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Remote laboratory concepts: A conceptual model of remote laboratory for solar energy engineering

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Abstract: *The notion of remotely controllable laboratories (RCL's) is the practice of providing control of scientific instruments from remote locations. The devices which can be accessed remotely include variety of equipment. Bearing in mind the cost and complexity of these devices, many specialized scientific instruments cannot be reached by some institutions, while the institutions that pose such instrumentation, scheduling and other logistical issues prevent full utilization of those tools. Therefore, initiatives that offer remote access tend to address issues of access and efficiency, ultimately improving educational quality and student opportunities. Given the aforementioned, the aim of this paper is to provide an insight on the most common concepts of RCL's that are encountered in engineering practice. Furthermore, a conceptual model of RCL's for solar energy engineering (SEE) is briefly displayed and discussed. Lastly, potential advantages and disadvantages of RCL's are stressed out concisely.*

Keywords: *Remote laboratory; engineering education; solar energy; Moodle*

1. INTRODUCTION

The concept of RCL's firstly appeared in the late 1990s at universities all over the world and became enabler of slowly creating environment for development of remote engineering. The RCL's were designed and implemented to address the issues faced by the modern universities such as limited capacity, as well as to provide cost-effective laboratories [1], efficiently utilized, and most importantly, able to provide students with adequate access to perform experiments [2]. Having this in mind, remote engineering is becoming an import element in engineering education, while accordingly there is growing need for new learning media and tools. Likewise, RCL's provide students with 24/7 access via the Internet while pointing out opportunities to share expensive and/or specialist laboratories with other institutions. Additionally, instead of developing the same types of laboratories by different entities and institutions, remote labs could be shared globally wherever adequate Internet access is available. Therefore, the purpose of remote labs is not to replace real time practical experiments, on contrary they are aimed to enhance these experiments, using modern and available technology [3]. There have been many evaluations of possible laboratory experiments, but in recent years, the RL is at the forefront [4].

2. REMOTE LABORATORY CONCEPTS

Most remote laboratories are accessible independent of space or time using a computer with an Internet connection and a web browser. Video and sound transmission can be used for remote observations but human senses other than sight and sound are more difficult to convey. Most instruments have a remote control option, and human fingers can often be replaced by a remotely controlled manipulator, a so-called “telemanipulator”, the level of sophistication of which may vary. The Internet is used as communication infrastructure. Each user’s instrument settings and other data required to set up a desired experiment are sent from the user’s computer to the lab server. The server sets up and performs the experiment and returns the result to the user’s computer. A block diagram of such a laboratory is shown in Figure 1. It is important to mention that the number of client computers that can be connected and perform physical experiments simultaneously varies from laboratory to laboratory [5].

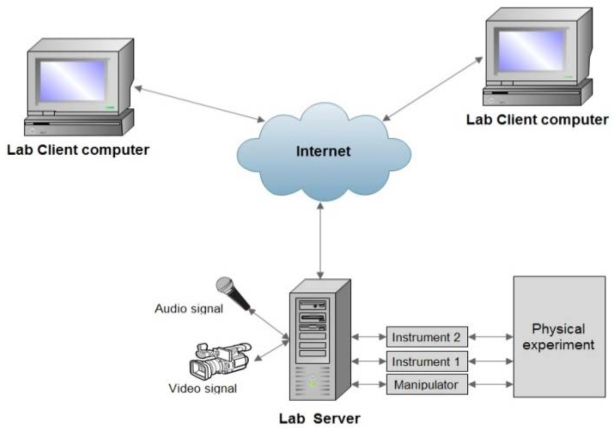

Figure 1. *Block diagram of a Remote Laboratory model*

In addition, most desktop instruments have a remote control connector for GPIB (General Purpose Interface Bus), which is often placed in the rear panel. In other cases, the instrument can be connected directly to the Internet through an Ethernet port. Computer-based measuring instruments consisting of a plug-in board, fitted with a tiny physical panel containing connectors and a software module in the host computer are frequently seen in laboratories today. There are instrument boards on the market that can be plugged into the mother board of a standard desktop PC. However, the normal PC chassis is a disturbing environment for an instrument board. The instrument platform used in the open electronics lab is PXI (PCI eXtensions for Instrumentation). Another platform which was introduced in 2005 is the LXI (LAN eXtensions for Instrumentation) which may become a LAN-based successor to GPIB. The software module displays a virtual front panel containing control knobs and buttons on the host computer screen. The user can turn the knobs and adjust the instrument settings with the mouse. The fact that the virtual front panel is separate from the plug-in board enables users to install this piece of hardware in the lab server and to display the virtual front panel on the screens of the client computers. The Figure 2 provides an insight to virtual front panel of a desktop measuring instrument.

