Knowledge Creation Supported by Intelligent Knowledge Assessment System

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ABSTRACT

The information age causes new challenges for industry and education. The intelligent tutoring systems try to fill the gap between human teachers and computer-based tutoring systems. The paper presents a novel approach in which ontologies transformed into concept maps are being used for systematic creation of knowledge structure of each individual learner. The motivation of the approach and the implementation of the intelligent knowledge assessment system are described.

Keywords: Intelligent Tutoring System, Ontology, Concept Map, Knowledge Management, Intelligent Knowledge Assessment System, Degree of Task Difficulty.

1. INTRODUCTION

Nowadays one can observe a historical evolution from the industrial age towards the information age. As a consequence, a new type of society, so called, knowledge society emerges. Knowledge is becoming the most important asset for people promoting their competitiveness on a labour market. Concurrently, constantly increasing influence of rapidly growing technology and its complexity puts forward new demands for highly skilled and educated technical workforce. Of course, it causes new challenges for education and, in particular, for engineering education. Rapid penetration of computer and communication technology into education has changed the forms of teaching and learning.

During the last decades a plethora of approaches, methods, systems, and environments has been proposed, developed, and implemented under the umbrella term of technology-based learning, for instance, eLearning, mLearning, computer-assisted learning, computer-supported learning, web-based teaching, online education, and many others [1]. Education from a teacher-centered activity has become a student-centered [2]. Although today's teaching and learning settings are quite different in comparison with those used in recent past, the lessons learnt show that learning effectiveness is still behind the desired level.

In this paper two major areas are pointed out that potentially look promising for promotion of improvements. These are intelligent tutoring systems (ITS) and knowledge management (KM) methods. Integration of both approaches promises the synergy effect. The ITSs try to fill the gap between human teachers and computer-based tutoring systems. At the same time, even the most advanced tutoring systems provide intelligent support of teaching and learning processes that is far behind of that provided by a human teacher who is able to adapt to each learner individually, and to give flexible feedback (help, explanation, assessment, etc.). In tutoring systems KM activities concern a diagnosis of misconceptions and missing knowledge. KM can be applied both at the learner side and at the teacher side. A teacher can manage learners' knowledge by tracking and assessing their knowledge level. Assessment results may be used to adapt a teaching material and methods in accordance with each individual's preferences and a progress towards the desirable knowledge level. It allows to put into practice the concept of process oriented learning and to assess the learner's knowledge at all levels of the well-known Bloom's taxonomy [3]. KM at the learner's side may be based on a self-assessment of his/her knowledge and enables keeping a track of learning progress.

The paper presents the approach in which ontologies and concept maps (CM) are being used for systematic creation of knowledge structure of each individual learner. The paper is organized as follows. In the second section is described a motivation that inspires this work. Ontology based knowledge creation process is discussed in the third section. The fourth section presents basics of implementation of the intelligent knowledge assessment system (IKAS). Conclusions summarize the developed approach and outline some directions of future work.

2. MOTIVATION

At present, the technology-based learning is widespread and becomes more and more popular. However, the vast majority of these systems including also such very popular learning management systems as Blackboard (www.blackboard.com) or WebCT (www.webct.com) have insufficient adaptability to each learner individually [4]. Adaptability may be increased by providing flexible feedback (explanation, help, generation of individual tasks and tests, etc.), which corresponds to the acquired knowledge level of a particular learner.

New hopes for better solutions emerged approximately thirty years ago when the first intelligent tutoring system SCHOLAR [5] gave an origin to the plethora of the successors, for example, SOPHIE [6], BUGGY [7], WEST [8], GUIDON [9], as well as systems for computer-assisted adaptive assessment [10, 11, 12]. ITSs are based on methods and techniques of artificial intelligence. Their architecture and operation provides the most comfortable learning for each learner's knowledge, skills, psychological characteristics, abilities, and needs. ITSs capture three knowledge types: what to teach (problem domain knowledge), how to teach (pedagogical knowledge), and knowledge about a learner.

The latest approach that has become a remarkably popular one for the development of ITSs is based on the usage of intelligent agent paradigm [13, 14, 15, 16]. Agents have such properties as autonomy, reactivity, proactivity, social capability, mobility, capabilities of learning and reasoning. They are also able to act in complex dynamic environments performing tasks entrusted to them and to cooperate providing each other with information and knowledge [17]. It is quite obvious that listed properties are desirable for ITSs, as well.

