

The VISIR Open Lab Platform 5.0 - an architecture for a federation of remote laboratories

I. Gustavsson¹, G. Alves³, R. Costa³, K. Nilsson¹, J. Zackrisson¹, U. Hernandez-Jayo², and J. Garcia-Zubia²

¹ Blekinge Institute of Technology/Electrical Engineering, Karlskrona, Sweden

² University of Deusto/Department, Bilbao, Spain

³ School of Engineering – Polytechnic of Porto / Electrical Engineering, Porto, Portugal

Abstract—This paper outlines a new laboratory learning infrastructure based on the VISIR (Virtual Instrument Systems in Reality) Open Lab Platform, which is an architecture for opening hands-on instructional laboratories for remote access 24/7 with preserved context. The aim is to embrace such laboratories in which telemanipulators can be used to remotely set up and/or start experiments and where the outcome can be observed remotely using instruments, video and/or audio transmission. As hands-on laboratories, VISIR ones can be used for exploring nature and for training laboratory workmanship. The current release (4.1) of the VISIR Open Lab platform can be used for opening electronics laboratories and laboratories for mechanical vibration experiments for remote access. Other subject fields will follow. So far, seven VISIR laboratories are online globally. The coming VISIR Open Lab Platform 5.0 will offer new functionality and will support a federation of VISIR laboratories.

Index Terms—Laboratory, Remote labs, Lab infrastructure.

I. INTRODUCTION

The amount of hands-on laboratory work in engineering education has bit by bit been reduced during the closing decades of the last century [1], [2]. The primary cause is clearly due to the task of handling the dramatically increased number of students, while staff and funding resources have not improved [3]. At the same time, the importance of physical experiments has increased. This fact is discussed in the next section. However, hands-on instructional laboratories are expensive to set up and to maintain and most universities cannot keep them open as many hours as would be desirable. Furthermore, students nowadays want extended access to learning resources and an increased freedom to organize their own learning activities, which is also one of the main objectives of the Bologna Process.

Today, the situation has improved thanks to Internet technology. Many academic institutions have created a variety of remote laboratories that support remotely operated physical experiments, which usually are accessible 24/7 [4], [5], [6], [7], [8]. However, most such laboratories provide a given set up for demonstrating particular phenomena in nature and only in a few it is possible for a remote student to set up or to thoroughly rearrange experiments and to perform genuine laboratory work such as train how to handle instruments [9]. The

VISIR Open Lab Platform designed at the Department of Electrical Engineering (AET), the Blekinge Institute of Technology (BTH), Sweden, is an architecture for opening existing types of hands-on laboratories for remote access with preserved context in order to in the first place supplement and increase the accessibility and the capacity of them. A unique interface gives the student a feeling of being in the hands-on laboratory [10]. Some types of laboratories are easier to open for remote access than others are. So far, the current VISIR platform (4.1) supports laboratories for electrical experiments and for mechanical vibration experiments. Online laboratories based on the current VISIR platform are related to hands-on ones in section III. The next version of the VISIR platform (5.0) will support a federation of VISIR laboratories and include a repository for sharing learning material. It is outlined in section IV.

Why create a new infrastructure of remote labs? There is a number of laboratory infrastructures already available worldwide [11]. It is concluded in the last section that VISIR complements them and is an extension of hands-on instructional laboratories.

II. PHYSICAL EXPERIMENTS AND SIMULATIONS

For centuries, scientists have conducted physical experiments in order to understand natural phenomena and to create theories and mathematical models describing them. Professional engineers have these models in their minds and use simulators based on them to design prototypes. Thus, to be engineers, students must become familiar with theories and models. Hand calculations and simulations are the best tools to learn useful models because no noise or other imperfections not included the models will hide the expected result. However, engineers also carry out experiments, and that is mainly for two reasons [1]. First, in the design process they often “ask” nature when they suspect that a particular characteristic of a model to be used may not be accurate enough. The second reason is to determine if a prototype meets its specification and performs as intended in the environment where the product is to be used.

