

## Data Acquisition for Process Monitoring and Control

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### Abstract

Texas A&M University-Corpus Christi recently finished equipping the Control Systems Laboratory with data acquisition systems and process training equipment. The laboratory provides several capabilities, including internet-based experimentation, data acquisition, process measurements, control system modeling and design, sensor technology applications, neural networks, and signal processing. This paper describes the major laboratory equipment and the implementation of online experiments that offer data acquisition, monitoring, and control from remote locations. A front panel in LabVIEW displays the results and allows storage of acquired data for later processing. A digital camera that provides real-time pictures of the monitored equipment is part of the system configuration.

### Introduction

Laboratory development is a major task that faculty at institutions of higher education are constantly addressing [1-3]. Texas A&M University-Corpus Christi (A&M-CC) recently established a new Control Systems Laboratory that provides interdisciplinary educational and research capabilities across several science and engineering areas. These areas include sensor technology, data acquisition, control system design, system modeling, signal and image processing, neural networks, and data visualization. The laboratory supports several courses and gives Computer Science (CS) and Engineering Technology (ET) students unique training opportunities and benefits by having both groups work on interdisciplinary projects.

The ability to monitor and control processes from remote locations makes proper and timely analysis possible. Advances in networking technologies and development of measurement hardware and software has turned PCs into platforms capable of continuous remote monitoring using the Internet. A software program that facilitates the developments of such applications is LabVIEW [4-9]. The software allows embedding a user on a web page with access to the system. Access can be granted using security features available through the software. Features such as password protection can prevent private information from being viewed by the general public. This feature is especially useful for offering online experimentation where students need to gain access to inaccessible laboratories outside of their class time. This paper presents the process

for developing online experiments for process monitoring and control using a data acquisition system that was developed for use in a control systems course.

## **The Laboratory**

The Data Acquisition and Control Laboratory consists of the following major equipment<sup>1</sup>: desktop computer stations, data acquisition systems, software (MATLAB and LabVIEW), level and flow measurement system, process control system, wireless data loggers, calibrators, and a variety of test equipment. The following paragraphs briefly describe the features and capabilities of some of the major components.

### Data acquisition systems

Each system consists of several components, including a data acquisition board, signal conditioning units, mounting terminal block, and chassis. These components are integrated into real-time measurement units that interface to desktop computers and process control equipment. The National Instruments (NI) Software Solutions Department license, which consists of LabVIEW 6.1, control and simulation toolkit, Internet, Gmath, and signal processing suites, is used for programming these units.

### MATLAB and associated toolboxes

MATLAB is one of the most popular programming languages used worldwide for a range of computing tasks in engineering and science. The package available in the laboratory consists of MATLAB 6.5, Simulink 5.0.1, Data Acquisition Toolbox, Signal Processing Toolbox, Control Systems Toolbox, Instrument Control Toolbox, Image Processing Toolbox, Neural Networks Toolbox, MATLAB C/C++ Graphics Library, MATLAB C/C++ Math Library, MATLAB Compiler, and Symbolic Math. A MATLAB Student version that has most of the full version capabilities at a reasonable price (around \$100.00) is available for students to buy online or from the University bookstore [10].

### Level/flow process control system

This system offers level and flow measurements and display. Temperature, displacement, pressure, and pH sensors and transducers will be added to provide input data to both LabVIEW and MATLAB through the data acquisition systems. The integrated laboratory environment is capable of supporting a wide variety of experiments that can be performed during regular lab hours or through remote access using LabVIEW and MATLAB. Access through MATLAB is limited to computers connected to the department network, however, access through LabVIEW will be available from anywhere there is an Internet connection.

### Process control workshop

This system offers real-time control via MATLAB and Simulink. This allows using the system for advanced control concepts and research-oriented projects. The process is

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represented by a heating element controlled by a thyristor circuit that feeds heat into the air stream circulated by an axial fan along a polypropylene tube. A thyristor detector may be placed at one of three points along the tube, sensing the temperature at that point. The volume of air flow is controlled by varying the speed of the fan via a potentiometer. The system allows experimentation with distance and velocity lag, calibration, proportional control, disturbance and system response, and frequency response.

