Adaptive Cruise Control (ACC) System in Automobiles

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ABSTRACT: ***In today's world of the automotive industry, efforts are still being made towards more autonomous vehicles (AVs). The primary focus of introducing autonomous technology is driver safety. According to a study 90 percent of injuries occur because of driver error. The adaptive cruise control system (ACC) is a system that integrates cruise control with an avoidance system for collisions. The ACC system is based on technologies such as laser and radar. This system is capable of automatically controlling vehicle speed to match the speed of the vehicle, bus or truck in front of the vehicle. In the world of today's automotive industry is still putting efforts towards the more autonomous vehicles (AVs). Driver safety is the main concern of implementation of the autonomous technology. According to a study, 90% of accidents occur due to driver's mistake. A system that combines cruise control with a collision avoidance system is the adaptive cruise control system (ACC). The ACC system is based on the technologies of laser and radar. This system is capable of automatically adjusting the velocity of the vehicle to match the velocity of the vehicle (bus, car or truck) in front of the vehicle. If the lead vehicle is slowed down or accelerated, the ACC system will automatically match that velocity. This paper focuses on more precise methods of detecting preceding vehicle through the use of lidar and radar sensors by considering the side slip of the vehicle and monitoring the distance between two vehicles. An improvement in driving stability was achieved by using this approach, i.e. logic for calculating former vehicle distance and controlling the ACC equipped vehicle throttle valve. If the ACC system slows down or accelerates the lead vehicle fits the velocity immediately. The paper proposed concentrates on more precise methods to detect the preceding vehicle using a radar and a lidar sensors by controlling the distance between two vehicles and considering the vehicle side slip. By using this approach i.e. logic for calculating the distance of the former vehicle and controlling the ACC equipped vehicle throttle valve, an increased driving stability has been achieved. The own contribution results with fuel efficient driving and a safer and more reliable driving system, but there are still some improvements to make it safer and more reliable.***

KEYWORDS: Adaptive Cruise Control (ACC), autonomous vehicles, driver assistance system, lidar, radar sensor, sensor system.

INTRODUCTION

A study by Partners Advanced Transit Highways (PATH) concluded that the damaged property and other costs almost equal three percentage of world gross domestic goods. Many researchers have been studying on smart and intelligent vehicles in recent years that contributes to the remedy, such as the elimination of the burden on drivers, the avoidance of accidents, the congestion mechanism etc. According to a survey a person dies an average of every minute due to accidental crash. Driving appears to be an simple job but driving takes a high degree of mental focus for a very long time and is prepared to face any situation in split seconds and respond in that short span of time. In the recent years lots of research on intelligent automobiles have been developed in order to solve the problems such as accident prevention, driver burden reduction, traffic congestion system etc. Efforts are still being made in today's world automotive industries towards the autonomous vehicles (AVs). Making driving safe by avoiding accidents is the main concern of introducing the autonomous technology. Driving seems to be an easy task, but driving requires a high degree of mental concentration for a very long time and is prepared to counter any condition in split seconds and react in that short period of time. A system known as the Adaptive Cruise Control System (ACCS) is discussed here to overcome the driver burden and accident problems on the long distances on highways[1], [2]. The first idea to implement cruise control devices for the driver assistance came in the USA in 1970. When this system was installed, this system takes up the task at a constant speed thereby operating acceleration and breaking. But the main problem was that, it was not designed by consider the other vehicle's safety on roads. Cruise Control (CC) was developed after a few years in 2009 to assist the driver on highways for the long distance. This machine was only able to the control velocity of the vehicle, but in the areas of traffic congestion, this system is less effective. The implementation of the Adaptive Cruise Control (ACC) would overcome this drawback. With the passage of time, the new technologies are changing now a day's driving activities that potentially improve driving. Driving technology that interferes actively, regulating vehicle speed and the direction may have greatest impact on the driver's safety.

A program known as the Adaptive Cruise Control System (ACCS) will be addressed here to address the crash issues and driver pressure on long distances on highways. The first idea to implement cruise control devices for assisting drivers came in 1970 in the USA. By operating the acceleration and breaking, this system takes up task at constant speed when this system was installed and made switched on as. But the problem was that it was not designed to take into account the safety of other vehicles on the road. Cruise Control (CC) was established after a few years in 2009 to assist the long distance drivers on highways. This system was only able to control velocity. But, in traffic congestion zones, this system is less helpful. This drawback is solved by the introduction of the Adaptive Cruise Control (ACC)[3]–[5]. With the passage of time, the new technologies are changing driving tasks that potentially improve driving. Driving technology that actively intervenes, controlling vehicle speed and direction may have the greatest impact on driver safety. One of them is adaptive cruise control which enhances safe driving.

