FSAE CAN SENSOR BOARD

ZOOX: DEVELOPMENT OF SELF-DRIVING CARS

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Computer Engineering

By
Casey Ladd

November 1, 2021

Technical Team Members:

Jack Basinet

Jack Hebert

Ethan Jacobson

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

Joshua Earle, Department of Engineering and Society

Todd Delong, Department of Electrical and Computer Engineering

Introduction

Imagine driving on a dangerous road with bumper-to-bumper traffic along the coastline in Big Sur, California. As you approach a sharp turn, the car in front of you slams on the brakes to avoid a bear, and you cannot react fast enough to slow down to avoid a collision. Two options could happen to you: you collide with the car, potentially leading to injuries and fatalities, or you swerve off the road, risking driving off a cliff or colliding with a tree leading also to potential injuries and fatalities. Which option would you choose?

The reality is that no one wishes to face such a dilemma, yet a situation like this highlights critical decisions that must be made. This hypothetical scenario resembles the ethical problem known as the "trolley problem" (Thomson, 1984). While rare, such instances emphasize the complex challenges associated with decision-making under uncertainty. This scenario is the main source of debate among the general public on the ethics of using self-driving cars. The “trolley problem” represents a significant ethical and technological barrier for autonomous vehicles. How would a self-driving car respond? Naturally, this question forms the grounds of an ongoing public debate about the ethics of deploying autonomous vehicles.

Before diving into the main research focus for my Science, Technology, and Society (STS) project, here is an introduction to my technical project. Jack Basinet, Jack Hebert, Ethan Jacobson, and I are designing a solution to renovate and simplify the wheel sensor data acquisition process for the Virginia Motorsports Education’s (VME) Formula Society of Automotive Engineers (FSAE) vehicle called the VM25. VME is a student-led organization affiliated with the University of Virginia that annually designs, constructs, and races a formula race car for the FSAE competition (Formula SAE, 2024). The current system that has been used for the last few years involves direct analog wiring from each sensor to the car’s main computer.

Our project seeks to replace the old setup with a Controller Area Network (CAN) bus system, which digitizes sensor data before transmitting, streamlining a more efficient data acquisition process.

For my STS project, I will be analyzing the societal implications of autonomous vehicles, focusing on their development, their involvement with policy and regulation, and associated ethical debates. Specifically, I will be examining Zoox, Inc.: a former start-up company that became a subsidiary of Amazon's Devices and Services Organization that has notably influenced the design of self-driving cars. For my research, I want to explore how Zoox's technologies, especially its navigational and collision avoidance strategies, shape public perceptions of self-driving cars and their role in the future of transportation.

Technical Project

The primary goal for our technical project is to address our main customer: the VME. The organization would like us to replace its outdated analog wiring system with a new system to streamline data to its vehicle's central data computer, a Nvidia Jetson, using a CAN bus-based transmission. The CAN bus protocol is the standard used in automotive applications, offering high-speed, reliable data transfer. The proposed system will enable the integration of data from various sensors found on a wheel (wheel speed, suspension, brake temperature, and tire temperature) into a unified data network, reducing wiring complexity and enhancing system reliability and efficiency (Controller Area Network (CAN) Overview & Specifications, 2024).

For our project, we are designing a printed circuit board (PCB) equipped with an ARM Cortex M7 processor, CAN transceivers, regulators for routing power from a 24 Volt battery, flash memory, and a bootloader. The final project is projected to collect analog or digital CAN 2.0 signals from the sensors on each wheel and transmit a digital CAN FD signal to the central control unit. The key challenge that my team may face is ensuring the PCB can withstand the noisy environment of the high-performance car and minimize errors in signal transmission.

Software testing will be conducted using the Teensy 4.1 microcontroller, which incorporates components similar to those in our PCB (Teensy® 4.1, 2024). The main software test will be a fully expected design that incorporates all of the steps used in the system and verifies their accuracy. Hardware testing will involve verifying the accuracy of component open-source values on each output pin and ensuring proper voltages across the PCB's traces. System integration testing will confirm that the board functions seamlessly with the same outcomes from the previous tests. Our project aims to deliver fast, consistent data transmission, stable power isolation, effective grounding and shielding, and a PCB design that is easy to fabricate.

STS Project

What if a car could predict and potentially mitigate the “trolley problem” scenario? Unlike humans, autonomous vehicles make decisions within microseconds, leveraging processors operating at several gigahertz clock frequencies, whereas the human reaction time is about a couple hundred milliseconds (How Fast Is Real-Time?, 2024). Through artificial intelligence, self-driving cars utilize neural networks as a machine learning strategy, an architecture that is similar to the structure of the brain. These vehicles gather sensor input data, apply learned weights and thresholds, and produce actionable outputs, such as turning on the headlights, increasing the speed, or turning the steering wheel (Explained, 2017).

