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The Study of Self-Driving Car Innovation, Development, and Implementation

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Abstract: *The invention of the self-driving car is one of the century's most significant inventions. The installation of an autonomous automobile has been a key subject among academics as technology advances. The history of self-driving vehicles, their research and development, the basic technologies that support self-driving, and the most critical components of bringing self-driving cars into practice are all covered in this article. The essay also goes through some of the challenges that completely autonomous cars face when it comes to widespread adoption, as well as possible solutions.*

Keywords: Advanced Driver Assistance System (ADAS), autonomous, navigation, positioning, selfdriving technology, radar, lidar, path planning, obstacle avoidance, Full Self driving (FSD), accidents, protests, advantages, challenges.

I. Introduction

Technology has advanced to the point that man is as omnipotent, omniscient, and omnipresent as a deity in the twenty-first century. It is being attempted to discover and complete any task with more efficiency, lower cost, and little effort. This prompts researchers to look into the fields of automation, machine learning, and artificial intelligence in order to perform the most difficult of duties that were previously laborious and time-consuming for people [1]. We are moving toward a future in which people are solely engaged in high-level mental abilities and all other tasks are mechanized [2]. Previous research in the subject of self-driving has been examined in this study. Progress was slow in the early years, from 1920 to 1950, although there was a lot of room for further study. The crude autonomous cars were tested on a particular route and in an unsuitable environment. Further research and testing significantly improved autonomous cars, as well as gaining financing [3]. Since the 1980s, the progress has accelerated, with research leading to improved self-driving technologies. Autonomous cars up to level 3 are already available on the market, and they can drive themselves in a variety of situations [4]. The study investigates the technology underlying self-driving cars. Navigation, planning, and control are all important aspects of technology. The vehicle must traverse the route going to the goal, design an appropriate course leading to the destination, and drive autonomously. Whenever a new technology or idea is launched, it confronts several hurdles in terms of mainstream adoption; self-driving vehicles are no different. When we speak about self-driving automobiles, we have to consider the many possibilities, the sort of future it leads us to, and what its future holds. One of the most challenging hurdles to overcome is the unambiguous identification of impediments at high speeds and across large distances [5]. To guarantee that the automobile can operate in every state of the road and in any weather, the system's controller must be exceedingly sturdy and modern. This article examines the technology underlying self-driving vehicles, how it is being implemented on a wide scale, and what the future may hold. This study investigates difficulties such as reduced job alternatives in driving and controlling, as well as Artificial Intelligence-related issues [23][25].