In general, ITSs perform the following tasks: selection and presentation of learning material, adaptation of teaching strategy, monitoring of learner's actions and responding to them by giving the appropriate feedback and help, and assessment of learner's knowledge level [4]. Developers of ITSs try to implement several basic ways of adaptivity: curriculum sequencing [18, 19], adaptive presentation of information [20, 21, 22], and adaptive problem solving support [23, 24]. However, the analysis of available publications reveals that developers of ITSs have not paid enough attention to such issues as sophisticated support of teaching and learning process (access to knowledge units represented as different learning objects, reaction on learner's actions in right time, etc.), as well as continuous assessment of learner's knowledge and task solving skills. As a consequence, the adaptivity of ITS is still unsatisfactory.

3. ONTOLOGY BASED KNOWLEDGE CREATION PROCESS

The idea to use ontologies in computer or technology based tutoring systems is not new at all. At present, ontologies are used for several purposes. Representation of particular subject [25, 26], a curriculum [27], a model of abstract content [28], and a student model [29] are only some examples. Moreover, such ITS as FLUTE [19], SlideTutor [30], or systems developed by Bakhtyari [26] and Tsovaltzi [31] use several ontologies mainly in pedagogical and expert modules.

The paper provides a conceptually novel approach for the development of adaptive ITS. The philosophy behind the approach is based on the usage of study course ontology, in that way supporting the knowledge creation of learners. The knowledge creation means building of so called knowledge structure, i.e., a set of concepts together with relationships between them. A learner starting a new course has only a prerequisite knowledge and may be some fragments of knowledge of the particular course.

The use of ontology follows several goals. First, an ontology is a knowledge structure, i.e., it reflects not only concepts acquired in the study course but also relations between them. Frequently students have knowledge about acquired concepts (notions), but they hardly can connect them both within one study course or across different courses. So, during studies a learner should not only acquire knowledge about concepts but he/she also should build a corresponding knowledge structure. The proposed approach uses the assumption that during studies a learner builds his/her knowledge structure. In the ideal case, this process of knowledge creation ends with the creation of knowledge structure that is isomorphic with the standard structure created by a teacher. Second, ontology may support reasoning for diagnosis of causes of learner's mistakes and misconceptions, which is a relevant function of student diagnosis module. Third, ontology can represent not only definite concepts and semantics of their relationships but also all synonyms of both, the concepts and the names of relationships. This may raise flexibility and adaptability of knowledge assessment allowing students to use any synonyms, which the system will assess as a correct concept or a relationship. For example, in automatic control there are synonyms: control signal, control command, desirable value, goal, and independent variable, and each of them should be recognized as a correct one. Fourth, at the moment in the Internet there are available quite a lot of ontologies that correspond to taught subjects. Their usage may help teachers who are creating their courses to reach a compatibility of the knowledge structure they wanted to create with the corresponding ontology. Last, but not least, each notion of an ontology may be supplied with references to corresponding learning objects that may be shown to a student if the mistakes or misconceptions are detected.

In the proposed approach an ontology is replaced with a corresponding CM. CMs are constructed by transformations of appropriate ontologies if they are available. If not, then CMs are created by a teacher and transformed into an ontology. Algorithms for transformations have been created and implemented [32]. Such transformations are needed for simplification purposes. CMs are one kind of mental models which uses a graph with labeled nodes corresponding to concepts in a problem domain and with arcs representing relationships between pairs of concepts (see Figure 1). Arcs are directed or undirected and with or without semantics (names or linking phrases) on them, which specify the kinds of relationships [33].

CMs have several advantages. The most important one is that they are graphical representations. Our experience confirms that for teachers it is much more easy to edit a CM transformed from an ontology or even to build it from scratch instead of mastering formalisms and languages for an ontology description. In addition, CMs are universal enough and are relatively independent from a study course, allowing to assess a learner's understanding of knowledge structure and to generate tasks with different degrees of difficulty. Thus, CMs are very suitable for the development of computer-assisted knowledge assessment systems based on manipulations with graphical objects.

