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Advanced Driver Assistance Systems in Cars: Intelligent Connected Cars

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Abstract: In this article, we provided a comprehensive overview of ADAS operating principles, various types and variants, and their functions and options. We discussed the specific features of ADAS based on their various safety applications. We also examined the importance of advanced communication systems, such as V2X, and sensor data fusion methods for future autonomous vehicles.

Keywords: Intelligent Connected Vehicles (ICV), LiDAR, ADAS level, Automatic Emergency Braking, Adaptive Cruise Control, Drowsiness Assist, Tilt Assist, Head-Up Display, Omnidirectional View.

INTRODUCTION:

Advanced driver assistance systems (ADAS) have become a crucial safety feature in cutting-edge vehicles. They are also a key foundational technology in emerging independent vehicles. Current ADAS are primarily based on visual recognition and feature color-coded controls. Automatic emergency braking systems (AEBS) and other advanced visual recognition technologies are also gaining popularity. This article provides an overview of key ADAS technologies or features for independent vehicles. We examine the approaches used for visual recognition and detector emulsion in ADAS outputs. We also highlight the benefits for future generations of ADAS. This comprehensive work describes active safety and reversing driver assistance systems in detail, examining both their structure and functionality. These include well-known standard systems such as Electronic Stability Control (ESC) or Adaptive Cruise Control (ACC), a surround view camera system (OmniView), and a head-up display. New systems for collision avoidance, lane change assistance, and disabled parking are also considered [1].

The purpose of this article is to provide an overview of key ADAS technologies, including EEA sensor technology, and their future trends. While numerous ICV demonstrators have been developed to demonstrate the concept of autonomous driving and the potential for ICV-based road efficiency improvements, there is a significant gap that needs to be filled before high-quality ICVs can be produced in large quantities. This article examines the root causes of this gap and the most important technologies needed to address it. This perspective offers a unique perspective on the current state of ICV development. The study combines these two perspectives to help researchers [2] from industry and robotics to collaborate more effectively and understand each other's work.

1. Characteristics of advanced driver assistance systems, or ADAS

One of the most serious socioeconomic problems in the world today is the number of road accidents. The WHO estimates that up to 50 million people are injured and 1.2 million are killed each year. If automated systems helped people with braking, many of these accidents could be avoided. While advanced driver assistance systems (ADAS) cannot completely prevent accidents, they can better protect us from some human causes, and most road accidents are the result of human error. We can change driver behavior, take vehicle-related actions, and implement road infrastructure measures to reduce the number of accidents. Shifting from passive to active safety measures is another strategy. Airbags, vehicle body design, seat belts, and head restraints are examples of passive safety measures. Electronic stability control (ESC), anti-lock braking systems (ABS), and other advanced driver assistance systems such as intersection collision avoidance assist (ICA) and straight-keeping assist are examples of active safety measures (ASAs). Currently, we can implement information and communication technology (ICT)-based driver assistance systems (ADAS) that continuously assist drivers in their work, preventing accidents. This document provides an overview of the most widely used and selected technologies and components for intelligent transportation systems. This overview only highlights a few representative examples of available technologies and does not cover all potential options. The table below provides a brief overview of driver assistance systems already implemented (for both passenger cars and commercial vehicles) as well as systems that are in the market launch stage. Below is a list of the characteristics of advanced driver assistance systems, or ADAS, as they are called in the automotive industry. ADAS is a general term. The individual technologies that comprise it are small autonomous systems. Taken together, ADAS is essentially an autonomous driving system, but it is not marketed as such for regulatory reasons.

Table . Existing and future vehicle automation systems/functions.

Level of automation	Current and future vehicle automation systems and functions	Market Introduction
0	Lane Change Assist (LCA)	Accessible
0	Lane Departure Warning (LDW)	Accessible
0	Forward Collision Warning (FCW)	Accessible
0	Park Distance Control (PDC)	Accessible
1	Adaptive cruise control (ACC)	Accessible
1	Parking Assistance (PA)	Accessible
1	Lane Keeping Assist (LKA)	Accessible
2	parking assistance	Accessible
2	assistance in traffic jams	Accessible
3	Driver in traffic jam	Accessible
3	Driver on the Motorway (MWC)	2022+
4	Highway pilot	2022+
4	Manned parking	2022+
5	Robot taxi (fully automated private vehicle)	2022+

The SAE, a global association of automotive engineers, has identified six levels of autonomy, ranging from Level 0—no autonomy, simply mechanical vehicles—to Level 5, which corresponds to fully autonomous driving. ADAS systems are classified into different levels of autonomy, depending on how many individual components are contained in the vehicle [3].

