Title: Autonomous Cars: An Incremental Innovation

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Abstract

This paper describes the market for autonomous car. It also throws light on the working principle of autonomous car and also discusses the impact of autonomous cars.
The paper describes some of the autonomous car features present in todays car.

Introduction

An Autonomous car is a car that can drive itself without human input. Autonomous driving is predicted to be the next big disruptive innovation. Autonomous cars use radar, laser light, GPS, odometry, and computer vision to detect their surroundings. Figure 1 is a timeline of few important events [1]. Companies such as Tesla, Mercedes-Benz, Toyota, Honda and Ford are in the race to build autonomous vehicles. These companies are investing a lot on their R&D to stay in the race. Most companies are using an incremental approach to get to fully autonomous. They will add autonomous features in existing cars which allow them to test them in real conditions. Features such as automated parking assistant, adaptive cruise control, Autonomous highway driving are considered as incremental changes that leads to fully autonomous cars [2]. Google on the other hand wants to release a fully autonomous car to the market. In Google's point of view there won't be any driver to intervene. Google's approach is not only technically difficult but also faces number of regulatory issues.

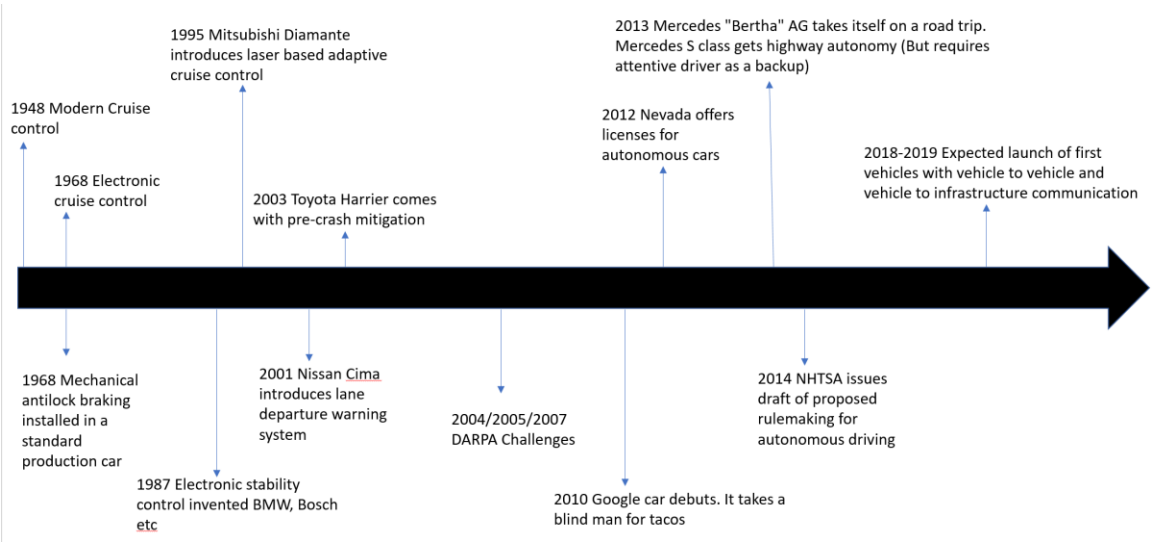

Figure 1. Notable events [1]

Not all vehicles are fully autonomous today. They may be termed as semi-autonomous or highly automated vehicles and still require driver intervention. Three to four years down the lane many car companies would probably start producing fully autonomous cars. It is reported that in United States 81 percent of the car crashes are because of human error, having a self-driven car would take a lot of danger out of the equation entirely. These self-driven cars are designed to efficiently accelerate and brake hence the fuel efficiency will improve and there will be a reduction in carbon emission. In order for autonomous cars to operate most efficiently they would need to communicate with each other in order to identify problems related to traffic and risks on the road [3]. Uber in Pittsburgh has begun picking up passengers in self-driven cars, albeit with driver ready to take over in case of an emergency.

