A Discussion of Key Aspects and Trends in Self Driving Vehicle Technology

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Abstract – Autonomous vehicles use remote-sensing technologies such as radar, GPS, cameras, and lidar to effectively observe their immediate environment and construct a comprehensive three-dimensional representation. The conventional constituents of this particular environment include structures, additional vehicles, people, as well as signage and traffic indicators. At now, a self-driving car is equipped with a wide array of sensors that are not found in a traditional automobile. Commonly used sensors include lasers and visual sensors, which serve the purpose of acquiring comprehensive understanding of the immediate environment. The cost of these sensors is high and they exhibit selectivity in their use requirements. The installation of these sensors in a mobile vehicle also significantly diminishes their operational longevity. Furthermore, the issue of trustworthiness is a matter of significant concern. The present article is structured into distinct parts, each of which delves into a significant aspect and obstacle pertaining to the trend and development of autonomous vehicles. The parts describing the obstacles in the development of autonomous vehicles define the conflict arising from the use of cameras and LiDAR technology, the influence of social norms, the impact of human psychology, and the legal complexities involved.

Keywords – Camera Technology, Autonomous Vehicles, Advanced Driver Assistance Systems, Light Detection and Ranging, Connected and Autonomous Vehicles.

I. INTRODUCTION

The phrase "autonomous driving vehicle" and the word "self-driving car" are sometimes used synonymously to denote a prospective technical advancement in the future. An autonomous vehicle has the cognitive ability to comprehend its environment and navigate safely with little or no intervention from the operator. Autonomous cars are equipped with a range of sensors, including cameras, radars, lidars, GPS, lane detectors, and measurement units, which serve the purpose of gathering and analyzing data. By using the provided data, it is possible to validate accurate navigation and discern the distinction between a stationary and a mobile target. The capacity to discern between a human being and an inanimate entity is a critical characteristic for autonomous vehicles. Numerous endeavors are now underway to develop a completely autonomous vehicle. Multiple initiatives are under underway to develop a self-driving commercial car, with each effort using distinct technological frameworks.

Waymo is one of the several enterprises engaged in the development of completely autonomous cars. The corporation known as Tesla has made significant contributions to the domain of autonomous vehicles, fostering innovation and transformative advancements. The firm has acknowledged the presence of competition within the autonomous cars industry. The successful realization of a fully operational autonomous vehicle necessitates the amalgamation of several technologies, including automation, artificial intelligence, computer architecture, and various others. The architecture shown in **Fig 1** consists of four primary subsystems, namely perception, mapping, organization, and command.

The vehicle's perceptual system is responsible for the detection and interpretation of its surroundings. The term "perception" in the context of a system pertains to its ability to acquire knowledge about its immediate surroundings and use this information to make informed choices. The enhancement of the state-of-the-art Perception system has the potential to increase the dependability, robustness, and safety of Self-Driving Vehicles. Localization is a fundamental aspect of autonomous vehicle design. The car has the capability to determine its location within a three-dimensional (3D) environment. The effectiveness of autonomous driving systems is contingent upon the accuracy of the localization process. Landmarks serve the purpose of ascertaining the precise position of a vehicle at any particular point in time. The use of Mixed Integer Linear Program (MILP) [1] enables the computation of the ideal trajectory for the Autonomous Vehicle, ensuring that a minimum of two Landmarks remain within the sensor range of the vehicle during its journey. The use of this information by the Robot may provide a more comprehensive comprehension of its spatial positioning. The inclusion of a planner component aims to enable autonomous cars to exhibit a level of intelligence comparable to that of human drivers. The decision-making process of the automobile encompasses all the decisions made from its initial point of departure to its final destination. Finally, the control unit initiates the implementation of the strategies formulated by the higher-order cognitive processes. The autonomous vehicle is capable of facilitating its own movement, as well as the actions of halting and deviating from its intended path.

