Computational Intelligence Approaches for Student/Tutor Modelling: A Review

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Abstract - **The intelligent tutoring system (ITS) is an educational software system that provides personalized and adaptive tutoring to students based on their needs, profiles and preferences. The tutor model and student model are two dependent components of any ITS system. The goal of any ITS system is to help the students to achieve maximum learning gain and improve their engagements to the systems by capturing the student's interests through the system's adaptive behavior. In other words an ITS system is always developed with the aim of providing an immediate and efficient solution to student's learning problems. In recent years a lot of work has been devoted to improving student and tutor models in order enhance the teaching and learning activities within the ITS systems. The aim of this paper is to investigate the most recent state of art in the development of these two vital components of the intelligent tutoring systems.**

Keywords: tutor model; student model; computational techniques, intelligent tutoring systems

I. INTRODUCTION

Intelligent tutoring systems (ITSs) are generic software systems designed using Artificial Intelligent techniques to provide personalized instructions to student based on his/her profile and learning styles. The advantages of intelligent tutoring systems in our today's educational environments are very clear; location independent, easy accessibility, high flexibility and above all students can learn at their own rates and they don't have to rely on rigid classroom schedules [3]. The aim of this paper is to review the state of art for tutor module and student module, two vital components of any ITS system. The emergence of the intelligent tutoring systems in the last three decades has significantly changes the content and practice of teaching and learning in our today's educational environments [2]. The most significant of this change is redefining the concept of education far from been just a traditional school setting and has increased the number of participants seeking knowledge from children to almost all adults from various age groups [1]. Before the advent of intelligent tutoring system, the trend in the teaching use to be the traditional one-on-one approach between a human teacher and student, then come the one-to-many classroom approach which later gave birth to the

e-learning and computer aided instruction (CAI) approaches. Both the e-learning and CAI systems have a major short comings compared to the ITS because of their one size fits all approach to teaching and learning that is to say they are not adaptive by design, same content is always provided to different users irrespective of the individual differences that commonly exist among the learners. But ITSs are adaptive in the sense that students can be tutored according to their profiles and preferences. Each individual student will be provided with learning content and instructional methodology that will suit his/her personal need. Unlike in the traditional one-to-one human student/teacher tutoring environment, in any typical ITS system setting, the interaction between the tutor (software system) and the student is not under the control of a human tutor who normally enjoys the total control of the learning environment, there is no such humanly face-to-face session between the student and the tutor in an ITS setting and the resulting consequence here is that the system's control over the learner is going to be weak to the extent that if at any stage of the learning activities the atmosphere becomes boring to the student he/she may decides to leave the session with the computers because he doesn't need the consent of the tutor.

II. RELATED LITERATURE

A. Overview of Intelligent Tutoring Systems

Human tutoring is certainly an old paradigm and is still one of the most effective techniques of instruction on earth. It has been proved experimentally that specialized human tutors can yields huge amount of learning gains [39]. The advent of computers indicated the capability of the computers to be a promising alternative to expert human tutors since they appear to be cost effective and untiring when compared to human tutors. Intelligent tutoring is considered today as one of the most recent advancement in educational technology. The concept of intelligent tutoring systems (ITS) started in the late 1960s. ITSs are powerful computer software that co-ordinates different types of knowledge modules such as domain module, students module, pedagogical module as well as

interface module. ITS is a multi disciplinary and therefore even the resources to build them has to be generated from different research sources like artificial intelligence, education, human-computer interface, software engineering as well as cognitive science [4],[5].

B. Research Methodology

The aim of this research is to investigate how the trend in tutor and student modeling is moving. To do this we have to search through published articles in order to enable the stake holders in the field of intelligent tutoring especially academics and educational administrators to understand the direction and the feature these two important components of ITS. We will examine the distribution of research articles on both two models by their year of publications and the distribution of the articles by the journals in which the research articles are published. And more importantly we will also examine the research papers by the artificial intelligence technique employed to model each paper in order to understand how the various techniques are pairing. For the purpose of this research we will limit our search within the following journals databases; Science Direct; ACM Portal; Springer; Scopus and Elsevier.

C. Architecture of an Intelligent Tutoring System

An ITS architecture is always designed with the following principles, who teach (student module), what to teach (domain module), how to teach (pedagogical/tutor module) and the user-system interaction environment (interface module). These four components will be explained briefly in the sections below.

