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A Review on Car Following Behaviour of Adaptive Cruise Control [ACC]

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***Abstract*: This paper reviews the car-following behaviour of an Adaptive Cruise Control (ACC) system with the help of evaluations from Mitsubishi Study, University of Michigan Study and BMW X5M on State-of-the art adaptive cruise control. The paper also focuses on ACC for road vehicles that improves the efficiency of the vehicles by managing the vehicle considering the surrounding traffic, speed limits and topographic data of the roads and reduce the risk of human errors to make the drive safer and more efficient.**

***Keywords*: Adaptive Cruise Control, RADAR Systems, Traffic information, car-following.**

1. Introduction

Road accidents have become a daily view in today's world. Some happen due to technical formalities and most happen due to human error and ignorance. Many a times motor accidents happen due to risky driving or driving to a longer time. Driving an automobile needs skill and require high attention. We may see driving as a low grade job but in reality driving is a skill. Many developments have been undertaken in recent world to ease driving. One such development is the cruise control.

Basically Cruise control means maintaining a constant speed of an automobile with less human efforts. Suppose we have a straight narrow road for hundreds of miles and we need a constant velocity throughout. This is the time when the concept of cruise control comes into picture. This reduces human efforts and also has less human risks. This helps in resting high skills of driving. Maintaining constant speed throughout a drive reduces unnecessary accelerations, which in turn improves the efficiency of an automobile.

However, "maintaining constant speed" is not a new method. James watt had developed a steam engine that used to move at constant speed Cruise control technique were adopted earlier usually by the car manufacturers in the United States. This is because US have highly straight narrow roads for a long drives.

In recent years the use of automobiles are increasing and resulting in increased traffic on roads. Due to this cruise control has been a difficult task to use. However, braking a vehicle under cruise control switched on disengages cruise control system. But this beats up the purpose of cruise control and increasing human interruption in maintaining constant speed. The use of accelerator and brakes becomes frequent under heavy traffic. This leads to unnecessary acceleration and deceleration of an automobile, which in turn affects efficiency of automobile. Hence these conventional methods of cruise control are replaced by another cruise control system called "Adaptive Cruise Control". The Adaptive Cruise Control (ACC) system is highly different from that of the conventional cruise control system. The adaptive cruise control system uses sensors and RADARs to maintain constant speed of an automobile. This system helps in tracking the vehicle ahead of it and control the acceleration and deceleration to the require extent. This helps autonomous slow down and speeding up in traffic without human intervention. Whenever the sensor senses the vehicle the system alters the engine throttle and braking operation autonomously. ACC also contributes in smooth and limited change in speed (acceleration or deceleration). This helps in maintaining efficiency of vehicle. The time taken to transmit and receive signals also plays an important role in shifting the throttle control system. Vehicles adopting ACC system are of high cost, need proper maintenance. Many popular Companies like Mercedes, Jaguar, volvo etc. are adapting ACC system in their vehicles.

2. Conventional cruise control

In a conventional cruise control, the automobile maintains the speed set by the driver. A control unit compares the set speed and the throttle speed and controls the throttle speed to the set speed. This system does not use any RADAR system and has no autonomous control of speed by the engine throttle. When brakes are applied, the cruise control system turn off automatically and the vehicle is back to manual driving mode.

3. Adaptive Cruise Control (ACC)

A. Basic definitions

- *ACC vehicle:* Vehicle equipped with ACC system.
- *Clearance:* distance from the forward vehicle's trailing surface to the ACC vehicle's front surface.
- *Target vehicle:* The forward vehicle in the path of ACC vehicle.
- Time gap: Clearance /ACC vehicle speed.

The ACC works by detecting the distance of the target vehicle from the ACC vehicle with the help of RADAR. The

distance of the vehicle is measured with the help of time taken for the RADAR signals to transmit and receive it back after the reflection from target vehicle. While the speed is measured by the change in frequency of the received signal. The brake and throttle operation is altered with the help of these signals.

