LEARNERS' SUPPORT IN INTELLIGENT TUTORING SYSTEMS

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Abstract. The paper describes the approach which improves learners' support in the mode of practical problems solving within intelligent tutoring systems. The approach has been developed on the basis of identification of drawbacks of existing systems. It provides two modes of problem-solving and uses a two-layer model of hints. The kinds of feedback within each problem-solving mode are specified. The algorithms of usage of the model of hints are given. In accordance with the proposed approach the learner solves problems in the mode which is the most appropriate for him/her and receives the most suitable hint. Implementation details of the offered approach in the intelligent tutoring system for the Minimax algorithm are described.

Keywords: Intelligent tutoring, problem-solving modes, feedback.

1. INTRODUCTION

Nowadays different information and communication technologies provide new opportunities for people to learn by choosing individual learning time, place, amount and pace. Technologies which are integrated into the learning process partially or completely take over a role of the human-teacher. To carry out this role effectively it is important that technology has similar intelligent and adaptive abilities with the human-teacher. In this context it is necessary to note that research is conducted in the field of intelligent tutoring systems for more than three decades. In [1, 2] systems of such kind are characterized as adaptive and intelligent computer-based systems which are based on the theory of learning and cognition, emulate a human teacher and try to provide benefits of one-on-one tutoring. Furthermore, intelligent tutoring systems store three basic kinds of knowledge [3, 4]: domain knowledge, pedagogical knowledge, and knowledge about learners. The types of knowledge determine three main parts of the general system's architecture: the expert module, the pedagogical module, and the student diagnosis module.

Thus, intelligent tutoring systems being based on stored knowledge provide adaptation of the learning process to a particular learner. The analysis of available information sources and developed systems allows to identify several the most widespread basic kinds of adaptation in these systems. Adaptive curriculum sequencing provides the most suitable individually planned sequence of knowledge units and tasks for a current learning session [5]. Adaptive presentation generates the most suitable learning units for a learner from the point of view of their content, detail levels and a kind of presentation and includes adaptive multimedia presentation, adaptive text presentation and adaptation of modality [6]. Adaptive problem solving support is related with adaptive feedback and help when a learner solves practical problems.
Despite of the prevalence of the described kinds of adaptation and thirty-year history in the development of intelligent tutoring systems adaptive abilities of these systems still are not high enough, particularly regarding modes of practical problems solving and support of a learner in this process. In addition to the analysis given in [1] the following conclusions are made:

- Typically the system gives a learner an immediate feedback after each performed action during problem-solving. In this case research idiosyncrasy of particular learners when learners would like to perform a series of steps, to receive feedback about their correctness and to find what step has led to the incorrect solution is ignored.

- Hints are organized in a range from the most general to the most specific and are given sequentially. Often it demands from a learner to pass through a chain of informativeless hints before he/she receives a hint that is appropriate to his/her knowledge level. It can cause dissatisfaction with the learning process and desire to request subsequent hints without attempts to solve a problem by him/herself.

- Absolutely different situation can be observed in intelligent tutoring systems which simulate natural language dialogue between the system and the learner. In these systems hints are given accordingly to the content of a learner's text-based answer. However, the structure and functional mechanisms of natural language dialogue systems are more complex, because it is necessary to implement not only constituent parts of the general architecture of intelligent tutoring systems, but also some modules for natural language processing.

Thus, it would be usefully to provide two modes of practical problems solving in order to support different learners: a mode in which feedback is given after each performed action, and a mode in which feedback is shown after a series of performed steps. Moreover, mechanisms, which will allow to implement system's individual 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 paper concentrates on the developed 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 implemented in the intelligent tutoring system for the Minimax algorithm. The initial ideas of the approach are described in [1, 2]. This paper fully states the main conceptions.

The remainder of the paper is organized as follows. Section 2 describes the developed approach in details. Section 3 outlines implementation aspects of the approach in the intelligent tutoring system for the Minimax algorithm. Finally, conclusions are presented, and some directions for future work are specified.