The developed scheme for CMs usage for knowledge creation and assessment is depicted in Figure 2 (for better comprehension CMs are replaced by the corresponding graphs). A teacher divides a study course into N stages and gets a CM (built from scratch or transformed from a given ontology) for each stage. Notice that a CM of the following stage is an extension of a CM of the previous stage or, in other words, a CM of the previous stage is a subgraph of a CM of the next stage. It is obvious that a CM of the last stage includes all concepts and relationships among them, i.e., this CM represents a complete knowledge structure of a study course. Starting from the first stage, the IKAS offers appropriate CM to an individual learner. The first offered CM belongs to tasks of medium difficulty. In this case a learner receives a structure of a CM in which only few (2-3) core concepts are inserted in correct places. A list of remaining concepts is given too, and a learner is asked to fulfill a "fill-in" task, i.e., to put all concepts from a list in correct places. In the case of difficulties, a learner can ask to make a task more easy, and the system inserts more concepts in the correct places and/or gives the names of links. On the contrary, a learner can ask the system to give a more difficult task, which belongs to the class of "build a map" tasks.

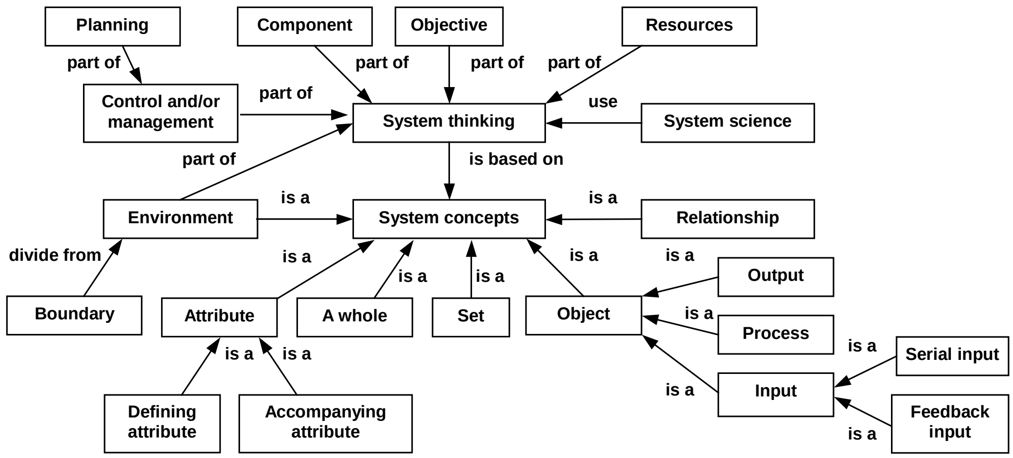

Figure 1. A part of concept map of study course "Systems Theory"

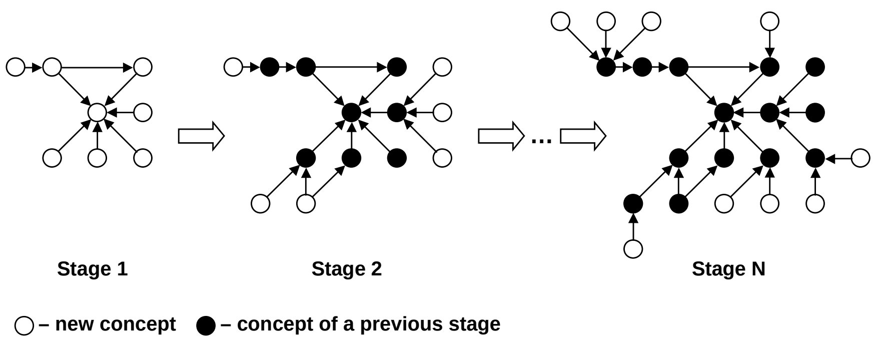

Figure 2. Scheme of concept map usage for knowledge creation and assessment

The most difficult task is when the system gives only a list of concepts and a list of relationship names [34].

The system keeps track of the knowledge creation for each individual learner offering him/her a task of the same difficulty level at the next stage. The system analyses a learner's CM, incorrectly inserted concepts are removed from it and are added back to a list of concepts. Thus, at the next stage a learner receives an extended CM of the previous stage, which includes correctly built part (assessed by the IKAS) together with a list of concepts, which were incorrectly inserted, and a list of new concepts [35]. A learner can correct mistakes in a CM of the previous stage and to fulfill a new task that has an appropriate level of difficulty. That is a way how creation of knowledge structure of each individual learner is guided by the system. It is needed to point out that in the case of the most difficult "build a map" task a learner can use synonyms of concepts and names of relationships. In this case a learner's CM is transformed into a corresponding ontology and the knowledge assessment system checks if the synonym of the concept is inserted into the correct place.

