COMPUTER BASED TRAINER FOR SIGNAL AND SYSTEMS UNDERGRADUATE STUDENTS

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Abstract

University students demand many exercises for practicing during their undergraduate courses. Although there are many resources where they can find proposed exercises, specially for basic courses, these resources include a fixed and limited set of proposed exercises. The students usually want to repeat similar exercises till they are sure they have the skill to solve it. Additionally they demand fast feedback about their trials. With the development of the European Higher Education Area, the work of the students must be assessed and this could be seen as a higher workload for the instructors, so the development of tools that help in the assignment and assessment of students work is necessary. Here, a tool that automatically generates thousands of numerical and wording variations of the same exercise and automatically assesses the solution given by the student is presented. The selected exercise is the convolution of two signals, a basic exercise for Signals and Systems undergraduate course for Electrical and Electronic Engineering students. Wording variations of the exercise include discrete time and continuous time signals, to find the output of a linear and invariant system for a given input and different presentations of the signals (analytic expressions, graphical or tabulated representation for the time span where the signals have non zero values). Both wording and numerical variations are obtained from a single seed. The remainders of division of the seed by different divisors are calculated and used to obtain a large set of variations of the exercise. One of these remainders is used to group the variations of the exercise by difficulty grade. The teacher can use this tool to automatically assign personalized exercises for each student that attends his/her course. This personalized assignment makes the cheating among students more difficult than when the same exercise is assigned to all the students. The teacher can be sure that all the assignments are in the same difficulty group. Moreover, this tool automatically grades the solution given by the student, so can be used as an assessment tool by the teacher. The basic algorithm to generate the variations in this exercise could be extended to almost all typical exercises in Signal and Systems course.

Keywords: Computer based learning, computer based assessment, automatic item generation, Electrical and Electronic Engineering education.

1 INTRODUCTION

Computer based and web-based based learning and assessment systems have become useful and widespread tools for educators in last years [1-20]. Many systems and platforms that allow the creation of quizzes with different types of question, adapted to the specific objective that must be reached at any step in the teaching-learning process have been developed. The quizzes are usually created by a tailored selection of test items from a previously stored item bank. A common drawback of these systems is that preparing a large item bank is time consuming [1, 2]. In fact, the developers of such systems emphasize that their system includes a module or a function to easily generate items and build item banks [3-8]. From the student's point of view, an important feature of the self assessment systems is the possibility of replicating the same kind of test with different data [3]. In engineering disciplines it is an easy task to repeat the same item question with different numerical data, although can be a tedious and consuming time for the instructor. In this paper, an algorithm to automatically generate numerically different exercises in the field of Signal and Systems analysis is presented. A questionnaire for assessment of the exercise solution given by the student is also proposed. Both parts are integrated in an application that can be used by the students as a tool for practising till they learn to solve studied type of problem, and by the instructor as an automatic and personalized assessment tool.

2 DESCRITPION OF THE APPLICATION

In the currently ongoing process of creating the European Higher Education Area [19], the educational outcomes of university courses are being defined in terms of competences that are to be acquired by the students in order to get their degrees. Accordingly the assessment of the students must be based on competence acquirements and on the student's workload. These changes can be easily assumed by the teachers when the number of students that attend a course is small enough but the teacher's workload increases with the number of students [9], then the learning management systems (LMS) becomes a very helpful tool. However the LMS usually do not have the possibility of automatically correct and evaluate typical engineering problems where the steps to find the solution many times are more important than the numerical value of the solution. Additionally, many kinds of problems in engineering that involve numerical parameters have physical sense and easy mathematical solution with very constrained values of the parameters. Most of automatic item generators and other tools use random generation of the parameters (restricted to predetermined intervals) to obtain numerical variations of a question [9-18]. This way to generate numerical variations of a problem could easily yields to nonsense numerical solutions.

Here a method to automatically generate numerical variations of a problem in a controlled way and that permits a personalized task assignment is presented. An automatic correction and evaluation of solution given by the students attending to qualitative and quantitative aspects is also presented. To illustrate the method, a basic question of Signals and Systems is analyzed.

An application has been developed to implement the generation of the problem and its automatic assessment. Different technologies have been studied for the development of the application. We have chosen to develop this application in java for some of its main advantages:

-Object Oriented Programming. Java creates modular and flexible programs. One of the main requirements of the developed application is to be modular, so it is easy to add different types of exercises.

-Platform independence. A Java application runs on virtually any platform and operating system. The main objective of the application is that students can use it as a learning tool by the repetition of an exercise. The students should have the possibility of using the application at any place and whenever they want. Java is used to create applications called Applets. The applets run inside the Web browsers, so these applications can be used from any computer with internet connection. The applets can be incorporated in SCORM packages that can be used in any LMS like Moodle [6].

