

Internet-Based Resources Sharing and Leasing System for Control Engineering Research and Education*

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In this paper, the development of an Internet-based resources sharing/leasing system useful for a university or research environment will be presented. The system allows a user to access a rich variety of equipment resources without having to incur high acquisition costs, using only available off-the-shelf components and the Internet. The principles of the system, the hardware and software requirements, as well as operational details will be elaborated in the paper. In particular, such a system for equipment resources sharing for research and education in the area of control engineering will be used for illustration.

INTRODUCTION

AN IMPORTANT PART of a control engineering research work is the final experimental verification of the developed results. This experimental test is useful and necessary to support the research findings and claims, and it will serve to instill a sense of confidence in possible downstream users of the technology. Since research is usually of a specialized nature, the equipment resources to enable these experiments are usually also of a specialized or customized nature in order to clearly bring forth the potential contributions beneficial to the real world. Since a research focus can be a rather dynamic one, the relevance of the experimental setup is limited and its continued usage can be rather limited. This means a high depreciation in value after the initial purchase of the equipment, and correspondingly, low cost-effectiveness associated with the purchase of dedicated equipment.

Short term leasing of such dedicated equipment for research purposes will be very useful in a university and research environment, as far as time-limited use of these equipment for research verification is concerned. With the advent in information technology (IT), available infrastructure and technologies are well poised to facilitate such resources sharing and leasing without having to physically relocate them [1–3], opening vast possibilities for implementation of Internet-based resources sharing/leasing systems. Distance learning is one beneficiary of this technology, since teaching and even laboratory practice can be done remotely [4–12].

In this paper, the development of an Internet-based resources sharing and leasing system for research purposes will be presented. The system allows researchers worldwide to have access to a

rich variety of equipment resources for their research without having to commit to a long-term cost by way of purchase, especially if the equipment is deemed to be of limited use. This virtual library of rich resources can belong to a single entity or it may be a ‘world-wide laboratory’ constructed from a consortium of participating parties, each with their own resources linked via the Internet such that to a user, he only has a single interface with the library without having to know who the associated resource belongs. Under this system, a potential user can apply to the system administrator for membership and will be assigned consequently with a member rights to access the system. The details and specifications of the equipment can be all available on the main server hosted by the administrator. The member may book to use a particular equipment and the time slot to operate it. He can download the necessary codes to run the equipment, modify them to include his algorithms and test sequences and upload them to the server to run on the actual system. Real-time video of the experiment can be delivered right to his monitor. The member can also specify the experimental results and parameters to be subsequently made available to him for his research documentation. Finally, he can be charged an amount for the type and time duration of the resources he has used. The paper will present the key components of such a system, using for illustration an example of a leasing system for researchers and educators working in the control engineering area.

OVERVIEW OF THE RESOURCES SHARING/LEASING SYSTEM

The resources sharing/leasing system can comprise multiple distributed resources under the

* Accepted 26 July 2005.

