

Adaptive Fuzzy Cruise Control System to Maintain Safe Distance and Set Speed

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Abstract — This paper presents an Adaptive Fuzzy Cruise Control (AFCC) system. The AFCC is modeled, designed and tested using MATLAB/SIMULINK. The presented AFCC gives numerous important points to the driver. It gives the driver the controllability of speeding intelligently. The proposed AFCC is simpler for a driver to drive in various driving conditions. It gives the driver a commanding on safety as well in various driving conditions.

Keywords—AFCC, Plant Model, Fuzzy Logic Controller, Structure, MATLAB, SIMULINK.

I. INTRODUCTION

The Cruise control (CC) is a security and safety structure that keeps up the speed set by the driver. It controls the engine speed and not the throttle or brakes. The structure controls the motor speed, so it may not have control over the transmission. The speed in such structure cannot change widely or alter gears if needed. CC is applicable in circumstances where the vehicle stays steady for freeway driving. The conventional cruise control is prominent a shut circle structure for keeping up the vehicle steady at a certain speed. This will be done by controlling the motor effects the speed of a car. The Adaptive Cruise Control (ACC) system structure is an improvement to the ordinary cruise control structure that permits a vehicles cruise control structure to adjust the vehicles velocity based on the environment. ACC is an idea that enhances the safety of vehicles. It is a step beyond the cruise control which just retains the vehicle speed constant. ACC not just retains a car speed, it is also coupled with the programmed brake control and throttle control to conform the brake and/or throttle and keep up a constant progress from any vehicle interferes with the driving vehicle.

ACC structure utilizes both throttle and braking control to track a car speed and to respond to the vicinity of a forward vehicle by guarantying a protected separation. If a slower moving vehicle is recognized by the sensors in front on the vehicle, the ACC structure will slow the vehicle off and control the speed between the ACC vehicle and the forward vehicle. In the event that the ACC structure identifies that the forward vehicle is not in the ACC vehicles way, then the ACC structure will accelerate the vehicle back to its set cruise control speed. The principal ACC structure was presented in the Japanese showcase in 1995 by Mitsubishi [6].

ACC can keep up securely the set distance among active vehicles but may not keep up speed in as indicated by the rate of the ahead vehicle. Accurate values to gauge the speed and distance among active vehicles are necessary and that is why fuzzy logic controller are used in this paper.

Researcher are focused on the set distance and set time gap between the vehicle and take speed as output parameter for the device [1]. The vehicle determine the speed based on these set time gap and set distance. In these paper the focus is to take the speed to the maximum level which is close to the set speed.

The ACC with fuzzy logic controller structure (AFCC) encompasses of a progression of interconnected segments and structures [3, 4, 5, 7]. The system that is used for communication among diverse modules is done through the Controller Area Network (CAN). The message with the most important need, as characterized in its header, will win the discretion and will be transmitted. The loosing message will retry to send its message when it

recognizes a transport free state. CAN is the most generally utilized vehicular system and is a strong savvy serial connection. Speed varies from 500 kb to 1 megabyte per second [2, 6].

AFCC has subsystems, actuators, and sensor segments that are associated with other electronic control units (ECU). The framework requires an ECU system for circulation of signals and a trustworthy information to transport the signals through CAN. CAN is needed for the ACC subsystem. Fuzzy controller, radar/sensor, instrument structures, brake module and the ECU are also required to transmit the data between them.

The paper is organized as follows: section 2 introduces the new proposed ADCC; section 3 introduces the Simulink model for the ADCC; section 4 presents the fuzzy development for the ADCC; section 5 shows the fuzzy rules base used for the ADCC; and section 6 presents the results and simulation.

II. FUZZY CONTROLLER ACC FUNCTION

The most essential capability of ACC with fuzzy logic controller is the Cruise Control ability which is in the steady speed control at the rate set by the driver. This can happen when there is not a vehicle which is needed to slow another. Another function of ACC with fuzzy logic controller is to follow a vehicle and adjust to its speed. This means that if a vehicle is moving with a steady speed then the other vehicle moves with same velocity at consistent distance. The relative speed of vehicles selects the protected separation. The time gap is a key part in deciding the comfortable separation between two vehicles which is one of the inputs to the ACC system. Another component of ACC system is the crash avoidance, wherein if the ACC system detects a potential impact; it will apply the brakes harder and fix the safety belts. Once the crash is avoided and the path is clear, then the ACC system will resume the cruising speed. Adjusting to curves is one more function of ACC system which includes give way in continuation of set speed control when sensor's perspective is not adequate in sharp curves to keep up with target vehicle while tailing it at a sheltered or satisfactory distance. Takeover is an additional request which is one more function of ACC system in which a driver is upheld if a takeover is vital. Figure 1 show a typical block diagram of an ACC system with a fuzzy logic controller.

