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A Critical Review on Autonomous Vehicle

Raghu Ram Kistamgari, Dharamsoth Srinivas Naik, Prasanthi Musunuri, Sanne Srikanth

* Department of Mechanical Engineering, Vidya Jyothi Institute of Technology, Hyderabad, T.S., India
Department of Mechanical Engineering, Vidya Jyothi Institute of Technology, Hyderabad, T.S., India
Assistant Professor, Department of Mechanical Engineering, Vidya Jyothi Institute of Technology, Hyderabad, T.S., India
Department of Mechanical Engineering, Vidya Jyothi Institute of Technology, Hyderabad, T.S., India

ABSTRACT

Of late, the demand for autonomous vehicles is increasing rapidly with the advancements in the fields of science and technology. The current paper encapsulates the complete details of the autonomous vehicles. It discusses the background, working and applications of autonomous vehicles. The scope of the paper further includes the discussion of advantages and disadvantages of autonomous vehicles along with few examples of notable projects.

Keywords: Autonomous Vehicles, Wages, LAN, Sensor

I. INTRODUCTION

An autonomous car (also known as a driverless car, auto, self-driving car, robotic car) is a vehicle that is capable of sensing its environment and navigating without human input. As of May 2017, automated cars permitted on public roads are not fully autonomous and require a human driver who is ready to take control of the vehicle. Autonomous cars use a variety of techniques to detect their surroundings, such as radar, laser light, GPS, odometry, and computer vision. Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage. Autonomous cars have control systems that are capable of analyzing sensory data to distinguish between different cars on the road, which is very useful in planning a path to the desired destination [1].

Some demonstrative systems, precursory to autonomous cars, date back to the 1920s and 1930s. The first self-sufficient (and therefore, truly autonomous) cars appeared in the 1980s, with Carnegie Mellon University's Navlab and ALV projects in 1984 and Mercedes-Benz and Bundeswehr University Munich's Eureka Prometheus Project in 1987. A major milestone was achieved in 1995, with CMU's NavLab 5 completing the first autonomous long distance drive in the United States. Of the 2,849 miles between Pittsburgh, PA and San Diego, CA, 2,797 miles were autonomous (98.2%), completed with an average speed of 63.8 miles per hour (102.3 km/h). Since then, numerous major companies and research organizations have developed working prototype autonomous vehicles.

The primary benefit of autonomous cars is a significant reduction in traffic collisions resulting in a lower need for insurance. Autonomous cars can enhance mobility for children, elderly, disabled and the poor. The relief of travellers from driving and navigation chores, lower fuel consumption and zeroed driver wages are the direct benefits of autonomous cars.

Among the main obstacles to widespread adoption of autonomous vehicles, in addition to the technological challenges, are disputes concerning liability. The time period needed to turn an existing stock of vehicles from non-autonomous to autonomous resistance by individuals to forfeit control of their cars, consumer concern about the safety of driverless cars, implementation of legal framework and establishment of government regulations for self-driving cars, risk of loss of privacy and security concerns, such as hackers or terrorism, concerns about the resulting loss of driving-related jobs in the road transport industry and risk of increased suburbanization as driving becomes faster and less onerous without proper public policies in place to avoid more urban sprawl. Many of these issues are due to the fact that Autonomous Things such as autonomous vehicles (and self-navigating drones) are allowing, for the first time, the computers to roam freely, with all the related safety and security concerns.

II. BACKGROUND

Much like electric vehicles, autonomous cars may seem like a very recent initiative but were first developed decades ago. These included both OEM driven initiatives like the GM Futurama exhibit at the 1940 World's Fair and running autonomous prototypes from GM and Ford in the 1950s. There have also been several independent attempts to build autonomous cars over the years in the US, Japan, and Europe, in the 1960s through the 1980s. Most of the early attempts at autonomous driving needed significant help from infrastructure (like special roads with metal guide strips and radio sensors to point out the right of way to the cars), but some also used early cameras, remote sensors, and actuators to allow the cars to control themselves—in much the same way as semi-autonomous cars can today. The early "self-driving" cars were able to complete test routes but were largely untested in real world traffic conditions.

The big breakthrough that brought autonomous driving out of the fringes of "skunkworks" programs and the odd science class project was the DARPA Grand Challenge. Organized by the US Defense Department's Defense Advanced Research Project Agency (DARPA), this competition brought a number of schools, OEMs, and innovators together to create the autonomous vehicle of the future—initially aimed for potential military use, but eventually with crossover to civilian applications.

