Integration of Computer-Based Electronics Laboratory into a Control Systems Course

Julio Garcia and Patricia Ryaby Backer
San José State University

Abstract

The goal of this project is to adapt the work of other researchers to improve the delivery of electronics lecture and laboratory content in the Electronics & Computer Technology (ECT) area of the BS in Industrial Technology at San Jose State University. There are several other demographic factors that serve to make the delivery of instruction challenging for the department. Approximately 70% of ECT students work at least 30 hours a week. SJSU also has a diverse student population with 62% of all undergraduates identified as having non-White ethnicity. A higher percentage (69%) of the undergraduate students in the BSIT are non-White and there are significantly more students from Asian backgrounds in the BSIT than in the university as a whole. From the research on ethnic and gender differences in learning styles, the evidence suggests that ethnic minorities and women work best when the material is organized so that students work in teams and have a high level of hands-on experimentation and problem-solving. To fund this curricular development, we received a NSF CCLI grant. The four objectives for this project are (1) Revise the lecture and laboratory content for Tech 167—Control Systems in line with theories of effectiveness in web-based instruction (Fisher & Nygren[1]; NSF[23]; Shiratuddin, Hassan, & Landoni[2]); (2) Develop multimedia lecture materials for the teaching/learning of Tech 167—Control Systems using WebCT (Sharer & Frisbee[3]); (3) Revise the laboratory activities to integrate an electronics kit (consisting of data acquisition hardware) so that students can complete them following the model established by Wang[4] and (d) Integrate LabVIEW and Multisim in the Tech 167 class to provide the students with realistic, industry-based simulation experiences

Introduction

The Department of Aviation and Technology at San Jose State University (SJSU) offers two bachelor's degrees: BS in Industrial Technology (BSIT) and BS in Aviation. BSIT has two concentrations: Electronics and Computer Technology (ECT) and Manufacturing Systems. The students are not distributed equally between the two concentrations; 25% of BSIT majors are Manufacturing Systems students and 75% are Electronics and Computer Technology (BSIT-ECT) majors. This inequity is not surprising considering the location of the university in Silicon Valley, CA. The university, as a whole, has large enrollments in electronics and computer-related fields including computer engineering, computer science, MIS, and the BSIT-ECT.

There are several other demographic factors that serve to make the delivery of instruction challenging for the department. Approximately 70% of ECT students work at least 30 hours a week. In addition, the BSIT program is also unique in that it is primarily a transfer program. Most of the students in the BSIT degree are transfer students from local community colleges and 88% of the majors are classified as juniors or seniors. Also, most of the BSIT students attend SJSU part-time as they finish their degrees. These transfer students generally spend between four to five years at SJSU finishing their BSIT degree after they transfer from a two-year community college. SJSU also has a diverse student population (see Table 1) with 62% of all undergraduates identified as having non-White ethnicity. A higher percentage (69%) of the undergraduate students in the BSIT is non-White and there are significantly more students from Asian backgrounds in the BSIT than in the university as a whole. This could be significant, as previous research has indicated that the ethnicity of the students could interact with their learning styles. Studies indicate that Asian students have different learning styles than Caucasian students do (Algee & Bowers[5], Park[6]).

Table 1. Fall 2000 Distribution of BSIT majors by Gender and Ethnicity as compared to SJSU numbers

		African American	Hispanic	Asian	Filipino	Other	Total Minority	White	Unknown
Female BSIT	**25**	**0**	**1**	**17**	**3**	**0**	**21**	**2**	**2**
Male BSIT	**228**	**10**	**28**	**90**	**22**	**3**	**153**	**43**	**32**
Total BSIT	**253**	**10 (4%)**	**29 (11%)**	**107 (42%)**	**25 (10%)**	**3 (1%)**	**174 (69%)**	**45 (18%)**	**34 (13%)**
SJSU Total UG	**21292**	**927 (4%)**	**3174 (15%)**	**7182 (34%)**	**1780 (8%)**	**280 (1%)**	**13343 (62%)**	**5217 (25%)**	**2732 (13%)**

The large numbers of working students in the ECT concentration make the scheduling of classes with laboratories a significant problem. All upper division courses in the ECT concentration are offered once a year and courses shift bi-annually from day to night rotation. Students who work often must wait a year to take a required course that meets with their schedule. The high numbers of non-native speakers of English in the ECT concentration make traditional lectures difficult to deliver.

