Studying Possibilities to Use Several Experts' Maps in the Concept Map Based Knowledge Assessment System

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Abstract: *The paper is related to the problem of increasing objectivity of the assessment process of students' concept maps in the concept map based knowledge assessment system. It is proposed to solve the mentioned problem by the use of concept maps of several domain experts. Four different solutions are identified and analysed from the point of view of their feasibility and suitability for the current prototype of the system.*

Key words: *Concept Map, Expert's Map, Concept Map Integration.*

INTRODUCTION

The obvious fact is that the qualitatively different structure of domain knowledge and volume of knowledge encoded in this structure differ the expert from the novice. Therefore, educational institutions must use teaching and knowledge assessment methods directed towards fine development and assessment of students' knowledge structure in order to prepare students for their professional activity in better way. One of such methods is concept mapping.

A concept map (CM) is a semi-formal knowledge representation tool visualized by a graph consisting of finite, non-empty set of nodes, which depict concepts of a domain, and finite, non-empty set of arcs (directed or undirected), which express relationships between pairs of concepts. A linking phrase can specify the kind of a relationship between concepts. A proposition – "concept-relationship-concept" triple **-** is a semantic unit of CMs. It is a meaningful statement about some object or event in a problem domain [2].

There is a wide variety of CM based tasks [12]. However, two main groups of them are: a) "fill-in-the-map" tasks where the structure of a CM is given, and a student must fill it using the provided set of concepts and/or linking phrases, and b) "construct-the-map" tasks where a student must decide on the structure of a CM and its content by him/herself.

The step-by-step construction of a CM and a sequence of CMs constructed by a student can illustrate the evolution of person's understanding of the topic [9]. According to [2], CMs can foster the learning of well-integrated structural knowledge as opposed to the memorization of fragmentary, unintegrated facts and externalize the conceptual knowledge that students hold in a knowledge domain. The representation of knowledge structure is the topmost quality which substantiates the use of CMs as an alternative tool for knowledge assessment in relation to different forms of tests and essays.

Researchers from the Department of Systems Theory and Design of Riga Technical University have been developing the CM based **i**ntelligent **k**nowledge **a**ssessment **s**ystem (IKAS) since the year 2005. The system is implemented as a Web-based application which uses CMs as a tool for knowledge assessment. It has twofold goals in the context of the integration of technology into the traditional educational process: 1) to promote students' knowledge self-assessment, and 2) to support the teacher in the improvement of learning courses through systematic assessment of students' knowledge and analysis of its results.

In the current prototype of IKAS the only one expert's (teacher's) CM is used as an evaluation standard. This fact introduces certain subjectivity in the assessment process of students' CMs. Therefore, the present research problem is related to the studying of possibilities to use for evaluation purposes several experts' CMs created by different teachers of the same course/topic. Comparison with many experts' maps can be useful, because domain experts with different experiences could have different expertise or understanding of each portion of the knowledge [8]. Moreover, this scoring approach allows for a more open-ended response—one in which students can show their competency in a variety of ways—while still ensuring that only students' responses matching expert standards receive high marks [6].

The paper presents results of the preliminary analysis. The next section provides a short description of IKAS. After that, related works are considered. Then, possible solutions of the problem under consideration are presented. Conclusions and directions of future work are given at the end of the paper.

THE OVERVIEW OF IKAS

In general, IKAS is used in the following way. The teacher defines stages of knowledge assessment and creates CMs for all of them by specifying relevant concepts and relationships among them in such a way that a CM of each stage is nothing else then an extension of the previous one. Thus, the CM of the last stage includes all concepts and relationships among them. During knowledge assessment a student solves a CM based task corresponding to the assessment stage. After the student has submitted his/her solution, the system compares the CMs of the student and the teacher, calculates the score of the student and generates feedback. Two modes of system's operation are provided: a) a mode of knowledge self-assessment which purpose is to allow a student to assess his/her knowledge level and to learn more about a specific topic in case of incomplete knowledge, and b) a mode of knowledge control intended for the determination of students' knowledge level by a teacher.

At the moment, six tasks of different degrees of difficulty are offered: four of them are "fill-in-the-map" tasks and two tasks are "construct-the-map" tasks. Ten transitions between tasks are implemented. Five transitions increase the degree of task difficulty. They are carried out automatically by the system after the analysis of the student's solution if the student has reached the teacher's specified number of points without reducing the degree of task difficulty of the original task. Other five transitions reduce the degree of task difficulty after the voluntary request from the student during the solving of a task.

