Development of an Autonomous Platooning Campus Vehicle System

Responsible Innovation in the Development of Autonomous Trucks

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Gilchrist Johnson

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Technical Team Members:

Cameron Chiaramonte

Patrick Dunnington

Alex Wilson

Nicholas Sofinski

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

Advisors

MC Forelle, Department of Engineering and Society

Tomonari Furukawa, Department of Mechanical & Aerospace Engineering

Introduction

Current trends suggest the future of driving is driverless, as odd as that sounds (VTPI, 2022). The global market for autonomous vehicles is expected to reach $2 trillion dollars by 2030, with no signs of stopping (Wire, 2022). This growing market is being led by various industries that see value in automating previously worker-dependant industries, with the biggest being the transportation industry (PWC, 2022). Defined by the U.S. Bureau Of Labor Statistics (BLS) as “providing [the] transportation of passengers and cargo, warehousing, and storage for goods” (BLS, 2022), the transportation industry is essential to the successful operation of many industries today. Given this importance, the industry looks to automation as a way to optimize its processes, increase safety, and increase profits (Lynch, 2021).

To discuss this transition to automation, we must clearly define what automation is. The Society of Automotive Engineers (SAE) categorizes automotive autonomy into 6 distinct levels (Figure 1), ranging from No Automation (Level 0) to Full Automation (Level 5) (SAE, 2021).

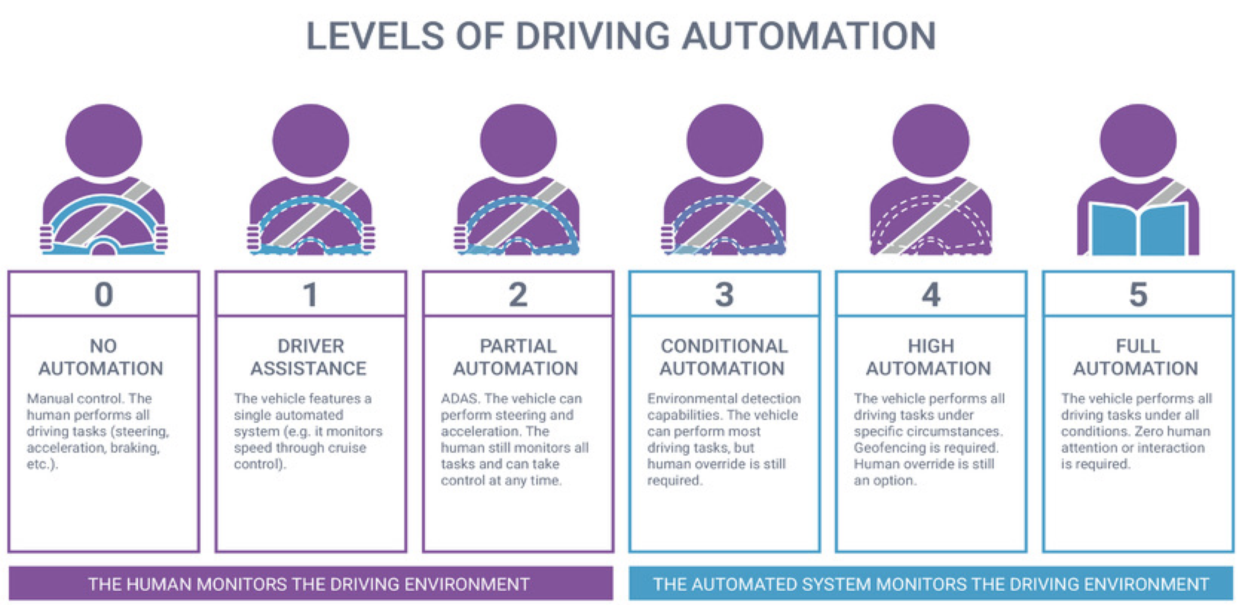

Figure 1:Levels Of Driving Automation, as defined by The Society of Automotive Engineers (Credit: Semiconducter Engineering, 2019)

While most commercial self-driving vehicles are currently between Level 1 and Level 2 autonomy, vehicles with higher levels are imminent (Morris, 2021). For the transportation industry, these higher levels of autonomy are necessary to reap the potential benefits outlined previously. These higher levels of autonomy do not come without their repercussions, however, as there are many social side effects attributed to such a large change in the transportation industry's infrastructure. To address both the technical and social aspects of the automation of the transportation industry, a technical project and Science, Technology & Society (STS) topic will be researched throughout the following semester.

