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Integrating Robotics into First-Year Experience Courses

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Abstract – Robotics are a popular component of many introductory engineering and computer science courses. At Southern Adventist University, the School of Computing faculty decided to integrate robotics into a discipline-specific section of the University's first-year experience course. The integration of robotics into a first-year experience course has created a hands-on introduction to college life within the Computing discipline while introducing students to the problem-solving process. This paper will introduce a very low-cost robotic platform kit ($50-75) that has been developed for the first-year experience course. Student assessment data from the first offering of this course with the SouthernBot 2.0 kit shows that overall, students were engaged in the open-ended design projects completed during the building of the robot platform.

Keywords: robotics, first-year experience, freshman experience.

INTRODUCTION

At Southern Adventist University, the first-year experience course is a one semester hour discipline-specific course that provides students with a roughly equal mix of general education content and discipline-specific content. This provided an opportunity within the School of Computing to include a small freshman design experience within the first-year experience course. This experience is designed to engage students in the basic problem-solving processes that are prevalent in computer science and engineering and introduce them to basic skills such as soldering, printed circuit board (PCB) design and simple programming logic.

Over the three years that the authors have taught the first-year experience course in the School of Computing, various robot systems (including LEGO MINDSTORMS NXT and iRobot Create) and projects have been used to engage the students in the problem-solving process and to excite students in their choice of a STEM career. Based on student feedback from previous classes, a new custom robot platform has been designed and distributed to students in kit form. Building a robot from a kit exposes students to the mechanical, electronic, and software aspects of the design process. In addition, the robot has been designed to be affordable ($50-75) so students can purchase them from the campus bookstore in lieu of a textbook. Providing each student with his/her own robot platform allows them to experiment with the robot outside of class and even after the semester is over. This is an important characteristic of the robot platform described in this paper, because as shown in one study, student performance can actually decline in programming classes that utilize classroom-based robots that are not available to students outside of class/lab periods [6]. Commercial platforms tend to be quite robust and easily available; however, their costs range from $150-300, which can still be rather prohibitive for students to purchase their own personal robot for an entry-level class.

Robotics have become a popular addition to introductory engineering and computer science courses because of their physical embodiment of the computing process and their ability to motivate students to learn computing principles [8, 9, 11, 13]. Many courses make use of commercially available platforms such as LEGO MINDSTORM [4, 5, 8, 10, 15], iRobot Create [14], Scribbler [1], TekBot [7], and Parallax Boe-bot [3], while a few courses use special-

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purpose kits [2]. Each of these robotic platforms have advantages and disadvantages including more or less flexibility, robustness and community and textbook support [12].

This paper overviews the design of a new inexpensive robot platform for first-year experience courses and the curriculum that is used for the first-year experience course at Southern Adventist University. It also reports on lessons learned from the first use of these robots in the first-year experience course and show results from an assessment of student attitudes regarding the robot project and their engagement in the course.

SOUTHERN CONNECTIONS

Southern Adventist University (Southern) is a private, accredited, co-educational institution offering masters, baccalaureate, and associate degrees. The student body is approximately 3000 students with a variety of religious backgrounds although ninety-four percent are Seventh-day Adventists. Southern is located in southeast Tennessee just east of Chattanooga. Southern has a 95-year history of liberal arts education. Although sixty percent of students on Southern's campus today major in areas other than those considered as liberal arts, this heritage is seen in the strong general education requirements still maintained by the university. Computer science and embedded systems students are required to complete 43 semester hours of general education courses in addition to their major and cognate courses. Through the general education program, students receive a broad foundation in communication, history, religion, literature, and psychology.

In 2006 Southern Adventist University initiated their first-year experience course entitled Southern Connections that meets 17 times during the semester (including extended sessions during orientation the week before school starts and a final exam period during exam week). The approximately 40 sections of this course are overseen by a first-year experience coordinator at the University level; however, the sections are implemented within each department and taught by faculty within each department. This loosely centralized structure provides for some common content across the sections while allowing the individual departments to customize the course to be more suited to students in their disciplines. As shown in Fig. 1, the official course description for this course allows for this flexibility.

