DEVELOPING A LEADER FOLLOWER SYSTEM FOR A PAIR OF GOLF CARTS IN A GPS DENIED ENVIRONMENT

AN EXPLORATION OF THE INFLUENCES ON THE INTEGRATION OF AUTONOMOUS ROBOTICS AND SENSORS INTO LAW ENFORCEMENT

A Thesis Prospectus
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Bachelor of Science in Mechanical Engineering

By
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Robotics is an actively developing technological field. It started from basic machines that had to be directly controlled by a human, which then advanced to having the option to be controlled remotely using systems, namely internet connectivity, Bluetooth systems, and various radio controllers. With the development of these remotely controlled systems and as increasingly complex directly controlled systems became more widespread in everyday life, there was increased demand for user assistance programs that could do functions such as stabilize systems experiencing momentary remote connection issues, process sensor data and output it in a more immediately understandable form for the user, or perform simple menial tasks for the user (Coetzee & Eksteen, 2011). The current goal of several products, such as the Waymo Driver (https://waymo.com/waymo-driver) or Peloton Technology's PlatoonPro, is to develop those systems so they can function with continuously decreasing amounts of human intervention, eventually leading to fully autonomous functionality (Fisher, 2020). Autonomy is desirable in a variety of fields for countless reasons, but some of the key traits that can describe those fields are tasks that are monotonous or time-consuming, tasks with situations where a human user would be in danger, and tasks where consistency is more important that creativity. This paper will focus on the activities of driving and law enforcement, both of which fit all these categories to various degrees that will be discussed later. The two topics are tightly coupled, both dealing with the development and implementation of robotics and autonomy. The technical portion, working on developing a pair of golf carts into a leader follower system in a GPS denied environment, will be completed with a group of Janani Chander, Sara Khatouri, Zach Kim, Charles Rushton, and Harjot Singh under the supervision of the mechanical engineering graduate student William Smith and the technical advisor of Tomonari Furukawa of the Mechanical and Aerospace Engineering department. They will provide oversite and technical guidance as needed to help the project progress and get access to any reasonable resources that are needed. The STS portion, discussing the influences on how sensors and autonomous robotics are integrated with law enforcement, will be analyzed using the lenses of Actor-Network theory and Pacey's Triangle of Technology, and it will be completed under the advisor Catherine Baritaud of the Science Technology and Society department (Law and Callon, 1988). As shown in Figure 1 below, the STS research portion will be completed over the course of the Fall 2021 and Spring 2022 semesters with the prospectus being completed in Fall 2021, and the rest of the STS research paper will be completed during the Spring 2022 semester. The various steps of the technical portion will be completed over the Fall 2021 and Spring 2022 semesters following the tentative schedule as shown in the Gantt chart.

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
Review of Existing Technologies	■	■	■	■	■																							
Customer Needs/Target Specs						■	■																					
Concept Generation/Selection								■	■	■	■	■																
Component Testing of Cart 788 (Follower)									■	■	■																	
Component Testing of Cart 789 (Leader)											■	■																
System Design												■	■	■														
Develop & Test Autonomous Following in Cart 788															■	■	■	■										
Develop & Test Autonomous Driving in Cart 789																		■	■	■	■							

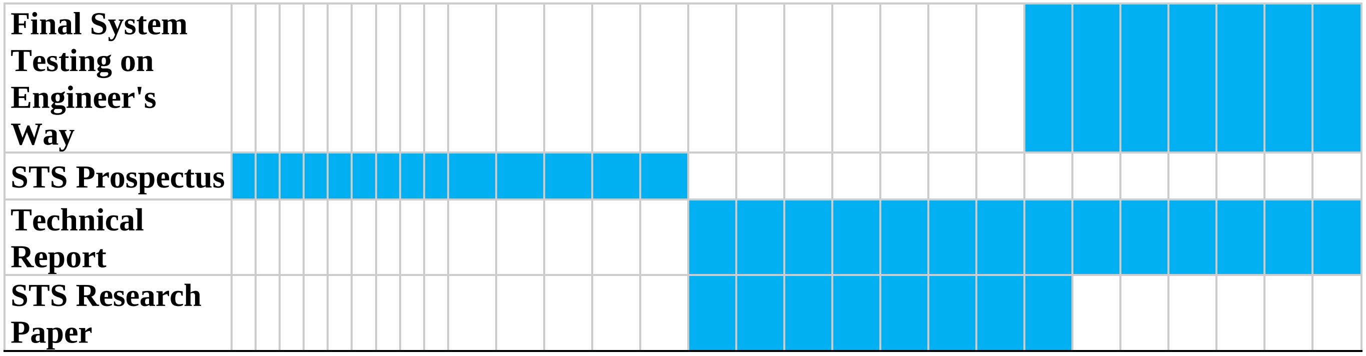

Figure 1. Project Gantt chart. This figure shows a Gantt chart of the tentative schedule for the components of the thesis project. (Created by Gregory Breza (2021)).

