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Experiences in Developing a Computer Engineering Capstone Design Course with a Start-up Company

Dr. Andy S. Peng, University of Wisconsin - Stout

Andy S. Peng is an assistant professor with Computer Engineering Program in Engineering and Technology Department at University of Wisconsin - Stout since January 2014. Andy S. Peng is also a systems engineer staff at Lockheed Martin MST since November 2005. From May 2003 to April 2004, Andy held a graduate research intern position with Aerospace Electronic System (AES) group at Honeywell International Inc. From July 1999 to July 2002, Andy held hardware design, sustaining, and test engineering positions at Dell Inc. In the summer of 1998, Andy was a summer research fellow with the Mayo Clinic. Andy S. Peng received the Ph.D. and M.S. degrees in electrical engineering from University of Minnesota, in 2010 and 2004, respectively. He received B.S. degrees in electrical engineering and computer science from Texas Tech University in 1999. His research interests include computer networks, network performance evaluation, network modeling and simulation, wireless sensor network, and engineering education.

Brian Eickhoff, Sentera, LLC
Dr. Kenan Baltaci, University of Wisconsin - Stout

Kenan Baltaci is an Assistant Professor at University of Wisconsin-Stout, in the Electrical Engineering Technology Department. He received B.S. in electrical engineering degree from Istanbul Technical University in Turkey. Following, a master's degree and doctoral degree in industrial technology was granted from University of Northern Iowa.

Dr. Liang Zhan, University of Wisconsin - Stout

Assistant Professor Computer Engineering Program University of Wisconsin-Stout

Dr. Robert M. Nelson, University of Wisconsin - Stout

Robert M. Nelson is currently a Professor of Computer Engineering at the University of Wisconsin – Stout in Menomonie, WI. Dr. Nelson received a B.A. degree in mathematics from Northland College, Ashland, WI in 1977, the M.S.E.E. degree from Washington State University, Pullman, WA in 1981, and the Ph.D. from NDSU in 1987. He has been a member of the technical staff of Bell Telephone Laboratories, has served on the faculty of the University of Idaho, and at North Dakota State University, has consulted with Michigan Technological University and Lawrence Livermore National Labs; NDSU Center for Nanoscale Science and Engineering (CNSE); Sverdrup Technology (Eglin Air Force Base); Otter Tail Power Company; and the Naval Undersea Warfare Center, New London, CT. Dr. Nelson has been working (teaching and research) in the area of applied electromagnetics, including antennas, transmission lines, microwave engineering, EMI/EMC since 1981.

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Abstract

Engineering faculty responsible for leading capstone projects are often faced with challenges in defining project topics for students. There is an ongoing need for developing new project topics that can be tackled by teams of upper-division undergraduate students. In contrast, during the early phases of establishing a profitable business, many startup companies are faced with an overwhelming number of research and development tasks required to build innovative products. Due to constraints in engineering resources or subject matter expertise, some of these projects may be deferred or left unsolved within the startup organization. Some of these small-scale projects, however, are very suitable to be undertaken by students in their last academic year. The students can apply knowledge learned from the engineering curriculum to real-world projects in their senior capstone design class. This paper focuses on discussing our classroom experiences in integrating industry sponsored projects from a startup company into a senior capstone design course in a computer engineering program. The capstone design course builds upon fundamentals of an ABET-accredited computer engineering curriculum. The design course simulates real-world project experiences and offers an opportunity for students to learn new skill sets including the design, debug, build, and test of prototype systems as well as oral communications and knowledge in engineering ethics from an instructor-led team-oriented environment. The industry sponsor also benefits from the project deliverables and an opportunity to interact with groups of students who are often eager for an opportunity to apply their knowledge and ultimately launch their career. Details of sample projects and feedback from students in meeting course objectives are discussed in this paper.

Introduction

One of the critical steps in the product realization process is the engineering design, which deserves special attention in undergraduate education to better prepare graduating engineers in satisfying the rapidly changing demands of the industry [1][2]. An engineering graduate should be able to apply the knowledge of mathematics, science, and engineering to analyze, formulate, interpret data, and design practical engineering systems. An engineering program is required to train the student for life-long learning, to work professionally and ethically in multi-disciplinary teams, to communicate orally, and in writing technical documentation [3][4][5]. Such an engineering program is often required to be accredited by the Accreditation Board for Engineering and Technology (ABET), which has been continually increasing its emphasis on the integration of system design into the engineering curriculum [6]. In fact, one of the criteria of an accredited undergraduate engineering program is to prepare for engineering practice through the curriculum, culminating in a major design experience based on the knowledge and skills acquired in earlier coursework [7][8]. Engineering employers also expect the engineering graduates to be able to engage in engineering practice as soon as they graduate or within a short time following graduation. It is the general consensus among the institution offering the engineering degree program and engineering industry to train and prepare the students to engage in interdisciplinary team projects and engineering experiences that are similar to what the graduates will encounter in the workplace.

