A Short Review of Innovation in Autonomous Car in Combination with Mechanical and Electronics

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1 Introduction

Vehicles were previously thought to be the domain of mechanical engineers [1]. However, extraordinary advances in automotive and information technology have transformed a typical car from conventional transportation into a fully-fledged, intelligent, infotainment-rich computer machine on the go [2]. The features and qualities provided both high-tech communications and computer technology, as well as the proliferation of high-end vehicles, give groundwork for the implementation of smart vehicles. These vehicles have been dubbed "autonomous vehicles" [3]. An autonomous automobile is a computer-controlled vehicle capable of navigating, acquaint itself with its environment, make judgments, and function completely autonomously. The requirement for driver and driving safety, population expansion, growing infrastructure, an increased traffic, a requirement for the efficient administration of time, active utilization of sources, are key reasons behind the introduction of autonomous automobiles [4]. In today's scenario transport infrastructure is poor, whether it be roads or parking lots to petrol stations and charging stations. Governments have taken substantial steps to improve road safety in recent decades, in abundance that includes both stationary and flexible mechanics like closed circuit television cameras (CCTVs), street sensors, and more [5]. Linked automobiles and autonomous vehicles are alternative technologies that are being investigated for the elimination of human mistakes and life-threatening condition on the road [6]. The development and emergence of self-driving automobiles are the product of outstanding research findings from disciplines of radio intelligence, installed regularities, sensors, temporary web technology, distribution, and analysis of data. The

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concept of self-driving automobiles began in the 1920s with "phantom autos," which were operated by a remote control unit [7]. The "Prometheus Project" was sponsored back in 1987 by Mercedes [8], clearing each significant success by the construction concerning the first robot vehicle for monitoring the traffic signals and additional carriers. Despite the fact, it was not entirely autonomous at the time but the capability to switch lanes autonomously was a significant development. The growing interest in self-driving automobiles in the twenty-first century has been spurred with less expensive technology, which works well in a variety of domains [9]. It is critical to distinguish between two opposing concepts: the automated automobile and a self-governing car [10]. The level of driving automation has been illustrated in Fig. 1. A general outlook of both terms conveys the idea of allowing these cars to be independent. The first, however, refers to a machine-controlled vehicle that may require human interference. Autonomous vehicles make use of the notion of linked automobile technologies [3]. The connected vehicle uses the technology of vehicular ad hoc (VANET) network, in which the onboard unit (OBU) is introduced. These automobiles are able to interact with one another only when available in the sphere of communication through the standard short-term communication protocol (DSRC) [11]. In contrast to Google, Microsoft has formed a partnership with Volvo and Toyota to create autonomous automobiles. NVidia has demonstrated great passion in self-driving vehicles. NVidia Drive PX2 has launched their flagship which is GPU-based a dominant processing program for self-driving vehicles [12]. Companies like Uber and Apple are also emerging players in the self-driving vehicle market. TATA, KIA, Nissan, and Hyundai are significant Asian businesses funding the scheme, production, and research of self-driving automobiles. Vehicle ownership has increased tremendously over the previous several decades as their costs have dropped; likewise, individuals pride automobiles further accessible as their earnings rise. However, this speed of car acquisition contributes to increased contamination and transportation obstruction [13].

In 2010 this globe was home to one billion automobiles, and the figure is predicted to double in 2030, necessitating a critical requirement for increased supplies and infrastructural assistance to accommodate this massive growth in the number of transportation [14]. Over 1.25 million people are losing their life every year in traffic accidents as reported by World Health Organization (WHO) [15], with the death