D. Student Model

The student module (knowledge of who to teach), the student module is responsible for managing the cognitive state through creating the student profile that includes such information like the student personal data, learning style, preference, current knowledge state of each individual student. The goal of student model is to provide adaptive and personalized tutoring to each individual student based on his/her profile. This model is considered as the base for making the ITS adaptive and also the most important decision making tool in any ITS system.

E. Tutor/Pedagogical Model

The tutor/pedagogical module are primarily concerned with the instructional methods. The goal of the tutor module in any ITS is to handle instructional decisions on a number of issues like the correct choice of the teaching methods that will suit each individual learner

base on the learner's profile from the student model, choosing the right learning content for the students and deciding the right time to study the content as well as assessing the cognitive state of each learner to be able to understand each student level of understanding in order to decides whether a student is to proceed to the next learning stage or to revised the previous stage.

F. Domain Model

The domain model (what to teach), this model is concerned with the knowledge of the particular domain to be taught. It coordinates the particular concepts within a particular domain.

G. Interface Model

The interface model (user-system interactive environment), this model is responsible for providing the environment for interaction between the system and the learner. Because ITSs are developed using computer system, the interactive interface that is usually created using graphical user interface provides the environment for which the students can interact with the system.

III. MODELING TECHNIQUES

A. Ontology

Ontology is defined as the shared knowledge and understanding of the relationship among entities and concepts within a domain of interest [31]. It can also be expressed as a vocabulary consisting of the formal definition of terms and the common relationship that exist among the relevant entities in the domain. The concept of ontology has been used as an instrument to present and convey meanings to the semantically-enriched contents with Metadata. The study of ontology has been going on for so many years, first by philosophers and then followed by logicians and recently in the field of artificial intelligence, particularly in student modeling aspect of an ITS for the designing and representation of knowledge base component.

B. Neural Networks

Artificial neural networks techniques are techniques that are influenced by the way the human brain functions [40]. The way artificial neural network operates is defined by the network of simple elements operating in parallel to achieve their processing power. The ANN always tries to mimic the process of manipulating information in the human brain in order to use its information to solve problems by means of computers.

C. Data Mining

Recently, the concepts of knowledge discoveries and data mining are considered synonymous to each other; this is because the term data mining can formerly be defined as the process of discovering knowledge from a very large homogeneous datasets [9]. Recent trends in the field of intelligent tutoring systems have shown how data mining techniques play active roles in the development of effective student/tutor models and the approach has contributed in widening and detecting the range of student's behaviors more than ever before.

D. Collaborative Filtering

An important goal of collaborative filtering (CF) is to generate better and accurate recommendations by relying primarily on previous user's behaviors like the items ratings from the users or information from the prior transactions with the aim of suggesting new items for a particular user. Collaborative filtering one of the common and most successful data analysis techniques used in recommender systems models. Collaborative filtering approach use to rely mostly on the past interactions performed by a user without having to bother about creating any user profile. The CF technique use to trace any relationships that exist between users and the interdependencies among products with the aim of generating a new user-item association [6].

E. Fuzzy Logic

Traditional logic is two-valued in the sense that any pre-position is either true or false, a fuzzy logic in contrast is many-valued logic and deals with reasoning that is not fixed and exact but approximate in nature. The variables in fuzzy logic usually assume values that range in degrees between 0 and 1 [10]. It is quite obvious that in order to solve real life problems, we often find ourselves dealing with pre-positions that are partially true and partially false and the truth value in this kind of instances can be ranging within the interval of completely true and completely false pre-positions.

F. Intelligent Agents

The agent technique has been used in various computational intelligent designs. An intelligent agent is a software system that perceived its environment and takes action based on the environmental condition [8]. The use of agents is one of artificial intelligent techniques for modeling domains like the student/tutor modules of a typical ITS system.

G. Bayesian Network

When dealing with many domains in real life systems, it is quite obvious that we need to reason in order to figure out how changes occur in those systems.

TABLE I. SUMMARY OF RESEARCH PAPERS BY PUBLISHING JOURNAL

JOUNAL NAME	FREQ.	PERC (%)
Expert Systems with App.	19	38
Computers & Education	8	16
Computers in Human Behav.	4	8
Human Computer Studies	3	6
Educational Research Review	2	4
Fuzzy Sets & Systems	2	4
Knowledge Based Systems	2	4
Artificial Intel. in Education	1	2
Learning Technology	1	2
Precedia in Computer Science	1	2
Information Technology	1	2
Applied Intelligence	1	2
Engineering & Science	1	2
Information Science	1	2
System & Software	1	2
Eng. App of Artificial Intel.	1	2
Advanced Comp Sci. & App	1	2

TABLE IIA. SUMMARY OF RESEARCH PAPERS BY ARTIFICIAL. INTEL. TECHN.

