Graph based framework for personalization of education process realized by the tutoring module of intelligent tutoring system

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Abstract. In the situation when there is tendency to move towards education for all people a large part of who cannot attend educational establishments the necessity of developing intelligent tutoring systems (ITS) becomes urgent. The paper proposes a conception of framework using the set of graphs which implementation in the tutoring (pedagogical) module of agent based ITS allow personalization of teaching and learning process for each individual learner. The personalization starts with defining of sequence of study courses build on individual study plan for the particular learner. This activity is supported by a AND – OR graph representing the structure of study programme. The next step is carried out using the graph that represents a structure of study course showing relationships between topics. The third graph is constructed by mapping each topic to the corresponding concept map which includes all taught concepts and their relationships. The fourth graph represents a concept and its relationships with all needed learning objects to acquire knowledge about the concept. The paper describes also how personalization of learning is supported by sequences of learning objects and usage of concept maps for knowledge self-assessment.

Keywords: intelligent tutoring system, tutoring module, agents, concept maps, personalized education.

1. Introduction

One of the most important characteristics of education in information age is the spread of education among all society's individuals. As a result besides traditional levels of learning (primary, secondary, and university education) the term "life-long learning" emerges. More and more people strive not only for higher education and/or improval of professional skills, but they simply want to learn something new. People not always have possibilities to attend the educational establishments and to choose one of the tutoring forms, such as full-time, part-time (evening or external) and distance learning. Importantly, that till now the best learning results is achieved under the supervision of human teacher even considering, that rather frequently educational establishments lack skilled teachers. Human teachers must create all learning materials and tests which they are able to adapt (at least theoretically) to each individual learner, and to provide flexible feedback. Moreover, during communication between tutors and learners the human teacher helps learners during their studies, gives assessment of their knowledge, analyses psychological characteristics of learners and chooses teaching activities according analysis results, etc. In case of part-time or distance learning this communication is not intensive enough. As a result, learners should organize their work by themselves and be motivated and well-disciplined. Additional factor - lack of skilled teachers - indicates the necessity of developing an alternative affordable, effective and attractive teaching platform. Here a concept of intelligent tutoring systems can be quite important because an ITS to a large extent address the abovementioned issues.

Research in the ITS's field has made over helming progress during last four decades but still there are scopes for further improvements. This paper focuses on tutoring (pedagogical) module which commonly is responsible for providing the knowledge infrastructure for adaption of teaching and learning process to the needs and characteristics of each individual learner. It tailors appropriate learning activities such as problem generation, receiving a learner's solutions and working out a feedback (explanation and help) as well as in close cooperation with the student diagnosis module selects the proper methods and strategies for teaching. Usually this module only provides personalized instructions, and offers to students a variety of materials with different media and alternative modes of explanation. The purpose of this paper is to propose a conception of framework based on set of graphs which extends the above mentioned functionality of tutoring module. The final goal of the proposed flexible framework is implementation of intelligent tutoring module which allows each student to tailor his/her study programme by adapting the modularized curriculum structure, to choose the suitable learning strategy for each study course, effectively suggests additional work by giving feedback, hints and supplies to the learner with learning objects given in preferable form.

The next section of the paper describes ITS. The third section is devoted to the brief motivation of our work, but the fourth one - to the adaption of core architecture of ITS and its implementation as the multiagent system presenting the concept of the proposed flexible framework based on the set of graphs. The paper concludes with short summary and an outline for the future work.

