Knowledge-Based Adaptive Assessment in a Web-Based Intelligent Educational System

Ioannis Hatzilygeroudis, Constantinos Koutsojannis, Constantinos Papavlasopoulos
Department of Computer Engineering & Informatics, School of Engineering
University of Patras, Greece
{ihatz, ckoutsog, papavlas}@ceid.upatras.gr

Jim Prentzas
Department of Informatics and Computer Technology
Technological Educational Institute of Lamia, Greece
dprentzas@teilam.gr

Abstract

In this paper, we present an adaptive and intelligent web-based educational system that uses AI techniques for personalized assessment of the learners. More specifically, we focus on a mechanism for on-line creation of a user-adapted test, which can be used alongside the predetermined test. The user can ask for such a test any time he/she is willing to do so, even if he/she has not studied all predetermined concepts of a learning goal. A small rule base is used by an expert system inference engine for making decisions on the difficulty level of the exercises to be included in the test. This is based on the evaluation of the learner during concept studying. Adaptive assessment of the learner can be repeatedly used until there is no further need. Another small rule-base is used for deciding on whether a new test is suggested or not. This is based on the learner's previous test assessment results. Preliminary experimental results show that the users need less time to study a learning goal when using the adaptive assessment capability of the system.

Keywords
Intelligent Web-Based Education, Intelligent E-Learning, Adaptive testing, Expert systems, Personalized assessment.

1. Introduction

Intelligent Tutoring Systems (ITSs) are systems used for personalized learning [1]. They were usually developed as stand-alone systems. However, the emergence of the WWW gave rise to a number of Web-based ITSs, a type of Web-Based Intelligent Educational Systems (WBIESs) [2]. Adaptive Educational Hypermedia Systems (AEHSs) are also systems that offer personalized education. They are specifically developed for hypertext environments such as the WWW [3]. Enhancing AEHSs with aspects and techniques from ITSs creates a type of Adaptive and Intelligent Educational Systems (AIESs) [2].

Student evaluation or assessment is a basic issue in AIESs. One of the standard ways of achieving that is through testing. Adaptive testing is an interesting and relatively new direction of research [4, 5]. By 'adaptive testing', adaptation of a test individually to each student is meant. There have been a number of efforts to this direction. However, most of them make use of the so-called 'item response theory' (IRT), a mathematical model and process to create adaptive tests. CAT (Computerized Adaptive Testing) is a well-founded technique that uses IRT [6]. According to CAT, the response to a question determines the next question to be delivered to the learner. In this way, one concept at a time can be examined. On the other hand, this is not always the case. Usually, there is need to examine a number of concepts simultaneously.

Furthermore, in most existing student diagnosis models [7, 8], tests refer to a predefined number of concepts; the learner cannot take a part of it, concerning a part of the associated concepts. So, an aspect that has not been paid attention to is the on-line creation of a test that refers to the concepts that the learner has dealt with up to that moment.

We constructed an Artificial Intelligence Teaching System (AITS) to assist learning and teaching in the context of the "Artificial Intelligence" course in our Department. AITS is an adaptive and intelligent system. It adapts the course material to the student's needs as much as possible, based on his/her profile and knowledge level [8, 9]. Knowledge level is evaluated after each concept via an expert system, which takes into account the difficulty level of questions/exercises. Additionally the system provides means to the tutor for constructing questions and tests in a structured way [8].

In this paper, we present a new capability of the system. With the help of a second expert system, AITS on-

line creates an evaluation test consisted of items related to the concepts that the user has just studied. The test is taking account the students' evaluation results, saved in the systems' student model. So, each test is fully personalized helping the user to improve his performance or for further guided study. Thus, it improves systems' adaptability in a dynamic way enriching its importance for education.

The structure of the paper is as follows. Section 2 presents the system architecture. In Section 3, the domain knowledge structure is described. Section 4 deals with the learning process, whereas Section 5 briefly refers to student evaluation. Section 6 presents the adaptive assessment process. Finally Section 7 concludes the paper.

2. System Architecture

The architecture of the system is depicted in Figure 1. The system consists of seven units: the User Interface (UI), the Student Modeling Unit (SM), the Tutoring Unit (TU), the Evaluation Unit (EU), the Test generation Unit (TGU), the Intelligent Unit (IU) and the Exercises database (EDB).

Through UI the student initially subscribes to the system. During subscription, the required personal settings, such as name, year of study, preferred type of media etc, are stored. After subscription the student can, at any time, enter the system through the UI.

SM contains all the information about students, like their preferences, interests, knowledge level for each concept, etc. We use stereotypes to acquire an initial profile for each student, so the system can use that profile for adaptation.