Model	Artificial Intelligence Technique							
	DM	NN	CF	ONT	BN	FL	AG	NF
IPA							●	*
Grubisic, 2013				*	*			
DEPTH						*		
Gamboa					*			
Huapaya, 2013						*		
OPENET4LD				*				
ATSs						*		
Amau, 2013						*		
Porayska, 2013	*							
Voskouglou, 13						*		
Wang, 2013					*			
Lin & Yeh, '13	*							
Detcher, 2012					*			
Sevarac, 2012								*
Bobadilla, 2012			*					
ITS-C						*		
FTCP-RS						*		
Fonte, 2012							*	
Oscar				*				
Paredo, 2012							*	
Ganapathy2011				*				
Voskouglo2011						*		
Goel, 2011						*		
Abdul&Tap '11						*		
EDUCA 2.0		*						
Yaghmaie,2011							*	
Sabourin, 2011					*			
SCAF				*				
Pena-Ayal2011						*		
Burder,2011			*					

For instance, faults diagnosis, financial risk management, evolutionary studies and sometimes even life history data analysis. But the reasoning about such systems is full of uncertainties and it may amounts to asking questions and certainly, the answers to all these kinds of questions can best be expressed as probability distribution over time [7]. A Bayesian Network is a directed graph model that handles probabilistic relationships among entities of interest [8].

TABLE IIA SUMMARY OF RES. PAPERS BY ARTIFICIAL INT. TEC. CONTINUED

Model	Artificial intelligent Technique							
	DM	NN	CF	ONT	BN	FL	AG	NF
Roll,2011	*							
Hsieh2010	*							
Alvi, 2010				*				
Drumond	*							
Mizoguchi				*				
GazeTutor							*	
Beldagli'10							*	
Reineke'10	*							
Porcel,2010						*		
Conati,2010					*			
Kumar , '10				*				
Zanebe2009						*		
Woolf,2009							*	
Fazlollahtab						*		
Lo´ peza,09				*				
NFPR								*
Sarrafzadeh08							*	
Tex-Sys				*				
ABM					*			
ATM							*	

IV. DISCUSSION/CONCLUSION

The objective of this research is to investigate the state of art in the tutor/student model designs with a view of finding relevant information that can help us to understand a little of the past, present and more importantly the feature of the modeling designs of these two important   components of intelligent tutoring systems. The review has succeeded in revealing the most recent computational techniques that are used to manipulates various research articles with a view to improve the performance and efficiency of the intelligent tutoring systems. A total of fifty student/tutor modeling research papers were examined in this review within the period 2008 to 2013. This was presented in the table 2a and 2b above. The performance of techniques like Fuzzy logic, Ontology, Bayesian networks and data mining within the period of the review appears to be very pronounced. The reasons for the use of Fuzzy and Bayesian techniques are very clear, this is because modeling student/tutor domains of ITS has been found to be characterized with a lot of uncertainty issues and both fuzzy logic and Bayesian techniques have been found to

be promising techniques to handle this uncertainty issue. Knowledge representation and management is a vital issue in both student/expert model designs and it is equally not surprising to see how the use of ontology is recently gaining popularity. The data mining techniques too appear to be pairing well recently, the use of such techniques like machine learning; association rule mining is equally getting stronger in these aspects of student/tutor modeling. The use of agents is one of AI's long term techniques so it is not surprising to see how a number of models in the review are making use of agent technique in their modeling. Neural network and collaborative filtering are also used to model the domain of student/tutor models. Recently researchers are beginning to apply hybrid approaches like use of neural networks and fuzzy or ontology and Bayesian as another alternative for modeling these two components of a typical ITS system.

However, the summary in table I has demonstrated how various journal groups are performing in the field of artificial intelligence in education. But it is equally important to state clearly one more, that work in the application of artificial intelligence in education has been spread across so many journal databases for the past three decades and our work here is only representing a fraction of different contribution of researchers in this field. The primary essence of a review is to try and explore the contributions made so far and to share the knowledge and ideas discovered from the various aspects of the review in order to widely open the windows for improvements on the existing architectures. The trend as for the years of publication is also found to be very encouraging with significant increase year after year and this is trying to suggest that the feature is looking very bright not only for the student and tutor components alone but the intelligent tutoring systems and computational intelligence as well.

