XVII IMEKO World Congress
Metrology in the 3rd Millennium
June 22–27, 2003, Dubrovnik, Croatia

THE DESIGN OF A WEB-BASED VIRTUAL LABORATORY – SELECTED PROBLEMS

Remigiusz J. Rak, *Paweł Pyszlak*

Warsaw University of Technology, Warsaw, Poland

Abstract –Virtual Instruments, as well as networked and distributed measurement systems, are the natural tools, which can be used in a modern didactic process for creating virtual laboratories offered by a group of Universities. In the paper the solution of the experimental model of the remote access to the measurement laboratory is presented. The project aims at designing the complete PC-based Virtual Instrument (VI) as a platform for acquisition, processing, presenting and distributing data throughout a global network. Computer network based measurement and automation is dramatically affecting traditional academic research and teaching. It makes researchers more productive, and improves the way students learn.

Keywords: virtual instrument, virtual laboratory, remote access to laboratory.

1. INTRODUCTION

The paper summarizes author's investigations in the field of the Web-based distributed measurement systems. They finally lead to the development of a Virtual Laboratory, accessible from the Web page, a very useful tool for distance learning. Virtual Laboratories can be offered by a group of universities. A student can access instruments via a computer network and carry out a real examination of a tested object directly by using a standard, commercial Internet Web browser. The laboratory of tomorrow will effectively help to overcome the barriers imposed by the traditional classroom setting by using an innovative combination of a new approach to learning and the development and application of new technologies. This will introduce a science teaching through everyday experience. Recent developments in virtual instrument technologies, remote access to laboratory and distance learning tools [1],[3],[5],[6],[7],[8] greatly changed the traditional approach to teaching.

It is well known that any modern traditional intelligent instrument includes four common blocks:

1. Data Acquisition
2. Data Processing
3. Data Presentation
4. Data (Signal) Generation

These elements need not necessarily reside in the same box and be delivered as a single unit in a fixed form from an instrument vendor. The PC revolution has equipped users with powerful processing and display capabilities of their own. Enhancing of the fixed capabilities of a traditional instrument with the flexible user-defined capabilities of the computer has created a virtual instrument. A definition of VI can be formulated as follows:

> "A layer of software and/or hardware added to a general-purpose (personal) computer in such a fashion that user can interact with the computer as thought it were their own custom-designed traditional measurement instrument."

The idea of a virtual instrument is presented in fig. 1.

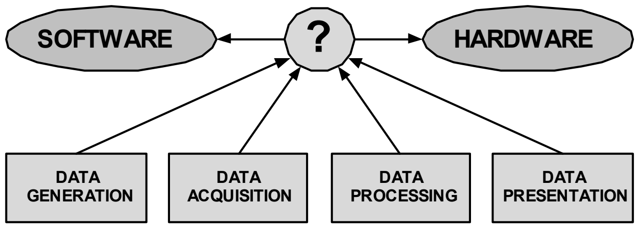

Fig. 1. The idea of a virtual instrument

It is good to keep in mind that virtual instruments, are the natural evolution of the first Digital Signal Processing systems. Their main feature consists of the exploiting of the still increasing computational power of the modern DSP processors to simplify the development of the measuring data analysis algorithm, the man-machine interface and the system interconnection.

Nowadays, any type of virtual instrument can be considered as a kind of the resource accessible throughout the computer network (fig.2).

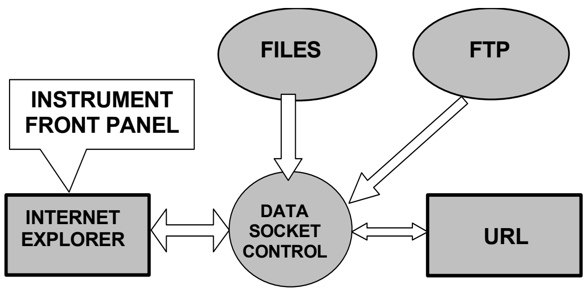

Fig. 2. The idea of a remote access to the resources throughout the Internet

Standard software languages such as C and Java can be used with of-the-shelf development tools to implement the embedded network node applications and the web-based applications, respectively. Internet based TCP/IP protocols and Ethernet technology and/or DataSockets can be used to design the networking infrastructure. DataSocket is a software technology for Windows that makes sharing all measurements across a network (remote Web and FTP sites) as easy as writing information to a file. It uses URLs to address data in the same way we use URL in a Web browser to specify Web pages. DataSocket included with any software tool is ideal when someone wants to complete control over the distribution of the measurements but does not want to learn the intricacies of the TCP/IP data transfer protocols.

Finally, an Internet user can download a web page with the "front panel" like any other web page and then can operate the controls such as tuning the knobs, moving the slides, and zooming on data on a graph, all within their Internet Explorer browser.

