
Client-Server and Gateway Systems for Remote Control in Engineering Education*

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With the rapid development of the Internet over recent years, in conjunction with the transmission protocol TCP/IP and the latest version of hypertext (HTML) facilities, new opportunities have come into existence for the use of the network for the remote control of experiments and other practical systems in engineering education. There are two prime benefits: students learn how network systems work and also how remote control technologies operate and the universities save money when students from several institutions utilise the same expensive equipment. Using graphical software environments in client-server systems can be easily designed. Client-server systems have some general advantages when compared with simple Remote-Access Systems (RAS) or proprietary (single-solution) systems. In recent years, gateway systems for remote control have become available for most measurement and instrumentation bus systems and this effectively permits direct access via LAN/Internet with a minimum of the transfer data-rates needed for control.

INTRODUCTION

The remote control of installations and systems has been a technical reality in research laboratories and automated industries for many years, particularly in process control industries. Due to the stringent demands of industry, a variety of bus systems have been developed to operate at the different hierarchical levels found in automated systems. Some examples of these demands are process control monitoring, the updating of services software at a distance and embedded Web-server services.

At the highest level (Intranet), Ethernet-based systems are frequently utilised to transfer data, using different protocols. With the rapid development of the Internet within the last ten years, and its associated transfer control protocol/Internet protocol TCP/IP, as well as the use of hypertext documentation as a basic technique on the World Wide Web (WWW), new possibilities have arisen for the utilisation of the

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Internet for remote control. It is now possible to design http-based client-server solutions and gateway systems for remote control problems with modest expenditure with the aid of graphical software development packages, such as *LabVIEW* [1][2] or *VEE PRO* [3].

The following institutions jointly undertook a remote-control project:

- Liverpool *John Moores* University, Liverpool, England, UK;
- Hochschule Wismar – University of Technology, Business and Design, Wismar, Germany;
- Rostock University, Rostock, Germany.

The goal of this project, which was started four years ago, has been to increase the attractiveness and effectiveness of laboratory work in research by remote-controlled experiments.

An attractive consequence of this development is that resources are saved because the partners need not cater for the whole spectrum of possible (and mostly expensive) research and teaching equipment and experiments, which also have to be updated and

maintained. Researchers from other locations could control and monitor their own experiments and investigations from a distance.

The concept and the advantages of using a http-based client-server system for remote control have already been discussed elsewhere [4]. The availability of gateway systems for LAN/RS232 and LAN/GPIB have opened up new possibilities for the remote controlled laboratory, particularly for remote access systems in general, as well as instrumentation [5-7].

As an example, this article describes the remote control of Rostock University's ultrasonic, eddy-current and optical (CCD) research measurement equipment using a http-based client-server system and gateway system, including the online visualisation of the dynamic runs of real research experiments

REMOTE CONTROL CLIENT-SERVER SYSTEM

Client-server systems have some advantages compared with simple Remote-Access Systems (RAS). They have better security, a higher functionality and can be administrated more easily and effectively on

the server side. With the introduction of the HyperText Mark-up Language (HTML) several years ago, and the associated hypertext transfer protocol, the possibility existed for communication between client and server using graphical elements (image maps).

The performance and functionality of http-based client-server systems has been extended through server extensions such as Java, the Common Gateway Interface (CGI), JavaScript, Standard Query Language (SQL) and many more, which enable the exchange of variables and the preparation of dynamic HTML documents. Figure 1 shows the general structure of a http-based remote-controlled experiment using the graphical programming language *LabVIEW* and an integrated http Web server (*Internet Toolkit*) [3].