Market for Autonomous Cars

The Autonomous Cars/Driverless Cars Market demand is expected to reach 138,089 units by 2024 [4]. This growth is attributed to reducing the number of accidents caused due to

human error. According to International Organization for Road Accident Prevention, more than 90% of road accidents across the globe are caused primarily due to human errors [4]. National Highway Traffic Safety Association (NHTSA) suggested that using autonomous vehicles in the U.S. alone could save more than 69 lives every year. Figure 2 is a representation of the projected autonomous car market 2017 to 2024. It is projected that the autonomous features would bring in a revenue of $250B by the end of 2030 and the revenue from the features will grow 15% in Compound Annual Growth Rate from now to 2024 [2]. It is expected that autonomous vehicles will bring in a revenue of $80B and 25% of the cars will be self-driving by 2030 [2]. The United States and Europe are the early adopters but there is a possibility that China would take over Europe as the second biggest market for the vehicles by 2030.

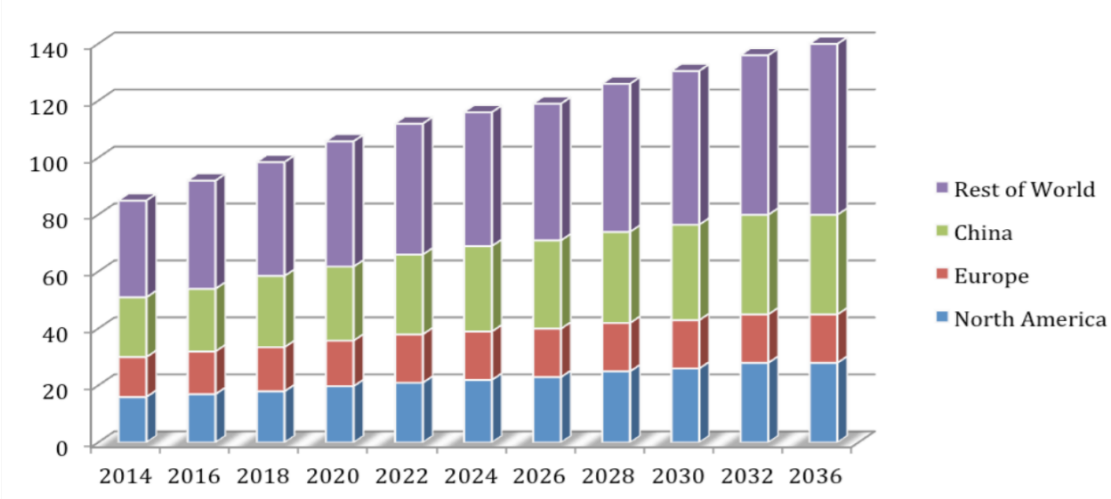

Figure 2. Global Autonomous Car Market 2017-2024 [2].

Figure 3 is a representation of big companies working on driverless cars [5]. Hotspot for research and investment in Silicon Valley is on the future of transport. According to a survey there are around 263 companies working on autonomous cars [6].

