CHANGING THE DEGREE OF TASK DIFFICULTY IN CONCEPT MAP BASED ASSESSMENT SYSTEM

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ABSTRACT

The paper describes concept map based knowledge assessment system which supports systematic learners' knowledge assessment. The novel approach is used which is related with changing of the degree of task difficulty. The system maintains five concept map based tasks of different difficulty which are given to learners. The paper describes the procedure of concept map usage in systematic assessment, tasks implemented in the system and the scoring mechanism of the task completed by the learner. Testing results of the developed system in the learning course are provided. Implementation details and used technologies are described in brief.

KEYWORDS

Concept map, knowledge assessment, task difficulty.

1. INTRODUCTION

Learning is a purposeful activity which success depends on its regulation by means of assessment of learners' knowledge and skills. According to the didactic principles knowledge assessment should be systematic and individual (Zelmenis, 2000). Regular assessment is closer to the nature of learning which is characterized by continuous accumulation and integration of knowledge (Pratt, 1994). Learners are diverse in their needs and interests, talents and abilities, knowledge and skills, temperament and character. More accurate assessment of a knowledge level of a particular learner can be achieved by taking into account individual features of learners.

Concept maps developed by Novak in 70th years of 20th century are widely used in the traditional learning process, inter alia for knowledge assessment. According to (Cañas, 2003) they allow to externalize and make explicit the conceptual knowledge (both correct and erroneous) that learners have in a problem domain. A concept map is represented as a graph with labeled nodes that correspond to concepts in a domain and with arcs that indicate conceptual relationships between pairs of concepts. Arcs can be directed or undirected and with or without linking phrases on them. Linking phrases specify the essence of a relationship between concepts. Moreover relationships of different types can be used in concept maps. For example, in (Anohina et al., 2006) important relationships and less important relationships are included. Important relationships show that relationships between the corresponding concepts are considered as important knowledge in the learning course. Less important relationships specify desirable knowledge. Semantic units in concept maps are propositions stated by concept-link-concept triples (Cañas, 2003). They are meaningful statements about some object or event in the domain. Typically concept maps are represented in a hierarchical fashion with the most inclusive, most general concepts at the top of the map and the more specific, less general concepts arranged below (Cañas, 2003). A particular hierarchically related group of concepts is referred as a segment of a concept map. At the same time concept maps allow to display non-hierarchical relationships by using cross-links. They make explicit relationships between or among concepts in different segments of a concept map. In practice, concepts in concept maps are not arranged in a strict hierarchy, but are arranged in a semi-hierarchical manner (Cañas, 2003).

As an instrument for knowledge assessment concept maps are usable in any stage of the learning course: at the beginning of teaching in order to determine knowledge which the learner already has, during the teaching itself to identify changes in learner's knowledge, and at the end of the learning course in order to determine the achieved knowledge level. Concept maps are valuable for systematic assessment in the learning course because they provide important information both to the learner and to the teacher. The learner can make sure that learning material and relationships between studied concepts are correctly understood, and reveal problems timely. The teacher can keep track of learners' understanding of learning material and their misconceptions, and to make corrections when necessary.

Concept maps allow to offer tasks of various degrees of difficulty therefore providing basis for individual knowledge assessment. These tasks vary in a range from “fill-in tasks” to "construct-a-map tasks". In “fill-in tasks” learners are provided with a blank structure of a concept map and lists of concepts and/or linking phrases which they should insert into the structure. “Construct-a-map tasks” allow learners to construct their concept maps freely by choosing which concepts and how many of them should be included and how they will be related in their maps. In (Ruiz-Primo, 2004) the variety of tasks is described taking into account what is provided, how much is provided and how relevant it is, as well as what the learner should do.

However, concept maps constructed by pencil and paper are difficult to revise, as well as the teacher cannot effectively provide appropriate feedback to learners during concept mapping. These difficulties cause efforts to build computer-based concept mapping software which helps learners to construct concept maps and supports teachers in their revising and assessment. There is a number of commercial and non-commercial concept map based graphical software tools, for example, AXON Idea Processor (web.singnet.com.sg/~axon2000/), Inspiration (www.inspiration.com), IHMC CmapTools (cmap.ihmc.us), which provide such functions as concept map construction, navigation and sharing, but do not assess created concept maps.

In contrast, a concept map based assessment tool COMPASS (Gouli et al., 2004) is a Web-enabled system that provides assessment of the learners’ knowledge level through various concept mapping tasks and supports the learning process by generation of informative, reflective and tutoring feedback tailored to the needs and characteristics of a particular learner. The system incorporates different activities for different outcomes: construction of a map, evaluation/correction, completion and extension of a given map, as well as combinations of the mentioned tasks.

