Fast, Safe, and Proactive Runtime Planning and Control of Autonomous Ground Vehicles in Changing Environments

(Technical Paper)

Autonomous Vehicles and Accessibility: A case study of the benefits and challenges posed by autonomous vehicles to people with disabilities

(STS Paper)

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Introduction

Over the past decade, the seemingly unreachable dream of autonomous vehicles has become reality. Autonomous vehicles are being developed worldwide, and many semi-autonomous cars are already on the roads. This shift towards autonomous vehicles is a result of many potential benefits over human-operated cars, such as fewer accidents, less traffic, and more accessibility. Before autonomous vehicles can make up a significant portion of the transportation industry, they must become more desirable to consumers than current modes of transportation. Thus, autonomous vehicles must be able to safely and quickly get to a destination. My capstone project aims to explore this problem by developing a method for autonomous ground vehicles to reach a destination as quickly as possible, while minimizing risk of unknown terrains and obstacles.

Ultimately, the goal of the capstone project is to discover methods to improve safety and efficiency of autonomous vehicles in hopes that autonomous vehicles become more commonplace and their benefits can be reaped. But a rise in the use of autonomous vehicles does not imply improved safety, less congestion, and more accessibility for consumers. The design of autonomous vehicles is catered towards consumers so that manufacturers can maximize their profit. Groups that do not represent a large portion of vehicle consumers are marginalized in the vehicle industry, but potentially have the most to gain from the rise of autonomous vehicles. In the STS research, I plan to explore the benefits and challenges posed by autonomous vehicles for people with disabilities, and how these impacts could be effectively regulated.

Technical Topic

According to the National Safety Council, in 2019 an estimated 38,000 people died in motor vehicle accidents and around 4.4 million people were injured in the United States. Of the accidents that occurred in the in the U.S., over 90% were a result of human error, which includes distracted driving, driving under the influence, and other causes not related to vehicle or road infrastructure failure (National Safety Council, 2020). Despite these safety concerns, vehicles have connected humans like never before and revolutionized mass production and the economy. Autonomous vehicles have the ability to preserve these benefits while improving safety, as well as mitigating other problems in the transportation industry like increasing greenhouse gas emissions and traffic congestion (Adnan et al., 2018). In order to do this, however, autonomous vehicles must be able to get from one place to another while minimizing risk.

I have been working with the Autonomous Mobile Robots (AMR) Lab at UVA under Nicola Bezzo to develop a method that allows an unmanned ground vehicle (UGV) to plan its trajectory and velocity on an unknown terrain in a way that maximizes safety and efficiency. To begin our work, we used Gazebo robotics simulator to evaluate and collect data about UGV performance while varying velocity, magnitude of turns, and friction of the terrain (Gazebo, 2018). This data was then used to train a neural network which outputs a model that predicts the maximum safe velocity of the UGV given terrain friction and magnitude of the upcoming turns the UGV will take. We plan to improve our velocity predictions by expanding the model domain to include environments with obstacles and elevation changes.

By using more complex environments, the model will have to adapt to include risk awareness. Not only is the UGV required to reach its goal, but it also must avoid crashes and other unsafe actions when obstacles are present. If an environment is unknown, the UGV cannot immediately take the shortest path to the goal – multiple paths must be considered and evaluated based on their length and safety.

Researchers from the California Institute of Technology have created a risk-averse path-planning algorithm that effectively identifies potential traversable paths, which can then be ranked in terms of safety and distance (Ono et al., 2015). Their approach utilizes sensors on the UGV which collect image data. Each pixel of the collected images is classified into one of five terrains, and the elevation change from surrounding pixels is recorded. Using this data, a graph is created of traversable paths using the UGV's wheel placement, which can be ranked using length or safety (Ono et al., 2015). This path-planning approach differs significantly from that of Guzzi et al. (2020), where a sample-based motion planning algorithm randomly calculates the traversability of different positions adjacent to a UGV. This approach only uses elevation and assumes static knowledge about the terrain to plan traversable paths, and therefore relies more on machine learning to determine the optimal path. While both of these approaches were reported to be successful, their success is relative to the environments and contexts in which they were tested. Our team plans to leverage the existing work on developing optimal path-planning methods to build our own method which will be successful on a variety of testing domains. Once our methodology incorporates risk into the proactive planning and control model, we plan to test it using more challenging, diverse, and unstructured environments, both simulated and with a variety of UGVs and environments from the AMR Lab.

