TECHNISCHE UNIVERSITÄT
CHEMNITZ

Advanced Driver Assistance System

Seminar Report

Chair of Computer Engineering
Dept. of Computer Science

Submitted by: Md Benajir Ullah Shuvo

Matrikel Nr.: 580236

Submitted on: 22.08.2021

Submitted tutor: Prof. Dr. W. Hardt and Ren´e Schmidt

Abstract

In today's automotive market, especially in North America and Europe, ADAS has cemented its place convincingly mainly because of its wide range of functionalities. This paper discusses about the basic understanding of what ADAS is, it's impact in the market, it's working principle and finally a couple of ADAS features. Furthermore, different ADAS components are talked about in details such as the RADAR or LIDAR. Finally, the report moves onto two distinctive ADAS features, Adaptive Cruise Control and Lane Departure Warning before concluding by providing an overall image of what ADAS is.

Keywords: ADAS, LDWS, ACC, Lidar, Radar, Cruise Control, FIR, OEM

Contents

List of Figures

List of Abbreviations

ADAS Advanced Driver Assistance Systems
WHO World Health Organization
OEM Original Equipment Manufacturers

GPS Global Positioning System
ECU Electronic Control Unit GHz Giga Hertz
RADAR Radio Detection and Ranging Technology
LIDAR Light Detection and Ranging kHz Kilo Hertz
FoV Field of View
SNR Signal-Noise Ration
ACC Adaptive Cruise Control
BSD Blind Spot Detection
HUD Head-up Display
ESC Electronic Stability Control Bourne-again shell
LDW Lane Departure Warning
LKA Lane Keeping Assistance
DMS Driver Monitoring System
NVS Night Time Vision System
ABS Anti-Locking Braking System
SCU Sensor Control Unit
TTC Time to Collision
LRR Long Variety Radar
SRR Short Variety Radar
UV Ultra Violet
IR Infrared
FIR far-infrared
BWS Blind Warning System
UN United Nation

1.0 ADAS

1.1 ADAS Motivation

According to the World Health Organization (WHO), around 1.35 million people lost their lives because of road accidents. Human caused errors such as distraction of the driver, over speeding or drunk driving are responsible for most of these accidents. [27] However, such type of casualties can be avoided by simply integrating an ADAS system into the vehicles. By proper education, training, and regulations the above figure can be diminished more. In the 'Impact of ADAS' section more details will be described.

1.2 What is ADAS

Advance Driver Assistance System in short for ADAS, is an advance assistance system integrated in autonomous vehicles that takes the pressure away from the drivers and provides a safe journey. To mitigate the outcome of an accident or avoid any critical situation, sometimes the ADAS technology overrides the driver and act accordingly. Such features make the ADAS system acceptable to the consumers. The prime goal of ADAS system is to develop a used-friendly human-machine interface so that the driver can easily interact with the system.

1.3 ADAS Origin

Adaptive Cruise Control (ACC) is the first ever ADAS technology introduced in automotive domain in 1958. Initially it has been named as 'Cruise Control' and change into 'Adaptive Cruise Control in autonomous vehicle. Later it will be described briefly.

European Manufacturer companies established the development of ADAS technology because of sub urban traffic problems. The following figure focussed the developments of ADAS technology through out the years.

Figure 1.1: Adaption of ADAS [26]

The demand of ADAS technology in increasing specially in mid-level priced cars. Original Equipment Manufacturers (OEMs) along with other manufacturers such as Autoliv and Continental has taken an initiative to produce a low-cost Driver Assistance System (DAS) that will end up with a more acceptable ADAS integrated autonomous vehicle. [26]

2.0 Impact of ADAS

ADAS technology has already have a phenomenal impact for a reduced accident frequency. World Health Organization (WHO) publishes a journal named “Save Lives, A Road safety technical package” reporting with the information that Up to 440,000 road accidents and death can be prevented and up to US$ 143 billion can be saved by 2030 by maintaining the basic vehicle regulations, determined by the UN in the Latin American Countries. [22]

	Road Map for Safer Vehicles 2020 UN Regulations* for:	All New Models Produced or Imported	All Vehicles Produced or Imported
CRASH TESTS	Frontal Impact (No.94) Side Impact (No.95)	2018	2020
SEAT BELTS	Seat Belt & Anchorages (No.16 & 14)	2018	2020
ELECTRONIC STABILITY CONTROL	Electronic Stability Control No.140 (GTR. 8)	2018	2020
PEDESTRIAN SAFETY	Pedestrian Protection No.127 (GTR. 9)	2018	2020
ANTI-LOCK BRAKES	Motorcycle Anti-Lock Brakes No.78 (GTR.3)	2018	2020
AUTONOMOUS EMERGENCY BRAKING	Autonomous Emergency Braking Systems	Highly Recommended	Highly Recommended

*or equivalent national performance requirements, with effective conformity of production

Figure 2.1: Road Map for safer vehicle 2020 UN

The possible safety benefit of equipping ALL cars with ADAS is anticipated to be significant, with up to a 40% decrease in accidents and a 29% reduction in deaths.

Total Numbers of Crashes, Injuries, and Deaths that Selected Advanced Driver Assistance Systems Could Potentially Help Prevent Individually and in Aggregate.

