Virtual Experiments and Instruments

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Abstract—**This paper describes Computer Aided Learning (CAL) methodologies incorporated in teaching at the Electrical and Computer Engineering Program of Texas A&M University at Qatar (TAMUQ). A set of virtual experiments and instruments are in use by the Electrical and Computer Engineering Program exposing students to latest CAL technologies and encourages the study and implementation of computer learning applications in teaching. The experiments are part of an undergraduate course, ECEN 455, Digital Communications, offered to final year students.**

The experiments are made available online via secure internet connection. Hardware equipment was set up at the laboratory and was connected to the campus network via a network server. Hence, the students were able to access and control the laboratory equipment at a distance. The experiment is performed virtually using software that resembles the hardware equipment set up. Nevertheless, students are able to vary hardware parameters of the laboratory equipment.

Index Terms— **Graphical User Interface (GUI).**

I. INTRODUCTION

CAL (Computer Aided Learning) provides an accessible, interactive, and flexible way of presenting curriculum material. CAL provides educators with an outstanding opportunity to deliver courses or to supplement existing courses using networked computers.

CAL experiments were designed to supplement the curriculum offered by the Electrical and Computer Engineering program at Texas A&M University at Qatar, hence, providing students with an alternative to traditional laboratories. For this reason, the Electrical and Computer Engineering Program at TAMUQ put great effort into incorporating CAL teaching in their courses with particular reference to the ECEN 455 course, Digital Communications. The laboratory component of the course was made accessible online.

The setup of the experiment was done ahead of time. Students were given instructions on setting up the experiment prior to coming to the lab. They were able to perform the experiment from any location at distance.

The experiments are made available online via secure Internet connection. Hardware equipment was set up at the laboratory and was connected to the campus network via a network server as shown in Figure 1.

II. COURSE STRUCTURE

It was our intention not to simply adopt learning at distance, but also to measure the effectiveness of learning at distance and its level of student acceptance as a teaching resource. So far, the course evaluation suggests that students are more motivated and keen to learn. Students learned the same or more than they would in on-site laboratory as they had more chance to experiment and learn.

Continuous development and exploring new methodologies are investigated to facilitate teaching and bring up-to-date technology to our staff and students.
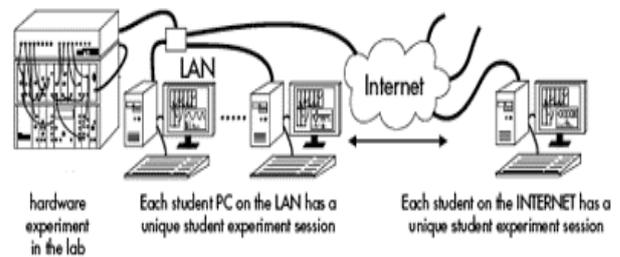

Figure 1. NET enabled system that offers real hardware experiment in real-time delivered across LAN and Internet

ECEN 455, Digital Communications, is a senior year elective course. It has been developed to enable students understand basic concepts in digital communications techniques. Mode of presentation for this course consists of two lectures a week and a weekly laboratory session. The laboratory part of the course utilizes CAL, enabling students to conduct experiments remotely via Internet access. Traditionally, the laboratory component of the course has been offered in a regular classroom format (a weekly three hours session) to roughly 20 students. Being a senior level course makes this course particularly suitable for CAL, offering as participants in this course were reasonably mature university students (senior students). In this case, students can better control their time and self-pace the course according to their needs while being able to engage in activities outside university.

III. BENEFITS OF COMPUTER AIDED LEARNING VERSUS TRADITIONAL CLASSROOM SETTINGS

CAL can provide for major benefits for organizations and individuals involved. The following benefits are of interest to our program as it will optimize its operation:

1. **Reducing environmental impact:** CAL allows people to avoid travel, thus reducing congestion and pollution. The fact that it takes place in a virtual environment also allows some reduction of paper usage. With virtual notes instead of paper notes and

online assessments instead of paper assessments, e-learning is a more environmentally friendly solution.