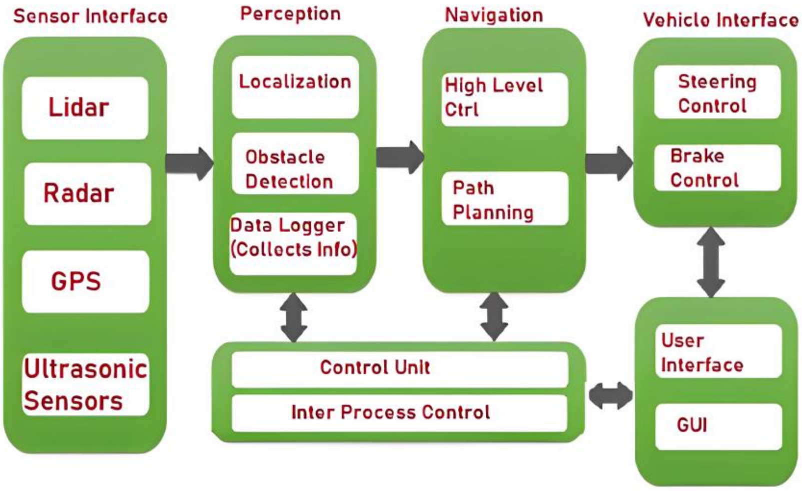

Fig 1. A Self-Driving Car's Architecture in Its Fully Operational State

Over an extended period, several stakeholders, including manufacturers, academia, and government organizations, have dedicated significant efforts towards the development and enhancement of autonomous driving technology. The successful deployment of an autonomous driving ecosystem necessitates the consideration of several factors, including technological automotive advancements, human conduct, ethical considerations, traffic management strategies, regulatory frameworks, and legal responsibilities. Consequently, numerous inquiries and challenges need to be resolved in this domain. Hence, manufacturers are not currently strategizing for an expeditious deployment of fully autonomous vehicles to the general public. The technology aspect of detecting obstructions at high speeds and at huge distances is a significant barrier in terms of achieving unambiguous results. In relation to the many approaches to traffic management, there is a consensus among them that emphasizes the need of fostering harmonious coexistence between automobiles and trucks. Different forms of vehicle-to-vehicle collaboration and platooning are now being deliberated. Design and validation are being mimicked via the implementation of many methodologies, each carefully constructed from different perspectives. Furthermore, within the realm of highly automated driving, there have emerged legal inquiries. The concerns may range from the need of a driver possessing a certain license to the allocation of liability for damages arising from an accident.

This article is structured into four distinct parts, each of which delves into a significant aspect and obstacle encountered in the development of autonomous vehicles. There exists a conflict between cameras and LiDAR technology, cultural norms, human psychology, and legal considerations. The paper is structured into the following sections: Section II presents a discussion of the major aspects that should be put into consideration for novel in-vehicle technology. These aspects include acceptance and learnability, of new in-vehicle technology; net effective of the application of novel in-vehicle advancement; traffic efficiency; influence of the mobility rate and on mobility patterns; and safety-related aspects. Section III presents a review of the trends and discussion of self-driving cars. These trends include contention between camera and LiDAR technology; social habits; human psychology; and law problem. Section IV presents a conclusion to the research, as well as future prospects.

II. KEY ASPECTS FOR NOVEL IN-VEHICLE TECHNOLOGY

Acceptance and Learnability of Novel In-vehicle Technology

When considering the purchase of automobiles, senior drivers present a paradoxical situation in terms of their ingenuity. The majority of contemporary automotive technology integrated into vehicles are often included as part of the overall cost of higher-end luxury cars, which are frequently acquired by those in their retirement years with discretionary financial resources. Individuals in an older demographic may have more challenges in acquiring and effectively using these technologies compared to individuals who were exposed to them during their formative years. Based on empirical studies conducted by the AAA Foundation for Traffic Safety [2], it has been shown that older drivers need more time to attain proficiency in operating novel technology integrated into their automobiles. Nevertheless, the challenge of learnability does not provide as conclusive proof that older individuals are incapable of acquiring proficiency in state-of-the-art software. On the contrary, empirical research indicates that providing older adults with information about the benefits of a product serves as a catalyst for their adoption and use of the product. Furthermore, a strong understanding of state-of-the-art technology might potentially enhance individuals' willingness to embrace and use it into their practices. To effectively engage senior drivers with the new interface or functionality, it is essential to devise a methodology that effectively demonstrates the potential benefits of in-vehicle technology.

The advent of autonomous driving (AD) has the potential to significantly alter consumers' transportation experiences. The use of an advanced driver assistance system has the potential to enhance the overall safety, comfort, and enjoyment experienced when operating a motor vehicle. The potential for optimizing the use of time whilst driving may be enhanced by activities such as engaging in phone conversations, enjoying comedic entertainment, or even doing productive tasks. The use of autonomous vehicles (AVs) has the potential to enhance productivity and decrease the duration of workdays for those who have long commutes. The ease offered by autonomous vehicles may potentially attract a larger number of folks to suburban and rural areas, therefore enabling them to live in closer proximity to natural environments. Furthermore, AD has the potential to augment mobility options for elderly drivers, giving them expanded access to a broader array of transportation alternatives. According to Kyriakidis, van de Weijer, van Arem, and Happee [3], the implementation of Advanced Driver Assistance Systems (ADAS) in Europe is projected to potentially reduce the occurrence of accidents by around 15 percent by the year 2030.The user's text is too short to be rewritten academically.

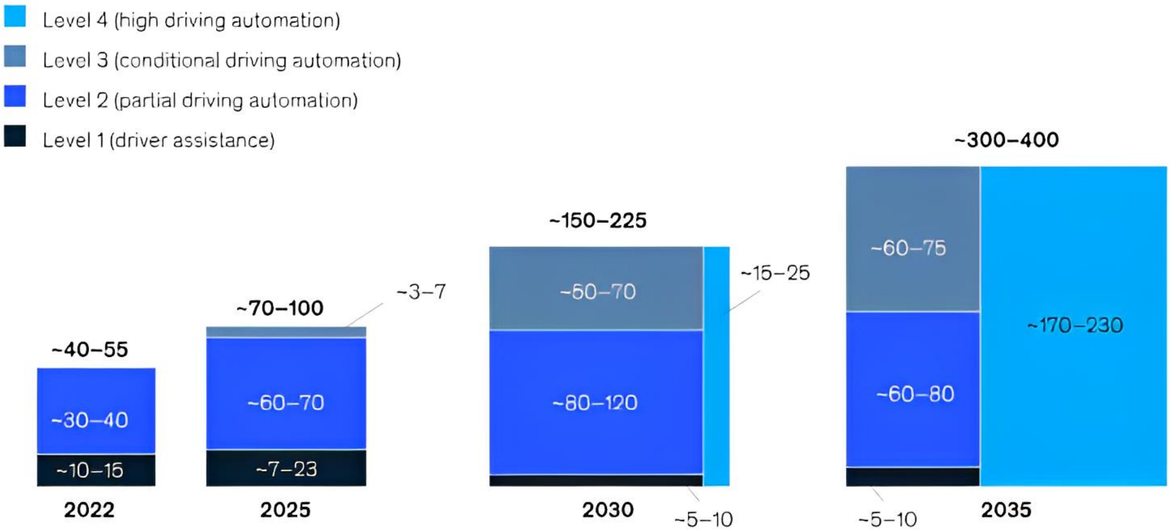

Fig 2. ADAS and AD Revenue (in $ billion)