The other example of an assessment tool based on concept maps is described in (Chang et al., 2001). It has two versions: one of them supports the task of filling in the blanks of an incomplete structure of a concept map, other offers opportunity to construct a concept map freely. Both versions provide evaluation and hint functions.

The online Web-based concept map testing system WCOMT (Tsai et al., 2001) offers series of fill-in questions. Each question is nothing more than a fragment of a concept map with one or more blank places which the learner should fill in without any suggestions from the system.

In spite of the fact that the mentioned systems support knowledge assessment, they consider assessment as a discrete event. So they are not suitable for systematic knowledge assessment. Moreover they offer the same task to different learners and do not support individual knowledge assessment. The paper presents a concept map based knowledge assessment system which implements a novel approach solving both mentioned problems. It supports systematic knowledge assessment by extension of the initially created concept map for the new stage of assessment and provides possibility to vary the degree of task difficulty.

The remainder of the paper is organized as follows. Section 2 describes the conception of the developed system focusing on concept map formation procedure, tasks offered to learners and scoring system. Some implementation details of the system are presented in Section 3. Evaluation results of the system in the learning course are given in Section 4. The last section presents conclusions.

2. CONCEPTION OF THE SYSTEM

2.1 Concept Maps Usage for Systematic Knowledge Assessment

The idea to use concept maps for systematic knowledge assessment is based on such their feature as easy extensibility through addition of new concepts and relationships. The majority of learning courses include a certain set of concepts, which learners should master during the learning process. These concepts are introduced sequentially. Therefore, it is possible to determine logically completed stages of the learning course when learners have acquired a set of closely related concepts. A stage can be a chapter of the learning course or a topic. Implementing systematic knowledge assessment control is carried out at the end of each stage to determine whether learners have mastered the current learning material and moreover, whether they have related it with materials of previous stages. The paper offers to use concept maps for such control using the following concept maps formation procedure.

The teacher prepares concept maps for each stage of the learning course and assesses knowledge at the end of each stage. The concepts taught to learners at the first stage of the learning course and relationships between them are included into the first concept map of the learning course. At the second stage learners acquire new concepts. The teacher extends the initial concept map by adding new concepts, but does not change the relationships among already existing concepts. Thus, a concept map of each stage is not anything else than extension of a concept map of the previous stage. A concept map of the last stage displays all concepts in the learning course and relationships between them. Figure 1 shows the idea of concept maps usage for systematic knowledge assessment (Anohina and Grundspenkis, 2007).