2. **Space Management.** CAL allows for optimal space management. Laboratory rooms can be reused to carry out other tasks while students can perform the experiment virtually from another general purpose computer lab or from home.

3. **Cost Reduction.** All is needed to perform our experiment is a GUI at the user PC that mimics the experiment front panel of the hardware component, and Internet connection. This eliminated the need to purchase multiple sets of hardware equipment to set up experiments and concurrently allows for larger number of students to perform the laboratory session.

4. **Quality education, made affordable.** Instructors and therefore educational institutions have the opportunity of making information available off site, across physical boundaries, to anyone interested at minimum costs. This can significantly reduce cost of education, making it more affordable and accessible to the masses. This will enable students undertaking technical studies to perform the practical component of courses off site without the need to be in physical contact with actual hardware equipment.

5. Students control real hardware from their PC and obtain immediate PC-scope display of the real signals. The hardware is remotely controlled via GUI.

6. Fault insertion capability for student debugging.

7. 24/7 access to real hardware experiments via browser/client.

8. Real-time logging of student experiment progress and access. A real-time monitoring of students can be done and a record of their activities is generated.

9. Flexible, fast experiment authoring using simulation package.

IV. HARDWARE EQUIPMENT

Telecommunication Instructional Modeling System (TIMS) telecommunication equipment, shown in Figure 2, is used to perform the laboratory component of the ECEN 455 course.

TIMS is a communications trainer that incorporates instruments needed to carry out communications laboratory experiment required in a technical university level course. It is used to present experiments in telecommunications theory and concepts by building experiments at block diagram level.

The TIMS basic system comprises two hardware components. The first of the two hardware components is the core system unit with fixed modules and slots for plug-in modules. The second hardware component is the plug-in -modules which comprises single function building blocks. Modules are selected to suit each specific experiment setup and these are then reused in other experiment setups.
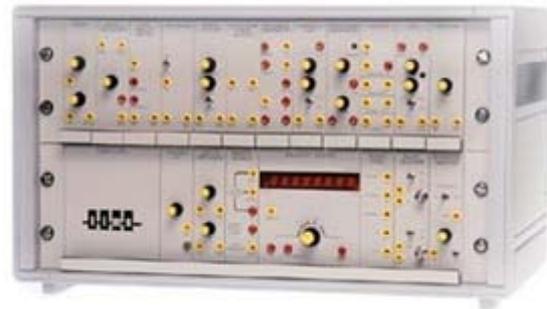

Figure 2. Telecommunication Instructional Modeling System, hardware used to carry out communications laboratory

V. NET ENABLED EQUIPMENT AND EXPERIMENT

Emona NET TIMS, a NET server that can be connected to the TIMS hardware basic system, allows instructors to set-up real telecommunication experiments in their own laboratory, which students can then access and control from within the lab and at a distance, to carry out experiments. NET system laboratory equipment was employed to deliver the laboratory component of ECEN 455 course.

A real hardware experiment was set up in our own laboratory, which students are able to access and control from within the lab and at a distance, to perform experiments. Figure 3 shows the hardware system and experiment as it could be set-up at College campus. The display on the computer is the same display a student would see via their browser, from home or another lab.

Experiment control and manipulation is the same as with standard hardware version. Students are able to vary parameters such as frequency, phase, amplitude and timing so that experimental results relate back to the theoretical and mathematical calculations.

