AI in Education – A Problem-based Learning System for Mathematics (MathsTutor)

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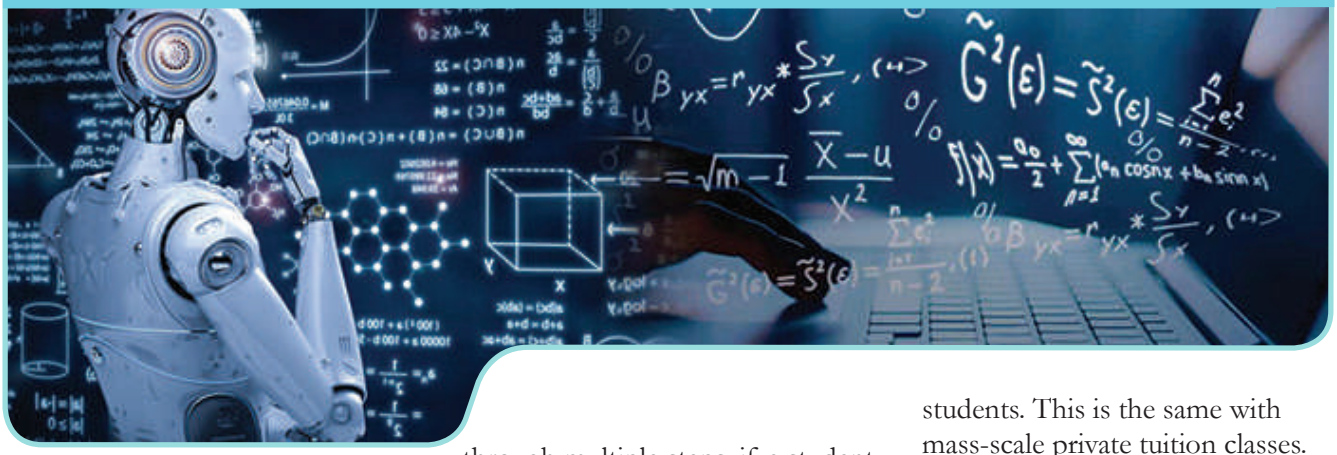

Mathematics is undoubtedly one of the most difficult subjects in the Ordinary Level (O/L) examination. Statistics show that close to 50% of the students fail mathematics in the GCE O/L examination. Many students find mathematics difficult because, unlike many other subjects, it is not possible to memorize mathematical theories/concepts and answer the exam paper. Rather, the student is expected to demonstrate that she can apply the learned theories and concepts in solving unseen mathematical problems. The best way to excel in mathematics is to practice solving many such mathematical problems. For many of these mathematical problems, partial marks are allocated to the intermediate steps of the solution. Therefore, the student should know the correct procedure to solve a mathematical problem. Moreover, when the Mathematical problem has to be solved through multiple steps, if a student makes a mistake in her solution, she cannot figure out the mistake simply by looking at the final answer. In such cases, a teacher will have to assist the student in identifying her mistake, and giving proper feedback. However, there is a scarcity of good mathematics teachers in many schools, and the available teachers do not have adequate time to allocate for personalized feedback to all the students. This is the same with mass-scale private tuition classes.

A solution to this problem can be provided with the help of computers, more specifically with the help of Artificial Intelligence (AI). This article presents such a system that is currently being developed by the Department of Computer Science and Engineering, University of Moratuwa. The aim of this system is to be capable of generating new questions, generating answers to these

