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The Viability of Owner-less, Driver-less Automobile Network

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Abstract

As services like Uber and Lyft increase in popularity, they prove that a public transit system consisting solely of automobiles is a viable business model. An emphasis and focus on the use of self-driving cars, though the idea has existed for decades, is beginning to yield consistent and viable results for potential implementations of autonomous road-going passenger vehicles. Various self-driving vehicle designs use a combination of standard video cameras, infrared scanners, radar, and LiDAR to detect obstacles and lane markings that allow the vehicle to safely steer itself. However, the technology is not the complete answer, as the need for a complete design has not been met. The technology to control the car is being studied, but the ethics and implications of each has yet to be fully explored. Technology that measures redundant information (like Google's LiDAR system), is better for avoiding any and all obstacles as they appear and offer the best method for ensuring safety and comfort for the passengers of the autonomous vehicle. In general, there is an inverse relationship between the cost of setup and the overall safety of the system, notably cheaper lateral camera systems offer far less safety than a 360-degree view system.

1. Introduction

Automobiles are designed to transport passengers from point A to point B, and have been designed to accomplish this task for the better part of a decade. Ever since the invention of the automobile, the control system has always required a person at the helm to take complete control and direct the vehicle. In recent years, since the development of cheap, high-performance computers and high-definition, low-latency video cameras, the idea of a driver-less car is slowly becoming the next step in the automobile's legacy.

Various companies and research groups have attempted to solve the issue of how to autonomously steer a moving vehicle with a computerized system. While they have had consistent success, the design documentations often neglect to describe the implications of their unique design.

This paper will make a few assumptions about the purpose of the vehicles. First, the autonomous vehicles will be transporting people, since transporting inanimate objects and cargo has its own set of implications. Second, the vehicle will likely behave similarly to the way cars behave now, only autonomously. Meaning, a self-driving car should be visually indistinguishable from a car driven by a human based on its movement patterns.

2. Driver-less Technologies

Many different companies and research groups are tackling the challenge of designing a reliable, sustainable, and cost effective self-driving car system. Although the goal of all the systems is essentially equal, each different system has its unique sets of pros and cons.

2.1 Google, LiDAR

Google was an early entrant into the self-driving car field of technology, and is also a notable pioneer for the popularity of the self-driving car. Though Google is known mainly for its Internet searching, the general philosophy of the company is to strive and develop new technology that can improve the world; Google views car fatalities as a world-health issue [1].

Google's self-driving car employs a LiDAR (Light Detection and Ranging) system, which provides a 360-degree scope around the vehicle. The rotating sensor on the top of the roof emits laser pulses and measures the reflections to get distance readings. The car also uses a secondary radar system to measure the translational velocity of the car. When the LiDAR is combined with regular cameras, the car's computer system can spot traffic lights and detect their color. The regular cameras also offer confirmation on whatever the LiDAR/radar system is detecting. After over 500,000 miles of accident-free testing (as of 2014), Google's self-driving car has proven to be incredibly reliable and safe [1].

However, the main drawback is the cost of computing. Since the car takes in such a massive amount of continuous data, the limiting factor is the amount of data that the computer can process at once. The imaging techniques used for figure detection can be taxing on the main computer system, especially when it needs to continuously analyze 360-degree video [1]. Fortunately, modern computers are fast and cheap, so packaging a viable computer system in a small space is a complete option and will only become easier in the future as technology improves.

2.2 H-Infinity Output-feedback Control

This second method, as tested by Chaun Hu, Hui Jing, Rongrong Wang, Fengjun Yan, and Mohammed Chadli, focuses on path control and the lateral steering of an autonomous, self-driving car [2]. In this system, the desired path is determined through GPS data, and lateral differences between the car's position and the closest path point's position are measured and controlled by an arbitrary maximum yaw turning rate [2].

The goal of the car is to take a desired trajectory and match it as closely as possible. The purpose of this design is to allow an autonomous ground vehicle to steer and follow a path without resorting to using the the vehicle's lateral velocity data [2], doing so will result in cheaper manufacturing costs.

