LEARNER MODELING TO FACILITATE PERSONALIZED E-LEARNING EXPERIENCE

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ABSTRACT

This article describes a learner modeling strategy that is employed by an adaptive learning system in order to provide each learner with a personalized e-Learning experience. Parameters related to the learners' prior knowledge, goal and learning style constitute the basis of the personalization and the adaptivity of the mentioned learning system. The present paper focuses on the mechanisms concerning the learner's prior knowledge and the goal parameters. The learner modeling that takes into account the prior knowledge of the learners is achieved by developing an ontological abstraction. Based on this ontological abstraction, a knowledge base is constructed in order to introduce the knowledge representations of the domain model and the curricular model, the knowledge and the learning structures. These knowledge representations specify how the prior knowledge of a learner will be represented, and also how it will be assessed and continuously updated.

KEYWORDS

adaptivity, prior knowledge, ontological abstraction, knowledge representation.

1. INTRODUCTION

An adequate representation of the learners' prior knowledge is the basis for achieving personalization in an adaptive learning system. This article introduces the conceived ontological abstraction that underlies the development of the knowledge representations to be defined for the learner modeling in terms of the learners' prior knowledge. These knowledge representations specify how the prior knowledge of learners will be represented and also how it will be continuously updated.

The ontological abstraction mentioned for the knowledge representations should reflect both the curricular aspects as the domain model and the curricular model, and the so-constructed knowledge base should hold the potential knowledge, competence and learning states of the learners. Thus, the knowledge representations turn out to be a knowledge base that should include the core class elements, the relationships among these elements, and the instances of these class elements. This knowledge base is to be stored in OWL (Web Ontology Language) format.

2. BODY OF PAPER

2.1 Learner Modeling

The diagram below depicts the ontological model of the knowledge representation that is developed to support the personalization of the learning experience.