Official Course Description:

> "This seminar is designed to equip first-year students for success in the university environment. Emphasis will be placed on the development of critical and creative thinking skills within a student's area of interest."

Modified Course Description in the School of Computing

> "A hands-on introduction to problem solving using computing technologies. Students will design and assemble printed circuit boards and program robots to achieve different missions with emphasis placed on problem solving and the team design process including project/time management, team management, hardware design, implementation, software development, testing, analysis, and documentation. Throughout the semester, students will learn valuable skills including note-taking, time management, test-taking strategies, soldering, problem solving, and real-time programming strategies."

Figure 1. The official course description for Southern Connections provides for flexibility in the content and method of pedagogy within each section. The modified course description for the Southern Connections section within the School of Computing reflects the emphasis put on the scientific/engineering process through hands-on problem-solving experiences in this section.

In the School of Computing's Southern Connection section, emphasis is put on hands-on experiences including soldering circuit boards, designing printed circuit board schematics and layouts, assembling custom robot structures, and programming basic autonomous robot functionality. This section uses a top-down methodology where students are introduced to larger systems then they can fully comprehend and then given just enough knowledge about the system to complete some basic tasks. This methodology allows students to experience the computer science discipline early in their university career and seeks to motivate their continued study in this discipline. Based on student feedback from earlier offerings of this course, the instructors have increased the amount of lab/hands-on activities in this course and decreased the amount of traditional lectures. In addition, the hands-on activities have been distributed throughout the semester more evenly with the lecture content to keep student interest high throughout the semester.

As shown in Fig. 1, the modified course description for the School of Computing's section of Southern Connections is quite aggressive in its content coverage. Most of these topics are introduced very briefly in lecture and then are weaved into the hands-on laboratory activities. In addition, the lab activities have been designed to build on each other as much as possible. During the first offering of this course in Fall 2008, it was determined that the School of Computing's section would use the design and programming of a robot as the underlying theme and the majority of lab activities and lectures would be taught within this thematic context. For example, a subject such as time management that is required to be taught in all Southern Connections sections is discussed in lecture within the context of managing a team-based project. Students then get to put these time management skills into practice throughout the semester as they design and program their robot in three-to-four person teams.

In the Fall 2008 offering of the Southern Connections, students in the School of Computing's section were divided into two categories – those currently taking a Fundamentals of Programming course and those not taking a programming course (including some students with majors outside of the School of Computing. This diversity of programming skills made head-to-head robot projects difficult. Therefore, student teams comprised of students with programming experience used the iRobot Create robot platform and programmed their robots using the C language (with a number of low-level functions provided to them). Student teams comprised of students without programming experience used the LEGO MINDSTORMS NXT platform and programmed their robots using the graphical programming tools provided with the LEGO MINDSTORM NXT kit. Separate lectures were provided to these two groups of students to familiarize them with their respective programming platforms and example code was provided. Teams were given flexibility to choose their own project goals and a wide diversity of outcomes were realized from dancing robots to maze following robots to Bluetooth-enabled remote-controlled robots. Students did seem to struggle to identify potential project ideas that were reasonable in scope for the time available and the ability of the team members. In addition, since each team was working on a different project, there was very little cross pollination of ideas and assistance between student teams some teams struggled in this environment.

In the Fall 2009 offering of the course, the Southern Connections coordination was improved at the University level and more students were enrolled in the section of the course designed for their major. Thus, the vast majority of the students in the School of Computing's section were also enrolled in Fundamentals of Programming and the iRobot Create platform was used exclusively. In addition, the instructors chose to assign a single project goal (finding and disabling a series of infrared beacons in a closed course) to all project teams. The results of these changes were quite positive as all teams were able to complete at least some of the project goals. In addition, students enjoyed the head-to-head tournament that was held at the completion of the course. Students did, however, provide feedback that they would enjoy assembling their own robot platform instead of using stock products such as iRobot Create and LEGO MINDSTORM NXT. The use of custom robot platform for this course is also consistent with best practices that suggest that the robot platform should be derived from the learning objectives of the course and not the other way around [16].