	Crashes	Injuries	Deaths
Total Passenger-Vehicle Crashes	6,950,000	3,034,000	32,702
Potentially Preventable by FCW/AEB	1,994,000 (29%)	884,000 (29%)	4,738 (14%)
Potentially Preventable by LDW/LKA	519,000 (7%)	187,000 (6%)	4,654 (14%)
Potentially Preventable by BSW	318,000 (5%)	89,000 (3%)	274 (1%)
Total Potentially Preventable by All Systems Above	2,748,000 (40%)	1,128,000 (37%)	9,496 (29%)

Figure 2.2: Impact of ADAS features [22]

A vehicle equipped with ADAS can offer the following overwhelming result in all types of passenger-vehicles. [23]

- 40% accidents prevention
- 37% of injury prevention
- 29% death prevention

According to a recent report, medium-sized passenger vehicles integrated with crash avoidance system have a 14 percent fewer chances of conducting an accident than a vehicle without ADAS technology. [24] The accidents rate is reducing since the enhancement of the ADAS system into the modern vehicles.

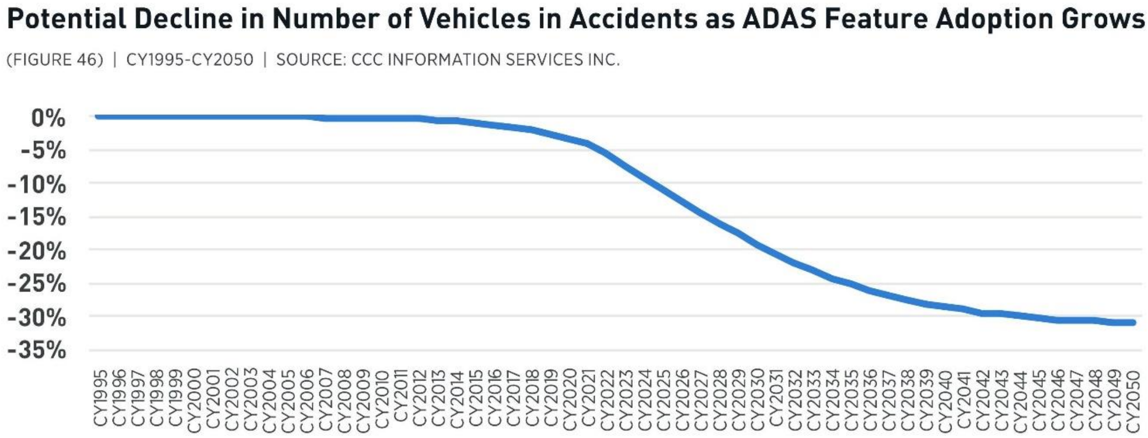

Figure 2.3: Reduced rate of the accidents after increasing ADAS adaptability in vehicles [25]

3.0 ADAS Working

ADAS works on three fundamental concepts -Sense, Plan, Act. The sensors act as eyes and ears of the car which sense and fetch different types of data from the ambience of the car. These retrieved data are processed with the ECUs and MCUs (processors). After processing the raw data, the processors come up with a strategic driving plan. Based on that plan, the actuators (steering, powertrain, braking) act.

Consider the following scenario of two vehicle A and B. Vehicle B may collide with vehicle A in the forward direction because of vehicle A's abrupt halt. ADAS technology can help to avert such situations. The sensors will collect data from the surroundings and send it to an ECU, which will analyse it before activating the brake actuators to reduce the hazard. [1]

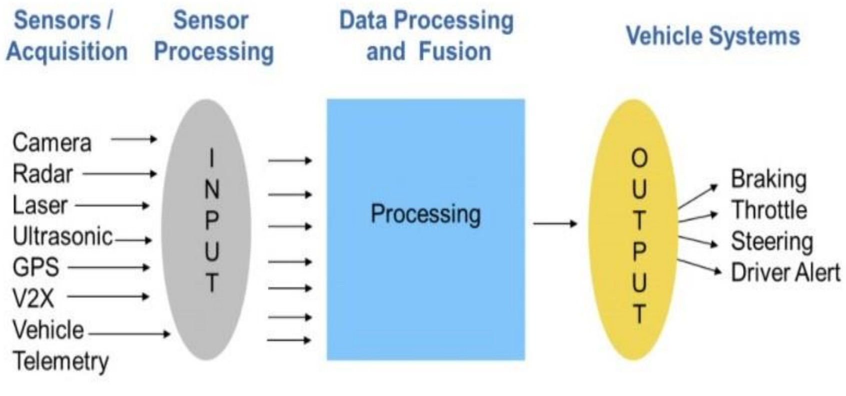

Figure 3.1: Information processing in ADAS [1]

4.0 ADAS Components

Vehicles using ADAS technology are more aware of their surroundings and, as a result, are safer to drive. ADAS consists of a variety of functions, along with adaptive cruise control, driver monitoring systems, automated parking, collision avoidance, lane departure warning systems, and traffic sign recognition. Most of these functions rely on data, which is retrieved in real time by a diverse range of in-vehicle sensors. Despite of having sensors such as LiDAR, automotive imaging, radar, image processing, computer vision, and in car networking as core data sources, Vehicle-to-vehicle (V2V), or Vehicle-to-Infrastructure (such as Cellular or Wi-Fi data network) systems are also used as additional data sources. [2]

Image and sensor data play a crucial role in ADAS systems. After collecting the data from different types of data sources, the system transfers the data through a verity of data communication busses across the sensor bridge to controller. The CPU/GPUs perform a machine learning algorithm on the provided data and UFS storage system provide 3D mapping according to the situation. The system warns the driver about the hazardous circumstances. For a more dangerous situation, sometimes the system overrides the driver and act accordingly. [3]