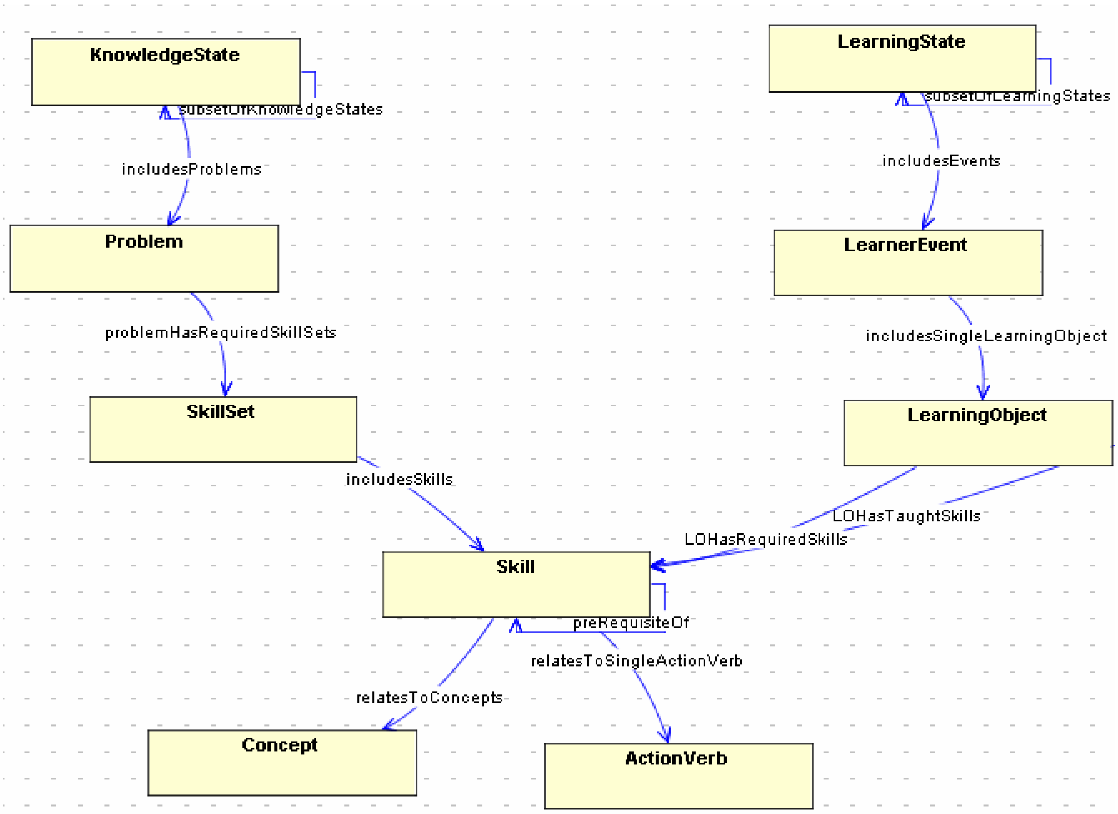

Figure 1. Ontological model for knowledge representations

In the introduced model, the entities *KnowledgeState*, *Problem*, *SkillSet*, *LearningObject*, *LearnerEvent*, *LearningState*, *Skill*, *Concept* and *ActionVerb* constitute the class constructs. The relations among these classes are represented by the arrows in the diagram above. They are classified as being either 1-to-1 or 1-to-many, which means that they can be described as functional and not-functional relations, respectively. According to the conceived model, the relations *includesSingleLearningObject* and *relatesToSingleActionVerb* are the 1-to-1 relations, thus a *LearnerEvent* instance contains a single *LearningObject* instance and a *Skill* instance contains a single *ActionVerb* instance.

As already evident from Figure 1, the *Skill* class plays the central role in the knowledge representation. It is the *Skill* class that, on the one hand, provides a link between the *Problem* and *LearningObject* classes, and, on the other hand, associates both of these classes to the conceptual level. In this paper, the term "Skill" defines the expected learning outcomes (objectives) by the curriculum. The instances of the *Skill* class are formed by a combination of a set of *Concept* instances and a single *ActionVerb* instance. The instances of the *Concept* class refer to the curricular model of the adaptive learning system that is based on a specific curriculum. The *ActionVerb* class is related to the learners' observable behavior or performance, and indicates the activities required to meet the learning objectives. The instances of the *Skill* class may be considered as a fixed vocabulary for characterising the instances of both the *Problem* and the *LearningObject* classes, which may vary in an open system that evolves by putting in or taking out problems and learning objects, respectively. The instances of the *Skill* class are ordered by the *preRequisite* relation, which captures possibly existing dependencies between skills and induces a skill structure by distinguishing certain subsets of skills.

The *Problem* and the *Skill* classes are not directly linked to each other. Their connection is mediated by the *SkillSet* class, which represents the fact that various alternative sets of skills may be sufficient for solving a certain problem (which is conceived as an exercise that may or may not be solved). Each instance of the *KnowledgeState* class represents the subset of exactly those problems that a learner is capable of solving. The collection of possible knowledge states together with the subset relation forms the knowledge structure.

The *LearningObject* class is related to the *Skill* class via two paths, which are the *RequiredSkills* and the *TaughtSkills* relations. This means that each learning object is tagged with a set of required skills (prerequisites necessary for learning from it), as well as with a set of taught skills (what it actually conveys). The instances of the *LearningObject* class are conceived to consist of a sequence of SCOs (Shareable Content Objects), which in turn are taken to be the content elements of the learning system that correspond to the finest level of granularity.

The *LearningState* class with the *subset* relation introduces a learning structure to be constructed by the instances of the *LearnerEvent* class that comprise the instances of the *LearningObject* class. This means that a learner is to experience events like seeing, solving, or covering in detail while consuming the learning objects. These event types are determined when the model is populated. Hence, they may vary in an open system. The introduced model allows for updating the competence state of a learner if the learner experiences activities external to the adaptive learning system. This updating is achieved by an assessment employed by the learning system, which involves the *Problem* instances in the knowledge structure. The competence state of the learner can also be updated if the learning system inserts relevant *LearnerEvent* and *LearningObject* instances to the learning structure.

