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DEVELOPMENTS IN INTELLIGENT TUTORING SYSTEMS 2010-2020

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Abstract
Intelligent Tutoring Systems (ITS) vary a lot in the architecture employed, the realization of domain knowledge, the student modelling techniques, the pedagogical techniques and in numerous other aspects. This literature review attempts to highlight the key theories and implementation technologies adopted in the design and development of ITSs during the period under review.
Keywords: Intelligent tutoring system • Adaptive learning • Literature review

1 Introduction

Ever since the inception of computers, researchers have been trying to use them to provide accurate, accessible and cheaper tutoring systems. The use of electronic technologies to facilitate the task of learning, or even for accessing educational curriculum outside of a traditional classroom is referred popularly as *e-learning.*
E-learning is a very broad domain, which encapsulates the study of all types of relationships between education and technology. It includes all the methods and mediums where technology is used to assist learning, spanning across multiple hardware and software research areas and use-cases. An excellent statement on education technology in [1] proposes that "Educational technology is the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources."
Online education was first seen in 1960 in the University of Illinois, nine years before the invention of the Internet. Linked computer terminals were used to provide necessary information to students. In 1966, two psychology professors from Stanford University proposed the use of computers to teach spelling and arithmetic via Teletypes (an electromechanical device used to send and receive typed messages) to school students [2].
In modern day e-learning systems, interactivity is a key element and a lot of two-way communication is expected between the student and the e-learning system. In a traditional classroom a human tutor performs a lot of interaction with the students apart from narrating the contents. A human tutor can adjust his tutoring according to the level of students. Researchers have been trying to incorporate this ability into e-learning systems for decades, and have apparently found its answer in the domain of Artificial Intelligence (AI). With AI, the necessary communication which the student needed to carry out with the tutor, can be partly (or wholly in some cases) performed with the machine itself.
Artificial Intelligence is being used to enhance the quality of learning from as early as 1970 [3]. This task can be made easier if the tutoring machine is portable, leading us to the field of *mobile learning*, which allows the student to carry the tutor with them wherever they go.According to [4]*M-learning* is "learning across multiple contexts, through social and content interactions, using personal electronic devices".
[5]suggest thatmobile technology combined with network technology can connect formal learning to informal learning. Formal learning refers to the education delivered in a traditional classroom environment by trained teachers and informal learning is any type of learning which is not formal. Mobile learning has the strength of being portable, which leads to more responsiveness and the ability to provide instant feedback.[6]observed that mobile learning can increase exam scores from the 50^{th} to the 70^{th} percentile and reduce the dropout rate by 22 percent in technical fields. Mobile learning is also relatively cheaper because the cost of mobile devices is relatively lesser than that of laptops and personal computers.

2 Intelligent Tutoring Systems

Intelligent Tutoring Systems are software that implement well established tutoring and learning strategies through technology and Artificial Intelligencewith a goal of providing personalized learning without requiring consistent intervention from a human expert. Their common aim is to use AI to provide teaching which, if performed by human, would be considered 'Good Teaching' [7].
In 1950s, Skinnerian type 'linear programs' introduced the world to Computer Assisted Instruction (CAI). Here the teaching material was arranged to take the student from one step to another through a series of frames.The

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main problem with such systems was that they were unable to provide one-to-one individualization to the students, because they were not designed to know what they were teaching. This style of CAI has been called as ad-hoc frame oriented (AFO CAI) by [3].

Carbonell believed that effective machine tutoring was only possible through the use of AI techniques and worked on the intersection of AI and CAI. He dreamed of a system which could use true natural language dialogue for effective tutoring with a student. Carbonell crafted an early version of his dream system which he called SCHOLAR [3]. SCHOLAR marked the beginning of an era of intelligent tutoring systems.

Intelligent tutoring systems combine AI, education theories, and psychological models of the student and the expert. Thus, building truly intelligent tutoring systems required experts from the AI community, psychology community and education community to come together.

The CAI systems have evolved over the past years to what are now called Intelligent Tutoring Systems in which the word 'intelligent' has always been debatable just like the word 'intelligence' in Artificial Intelligence. Finding out what makes a tutoring system intelligent, and what does it mean to be an intelligent tutoring system as compared to just being a series of frames shown to a student for step-by-step tutoring, or just being an electronic representation of a textbook, or a recording of a classroom session, has been the subject of multiple researchers' interest. Out of the countless explanations on this topicgiven by different researchers, we often find the one given by Self to be the simplest, which states that a computer tutoring system should have a representation of *who*is being taught,*what* is being taught, and *how*it's being taught[8].