The DARPA Grand Challenges were held in 2004 (open desert), 2005 (desert course), and 2007 (urban course). While the participants had varying degrees of success (the first Grand Challenge saw no participant complete the course and had no winner), the reliability and capability of the machines improved dramatically with each iteration. The first Grand Challenge winner was Stanford's Stanley vehicle in 2007—a modified Volkswagen Touareg that earned the team the $2 million winning purse. The Grand Challenges got many of the OEMs and other participants in the autonomous vehicle field today, including Google and Cisco Systems, seriously thinking about the technology. Many members of participating teams are spearheading autonomous vehicle development at the auto OEMs and other companies today [2].

III. NOTABLE PROJECTS

- The DARPA Grand Challenge has been held in 2004, 2005 and 2007 as an autonomous driving competition with millions of dollars in prize money.
- In November 2010, Hyundai Kia Automotive Group held the Korean Autonomous Vehicle Competition (AVC), with a top prize of $100,000.[*citation needed*] The Hanyang University A1 team won the prize.[*citation needed*]
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- In October 2013, KSAE and KATECH held the Korean Autonomous Vehicle Competition (AVC), with a top prize of $100,000.[*citation needed*] The Hanyang University A1 team won the prize.[*citation needed*]
- The Google driverless car project maintains a test fleet of autonomous vehicles that has driven 300,000 miles (480,000 km) with no machine-caused accidents as of August 2012.
- The €800 million EC EUREKA Prometheus Project conducted research on autonomous vehicles from 1987 to 1995. Among its culmination points were the twin robot vehicles VITA-2 and VaMP of Daimler-Benz and Ernst Dickmanns, driving long distances in heavy traffic.
- The $90 million Automated Highway System program demonstrated vehicle automation to thousands at Demo '97 in San Diego, California.[*citation needed*]
- The 2010 VIAC Challenge saw four autonomous vehicles drive from Italy to China on a 100-day 9,900-mile (15,900 km) trip with only limited human intervention, such as in traffic jams and when passing toll stations. At the time, this was the longest-ever journey conducted by an unmanned vehicle.
- The ARGO vehicle (see History above) is the predecessor of the BRAIVE vehicle, both from the University of Parma's VisLab. Argo was developed in 1996 and demonstrated to the world in 1998;

BRAIVE was developed in 2008 and demonstrated in 2009 at the IEEE IV conference in Xi'an, China.

- In 2012, Stanford's Dynamic Design Lab, in collaboration with the Volkswagen Electronics Research Lab, produced*Shelley*, an Audi TTS designed for high speed (greater than 100 miles per hour (160 km/h)) on a racetrack course.
- Oxford University's 2011 Wildcat Project created a modified Bowler Wildcat which is capable of autonomous operation using a flexible and diverse sensor suite.
- The Volkswagen Golf GTI 53+1 is a modified Volkswagen Golf GTI capable of autonomous driving. In his 2010 book, *Democracy and the Common Wealth*, Michael E. Arth claims that autonomous cars could become universally adopted if almost all private cars requiring drivers, which are not in use and parked 90% of the time, were traded for public self-driving taxis, which would be in near-constant use.
- AUTONOMOS – part of the Artificial Intelligence Group of the FreieUniversität Berlin.
- Toyota has developed prototype cars with autonomous capabilities for demonstration at the 2013 Consumer Electronics Show.
- In February 2013, Oxford University unveiled the Robot Car UK project, an inexpensive autonomous car capable of quickly switching from manual driving to autopilot on learned routes.
- Israel has significant research efforts to develop a fully autonomous border-patrol vehicle. This originated with its success with Unmanned Combat Air Vehicles, and following the construction of the Israeli West Bank barrier. Two projects, by Elbit Systems and Israel Aircraft Industries are both based on the locally produced Armored "Tomcar" and have the specific purpose of patrolling barrier fences against intrusions.
- The Oshkosh Corporation developed an autonomous military vehicle called TerraMax and is integrating its systems into some future vehicles [3].

IV. Working of Autonomous Vehicle

4.1. Hardware systems

To develop a vehicle with automatic driving capabilities, the first step is to modify the actuators to permit their automatic control. In this section, the hardware modifications applied to the steering wheel, the throttle and the brake are presented.