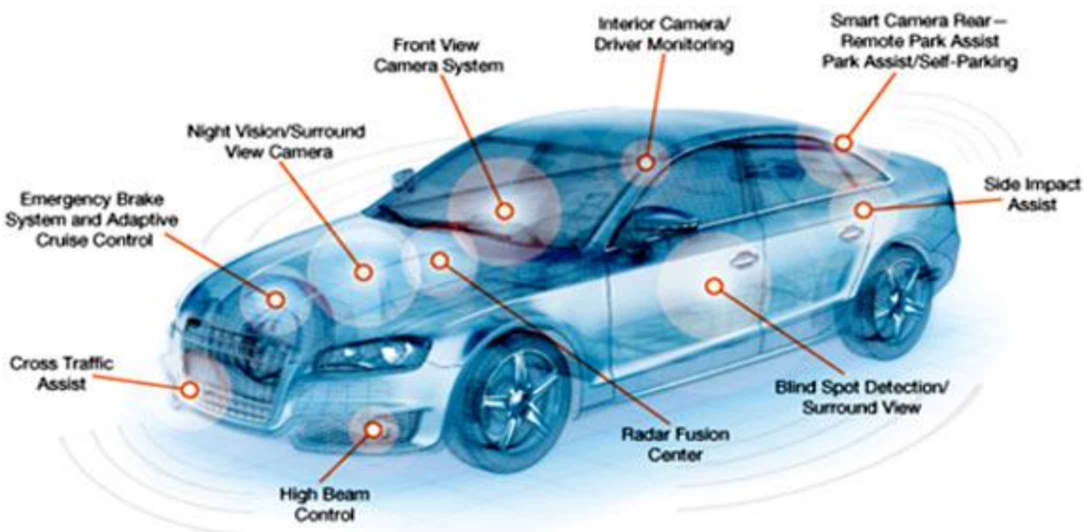

Figure 4.1: ADAS functionalities [4]

4.1 LIDAR

LIDAR is a modernized sensor and an integral component of ADAS (Advanced Driver Assistance Systems) sensor system, eventually in autonomous vehicles. LIDAR depicts Light Detection and Ranging. The main use of LIDAR technology in ADAS system is to determine the position of an object surround by the vehicle. The system radiates laser beam until they hit an object and then reflect and return to the receiver. Despite of using the same technology as SONAR, LIDAR operates with the light wave instead of sound wave which makes it 10,00,000 times faster than SONAR. [5]

LIDAR is focussed on the returned time-of-flight (TOF) of the detected object. The “time of flight” is the amount of time it takes for a laser beam to hit the front object and reflect and return to LIDAR. A “point cloud” of 3D location points may be constructed inside the system FOV by associated that return delay with angular direction. Depending on the provided spatial information to the system, LIDAR technology can be categorized into two different types:

- Scanning LIDAR

  Scanning LIDAR system steer laser waves and detect a spot or a line of light waves across the system. While scanning, the laser pulses frequently, and the angular range and scan rate of the laser define the system's angular resolution. For a 2D (raster) scan, the return light is captured by a scanning optic with a single point detector and a linear array of detectors for a line scan.

- Flash LIDAR

  Flash LIDAR also known as Non-Scanning LIDAR. This type of flash system use laser to illuminate the entire FOV of a 2D detector array. During this circumstance, the angular resolution of the system can be achieved directly by detector array.

The popularity of scanning LIDAR is higher because of its higher SNR in comparison with other LIDAR systems. [6]

Parameter	Short Range	Long Range
X, Y resolution	~1°	0.1 – 0.15°
Z (depth) resolution	a few cm	
Frame rate	>25 Hz	
Range	20 – 30m	200 – 300m
FOV	>90°	< 90°
Temperature range	AEC-Q100 grade 2 (-40-105C) or better	
Reliability	AEC-Q100	
Laser safety	IEC60825-1 Class 1	
Size	100 – 200 cm^3	
System Cost	$50	$100 - 200

Figure 4.2: Automotive LIDAR Performance Specification [6]

The TOF LIDAR is the most frequent form of LIDAR used in autonomous cars depending on functional approaches. With the help of its wider range of vision, this LIDAR can scan the object, reflector, lanes, and the road signs concurrently. This LIDAR detects forward objects by discharging a laser beam ahead and scanning it in two dimensions with the help of a spinning hexagon mirror. [7] The following formula is used to calculate the estimated time:

$$distance = \frac{(time\ of\ flight * speed\ of\ light)}{2}\ [8]$$

LIDAR sensor is more expensive compared to other sensors used in ADAS system. However, with the help of its laser technology, LIDAR can provide a high accuracy and reliability as well as high resolution even in the bad weather condition such as, foggy, rainy, or shady weather when image processing techniques are inadequate.

4.2 RADAR

Radio Detection and Ranging, in short for RADAR, designed in 1930 and first used in automotive sector in 1998 by the Mercedes S class underneath the 'Adaptive Cruise Control' (ACC) application. RADAR technology uses radio waves for object detection. A source transmits a radio wave which is reflected by the surface of an obstacle and typically received and processed by a receiver system. Radio waves can work perfectly even in the rough weather condition. Therefore, RADAR technology provides higher accuracy and reliability compared to LIDAR and camera sensors. However, the pedestrian can't be detected precisely by the RADAR technology. [9]

Two types of RADAR systems are used in automotive industry. One is 76 GHz long-range radar, and the other one is 24 GHz short-range radar. However, both the RADAR pointed ahead of the vehicle. Despite of consisting a transmitter, waveguides, a processing unit, and a receiver in a typical RADAR system, antenna is the most vital component of an automotive RADAR system. The range between the surface and the source can be found by the waveform while the angular position of the obstacle can be detected by the antenna. To make the RADAR system more convenient, both the antenna works parallelly. [8] The long-range RADAR system mostly used in those systems which provide the safety features in ADAS system. Adaptive Cruise Control (ACC) and collision avoidance are such systems that provide the safety features in autonomous vehicles. The short-range RADARs are used for lane departure, parking assistance, collision warning, and blind-spot detection.