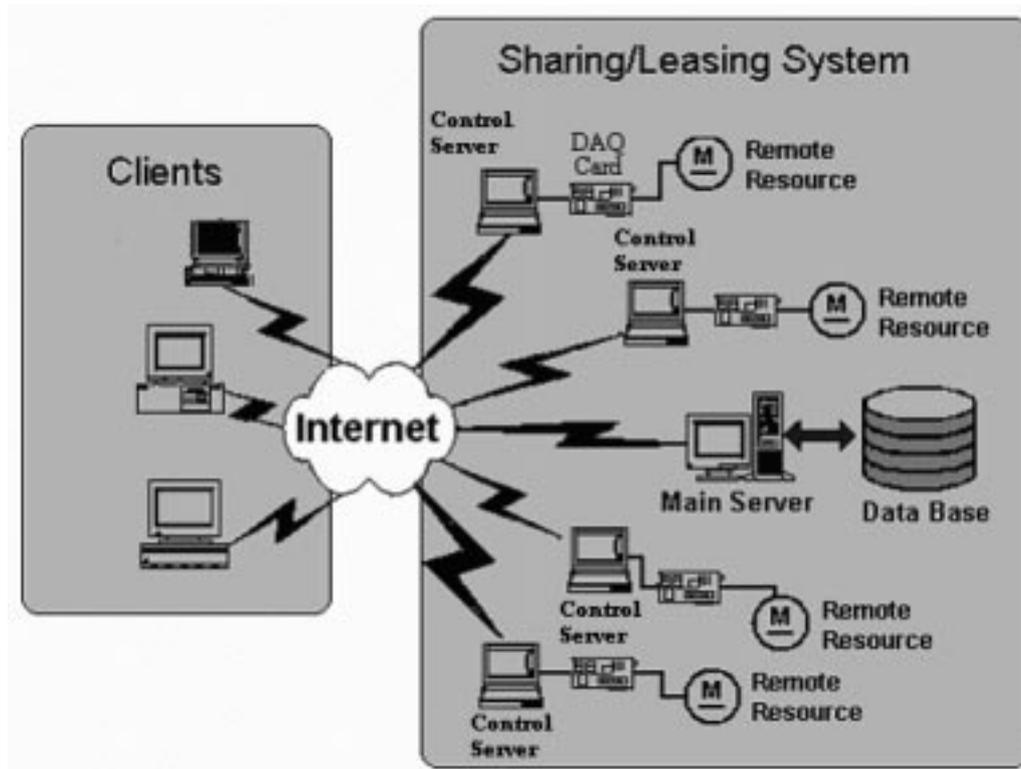


Fig. 1. Overview of the resource sharing/leasing system.

management of a main server. Physically, these resources can be located in different vicinities, even on different continents. Figure 1 shows the overall configuration of the system. In this paper, we will consider such a system for control engineering research [4] which focuses on control algorithms design to meet certain objectives. The main server will maintain a user database which records information relating to both the available resources and the members. The resource information includes the IP address and operational schedule specific to each distributed control server, the applicable charges and other equipment-specific parameters and specifications which the user should know. The member information will include the account name, password, and other information to facilitate the bill accounting process. The main server will route the user to the appropriate control server to which the selected equipment is connected.

The individual remote control servers will serve to accept the user-designed control algorithm, execute it on the appropriate apparatus, and log the control results and experiment duration and charges to be provided to the user. It allows the users access to sample control algorithms and guidelines for the users to be able to design their control algorithms which will be subsequently uploaded from the user to the control server. In order for this aspect to function efficiently, a standard control platform has to be maintained at each control server. In addition, key parameters such as input, output and sampling variables have to be standardized and users have to conform to

them when developing their algorithms, so that these algorithms can be executed properly on the control server.

The Internet serves as the backbone of the whole system, linking the main server to clients located all over the world, as well as the control servers and the available and distributed resources. Figure 2 shows an overview of the data flow within the system. On the client's side, the user uses a web browser to link to the main server. For the actual operations, the server will route the user to the appropriate control server accordingly. Through the web browser, the user will provide his desired control actions and receive the control results. The LabVIEW [3] run time engine is installed to ensure efficient and secure data transmission.

Across the Internet, the control server runs a LabVIEW G-Web server to feed web pages to browsers around the world. The control server serves as the connecting medium between the user and the remote machine. It also runs a FTP server to provide file system operations to authenticated users via the Internet.

Hardware requirements

The key control components necessary at the control server include typically a personal computer (PC), data acquisition (DAQ) card and accessories (in this case, DAQ cards from National Instruments are used), power supplies, and possibly web-cameras to provide video transmission of the operations to the user where necessary.