At University of Wisconsin−Stout (UW−Stout), all computer engineering program students are required to complete a two-semester sequence of capstone design courses in their final academic year. The multi-disciplinary course includes students from computer engineering, manufacturing engineering, mechanical engineering, plastics engineering, and engineering and technology programs. The elements of the system design process are emphasized in the capstone class. Students have the opportunity to obtain hands-on experiences from working in a team-oriented environment. Essential concepts such as project planning, designing, and scheduling are emphasized throughout the team project. In addition to the invaluable, practical technical experience, the capstone project enables students to develop their communication skills through a visual and oral presentation before an audience of peers, faculty, and invited experts from relevant engineering industry.

One industry sponsor, Sentera, specializes in the development of various technologies based on small unmanned aerial systems (UAS) platforms [9]. Sentera is growing and wishes to open up avenues of collaboration with engineering students in nearby universities [10]. The capstone course can be structured to support this demand. During the fall 2015 semester, Sentera sponsored three capstone projects for a group of capstone design students from the UW−Stout computer engineering program. This course setup helped students get a jump-start on what it is like to work on a real-world project with unique system requirements. They had an opportunity to manage the scope, time, and cost of each project. Throughout the semester, the course instructor acted as internal management and liaison with the startup company, while the industry sponsors played the role of a customer. The industry sponsor also provided funding and mentorship to assist students towards the completion of their capstone projects.

Course Curriculum and Objectives

The capstone design course curriculum is intended to simulate a team working environment similar to the industry workplace. The class is divided into design teams to develop solutions for existing problems from private, public, and/or industrial sectors of society. Each team project goes over at least one iteration of the product development cycle from the initial phase to the completion of the final documentation required to manufacture and use the product. Derived from the course syllabus, a list of course objectives is shown below.

- To foster the atmosphere of individual achievement through the success of the team.
- To utilize independent creative thought and research in the solution of a design problem.
- To apply previously acquired skills, knowledge, and experience to practical applications encountered in the industrial environment.
- To appreciate the structure, format, and procedure necessary in carrying a project through to completion.
- To communicate both orally and with technical documentation about the design solutions.

Course Structure/Schedule

The engineering capstone design course at UW−Stout combined students from multidisciplinary programs as well as both capstone I and capstone II courses. The class meets twice a week for two-hours each class time. To enhance the learning experiences, a few required lectures are integrated within this course. The lectures introduce engineering design process, system analysis, project planning, and other relevant knowledge to support the successful completion of a team project. Students are also encouraged to use project work time for team discussions and resolving project related issues. A detailed class schedule from the course syllabus is shown in Table 1. There are five required design reviews planned in a 16-weeks semester course schedule. They closely follow a general sequence of events towards the completion of a team project. The schedule consists of the initial proposal, system design analysis, two project status updates, and a final product demonstration.

Table 1. Detailed Schedule of the Capstone Design Course

Week #	**Activities**	**Week #** (*con't*)	**Activities** (*con't*)
1	**Lecture:** Introduction, Syllabus, Engineering Design, Design Flow, Teamwork.	9	Project Work
2	**Lecture:** Project scheduling, Team grouping, Presentations of possible project topics (Industry sponsors visit campus)	10	**Design Review #3:** Project status update #1
3	Project Work	11	Project Work
4	**Design Review #1**: Project definition and proposed schedule	12	Thanksgiving Break
5	**Lecture:** Engineering design analysis; Project Work	13	**Design Review #4:** Project status update #2
6	**Design Review #2**: Concepts developed and rationales	14	Project Work
7	Project Work	15	Project Work
8	Project Work	16	**Final Design Review**: System demonstration and final documentation (Industry sponsors visit campus)

This course structure outlines some guidance to keep students on track in meeting their project deliverables and for the course instructor to monitor their progress throughout the semester. Each initial project proposal is reviewed and approved by the course instructor and the industry sponsor. They also provide preliminary feedback to the students in terms of their project complexity, time frame, budget, and potential design issues. Students are allowed to make modifications to their project plan and deliverables as long as sufficient technical justifications are provided. Individual team meetings begin and each team selects a team leader who manages the progress of the project and assigns tasks to each team member. Each team may seek help from the instructor during class periods or office hours, and from industry sponsors via e-mail or a teleconference call as needed. Such an arrangement simulates an engineering working environment similar to the industry, where an engineering lead or manager typically does not constantly monitor the progress of the project until support is needed or a status report is due. This setup also allows students to develop communication and teamwork skills, which ultimately helps them succeed in their design projects.