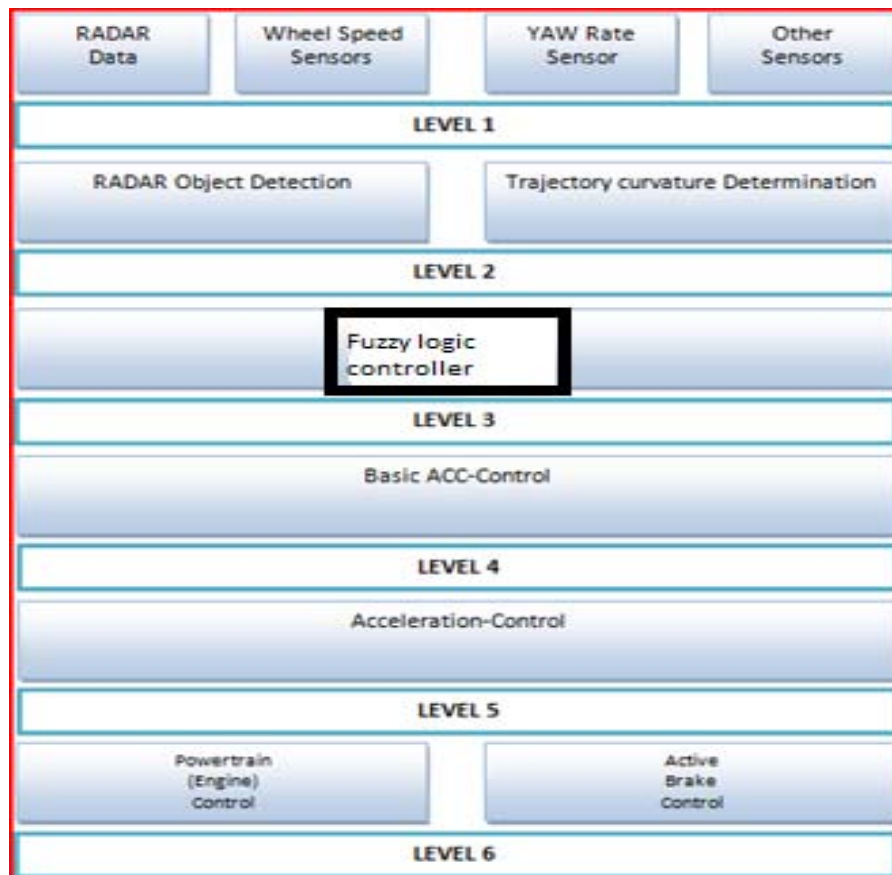


Figure 1. Representation of ACC with fuzzy controller

III. ACC with Fuzzy Controller in Simulink Model

The adaptive cruise control model for a vehicle was developed as shown in the figure 2. The inputs to the ACC system are the speed set by the driver for cruise control, analog relative separation from the sensor, and the time gap set by the driver. Figure 2 shows that there is a choice between applying a brake to adjust the speed of the ACC with fuzzy controller vehicle when there is a forward vehicle moving at a slower speed or to build throttle by opening up the throttle to permit more wind stream once the forward vehicle is not in the vicinity of the ACC with fuzzy controller vehicle to retain back the speed. If the logic is 1, then a vehicle is discovered and braking control assumes control. If the logic is 0, then a vehicle is not discovered and throttle control is assumed to keep up the set speed that is placed by the driver. The simple relative separation from the sensor is thought to be an analog sine wave. The output of the ACC with fuzzy controller system is the ACC vehicle speed changes.

