An Intelligent Tutoring System using Bayesian Network – A Review

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Abstract—**An intelligent tutoring system is computer software designed to simulate a human tutor's behavior and guidance. In order to develop the software's that present students effective instruction methods and provide education with being adapted to students, studies are carried out. Intelligent Tutoring Systems (ITSs) are designed with using Artificial Intelligence (AI) techniques in computer programs and called cognitive tutors or Knowledge Based Tutoring Systems which can guide learners to progress in the learning process at their best and to facilitate instruction. This paper describes structure of ITS and deals with the review of various Intelligent tutoring systems using AI and how that system can be used for efficient decision making.**

Index Terms— Bayesian Network (BN), Intelligent Tutoring Systems(ITS), Pedagogical Module, Report Module

I. INTRODUCTION

An Intelligent Tutoring Systems is educational software containing an Artificial Intelligence component. The software tracks the student's work, tailoring feedback and hints along the way. By collecting information on a particular student's performance, the software can make inferences about strengths and weaknesses, and can suggest additional work. The basic underlying idea of ITSs is to realize that each student is unique. These systems can be used in the traditional educational setting or in distant learning courses, either operating on stand-alone computer or as applications that deliver knowledge through the internet. ITSs have been shown to be effective in increasing student's performance and motivation levels compared with traditional instructional methods.

One of the key element that distinguishes ITSs from more traditional CAI systems is ITS's capability to dynamically maintain a model of a student's knowledge during the study. ITSs have been shown to be effective in increasing student's performance and motivation levels compared with traditional instructional methods. One of the key element that distinguishes ITSs from more traditional CAI systems is ITS's capability to dynamically maintain a model of a student's knowledge during the study.

ITS must be able to achieve three main tasks:

1. Accurately diagnose a student's knowledge level using principles rather than programmed responses.
2. Decide what to do next and adapt instruction accordingly.
3. Provide feedback.

II. ARCHITECTURE OF AN ITS

In the proposed ITS consist of six emerging subsystems, namely:

1. Student Module
2. Knowledge Module
3. Tutor Module
4. Pedagogical Module
5. Report module
6. User Interface Module

Two major issues related to an ITS are "what to teach" and "how to teach". The student module and knowledge module deals with the "what to teach" part, whereas the tutor module and pedagogical module are concerned with "how to teach" part. This proposed module also deals with "how to report" part by using report module and user interface module.

The knowledge Module is also important as it is the representation of the domain knowledge. Good design principles adapted in designing this module would help the system in selecting the proper methods for teaching. This would also help the system in the search for alternative teaching plans when a particular method fails to produce success.

The most important part of an ITS is the tutor module. This module is the centre of the whole system. It communicates with the other modules and does the entire decision making. The structure of the ITS is shown in the figure 1.

A. Student Module

The student module contains descriptions of student knowledge or behaviors, including his misconceptions and knowledge gaps [1, 10]. In other words, the cause of collecting information about student is to determine the education level of student and the most suitable learning method for him. The collected information is stored in data base and whenever necessary it can be retrieved and used.

ITSs serve two basic aims [5, 6, 11, 14, and 18]:

1.To form a learning program adaptable according to the student

2. To be a guide to solve student's problem.

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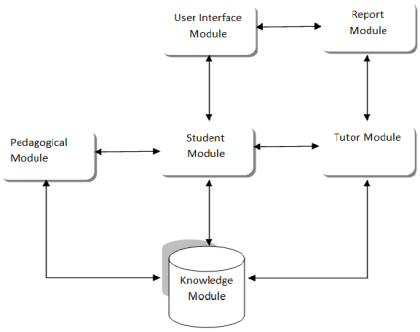

Fig. 1. Structure of ITS

B. Knowledge Module

The Knowledge module references an expert or domain model consist of a description of the knowledge or behaviors that represent expertise in the subject-matter. It is the module in which main information and tutorial information that are going to be taught resets. We can say that the designing of better knowledge module helps more in proper tutoring and assessment. Expert module should be parallel with the knowledge's which are stored in student module [5, 10, 17]. It is to say, when a student module is identified, the data base suitable for this module should be able to present to the user easily.

C. Tutor Module

A mismatch between a student's behavior or knowledge and the expert's presumed behaviors or knowledge is signaled to the tutor module, which subsequently takes corrective action, such as providing feedback or remedial instruction with the help of pedagogical module. This module contains the information which includes tutoring strategies and tactics which are stored in knowledge module. Tutor module provides necessary information so that tutoring aims can be achieved. Besides, it will answer students' questions properly and will present the needed help when they solve a problem or perform their skills. It must have a mechanism which will be able to determine what kind of help to be presented.

D. Pedagogical Module

The pedagogical module is the driving engine of the teaching system and is closely linked to the student module. It designs and controls instructional interactions with the student for their better understanding . It uses the student model and knowledge model to make its pedagogical decisions. The pedagogical module forms and updates the student model and offers hints when the student is struggling, supplies advice, support and explanations, selects a new topic, etc.

F. Report Module

This module generates report related with the performance of the student as well as produces status of knowledge acquainted by the student. This module also support tutor to update the information about his student. A report module visualizes the knowledge module and the Student Module to analyze the various learning parameters of the learner such as the allotted time for studying a specific content in order to generate report of assessment with the help of tutor module. Based on the strategy of the tutor module, the learner at any time is able to choose the learning contents himself which leads to the updating of the Student Model

E. User Interface Module

The user interface module provides the means for the student to interact with the ITS, usually through a graphical user interface and sometimes through a rich simulation of the task domain the student is learning [5, 10, 13, and 18].

