AC 2011-211: BENEFITS OF MENTORING STUDENTS IN DESIGN COMPETITIONS

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Benefits of Mentoring Students in Design Competitions

Abstract

A very rewarding opportunity, that many educators overlook, is the chance to mentor students who are participating in student design competitions. Student design competitions often provide projects that can be used as course material for independent study courses involving small groups of students that benefit both the students and the faculty member involved. The most immediate benefit to the students is the application of material they may have covered in lecture courses but never applied to real-life problems. This setting is the definition of problem based learning. The students also develop skills that will later be used at industry jobs or graduate school. Furthermore, the contact time with the students is beneficial in determining if the students are well suited for a graduate research program, and can stimulate discussions about graduate school. Offering an independent study course using a student design competition project is a great way to maximize the benefit of time spent by both the students and the course instructor. In addition, if the projects do well at the student design competitions, it is also excellent publicity for the faculty member and the school.

This paper describes two different independent study courses taught using student design competition projects. One of the courses was taught at a small, primarily undergraduate, university, and the other was taught at a large research university. The benefits to the students were very similar in the two cases, but possible benefits to the instructor were greater in the research university. Because of the small number of students involved, student assessment was done solely with personal interviews.

1. Introduction

Student design competitions can provide an excellent opportunity for both undergraduate students and instructors. While time is usually the most constricting factor in the lives of both students and faculty, teaching independent study courses that involve the completion of projects to compete in student design competitions is a great way to maximize the results of time spent. Instructors can introduce material necessary to a design project to a small group of students without preparing involved lecture notes and homework sets. The instructor can then get immediate feedback in the small independent study meetings when the material is presented, and they can provide more information if necessary. The application of the material is then covered directly in the design project, so no homework sets or exams are required for student assessment. The design projects often include both material that has already been covered in other traditional lecture courses, as well as new material that often includes independent research by the students. Clearly, many of the educational objectives suggested by the ABET a-k criteria are naturally covered in these independent study courses. (It is too bad that they can't be used in the self-study report.) In addition, the skills that the students develop during the completion of the design projects are beneficial whether the students take an industry job after they graduate, or go on to graduate school. Assuming that the faculty member chooses a design competition in their research area, these courses can also provide the opportunity to develop skills that can be later used by these students in the faculty members graduate research program.[1] The projects themselves also provide indirect benefits because they can be used as recruiting tools for attracting new students and they can get the university national recognition.

Specifically, this paper recounts the experience of two different groups of students at two different universities taking independent study courses. The first group of students created a recyclable material sorter for the ASME Student Design Competition and was taught at a large research university. The second group of students created a robot for the Trinity College Fire Fighting Robot Competition and was taught at a small undergraduate university.

2. ASME Student Design Competition – Recyclable Material Sorter

Each year, ASME holds Student Professional Development Conferences throughout the United States.[2] These conferences are a way for students to connect with engineers and engineering students across the country, and offer various competitions for students to compare their best work with their peers. Competitions include technical writing, technical poster presentations, and oral presentations, but one of the most exciting events is the annual Student Design Competition. Each summer, ASME sets competition guidelines for the following year. In the following March-April timeframe, district competitions are held. District winners are invited to compete on the international level in November of the following year at the ASME International Congress.

Four students who were attending a large research institution decided that they would like to participate in the ASME contest in exchange for independent study course credit. The student section of ASME at the institution had always sent a group of students to the district conference, at which the institution's teams had always done well. The instructor of the independent study course was, in fact, recruited by the Associate Chair of the Department to carry on this tradition and the instructor recruited the four students. With the established tradition, the Department already had mechanisms in place to support the students' project.