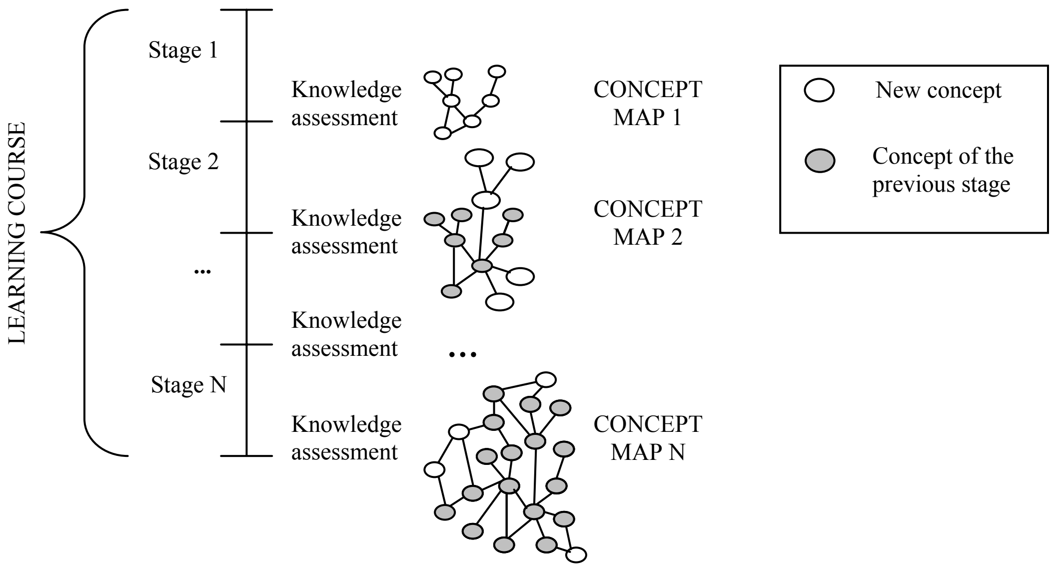

Figure 1. The usage of concept maps for systematic knowledge assessment

2.2 Tasks and Their Degrees of Difficulty

A variety of concept map based tasks allows to offer tasks with different degrees of difficulty and therefore to assess more accurately a knowledge level of a particular learner. Five tasks have been selected which are logical and realizable from the point of view of transitions among them (Anohina and Grundspenkis, 2007). There are both "fill-in" and "construct-a-map" tasks. The tasks are ranged from the easiest to the most difficult based on information given to the learner and workload needed to complete the task (Table 1).

In order to support different learners it is necessary to provide a possibility to change the degree of task difficulty. There are two time moments when it may be done: during the task performance and after receiving the learner's solution. In the first case it is based on the voluntary request from the learner and is performed using a special tool, for example, a button. The second case is an adaptive system's reaction to the learner's actions. Adaptation after receiving the learner's filled or created concept map is made on the basis of the analysis of learner's score. For this purpose the teacher should define percentage value from maximum score for the task of the given stage. If the learner will reach the preset value the degree of task difficulty at the subsequent stage will be increased.

Table 1. Tasks for the concept map based knowledge assessment system

The type of the task	Ordinal number of the task	The structure of a concept map	Linking phrases	Concepts	Degree of task difficulty	Comments
Fill-in	1	Is given	Inserted in the structure	Need to be inserted	The easiest ↓	Linking phrases that are inserted in the structure can help to find where a particular concept should be inserted
	2	Is given	Are not used	Need to be inserted	↓	There is not any information which would allow to understand, where a particular concept should be inserted
	3	Is given	Need to be inserted	Need to be inserted	↓	There is not any information which would allow to understand, where a particular concept should be inserted, as well as the amount of work is increased
Construct-a- map	4	Is not given	Are not used	Need to be related	↓	
	5	Is not given	Need to be inserted	Need to be related	↓ The most difficult	The amount of work is increased in comparison with Task 4

At the first stage the learner receives the task which has the teacher's pre-defined degree of difficulty. During the task solving the learner can request to reduce the degree of difficulty. In this case the transition is performed, reducing the ordinal number of the task by 1 (Table 1). Of course, it is not valid for the first task. The learner can request to reduce the degree of difficulty several times during the same stage. In the subsequent stages the degree of task difficulty depends on the learner's result in the previous stage. If the learner has reached teacher's specified number of points without reducing the degree of difficulty of the original task, the degree of task difficulty at the subsequent stage is increased by 1 (by number in Table 1). Otherwise the degree of difficulty remains the same. The process continues until the learner reaches the highest degree of difficulty or performs the tasks of all stages. Let's consider an example. The teacher has chosen Task 3 as an initial degree of difficulty. The learner receives this task at the first stage of assessment and completes it successfully, having reached the number of points specified by the teacher. At the second stage the system offers more difficult task, i.e. Task 4. Suppose that the learner cannot complete it and reduces the degree of difficulty. Task 3 is given to him/her again. Repeatedly reducing the degree of difficulty the learner receives Task 2. He/she completes it and at the following stage the system offers Task 2 because previously the degree of difficulty was reduced.

Thus eight transitions between tasks are implemented in the system (Figure 2). Transitions A, B, C and D are transitions that increase the degree of task difficulty. They are carried out after the receiving and analysis of the learner's solution. This is a system’s adaptive reaction to the learner’s behavior. Transitions E, F, G and H are transitions which reduce the degree of task difficulty. They are carried out by voluntary request from the learner.

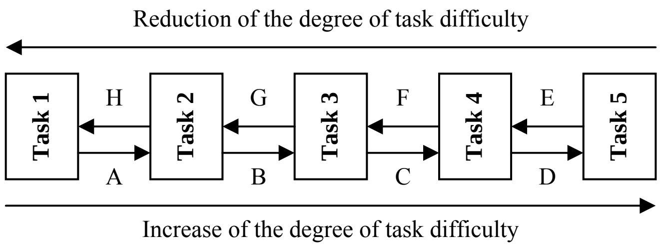

Figure 2. Transitions between concept map based tasks

2.3 Scoring System

The algorithm that compares the teacher’s and the learner’s concept maps and is sensitive to the arrangement and coherence of concepts has been developed. It allows to recognize possible patterns of learner's solutions. Taking into account, that a value of the fully correct relationship between concepts is 100 %, the following contributions of particular parts are defined:

- presence of the relationship in the learner's concept map - 40% (a fact that the learner understands presence of relationships between concepts has the primary value);
- correct linking phrase - 30 % (semantics of relationships are important knowledge units);
- correct type of the relationship - 20% (the learner should be able to distinguish, what is important and what is less important in the learning course);
- both concepts related with relationship are placed in correct places - 10% (this factor has the greatest subjectivity).

