DEVELOPMENT OF AN AUTONOMOUS PLATOONING CAMPUS VEHICLE TRANSPORTATION SYSTEM

THE IMPLICATIONS OF CRUISE SELF-DRIVING CARS ON SAN FRANCISCO

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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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INTRODUCTION

Autonomous vehicles are gaining traction in today's society, with more and more manufacturers developing autonomous technology. In 2022, driver-assistance systems and autonomous technology created between $40 billion to $55 billion in revenue, with an expected uptick to $300 billion to $400 billion in revenue by 2035 (McKinsey & Company, 2023). With the growth of autonomous vehicle technology, it is important to understand the implications of this advanced technology on environments it is placed into. This can help to create a better future living with autonomous vehicles (AVs).

My technical team will work to continue the development of an autonomous campus vehicle system to transport students and faculty from the Observatory Mountain Engineering Research Facility (OMERF) laboratory to Engineer's Way on the University of Virginia Grounds. This transportation system consists of two modified golf carts: a lead cart and a fully-autonomous follower cart, connected through platooning. We will develop these autonomous vehicles with features to create a more safe and accessible transportation alternative for users. However, it is important to consider potential harm that could come from implementing autonomous vehicle technology. According to the National Highway Traffic Safety Administration, cars equipped with automated driving systems were involved in 168 reported crashes in 2022 (NHTSA, 2023). In order to mitigate the negative impacts this technology will have on society, I will observe a specific instance in which autonomous vehicle technology has been implemented into one community.

I will conduct research to examine one case study: Cruise self-driving ride-sharing vehicles impact on the San Francisco community and the state of California as a whole, where applicable. I will observe the reasons for use, intended and unintended consequences of adoption, and ultimately draw conclusions of whether autonomous vehicles are ready to be implemented in societies. Pointedly, what have the effects of Cruise self-driving cars been on the San Francisco community? I want to consider this question because examining this specific scenario with autonomous vehicles as the focal point may guide the future development of this technology to be safer and more regulated, or if this technology is safe enough to use at all. I will research this case study with the goal to determine the source of adverse effects, and to determine what can be done to minimize the negative consequences imposed on society by autonomous vehicles. My research from this topic will affect the choices made by my team in the development of our autonomous campus vehicle system as both Cruise self-driving cars and the developing campus vehicle system are autonomous transportation systems. Therefore, my conclusions drawn from my STS research will impact design choices made in my technical project.

Within this report, I will discuss specific details of my technical project and my research project, followed by research strategies that I will use in this investigation.

DEVELOPMENT OF AN AUTONOMOUS PLATOONING CAMPUS VEHICLE TRANSPORTATION SYSTEM

My technical team will work on the continuous development of an autonomous campus vehicle system, in an attempt to continue past team efforts of platooning a fully-autonomous cart behind a manually-driven lead cart. We will improve this transportation system with the goal of providing an alternative mode of transportation from OMERF to Engineer's Way on UVA's Grounds.

Platooning is when multiple cars can travel closely to each other through communication. According to the U.S. Department of Transportation, "platoon formations improve travel time, increase lane capacity, and reduce congestion—which means we spend less time sitting in traffic, less money adding new lanes, and less money buying fuel," (2017). In the campus vehicle system my team is developing at the University of Virginia, the current platooning algorithm from past team efforts effectively observes the actions of the lead car in the system, and sends this signal to the following car in order to directly copy its actions. The systems that communicate this information include the steering, braking, and acceleration systems. I will discuss each of these systems and their necessary components below.

The main component of the steering systems on both of the cars is the Nexteer Electric Power Steering System (EPS). This system includes an absolute encoder, an internal servo motor, a computer for communication between these two, allowing for the positioning of the steering wheel on the lead cart to be measured. This data is then sent to the following cart through CAN communication, which is then copied by the second cart. The EPS is powered off of 12V, and allows for the steering in the following cart to be controlled completely digitally. As this system has worked in the past, my team plans to keep this general system to control the steering of the carts, only making modifications and improvements where needed.