Sponsored Capstone Projects

At the beginning of the fall 2015 semester, an engineer from Sentera proposed five different project topics to computer engineering students. Two project topics were initially selected by two teams of students. One related project topic was individually proposed by the third team after the project topics presentation. The startup company agreed to sponsor all three related projects.

Project #1: Low-Cost Thermal Sensor Payload

This project had a group of four students from the capstone design II course. The student team designed and created a low-cost, power efficient, and lightweight payload for obtaining and processing thermal images. The payload may be attached to a drone to perform varying tasks, such as agricultural research involving crop and cattle analysis. This is achieved by using the FLIR Lepton longwave infrared (LWIR) camera module integrated with the Raspberry Pi Model B+ [11]. The Lepton LWIR module is packed into a small camera body, capable of taking images with a resolution of 80 × 60 pixels. Once acquired, the images are converted to the appropriate file format and stored on a microSD card located on the Raspberry Pi. The system diagram is illustrated in Figure 1.

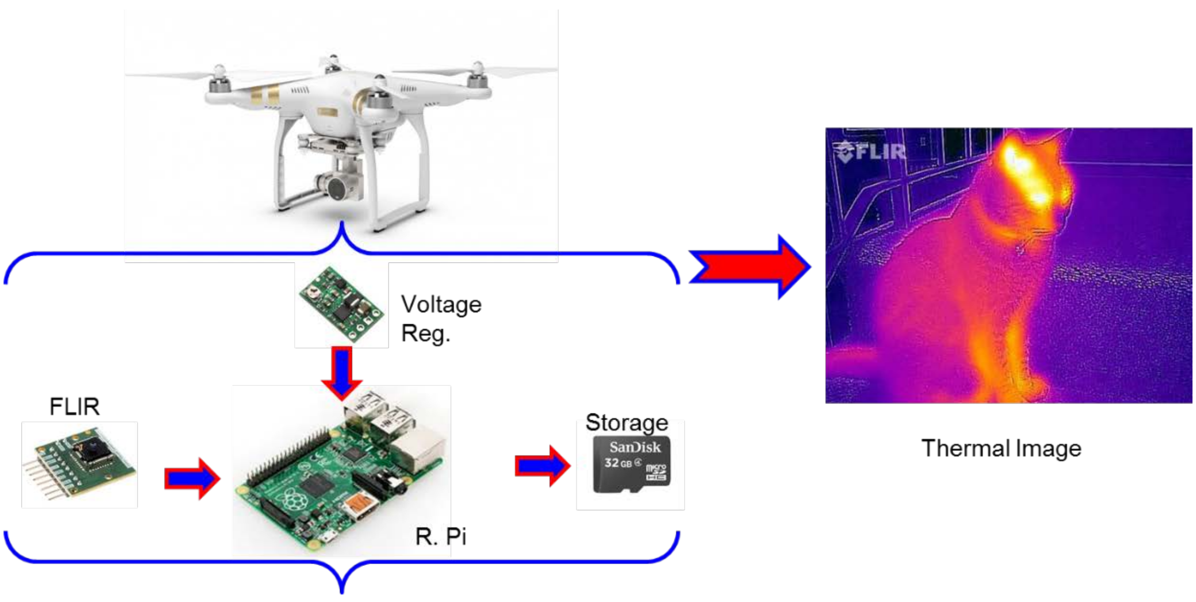

Figure 1. Low-Cost Thermal Sensor Payload System Diagram

Project #2: Image Collection to KMZ Using C++ for Viewing in Google Earth

This project had a group of two students from the capstone design I course. The project team developed a command line program using the C++ programming language that accepts an input data set consisting of images taken with a quadcopter and a metadata text file containing GPS data referencing those images. The program output creates a Keyhole Markup Language Zipped (KMZ) file that can be viewed with the Google Earth application. When opened, the points in the dataset appear as points on the map, and can be clicked to show the image that corresponds to that data point. This is very useful because the metadata text file is not meant to be human readable. By quickly translating the data into a visual format, it can be analyzed for whatever purpose it was created for in the first place. For testing and developing the program, a forty-eight element data set was initially provided by Sentera. Using the final build of the program on the laptops the program was developed on, this data set could be converted into a KMZ file in under thirty seconds. Even on a basic netbook, it is expected that conversion time would remain low, allowing the program to be powerful out in the field. The drone operator could easily move the data set onto a laptop and quickly convert it to KMZ file so that it can be analyzed immediately. The output of the program is shown in Figure 2.

