Automatic Concept Map Scoring Framework Using the Semantic Web Technologies

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Abstract

Over recent decades, concept mapping has been used as a valuable Learning and Teaching tool. Several types of scoring methods for concept map based assessment have been developed. In this paper, we describe the development of an automatic scoring framework that implements those techniques. We contribute a design that uses semantic web technologies for both the management and the scoring of the concept maps.

1. Introduction

Concept maps have been described as tools for organization and navigation, and as a cognitive tool [1] Concept mapping can be seen as a means for eliciting the conceptual knowledge that students hold in a subject domain [7]. Concept maps have been used as an assessment tool in educational settings. A number of concept map scoring methods for assessment have been developed. The traditional scoring methods are based on the components and structure of the concept map. The methods have proven to be time-consuming since they require careful human judgment [4]. Some researchers are exploring the possibility of providing automated assessment of the structural components of the concept maps [3, 4, 5]. However, these projects use tools that do not benefit from the current progress made on semantic web technologies.

The Semantic Web is an extension of the World Wide Web, where content is expressed in a language with enough semantics so software tools can locate, exchange and interpret information more efficiently [9]. The Semantic Web technologies can provide an easy and effective methodology to develop knowledge management applications. In this paper, we adopt the benefits of the Semantic Web technologies for development of an automatic scoring system. For the purpose of knowledge exchange, we design a method to translate a concept map into the Semantic Web expressions (RDF, RDFS). Then, we design and implement an effective automatic concept map scoring framework using the well-known Semantic Web tools, such as Protégé, Sesame, and SeRQL [10-12].

2. Concept mapping tasks

Concept mapping tasks can be identified in several ways [8] including, tasks which could be used for automatic scoring such as fill-in-the-map and construct-a-map. The fill-in-the-map technique provides student with a pre-drawn map where some of the concepts and/or the linking phrases have been left out [8]. Students fill the blank nodes or blank linking phrases. In construct-a-map technique, students are asked to construct a map from scratch. In the two techniques, students may or may not be provided with the selected concepts (called the selected node list) and/or the selected linking phrases (called the selected link list) used in the task. Thus, we can classify concept mapping tasks for automated scoring with four different types shown in Figure 1.

	Task Constraints	
	Given List	No List
Fill-in-the-map	Fill-in-the-map with a selected node/link list (F_SL)	Fill-in-the-map with created nodes/links (F_NSL)
Construct-a-map	Construct-a-map with a selected node/link list (C_SL)	Construct-a-map with created nodes/links (C_NSL)

(Task Demands along left axis)

Figure 1. Classification of concept mapping tasks for automatic scoring

238

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3. Knowledge exchange between concept map and the Semantic Web

A method for knowledge exchange between the concept map and the Semantic Web data is necessary for developing our scoring system. Knowledge in RDF/RDFS form of the Semantic Web is expressed by a set of subject-predicate-object triples [10]. In the triple, predicate is also known as property and relationship of subject, and object is also referred to as property value. This is very similar structure to the concept-link-concept triple forming a proposition in concept maps.
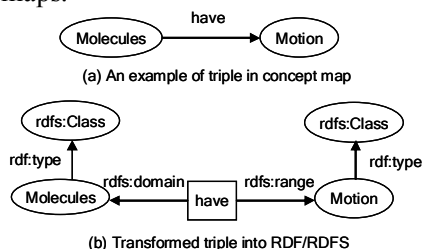

Figure 2. An example of transformation of triple in concept map into RDF/RDFS form

Since concepts contained in the triples of concept maps are considered as important or general things in a subject domain, they are classified into classes in RDF/RDFS representation. Links between concepts can be transformed into properties representing relationships between those classes. Thus, we can easily transform a concept map into a RDF/RDFS form of the Semantic Web as shown on Figure 2.

4. Automatic concept map scoring framework

4.1. System overview

We have implemented a prototype system to provide (1) an environment for testing feasibility of our concept map scoring framework, and (2) expand it toward an on-line concept map assessment system in the future.