2.1 Contest Description

The growing concern for the sustainability of the Earth is leading a movement toward the expanded use of recycled material.[3] With 100 billion in annual revenue for over 600 million metric tons of recycled material worldwide each year, the industry is continuing to grow. From car tires to graduation gowns, recycled material has a place in today's market. The steady increase in materials recycled will inevitably lead to a need to automate the process, where a device will be needed to sort ferrous metals, non-ferrous metals, plastic, and glass material for further use. Because of this need, the American Society of Mechanical Engineers proposed the "Earth Saver" for its 2010 Student Design Competition. The contest was designed to give teams of students the opportunity to design an autonomous material sorter for recycling purposes. This team developed a prototype solution to compete in the contest using induction and weight sensors to properly identify and sort commonly recycled materials.[2] Industrial versions of this model would be much larger; fixed in trucks, grocery stores or recycling plants, while comparably sized models have potential for home use.

For the design competition, ASME provided standardized, nationwide rules. As mentioned above, the device was required to sort ferrous metal, non-ferrous metal, plastic, and glass rapidly into four separate waste containers. For competition purposes, twelve recyclable containers were to be sorted by the device. These containers adhered to the following specifications:

Plastic: Three empty, irregularly - shaped bottles, measuring approximately 75mm (± 20 mm) in maximum diameter and 220 mm (± 20 mm) tall.

Aluminum: Three empty, irregularly - shaped cans, measuring approximately 65mm (± 20 mm) in maximum diameter and 120 mm (± 20 mm) tall.

Steel: Three empty, irregularly - shaped tin - coated steel containers, measuring approximately 75 mm (± 20 mm) in maximum diameter and 110 mm (± 20 mm) tall.

Glass: Three empty, irregularly - shaped containers, measuring approximately 60 mm (± 20 mm) in maximum diameter and 95 mm (± 20 mm) tall.

The sorting device was also required to fit inside a volume of 340 mm by 400 mm by 580 mm. Furthermore, the device was required to be fully automated and could not have any human interaction once it was turned on. To demonstrate its ability, the device was given five minutes to correctly sort the twelve recyclable materials. Scoring of the device was defined by the scoring formula given in Equation (1).

$$Score = (1000\,xCorrect) - (1500\,xIncorrect) + (100\,xUnsorted) - (3xTime) - (Weight/10) - (4000\,xBrokenGlass) \quad \textbf{(1)}$$

In this equation, the weight of the device was measured in grams and the time to process the items was measured in seconds. In the very beginning of concept generation, the design team made a few conclusions from the above equation. Correct sorting is obviously the first priority, but the team decided that time and weight should be low on the design parameter hierarchy, while every effort should be made to avoid broken glass due to its harsh penalty. [2]

2.2 Design Description

Based on given constraints, and the scoring criteria, the team modeled the sorting process in a flow chart. The process flow chart consisted of only two physical tests to determine the material. The two necessary tests utilized an inductor coil in an RCL circuit to determine the difference between aluminum and steel, and variable resistance weight sensors to determine the difference between glass and plastic. The physical movements of the recyclable materials were achieved using a rotating cam, trap door, rotational platform, and servo motors. The servo motors and decisions were controlled by a microprocessor. A picture of the physical components and the flow chart are included below in Figure 1 and Figure 2 respectively. A more in depth analysis of each component of the device is discussed following the figures.