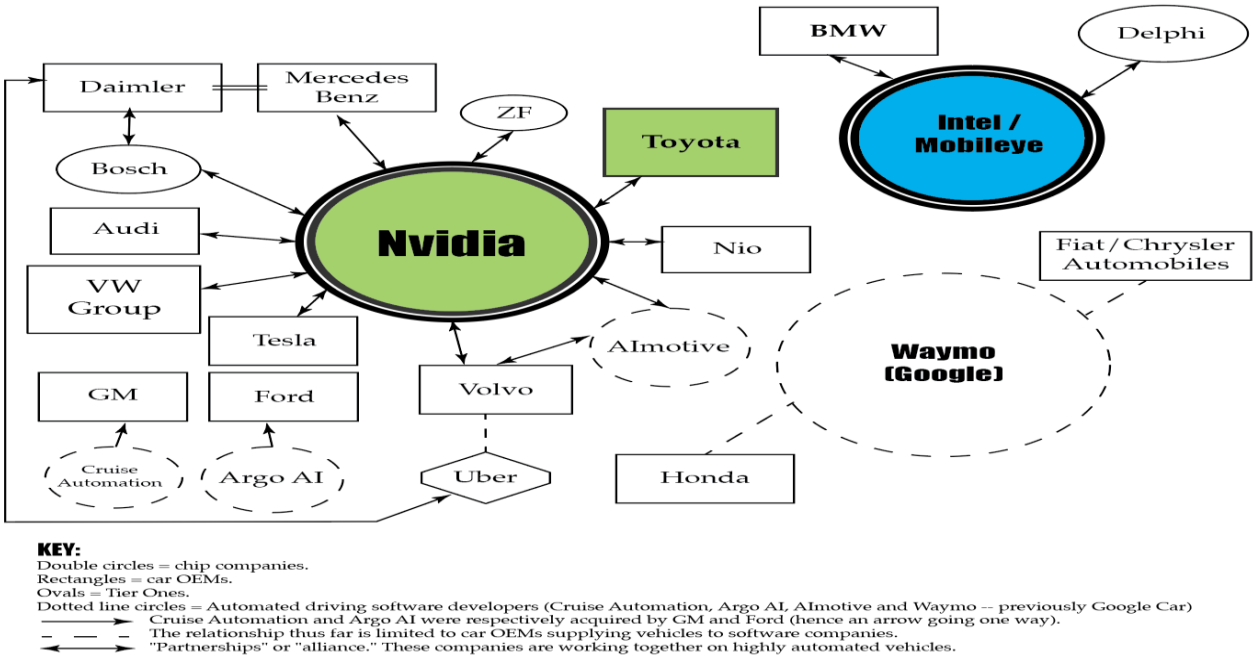

Figure 3. Representation of Top Companies working on autonomous cars [5].

The driverless cars are expected to be launched in two phases: Phase 1 – beta testing or testing at the consumer's end and Phase 2 –commercialized cars. Additionally, universities have taken a keen interest in the development of the technology and have collaborated with different manufacturers to instigate research [4].

Working of Autonomous Car

Self-driving cars can be successful by implementing efficient Advanced Driver Assistance System (ADAS). Many car manufacturers have already incorporated these systems. ADAS uses a combination of sensors with actuators, control units and integrating software to enable cars to monitor and respond to their surroundings [7]. Accident avoidance system based on brain response of driver on the road is also revealed. In this system head mounted sensor arrangements cap being worn by driver which checks the alertness of the driver an in case of careless driving the engine speed will be automatically controlled. Figure 4 shows the basic components in an autonomous car [8].

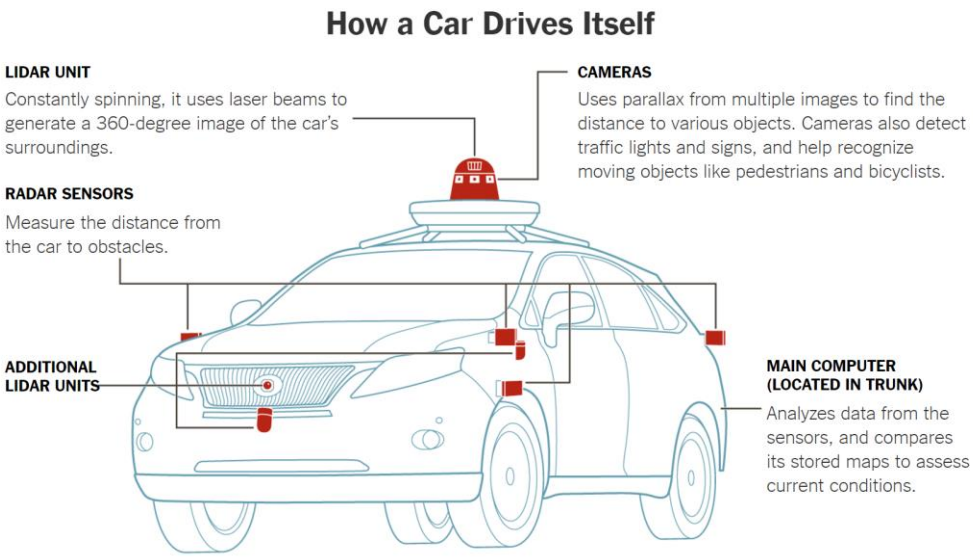

Figure 4 components of an autonomous car [8]

For example, Google's autonomous car is powered by an electric motor with around a 100-mile range, it uses a combination of sensors and software to locate itself in the real world combined with highly accurate digital maps [9]. A GPS system is used in most cars, to get a rough location of the car, at which point radar, lasers and cameras take over to monitor the surroundings of the car (360 view).