Acquiring and maintaining a fleet of commercial robot platforms can be expensive. With the appropriate add-on modules, the iRobot Create, LEGO MINDSTORM NXT and Scribbler products cost $200-300. This is a fairly common price point for entry-level robots. To improve the students' learning and motivation in this course and to reduce the cost overhead for the University, the Fall 2010 offering of this course featured a custom robot platform that was designed by the instructors and cost in the $50-75 range. The assembly of the robot was accomplished by the students over a four week period. These lab activities were relatively unstructured allowing the students to use their creativity and team management skills to divide up the various assembly tasks and distribute the workload among their team members. Later lab periods provided an opportunity for students to program their robot to accomplish basic tasks.

Figure 2. SouthernBot 2.0 is designed to be a flexible, very low-cost robot platform. It includes two continuous-rotation servo motors with custom rotation sensors as well as an omni-directional bump sensor, microphone, light sensor (phototransistor), and line-following sensor array.

SOUTHERNBOT 2.0

The SouthernBot 2.0 robot platform was designed by the authors to be an inexpensive platform ($50-75) that students could easily assemble and program to complete basic autonomous tasks. As shown in Fig. 2, the basic structure is a round acrylic disk with snap-in two servo motor mounts. In addition to the two wheels driven by continuous-rotation servo motors, a ball caster is mounted in the back to provide the third contact point. The battery is also mounted in the back to provide ballast.

The sensors on the SouthernBot 2.0 robot platform include an omni-directional bump sensor, a microphone, light sensor (phototransistor), line-following sensor array, two rotation sensors (mounted on the servos/wheels), and an additional sensor port that can used for add-on modules such as sonar distance sensors and infrared proximity sensors.

With the exception of the screws and springs, all of the mechanical platform components (including the round disk, snap-in server motor mounts, omni-directional bump sensor ring and mounts, and circuit board stand-offs) are manufactured in-house using ¼” acrylic. Parts are cut out from large acrylic sheets using a laser engraving machine. Designing the robot in this manner significantly reduced the time and cost for developing prototypes and the initial small quantity production runs.

Software

The details of interrupt handlers, timers, and pulse-width modulation drivers are well beyond the scope of this course. Therefore, a library of functions is provided to the students to allow them to acquire sensor data and control the motors without knowing the details of microcontroller programming. Figure 3 provides a listing of the function prototypes provided. In addition to this listing, detailed documentation for each function along with examples of their use are provided to the students.

```
void InitializeSouthernBot();
void Drive( int8_t left_speed, int8_t right_speed );
uint8_t GetSwitch();
uint8_t GetBump();
uint16_t GetSound();
uint16_t GetRightRotations( uint8_t clear );
uint16_t GetLeftRotations( uint8_t clear );
uint8_t GetLeftLightSensor( uint8_t clear );
uint8_t GetRightLightSensor( uint8_t clear );
uint8_t GetTopLightSensor( uint8_t clear );
void SetLEDs( uint8_t LED_value );
void DelayMs( uint16_t milliseconds );
```

Figure 3. A library of these functions is provided to the students to allow them to acquire sensor data and control the motors without knowing the details of microcontroller programming.

STUDENT ASSESSMENT

A survey was prepared and given to the students while they were in the final steps of building the robots. The students were asked after completing the survey to fold it in half and turn it in. Role for the period was taken as the students turned in the survey assuring every student present filled out a survey. Of the 25 students that originally registered for the class, 18 were present. No effort was made to have the missing students complete the survey.

The responses to first nine questions were based on a five position scale (strongly agree = 5, agree = 4, neutral = 3, disagree = 2, and strongly disagree = 1). Since this is ordinal data a median was calculated (see Table 1).