NET enabled modules have switches and potentiometers which are remotely controlled via Ethernet. The NET enabled modules are plugged into a System Unit and are patched to the NET server, which is connected to the LAN/Internet via an Ethernet port. It is important to note that, students actually manipulate real hardware and view real electrical signals. They are able to control the experiment from across a LAN or the Internet via an experiment GUI control panel/screen displayed in their browser, as seen in Figure 4. The key difference between standard hardware and virtual LAN/Internet experiment is that in the virtual version, parameters that could be varied using knobs and switches are adjusted via a graphical display on the user's computer screen.
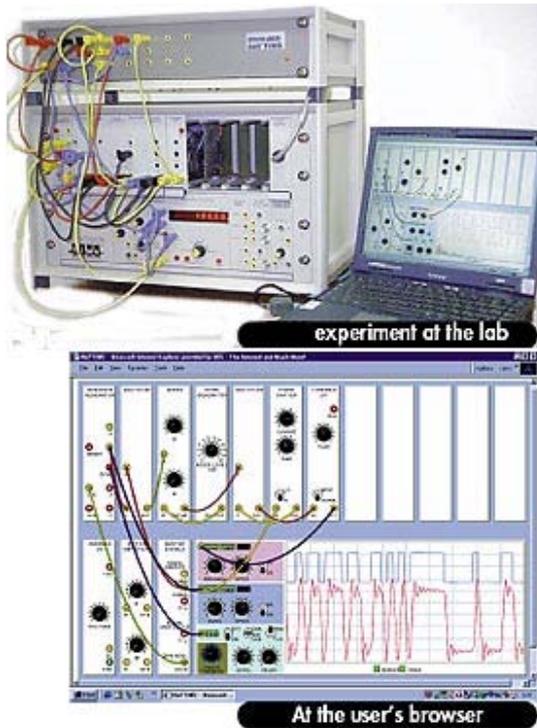
Figure 3. Hardware NET system set-up at college campus and GUI experiment as seen by users

The GUI at the user PC mimics the experiment front panel and displays acquired real signals, using a digital channel oscilloscope from different points in the experiment for each channel. All waveforms can be viewed in both the time and frequency domain.

The NET enabled system allows for the following features:

A. Simple Browser Log-on

A user logs on to the NET server using standalone client software that they can download from an e-learning web-supported system linked to the university database. They receive a JAVA-based client screen, as shown in Figure 4, corresponding to the particular experiment set up on the NET system. The student can simultaneously access other course material provided by the instructor and also transfer actual experimental results between the NET screen and other applications to create Lab reports.

B. Multiuser Environment

The NET server manages a multiuser environment, allowing several students, each at a different location, to be logged onto the same NET server and independently carry out their own session of the same experiment.

C. Access Management

The NET server provides gate keeping access and a log of all student activities. The instructor can manage the NET server from a password protected administration page via their browser.
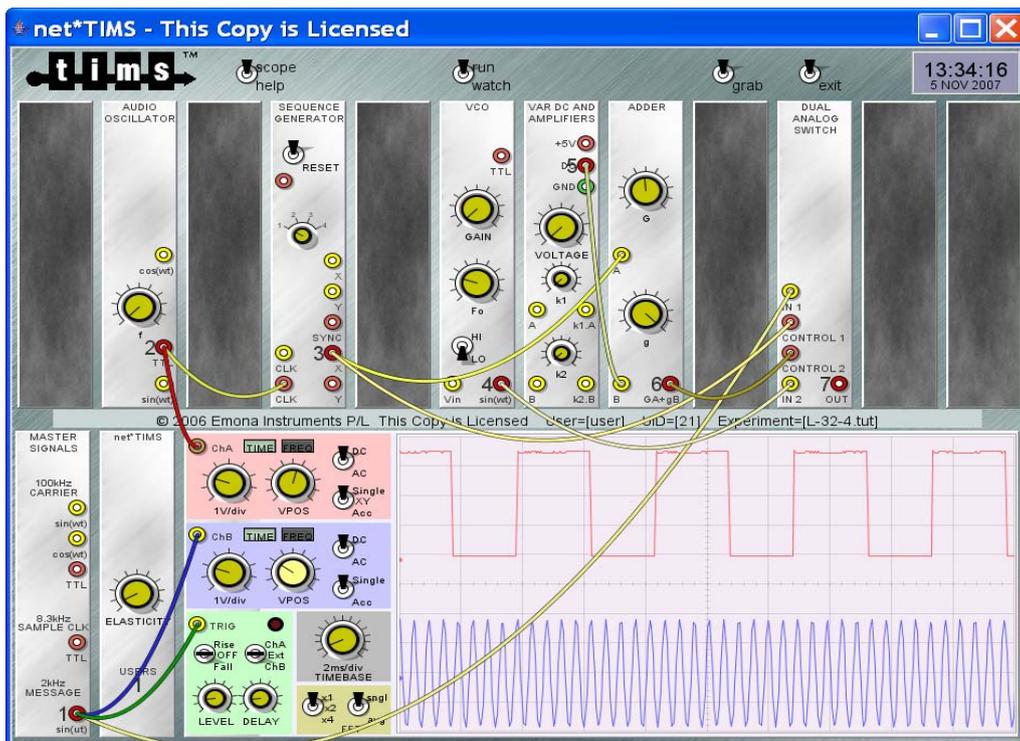

