Autonomous Platooning Golf Cart for Short Distance Campus Travel

(Technical Paper)

Autonomous Vehicles and The Social Construction of Safe Roads

(STS Paper)

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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

The integration of self-driving cars into society is still in its infancy, but recent technological advances show their potential to reshape transportation. Transitioning from traditional human controlled automobiles to self driving autonomous vehicles (AV's) can be beneficial in a multitude of ways. Convenience, mobility, as well as economic and social improvements are just a few of the benefits that fully functioning AV's can potentially provide. However, technological, societal, and economic costs must be considered when dealing with a device as potentially world changing as a self driving car. Whether or not these benefits outweigh the cost of development will determine the success of AV's in society.

The goal of the technical project is to locate some of the specific costs associated with AV development, and to create a solution that will provide insight for large scale AV integration. The development of an autonomous golf cart transportation system will help provide information on the associated economic and technological costs involved with building a working AV system. The short distance vehicle would allow users to ride to and from a predetermined list of destinations and help users reach out of the way locations such as the VICTOR lab at the University of Virginia (UVA). By implementing the vehicle on UVA's grounds, social issues can be observed through how the vehicle is received by members of the community.

Currently autonomous vehicle development is driven by the desire for safety and mitigation of vehicular accidents. By looking at the issues with AV development through the framework of Social Construction of Technology, it is evident that there are many problems with integrating AVs into society and there are many stakeholders contending over its development. These issues and their potential solutions must be understood to help realize how society will shape and transform the notion of creating a "safer driving world."

Technical Topic

Interest in automated vehicles has peaked in recent years due to their potential for reducing accidents and harm to the environment (Precedence Research, 2020). With the bulk of research in the AV sector focusing on complicated automobiles, investigating simpler model systems can flesh out problems that could otherwise be hard to diagnose. A number of smaller systems have been innovated and made autonomous such as drones, vacuum cleaners, and even food delivery robots. These robots however are not well represented model systems of a standard AV, since they do not use all of the same essential components (sensors, mapping capabilities, etc). These essential components require more analysis and what the technical project will be focusing on developing as part of a golf cart model system.

At present, UVA's VICTOR Lab has a partially working autonomous golf cart managed by Tomonari Furukawa, who is the team's advisor and sponsor. This capstone project has gone through many iterations, and has followed Professor Furukawa from Virginia Tech to UVA. Detailed presentations and results from previous teams have been provided so our project will build upon these past works. Two major design iterations have been attempted but were left incomplete. The first was to have a single golf cart be fully autonomous and drive on its own. The second was to have a system of autonomous golf carts that follows in the path of a lead cart driven by a person. The technical goal of the capstone project is to fuse these two designs and develop a system with an autonomous leading cart and another cart autonomously following behind.

As of now, the first golf cart has all the parts required to be autonomous, but do not work in conjunction with each other. The second cart has had a new steering column installed, but otherwise very limited work has been done on it. The second will serve as the follower cart and is aimed to be completed by the end of the Fall semester, while the first will be the leader cart and repaired by the end of the Spring semester. We will start with the follower because it is less complex, and will teach us how to work with important subsystems that the leader also requires. We intend for our final autonomous golf cart system to be implemented on grounds to allow students to reach farther buildings in a safe and more sustainable way.

Our team is currently wrapping up the research process and beginning hands-on testing. Looking at past teams' work we have identified strengths and weaknesses of their designs, and begun to plan how to refine and integrate the two major designs. We have reviewed the market for products with systems and primary functions similar to ours. Work done by Waymo and Peloton have provided us with ideas on how to create autonomous driving and autonomous following vehicles respectively (Waymo, 2019; Roberts, 2019). By interviewing potential customers and project managers, we have identified primary and secondary customer needs for what users want in an autonomous campus vehicle. Emergency stop buttons and vehicle decision transparency are some of the features that we found essential in our discussions. Overall these steps have provided a groundwork and a better understanding on how to progress with the project.

