# Recent developments in remote laboratory NetLab

**Hugh Considine**, **Ming Teng**, **Andrew Nafalski & Zorica Nedić**

University of South Australia
Adelaide, Australia

ABSTRACT: NetLab is a remote laboratory developed at the University of South Australia and has been used in teaching to both onshore and offshore students for more than 15 years. The development of NetLab started in 2001 and was funded by a Teaching and Learning grant awarded by the University of South Australia. The system has been continuously improved over the time by including more features to enhance students' learning experience, but also by providing academic staff with information on how students use the system. NetLab is an interactive learning environment that also enables students remote from each other to collaborate and, as such, it is a unique system. Currently, there are two almost identical NetLab systems. Both provide open access and can be used by everyone to perform experiments on real laboratory equipment over the Internet from anywhere in the world. In this article, some recent developments are presented with a particular focus on learning analytics on how the system is used by the students.

Keywords: NetLab, remote laboratory, learning management system, engineering education, learning analytics

INTRODUCTION

In the past decade remote laboratories have been developed at many universities worldwide for their students to perform laboratory experiments on-line via the Internet. NetLab is one of them; it was developed at the University of South Australia (UniSA), and is used by undergraduate students to perform experiments on electrical circuits. Unlike the majority of other laboratories, from the beginning NetLab was designed to be an interactive collaborative environment where a number of students can access the equipment remotely from different places in the world and jointly wire circuits, connect and set up instruments and perform measurements. All users that are logged on concurrently have the full control of the system. Because NetLab is an interactive learning environment, students are required to coordinate their actions. Unlike in a real laboratory where students can see what everyone else is doing, collaboration in a remote laboratory is not a trivial task. To enable this collaboration, NetLab has a number of features that support interactive collaborative work [1].

NetLab was initially developed with the financial support of UniSA through a Teaching and Learning Improvement grant and has been used in teaching since 2001 in a number of undergraduate courses, including Introduction to Electrical Engineering, Electrical Circuit Theory and Signals and Systems. NetLab was used by on-campus and off-campus students, in Adelaide and in Whyalla, respectively, and also by offshore students in Sri Lanka and Singapore. Recently, NetLab has been used for teaching students in Poland.

The capacity of the system doubled when NetLab was replicated. The development of the second system, NetLab2 was supported by the Diversity and Structural Adjustment Fund of the Australian Government Department of Education, Employment and Workplace Relations. UniSA was a partner institution in the project LabShare - *National Support for Laboratory Sharing*, coordinated by the University of Technology, Sydney (UTS) (see Figure1).

LEARNING ANALYTICS IN NETLAB

Learning analytics (LA) is a relatively new research field that emerged six or seven years ago as a merger of educational and computational research methodologies, notably drawing from the field of data mining; in this case called educational data mining. In addition, LA can draw from other disciplines, such as information visualisation, psychology and sociology.
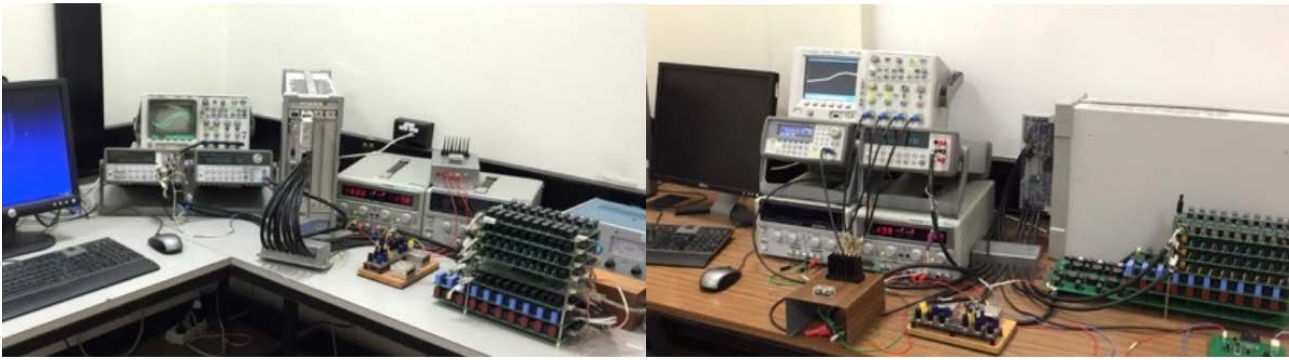
Figure 1: Comparative photographs of the original NetLab system (left) and the new NetLab2 system (right).