It seems that in the near future LAN can be considered as a kind of measurement bus, from the viewpoint of measurement and control distributed systems. The multilevel data communication capability becomes a viable one as a result of standardized networks, protocols and interfaces. Common Internet-based software technology can be used to provide the easy of data migration between the various communication pathways.

In this paper there is enclosed a short description of the designed framework of a virtual laboratory realized as a remote access to distributed virtual instruments and other objects. The main goal of the project was to carry out the practical tests in order to disclose the possibilities and limitations of the control software prepared under JAVA environment.

2. THE LAYER MODEL OF DISTRIBUTED SYSTEM

The idea of virtual instrument had strongly influenced architecture of a distributed measurement system based on a computer network. The integration of measurement system with a computer network makes it possible to create advanced multi-layer information system structures. Such a systems, thanks to the developed protocol and interface standards, are totally opened and scalable. The most important implementations are based on a Local Area Network (LAN), which can be in that case, as it was already mentioned, considered as a kind of a "measurement bus".

The architecture of the developed system is distributed not only in the sense of space but also in the area of management and control. It consists of four layers. The sensor layer is the lowest one. Control layer is the next. As a matter of fact they are together qualified as a classical, but modern, measurement systems. The third layer, called system layer, is based on a computer network. It includes application servers, data base servers and stands for service and control of all the system components. Management layer is the last one.

The controllers of second layer are attached to the computer network, which integrates parts of the system directly, or by the use of special devices, called "gateways". There is growing standardization in the area of complex communication protocols (DataSockets, Industrial Ethernet, Industrial Networking, Java – Jini).

The architecture of the proposed described system is presented in fig.3.

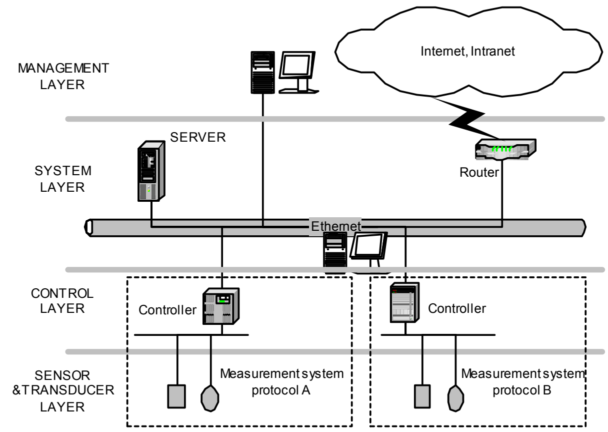

Fig. 3. Architecture of the proposed system

The most popular LAN in nowadays, is still Ethernet (simple structure, high reliability, fast transmission - 100Mbps, low price). Unfortunately Ethernet is not able to service the real time systems. It is the most meaningful drawback, from the viewpoint of a measurement system. But the recent update of its specification (IEEE-802), guarantees the highest delay in information delivering on 4ms [2]. It means that Ethernet can be successfully used in system layer and in some cases in the control layer.

The modern computer networks are widely implemented in the area of distributed measurement systems. As an example it can be depicted the system designed and examined in the National Institute of Standards and Technology [2]. A movement from the very specialized and centralized systems to the flexible, opened and scalable ones is a very important trend in the modern methodology of the design of distributed systems. There are more and more often implemented object-oriented platforms and high level programming languages.

Virtual instruments and modern distributed measurement systems provide the powerful tools for the design of so called virtual laboratories.

3. THE IDEA OF VIRTUAL LABORATORY

The idea of virtual laboratory is very simple. Let us imagine that some research center, let us say the University A, offers in a LAN some selected resources. All the researchers, scholars and students have limited access to this environment. After connecting the A center to the Internet the offered instruments can be also used by the B center students. The resources can certainly be shared in much wider scale, from both sides. It is very important in the case of very specialized, expensive equipment not available to the every research center. The idea of a virtual laboratory is presented in fig.4.

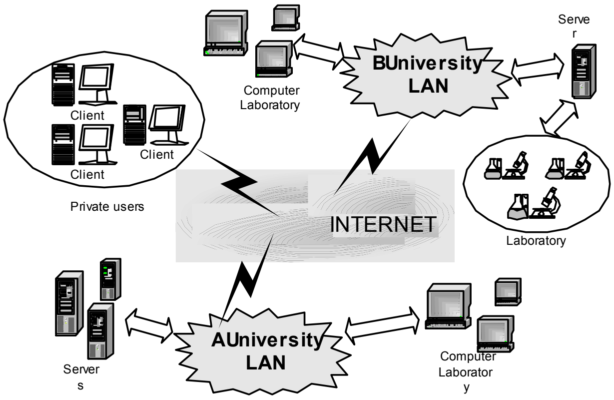

Fig. 4. The idea of virtual laboratories

Certainly, the most important usage is concerned around distance learning. On-line experiments give the possibility to have an impact on a real process or object. The advantages of virtual laboratory are exposed in quite a number of papers [1],[3],[4]. In order to create a useful virtual laboratory it is necessary to take into consideration many additional (secondary) tasks, which should be "carefully" implemented.