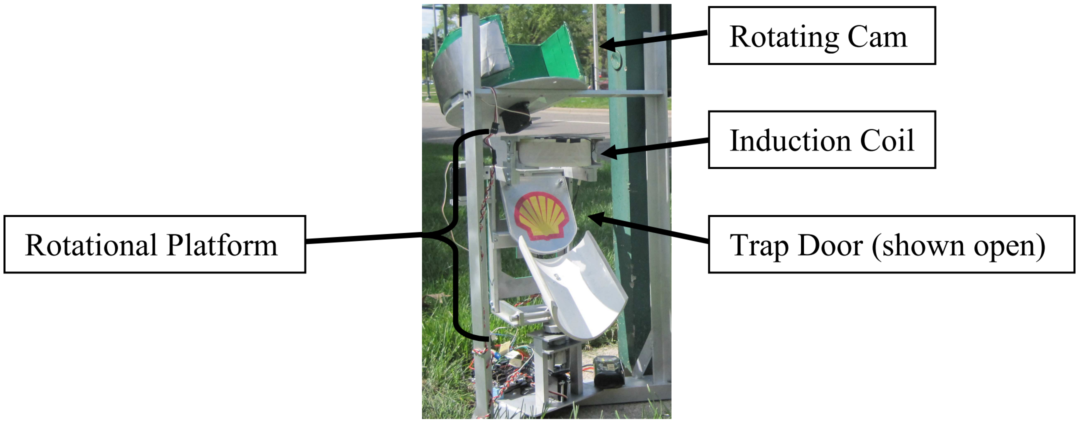

Figure 1. Physical Components of Recyclable Material Sorter

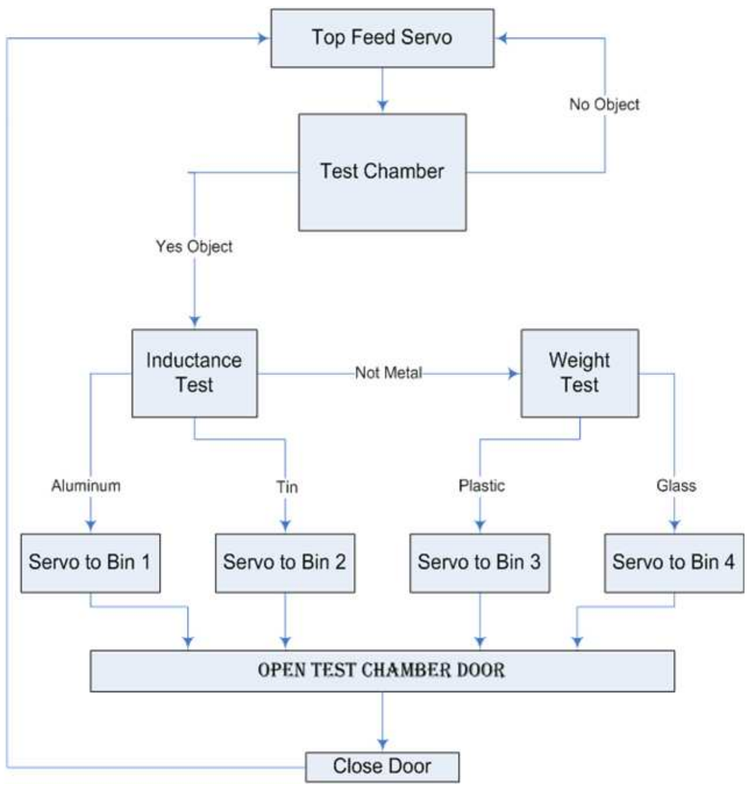

Figure 2. Logic Flow Chart

2.2.1 Induction Coil

In order to accommodate the sizes of the objects given in the competition, the design team constructed its own inductor coil using magnet wire wrapped around PVC pipe. If the object to be sorted was aluminum or steel, it would change the value of inductance when it was passed through the center of the pipe. The coil was then placed in an RLC circuit with an input voltage that was near the natural frequency of the system, and the output voltage was measured across the capacitor. The circuit resulted in a transfer function as shown in Equation (2).

$$T(s) = \frac{1}{s^2 + \frac{R}{L}s + \frac{1}{LC}} \quad \textbf{(2)}$$

The transfer function was used to create Bode plots of gain and phase angle for the different values of inductance. The plots were then used to predict the behavior of system when aluminum and steel materials were placed in the inductor coil. It was quickly determined that the gain of the system would be difficult to use because of how it fluctuated around the natural frequency of the system. However, the phase angle changed in a predictable manner with the variable values of inductance value (L), and the phase change at the natural frequency of the system made a significant enough difference in the time scale that it could be read by the microprocessor. The three phase curves for aluminum, tin and unaltered coil are shown in Figure 3. In practice, using the phase change worked out very well and provided for a reliable way to determine if a material was aluminum, steel, or neither.