Experimenting can be compared to a kind of conversation with nature. Perform a physical experiment and nature answers. The tricky point is to formulate a useful question and to interpret the answer. Students need a lot of practice to become fluent in the language of nature to become engineers who are able to design goods and

services compatible with the principles of nature that fit in a sustainable society. Thus, students must spend a lot of time in instructional laboratories to learn how to perform experiments and to explore the relevance of existing models i.e. the degree of correspondence between results of calculations based on a model and results of observations of nature. At least some of the laboratory work must be hands-on. Home experimentation may be a method for off-campus students without laboratory experience to acquire introductory hands-on experience and to become familiar with, for example, electronic components, instruments, and wiring. [12], [13].

III. HANDS-ON LABORATORIES AND ONLINE ONES BASED ON THE CURRENT VISIR PLATFORM

In instructional hands-on laboratories, the students usually use their hands to arrange and to conduct experiments and they use instruments and/or their human senses to observe the outcome. Some experiments may be set up by the staff and then the student needs only to perform the actual experiment and to observe/record the outcome. When opening a laboratory for remote access using the VISIR platform existing hands-on workbenches are not modified but new ones that can be remotely controlled are added. In an online VISIR laboratory, the human hands are replaced by telemanipulators or other actuators that can perform the manual actions required. Unfortunately, such devices including control interfaces that are appropriate for laboratory exercises are rare commercially. However, most instruments on the market have virtual front panels that can be displayed on a remote client computer. Visual and sound effects if any can be transmitted by standard equipment. Haptics is coming but transmission of taste and odor is not yet contemplated.

Would it be possible to open all types of instructional laboratories for remote access with preserved context using the VISIR platform? The main challenge is the telemanipulator. The current VISIR platform supports opening laboratories for electrical experiments where the outcome can be observed using an oscilloscope or a multimeter. The solderless breadboard is replaced by a relay switching matrix designed at AET [14]. The matrix accommodates an assortment of components and a circuit can be assembled by closing a number of relay switches. Of course, the instruments can also be connected to the circuit created in the same way. Thus, the matrix replaces the solderless breadboard and is an online component store as well. The student controls the matrix by wiring her circuit and connecting the instruments on the virtual breadboard. The platform supports also laboratories for mechanical vibration experiments where the electrical circuit is replaced by a mechanical structure. However, the telemanipulator is somewhat restricted. Assembling the structure from parts is not yet supported but multiple sensors located at interesting points of the structure are connected to a signal analyzer replacing the oscilloscope [15].

Hands-on instructional laboratories contain a number of usually identical workbenches at which students, often in pairs, perform experiments supervised by an instructor. If the equipment is very expensive, a laboratory may contain only one workbench. Optimal is if the number of workbenches balance the capacity of one instructor. Each existing VISIR laboratory has only one workbench. However, electrical experiments can usually be performed

in sub second scale, i.e., in machine time. VISIR uses this characteristic in order to allow simultaneous access to one online workbench from more than one student computer by time-sharing. In the current VISIR laboratories for electrical experiments, each student wires her circuit, sets the instruments, connects them in her own computer in human time, and then performs the experiments in machine time in an online workbench (server). Thus, when the student has specified the experiment in her own computer, she presses a *Perform Experiment* button to send a message containing the experiment specification to the server. The workbench reads the message, and if no other experiment procedure is in progress (otherwise the message will be queued), the experiment is conducted in a proper predefined order. Thus, one online workbench for electrical experiments can support a great number of simultaneous users [16]. Removing this restriction and the *Perform Experiment* button requires more equipment and a proper remote laboratory methodology.

The time-sharing scheme discussed in the previous paragraph allows a single time-shared online workbench for electrical experiments to emulate a whole laboratory with many workbenches but it is a trade-off between high capacity and experiment fidelity. Time-sharing implies batch mode operation i.e. the experiment that the student defines is performed in a predetermined order in the server. Thus, to allow students to control every detail of the experiment process they must have exclusive access to one workbench. In other types of instructional laboratories the experiments must be performed in human time and then time-sharing the equipment is no option. The normal mode of operation of a laboratory based on the VISIR platform 5.0 is one user per workbench i.e. no time-sharing because most experiments in common disciplines are performed in human time. However, the workbench 5.0 for electrical experiments will still support time-sharing as an option. Evaluations have shown that this low-cost option is appreciated [10], [16].

