The VISIR project – an Open Source Software Initiative for Distributed Online Laboratories

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Abstract— **Blekinge Institute of Technology (BTH) in Sweden has started a project known as VISIR (Virtual Instrument Systems in Reality) together with National Instruments in USA and Axiom EduTech in Sweden to disseminate an online laboratory concept created at BTH using open source technologies in collaboration with other universities and organizations. The concept is about adding a remote operation option to traditional instructional laboratories to make them more accessible, irrespective of whether the students are on campus or mainly off campus. The BTH option is equipped with a unique interface enabling students to recognize on their own computer screen the instruments and other equipment most of them have previously used in the local laboratory. The first remote control option implemented is for an electronics laboratory and the second one is for a signal processing laboratory with emphasis on mechanical vibration experiments. The electronics lab option features remote circuit wiring using a virtual breadboard and a relay switching matrix combination. The goal is an international standard, enabling teams worldwide to expand and develop jointly this powerful approach into distributed online laboratories by using standardized software such as IVI (Interchangeable Virtual Instruments) and equipment platforms such as PXI (PCI eXtensions for Instrumentation) and LXI (LAN eXtensions for Instrumentation).**

Index Terms—**Electronics, online lab, remote lab, signal processing, VISIR project .**

I. INTRODUCTION

Cooperation between universities is likely to favor their competitiveness and improve their ability to handle the large issues of the society of today. Mankind must live up to the principles of nature and utilize our environment with a focus on sustainability. The engineers who design the new technologies required in the modern society must during their education study how to "communicate with nature" to learn its principles. Engineers' method of communicate with nature is since centuries named physical experiments. However, during recent decades the amount of laboratory work in engineering education has been reduced. The prime cause is clearly the task of coping with greatly increased student numbers, while staff and funding resources have scarcely changed. Contributory factors include the seductive appeal of simulating experiments on computers, where there are no unexpected or unpleasant clashes between theory and simulation [1].

Reducing the number of lab sessions is easy because the laboratory work is seldom evaluated and the cost reduction obtained is often considerable. However, for example, ABET (Accreditation Board for Engineering and Technology) in USA has recently pointed out that learning objectives for laboratory work must exist and be evaluated [2]. Thus, the amount of laboratory work in a course dealing with physical phenomena must be correlated to the learning objectives of the course. Unfortunately, few well-informed persons believe in a substantial rise of course funding resources despite the fact that mankind today need to penetrate deeper and deeper into nature in order to progress. Universities must produce new great experimenters such as Michael Faraday in the nineteenth century.

Flexible education means providing students with extended accessibility to learning resources and increased freedom to organize their learning activities. From a technological perspective, flexible education corresponds to an adequate exploitation of information and communication devices and infrastructures, especially the Internet. Today, many academic institutions offer a variety of web-based experimentation environments so called remote laboratories that support remotely operated physical experiments [3]-[7]. Such remote experiments entail remote operation of "distant" physical equipment offering students more time for laboratory work. This is one way to compensate for the reduction of lab sessions with face-to-face supervision without significant increase of cost per student. Remote experiments are adapted to the flexible environment of the students of today and permit low cost methods for lab work evaluation.

Web-based experimentation is an excellent supplement to traditional lab sessions. The students can access lab stations outside the laboratory and perform experiments around the clock. It is possible to design virtual instructors in software which will protect the equipment from careless use; also theft of equipment will not be a problem. Interfaces enabling students to recognize on their own computer screen the instruments and other equipment in the local laboratory may easily be created. Apart from the fact that each student or team of students works remotely in a virtual environment with no face-to-face contact with an instructor or other students in the laboratory, the main difference between a lab session in the remote laboratory described here and a session in a local laboratory is that it is not possible for students to manipulate physical equipment e.g. wires and electronic components with their fingers in a remote laboratory. However, students can, for example, sit at home in peace and quiet and learn how to use a function generator and an oscilloscope in the same way as in a noisy local laboratory where time is limited.

