Remote Laboratory Operation: Web Technology Successes

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Abstract

National Aeronautics and Space Administration (NASA) has awarded Fort Valley State University (FVSU) a three-year project to develop an undergraduate minor program in computer based measurement and instrumentation. The primary objective of this program is to enhance the existing mathematics, engineering technology, and computer science programs at FVSU. This program will help students gain a solid foundation in computer science, engineering, physics, and modern experimental sciences through hands-on laboratory-based approaches with state-of-the-art technologies.

A modern computerized instrumentation lab is currently being developed at the Department of Mathematics and Computer Science of FVSU to support the curriculum of the minor program. We are planning to equip the lab with various experimental setups that could be used to perform scientific experiments for lab science courses offered at FVSU. These setups will be fully controlled, monitored and operated by computer systems using virtual instrumentation technology. They will also feature on-line capabilities that would allow users to operate them remotely through the Internet.

The setups are: (1) a motor-generator with a variable speed motor and a variable resistive load and (2) a variable-speed water pump, flow and level system. This paper discusses the way we use these in classes for teaching programming and data-acquisition. The paper presents typical assignments and a survey of student satisfaction and student complaints.

Computer-Based Measurement and Instrumentation

We believe that students majoring in computer science and engineering technology need computer experience that goes beyond standard "computer literacy" and programming. Computers are now routinely used for data acquisition and equipment control. With rapid growth in this area, more trained and knowledgeable college graduate are needed.

In our laboratory, computers are being used to make physical measurements with sensors that send signals to data-acquisition boards and an instrument-based software (virtual instrument) reads the experimental data. This technology has helped create measurement systems that are dramatically more robust and efficient than traditional ones such as voltmeters, ammeters, thermometers, torque indicators, tachometers, level sight-gauges, rotameters, etc. In addition to taking the readings, the software can collect and record the data, present the data graphically and publish results to the World Wide Web. The following section includes further details of this technology.

The computer-based measurements in our systems are made using LabVIEW software and data acquisition boards from National Instruments. All computers are IBM compatible Pentinum PCs.

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The following are some details regarding the measuring sensors used in our systems.

- **Voltmeters**: The data acquisition boards are inherently DC voltage measuring devices. They have 16 channels of analog voltage inputs. They are typically configured to read in the range of 0-10 volts DC. To read higher DC voltages we simply build resistive voltage dividers. To measure lower voltages, the input channels can have on-board gain applied. Using this, they can read voltages down into the millivolt range. To measure AC voltages, we use signal conditioners. The ones we use are in the "6B" series from Analog Devices. These are available to have (virtually) any specified range of AC input voltage and produce a proportional DC voltage in the range of 0-5 volts DC to be read by the data acquisition board. Then the software converts it to the real experimental value.

- **Ammeters**: For measuring DC current, we simply put a small resistor in the circuit and then measure (with the data acquisition board) the voltage across the resistor, then use Ohm's Law to calculate the current. In one example, the "small resistor" is actually a length of copper wire. The resistance is on the order of 50 milliohms. Thus the voltage for, say 10 amps is about 500 millivolts. For this low voltage, we have used a signal conditioner which produces a proportional DC voltage in the range of 0-5 volts DC to be read by the data acquisition board. This accomplishes the reading of the low voltage with less noise than by using a high gain in the data acquisition board amplifier. For measuring AC current, we use current sensors from American Aerospace Controls. These sensors are available in various sizes and convert the AC current into a DC voltage in the range of 0-10 volts DC to be read by the data acquisition board.

- **Thermometers**: For measuring temperatures, we use integrated circuit temperature devices. These are known as "LM-35" devices from National Semiconductor. They are much lower cost than either thermocouples or resistance temperature devices (RTDs) and are simpler than thermisters. These devices are about the size of a No. 2 pencil eraser.   They require a source of DC voltage (about 12 volts) to operate. They produce a DC output voltage that is the temperature divided by 100. So the data acquisition board can read this voltage and the software converts it to the real observed temperature. They are available in either Celsius or Fahrenheit models.

