International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

Radar Based Adaptive Cruise Control

Prashik Shende[1], Vignesh Kumar[2]

[1]*Department of Automotive Electronics, VIT University, Vellore – 632014, India.*
[2]*Department of Automotive Electronics, VIT University, Vellore – 632014, India*

Abstract - *Since 1980s, it has been a trend to develop a Collision Avoidance system (CAS). Today autonomous vehicles are a trending topic. For ADAS improvement of Collision Avoidance device is wanted. Development of CAS were for 2 years. There are many complex Collision Avoidance algorithms needed to avoid collision into infrastructure of vehicle. Many are of the complex product of AVs need of integration of other components in vehicle to avoid the implementation of new components. One of such products designed by Opel Vectra i.e. Adaptive Cruise Control (ACC). Adaptation of this algorithm helped to reduce the accidents. In this paper we will discuss about challenging scenario, detail hardware and algorithm, system integration issues, actual road test results, development of ATI intelligent vehicle and about benefits for using ACC to driver.*

Key Words: Collision Avoidance, Opel Vectra, Adaptive Cruise Control, Autonomous Vehicles.

1. INTRODUCTION

Automotive Collision Avoidance System (ACAS) is one of the trending topics for autonomous vehicles. This collision avoidance system helps in many ways by reducing the accidents using different technology. It is beginning of milestone on such ACAS product. Now a days this product is used worldwide and everyone is interested in development of ACC to fulfil further requirement. The ACC requires integration of many others systems such as steering, brake, harness, engine management and different sensors. The difficult part for successful production of ACC is to introduces a new component to automotive that can sense different parameters such as distance, relative velocity, etc. of other vehicles. For this purpose, the components mostly used to detect such parameters are lidar and radar. Delphi Delco Electronic Systems (DDES) offers ACC products of two types i.e. radar and lidar.

Radar based ACC focus on two main parameters i.e. distance and velocity. It helps to reduce driver stress by acting control pilot. ACC helps to maintain proper distance between vehicles using velocity adjustment.

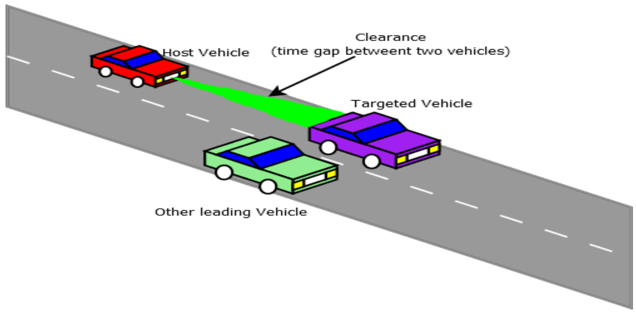

Fig. 1. Working of ACC

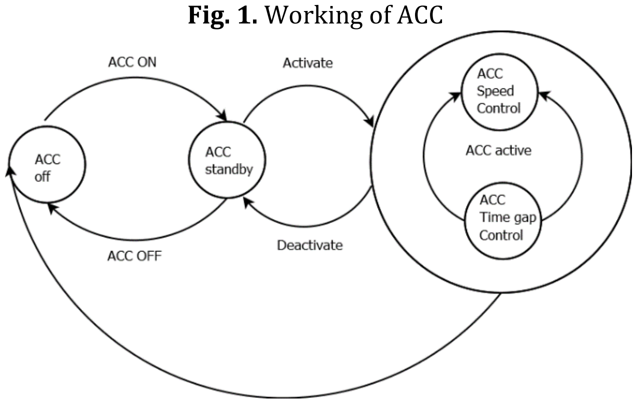

Fig. 2. State diagram of ACC device

For different speed ACC is useful to maintain the distance between the vehicles especially of lower speed vehicles radar based ACC is very useful, it helps to operate in traffic conjunction to maintain the short distance between the vehicles distance and this type of ACC is known as "stop -and -go ACC". Early days this system was known as "stop – and – wait" in this the driver has to initiate the vehicle after it stops. Due to problems like traffic conjunction accidents are frequently happens and that affect human life to encounter such problems Autonomous Driving Assistance System (ADAS) is one of the solutions [1]. In Figure 1. we explain working of an ACC using radar sensor. Here host vehicle radar sensor sends the wave and measure the separate distance between leading vehicle. The separate distance between two vehicle is known as Clearance time. In figure 2. we explain the structure diagram of ACC device. In this figure at the beginning ACC is off when we start the vehicle it ON the ACC and send signals to car while sending the information ACC is in standby mode. This standby send signals to vehicle and using the reading vehicle controls the speed and time gap control between leading vehicle.

