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A Learning Management System Including Laboratory Experiments on Measurement Instrumentation

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Abstract *– The paper presents a comprehensive approach to distance learning for electric and electronic measurement courses. The proposed approach integrates a traditional Learning Management System (LMS) with the remote access to real instrumentation located in different laboratories, without requiring specific software components on the client side. The advantages of using LMSs in distance learning of measurement related topics are summarized focusing on the LMS characteristics. Then, the remote laboratory system relying on Virtual Instruments (VIs) developed in LabVIEW and its integration with a commercial LMS is described referring to a project financed by the Italian Ministry of Education and University.*

Keywords *– Remote laboratories, Learning Management Systems, Measurement, Didactics.*

I. INTRODUCTION

E-learning has been a topic of increasing interest in recent years. It is often perceived as a group effort, where content authors, instructional designers, multimedia technicians, teachers, trainers, database administrators, and people from various other areas of expertise come together in order to serve a community of learners [1].

In order to simplify their joint work, a lot of software systems have been developed. They are generally referred to as *Learning Management Systems* (LMSs) and *Learning Content Management Systems* (LCMSs).

The primary objective of a LMS is to manage learners, keeping track of their progress and performance across all types of training activities.

The LCMS usually includes a LMS and adds an authoring system providing an infrastructure that can be used to rapidly create, modify, and manage content for a wide range of learning to meet the needs of rapidly changing business requirements.

These software systems also provide support for interaction between learning space participants, a mechanism to deliver course materials over the Web, administrative components to allow instructor tracking student records and monitoring their progress, and collaborative components like bulletin board, chat, forum, e-mail etc. [1]

Most existing web-based learning environments are based on basic instruction models. Their main functionalities are centred on the management and distribution of learning materials, synchronous and asynchronous communication, and progress tracking and reporting [2]. One of the most interesting new teaching strategies proposed for distance learning systems is Project Based Learning (PBL) pedagogy [2-3]. The approach provides teaching through the development of a project that involves the learners.

In 2000 the European Union officially announced the mission of improving the education systems in Europe with the declaration of Lisbon. Two of the main objectives to realize such mission are: to give to all citizens the same opportunities of improving his/her degree of instruction and to promote the institution of a life-long learning system to update the competences and to encourage new specializations of the adult people, thus increasing their capability of finding or changing their work. E-learning seems to be the best way to reach these objectives, as it removes the physical, geographical and cultural barriers to the education and enables the learners in choosing their own learning path and time.

Laboratory activity is an open challenge for on-line teaching applied to scientific domains. The remote control of instrumentation and the execution of real experiments via Internet are topics of interest for many researchers [4-8].

In this paper, a distributed platform based on a LMS is proposed in order to provide full courses of electric and electronic measurement including theory as well as practical experiments on actual instrumentation. The proposed solution integrates the advantages provided by an off-the-shelf LMS, compliant with international standards for web based training, and a new approach for providing remote experiments on measurement instrumentation, based on web services and the thin client paradigm. The proposed approach relies on VIs developed in LabVIEW and ensures that the students access the instrumentation without downloading heavy plug-ins.

The work described in the paper includes a project financed by the Italian Ministry of Education and University within the National Operating Programme (PON) 2000-2006 [9]. The initial infrastructure is composed of the laboratories at the University of Sannio and at the University of Reggio Calabria “Mediterranea” under the patronage of the National Research Association on Electric and Electronic Measurement (GMEE), and the collaboration of about twenty Italian universities and some specialized instrumentation, e-learning and publishing companies such as National

Instruments, Tektronix, Agilent Technologies, Yokogawa, Keithley, Rockwell Automation, Didagroup, Augusta publishing.

Moreover, the work carried out until now led to a second project, financed by the Italian Space Agency, aiming to design a satellite-based distance learning system [10].

The paper is organized as follows. Section 2 describes the main functions and the trends in development of LMSs. Section 3 summaries the most recent proposals for realizing remote laboratories for didactic purposes. Section 4 describes overall architecture of the proposed platform and the delivered functionalities. Section 5 presents the system architecture and its hardware and software components. Section 6 illustrates some performance evaluations of remote visualization of instruments panels based on the proposed solution.

II. LEARNING MANAGEMENT SYSTEMS

A general agreement seems to exist regarding roles played by people in a learning environment as well as regarding the core functionality of modern e-learning platforms [11-13]. The main players in these systems are the *learners* and the *authors*; others include trainers and administrators.

