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ADAPTIVE CRUISE CONTROL

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Abstract

Almost every day we will see disturbing news about road accidents. One study even estimated that the cost of accidents and other expenses associated with traffic will account for about 3 percent of the worlds Gross Domestic Product GDP. In most cases, such crashes can be avoided by building a technology that helps the users steer to their vehicles better. Many car manufactures and research bodies have been working on this and it is known as autonomous driving feature. The purpose of this paper is to present one such concept in autonomous driving which is called as Adaptive Cruise Control (ACC). It is a modification of the existing usual cruise control function with some intelligent enhancements. This system has a built-in function where the speed of the car is controlled according to the space from the vehicle directly in front. The driver sets the maximum speed same like the native cruise control but then a radar sensor is employed to watch for the traffic ahead and to locks the car in a lane. It instructs the car to stay 2, 3, or 4 seconds behind the car in front of it. The driver has the ability to see the follow distance within reasonable limits. ACC is now almost always paired with a pre-crash system that alerts you and often begins braking

***Index Terms** – Cruise control, adaptive cruise control, road safety.*

I. INTRODUCTION

Adaptive cruise control (ACC) is also known as active cruise control, autonomous cruise, intelligent cruise control, or radar cruise control. This is because it enhances the cruise control by leveraging the intelligent radar systems. The radar unit is responsible for measuring the distance from the current vehicle to the vehicle in front. This distance is then used by the employed intelligent systems either to continue the maximum speed set by the user or to decrease the speed in order to avoid collision. Some systems use lasers to achieve this, while Subaru uses cameras that work like human eyes to monitor the road [2]. No matter what technology is used, ACC works both day and night but can struggle in bad weather like heavy rain, fog, or snow [4].

ACC is an important part of the technology needed for self-driving cars in the future. In fully autonomous vehicles, ACC will not only follow the car in front but will also track the vehicles in nearby lanes for safe lane changes.

ACC is usually combined with forward collision warning. Forward collision warning works even when ACC is turned off. When ACC is on, the car will automatically slow down, and this is not done all of a sudden but it gradually decreases the speed according to the to avoid discomfort from the harsh braking. In some cases if a possible collision is detected, red warning lights flash, with messages like "Brake!" or "Brake Now!" combined with a loud sound. Even when ACC is off, the system keeps monitoring traffic and will warn the driver if it detects a possible accident [4].

II. WORKING OF ACC

To use adaptive cruise control, you follow the process similar to the standard cruise control. First, the driver turns on ACC, accelerates to the desired speed, and then presses the "Set" button. After that, the driver can increase or decrease the speed using the "+" and "-" buttons, typically in small steps, like 1 or 5 mph at a time. Also, the driver can also set how much space he wants to keep between his car and the car in front by choosing through options for short, medium, or long distances. Some cars show this with icons of 1, 2, or 3 bars between two cars, while others, like Mercedes-Benz, display the distance in feet, but it's really measured in seconds. For example, a 200-foot gap at 60 mph is about 3 seconds of following time [4].

On the dashboard or in a head-up display, there's typically an icon of a car and lines representing the road. When the radar detects a vehicle in front of you, a second car icon might appear, or the first one may change colour showing that ACC is tracking the vehicle ahead.

If you are new to using ACC, it is a good idea to start with the longest following distance. This gives you more time to react and builds confidence in the system. If you set a closer distance, you might feel nervous because the car seems too close to the one in front, especially if you are not yet sure about the ACC and it's working. The ACC, gets disabled when a brake pedal is pressed. So sometimes, when you have accidentally touched the brake pedal ACC might be disabled. So you need to keep an eye on it and it can be re-engages by resetting it.

Fig. 1. Display of ACC Indicator [4]

III. TECHNOLOGY BEHIND ACC

Adaptive cruise control typically uses radar that operates on a frequency different from police radar, so it doesn't interfere with or trigger radar detectors. For a full-range ACC, which works at both low and high speeds, some carmakers use two radar units: one for close distances up to about 100 feet, and another that can detect up to 600 feet away, which is about 6-7 seconds ahead at highway speeds. Partial ACC systems usually use a single radar, though some newer full-range ACC systems can also function with just one radar unit.

