A Distance Learning System for Measurement Experiments

L. Peretto[1], S. Rapuano[2], M. Riccio[3], D. Bonatti[1]

[1]University of Bologna – Department of Electrical Engineering, (Viale Risorgimento, 2 – 40136 Bologna, Tel.: 0512093483, Fax: 0512093588, lorenzo.peretto@mail.ing.unibo.it)
[2] University of Sannio – Department of Engineering, (Corso Garibaldi,107 - 82100 Benevento, Tel.:0824305804,Fax:0824305840, rapuano@unisannio.it)
[3] Didagroup S.p.A. (Viale dei Sanniti,1-82018 S.Giorgio del Sannio (BN), Tel.: 082440624,Fax:082440624, mriccio@didagroup.it)

***Abstract* -** The paper presents a remotely accessible laboratory for real-time electric and electronic measurement experiments, distributed on geographical scale and accessible to users through common Web browsers. The remote laboratory is part of an innovative platform for distance learning including a traditional Learning Management System and innovative modules enabling the learners to control real instrumentation. The paper describes the platform structure and its innovative functionalities in comparison with classical web-based training systems focusing, in particular, on a set of hardware components designed to emulate the electronic measurement instrumentation. Such components are used to teach the learners how to create their own test benches. The correctness of the connection scheme, remotely set by the learners, is automatically verified, in real-time, by a specific module of the e-learning platform.

I. Introduction

The wide spread of the Internet and, recently, of the broadband and advanced support to multimedia communication, simplify the diffusion of distance learning. The Internet makes available resources (hardware, software, data and knowledge) distributed worldwide, reaching the learners or workers at their homes with a minimum connection cost. The potentiality of distance learning for engineering topics [1] remains unchanged also in fields where the practical experience on real instrumentation is mandatory, such as in teaching of electric and electronic measurement. In fact Distributed Measurement Systems (DMSs) based on Internet can be set up to share the limited resources of one or more laboratories among a large number of teachers and learners. In such way, the costly tutored training and the learner mobility are reduced, while preserving the problems that they could encounter in the real laboratory [2] [3]. Moreover, using Internet, it is possible to deliver different types of digital contents to learners and provide them with synchronous and asynchronous didactic activities. The software environments used to achieve these results are called Learning Management Systems and are currently widely used for professional as well as university learning.

In scientific and engineering fields, the crucial phase of the learning process is the application of the acquired theoretical knowledge. In fact, from technical high schools and university courses to industry, a massive practical training is fundamental to ensure a good knowledge transfer from the teacher to learners to train qualified professionals. In particular, in electric and electronic measurement field, in order to understand the measurement procedures and system design, learners have to reach a suitable practical experience by working out on real instrumentation and by repeating the same experience many times [4]-[6].

Some drawbacks make it difficult to provide a complete set of updated workbenches to each learner. The most relevant are: (i) the high cost of measurement instrumentation and in general the high management cost of experimental laboratories in both educational and industrial sites, (ii) the increasing number of learners and the need for specialized technicians in electronic measurement field, (iii) the reduced number of laboratory technical personnel, and (iv) the continuous evolution of measurement instrumentation, that makes the staff updating difficult and very expensive.

Following the evolution of general purpose Web-based training (Fig.1), the main approaches to remote teaching of measurement related topics have been: (i) Web support to University courses, including slides of the lectures and exercises [7] [8], (ii) Web based lectures and seminars, sometimes interactive, provided by on-line Universities and hardware or software producers, mainly directed to professionals [9], and (iii) simulation of actual experiments to be executed remotely on the learner's PC [10].

