Adaptive Cruise Control Systems for Vehicle Modeling Using Stop and Go Manoeuvres

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Abstract

This research paper deals with the design of adaptive cruise control (ACC) which was implemented on a passenger car using PID controller. An important feature of the newly based adaptive cruise control system is that, its ability to manage a competent inter-vehicle gap based on the speed of host vehicle and headway. There are three major inputs to the ACC system, that is, speed of host vehicle read from Memory unit, headway time set by driver, and actual gap measured by the Radar scanner. The system is been adapted with the velocity control at urban environments avoids mitigate possible accidents. This paper deals with the design, modulating, and estimation of the controllers performing actions on the longitudinal control of a car to accomplish stop-and-go manoeuvres.

Key words: Adaptive Cruise control, Inter Vehicle Gap, Stop and Go Manoeuvres

I. INTRODUCTION

Cruise control system one of the advanced system and has become a common feature in automobiles nowadays. Instead of driver frequently checking out the speedometer and adjusting pressure on the throttle pedal or the brake. Cruise control system takes over the control the speed of the car by maintaining the constant speed set by the driver. Therefore, this system can help in reducing driver's fatigue in driving a long road trip [7].

In the process of the cruise control system: Firstly, the driver sets the desired speed of the car by turning on the cruise control mode at the desired speed, such that the car is travels at the set speed and hits the button. An alternate way to set the desired speed of the car is by tapping the set/acceleration button to increase the speed of the car or by tapping the coast button to decrease the speed of the car.

Secondly, the processing unit in the system receives the input signal, and progress the output signal to the actuator. Thirdly, the actuator adjusts the throttle position according to the command of controller. Finally, the changes in the throttle position leads to the change in the speed of the car travelling and obtains the desired speed. The actual speed of the car is continuously monitored by a sensor and fed to the processor. The process of transmitting the current speed of the car continues to the processor to maintaining the desired speed, as long as the cruise control is engaged [1].

Following sections are classified as described in below. In section II modelling of vehicle dynamics is discussed. Conventional control system is explained in section III. Complete system described in section IV. Simulink model developed and results are discussed in section V and finally concluded in section VI.

II. VEHICLE MODELING DYNAMICS

(A) Physical Model

Normally, the inertia of the wheels of the car is neglected. Assuming the friction of the car is obtained by the friction caused by the motion of the car. A physical model of the cruise control system is illustrated as shown in Fig. 1 [3]. The m indicated as the mass of a car.

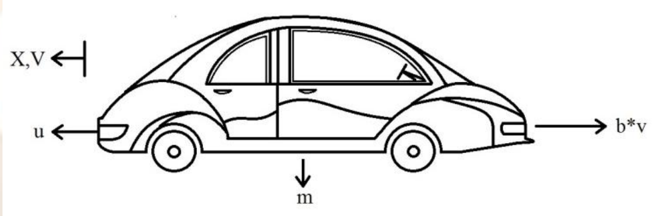

Fig.1. Free-body diagram of a car

From the Newton's second law of motion, a differential equation of the cruise control model can be obtained, as in Eqn. (1)

$$m\frac{dv}{dt} + bv(t) = u(t) \qquad (1)$$

Where, v is the velocity of the car, b is the friction obtained by the car and u is the force from the engine.

Then, by applying Laplace Transform theorem, Eqn. (2)

$$mS.V(s) + bV(s) = U(s) \qquad (2)$$

After rearranging the above equation, the transfer function of the open-looped cruise control system is obtained as in Eqn. (3).

$$\frac{Y(s)}{U(s)} = \frac{1}{mS + b} \qquad (3)$$

(B) Controller Action

(i) P Controller

Considering Proportional control (k_P), the closed loop transfer function of the cruise control system with a proportional control is obtained, as in Eqn. (4).

$$\frac{Y(s)}{U(s)} = \frac{K_P}{mS + (b + K_P)} \tag{4}$$

(ii) PI Controller

Now considering Proportional control (K_P) and integral control (K_I), the closed loop transfer function of the cruise control system with PI controller is obtained, as in Eqn. (5).