Authors (teachers or instructional designers) create content, which is stored under the control of a LMS and typically in a database [12,14]. Existing content can be updated or exchanged with other systems. The LMS is managed by an administrator, and it interacts with a run-time environment which is addressed by learners, who in turn may be coached by a trainer. Importantly, these three components of an e-learning system can be logically and physically distributed [11]. In order to make such a distribution feasible, standards such as the *Aviation Industry Computer-Based Training Committee* (AICC) [15] and the *Instructional Management Systems* (IMS) guidelines [16], the *Sharable Content Object Reference Model* (SCORM) [17], and the *Learning Object Metadata* (LOM) [13] specifications, try to ensure plug-and-play compatibility and enable interoperability, accessibility, and reusability of Web-based learning content.

E-learning systems may rather be implemented in such a way that a customization of features and appearance to a particular learner's needs is supported. To fulfil the needs of a flexible system, a learning platform has to meet a number of requirements, including the integration of a variety of materials, the potential deviation from predetermined sequences of actions, personalization and adaptation, and the verifiability of work and accomplishments [11].

Content consumed by learners and created by authors is commonly handled, stored, and exchanged in units of *learning objects* (LOs). Basically, LOs are units of study, exercise, or practice that can be consumed in a single session, and they represent reusable granules that can be authored independently of the delivery medium and be accessed dynamically, e.g., over the Web [14]. Ideally, LOs can be exchanged between different LMSs and plugged together to build classes that are intended to serve a particular purpose or goal.

Learning objects can be stored in a relational or an object-relational database and are typically broken down into a collection of attributes, some of which are mandatory, and some of which are optional; a more concrete proposal appears in [14]. Indeed, the area of e-learning consists of a multiplicity of complex activities that can be modelled as processes or workflows and can be attributed to and associated with the various components of a learning platform. By using a workflow management system, for example, one can think of a college degree program that is fully supervised by an electronic system [11]. Currently, in Italy, there are some examples of Universities providing college degree programs at distance that have been certified by the Ministry of Education and University, e.g. the "Guglielmo Marconi" University [18].

Recently, much research has been focused on e-learning technologies, and many topics have been presented covering accessibility, interoperability, durability, and reusability of components [19]. A deep review of a wide number of LMSs on the market can be found in [20], where a guide to choose among their functionalities is also provided.

Nowadays, the trend in education strategies goes in the direction of learner-centric learning. A learner-centric learning places learner at its heart. Learners are expected to actively engage in the learning process to construct their own learning. A learner-centric learning will give learners a deeper and richer learning experience, as there is greater participation and involvement in the learning [21].

The practical experience provided by LMSs and LCMSs is still mainly limited to simulations.

III. REMOTE LABORATORIES

In order to understand the measurement procedures and measurement system design, it is necessary to repeat the same experience of actual measurements of physical phenomena many times in order to make all learners able to operate the measuring instrumentation [22-23]

Some drawbacks make it difficult to provide a complete set of updated workbenches to every learner. The most relevant are: (i) the high cost of measurement equipments and in general of the experimental laboratories in educational sites and industry, (ii) the growing number of students and specialized technicians, (iii) the reduced number of laboratory technical staff (iv) the continuous evolution of measurement instrumentation involved, that makes it difficult and very expensive to keep the technical staff up-to-date.

The potentiality of remote teaching [24] and, in particular, the use of the Internet as a channel to reach the students or workers at their homes was soon recognized [25-27]. Therefore, currently a lot of teaching material can be found as (i) Web based lectures and seminars [28-30], (iii) simulation of experiments [31,32], and, more rarely, (iv) remotely accessible laboratories, where the learners can access real instrumentation through a Web page [7,8,33-35].

As the off-the-shelf LMSs are usually closed, proprietary software, often not customizable at all, the research carried out by scientists to provide teaching of electric and electronic measurement including experiments didn't take in account the possibility of integrating remote laboratories and LMSs.

The focus of their activity, instead, was the development of the remote laboratory itself, and adding scheduling and user account management modules. From the realization point of view, most of the solutions found in literature, require that the software enabling the remote control of the instrumentation (virtual instruments or VIs) is developed almost from scratch, in C, C++, Java language. The project [33], following the research trend in [6,7,36], reverses the problem relying on the use of LabVIEW from National Instruments, a standard language for VI development, for producing the VIs and the software AppletView, from Nacimiento, to produce Java applets that constitute a remote interface of LabVIEW VIs. In such a way it is possible to reuse the wide number of already developed VIs for integrating existing instrumentation in a remote laboratory without developing new software. These solutions require the development of the accessory software applications enabling the sharing of the laboratory instrumentation, such as the scheduling and security policy. Following the same approach found in the LMS oriented research, in the last years a new trend started for ensuring the VI interoperability and reusability using the XML (eXtensible Markup Language) and SOAP (Simple Object Addressable Protocol). The VIs are realized and could be accessed as web services [6,8]. The main advantage of these solutions is that they can be easily integrated in LOs for existing LMSs.