The server itself has to fulfil two important tasks. Firstly, it controls the experiment. In the actual version the control of the experiment works with the graphical elements, the so-called virtual instruments, which were developed using the graphical programming language G (by means of the *LabVIEW* software development environment, National Instruments) [1]. The virtual instruments realise the hardware access to the experiment: analogue and digital server

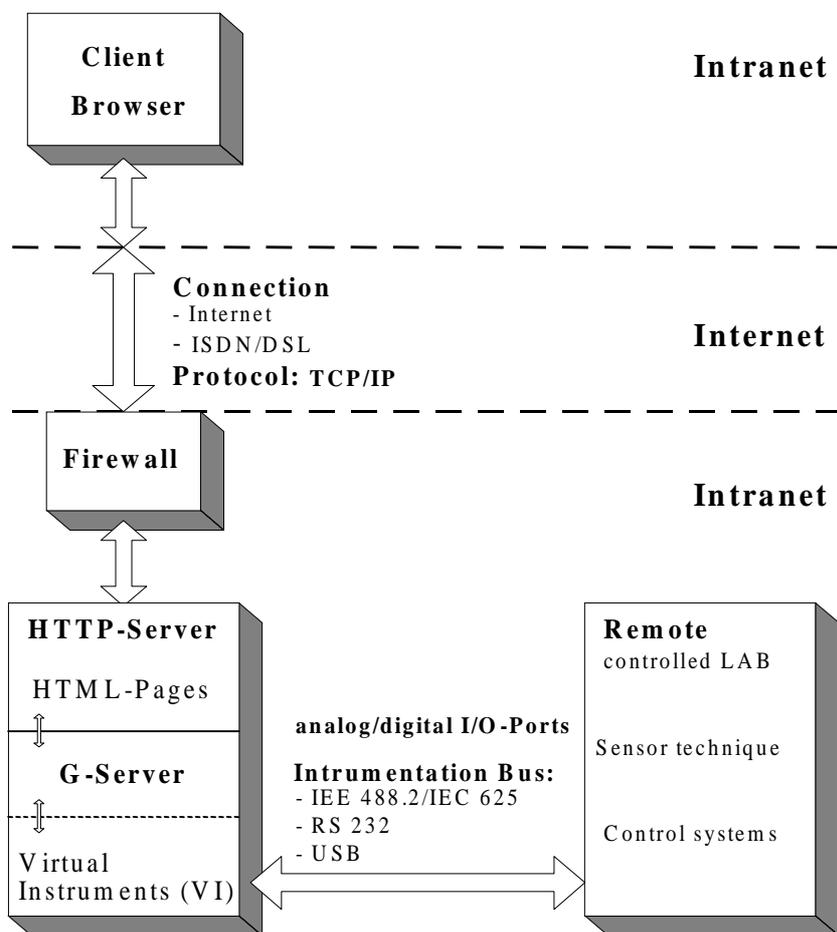


Figure 1: Structure of an http-based remote controlled laboratory or experiment.