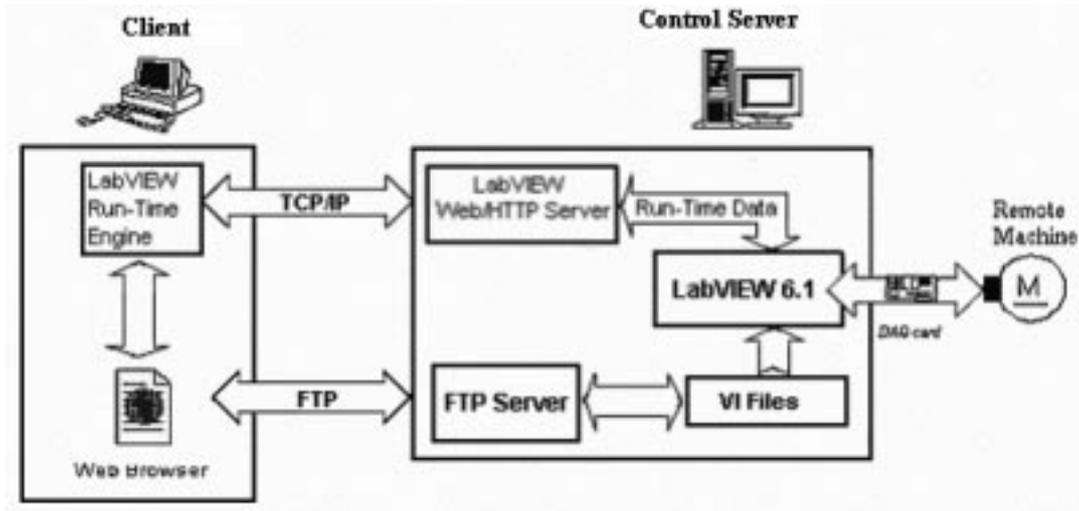


Fig. 2. Data flow between client and control server.

In the area of control engineering research, possible equipment resources which can be put together can comprise a rich set of systems with different dynamics: single-input-single-output (SISO) systems, multiple-input-multiple-output (MIMO) systems, linear systems, nonlinear systems, interacting systems, large scale discrete-event systems, etc. Such systems can be derived from different kinds of motors, process control apparatus, single or co-operating robots, and large-scale assembly and manufacturing processes.

The user to such a resources sharing and leasing system will be able to use these resources to test and generate his control results, and incur only a small fraction of the costs otherwise necessary to acquire the equipment. The equipment is connected to the DAQ card within the PC and through this DAQ card, electrical control and measurement signals are transmitted to and from the equipment. The PC which is linked to the Internet, is used primarily for data acquisition and control of the remote machine, although it

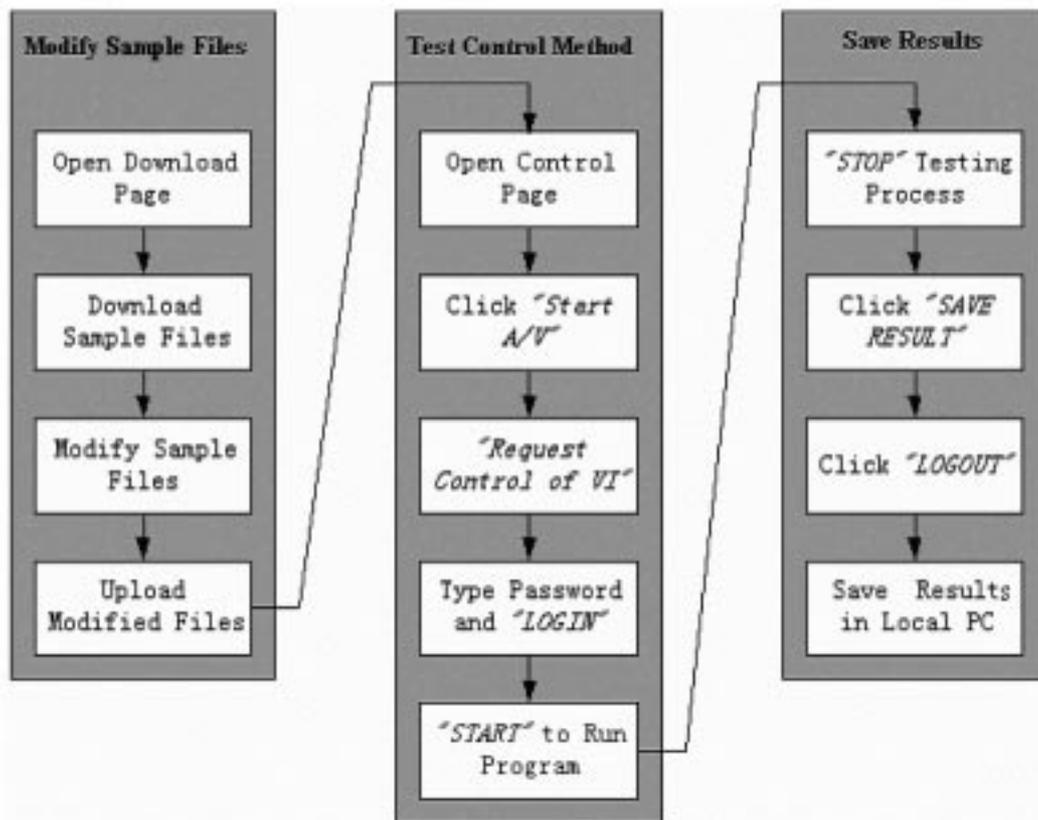


Fig. 3. Main user steps.

