LearnMath - A web app for teaching mathematics based on Intelligent Tutoring Systems

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July 30, 2017

Abstract

One –on –one in person tutoring has been an effective way to improve the learning experience of students. Private tutors have played an important part in helping students, but this option proves to be very costly for students. Intelligent tutoring systems were developed to overcome this problem. An intelligent tutoring system is computer software, which aims to mimic a human tutor by using artificial intelligence techniques. There have been some successful ITS projects in US and EU but their usage has been limited and dependent on the willingness of teachers and schools to adopt such solutions. ITS based software like cognitive tutors have performed well, but such solutions are limited to selected high schools in US. These solutions are not easily and widely accessible to international students or schools that cannot afford to use such programs. In this paper, the design of a web-based tool called LearnMath is described. This tool can be accessed from anywhere and it is designed to provide personalized learning feedback and exercises to students based on their performance .The tool is focused on teaching math concept to students and it focuses on teaching basic trigonometry to students. The framework has been designed to add other topics in mathematics as well.

Keywords: Intelligent tutoring system, human learning, web based tool

1 Introduction

The research interest in ITS goes back to the 1960s as the researchers have tried to leverage artificial intelligence techniques to create a program that can mimic human tutor. ITS can provide instructions delivered tailored to the need of individuals. It is an interdisciplinary field, which aims to unite educational theory with technology. ITS research and development encompasses many fields like computer science, cognitive psychology and educational research.[Nwa90][GS88] ITS evolved from CAI (Computer Aided Instruction) "linear programs" proposed by Skinner. In this approach the student is guided through a series of step to the solution, but there is no individualized feedback or support to the student. The system was improved by using "branching programs" which was able to change the steps according to student response. These programs led to the "generative systems" in the 60s . These generative systems were used to design arithmetic problems keeping in mind student's needs. The major drawback of this field was that it was restricted to well structured domains like mathematics where it was easier to generate problems.[PRZ12] These advancements lead to the need of a system, which had a knowledge database about a subject matter. The system can generate responses to student's query or initiate interaction in a language easily understood by the student. This idea was put forward by Jaime Carbonell in 1970 .The system should address the following questions as "what is being taught, who is being taught and how to teach him/her".[Sel74]

*Use footnote for providing further information about author (webpage, alternative address)—*not* for acknowledging funding agencies.

2 General ITS architecture

Though the existing ITS systems varies tremendously in architecture, the ITS system usually contains these essential components.

2.1 The expert knowledge module

It contains the facts and rules pertaining to particular domains, which is conveyed to the student. This knowledge is derived from experts of a specific field with years of work experience. This knowledge is used for generating questions, explanations and responses. It also helps in evaluating a student response. This can be only possible if the module generate answers in a manner, which is comparable to the answer given by student.

2.2 The student model module

This module contains information about skill set and knowledge of the student. It is very difficult to obtain the complete knowledge about capabilities of a student. Human tutors can easily understand a student's interest by gauging their facial expression and their body language. They can also sense a student's motivation and boredom. This invisible information is not captured by ITS . Despite these restrictions, the student models can be used for the following functions Self(1988b):-

1. Corrective: The student is encouraged to correct wrong answers
2. Elaborative: The student is aided in correcting 'Incomplete' knowledge
3. Strategic: Changing the tutoring strategy if the student fails to benefit from corrective and elaborative approach
4. Diagnostic: Helps in finding the reason for a student's mistake.
5. Predictive: Predicts student's response to tutoring actions.
6. Evaluative: Helps in accessing student and ITS.

2.3 The tutoring module

This part designs and dictates instructional interaction with the students. This module is closely coupled with the student model. It takes into account a student skill set and the instructions are presented in accordance with students need. The module also provides hints and explanation to students. ITS also aims to represent tutoring knowledge explicitly so that the same knowledge can be applied to other domains.

2.4 The user interface module

It controls the interaction between the student and the system.

3 Overview of the ITS solutions created over the years

Examples of some classic ITS are

- **SCHOLAR**: It is the first ITS to be created by Jaime Carbonell. Student and the system can easily initiate a conversation between themselves. The system provided answer in a manner, which can be easily understood by the students.
- **SOPHIE: (a Sophisticated Instructional Environment)**[BBB75]: It provided an environment to the student where students can learn by doing . Students were given freedom to try their ideas and feedback was given to them.
- **GUIDON**: This system adopted diagnostic problem solving approach and adopted a pre existing expert system.