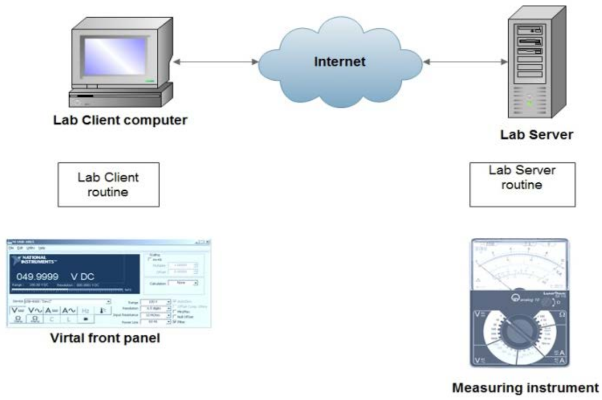

Figure 2. *Remotely controlled instrument*

Moreover, it is possible to combine a virtual front panel representing an instrument from one manufacturer with hardware from another as long as the performance of the hardware matches that of the depicted instrument. Additionally, another convenient alternative requiring only modest programming experience is to write these routines using LabVIEW, which is graphical software development environment for measurement and automation [6].

3. A CONCEPTUAL MODEL OF RCL'S FOR SOLAR ENERGY ENGINEERING

A model of RCL's for Solar energy engineering (SEE) consists of a solar energy conversion plant which consists of several flat plate solar collectors located on the flat roof of the facility, an insulated thermal storage tank located in the solar energy laboratory (SEL) and other auxiliary equipment and accessories. In addition, SEL should be equipped with all necessary instrumentation, control and communication devices which are needed for remote access, control, and data collection and processing. The schematic diagram of the solar facility system is illustrated in Figure 3.

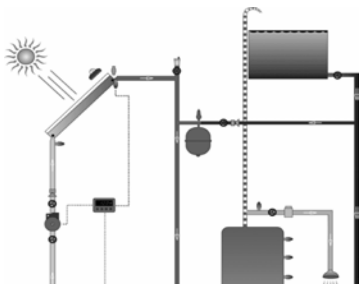

Figure 3. *Schematic diagram of the solar facility system*

Moreover, integrated hardware and software provide features for controlling external devices, responding to events, processing data, creating report files, and exchanging information with other applications. Likewise, specific weather data, as well as operational and output data of the system are being registered during an experiment and temporarily stored on the controlling PC, while being available for downloading for subsequent calculations and/or documentation. The main focus of this concept is to use Internet as a tool to ensure RCL's being accessible to engineering students and technicians located outside the facility premises. In this way, the SEL and its equipment and experimental facility will be available for sharing, resulting in reducing facility running and maintenance costs. Furthermore, this concept offers a unique opportunity to students from countries of poor sunshine to have access to real conditions experiments. The system will enable real-time, remote control, data acquisition and evaluation. Likewise, it allows remotely located students to conduct experimental work in an interactive and independent way.The system architecture consists of four different layers where each layer provides its services to the next lever by using the services of the layer below it. Figure 4outlines the different layers with a short description of their responsibilities.

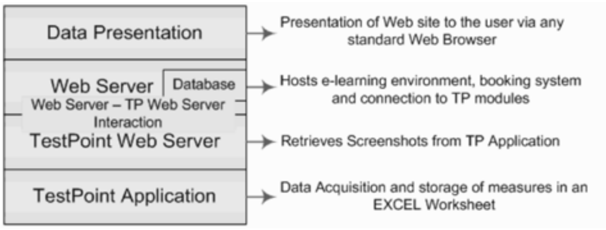

Figure 4. *The system architecture layers*

Having in mind that for the implementation of this architecture two different computers are needed, in the Figure 5, a graphically displayed architecture is shown where the previously mentioned layers are separated by dotted lines.

