

REMOTE CONTROL OF EXPERIMENTS USING CLIENT-SERVER AND GATEWAY-SYSTEMS

B. Himmel¹, H. Ewald¹ and G. F. Page²

1. Rostock University, Rostock, Germany
Bernhard.himmel@uni-rostock.de

2. Liverpool John Moores University, Liverpool, United Kingdom
g.f.page@livjm.ac.uk

Abstract

With the rapid development of the Internet in recent years in conjunction with the TCP/IP transmission protocol and the latest version of the hypertext (HTML) facilities new possibilities have come into existence for the use of the network for remote control of experiments in research labs and other practical systems. There are two benefits: (i) the Ethernet-based systems are frequently utilized to transfer data (ii) for the used transfer control protocol/internet protocol TCP/IP different hardware solutions are available. Using graphical software languages 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. The disadvantage of http-based client-systems is the need for a minimum stable transmission rate of 7 kbyte/second. Router, hub and switcher technologies reduce the effective transmission rate of high speed Internet connections. In recent years gateway systems for remote control have become available for most measurement and instrumentation bus systems and this effectively allows direct access via LAN/Internet with a minimum of transfer data-rates needed for control. Furthermore, the new upcoming IEEE Standard 1588 permits distributed real time remote control.

Keywords: Remote Control, Client-Server, Gateway, HTTP-Server, Graphical Programming Languages, Online Visualization

1 Introduction

Remote control of installations and systems has been a technical reality in research labs and automated industries, particularly in process control industries, for many years. 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 utilized 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 of using the net for remote control as well as for e-learning systems in engineering education. With the aid of graphical software development packages, such as LabVIEWTM [1],[2] or VEE PRO[®] [3], it is now possible to design http-based client-server solutions and gateway systems for remote control problems with modest expenditure.

The goal of the remote-control project of Liverpool John Moores University, Hochschule Wismar and Rostock University, which was started 6 years ago, is 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 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 latency issues of the web should have not any influence on the real-time experiment (of the server side, where the laboratory experiment runs). The full 'stand-alone' control software and the schedule of the experiment resides on the server's side of the system.

The concept and the advantages of using an http-based client-server system for remote control have already been discussed in previous publications [4]. The availability of gateway systems for LAN/RS232 and LAN/GPIB have opened up new possibilities for the remote controlled laboratory, particularly for instrumentation [5], [6], [7] and remote access systems in general.

For example, the remote control of Rostock University's ultrasonic, eddy-current and optical (CCD-) research measurement equipment using an http-based client-server system and gateway system, including the online visualization of the dynamic runs of real research experiments is described in this paper.

2 REMOTE CONTROL CLIENT SERVER SYSTEM

Client-Server systems have some general advantages if you compare them 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.

The general structure of a Client-Server system for remote control is shown in figure one.

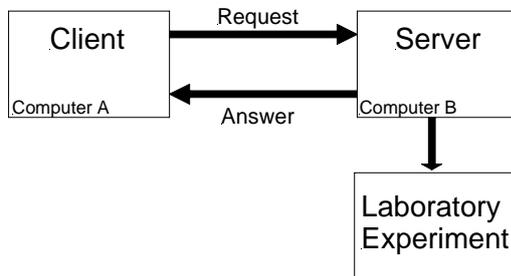


Figure 1: Structure of a Client-Server system for Remote Control

The server responds to all requisitions from the client (commands and data to and from the experiment) and also controls the laboratory experiments.

With the introduction of the hyper-text mark-up language (HTML) several years ago, and the associated hyper-text transfer protocol, the possibility existed of 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. Other solutions for remote control systems use for the dynamic visualisation of the controlled processes the VRML and JAVA programming facilities on the server and on the client side [8].

Figure two shows the general structure of an 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 (VI), which were developed using the graphical

programming language G (by means of the LabVIEW™ software development environment, National Instruments Corporation) [1]. The VI enables the hardware access to the experiment: analogue and digital server I/O-systems or the standard measurement bus systems such as IEEE 488.2 (GPIB), RS 232 or USB.

Secondly, it has to do duty as an 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

