Student interactions with the remote laboratory NetLab

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ABSTRACT: Remote laboratories, in which experimentation on real equipment is controlled over the Internet, with downloadable experimental results for further analysis and reporting, have been available since the 1990s. Sharing them on the computer network provides opportunities for creating large pools of diverse laboratory experiments, available either on a commercial or an open-access basis. The remote laboratory NetLab has been developed at the University of South Australia and has been used in teaching of a number of courses on-campus and off-campus including transnational teaching since 2002. In this article, the authors report on computer software developed to track and record students' activities during their experimentations in the remote laboratory NetLab as a first step towards the design and the development of an intelligent tutoring system. Usually, students work in remote laboratories unsupervised and a common feedback from students in surveys is that there is no one assisting students during their laboratory sessions. The purpose of the intelligent tutoring system will be just that, to assist students during their work in the remote laboratory.

INTRODUCTION

There are numerous advantages in the use of remote laboratories, but there remain some challenges. For instance, there is a lack of readily available assistance for a student struggling with a particular practical task or related theoretical concept. These circumstances prompt investigation into the application of an intelligent tutoring system. At present, while there are many tutoring systems available, they have not been designed or implemented to assist students working in remote laboratories [1]. The study described in this article examines student interactions with the NetLab remote laboratory developed and used at the University of South Australia, Adelaide, Australia (UniSA) as it is, a part of a wider project to develop an intelligent tutoring system [2].

This study also examines the way in which students currently interact with the NetLab remote laboratory, and aims to guide the development of an intelligent tutoring system for this laboratory.

The actions performed by students using the remote laboratory, such as configuring a circuit or taking a measurement, are now being recorded in detail by the remote laboratory software. From this, the exact steps taken by students when conducting an experiment can be seen. This gives a greater understanding of how each individual student carries out the experiments, and in future will provide feedback to an intelligent tutoring system as it assists the students in their laboratory work.

A user study has also been conducted and some key results from this are highlighted in this article. In particular, some contradictions in the survey results have been noticed when analysing student actions and responses.

Analysis of the data is still underway, but at this point some interesting observations can be made. Students often re-use the circuits configured by other students without checking the correctness. In some cases, student actions show a clear lack of understanding, such as taking readings on the oscilloscope without first providing any input signal from the function generator.

The use of remote laboratories is being constantly evaluated, in terms of contribution to learning outcomes. A recent article indicates that the remote laboratory VISIR has a positive effect on students' learning, if an appropriate activity is undertaken [3].

NETLAB

NetLab, presented in many publications as it is a free open-access remote laboratory available from anywhere in the world with the Internet access [4][5]. NetLab was first introduced in 2002, and records show thousands of users from

some 57 countries experimenting on real laboratory equipment and components since accurate logging began in 2009. In a typical year, between 600 and 900 user experiment sessions are conducted. The laboratory is physically located in the Sir Charles Todd (named after a famous Postmaster General of South Australia in the 19th Century) at the Mawson Lakes Campus in Adelaide at the University of South Australia.

To access NetLab, users should use the following links: http://netlab.unisa.edu.au or http://netlab2.unisa.edu.au as there are now two nearly identical systems of NetLab available to anyone in the world who registers to use the self-defined configuration of a circuit to conduct remote measurements.

USER STUDY SURVEY RESULTS

To gauge the level of background knowledge possessed by the students, a survey of 30 students in a second year Electrical Circuit Theory course of a Bachelor of Engineering degree was conducted in 2017. The questionnaire used for the survey is presented in Appendix 1. With one exception all were full time students and most (22/30) were studying entirely on campus. The survey results give a strong indication of two key points: first, that there is a need for a tutoring system; and second, that the survey responses are sometimes questionable.

On the need for a tutoring system, one can observe that in an in-person class, all students reported requesting help from the instructor - 7 *often*, 15 *sometimes* and 8 *occasionally*. When asked whether they prefer self-guided or instructor-guided learning in practical classes, 21 expressed a preference for instructor-guided learning.

The survey also showed that some students do not have the knowledge required to perform some tasks - only 13 correctly identified both ways to set a function generator to a specific amplitude. Seven students believed that a voltmeter has a low resistance. The survey also highlights that most students did not understand how a resonant circuit would behave before conducting their experiment on resonant circuits.

Some curious answers from students are a reminder that surveys are not always as accurate as it would be desired. Examples include a student who claimed not to know the difference between series and parallel circuits, a student who said they had never heard of a multimeter, but that they had used one. An analysis of the student actions provides a clear indication of what students are capable of doing, without relying on the student to tell the authors what they think they can do.

