The Viability of Autonomous Vehicle Technology

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Abstract

This paper analyzes the status of autonomous vehicle technology and how it is implemented today. It then discusses factors such as technologic feasibility and marketability to make conclusions about whether or not self-driving cars may become successful as replacements from manually operated cars as they are now and possibly in the future. Manual cars have existed in the United States for over a century and they have become ingrained in our culture and day-to-day lives. Because of this, it is not safe to assume that autonomous cars will simple be accepted. It is important to debate this topic because driverless cars have the potential of providing huge benefits in safety and convenience idealistically, however, that is only the case if some shortcomings can be remediated first.

Keywords: robotics, autonomy, vehicles, sensors, security

1) Introduction

In 2013, the National Highway Traffic Safety Administration defined a fully autonomous vehicle as a vehicle that performs all safety-critical functions and constantly monitors its surroundings for potential hazards. To operate the vehicle, all that is expected of the driver is to provide a destination or some other form of navigation input, everything else is left to the car itself.[1] These safety-critical functions mentioned include everything from simply staying on the road and obeying regulations to reacting to incoming collisions or other spontaneous, hazardous situations.

The topic of autonomous vehicle technology is important because of the benefits it would offer if it were approved for commercial use. With a wide adoption of computer drivers, issues like falling asleep while driving or driving under the influence become less likely to occur. Poor decisions resulting from being unaware of surroundings or the pressure of incoming accidents also would be mitigated by taking out the human aspect of driving.[8] However, it is also important to consider the various barriers that prevent autonomous vehicles from being used commercially. The public transportation and automotive insurance industries would take a huge blow from the convenience and safety offered by robotic cars. Unprecedented hazards may also prove more dangerous than before without a sufficiently adequate artificial intelligence program running on the car.

This paper looks at what progress has been made towards developing a self-driving car and what more is needed before self-driving cars can be widely used in real driving situations by actual consumers. It will then analyze the actual marketability of autonomous vehicles and how the public transportation industry would likely respond to its emergence. Lastly, both the pros and cons of having self-driving cars commercially available will be overviewed to provide that remaining insights on how viable autonomous vehicle technology really is.

2) History

One of the earliest attempts at creating a driverless vehicle was in 1977 by the Tsukuba Mechanical Engineering Laboratory in Japan.[4] The car navigated by using white markers placed on the road and had a maximum speed of 20 mph; neither fast enough nor usable on normal, un-markered roads, this initial attempt at an autonomous vehicle was far from becoming a consumer product.[9]

Almost three decades later, the growth of autonomous vehicle technology became apparent though the results of DARPA's 2004 Grand Challenge where teams sponsored by top tier universities and tech companies raced their driverless cars for a chance at obtaining the one million dollar prize. Specifically, the challenge was to build a self-driving ground vehicle that could navigate a 142 mile desert course**.** Although the best scoring team was only able to travel 7.5 miles along the course, the level of interest shown towards the 2004 Grand Challenge inspired DARPA to create a second 132 mile desert race in 2005, which five teams completed, and a race though a complex, fully simulated, urban environment in 2007 consisting of moving traffic and simulated pedestrians. In total, six teams were able to complete this ramped up, more realistic course, showing the capabilities of driverless vehicles using the technology available at the time.[7]

In 2011, Nevada's Committee on Transportation passed assembly bill 511, creating a special license that would allow autonomous vehicles on Nevada roads.[2] The first licensed autonomic vehicle was a Prius modified by Google to be driverless. Since then, Google and many other tech and automotive companies have been able to make leaps and bounds, testing and improving their driverless cars in actual roads. As of March 2013, Google reports to make logged 500,000 hours of autonomous driving in unsimulated situations.[1] Even with the recent popularity and freedom given to testing self-driving cars, however, there is still not much data on rare occurrences such as crashes and autonomous vehicles still struggle with many common issues such as heavy rain or snow.