#### Wireless logging system

The logging system consists of two wireless data loggers communicating to a base station consisting of a modem and application software. The software allows a variety of functions, including instrument setup, data collection, creating real time trend graphs, and other data acquisition tasks. The wireless data loggers use spread spectrum radio transmission to reliably send data with a high degree of immunity to electrical noise and interference. Range of transmission may be up to 120 m inside buildings and to over 300 m line of sight. The base station can support up to 20 remote data loggers. The software allows exporting data in real time to Lotus 1, 2, 3, and Excel by using a Dynamic Data Exchange (DDE) link.

#### PC workstations and test equipment

The PC workstations are interfaced to the data acquisition systems. A direct connection exists between one of the PCs and the process control workshop. Test equipment that supports the laboratory includes thermocouple calibrators, digital thermometers, temperature calibrators, scopemeters, hand-held meters, multi-meters, function generators, power supplies, and frequency counters.

### **The Data Acquisition System**

The data acquisition system consists of a data acquisition board (PCI-MIO-16E-4), terminal blocks (SCXI 1303 and SCXI 1325), signal conditioning hardware (SCXI 1102), and a digital to analog conversion module (SCXI 1124). The PCI-MIO-16E-4 has the following specifications:

- NI-DAQ driver with Measurement & Automation Explorer for easy configuration for Win 2000/NT/Me/9x and Mac OS
- Two 12-bit analog outputs; 8 digital I/O lines; two 24-bit counters
- Up to 16 analog inputs; 12-bit resolution; up to 500 kS/s sampling rate

The SCXI 1102C is ideal for higher bandwidth analog signals. Each channel can be configured for a gain of 1 or 100 allowing any combination of thermocouples to be used. This module has the following specifications:

- 10 kHz low-pass filter on every channel
- 32 channels, up to 333 kHz scanning rates
- For low-bandwidth mV, volt, and current inputs (1102B, 1102C)
- Over voltage protection to +/-42V

- Programmable instrumentation amplifier on every channel

The SCXI 1303 connects to the SCXI 1102C and is designed for high accuracy thermocouple measurements. This module has the following specifications:

- Isothermal construction that minimizes errors caused by thermal gradients
- Mounts to front of SCXI module
- Open-thermocouple detection circuitry
- Offers high-precision thermocouple temperature measurement applications
- Interfaces with the SCXI-1100/1102/1102B/1102C

The SCXI 1000 houses all of the component and power modules. Its architecture includes the SCXI bus, which routes analog and digital signals while acting as a communication conduit between modules. The chassis has the following specifications:

- Low noise environment for signal conditioning
- Rugged, compact chassis
- Forced air cooling
- Combination chassis for SCXI and PXI/Compact PCI modules
- House all SCXI modules

Assembling the system requires the use of the SCXI 1349 shielded cable assembly and the SCXI 1357 high voltage backplane. The cable assembly connects to the front-end signal conditioning SXCI. The high voltage backplane has the following specifications:

- Cable lengths up to 2 m
- Connects SCXI systems to measurement devices
- Includes 4-slot high-voltage analog bus
- Mounting bracket for reliable connection to the SCXI chassis
- Shielded for better accuracy; multi-chassis configurations available

The SCXI 1124 is a 6 channel isolated source for DC voltage or current signals. It is ideal for applications requiring isolated voltage or current outputs to a control process. The SCXI 1124 comes with 6 isolated 12-bit channels that can be configured for any of the available unipolar or bipolar ranges. This module has the following specifications:

- 12-bit resolution
- 6 isolated channels, 250 V<sub>rms</sub> working isolation per channel
- Combine output channels for larger voltage ranges
- For isolated DC voltage and current output
- Independently configure channels for voltage or current
- Driver Software: NI-DAQ Software for Windows 2000/NT/Me/9x or Mac OS
- Application Software: LabVIEW, Measurement Studio and Lookout

