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A Comprehensive Review on Advanced Driver Assistance System

S. Ayyasamy

Professor, School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India.

E-mail: ayyasamyphd@gmail.com

Abstract

In recent years, automotive industry is experiencing an unprecedented transformation with the rise of digital technologies. While in the past, acceleration, top speed, and mechanical design were the most essential factors for purchasing an automobile, electronics and software innovations define the characteristics of the future. One among such innovations is the Advanced Driver Assistance System (ADAS). This innovation is now considered as the major drive force of the automotive domain with the intelligent electronic and software architectures. ADAS is primarily designed with an objective to assist drivers by providing an alert/automate the manual tasks in any adverse conditions. ADAS functions will also have the capability to obtain the signals from roadways, Road Side Units (RSUs) and other vehicles. This research article attempts to provide a comprehensive review on the research developments and technologies used in design, development and implementation of advanced driver assistance systems. The sections included in the proposed study describe about the different ADAS methods such as adaptive and automated cruise control, smart navigation with collision warning and avoidance system, automated vehicle parking assistance and object detection. The primary goal of this research study is to achieve a collective knowledge of ADAS operational capabilities and limitations, as well as to suggest research requirements for future investigations.

Keywords: Advanced Driver Assistance System (ADAS), warning system, human machine interface, crash detection, collision warning and avoidance

1. Introduction

With the recent technological advancements in sensing, communication, and computer technology, there has been a tremendous increase in the design and development of

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Advanced Driver Assistance Systems (ADAS) across the globe. ADAS focuses on assisting drivers by either giving warnings to lessen the exposure to risk or automating some manual control activities. From an operational perspective, such systems represent a significant paradigm shift in the automotive development in which drivers have had complete control over all driving activities at all situations. ADAS replaces certain manual driver decisions and actions with sophisticated automation activities, eliminating several driver mistakes [1] that could cause accidents, as well as developing more controlled and seamless vehicle control with higher capacity and sustainability.

Today's automotive industry is being impacted by three main trends of ADAS, they are:

- The paradigm shift from traditional automotive control to a shared mobility and automation.
- Enhanced connectivity and control (V2V, V2X)
- The transition from manual human controlled cars to autonomous (driverless) cars.

The tasks involved in ADAS can be accomplished in two ways: autonomously with all sensors and intelligence on board the vehicle, or cooperatively by obtaining the decisions/recommendations from the roadways and other automobiles [2]. Despite numerous research studies available on the design, development and implementation of ADAS systems, minimal attempts have been made to compare the automated and cooperative methods in terms of its technical capabilities, functional requirement, real-time system implementation and consequences.

This article investigates the recent research advancements in smart and collaborative autonomous ADAS systems, notably the advanced communication architectures [3]. The primary goal is to develop a collective understanding on the functional potentials and limitations of ADAS systems based on various methodologies, architectures, and real-time applications.

Section '*Classification of ADAS*' discusses about the classification of ADAS devices in different sectors of automotive industry. Section "*State-of-the-art ADAS Methods*" explains the different popular ADAS methods available in the market by covering all the aspects ranging from automated sensor based control to smart parking assistance system. The next section '*Electronics & Communication based ADAS Architectures'* includes a discussion on the advanced communication architectures and the real-time applications of ADAS in different sectors. Additionally the applicability of different ADS techniques according to its use cases are also described in a table. Finally the issues that need a significant research attention in the near future is stated followed by a conclusion on the proposed review study.

1.1 Classification of ADAS

ADAS systems can be categorized in different ways. The most frequent and effective ADAS will be more focused on the use cases such as lane guidance [4] and automatic braking with collision avoidance. Another option is to emphasize on the different types of sensors used. Another approach is based on the degree of automation. Price and availability in the ADAS sector are crucial factors for consumers. Anti-lock braking systems have become a standard method and additionally blind spot detection and turning assistance systems are considered as the future of ADAS [14].

Here, we have categorized ADAS into 5 types based on its use case, functionality, sensors, product cost, and automation.

