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Intelligent Tutoring System for teaching 1st year engineering

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ABSTRACT: Teaching 1st year engineering courses is an important and demanding task. Students face an adaptation period from secondary education to the university style of teaching and learning. They form a diverse population not only due to their various cultural backgrounds but also due to the differences in their level of knowledge obtained during their previous learning experiences. On the other side, lecturers face large classes of diverse students. Lecturers teaching senior years expect 1st year students to gain deep understanding of fundamentals to be able to follow the more advanced topics in the particular engineering field. Students are also expected to acquire thorough mathematical, numerical and problem-solving skills related to their field of study. For many students, this means they need extensive practice in order to achieve the proper level of proficiency in these skills. For better-prepared students, this may be a waste of time and result in boredom and loss of motivation. The Intelligent Tutoring System (ITS) proposed in this article aims to adaptively adjust the training for each particular student on the bases of his/her own pace of learning. This means that the ITS will monitor the student's progress and have the ability to make decisions about the next step in training.

INTRODUCTION

The field of Intelligent Tutoring Systems (ITSs) is a fast developing area of research. However, not many ITSs are readily available for teaching undergraduate students. At present, none is available for teaching 1st year electrical engineering courses.

The authors' previous work resulted in the development of several interactive electronic tutoring systems that proved to be useful in teaching and learning but, admittedly, not as efficient as they could have been [1].

Therefore, the authors intend to develop a new tutoring system that will be adaptive, which automatically means that it will also include some attributes of intelligence.

In this article, the authors propose the architecture of an Intelligent Tutoring System to be developed for the 1st year course, *Electrical Circuit Theory*, which will train students in circuit solving skills to the required level.

ARCHITECTURE OF ITS

The proposed ITS is based on the implementation of fuzzy logic and the fuzzy rule-based reasoning introduced by Lotfi Zadeh [2]. The structure of the ITS is shown in Figure 1. It includes:

- A database with a pool of questions.
- A database with students enrolled in the course and their performance in the course.
- An expert system with fuzzy rule-based decision making system that would guide the ITS's behaviour.

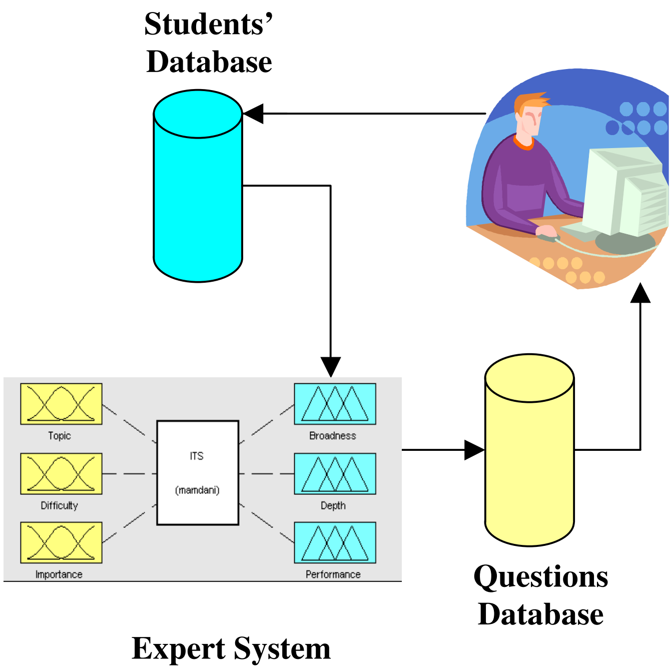

Figure 1: Structure of the ITS.

Questions Database (QD)

The system requires a database with a pool of questions for training. Three parameters have been assigned to each question in the pool, as follows:

- Topic covered in the question.
- Difficulty level of the question.
- Importance level.

The pool of questions, together with these parameters, represents the Questions Database (QD). It is proposed that questions with variable parameters should be used for increased flexibility of the system. Questions with variable parameters are designed to appear with a set of different parameters every time a student attempts them [3]. This is useful to avoid repeating the same question as students usually find it easier to memorise the answer to a question rather than to attempt solving it. It also reduces the size of the QD. The parameters of such questions are generated randomly and answers are tested against the correct answers calculated from pre-programmed formulae.

In the case of multiple-choice questions, the incorrect answers are also generated randomly to avoid student's attempt to memorise the incorrect answers.

Expert System (ES)

The Expert System (ES) is based on fuzzy logic. For each student, the expert system draws the information about the student's performance and tests it against the membership functions for each topic, difficulty level and importance level. An example of membership functions implemented in *Matlab* is represented in Figure 2.