4. IMPLEMENTATION

There are two groups of actors – teachers (supervisors) and learners (students) who are working with knowledge in all education systems regardless of their kind (face-to-face, hybrid or blended, distance, mobile, etc.). The approach described in the previous section partly has been implemented in the ITS that is based on the conceptual model in which actors are considered to be the knowledge workers embedded into a KM system [36]. The conceptual model has two layers – a system's layer and a knowledge worker's layer. Functioning of both layers is supported by sets of agents. The system's layer of the developed system in its essence corresponds to traditional components of ITS, such as, communication, pedagogical, expert, and student diagnosis modules. Each module is built in accordance with a conception of open architecture of multi-agent systems, and includes a set of agents [37]. The knowledge worker's layer supports learners and teachers by using a set of agents, for instance, personal agents (search, assistant, filtering, and/or workflow agents), internal communication agents (messaging, team, collaborative, and/or cooperative agents), and external communication agents (database, connection, network, access, and/or Web agents) [37].

At the present moment only a part of the system's layer of conceptual model already has been developed, implemented, and tested, while others parts are under the development. The core of the implemented part is the IKAS, which is shown in Figure 3.

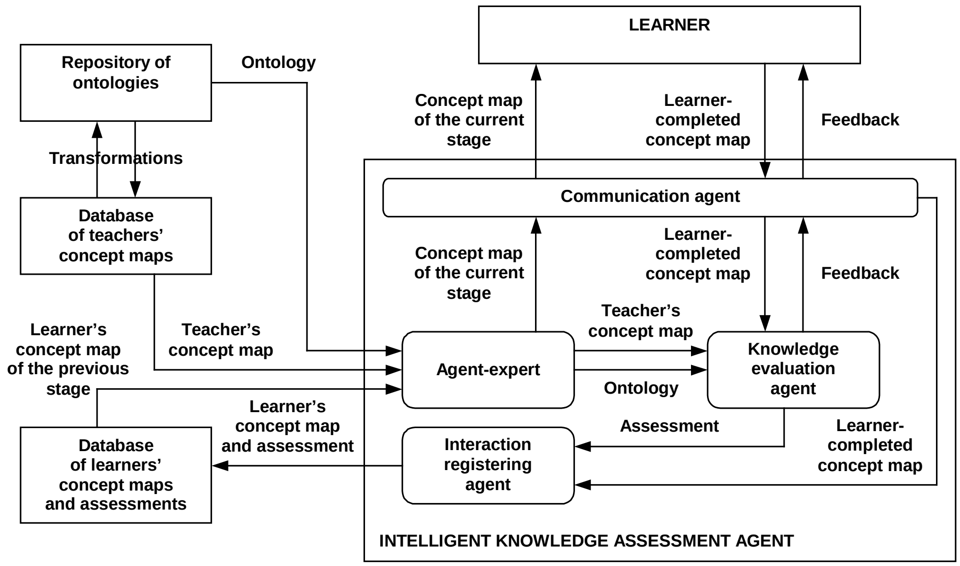

Figure 3. The architecture of the intelligent knowledge assessment system

The agent-expert forms a CM of a current stage using a teacher's map and a learner's CM of previous stage, and passes it to the communication agent for visualization. The agent-expert also delivers a teacher's CM and corresponding ontology to the knowledge evaluation agent for a comparison.

The communication agent perceives the learner's actions and is responsible for visualization of CM received from the agent-expert, and for the output of feedback received from the knowledge evaluation agent. The knowledge evaluation agent compares a learner's CM with a teacher's map and a corresponding ontology, and recognizes synonyms and several patterns (correct or incorrect) of learner's solution. Patterns of solutions are subgraphs, for example, a learner's defined relationship exists in a teacher's map but the type of relationship is incorrect, or a learner's defined relationship exists in a teacher's map, concepts and names of relationships are correct, but at least one of the concepts is placed in an incorrect place, etc. The interaction registering agent after receiving a learner's solution and its assessment, stores them in a database.