2. ITS overview

ITS are computer-based tutors, which to a certain extent simulates human tutors and act as a supplement of them trying to ensure advantages of face-to-face learning, as well as use methods of artificial intelligence knowledge representation, inference, machine learning, natural language processing [5]. More precisely, ITS is educational software which keeps track of students work, collects information on an individual

students performance, infers his/her strengths and weakness, as well as suggests additional work by giving feedback and hints.
There are two research areas that are primary connected with acquisition, capacity, and usage of explicit knowledge, namely artificial intelligence and knowledge management. Literature analysis reveals rather strange picture. Currently with the promotion of education process by modern information and telecommunication technologies (ICT) during last decades a lot of approaches, methods, systems, and environments have been promoted, developed and implemented under the umbrella term of technology-based learning [3]. Educational environments in large extent were influenced by the development of intelligent tutoring & knowledge management systems. More and more distance education environments, e.g., e-learning, web based learning, blended learning, etc. are used but usually these environments and systems like Blackboard (http://www.blackboard.com) and Moodle (http://moodle.org) cannot generate learning materials and/or objective or subjective tests which allow to adapt to specific characteristics and learning styles of individual learner [12, 25]. Even more, the dissemination of distance learning knowledge assessments has become a constant concern [14] as all mentioned tutoring systems are based on expert knowledge and represent a way how universities can keep their intellectual capital.
The first ITS named SCHOLAR for teaching South America's geography [8] gave the origin of the successor systems. Such ITS as BUGGY [6], GUIDON [10], SOPHIE [7], LISP Tutor [1], FLUTE [15] and Slide Tutor [13], have established a common viewpoint that modern ITS must include knowledge on "what to teach" and "how to tech", and knowledge on learners' qualities. A common functional architecture was established which nowadays constitute the core of every ITS: the domain knowledge module, the tutoring module, and the student diagnosis module.

3. Research motivation

One of the main purposes and at the same time advantages of ITS is support to individualized teaching and learning, i.e., potency of personalized instruction delivery (generation of learning objects, problems, examples, explanations and hints) and knowledge assessments which means that the system adapts itself to the different categories of students. It is found that students have different preferences in respect of forms of learning materials (text, audio, video, etc.), different learning styles [25] and different preferences of desirable feedback from the system. Briefly, a real group of students is heterogeneous and there are different kinds of students, ranging from slow to fast learners. In these circumstances practically it is hard to provide attention to them individually, and, as a consequence, the teaching and learning process may not be effective and beneficial for all students. ITS to large extent can dispose this problem which is not so peculiar to be typical for face-to face learning but is topical for part-time, external and distance learning because the tutor and the student has virtual one-to-one relationship. Using ITS for teaching students they can learn in their own pace and place; the teaching can be accomplished with minimum immediate intervention from the teachers [11]. Thus, ITS can be effective in areas with the deficiency of well trained tutors and in part-time, external and distance learning.

The main objective behind any ITS, is its intelligence, i.e., ensuring of adaptive teaching methods including adaptive knowledge assessments and feedback [11]. It is not surprise that according to aforementioned, the most part of already developed ITSs are focused [9, 24, 33]. Consequently, another aspect of adaptation – development of individual curricula corresponding to both students' preferences and interests, and to the needs of industry is somehow disregarded. Practically it means the development of flexible individual curriculum in which well known Bloom Taxonomy [2] is taken into account for each particular study course (each of the outcome based learning objectives of the courses was processed for level of skill based on the Bloom Taxonomy [22]). In this paper we propose the framework and analyse all important aspects for adaptive ITS.

