Joint **IMEKO TC-1 & XXXIV MKM Conference 2002**
Wrocław, 8 - 12 September 2002

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VIRTUAL LABORATORY - A FUTURE PART OF THE NEW WEB-BASED MODEL OF UNDERGRADUATE ENGINEERING STUDIES DEVELOPED BY WARSAW UNIVERSITY OF TECHNOLOGY

The article gives a review of reasons for developing and adopting a new web-based model of studies by Warsaw University of Technology. That is followed by a description of the Internet and multimedia - based educational model, known as SPrINT. The article presents also a structure of the four-year engineering studies offered by Electrical Engineering Faculty, Faculty of Electronics and Information Technology and Faculty of Mechatronics for given specialization. Then follows a description of the structure and tools of the electronic books. One of the subjects common for all students of the three Faculties is Virtual Laboratory. 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.
Keywords: distance learning, virtual instrument, virtual laboratory, distributed system.

1. INTRODUCTION

The assumption that education should not be separated from our professional and family life, led many societies to provide and develop new systems of distance learning. The advantage of Distance Learning over a traditional model of education is its flexibility. The model of education and its tools is directed to the needs of an individuals, it enables self managed learning, saves time and ensures cost savings, including travel

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costs and cost of accommodation. The education is usually home-based what guarantees friendly and comfortable learning conditions.

Traditional model of education is based on a direct "face-to-face" contact between student and teacher, in which textbooks play a role of supplementary self-learning tools. New technological developments, such as telecommunication (radio and television), computer engineering, multimedia and Internet, have enriched a traditional classroom with new tools, improved learning quality in both residential universities and geographically-dispersed learning groups. Of all the technical innovations, the Internet has become an indispensable tool in introduction of the new technology to education, and its growing impact on the future of the educational model is inevitable [8,12].

Two years ago, the Warsaw University of Technology (WUT) authorities agreed it was high-time the WUT developed and adapted a new model of studies. The Internet and multimedia have become the basic tools of a new model of education – known as SPrINT (in Polish: **S**tudia **P**olitechniczne **r**ealizowane w **INT**ernecie).

The introduction of an entirely new model of studies by the WUT, a university with 30 thousand students enrolled in 18 faculties, had to be accompanied by the establishment of a new university unit – Center of Open and Distance Education: CODE (in Polish: Ośrodek Kształcenia na Odległość OKNO).

As a principle, CODE does not have full time academic teachers. The lecturers of the particular faculties are responsible for the creation of didactic materials, student supervision, and conducting examinations.

2. OVERALL DESCRIPTION OF SPRINT MODEL

The basic tools used by student in a SPrINT model of distance learning belong: computer and Internet. These tools enable e.g.:

- access to the Internet,
- e-mail correspondence,
- access to didactic materials stored on CD-ROM,
- solving tasks and problems,
- writing reports and projects, etc.,
- online meetings,
- discussion with lecturers and other students.

Direct, personal contacts between student and teacher are very rare in the SPrINT model, but they are still considered as important and essential elements of education. The students have an opportunity to meet tutors during examinations, and every year one-week laboratory meetings. During that time students are instructed and consult how to use measuring instruments, conduct scientific research (computation and simulation) with the use of advanced software.

The four-year studies lead to a B.Sc. degree in engineering of a chosen Faculty and specialization. The academic year is divided into four half-semesters: autumn, winter, spring and summer. The division of the academic year into four, enables students to study no more than two subjects at the same time. Each semester lasts 8 weeks and finishes with two weekend's examination sessions.

The grading of the subjects is based on the **c**redit **p**oints **s**ystem (cps), used in the university teaching systems of the majority of European countries. The credit system gives students the opportunity to gather credit points. The total number of credits for the subjects is 248.

There is obligatory a three-level system of studies:

i. **Fundamental courses**, 1 year, whose program is fairly universal and basic; within the course student is required to credit 4 major courses, 4 minor courses and 2 laboratory sessions, what brings 67 cps.

ii. **Faculty courses**, 2 years, whose program is dependent on the faculty chosen; student is required to credit 8 major courses, 8 minor courses, 2 laboratory sessions, and a language course, what brings 124 cps.

iii. **Specialization courses**, 1 year, each Faculty can offer more than one specialization; student is required to credit 3 major courses, 3 minor courses and complete a diploma thesis, what brings 57 cps.