Fig.1 shows the main modules of the application: the graphical user interface (GUI), which provides a visual and friendly environment, the module that generates the parameters of each question from a given seed, the module that generates the different exercises, the module that calculates the solutions to the questions and the one that manages the correction. Briefly the application modules are:

-The GUI provides the user interface, this module manages the graphics, the data presentation and the data input by the user.

-The Parameter Generator selects the type of exercise and generates the different parameters of the question from the seed entered by the student.

-The Question module generates the exercises. This module contains all the common attributes of the different types of exercises. This Question module includes a sub-module for each type of exercise that manages the characteristics of each type of question.

-The Solution Manager calculates the solutions to the exercises. There is a sub-module for each type of exercise that does the necessary calculations to provide the question's solution.

-The Assessment module provides the correction of the exercises. It checks if the answers given by the students are right and provides feedback. There is a sub-module for each type of exercise that shows the rule applied in each case.
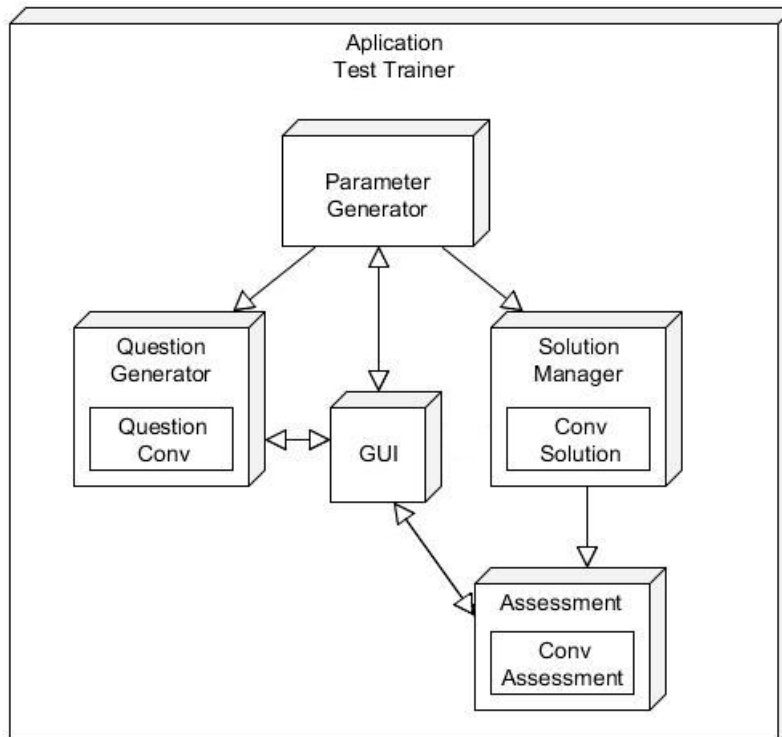
Figure 1: Schematic description of the application

2.1 Time domain analysis of linear and time invariant systems

Signal and systems appears as a main topic in many engineering disciplines (for example in Electrical and Electronics Engineering). The analysis of linear and time invariant (LTI) systems in time and frequency domains is one of the most important problems in Signals and Systems [19]. The input/output relation of a LTI system can be expressed as the convolution of the input signal with the impulse response of the system. The convolution of two signals is an easy but usually tedious task. However, many times it is enough to know the time span (or the bandwidth when working with spectra) of the output signal for a given input and system. Here we present a way to automatically generate different pairs of finite duration signals that can represent the impulse response of a LTI system and the input signal respectively. Restrictions to the parameters that define the two signals are imposed in order the students could solve the convolution of the signals in a few minutes. This method uses a single seed to generate all the parameters that define the signals.

An application has been developed that presents the wording of the problem with different presentations of the signals (graphical or analytical expression) and that include the numerical variations for the two signals. This application also presents questions about the time span of the output and about the value of the output for particular times. The times where the output must be evaluated is also automatically varied. The application includes the assessment of the student work. There are two different modes of the application: training mode and assessment mode. The students can use the application in training mode as many times as they want till they learn how to solve a convolution. They just introduce a new seed (or the same seed if they want to repeat the same numerical values) to made a new trial. Afterword, the instructor uses this application in assessment mode: he assigns a seed for each student that attends the course.

