ADAPTIVE CRUISE CONTROL

A Seminar Report

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Bachelor of Technology

in

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By

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I **Rithujith TM** hereby declare that the seminar report **Adaptive Cruise Control**, submitted for partial fulfillment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of Seminar guide.

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ABSTRACT

The concept of assisting driver in the task of longitudinal vehicle control is known as cruise control. Cruise control is a new technological development which incorporates a factor of comfort in driving. Safety is only a small benefit of this system. In short, cruise control can be said to be a system which uses the principles of radar to determine the distances between two consecutive moving vehicles in which either one or both of them is incorporated with this system.

An '**Adaptive Cruise Control' (ACC)** system developed as the next generation assisted the driver to keep a safe distance from the vehicle in front. This system is now available only in some luxury cars like Mercedes S-class, Jaguar and Volvo trucks the U.S. Department of transportation and Japan's ACAHSR have started developing 'Intelligent Vehicles' that can communicate with each other with the help of a system called 'Co-operative Adaptive Cruise Control'. ACC works by detecting the distance and speed of the vehicles ahead by using either a Lidar system or a Radar system. The time taken by the transmission and reception is the key of the distance measurement while the shift in frequency of the reflected beam by Doppler Effect is measured to know the speed.

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Chapter 1

Introduction

Cruise control system is developed for highway driving. This system is useful for driving in the roads which are big, straight, and the destination is farther apart. When traffic congestion is increasing, the conventional cruise control becomes less useful. The adaptive cruise control (ACC) system is developed to cope up with this situation. The conventional cruise control provides a vehicle with one mode of control, velocity control. On the other hand, ACC provides with two modes of control, velocity and distance control. ACC reduces the stress of driving in dense traffic by acting as a longitudinal control pilot.

ACC can work like the conventional cruise control that it is used for maintaining the vehicle's preset velocity. Unlike the cruise control, however, ACC can automatically adjust velocity in order to maintain a proper distance between obstacle and the vehicle equipped with ACC. This is achieved by using laser or radar to measure the relative distance between the host vehicle and a vehicle in front. To develop the adaptive cruise control system, the original throttle system and braking system of the vehicle have to be modified. The original throttle valve which is controlled by a cable from the accelerator pedal is modified to the drive-by-wire system by using a dc motor with a position control algorithm. The braking system is modified by using a dc servo motor to directly control. the brake pedal. A proportional and derivative control with error compensation algorithm is proposed to perform the velocity control mode. In the distance control mode, a fuzzy logic algorithm is applied. Inputs of the fuzzy controller are distance error and relative velocity read from a laser range finder. The experiments on a racing circuit show that the vehicle can perform adaptive cruise control efficiently.

Chapter 2

Literature Review

Recent developments in autonomous driving field have led to a considerable interest in the sub-fields of vehicular autonomy. Researchers have practiced a significant number of longitudinal studies focusing on these sub-fields and vehicle platoons has become a recognized area over the past decade. To develop the adaptive cruise control system, the original throttle system and braking system of the vehicle have to be modified. A proportional and derivative control with error compensation algorithm is proposed to perform the velocity control mode. In the distance control mode, a fuzzy logic algorithm is applied. Inputs of the fuzzy controller are distance error and relative velocity read from a laser range finder. The experiments on a racing circuit show that the vehicle can perform adaptive cruise control efficiently.

Several studies has been made in the field of Cruise Control. Some of them are:

1. Cooperative Adaptive Cruise Control Algorithms for Vehicular Platoons Based on Distributed Model Predictive Control :

This paper argues Cooperative Adaptive Cruise Control (CCAC) algorithms for vehicle platoons using Distributed Model Predictive Control (DMPC) under bidirectional communications. This paper presents a DMPC algorithm to control a nonlinear vehicular platoon under bidirectional topologies. It has been observed via simulations that DMPC can process the additional information without violating string stability which is still a challenging problem of nonlinear systems. Effects of possible failures in communication are also studied in this paper.

2. Adaptive Cruise Control: A Model Reference Adaptive Control Approach :

In this paper, a Model Reference Adaptive Control (MRAC) has been applied to design an ACC system.. The ability of MRAC to perform despite uncertainties has been demonstrated. . Simulation results were presented. The structure of the controller is suitable for real-time implementation. The controller is a good candidate for practical implementation, in addition to the vehicle velocity, only a sensor that measures relative distance is needed for practical implementation. It is concluded that the performance of MRAC is better than nominal feedback controller for all uncertain scenarios. When the uncertain parameter increases, the performance of the nominal controller deteriorates and even leads to oscillation

3. Adaptive Cruise Control for an Intelligent Vehicle

In this research, an adaptive cruise control system is developed and implemented on an AIT intelligent vehicle. To develop the adaptive cruise control system, the original throttle system and braking system of the vehicle have to be modified. The ACC system which is developed for the AIT intelligent vehicle is able to control the vehicle to run at desired velocity when operated in velocity control mode and efficiently maintain the distance between the host vehicle and the obstacle vehicle.