Fig.1 shows the structure of the SPrINT model.

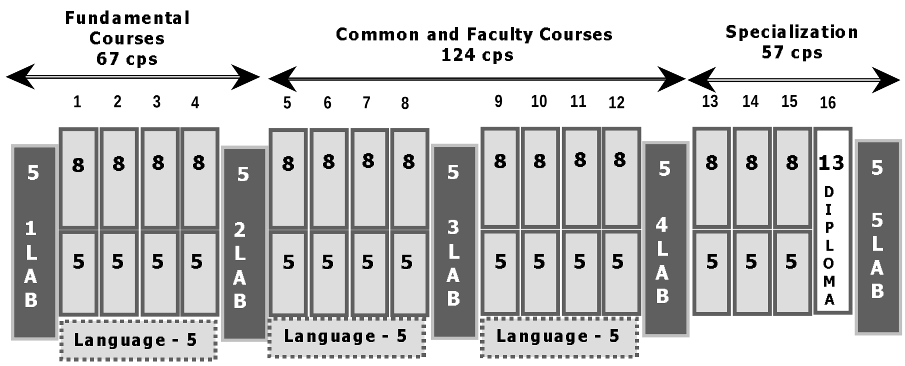

Fig.1.The structure of the SPrINT model

The model of the studies is entirely open. It means, one can become a 'regular' student of the University and credit all the courses required to get a diploma in engineering, one can also study chosen courses, or group of courses as a 'short-term' student. Once a year, a progress of 'regular' student is verified. In order to be admitted to the registration for the next year, student should have at least half of the required points for a given year. Thus the pace of individual learning and gathering credits is student dependent. If the student is not registered for the next year, he still has a chance to continue his education. He keeps all his credits and has the opportunity to be enrolled once again.

The three faculties of the WUT, Electrical Faculty, Faculty of Electronics and Information Technology and Faculty of Mechatronics, offer courses in the following specializations:

- Industrial Informatics (Faculty of Electrical Engineering),
- Computer Engineering (Faculty of Electronics and Information Technology),
- Multimedia (Faculty of Electronics and Information Technology and Faculty of Mechatronics),
- Mechatronics (Faculty of Mechatronics).

The structure of the studies program offered by particular faculties is presented in fig. 2.

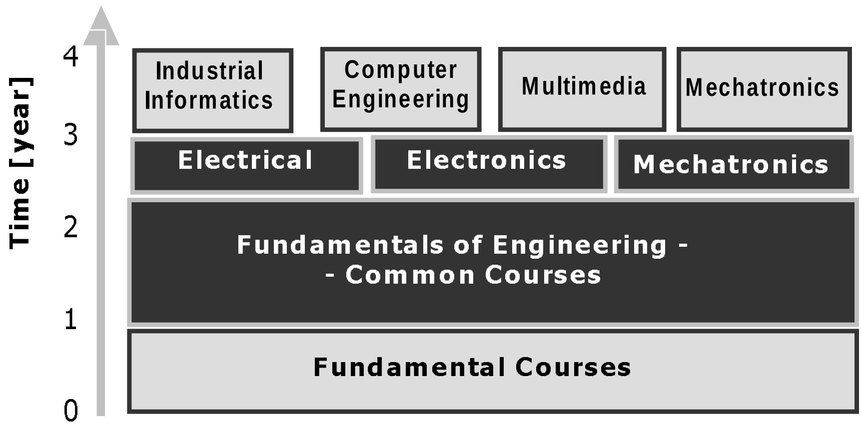

Fig.2.Program of studies structure

The Fundamental Courses, offered during the first year of studies (Mathematics, Physics, Basics of Computer Engineering), are universal for the three Faculties and can be accepted by nearly every Faculty of the Warsaw University of Technology.

Fundamentals of Electrical, Electronics and Mechanical Engineering offer a set of courses for the second and third years of studies. What is very important, there is a large number of common courses for each specialization (Faculty).

During the fourth year students attend only courses of their specialization and they are completed their final B.Sc. diploma thesis.

3. ELECTRONIC BOOKS

The didactic materials of the particular courses are prepared by professors and experienced lecturers in the form of electronic lectures (books) and stored on CD-ROM.