The main benefit of this design is its robustness to parametric uncertainties and external disturbances [2]. The uncertainties include tire cornering stiffness, vehicle longitudinal velocity, yaw rate, and road curvature [2]. The conclusion of the tests demonstrates how an autonomous ground vehicle can steer without resorting to expensive radar sensors which measure lateral velocity. However, the model does not consider any unexpected obstacles or changes in path. With this system, there are no forward-facing sensors that can detect any pedestrians or obstacles; the design emphasizes precision path following over general safety. Also, the path must be determined ahead of time, meaning the roads must be measured before the can can set off [2]. Services like Google Maps and Apple Maps have already done a massive amount of work to map the world's road networks, however this system requires precision data that does not currently exist; implementing this system would require re-mapping any and all roads that are planned to be used by the autonomous vehicle.

2.3 Lateral Cameras

One team, consisting of Dominique Gruyer, Rachid Belaroussi, and Marc Revilloud, designed a car that used lateral tracking cameras that accurately detected lane markings. The car they designed was equipped with two identical cameras, one on each side, both pointed towards the ground. Their purpose was to scan the road as the car moves and measure the distance from the lane markings to the sides of the car. The car is also equipped with a limited-refresh-rate GPS-receiver (updating once per second, or 1 Hz), a motion sensor that detects acceleration and rotation on three axes (X, Y, and Z), an odometer for measuring distance traveled, and a shaft encoder for measuring the angle of the steering wheel [3]. Note that these components all update fairly slowly with the exception of the the motion sensor; the parts are low cost in comparison to higher-end, comparable parts.

The main function of the steering system is to determine the axis of the road it's currently navigating and to follow it while moving forward. The cameras take in raw video and use an algorithm to detect primitive shapes painted onto the road (lane markings). The system turned out to be fairly inaccurate on its own; it could not remain on track once it lost its way [3]. However, with the addition of the GPS-receiver, the car was able to remain on the track during tests and consistently passed tests.

The main benefit of this system is the low cost to build; the cameras only required basic functionality and the various sensors require only limited functionality. However, due to the simplicity of the system, there are certain drawbacks. First, the road must be nearly completely clear in order for the camera systems to work; if the road is covered in any particulate (snow, dirt, sand, etc.) then the cameras will not be able to detect the lane markings. Second, the lane markings must be visible at all times. If the system encounters a road that is missing markings, the system will not be able to determine the axis of the road it is currently travelling on [3]. Third, the road markings must consistent, and the system must understand the markings before encountering them. Meaning, if the road markings are unique to one road, they system may not be able to understand its meaning. Luckily, most road markings are standardized (usually by country), so encountering a new type of marking is unlikely.

The system also has several implications. First, the cameras are lateral, therefore they only "see" what is to the side of the car. The system cannot prevent head-on collisions unless an additional front-facing sensor is added. Second, the system is limited to the design of modern roads. The system is only designed to find the axis of roads that currently exist, therefore if any aspect of the design of roads were to change the system would no longer be able to function properly [3]. The system operates on the assumption that roads will be predictable and marked with paint. This design is convenient for implementing self-driving cars that work on pre-existing roads, but if industrial engineers desire to update the design of roads alongside cars, this system will no longer be a viable option.

2.4 Internet of Cars

Keyvan Golestan, Ridha Soua, Fakhri Karray, and Mohamed S. Kamel described a safety system that employs situational awareness across a large number of nearby autonomous cars [4]. As they described it, their Internet of Cars network would allow autonomous cars to broadcast their position and velocity data. The main focus of the system is to ensure safety in crowded areas with many travelling autonomous vehicles.

In order for the Internet of Cars to function, it would require many levels of technological infrastructure. First, a large cloud-computing network is required for transferring vehicle information and any other potential process on that data. In order to reduce processing latency, the computers would likely need to be placed strategically over a large area, clustered around areas of high vehicle traffic. Second, the system would need specialized towers to connect the cars to the computer network. The connection would likely be made using either 3G/4G/LTE/WiFi/802.11p Wired or a combination of them to maintain a stable connection [4].

In practice, the Internet of Cars would be a consistent and suitable method for ensuring the safety of a congested self-driving network. However, the amount of available wireless bandwidth becomes the limiting factor when trying to implement such a massive network. Most cities are equipped to handle the transmissions from millions of unique smartphones, but the bandwidth cap is still a massive concern for the future of mass-media wireless communications (known as the "spectrum crunch"). The Internet of Cars would require a massive amount of infrastructure to be able to handle the new waves of incoming data, but even if the system could handle it, the limiting factor is the amount of physical space in the air (or the total bandwidth available).

