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# SAFETY PROBLEMS IN VEHICLES WITH ADAPTIVE CRUISE CONTROL SYSTEM

# PROBLEMY BEZPIECZEŃSTWA W POJAZDACH Z AUTONOMICZNYM SYSTEMEM STEROWANIA

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***Abstract**: In today's world automotive industries are still putting efforts towards more autonomous vehicles (AVs). The main concern of introducing the autonomous technology is safety of driver. According to a survey 90% of accidents happen due to mistake of driver. The adaptive cruise control system (ACC) is a system which combines cruise control with a collision avoidance system. The ACC system is based on laser and radar technologies. This system is capable of controlling the velocity of vehicle automatically to match the velocity of car, bus or truck in front of vehicle. If the lead vehicle gets slow down or accelerate, than ACC system automatically matches that velocity. The proposed paper is focusing on more accurate methods of detecting the preceding vehicle by using a radar and lidar sensors by considering the vehicle side slip and by controlling the distance between two vehicles. By using this approach i.e. logic for calculation of former vehicle distance and controlling the throttle valve of ACC equipped vehicle, an improvement in driving stability was achieved. The own contribution results with fuel efficient driving and with more safer and reliable driving system, but still some improvements are going on to make it more safe and reliable.*

***Keywords:** Adaptive Cruise Control (ACC), driver assistance system, sensor system*

***Streszczenie :** Obecnie w koncepcji autonomicznych pojazdów typu AVS (ang.: Autonomous Vehicles) poszukuje się możliwości skutecznego polepszenia bezpieczeństwa w ruchu drogowym. Według różnych źródeł ocenia się, że około 90% wypadków w ruchu drogowym jest skutkiem błędu kierowcy. Znane obecnie rozwiązania typu ACC (ang.: Adaptive Cruise Control), ICC (ang.: Intelligent Cruise Control) mają za zadanie utrzymanie bezpiecznej pozycji pojazdu na pasie w odniesieniu do innych użytkowników ruchu, w rezultacie odpowiednich sterowań parametrami użytkowymi pojazdu. Przedmiotem artykułu jest opracowanie koncepcji poprawionego modułu identyfikacji pojazdów poprzedzających i jadących w kolumnie, z użyciem czujników radarowych i lidarów, pozwalających na uwzględnianie możliwego poślizgu bocznego pojazdu, przy zachowaniu kontroli odległości pomiędzy pojazdami. W rezultacie przeprowadzonych badań możliwa jest poprawa stabilności jazdy pojazdu, skutkująca efektywniejszym zużyciem paliwa przez pojazd, poprawą niezawodności systemu napędowego.*

***Słowa kluczowe:** Interfejs kierowcy pojazdu, system wspomagania kierowcy, inteligentne sensory, adaptacyjny system sterowania pokładowego*

## 1. Introduction

Every day media brings horrible news about road accidents and about the people affected by these accidents. In today's world automotive industries are still putting efforts towards more autonomous vehicles (AVs). The main concern of introducing the autonomous technology is to make driving safe by avoiding the accidents. According to a survey 90% of accidents happen due to mistake of driver [Lumb M. et al., 2014].

A report by Partners of Advanced Transit Highways (PATH) concluded that the damaged property and other costs are nearby equal to 3% of world's gross domestic products. In the recent years many researchers study on intelligent vehicles contributed to solve, such as driver burden reduction, accident prevention system, traffic congestion system etc. According to a survey, on an average every minute a person dies because of accidental crash. Driving seems easy task but actually driving requires high mental concentration for very long time and be ready to face any situation in split second of time and react in that short span of time. To overcome the accidents problems and driver burden on long distances on highways, here we are going to discuss a system which is known as Adaptive Cruise Control System (ACCS). The first idea to implement of cruise control devices for driver assistance came in 1970 in USA [Winkle T., 2016]. When this system was installed and made it switched on than, this system takes up task at constant speed by operating the acceleration and breaking. But the problem was that it was not designed by considering the safety of other vehicles on roads.

After few years in 2009 Cruise Control (CC) has been developed to assist the driver for long distances on highways. This system was only able to perform velocity control [Pananurak W. et al, 2008]. But this system is less beneficial in the areas of traffic congestion. This drawback is overcome by introducing the Adaptive Cruise Control (ACC). With the passage of time, now a day's new technologies are changing driving task which is potentially enhancing driving. Driving technology that actively intervenes, control the speed and direction of vehicle may have the greatest effect on safety of driver. Adaptive cruise control is one out of them which enhance safe driving The main objective of ACC is to maintain a safe distance so that it can avoid rear end collision [Jing-Liang L. et al., 2009].