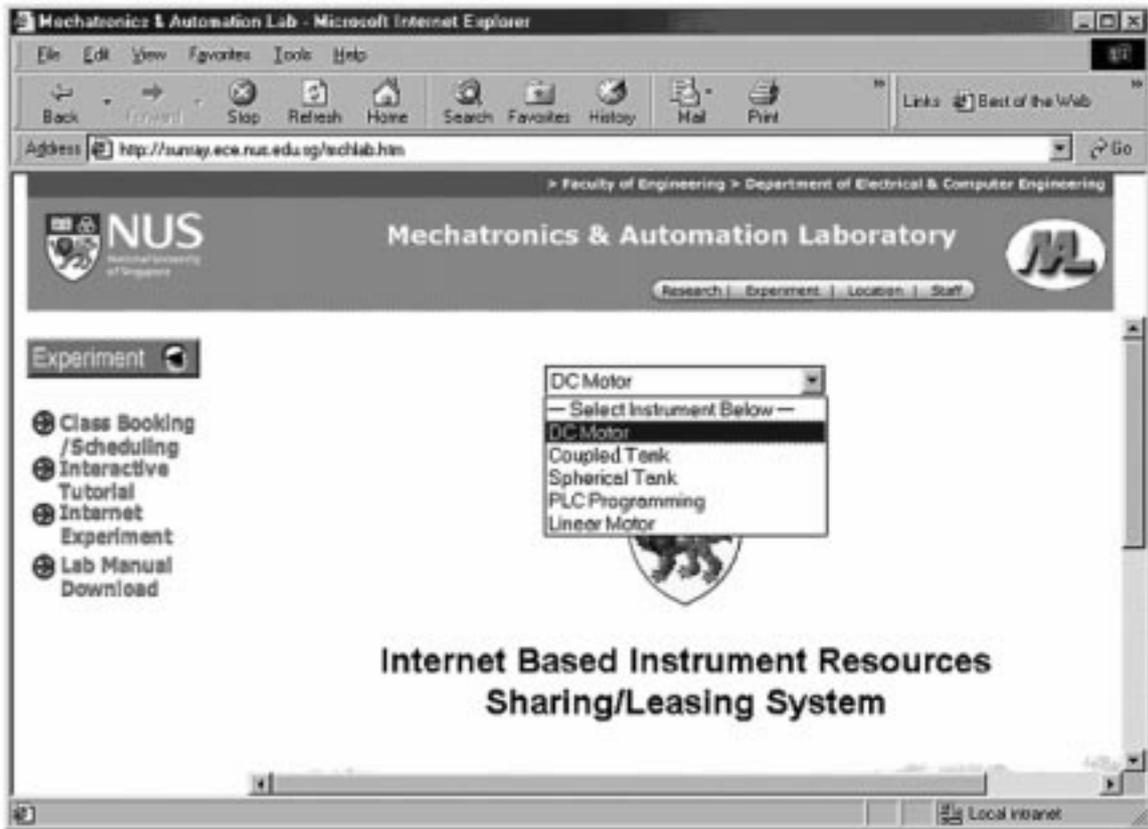


Fig. 4. Home page on the main server.



Fig. 5. Home page at the control server for DC motor control.