The VISIR Initiative emanates from a remote laboratory project started at BTH in 1999 to ascertain that it is feasible to design a remote electronics laboratory comprising standard equipment to supplement local instructional laboratories and provide free access to the experimental equipment to students enrolled in circuit analysis and electronics courses. Today BTH has two online laboratories one electronics lab and one signal processing lab for mechanical vibration experiments based on the BTH Open Laboratory concept. The concept is about providing new possibilities for students to do laboratory work and become experimenters by adding a remote operation option to traditional instructional laboratories to make them more accessible for students, irrespective of whether they are on campus or mainly off campus. This option is equipped with a unique interface enabling students to recognize on their own computer screen the instruments and other equipment most of them have previously used in the local laboratory. The software produced is released as open source.

This paper presents the VISIR project started in late 2006 at the Department of Signal Processing, BTH, in cooperation with National Instruments and Axiom EduTech and with financial support from VINNOVA (Swedish Governmental Agency for Innovation Systems) to disseminate the online laboratory concept using open source technologies. Other universities and organizations are invited to participate. Section II of the paper describes briefly the Open Laboratory concept. In section III the current online laboratories is presented. Finally in section IV the VISIR project is described.

II. TRADITIONAL LAB SESSIONS SUPPLEMENTED BY REMOTE EXPERIMENTATION

An experiment is a set of actions and observations, performed in the context of solving a particular problem. Experiments are cornerstones in the empirical approach to acquire deeper knowledge of the physical world. The experimenter sets up and operates the experiment with his or her hands and/or with actuators. As an example, a lab station in an instructional laboratory for low-frequency electronics at BTH is shown in Fig. 1. The experimenter creates a test circuit on the breadboard with the fingers and uses instruments to measure what he or she cannot perceive directly with the human senses as, for example, the electrical current. The electrical experiments possible to perform in this environment are mainly limited by the components provided by the instructor.

In instructional laboratories at most universities there are a number of lab stations where at maximum the same number of students or mostly pair of students perform experiments supervised by an instructor. Supervision means tutoring but also looking after that the expensive equipment is handled properly and is not damaged or stolen. The students are permitted to be in the laboratories only during lab sessions when an instructor is present. The number of lab stations in a laboratory is usually selected considering how many students an instructor can supervise if a lab station is not too expensive. Typically, electronics instructional laboratories are equipped with eight identical lab stations. Fewer lab stations mean more teaching hours per course but less investment. It is a pedagogical advantage if the lab stations are identical because then the students can perform the same experiments in each session and in the correct order required by the course. On the other hand it implies larger investments i.e. more copies of the same instrument.

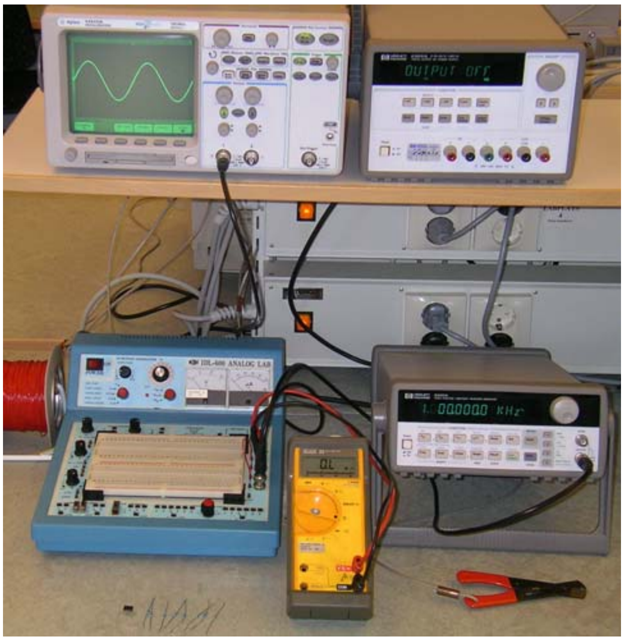

Figure 1. Lab station in a local electronics laboratory at BTH.