Furthermore, apart from the aforementioned benefits for customers, it is worth noting that AD has the potential to generate profitability for the automobile industry. Significant advancements in AD capabilities are anticipated in the near future. However, at now, the majority of vehicles only provide basic Advanced Driver Assistance Systems (ADAS) functionalities. The achievement of Society of Automotive Engineers (SAE) Level 4 (L4), denoting complete autonomous operation, is anticipated to be realized in the foreseeable future for a significant number of cars. In 2021, McKinsey did a consumer survey which revealed that customers have a keen interest in advanced driver (AD) capabilities and demonstrate a willingness to incur financial costs in order to get them. The increasing demand for AD systems has the potential to provide substantial financial returns. The costs associated with automotive components that include Level 3 (L3) and Level 4 (L4) choices are much more in comparison to cars equipped with lidar-based Level 2+ (L2+) capabilities, which typically range between $1,500 and $2,000. According to McKinsey's estimation (see **Fig 2**), the implementation of Advanced Driver Assistance Systems (ADAS) and AD technologies has the potential to produce a revenue degree of $300 to $400 billion in passenger automotive sector by the year 2035. This projection is based on the level of consumer demand for AD features and the availability of commercial solutions currently offered in the market.

Elderly individuals are likely to exhibit increased motivation to use in-vehicle technology subsequent to acquiring the essential skills and knowledge to operate it effectively. This approach will facilitate the industry in successfully engaging its affluent customer in the process of formulating a novel perspective on automotive transportation. Elderly drivers often possess over three decades of driving experience, making them among the most experienced individuals in this domain. Paradoxically, the same encounter may impede their comprehension and aptitude in relation to the novel in-vehicle technology. According to research conducted by Regev, Rolison, and Moutari [4], it has been shown that drivers belonging to different age groups exhibit varying patterns of adaptation to emerging technology. Experienced drivers who have been driving for over thirty years without the use of automated features will be required to enhance their driving abilities in order to effectively utilize emerging self-driving technologies and advanced driver assistance systems (ADASs), including but not limited to LKAS, SPAS, ACC, brake assist system, and head-up display (HUD). In order for the industry to anticipate older drivers' ability to operate the newest technology in automobiles, it is imperative to provide them training. Continuous education and training for drivers is vital throughout their lifespan. The integration of technology education and training with conventional driver training and education is shown by the AARP Driver Safety Program, as highlighted by Haleem, Javaid, Qadri, and Suman [5].

Overall Efficiency of Use of Novel In-vehicle Advancement

Elderly drivers may experience distraction when the cause for the activation of a warning structure is ambiguous. Due to their gathered knowledge and critical thinking abilities, individuals may develop a tendency to question the reliability of the warning and initiate an inquiry into the possible underlying factors. Younger drivers, characterized by their limited driving experience, have a greater degree of trust in warning systems and are more inclined to rely only on them. The phenomenon of trust calibration failure occurs when drivers exhibit caution towards an automated function due to several factors such as perceived ambiguity, complexity, or lack of reliability. Various strategies may be used to mitigate concerns about automation or the occurrence of false alarms. The enhancement of driver-vehicle system sensitivity is achieved by enabling systems to provide a wide range of confidence levels in the communicated warning. Insufficiently advanced in-vehicle technology has the potential to heighten distractions and the driving workload for older individuals, so presenting a risk to the overall safety of roadways. Several studies have provided evidence suggesting that older drivers exhibit distinct decision-making patterns while using novel technology compared to younger individuals.

Based on the synthesis of Biernacki and Lewkowicz [6], it was shown that senior drivers exhibited a greater level of satisfaction with NVE systems compared to younger drivers, although using these systems less often. In spite of some factors that may cause diversion within the system, older drivers expressed heightened feelings of security and assurance while using navigation assistance and exhibited a more favorable perception of the forward collision warning (FCW) in comparison to younger drivers. Studies conducted by Stanton and Young [7] have shown that individuals of various age groups have reduced stress levels and increased trust in the system while adopting Adaptive Cruise Control (ACC). Madl and Radebner [8] delineated four possible benefits associated with contemporary technology. Initially, there exists the possibility that individuals may not effectively use it, so nullifying any advancements in safety. Furthermore, Trimpop [9] proposed the risk homeostasis theory, which suggests that the presence of novel technology may lead motorists to engage in more hazardous behavior. Furthermore, it is worth noting that the system's false warning rate may be deemed inappropriate for older drivers, who show a high level of caution when driving compared to their younger counterparts. Furthermore, after their exposure to the novel autonomous technology, drivers may potentially develop new behavioral patterns.