One component of autonomous vehicles that I find interesting and would like to study more about is their navigation system. Global Positioning System (GPS) is the de facto source of navigation that is used for providing route guidance, location-specific data, and real-time updates on subject matters such as traffic, weather, and road conditions (GPS: The Global Positioning System, 2024). Autonomous vehicles have to rely on vehicle-to-vehicle and vehicle-to-infrastructure communication for their navigational system to succeed (Adnan, 2018). The navigation system will assist self-driving vehicles to analyze and act accordingly based on appropriate data, such as avoiding current hazardous roads as well as pinpointing the best and safest route to do errands. However, deficiencies in infrastructure, such as missing road signs and outdated information, can hinder the safe operations of self-driving cars (Van Brummelen, 2018).

Also, I wanted to uncover some autonomous vehicle start-up companies that have appeared in the last ten years and have attempted to innovate and amplify potential advantages of the self-driving car. One of these companies is Zoox, Inc; founded in 2014 by Tim Kentley-Kay and Jesse Levinson. The company's focus is to specialize in designing autonomous electric vehicles for the taxi industry (How This Self-Driving Car Company Aims to Make the Roads Safer with a New Type of Vehicle, 2018). The company has applied techniques from the automotive, robotic, and renewable energy industries to produce a vehicle that solves many problems in all those fields. Zoox has prioritized innovations such as thermal system control to improve battery efficiency, passenger comfort, and vehicle safety (Zheng, 2021).

My research will, therefore, explore Zoox's approach to navigation technology, safety, and public perception. The main research question I am asking is: How has Zoox and its development of autonomous vehicles affected the general public's thoughts on self-driving cars?

The technological innovation of autonomous vehicles is both fascinating and apprehensive. Many people have articulated that they are leading us toward a brighter future, while others believe it is more toward a dystopian world. Human error is one of the main reasons why driving is dangerous, so the consideration that autonomous vehicles can fix this idea is both liberating and alarming. However, due to the economic decisions that some companies have made, some people believe that autonomous vehicles are not ready to be sold to the public and the vehicles will not work with the best intentions.

The main social groups that I will be addressing include Zoox's board of directors and employees, the federal, state, and local governments in the United States where Zoox is currently conducting its testing, and the general public. Zoox's competition may also be relevant, but I will most likely be leaving it out unless it directly affects the company's mission or its technological development. From there, by looking at all of the key figures and groups from Zoox, I will be able to expand on the content for the focus of my research.

The main method and framework that I will try to use is the Actor-Network Theory, in which I will try to connect the dots between all social groups as well as any newcomers that come up in my research. Because autonomous vehicles are still in development and multiple parties are still trying to perfect the technology, the Actor-Network Theory will be a good framework to use for my research project. By researching the history, policy, and ethics of Zoox's self-driving cars and their relationship with the rest of the social groups, I will be able to define all important information for examining my research question (Latour, 2005).

For my research, I plan to build a timeline in which I will investigate the history of Zoox's development of their specific autonomous vehicle, information used in previous developments, adaptations from government policies, and the ethical opinions of the general public. I am hoping to find specific studies that employees of Zoox contributed in the investigation of the development of a more improved navigation and collision awareness system. More information on Zoox's involvement in producing better ethical decision-making vehicles, especially when they are involved in detrimental health risks, will also be investigated. By February 2025, I plan to complete my research with notable amounts of credible sources for my research questions.

Key Texts

Based on the background of the company Zoox, I want to investigate specific areas of Zoox based on four key texts.

My first key text is a research brief from the Technical University of Munich's Institute for Ethics in Artificial Intelligence. Its key objective is "working on advancing autonomous driving technology with a major goal of increasing road safety and comfort of motorized transport" (Geißlinger, 2021). Some of the major ethical considerations for autonomous vehicles are technical safety, human agency, inclusiveness, and societal well-being. By incorporating this into my research, I will be able to target the ethical standpoints towards Zoox as well as develop an argument about how they stand on all of these criteria (Geißlinger, 2021).

My second key text is the foundational practice of how autonomous vehicles navigate in urban environments. The Department of Computer Science at George Mason University created an image-based localization, which "given a database of views of city street scenes tagged by GPS locations, the system computes the GPS location of a novel query view" (Zhang & Kosecka, 2006). I can expand on the research in the development of machine learning tools used to improve upon the navigational strategies that autonomous vehicles and Zoox in particular have used and built their company (Zhang & Kosecka, 2006).

