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ICT Tools in a Signals and Systems Course at the University of Rosario

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Abstract— **In this paper, the use of Information and Communications Technologies (ICT) tools in a course on Signals and Systems at the University of Rosario is described. The course is now in its sixth year. The format of the course as well as the ICT resources employed as a support for the lectures and laboratories are described. The use of these new technologies has proved to increase the level of students' participation and the students' satisfaction rate with the course. Some ongoing projects are also presented in this paper.**

I. INTRODUCTION

In the last decade the use of new ICTs tools, such as the Internet, video-conference, multimedia lecture rooms, etc., in education has become a standard in industrialized countries. Most university courses in developed countries incorporate a Web site to deliver course materials such as Lecture Notes, Laboratory Guides, Assignments Handouts, etc., online to their students, to communicate with them at any time, and to make available to them virtual labs and demos, etc.. This trend on the use of Internet and, in general, on the use of novel ICTs in education has arrived with some delay to developing countries such as Argentina, mainly due to economic reasons.

At this point in History there is an almost unanimous agreement about the benefits of the use of Internet in Education and there is a notable trend to increase the number of online resources available for the students. However, an effective use of these novel ICT tools requires careful consideration, as pointed out in [11] and the companion Web site [10], where an excellent guide on how to integrate Internet resources into Engineering courses can be found. In the area of Control Engineering Education, an interesting example of a Web-supported undergraduate course on System Identification based on WebCT [17] and Matlab [15] is presented in [3]. The use of interactive tools for education in automatic control is described in [8]. More recently, several ICT tools for control education, ranging from Simulation Software to Virtual and Remote Labs, has been described in the works [1], [16], [9] included in the Special Section of the IEEE Control Systems Magazine [2]. An Interactive Tool for Teaching Generalized Predictive Control is presented in [7]. Finally, interactive exercise and demonstration modules (using Java Applets) for fundamental topics in Signals, Systems and Control at Johns Hopkins University are available in the *award winning* Courseware[1] described in [4]. Also, to help create interactive scientific simulations on the web, Sanchez, Esquembre and coauthors [12] [6] developed Easy Java Simulations, a Java-based tool for the design of virtual laboratories and a Java/Matlab-based environment for remote control system laboratories [13].

In this paper, a Web-supported course on Signals and Systems at the University of Rosario is described. The course incorporates some ICT tools such as the use of Internet and online demos and tests, multimedia lectures, virtual labs, etc., as a support and complement to classical classroom teaching and laboratory work. It is the authors' belief, based on their experience on the development and implementation of this course, that the application of these new technologies has produced an improvement in the teaching-learning process, when compared to classical teaching methodologies. It is important to mention that these developments have been completely carried out by the staff of the course (the authors) without any financial or technical support.

The rest of the paper is organized as follows. The outline of the course is presented in section II. Section III describes the Web site organization. The lectures and laboratory sessions are described in sections IV and V, respectively, and a set of virtual labs developed using Easy Java Simulations software [12] is described in section VI. The students' assessment methodology is presented in section VII, while the results of a student evaluation of the course survey is presented in section VIII. Finally some future work and concluding remarks are presented in sections IX and X, respectively.

II. OUTLINE OF THE COURSE

The course on Signals and Systems at the University of Rosario is a one term (sixteen weeks), six-hours per week, compulsory subject in the third year of a (five year) degree in Electronic Engineering. The course is the basis for subsequent courses on Control, Communications and Signal Processing. The main topics covered by the course are: Basics of Signal Representation and System Modelling, Linear Time-Invariant System Response in continuous and discrete time, in both time and transformed domain (Laplace and Z Transforms, respectively) to arbitrary inputs, Signal Analysis using the Fourier transform in continuous and discrete time, Discrete Fourier Transform (DFT) algorithms, Fundamentals of Amplitude Modulation (AM) and Frequency Modulation

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[1]The Courseware on Signals, Systems and Control was the recipient of the *Premier Award for Excellence in Engineering Education of 2001*, by the National Engineering Education Delivery System (NEEDS), USA.(http://www.needs.org)

(FM). A detailed course program can be found at the course Web site [14].

The course involves different activities: lectures (where the main topics are developed), exercise solving sessions, and Computer Laboratory sessions. There are three exams during the course and a final exam. The final mark of the course is computed as a weighted average of the marks in these exams, and the laboratory report marks.

