

A Review on Adaptive Cruise Control and Cooperative Adaptive Cruise Control

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ABSTRACT: Adaptive Cruise Control (ACC) is a Cruise Control system for Passenger cars in which vehicle speed is manipulated to achieve and maintain a safe inter-vehicle distance by various range sensing techniques. Cooperative Adaptive Cruise Control (CACC) was introduced as an advancement to ACC which is essentially employed in Connected Automated Vehicles (CAVs) realises longitudinal automated vehicle control in which feedback loop operation is coupled with a feed-forward loop to derive and analyse preceding vehicle's acceleration using Cooperative Awareness Messages transmitted using DSRC/WAVE technology. There are two primary transportation system goals for the development of CACC - Improving traffic flow and decreasing fuel consumption. However, additional goals for CACC include safety, comfort, and convenience for the driver. In this paper, the level of autonomy imparted by both the systems is compared and analysed. A series of equivalences are summarized and discussed. Results show that CACC prioritizes crash avoidance/mitigation when required and thus holds potential to bring smooth and safe driving experience.

KEYWORDS: Adaptive Cruise Control, Cooperative Adaptive Cruise Control, Connected Automated Vehicles, safety.

I. INTRODUCTION

Adaptive Cruise Control is a system employed in automobiles as a part of safety and driver assist technologies. A millimetre wave radar system is attached to the front of the vehicle which is used to detect vehicles in the frontal visual range and a camera is placed between rear view mirror and front windshield for object detection. As an extension to the conventional cruise control, ACC primarily adjusts vehicle speeds set by the driver but has an additional feature of maintaining a set interval behind the relatively slower vehicle in front using throttle position control. Anti-Collision Breaking System may be integrated with the ACC that alerts the driver through audible or visual warnings about potential collisions initially, and applies brakes autonomously to mitigate the severity if the collision is unavoidable. However, ACC may not be able to exhibit string stability, resulting in phantom traffic scenarios or head-tail collisions.

In CACC systems, CAVs share their parameters with other CAVs in the network by V2V communications. Dedicated Short Range Communication (DSRC) is the most prominent protocol used currently for such communication. CACC makes use of V2V communications to permit CAVs to form platoons and be driven at harmonized speeds with much shorter time headways. By sharing vehicle information such as acceleration, speed and position in a distributed manner, CAVs in a certain communication range can cooperate with others to obtain the following benefits:

- 1) Increased driving safety as actuation duration is less compared to manually driven, and downstream traffic can be broadcasted to following vehicles beforehand;
- 2) Increased roadway capacity due to the reduction of time/distance headways between vehicles;
- 3) Reduction in energy consumption due to minimized unnecessary velocity shifts.
- 4) Reduced air drag experienced by other cars.

The remainder of this paper is organized as follows: In Section II, operational overviews of both the systems are compared and system configuration along with components of both systems is reviewed. Section III comprises of literature related to the working principles of ACC & CACC systems along with various ways through which CACC is implemented. Finally, all of the above is summarized in section IV.

II. WORKING PRINCIPLES

A. ADAPTIVE CRUISE CONTROL:

A.1 ACC SYSTEM CONFIGURATION:

The whole ACC system is built as a distributed system using common Electronic control units (ECU) and Powertrain control module (PCM), which comprises of Range sensor and ACC controller. Various ECUs are connected via CAN (Controlled Area Network) data bus. The combination of Range sensor and ACC controller is mounted in the front of the car. There is also a Curve sensor which predicts the future course of the vehicle. The actuators in the ACC systems are slightly modified standard ECUs for engine control, transmission control and active brake control.

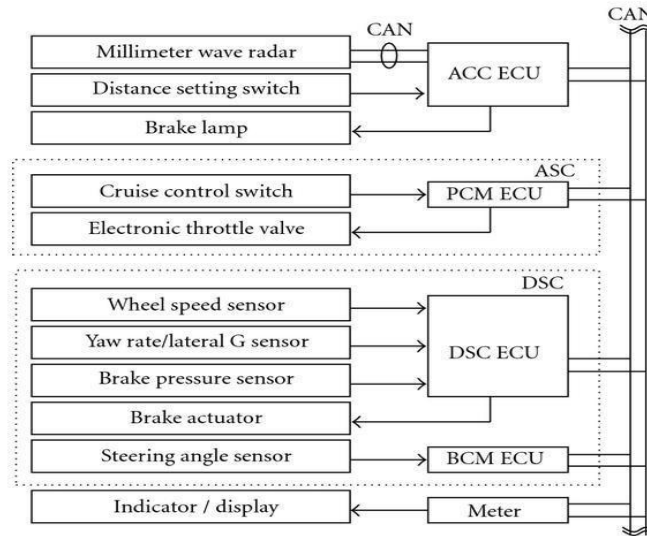


Fig. 1: ACC System Configuration

Figure 1 shows ACC System Configuration described as follows:

