Remote laboratories to support electrical and information engineering (EIE) laboratory access for students with disabilities

Ian Grout
Department of Electronic and Computer Engineering
University of Limerick
Limerick, Ireland
Ian.Grout@ul.ie

***Abstract*— In this paper, consideration is given to accessibility aspects for students with disabilities in electrical and information engineering laboratories who have limited mobility and who would need to access physical electronic and computer engineering laboratories. Specific consideration is given to the use of remote laboratories which are real experiments that are accessed remotely by a user via an Internet connection. In this arrangement, a traditional laboratory experiment is made accessible via a Web server and using a software application, the experiment can be controlled remotely via the computer interface. As such is complements the traditional "at-presence" laboratories and virtual laboratories (simulated laboratories).**

Keywords*— *Remote laboratories, laboratory adjustments, assistive technology. disabilities

I. Introduction

Laboratories form an essential part of the student learning experience in the electrical and information engineering disciplines. The exact nature and content of the laboratory is dependent on the particular subject being studied and what the required learning outcomes from the particular laboratory session (or set of laboratory sessions) are. How the subject material could be introduced and included in the laboratory, and hence the overall programme of study, in order to meet the required programme learning outcomes would depend on many requirements including how much time would be available to include practical (laboratory) work and also to what level that any practical work could be incorporated. In addition, whatever concepts would be considered and how they would be included would need to meet clearly identifiable learning outcomes according to the three 'classical' domains of learning:

1. Cognitive (thought processes).
2. Affective (feelings, emotions and attitudes).
3. Psychomotor (manual skill performance).

A range of teaching strategies would be adopted in order to meet the learning outcomes. As identified in [1], a number of possible teaching strategies could be adopted (and which a range of these would be seen in a programme of study in the electrical and information engineering (EIE) area). It is the laboratory/workshop teaching strategy that is of primary concern within this paper and how students with disabilities can be supported within a laboratory context by the use of a range of appropriate technologies. Each teaching strategy (more detail can be found in [1]) would map to a certain extent (or not at all) to each of the three domains and could be used effectively to provide both an introduction to theoretical material and to the development of practical (work place relevant) skills. In addition, having good visual and audio support in the materials and equipment used which can quickly highlight basic concepts, and bring a meaning to the most abstract of concepts, can be provided by a mixture of electronic hardware and software. Suitable design of teaching and learning aids can enable an idea to be visualized and readily related to aspects that are be seen in everyday life. In this paper, consideration is given to accessibility aspects for students with disabilities in electrical and information engineering laboratories who have limited mobility and who would need to access physical electronic and computer engineering laboratories. Specific consideration is given to the use of remote laboratories [2, 3] which are real experiments that are accessed remotely by a user via an Internet connection. In this arrangement, a traditional laboratory experiment is made accessible via a Web server and using a suitable Web browser tool (or other software application), the experiment can be controlled remotely via the computer interface. As such is complements the traditional "at-presence" laboratories and virtual (simulated) laboratories. This paper will consider the field of remote engineering and how it can be utilized to support students with disabilities. The paper will commence with an overview of remote laboratory design in section II. Then, assistive technology will be considered and how technology enhanced learning tools can be developed and used to support students with disabilities will be discussed in section III. Building on previous experience in developing remote laboratories, an example system will be constructed and its design will be discussed in section IV. The system will utilize an electronic hardware interface used to send control signals to a remote experiment and results will then be returned to the user. The main building blocks of the overall system will be presented. The paper will conclude in section V.

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II. Remote Laboratories

Remote laboratories [2, 3] have developed considerably over the last few years [4]. These are real (physical) engineering and scientific laboratories that are accessible by a user from a remote location. Such laboratories can be utilized in education and research activities and are classified as one type of online laboratory.

> *Remote laboratories provide the ability for students to access experiments and laboratory equipment via an Internet connection and Web browser or other software application that they would not necessarily otherwise be able to access. In addition, they allow for 24/7 access to laboratories and physical presence within the laboratory is not required. This allows the student to access the laboratory and experiment anywhere, in their own time and at their own pace.*

Laboratories are generally classified as being either for local access (at-presence) or remote access [2] (online) depending on the location of the experimenter. Online laboratories can then be further classified [5] as being remote, virtual or hybrid. Here, these three types of laboratory are defined as:

1. **Remote Laboratories** are physical laboratories that allow for the real experiments to be accessed from a remote location.
2. **Virtual Laboratories** are software simulations of experiments also performed from a remote location.
3. **Hybrid Laboratories** are a combination of remote and virtual laboratories.