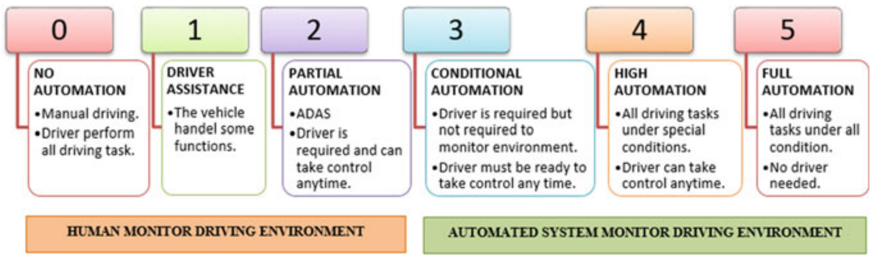

Fig. 1 Level of driving automation

toll expected to grow to 1.8 million by 2030 [14]. As a result, there is an urgent demand for a technologically sophisticated, completely automated, dependable, and safe mode of transportation, and the autonomous car sector has been working hard to achieve these expectations. After nearly five decades, the quality of the automatic transmission system had improved and the cost had been decreased to the point where it could be used in most vehicles [16]. The same logic applies to electric and hybrid cars [17]. In a word, owing of its initial high price and limited dependability, autonomous automobile technology will take time to become available and accessible to customers. However, vehicle makers must overcome these difficulties before autonomous cars can be successful and transform the automotive industry. In this paper, the recent developments in autonomous car technology are summarized and current concerns and challenges in development of autonomous vehicles has been reviewed.

2 The Autonomous Car

Driving an autonomous car needs support, mainly in the case of sudden vehicle action. Therefore, showing these findings and their predicted movements is very important to understand the situation [18]. The design of a standalone vehicle should take into account size, speed, character, heterogeneity, and real-time info environment [19]. Its deserving mentioning that various automakers use onboard sensors and controlling technology for a variety of optimal applications. However, the ability to function independently is a crucial necessity at the heart of autonomous automobile design [20]. In other words, the autonomous automobile must-have capabilities allow it to anticipate, determine, and maneuver safely and reliably following a plan. The key components of a high-performance autonomous vehicle system are shown in Fig. 2. The tiered structure comprises data collecting conducted with hardware parts such as sensors (in-car and onboard), radar (long-range and short-range), LIDAR, cameras, and transceivers [21]. The data obtained by those elements is analyzed by a central computer system of an independent vehicle, which is following used by the resolution guide operation. The autonomous car is activated by the decision support system [22]. This is important to note that condition awareness is achieved using both short and long-distance thinking systems such as detectors, LIDAR, and cameras. These regions comprised by these sections are shown in Fig. 3. Different levels of situational awareness are appropriate for different applications and have been attained through various components [3]. Infrared technologies, for example, avoid front and rear bumper collisions, while short-range radars give lane-change warning, short-distance object recognition, and construction of traffic viewing [23]. The self-driving car is also outfitted with several cameras to provide a 360° picture of its surroundings, as well as LIDAR for collision avoidance and emergency braking. Long-range radars enable cooperative cruise control and the building of long-range traffic views [24]. An autonomous automobile must go through a sequence of steps: the car must sense and become aware of its surroundings, plan a route, operate, also

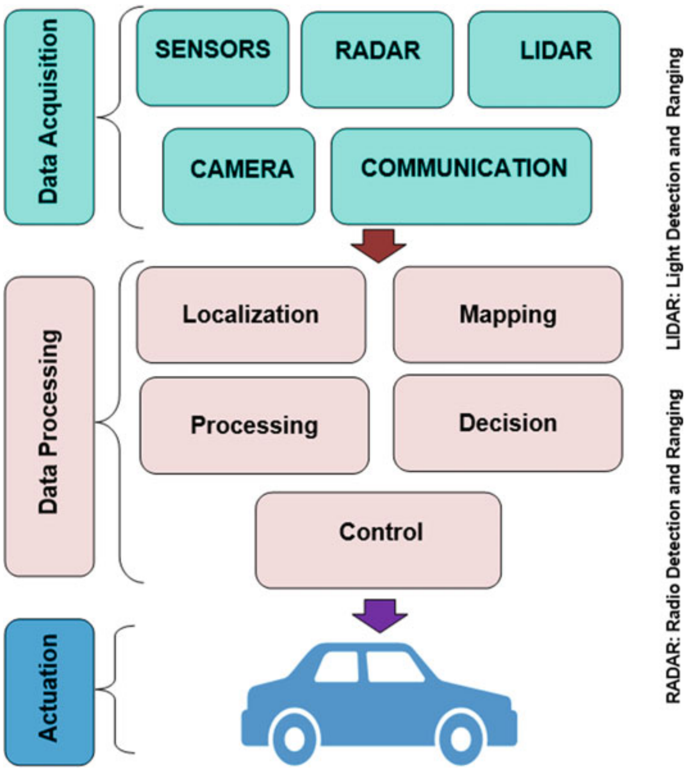

Fig. 2 Autonomous cars: functional architecture [27]