- 1) Millimetre Wave Radar - It is used to detect objects ahead of the vehicle. Working of the RADAR and the Camera associated with it is subject to operate properly in ideal conditions however, in rainy conditions overcast weathers the device may fail.
- 2) ACC Electrical Control Unit (ACC ECU) - It is used to calculate control values for engine and brake.
- 3) Distance Setting Switch - It is used to set a time interval for following the preceding vehicle (in order to maintain a constant distance).
- 4) For brake control - The DSC brake actuator function is extended to perform feedback control, so whenever braking is required, it is achieved. Brake control module also determines vehicle speed via each wheel when requested by the ACC Module. The braking system is similar to that of ABS.
- 5) For engine control - The vehicle velocity set by ACC is transmitted to the existing ASC, and system then controls the vehicles velocity so as to follow vehicle ahead. Values for the vehicle velocity and other items set from the operation switches are transmitted to the PCM ECU. The transmissions between the Millimetre Wave Radar and the ACC ECU are carried out via CAN.
- 6) Brake Lights - When the Brake Control Module applies the brakes on demand by ACC, the brake lights will glow to warn vehicles which are behind the ACC vehicle that it is in the process of deceleration.

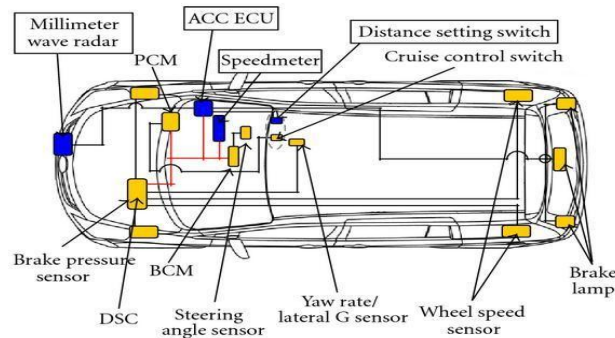


Fig. 2: ACC Unit layout

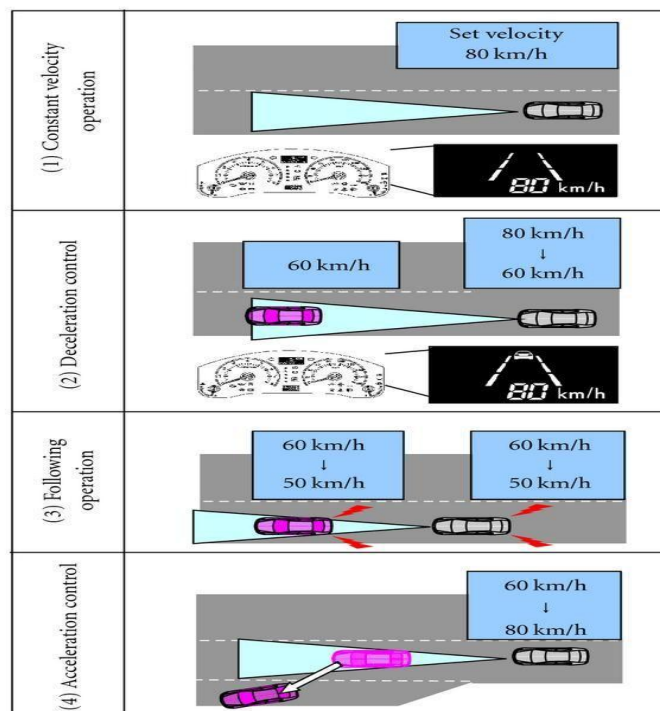


Fig. 3: Modes of operation of an ACC System

A.2 ACC MODES OF OPERATION:

The Adaptive Cruise Control framework (ACC), a framework which diminishes the driving burden on the driver. The ACC framework principally underpins the four driving modes as shown if Fig. 3 above and are discussed below.