These online laboratories for "remote learners" are used to complement the "traditional" at-presence (local) laboratories where the learner is physically at the same location as the experiment. The differing laboratory implementations now provide the curriculum developer with a range of options for including suitably designed experiments into a curriculum. Remote laboratories can be located anywhere and the students can access the laboratories from any location. The only requirement is for access to a computer and a suitable Internet connection [6]. Typically, such laboratories have been developed to provide access to engineering [7, 8] and science laboratories. A range of laboratory designs have been developed over the last number of years and a typically based on WAMP (Windows, Apache, MySQL and PHP), LAMP (Linux, Apache, MySQL and PHP) [9] or LabView [10]. Today, Javascript and HTML5 are integral to the design of the Web page interface.

In electronic engineering laboratory experiments, students are required to build and test specific circuits which are set-up to demonstrate specific circuit characteristics that are important for the student to see. The experiment also allows the student to develop skills in working with real, physical circuits and to learn how to use test and measurement equipment. Traditionally, the experiments have not involved the use of computers (PCs) and the use of computer controlled test and measurement equipment. However, based on the idea of student electronic engineering experiments and using a PC interface, these two considerations in the laboratory can be used to create experiments whereby the experiment can be controlled via a PC interface as shown in Fig. 1.

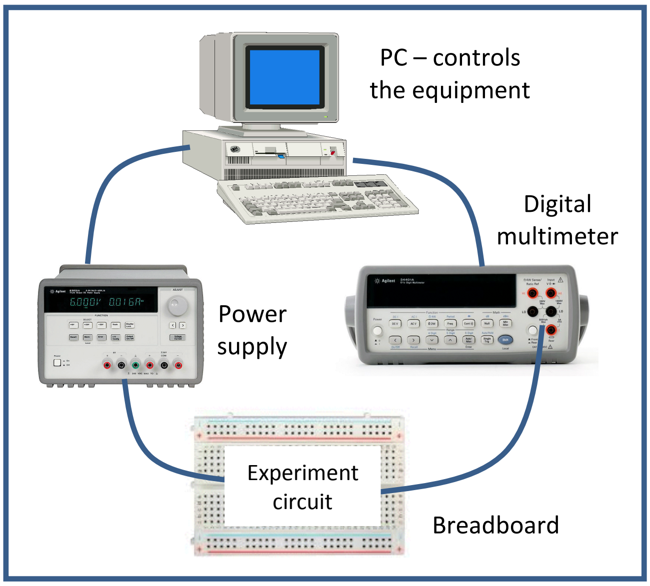

Fig. 1. PC centred experiment arrangement

Here, the circuit is set-up on the breadboard and connected to the required power supply (and signal generator) and test & measurement equipment such as a digital multimeter (DMM) (and oscilloscope). Given that the equipment used would interface to the PC (typically using RS-233, GPIB and USB) then this would enable assistive technology, if required, for the student to be incorporated into the laboratory arrangement using the PC also. However, a student with a physical disability might have difficulty in undertaking an experiment of the form shown in Fig. 1, particularly where the equipment dials and switches require fine motor skills in the hands.

III. Assistive Technology

In order to make a laboratory accessible to a student with a disability then a number of actions would need to be put into place and for the necessary equipment and tools used to be supported. Generally, access to a laboratory would require accessibility to be built-in from the concept design of the laboratory (prior to building and equipping the laboratory) or for a laboratory to be refurbished in order to make it accessible, taking into account the need for:

1. Physical access to the laboratory.
2. Physical access to facilities within the laboratory.
3. Access to assistive technology within the laboratory.
4. Access to personal support personnel.
5. *Assistive technology to provide remote access to the laboratory equipment - the theme of this paper.*

Such an approach requires the necessity to provide an understanding and support from the education providers, with the necessary national legislation [11, 12] and the provision of assistive technology that meet the users' needs [13 - 15]. With assistive technology, whilst examples of solutions exist (mechanical, electronic hardware and software), there a many possibilities to develop new solutions. In addition, assistive technology has a number of definitions [16]. These would then provide a suite of various assistive technology implementations that could meet the needs of particular individuals. A detailed review of the current state of assistive technology can be found in the 2012 report "Current Perspectives on Assistive Learning Technologies 2012 review of research and challenges within the field" [17] by The Kellogg College Centre for Research into Assistive Learning Technologies. Examples of existing assistive technology solutions include:

1. Speech recognition software [18] which converts the spoken word to text and can be used to dictate essays, etc.
2. Screen reading software [19] which turns text into the spoken word and can be used by individuals with sight impairment.
3. Wearable electronics that allow for computer control using various physical attributes [20].

IV. Case Study: Remote Laboratory Access Design

This section will discuss a case study experiment and remote laboratory design. The aim here is to demonstrate the principles involved in designing and prototyping such a remote laboratory arrangement. The experiment is a simple diode in forward bias arrangement as shown in Fig. 2. Here, a BAT86 Schottky diode is used and connected in series with a resistor. A variable dc power supply is applied and is set by the student to vary in +0.5 V steps from 0 V to +6 V. A digital multimeter is used to measure the voltage across the resistor. This would be a typical type of electronic engineering first year undergraduate experiment which, in a traditional in-lab (local) set-up requires the student to (i) build the circuit, (ii) control the power supply unit, and (ii) control and observe the test and measurement equipment (here the digital multimeter).