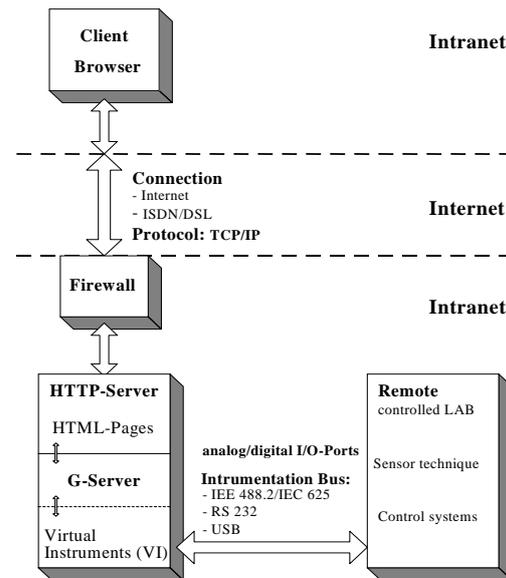


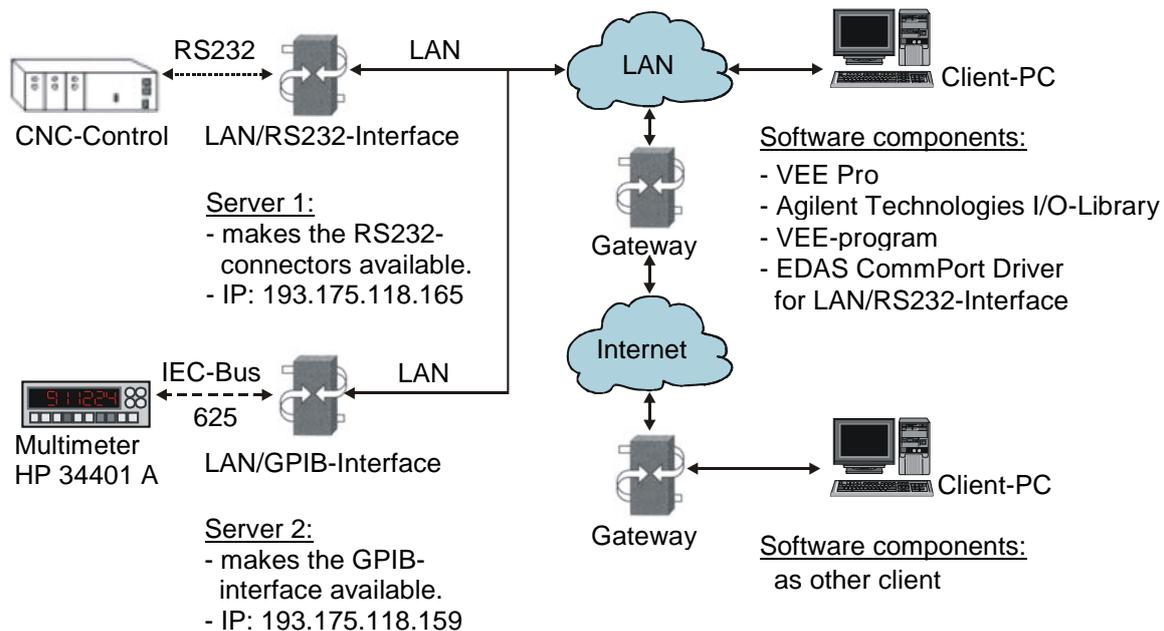
Figure 2: Structure of the http-based remote controlled laboratory / experiment

the VI of the LabVIEW™ control program (e.g.: input/output) into the HTML document is performed by a G-server. The G-server is a part of the Internet toolkit (National Instruments Corp.) which also provides VI's for the use of other Internet services, such as the file transfer protocol (FTP) and e-mail. The functionality between client and server can be extended by means of elements such as 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.

3 REMOTE CONTROL GATEWAY

Gateway technology enables communication between a (Client-)PC and the gateway with Instrumentation bus connectors such as GPIB or RS232 via a LAN. The gateways themselves have the structure of a

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



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 references model (OSI) using SICL software (Standard Instrument Control Library [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 realized by means of a simple IP-list in the Gateway; on the other hand, if a client had a right of access to a gateway then he would control everything on the instrumentation bus!

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

4. ONLINE VISUALISATION

Online visualization of the remote control process is one of the major problems which have to be solved:

In the first version of an 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 visualization of the dynamic actions of the experiment. This can be embedded within the VI as a static picture (JPEG, BMP). On the client side, e.g.: 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 for the internet control that the clients' browser is able to implement the server-push technology (e.g. Netscape Navigator) because the G-

server uses this technology to display the (graphical) control VI 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 [9]. With the use of remote controlled high resolution CCD ZOOM-cameras and video streaming technology the requirements on dynamic process visualization can be eased and 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.

