Intelligent Tutoring Systems

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Abstract. The importance of intelligent tutoring systems has rapidly increased in past decades. There has been an exponential growth in the number of end users that can be addressed as well as in technological development of the environments, which makes it more sophisticated and easily implementable. In the introduction, the paper offers a brief overview of intelligent tutoring systems. It then focuses on two types which have been designed for education of students in the tertiary sector. The systems use elements of adaptivity in order to accommodate to as many users as possible. They serve both as a support of presence lessons and, primarily, as the main educational environment for students in the distance form of studies – e-learning. The systems are described from the point of view of their functionalities and typical features which differentiate them. The authors conclude with an attempt to choose the best features of each system, which would lead to the creation of an even more sophisticated intelligent tutoring system for e-learning.

Keywords: Adaptive systems · e-learning · ITS · Intelligent tutoring systems

1 Introduction

Computer-based learning is very favoured among the users of e-learning, mainly if it concerns languages [1], and as described in paper [2]. Languages can be taught and learnt through e-learning although with limited possibilities and results. Thus, various systems have been developed in order to overcome this insufficiency.

If any discussion about e-learning, adaptive learning and similar issues are to be discussed, recognised researches in this field should also be mentioned in order to define our approach. The most suitable starting point is undoubtedly Brusilovski's work concerning adaptive hypermedia and educational systems [3] and primarily [4]. His approach is the basis for other researchers that have been dealing with Intelligent Tutoring Systems (ITS). An example of an ITS is presented by [5], who developed "*Passive Voice Tutor*", which is a system for teaching the Passive Voice to Greek students. This ITS, in fact, includes knowledge of one domain, tools for modelling a student, recommendation generator to a student, and user interface. In [6] was created another ITS system, this one aimed at the system of English tenses – *English Tutor*. *English Tutor*, similarly to *Passive Tutor,* is usable only for a limited spectrum of the

G. Vincenti et al. (Eds.): eLeot 2016, LNICST 180, pp. 71–78, 2017.
DOI: 10.1007/978-3-319-49625-2_9

language, grammar tenses. Moreover, it was overcome by *Passive Voice Tutor* in its ability to identify not only mistake in tenses, but also spelling and other mistakes likeable to occur in the answer. *Passive Voice Tutor* also creates a long-term profile of the student, which is not possible in *English Tutor*.

Comparing the above-mentioned systems, all of them differ from the two systems described. Either they do not work with learning styles and focus only on a limited spectrum of a subject matter, see [5, 6], or they do not use fuzzy-oriented expert systems for adaptation of the system, see [7]. Thus, a comprehensive, universal adaptive system that would combine elements necessary for modern e-learning, such as integrating learning styles/sensory preferences, identification of student's knowledge, assigning suitable learning objects and creating a personalised study plan, which has been tested and run in practice cannot be found in current sources.

The following chapters introduce two systems which were designed to eliminate/remove the above-mentioned limitations.

2 Virtual Teacher

There are numerous ways how to try to make learning more effective using new technologies. New technologies are represented by a computer in our case. A teacher can use the computer more than just for a passive transfer of electronic study materials to students. A teacher can, to a certain limit, pass over his knowledge to a computer, his active way of teaching, reactions to certain situations or problems. And a computer can, to a certain limit, repeat teacher's behaviour. This results in an imperfect computer copy of a teacher, virtual teacher. Compared to a real teacher, a virtual teacher has its limits as well as several key advantages:

- it can be at more places at the same time, i.e. it can serve to more students scattered throughout the world. Their number is limited only by hardware means,
- it can gather experience from a lot of real teachers. The amount of experience is limited by hardware means,
- it can reliably remember a large number of data about each student's progress. It can then adapt the learning process,
- it can last hundreds of years and improve itself,
- after initial operation, it has low operational costs compared to real teachers [8].

This idea led to a proposal of a complex system to realise e-learning adaptive education, primarily focused on adaptation of the content as it is the major source of information for a student in electronic environment and significantly influences the learning process.

Structure of the system Barborka. LMS Barborka, as the system was named, works with a deeply structured study material to adapt it with respect to sensory preferences and levels of difficulty. The study is controlled by an algorithm whose parameters are set by an expert on adaptive education [9]. The system activities are divided in modules *Student, Author and Expert* described below.

2.1 Module *Author*

The content of this module consists of individual courses prepared for adaptive learning. Each course is divided into lessons, frames, variants and layers. The learning content is inserted into the system by an author using forms as formatted text added with metadata. The author creates only the content, but has nothing to with adaptation. Technically, the author has to be familiar only with basic work in the editor and know the meaning of individual form fields. The author does not have to know HTML or any other language.

2.2 Module *Student*

In adaptive learning, this module is primarily responsible for gathering information about a student, i.e. to find out his learning style and to evaluate the learning progress. Currently, the learning style is analysed using a questionnaire [10], whose results are not very accurate, but it can be filled in in 5 to 10 min compared to other questionnaires taking one hour and more. This module follows student's learning progress, primarily time in individual parts and the level of correct answers. The student is offered those materials that corresponds his characteristics the most. The student can also adapt the displayed study material to his needs. Thus, he can choose another sensory form or another level of knowledge. The system monitors such changes together with other student's activities.

