A GENERIC FRAMEWORK FOR ASSESSMENT IN ADAPTIVE EDUCATIONAL HYPERMEDIA

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ABSTRACT

An important concern in web based educational environment is the task of designing and preparing learner assessment, which would enhance the learning process. Currently the majority of Computer Assisted Assessment tools provide an assessment of the learners, without an analysis of the adaptive content presentation. In this paper we propose a logic-based formalism to characterize adaptive content presentation according to learner assessment. Recent researches in Adaptive Educational Hypermedia Systems can be effectively used to specify an assessment framework able to present parts of online courses according to an accurate evaluation of the learner's current knowledge level. Course implementation through the standards IEEE LOM and IMS QTI permits the organization of the learning and the assessment content in units, offering multiple views on the material, by a separation of the content and its description and putting in place a self evaluation mechanism.

KEYWORDS

Adaptive Hypermedia, Adaptive Web Systems, E-learning, Computer Assisted Assessment, Web personalization.

1. MOTIVATION

This paper aims at improving assessment methodologies for interactive Online and Distance Learning Environments (ODLE). One of the main objectives of ODLE is to design systems that can be efficiently used for teaching while taking into account the profile and characteristics of each learner. This can be done through the identification and interpretation of the learner's response to the system based on assessment of the knowledge acquired at each step of the learning process. The content presentation will then be based on the results of the learner assessment.

Web-based educational systems have been developed in order to improve the learning process and allow new teaching strategies to be used. In this context, Adaptive Educational Hypermedia Systems [3], which have been developed and tested in many disciplines, have shown to improve learning. They offer personalized support according to the personal needs and abilities of each learner. Knowledge assessment provides, as part of these systems, a fast feedback to students and teachers on the progress of the learner. Besides, the estimation of the learner performance can be used to guide the adaptation process in the AEHS.

According to [3] we can distinguish two kinds of adaptation. The first category of adaptation is the content level adaptation, in which an adaptive presentation of the learning content is offered for each individual user, through combining the content fragments that are relevant to his/her needs. The second category is the link level adaptation, in which an adaptive navigation support is offered to the learner through selection and sorting of the links according to his/her preferences. With regards to our objectives, we propose to use both kinds of adaptation. On the one hand, content adaptation, can be combined to the assessment of learner performances by selecting the appropriate learning content and composing customized learning materials automatically. On the other hand, through the link adaptation it is possible to give the learner further details on some concepts in the content by selecting and sorting some appropriate links for him.

Our intention is to provide the learner with content tailored to his needs that permits to reduce the time spent in the training. Hence, this content should have a high educational quality. This could be achieved through the standardization of the learning and the assessment content, enabling the reuse of content like the identification and the search of course parts that could be reassembled together.

The paper is organized as follows: in section 2 we discuss the role of assessment in AEHS. Section 3 discusses the assessment of knowledge on top of standards of learning and assessment contents respectively according to the standards IEEE Learning Object Metadata (LOM) [12], IMS Question & Test Interoperability (QTI) [11] and IEEE Public and Private Information for learner (PAPI) [8]. In Section 4 we present a logic based specification of assessment in AEHS according to the standards stated above. Section 5 discusses related work and Section 6 concludes with a summary of our achievement and presentation of our future work.

2. ASSESSMENT FOR ADAPTIVE SYSTEMS

The purpose of the presented framework is to provide students with an automated knowledge assessment system, which is able to select and present the content of an online course for each student individually, according to the students' actual learning progress and knowledge.

Certainly, assessment plays a prominent role in any educational system: it helps students to check whether they have correctly received the message that the teacher intended to transmit, but also provides appropriate and timely feedback to both parties. Therefore, assessment is an important part of an online course. The presence of an effective assessment mechanism in an educational hypermedia system is essential, since the assessment of learning is a crucial part of the instructional design process and therefore of an educational system [15].

Computer Assisted Assessment (CAA) is a good alternative to traditional paper based assessment, since it offers a more precise and faster marking process, as well as a timely feedback.

According to the Quality Assurance Standards [17], three types of assessment could be used in any educational program:

- Diagnostic assessment: provides an indicator of a learner aptitudes and preparedness to a course.
- Formative assessment: provides feedback to learners on their progress but does not contribute to the overall assessment.
- Summative assessment: provides a measure of achievement or failure made in respect to a learner performance in relation to the program of study.