Remote Controlled Experiments

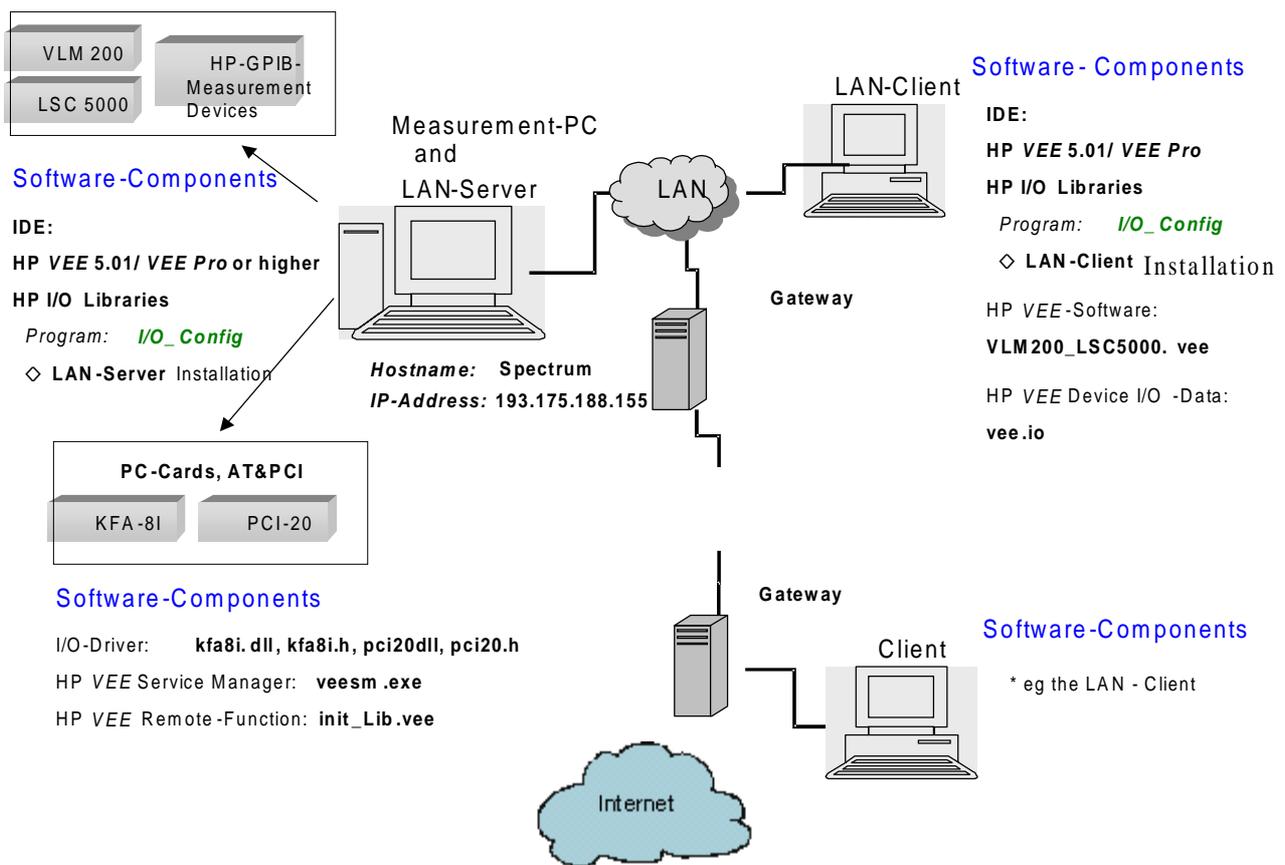


Figure 2: Structure of a proprietary client-server system for remote-controlled experiments using VEE.

I/O-systems or the standard measurement bus systems such as IEEE 488.2 (GPIB), RS 232 or USB.

Secondly, it has to perform its duty as a http server at the disposal of requesting clients, which means that the transfer of a requested HTML document, in which the graphical elements are embedded, is also one of its tasks. The conversion from the graphical elements of the virtual instruments of the *LabVIEW* control program (eg input/output) into the HTML document is performed by a G-server. The G-server is a part of the Internet toolkit (National Instruments), which also provides virtual instruments for the use of other Internet services, such as the File Transfer Protocol (FTP) and e-mail.

Figure 2 shows the structure of a proprietary client-server system for remote-controlled experiment using the graphical programming language VEE [2].

The functionality between client and server can be extended by means of elements like CGI and Java. Through these technologies, the access rights of clients to stored data from the server, password protection and much more can be achieved. These include solutions for active task control of IP number and/or additional password control for cases where more than one client has the right to access the remote controlled experiments, using *time stamp* or

time slot techniques. A software and/or hardware firewall solution is helpful for these configuration and administration problems.

REMOTE CONTROL GATEWAY SYSTEM

Gateway technology enables communication between a (client) PC and the gateway with instrumentation bus connectors, such as GPIB or RS232 via a Local Area Network (LAN). The gateways themselves have the structure of a server: the internal server transmits the data from the LAN to the other bus system (GPIB or RS232) over layer 3, or higher, of the Open System Interconnection (OSI) references model using Standard Instrument Control Library (SICL) software [2]. The SICL software also includes a LAN/GPIB server so that any PC GPIB- interface card could act as a gateway. The access control could be easily realised by means of a simple IP-list in the Gateway. On the other hand, if a client has the right of access to a gateway, then he/she controls everything on the instrumentation bus!

Figure 3 shows the general structure of a gateway-based remote-controlled experiment/laboratory using the graphical programming language VEE PRO [3].

