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Viability of Autonomous Cars

Abstract
Autonomous cars, given the right technology, have the potential to make the human driver obsolete on public roads. It has been shown that, in some situations, the technology available to allow the driver to hand over full control to the car. In this paper, the current technologies and big players in the field of autonomous cars will be explored. Additionally, some of the advantages will be detailed including the ability to diminish phantom traffic and give the blind and elderly the freedom of driving. There are also many obstacles that will also be explored such as the ethics and legislation regarding self-driving cars. While autonomous technology may be ready in some situations, there is still a fair amount of development required before they can perform as well as or better than their human counterparts in all situations.

I.   Introduction

Autonomous cars, also known as self-driving cars, are vehicles that are able to operate without the need for human interaction. These vehicles have been a part of science fiction tv shows and movies for decades such as in *Knight Rider* and *I, Robot* in which the cars are able to function completely on their own but can also be switched into a manual mode so they can be human operated. More recently, autonomous cars have been showing up in the news for both the achievements and accidents in which they have been involved, showing that perhaps they are not entirely ready to replace their human counterparts.

In 2014, more than thirty thousand people died in car crashes in the United States alone [1]. These crashes could be the result of a number of different factors including distracted driving and poor road conditions, some of which can easily be controlled for. This is true for distracted driving in which activities such as texting or making a phone call are not necessary when operating a vehicle. However, it is a difficult thing to enforce and people are going to continue doing it despite the resulting accidents. One possible solution, and something that has been gaining popularity in the past few years is autonomous cars. The potential benefits of autonomous cars could be endless including everything from allowing the driver to sleep during long commutes to eliminating stop-and-go traffic altogether. However, this technology also comes with its own risks and downfalls. Many people worry that a computer will not be as safe in traffic or under poor road conditions as a human. There is also the age-old ethical concern of who the car should protect if there is no way around a collision and how the computer should be programmed to handle such a situation. Based on these concerns, is the technology for autonomous cars currently viable or will it be in the future and do the benefits outweigh the potential failures of the technology?

The first step in judging the viability of self-driving cars is to examine what current technology is available from companies in the field like Google and Tesla. Next, based on this technology the potential advantages can be detailed along with the concerns that many people have. Finally, the projected impact of autonomous cars on the future can be assessed .

http://www.nhtsa.gov/About-NHTSA/Press-Releases/U.S.-Department-of-Transportation-Releases-Policy-on-Automated-Vehicle-Development

II. The Present State of Autonomous Vehicles

Autonomous technology in vehicles can be defined as any action that is executed by the computerized system of a vehicle without the need for human interaction [2]. This includes everything from stability control to the use of radars for cruise control functions. In this way nearly every vehicle on the road has some form of automation. There are, however, multiple companies that are trying to push automation to the limits by using advanced sensors and computing in order to eventually manufacture fully autonomous vehicles. For this to happen, there are two essential things that a car needs to be able to determine in order to drive autonomously.

A. Determining Location

The first required information for an autonomous car to know is where it is going which it can identify by using an array of sensors [3]. A GPS (Global Positioning System) is the primary way for the vehicle to know where it is located in the world. Just like how a phone or navigation system uses a constellation of satellites to provide its location, an autonomous car can tap into the same technology to know where it is and where it is going most of the time [3]. GPS units are not perfect, however, and are completely useless when blocked by structures like canyons and tunnels or by radio interference. In situations like this, a different kind of sensor is required, namely an Inertial Measurement Unit, or IMU. This sensor features three gyroscopes to judge direction as well as three accelerometers to judge motion, one for each of the three axis [3]. In this way, the vehicle doesn't need external signals and relies only on its internal sensors to determine its location. IMUs can not judge absolute location and therefore a GPS is still required for essential initial information. These systems are both necessary for the operation of an autonomous car. Without them, it could still sense objects around it, but it would be driving blindly in terms of its final destination.