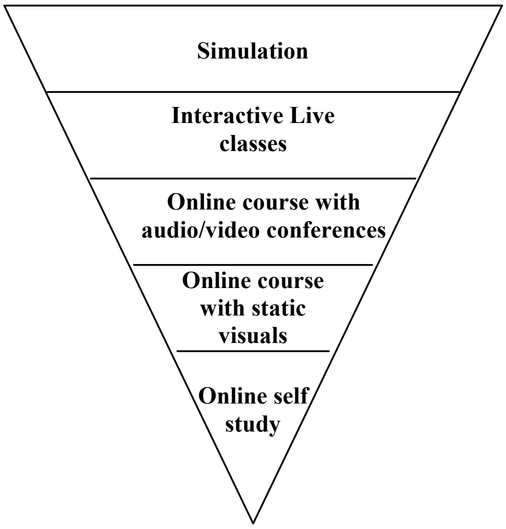

Figure 1. Evolution of Web-based training.

In order to overcome the intrinsic limits of simulation in teaching how to use real instrumentation, researchers are developing increasing efforts to implement remotely accessible laboratories providing access the instruments through a Web page [11] [12]. The DMS technologies have been used with this aim [13-16].

Almost all current proposals, nevertheless, do not integrate a LMS, so they are not able to leverage typical LMS features such as the management and monitoring of the entire learning process.

II. Remote access to measurement experiments

In this paper an innovative remote measurement laboratory based on Web technologies is proposed. It is a part of a wider project aiming to realize an international laboratory system sharing measurement resources that will operatively provides the learners of electric and electronic measurement courses with a large number of practical experiments available in geographically distributed didactic laboratories. The project has been financed by the Italian Ministry of Education and University (MIUR) within the National Operating Programme (PON) 2000-2006.

The laboratory architecture is shown in Fig.2. A learner can access the remote laboratory functionalities through standard Web browsers, without the necessity of specific software components on client side. Remote laboratory access is controlled by an off-the-shelf LMS executed on a central server that delivers the lectures and didactic material to users through Web Service technologies. The

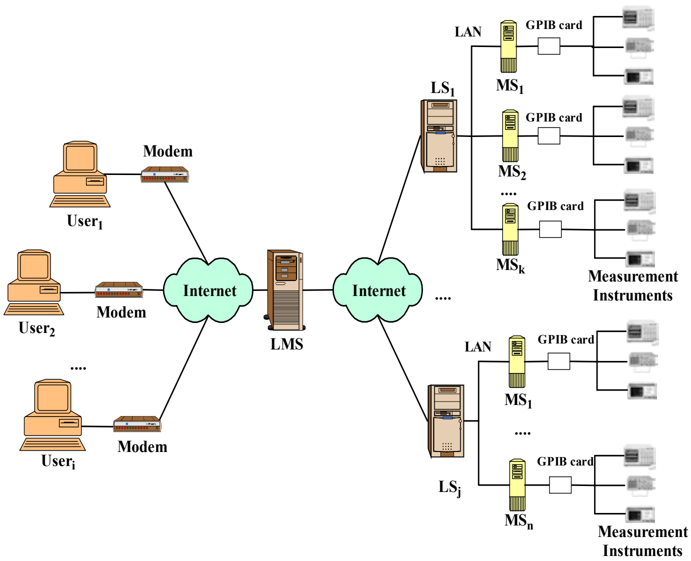

Figure 2. Architecture of the remote laboratory. LS stands for Laboratory Server.

LabVIEW environment is used for local control of the instrumentation. A self-developed access module enables the remote users in transparently getting the control of an instrument and displaying the measurement results [17].
The services delivered by the remote access and control module to the learner are mainly the following: (1) *experiment visualization*: the learner can see on her/his computer the desktop used by the teacher to control the measurement instruments involved in the experiment; (2) *experiment control*: the learner can perform an experiment by controlling remotely one or more measurement instruments; (3) *experiment creation*: the learner can remotely create a VI interacting directly with the LabVIEW environment executed on a server managing the instruments, called Measurement Server (MS).
This paper proposes a new service, called *experiment setting*, that enables the learner in setting up a measurement bench at his location that is a low-cost emulation of the real bench located in the remote laboratory and then performing the experiment by remotely controlling the laboratory instrumentation.

