# Students' Telepresence in a Remote Laboratory: a Case Study - NetLab

Zorica NEDIC
University of South Australia, Zorica.Nedic@unisa.edu.au, http://people.unisa.edu.au/Zorica.Nedic

Jan MACHOTKA
University of South Australia, Jan.Machotka@unisa.edu.au, http://people.unisa.edu.au/Jan.Machotka

KEYWORDS: *NetLab, remote, laboratory, telepresence, Internet*

ABSTRACT: *This paper presents the structure and the effective use of the remote laboratory NetLab developed at the University of South Australia for teaching students enrolled in early years of engineering programs in the School of Electrical and Information Engineering. The remote laboratory allows students to work on real equipment via the Internet. Recently a number of remote laboratories have been developed worldwide and although the concept is not new, NetLab represents a unique development because of our primary aim to make it "look and feel" as realistic as possible. For this purpose a special Graphical User Interface (GUI) has been designed. It uses photographic images of front panels of the laboratory instruments and animated buttons and controls which respond to user's actions the same way as the real equipment. To enhance the students' impression of "being there" a web camera is used to broadcast the real time video from the laboratory. Students can fully control the camera to view the equipment or just look around the laboratory. They can also download real measurement data from the digital instruments via the Internet. Netlab is based on a client-server architecture, with the server being the intermediary between clients and instruments. Unlike other remote laboratories, Netlab is a multi-client environment, allowing for multiple users to log in simultaneously. This is designed to mirror the normal practical laboratory sessions where students work in groups. A chat window of the Netlab GUI allows students to communicate with each other while working simultaneously on an experiment. Even though NetLab gives students telepresence in the real laboratory, thus making their work as realistic as possible, it is effectively used to supplement students' hands on laboratory experience rather than to replace it. Its main advantages are twofold: it allows students to learn to control the real equipment before coming to the real laboratory and therefore use their time more efficiently; and it offers students the opportunity to repeat experiments and check their measurement results, which is not the case with real laboratory where students cannot work without the supervision. These advantages are already highly praised by students who used NetLab.*

## 1  INTRODUCTION

Laboratory experiments are an essential part of tertiary education, particularly in engineering disciplines. Until recently, laboratory experiments were considered not suitable for distance education. With the introduction of the Internet and later its phenomenal rise and spread into all areas of human activities, exciting and promising possibilities emerged for the development and implementation of remote laboratories all over the world. They brought in the potential to further enhance the exponentially developing e-education, especially in information and communication technology (ICT) and engineering education. In October 1994, Mosaic Communications Corporation (renamed to "Netscape Communications" on 11th November 1994) introduced the first public beta of their browser, "Mosaic NetScape". In less than 10 years, a number of practical courses have been developed and already offered to students in a distance mode [2]. Using the latest version of the Netscape browser, or its younger, but ambitious sibling, the Internet Explorer, students can participate in practical classes without technical means other than a personal computer and a connection to the Internet. For example, some of the very first attempts to create a remote laboratory were accomplished at the Norwegian University of Science and Technology in 1997 and 1998 [3].

Interacting with real equipment remotely over the Internet is exciting. However, it can be dull and lifeless if the graphical user interface of the equipment is simulated in an unrealistic appearance. The NetLab system developed in the School of Electrical and Information Engineering at the University of

South Australia, takes an unprecedented approach to generate a realistic laboratory environment. This is accomplished by using real static images of the actual equipment with interactive features such as buttons and knobs and live data display. Also, a web camera is available for observing live streaming of the experiment in the remote laboratory. These features make the experiment inherently "hands-on" and give the users a feeling as though they are physically present in the laboratory interacting with the actual equipment. NetLab can be accessed from the UniSA web site at the URL: http://www.unisanet.unisa.edu.au/netlab/. NetLab's main access page is shown in Figure 1.



Figure 1 – NetLab main access page

## 2    NETLAB GUI

As mentioned in the introduction, NetLab is a unique remote laboratory because of its Graphical User Interface (GUI) specifically designed to give students impression of working in a real laboratory. The current version of the NetLab GUI is shown in Figure 2. The GUI has several sections: main area is in the top left-hand side corner where instruments' front panels are shown and students can use them to control the instruments; top right-hand side is reserved for live video steaming from a web camera placed in the laboratory. This area also includes camera control panel which allows students to fully control the camera including pan, tilt and zoom. There are three parts of the bottom area: a chat window in the left-hand side corner; an action monitoring window in the middle and an instruments' library window on the right-hand side.

