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The Problem-Solving Modes and a Two-Layer Model of Hints in the Intelligent Tutoring System for Minimax Algorithm

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Abstract

As a rule, intelligent tutoring systems offer a learner only one problem-solving mode, i.e., feedback is provided after each solution step. Moreover, system's hints are ordered on the basis of a degree of informativeness and are delivered to a learner sequentially from the most general to the most specific. The paper presents an approach which provides greater adaptive abilities of intelligent tutoring systems. It supports two modes of problem-solving and uses a two-layer model of hints. Therefore, the learner solves problems in the mode which is the most appropriate for him/her and receives the most suitable hint. The aforementioned approach is being implemented in the intelligent tutoring system for Minimax algorithm at present.

Keywords: Intelligent tutoring system, Hint, Problem-solving mode

1. Introduction

Emerging of a knowledge society and growing demands for highly skilled and educated labor force claim for changing traditional teaching and learning processes. Changes are related with an integration of various kinds of computer-based learning systems as supplements to conventional teaching methods. However, it is necessary to provide intelligent and adaptive abilities of a software system in order it could take over a role of a teacher in effective way. This idea is not new one as it is exploited in intelligent tutoring systems for more than three decades. However, adaptive abilities of such systems still are not high enough. As a rule, intelligent tutoring systems offer a learner only one mode regarding solving of practical problems: a learner receives feedback after each solution step. Moreover, system's hints are ordered on the basis of a degree of informativeness and are given to a learner sequentially from the most general to the most specific. The paper describes an approach which provides greater adaptive abilities of intelligent tutoring systems supporting two modes of problem-solving and using a two-layer model of hints. Thus, the learner solves problems in the mode which is the most appropriate for him/her and receives the most suitable hint. The aforementioned approach is being implemented in the intelligent tutoring system for Minimax algorithm at present.

The paper is organized as follows. Section 2 defines the concept and the main architectural parts of an intelligent tutoring system. Section 3 presents some problems and conclusions regarding system's response to learner's actions. The developed approach based on two modes of problem-solving and a two-layer model of hints is described in Section 4. Finally, conclusions are presented and some directions for future work are outlined.

2. Intelligent Tutoring Systems

Research has been carried out in the domain of intelligent tutoring systems for more than 30 years since the earliest SCHOLAR system (Carbonell, 1970) appeared. During this time a huge amount of intelligent tutoring systems has been implemented for different areas, for example, for mathematics, physics, medicine, informatics and computer science (Brown and Burton, 1978; Brown et al, 1982; Anderson and Reiser, 1985; Alpert et al, 1999; Devedzic et al, 2000; Hospers et al, 2003; Matsuda and VanLehn, 2005; VanLehn et al, 2005; Crowley and Medvedeva, 2006). Despite of a broad variety of the developed systems an unequivocal and exhaustive definition of an intelligent tutoring system still does not exist. However, it is possible to list the most often mentioned characteristics of systems of such kind (Cheikes, 1995; Capuano et al, 2000; Bell and Ramachandran, 2003; Butz et al, 2004; Remolina et al, 2004; Crowley and Medvedeva, 2006; Gascueña and Fernández-Caballero, 2005). Thus, the intelligent tutoring system is a computer-based system; is an intelligent system because it uses principles and methods of artificial intelligence (Brusilovsky and Peylo, 2003) such as knowledge representation, inference mechanisms and machine learning in its structure and operation; is an adaptive system as it alters aspects of its structure, functionality or interface for the concrete user and his/her changing needs over time (Benyon and Murray, 1993); emulates a human teacher; tries to provide benefits of individual (one-on-one) tutoring, and is based on the theory of learning and cognition.

Furthermore, intelligent tutoring systems are characterized by the fact that they store three basic kinds of knowledge (Frasson et al, 1997; Capuano et al, 2000): domain knowledge, pedagogical knowledge, and knowledge about learners. The knowledge types determine three main parts of the system's architecture: the domain knowledge, the pedagogical module, and the student diagnosis module. However, each system can contain additional components the presence of which depends on the following factors: features of problem domain, locking down of separate functions of the basic constituent parts in the isolated components of the structure, technology used for system implementation, and additional functional capabilities of the system.

The student diagnosis module carries out the student diagnosis process that collects information about the learner, analyzes it and stores in the student model. The student model is a basis for tailoring the learning process to the needs of a particular learner. It contains learner's identifying information, information on the current knowledge level of the learner, information about learner's cognitive, emotional and psychological features, his/her past experience, interests, and system's options usage by the learner.

