LabVIEW-Based Automatic Control Systems Laboratory Using Local and Remote Experimentation Approaches

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Category:
Academic

Products Used:
LabVIEW™ Version 5.0
AT-GPIB/TNT
LAB-PC-1200
Internet Developers Toolkit for G (Version 5.0)
LabVIEW Basics

The Challenge:
Providing engineering students at the University of Texas at El Paso with real world relevant laboratory experimentation. The challenge was to actively engage students in the development of automatic control systems to provide a deeper and more complete understanding of control system design and implementation.

The Solution:
Introducing LabVIEW and relevant PC-based data acquisition and control experimentation through the revamping of a one unit, three-hour automatic control systems laboratory. The coursework included basic LabVIEW familiarization, computer-controlled projects using student-generated programs, and a final assignment involving the development of a wind tunnel velocity control system.

Abstract
A one unit, three-hour automatic control systems laboratory course was modified to incorporate LabVIEW-based student-developed controls projects. After learning LabVIEW during the first three weeks of the course, each student was required to develop and perform three PC-based data acquisition and control experiments. The final experiment involved the development of a proportional-integral-derivative (PID) wind velocity control system for a small subsonic wind tunnel. In addition to the course, students and researchers can access the wind tunnel speed control system via the Internet to investigate the effects of different gain settings on the PID wind tunnel control system.

Introduction
The University of Texas at El Paso (UTEP) has been investing in improving its laboratory curriculum and infrastructure [e.g., Wicker and Loya, 2000]. Most recently, the Mechanical & Industrial Engineering (M&IE) and Electrical & Computer Engineering (E&CE) Departments have established the Dynamic Systems and Controls Laboratory (DSCL). Using grants from the National Science Foundation and Hewlett-Packard, the DSCL strives to increase student motivation to learn automatic control systems theoretical concepts by practicing model-based simulation-oriented approaches to control system design and implementing controllers for educational and industrial hardware systems.

Figure 1. UTEP Dynamic Systems and Controls Laboratory.

At present, the DSCL, shown in Figure 1, consists of ten computer workstations, a network server, printer, and hardware used for dynamic systems and controls projects. This multidisciplinary laboratory provides controls experimentation capabilities to Science and Engineering departments on the UTEP campus. One objective of the laboratory is to act as a test-bed for technologies that can enable off-campus students and researchers to conduct experiments on systems located in any of UTEP's Science and Engineering laboratories via the Internet. Such technologies are pivotal for improving distance education in the fields of Engineering and the Sciences as well as for more effectively utilizing scarce research hardware resources.

The UTEP educational improvement strategy utilizes modular experiments that can be used throughout the engineering curriculum [e.g., Wicker and Loya, 2000]. As part of this strategy, UTEP obtained a small subsonic wind tunnel, also shown in Figure 1, to be used for research and education. With the previously mentioned grants and equipment, a one unit, three-hour automatic control systems laboratory was modified to actively engage students in relevant PC-based data acquisition and control experimentation. The active involvement of students in the learning process can provide a more fundamental understanding of the concepts highlighted in the activity, and thus, our challenge was to actively engage students in the development of a practical automatic control system [*cf.*, Wicker and Quintana, 2000].

The modified coursework included basic LabVIEW familiarization and computer-control projects using student-generated LabVIEW programs. Since the students had no previous LabVIEW programming experience, the first three weeks of laboratory were devoted to learning LabVIEW. Students independently worked through the LabVIEW Basics manual, and after three weeks, were given an in-lab LabVIEW proficiency exam. After learning LabVIEW basics, the two preliminary projects introduced the students to communication via RS-232, DAQ, and GPIB interfaces. The projects provided a prelude to the final assignment involving the development of a proportional-integral-derivative (PID) wind tunnel velocity control system.

The centerpiece of the student-created velocity control system is the LabVIEW graphical interface. The control system design is accomplished entirely within LabVIEW, allowing easy modification and augmentation. The use of LabVIEW allows different types of control strategies to be easily implemented enabling the control system to accommodate a wide range of experimental and educational needs. The following describes in more detail the design and implementation of the PID control system using student-generated LabVIEW programs.

Final Project Experimental Setup

The experimental setup, shown in Figure 1, includes a small subsonic wind tunnel, a pitot-static probe and pressure transducer, two DC power supplies with GPIB interfaces, and a computer loaded with LabVIEW and a Lab-PC-1200 and GPIB boards. The pitot-static probe provides the velocity feedback measurement required for the PID control system. A pressure transducer measures the pressure from the pitot probe, and is in turn electrically connected to the host computer via the Lab-PC-1200 data acquisition board. The student-generated program monitors the pressure measurement, converts the pressure measurement to a wind tunnel speed, and makes appropriate changes to the wind tunnel speed via a GPIB card connected to the two DC power supplies. The power supplies are connected to a set of DC fans located at the top of the wind tunnel, allowing for variable speed control within the wind tunnel test section [Hennessey *et al.* 1999].

