**Self-Driving Golf Cart as a Mode of Public Transportation**

(Technical Paper)

**Analyzing Case Studies of Transitioning from Human-Driving to Self-Driving Vehicles**

(STS Paper)

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## Introduction

The transition from the traditional way of driving into the realm of self-driving vehicles offers significant potential perks in many ways. It is acknowledged that autonomous vehicles (will be abbreviated as "AV's") have both economic and societal benefits. In 2015, there were more than 35,000 highway fatalities on United States' roadways, with 95 percent having involved at least an element human driver error (Husch & Teigen, 2017). One of the main goals of autonomous vehicle technology is to eradicate as much human error as possible in hopes to reduce said overall fatality rates. However, as the new technology continues to improve and develop, concerns regarding their safety and their unintended consequences arise. In order to maximize those benefits while simultaneously minimizing consequences, strategic legislation, on both the state and federal levels, has been put into place (Taeihagh & Lim, 2017). For example, the National Highway Traffic Safety Administration (NHTSA) provided a roadmap for states wanting to eventually deploy AV's, rather than declaring one institution to be the overall lead regulator (Husch & Teigen, 2017). This would provide sovereignty among the states as well as difference of opinions towards AV's by the public to be expressed and heard on a wide range of levels.

Conversely, the technical project gives the capstone team two benefits: the ability to explore the features and their implementation that allow autonomy, and also allows team members to acquire firsthand experience and wisdom on the impact that autonomous technology has on stakeholders and vice versa. The team is tasked with adding and modifying features to two golf carts so that it is capable of travelling safely along the University of Virginia's Engineering Way, while also picking up and dropping off passengers. As a result, from a cumulation of past endeavors from previous capstone teams, the golf carts currently have essential autonomous features already in place that can feasibly be built upon. Conversely, the cart has unreliable object detection at high speeds, performs poorly in inclement weather, and has difficulty responding to varying human traffic conditions (i.e., pedestrians). The golf carts will be improved upon by adding automated passenger detection, pickup and drop-off at certain points along a route, as well as object detection/avoidance features.

Whether or not these features are successfully implemented, the STS paper seeks to analyze the controversies surrounding the push for AV's becoming the norm. The idea of introducing self-driving cars to public roads has both been sensationalized as well as feared. The main STS framework used will be Social Construction of Technology (SCOT), assisted by the concept of paradigm shifts. Since the STS and technical projects directly overlap each other, the team members are more than likely to empathize and build a unique perspective resemblant that of real-world AV engineers, who have had to make important design decisions directly affected by the differing public opinions of self-driving cars.

**Technical Project**

The team is able to work with 2 golf carts, each serving as a prototype. The carts were initially donated by Club Car to allow students to develop commercialized products and test concepts. Since 2015, the carts have been passed down through generations of senior design project teams. Now, in the 2020-2021 academic year, the starting point for the project is that the carts are able to track and follow each other, forming a "leader - follower" system. While image tracking was successfully developed and implemented to accomplish this, the carts have yet to be programmed and automated to detect humans and act accordingly.

This leads to the primary goal that the team wishes to accomplish for the 2020-2021 academic year – to add human detection, also allowing them to board and disembark safely at specific points along a route, all while operating independently of each other. The route the golf cart has to navigate through is Engineering Way, avoiding moving obstacles (more specifically, humans). The secondary goal is to make improved usage of space and reconfigure components of the system to improve the overall aesthetic of the vehicle. Achieving the primary goal would place the level of autonomy to be level 5 - the highest level of autonomy. Level 5 AV's do not require human attention, which is one of the main motivators for reaching autonomy in general (although, human override will be implemented for this project, as it is necessary). Another main benefit of completing this project is that the autonomous golf carts would showcase a new form of short-distance transportation on the university campus as a successful concept.

Driverless cars require a plethora of key systems and components to achieve autonomy. The following are necessary components used across almost all autonomous vehicles, and consequently are also included in the scope of this project. Image tracking sensors (usually in the form of LiDAR) are used for detecting and acquiring relative distances of objects. Cameras are also used for the same purpose, visualizing surroundings and displaying that to the user. Various processors are used to automate actuators (ex. braking, steering, drive motor activation, etc.), which are powered by Robot Operating Software (ROS) programs. Most ROS algorithms that are needed are already included to assist the team in the process, notably the Image Tracking packages. The last major AV component in the scope of this project is the Human-Machine Interface (HMI). HMI's are used as a median between the technology and user, in this case, the driver. For this project, the HMI currently takes the form of a 17" touchscreen display, mainly to inform the user the location of the other cart, as well as its speed, battery level, and also the status if tracking is turned on/off.

The design process will involve exploring and adding necessary components, testing and optimizing (and ultimately choosing) sensors, and optimizing ROS code for faster autonomy run-time and faster object detection.