Chapter 3

HISTORY OF ADAPTIVE CRUISE CONTROL

Ever since the first automobiles rolled onto the road, manufacturers have been introducing technology to ensure they avoid crashing into each other. But it wasn't until the mid-1990s that innovation really moved up a gear and cars could intelligently assist drivers to keep their distance from those in front. Adaptive cruise control was one of the first functions to appear on production cars that could truly be considered a first step toward 'autonomous' driving. However, it did take time – and some trial and error – to settle on a technology that worked.

In 1991, Mitsubishi dabbled with lidar by installing a system in its Debonair, but it was just a rudimentary warning system and did not regulate speed. Four years later Mitsubishi became the first OEM to offer an adaptive cruise control system after equipping its 1995 Diamante sedan with a Preview Distance Control system, which introduced lidar in the front bumper and a miniature camera mounted in the rear-view mirror. It was able to sense when the distance to the vehicle ahead was closing and would automatically ease off the accelerator or make the transmission downshift to slow the car. Its limitation, however, was that it could not operate the brakes, so when the speed difference with the vehicle in front was too great, it had to resort to alerting the driver with audible and visual warnings. With no braking intervention, an operational limit of 67mph (108km/h) and poor performance in the rain, Mitsubishi decided to keep the system solely for the Japanese market, where it suited the road conditions and generally clement weather.

Toyota followed its Japanese rivals with a more robust Denso-developed system on the 1997 Celsior – a Japanese-market version of the Lexus LS. Also using lidar but still without any control over the brakes, Toyota's system provided a horizontal sensing range of 16º and a vertical range of 4º and was able to track other vehicles up to 100m (330ft) away.

3.1. Distronic Radar

In 1999 Mercedes introduced "Distronic", the first radar assisted ACC,on the Mercedes-Benz S-Class (W220)and the CL Class.

Notably, Mercedes’ system was designed to work at higher speeds – essential for use on unrestricted German autobahns, but the company also introduced two other critical features. In the aftermath of the infamous A-Class elk test in 1997, where the vehicle overturned trying to avoid an obstacle at speed, Mercedes had started to make its ESP stability control system a standard feature on all its cars. This meant that provisions for automatic braking were already in place, correcting the biggest omission from the Japanese systems. Secondly, it featured radar rather than lidar. While the latter may be the popular option today for autonomous driving systems, back in 1999, high-quality radar systems were an advantage as they were available at a far lower price point

3.2. Distronic plus display

Chapter 4

ADAPTIVE CRUISE CONTROL SYSTEMS

Adaptive cruise control (ACC) is an enhancement of conventional cruise control. ACC automatically adjusts the speed of your car to match the speed of the car in front of you. If the car ahead slows down, ACC can automatically match it. Once the car ahead moves out of your lane or accelerates beyond your car's set speed, your ACC allows your car to return to the speed that you have set. Other than setting your speed, you only need to turn on the system and select your preferred following distance.