Hands-on laboratories are usually open for students only during supervised experiment sessions when an instructor is present for reasons of security. Scheduled supervised such sessions can also be delivered online. Video conferencing tools such as Adobe Connect providing common desktop can be used to communicate between the students themselves and between the students and the instructor [17]. A typical supervised experiment session is four hours. This period may not be enough for some students to finish their experiments. For example, a student at a university with a VISIR laboratory who has not completed an experiment during a supervised session in the hands-on laboratory may repeat parts of the session remotely at home. Students enrolled in certain courses with a laboratory component at BTH are permitted to perform the experiments of every session of that course at any time when there is a free online seat. The number of seats in the laboratory for electrical experiments equipped with one time-shared workbench is set to 16. Maybe the number could be higher without risking to long response time but 16 is sufficient for BTH.

IV. VISIR PLATFORM 5.0

The new laboratory learning infrastructure will be composed of two "clouds" as is illustrated in Figure 1. One will be an open repository comprising learning material especially laboratory instruction manuals

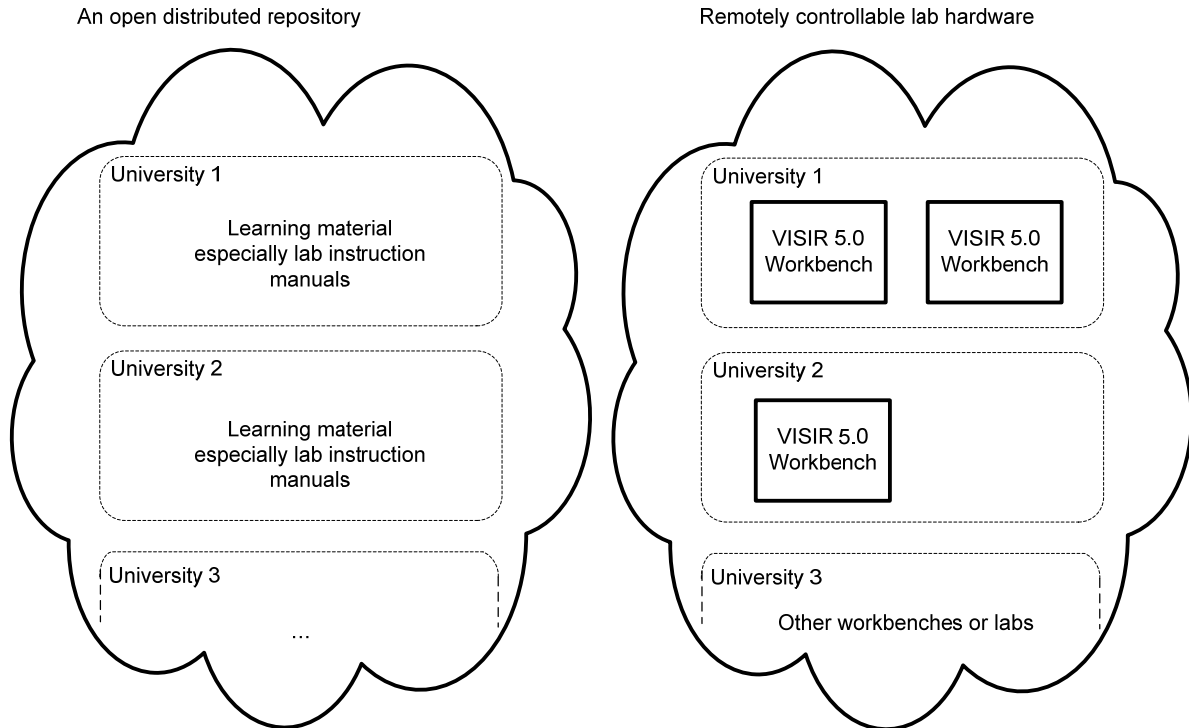


Figure 1. Laboratory learning infrastructure.

supplied by teaching organizations within the VISIR Community. Schools and universities will be welcome to contribute material to the repository and to be members of the Community. The other “cloud” will be composed of online laboratory workbenches based on the VISIR platform 5.0 located at collaborating schools and universities. Each of the institutions will contribute one or more workbenches. The existing VISIR workbenches are expected to be upgraded and become the initial laboratory “cloud”. Every organization is expected to control and to maintain its own learning material and equipment. The idea is that the learning material will be free to use for everybody but the equipment will not. Each institution will decide when other organizations are permitted to use it.

