Internet Based Virtual Laboratory in Bioengineering Field

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***Abstract* — This paper presents a conceptual architecture for the virtual instrumentation remote control over the Internet network. It is based on a multiple-layered structure that combines web services with client-server procedures. The system allows a high flexibility with respect to physical devices supported as network procedures but also as development efficiency. Moreover, due to highly modularized structure it can be easily expanded and integrated with commercially available development suites.**

***Index Terms* — Computer networks, Internet, Instrumentation, Remote measurement, Virtual laboratory.**

I. INTRODUCTION

Telecommunication providers are dedicating considerably efforts to the development of computer controlled test and measurement techniques. At physical layer, most networks use clusters of devices variously interconnected that cooperate in order to forward information signals. Such clusters are in practice physical racks, and often one or more slots of a rack can be dedicated to a measurement device. The aim is usually to continuously monitor network performances or the quality of transmitted signals. Nowadays, modern test systems available in the ICT industry as well as in research laboratories are again commonly organized as instrument clusters controlled by a host computer via suitable standardized interfaces. This operating scheme has considerable advantages especially in the organization of repeatable and well-designed test procedures, where for ISO certified factories it is mandatory to develop most of their test procedures in computer-controlled way. A natural, even though not trivial, extension to the computer controlled test system is represented by a remotely controlled test system. In this case the logical structure of a test system can be represented by a set of clusters, each composed by more devices or instruments, connected to some communication network. An operator can control separately the devices of each remote cluster or more clusters simultaneously by sending commands, and by receiving the corresponding answers. One really interesting case of transport network is constituted by the Internet network. In fact, services can be designed where test applications could coexist with well-known general purpose network services in an integrated way. The final end-user can benefits from many other advantages including, indeed not limited to, the deep diffusion of the network at a reasonably low cost. At the present time well-accepted standards are available at the level of physical and logical neighborhood between computers and instrumentation or devices, such as the well-known IEEE-488 standard, just to provide a simple example. Moreover, standards are available at the network side at many level of abstraction, from the physical level, up to the definition of rather high-level protocols such as TCP or HTTP. A skilled system designer or integrator can also advantageously exploit well accepted or quickly evolving tools for the delivery of end-user services. One simple example consists in the use of applet techniques associated to web services, even though more promising approaches based on JINI are currently under discussion. Besides, commercial products originally designed for the control of physical devices and instruments through some computer interface, are now being expanded by manufacturers in order to add network-aware services. Despite the presence of all the previous available resources, still the organization of a complex application where multiple instruments or devices have to be controlled is not a trivial task. The designer has to cope with many different design aspects. For instance, a good design should take into account the possibility that instruments are substituted with the passing of time with more updated versions of themselves, or also that functionally identical devices could be used in a unified way, despite each could require different programming procedures. On the other side, access policies to devices have to be planned in a way that could depend on run-time considerations. Different procedures could simultaneously require the use of the same remote physical device, so that some time-sharing policy has to be assessed.

This paper presents architecture for a rapid prototyping of test and measurement applications in a networked environment. The main goals of the proposed system are its open architecture, the facility of integration with both existing development tools (Java and LabView), the compliance with both interface standards from the device's side, and network protocols at the Internet side. The described approach provides abstraction layers that allow the designer a unified view of devices in terms of easy interchangeable commands, which noticeably simplify programming issues. It also yields a simple yet effective separation between functional services that a networked system should provide. This logical separation considerably lowers the design efforts and hence provides a clearer approach both from the point of view of development and of maintenance of a remote test system. In the next section it is discussed the architecture of the proposed laboratory.

II. THE ARCHITECTURE OF THE VIRTUAL LABORATORY

A deep knowledge about computer network programming is required to develop a remote laboratory from scratch. Such prerequisite could be a major constraint and hence could constitute a serious limit to the development of a number of experiments. To overcome this problem, the authors have firstly tried to define a simple though flexible communication protocol between client and server computers and then have developed a set of programs and libraries that are intended to help the organization of a remote experiment; therefore they will no longer be required to tackle with network programming issues. By using these programs that constitute a "service layer", the operator can concentrate the attention strictly on the organization of the standard computer-controlled laboratory experiment. The topology of the distributed measurement laboratory developed in this work is schematically represented in the Fig.1.

