Integrating Solid Modeling and Computer Programming Through A Freshman Design Experience

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Abstract - Although courses in solid modeling and computer programming are required in many engineering curriculums, students typically study these topics in separate courses. At Michigan Technological University, both of these topics are taught in the same course to meet the first-year engineering program objective of developing proficiency in the use of computers in solving engineering problems. Another objective of the program is for students to understand the design process through a practical, hands-on design experience. Michigan Tech uses these objectives to engage second semester freshmen in engineering design in a unique way. Students are challenged to create an innovative design concept, produce CAD solid models and assemblies to convey their concept, and develop a mathematical model in Matlab to predict the performance of their design. This paper will discuss the design projects used in this first year course to innovatively integrate solid modeling and computer programming throughout the freshman design experience.

Index Terms – first year programs, freshman design projects, Matlab, solid modeling

INTRODUCTION

Many engineering curriculums have incorporated an engineering design project in their first year course(s) in order to attract and retain more students, as well as to expose students to the “soft” engineering skills of teamwork and communication [1,2,3,4]. Since the fall of 2000, Michigan Technological University engineering students take a two-semester sequence of introductory, multi-disciplinary courses, both of which include a team design project. The design project in the first semester course is a design-build project based on the thought that first semester students would most enjoy a project where they could see tangible results from their efforts. These projects have ranged from mousetrap vehicles to bungee egg drops. However, the second semester course has focused on more abstract design projects.

The second semester engineering course, called ENG1102: Engineering Modeling and Design, has four main objectives:
1) To develop an appreciation for the engineering profession
2) To develop proficiency in the use of computers in solving engineering problems
3) To improve graphical communication and visualization skills
4) To understand the design process through a practical, hands-on design experience.

To meet these objectives, solid modeling, computer programming and a semester-long design project form the bulk of the course content.

During the initial offerings of the course, the design project focused on graphical and written communication, and computer programming was taught independently of the design project. These early design projects consisted of designing furniture constructed of plywood and PVC pipe or playground equipment. The projects focused mainly on form and little on function; i.e., hand sketches, 3-d solid models, cost analyses, project management and technical communication.

While students generally enjoyed these design projects, and this type of project gave students an exposure to the design process and a wide variety of communication tools used by engineers, these projects failed to include a major component of the course, computer programming.

DESIGN PROJECTS INTEGRATING SOLID MODELING AND COMPUTER PROGRAMMING

In order to fully integrate the design project with the course content, new design projects which include both solid modeling and computer programming elements were developed. These design projects have these general deliverables:
1) Preliminary investigation
2) Project proposal
3) Solid models to convey design concept
4) Hazard analysis
5) Energy budget
6) Computer simulation code (and corresponding flowchart)
7) Project presentation
8) Project book.

The projects begin with a preliminary investigation where students research and report background information on the design project topic. Once they have an understanding of current technology/products on the market, they then propose an innovative design. They create solid
models to convey their physical design concept, first by individual team members creating a solid model(s) of a component or components of the design, then assembling the components as a team. They perform a hazard analysis using the Failure Modes and Effects Analysis [5] on their design to manage risk. Energy budgets vary according to the type of project, as does the computer simulation code. In the last week of the term, teams are able to present their concept design to other teams (who have typically done other types of projects). They present both form and function; the physical concept using their solid model assemblies and performance using Matlab simulation programs. All phases of the design project are compiled and resubmitted in a “job book” at the end of the semester. Specific design projects which have been developed along these lines are described in the following sections.

Vending Machine Design Project

This design project asks students to design a vending machine with at least one advancement beyond the current technology. Students are shown the interior of a vending machine to gain insight on its mechanical workings and are directed to internet resources for more information related to vending machine design. After researching current vending machine technology, students design a vending machine that is somehow different than the current machines. Some students design machines to dispense soup for a late night dorm meal, burn music cds, dispense common school supplies like pencils and notebooks, or utilize a touch screen pad. The students create solid models to convey their design idea, an example of which is shown below.

For this project, students create controls configuration diagrams and functional specifications for the vending machine in addition to the general deliverables listed above. The configuration diagram shows all the electrical systems and major control components in the vending machine. The diagram is to clarify how each component of the machine will be powered and controlled. Figure 2 shows an example of this.

Remote Controlled Vehicles

This project challenges students to design a remote controlled vehicle with exciting new features to attract sophisticated customers willing to invest in high-end models. One of the features the vehicle needs to have is the ability to avoid running into obstacles even if the driver tries to hit one.