An average of 100 students attend the course each year, and the teaching duties (course development, lectures, laboratory sessions, marking, student examinations, Web site development and maintenance) are carried out by one full-time Adjunct Professor and two part-time Teaching Assistants.

III. WEB SITE ORGANIZATION

The course is supported by a Web site [14] which is used for several purposes among which the following can be mentioned:

- To provide students with general course information such as class, laboratory, and examination schedules, consultation hours, course syllabus, bibliography, teachers' contact information, the marking scheme, etc..
- To deliver online course materials such as lecture notes (as PowerPoint presentations), and exercise and laboratory guides in PDF format.
- To provide the students access to an e-mail list to communicate with the teachers and classmates at all times.
- To provide links to Signals and Systems Demos and related sites.
- To provide access to Java Script based self-examination tests.
- To provide access to Java-Applets based Virtual Labs.

The opening page of the Web site is shown in Fig. 1, where the main menu can be seen on the left.

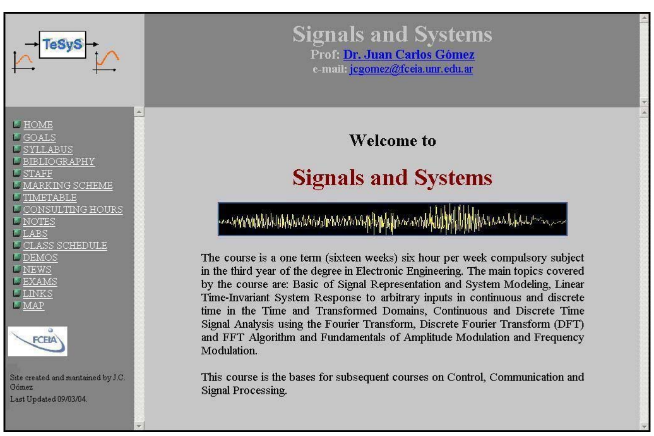

Fig. 1. Web site opening page.

Fig. 2 shows part of the Class Schedule for the 2004 edition of the course.

Class Schedule - 2004

WEEK	TOPIC / ACTIVITY
Week 1 (Wed 03/03 - Fri 05/03)	Chap. 1, Sections 1.1 and 1.2
Week 2 (Wed 10/03 - Fri 12/03)	Chap. 1, Sections 1.3, 1.4 and 1.5
Week 3 (Wed 17/03 - Fri 19/03)	Chap. 2, Sections 2.1, 2.2 and 2.3
Week 4 (Wed 24/03 - Fri 26/03)	Chap. 2, Sections 2.4 and 2.5
Week 5 (Wed 31/03 - Fri 02/04)	Chap. 3, Sections 3.1, 3.2 and 3.3
Week 5	**Lab 1: Introduction to *Matlab***
Week 6 (Wed 07/04)	Chap. 3, Sections 3.4, 3.5 and 3.6
Week 7 (Wed 14/04 - Fri 16/04)	Chap. 4
Week 7	**First Mid-Term Examination**

Fig. 2. Zooming in of the Class Schedule for 2004.

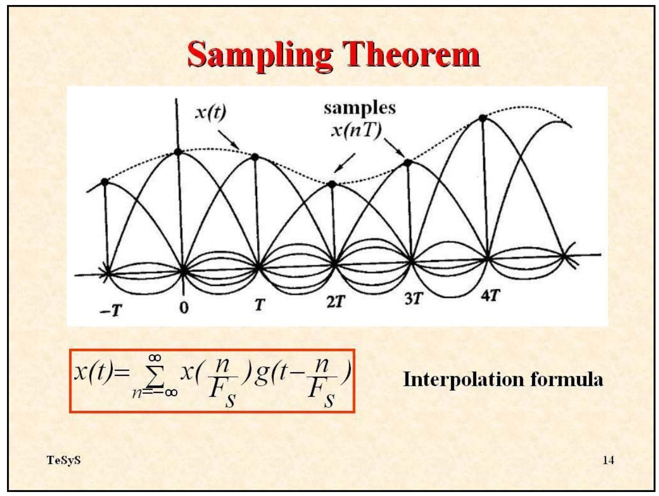

Fig. 3. A typical page of the PowerPoint presentations.

IV. THE LECTURES

The lectures are organized into two three-hour sessions per week. The students are aware of the topics being developed each week, which are presented to them at the beginning of the course, and are available from the Web site in the Class Schedule section. They can also download the lecture materials in advance.