A teacher's created CM serves as a standard against which students' CMs are compared in the system. Moreover, a comparison algorithm [1] has been developed which is sensitive to the arrangement and coherence of concepts taking into account such aspects as existence of a relationship, locations of both concepts, type and direction of a relationship, correctness of a linking phrase, etc. Two types of relationships are used: a) important relationships (weighted by 5 points) showing that a relationship between concepts is considered as important knowledge units in a course, and b) less important (weighted by 2 points) relationships specifying desirable knowledge. At the moment, the system can recognize more than 36 different patterns of correct and partly correct propositions in students' CMs.

RELATED WORKS

There are two different approaches to usage of many experts' CMs for scoring of students' CMs: 1) using one criterion map created by several experts, and 2) using multiple maps created by several experts.

According to [10], the goal of constructing the criterion map is to identify those key concepts and propositions, that are considered to be essential in the domain and that students should know. The basic procedure for the construction of the criterion map is the following [10, 11]: 1) each expert provides a list of most important concepts in the domain;

2) experts compare and discuss their concept lists and agree on number of key concepts that will be used in the criterion map; 3) each expert constructs his/her CM from the previously selected key concepts; 4) experts compare CMs, discuss them and agree on common propositions and linking phrases; 5) the common criterion map is created.

Another method for the construction of the criterion map is used by Yin et al.[13]. They construct the criterion CM on the basis on experts' and students' maps. First of all, the authors identify concept pairs with scientific relationships and then label those concept pairs with their corresponding relationships as "mandatory" propositions. These concept pairs form the criterion map. After that the criterion map is compared with students' maps and different assessment algorithms can be used for this purpose.

The second approach considers possibility to use CMs of several experts. The procedure is rather similar to the construction of the criterion map [7]: 1) experts generate a list of all possible concepts in a particular domain; 2) the list of concepts and linking phrases is refined; 3) the final list of concepts and linking phrases is created; 4) experts create CMs on the basis of the final list of concepts and linking phrases.

In this approach the assessment process assumes comparison of a student's CM with all experts' maps. Scoring methods can be different. Klein et al. [6] use two experts' maps and students receive half a point for each proposition that matches a proposition in one expert's map, and a full point if the proposition matches a proposition existent in both experts' maps. Delacruz et al. [3] generate their scores by holistically comparing students' knowledge maps against eight experts' maps. Students receive a point for each matching proposition. Osmundson et al. [7] use five experts' maps (four science experts' maps and one of the classroom teacher). Students' maps are scored via a computer-based matching algorithm, proposition by proposition, with each proposition sub-score dependent upon the proportion of experts (from none to all) who included the particular proposition in their maps. These sub-scores (each ranging from 0 to 1) are then summed in order to acquire a final map score.

In the field of ontology development there is a concept of ontology merging which can be applied to CMs as well, because CMs and ontology are very similar in several aspects [5]. According to [4], ontology merging involves the following processes: a) mappings between identical or similar concepts held in each ontology, b) extraction of concepts required in the task or viewed as distinct, and c) extension of the merged ontology by adding new concepts or additional axioms.

ANALYSIS OF POSSIBLE SOLUTIONS

The common idea behind the use of several CMs in IKAS is the following. There is a particular topic or course and several teachers/experts in this topic or course. Each of them has specific viewpoint of the domain and each is capable to create a CM displaying this viewpoint. The main research question is how to use experts' CMs in the assessment process of students' CMs?

The approach chosen must meet several restrictions imposed by the current prototype of IKAS: 1) compatibility with task types implemented in IKAS, ie. the approach must be applicable both to "construct-the-map" and "fill-in-the-map" tasks, 2) compatibility with content of tasks, ie. all tasks in IKAS use lists of concepts and linking phrases extracted from a teacher's CM.

According to [4], there are three principal problems with data integration that need to be overcome: a) syntactic or structural differences between the data sources, b) semantic differences between the domains of interests, and c) semantic differences within a domain. It is obvious that in case of IKAS there will be structural differences between CMs of different experts, because experts can relate concepts in different ways and, as a result, create different topologies of CMs. Moreover, semantic differences within a domain are applied because experts can use different labels of concepts and linking phrases.

In general, there are four possible solutions: 1) independent use of several experts' CMs created from the same set of concepts and linking phrases; 2) independent use of several experts' CMs created from (partly) different concepts and linking phrases; 3) use of an integrated CM; 4) semi-independent use of several experts' CMs.

Independent use of several experts' CMs

Independent use of several experts' CMs can be implemented in two ways: a) each expert creates his/her CM from any concepts and linking phrases, or b) experts agree on concepts and linking phrases and create their CM from them. Taking into account the previously defined restrictions, in both cases this approach assumes that it is possible to extract all concepts and linking phrases from CMs of all experts and to offer them as the corresponding lists to students. Assessing students' CMs, presence of a particular proposition at least in one teacher's map must be found. If the presence is identified, the student receives points, otherwise – he/she does not receive them.