4.1.1. Steering wheel

The vehicle is a gasoline car whose steering assistance is electric, what is used to aid its automation. The CAN bus of the car provides the control computer with readings of the speed and steering wheel angle. In order to use the assistance electric motor for the automatic steering this motor is controlled by the computer. So the lines leading to the assistance electric motor have been cut and replaced by a line taken directly from the battery, width pulse modulated according to an analog signal controlled by the computer. Actually a relay card has been developed to commute the original lines leading to the motor with the computer controlled ones. A switch in the board activates these relays and so the car can change from being manually controlled to being computer controlled.

4.1.2. Throttle

The throttle is controlled with an analog signal that represents the pressure on the pedal, generated with an analog card. The action over the throttle pedal is transformed into two analogue values -one of them twice the other- between 0 and 5V. These values are obtained from the same I/O digital analog card used to manage the steering wheel.

4.1.3. Brake

Since the brake action is the more critical to allow stopping the car in case of a failure of any of the autonomous systems, an electro-hydraulic braking system was mounted in parallel with the original one [3]. Two shuttle valves are installed connected to the input of the anti-lock braking system (ABS) in order to keep the two circuits independent. Each valve permits flow from either of two inlet ports to a common outlet by means of a free-floating metal ball that shuttles back-and-forth according to the relative pressures at the two inlets. One of the inlets is connected to the electro-hydraulic braking system and the other to the original one. These valves permit the two braking systems to coexist, but independently of each other. A pressure limiter tube set at 120 bars is installed in the system to avoid damage to the circuits. Two more valves were installed to control the system: a voltage-controlled electro-proportional pilot to regulate the applied pressure, and a spool directional valve to control the activation of the electro-hydraulic system by means of a digital signal. These two valves are controlled via an I/O digital-analogue CAN card [4].

4.2. Sensor system

To analyze the environment and take the best control actions, different sensors have been mounted in the vehicle. A brief explanation about the behavior and target of each one of them is presented in this section. The vehicle is equipped with an industrial PC to connect peripherals.

4.2.1. Wireless LAN

A PCMCIA Proxim Wireless ComboCard is installed in the PC of the car. The goal of the communications system is to receive the information coming from either the infrastructure or the vehicles to take the control actions. To avoid an excessive number of communications channels open, an interest zone -up to 80m- is defined into the surrounding area.

4.2.2. RTK-DGPS

The main sensor used for acquiring driving information is an RTK-DGPS that gives us a 1- centimeter precision. With this data and a precise map of the test circuit we can perform automatic driving in a way similar to human drivers. The guidance system with the RTK-DGPS is modeled using fuzzy variables and rules to correct the trajectory errors computed with the on-board GPS receiver and the high-precision digital cartography that defines the target route.

4.2.3. IMU

RTK– DGPS information is optimal to reference the car to the digital cartography that defines the target route. However, it is necessary to add a secondary positioning system that complements the GPS when its accuracy is not enough to allow safe driving. In our case we have added an inertial unit to improve the positioning. This is done complementing the inertial unit signal with the the odometry signal of the test-bed car. This information is used to obtain the car's true position (North, East) either when there is a short-time fault of the GPS signal - i.e , in a city, where buildings may occlude satellite signals - or when there is a long-time fault -, i.e., in a tunnel or circulating through a tree canopy - . To overcome these failures, a Crossbow IMU300CC was placed close to the center of gravity of the vehicle and a positioning system was developed, in case of GPS faults [5].

4.2.4. Cameras

Two cameras located in the rear-view mirror are used to perform pedestrian detection. The camera characteristics are images resolution of 320x240 pixels, a baseline of 30cm and a cameras focal length of 8mm. Their inclusion in the control algorithm is to increase the environment perception. Specifically, they are in charge of detecting pedestrians.

4.3. Implemented Maneuvers

We will describe here the different maneuvers that the prototype vehicle is capable of performing in the order they were developed. They are based on real traffic circumstances and deal with real traffic problems. The controllers for each one of the maneuvers are based on an experimental fuzzy coprocessor (ORBEX, acronym of Experimental Fuzzy Processor in Spanish), which is an inference motor with a natural-language-based input language [6]. ORBEX functions with Mamdani's inference method, with singleton-type membership functions to codify the output variables, and allows control decisions to be very rapidly and very precisely made.