Figure 4. GUI at the student PC that mimics the experiment front panel to display and manipulate acquired signals

VI. INSTALLATION OF THE NET SYSTEM

To get the NET enabled system working; the NET system including the server needs to be installed on the LAN or Internet. Once installation is completed, experiments can be edited and loaded onto NET system. This is described below. Following is a summary of the steps involved in installation and experiment loading:

1. Connect the NET core system to the NET server and in turn connect the NET server to the campus network. The IP address at which the server is connected need to be recorded as students will need it to connect to the server.

2. Set up the NET system with a single computer to verify the correct operation of the NET enabled System which is shown in Figure 5

3. Enter student log-in information manually or upload a student file into the NET system class list via the instructor's secure NET enabled Administration Web Page.

Our NET experiment system was not directly connected to Internet but through the campus network to provide increased security and protect equipment from hostile access.

Figure 5. NET system hardware unit set-up with single computer to verify correct operation

VII. SETTING-UP NET EXPERIMENTS

Any experiment is easily set-up in the steps described below:

1. The experiment is patched together on-screen using a simulation software. The completed experiment is saved in format compatible with the NET server;

2. The saved file (experiment) is uploaded to NET system via the instructor's secure NET Administration Web Page. It is this file which provides the display screen that students will see when they log-on to NET equipment;

3. Set up the hardware experiment by inserting the plug-in modules into the NET system hardware unit and patch inputs and outputs together exactly as per the on-screen experiment of the saved file which has just been loaded.

NET experiments are thus ready via the NET server for students and instructors to log-on and perform through LAN or Internet.

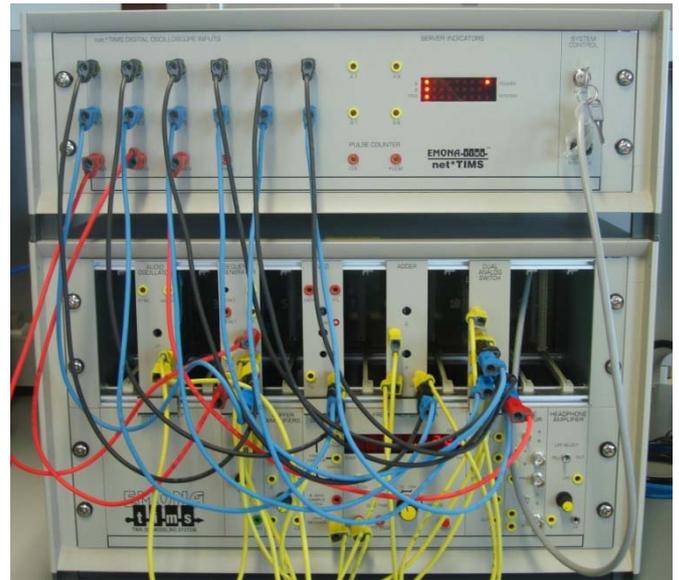Figure 6 below shows a NET experiment that is patched on the NET hardware unit.

Figure 6. NET system hardware unit fully patched as per the NET experiment screen

VIII. RUNNING THE NET EXPERIMENT

At this stage, the experiment is uploaded to the NET server and is ready to be accessed by students. To access the NET experiment, students need to follow the steps below:

1. Since the Net server is connected to college campus network, students must connect to the campus network. For this purpose, students can use VPN (Virtual Private Network) service for remote users who need access to campus resources. The remote user's traffic is tunneled past the campus.