Two versions of prototypes of the IKAS already have been implemented. The first prototype has been developed using the following tools: Borland JBuilder 9.0, JGraph, PostgreSQL DBMS 8.0.3 and JDBC drivers for PostgreSQL. It is a Web based application and has the convenient graphical user interface that supports concept map building both for teachers and learners. The prototype supports process oriented learning and allows a teacher to extend the initially created CM for the new stage of assessment. A novel algorithm for comparison of teacher's and learner's concept maps has been developed and implemented in the system [4]. This algorithm is sensitive to the arrangement and coherence of concepts. For all that this prototype has limited capabilities to change the degree of task difficulty and has not enough informativeness of used feedback. Actually this prototype has not adaptability at all because all learners can receive only a given structure of a concept map of the current stage where a teachers predefined concepts are already filled out. The number of concepts and links is unlimited because scrolling is used for displaying a CM. The task of a learner is to put concepts from a given list in correct places. At the next stage a learner can see an extended CM where only correctly placed concepts are given. Concepts placed incorrectly as well as new ones are given in corresponding lists.

These drawbacks have been eliminated in the second prototype which has been implemented using open code environment Eclipse 3.2 for code generation and several other tools, such as, JGraph for graph building and editing, PostgreSQL as database management system, etc. This prototype is much more adaptable to each learner's knowledge level, because it supports both tasks ("fill-in" and "build a map") and can change the degree of task difficulty.

The IKAS is operating in two modes. In the first mode only "fill-in" tasks are available. During a task performance, a learner can ask to reduce the degree of task difficulty, and the system inserts additional concepts into a structure of a given CM. Reduction of task difficulty has two steps. First, the analysis of learner's CM is carried out, incorrectly inserted concepts are removed and added to a list of concepts. Second, a learner chooses the number of concepts he/she wishes the system would insert. The system reacts by inserting additional concepts according to the degrees of free nodes of CM. This is the duty of agent-expert which provides adaptation to each learner's current knowledge level [38].

In the second mode, both "fill-in" and "build a map" tasks are used which provide additional adaptive capabilities of the developed system. Five tasks have been selected starting with the easiest one where a structure and linking phrases are given but concepts must be inserted, and ending with the most difficult task where a concept map must be constructed if only lists of concepts and linking phrases are given [34, 35]. At the first stage, a learner receives a task which has a teacher's predefined degree of difficulty (usually it is a medium degree). During the task performance, a learner can ask to reduce the degree of task difficulty. If a learner has reached a teacher's specified score without reducing the task difficulty, the system increases the task difficulty at the next stage.

The IKAS has been tested in four different study courses (engineering courses as well as courses of social sciences). Around one hundred students have been involved in testing. Approximately 70% of students found that for them given tasks based on CMs were difficult. More detailed analysis revealed that it is true mainly for students of the social science study programme. Students of the computer science study programme who were familiar with various diagrams used is software engineering achieved much better results because they can easily understand interpretation of CMs.

It is noticed that only one third of students used a possibility to reduce the degree of task difficulty (others did not want to reduce their score). They agree that this possibility has facilitated the further performance of the task. For one third of students the IKAS increased the degree of task difficulty after the successful completion of the task at the previous stage. In total, 62% of students answered that the work with the system helped them to create their knowledge structures.

5. CONCLUSIONS

In this paper is presented an approach based on usage of study course ontologies, which are transformed into CMs. The implementation of the proposed approach is already ongoing, and two prototypes of the IKAS (part of the ITS under development) have been implemented and tested. Full functionality of the architecture of such a system will be implemented within a new project that started this year. This new version will provide more flexible knowledge assessment taking into account semantics of relationships. The future work is also directed towards improvement of feedback given to a teacher and to each individual learner. In addition, to reach the final goal – to develop truly intelligent adaptive tutoring systems, it should generate recommendations and should choose a learning material that learners should revise to fill gaps in their knowledge structure.

Despite that a lot of work is needed to implement the developed conceptual model of ITS in which intelligent agent and KM perspectives are integrated, the prototype has a good potential for a further evaluation and research. A synergy effect is expected from such kind of integration especially in a hybrid or blended course development where course contents are partly taught in a traditional face-to-face manner in auditorium, and partly using distance learning facilities.

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