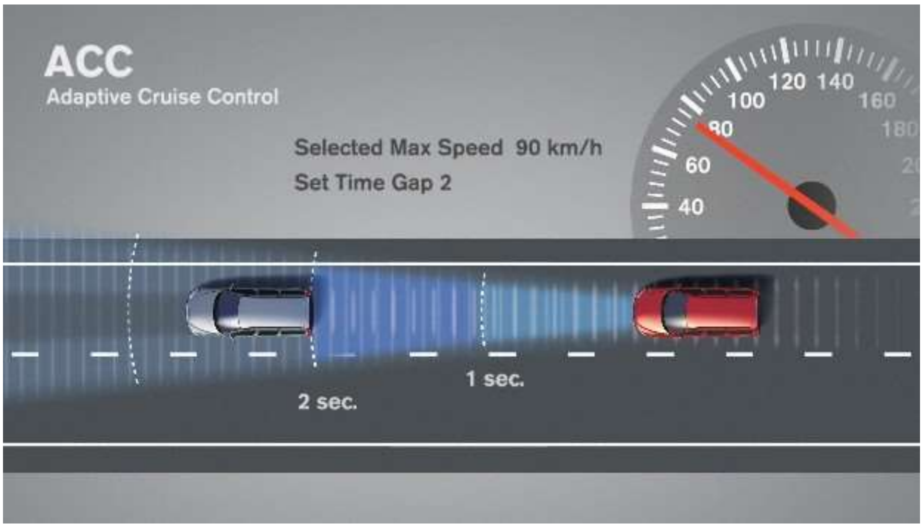
Low-speed ACC is one of the systems, which operates under congested traffic to maintain the distance behind the obstacle vehicle. This type of ACC system is sometimes called "stop-and-go ACC." Early versions may only perform a "stop and wait" function which requires drivers to initiate a resumption of forward movement when appropriate. The reason is that manufacturers are hesitant to offer such a system to automatically operate in complex low-speed traffic environments, which may have bicycles and pedestrians. The general low-speed ACC system is operated at very low speed (approximately 5 km/hr) and requires the driver to interfere to stop and restart vehicle motion. Low-speed ACC was introduced to the Japanese market in 2004.

High-speed ACC system is the evolution of the cruise control. The system provides velocity control as in conventional cruise control when there is no vehicle in front of the host vehicle. If a vehicle runs in front of the host vehicle at a slower speed, the throttle and braking system are controlled to maintain the inter-vehicle gap which is set by the driver. The host vehicle will run at the pre-set velocity again when the way ahead is no obstructed, resulting from either the slower vehicle ahead changes the lane or the driver of the host vehicle moves to the other lane. The first ACC systems were designed to operate at moderate to high velocity, 40 km/hr and above. Most European systems operate from 30 km/hr and higher because this is a typical speed limit in city areas. The upper speed range goes as high as 200 km/hr. In cases where the distance to the vehicle ahead is near and the braking authority of the host vehicle is inadequate to maintain the inter-vehicle gap, audible alerts are sounded to force the driver to take control of the vehicle.

Chapter 5

5.1. PRINCIPLE OF ACC

ACC works by detecting the distance and speed of the vehicles ahead by using either a Lidar system or a Radar system. The time taken by the transmission and reception is the key of the distance measurement while the shift in frequency of the reflected beam by Doppler Effect is measured to know the speed. According to this, the brake and throttle controls are done to keep the vehicle the vehicle in a safe position with respect to the other. These systems are characterized by a moderately low level of brake and throttle authority. These are predominantly designed for highway applications with rather homogenous traffic behavior .



5.1 Adaptive Cruise Control

The second generation of ACC is the Stop and Go Cruise Control (SACC) whose objective is to offer the customer longitudinal support on cruise control at lower speeds down to zero velocity. The SACC can help a driver in situations where all lanes are occupied by vehicles or where it is not possible to set a constant speed or in a frequently stopped and congested traffic. There is a clear distinction between ACC and SACC with respect to stationary targets. The ACC philosophy is that it will be operated in well structured roads with an orderly traffic flow with speed of vehicles around 40km/hour. While SACC system should be able to deal with stationary targets because within its area of operation the system will encounter such objects very frequently.

The conventional cruise control provides a vehicle with one mode of control, velocity control. On the other hand, ACC provides with two modes of control, velocity and distance control. ACC reduces the stress of driving in dense traffic by acting as a longitudinal control pilot. ACC can work like the conventional cruise control that it is used for maintaining the vehicle's preset velocity. Unlike the cruise control, however, ACC can automatically adjust velocity in order to maintain a proper distance between obstacle and the vehicle equipped with ACC.

5.2 CONSTITUENTS OF AN ACC

The main constituents of an Adaptive Cruise Control System are :

1. A **sensor (LIDAR or RADAR)** usually kept behind the grill of the vehicle to obtain the information regarding the vehicle ahead. The relevant target data may be velocity, distance, angular position and lateral acceleration.

2. **Longitudinal controller** which receives the sensor data and process it to generate the commands to the actuators of brakes throttle or gear box using Control Area Network (CAN) of the vehicle.

Chapter 6

SENSOR OPTIONS

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

- RADAR
- LIDAR
- VISION SENSORS
- ULTRASONIC SENSOR

6.1 RADAR (Radio Detection and Ranging):

RADAR is an electromagnetic system for the detection and location of reflecting objects like air crafts, ships, space crafts or vehicles. It is operated by radiating energy into space and detecting the echo signal reflected from an object (target) the reflected energy is not only indicative of the presence but on comparison with the transmitted signal, other information of the target can be obtained.