ACC's goal is to avoid the collision at the rear end by maintaining safe distance. By acting as a longitudinal monitoring operator, ACC eliminates the tension of driving in dense traffic. Without driver interference, the device makes it possible to change the distance to the car ahead, essentially relieving the driver[3]. The Adaptive Cruise Control (ACC) is an automotive feature which allows the cruise control system of a vehicle to change the speed of the vehicle to the traffic situation. To determine if slower moving vehicles are in the direction of the ACC vehicle, a radar system mounted to the front of the vehicle is used. Upon sensing a slower moving vehicle, the ACC system slows down the vehicle and monitors the clearance or time difference between the ACC vehicle and the forward vehicle. The ACC system will accelerate the vehicle back to its set cruise control speed if the system detects that the forward vehicle is no longer in the path of the ACC vehicle. This operation enables the ACC vehicle to slow down and speed up with the traffic autonomously without driver intervention. The method through which ACC speed of the vehicle is controlled is via limited brake operation and engine throttle control.

Adaptive cruise control system is available in luxury and less expensive versions vehicles. ACCS is an automotive feature which allows the cruise control system of the vehicle to adapt the speed of the vehicle to the environment of traffic. ACC system is an improved version of the CC system in which the vehicle speed is controlled by the previous vehicle movement by controlling the throttle valve and breaking system. A radar system installed at the vehicle's front is used detect if slower moving vehicles are in the ACC lane. If a bit quicker the car moving is observed, the ACC device slows down the car and monitors the clearance and time distance between the ACC vehicle and the forward driver. The ACC system's main objective is to offer longitudinal support at lower speed or at zero speed. This ACC Stop and GO system is valid only for stationary objects coming in the vicinity of a vehicle. In this type of system a constant speed cannot be set. And this type of ACC program only refers to stationary goals in a specific way. An improved form of ACC came after doing a long research on the drawbacks of conventional ACC and Go and Stop ACC. It surmounts nearly all the limitations and disadvantages of previous systems. But there are already some drawbacks that can be solved in the future to make it more stable and safer for human beings.

Generally, regular use of braking and accelerator by the vehicle’s driver happens in traffic areas or traffic congestion. Often, instead of braking, driver applies accelerator or vice versa after a long drive and tension pressure in the traffic area. The ACCS thus removes the constant need for accelerator and breaks in the traffic area and reduces the risk of accident by ensuring driver and passenger safety. There exists ACC system in the preceding generation but that included just few features such as “Go” and “Stop”. An improved form of the ACC came after a long research on the conventional ACC drawbacks. This overcomes nearly all drawbacks and limitations of the previous systems, but there are still some obstacles that can be solved in the future in order to make the human being more reliable and safe.

1. *Adaptive Design of Cruise control*

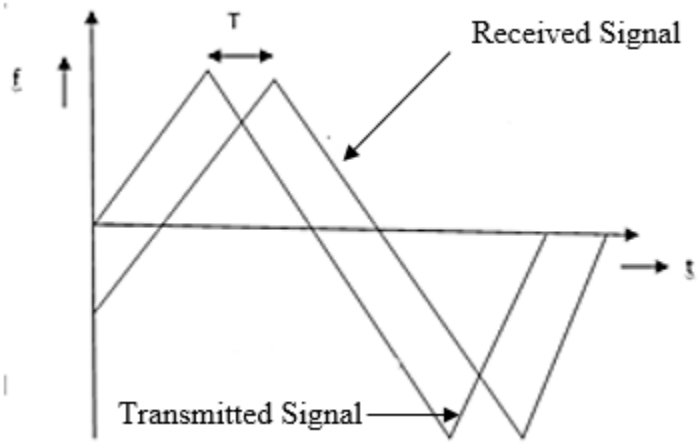

Figure 1: Working Principle of ACC system

As explained at the beginning, the main concern and aim of implementing this type of system in vehicles is human safety by avoiding crash caused by driver error. ACC works on the principle of using some sensor to calculate the distance and speed of the vehicle ahead. This sensor can be a sensor for lidar, or a sensor for radar. Transmission and reception time in ACC system is the key to distance measurement. Shift in reflected beam frequency is measured as speed by the Doppler effect. Control on break and throttle can be done on the bases of speed and distance calculation to keep the vehicle in a safe position. Here in Figure 1 the time and frequency graph is shown to measure the distance and speed.