2. Automotive Safety Review

Automotive safety has been a central concern since the early days of automobiles on public roads. Some original equipment manufacturers (OEMs) have attempted to address this issue by creating various safety systems to protect occupants inside the vehicle and prevent injuries to those outside the vehicle. These systems are generally divided into two types: (1) passive (or reactive) and (2) active (or proactive). Passive safety systems protect vehicle occupants from injury after a crash, such as seat belts, breathing apparatus, and soft dashboards. Due to growing consumer demand for safer vehicles, the underlying safety systems, which have been continuously improved over time, have been supplemented by dynamic safety systems that aim to prevent accidents altogether. Dynamic systems are a key area of interest and have evolved significantly in modern vehicles. Examples of such systems include lane keeping assist, automatic braking, and active traffic management. These systems are commonly known as ADAS and are becoming increasingly popular as a way for automakers to differentiate their products while simultaneously improving consumer health.

Advanced driver assistance systems (ADAS) are also crucial technologies for the development of autonomous vehicles. However, a number of challenges related to the design, implementation, and operation of ADAS remain to be overcome. These include minimizing energy consumption, reducing response latency, adapting to changing weather conditions, and safety. In this article, we provide a brief overview of the geography of ADAS research and development to address these challenges [4].

3. How ADAS works

ADAS systems use camera-based sensors to help drivers better navigate the road. Cars are the foundation of the future of mobility, and significant progress is being made in the field of autonomous vehicles. Systems on a chip (SoC) are sets of integrated circuits used to independently perform operations. These circuits connect sensors to selectors via interfaces and high-performance electronic control units (ECUs). ADAS systems are integrated into the initial design of many modern cars and are upgraded by automakers as they introduce new models and features. To ensure effective safety mechanisms, the systems utilize a variety of data sources. A combination of high-quality detection systems that match or exceed human vision is known as machine vision. This includes real-time data (one data source), 360-degree content, 3D object resolution, and good visibility in low light and rain.

This demonstrates that equipment designers are using increasingly sophisticated manufacturing processes to meet ever-increasing performance standards while reducing power consumption and space requirements.

Beyond the vehicle's core platform, data can be acquired from other sources, such as other vehicles or vehicle-to-infrastructure communications, such as Wi-Fi. Future generations of ADAS will continue to connect to wireless networks to improve safety and cost effectiveness. Using these visual processing capabilities, ADAS annotation services help the surrounding machine vision systems see the vehicle within a safe zone, protected from driver error, road obstacles, other vehicles, and pedestrians. ADAS transmits recognition and tracking information to onboard safety systems to detect driver drowsiness, alert for lane departure, prevent collisions, and implement protective measures to prevent accidents and improve driving quality. Similar to adaptive cruise control, which adjusts the vehicle's speed to maintain a safe distance from the vehicle in front, ADAS systems also include traffic management capabilities. More advanced ADAS functions allow steering and traffic control without direct driver intervention in certain situations, such as highway driving or stop-and-go traffic. These systems, commonly referred to as Level 2+ active safety systems, include some of the most comprehensive features currently available. The life-saving potential of advanced driver assistance systems (ADAS) can be significantly increased by these features. For example, the Insurance Institute for Highway Safety found that forward collision warning systems reduce front and rear collisions by 27% when equipped with autonomous braking. Furthermore, reverse automatic braking and rearview cameras reduce the number of reversing accidents by 17% and 78%, respectively [5].

3.1. Main components for automated driving: key technologies

To improve safety and response times, ADAS technology, which stands for Advanced Advanced Driving Systems (ADAS), was developed. These technologies were designed to automate and improve driving procedures to prevent fatal errors and related problems in vehicle control, as the majority of road accidents are caused by human error. By reducing the overall number of road accidents, these safety systems aim to improve road safety and reduce the number of injuries. Vehicles capable of (highly) automated driving are controlled agents that integrate environmental perception and modeling, localization and map generation, trajectory planning, and decision making.