When an instrument is selected from the library, its photographic image appears enlarged in a new window with a higher resolution as shown in Figure 3. A student can use controls on the front panel of the instrument in the same way as he/she would use it in a real laboratory. A program written in Java Script allows user to press and turn around the animated buttons using the computer mouse. The switches and buttons are animated so they pop-in or pop-out when pressed or released respectively. Some of the switches glow when switched on as on the real instrument. Figure 2 shows the font panel of an oscilloscope which also includes a graphical display of the waveforms of monitored signals. This display is animated, but plotted signals are real time signals downloaded from the real oscilloscope in the laboratory. Therefore, the signals plotted include the real noise which is a great advantage of NetLab over virtual laboratories that give ideal data obtained from simulations.  All user actions are followed by control commands that Java program sends to the NetLab server. The NetLab server communicates with all instruments in the laboratory through the standard communication interface IEEE 488.2, also known as General Purpose Interface Bus (GPIB). Through this interface all user actions are followed by the response of the instruments in the laboratory.  This way, students are able to operate the instruments and

at the same time the instruments respond to their actions and produce realistic data. Students can save measurement data in the same way as they would in a real laboratory by pressing the "save" button on the front panel of the oscilloscope which opens a dialog window for saving data in a file on the student's remote computer as shown in Figure 4. Later, students can perform analysis on realistic measurement data obtained remotely without a need to be physically present in the laboratory. A section of the text file with saved data is also shown in Figure 4.
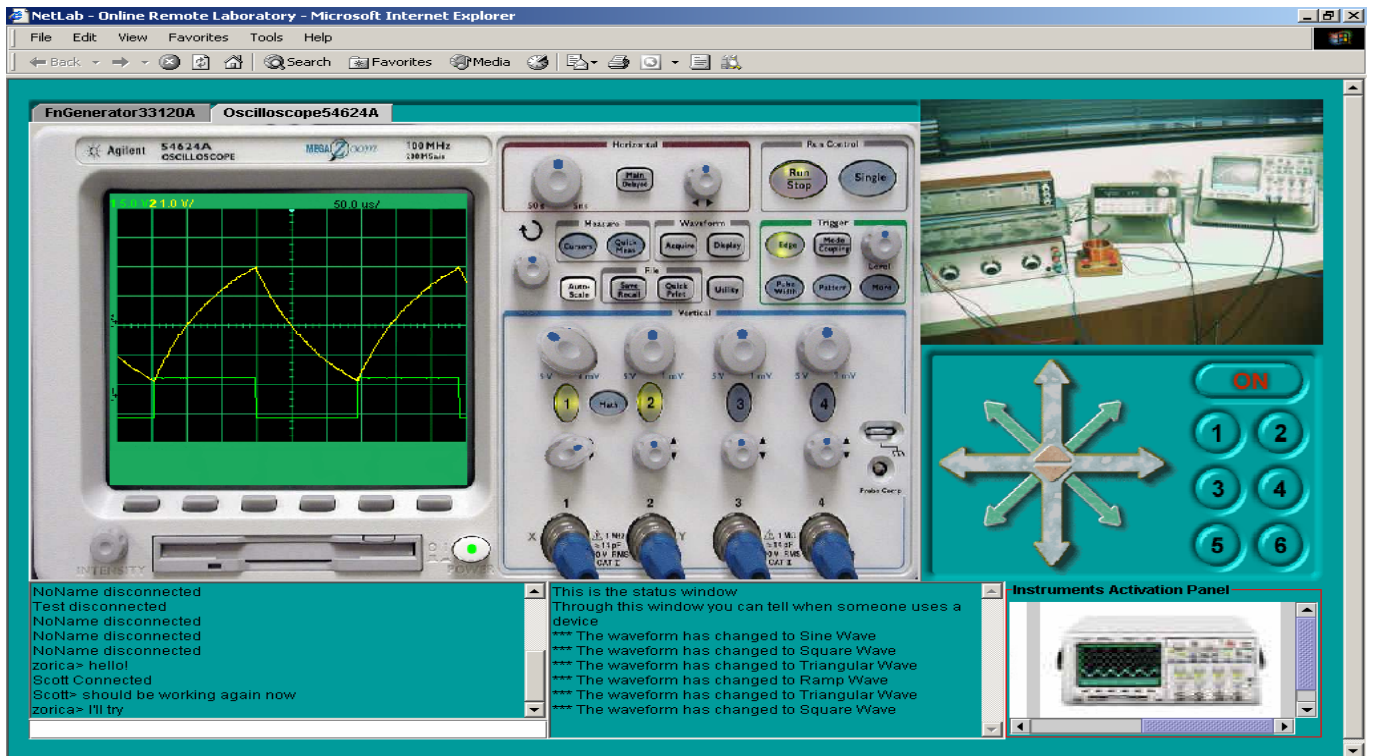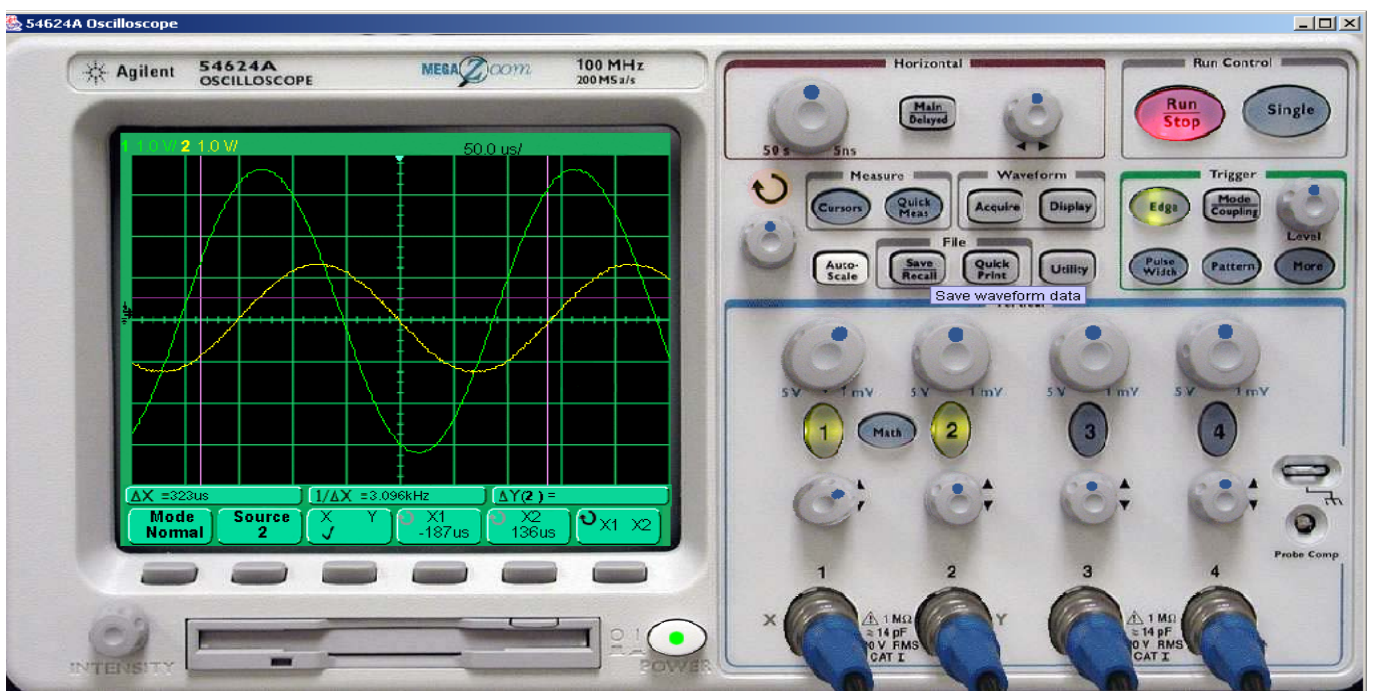