2. Student need to download a standalone client which is made available through an e-learning web-supported system linked to the university database. This standalone client is software students need to use on their PC to interact with the NET server and NET experiment. The standalone client requires downloading and saving on the student PC once only. Upon launching, the standalone client will request the student to enter the NET server's IP address so that 'live' connection is established to the NET server.

3. Next, the student will be asked for their username and password which will be supplied to them though an e-learning web-supported system linked to the university database.

4. Assuming the student is successful in connecting to the experiment, the NET experiment GUI will be displayed as shown in Figure 4.

Now the student can control the experiment using switches and knobs shown in Figure 7.

Recall that these experiments will not function until corresponding hardware modules have been plugged into the NET system hardware unit and patched together, exactly as displayed on the student's screen. This is due to the fact that the NET system is real hardware and is not a simulation. The modules are plugged into the same

locations in the NET system unit as the slots shown on the experiment screen at the student side.
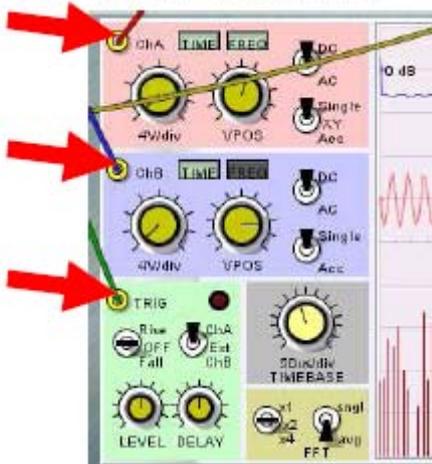

Figure 7.   Switches and knobs that control hardware variables

IX.   FUTURE WORK

Following this initial attempt for CAL, we plan to follow it up with more NET enabled experiments offered in this course and other courses offered by the Electrical Engineering Program at TAMUQ.

CAL system's development will be concentrated on increasing system's performance which includes higher speed of processing and stronger software.

Currently, we connected all of our equipments to the LAN to utilize available CAL features to make the equipment available to students at a distance. Hopefully, this will facilitate further experimentation with CAL for Electrical and Computer Engineering.

CONCLUSIONS

A discussion of the author's use of CAL to supplement a senior level university course, ECEN 455, offered to undergraduate students at Texas A&M University, Qatar campus, was presented in this paper. Implementation of NET system accessible through LAN or Internet to deliver the laboratory component of the above mentioned course, overall, has been a success.

The papers discussed benefits of NET system offering, in addition to steps to set-up, access and control the NET system. The NET experiment system offers real hardware experiments delivered simultaneously to multiple students across LAN & Internet in real-time. The student can connect to the NET server that makes the hardwired experiment available through LAN or Internet via simple standalone client software. This client enables students to receive a screen corresponding to a particular experiment set up at the NET server. The NET server provides gate keeping access and a log of all student activities. The instructor can manage the NET server from a password protected administration page via their browser.

Students were generally satisfied with the method of laboratory delivery. Students learned the same or more than they would in an on-site laboratory as they had more chance to experiment and learn. Taking CAL based learning requires more personal responsibility than on-site laboratory, which was not a concern in our case as the participant in this course were reasonably mature university students (senior students). Nevertheless, the instructor's assistance was vital; however, interaction was for less amount of time than the usual time allocated for laboratory session.

In arriving at conclusion, the reader must remember that this was a limited experiment in terms of the number of students involved (fewer than 50). For larger student base, increased course quality and optimized operation of laboratory sessions can be observed. Course evaluation suggests that students are more motivated and keen to learn.

Recent advances in science and technology have enforced changes in teaching methods. CAL systems are useful and necessary tools for today's education. Multimedia facilities, fast, affordable PCs and worldwide networks make them powerful and available. In the future, CAL systems will be an integral part of equipment and will have more intelligence attributes that are practical and make instructors' duties lighter. CAL is not the whole future of the education. However, as time goes by, CAL systems will become more essential in the teaching process.

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