Adaptive Cruise Control - Towards a Safer Driving Experience

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Abstract- *There is perhaps no better symbol of the 21st century than the automobile. It is the dominant means of transport aspired to throughout the world; indeed, many a politician throughout this century has furthered his or her career by promising constituents a greater economic ability to own an automobile. Furthermore, there are more automobiles on the road than any other motorized vehicle. As of 1986, almost half a billion vehicles were on the road throughout the world; over three-quarters of these were cars. With this comes the responsibility of making safety a primary concern in vehicle technologies. Technologies like Anti lock braking system and Vehicle stability Control System are being used to monitor vehicular safety. Similarly, a new type of speed control, called adaptive cruise control, is being used on some new model vehicles. Adaptive Cruise Control (ACC) is an automotive feature that allows a vehicle's cruise control system to adapt the vehicle's speed to the traffic environment. It is basically an extension of conventional cruise control systems. These systems allow you to set a following distance, or time interval, between your vehicle and the vehicle ahead, as well as a maximum speed. In this paper, we present a case study on adaptive cruise control as modelled on the Audi A8.*

Index Terms- *ACC, ACC function expansion by Audi, ACC module, ACC states, ACC system, CAN, instrument cluster, set distance, set speed, target vehicle.*

1 INTRODUCTION

IN recent years many studies on intelligent vehicles have been devoted to solve problems such as driver burden reduction, accident prevention, traffic flow smoothening. Every minute, on average, at least one person dies in a crash. Mentally, driving is a highly demanding activity - a driver must maintain a high level of concentration for long periods and be ready to react within a split second to changing situations. Cruise control (CC) system has been developed to assist the driver for driving long distances on highways. Cruise control can perform only velocity control [Worrawut Pananurak *et al.*(2009)]. The conventional CC becomes less useful in the case of traffic congestion. This drawback can be overcome by Adaptive Cruise Control (ACC). The goal of ACC is to avoid rear end collision by maintaining a safe distance [Li Jing-liang *et al*(2009),Nassare Benalie *et al*(2009)]. ACC reduces the stress of driving in dense traffic by acting as a longitudinal control pilot. The system makes it possible to adapt the distance to the car ahead without the driver's intervention, effectively relieving the driver.

Adaptive Cruise Control (ACC) is an automotive feature that allows a vehicle's cruise control system to adapt the vehicle's speed to the traffic environment. 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, or time gap, between the ACC vehicle and the forward vehicle. If the system detects that the forward vehicle is no longer in the 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 traffic without intervention from the driver. The method by which the ACC vehicle's speed is controlled is via engine throttle control and limited brake operation.

2 DEFINITIONS

ACC vehicle – the subject vehicle equipped with the ACC system.

Active brake control – a function which causes application of the brakes without driver application of the brake pedal.

Clearance – distance from the forward vehicle's trailing surface to the ACC vehicle's leading surface [1].

Forward vehicle – any one of the vehicles in front of and moving in the same direction and travelling on the same roadway as the ACC vehicle.

Set speed – the desired cruise control travel speed set by the driver and is the maximum desired speed of the vehicle.

Target vehicle – one of the forward vehicles in the path of the ACC vehicle that is closest to the ACC vehicle.

Time gap – the time interval between the ACC vehicle and the target vehicle. The 'time gap' is related to the 'clearance' and vehicle speed by:

Time gap = clearance / ACC vehicle speed

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3 PHYSICAL LAYOUT

The ACC system consists of a series of interconnecting components and systems. The method of communication between the different modules is via a serial communication network known as the Controller Area Network (CAN).

ACC Module – The primary function of the ACC module is to process the radar information and determine if a forward vehicle is present. When the ACC system is in 'time gap control', it sends information to the Engine Control and Brake Control modules to control the clearance between the ACC Vehicle and the Target Vehicle.

Engine Control Module – The primary function of the Engine Control Module is to receive information from the ACC module and Instrument Cluster and control the vehicle's speed based on this information. The Engine Control Module controls vehicle speed by controlling the engine's throttle.