Based on the radar reflection, ACC uses distance, direction and relative speed to detect if the car is within the distance you set. ACC predicts the path of your car and then decides whether any of the vehicles ahead are within your set distance.
Radar based ACC focus on two main parameters i.e. distance and velocity. It helps to reduce driver stress by acting control pilot. ACC helps to maintain proper distance between vehicles using velocity adjustment.

6.2 LIDAR (Light Detection and Ranging) :

LiDAR-implemented systems can enhance various ADAS features, like the automatic emergency brakes, lane centering and ACC. Compared with traditional radar solutions, LiDAR comes with higher resolution and more stable performance and thus guarantees more accurate detection of objects. It also provides precise depth perception and correct distance of up to a few centimeters, making it a better option over cameras. This translates to easy detection and proper vehicle positioning. LiDAR with higher refresh rates than other sensing solutions, has excellent performance on detecting fast-moving targets, such as vehicles on the highway.

6.1 TF03 Lidar sensor

Benewake TF03 is an intelligent long-range lidar sensor, providing reliable driver safety and assistance solutions with mass-production price. The TF03 is an upgrade of the previous sensors, featuring compact-integration and cost-effectiveness. It solves various challenges that most drivers face, ranging from detecting the distance between the driver and the forward vehicle, especially at dark environment. With the build-in algorithm for raining and fogging weathers, the system offers you a long-range reliable results.

LiDAR technology is setting off waves in the auto industry. With the ability to provide better driving assistance and safety solutions, LiDAR has solved various problems that most drivers have experienced. We all agree that multi-sensor solution is the trend of the future. LiDAR can be coupled with camera AI system, radar system and other short-range sensors to assist our daily driving.

Chapter 7

TYPES OF ACC SYSTEM

Laser based systems do not detect and track vehicles in adverse weather conditions nor do they reliably track dirty (and therefore non-reflective) vehicles. Laser-based sensors must be exposed, the sensor (a fairly large black box) is typically found in the lower grille, offset to one side.

Radar-based sensors can be hidden behind plastic fascias; however, the fascias may look different from a vehicle without the feature. For example, Mercedes-Benz packages the radar behind the upper grille in the center and behind a solid plastic panel that has painted slats to simulate the look of the rest of the grille.

Single radar systems are the most common. Systems involving multiple sensors use either two similar hardware sensors like the 2010 Audi A8 or the 2010 Volkswagen Touareg or one central long range radar coupled with two short radar sensors placed on the corners of the vehicle like the BMW 5 and 6 series.

A more recent development is the binocular computer vision system, such as that introduced to the US market in model year 2013 by Subaru. These systems have front-facing video cameras mounted on either side of the rear view mirror and use digital processing to extract depth information from the parallax between the two cameras' views.

7.1 Assisting Systems

Radar-based ACC is often sold together with a pre-crash system, which warns the driver and/or provides brake support if there is a high risk of a collision. Also in certain cars, it is incorporated with a lane maintaining system which provides a power steering assist to reduce steering input burden on corners when the cruise control system is activated.

7.2 Multi-sensor Systems

Systems with multiple sensors can practice sensor fusion to integrate the data to improve safety and/or driving experience. GPS data can inform the system of geographic features such as a freeway off ramp. A camera system could notice driver behaviour such as brake lights and/or a turn signal. This could allow the following car to interpret a turn signal by an exit as not requiring the following car to slow down, as the leading car will exit. Multi-sensor systems could also take note of traffic signs/signals and not, e.g., violate a red light while following a vehicle that crossed before the signal changed.

7.3 Predictive Systems

Predictive systems modify vehicle speed based on predictions of other vehicles' behavior. Such systems can make earlier, more moderate adjustments to the predicted behavior, improving safety and passenger comfort. One example is to predict the likelihood of a vehicle in a neighbouring lane moving in front of the controlled vehicle. One system predicts a lane change up to five seconds before it occurs