Another important actuation system for the safe operation of these vehicles is the braking system. The brakes on the following cart are controlled by a cable in tension, passing through a pulley and attached to the ClearPath MC servo motor. This servo motor takes one of four determined positions given specific braking data: no brake, light brake, heavy brake, and full brake. This allows the following cart to stop whenever the lead cart does, preventing collisions between the two without a manual driver in the following cart.

In terms of acceleration, the lead cart operates as designed with a manual acceleration pedal. The velocity of the lead cart is then relayed to the following cart, which copies the signal and actuates this velocity through a digital potentiometer (digipot). The digipot is used to adjust the velocity of the cart digitally to match that of the lead cart, allowing for the follower cart to be fully autonomous.

While previous teams have developed these systems and code to make this copying platooning algorithm work, the carts currently cannot travel far due to the fact that the algorithm does not consider the relative positioning of the carts. In order to solve this important issue, my team will implement a new platooning algorithm over the course of the Fall and Spring semesters, which probabilistically determines the optimal path for the following cart to take based on the calculated instantaneous radius of curvature of both carts. In order to implement this new algorithm, we will need to make additional modifications to both carts. The most important of these necessary improvements is the need for additional sensors to obtain visual information on the relative positioning of the carts with respect to their surroundings. This will be the focus of my team: improving the systems already implemented on both carts to obtain necessary measurements for the use of a new platooning algorithm. This new algorithm is important as it will allow for the transportation of greater distances and increased accessibility for both students and faculty, which is one of our overall goals of this project.

THE IMPLICATIONS OF CRUISE SELF-DRIVING CARS ON SAN FRANCISCO

For this research project, I will be exploring how Cruise self-driving ride-sharing cars have impacted San Francisco to look into the overall safety of autonomous vehicles. Specifically, what have the effects of Cruise self-driving cars been on the San Francisco community? As one case of AV integration into society, my research topic is important to investigate as an example of large-scale usage of autonomous vehicles, and I will be able to draw conclusions about the future of autonomous vehicle technology from this specific case. I will conduct this research with the goal of being able to decrease the amount of negative consequences through AV development and adoption, as well as evaluate whether or not this technology is safe enough to be used in its current stage of development.

I must consider those who are affected by the integration of Cruise self-driving vehicles, particularly the people of San Francisco. Particularly, I want to look into those interacting with and those developing this technology. This includes users/passengers of Cruise self-driving cars, people involved in accidents as pedestrians, other drivers on the road, and Cruise as a company. My research into Cruise will include discussions of their business models and statements released to the public. I will include these groups in my research because it is essential to look at both how these vehicles are being developed as well as how they are affecting roads and responding to certain situations with user groups. An additional group of people that are important for consideration are people with disabilities. While autonomous driving can be liberating for people with disabilities, they will be excluded from my research as Cruise has only just started to develop accessible vehicles, which have not been put out onto the roads for use yet (Saab and coauthors, 2023).

The focus of my research will be on the specific case study of Cruise self-driving cars in San Francisco. However, I will supplement my findings with additional research into causes for complications in San Francisco, surrounding an ethical discussion of the development of AVs. I will research the choices made when designing autonomous vehicles, and how this technology can have intended and unintended biases from developers. This will include a discussion of the politics related to the development of autonomous vehicles, as described in Langdon Winner's *Do Artifacts Have Politics?* (Winner, 1980), as well as the ethical decision-making this technology encounters, discussed in Noah J. Goodall's *Machine Ethics and Automated Vehicles* (Goodall, 2014).