RECORDED USER ACTIONS

The NetLab remote laboratory system records all actions taken by users for debugging purposes. Events recorded include system start and stop, reconfiguration of circuits, commands being sent to various instruments, and the readings collected by the oscilloscope and multimeter. Specific actions recorded for each instrument are shown in Table 1.

Table 1: Specific actions recorded by the NetLab system.

Instrument	Actions recorded
Function generator	Changes to output wave shape (sine/square/triangle), amplitude and frequency.
Digital multimeter	Changes to function (voltage/current/resistance) and range. All readings taken are also recorded.
Oscilloscope	Changes to each channel state (on/off), horizontal and vertical scale, horizontal and vertical position, presses of the run/stop and autoscale buttons, changes to channel settings (coupling, inversion, bandwidth limit), trigger setting changes (edge, source, mode, level). Use of cursors is also recorded and all waveforms captured are stored.

Configured circuits are stored as a netlist in XML format. This records all components used, values set for variable components and connections between the components. The exact circuit configured by a user can be recreated and analysed later.

ACTIONS DURING AN EXPERIMENT

An example of a basic experiment that can be performed with NetLab is the construction of a voltage divider circuit. Table 2 shows some of the events recorded during the experiment.

This illustrates the level of details recorded. The log shows the user logging in (ID: 11), connecting together components to form a circuit (15), setting the function generator amplitude (16); and finally, adjusting oscilloscope settings (22, 26) and receiving back raw oscilloscope data after each setting change (20, 23, 27 and 28).

For clarity, some extra oscilloscope readings have been omitted and only a few samples of each reading have been shown. The system measures and stores 500 samples each time it takes a reading from the oscilloscope.

Table 2: Example of user interaction with Netlab.

ID	Time	Event	Data
11	30/10/2017 17:22	NETLAB_LOGIN_SUCCESS	NETLAB2.UniNet.unisa.edu.au
15	30/10/2017 17:22	NETLAB_CIRCUIT_CONFIG	<?xml version="1.0" ?><circuit uuid="c6098ed4-dbe7-41b0-a162-b9d18fbf6264"><components><component id="PASSIVE" x="218" y="247" params="VALUE=10000.0"></component><component id="CRO54624A" x="408" y="131"></component><component id="PASSIVE6" x="215" y="321" params="VALUE=10000.0"></component><component id="FG33120A" x="138" y="89"></component></components><leads><lead c1="PASSIVE" c2="PASSIVE6" t1="1" t2="0" color="-16641630"></lead><lead c1="FG33120A" c2="PASSIVE6" t1="0" t2="1" color="-9922572"></lead><lead c1="FG33120A" c2="PASSIVE" t1="1" t2="0" color="-5636096"></lead><lead c1="PASSIVE6" c2="CRO54624A" t1="1" t2="0" color="-65536"></lead><lead c1="PASSIVE" c2="CRO54624A" t1="0" t2="1" color="-10681694"></lead><lead c1="CRO54624A" c2="PASSIVE" t1="2" t2="1" color="-65434"></lead></leads></circuit>
16	30/10/2017 17:23	NETLAB_SERVICE_FG33120A	amplitude: 2Vpp
20	30/10/2017 17:23	NETLAB_SERVICE_CRO54624A	DATA1:6.25000e-01,-6.25000e-01,-6.25000e-01,-7.81250e-01,-4.68750e-01,-3.12500e-01,-7.81250e-01,-7.81250e-01,-4.68750e-01,-7.81250e-01,-4.68750e-01,-4.68750e-01,-4.68750e-01,-6.25000e-01,-6.25000e-01 , […]
22	30/10/2017 17:23	NETLAB_SERVICE_CRO54624A	Channel 2 to on
23	30/10/2017 17:23	NETLAB_SERVICE_CRO54624A	DATA2:3.12500e-01,-3.12500e-01,-1.56250e-01,-1.56250e-01,-3.12500e-01,-3.12500e-01,-3.12500e-01,-1.56250e-01,-3.12500e-01,-1.56250e-01,-3.12500e-01,-3.12500e-01, 0.00000e+00, 0.00000e+00,-3.12500e-01,[…]
26	30/10/2017 17:23	NETLAB_SERVICE_CRO54624A	Channel 1 scale to 200mV
27	30/10/2017 17:23	NETLAB_SERVICE_CRO54624A	DATA1:5.00000e-02,-6.87500e-02,-8.12500e-02,-8.75000e-02,-1.06250e-01,-1.18750e-01,-1.31250e-01,-1.43750e-01,-1.62500e-01,-1.68750e-01,-1.68750e-01,-1.93750e-01,-2.06250e-01,-2.18750e-01,-2.18750e-01,[…]
28	30/10/2017 17:23	NETLAB_SERVICE_CRO54624A	DATA2:3.12500e-01,-6.25000e-01,-3.12500e-01,-4.68750e-01,-4.68750e-01,-7.81250e-01,-7.81250e-01,-6.25000e-01,-4.68750e-01,-6.25000e-01,-3.12500e-01,-6.25000e-01,-4.68750e-01,-6.25000e-01,-4.68750e-01, […]