The following is an outline working of the Adaptive Cruise Control.

ACC module: The ACC module comprises of sensors and RADARs that transmit and receive signals. The ACC module forward the signals interpreted to the engine control module and Brake control module through control area network (CAN).

1. CAN (Controller Area Network): The CAN is an automotive standard network that utilizes wire buses to transmit the signals from ACC module to engine control module and break control module. The wires can carry data up to 0-8 bytes.
2. Cruise switch the cruise switch is mounted on the steering wheel that helps on operating the ACC.
3. Engine module: The engine module receives signal transmitted from the ACC module and the instrument cluster and controls the speed of vehicle by controlling engine throttle.
4. Brake module: Brake module decelerate the vehicle speed with the help of the signal transferred from ACC module.
5. Instrument Cluster: Instrument Cluster carries the command given by the cruise switch to the engine throttle.

4. Operation

ACC has a similar interface as that of conventional cruise control. The driver operates the system with the help of switches on steering wheel. Also the driver has to set the time gap. Once the system is activated, the vehicle controls the speed based on the set speed. Also there are provisions of displaying text messages on displays, which can issue any emergency warning to the driver. Sensors play a vital role in adaptive cruise control. Various sensors are available for various applications. Sensors (RADAR) transmits the reflected signals to engine and brake modules so the speed can be altered.

The commonly used sensors are RADAR. However, there are following sensors options for cruise control.

A. Radar

RADAR stands for Radio Detection and Ranging. RADAR works in all weather conditions, such as heavy rain and fog. Various sets of RADAR can be incorporated that can function at a same time. The RADAR can penetrate obstacles such as tall grasses and shrubs.

B. Lidar

LIDAR stands for Light Detection and Ranging. These can be used in place of RADARs as sensors. It uses a beam of Laser light at another object. The time taken for the Laser to reflect back determines the distance between the target and ACC vehicle. And variation of frequency can measure the relative speed of target vehicle with respect to ACC vehicle. LIDAR, are in use presently in place of RADAR. Advantage of LIDAR is the use of laser light that has more absorption compared to RADIO wave. The LIDAR based system are incorporated in recent trend, due to following reasons

1. It is less expensive.
2. Light beams have higher absorption than radio waves.

LIDAR based system works on a pattern similar to that of radar system function, except the use of LASER light rays in place of RADIO waves.

C. Visual sensor network

Visual sensor network is spatial distribution of smart cameras that are capable of gathering and processing of an image from variety of viewpoints. These sensors can be used in cruise control and autonomous movement of vehicle.

5. Components of visual sensors network

1. Visual processing.
2. Binary visual marks.
3. Guidance controller.
4. Guidance controller.
5. Car controller.

The visual sensor system comprises of a computer vision system. It is also called visual processing that tracks local information of position of vehicle. Usually these visual sensors are programmed to move only in a specified path. The specified path may have mark paintings that encodes information or data that leads the vehicle to move. The computer vision system detects these marks paintings and reads the binary visual marks to follow the path. To avoid any kind of deviation in a path, guidance controllers are used. Positioning system allows calculating the exact position of vehicle on track. Speed decision system limit the speed at which the vehicle has to move with respect to that of the visual marks. These systems adjust the speed of the vehicle by itself and do not allow any human interference for speed management. These decisions are transmitted to the can controller. Also the turning commands are set by car controller.

These systems tend to active the motors and command to the car engine and read the speed. However, adopting visual control system are costly as it uses more advance techniques.

6. Case study-1

The operation of ACC system in BMW X5 was studied.

Fig. 1. Front view of BMW- X5

1) ACC requirements

1. Left and right adaptive cruise control sensors.
2. Transmitter and receivers.
3. Specially designed antenna in the shape of cone.
4. Distance regulation module.

2) Map out of ACC System

BMW series x-5m promotes for the better communication between the traffic and driver ACC system is one of the best instances for the above statement. X-5M has 2 sensors which is stationed at the front of the vehicle under the bumper. For the impetus display has been situated at 2 places, one at wind shield and the other at display gauge. For manual control it is situated at the left side below steering wheel.