The SCXI 1325 is a screw terminal block that has 26 terminal for signal connections to the SCXI 1124 module. This module has the following specifications:

- 26-screw terminals for signal connections
- For isolated analog output applications
- For use with the SCXI-1124; Mounts to front of SCXI module
- Shielded for quick, convenient signal connections

Installing the components involves the following steps. First, the data acquisition board (PCI-MIO-16E-4) and all of its drivers are inserted into a PC that already contains LabVIEW. Second, the chassis (SCXI 1000) is attached to the board using the cable. Once this is completed, the signal-conditioning module (SCXI 1124) and the 32-Channel Amplifier (SCXI 1102C) can be inserted into the chassis. Finally, the Screw Terminal Block (SCXI 1325) is connected to the SCXI 1124 and the Isothermal Terminal Block (SCXI 1303) to the SCXI 1102C. Fig. 1 shows a picture of the actual system with wiring from the thermocouple to the input channel and from the output channel to an LED. The input channel was channel 11 of the SCXI 1303 and the output channel was channel 2 of the SCXI 1325.

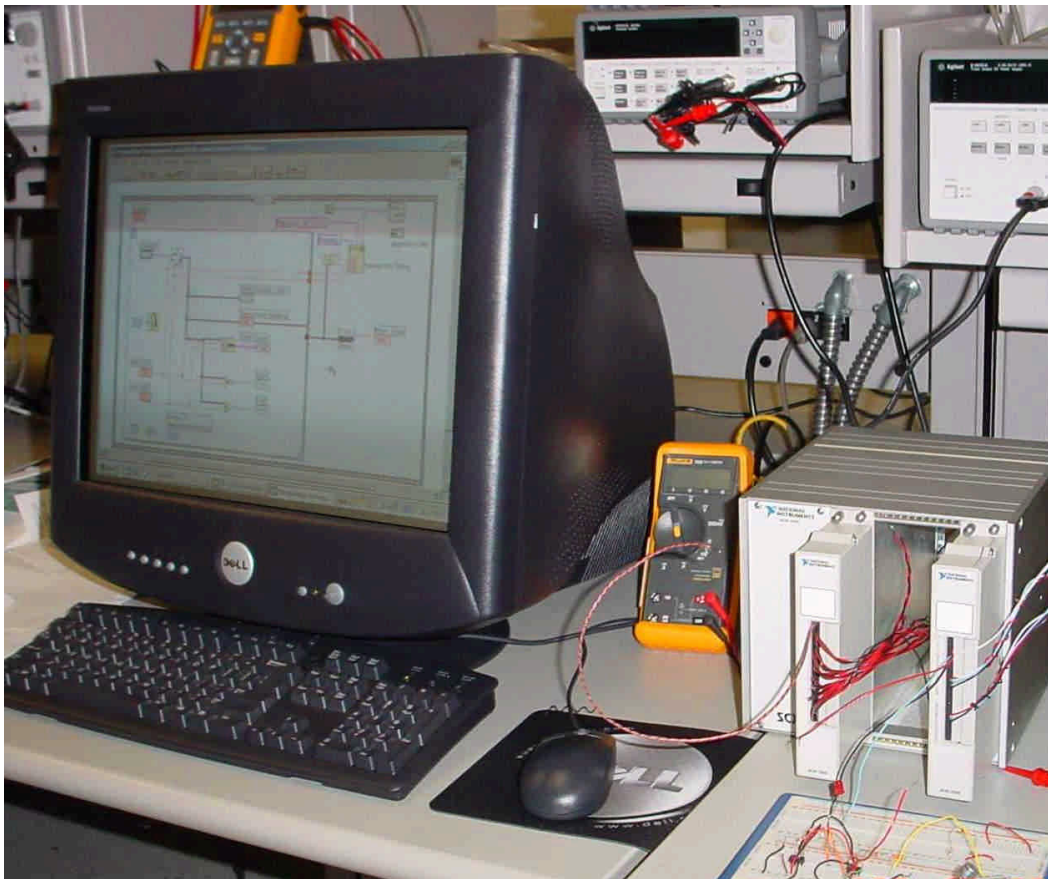


Fig. 1 Data acquisition system set-up

## Online Data Acquisition, Monitoring, and Control

MAX is a program that comes with the professional version of LabVIEW. It is used to configure the data acquisition system. The instruction tree in MAX has two important folders. One of the folders is called “Data Neighborhood.” This folder is where channels are assigned and are given values to use throughout the data acquisition process. The software gives the user the option to click on “Create New-Virtual Channel” and then choose the type of channel needed. Analog Input, Analog Output and Digital I/O are the choices it provides. The other folder is called “Devices and Interfaces”. Here, the modules that have been connected should be listed and can be configured by choosing properties. Once all of the modules and channels have been configured they can be tested using the button called “Test Panel”.

The Temperature System Demo VI that comes with LabVIEW was modified to accomplish real time measurements by reading data coming through the channels that were configured in MAX. The wiring diagram is reprogrammed by removing the randomly assigned numbers given in the subVI called, “Temp” and inserting the subVI called analog input and adding a DAQ channel control. The diagram is also modified so that an output voltage of five volts is sent through the output channel to the LED.

LabVIEW comes with many Internet capabilities. It allows a user to publish a static report on the Internet, share data for processing, data storage, or data monitoring. It also allows the user to control a process from a remote location and provides distributed execution of a program.