2. THE MAIN CONCEPTIONS OF THE APPROACH

Generally, there are two possibilities regarding moments of feedback delivering [1, 2]: immediate feedback after each step or action in problem-solving and feedback after submission of a whole solution of 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 him/herself should determine what step has led to the incorrect solution. This mode is similar to reinforcement learning [7] which is widely used in artificial intelligence. In the *step-by-step mode* the system monitors each problem-solving step and gives feedback about its correctness. It is necessary to stress, that the described problem-solving modes can be implemented only if the process of finding a problem solution consists of several steps. Granularity and meaning of a step depend on specificity of a task in a problem domain.

Both modes are further subdivided on the basis of a kind of information given to a learner. There are four variations of the step-by-step mode [1, 2]:

- 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 rewarded (receives a positive feedback). If the step was incorrect, criticism (negative feedback) is given to the learner. Moreover, negative feedback can be given 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 performance.

- The learner receives only negative feedback. The system does nothing if the learner performs a correct step. In the case of an incorrect action negative feedback also can be given in two different ways described above.

In the completeness mode the learner is not rewarded or criticized for each performed step. Instead of it he/she receives a total estimation of all performed actions. The estimation specifies how far the learner is from his/her goal: the correct solution of a problem. Thus, there are two variations of the completeness mode [1]:

- The learner receives only a total estimation of the performed steps.

- The learner receives a total estimation of the performed steps together with a hint about how to improve his/her performance.

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 a text of negative feedback or a total estimation of the performed steps. Moreover before the learner will start to solve practical problems it is necessary to determine a problem-solving mode and a kind of feedback suitable for him/her. In the simplest case the learner can be suggested to make a choice by him/herself based on the received explanations of the problem-solving modes and the kinds of feedback. In more sophisticated case it is necessary to develop a series of tasks or questions, which analysis will allow to determine the most suitable mode and feedback. Thus, scheme of the problem-solving modes and kinds of feedback is displayed in Figure 1.

In order to support adaptive delivery of hints in both mentioned problem-solving modes a two-layer model of hints has been developed. It consists of a layer of the general hint categories and a layer of hints within these categories. There are three general hint categories:

- Specific hints directly say or show, what should be done, or refer to the step earlier performed by a learner from which it is possible to conclude where a mistake is and how it can be corrected.

- Hints of average informativeness indirectly specify an erroneous action and opportunities to correct it, for example, offering a definition of a concept underlying a mistake.

- General hints are based on information which in an abstract form specifies an erroneous action and high level knowledge are necessary in order to find a place of a mistake and to determine ways of correction.

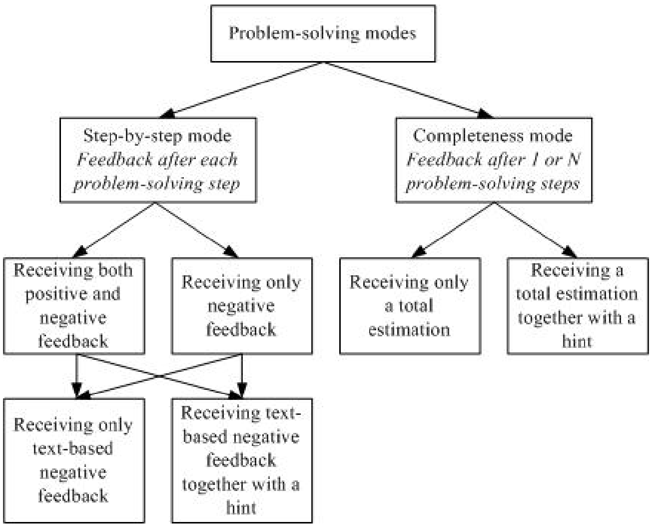

Fig. 1. The problem-solving modes and kinds of feedback for an intelligent tutoring system

Each category contains one or more hints which also are ranged from less informative to more informative.

The offered two-layer model of hints can be described using the set theory. Let H is a set of all hints for a mistake of a certain type. The set contains from *1* up to *t* hints:

$$H = \{H_1, H_2, ..., H_t\}.$$

C_h is a set of the hint categories:

$$C_h = \{C_g, C_{ai}, C_s\},$$

where C_g is the category of general hints:

$$C_g = \{H_1, H_2, ..., H_k\},$$

C_{ai} is the category of hints of average informativeness:

$$C_{ai} = \{H_{k+1}, H_{k+2}, ..., H_p\},$$

and C_s is the category of specific hints:

$$C_s = \{H_{p+1}, H_{p+2}, ..., H_t\}.$$

In this case hints in the particular categories are subsets of the set H:

$$C_g \subset H,$$
$$C_{ai} \subset H,$$
$$C_s \subset H,$$
$$C_g \cap C_{ai} \cap C_s = \varnothing.$$

The model of hints is presented in Figure 2.

