# Extending Remote Experimentation Environments to Support Visual and Audio Impaired Users

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***Abstract*—Remote experimentation provided as part of a web-based learning approach affords a number of critical benefits, allowing flexible access to campus based laboratory resources. Increasingly, educational institutes are offering remote experimentation environments which allow users to undertake courses in practical engineering disciplines remotely controlling and manipulating laboratory instrumentation and equipment. The degree of functionality and level of user access to remote laboratory environments has evolved greatly expedited by advances in web technologies and applications. Recently the provision of web based environments which accurately recreate the lecturer-led and group working experience of traditional on campus based laboratories have been explored. These environments unify the online lecture and lab experiment aspects of e-learning to provide a comprehensive media-rich, highly interactive and engaging experience. However the majority of current remote experimentation environments fail to cater for users with disabilities e.g. visual or audio impairments. This paper will present a case study on the ProculTech remote experimentation environment which explores the issue of usability and accessibility in this context and illustrates how to create appropriate interfaces which will enrich the learning experience of visual/audio impaired users.**

***Index Terms* — Accessibility, visual and audio impaired users, remote collaborative experimentation.**

## I. INTRODUCTION

There are a significant and increasing number of education institutions and professional development organisations now offering courses and degree programs via e-learning. The University of Ulster, N. Ireland in particular advertises to potential students via its ‘Campus One’ e-learning division, with over 200 courses on its website ranging from Information Technology, Nursing practice to Construction studies [1]. Students can complete these courses remotely via access to a web-based learning environment with traditional online media and delivery formats. The advantages of online learning are evident but for students with disabilities the material is often presented in a format which can be difficult to view or interpret, for example, reading text from slides or online notes. In a study of over 200 environments and web sites from several leading e-learning providers it was revealed that almost 75% of sites had high levels of inaccessible material and pages [2]. It is essential that the needs of all users, regardless of physical capabilities are catered for in the design of online learning resources. More importantly, the 1995 UK Disability Discrimination Act, which was amended in 2003, places responsibility on Higher Education Institutions to ensure that disabled students are not at a substantial disadvantage in comparison to students who are not disabled [3]. This includes a responsibility to make reasonable adjustments in order to remove any disadvantage that may exist. To address this issue, all online teaching materials must be designed using best practice related to usability and accessibility. In accordance with this transition the World Wide Web Consortium (W3C) developed guidelines explaining how to make all Web content accessible to people with disabilities [4].

The demand for e-learning courses poses unique challenges for disciplines involving high levels of practical work. For electronic and electrical engineering disciplines hands-on experience is essential for effective learning [5]. The traditionally on campus laboratory experience restricts access to resources to normal working hours which does not meet the needs of university students requiring more flexible attendance patterns in line with current lifestyle commitments. Remote experimentation facilities offered as part of a web-based learning approach enable remotely located users to complete lab assignments unconstrained by time or geographical considerations, facilitating the development of highly practical skills in the use of real systems/instrumentation. Currently there are several environments available which support access to remote labs where practical experiments can be completed and key practical skills developed [6-9]. For example these facilities support several disciplines including analog [6] and radio frequency [7] design. In particular, MIT have recently developed ‘ilabs’ which extends their current OpenCourseWare programme [8] to effectively support practical-based subject disciplines.

The ProculTech environment [9] developed by the University of Ulster extends the current trend of single user environments to accurately recreate the group-working experience of traditional on-campus based laboratories. However, issues pertaining to the usability and accessibility of users in the context of remote experimentation environments have not been fully investigated to date. To support users with physical disabilities such as visual and audio impairments requires the development of remote access environments which can accommodate the delivery of tailored content and experiment interfaces.

This paper will present a case study on the ProculTech remote experimentation environment and will illustrate how to create appropriate interfaces which enrich the learning experience of users who suffer from visual/audio disabilities. Section 2 will present the ProculTech environment and section 3 will highlight the strategies to support appropriate interfaces. Section 4 and 5 will provide a case study on how the interfaces of the ProculTech environment were adapted and also provide a summary on the feedback from disabled users who evaluated the environment.

