Auditory Assistant – Perspectives on a Robotic Senior Design Project

Michael Brunet, Dietrich Heinz, Robert Rabb, Alyson Eggleston
The Citadel, Charleston, South Carolina

Abstract

The importance of the capstone design has increased in undergraduate engineering programs, viewed as a critical portion of engineering education. Typically, much of the curriculum is devoted to engineering analysis. In contrast, senior capstone design stresses application of a broad base of knowledge in much more specific contexts. Senior design allows students to enhance their learning and problem-solving experience with open-ended problems and real world constraints and perhaps allows them to conduct research and solve engineering problems with experts or multiple stakeholders beyond the typical single instructor.

In some engineering programs, capstone courses play a critical role in further developing the professional skills necessary for effective engineering practice, including project management, communication, and collaboration. This paper highlights student perspectives working on a follow-on robotic senior design project that stemmed from a robotic hand. They will discuss their design project, processes, software development, and lessons learned from designing a robotic hand. Students will self-report the learning that occurs in these senior design projects, challenges, and their level of preparation once they graduate.

Keywords

Senior Design Project, Multiyear Project, Mechatronics

Introduction

A Senior Design Project is a required element of many undergraduate engineering programs. The requirement offers abundant challenges for faculty and students due to the variety of projects in any year as well as from year to year. Learning to do good design work is a skill that is best improved experientially. However, by the time the students are ready to undertake a senior design project, their timelines do not support staying longer than available for the senior design experience. Unfortunately, students often lack the time to conduct testing or produce improved design iterations.

At The Citadel, a two-semester senior design project is part of all engineering programs. Some projects are new every year, while others build upon a previous iteration of a project. There are obvious advantages and disadvantages to each, such as: defining scope of project, originality, and integration. However, through a process of review and continuous improvement, the school is consistently producing quality and successful senior projects. Several factors contribute to this success. These include: early identification of project and technical advisor - the students now identify their groups, project, sponsor, and technical advisor about mid semester of the spring term before senior design begins. This gives them ample time to understand the problem and ask questions while they are in their junior year. In an earlier project selection scenario where projects were not proposed until the beginning of senior year, most groups would consume considerable amounts of time with their final project culminating in a glorified, but simple proof of concept. In the senior year, the senior design projects are two semesters. In the fall semester, teams define the problem and gather background information, generate customer and engineering requirements, generate and evaluate concepts. In the second semester, teams build, test, and document their project.

Multiyear projects

A search of the literature reveals a limited number of multiyear project papers[1-4]. This is due in part to the considerable logistical challenges inherent in such undertakings. One variation is a progressive elaboration of a senior design project where additional features or subsystems may be developed for a larger, complex system. Instructors take steps to ensure a continuity of knowledge between years. Keeping a faculty advisor who has had the history and expertise to the project is essential. This means that the skills and knowledge developed in one year need to be transferred to the next year's team members. Lemley et al. report how senior design projects can be linked to a faculty's research. Lemley et al. makes the distinction that the senior design project focus is design and not research[5]. Currently, periodic advisor and student meetings are scheduled to check progress and capture information. Using weekly, thirty-minute in progress reviews, the students report progress through a presentation of deliverables, discussion of issues and concerns, and creation of action items. The results of this new process have been excellent. The quality and success of senior design projects has improved. Although the weekly status reports are intended to be a technical review of progress and to provide input on upcoming activities, the meeting can also be used to solicit ideas and evaluate solutions to problems. In addition to the weekly meetings, the project team often sought out their advisor to ask questions. However, new teams prefer to explore their project independently and had difficulty starting where the previous team had ended.

Faculty and advisors should consider the level, scope, time-frame, and cost of the potential project and whether the project will have the desired impact on the larger system. Other considerations should include the team personnel, size, and background. Team members should be carefully evaluated for projects that require any special technical skills.

Robotic Hand Senior Design Project

Design teams are required to develop product specifications, generate alternatives, make practical engineering approximations, perform appropriate analysis to support the technical feasibility of the design, and make decisions leading to an optimal system design. Design teams address in their projects and reports factors such as system integration, human factors, computer-aided design, maintainability, and fabrication techniques. A robotic hand for American Sign Language (ASL) is one of the successful examples of these types of projects. Over three years, working with teams of 4-5 members annually, the robotic hand evolved from simple finger manipulation (two knuckles per finger) device to a much more dexterous hand, with finger crossing and wrist manipulation to depict accurately all letters and numbers. Teams have consisted of various levels of motivation and experience (some students have known ASL due to deaf member of the family). From several years of developing a robotic hand, feedback from potential customers indicated that an important part of ASL is facial gestures.