The Environment Perception and Modeling block provides a real-time model of the environment.

3.2. ADAS system type

ADAS systems are divided into two types:

Passive ADAS systems Active ADAS systems

a. Passive ADAS system:

In a passive ADAS system, the computer alerts the driver to a hazardous situation, regardless of the presence of any or all sensors. To avoid a crash caused by this condition, the driver must change lanes. Typical warning systems include sirens, flashing lights, and, in some cases, an additional blind spot detection system (for example, a vibrating steering wheel to alert the driver to an approaching zone). The driver receives important information that allows them to make informed decisions while driving. Passive ADAS systems, using the human-machine interface (MMI), provide real-time road surface information and warnings about potential hazards. There are three modes of data transmission: haptic, auditory, and visual. ADAS systems have traditionally made extensive use of visual and audible warnings. Visual signals are easy to understand and can be used to convey vivid messages using color and symbolic information. This is the most common method of disseminating information. Warnings can be displayed visually on the vehicle's center console or instrument panel. However, this can lead to driver distraction, known as "eyes off the road."

Examples:

- Rear view camera.
- ESC — electronic stabilization system.
- Traction Control System (TCS): Combines elements of the ABS and ESC described above to help the driver maintain adequate traction when cornering and going into bends.

b. Active ADAS system:

In these ADAS systems, the vehicle actively interacts with its surroundings. The car can operate autonomously to prevent worst-case scenarios. Automatic emergency braking (AEB) recognizes an impending collision and automatically applies the brakes. Adaptive cruise control (ACC), lane keeping assist (LKA), lane centering assist (LC), and traffic jam assist are examples of these features. An active ADAS system automatically adjusts the vehicle's speed relative to a set level if a slower vehicle is in its path (similar to conventional cruise control). The LKA and LC systems automatically follow the vehicle to ensure it stays within its lane. Traffic jam assist for business combines adaptive cruise control (ACC) and lane centering assist for use in commercial traffic (LC). These automated components form the basis of vehicles that are partially or fully autonomous [6].

Example: -

- Adaptive cruise control
- Lane Keeping Assist and Lane Centering Systems 3.3 The Importance of Lane Keeping Assist Systems

3.3. Automation of security systems.

As safety systems are implemented and modernized, the number of drivers increases. By alerting drivers to hidden problems or taking control of the vehicle to avoid them, ADAS systems are designed to prevent collisions.

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3. 4. Information about the traffic situation.

The driver is at the center of the driver-vehicle cycle. Information about the road situation enters the driver's perception system, which then acts as a motivator for their intentions. Thus, the intention-determining system will be improved by knowledge of the current road situation.

3.5. Analysis of driver behavior while driving.

Driver actions, such as checking the rearview mirrors before changing lanes, are the most important cues. Before changing lanes, drivers must perform a series of checks to ensure they are fully informed. Therefore, analyzing driver gestures is essential for determining their intentions. To anticipate a driver's intention to change lanes, it is important to understand the human intention-formation process, including how these intentions are generated and what factors trigger them. The nature of the driver's intentions is the first question to be addressed. Through a combination of Pall computing systems, edge computing, sensor data collection, and analytics, predictive technologies analyze risks and transmit data via the cloud to notify customers of any vehicle issues. Fuel level, tire pressure, engine status, navigation route, speed, and temperature are all monitored by onboard sensors to alert the driver and ensure safety. By predicting and prioritizing performance goals, many energy-saving issues can be prevented in advance [7].

4. ADAS Features

Significant advances in automotive safety throughout history (e.g., impact-resistant glass, three-point seat belts, airbags) were passive safety measures designed to minimize injuries during a crash. Today, ADAS systems actively improve safety through integrated visual monitoring, reducing crashes and occupant injuries. A new artificial intelligence feature is built into vehicle cameras that uses a detector emulsion to identify and reuse objects. Using image recognition software, ultrasonic detectors, LIDAR, and RADAR, the detector emulsion combines large volumes of data similar to how the human brain processes information. A human driver could never physically react as quickly as this technology. It can evaluate video footage in real time, determine how to respond, and analyze the footage itself. ADAS functions are divided into four categories, and each category represents a full range of features.