The pedagogical module implements the learning process on the basis of teaching strategies and instructions held in the pedagogical model. The primary tasks of this module are selection and sequencing of learning material that is the most suitable for the learner, determining of the type and content of feedback and help, and answering questions from the learner.

The domain knowledge is the knowledge the system is teaching. Most often it is incorporated in the expert model which represents skills and expertise that an expert in a particular domain has. The model serves as a standard for evaluating the student's performance. The expert module generates solutions of problems for their further comparison with solutions of the learner.

An intelligent tutoring system, as any other software intensively communicating with users, needs a part of the architecture responsible for the interaction between the system and the learner. It is a communication module or interface. It controls screen layouts, interaction tools, and so on.

The general architecture of an intelligent tutoring system is shown in Figure 1.

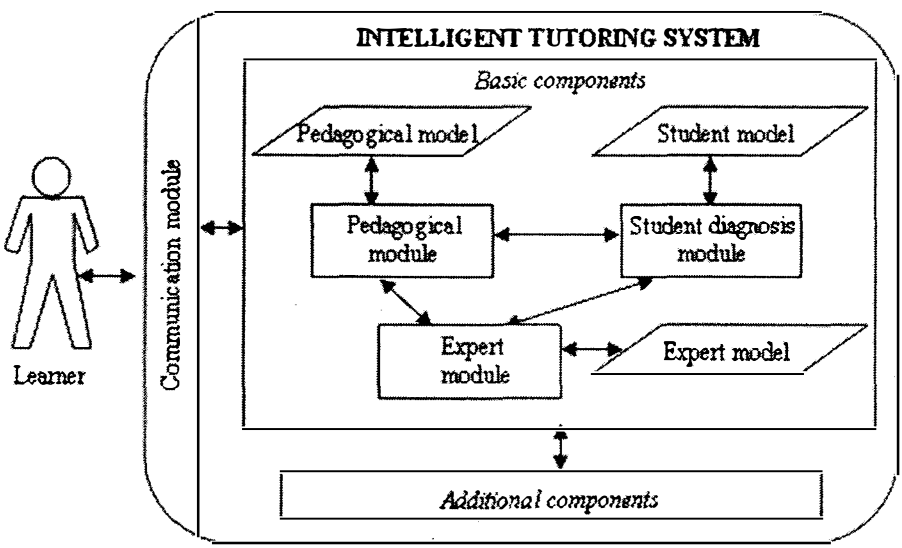

Figure 1. The General Architecture of an Intelligent Tutoring System

3. Feedback and Hints in Intelligent Tutoring Systems

Presentation of feedback and help when the learner solves problems or performs tasks is one of the most important responsibilities of intelligent tutoring systems. Solving of domain problems allows to deepen the acquired theoretical knowledge in practice. However, the mere solving is unlikely to lead to improved skills or deeper understanding of a subject matter. Learning often takes place best when the learner receives feedback from the system. Feedback is a way to improve the learning process on the basis of a continuous assessment of learning results, the analysis of their quality and performance of necessary corrections. Feedback is the various reactions of the system to a learner's learning behavior. It is necessary in order to provide an effective learning experience. Feedback encourages desired learning behavior and discourages undesired one, allows to understand how successfully the learner acts, whether he/she applies relevant knowledge and provides opportunities to correct misconceptions.

Hint is a form of feedback. Unfortunately, little prior researches have been done in this direction. The most significant work is (Hume et al, 1996), containing the description of the results of studying hints used by experienced tutors, and an attempt to formulate a strategy for using hints in intelligent tutoring systems. According to (Hume et al, 1996) hints encourage the student to engage in active cognitive processes that are thought to promote deeper understanding and long-term retention.

As it is pointed in (Matsuda and VanLehn, 2003), the developed intelligent tutoring systems have relatively simple and inflexible hinting policies, which more often demand from the learner to follow a prescribed problem-solving strategy and, therefore, hints are always aimed at the next step which should be taken accordingly to the strategy. The authors draw attention to two problems: inflexible choice of the steps targeted by hints and proceeding of hints from the most general to the most specific.

