Introducing Computer Engineering Major for First Year Students Using Robotic Projects

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***Abstract*—In almost every engineering curriculum, an introductory engineering course to enlighten students knowledge on the different engineering disciplines is offered for the freshman students. To better describe the engineering majors and increase students interest, practical projects are often requested to complement the theoretical lectures and concepts covered in these classes. In here we present a robotic-based design project that is designed and developed to serve as one of several final projects available for an introduction to engineering class. The projects require minimal-to-no previous knowledge in programming and attempts to give the students an enjoyable and rewarding experience while being introduced to the computer engineering discipline. The survey results clearly show that the projects enhance students' motivation and improve their interpretation to the engineering design process.**

I. Introduction

The freshman year in every curriculum is an important stage and may be even more important for an engineering program. Graduating from high school, a student may not know the right program that fits his background and interest. Moreover, in their first semesters, many students find it difficult to relate the theoretical concepts to practical engineering problems and consequently their motivation drops. In most engineering schools, the college offers an introductory engineering class to bring clarity to their decision making regarding their major choice. Several approaches to teach first year engineering students have emerged over the past several decades. Some universities [1] have been focusing on academic survival skills such as time management and studying for exams. Some other universities require all first-semester students to take a course in software topics such as drawing for mechanical engineering or programming for electrical and computer engineering [2], [3].

In Valparaiso University [4], first-year engineering students enroll in an introductory engineering class, Fundamentals of Engineering, to introduce them to the fundamental concepts of engineering, from circuits to structures to heat transfer. The objectives of this course are to provide an opportunity for students to explore the different engineering disciplines [5]; to develop teamwork skills [6], problem solving, and computational skills [3]; and to discover the increasingly multidisciplinary nature of engineering [7]. The main components of this introductory class are lectures, demonstrations, and hands-on lab experiments to teach students how to apply the concepts.

In the last week of the semester, students are required to complete an appropriate design project in at least one discipline by applying the fundamental concepts and skills learned throughout the course. For the past 15 years, the outdated LEGO NXT Robotics set has been used as one of these projects suggested. The objectives of the project was to design, build and demonstrate a vehicle. The LEGO NXT has been used intensively as a freshmen engineering projects in different universities [8], [9]. In addition to their complexity, the programming language used (RobotC) is uncommon to computer engineering students which made it harder for the students to accomplish a fully functional and reliable project in one week [10]. Therefore, the LEGO NXT robots have been finally replaced by one of the state of the art robots, ActivityBot robot [11]. The new robots have advance sensing and controlling features such as optical sensor and encoder, X-bee communication modules. They also feature a multicore propeller that can be programmed in C. These robots have been previously used to help the transition between high school and Electrical and computer Engineering [12], [13]

The most effective and successful learning techniques as realized by Saint-Nom and Jacoby is that "no matter how many concepts we teach, no matter how deep we go, no matter how tough our exams are, the only lessons that will remain in their minds are those that touch them" [14]. Thus, a pedagogical approach were students design and build like engineers is likely to increase their motivation towards the major. Several universities have considered to include a robot-based project in the engineering freshman year to apply the theory learned in their first-semester lecture from linear algebra, to statics and rotational dynamics. For instance, in [9], they proposed an eight-day full-time block course focusing entirely on the robotic project. While at Oregon State University, the issue was addressed by building a robot platform in the freshman year that will be used for learning throughout their entire four-year curriculum [15].

In this paper, we will first present an overview of the project objective for this class, highlighting the steps used in designing process: problem definition, evaluation, decision, implementation and review. Next, we will describe the robotic projects, which were offered for the first time in the fall semester of 2015. The description will cover a complete study on the different aspect learned and discipline learned by the

students from programming to wave propagation to rotational dynamics including. Finally, the students survey results will used to assess the project effectiveness while mentioning the lessons learned for future terms.