In order to make the lectures more interactive, there is no formal division between the presentation of the theoretical aspects of the main topics and the resolution of problems addressing them. The lectures consist of PowerPoint presentations, blackboard explanations, sessions of exercise solving, and short demonstrations using Matlab or Java Applets. The teacher also challenges students with short questions regarding the topics being taught.

V. THE LAB SESSIONS

A fundamental part of the course are the Laboratory Sessions which are designed to reinforce the concepts of the core topics through computer simulation in the Matlab/Simulink environment.

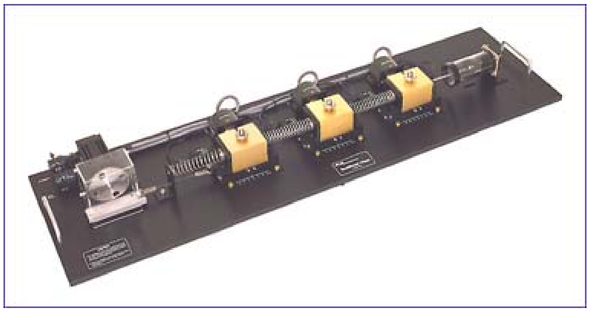

Fig. 4. Rectilinear Mass-Spring-Dumper System.

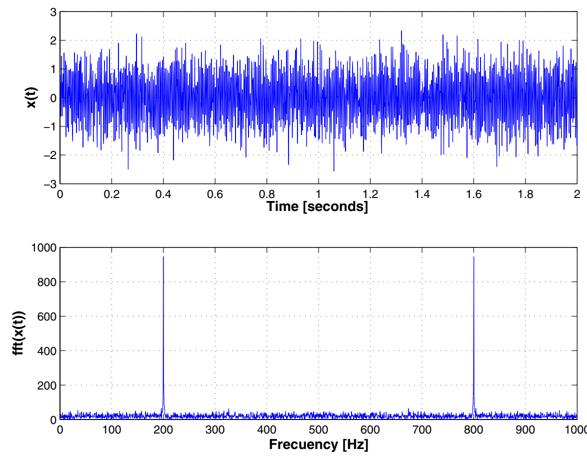

Fig. 5. Top Image: Sinusoidal signal corrupted by noise. Bottom Image: Corresponding signal spectrum computed using the `fft` Matlab function.

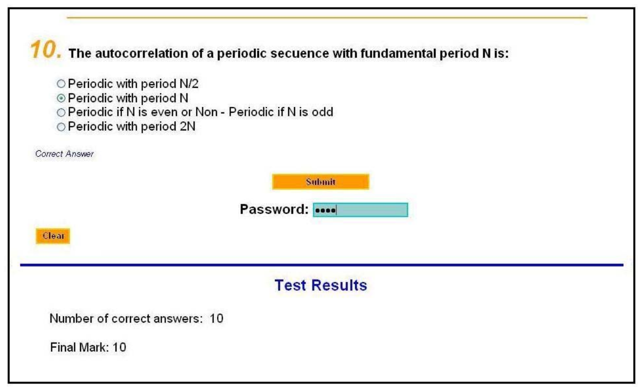

Fig. 6. Example of the online test.

Three lab sessions are scheduled during the course. The main topics covered by the Labs are:

- **Lab 1 - Introduction to Matlab:** Simple programming problems are proposed to the students, since this is their first contact with Matlab. The basic commands and programming techniques are introduced. Simple signal processing applications are also proposed (*viz.*, signal extraction from noisy measurements using correlation analysis).
- **Lab 2 - System Dynamic Simulation:** Modelling and simulation of simple real systems are proposed. The systems correspond to two different commercially available electro-mechanical equipments by ECP (Educational Control Products) [5]. One of them, the rectilinear mass-spring-dumper system, is shown in Fig. 4. The students are asked to compare the simulation results with data measured on the real systems.
- **Lab 3 - Frequency Domain Signal Analysis:** The students are asked to program algorithms for the computation of the Discrete Time Fourier Transform (DTFT). They are also introduced to the use of windows for signal analysis and the FFT algorithm as implemented in Matlab. Some simple signal processing problems are proposed as application of these concepts (*viz.*, signal parameter estimation from noisy measurements). In Fig. 5, a typical Matlab plot corresponding to one of the proposed exercises in this Lab session is shown. A sinusoidal signal corrupted by noise is shown in the top image while its corresponding signal spectrum computed using the `fft` Matlab function is shown in the bottom image. The amplitude and frequency of the sinusoidal signal can easily be computed from this later plot.

