

Expanding Student Engineering Experience Through Building an Astromech Droid

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Abstract—In this work, we outline the start of a project to expand engineering interest at our campus robotics club: the development of an autonomous Star Wars astromech robot. This project involves students from various undergraduate engineering majors and the overall goal of this project is to adapt our autonomous navigation software stack into a new robot that will be constructed over the next 2 academic years. During Fall 2021, a large number of the students arriving on campus were new, many of whom had not stepped on campus before. We use this project to aid in student development – both technically and in their acclimation to campus life. The student club lost many upperclassmen during the 2020-2021 academic year and we outline how we organized the newer students into functioning groups.

I. INTRODUCTION

We present a case study into a project-based learning experience where undergraduate students participate in the construction of an Astromech droid from the Star Wars [1] series of movies. This robot project serves as a platform where students from various engineering majors can participate in building a familiar design while gaining hands-on experience.

The robotics club at California Polytechnic State University, San Luis Obispo, USA, serves as an extracurricular club where undergraduates can gather to work on various robotics projects. Past projects have included underwater ROVs, an autonomous golf cart, and other small robotics projects. Club members consist primarily of undergraduate engineering majors where the most common are mechanical, electrical, and computer engineering majors along with computer science.

During the COVID lockdown of the 2020-2021 academic school year, the club switched to virtual meetings. As a result, there was reduced progress on actual projects themselves during this time. In this paper, we outline an effort after the lockdown year to rejuvenate the robotics club at our university through a project to develop an autonomous Star Wars [1] astromech robot. A sample image of an astromech droid is shown in Figure 1. While we expect this to be a multi-year project, this is an effort that started in Fall 2021 and continues at the time of writing of this paper. The focus of this paper is to document the impact of the project on the students returning to in-person instruction on our university campus and to describe the benefits the project has provided to the engineering education at the campus robotics club.

This paper is organized as follows: Section II outlines prior work that is related and relevant to this project. Section III



Fig. 1: A sample astromech image from the astromech.net builders' club brochure [2]

outlines the background material regarding astromech robots, the technical aspects of our design, and budgetary information. Section IV covers the experience of running this project in our robotics club. Section V concludes.

II. RELATED WORK

Various work has shown the benefit of a university extracurricular robotics club in both student technical knowledge growth and in student interaction [3], [4]. These prior works mention several benefits such as peer-to-peer learning, exposure to technologies not covered in class, and fruitful social interaction with peers.

Karp et al. [5] provide an introduction into the construction process of an astromech droid. This work covers the different materials, electronics, and motors used in model astromech droids. Causer [6] covers the process of adding emotion and character to an astromech running in an amusement park. This work also covers the challenges of building the robots to be robust in the presence of changing environments.

Work that is similar in spirit to our work is described by Lara-Prieto et al. [7] where the authors use a Star Wars droid as an educational tool. In that work, authors describe having groups of first year engineering students participate in a workshop initially working with a commercial BB-8 radio controlled droid and then eventually, the students build a functioning prototype. The prototype is at a smaller scale than the movie design, but the prototype rolls and functions as expected. That work highlights the enthusiasm that is



Fig. 2: Photograph of the student-assembled wood frame and wood legs. The diameter of the cylindrical main body is approximately 46 centimeters.

brought about when working with recognizable robots and we experience the same.

Additional Star Wars inspired educational academic projects include: Star-force [8] (a mixed reality simulator employing haptic feedback and augmented reality) and using Star Wars to teach recursion in programming courses [9].

III. ASTROMECH DROIDS

Astromech droids are robots portrayed in the Star Wars series of movies. R2-D2 is the most famous and iconic astromech droid, and BB-8 is another well-known example. Members of the R-series of astromech droids are cylindrical in shape and approximately 1.0 meter tall with a diameter of 46 centimeters. Because of the complexity involved in constructing a rolling, spherical robot, such as BB-8, we choose to target a standard 3-wheel R-series astromech. A sample image of an astromech droid can be seen in Figure 1. Although similarly styled, the astromech droids themselves come in various color schemes and configurations.

Many movie fan builders have constructed astromech droids, but because of licensing restrictions with Disney [10] and Lucasfilm [11], fan builders are not allowed to offer a complete astromech kit for purchase. While the trademark owners of the astromech droid designs do not allow the sale of complete and movie-accurate model kits, the companies do allow the hobbyists to construct replica parts and sell those parts to other builders.

The primary knowledge source for astromech building information is the online forum: <http://astromech.net>. The forum was founded in 1999 and on this forum, builders can purchase parts, download plans for wood frames and 3D-printable components, and discuss with other builders in general. At the time of writing, the forum has over 2,000 active members worldwide.