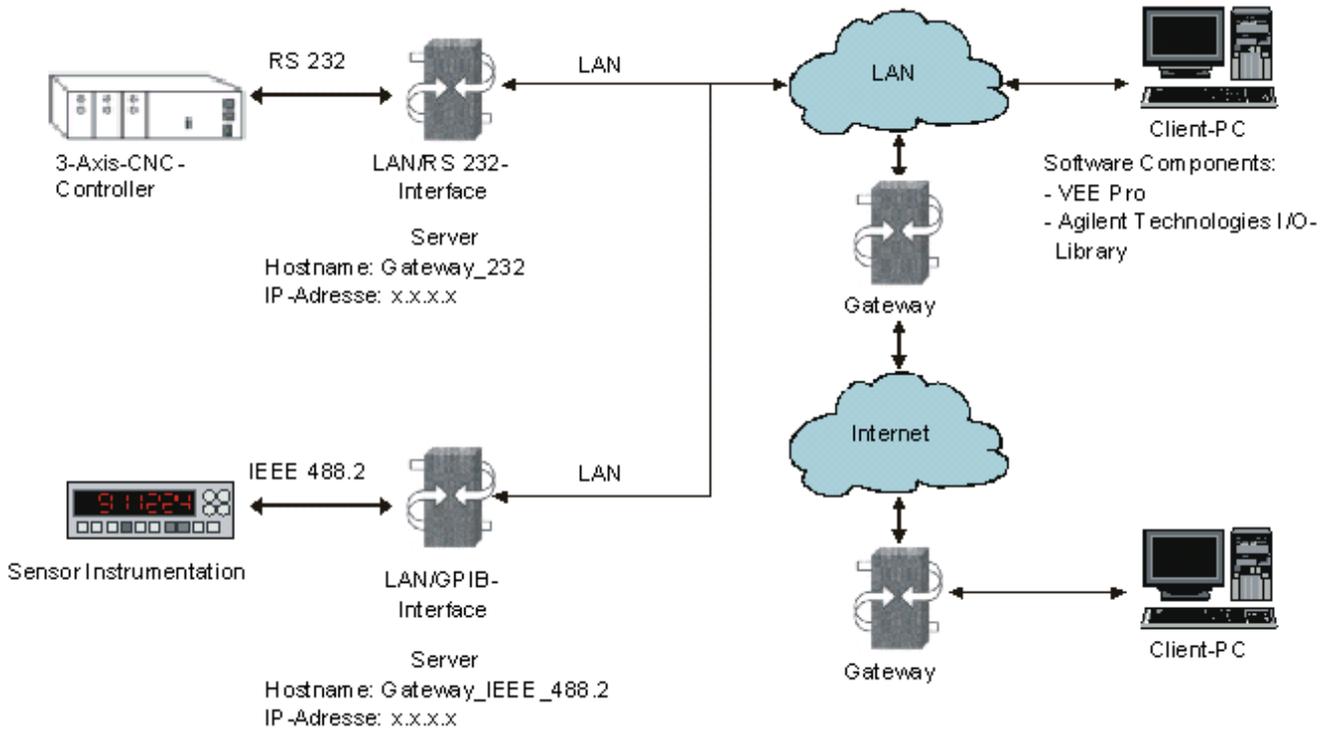


Figure 3: Structure of a gateway-based remote controlled laboratory.

ONLINE VISUALISATION

Online visualisation of the remote control process is one of the major problems that have to be solved. In the first version of a http client-server system using *LabVIEW* software, a one or two simple CCD camera system, connected on the server via USB, is used for the visualisation of the dynamic actions of the experiment. This can be embedded within the virtual instrument as a static picture (.jpg, .bmp).

On the client side, eg from a random PC on the Internet, the HTML document, which was sent by the server and had been transferred, will be displayed in a browser, and some – also transferred – contents (such as Java applets) will be executed. In this case, it is important for the approach used to gain Internet control that the clients' browser is able to implement the server-push technology (eg *Netscape Navigator*) because the G-server uses this technology to display the (graphical) control virtual instruments and the client receives a display of the interface and access to the control of the experiment program.

In the case of the graphical languages, *VEE PRO* runs on the client side so that only a small amount of data and a few instructions need to be transferred from the server side to the client.

However, it has been found during experiments that a better transfer quality is achieved if a separate (second) server and streaming video are used [8]. With the use of remote controlled high resolution CCD zoom cameras (VCS Corp. video conference system with

up to four cameras) and videostreaming technology, the requirements on dynamic process visualisation can be eased; this has increased the success and acceptance of remote controlled experimentation [4]. The disadvantage of this solution is that the software for the remote controlled camera system must be installed at the client side of the system, as well as the server side.