III. Remote set up of the experiments

As stated above, a set of hardware modules, emulating actual measurement instruments and a bread-box for the circuits assembling are provided to the learner on demand. The learner can act on her/his measurement bench by assembling the circuit and by connecting the emulated instruments and power supply to the circuit as it actually should be done in the laboratory according to a selected exercise. The correctness of both the circuit connections and of the instrument wirings is dynamically and automatically verified by the system. If the learner correctly performs all the hardware operations the measurement on the actual system will be performed and the results sent to the front panel of the learner's PC [18].
The whole system consists in a server unit and in a given number of client units. The MS unit located in the laboratory allows the measurement benches to be controlled. Each client unit is realized by means of suitable devices connected to a PC which allows the emulation of a real measurement bench. Such devices represent a novelty in the field of the e-learning. Let us refer to Fig.3 for a better explanation of the system.
The learner is provided with all the stuff for performing the exercises along with a CD-ROM containing a proper software.
When running it, a certain number of html pages are opened, which introduce the learner into the practical activity and a guide to perform the initial settings and the experiments. Then, the learner is asked to choose an exercise. By double-clicking on the proper link, some pages dealing with the theory relevant to the chosen experiment will be displayed. Then, he/she starts to build the circuit on a breadboard and to connect it to the devices, according to the chosen exercise. Only when all the wirings are correctly performed and the circuit is correctly mounted on the breadboard (a suitable software helps the learner to correct her/his mistakes), the PC accesses, via Internet, to the MS unit. The front panels of the remote-actual instruments will appear on the screen of the learner's PC allowing her/him to interact with them by setting the proper controls. Finally, he/she will perform the measurement on the actual circuit and receive the instrument readings. In the following subsections, a description of both the client and server units is reported.

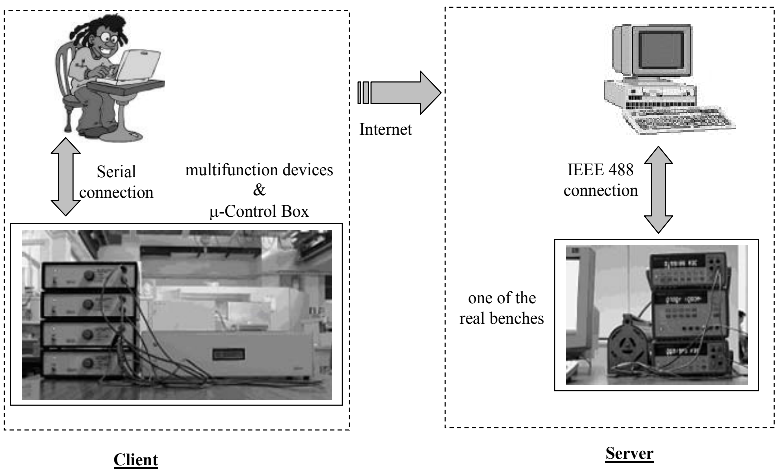

Figure 3. Schematic diagram of the system.

A. The Client Unit

Each client unit consists of six different elements [19]: (i) a personal computer, (ii) a proper software and a set of html pages, (iii) the micro-control box, (iv) multifunction devices, (v) a smart breadboard, and (vi) a set of electric and electronic components. As far as the html pages are concerned and according to Fig.4, the home page presents a system overview, addressing its novelties and main characteristics; a second page describes the proposed system architecture and its operating principle. By means of some snapshots, it also helps the learner in understanding the setup of the whole system and the features of the used devices. Finally there is a wide section dedicated to the exercises. Before the learner chooses one of them, a popup describes the procedure to follow for installing and configuring properly the received hardware; this set of operations consists in connecting each multifunction device and the smart breadboard (used to build the circuit to test) to the micro-control box, which feature an interface with the PC. Furthermore, the required software will be installed on the PC through a custom wizard. For each selected exercise, the first part of the relevant page, is dedicated to a revision of the theoretical background which the relevant exercise is based on, including a schematic diagram of the circuit to be implemented. Then, a section dedicated to which instrumentation must be used and how to build the circuit, according to the schematic diagram, is reported.