Certainly, the same material is placed on the web sides, available via Internet. The electronic books have the advantage of presenting the whole material of a single subject on one CD, and the cost of copying the material is relatively low. For the production of the material the DynamicHTML technology was used (HTML, Cascading Style Sheets, Java Script and FrontPage tools). Thus the navigation system is based on HTML and dynamic Web page processing by Java Script [4].

The electronic books have an advantage over traditional textbooks by presenting the material in different ways: written form, audio-video, simulations and animation etc. These tools enable easy and fast understanding of the course materials. The material of an electronic book is divided into two main parts:

I. Introductory part,
II. Learning Units
III. Exam requirements.

I. The introductory part includes:
- **Authors' note**, which describes course objectives. The authors explain what level of knowledge and what skills are expected from students after examining all the materials presented in the book.
- **Requirements for computer** – includes description of requirements for computer.
- **How to use an electronic book** – it is a clear, step-by-step instruction of how to use the material stored on the CD-ROM.
- **What to know, to understand?** – the authors explain conditions for understanding the didactic materials: minimal level of knowledge enabling student to understand the material presented.

II. The Learning Unit includes a series of basic didactic parts that should be learnt in a suggested order. Every learning unit is composed of several basic elements like:
- **Introduction,** which presents the aim of the particular Unit.
- **Knowledge segments**, which include basic didactic material, to be required from the students. Some parts of the material contain additional information for further readings.
- **Problems**, this part includes examples of partly solved problems and tasks to be finished by the student himself. Also, it enables students to revise their understanding and command of the material required during examinations.
- **Glossary** includes new terms and definitions.
- **Bibliography** includes a list of important publications for further reading.

III. The **Exam requirements** unit is included only if the given course ends with an examination.

A structure of the electronic book is presented in fig.3.

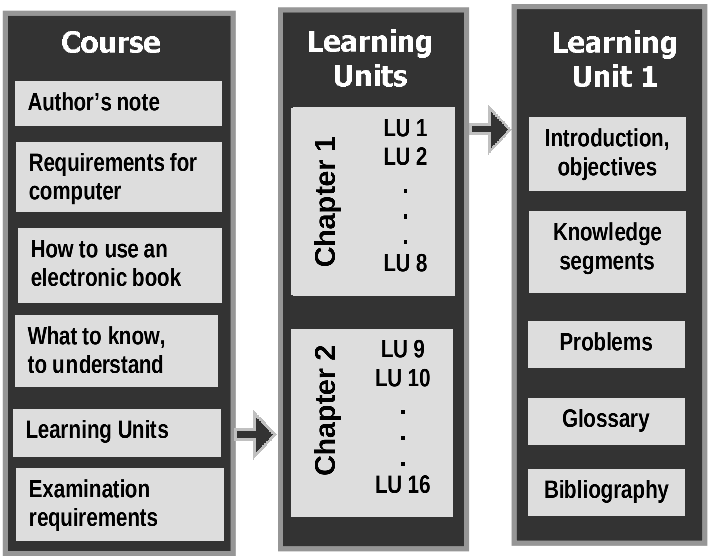

Fig.3. Structure of the electronic book

4. VIRTUAL LABORATORY

SPrINT as the novel web-based model of undergraduate engineering studies, adapted by the WUT is still in a forefront of really important improvements and developments. More technological innovations create new possibilities. Thus, one of the objectives of the WUT is to develop and enrich the model with a set of new multimedia tools e.g. preparing lectures on DVD, designing new simulation tools, installing an advanced software accessible by the Internet, and creating a remote access to laboratories.

The critical element of testing theories through experiments can not be missing in our model. The missing link is the ability to carry out physical experiments over the web, fully integrated with other media for delivering classroom content, worldwide. In addition to simulating a virtual experiment, the reality of science and engineering can be learned better by remotely controlling an actual physical experiment. By supplementing classroom teaching with web-based experiments, the student should be able to interact with physical systems, much in the same manner as modern experiments are carried out today, under computer control. Laboratories accessible from the Internet provide enrichment to the educational experience that is hard to obtain from other video based remote teaching methodologies. Remote control of experiments and equipment over the web is an idea that is just being explored. Tools are now becoming available for remote control of instrumentation using network communication. And several demonstrations of camera control and data acquisition as well as simple experiments have already been made [5].