Figure 2 – NetLab GUI

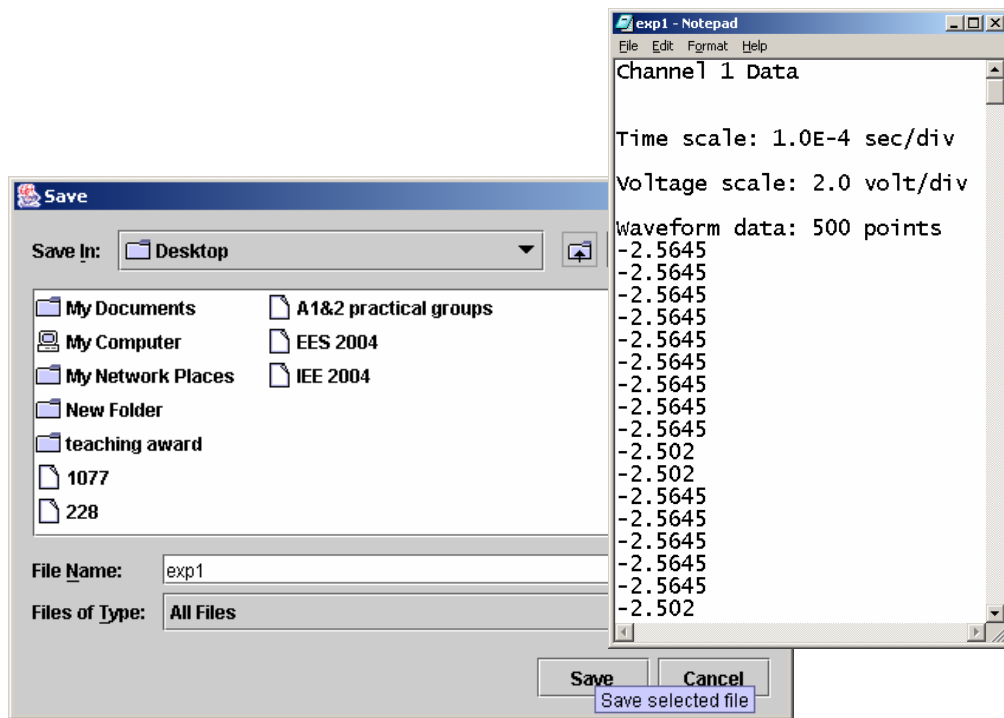

Figure 3 – Instrument control panel

Figure 4 – Saving measurement data at a remote location

In some remote laboratories a real tutor is used to guide students during experiments [5]. To provide remote experimentation to a group of students, where the tutor explains the details of the experiment and controls the experiment, synchronous communication techniques are required. With the use of the Internet, a few techniques are available:

- text – chat technique, which enables users to exchange messages in the allocated window on the monitor
- audio communication, where the voice is captured and transmitted over the Internet to all participants
- video technique, where the live image from the laboratory is transferred via the Internet.

Unlike the previous example, NetLab is based on students' centred learning and the supervisor is not guiding students while they perform experiments. Students perform experiments in groups of three and communicate with each other via the text-based chat room, which is allocated in the bottom left corner of the NetLab GUI. This is very similar to the real laboratory learning environment, where students work together in teams. This learning paradigm is often called collaborative learning, which develops team's problems solving skills. Students in the group must organize their activities themselves and decide upon the roles of the different members via consultation and negotiation [6]. The technology behind a collaborative learning environment is a mechanism that enables a user to send updates to other users about the interactions that are made in the shared learning environment. Using the NetLab GIU, this is done automatically inside the other window, where all steps in setting parameters and the control of the equipment are broadcasted to all participants. It is also necessary that all team members can have the same view of the experiment in real time [7]. This is accomplished via the live Internet camera, which can be controlled by all members of the team.

## 3    ADVANTAGES OF NETLAB

Observing a number of other remote laboratories available on the web [8-10] we realised they do not offer students real hands-on practical experience. Although they offer realistic data for analysis, it is hard to perceive them as anything different from a simulation environment. They all acquire data through the reading of inputs in text fields. The NetLab however, uses the interactivity of its instrument panels to obtain its inputs and to display the results. In other remote laboratories the results are displayed in the form of graphs and/or text. This approach is unrealistic and does not reflect the displaying of results seen by students in the physical setting. The method of obtaining results for the other remote laboratories is

also unrealistic as the steps in determining the results are automated and are completed behind the scenes. In NetLab each step must be carried out by the student as it would be done in a physical laboratory.

The client Java applet also provides functionality for chat allowing for collaboration between users distant from each other. This is especially important, as peer interaction is an integral part of laboratory sessions, but it also reduces feeling of isolation, often experienced by students studying in a distance mode. Furthermore, NetLab broadcasts the live image from the real laboratory. For that purpose a sophisticated web camera, shown in Figure 5, was positioned in the laboratory. The image from the camera is shown in Figure 6. It can also be seen at the top right-hand corner of the NetLab GUI. This image is provided for students to allow them to view the equipment and also to monitor the response of instruments to their remote commands. Although the image from the camera is not used for reading any measurement data, the image has an important role in enhancing students learning experience. Students can control camera in order to view equipment in the laboratory or just to see what or who is in the laboratory due to their curiosity nature.

Using a GUI based on the front panels of the instruments creates a realistic practical experience that can substitute for laboratory attendance in the case of distance and external students and can provide training for traditional students so that their laboratory time using physical equipment is used more effectively. The realistic remote laboratory can also be used as a cost effective training tool for students before they use similar equipment in an industrial setting, as a self-learning medium and as a way of introducing new and expensive equipment to the practical curriculum. This can be done due to reduced operating costs as a greater number of students can use the facility and after the initial start up costs the expense of running NetLab is minimal. The savings involved come from purchasing only one set of equipment and not having the need for teaching staff to be present. In addition there are also savings associated with the amount of space required for a practical class and the amount of maintenance required.