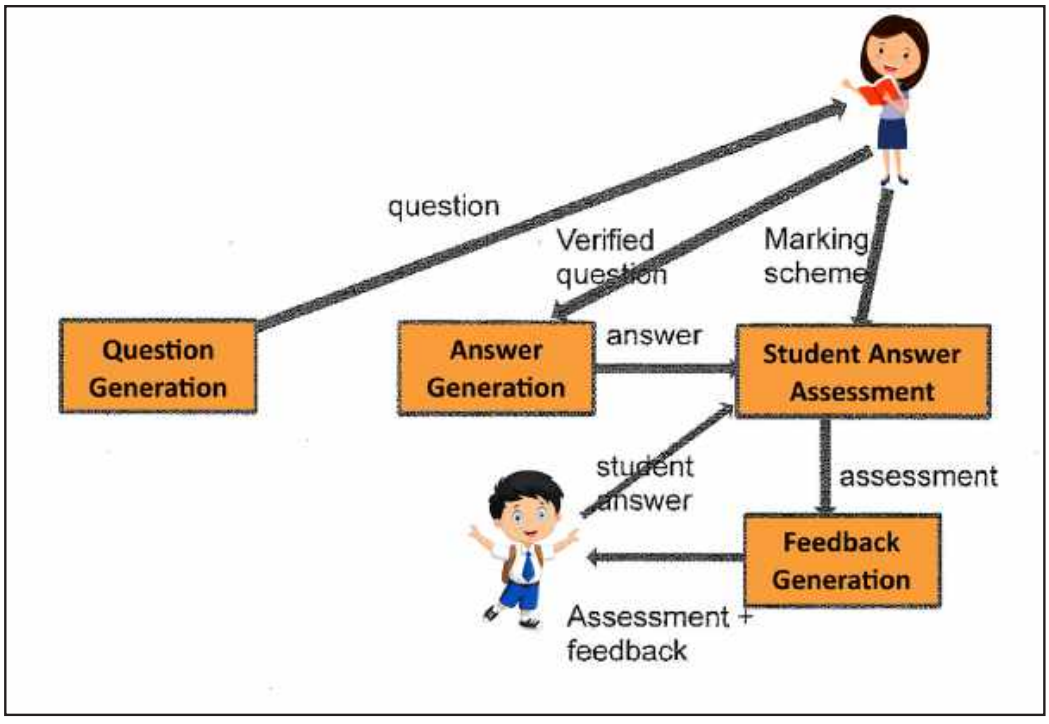

Fig 1 : Maths Tutor System

questions, assessing student answers according to a marking scheme, and to provide feedback to individual students. We call this system as MathsTutor. AI is a very broad field of study, and is broken into several sub-problems. The main sub-fields include reasoning, knowledge representation, planning, learning (Machine Learning (ML)), Natural Language Processing (NLP), and perception.

generates answers to these mathematics questions. When a student submits her answer, it is compared with the system generated answer. If a teacher provides a marking scheme, then marks are allocated to the student's answer. If the answer is wrong/ partially correct, the system provides feedback to the student.

Although this system looks

main advantage of this kind of modular approach is that different components of the system can be used without having to rely on other components. For example, the teacher can provide a question she created and get the machine to generate the answer. Similarly, she can manually provide the sample answer along with the marking scheme for the system to assess the student's answer.

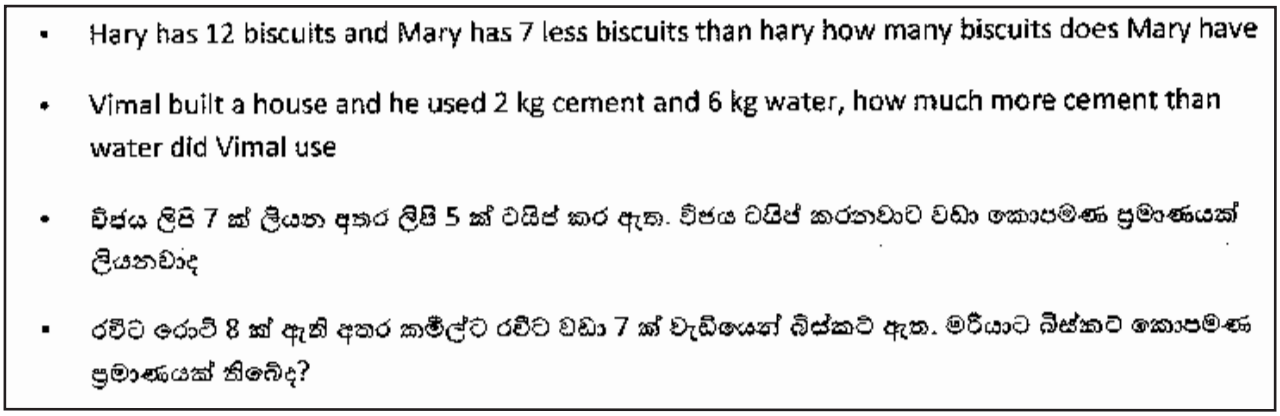

Fig 2 : System generated Sinhala and English elementary Mathematics questions

MathsTutor is based on NLP, ML, and reasoning.

It is important to note that MathsTutor is not intended to completely remove the teacher from the learning process of the student. This is the same with many other AI applications. Rather, the teacher is expected to play the role of a verifier and a facilitator, so that with the available time the teacher can serve/support more students.