## II. PROCULTECH ENVIRONMENT

The ProculTech e-learning environment was developed by the Intelligent Systems Research Centre of the University of Ulster, Northern Ireland and provides remote-access to laboratories in electronic engineering modules on a range of undergraduate and postgraduate courses in the University's School of Computing and Intelligent Systems [9]. The 5 year project was initially funded by the Engineering and Physical Sciences Research Council (EPSRC) of the UK.

The facilities developed complement, extend and augment existing course provision by enabling students to conduct practical experiments in electronic engineering remotely via the Internet. In particular, the environment supports collaborative working as students typically work in groups to complete experiments, mentored and guided in this process by lecturers and support staff. The environment attempts to accurately recreate the group working aspect of the on-campus laboratory experience and allow remotely located users to work together on the same experiment hosted on the same remote workstation, simultaneously, while accessing, viewing and controlling each element of the learning environment, e.g. lecture video, webcams of circuits with LED lights, instrumentation, remote desktop viewer. For example any changes made by one user to any of the components of the environment are immediately replicated to all users. Currently, the environment provides access to a comprehensive range of modern embedded system technologies and design tools, with experiments ranging in complexity from microcontroller to Field Programmable Gate Array (FPGA) design.

Fig.1 illustrates the architecture of the ProculTech remote lab. The generic architecture consists of a gateway server (laboratory administrator) connected to the Internet and a number of experimental workstations connected to the server via a network-hub. The architecture is functionally composed of four interacting components; a server-based booking system, accessible through the web which allows students to reserve a time slot on any available experimental workstation; a collaborative working server to facilitate/control remote working between groups of students or students and lecturers; a client application which the end user installs on their PC to facilitate access to remote experimentation resources; and a server application which runs on each remote workstation in the lab to facilitate the remote access process. The server application is accessed through the client allowing the user full access and control to all the functionality required to complete a laboratory session on a remote workstation. Students accessing the remote laboratory initially connect to the gateway server which handles administration and authorization duties and connects validated users to available experimental workstations.

Fig.2 provides and overview of ProculTech client environment showing a tabbed system which allows for easy navigation between the various elements. Students install the client by downloading the software from the ProculTech website [10] and book lab sessions or access time via a scheduling system. During the online booking process fellow students can be invited to join in a designated session. A comprehensive help system is also available outlining and demonstrating general operation of the remote laboratory and how to book collaborative sessions.

The tabbed window of the environment provides access to "Lab Notes", "Lecture Video", "Lecture Slides", "Practicals", "Remote Desktop" and the "Board". The respective teaching materials including video lecture, notes, slides, and control of the software tools and hardware, are accessed through the appropriate tabbed windows and can be updated remotely with new material as required. In Fig.2, synchronous communication facilities are depicted on the left-side of the environment and show how students (currently 4 in any one session which reflects the typical lab group size) can communicate in real-time using audio/video. Text messaging is also available so students can communicate asynchronously during a lab session. The ability to provide both forms of communication and support collaborative working, more closely recreates the group problem solving experiences often encountered in the traditional campus-based laboratory. The ProculTech environment and its collaboration features are described in detail in [9].

## III. ACCESSIBILITY

In the context of online accessibility, learning environments can be separated into structural and content/presentation components. The structure can be considered in terms of how the environment is organised in respect to the user-interface, layout, navigation, subject headings and titles. The content/presentation component examines the actual information and media which is presented to the end user. In this paper the discussion focuses on the content/presentation component.

Considerable research has been undertaken in identifying how e-learning can support users who suffer from learning and/or physical disabilities [11]. For example, haptic computer interfaces for web sites that relay touch-sensory feedback to the user have been investigated. The importance of touch to cognition and learning has been identified with further work currently investigating the use of haptic interfaces in supporting accessibility for blind and physically impaired users [12].