Students are provided with Lab Guides where some introductory examples are presented and the problems are proposed.

The Computer Room is equipped with 12 Personal Computers (PC). The class is divided into groups of two people, and each group is assigned to one computer. With this configuration two weeks are required for the whole class to finish one lab. The lab sessions last three hours and two teachers are present in each session to assist and evaluate the students. Previous to the beginning of the lab sessions each student is asked to take an online multiple choice test, which has been developed using Java Scripts. The obtained mark, computed automatically when the student submits the answers, contributes to her final laboratory mark.

A part of one of the online tests is shown in Fig. 6. A report for each lab session is required to the students, and the report marks also contribute to the final lab mark.

VI. VIRTUAL LABS

A set of Virtual Labs has been developed using the Easy Java Simulation software by Sanchez and coauthors [12]. The program allows users to design Java Applets in a simple and rapid way without the need of expertise in the Java Language.

The Virtual Labs allow to study physical systems without the requirement of expensive experimental apparatus and also provide the students with more flexibility with regard to Lab time allocation and space limitations. This is an important factor due to the limited facilities available at this School of Electronic Engineering.

The labs explore several topics on signals and systems, among them the following can be mention:

- Simulation of Dynamic Systems
  - Mass-Spring-Dumper System

- Single Tank System
- Pendulum System
- DC Motor

- Time Response of Linear Time-Invariant (LTI) Systems
  - Impulse Response of LTI Systems
  - Step Response of LTI Systems
- Approximation of Periodic Signals using Fourier Series

As an example, the main window of the virtual lab for the simulation of a tank system is represented in Fig. 7.

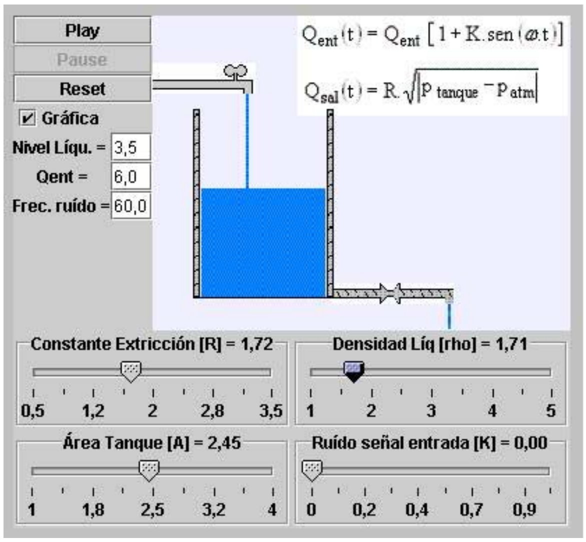

Fig. 7. Virtual Lab Single Tank System main window

In this experiment the students can visualize an animation of the fluid level in the tank. They can also configure the system parameters (density of the fluid, area of the tank, output restriction parameter), the input flow, and the initial conditions. The time evolution of the input and output flows as well as the fluid level in the tank can also be visualized.

VII. STUDENTS' ASSESSMENT

The final mark (M) of the course is obtained as a weighted average of three marks corresponding to:

1) **Mid-Term Examinations (MTE):** There are three written examinations during the course, covering all the topics in the course program. The exams consist of theoretical questions and exercises. The corresponding mark (MTE) is obtained as the average of the three exam marks.
2) **Laboratory Work (LW):** The mark of each lab takes into account the results of the online test previous to the lab session, the student's work during the lab, and the lab report mark. The final mark (LW) for the labs is computed as the average of the three lab marks.
3) **Final Exam (FE):** Students are required to sit for a written final exam integrating the main concepts developed during the course.

Summarizing, the final mark of the course is computed as:

$$M = 0.2 \times LW + 0.5 \times MTE + 0.3 \times FE.$$

Fig. 8 shows the number of students that passed the course and the total number of students enrolled in the course in the last six years.