II. Fundamental of Engineering: Objectives and Engineering Design Process

One of the objectives of the Fundamentals of Engineering class is to complete an appropriate design project by following the engineering design process in at least one discipline using the fundamental concepts and skills learned throughout the course. During the last lecture before the project week, the students learned the six steps used in design engineering process:

1) **Problem definition:** Identify the problem that need to be solved and determine the design requirements and criteria.
2) **Invention:** Analytically solve their problem by first generating as many potential solutions as possible.
3) **Evaluation:** Once many solutions have been generated, evaluate their quality.
4) **Decision:** After the evaluation, select the best solution while considering the different design requirement and criteria.
5) **Implementation:** Build a prototype for the selected design to demonstrate the problem solution.
6) **Review:** Finally, determine whether or not the design achieved the project requirements and suggest improvements and corrections.

These six steps are used as guidelines in every engineering project. The robotic project, with several other projects, are presented to the students at the end of the lecture while highlighting the disciplines of each project. The students then select the project that are fascinated about. The robotic project was designed for the computer engineering majors. The project is structured around the use of a the engineering design process described above. Typically students have no exposure to such a formal process. They may have accomplished some scientific experiments in high school but they have no experience in engineering a produce or service. This process is a crucial step to learn the engineering process. On the other hand, the project is designed to be fun and enjoyable for the students and to show them some applications for the theories that they have learned in class while exploring one of the engineering discipline they are interested in.

III. Project Overview

The robot used in these projects features a multi-core propeller microcontroller brain. Additionally it includes other electronic hardware such as the optical encoders on the wheels to increase consistency and accuracy. The built-in breadboard available on the platform increases the robot's flexibility and students' creativity. On top of that, the students have the ability to add navigation systems on the robot using touch, visible light, infrared light, or ultrasonic sensors.

Two different project objectives have been designed. In the first project, the goal is to build and demonstrate a maze solver vehicle. The vehicle is to enter and leave the maze as quickly as possible. The vehicle must navigate inside the maze and each time it reaches an end, it rotates either left or right. The team will demonstrate their project in a 5 x 5 feet maze constructed for this project as shown in Fig. 1. In this project students require some programming and algorithm skills. Using the ultrasonic or touch sensor, the robot can determine the end of the path and rotate accordingly. The robot has to autonomously navigate any unknown maze.

In this project, the students are challenged to achieve their goal by overcoming various engineering problems. For instance, some students had to understand the wave propagation of the ultrasonic sensor in order to avoid the echo generated inside the maze.

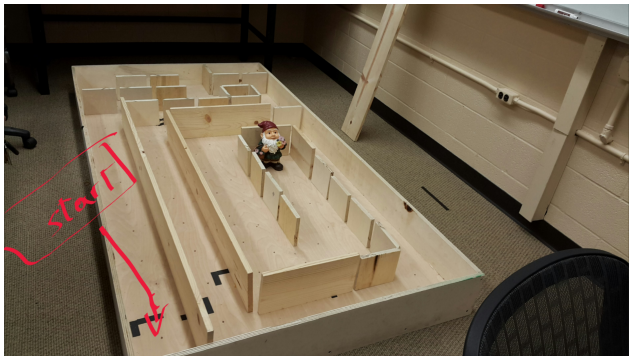

Fig. 1. The maze setup to demonstrate the maze solver vehicle. The vehicle is to enter the maze and reach the Gnome as quickly as possible.

In the second project, the goal is to build and demonstrate a waypoint navigator vehicle. When waving to the vehicle, the servo motors start to accelerate and navigate a predetermined course shown in Fig. 2 and return to its start location as soon as possible. The start line is marked by a foot-wide piece of black tape. The course is half foot wide marked with black tape. This project requires some algebra and rotational dynamics skills. Using the optical encoders and the wheels dimensions (shown in Fig. 3, the students can accurately and consistently navigate the robot through the waypoint. However, the challenge in this project is the open-loop system: the robots do not provide feedback for the user on their location. Therefore, the students have to carefully select their acceleration and speed to have enough friction on the wheels.

