 Ontology as a Foundation for Knowledge Evaluation in Intelligent E-learning Systems

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Abstract. WWW service has enabled development of e-learning systems that are considered to be direct application of the information and communication technology. xTEx-Sys system is an Web-based authoring shell with adapted environment to each actor of the system. Formal representation of course material in xTEx-Sys involves ontology driven knowledge description. Student’s knowledge evaluation in xTEx-Sys is realized using dynamic quizzes. This paper describes ontology’s role of xTEx-Sys knowledge evaluation process.

Introduction

Information and communication technology combined with multimedia, networking and software engineering, have enabled development of new learning and teaching environment. Last great milestone in this environment was made by introducing Internet and WWW service, and it was expected that all educational systems are to be reengineered. Learner is “placed” in centre of the learning environment with regard to the time and the place as well as the way of learning and everything is embraced by single phrase – learning resources (people, knowledge, technology, medium, organization,…). WWW service has enabled development for thousands of systems that are considered to be direct application of the information and communication technology. Most of these systems have very limited learning and teaching capabilities because they base their work on static presentation of subject matter. Educational systems capabilities incensement is gained by adding interactive, adaptive and intelligent functions. Those functions can be implemented by using some dynamic generation techniques of Web content which depend on students’ answers on asked questions. Usage of those technologies enables the development of Web based authoring shells for constructing Web oriented intelligent tutoring systems (ITS). Intelligent tutoring systems are kind of intelligent e-learning systems whose aim is to support and improve learning and teaching process in certain domain knowledge, respecting individuality of the learner as in traditional “one-to-one” or “face-to-face” tutoring. The individualized learning and teaching approach is now enriched with e-learning paradigm and, what is more, makes fundaments of our research. According to ITS traditional modular architecture [1] and the idea of the cybernetic model of the system [2, 3] we have developed intelligent hypermedia authoring shell called Tutor-Expert system (TEx-Sys) [4]. The TEx-Sys authoring shell was initially developed and implemented as an
on-site system (1992-2001, on-site TEx-Sys), and after that followed research, development and implementation of Web-oriented realization based on dynamic Web document (1999-2003, Distributed Tutor-Expert System, DTEx-Sys) [5]. The TEx-Sys and the DTEx-Sys have been applied on students of different ages (from elementary school to academic level). We have created our own learning and teaching model as well as scenario for knowledge evaluation by using knowledge bases developed by TEx-Sys. Achieved results had an impact on further research that relied on Bloom’s experiment [6] and Fletcher’s consideration [7] with a view of developing our own research methodology. Nowadays we have been working on the implementation of a prototype of the extended version of the TEx-Sys, eXtended Tutor-Expert System, xTEx-Sys [8], within a technology project founded by Ministry of Science and Technology of the Republic of Croatia.

![Figure 1. TEx-Sys model through technical generations](image)

xTEx-Sys is an authoring shell with environment adapted to every actor of the system: (i) expert to design domain knowledge on specially defined ontology for knowledge design and representation, (ii) teacher to design courseware using defined ontology for hierarchical organization of course content on units, lessons, topics and instructional items for student learning and teaching process as well as tests of quiz type for student knowledge evaluation (courseware structure elements) (iii) student to select course and navigate through domain knowledge content via didactically prepared course content, (iv) administrator for system supervision. Architecture of xTEx-Sys incorporates advanced technologies to gain interoperability and reusability towards other educational systems. System architecture is 3-tiered where service oriented technology connects parts of the system: (i) data layer with three databases semantically connected using XML schema, (ii) Web service adopting actor’s functionalities, and (iii) user interface capability for domain knowledge and courseware design. [9]. Scenario for student knowledge evaluation is of a great interest to us during TEx-Sys, DTEx-Sys and now with xTEx-Sys research, implementation and employment. Consequently, we have developed two methods for knowledge evaluation: overlay [10] and quiz [11]. Supported by our previous experience, a new knowledge evaluation method, based on dynamic quiz, is designed. In this paper, first section introduces the structure of knowledge representation in TEx-Sys and DTEx-Sys, as well as, points out motivation for enhanced approach to specially designed didactical ontology. xTEx-Sys domain knowledge representation is given in second section, while the third one discusses teacher’s and learner’s view of the knowledge evaluation process. The last section gives concluding remarks.

1. Background

Within TEx-Sys model, knowledge is represented by semantic networks with frames [12]. In semantic networks (SN), conceptual entities such as objects, actions, or events are represented as a graph of linked nodes. Nodes are used to present domain knowledge objects, while links show relations between pairs of objects. Beside nodes and links, the system supports properties and frames (attributes and respective values), along with
property inheritance. The system relies heavily on modern supporting technologies, such as hypermedia, with the structure attributes: picture, animation, slides, URL addresses and hypertextual descriptions. Simple example of animal world, represented by our approach to semantic networks with frames enhanced with hypermedia, is shown on Figure 2.

