A technique for remote management of instrumentation based on Web Service

Pasquale Daponte[1], Claudio De Capua[2], Annalisa Liccardo[2]

[1]*University of Sannio – P.zzo Bosco Lucarelli, Piazza Roma, 82100 Benevento, Italy*
Phone: +39-0824-305817, Fax: +39-0824-305840, Email: daponte@unisannio.it
[2]*University "Mediterranea" of Reggio Calabria -Via Graziella, Loc. Feo di Vito,*
89100 Reggio Calabria, Italy, Phone: +39-0965-875214, Fax: +39-0965-875247
Email: decapua@unirc.it, aliccard@unina.it

Abstract - In the paper the authors propose an original solution to perform the remote control of measurement instrumentation, with the aim of realizing the experimental section of an E-Learning portal of Electrical and Electronic Measurement courses, based on Web Services implemented in Visual Basic.Net. The .Net technology proves to overcome drawbacks typically affecting most of the techniques for remote instrument control till now adopted, allowing, at the same time, the integration among different softwares and communication protocols and the connection to measurement stations only by means of a common browser. Web Services use, in fact, XML language, that is well understood by each program, and SOAP protocol, which is recognized by any software environment supporting communication over Internet. Details of the implemented Web Service are given in the following, focusing the attention on the utilities provided by Visual Basic.Net for the management of connections (as queuing procedure, reading of UDDI registry, polling of the administered servers) and implementation an E-Learning portal.

I. Introduction

Thanks to the diffusion of Internet, the high speed of networking and the growing number of people enabled to be connected to the network, E-Learning, as distance-learning method is particularly becoming interesting. This teaching technique can be useful in some situations, such as *(i)* facing problems as low availability of expert teachers, technical personnel or suitable classrooms, *(ii)* offering to students a grant for a better understanding of topics learnt during class lessons, and *(iii)* providing training courses to update technical skills. It becomes essential in other cases such as giving the chance to disabled students or people too far from the University to attend courses. In most of the engineering disciplines, experimental activities are fundamental. In particular, for an Electrical and Electronic Measurements course, laboratory experience is needed, to fix and apply the studied theory and to have an hands-on contact to the measurement instrumentation [1]. Not only do laboratories demonstrate course concepts and ideas, but they also bring the course theory alive so students can see how unexpected events and natural phenomena affect real-world measurements and control algorithms. Hence, the implementation of remote laboratories, to allow students to perform measurement experiences through Internet, proves to be an essential issue during the realization of an E-Learning portal [2]. In solutions already available in literature, the practical session of the course is provided by means of models implemented on a computer, which simulate the physical systems; they accept inputs from the remote user, process them and reply, presenting outputs to the user, according to the model they have implemented on [3-5]. However, simulation has a significant limitation: experiments on models often can be viewed as an automation solving of equation system, that can't substitute the actual observation (one of the first concept learned in a measurement course is the difference between the studied models and the real circumstances).

The achievement of remote laboratory is a complex problem and, probably, there is not a unique way to solve it; each solution has its peculiarities and drawbacks [6].

Aim of the presented research is the realization of the experimental section of an E-Learning portal for Electrical and Electronic Measurement courses [7]. It will manage a laboratories system distributed on geographical network covering the whole national territory (even though its expansion to an international network is expected). The starting core of the portal relies on laboratories provided by University of Sannio and University "Mediterranea" of Reggio Calabria, while other Italian universities and private undertakings will support and integrate the project through their own issues. In its final version, the system will provide remote users (able to access with the minimal waiting time) with a wide set of possible experiments. Accessing times will be reduced by replicating the same experiment on different physical laboratories; this way, concurrent accesses to a particular experimental application would effectively be managed through a suitable parallelism of the actual measurement station. At this

aim, several solutions have been evaluating [8]. In this paper the desired task has been reached by means of .Net – based Web Services, which represents an innovative technique that solves the problems relative to protocol's conflict between client and server and paves the way to a new remote instrumentation control approach.

After a description of the main features of the E-Learning portal that the authors have been realizing and a brief analysis of the alternative methods enabling remote instrument control, the solution proposed by the authors will be presented. In particular, details about its performance will be given with reference to an application example.