The model allows a learner to receive a hint that is the most suitable for him/her. Before a learner starts to solve practical problems testing should be taken with the purpose to determine a general hint category which is suitable for the learner. It is important to note, that the model of hints is based on the assumption, that one or several concepts typically underlie any practical task. A mistake performed by a learner is related to weak knowledge of one of these concepts. It demands to determine a learner's knowledge level of each concept. In the simplest case for usage of the model it is enough to define a knowledge level using three values: low, average and high. The following procedure has been developed for usage of the model in intelligent tutoring systems. If the learner has made a mistake of a certain type for the first time and a knowledge level of a concept underlying the mistake is known then:

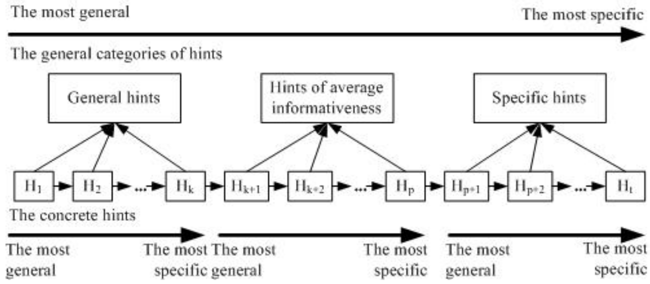

Fig. 2. The two-layer model of hints

- If a value of the knowledge level is low then a category of hints suitable for the learner for this kind of mistakes is the category of specific hints.

- If a value of the knowledge level is average then a category of hints suitable for the learner for this kind of mistakes is the category of hints of average informativeness.

- If a value of the knowledge level is high then a category of hints suitable for the learner for this kind of mistakes is the category of general hints.

Requesting help during problem solving the learner receives an average by number hint from the hint category suitable for him/her. If after receiving a hint the learner is not capable to perform a correct action, repeatedly committing the same mistake, he/she is presented with a subsequent by number hint. The process proceeds while he/she will not reach the last hint for the mistake of a certain kind. 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. The algorithm for delivery of hints is displayed in Figure 3.

Taking in account the fact that several mistakes can characterize the same task, for each of them it is necessary to implement the two-layer model of hints. In case when the learner has reached the last (most specific) hint for a mistake of any type, the system should perform remedial pedagogical actions, for example, to offer the same task with other initial data or to display teaching material which corresponds to the task.

There is a difference between usage of the model of hints in the completeness and in the step-by-step problem-solving modes. In the step-by-step mode the model is applied after each incorrectly performed step or when a learner has requested a hint. In the completeness mode a hint can be given after performance of several steps. The performed steps can be both correct, and incorrect. Moreover incorrectly performed steps can correspond to several mistakes of different types. Therefore before usage of the model of hints it is necessary to identify a type of a mistake, the hint on which will be given to the learner. First of all it is necessary to calculate a number of mistakes of each type. Further it is necessary to choose a type of a mistake which has the greatest number of incorrectly performed steps, and to give out a hint according to the algorithm described above. In case when several types of mistakes have identical numbers a priority mistake should be chosen. The algorithm of determination of a type of a mistake is displayed in Figure 4.