IV. REMOTELY ACCESSIBLE EXPERIMENTS AND THE LMS

The paper proposes a new distance learning environment for teaching electric and electronic measurement that integrates an off-the-shelf LMS and a geographically distributed laboratory. In particular, the next sections describe the main services provided focusing on the distributed laboratory accessed through the LMS. The distributed laboratory, its architecture and innovative functions as well as its integration with the LMS will be described.

A. Delivered services

The developed distance learning environment delivers the typical functionalities of a common LMS described above, including user authentication and management and tracking of learning process at user level. Moreover, it provides several innovative functionalities encapsulating in specific LOs the remote control of measurement instrumentation. This objective has been achieved by developing an additive module for the LMS Inform@ by Didagroup [37]. The module ensures the integration of VIs written in LabVIEW in the LMS as LOs, thus enabling remote users to transparently get the remote control of a real measurement instrument and to display the measurement results within the normal learning activities.

The remote laboratory is distributed on geographical scale since the measurement instruments are physically located in laboratories belonging to different universities.

Different user profiles are managed by the system: *student*, *teacher* and *administrator*.

The services delivered by the remote measurement laboratory module to the student are mainly the following:

(i) *Experiment Visualization*, this service allows the student following on-line the laboratory activity of the course teacher.

(ii) *Experiment Control*, this service allows the student to perform an experiment by controlling remotely one or more actual measurement instruments.

(iii) *Experiment Creation,* this service allows the student to remotely create a VI using the development environment executed on the servers connected to the measurement instruments.

The services delivered to a teacher are related to the remote handling of the available experiments.

Finally the administrator is responsible of the correct working of the overall distributed system and of handling of user profiles.

B. Architecture of the distributed laboratory

In order to allow a student to access a remote and geographically distributed didactic laboratory, the paper proposes a Web-based multi-tier distributed architecture centered on the LMS, that can be considered as the core component of the overall system.

The module designed to manage the remote laboratory is based on a scheduling system, that manages the catalogue of available measurement instrumentation, and re-directs the user request to the measurement laboratory, chosen among the partner laboratories, in which the required instrument is currently available.

The proposed multi-tier architecture is composed of the following three tiers :

i. *the presentation-tier* manages the experiment visualization on the client-side. It is based on standard Web browsers, with no need of specific software components. The only software component needed is the Java 2 Runtime Environment.

ii. *the middle-tier*: manages the system logic on the server-side. It includes the following components:
   - The LMS, executed on a central server of the overall e-learning environment, called *Laboratory Portal.* The LMS interfaces to the users through a Web Server, that is hosted on the same machine.
   - A *Laboratory Server* (LS) that is used to interface a real measurement laboratory with the rest of the architecture. There is a LS for each measurement laboratory of the universities involved in the project. It delivers the access to the laboratory measurement stations through a bridge service. The LS is the only

machine in a measurement laboratory directly accessible through the Internet. For this reason the LS can also be used for security purposes.

- A *Measurement Server* (MS) that is a PC enabling the interaction with one or more instruments. A MS is physically connected to a set of different electronic measurement instruments through a GPIB interface.

The used VIs are stored in a database of the MS, where the LabVIEW environment is installed. No adjustment is necessary to include a VI in the virtual learning environment, therefore the wide number of existing VIs can be reused without requiring additive work.

iii. *the storage-tier*: it performs the data management. It is based on a series of geographically distributed databases, managed using the Relational Database Management System (RDBMS).

In order to overcome the well-known security weakness of Microsoft based networks, each laboratory is protected by a Linux-based gateway machine which operates firewalling and Network Address Translation (NAT).

C. Design of the distributed laboratory subsystem

One of the most relevant problem designing the laboratory subsystem is the remote visualization and control of an experiment.