The XML data seen in the Table 2 (log item 15) corresponds to the circuit in the NetLab circuit builder (Figure 2). This circuit is a simple resistive voltage divider, supplied by a function generator and with an oscilloscope measuring both the input to and output from the voltage divider.

A brief review of the recorded events also reveals some interesting patterns. The logs show that:

- Users will often avoid reconfiguring circuits. The NetLab system currently does not erase circuits automatically on logout of a user, so a student logging in may find that the previous user has already configured the circuit they require.
- Some actions do not make sense. Examples include taking a reading without first providing any input to the circuit or taking measurements from instruments that are not in any way attached to the circuit.

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- Some users appear to log in once, log out without doing anything and never return. Whether these are actual users who do not know how to proceed or whether these are automated bots is unknown. One user was observed to log in, set the digital multimeter to resistance mode and, then, log out 40 seconds later without configuring the circuit or actually taking a reading.
- Some remote laboratory experts from Australia's leading universities used NetLab regularly for several years; the motivation is unclear - is it learning from a successful example?
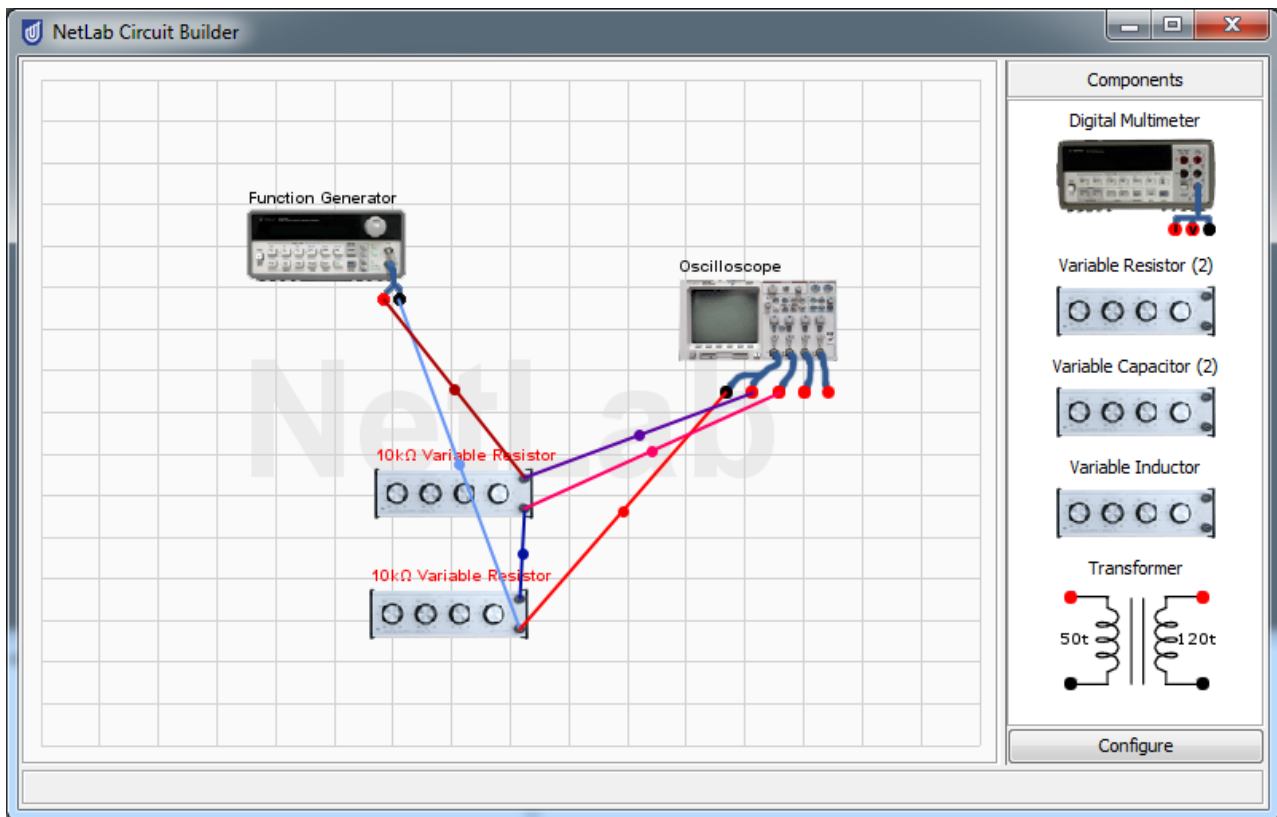