DEVELOPING A GOLF CART LEADER FOLLOWER SYSTEM

As mentioned in the introduction, driving fits into all three of the listed characteristics that encourage automation of tasks that are time consuming, potentially dangerous, and require consistency. It is repetitive because most people drive at least twice a day commuting to and from work and it can be monotonous due to having to constantly watch the road. A human user could be at risk from a collision with another vehicle or a pedestrian, although in its current state there is inconclusive data on if automation actually reduces accident risks (Levin, 2021). Creativity is not required for driving because there are a very limited number of possible actions to perform in a car. It is all combinations of braking, accelerating, maintaining speed, and turning. The challenge is creating a program that can sense and understand the variety of potential environments to select the appropriate reaction. To aid in communicating the capabilities of various vehicles, SAE International (2021) defined a set of industry standards for automation in driving with levels from zero to five. A level zero car is entirely under human control with only notification and warning systems, while a level five car would be able to function entirely autonomously under any circumstances. An important milestone in the process is the transition from level two to level three. It is the point where the programs shift from driver assistance features to being autonomously controlled under various restricted conditions or limited functionality.

One technique that is being developed on the path to making vehicles fully autonomous is creating a leader follower system or platooning. A leader follower system has a leader vehicle which is entirely human operated and at least one follower which is automated. It has been implemented for long distance trucking where the leader and the follower will temporarily link up while they are on the same path allowing the follower's driver to rest for a period. Platooning also reduces the amount of gasoline used because the vehicles maintain a closer following distance than usual, which reduces the drag force for the following vehicles. When it is implemented in more common vehicles, it could also reduce traffic jams on highways and other streets where pedestrian crossings are not a major concern (Fernandes & Nunes, 2010).

Most current attempts at autonomous vehicles make use of GPS data in combination with sensor data. There has been research into platooning while one of the vehicles is being denied GPS data or provided incorrect GPS data, but that project assumed that there would be multiple other vehicles in the platoon with access to accurate GPS data instead of there being no reliable GPS data due to reasons such as the surrounding landscape (Hashemi & Johansson, 2020). This project will be working on creating a leader follower system in a GPS denied environment. It is currently planned to combine LIDAR and stereo camera data on each car to create a map of the surrounding environment and have the carts communicate their current location and motion as well as their planned actions.

The technical portion of the project has access to UVA's Virginia Cooperative Autonomous Robotics (VICTOR) Lab with the ability to use its workshop tools, spare parts, and pair of 3D printers. It also is using two golf carts, cart 788 and cart 789. Both carts have been modified by previous projects. Figures 2 and 3 on the next page show the electrical diagrams of the two carts. Cart 788 already has stereo and LIDAR sensors installed as well as modifications to allow for remote operation of individual components. There are systems in place that can measure and modify the braking, steering, and accelerating system from an on-board computer, but they cannot currently be controlled simultaneously. The electrical control modifications on cart 789 are in a less ideal state, so most will need to be changed, but it already has a linear actuator and acceleration encoder that could be useful for controlling and monitoring the brake and acceleration systems respectively. It also has Stereo and IR cameras installed. The primary goal of the project is to create a leader follower system from the two carts. In the process of completing the project, the major milestones will be to combine the various cameras' sensor data into a map, reconfigure the control mechanisms for the systems, and communicate the desired information between the carts. The project results will be written up as a scholarly article.