All universities in developed countries use learning management systems (LMS), such as Moodle and Blackboard, in addition to their own student information systems (SIS). Student interactions with on-line learning activities are captured and stored as logs. These digital traces can be analysed by data mining algorithms to identify patterns of learning behaviour and their circumstances, leading to insights into the learning process [2]. The learning analytics has been defined by Siemens and Gasevic …*measurement, collection, analysis and reporting of data about learners and their contexts, for purpose of understanding and optimizing learning and the environments in which it occurs* [3].

Since 2009, the NetLab server software has maintained a database of user interactions with the system. By connecting a business intelligence tool to this database and designing appropriate queries, several useful reports have been generated to describe the exact usage of the system, as shown in Figure 2.
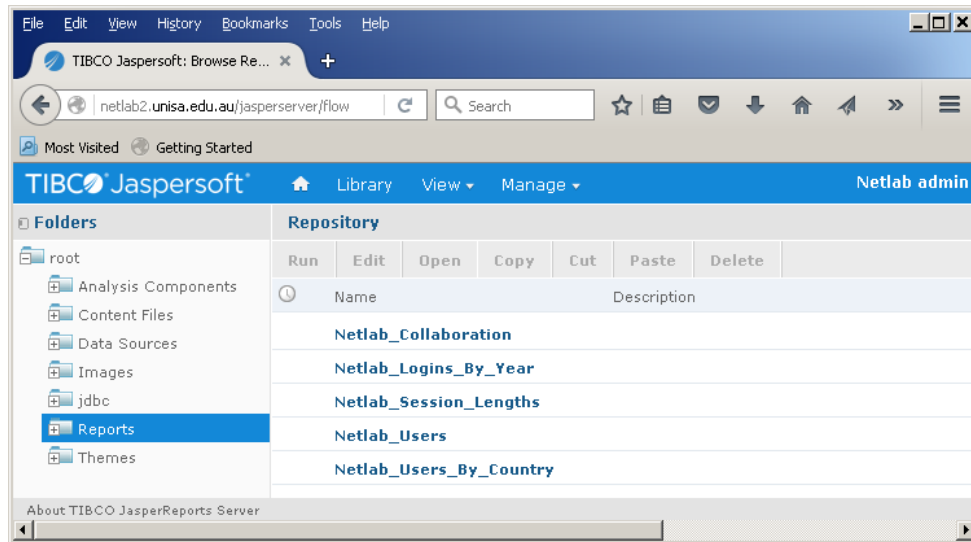


Figure 2: NetLab reporting system.

The Netlab_Collaboration report shows international collaboration that has occurred in NetLab. By looking at users who have logged in to the system simultaneously, and at the countries those users have entered as their location when signing up, the report gives a list of users from different countries who have worked together. Most international collaborations involve a user from Australia, but some include users who are all located far from the physical NetLab system and from each other.

The Netlab_Logins_By_Year report measures the usage of Netlab, by counting how many times user login events are recorded on each system per year.

Usage in recent years has stabilised at around 800 logins per year. The Netlab_Users_By_Country report shows how many registered users come from a particular country. Approximately, half of the registered Netlab users are in Australia, with many from Singapore and Poland. In total, 57 countries are represented by NetLab users. The Netlab_Session_Lengths report shows how long users stay logged into NetLab for in a typical session. A noticeable number of users are disconnected by the system on reaching the end of their booked 1, 2 or 3 hour session, but can easily book another short session later to complete a task or verify a result. Many sessions last for less than 20 minutes.

Some unexpected issues occurred in the user logging system during 2015 after a software upgrade that have rendered data from that year inaccurate. These problems have been now rectified, and 2016 data are now being analysed.

STUDENT EXPERIMENTS

The remote laboratory NetLab, in operation in University of Australia (UniSA) for some 15 years, is an open access remote laboratory. Several local and international institutions, and universities have used the NetLab as part of their practical activities in the delivery of some engineering subjects. These includes Australian students from UniSA and Open University Australia, UniSA students from Singapore, students from Blekinge University of Technology in Sweden and Lublin University of Technology in Poland. In the following, two examples of the use of NetLab in engineering teaching will be discussed, one in Poland and one in Australia.