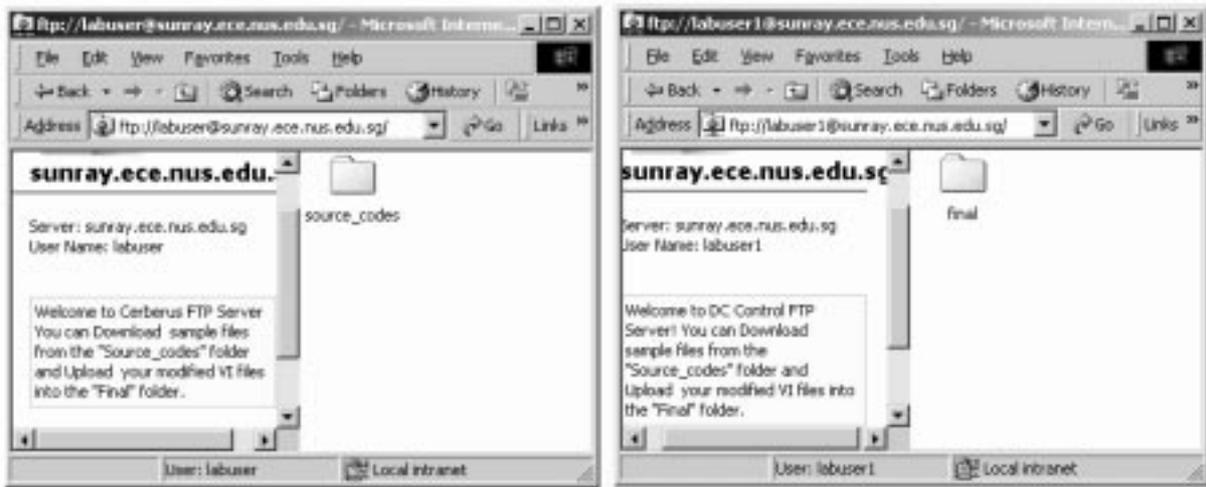


Fig. 6. File directories for the source (sample) and final programs.

also serves an administrative function of accounting for the amount of resource usage by the user.

Software requirements

To allow users to control the equipment remotely, a software to create an interaction between the user and the hardware is necessary. In this particular case, LabVIEW 6.1 is used. It operates the DAQ card to control the equipment and also run a web server to communicate with the clients.

To enable the user to download and upload the algorithms, an FTP server is installed and run with pre-configured security settings to protect the local file system from malicious access. Windows

NetMeeting is used to for video transmission to feed the user with live video of the remote operations. On the client's side, all he needs to install is LabVIEW running under windows operating system, and a DAQ add-on component to manipulate the sample control programs. These requirements are rather mild and should be easily satisfied.

USER INTERFACE

The procedures to use the resources maintained on the system comprise three main steps as depicted