3) Operation

Initially the distance regulation module plays a vital role, using radar sensors which has a range of 2m-170m.when the lane is free from other vehicles, ACC performs normal according to speed adjusted by driver.

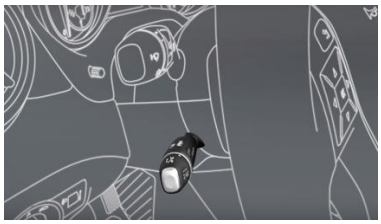

Fig. 2. ACC Control Bar.

When the radar sensors senses the vehicle in front of it within the range. But for the effective reduction in the speed, the driver has to apply brakes. In case of the emergency, where the distance between vehicles is reduced but not speed there will be alert sound which is signaled. So from this driver is made alert. When it comes to performance of acc. It can cover widely an angle of 40degree [+-2degree], with a mean power transmission of 1mwatt.ACC has a diverse speed range varying from 30km/hr to 210km/hr.

ACC in BMW X-5M works on major principle of "stop and go". For this principle to achieve first the driver has to set a speed to maintain it as constant. Whenever the radar senses the vehicle within the range it automatically activates the "stop" function and reduces the speed till it reaches zero or till when the radar stops sensing the vehicle.

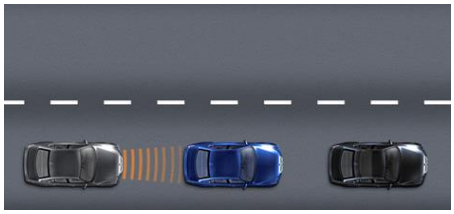

Fig. 3. ACC Radar Signals.

Once when the vehicle reaches to zero and stops, there will be still activation of the ACC system. When the radar range is cleared/when the vehicle in front starts moving the "go" function is activated and till it reaches the speed set by driver it is accelerated with constant rate of increase in speed/min. Once it achieves the speed then ACC helps in maintaining that constant speed then ACC helps in maintaining that constant speed. By this ACC made driving without a hitch and a piece of cake.

7. Case study-2

The University of Michigan Transport Research Institute (UMTR) conducted a study of the effectiveness of ACC. It involved 36 devices who drove an 88 km route during an off peak hour. Both velocity and braking of all participants were analysed for velocities above 88km/hr. Number of statistical difference were observed between ACC, CCC and manual driving. The mean no of break applications was found to be statically different with 5-8 application for manual driving, 11.3 for CCC and 74 for ACC DRIVING. The study also demonstrated that drivers tend to be moving accelerator pedal continuously with a ratio of standard deviation to the mean of approximately 0.43 at high way speeds. To the extent that the benefit of removing this effort greatly reduces the driver's work, the ACC system leads to safer s well as pleasant driving.

The Mitsubishi corp. conducted vehicle tests considering the effects of ACC on headways distance distribution and driving load. The study considering the distance headway distribution at speeds of 80 to 100 km/hr and conclude that the use of ACC reduced the headway variability relative to manual driving. Furthermore, the study demonstrated that manual driving occasionally experienced headways under 25m. The study also compared the frequency of accelerator pedal press, acceleration/deceleration cruise control switch, brake pedal between ACC and CCC. The results of testing indicated a reduction of driver operation with the ACC systems.

Table 1
Mitsubishi driving load test results

Operation	CCC	ACC
Acceleration pedal	12	3
Acceleration/deceleration	85	1
Brake pedal	18	4

8. Conclusion

A review on Adaptive Cruise Control based on few studies was conducted. It has been understood the effectiveness of car-following improves significantly with the assistance of ACC. The comparison between ACC assisted driving and manual driving with objectives such as the frequency of acceleration/ deceleration, efficiency of the vehicles and safety has been noted. These studies indicate that ACC makes the drive safer. Further research on the subject of ACC could set a new benchmark on road safety and automation of driving vehicles.

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