- (1) Constant speed control: When there are no vehicles straight ahead, or when there is a huge separation between the host vehicle and the former vehicle, the framework keeps up a steady vehicle speed.
- (2) Deceleration control: When a vehicle travelling ahead at some lesser speed than host vehicle's is detected, the system uses the throttle to decelerate the vehicle. In the event that this deceleration is insufficient, the framework utilizes intensive braking to decelerate the vehicle.
- (3) Following control: When the driver's vehicle is following behind the first vehicle, the framework controls the throttle and brake with the goal that the time interval between the vehicles (which corresponds to a remove between the vehicles that is corresponding to the speed of the driver's vehicle) is the time which was set by the driver.
- (4) Acceleration control: When, due to a lane change, there is no longer a vehicle ahead of the driver's vehicle, the framework quickens the vehicle up to the speed set by the driver, and after that keeps up a steady speed. Besides, when the driver's vehicle approaches a vehicle in front of it without backing sufficiently off, a ready bell and show provoke the driver to apply the brakes or make other fitting move.

B. COOPERATIVE ADAPTIVE CRUISE CONTROL:

B.1 CACC SYSTEM ELEMENTS:

Introduced as an advancement to the ACC, CACC uses the same working principle as of ACC with advantage of V2V communication to form vehicle platoons. Basically, ACC is expanded to a new level of autonomy where surrounding data of vehicles or infrastructure is conveyed to the system through DSRC (Dedicated Short Range Communication Systems).

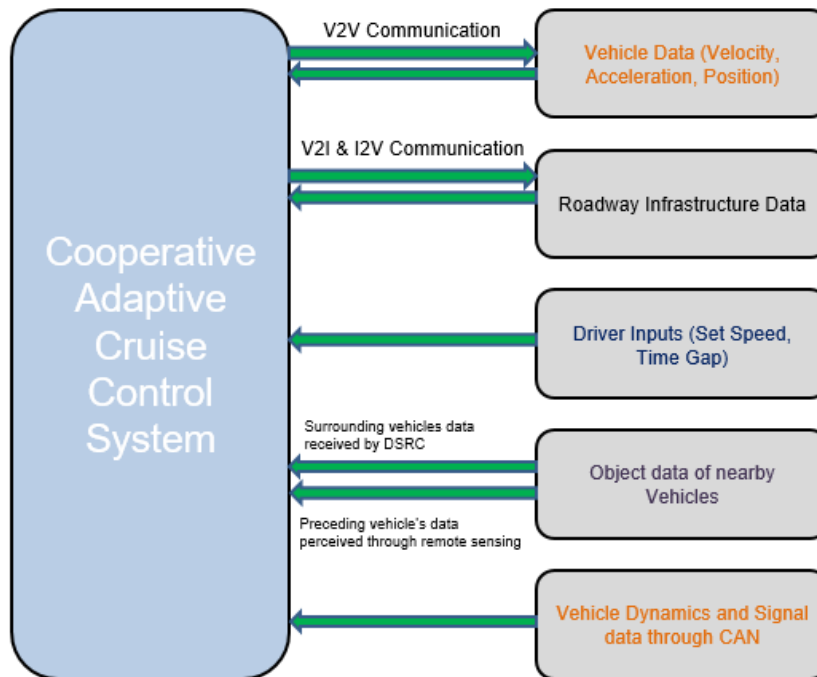


Fig. 3: CACC System Elements

In CACC, the focus is more on platooning of vehicles so that shared and analysed data is used effectively to obtain lesser time headways than a generic ACC System. Lowering time headways is of crucial importance because if the recognition and reaction delay is let's say 1 sec using an ACC (for an Elite vehicle), the successive vehicles in the platoon impose a risk of multiplying this delay which will in turn cause phantom traffic in the best case scenario and might cause head-tail collisions to consider the worst.

III. LITERATURE REVIEW

Shigeharu Miyata, Takashi Nakagami, Sei Kobayashi, Tomoji Izumi, Hisayoshi Naito, Akira Yanou, Hitomi, Nakamura and Shin Takehara^[1]'s research article proposed working principles of ACC along with operating modes and system as discussed in earlier section. Klaus Schmidt^[2] has worked on operation of CACC in vehicle platoon following.