In the early days of ACC, some cars used lasers while others used radar. Radar became more popular because it works better in bad weather and became cheaper over time. Despite radar's dominance, some systems still rely on optical technology. For example, Subaru's EyeSight system uses two cameras mounted near the rearview mirror. It can also provide automatic braking at low speeds if a pedestrian or stopped car is detected in your path.

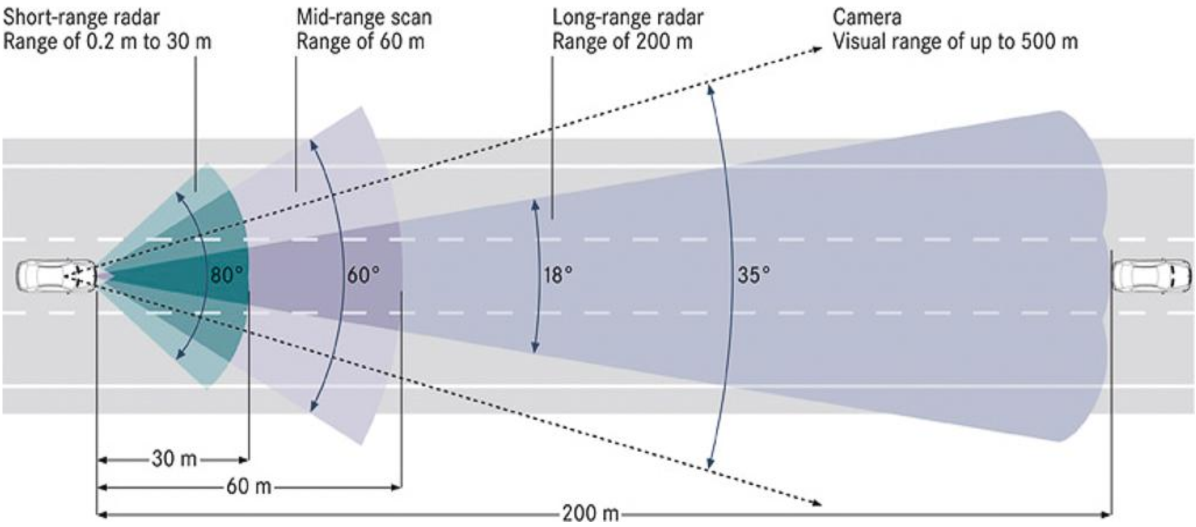

Fig. 2. Working of ACC Technology [4]

Even radar-based adaptive cruise control suffers from bad weather. In the cases of heavy rain or snow, the system may stop working and you will receive a notification. It can also stop functioning when the radar sensor which is situated in the grille or underneath the bumper gets obstructed by snow or mud.

Currently ACC does not automatically adapt to the variable speed limit conditions. However, there are ongoing works address this problem. As of we one can find the speed limit data on the maps installed in the navigation systems, and also some cameras used for monitoring lane departure can recognize the speed limits. In future, it might be possible to set ACC with respect to speed limits with a proper buffer like 5 mph over the limit. When you enter a construction zone and there is a drop in the speed limit then the car would also try to adhere to that speed limit as much as possible

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IV. SENSOR OPTIONS

Currently four means of object detection sensors are technically feasible and applicable in a vehicle environment. They are:

- Lidar
- Radar
- Pulse Doppler Radar
- Fusion Sensor

A. Lidar

Lidar stands for Light detection and ranging. Toyota's first adaptive cruise control (ACC) system used this method. LIDAR works similarly to an Electronic Distance Measuring Instrument (EDMI). A laser beam (either in pulses or continuous waves) is sent from a transmitter and the reflected energy is captured. By measuring the time it takes for the laser to travel to the object and back to the system (Time of Travel or TOT) the distance between the transmitter and the object is calculated.