TU is responsible for the teaching process. A student can select a learning goal from the learning goals tree. The corresponding material is then presented to the student. The material consists of theory and examples. The student is also able to select a test to evaluate him/herself about how well he/she has learned a concept so far. After the student has taken a test, the system stores the results concerning each concept, which the student has been examined at, and, if the results are not satisfactory, it advises him to study again the corresponding concepts and suggests some new tests containing questions only those concepts.

The main goal of EU is to evaluate student's progress due to his/her interaction with the system. This evaluation is achieved through testing. From testing results, the tutor is able to watch each student's progress. He/she is also able to see some statistical results over the concepts and sections the student has been examined at. The system can also provide the overall results to the tutor, about all students that were examined at a specific test. SES decides upon the knowledge level of a student.

TGU has as main goal to generate assessment tests consisted of a number of exercises with specific levels of difficulty according to the SM and thus improve system's

adaptivity to the students' needs. This is achieved through suggestions given by IU, which takes into account the interaction of the students with the system from the beginning of the learning process to the current state.
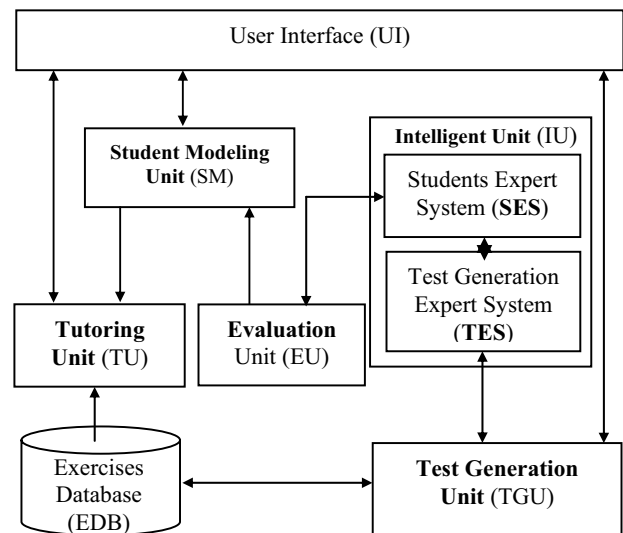

Figure 1. System Architecture

IU consists of two intelligent systems. The one is an expert system (SES) that deals with student evaluation. The other, is the Test Generation Expert System (TES), that deals with the selection of the appropriate questions/exercises, which are stored in EDB, in order to construct the assessment tests.

3. Domain Knowledge

The domain knowledge of the system, at the moment, concerns fundamental aspects of knowledge representation. Domain knowledge is structured in a tree-like way. The root of the tree is the above subject. The subject is divided in sections and the sections into sub-sections. Each sub-section deals with a number of concepts, which are the leaves of the tree. Sub-sections may have some concepts in common.

The domain knowledge tree, described above, is displayed, as far as the subsections level, at the navigation area, at the left side of the user interface. From that tree the student can choose a learning goal (subsection). Each subsection corresponds to a learning page. That is, only subsections correspond to displayable material. The learning page of the selected subsection is currently presented in the content area. Each *learning page* deals with a number of *concepts*. More specifically, it contains an ordered list of concepts. Each concept is linked to the corresponding concept page. Concept pages constitute the real teaching material.

The teaching material, apart from concept pages, however, includes all the available questions/exercises, which are stored in the exercises database (EDB) (see Fig.

1) and are used for the creation of the tests. Each learning page is associated with a predefined test. Each test consists of a number of exercises that examine the concepts of the associated learning page. An exercise may be a multiple choice question or something more complex (e.g. to apply a process). Each exercise is associated with one or more concepts. Also, each concept page offers a predefined test concerning the concept.

4. Learning Progress

The learning method (implicitly followed) is based on the traditional theory-examples-exercises paradigm (although the user can follow his own method). That is, for each topic, the theory is first presented. Then, some examples are given. Finally, the student is called to do some exercises. Theory consists in presenting a number of concepts. Those concepts are presented in a simple-to-complex way. That is, the simple concepts are presented first and the complex concepts (that require the knowledge of one or more simpler concepts) are presented afterwards. This is depicted in the ordered list, which however is randomly accessible. Furthermore, the student can review a previous concept at any time. He/She is also not forced to follow the system's way of teaching, but can make his/her own choices for studying a learning page. Any time a student has finished the study of a particular learning page, he/she can take the corresponding concept-level test. The questions of the test are presented one at a time. The student can answer each question independently and in his own sequence. In case the student gives a wrong answer to a question, he/she can try again. Before that, he/she may either see a hint or the correct answer. Doing any of those, the mark assigned to the student for that question is affected. AITS collect from each user the number of hints for each exercise, the total time that he/she spent to answer it correctly and the number of tries. Each exercise's difficulty level is determined by all the above information and the nature of corresponding concept according to tutors' experience [10].