An ITS is only as effective as the various models it relies on to adequately model expert, student and tutor knowledge and behaviors. Thus, building an ITS needs careful preparation in terms of describing the knowledge and possible behaviors of experts, students and tutors [15]. This description needs to be done in a formal language in order that the ITS may process the information and draw inferences in order to generate feedback or instruction. One of the biggest challenges in designing ITSs is the effective assessment and representation of the student's knowledge state and specific needs in the problem domain. Such ITS can be developed using various AI technologies. Some of them are mentioned below.

Bayesian networks
Rule-based systems
Fuzzy logic
Dempster Shafer theory of Evidence
Neural networks

Bayesian networks are a powerful loom for developing ITS.

III. BAYESIAN NETWORKS

A Bayesian Network (BN) is a graphical description of a probability distribution that permits efficient probability propagation combined with a rigorous formalism. A BN for a given domain represents the joint probability distribution, p(x), over the set of random variables, X, of the domain, as a set of local distributions combined with a set of conditional independence assertions. Researchers have applied Bayesian networks to many tasks [6], including

1. Student Modeling
2. E-Commerce and
3. Multi Agents

In student Modelling, there are two tasks involved in helping a student navigate in a personalized learning environment.

1. The structure of the problem domain must be modeled.
2. Student knowledge regarding each concept in the problem domain should be tracked.

Bayesian Networks can help us meet both these objectives. A Bayesian network (BN) consists of directed acyclic graph (DAG) and a corresponding set of conditional probability distributions (CPDs). Based on the probabilistic conditional independencies encoded in the DAG, the product of the CPDs is a joint probability distribution (jpd). In other words, Bayesian networks serve as both a semantic modeling tool and

an economical representation of a jpd. There are many inference algorithms in BNs for computing probabilities of variables given other variables to take on certain values [7].

A Bayesian Network combines the contents structure with the user profile and learning style to suggest pedagogical directions. In the context of ITSs, Bayesian Networks have been applied to user modeling (VanLehn et al. 1998) in a diagnostic perspective: given a student action (symptom) the network provides the most likely state of knowledge (diagnosis)[8].

IV. Results and Discussion

1. **Andes** (Conati et al, 2002; Gertner & VanLehn, 2000) is an ITS which was developed to teach physics for the students in Naval Academy. Bayesian networks were primarily used in Andes for decision making.

The major foci of the system are
(1) Select the most suitable strategy for the student
(2) Predict Student's actions
(3)Perform a long term assessment of the student's domain knowledge.

Andes is a domain dependent ITS. Each problem in the system was broken into some steps and Bayesian network was formed using those steps as nodes. So, the problems were represented in the system as Bayesian networks. The Bayesian network would predict the most probable path for the student during a course. Each student could have different approaches to a problem, the network would be adjusted accordingly (the probabilities would change) and finally for a new problem it would predict the best strategy for the student[4].

2. **ViSMod** is another ITS which used Bayesian network (Zapata-Rivera et al, 2004). In the system the Bayesian network was divided into three levels. At the top most level the concepts (to be taught) were represented in a hierarchical manner. After that in the second level student's performance and behavior were described. Finally the third level nodes represented some analysis on the student's performance. Only the first level is domain dependent, whereas other two levels would remain same over different domains. Again student can observe only the top two levels of the Bayesian net. The third level is only visible to the teachers. During a course the probabilities in the second and third level of the Bayesian network changed according to the student's performance.

3. **BITS**, a web based Intelligent tutoring system for Computer Programming, uses Bayesian Networks for making the decisions. Using the Bayesian Network, the prerequisite relationships among the concepts are represented directly and clearly. In BITS, there are two methods of obtaining the evidence required to update the Bayesian Network:
   A student's direct reply to a BITS query if this student knows a particular concept. A sample quiz result for the corresponding concept to determine whether the student has understood a particular concept or not[3].

4. Hossam Meshref, in his An **Intelligent Tutoring System for Logic Circuit Design Problem Solving**, uses the Bayesian Networks to facilitate the modeling of the structure of a problem domain. In this research, a Bayesian inference is used to guide the tutoring process. In addition it allows tracking students' knowledge as they navigate within the problem domain. In this network, only clusters of concepts that could interact are considered and presented. Each concept within the problem domain is represented by a node in the Bayesian Network.

5. **KERMIT** uses A Bayesian network to represent the student model and could also predict the student.s behaviour with respect to the constraints. The Bayesian network can be used in selecting feedback and selecting new problems for the student.
   In this section we show an example of an ITS, developed using the previously described shell, in the area of Pattern Recognition. In the design phase the contents were produced using available tools to create html pages and graphics. We added a set of questions for each topic, and the interdependence among the different topics were identified and mapped into the tutor. After the design phase the system was used as an auxiliary tool. Figure 6 shows a typical screen of the system in the topic related to clustering algorithms. When the user starts using the tutor, he/she is asked to do a short test to assess his prior knowledge in the subjects to be taught. This test will initialize variables in the BN. The ITS then starts showing the topics, making question and suggesting paths. It acquires information about the user via the interaction with the browser in the presentation module. At the end of the tutor usage, an evaluation test will compare the first results with those of the final test.

V. Conclusion

The proposed research is a framework for an ITS, provide an excellent one-on-one support to improve students' conceptual understanding [14]. This ITS is expected to improve the understanding and knowledge level of the students by correcting their errors during problem solving. The better use of Pedagogical agents helps students during their work out. Also Bayesian Networks is a reliable technique to deal with knowledge assessment of the student.

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