Our knowledge concerning processes resulting from experiments, ability to control these processes and a set of tools needed for digital recording and transmission are good enough to introduce a new model of laboratory research – s.c. Virtual Laboratory. The introduction of the model is a forthcoming development of WUT. The most important elements of Virtual Laboratory are: Virtual Instruments and Distributed Measurement and Control Systems.

4.1. THE IDEA OF VIRTUAL INSTRUMENT

In order to construct a Virtual Instrument there is necessary to combine the hardware and software elements which should perform the data acquisition and control, data processing and data presentation in a different way to take maximum advantage of the PC [1,14]. It seems that in the future, the restrictions of instruments will move more and more from the hardware to the software side. Such an idea of VI is presented in fig.4.

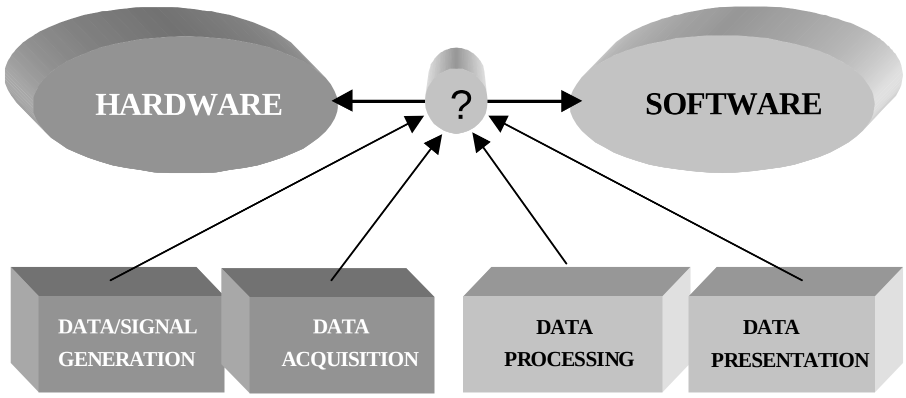

Fig.4.The idea of a Virtual Instrument

Definition:

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

The main categories of Virtual Instruments are presented below:

A. Computer controlling GPIB or RS232 instrument, with a graphical front panel on the computer screen to control the instrument;

B. Plug-in DAQ board or a VXI module instead of an external GPIB instrument, with a graphical front panel on the computer screen to control the instrument;

C. Graphical front panel with no physical instruments at all connected to the computer. Instead, the computer acquires and analyzes the data from files or from other computers on a network, or it may even calculate its data mathematically to simulate a physical process or event rather then acquiring actual real world data.

The main, representative features of Virtual Instruments describing their functionality are following:

- Enhancing traditional instrument functionality with computers;
- Opening the architecture of instruments;
- Widespread recognition and adoption of virtual instrument software development frameworks.

The computer platforms captured by the expansive Virtual Instrumentation techniques are following:

- Operational systems: DOS, Windows, X Windows, Windows NT, Unix;
- Processors: 386, 486, 486DX2, Pentium, Sun Workstation;
- Buses: PC, EISA, ISA, PCI, PCMCIA;
- Programming languages: BASIC, C, C++.

4.2. IMPLEMENTED SOFTWARE

Software implemented in the design process can be divided into few levels which can be described in a hierarchical mode.

4.2.1. REGISTER LEVEL SOFTWARE

Register-level software requires the knowledge of inner register structure of the device (like DAQ board, VXI module or GPIB/RS232 programmable instrument) for entering the specific bit combinations (taken from the instruction manual) in order to program measurement functions of the device. This way of programming (a low-level) is the hardest one.

4.2.2. DRIVER LEVEL SOFTWARE

One of the most important components in measurement systems today is device driver software. Device drivers perform the actual communication and control of the instrument hardware in the system. They provide a medium-level easy-to-use programming model that gives you complete access to the complex measurement capabilities of the instrument via an intuitive API. In the past, programmers spent a significant amount of time writing this software from scratch for each instrument of the system. Today, instrument drivers are delivered as modular, off-the-shelf components that we can use in our programs.

In 1998, several leading companies formed the Interchangeable Virtual Instrument Foundation. The IVI Foundation was formed to establish formal standards for instrument drivers and to address the limitations of prior approaches.