STS Topic

Access to vehicles, particularly in non-urban areas, exponentially increases access to stores, job opportunities, schools, and more. Car ownership gives people more independence and flexibility in their daily lives, as they are not reliant on public transportation and travel times are often decreased by driving. Unfortunately, these benefits are not made equally accessible to all people. Groups who are unable to afford car ownership, have a disability that prevents them from driving, or people who live in areas where transportation infrastructure does not make owning a car realistic are examples of groups currently experiencing unequal access to vehicles (Bezyak et al., 2017). These groups, however, could benefit the most from the rise of autonomous vehicles. The designs and features of autonomous vehicles are decided by the corporations that produce them, and they are based on the desires of potential customers. In an industry as large as transportation, it is very possible that smaller user and non-user groups are ignored in order to cater to the majority of consumers. As the future of autonomous vehicles becomes more realistic, manufacturers, consumers, and legislatures should be aware of how autonomous vehicles benefit or harm smaller demographics that could easily be marginalized. This research will explore the competing interests of people with disabilities that prevent them from driving human-operated vehicles and the large companies developing autonomous vehicles, and how these interests could be meaningfully legislated.

The ways in which people with disabilities interact with the transportation industry has shifted drastically with the introduction of ride-share services. These services, like Uber and Lyft, have allowed people who cannot physically operate a vehicle to still gain many of the benefits vehicles offer. Nevertheless, over 10% of the 57 million disabled citizens in the U.S. reported difficulties and dissatisfaction with transportation opportunities (Bennett et al., 2019). This issue of unequal access is present despite Title II of the Americans with Disabilities Act, which requires public transportation services to "not discriminate against people with disabilities in the provision of their services" (U.S. Department of Justice, 2020). Regulation to protect people with disabilities will become even more difficult as autonomous vehicles become accessible to the public, since U.S. lawmakers will also be working to understand the technology behind autonomous vehicles so that safety, accessibility, and user privacy can be regulated (Cohen et al., 2020).

The extent to which disabled groups benefit from autonomous vehicles depends heavily on how autonomous vehicles interact with the current state of society. Cohen et al. (2020) describes possible futures for autonomous vehicles which will help frame how people with disabilities interact with autonomous vehicles throughout this research. One possibility described for autonomous vehicles is that they would very similar to current cars. In this scenario, autonomous vehicles are privately owned, but will not require human operation (Cohen et al., 2020). On the other hand, transportation may evolve into many mobility-as-a-service systems, where vehicles are not privately owned and instead transportation is paid for in a per-ride method (Sparrow & Howard, 2020). Either of these scenarios have vastly different effects on society, and therefore significant implications for people with disabilities.

One of the largest benefits of autonomous vehicles is the ability to provide broader and more convenient transportation options for people who cannot drive. This benefit, however, may only be accessible to people in certain geographic regions, and people who can afford autonomous vehicles. Furthermore, certain groups of people with disabilities, like those who use wheelchairs or other physical equipment, will likely not have as broad of access to autonomous vehicles due to space requirements in the vehicles. Wheelchair accessible vehicles are often more expensive to purchase, and ride-sharing services that accommodate wheelchairs often result in longer wait times and higher services charges (Louise, 2018). Some people with disabilities have also expressed concerns that, after a collision, they fear they will be helpless and unable to escape a dangerous situation or call for help (Bennett et al., 2019). These concerns of cost, space requirements, and safety make the accessibility of autonomous vehicles for people with disabilities even more complex.

This research will analyze the implications of different autonomous vehicle futures and how each impact accessibility for people with disabilities, alongside what can be done in the U.S. to legislate these challenges. Through published surveys of people with disabilities, literature reviews, and articles detailing current and future planning of autonomous vehicle design, the research will investigate the different benefits and harms autonomous vehicles could cause through the lens of people with disabilities. The interests of corporations, specifically technology companies who design autonomous vehicles, as well as the U.S. government will also be taken into account throughout the research to help explain how autonomous vehicles will interact with society. In order to fully explore the impacts of autonomous vehicles on people with disabilities, the research will need to explore the current challenges people with disabilities face in transportation, optimal autonomous vehicle designs and futures for different stakeholders, and how the challenges faced would be addressed or ignored in different autonomous vehicle scenarios. Furthermore, the research will need to explore whether the U.S. government should regulate potential conflicts of interests in regards to autonomous vehicles, such as accessibility requirements, and if so, whether it will be able to do so successfully.

Next Steps

A deeper analysis of how the current transportation industry and different autonomous vehicle futures will affect safety, accessibility, and security will be conducted through a case study of people with disabilities in the U.S. Different autonomous futures will be investigated primarily through the expected design decisions of corporations in order to maximize profit and make autonomous vehicles publicly available in a competitive timeframe. Since people with disabilities could significantly benefit from autonomous vehicles, I will explore what initiatives companies are currently planning or investigating in order to include the interests of people with disabilities in their design, and what measures advocacy groups for people with disabilities are taking to make their voices heard. Furthermore, the challenges to legislate the autonomous vehicle industry will be analyzed in the context of their effects on disabled people. By understanding the social implications of how accessibility and representation are engrained into autonomous vehicle futures, algorithms and other technical developments in this field can be designed with a variety of user and non-user groups in mind, rather than solely groups who are expected to bring corporations the most profit.

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