II. Features of E-Learning web portal

The first and basic step during the realization of an E-Learning portal is the choice of the Learning Management System (LMS), which allows to build Web-based applications according to AICC (Aviation Industry Computer-Based Training Committee) Standard [9]. A scheme of LMS is shown in Figure 1. Through an unique ID and password, clients can access in hosting (connection to a virtual server shared among clients) and housing (connection to a dedicated server) mode; the portal configuration is, then, characterized on the basis of number and nature of connections. Other essential requirements of Web-based learning system are: *flexibility*, i.e. successive applications and functions can be easily integrated; at this aim the portal has to be realized with a modular open architecture; *interoperability*, which means the system must simply interface with any kind of learning object, as Word or PDF Documents, JPEG images, Video files, applications for exchanging messages with instruments. Through this portal undergraduate students can take advantage of *(i)* virtual classroom for interactive course lessons, *(ii)* handouts provided by lecturers belonging to different Universities, and *(iii)* remote laboratory for experimental activities. In particular, the realized experimental section allows students, by means of a common standard browser (Explorer, Netscape, etc.), to perform measurements controlling real instruments and face the problems that they could encounter as they were in a real laboratory [10].
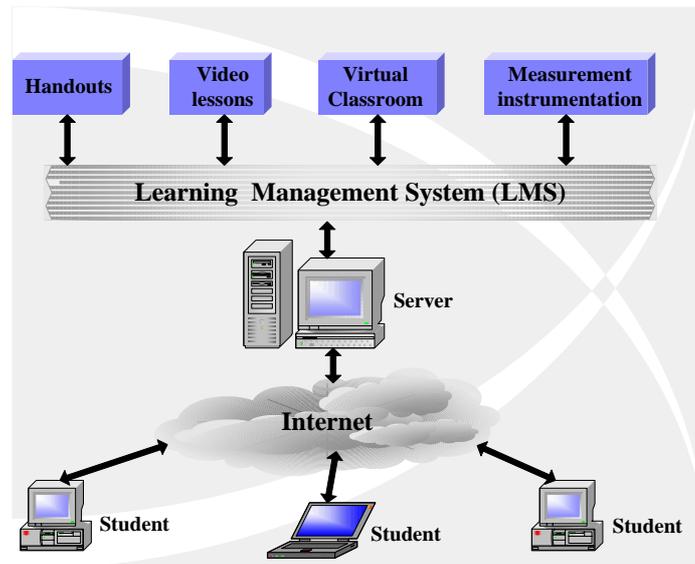

Figure 1. Scheme of LMS function.

The learning activity management allows to provide specific theoretical courses and experimental activities according to the three main teaching strategies: *(i)* blended learning, i.e. an integrated strategy involving a planned combination of approaches, such as participation to an online class, reference to manuals, and online communities, *(ii)* self learning, that allow students to administer time to spend for each argument and assess the acknowledgement level on their own, with a teacher put at their disposal as tutor, for explanations, and *(iii)* cooperative learning, in which students of different levels and abilities improve their understanding through confrontation with each other. The portal provides other accessories as Live teaching, through which students can access to a virtual classroom to take part to the lessons. Moreover, in order to check the acknowledgement state of each undergraduate a monitoring of students' activities is necessary; at this aim, the access number and the attended hours of lesson are controlled. Specific check tests are finally provided to trace the successive didactical path.

III. Analysis of remote instrument control solutions

As well known, most of the applications for measurement instrumentation control are realized through National Instrument LabVIEW™ software. A brief representation of typical solutions to realize the instrumentation control is shown in Figure 2.
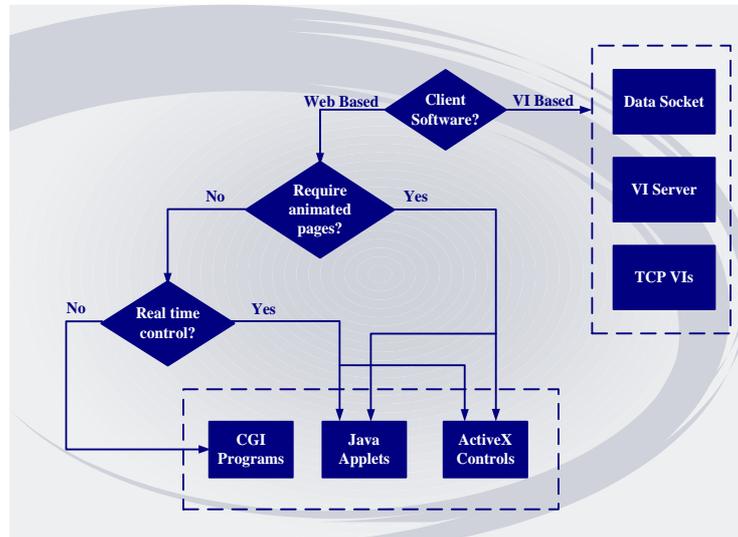