Formative assessment assess the quality of learning, whereas Summative assessment assesses the quantity and retention of learning by the end of the unit of instruction. A learner may receive a piece of work and receive feedback from the tutor (i.e. formative assessment), but for the same piece of work the learner might also be given a grade that contributes to the overall mark of the course (i.e. summative assessment). Both formative and summative assessment can have a diagnostic functionality that checks, before presenting the learning material, each student's strengths, weaknesses, knowledge, and skills (e.g. state of knowledge of prequisite concepts for a given course). Therefore it is interesting to take both kinds of assessment into account in online courses.

In addition, it is important to note that assessment combined to adaptive content generation would enable a dynamic learning process to the learners. In this context AEHS emerges as an alternative to the "one-size – fits-all" approach used in the educational systems. It focuses on providing learners with content according to their preferences and needs. Adding assessment capabilities to AEHS enhances the learning process and give the learner the chance to keep track of his/her learning progress. The calculated learner competency at each step of the learning process will then be used to guide the adaptation of the system.

With regard to our assessment framework, we can distinguish three main tasks:

- The generation of assessment content based on the current learning content presented to the learner.
- The generation of an adaptive learning content according to assessment of the learner performance.
- The presentation of the content to the learner.

AEHS are able to provide learning content according to the needs of the users; nevertheless they can not easily permit to reuse or exchange learning content between learning management systems. Indeed, most adaptive courseware lack reusability and interoperability as there is no standard to combine the learning objects and their different aggregations with their expected sequencing behaviors.

3. STANDARDISATION OF LEARNING AND ASSESSMENT CONTENT

Today the object based learning has emerged as a new learning technology paradigm. The idea is to decompose existing course material in so-called “Learning Objects” [12], which permit to describe the course through modular pieces, self contained and associated to metadata. The goal of developing such an approach is to set up an open architecture for online learning that allows adapting the learning process to the various needs of the learners enabling the reusability and the flexibility of the learning content. Besides “learning objects” many terms are used in order to apply the object oriented approach in the e-learning environment such as “content object” [20], “knowledge object” [13], “pedagogical document” [1], “online learning material” [14].

Regarding all the terms above, we consider the term “learning object”, defined by IEEE LOM (Learning Object metadata) [12] standard to be very suitable for our purposes. The IEEE LOM standard specifies the syntax and semantics of Learning Object Metadata required to fully and effectively describing a learning object and is gradually becoming the reference standard for educational systems managing learning objects of many kinds. The LOM data model standard, or IEEE LTSC 1484.12.1 [12], focuses on the set of attributes needed to allow the learning objects to be managed and describes the learning object through data elements grouped into nine categories. Indeed resources are described through 70 attributes organized in a tree-like structure and divided in the following categories: 1. General, 1. General 2. Lifecycle, 3. Meta-Metadata, 4. Technical, 5. Educational, 6. Rights, 7. Relation, 8. Annotation, 9. Classification.

One of these Attributes is the AggregationLevel attribute (1.8: General.AggregationLevel), which defines the functional level of granularity of the learning object. For the design of the learning content, it is important to note that the aggregation level of the learning objects is scaled from 1 to 4 , from the smallest level, which corresponds e.g. to raw media data or fragments, to the largest level of granularity, corresponding for example to a set of courses. Furthermore the structure of the learning object is specified through the Structure attribute (1.7: General.Structure), which distinguishes five kinds of structure: atomic, linear, collection, hierarchical and networked. We propose to use the two first types atomic and linear, respectively designing an indivisible object and a set of ordered objects, connected by „previous" and "next" relationships. However, it can be easily seen that this Data model is not robust enough to describe the learning resources and enabling the knowledge assessment and the dynamic generation of the content according to the learner performances. Indeed an important functionality in our framework is the use of test assignments, in order to assess the learner performance at predefined steps of the learning process.

Although the attribute LearningRessourceType (5.2 Educational.LearningResourceType) can assign to a learning object the type Questionnaire, Exam, Exercise, ProblemStatement or SelfAssesment, LOM data model is not able to support the definition of assessment resources and to distinguish them from other learning resources. Unfortunately, the current version of LOM does not provide a formal model for design and delivery of assessments, or for interoperability of assessment content. The existing learning model in LOM assumes that assessment are embedded and integrated with other content. Hence we propose to use additionally for the definition of the assessment learning objects the IMS QTI ASI Model [9] which describes a basic structure for the representation of question (item) and test (assessment) data. QTI enables developing and sharing banks of questions and activities that could be shared for compiling a variety of assessment vehicles such as tests, exams, and worksheets. Therefore the assessment information in this standard format can be interoperable and reusable among different systems.

