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STATE OF THE ART: INTERNET ACCESSIBLE REMOTE EXPERIMENTATION

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ABSTRACT

Use of computer and computer-related technologies to enhance learning began in the 1960s. The presence of computer technology in education has increased dramatically since that time, and predictions are that this trend will continue to accelerate. One of the extensions of computer technology is the Internet, which has extensively been used as a connectivity and reference tool for commercial, personal, and educational purposes. It appears that Internet-based education will continue to evolve and that the process is irreversible. One of the relatively recent uses of the Internet is Internet accessible remote experimentation (IARE). Although used mostly for academic activities, it has the potential to benefit research, industry, and other walks of life.

Keywords: *Remote laboratories, online learning, learning pedagogy, and flexible manipulator.*

1.0 WHAT IS IARE?

The Internet accessible remote experimentation (IARE) provides a means of performing experiments on real hardware from a remote location over the Internet. Figure 1 shows a general block diagram of such a system to illustrate the concept in which clients and remotely accessible facilities are connected via the Internet cloud. For the facility part, the experimental hardware should be connected to a server/computer using suitable hardware and software; while for clients, the only requirement is to have a computer with an Internet browser.

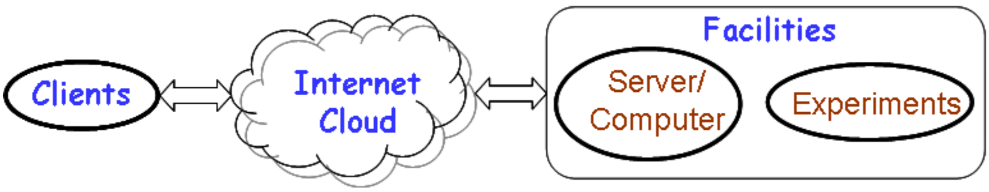

Figure 1: A structure of Internet accessible remote experimentation

So far, developments in computer and technology have not drastically changed how teachers teach and students learn, and this is even truer for the engineering and technology disciplines [1-3].

However, IARE will promote a major shift toward the use of computer and other emerging technologies to bring about radical change in delivering experiment-based courses that provide engaging and effective teaching and learning practices [4, 5].

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2.0 WHY IARE?

Considering the mixed ability level of students, the allocated time for a laboratory class is often not enough for all students to complete their tasks satisfactorily and also gain sufficient experience through the process. Sometimes students want, or feel a need, to perform additional experiments beyond their assigned tasks, but it is difficult to keep the laboratories open extra time [6]. Additionally, experiment facilities are often inaccessible to students of other departments within the same institution because of their geographical location, so ironically, too much experiment equipment lies idle most of its usable lifetime. In the research arena, some of the equipment is very expensive and difficult to own due to limited financial resources and trained manpower. Remote experimentation can allow research organizations to share their resources and foster collaboration among universities and research centers at geographically distant locations [**7**].

In industry, having the advantage of an open market economy, production lines are being decentralized and are located in geographically distant locations (different parts of the world). To keep these industries viable and maintain safe operation, skilled engineers and technicians are also essential. Because of the fast growing demand and remote location of these production lines, it is difficult to get enough skilled engineers and technicians; however, remote experimentation has the potential to provide experts real time access to the plant. Therefore, IARE has enormous potential for industry applications, such as vital sign diagnosis for manufacturing processes, disaster prevention, and training. Similar scenarios also apply to healthcare in terms of emergency diagnosis and critical patient care as well as long term care of elderly patients.

3.0 IARE AS A DISCIPLINE

Performing experiments (on real hardware) over the Internet is a relatively new concept, and any development in IARE warrants expertise from a number of disciplines. This includes computer interfacing, data acquisition and analysis, web application development, computer networking, web security, and real-time control. Symbolically this can be represented through a picture as shown in Figure 2. As one can see this creature is a brand new entity, and the research community is in the process of learning how to pursue this creature in an effective manner so there will be an efficient, affordable, and sustainable infrastructure that can support future developments for many years to come.

Figure 2: Symbolic presentation of remote experimentation systems

With a growing need for IARE and exponential advancement in the Internet and computer technologies and instrumentation, researchers/educators are developing a number of IARE facilities. Some of the leading initiatives are from the USA, Australia, Austria, Germany, and the UK [8].

4.0 COMPONENTS OF AN IARE SYSTEM

The author has been working on IARE for the last ten years. During this period, he has attracted research and development grants from various federal and state agencies, and industries to deliver laboratory courses within an electrical engineering technology program that involves design and development of IARE and pedagogical design and evaluation. A generic architecture of the developed systems is provided in Figure 3 [9].

