Autonomous cars : A Systematic Literature Review

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***Abstract*—Autonomous vehicles (AVs) have been a subject of growing interest and research within recent years, primarily due to their potential to revolutionize the way we travel. This systematic literature review explores the levels of automation as published by the Society of Automotive Engineers (SAE), highlighting the functioning of autonomous vehicles (AVs) through sensor-based technology. The paper delves into the ethical implications of decision-making during accidents and addresses various challenges faced by self-driving cars. Furthermore, this review discusses the acceptance of AVs by examining its importance in solving contemporary transportation issues and stimulating reader interest in the broader work. This paper employs an extensive analysis of existing literature, focusing on technological advancements, ethical considerations, and challenges faced in AV development. Our findings reveal several practical and theoretical applications for AV technology .**

***Index Terms*—Autonomous cars,Self-Driving cars,SAE level ,technology,Acceptance, automated driving.**

I. Introduction

Autonomous cars have emerged as a transformative innovation within the transportation industry, holding the potential to reshape our daily commutes and urban environments. The development of these self-driving vehicles can be categorized into various levels of automation, as classified by the Society of Automotive Engineers (SAE). Ranging from basic driver assistance to complete vehicle autonomy, these levels integrate sophisticated sensors and technologies that enable vehicles to navigate independently and make complex decisions in real-time.

This paper systematically reviews the current literature on autonomous cars, evaluating their operational mechanisms, ethical implications, challenges faced, and public acceptance. Self-driving cars employ advanced sensor technologies that process massive amounts of data to facilitate decision-making, particularly in critical scenarios such as imminent accidents. One pressing ethical concern revolves around programming autonomous vehicles to make morally sound decisions amidst unavoidable collisions. As autonomous cars transition from concept to reality, numerous hurdles must be overcome, including technical constraints, regulatory measures, and infrastructure adaptations.

Moreover, public acceptance remains a vital aspect for the widespread use of autonomous vehicles. Understanding the factors influencing individuals' willingness to adopt this technology is crucial for ensuring a smooth integration of self-driving cars into society. This systematic literature review aims to provide a comprehensive analysis of the current state-of-the-art in autonomous vehicle research while highlighting the importance of addressing key challenges and fostering user trust for successful implementation.

II. Research method

The research method applied in this survey followed the classical three-stages process for running systematic studies : Planning, Conducting, and Reporting. We briefly report the main activities carried out for running this study

A. Planning

Research Questions: the study goal has been achieved by investigating four research questions, reported in Table 1:

RQ ID	Reserch Question
RQ1	How Do Avs work ?
RQ2	What the challenges that face self-driving cars?
RQ3	Programming Self-Driving Cars for how to React in the Event of Accidents ?
RQ4	What do people think of accepting self-driving cars?

Table 1

Search Strategy: The search strategy combines a manual search with an automatic search. The search strategy has been designed as a multi-stage process to carefully select all the primary studies that are relevant for our study . In the following we give a brief description of each stage of our search and selection process.

Stage 1: Manual search. We manually searched the digital libraries ScienceDirect,IEEE and scolar with the search string ("Self-driving cars" OR "autonomous vehicles" OR "driverless cars" OR "Auto-driven cars "AND "artificial intelligence" OR "Deep learning "). Then, we manually browsed relevant journals proceedings (available in the replication package). The output of this stage consists in 4 pilot studies, 42 primary studies, the definition of an initial search string, and the definition of inclusion and exclusion criteria.

Stage 2: Automatic search. We performed automatic searches on ScienceDirect. We used the following search string:

("Self-driving cars" OR "autonomous vehicles" OR "driverless cars" OR "Auto-driven cars "AND "artificial intelligence" OR "Deep learning ")

Stage 3: Combination and duplicates removal. In this stage all the results from previous stages are combined together into a single spreadsheet, and duplicates are removed.

Stage 4: Selection of studies. The main goal of this stage is to filter all the selected studies according to a set of well-defined inclusion and exclusion criteria. The criteria are described below.

Stage 5: Exclusion of studies during data extraction. This stage was performed in parallel with data extraction. When reading a study in detail (to extract the data), and based on inclusion and exclusion criteria, studies where definitively selected or rejected.

Inclusion and Exclusion criteria: A study was selected if it satisfies all inclusion criteria, and discarded if it meets any of the exclusion criteria.

Inclusion criteria:

(1) Review/survey papers on AV.

(2)Papers focusing on AI/ML algorithms in AV.

(3)Papers focusing on environment perception and pedestrian detection.

(4)Papers focusing on motion control.