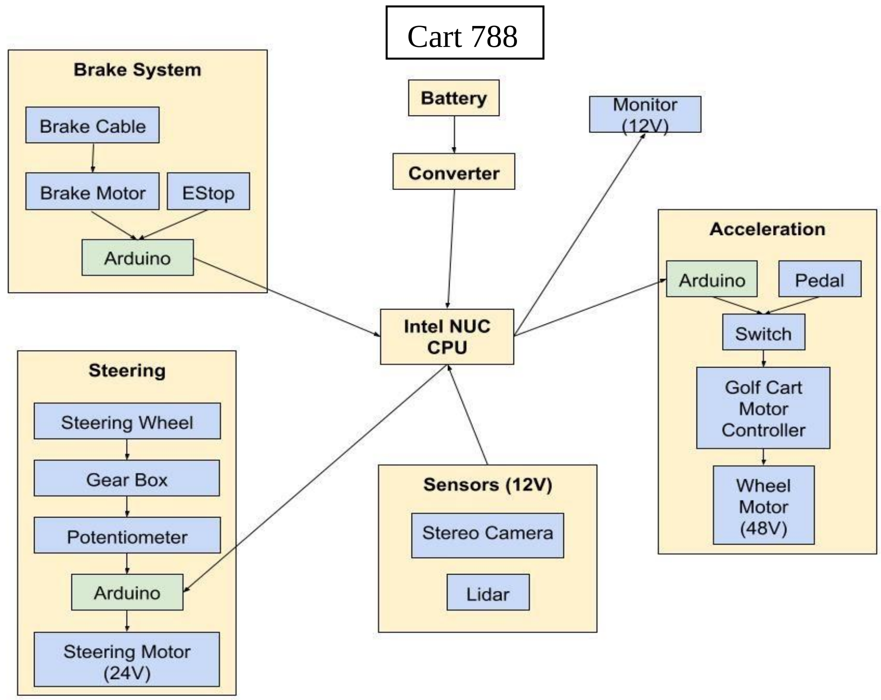

Figure 2. System diagram of Cart 788. This figure breaks down the major components that currently exist on the 788 cart. (Created by Gregory Breza (2021)).

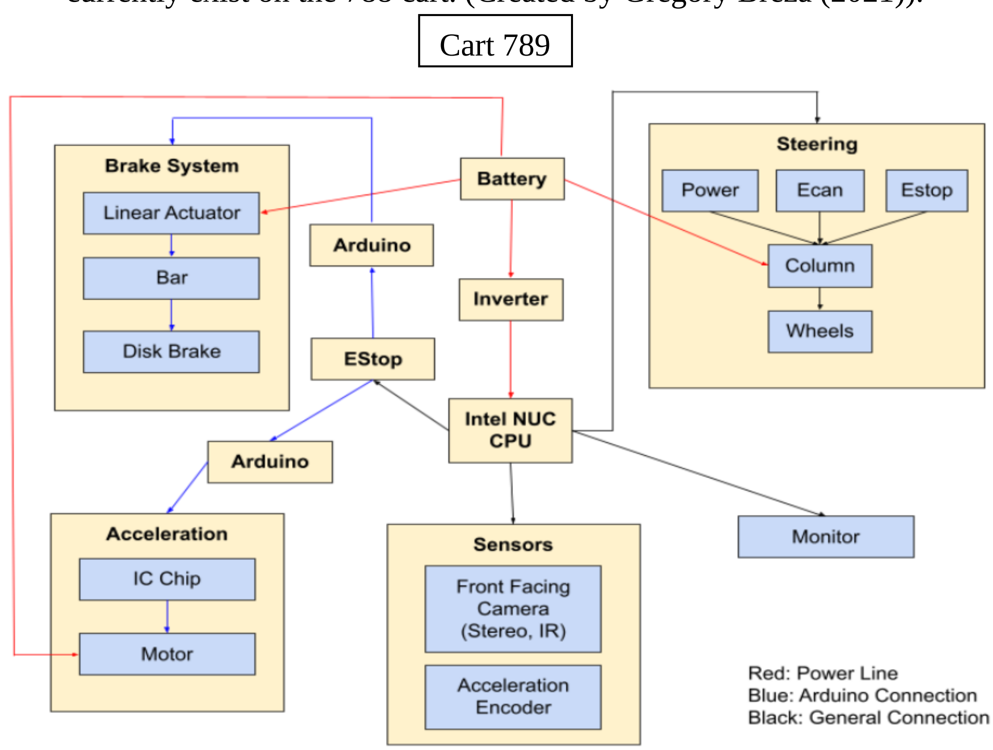

Figure 3. System diagram of cart 789. This figure breaks down the major components that currently exist on the 789 cart. (Created by Gregory Breza (2021)).