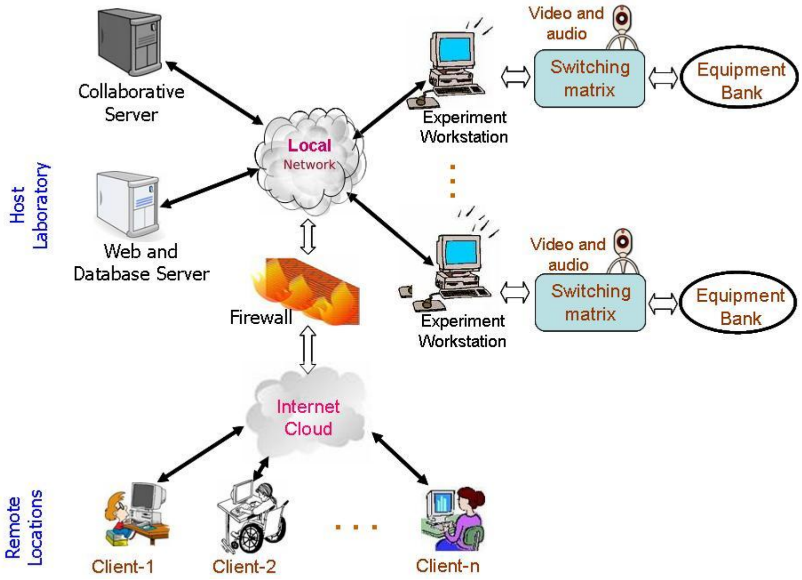

Figure 3: Proposed system block diagram

4.1 Design and development of IARE

IARE consists of eight main components: Web and database server; Collaborative server; Experiment workstation server; Switching matrix; Equipment bank; and Video and audio; Graphical user interface; and Web applications. The web and database server, collaborative server, and experiment workstations are connected to a local network, which is then tied to the global Internet cloud via a firewall.

Web and database server – allows the faculty/facilitator to integrate and configure experiments within the environment; create and manage user accounts; upload experiment guidelines, pedagogical and assessment tools, and survey questionnaires; activate/deactivate equipment; monitor student activities in terms of use of the experiment; and monitor assessment outcomes.

Collaborative server – provides an integrated learning environment to facilitate a collaborative approach to allow educational institutions and training providers to provide access to campus-based experiment resources for remote experimentation augmented by live lectures and tutorials given by tutors.

Experiment workstation – is connected to the equipment bank via a switching matrix, along with a video camera and microphone. A number of experiment workstations are connected to equipment to run multiple experiments that may be required for a laboratory session.

Switching matrix – is directly connected between the equipment bank and experiment workstation. This module is designed by using emerging switching hardware usually found in the telecommunication area. With the appropriate control signal, the switching matrix allows the user to configure a system remotely.

Equipment bank – consists of equipment to be used for a given experimental exercise. Equipment is connected to the switching matrix and can be configured for almost any experimental arrangement (limited by prohibiting any undesired configuration for safety and protection).

Video and audio – are provided with a video camera and a microphone. Performance of some experiments may produce a physical motion and sound. A video camera with pan, tilt, and zoom capability allows a client to monitor a physical motion for a given experiment. In addition to a graph and plot, video and audio feedback enhances the learning process for the clients.

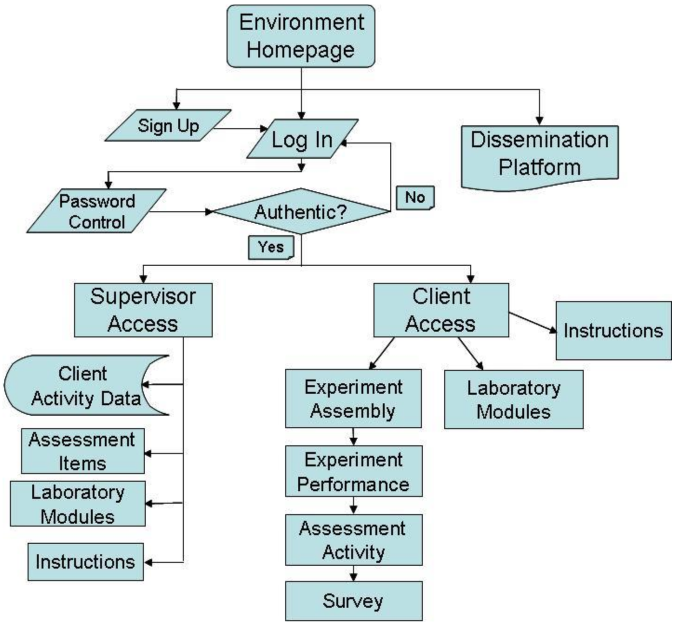

Figure 4: Flowchart for server module activities

Graphical user interface (GUI) – is one of the main components of IARE and serves as the media link between experiments and clients. It is important to provide a user-friendly, effective GUI that attracts clients, since there will usually be no physical supervision or assistance available during a traditional laboratory class.