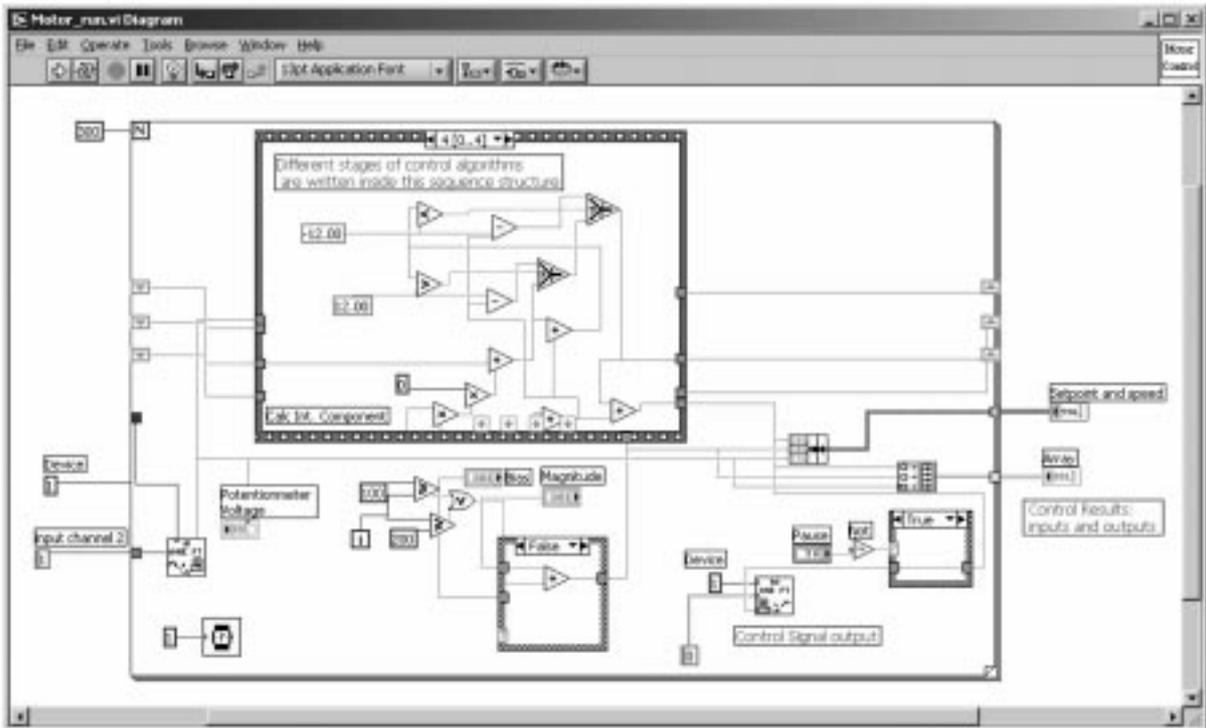


Fig. 7. Sample source code for DC motor control.

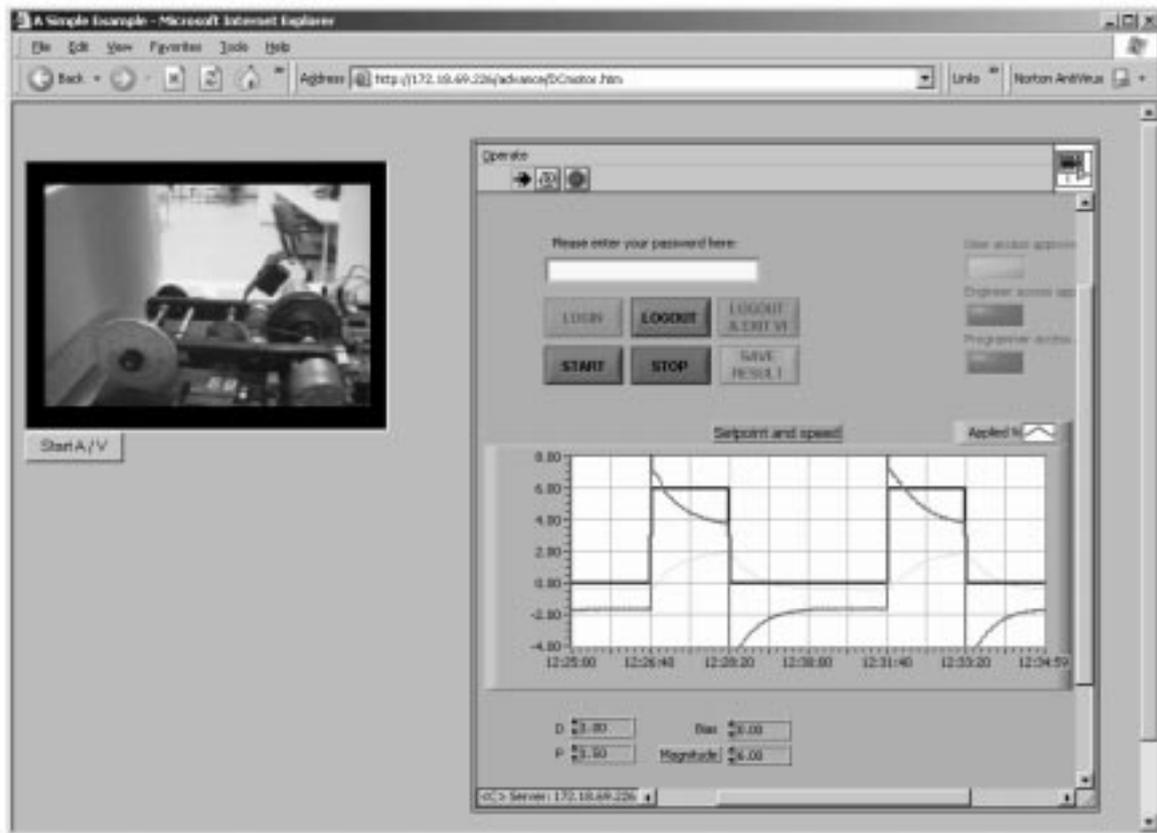


Fig. 8. Snapshot of the front panel for DC motor control.

in Fig. 3. First, the user logs on to the host web page, as shown in Fig. 4. From this page, he can view the resources available to him and select the resource needed. Upon selection, he will be redirected to the home page provided by the control server. From this page, he will be able to access the FTP page to download sample files by following the appropriate link on the page. Downloading of the sample files does not require authorization. However, uploading of the user's control algorithm requires the user to be registered with the administrator. Figure 5 shows a typical home page at a particular control server for a DC motor [2] setup.