INTEGRATION OF ROBOTICS AND SENSORS INTO LAW ENFORCEMENT

Robotics and sensor technology have expanded into the consumer market over the past several years in a move from businesses aiming to provide users with maximum satisfaction using minimal active management from said user. This has led to a rapid increase in the diversity and specialization of devices under those technological umbrellas. Due to the rapid development and the ease of integration into existing systems, there has been a lag in legislature handling certain aspects of how robotics and sensors can be used (Joh, 2018). One of the major industries that has been an early adopter to make use of this legislative gap is law enforcement. The integration of these technologies into law enforcement makes more sense when it is considered in context of the three key properties that encourage automation mentioned earlier, which to briefly review were tasks that are time consuming, potentially dangerous, and require consistency. Police officers frequently spend a large portion of their shift on patrols and occasionally go on stakeouts, both of which involve long periods with little active work. In the moments where their work is active, it can involve confronting violent criminals, which can escalate to violence. Finally, consistency is a goal of law enforcement because ideally everyone should be treated equally under the law.

On paper, everything about introducing robots and sensors to policing seems entirely beneficial. In practice, it is less clear cut because as shown in Figure 4 on page 9, there is more to law enforcement than the new technology being used by the police forces. Figure 4 uses a Pacey's Triangle of Technology model, which is a model designed to expand beyond a more limited definition of a technology of only mentioning the scientific and engineering principles behind something by also including the cultural and organizational aspects and influences on the technology (Pacey, 1985). On that base technical level, there is the development of technologies that could be used in law enforcement like robotics, sensors, predictive algorithms, and facial recognition software. On the organizational level, there is the legislative gap, especially in context of the fourth amendment considering what is private or publicly available information when evidence is no longer physically collected by a person. There is also a complication from businesses trying to maintain their proprietary products, so some court cases do not have access to how all the decisions were made or information was gathered when privately developed algorithms were used (Joh, 2019). On the cultural level, there is the ideal of everyone being treated equally under the law, contrasting with the reality of biases like racism and sexism being in present law enforcement (United Nations, 1948). There is also the concept of Big Brother, or surveillance states, where citizens are under constant surveillance by governmental organizations. In Foucault (1975), the concept of a surveillance state was explored with the theoretical prison of a panopticon where all the prison cells could be observed from a central watchtower, but the prisoners cannot see where the guard is watching. It is effective at making the prisoner regulate themselves, but that regulation is based on a fear of punishment instead of a desire to do the right thing.

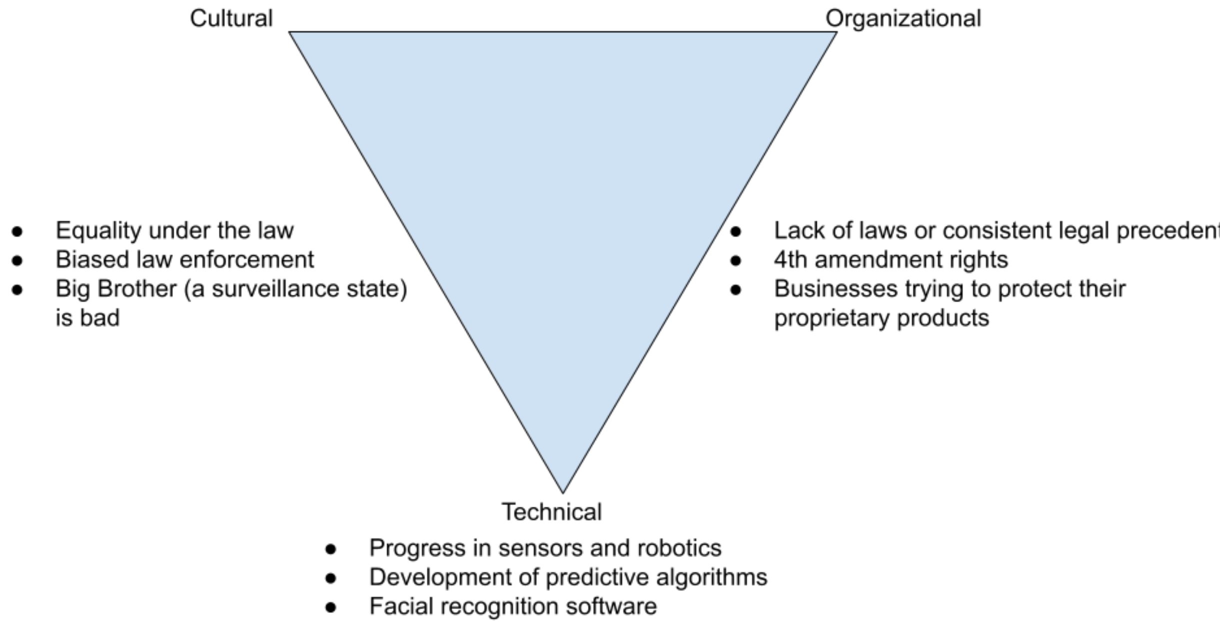

Figure 4. Technology in Law Enforcement. This figure uses Pacey's Triangle to show the variety of influences on technology use in law enforcement. (Created by Gregory Breza (2021)).

