Design of a Cooperative Adaptive Cruise Control Platooning System in Golf Carts

Analysis of the Underperformance of Peloton Technology's Platooning System

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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

In 2019 alone, there were 12.15 million vehicles involved in car accidents in the United States (Carlier, 2022). This, coupled with the emissions these vehicles put out into the environment, shows how inefficient the current driving system is in the United States. While technology is rapidly changing and car companies are switching to electric and autonomous vehicles, society has yet to deal with some of the problems that create unsafe environments on the roads and ecosystems. Platooning systems have been researched since the 1980s in order to decrease fuel emissions and increase safety on roadways, but they still have yet to gain popularity in the transportation industry (Bhoopalam, Agatz, Zuidwijk, 2018). These systems work by using advanced sensing and communication between vehicles that are following each other (Puplaka, 2016). The safety among vehicles is increased due to the awareness of where each vehicle is located around them, and the fuel emissions are decreased because vehicles can drive closer to one another and decrease their drag coefficient. Peloton Technology was founded with the goal of doing just this in trucks, but because of multiple factors, the company went under and did not succeed in growing the commercial use of platooning systems.

To further understand how platooning might be used in this day and age, I propose the development of a transportation system on a college campus using Cooperative Adaptive Cruise Control. This system will be implemented onto an existing platooning system consisting of two golf carts. As this technical project requires the construction of a diverse network, composed of technical, social, conceptual, and other resources, to support its development and implementation, understanding the mechanisms behind successful network formation is critical to the success of this project. To examine such mechanisms, I will draw on the STS framework of Actor Network Theory (ANT) to analyze the failure of a company who tried to commercialize their platooning system, Peloton Technology. Specifically, I will investigate how the interactions among technical and social factors such as the design of the system itself, the perceptions from society, and legality of the system contributed to the technology's underperformance.

Failure to acknowledge the interconnectedness of various factors in a project's success, and isolating the proposed system from its socio-technical context, may result in a system incapable of interacting effectively with essential elements crucial to its success. Such an outcome could severely hinder the system's capacity to efficiently transport students and staff with platooning vehicles, ultimately leading to the project's failure. Given that the objective of improving unsafe driving environments is inherently socio-technical, it is imperative to address both its technical and social dimensions. In the next section, I describe in more detail the two related research proposals mentioned above: the technical project that sets out a design for a CACC golf cart platooning system and the STS project that examines the interconnections among technical and social factors that led to the failure of Peloton Technology's platooning system company. As I work on developing the proposed new college transportation system incorporating CACC, I will apply insights from the technical success and failures of Peloton Technology to develop a system that can efficiently transport staff and students who have limited mobility.

Technical Project Proposal

In the past 30 years, a lot of research has gone into different platooning systems since they can save money on fuel emissions, potentially save money on wages for drivers, and also provide a potentially safer driving system on roadways. Most of these technologies use the same basic structure, using sensors to relay information between vehicle to vehicle communication (V2V) (Shaver and Droege, 2021). The difference between the research done at companies and universities comes in the algorithms they develop that take in sensor data and control the distance between vehicles. Some of the groups that have ongoing research on this are Peloton Technology, Daimler, Isuzu and Hino, Volvo Trucks, and Partners for Advanced Transportation Technology, PATH (Bhoopalam, Agatz, Zuidwijk, 2018). Each has their own algorithm of allowing the vehicles to platoon, and some groups have even been able to implement their system on public roads in other countries.

The two American groups above, Peloton Technology and PATH, had different approaches to the system. Peloton Technology equipped all of the vehicles with different sensing capabilities like camera, GPS, radar, and LiDAR sensors, and used this in conjunction with a 5.9 GHz Dedicated Short- Range (DSRC) device for reliable V2V. The system used the sensors and the communication between vehicles to maintain a fixed gap, and the platoon also connected to the cloud which allowed for it to operate (Syed and Abadin, 2020). PATH has been researching more efficient algorithms to use in their platooning systems and has conducted highway tests on trucks using Cooperative Adaptive Cruise Control (CACC). They have shown that using their system compared to only Adaptive Cruise Control, has been proven to realize faster braking and acceleration responses in the following vehicles and shooter headways. In addition to using the sensors to derive the measurements to the vehicle in front of it, CACC also finds the vehicle before it's acceleration and uses it in a feed-forward loop. This decreases the chances of amplified braking and acceleration which could cause traffic jams in the platoon (Yang, Shladover, Lu, Spring, Nelson, Ramezani, 2018).