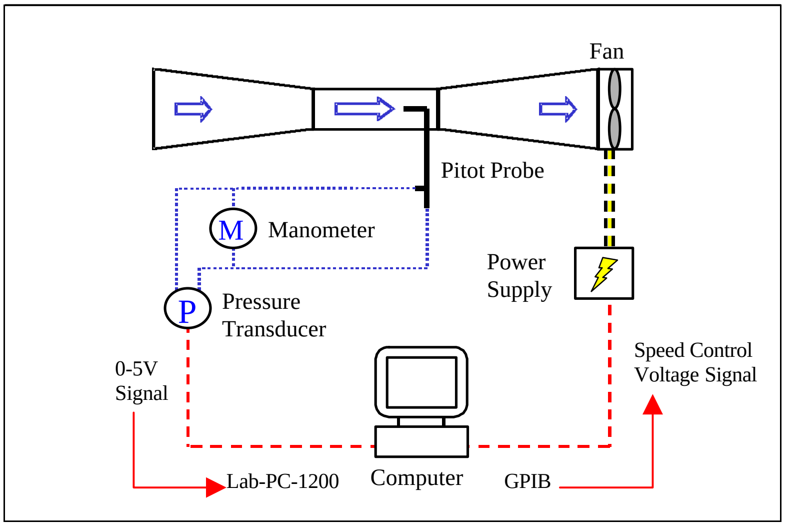

Figure 2. Speed control system schematic diagram.

Control System Design

The implementation of a control system in the LabVIEW software environment allows unprecedented flexibility in design and testing [Matey, 1993]. The architecture of the wind tunnel control system is a classic digital system that samples the input signal at discrete time intervals and adjusts the output according to an appropriate control algorithm. Figure 3 shows the path of data through the system. The blocks marked with “A/D” or “D/A” change signals from the analog domain to the digital domain, respectively. By actively engaging the students in the control system implementation, the students are developing a more complete understanding of PID control systems and the issues involved in control system implementation [*cf.*, Wicker and Quintana, 2000].

Computer data acquisition and control is used to provide unique capabilities for research and instruction. In this case, using LabVIEW enables us to easily and rapidly implement and test alternative control algorithms. Using LabVIEW, the students were able to quickly develop the wind velocity control system utilizing a PID control strategy. After developing the PID control system, the students were required to determine the “optimal” gain settings for a pre-determined wind tunnel speed profile.

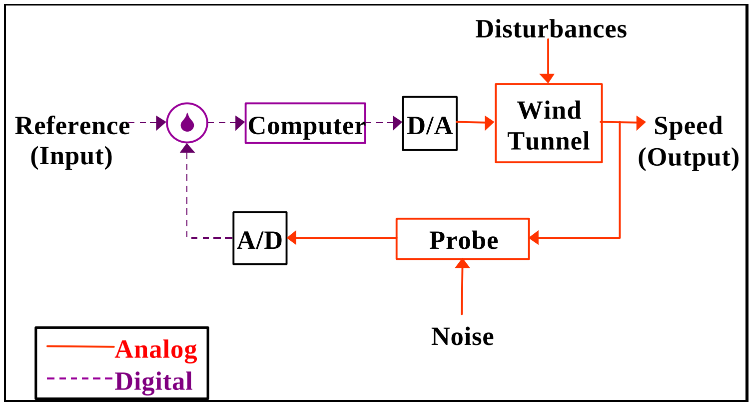

Figure 3. Simplified digital control system diagram.

Different experimental trials using a PID control strategy were run to test the wind velocity control system. The "optimal" values for the proportional and derivative gains were determined by trial and error based on each student's given criteria for settling time, overshoot, and steady-state error. A sample of a student-generated Virtual Instrument (VI) front panel and control diagram is shown in Figure 4.