Operation	Short range mode	Long range mode
Max Range	50 (m)	200 (m)
Range Resolution	0.15 (m)	0.15 (m)
Velocity Resolution	1.8 (Km/h)	1.8 (Km/h)
Velocity accuracy	0.36 (Km/h)	0.36 (Km/h)
Operating temperature	-40 c to +120 c	-40 c to +120 c

Figure 4.3: Specification of ROACH systems RADAR [9]

4.3 Camera

Images are smoothly captured by charge-coupled device (CCD) in recent times. To access the information within an image, many computational techniques are used to process the raw image data depending on the requirements by the system. These computational methods are very crucial facts in case of autonomous driving applications.

Two core techniques are used to process the raw image which can perform concurrently and conveniently. One technique is to process the frame of image and the other one is to process the sequence of image. Detecting obstacle and identifying the distance between source and obstacle are covered by the image frames. On the other side, image sequence tracks the obstacle and determine the relative distance. Both image processing approaches are performed at the same time. It begins by detecting obstacles in images, then continues to track the location of the obstacle by examining the image sequence, and lastly, it resolves the distance between the obstacle and the vehicle. [10]

Mono-vision cameras are used to detect puddles and wet area. RGB and HSB colour information are used by the Mono-vision camera to distinguish the moist or wet areas from the dried areas. Stereo cameras can also be used to separate the puddle from the wet area. Despite of having so many features and techniques, camera sensors may have some drawbacks based on bad weather conditions such as blinded indirect lighting conditions, limitations in night conditions. However, LIDAR and RADAR can be used to overcome such limitations. [11]

One multi-purpose camera, pointing forward, placed in the windshield, can perform many tasks for an ADAS system. [12] Such systems are:

- Adaptive cruise control (ACC)
- Lane departure warning (LDW)
- Forward collision warning (FCW)
- Pedestrian detection
- Traffic sign recognition
- Traffic light recognition
- Windshield wiper control

4.4 ADAS Future Sensors

Many autonomous vehicle manufacturers are working on the development of the ADAS system. Some of them have been working on far-infrared technology. The far-infrared (FIR) technology is a new type of sensor technology that has been used in the defence system for a while. With the help of FIR technology, the autonomous vehicle can get its complete autonomous function. This technology can detect all the objects including those which can’t be detected by other sensors, such as LIDAR, RADAR, and Camera. It can sense the heat of an object and detect its position. To refrain the vehicle from a collision, it can also sense the direction of a pedestrian and can increase the road safety. [13]

Wireless sensors have been another significant research and development sector of ADAS system in recent years. Since the revolution of wireless sensors in modern vehicles, WI-FI and Bluetooth are available at present. There have been many ongoing research projects for the development of wireless sensor. A noteworthy research project, named "Cooperative Hybrid Object Sensor Networks", funded by the European Union, is to merge multiple sensors within a wireless network connection. All sensor's collected data are combined and provided to the ADAS system to help the driver. However, there's a security issue of cyber-attack over the wireless interface. [14]

5.0 ADAS Classification

ADAS system can be classified into two general systems. Such as:

- Active Systems

  This system playing an active role in the system. The motto of this system is to prevent the car from any type of mishaps. To moderate the crashes or accident, such system provides the driver an additional help to direct or control the vehicle.

  Examples: Anti-Lock Braking Systems (ABS), Electronic Stability Control (ESC), Tire Lane Departure Warning System (LDWS), Adaptive Cruise Control (ACC).

- Passive System

  Passive systems paly a passive role to mitigate the damage. This type of system reduces the level of injury of the driver or passengers after the accident has happened.

  Examples: Airbags, Seatbelts.

Depending on different functionalities, ADAS active system can be classified into three more systems.

- Aid

  To aid the driver visually, these systems are used in ADAS. Visual aids such as rear-view cameras, night vision, adaptive front headlights, and surround-view systems are among these features. Mono-vision cameras, infrared lights (useful for night vision), and lasers are among the technologies that enables such features.

  Examples: Rear camera park assist, Night vision, Adaptive front lights, Surround view systems.

- Warn

  Such type of features warns the driver through actuators such as audio or video signal or vibration. When the reversing car approaches near to an object on the rear side, park assist warns the driver by triggering a beeper. Forward collision warning system helps the driver to avoid a probable collision through audio or visual signals. Lane departure warning system (LDWS) warns the driver about the lane deviation by vibrating the driver's seat or activating a beeper.

Examples: Forward collision warning system (FCWS), Lane departure warning system (LDWS), Reverse Park assist, Blind spot detection.

- ❖ Assist

  This type of features is initiated into the system (acceleration, steering, braking system) actively to ensure the highest safety. These features assist the driver to avoid the collision such as Adaptive cruise control (ACC), Forward collision assist. To avoid accidents, such type of features takes the control over the vehicle and halt it according to the situation. RADAR, LIDAR, and mono or stereo vision camera sensors are actively involved to operate such assistance. Example: Lane Keep assist (LKA), Forward collision assist (FCA), Adaptive cruise control (ACC), Autonomous parking system.