There is currently disagreement between experts on how these technologies should be applied to law enforcement and to what extent the government should set those limits that should be consolidated. Abylkasymova & Szocik (2021) sees integrating those technologies as a net positive by improving the abilities of police officers, while removing human emotions that could bias decisions from the problem. Hartzog et al. (2015) offers an alternative perspective that some inefficiency and leniency are necessary in law enforcement to maintain a functional society because laws were written with human police officers in mind, and likelyhood that a crime would get caught considered when setting the fine. Joh (2019) discusses a more negative perspective on continuing to integrate technology into policing. It mentions the effects of biases on data input into predictive algorithms creating a feedback loop because officers will be sent to those locations more often leading to more arrests, likely causing the algorithm to then allocate more officers to patrol that area. It also discusses the potential for more privatizaton of law enforcement. As private companies develop the technology that police forces use, it could lead to those companies providing trained experts in using that technology which replace parts of the current police force. One thing that is lacking from many of these articles' consideration is an analysis of the current influences promoting the integration of robotics and sensors in some areas and preventing it in others, and how those could go on to affect the more widespread outcomes in the future.

These influences that lead to the technology being integrated or not will be discussed from the perspective of actor-network theory (ANT). ANT is useful because it views all influences on the network equally by modeling the system as a web of relationships with each actor having an equal weight inside it, and actors being anything that is involved from people to ideas and objects (Law and Callon, 1988). It will hopefully show that this balance of negative and positive influences will moderate each other, leading to a result that mitagates some of the downsides of integrating technology into law enforcement without the severity of needing to harshly restrict their use through legislature. The STS Research Project will be written as a scholarly article considering the actors that influence technological adoption in law enforcment. Figure 5 shows an example of a simple theoretical network that could be discussed in the paper.

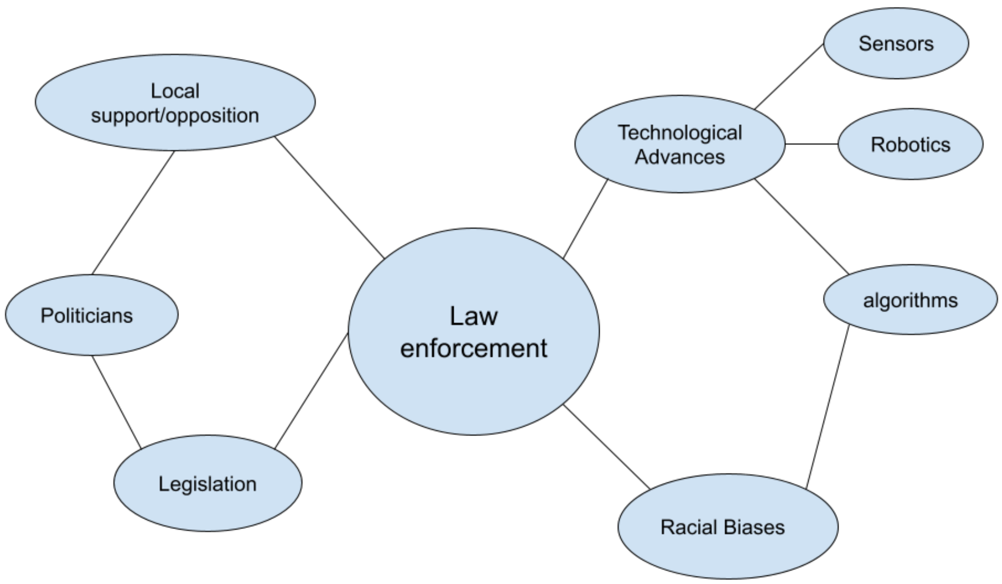

Figure 5. Network of Influences on Law Enforecment. It shows a theoretical network of actors that influence the adoption or rejection of technology in law enforcement. (Created by Gregory Breza (2021)).

Final Remarks

Automation is a quickly growing field that needs to be nurtured and cultivated to keep it going in a direction that influences society for the better. An important step in that process is improving the uses for the base technologies. A more important aspect is understanding what makes certain devices using those technologies flourish more than others, so useful inventions are not lost and harmful products are not incidentally supported. The technical portion of this project will be design and constructing a leader follower system from a pair of golf carts. The STS research portion of this project will be breaking down the actors that influence the integration of sensors and autonomous robotics into law enforcement.

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