This project has phases identical to the vending machine project, but the energy budget for the remote control vehicles focuses on predicting and extending battery life. The Matlab code simulates the vehicle being driven through an “obstacle” course. The code asks the driver for directional and speed input, and the vehicle moves according to the user’s directions except when encountering a barrier which it is programmed to avoid.
**Human powered/super mileage Vehicles**

Students are asked to design a primarily human-powered commuter vehicle (HPV) to combat problems of climate change, rising fuel costs, traffic congestion, and obesity. The first step in this project, the preliminary investigation, directs students to research the factors which influence HPV performance such as aerodynamic drag and rolling resistance. Students are also encouraged to research different types of drive systems such as motor-assist systems. Based on their research, students design an HPV which they believe will be marketable, either by filling a niche in the market or by appealing to a wide group of users. Students have designed HPVs for snow, water and multi-rider use as well HPVs which utilize unique drive systems such as rowing or hand-crank mechanisms. Below is an example of a solid modeling assembly created by a student team to convey their design concept.

The energy budget for this project focuses on how much energy a human could produce while riding an HPV and how much energy would be consumed by such things as aerodynamic drag and rolling resistance. Students use parameters from their own HPV design concept to complete the budget. This energy budget is the basis for the computer code which predicts the speed of the vehicle.

Students create a Matlab code which asks the user to input their weight, something related to their fitness level, the distances, directions, and grade of each segment of their commute, and the prevailing wind direction and speed. From this user input, the code uses numeric integration to predict the speed of the vehicle for each trip segment and calculates the average speed and total time of the commute. Typical graphs output by the codes are shown below.

A variation of this project has students design and simulate the performance of a super mileage vehicle.

**Microbrewery Concept Design**

Teams are challenged to create a brewing process that would be applicable for a typical brewpub operation; i.e., 12 to 20 bbl per batch. In order to do this, students investigate the basic unit operations including milling, mashing (to create enzymes), brewing and fermenting (to create ethanol, CO₂ and more yeast) and report their findings. Their design proposal describes their planned approach to the project as well as their general brewery concepts. Teams are required to find a unique feature or advancement that differentiates their design from existing commercial designs.

Each team member creates a physical model of one or more components that illustrate their concepts. These components are then assembled to show the overall brewery. Figure 5 shows an example of student work.
The heart of the brewing process is fermentation. Students are able to get insight into the yeast growth dynamics by writing Matlab programs for mass balance which provide the initial conditions for simulating fermentation. Because the first year students have had no exposure to biochemistry, the instructor provides teams with an information packet including the rate equation for yeast/bacteria growth and typical yield and time constant parameters. The students then simulate fermentation using numeric integration to track sugar consumption and yeast/ethanol/CO2 production. A sample program output is shown in Figure 7.

In this project, students are charged with designing new infrastructure for the city of New Orleans and surrounding communities. The infrastructure design includes new levees, material handling equipment, and flood control and mitigation programs. Based on their infrastructure design, students create a flood management and evacuation plan. In addition to calculating an energy budget for the pumping stations, student teams also create a materials and time budget to raise the levee system or build the seawall to 24 feet above sea level. The function of their design is conveyed by a Matlab program that simulates an automatically controlled flood control system given a hurricane weather event. The system includes automatic pump cycling, evacuation warnings and route management, and predictive time to return to “non-flood” state. Kemppainen et al. [6] give a more complete description of this project.

**ASSESSMENT DATA**

In conjunction with the end of semester course evaluations, students are asked to rate the design project. Table 1 contains evaluation data for both the graphics-based and the integrated design projects. From the evaluation scale used, a higher number correlates with stronger agreement with the statement that the design project was a meaningful experience. As can be seen, students feel the integrated design project is more meaningful than the graphics-based projects. Also, the students appear to put more time into the integrated design project. The differences in the means reported below are statistically significant ($p < 0.005$).

**TABLE I**

<table>
<thead>
<tr>
<th>Course Evaluation Data</th>
<th>Graphics-Based Design Projects</th>
<th>Integrated Design Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall, I thought the team design project was a meaningful experience (1)</td>
<td>2.88 (n = 91)</td>
<td>3.36 (n = 233)</td>
</tr>
<tr>
<td>The total amount of time I spent on this course was (2)</td>
<td>3.32 (n = 84)</td>
<td>4.02 (n = 224)</td>
</tr>
<tr>
<td>The average number of hours per week I spent on homework in this class was (3)</td>
<td>3.82 (n = 91)</td>
<td>3.09 (n = 233)</td>
</tr>
</tbody>
</table>

1. 5 = Strongly agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree
2. 5 = Excessive, 4 = Too Much, 3 = About right, 2 = Too little, 1 = Minimal
3. 5 = <3, 4 = 3-5, 3 = 5-7, 2 = 7-9, 1 = >9

This data reinforces the anecdotal data by way of student comments on course evaluations. Frequently students list the design project as the part of the course they most recommend keeping.

**CONCLUSION**

Based on the data and general impressions of the faculty teaching ENG1102, we believe integrating both solid modeling and Matlab programming into a semester design project best accomplishes the course objectives. Further, it
gives the first year engineering student a chance to practice creative problem solving using typical engineering tools.

REFERENCES


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