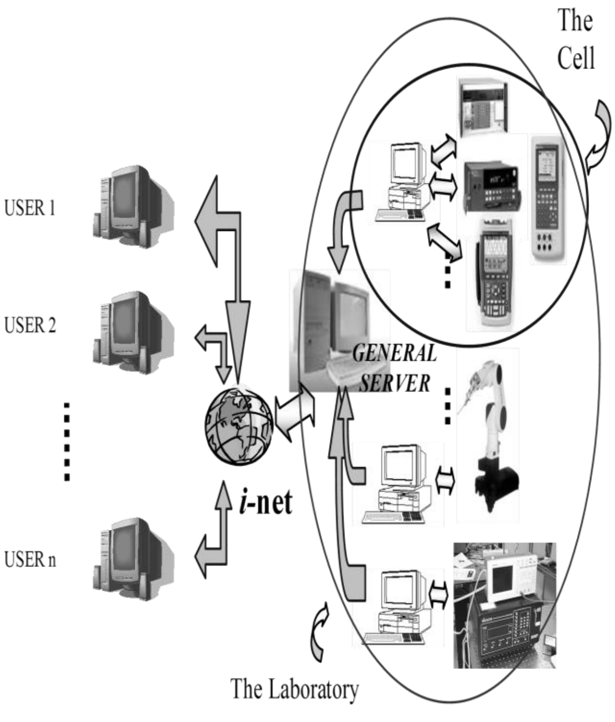

Fig. 1 Laboratory Architecture

The laboratory (Fig.1) can be composed from any number of "test stations" each controlled by a server computer. The server is connected at one side to a network, and on the other side it interacts with programmable instruments. The instruments are permanently connected to one or more Devices Under Test by means of a switch matrix, not shown in the figure for the sake of clearness. The "client side" (Fig. 2) of the laboratory is composed of several workstations installed at the same laboratory location. Such workstations are connected to the same computer network of the laboratory and provide the location. Such workstations are connected to the same computer network of the laboratory and provide the programs used by the students. During a classroom guided exercise, the students use pre-arranged programs that interact with the instrumentation to highlight the lesson topic.

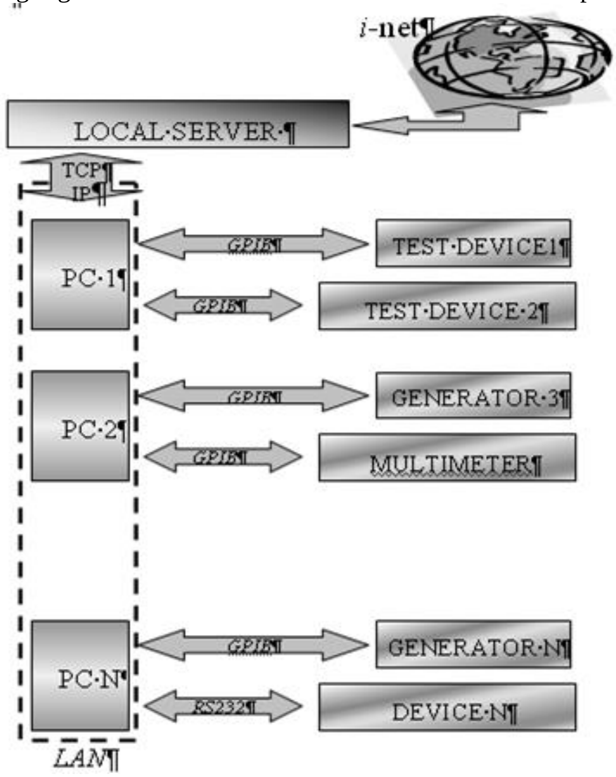

Fig. 2 Internal Laboratory Structure

The students can freely choose an application and a test station to work with. If more student groups decide to use the same test station, the server programs which control the instruments grant the remote access to the device under control in time-sharing fashion with suitable priority policies. The local computer network of the laboratory can be connected to other computer networks, in particular to the Internet one, by means of an optional firewall computer. In this case, other external workstations may access the instruments and device under control controlled by the laboratory server computers by exchanging information with the General Server. In this way, the students can use the laboratory devices without reaching the university location, for instance from their home.

The General Server is responsible for applying proper user authentication procedures and for hiding the IP addresses of SVR and WS computers to the rest of the network. Several advantages are obtained by employing this configuration. First of all valuable and expensive instrumentation can be shared between many users. This allows the development of laboratory experiments even when many students attend the same course, without making overwhelming money investments. The availability of remote test stations that can be used from any far location allows the students to best tailor the number of laboratory hours to their effective needs. The laboratory can be left unattended, or unqualified personnel can be employed for laboratory surveillance. Hence, the teacher can better be involved in discussions with the students concerning the problems they have encountered in the development of the exercises, rather than in trivial supervision activities. The network topology supports a high flexibility in the definition of the number and on the kind of test stations. Moreover, the work computers and the server computers can also host hypertext web pages, which explain better the experiments available by connecting to that computer, and the procedures that they have to follow. This additional documentation can greatly decrease the time required by the students for carrying out the experiments.