When the vehicle stops behind the leading vehicle the ACC turns OFF or get deactivated. Generally, the speed of vehicle is about five km/hr. High pace ACC is evolution of cruise manage. When no car is in the front of host automobile the ACC works on precept of speed. When the vehicle runs in front of the host vehicle at lower speed approximately at 5 km/hr the throttle and barking system is controlled to maintain the approximate distance between the vehicles. When no vehicle is in front of host vehicle it will maintain the host vehicle in the original speed or present and when no obstacle is in front of the host vehicle it will maintain the reduce the speed of vehicle while changing lane, road, etc. First ACC is advanced to perform car at moderate velocity up to 40 km/hr and above. Radar scans front of host vehicle and check different vehicles speed to maintain host vehicle speed and distance this system now a days are known as vehicle following control system [2]. Usually such maintaining distance lead to fuel consumption and emission of CO2 increases further, the lager distancing between the vehicles lead to traffic. Now, the development of vehicle to vehicle communication (V2V) and vehicle to infrastructure (V2I) is a trending topic which is based on IEEE 802.11p protocol [3][4]. The ACC have upper and lower control where upper control level calculates desire acceleration and transaction forces while the lower level determines actuator input such as torque, throttle, etc. The upper level consists of two modes i.e. speed control (velocity) and distance control (time).

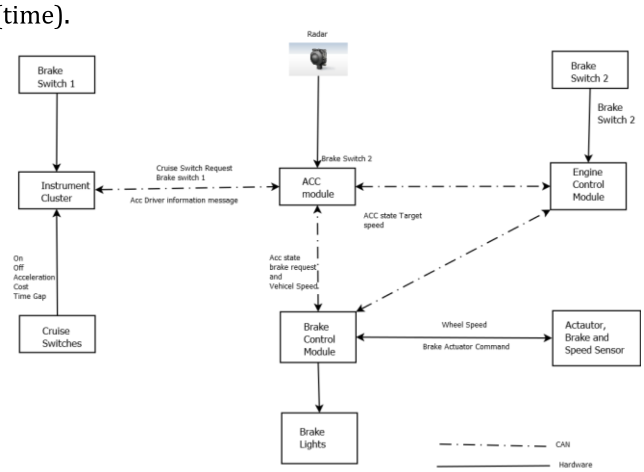

Fig. 3. ACC Signal and Information Flow

Adaptive Neuro-Fuzzy Predictor-Based Control for Cooperative Adaptive Cruise Control System [5] in this paper Ha Ly Thi Nguyen et.al. proposed a method to calculate distance between vehicles using radar sensor and using neuro fuzzy logic maintaining the distance between the vehicles and maintaining fuel efficiency this is consist of two parts first using the radar sensor calculating the distance between two vehicles and determining the speed and velocity of the vehicles and in second part maintaining the speed and distance of host vehicle with good fuel efficiency. Dynamics model and Design for Adaptive Cruise Control Vehicles [6] in this paper Ciprian Lupu. et.al. propose a two controller for ACC for ACC where upper level calculates acceleration of the other vehicles and send data to the sensor while the lower level used to determine throttle position and finds the torque. Dynamics model and Design for Adaptive Cruise Control Vehicles [7] in this paper V.N.Burov et,al. proposed a model of radar about 24GHz range to improve the connections and improve parameters such as frequency transceiver modules, antenna system ,etc. Radar Based Adaptive Cruise Control for Truck Applications [8] in this paper Jerry D. woll discussed about radar enhancement, radar operations & ACC benefits by comparing standard cruise control of heavy trucks and ACC. Adaptive Cruise Control for an Intelligent Vehicle [9] in this paper Worrawut Pananurak et.al. discussed about improving of ACC for AIT intelligent system by improving throttle and braking system. The systems are modifies using dc servo motor that controls brake pedal. A derivative and proportional algorithm is proposed for ACC while fuzzy logic is used for distance measurement. Comparison of Lidar-Based and Radar-Based Adaptive Cruise Control Systems [10] in this paper Glenn R. Widmann et.al. discussed about comparison of ACC based on lidar and radar developed by Opel Vectr this comparison includes detail hardware, integrations issues and many more.

