Teaching Innovation in Higher Education: A Multidisciplinary Class

Samy El-Tawab, Nathan Sprague, and Michael Stewart
College of Integrated Science and Engineering, James Madison University, VA, USA
eltawass@jmu.edu, spragunr@jmu.edu, stewarmc@jmu.edu

Abstract: This paper proposes a new multidisciplinary set of classes that can help undergraduate students achieve learning objectives related to hands-on project-based skills. Employers are looking for students who have experience in realistic work environments while also having a strong foundation in their major. During spring 2018, the authors created a multidisciplinary class titled: "Autonomous Vehicles." This class brought together a multidisciplinary group of students to convert a traditional golf cart to autonomous operation. To our knowledge, this is the first course of its type to be offered in the state of Virginia. With research expanding in this field, it is valuable for students to have experience working with hardware and software related to robotics and automation. This project taught students' important technical skills as well as soft skills related to working with large teams, communication, and project management. The authors offered this class again in Fall 2019 with a different theme, as a demonstration of the effectiveness and the reproducibility of this approach.

Keywords: Innovation, Technology Education, Multidisciplinary class, project-based classes

Introduction

At the university undergraduate level, students learn a range of skills in the sciences and humanities. However, there are generally few opportunities for students to practice real-world problem-solving in a multidisciplinary environment. Autonomous vehicle development represents a good candidate area for introducing this sort of work into the undergraduate curriculum. The transportation industry is currently undergoing a drastic shift towards autonomous vehicles (AV). Tesla, a leading AV company, has plans to release an autonomous truck in the near future that will deliver cargo from a start point to a destination without human intervention. In addition to this, many car companies have begun to incorporate automated features such as autonomous lane changing, parking, and braking in their cars. Rapid changes in technology like this have a tremendous impact not only on the job market, infrastructure, and economy but also on policy and ethics. Students need to be exposed to these types of innovation.

At James Madison University, we offered during the Spring 2018 semester, an "Autonomous Vehicles" class to undergraduate students from different disciplines. The students' goal in the course was to develop an entirely autonomous vehicle using a standard electric golf cart. While this project does not touch on the societal impacts of autonomous vehicles, it does give students the ability to explore and extensively understand the technology involved. To help facilitate this learning experience, different teams were created at the start of the project, and each one was responsible for creating a core function of the overall system. The purpose of this paper is to dive into each of these responsibilities, the methodology of dividing the teams and explain the technical components involved in each subsystem.

Objective / Research Question

The project objectives are to develop a fully autonomous vehicle by the conclusion of the course that can drive a predetermined route without a human presence in the car. Ideally, the vehicle will also be able to detect objects in its path and either maneuver around them or come to a stop.

The research question is whether a multidisciplinary group of undergraduate students can successfully convert a traditional golf cart to an autonomously driven one using the collective skill sets they bring to the project.

Literature Review

The transition from traditional teaching methodology to an unfamiliar teaching method is fraught with challenges (Salib et al., 2019). In particular, a project-based teaching methodology raises several difficulties (Peterson et al., 2011). However, there significant benefits to active and student-centered learning methodologies (Dunlap, 2005; Salib et al., 2013). Student-centered learning is a teaching method that replaces lectures with active learning class environments, supportive group projects, and integrated self-paced learning materials (Nanney, 2004; Salib et al., 2019). Active learning approaches are well suited to courses that are tied to research activities (Hartman et al., 2018; El-Tawab et al., 2018). The idea of class-based projects with a multidisciplinary group of students is very appealing but challenging (Trisdiono et al., 2019; McCarthy et al. 2018).

Methodology and Team Creation

At James Madison University (JMU), the existence of the JMU X-Lab has provided a unique opportunity for project-based classes. For the JMU X-Lab Autonomous Vehicles class (Spring 2018), teams were divided into four technical categories; Planning and Navigation, Sensing and Processing, Front End Development, and Motor Control, to comprise a fully functioning service at the end of the semester. In addition, a Management/Integration was tasked with making sure that the flow of communication between teams occurred, and with preparing presentations and reports. The Planning and Navigation team needs to determine the path of the vehicle to reach an end goal or destination. The Sensing and Processing team gathers information surrounding the Autonomous Vehicle. It must send it to the planning team so that they can make better-informed decisions on how to move the Autonomous Vehicle. The motor control team is responsible for these movements, which include automated steering, braking, and acceleration. The front-end team is responsible for the development of a website and a mobile app where the user can actively control the vehicle, as shown in (Fig. 1). It is crucial to provide multidisciplinary instructors/Teaching Assistants (TAs) who can guide the class through the semester. We had several majors in the class. For the class to create a successful end-to-end solution, it is important to divide sub-team, keeping in mind the knowledge and background of each student. This was accomplished through a skill survey at the beginning of the semester along with a survey of group preferences.