The technical project, titled The Campus Vehicle Project, will be the development of a Level 3 autonomous platooning campus vehicle system. This system will be used to transport students to and from various destinations around the University of Virginia's main campus. Platooning – defined by the American Legislative Exchange Council (ALEC) as "a group of individual motor vehicles traveling in a unified manner at electronically coordinated speeds at following distances that are closer than would be reasonable and prudent without such coordination" (ALEC, 2018) – will be implemented in order to increase both the capacity and efficiency of the final system. The development cycle will focus on building upon previous research conducted into developing the system and addressing customer needs.

The STS topic will be to analyze current strategies for automating the transportation industry through the framework of responsible innovation as outlined in the article "Developing a framework for Responsible Innovation" (Stilgoe et al., 2013). By conducting this analysis, I hope to address the potential social and ethical ramifications that automating the transportation industry will bring. I will also use my findings to assist in the development of the previously mentioned technical project.

The Development of an Autonomous Platooning Campus Vehicle System

Background

The Campus Vehicle Project was initially started as the Self Driving Vehicle Project by Professor Tomonari Furukawa at Virginia Tech (VT) in 2015. Proposed as a multi-year senior design project, students were tasked with modifying a golf cart – provided by Club Car – to add Level 3 autonomy. As the project evolved throughout its lifetime, so did its goals, eventually shifting to developing a platooning system instead of an independent one. By implementing platooning into the Autonomous Golf Cart Project, the system would be capable of transporting a much higher capacity of students through an additional cart. When Prof. Furukawa transferred from Virginia Tech to the University of Virginia (UVA) in 2020, so did his research, resulting in the Campus Vehicle Project. The project has since been developed at UVA.

Review of Previous Research

The two previous iterations of the Campus Vehicle Team at UVA have successfully completed the construction of the first cart. Both these teams and the Virginia Tech teams have kept a record of their previous work. This includes testing data, system schematics (ex. Figure 2), and presentations. Additionally, previous team members from both the Virginia Tech and UVA teams – Jeronimo Cox and William Smith, respectively– were contacted to further comprehend previous design decisions. This data along with the completed cart was used to reverse-engineer the previous team's work.

The most recent iteration of the Campus Vehicle System at UVA uses data from various sensors on the cart to create a map of the surrounding environment. This map along with various computations conducted from and central computing unit running the Robotic Operating System (ROS) would allow the cart to navigate to various pre-set locations with Level 5 autonomy