New technologies such as the Internet and Web 2.0 offer new possibilities to share online lab stations. The desktop instruments in the instructional laboratories can be replaced by computer-based ones and the latter are more suited for remote control. Human fingers can often be replaced by a remotely controlled manipulator, the level of sophistication of which may vary. Video and sound transmission can be used for remote observations. It is, however, not possible share single instruments because, for example the waveform generator, the voltage source, the test circuit, and the oscilloscope in an electronics experiment must be located close together.

Instrumentation platforms such as PXI (PCI eXtensions for Instrumentation) and LXI (LAN eXtensions for Instrumentation) are suited for remote control [8]-[9]. The latter is expected to become a LAN-based successor to GPIB (General Purpose Interface Bus). The front panels of instruments compatible with these platforms have no control knobs only connectors on their tiny front panels. Virtual front panels are used to set them and to display results. A simplified block diagram of an oscilloscope remotely controlled via web services is shown in Fig. 2. When the oscilloscope is in run mode the virtual front panel display should be updated approximately once per second and when the experimenter modifies a setting a message is sent to the instrument controller.

The IVI Foundation is a group of end-user companies, system integrators, and instrument vendors, working together to define standard instrument programming interfaces [10]. The IVI standards define open driver architecture, a set of instrument classes, and shared software components. To enable interchangeability, the foundation creates IVI class specifications that define the base class capabilities and class extension capabilities. There are currently eight instrument classes, defined as:

- DC power supply

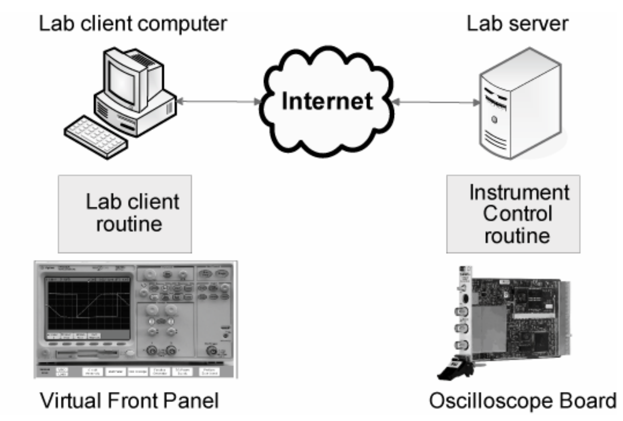

Figure 2. Remote- controlled instrument.

- Digital multimeter (DMM)
- Function generator
- Oscilloscope
- Power meter
- RF signal generator
- Spectrum analyzer
- Switch

Base class capabilities are the functions of an instrument class that are common to most of the instruments available in the class. For an oscilloscope, for example, this means edge triggering only. Other triggering methods are defined as extension capabilities. The goal of the IVI Foundation is to support 95% of the instruments in a particular class.

The manipulator component is often the most complicated in a remote laboratory and very few, if any, such devices are commercially available. The manipulator must be designed for each type of laboratory using various remote-controlled actuators, i.e. transducers that transform an input signal into motion. Examples of actuators are electrical motors, relays, hydraulic pistons, electroactive polymers etc. An example of a manipulator is shown in Fig. 3. A number of relays arranged in a matrix pattern together with instrument connectors and component sockets on stacked printed circuit boards are used in an electronics laboratory for the purposes of remote circuit wiring. The relay switches are embedded in the circuit under test to confine the length of the wires and gain bandwidth. The corresponding virtual panel is a breadboard. Photographs of components mounted in the sockets of the matrix are displayed in a component box at the top of the breadboard. In this way, the circuit the learner creates on the virtual breadboard is transformed into a physical circuit in the matrix.