**STS Topic**

Introducing AV's to public roadways sparks a vast concern and discussion of safety. While AV's are intended to increase general safety of passengers by uninvolving and minimizing human error, there still exist problems within the autonomous features and their reliability. The goal of the STS Research Paper is to analyze the impact that public outlook has on the development of autonomous vehicles. As mentioned before, the STS framework that the analysis will be based on is Social Construction of Technology (SCOT) theory. SCOT theory will be essential in understanding how this technology was developed in response to different perspectives from different social groups. By definition, SCOT states that rather than technology determining human action, it is human action that shapes technology.

To showcase the applicability of the SCOT theory framework, and to analyze the impact that social institutions/groups had on the development of autonomous vehicles, case studies, showing both the pros and cons of self-driving cars, will be carried out. There are five total case study items chosen. These include: a recent German court ruling that Tesla cannot use the phrase "full potential for autonomous driving" (Beresford, 2020), the Uber self-driving car fatal crash in 2018 (Lee, 2019), an article informing the reader about the harassment of Waymo vans (Randazzo, 2018), a Congressional Research Service (CRS) report on the issues of autonomous vehicle testing and deployment (Congressional Research Service, 2020), and a podcast released by the University of Pennsylvania School of Wharton discussing the pros and cons of self-driving cars (Wharton Business Daily, 2019).

In the first item, in which a German court ruling determined that Tesla's usage of the phrase "full potential for autonomous driving," it was argued that those phrases mislead customers that the vehicles can drive on their own without any human intervention, which is untrue, pressuring Tesla to modify its advertising practices. In the second item, the Uber self-driving car user's lack of attention to the road led to the death of a pedestrian, resulting in an increased transparency of Uber's operations in their development of autonomous technology, and how they research human behavior when on the road. In the third item, the main subject at hand is that of Waymo van's aesthetic and appearance having been humiliated by the public on and off the road, leading to design changes. In the fourth item, it can be observed that a recently released CRS report directly led to modifications in research and development practices for companies deploying autonomous vehicles. In the last item, being a podcast, the listeners receive insight from an AV engineer on the topic of how society's sensitive outlook and reaction to AV's being the new normal on roads can impact the future of the technology. Various examples of predicted human reaction to AV's are discussed within the podcast. These if-cases include: actively replacing public transportation with AV's, reducing the number of pedestrians, the human desire to have AV's do specific tasks without being physically present the whole trip (ex. grocery shopping, delivering food, dropping humans to and from work without staying at their workplace's parking lot, etc.), and as well as the desire for society to own a lesser number of personal cars, encouraging the reusing and recycling of land use. The theme of SCOT is present in all of these items, ultimately arguing that the theory holds true in the relationship between society and technology.

**Research Question and Methods**

The research question proposed is to discern the extent in which autonomous vehicles can be a truly viable, and safe, replacement of traditional vehicles. Using the five case studies as examples, it can be contextualized how predominant the technology already is in the field. This calls for the application of an STS idea that is a paradigm shift, the idea that, in relation to technology, there is a fundamental change in the way we approach and carry underlying assumptions (Mansour, 2009). In this case, it is the shift from needing a driver to be attentive at all times to perhaps completely driverless vehicles that is being observed.

Uber's self-driving car incident serves as one of the most famous examples showcasing an expected fault of AV's. In 2018, a self-driving car developed by Uber was involved in a fatal crash, resulting in the death of Elaine Herzberg, a crossing pedestrian. The self-driving car was operating in autonomous mode, with Rafaela Vasquez as the safety driver. Vasquez was said to have paid attention to her mobile phone 36 percent of the duration of the trip. The Uber self-driving car detected Herzberg 5.6 seconds before impact, but did not currently identify her as a human. The National Traffic Safety Board (NTSB) ruled, "Had [Vasquez] been attentive, she would likely have had sufficient time to detect and react to the crossing pedestrian." After NTSB criticized Uber for "inadequate safety culture," Uber increased their transparency by providing them complete access to their operations and development of the technology (Lee, 2019). In addition, Uber scaled back its operations. More discussion about the implication of this event would then follow in the actual STS paper, building around the STS framework of SCOT. The applicability of SCOT is certainly present, since criticism from an institution led to a significant change in the way technology is developed.

The format of the analyses for the other case studies will be the similar – first, parsing the applicable parts of each event/case study (giving context to the reader), and then discussing how an interaction within the item implied change in its technology and progress. Comparing and contrasting autonomous technology’s disadvantages with their traditional counterparts will also occasionally be mentioned.

**Conclusion**

The complex interplay between humans and technology has always been an uphill battle when it came to going in a different direction from old traditions. This is investigated both technically and socially through the technical project and STS research paper, respectively. As the practicality of making machines autonomous improves, so does the concern of its reliability. Even if human override is a feature, one fatal incident is one too many to set a dangerous undertone for future AV developers and engineers involved that will be held accountable. However, focusing attention on the benefits, there is still reason to be optimistic about the future of AV’s. Like the technical project, it will be a dauntingly long iterative process to perfect the performance of AV technology.

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