Figure 2: Semantic networks with frames and hypermedia representation of Animal world

Considering creation of course structure elements (aggregation, Sharable Content Object – SCO, asset) according to SCORM (Shareable Content Object Reference Model) model [13] we manage not only documents and media files, but also elements of semantic network with frames. That is the major difference of our approach compared to content aggregation model of SCORM (see Figure 3.).

Network methods’, including SN, implicitly derives knowledge by suitable algorithms following linked nodes. In logic methods, implicit knowledge is deduced by using automatic reasoning systems tailored on the sets of axioms and rules characteristic of the specific formal system chosen. So, with respect to logical representation of knowledge semantic networks do not have quantifiers, connectives and cardinalities. Ontological representation of knowledge stands between knowledge networks and logical based system [14]. In conclusion, ontologies join standardization issues with quite good expressive power and computational costs.

2. xTEx-Sys Domain Knowledge Representation

xTEx-Sys progress towards better understanding and refining formal representation of knowledge involves ontology driven knowledge description. Such knowledge representation, which uses semantic networks with frames, is appropriate for defining ontology because nodes are easily translated to concepts and the link between two concepts is nothing else than a relation. Frame attribute is also relation between two concepts where one of them is a node, containing frame and the other one is some standard data value.
We used today’s Web Ontology Language (OWL) [15] as higher-level interpretation of domain knowledge in xTex-Sys (see Table 1). OWL is intending to describe the terminology of domain knowledge in the terms of classes/concepts describing sets of individuals, and properties/roles relating these. It consists of a set of axioms that assert characteristics of these classes and properties. Rules for semantic type transformation to OWL terms are simplified on the level of recognition; SN’s generic node as blueprint for an individual is considered as OWL class.

<table>
<thead>
<tr>
<th>SN with Frames</th>
<th>OWL Ontology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nodes</strong></td>
<td>Class(genericNodeName)</td>
</tr>
<tr>
<td></td>
<td>Individual(instanceNodeName type genericNodeName)</td>
</tr>
<tr>
<td>Class(genericNodeName1)</td>
<td>Class(genericNodeName1 type genericNodeName2)</td>
</tr>
<tr>
<td></td>
<td>Link</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Link</td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Frame</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1. SN with frames and hypermedia OWL translation

Inheritance mechanism between two classes incorporates IS_A relationship which is realized by using OWL SubclassOf constructor. Instances of node are class’s individuals, so INSTANCE_OF relationship between individual would have this syntax Individual(IndividualName Type ClassName). PART_OF and other kind of links are object properties that firstly have to be declared with ObjectProperty and afterwards individual’s Value constructor would be two-parameter function of declared link and node. SN properties and frames along with media descriptions are also realized on same rules as non-standard links.

Considering the given SN example of the animal world (see Figure 2), telling that dog is an animal using OWL abstract syntax [16, 17], would be Class(Dog SubclassOf(Animal)) (see Figure 4). Fido as an instance of a dog will be Individual(Fido Type Dog Value(Gender Male) Value(Weight 20kg) Value(Height 56cm)). Max has a picture as a media descriptor and his OWL description is Value(Picture1 http://www.animalworld.net/pivtures/dog/max.jpg).
It is clear that ontological representation of data can be published over the Internet and can be distributed to some other system or client. Considering upcoming Semantic Web technology as a new learning and teaching environment, xTEx-Sys architecture is service oriented and ready to exchange knowledge in form of ontology. Ontology as a foundation for knowledge evaluation emphasizes dynamic quiz potential in process of testing student. Following chapter gives a brief introduction of knowledge evaluation, as well as, detailed process of preparation, and finally testing student’s knowledge.

3. Knowledge Evaluation

Student’s knowledge evaluation in xTEx-Sys is realized by using quizzes. Quiz is an implementation of the test where learner gets a set of questions with attached answers that can be correct or incorrect. Teacher is responsible for assigning quizzes in course. Dynamic quizzes, which are generated by the xTEx-Sys, are often used for fast evaluation of student’s knowledge. This kind of quiz has questions structured on queries about concepts and relations.

For example, system will generate and student will answer on question types like “What is a concept” or “Are two concepts in relation”. If questions are to be generated above animal world domain knowledge than they would look like “Who is Max?” or “Does Fido loves Greta?”.

Dynamic quiz generates questions over some domain knowledge. Considering OWL syntax for knowledge representation, queries about concepts are translated into questions about classes or individuals, while relations in questions are expanded with properties as a special kind of relation (see Table 2). xTEx-Sys dynamic quiz has three categories of questions of different levels of difficulty.