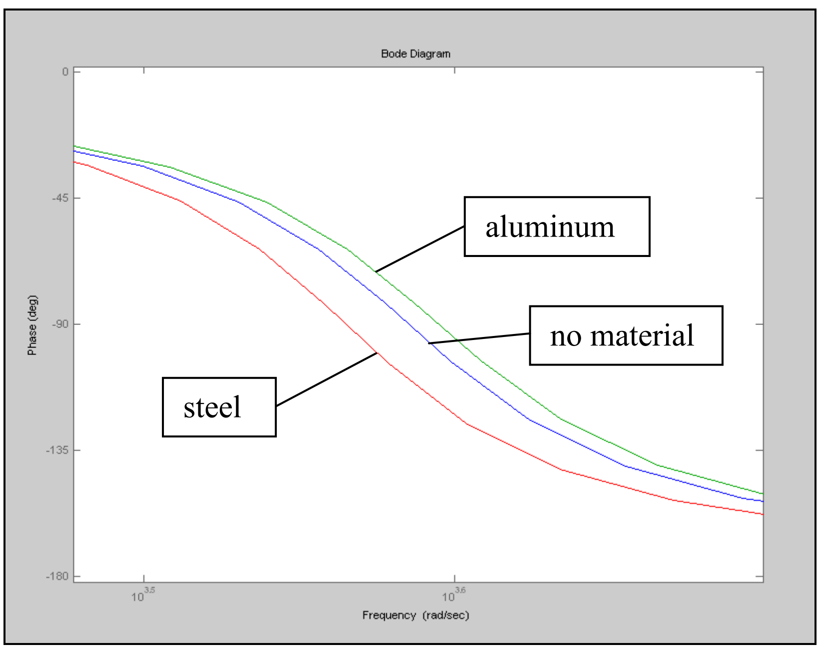

Figure 3. Phase Angle Bode Diagram

2.2.2 Weight Sensor

Once an object was determined not to be aluminum or steel, plastic and glass containers were distinguished by weight. With the size constraints of containers defined for the competition, the heaviest plastic containers always weighed less than the lightest glass containers. To measure weight, three pressure sensitive resistors were placed under a hinged metal plate in the test chamber. This allowed for the weight to be calculated using an average of the three sensors, giving accurate measurements regardless of where the container was placed on the plate. Each of the resistors was included in a voltage divider circuit and connected to a microprocessor pin.

By this configuration, increased container weight caused increased voltage as read by the processor. Using the voltage divider setup, the cutoff voltage between plastic and glass was calibrated to complete the decision process that is outlined in the flow chart.

2.3 Project Summary

The Recyclable Material Sorter was a very successful project for the students involved, and the design team was awarded 8th place at the ASME International Student Design Competition. Two of the students involved in the project are headed for graduate school, another of the students is currently an officer in the US Air Force, and the final student is currently in a management training position with General Electric. All of the students were very grateful for the experience and skills that they were able to develop through the project. One of the students was even able to apply what he had learned from the inductor circuit to a project for a vibrations course the following semester.

In addition to participation in the competition, the four students were required to produce a written project report. They are currently working on a conference paper documenting their design experience based on that report. The project was also given articles in two different editions of the departmental newsletter.

3. Trinity College Fire Fighting Robot Competition

For the past fifteen years Trinity College has been holding a fire fighting robot competition.[4] The competition has several different levels at which participants may compete making it ideal for any group of mechanical engineering students. Students with no programming experience or electrical background can compete, as well as multidisciplinary groups with electrical and computer engineering students included.

Three students at a small undergraduate engineering school decided to participate in the competition in exchange for independent study course credit. A very short proposal was constructed, and the project was supported by a small grant from Eli Lilly.