6.0 Adaptive Cruise Control

Adaptive cruise control (ACC) is one of the significant features of ADAS technology that adapts the speed of the vehicle autonomously to assure a safer distance than the forward vehicle. Before activating the feature, driver pre-sets the speed and the safer distance. After reaching the desire speed, adaptive cruise control takes control over the vehicle. With the assistance of RADAR sensor technology, the system detects any moving or standby objects and adjust the speed of the vehicle according to the situation to maintain the safer distance predetermined by the driver. The actuators that have used to perform the speeding up and speeding down functions are engine throttle control and limited break operation. By using ‘limited break operation ‘actuator, the system reduces the speed of the vehicle. However, when the obstacle gets out of the range of safer distance, within three seconds the system accelerates the speed of the vehicle with the help of engine throttle control actuator. [15]

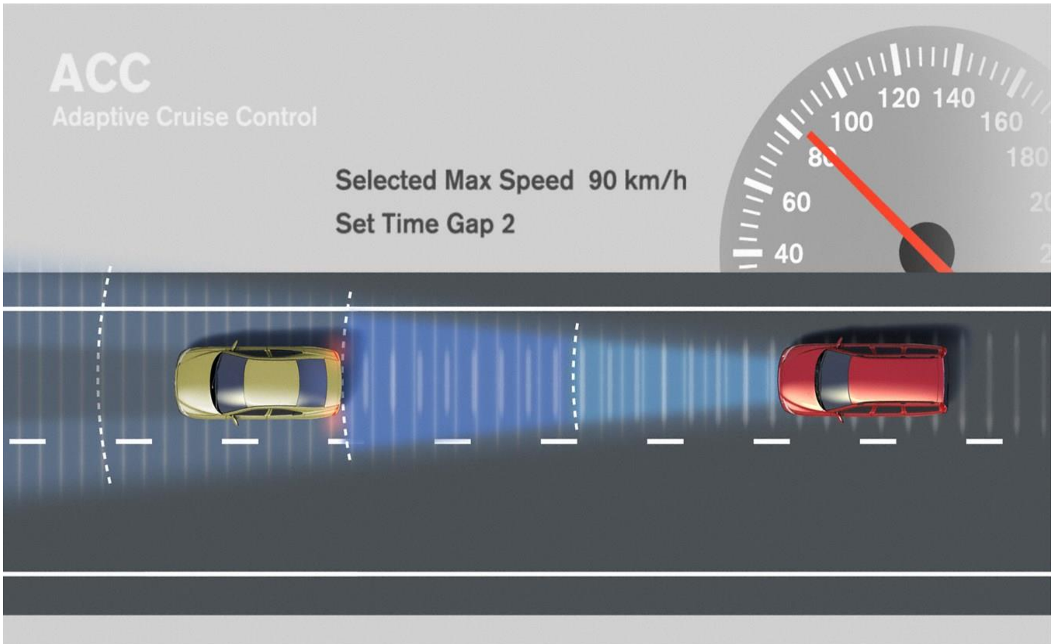

Figure 6.1: Adaptive Cruise Control (ACC) [16]

6.1 Adaptive Cruise Control (ACC) operation

Alike the typical cruise control system, driver also must communicate with the system through a set of switches to perform the adaptive cruise control feature. Adaptive cruise control system has two more extra buttons than a conventional cruise control system. Driver initiates the ACC system into a stand-by state by pressing 'On' button. After pressing the Set' button, ACC system activates and takes control over the vehicle according to the situation by the provided time gap predetermined by the driver. [15]

6.2 Engaging Cruise Control

Figure 6.2: ACC Navigation Interface [17]

ACC has three states in accordance with the availability of the system.

- **Standby State**

  ACC system enters the standby state after pressing the 'ON' button of the system. Before entering the standby mode, the system checks for the imperfection of the power train and cruise control system.

- **Active State**

  After pressing the 'SET' or 'RESUME' button the system goes in the active state. If the system already has any previous input data, then it starts retrieving the data from the system by pressing the 'RESUME' and act accordingly. However, the driver must use the ACC interface to provide new input by pressing the 'SET' button.

- **Time Gap Control**

  This state also known as the follow mode. This state activated as soon as the RADAR sensor technology detects any vehicle within the predefined clearance distance. A variable speed is provided to the powertrain to adjust the speed of the host vehicle according to the instructions (Time Gap, Set Speed) predetermined by the driver.

ACC has three more state to control and maintain the gap.

- **Deceleration Control**

ACC instructs the power train to reduce the speed of the host vehicle with respect to the time gap and set speed as soon as any obstacle is detected within the clearance distance.

- **Acceleration control**

  When the detected obstacle gets away from the clearance distance, the adaptive cruise control accelerates the speed of the host vehicle by instructing the powertrain.

- **Adjusting Time Gap**

  By toggling the '+' or '- 'button, the driver can adjust the time gap between the host vehicle and the object vehicle.

According to the external circumstances, adaptive cruise control switches speed control mode and follow mode spontaneously and automatically. When there is no obstacle detected within the pre-set distance, adaptive cruise control maintains the gap according to the set criteria. On the other hand, whenever any obstacle is detected in front or behind the host vehicle or the distance between two vehicles is deteriorating, adaptive cruise control switch into the follow mode according to the situation.