While lots of work is ongoing on the benefits of platooning in trucks and cars that go on the highway, there is limited research on platooning systems made for college campuses. The past four years, The University of Virginia has been developing an Autonomous Campus Vehicle with the intentions of using a platooning system to have 3 golf carts drive a route from Engineer's Way to OMERF. As of now, there is one leader car that is controlled by a human, and one follower car that copies the actuation and braking of the leading car. This allowed for the platoon system to follow a route around OMERF, but did not allow for the 1 mile route to Engineer's Way and back. The technology behind the platooning system used ROS to communicate between the two carts, and had an algorithm that determined the distances between the carts using their velocity vectors (Chiaramonte, Dunnington, Johnson, Sofinski, Wilson, 2023). Neither of the carts used sensors in their algorithms because the previous team found the LiDAR sensors and cameras in place were ineffective with route mapping.

This system and others that have been developed at other universities, have failed to make a more accessible transportation system for college campuses using a platooning system that can travel the distance needed to go from OMERF to Engineer's way and back. To remedy this technical design challenge, my team is going to adapt the existing campus vehicles to use a CACC platooning system with LiDAR and camera sensors. The CACC algorithm that will be used on the carts has been written as part of Professor Brian Park's research on platooning systems. In order to be able to use this algorithm effectively on the system, the team must include sensors to probabilistically determine the distances between the carts at all times. Past years were unable to get the cameras to work because of angling and insufficient lighting, while the LiDAR sensor could account for any moving object in its field. Using both of these together could suppress the problems featured in both, while dodging the high prices of other sensor technologies. For the carts to be running as wanted, several design components will also need to be redesigned and created, such as the steering mounting bracket and duplicating the electric system to place into the third golf cart.

The team will follow the product design method layed out in “Product Design and Development,” by Karl T. Ulrich and Steven D. Eppinger: Planning, Concept Development, System-Level Design, Detailed Design, Testing and Refinement, and finally Production Ramp-Up. In order to analyze the design and demonstrate its viability, the team will collect data on the distance the carts are able to use the system successfully. There will also be intermediate steps where the team will collect data from the sensors, ROS when the algorithm is implemented, and electrical components within the car to make sure all of the components are working properly.

STS Project Proposal

Peloton Technology was established in 2011, and aimed to develop a vehicle platooning system that increased safety and fuel efficiency (Peloton Technology, 2020). It was the first non-research company to test a system like this on public roads in America and to offer their system for sale to truck fleets (Syedand Abadin, 2020). Despite the positive effects that their research found, the company did not take off as much as expected, and ceased operations in 2021 (Gehm, 2022).

Some writers argue that the lack of demand from the trucking industry was the primary reason for the company’s failure. While this perspective is accurate, it overlooks the contributory role of other factors in its failure. Examples include the quality and pricing of the system, society's perception of it, and the legal aspects surrounding it (Gehm, 2022). If we attribute the project’s failure only to the lack of demand for it, then we will not have a more comprehensive account of the range of factors that contributed to the failure. Drawing on ANT, I will argue that it was the lack of demand in the trucking industry in addition to these other factors that caused the company to fail. Specifically, it was the interconnections among these actors that contributed substantially to the network's failure.

ANT uses a network of actors that come together in order to accomplish a certain goal. There is a network builder, who is the creator of the overall goal and recruits the actors into the network. The recruits all align their specific goals to the ones of the network, in order to help achieve the sought out goal. These actors do not need to be people, they can be technical, social, natural, economic, and conceptual (Cressman, 2009). In the case above, Peloton Technology was the network builder, and their actors consist of the physical technology made, the business side of the company, society's perception of their technology, the government's who created laws on their technology, and more.

To support my argument, I will analyze evidence from primary sources like Peloton Technology's website, which provide me information about their goals and research they have put out to the public. I will also be using research articles to understand the technical aspect of their system in addition to their business model, society's perception of platooning, and the legality of their system.

Conclusion

The combined results of the technical report and STS projects will serve to address the issue regarding inefficiencies in driving systems in the United States from a socio-technical lens, highlighting the failure of Peloton Technology's platooning company. The technical project will deliver applied research on a CACC platooning system running on golf carts, and the STS project will deliver pure research on the failure of Peloton Technology's company. The STS project will inform me of what mistakes can be made in a platooning company and how to avoid them in my work. Both contribute to the betterment of efficiency on roads because platooning has been shown to help the fuel emissions and safety between cars.

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