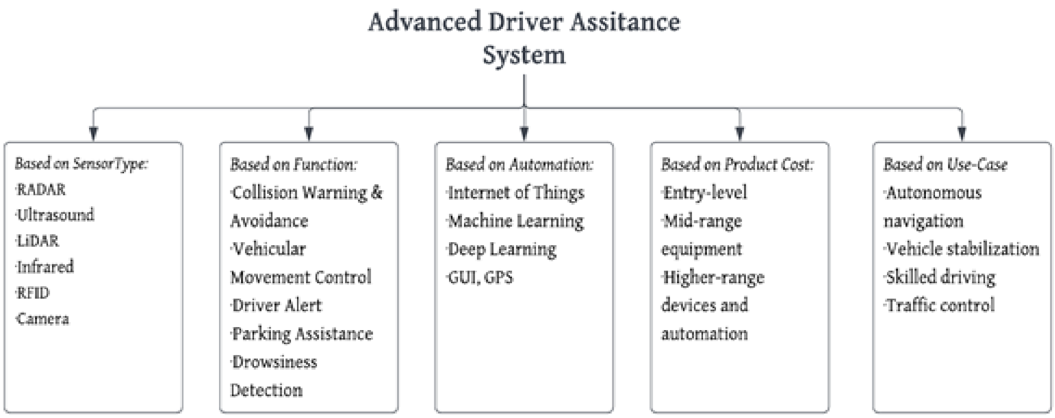

Figure 1. Classification of ADAS

1.2 State-of-the-Art ADAS Methods & Architectures

Different methods are incorporated in the development of advanced driver assistance systems. Each of the below-mentioned methods are designed to deliver exceptional benefit to the user. While certain technologies are essential to enhance the driver's safety and provide an extra assistance to the driver to avoid even minor accidents.

1.2.1 Adaptive and Automated Cruise Control:

Since 1900s, centrifugal governing technologies are available to automatically control the movement/speed of motor vehicles. An electronic circuit based cruise control was developed in late 1960s but was not widely used in automotive until the mid of 1980s.

Kazumasa Nakamura [6] designed the first authentic and intelligent embedded system for cruise control. The system has been depicted in Figure 1.

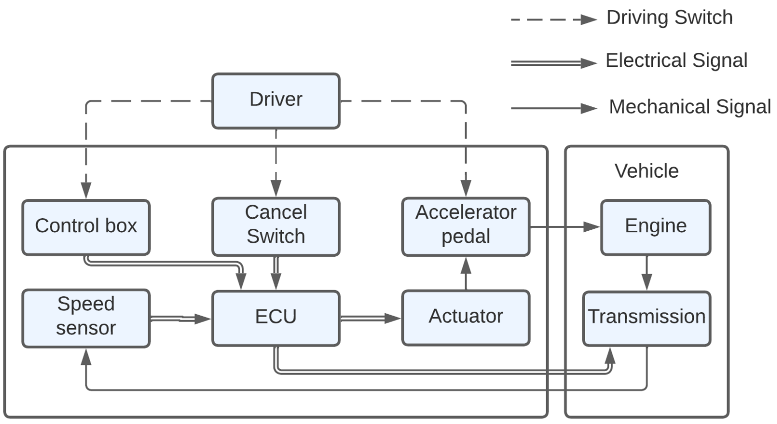

Figure 2. Cruise Control System [6]

The aforementioned advancements led to the development of adaptive cruise-control system. With this system, the vehicle can scan its surrounding area in the front by using a forward-looking sensor. ADAS sensors are essential for perceiving the surrounding environment and measuring the car's distance, location, and movements based on its surroundings. When activated, the technology operates like a regular cruise control system, but it will respond to any automobiles that enter into the sensor range. ADAS sensors are essential for perceiving the surrounding environment and measuring the inter-vehicle distance, location, and movements based on its surroundings. Multi-sensor fusion algorithms can mitigate the challenges in individual sensor technologies by providing a more accurate and detailed pictorial representation of the environment. High level of automation usually necessitates the integration of sensor signals obtained from different sensor types.