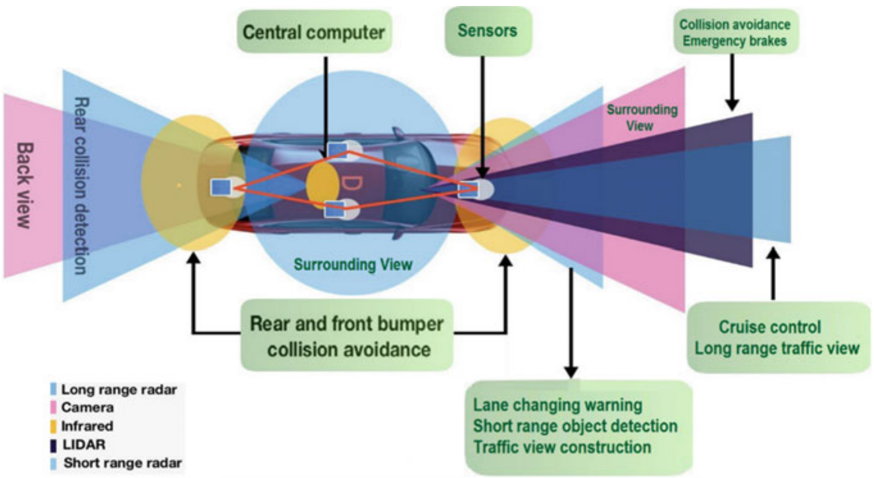

Fig. 3 Autonomous cars: system architecture [27, 28]

perform the controlled movement on the path [25]. Major stages involved in carrying out the aforesaid activities [26] in an autonomous vehicle are as follows:

- Situational and Environmental Awareness
- Navigation and Path Planning
- Maneuver Control.

2.1 Environmental and Situational Awareness

The primary plus most crucial stage in self-driving cars is to become aware of their surroundings, which adds target monitoring, self-positioning, and plane finding [29]. These automobiles need to be able to sense what is ahead of them, as well as have 360° neighborhood awareness [30]. As previously stated, a variety of hardware components, ranging from onboard and in-car cameras to common and short-distance detectors, are utilized for this purpose [31]. However, each of these components has advantages and disadvantages. Cameras can help people become more aware of their surroundings and the environment. However, the amount and rate of real-time info needed for area recognition are required in terms of automotive computing [32]. Radar technology performs much more effectively at tracing an object than cameras in this context, giving it one of the most effective vehicle modes [33]. LIDAR tracking is employed in an autonomous vehicle. LIDAR's key features include 360° visualization and tracking of long-distance efficiency. As result, a LIDAR device may be put on the automobile to provide a comprehensive picture of the surroundings [34]. However, it is important to note that LIDAR does not perform well in obtaining a solid object, such as collision-resistant parking, avoiding a collision, and bump protection [35]. Instead, for the aforementioned functions, specialized radars are positioned in the front, back, and sides of the vehicle. The data collected by these gadgets aid independent vehicle decision-making systems to control speed, use brakes, switch lanes, and navigate. The info collected by these methods are utilized in sophisticated software to create a three-dimensional representation of the surrounding area [36].