2. Adaptive cruise control design

In this section we discussed about structure of ACC as shown in Fig 4. The ACC system has top and bottom control levels. The first part of controller i.e. top level is used to calculate acceleration of the vehicle while bottom level is to calculate throttle position for controlling engine based on the upper input i.e. acceleration to maintain the distance and adjust the speed of host vehicle.

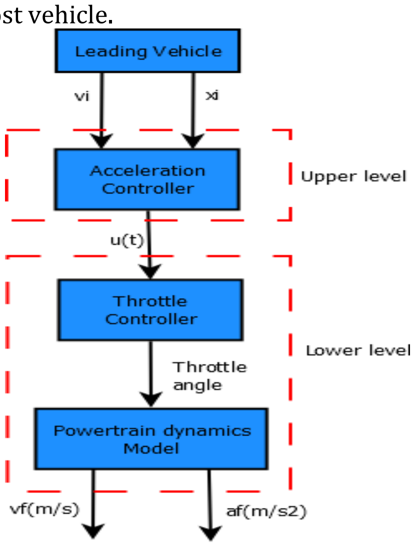

Fig.4. Design of ACC

A. Top Level Controller

The figure as shown above describes the working of first controller. This controller works on the basis of radar sensor reading to detect other vehicles in front of host vehicle to measure the speed and distance.

Here vi and vf are respective velocity of leading vehicle and host vehicle. To calculate leading vehicle velocity many parameters are consider such as

Relative velocity (δ) i.e. velocity between leading and host vehicle:

$$\delta = \Delta v = v1 - v2$$

Linear distance (d) between host vehicle and another vehicle is not linear it changes linearly:

$$d = r0 + h.\delta$$

Where,

h: - time taken by the host vehicle to reach a particular position where the vehicle was present (time headway).

$r0$ = minimum distance that must maintain between host and leading vehicle (at zero velocity).

Actual distance between leading and host vehicle df:

$$df = xl - xf$$

Where,

xl: - longitudinal position of leading vehicle.

xf: - longitudinal position of host vehicle.

The error between the actual and desire vehicle distance ef:

$$ef = (ro + h.vf) - (xl + xf)$$

Desired acceleration of top level is calculated as:

$$u(t) = K3.\delta + K4.ef$$

Where, $K3$ & $K4$ are gain factors.

B. Bottom level controller

In this section PID controller is used to determine angle of throttle. The gains of PID is fixed which is applicable for many applications and it is the simplest controller. To calculate the angle throttle angle following equation is used

$$\alpha = \alpha 0 + K1.\delta f + K2.ef + \int (K3.\delta f + K4.ef)d\tau$$

Where,

$\alpha 0$: - Equilibrium control value.

$K1.\delta f$: - Integral action.

$K2.ef$: - Derivative.

$K1 - K4$: - Are gains to meet objective.

It helps to calculate the angle to give needed acceleration using information of top controller. The output is calculated by throttle angle percentage and powertrain dynamic model. The throttle angle range is from 0° – 90° and that is from 0% - 100% respectively.