A large number of software tools now have good accessibility capabilities but the effective use of that capability is still completely at the control of the author. For example, the Universities of Dundee and Sheffield have looked at the repercussions of accessibility requirements on educational multimedia, basing their findings on the development of 'Skills for Access', a web resource using accessible multimedia for learning [13]. They identified the inability to process and understand information presented on screen is, for many e-learners, the main cause of accessibility problems and is mainly due to the bad presentation and content of on-screen text. The study suggests avoiding long pages of on-screen text and incorporating alternative media elements instead, such as pictures, animated diagrams and video lecture clips. The study reported that multimedia is an accessibility solution, an assistive technology, and in an educational environment can offer great potential in making content more accessible to disabled students.

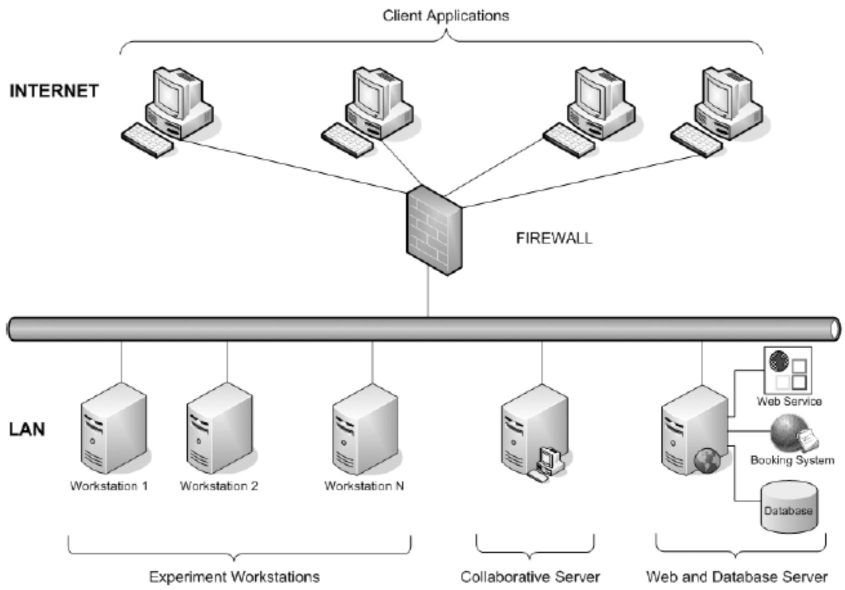


Fig.1. ProculTech Facility – remote lab architecture

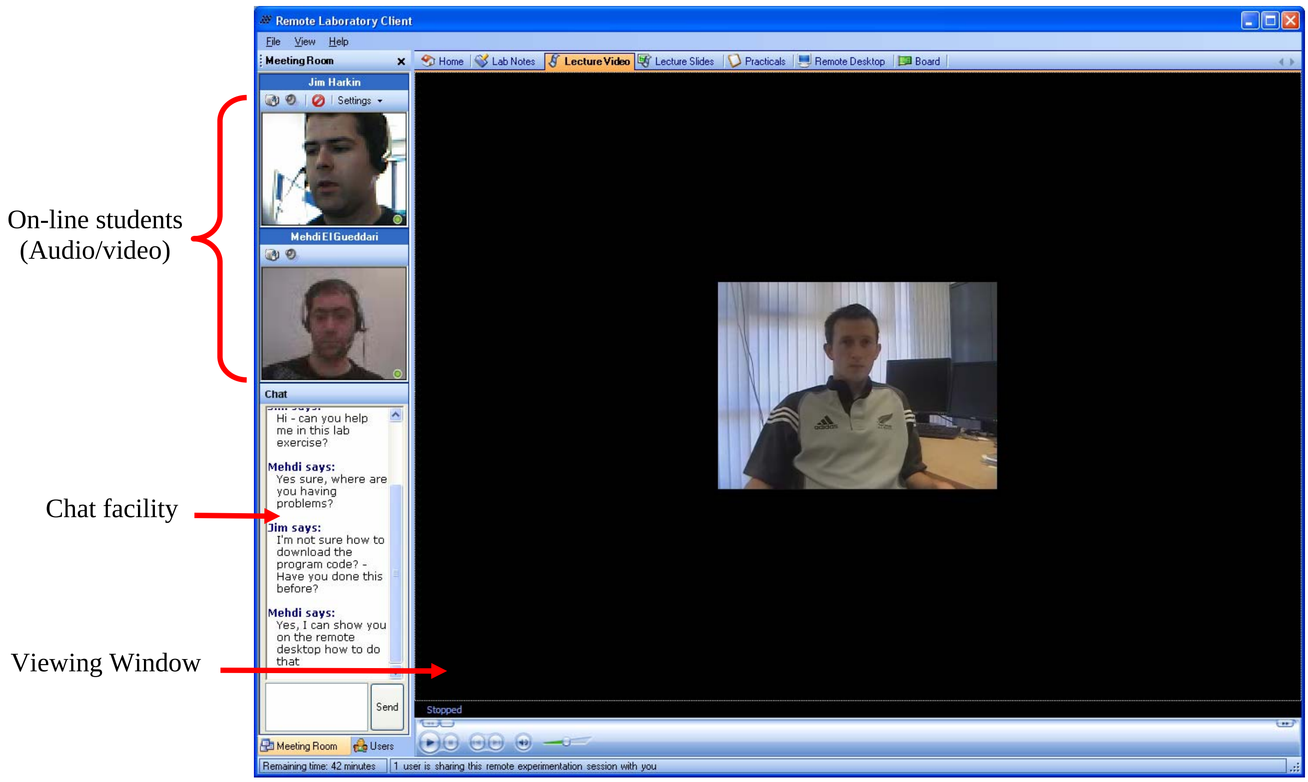


Fig.2. ProculTech Environment – remote desktop viewer

Few have investigated the issue of accessibility in the context of remote experimentation, however, the ability of users to access remote experimentation resources and use the information provided to conduct experiments, can be challenging if the information cannot initially be interpreted or understood. For example, if the lecture video, which is used in the ProculTech environment to display the tutor discussing the various steps of an experiment, cannot be understood audibly, a user could potentially become confused as to the objective of the experiment or what steps are required to complete the exercise. Users with audio impairments often experience this confusion and frustration with e-learning material where the media content is only tailored for non-disabled users [14]. Often such users have an increased awareness of their visual surroundings than