4.2.3. HIGH-LEVEL TOOL SOFTWARE

Currently the most popular way of programming is based on the high-level tool software. With easy-to-use integrated development tools, design engineers can quickly create, configure and display measurements in user-friendly form, during product design and verification. The most known, popular tolls are as follows:

- LabVIEW (National Instruments) [8] – is a highly productive graphical programming language for building data acquisition and instrumentation systems (Virtual Instruments). To specify our system functionality we intuitively assemble block diagrams – a natural design notation for engineers. Its tight integration with measurement hardware facilities rapids development of data acquisition, analysis and presentation solutions.
- LabWindows/CVI (National Instruments) [9] – is a Windows based, interactive ANSI C programming environment designed for building virtual instrumentation applications. It delivers a drag-and-drop editor for building user interfaces, a complete ANSI C environment for building test program logic, and a collection of automated code generation tools as well as utilities for building automated test systems, monitoring applications or laboratory experiments. The main power of CVI lies in the set of libraries.
- HP VEE (Hewlett-Packard) [6] – is a kind of Visual Engineering Environment, an iconic programming language for solving engineering problems. It also gives the ability to gather, analyze and display data without conventional (text-based) programming.
- TestPoint (Keithley) [15] – is a Windows based, object-oriented software package that contains extensive GPIB instrument and DAQ board support. It contains a novel, state-of-the art user interface that is easy to use. Objects, called “stocks” are selected and dragged with a mouse to a work area (panel). Logic flow is easily established with a point and drag action list. TestPoint takes advantage of very Microsoft Windows features including DLLs for extendibility, bi-directional DDE for data exchange to and from other software and Windows-style interface conventions.