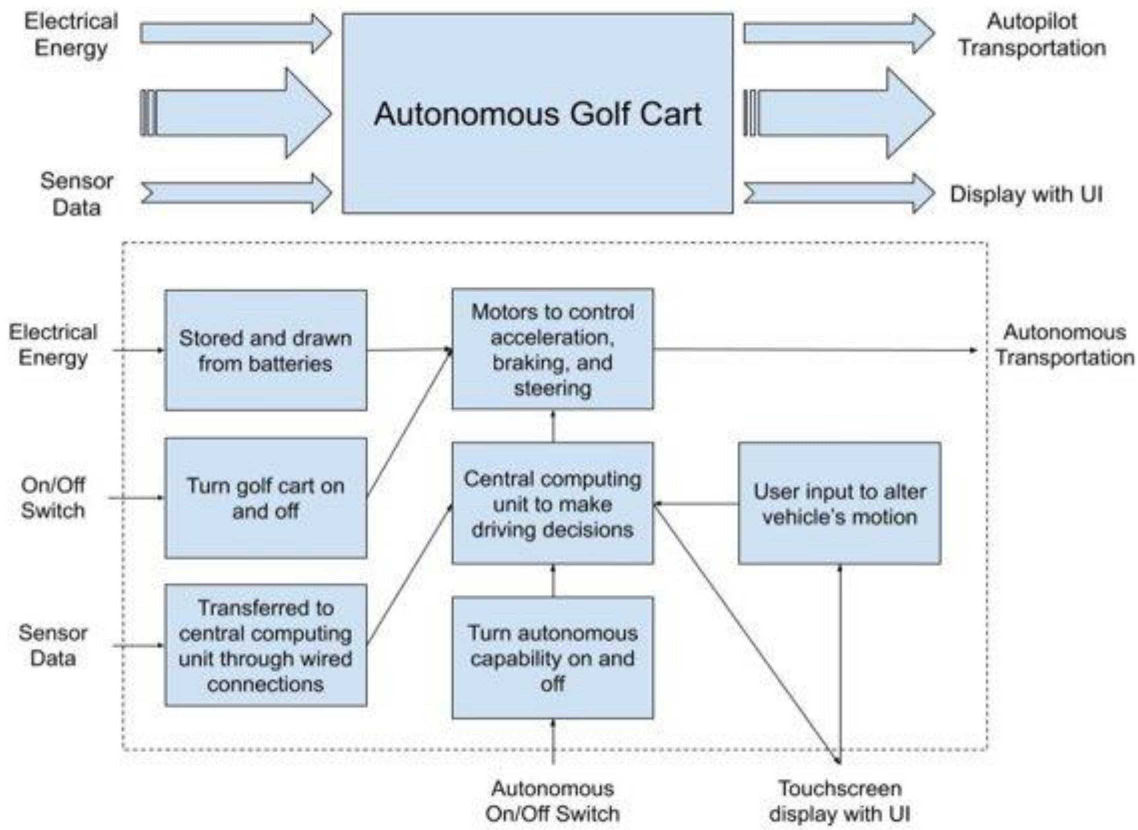

Figure 2:System Diagram from the 2020-2021 Campus Vehicle Team (Credit: Furukawa, T. et al., 2021)

(Furukawa, T. et al., 2021). As the previous team did not pursue a platooning system, this design will be modified to include this feature.

To accomplish this modification, the addition of QR Codes tracking will be implemented. In 2017, the Virginia Tech Campus Vehicle Team experimented with using QR Code tracking for platooning with mixed results (Furukawa, T. et al., 2017). While the tracking method was easy to implement due to the high integration with ROS, it presented various reliability issues with the field-of-view (FoV). Despite this, the team concluded that further improvement of the QR Code method would increase its reliability while still retaining the overall simplicity of the system (Furukawa, T. et al., 2017). Taking this suggestion into consideration, our team will attempt to address these concerns by allowing the use of QR codes with the platooning system.

Objectives

The goal of the current Campus Vehicle Team is to further develop the previous team's design by adding platooning capabilities to the system. This will be accomplished by pursuing the following objectives:

1. Repair both golf carts to working order.
2. Develop and implement a consolidated mechatronic system to control both golf carts.
3. Develop a mobile base ROS package for use with the Campus Vehicle System.
4. Develop a platooning ROS package for use with the Campus Vehicle System.
    a. Implement an option for open-loop operation.
    b. Implement an option for closed-loop operation using QR code tracking.

To efficiently pursue these goals, we will pursue objectives 1 and 2 during the fall semester and objectives 3-5 during the spring semester. Finally, a final demonstration of the completed Campus Vehicle System is planned to take place in early April of the spring semester.

Responsible Innovation in the Development of Autonomous Trucks

Background

According to the U.S. Department of Transportation, the transportation industry employs 14.9 million people, 10.2% of the labor force in the United States (BTS, 2022). Many of these people are commercial truck drivers. As the industry transitions into an autonomous future, many of these drivers could lose their jobs. Current research suggests that the adoption of autonomous cars could eliminate between 1.3 to 2.3 million jobs, depending on how it's implemented (Grosne, et al., 2019). While it's easy to ignore this fact in the face of innovation, it's important for engineers to understand the context and ethical ramifications of their work. (Johnson, 2020). To accomplish this, we must first look at why this transition to automation has become so prevalent.

Acceleration due to COVID-19

The coronavirus (COVID-19) pushed unemployment to an all-time high (BLS, 2021). In the first two months of the pandemic (March-April, 2020), employers cut 22 million jobs, and the unemployment rate dropped to 14.8 percent (Casselman, 2021). Many Americans felt as if working during the pandemic wasn't worth the risk of infecting themselves (or others) (Depillis, 2022). During this phase, some industries were able to regain workers by offering virtual working options, while others – such as the aforementioned transportation industry – were unable to make such adaptations due to the nature of the jobs (Depillis, 2022). More than two years later, many industries are still struggling to find workers (Casselman, 2021). While many industries have attempted to incentivize workers back, others look to automation as a solution (Petropoulos, 2021). When asked about employers' difficulties retaining employees, Stephen Steinour, chief executive of Huntington Bancshares, states "Universally, they [employers] talk about [the] inability to get adequate labor, very high turnover, and clear wage inflation at the low end. A consequence of that will be more investment by many of them into automation" (Steinour, 2021, as cited by Lynch, 2021). While full automation is still a few years away for the transportation industry, many workers are worried about losing their jobs (Mitz, 2022). To address this, we must consider the ethical ramifications of our work as engineers (Johnson, 2021).