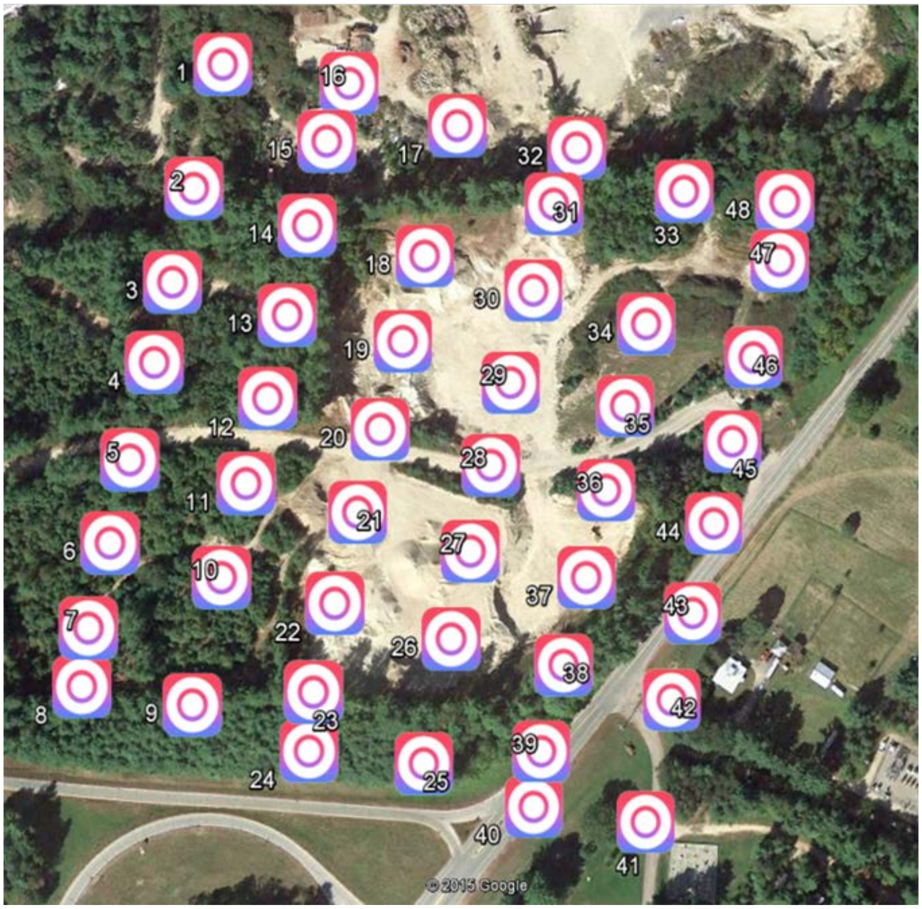

Figure 2. Output KMZ file shown in Google Earth application

Project #3: Drone Camera Image Payload using a Low-Cost Camera Module

This project had a group of three students from the capstone design I course. The project team developed a camera payload system which captures video from a drone, storing data for post analysis. The objective of the project is to keep the system design simple and self-contained to limit the number of other systems it would be dependent on. Since this design is intended for use with a drone, the deliverable design needed to be in a small form factor. Ideally mounted on the bottom of a typical drone, the module would rely on the drone only for its power source and potentially a sensor data interface for logging. This form factor was achieved by using a small single board computer with the camera mounted on top of it through its pin headers as illustrated in Figure 3. The diagram also illustrates the interfaces between the camera and the processor.