Figure 2. Brief representation of typical solutions for remote control of measurement instrumentation.

With regard to the client system software, typical solutions to share these applications on the network mainly consist of VI-based or Web-based programs. VI-based solutions are typically adopted when there is the certainty that the client is equipped with LabVIEW™ software. These solutions allow an easier implementation and more flexibility; but they impose a specific version of LabVIEW™ software to be installed on client computer. Moreover, any modification on the control software will require a new version of client program to be downloaded. The techniques available are Data Socket, VI Server, TCP VIs [11]. On the contrary, Web-based solutions are more difficult to implement, but remote users only need a standard browser to access the instrumentation control.

Remote interaction with LabVIEW™ virtual instrument through the Web, can mainly be realized by means of:

> Common Gateway Interface (CGI) programs, working on all browsers, easy to realize and interface with Hyper Text Mark-up Language (HTML) forms; unfortunately, HTML pages are static and this solution seems to be not suitable for real-time control and acquisition;
> Java applets solve the previous problem, since they are the proper solutions to public dynamic pages on the Web; their implementation, however, is quite difficult and Java Virtual Machine installed on computer client is needed;
> ActiveX controls, able to grant high flexibility level to user interface implementation; at this aim, the user has to download them. Since typical size of these controls is equal to a few Megabyte, the download process may be quite long and not all browser can allow execution due to security issues.

IV. Proposed solution

To suitably face the aforementioned problems of communication protocol, flexibility and easy implementation, the authors present an innovative solution based on Web Services, realized in Visual Basic.Net software [12]. Web Services are programmable applications that achieve a wide variety of functionality accessible through the Internet. The set of tools provided by Web services includes: *(i)* a standard to public registries known as Universal Description Discovery and Integration (UDDI), *(ii)* a description language called Web Services Description Language (WSDL) to display the functions that the web service is able to execute [13], *(iii)* an object communication protocol named Simple Object Access Protocol (SOAP) [14], and *(iv)* a dynamic self-defining information language which is known as eXtended Markup Language (XML). The great advantage of this solution consist of its general nature: combining SOAP and WSDL, a lightly coupled distributed services system able to exchange information can be built up without worrying about programming language implementations or internal data structure representations. In fact, SOAP is a standard exchange protocol understood by software

environments supporting communication over Internet, while WSDL consists of expressing the program's interface in neutral-language syntax [15]. Furthermore, integrating the Web Service with LabVIEW[TM] utilities (which remains the most confirmed way to communicate with measurement devices, through the IEEE-488 protocol) is not much difficult, so that existent applications can be included in the LMS with a small reengineering process. In fact, recent version of LabVIEW[TM] software put at programmer's disposal libraries with a variety of .Net classes and functions able to build, send and receive SOAP messages [16]. So it is enough to import some LabVIEW[TM] classes in the Visual Basic.Net project and use GPIB commands in code lines to communicate with instruments.