4.1. Collision avoidance

Automatic braking and collision avoidance systems are beginning to be integrated into ADAS (advanced driver assistance systems). A safety system called a collision avoidance system helps drivers avoid unavoidable collisions and reduces the risk of them. This is achieved by combining several previously mentioned functions, such as distance estimation, vehicle detection, and object tracking. Based on this combination of data, the car can predict a collision and prevent it by braking or even swerving. Collision avoidance systems use technologies and sensors such as radar, lasers, cameras, GPS, and artificial intelligence. Some collision avoidance systems warn or inform the driver of potential consequences, while others ignore the driver's actions, helping them avoid collisions and reduce the risk.

Fig. 1: Collision avoidance

4.2. Automatic emergency braking

Sensors are used by the automatic emergency braking system to determine whether the driver is about to collide with another vehicle or anything else on the road. This system can measure the distance between adjacent vehicles and alert the driver to the danger. Some emergency braking systems can also apply preventative safety measures, such as tightening seat belts, reducing speed, and adaptive steering, to help prevent a collision.

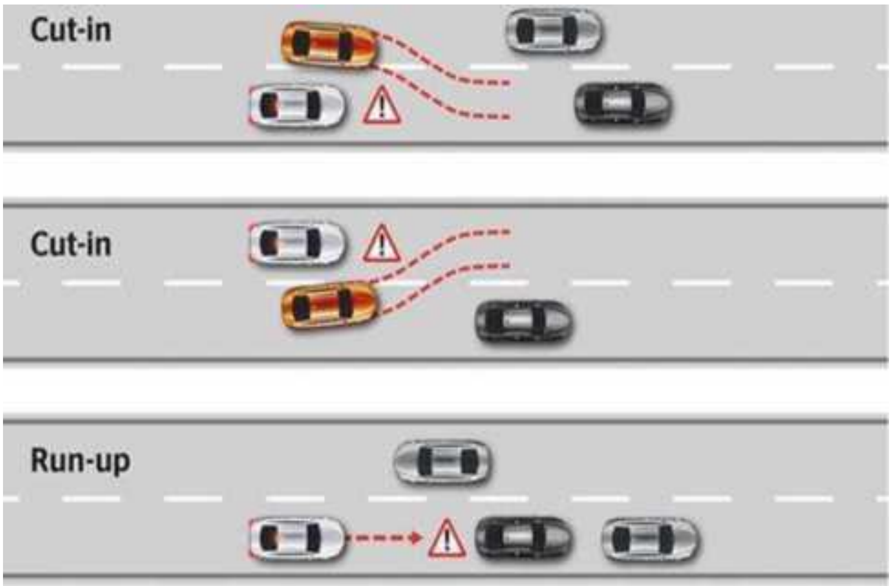

Fig. 2: Emergency braking

EBA is an abbreviation for Emergency Brake Assist, while BA is simply an abbreviation for Brake Assist. Both terms are used interchangeably. Although they are virtually identical, some manufacturers prefer one over the other. This technology helps the driver reduce overall stopping distances and is an active safety feature of the vehicle.

The Emergency Brake Away (EBA) system is a mechanism that provides braking assistance when needed. However, it only operates in emergency situations and does not always provide braking assistance. When the driver is unable to apply full braking force, the EBA system is activated to ensure the vehicle stops as quickly as possible and provide assistance [8].

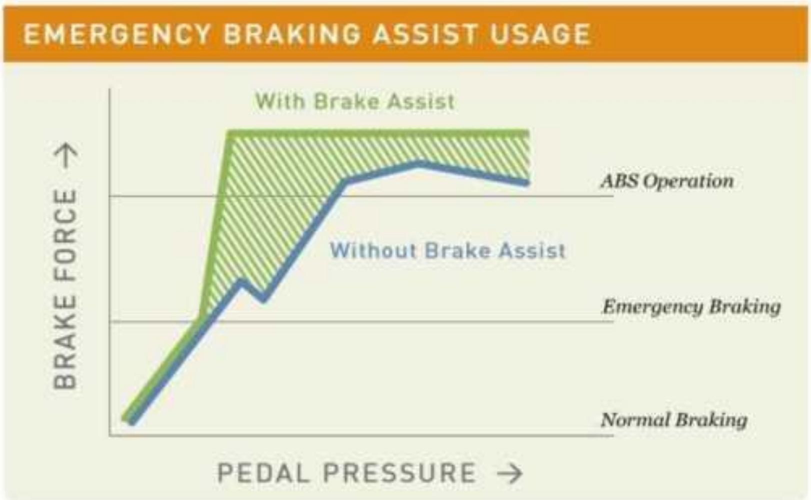

Fig. 3: Emergency braking graph. Braking force depending on pedal pressure.

