AC 2008-2104: RECENT CAPSTONE DESIGN PROJECTS AT WESTERN KENTUCKY UNIVERSITY

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Recent Capstone Design Projects at
Western Kentucky University

Introduction

The electrical engineering (EE) program at Western Kentucky University (WKU) was created in 2001, graduated students for the first time in 2004, and is now fully accredited by ABET. Our mission is to be relevant to the region and to produce graduates who can immediately contribute. We believe that students should be involved in project based activities during their entire undergraduate experience. The EE program is dedicated to project-based learning (PBL). Engaging students with the concrete, hands-on, and real-world problems is a great motivator. PBL has grown in acceptance in the undergraduate community during the past two decades. [1-4]

WKU's EE faculty are focused on undergraduate education. Our faculty are rewarded and required to engage students in activities to support the development of a clear understanding of engineering practice.[5] Our goal is to provide students with relevant project experiences inside and outside the classroom. Faculty have developed a series of experiences throughout the curriculum to support this mission which culminates in a year long design sequence. Students prepare for outstanding professional leadership by participating in real-world projects undertaken by multidisciplinary teams using state-of-the-art tools and facilities. Many of these projects are done with the support of local industry.

This paper discusses recent projects completed in the senior capstone design course. Projects have been sponsored by regional industrial partners, government partners and internal faculty. The capstone course is a two semester experience in which the students propose solutions for large scale projects during the first semester and implement and test the design during the second semester. The industrial advisory board is used as a resource for projects and to assess the students at the completion of the project. Ideas on how to address large-scale, multidisciplinary, multi-year projects in an undergraduate project-based curriculum will also be presented.

Role of Design Courses

The EE Program includes a five course design sequence. The first design course, **EE 101**, introduces students to the university and the EE program. Students are taught how to solder and to how to use the departmental prototyping facilities. Students are exposed to programming in BASIC, MATLAB and HTML. Student teams design and build a small robot.[6]

The second design course, **EE 200**, further builds on the project-based mission. Students learn to construct circuits using the departmental print circuit board facilities. Students continue to develop programming skill with PSPICE and MATLAB. Students design and build a clock.

During the third design course, **EE 300**, EE students are assigned to teams. Each team is assigned a unique design project and must solve and implement a design problem throughout the semester. These projects are often industrially supported. Recently, some projects have been extended into the senior year. EE300 is taken the spring semester before the year long senior design sequence and is an important foundation to the senior project experience.

The first course of the senior year experience is **EE 400**, EE Design IV. During this course, students thoroughly plan their capstone project. At the beginning of the semester, students are placed on teams and are assigned projects. Each of these projects has a sponsor external to the EE faculty. Some of the projects are funded through industry sponsors and others through grants. The students interact with the faculty as technical sponsors for their projects and also interact with the industry liaisons. During this semester, the following topics are presented: teamwork skills, steps in effective design (understanding the problem, brainstorming, research, preliminary design, Gantt charts/project planning), manufacturability, assembly, affordability, reliability, and sustainability. By the end of the semester, the students have completed the project proposal.

The second course in the senior capstone experience is **EE 401,** EE Capstone Design. Students demonstrate their ability to design, build, and test a system to meet specified criteria. Also, students demonstrate their ability to communicate their project design and results in a written format and in an oral presentation. The entire semester is spent implementing the capstone project. The end of the semester culminates with presentations and demonstrations to the faculty, industrial advisory board members, and fellow students. These presentations are assessed by all three groups. The teams also present their results at their sponsoring industries.

Multi-year Projects

A struggle in undergraduate-only institutions is conducting applied research projects with students that require a time frame larger than a single semester. Students tend to lack skills and experience during the early parts of their undergraduate experience. Often the only students engaged in applied research projects are seniors. These students have completed many of their engineering classes and are prepared to positively impact a project. However, seniors tend to have a nasty habit of graduating. The combination of younger students lacking skills and needed coursework and seniors graduating makes successful large scale or multiyear projects more challenging. The EE program has successfully used a few approaches to implement these projects. Four projects that have been successfully completed are discussed below.

Project #1 – Curl Detection in Automation Process

The first project discussed is an automation design project with local industry. Two seniors were assigned this project as part of their one year capstone experience. The sponsor's production line uses a series of presses and cuts to process large blocks of aluminum into very thin sheets of aluminum, which are rolled into large coils and shipped to its customers. A concern on one of the production lines is edge curl. During the production process aluminum is unrolled treated then re-rolled. During this process the outer edges of the aluminum can curl. The curled aluminum must sometimes be cut (to remove the curl) resulting in a higher production cost.