REMOTE CONTROLLED LABORATORY

In the first phase of the remote-control project, the performance of the http-based client-server system using *LabVIEW* software with different configurations (online visualisation, task control, firewalls) was investigated. In the second phase, real and complex computer-controlled laboratory experiments were designed [4][8-10]. Complex research experiments involving remote control of ultrasonic, eddy-current and optical sensors have been designed at Rostock University and Hochschule Wismar.

For example, the ultrasonic measurement research experiment consists of an ultrasonic sensing array, a 3-axis scanner to manipulate the ultrasonic sensor, the server and a remote controlled CCD camera system (640 x 480 pixels) with a second (videojet) server to observe the dynamic responses. This is shown in Figure 4.

Experiments within a frequency range from 0.5 to 15 MHz are possible using the continuously tuneable ultrasonic array. The sensors can work in impulse-

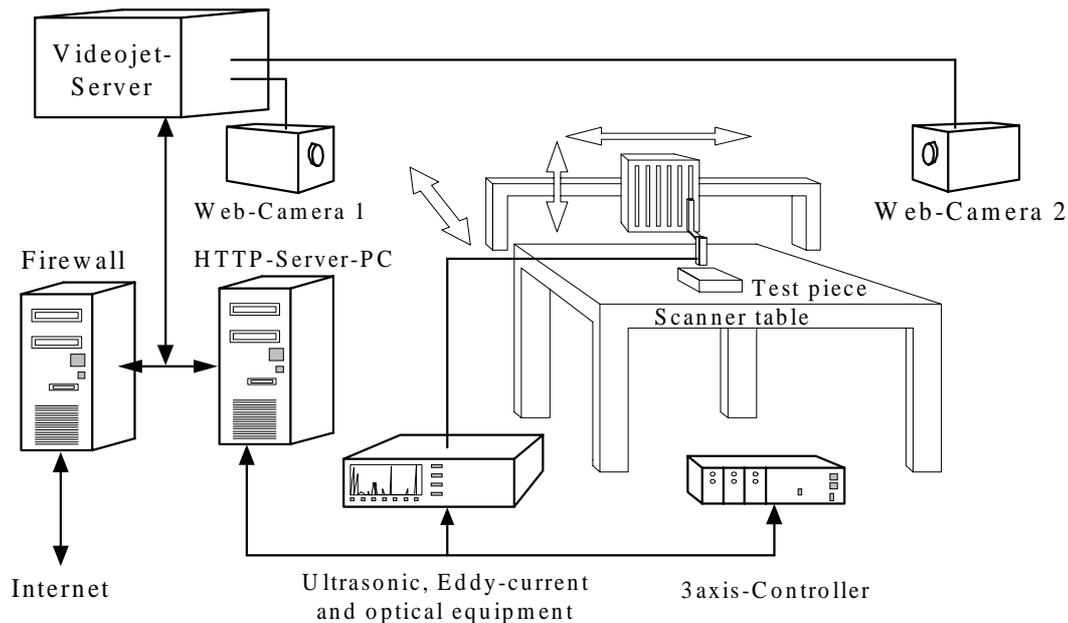


Figure 4: Remotely-controllable ultrasonic, eddy-current and optical measuring equipment [9].

echo or in continuous mode. All experiments are designed in such a way so that the ultrasonic sensors have to be water-coupled. The ultrasonic equipment and the 3-axis scanner are controlled by the server over a serial interface (RS232). By utilising the equipment for the ultrasonic sensors, it is possible to design a variety of research experiments to capture the so-called A-, B- and C-scan ultrasonic signals, such as profile measurements on surfaces and building up in stages to 3-D measurements on solids.

The structure of the Web page of the remote-control project using *LabView* is shown in Figure 5 (eddy-current and ultrasonic laboratory).

In the case of the eddy-current research experiments, such as surface or thin film inspection and also crack detection, the sensor is a coil probe that is connected with the eddy-current equipment and has a frequency operation range from 10 Hz to 10 MHz. The control and the various data streams are also transmitted to the http server over a serial interface (RS232).