A. Construction Process

Because there is no reference construction kit for an astromech droid, there is a fair amount of background research



Fig. 3: Photograph of the current members and astromech dome of the astromech development project.

that needs to be performed before proceeding. Due to the robot parts being low volume items, some parts are fabricated by hobbyists only on an as-needed basis. This means that some parts are built in part runs, where parts are fabricated once a sufficient number of buyers are interested. Because of this, there is a fair amount of planning and scheduling for part procurement.

The droid frames can be constructed of aluminum, wood, styrene plastic sheet, or 3D-printed parts. Frames are the inner support for the cylindrical aluminum skin and are not visible once the robot is complete. We desire a frame that can easily be constructed without specialized tools and thus we select wood for our frame material. Available on the astromech forum are plans describing how to CNC a wood frame from plywood. Instead, we opt to purchase the pre-cut Tex-Mex wood frame [12] as shown (after assembly) in Figure 2. This frame is CNC routed from Baltic birch plywood and the pieces are of high quality. For the dome, we choose an aluminum part which is lasercut with the appropriate openings. This can be seen in Figure 3. The aluminum skins are the externally visible aluminum shell that defines the iconic look of an astromech. We select ones that are pre-curved and have lasercut panels.

The robot is driven using a 2-wheel differential drive configuration with a third leg in a caster setup. In the Star Wars movies, astromechs can switch from an upright, 2-wheel configuration to an angled 3-wheel stance. This transformation is quite complex to implement when building an actual functioning robot so we opt to build a fixed 3-wheel configuration. The drive motors are standard Neo brushless motors [13] from high school robotics competitions.

B. Autonomous System Design

For this astromech, we adopt a navigation framework that is available to us at our university and it is based on the ROS Navigation Stack [14]. This navigation system is already functioning on another existing robot. The sensor configuration for the two robots is the same, a single monocular camera for sensing. We do not delve into detail into the operation of the system in this work, but we will provide an overview of the system sensing and actuation requirements.

In terms of autonomous navigation, the goal of the project is to have the ability to autonomously navigate an outdoor quad area in between 2 university buildings. This is an area marked by clearly delimited sidewalk areas and grass areas. This known area is subdivided into linear segments that can be classified by the neural network running on the robot.

Because of the desire to have a similar look to a movie-spec astromech droid, a primary goal is to minimize the number of externally visible sensors. Our in-house navigation system uses a single monocular camera (M12 lens size) to obtain 640x360 HDR color images to perform obstacle detection, coarse robot localization (at the granularity of hallways), and path planning. Neural networks are used to perform these tasks on a per-frame basis. The single camera can be hidden near or potentially behind one of the decorative astromech ports (becoming visible with a flip-up servo). Our target is to have the camera located in the upper of the 2 horizontal gray ports located in the midsection of the R3-A2 astromech shown in Figure 1.

The computer system runs an embedded Ubuntu Linux distribution and contains a multi-core ARM CPU with a 512-core GPU for running the neural networks. Given our current neural network architecture, a single inference pass takes on the average 30ms.

In terms of support electronics, we use a custom Arduino shield with encoder counting hardware and RC receiver interface circuitry. This shield is shown in Figure 4. The robot is powered using RC-car style 4S lithium-polymer batteries (6000mAh) and for manual control by a human operator, we select a standard RC-style transmitter.

C. Budgeting

The construction of an R-series astromech can be a quite expensive project and the overall cost varies greatly on the type of build material, with aluminum being the most expensive.

The most expensive non-electronic component is the hemispherical aluminum dome. This a quality component that can only be sourced from one vendor. After the dome, the frame and the drivetrain components are the most expensive parts. In terms of components for compute and autonomy, we use the NVIDIA Jetson AGX Xavier as our primary embedded computer, which typically retails for \$699 USD and is currently much more expensive due to current shortages. Fortunately, we are able to utilize the NVIDIA board from a previous project.

IV. EXPERIENCE

In this section, we outline the process of recruiting students to join the club, organizing them into an effective engineering team, and managing aspects of the robot construction process.