USE OF NETLAB IN POLAND - LUBLIN UNIVERSITY OF TECHNOLOGY

Since 2014, one of the co-authors of this article has taught remotely from Adelaide via Skype or face-to-face. A total of 180 BEng, MEng and PhD students from Poland's Lublin University of Technology (LTU) have been taught in this way. The courses included: Monographic Lectures, covering entire remote laboratory topics, with the pronounced emphasis on NetLab, Final Year Project Seminars, Information Technology, Engineering Applications of Information Technology, Modern Methods of Teaching, IT Tools in Scientific Research and Scientific-Technical English. In all these courses, students have been exposed to NetLab applications as a robust, reconfigurable, flexible, interactive and collaborative remote on-line laboratory environment.

In one of the Monographic Lecture courses for non-stationary (remote) LTU Master Programme in Information Technology, the students were required to conduct an Instrumentation Laboratory Experiment using NetLab from their locations in Poland and write a report for assessment.

The program of the remote laboratory above included generation and measurement of parameters of various signals, use of a digital oscilloscope for simple and advanced measurements, saving waveforms data for further visualisation and analysis using MATLAB, Spice or Excel. Figure 3 shows the circuit connection in the Circuit Builder of NetLab for measurements in an R-C Voltage Divider [4], one of the experiments students had to do.
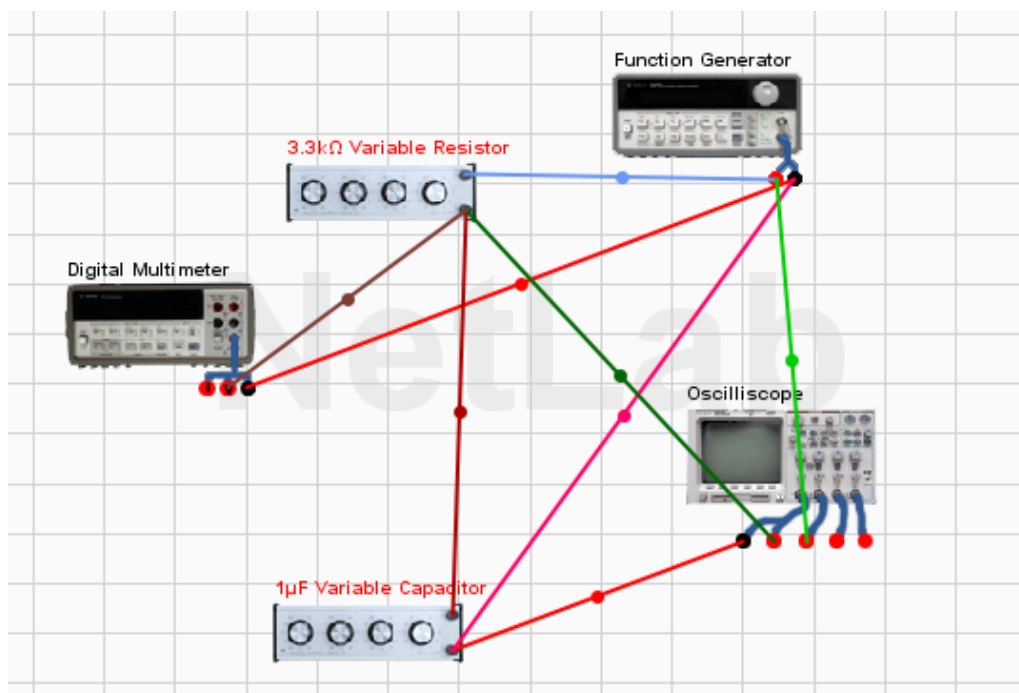


Figure 3: R-C voltage divider wired in the Circuit Builder.

USE OF NETLAB IN AUSTRALIA - UNIVERSITY OF SOUTH AUSTRALIA

As mentioned before, the remote laboratory NetLab has been widely used by UniSA academic staff and students since its development, in courses such as Electricity and Electronics (formerly Introduction to Electrical Engineering), Electrical Circuit Theory, Signal and Systems and several other courses offered by the School of Engineering and its predecessors, as part of the practical laboratory activities.

For the delivery of Electrical Circuit Theory, students are required to participate in three practical experiments. The first experiment is an introduction to NetLab. In this practical, students are given opportunity to explore the NetLab systems, and understand the needs and role of remote laboratory in remote learning, and in electronics/electrical engineering

studies. Students are instructed on how to access NetLab in this practical and also the procedure required to create a NetLab login account and making booking on a particular NetLab system.

