A Laboratory Approach to Multidisciplinary Freshman Computer Engineering

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Abstract

A student's first laboratory experience is formative not only in terms of concepts covered but also with respect to that student's attitude toward his or her chosen field of study. RIT's freshman seminar in computer engineering is designed to provide hands-on exposure to computer engineering concepts and skills early in the curriculum. This course includes aspects of electronics, computer programming, robotics, digital systems, and signals. In the investigation of these areas, the course also develops students' basic engineering and laboratory skills such as measurements, calibration, data visualization, tolerance evaluation, technical writing, and teamwork. The course offered this past academic year differed from previous years in its intentional focus on developing basic laboratory skills and technical writing. Qualitative assessment in the laboratory course next in the curriculum sequence indicates that students who had completed this freshman seminar performed better than freshman in previous years. The multidisciplinary approach of this course gives students a broad view of the field, which helps them better understand the many areas of computer engineering, develops a basic engineering skill set, and offers them early in their academic career some basis for choosing their concentration(s) within the field

Introduction

For many computer engineering students, the first computer engineering laboratory course in their curriculum is their first hands-on exposure to the field. In some baccalaureate computer engineering programs, this first laboratory experience may typically occur as late as the last unit of the computer engineering student's second year.[1] While course prerequisites for a curriculum-substantive laboratory course may necessitate scheduling it after or concurrently with corresponding theory courses, delay in practical exposure to the student's chosen field may slow his or her appreciation of and development in computer engineering fundamentals. In other words, with no positive hands-on perspective in the earliest stages of their academic careers, students may not possess sufficient motivation and enthusiasm to carry them through intensive theory courses. This paper deals with one way of providing an engaging, tactile experience early in the computer engineering curriculum.

Background

In recent years, many undergraduate engineering programs have sought to incorporate an inspiring first laboratory course for their freshmen.[2, 3, 4, 5, 6] Some such courses involve building hardware (e.g., a robot) that is then used as a platform for subsequent courses in the curriculum,[3]

while others involve one or more projects whose scope does not extend beyond the course.[2, 4, 5] A variant of the latter approach extends the laboratory experience from a single course to a yearlong course sequence for freshmen engineering students.[7] In this particular program, all freshmen engineering students are exposed to the various engineering disciplines.

This paper describes the freshman laboratory approach in the undergraduate computer engineering curriculum at the Rochester Institute of Technology (RIT). Typically RIT freshman computer engineering students take a lecture course (1 hour per week), Introduction to Computer Engineering, in their first quarter. The following quarter, they take Computer Engineering Freshman Seminar, the two-hour per week laboratory course that is the focus here.

Laboratory approach

Providing a laboratory experience for students who have little theoretical exposure requires some care with regard to appropriate content for those students and reasonable expectations of them. In particular, there is a desire is to expose them to higher-level applications while requiring minimal conceptual knowledge or experience. Additionally, time and project scope constraints particular to the RIT curriculum preclude following some of the types of programs mentioned previously.[3, 7]

Therefore, the task of designing the Freshman Seminar laboratory experience is one of complementing the introductory conceptual awareness that students have from their prerequisite lecture course with real-world applications that give them a similar hands-on awareness of the computer engineering career path. The seminar aspect of this laboratory is ideal for this purpose in that it allows for presentation and discussion of underlying concepts only to the extent students require for a particular hands-on laboratory exercise; exercises are designed so that students do not have to understand theoretical concepts to any great extent before working with their applications.

In addition to offering hands-on experience, the laboratory approach equips students with practical lab skills and introduces them to common lab equipment. Each computer engineering application is presented in a seminar followed by a laboratory exercise in the same class session. In the exercises, students investigate the application presented to collect prescribed data or to produce some prescribed behavior. These investigations acquaint students with aspects of multidisciplinary interactions, basic engineering design, and professional communications.

Multidisciplinary aspects

Since computers intrinsically involve electronics, the first laboratory exercises investigate electronics principles. These exercises serve as experiential validation of basic direct-current (DC) circuit theory introduced in the prerequisite course. Furthermore, they familiarize students with electronics test equipment (e.g., multimeters and oscilloscopes) and components (e.g., resistors, breadboards, power supplies, and function generators).

Likewise, the last half of the course investigates robotics. Using a commercial off-the-shelf (COTS) platform, students learn to manipulate a robot. They then use this robot for the class

project: making the robot navigate a prescribed course. Students are assigned the course, given two weeks to program their robot, and then scheduled for a demonstration time during the last class of the quarter. Using robotics is not unique to this introductory laboratory class;[2, 3] however rather than using an assembly language[3], BASIC, C [3], or strictly icon-based graphical user interface (GUI),[2] these robots are programmed in a Java-based programming environment, which reinforces the students' required three-course computer science sequence in Java.