Figure 5 – Web Camera used in NetLab



Figure 6 – Live image from the web camera

## 3    CONCLUSIONS

GUIs of NetLab are realistic interactive images of the instruments and are operated by entering inputs graphically, as one would do, if physically operating the instruments. For example, inputs are entered into the waveform generator using a mouse to click on the various buttons in the same fashion, as a student would use their finger to press the buttons in a physical laboratory. Also on the oscilloscope, to adjust the sensitivity of the vertical axis that displays the amplitude of the waveform, a corresponding knob needs to be turned using the mouse with the same level of finesse as is required when physically turning the knob on the instrument. This level of realism of entering parameters allows students to 'feel' the peculiarities of an instrument and experiment with their various settings, as these are the same tasks they would perform if in a physical laboratory. To further promote this feeling of 'being there' a web camera is used to show

the output of the physical instruments in the laboratory. This is intended to remove all doubts from a student's mind that the remote laboratory is a simulation, hence focussing the student's attention on operating the instruments. The NetLab allows more than one user to control instruments at the same time. Having each student to remotely operate the instruments aids the student's own learning process. This also facilitates group work and the development of leadership skills, as would be generally the case in a real laboratory where work is conducted in groups due to resource constraints.

The Netlab is fully operational and has been already used in teaching. In 2003 students used NetLab to perform two experiments in two first year courses. Apart from some problems due to technical difficulties, the feedback from students is positive and the use of the NetLab has been expanded in 2004. We believe that NetLab is a unique example of a remote laboratory that provides students with a "telepresence" in a real laboratory enhancing their practical learning experience.

## REFERENCES

[1]  MACHOTKA, J. & NEDIC, Z. Online remote laboratory (NetLab). In *Proceedings of the 5ᵗʰ UICEE Annual Conference on Engineering Education*. Chennai, India: 2002. 179-183 s. ISBN 0 7326 2192 5.

[2]  IBRAHIM, A. *Interactive web laboratories and demonstrations for EE undergraduates*. Web publication <URL:http://www.ijee.dit.ie/specialissues/interactive/EEInteractiveWebJune02.html> .

[3]  KRISTIANSEN, V. *Remotely operated experiments on electric circuits over the Internet - An implementation using Java.* M.Sc. thesis, Norwegian University of Science and Technology: 1997.

[4]  KO, C.C., CHEN, B.M., CHEN, S.H., RAMAKRISHNAN, V., CHEN, R., HU, S.Y. & ZHUANG Y. A large scale web-based virtual oscilloscope laboratory experiment. *Inst. Elect. Eng, Eng. Sci. Educ. J.*, 9, 2000, pp. 69–76.

[5]  RÖHRIG, C.and JOCHHEIM, A. 2001. Group-based Learning Using a Remote Laboratory Arlington, Proceedings of the American Control Conference, Arlington VA June 25-27, 2001, pp.1153-1154.

[6]  KIRSCHER, P. Using Integrated Electronic Environments for Collaborative Teaching/Learning 1999 Göteburg, Proceedings of the 8th Annual Conference of the Europan Association for Research on Learning and Instruction, Göteburg, Sweden , Aug.1999.

[7]  SHIRMOHAMMADI, S., OLIVIERA, J. C. and GEORGANAS, N. D. 1999 Applet-Based Telecollaboration: A Network-centric Approach  IEEE Multimedia, vol. 5 no. 2, pp  American Control Conference, VA June 25-27, 2001, pp. 64-73, 1998.

[8]  UNIVERSITY OF TENNESSEE AT CHATTANOOGA. *Engineering Laboratories on the Web*. Available on the web, <URL: http://chem.engr.utc.edu/Webres/Stations/V-SINE.HTM >.

[9]  SVEN ESCHE. *Remote Laboratory*.  Stevens Institute of Technology Remotely Accessible Dynamical Systems Laboratory available on the web: <URL: http://www.soe.stevens-tech.edu/Academics/remote_lab.html >.

[10] CASINI, M., PRATTICHIZZO, D. & VICINO, A.. The Automatic Control Telelab: a Remote Control Engineering laboratory. *Proceedings of the 40th IEEE Conference on Decision and Control*, Orlando, Florida USA: December 2001, pp. 3242-3247.