The main design objectives taken into account were the following:

(i) *portability*: the visualization environment has to be portable on different hardware platforms and operating systems;

(ii) *usability* and *accessibility*: the visualization and the management of an experiment have to be easy to understand and to perform and the system features have to be accessed easily and homogeneously by students operating at University laboratories or at home;

(iii) *maintenance*: reduced maintenance costs. This can be made possible through a client-server approach;

(iv) *client-side common technologies*: students have to access the system using their desktop computers with no need of powerful processors or high memory capacity, connected to the Internet through narrow band dialup connections;

(v) *security*: the remote access of the students through the Internet must preserve the integrity of recorded and transmitted data and of the system;

(vi) *scalability*: the system performance has to not be degraded with the increase of the connected users.

In order to achieve these objectives the paper proposes a solution in which a student obtains the remote displaying on his home computer of the application executed on the MS for controlling the instrumentation (*thin client model*).

A *thin-client model* is based on a distributed computing paradigm in which the network separates the presentation of the user interface from the application logic. It is a client-server architecture in which the application execution and data management is performed on the server, called *Terminal Server*. The user interacts with a lightweight client, called

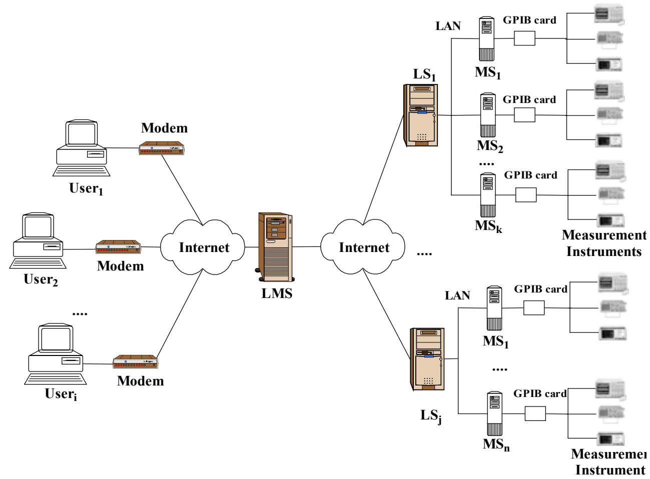

Fig. 1. Hardware components of the proposed architecture.

Presentation Client, that is generally responsible only for handling user input and output. As a result, the client generally does not need many resources and can have a simple configuration, so reducing support and maintenance costs. By using thin client technologies students are also able to use limited hardware devices, the so called *thin client devices* equipped only with a processor and a flash memory. This solution extends the class of possible learners to mobile users, owning a smart phone, a personal data assistant or a notebook with a modem or a wireless LAN adapter.

The thin client paradigm allows the platform to visualize and control a remote device through the interaction flow among the distributed system components described in the following points:

i. the student executes the authentication phase on the LMS platform using a login and password, interacting with the Web Server used by the LMS platform;
ii. the student chooses a service (*Experiment Visualization*, *Experiment Control*, *Experiment Creation*);
iii. the student visualizes on his/her desktop the VI front panel on the MS which he/she is connected to.

If the chosen service is the Experiment Visualization:

a. the student is connected to the LS where the teacher is performing the experiment;
b. the Bridge Service of the LS finds the MS that is currently used by the teacher, and allows the student to connect to the related Terminal Server in order to visualize the experiment on his/her own computer.

If the chosen service is the Experiment Control or Experiment Creation:

a. the student chooses an experiment among a list of available ones;
b. on the basis of the required experiment, the student is connected to a LS of a partner University which is equipped with the required measurement instruments available for the deployment of the experiment, chosen by the scheduling system of the LMS platform;

c. the Bridge Service of the LS finds the MS that is connected to the required measurement instruments, and allows the student to connect to the related Terminal Server in order to visualize and manage or develop a new VI from his/her own computer.

It is worth to note that sharing the Experiment Creation phase, once a project has been assigned to a student, the related instrumentation is also known. The main difference between the Experiment Control and Creation is the student access to a VI front panel only or to the whole LabVIEW development environment.

In order to allow a client to access the system without the need of pre-installed software, a *Remote Desktop Protocol* (RDP) client has been used, allowing the remote desktop to be visualized on the client-side using a standard Web browser. In particular, on the client-side, the *Terminal Server Advanced Client* (*TSAC*) released by Microsoft, that is a Win32-based ActiveX control, can be used to run Terminal Services sessions within Microsoft Internet Explorer.

In order to avoid malicious attacks to the system, the student has to obtain the remote visualization of the VI front panel without the privileges of a full user account on the MS, that is, instead, necessary to exploit the functionalities of the Terminal Server executed on that machine.