3) Features

Although many factors need to be considered in order to discuss how feasible self-driving cars would be commercially, the first question that often comes to mind is whether or not it's even possible to produce safe and reliable driverless cars with modern technology. As is typical in robotics, there exists both a hardware component and a software component to driverless cars. It is widely agreed that the best way to design a self-driving vehicle is to make the additional features added to the car as human-like as possible.[5] In terms of hardware and software, this means have sensors to perceive everything a human driver would need to perceive, from being aware of the positions of surrounding vehicles to the sound of ambulance sirens behind the car. On the software side, it's important to have code that processes the input from all of the car's sensors and used that data to make decisions without delay. When evasive maneuvers are necessary, every millisecond of processing time matters.

3.1) Hardware

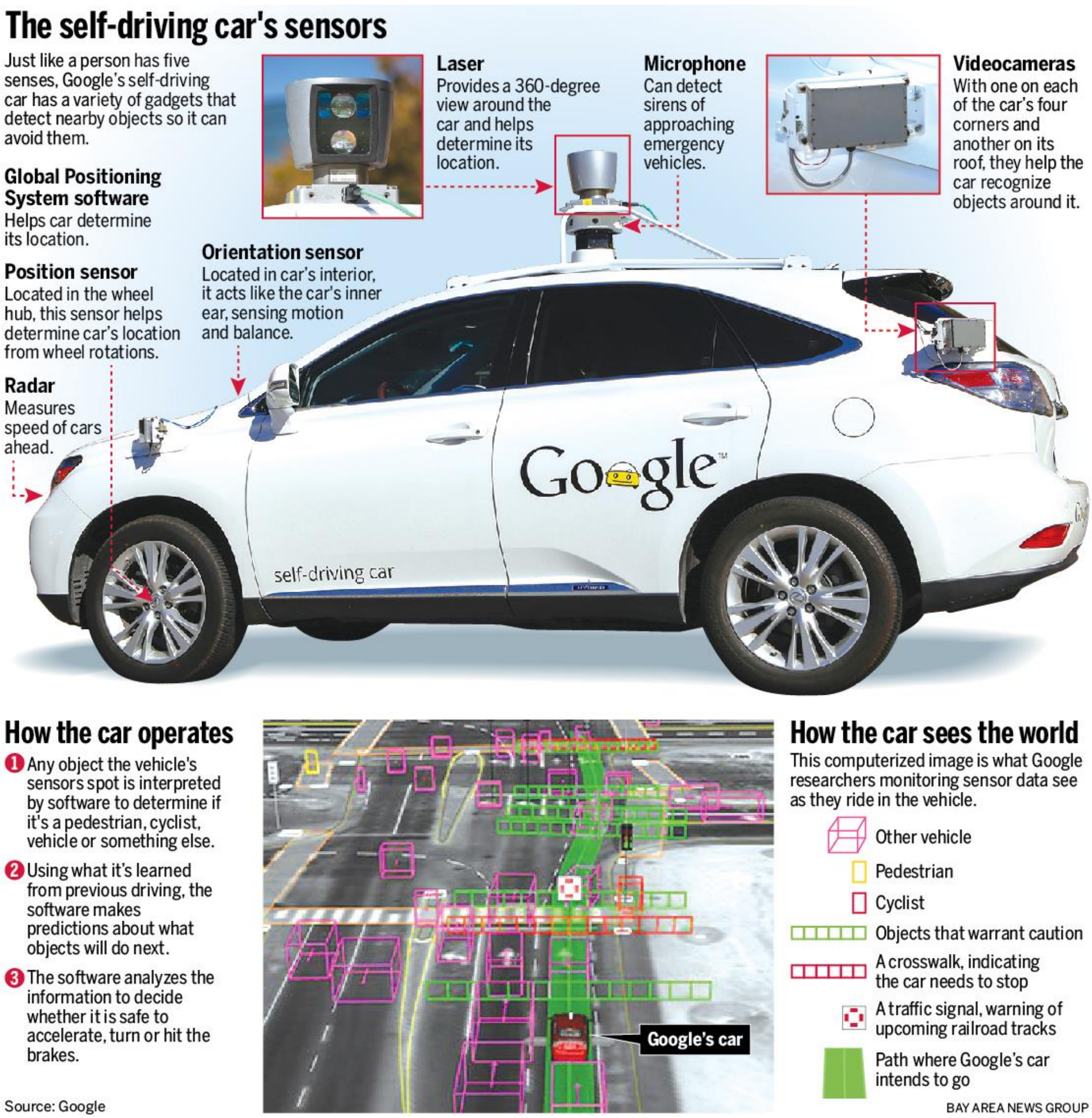

Figure 1: A diagram of the sensors on Google's self-driving car and a high-level description of how the software uses the information from these sensors.[5]