They are generally divided into two categories: mechanical and electronic. The difference between them lies in the technology used. Electronic brake assists systems, which use the engine control unit (ECU), predict an emergency situation based on the current threshold, pedal speed, brake pressure, and other factors. Electronic calculations are used [9].

4.3. Automatic braking force system type

Even when other vehicles or bad weather obstruct the driver's view, the system warns them of sudden braking ahead. It also allows the vehicle to communicate its automatically generated emergency braking to other nearby vehicles. The Cross Traffic function provides drivers with assistance from other road users at intersections in critical situations. If necessary, it applies heavy braking and provides a visual or audible warning. The EBA-Pedestrian system, using visual and audible signals, as well as automatic full braking, prevents collisions with pedestrians.

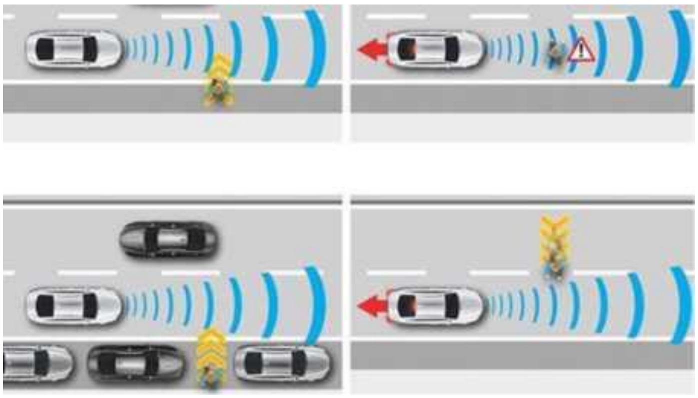

Fig. 4: Pedestrian

4.4. Blind Spot Monitoring

Blind spot detection systems use sensors to provide drivers with important information that is difficult or impossible to obtain otherwise. For example, when a driver attempts to change lanes, some systems sound an audible warning when they detect an object in the driver's blind spot.

As noted in previous chapters, the development of advanced driver assistance systems (ADAS) was aimed at improving road safety, ensuring vehicle reliability, and helping drivers avoid accidents. Research focused in particular on lane change assistance, taking into account the blind spot, which the driver cannot see in the side mirrors. Visual and audible warnings alert the driver to the possibility of a collision with an oncoming vehicle if the system detects such movement in the dangerous zone.

The system becomes more complex when the camera is mounted under the side rearview mirror: various factors, such as camera tilt angle, perspective deformation, and camera vibration, were taken into account, as they can affect system performance, and the operating scenario is not static. Furthermore, the resulting images are rotated whenever the camera's roll angle is not zero [10].

4.5. Driver Drowsiness Detection

Driver drowsiness detection alerts drivers when they become drowsy or distracted while driving. There are several ways to detect a driver's loss of concentration. In one case, sensors can analyze the driver's heart rate and head movements to determine whether they indicate drowsiness. Similar to lane departure warnings, other systems issue warnings to the driver.

5. Adaptive cruise control

Adaptive cruise control (ACC) is especially useful on highways, where it can be difficult for drivers to maintain a constant balance between their own speed and that of other vehicles. Depending on the behavior of nearby vehicles, advanced cruise control can automatically accelerate, decelerate, and sometimes stop the vehicle. ACC maintains speed and maintains a constant distance from the vehicle in front. Depending on the distance between the vehicle in front, ACC can automatically brake or accelerate. With the stop-start function, ACC systems can come to a complete stop and then accelerate back to the set speed. Because the system only monitors your speed and the distance from the vehicle in front, it still requires the driver to remain aware of the surroundings [11].