The analysis of the existing intelligent tutoring systems allows drawing the following conclusions about reactions of a system to actions of a learner. Typically the system gives the learner an immediate feedback after each performed action or step during problem-solving irrespective of the fact whether the action or the step was correct or incorrect. Such policy prevents the learner from proceeding along a wrong solution path. The examples of immediate feedback are found in (Alpert et al, 1999; Kinshuk et al, 2002; Nunes et al, 2002; Matsuda and VanLehn, 2005; VanLehn et al, 2005).

The systems usually provides the special button or tool, which the learner can use to request a hint. In AlgeBrain (Alpert et al, 1999) such tool is an animated agent. The system responds with two types of support: generalized "Here's what I'm expecting you to do at this point" help text and a hint specific to the current state of the problem. In Andes (VanLehn et al, 2005) there are two buttons. One of them gives help "what's wrong with that?" on an incorrect entry. Other button provides a hint about the next step in problem-solving.

Typically hints are organized in a range from the most general to the most specific. The general hint as a rule contains a minimum information on an error. Further the informativeness of hints increases. The most specific hint clearly specifies or shows what should be done. Hints are given sequentially. There is a number of systems which use this approach, for example, (Alpert et al, 1999; Suraweera, 1999; Kalayar et al, 2001; Kinshuk et al, 2002; Matsuda and VanLehn, 2005; Crowley and Medvedeva, 2006). The organization of hints from the most general to the most specific is not flexible enough. The insufficient amount of information in a hint can cause frustration and desire to request the subsequent hints without attempts to solve a problem by the learner. Information, in its turn, which specifies necessary actions after first request of a hint, is contradictory to the learning process. Thus, mechanisms which will allow implementing individual system's reactions for each learner giving such amount of information which will help and at the same time will provide certain cognitive load are necessary. The example of adaptive hinting is described in (Stern et al, 1996). They use learner's proficiencies to select an appropriate hint. The learner with high proficiency at a particular skill receives the more subtle hint. The less proficient student is presented with a more obvious hint. The authors point out that this is better than require students to wade through several levels of hints before they receive material that is appropriate to their knowledge level.

4. Proposed Approach

4.1 Intelligent Tutoring System for Minimax Algorithm

The intelligent tutoring system is being implemented for a topic of the learning course "Foundations of artificial intelligence" at the faculty of Computer Science and Information Technology at Riga Technical University. The topic is related with the algorithm for implementing two-player games of perfect information, i.e., the Minimax algorithm which is described in (Anohina, 2005) in details. The system provides assessment of an initial learner's knowledge level on the topic, the theoretical knowledge acquiring mode, the practical problems solving mode with preliminary determining of the problem-solving mode and a category of hints most suitable for the learner, and a final assessment of the achieved knowledge level. The practical problems solving mode consists from three blocks of tasks which allow to master the basic skills concerning an application of the Minimax algorithm. On the basis of the analysis of possible tasks and being guided by motivation to solve the abovementioned problems a scheme of possible problem-solving modes and a model of hints have been developed.

4.2 Problem-Solving Modes

Generally, there are two possibilities regarding moments of feedback delivering: an immediate feedback after each step or action in problem-solving and feedback after submission of a whole solution to the problem. It is a basis for two modes of problem-solving in the proposed approach. In the *completeness mode* a learner chooses the moments of feedback presentation to check correctness of a series of steps. So, he/she can perform one or more steps solving a problem and then to require checking of the performed steps. The system provides feedback about correctness of his/her previous actions and the learner by his/herself should determine what step has led to the incorrect solution. In the *step-by-step mode* the system monitors each problem-solving step and gives feedback about its correctness.

There are four variations of the step-by-step mode regarding a kind of information given to a learner:

- The learner receives both positive and negative feedback solving a problem. In the case when the learner has performed the correct action he/she is praised (positive feedback). If the step was incorrect, criticism (negative feedback) is given to the learner. Moreover, negative feedback can be in two different forms: only as a text which informs that the action was incorrect and as a text about the incorrect step together with a hint about how to improve his/her operation.
- The learner receives only negative feedback. In this case negative feedback also can be given in two different ways described above.

It is obvious, that it is necessary to provide an opportunity to a learner to change the problem-solving mode and a kind of feedback by him/herself, as well as to request a hint in case when he/she receives only the text of negative feedback. Thus, the general scheme of the problem-solving modes and kinds of feedback is displayed in Figure 2.