Traffic Efficiency

In the first stages of autonomous vehicle (AV) development, there was a strong emphasis on prioritizing safety and practicality, resulting in the adoption of rather cautious and conventional designs. As an example, AVs exhibit a latency period of 2 seconds prior to their activation, while human drivers typically experience a waiting time ranging from 0.8 to 1 second. Moreover, AVs would only execute lane changes in optimal conditions and exhibit seamless acceleration and deceleration. The results of many studies suggest that the introduction of a substantial number of AVs with a certain driving style into the traffic flow will lead to a deterioration in congestion levels due to reductions in capacity. According to Knoop and Hoogendoorn [10], the estimated lost capacity for an average highway is around 600 vehicles per hour per lane. The acceptance of autonomous vehicles that exhibit aggressive driving behaviors akin to human drivers is likely to be limited among the general population, therefore indicating that a clear resolution to this issue is not readily apparent. The solution may be found in the concept of cooperative driving, whereby vehicles collaborate by exchanging information and coordinating their actions to optimize both system-wide safety and efficiency. The emergence of autonomous cars offers an opportunity to implement dynamic traffic management strategies using suitable technologies and in a coordinated fashion. It is essential to develop these strategies concurrently with AV automation and implement them as the prevalence of autonomous vehicles on roadways increases.

With the proliferation of AVs in the transportation landscape, there arises a need to modify existing traffic management systems in order to effectively cater to a wider range of vehicle types. Considering that i) motorway traffic is subject to extensive regulations, making it an optimal setting for conducting first tests, and ii) there are already many motorways equipped with some of the necessary equipment, it is probable that addressing this scenario will be prioritized. Freeway platooning might potentially emerge as an initial traffic control strategy in the context of AVs. This requires the establishment of a road train, whereby AVs may operate at elevated velocities while adhering to much reduced inter-vehicle distances, surpassing the spacing seen among human-operated vehicles. The idea has been in existence for a considerable period of time, with the PATH program at UC Berkeley having performed field testing as early as 1997.

The restricted availability of advanced technologies at that period constrained the broad use of the platooning strategy. In some scenarios, a number of freight trucking companies have adopted a strategy including the use of SAE2-level vehicles equipped with ad hoc platooning technology. There are many unresolved inquiries pertaining to the implementation of motorway platooning on a large scale. These include determining the minimum level of vehicle automation required, specifying the permissible vehicle types (such as cars, vans, trucks, or their combinations), establishing the average distance maintained between platoon vehicles, defining the average speed at which platoons operate, determining the maximum allowable duration of platoons, and other related considerations. In terms of their coexistence with traditional autos, such as on shared lanes or dedicated routes, etc. The ingress and egress of vehicles into and out of the platoon is an additional significant consideration. Guo and (jeff) Ban [11] introduced a hybrid platooning formation strategy developed by the "Traffic Engineering" research team at the ETH Zürich and the Transport Planning and Systems Institute, aiming to enhance this particular approach. Additionally, they proposed the use of consensus algorithms as a means to establish and modify truck platoons in a distributed and collaborative manner.

These findings might be particularly advantageous for the implementation of passenger car platooning. The need for research in traffic management has become more imperative due to the imminent resolution of technological limitations associated with platooning and other advanced traffic management strategies. In the context of coexistence between AVs and human drivers on roadways, it is imperative to place a heightened emphasis on ensuring the comfort and safety of human drivers, while simultaneously maximizing the potential productivity advantages. Research has shown that an increase in the quantity of connected and autonomous vehicles (CAVs) present on roadways leads to enhanced traffic flow efficiency. According to Faheem, Ridwan, Muneer, Aneeque, and Afghan Khan [12], when enhancements reach around 30 percent of the flow, their impact becomes readily apparent. The current unavailability of completely autonomous vehicles has led to the use of semi-autonomous probe cars or simulations in order to investigate the effects of these novel traffic management strategies. Microsimulation programs have played a vital role in the research and development efforts conducted so far. Initially, the use of this micro method seems to be a more rational approach for investigating the collaboration among vehicles, as it enables the assessment of suitable gaps and velocities, among other factors. In contrast, macroscopic studies just focus on analyzing the average attributes of traffic.

Nevertheless, a considerable quantity of parameters is necessary, and the process of empirical calibration is now unattainable. This does not suggest that prior research is incorrect; instead, it indicates that the results will depend on the effectiveness of parameter configuration. The objective of the study conducted by researchers affiliated with UPC-BarcelonaTech is to analyze the influence of AVs on the movement of traffic, specifically focusing on a mesoscopic viewpoint. The aim is to find ways to overcome certain limitations associated with this phenomenon. The COOP project aims to establish specific objectives, which include the development of platoon traffic management strategies within a heterogeneous setting including both autonomous and conventional vehicles. In essence, the mesoscopic approach entails the examination of data on a higher scale, namely at the level of individual lanes. Although more micro-hypotheses are required, their quantity is much lower compared to a microscopic model. Moreover, all of these hypotheses has tangible significance and are thus more straightforward to forecast. The preliminary results so far are promising.