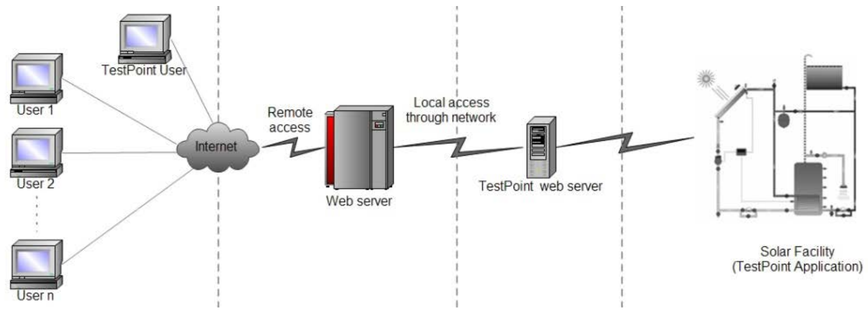

Figure 5. *The system architecture layers - graphically displayed*

3.1. Challenges, problems and overcoming solutions

Although the benefits and importance of this concept are obvious, there is one concerning issue common for all entities that offer their services through internet, and that is security. Having this in mind, the primary concern is security of both, the Main and the TestPoint Web server. The web server could be integrated under the university domain so the security mechanisms for the whole institution are inherited by the computer hosting the web server. On the other hand, additional security is needed at the Test Point web server hosting device.

If this device is also under the university domain, restrictions from within the university could be applied.

3.2. E-learning platform

Having in mind that the University of Novi Sad (UNS) has already integrated Moodle as an e-learning platform as a part of its standard teaching methodology, aforementioned RCL's could be hosted on it. Moodle, which is a course management system provided freely as Open Source software (under the GNU Public License), runs on any computer that can run PHP. In addition, it can support many types of database, particularly MySQL. Therefore, this choice allows flexibility in learning while providing various learning environments to fulfill the requirements of the various courses. So far, Moodle was used as a demonstration, a quiz and an experimental tool. However, Moodle capabilities could be enhanced and adapted in such a way that the running of the actual experiment is allowed only after the successful completion of the preliminary exercises or tasks. It is important to mention that with this platform the user can work both independently or as a part of research group.

4. CONCLUDING REMARKS REGARDING FUTURE SCENARIOS AND IMPLICATIONS FOR TEACHING AND LEARNING PROCESS

Providing remote access can improve scheduling for on-campus users, who can conduct experiments outside class or lab times, and promotes more efficient use of specialized equipment that might otherwise remain idle for long stretches, only to be swamped during peak times. Remote users benefit by having access to extremely rare or unique scientific instruments. In some cases, instruments can be quite expensive or specialized that there might only be a handful or even just one in existence. Exposing students to such equipment, allowing them to engage in authentic learning experiences rather than just simulations or canned exercises using archival data, creates more compelling learning opportunities. Working with the actual tools of a field deepens students' understanding of the concepts at work and prepares them for careers using those devices. Effective RCL's could save time and the expense of travel, preserving or even expanding access to scientific facilities in times of stalled or shrinking budgets. Moreover, by providing access to the general public or students, researchers may fulfill a requirement to disseminate publicly funded research as broadly as possible. As network infrastructure matures, it offers greater speeds, improved security, and increased access while opportunities grow for bringing experiences of genuine scientific instrumentation and work to a wider range of students. As institutions reap synergistic benefits of RCL's, higher education will likely undertake more partnerships in which universities maintain different pieces of scientific equipment and share access to those resources, maximizing their utilization while eliminating multiple purchases of similar hardware. As scientific instrumentation is increasingly controlled solely through computer interfaces, and as security measures and software to manage resources become more sophisticated, the number and kind of instruments available through remote channels will increase. In addition, as the means of connecting scientific devices to the Internet become simpler and less expensive, institutions will be more willing to give remote access to older instruments that have been replaced with new equipment but remain valuable for teaching purposes. RCL's have the potential to bring authentic learning experiences to a wide range of students, resulting in richer learning and a deeper understanding of the material at hand. It's the difference between simply reading about a principle in a textbook and being able to perform experiments that apply those principles. For some students, remote instrumentation opens the door to hands-on experiences they could not gain otherwise. For other students, remote instruments can add considerably to the amount of time they can work with scientific equipment, broadening the range of experiments they are able to conduct and the opportunities for learning. Likewise, RCL's could allow courses to be taught online that otherwise would have to be taught face-to-face because of their reliance on specific equipment, and faculty can include real-time demonstrations in lectures, bringing authentic examples of experimentation or problem-solving to students. Undergraduate learning in particular can benefit from linking course content to the tools and experiments of the discipline.

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