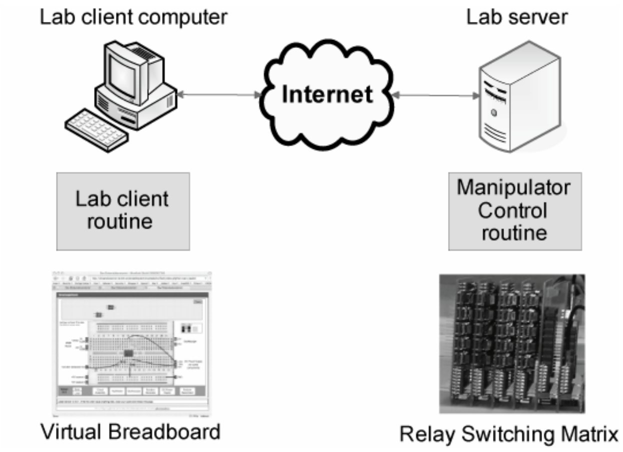

Figure 3. Example of remote-controlled manipulator.

III. THE CURRENT OPEN ELECTRONICS LABORATORY

An open laboratory is defined as a local laboratory equipped with a remote control option. One or more lab stations may be accessible remotely or made for remote access only. The signal processing department at BTH has opened two local instructional laboratories for remote operation and control, one for electronics and one for signal processing − more precisely, mechanical vibration analysis [11]-[12]. The laboratories are used in regular education. They are equipped with a unique virtual interface enabling students to recognize on their own computer screen the desktop instruments they have previously used in the local laboratory. In the electronics laboratory, the physical breadboard has been replaced by a circuit-wiring manipulator i.e. a switching relay matrix shown in Fig. 3. In the signal processing laboratory, the device being tested is not an electrical circuit but a mechanical structure. The organization of the laboratories is shown in Fig. 4. They are composed of four parts.

- A web interface handling user admission, resource scheduling and other administration.
- An experiment client software module presented through a HTML page containing the module as an embedded object.
- An equipment server hosting instrument hardware for electronics experiments, plus a relay switching matrix [11]. This server was in early versions of the electronics laboratory acting as a stand-alone online electronics laboratory. The server software is written in LabVIEW and the instrument drivers are IVI compliant.
- A measurement server handling requests from experiment clients. A virtual instructor module checks the desired circuits before they are passed on to the equipment server. The experiments results are passed back to the client computers. The signal analyzer in the signal processing laboratory is connected directly the measurement server.

The equipment server i.e. the online lab station in the open electronics laboratory which is accessible remotely looks different from the traditional one in Fig. 1. The instruments and the host computer are installed in a PXI chassis as shown in Fig. 5. This equipment is manufactured by National Instruments. The corresponding virtual front panels are photographs of the front panels of the instruments in Fig. 1. 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. As an example, a screen dump displaying the multi-meter is shown in Fig. 6.

In electronics it is possible to perform the same experiment in different time scales by selecting the