4. Core architecture and functionality of agent based ITS

Review of different literature sources, for instance, [16, 31, 32] show that the common functional modular architecture (the core of ITS) consists from the following modules: the domain knowledge module, the tutoring module, the student diagnosis module and the communication module (particular ITS may include also additional components, like, explanation module for explanatory reasons of mistakes). The tutoring (pedagogical) module provides the knowledge infrastructure for adaption of teaching and learning process to the needs and characteristics of each individual learner, i.e., it functions as a helper in a tutoring process, adjusts the later to the learner according to his/her knowledge level, and stores knowledge about tutoring methodology. It tailors appropriate learning activities such as problem (task) generation, receiving of learner's solutions, and giving a feedback (explanation, hints and help). In fact, it is the centre of the whole ITS, that communicates with all other modules and does the entire decision making. The domain (expert) module includes algorithms for generation of problem solutions using the represented domain knowledge. As it is pointed out in [11] domain knowledge representations are not generic, i.e., they are domain depended. Moreover, learning materials are implicit to the systems, and adding the new ones is rather incommodious. Furthermore, materials supported in these systems are mostly monolingual [11]. The student diagnosis module processes information about learners for estimation of their current state of knowledge, carries out knowledge assessment and constructs a student model. Thus, this module realizes adaption function of ITS's deciding "how to teach" taking into consideration student's current knowledge level and his/her preferences. The communication module (interface) provides functionality that supports interaction between the ITS and its users.

Operations of core modules are based on corresponding models. The pedagogical model holds and/or plans teaching strategies and instructions needed to implement learning activities. The expert model stores the knowledge about "what to teach" and represents objects, i.e., learning objects and their relationships (expert's knowledge). It is important as it is the representation of the domain knowledge. Good design principles adapted in designing the expert's model would help the ITS in selecting suitable methods for teaching or in searching for alternative teaching plans when a

particular method fails to give the planned result [11]. The student model contains information about each individual learner: his/her personal data, achieved results, current knowledge level, preferences, learning styles, etc.
The modern approach to artificial intelligence based on agent paradigm [34] has influenced the development of ITS's. Analysis of already developed agent–based ITS allows to conclude, that all core modules might be implemented using agents [16]. A typical set of agents which may constitute the architecture of agent-based ITS is shown in [17].
A conception of framework based on the set of graphs for personalization of study programme and learning process. The main task of ITS's is to support learning taking into consideration his/her goals, preliminary knowledge, preferences, needs, desires, learning style and psychological characteristics. It means that the ITS must be so flexible that it could be used for personification of teaching and learning process by giving a learner options to personalize this process, i.e. to choose between different learning scenarios taking into account abovementioned aspects. A personalized teaching and learning means that a learner selects an individual study plan (the set of subjects and their sequence), personified content of the particular study course, as well as personified learning materials and form, for example, tests or concept maps for knowledge self-assessment [20]. Literature describes research activities related to personalization of learning [23, 27]. In [27] personification is realized using different learning scenarios each of which is meant for a particular group of learners, i.e. latter's are arranged in groups by the most corresponding learning model for them. It is obvious, that this approach does not guarantee a real personalization of learning for each individual.

4.1. Graph representing conceptual structure of study program

As already mentioned the proposed framework is based on the set of graphs. We focus on the scenarios in which learners start personalization with choosing the sequence of study courses to build their individual study plans (in principle, the process may start also with choosing between study programmes but this case is skipped in the paper). This first personalization phase supported by the framework is based on AND-OR graph $G_1(V_1,Q_1)$ where V_1 is the tree (a hierarchy). The root node represents the name of the study programme and is labelled by the total number of ECTS needed for graduation. Descendants (children) of the root node represent study years with corresponding ECTS, while the third level nodes correspond to terms with ECTS. The nodes at the fourth level represent traditional modularized curriculum structure, namely, compulsory (mandatory) courses restricted electives and free-choice courses. If between all mentioned levels the ancestor nodes are connected with their descendants with logical operation AND, then between the fourth and the fifth level nodes (representing particular courses) there are logical AND as well as OR used. That is because in case of compulsory courses all of them must be taken while in case of restricted electives and free-choice courses only limited numbers of them (defined by the program) are required.
The specific graph with 89 nodes and 88 links for the bachelor's study programme Computer science at the Ventspils University College has been developed. The usage