Brake Control Module – The primary function of the Brake Control Module is to determine vehicle speed via each wheel and to decelerate the vehicle by applying the brakes when requested by the ACC Module. The braking system is hydraulic with electronic enhancement, such as an ABS brake system, and is not full authority brake by wire.

Instrument Cluster – The primary function of the Instrument Cluster is to process the Cruise Switches and send their information to the ACC and Engine Control Modules. The Instrument Cluster also displays text messages and telltales for the driver so that the driver has information regarding the state of the ACC system.

CAN – The Controller Area Network (CAN) is an automotive standard network that utilizes a 2 wire bus to transmit and receive data. Each node on the network has the capability to transmit 0 to 8 bytes of data in a message frame. A message frame consists of a message header, followed by 0 to 8 data bytes, and then a checksum [2]. The message header is a unique identifier that determines the message priority. Any node on the network can transmit data if the bus is free. If multiple nodes attempt to transmit at the same time, an arbitration scheme is used to determine which node will control the bus. The message with the highest priority, as defined in its header, will win the arbitration and its message will be transmitted. The losing message will retry to send its message as soon as it detects a bus free state.

Cruise Switches – The Cruise Switches are mounted on the steering wheel and have several buttons which allow the driver to command operation of the ACC system.

Brake Lights – When the Brake Control Module applies the brakes in response to an ACC request, it will illuminate the brake lights to warn vehicles behind the ACC vehicle that it is decelerating.

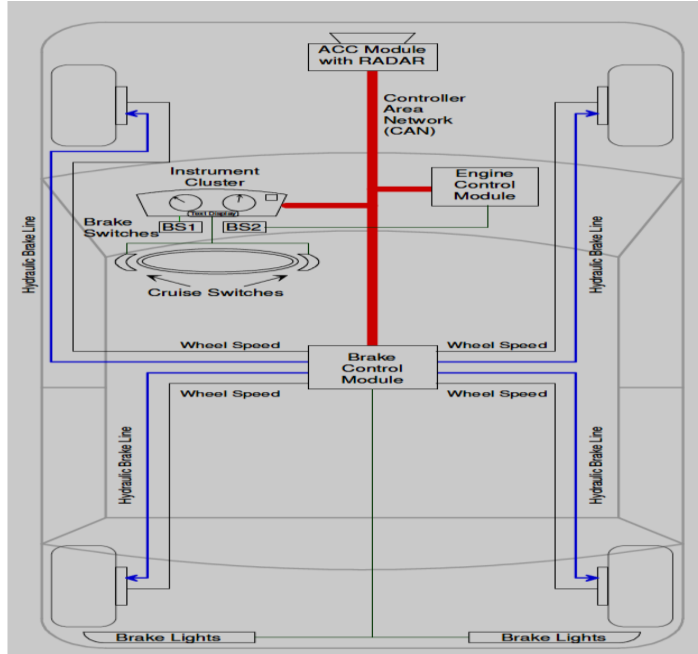

Fig.1 Physical Layout

4 OPERATIONAL OVERVIEW

The driver interface for the ACC system is very similar to a conventional cruise control system. The driver operates the system via a set of switches on the steering wheel. The switches are the same as for a conventional cruise control system except for the addition of two switches to control the time gap between the ACC vehicle and the target vehicle. In addition there are a series of text messages that can be displayed on the instrument cluster to inform the driver of the state of the ACC system and to provide any necessary warnings. The driver engages the ACC system by first pressing the ON switch which places the system into the 'ACC standby' state. The driver then presses the Set switch to enter the 'ACC active' state at which point the ACC system attempts to control the vehicle to the driver's set speed dependent upon the traffic environment [4].