4.3.1. Autonomous guidance

The first developed maneuver consisted on providing autonomous driving capabilities without taking into account the environment, that is, the interaction with other cars or possible obstacles. The autonomous guidance was achieved through three controllers: straight stretches and bend stretches for the steering control and another controller to perform the longitudinal control. For the lateral control two variables were used: the lateral error and the angular error. The former is the deviation –in meters- of the front of the car from the reference trajectory, measured perpendicularly to it. The latter is the angular deviation -in degrees- of the vehicle from the reference trajectory and is represented by a director vector. For the longitudinal control we use the speed error-in kilometer per hour- defined as

$$Speed_{error} = Speed_{current} - Speed_{target}$$

where $Speed_{target}$ is obtained through a pre-defined digital cartography route [7]. The vehicle´s speed can be up to the urban limit in straight stretches and is reduced in bend stretches. To improve the comfort during the speed´s changes, both the car´s acceleration and the speed error are used as inputs to the longitudinal fuzzy controller.

4.3.2. ACC+Stop&Go

The first cooperative implemented maneuver was the ACC with Stop&Go capatibility[8]. This maneuver is an extension of the CC maneuver and permits to follow a leading vehicle at a safe distance. The fuzzy controller developed uses two inputs: the time-gap (TG) error defined as

$$TG_{error} = TG_{current} – TG_{target}$$

and its derivative. Through the Wireless LAN previously presented, the unmanned car received the information about the leading vehicle in order to determine the TG.

4.3.3. Overtaking

As first consideration, we assume than an overtaking follows an ACC. > From a functional point of view, an overtaking in a two-way road can be considered as a double lane-change maneuver. First change from the right lane to the left one is needed to overtake the leading vehicle. A second lane change is performed in order to come back to the right lane. For this controller the same variables that were considered for the lateral control are taken into account. The designed controller [9], when compared with the autonomous guidance mode, results softer than controller of the bend stretches and harder than that of the straight stretches on in its action upon the steering wheel.

4.3.4. Intersection management

The development of this system is naturally divided itself in two parts. The first of them is a system capable of detecting the position and intention of the other cars in its vicinity. The second is a fuzzy controller to act on the actuators. The detection system was designed on the basis of a local topological analysis. If a vehicle is close to the intersection and coming from the right-of-way, the intersection fuzzy controller is activated. As inputs, the distance of each car to the cross point and the relative speed between them defined as

$$Speed_{dif} = Speed_{right\text{-}of\text{-}way\text{-}}Speed_{automated\text{-}car}$$

are used. The system is capable not only of stopping the vehicle should another vehicle be entering the same intersection point but also proceeding to cross the intersection if the speed of the other vehicle is too slow, even if the approaching vehicle has the right-of-way [10].

4.3.5. Pedestrians

A vision-based system was installed in the car to perform pedestrian protection. Pedestrian detection is carried out using the system described in [11, 12]. Non-dense 3D maps are computed using a robust correlation process that reduces the number of matching errors. The camera pitch angle is dynamically estimated using the so-called virtual disparity map. This pedestrian detection system in combination with the information coming from the vehicle’s CAN bus is used to estimate the time-to-collision (TTC). This value is used as a trigger in order to perform a pedestrian collision avoidance maneuver.

4.4. Environment Evaluation System

The autonomous car described and its associated maneuvers are selected taking into account an environment evaluation system. The autonomously driven vehicle continuously checks a circular area of up to 80-m radius. When another vehicle or a pedestrian is detected within this area, its trajectory is analyzed to select among the different controllers in order to perform the safer maneuver. A priority system is used to determine the controller to use i.e. a pedestrian avoidance will have a greater priority than an ACC. In this case, the vehicle receives the information about a vehicle driving in front of it and the change from autonomous guidance to ACC+Stop&Go controller is carried out. If a pedestrian is detected during the ACC or an overtaking maneuver can be performed, the fuzzy controller selected is changed.