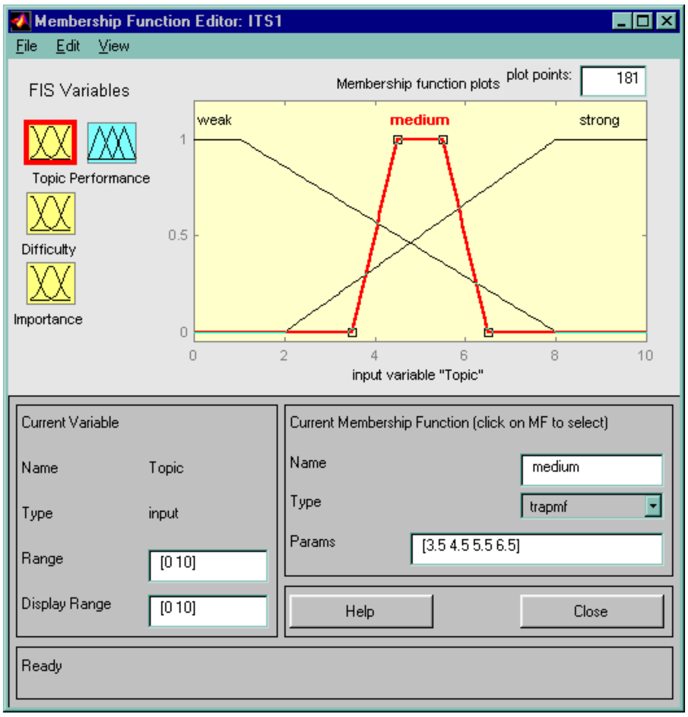

Figure 2: Membersip functions for students performance in a selected topic.

Fuzzy logic membership functions are created in the following way:

- If a student's score in a topic is below 10% the performance is scored as weak.
- If a student's scores between 35% and 65%, the performance is considered medium.
- If a student's score lies above 80%, the performance is considered strong.

Similar membership functions are created for the difficulty level and the importance level. These three indicators are fed into the ITS as inputs. On the basis of these three performance indicators the fuzzy expert system creates the feedback information about the broadness, the depth and the overall student's performance that is then recorded in the database. Based on this new information about the student's performance the ITS system also decides what the next question is with which the student should be presented. The decision is made automatically by the ITS based on the student's performance history. For example, if a student has a strong performance in a particular topic, the system should only rarely ask the question from that topic. On the other hand, if the student's performance in a topic is very weak, the ITS should most often ask the student easy questions from that particular topic until the student's performance improves. Then the ITS will increase the frequency of the questions with medium and high levels of difficulty.

Each question in the QD database has an indicator that reflects the importance of the question topic. The main aim of the ITS is to train students in the most important topics. Therefore, the system initially only asks students questions of the most important topics. If a student performs well in all high importance topics, then the system may increase the frequency of less important topics in order to broaden the student's knowledge.

Students Database (SD)

The Students Database (SD) keeps a record of each student's performance. The record is automatically updated by the fuzzy logic expert system and indicates the depth and breadth of a student's knowledge, as shown in Figure 3.

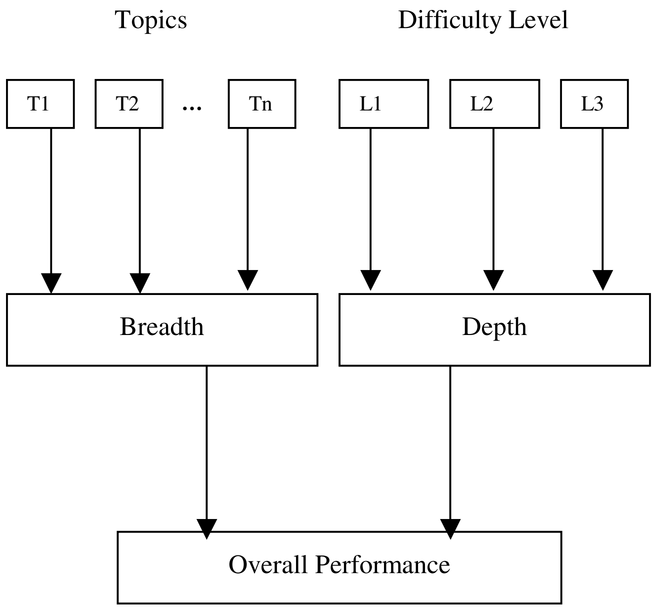

Figure 3: Performance evaluation.

The student should be able to request feedback about his/her performance at any time during the training session. Furthermore, the SD, with the recorded performance for each student, should be available to lecturers at any time so as to allow monitoring of students' progress.

WHY FUZZY LOGIC?

Fuzzy logic has been chosen for the base of the ITS expert system because it makes decisions in a similar way humans do. It does not require complex calculation; rather it utilises a set of simple rules similar to those a lecturer would apply in judging students' performance. It is also very easy to use and very easy to make modifications to customise the system to anyone's requirements. However, the authors consider the main advantage to be the fact that fuzzy expert systems are able to easily make decisions, even when not all of the parameters are clearly defined or available. Additionally, the flexibility of the system is indispensable in judging the overall performance of a student. Without complex formulae a student's performance can be easily judged in a similar way that a lecturer would do with a student present in front of him/her.