Figure 2: Configuration of the resistive voltage divider in the circuit builder.

CONCLUSIONS AND FUTURE DEVELOPMENTS

From this work, the need for, and feasibility of, an intelligent tutoring system for the remote laboratory system are clear. The survey results show that most students prefer to have at least some source of interactive assistance, if they encounter difficulties, while conducting experiments; and many prefer to have some guidance on the overall procedure to carry out the experiments. From a brief review of the student action logs, it is already apparent that student errors in the laboratory context appear to be predictable.

Existing intelligent tutoring systems for strictly theoretical content work well when the student errors are clearly defined. Since student errors are predictable in both practical and theoretical contexts, an intelligent tutoring system should be able to detect mistakes and provide context sensitive assistance to students, when they require it in a practical exercise. Development of such a system is the next step in this project.

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Appendix 1: The student questionnaire on using the remote laboratory NetLab.

Thank you for agreeing to participate in this research. Please complete the questionnaire below before using the NetLab system.

Part 1/4: We need to know some basic information about you.

What is your gender? (Female, Male or Other)
What is your current age?
On average, how many hours a week do you use a PC - either a desktop computer and/or a laptop?
Of the hours using a PC each week, approximately how many are for study purposes?
How many hours each week do you spend using a handheld device, such as a smartphone or tablet?
Of the hours you spend using a smartphone or tablet each week, how many are for study purposes?

Part 2/4: We also need to know about how you study.

What are you currently studying?
Are you studying full or part time?
Are you studying on-line? *(Entirely On-line, Mostly On-line, Both, Mostly Offline, Entirely Offline)*
In a learning environment with an instructor present, how often do you ask the instructor for assistance? *(Often, Sometimes, Rarely or Never)*
If you have a choice between classes where the instructor sets the way that you learn, or classes where you guide your own learning, which do you prefer? *(Instructor-guided, no preference, self-guided)*

Part 3/4: We need to know a bit about your current level of theoretical knowledge - we need to know which concepts we need to provide more support for.

Which of the following concepts do you have a strong understanding of? *(Ohm's Law, Behaviour of series and parallel circuits, Impedances and phasor analysis, Transients - first order, Transients - second order, Passive filter circuits)*

Part 4/4: Finally, we need to know your level of knowledge working with real electronic circuits. Some questions in this section are like quiz questions - but do not worry, you are not being judged on this. We need to know accurately what level of assistance people using the tutoring system will need, so getting a question wrong now will help someone else later!

Which of the following components have you heard of before? *(Function generator, Resistor, Multimeter, Capacitor, Oscilloscope, Inductor)*
Which of these components have you used when building a circuit before? *(Function generator, Resistor, Multimeter, Capacitor, Oscilloscope, Inductor)*
If you were setting a function generator to produce an output voltage of 3 V_{RMS}, tick any of the amplitude settings that would do this. *(3 V_{RMS}, 3 V_{pp}, 8.48 V_{pp}, 50 Hz)*
If the signal on an oscilloscope was moving too fast to see, which control should be checked? *(Horizontal scale, Trigger level, Frequency control, Input coupling)*
Tick any of the following statements that are correct when using a multimeter to measure voltage *(Voltage should be measured in parallel, The multimeter has a low resistance when measuring voltage, If measuring AC, the multimeter will show the peak to peak voltage, The multimeter could be damaged if it is set to measure frequency without changing connections, The multimeter could be damaged if it is set to measure current without changing connections)*
What tools have you used to build circuits before? *(Breadboards, Printed circuit boards, Simulation tools, Wire wrapping)*