5. Student Evaluation

In web-based educational systems, one of the most important functions is adaptation. Adaptation has mainly to do with the learning content presented to the user. One of the most important functions of an adaptive system, which is crucial for the specification of the appropriate learning content, is student evaluation. Student evaluation usually refers to the evaluation of the knowledge level of a student after having dealt with a learning page. In other words, how well a student has learnt the concepts of a learning page. This is achieved by processing the results of the exercises offered at the end of a learning page. Student evaluation is important for both the student and the tutor. A student can be evaluated at two levels: (a) the concept-level and (b) the topic-level. The concept-level evaluation deals with the level of understanding of the concepts of a learning page test, whereas the topic-level evaluation deals with the level of understanding of the topic of a learning page, i.e. the test as a whole. The knowledge level of a student, as far as both a concept and a topic are concerned, is classified in one of the following five categories: (a) excellent, (b) very good, (c) good, (d) average and (e) low. In AITS, student evaluation is achieved with the help of a rule-based expert system (SES), which is part of IU (see Fig. 1). The test results are passed to the SES, which decides on the knowledge levels of the students for the associated concepts. Details of two alternative approaches to this process are presented in [8] and [9].

6. Adaptive Assessment

In previous versions of AITS [8, 9], the learner was required to take a predefined test, after the completion of the study of a learning page, which consists of a number of concepts. The problem identified was that sometimes a learner wanted to stop and take a test after having studied some, but not all, of the concepts. There was no way to have a test related only to the concepts he/she has just studied via the system. So, a need arose for creating evaluation tests, on-line, at learner's request as soon as he/she has studied a number of, but not all of, the concepts associated with a learning goal. This can be done in the new version of the system presented here. A learner evaluation test is constructed based on his/her recent performance on the already studied concepts. This is achieved by TGU, which calls TES to do the main work, make the main decisions.

6.1 The Assessment Process

Initially, the learner selects a learning goal (i.e. a learning page) and starts studying each concept included in the goal. At the end of each concept studying, there is a short test given to the user. Based on the response of the user to the short test, the system evaluates him/her and updates the student model (see Fig, 2). Then the learner continues with the next concept and so on, until either he/she finishes with all concepts included in the learning goal or accepts the system's proposal for an on-line test or asks by him/herself for an on-line test.

Actually, during the above described process, when a sufficient amount of data has been gathered, and the student-learner has studied more than 30 % of the total number of concepts, the system proposes to use the process for a personalized on-line test. If accepted by the student, the TGU takes over. TGU uses TES to construct a test, based on the students' interaction data, i.e. the evaluation data stored in SM. However, the student can reject system's proposal and request a personalized test later on. Also, in some cases he/she can ask for such a test before system's proposal. The test consists of two exercises/questions for each concept.
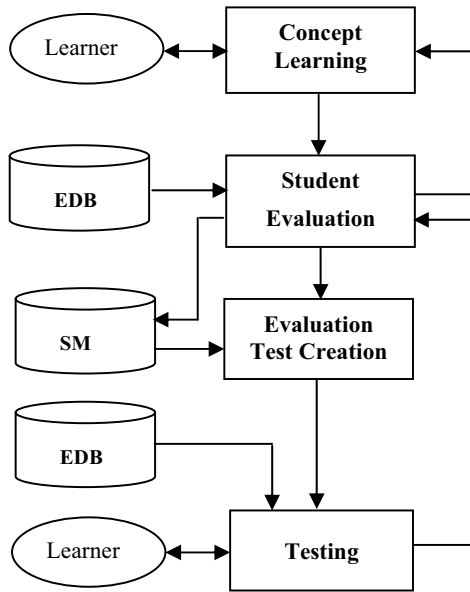
Figure 2. Adaptive Assessment Process

After taking the test, the student-learner is evaluated by the system, more specifically by SES (see Fig. 1), based on the answers to the test, and SM is updated. The system then may suggest the student to take a second personalized test (immediately after the completion of the first) to improve his knowledge-level and so on and so forth, until he/she feels or the system decides that no further improvement can be achieved. Those new tests may include fewer exercises (corresponding to fewer concepts), depending on the recent evaluation results. Also, the student can ask for a test after having continued and studied some more concepts.