B. Autonomous Vision

Secondly, the car has to "see" where it is going [3]. This requires an even more extensive array of sensors which can all accomplish a similar task but some are better suited for some situations than others. The first technology is cameras which can be positioned to have a 360 degree view of the environment around the car. However, cameras use up a lot of resources in terms of both space and processing power. Furthermore, it can be difficult to keep them clean, they lack depth perception and they are easily affected by lighting conditions [3]. They are, however, much cheaper than some of the other available sensors such as the Light Detection and Ranging (LIDAR) sensor which can also provide 3D info of the surrounding environment. LIDAR works by sending out pulses of laser-light and using the response to form a 3D image of points [3]. Similarly, radars can be used to provide the same information for nearby objects. Therefore, LIDAR is currently only being used on non-commercial cars while cameras and radar, which are much cheaper are finding their way onto both semi and fully autonomous cars.

C. The Google Self-Driving Car

Perhaps the most iconic vehicle that uses this technology is the Google car which features what appears to be a fez for the roof of the car. In reality, the fez is a LIDAR sensor which is just one of the advanced sensors on the vehicle that allow it to "see" the world around it in a radius of 60 meters [4]. Based on the information it receives from the LIDAR, the vehicle is able to determine its position, speed and direction relative to the objects that it detects [4]. This is important in order to accomplish collision prediction and avoidance maneuvers safely. Also featured on the car are four distance sensors on the front and rear

bumpers. These radars are able to measure the distance of obstacles from the car and allow it to brake, lane-change and park itself which are concerned with closer objects that the LIDAR sensor can not accurately detect. There is also a single video camera mounted on the front of the car which is used to read road signs and stoplights and can detect moving objects. Finally, the car has a sensor on the wheel which is used to determine the car's position on a map [4]. This vehicle exemplifies the previous ideas of what is required for an autonomous car to function and shows the technology is already quite advanced and there is testing being done to assess its viability.

http://cet.berkeley.edu/wp-content/uploads/Self-Driving-Cars.pdf

D.Tesla Autopilot

Another player in the field of autonomous car technology is Tesla, headed by founder Elon Musk. While Google has developed a fully autonomous car all in one step, Tesla is incrementally working its way in that direction. This allows the company to release its technology to the public while it is still developing its vehicles. Therefore, Tesla cars provide assistive features to the driver, rather than a fully autonomous experience. Tesla has many of the same sensors as the Google car, but its vehicles are classified as a Level 2 automated system by the National Highway Transportation Safety Administration which means that it features two or more control systems that can be controlled autonomously [5]. Included with the electric cars that Tesla manufactures are a few different types of sensors similar to the setup of the Google car. Rather that just one camera, Teslas have eight surround cameras that provide 360 degree visibility at a range of up to 250 meters [5]. Additionally there are three times the amount of ultrasonic sensors positioned around the vehicle. Finally there is a forward-facing radar which is able to see through rain, fog, dust and even the car ahead [5]. The omission of the LIDAR allows Tesla to sell its products at a reasonable price that is within the price range of other new vehicles while also being fully electric. This helps to further prove the viability of autonomous cars since there are currently members of the general public that have access to the semi-autonomous features that exist in Tesla cars.

http://www.bbc.com/autos/story/20160428-how-ai-will-solve-traffic-part-one

II. Advantages of Autonomous Cars

Due to the advanced sensors and software that go into manufacturing an autonomous car and the fact that these cars are operated by a computer rather than a human means that they have the potential to have many advantages over modern vehicles. In the Google car, for example, there at least seven sensors constantly looking for obstacles at all time which is far greater than what a human driver can perceive at once[4]. Additionally, autonomous cars will be able to communicate with other cars and traffic signals around them which humans can only hope to accomplish with their horn [6].

http://www.bbc.com/autos/story/20160428-how-ai-will-solve-traffic-part-one

A. Communication

In addition to creating a safer environment for commuters, autonomous cars might also be able to shorten the amount of time a person spends in their car. According to David Gibson, "A traffic jam, by definition, is caused by all of us" [6]. When there is a large traffic jam on the interstate people will tend to think that maybe it was caused by an accident or that it traffic is just inevitable when really it was all because of one car's braking which created a ripple effect. The idea behind it is that when one person brakes abruptly, it causes the cars behind it to do the same. Once the front car starts accelerating again, the cars behind can

as well. However, there is now what can be described as a wave going down the line of cars which forces them each to decelerate before continuing which is known as "phantom traffic" [6]. The solution to this problem should not require autonomous cars, but it does when people drive aggressively with the objective of arriving to their destination a few seconds earlier.. To get rid of phantom traffic, people just need to get rid of the medium through which the wave travels; the cars themselves [6]. This means that if the space between cars is increased, people will not have to quickly react to cars ahead of them and therefore braking, which is the main cause of phantom traffic, will be unnecessary.