The optical sensors consist of line and matrix CCD camera systems with a serial interface (RS232) or a high-speed analogue data-acquisition system to http server using the *VEE PRO* software, as shown in Figure 6. An advantage of this solution is the opportunity of utilising the *remote controlled function*, which allows for the inclusion of a personal driver for special hardware on the server side. Optical inspection problems could also be investigated using these methods.

It is essential for the actual development of the project that real data, rather than simulated measure-

ments, are recorded as packed files and then transferred to the PC. The users can then repeat an experiment as often as they wish and, if necessary, under various configurations in order to be able to evaluate the results of different instrument settings.

In order for this to be accomplished, a manual remote-controlled installation is planned. This installation (positioning of the ultrasonic sensor, the eddy-current test piece or optical sensor plus other configurations) makes online visualisation of the experiment necessary. It has been found that with a simple Web camera of 320 x 240 pixels and a reasonable picture transmission quality, a continuous and stable data transfer rate of at least 7 Kbyte/s is needed. Router, hub and switcher technologies reduce the effective transmission rate of high-speed Internet connections [11][12].

In this context, the access rights for the clients from the server-administration are an important part of the functionality of the experiment. Furthermore, it can also be influenced by which clients have the access rights and the ability to control the experiment. Administration would be easier over direct ISDN telephone line connection but – would also be more expensive.

CONCLUSION

With the aid of the *LabVIEW* and *VEE PRO* software, http-based client-server systems and gateway systems for the remote control of experiments were developed, built and tested. One example involves a complex experiment using ultrasonic, eddy-current and optical

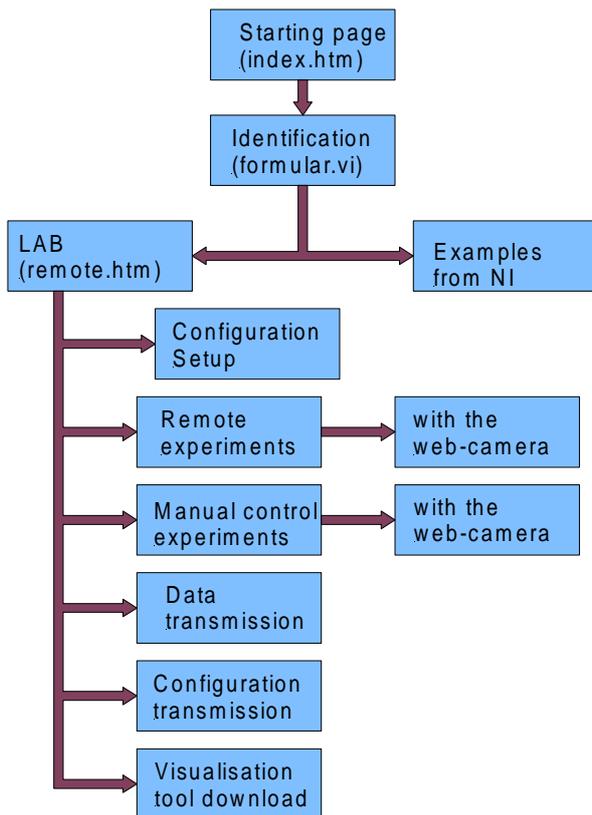


Figure 5: Structure of the Web page of the remote-control project using *LabView*.

sensors. If Java is used as a software platform, all access to the hardware components must be made using programming methods, eg by an OSGI-Sever, which can be very time-consuming [13].

The online visualisation of remote-controlled experiments and the interactive control possibilities is one of the most important challenges that have to be solved. In the case of a data transfer transmission rate >100 kbit/s videojet (videostreaming) technology could be a powerful contender.

Client-server systems are more difficult to implement but have greater potential. HTTP servers are easier to implement but they need a high transmission rate (virtual instruments). Proprietary client-server systems are faster but are also less flexible.

Gateway-systems are easier to install but the rights of access must be carefully controlled. They can also reduce installation and services costs. They are easier to handle and there are no limits for the programming language used. Gateways are available for all standard measurement and industrial bus systems. Access can be controlled by a simple firewall.

