Conceptual Model for Ontology-based Adaptive Assessment System

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ABSTRACT
The paper describes an attempt to extend traditional adaptive assessment of student's knowledge with the tasks based on the concept maps. The rules how to generate concept maps from ontologies are also proposed, as well as suggestions given how to use ontologies for student's created concept map's evaluation. The conceptual model of system's architecture is described.

Categories and Subject Descriptors
K.3.1 [**Computers and Education**]: Computer Uses in Education – *distance learning*.

General Terms
Algorithms, Design, Experimentation.

Keywords
Adaptive assessment, concept map, ontology.

1. INTRODUCTION
Rapid penetration of computer technology into education has changed forms of teaching/learning. Different new forms and ways, like computer-assisted training, computer-supported learning, internet- and web-based teaching, online education and other have appeared [2]. Education from teacher-centered activity has become student-centered [27]. Not only teaching/learning has changed, but also new trends have emerged into students testing, knowledge assessment and evaluation. One of these is computer-based assessment where a computer is used for test delivery and evaluation of student answers. The following terms: computer-aided assessment, computer-based assessment, computer-based testing, e-assessment, online assessment, technology-enhanced assessment, etc., are used to describe shades of used technology for assessment or characteristics of assessment process. More details of the terms formative words can be found in [2].

Traditionally, in computer-based testing a student receives a set of questions formed from one or more types of questions with already pre-defined answers [7]. Mainly questions are multiple choice questions, multiple response questions, graphical hotspot questions, fill in blanks, text/numerical input questions and matching questions [9]. Most of the learning management systems (for example, Blackboard (www.blackboard.com), WebCT (www.webct.com)) have built-in mechanisms to operate with the tests. They support input for different types of questions, test item pool creation, functions for test items randomised display, setting up time limits for testing sessions, test answers evaluation and automatic grading. This kind of knowledge assessment has several advantages in comparison with paper-and-pencil testing, such as greater flexibility regarding place and time of assessment, potential for providing assessments for large number of learners efficiently, instant feedback to learners, extensive feedback to teachers, reduced errors in comparison with human marking, decreased time needed for supervising and marking of assessments, and potential for frequent assessments, statistical data collecting about student achievements, typical errors etc., [15, 17, 21, 26]. However, these systems don't exploit all possibilities that can be offered by computer-assisted assessment. More considerable is a special type of computer-based testing, i.e., computer-assisted adaptive assessment [16, 22, 28], where the student receives more difficult or easier test items, depending on his/her previous testing results, i.e., the sequence of the test items depends on the answer given to the previous test item. If the answer is wrong, next item will be easier; otherwise the item will be more difficult.

This paper describes novel attempt to improve adaptive assessment, i.e., not only to assess knowledge, but also assess its structure. There is proposed to use concept map-based tasks for students testing. The remainder of this paper is organized as follows. The next section describes main advantages of adaptive assessment, and possibilities of using concept maps in it. Then differences in the concept map-based tasks are discussed. After that rules for concept map generation from ontologies are presented. In the last sections the model of the assessment system as well as conclusions and future work is given.

2. ADAPTIVE ASSESSMENT
Traditionally computer adaptive testing is based on the so called Item Response Theory (IRT) [14, 16, 22, 23], where multiple-choice questions are used. IRT is statistical framework in which students are described by ability scores that are predictive through mathematical models, linking actual performance on test items,

item statistics and students abilities. Computer adaptive testing can may be implemented when an item bank exists with IRT item statistics available on all items [23]. The main advantages of computer adaptive assessment are the following [22, 28]:

- Students' knowledge levels are more accurately estimated, especially for high and low achieving students. Reducing negative psychological effects (despondence or test anxious for not so able students, because they don't need to give answers to difficult questions, and boredom for very able students, because they don't need to answer simple questions).
- Tests are shorter, because fewer items are needed to obtain reliable results about students' knowledge level.
- Assessment results are immediately available.
- Interactive questions with multimedia support is possible to define.

But despite of the range of advantages mentioned above this testing doesn't support sufficiently wide and comprehensive knowledge assessment. Those tests don't allow to assess student's knowledge structure, i.e., how he/she has understood relations between concepts or how new concepts are connected with the previously mastered concepts.