A solution to this problem is communication between cars which is where autonomous cars will really excel. Modern technology only allows for a few means of communication between drivers including turn signals, horns and dirty looks which allow for minimal cooperation between drivers. Autonomous cars will communicate with each other and therefore will know what cars around them are doing without needing to have direct perception of the other vehicles [4]. This helps in avoiding collisions as well as reducing the aforementioned phantom traffic. With the ability to quickly send, capture and retransmit incoming signals, autonomous cars could easily warn cars a mile behind of slowdowns ahead [4]. Arising from this communication could come multiple new applications for alerting vehicles including "Speed Harmonization" which would dynamically set the speed limit and "Queue Warning" which would alert other vehicles to traffic jams ahead [6]. In this situation, autonomous cars are both a luxury and a necessity in larger communities where traffic jams are common and could make commutes safer and quicker.

http://www.aarp.org/home-family/personal-technology/info-2014/google-self-driving-car.html

C. Opportunity for the Elderly and Blind

It is dangerous and illegal for blind people to drive and as people get older, it gets increasingly dangerous for the elderly to drive as well. Currently, there are more than 45 million people over the age of 65 in the U.S. and that number is going to continue to grow [7]. This means that there is a growing number of people on the road who are at risk for deteriorating vision and reactions. The majority of these people also live in suburbs where they are dependent on cars for transportation. Therefore, the elderly are either at a greater risk of crashing or otherwise they have to give up driving which provided them freedom. In the future, it could be as simple as getting into a car, saying where you want to go, and getting there more safely and efficiently than with standard cars today. For now, there are already many features that aim to make the human-operated driving experience safer and there are many more in development. This includes systems that assist in lane changing and parking [4]. These features in combination with sensors and upcoming software that will enable vehicle to vehicle communication can make driving safer for these people and, in the future, make driving unnecessary.

III. Obstacles to Overcome

As with any new technology that hits the market, there is a lot of skepticism as to how well the technology works and whether or not it is worth investing in. With autonomous cars this skepticism is even higher due to the fact that, while they might have great advantages, they create a danger not only for the operator but also for pedestrians and other drivers on the road.

https://www.bloomberg.com/news/articles/2016-02-10/robot-cars-succumb-to-snow-blindness-as-driving-lanes-disappear

A. Dangerous Conditions

With 70 percent of the U.S population living in the areas with some amount of snowfall, snow, ice, and dust are some of the biggest dangers that face the develop of autonomous cars [8]. All of these are particles that can cover up sensors and confuse the car as to what it is looking at. Cameras and lidar sensors can easily be covered up by snow and falling snowflakes can affect the image processing algorithms of the car. Snow can also obscure road markings and signs. Currently, if a Tesla car becomes confused, it requires that the driver takes back manual control. This is a temporary fix for now, but if autonomous technology is to advance to a place where human intervention is unnecessary, new technology needs to be developed. One way this is already being accomplished is by utilizing a large array of sensors. In this case, radars are the most reliable at functioning in adverse conditions and are what are currently being used in adaptive cruise control for this reason. Trying to push the technology further, Ford is developing software that can filter out "noise" caused by snowflakes [8]. Combining this technology with data from 3D maps, they claim to be able to pinpoint the location of the car within a few centimeters. Perhaps the most viable solution is the use of artificial intelligence. This way, in a similar fashion to humans, the car could learn and adapt to changing conditions and therefore be prepared for virtually any situation that could occur. Additionally, icy conditions already pose a threat to human drivers and it's not certain how well computer-driven cars will react to these dangerous conditions. However, technology is in development and it could be just a matter of time before autonomous cars are superior to humans in risky situations.

https://www.technologyreview.com/s/542651/drivers-push-teslas-autopilot-beyond-its-abilities/

B. Incorrect User Operation

As autonomous technology is developing, companies like Tesla are incrementally releasing their autopilot functions to the public which are giving more control the car and the opportunity for less control by the operator. Tesla's autopilot is a automated driving system which is meant to be used to assist drivers on the road and not as a fully autonomous car. Currently, it is designed to be used for highway driving and the driver needs to be ready to take over if the software gets confused or makes a mistake because of unknown conditions. However, there are people that are trying to use the software as a fully autonomous system which is resulting in dangerous driving and near crashes [9]. It is these kinds of actions that cause people to be skeptical about the future of self-driving cars. In reference to this Alain Kornhauser, the director of the transportation program at Princeton University says "you have to show some respect, because you're driving a lethal weapon" [9]. For autonomous technology to continue incrementally, drivers need to understand the severity of not using the technology in the way that it was intended.