In this project a nondestructive, no-touch, system prototype to detect the presence of edge curl on coils of aluminum, as well as detect the magnitude and direction of the curls was developed. Currently, the operators visually check the aluminum at the tension level area of the line, and make the appropriate adjustments to "fix" any curl that may be occurring. The system developed during this project provided an automatic method of detecting and measuring the curls, provided a digital readout, and displaying magnitude and direction of any edge curl to the operators in the control room so they no longer have to visually inspect the aluminum.

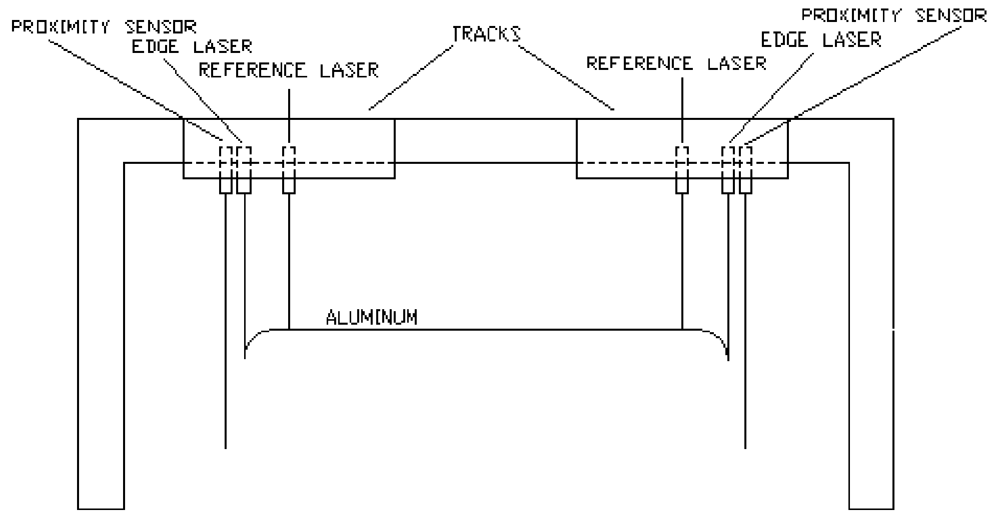


Figure 1: Curl Detection System

The approach chosen for this project is a system shown in Figure 1. One laser is suspended over each end of the aluminum, approximately 7 inches away from the edge, and pointed down to serve as a reference measurement, against which all other measurements on that side are compared. The purpose of this reference laser is to negate the effects of the aluminum's bounce as it passes through the line. Another laser (the 'edge laser') is suspended above each edge of the aluminum and pointed down. Alongside each edge laser is a proximity sensor that continuously searches for a void. All three sensors on each side of the aluminum are installed in a track. If the proximity sensor detects an object (the aluminum), then the system assumes that the edge laser is not on the outer edge of the aluminum, so the lasers and proximity sensor move horizontally away from the center along the track until the proximity sensor detects a void and the corresponding edge laser can record measurements. Inversely, if the proximity sensor detects a void and the edge laser measures a distance much greater than the distance of the aluminum, then the system assumes that the edge laser is off of the aluminum, and the lasers and proximity sensor moves horizontally toward the center until the proximity sensor detects a void and the edge laser records a valid measurement.

Educational Benefits

This project was completed in one year as part of a single capstone experience. There were several benefits associated with this project, including:

- The technical knowledge gained in putting to use their prior background in science and engineering coursework;
- Working with local industry to develop a system in a production line.
- Using concepts from classes in Industrial Automation, Electronics, Robotics, and Optoelectronics; and
- The satisfaction, and enthusiasm, gained through the involvement in a real-world project.