$$\frac{Y(s)}{U(s)} = \frac{K_P S + K_I}{mS^2 + (b + K_P)S + K_I} \tag{5}$$

(iii) PID Controller

By considering all three control parameters i.e, proportional control (k_P),integral control (k_I) and derivative control(k_D),the closed loop transfer function of the cruise control system with PID controller is obtained, as in Eqn. (6)

$$\frac{Y(s)}{U(s)} = \frac{K_D S^2 + K_P S + K_I}{(m + K_D)S^2 + (b + K_P)S + K_I} \tag{6}$$

(c) Braking Model

A brake is a mechanical model described by Eqn. (7-8) which inhibits motion. Most commonly brakes use friction to convert kinetic energy into heat. Since kinetic energy increase quadratically with velocity.

$$F = ma \qquad (7.a)$$

$$a = \frac{v_1}{t} \qquad (7.b)$$

$$D_1 = v_1 t - \frac{1}{2} a t^2 \qquad (7.c)$$

m = Mass of the Vehicle,
a = Acceleration,
v_1 = Vehicle Speed,
D_1 = Stopping Distance,
F = Braking Force

Therefore

$$F = m \frac{1}{2} \frac{v_1^2}{D_1} \tag{8}$$

III. CONVENTIONAL CONTROL SYSTEM

(A) Adaptive Cruise Control

Adaptive Cruise Control (ACC) is an advancement of cruise control system. It's an automotive feature allows the vehicle to adopt set vehicle's speed to the traffic environment. A sensor system is attached to the front of the vehicle which is used to detect former slow moving vehicles are in the ACC vehicle's path. If a foregoing slow moving vehicle detected by the sensor system in the ACC vehicle's path, then the ACC system will automatically adopts the former vehicle speed and control the vehicle speed according to clearance, or time gap, between two vehicles. If the system detects that the ahead vehicle gets higher speed than ACC vehicle cruise speed or no longer in the ACC vehicle's path, then automatically ACC system will stimulate back the vehicle speed to its pre-set cruise control speed. This action of control system allows the ACC vehicle to self-governing slow down and speeds up with traffic without arbitration from the driver. Normally ACC vehicle speed is controlled with the following systems, that is, engine throttle control and limited brake operation [1] as in Fig. (2).

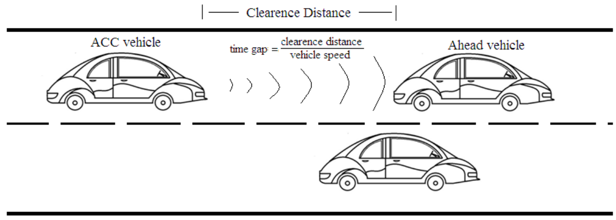

Fig. 2 ACC vehicle relationship

(B) Stop and Go manoeuvres

Commercial systems capable of stopping the vehicle when a collision is imminent at speeds below15 km/h have been developed by car manufacturers, but their dependence on the human driver to restart the vehicle might cause traffic jams. Thus, autonomous intelligent driving in traffic jam conditions is one of the most challenging topics of large city traffic management. These kinds of system are known in the literature as stop-and-go systems [2]. They deal with the vehicle in urban scenarios with frequent and sometimes hard braking and acceleration. The main idea of these control systems is to regulate the vehicle around the well-known 2-s headway rule, which attempts to maintain a distance proportional to the human reaction time (approximately 2 s) [4] as in Fig. (3). Some approaches have tried to reproduce human behaviour with deterministic models in order to achieve smooth control actions.

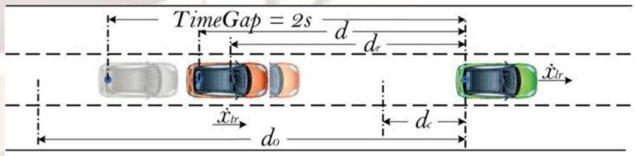

Fig. 3 stop and go scheme

IV. SYSTEM DESCRIPTION

(A) Constructional View

ACC is an extension of cruise control (CC)—CC allows the driver to set a driving speed—in which the vehicle is capable of following a leading car on highways by actions on the throttle pedal. These commercial systems work at speeds greater than 30 km/h. Their main drawback is that they are useless in urban environments.