(5)Papers focusing on path planning.

(6)Papers focusing on vehicle cybersecurity.

(7)Papers focusing on networking and communication.

(8)Papers focusing on psychology towards AV.

(9)General papers that do not have a specific focus.

Exclusion criteria:

(1)Papers that were just posters.

(2)Papers that did not have full text available.

(3)Papers where English was not the primary language.

(4)Papers where AVs were taken in a different context.

(5)Papers that were totally out of scope for our research questions.

Data Items: Table 2 gives an overview of the data items that were extracted from the primary studies to answer the research questions.

Data Item	Data Field	RQ
F1	Study Title	DOC
F2	Publication Year	DOC
F3	Venue	DOC
F4	Context study	DOC
F5	Technology used in Avs.	RQ1
F6	The Challenges that face AVs .	RQ2
F7	Ethical decision making .	RQ3
F8	Acceptance of self-driving cars .	RQ4

Table 2

Except for the first item, we derived these data items directly from the research questions as indicated in the left column

B. Conducting

In this phase we set the previously defined protocol in practice. More specifically, we performed the following activities: (i) studies search, (ii) studies selection,(iii) data extraction.

C. Reporting

Data extracted from the selected primary studies was collected in a spreadsheet including, for each paper, the following fields: paper ID, paper title (F1), authors, country, abstract, and F2-F8 data items. Sheets have been created for each data item, and for combinations of data items. The spreadsheet is available in the replication package in the excel sheet.

III. Background

Self-driving cars, also known as autonomous vehicles (AVs), are vehicles that are capable of operating and navigating without human intervention. These vehicles leverage advanced technologies such as sensors, machine learning algorithms, and artificial intelligence to perceive their surroundings, make decisions, and control their movements.

The Society of Automotive Engineers (SAE) currently defines 6 levels of driving automation ranging from Level 0 (fully manual) to Level 5 (fully autonomous). These levels have been adopted by the U.S. Department of Transportation.

So here are the six levels: Level 0 (No automation): This is where the vast majority of cars and trucks are today.

The driver handles steering, throttle, and braking (ST& B)monitoring the surroundings, as well as navigating, and determining when to use turn signals, change lanes, and turn. But there can be some warning systems (blind-spot and collision warnings).

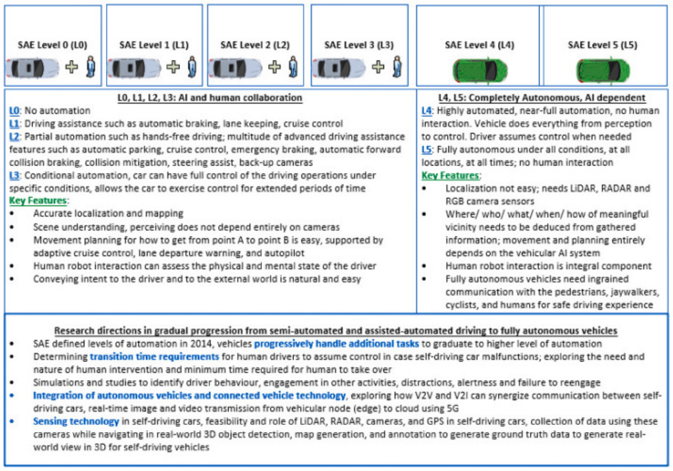
Level 1 (Driver assistance): Vehicles in this level can handle S or TB, but not in all circumstances, and the driver must be ready to take over those functions if called upon by the vehicle. That means the driver must remain aware of what the car is doing and be ready to step in if needed.

Level 2 (Partial assistance): The car handles ST&B, but immediately lets the driver take over if he detects objects and events the car is not responding to. In these first three levels, the driver is responsible for monitoring the surroundings, traffic, weather, and road conditions.

Level 3 (Conditional assistance): The car monitors surroundings and takes care of all ST&B in certain environments, such as freeways. But the driver must be ready to intervene if the car requests it.

Level 4 (High automation): The car handles ST&B and monitoring the surroundings in a wider range of environments, but not all, such as severe weather. The driver switches on the automatic driving only when it is safe to do so. After that, the driver is not required.

Level 5 (Full automation): Driver only has to set the destination and start the car, the car handles all other tasks. The car can drive to any legal destination and make its own decisions on the way. (Standard SAE J3016, 2016) The above levels are important because they serve as general guidelines for how technologically advanced a car is. The biggest difference is that, starting at Level 3, the automated driving system becomes able to monitor the driving environment.[1]



Levels of Automation

IV. RESULTS

This section provides the results of our four research questions.

