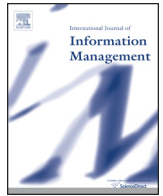




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Research Note

Evaluation module based on Bayesian networks to Intelligent Tutoring Systems

Alan Ramírez-Noriega^{a,*}, Reyes Juárez-Ramírez^a, Yobani Martínez-Ramírez^b

^a Autonomous University of Baja California, School of Chemical and Engineering Science, Calzada Universitaria 14418, Parque Industrial Internacional, Tijuana, Baja California, C.P. 22390, Mexico

^b Autonomous University of Sinaloa, Fuente de Poseidon y Angel Flores s/n, Col. Jiquilpan, Modulo B2, Los Mochis, Sinaloa, C.P. 81223, Mexico

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ABSTRACT

Assessing knowledge acquisition by the student is the primary task of an Intelligent Tutoring System (ITS). Assessment is needed to adapt learning materials and activities to student's capacities. In this paper, a proposal to infer the level of knowledge possessed by the student is presented. A general structure of an ITS is shown, an evaluation module based on Bayesian network is proposed. The module mainly based on a test was implemented to know what student knows. During the test, the software system chooses the new questions based on the responses to the previous ones, that is, the software system makes an adaption in real time. A network of concepts was used to get the inferences, which contains the relationships between concepts. Evaluation module could infer many questions and concepts through the relations and the probabilistic inference of the Bayesian network. It information easily can be used to reinforce weak topics in order to cover the student's needs. Given the positive evidence is considered that testing the rest of variable examined in the Bayesian network can provide better accurate in the diagnostic of student' knowledge possession.

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1. Introduction

Learning can be defined as internal processes of change, as the result of learner's personal experience. Also, it can be defined as the acquisition or adding of something new, which involves any variation or modification previously acquired (Rivas Navarro, 2008).

Teachers guide students during the learning and must perceive the students needs to improve the teaching. However, in group tutoring environments, one-on-one time dedicated by professors to each student decreases considerably. For that reason, some authors propose the use of a software system (Carbonell, 1970; Cataldi & Lage, 2010a; Huertas & Juárez-Ramírez, 2013; Santhi, Priya, & Nandhini, 2013) to satisfy that needs. Furthermore, the software system should be adapted to the student's needs.

Adaptability to students needs is a challenge for software engineering (Luckey & Engels, 2013). Adaptability is defined as the software adaptation to individual user characteristics according to user aims (Radenkovic, 2011). Different types of software adaptations are defined (Radenkovic, 2011; Razek & Bardesi, 2013),

but this research focuses on the content adaptation; that is, what information is shown to the user according to the software interaction and user characteristics. This adjustment of the learning environment can be achieved with artificial intelligence strategies (Razek & Bardesi, 2013), carrying out intelligence for deducing user needs.

A special type of software that meets the characteristics mentioned above is called the Intelligent Tutoring System (ITS). This can be defined as a software system that uses artificial intelligence techniques to interact with students and teach them (Huertas & Juárez-Ramírez, 2013; Santhi et al., 2013) in the same way as a teacher does to his students (Cataldi & Lage, 2010a). Carbonell (1970) proposed a generalized architecture for ITS, which considers three core modules (Cataldi & Lage, 2010a; Santhi et al., 2013): which are the tutoring model, domains model, students model, further of users interface.

An important problem in ITS development is the assessment of student knowledge (Conejo, Millán, Pérez, & Trella, 2001). ITS must be able to determine accurately and quickly the student cognitive level to decide what is important to teach them. Probability theory has been proposed by some authors for handling the uncertainty in diagnosing student knowledge (Conejo et al., 2001; Huertas & Juárez-Ramírez, 2013; Santhi et al., 2013). The Bayesian Network (BN) theory is proposed, within a framework of probability and artificial intelligence, for modeling the way how an intelligence

* Corresponding author.

E-mail addresses: alan.david.ramirez.noriega@uabc.edu.mx (A. Ramírez-Noriega), reyesjua@uabc.edu.mx (R. Juárez-Ramírez), yobani@uas.edu.mx (Y. Martínez-Ramírez).

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system should infer causality (Taborda, 2010). Besides, this theory has representation and behavior similar to people's mind (Rivas Navarro, 2008).

Our research project considers the causal relationships to refer to nodes that represent concepts, and they are related to other nodes to obtain the domain knowledge representation (Millán, Descalço, Castillo, Oliveira, & Diogo, 2013a). This paper proposes a general architecture of an ITS to implement a knowledge evaluation module (Ramírez-Noriega, Juárez-Ramírez, Martínez-Ramírez, Jiménez, & Inzunza, 2016). To diagnose the student learning needs efficiently and to reinforce weak topics. The BN theory supports this research. Its paradigm is wide used by supporting uncertainty handling, knowledge representation, and diagnostic and pattern recognition (Liu & Wang, 2007; Misirli & Bener, 2014; Santhi et al., 2013).

