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# An Experience De-localizing a Freshman Electrical Engineering Laboratory*

A. ALMENDRA, F. J. JIMÉNEZ-LEUBE, C. GONZÁLEZ and J. SANZ-MAUDES
*Departamento de Tecnología Electrónica, E.T.S.I. de Telecomunicación–UPM, Ciudad Universitaria s/n, 28040 Madrid, Spain. E-mail: almendra@etsit.upm.es*

*A summary of the activities done by the authors in order to evaluate the feasibility of the extension to de-localized teaching of experimental matters using the Internet is presented and discussed. We have considered a basic configuration: students that do their practical work at a remote bench authenticated by a laboratory server. The existence of remote benches requires us to contemplate problems related to some kind of real time supervision and validation of the work done at the remote site as well as with the communications that are necessary to demand and deliver remote assistance. These issues are usually addressed 'in-situ' in a local lab. The work at the bench is done under the immediate supervision of a local computer that also sends information to the server about the progress of the assigned work, and that is also able to communicate with an instructor using different tools developed during this work. These isolated remote benches could be aggregated to form a remote laboratory or, in general, a virtual laboratory under centralized supervision; the activity carried out at each remote bench is monitored without the need of intervention of the student. The target we had in mind when we began the experience was to evaluate the possibility of sharing expensive resources between different users. Our conclusions and suggestions are finally stated.*

## INTRODUCTION

EDUCATIONAL HARDWARE laboratories are usually organized in groups of small numbers of collaborative students supervised 'in situ' by an instructor in order to perform an assigned experimental work. We have been using this method in the case of a first term instrumentation laboratory where the students must learn how to use basic instrumentation to conduct some assigned measurement work on set-ups they must implement. A significant advantage of this approach is that the students get hands-on experience working with 'real' set-ups. A major drawback of this method is that mistakes used to pass undetected as the students only demand the intervention of an instructor only if they think they are wrong. Alternatively, mistakes can be detected by the instructor if he is present at the bench supervising the work conducted at that time by the students. The first situation requires that the students validate their own results, and often they do not even realize they made a correct measurement on an incorrect set-up or they made an incorrect measurement on a correct set-up, or if they have used the correct settings. In this case, the supervision of the instructor is less likely if he/she has to attend to a large number of benches at a time.

The authors have recently reported a method that can improve the efficiency of the classic learning process in the scenario described above [1]. In this method, the supervision of the work done at the bench is carried out by a computer that has instrumentation control capability and that runs a program developed specifically for this purpose. In short, the program running on the computer takes the role of a 'front-line' instructor assistant, so that mistakes that used to pass undetected are now caught by the 'virtual instructor' which is also capable of suggesting a possible cause of error. We can mention, as examples, the case of incorrect selection of components for implementing a circuit, an incorrect use of the excitation, such as frequency, and voltage, incorrect measurement settings, etc.

On the other hand, the recent expansion of public use of data-oriented networks, and more specifically the Internet, has made easy the access to resources from geographically diverse locations. Using this trend, a number of web-based education experiences have been performed on the Internet; reference to some of the early work is in the bibliography [2, 3]. Nowadays, a much larger number of experiences and educational resources, not only for electrical and computer engineering, have been developed and made available to the education community [4, 5]. Most of them load the contents of the course in servers and give some kind of support by different means that span from synchronous videoconference, chat, telephone, etc., to asynchronous services such as e-mail or on-line tests. There are also solutions that require the students to download full courses for local interactive learning. These solutions have been mainly oriented toward theoretical matters. The extension of this approach to matters of experimental content has a number of additional

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challenges when exporting 'experimental work' to the Internet. The most general approach is based on the use of programs that emulate a real experiment and that allow the realization of experiments in a simulated environment, either locally or in remote mode. This virtual approach, that we consider useful as a first approach, lacks the hands-on experience that is acquired when working with real-world set-ups.