2.2 Navigation and Path Planning

The fundamental role of navigation or guiding in an autonomous car is to let the car drive in the direction you want. If the self-driving vehicle knows its surroundings, it should determine its route according to its purpose [3]. The automobile constructs a time-dependent path between the present place and the destination using navigation technology as a well-known global positioning system (GPS) control system [37]. Due to its precision, efficiency, and compacted hardware, architecture (on-chip), cheap cost, and usage, GPS is the principal method of routing for the automobile. Furthermore, the path is dynamically recalculated in the event of specific occurrences such as road closures, detours, and soon. The navigation system in the automobile must be strong enough to accommodate abrupt and consequent adjustments to the path by changing the path made by the computer in the past. Path networks are substantially predetermined, and the self-driven vehicle's steering system compares car continuity in a regular study [38]. Various research initiatives were carried out and evaluated real-world data which produces a map for self-driving automobiles [13]. The results are encouraging and will help in the first phase of self-driving car sales.

2.3 Maneuver Control

The autonomous automobile begins its trip when it observes its surroundings and uses this knowledge, coupled with its destination information [39]. For a smooth, safe (or at least unsuccessful) journey along the way, various motions should be properly regulated [40]. As previously noted, the autonomous vehicle is outfitted with a plethora of detector and controller. Most auto components are electronically commanded by Electronic Control Units (ECUs) [41]. During its voyage, the autonomous car has to do a few things like taking care of the road, the distance from bump to bump, sudden brakes, jumping, and stopping on-road signals. This movement requires hardware/software support, as well as large-scale communication and real-time data exchange across multiple vehicle control systems [42].

3 Autonomous Cars Major Advantages

Despite its complexity, the autonomous car idea offers up new apps to innovate and provide users with security, efficiency, convenience, and additional aids. In this part, there is a need to go over some of the primary advantages of self-driving vehicles as well as prospective uses for self-driving automobiles.

3.1 Improved Security

Safety is a character with many features in the automotive environment, where people's lives are at the forefront when it comes to driving. One of the most essential uses of self-driving vehicles is safe driving for its passengers [40, 43]. With high-tech sensors onboard, the autonomous automobile can correctly detect its rightful owner and issue an alarm to the owner in the event of an uncomfortable circumstance [44]. Biometric such as fingerprints, retina scans, speech recognition software, and/or synthetic telepathy might be used in self-driving automobiles [24].

3.2 Usefulness and Convenience

Another advantage of self-driving automobiles is their simplicity of use and convenience [42]. People are sometimes unable to drive an automobile due to medical/disability issues or drunkenness. Self-driving car may be an appropriate form of transportation for the elderly, young people who do not have a driving license, and individuals who cannot meet the expense of a car [45].

3.3 Improved Traffic Conditions

Autonomous vehicles will improve traffic conditions by increasing the occupancy of each vehicle and reducing the number of automobiles on the highways [46]. Self-driving cars can assist in more accurately complying with traffic regulations, minimizing the need for traffic cops on the road. In situations such as excessive running, erratic driving, starting and stopping, and rapid braking self-driving car may prevent unpredictable driving habits that result in fuel inefficiency [45, 47].

3.4 Autonomous Parking

The growing number of vehicles, overcrowded people, spaces between cars in parking lots are one of the main problems in metropolitan centers today [48]. After dropping off passengers, autonomous cars can park even in the smallest of available parking spaces (where people will look for larger parking spaces for each car) [42].

3.5 Customer-Centered Experience

Drivers will be able to relax, sit down, and enjoy the journey of self-driving cars. It is worth mentioning that Tesla, the electric automobile company, has already made strides in these areas, including “summon” [48] applications in its high-end models [36]. Autonomous vehicles will open the way for a slew of passenger-centered apps, allowing passengers to tailor their travel experience depending on factors such as speed, amount of danger, in-car entertainment, and so on [49].

4 Design and Implementation Issues

Security, durability, good demolition, environment failure, hardware/software architectures, and user satisfaction will determine the future of self-driving automobiles [2]. However, in order to accomplish these objectives, the concept and production of self-driving vehicles must provide maximum accuracy, protection, and substantiality, as human lives are directly dependent on them. Road acquisition is one of the most important mobile vehicle needs and is often seen with various sensors such as radar, LIDAR, location, sonar, advanced sensors, and softwares are all used in the self-driving automobile. The conceptual and implementation concerns are summarized in Table 1. In this part, there's a discussion over design and use-issues that the autonomous car industry is facing. Existing validation tools has been described (such as simulators) for simulating and testing various components of the autonomous vehicle.