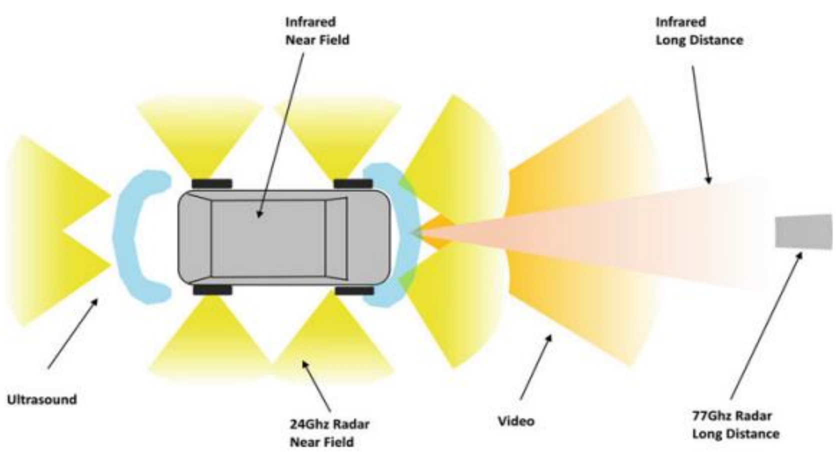

Figure 3. Utilization of Different Sensors – A Multi-Sensor Fusion Model

ADAS sensors enabled advanced cruise control system [7] may communicate data to the cloud in order to make any emergency information available to other vehicles. The below depicted figure shows the incorporation of sensors in enabling advanced cruise control. Involvement of different types of sensors in ADAS has been illustrated in the table 1.

Table 1. List of sensors in ADAS system

Sensor Type	**Advantages**	**Disadvantages**	**Real-time ADAS Applications**
LASER	Detects small obstacles and accurately detects the vehicle speed and distance covered	The model has poorly performed lane detection and vehicle/pedestrian detection	Lane Departure Warning [8] Near Field Collision Warning
Ultrasonic	Good short-range detection and improved angular range	Poor angular position, high distortion,	Blind Spot Detection [10]
Radar	High accuracy in speed and distance detection; Performs both long and short range detection; Can be used in any environment with reflection	The model has poorly performed lane detection; Huge in size; Beam obstruction	Lane Departure Warning [8] Adaptive cruise control [7] Pre-crash collision and mitigation system [9]
LiDAR	Advanced obstacle detection Enhanced speed and distance detection	Inadequate vehicle/pedestrian detection	Pre-crash collision and mitigation system [9] Blind Spot Detection [10]
Camera	Accurate lane detection; Useful in low-light conditions	Shows poor contrast in traffic signs	Rear view system [11]

Vision	Accurate lane detection; Accurate pedestrian/vehicle detection	Complex DAEs for data processing; Inadequate obstacle, distance and speed detection	Lane change assistance [12] Road Departure Protection Traffic Sign Recognition [13]

2. Smart Parking Assistance Systems

Parking constitutes to at least 30% of traffic in urban areas, since automobiles typically search many times to find a free parking spot. Furthermore, automobiles often remain parked. On-road parking and off-road parking can also be distinguished, for example, parking spaces at shopping malls, train stations, airports, and so on [15].

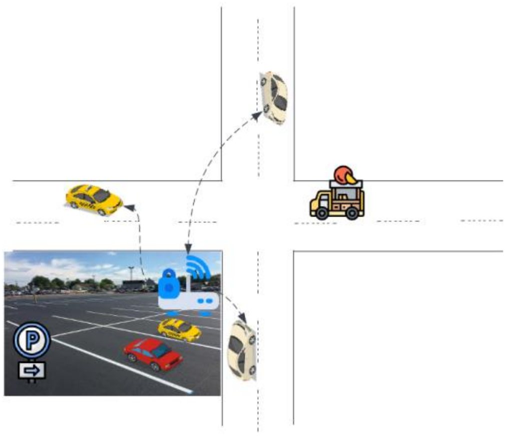

Figure 4. Smart Parking Assistance System

The emerging smart parking systems have been developed to combine the real-time traffic information and the sensors and functions of driver assistance systems to discover parking spaces. The below figure depicts a unique application of a smart network connected car: smart networked off-road parking. While driving down the street, sensors embedded inside the automobile will identify and measure the available parking places. This information will then be automatically provided to all service subscribers. If the service is provided by an automotive OEM, such as Toyota, the information is normally shared exclusively among cars of the same manufacturer.