With this experiment, the diode voltage and current can be determined from the input voltage and the resistor voltage. The power supply unit is remotely controlled via either its RS-232 interface. In this arrangement, the RS-232 interface is used and the remote laboratory web server PC controls this using a PC USB port. An application running on the PC is controlled by the web server and sends commands from the student to the power supply unit. The user interface (to control the operation of the PSU) is based on a magnetic sensor arrangement and PC software application. Here, the user wears a suitable band or glove on their hand and embedded in the band/glove is a small magnet. Fig. 3 shows the implemented circuit board. Here, the magnet can be seen placed over sensor *s2* and the USB interface is shown at the bottom-right of the circuit board. The user moves their hand (and hence the magnet) over the sensor array which in this prototype is a 3x3 Hall latch arrangement.

Fig. 2. Schottky diode experiment (forward bias), web cam view

When the magnet is placed over the sensor, the presence of the magnet is sensed and a latch inside the sensor is set.

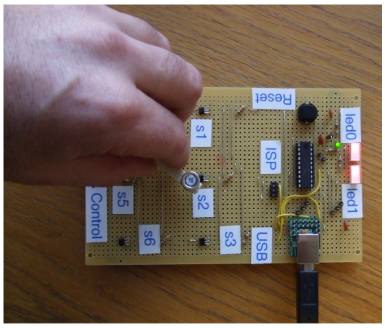

Fig. 3. Contactless control circuit

This logic level is read into a microcontroller (the Atmel ATTiny2313 is used here) running an embedded C-program and once the sensor signals have been read, a code is sent via USB (universal serial interface) to the PC. A software reads in the transmitted code and acts according to the specific code received. The overall student experiment arrangement is shown in Fig. 4.

With this arrangement, the student only needs to move his or her hand in small motions over the sensor array area and so:

1. Large hand movements are not required.
2. Fine motor dexterity is not required.
3. The sensor readings can be made tolerant to motor skill impairments such as hand tremors.
4. There is no need to physically touch any equipment.

With this arrangement, the PC and sensor array need to be initially set-up. Hence, support would be required to initially set-up (and check the operation of) the system but then there should be no further need for adjustments. The PC application communicates with the remote laboratory via an Internet connection and static IP address. The application was written using Microsoft Visual Basic 2010 with provides software components to access the USB connections (COM ports) and the Internet. The student would control the experiment and obtain experiment results from the remote laboratory using their own PC set-up.

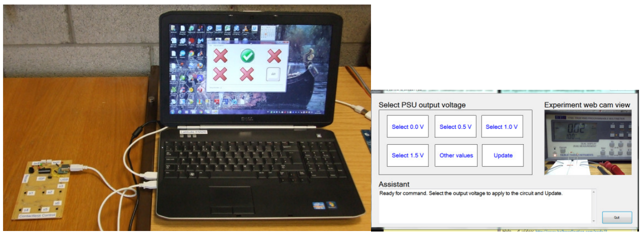

Fig. 4. Student experiment arrangement

The experiment itself will be based on a Web server (WAMP arrangement used here), PC controlled test and measurement equipment, the experiment circuit and a Web cam. This arrangement is shown in Fig. 5.

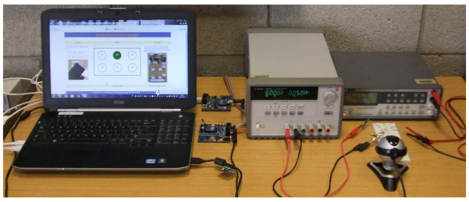

Fig. 5. Remote laboratory set-up

The web server receives commands from the student and uses these commands to set the PSU output voltage. A DMM is connected across the output resistor of the circuit and displays the voltage level. The user can see the remote experiment results in one of a number of possible ways. For example, the user software application can retrieve the experiment results as text data. This would be common in remote laboratories. An alternative which is also commonly used in remote laboratories is to use a Web cam. In Fig. 2, the Web cam used shows the experiment circuit. The experiment arrangement can be established in various ways in order to obtain a suitable and workable arrangement. Essentially, a platform can be created which enables the user interface to be customised to the individual's needs.

V. Conclusions

This paper has considered the use of assistive technology to support students with disabilities in accessing electronic engineering experiments using contactless control of test and measurement equipment and the use of a remote laboratory arrangement. The remote laboratory, located remotely from the student, can be accessed via a suitable software application and/or Web browser arrangement and this allows access to the experiment on a 24/7 basis might be used to provide support to students with particular physical disabilities.

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