The second experiment required students to construct a low-pass RC filter and investigate the frequency response of the filter. This experiment allows students to familiarise themselves with connecting circuit components and equipment using the NetLab's Circuit Builder and to learn the procedure on setting up the NetLab's remote oscilloscope and the function generator to produce a sinusoidal input signal. Figure 4 shows the input and output signals of the filter observed in NetLab using the digital oscilloscope.
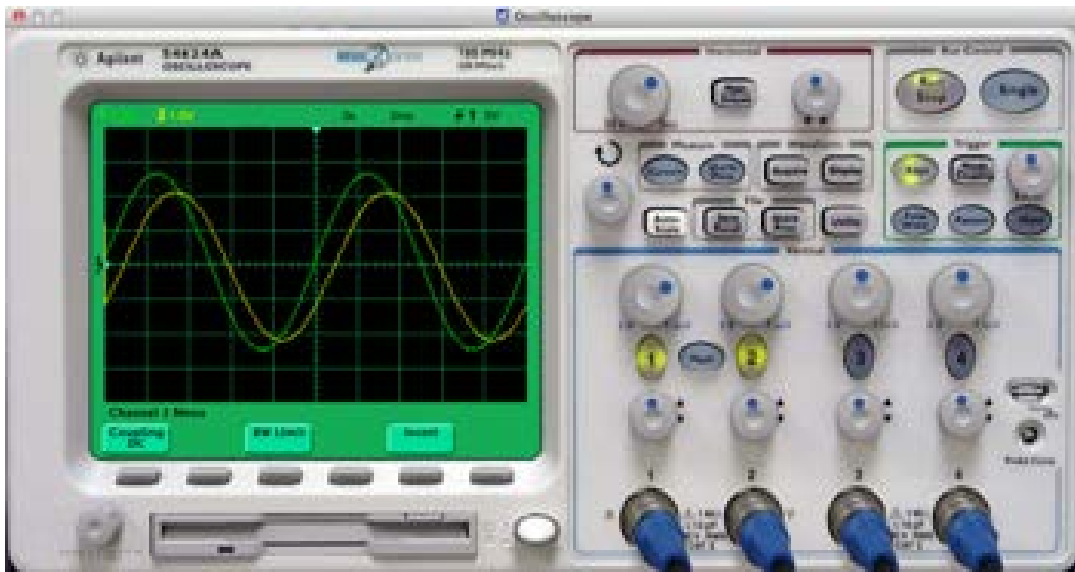


Figure 4: Low-pass RC filter input and output sinusoidal signals observed on the oscilloscope.

The last experiment in the Electrical Circuit Theory practical was to investigate the low-pass RC filter transient response using NetLab. Students used the same circuit setting from the previous experiments, but with a square-wave input signal applied to the RC filer. Students were required to capture the input/output transient response of the RC filter using the NetLab oscilloscope and compare the results with pre-calculated results for verification. Figure 5 shows the transient response of the low-pass RC filter obtained by a student.
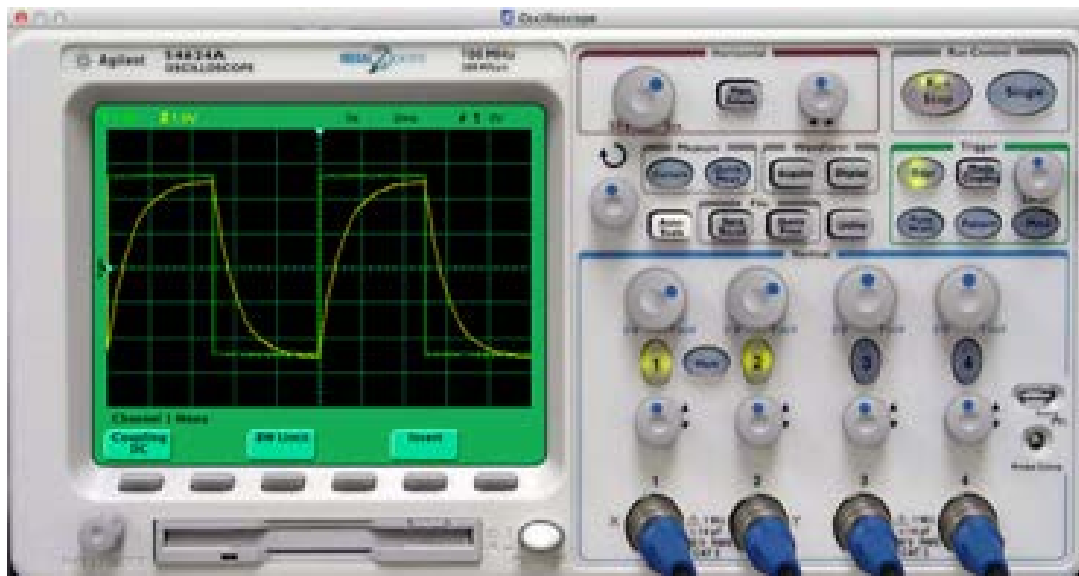