An intelligent tutoring system could utilize any structure as long as it fulfils the goal of intelligent and effective tutoring. However, the earliest recollections of the structure of an intelligent tutoring system provide for the following essential components[9]:

1. The Curriculum (domain) Model.
2. The Student Model
3. The Tutor (pedagogical) Model
4. The Interface Model

The field of intelligent tutoring systems have evolved into various sub-areas, like Dialogue Based Tutoring Systems which provide tutoring to the student using natural language dialogue, Cognitive Tutors[10] which utilize a cognitive model (an approximation of animal cognitive processes) to provide feedback during the learning process, tutoring systems for Intelligent Computer Assisted Language Learning, etc.

In addition to these, there have been various authoring tools to support the creation of intelligent tutoring systems, like Cognitive Tutor Authoring Tools [11], ASSISTment Builder[12], GIFT [13], ASPIRE [14], AutoTutor Tools [15], etc.

Some noteworthy intelligent tutoring systems from the past decade showing diverse characteristics have been discussed in this paper.

3 Review of Existing Intelligent Tutoring Systems

The researchers in [16] propose an intelligent tutoring system that attempts to teach JAVA programming, by using a notation that has been called ANGELA ("notAtioN of road siGns to facilitatE the Learning of progrAmming"), which the system auto-generates using the provided source code. The system employs 3D graphics, presented through an augmented reality environment. The JAVA source code is used to generate an abstract syntax tree, which is then used to generate JavaScript Object Notation data to be processed by the AR device to create the necessary visualization. The authors suggest that teaching programming this way makes it easy to understand because it includes some very familiar elements from daily lives of students – roads and traffic signs. The system is intended to be used by university students who are just beginning to learn programming.

In [17], the researchers have presented a hybrid tutoring system with didactic transposition of contents. Rules mapped from teacher's knowledge and an artificial neural network SOM (Self Organizing Maps) guide the didactic transposition of contents. The neural network adjusts the teacher's rules according to how the student navigates through the educational contents. The neural network strengthens the decision of choosing the next step according to the next step chosen by the successful students.The proposed system works without the requirement of extensive data collection and minimal neural network trainings. The system was built using Ruby® and PostgreSQL was used for the database operations.

[18] have proposed an adaptive network-based fuzzy inference system that employs artificial intelligence techniques to enhance second language acquisition. This work is a part of the subfield of Intelligent Tutoring called Intelligent Computer-Assisted Language Learning. This work proposes a hybrid model of "misconceptions detection and identification" using machine learning and a technique for automatic modelling of students' learning. The system uses relationships established between the educational concepts in the domain model to model the learning and forgetting process of the student. There are pre-defined error categories such as mistakes in the use of tenses, verbs, etc. The system detects learner's misconception and enters the appropriate error routine and places the appropriate learning material in front of the user using the fuzzy inference system.

[19] have proposed an evaluated a Fuzzy-ITS which employs a fuzzy rule set to teach the basic concepts of C language through what the researchers call the "learn module" and analyses the student through the "fuzzy test module" at every step of the tutoring process. If the student produces incorrect answers to the fuzzy test module, the system analyses the fuzziness and helps the student understand the topics more clearly. Motivation is provided through the use of encouraging words like "You were very close" and "All the Best :)". The system was evaluated on 50 students and showed satisfactory improvements in performances of the learners.
[20] has proposed an ITS for teaching punctuation in Turkish, that uses two student models – the Overlay Model and Case Based Model (CBM). The CBM records each mistake made by student and provides feedbacks and hints accordingly. This information is used to determine the student's learning of the topic and it's updated in the overlay student model. Learning gaps are identified after student attempts all the questions and appropriate content is shown to the student. The domain knowledge is stored as constraint sets that define all the possible answers for each problem. This intelligent tutoring system has an original evaluation method that uses MYCIN certainty factor, the number of attempts student uses, and a fuzzy logic decision system.The fuzzy logic decision system was implemented in C#.
[21]have proposed a Dialog Based Tutoring System (DBT) that is scalable and works across domains. A DBT is a special type of intelligent tutor that is based on the Socratic principle of cooperative dialogue in natural language. It works because forming a response in natural language requires recalling and reflection of learned knowledge. The work reflects the common challenges faced in the creation of DBTs such as preparation of a dialog strategy, content design and structuring in such a way that drives the tutoring agenda. This work suggests use of scaffolds to help keep the student motivated, a common technique across many of the ITSs discussed in this review.
[22]proposed an entropy normalization method to update a unified model of a child's understanding of a word, and enable assessments of multiple types. The proposed learner model normalizes different assessment types, mainly single-answer MCQs, multiple-answer MCQs, blank filling, matching, etc. Because these have different amount of information gain, the system uses exponentially weighted moving average (on the scale of 0 to 1) to update the learning score which determines the confidence that the learner knows the word.
[23]have described the design of Droid-Tutor, a web based intelligent tutoring system for a systematic introduction to Android application development. The system claims to automatically generate problems using templates under the Problem Generation Module for tutoring and adapt to every student's individual learning automatically during the tutoring process. The questions ask the student to either correct a piece of code, write a piece of code, multiple-choice or true/false type questions. The evaluation of the system was done through a questionnaire filled by a group of lecturers and students and the outcomes were mostly positive.
[24] presentedArtificial Intelligence Teaching System (AITS) – an intelligent tutoring system for tutoring of AI Search Algorithms through multiple learning activities. It employs a process that can visualize the operation of algorithms and during visualization, it can stop and ask the student for the next step, or for the explanation of an intermediate decision. The system provides two type of interactive exercises – practice interactive exercise provide help and immediate feedback after incorrect input, and interactive assessment exercises that are used to determine the student's progress. The student's answer is categorized into one of 7 predefined categories and appropriate actions are taken based on that. The system employs an Automatic Marking Algorithm to estimate the overall student understanding of a topic, which works upon the type of student answer and the type of errors made.
[25]have discussed a mobile based intelligent tutoring system for tutoring of computing laws of exponents in which a virtual assistant named Teacher AICA (Artificially Intelligent Cognizant Agent) guides the student in solving a problem and can also solve a problem on its own. The system has reading materials as well as lectures dedicated to teach students similar to a classroom setting. The materials and lectures are sorted according to the skillset and needs of the student. Various skillsets are defined within exponents, which are taught by the agent Teacher AICA. The agent also provides necessary feedbacks and hints during the tutoring process, just like many other ITSs presented in this paper.
[26] proposed ITALIC, a system for tutoring grammatical voice conversion aimed at students in the age group of 12 to 16 year. ITSs like these come under the sub-category ILTS (Intelligent Language Tutoring Systems). Generation of new sentences for tutoring is a common concern in these types of systems and this paper solves it through a sentence-generation mechanism that uses template structures to generate large number of meaningful and grammatically correct sentences. It uses a rule-based model to store domain information in the knowledge base which is used to analyse student's response and provide appropriate feedback. The system also contains theory on topics such as inflection of the noun, use of articles, etc. This system is web-based for easy access, and provides learning under the "continuous-practice" philosophy. Its feedback system uses text-based interaction.
[27] proposed an intelligent tutoring system architecture to discuss on the problem of designing a web-based adaptive system for learning how to write ladder logic programs for PLC control. The system utilizes colourful diagrams and animations to attract students' attention. Case-Based Reasoning (heuristic functions) are used to