Four multifunction devices and the smart breadboard must be properly wired, by means of the provided cables, in order to emulate the actual measurement bench. Each multifunction device can emulate a DC voltage supply, a function generator, a voltmeter, a digital storage oscilloscope (DSO), and, finally, an ampermeter. The learner performs the selection by acting on a knob. Two input/output plugs (one red and one black) are available for the connections to the circuit as well as a power-on/off switch.

As for the smart breadboard, it consists of a 6-row breadboard equipped with a microcontroller-based system, as shown in Fig.5. It allows the learner to implement, by means of the provided electric and electronic components, a real circuit.

The built-in microcontroller-based system checks the correctness of the circuit assembled by the learner by acting on the 6 switches Sw0-Sw5 and communicates the test results to the micro-control box. Moreover, six input/output plugs are available for the connection with the multifunction devices.

Both the multifunction devices and the smart breadboard are connected to the micro-control box through a custom bus on the device backside. The micro-control box is the heart of the proposed system. It is a microcontroller-based tool aimed at interfacing all the devices with the local personal computer through serial connection. Its schematic block diagram is shown in Fig.6.

All the multifunction devices configurations and connections, along with the circuit topology and components relevant to each exercise, are controlled by a dedicated microcontroller. In Fig.6 seven microcontrollers (μ0-μ6) are shown; it means that currently seven exercises can be implemented by the system. After the learner has selected the exercise by properly clicking on the relevant link in the ‘Experiment’ section of the html pages (Fig.4), an algorithm, developed under LabVIEW environment, provides to μG the information, that, in turns, wakes up the relevant microcontroller (Fig.6). At this point the learner starts to build the circuit and to connect all the instruments and generators. When

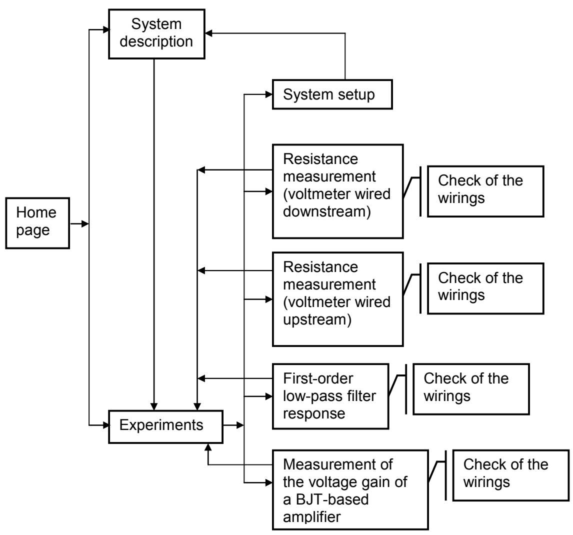

Figure 4. Tree-structure of the html pages.

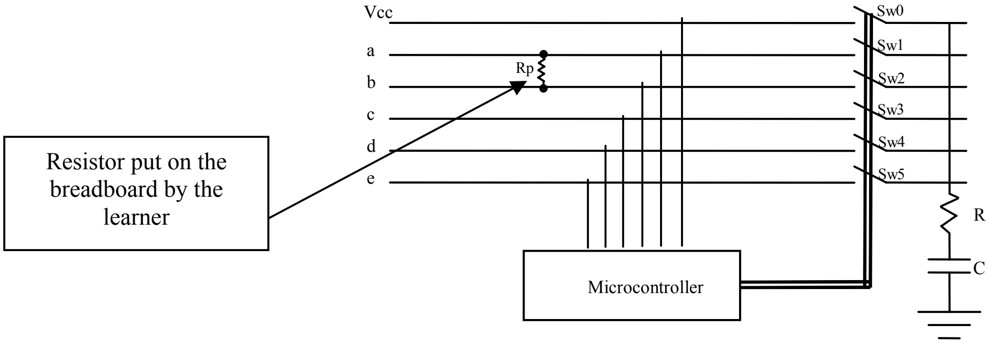

Figure 5. Electric connections of the smart breadboard.

