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Evaluating student learning using concept maps and Markov chains

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ABSTRACT

In this paper we describe a tool that can be effectively used to evaluate student learning outcomes using concept maps and Markov chain analysis. The main purpose of this tool is to advance the use of artificial intelligence techniques by using concept maps and Markov chains in evaluating a student's understanding of a particular topic of study using concept maps. The method used in the tool makes use of XML parsing to perform the required evaluation. For the purpose of experimenting this tool we have taken into consideration concept maps developed by students enrolled in two different courses in Computer Science. The result of this experimentation is also discussed.

1. Introduction

Concept maps are visual representations of a particular topic. They are used for organizing and representing knowledge. Concept maps can be utilized more effectively to determine the depth of knowledge possessed by a student (McClure, Sonak, & Suen, 1999; Nesbit & Adescope, 2006), when compared to using traditional forms of assessment such as multiple-choice exams. Concept maps provide visual data to the instructors on student misconceptions and their level of understanding. Hence the concept maps can be helpful to develop certain abilities such as:

- The ability to draw reasonable inferences by identifying the key concepts on a topic.
- The ability to synthesize and integrate the information and ideas.
- The ability to learn concepts and theories in the area of study.

A concept within a concept map is usually represented in rectangular boxes or labels and is connected with relationships with labeled arrows. The label can be a word, number or a special symbol. These concepts are linked by linking phrases or relationships. The technique or framework for organizing the conceptual information in process of defining a sentence using the relationships among different concepts is called "Concept Mapping" (Funaoi, Yamaguchi, & Inagki, 2002; Gurupur, Sakoglu, Jain, & Tanik, 2014; Lin, 2002; Strautmane, 2012). When two or more concepts are connected using phrases and relationships to form meaningful statements, such a statement is termed as a "Proposition" as described by Daley, Canas, and Schweitzer (2007). These are also considered as semantic units or units of meaning (Castles, 2008). These propositions (Correia, 2012; Dabbagh, 2001; Mahler, Hoz, Fischl, Tov-Ly, & Lernau, 1991; Álvarez-Montero, Sáenz-Pérez, & Vaquero-Sánchez, 2015) represent information about a particular topic as seen in Fig. 1.

In Fig. 1, "Includes", "Has" and "Is" are examples of relationships that are used to link concepts. Here Root Concept → Includes → General Concept 1 is a meaningful statement. One can use the concept maps not only as a learning tool but also as an evaluation (Najdawi & Ghatasha, 2012) tool for classroom assignments. This encourages students to use meaningful mode learning patterns (Calafate, Cano, & Manzoni, 2009; Siddharth, 2010).

Based on the aforementioned statements a project was developed based on the following objectives:

- To develop a tool that can be used to evaluate a student's depth of understanding (Jain, Gurupur, & Faulkenberry, 2013) using concept maps and Markov chains.
- To develop a user friendly tool for the instructors to evaluate the concept map (Jain et al., 2013).

Based on these objectives, a tool is developed that evaluates concept maps where the instructor can use this tool to measure the performance (Leake, Maguitman, & Reichherzer, 2013; Novak & Canas, 2006; Wang & Yisheng, 2003; Zvacek, Restivo, &

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Chouzal, 2012) of the students enrolled in the course. The research question targeted by the tool is, "Can we use concept maps in conjunction with Markov chains to measure a student's understanding of a topic in study?" The research question is based on the following criteria: Markov chains can be a powerful method of measuring predictability and pattern recognition. Although, this is not of the stated objectives of this particular project, it opens the door to the development of more powerful techniques using neural networks and fuzzy logic.

1.1. Related work

McClure et al. (1999) evaluated psychometric and practical aspects of using concept maps in class room assessments. Their work compares the following six evaluation methods.

(1) Holistic (score awarded by examining concept map as a whole).
(2) Holistic with master map (used as a reference for awarding scores).
(3) Relational (score awarded by examining each proposition connecting two concepts).
(4) Relational with master map.
(5) Structural (score awarded based on the number of hierarchical levels and crosslinks identified on the maps).
(6) Structural with master map.