In our case, we proposed ourselves to keep hands-on experience when working at a remote site. That raises the problem of the need of supervision and validation of what is being done at the bench. We understand that this real-time supervision is the most significant challenge in our architecture, which implements a mixed model where real/non-simulated work is done at the remote site with real components which may be combined with some simulation, and it is evaluated at a first step by the local computer and eventually by a central server. A second challenge is to implement communication services that allow the student to feel that he/she has a contact of reference to place question and receive answers in a short time. We intended to evaluate the porting of our hardware laboratory to a remote site using the Internet to supervise the work conducted. We thought this could be achieved if the bench computers were networked under the control of a server acting as the trainer's console. This could be a first step towards a tele-immersive environment that would be desirable in future and that would maintain the interaction with real experiments.

In this work, a laboratory architecture along with the developed tools that implement our proposal are described. As a consequence, remotely located students can be integrated in the laboratory sessions as if they were local and the instructor is able to control remote laboratory sessions via the Internet. Herein, we present also our experience when evaluating the use of this method. The idea behind this experience was to test the feasibility of using an expensive laboratory facility in an asynchronous way (anytime, anywhere) so that it could be shared by a larger number of users at a lower cost.

## TECHNICAL SOLUTION ADOPTED

The local laboratory architecture consists of a LAN networked set of benches where the application running on each bench computer that guides the work to be performed by the students, is also capable of communicating with a central server that acts as a trainer's console. Each bench has all the necessary general-purpose instrumentation required to conduct the practical work. The central server application and the communication protocol developed allow the centralized supervision of the practical work done at each bench and the registration of every event that arises during a laboratory session. With this architecture, the assistance to the students that demand help can be delivered in person by the instructor.

We have extended this architecture to include remote benches using the Internet so that they could be dealt with as if they were connected to the LAN as any other local bench. Figure 1 shows a schematic representation of the architecture implemented.

In this scenario, some new challenges arise: first, the already existing data communications between the bench and the central server has been upgraded to allow user login and data transfer through the Internet. Second, when a student at a remote bench requires assistance, the instructor is not able to deliver it in person. To overcome this inconvenience, we have provided some extra functionality to both the server and bench (client) applications. Such add-ins consist of online communication services: voice, video and chat. Prior to initiating a session, each remote client willing to register at the lab has to be validated at the central server by the instructor. Each event, including those related to the communications, such as connection, disconnection, etc., is stored in a log file along

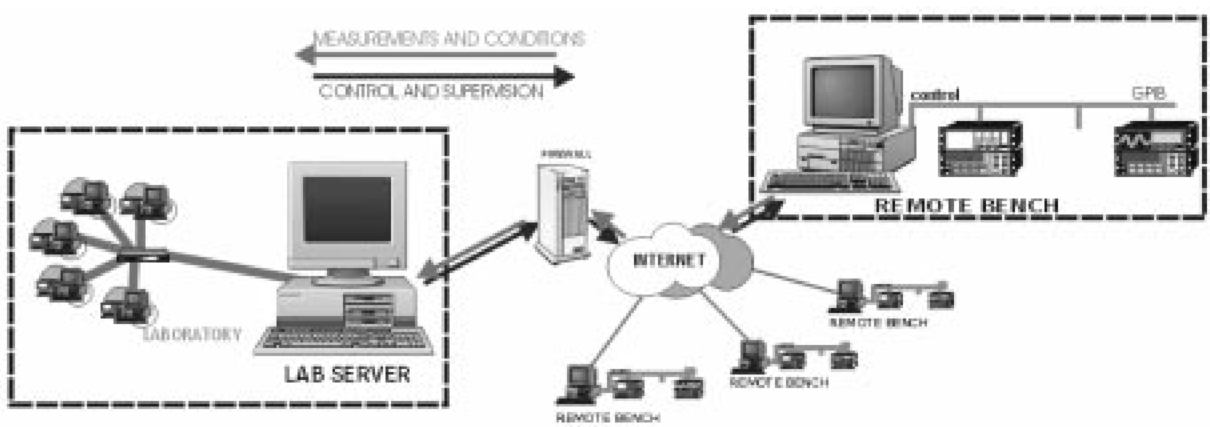


Fig. 1. Overall architecture of the laboratory (local and remote).