Plan for this project

This project proposes to develop online lecture and laboratory materials for Tech 167--Control Systems, an upper division ECT course, whose description is as follows:

> Tech 167. Theory and applications of feedback systems, transfer functions and block diagrams. Transducers, analog and digital controllers, signal conditioners, and transmission. Analysis, testing, and troubleshooting of electronic systems with feedback. Prereq: Tech 62, Tech 63, Math 71, Tech 115.

Although an upper division course, Tech 167 is typically taken by ECT students during their first year after transfer from a local community college. Students have had basic electronics, basic analog electronics, basic digital electronics analysis, and an instrumentation course before registering for this course. This curriculum project will convert the lecture content of Tech 167 into WebCT lectures that will be delivered to the students in an asynchronous mode. This innovation will address two issues. Working students can take this course early in their SJSU career. Also, students from non-English speaking backgrounds can complete the lecture materials at their own pace.

Hundreds of courses have been developed for delivery using WebCT as a medium for online instruction but few are available for electronics courses. Since many electronics courses include a laboratory or hands-on component, it is challenging to develop the complete course through distance education. Sharer and Frisbee[3] developed a junior level microelectronics course entitled Active Networks I for the Electrical emphasis in the Engineering Technology Department at the University of North Carolina—Charlotte. They used a variety of synchronous and asynchronous delivery methods. Their asynchronous WebCT site for this course included a detailed course syllabus, a course schedule, lecture notes, examples, homework solutions, test solutions, and computer simulations. These researchers used Centra for synchronous delivery for problems sessions and electronic supplemental instruction.

These researchers found that the students liked the delivery of the course through distance education. Similar to the student population at San Jose State, the students at UNC-Charlotte are generally non-traditional and have full time employment and family obligations. The online microelectronics WebCT class[3] was used as the model for the lecture portion of this project's curriculum development. Instead of Centra, this project intends to use Microsoft NetMeeting as the mechanism for student-teacher problem sessions. Each week, the instructor of this class will be available for several hours to answer student questions in a synchronous format.

The demographics of the diverse student population in the Electronics Technology area at SJSU is a good match for learning through distance education. Most of the students in this area are part-time, older, and working 30-40 hours a week. They tend to be self-sufficient and self-directed. These characteristics have been proven to be descriptors of successful distance learners (Biner & Dean[7], Guglielmino & Guglielmino[8]).

The multimedia lecture materials will help students understand control systems concepts, circuit and systems analyses, and problem solving of control systems related material. Concepts such as analog and digital signal conditioning, thermal sensors, optical sensors, and controllers will be emphasized. Procedures for designing control circuits as well as systems analyses will be included. The web-based multimedia learning materials will consist of text, graphics, and animations integrated into a WebCT course site. The web-based lecture materials will be designed to ameliorate known problems with web-based learning. In particular, Sharer and Frisbee[3] note that several considerations exist for successful completion of web-based courses. These considerations for engineering-related instruction include, but are not limited to: more self-discipline is required to get through lecture material than in a traditional class; the student does not have the benefit of face-to-face interaction with the instructor; and communication between student and instructor is not immediate and requires more planning (Cohen & Ellis[9], Kubala[10], Lake[11]).

The laboratory exercises for Tech 167 will be redesigned to use LabVIEW, Multisim, and digital acquisition equipment. This project uses the SC-2075 Prototyping Signal Accessory Box with the NI PCI-6024E DAQ and the R6868 Ribbon Cable manufactured by National Instruments. The SC-2075 is a connector accessory for constructing circuits and evaluating the circuits using virtual instruments. The kit consists of all the components and devices needed for students to build ten laboratory exercises. The students can reuse these materials to perform other experiments related to control systems and industrial electronics as well as design and build a control system project.