The state of the art ITS systems, which are in present use, are described as below:

- Carnegie Learn:It can be seen as one of the most notable example of ITS systems, which have been quite successful in teaching high school algebra to students. Cognitive tutor mathematics courses are being taught regularly twice a week to 600,000 students a year in 2600 middle or high school. The full year evaluation studies of cognitive tutor algebra have demonstrated better student learning as compared to traditional methods. [RAKC07] All the content of this system is available to customers only, and this system also provides various data analysis services to the teachers and help them in creating content based on student's need. This service is mostly available in US schools and is not accessible to international students.
- ITutor project: This application monitors and track student's progress in online learning and give them feedback. It also gives input to tutors and teachers, to further improve their style of teaching. This system requires technical expertise on the part of teachers, as they have to configure the system based on their needs. The usage of this software is not very straightforward and requires a bit of training.
- Guru tutor: This system is modeled on the strategies and dialogue of expert human tutors.
- ASSISTments:A web based tool for helping students to do homework. The students require teacher's reference before using this site.

4 Motivation for the project

After examining all the available state of art ITS systems, it was evident that they are suffering from some limitations. Most of these systems either cater to specific subset of students, or these systems can only be used when teachers are trained to use this system. Unlike online learning where any student can access any content from any part of the world, the usage of ITS system has been limited to few countries. These limitations were the motivation behind creating a web app called LearnMath which can provide a personalized learning experience to users. The students attending schools, which do not support such ITS systems, should also be able to use it. They can easily access this site as they use other web resources like Wikipedia etc. without depending on their school or teacher.

5 Description of Design of tool LearnMath

LearnMath is a web based app which exploits the general architecture of ITS to create a system which is easily and widely accessible. This app is targeted towards students who are in middle school and aims to teach them basic mathematics. Presently,this app is focusing on teaching basic trigonometry to students (middle school level) but it can be easily expanded to cover other areas of mathematics as well. A simple mathematical topic is chosen, to avoid the complexities involved in designing and representing content for advanced fields. Since this prototype is aimed at kids and there is no prior knowledge or data about the skill set of the user base, it is assumed that the user has no prior understanding of trigonometry formulas and this tool will help them in teaching those formulas, and their application.
Since the app leverages general architecture of ITS, the different modules of the ITS system are implemented in the following manner:-

5.1 Expert module

It contains all the course contents, quizzes, hints and answers for each question.There are two sets of question banks associated with each concept. The first sets of question are used to assess student's understanding and the other set is used to provide additional practice to the students in case the student falters. All the data is stored in the expert module. This is implemented in code by storing all these information in sqlite3 database.

5.2 Student module

Every time a user completes a set of problems his/her proficiency level are recorded and his/her profile is updated in the system. This information is saved in the student module of ITS. This

is implemented in code by storing user's profile information in the database. Whenever a user completes a quiz on a particular concept, all mistakes are being recorded and this information is used to provide extra questions to students, which will test the concepts, which they got wrong or were able to solve, only by using a hint.

5.3 Tutorial module

This module will work as a connecting layer between user interface and expert module. It will accept the user's request of accessing a lesson from the expert module and present the content to the user after fetching it from expert module. It would be responsible for presenting hints and answers to the user after fetching it from the expert module. This module is responsible for creating a customized quiz for each user after extracting student performance information stored in student module.

5.4 User interface

The user interface designed is simple and intuitive so that the user can easily navigate the system.

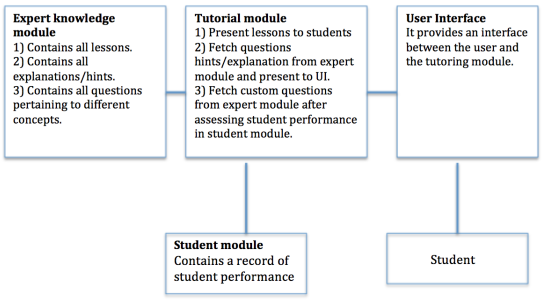

Figure 1: High level design of ITS tool LearnMath.

6 How does LearnMath actually work?

Every course provides lessons on certain concepts related to that topic. These concepts are explained using text and pictures. Once the user has completed a particular lesson, user can test his/her knowledge by taking a quiz. Students are given an option to take a hint before submitting their solution. The user's performance in the quiz is captured and additional questions are presented to the user based on the concept he/she got wrong. The questions are multiple choice questions so that there is no ambiguity in understanding user's answer. Initially the lessons presented are easier, but later lessons are built upon those initial lessons. The quiz questions are framed in a manner, which leverages the knowledge acquired by the user in current lesson as well as the prior lessons. This approach is chosen, as cognitivist school of learning suggests that deeper learning is enabled if the learner can make connections between new and prior knowledge.[All04] The lessons are kept small, and a quiz does not contain more than six questions, so that user does not feel overwhelmed by information overload. This general framework will be followed for creating content on any topic.