Users can download sample programs from the source directory and modify them locally in their own machines, adhering to the standard key parameters necessary for the program to work. When the final program is uploaded to the target directory in the server, the user program can be run on the equipment. Figure 6 shows the file directories accessible to users for the file transfer. Figure 7 shows the diagram of a sample file containing sufficient information for the user to proceed with the design of his control algorithm.

After the user has uploaded the final control program to the target directory, the user can invoke a CGI (Common Gateway Interface) program which will execute the program and redirect the user to the control web page. The new web page will load the user program and

embed an appropriate control front panel. The user thus assumes control of the equipment via this panel. A typical control panel for the DC motor control server is shown in Figure 8.

Once the user has cleared an authentication procedure, he can initiate the control operations by clicking on the *START* button. In the video window on the left side of the panel, real-time video images of the remote operations can be transmitted to the user. The parameters listed on the panel can be adjusted manually throughout the process.

When sufficient information has been collected or the desired performance is achieved, the user can click on the *STOP* button to stop the process. The *SAVE RESULT* button will trigger a function to write the required results into an ASCII file which will be made available to the user. The file will also contain the resources usage information necessary for the accounting process.

Figure 9 shows typical control numerical results contained within the logged file. It is in spreadsheet format and can be analyzed by any software to get the precise performance of the control method.

SECURITY AND ACCOUNTING ISSUES

Security is one key consideration in the setup of an Internet-based system, since the system is