We propose to use concept map based tasks as test items for assessment, which allows to assess students' mastery of concepts and their relationships. This is a way to see the students' cognitive structure i.e., their knowledge structure. Each test item is some kind of the tasks based on the concept maps. The concept maps as the teaching/learning tool are used already from the beginning of 1980's [19]. Concept maps are graphs, which include concepts as nodes and relations between them as arcs, for organizing and representing knowledge. Sometimes there are words, called linking phrases or labels on the linking arcs. Usually concept maps are represented in a hierarchical fashion with most general concepts at the top of the map and the more specific concepts are placed at the lowest levels of the hierarchy [18]. Only after computer has become a widespread tool in education, concept map based tasks become popular, because use of computers prevented range of drawbacks of concept map construction on paper [5, 6]:

- Students have difficulties with their concept map revision and refinement. In computer-assisted concept map construction it is easy to add new concepts, to arrange them and to add/remove links.
- It is impossible to teachers to provide all students with necessary feedback during concept map construction, at the same time computer-assisted systems can provide students with different feedback, hints helping them to construct concept maps.
- Teachers need to spend significant time and effort to evaluate students' concept maps. Computer-assisted systems not only facilitate evaluation, but also provide them with statistics about students' achievements.

Analysis of literature showed that different computer-assisted systems exist for students knowledge assessment based on tasks connected with concept map construction. Those systems differ not only in tasks needed to solve, but also in used conceptual structures, like concept maps [3, 4, 5, 6, 12, 24, 25], semantic networks [10, 11], ontologies and genetic algorithms [8].

3. DIFFERENCES IN CONCEPT MAP BASED TASKS

Search for the literature in the field reveals that the tasks based on concept maps are quite different. First of all, concept maps themselves are different. Concept maps can be with or without labels on the links between concepts, links are directed or not, with or without cycles, the structure is hierarchal or with crosslinks, links have the same or different weights, i.e., some links are more important than others [1, 4]. Second, tasks can be different. In [24] it is proposed that tasks differ at the degree of directedness. Tasks can be ranged from high-directed to low-directed depending on information provided to the students. In the high-directed tasks students are provided with the concept map structure and the list of concepts for filling in the provided structure. In the low-directed tasks students need to define concepts and their connection structure by themselves. Studies of [24] showed that all tasks could be divided into fill-in tasks where concept map's structure is provided and construction tasks where students themselves need to create a concept map's structure.

Fill-in tasks also can be different, depending on whether students need to fill-in only concepts or also labels on links (so, called linking phrases) or they need to define concepts or linking phrases. Provided concept map structure also can be different, are there already filled linking phrases or not, or may be links are marked with weights (for instance, important and not so important links) and how many concepts are already filled-in by the system.

In construction tasks system doesn't provide the structure for the concept map. Lists of concepts or linking phrases can be provided or students need to define them by themselves. Construction tasks can differ not only with map's elements that students need to define, but also with constraints about structure of concept map, for example, the structure should be hierarchal. There can be remarks about the size of the concept map, too.

Previously mentioned task differences allow to conclude that the concept maps are suitable for adaptive assessment. Each student can be provided with the task of the appropriate level of difficultness. The Table 1 summarises most important tasks based on the concept maps. In the Table 1 tasks are ranged from the easiest to more difficult. First, tasks Nº1 till Nº6 are fill-in tasks where some kind of the map's structure is given, as well as concept and/or linking phrase list. Then for the tasks Nº7 and Nº8 the structure is given, but some elements are needed to be defined. And the last group of the tasks (Nº9 to Nº14) are construction tasks, where the structure isn't given, but the list of concepts can be given or not.

The level of difficultness for each task can be also varied. A different number of already filled concepts and a number of blank places provides tasks with the different level of difficultness.

Taking into account how many different concept map-based tasks exist, adaptiveness to students' knowledge level can be developed in different ways. First, it is possible to use all or majority of the concept map-based tasks. In this case, for instance, testing could begin with the task Nº7, where the empty structure and the list of the concepts is given, but linking phrases need to be defined. If this task turns out to be too difficult then easier task is proposed, for example task Nº3, where structure with already filled-in linking phrases and list of the concepts is given. Second way to implement adaptiveness is to work within the framework of one task. For example, task Nº1, where the list of concepts and the structure with few filled-in concepts is given. If this fill-in task turned out to be too difficult for a student, then the task is made easier. The student receives the same structure, but with more filled-in concepts. Thus student has to fill-in less concepts than in the previous task.