someone with full hearing ability, and typically communicate through the use of sign language, e.g. the British Sign Language [15]. This is a visual language which can be used to aid the users in the learning experience. For example, a software environment called Sign Language Europe has recently been developed in Holland that makes educational TV broadcasts/movies accessible in two languages; including Dutch sign language and Dutch with subtitles [16]. Dutch school-TV broadcaster, Teleac, at present provides the content and allows users to access alternative media content depending on their accessibility requirements.

Similarly, those users with visual impairment who are partially sighted or suffer from colour blindness often experience text which cannot be read or different colours which they cannot distinguish [2]. Often text to speech software is used which reads text from the screen with a synthesized voice, or images/symbols are used instead of text to convey the same information. These issues are proliferated in the context of remote experimentation where video lectures are often used to explain the steps required to complete an experiment, and the colours of LEDs/instruments used to convey feedback on experiments. To initially address these accessibility issues it is proposed to incorporate the use of sign language with video lectures in the ProculTech environment and to replace visual icons such as LEDs with symbols/images. These extended features will enable the ProculTech environment to take the first step towards supporting visual and audio impaired users.

## IV. CASE STUDY - PROCULTECH

The ProculTech environment is used as a case study and will highlight some of the initial modifications or extensions required by remote experimentation environments to enable the support of users with audio impairments and/or partial sight. This study does not aim to address all the issues pertaining to accessibility but rather attempts to identify how alternative media content can be included in the context of remote experimentation for audio/visual impaired users.