A. RQ1 :How Do Autonomous cars work ?

The answer to RQ1 is derived from Technology used in Avs (F5) .

Technology used:

Autonomous cars use a variety of techniques to detect their surroundings, such as radar, laser light, GPS, odometers, and computer vision. Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage. Autonomous cars have control systems that are capable of analyzing sensory data to distinguish between different cars on the road, which is very useful in planning a path to the desired destination. (Anderson et al., 2014) The systems used in the autonomous car consist of (see fig. 2b) :

1) LIDAR (Light Detection and Ranging) :

It is a remote sensing technology which measures distance by illuminating a target with a light beam and analyzes the reflected light. It is mounted on the roof of the vehicle on a cylindrical enclosure which rotates 360 degree and is the most important device in the Autonomous vehicles. Lidar consists of emitter, mirror and receiver. It maps a 3D structure of environment and location on the road in 360°. It uses laser, ultra violet, visible light or infrared light to image objects. The emitter sends out a laser beam that bounces off a mirror that is rotating along with the cylindrical housing at 10 revolutions per minute. (Chang et al., 2019, Yum et al., 2019) After bouncing off objects, the laser beam returns to the mirror and is bounced back towards the receiver, where it can be interpreted into data. This data is fed in to the computer which generates high precision 3D map of the surrounding environment (see fig. 2b). The vehicle can use the map to avoid objects. This accuracy of this map is in centimetres because the wavelength of light used is very small and is able to reflect of all types of surfaces and small objects.

2) RADAR (Radio Detection and Ranging) :

This equipment can estimate the mutual velocity of the object and the vehicle, using the electro-magnetic waves. During the measurement it sends out a signal, than it waits until it is sent back. The frequency of the sent back signal is in case of mutual movement slightly changed (Doppler's effect); therefore it is possible to instantly calculate the velocity of the forehead driving vehicle. (Šarkan et al., 2017) The radar, compared to Lidar, uses a bigger wave length and lower signal energy. It is however not able to describe the shape of the scanned space. It can also have a problem with non-metal items, or items which have a specific shape. Most of the radars work in the range of approximately 77 GHz and the scanning beam is relatively directional. The radar scans the road in front of the vehicle up to approximately 200 meters distance. Some vehicles use two radars with different ranges. The Radar systems are installed on the front and rear bumper of the vehicle. Radar detects the surrounding environment and the central computer combines this result with that of the Lidar system. The radar system are used for detecting oncoming vehicles, their speed, other obstacles, for self parking, blind spot detection, lane-change assistance, adaptive cruise control, side impact warning, cross-traffic alert. etc. (Gestmair et al., 2019) ULTRASONIC SENSORS: These are mounted on various sides of the vehicle to detect objects very near the vehicle or measure the position of other vehicles during parking. These sensors provide parking assistance, collision warning, lane departure among other functions.

3) VIDEO CAMERAS :

They are installed at the top of the front glass, near the rear view mirror and build real-time 3D images of the road ahead. These are used to detect the traffic lights, traffic signs, unexpected things like animals or pedestrians, etc. They also detect different road signs like "STOP" signs, zebra crossings, sign boards etc. Video cameras also help in recognizing certain gestures which other sensors can't comprehend like hand waving or traffic cones. (Yun et al., 2019).

4) GPS (Global Positioning System) :

It is a space-based satellite navigation system that provides current location and time information anywhere on earth where there is an unobstructed line of sight to four or more satellites. It is the basis of all the maps that vehicle uses while on the road. All satellites broadcast at the same two frequencies, 1.57542 GHz and 1.2276 GHz. GPS uses satellites to gather information about the current position of the vehicle.

5) CPU or Computer :

All the data obtained from each and every sensor systems is fed to the central computer, which process this data at high speed. The central computer is a very powerful processing unit mounted on the inside of the vehicle. With the help of highly sophisticated software makes the required decision and sends the output to electro-mechanical units like automatic steering, throttle and breaking systems. This computer is also connected to the internet and GPS system to provide real time monitoring and updates.[1]