REFERENCES

[1] Li, X., & Soh, L., " A literature review on learner control strategies in software tutoring" J. Sciece & Engineering, 2003
[2] Kay, J. "Learner control user modeling and User-Adapted Interaction" 2001.
[3] Self, J. ByPassing the intractable problem of student modeling" 1990.
[4] Alpert, S.R., Singley, M.K., & Fairweather, P.G. " Web-based E-learning System". 1999.
[5] Kulik, J.A., & Kulik,C.L.C ;Effectiveness of Computer-Based Instruction; An Updated Analysis" Comp in Human Behavio1991
[6] Hu, Y., Koren, Y., & Volinsky C., "Collaborative Filtering for Implicit Feedback Datasets"
[7] Heckermen, D., "A Tutorial learning with Bayesian Network". 1995.
[8] Russel, S., & Norvig, P., "Introduction to Artificial Intelligence. 2000.
[9] Agrawl, R. Fast Algorithms for Mining Association Rules" 1994
[10] Zadeh, L.A., "Fuzzy sets information control" 1980.
[11] Bodaracco, M., & Martinez, L. "A fuzzy linguistic algorithm for adaptive test in Intelligent Tutoring System based on competences" Expert System & Application 2013.

[12] Letham , A., Crockett, K., Mcleans, D., & Edmonds, B., "A conversational intelligent tutoring system to automatically predict learning styles" Computers & Education. 2012.

[13] Hefferman, N.T., Koedinger, K.R., & Razzaq L. "Expanding the model-Tracing Architecture; A 3rd Generation Intelligent tutor for algebra symbolization. 2008.

[14] O'Shea, K., "An approach to conversational agent design using semantic sentence similarity. 2012.

[15] Mikic Fonte, F.A, Burguillo, J,C., & Nistal, M.L. "An intelligent tutoring module controlled by BDI agents for an e-learning platform" Expert System with Application. 2012.

[16] Kumar V.S, Gress C.L.Z, Hadwin A.F, Winne, P.H."Accessing Process in CSCL: An Ontological Approach. Computers in Human Behaviors. 2010.

[17] Dechtar, R., "Bayesian Networks and Belief Propagation. 2012.

[18] Conati, C., Bayesian Student Modeling. 2010

[19] Fazlollahtabar, H., & Mahdavi I., "User/Tutor optimal learning path in e-learning using comprehensive neuro-fuzzy approach" Journal of Education & Review. 2009.

[20] D'Mello, S., Olney, A., William, C., & Hays, P., "Gaze tutor: A gaze-reactive intelligent tutoring system" 2012.

[21] Lin C.F., Yeh, Y., Hung , Y.F., & Chang, R.I.," Data Mining for providing a personalized learning path in creativity: An application of decicion trees" Computers & Education. 2013.

[22] Porcel, C. & Herrera-Viedma, E. "Dealing with incomplete information in a fuzzy linguistic recommender system

[23] Kopp, B., Matteucci, M.C., & Tomasetto, C, "E-tutorial support for collaborative online learning: An explorative study on experienced and inexperienced e-tutors" Computers & Educatin. 2012.

[24] Cabada, R.Z., Estrada, M.L., & Garcia, C.A., "EDUCA: A web 2.0 authoring tool for developing adaptive and intelligent tutoring systems using a Kohonen network" 2011.

[25] Hernandez, Y., & Arroyo-Figueroa, G., "Evaluating a Probabilistic Model for Affective Behavior in an Intelligent Tutoring Systems" 2008.

[26] Bobadilla, J., Ortega, F., Hernando, A., & Bernal, J., "Generalization of recommender systems: Collaborative filtering extended to groups of users and restricted to groups of items" Expert systems with Applications .2012

[27] Roll, I., Aleven, V., McLaren, M.B., & Koedinger K.R. "Improving students' help-seeking skills using metacognitive feedback in an intelligent tutoring system". 2011.

[28] Buder, J., & Schwind, C., "Learning with personalized recommender systems: A psychological view". 2011.

[29] Grubisic, A., Stankov, S., Pereic, I, Ontology based approach to Bayesian student model design" Expert Systems with App. 2013

[30] Peña-Ayala, A., Sossa-Azuela, H., Cervantes-Pérez, F., Predictive Student Model Supported by Fuzzy-Causal Knowledge and Inference, Expert Systems with Applications .2011.

[31] Vesin, B., Ivanovic, M., Aleksandr,L., & Budimac, Z., "Protus 2.0: Ontology-based semantic recommendation in programming tutoring system" Expert Sys with App. 2012.

[32] Woolf, B., & Burleson, W., "Affect-aware tutors: recognising and responding to student affect" J. Learning Technology. 2009.