If there is an adequate parking space, the smart assistance system can assist driver in parking the automobile as safely as possible by managing both the longitudinal and steering motions. Soon, the entire valet parking systems will be automated without the need for a driver [16].

3. Electronics & Communication based ADAS Architectures

Automobiles can connect with one another, as well as with the infrastructure and the cloud to become more aware of its surroundings and also to enhance the ability to handle a large amount of data, and provide valuable data that can be widely utilised in a variety of new services such as remote monitoring, location based solutions and also the utilization dependent reinsurance.

Mobile communication architectures such as LTE, 4G, 5G and recently B5G or other specific standards can be used for establishing communication between vehicles. Further, the IEEE 802.11p or any DSRC technologies [17] can be used to enable connectivity. However, in many situations, the latency is inadequate for processing the real-time solutions in the context of driverless vehicles. The emerging B5G standard generates latency as low as 0.9 millisecond. This would be adequate for higher automation levels of ADAS and AD models to work efficiently in real-time traffic scenario and traffic signals.

The recent uptrend of electronic circuit units have introduced autonomous functions in automotive. Today, several domains are combining to construct high performance computing platforms, which are networked via cloud in order to implement cloud services as well as the computing capabilities. The processing demands of ADAS and autonomous driving functionalities will generate a substantial demand in the market.

The Driver Assistance Electronics [DAE] play an indispensable role in ADAS by incorporating electronic circuits and models to assist the manual driving process and advance both automotive safety and driving. DAE is primarily focused on preventing collisions and accidents by alerting the driver on the potentially critical situations or to avoid collisions by incorporating safety measures and control the vehicle.

There are several DAE components available. Some are incorporated into automobiles, while others are offered as add-on packages. [18] DAE is highly dependent on the data obtained from a variety of sources, including computer vision, automotive imaging, light imaging detection and ranging (LiDAR), in-vehicle networking, and radar. LiDAR is a measuring technique that uses laser light to illuminate a target and estimate the distance. Future autonomous cars will employ rotational laser beams for obstacle identification and safe navigation across the dynamic environment.

Next-generation DAE will increasingly rely on wireless internet connectivity to provide a better value by utilizing the vehicle-to-vehicle/Everything via Wi-Fi based networking architectures. V2V is one of the sub-domains of adhoc networks. V2I refers to the wireless exchange of data between vehicles and the nearby road infrastructure in case of any unfavourable situations with a goal to prevent accidents by leveraging mobility, safety and sustainability benefits.

The increasing convergence of automotive embedded systems, computer networks, and traditional IT systems has resulted in powerful architectures, but it has also introduced cybersecurity challenges [19]. Researchers recently [20] explore the progression of automotive electronics from gateway designs from domain-oriented ideas to centralized/decentralized server-based systems.

Despite recent advances in the use of DAS during the last three decades, drunk driving costs thousands of lives every year As a result, the Driver Alcohol Detection System feature was implemented as a recent advancement of DAE measure [21]. This feature is based on an advanced technology to autonomously detect whether a driver has consumed alcohol and it consecutively stop the vehicle from moving.