The software can recognize objects, people, cars, road marking, signs and traffic lights, obeying the rules of the road and allowing for multiple unpredictable hazards, including cyclists. It can even detect road works and safely navigate around them. The new prototype has more sensors fitted to it that can see further (up to 600 feet in all directions) and in greater detail than the ones available on the previous repurposed Lexus and Toyota vehicles [9]. Figure 5 is basically what the autonomous system in the car will see [8].

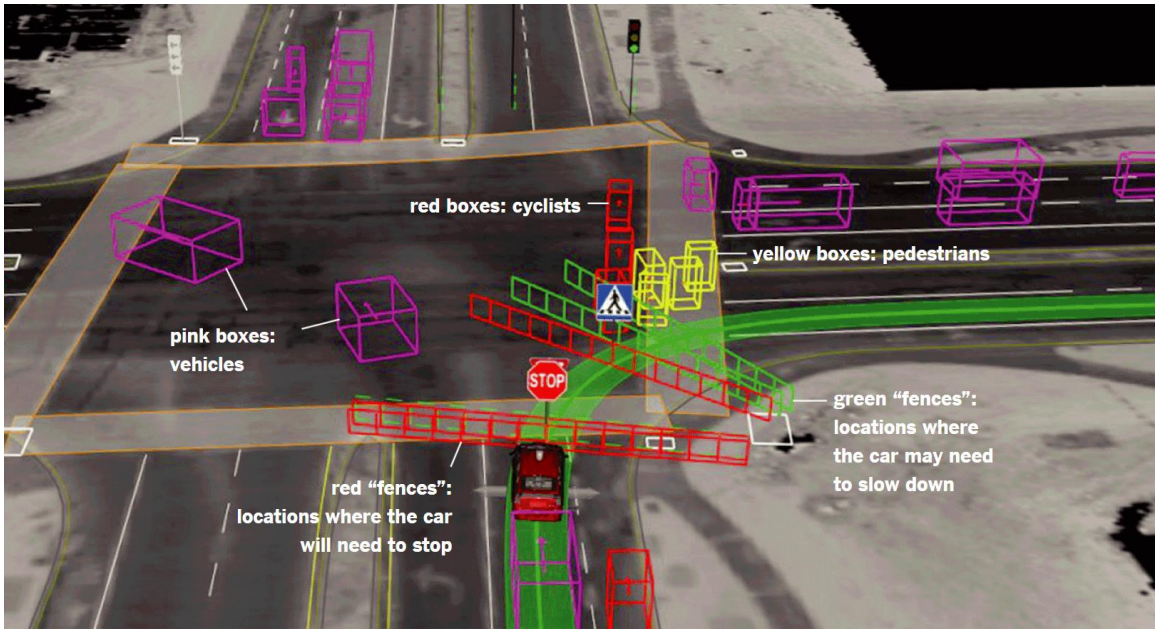

Figure 5. 360-degree view of the autonomous car system [8]

Dedicated Short Range Communication (DSRC) is the technology which has the potential to make an impact for self-driving cars. This technology could be used for vehicle to vehicle and vehicle to infrastructure communication. Figure 6 is the block diagram representation of this technology. It is the only short-range wireless alternative that provides fast network acquisition, low latency, high reliability, priority for safety applications, interoperability, security and privacy [10]. Figure 7 shows range and layout of DSRC system at four-way intersection [11].