2.3 Module *Expert*

This module defines the activities of the so-called **virtual teacher**, which displays suitably sequenced layers of the given frame in a suitable variant. The activities of the virtual teacher are set by a set of rules designed by an expert in adaptive learning. Each rule consists of assumptions and inferences. An assumption of the rules is student's knowledge.

The inference is the depth individual layers should have and the sensory type of the given frame. The inference can also be adapted in the sequence of individual layer types using three methods: by defining the basic sequence, which determines the basic sequence of layer types; by defining the sequence at the beginning and at the end; by defining the way of displaying of so-called multi-layers, i.e. more layers of the same type. Those are displayed either gradually with all layers of the same type, or individual types of multi-layers alternate according to the multi-layer sequence.

The system uses two algorithms. The following part briefly introduces their principle.

Algorithm of adaptive selection of learning style. Based on the rules, this algorithm creates a recommended learning style for a given student (i.e. it specifies sensory variants and defines the sequence and depth of a layer). The algorithm contains abbreviations and their values as follows:

- sign **Fix** gets values 0, 1 and 2 and determines the rule activity:
  - 0: the rule determines the sequence at the beginning or at the end,
  - 1: the rule determines the basic sequence,
  - 2: the rule determines the layer depth.
- sign **Int** gets values 0, 1 and 2 and determines the sequence of displayed layers:
  - 0: sequence set by the author
  - 1: successive multi-layers
  - 2: alternate multi-layers
- variables **MSt** represents individual characteristics of a student
- variable Form represents one of sensory types: verbal, visual, aural and kinesthetic
- variables **Vri,** where i is a natural number, represent layer type
- variables **Hli**, where i is a natural number, represent layer depth

In [14], the algorithm is introduced as follows:

Input: *Vector of static characteristics of a real student*
Student ({ver,viz,aud,kin}, MStAfek, MStSoc, MStSyst, {MStExp,MStTeor}, {MStHol,MStDetail}, MStHloub, MStAutoreg, MStVysl)
Output: *Learning style recommended for a givens student in a form of a vector*
StylSt (Form, {Vr1, Hl1}, {Vr2, Hl2}, {Vr3, Hl3}, ..., Int)

The algorithm itself was described in [11] in detail.

Algorithm of adaptive control of learning. Based on the above-selected learning style, this algorithm selects particular layers which are to be displayed. Apart from that, the algorithm controls system's reactions to an incorrect answer to a question.

This algorithm uses similar abbreviations and terminology as the previous one.

Input: *1. recommended learning style of the student*
StylSt (Form, {Vr1, Hl1}, {Vr2, Hl2}, {Vr3, Hl3}, ..., Int)
2. selected course, lesson, frame
3. metadata of frames of current lesson of current course
Output: *Recommended sequence of displaying particular layers of current frame.*

The algorithm itself was described in [11] in detail.

The used expert rules (IF-THEN type) constitute "pedagogical experience, knowledge and skills" in controlling personalised learning. Of course, it cannot be assumed that the currently defined rules will be optimal for all types of students. Similarly, pedagogues can be of different opinions on their formulation. Thus, the system is designed and implemented in a way that enables to easily refine or replace them without any program change. Every pedagogue-expert can adjust and verify his own theory on controlling adaptive learning.

3 Adaptive ELearning

3.1 Focus

The objective was to create an adaptive e-learning system, primarily for language education.

The pedagogical perspective considered the student itself, i.e. to gather information about his learning and absorbing information (sensory preferences), to gather information about his input knowledge of language. Such information is used to adapt the learning process at the beginning as well as during the learning process according to the initial and progress tests. The primary objective in this perspective was to adapt current e-learning courses which are rigid and the same for all students towards individual students' needs.

The technical perspective considered a proposal of a new methodology in language education, which stems from a general model of decision-making under indeterminacy [12] when deciding on next step in the learning process. It means to introduce such processes into current LMSs, which would result in more effective adaptation of the content and form of the content. It is done based on identification of student's knowledge and its assessment (adaptation of the content) and identification of student's sensory preferences (adaptation of the form of the content). It leads to the creation of a personalised study plan for a given student. Identification and creation of a personalised study plan is done using a fuzzy oriented expert system containing a knowledge base with IF-THEN linguistic rules. The rules have been created by an expert on language education.

A complex model of an adaptive e-learning system has integrated the above described areas into several subsequent processes in a way that enables to adapt the whole learning process. Processing information from a student, teacher and expert leads to a significantly effective and user-friendly way of teaching/learning of language using e-learning.

3.2 Structure of Adaptive eLearning

Adaptive eLearning is the name of an application designed as a new e-learning tool. Figure 1 depicts the scheme of its decision-making processes.