2. *ACC System: Physical layout*

The ACC system consists of a series of components and structures that are interconnected. In this section, the components that are primarily used in the ACC system and their purpose are described, and how they contribute to making driving safe. The ACC package consists mainly of Auto Speed Control (ASC), ACC Electrical Control Unit (ECU), Dynamic Stability Control (DSC) and Distance Configuration Switch, indicator display and millimeter wave radar (Fig. TAC in figure 2 means Throttle Actuator Control, TA (Throttle Actuator), BAC (Break Actuator Control) and BA (Break Actuator).

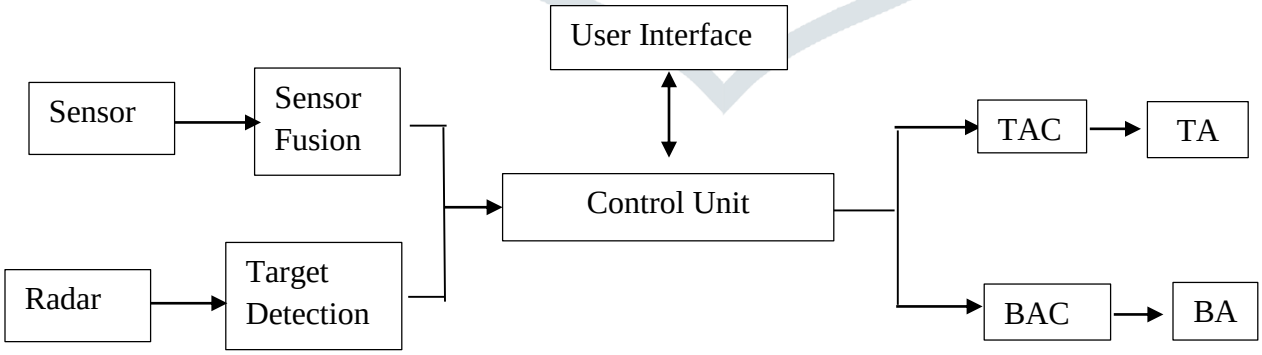

Figure 2: Simplified view of ACC system

ACC System Components is made up of a large number of components that are designed to perform their own task in a particular way. A set of communication networks known as the Controller Area Network (CAN) are the method of communication between different modules[5]. An important function of ACC ECU Module is processing the information generated by the radar sensor if any processing vehicle is present. In “time gap control” it sends the information to brake control module and engine control module to maintain and control the distance between the ACC Vehicle and the Target vehicle.

As described above, Radar is used to detect vehicles that travel ahead of the vehicle fitted with the ACC. The driver can easily identify the preceding vehicles on the same route when the road is straight. In some cases, however, it is very difficult for the drivers to see and recognize the vehicle that is going forward, particularly during the road curves. Suppose in one case three vehicles move ahead of the driver's vehicle on a curve lane. First, in this situation, it is necessary to find the vehicle is on the same track as the vehicle of the driver. It helps to assess which vehicle to obey the ACC system[7], [8]. After that, the ACC system assesses whether the radar sensor detected object is a static object or a moving object by comparing the driver's vehicle speeds and the vehicle detected. If the previous vehicle travels at the same speed, it is generally considered to be a static object. At the same time, path is estimated based on the observed yaw rate, vehicle speed, steering angle by calculating the appropriate radius of the driver's vehicle. As the vehicle travels constantly, the system must determine that the current detected vehicle is the same as the previous detected vehicle when each radar scan takes place. The system must compare the situation of the detected vehicle with the estimated position to judge this situation.

Engine Control Module: Engine Control Module's main function is to control a vehicle's speed by regulating the throttle of the engine. When the ACC module receives information from an engine control, it starts controlling the vehicle speed.

Break Control Module: The key function of the brake control module is to implement brakes when it is needed by ACC module. The brake system is the hydraulic system with the electronic enhancement.

Instrument Cluster: The Instrument Cluster is mainly used for processing the functions of the cruise switches and for transferring the information of those specific switches to the ACC and the control module. The Instrument Cluster also shows text messages to notify the driver about the process taking place in ACC systems.

CAN (Controller Area Network): Sensor (LIDAR or RADAR) is mounted in front of vehicle in order to acquire advance vehicle information. The information may be speed, distance and the lateral acceleration. A controller receives signal and commands the throttle and break to take action[3]. This system uses the Control Area Network (CAN) to communicate between the vehicle components.

Sensors: Throttle Pedal Sensor, Brake Pedal Sensor, Four Wheel Sensor, Radar Sensor.

Actuators: Throttle Actuator and Brake Actuator. The main function of the break actuator is to assess the vehicle’s speed by controlling the vehicle by giving signal to the vehicle’s throttle actuator. And the main function of the throttle actuator is controlling the valve of throttle according to the need of ACC system[6].