for personalizing the learning process in this case is quite limited because each student has alternatives only for choosing restricted electives and free-choice courses. Regardless of that the graph $G_1(V_1,Q_1)$ clearly shows the content of the study programme and the sequence of courses taught term after term. The graph $G_1(V_1,Q_1)$ may be transformed from the tree to the network by adding cross-links representing prerequisites for the courses. At the basis of the idea of the graph there are independent nodes which are not limited by sequence and which students can choose to acquire in any semester. Such nodes are independent from previous and following ones. The dependent nodes are restricted by sequence which says in what order the subjects must be acquired, e.g. the student can acquire the course “Programming in JAVA language” only after he/she has acquired the courses “Basics of Computer Sciences”, “Programming”, “Data Structures and Basic Algorithms”, and “The Theory of Algorithms”. In this case the value of $G_1(V_1,Q_1)$ considerably increases because students can personalize their studies choosing sequences of courses from restrictive electives and the set of free-choice courses. Such modification of $G_1(V_1,Q_1)$ also may serve to choose a particular course for persons who wanted acquire specific knowledge because they can see the needed prerequisites before making a decision. And finally, if regulations of university allow more flexible construction of individual study plan then the graph fully supports personalization.

4.2. Graph reflecting of study course

The next step of the framework is construction of the graph $G_2(V_2,Q_2)$ for each study course. The root node represents the name of the course and its descendents represent topics with prerequisite relationships between topics (nodes). The framework suggests

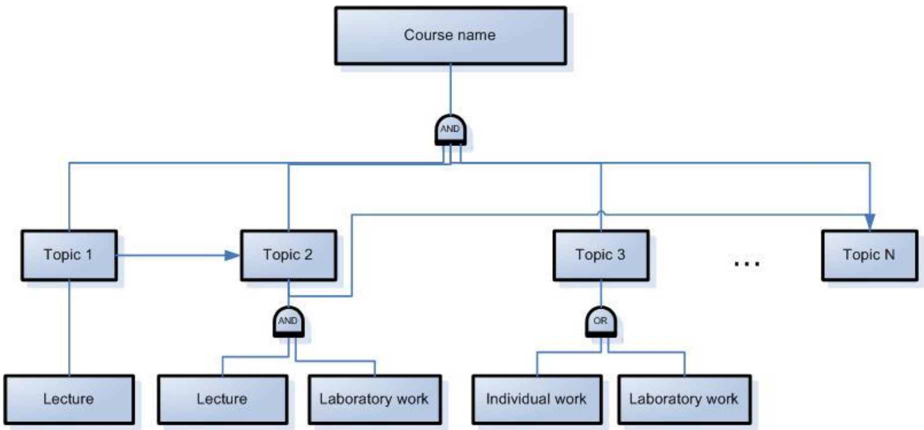

Fig. 1. The structure of study course

also a modification of their graph where the third level nodes are added representing the structure of each topics, namely, the way of its teaching - lectures, practical seminars, laboratory works and individual work. An illustration of their graph is depicted in Figure 1.

If the graph $G_2(V_2,Q_2)$ contains logical operation OR then students have alternative ways of acquiring knowledge of this topics (as it is shown in Figure 1, for example, topic 3 may be taught in form of laboratory or individual work, i.e., they can personalize their learning scenario). Besides the nodes of this graph may have labels (not shown in Figure 1) which shows at what level of Blooms Taxonomy, the topic should be learned. So each student can personalize his/her level of knowledge of particular topic depending on his/her specialization and interests [2].

4.3. Graph visualizing of each topic using concept map

The third step proposed in the framework is mapping of each topic to the corresponding concept map (CM) [30]. CM is a semi-formal knowledge representation tool visualized as graph [19]. This graph $G_3(V_3,Q_3)$ consists of a finite, non-empty set of nodes V_3 representing concepts and a finite, non-empty set of arcs Q_3 representing relationships among concepts. Graphs visualizing CM's themselves may be undirected or directed, homogenous or heterogeneous, and also may be represented as attribute graphs (arcs have linking phrases specifying the kind of relationships between a concept pair). The variety of graph is described in [19].
The graph $G_3(V_3,Q_3)$ can be extended by connecting each concept with nodes representing the structure of each topic (see Figure 1). Thus students can personalize the way how they acquire knowledge about particular concept.