[33] Thai-Nghe, N., Drumond L., Artus, K., & Schmidt-Thieme, L., "Recommender System for Predicting Student Performance" Precedia in Computer Science. 2010.

[34] Zenebe, A., & Norcio, A.F., "Representation, similarity measures and aggregation methods using fuzzy sets for content-based recommender systems" Fuzzy sets & Systems, 2009.

[35] Alvi, A.S., & Ali, M.S., "Revival of Tutor Model: A Domain Independent Intelligent Tutoring System (ITS)" Inf. Tech. 2010.

[36] Ajiboye, A.R., Arshah, R.A., & Qin, H., "Risk Status Prediction and Modelling Of Students' Academicachievement - A Fuzzy Logic Approach" Journal of Eng. & Science. 2013.

[37] Mitrovic, A., Ohlsson, S., & Barrowa, D.K., "The effect of positive feedback in a constraint-based intelligent tutoring system" Computers & Education. 2013.

[38] Langsetha, H., & Nielsen, D.T., "A latent model for collaborative filtering" Approximate Reasoning. 2012.

[39] Bloom, B.S., "The search for group instruction" 1984.

[40] Haykins, S., "Neural Networks: A comp. Foundat" 1999

[41] Sabourin, J, Mott, B., & Lester, J., "Modeling Learner Affect with Theoretically Grounded Dynamic Bayesian Networks" 2011.

[42] Yaghmaie, M., & Bahreininejad, A., "A context-aware adaptive learning system using agents" Expert Systems with Appl. 2011.

[43] Fonte, F.A., Burguillo, J.C., & Nistal, M.L., "An intelligent tutoring module controlled by BDI agents for an e-learning platform" Expert Systems with Applications. 2012.

[44] Lo´ pez a, C., Inostroza, P., Cysneiros, L., Astudillo, H., "Visualization and comparison of architecture rationale with semantic web technologies" System & Soft. 2009.

[45] Wang, Y. & Beck, J., "Class vs. Student in a Bayesian Network Student Model" 2013.

[46] Voskoglou, M., "Fuzzy Logic as a Tool for Assessing Students' Knowledge and Skills" Education Sciences. 2013.

[47] Abdullah, L., Tap, A.O. & Abdullah, W.S. "Fuzzy Set Conjoint Model in Describing Students' Perceptions on Computer Algebra System Learning Environment" Comp. Science Issues. 2011.

[48] Goel, G., Lallé, S., & Luengo, V., "Fuzzy Logic Representation for Student Modelling" 2011.

[49] Peredo, R., Canales, A., Menchaca, A., & Peredo, I., "Intelligent Web-based education system for adaptive learning" Expert Systems with Applications. 2012.

[50] Voskoglou, M. "Measuring Students Modeling Capacities: A Fuzzy Approach" Journal of fuzzy systems. 2011.

[51] Porayska-Pomsta, K., Mellish, C., "Modelling human tutors' feedback to inform natural language interfaces for learning" Human-Computer Studdies. 2013.

[52] Arnau, A., Arevalillo-Herráez , M., Puig, L., González-Calero., J. "Fundamentals of the design and the operation of an intelligent tutoring system for the learning of the arithmetical and algebraic way of solving word problems" Comp. & Educ. 2013.

[53] Mao, X., & Li, Z., "Agent based affective tutoring systems: A pilot study" Computers & Education. 2010.

[54] Ganapathy, G., & Sagayaraj, S., "To Generate the Ontology from Java Source Code" Advanced Computer Science & Application. 2011.

[55] Vidal , J.C., Lama, M., & Bugarín, A., "Petri net-based engine for adaptive learning" Expert Systems with Applications. 2012.

[56] Huapaya, C., "Proposal of Fuzzy Logic-based Students´ Learning Assessment Model" 2013.

[57] Jeremic´ ,Z., Jovanovic´, J., & Gaševic´, D., "Student modeling and assessment in intelligent tutoring of software patterns" Expert Systems with Applications. 2012.

[58] Kaklauskas,A., Vlasenko, A., Raudonis, V., Zavadskas, E.K., Gudauskas, R., Seniut, M., Juozapaitis, A., Jackute, I., Kanapeckiene, L., Rimkuviene, S.,Kaklauskas, G., "Student progress assessment with the help of an intelligent pupil analysis system" Engineering Applications of Artificial Intelligence. 2013.

[59] Gamboa, H., "Designing Intelligent Tutoring Systems: A bayesian approach" 2013.