3. Implications Toward Users

Many of the aforementioned designs for control systems do not consider the passengers inside the self-driving vehicles. They generally make the assumption that the systems will be implemented on top of standard, modern car designs (e.g. the steering system will be added to an existing car, rather than designing a new car around the new design features).

Assuming that the basic design of the car is unchanged, adding a new steering system requires considering the hidden implications.

3.1 Control Delegation

A major concern in designing a self-driving system is the amount of control the passengers have while inside the moving vehicle. Before the vehicle sets off, the user has control over the final destination (and possibly the route the vehicle will take, too), but once the vehicle begins moving, the delegation of control becomes an issue.

A delegation model was proposed in 1978 by Sheridan and Verplank (and later revised in 2000 by Parasuraman et al.), in which there are ten discrete levels of automation. When applied to a self-driving car, the lowest level of automation, level 1, offers no computer assistance to the driver (i.e. full manual control), and the highest level of automation, level 10, is considered fully autonomous. The levels in-between are a blend of user control and automated computer control.

Studies [5][7] found that when given the option of an automatic steering system, most people chose to only use it when it detected an imminent accident. Meaning, most people preferred to drive by themselves (level 1) until an accident scenario occurred and the computer would take complete control (level 10). While the other options (the computer asking permission to enter level 10, and the computer only ever warning about danger) were less popular, many still preferred them over the safer automatic kick-in.

3.2 Safety

The safety of the user is of utmost importance when designing an autonomous system; if the user has little control over the behavior of the system, then the ability to trust the system is paramount. The overall design for each model has its own implications of the amount of safety that model provides.

Google's Self-driving car, for example, focuses of a complete, 360-degree view of the surrounding area. Google aims for completeness since it wants to avoid any obstacle that vehicle may encounter, especially any people who may be in the path. Conversely, the methods that use limited sensors to save costs [2] sacrifice elements of safety; if the car cannot "see" everything around it, there is the chance of it not seeing a potential obstacle as it appears.

3.3 Comfort

The comfort of the user is also very important in the experience of a self-driving car. The car's design itself accounts for basic elements of ride comfort (suspension, steering sharpness, seat materials), but the potential unpredictability of the autonomous system can be off-putting for the riders inside the car.

The biggest concern for rider's comfort is the occurrence of motion sickness. Motion sickness already affects a sizeable portion of riders in normal cars. In order for self-driving cars to become part of normal society, the designers must consider the comfort and the implications of the well known consequences of carsickness [6].

4. Conclusion

Technology has improved in speed and cost to the point where it can now safely be used in a self-driving steering system for autonomous vehicles. Google's tests prove that the concept is not only viable but consistent. Competitors that use different techniques for steering also prove that it can be done relatively cheaply. Although the technology has been proven, the implications of switching to an autonomous driving system have not been fully realized and may be the largest hurdle when moving forward. The comfort and safety of the passenger are paramount when designing the autonomous system. Furthermore, manufacturers must prove to car consumers that the steering system is completely trustworthy and safe to rely on. The public's emphasis on safety will likely result in early self-driving cars in having redundant systems as a fail-safe to prevent any kind of vehicular accident.

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References

[1] Birdsall, M. "Google and ITE The Road Ahead for Self-Driving Cars" *ITE Journal-Institute of Transportation Engineers,* 2014. 84: 36-39.

[2] Hu, C. A., Jing, H., Wang, R. R., Yan F. J., Chadli, M. “Robust H-infinity output-feedback control for path following of autonomous ground vehicles” *Mechanical Systems and Signal Processing*, 2016. 70-71: 414-427.

[3] Gruyer, D., Belaroussi, R., Revilloud, M. “Accurate lateral positioning from map data and road marking detection” *Expert Systems with Applications*, 2016. 43: 1-8.

[4] Golestan, K., Soua, R., Karray, F., Kamel M. S. “Situation awareness within the context of connected cars: A comprehensive review and recent trends” *Information Fusion*, 2016. 29: 68-83.

[5] Richards, D., Stedmon, A. “To delegate or not to delegate: A review of control frameworks for autonomous cars” *Applied Ergonomics*, 2016. 53: 383-388.

[6] Diels, C., Bos, J. E. “Self-driving carsickness” *Applied Ergonomics*, 2016. 53: 374-382.

[7] Soudbakhsh, D., Eskandarian, A. “Steering control collision avoidance system and verification through subject study” *IET Intelligent Transport Systems,* 2015. 9: 907-915.