growing complexity and it requires many different types of knowledge and considering various constraints, requirements and educational strategies [Nkambou et al, 1996]. Aiming at (semi)-automated IES authoring we need to have explicit representations of the strategic knowledge (rules, requirements, constraints) in order to be able to reason within different authoring contexts and situations. Managing of the increased intelligence is therefore a key issue in authoring support.

Second, we consider the conceptual distance between the user and the system. According to [Mizoguchi et al, 2000; Redfield, 1997] the authoring tools are neither intelligent nor user-friendly. Special-purpose systems provide extensive guidance, but the disadvantage is that changing such systems is not easy, and the knowledge and content can hardly be reused for their educational purposes [Murray, 2003b]. Thus, structured guidance is needed in this complex authoring process.

Our ultimate aim is to attain seemingly conflicting goals: to define authoring support in a powerful, generic and easy to use way. The power comes from the use of ontology-based approach. The generality is achieved with the help of a meta-authoring tool, instantiated with the concrete learning context to achieve also the power of a domain specific tool. The ease of use comes from the combination of the previous two. A characteristic aspect of our approach is the use of Authoring Task Ontology (ATO) [Aroyo et al, 2002a; Aroyo et al, 2003] as part of the authoring environment, which enables us to build a meta-authoring tool [Aroyo et al, 2004] and to tailor the general architecture to the needs of each individual system.

2.1 IES Authoring

Characteristically, ITS, maintain and work with knowledge of the expert, learner, and tutoring strategies, to capture the student’s understanding of the domain and to tailor instructional strategies to the concrete student’s needs. Thus, the provision of user-oriented (adapted) instruction and adequate guidance in IES depends on:

- maintaining a model of the domain, describing the structure of the information content within IES (based on concepts and their relationships);
- maintaining a personalized portal to a large collection of well organized and structured learning/teaching material resources.
- maintaining a model of the user to reflect the user’s preferences, knowledge, goals, and other relevant instructional aspects;
- maintaining instructional design, assessment, adaptation and sequencing models;

In line with this we structure the complexity of the entire authoring process by grouping various authoring activities to:

- model the subject domain / domain knowledge;
- maintain and modify learning objects;
- define the learning goals / learning activities;
- apply instructional strategies for individual and group learning;
- apply assessment strategies for individual and group learning;
- specify a learner model / characteristics;
- specify learning sequence(s) out of learning and assessment activities.

To support these authoring tasks we employ knowledge models and capture all the processes related to those tasks in corresponding authoring modules. Our final goal is to realize an evolutionary (self-evolving) authoring system, which will be able to reason over its own behavior.

We follow explicitly the principles supported also by KBT-MM [Murray, 2003a] to separate ‘what to teach’ into modular units independent of ‘how to teach’ and to present learning goals separately from the instructional content. Thus, we have a clear distinction between the content and the computational knowledge, where the learning goal plays a connecting role in order to bring them together within the specific context of each IES (Fig. 1). In this way we also allow reusability of general knowledge on instructional design and strategies.

In other words, the Collaborative Learning Strategy (CLS) module provides the author with the appropriate group learning strategies and requirements for them via the Sequence Strategies Authoring (SS) module. To generate explanations and guidance about the recommended strategies CLS uses Collaborative Learning Ontology which is a system of concepts to represent collaborative learning sessions and Collaborative Learning Models inspired by learning theories [Inaba et al, 2000; Supnithi et al, 1999].

