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A comparison of machine learning techniques in building an intelligent tutoring system

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Abstract. An Intelligent Teaching System (ITS) integrates Artificial Intelligence (AI) to the field of education, in order to dynamically adapts to users with different background and provide optimal teaching methods. Recent advancements in intelligent tutoring have proved its effectiveness in enhancing the achievement and abilities of learners. At the same time, with the rapid development of AI technology, various AI and machine learning algorithms have been applied to the design of ITS, optimizing their performance to varying degrees. This paper provides an overall review of previous ITS research using various techniques of artificial intelligence and machine learning (ML) and provides an overview of ITS and its architecture. In addition, it discusses and summarizes current research efforts and barriers to ITS using AI, as well as some future opportunities. This paper provides an overall comparison of various machine learning techniques that have previously been applied to ITS and an overview of ITS and its architecture. In addition, it discusses and summarizes the current barriers to ITS using AI, as well as an expectation of its future development.

Keywords: Machine learning; Education; Intelligent Tutoring System.

1. Introduction

The field of education has always been taken seriously by both government and the general public. After artificial intelligence emerged in the 1950s and demonstrated a great potential for solving all kinds of social problems, people started to consider applying artificial it to the field of education and creating intelligent tutoring systems (ITS) to enhance the quality of both teaching and learning [1, 2].

Since the 1960s, artificial intelligence technology has been incorporated into the field of education. Through the creation of Intelligent Tutoring Systems that assist students' learning environments, AI approaches have been applied in schools and universities. Recent developments in intelligent tutoring have clearly shown that users of these systems can quickly improve and largely raise their achievement in particular subjects and abilities [3].

Although many machine learning methods which are adapted into ITS have proven effective, the issue of which algorithm combinations can best improve the performance of ITS remains unsolved. This passage is primarily to summarizes machine learning techniques applied to ITS, compares their uses, features, and advantages. Here's the organization of the rest of the paper: First, Part 2 shows an overview of intelligent tutoring systems, and describes its components. Next, Part 3 presents machine learning techniques applied with different parts of the ITS separately and gives a brief comparison.

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Finally, Part 4 discusses and summarizes the current barriers to ITS using AI, and an expectation of its future development.

2. Intelligent Tutoring Systems

An intelligent tutoring system is a computer system, which integrates Artificial Intelligence to the field of education, in order to dynamically adapts to users with different level, age or culture and provide optimal teaching methods. It can offer learners quick, personalized education or feedback, typically without a human teacher's involvement. There are 3 common goals of ITSs: providing opportunities to every student to access to high quality education, facilitating users to learn in a meaningful and effective manner by replicating the proven advantages of individualized, one-to-one tutoring and reduce the workload as well as stress on human teachers. ITSs are essential in education, since it offers students individualized one-on-one teaching support on how to solve learning difficulties by offering guidance and rapid feedback. Recent developments of ITSs have explicitly shown that users of these systems may quickly improve and greatly increase their accomplishment in particular topics and talents [1].

There are different approaches to the description of ITS system structure, that is, the division of system modules. However, the four-module structure as shown in Figure 1 is accepted in terms of the functions performed by each part of ITS. Therefore, different machine learning methods have been applied to these four modules [4, 5].

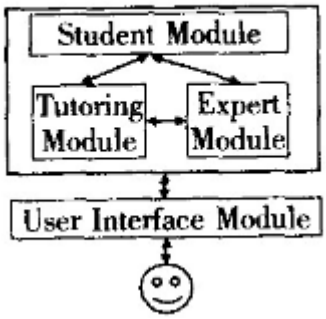

Figure 1. Four-module structure of an ITS [6].

1. Tutoring module. The core topic of this module is how to teach, specifically how to choose relevant teaching materials while using proper teaching tactics and how to give those materials to students in an appropriate form at an appropriate time.

2. Expert module. The primary issue addressed by this model is what to teach. The knowledge base, which houses the expertise of teaching specialists in the field of problem-solving, plays a significant role in the expert module. The expert module responds to queries posed by learners by using the knowledge base for diagnosis, reasoning, and problem-solving.

3. Student module. The issue of who to teach is resolved in this module, which also gives the tutoring module various student data for tailored training. The student module contains fundamental data on students, like their learning preferences, ways of acquiring knowledge, mistakes, and misunderstandings.

4. User interface module. This module regulates how the learner and system interact with one another. It is the communication module. The user interface module is the only component of the ITS that can present instructional content to the user, accept user input, and give the user feedback.

3. Machine Learning Techniques in Developing an Intelligent Tutoring System

3.1. Machine learning in expert module

The material stored in the system is critical to its performance and is the basis for the subsequent teaching process. For instance, one of the key issues of vocabulary instruction is how to find or build good

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example contexts to help kids learn a word. Before they can be part of the materials in the database, the data we collect must be pre-screened and classified. This is gradually becoming a more significant problem as the amount of data on the Internet continues to grow. A statistical machine learning algorithm called Naive Bayes (NB) is commonly used in solving this problem [7].