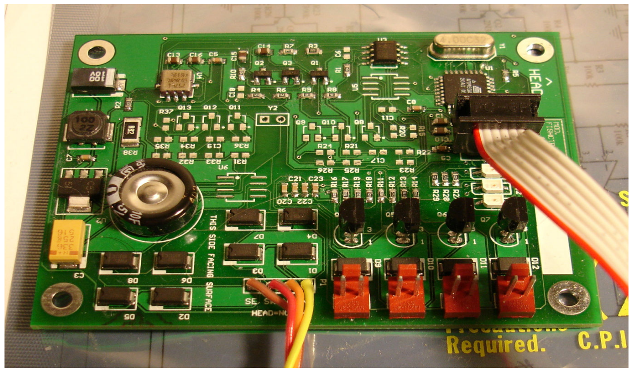


Figure. 2: Circuit Board for Robotic Fish

<u>Project #2 – Robotic Fish Project</u>

The Central Region Innovation and Commercialization Center (ICC) requested that a robotic fish be designed and built to be displayed at the center facility as part of a technology exhibit. The project specifications require a technology "wow" factor. Due to the complexity of this project it has been spread over several projects and one class. The industrial sponsor wanted the fish to have a novel power source and left all details up to the design team.   The first part of the project was conducted in a course entitled 'Introduction to Robotics'. The students were given the job of proposing how to power the robot and were divided into teams. Each team presented a proposal to the class and the best design was selected.

The second part of the project was then given as a capstone project. The students from the robotics course that proposed the design were assigned to the project. This group proposed getting current directly from the pool.   The key to the problem was to have enough current to drive the microcomputer and the electronics and low enough current to ensure safety. The voltage level needed to be high enough for the electronics.   The students then designed a board that could control small motors run directly from the pool. The main artifact from this project is the electronics design of the embedded system that will control and power the robot as shown in Figure 2.

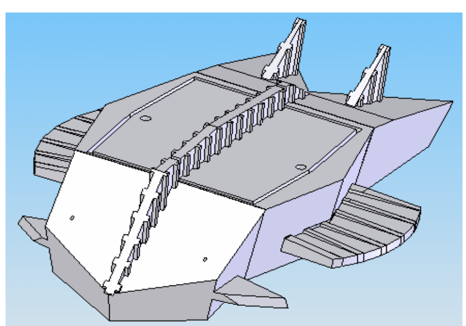


Figure 3: Robotic Shell

The third phase of the project was to select motors and design and build the outer body of the robot. The body was to be capable of housing the motors and keeping the circuit board in a watertight housing. Another senior project team was assigned this task (the following year).

The students designed the body in Solid Works® (Figure 3) and produced the body using the 3-D plotter.

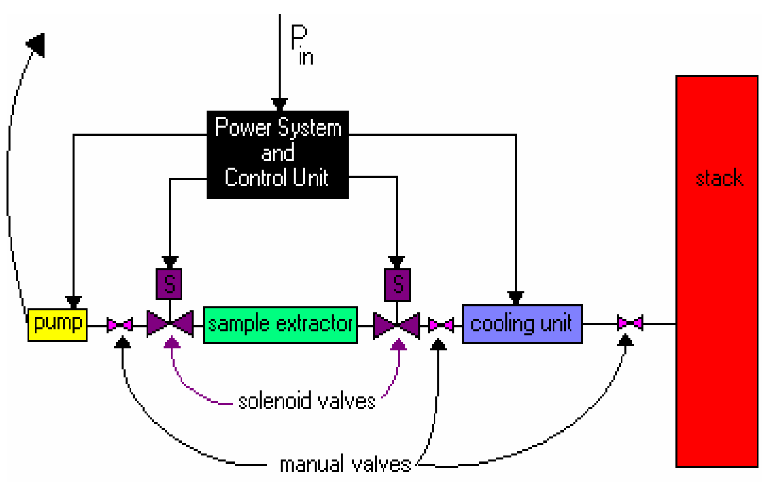
Educational Benefits

This project is an example of a three-year project. It involved a traditional class and two different capstone experiences. There were several benefits associated with this project, including:

- The technical knowledge gained in putting to use their prior background in science and engineering coursework (Circuits, Electronics, Robotics, Power);
- The satisfaction, and enthusiasm, gained through the involvement in a real-world project that could be on display at the regional center;
- Requirements for a true multidisciplinary approach to solving the problem; and
- Opportunity to interact with external organizations, such as Innovation and Commercialization Center (ICC).

Project #3 Flue Gas Extraction

In 2005, the Environmental Protection Agency (EPA) issued the Clean Air Mercury Rule, requiring phased-in reductions of mercury over the next several years[7]. In October of 2005, WKU engineering faculty met with Tennessee Technological University (TTU) electrical engineering faculty to discuss how they could work together to propose novel methods to help meet the EPA requirements. It was decided that WKU would work on a new method for mercury (and other toxic element) detection and quantification. The mercury detection and quantification project would involve sampling flue gas emissions from a power plant stack for subsequent, ultimately on-line, analysis using Laser Induced Breakdown Spectroscopy[8].