From Figure 1, it's apparent that a lot of technology is needed to even attempt to replicate what a human driver can perceive with ease. The traits that the sensors must account for include, but are not limited to: vision, and the ability to estimate an object's speed and its distance away from the autonomous vehicle; location and orientation, both geographically and in relation to other objects; and sound.

Vision is arguably what provides the most information for a driver. In order to determine when a car should turn, figure out whether or not it is okay to accelerate or merge, detect stop signs and traffic lights, or spot hazards, vision is a necessity. Of course, a simple camera would be able to gather all the information the human eyes can; however, there are other ways of gathering data that simplify the steps needed to process vision data. It is for this reason that the Google self-driving car has not only cameras, but also radar and a spinning laser mounted to the top of the car. Radars use either ultrasound or light to measure the distance of some object, simply reading the output of a radar to determine how far away a car is and using data over time to determine the car's speed is much less process-heavy than trying to tease similar information from frames of a camera feed. The rotating laser is necessary to simulate drivers' abilities to turn their heads and look at mirrors to check their surroundings. Instead of having a camera mounted on a slow rotating platform, it is much faster to have a quickly spinning laser to efficiently generate an up-to-date map of the area around the car. In some cases, however, cameras are still necessary; according to Figure 1, there are cameras mounted on each of the car's four corners and roof in order to recognize objects and read information like the color of a traffic signal or the words on a sign.

Typically, a driver driving in familiar territory does not need a map or GPS because they have committed important turns and landmarks to memory. Instead of using up storage space to navigate in a similar manner, Google's self-driving car relies on a GPS to locate its current location and destination. To improve the accuracy of the GPS in order to make well-timed turns, a rotation sensor is placed on the car's wheels. Knowing how much each wheel turns and the circumference of the wheels allows the autonomous vehicle to know precisely how far it has gone and at what angles it is turning.

The last sense that an autonomous vehicle must simulate is audioception, being able to detect sounds. Sounds are used while driving typically as a form of communication between drivers.[8] If a driver is attempting to merge and hears a honk, it is likely that the driver to the right did not feel comfortable with the merge happening. Drivers of emergency vehicles use sound in order to alert other drivers of their presence and to tell others to pull over so that they may pass. Without the ability to perceive sound, a driverless car would be unable to respond to any prompts by other drivers to do perform certain actions, this can often lead to unwanted if not dangerous situations.

3.2) Software

Innately, a computer has no idea what a cyclist is or how they can be identified and avoided. Human drivers own know how to safely deal with random potential hazards because they have been taught or have had past experiences where they saw some other driver deal with a problem in a certain way. It is also through past experiences that humans are able to learn what a “cyclist” looks like and how it behaves. In short, driving requires a repertoire of knowledge in order to identify certain objects, and some way of taking known information and using it to make solutions for completely new situations. There exists a technology in computer science that allows for these feats of machine vision; it is called an artificial neural network.

From the field of machine learning, the artificial neural network (ANN) a computational model based off the central nervous system of animals. With ANNs, it is possible for a program to learn for a set of inputs, just like the brains of animals. By feeding an ANN with many images of certain objects, say cyclists, it’s possible for a program to be made that can identify the objects that it sees somewhat accurately. Image recognition isn’t the only thing ANNs are capable of, by making decisions and then having its decisions rated, it’s possible to fine tune an ANN’s ability to make choices when faced with new problems.[10]