In another method, the distance is determined by measuring the difference in beat frequency between a Frequency Modulated Continuous Wave (FMCW) and its reflection.

B. Radar

RADAR is a system that uses electromagnetic waves to detect and locate objects like aircraft, ships, spacecraft, or vehicles. It works by sending out energy into space and detecting the echo that bounces back from the object (the target). By comparing the reflected signal with that of original one, additional information about the target like distance and speed can be calculated.

Radar systems use different methods to sense and process the information about the position and speed of vehicles. Two different antennas are used for this purpose

- Mechanically steered antenna
- Electronically steered antenna

C. Pulse Doppler radar

The block diagram of pulse Doppler radar is

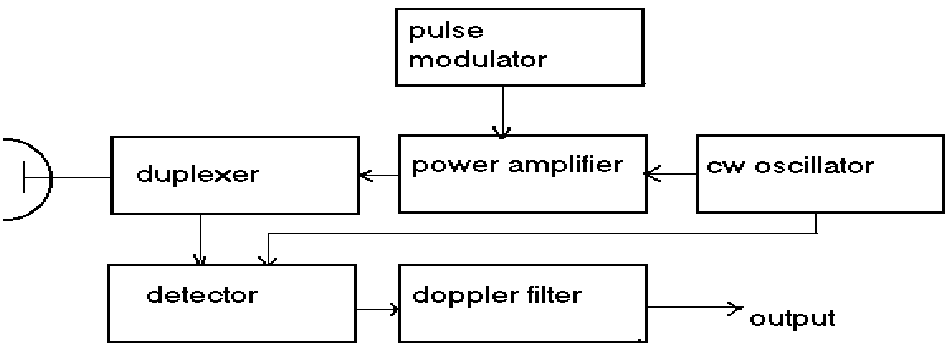

Fig. 3. Block diagram of Pulse Doppler Radar [5]

The continuous wave oscillator generates the signal that needs to be transmitted, which is then modulated into pulses and amplified for more power. The 'duplexer' is a fast-switching device that allows a single antenna to quickly switch between sending and receiving signals

D. Fusion Sensor

Fusion sensor is introduced by Fujitsu Ten Ltd. and Honda through their PATH program, which combines millimetre wave radar with a 640x480 pixel stereo camera that has a 40-degree field of view. These two components work together to differentiate and track moving cars from stationary objects.

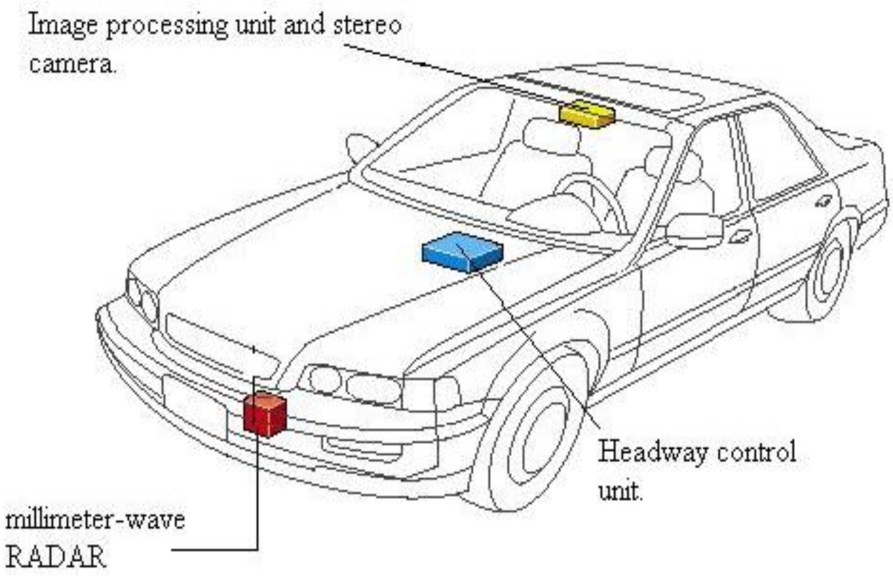

Fig. 4. Overview of fusion sensor [6]