However, there are several problems with this approach:

- IKAS includes four tasks where the structure of a CM must be presented to students. Using this approach, it is not clear the structure of which expert's map must be given, because experts definitely will have different structures.
- In the first case, experts' CMs can have concepts or linking phrases, which have the same meaning, but are different because they are written in different way, or they are synonyms. As a result, the lists of concepts and linking phrases will be overburdened by repetitious items and will confuse students.
- Assessing students' maps, it is not clear how to score propositions which in one expert's map are defined as less important, but in another one – as important. They give different number of points to students. The same is valid for directions of arcs and linking phrases.

Of course, it is possible to find solutions appropriate for all of the mentioned problems, but in this case crucial changes in the implementation of IKAS are needed. Therefore, this solution is not feasible taking into account very high time and resource costs for elimination of drawbacks.

Use of an integrated CM

Use of an integrated CM offers more feasible solution, because in this case there is only one CM which can be compared with students' CMs. As a result, the integrated CM will have the definite structure eliminating in such a way the problem with "fill-in-the-map" tasks and will have the definite set of concepts and linking phrases solving the problem of overburdened lists.

This approach assumes that the integrated CM is acquired from experts' maps by merging them in a special way. If there are several CMs of different experts, then the following situations are possible taking into account components of CMs:

1. Concepts:
   - Some concepts can be identical in all experts' CMs. Such concepts can be directly integrated into the integrated CM.
   - Part of concepts can be different in experts' CMs, because:
     - they are synonyms;
     - they are written in different ways;
     - they are totally distinct (for example, one expert has the concept "car", but others do not have it).
2. Relationships. In this case, it is worth to consider only relationships between identical or similar (synonyms or written in different ways) concepts. The main differences between relationships are displayed in Table 1. Therefore, only the first

pattern in the table is not problematic and such relationships, if they are defined between identical concepts, can be integrate into the criterion map in direct way.

Table 1

Differences between relationships in experts' CMs

Correct direction of an arc	Correct relationship type	Correct linking phrase
+	+	+
+	+	-
+	-	+
-	+	+
+	-	-
-	-	+
-	+	-
-	-	-

„+" – correct, „-„ – incorrect

Summarizing all the previously described, it is necessary to find solutions considering differences between concepts and relationships in experts' CMs. For this purpose, some kind of an agreement interface is needed. In this case, the construction of the integrated map may include the following steps: 1) experts create their maps; 2) the system identifies identical and different concepts in the created maps; 3) experts use the agreement interface in order to agree on different concepts: a) to identify synonyms and choose the one, which will be offered to students, b) to identify differently written concepts and choose the right one, and c) to identify totally distinct concepts and to agree which ones of them must be left; 4) according to expert agreement, the system performs modifications in experts' maps: a) replaces synonyms by the chosen primary concepts, b) replaces differently written concepts with the right ones, c) removes concepts which must be removed together with their relationships, and d) inserts concepts missing in some experts' maps, but selected by experts as necessary concepts; 5) after modifications the system retrieves all different propositions from experts' maps; 6) experts using the agreement interface agree what to do with different propositions: a) accept identical propositions, b) agree on types of propositions if they have different types, c) agree on directions of arcs, and d) agree on different linking phrases; 7) after that the system performs modification of experts' maps and generates the integrated map; 8) experts can initiate additional modifications after acquiring of the integrated map; 9) all experts must accept the integrated map and only after that it can be published for students.

Semi-independent use of several experts' CMs

This approach assumes that experts can agree on key concepts and propositions and use them for the construction of their maps. However, experts can expend their maps by any additional concepts and relationships. After that, the system can create the integrated CM as described in the previous section on the basis of key concepts and propositions. Distinct concepts and relationships will be left only for evaluation of students' maps. If the student creates a proposition which exists in the integrated CM, then he/she receives more points. If the student creates a proposition presented only in one expert's map, he/she receives fewer points. However, this approach faces the same problems as independent use of experts' CMs.

CONCLUSIONS AND FUTURE WORK

The paper presents results of the preliminary analysis performed with aim to identify possibilities to use several experts' CMs for scoring of students' CMs in IKAS. The authors believe that involving of several experts will increase the objectivity of the assessment process. Four different solutions are considered in the paper, but only one of them seems suitable for implementation, because it does not demand crucial changes in system architecture and functional capabilities and meets restrictions imposed by the current prototype of IKAS. The future work is related to the detailed design of the chosen approach and development of the agreement interface needed for the creation of the integrated CM.

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