The realized system consists of a Web Service (in the following called General Web Service, GWS) running on a main server, mandated to administer several Instrumentation Servers, ISs, each of which is furnished with its own Web Service. According to the instrumentation connected to IS, via IEEE-488, each IS is able to perform a defined set of exercises; the distribution of the exercise on the various ISs is known to GWS by querying the UDDI registry. When a student accesses to the web portal, the GWS has to detect a client query to perform a measurement activities, register and authenticate the client and show him/her the available exercises. When an application is selected, the GWS locates, among the various administrated measurement stations, the one including the proper instrumentation to perform the required exercise, through the description of the Web Service implemented on the IS. Once located the right measurement stations, GWS executes a poll, querying the lines of the IEEE-488 bus, in order to verify the availability of ISs. If there is a free station, the student is redirected, by means of a web reference, to the application available on the free station and is able to perform the desired exercise. Differently, if all the stations are engaged by other users, the client has to be necessary queued. In this way, queuing process is managed complying with the load balancing concept; i.e. when a new client log on the Web Site, he is not queued for the access to the General Web Server, but with regard to the application required, such as the shortest waiting time is assured. The General Web Service functions and its location in communication chain are shown in Figure 3.
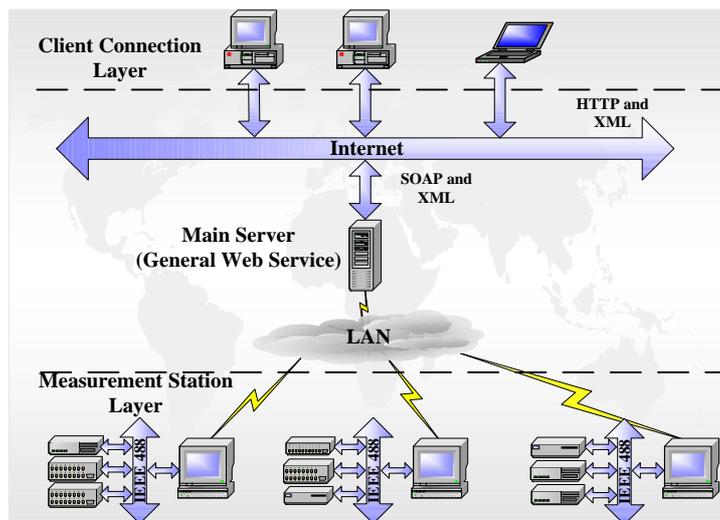

Figure 3. Connection chain and General Web Service function.

From now on, the Web Service of the instrumentation server is involved. Client interacts with a Web form, i.e. an ASP page, where the images of the instruments has been implemented; the various buttons, when pushed, produce an event invoking a Web Method (a Web Service's function) which exchanges GPIB messages with instruments. In practice, Web Service on the instrumentation server acts as an hidden layer between the user and the measurement station; the user, in fact, exchanges formatted messages with the main server through a common web protocol, as HTTP, in order to control the instrumentation. The IS forwards these messages to the measurement instrumentation, according to a suitable format (GPIB commands); in a similar way, messages generated from the station are correctly structured in a data format understandable to user's browser.

V. Example of realized application

As an example, the implementation of a web form (i.e. an Active Server Page, ASP) controlling a multimeter is discussed in the following. In Visual Basic.Net environment, event-driven programs can be implemented; when the user activates a particular event, by clicking one of the buttons displayed in the web page (shown in Figure 4), the specific subroutine is invoked and executed. This subroutine
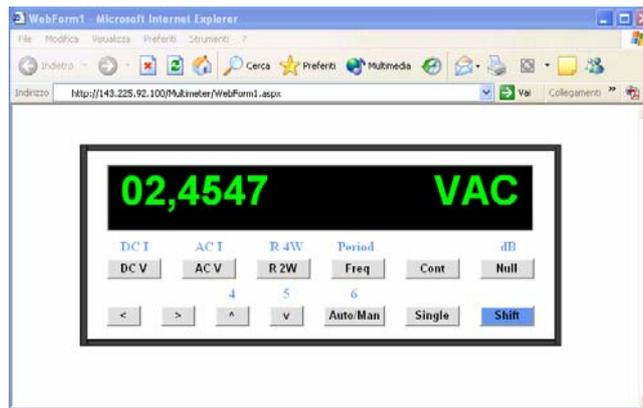
Figure 4. Web form for multimeter control.

sends the appropriated GPIB commands to the multimeter connected to server via IEEE-488, reads the measurement result and writes it in the text box simulating the instrument display. Each one of these events (i.e. each button) involves the refresh of the page, such a way that the web form can be considered interactive.