ACC system provides assistance to the driver in the task of longitudinal control [Dang R. et al, 2015] of their vehicle during driving. Of these the system controls the accelerator, vehicle breaks and engine powertrain to maintain a desired time gap to the vehicle ahead it.

An ACC system maintains the vehicle at the speed set by driver and when ACC vehicle detects a preceding vehicle running at lower speed than the ACC vehicle, it automatically control the speed of vehicle to match the speed of preceding vehicle.

It also maintains and calculates the distance between two vehicles which was first set by the driver.

Adaptive cruise control system is available in luxury, as well as less expensive vehicles. ACCS is an automotive feature that allows vehicle's cruise control system to adapt the vehicle's speed to the traffic environment.

ACC system is an improved version of CC system in which the velocity of vehicle is controlled by the movement of preceding vehicle by controlling the throttle valve and breaking system. A radar system attached to the front of the vehicle is used to detect whether slower moving vehicles are in the ACC vehicle's path. If a slower moving vehicle is detected, the ACC system will slow the vehicle down and control the clearance and time gap between the ACC vehicle and forward vehicle. If the System detects that the forward vehicle is no longer in ACC vehicle's path, the ACC system will accelerate the vehicle back to its set cruise control speed. This operation allows the ACC vehicle to autonomously slow down and speed up with the traffic without intervention from the driver. This system can operate in traffic area also not like CC (Conventional Control) system which cannot operate below velocity of 30 [km/h]. Generally in traffic areas or in traffic congestion there is frequent use of brakes and accelerator by the driver of vehicle. Some times after a long drive and stress burden in traffic area, instead of putting brake, driver applies accelerator or vice versa. So in traffic area ACCS eliminates the frequent need of accelerator and breaks and avoid the chances of accident by maintain the safety of driver and passengers.

In the previous generation, there was ACC but that was only providing few features like Go and Stop [Stanton N.A., 2010] . At that time the main objective of that ACC system to offer a longitudinal support on lower speed or at zero velocity. This Stop and GO ACC system is only valid for stationary object which comes in vicinity of vehicle. In this type of system, it is not possible to set a constant speed. So in a simple way this type of ACC system is only applicable in stationary targets. After doing a long research on the drawbacks of conventional ACC and Go and Stop ACC, an improved form of ACC came. It overcomes almost all the limitation and drawbacks of previous systems. But still there are some limitations which can be overcome in future to make it more reliable and safe for the human being.

## 2. Adaptive Cruise Control Design

As explained in the beginning the main concern and objective of implementing of this type of system in vehicle, is the safety of human being by avoiding the accidents caused by driver mistake. ACC works on the principle of calculating the distance and speed of vehicle ahead by the use of some sensor. This sensor can be a lidar sensor or a radar sensor [Shakouri P. & Ordys A., 2012]. In ACC system, transmission and reception time is the key of measurement of distance. By Doppler effect, shift in frequency of reflected beam is measured as speed. On the bases of speed and distance calculation, control on break and throttle can be done to keep vehicle in a safe position. Here in Fig.1 the time and frequency graph is shown to calculate the distance and speed.

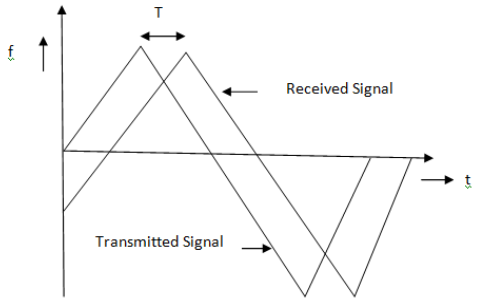


*Fig.1 Working principle of ACC system [Sankar V., 2014]*

ACC system is classified into two types: RADAR type ACC and LIDAR Type ACC.

Radar system consists of a Radar sensor mounted in front of vehicle to detect the presence of vehicle [Benhard K. et al, 2012]. This system has three overlapping radar beams of having frequency 76-77 [kHz]. This type of system can detect vehicle up to a distance of 120m.The main advantage of this system is that it can work in poor weather also.