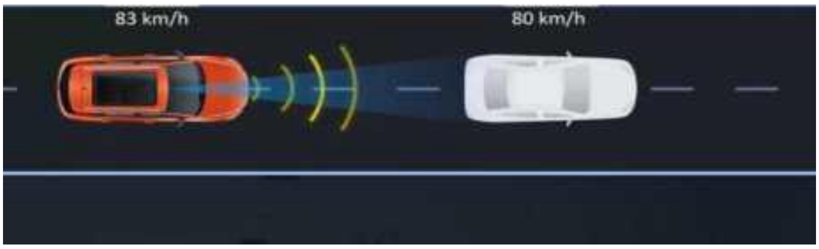

Fig. 5. Adaptive cruise control

Typical ACC/CACC system operation mode. The vehicle in question, equipped with ACC or CACC, follows its predecessor. Figure 16 shows the transition to ACC system operation mode. As with conventional cruise control, the system will control the vehicle's speed if there are no other vehicles in the path when it is activated. The system will adjust the vehicle's speed to maintain the driver-set distance based on distance sensor measurements, such as the relative distance dr and relative speed (vr), without the need for the driver to control the system. By disengaging the ACC system or using the brake/throttle pedal to override ACC commands, the driver can assume longitudinal control.

To exchange data in the CACC system, wireless communication is required between at least two vehicles, as shown in (Fig. 6). With the Park Assist system, you can park parallel and perpendicular to, as well as exit, parking spaces. Once activated, Park Assist uses sensors located around the entire perimeter of the vehicle. The controller enters CACC mode whenever a vehicle is detected directly in front of the preceding CACC vehicle. Target ID mode displays the position of each vehicle directly interacting with the CACC target vehicle and identifies, for example, the communication data stream coming from the immediately preceding vehicle detected by the proximity sensor. A simple pattern recognition algorithm was implemented for a small team working with two CACC vehicles in 2010. However, it is possible that the algorithm will not work well with multiple vehicles in multiple lanes. A more comprehensive solution requires a positioning system capable of accurately determining the position of vehicles down to their position within the lane.

6. Automatic parking

Automated parking helps drivers understand when to turn the wheel and stop to avoid blind spots. Compared to cars with traditional side mirrors, cars with rearview cameras have an excellent view of the surrounding area. In some cases, parking systems can complete the parking process automatically, without driver intervention, by combining data from multiple sensors.

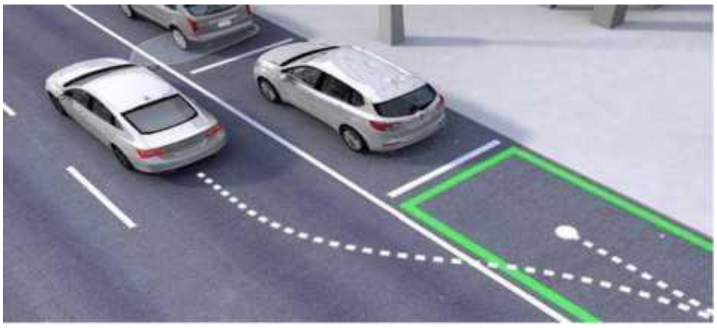

Fig. 6. Parking assistance system

After detecting a space at least 20% larger than your vehicle, the system prompts you to stop, release the steering wheel, and engage reverse. After this, the system will take over steering control when reversing. However, if you attempt to steer the car yourself, the system will stop. It automatically steers around obstacles and other vehicles, but you should always be aware of children and other animals nearby. You can drive as slowly as you like and stop, when necessary, because the accelerator and brake pedal are under your control. This relatively new ADAS feature allows the car to counteract strong crosswinds. Its sensors can detect excess air pressure in the vehicle while driving and apply the brakes to the wheels exposed to the crosswind. The CWS system uses yaw rate, lateral acceleration, steering angle, and speed sensors to determine how much assistance to provide to the driver in various situations, such as driving at different speeds or turning. CWS is able to provide the driver with the necessary assistance in a specific situation using force sensor readings from various vehicle components such as brakes, differentials and suspension [12].