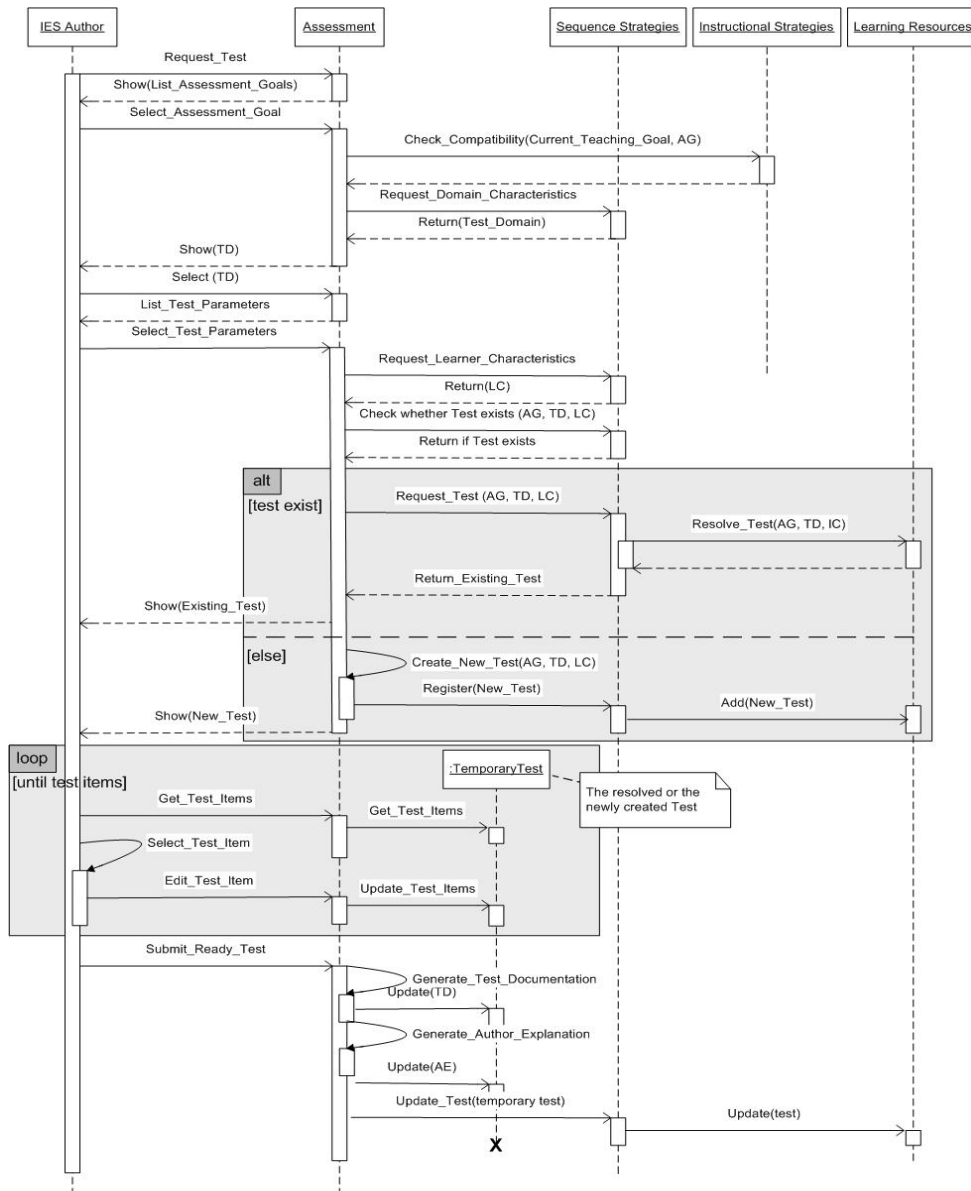


Figure 2. Assessment Module Interactions

The core of the intelligence in the EASE architecture comes from the communication or interactions between the components. There are two "central" components here, the Sequencing Strategies Authoring (SS) and the Authoring Interface (AI). The AI is the access point for the author to interact with the underlying concepts, models and content. The SS interacts with the other components in order to achieve the most appropriate learning sequence for the targeted learner (Fig. 2).

At a conceptual level the IES author interacts with the Learning Resources (LR) and with the Domain Model (DM) authoring modules, for example to handle the learning objects. While the author is working with DM, an interaction is required between DM and LR to determine available resources to link to domain concepts. At the user (learner) level the author interacts with the Simulated User Model (SUM) component in order to determine the use of UM (update rules) within the IES application. At the application level the author interacts with the A and SS modules.

The authoring rules in the Assessment knowledge base trigger interaction in order to realize various aspects of the test generation process. An authoring support rule in the CLS's knowledge base, on the other hand, produces recommendations and can be triggered by either the author or the system.

5 Conclusion

The goal of this research is to specify a general authoring framework for content and knowledge engineering for Intelligent Educational Systems (IES). The main added value of this approach is that on the one hand the ontologies in it make the authoring knowledge explicit, which improves the basis for sharing and reusing. On the other hand, it is configurable through an evolutionary approach. Finally, this knowledge is implementable, since all higher-level (meta-level) constructs are expressed with a limited class of generic primitives out of lower-level constructs.

Within the EASE framework we have identified the main intelligence components and have illustrated their interaction. Characteristic for EASE is the use of ontologies to provide common vocabulary and common understanding of the entire IES authoring processes. This allows for interoperation between different applications and authors.

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architecture, particularly with respect to the collaborative learning and testing aspects of the authoring process.