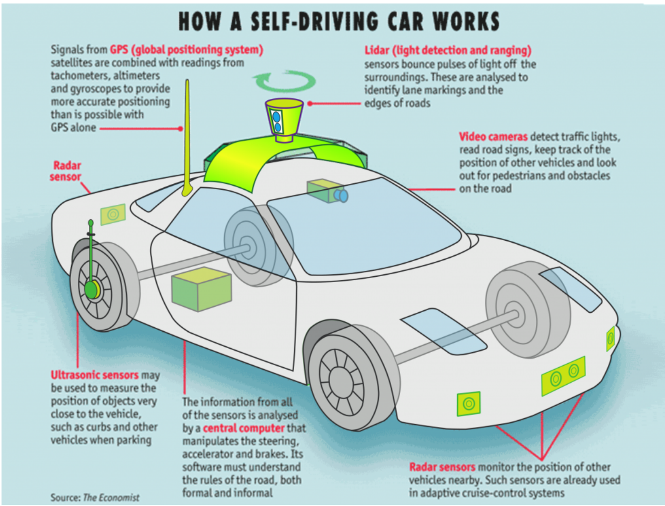


fig. 2b

B. RQ2: What the challenges that face self-driving cars?

Shladover (2017)[2] writes that the key technological challenges comprise:

1. Developing comprehensive and reliable environment perception capabilities to be used under the full range of environmental conditions under which the vehicle is intended to operate (i.e. weather and lightning conditions).

2. Providing the automated driving system with comprehensive fault detection that can rapidly diagnose its own malfunctions and switch to fallback mode that can maintain safety.

3. Ensuring sufficient cybersecurity protection.

4. Resolving questions of “robot ethic”, enabling system software to make life or death decisions that impacts the safety of all road users And most importantly.

5. Designing software systems for a level of safety so that the rate of error in the system requirements, specifications and coding is sufficiently low that the system will be no less safe than human driving.

C. RQ3:Programming Self-Driving Cars for how to React in the Event of Accidents ?

In the event of accidents, self-driving cars need to be programmed to react appropriately. While self-driving cars aim to minimize collisions, they cannot always avoid accidents due to the limitations of physics and sudden changes in the environment. The presence of other vehicles, pedestrians, and human-driven cars adds complexity to the situation.

Automated vehicles must be programmed to handle situations where a collision is unavoidable. Transferring control to human passengers may not be effective due to human reaction times. Therefore, self-driving cars need to be prepared and programmed for how to crash. This approach has advantages over relying on human reactions, as the car can make calculated decisions based on sensor inputs and available information.

Consider a scenario where a self-driving car with five passengers faces an oncoming conventional car (e.g., a heavy truck) suddenly departing from its lane. The self-driving car recognizes that a high-impact collision is inevitable, which would endanger the five passengers. However, swerving to the right towards the pavement would result in the death of an elderly pedestrian. In such cases, the self-driving car needs to respond on its own, as the human passengers cannot react quickly enough. In order to save the five passengers, the car may need to make a maneuver that would likely result in the unfortunate death of one person.

Overall, programming self-driving cars to react in the event of accidents involves making ethical choices and considering the best course of action based on the available information and potential consequences.[3][4][5]

D. RQ4:What do people think of accepting self-driving cars?

The public acceptance of autonomous vehicles (AVs) is influenced by various factors, and understanding the public perception is crucial for adoption.

1- Impact of previous experience (awareness): Previous experience with AVs has a significant impact on acceptance. Studies have shown that people with previous experience tend to be more optimistic about AV technology, prefer autonomous buses over human-driven ones, and have a higher preference for AV trips. Simulators have also been used to assess acceptance, with participants who had prior knowledge of AVs showing more positive attitudes. However, there has been a negative shift in public opinion over time, with concerns rising due to reported accidents involving AVs. This highlights the importance of addressing safety concerns to improve public acceptance of AV technology.

2 - Impact of economic conditions on public acceptance of Avs:

According to a study by Bazilinskyy et al. (2015), the economic conditions of a country can influence the public acceptance of autonomous vehicles (AVs). The study surveyed 8862 respondents across 112 countries and found that people from low-income countries were more likely to have a positive attitude towards AVs compared to those from high-income countries. Concerns about AV technology were also observed, with 40% of respondents from high-income countries expressing concerns, while the figures were 20% and 23% for medium and low-income countries, respectively. Specifically, respondents from high-income countries were more concerned about software failures in AVs, while developed countries showed less comfort with the idea of vehicle data transmission compared to developing countries. This suggests that economic conditions play a role in shaping public acceptance and concerns regarding AV technology. [6]