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The problem of flue gas extraction was assigned to an undergraduate team of EE juniors as part of their EE 300 design course. The assigned goal was to thoroughly study the issue of mercury pollution, and suggest the most reasonable approach for extracting a sample of flue gas. Note that at this stage there was no requirement to actually build a device; rather, proposing a sample extraction scheme was the goal in the one-semester EE 300 course. The result of this assignment was that a miniature electrostatic precipitator (ESP) was proposed to attract particles containing mercury to two charged plates[9,10]. Upon the completion of the EE 300 phase of the project, the assignment was carried over into the EE 400/401 design sequence, in which the requirement was actually to build and test a device for extracting flue gas samples. Arrangements were made to analyze collected samples using LIBS at Oak Ridge National Laboratory.

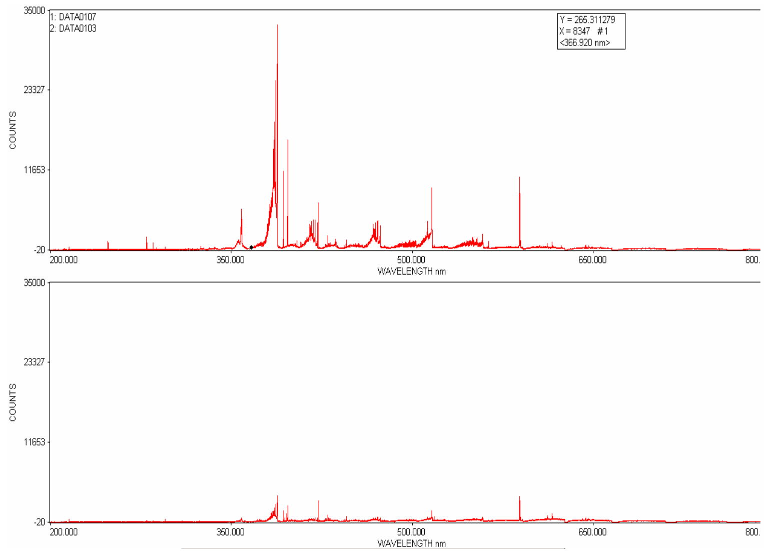

Figure 5. Sample LIBS Spectrum.

A prototype system involving an activated carbon filter system was developed, as shown in Figure 4. Activated carbon is a known sorbent for mercury, and finds use in other types of filtration systems. The filter and associated electrical and mechanical elements were constructed. Although the device could not be tested on a real stack, LIBS analysis was performed on an activated carbon filter sample, in order to provide the 'background' signals to be subtracted from the overall spectra upon completion of a full test. A sample spectrum is shown in Figure 5.

Educational Benefits

This project involved a project team that started in the Design III (EE 300) class and continued as a year long senior capstone experience. There were several benefits associated with this project, including:

- The technical knowledge gained in putting to use their prior background in science and engineering coursework;
- The satisfaction, and enthusiasm, gained through the involvement in a real-world project of potentially global consequence;
- Requirements for a true multidisciplinary approach to solving the problem; and
- Opportunity to interact with external organizations, such as Oak Ridge National Laboratory and the Institute for Combustion Science and Environmental Technology (ICSET).

Project #4 Void Detection Robot

The final project described is the conversion of an all terrain vehicle (ATV) into a remotely controlled robot capable of determine subsurface voids using microgravity. This multiyear project involved several project teams of undergraduate students.

The project was sponsored by Center for Cave and Karst Studies (CCKS) funded with a grant from the Kentucky Science and Technology Corporation. CCKS has a long and successful history of determining the location of caves using microgravity technology. The microgravity meter (MGM) is cumbersome and must be physically moved. Once the meter is in position the microgravity measurements must be taken manually. Therefore the purpose of the project was to develop a platform to properly position and move the MGM to desired locations. A robotic platform allows for the process to be streamlined and a larger area to be examined in same amount of time. In addition, a single person could conduct the process. The remotely controlled robot developed carries the microgravity equipment across rugged terrain to make remote measurements. The robot is shown in Figure 6. This robot will have many applications that include search and rescue and location of underground caves or tunnels[11].