References

- [Ainsworth et al, 2003] Ainsworth, S., Major, N., Grimshaw, S., Hayes, M., Underwood, J., Williams, B., & Wood, D., REDEEM: Simple Intelligent Tutoring Systems from Usable Tools, In Murray, Ainsworth, & Blessing (eds.), *Authoring Tools for Adv. Tech. Learning Env.*, 205-232.
- [Aroyo et al, 2002a] Aroyo, L. & Dicheva, D., Courseware Authoring Tasks Ontology. International Conference on Computers in Education (ICCE'02), December 2002, Auckland, New Zealand.
- [Aroyo et al, 2002b] Aroyo, L., Dicheva, D., & Cristea, A. (2002). Ontological Support for Web Courseware Authoring. In *Proceedings of ITS 2002 Conference*, 270-280.
- [Aroyo et al, 2003] Aroyo, L., & Mizoguchi, R., Authoring Support Framework for Intelligent Educational Systems. In *Proceedings of AIED 2003 Conference*.
- [Aroyo et al, 2004] Aroyo, L. & Mizoguchi, R., Towards Evolutional Authoring Support. *Journal for Interactive Learning Research*. (in print)
- [Anderson et al, 1995] Anderson, J., Corbett, A. Koedinger, K., & Pelletier, R., Cognitive tutors: Lessons learned. *The Journal of the Learning Sciences*, 4(2), 167-207.
- [Breuker et al, 1999] Breuker, J., Bredeweg, B., Ontological Modelling for Designing Educational Systems, In *Proceedings of the Workshop on Ontologies for Intelligent Educational Systems at AIED'99 Conference*.
- [Brusilovsky, 2003] Brusilovsky, P., Developing Adaptive Educational Hypermedia Systems. In Murray, Ainsworth, & Blessing (eds.), *Authoring Tools for Advanced Technology Learning Environments*, Kluwer Academic Publishers, 377-409.
- [Chen et al, 1998] Chen, W. Hayashi, Y., Kin, L. Ikeda, M. and Mizoguchi, R., Ontological Issues in an Intelligent Authoring Tool, In *Proceedings of ICCE 1998 Conference*, (1), 41-50.
- [Devedzic et al, 2000] Devedzic, V., Jerinic, L., Radovic, D., The GET-BITS Model of Intelligent Tutoring Systems. *Journal of Interactive Learning Research*, 11(3), 411-434.
- [Ikeda et al, 1997] Ikeda, M., Seta, K., Mizoguchi, R., Task Ontology Makes It Easier To Use Authoring Tools. In *Proceedings of IJCAI 1997 Conference*.
- [Inaba et al, 2000] Inaba, A., Supnithi, T., Ikeda, M., Mizoguchi, R., & Toyoda, J., How Can We Form Effective Collaborative Learning Groups - Theoretical justification of Opportunistic Group Formation with

- ontological engineering. In Proceedings of ITS 2000 Conference, 282-291.
- [Jin et al, 1997] Jin, L., Ikeda, M., Mizoguchi, R. & Kitaoka, Y., Role Explication of Simulation in Intelligent Training Systems by Training Task Ontology, In Proc. of AI-ED-97 Workshop on Architectures for intelligent simulation-based learning environments, p. 41-48.
- [Mizoguchi et al, 1997] Mizoguchi, R., Ikeda, M., & Sinita, K., Roles of Shared Ontology in AI-ED Research: Intelligence, Conceptualization, Standardization, and Reusability. In Proc. of AI-ED 97, pp.537-544, Kobe, Japan
- [Mizoguchi et al, 2000] Mizoguchi, R., & Bourdeau, J., Using Ontological Engineering to Overcome Common AI-ED Problems, *International Journal of AIED*, 11(2), 107-121.
- [Murray, 2003a] Murray, T., Principles for pedagogy-oriented Knowledge-based Tutor Authoring Systems. In Murray, Ainsworth, & Blessing (eds.), *Authoring Tools for Advanced Technology Learning Environments*, Kluwer Academic Publishers, 439-466.
- [Murray, 2003b] Murray, T., An Overview of ITS authoring tools. In Murray, Ainsworth, & Blessing (eds.), *Authoring Tools for Advanced Technology Learning Environments*, Kluwer Publishers, 491-544.
- [Nkambou et al, 1996] Nkambou, R., Gauthier, G., Franson, C., CREAM-Tools: An Authoring Environment for Curriculum and Course Building in an ITS. *Computer Aided Learning and Instruction in Science and Engineering*, 186-194.
- [Redfield, 1997] Redfield, C. L., An ITS Authoring Tools: Experimental Advanced Instructional Design Advisor, AAAI Fall Symposium, 72-82.
- [Ritter et al, 2003] Ritter, S., Blessing, S., & Wheeler, L., Authoring tools for Component-based Learning Environments. In Murray, Ainsworth, & Blessing (eds.), *Authoring Tools for Advanced Technology Learning Environments*, Kluwer Academic Publishers, 467-489.
- [Supnithi et al, 1999] Supnithi, T., Inaba, A., Ikeda, M., Toyoda, J., & Mizoguchi, R., Learning Goal Ontology Supported by LearningTheories for Opportunistic Group Formation, Proc. of AIED'99, Le Mans France, 67-74.
- [Vassileva, 1995] Vassileva, J., Dynamic Courseware Generation: at the Cross Point of CAL, ITS and Authoring. In Proceedings of ICCE 1995 Conference, 290-297.