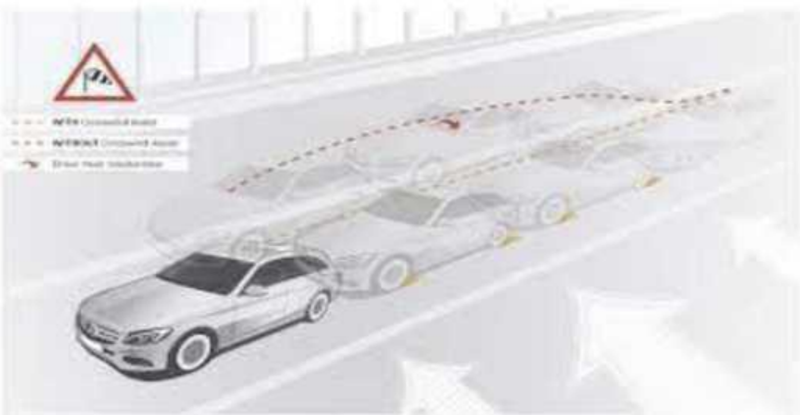

Fig. 7. Crosswind Stabilization (CWS)

7. Lane Keeping Assist

Automatic braking and collision avoidance systems are beginning to be integrated into ADAS (advanced driver assistance systems). This is achieved by combining several previously mentioned functions, such as distance estimation, vehicle detection, and object tracking. Based on this combination of data, the car can predict a collision and prevent it by braking or even swerving.

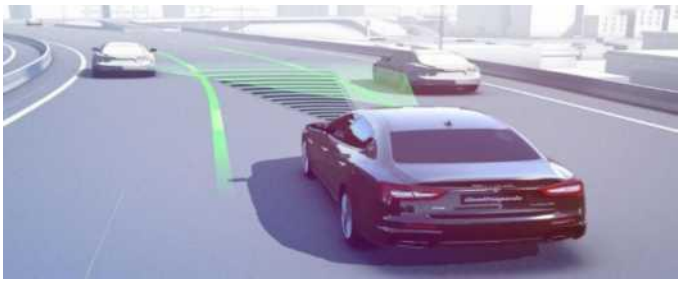

Fig. 8. Detection of the object's lane

8. Perforation control

Information is displayed exactly where you need it, in the driver's field of view, on a head-up display (HUD). Drivers don't need to look down at the instrument panel or an additional display; they have access to all the information they need for navigation, including speed, warning signals, and turn signal arrows. Currently, head-up displays (HUDs) are used to display selected instrument panel data. This can include the current speed, relevant road signs, warning signals, active turn signals, navigation arrows, and much more, depending on the design. As a result, the HUD serves as a sensory filter and offers advantages that will lead to its growing popularity. Expanding the field of view of the current HUD to accommodate more relevant information is one example of ongoing development work. The HUD's full potential is still far from being realized. The human-machine interface (HMI) must be optimized specifically for new driver assistance systems to reduce the amount of work required of drivers and improve road safety. Additionally, a significant advantage of the HUD is its ability to reduce the time spent on “eye distraction”.

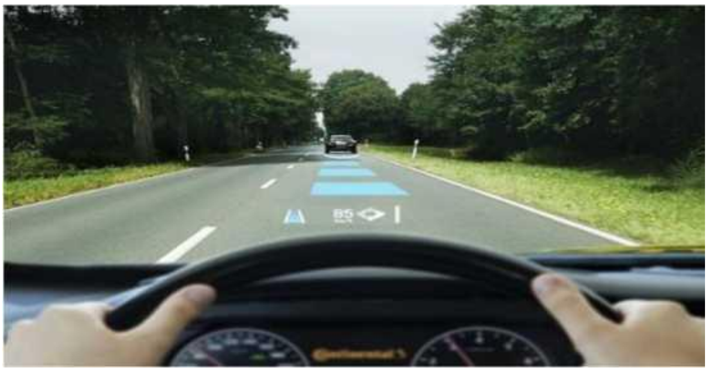

Fig. 9. Head -up display (HUD)

Advantages of a HUD: A head-up display (HUD) is primarily an active safety feature, as it eliminates the need for the driver to look at the regular display. Modern HUDs can also display information such as navigation directions, warning lights, and engine speed, significantly reducing the number of times the driver has to take their eyes off the road. This also has a certain semantic and technological aspect.

9. Navigation system

To provide drivers with up-to-date traffic and navigation information, use digital mapping tools such as the Global Positioning System (GPS) and Traffic Message Channel (TMC). A car navigation system can transmit and receive satellite data signals about the vehicle's current location relative to its surroundings via a built-in receiver. To help drivers stay on track, car navigation systems provide voice and on-screen instructions. Some navigation systems can display accurate traffic data and, if necessary, plan a new route to avoid traffic jams.