- **Torque indicators**: For measuring torque, we are using a strain-gauge-based torque sensor from Futek Sensors. As with many strain gauges, it has strain gauges in a Wheatstone Bridge. Thus, when an input voltage is applied across two terminal of the bridge, an output voltage appears across the other two terminals that is proportional to the torque. This output voltage is in the order of millivolts, therefore, for this low voltage, we have used a signal conditioner which produces a proportional DC voltage in the range of 0-5 volts DC to be read by the data acquisition board. Using the calibration constant of the torque sensor, the software then converts it to the real observed torque.

- **Tachometers**: For measuring rotational speed, we are using reflected-light photo sensor which has a square-wave voltage output with a frequency proportional to the frequency at which reflective spots on the motor shaft pass the sensor. This output voltage is sent to a signal conditioner, which produces a proportional DC voltage in the range of 0-5 volts DC to be read by the data acquisition board. Using the number of reflective spots per revolution and the calibration constant of the signal conditioner, the software then converts it to the real observed rotational speed.

- **Level sight-gauges**: For measuring level of liquid in a tank, we are using an amplified piezoresistive pressure sensor from Sensym. This sensor requires a source of DC voltage (about 12 volts) to operate. It produces a DC output voltage that is proportional to the pressure at the bottom of the tank. Using Bernoulli's Equation for hydrostatics, the pressure is proportional to the height of the liquid above the sensor. The data acquisition board reads the voltage and the software converts it to the real observed liquid level.

- **Rotameters**: For measuring flow rate of liquid, we are using a paddle-wheel flowmeter from Davis Instruments. This instrument has magnets embedded in a paddle-wheel that rotates at a rate proportional to the liquid velocity in the sensor. There is a coil near the paddle-wheel. The voltage induced by the magnets passing near the coils is of a frequency and magnitude that is proportional to the rotational speed of the paddle-wheel. This small AC voltage is sent to a signal conditioner that produces a proportional DC voltage in the range of 0-5 volts DC to be read by the data acquisition board. The software converts it to the real observed liquid flow rate.

Experimental Setups

The following describes three experimental setups at Fort Valley State University.

The motor-generator station is a table-top unit that has a three-phase AC motor driving a DC generator. The motor is driven by a variable-voltage, variable frequency AC inverter. The inverter receives an analog output signal from the computer to control the speed of the motor. The coupling between the motor and generator has 4 strips of reflective tape that is sensed by the reflective photosensor. The photosensor sends a pulse train to the frequency signal conditioner that converts the frequency to a voltage that is fed to the analog input signal. The voltage generated by the DC generator is sent directly to an analog input channel. A reaction torque sensor measures the torque on the generator. The torque sensor output is sent to a low-voltage signal conditioner and then to an analog input channel. The generator's DC output current can go to any of eight filaments on light bulbs. The choice of filaments is made by the computer user and digital outlet lines control relays to choose the appropriate filaments. The DC current to the filaments is measured by Ohm's law, as mentioned above. The Ohmic voltage is sent to another analog input channel. Five temperature sensors monitor the temperature at various places on the unit: the ambient air, the AC inverter, the motor case, the generator case and the air heated by the lighted filaments. (A small fan blows ambient air across the bulbs.)

Figure 1. Motor Generator station

The pump-flow-level system consists of a DC motor-driven centrifugal pump that pumps water from a reservoir to a gravity-drained receiving tank. The receiving tank drains back to the reservoir for a closed-loop water circuit. The pump speed is controlled by pulse-width modulated digital line out of the computer. The flow rate of the pumped water is measured by a paddle-wheel flow meter. The paddle-wheel sends a pulse train to the frequency signal conditioner that converts the frequency to a voltage that is fed to the analog input signal. The height of liquid in the tank is measured by the hydrostatic pressure with a pressure sensor at the bottom of the receiving tank. The liquid efflux line can either be siphoned off or free flow out of the tank. A solenoid valve controlled by the computer makes that choice.