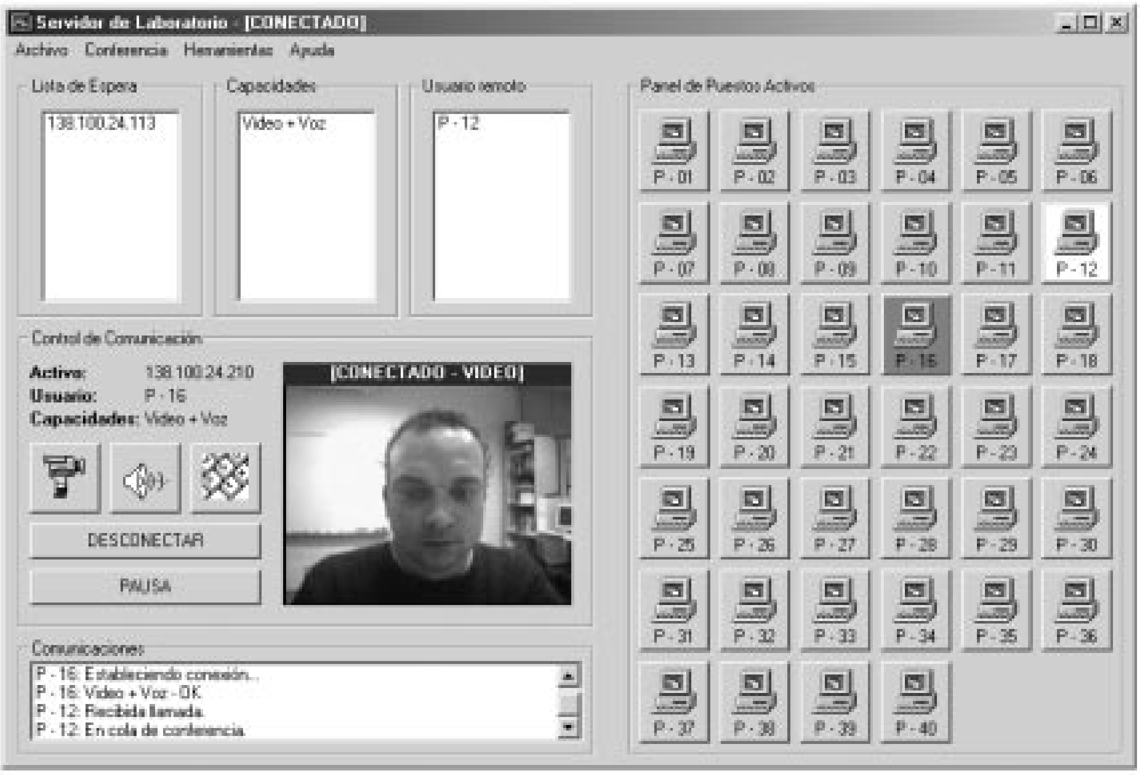


Fig. 2. Screenshot of the application interface running on the lab central server.

with a timestamp for each bench and each session. The remote test benches, as well as the server, are equipped with a low cost web cam to permit views of the experimental setting in case of problems. The functionality added to the server and client applications are based on self-specified and self-implemented high-level protocols and the H323 standard.

Figure 2 shows a screenshot of the application interface running on the central server. In this example, the server application is registering the events generated at 40 benches and simultaneously, the instructor is attending a videoconference established after an accepted incoming call. The server can, not only accept incoming calls, but can also initiate a call to any of the registered remote benches. The type of service: chat, voice and/or video is chosen by the instructor when establishing a communication.

## TRIALS AND EVALUATION

We conducted the trials with the help of some volunteer students that carried on their practical work at remote benches while their mates were doing it locally. The course has a total of seven practical assignments. Each one is intended to be carried out in three hours. The volunteers conducted three assignments remotely and the rest in local mode.

The experiments were carried out using the LAN of our department withstanding regular IP traffic. Since that LAN, at the time of this test, was a single segment one (hub connected) we can basically assume, on the average, that it supported a service equivalent to a T1 connection.

After finishing the complete experience, we surveyed the volunteers' opinions about it. Their feedback gave us their views and pointed out some improvements they considered that were needed to be done. In the following paragraphs we document their opinions as well as that of the instructor that was at the server side.