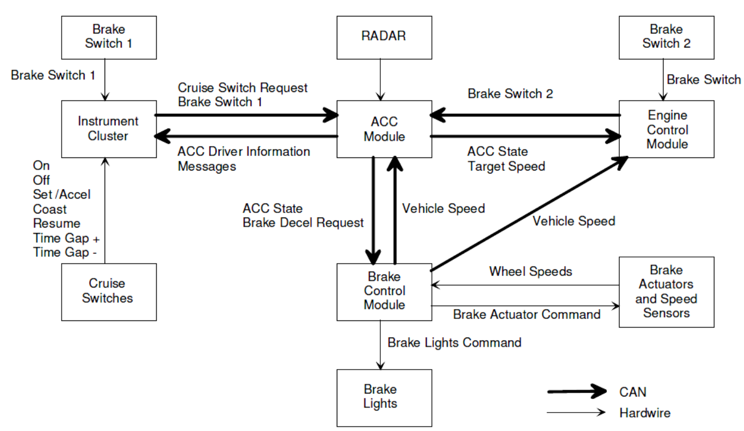

Fig.2 ACC signals and information flow

5 CASE STUDY: THE AUDI A8

As on the 2010 Audi A8, the Adaptive Cruise Control (ACC) system is an option on the new A8, and is available for all engine/transmission configurations. A new generation of Bosch ACC is used in the 2011 Audi A8 [5]. For the first time, two ACC sensors are installed on the front right and left of the vehicle. With corresponding vehicle equipment, including the video camera for Audi lane assist, rear radar sensors for Audi side assist, and ultrasonic sensors for the Audi Parking System, it is now possible to view vehicles ahead and behind.

Fig.3 Front View of vehicle with ACC Sensors

5.1 System components

– Left Adaptive Cruise Control Sensor G258
– Distance Regulation Control Module 2 J850
– Right Adaptive Cruise Control Sensor G259
– Distance Regulation Control Module J428 [5].

5.2 Design

The main innovation is the communication between the control modules using the Flex Ray data bus. A more powerful processor is capable of processing sensor data (from the camera, rear radar, parking aid sensors, and navigation data). Sensor heating makes the system suitable for winter driving conditions. The sensors and control modules are installed in a common enclosure. The sensors are adjustable along their x- and y-axes.

5.3 Function

The function of the radar sensor remains unchanged from the previous A8 model. However, greater operational performance is achieved by including video data, navigation data, and other data in the control procedures.

The two control modules have master/slave architecture. Distance Regulation Control Module J428 (installed on the right) acts as the master while Distance Regulation Control Module 2 J850 (installed on the left) acts as the slave [5].
Radar range has been increased compared to previous ACC systems. The measuring range begins approximately 1.6 ft (0.5 m) in front of the vehicle and extends to approximately 820 ft (250 m) [5]. With the double radar design, the side-to-side detection range of approximately 52.4 ft (16 m) at a distance of 98.4 ft (30 m) in front of the vehicle, is wider than a three-lane highway (820.2 ft) [5].

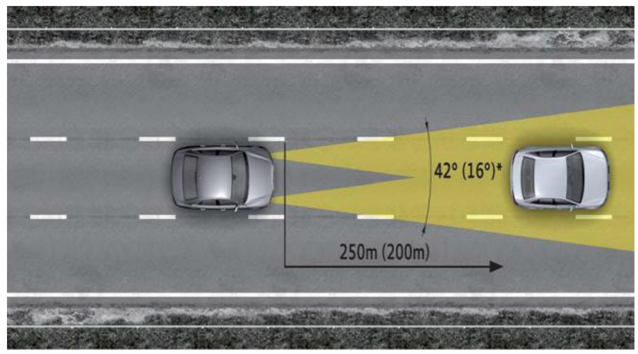

Fig.4 Area covered by the radar

The functional scope for the new ACC system has been extended, with the speed range increased to 0 mph (0 km/h) – 155.3 mph (250 km/h) [5]. The functions of distance and speed maintenance, as individually set by the driver, remain the same as on the 2010 Audi A8. The ACC "observes" the traffic situation even when the ACC is switched OFF at the operating stalk.