4.1 Cost

The cost of hardware and software is a key impediment to the widespread manufacture of self-driving automobiles [50]. Earlier LIDAR hardware costs roughly US $75,000, which is significantly more expensive than the automobile itself, but with technological advancement currently, it cost US $7500 [51]. As a result, it is fair to expect that hardware costs will be critical in the design and implementation of self-driving automobiles.

4.2 Maps

The maps utilized for self-driving cars differ those created by regular GPS systems [52, 53]. These maps make extensive use of road features including lane length, distance from pedestrians, and steep elevation. Using big data technology to solve these difficulties may be an option you can consider in the future [13]. Data is gathered by various sensors like 3-D LiDAR [34], odometer sensors, and economical GPS; nevertheless, changing landscapes and road constructions continue to pose challenges for effective mapping [54].

4.3 Software Complexity and Quality

The accuracy of the system generated by the software must be extremely reliable [44]. The level of expertise in self-driving car software must be able to reflect a

Table 1 Summary of design and implementation issues

Aspect	Challenge	Possible solutions	References
Cost	• Hardware cost • Software cost • Management cost • Maintenance and testing are expensive	• Mass production	[50, 51]
Maps	• Massive processing resources required for real-time map production • Storage expense • Unpredictable weather circumstances • Dynamic environment as well as road layouts	• Big data applications • Collaborative mapping with neighbors	[34, 52, 54]
Software complexity	• Testing as well as verification • Requirements remain incomplete • Natural challenges cause software inconsistency • Program expense • Program protection • Difficult to get permission to use the software	• Fail-safety profiles and driving qualities • Put a greater emphasis on AI as well as deep learning-based technologies	[3, 42, 55, 56, 70, 71]
Validation and testing	• No comprehensive list of prerequisites • Strong and uncomplicated activities • Complication of action • Aim-demanding quality	• Restricted operating paradigms • Pedagogical guidance as well as machine learning methodologies • Error prevention • Logical division of programming modules	[57–61, 70]
Security and reliability	• The similarity of a person's level of self-reliance requires many resources • Distance traveled during test drives has no bearing on loyalty measure is imprecise • Removal of abortion work is dangerous • Uncertain verification period	• Appropriate short-term objectives • Comprehensive inefficient systems • Developing sophisticated algorithms for small tasks • Using machine learning, deep learning, and artificial intelligence	[39, 62–67, 70–72]

(continued)

Table 1 (continued)

Aspect	Challenge	Possible solutions	References
Sensors management	• Data of several sensors need to be handled in the problem-solving moment • In-depth learning algorithms that store and operate a computer • Lack of data, external factors, and granularity from sensory data • Verification of observed data	• Increasing computation and transmission means • Finding crowds and seeing crowds • Sensory data sharing throughout all units • The trade-off between the number of sensory inputs and the speed	[2, 21, 50, 70, 73]

person's mind and/or behavior [55, 56]. With self-driving cars, the driver is not there, necessitating even more strict procedures to maintain the greatest software quality [3]. As a result, it is significant for independent software developers to ensure that the software retorts to a variety of unexpected events [56].

4.4 Validation and Testing

There are many verification methods and testing methods available, from bug fixes to full quality tests [57]. On the other hand, the design/actuator design will help with the demand problem and provide fail-safe modes for autonomous vehicles [58]. The third option is an error vaccine, which can help in the certification of autonomous cars. Koopman and Wagner [59] proposed that at least in part, the complicated requirements difficulties may be minimized by restricting the autonomous car's operating principles [60]. The present testing methodologies for autonomous vehicles, while large and concrete, it cannot cover the entire safety spectrum and operational requirements, as well as the unpredictable behavior displayed by autonomous vehicles [61].