Figure 1 shows how the MathsTutor system will look, when it is fully implemented. As can be seen, MathsTutor is capable of generating mathematics questions. The generated questions may not be 100% accurate. Therefore a teacher is expected to verify them. Once verified, MathsTutor

simple, its implementation is quite challenging. Different questions are written down in different formats, and are solved in different ways. For example, in O/L mathematics, quadratic questions and simultaneous questions mainly have mathematical equations, with little text in natural language. In contrast, Geometric construction questions have detailed textual descriptions, and Venn diagrams have a detailed description and an associated diagram. Thus, based on the type of the questions, different techniques have to be applied to process them. Therefore, we followed a divide-and-conquer approach in implementing MathsTutor, where different components in the system are separately implemented for different questions. The

The manner in which we implemented the system components for some questions is discussed below.

Question Generation

Here we first focus on generating questions that have only textual descriptions. This is a problem of Natural Language Processing, which is a sub-field of AI. In particular, this is a problem of Natural Language Generation. This is implemented with a state-of-the-art Deep Learning technique called Long-Short-Term Memory (LSTM) network. Generating text using this type of deep learning techniques is known as 'neural language generation'.
The power of this technique is that it can generate questions for

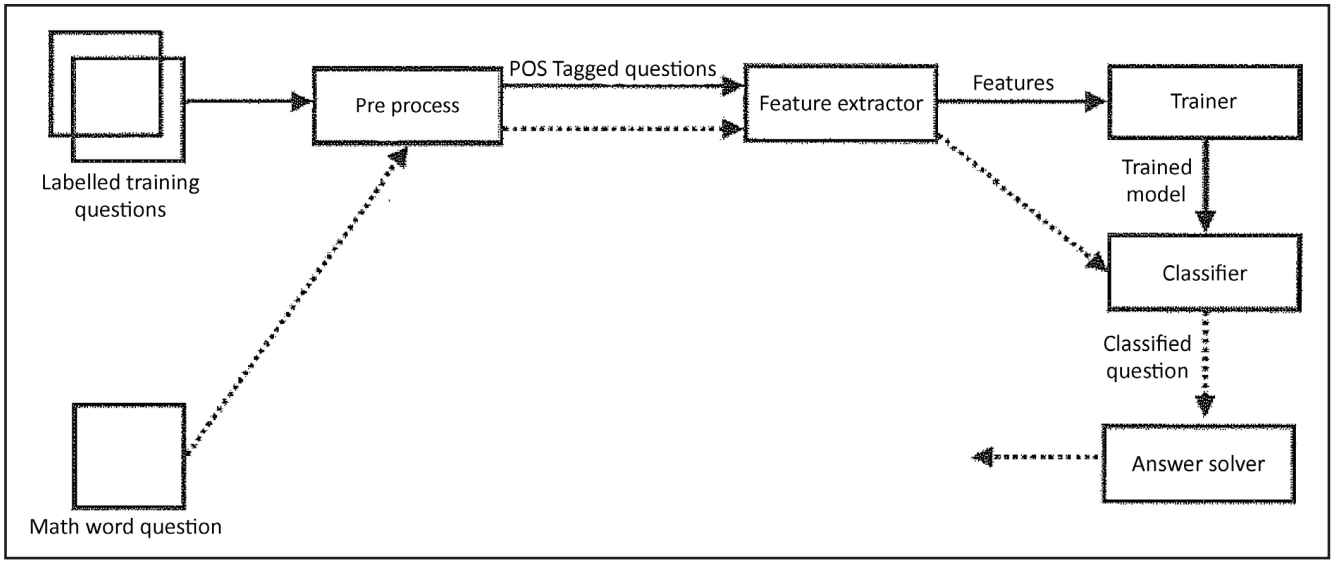

Fig 3 : System for generating answers for elementary Mathematics questions

Change Type: Pete had 3 apples. Ann gave Pete 5 more apples, how many apples does Pete have now?

Compare type: Joe has 3 balloons. His sister Connie has 5 balloons. How many more balloons does Connie have than Joe?

Whole-part type: There are 6 boys and 8 girls in the volleyball team. How many children are in the team?

Fig 4 : Elementary Mathematics Questions that can be handled by the answer generator

any language, given that there is a sample set of similar questions. Currently we are generating simple elementary Mathematics questions as the ones shown in Figure 2. As can be seen, the generated questions are not 100% correct. Therefore at this stage, we have to keep the teacher in the loop, where the teacher will finalize the generated question. From the evaluations we carried out, we found out that teachers find it more efficient to correct the machine-generated question rather than writing a question from scratch.