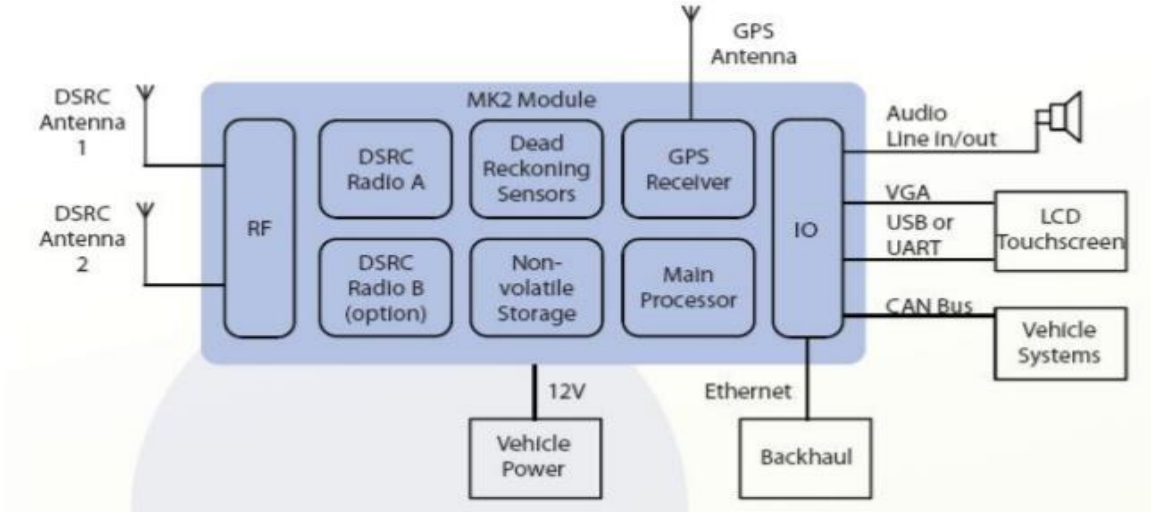

Figure 6 Block Diagram of DSRC technology[7]

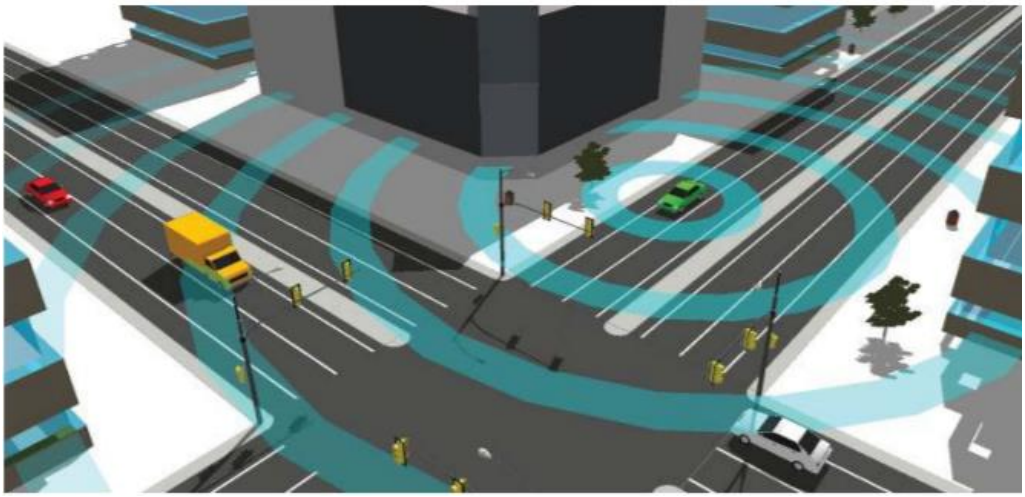
Figure 7 DSRC system at four-way intersection [11] [12]

Autonomous Car Features on the Road Today

Carmakers are charging between $3000 on midrange to $15000 on luxury models [2] for these features.

1. Adaptive Cruise Control:

   This feature is available for over a decade. This feature adjusts the speed of the car depending upon the vehicle in front of you. It can also maintain a desired

following distance. The best systems can bring a car to a complete stop and get it started again once traffic in front begins to move. Figure 8 is an illustration of adaptive cruise control.

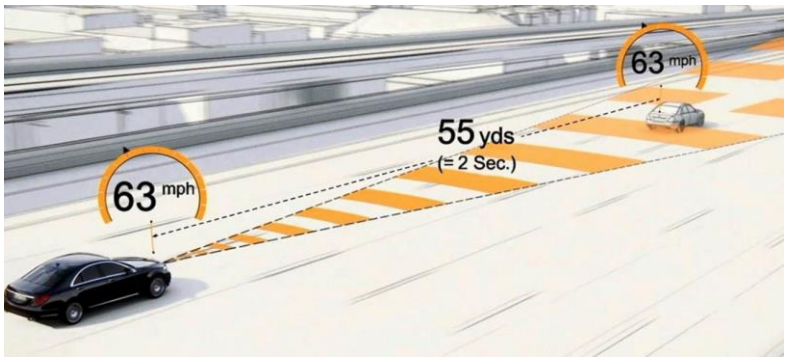

Figure 8. Adaptive Cruise Control [13]

2. Automatic Forward Collision Braking:

   This feature is rapidly increasing. It is offered in a large range of cars from compact to luxury. forward-collision braking systems detects an about to happen collision on the front-side and alerts the driver to the possible accident ahead and also quickly applies the brakes in order to ensure the car stops in time. Figure 9 is an image of automatic forward collision braking at work [13].