Thus, the learner’s solutions which the system is capable to distinguish are the following:

Pattern 1. The learner has defined a completely correct relationship. In this case the learner receives 5 points regarding every important relationship and 2 points for less important relationship.

Pattern 2. The learner has defined a relationship, which does not exist in the concept map of the teacher. In this case he/she does not receive any points.

Pattern 3. The learner’s defined relationship exists in the teacher’s map, both the type of the relationship and the linking phrase are correct, but at least one of concepts is placed in an incorrect place. The learner receives 90% from maximum score for that relationship.

Pattern 4. The learner’s defined relationship exists in the teacher’s map, but the type of the relationship is incorrect. The learner receives 80% from maximum score for the correct relationship. This pattern is characteristic only for "construct-a-map" tasks (tasks 4 and 5 in Table 1) where places of concepts are not important.

Pattern 5. The learner’s defined relationship exists in the teacher’s map, but the linking phrase is incorrect. The learner receives 70% from maximum score for the correct relationship.

Pattern 6. The learner’s defined relationship exists in the teacher’s map, the type of the relationship is incorrect, and at least one of concepts is placed in the incorrect place. The learner receives 70% from maximum score for the correct relationship.

Pattern 7. The learner’s defined relationship exists in the teacher’s map, the linking phrase is incorrect, and at least one of concepts is placed in the incorrect place. The learner receives 60% from maximum score for the correct relationship.

Pattern 8. The learner’s defined relationship exists in the teacher’s map, but both the type of the relationship and the linking phrase are incorrect. The learner receives 50% from maximum score for the correct relationship. This pattern is characteristic only for "construct-a-map" tasks (tasks 4 and 5 in Table 1) where places of concepts are not important.

Pattern 9. The learner’s defined relationship exists in the teacher’s map, both the type of the relationship and the linking phrase are incorrect, as well as at least one of concepts is placed in the incorrect place. The learner receives 40% from maximum score for that relationship.

The learner's score assessing the learner's solution of the task is calculated using the following equation:

$$P = \sum_{i=1}^{n} lk_i * p_i * c_i \,, \qquad (1)$$

where P- the learner's score for the given task;

lk_i- the coefficient of the degree of difficulty for the given task;

p_i- maximal score according to the type of i-th relationship (5 points for each important relationship and 2 for less important relationship);

c_i- the coefficient which corresponds to the degree of i-th relationship's correctness (based on previously described patterns);

n- number of relationships in the teacher's concept map.

The concept map of the current stage can contain relationships which were defined in the previous stages on different degrees of difficulty. Therefore, the coefficient lk_i is assigned to each relationship, but not to the whole task. Assignment is made during the task performance and depends from the degree of task difficulty:

- for Task 1 and Task 2 the coefficient is assigned to a relationship when the learner inserts or changes concepts related with this relationship;
- for Task 3 a relationship acquires the coefficient if the learner inserts the concept related with this relationship or he/she changes the linking phrase on the relationship;
- for Task 4 the coefficient is assigned to a relationship when the learner creates a new relationship or he/she changes the linking phrase of the existing relationship;
- for Task 5 a relationship acquires the coefficient if the learner creates the relationship, changes the linking phrase on the relationship or the type of relationship.

The following values of the coefficient lk_i have been found empirically by analyzing 10 different concept maps: Task 5 – 1; Task 4 – 0.71; Task 3 – 0.89; Task 2 – 0.65; Task 1 – 0.67.

3. IMPLEMENTATION DETAILS AND USED TECHNOLOGIES

The conception described in Section 2 has been implemented in the Web-based system which is composed of three modules. The modules provide a set of functions for a particular category of system's users. Module of administrator helps to maintain the system, providing such functions as data adding, editing and deleting. The data are related with the system's users, learners, teachers, learning courses, and so on. The teacher's module supports the teacher in the creation of concept maps and visualization of learners' results. The module of the learner provides performance of the task, comparison of learner's and teacher's concept maps, as well as receiving of feedback (Table 2). The modules interact sharing a common database which stores data about teachers and their learning courses, learners and groups of learners, teacher-created and learner-completed concept maps, learners' final score and system's users.