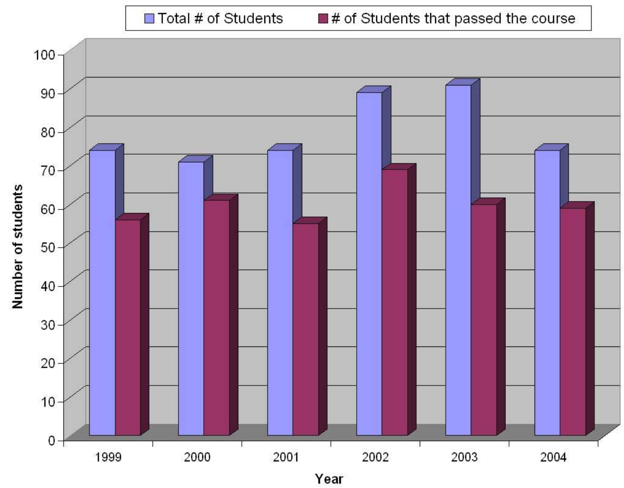

Fig. 8. Number of students that passed the course and total number of students enrolled in the last five years.

VIII. STUDENT EVALUATION OF THE COURSE

At the end of the course the students are asked to complete a survey regarding different aspects of the course, such as the integration of the different components, the sequencing of the topics, the workload of the subject, the assessment and the ICT tools employed.

Fig. 9 shows statistics (from a total of 47 students) corresponding to the answers to the following questions regarding ICT tools

1) The material (lecture notes, demos, virtual labs, lab guides, etc.) available to support the course is appropriate.
2) It is important the use of simulation programs such as Matlab and Simulink for the lab sessions.
3) The Website was very useful to access the study material, demos and virtual labs and to communicate with the teachers.
4) The e-mail list was very useful to communicate with the teachers and other students.

The possible answers were: A. Strongly Agree , B. Agree, C. Neutral, D. Disagree, E. Strongly Disagree.

IX. FUTURE PROJECTS

The authors are involved in some projects to incorporate new tools to the Signals and Systems course described in this paper. Among them, the development of new Java Script based self evaluation online tests covering the core topics of the course, can be mentioned. The authors have also the intention to increase the number of virtual lab experiments, incorporating new topics to the existing ones.

Another important initiative the authors would like to undertake in the near future is the writing of a text book of the course with multimedia support.

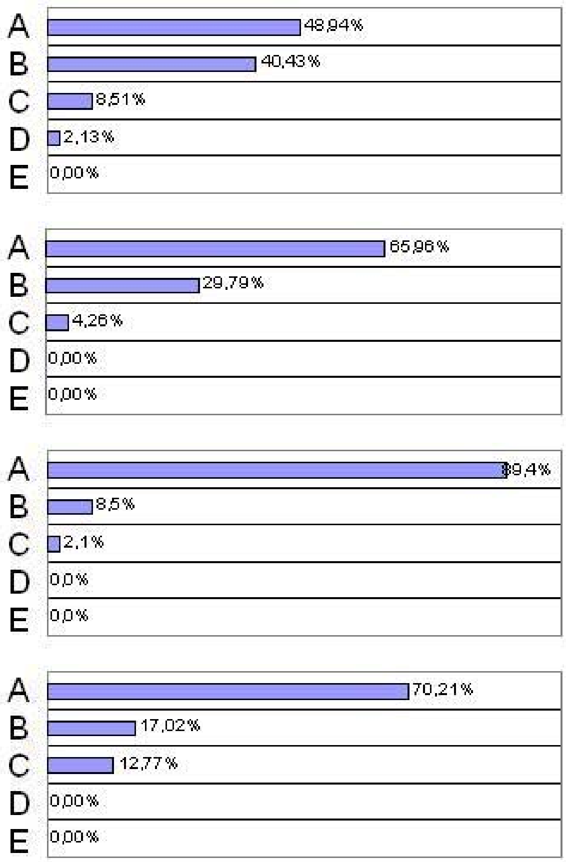

Fig. 9. Statistics for the answers to questions 1-4 from top to bottom

X. FINAL REMARKS

The use of new ICT tools in the design, development and implementation of engineering courses has proved to be very helpful in enhancing teaching-learning activities and improving course management as well as the communication between teachers and students. The interactive tools generate stronger interest of the students in the topics treated in the course and contribute to their familiarization with new technologies which are of widespread use in Engineering nowadays.

Since the use of this kind of technology in education is relatively new in the academic institutions in Argentina, it is not easy to make fair comparisons with classical teaching approaches in this country. However, the authors believe, based on their experience in the area, that this trend toward Internet-based Education and in general the application of novel ICT tools in education, will have an increasing acceptance worldwide. This will be of fundamental importance, especially in developing countries like Argentina, since it will contribute to the improvement in the graduate engineering programs with limited resources.

Finally, it is worth to mention that due to the modular structure of some of the ICT tools developed, they could be easily adapted to e-learning environments, or to be employed in different traditional engineering courses.

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