### The Web Publishing Tool

The Web-Publishing Tool facilitates publishing a VI on the Internet while granting and denying access to certain computers. The following steps are necessary for publishing a VI to the Web.

1. Run the VI to make sure it is working as required. The VI must stay open on the main computer. The server will not recognize a closed VI.
2. Go to “Tools” and click on “Options”. This will lead to a pull down menu where both configuration of the web server and browser access can take place.
3. Go through the pull down menu and click on “Web Server Configuration.”
4. In this screen, click on “Enable Web Server” to start up the server.
5. After clicking OK head back to “Tools” and click on “Web Publishing Tool.”
6. On this screen, choose the VI to be published. Choose the embedded label, and type any text that is needed on the Web page. Once this is accomplished click on “Save to Disk”. A screen will pop up with a URL address. Copy this address and paste it into either Netscape’s or Internet Explorer’s address bar.

Once the above steps are completed, the VI should be seen on the web site. The main server can grant anyone to take control of the VI but it also has the ability to regain control at any time. Denying access to a VI can be accomplished as follows. Go to the LabVIEW screen and click on “Tools – Options” as noted before, but this time click on

“Web Server Browser Access.” Here you are given the options to allow viewing and controlling, only viewing, or to deny access. In the small window above these choices, type the Internet Provider’s address’s of computers that should not have access to this VI, and click OK. This will forbid users of those computers from opening the Web site.

### The Internet Toolkit

The Internet Toolkit is another easy way to publish a VI with password protection. It does not, however, allow a user to control the VI remotely. To use the Internet Toolkit, follow these instructions:

1. Go to the VI you want to publish, click on “Tools” and scroll down to “Internet Toolkit” and click on “Internet Toolkit Configuration.” See Fig. 2.
2. Once in the Configuration menu, click on “User File Editor.” Add the names you wish to grant access and assign them their passwords. Save this file under “users.txt” in the internet/http/conf directory. See Fig. 3.
3. Repeat the steps for the “Group File Editor”, but call it “groups.txt”. Click “Done.”
4. Create a directory called “special” in the internet/home directory and save the VI as a web page in this directory.
5. In this menu click “New Panel” and choose the VI needed. Then click on “Edit Directories” and find the directory it is located in.
6. Once all of the settings have been completed, click on “Start Server”. Be sure that you disable the Web Publishing Tool server. Two servers cannot work together.