A. Student Recruitment

The typical process of student recruitment for the club is for the current club leaders to attend the campus club fair at the beginning of the school year. At this event, the club leaders gauge student interest and contact freshmen that

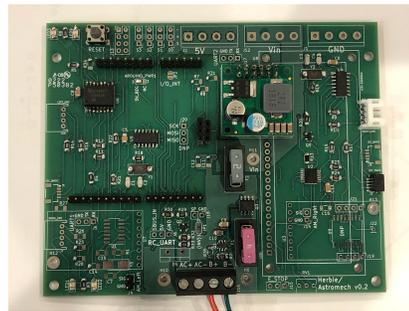


Fig. 4: The custom designed controller board for the project. The board functions as a large Arduino shield.

have already arrived on campus. During this most recent club fair in the post-lockdown academic year, the makeup of interested students included incoming freshmen, incoming transfer students (those who had studied 2-years at a local community college), and junior-level students who had only partially completed their freshman year in-person in the 2019-2020 academic year. Because this was the return to in-person operation of the campus, it was evident that there was great interest in students to become involved in extracurricular activities after being separated from each other during the 2020-2021 academic year.

B. Student Experience

The first two club meetings involved presenting the current projects to the new club members. During these initial meetings, the makeup of students was approximately 85% new members and 15% returning upperclassmen members. This was a marked difference to prior years, where the fractions of new and return members were approximately equal. This was not particular to the robotics club in the university, and was a university-wide phenomenon.

As can be imagined, there was a substantial amount of interest and excitement for the project and it was a practical challenge to get the incoming students organized into productive groups. For the project, students were divided into 3 teams: mechanical, electrical, and software. During this initial quarter, there were 3 returning upperclass students who were able to function as team leads for the mechanical and software groups. The faculty advisor served as the lead for the electrical group. It was noted that a number of the incoming freshmen had experience in high school working on teams building robots for competitions such as FIRST robotics [15]. At the same time, many of these students had their high school competitions canceled the previous academic year due to COVID.

With the large percentage of new club members that are freshmen and given the fact that this is a new project in the club, there are challenges to be expected. The first challenge is that it is difficult to expect incoming freshmen to commit to a project while they are getting acclimated to the university academic environment and college culture in general. For many of the students, upon arriving at a new school, they are

learning which extracurricular activities to participate in and how to balance their academic workload. During the beginning of the first academic term, the average student attendance for the teams was as follows: mechanical (~7 students), electrical (~5 students), software (~10 students).

During the past few months of the project, there have been many observed successes within the astromech project. Various freshmen and new transfer students have developed practical skills in woodworking, surface-mount soldering, programming microcontrollers at the register level, and working with ROS recording files. In addition to the technical skill growth in students, the club project has provided an environment where these new students can meet others, build friendships, and take a step towards a typical, post-COVID educational environment. The technical skills of some of the students has been quite impressive and this project has been a true motivator in that growth.

With any project involving many students, there will always be challenges present. One of the initial challenges was the distribution of work for students. In particular, the software group often felt a lack of direction because of the delay in having an actual functioning platform to test on. This is a problem that arises in many robotics projects that involve hardware engineering before software development can be done. Our problem is not unique and the solution involves guiding students to develop software background knowledge while the hardware is being engineered. A second problem is that separating the members into one of the three technical groups can lead to students feeling locked in to that particular area. This can be addressed with periodic checkins with each member to assess how the student is feeling about their work on the project.

C. Survey Results

In Table I we show results of a student survey regarding the impact of the project on their impression of the engineering field. The questions were: (Q1) *I have learned engineering ideas and practices that I have not learned in class* and (Q2) *The project has helped to confirm (or disprove) I have selected the appropriate major*. We find that students report favorably that the project has exposed them to engineering concepts that they would otherwise not cover in the classroom and this is a primary goal of our project. Students also report favorably on Q2 which probes whether students feel they have selected the correct engineering major. Additionally, 83.3% of the students reported that working on the project has confirmed their interest in engineering.

V. CONCLUSION

In this work, we describe a project at our university robotics club to expand engineering education through building an autonomous Star Wars astromech droid. Our project goal is an R-series astromech body style. This project started in the academic year after the COVID lockdown of 2020-2021. We use this project as a way to motivate freshmen and other incoming students to participate in engineering extracurricular

Question	Results (5-point Likert scale, 5=strongly agree)
I learned engineering ideas and practices that I have not learned in class (Q1)	4.5
This project has helped to confirm (or disprove) I have selected the appropriate major (Q2)	4.5

TABLE I: Student survey results.

activities. The students that arrived on campus at the beginning of the 2021-2022 had missed an entire year of in-person instruction and this is an opportunity to engage those students in engineering outside of class.

We find that the students have varying degrees of robotics experience with several of them having had their high school robotics club canceled because of the COVID lockdown. During the initial months of this longer term project, students are successful in learning practical engineering skills that they might otherwise only pick up in their later years of college.

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