10. Night vision

Night vision systems allow drivers to see things at night that would otherwise be difficult or impossible to see. Night vision systems are divided into two groups. Passive night vision systems use the thermal energy emitted by buses, cars, living organisms, and other objects, while active night vision systems emit infrared light.

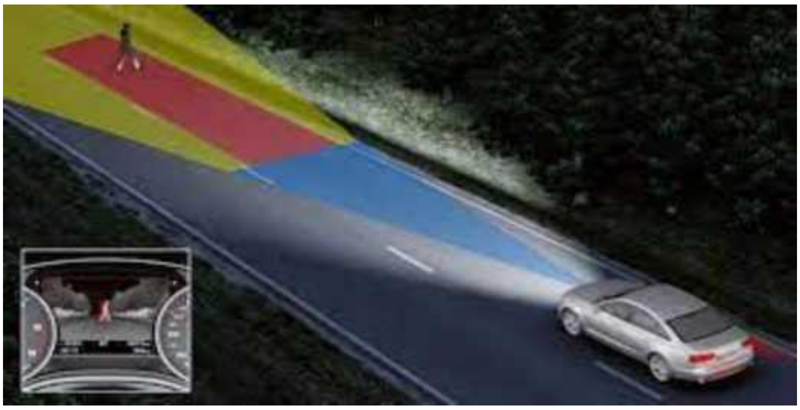

Fig. 10. Night vision

This advanced ADAS system, featuring increased reliability and reduced noise levels, enables communication between the vehicle and other vehicles or pedestrians. Today, most vehicles connect to mobile networks for continuous route guidance. This application will enhance existing systems and the mobile network to enhance situational awareness, provide guidance or recommendations for adjusting speed according to traffic conditions, and provide real-time GPS map updates. Support for over-the-air software updates for a growing number of software-driven vehicle systems—including map updates, bug fixes, security updates, and more.

11. Bird's eye view or omnidirectional view

An assistance technology known as Omni-View is designed to help drivers park their cars in tight spaces. In the early days of parking assistance systems, proximity sensors or a single rearview camera was used to detect potential obstacles and alert drivers with an audible alert or a video image from the rear. A typical Omni-View system uses four wide-angle cameras: one in front of the vehicle, one in the rear, one in the left rear window, and one in the right outer window. The entire area around the vehicle is captured by all four cameras. By merging images, correcting deformations, and transforming curvatures, the system creates a top-down view of the road ahead of the vehicle. The inputs and outputs of a typical Omni-View product are shown in the images below. If you've ever taken your driver's license test and had to parallel park your car, you may remember how terrifying it was. Parallel parking in front of other people is something many of us simply don't want to do. It's on par with public speaking. Ever. This requires judgment and skill, which many people seem to lack, perhaps for evolutionary reasons. When attempting to park a large car in a tight space parallel to a curb, many have undoubtedly thought, "I wish I could see everything from above, like a bird." Well, as was once wisely said: seek and ye shall find. The ability to assess a parking situation from above has become possible thanks to computer technology. While a typical configuration includes four cameras, surround-view systems can use up to six cameras. One is typically located in the front grille. Two wide-angle cameras are mounted in the outside rearview mirrors, and a fourth camera is mounted at the rear of the vehicle and serves as a rearview camera. Six-camera systems add side cameras in front of the front wheels, allowing the car to show the driver what is on the other side of walls and other vehicles.

CONCLUSION

In conclusion, intelligent algorithms and technological improvements to vehicle platforms are essential for the mass production of self-driving cars or driver assistance systems. The most promising approaches to developing vehicle platforms for the next generation of self-driving cars are domain-specific and centralized architectures, which provide significantly increased bandwidth and communication capabilities. Vehicles are expected to rapidly integrate computing platforms based on self-driving encyclopedias and multi-core computing systems. A futuristic vehicle platform should be equipped with advanced sensors in addition to its robust architecture. These sensors must be capable of collecting data and producing recognition results using perception algorithms. Numerous companies and academic institutions are already collaborating to integrate sensor hardware and perception algorithms. A successful example is Mobileye, which has integrated machine vision algorithms into its sensor product.

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