4.3. Model of Hints

The model of hints in the proposed approach defines two layers (Figure 3): a layer of the general hint categories and a layer of hints within the general categories. There are three general hint categories: general hints, hints of average informativeness, and specific hints. Each category contains one or more hint which also are ranging from less informative to more informative.

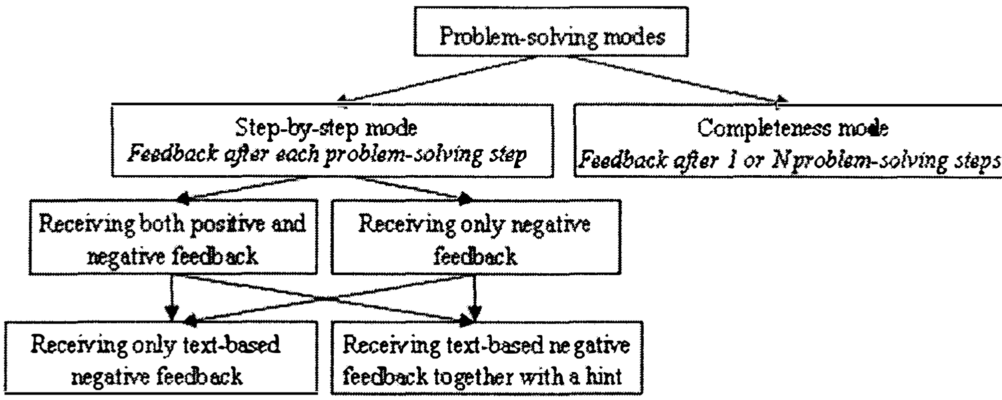

Figure 2. Problem-Solving Modes and Feedback in the Intelligent Tutoring System for Minimax Algorithm

The model allows the learner to receive a hint that is the most suitable for him/her. Before the learner starts to work in problem-solving mode testing will be taken with the purpose to determine a general hint category which is suitable for the learner. Further requesting help during problem solving the learner will receive an average by number hint from the hint category suitable for him/her. If after receiving of a hint the learner is not capable to execute a correct action, he/she is presented with subsequent hint. The process proceeds while he/she will not reach last hint for the given error. Such approach spares the learner from being presented with informativeless hints. Contrary, the learner timely receives a hint providing help and certain cognitive load, therefore, reducing an opportunity of frustration, floundering and loss of interest to learning.

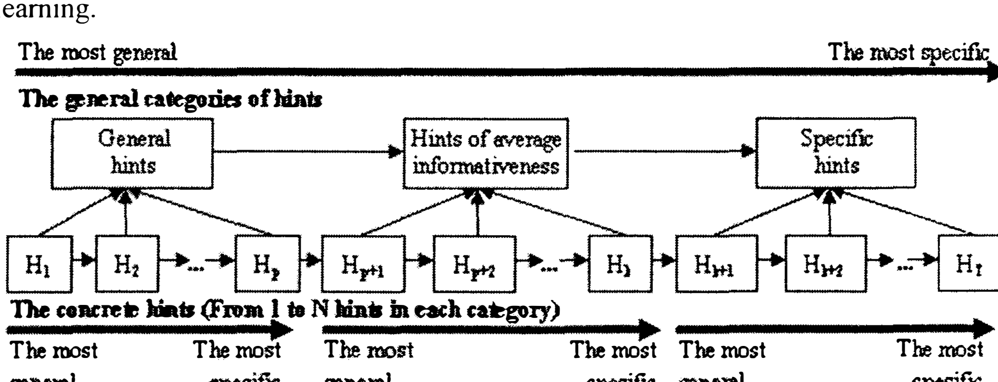

Figure 3. The Two-Layer Model of Hints

5. Conclusions and Future Work

Adaptive abilities of intelligent tutoring systems are not high enough especially regarding problem-solving modes offered to a learner and ordering of hints from the most general to the most specific. The paper presents an approach which allows the learner to work in the problem-solving mode which is the most appropriate for him/her and to receive the most suitable hint. The proposed two-layer model of hints can reduce frustration, floundering and loss of interest to learning that are inevitable in case when the learner receives too little support solving the problems.

The proposed approach is in a stage of development at present. Firstly, it is necessary to determine, how testing for the problem-solving mode and a category of hints most suitable for the learner can be made. Further, the completeness should be analyzed mode from the point of view of kinds of feedback. Also it is necessary to specify both psychological and pedagogical foundations of the proposed approach.

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