For the follower system, beacons (LEDs or other markers) will be attached to the leader, and an IR camera onto the follower to help sense the leader's movements. In addition, the follower will be installed with a new drive by wire system, which is when the acceleration, braking, and steering subsystems are controlled electrically instead of mechanically from a central computer system (Fuller, 2009). Performance criteria including accurate following of the leader, working subsystems, and safety (safe following distance, detecting dangers) will be used to determine the success of our vehicle. For the leader, the same subsystems will need to be repaired, in addition to the previously installed LIDAR and stereo sensors for environment mapping and danger detection. The heads up display and emergency stop features will also be tested to increase safety and reduce potential fear. My personal responsibilities will include building the cart as well as focusing on the electronic and coding aspect of the project. We also plan to heavily use the expertise of our graduate teaching assistant, Billy Smith, who worked on the golf cart last year.

Our autonomous golf cart system aims to provide a unique short distance transportation alternative for those around grounds. If our system can be proven to work consistently, it can serve as a basis for analysis on the costs of AV development, and a model on how to implement AV's onto a larger scale.

STS Prospectus

A fully autonomous vehicle future has continued to make strides as more money is flowing into the industry following developments in potential accident reduction. According to the United States Department of Transportation (DOT) the 94% of serious accidents in 2017 involved driver-related factors (National Highway Traffic Safety Administration, 2018). Later in 2019 the DOT announced $60 million in grants to test safe AV integration on national roads to gather safety data that AV's can provide (U.S. Department of Transportation, 2019). Many other stakeholders are involved in the rise of AV's, and negotiations between these different groups are shaping current AV development. This paper will outline and analyze the issues related to the push for an increase in autonomous vehicles made by the DOT and what it means to have "safe roads" using the framework of Social Construction of Technology (SCOT).

Social Construction of Technology in Automobile Development

SCOT as defined by Pinch and Bijker (Pinch & Bijker, 1984) argues that technology is "embedded in a social context" and that relevant social groups perceive artifacts in different ways that can either support or renounce innovation. These differing perceptions of artifacts lead to conflict between the relevant social groups. It is important to analyze these conflicts and identify each side's perspective as it allows for connections to be made to the design features of the technological artifacts.

Social construction of technology has been a part of the American automobile industry from the very beginning. The first cars were unreliable, expensive, and perceived as dangerous which led to a lack of success compared to the popular bicycle and horse. Through his desire to develop a cheaper alternative, Henry Ford redesigned the manufacturing process using interchangeable parts to keep cars cheap, reliable, and production prices low (Onion et al., 2010). The roads which were once quietly run by bicycles and pedestrians, quickly became violently controlled by the new automobile (Smithsonian, 2019). To make areas better for automobiles, lobbyists called for restructuring of entire cities and roads to accommodate them (Ladd, 2008). With the physical restructuring of cities came a social restructuring as new interactions formed between automobiles and pedestrians. The way lobbyists and companies pressed for such large changes was by presenting the automobile as part of a "perfect future, delivered by their latest technology" (Zipper, 2021). Current AV integration methods are also utilizing these methods by illustrating AV's as part of a more "perfect world" with "safer roads".

AV's For Safer Roads?

One of the many definitions of what a "safe road" is could be interpreted as the elimination of any severe incident involving a vehicle. The Vision Zero project uses this definition to guide their goals to ideally reform the road system and related policies to account for human error which could both prevent and eliminate incidents (Vision Zero, n.d.). They seek to "prioritize traffic safety as a public health issue" by integrating traffic planners, engineers, policymakers, and public health professionals in the process of infrastructure reformation (Vanterpool, 2019). Others say that the problem is that there are too many cars on the road which leads to higher chances of accidents. This notion is supported by England's implementation of a congestion tax which has led to fewer vehicles on the road, and shown that a 1% reduction in vehicle miles traveled generally results in a 1% drop in crashes (Wilson, 2020). There are also those that believe that the amount of cars on the road is not the issue, but rather the actors who use the roads. They believe that cars need to become smarter and make up for what humans lack without the need to reform most of the current system.