II. Survey Of Previous Researches On Self-Driving Cars

The development of self-driving automobiles began in the twentieth century, in the 1920s. Since then, several trials and studies have been carried out. In New York, Houdina Radio Control displayed the American Wonder (a 1926 Chandler modified with a transmitting antenna and tonneau), a remote-controlled automobile that went around the city in a dense traffic bottleneck [3]. Norman Bel Geddes, who promoted advances in highway design and transportation and predicted that humans would be removed from the process of driving one day, depicted a radio-controlled electric car controlled by the electromagnetic field provided by circuits embedded in the road at the 1939 World's Fair [6]. In 1957, RCA Labs and the State of Nebraska exhibited a driverless automobile system on a 400-foot length of Nebraska Highway in the United States. A number of experimental detector circuits and illumination along the road's edge were implanted in the roadway [7]. In the Communication and Control Systems library at Ohio State University, Dr. Robert L. Cosgriff started a project to produce autonomous automobiles in 1960 [8]. In 1966, it was predicted that this technology will be ready for widespread use within 15 years. William Bertelsen designed an air-cushion vehicle (ACV) called Aeromobile 35B in August 1961, according to Popular Science. It was designed to revolutionize the transportation sector, with personal autonomous automobiles capable of speeds of up to 1,500 miles per hour [9][10]. In the 1980s, Carnegie Mellon University's Navlab unveiled the first self-sufficient and totally autonomous automobile prototype. In 1987, Mercedes-Benz cooperated with the Bundeswehr University Munich to create the Eureka PROMETHEUS Project [11]. It was one of the greatest R&D initiatives in the area of driverless cars, with 749 million Euros in financing. This pan-European collaboration included a number of colleges and automobile manufacturers. Carnegie Mellon University (CMU) pioneered the use of neural networks to steer and control autonomous cars in 1989, laying the groundwork for today's control systems [10]. In the same year, the United States Congress enacted the ISTEA Transportation Authorization bill. The US Department of Transportation organized a portrayal of autonomous cars in response to this law. General Motors and the Federal Highway Administration headed the project, which also included Delco, Caltrans, Bechtel, the University of California-Berkeley, Parsons Brinkerhoff, CMU, and Lockheed Martin. In 1995, DaimlerBenz and UniBwM's Ernst Dickmanns tested twin-bot cars VaMP and Vita-2 on a 3-lane highway in regular heavy traffic for more than 1000 kilometers with human assistance, i.e. semi-autonomously [12]. Dickmanns' re-engineered Mercedes Benz S-Class was autonomously driven 1590km from Munich, Germany to Copenhagen, Denmark and returned in the same year [12], employing Saccading computer vision and transputers in real-time. Prof Alberto Broggi of the University of Parma drove a modified Lancia Therma at an average speed of 90 km/h through a stretch of northern Italian motorways named Miglia in Automatico in 1996, with 94 percent of its trip being automated [13]. The Defense Advanced Research Project Agency (DARPA) conducted the inaugural Grand Challenge in March 2004, offering a $1 million reward to engineers who could build an automated vehicle capable of covering 150 miles in the Mojave Desert [14]. The first year, none of the vehicles finished the route, but the next year, five cars did. Many manufacturers are enthused about self-driving technology and semi-autonomous driving, according to Willie Jones [15]. Toyota introduced Automatic Cruise Control in their vehicles for the first time in May 1998. In 2009, Google began work on their self-driving vehicle project [16]. Many major automakers, including Mercedes-Benz, General Motors, Volkswagen, Ford, Audi, Toyota, Nissan, BMW, and Volvo, are experimenting with self-driving cars. Since 2005, Bayerische Motoren Werke (BMW) has been testing autonomous vehicles. Prof. Alberto Broggi of the University of Parma, Italy, successfully drove four electric vans from Parma, Italy, to Shanghai Expo in China in 2010, completing a 15900-kilometer test run [13]. In 2010, Germany became the first country in the world to provide a license for autonomous vehicles to be driven on public roads. It was a modified research vehicle Leonie [17] created by Technische Universitat Braunschweig. In 2011, Oxford University unveiled its WildCat Project [18], which aimed to build an automated automobile out of a modified Bowler WildCat. Nevada, a US state, approved a legislation in 2012 allowing autonomous cars to be tested. In Nevada, the first licensed Automated vehicle was a modified Toyota Prius. The testing of driverless automobiles was also permitted in Florida and California in the same year [19]. Shelly, a modified Audi TTS, was created by Stanford's Dynamic Design Lab for the track used at speeds more than 160km/h [20]. Delphi Automotive created a self-driving automobile in April 2015 that completed the first coast-to-coast travel under computer control from San Francisco to New York in 99 percent of the time [21]. Apple began working on Project Titan, an autonomous car (iCar) project, in 2015 [22]. Tesla introduced their Full Self-Driving (FSD) computer in April 2019, which would be placed in their vehicles to allow completely autonomous driving with minimum human intervention [23].

III. Technology Behind The Autonomous Vehicle

When compared to manual driving, automated automobiles include a variety of technological features. According to SAE, the basic technology of self-driving vehicles may be grouped into six groups [24] based on the characteristics and functional requirements of the driving and on-board equipment modules:

Level 0	There is no automatic technology in this level. The driving solely depends on the human driver.
Level 1	This is the first level of automation. The Advanced Driver Assistance System (ADAS) assists the human driver with steering, braking, accelerating, though not simultaneously. The driver has to drive the car himself with limited assistance from the ADAS technology.
Level 2	The ADAS is more advanced in this level. It can steer and either brake or accelerate simultaneously while the driver remains fully aware behind the wheel and continues to act as the driver.
Level 3	An Automated Driving System (ADS) can perform all driving tasks under certain circumstances, such as parking the car, driving in the highways with lane following etc. In these circumstances, the human driver must be ready to re-take control whenever the system faces any difficulties and is still required to be the main driver of the vehicle.
Level 4	An ADS is able to perform all driving tasks and monitor the driving environment in certain circumstances. In those circumstances, the ADS is reliable enough that the human driver needn't pay attention.
Level 5	In this level the vehicle's ADS acts as a virtual chauffeur and does all the driving in all circumstances. Steering wheels, brakes and other controllers are optional. Occupants need not to face the windscreen. The human occupants are passengers and are never expected to drive the vehicle.