The system concept is based on user-server paradigm. The purpose is to allow the user to drive a test or an experiment to an instrument trough Internet. Grosso modo, the system has four parts: the user interface, the server, the process computer (measurement server) which commands the instruments and the instruments.

The users will work on a normal internet explorer where through the virtual instrumentation they can have access to one real instrument resource in order to effectuate a test or they can imagine and develop a process testing and in same time they have the visual information about the process running from a video-camera installed on every process stands.

Client

The user needs a computer with internet connection and a web browser. There are different possibilities in the transport layer: TCP, UDP, DataSocket, etc. The only application needed for the client is a web browser. To easily develop a client application it is mandatory to have simple tools to communicate through the network and to dialogue with the instruments. This role is accomplished by the Server side of the environment, so the client developer is free to concentrate on the peculiar characteristics of the measurement system she or he wants to prepare.

Laboratory server

A general server has to manage the queries from the clients, redirecting them to the correct local laboratory server. Two cases have been foreseen for remote teaching and education. In the first case, a professor can teach in the same time all the students connected to the local server from all partner countries. In order to obtain such a pursuit, the local server has to be set to all users slave mode. This way, the students from their home study points can receive and follow the lessons on a common web page. Due to the web publication, the number of students that can connect to the system at the same time is unlimited.

In the second case, the students should carry out some research activity based on the instruments. In this case, the local server has to be set to all users master mode. Of course, the number of students that can establish the connection at the same time is less or equal to the number of operational measurement stations within the two distributed laboratories.

A laboratory server is needed in each laboratory. It consists in a computer with a web server, a data base and management applications. The laboratory needs to know the equipment, instruments, setups, users, therefore a resource manager is the main application needed. It checks the measurement servers connected to the laboratory, and gets from them the data about instruments and setups available in each measurement server.

Process computer

The rapid development of new instrumentation, test procedures and software tools implies that a networked test system has to be continuously updated in order to reflect the changes in current technology or in the whole system to be monitored. Furthermore, instrumentation is sometimes rather expensive. Hence some instruments should be shared in order to save and optimize money investments. This means that at a same location various instruments can be placed, all organized in different benches. The benches can be used both in order to perform different measurement tests or also the same test but with different instruments for comparison. Due to the possible large variety of computer controlled experiments there is needed a method that allows the management of the instruments set-up and software programs. The management procedure should not affect the need of flexibility in the usage of resources, because of the sharing of laboratory instruments. Hereby, the process computer is the computer that joins the instrument with the virtual laboratory. There may be multiple measurement servers. Each measurement server must have information about instruments and setups available for measuring. This information of all the measurement servers will be transmitted to the laboratory server to obtain the virtual laboratory capabilities. Once checked and authorized the user access by the laboratory server, it transfers the user control to the measurement server. Proceeding in this way, the lab server is released so all measurement transactions travel directly from the measurement server to the user.

Instrument

The first aspect that should be taken into account consists in how to manage the various instruments to obtain an efficient use of both instruments and computers. In fact, in a modern laboratory many instruments can coexist. They can be simply different models in a same family or they can have a completely different structure and functionality. For instance, stand alone traditional instruments such as Digital MultiMeters (DMM’s) from different vendors can be used together with rack mounted instrumentation (VXI, PXI, etc.). Moreover, one can prefer the use of Analog to Digital (A/D) or Digital to Analog (D/A) expansion boards mounted inside a computer. Besides the choice of instruments one should also deal with a number of different and well-standardized options for the connection between instruments and a host computer. The protocols provided by IEEE-488, EIA RS-232, CAMAC, VXI and Ethernet link are just a few well-known examples of such options. These interface standards are similar from a very high-level point of view. In fact, they all offer an end user basic operation such as ‘send’ and ‘receive’ of data or commands. Unfortunately, they often implement such operation in a subtly different way so that user-developed software is seldom easily portable from one interface set-up to another one.