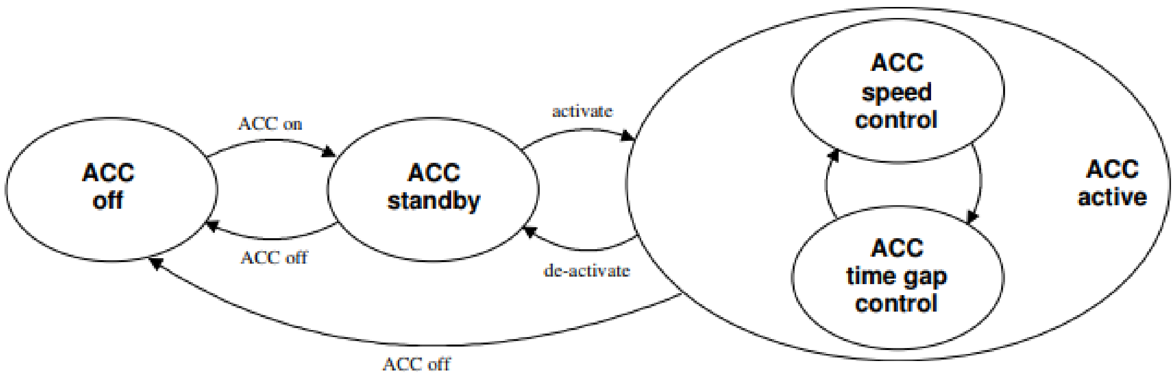

Figure 6.3: Adaptive Cruise Control states [16]

6.3 ACC Hardware

Three types of common hardware are used for Adaptive Cruise Control. Such as:

- Throttle Value Control System

  A potentiometer is initiated into the system to determine the amount of throttle pressed and a 12-dc servo meter is used to control the position of throttle value.

- Automatic Braking Control System

  A closed loop motor directed by a 32-bit RISC microchip is used to take control over the braking system of the vehicle.

- Distance Sensor

  A simple RADAR or LIDAR sensor is integrated into the forward bumper of the vehicle to measure the distance between the host vehicle and the vehicle ahead.

7.0 Lane Departure Warning (LDW)

Sometimes a simple negligence from the driver, such as: tiredness, sleepiness or a simple distraction of the driver can lead the vehicle into a serious accident. To ensure a better safety to the driver, many research have been done to establish a driving assistance system. Real time lane departure warning system has been one of the significant technologies introduced into the automotive sector. With the help of many sensor technologies, Lane departure warning system prevent the vehicle from lane deviation. If the vehicle starts to depart from its lane, lane departure warning system encounters such situation with the help of vision-based sensor and warns the driver by audio or visual signal within a short period of time.

The camera mounted onto the windshield of the vehicle is used by the lane departure warning system to perform its activity. The camera starts to capture images of the moving view of the road up to 130-15 feet forward. The lane markings are generated by converting the digital image into straight or dashed lines. Whenever the vehicle departs from the lane markings, the driver gets warned by the audio or the visual signal or vibration in the seat or the steering. When the turning indicator is switched on, the system will recognise the situation as a normal turnover and will not notify the driver about the lane departure. [12]

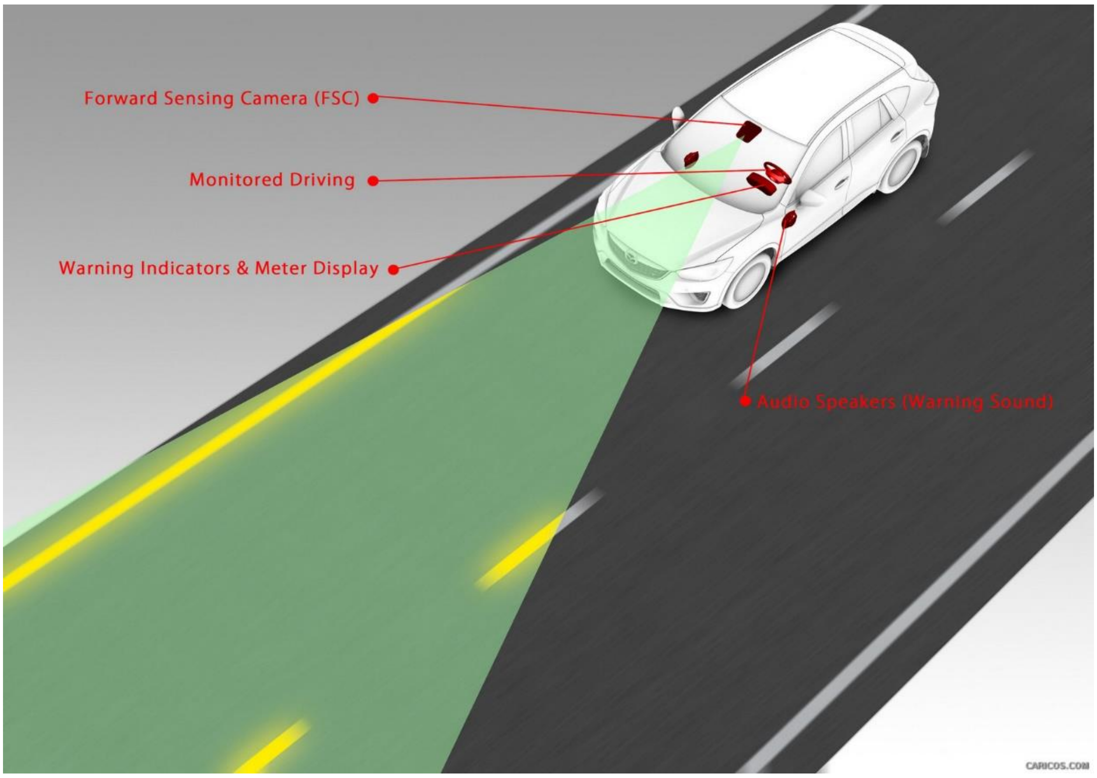

Figure 7.1: Lane Departure Warning System

7.1 Vision-based sensor:

Passive sensors got their popularity in the automotive industry because of their cheap prices. These passive sensors are used as vision-based sensor to operate the lane departure warning system such as Monocular camera and stereo vision camera. They are responsible for detecting an environment with a diversity of wavelength ranges. These cameras use one-dimensional array and two-dimensional array to capture partial and complete images respectively.