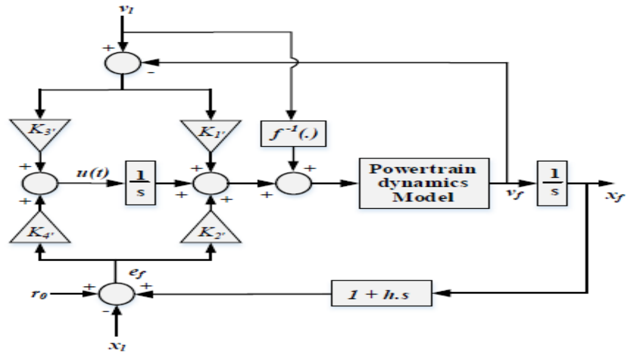

Fig.5. Simulation model of powertrain dynamics model

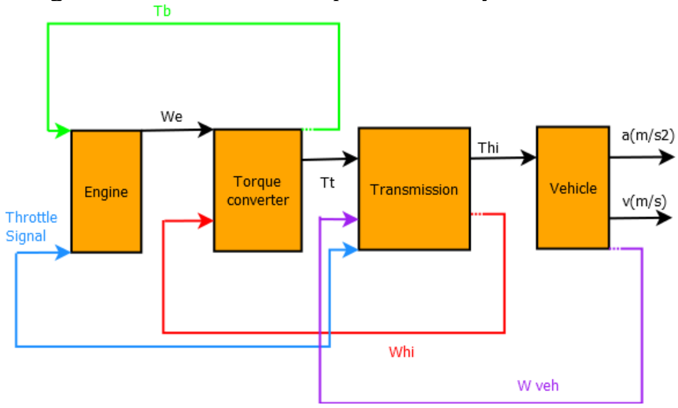

Fig.6. Model of ACC

Following are some parameters to describe PID controller: -

a. $\alpha 0 = f^{-1}(v1)$

b. $Kv = \frac{\lambda 0 + 2\varsigma \omega n - bK2.h - a}{b}$

c. $K2 = \frac{0.2}{b}$

d. $K3 = \frac{2\varsigma \omega n \lambda 0 + \omega n^2 - bK2 - h\lambda 0 wn^2}{b}$

e. $K4 = \frac{\lambda 0 \omega n^2}{b}$

Where,

λ0: - real pole, ωn: - natural frequency, ς: - Damping ratio and K1- K4 depends on h and other parameters like a & b.

4. ACC distance maintaining using fuzzy logic:

To maintain the distance between the vehicles two most important parameters are important. In first parameter is to consider all the input parameters i.e. speed of each vehicle and second parameters are to be consider is fuel efficiency, torque, etc. In figure 7 we analysis a real scenario where a number of vehicles are maintaining in a lane line. In this scenario we consider N number of vehicles maintaining in a lane line. From these vehicles we consider an i^{th} vehicle having some velocity v_i and acceleration as acc_i. Then many other vehicles that is on that lane line having different velocity and acceleration varying from i^{th} position to N^{th}

as shown in figure 7. These different vehicle speeds are differing form $v_i - v_{i-1}$ and $acc_i - acc_{i-1}$. The distance between two respective vehicles is D and length of vehicles is L_i

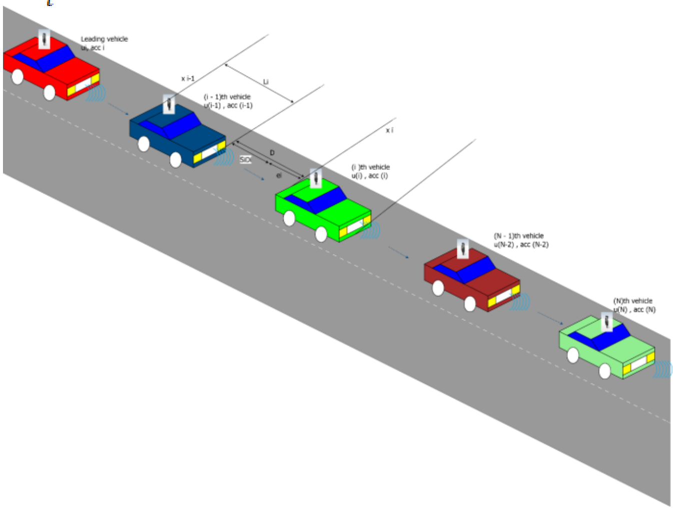

Fig.7. Vehicles on the lane line

Considering, i^{th} vehicle model as:

$x_i(k+1) = A_i.x_i(k) + B_i u_i(k)$

Where

$x_i(k) = [\,x_i(k)\ \ v_i(k)\ \ acc_i(k)]^T$ i.e the position, velocity and acceleration respectively.

$u_i(k)$ is the controller of that i^{th} vehicle.

$$A_i = \begin{vmatrix} 1 & T & 0 \\ 0 & 1 & T \\ 0 & 0 & 1 - \frac{T}{\varsigma_i} \end{vmatrix}^T$$

$$B_i = \begin{vmatrix} 0 & 0 & \frac{T}{\varsigma_i} \end{vmatrix}^T$$

ς_i: - Time constant and

T: - Sampling time

k: - Time step

The distance between two vehicles of the lane is calculated as

$$D_i(k) = (x_{i-1}(k) - L_{i-1}) - x_i(k)$$

Where,

x_i *and* x_{i-1} are the position of host and leading vehicle.