These six evaluation methods are evaluated in terms of their reliability and validity by collecting and evaluating concept maps constructed by students. Results of the study suggested that the selection of a scoring method has an effect on the score reliability and that most reliable scores are produced by using the relational scoring method with a master map.

Anohina, Vilkelis, & Lukasenko (2009) argue that it is not correct to compare a teacher's and a student's concept maps only by examining the equivalence of relationships between both maps because people construct knowledge differently (Anohina & Grundspenkis, 2009). Their work presents a mechanism that can be used in conjunction with a tool that enables systematic knowledge assessment of a student's concept maps.

Their system offers concept map based tasks that increase in difficulty from low to high. The tool allows teachers to configure assessments that incrementally examines the knowledge possessed by students. In order to calculate the total score, all possible patterns of answers for each task are assigned with a pre-defined score.

Anderson & Huang (1989) investigated the effectiveness of learning with the help of concept maps and measured the effect of reading expository text during assessment. They have used the following in their research method:

- Provided high school students with initial training in constructing concept maps.
- Conducted mapping test to gauge students' ability in building concept maps.
- Divided students into two groups, good-mappers and poor-mappers based on their score in the mapping test.
- All students were further divided students into following instructional groups:
  a. No instruction: no instructions provided about the topic in the mapping test.
  b. Read only: provided a passage about the topic in the mapping test.
  c. Read plus slides: provided slides in addition to the passage about the topic in the mapping test.
- All students took an additional post-instructional mapping test where students were given instructions based on their instructional groups and were provided with the structure of the concept map and were requested to construct the concept map.
- Students' concept maps were compared to a master map and the required score was assigned using twenty pre-defined accuracy categories.

Their results provided the following observations:

- Good-mappers scored significantly higher than poor-mappers.
- Students in read plus slides and read only groups scored better than no instruction group.

AISLE (Jain, Gurupur, Schroeder, & Faulkenberry, 2014) is also a tool that has similar objectives and methods to evaluate students. Here we would like to take the opportunity to inform the readers that this paper is an extension of the research conducted with AISLE. Like any other tool AISLE suffered from some drawbacks. Some of these limitations have been successfully addressed in this project.

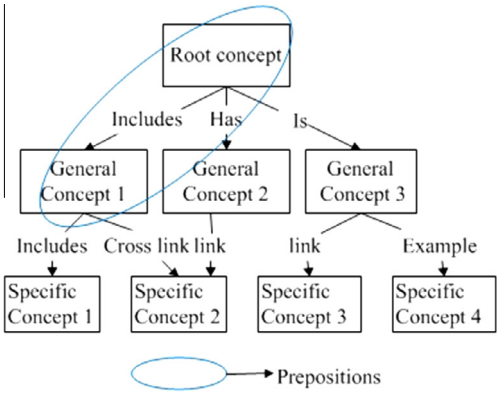

Fig. 1. Concept map for showing prepositions representing information.

2. Material and methods

The method used by the tool to evaluate a student's understanding on specific topics as discussed in the class is different from the regular methods such as quizzes, oral presentations on topics related to the course.

In order to make the tool successful and different from other existing tools which are used to evaluate the concept maps, it has to include the following features:

- A plausible mechanism to measure the knowledge contained in the concept maps.
- A usable interface for the instructor to upload XML-based documents developed from concept maps and then perceive the results.
- Accommodating large concept maps in the process.

As mentioned before, there is a need to develop a tool that can evaluate the knowledge present in the concept maps. If the student uses concept maps in planning and representing the knowledge based on his understanding of a specific topic, this may help students to realize the gaps in their understanding (Darmofal, Soderholm, & Brodeur, 2002; Jihong & Wen, 2011). Sometimes students may find it difficult in identifying the key concepts in a text, lecture or other forms of representation (Jain et al., 2014). Such students may fail to construct powerful concepts and propositional