This project uses LabVIEW software (Laboratory Virtual Instrument Engineering Workbench) integrated with data acquisition equipment to provide a virtual electronics laboratory for students. First developed in 1983 by National Instruments, LabVIEW has become a standard tool for engineers and scientists. LabVIEW is a powerful graphical development program for signal acquisition, measurement analysis, and data presentation. Data acquisition (DAQ) involves connecting computers to a wide variety of gadgets via electronic signals; the computers then control these gadgets or read data from these gadgets.

Along with the C/C++ programming languages, LabVIEW is among the most used programming languages for technical and scientific applications today, used to solve technical and commercial problems. LabVIEW's programming features are clear, coherent, powerful, comprehensive and entertaining, enabling an instructional presentation of computer-based experimentation in which students create meaningful programs that illustrate useful concepts at each step of the learning curve. LabVIEW programs are modular, so that after each is created and understood, it becomes part of a library that can be used later as a building block of a more sophisticated program. The LabVIEW software is already owned by the Department of Aviation and Technology at SJSU.

Lee[12] integrated LabVIEW software into an instrumentation and experimental methods course for mechanical engineering students. Other researchers have developed LabVIEW applications for students in agricultural and biological engineering (Sumali[13]), mechanical and industrial engineering (Crist[14]), and engineering technology (Bachnak[15], Chen[16], Chickamenahalli et al[17], Krygowski[18], Yousuf[19]).

Wang[4] developed a series of LabVIEW modules to use in sophomore electrical circuits and mechanical mechatronics laboratory courses at West Virginia University. Students are able to measure the voltage, temperature changes by using LabVIEW, see the real time responses from the computer screen, and switch controls between computers through the Internet.

In the past ten years, companies have developed several interfaces for computer-based electronics simulation. The SC-2075, for example, is used widely in industrial settings for the control and testing of a variety of electronics-based applications. Digital acquisition equipment produced by National Instruments has also been used in academic settings. Stevens Institute of Technology uses a microcomputer-based data acquisition system with LabView and MatLab software in the laboratories that support their expanded design course sequence (Sheppard et al[20]). Chickamenahalli et al[17] used a data acquisition board produced by National Instruments to develop a real-time visual controller for manufacturing processes as part of an NSF funded Greenfield Coalition's Manufacturing Engineering curriculum development program.

To ensure students' understanding of computer simulation, students will perform these experiments using Multisim 7, a power computer simulation widely used in industry. Students will compare the measurements obtained using Multisim 7 and using real devices and components, and compare the values obtained using LabVIEW. Multisim is a comprehensive circuit analysis program that permits the modeling and simulation of electrical and electronic circuits. It provides a large component database, schematic entry, analog/digital circuit simulation, and many other features, including seamless transfer to printed circuit board (PCB) layout packages. Multisim is interactive and offers a number of user-friendly features. A major feature of Multisim is that the schematic diagram is created on the screen using a mouse and various windows options. The type of analysis desired is then applied to the circuit, and the results can be observed in a number of ways.

One of the most valuables features of Multisim is that the source excitation and instrumentation functions closely parallel those of a basic electronics laboratory, and the procedures that are used in obtaining data are very similar to those of the "real world." Hence, it closely approaches the concept of an ideal "virtual laboratory." For example, the test and measurement models contain voltmeters, ammeters, a multimeter, a function generator with several output waveforms, a two-channel oscilloscope, a frequency counter, a distortion analyzer, and other instruments. These instruments must be wired into the circuit in essentially the same fashion as in an actual laboratory. Thus, good laboratory skills can be taught very easily using a computer and the software.

Hackworth and Stanley[21] used Multisim in the development and implementation of a junior-level virtual linear electronics laboratory at Old Dominion University. All experiments and projects in the virtual laboratory course are analogous to the experiences in the on-campus traditional course. The researchers found that the virtual laboratory was as effective as the traditional laboratory in terms of student achievement. At Northwestern State University, Hall[22] compared groups of students who were enrolled in two different electronics courses, a basic DC circuits laboratory course and an advanced device electronics laboratory course. He found that there were no significant differences in posttest scores between students using Multisim and those performing the labs using traditional lab equipment.