LIDAR type of ACC system are laser based system. It has a beam of ray which is narrower than a water droplet. The main advantage of this system is to be less expensive and easy to install. While using ACC system there are few common terms which are useful:

- Response time of driver: It is the time taken by the driver in an unwanted situation to respond. Generally respond time is 2-3 seconds [Sankar V., 2014];
- Safe distance: It is the minimum distance between the leading vehicle and the vehicle equipped with ACC system, in this distance the driver has to take necessary action in emergency situation by applying brake. In vehicle a switch is provided to set the distance which is shown below in (Fig.2).

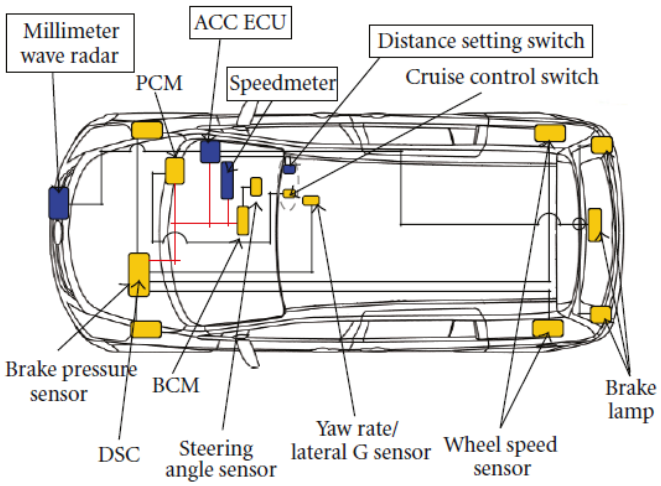


*Fig.2 ACC Vehicle Unit Components [Miyata S., et al 2010]*

Calculation of the safe distance is presented base on the following equestion: Vs*t, where: Vs is the speed of ACC vehicle, and t is respond time between 2-3 second).

The ACC System Function is represented bellow mentioned parameters:

- preset the value of speed of vehicle and maintain that;
- measurement of distance and speed of vehicle ahead;
- adjustment of speed of ACC equipped vehicle;
- change the speed of car by controlling throttle valve and brake;
- do proper function in poor weather condition;
- works good in between speed of 30 – 180 [km/h].

## 3. ACC System Operational View

As we mentioned above that main function of ACC system takes over the control the speed of a vehicle by maintaining a constant speed set by the driver. For maintaining the speed and to keep a proper distance between the two vehicles, ACC system performs mainly four control operations in a sequence (Fig.3):

- Constant Velocity Control operation: When there is no vehicle in the vicinity of ACC equipped vehicle sensor or a very large distance between two vehicles than this operation helps the system to maintain a constant velocity;
- Deceleration Control Operation: When a vehicle moving in front of ACC equipped vehicle drops its speed or detected a slower speed, than the system controls the throttle to decelerate the driver's vehicle in minimum time of span. If in some case throttle declaration not sufficient the slow down the driver's vehicle than the system automatically uses the breaks to decelerate the vehicle;
- Acceleration Control Operation: During some cases like Lane change, Overtake, when driver's vehicle detected that there is no vehicle ahead than the system automatically accelerates the vehicle up to the predefined set velocity;
- Following Control Operation: When ACC equipped is following a vehicle preceding it .the system controls the throttle and break so that it can maintain proper distance and equip the same velocity of preceding vehicle.

Every system which is used for safety of vehicle should have a good interface between man and machine. ACC system is an extension of conventional cruise control system (CCCS). In this system there are some switches on the steering wheel, driver has to operate these switches to take necessary action. As earlier mentioned this system is extension of conventional cruise system, so it has almost all switches which are already in Conventional Cruise System. But ACC system has extra two switch on steering wheel to control the time gap between the ACC vehicle and target vehicle. To provide a good interface and current state of ACC system to the driver, there are some messages that can be displayed on the instrument cluster, which helps the driver to take proper action during warning situation.

To put the ACC system in "*ACC Standby State*", driver first presses the ON button. Than by pressing the "*Set Switch*" vehicle's driver can put the ACC system into active state and driver can decide at which point the ACC system attempt to control the vehicle to the driver's speed.