Aside from learning, a lot of the software necessary for the production of autonomous vehicles lies in the field of machine vision. As stated earlier, vision and vision processing are vital to the operation of a driverless car. Just as an example, machine vision programs are necessary for even the simplest things, things like traffic lights. Traffic lights present an issue for autonomous vehicles for a variety of reasons. Not all traffic lights are in the same place relative to the road, so machine vision technology is actually needed to determine both where is traffic lights are on the camera and which one applies to the lane the car is currently in. Also, it is necessary to know where a traffic light is expected to be so not all vertically aligned red, yellow, and green lights trigger the car’s response to traffic lights. Google has actually done significant research on traffic light detection alone in its paper “Traffic Light Mapping and Detection”.[3] One of the key barriers for the commercialization of self-driving cars actually has a lot to do with Google’s issues with traffic lights. Because there are so many rules involved in regard to driving, and so much variance in where signs are placed and how roads are mapped, a lot of processing power needs to go towards accounting for all these variations. On pre-scouted, tested routes like the ones that most autonomous vehicles are tested on, this issue isn’t very prominent; however, it will be quite the hassle to deal with if driverless cars were to become available to customers everywhere.

Marketability

Judging from the technologies available to manufacturers and programmers right now, autonomous vehicles can be made, but it is extremely difficult to write software that accommodates for enough scenarios for them to be safe and also universal. For now, it seems very feasible for driverless vehicles to become a form of local transportation within a certain area where every road has been scouted out and tested.

Disregarding the feasibility of autonomous vehicles, one must still take into consideration how much certain industries might be in opposition of self-driving cars. In theory, having driverless cars would decrease the number of car accidents that would occur just because it is not possible for a computer to be intoxicated or suffer from fatigue; this would be a huge blow to any insurance companies that get revenue from auto insurance. The public transportation industry would also be quite opposed to the idea of self-driving cars. Ideally, a robot car would act just like a personal taxi: it can park itself and find its way back to its owner, and the owner can travel without having to do any driving personally.

Potential Benefits

The automotive industry is currently dominated by manually driven automobiles. In order for the market to consider shifting towards autonomous cars, there needs to be tangible benefits to make the switch. In theory and from the results of various tests of self-driving cars, it has been shown that several key benefits exist that would increase the demand for autonomous vehicle technology even from drivers who already own manually automated cars.[6]

In 2011, over 5 million incidents of automobile crashes were reported in the United States alone. These crashes caused over 2 million injuries and over 30 thousand fatalities. (rand source) Needless to say, the amount of money spent on repairs and medical attention was also absurdly huge. Ideally, autonomous vehicle technology has the ability to reduce the frequency of automotive accidents. The sensors on self-driving cars provide up-to-date data on the car’s surroundings, so the computer has a better understanding of what is occurring around it than a human driver would. Also, computers today operate at speeds around of around 3GHz and do not panic under pressure, meaning the reactions of self-driving cars to incoming collisions have the ability to be more rational and better controlled. The fact that a passenger of an autonomous vehicle doesn’t need to be behind a wheel also means that there is no chance of suffering harm from airbag deployment.

In addition to safety, driverless cars offer the convenience of allowing their owners to travel without having to actually drive themselves. This is not limited to only being beneficial when one is intoxicated or fatigued. In large urban areas where parking is limited and scarce, owning a self-driving car would allow clients to be dropped off wherever they want and have the car worry about finding parking. If the car’s owner is worried about parking fees, they can just have their car park itself at a suburban area nearby. Furthermore, chores like picking up one’s kids from school or driving someone back from the airport could become automated. With a driverless car, own a driver’s license would not even become a necessity, giving potentially anybody the benefits of owning a personal vehicle.

Dangers

While the ideal self-driving car may sound amazing, there are a few issues that need to be dealt with before such a vehicle can become a reality. Many of these issues deal with safety, because a safe bare-bones autonomous vehicle is still marketable, while a feature-rich but unstable one is not. For this reason, the dangers of releasing self-driving cars to the public need to be discussed and solutions need to be found.

The first topic that needs to be discussed is why a lack of safety is the largest barrier holding autonomous vehicles back from widespread commercialization. The issue with finding and circumventing potential dangers is that events like car accidents and near-collisions are very difficult to produce or replicate.