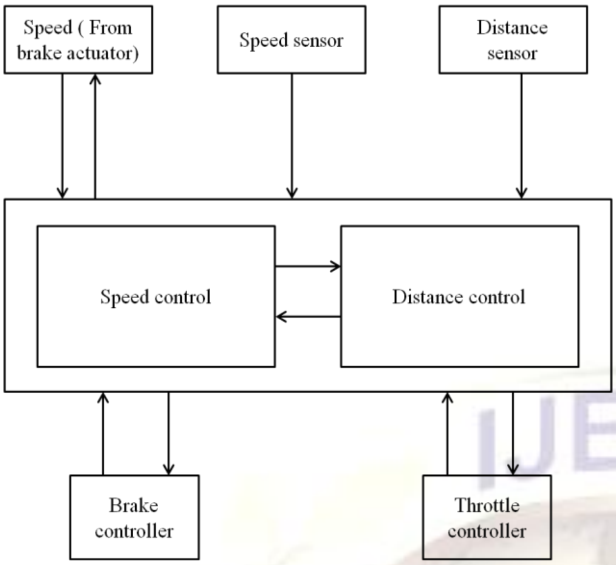

Fig.4 ACC signals and information flow

ACC system is developed by classifying into two distinguished loops (cascade control) as in Fig. (4-5) and highlighted in big rectangular box. First, the outer loop control (OLC) known as distance tracking controller aims to control the distance between the ACC equipped vehicle and leading vehicle. This is accomplished by use of a simple proportional (P) controller which takes the deviation of detected distance between the vehicles from the desired distance. Therefore, in order for the vehicle to effectively follow other vehicle in front of it by keeping a desired distance, the new reference speed is calculated by outer loop controller. OLC is also capable of switching between the cruise control (CC) and ACC mode depending on the situation in front of the ACC equipped vehicle. Second, the inner loop control (ILC) is provided to track the reference velocity calculated by OLC. Furthermore, a simple switching rule coordinates the brake and throttle operations. The schematic block diagram of an ACC system considered from [7] is depicted in Fig. 5

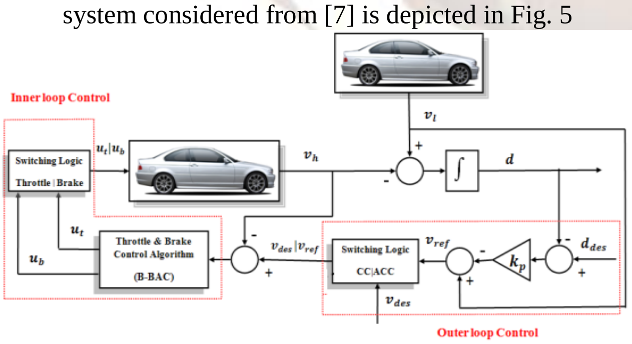

Fig.5 the block diagram of ACC system including inner loop control, the outer loop control and the switching logic from [6]

(B) PID Controller

The PID controller has three tuneable parameters, whose sum constitutes the adjustable variable (AV). The summation of proportional, integral, and derivative terms gives the output of the PID controller. Defining u(t) as the controller output, the final form of the PID design as described in Eqn. (9) and Fig. (6).

$$u(t) = AV(t) = K_P e(t) + K_I \int_0^t e(t)\,dt + K_D \frac{d}{dt} e(t) \quad (9)$$

Where,

K_p: Proportional gain, a tuning parameter
K_i : Integral gain, a tuning parameter
K_d: Derivative gain, a tuning parameter
E : Error = SP- PV
T : Time or instantaneous time
S : set point
c.s : control signal
O : Output

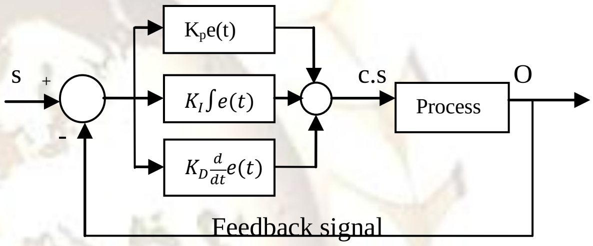

Fig.6 PID Controller

V. SIMULINK MODEL AND RESULTS

A trial ACC model in a merge-in situation is constructed on Simulink as shown in Fig.7.