The other mostly used DAE components in ADAS systems are:

- ***Smart Navigation System:*** Global Positioning System (GPS) with traffic management solution will provide vehicle positioning, timing and navigation services to users. This system provides vehicle drivers with recently updated traffic and transit information [22]. It sends messages using the cognitive communication protocol for integrating the generated digital data in information broadcasts.
- ***Pre-crash/Collision Avoidance System:*** When an accident is detected, it will either notify the driver or autonomously take any necessary action without receiving any input from the user via the brake/steering system [23]. Collision avoidance by utilizing the brake is applied for low speed vehicles (Vehicles travelling below 50km speed), whereas collision avoidance by steering is suitable for high speed vehicles (Vehicles travelling above 50km speed).
- ***Drowsiness Detection:*** This system can detect the drowsiness of the driver by monitoring the steering pattern, lane position, vehicle direction, driver’s eye blink

related data, face detection. [24] Recently, wireless body sensors are used to monitor the human activity inside the vehicle.

- ***Emergency Assistance:*** This feature analyses the behavior of driver. If the driver is unable to safely drive the car due to a medical emergency, the vehicle automatically takes control of the brakes and steering until the vehicles completely stop.
- ***Lane Change Warning (LCW):*** This function alerts the driver if the vehicle starts to drift out from the actual lane unless a turning signal gets activated in that direction. This technology also generates an audio warning as well as a graphical alert, assisting in the prevention of major accidents caused by wrong-way driving [5].
- ***Traffic Sign & Intersection Assistance:*** The system can recognize and alert the drivers based on the traffic signs. The systems also supervises cross-traffic situation in a road intersection and if the system identifies a possibly dangerous scenario, it alerts the driver by triggering both visual and audio warnings and immediately activate the brakes.

Table 2. Transition of traditional to autonomous driver assistance system

Level	**Steering Control**	**Autonomous Control Monitoring**	**Automation Capability**	**Example**
No Automation	Human based	Human based	-	-
Traditional Driver based Automation	Human based	Human based	Selective Driving Modes	Automated Cruise Control [7]
Partial Automation	System based	Human based	Selective Driving Modes	Night Vision [25]
Condition based Automation	System based	System based	Selective Driving Modes	Traffic Sign Recognition [13]
Advanced Automation	System based	System based	Selective Driving Modes	Collision Avoidance System [23]

Full Automation	System based	System based	All Driving Modes	Driver Drowsiness Detection [24]

4. Summary, Conclusion and Future Research Directions

The article has discussed about the different ADAS functions and how efficiently they make the vehicles safe and efficient to drive autonomously. A broad overview has been provided on the significant emerging functions such as lane assistance and wrong-way warning, collision avoidance, parking assistance, traffic sign and road intersection and turning assistance, etc. Also, the ability of ADAS to deploy different technologies such as multi-sensor fusion and road sign analysis. The overview of underlying DAE architectures present in ADAS are also reviewed. The evolution of different level of automation in ADAS has also been discussed. Driverless vehicles are on the way, but there are still a number of challenges to work out, including ethical concerns of increasing automation and autonomous driving. The challenges also include data security, communication latency and so on. In the near future, the automotive sector will undergo significant transformation by combining the hardware and software domains in the context of Artificial Intelligence.

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Author's biography

S. Ayyasamy obtained his Bachelor's degree in Electronics and Communication Engineering from "Maharaja Engineering College, Avinashi" under Bharathiyar University and Masters Degree in Computer Science and Engineering from "PSG College of Technology, Peelamedu, Coimbatore." under Bharathiyar University. He completed his Ph. D in the area of Peer to Peer Overlay Networks under Anna University, Chennai. He has 19 years of teaching experience. He is currently working as Professor in the School of Computer Science and Engineering at Vellore Institute of Technology, Vellore, India. He has been working as Reviewer for reputed journals like Human-computer Interaction journal -Taylor & Francis, Journal of Network and Computer Applications–Elsevier and Information Security Journal-Inderscience. He was also working as the Editor for International journal of Engineering Technology and Science. He was acted as coordinator for the Establishment of New Course B. Arch and Information Technology lab, for conducting Info science microsoft conference RACHNA'09, for the Recognition of Anna University Research Center, to start a new journal entitled "International Innovation Journal of Engineering and Applied Research" through SRDC, Infosys Campus Connect Assistant Coordinator and many more prestigious activities. His Research areas of interest are Peer to Peer Networks, Overlay Networks, Automation, Machine learning and Artificial Intelligence.