Fig.5 Operating Stalk

5.4 Stop and Go Function

With the ACC activated, the vehicle will automatically brake to a standstill if required. The pre-condition is that the vehicle ahead is moving before it comes to a standstill. Targets that are stationary at the moment of detection are not included in the control function (for example, in a traffic jam). ESP initiates braking operations by active pressure build-up. The resulting deceleration is dependent on vehicle speed. At speeds lower than 31.0 mph (50 km/h), maximum deceleration is approx. 8.9 miles/second (4 m/s squared) [5]. The last 6.5 to 9.8 ft (2 – 3 m) before the vehicle comes to a standstill are covered at a "crawling" speed of approx. 1.2 – 1.8 mph (2 – 3 km/h) [5]. Stopping distance to the vehicle ahead is approximately 11.4 – 13.1 ft (3 – 4 m) [5]. After the ACC-equipped vehicle has braked to a standstill, the "Go" function is initiated by the driver. It does not occur automatically. The driver must pull the cruise control stalk or touch the gas pedal to activate "Go".

When the ACC is ready for operation, notification is displayed in the Driver Information System of the instrument cluster.

The ACC system can be activated when the brake pedal is depressed. However, the driver seatbelt must be fastened. Automatic start-off can be deactivated using the VAS Scan Tool.

Under the following conditions, the ACC is automatically deactivated and the Electromechanical Parking Brake (EPB) [5] is activated while the vehicle is stationary:

– Opening a door: The driver's door is monitored redundantly by the door contact and micro switch in the door lock. All other doors are monitored by the door contact switch. The ACC receives information from the corresponding door control modules and redundantly from the ABS control module.

– Opening the hood

– Longer parking period: ESP (Electronic Stability Program) enables the pressure holding function by actuating the valves. Since the valve coils heat up due to the actuating current, the maximum vehicle holding time that can be maintained by ESP is limited. Once this period of time has been exceeded, the function is transferred to the EPB.

– ESP fault

–Fault in another control module relevant to the ACC function (except a fault in the EPB control module)

– Engine turned OFF

The ACC is deactivated if the EPB is operated while the ACC is active. If a fault occurs in the EPB system, the ACC is deactivated. Simultaneously, park position "P" is activated automatically. "ACC: TAKE OVER!" is shown in the instrument cluster.

ACC is also deactivated on an uphill grade greater than 18% [5]. ACC deactivation is accompanied by acoustic and visual signals.

5.5 Start Off Monitoring

ACC automatically scans the area directly in front of the vehicle before the vehicle starts moving. Detection takes place in three ways: *by radar sensors, video camera, and by the four ultrasonic sensors* of the Audi Parking System. Through a different configuration, ACC ultrasonic sensors are operated in a different mode so that objects are still detected at a distance of approximately 13.1 ft (4 m) [5]. A visual warning is shown in the instrument cluster and an acoustic warning (gong) sounds if an obstacle is detected. The vehicle starts moving, but very slowly so that the driver has sufficient time to respond (braking, evading). If a signal from the video camera or the ultrasonic sensors is not available, the vehicle will always start moving automatically at reduced acceleration. Automatic start-off will not take place if both signals are not available. The system is deactivated and the driver is requested to take over.

5.6 ACC FUNCTION EXPANSION

5.6.1 Vehicles with Audi Side Assist

If the vehicle is equipped with Audi Side Assist, the data from the rear radar sensors are included in the calculation of ACC control procedures. If the system detects that the left (right) adjacent driving line is available for a lane change (is clear), automatic brake intervention may take place a little later. In this scenario, the ACC "waits" to "see" whether the driver will initiate a lane change.

The objective of this control strategy is not to curb the driver prematurely and not to regiment the driver more than is necessary.

5.6.2 Function Expansion Preventing Over-taking in the Right (Left) Driving Lane

In active ACC mode, overtaking/passing in the right (left) driving lane is only possible, without restrictions, up to a vehicle speed of approximately 50 mph (80 km/h). At speeds in the range of approximately 50 – 56 mph (80 – 90 km/h) [5], it is only possible to pass a vehicle with limited relative speed. This function is active at speeds in excess of 56 mph (90 km/h) [5]. The function can be cancelled by manual acceleration with the operating stalk (RESUME), by pressing the accelerator pedal, or by increasing the set speed.

5.6.3 Operation and Driver Information

The familiar operating functions of switching the Adaptive Cruise Control system ON and OFF (ON, OFF), setting speed (SET), interrupting control (CANCEL), resuming control (RESUME), setting distance, as well as increasing/decreasing control speed, are driver initiated via the ACC operating stalk.