TABLE 1. MEDIAN SCORES FOR THE STUDENT SURVEY QUESTIONS

No	*Question*	*Median*
1	This class improved my problem solving skills.	4
2	This class broadened my understanding of problem definition.	3.5
3	This class has helped me better integrate into university life.	3
4	I enjoyed this class.	4
5	Building a robot was fun.	4.5
6	Building a robot was too hard.	2
7	Learning to solder and work with electronics helped me better appreciate the electronic devices that I purchase or own.	4
8	There was sufficient help available.	4
9	The lack of a step-by-step detail description of how to build the robot provided me with a chance to be creative and exercise my problem solving skills.	4

Question 10 & 11 were opened ended questions. Question 10 asked the students to rate the class in their own words. Question 11 asked for any suggestions that the students might have for the course.

The questions can be broken up in to four categories: problem solving, preparation for college life, appreciation for electronic devices, and building the robot.

Problem solving

The first two questions involve problem-solving skills. The vast majority of the students did see that this course provided at least some improvement of their problem solving skills. That is they at least agreed with the first question. However, while most felt something of an improvement of the problem definition skills it was not as strong as that of problem solving skills. This would indicate that an increase emphasis on problem definition would be appropriate.

Preparation for College life

The usefulness of the course in preparing students to deal with university life seems to be neutral. A better measurement of this would be to compare the academic results of this class with the other Southern Connection classes. This does not mean that the course did not meet some of the goal of helping students to succeed in their University experience but rather that the students did not perceive the help. It also could be that with the excitement of robot building and the other activities the student did not really see the changes and improvement that they had made.

Appreciation for electronic devices

Question seven asked if the soldering and other work that the student completed for this course helped increase their appreciation of electronic devices. The results support the reasoning that the construction of electronic devices would help students to understand the difficulty and the limitation of producing the gadgets that this generation is so fond of having and using.

Building the robot

Most of the questions attempted to understand the impact of having the students build robots in this course. There is no question that the responses to all questions including 10 & 11 demonstrate a very high level of enjoyment during the course. Question five “Building a robot was fun” having a median of 4 along with the written responses to 11 very strongly support this. Furthermore the median of 2 for question six shows that the students did not perceive the construction of a robot as difficult.

While in general the questions about the help and the directions given to students during the course was good, there was an significant number of students answering question 11 who thought that parts should be better organized and more readily available. Several also suggested a need for greater detail in the published directions.

In the responses to question 11 there were four students that indicated some lack of appreciation for the robot project. Most suggested that more information about preparation for campus life should be provided.

Question 10 provided the most positive results. Converting all the responses to a 0-10 scale, with 10 being best, gave a median of 8. In fact five of the respondents used the word fun or some other superlative in their response.

FUTURE WORK AND CONCLUSION

Looking back on teaching this semester, many of the students seemed swamped with all the soldering especially the surface mount parts. Furthermore, it is not possible to solder these components with the cheap soldering irons provided each student in the course. The laboratory does not have a large number of soldering stations capable of soldering surface mount components. Even when the authors bring their personal soldering stations there is bottleneck around the stations. Since the students had already designed, assembled and soldered a game, it might be better to pre-solder the surface mounted components.

Some students seemed lost and had trouble determining the order of assembly. In fact the request of several respondents the student assessment indicate that it might be better to have a step-by-step guide to the construction of the robot. But if this were done part of the problem solving benefit would be lost. A compromise might be to have a list of steps necessary to assemble the robot but without detail. This would guide the student that is lost but would not inhibit the creative problem solver.

There were students that wanted more class time spent on reviewing how to succeed at the university. Such students might feel that this is being done if the first 10 minutes of class was devoted to discussing these materials. Secondly, those students motivated by building the robot would not see the study as boring and/or discouraging. They could look forward to the robot construction.

There is no question that the students with rare exception see this course as a positive experience. With minor improvements to the robot kit and it supporting materials along with changes in scheduling the authors plan to continue using this course in the years to come.

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