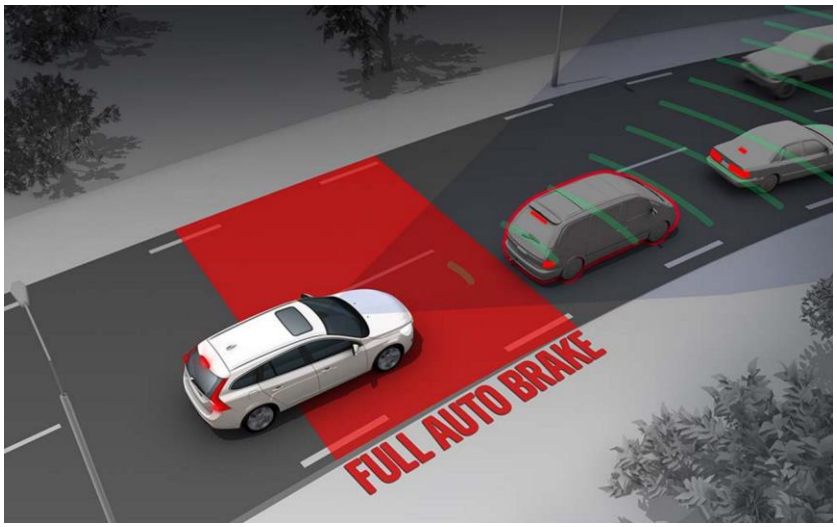

Figure 9 Automatic forward collision braking [13]

3. Automatic Parking:

This is the latest feature. These systems can decide whether a vehicle is large enough to fit in a certain parking spot and then automatically steer the car into the spot. While some versions only control the steering, and require drivers to work the brake and gas pedals, other versions do it all for you [13]. Figure 10 shows an image of automatic parking.

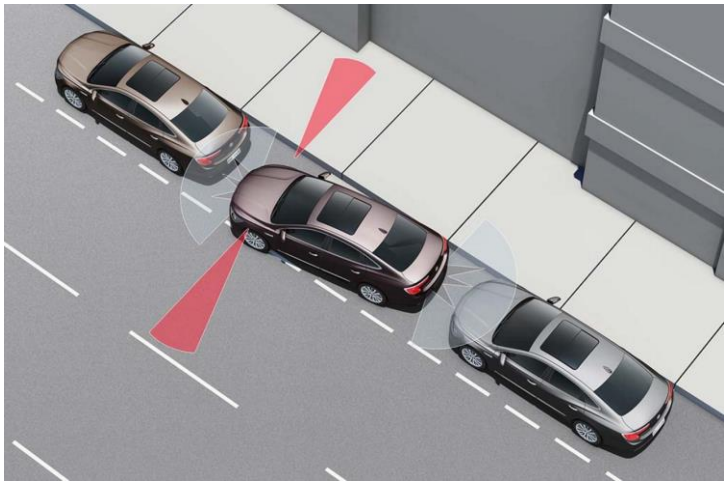

Figure 10 Automatic Parking system

4. Autopilot:

   Tesla's Autopilot system is possibly the most advanced autonomous system available in the market today. While many automakers are focusing on making sure vehicles remain in their lanes (lane-keep assist), avoid collisions (forward-collision braking) or slow down and speed up based on traffic (adaptive cruise control), Tesla has put together every piece of the puzzle in the best and most useful way possible [13]. Though the system won't work in some conditions, Tesla reminds drivers to always keep their hands on the wheel.

5. Lane Keep Assist:

Lane-keep assist will automatically steer you back into your lane should you start to drift out. There are a few limitations to lane-keep assist systems. They won't work if lane lines aren't easily visible.