4.4. Graph representing of learning objects

The forth and the last graph is $G_4(V_4,Q_4)$. The root node of this graph (a tree) represents a concept and arcs represent learning objects which are available to acquire knowledge about it (see Figure 2).

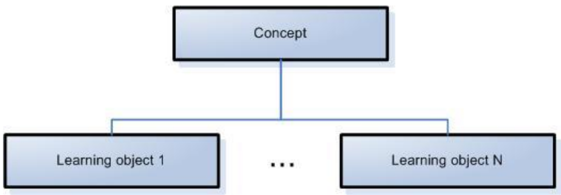

Fig. 2. Concept and learning object

According to the standards, for example, SCORM [21] a learning object is an entity that contains information on study content. From literature [21, 35] it may be concluded that learning objects can be digital or non-digital, they can be used with educational technologies once or several times, they may be presented in different forms (as a text, video, audio, etc.), used in different courses, may be modular, inter-connectable, dividable, combined in different ways and easy integrated in different courses. Characteristics of learning objects give clear picture about their role in personalized learning, but the effectiveness of personalization depends very much on the quality of student model implemented in the ITS (due to the scope of this paper this aspect is not discussed here). Let us only add that from the learning object usage point of view there are two sequences of learning objects which may be used for knowledge assessment or self assessment – traditional sequence and Socrating sequence [29].

It is also worth to mention that intelligent knowledge assessment system offers quite a wide range of opportunities to personalize study process. For example, the IKAS which is based on concept maps [4, 18, 19, 20] has a capacity for adaptation to each learners current knowledge level which is realized in two ways. First, change of the degree of task's difficulty may be initialized by the IKAS (the decision in based on a learner's previous task solving results) or by a learner who can ask the system to reduce the task difficulty. The IKAS, in its turn, keeping track of learner's performance can increase the task difficulty at the next stage of concept map task solution. Second, a learner can choose the initial form of feedback (definition of concept, its short description or an example) and change it during solution of task.

Summarizing the content of this section, let us point out that it presents a flexible framework based on four graphs and their extensions combined with knowledge self-assessment methods using test's or concept maps allow really wide range of opportunities how to personalize teaching and learning process.

5. Conclusions

In circumstances where on the one hand nowadays we can observe wide spread of learning but on the other hand no all people who desire to acquire new knowledge and skills can attend educational establishments which, in their turn, rather offer lacking skills teachers, there is obvious necessity to develop an alternative, affordable, effective and attractive teaching platform. In these education settings a concept of intelligent tutoring systems is quite important because these systems to large extent address the abovementioned issues. The article shows how graphs can be used for the design of study program and study course for individual learning.

In real life there often appear situations when it is necessary to deviate from the strict sequence of the acquisition of the studying program. Acquisition of the studying program is necessary if student for some time studied in the exchange program: if the student has got to learn from other universities; in case of certify the existing and in the lifetime gained skills; if a student studying by individual plan; in lifelong learning if course structure is module oriented. Latvia doesn't offer such a system. University staffs perform this procedure manually for each individual learner. Therefore, the implementation of such system in the future will optimize the work with an individual training schedule for courses or training sessions. This paper focuses on the extension of functionality of the tutoring (pedagogical) module which commonly provides the knowledge infrastructure for adaptation of educational process to the needs and characteristics of each individual learner. The paper proposes a conception of framework based on the set of graphs to implement truly intelligent tutoring module which allows personalization of teaching and learning process for each individual learner. The further research is concerned not only with implementation aspects of proposed framework but also will be aimed at usage of graph structural properties such as, for example, connectedness to determine the most important topics and/or taught concepts. Another foreseen research field is investigation of potential of ontology's for inference of personalized sequences of learning objects.

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