A teacher may reserve a number of workbenches for a particular time period located anywhere in the “cloud”. The time period could be the duration of a course or an experiment session. This sort of collaboration/cooperation scheme should adhere to a set of requirements satisfying the views of all involved actors, both human and technological [18], [19]. For instance, Figure 2 depicts a case where the LMS of one particular institution could have some sort of access capabilities to the VISIR workbenches hosted by a co-operating institution. Another alternative could be the direct access from one particular course, integrated in the LMS of one institution, to one or more experiments supported by the VISIR platform of another institution. Whether this sort of collaborative/cooperative mechanism is purely technology or human regulated, or even a combination of both, is yet to be determined. In any situation, the role played by each actor in a collaborating/cooperating scheme involving remote laboratories - in the present case the VISIR

platform – should be carefully considered to take the most out of a federation of VISIR laboratories.

The platform should support some kind of accounting. Then it would be possible to compensate organizations providing many workbenches and offering much time for students of other organizations. It would also be possible for organizations without VISIR laboratories to benefit by the resources provided. Furthermore, it would be possible

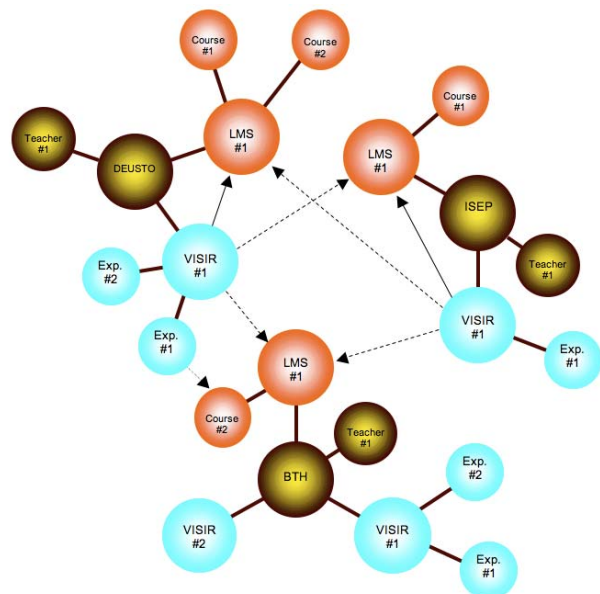


Figure 2. Topology for a collaborative/cooperating scheme among educational institutions involving a number of LMS and a federation of VISIR laboratories.

for commercial organizations to participate. For example, a student would receive some money tokens to spend on experiments and a workbench could charge one or more tokens per time unit. This could maybe be a type of micro-charging. However, this is not a trivial issue [20], [21].

Figure 3 shows a block diagram of a VISIR 5.0 workbench. It can provide; inter alia the following:

- A list of equipment provided
- Virtual instructor rules if any
- Client module and modules of the virtual front panels of the telemanipulator and of the instruments to be automatically downloaded to a client computer
- A specification of audio, and video transmission if any
- A schedule showing time reservations
- Accounting information
- A list of restrictions and known errors

Everybody can access the information pages of a VISIR workbench. The teachers create an environment in the local LMS (Learning Management System) with links to the laboratory instructions manuals and to other learning material of her particular course. The environment includes money tokens and links to the “cloud” laboratory composed of the workbenches reserved as is illustrated in Figure 4. Each enrolled student log on to the local LMS and works in the environment the teacher has created and she does not need to know which workbench she uses or where it is located. Guest users can only access the workbenches if an organization in the VISIR Community creates a guest course using its own equipment or offers money tokens to be used for accessing other workbenches.