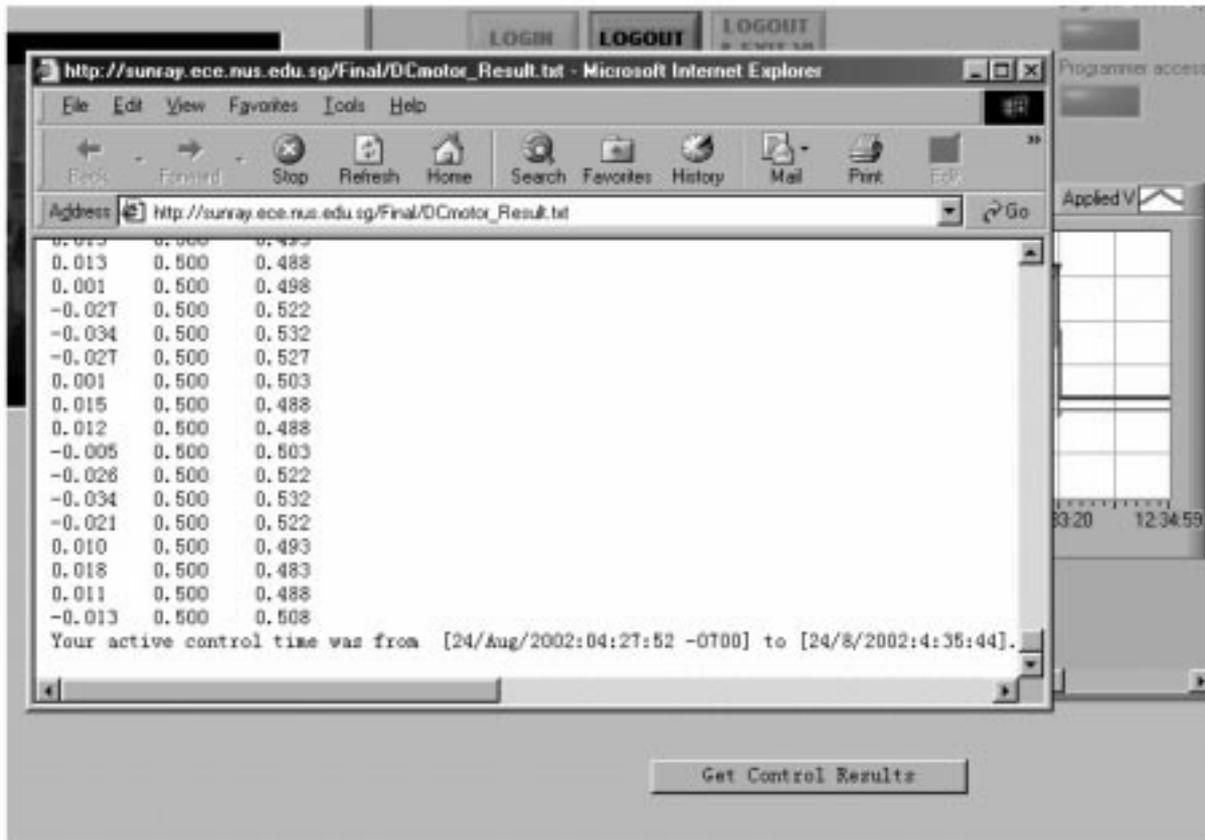


Fig. 9. Snapshot of the control results.

expected to be accessed by a huge number of people all over the world. The integrity of the system should be ensured through the use of user authentication schemes and security access control methods for the servers. Intellectual Property Rights (IPRs) associated with the members' programs should be properly addressed too. The measure adopted here is to remove the customized programs once the user has completed his session on the control server. Operational safety is another issue concerning safety, since equipment is expected to be operated remotely without on-site supervision. At the remote sites, it may be necessary to have hard protection measures in place to cut-off operations when safety limits are breached.

The usage charges can be based on the time duration, which is from the time the user assumes control over the equipment to the instant when it is

freed to be available to other users. The time duration can be calculated from the log file in the G-Web server.

CONCLUSIONS

In this paper, the development of an Internet-based resources sharing/leasing system useful for a distant education or for research purposes is presented. Such a system allows a user to access a rich variety of equipment resources without having to incur high acquisition costs. The principles of the system, the hardware and software requirements as well as operational details have been elaborated, using a system for control engineering equipment resources for illustration.

REFERENCES

1. L. Podesta, Hypertext and virtual instrumentation for practical electrical measurements exercises, *IEEE Instrumentation and Measurement Technology Conference, IMTC 97*, Ottawa, Canada, May 19–21, 1997.
2. K. K. Tan, T. H. Lee and F. M. Leu, Development of a distant laboratory using LabVIEW, *Int. J. Eng. Educ.*, **16**(3), 1999, pp. 273–282.
3. B. Aktan, C. Bohus, L. Crowl and M. Shor, Distance learning applied to control engineering laboratories, *IEEE Transactions on Education*, **39**(3), 1996, pp. 320–326.
4. R. Pascoe, Introducing WWW technology into tertiary teaching: a personal perspective, *North American Web Conference, 1997*, New Brunswick, Canada, pp. 97–101.

5. S. E. Poindexter and B. S. Heck, Using the Web in your courses: What can you do? What should you do? *IEEE Control Systems Magazine*, **19**(1), 1999, pp. 83–92.
6. J. Bourdeau and A. Bates, Instructional design for distance learning, *J. Science, Education and Technology*, **5**(4), 1996, pp. 267–283.
7. W. Horton, *Designing Web-based Training*, John Wiley and Son, USA (2000) pp. 481–518.
8. L. R. Porter, *Creating the Virtual Classroom: Distance Learning with the Internet*, John Wiley and Son, New York (1997) pp. 103–125.
9. C. McCormack and D. Jones, *Building a Web-based Education System*, John Wiley and Son, USA (1997) pp. 233–289.
10. Richard E. Clark, Reconsidering research on learning from media, *Review of Educational Research*, **53**(4), 1983, pp. 445–459.
11. Richard E. Clark, Media and method, *Educational Technology Research and Development*, **42**(3), 1994, pp. 7–10.
12. J. Rosenblum and E. Healy, Developing an educational Intranet, *North American Web Conference*, 1996, Brunswick, Canada, pp. 23–26.
13. Application notes and other references on National Instruments LabVIEW webpage. <http://www.natinst.com/labview>.

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