Robotic Face Senior Design Project

As a follow on to the robotic hand, a new project for a robotic face was conceived. Although related to a larger project of the faculty advisor, this was a first iteration of the robotic face. The five-person team consisted of above average GPAs and a balanced knowledge base from previous coursework. Given an open project to design, the team was asked to make a robotic face to complement and integrate with the previous year's robotic hand—and the team has done well thus far. They are developing a 3D printed face enclosed with motors and linkages to mimic facial movements. These include eyebrows, eyes, mouth, and head movement from the neck. The team was provided with the computer code from the previous year as a basis to understand the programming structure and integrate these commands into their design if possible. Currently, the team is developing linkages and assemblies to control the eyes, eyebrows, mouth, and cheeks.

With adequate direction, time, and resources, undergraduate students are capable of working on complex projects. The key is to scope their portion so that they can be successful given their level of expertise and available time and connect them to resources when necessary. Due to the complexity of a robotic face, a diverse group of faculty from various departments teamed to provide the necessary technical guidance. The lead advisor from Mechanical Engineering provided overall project leadership and mentored students from Mechanical Engineering. A faculty member from the Department of English had competency in ASL and knew other ASL signers on campus. The School of Education connected students to the local school districts who employed ASL interpreters. These non-engineering contacts provided specific expertise on facial gestures and integration with ASL. The team conducted project planning to set achievable milestones to complete the project in the allotted time provided. The team met with the lead advisor once a week to ensure the students were staying on track to complete the project. The students developed questions and surveys to collect information from ASL signers and instructors. With the help from survey results, the students were able to narrow down the constraints and most important features of the robotic face. Preliminary research also gave the team a short list of the most important emotions and associated facial expressions needed for ASL. Each of the students created five separate designs that were narrowed down to one final design. This design prioritized realistic appearance and was simple enough to complete the project with time constraints in mind.

The students chose to name the robotic face "Alex" due to its neutrality and non-threatening sound. The preliminary prototype will consist of a 3D printed face, a scan of one of the team member's face, and will have the moving parts attached on this skeletal base. The moving parts will include the eyebrows, eyelids, eyes, cheeks, and mouth. The parts will also be 3D printed, and attached with a variety of fasteners. The movement of each individual part will be initiated by several servo motors mounted on the inside of the head. After all parts are attached, the face will be covered with a synthetic skin material, such as the prosthetics used in movies, in order to give the face a life-like appearance. As a final touch, a wig will be placed on the head to add one last level of personability to “Alex.” See Figure 1.

For this preliminary prototype, the face will be controlled with a series of buttons, specified to run each emotion and expression. The future goal is to pair this face with a set of previously developed robotic hands and arms and be completely voice activated, so that there is no hands-on control needed. This will be helpful not only for those controlling the robot, but will also provide a more immersive experience for those utilizing the aid of The Auditory Assistant.

Figure 1: 3D Printed Model (Alex)

Initial work with additional faculty members (non-engineering) gave the student team additional background information. For instance, during an “Elevator Pitch” for a contest, the Robotic Face team could answer judges’ questions concerning facial expressions and cultural differences. Students were well positioned to discuss that ASL signers actually form their own cultural community, and facial expression in signed languages. Facial expressions are not used the same way in spoken languages. For example, American Sign Language uses facial expression to mark grammar more than it does to convey emotion as most, hearing, English-speakers use it[6].

Student Experience

The educational benefits of senior design projects are varied, and experiences are unique to each project and student team. However, all students should receive hands-on experience working on a real world project that has practical application. Many capstone projects tend to be focused, discipline-specific projects[7] but some senior design projects may be the first time the students are exposed to a multidisciplinary effort.

Lessons Learned

The students learned much about the design process and the iterative nature of design during the senior design project. Having experienced a complex project that is part of a larger system, they understand the significance of these experiences to the academic education. Before starting a multi-year design project, faculty advisors should carefully study the level, scope, time-frame, and cost of the potential project and whether the project will have the desired impact on the student experience. Other considerations should include the team personnel, size, and background. Team members should be carefully assessed for projects that require any special technical skills. For instance, the robotic hand and robotic face were projects that require above average skill from mechatronics and CAD courses. A majority of the students working on these projects should be competent in these areas or willing to learn the material on their own.