Table 1. Concept map based tasks

	Concept list	Linking phrase list	Structure: Empty	Structure: With few filled concepts	Structure: With filled all linking phrases	Structure: With weighted links	
1	G			G			Fill-in tasks
2	G		G				Fill-in tasks
3	G				G		Fill-in tasks
4	G					G	Fill-in tasks
5	G	G		G			Fill-in tasks
6	G	G	G				Fill-in tasks
7	G	N	G				
8	N			G			
9	G		N				Construction tasks
10	G					N	Construction tasks
11	G	N	N				Construction tasks
12	N		N				Construction tasks
13	N					N	Construction tasks
14	N	N	N				Construction tasks

G-is given
N-need to define

4. CONCEPT MAP GENERATION FROM ONTOLOGY

An ontology after its definition [20] "is a formal explicit description of concepts in a domain of discourse (classes (sometimes called concepts)), properties of each concept describing various features and attributes of the concept (slots (sometimes called roles or properties)), and restrictions on slots (facets (sometimes called role restrictions))". Classes describe concepts of the domain and they are placed hierarchically. The same is true for concepts in the concept maps. In addition, properties and their values can be perceived as concepts, too.

On the basis of previously described characteristics of ontology and its obvious similarities with concept maps, concept maps used in tasks for students are proposed to be generated from the course ontology build by the teacher of the particular course. To transform the course ontology in the concept map the following rules are defined:

1. An ontology's class, a property of the class, a value of the property and an instance corresponds to the concepts in the concept map.
2. Relationships between ontology's concepts correspond to links in the concept map:
   a. if the relationship doesn't have a label, the link will have a range of labels {"is-a", "part-of," "has-a-part", "contains", "consists", "consists-of", "includes"};
   b. if the relationship between concepts has a label, the link has the corresponding label;
   c. links can be without labels, if the task doesn't need them at all.
3. The link between concepts which correspond to the ontology's class and its property, always has a label "has-a".
4. The link between concepts which correspond to the property of the class and the value of the property, always has a label "is".
5. The direction of link in the concept map corresponds to the relationship direction in the ontology.

Main correspondences between the elements of the ontology and the elements of the concept map are shown in Figure 1.

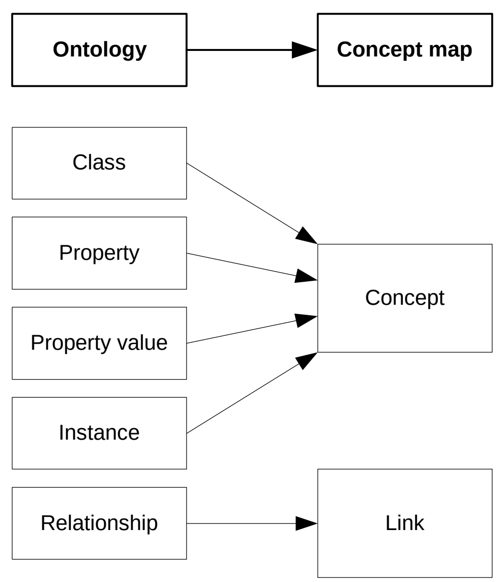

Figure 1. Ontology transformation in concept map

Protégé (available at: http://protege.stanford.edu/) which is one of well-known, freely available ontology development tools is used to create an example ontology. This tool can be upgraded with different plugins. The ontology for one topic of the course "Methods of Systems' Theory" has been defined and shown in Figure 2.