Chapter 8

WORKING

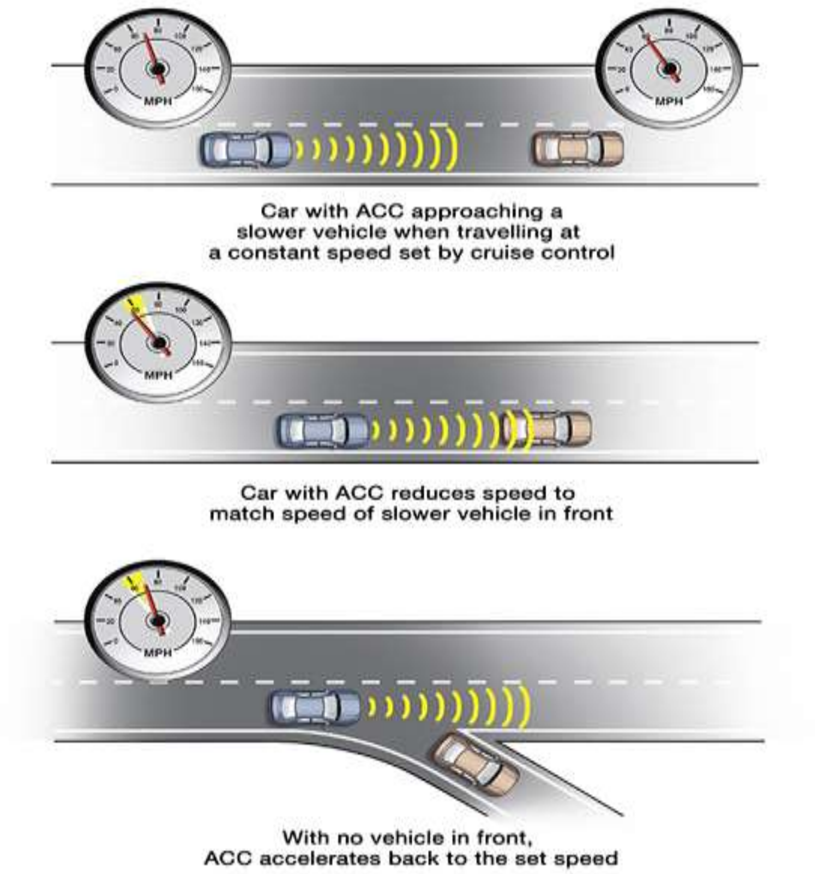
ACC systems use onboard computers and sophisticated sensors, such as radar or laser systems, to monitor the other vehicles on the road. Because of this, adaptive cruise control is also called radar cruise control or autonomous cruise control.

Once the driver locks his or her preferred speed into the ACC system, the vehicle will monitor its surroundings. The system runs a signal from its radar headway system through a digital signal processor to determine the distance to the nearest car, and it then uses a longitudinal controller to determine a safe following distance.

If the driver's vehicle has too little following distance, the ACC system sends a signal to the engine or brakes, slowing the vehicle down. Once the path is clear, the ACC system will accelerate the vehicle back to the driver's preferred speed. By restricting airflow to the engine when the vehicle is close to its speed setting and increasing airflow when the vehicle is below its speed setting, the cruise control system helps the car maintain a near-constant speed.

The system itself is composed of several parts, each with its own task:

The ACC module processes sensor data to determine if there's another vehicle in front of the car. The engine control module regulates the engine throttle according to data from the ACC module and the instrument cluster. The brake control module checks the vehicle's speed and applies the brakes when necessary. The instrument cluster relays information about the system back to the driver and sends information from the cruise switches to the ACC module and the engine control module. The cruise switches receive input from the driver, turning the system on or off and setting the desired speed. The brake switches monitor the braking system and disengage the cruise control system when the driver applies the brakes manually. The brake lights illuminate when either the driver or the ACC system engages the brakes.



8.1 ACC demonstration

8.1 HOW TO USE IT?

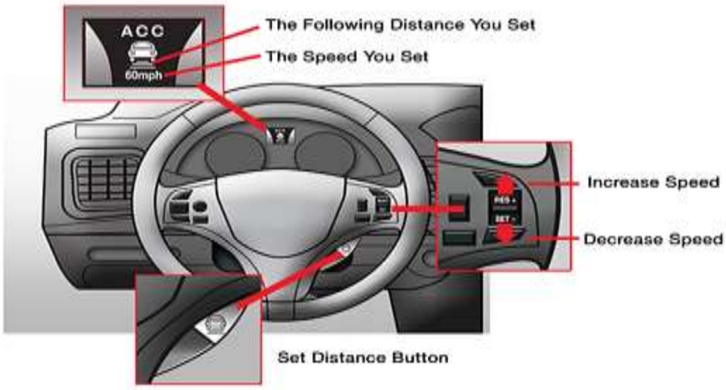
The specific controls will be different depending on your particular car type, but usually you will have to start by setting a cruising speed and a following distance to the car ahead.

Activation/Deactivation

Most systems are operated by controls on the steering wheel. You can also intervene at any time by use of the brake or accelerator pedal.