IV. Project Structure and Stages

The students were asked to form teams of 3 to 4 members. Each team was given a complete robot with additional electronics parts, like the ultrasonic sensors, touch sensors, resistors and wires. The projects have to be completed within one week. There was minimal-to-no homework other than the final report and presentation that need to be submitted at the end of the week. The students can accomplish the project in an ad hoc manner but from the project objectives is to learn and apply the engineering design process. Thus the students

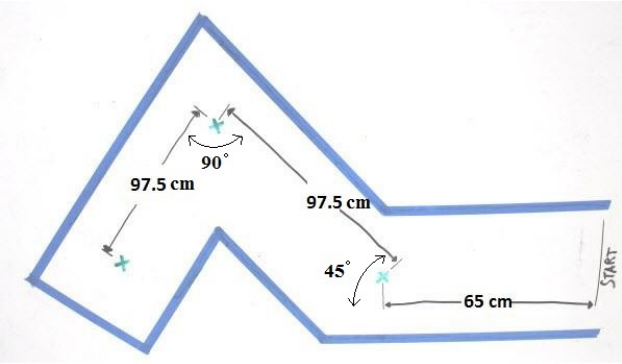

Fig. 2. The waypoint dimensions that the robot navigate. by waving to the vehicle, the servo motors start to accelerate and navigate the course and return to its start location as soon as possible.

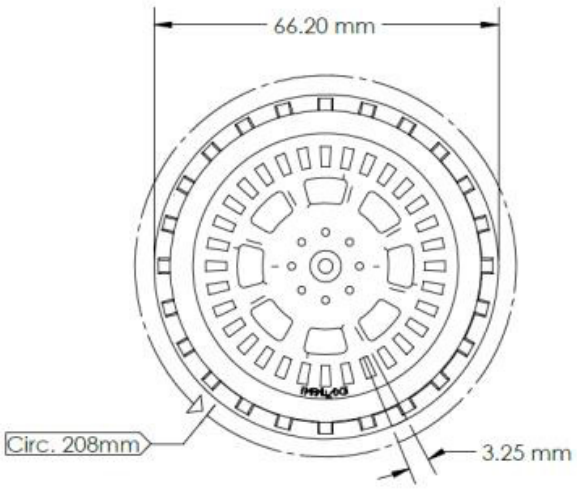

Fig. 3. The robot wheel dimensions used by the waypoint project to calculate the rotations needed to navigate the course accurately.

are guided in their work as a team to follow the engineering process described earlier.

Since the projects is offered in the end of the Fall semester of the freshman year, students have very minimum experience in programming. In fact, one of the topics covered in the fundamental engineering class is computer programming [4]. In this module, students get exposed to some basic programming functions that are common in must programming languages, such as *if-else* statement, *for-loop* and *while-loop*. However, these tools alone are not enough to complete the required task.

To that end, background information and info session is needed before diving into the engineering process. In this step students learn some advanced programming skills that they may need to successfully accomplish their design. The info sessions also serve to emphasis the importance of the lectures and theories to the succeed in the engineering design. On day one of the projects week, students attend a 50 minutes info session learning about the robot and its programming software (SimpleIDE). In this session, students learn how to import and use libraries in C, write some simple programs, define variables and solve algebra in C. At the end of the session, students are provided with a step-by-step tutorial handout with instructions and examples on how to write simple programs in C for the multi-core Propeller microcontroller.

After that, spend the rest of the week brainstorming and implementing their ideas. At the end of the week and after they demonstrate their projects, students are required to write a report and prepare a 15 minutes presentation that discuss the project requirement and criteria, the modeling, analysis, design and implementation results. This will help improving their technical writing skills as well as evaluating their engineering design process.

V. Project Surevey & Assessment

The ActivityBot project has been used for the first time in Fall 2015 and has been well-received by students, mentors and instructors. A survey specific to the robotic project was sent to the students to evaluate its impact and get feedback for future improvements.