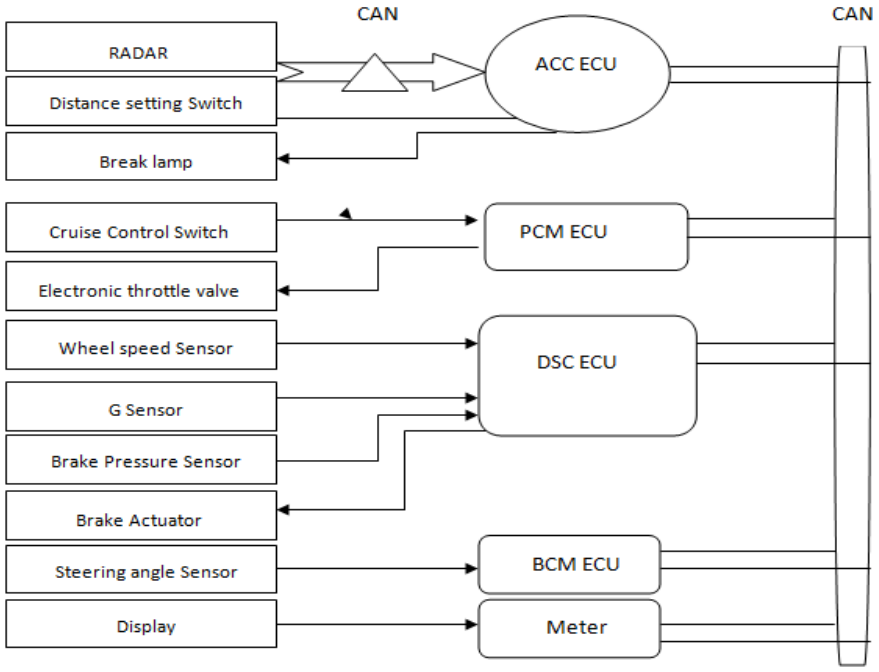


*Fig.3 ACC System Configuration [Miyata S. et al., 2010]*

The main objective of Modes of Operation of ACC system in to provide comfort and safety to the driver by taking over control on vehicle. Safety of vehicle is classified into two types: active safety and passive safety.

ACC system is integration of both active and passive safety. According to a survey ACC system can prevent 40% of accidents depending on the type and scenario of accident. Driver of vehicle also expect an ACC system to meet the requirements in terms of performance, reliability (in terms of low rate of false alarms) and safety (in terms of low rate of missed detections). Currently ACC system operates in few modes:

- Velocity Control Mode (CC): The system operate in this Cruise Control mode when the distance between the vehicle is greater than the desired distance..Another one reason to come in this mode when the target vehicle speed gets higher than the speed set by the driver;
- Space Control Mode (ACC): The system operates in this mode when the target vehicle moving slower in front of the ACC equipped vehicle. Than the system maintains a distance between them;

- Stop and Go Mode (SG): This Mode gets activated particularly in traffic situation when vehicle has to stop and move frequently .When the target vehicle stop down to a static position in traffic than ACC equipped vehicle also has to stop;
- Collision Avoidance Mode (CA): Collision Avoidance system in a vehicle is designed to avoid and reduce the rate of accidents. It uses some sensors like radar, laser or sometimes camera. When some unwanted situation occurs it provides warning to the driver to take action immediately to avoid accident.

## 4. Physical Layout of ACC System

The ACC System consists of series of interconnecting components and systems. In this section we are going to describe the mainly used components in ACC system and their function, how these contributes to make the driving safe. Mainly an ACC unit consists of Auto Speed Control (ASC), Dynamic Stability Control (DSC), ACC Electrical Control Unit (ECU) and Distance setting switch, millimeter wave radar and indicator display (Fig. 4). TAC in figure signifies Throttle Actuator Control, BAC (Break Actuator Control), TA (Throttle Actuator), BA (Break Actuator).

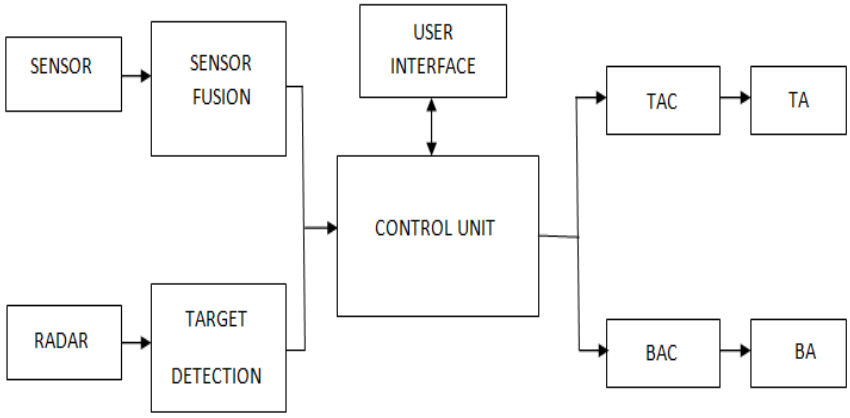


*Fig.4 Simplified view of ACC System [Sankar V., 2014]*

ACC System Components consists of large number of components which are arranged in a particular way to perform their own function. The method of communication between different modules is through a series communication network which is known as Controller Area Network (CAN). In this chapter we will discuss about the different modules of ACC System.