Teams were encouraged to use the Scrum project management methodology with two-week sprints (Pries, 2010). Many of the students were familiar with Scrum from prior course work or internship experiences. All students were assigned introductory readings on Scrum at the beginning of the semester.

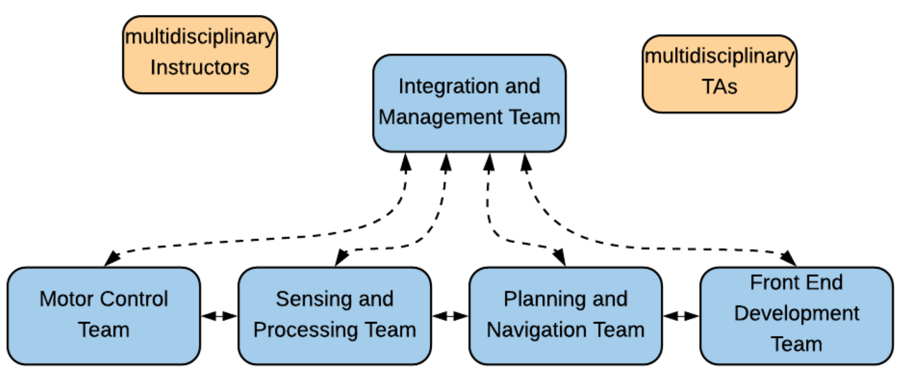

Figure 1. Class Organizational Chart

Data Flow: Since there are a lot of data streams and interfaces involved with the AV, a data flow diagram shown in (Fig. 2) is used to explain the flow of data between different components in the class project. The Robot Operating System (ROS) network map allows data to flow across the appropriate subsystems seamlessly. The planning and navigation team is responsible for the server and the ROS network map. The Arduino, the drivers, and the motors are all owned by the motor team. The sensor team holds the 2D and 3D sensors. Finally, a front-end team developed a mobile app to make requests to the Autonomous Vehicle. From a workflow standpoint, selecting a destination in the app triggers the Autonomous Vehicle to begin driving towards that goal.

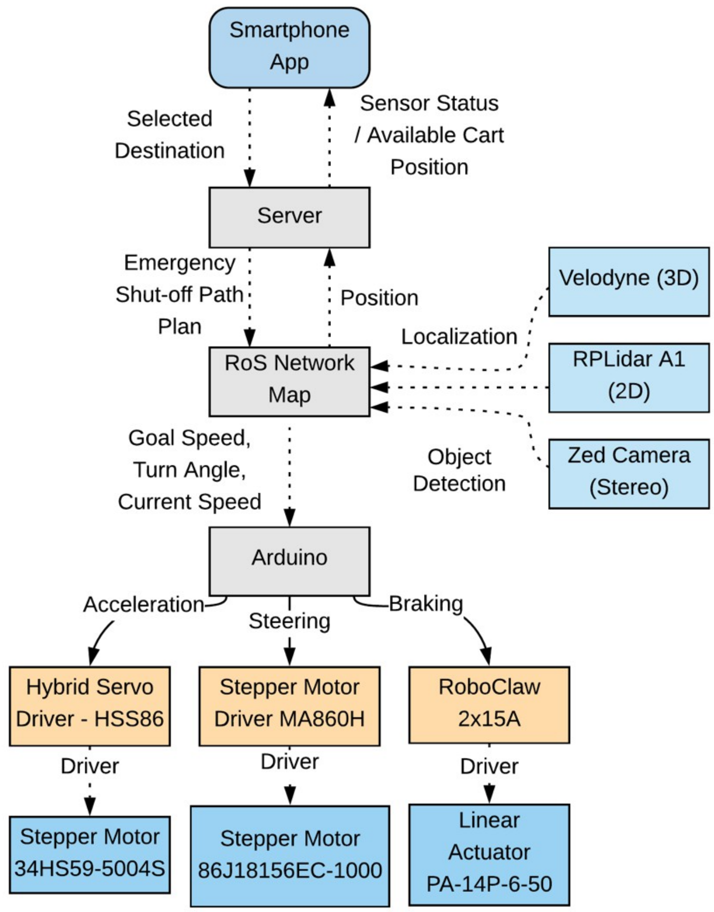

Figure 2. Technical Data Flow Diagram

This project-based class taught students many skills involved in working with large teams, communication, and cutting-edge technologies as the world continues to transfer towards process automation. The project objectives were to develop a fully autonomous vehicle by the conclusion of the course and to drive a predetermined course, in a controlled setting, without a human presence in the car. The golf autonomously driven car was able to detect objects in its path and either maneuver around it or come to a stop. The JMU X-Lab has provided a golf cart to this project to help achieve these objectives. In the following, we highlight some of the preliminary data and challenges that we had:

Localization and GPS Position: Mapping and localization were handled using the NDT Mapping package provided by Autoware, an open-source autonomous vehicle library. This package generates a 3-D point cloud map using sensor data gathered from a VLP-16 Velodyne Lidar. Mapping data was collected by manually driving the golf cart through the navigation area while collecting Lidar readings. The map is then generated offline by combining those readings into a single, integrated point cloud. We discovered that the mapping process consistently failed unless we provided data from an inertial motion unit (IMU) to the mapping software.

With the addition of a low-cost Phidget Spatial 3/3/3 IMU, we were able to reliably construct high-quality maps (Fig. 3).

During navigation, the NDT package is able to localize the cart by comparing incoming Lidar data to the existing map. The localization process is computationally intensive. Real-time localization required the use of a GPU-enabled version of the matching algorithm. Running on a laptop with a discrete Nvidia GPU, we found the localization performance to be reliable and accurate. While we did not perform any quantitative measurements of accuracy, the localization was generally correct to within a few centimeters. Once the cart is localized, the position is communicated to the ROS nodes responsible for planning and navigation.

In addition to Lidar-based localization, the cart used a Garmin 18 LVC GPS. This GPS is hooked to the Velodyne through an Ethernet connection and sends packets of data that are converted to National Marine Electronics Association (NMEA) form, which can then be used to retrieve latitude and longitude. The GPS location data was not used for navigation. Instead, it served as a reliable source of location data for the front-end interface. This allows the interface to display the general position of the vehicle even if Lidar localization is not active or if the cart is moved outside of the mapped area.

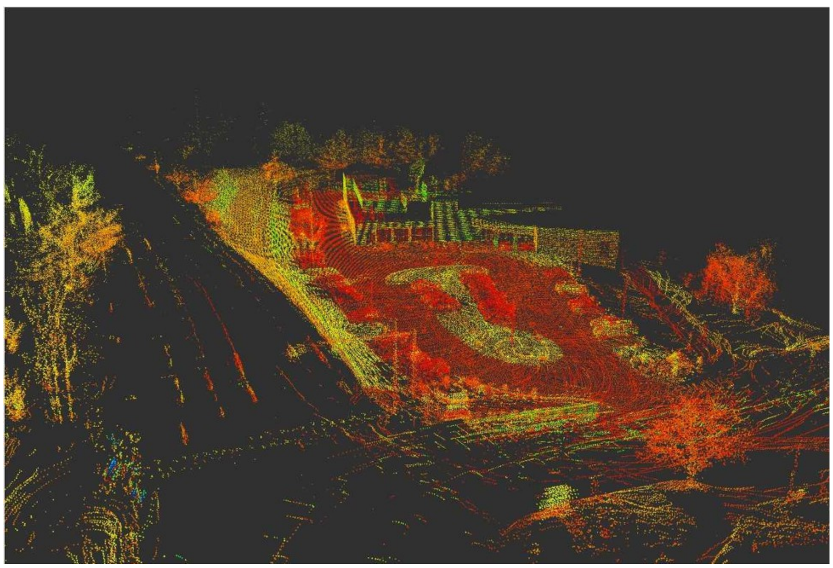

Figure 3. Point Cloud Map of Lakeview Parking lot at James Madison University

Object Detection: Regarding the scope for object detection, for simplicity, we focused on objects in front of the autonomously driven golf cart. A 2D RP Lidar A1 camera was used. Using a 2D scan in front of the Autonomous Vehicle simplified the detection, as shown in (Fig. 4). The solid red box defines the "danger" bounds, and any point or object within this box means there is an object detected that is in harm's way of the AV. In the initial implementation, the cart simply stops if an obstacle is detected in the designated box.