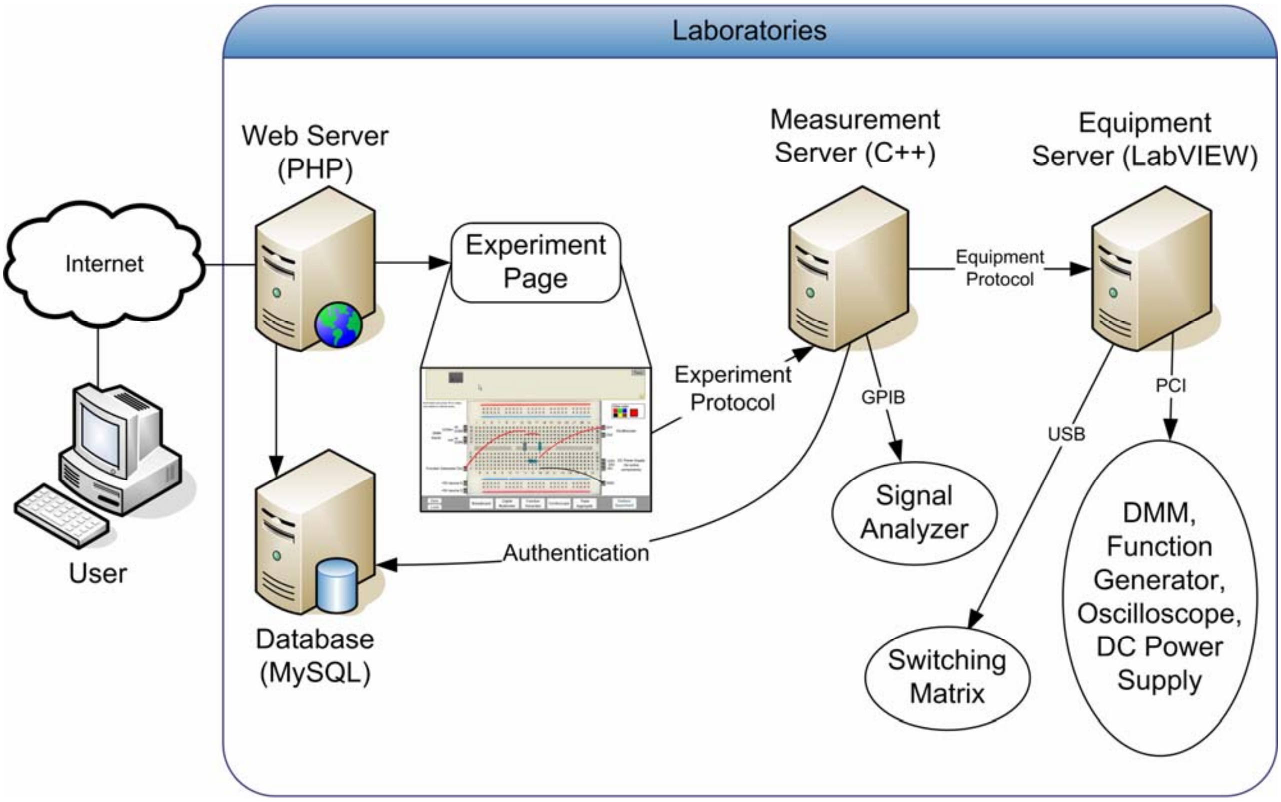

Figure 4. Organization of the online laboratories.

electrical size of the components of the test circuit. This "feature" is used in the open electronics laboratory at BTH to allow simultaneous access by time sharing the lab station. Using this approach a single lab station can replace a whole laboratory with many lab stations but the following restrictions apply.

- A single experiment i.e. circuit wiring and measurement procedure must not last longer than 0.1 second to get a reasonable response time even with a large number of experimenters. Please note that the experimenter performs the circuit wiring and instrument settings locally in his or her computer and may then use all the time the experimenter needs. In this way the lab station at BTH can serve many students simultaneously by time sharing. The components mounted in the relay switching matrix in Fig. 4 are selected by the teachers to allow this long experiment duration.
- An extra control button, *Perform Experiment*, is required in the user interface. The experimenter presses this button when s/he has wired the circuit and set the instruments and wants to perform the experiment. A message containing the circuit and the instrument settings is sent to the remote lab station. Then the station performs the desired experiment and returns the result to be displayed on the front panels of the client computer screen.
- The time line of the actual experiment in the server is fixed. First the circuit is created and the test probes are connected. Then a time delay (25 ms) is added to let all switching transients

Figure 5. Equipment Server.

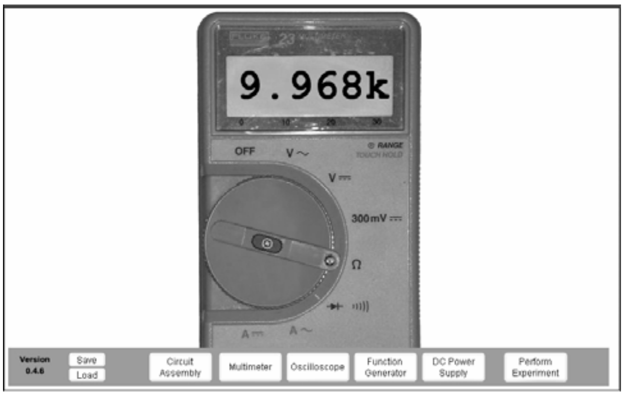

Figure 6. Screen dump showing the multi-meter.

generated by the relays disappear before the measurement procedure starts.