The main function of ACC ECU Module is to process the information given by the radar sensor if it finds the presence of any proceeding vehicle. In "*time gap control*" it sends information to the engine control module and brake control module to maintain and control the distance between ACC Vehicle and Target vehicle.

How ACC System is helpful in safety of vehicle? As we mentioned earlier Radar is used to detect the vehicles travelling ahead of the ACC equipped vehicle. When the road is straight, the driver can easily identify the preceding vehicles travelling on the same path. But in some situations, it is very hard for driver to see and identify the vehicle moving ahead specially during the curves in road. Suppose in a case three vehicles are travelling on a curve road ahead of driver's vehicle. In this case first it is necessary to find which vehicle is on the same path as driver's vehicle. It helps the ACC system to decide which vehicle he has to follow. After that ACC system judges whether the detected object by radar sensor is a static object or a moving object by comparing the velocities of driver's vehicle and detected vehicle. If the preceding vehicle is moving with the same velocity, generally it is considered a static object.
At the same time, the path estimated by determining the concerning radius of driver's vehicle based on the detected yaw rate, steering angle, and vehicle velocity. As the vehicle is continuously moving, when each radar scan occurs, the system has to judge that the current detected vehicle is same as the previous detected vehicle. To judge this situation, system has to compare the position of detected vehicle with the estimated position.

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

**Break Control Module:** The main function of brake control module is to apply brakes whenever it is needed by the ACC module. The brake system is hydraulic system with electronic enhancement.

**Instrument Cluster:** Instrument Cluster is used mainly to process the functions of cruise switches and pass the information of those particular switches to the ACC and engine control modules. Instrument cluster also display text messages to inform the driver, regarding the process occurring in ACC system.

**CAN (Controller Area Network):** A Sensor (RADAR or LIDAR) is placed in front of the vehicle so that it can get information of ahead vehicle. The information can be distance, speed and lateral acceleration. A controller unit receives the signal and commands the actuators of throttle and break to take action. This system uses Control Area Network (CAN) for communication between components of vehicle.
**Sensors:** Brake Pedal Sensor, Throttle Pedal Sensor, Radar Sensor, Four Wheel Sensor**.**

**Actuators:** Brake Actuator & Throttle Actuator. The primary function of break actuator is to determine the vehicle speed and decelerate the speed of vehicle by controlling by giving signal to throttle actuator of vehicle. The main function of throttle actuator is control the throttle valve according to need of ACC system.

**Communication:** Common Area Network (CAN) is a standard network in ACC system which utilizes 2 wires to receive and transmit the data. Each node is able to transmit 0 to 8 bytes of massage which will be consisting of message header with checksum. The main role of message header to decide the priority of message. The message with the highest priority will be transmitted first. The losing message will retry to send its message as soon as it found the bus free to transmit.

## 5. Conclusion

The increasing rate of accidents caused by driver mistakes is making millions of people die every year. There is a drastic improvement in the safety of vehicle by implementing many technologies like ABS, Airbags, Obstacle avoidance sensors and many more. These technologies minimize the rate of fatality but not avoiding accidents. ACC system provides assistance to the driver in driving in vehicle. We can say that ACC is a medium of making driving perfect and keeping the vehicle away from accidents. During foggy situation or in poor weather, driver is not able to judge the distance between the preceding vehicles. But ACC system provides an easier way to drive in foggy and poor weather condition also.ACC System has a potential to reduce the number of accidents.

The Adaptive Cruise Control was developed was developed to make driving safe and comfortable. It reduces the number of brake and switch operation that are required of the driver. So this system reduces the burden on driver so that the vehicle driver can be in comfort. ACC system provides fuel efficient driving. Automatic acceleration and deceleration in the vehicle make it driving safer as well reliable.

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