Table 2. System's functions for the teacher and the learner

System's user	Functions provided by the system
Teacher	• providing of information about learning courses taught by the teacher and about learners studying a particular learning course, as well as about the number of concept maps within a learning course, the maximum score, the publication status and the date of a particular concept map • setting/unsetting of a publication date of a particular concept map • tools for developing concept maps such as concept inserting, formatting and linking, defining of semantics of relationships, setting of publication date and initial degree of difficulty, concept map annotation, saving and zooming • tools for editing and deleting concept maps • tools for examining of learners' concept maps and score, as well as for deleting the learners' results • different possibilities for information searching and retrieval
Learner	• providing of information about learning courses studied by the learner and about concept maps within a learning course (stage, status of publication, and learner's score) • tools for filling and creating of concept maps such as concept adding and removing, defining of relationships and their semantics, as well as solution submission • tools for viewing feedback after the learner has submitted his/her solution

The system has been developed using the following tools: Borland JBuilder 9.0., JGraph, and PostgreSQL DBMS 8.1.3. The learner access the system using any browser, for example, Internet Explorer or Opera. If it is the first user's connection from the given computer, then the files of the client application are downloaded from the server on which the system is resided. The application according to a category of the user is installed on the computer. Otherwise checking is done, whether there are some updates of the client application, and only the updated files are downloaded. During the interaction with the system data exchanges take places between the database located on the server and the client application.

4. EVALUATION RESULTS

The system's experimental evaluation occurred in spring of the year 2007 in the learning course "Fundamentals of artificial intelligence", which is taught to the 3rd year students of the bachelors study program at the Faculty of Computer Science and Information Technology of Riga Technical University. Thirty students participated in system's evaluation and 28 of them filled out the questionnaire after the finishing of knowledge assessment.

The purpose of the questionnaire was to get students' opinion on the method of knowledge assessment, advantages and disadvantages of the developed system and an opportunity to change the degree of task difficulty. Questions were divided into 3 categories: 1) use of concept maps for knowledge assessment (4 questions), 2) changing of the degree of task difficulty (6 questions) and 3) usage of the system (9 questions). Totally 19 questions were included in the questionnaire.

The students positively evaluated concept map based knowledge assessment (19 students or ≈68%) and stated the desire to use it in other learning courses (23 students or ≈82%). The learners pointed out that such knowledge assessment helps to understand teaching material (19 students or ≈68%) because it shows its logic organization and interrelation.

In general, it was difficult for students to complete a concept map based task (16 students or ≈57%). They explained that such method of knowledge assessment is not used in other learning courses and thus is unusual, as well as that it is necessary to activate thinking processes. Twelve (≈43%) students from those, who had difficulties to complete a task, used the opportunity to change the degree of task difficulty. Others did not want to reduce a score. Nine (75%) respondents from those, who reduced the degree of task difficulty, have pointed out that it has facilitated the further performance of the task, and 3 (25%) students have disagreed with this assertion. In general, 11 (≈92%) students have found that after reduction of the degree of task difficulty the easier task was offered to them. The degree of task difficulty was increased for almost one third of students (9 students or ≈32%) after successful completion of the task of the previous stage. Eight (≈89%) from these students have found that the more difficult task was offered to them, especially, if it was necessary to complete a task of concept map construction. Thus, it is possible to conclude, that the transitions between tasks implemented in the system are logical.

Students positively evaluated the user interface of the system and pointed out that a feedback after the completion of the task in the form of the learner's concept map and mistakes displayed on it specifies what the learner does not know (18 students or ≈64%) and is demonstrative (17 students or ≈61%).

Students have specified three main possibilities to improve the system: teacher's concept map displaying after the completion of the tasks of all stages, providing of the help information about the usage of the system and resolution of the technical problems related with the access to the system through a proxy server and a firewall.

5. CONCLUSIONS AND FUTURE WORK

The developed system has three discriminative features in comparison with other systems based on concept maps. Firstly, the system supports systematic knowledge assessment and allows the teacher to extend the initially created concept map for the new stage of assessment. Secondly, the algorithm that compares the teacher's and the learner's concept maps and is sensitive to the arrangement and coherence of concepts has been developed. Thirdly, possibility to change the degree of task difficulty is included and allows more accurate assessment of a knowledge level of a particular learner. Results of experimental evaluation allow to conclude that the opportunity to change the degree of task difficulty is a useful system's function, taking into account that typically students have problems to complete a concept map based task.

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