Table 1: The Classification of the Self-Driving Cars

1. **Navigation System:** The automobile must navigate its way through the streets to reach its goal. The Geographic Information System (GIS) and the Global Positioning System (GPS) work together to determine the precise position of a vehicle using latitude and longitude, a digital map database, and other methods. In order to find an appropriate route, intelligent path mapping techniques (e.g. Dijkstra's Algorithm, Bellman-Ford Algorithm) are used. After calculating the vehicle's position and destination, certain algorithms may be used to train the automobile to find its route using a path planning model.
2. **Positioning System:** This system identifies the vehicle's position, which might be absolute or relative. The Inertial Navigation System (INS) is a typical relative positioning system (Farrell and Barth, 1999) that uses a gyroscope and accelerometer to compute the angular and absolute velocity of a vehicle. Different sorts of computations, such as relative course angle and speed, may be done using this data. Satellite-based systems such as GPS, GLONASS, Galileo, Biedou, and others may be used to ascertain an absolute position. In self-driving automobiles, hybrid location, which is a blend of absolute and relative position, is often employed. For sophisticated computation and determination of the Hybrid positioning system, Gmouse UB-353 GPS model, analog device ADIS16300 INS, SPANCPT integrated navigation system, SPAN-FSAS fractional navigation system, and others are employed.
3. **Mapping:** This includes information such as the area's geographical features, traffic information, buildings, traffic signs, signals, road amenities, parking spots, and so on. The vehicle's computerized mapping technology makes it easier for it to find its way to its destination. Nowadays major car-makers and tech-giants are working on selfdriving vehicle specialized technologies as automated road sign detecting system, interactions between selfdriving cars and pedestrians, etc. The active layer, which contains road-level data, lane characteristics, elevated objects, and other information, is the first of three layers in electronic maps for driverless cars. (ii) A dynamic layer that updates in real time with traffic statistics. It's the collaborative network integration perception. (iii) Analysis layer: This layer instructs the self-driving automobile by evaluating real-time huge data from human driving records. The current HD map is ADAS level, which aids self-driving car technology at levels 2-3.
4. **Map Matching:** This is the process of determining the location of a vehicle using data from a map. In this industry, advanced GPS systems are crucial.
5. **Path Planning:** This is used to figure out the most efficient and optimum route to the goal. This technique is presently in widespread usage in a variety of driving apps and maps.
6. **Laser Perception:** Lasers are utilized as a kind of radar. Continuous or discrete laser beams are utilized in laser perception to detect any barrier; object information, distance, size, and velocity may all be computed. In self-driving automobiles, the LIDAR approach is employed, which involves mapping and scanning in 3D technology. HDL-64E, HDL-32E, and VLP-16 are produced by Velodyne LiDAR Inc., a leading lidar system manufacturer. These are also utilized in self-driving cars.

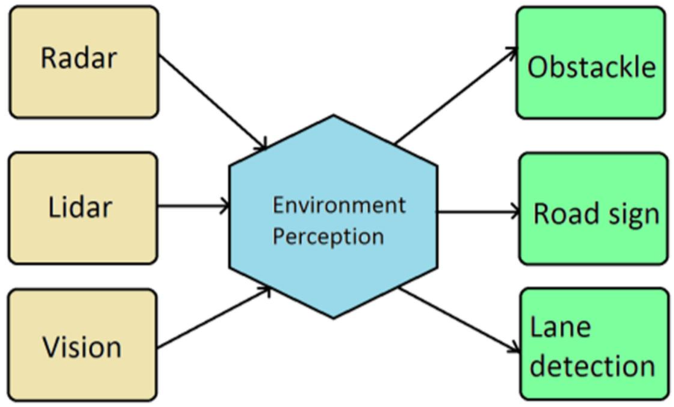

Figure 1: Block Diagram Representation of Self-Driving Mechanism

7. **Radar Perception:** A radar system is used to determine distance by calculating the millimeter waveform's return time. These businesses create industrial-level radar systems: DENSO, Bosch, TRW, Delphi, and Hella. LRR4 is the most recent device, and it can detect moving cars from a distance of 250 meters.
8. **Visual Perception:** All traffic lights and systems are now built with human drivers in mind. Self-driving vehicles will need to be able to read all of these signals. Simultaneous Localization And Mapping (SLAM) and visual understanding based on the captured image are the two main navigation systems. The radar and vision sensors, on the other hand, must be sturdy and trustworthy in order for automated cars to be marketable.
9. **Vehicle Direction Control:** The longitudinal and lateral vehicle direction control methods are used. Advanced control techniques derived from driving experiences may be used to accomplish longitudinal control. The lateral control method is based on a PID controller and a Cerebellar Model Articulation Controller. When combined with longitudinal control, the system can automatically correct even when the model and input signal change fast and unexpectedly, allowing the autonomous vehicle to drive itself precisely and without error in any driving situation or environment [25].