The volunteers thought that the experience was valid and applicable for a student who for any reason was not able to attend a laboratory session. They performed their practical work without any additional difficulties when compared to the sessions at the local lab. In general, they could do the assigned work with minor assistance from the instructor, but they missed the interaction with other mates while conducting their work. They all agreed that the application interface at the client side was very intuitive and user friendly. The videoconference service was, in general, considered overkill. The volunteers thought using the chat service and sending good quality still/low-rate images could suffice. They also indicated that if videoconferencing was used, a better quality of service in the voice communication and in the resolution of the images was needed.

Regarding the voice communication, the poor evaluation was due to the discontinuity of the voice links that did arise at the peaks of traffic in the LAN. As a standard IP communication with no resource reservation, the quality of service was not guaranteed, an issue that we wanted to test during the trial. We sometimes needed to repeat the sentences over the microphone until they reached their destination. This was an uncomfortable feeling that annoyed students during the experience. Concerning the images, the discontinuity is not a major cause of problems since most images are related to the experimental setting and it can be satisfied by low rate asynchronous transmission. However, higher resolution cameras are needed to effectively see the details of an image, but higher resolution cameras increase the cost of the bench, and their use was not an initial aim of the experience.

As far as the instructors' evaluations are concerned, most of the advantages and drawbacks are common to those expressed by the students. They found that the adopted solution was feasible and applicable to the course. Their perception about the application interface, ease of use, etc. was also positive as in the case of the students. They found the chat service to be the most effective way of communication, but it is necessary for the student to be able to define in writing what the problem is. Usually, this inconvenience is solved by posing a successive set of questions, which necessitates that the instructor has detailed knowledge of the practical work that the students have to perform and what kind of problems are most commonly expected at each experimental step.

The time devoted to follow and answer the questions from each bench sets a practical limit to the number of remote benches that can be realistically attended at a session. We estimate five as a reasonable number, in order to avoid long latencies that would be produced when several simultaneous incoming calls need to be answered.

Initially we planned to extend this approach to the case of students that followed the work being done by some mates at the lab bench and also to the case of geographically diverse benches forming what could be termed a 'virtual laboratory'. At this moment, we consider that more resources would be necessary to carry out an experience of this type, and some expertise on the client side would be necessary as the students need to act as a technical operator when asked to get a specific shot. The student needs some background to be able to clearly define the problem, which may not always be obvious. We have found that this approach, although useful, comes at a high price as a hardware set-up of certain quality is needed.

A lower cost approach that we are also working on, consists in sharing the instrumentation using the Internet to control the equipment at a given site after authentication; this technique has already been used in different environments. In order to apply this approach in an educational environment, we are developing a server that regulates the access to the instrumentation based on a preset hierarchy and a set of client applications to remotely control the instrumentation. However, we think this is not a good pedagogical method to be used by first-term students (freshmen) since one initial premise we wanted to keep when we chose the described architecture was to preserve real circuit problems when the student performs the practical work. Controlling remote instrumentation through a computer software interface could be a good solution for advanced users, but it suppresses hands-on experience, which represents a step back when applied to undergraduate students that need some motivation.

Although out of the scope of the work we are reporting, a set of complementary Web-based tools have also been developed in order to encourage students' motivation. We can mention, as an example, a Web application that acts as an 'intelligent mentor' posing personalized tests to the student depending on his level and rate of achievement. Applied to the teaching of electronics, we have also developed a set of tools that allows us to pose to the student different circuit topologies, so that he/she can use specifically designed virtual instruments to perform measurements on them. The results are then sent back to a server application that evaluates and either validates them or feeds back in case of mistakes.

## SUMMARY

An overview of our experience to de-localize a hardware laboratory based on the Internet has been presented. The main challenges that we have encountered in the proposed architecture are the need to maintain real-time supervision at remote sites and to provide communications that permit the demanding of assistance or activity monitoring. The developed tools permit the inclusion of chat, voice and video services. When the lab is remotely supervised using these services a number of inconveniences are detected. The most significant one is related to the fact that in standard IP protocols the quality of service is not guaranteed. This has an impact on the quality of voice links. The use of low-cost web cams permits standard IP video conferences, that is, with low rate images. The low rate is not the most immediate limitation, but the low resolution of these inexpensive cams, that degrades its utility when images of the experimental set-up are to be captured. Better performance hardware can overcome these limitations but at a cost that is not possible for an average user to pay. Despite these inconveniences, the developed tools proved to be functional and allowed a successful experience. The users (students and instructors) agree that the approach can be useful within certain specific scopes.