Acquisition of information about a student. Input information is information gathered before the learning process itself as well as during its progress. The input is a Didactic test and a Questionnaire of sensory preferences. Selection of the didactic test depends on the course that the student has selected in the given semester. Selection of the didactic test implies values related to the given course and test. The Questionnaire of sensory preferences is only one, standardised. It does not relate to any particular course or to other values.

Process M1a. Process M1a determines the combination of sensory preferences based on percentage calculation of frequency:

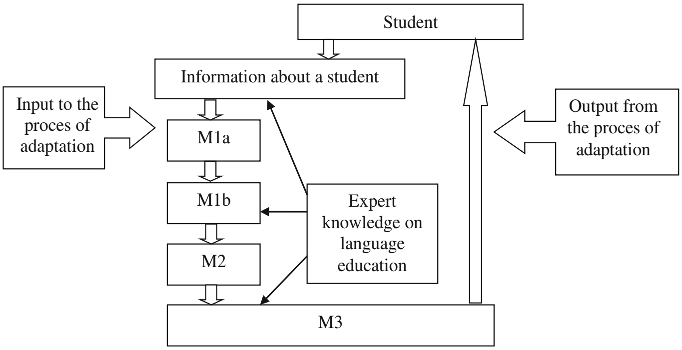

Fig. 1. Scheme of the decision-making process

$V_{\%}$ = [Frequency*V*/(Frequency*V* + Frequency*A* + Frequency*R* + Frequency*K*)]*100
$A_{\%}$ = [Frequency*A*/(Frequency*V* + Frequency*A* + Frequency*R* + Frequency*K*)]*100
$R_{\%}$ = [Frequency*R*/(Frequency*V* + Frequency*A* + Frequency*R* + Frequency*K*)]*100
$K_{\%}$ = [Frequency*K*/(Frequency*V* + Frequency*A* + Frequency*R* + Frequency*K*)]*100

A detailed study was presented in work [13].

Process M1b. Process M1b is a process which assesses the level of knowledge of the given student in the given course. The didactic test is assessed as a whole:

$$\left(Q_i + Q_j + \ldots + Q_n\right) \geq Q_{\mathrm{TOTAL}} * 0.4$$

If the minimum requirements are met, step 2 follows. This step consists in assessment of each category separately. The process uses a fuzzy logic expert system [14] and a knowledge base containing a set of IF-THEN rules to process the input variables (V1−V4) and assess the output variable (V5). The knowledge base contains 135 linguistic rules. A detailed study was presented in work [15, 16].

Process M2. This process consists in selecting only relevant study objectives (Category_i, Category_j, …, Category_n) for the given student out of the set of all study objectives. This is done based on the assessed objective relevance from M1b. Relevance assessment means meeting or failing to meet the requirements for the given objective, i.e. acquiring the needed knowledge (expressed by V5 value, or by Progress and Cumulative test results). At the end of the learning process, the selected relevant objectives, if successfully met, are added to already completed study objectives and thus create a whole set of study objectives.

Process M3. Activities in this process lead to the creation of a personalised study plan itself. When creating a plan, the input data is processed in several follow-up steps. The whole process is affected by factors influencing the final form of the generated study plan. A detailed study was described in [17].

4 Merging the Systems

A comparison of the two above-mentioned systems can be done only partially. It is obvious that the systems differ right in the core of their structure and in the principle of using adaptive elements.

A different and more interesting view than a mere comparison is the view how to merge both systems into one – in a system that would take over the best of *Virtual Teacher* and *Adaptive eLearning*. It means such features that make them specific against other ITS as well as those that make them adaptive. Individual features are described according to the processes used/done by the systems:

1. Testing and assessing sensory preferences – used by both systems. Adaptive eLearning without manual interference.
2. Testing and assessing the level of knowledge – assessment by an expert system (Adaptive eLearning)
3. Creating a study plan – various depths of study materials (Virtual Teacher); no predefined students' models (Adaptive eLearning, each student has a unique study plan); works with time (Adaptive eLearning).
4. Possibility to adjust the form of study materials – Virtual Teacher.
5. Diagnostics of student's progress – used by both systems but assessed by different algorithms.
6. System versatility – yes for Virtual Teacher; Adaptive eLearning was verified on language learning and shows signs of versatility.

Adaptive eLearning is a modular system, i.e. a part (module) can be added or taken out (or used in another system). Adaptive eLearning has its strength in the area of assessment of student's knowledge by an expert system which, used by Virtual Teacher, would lead to more accurate selection of the lesson, layer and depth of study materials. Integrating the time perspective of studying into Virtual Teacher would also significantly bring Virtual Teacher closer to optimisation of the learning.

5 Conclusion

This paper presented two representatives of existing Intelligent Tutoring Systems- *Virtual Teacher* and *Adaptive eLearning*. These systems use adaptive elements in order to be usable for as wide target group as possible. The systems are different in their structure of processes taking place in them and in the methodology of using study materials. However, a deeper analysis reveals that keeping the identical elements and implementing the differences (with certain limitations), it can lead to a newer, more sophisticated ITS. This finding lays bases for future research of the authors.

Acknowledgment. The research described here has been financially supported by University of Ostrava grant SGS02/UVAFM/2016.

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