According to the outlined model, at each point in time the learner can be characterized in three different ways: By the subset of available skills, by the subset of problems the learner is capable of solving, and by the subset of learning objects the content of which is mastered by the learner. These characterizations, however, are not independent from each other, but are highly related. In fact, the set of available skills provides a complete characterization of the learner (aside from the objectives or the learning style mentioned in the introduction). It induces the learner's knowledge state as well as his or her learning state via the skill assignments to problems and learning objects, respectively, as they are specified by the relations illustrated in the diagram above.

2.2 Building the Knowledge Base

The knowledge base described in the previous section is built by populating the introduced ontological model, which involves inserting the instances of the respective classes that make up the model. The ontology editing tool Protégé is employed for developing the knowledge base in OWL format. The diagram in Figure 2 below depicts the framework for ontology editing.

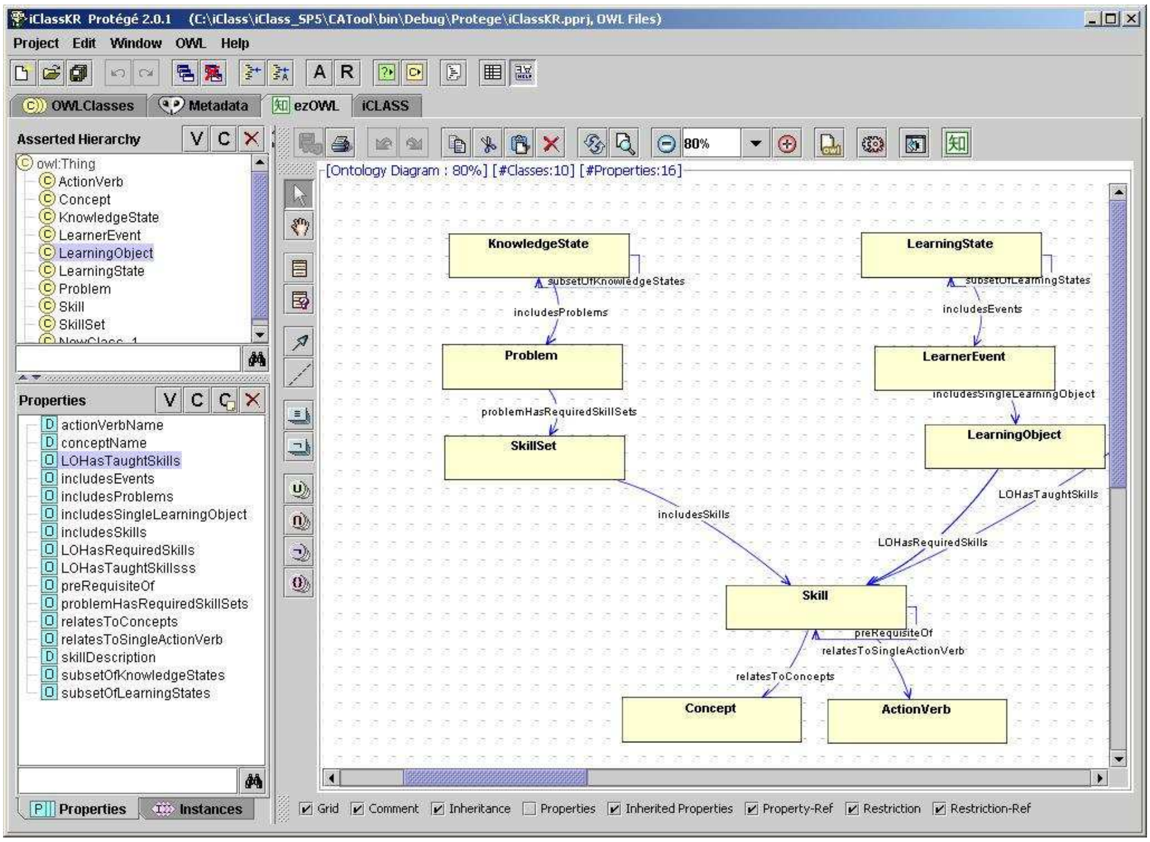

Figure 2. Ontology editing for knowledge representations

The dependencies between the class elements, represented by the directions of the relation, arrows, suggest to populate the ontological model by proceeding bottom-up. Initially, the instances of the *Concept* and the *ActionVerb* classes are added to the knowledge base. Then the instances of the *Skill* class are defined by associating them with the instances of the *Concept* and *ActionVerb* classes. Essentially, this effort creates a model that reveals curricular aspects, as the values of these classes are extracted from the curriculum. "Identify the importance of food" exemplifies a skill instance that is derived for the "food and digestion" subject of the science course, and includes "food" as the *Concept* and "identify importance of" as the *ActionVerb*. As another outcome of this effort a skill structure is induced by the reflexive *prerequisite* relation of the *Skill* class. Each learner is characterized by a so-called competence state, which is the set of available skills, and forms a subset of the *Skill* instances. The reason that the skill structure is not explicitly represented in the model is that the competence state of a learner is derived as an outcome of the adaptive learning experience instead of pre-structuring before the learner practices the learning process with the adaptive system. Modeling as well as continuously updating the competence states of the learners is discussed in [3].