2.1.1 Generation of the impulse response and input signals and wording of the exercise

In order to generate different pairs of input signal and impulse response of the LTI signals, a single seed N is used. Modulo operation is applied to the seed with several divisors to obtain the following values:

$$
\begin{pmatrix} m_2 \\ m_3 \\ m_5 \\ m_7 \\ mm_2 \\ mm_5 \\ mm_3 \\ mm_4 \end{pmatrix} = \begin{pmatrix} N \bmod 2 \\ N \bmod 3 \\ N \bmod 5 \\ N \bmod 7 \\ (N \bmod 11)\bmod 2 \\ (N \bmod 11)\bmod 5 \\ (N \bmod 13)\bmod 3 \\ (N \bmod 13)\bmod 4 \end{pmatrix} \qquad (1)
$$

For the case of discrete time exercise the generated input signal ($x[n]$) and impulse response ($h[n]$) are:

$$
x[n] = (1 + mm_3) \cdot n^{m_2} \cdot \left(u[n + 4 - m_7] - u[n - m_7 - m_4] \right), \qquad (2)
$$

$$
h[n] = (1 + mm_4) \cdot n^{(1 - m_2)} \cdot \left(u[n + 3 - m_5] - u[n - m_5 - m_3] \right), \qquad (3)
$$

For continuous time case we have used the following signals:

$$
x(t) = \left(\frac{2 + mm_3}{2} \right) \cdot t^{m_2} \cdot \left[u\left(t + 2 - m_7 / 2\right) - u\left(t - m_7 / 2 - m_4\right) \right], \qquad (4)
$$

$$
h(t) = \left(\frac{2 + mm_4}{2} \right) \cdot t^{(1 - m_2)} \cdot \left[u\left(t + 1 - m_5 / 2\right) - u\left(t - m_5 / 2 - m_3\right) \right] \qquad (5)
$$

In these equations $u[n]$ is discrete time step function and $u(t)$ is the continuous time step function.

The value mm_2 is used to change the wording of the exercise: the signals will be presented as their analytical expressions ($mm_2=0$) or by a graphical representation ($mm_2=1$).

It is easy to check that in this way $2 \times 3 \times 5 \times 7 \times 2 \times 5 \times 3 \times 4 = 25200$ numerical and wording variations of two different exercises are generated.

The student is asked to obtain the output of the system (he/she must perform the convolution of the two signals). Afterword he/she must answer the following questions:

a) Which is the minimum time where the output signal has a non zero value?

b) Which is the maximum time where the output signal has a non zero value?

c) Which is the time span or duration of the signal?

d) Which is the value of the signal for $n=m_5$ (or $t=m_5/2$ in the continuous time case)?

e) Which is the value of the signal for $n=m_4$ (or $t=m_4/2$ in the continuous time case)?

The answer to these questions is easily obtained from the given seed N. The student can send its answer step by step or all together.

The application, in the training mode shows a congratulation message when a student answer is correct and gives a second chance when the answer of the question. After a second fail, a message with the right answer and the rule applied to obtain it is shown. When all the questions are answered a global mark is indicated. When used by the instructor, only the global mark is shown when the student sends all his/her answers. Fig. 2 shows an example of an exercise generated by the application.

Figure 2: Example of automatically generated problem and its correction given by the application in training mode (Spanish version)

3   DISCUSION AND CONCLUSIONS

An application has been developed for implementing an algorithm that generates up to 25200 numerically or wording variations of two different exercises. A set of test questions are proposed for self assessment. The application permits two modes of use: training mode and assessment mode.

When used in training mode, the students that attend the course could use the application entering several input seeds to generate as many exercises as he/she wants. The student should solve enough exercises to be sure that he/she is able to correctly do a similar exercise with different numerical values. The application assesses and grades each attempt of the student. When the solution given by the student is not correct, the application shows a message with the right solution and the rules to obtain it.

The instructor can use the application in assessment mode for automatically assess and grade all students that attend the course. There are several ways of assigning the seed, for example:

a) The instructor decides an arbitrary seed to generate the same numerical and wording exercise to be solved by all students.

b) The instructor assigns a random seed to each student. The seed could be personalized by using the identification card number or the student, its ordinal in an ordered list of the students or other number that identifies the student. However, some student could claim that he/she had to solve a more difficult variation than their mates. For example, some student can consider that to handle analytical information is a harder task than to handle graphical information, or vice versa.

c) In order to all the students solve a similar version of the exercise the instructor can assign seeds following the rule $N = 2k \times 11 + L_0$ with $0 < L_0 < 11$ and integer k so all students have to solve the exercise with graphical presentation (for odd L_0) or analytical presentation (for odd L_0) of the signals.

Similar rules can be followed for obtain signals with the same time span, the same beginning and so on. An additional advantage of the described application is that cheating among the students becomes quite difficult when both b and c strategies are followed, because each student probably solves a different exercise.

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