3-Precepting of AVs for different age groups

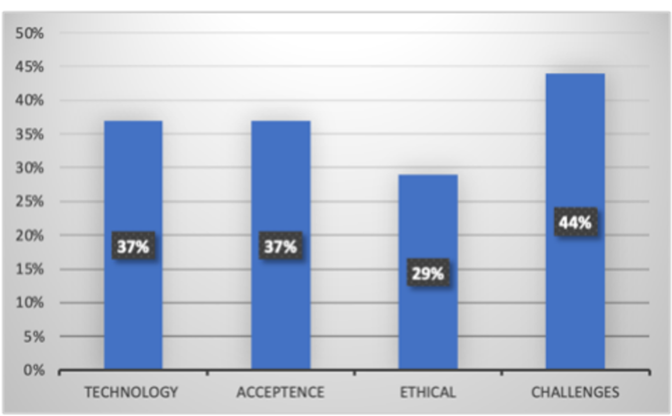
Studies have shown that younger people are more interested in autonomous vehicles (AVs) than older individuals. While some assume that AVs would increase accessibility for the elderly, results show that younger people are more likely to consider making trips with AVs. Additionally, further surveys are needed to understand the perception of disabled individuals towards AV technology.[7]

4- Perception of males and females and educational level on AVs' acceptance

Surveys showed that males are more optimistic towards AVs than females, with 19% of males fully AVs compared to 12.4% of females. Piao et al. found that males are more likely to use AVs than females, with 64% having no problem making trips in AVs compared to 55% females. Higher education people are more aware of AVs' benefits and generally skeptical, with 71% of high education respondents preferring AVs compared to 52% for people with low education.[8],[9]

V. DISCUSSION

This systematic literature review sheds light on the functionality of Avs which uses sensors to detect its surrounding and make decisions and we looked at the number of studies that concern the technology used in Avs are 37% of studies. it indicates a strong focus on the challenges faced in their development and deployment and the percentage of studies that talk about it 44%, the importance of public acceptance toward using self-driving cars (37% of studies), and the ethical implications of decisions making in cases that the accident certainly and how the cars act in this cases, we found 29% of the studies discuss this topic.



VI. CONCLUSIONS

Autonomous cars have garnered significant attention in recent years, with the development of advanced technologies and the publication of SAE's levels of automation. This systematic literature review has explored the functioning of autonomous vehicles (AVs) which primarily relies on sensor technology for navigation and decision-making. Furthermore, this paper delved into the ethical implications raised when AVs are faced with making crucial decisions during accident scenarios. Overcoming these challenges is vital for the successful implementation and widespread acceptance of self-driving cars. By starting with a broad research area and gradually narrowing down to specific topics, this review provided comprehensive insights into the overarching field of AVs while simultaneously discussing a variety of pressing concerns. The findings emphasized the importance of understanding and addressing both technological advancements and ethical considerations in order to shape a future wherein autonomous cars can be safely integrated into our daily lives.

REFERENCES

1 Ondruš, J., Kolla, E., Vertal', P., and Šarić, Ž., "How do autonomous cars work?" *Transportation Research Procedia*, vol. 44, pp. 226–233, 2020.

2 Renneby, V. and Sommer, J., "The transition to autonomous–impact & challenges in the race toward self-driving cars," 2018.

3 Nyholm, S. and Smids, J., "The ethics of accident-algorithms for self-driving cars: An applied trolley problem?" *Ethical theory and moral practice*, vol. 19, no. 5, pp. 1275–1289, 2016.

4 Karnouskos, S., "Self-driving car acceptance and the role of ethics," *IEEE Transactions on Engineering Management*, vol. 67, no. 2, pp. 252–265, 2018.

5 Gogoll, J. and Müller, J. F., "Autonomous cars: in favor of a mandatory ethics setting," *Science and engineering ethics*, vol. 23, pp. 681–700, 2017.

6 Bazilinskyy, P., Kyriakidis, M., and de Winter, J., "An international crowdsourcing study into people's statements on fully automated driving," *Procedia Manufacturing*, vol. 3, pp. 2534–2542, 2015.

7 Abraham, H., Lee, C., Brady, S., Fitzgerald, C., Mehler, B., Reimer, B., and Coughlin, J. F., "Autonomous vehicles and alternatives to driving: trust, preferences, and effects of age," in *Proceedings of the transportation research board 96th annual meeting*. Transportation Research Board Washington, DC, 2017, pp. 8–12.

8 Schoettle, B. and Sivak, M., "A survey of public opinion about autonomous and self-driving vehicles in the us, the uk, and australia," University of Michigan, Ann Arbor, Transportation Research Institute, Tech. Rep., 2014.

9 Piao, J., McDonald, M., Hounsell, N., Graindorge, M., Graindorge, T., and Malhene, N., "Public views towards implementation of automated vehicles in urban areas," *Transportation research procedia*, vol. 14, pp. 2168–2177, 2016.