We selected BN for this study over Fuzzy Cognitives Maps (a similar technique), because they have significant attributes as (Cheah, Kim, Yang, Kim, & Kim, 2008): (1) forward and backward chaining, (2) efficient evidence propagation mechanism, (3) enough implementation and support tools, (4) mathematical theorems derivable from well-defined basic axiom, and (5) correctness of the inference mechanism is provable.

This paper is organized into six sections. Section 2 defines some related work. Section 3 shows how the evaluation module is integrated into an ITS. Section 4 explains our proposal for knowledge's assessment. Also, it shows how the BN is implemented for knowledge representation and its evaluation; moreover, it presents a question-based evaluation design that we used for student evaluation. Furthermore, this section explains the algorithms employed in the module. Section 5 defines the methodology for experimentation that we employed. Section 6 shows the experiment results and discussions. Lastly, Section 7 presents the conclusions and future work.

2. Related works

In this section presents the related work, emphasizing the use of BN for improving learning and education, taking into account that BN is used to assess the knowledge.

Liu and Wang (2007) proposed a student modeling method built with BN. To evaluate the students performance, they adopted a logistic model with three parameters to calculate the conditional probability distribution of the testing item. They were focused on a course of Data Structures, especially on Binary Trees. This work just was a proposal, but they did not implement the model.

Gogvadze, Sosnovsky, Isotani, and McLaren (2011) presented the design and evaluation of a Bayesian approach for modeling student misconceptions in the domain of decimals. The results showed that the models predictions reach a high level of precision, especially in predicting the presence of student misconceptions. They did not explain precisely how the BN was built.

Torabi, Moradi, and Khantaimoori (2012) worked in predicting the student courses score based on the student's educational history. They proposed a BN model for the inference process. The results show that applying their proposed method has primary effects on the quality of the students learning and can be used as a helpful tool for them.

Millán et al. (2013a) developed, integrated and evaluated a Bayesian student model. This work is focused on the mathematics area, specifically on first-degree equations. They used twelve concepts to assess the knowledge. Each concept is evaluated in batches of four questions or exercises; this means students need answer four questions as one.

The main model used is similar to the Millán (2000); however, some differences are considered with the previous work. Our model

evaluates the fundamentals of algorithms as learning topic. We did a complete analysis of the domain knowledge to represent it. Also, to adapt the questions according to Student's knowledge level, Bloom's taxonomy (De Bruyn, Mostert, & Van Schoor, 2011) was implemented organizing the questions into five levels of complexity. We used own algorithms to switch-on the levels and to select the appropriated question to the student. Finally, It is proposed to integrate the evaluation module to an ITS, considering five factors to inference the knowledge.

3. Evaluation module in ITS

This section explains how the evaluation module (Ramírez-Noriega et al., 2016) can be adapted to the general architecture of the ITS. Besides, It explains a complete Bayesian network to obtain better accurate in the diagnose of the student's knowledge possession. In order to test the network was only used a variable (test questions), but its use is the same.

3.1. ITS characteristics

3.1.1. Knowledge organization in education

Education in institutions is organized by subjects; these subjects are topics related to the chosen career. Besides, subjects consider an order and planning to work with students. The index of contents in a subject represents the topics that students have to learn and its order. The information is organized by chapters or units, topics, and subtopics. Fig. 1 clearly represents a hierarchical structure where are established categories organized into topics and subtopics. This hierarchical order is organized by complexity degrees; first topics are easy to assimilate with small reasoning degree, after topics increase the knowledge level to advance to complex topics.

The previous order is related to Bloom taxonomy (De Bruyn et al., 2011; Rodrigues & dos Santos, 2013), where the first knowledge is simple concepts, and final concepts are a complex process of analysis, synthesis, and evaluation. For instance, in algorithm course the first topics could answer questions such as What is an algorithm? What is a variable?, Which are the kind of algorithms? etc. these questions are simple concepts without reasoning. At the end of the course, the students could develop small programs in an algorithm editor, testing their reasoning and applying all the concepts previously learned.

Graphs can represent this educative organization, so, a computer could easily analyze this information through a knowledge representation approach based on nodes and relations. Fig. 2 represents a tree structure founded in the contents displayed in Fig. 1. The chapter one was only considered to simplify the idea. Tree root is the chapter, the topics arising from the root; finally, subtopics are leaf nodes.

A greater level of granularity can be represented adding concepts of each subtopic as shown in Fig. 3. This structure, in its complete form, should be represented in the student's memory at

1 Algorithms

1.1 Introduction to the algorithms

1.1.1 General concepts

1.1.2 Characteristics

1.1.3 Types of algorithms

1.1.4 Algorithms classification

1.2 Analysis of the problem

1.2.1 Analysis

1.2.2 Examples

Fig. 1. Topics of the algorithm course.

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