4. THE MAIN TASKS OF THE PROJECT

The predicted tasks of the project, which should be realized by the application software, can be presented in the following points:

- Communication between user and laboratory,
- Access to laboratory resources (systems, instruments, functions),
- Management over the laboratory resources,
- Organization of the users (groups, rights to resources, rights under conditions, changes of rights, priorities),
- Control over the single users and groups (authorization – rights, authentication - password).

The measurements should be realized in two modes: "on-demand" and "on-line". The first mode includes two separate cycles: "question" and "answer". In the "on-line" mode the user has a constant access to the virtual instrument (on-line selection of functions and parameters, watching results).

Software, the most important part of the project, includes two main parts: server application, and client application. Each client includes control panel of virtual instrument. It can be attached to server as a gateway to real instruments. After login there is opened a session for programming the instruments and receiving measuring data. Additionally server plays a role of rights control, security carefulness and much more (concurrency of processes, multi-access).

5. PROPOSED SYSTEM ARCHITECTURE

The system offering remote access to laboratory has been designed on the basis of a single central server. The architecture of the system is presented in fig.5.

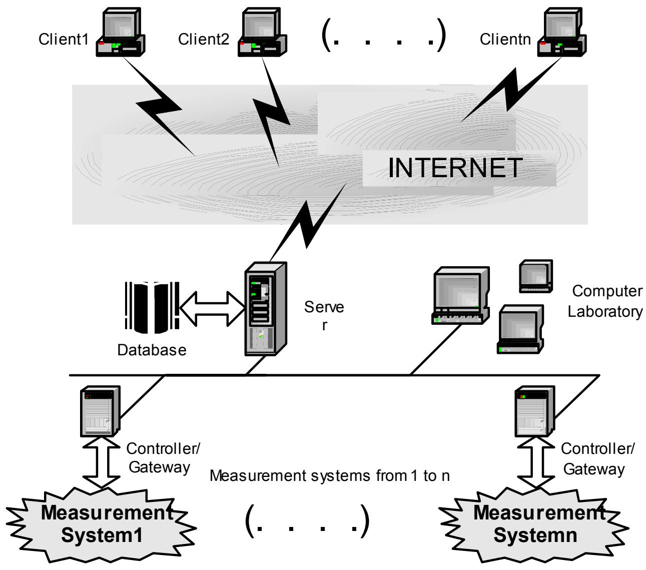

Fig. 5. Architecture of the proposed system

There are a few of measurement systems controlled by personal computers. Every computer plays a role of the "gateway" distributing measuring data to the single central server. The central server distributes data to every client throughout the Internet. On the other hand each client can send a control data (commands) directed to specified measuring instruments of the selected measurement system.

The architecture, based on a single server, is very convenient. It releases the client from all the controlling processes (access rights and so on). The client must only acquire data and send them to a server. It does not need a productive computer with complex software. Any excess of the efficiency can be used for data compression or coding. The only disadvantage is a need of high efficiency for the central server, especially in a case of a large number of clients. In that case a meaningful role plays the configuration of the local network, servicing the attached measurement system.

Both, the users and instruments are divided into groups, like in a real life case. The user groups can have different access rights to control instruments and to receive measuring data. Information about all instrument groups (subsystems), all the users and/or groups of users together with their access rights is stored in a relational database. The diagram of the database relations is presented in fig.6.

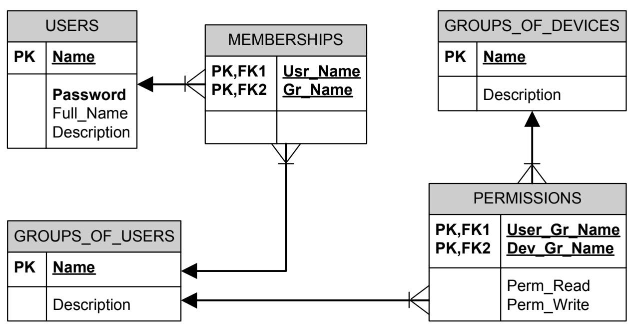

Fig. 6. Architecture of the database

This kind of database guarantees not only a convenient way of storing data but also, thanks to relations, its integrity. Information about connected (active) instruments is stored in the inner structures of the software (class `InternalDB`) but not in a database. It is because the instruments are not attached to server constantly, but can be assigned dynamically. Additionally the rights are assigned not to the single instruments but to groups.