V. CONCLUSIONS

VISIR laboratories supplement hands-on instructional laboratories. So far laboratories for electrical experiments and for mechanical vibration ones are supported. The fact that most electrical experiment can be performed in sub second time intervals is used to make a single time-shared online workbench emulate a whole laboratory for

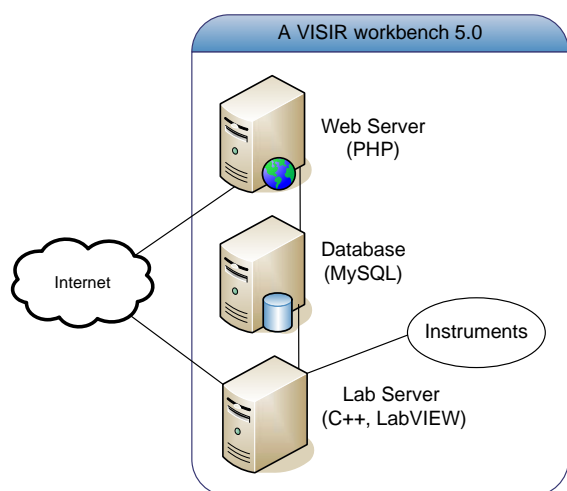


Figure 3. VISIR workbench 5.0.

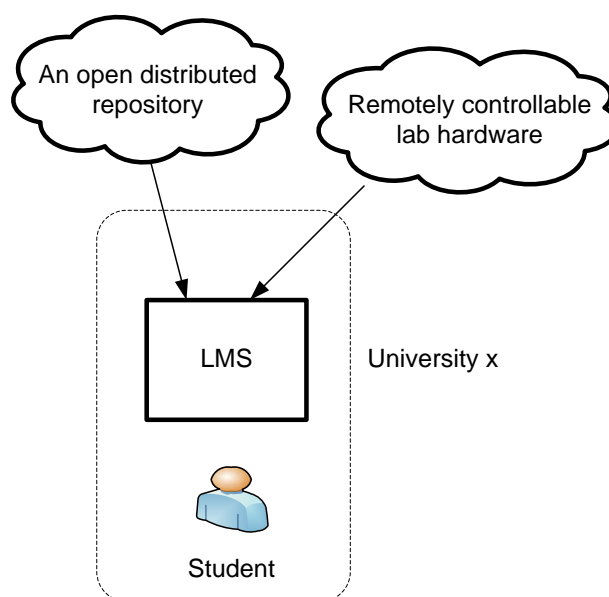


Figure 4. The student interface.

electrical experiments. This is a trade-off between high capacity and experiment fidelity. In other subject fields, time-sharing is no option. By organizing “cloud” laboratories composed of a number of shared online workbenches, teaching organizations could offer each student or student team exclusive access to an online workbench and full control of the experiment process. Such laboratories would be replicas of hands-on ones albeit the human hands would be replaced by a telemanipulator. A number of students could perform experiments and genuine laboratory work simultaneously and work together and help each other without being collocated.

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AUTHORS

I. Gustavsson is with Blekinge Institute of Technology, ING_AET, SE-37179 Karlskrona, Sweden, (e-mail: ingvar.gustavsson@bth.se).

K. Nilsson is with the Blekinge Institute of Technology, ING_AET, SE-37179 Karlskrona, Sweden, (e-mail: kristian.nilsson@bth.se).

J. Zackrisson is with the Blekinge Institute of Technology, ING_AET, SE-37179 Karlskrona, Sweden, (e-mail: johan.zackrisson@bth.se).

J. García-Zubía is with the University of Deusto, Avd. Universidades 24, 48007, Bilbao, Spain (email: zubia@deusto.es).

U. Hernández is with the Deusto Research Institute, Avd. Universidades 24, 48007, Bilbao, Spain (email: unai.hernandez@deusto.es).

G. Alves is with the School of Engineering – Polytechnic of Porto, Rua Dr. Antonio Bernardino de Almeida, 431, 4200-072 Porto, Portugal (e-mail: gca@isep.ipp.pt).

R. Costa is with the School of Engineering – Polytechnic of Porto, Rua Dr. Antonio Bernardino de Almeida, 431, 4200-072 Porto, Portugal (e-mail: rjc@isep.ipp.pt).

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