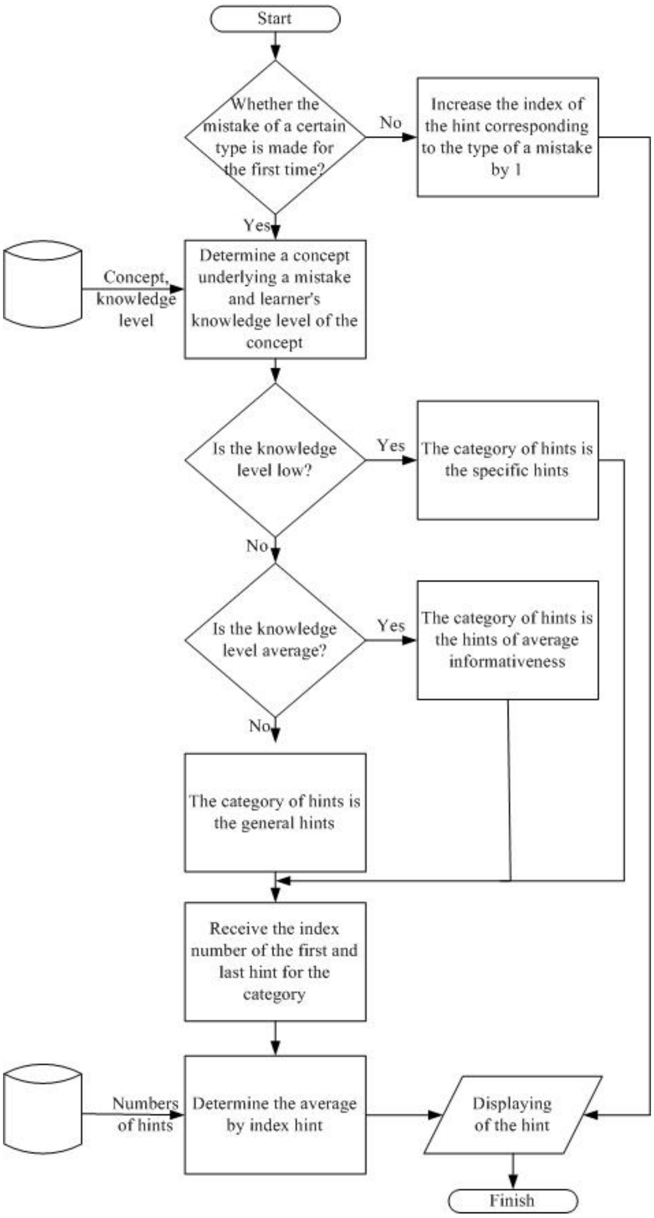

Fig. 3. The algorithm for hints delivery

Thus, the two-layer model of hints demands to store the following information in intelligent tutoring systems: types of mistakes, identification of the task in which the certain mistake is valid, concept underlying a certain type of a mistake, ordinal numbers of the first and the last hint for the general category of hints, ordinal numbers of the first and the last hint for the category of hints of average informativeness, ordinal numbers of the first and the last hint for the category of specific hints, priorities of mistakes within particular tasks and texts of hints.