For our framework we propose to organize our questions in accordance with the Question and Test Interpretability’s ASI (Assessment Section Item) model provided by IMS Global Learning Consortium, Inc. According to this model every assessment is divided into several sections and each section consists of several items. An Item is the smallest object needed for the assessment which represents generally a question, defined as a combination of interrogatory, rendering, and feedback information. The IMS QTI specification will enable us to exchange assessment items and results during the learning process.

Furthermore one of the tasks that have to be fulfilled by any assessment system is to record the performances achieved by the learner, so that learning content will be presented according to his/her current state of knowledge. The IMS QTI Results reporting [10] specification enable us to store the students performances. To build the user profiles we apply the standard proposed by IEEE PAPI [8] (Personal And Private Information), which contains six elements categories for describing learner information. The most interesting category for our framework is the category Performance in which we can store the measured performance of the learner for a given course in order to customize a learning experience.

The Assessment framework for adaptive educational systems, thus in place, will be based on atomic learning objects and linear learning objects for the learning content and items, sections and assessments for the test content. The first step is to decompose the course material according to the selected standards and to the academic objectives of the course, and the type of the objects (Lesson or Exam).

During the assessment process, the student answers are analyzed. In case s/he gives wrong answers, the assessment framework should detect the Atomic Learning Objects that have to be studied again, highlights them and gives, if necessary, some additional links that could be used to better understand the current lesson (linear learning object). In case the answers are correct, the learner is allowed to continue; new course material is generated (next linear learning object). The framework has to provide the student with a dynamic assessment process, that selects for the student at each stage of the learning process the appropriate tests and adapts the content and the user interface to each student depending on his/her level of understanding. The adaptation functionality as well as the course decomposition in learning objects (linear and atomic) and test objects (Items Sections and Assessments) will be respectively according to the LOM and QTI standards. The framework keeps track on the progress of the student in order to be able to offer a personalized content.

4. LOGICALLY CHARCTERIZING OF ASSESSEMENT FOR AEHS

During the last few years many adaptive educational hypermedia systems have been developed. Nevertheless these systems do not have any common language for expressing the adaptive functionalities. This makes the comparison of these systems difficult. In [7], a logic description framework for AEHS has been developed which allows expressing the different components of any AEHS based on FOL (First Order Logic).

According to this formalism, each of these systems is composed of hypermedia documents. These documents are in relation in a document space. In the user model, the various characteristics of individual users or user groups could be modeled and stored. During runtime, the system collects observations about the user interactions. Based on the organization of the underlying document space, the information from the user model and from the system observation, the adaptive functionality could be generated, which defines rules for the adaptive learning process. The Assessment Framework could consequently be defined as follows:

$$AF= (DOCS, UM, OBS, AC)$$

DOCS designs the documents and their relations in the system. UM is for modeling the users, OBS is for the Observations on users and documents and finally AC designs the Adaptation Component, which describes the adaptive functionalities.

The knowledge assessment framework will use the functionalities of adaptive hypermedia systems through bringing a personalized assessment to the learner at each moment of the learning process. Based on the formalism of the AEHS, a logic-based-analysis of assessment for adaptive content presentation will be established according the selected E-learning standards LOM and QTI.

4.1 Document space

Regarding the learning content, the document space consists of atomic learning object (the smallest part of a lesson) and of linear learning objects (set of atomics). For the test content, as stated above, we will use three kinds of documents: items (the smallest part of a test, e.g. a single question plus its possible answers), sections (containing a set of a question for e.g. a user defined subject) and assessments, to represent a whole test for a given lesson.

Atomics: $A_1, A_2, \ldots, A_n$ Linears: $L_1, L_2, \ldots, L_m$;

Items: $I_1, I_2, \ldots, I_k$; Sections: $S_1, S_2, \ldots, S_l$; Assessments: $M_1, M_2, \ldots, M_h$;

- **Logic – based description of learning documents**

The system distinguishes learning documents according to their types in the learning system. For the linear objects we have the following types according to LOM specification:

```
Type(L, Course)  Type(L, Lecture)      for certain Linear L
```

Atomic learning objects have also types in the information space such as: (for certain Atomic A)

```
Type(A, NarrativeText)  Type(A, Figure) Type(A,Table)   Type(A,Diagram)
```