Answer Generation

The implementation of this module is very much dependent on the type of question. Current system can support simple elementary mathematics and Venn diagram questions. Some sample questions are shown below.
Figure 3 shows the system that generates answers for simple elementary Mathematics. This is a system that makes use of Machine Learning, another sub-area of AI. Here a Machine Learning classification algorithm is trained with a sample set of question-answer pairs. The task of pre-processing and feature extractor is to convert the question into a format that can be understood by the classifier. The task of the classification algorithm is to identify the type of the question, for which an answer should be generated. Answer generation is done by the 'Answer Solver'. The types of questions (change, compare, whole-part) handled by this classifier are shown in Figure 4.

Answer Assessment

Answer assessment module is the one that is the most complete module at the moment. MathsTutor

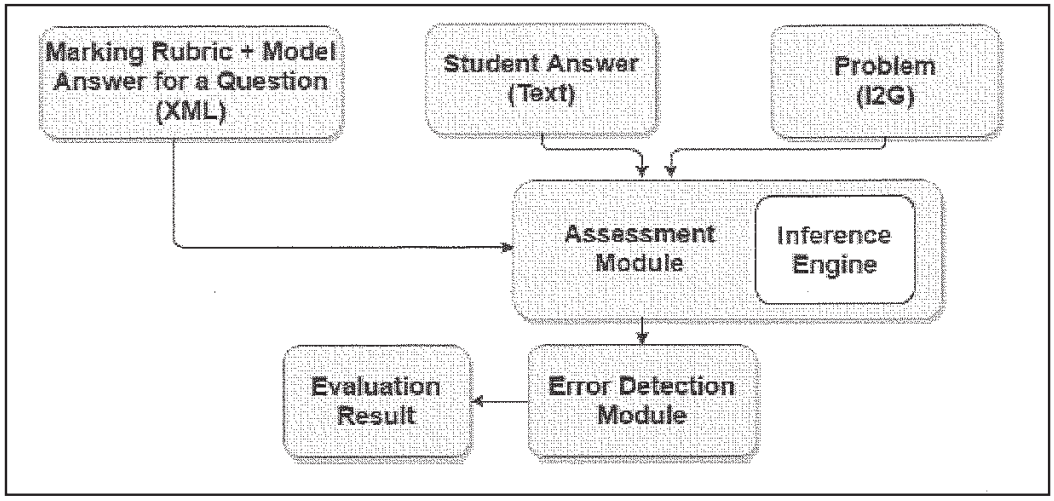

Fig 5 : System to assess Geometric theorem proving questions

In triangle ABC, AB=AC. The line drawn parallel to AC through D; the mid-point of AB, meets BC at F. AC is produced up to E such that BD=CE.

Show that,

I. DBF and DFB are equal angles

II.DFO and ECO triangles are congruent

III.OC = (1/4) BC

IV.DFEC is a parallelogram.

Fig 6 : An example Geometric theorem proving question that can be handled by the system

can currently support following types of questions.

•Geometric theorem proving
•Geometric constructions
•Venn diagrams
•Algebraic Math word problems
•Linear and Simultaneous equations

The system to assess Geometric theorem proving questions is shown in Figure 5. Here, the inference engine is based on a concept called 'Reasoning', which is another sub-field of AI. Moreover, the student answer and the problem text have to be converted into a machine-understandable format. In order to do that, the natural language text should be 'parsed' to extract the meaningful elements as those shown in Figure 5. An example question that can be handled is shown in Figure 6.

Future Work

We are still working on improving and completing the MathsTutor system. None of the components provide 100% accuracy, and teacher input is needed to do the final validation. However, as mentioned earlier, when teachers have only to validate rather than to create questions/answers or grade from scratch, they are more efficient and can support more students.

Only some components such as the question generator are language independent. Many other components work only for English, therefore local language support should also be added. Another main drawback of Mathstutor is that it expects the teachers and students to 'type-in' their input. Especially when writing student answers, this might alter the student's thought process. Therefore we plan to start integrate Optical Character Recognition (OCR), which is another sub-field of NLP in order to read hand-written text. Once the OCR component is added, the student can simply take a picture of her answer and upload it to the MathsTutor system.
Once fully implemented, Maths Tutor can be accessed through a web interface, so that any student or teacher can use the system from anywhere in the country/world.

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