Remote laboratory to attract engineering students

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Abstract
Technology today is developing very fast and the demand from the industry for highly skilled and qualified professionals is increasing. Yet the number of high school graduates entering engineering and science programs at universities is decreasing. In this paper we describe a unique way we attract future engineering students and at the same time produce highly skilled, self confident and motivated graduates.

Remote laboratories (RL) have been developing rapidly in the last decade. RLs allow students to perform experiments using real laboratory equipment from a distance via the Internet. At the University of South Australia (UniSA), the remote laboratory NetLab has been developed and incorporated into the curriculum for our onshore and offshore programs. It has gained international recognition as an excellent collaborative learning environment pedagogically structured around student centred learning. Furthermore, during open day sessions and exhibitions, the NetLab is showcased as an example of UniSA engineering students’ achievements. It is a complex engineering system developed as an in-house product by our students under the authors’ guidance and supervision.

Keywords: engineering education, remote laboratory, the NetLab

1. INTRODUCTION

It has been widely acknowledged that maximum learning outcomes are achieved if the theory is supported by practical experimental work [1]. Many virtual laboratories have been developed to help students gain the understanding of new concepts by simulating physical systems. Although simulation is a useful and convenient teaching tool, it is widely perceived as a poor replacement for real experimental work in an engineering laboratory [2,3,4]. Until recently, very little has been done to employ new technologies into university programs in order to make experimental practical work more accessible to students.

The remote laboratory NetLab has been developed and enhanced since 2002 through a number of final year and postgraduate students’ projects [5]. Now, the NetLab is an impressive system which involves the development of both hardware and software. Students who have previously worked on its development then go on to present it to potential future students. This showcases their knowledge and skills they have gained during their four, or five in the case of a double degree, year engineering programs at the School of Electrical and Information Engineering. Programs at the School are: Computer Systems Engineering, Electronics and Microengineering, Telecommunications and Electrical and Mechatronic Engineering.

Currently students use NetLab in the first and third years of their program. If they choose to work on NetLab during their final year project, they can make modifications from a user’s point of view. The newest initiative for NetLab is to enable students to gain international collaboration and intercultural communication skills by providing an opportunity to collaborate with overseas students in Singapore, Sweden and Portugal. These important skills will enable our graduates to work effectively as a part of international engineering teams in the future.
2. THE REMOTE LABORATORY NETLAB TO ATTRACT ENGINEERING STUDENTS

The remote laboratory NetLab, described in part 3, is frequently showcased during the University Open Days in Adelaide, South Australia, and it is also presented overseas. In addition the School of Electrical and Information Engineering has offshore programs at KBU (International College Bandar Utama) in Malaysia, APMI Kaplan (Asia Pacific Management Institute) in Singapore and SINEC (Colombo International Nautical & Engineering College) in Sri Lanka. Students from Malaysia and Sri Lanka start studying from the first year, however students from Singapore are graduates from Polytechnic schools and are therefore given advanced standing to finish last 2 years of our programs. The NetLab is also presented to high school students who visit our School. This allows students to preview the work of the university’s engineering students which may entice them to enrol into an engineering program. Often these high school students are very impressed and have the opportunity to ask questions. They also have an option to use RL by themselves during this time. More importantly, they can later register, book their time session and use the NetLab from a remote location such as their own home. After each demonstration it can be seen from the booking web page that the future potential students are “working” in the RL. We have observed that high school students are often moving and zooming the camera, however students from Singapore, who already have some technical knowledge, often are trying to conduct simple experiments. As the NetLab has the possibility to remotely connect components and devices, to change values of components and to control devices, they are really having their first hands-on online experience. In Singapore there are a few overseas universities offering a similar degree as the UniSA, but the practical component of the engineering programs are is commonly conducted in the form of simulations. From our recent students’ feedback in Singapore, some of the students have chosen our degree because the practical sessions are preserved in the form of remote experiments. In today’s Internet environment all students know how to communicate online even on an international level. The NetLab is designed to allow online communication for up to 3 students at the same time. Some first time users have the opportunity to work with students from different countries during their first encounter with RL.

3. THE REMOTE LABORATORY

From the beginning of technical education all scholars have shared their acquired knowledge with their pupils and have taught them the theory and its applications in the real world. In tertiary engineering and science education, the classical approach, which has been used for centuries, has usually consisted of three components. The first component involves lectures to explain the fundamentals followed by advanced theory and its applications. The second component involves tutorials, where students have to solve theoretical problems based on the learned theory. The third component involves practical sessions, to apply the acquired knowledge to real systems using their minds and hands. All three components have remained basically the same for the last few centuries. With new technologies available, inevitable changes have occurred. The black boards have been replaced with white boards, which continue to be important components in teaching, but they are now supported by computer based tools. Some presentations are animated, interactive and even self guided, thus can be used for independent learning [6]. The third practical component of engineering and science education within the laboratory sessions, have remained relatively unchanged with students attending practical sessions.