Web applications protocol – is illustrated through a flowchart, shown in Figure 4. After password authentication, in the *client access* mode, the protocol allows a client to a) assemble an experiment using the equipment connected to the system; b) customize a graphical user interface using various kinds of graph windows, tabular data windows, and video windows, and audio; c) perform an experiment and visualize the result of the designed experiment; d) take an assessment test after an experiment session; e) observe his/her own progress as well as the progress of the whole class; and f) provide feedback about the system itself (through a survey). The *supervisory access* mode allows the monitoring of clients' activity, in which the faculty/facilitator can track an individual student in terms of use of this environment and personal growth and the growth of the whole class as well as incorporate/modify assessment items, instructions and documents for experiment modules. One of the important features within the supervisory access is that within the environment, arrangements can be made to collect assessment data, learning behavior and engagement data, and facility performance data.

4.2 Pedagogical design and evaluation

In addition to the technical issues when offering a remote experimentation, pedagogical design and evaluation issues have also been considered (Figure 5). Depending on the nature of a course, various forms of activities can be integrated: periodic face-to-face instruction, discovery learning, collaborative learning, and cognitive apprenticeship. In addition to these activities, the teaching philosophy integrates emerging technologies, individual learning, knowledge centered, embedded assessment, community centered, and scaffolding.

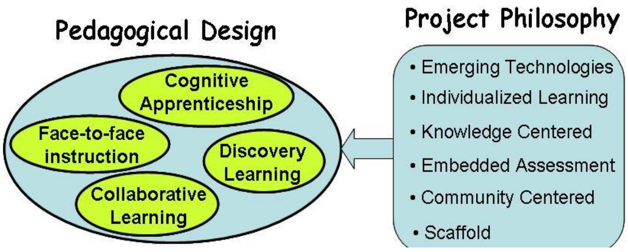

Figure 5: Pedagogical model in light of project philosophy

An evaluation scheme was put in place to address four issues: students' learning outcomes, students' learning behavior, and the effectiveness of the IARE facility. Most of the outcomes indicated the positive contribution of IARE. In terms of access to the facility, it was found that the time of day students performed their experiment tasks ranged from 9:00 a.m. to 1:00 a.m. of the next day, which is a duration of 16 hours, indicating great flexibility and convenience for students that is otherwise impossible because of the cost and administrative limitations under a traditional experiment configuration. Figure 6 shows the access profile to the remote experiment experiments.

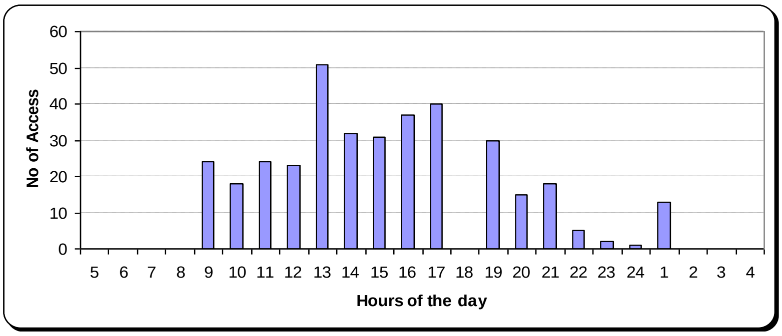

Figure 6: Shows the access profile to the facility in terms of time of the day

5.0 RECENT DEVELOPMNET

One of the recent developments the author is working on is an IARE for a single link flexible manipulator system. The system was acquired from Quanser Systems – a commercial developer that designs and develops education and research-based systems for real-time control design and implementations [10, 11]. The system is actuated with a motor at the joint and can move on a horizontal plain. The system is designed to study the behavior of the system in terms of model development and verification of various controllers. There are a number of transducers mounted on the flexible manipulator to monitor the status of the system as well as its vibration behavior: shaft encoder (joint angle), tachometer (joint velocity), strain gauge (vibration at the joint), and accelerometer (end-point acceleration). The system is connected to a PC using suitable hardware and software tools along with the development of a GUI to control/manipulate the system. The GUI is then transformed as a dynamic web page and integrated with an IARE portal to make remote access available over the web. The software tools used for this development are LabVIEW, extensible markup language (XML), simple object access protocol (SOAP), web services description language (WSDL), active server pages (ASP), .NET technology, and hyper-text markup language (HTML). An image of the remotely accessed GUI is provided in Figure 8. The GUI has controls on the top, input signal and video of the system, followed by all the sensor data both in time and frequency domains. The user has a choice of selecting an input from a number of input types and observing the vibration behavior of the system. A user can upload additional input to the system and use it to excite the system.