As stated earlier, the ACC function can be activated in a speed range of 0 mph (0 km/h) – 155.3 mph (250 km/h) [5]. If the system is activated at speeds below 18.6 mph (30 km/h), the vehicle is accelerated to 18.6 mph (30 km/h) and is controlled at this speed [5]. Another new feature is that the vehicle can be accelerated manually by pulling the operating stalk (RESUME) while ACC is active. Control is suspended for as long as the stalk is held in this position.

The vehicle returns to the set speed again after releasing the stalk.
The distance is reset to the "Distance 3" setting every time the ignition is switched ON or OFF. It is possible to activate a different presetting with the VAS Scan Tool. In this case, the menu item "Basic settings" is enabled for the customer.
The indicators in the display and speedometer generally correspond to the familiar displays/indicators of the ACC systems in other vehicle models.
The driver has the capability of selecting via the MMI how dynamically the ACC system will respond. On request, the visual/audible distance/collision warning functions, as well as Audi braking guard can be deactivated in the MMI. Audi braking guard is also deactivated when ESP is switched to sport mode by pressing the ESP OFF button.

6 Networking/CAN Data Exchange

The ACC control module reads approximately 1,700 different signals from other control modules and sensors [4]. The following overview shows the control modules involved in this data exchange.

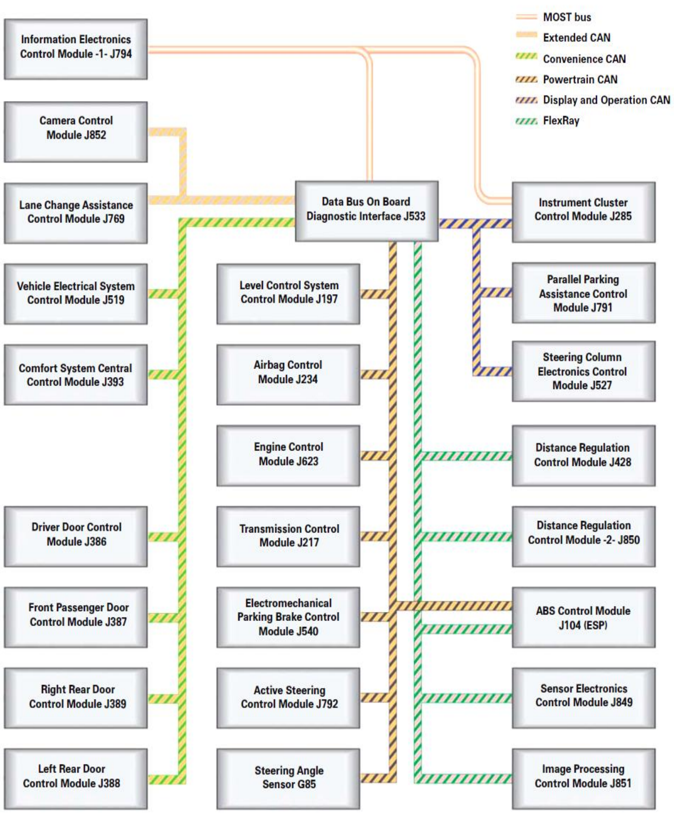

Fig.6 Data exchange in an ACC system

7 Advantages

1. The driver is relieved from the task of careful acceleration, deceleration and braking in congested traffics.
2. A highly responsive traffic system that adjusts itself to avoid accidents can be developed.
3. Since the breaking and acceleration are done in a systematic way, the fuel efficiency of the vehicle is increased.

8 Disadvantages

1. A cheap version is not yet realised.
2. It can lead to severe accidents if the system is malfunctioning.
3. The ACC systems yet evolved enable vehicles to cooperate with the other vehicles and hence do not respond directly to the traffic signals.

9 Conclusions

Thus, we have seen how adaptive cruise control system differs from conventional cruise control system. We have also seen the latest modifications and additional functions for an ACC system as modelled on the Audi A8. It shows how safety and ease of driving can be achieved using ACC. The main disadvantage of the system being the accidents caused due to system malfunctioning.

10 References

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