The advantages of the proposed solution are obvious if compared with VI-based solutions and Active X controls, since the users only need a common browser and have not to download anything. Differently from CGI programs, the proposed solution exhibits also the benefit of interactivity. In fact, CGI programs receive the user request from an HTML page, execute a sub-program and reply to user through another HTML page; during this time interval clients can do nothing but only to wait.

VI. Conclusions

In the paper a new technique to remotely manage instrumentation for an E-Learning portal of Electrical and Electronic Measurement courses has been presented. After a deep examination and the realization of most frequently adopted solutions, the authors have undertaken an innovative approach, founded on .Net-based Web Service. .Net-Web Service, in fact, allows to achieve various tasks such as: *(i)* clients are able to access to the stations only by means of a common browser (Explorer, Netscape, etc.); *(ii)* the system is flexible, thanks to its capability to communicate with all kind of programs; and *(iii)* easy implementation of applications for instruments control, such as the integration of existent applications in the portal, due to the .Net functions and utilities offered by LabVIEW[TM] software. Moreover, .Net Framework provides a wide variety of utilities necessary to easily perform a connection management and realize an E-Learning portal.

Acknowledgement

References

[1] P. Arpaia, P. Daponte, M. Marinov, "Measurement systems distributed on geographical networks for educational purposes", *Proc. of 2000 IEEE International Workshop on Virtual and Intelligent Measurement Systems*, Annapolis, MD, USA, pp.62-68, April 2000.

[2] M. Bertocco, S. Cappellazzo, S. Corbellini, M. Parvis, P. Pegoraro, A. Vallan, "E-Learning in instrumentation and measurement courses", *Proc. of IMTC Instrumentation and Measurement Technology Conference*, Como, Italy, pp.1146-1150, May 2004.

[3] A. Ferrero, V. Piuri, "A simulation tool for virtual laboratory experiments in a WWW environment", *IEEE Transactions on Instrumentation and Measurement*, Vol. 48, pp. 741-746, June 1999.

[4] N.H. Kapadia, M.S. Lundstrom, J.A.B. Fortes, K. Roy, "Microelectronic systems education", *IEEE International Conference on Proceedings*, pp. 23-24, July 1997.

[5] M. Joler, C.G. Christodoulou, "Virtual laboratory instruments and simulations remotely controlled via the Internet", *IEEE Antennas and Propagation Society International Symposium, 2001*, Vol. 1, pp. 388-391, July 2001.

[6] A. Ferrero, S. Salicone, C. Bonora, M. Parmigiani, "ReMLab, "a Java-based remote, didactic measurement laboratory", *IEEE Transactions on Instrumentation and Measurement*,Vol.52, pp. 710-715, June 2003.

[7] URL: *http://www.misureremote.unisannio.it/progetto/cont/index.htm.*

[8] N. Ranaldo, S. Rapuano, M. Riccio, E. Zimeo, "A platform for distance learning including laboratory experiments", *Proceedings of XLII AICA Annual Congress*, September 2004.

[9] URL: *http://www.aicc.org.*

[10] P. Arpaia, A. Baccigalupi, F. Cennamo, P. Daponte, "A measurement laboratory on geographic network for remote test experiments", *IEEE Trans. on Instrum. and Meas.*, Vol.49, No.5, pp. 992-997, October 2000.

[11] R. Brussee, A. Salden, P. Boekhoudt, H. van Vliet, "A Web-based E-Learning infrastructure", *Proc. Of International conference on advances in infrastructure for electronic business, science and education on the internet*, Vol.1, pp. 311-314, August 2001.

[12] P. Daponte, L. Nigro, F. Tisato, "Object-oriented design of measurement systems", *IEEE Trans. on Instrum. and Meas.*, Vol.41, No.6, pp.874-880, December 1992.

[13] URL: *http://www.ni.com/academic/distance_learning.htm,* "Distance learning solution guide".

[14] URL: *http://www.w3.org ,* "Web Service Description Language".

[15] URL: *http://www.w3.org ,* "Simple Object Access Protocol".

[16] Chung Jen-Yao, Lin Kwei-Jay, R.G. Mathieu, "Web services computing: advancing software interoperability", *Computer*, Vol. 36, Issue:10, pp.35-37, October 2003.

[17] URL: *http://zone.ni.com,* "Building a Web Service-based application in LabVIEW[TM] 7.0".