Besides, there is also a finite set of predicates stating the learning dependencies between the learning objects:

Each linear object is composed of a number of atomic objects:

```
Atomic_of_Linear(A, L) for certain Linear L, Atomic A
```

Some of these atomic learning objects denote the learning outcome (also called objective) for a given linear learning object:

```
Objective_Atomic(A, L)   for certain Linear L, Atomic A
```

A prequisite-relation assigns those atomic objects to a linear object that have to be learned before assessing the linear object itself:

```
Prequisite_Atomic(A, L)  for certain Linear L, Atomic A
```

In addition, a hierarchical structure of the atomic objects will be very helpful during the adaptation of the content. Therefore the following relations are defined:

The "Successor _relation" that defines the atomic object that can be learned whenever the current atomic object is learned:

Succ(A_i , A_j)   for certain Atomics A_i, A_j

"Question_of_Atomic" relation that assigns a question to a given atomic object:

```
Question_of_Atomic(I , A)       for certain Atomic A, and Test_Item I
```

- **Logic – based description of test documents**

We define the following types for the test documents according to the IMS QTI standard:

```
For certain Assessment M and Item I
Type(M, Exam)             Type (M, Self_Assessment)
Type(I, Multiple_choice) Type(I, Fill_in_blanks) Type(I, Problem_solving)
```

It is important to note that the type "Problem_solving" does not exist in QTI. We have considered this type according to Bloom´ taxonomy [2], as we plan to test our assessment framework on Programming courses. "Problem_solving" are exercises proposed to the learner and assessed based on test data and through invoking of the corresponding compiler.

The relationship between the various tests documents is defined as follows:

For certain Assessment M, Sections S, S_i ,S_j and test_Items I, I_l and I_h

Item_of_Section(I, S)   Section_of_Assessment(S, M)

Succ_Item(I_l, I_h)   Succ_Section(S_i, S_j)

By using a transitivity argument we can specify the following rule:

Item_of_Section(I,S)AND Section_of_Assessment(S,M)$\Rightarrow$ item_of_Assessment(I,M)

4.2 Observations

User interactions with the various linear and atomic objects could be summarized in the following observations:

- The user has visited a linear object:
  Obs(L, U, *Visited*)
- The user has successfully worked on the question (Item) corresponding to the atomic object:
  Obs(I, U, *Solved*)

4.3 User Model

In this component the interactions of the user with the various learning objects will be recorded based on the observations. We can then generate the following processed observation rules (p_obs):

- An atomic learning object could be considered to be "Learned" in case one of its respective questions (Item) is Solved:
  $\forall$A,U ($\exists$I Question_of_Atomic(I,A)AND Obs(I,U,*Solved*))$\Rightarrow$ P_Obs(A,U,*Learned*).
- A linear learning object is learned once all its objectives have been mastered by the learner:
  $\forall$ L, $\forall$U

```
∀A  (Objective_Atomic(A, L) ⇒ P_Obs(A,U,Learned))⇒ P_Obs(L,U,Learned).
```

4.4 Adaptation Component

The adaptive functionality of the system is generated based on the characteristics of the users and their interaction with the system.

- For an atomic object we define the following rule : each atomic that is not learned will be highlighted
  `∀ A , ∀ U   NOT P_Obs(A, U, Learned) ⇒ P_Obs(A,U ,Highlighted).`

We can define four annotations for a given linear object, regarding the kind of assessment that is recommended for it:

Pre_assessment_recommended, *Post_assessment_recommended,*
Pre_assessment_not_recommended, *Post_assessment_not_recommended:*

Various rules could be established in order to set up the linear annotation. As an example we could present the following rules:

- A linear learning object is recommended for pre-assessment if at least one of its prerequisite atomic objects has not been learned by the user.
  ```
  ∀ L, ∀U
  (∃ A Prequisite_Atomic(A,L) AND P_Obs(A,U,highlighted) ⇒
        Linear_annotation(L,U,Pre_assessment_recommended).
  ```
- Candidate items are derived for pre-assessment via the following rule:
  ```
  ∀ A, ∀L, ∀U
  Prequisite_Atomic(A,L) AND P_Obs(A, U , Highlighted) AND
  (∃ I, Question_of_Atomic(I,A) AND NOT Obs(I,U,Solved))
  ⇒ Candidate_Item(L,I,U, Pre_assessment).
  ```
- A linear object is not recommended for post-assessment if all its objective atomics have been learned by the user.
  ```
  ∀ L, ∀ U
  ∀A (Objective_Atomic(A,L)⇒P_Obs(A,U,Learned))
     ⇒ Linear_annotation(L,U,Post_assessment_is_recommended).
  ```