4.2.4. SCPI – STANDARD COMMANDS FOR PROGRAMMABLE I NSTRUMENTS

The ideal tool enabling easy control of programmable instruments is specialized command set called SCPI (Standard Commands for Programmable Instruments) [2]. SCPI dramatically decreases development time and increases a readability of test programs. It has its own set of required common commands in addition to the mandatory IEEE 488.2 common commands and queries. Although IEEE 488.2 is used as its basis, SCPI defines programming commands that we can use with any type of hardware or communication link. It has an opened structure. The SCPI Consortium continues to add commands and functionality to the SCPI standard. For example, the following command programs a digital multimeter to configure itself to make an AC voltage measurement on a signal of 15V, with a 0.005 resolution:

```
:MEASure:VOLTage:AC? 20, 0.005
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4.3. AN EXAMPLE OF VI

Dual channel spectrum analyzer establishes a very impressive example of virtual instrument. The block diagram of spectrum analyzer configuration is presented in fig.5.

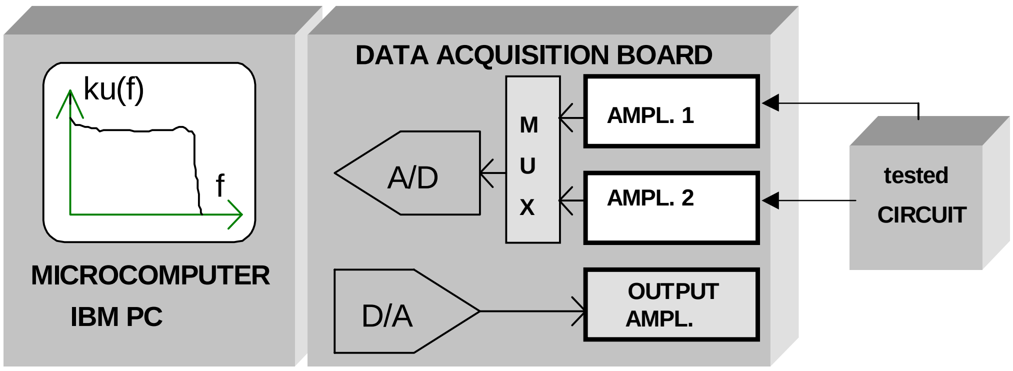

Fig.5.Block diagram of spectrum analyzer based on DAQ

Its hardware part includes universal “plug-in” DAQ board with at least two analog inputs and one analog output. The software part is written under LabWindows/CVI environment, so that the graphical user interface (control panel) has a user-friendly form. It is divided into three separated parts. Each part includes different control panel. The user can select the most appropriate to the specific measuring or analysis function. It is also possible to build a hierarchical structure of control panels. A control panel designed for both signal and spectrum presentation in the on-line mode is presented in fig.6. Presented panels are converted to binary black&white form for convenience.

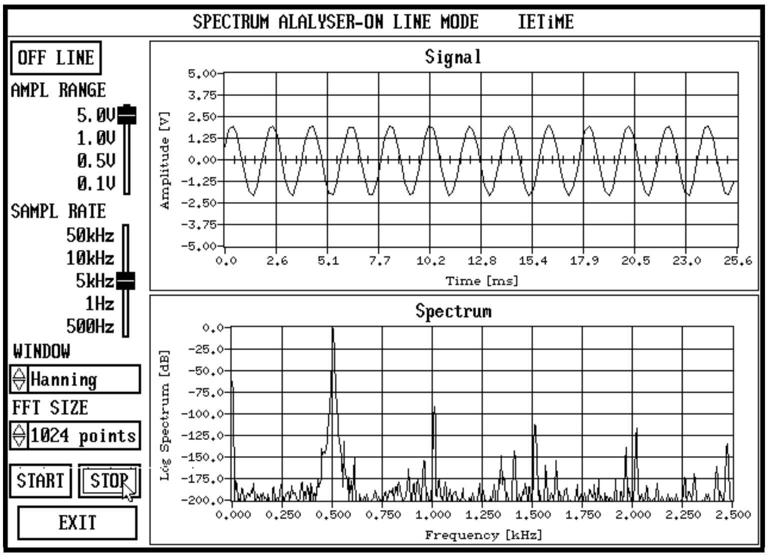

Fig.6.Control panel of spectrum analyzer in on-line mode

Further, a user can select two different control panels for the off-line mode: control panel for signal presentation (fig.7) and control panel for spectrum presentation (fig.8).

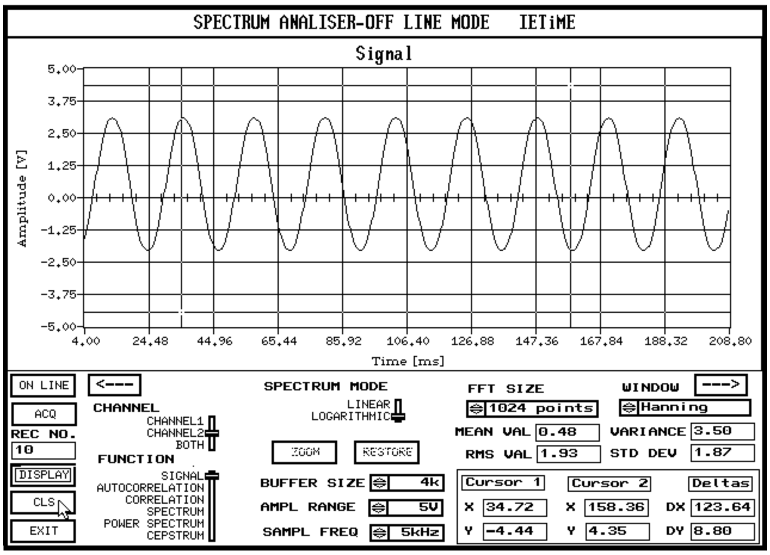

Fig.7.Control panel of spectrum analyzer in off-line mode for signal presentation

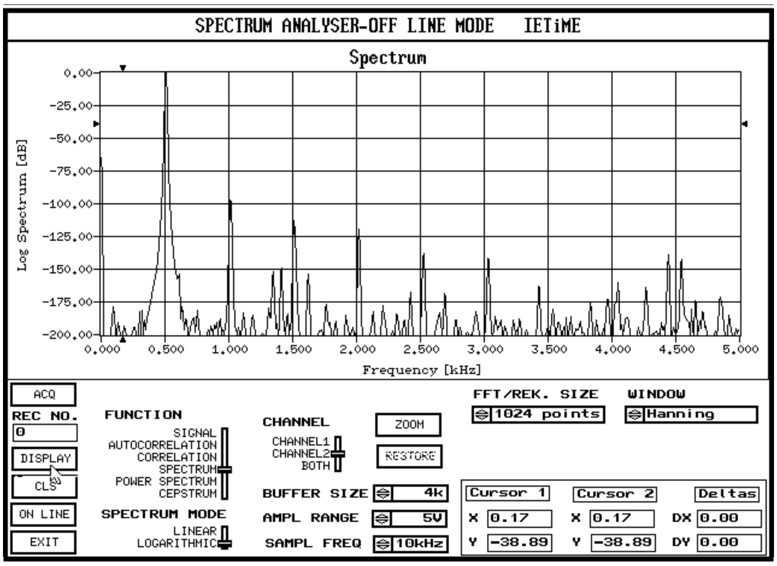

Fig.8.Control panel of spectrum analyzer in off-line mode for spectrum presentation

4.4. DISTRIBUTED SYSTEMS