L_{i-1} is the length of the preceding vehicle.

In order to maintain distance between host and leading vehicles $D_i(k)$ must be safe this safe distance is constant time headway [11] is expressed as

$$SD_i(k) = D_{min} + SIVD_i(k) = D_{min} + hv_i(k)$$

Where,

$SIVD_i(k) = hv_i(k)$ is fixed distance between the vehicle.

D_{min}: - Standstill distance i.e. 3m

$v_i(k)$: - Velocity of i^{th} vehicle

h: - Headway time

According to Figure () error of velocity, position and acceleration of i^{th} and $(i-1)^{th}$ vehicle is:

$$e_{pi}(k) = D_i(k) - SD_i(k)$$

$$e_{vi}(k) = v_{i-1}(k) - v_i(k)$$

$$e_{ai}(k) = acc_{i-1}(k) - acc_{i-1}(k)$$

The system considers to have more limitations such as

a. Actuator Limitations: - Using the model we can determine the acceleration value and the value that is obtain from the control constraint know as comfortable acceleration range and limitations are by

   $u_{min} \le u_i(k) \le u_{max}$

   Where u_{min}, u_{max} equal to $0.25g$ & $-0.5\,\frac{gm}{s^2}$ [12]

b. Desire Velocity Limitations: - To determine whether controller is working properly or not allow vehicle for backward drive this constrain is set as

   $0 \le v_i(k) \le v_{max}$

   Where, v_{max} is maximum velocity to be allowed as per [13] $v_{max} = 36\ \frac{m}{s}$

Fault and diagnosis of ACC: -

Sr. No.	Causes	Diagnosis
	Surface of radar is covered in snow	Frequently clean the radar surface
	Rain and snow blocks radar signal	No remedy till now it doesn't work good in rain and snow
	Sometimes after cleaning the radar the message of fault remains	No action needed wait for sometimes to get reading

5. Conclusion

In this paper, we discussed about working and design of adaptive cruise control. Beside we also discussed about the fuzzy logic distance measurement between two vehicles. Main aim of our work is to discussed a detail hardware and working of the adaptive cruise control. We discussed about how to maintain the distance between the vehicles using fuzzy logic and all the terms that affected during this process and how it is important. This includes radar sensing and maintain the distance between host and the front vehicles. Using the V2V communication an estimate model is developed which can estimate future state of front vehicle.

6. References

1. K. Bengler, K. Dietmayer, B. Farber, M. Maurer, C. Stiller, and H. Winner, "Three decades of driver assistance systems: Review and future perspectives," IEEE Intell. Transp. Syst. Mag., vol. 6, no. 4,pp. 6–22, Oct. 2014.
2. V. L. Bageshwar, W. L. Garrard, and R. Rajamani, "Model predictive
3. control of transitional maneuvers for adaptive cruise control vehicles,"
4. IEEE Trans. Veh. Technol., vol. 53, no. 5, pp. 1573–1585, Sep. 2004.
5. 5. 3. R. Sengupta, S. Rezaei, S. E. Shladover, D. Cody, S. Dickey, and
6. H. Krishnan, "Cooperative collision warning systems: Concept definition
7. and experimental implementation," J. Intell. Transp. Syst., vol. 11, no. 3,
8. pp. 143–155, 2007.
9. B. Liu and A. El Kamel, "V2X-based decentralized cooperative adaptive
10. cruise control in the vicinity of intersections," IEEE Trans. Intell. Transp.
11. Syst., vol. 17, no. 3, pp. 644–658, Mar. 2016.
12. Lin, Y. C., & Nguyen, H. L. T. (2019). Adaptive Neuro-Fuzzy Predictor-Based Control for Cooperative Adaptive Cruise Control System. IEEE Transactions on Intelligent Transportation Systems.

BIOGRAPHIES

	I am Prashik Shende student of Automotive Electronics in VIT Vellore. My research topics are autonomous vehicle. How it works and what things are need to improve. My favorite topics are Machine Learning and Deep learning
	I am Vignesh Kumar student of Automotive Electronics in VIT Vellore. My research topics are autonomous vehicle. How it works and what things are need to improve. My favorite topics are python3 development and battery management systems.