finished, he/she clicks on a button on the screen for checking the realized system correctness. This turns into sending on the serial bus a proper command to the micro-control box.

The microcontroller, relevant to selected exercise, receives, through μG, the command and runs suitable developed algorithms. Indeed, it reads the status of the dedicated-bus pins and compares the read configuration with that of a look-up table. The comparison result is sent to the local PC through μG. It must be pointed out that at the occurrence of wrong operations performed by the learner, the check report contains clear information on what the learner has not made correctly (circuit bad mounted, wrong instrumentation chosen, bad connections, …). Such information is displayed on the screen. This helps the learner to quickly correct the mistake and to fix the system.

B. The server unit

The MS unit is a personal computer which hosts a web server and performs the measurements by controlling the instrument bench. It is realized by exploiting the functionality of the LabVIEW Server. This choice is due to the fact that this is a ready-to-use environment and allows an easy implementation of new experiments. However, it must be noted that the proposed system is independent of the software platform chosen for the server, therefore, it can run in the developed distributed laboratory system without any change.

On the request for accessing, the server sends to the browser of the learner's PC a virtual instrument allowing her/him to take control of the real instrumentation, according to the selected exercise.

Once all the parameters are selected, the measurement can be started by clicking on a suitable button located on the panel. At the end of the measurement, the waveform representing the input and output voltages are displayed on the scope. The learner can change the settings and run another waveform acquisition.

The system can manage a queue of learner requests attempting to access the same experiments. Each learner can take the control over an experiment for at least 30 minutes; after this time interval the server stops the connection to the present user and allows the next user to perform the exercise.

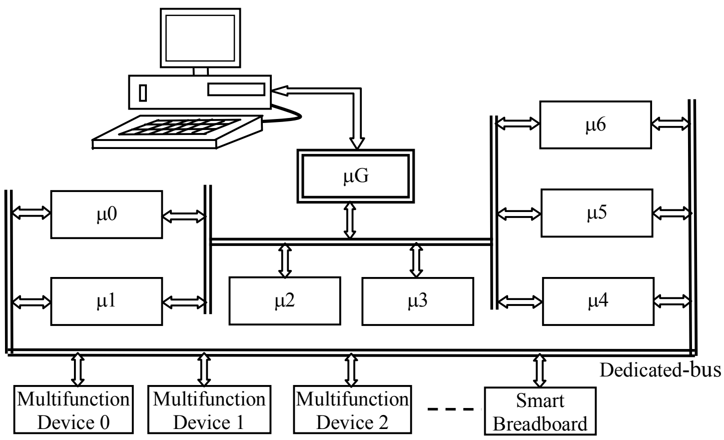

Figure 6. Schematic block diagram of the micro-control box.

Conclusions

The paper presented an innovative platform for web based training of Electric and Electronic Measurement subjects including experiences on real instrumentation. In particular, the experiment setting service has been described in its hardware and software implementation. This new service gives to the learners the possibility of acting on physical low-cost emulators of the laboratory instrumentation to build their own circuit under test.

References

[1] M. Cobby, D. Nicol, T.S. Durrani, W.A. Sandham, “Teaching electronic engineering via the World Wide Web”, *Proc. of IEE Colloquium on Computer Based Learning in Electronic Education*, London, U.K., 7/1-11, 1995.

[2] M.A. Pine, L.A. Ostendorf, “Influencing earth system science education: NASA’s approach”, *Proc. of Int. Geoscience and Remote Sensing Symp., IGARSS’95*, Italy, vol. I, pages: 567-569, 1995.