The server is able to manage quite a number of measurement systems and quit a number of clients at the same time. The communication algorithm is based on the set of *classes*, which include *objects* realizing transfer of data and commands. There was implemented the UDP protocol for on-line data transmission and TCP protocol for messages (commands) exchange, communication control and measuring data transmission in the on-demand mode. An access to the communication layer is organized throughout the DataSockets with multithread mechanism.

6. CONCLUSIONS

Practical tests and experiments of the project were carried out on different hardware and software platforms with the usage of Java Virtual Machine ver.1.3, both in local and global network. Windows-98/NT/2000 and Linux RedHat 7.2 were used as operating systems.

Implemented computers had a constant access to the Internet throughout the wide-band links. In the majority of tests the developed software worked properly with the sufficient productivity. All the problems have been caused by the environment configuration. The most important one appeared in a case when a client was attached to the Internet throughout a "firewall". In that case the UDP will need special widening or even should be replaced by the other type protocol (RTP).

Practical experiments have also shown that a useful version of the developed software should include some more sophisticated functions like:

- implementation of the SSL (Secure Sockets Layer),
- introduction of the dynamic assignment of the virtual instrument boards to the current clients, by the use of RMI or CORBA tools,
- possibility of a cascade connection of servers.

In all types of networked and distributed measurement systems, presented above, real-time operation and constraints are critical issues to be considered during system design to ensure the correct system operation.

Additionally all problems related to DSP theory must be carefully considered to avoid all those measurement errors that may easily occur in these intrinsically non-linear measurement systems.

It is also clear that all the innovations provided in modern distributed measurement systems seem to be coming more from the computer science field rather then measurement science. It means that Metrologists are forced to keep pace with technological advance in the area of computer engineering.

At the end it would be good to mention that the traditional definition of a distributed measurement system is not good enough nowadays. Modern distributed measurement system is distributed not only in the sense of space (geographically). What is more important, it is distributed in the sense of the all available resources like: measuring instruments, measurement subsystems, management and control, data processing and data presentation. All these features are also directly taken from the distributed computer systems and computer networks.

REFERENCES

[1] L. Hesselink, D. Rizal, E. Bjornson: „CyberLab: Remote Access to Laboratories Through the World-Wide-Web" *International Conference on Advances in Infrastructure for Electronic Business, Science, and Education on the Internet*, July 31-August 6, 2000, L'Aquila, Italy.

[2] K, B. Lee, R. D. Schneeman: „Distributed Measurement and Control Based on the IEEE 1451 Smart Transducer Interface Standards*", IEEE Transactions on Instrumentation and Measurement Magazine*, Vol 49, NO. 3, czerwiec 2000.

[3] A. Ferrero, V. Piuri: „A Simulation Tool for Virtual Laboratory Experiments in a WWW Environment", *IEEE Transactions on Instrumentation and Measurement Magazine*, Vol 48, Nr. 3, czerwiec 1999.

[4] L. Benetazzo, M. Bertocco, F. Ferraris, A. Ferrero, C. Offelli, M. Parvis, V. Piuri: „A Web-Based Distributed Virtual Education Laboratory", *IEEE Transactions on Instrumentation and Measurement Magazine*, Vol 49, Nr. 2, kwiecień 1999.

[5] R.J. Rak, "Virtual Instrument – the main part of Internet based distributed system", *International Conference on Advances in Infrastructure for Electronic Business, Science, and Education on the Internet*, July 31-August 6, 2000, L'Aquila, Italy

[6] R. J. Rak: „Modern Tools for Development and Design of Virtual Instruments", *Third International Conference on Enterprise Information Systems Proceedings,* vol.2, Setubal, Portugal, July 7-10, 2001 pp.1166-1169.

[7] B. Galwas, R.J. Rak, "Virtual Laboratory - A Future Part Of The New Web-Based Model of Undergraduate Engineering Studies Developed By Warsaw University Of Technology", *Joint IMEKO TC-1& XXXIV MKM Conference 2002,* 8 - 12 September 2002, Wrocław.

[8] E. Michta: „Communication Models of Networked Measurement and Control Systems", *Wydawnictwo Politechniki Zielonogórskiej*, Zielona Góra, 2000.

[9] G. Coulouris, J. Dollimore, T. Kindberg: „Distributed Systems Basics and Designing", *WNT*, Warszawa 1998.

Authors:
Prof. Remigiusz J. RAK, Ph.D.,D.Sc.
Paweł PYSZLAK, M.Sc.,
Institute of the Theory of Electrical Engineering and Electrical Measurements,
WARSAW UNIVERSITY OF TECHNOLOGY
Pl. Politechniki 1, 00-661 Warsaw, Poland
Tel. +48 (22) 660-7291, fax: +48 (22) 660-5642
email: rakrem@iem.pw.edu.pl