### *A. Adjustments for Audio Impaired Users*

In section 3 the video lecture and visual feedback/control interfaces were outlined as initial areas which could be adjusted to accommodate users. Initially, the ProculTech environment only provided a pre-recorded video lecture as shown in Fig. 2.

After consultation with Disability Action, part of the Deaf Association of Northern Ireland, it was decided that it would be possible to record a member of Disability Action performing sign language of the recorded lecture script. This required a significant level of effort as the translation from technical descriptions into sign language was made difficult as there were no direct translations for key technical words.

The recorded sign video was incorporated into the ProculTech environment as shown in Fig. 3, and was integrated using Adobe Flash Player [9]. In Fig. 3 a toolbar is located at the top of the Flash video interface which enables the user to select between several modes of viewing including *sign-only*, *subtitles* or *standard*. The three modes were included after discussions with Disability Action indicated that not all students who suffered from hearing impairments would always wish to receive both sign and subtitles at the same time. As a result the different modes of viewing were provided with *standard* viewing providing combined sign language and subtitles.

The screenshot of Fig.3 depicts the *sign-only* mode and shows how the sign language video is included to support users with audio impairments. In this particular example, there are no subtitles and the dialogue spoken by the recorded lecturer is replicated in the second recorded video by a sign-language tutor. The sign video provides an alternative medium whereby the student user can interpret the instructions given by the tutor. This adjustment addresses the issue of accessibility in relation to video lecture material.

### *B. Adjustments for Visually Impaired Users*

Another common accessibility issue resides in the visual feedback/control interface of remote experimentation environments, where the colour of led lights are often used to indicate button presses and/or convey the on/off status of switches. For example the colour green is often used in engineering to signify that a device is active and the colour red to indicate that it is de-activated or turned off. The diagram of Fig.4 illustrates the visual feedback and control interface of ProculTech with the live video and control panels. The interface depicts a washing machine experiment board where students download compiled programs and select different program modes via switches to test the turning of the washing machine motor etc. The live panel provides a real-time camera feed of the experiment board and the control panel provides all the necessary user buttons and leds for control and feedback. In a normal lab experiment the user sets the program buttons and the leds light up indicating the program settings. To accommodate users with impaired vision the LEDs in the original control panel were replaced with the symbols ‘X’ and ‘√’. When a user presses one of the *Program Selector* buttons in the control panel the symbol ‘√’ appears to indicate the button has been activated or pressed. The use of these example symbols enable users to know whether the leds or buttons are turned on or off, providing a more visible method than the traditional green/red colour changes.