7 Description of the application

The project is implemented using Django framework, which uses python language to develop web based application. The web app is deployed using pythonanywhere.com and users can access LearnMath by using the following link: LearnMath The app provides the following functionalities

- User can log in /register for the app. The user can access the account after registering for the app. This will help in creating a user profile and helps in storing student's performance.

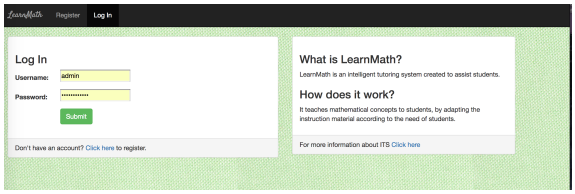

Figure 2: Log in/Register scree

- User can view and access all the courses.

Figure 3: Screen displaying all courses

- All the lessons related to a particular course are displayed. Each succeeding lesson is built on the previous lessons. There is a quiz related to each concept.

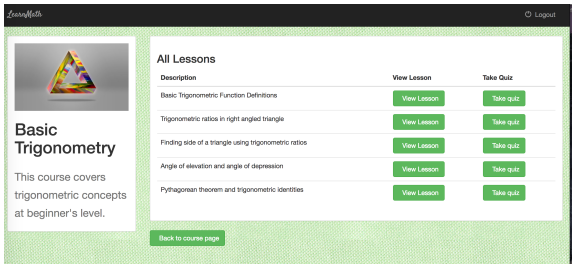

Figure 4: Screen displaying all lessons and quizzes in a particular format.

- User can take a quiz after viewing the lesson. Hints and feedback are provided for each question in the quiz.

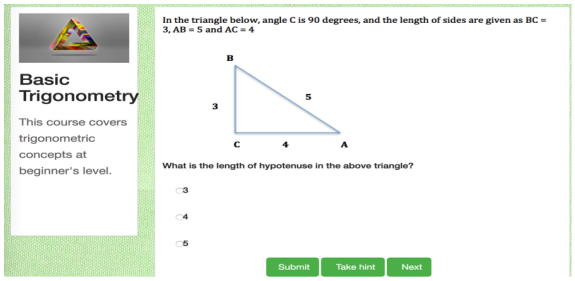

Figure 5: Screen displaying quiz question along with hints and feedback

- The feedback is provided after taking each quiz and the user has an option to take an additional quiz, which is generated, based on student's performance.

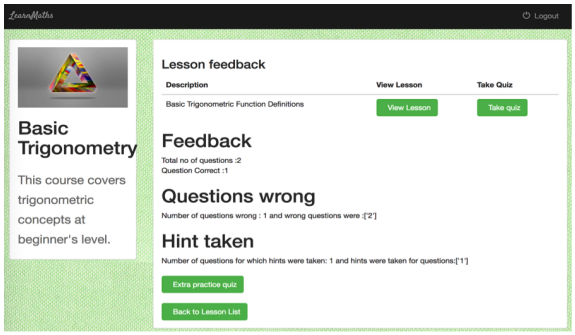

Figure 6: Screen displaying feedback and an option to take extra quiz

8 Future work

There is a lot of scope to improve and enhance LearnMath app and in the future following changes will be made to the app.

- More courses will be created covering different topic in Mathematics.
- Course content will be created using video format.
- Multi step questions will be incorporated. Presently the app presents questions in a MCQ format, but in future questions will be created where users have to solve multiple steps.
- Exhaustive question bank will be created for each concept to improve the learning experience of users.

9 Conclusion

Intelligent Tutoring System like Carnegie Learn has proved that ITS systems can greatly enhance the learning experience of students but they are limited to few schools and not widely available. LearnMath was developed so that it can be accessed easily by anyone having an Internet connection .The tool exploits the ITS architecture which has been well researched over the years. The app is designed in an intuitive manner and no training is required to use the app. Presently it is focusing on just one topic, but a framework has been designed to include other topics as well and this app can be enhanced by creating more engaging content and by expanding it to tackle more challenging topics in mathematics.

10 Acknowledgement

I would like to thank Dr Joyner and my mentor Greg Weber for guiding me throughout the project.I would also like to thank my classmates (Educational Technology Summer semester 2017) for giving valuable peer feedback which helped me in improving my project.

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The following resources were used in developing the web app LearnMath

- Django video tutorials on youtube
- Django official documentation
- Bootstrap documentation
- Javascript documentation
- pythonanywhere.com