In her book *Engineering Ethics: Contemporary and Enduring Debates*, Deborah G. Johnson discusses how "it is essential to think of autonomous cars as systems themselves and as systems embedded in broader sociotechnical systems," (Johnson, 2020, p. 148). Because autonomous vehicles are greater than just their internal technology and in turn affect specific groups of people, I will consider relationships between this technology and other external factors in my research. Consequently, I will be using an Actor-Network Theory framework to conduct my research. Sergio Sismondo notes Actor-Network Theory as "a general social theory centered on technoscience" that represents "technoscience as the creation of larger and stronger networks," (Sismondo, 2010, p. 81), and therefore, this will be an effective framework for my research. I will explore how different actors create networks through their interactions with each other. As stated previously, my chosen method of research will be to observe one specific case study. Specifically, I will look into the relationships between Cruise autonomous vehicles, Cruise as a company, and varying interacting groups (users, pedestrians, other drivers). I am including multiple actors in my research because AV technology will have a relationship with the developing company as well as all other consumer groups it may intentionally or unintentionally impact.

I will conduct my proposed research primarily over the course of the current semester, with my technical project being the focus of next semester.

KEY TEXTS

- Deborah G. Johnson, *Engineering Ethics: Contemporary and Enduring Debates, Chapter 7: Will Autonomous Cars Ever Be Safe Enough?*

  Deborah Johnson discusses the safety issues regarding the implementation of autonomous vehicles into society. Additionally, regulation of AVs, or lack thereof, is briefly touched upon, which is important to the environments in which autonomous vehicles are placed into to determine the safety of this technology. Johnson also considers the ethical design that must go into the development of autonomous vehicles, which is an ongoing debate and can lead to safety and trust of this technology. All of these factors are essential to the safe development of AV technology, and should be looked into for any autonomous vehicles that are implemented in today's society to ensure the safe operation of the technology. Finally, Johnson discusses the scenario in which it is decided that fully autonomous vehicles will never be safe enough for complete use in society, which is not a total waste of effort as helpful assistive technologies developed in this process can still lead to reduced accidents on the road.

- Noah J. Goodall, *Road Vehicle Automation: Machine Ethics and Automated Vehicles*

  In this chapter, Goodall explores the ethical decision-making autonomous vehicles are programmed with in situations where a crash or collision is unavoidable. Goodall responds to criticism against the importance of machine ethics research, while highlighting that programmable ethics into autonomous vehicles is unavoidable and necessary. However, this leads to many questions of how humans weigh risk in driving scenarios and how to implement this into the technology as ethical decision-making. This piece discusses the importance of research in moral behavior of technologies, whether this be through machine learning algorithms or pre-determined actions based on specific scenarios, which is applicable to AVs when implemented into society, as the development of this technology is flawed and crashes will continue to happen.

- Kylie Kirschner, *Cruise says one of its driverless taxis ran over a woman in San Francisco after a hit-and-run driver 'launched' her into the car's path*

  In this news report, Kirschner describes an incident in which a Cruise self-driving vehicle was involved in a pedestrian crash, as well as enumerates other instances in which Cruise vehicles have been seen to have complications. Ultimately, this led to the suspension of these vehicles as described in Michael Liedtke's *California regulators suspend recently approved San Francisco robotaxi service for safety reasons* (Liedtke, 2023). This is important to investigate the safety concerns with this emerging technology as well as look at the result of multiple instances of Cruise autonomous vehicle complications: suspension of these vehicles by the California DMV, ultimately impacting the San Francisco community.

- Rachel Gordon, *Explained: Levels of autonomy in self-driving cars*

  Gordon gives a brief overview of the six levels of autonomy that can be present in current technology. This includes anywhere from no autonomy (fully manual control) all the way to full automation. These categorizations are important to consider as statistics of crashes and current safety features in vehicles today are dependent on the level of autonomy present, with the lower levels of autonomy being more popular and well developed. More research needs to be done into the regulation of level 4 (high driving automation) and level 5 (full automation) autonomous vehicles and how this technology will be regulated. This technical information is important to understand when looking into autonomous technology used in society today, such as Cruise's level 4 self-driving vehicles in San Francisco, to understand the level of safety that is currently achievable with each level of autonomy, and whether or not higher levels of autonomy will ever be "safe enough" to implement into society.

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