4.5 Safety and Reliability

The safety and dependability of self-driving automobiles is vital problem to overcome [28, 62]. It is arguable that before the commercialization of autonomous cars, couple hundred millions of kilometers testing must to complete [63]. The time necessary for autonomous automobile technology to drive itself safely is in the tens, if not hundreds, of years [64]. This is a massive test run for a self-driving automobile [65]. The autonomous automobile must be able to work on its own without personal involvement, even during testing [66]. The automated car's safety and dependability are still in their start, and it will take time to satisfy the rules of security and accuracy. The safety benefits of autonomous cars can be brought about by the installation of idle safety features in the integrated safety system [39]. The in-vehicle network must also be secured form attacks [67].

4.6 Sensor Management

Autonomous vehicles contain several sensors that create a massive quantity of info in actual time. This info is utilized by several automotive components to work properly [21]. Currently, the major issue for self-driving cars is not efficiency. As a result, crowd sourcing and crowd sensing will be demanding in the improvement of autonomous vehicles afterward [2]. In other words, rather than having a big number of detectors, having a complete number of detectors and exchanging sensory info between neighbors is likely to produce superior results. In addition, a trading solution to this problem can be reached by reaching an agreement on the value of these detectors, the number of detectors, and the expenses they put into data processing and decision-making processes [51].

5 Limitations

If an object is at an angle nearly perpendicular to the sensor, the limited resolution of the LiDAR may cause consecutive points in the scan to be measured at far away different distances, causing the check to fail even though the object is actually connected. This is a fundamental limitation of LiDAR information; there is no way to determine based on the sensor data whether the object is fully [68]. Ethical and ethical considerations are taken into account when developing program that determines what step a car takes in certain casualty [40]. Susceptibility of navigation system of the car to different types of weather (snowy conditions, floods, heavy rain, etc.) is also a major limitation factor [69].

6 Conclusion

In this modern era, autonomous technology and vehicles are becoming fast-growing technology. Various automakers like technology business owners are experimenting with them. The complete functional cycle of an autonomous vehicle is divided into various patterns such as situational awareness, planning, control, and inclination. The principal advantages concerning self-driving vehicles incorporate increased security for passengers, fresh business possibilities, upgraded traffic situations, learners, and the creation of customer participation. Notwithstanding certain advantages, still, there are few design and applications difficulties which are needed to be solved before these practical autonomous vehicles can be completely deployed. The software complexity and quality, object detection accuracy, sensor management, decision-making, actuation, and testing were looked at along with the security and authenticity of these vehicles. In addition, nontechnical difficulties were examined like variety, customer support, unpredictable expenses of autonomous vehicles, and sociological hurdles: for instance, human behavior upon driving, as well as moral and honest implications. Ultimately, presented ideas to assist designers and policymakers in developing viable regulations for the design, construction, and deployment of autonomous vehicles were explored. This must be acceptable to consumers as well. Despite the outstanding accomplishments obtained with autonomous automobile technology thus far, still a bit too hasty to predict the commercial phase of the driverless vehicle. Nonetheless, it is expected that more research findings will propel the autonomous vehicle sector toward commercialization in the near future. The summarized conclusions and future outlook are:

- Radar is the most effective technology to trace an object in autonomous vehicles.
- LIDAR is lacking to provide collision-resistant parking, avert a collision, and provide bump protection.
- The maps make considerable use of road characteristics such as lane length, pedestrian distance, and steep elevation. Big data technologies implementation for road characteristics can be explored for more understanding.
- Road acquisition is one of the most significant requirements for mobile vehicles, and it is generally accomplished using a variety of sensors such as radar, LIDAR, position, sonar, sensors, and software optimization.
- The navigation system which can be explored for more understanding of accommodating abrupt and consequent variations in the path by altering the path taken previously by the computer.
- It may also be worthwhile to secure in-vehicle network from attacks.
- Autonomous vehicle has a large number of detectors to exchanging sensory information. It could a great innovation to develop superior structure having a small number of detectors.
- Lastly, software used in autonomous vehicles should capable of responding to a wide range of unforeseen circumstances.

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