Impact on Mobility Patterns and Mobility Rate

The application of ride-hailing, ride-sharing, and ride-sharing services is consistently increasing. In light of recent analyses, it has been observed that private vehicles tend to remain stationary for a significant portion of the day, approximately 20-23 hours. This, coupled with the considerable expenses associated with their acquisition and maintenance, as well as the prevalent challenges of parking and congestion in urban regions, has led to the emergence of alternative mobility options that offer greater efficiency. Moreover, the increasing consciousness surrounding sustainability within developed societies has further contributed to a shift in perspective, particularly among younger individuals, who increasingly perceive vehicle ownership as superfluous or potentially unwise. In the forthcoming years, there is anticipated to be a substantial surge in the prevalence of automobile sharing and ride hailing services, resulting in enhanced accessibility and affordability for the broader populace. Furthermore, AVs are highly suitable for enhancing these mobility initiatives due to their inherent technological capabilities. Additionally, the cost savings resulting from reduced labor expenditures are likely to be appealing to company owners.

Moreover, the escalated costs associated with AVs would likely incentivize a shift towards community use as opposed to private ownership. Electric autonomous vehicle (AV) sharing programs are expected to have widespread support from both the general public and government entities. The aforementioned causes are expected to lead to a reduction in overall vehicle fleets. According to Gössling and Humpe [13], it has been projected that the automotive fleet in the United States and Europe would see a reduction of 22-25% by the year 2030. There exists a disparity in the available statistics about mobility rates, as several studies indicate a decrease in vehicle-kilometers per passenger while simultaneously seeing an increase in overall vehicle-kilometers. Collectively, these findings imply that individuals possess far more autonomy in terms of mobility within the broader social context. The first option is linked to the concept of sharing, as it enables a greater number of people to travel in each vehicle. Currently, the average automotive occupancy is at 1.3 passengers, but this figure is expected to increase with the adoption of shared automobiles. Contrary to the aforementioned forecast, recent studies conducted by Chen, Wu, Chen, and Wang [14] provide contrasting findings. These studies propose that the number of vehicle kilometers traveled per passenger will actually increase due to the use of private AVs engaging in empty excursions, such as parking after their owners have reached their destinations.

The configuration of public transportation networks has comparable significance. In order for sharing systems to enhance mobility efficiency and sustainability, it is imperative that they supplant private automobile trips rather than public transport travels, since the latter exhibit higher occupancy rates and hence possess better sustainability potential. This objective may be achieved by the use of sharing mechanisms to complement the existing public transportation system, particularly by facilitating the transportation of commuters in sparsely populated regions during the last segment of their journey. The integration of on-demand services, such as Mobility as a Service (MaaS), is necessary in order to align public transportation with contemporary demands. Based on initial cost-benefit analyses, it may be inferred that undertaking such action would be a prudent choice. The expected reduction in transportation costs resulting from increased automobile utilization and shared car use would lead to an increase in total vehicle kilometers. As a result, it is expected that there would be a rise in the movement of both commodities and people. A broader range of persons across different age groups will have the opportunity to get advantages from AVs due to the elimination of the need for possessing drivers' licenses in order to operate them.

Safety-Related Aspects

The correlation between road fatalities and various factors, including the absence of safety systems, speeding, driving while impaired by alcohol or drugs, and the use of mobile phones while operating a vehicle, has been well-established. However, advancements in vehicle technology, such as driver assistance systems, reinforced body structures, and passive and active safety systems, coupled with the proactive measures undertaken by traffic administrations, have resulted in a decline in fatalities across the majority of developed nations. On the contrary, there exists a contrasting tendency in India and other growing countries. Despite substantial advancements, the attainment of Zero Vision, which refers to the absence of accidents, remains a distant objective for several countries. In a hypothetical scenario of a completely automated system whereby all drivers collaborate, the occurrence of accidents remains a possibility. However, it is expected that the occurrence of accidents would be limited, since research suggests that 90% of accidents are caused by human error. For this scenario to occur, it is imperative that two essential conditions be satisfied [15]: firstly, a significant proportion of cars operating on the road must be fully autonomous; and secondly, the implementation of cooperative traffic control approaches must be successful.

However, the decrease in accidents might be somewhat offset by the increase in vehicle-kilometers-traveled. In addition to fire concerns, there are other potential risks that must be mitigated. One potential outcome is that individuals who use AVs may develop a sense of overconfidence, leading them to neglect the usage of seat belts. Additionally, there is a possibility that pedestrians may engage in reckless behavior such as crossing the street without proper caution, on the assumption that AVs would not pose a threat to their safety. Moreover, the susceptibility of AVs and V2X to cyber threats is a matter for concern, as it presents an enticing opportunity for hackers and terrorists to exploit. The seamless dissemination of malware and ransomware over interconnected networks further amplifies this risk. Governments are actively examining these challenges with the objective of developing a robust and impregnable system capable of withstanding such attacks. Although the possibility of communication systems being compromised remains, it is plausible to swiftly retake control.

III. TRENDS AND DISCUSSION OF SELF-DRIVING CAR

It is well-established that there have been advancements in the development of self-driving vehicle prototypes. Extensive testing has been conducted on several conventional self-driving cars, with distances exceeding one million kilometers. Additionally, some states within the United States have authorized the issuance of test-driving licenses specifically for self-driving vehicles. The commercial availability of completely autonomous cars is still a considerable distance away. The commercialization of autonomous cars will be influenced by several variables that extend beyond the technological aspects.