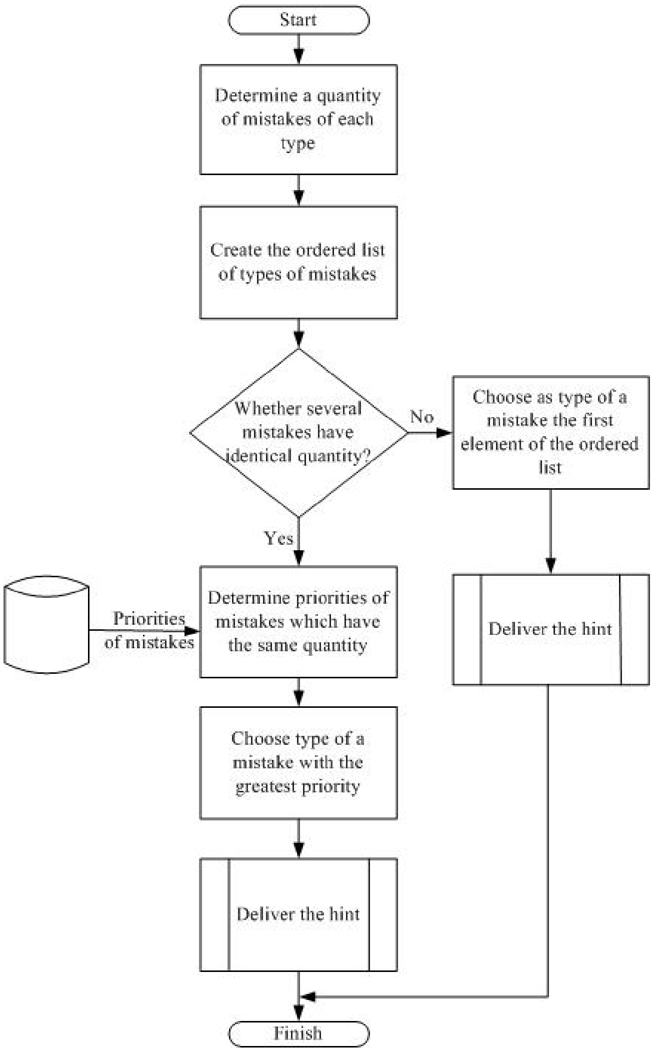

Fig.4. The algorithm for determination of a mistake type

3. IMPLEMENTATION DETAILS OF THE APPROACH

The concepts described in Section 2 are implemented in an intelligent tutoring system "MINIMA" which helps to learn the topic "Using heuristics in two-person games" within the learning course ”Fundamentals of artificial intelligence” for third year students of bachelor programs at the Faculty of Computer Science and Information Technology of Riga Technical University. The topic is related with the algorithm for implementing two-person games with full information, i.e., the Minimax algorithm [8] (its example is given in [9]). The developed system is an intelligent tutoring system of full functionality which provides knowledge preassessment before the beginning of learning, the mode of theoretical knowledge acquiring, the practical problems solving mode and final assessment of a knowledge level after finishing of learning. Due to the scope of the paper the attention is given only to the practical problems solving mode.

The practical problems solving mode consists from three blocks of tasks: refining of a game tree, propagation of heuristic values and determining of winning paths. The tasks allow to master the basic skills concerning application of the Minimax algorithm. All tasks consist of a sequence of steps. In the task of game tree refining a step means the removing of one arc from a graph representing a state space of a game. Obtaining a heuristic value for one node of a game tree is a step in the task of propagation of heuristic values. In the task of determining of winning paths adding of one sector to a current path is one step. It allows to provide two modes of practical problems solving (Section 2) in the system.

Before the learner will start to solve practical problems he/she is offered with several questions which allow to identify a learner's knowledge level of each concept underlying the tasks. For each concept there are three questions with different degree of difficulty: simple, average and difficult. The questions are multiple choice questions. Each constituent part of an answer has a definite number of points. The questions have their weights corresponding to the level of difficulty. So, for each concept the learner receives the following score:

$$S_q = \sum_{i=1}^{3} q_{wi} * p_i, \qquad (1)$$

where S_q- a total score for a particular concept,
q_{wi}- the weight of i-th question,
p_i- learner's received points.

The knowledge level of a particular concept is determined in the following way:

- if S_q in [0…4} then the knowledge level is low;
- if S_q in [4…8} then the knowledge level is average;
- if S_q in [8…10] then the knowledge level is high.

After that the system explains to the learner the problem-solving modes and the kinds of feedback and then offers to make his/her choices without any assistance. However there are three opportunities when the learner can change the mode of practical problems solving and the kind of received feedback:

- If the learner has stopped the previous tutoring episode solving practical problems then before beginning a new tutoring session a report window about tasks performed earlier is shown. In this window the learner can change both the practical problems solving mode and the feedback.
- During the solving of any practical problem the learner can change the kind of feedback within the framework of the mode in which he/she is currently working.
- After completion of the current task a result window is shown in which the learner can change both the practical problems solving mode and the feedback.

In the step-by-step mode the system keeps track of each learner's performed step and delivers him/her reward if the learner has performed a correct action and criticism in case of an incorrect step. In the completeness mode the special button is provided in order to check correctness of a series of performed steps. After the analysis of the learner's solution the learner receives feedback in the form of a total estimation which includes: the number of correctly and incorrectly performed steps after the previous check of the solution and the number of correct and incorrect steps after the current check. In both modes if the learner receives feedback which does not provide an automatic delivery of hints there is a button for hint requesting.

In order to provide usage of the two-layer model of hints, the possible types of mistakes and their priorities were defined for each task. Types of mistakes were determined on the basis of the analysis of course and examination works of third year students of bachelor programs. The two-layer model of hints is maintained for each type of a mistake. Delivery of hints during practical problems solving is carried out on the basis of algorithms described in Section 2.