Responsible Innovation

To address workers' concerns about an unethical future, we must find a framework to analyze the ethical effects of innovation. For this project, I will use responsible innovation, as outlined in the article "Developing a framework for Responsible Innovation" (Stilgoe et al., 2013).

Figure 3:Diagram of the Responsible Innovation Framework (Stilgoe et al., 2013). (Credit: Gilchrist Johnson)

Utilizing a multi-dimensional analytical approach (Anticipation, Reflexivity, Inclusion, and Responsiveness), responsible innovation aims to address the social and ethical concerns of technological evolution. Each of the four dimensions represents an aspect of "responsibility", as defined by the authors (Figure 3). By comparing the innovation in question to these dimensions, we can determine the shortcomings of autonomous innovation in the transportation industry.

Anticipation

Anticipation refers to the process of researchers asking "what if…?" questions to determine and estimate harm done by technological innovation (Stilgoe et al., 2013). In the context of the transportation industry, this means asking what ramifications automating the industry could have. This includes the effects on workers, companies, engineers, and consumers.

Reflexivity

As stated in "Developing a framework for Responsible Innovation", "Reflexivity directly challenges assumptions of scientific amorality and agnosticism. Reflexivity asks scientists, in public, to blur the boundary between their role responsibilities and wider, moral responsibilities" (Stilgoe et al., 2013). In the context of the transportation industry, this means assessing the means by which automation is implemented. Are we giving transportation employees who may be replaced by automation a way out? Or are we setting them to the wayside in the advent of autonomy?

Inclusion

Inclusion refers to the questioning of who is making – and benefiting – from innovations. Within the transportation industry, it's essential to make sure all of the parties involved (such as the transportation workers, consumers, and engineers) have a voice in the automation of the transportation industry. One such example is the Transport Workers Union of America's (TWU) protest campaign "People Over Robots". After protestors argued various sociotechnical issues with the automation of buses; Ohio senators passed a resolution, titled "Addressing the Challenges and Threats of Autonomous Vehicles to Transportation Worker Jobs in Ohio.", to combat the concerns voiced by the protesters. (TWU, 2018)

Responsiveness

In response to the prior three prompts, responsiveness asks if a change is possible when faced with ethical issues. If the innovation of automation in the transportation industry is unethical, are there resources that allow change to happen?

Research Question / Purpose and Methods

The purpose of this study is to examine the ethical implications of the rise of automation in the transportation industry. As “Developing a framework for Responsible Innovation” is the guiding framework of this research, the following research questions are framed in relation to responsible innovation (Stilgoe et al., 2013). The following research question guided this study:

1. Does the trajectory of automation in the transportation industry adhere to the guidelines of responsible innovation?

To address these research questions, an analysis of various literature sources will be conducted with each source corresponding to a dimension of responsible innovation (Stilgoe et al., 2013). To find these literature sources, various forms of reactions to the automation transportation industry will be considered. Various news sources and opinion-based articles will be reviewed. As commercial truck drivers are one of the larger populations of workers that will be affected, the automation of commercial trucks will be prioritized. Local transportation applications, such as bus systems, railways, and taxis will be referenced as supporting evidence for the claims made by the commercial truck drivers. Finally, *Preparing U.S. Workers and Employers for an Autonomous Vehicle Future* (Groshen, et al., 2018) will be used as a reference for the projected statistical effect of automating the transportation industry on a social level.

Conclusion

As stated by Deborah Johnson in her book *Engineering Ethics* (2020), it's important for engineers to not only understand the technical aspects but the context and ethical ramifications of their work. As I further my career as an automation engineer, it's important to keep these effects in mind. To reinforce the concepts of synergy between social and technical sciences, I will pursue two projects related to both sciences respectively. First, I will attempt to further develop the Campus Vehicle Project and understand the processes that go into socially-aware product development. Next, I will analyze and reflect on my findings from analyzing the effects of related innovations in the transportation industry through the lens of responsible innovation. By analyzing these effects, I can give myself and future readers of my prospectus context into the sociotechnical and ethical considerations that go into the development of autonomous vehicles. By doing so, I hope to improve my capability as an engineer and give readers a wider context into the effects of industrial automation.

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