The learning structure is built with the instances of the *LearningObject* and *LearnerEvent* classes, and by drawing upon the reflexive *subset* relation of the *LearningState* class. Associating the instances of the *LearningObject* class with the instances of the *Skill* class reveals the mechanism of creating the metadata of the content to be developed and the personalization of the content, which in turn reveals the association of the learner model with the content model. The *LearnerEvent* class is introduced in order to describe how the learning object is consumed by the learners to acquire the respective skills.

Similarly, the knowledge structure collects the potential knowledge states of the learners, which are the possible subsets of problems the learners are capable of solving. It is built with the instances of the *SkillSet*, *Problem* and *KnowledgeState* classes, and an order is induced on it by the reflexive *subset* relation on the *KnowledgeState* class. The *Problem* class is populated with the questions that constitute the knowledge structure derived as domain model. Each *KnowledgeState* instance comprises a set of *Problem* instances. The assignment of skill sets to the problems completely determines the set of potential knowledge states. The resulting knowledge structure forms the basis for the assessment and pre-test procedures employed by the adaptive system. It also offers an opportunity for empirical validation of the knowledge representation. The theoretically predicted knowledge states may be contrasted with either empirically observed answer patterns, or with expert judgments on the solution behavior. Querying experts for identifying the knowledge states is a rather tedious procedure because the number of queries increases exponentially with the number of problems. This requires the aid of an auxiliary program that provides the experts with an interface asking a minimum number of questions in order to determine the surmise and entailment relations that capture dependencies between the problems. The reduction of the number of queries is achieved by drawing inferences from the answers provided so far. The determined surmise and entailment relations among the problems lead to defining the knowledge states, and thus the knowledge structure (which actually is a knowledge space, i.e. a collection of knowledge states closed for union).

The mentioned auxiliary program exploits "Koppen's Algorithm for Constructing a Knowledge Space", which is discussed in [2]. In brief, the algorithm depends on an entailment relation on the problems, which represents expert judgments stating that a learner who fails in a set of problems, will also fail in an other problem. Thus, the aim of this auxiliary program is to get this kind of input from the experts by providing them with the check/uncheck options to determine the entailment relations. The figure below depicts the interface of this program for a knowledge space consisting of 50 questions:

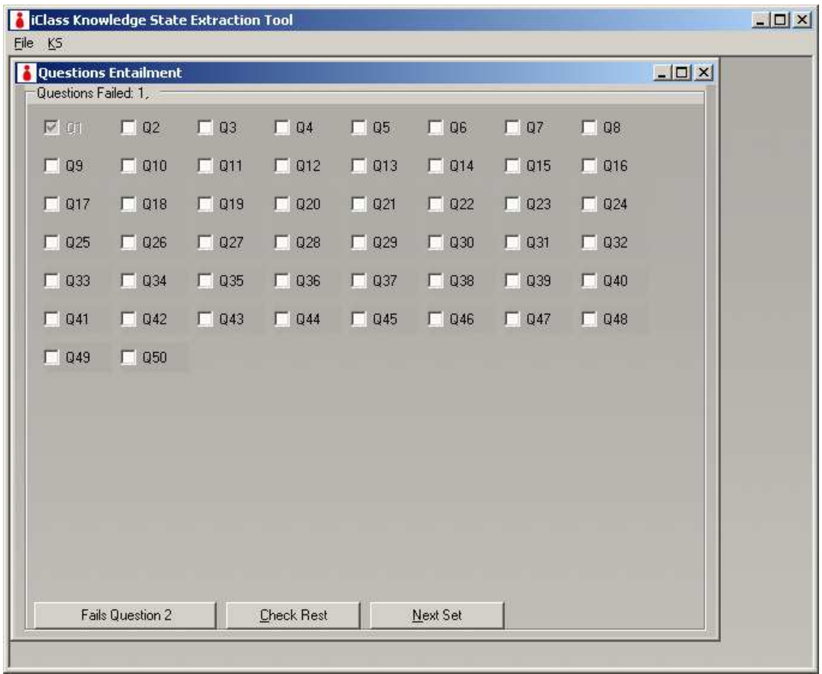

Figure 3. Knowledge state extraction for a set of questions

The output of this knowledge state extraction effort is the set of potential knowledge states of the learners for a set of problems derived for a domain. These knowledge states may then be compared to those predicted by the knowledge representation within the ontological model. This information may then be used to properly adjust the representation whenever necessary to obtain a theoretically sound and empirically valid model.

2.3 Exploiting the Model

A personalized learning experience is accomplished through adapting the learning material to the knowledge state and the already acquired skills. This involves the creation of the individualized learning paths for the learners. Learning paths are portions of the curricular model or the skill structure. The knowledge representation of the learner is continuously updated throughout his/her learning experience with the adaptive system. The IMS LIP (Learner Information Package) specification is employed by the adaptive learning system in order to store the up-to-date knowledge and competence states of the learners.

Targeting personalization and being adaptive constrain the learning content to be developed and exploited by the adaptive learning system. The learning objects are to be developed according to the created knowledge representations.

3. CONCLUSION

This paper has described a learner modeling strategy that has been employed by an adaptive learning system. The introduced representation of the learners' prior knowledge constitutes the basis for the adaptation.

This article has also introduced the conceived ontological model that underlies the creation of the knowledge representations to be defined for the learner modeling. The ontological model reflects curricular aspects as both the domain model underlying the knowledge structure and the curricular model underlying the learning structure. The knowledge base constructed from it holds the potential knowledge and competence states of the learners. Moreover, the knowledge representation can be implemented by a knowledge base stored in OWL format.

According to the introduced model, the learners are to own three states: knowledge state, competence state, and learning state. The up-to-date states of the learners are kept and exchanged among the concerning modules of the adaptive learning system conforming to IMS LIP which is an open and well-accepted specification.

It is imperative to mention that content should be developed in accordance with the introduced ontological model. This leads to the necessity that the content model comprising the metadata schema profile of the content should be developed accordingly so that the harmony between the two models is achieved.

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REFERENCES

Book

[1] Albert, D. and Lukas J., 1999. *Knowledge Spaces: Theories, Empirical Research and Applications*. Lawrence Erlbaum Associates Inc. Publishers, USA.

[2] Doignon, J. and Falmagne J., 1999. *Knowledge Spaces*. Springer-Verlag Berlin Heidelberg, Germany.

Conference paper or contributed volume

[3] Muehlenbrock, M., Winterstein S., Andres E. and Meier A., 2005. Learner Modeling in iClass. *Proceedings of the World Conference on Educational Multimedia, Hypermedia, and Telecommunications EdMedia 2005*. Montreal, Canada.

Other

[4] Protégé Ontology and Knowledge Base Framework, http://protege.stanford.edu.

[5] OWL Web Ontology Language Reference, http://www.w3.org/TR/owl-ref.

[6] IMS Learner Information Package Specification, http://www.imsglobal.org/profiles/index.html.

[7] iClass Integrated Project, Annex1, Description of Work, http://www.iclass.info.