AV's are imagined to be one of the solutions to help create "safer roads" by making cars adapt to situations instead of humans. AV manufacturers are proposing an abundance of benefits and solutions to problems in the world today from a fully functioning AV. A major proposed benefit is the reduction of human error and thus accidents by using an onboard system that plans every movement the vehicle makes. Using vehicle to vehicle (V2V) communication AV's can also change routes in real time to quickly optimize fuel efficiency and time spent on the road. Since AV's are primarily electrically powered they will also mitigate some of the issues regarding pollution from standard automobiles (Robinson, 2017).

With the increase in funding for AV research, the DOT seems to view the development of AV's as a potential solution to the notion of "safer roads." However, the DOT and NHTSA set strict design guidelines that AV’s must follow to be approved for road use. The NHTSA lays out these guidelines for partial driving automation (L2) and conditional driving automation (L3) vehicles (Campbell et al., 2018). L2 automation is the only level legally allowed on US roads as the driver is required to supervise and be ready to take control of the vehicle at all times. NHTSA guidelines are split up into five categories: general design, message characteristics, driver input, visual, auditory, and haptic interfaces. The general design category highlights the need for L2 vehicles to have the ability to signal the transition between automation and user control to help the user maintain focus. A main reference for this need was highlighted by the success of General Motors HAVEit project which used detection algorithms to determine driver status and use of signals to regain driver attention (Salinger, nd). The message category highlights the need for effective forms of communication to drivers that are easy to interpret and can result in quick action. NHTSA references the CityMobil project recommendation to limit auditory messages to 3 or 4 information units, and messages requiring immediate reaction be as short as possible (Toffetti et al, 2009). Driver input is a broad category that NHTSA narrows to focus on control placement and interaction between an interface system. Based on similar restrictions set by the European Union, controls can be placed anywhere as long as they do not affect user ability to drive, and all interfaces should be interacible while keeping one hand on the wheel (Official Journal of the European Union, 2008). The final sections regarding visual, auditory, and haptic interfaces discuss proper placement of such systems to aid in driving and user engagement. For the most urgent messages, NHTSA cites sensory research and recommends that a combination of visual, auditory, and haptic devices are used to ensure messages get received (Hecht & Reiner, 2009).

Future Research

With government regulations set by the NHTSA on AV safety and design, there has been significant pushback by companies and engineers to loosen restrictions. The characteristics that define safety in AVs are complicated and will be what this paper continues to develop. Future work will involve analyzing the pushback made by AV companies. Interestingly companies whose work originally helped create requirements for AV's are now pushing back against those requirements. In 2018, GM made a request for a two-year temporary waiver on features like mirrors, dashboard warning lights and turn signals (Shepardson, 2019). This type of data will be the focal point of future work as it will showcase the interactions between the two main social groups on how AV technology will develop "safer roads".

A discussion of how AV's will integrate into society will also be included. Similar to the first automobiles, what parts of society will have to change in order to make AV's successful. Will roads have to be restructured again? How will laws have to change to accommodate accidents and things of that nature?

Next Steps

Capstone

- Finalizing concept generation and selection on possible solutions for the system by the end of October/very early November.
- Order parts to be installed.
    - IR Distance sensor
    - Drive by wire components
- Showcase theoretical full system design.
- Finish follower cart system by end of semester (End of November 2021)
    - Drive by wire
    - Following capabilities using IR sensor and potentially LEDs
- Finish leader cart by end of school year (April 2022)
    - Fusing sensor mapping data.

    - Object detection.
    - Drive by wire.
    - Accurate environmental mapping software.
    - Real world testing.

STS Paper (Throughout Next Semester)

- Research more about government regulations
- Find more about development of AV’s through what companies struggle with.
- Want to see more about the socio technical development
    - How companies push back against government regulations
    - What incidents has led to the regulations being set up in the first place
        - Uber test car killed someone
    - How testing has disrupted society in some places.
        - Waymo, Uber, Ouster, and major car companies.
        - Government head of AV development v.s. Uber
    - Find more relevant social groups beyond car manufacturing companies and the government.
- Bridge more about what safe roads are with AV’s into writing

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