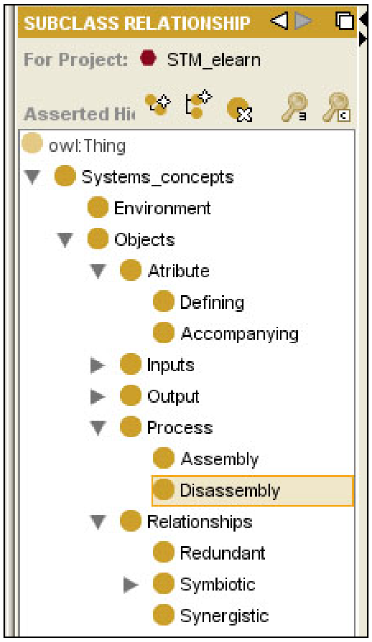

Figure 2. An example of ontology

The example ontology is transformed into a concept map (see, Figure 3) using rules defined above. In the given example the ontology is transformed into the concept map without link labels for the simplest assessment task, i.e., fill-in task, where students have been provided with the list of concepts needed to be filled-in.

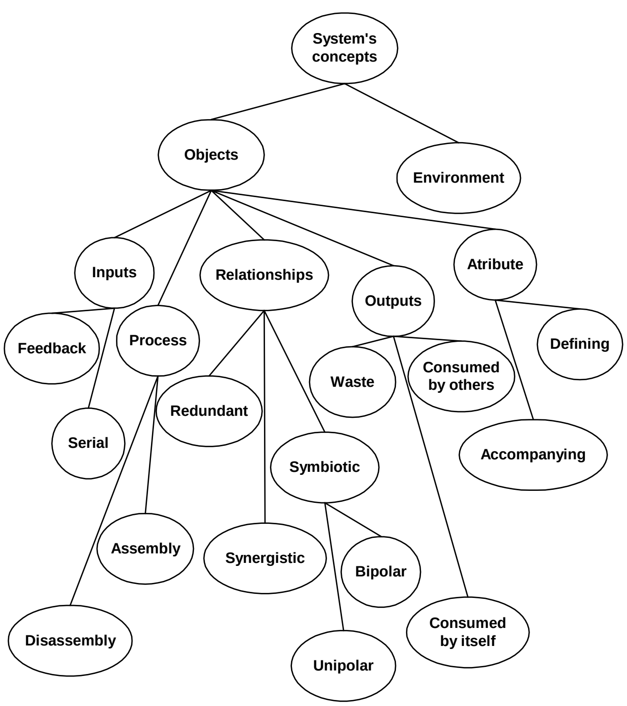

Figure 3. A corresponding concept map

After the concept map is generated it is adjusted for the necessary concept map-based task, like as in this example, where the concept map is generated without labels and it can be used for tasks N°1, N°2, N°8, N°9 and N°12 where labels aren't used.

In proposed concept map-based assessment, ontologies are used not only as the way to store knowledge structure for the task generation. After the concept map is constructed, the ontology is used once more. This time the ontology plays the role of the standard concept map, with which students' maps are compared to assess student's knowledge. Use of the ontology gives opportunity to make better comparison of corresponding maps due to additional knowledge (synonyms, constraints, inverse relations, etc.) stored in the ontology [3].

In case of fill-in tasks ontology is used for concept map's structure and concept list generation as well as for student's map evaluation. In construction tasks the ontology is mainly used for evaluation and, if necessary, also for the concept list generation. Literature search has showed that only in year 2004 ontologies are used the first time in the concept map-based tasks. In [8] it is proposed to use ontologies in the concept map evaluation to determinate semantic distance between two concepts, which are included in student's created concept map.

5. CONCEPTUAL MODEL OF SYSTEM'S ARCHITECTURE

System's architecture, which realizes concept map-based adaptive assessment, is based on the paradigm of intelligent agents. Since assessment system is intended to be a part of intelligent tutoring system, which architectures traditionally is agent-based [13], also assessment part as well is agent-based. All assessment system's functions are built-in in intelligent agents. The assessment agent and the remedial agent form assessment system's core as it depicted in Figure 4. Main functions of the assessment agent are the following:

- to generate concept map based task with appropriate level of difficultness;
- to compare students' constructed concept maps with course ontology (called also as a standard ontology);
- to provide students with appropriate feedback and score after concept maps are constructed and submitted;
- to analyse submitted concept maps to determine whether the given task is appropriate (not too easy or too difficult);
- to analyse submitted concept maps to determine which concepts are incomprehended; non-mastered concepts are forwarded to the remedial agent.