With the fast developing technologies, new and better technical appliances and applications are introduced almost on a daily bases. In the global context, the educational sector is a very competitive environment. Universities have to educate their graduates equipped with the newest up-to date knowledge and skills. They have to know the recent theoretical developments in their field as well as to be able to use the latest software and hardware. This requires specialised and expensive equipment. To keep upgrading existing laboratories is very costly. However, with the unpredicted phenomenal development of the Internet and new technologies, the solution to the problem has emerged in the form of remote laboratories [7,8,9,10,11]. A real laboratory with all their instruments and components can be used by students in the RL environment in a nearly identical way as in the classical approach but without students being present in the laboratory. Students are able to conduct their experiments from a remote location at their own chosen time, from computer pools or sitting comfortably in front of their computer at home. Only one set of equipment is required for potentially hundreds of students and it can be upgraded regularly. Conducting experiments in RLs helps students to develop skills which are required to control the newest equipment interconnected and available globally. Future successful professionals will have to have skills to work independently and also as members of international teams distributed globally.

3.1 The remote laboratory NetLab

It can be accessed at http://netlab.unisa.edu.au. The remote laboratory NetLab has been developed at the University of South Australia since 2002 and it has been subject to continuing refinements and improvements. It
Remote laboratories, which started their development about two decades ago, are currently seen as the humble beginning of the future global systems [12]. They can be considered as a good structured and teaching environment for developing skills required for the efficient collaboration and communication on the local and global scale. In 2007 there were about 120 RLs at universities around the globe [13], yet only a few were constructed in such a way so as to allow involved participants to collaborate in real time, such as RLs developed as part of the MARVELL (Virtual Laboratory in Mechatronics: Access to Remote and Virtual e-Learning) project [14], DIESEL (Distance Internet – Based Embedded System Experimental Laboratory) project [15] and WebLab at MIT (Massachusetts Institute of Technology) [16]. The NetLab has provided the collaborative learning environment from the beginning. It can be used up to 3 users at the time. The real physical laboratory is in the Sir Charles Todd Building at the School of Electrical and Information Engineering at the Mawson Lakes Campus of the UniSA. The picture of the NetLab real physical environment is shown in Figure 1.

The NetLab has its own dedicated server which is connected on one side to the Internet allowing users to access the RL. On the other side, the server communicates with a number of programmable laboratory instruments via the IEEE 488.2 standard interface, also known as the General Purpose Interface Bus (GPIB). These instruments include the digital oscilloscope, the function generator and the digital multimeter. All these instruments are also connected to a 16x16 programmable matrix relay switch which provides the user with an option to wire and configure various electrical circuits from available components and instruments. Special software, the Circuit Builder, has been developed for these purposes.

The NetLab’s Graphical User Interface (GUI) is written in Java (initially it was written in LabVIEW), therefore the Java Runtime Environment (JRE) must be installed to allow the NetLab application to run. The user can control the real instruments through the client software, consisting of the interactive GUI. The users’ commands are then sent to the NetLab server and processed by the server software. The NetLab server uses an implementation of the Virtual Instrumentation Software Architecture (VISA) Application Programming Interface (API) to direct the commands to the appropriate programmable instrument. The VISA API allows software to communicate with a variety of hardware devices using connections from the same software interface. The GPIB port is used to retrieve the relevant data from the instruments and passed on to all connected users. The data, acquired with the oscilloscope, can then be exported to a file for the use with relevant software such as MATLAB (MATrix LABoratory - software package from MathWorks) for further processing and analysis.

Components that are currently available are resistors, capacitors, inductors and transformers. In addition, programmable variable resistors, inductors and capacitors have been developed and interfaced into the system. Additional components can be easily added to or removed from the system at any time.
The NetLab also includes a camera which has its own web server and is fully controllable by the user. The camera controls include pan, tilt and zoom functions. The video feed from the camera is not part of any experiment and can be switched off to save on the bandwidth. However, it is an important part of the system because it provides distant users with telepresence in the laboratory.

3.2 The NetLab GUI
NetLab GUI is the most distinctive part of this RL. From the beginning of its development it has been designed with the intention of giving students the feel of working in a real laboratory as much as possible. When the NetLab is accessed, the client software is downloaded onto the user computer, which requires the Java runtime environment to be installed on it. The client software opens the NetLab GUI shown in Figure 2, which includes a video image of the real environment through the web camera.

![Figure 2. The NetLab main GUI](image)

It has been designed in such a way that it allows users to collaborate during the remote experiments in a similar way as students collaborate in the real laboratory. The window in the right lower corner is a control window where all past actions of all users are recorded. The each action is recorded together with the user’s name, so all present students can recognize who is responsible for the action. The communication between users is done in the lower middle chat window. The last bottom window on the left is showing all users names currently logged-on.

Users have full control of a web camera and can view instruments and components or just look around the laboratory. The NetLab camera provides an option to preprogrammed 10 positions. This is very useful as students can view different instrument by simply selecting them from the camera menu. We believe that a camera is an important part of every remote laboratory, in order to give students the feeling of presence in the laboratory. Otherwise the interaction between a student and the system would be the same as in the case of simulation. Our experience and surveys show that students like to use the camera, sometimes just for fun, but more often to make sure the instruments in the real lab respond to their actions. They always question the differences between signals shown by the real instrument through the camera video feed and the animated image of the instrument.