This goal has been achieved through the insertion, made by the bridge component, of a valid username and password in the connection request made by the RDP client.

Because of the legacy nature of the TSAC, it is not suited to modify at run-time the RDP connection request in order to insert the valid username and password. For this reason the development of a specific RDP client using the Java Applet technology was decided thanking to Java support to multithreading, code mobility, and security. The applet permits the connection and the automatic authentication on the Terminal Server of the chosen MS.

V. First Results

The proposed learning environment, called LADIRE [38], has been realized in its software components and is currently being tested at the Laboratory of Signal Processing and Measurement Information (LESIM) of the University of Sannio [30]. The LADIRE has been realized with 1 LS, 1 firewall/NAT, 10 MSs, 40 measurement instruments going from simple Agilent 6.5 digit multimeters to the most up-to date Tektronix TDS 7704 oscilloscope and LeCroy SDA 6000 serial data analyzer, including spectrum analyzers, impedance meters, power meters, signal generators, power supplies. The enhanced LMS has also been installed on a Dell PowerEdge server, located in the same LESIM and a Web portal (www.misureremote.unisannio.it) has been realized to enable the authoring of didactic contents from other universities.

The collaboration of electric and electronic measurement professors coming from about twenty Italian Universities and the Italian Association of Electric and Electronic Measurement Researchers is providing such didactic contents as well as several measurement experiments. Some others are currently being developed at the LESIM.

The RDP clients based on ActiveX and Java Applet technology have been tested measuring the bandwidth occupation of the client-server interactions, during the remote execution of an experiment. Because thin-client platforms are designed and used very differently from traditional desktop systems, quantifying and measuring their performance effectively is a very difficult task [39]. The use of optional mechanisms of the thin-client protocol, the application executed on the server, the network bandwidth and the kind of traffic that shares the bandwidth segment, etc., can influence a performance comparison.

In order to carry out the performance evaluations for the project, it has been used a reference experiment, the Spectrum Measurement VI provided as a LabVIEW example from National Instruments. It doesn't control any instrument, so the bandwidth measurement is independent from the programmer's efficiency and from the GIPB communication latencies.

The server configuration on which the Terminal Server is executed is one of the MSs already operating in the laboratory in Benevento, its characteristics are: Pentium IV CPU at 2.80GHz, 512MB of RAM, Windows 2003 Server. Its network bandwidth towards the Internet is currently about 768 kbps. The client was located at the site of Didagroup company in San Giorgio del Sannio, a town near Benevento. The configuration of the client is: Pentium IV CPU at 2.0GHz, 256MB of RAM, Windows XP Professional. Its network bandwidth towards the Internet is 56 kbps.

Using the ActiveX-based client, during the time interval in which the user performs some operations on the VI, the bandwidth is nearly entirely occupied. Outside these time intervals, thanks to the use of the compression and persistent caching mechanisms of the RDP protocol, the bandwidth occupation decreases, up to about 5.6 kbps. Using the developed Java RDP client, it has been achieved a similar performance. This is made possible mainly to the use of the same persistent caching mechanism of the RDP and to the possibility of opportunely changing the cache dimension on the client-side. In particular, during the time intervals in which the user performs some actions on the VI, the bandwidth occupation is included between 32 and 56 kbps. In the other time the bandwidth occupation decreases to about 5.2 kbps. Relying on such bandwidth occupation, the hardware requirements on the client side are limited to a 56 kbps modem. On the laboratory side, 768 kbps are enough to manage 10 different experiments contemporarily active in the Experiment Control or Experiment Create modes. As the LMS already support multicast communication, the laboratory bandwidth is not a problem in the Experiment Visualization mode.

Ongoing activities focus on the experimental assertion of the robustness of the scheduling system when many VIs are being executed contemporarily and a long request queue should be managed. Moreover, a deep analysis of the security of the proposed thin client model is being carried out.

VI. CONCLUSIONS

The paper presented a distance learning system for teaching electric and electronic measurement. The theoretical parts of the courses are provided by a standard LMS, enabling (i) the account management; (ii) the security protection; (iii) the collaborative learning; (iv) the student activity tracking, and (v) the feedback collection. The experiments on actual instrumentation are supported by a distributed laboratory system including remotely accessible instrumentation. The experiments are managed by the students from their homes requiring a web browser only. The remote visualization of the experiments is going to be improved by means of video cameras and low bandwidth video streaming technologies. The project, started in 2003, is going on with the collaboration of several Italian universities to be certified by Italian Ministry of Education and University.

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