3.1 Contest Description

The independent study group of students that competed at the Fire Fighting Robot Competition did not have any previous programming experience, or any experience designing and constructing electrical circuits. Therefore they completed at one of the lower levels. Their task was to design a robot that could autonomously navigate through a scale model of a home, locate a candle burning in one of four possible rooms, and extinguish the candle. The dimensions of rooms and hallways was known ahead of time, the floor of the model was painted black, and there were white lines at the entrances to each of the rooms.

3.2 Design Description

The design team first designed a chassis and drive train for the robot. They decided to use two drive wheels with independent control followed by a single pivoting wheel trailing the drive wheels. They decided to use off the shelf DC motors with gearboxes that could be mounted directly to a round body chassis (to avoid getting caught in corners) and connected directly to the wheels of the robot. To better control the exact position of the wheels, wheel encoders were added to each of the two drive wheels.

With the drive system and chassis in place, the navigation sensors were then chosen. The design team decided to use an infrared sensor package manufactured by Sharp. The sensor provided an analog voltage as a function of distance to the nearest object. The group decided to use three sensors to locate objects to the front, left, and right sides of the robot. These sensors were then used in conjunction with the wheel encoders to locate walls and doors and accurately navigate the robot. In addition to standard navigation and movement, the design team added an infrared emitting diode and infrared transistor to verify their position by detecting the white lines that were present at the door of each room.

Once the navigation system was in place, the design group moved to the detection of the candle. They decided to purchase a sensor sold by Acroname Robotics that was specifically designed to detect the presence of a flame. The sensor gave a digital output that signaled only the presence or absence of a flame. In conjunction with the flame detector, because the size of the rooms was relatively small, the group decided to use visible light to move to the exact position of the candle. They simply constructed a small configuration of photo resistors in voltage divider circuits that could be used to determine the direct of the maximum amount of visible light.

With navigation and candle location detection in place, the last design decision was how to extinguish the flame. The group decided the simplest solution would be the best, so they simply mounted a propeller from a model airplane on a DC motor.

Of course, all the sensors and actuators included in the robot were controlled by a microprocessor. Because of the very little experience of the group, a simple processor was chosen that could be programmed in Basic. The design group did do a considerable amount of planning and flow charting (not to mention debugging once things were put together) to get the logic correct, but the complexity of the programming was not very involved.

3.3 Project Summary

The fire fighting robot constructed by the students involved in this project was also very successful. The robot did not compete in the final stages of the competition because one of the drive gear boxes broke off a few of its gear teeth in one of the preliminary rounds. However, the robot did show very well in the first stages of the competition, and again the students were very grateful for the experience and skills that they were able to develop through the project. One of the students has completed his PhD and is currently teaching at the university level, and the other two have gone on to design positions and prominent companies. One of the students in the design positions is currently the "electronics expert" in his design group.

4. Summary and Conclusions

Having students participate in student design competitions as part of independent study courses was very beneficial to the students, to the instructor, and to the universities where they were conducted.

The projects were beneficial to the students in terms of increasing their confidence level towards engineering design, and improving their aptitude in the topics covered. They were also able to attend conferences at the locations where their competitions were held, giving them another experience to help prepare them for graduate school. In fact, as previously mentioned, three of the seven students involved in the projects have completed, or are enrolling in graduate programs.

The instructor was very satisfied with the outcome of these projects, and the amount of time spent was small considering the benefits. The program helped develop students ready for graduate research work and developed conference publications. The instructor also learned a great deal while working closely with the students involved and was able to quickly assess how each of the students involved in the projects would perform as graduate students. Such relationships are not often developed with students in standard undergraduate engineering courses.

Both projects also resulted in positive recognition from the universities where they were completed and gave the universities national exposure at the contests. In addition, the projects were later used at recruiting activities to convince K-12 students to go into engineering and consider attending the institution were the projects were conducted.

5. Bibliography

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