The GUIs of NetLab instruments are created from photographic images of the instruments' front panels. A click on one of the instrument images brings up a larger interactive image of that instrument giving increased readability. Figures 3(a) and 3(b) are showing an example of the resulting window when the oscilloscope icon is clicked on, which contains an interactive image of the oscilloscope that is approximately 1:1 ratio, on a standard 17” monitor, with the size of the physical oscilloscope. Users are then able to interact with these instrument images, which includes animated controls and displays, in the same way that they would when physically operating the instruments. For example, the mouse is used to click on a button or rotate a knob or dial in the same way that a finger would be used to press the button or turn the same knob or dial. The GUI represents the
instruments with a sense of realism and functionality that matches the physical instruments. Most of the instruments’ functions are implemented in the GUI of the device. This is a great advantage, especially for new users, where they can learn and practice to control the instrument being able to see responses on the instrument GUI as well using the camera image. As an example, the difference of DC and AC coupling for channel 2 is shown in Figures 3(a) and 3(b).

![Figure 3(a). The correct channel 2 trace](image)

![Figure 3(b). AC coupling for the channel 2 producing the distorted trace](image)

### 3.3 The NetLab Circuit Builder

The Circuit Builder is available from the NetLab main GUI from the task bar from Instruments using the pull down menu. It allows users to wire remotely different circuits [17]. Available instruments and components are represented in the Circuit Builder GUI by their photographic images or a schematic (the transformer).

By mouse pointing to the terminal to be connected and then dragging it to the destination terminal a wiring can be established that is the same as in the real laboratory except that here the mouse is used to connect instruments and components instead of wires. The wiring sometimes gets really messy, as in a real laboratory as shown in Figure 4. Circuit Builder allows students to capture an image of the wired circuit which can be later checked by them and more importantly by a lecturer who can then point out to students what went wrong in their experiment. This way a student can produce a better documented report of the experiment by simply capturing images from the computer screen of wired circuits, observed signals and instrument panels.

The main hardware component that allows connection of selected circuit components is a relay matrix switch. A 16x16 relay matrix module was chosen from Agilent, E1465A, for this purpose. This relay matrix switch
required supporting hardware that included: E8408A 4-slot VXI Mainframe and the E1406A Command Module. These components form a relay matrix-switching unit that is capable of communicating externally with the NetLab server through the standard instrument communication bus, GPIB (General Purpose Interface Bus). The matrix module consists of 256 nodes formed by 16 rows and 16 columns. Switching of nodes is performed by double pole double throw (DPDT) latching relays. The structure of latching relays in the matrix allows having two separate layers. Each layer can have its own set of components connected to it and thus doubles the number of components, which can be wired remotely.

3.4 The NetLab booking system
The system requires a new user to create an account and then to book a session. As a multiuser collaborative environment, NetLab allows more than one user to have full control of the system at the same time. However, the number of concurrent users is now limited to three. The flexibility of the system allows each student to book 1, 2 or 3 sessions, so that the students can work in groups of 3 or 2, or alone. To prevent excessive booking, a lecturer (administrator) can set a limit on a number of hours per week that each student can book.

When the mouse is positioned over a booked slot, the user name and his/her country (except Australia as a default) is displayed. This provides students with an option to choose a laboratory partner from another country. An unlimited number of users with administrative privileges can access and control the system at any time without booking even if three other users are logged on. All booking are done according the local time zone installed on the user’s computer. The Figure 4(a) is showing the students’ booking in Singapore for 14/02/2009 as they can see it there. The Figure 4(b) is showing the same booking, but in the Adelaide time zone and additional time slots booked by the author.

Figure 4. – The Circuit Builder

Figure 4(a). NetLab booking for Saturday 14/02/2009 in Singapore
4. CONCLUSIONS

The remote laboratory NetLab is fully incorporated into the Engineering curriculum at our School at UniSA. It has become an integral component in engineering education allowing for additional time and location flexibility not typically associated with traditional learning methods. Student learning outcomes are equal if not improved with its use compared with the traditional laboratory environment. NetLab has also demonstrated its potential as a valuable recruiting tool for students deciding on a path of engineering studies. During open days and other promotional events its immediacy and availability provides a genuine short term experience of modern engineering learning for today's Internet savvy students. The NetLab's universally familiar and accessible online features have allowed it to be incorporated in offshore programs and this has initiated and enhanced the relationships between UniSA and its partner teaching institutions. This has created a level of uniformity of learning outcomes never before seen at an international level.

The future development of the NetLab will be driven by a combination of advancements in the Internet and online environments along with the latest engineering techniques. As the Internet incorporates an ever increasing role of all student's and teacher's lives, the acceptance and indeed the preference for Internet based learning tools, like NetLab, will continue to expand.

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References