[3] G.C. Orsak, D.M. Etter, “Connecting the engineer to the 21st Century through virtual teaching”, *IEEE Transactions on Education*, vol. 39, No. 2, pages: 165-172, 1996.

[4] K. Mallalieu, R. Arieatas, D.S., O’Brien, “An inexpensive PC-based laboratory configuration for teaching electronic instrumentation”, *IEEE Transactions on Education*, vol. 37, No. 1, pages: 91-96, 1994.

[5] L. Finkelstein, Measurement and instrumentation science - an analytical review, *Measurement*, vol.14, No. 1, pages: 1994, 3-14.

[6] S.S. Awad, M.W. Corless, “An undergraduate digital signal processing lab as an example of integrated teaching”, *Proc. of IEEE Instrumentation and Measurement Technology Conference,* Ottawa, Canada, pages: 1314-1319, 1997.

[7] Laboratory of Signal and Measurement Information Processing - Engineering Faculty of University of Sannio. http://lesim1.ing.unisannio.it.

[8] Nettuno. http://www.uninettuno.it.

[9] TechOnLine - Educational Resources for Electronics Engineers. http://www.techonline.com.

[10] V. M. Rodrigo Penarrocha, M. Ferrando Bataller, “Virtual instrumentation: first step towards a virtual laboratory”, *IEEE International Workshop on Virtual and Intelligent Measurement Systems VIMS’2000, Annapolis*, MD, USA, pages: 52-56, 2000.

[11] L. Benetazzo, M. Bertocco, “A distributed training laboratory”, *Proc. of Eden Annual Conf. on Open and Distance Learning in Europe and beyond*, Spain, pages: 409-414, 2002.

[12] M. Albu, K. Holbert, G. Heydt, S. Grigorescu, V. Trusca, “Embedding remote experimentation in power engineering education”, *IEEE Transactions on Power Systems*, vol. 19, No. 1, pages: 144-151, 2004.

[13] P.Arpaia, A.Baccigalupi, F.Cennamo, P.Daponte, “A distributed measurement laboratory on geographic network”, *Proc. of 8th IMEKO Int. Symp. on “New Measurement and Calibration Methods of Electrical Quantities and Instruments”*, Budapest, Hungary, pages: 294-297, 1996.

[14] P. Daponte, D. Grimaldi, M. Marinov, “Real-time measurement and control of an industrial system over a standard network: implementation of a prototype for educational purposes”, *IEEE Transactions on Instrumentation and Measurement*, vol. 51, No. 5, pages: 962- 969, 2002.

[15] D.L. Gaissert, “A Java based test program set development environment”, *Proc. of IEEE AUTOTESTCON ‘99*, San Antonio, TX, USA, pages: 775-785, 1999.

[16] G. Fortino, D. Grimaldi, L. Nigro, “An agent based measurement laboratory over Internet”, *Proc. of IEEE AUTOTESTCON ‘99*, San Antonio, TX, USA, pages: 61-71, 1999.

[17] S. Rapuano, F. Zoino, “A learning management system including laboratory experiments on measurement instrumentation”, *Proc. of IEEE Instrumentation and Measurement Technology Conference (IMTC/2005)*, Ottawa, Canada, vol. 2, pages: 1227-1232, 2005.

[18] P. Rinaldi, R. Tinarelli, L. Peretto, “E-learning applied to the degree’s course in electrical engineering: the case of electrical measurements”, *SPEEDAM 2004*, Capri, Italy, pages: 500-505, 2004.

[19] D. Bonatti, G. Pasini, L. Peretto, R. Tinarelli, “An interactive measurement system for remote laboratory activities”, *Proc. of IEEE Instrumentation and Measurement Technology Conference (IMTC/2005)*, Ottawa, Canada, vol.3, pages: 2107-2112, 2005.