http://spectrum.ieee.org/transportation/self-driving/can-you-program-ethics-into-a-selfdriving-car

C. Ethics

How should a self-driving car react when faced with a moral decision? This question addresses another big issue that autonomous car manufacturers face before releasing vehicles to the public. By its nature, there is risk involved with all forms of driving. Dealing with these risks such as the risk of hitting a pedestrian or another driver requires an ethical choice. There are a few different directions in which the programming of an autonomous car could go in terms of how it makes these choices. The first option is

to force the car to never break the law [10]. This means that it would not cross over a double yellow line even if there were a pedestrian ahead. Therefore, it is a better option to allow the vehicle to have some amount of judgement so that it can decide, similar to how a human would operate, what course of action is best. Google is already putting this to the test in an application they have patented which assigns potential outcomes a likelihood and a positive or negative magnitude. If one outcome's benefits outweigh its costs, it will choose to execute that action [10]. The issue with this, however, is deciding how much judgement to give to a computer and how to prepare it for situations like the "trolley problem" in which it could either hit a pedestrian straight ahead or swerve into oncoming bus, potentially causing many more casualties [10]. In this way, an autonomous car needs to be able to weigh the benefits and costs as well as consider all options and the likelihood of each option resulting in more costs than the others all in a very small amount of time. Luckily for autonomous car manufacturers, the public does not need vehicles that can produce superhuman wisdom. The decisions made just need to be "thoughtful and defensible" [10].

http://www.ncsl.org/research/transportation/autonomous-vehicles-legislation.aspx
D. Legislation
Even if autonomous cars can be shown to be a superior option to human-operated vehicles, it will still be a while until they can begin to be utilized due to current state legislation. According to the National Conference of State Legislatures, most states have introduced legislation which would allow autonomous vehicles to be used with the requirement that it is used for testing purposes and there has to be a human in the car with the ability to take over control if needed [11]. Some states such as California and Nevada, however, allow autonomous cars to be without pedals, steering wheels and passengers as long as some other requirements are met [11]. As autonomous technology continues to develop and become more viable, legislation will continue to be passed to limit the operation of these vehicles and it will have to be through extensive testing that they will finally be ready to be placed in hands of the public. If the technology proves to be as viable as many of these sources say it is, however, it should be easy to show its advantages and therefore legislation will change in a way to accommodate for the future of autonomous cars.

http://cet.berkeley.edu/wp-content/uploads/Self-Driving-Cars.pdf
http://money.cnn.com/2015/04/03/autos/delphi-driverless-car-cross-country-trip

IV. Conclusion
With the direction in which large car manufacturers like Tesla and Ford are directing the future of their vehicles, it seems like autonomous cars are a guaranteed technology of the future. Additionally, a driverless car created by Delphi was able to drive autonomously from coast to coast of the United States in 2015 [12]. Using problem solving techniques and advanced sensors it was able to face the majority of complicated situations that it was faced with on its own. This shows that, to some extent, autonomous cars are already viable, just a bit more time, research and testing is required. Hence, it is important to consider the implications of the technology on the world. As with any automation technology, or any technology for that matter, there will always be some clear winners and losers. The obvious winners car and software companies that choose to participate in the release of the new technology including Google, which can license its maps and traffic, software makers like IBM and car manufacturers like Tesla. Ride

sharing companies like Uber will also benefit since it will no longer be necessary for them to share their profits with human drivers. Finally, people who rely on cars as their primary transportation, and the public in general will benefit from the safety and convenience that autonomous driving will provide. While these people will win with this technology, there will also be losers including traditional auto manufacturers and taxi drivers, Also since there will be potentially fewer accidents, auto insurance companies and the auto service industry will suffer. These are the costs that will need to be faced if autonomous cars are to become viable and the losers will have to learn to adapt to the changing conditions. With this is mind, the future appears bright for the introduction of autonomous vehicles, the only thing holding it back now is time.