The architecture we have used in these trials probably will not be deployed as the expense of the bench becomes too high when standard instruments are used. We did not want to use a simulated instrumentation environment because we intended to keep the real experimentation. We consider that our challenge in the future is to study how to combine at the remote bench some form of low-cost instruments to probe real circuits that might be complemented with access to more expensive instruments located at a centralized site, and maintaining some form of supervision either done by the local computer or at the 'remote' central server. In this later case, communications that allow near real-time response are necessary.

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**A. Almendra** received the Telecommunication Engineering degree in 1991 and the Doctor in Telecommunication Engineering degree in 2001 from the Polytechnic University of Madrid (UPM), Madrid, Spain, in 1991. He has been an Assistant Professor in Telecommunication Engineering at the Electronic Technology Department, UPM, since 1991. He has worked in the development of technologies for far-infrared detectors fabrication on HgCdTe (1989–1991) and IrSi (1991–2001), and new applications of information technologies to Education in Engineering (1996–present). Since 1993, he has been responsible for the Internet/Intranet Services of the Electronic Technology Department. Dr. Almendra received the 1998 Educational Innovation Award from the UPM and he has coauthored the winning proposal of the Hewlett Packard Instructional Initiative on Telecommunication Systems/distributed/Systems Grant in 1998. His current interest is in the application of information technologies to Education.

**F. J. Jiménez-Leube** received the Telecommunication Engineering degree in 1990 and the Doctor in Telecommunication Engineering degree in 1999 from the Polytechnic University of Madrid (UPM), Madrid, Spain. He was an Assistant Professor at the Electronic Technology Department, UPM, since 1991 to 2000, and has been Associate Professor since 2000. He has worked in the development of amorphous germanium bolometers (1989–1991), far-IR detectors on IrSi (1991–2000), and new application of information technologies to Education in Engineering (1996–present). Dr. Jiménez-Leube received the 1998 Educational Innovation Award from the UPM and he has co-authored the winning proposal of the Hewlett Packard Instructional Initiative on Telecommunication Systems/distributed/Systems Grant in 1998, and the XXI COIT/AEIT Best Thesis Award in Basic Technologies for Communications.

**C. González** received the Telecommunication Engineering degree in 1980 and the Doctor in Telecommunication Engineering in 1983 from the Polytechnic University of Madrid (UPM), Madrid, Spain. He worked in trench etching in silicon at the ICLab at Stanford University (1984–mid-1985). He has been teaching electronics at the Department of Electronic Technology at the ETSIT-UPM since 1985, and he is currently an Associate Professor. After a short period working with silicon processing, he worked in the development of far-IR detector on MCT (1985–1992), flexible neural probes (1993–1995) and the application of information technologies to Education in Engineering (1996–present). His current interest is in the application of personal area network technologies to Education.

**J. Sanz-Maudes** received the Telecommunication Engineering degree from the Polytechnic University of Madrid (UPM), Madrid, Spain, in 1974, and the Doctor in

Telecommunication Engineering from the same University in 1980. He has been teaching electronics at the ETSIT-UPM from 1978 until present, where he is Full Professor. He is currently the Head of the Department of Electronic Technology. After a period working in Solar Energy materials and devices (1978–1985), he worked in the development of far-IR detector on MCT (1985–1992), Iridium Silicides (1992–1998) and the application of information technologies to Education in Engineering (1996–present). Dr. Sanz-Maudes received the 1998 Educational Innovation Award from the UPM and he has co-authored the winner proposal of the Hewlett Packard Instructional Initiative on Telecommunication Systems/distributed/Systems Grant in 1998. He was awarded with the Premio Extraordinario de Doctorado in 1981.