The Naive Bayesian classification algorithm is one of the most widely used classification algorithms. The weight is assumed to be conditionally independent of one another for a certain target value, which simplifies the Bayesian method. As a result, no attribute variable has a bigger weight than the choice outcome or a smaller weight than the decision outcome. In spite of the fact that this modification somewhat lessens the efficacy of the Bayesian classification algorithm, it substantially decreases the complexity of the Bayesian method in real-world application settings. Thus, it enables developer of ITSs to classify the needed knowledge with a small amount of training data.

3.2. Machine learning in tutoring module

An ITS can vary the difficulty and order of the material according to students' abilities or preferences and generate and monitor remedial exercises for each error. To achieve this, techniques like Reinforcement Learning (RL) and Artificial Neural Networks (ANNs) have been used.

When an agent interacts with the environment, reinforcement learning is a type of machine learning technique for describing and solving issues in which the agent learns how to maximize gains or accomplish particular objectives. In order for the system to automatically choose the optimum teaching strategy for students, RL can be incorporated into the tutoring model in ITS.

ANN in ITS is also highly effective. The key reasons are its capacity to link student characteristics to themes and its ability to update both the screen's content and the record of educators as they use the system [1, 8].

3.3. Machine learning in student module

The student module contains fundamental data on students, like their learning preferences, ways of acquiring knowledge, mistakes, and misunderstandings. It gives the tutoring module various student data for tailored training. Methods such as Bayesian Network (BN), Clustering, Fuzzy Logic (FL) have been applied in this field.

Bayesian networks are currently one of the most effective theoretical models in representation and reasoning uncertain knowledge. By fusing the material structure with the student profile and learning style, BN can be utilized in ITS student modelling to recommend teaching tactics [9]. In order to carry out the operation, a number of factors relating to the user's learning preferences and others connected to their level of expertise are defined. To alter and give updated knowledge to increase student accomplishment as outcomes during the learning process, the system modifies the learner's current state of knowledge using the Bayesian network.

An unsupervised data analysis technique called clustering is also used to identify patterns in incoming data and divide it into several groups according to shared traits. The majority of clustering algorithms can be used on the ITS student model by grouping the students according to their performance and learning behavior data.

Fuzzy logic is a technique to decision-making that helps with ambiguity. It functions as a range of possible inputs that result in a specific output. Unlike Boolean logic, which can only be used to express YES or NO, it encompasses all possible outcomes in between. FL is frequently used in ITS to create student models. The main goal is to gauge and assess a learner's academic performance. By determining and updating learners' knowledge level, it implements the idea of a fuzzy set theory that maps an input to a fuzzy output [1, 9, 10].

3.4. Machine learning in user interface module

In ITS, human-computer communication should also be intelligent. This involves the strategy of dialogue, and the requirement that the system not only understand natural language, but also respond appropriately. One of the difficulties in dialogue processing is that some utterances in a dialogue are

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ungrammatical and must be understood correctly with the help of the contextual environment. The system should know the topic under discussion; c) the system should be able to respond appropriately, generating the right information for the student at the right moment.

Natural language processing technology has developed significantly in recent years, and the research and development of natural language processing system for intelligent computer teaching system is of great significance for the performance and application of ITS.

Without Automatic Speech Recognition (ASR), Computer tutors are limited to keyboard and mouse input, while human tutors can make use of a wider range of input and output modalities, including vision, gaze, speech, and gesture. The application of ASR allows computer instructors to have better human-computer interaction performance and thus achieve greater teaching effectiveness.

Table 1. Comparison of different AI techniques

Modules	AI techniques	Applications
Student Module	Bayesian Network (BN)	Using BN for ITS student modeling to suggest instructional strategies by aligning learning content with student profiles and learning styles [1].
	Clustering	Clustering students' learning behaviors and build a more accurate student model to help personalized teaching.
	Fuzzy Logic (FL)	Use the fuzzy classification tree to predict and adapt the learning style of students in the whole coaching dialogue and modify the teaching content accordingly.
Tutoring Module	Reinforcement Learning (RL)	Set test questions in ITS and use learners' performance on the test as input to RL to discover the best learning strategies for learners.
	Artificial Neural Networks (ANNs)	Include individual characteristics of students and the teaching content arranged by ITS together into the training of ANN and find the learning method most suitable for specific student groups.
Expert Module	Naive Bayes Classification Algorithm (NB)	classify the needed knowledge of a particular area using limited training data.
User Interface Module	Techniques Related to Automatic Speech Recognition (ASR)	/

4. Conclusion

With the development of natural language processing and machine learning, ITS has made great progress in recent years. It is believed that with the further development of artificial intelligence, ITS will become more intelligent and personalized. However, it may take a long time for ITS to completely replace human teachers, after all, ITS is only a teaching system in a certain direction, not a panacea; and there is still a long way to go for ITS to fully adapt teaching methods and teaching strategies to students' situations, and the teaching effects need to be further investigated in depth.

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