Any practical task can be completed in two cases: the learner has solved it or the last hint for any type of a mistake has been given. In any case the system checks, which time the learner carries out the given task, whether he/she has made mistakes and has used hints. In the developed system each task can be performed only two times. It is based on the following assumption. If the learner was offered to repeat the task, it means, that he/she has received the last hint for a certain type of a mistake. The last hint includes demonstration of task performance and reading of explanatory material. Thus, after that it will be easy to solve the same task even with other initial data. In the worst case repeated task execution also can be finished with demonstration.

If the learner has completed the task at the first time then the analysis of the solution is the following:

- The learner should perform the task repeatedly in the following cases:
  - If for any type of mistakes the learner's category of hints was specific hints and the learner has made mistakes of the given type, or
  - If for any type of mistakes the learner's category of hints was hints of average informativeness or general hints and the learner has reached the specific category of hints.
- The system gives the learner opportunity to choose between repetition of the same task and execution of the subsequent task in the following cases:
  - If for any type of mistakes the learner's category of hints was the hints of average informativeness and the learner has received more than one hint from this category, or

- If for any type of mistakes the learner's category of hints was general hints and the learner has reached the category of hints of average informativeness.

- The learner passes to the subsequent task in the following cases:

  - If for any type of mistakes the learner's category of hints was the general hints and the category has not been changed, or

  - If for any type of mistakes the learner's category of hints was hints of average informativeness and the learner has received only one hint from this category, or

  - If for any type of mistakes the learner's category of hints was specific hints and the learner has not received hints from this category.

After the made analysis the category of hints is changed for each type of mistakes, reducing a degree of informativeness. Thus the category of the specific hints is replaced by the category of hints of average informativeness and the hints of average informativeness are replaced by the category of general hints.

4. CONCLUSIONS AND FUTURE WORK

The paper describes in details the approach directed to the improvement of adaptive abilities of intelligent tutoring systems in support of a learner in practical problems solving. The approach offers two modes of problem-solving and uses a two-layer model of hints. Therefore, the learner can solve problems in the mode which is the most appropriate for him/her and receive the most suitable hint.

The proposed approach is implemented in the intelligent tutoring system for the Minimax algorithm. At present the system is ready for experimental testing. The main purpose of experimental testing is to check efficiency of the offered approach. After finishing of learning, students will be offered to fill the questionnaire which under the development at the moment.

5. REFERENCES

[1] Anohina, A.: Advances in Intelligent Tutoring Systems: Problem-solving Modes and Model of Hints. International Journal of Computers, Communication and Control. Vol. II, 2007, No. 1, pp. 48-55

[2] Anohina, A.: The Problem-solving Modes and a Two-Layer Model of Hints in the Intelligent Tutoring System for Minimax Algorithm. Proceedings of the 1st International Conference on Virtual Learning, Bucharest, Romania, October 27-29, 2006, pp. 105-112

[3] Capuano, N., De Santo, M., Marsella, M., Molinara, M., Salerno, S.: A Multi-Agent Architecture for Intelligent Tutoring. Proceedings of the International Conference on Advances in Infrastructure for Electronic Business, Science, and Education on the Internet SSGRR 2000, L'Aquila, 2000

[4] Frasson, C., Mengelle, T., Aimeur, E.: Using Pedagogical Agents in a Multi-Strategic Intelligent Tutoring System. Proceedings of the 8th World Conference on Artificial Intelligence in Education AI-ED97, Workshop V: Pedagogical Agents, Kobe, Japan, 1997, pp. 40-47

[5] Brusilovsky, P.: Adaptive and Intelligent Technologies for Web-based Education. Künstliche Intelligenz. Vol. 4, 1991, pp.19-25

[6] Brusilovsky, P.: Adaptive Hypermedia. User Modeling and User Adapted Interaction. Vol. 11, 2001, pp. 87–101

[7] Russell, S., Norvig, P.: Artificial Intelligence: A Modern Approach. Prentice Hall. 2003.

[8] Luger, G. F.: Artificial Intelligence: Structures and Strategies for Complex Problem Solving. Addison Wesley. 2001.

[9] Anohina, A.: Intelligent Tutoring System for Minimax Algorithm. Scientific Proceedings of Riga Technical University, Computer science, 5th series. Vol. 22, 2005, pp. 122-130.

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