Figure 2. Variable speed pump-flow-level station

The heat transfer station is composed of a pencil soldering iron. The iron is in contact with a long rod along which several thermocouples have been attached. We have rods made of various metals. Conduction and natural and/or forced convection heat transfer are taking place. The thermocouples are connected to signal conditioners that then send a voltage to the analog input channels.
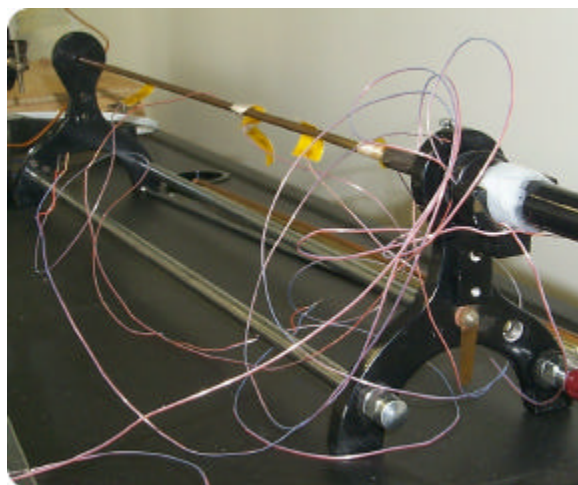
Figure 3. Heat Transfer Station

On-Line Capabilities

Two of our experimental setups at Fort Valley are entirely controllable from the Web. The systems are the motor-generator station and the variable-speed pump-flow-level station. The LabVIEW experiment-controlling program on the laboratory computer is connected to the Web. Another computer connected on the Web can run a LabVIEW program that communicates with the laboratory computer. This remote computer thus can operate the equipment just as easily as a user sitting in the lab. The equipment is operated from the remote site and the data is returned to the hard drive disk on the remote computer. A diagram of this connection is shown in Figure 4.
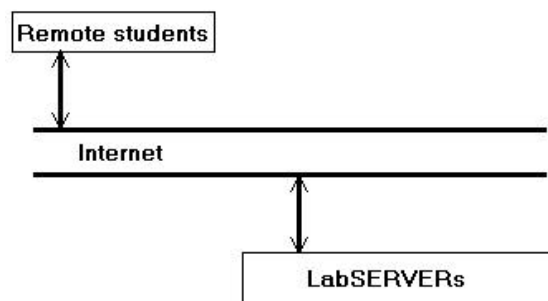
Remote students

Internet

LabSERVERs

Figure 4. Connection of Remote Users to the Laboratory

Typical Assignments

We introduce the students to operation of each of these stations. Students are required to collect data over a range of operating conditions and display the results graphically. The LabVIEW software is programmed to collect the data and create a text file of the data versus elapsed time. Students use a spreadsheet program such as Microsoft Excel to read the data files and plot their results.

We require the students to submit a report that includes their results and analysis and a description of the principles that can be observed in their data and graphs.

We have the students make physical measurements, where possible, using conventional measuring instruments to make spot verifications of the computer-based measurements.

We ask the students to build simple virtual instruments using LabVIEW software to become familiar with computer-based measurement techniques.

Student Responses

We have surveyed some of the students who have used the Web-capable laboratories. Their responses include those listed here:

- We can pick the time to meet to run the labs instead of being required to be here for a set class time

- The ability to perform experiments from remote locations

- You can run experiments during class time or at 3AM as well as turn in your reports at any time over the web

- I liked the freedom of the lab

- It worked out well being able to work at different times

- This was a new experience. Especially running the experiments on the Web, and sending the assignments by e-mail

- Web access learning is very important these days, when a lot of information is available and e-mail is taking the place of traditional phone calling and letter writing.

Some major concerns were network congestion, non-availability of the remote site, and long queues due to too many co-current users.

Conclusions

We have found computer based measurement and instrumentation is a very effective way to provide students with a solid foundation in state-of-the-art technologies.   In addition, it helps prepare students to take on the technological challenges of tomorrow and encourages them to pursue graduate studies in mathematics, science and engineering. We have concluded that extending this technology to include remote access on the Web, adds to the students' learning processes

Acknowledgements

References to Suppliers

American Aerospace for AC current sensors
http://www.a-a-c.com/0.htm

Analog Devices for signal conditioners
http://www.analogdevices.com/

Davis Instruments for paddle-wheels
http://www.davisontheweb.com/

Digikey for temperature measuring integrated circuits
http://www.digikey.com/

Futek for torque sensors
http://www.futek.com/

National Instruments, for LabVIEW programming and data acquisition boards
http://www.ni.com

Omega Engineering for signal conditioners
http://www.omega.com/

Omron for photosensors
http://www.omron.com/

Sensym for pressure sensors
http://www.sensym.com/

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