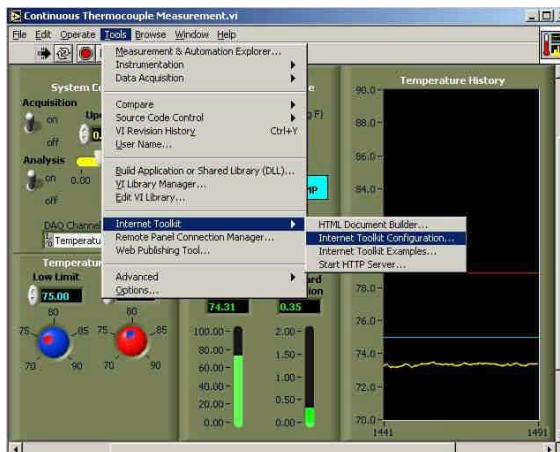


Fig. 2 Internet toolkit configuration

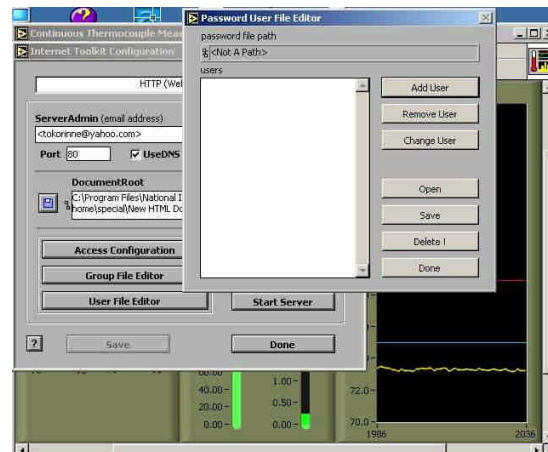


Fig. 3 Granting access screen

### Testing the System

The system was tested using Netscape. Typing in the address of the VI will display a user id and password screen as shown in Fig. 4. Typing in a proper ID and password will result in displaying the image in Fig. 5. Running the VI will continuously display room temperature. If the LED is lighting up as the program states then everything is working correctly.