My third key text is a paper that describes another important component of the development of autonomous vehicles: collision risk assessment. From this paper specifically, Katrakazas, Quddus, and Chen developed “a new risk assessment methodology that integrates a network-level collision estimate with a vehicle-based risk estimate in real-time” (Katrakazas et al., 2019). This is one of the most important issues with autonomous vehicles that most ethical debates originate, especially the example of the “trolley problem” from the introduction. My goal with this topic is to research strategies and any data that show trends in changes that are incorporated in newer models and any changes to the opinions of people who use Zoox’s cars (Katrakazas et al., 2019).

My last key text is a paper by Hemphill on the discussion of autonomous vehicle regulation in the United States government. The paper summarizes the current implications of autonomous vehicles at the federal, state, and local levels addressing initiatives, executive orders, legislation, policy frameworks, and most importantly, the Society of Automotive Engineers’ self-driving autonomy levels. From there, I will continue to find policies that were influenced by Zoox’s corporate actions or policies that have directly influenced Zoox’s corporate decisions (Hemphill, 2020).

Conclusion

Through the development of standard computer hardware components and the study of machine learning applications in vehicles, I aim to deepen my understanding of the automotive industry's current innovations and future challenges. Collaborating on my technical project will provide valuable hands-on experience, while my STS research will contribute to broader discussions on the societal, ethical, and regulatory implications of autonomous vehicles. Ultimately, I aspire to apply these insights to support the responsible and effective integration of self-driving technology into society.

References

Adnan, N., Md Nordin, S., bin Bahruddin, M. A., & Ali, M. (2018). How trust can drive forward the user acceptance to the technology? In-vehicle technology for autonomous vehicle. *Transportation Research Part A: Policy and Practice*, *118*, 819–836. https://doi.org/10.1016/j.tra.2018.10.019

Controller Area Network (CAN) Overview & Specifications. (n.d.). from https://www.ni.com/en/shop/seamlessly-connect-to-third-party-devices-and-supervisory-system/controller-area-network--can--overview.html

Explained: Neural networks. (2017, April 14). MIT News | Massachusetts Institute of Technology. https://news.mit.edu/2017/explained-neural-networks-deep-learning-0414

Formula SAE. (n.d.). from https://www.fsaeonline.com/cdsweb/gen/DocumentResources.aspx

Geißlinger, M. (2021). *AI and Autonomous Driving: Key ethical considerations*. https://www.academia.edu/107971849/AI_and_Autonomous_Driving_Key_ethical_considerations

GPS: The Global Positioning System. (n.d.). from https://www.gps.gov/

Hemphill, T. A. (2020). Autonomous vehicles: U.S. regulatory policy challenges. *Technology in Society*, *61*, 101232. https://doi.org/10.1016/j.techsoc.2020.101232

How Fast Is Real-Time? (n.d.). PubNub. from https://www.pubnub.com/blog/how-fast-is-realtime-human-perception-and-technology/

How this self-driving car company aims to make the roads safer with a new type of vehicle. (2018, October 24). CNBC. https://www.cnbc.com/video/2018/10/24/zooxs-driverless-cars-will-operate-like-lyft-and-uber.html

Katrakazas, C., Quddus, M., & Chen, W.-H. (2019). A new integrated collision risk assessment methodology for autonomous vehicles. *Accident Analysis & Prevention*, *127*, 61–79. https://doi.org/10.1016/j.aap.2019.01.029

Latour, B. (2005). Introduction: How to Resume the Task of Tracing Associations*. In B. Latour, *Reassembling the Social* (pp. 1–17). Oxford University PressOxford. https://doi.org/10.1093/oso/9780199256044.003.0001

Teensy® 4.1. (n.d.). Retrieved November 1, 2024, from https://www.pjrc.com/store/teensy41.html

Thomson, J. J. (1984). The Trolley Problem Comment. *Yale Law Journal*, *94*(6), 1395–1415.

Van Brummelen, J., O'Brien, M., Gruyer, D., & Najjaran, H. (2018). Autonomous vehicle perception: The technology of today and tomorrow. *Transportation Research Part C: Emerging Technologies*, *89*, 384–406. https://doi.org/10.1016/j.trc.2018.02.012

Zhang, W., & Kosecka, J. (2006). Image Based Localization in Urban Environments. *Third International Symposium on 3D Data Processing, Visualization, and Transmission (3DPVT'06)*, 33–40. https://doi.org/10.1109/3DPVT.2006.80

Zheng, Q., & Mueller, P. (2021). An Overview of the Zoox Smart Automatic Thermal Control Design– An Autonomous Electric Taxi. *2021 5th CAA International Conference on Vehicular Control and Intelligence (CVCI)*, 1–4. https://doi.org/10.1109/CVCI54083.2021.9661241