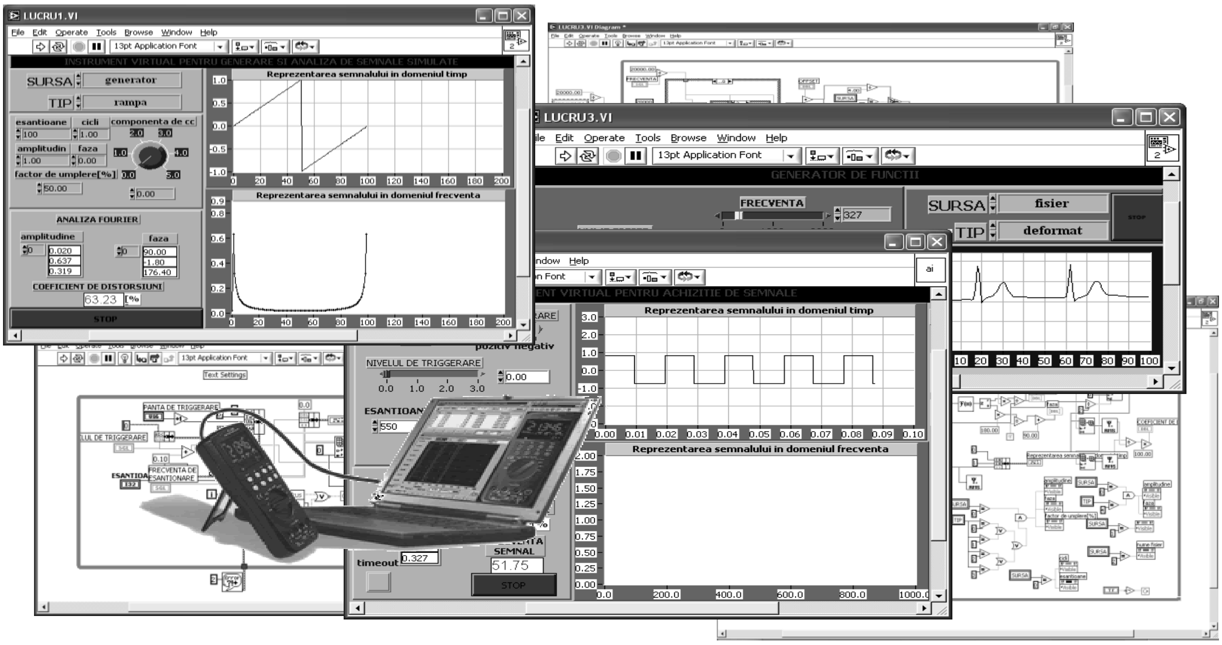

Fig. 3 Instrument Front Panel Examples

The instrument includes the signal routing block. This block is very important in order to provide a single instrument with multiple devices for making measurements. The test signal must be routed to the right device, and the output signal must reach the measuring instrument through the adequate routing.

Example of laboratory tests

Different programs may be made available to the students, depending on the actual need of courses. Moreover different remote devices can be remotely controlled by means of simple plug-in modules that can be easily added at the server side in run-time. For a theoretical point of view any equipment which can offer an electronic interface toward a computer can be controlled in the above system; it suffices to write down the code for a suitable driver. Such a code fragments are reasonably simple and basically have to translate a function at the server side in the corresponding operating system toward the actual device interface. At the present time the driver for any measurement instruments provided with serial and IEEE-488 standard interfaces are supplied. For the sake of simplicity some case study are presented in the following in order to let the reader understand the capabilities of the whole system The simplest example is just constituted by client applications which present a replica of the front panel of one or more instruments physically connected to the test stations. The students can interact with the remote instruments by means of the graphical interface provided by the programs. They can easily change the instrument configuration and observe the corresponding effect. Such programs are designed to prevent the user from using improper set-up conditions, so that the students can quickly learn the correct use of complex instrumentation. Fig.3 shows the front panel of three client programs of this type. Programs 1 is designed to remotely control a Signal Generator, Program 2 controls a signal acquisition board connected to a suitable demo test circuits and Program 3 is a Function Generator. It is also important to remind that the execution speed of the client application is comparable with that of a direct interaction with the instrumentation, provided that the physical network is sufficiently fast. Besides, the development of a Laboratory Client requires more or less the same time required to build an application for a direct dialogue with the instrumentation through a computer interface.

III. CONCLUSION

The usage of internet-based tools as a support to traditional laboratory experiences can significantly improve the learning curve of students. Moreover an internet based distributed laboratory considerably lower the costs since expensive equipment can be more efficiently shared between more courses for teaching purposes.

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