It is the contention of the authors that remote-control experiments should be an integral part of engineering education. The advantages for students in being exposed to these technologies is that they gain an insight into modern uses of protocols, LANs and the Internet. They can access experiments from any

Server call and 1st authentication (password and IP-number)

2nd authentication (user name & 2nd password)

Scanner setup: area and scanning points

Automatically or manually controlled experiment, remote controllable (Web) zoom-cameras with different resolutions

Transmission of the data, configuration setup and visualisation tool

location and at any time. Furthermore, they can repeat experiments at any time. In addition, students will obtain real data from the experiments – not simulated results.

The financial advantages to universities can be considerable. If a consortium of, say, eight universities were to share the use of their equipment via the Internet then the savings in capital outlay would be over 80%. They would also have access to a greater range of experiments and equipment for the main courses than they could afford on their own and major rigs could be built as a central resource.

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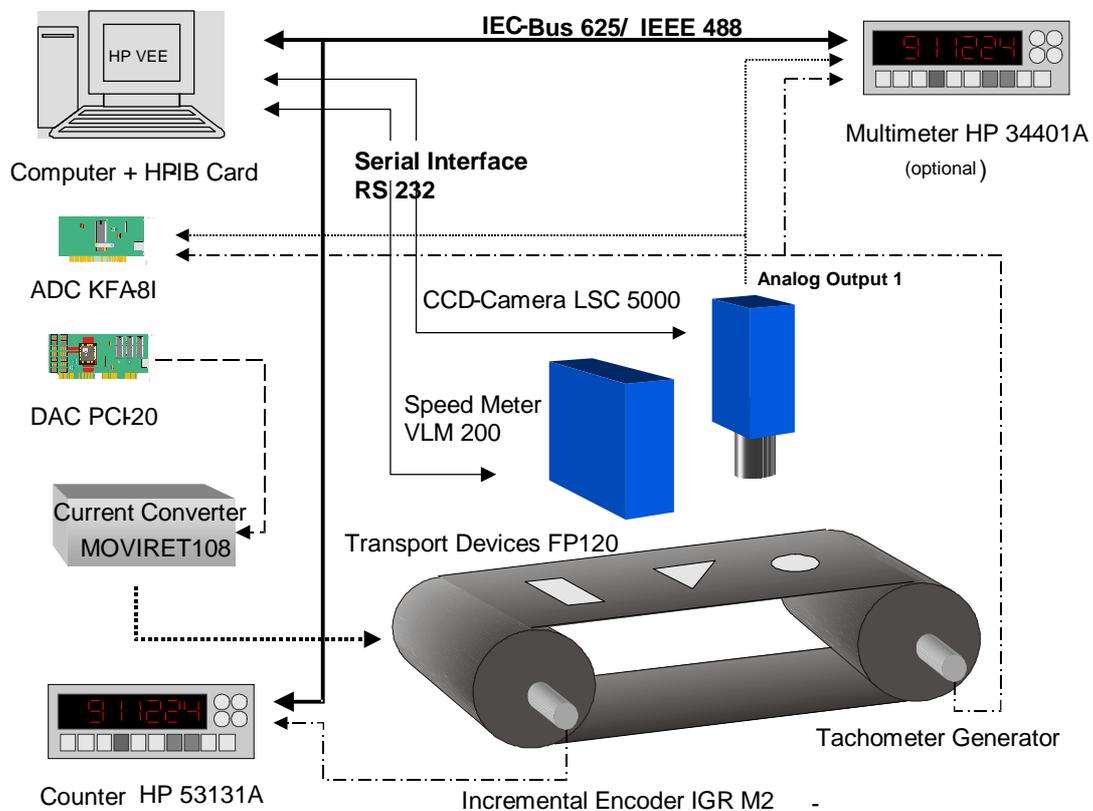
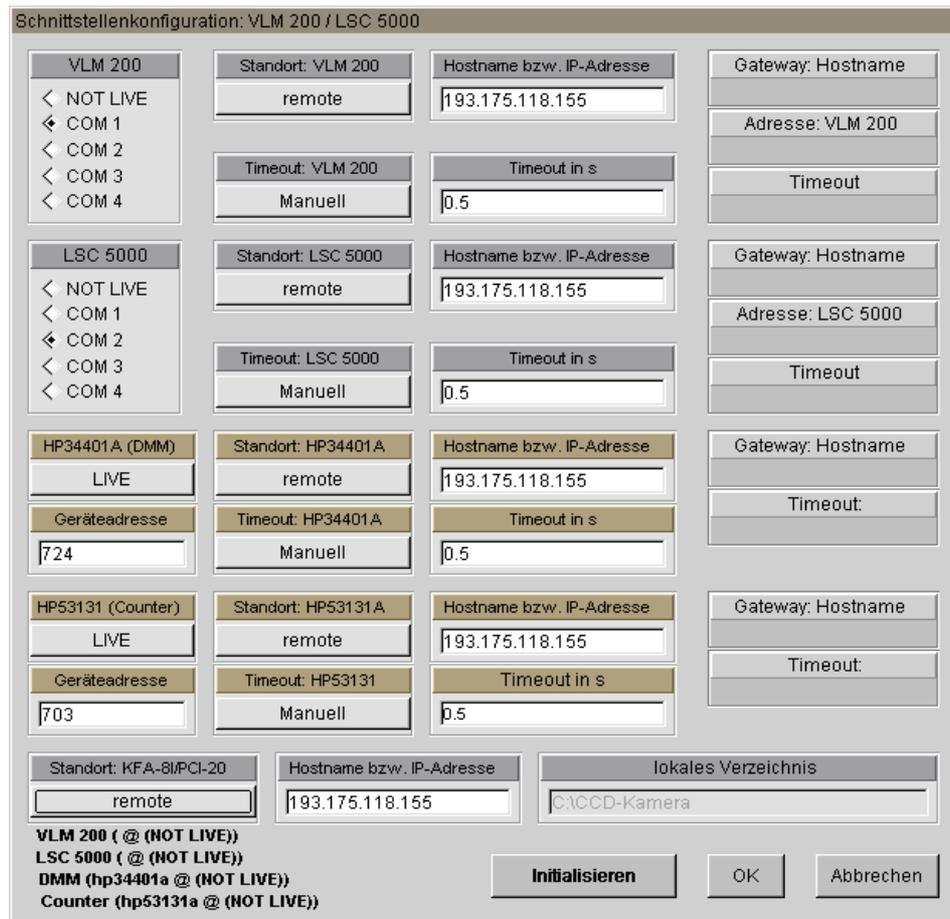
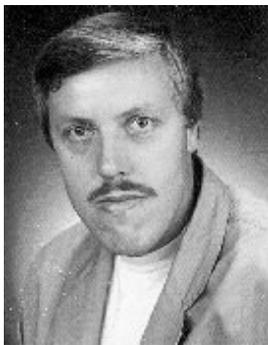