Main functions of the remedial agent are the following:

- to find appropriate additional learning material to help students learn non-mastered concepts;
- to deliver additional materials to students.

Three databases form data storages for the course ontology, students' concept maps and learning materials, respectively. These databases are used and processed by the main agents:

- Course ontology DB stores teacher created course ontologies, which are used for concept map based task generation and appropriate additional learning material searching after student has submitted his/her answer.

- Students' concept maps DB stores all concept maps, which students have submitted. Analysis of submitted concept maps helps the system to generate task with appropriate level of difficultness in the next step of assessment and provides teacher with statistical data about typical errors.
- Learning materials DB stores slides, texts, diagrams needed for improvement of students' knowledge. Appropriate learning material is chosen after student has submitted his/her answer and misunderstandings, as well as after non-mastered concepts and missing knowledge are detected.

Assessment part of intelligent tutoring system has two types of users, the teacher and the student. The teacher inputs course ontology and learning materials and receives feedback about students achievements. The student get tasks from the system, submits filled concept maps, receives hints during task solving and feedback after answers are submitted as well as additional learning material to improve discrepancies in knowledge.

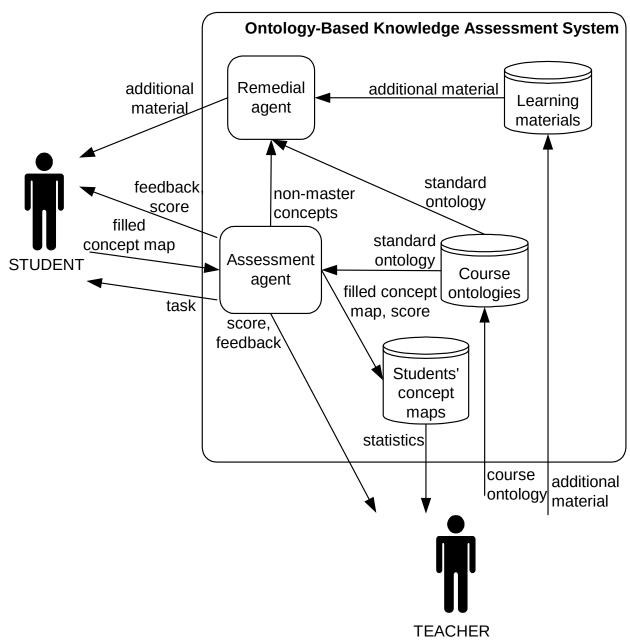

Figure 4. Data flow within ontology-based knowledge assessment system

In addition to already mentioned agents, full-fledged system's functionality would be provided with other agents [13], like communication agent, which supports interaction between the user and the system, i.e., user interface, including task, feedback, score and material visualization, student's modelling agent which builds student's profile of his/her psychological characteristics, learning preferences and styles, and other tutoring agents for teaching strategy and curriculum support.

6. CONCLUSIONS AND FUTURE WORK

This paper describes the attempt to improve adaptive assessment of student's knowledge, i.e., not only to assess knowledge, but also assess its structure. There is proposed to use concept map-based tasks instead of multiple choice questions for students testing. Most important advantages of adaptive assessment and possibilities of using concept maps in adaptive assessment are given. Differences in the concept map tasks are presented. At least two alternatives of providing adaptiveness with concept map-based tasks are discussed. The rules how to generate concept maps from ontologies are also proposed, as well as suggestions given how to use ontologies for student's created concept map's evaluation. The conceptual model of system's architecture is suggested.

At the moment the analysis of the described possibilities is at its early stage. A lot of work is needed to implement proposed conceptual model as a whole. The nearest planned task is to develop a tool for concept map generation from ontology and further studies of the methods how to determine is given task appropriate for the student or not. The next step is to implement algorithms for students' concept maps evaluation. After that testing of proposed system is planned for different types of study courses, i.e., IT, engineering, social sciences.

7. ACKNOWLEDGMENTS

This work has been partly supported by the European Social Fund within the National Program "Support for the carrying out doctoral study program's and post-doctoral researches" project "Support for the development of doctoral studies at Riga Technical University".

The main results are outcomes of the research project "Concept maps and ontology based intelligent system for student knowledge self-assessment and process oriented knowledge control".

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