Cruise Switches: Cruise Switches are attached on the vehicle’s steering wheel having several knobs that allows driver to command the operation of ACC system.

Communication: Common Area Network (CAN) is a typical ACC system network for receiving and transmitting data using 2 wires. Each node transmits between 0 and 8 bytes of massage, consisting of a message header with checksum. The message header's main role is to assess the message's priority. Next, the message will be transmitted with the highest priority.

3. *ACC System: Operational View*

As mentioned above, that the primary function of ACC system by maintaining the constant velocity set by driver takes over the control of vehicle’s speed. For retaining the velocity and for keeping proper distance between two vehicles, the ACC system executes mainly four control operations in a sequence:-

- Constant Speed Control Operation: If there is no vehicle in vicinity of an ACC-equipped vehicle sensor or a large distance between the two vehicles, this operation helps the system to maintain a constant speed;
- Deceleration Control Operation: If a vehicle is moving in front of an ACC-equipped vehicle decreases its speed or detects a slower speed than the system will controls the throttle to slow down the driver's

vehicle in a minimum time span. If the slowing down of the driver's vehicle is not sufficient in some cases, the system automatically uses the breaks to decelerate vehicle;

- Acceleration Control Operation: In some cases such as Overtaking, Lane changing, when driver of the vehicle detects that there is no vehicle ahead, than the system accelerates the vehicle automatically up to predefined set velocity;
- Following Control Operation: If ACC is fitted with a vehicle that precedes it, the system controls the break and throttle, so that it can maintain the correct distance and carry the same speed as the previous vehicle.

The main goal of ACC system modes of operation is to provide the driver with comfort and safety by taking over vehicle control. There are two forms of vehicle safety: active safety and passive safety. ACC system is both active and passive safety integration[10]. According to an ACC survey system, 40 percent of injuries can be avoided depending on the incident type and situation. Vehicle drivers also expect an ACC system to meet the performance, reliability (in terms of the low false alarm rates) and the safety (in terms of low missed detection rates) requirements. ACC system is currently running in a few modes.

- Velocity Control Mode (CC): The system operates in this Cruise Control mode when the distance between the vehicles is greater than the desired distance. Another reason to enter this mode when the speed of the target vehicle is higher than the speed set by the driver;
- Space Control Mode (ACC): In this mode, the system operates when the target vehicle moves slower in front of ACC equipped vehicle. Then the device maintains a gap between them.
- Stop and Go Mode (SG): This mode is enabled specifically in traffic situation when the vehicle has to move and stop frequently. When the target vehicle stops in traffic to a static position, the vehicle equipped with ACC must also stop;
- Collision Avoidance Mode (CA): Collision Avoidance system is designed to avoid and minimize accident rates in a car. This uses sensors such as radar, laser or camera at times. When an unexpected situation occurs, it warns the driver to take appropriate action to immediately prevent an accident.

4. Advantages:

i. In congested traffic, the driver is relieved of the duty of vigilant acceleration, deceleration and braking.
ii. A highly responsive traffic system that changes itself to prevent accidents may be developed.
iii. Since the acceleration and break are done systematically, the vehicle's fuel efficiency is increased.

1. Disadvantages:

i. There is not yet a cheap version.
ii. If the system is malfunctioning, it can lead to serious accidents.
iii. The up-to-date ACC systems allow vehicles to cooperate with the other vehicles and therefore do not respond directly to traffic signals.

CONCLUSION

The Adaptive Cruise Control was built to ensure safe and easy driving. It reduces the amount of brake and turn operations the driver needs. This device thus reduces the strain on the driver, so that the driver of the vehicle can feel relaxed. ACC program provides efficient fuel operation. Auto vehicle acceleration and deceleration make it smoother as well as more efficient to drive.

The rising rate of the accidents caused by driver mistake is causing the death of millions of people each year. Vehicle safety has been dramatically improved by introducing many innovations such as Airbags, Obstacle avoidance systems or sensors, etc. These technologies reduce the fatality rate, but do not prevent accidents. ACC system provides the driver with assistance in vehicle driving. It may conclude that ACC is a means to

better driving and to keep the car safe from collisions or accidents. The driver is unable to judge the distance between the preceding vehicles during the foggy condition or in poor weather, but the ACC system also provides a safer way to drive in poor weather and foggy conditions. The ACC system has the potential to decrease the number of accidents. It minimizes the number of brake and the switch operations that are needed for driver. This system therefore reduces the burden on the driver so that the driver of the vehicle can be comfortable. ACC is a fuel-efficient driving system. Automatic vehicle acceleration and deceleration make it safer and more consistent to drive.

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