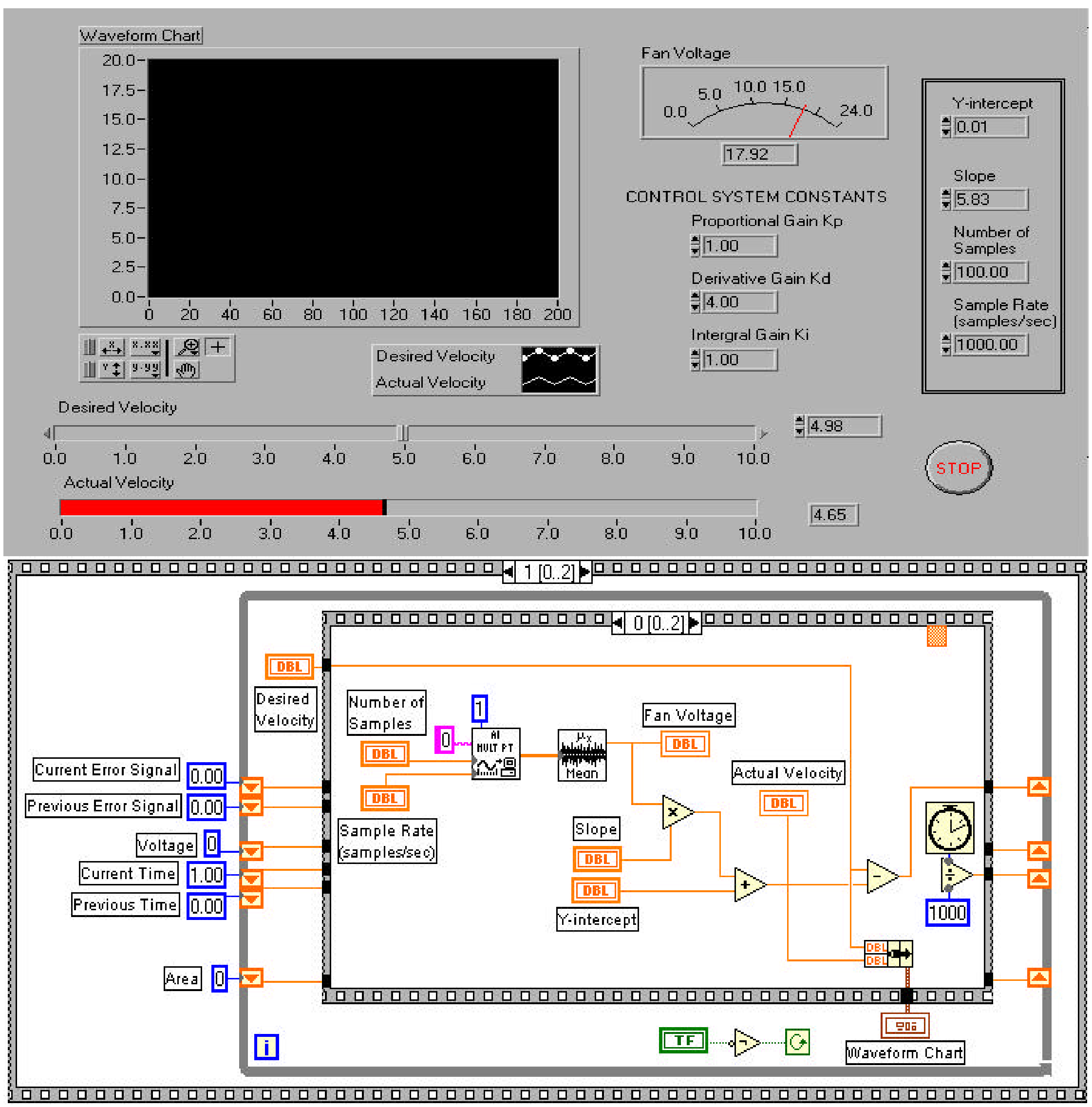

Figure 4. Sample student-generated VI front panel and block diagram.

Conclusions

The application of LabVIEW as a rapid prototyping tool in the development of a PID controller allowed students in the automatic control systems laboratory course an unprecedented opportunity to independently produce one such controller. The student created the VI shown in Figure 4 with less than three months of LabVIEW experience, thus validating LabVIEW as the world leader in PC-based data acquisition and experiment control. Furthermore, the use of LabVIEW allowed the students to actively engage in the development of the control system, providing a more fundamental understanding of control system design and implementation. LabVIEW provides an incredible opportunity for real-world relevant laboratory exercises, and the student response to this new approach has been overwhelmingly positive. This flexibility provides UTEP with a valuable asset in both instruction and research.

In addition, as an enhancement of the above activities aimed at future students taking this course, a project has been undertaken using the Internet Toolkit to enable students to conduct experiments on this wind tunnel system while off-campus via the Internet and a Web browser. Specifically, this allows the remote user to vary the PID controller gains and then monitor the effect of such variations on the dynamic response of the air velocity in the wind tunnel [Wicker and Diong, 1999]. Ultimately, this project will scale to the entire UTEP campus so that students and researchers off-campus can conduct experiments on various systems located in any of UTEP's Science and Engineering laboratories via the Internet. This should then provide an excellent springboard for improved distance education in the fields of Engineering and the Sciences as well as for more effective utilization of scarce research hardware resources.

Acknowledgments

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