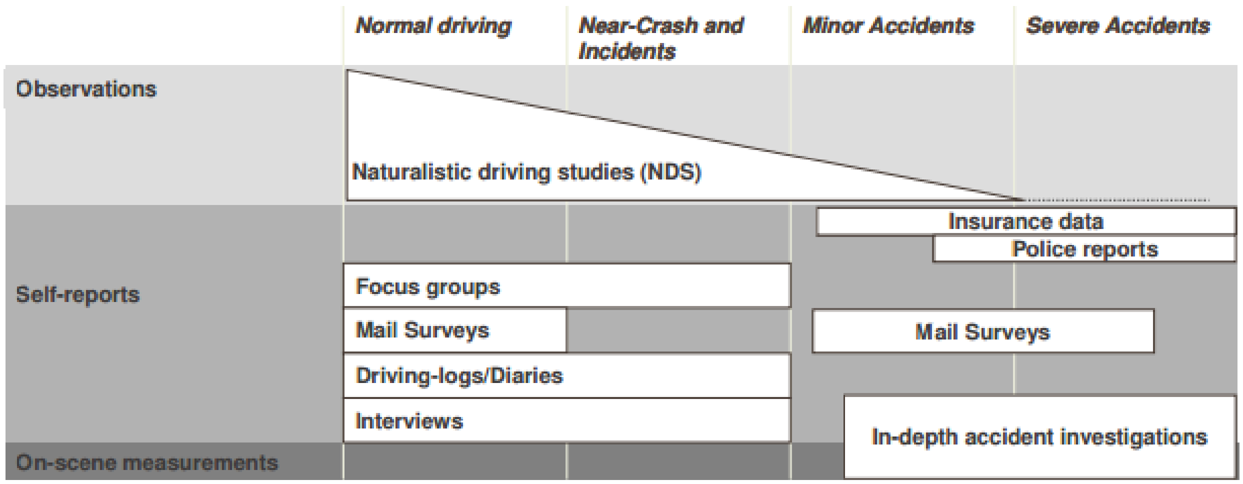

Figure 2: A summary of the different methods used to collect data on autonomous vehicles and the types of incidents each method covers.[8]

From Figure 2 above, it can be seen that there is much less data collected from accidents caused by autonomous vehicles than from them normally driving. This fact appears obvious, but it says a lot about what can be known about the dangers of self-driving cars. Because it's necessary to test autonomous vehicles in realistic driving environments to determine any realistic accidents that may occur, and because doing so would endanger the lives of other drivers and potentially result in very expensive repairs, not a lot can be easily known about the dangers that having an autonomous vehicle on the road entails. This issue is unavoidable without extensive amounts of money being spent towards producing accidents in controlled environments; however, data will be collect in due time as the technology matures.

Security plays a huge factor in regards to self-driving cars. As with most computer-operated devices, self-driving cars have the potential of being hacked in some way. A hacked autonomous vehicle can have some frightening consequences. While inside a fully automated car, a passenger has very little control over their environment: unless a manual override function or a physical break is added to the interior of the car, kidnappings would be very easy to undertake with a hacked car. Security breaches are issues that all computers need to deal with, the best way to handle them is to take precautions like setting up strong passwords and running a secure operating system on the computer such as linux or unix.

Conclusion

Autonomous vehicle technology is an emerging field that appears to hold a lot of potential as a technology that could change personal transportation as it is currently known. It has already been demonstrated through Google’s self-driving car that these vehicles can indeed exist, however several concerns about safety and processing power exist that prevent autonomous vehicles from being adopted yet. While these issues exist, they are bound to get resolved as more testing is done on self-driving cars and as the technology advances. What really matters is how willingly the automotive world will accept widespread usage of autonomous vehicles. Driverless cars threaten to damage the public transportation industry and auto insurance companies. However, it offers benefits that vastly increase the safety and convenience of transportation for anybody who travels. All in all, self-driving cars look like they will become viable and replace manually automated cars in time. The potential demand for autonomous vehicles should outweigh the voices of lobbyists for industries who would lose out after the acceptance of this technology.

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