At now, a self-driving car is equipped with a wide array of sensors that are not found in a traditional automobile. Commonly used sensors include lasers and visual sensors, which serve the purpose of acquiring comprehensive understanding of the immediate environment. The cost of these sensors is high, and they exhibit a high degree of selectivity in terms of their use requirements. The installation of these sensors in a mobile vehicle also significantly diminishes their operational longevity. Furthermore, the issue of trustworthiness is a matter of worry.

Furthermore, the integration of self-driving automobiles necessitates a period of adjustment for both human psychology and the legal framework. Several elements may be considered when examining the impact of autonomous cars. These factors include the ownership rate among the population, the presence of automated support systems for energy compensation in autonomous vehicles, and the frequency and severity of traffic incidents involving such vehicles.

Hence, the development of autonomous vehicles presents a set of distinct obstacles, which may be categorized into four main parts: (i) camera and LiDAR technology; (ii) social habits; (iii) human psychology; and (iv) law problem

Contention between Camera and LiDAR

LIDAR and Vision are considered to be crucial sensors for facilitating the perception of a self-driving car's environment. Both sensors possess distinct advantages and disadvantages. The primary advantage of LIDAR technology is in its ability to enhance the perception of the surrounding environment for a mobile vehicle, especially under situations of limited illumination. The optimal combination of sensors is the primary determinant in differentiating the performance of autonomous vehicles. Two predominant sensor types used in autonomous cars are Light Detection and Ranging (LIDAR) and cameras (see **Fig 3**). In order to generate a three-dimensional representation of the Earth's surface, LIDAR technology utilizes laser pulses to measure distances, while cameras capture visual imagery using visible light. Both systems assess the near vicinity of a vehicle, although each has distinct merits and drawbacks. LIDAR operates by emitting a laser beam and quantifying the duration it takes for the beam to return after encountering obstacles in its trajectory. The data that has been gathered is afterwards used to generate a comprehensive three-dimensional representation of the vicinity around the self-driving car.

LIDAR (see **Fig 4**) is particularly advantageous because to its provision of precise distance and depth data, which is important for the purposes of object identification and avoidance. The use of short wavelengths in LIDAR enables the system to not only ascertain the existence of an object within the surrounding environment, but also determine its identity, as well as classify it according to its dimensions and form. The enhancement of the autonomous system's planning and navigation capabilities may be achieved via the use of this data for the creation of an accurate three-dimensional map. LIDAR utilizes an active lighting sensor, enabling its operation in both diurnal and nocturnal conditions. Hence, it exhibits immunity to fluctuations in illumination conditions. Nevertheless, LIDAR does have some limitations. Although the high-resolution data obtained through sensors is valuable, it does not possess the same level of density as that captured by a camera. Moreover, objects characterized by low reflectivity, such as black vehicles or asphalt surfaces, might provide challenges for LIDAR sensors in terms of detection.

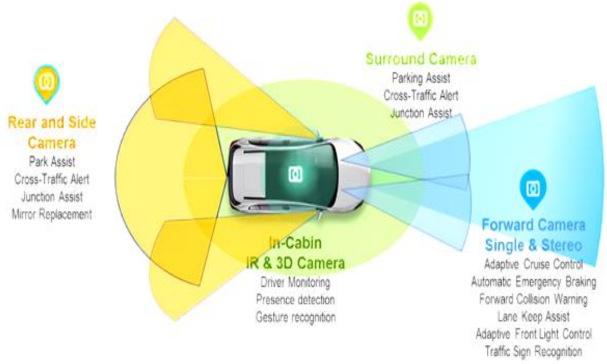

Fig 3. Camera Technology

Fig 4. Lidar Technology

Cameras have become an omnipresent kind of sensor, with a multitude of surveillance devices monitoring individuals in their homes, workplaces, and public environments on a daily basis. This is due to the affordability of cameras and their ability to provide a comprehensive visual representation of the environment via the capture of high-definition videos and still images. This is the reason why autonomous vehicles find them so advantageous, since they may be effectively used for tasks such as lane detection and object recognition. Cameras provide valuable capabilities for the purpose of object identification and categorization due to their capacity to perceive color and texture. Moreover, cameras exhibit exceptional proficiency in discerning intricate features even under conditions of diminished illumination.

Historically, the majority of vehicles were equipped with a single camera, which therefore limited the ability to get three-dimensional perspectives of the vehicle's surroundings. The use of inferencing in generating depth information has become possible due to recent breakthroughs in Neural Networks technology. In order to accomplish this task, the first step involves using inferential reasoning to ascertain the spatial separation between the identified objects and the dataset used for training the Neural Network. However, stereo vision extends beyond just distance measurement. A three-dimensional representation is generated by using a pair of cameras positioned at a little distance from each other, capturing two photos of the same scene simultaneously. The determination of pixel depth and object distance from the cameras is achieved by the analysis of pixel disparity between the two images using advanced algorithms. This process subsequently provides a three-dimensional representation of the observed scene. The use of 3D stereoscopic cameras in autonomous vehicles has the potential to provide significant advantages in terms of visual navigation, object recognition, and the establishment of a precise three-dimensional perception of their environment. The efficacy of 3D stereo vision cameras in accurately detecting minuscule objects at extended distances and under situations of reduced illumination is limited by several variables, including the contrast and texture of the image as well as the resolution capabilities of the camera.