IV. Practical Implementation Of Autonomous Vehicles

We can't call research and development effective until we can put it to use in the actual world. Self-driving cars, also known as autonomous vehicles, are a revolutionary undertaking that will one day take over the world's highways. Many firms are also experimenting with and attempting to integrate self-driving freight vans. In August 2016, Uber purchased Otto, a self-driving trucking firm. On highways, Otto tested self-driving trucks [26]. In March 2018, the San Francisco-based startup Starsky Robotics made a 7-mile completely autonomous trip in Florida in a self-driving truck [27]. The French government permitted PSA Peugeot-Citroen to test and evaluate their self-driving vehicles in real-world situations in Paris in summer 2015. Cities in Belgium, France, Italy, the United Kingdom, and others are aiming to use self-driving vehicles to manage their transportation systems [28]. New Zealand is following suit, with plans to utilize self-driving cars in public transportation in towns such as Tauranga and Christchurch. Baidu and King Long [29] are working together to develop level 4 autonomous minibuses without driver seats in China. Yandex, a Russian internet business, is working on self-driving automobiles. In 2018, they tested a prototype of their self-driving car, Yandex-taxi, in Moscow [30]. Tesla Automobiles unveiled their autopilot technology in the United States in October 2015. For a brief time, this device permitted the car to navigate itself on roads under specific situations. It also made it possible for the car to park itself [23]. Google's self-driving automobile, known as Waymo, has now completed 2400000 kilometers of testing. Google and Waymo will continue to operate as divisions of Alphabet [31]. Uber has completed a successful test of 2 million miles in automatic mode by December 2017. Company for Electric Vehicles Tesla claims that the vehicles will arrive with all of the necessary hardware for self-driving already installed. Full autonomy will only be possible with future OTA software upgrades. Tesla revealed the Full Self-Driving (FSD) computer in April 2019, and it is already in production and will be available shortly. This technology will allow automobiles to operate completely autonomously. In October 2019, Tesla debuted Smart Summon, which enables the vehicle to drive itself from parking to the owner with no driver inside using just a smartphone app [32].

4.1 Success and Advantages of Self-Driving Cars

Self-driving automobiles will make travel more convenient and relaxing for humans. Cars would turn into a little leisure room without drivers, with additional space and high-end entertainment devices such as TV displays, game consoles, workplaces, and so on. Without the burden of driving, travelers may journey overnight and sleep for the period. People may engage in more productive activities such as board meetings, learning, working, and so on without having to drive a car. This will save time and boost humanity's overall productivity [33]. Driving safety researchers believe that once self-driving technology is widely used, the number of accidents and incidents caused by human error will plummet. According to McKinsey & Co, widespread deployment of autonomous cars may lower accident rates in the United States by 90%, save $190 billion in damages and health-care expenses, and save thousands of lives each year [34]. The cost of labor will be reduced as well, owing to the fact that self-driving vehicles need less human intervention. Self-driving vehicles will also make it simpler for physically or mentally challenged persons to drive or ride in automobiles. Autonomous automobiles might improve mobility for the young, the elderly, individuals with impairments, and people from the lower and middle classes. Other advantages of autonomous cars include greater speed limits, smoother and more efficient trips, more highway capacity, lower insurance costs, reduced traffic congestion, better safety, and so on [35]-[37]. According to one research on road capacity and automobiles, autonomous autos may boost road capacity by 273 percent. According to the research, with 100 percent linked automobiles on the road employing vehicle to vehicle communication, capacity may reach up to 12000 passengers per vehicle per hour, a 545 percent increase over the present rate of 2200 pc/h per lane. This considerably enhances roadway capacity, reducing massive traffic congestion, particularly in metropolitan regions [38]. Because of the more data and predictability of driving behavior, as well as the reduced usage of traffic controllers, the authorities' capacity to manage traffic will vastly increase. By reducing wasteful engine usage and therefore optimizing the drive cycle, the self-driving vehicle may also assist increase fuel efficiency [39]. An autonomous vehicle can brake and accelerate more effectively than a traditional automobile, which improves fuel economy and mileage by decreasing the lost energy associated with inefficient speed changes. Modern self-driving technology will most likely be used in completely electric vehicles, which emit no pollutants and are more efficient. Increased intelligence in the vehicles might help law enforcement by reporting on unlawful passenger behavior and reducing crimes such as purposefully colliding with other individuals or automobiles [40].