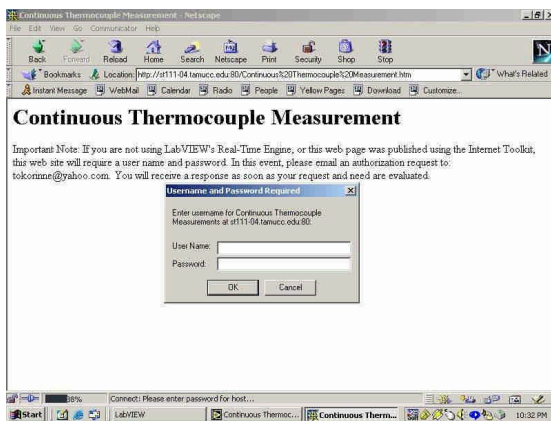


Fig. 4 Password screen

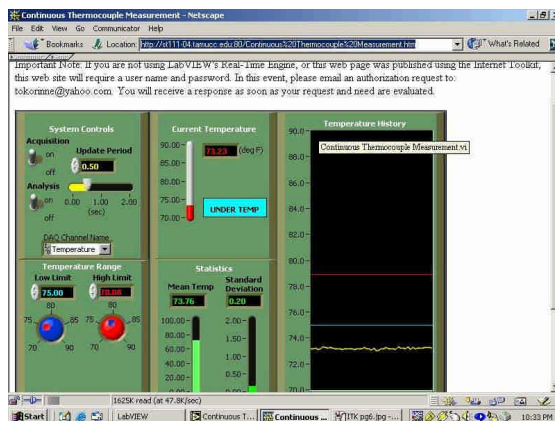


Fig. 5 Access granted

## Integrating a Video Camera

National Instruments Measurement & Automation Explorer (MAX) is available for Configuring Cameras [11]. MAX automatically detects cameras and the available image acquisition board. MAX also provides the functions to change the configuration or test the camera. After MAX has launched, the properties of the camera can be set by right-clicking on the camera name in the IMAQ IEEE-1394 Devices folder in the MAX configuration tree (See Fig. 6). A user can select Properties from the pop-up menu and adjust the attributes of the camera and click OK to save the camera file. Three NI-IMAQ image acquisition types are available in LabVIEW: snap, grab, and sequence. A snap acquires a single image into a memory buffer. A grab is a continuous, high-speed acquisition of data. This function performs an acquisition that continuously loops, so it is suitable for the Web-Cam applications. Two VIs, IMAQ1394 Grab Setup and IMAQ1394 Grab Acquire, should be used for a grab acquisition. IMAQ1394 Grab Setup initializes the acquisition and starts capturing the image to an internal software buffer. IMAQ1394 Grab Acquire copies the image currently stored in the internal buffer to a LabVIEW image buffer. A sequence initiates a variable-length and variable-delay transfer to multiple buffers. A sequence can be used in applications that process multiple images.

There are two main ways to display images [12]. First, a user can use IMAQ WindDraw provided by IMAQ Vision. IMAQ WindDraw provides a good functionality so it can display any type of images (JPG, PNG, BMP, 8-bit or 16-bit monochrome image, RGB image, etc.) and any acquisition types (snap, grab and sequence). However, it doesn't support Web Publishing Tool. Another way to display the images is to use picture control in LabVIEW. It supports Web Publishing Tool but a user has to know the exact image type. For instance, IEEE 1394 Cameras usually support three kinds of the image types: 8-bit and 16-bit monochrome, and RGB images.



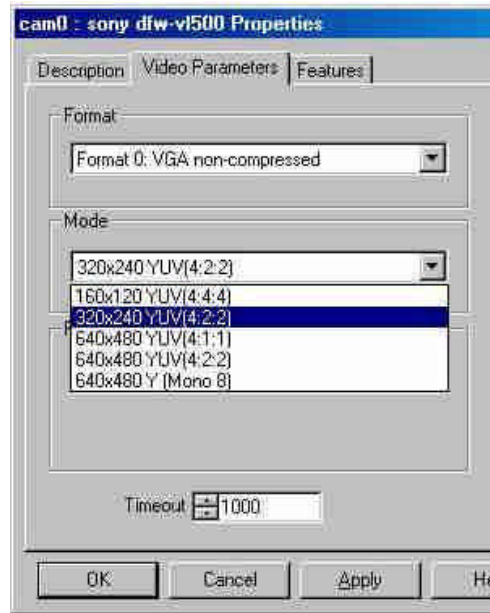


Fig. 6 Properties menu in MAX

Figure 7 and 8 are the Front Panel and the Block Diagram of a Web-Cam application. This application uses the grab acquisition type to continuously acquire RGB images captured by a Sony DFW-VI500 camera.