At now, the 3D imaging laser radar stands as the most efficient sensor for capturing a wide-angle 3D scene image of superior quality. Using the Velodyne HDL-64 as a case study, it is seen that the prevailing market price for this LIDAR system may reach a substantial amount of $80,000. However, it is important to note that a significant drawback associated with LIDAR technology lies in its intricate and expensive production process. When comparing LiDAR with Vision, it can be seen that Vision is a more cost-effective option. However, it is important to note that Vision has some limitations in its ability to perceive and understand its surroundings. These limitations are influenced by several variables, including the quality of the algorithm used and the environmental conditions, notably the level of illumination. The constant discourse regarding the interpretation of our environment is influenced by both good aspects and negatives. Google mostly utilizes LiDAR technology for the installation of self-driving vehicles, whereas Tesla largely relies on Vision-based systems. In contrast to assertions made by Wang and Menenti [16], it is expected that there would be a substantial decrease in the cost of LiDAR. This projection is based on a convergence of enhanced production techniques and a growing market demand, as highlighted by Kelly, Wilkinson, Abd-Elrahman, Cordero, and Lassiter [17]. In fully autonomous driving mode, laser technology will serve as the main sensor for environmental perception. However, visual sensors will also be used to assist in the perception of the surrounding environment for self-driving purposes. In the near future, there will arise a need for a mixed environment perception model that is supported by LIDAR and helped by vision.

Social habit

The study of social behavior patterns has a significant position within the discipline of sociology. The development of self-driving technology is anticipated to have significant implications for the transportation sector. Firstly, the taxi and truck industries will see significant disruptions as a result of technological advancements. Additionally, effectively managing the consequences of technological innovation in other sectors will prove to be an arduous task. Furthermore, what impact will it have on public transportation? The existing social transportation paradigm may face possible collapse due to the emergence of autonomous vehicles, leading to a reduction in bus services and an increase in urban traffic congestion. The emergence of autonomous cars has the potential to alter individuals' assessment of financial prosperity. The potential for a future in which individuals are more motivated to participate is contingent upon the growth of the sharing economy within the domain of road transportation, a development that may be facilitated by the adoption of self-driving vehicles.

One of the primary challenges associated with autonomous driving is to the establishment of effective communication channels between autonomous vehicles and human drivers. To effectively operate in practical settings, AVs must possess the capability to navigate challenging scenarios, such highway merging and executing left turns without the aid of traffic signals or protected lanes, which are often demanding for human drivers. In the year 2015, it was observed that there were more than 450,000 events related to lane changes and merging, along with over 1.4 million accidents involving right or left turns, inside the United States [18]. In order to guarantee the safe operation of AVs, it is essential to implement precautionary measures due to their present lack of understanding of human behavior. When drivers exercise caution, they decelerate the rate of traffic movement, especially at intersections. Waymo, a prominent contender in the realm of autonomous driving, currently faces certain challenges that need to be addressed in order to successfully execute maneuvers such as left turns and exhibit consistent behavior [19].

The application of a cautious strategy in the advancement of AVs has many implications. Firstly, this strategy renders AVs more vulnerable to aggressive human drivers and compromises their capacity to accurately perceive human intentions. Secondly, it heightens the probability of unforeseen behaviors, which may be both perplexing and hazardous. A recent study conducted in California revealed that in instances when AVs encountered traffic issues, human drivers were responsible for rear-ending them in around 57% of cases [20]. A significant number of these incidents occurred due to the autonomous vehicle's behavior deviating from the anticipated actions of the human driver. For AVs to coexist harmoniously with human drivers on the road, it is essential that they possess the capability to comprehend the intentions of these drivers and respond appropriately.

When there is no traffic present, an autonomous vehicle (AV) may easily devise a strategy for executing a left turn. However, this task becomes much more complex and difficult when the path is congested with vehicles. According to empirical evidence, it has been shown that human drivers may minimize the risk associated with making an unprotected left turn by strategically timing their maneuver when the preceding vehicle decelerates to yield. The capacity of an autonomous vehicle to interpret and react to social cues indicating self-centeredness or cooperation plays a vital role in ensuring the efficient operation of the transportation system and the well-being of its users. AVs prioritize explicit communication, state machines, or geometric reasoning when it comes to driving interactions, disregarding social cues and driver personality. The efficacy of these strategies is constrained when it comes to managing intricate relationships, resulting in a cautious approach and limiting autonomous solutions to those that just pertain to the road. Measuring and conveying the activities and decisions of individuals to autonomous entities pose significant challenges.

Human Psychology

The need for safety among individuals is identified as a primary contributing factor to the issue, with the presence of social and ethical considerations. For more than a century, individuals have been engaged in the operation and navigation of motor vehicles. In contrast to other innovations, the autonomous vehicle poses a much-elevated potential for severe harm or fatality to anyone within the vehicle. The psychological impacts are significant. Certain people exhibit reluctance in adopting self-driving vehicles due to concerns over their perceived lack of safety, whilst others resist their use as they get enjoyment from the act of driving themselves. Consequently, there will be a significant period during which both self-driving vehicles and human drivers will coexist. Is there an ethically defensible approach to prioritizing the safety of passengers above pedestrians in situations when both groups are in danger? When faced with a crisis, what factors are considered in determining the appropriate course of action between a young individual and an older one? The perpetual psychological dilemma of devising strategies for establishing an emergency sanctuary is a persistent concern. Scholars have also acknowledged this issue.