V. Challenges For The Mass Implementation Of Self-Driving Car And Possible Solutions

- The loss of driving-related employment in the transportation business is a direct consequence of broad use of self-driving technology [41]. Many linked occupations, like as drivers, public transportation, and wreck repair shops, may become outdated, putting the vehicle sector at risk. Many employment might be lost as a result of driverless autos, according to a widely referenced research by Michael Osborne and Carl Benedikt Frey [42]. This issue may be addressed by expanding career possibilities in disciplines such as machine learning, artificial intelligence, and computing. In the automation industry, there will be a greater need for new qualified mechanics and laborers.
- There is also a growing privacy problem, since all linked vehicles can be monitored and other individuals may see the vehicle's real-time location. [43] Customers' privacy must be valued by major automotive manufacturers and technology giants, who must secure personal data under total consumer control.
- The likelihood of autonomous automobiles being equipped with explosives and deployed as bombs raises the danger of terrorist strikes. [44]
- There's also a good probability that the car's self-driving software system will be hacked. Hackers may be able to breach the security of the V2V (Vehicle to Vehicle) and V2I (Vehicle to Infrastructure) communication systems and steal data. We don't know how secure this communication is since it's only been tested in a limited environment. There's a danger that the self-driving technology may be hacked and the vehicles forced to follow a desired path specified by the hackers. [45] Automobile manufacturers must make certain that all communications are encrypted and safe. In this communication system, network security is critical.
- While programming the self-driving software that determines whether the self-driving car will crash into another vehicle, potentially killing people inside, or smash into something else, potentially killing its own passengers or nearby pedestrians, ethical and moral reasoning enters the picture [46]. Scientists and researchers are attempting to

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create a more sophisticated humanoid artificial intelligence that will operate the automobile like a professional driver. In the beginning, there should be separate lanes for self-driving vehicles and regular automobiles. This might make it easier to communicate with and operate the autonomous car.

Why Human pedestrians and drivers may find it difficult to communicate with self-driving cars on the road. They need to figure out how to recognize the autonomous vehicle's intentions. Drive.ai is experimenting with a solution that comprises LED signs installed on the exterior of the car that announce statuses like "going now, don't cross" vs. "waiting for you to cross" [47]. MercedesBenz has shown this technology, in which self-driving automobiles interact with people and pedestrians by projecting signals and images onto the road. Several mishaps have occurred as a result of the widespread use of self-driving automobiles. On January 20, 2016, a Tesla with Autopilot crashed in China's Hubei region, resulting in China's first unintentional fatality as a result of the automated system [48]. However, whether or not the autonomous mode was operational at the moment is unknown. The second fatal accident occurred on May 7, 2016, in Williston, Florida, when a Tesla Model S in Autopilot mode collided with a trailer, killing the driver [49]. There have also been a few examples of public pushback to the adoption of self-driving cars. Waymo's self-driving test vehicle was assaulted in October 2018 by an attacker who used sharp items in his assaults [50]. In yet another terrifying event, a guy threatened an autonomous car with a revolver-wielding backup driver. After further inquiry, it was discovered that the individual was seeking vengeance for a prior tragedy in which a lady was killed by a self-driving vehicle [51]. According to the Arizona Republic, at least 21 assaults on Google Waymo vehicles occurred in Chandler in 2018 [52]. The rise of self-driving automobiles poses a danger to people's jobs [41].

V. Conclusion

Self-driving cars are unquestionably a step forward in the evolution of transportation. It is expected that, with a few more upgrades, the self-driving vehicle will be ready for widespread use. Because autonomous cars need significant research and development, it may take some time to completely integrate them into daily life. The need for reliable control components and cutting-edge technology presents a huge potential for research in this subject. The autonomous vehicle's future is bright.

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