Setting the speed

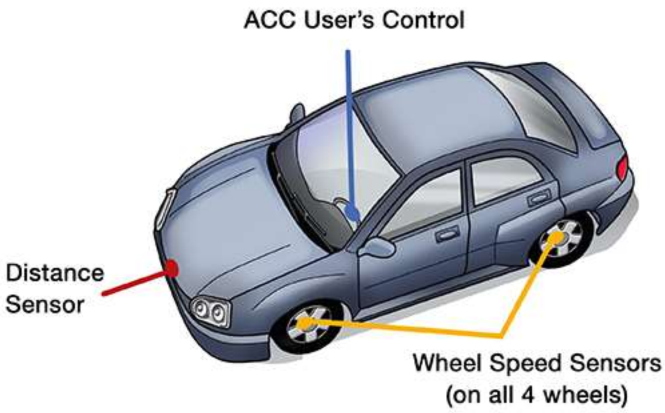
You can set the speed using the +/- speed button. You can also accelerate as normal until the desired speed is reached. Then you press a button to have the ACC “remember” the speed. Most ACC systems will work down to about 25 MPH.



8.2 Steering ACC Control

Setting the distance

ACC systems allow you to set a following distance, or time interval, between your car and the car ahead. ACC systems provide various car-to-car distance options, such as: short, medium, or long distance. You can change the setting at any time as traffic conditions change. A longer setting is recommended for most driving.



8.3 Parts related to ACC system

Chapter 9

ADVANTAGES

Adaptive cruise control systems offer multiple benefits. Some of them are discussed below:

- **It increases road safety**:

  As cars with this technology will keep the adequate spacing between them and other vehicles. These space-mindful features will also help prevent accidents that result from an obstructed view or close following distance.

- **It can increase the vehicle’s fuel efficiency:**

  Both standard and adaptive cruise control can help your vehicle consume less fuel on a trip. That’s because your vehicle is better at maintaining a steady speed than you are, which makes it use gas more efficiently. Adaptive cruise control is even more efficient than standard cruise control, as it can reduce the need for braking and accelerating in response to the behaviors of drivers in front of you.

  And while the savings may not be much per trip, they can quickly add up over time. They can also make a difference in your total fuel bill when you’re on long trips, especially on flat, straight highways and interstates with relatively little traffic.

- **ACC will help maximize traffic flow because of its spatial awareness.**

- The driver is relieved from the task of careful acceleration, deceleration and braking in congested traffics.

- As a driver, you don't have to worry about your speed, and instead, you can focus on what is going on around you

9.1. LIMITATIONS

Although there are many advantages to adaptive cruise control, there are still limitations to consider.

- **It Can Make Drivers Less Aware and Prepared:**

  When you use cruise control, you are no longer giving your full mental and physical attention to the task of driving. When driving on straight stretches of road with cruise control activated, you may not even need to steer constantly. That can increase your risk of daydreaming, becoming distracted, or suffering from “highway hypnosis”—all of which can make it more difficult to react immediately in the event of a potential crash situation.

- **It Can Cause Unexpected Results in Inclement Weather:**

  Adaptive cruise control may struggle to perform safely and efficiently at night or during bad weather. When any type of cruise control is activated, your vehicle may not properly adapt to increased braking distances during rainstorms or winter weather. That means that if you rely on it to slow down or maintain a safe speed, it may brake too late or accelerate too early, causing a crash.

- **It is comparatively costlier:**

  Most of the vehicles that have the adaptive cruise control system installed are much expensive. A cheaper version is not yet realized.

Chapter 10

CONCLUSION

The accidents caused by automobiles are injuring lakhs of people every year. The safety measures starting from air bags and seat belts have now reached to ACC, SACC and CACC systems. The Adaptive cruise control system is being evolving every year and more and more car companies are implementing it. To increase comfort and safety of this function, a multi purpose camera can be installed in addition to the radar sensor. By this, for instance, ACC can, thanks to the lateral measuring accuracy of the multi purpose camera, detect a vehicle entering the driver's own lane – either planned or unplanned – much earlier, enabling the system to respond more dynamically.

Car companies are continuously making adjustments to this technology and, in doing so, creating more common and affordable options that can be purchased with a new car or added to older car models, making driving safer for everyday people. While adaptive cruise control brings some automation to driving, it is by no means a substitute for the driver. Despite the comfort drivers experience on the road by using adaptive cruise control, they should still stay vigilant and ready to react if necessary.

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