Figure 6: Void Detection Robot

The initial phase was to design a platform to keep the MGM level. A capstone project team of senior mechanical engineering students designed a leveling platform to keep the MGM level when positioned over rugged terrain. ME students also converted the stop/start and steering so that robot could be remotely controlled. The second phase of the project was to convert the ATV to remotely controlled robot. A team of three electrical engineering students were hired during their junior year and continued over the summer and into their two course senior project and capstone project. The team successfully converted the ATV to a robot which is controlled via wireless Ethernet via a laptop computer. The third phase of the project was conducted by another team of 2 EE students as part of the 2 course senior design class and capstone experience. These students installed sensors to measure distance from the MEM to group and added a GPS systems to map the MGM sensor data. Another group of seniors will add the microgravity meter to the robot and integrate the controls of the MGM so that the entire process can be remotely controlled.

Educational Benefits

This project is an example for how undergraduate students can be involved in large scale multiyear projects. This project was split into 3 different capstone projects. In addition, one of the teams was hired to work on the project outside of normal coursework. There were several benefits associated with this project, including:

- The technical knowledge gained in putting to use their prior background in science and engineering coursework (Circuits, Electronics, Robotics, Power, Microprocessors);
- The satisfaction, and enthusiasm, gained through the involvement in a real-world project that could be on display at regional center;
- Requirements for a true multidisciplinary approach to solving the problem; and
- Opportunity to interact with external organizations, such as CCKS.

Role of the Advisory Board in Capstone Design Course Assessment

The EE industrial advisory board (IAB) is composed of faculty, students, alumni, and representatives from various industries. Each spring the IAB is approached as a source for potential capstone projects. During the following summer, faculty consult with the industry partners to determine the projects that are appropriate for capstone experiences. The industry members who agree to sponsor senior projects work with the students throughout the year as they develop and ultimately implement their projects. Each spring during finals week, the IAB has their annual meeting. A substantial part of the agenda of the meeting is the presentations demonstrations by the senior project teams. These presentations usually take thirty to forty-five minutes. At the end of the presentations, the board, faculty, and students assess the communication skills of the teams[12].

Conclusions and Discussion

This paper discussed recent projects completed in the senior capstone design course. These projects were sponsored by regional industrial partners, government partners and internal faculty. The EE program has an extensive design sequence that includes 5 courses. The design sequence was developed to produce graduates who can immediately contribute. The design sequence engages students early in the curriculum through projects. Engaging students with the concrete, hands-on, and real-world problems is a great motivator. Students prepare for outstanding professional leadership by participating in real-world projects undertaken by multidisciplinary teams using state-of-the-art tools and facilities.

The four projects described in this paper were examples of how projects could be organized. Our faculty have the flexibility to split a project into several pieces that can be incorporated as part of traditional classes and/or the design classes. Larger projects are often incorporated as part of a traditional class or in the junior design course (EE 300). These projects can than continue as they progress into their senior year, with aspects of the project potentially continued with summer employment. We are able to get a group of undergraduate students to engage with a project over a two year period.

The first project, "Curl Detection in Automation Process", was a traditional industrial sponsored capstone project. The project was successfully concluded in a single year experience. The second project, "Robotic Fish Project", was split into several projects over three years. The project started in a traditional lecture class and continued over two different capstone experiences. The third project, "Flue Gas Extraction" is an example of a two-year project. This project started in the junior design course (EE 300) and continued as a capstone experience with the same group of students. The fourth project, "Void Detection Robot" is another mutli-year project. The project was split into multiple teams. Two project teams had a single year experience while a third of students were hired during their junior year and continued the project as their capstone experience. Each project is an example for how undergraduate students can be involved in larger scale projects.

Three of the four projects demonstrated that it is possible to incorporate complex, multi-year projects into an engineering curriculum. In soliciting projects from external industry sponsors, one need not request only those types of projects which may be completed in a one-semester time frame. Large, long term, multidisciplinary projects can be undertaken by assigning various undergraduate student teams to portions of a project. The student teams can be comprised of electrical, mechanical, or civil engineering majors, or any other discipline needed to complete project requirements. The teams can change from year to year, as students may graduate prior to project completion. Projects may also be solicited from government sponsors, and can have a strong research component. This should not be avoided, as research is often a real part of the engineering practitioner's work, and may help to enhance the critical thought process so beneficial in the workplace.

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