7.2 Algorithms for lane detection

Lane departure warning system determines whether the vehicle departs from its actual lane through image processing. The lane markings from the image plane are determined at first. Multiple feature-based approaches are performed to detect the lane markings. To determine the lane, line gradient estimation method is performed. [19]

- High Gray Scale Value

  Despite of having so many colour variations on the road, the lane markings still have a higher grayscale value than the road surface. To determine the threshold value of lane markings, the data from greyscale is used. The system adds the multiplication of the pixels values of red, green, and blue components of the image with 0.3, 0.59 and 0.11 respectively and transforms a 24-bit, three channels and colourful image into an 8-bit single channel grayscale image. [20]
- Edge Detection

  Detecting the lane border is one of the major tasks of lane departure warning system. The edges of an image are detected by comparing the lane markings and road surface that facilitates the prerequisite data with an insignificant amount. 'Canny edge detector' is the most efficient edge detector that detects wide range of edges in images. [20]
- Line Detection

  Another distinct task of the system is detecting the line which has been done by so many detecting methods. Hough transform is one of the famous techniques that has been used in automotive domain thoroughly because of its robustness and being economical. After detecting the edges, they are being transferred into lines in the edge map (Hough space). Upon doing so the most intersected lines can be determined in the Hough space, that can be considered as the true lines. The following mathematical equation is used to detect the line where r and θ represent the angle of the line whereas x and y represent two lines. [21]

$$\mathrm{r} = \mathrm{x}\cos\theta + \mathrm{y}\cos\theta$$

A lane model is demonstrated with the help of Recursive Least square technique and the middle positions. Middle position of a lane is determined after detecting the edges in the image. After measuring the distance between the host vehicle and the lanes, that is compared to the threshold value to determine the lane deviation.

7.3 Implementation Platforms of LDWs

LDWS has been implemented in numerous platforms including FPGA, ARM, DSP because of its powerful features such as adaptability, reconfigurability, being compact and time efficient as well as economical. However, FPGA is most preferred platform because of its parallel processing and agile computational power. DSP and Microprocessors are also renowned for their adaptive symbolic operations. They use SISD structure for stream data manipulation and SIMD structure for large stream data. Hsiao et al. introduce a new architecture model to attain both the facilities for data handling and manipulation by combining FPGA and ARM architecture. [20]

8.0 Conclusion

ADAS delivers many effective features in autonomous vehicles that take the pressures off the driver and increase the safety. There has been a huge influence of ADAS system in the automotive domain and acknowledged by the original equipment manufacturers (OEMs) and the suppliers all over the world. Despite of being early days of ADAS system, OEMs have already realized the outrageous demands of ADAS technology soon. Many research and projects have been going over the ADAS system to make it more scalable and robust. Limited technological knowledge of the user may restrict the market demand of the ADAS system. Unstable updates of the system also responsible for increasing a higher price of the vehicle that restricts the consumers to afford such technology into the system. However, after comparing all the facts of automotive driver assistant system we can conclude that ADAS technology will dominate the automotive domain in the future providing a more accurate and safer journey.

Bibliography:

[1] "Complex Trends and Challenges in Designing ADAS Systems", *Edge AI and Vision Alliance*, 2021. [Online]. Available: https://www.edge-ai-vision.com/2014/09/complex-trends-and-challenges-in-designing-adas-systems/. [Accessed: 18- Aug- 2021].

[2] "Developing Smarter, Safer Cars with ADAS (Automotive Advanced Driver Assistance Systems) IP", *allaboutcircuits.com*, 2017. [Online]. Available: https://www.allaboutcircuits.com/industry-articles/developing-smarter-safer-cars-adas-automotive-advanced-driver-assistance-ip/. [Accessed: 18- Aug- 2021].

[3] "Teledyne LeCroy Automotive Solutions Group - A Measured Approach to the Connected Car.", *Teledynelecroy.com*, 2017. [Online]. Available: https://teledynelecroy.com/automotive/adas/. [Accessed: 19- Aug- 2021].

[4] S. Daily, "Advanced Driver Assistance Systems Technologies Double Repair Bills for Minor Collisions", *Space Coast Daily*, 2018. [Online]. Available: https://spacecoastdaily.com/2018/11/advanced-driver-assistance-systems-technologies-double-repair-bills-for-minor-collisions/. [Accessed: 19- Aug- 2021].

[5] "Lidar vs Radar: pros and cons for autonomous driving", *Cprime | Archer*, 2021. [Online]. Available: https://cprimestudios.com/blog/lidar-vs-radar-pros-and-cons-autonomous-driving. [Accessed: 19- Aug- 2021].

[6] M. Warren, *Automotive LIDAR Technology*. Albuquerque, New Mexico, USA: TriLumina Corporation, 2019.

[7] K. Takagi, K. Morikawa, T. Ogawa and M. Saburi, "Road Environment Recognition Using On-vehicle LIDAR," 2006 IEEE Intelligent Vehicles Symposium, 2006, pp. 120-125.