Due to the inherent possibilities, it is essential to conduct human-factors research to examine how drivers navigate the challenges posed by malfunctions in automated systems. According to prior studies conducted by Arakawa, Hibi, and Fujishiro [21], it has been shown that the physiological states of drivers may exhibit differences based on whether they are operating their vehicles in manual mode or autonomous mode, especially during the process of transitioning control of the vehicle. When individuals engage in manual driving, they typically direct their attention on their surroundings. However, in the event of autonomous systems assuming control, there is a possibility for individuals to get disengaged or lose focus. Furthermore, the requirements of autonomous driving have the potential to alleviate drivers' stress levels compared to the experience of manual driving. The transition from complete automation to complete manual driving might present notable disparities. To the best of our current understanding, there is a lack of existing research that has investigated the possible disparities in human factors between manual and autonomous driving. Furthermore, this study has importance not just for the security of autonomous cars but also for the broader understanding of drivers in general.

Law Problem

The current legislation is insufficient in addressing the challenges posed by driverless cars. There are four concerns that need to be addressed, which are as follows: The license problem is first present. Currently, several countries have a deficiency in their ability to effectively control autonomous automobiles. Given the advancements in autonomous vehicle technology, is it ethically acceptable to retrofit conventional autos with self-driving capabilities? At now, there are no countries or areas that provide licenses for driverless cars. The issuance of test permits for autonomous vehicles is limited to California and a select number of states within the United States. Additionally, there are regulations pertaining to the act of driving. There exists a division among the legal world over the appropriate foundation for establishing rules for autonomous vehicles, specifically whether they should be derived from the requirements of human driving. The third aspect pertains to the many manifestations of responsibility. Where should the demarcation of accountability be established? The legal considerations pertaining to autonomous vehicles revolve around the necessity of human presence in the driver's seat, the requirement for licensed drivers occupying the driver's position, and the allocation of responsibility among passengers in that role. Data protection is ranked as the fourth priority. In the context of documenting the trajectory followed, should an autonomous vehicle be permitted to do this task? Is there a correlation between the level of information security within a country or region and the implementation of autonomous vehicle mapping systems?

Nevertheless, the ongoing dispute about the legal matter persists. On March 23, 2016, the United Nations implemented amendments to the Vienna Convention on Road Traffic pertaining to the regulation and control of road traffic. The implementation of automatic cars into the transportation system becomes feasible. The United Nations Coordination Forum on World Vehicle Regulations, responsible for the drafting of the 1958 Agreement, is set to conduct an examination in 2017 on the potential elimination of speed restrictions pertaining to the use of active steering [22]. Significant progress has been observed in the development of a legal framework for self-driving cars in the United States. This advancement is evident through the collaborative efforts of state and federal governments in formulating regulations and legislation pertaining to this domain. Notable examples include the Research in Vehicle Evolution Act, the Federal Automated Vehicles Policy, and the Safely Ensuring Lives Future Deployment. Certain countries are now implementing just a portion of the testing terms, while others are considering the enactment of such legislation.

IV. CONCLUSION AND FUTURE PROSPECTS

Currently, an increasing number of technological advancements initially designed for autonomous vehicles are being integrated into regular autos. The anticipated trajectory of autonomous vehicle technology is a gradual advancement from aided driving to self-driving in particular environments, such as highways, culminating in the attainment of complete autonomy. In recent years, a variety of driving assistance structures, such as adaptive cruise control and lane keeping assist, have become more prevalent among the general population. The next significant advancement in autonomous cars pertains to the commercialization of self-driving automobiles capable of operating with little human supervision in restricted settings, notably on highways. The rate of technological advancement is rapid and a wide range of vehicles, including cars, buses, the London Underground, bicycles, motorcycles, and others, may be seen traversing the roadways. The distinguishing factors that differentiate items within their various categories include kind, brand, equipment, drivetrain, luxury, and maintenance needs. Contemporary consumers have a preference for automobiles that provide a combination of safety, convenience, user-friendliness, and uncomplicated operation. As a consequence, the field of autonomous vehicles is seeing significant expansion.

Due to customer demands, there is a growing focus on the development and implementation of novel advancements in autonomous vehicle technology. Numerous automotive manufacturers have developed their own iterations of autonomous vehicles and have identified inherent limitations within their designs. The potential infiltration of autonomous vehicle software systems by hackers remains a significant concern, hence putting cyber security as the foremost challenge associated with these automobiles. The continued process of resolving this significant issue is now underway. The advent of autonomous vehicles has facilitated the practice of ride-sharing among users, leading to a reduction in traffic congestion and financial savings, all without necessitating a centralized pick-up point. Currently, there are smartphone applications that enhance the convenience of carsharing. Consumers express a strong need for a substantial level of safeguarding measures, while also seeing these automobiles as notably pleasant and sophisticated. Autonomous vehicles have shown significant potential in enhancing the mobility of those belonging to vulnerable populations, such as the elderly, disabled, and those with physical impairments. Certain specialists posit that the general use of driverless vehicles remains distant, notwithstanding the numerous advancements and enhancements anticipated in the forthcoming decade. The achievement of full self-driving capabilities, surpassing human performance levels, is anticipated to become a tangible reality by the year 2031. The phrase "full self-driving" is often used as a concise way to refer to the autonomous vehicle technology known as self-driving cars.

Data Availability
No data was used to support this study.

Conflicts of Interests
The author(s) declare(s) that they have no conflicts of interest.

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Competing Interests
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