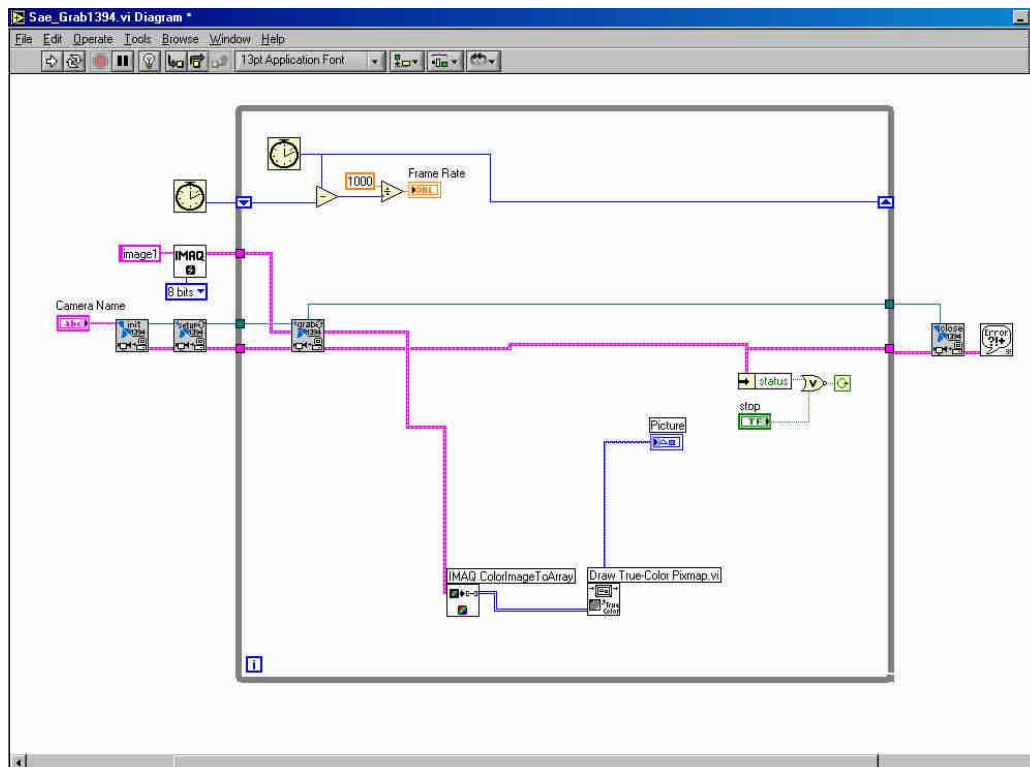


Fig. 7 Block diagram of a Web-Cam application



Fig. 8 Front panel of a Web-Cam application

## Conclusion

This paper presented a closed-loop data acquisition system and used it to illustrate a process monitoring and control application. Using either the Internet Toolkit or the Web Publishing Tool, a programmer can easily grant or deny access to networked computers. The implementation of a digital video camera that offers real time images on the published front panel was also described.

## Bibliography

1. G. Plett and D. Schmidt, "A multidisciplinary digital-control-systems laboratory," 2002 ASEE Annual Conference Proceedings, Session 1526, 14 pages.
2. R. Ramachandran, R. Ordonez, S. Farrell, Z. Gephardt, and H. Zhang, "Multidisciplinary control experiments based on the proportional-integral-derivative (PID) concept," 2001 ASEE Annual Conference Proceedings, Session 1526, 17 pages.
3. R. O'Brien, Jr., "Matlab simulation projects for a first course in linear control systems," 2000 ASEE Annual Conference Proceedings, Session 2520, 7 pages.
4. B. Diong, "Providing an updated dynamic systems and controls lab experience," 1999 ASEE Annual Conference Proceedings, Session 2532, 9 pages.
5. N. Swain, J. anderson, M. swain, and R. Korrapati, "State-space analysis of linear, time-invariant control systems using virtual instruments," 2001 ASEE Annual Conference Proceedings, Session 1547, 7 pages.
6. L. Sokoloff, "LabVIEW implementation of ON/OFF controller," 1999 ASEE Annual Conference Proceedings, Session 3659, 10 pages.

7. N. Kim, "Process control laboratory experiments using LabVIEW," 2001 ASEE Annual Conference Proceedings, Session 3220, 15 pages.
8. Egarievwe, S., Okobiah, O., Ajiboye, O., Fowler, L., Thorne, S., and Collins, W. "Internet Application of LabVIEW in Computer Based Learning." European Journal of Open and Distance Learning. 2000.
9. Travis, J. *Internet Applications in LabVIEW*, Prentice Hall, 2000.
10. MATLAB Student Version Release 13, including the Control Systems Toolbox, The MathWorks, <http://www.mathworks.com/products/studentversion/index.shtml>.
11. National Instrument: Getting Started with NI-IMAQ for IEEE-1394 Cameras  
Available at <http://www.ni.com/pdf/manuals/322885a.pdf>
12. National Instrument: NI-IMAQ for IEEE-1394 Cameras User Manual  
Available at <http://www.ni.com/pdf/manuals/370362a.pdf>

## Biography

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Rafic (Ray) Bachnak is an Associate Professor of Engineering Technology at Texas A&M University-Corpus Christi. He received his B.S., M.S., and Ph.D. degrees in Electrical and Computer Engineering from Ohio University in 1983, 1984, and 1989, respectively. Dr. Bachnak was previously on the faculty of Franklin University and Northwestern State University.

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