6. Sign recognition:

   Road-sign recognition is a tool that automatically views signs on the side of the road and relays that information to the driver. This system will automatically capture and display the sign. Figure 11 shows an illustration of this system

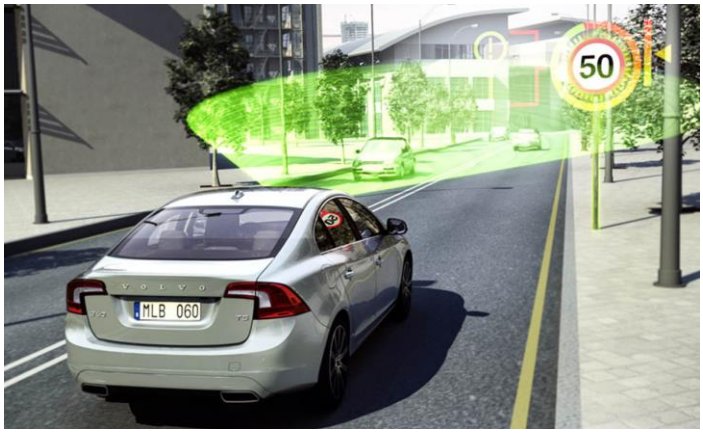

Figure 11. Sign recognition system

7. Steering Assist:

   Several high-end luxury cars like the BMW 7 Series, the Mercedes-Benz S-Class and the Volvo S90 offer full steering-assist systems in addition to more common autonomous technologies like lane-keep assist and adaptive cruise control. While steering-assist systems from these are not as good as Tesla's Autopilot system, and they usually only last a few seconds or a minute before handing control back to the driver, but the idea is similar [13].

Benefits and Threat of Autonomous Cars

Major benefit of autonomous cars is safety given that there are more than a million road accidents globally each year [14]. There would be reduction of accidents due to human error. Autonomous cars can help drivers to drive globally in all conditions for example an autonomous car could help an Indian driver (drives left side of the road) to drive in US (drives right side of the road).

Another expectation is that there would be minimum human interaction during the travel which increases the driving disutility, increasing comfort and offering the opportunity to engage with other work or leisure activities while on board. Traffic and fuel efficiency will greatly improve. People might start using self-driving taxis and the total number of cars on the road will decrease. These vehicles are designed to optimize efficiency in acceleration and braking they will help improve fuel efficiency and reduce carbon emission.

An article from Forbes [15] points out there is also a cost saving associated with time. According to [16] self-driving cars in large number participate in a behavior known as platooning, which would significantly improve traffic conditions and congestion. This would help to reduce commute times for drivers in high-traffic areas but also to maximize on gasoline usage. Over time, higher speed limits might be considered as an option if more people are using self-driving cars. Since the computers calculate operation of the vehicle safely, driving time could be reduced by faster speeds allowed on the road [17]. Drunk driving incidents should decrease, because there's no designated driver needed when the car drives itself. Sensors in the autonomous cars allow vehicles to ride closer together, therefore allowing more cars on the road with actually less traffic [17]. Less

parking structures and parking headaches would be required, since your car could actually drop you off and locate a parking space farther away. Self-driven cars would help senior citizen travel around hassle free.

There are some cons of autonomous cars [17]. The cost of implementing the new technology could be way out of reach for most Americans. Currently, the engineering, power and computer requirements, software, and sensors add up to more than $100,000. Probably this cost will come down once mass production starts.

The most savings in terms of cost, time, and lives is going to come from when more people "opt in" to the service. If self-driving cars are not adopted widely, accidents can and will still happen [17].

In order for a computer to operate a vehicle, a lot of information would have to be stored on the software. Some individuals are concerned about the opportunity for a computer built into the self-driving car to collect personal data.

Even though there are concerns about the adequate nature of public transportation, self-driving cars would eliminate many jobs in the transportation sector, especially when it comes to freight transportation and taxi drivers. This could have a negative impact on the unemployment rate and the economy [17]. If other technology fails, such as traffic signals that the cars rely on, there's no accounting for human traffic signals. Cars cannot interpret human signals. It's unclear how self-driving cars would maneuver through hazards like roadblocks or unique local driving laws. A good example is the difference between states regarding turning right on red. The computers could have difficulty identifying the different local and state rules with regard to the road.