Figure 5: Low-pass RC filter response to square wave input signal.

At the end of the three experiments on RC low-pass filter using the remote laboratory NetLab, students were encouraged to perform the same experiment using the computer circuit simulation program and also using the real laboratory setting. These two additional tasks allowed students to compare the results obtained from NetLab across other platforms against any discrepancies. Also, it served as a comparison on students' preference and view on using the remote laboratory NetLab to perform circuit analyse experiments compared with other platforms like simulation and real physical laboratory.

The NetLab experiments were usually highly valued by the students, locally and remotely. The section of Conclusions and Recommendations in the laboratory report [5] provides some evidence of it:

*During the workout, we have learned to operate a digital multimeter, use an oscilloscope. We got to know the secrets of the function generator. Visually we saw how the sine wave, square, and learned to study their characteristics. We have gained the ability to calculation of voltage drops in the resistive circuits and RC circuits. Practically, we used Ohm's law, Joule and many other useful features of circuits. Working in a laboratory remote NetLab opened the way to explore the secrets of electronics and showed that it is possible to work in a professional lab away several thousand kilometres* [5].

CONCLUSIONS

In this article, some recent developments have been presented and, in particular, the data that can be extracted from the NetLab database in order to analyse student activities in its learning analytics environment. The analytics of students' actions in the NetLab remote laboratory is an important step toward the development of pedagogy to support student learning in this on-line environment and for the development of an intelligent tutoring system that will enhance students' learning experiences, as well as the development of students' learning environment to maximise their learning outcomes in the future.

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Hugh Considine completed a Bachelor of Software Engineering (Honours) at the University of South Australia in 2010, and a Bachelor of Engineering (Computer Systems) in 2014. He has worked on several short term contracts in the areas of software engineering and electronic engineering, including some development work on NetLab. He has participated in several on-line course development programmes, and has been the tutor for a first year on-line electrical engineering course since 2012. He is currently undertaking a PhD in the area of remote laboratories. Hugh founded and continues to work with a team producing an open source programming tool for microcontroller programming.



Ming Teng received his Electronics Engineering diploma from Sepang Institute of Technology, Malaysia, and BEng with First class Honours in Electronics and Computer Engineering from the University of Aberdeen, United Kingdom. He worked as an electronics design engineer in Malaysia prior to his education at the University of South Australia, where he earned his MEng in Micro-Systems Technology and PhD in Electronics Engineering in 2005 and 2012, respectively. He worked as a research assistant in the Centre for Advanced Manufacturing and Research at UniSA between 2006 and 2008. He is currently lecturing at UniSA and in the Institute of Business and Technology in Adelaide, Australia. Ming is actively promoting the use of NetLab in engineering education. He is also leading a group of students working on research and implementation of low cost-portable learning devices for electronics engineering students.



Andrew Nafalski's career includes assignments in academic and research institutions in Poland, Austria, Wales, Germany, France, Japan, USA, Canada and Australia. He holds BEng (Hons), GradDipEd, MEng, PhD and DSc degrees. He is currently a Professor of Electrical and Information Engineering at the University of South Australia in Adelaide and a Visiting Professor at the Lublin University of Technology, Lublin, Poland. His current research interests are related to remote laboratories, electromagnetism, magnetic materials, electrical power, human computer system interfaces and innovative methods in engineering education. He has published over 400 scholarly peer refereed works in the above fields.

Zorica Nedić holds a PhD in Engineering from the University of South Australia. Before her academic career at the University of South Australia, she spent six years working as an R&D engineer at the Institute Mihajlo Pupin in Belgrade, Serbia, after completing her BEng (Electronics) at the University of Belgrade. Her research interests focus on remote laboratories and technology applications in engineering education. She has authored and co-authored over 150 fully refereed publications.