Work Completed

This project uses LabVIEW, Multisim and the SC-2075 data acquisition device to create virtual laboratories for Tech 167--Control Systems (see Figure 1 for a description of the ten laboratories to be developed). The researchers work at a teaching institution in California so the majority of the development work will be conducted during Summer 2004 and Summer 2005. The PI, Dr. Julio Garcia, is primarily responsible for designing and creating the laboratory experiments and the co-PI, Dr. Patricia Backer, is responsible for the creation of the multimedia learning materials in WebCT.

In Fall 2004, Tech 167 is being taught as a traditional lecture/laboratory class in order to collect baseline data for this project. This project includes student assistants from the ECT concentration who will assist in the development and assessment of the web-based lecture and virtual laboratory modules. The researchers have assembled a team of student assistants who are working in teams to test the integration of LabView and Multisim into the laboratory modules. In Summer 2005, the researchers will further develop the multimedia lectures and online laboratories.

In addition to the formative assessment of these modules by the student assistants, these online laboratories will be field-tested in the Fall 2005 and Fall 2006 classes for Tech 167. The PIs will choose four labs and randomly assign student teams to either the online laboratory or the traditional lab using electronic equipment. The student assistants will videotape a sample of the student teams so that there is a record of the students' behaviors as they complete the labs. The PIs and the student assistants will analyze the videotaped records and this information will be used to further refine the online laboratories.

Figure 1. Laboratory experiments to be developed

Lab	Topic	Lab Objectives
1	Digital amplification	• Build, test, troubleshoot, & verify a digital amplification circuit • Verify the behavior of the digital amplification circuit when used with analog signals and digital signals.
2	Analog Signal Conditioning	• Build, test, troubleshoot, & verify an application of the Wheatstone bridge to convert resistance changes to voltage changes • Build, test, troubleshoot, & verify an analog signal-conditioning system that converts a given input voltage variation into a required output voltage variation
3	Digital Signal Conditioning	• Build, test, troubleshoot, & verify logic hardware to implement a Boolean equation • Build, test, troubleshoot, & verify an alarm for analog voltage signals using a comparator with hysteresis • Build, test, troubleshoot, & verify a successive-approximation ADC • Determine and verify experimentally the expected output voltage of a DAC for any digital input
4	SCR/TRIAC	• Build, test, troubleshoot, & verify SCRs and TRIACs circuits

	Circuits	used to control electric power • Build, test, troubleshoot, and verify a stepping motor circuit.
5	Sensors and transducers	• Build, test, troubleshoot, & verify an RTD temperature sensor • Build, test, troubleshoot, & verify a thermistor circuit
6	Proportional Controller	• Build, test, troubleshoot, & verify an op amp circuit that will implement the proportional control mode • Verify the behavior of the proportional controller under different variations of the error signal
7	Integral Controller	• Build, test, troubleshoot, & verify an op amp circuit that will implement the integral control mode • Build, test, troubleshoot, & verify an op amp circuit that will implement the proportional-integral control mode
8	Derivative Controller	• Build, test, troubleshoot, & verify an op amp circuit that will implement the derivative control mode • Build, test, troubleshoot, & verify an op amp circuit that will implement the proportional-derivative control mode
9	PID Controller	• Build, test, troubleshoot, & verify an op amp circuit that uses the proportional-integral-derivative (PID) control mode • Verify the behavior of the proportional-integral-derivative (PID) control mode under different variations of the error signal
10	Closed-loop systems	• Build, test, troubleshoot, and verify a circuit that will implement a closed-loop system using op-amps. • Verify the behavior of a closed-loop system under the presence of disturbances

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JULIO GARCIA
Dr. Julio Garcia is a Professor of the Department of Aviation and Technology in the College of Engineering at SJSU. He teaches electronics and computer courses to undergraduate students and has taught one class in the MS of Quality Assurance in the department. He holds a Doctorate in Industrial Technology from the University of Northern Iowa

PATRICIA RYABY BACKER
Patricia Backer is a Professor and chair of the Department of Aviation and Technology in the College of Engineering at SJSU. She holds a BS degree in Chemical Engineering from Rutgers University, a MA and MS degree from Tennessee Temple University, and a MA and PhD from Ohio State. Her research interests are in the integration of multimedia and web-based learning into technology instruction.