The progressive projects provide the school with a great marketing tool. Spotlighting these projects are one way schools can attract high performing students desiring real-world experience as part of their education. Students are facing ever increasing college expenses and want to be assured that they will be leaving the institution fully marketable. Senior Design Projects can play a vital role on student resumes. Emphasis and recommendations for future work on final reports provide connections to future year's designs. In typical senior design projects, final reports and related product design documentation were required and graded but since it was not really used after they were developed, it was easy to overlook details and not correct deficiencies. Even the students have seen the problems this creates when the next student team works on the next iteration of a progressive project and tries to understand what has been done. As a result, they now see first-hand the importance of good communication and documentation. The students also experience first-hand the challenges of handoffs of designs from one part of an organization to another. These operations, while uncommon in school or senior design settings, are increasingly common in industry where sub-contractors may do much of the work. The more we can prepare our students for this 'real world', the better off the students will be. They have also learned more about using video conferencing to efficiently conduct business and the tools that can help, such as agendas and minutes. Connected to this is the principle that each year's student work is built on the work of earlier students and contributes to the work of future students. Thus, the students' work is seen in a much larger context than is common in some of the senior design projects.

There are several lessons learned that we have already identified. Our program has had occasional progressive senior design projects and have seen the need to transition from one team to another. However, we have found the transitions in this project to be harder than expected with new teams wanting to start from the beginning rather than continue where the previous team left off. In our previous experiences with this, it was possible either to manage the degree of duplication or the duplication was necessary due to poor performance in the previous year. In this project, it has proven much harder to control. In future iterations we intend to focus the students' attention on reviewing and accepting prior years' work[2] and defining the projects so teams can start at a more advanced point of their deliverable. Some students are more comfortable starting a project from the beginning to understand the project better and launch from their comfort zone when they feel ready.

As cited in the literature, multi-semester senior design projects take more time and coordination to execute. In particular, successful implementation of progressive projects requires:

- Proper scoping of projects so that students can progress through their design process and defined scope in one year;
- Alignment of design course instruction (theory) and the capstone project work (practical application) to help students draw connections;
- Coordination of faculty teaching engineering design, engineering science, project management, and other engineering topic courses to help students identify knowledge pertinent to their capstone project and view all engineering problems as sustainable design problems;
- Flexible assessment that allows student teams to progress through the design process at an appropriate pace for their project;
- Coordination of project advisors and design course instructors to provide consistent assessment across projects; and
- Monitoring and assessment to ensure student outcomes are being met[4].

Conclusion

Although there are challenges related to conducting senior capstone design projects that are multi-year projects, there are ways to minimize the potential issues and have the projects succeed in terms of meeting the capstone design requirement, giving students design experience, and furthering the larger effort / project.

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Michael Brunet

Michael Brunet is a student at The Citadel. He is a mechanical engineering senior who will graduate in May 2022. He has an interest in robotics, coding, and manufacturing. He plans on staying locally in Charleston, South Carolina for post-graduate employment opportunities.

Dietrich Heinz

Dietrich Heinz is also a student at The Citadel studying Mechanical Engineering. His interests are in Power & Energy as well as Mechatronics. Cadet Heinz received a Navy contract at the end of his freshman year, and following graduation in May will be reporting to Pensacola, FL for Naval Flight School.

Robert Rabb

Robert Rabb is a professor and the Mechanical Engineering Chair at The Citadel. He previously taught mechanical engineering at the United States Military Academy at West Point. He received his B.S. in Mechanical Engineering from the United States Military Academy and his M.S.E. and PhD in Mechanical Engineering from the University of Texas at Austin. His research and teaching interests are in mechatronics, regenerative power, and multidisciplinary engineering.

Alyson Eggleston

Alyson G. Eggleston is an Assistant Professor in the Department of English, Fine Arts, and Communications at The Citadel, The Military College of South Carolina, where she teaches STEM-focused technical writing and communication, writing-intensive courses for international students, and linguistics. She received her PhD from Purdue University in Linguistics, and she has a BA and MA in English with concentrations in TESOL and writing pedagogy from Youngstown State University. Her research and teaching interests are in technical and scientific writing pedagogy and the interaction of language and cognition. She is a member of Sigma Xi and ASEE.