[8] M. Li et al., "A High-Performance Low-Cost CMOS Radar for Advanced Driving Assistance Applications," 2012 International Conference on Connected Vehicles and Expo (ICCVE), 2012, pp. 197-200.

[9] R. Yadav, P. K. Dahiya and R. Mishra, "A high performance 76.5 GHz FMCW RADAR for advanced driving assistance system," 2016 3rd International Conference on Signal Processing and Integrated Networks (SPIN), 2016, pp. 383-388.

[10] Chu Jiangwei, Ji Lisheng, Guo Lie, Libibing and Wang Rongben, "Study on method of detecting preceding vehicle based on monocular camera," IEEE Intelligent Vehicles Symposium, 2004, 2004, pp. 750-755, doi: 10.1109/IVS.2004.1336478.

[11] Kim, J. Baek, H. Choi and E. Kim, "Wet area and puddle detection for Advanced Driver Assistance Systems (ADAS) using a stereo camera", *International Journal of Control, Automation and Systems*, vol. 14, no. 1, pp. 263-271, 2016. Available: 10.1007/s12555-015-0024-0.

[12] A. A. Assidiq, O. O. Khalifa, M. R. Islam and S. Khan, "Real time lane detection for autonomous vehicles," 2008 International Conference on Computer and Communication Engineering, 2008, pp. 82-88.

[13] A. Yakov Shaharabani, "FIR Sensors Are The Future Of Autonomous Vehicle Technology | Electrical Engineering News and Products", *Electrical Engineering News*

and Products, 2018. [Online]. Available: https://www.eeworldonline.com/fir-sensors-are-the-future-of-autonomous-vehicle-technology/. [Accessed: 20- Aug- 2021].
[14] L. D'Orazio, F. Visintainer and M. Darin, "Sensor networks on the car: State of the art and future challenges," 2011 Design, Automation & Test in Europe, 2011, pp. 1-6.
[15] L. Baures, "Ford Adaptive Cruise Control How To Set Up (Video)", *Trusted Auto Professionals*, 2019. [Online]. Available: https://tap.fremontmotors.com/ford-adaptive-cruise-control-how-to-set-up-video/#.YE5aJp1KhPZ. [Accessed: 21- Aug- 2021].
[16] "Adaptive Cruise Control (ACC)", *Media.volvocars.com*, 2004. [Online]. Available: https://www.media.volvocars.com/global/en-gb/media/photos/8158. [Accessed: 21- Aug- 2021].
[17] "Cruise control | Wikiwand", *Wikiwand*, 2021. [Online]. Available: https://www.wikiwand.com/en/Cruise_control. [Accessed: 22- Aug- 2021].
[18] "2013 Mazda cx-5", *Caricos.com*, 2013. [Online]. Available: https://www.caricos.com/cars/m/mazda/2013_mazda_cx-5/images/144.html. [Accessed: 12- Aug- 2021].
[19] J. Liu, Y. Su, M. Ko and P. Yu, "Development of a Vision-Based Driver Assistance System with Lane Departure Warning and Forward Collision Warning Functions," 2008 Digital Image Computing: Techniques and Applications, 2008, pp. 480-485.
[20] X. An, E. Shang, J. Song, J. Li and H. He, "Real-time lane departure warning system based on a single FPGA", *EURASIP Journal on Image and Video Processing*, vol. 2013, no. 1, 2013. Available: 10.1186/1687-5281-2013-38.
[21] "Line Detection by Hough transformation", *Web.ipac.caltech.edu*, 2009. [Online]. Available: http://web.ipac.caltech.edu/staff/fmasci/home/astro_refs/HoughTrans_lines_09.pdf. [Accessed: 22- Aug- 2021].
[22] "Impact of Advanced Driver Assistance Systems (ADAS)", *Exavalu.com*, 2019. [Online]. Available: https://exavalu.com/wp-content/uploads/2019/02/ADAS-impacts.pdf.
[23] Benson, A., Tefft, B.C., Svancara, Austin M. & Horrey, W. (2018). Potential Reduction in Crashes, Injuries and Deaths from Large-Scale Deployment of Advanced Driver Assistance Systems. AAA Foundation for Traffic Safety.
[24] R. Lanctot, "AFTERMARKET SYSTEMS (ADASRELATED)", *Higherlogicdownload.s3.amazonaws.com*, 2017. [Online]. Available: https://higherlogicdownload.s3.amazonaws.com/AUVSI/14c12c18-fde1-4c1d-8548-035ad166c766/UploadedImages/2017/PDFs/Proceedings/BOs/Bo16-1.pdf. [Accessed: 17- Aug- 2021].
[25] J. Huetter, "Frequency down, but CCC says not yet tipping point of theorized ADAS crash decline - Repairer Driven News", *Repairer Driven News*, 2019. [Online]. Available: https://www.repairerdrivennews.com/2019/03/26/frequency-down-but-ccc-says-not-yet-tipping-point-of-theorized-adas-crash-decline/. [Accessed: 13- Aug- 2021].
[26] "Advanced Driver Assistance Systems Market | 2021 - 26 | Industry Share, Size, Growth - Mordor Intelligence", *Mordorintelligence.com*, 2021. [Online]. Available:

https://www.mordorintelligence.com/industry-reports/advanced-driver-assistance-systems-market. [Accessed: 22- Aug- 2021].
[27] "Global status report on road safety 2018", *Who.int*, 2018. [Online]. Available: https://www.who.int/publications/i/item/9789241565684. [Accessed: 22- Aug-2021].