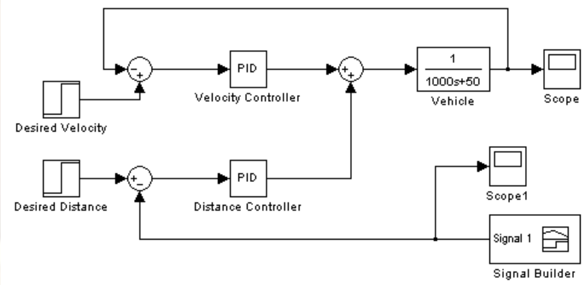

Fig7. A Trial ACC Simulation Model

The PID controller is being employed for the vehicle in cruise control model in the simulation. The actual distance is being measured and it's modelled with a signal builder on Simulink, as shown above. The signal builder is allowed to interact with the distance loop and it is fed back to the cruise control loop after the measured distance. Here the interaction is provided with a negative feedback, such that it subtraction process obtains between the desired distance and actual distance.

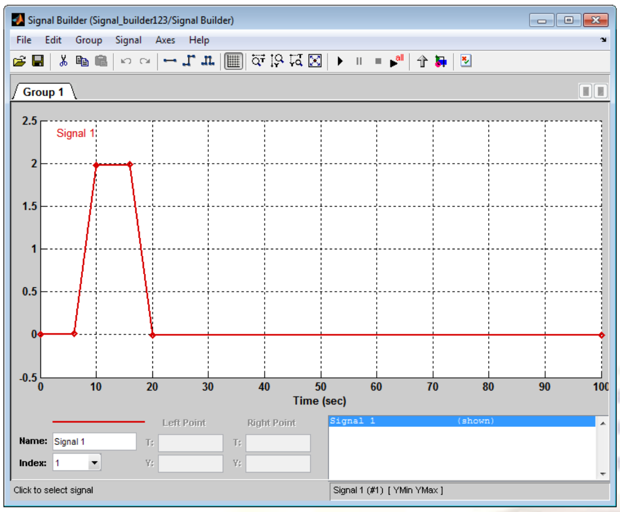

Fig 8. Distance Input vs time

Distance variation to the model is generated using Signal Builder block in Simulink and generated signal is as shown in Fig. (8) In the beginning of simulation, the ACC vehicle is travelling behind the preceding vehicle at a desired distance. At time = 6 sec, the preceding vehicle suddenly drops speed, it creates an interrupt to the controller and requires a time of 4 seconds to adjust its new distance. The new set speed between the ACC vehicle and the host vehicle is adapted to the controller. Then, at time = 16 sec, the merge-in vehicle starts to cross over to another lane. Finally, at time = 20 sec, the distance between the host vehicle and vehicle ahead is back to the desired distance.

The trail ACC model is simulated, and its response to a step input is shown in Fig. 9

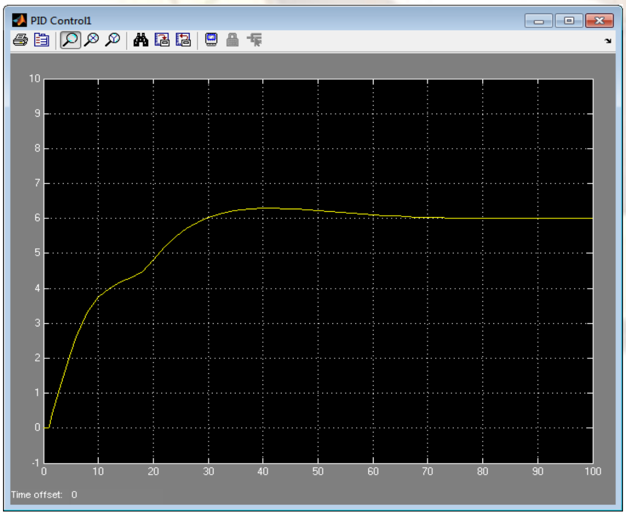

Fig. 9 Response of the trial ACC model

As the change in the old set desired speed to the new desired set speed. The system response will provide damping oscillations and comes to rest wit increase in time. It is viewed from the trail ACC Model, The systems stabilizes at a range of 20mS.

VI. CONCLUSION

Stop-and-go manoeuvres constitute one of the most important and as yet unsolved topics in the automotive sector. Yet this paper proposed ACC for stop and go manoeuvres of an intelligent Vehicle using hybrid PID controller. The Proposed method provides distance and speed tracking as well as providing the smooth variation of the vehicle acceleration.

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