<table>
<thead>
<tr>
<th>1st category</th>
<th>2nd category</th>
<th>3rd category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recognize class/individual!</td>
<td>What is class/individual?</td>
<td>What are the properties of class?</td>
</tr>
<tr>
<td>What kind of relation is between two classes/individuals?</td>
<td>Who is in relation with class/individual?</td>
<td>What is value of individual’s property?</td>
</tr>
<tr>
<td>Does class has property?</td>
<td>What relation is between two classes/individuals?</td>
<td>Who is and how in relation with class/individual?</td>
</tr>
<tr>
<td>Are two classes/individuals in relation?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Categories and questions in dynamic quiz

First category contains the easiest questions and third category contains the hardest questions, and the questions of middle difficulty level are in second category. Process of knowledge evaluation can be observed from teacher and learner point of view. Teacher as courseware designer has to define when students are about to be tested. He prepares ground for knowledge evaluation performed by the learner. In the following, algorithms and tasks from teacher and learner’s viewpoint are described.
3.1 Teacher’s View for Knowledge Evaluation Process

Test as part of courseware content can be created only in course aggregation or some other aggregation. Generally, first condition that teachers meet, while building course, is existence of domain knowledge. When teacher wants to add test, he must select one aggregation from courseware learning elements set which will hold newly added SCO for testing. After entering the name of testing, SCO system calculates possible number of question series (see Figure 5.).

In the case of dynamic quiz, chosen aggregation has to have at least one SCO because questions are generated over some subset of domain knowledge assigned to aggregations’ SCOs. Calculation for proposing amount of question series is based on number of distinct SN elements gathered from all SCOs’s in the same aggregation where testing SCO will be put. Algorithm for proposing number of possible question series will count these elements of domain knowledge: C – classes count, I – individuals count, R – relations count, P – properties count, M – media properties count.

For every dynamic question, minimum of dynamical generation condition has to be defined. If we look, for example, at second question type “Are {Class/Individual1} and {Class/Individual2} in relation?” we can see that it is assembled from non-changing question text and as well of a dynamic text placeholders. In this template, {Class/Individual1} and {Class/Individual2} are two dynamic text placeholders which are in process of testing filled up with name of randomly chosen class or individual. Answers can also have placeholders, but this template has constant text values which are: (i) No, (ii) Yes, directly (iii) Yes, indirectly. For this question type, number of relations count (R) has to be above 1 to generate question with “Yes, indirectly” as a correct answer. In other case, number of classes/individuals (C+I) has to be greater or equal to 2 so that the question could include two concepts. These two conditions make minimal dynamical generation condition for that question type. Quiz in xTEx-Sys must have at least one question type from every category. Minimal dynamical generation condition for category of questions is made by combining minimal dynamical generation conditions of every question types in that category. Consequently, minimal condition for dynamic quiz generation includes minimal conditions of every category.

If minimal condition for dynamic quiz generation is satisfied then maximal possible number of question is a minimum of set of maximum number of generated questions for each question types. For example, second question type has minimal condition R>=1 and (C+I)>=2, so maximal number of generated questions has to be min{R, C+I}. Finally, when all maximal number of questions for every question type is calculated, then maximal number of questions that could be dynamically generated in quiz is a minimum of all maximal number of questions that can be generated for each question type. That number is presented to teacher, therefore he can select less or equal value of questions for his new SCO test.

3.2 Learner’s View

Afterwards when learner selects testing SCO, system initializes process of generating and
presenting dynamic quiz questions. Dynamic quiz generation in xTEx-Sys means run-time creation of question text and answers over prepared set of domain knowledge elements. If there is going to be generated question based on second question template, then algorithm is randomly choosing knowledge domain elements according to placeholder’s requests for particular domain knowledge element (Figure 6).

When student enters the dynamic quiz, the initial level of difficulty of a problem is sent to the problem generator. According to this difficulty level, the system generates pair of questions and sends it to the student. First pair consists of two questions from second category. After solving the pair of questions, student submits his answers that are going to be evaluated, giving thus partial results of the test. These partial results are used by the system and have significant role. Problem generator, according to these partial results feedback, decides from which difficulty category will be the next pair of questions distributed to the student (Figure 7) or, in the worst case, violently interrupts testing and gives unsatisfying mark.

After last series of question entire result is estimated towards calculating final mark according to the relation between accomplished points and the maximal possible points. Calculated mark varies from unsatisfying to excellent. Presenting the result of the test not only involves displaying final mark; but also it gives back set of all solutions of the answered questions as well as question category sequence. Student can actually see where he or she was wrong and afterwards choose concept or relation to see exactly where, how and why he or she had made a mistake.

4. Conclusion

From TEx-Sys to the newest xTEx-Sys some parts of the system model has passed through major or minor revisions. Differences between first two versions were from architectural aspect, but upcoming xTEx-Sys will have major functional and architectural upgrading. Firstly, ontological representation of knowledge gave better and refined view of knowledge than semantic network technology. Such knowledge base is used for improving algorithms involved in process of knowledge evaluation by using dynamic quizzes. Static quizzes as new method of knowledge evaluation incorporates templates for building questions more alike to human language. Considering all of that, learning and teaching content as well as basis for student knowledge evaluation are assembled into organized course elements built upon SCORM.

From architectural side, xTEx-Sys opens its resources throughout Web service interface to any kind of Internet ready systems. By using XML, ontological and course information
are easily exchanged between different types of hardware using different types of operating system and application languages.

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References