V. CONTROLLER

The controller in an adaptive cruise control (ACC) system takes in information about the current driving situation and translates it into actions, such as applying the brakes or adjusting the speed. Depending on the traffic conditions, the system can perform two types of controls:

1. Speed Control: If there are no vehicles in front, the system adjusts the car's speed to match a set point.
2. Headway Control: When there's a vehicle ahead, the system adjusts the car's speed to maintain a safe distance from the car in front.

For headway control to work well, it must give the driver the right response while keeping the system stable. The system processes information in two main steps:

1. Analysing the traffic conditions
2. Making decisions based on the situation

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The controller then converts this information into appropriate actions, like adjusting the brakes or speed. This process is shown in a simple flow diagram below.

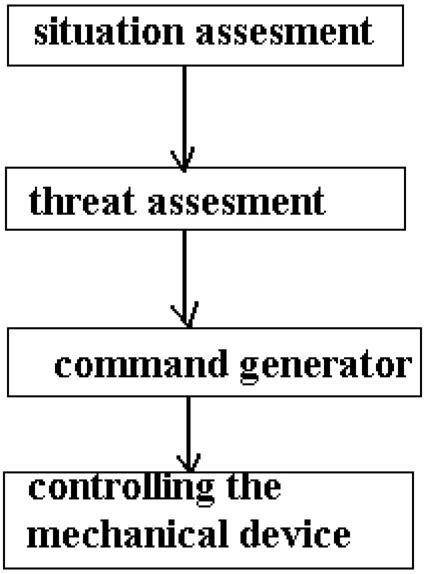

Fig. 5. Flow diagram of controller [5]

VI. CO-OPERATIVE ADAPTIVE CRUISE CONTROL:

Although traditional Adaptive Cruise Control (ACC) and Stop-and-Go Adaptive Cruise Control (SACC) are still expensive and relatively new technologies, a more advanced version called Cooperative Adaptive Cruise Control (CACC) is being tested.

While regular ACC systems only react according to the actions of the vehicle directly in front, CACC takes things a step further by allowing vehicles to communicate with each other to prevent collisions. This communication is faster and more reliable than ACC's sensors alone. By sharing information such as braking capabilities and speed, CACC enables safer and closer driving between vehicles. In CACC mode, the vehicles in front can actively communicate with those following behind, helping them coordinate their speeds for smoother traffic flow [4].

VII. ADVANTAGES

- The driver does not have to worry about constantly adjusting speed or braking in heavy traffic.
- A smart traffic system can be created in future that responds quickly to prevent accidents.
- Since the braking and acceleration are done more smoothly, the car uses fuel more efficiently. [5]

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VIII. DISADVANTAGES

- A cheap version of the ACC system is not yet realized [5].
- For the network of smart vehicles to work well, many cars need to have this technology [5]
- ACC might make drivers less attentive, which could cause serious accidents in case of system failure.
- Current advanced ACC systems focus on communicating with other vehicles but don't react to traffic signals directly.

IX. CONCLUSION

Each year, accidents caused by automobiles are injuring lakhs of people. While safety features like airbags and seat belts have been improved over the years, technologies like ACC, SACC, and CACC are emerging to reduce the accidents even further. While ACC relies on sensors inside the car, CACC goes further by incorporating data from external sources, such as satellites, roadside sensors, or communication with other vehicles. The researchers of Intelligent Vehicles Initiative in USA and the Ertico program of Europe are working on technologies that may ultimately lead to vehicles that are wrapped in a web of sensors with a 360 –degree view of their surroundings [9]. ACC has the potential to be seen as a essential technology in future cars. It not only improve safety and convenience for drivers but also help optimize traffic flow, reduce human error, and increase the road capacity by maintaining safe distances between vehicles.

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