Problems for Autonomous Cars that need Solution

Tesla Model S was involved in the first fatal crash while Autopilot was activated. Tesla wrote in a blog post that the system did not notice “the white side of the tractor trailer against a brightly lit sky so the brake was not applied” [18]. It shows that despite how far autonomous technology has come, there are still some situations that are better handled by human drivers.

Driver less cars struggle going over the bridges. This is because the roads are mapped so that the driverless car can compare what its seeing with what is supposed to be there helping it avoid objects and pedestrians. Bridges do not have environmental cues like surrounding buildings, it is hard for the car to figure out where it is. GPS helps the car position itself, but not to the accuracy the company would want. Uber has this issue with its car [18].

Heavy snow and rain tend to confuse LiDAR sensors and also cameras. LiDAR refers to the light sensing radar that uses lasers to map the car's surroundings so it can "see" the world. When there's snow on the ground, the cars' LiDAR sensor and camera have a difficult time seeing the lane markers and other markers that help them drive safely.

To overcome this Ford created high-resolution 3D maps that come with information not only about the road, but also what's above the road, like its topography and nearby signs and landmarks. This way, when the car can't see lane markings, it can use landmarks to pinpoint itself on the map [18].

Driverless cars struggle on roads without clear lane markings. Tesla CEO Elon Musk vented about this problem to a group of reporters in October, according to the

Washington Post [19]. When driverless cars can't distinguish the lanes, it makes it nearly impossible for them to drive or change lanes safely.

Driving in cities is much harder for autonomous cars than cruising on the highway. Cities are a mess of pedestrians, cars, potholes, traffic cones [18]. Driverless cars have a lot to keep track of, and it can be easy to miss something. It is hard to receive GPS where there are tall buildings. Robot cars can't interact the same way humans can, which is problematic. Human drivers try to merge onto roads with cars traveling at higher speeds, they tend to inch forward to make sure it's ok. Often, people will pull out in front of traffic under the assumption that cars will slow down for the merge. But a driverless car probably wouldn't take that risk because if it projected the velocity of the upcoming car, it would pull back to avoid a crash [18]. There are lot of research and development going on hopefully in the upcoming years the carmakers would find a solution to all the above-mentioned scenarios.

Autonomous vehicle regulations must provide that driverless cars gather only the information necessary to operate the vehicle and retain the data only as long as necessary for the vehicles operation. “Failure to act should mean substantial privacy risks from the manufacturers’ driverless car technology if there are not protections from what Google is best known for collection and use of voluminous personal information about us and our movement” [2]. There should be strict rules and regulation by the government to protect one’s privacy.

Insurance Industry

Questions of liability in an accident involving at least one party operated by a self-driving vehicle are also unclear and open to interpretation. At least for now, coverage for cars

using self-driving technology works the same way as coverage for traditional vehicles, according to the insurance industry.

When an investigation of the accident is completed, the insurer of the driver at fault pays for injuries and damage to others, up to the limits of the policy. There is a potential question about whether the driver or the software is at fault. The insurer would pay the claim and then have the right to subrogate or file a claim against someone else, like the manufacturer or another insurer to recoup its payment. The auto insurance industry and lawmakers should come up with rules and regulation for autonomous cars.

Since the autonomous car would definitely reduce the rate of accident the insurance premium prices would fall and the auto insurance industry would be affected and reduced to a $20B industry leaving little room for today's larger insurance firms. A fully autonomous vehicle can only be perceived as a massive threat and disruption to the health of the existing industry [2].

Conclusion

Many individuals are nervous about handing over all the power to a computer, which could malfunction and put the driver in a more dangerous situation than if the driver were manning the vehicle himself or herself. GPS devices are not always accurate. There are security concerns about self-driving cars, too. If carmakers can work around a solution for the drawbacks of the fully autonomous cars then this innovation would definitely be the next big profitable thing in the market.

Autonomous cars will greatly impact us. It will make driving safer, more convenient, less energy intensive and cheaper. It will reduce carbon emission and also the number of

deaths in an accident. Semi and fully autonomous car adopters, component suppliers and sensor manufacturers would make a fortune if this works out. Rental and ride sharing companies will flourish as more people would move from car owners to ride-sharers. Younger and older adults will be early adopters of the new model. Traditional automakers, taxi services and professional drivers, auto insurance companies, auto service industry will be severely impacted.

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