Timesharing is a way making a single online lab station look like a whole laboratory from the experimenters' point of view. The results produced are genuine and the price per experiment is low. However, a lab station per experimenter is preferable if the experimenter wants to control the process in detail.

IV. THE VISIR PROJECT

The aim of the VISIR project is to form a group of cooperating universities and other organizations, a VISIR Consortium, creating software modules for online laboratories using open source technologies and/or setting up online lab stations. A number of such scattered lab stations may form a distributed laboratory. At least the following four different scenarios will be possible.

- A face-to-face lab session can take place in a computer room where the students are sitting in front of computers performing experiments simultaneously on remote lab stations supervised by an instructor present in the room. Together these lab stations may be considered as a distributed laboratory formed only for a particular lab session using an advanced time reservation system which may include accounting.
- Combinations of local and remote access are also possible in traditional lab sessions in a local laboratory where some students can perform the experiments in the traditional way and others can use remote access. This is an attractive option to provide additional lab stations to accommodate more students in a session. Students who are familiar with the physical equipment might prefer a remote lab station. It is, for example, easier to wire a circuit with the mouse pointer on a virtual breadboard than with the fingers on a physical one.
- In a remote lab session the students and the instructor can be scattered. Some of the students may sit at home. It is not necessary for the students or the instructor to know where the physical processes are executed and they can, for example, use Microsoft Messenger for communication.
- If a lab station is free and not occupied by a supervised lab session an authorized student or student team can perform experiments alone without supervision to, for example, prepare a lab session or repeat experiments afterwards.

The VISIR Initiative is not confined to electronics laboratories but the VISIR project will start with lab stations for electrical experiments. The three main reasons are the following.

- Today BTH has an online electronics laboratory running in regular education. The software produced is released as open source and should be useful to start with. An Austrian university, FH Campus Wien, is creating a laboratory using it.
- Most instructional electronics laboratories for engineering education at universities around the world contain the same equipment, (oscilloscopes, waveform generators, multi-meters, power supplies, and solderless breadboards) although models and manufacturers may vary. Such laboratories are already in a way a de facto standard.
- There are driver standards created by the IVI Foundation defining the functionality for all the instruments in an electronics laboratory.

Partners in the VISIR project are Axiom EduTech in Sweden, BTH, and National Instruments in USA. So far the following universities are interested in participating in the project FH Campus Wien in Austria, University of Deusto in Spain, University of Genoa in Italy, Carinthia University of Applied Sciences in Austria, Gunadarma University in Indonesia, and UNINOVA (Institute for the Development of New Technologies) in Portugal. BTH will act as a hub for the development and maintain a server from which the current version of the software can be downloaded. The objectives of the VISIR project are.

- Online lab stations for electronics experiments based on standardized hardware platforms and open source software.
- Online lab stations for experiments in other domains. BTH will together with National Instruments, Axiom EduTech and other interested members of the VISIR Consortium concentrate on a lab station for mechanical vibration experiments. There is, for example, not yet any IVI driver for the signal analyzer which is the main instrument required in such experiments.

The overall goal of the VISIR project is increasing the access to experimental equipment in many areas for students without raising the cost per student significantly for the universities. The means are shared online laboratories created by universities in cooperation and supported by instrument vendors. Sharing of laboratories may lead to sharing of course material. The ultimate goal of our research at BTH is ubiquitous physical experimental resources accessible 24/7 for everyone as a means of inspiring and encouraging children, young people and others to study engineering and become good professionals or to be used as a means of life-long learning for teachers and other professionals.

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