build the adaptive part of the system – it uses heuristic functions to match the current user's configuration to one of the built-in error patterns. The system tries to fix the student's error step-by-step with the guidance of the matching error pattern and also provides the student with detailed tutorials and tests on each topic. The system's accuracy of mapping to the most similar error pattern was reported at 90%.

[28]have proposed a system that consists of a Proposed Adaptive and Intelligent Tutoring System (P-AITS) and an Ordinary Adaptive and Intelligent Tutoring System (O-AITS) as twoseparate learning modes, withP-AITS having a scheme to generate a personalized learning path for the student and with an aim to propose a domain-independent model to represent teaching activity. Curriculum sequencing is very helpful for students who have very specific learning needs and not much patience or time to learn all the concepts. The fact and rule based expert system ensures questions don't repeat when a learner learns the same concept multiple times, the question must be planned for all sections of a topic, and finally questions must be planned for all levels.

[29]have discussed a mobile application with an ability to teach multiple languages in a user-friendly way. The researchers exploit the fact that educational systems have a large number of users, and so machine learning can be applied to individual student models to generate paths for new students. The system employs clustering of students using the k-means algorithm to recognize similarities between certain groups of students. This data helps put every new student in a particular cluster, which helps the system adapt to their behaviour. The proposed system employs a client-server architecture. The machine learning processing was done on a separate server and the output was sent to the mobile device for use.

[30] proposed PCULS (Personalized Context-aware Ubiquitous Learning System) for teaching English vocabulary based upon "The Situational Learning Approach" which states that social, cultural and life's "context" affects a learner's interest and efficiency. The system uses learner's location, learning time, vocab ability and leisure time to recommend appropriate English vocabulary for learning. Learner's location estimation is done through a system that utilizes WLAN and back-propagation neural networks exceeding an accuracy rate of 92%. The system's evaluation revealed that learning performance using personalized vocab learning exceeds the performance of learners who learned without the context-aware service. Also, 72.2% of learners preferred context-aware learning after trying both the modes.

4 Conclusion

There have been very interesting developments in the area of intelligent tutoring systems in the past decade, and present review tries to reflect upon them.In the decade under review, considerable expansion has been seen in the areas of fuzzy logic based ITSs, Dialogue Based Tutoring Systems (DBT), Intelligent Language Tutoring Systems (ILTS), as well as numerous improvements on the aspect of adapting to individual student are seen. The systems are seen to adopt different architectures, revolving around the same theme of having the four modules listed in section 2. Some systems just gave new names to the modules, while others added extra modules or combined two or more modules into one.Because mobile devices have become a major part and sort of an essential element of today's lifestyle, extensive work is required in the direction of mobile based intelligent tutoring systems.

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