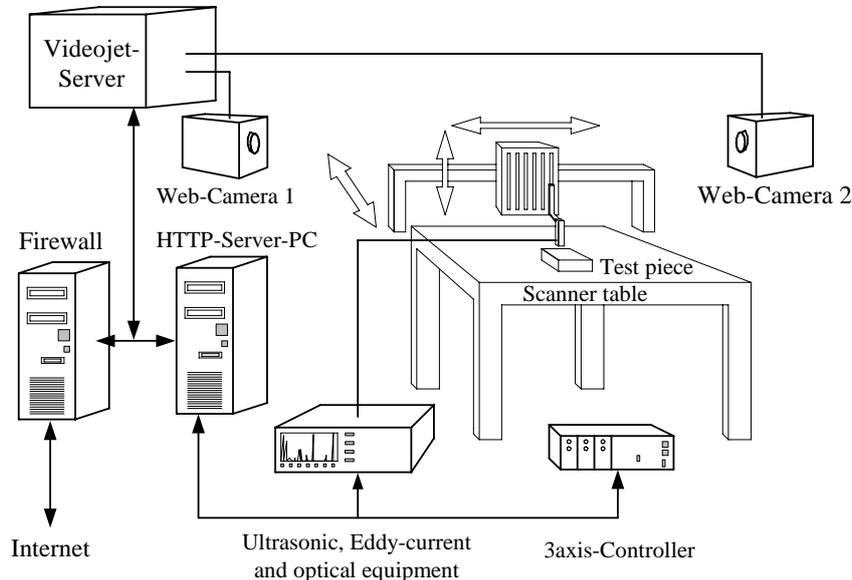
5. REMOTE CONTROLLED LABORATORY

In the first phase of the remote-control project the performance of the http-based client-server system using LabVIEW[™] software with different configurations (e.g.: inclusion of online visualization, task control, firewall) was investigated. In the second phase real and complex computer-controlled lab experiments were designed [4],[8],[9]. At Rostock University and at Hochschule Wismar complex research experiments involving remote control of ultrasonic, eddy-current and optical sensors have been designed.

For example, the ultrasonic measurement research experiment consists of an ultrasonic sensing array (a 3-axis scanner to probe the so called A-, B- and C-scan signals with the ultrasonic sensor), the server and a remote-controlled CCD camera system (640 x 480

system for the ultrasonic sensors it is possible to design a variety of research experiments such as profile measurements on surfaces and the building up in stages to achieve 3-D measurements on solids.

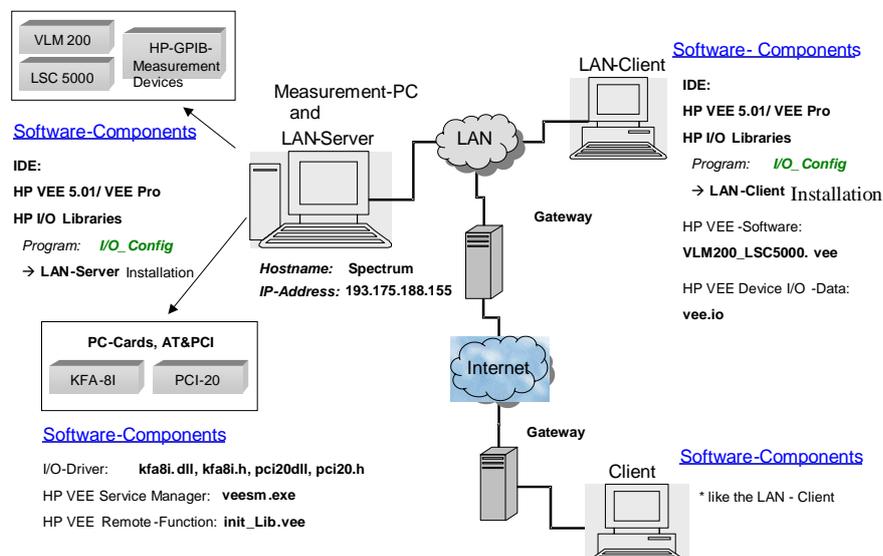
Figure 4: Http-based remotely-controllable ultrasonic and eddy-current measuring equipment



pixel) with a second (video-jet) server to observe the dynamic responses - as shown in figure 4. Using the continuously tuneable ultrasonic array experiments within a frequency range from 0.5 to 15 MHz are possible. The sensors can work in impulse-echo or in continuous mode. All experiments are designed in such a way 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). Using the equipment

In case of the eddy-current research experiments, such as surface or thin film inspection and also crack detection, the sensor is a coil probe which 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). For the optical sensor lab a proprietary client-server system has been designed using the graphical

Figure 5: Proprietary Client –Server System using VEE PRO



language VEE Pro. The structure of the a proprietary client-Server system is shown in figure 5.

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. An advantage of this solution is the possibility of using the 'remote controlled function' which allows the inclusion of your own 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 measurements 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 and other configurations) makes online visualization 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 [10]. Router, hub and switcher technologies reduce the effective transmission rate of high speed Internet connections [11][13].

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 it would also be more expensive.

6. Summary

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. e.g.: a complex experiment using ultrasonic, eddy-current and optical sensors.

If JAVA is used as a software platform all access to the hardware components must be made using programming methods, e.g. by an OSGI-Sever [14], which is very time-consuming.

The on-line visualization of remote-controlled experiments and the interactive control possibilities is one of the most important challenges which have to be solved. If the latency issues of the web should have not any influence on the experiment, than a 'stand-alone' control software and a schedule of the real-time experiment on the server side is necessary.

In case of a data transfer transmission rate >100 kbit/s video-jet (video-streaming) technology could be a powerful contender. With the new upcoming IEEE

Standard 1588 *distributed* real time remote controllable systems will be possible [15].

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