It seems that in the nearer future LAN can be considered as a kind of measurement bus, from the viewpoint of measurement and control systems. A typical example of such a system, including various VIs, is presented in fig.9. It can be considered as a first step to a wider, Internet based technology [1,5,10,13].

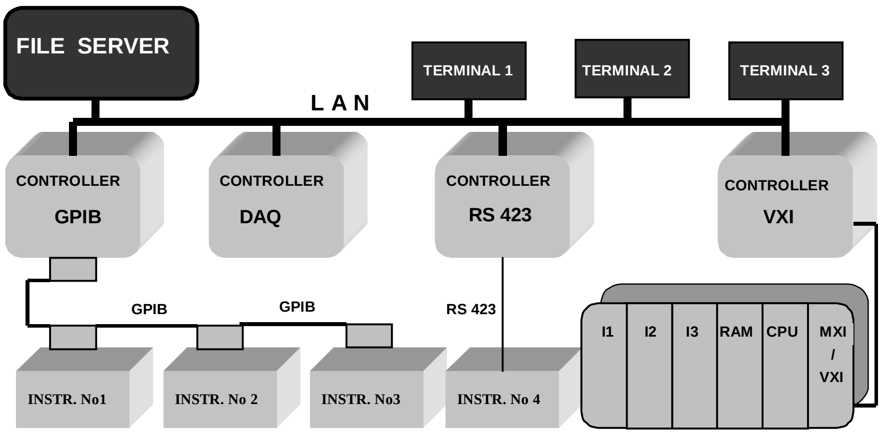

Fig.9.Block diagram of distributed measurement system based on local network

Common Internet-based software can be used to provide the easy of data migration between the various communication pathways. Multi-computer processing systems are effective in creating complex systems by overcoming the limitations of a single computer concerned with the overall computing power or the number of signals to be acquired and processed.

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 [11], Ethernet technology and/or DataSockets can be used to design the networking infrastructure (fig.10).

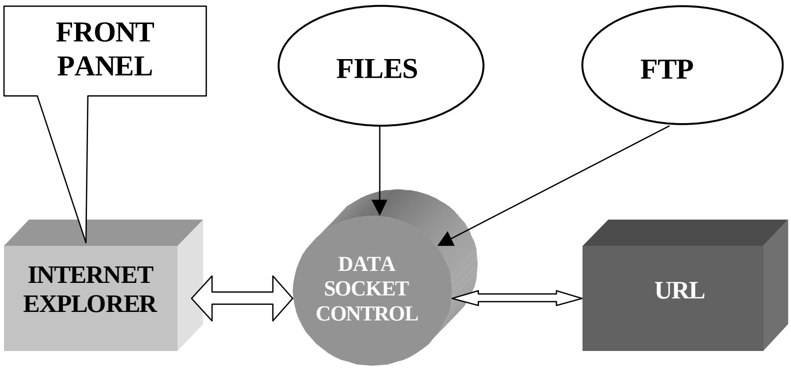

Fig.10.The architecture of a distributed system based on Internet

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 want to complete control over the distribution of the measurements but do not want to learn the intricacies of the TCP/IP data transfer protocols.

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.

5. CONCLUSIONS

As soon as the new model and program of studies, was approved by the Warsaw University of Technology authorities, a group of specialists and tutors started production of new electronic books. A group of computer scientists, with the help of IBM Lotus LearningSpace software platform, prepared an educational portal OKNO.

In October 2001, two hundred students enrolled and started education in a new web-based model of undergraduate engineering studies.

An important objective for the future is a remote virtual laboratory, a very useful tool for teaching purposes in distance learning. Students can access virtual instruments via a geographic network and directly carry out real experiments by the using of a simple standard commercial Internet Web browser. In this way, a more complete educational proposal, can be offered by several laboratories specialized in different measuring fields. The remote laboratory concept allows measuring resources located at different geographically remote sites to be utilized by a wide distribution of students.

Another objective for the future is the establishment of a network of universities offering distance education. This would lead to creation of a new model of distance education based on the NETTUNO model.

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