Results of the student survey indicated that the project was a success. Student feedback was mainly positive where most students enjoyed the project as they felt they had learned and improved their skills. Some of the comments mentioned in the survey were

- "The most beneficial aspect of this course to me was the final project."
- "As a suggestion to improve this class is to add more projects."
- "Because of the final project, now I have a better understanding of the computer engineering major and my future career."

In the survey, the students also responded to a survey questionnaire using a typical five-level Likert scale. The questions are scaled from " Strongly Agree" to "Strongly Disagree". 32 students out of 54 complete the survey form. Among questions asked in the survey, the following questions were selected to analyze in this paper:

- **Statement 1** (S1) *The 50-minutes info session was very helpful for the project.*
- **Statement 2** (S2) *The step-by-step handout tutorial was very helpful for the project.*
- **Statement 3** (S3) *The project has been effective in teaching me about the engineering design process.*
- **Statement 4** (S4) *The project has helped me to better understand the application and the implementation of the theory learned in class.*
- **Statement 5** (S5) *The project was very difficult to accomplish in one week.*
- **Statement 6** (S6) *I will definitely recommend to my peers to select this project.*

The results are shown in Table I. The majority of the students (an average of 76.0%) are satisfied with the info session and the handout tutorial for the project. This result is almost consistent with both projects. However, by comparing

the third and the fourth statement results, the two projects has a small difference in their outcome. In the maze project, an average of 75.1% of the students agree that the projects are effective in learning the engineering design process and applying the theory learned in class. This result is slightly higher than the percentage of students in the waypoint project (an average of 62.6%) who agreed with both statements. This difference is also reflected in the project difficulty where the waypoint project was slightly easier to accomplish than the maze robot project. This feedback has enlighten the instructors to revise the waypoint project for next term.

Overall, the evaluation results clearly show that the freshman students were motivated by the project. The groups were highly active competing among themselves, and even spending additional time on refining their robot algorithms to score the fastest time. Furthermore, three quarters of the students will definitely recommend this project to their peers. This projects also helped the students to acquire social skills, like working in a team, and cooperating and communicating with their peers. In addition to that, the students were able to apply some of the fundamental concepts they have learned to a real life application.

TABLE I
SURVEY RESULTS OF THE TWO ROBOTICS PROJECTS

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
S1	Maze	0.0%	9.1%	18.2%	36.3%	36.4%
	Waypoint	0.0%	12.5%	18.7%	43.8%	25.0%
S2	Maze	0.0%	6.2%	25.0%	43.8%	25.0%
	Waypoint	0.0%	0.0%	6.2%	75.0%	18.8%
S3	Maze	0.0%	0.0%	31.2%	56.3%	12.5%
	Waypoint	0.0%	6.2%	37.5%	37.5%	18.8%
S4	Maze	0.0%	0.0%	18.7%	56.3%	25.0%
	Waypoint	6.2%	0.0%	25.0%	31.3%	37.5%
S5	Maze	0.0%	12.5%	50.0%	37.5%	0.0%
	Waypoint	12.5%	18.7%	56.3%	12.5%	0.0%
S6	Maze	0.0%	0.0%	18.7%	62.5%	18.8%
	Waypoint	0.0%	0.0%	31.2%	56.3%	12.5%

VI. CONCLUSION AND FUTURE WORK

In this paper, we have presented two robotic projects that have been selected for freshman engineering students to demonstrate the engineering application, more precisely the computer engineering discipline. It is organized as a one week project where the students can apply some of the fundamental concepts they have learned throughout the semester and transfer them to robot applications. These projects have also helped the students to learn the engineering design process.

Based on these first experiences and the assessment results, the number of robots sets will be doubled for the next term to reduce the team size, especially where student feedback revealed this issue. As mentioned above, the waypoint robotic project will have some minor adjustment to slightly increase the challenge level and to cover more engineering concepts learn throughout the semester. Finally, some parts of the step-by-step tutorial handout will be considered to include them in the computer programming modules covered in the class lectures. Stimulated by these results, further improvement and extensions of these projects concepts is currently under consideration

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