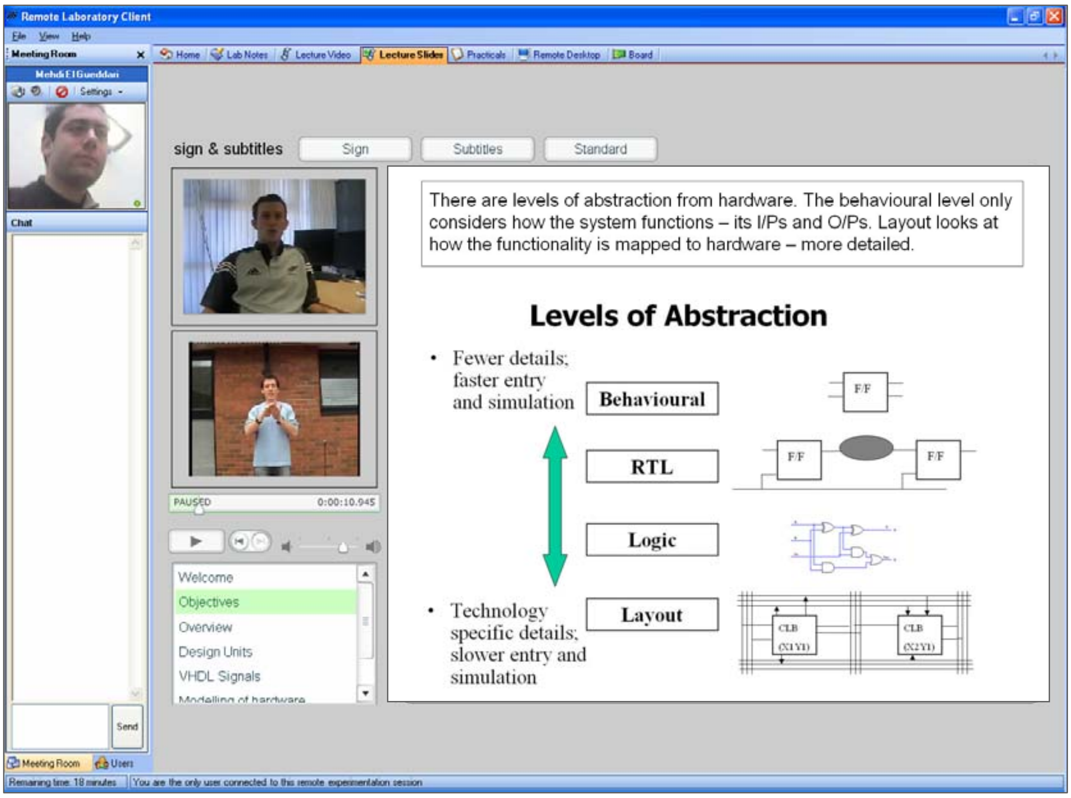


Fig.3 ProculTech Environment – sign language supported


Fig.4 ProculTech Environment – board control interface with symbols

### *C. User Feedback and Recommendations*

The new accessibility features of the ProculTech environment were evaluated by members of staff and young student members from Disability Action. The feedback was positive in terms of the system being able to present information in a format which accommodated disabled users. The users did comment that the system provides a good step towards greater usability however they did highlight a greater need for further improvements in relation to the control panel and the remote desktop viewer. Suggested improvements included more use of symbols and larger buttons, and the move away from traditional colouring schemes. It was recommended that symbols should be used in the navigation of the lecture slides and text colouring be limited. Additionally, the utilisation of text-to-speech software was recommended in the lecture notes to provide an alternative mode of delivery; and screen enlarging software for the remote desktop viewer of the client to assist students in viewing the more detailed aspects of example programs or development tools being utilized in an experiment.

### *D. Implications for Browser-based Environments*

The accessibility extensions to the ProculTech environment have proved beneficial to the target end users, and have enabled a more pragmatic evaluation of the needs and requirements of disabled users. In particular it has highlighted some of the technical challenges in the provision of such environments. Although the ProculTech system was used as example case study the extension presented can be replicated in other web-browser based environments. For example, the extended sign lecture video and feedback/control panels were developed using Adobe Flash and could easily be supported and deployed in a standard web browser. The current ProculTech environment makes extensive use of Flash technology as it is widely supported on many systems. However, it should be noted that for future developments of the remote desktop viewer it will become more difficult for web-browser based environments to support accessibility extensions such as screen enlargements.

## V. CONCLUSION

The paper presented a review of the current needs of disabled users in the context of remote experimentation and identified an initial set of extensions which accommodate users with hearing and visual impairments. The extensions were adapted to the existing ProculTech system to evaluate the technical challenges and benefits to disabled users. Example interfaces of the extensions were presented and feedback on the effectiveness of the new extensions in the context of remote experimentation was provided by a survey of disabled users. The feedback was positive and provided a good insight into the level of support required in order to provide a comprehensive environment for disabled users. The evaluation highlighted several recommendations which require further investigation. Based on the recommendations from the user evaluation, future work will investigate the incorporation of facilities in the remote desktop viewer to support zoom/enlargement capabilities, and the utilisation of screen reader software in the provision of the lecture and lab note material.

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