4.5. Related Experiment

We present here an example about the behaviour of the autonomous car in a real traffic circumstance. The test consisted on performing a pedestrian avoidance maneuver plus an intersection without right-of-way crossing. Solid black will be used to correspond to the autonomous vehicle, and gray symbols to the manually driven one. The test begins when the autonomous vehicle is started, marked with the time equal to zero. Until the first bend, the vehicle is driving using the autonomous guidance mode. Around second 20, an unexpected pedestrian is detected in the lane and the pedestrians mode is activated. A steering change is done occupying the other lane to avoid the pedestrian collision. One can observe how the maneuver is carried out in advance and the pedestrian is avoided safely. After second 28, the vehicle is coming back to the reference lane and the autonomous guidance mode is activated again. Around second 32, a vehicle approaching to the crossroad with right-of-way is detected and the intersection management mode is activated. The speed of the autonomous vehicle decreases slightly between seconds 32 and 36 to permit the manually driven vehicle to traverse the intersection. Then, around second 40, the autonomous vehicle detects the intersection is free and it accelerates significantly to ensure traversal of the crossroad. Then, the autonomous guidance mode is in charge of performing the longitudinal as well as the lateral control. Around second 44, the manually driven vehicle position is lost because is out of our interest area [13].

V. APPLICATIONS

5.1. Military & industry applications

US military continues to test self-driving vehicles. The defence contractor Lockheed Martin has deployed driverless convoys of off-road trucks through uninhabited and difficult terrain in Fort Hood, Texas. Using GPS and laser sensors, these vehicles keep close to each other and captured the terrain to follow the route. It´s not clear yet when driverless vehicles such as these could be used in real operations.

Another early adopter of autonomous driving is the aerospace industry. The Mars Rover Curiosity is an autonomous extraterrestrial vehicle developed by NASA.

Agriculture is another industry in which autonomous driving has a valuable niche, using self-driving tractors in a number of different applications. For example, Fendt, a German manufacturer of agricultural tractors and machines, has launched Fendt GuideConnect – a system that connects two tractors via satellite navigation and radio communication to form one unit. The obvious benefit is that agriculturalists can improve the productivity and efficiency of their operations.

5.2. Consumer applications

Closer to home, some of our appliances – including lawnmowers and vacuum cleaners – are beginning to feature autonomous driving technologies. The Homerun vacuum cleaner from consumer Electronics Company Philips runs autonomously through the house and vacuums the dust and dirt beneath it into a built-in receptacle. When the batteries run low, Homerun drives itself back to a charging station; once recharged, it resumes the housecleaning task. Infrared sensors on the bottom of the unit continually monitor the environment to prevent, for example, an accidental fall down a staircase.

5.3. Automotive applications

The most popular application, available as an optional accessory in many new cars, is the parking assistant system. This detects the immediate environment and autonomously parks the vehicle in a parking space.

This system takes entire control of the steering, freeing the driver to focus on other traffic and to control the parking operation via acceleration and braking. Drivers can choose either parallel parking or parking at a right angle to the road. Tests indicate that today’s parking autopilots are superior to human drivers in terms of speed and precision.

5.4. Public transport applications

This can be used in self driving cars by which human power decreases and the cars gets starts automatically and drivers itself and it automatically navigates itself to the destination at which the passenger should be reached [14].

VI. ADVANTAGES

6.1. Nearly No Error

The incredibly complicated technology behind self-driving cars lets the on board computer make hundreds of calculations a second. These include how far you are from objects, current speed, behaviour of other cars, and location on the globe. These super accurate readings have virtually eliminated driving errors for test cars on the road, as the only accidents so far are while human drivers have been in control.

6.2. Eases Congestion

Because self-driving cars are rarely involved in accidents, their potential to ease congestion is high. Not only that, because self-driving cars can communicate with each other, they would eliminate the need for traffic signals. By driving at a slower rate but with less stops, better coordinated traffic would lead to less congestion.

6.3. Eases Parking Woes
Because self-driving cars don't require a driver, they could alleviate parking concerns in highly populated areas. For example, a passenger could get out at their destination, and if no parking was available the car could circle the block until the passenger was ready to leave. Because the cars can coordinate traffic flow, this is expected to have little impact on traffic congestion. This may be a hugely useful aspect for drivers in large urban centers.

6.4. Potential for New Design
Because a vehicle may eventually function as a sort of self guided train car, the potential for new car designs is huge. With no need for complicated driving tools, self-driving cars could include new ways to relax or to stay entertained. The new design opportunities are not limited to the interior however, and self-driving cars may soon look unrecognizable to cars today. Ultimately, some people think cars could become like a high tech living room you kick back in until you reach a destination.

6.5. Potential for More Powerful Vehicles
Because self-driving cars don't require a driver, technicians could potentially rearrange where on the car the various mechanical parts are stored. This may also lead to cars with more capable and powerful engines. With less driver errors, cars could eventually be capable of going much higher speeds.