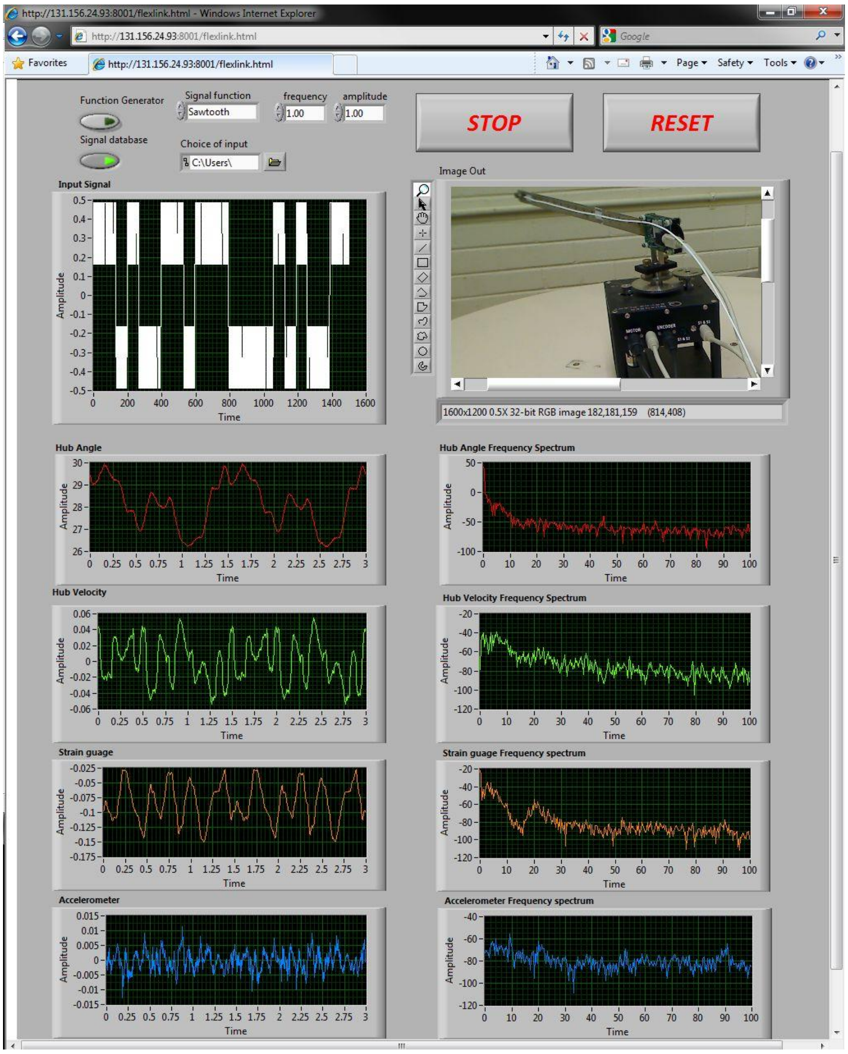

Figure 7: GUI for a single link flexible manipulator system

6.0 MOVING FORWARD?

Looking from an overall prospective, it is true that the IARE area has exploited recent technological progress in software and hardware to make remarkable improvements. Some of the current developments have features that were unthinkable a few years ago. However, the use of these facilities is very limited and very few systems have been integrated into our regular educational infrastructure [12]. With this notion and scenario, a few important issues need to be addressed to make the use of IARE widespread and sustainable: Common design framework, Awareness initiatives, Industry applications, and Commercial products.

- MIT (USA) has led an initiative with researchers and academics around the world to form a consortium to discuss major developments in this area and work toward a broader framework for IARE developments. This will streamline future developments through a modular design of system components with pre-determined inputs/outputs for each module. This kind of approach will foster interaction between the systems, the ability to handle different kinds of experiments, and the sharing of resources to maximize the use of available resources.
- Awareness about the potential of remote experimentation among engineering, academic, and industry leaders is essential to attract research and development investment in this area. This includes engineering deans and higher academic administrators, professional organization leaders, and industry executives. In this respect, the International Association of Online

Engineering (IAOE) and other national and regional forums can take a leading role in this effort.

- Need is a mother of invention; therefore, the industry sector is a major power house for the development of new technology. The responsibility to highlight the possibility of using remote experimentation for industry benefit rests on the remote experimentation community.
- In terms of the development of commercial products, there should be collaboration between academia and industry to launch projects that will design and prototype custom products that can be utilized in IARE design. In this respect one can look for federal, state, and company funding, as well as international collaboration.

7.0 CONCLUSIONS

IARE is a relatively new discipline; however, with the development of emerging technologies, it has the potential to be utilized in many areas of our life. Currently IARE is mostly used in academic areas, but with growing awareness of and appropriate initiatives, IARE can benefit research, industrial, and healthcare applications. This feature also highlights some issues to foster more collaboration in developing IARE systems for wider applications, which will help this area emerge as a sustainable entity worldwide.

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