Simulation of adaptive cruise control for autonomous vehicle using throttle by wire and electronic wedge brake

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ABSTRACT: This paper present the simulation of adaptive cruise control (ACC) using MATLAB Simulink software. The simulation of ACC was made by integrating a validated five degree of freedom vehicle model with a validated throttle by wire and an electronic wedge brake model as the throttle and brake actuator. A new ACC algorithm has been developed to meet the dynamic requirement such as safe time and safe distance between lead and ACC vehicles using the validated throttle model and electronic wedge brake as the braking system. Other than that, it also improves the shifting between the throttle and brake of the vehicle. On that basis, several simulation tests were conducted. The result shows that the developed ACC algorithm can track the speed of the lead vehicle within 22% error at initial and provide the safe allowable distance between the ACC and lead vehicle during dynamic.

1. INTRODUCTION

Today, car technology becomes more sophisticated with the Advanced Driver Assistance System (ADAS) to provide better driving and reduce the risk of collisions and provide driver comfort. One of the technological solutions in the ADAS system is Adaptive Cruise Control (ACC). According to Pauwelussen et al [1], the ACC could be defined as an extension of the cruise control (CC) and maintains a certain set distance concerning the lead vehicle next to a certain set speed. It is also known as the improvement of the cruise control system which the ACC velocity was followed by the velocity of the vehicle ahead in a safe distance and safe time by some adjustment to the throttle valve and braking system [2-4].

Several disturbances need to be declared in developing the ACC algorithm, such as the vehicle suddenly speeding or braking. So that the model will estimate all of the parameters need to be declared to figure out the performance of the ACC vehicle in real condition and the method used to counter the effect of the disturbance and maintain the vehicle's performance. In order to maintain and adjust the speed of the vehicle with ACC, the ACC control logic need to be designed.

2. ACC CONTROL LOGIC

Equation (1) describes the ACC logic controller that can modify the speed of the ACC vehicle by calculating the default spacing, time gap, and velocity of the ACC vehicle or longitudinal velocity.

$$D_{safe} = D_{default} + (T_{gap} \times V_{ACC}) \qquad (1)$$

Here D_{safe} defines the safe distance between the ACC vehicle and the lead vehicle while $D_{default}$ is the default spacing of the vehicle that can be assumed as minimum spacing in between lead vehicle and ACC vehicle. T_{gap} is the time gap between the vehicle, which also known as the safe time when following the lead vehicle. Finally, V_{ACC} is the velocity of the ACC vehicle or longitudinal velocity of the vehicle.

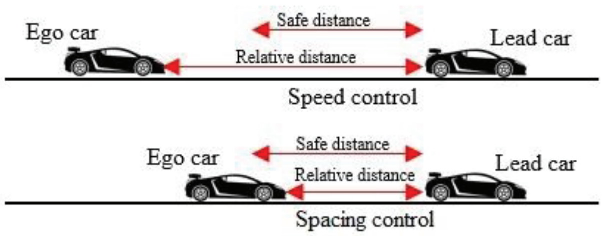

Figure 1: Adaptive cruise control working theory

Based on Figure 1, the following rules are used to determine the ACC system operating mode:

If $D_{rel} \geq D_{safe}$, then speed control mode is active. The control goal is to track the driver-set velocity, V_{set} (2)

If $D_{rel} < D_{safe}$, then spacing control mode is active. The control goal is to maintain the save distance, D_{safe} (3)

3. MODEL FOR SIMULATION ACC

In order to simulate the effectiveness of the ACC algorithm, a validated vehicle dynamic model was used in cooperating with the throttle model and EWB. The model consists of a five-degree of freedom passenger vehicle model consisting of a single sprung mass (vehicle body) connected to four unsprung masses (wheels) where the sprung mass is represented as a single plane model that will allow pitching as well as displacement in the longitudinal direction. In addition, each of the wheels is also allowed to rotate about its axis. The mathematical equation of the vehicle model, the throttle by wire and the EWB can be depicted in [5], [6].

4. RESULT AND DISCUSSION

The performance evaluation of the ACC controller is made based on two test cases: (1) the speed of the ACC vehicle is greater than the speed of a lead vehicle, and;

(2) the lead vehicle is suddenly braking when followed by the ACC vehicle. In addition, three parameters were observed such as acceleration, velocity, and safe distance.

Figure 2 shows the result of the first test case, which is the speed of the ACC vehicle is greater than the speed of a lead vehicle. Lead vehicle moving with a velocity of 13.89 m/s and following by the ACC vehicle at 19.44 m/s. It can be seen that the ACC vehicle is starting to decelerate from 0 to 7 seconds at -3 m/s^2 and accelerate to 2 m/s^2 from 7 to 8 seconds and remain constant for 10 seconds. It decelerates to 0 m/s^2 to follow the velocity of the lead vehicle. By referring to the velocity graph, it is shows that the initial velocity of the ACC vehicle moving at 19.44 m/s and slow down the speed until the velocity of the ACC vehicle is equal to the velocity of the lead vehicle and following the behaviour of the lead velocity thus maintaining the safe distance between the lead vehicle which is 7 meters.

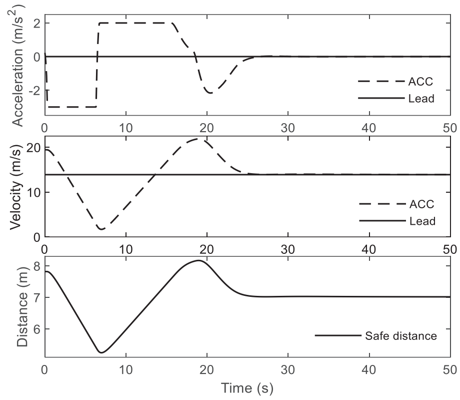

Figure 2: Performance evaluation of case (1) the speed of ACC vehicle is greater than the speed of a lead vehicle

Figure 3 shows the second case where the lead vehicle is suddenly braking when followed by the ACC vehicle. It can be seen that the behaviour of the vehicle is the same as the first test case from 0 – 50 seconds, the difference is when the lead vehicle is suddenly braking at 50 seconds, causing the vehicle velocity to decrease at 2.78 m/s while the ACC vehicle is also suddenly braking to maintain a safe distance and time between the lead vehicle. The lead vehicle starts to accelerate at 2 m/s^2 in 10 seconds to reach the velocity of 13.89 m/s at 75 seconds, constantly followed by an ACC vehicle with the same velocity.

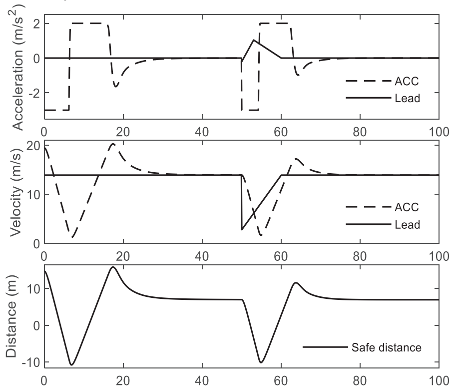

Figure 3: Performance evaluation of case (2) the lead vehicle is suddenly braking when followed by the ACC vehicle

5. CONCLUSION

ACC controller consists of two main elements, which is ECU and actuator controller. The performance evaluation of the controller has been tested by using the five degrees of freedom vehicle model, and the result is shown in three main graphs: acceleration, velocity, and distance. The result shows the ACC logic controller that has been developed can provide good performance in tracking the lead vehicle speed with 22% error at initial while maintaining the required safe distance.

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