Engineering design

From the first laboratory exercise working with electronics components where resistors are inspected for their rated resistance and tolerance and then measured for their actual resistance using a multimeter, students recognize that components vary somewhat from their ideal specification. In the second exercise where various DC circuits are constructed and analyzed, students see first-hand the effects of such component tolerance on actual circuit operation. This observation is likely their first encounter with the role of component tolerance in design.

Another first encounter for many students is that of interfaces to sensors and other devices. From their prerequisite course, students know something about binary data representation such as high and low voltages. In one exercise, after learning to use the oscilloscope, students were able to observe the electrical interface between their robot and its servo motors. They consulted the data sheet for the robot's servo motors to set the function generator to generate a square wave similar to the ones used to operate the motors. They then used the oscilloscope to capture and store the image of this reference square wave. After programming the robot for a specific pattern of motion, they captured the resulting waveform sent from the robot to its servo motor. By analyzing that waveform, comparing it to the reference waveform, and seeing the resulting motion, they gained a hands-on understanding of the interface between the digital robot controller system and the servo motor component.

Additionally, this course involves teamwork, another common aspect of engineering design. For each of the laboratory sessions before the class project, students are assigned to random teams so that they experience working with as many different people as possible. As part of the lab exercise, each team member submits an evaluation (consisting of scaled numerical rankings of several indicators of contribution, expertise, and satisfaction) of the other team members. The class project teams are also randomly assigned, and they submit team evaluations as well.

Professional communication

After certain sequences of laboratory exercises, teams submit various technical reports regarding their work. During the quarter they submit a formal technical report on one lab exercise, a lab report (a shorter technical report) on another exercise, and an e-mail memorandum (a product evaluation) following their initial experience with the robot. For their class project, teams submit project reports, which include a plan of work and milestones in the first week, a status report in weeks before the demonstration, and a final report after the demonstration.

Among the motivations for incorporating professional communication aspects into this course are past experience with computer engineering students in an undergraduate professional

communication program at another institution[8] and observation of generally poor writing in reports from a subsequent laboratory course. At this point in their undergraduate career, students are still taking English courses. If that level of writing is harnessed and transferred to technical writing for computer engineering while it is still actively required of them in other coursework, then those students will never form the opinion that their engineering writing need only communicate relevant equations, numbers, figures. In other words, from their very first engineering writing assignments, students are held to standard principles of good writing and are never given the opportunity to conclude that technical writing requires any less diligence than their formal writing.

Another focus of the professional communication aspect of the course is presentation format. By experimenting with different formats during the quarter, students learn that following prescribed formats allows their ideas to be presented and evaluated independently of format. In other words, the students gain some appreciation for the role of standardized formats in the equalization of communication medium such that format does not obstruct the presentation of their content among peers.

Conclusions

The particular implementation of RIT's Computer Engineering Freshman Seminar described in this paper was offered in the 2005-2006 academic year. Around 100 students enrolled, and the class was divided into five sections, each of which met for two hours in one session each week. To encourage exploration and independent thinking, students were given fewer explicit guidelines for the laboratory exercises over the course of the quarter. At their next session, students were given feedback on their work and any implicit engineering aspects of the previous exercise along with examples relating either directly to their academic career and/or to their anticipated engineering career.

In this laboratory approach to a freshman computer engineering course, students gained hands-on experience with real-world computer engineering applications and observed practical, necessary interactions with other disciplines. They also developed laboratory skills and experience with laboratory equipment required in subsequent courses. In addition, they were exposed to technical writing aspects of professional communication at a point in their academic career where they are consciously developing classical writing skills.

The course offered this past academic year differed from previous years in its intentional focus on developing basic laboratory skills and technical writing. In the next laboratory course in their curriculum sequence, students who had completed this freshman seminar performed better than freshman in previous years. It was observed that their laboratory work was more thorough and that their laboratory reports met prescribed criteria from the first lab, whereas previous years' reports on the first lab were generally of poor quality and did not follow course specifications.

Since a student's first computer engineering laboratory experience has strong implications for his or her enthusiasm for computer engineering in general and for subsequent coursework in particular, freshman seminar was designed to provide high-level hands-on exposure early in the curriculum through a low-pressure, laboratory environment. The freshman seminar offers

experiential exploration of computer engineering coupled with an introduction to engineering and laboratory skills. The multidisciplinary approach of this course gives students a broad view of the field, which helps them better understand the many areas of computer engineering, develops a basic engineering skill set, and offers them early in their academic career some basis for choosing their concentration(s) within the field.

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