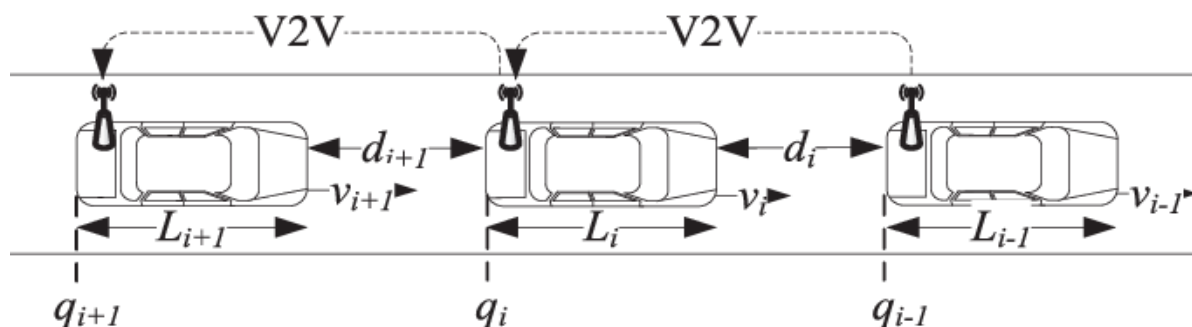


Fig. 4: Vehicle String with CACC

For every vehicle i , a back guard position q_i , the length L_i , the speed v_i and the inter-vehicle spacing between vehicle i (front bumper) and $i-1$ (rear bumper) is considered.

$$d_i = q_{i-1} - q_i - L_i \text{ OR } d_i = q_i - q_{i+1} - L_{i+1}$$

d_i is estimated by Radar or LIDAR in relationship to adaptive cruise control (ACC). Furthermore, data from different vehicles can be gleaned through vehicle-to-vehicle (V2V) communication. There are different approaches for the desired vehicle spacing. The research is centred about consistent time-gap strategy. In addition to that, following multiple vehicles during/before lane change is approached analytically.

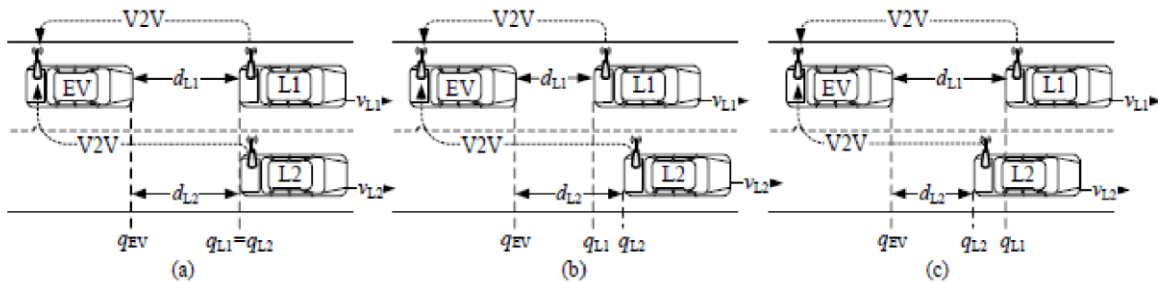


Fig. 5: Following multiple vehicles during/before lane change

Part (a) demonstrates the most basic configuration, where cars L1 and L2 are at a same position and go at a constant same speed. All things considered, path evolving vehicle signified as Ego vehicle (EV) can implement CACC while shifting the lane. However, as in parts (b) and (c) when the relative speeds of cars L1 and L2 change, abrupt braking pattern of the EV leads to lesser driver safety. To overcome this, a Virtual Vehicle (VV) is defined which tracks the path of rearmost predecessor vehicle in order to determine whether lane change is feasible.

IV. CONCLUSION

In this report, advantages of CACC over ACC are reviewed keeping in consideration the level of autonomy imparted by both the systems. Based on the working principles and implementation techniques discussed above, some conclusions are drawn:

- 1) ACC system fails in several situations like overcast weather or if there is no preceding vehicle the vehicle equipped with ACC will run on set speed which is not economical. Thus, for the sake of even better and efficient automated driving experience, a concept of Cooperative Adaptive Cruise Control (CACC) was introduced.
- 2) CACC system comprises of V2V and V2I-I2V communications for better analysis of surroundings through wireless mediums whereas ACC system is limited to camera and millimetre wave RADAR as it's source of object sensing.
- 3) The V2V CACC functionality appears to produce the greatest benefits on limited-access highways, the I2V CACC functionality is likely to be more beneficial on urban and suburban signalized areas
- 4) This report extends CACC to the case where a vehicle follows two predecessor vehicles on different lanes simultaneously, for example when preparing or carrying out a lane change.
- 5) To this end, the paper defines a virtual vehicle (VV) that can be used for safe and smooth vehicle following and that can be computed in real-time.

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