VII. DISADVANTAGES

7.1. Expensive
Self-driving cars are so exciting because they are stuffed to the brim with space age technology, but all this technology is currently astronomically expensive. In general, technology grows cheaper the longer it is available to the public, so self-driving cars may eventually be something anyone can afford. For now however, most companies have not released a price for their driverless cars.

7.2. Potential for Technology to Go Wrong
Though successful programming lets us do incredible things, there is always the potential for some unexpected glitch to emerge. Even if a self-driving car performs flawlessly at first, it is possible for the programming that runs the cars to be updated by the car company with a fault string of code. Errors like this cause annoyance on our computers and mobile devices, but could potentially cause car accidents with self-driving cars.

7.3. Licensing Infrastructure Not Yet In Place
Self-driving cars also present a challenge for state and federal licensing infrastructure. The companies claim these cars are safe, yet it is up to public institutions to keep drivers safe. Not only do our local car licensing offices need to make sure these cars perform as advertised, they need to come up with a way to quickly and efficiently license and control them. Should our technology and hunger for these cars outpace our ability to investigate and approve them, public safety may be at risk.

7.4. Potential for Greater Pollution
While many companies are looking at self-driving cars that use fuel-efficient or hybrid models, should our access to self-driving cars outpace our commitment to clean energy, we may be looking at much more pollution. Getting out of your car at the front of the movie theater without needing to park sounds good in theory, but if the car you're driving isn't electric, emissions would be worse than leaving your car idling while you watch the movie.

7.5. Potential Loss of Privacy
Finally, though the companies testing self-driving cars claim all pros and no cons, using a self-driving car means a third party would have the opportunity to track your movements. While many companies will likely avoid this due to consumer backlash, a massive loss of privacy still exists. Because your car would be receiving

or communicating with data centers, your location would be potentially accessible to people or organizations who could hack into the network.

All in all, self-driving cars have the potential to be an incredible new wave in the future of humanity. Increased productivity, rest time, and possibly eliminating risk while driving, have the potential to greatly improve all of our lives. Should self-driving cars be available to the public before certain safety and privacy considerations are solved however, they may also present serious new complications for consumers. Regardless, self driving cars present a wide range of uses, and a mammoth new technological world.

VIII. LEGAL ISSUES

As the cars will be driving themselves, the responsibility and liability picture will look a little different of course. In case of a car accident for instance, the liability will belong to whoever is responsible for not maintaining the software and the mechanical condition of the responsible car according to the laws and regulations. If you are the car owner, you will be responsible to make sure your car is maintained per the current laws. If you are the mechanic, you will be responsible for doing the maintenance per the standards. Owning a car that drives itself also means you do not have to go to the repair shop anymore. Your car will automatically go there when it needs to. I am suspecting that by the time we have widespread use of autonomous cars, auto mechanics will also be in a transition phase of losing their jobs to robots, so this whole maintenance process will look much more automated but that is another subject.

Nevada, Florida and California have already passed laws about driverless cars, as of January 2013. The laws require the motor vehicle department to establish the rules and standards for autonomous vehicle operation and serves to pave the way for mainstreaming the technology on the highways.

In Europe for instance, Volvo has teamed up with Car to Car Communication Consortium, in order to have the infrastructure of vehicle to vehicle communication, or the traffic lights and signs that communicates with vehicles to start to be in place within the next several years. If you remember the fact that chips are becoming more of a commodity like water or electricity, with ever decreasing prices and dimensions, it is inevitable in the very near future that everything around us will be intelligent. Another thing to consider when comparing the autonomous systems versus the manually driven system is the elimination of the human judgment, which is still far better than Artificial Intelligence and will be this way for a long time. It is true and we have already mentioned that the driverless cars will make less number of mistakes in comparison to the human drivers, but there will be some points in time that using an automated system will not be as good as a human making judgment with his common sense. All these different scenarios will needed to be sorted out before the driverless technology will be allowed but as we argued above, even with occasional possible glitches, the overall benefits will far overweigh the costs [4]**.**

IX. CONCLUSION

Autonomous vehicles seem to be a promising alternative to the current day automobiles especially in hazardous, adverse climatic conditions and hostile environments. The economic feasibility of the autonomous vehicles as on date needs a drastic improvement. Subsequently the on-road implementation of these vehicles can become a reality only after a strong legal framework is created.

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