An example of the output of such reasoning is represented in Figure 4. As can be seen from the example shown, if a student's score in a topic is 50.8% on questions with an average difficulty 41.1% and the average importance indicator 3.3 (on a scale 1-5), the student's performance is calculated to be 52.3%.

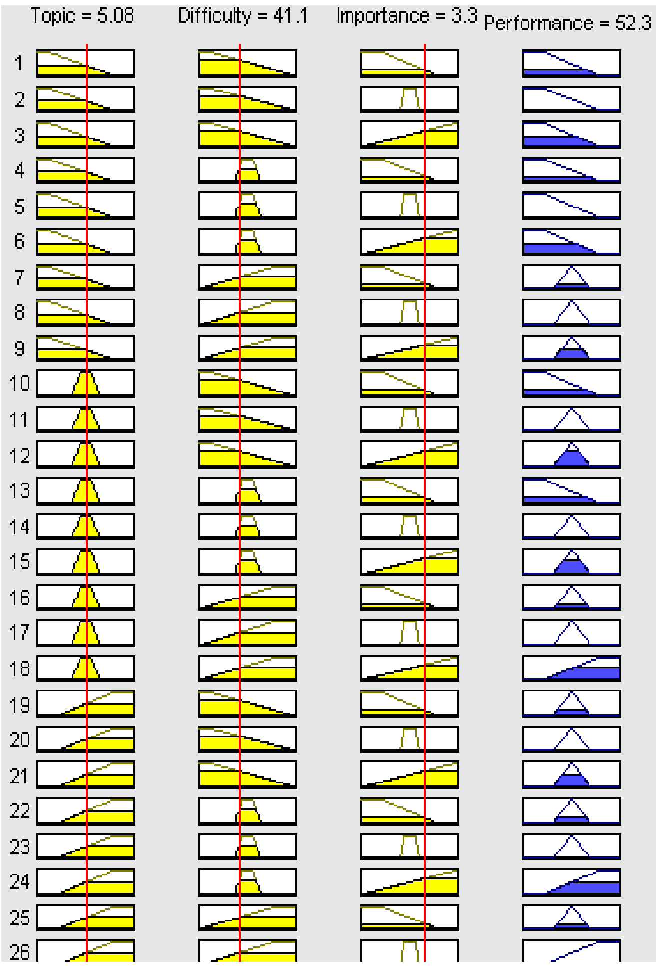

Figure 4: Example of a performance calculation.

This result is obtained using a set of fuzzy rules, some of which are shown in Figure 5. A lecturer can easily modify the system's parameters, including the set of fuzzy rules, in order to better reflect his/her criteria for assessing student performance.

Another important advantage is that the proposed ITS permits flexibility in making decisions about a student's performance. For example, if a student correctly answers difficult questions, an accidental failure in an easy question of a high importance may not have any influence on student's record as the student's knowledge will be automatically tested on similar questions from the same topic.

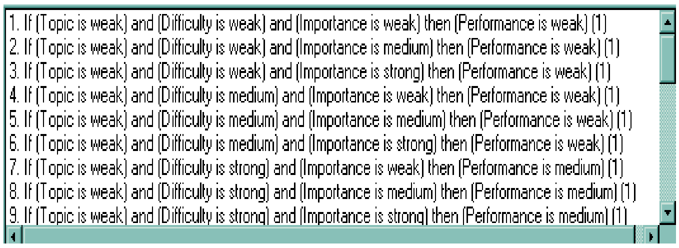

Figure 5: A set of fuzzy rules.

CONCLUSIONS

Although the system is in the stage of a preliminary design and therefore has not yet been implemented, the authors expect that its implementation will bring significant benefits in teaching the course *Electrical Circuit Theory*. It is expected that the proposed ITS will be also useful for teaching other courses, particularly where extensive training in a problem-solving skills is needed.

The main advantages of this proposed ITS are its dynamics, flexibility and simplicity to set up. Its dynamics are accomplished by its inbuilt intelligence that makes the system adaptable to each student performance. If a student has difficulty with the particular topic, the system automatically adjusts to a slower pace and asks only important and simpler questions. If a student performs well on simple questions the ITS quickly introduces more difficult questions allowing the student to perfect his/her skills at their own pace. It also allows such students to broaden their knowledge in the field by attempting the *least important* questions that would normally be omitted for weak students.

This flexibility is of high importance, especially in classes with very diverse populations of students, such as 1st year classes. In such classes, it is easy to overlook poor performance of some students or hold back more advanced students by not giving them a chance to fully develop their skills as an average pace of learning is enforced. Therefore, it is predicted that the development of an ITS, such as this one based on fuzzy logic or other intelligent paradigms, will soon be a necessity of every course that requires extensive practice for developing a required level of particular skills.

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Proceedings of the 3rd Asia-Pacific Forum on Engineering and Technology Education

edited by Zenon J. Pudlowski
and David W-S. Tai

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