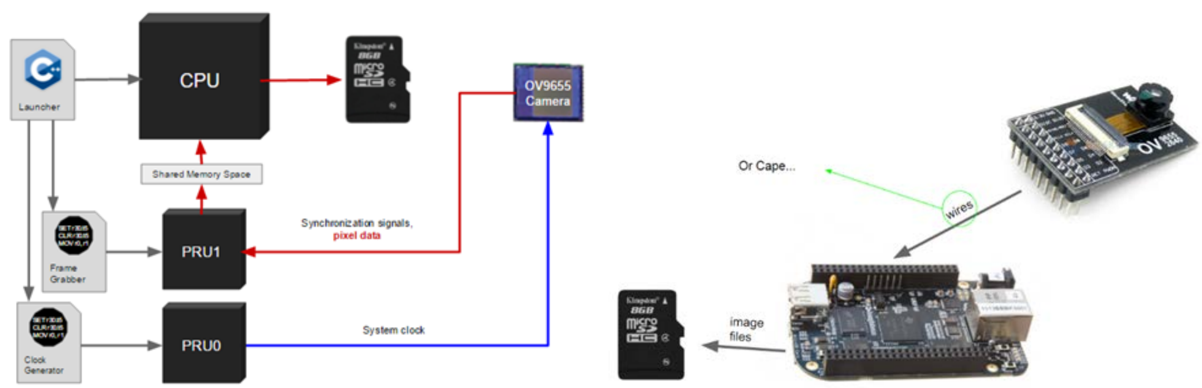

Figure 3. System Diagram of the Camera Payload

The first two projects met the proposed project objectives whereas the third project failed to deliver an adequate technical solution. However, the lesson learned from the third project was well documented to explain all the technical issues encountered during the product development process. This also indirectly met the learning objective of the capstone design course. Table 2 shows the summary of the sponsored projects and their outcomes.

Table 2 Summary of the Sponsored Projects and their Outcomes

Project #	Project Title	Project Description	Project Outcomes
1	Low-Cost Thermal Sensor Payload	Design and create a low-cost, power efficient, and lightweight payload for obtaining and processing thermal images.	Delivered preliminary proposed solution.
2	Image Collection to KMZ Using C++ for Viewing in Google Earth	Design a command line program used to import data collected by a Drone (tag and images) and create a visual representation of it in Google Earth as a KMZ file.	Delivered preliminary proposed solution.

3	Drone Camera Image Payload using BeagleBone Black and External Camera Module	Development of a low-cost, power efficient, and lightweight camera payload for obtaining and processing color images.	Encountered hardware limitation. Unable to deliver the proposed solution. Developed lesson learned information with alternate proposed redesign.

Course Outcomes and Assessments

Throughout the semester, sample comments were collected from the students. Table 3 summarizes the assessment of capstone design experiences based on students' feedback. While the sample size may seem small to draw any conclusive result in a single semester, students generally like the project experiences and knowledge gained from the capstone course. Students indicated that constant feedback from the course instructor and mentorship provided by the industry sponsor were beneficial and contributed to the success of their project. To better assess the overall impact, more samples will need to be collected in a similar setting across few semesters of capstone design courses.

Table 3. Assessment of Capstone Design Experience: Students' Comments (*N*=9)

Question	SA	A	N	D	SD
Q1: My capstone design project was successful.	4	2	0	3	0
Q2: This class simulates experiences from engineering industry.	5	2	1	1	0
Q3: The class expectations were clear, logical, and easily understood.	0	4	2	3	0
Q4: Course objectives were clearly defined and reflected in the course evaluation	0	3	4	2	0
Q5: The instructor's feedback was valuable	1	4	3	1	0
Q6: Industry sponsor mentorship was valuable	2	5	2	0	0

SA = Strongly Agree, A = Agree, N = Neither Agree nor Disagree,
D = Disagree, SD = Strongly Disagree

Conclusion

The capstone course provides important experiences in the early days of engineering students' careers for them to interact with professional engineers from the industry. The intent of an engineering education and the capstone design project is to provide the graduate with the ability to perform practical life-long engineering missions in collaboration with multi-disciplinary teams in the industry following graduation. By integrating industry sponsored projects with the capstone design course, the setup enables students to experience one iteration of the engineering design process: needs refinement and formulation, setting target specifications, concept generation and down-selection, specification refinement, functional prototyping, testing, and redesign. Throughout the semester, each student receives ongoing support from their peers, course instructor, and industry sponsor via team discussions and formal design reviews. This represents a core aspect of the capstone experience. Based on the outcome of students' projects and the assessments from students' feedback, most students appreciate the positive learning experiences from the capstone design course. The startup company also appreciates the creative design that goes into the proposed solution of each project. This study concludes that the designed capstone course structure and collaboration with the startup company helps engage students to learn new skill sets and motivate them to succeed in their projects. It is necessary to collect more statistical data across multiple semesters to ensure that this course model is sustainable.

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