6.2 The Test Expert System

SM contains details for each student performance i.e the sections, sub-sections and concepts that he/she has studied as well as the evaluation results for each concept. TES consists of two components: the Rule Base (RB) and the JESS Inference Engine (IE). The RB contains a number of rules that are used for the selection of the questions/exercises according to the students' performance. Actually, there are two different sets of rules in RB.

The first set represents knowledge for choosing the appropriate exercises from the EDB for the on-line evaluation test. By "appropriate", we mean "of appropriate difficulty level". Notice that each exercise in EDB is assigned an integer number indicating its difficulty level. There are five difficulty levels: 1-5, with 5 being the most difficult level. Those rules are presented in Table 1. As it is clear, each rule suggests the difficulty levels of the two

exercises/questions from EDB for each concept, to be used in the test. E.g. "2 and 3" means two exercises with difficulty levels 2 and 3respectively ; "= and +1" means an exercise with level equal to the student's concept level and another with level equal to the concept level plus 1 (i.e. if concept level is 3 the difficulty level is 4).

The second set of rules decides about whether it is reasonable for a student to take another on-line test, having already taken one or more of them. The decision is based on the student's performance on the previous test. Those rules are presented in Table 2. The rules refer to a concept. For example, rule 1 states that if the result of the evaluation of a concept based on the on-line test is greater or equal to the old one and the exercises related to the concept in the test had difficulty levels, the one equal to the old level and the other greater than the old one, then a new test is suggested. The new test is produced based on the rules of Table 1. In the case of rule 4, a new test has no meaning and the system suggests that the student should study again the concept.

Table 1. Exercise difficulty level selection rules

A/A	Student Concept Level	Portion of Accessed Concepts	Exercise Difficulty Level
1	=5	>30 %	5 and 5
2	3-4	>30 %	= and +1
3	<3	>30 %	2 and 3
4	=5	<30 %	4 and 5
5	3-4	<30 %	-1 and =
6	<3	<30 %	No new test

Table 2. Rules for student re-testing

A/A	New Student Concept Level	Exercises Difficulty Levels	TES Suggestions
1	5	5 and 5	Go on
2	> or = old	= and >old	New test
3	< or = old	= and >old	New test
4	< 3	= and >old	New test
5	< 3	< 3	Re-study

The JESS IE is the inference mechanism that applies the rules and produces the suggestions of the corresponding rule sets. TES is implemented in the Jess, a Java based expert systems shell [11].

6.3 An example

Let's look at the following example. Suppose that a student has accessed and studied e.g. 5 concepts and has

been evaluated by the system as having performance levels 5, 4, 3, 4 and 2, respectively for each concept. The system then provides the option to evaluate the student at the current state via the use of a personalized assessment test (given that 5 is over 30% of the concepts associated to the current learning goal). The student accepts the proposal and this triggers TGU and TGU triggers TES in turn. Rules 1-3 (Table 1) are activated and the following exercise difficulty level pairs are suggested for each concept respectively: (5, 5), (4, 5), (3, 4), (4, 5) and (2, 3). TGU randomly retrieves from EDB five such pairs and creates a test of 10 items, which is then presented to the student for testing. After the student has taken the test, the new evaluation results for each concept (computed via EU and SES) are saved in his/her student model. Let assume that the new evaluation concept levels are 5, 4, 4, 3 and 1 respectively. Now the second set of rules (Table 2) is taking over. According to them, a new test is suggested for the second-fourth concepts for further level improvement. For the first concept, there is nothing to suggest (rule 1), whereas further study is suggested for the fifth concept (rule 5). If the proposal is accepted by the user, a new test of 6 items is created and delivered to him/her. This can be repeated until all concept levels become 5.

7. Conclusion and Discussion

In this paper, we present an adaptive and intelligent web-based educational system, called AITS, that teaches AI aspects and uses AI techniques for personalized assessment of the learners. More specifically, we focus on a mechanism for on-line creation of a user-adapted test. The user can ask for such a test any time he/she is willing to do so, even if he/she has not studied all predetermined concepts of a learning goal. A small rule base is used by an expert system inference engine for making decisions on the difficulty level of the exercises to be included in the test. This is based on the evaluation of the learner during concept studying. Adaptive assessment of the learner can be repeatedly used until there is no further need. Another small rule-base is used for deciding on whether a new test is suggested or not. This is based on the learner's previous assessment results.

This new facility of AITS was used from the students that participated in the "Artificial Intelligence" course during current academic year. Most of the students (85%) preferred to use the on-line evaluation tests to improve their performance and spent significantly less mean time (-30%) for learning with AITS. Additionally, according to the data collected through the systems' included questionnaire the adaptability of the system has been significantly improved (70%) with the new personalized assessment facility provided with the latest version of the system.

8. Acknowledgements

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