5. DISCUSSION AND RELATED WORK

In this paper we propose a logic based analysis of an Assessment framework for adaptive content presentation. This framework will provide the learner with a dynamic assessment and presentation of the course content according to his/her level of knowledge. It is composed of three main components: the Content Presentation Module, whose responsibility is to transform the content according to the LOM metrics and to present to the learner the appropriate part of the course according to his/her level of knowledge, a Test Generation Module responsible for generation of the test documents according the IMS QTI standard and the dynamic selection of questions based on an estimation of learner's knowledge and a Test Assessment Module responsible of evaluation and grading of tests.

Related work to our approach can be found in the areas of adaptive hypermedia and computer assisted assessment. In the last few years many Adaptive Educational Hypermedia Systems have been developed such as NetCoach [25], ELM-ARTII System [26] and KBS_Hyperbook System [6]. A component based definition for some systems based on First Order Logic was given in [7].

The decomposition of the learning content according to the LOM data model facilitates the reuse and the personalization of the educational content to various learners. The use of the learning objects approach was already discussed in several research works such as E-Aula [4]. However, as far as the authors know, a description of adaptativity rules based on learning content standardization has not been discussed in literature so far.

A very important point in our framework is assessment. Indeed, by integrating assessment in AEHS, it would be possible to provide a good support to the various learners through an accurate estimation of their knowledge level at each stage of the learning process. There are some available computer based assessment tools, WebCT [24], QMWeb [18], QUIZIT [22] and others. Each tool was developed in order to assist teachers in delivering and assessment of courses and presents different features. However most o them lack adaptability and could be assimilated to a paper and pencil tests presented online. There are also some adaptive assessment systems [16]. However these systems are not web based and require preinstalled software to use them. While some CAA tools claim to be QTI "compliant", only QuestionMark [23], which itself had a major input to the development of the specification, currently allows the import and export of questions in QTI format [19]. Furthermore, the majority of the developed assessment tools can only conduct knowledge based tests and do not encourage learners to develop their skills in solving problems. The assessment methods are in most cases restricted to multiple choice questions. The main improvement of the knowledge assessment framework that we are developing compared with the former systems is the flexibility to various learner profiles as it provides content adapted to their knowledge, through different kinds of assessment methods. Related approaches in combining assessment to AEHS can be found e.g. in INSPIRE/PASS [5], where an approach for adaptive assessment process based on Item Response Theory (IRT) was proposed. The approach in INSPIRE focus mainly on the techniques of selections of the tests. However in INSPIRE formalism and logical description of an assessment model for adaptive content generation, were not explored. With the Logic based analysis presented above:

- we can formalize an assessment model for courses conformant to LOM, and Test compliant with IMS QTI,
- we can describe the taxonomy of concepts (Linears, Atomics, Items, Sections and Assessment) used by the system in document space, user model, observations and adaptation component, which enables us to manage user interactions and user assessment effectively,
- we can provide adaptation rules in the adaptation component, which implement individual learner support based on the learner assessment,
- we establish the connection between the content presentation and the generation of the tests and the assessment based on the rules that describe the conditions for presenting the different parts of the course.

The strict separation of content, content description according to standards for annotating learning resources, assessment and personalization establish a flexible framework for personalized content presentation in e-learning. Personalization functionality expressed via rules in the adaptation component can reason on a sophisticated assessment system, and can be used for a variety of e-learning courses which follow the selected standards.

6. CONCLUSION AND FUTURE WORK

In this paper, we have proposed a logic based formalism of the dynamic learner assessment for personalized and adapted content generation in e-learning courses. The presented framework operates on learning resources which are annotated according to the IEEE LOM standard and IMS QTI specification. It explicitly supports the reuse of assessment and personalization strategies for individual content presentation of online courses by following a strict separation of content, standard - based content description, and assessment and adaptation strategies.

Currently we are implementing a personal content presentation system based on the proposed framework for the personal reader environment (www.personal-reader.de). We have implemented the logic-based assessment framework in the TRIPLE language [21], a rule and querying language for the semantic web and are currently setting up a prototype. In future work we plan to evaluate this generic assessment system for LOM/QTI-annotated online courses with respect to learning support, learners' acceptance and re-usability aspects.

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