Figure 6: Configuration and structure of the proprietary client server remote controlled laboratory using *VEE Pro* (optical sensor laboratory with an optical speed- and distance sensor VLM200 and a high resolution line CCD-camera LSC5000).

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BIOGRAPHIES



Hartmut Ewald is a professor of technical electronics and sensor techniques in the Department of Electrical Engineering and Information Technology at the University of Rostock, Rostock, Germany, since 2001. He graduated as an electrical engineer in 1978, received a doctorate in physics in 1983, and the habilitated doctor's degree in 1991. From

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His main research fields are pattern recognition, measurement instrumentation and control, and non-destructive testing. He received the Marie-Curie-Research Grant (Marie-Curie Fellowship) from the European Union (EU) to the University of Limerick, Ireland, in 1998. He is a member of the German Society of Non-Destructive Testing and a member of the Organising Committee of annual conferences of Artificial Neural Networks in Engineering (ANNIE).



George Page was born and went to school in Lancashire in England, United Kingdom. He attended the universities of Wales (at Bangor), Manchester and Liverpool. His initial subjects were physics and mathematics but his current teaching and research interests are in the field of intelligent control systems and novel uses of the Internet.

He has considerable experience in engineering education and has served on numerous national and international committees. He has been an examiner in control engineering for the British Engineering Council, guest editor for several international journals, and is the author of one book and many papers and articles. He has taught for the Open University and for Liverpool *John Moores* University in the UK. He also has close links with several universities in France and Germany. He returned to the School of Engineering at Liverpool *John Moores* University from Hochschule Wismar in 1999.