Figure 3 shows a structural overview in our system. Our system used Sesame 2 to construct repositories for a concept map base based on RDF/RDFS formats and retrieve RDF/RDFS data from the repositories. The concept map base manager provides functions for (1) reading concept map files and (2) creating, initializing, and connecting repositories. The automatic concept map scoring framework consists of several API functions for automatic scoring methods, which will be described in the following section. Finally, the concept map assessment service layer contains some main programs to test and evaluate scoring concept maps for assessment.
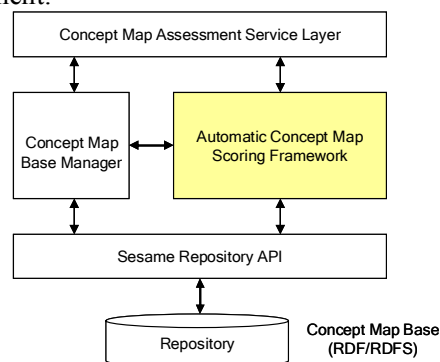

Figure 3. Structural overview of prototype system

The system has implemented in Java using Eclipse SDK 3.2.2 tool and requires at least Java 5.

4.2. Scoring methods

A number of scoring methods for concept map assessment have been developed in the education field [4, 8]. However, since rubrics and methodologies for scoring can depend on teacher's preferences, aspects of the subject domain, teaching-and-learning methods, concept mapping task types and so on, there is no dominant scoring method for assessment for a general educational setting.

Table 1. Summary of scoring methods provided in our framework

Task Type	Scoring Method	Type of Score
Fill-in-the-map (F_SL, F_NSL)	- Exact matching	Count, Weighted Count
Construct-a-map (C_SL, C_NSL)	- Measuring Structural Similarity - Exact node matching - Exact propositional matching	Structural Similarity Count, Weighted Count Count, Weighted Count Congruence Salience

One of the aims of our framework is to develop a flexible environment where teachers can choose their scoring strategies. To make it possible, we investigated and implemented scoring techniques that can be used to automate the scoring of the concept mapping types shown in Figure 1. Through our investigation, we conclude that a criterion map given from teachers or experts is necessary for development of the automated scoring methods. Table 1 shows the scoring methods

adopted in our framework depending on four major task types (F_SL, F_NSL, C_SL, C_NSL).

Although the framework can assess the hierarchical structure used in the concept map, it does not look at the visualization aspects (e.g. that the branching should happen downward).

The exact matching method in Table 1 consists in comparing exact component matches (node or link) between student components and teacher components. The score for the exact matching method is the number of exactly matched components between student map and teacher map. The weighted count is a score that is evaluated by considering weighting factors given by teacher for each component of teacher map. The structural similarity between the student map and the teacher map is assessed using a graph similarity method, proven as an effective method by [6], described by [2]. Congruence is defined by a proportion of valid student proposition over all criterion propositions and salience is defined by proportion of valid student proposition over all student propositions [8].

4.3. Framework design and evaluation

Our framework contains three major Java API classes for scoring: (1) The F_Score class is used for scoring of F_SL and F_NSL task types. (2) The C_MatchingScore class is used for exact matching scoring method for C_SL and C_NSL task types. (3) The C_Similarity class is used for measuring the structural similarity for C_SL and C_NSL task types.

The feasibility and correctness of our framework were evaluated by executing some testing programs. We adopted tasks and processes described in [6] as the basis of a realistic scenario, and as sample student and teacher maps for testing. Because concept map editing and translation modules are currently not implemented in our system, the sample maps with RDF/RDFS forms for development and testing of our framework were created by using Protégé ontology and RDF editor [12].

6. Conclusions

In this paper, we presented the following contributions: (1) a translation method for knowledge exchange between concept map and the Semantic Web standard expression (RDF/RDFS). (2) a classification of concept map tasks that can be automated and our investigation of scoring methods suitable for the task types. (3) an automatic concept map scoring framework using the Semantic Web technologies.

We believe that our proposed framework will provide (1) a flexible environment that teachers can select scoring rubrics and methods according to their educational setting, (2) an efficient and easy interface (API) for the development of concept map based applications. At this stage of the project we have not performed evaluations with real users (students or teachers). An evaluation with data produced by students in a real University subject is planned to support assertion 1. The development of front-end applications should provide evidence for assertion 2.

7. References

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