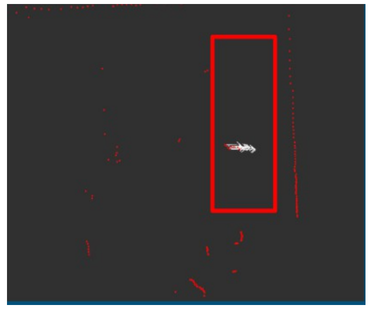

Figure 4. Object Detection: Collision Box

Odometer: In order to get the current speed needed by the motor, the Velodyne sensor was used. The Velodyne can estimate the current pose of the AV, and since it knows the localization point at one time and then another time, speed can be estimated by simply using the distance traveled over time. Placement if all sensors is shown in (Fig. 5).

Figure 5. Approximate Sensor Placement

Discussion

Throughout the project, the teams were very agile in responding to issues and conflicts that arose. In a system of this magnitude, a small change in one subsystem could lead to significant changes for other teams. The management team was responsible for communicating these problems to the rest of the team frequently and rapidly. A lot of work went into making this project successful, and at the end of the semester (14 weeks), the team got the Autonomous Vehicle to do a complete lap in the JMU X-Lab (Lakeview) parking lot with no one sitting in or controlling the vehicle.

There are a large number of open problems and extensions to this project left to be explored in future offerings:

- Reverse/parking automation: currently, the vehicles only drive forward which is not realistic in all cases;
- Traffic light detection and enhanced collision navigation where instead of just coming to a stop when an object is detected the AV can maneuver around it legally and safely;
- A manual/autonomous driving mode switch is essential and may help switch to manual driving in case of an emergency or to drive the golf-cart manually. Several hardware modules take more time to react when planning and navigation, optimization for all the scripting running.

Conclusion

James Madison University is an undergraduate teaching university (despite the number of well-established graduate programs around the university). We are working with undergraduate students who are excited, encouraged, but they are also loaded with tons of course load that they need to finish. We plan to solve this limitation by offering the students an independent study course where it is counted toward their electives and having one graduate student who can be a role-model for them to perform well in the project. Our previous experience with the Autonomous Vehicle conversion is an example that it can be done with undergraduate students.

Acknowledgement

This work is funded through Jeffress Trust Awards Program in Interdisciplinary Research (Grant No. 550923). The authors would like to thank the class of Autonomous Vehicle (CS497/ISAT480) Spring 2018. The authors also would like to thank Mr. Nick Swayne, the director of the JMU X-Lab, for his support and help.

References

Dunlap, J. C. (2005). Problem-based learning and self-efficacy: How a capstone course prepares students for a profession. *Educational Technology Research and Development*, *53*(1), 65–83.

El-Tawab, S., Iskandarova, S., Almalag, M., & Ghazizadeh, P. (2018, March). A methodology of teaching mobile development for undergraduate students in project-based classes. *In Society for Information Technology & Teacher Education International Conference* (pp. 749-754). Association for the Advancement of Computing in Education (AACE).

Hartman, W. T., Hansen, A., Vasquez, E., El-Tawab, S., & Altaii, K. (2018, April). Energy monitoring and control using Internet of Things (IoT) system. *In 2018 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 13-18). IEEE.

McCarthy, S., Barnes, A., Holland, K. S., Lewis, E., Ludwig, P., & Swayne, N. (2018, July). Making it: Institutionalizing collaborative innovation in public higher education. In *4th International Conference on Higher Education Advances (HEAD'18)* (pp. 1549-1557). Editorial Universitat Politècnica de València.

Nanney, B. (2004). Student-centered learning. *Retrieved November, 30*, 2012.

Peterson, S. M., Phillips, A., Bacon, S. I., & Machunda, Z. (2011). Teaching evidence-based practice at the bsw level: An effective capstone project. *Journal of Social Work Education*, 47(3), 509– 524.

Pries, K. H., & Quigley, J. M. (2010). *Scrum project management*. CRC press.

Salib, E. H., Erney, J. A., & Schumaker, M. E. (2013). Designed-for-motivation based learning for large multidisciplinary team one semester hands-on network based course case study. *In Proceedings of the 2013 American society for Engineering Education annual conference & exposition*.

Salib, E., Iskandarova, S. & El-Tawab, S. (2019). Effect of Different Instructor(s) on CAMPing. In K. Graziano (Ed.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2019* (pp. 2045-2053). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

Trisdiono, H., Siswandari, S., Suryani, N., & Joyoatmojo, S. (2019). Multidisciplinary Integrated Project-based Learning to Improve Critical Thinking Skills and Collaboration. *International Journal of Learning, Teaching and Educational Research, 18*(1), 16-30.