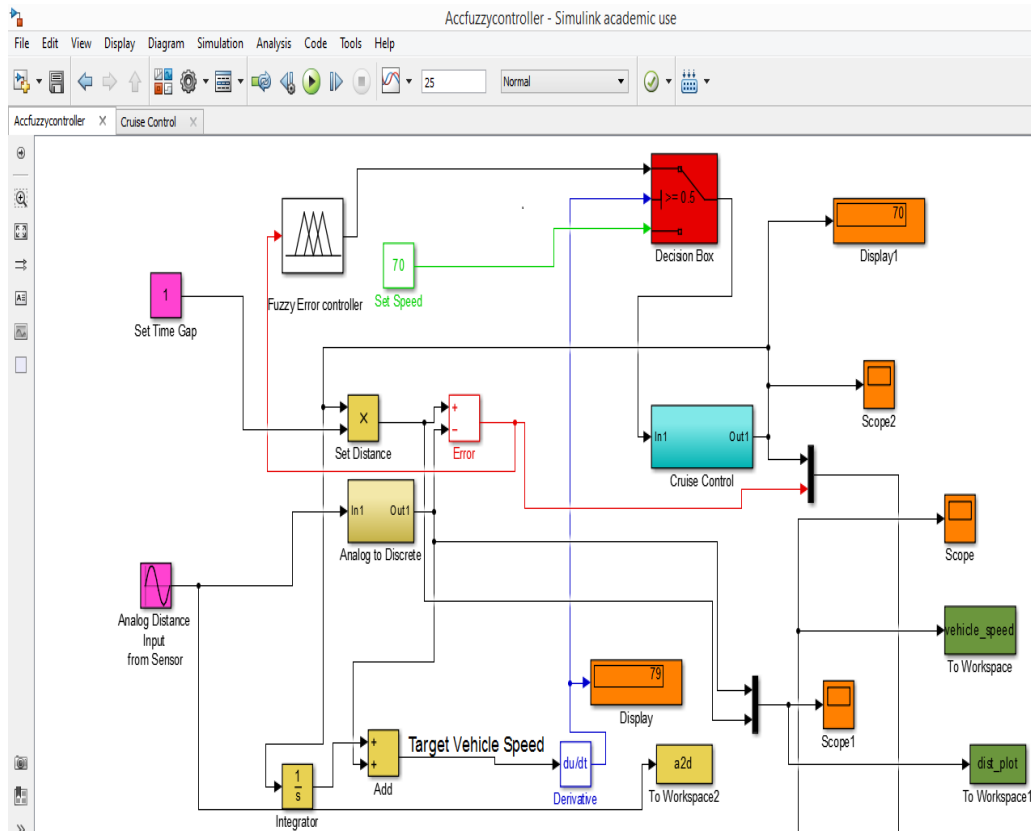


Figure 2. Simulink model

The relative separation formed by the sensor is presumed to be a sine wave. This will form the changing values for the relative separation between the two vehicles (back vehicle and in-front vehicle) to test the ACC with fuzzy logic controller system. The relative separation is changed over to discrete relative separation by utilizing an analog to discrete transformation block as shown in figure 2. A quantizer is used which quantizes the signal to the closest number value and gives a discrete sign for the relative separation. Presently, the set separation is computed by increasing the real vehicle speed with time gap set by the driver.

In the Simulink model the speed is set to 70 miles per hour. The ACC system will not change the car speed to reach 70 mph every time while the car is operating because the fuzzy logic controller within the ACC will decide the safe speed that will maintain the safer distance. To choose whether the host vehicle (the first vehicle) ought to take after the set speed or the speed of the former vehicle (the second vehicle), this set separation ought to be continually compared to the relative separation of the first vehicle. This is controlled by keeping the set separation and the relative separation of the first vehicle and looking at it against a threshold value of 0.5. If the difference is less than the host vehicle, then the host vehicle follows the cruise speed set by the driver otherwise it follows the adaptive cruise control speed which was generated from the fuzzy controller block.

IV. Fuzzy Development for the AFCC

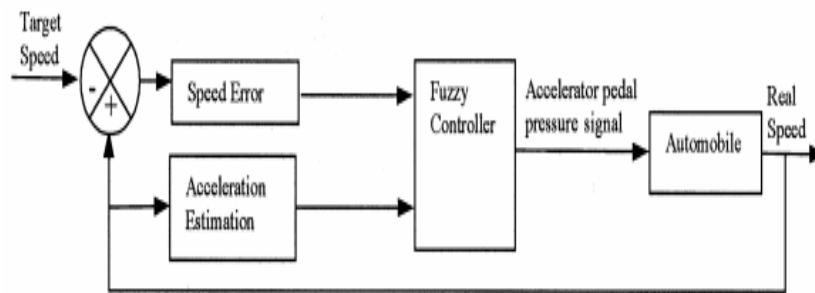


Figure 3. Fuzzy adaptive cruise controller ADCC block diagram

The target speed is inputted to the addition block which produces the speed error, i.e. the relative distance between the vehicles and the difference in speed is measured using the speed error calculation which is the input for the fuzzy controller. It also generates the Accelerometer pedal pressure signal to the automobile which gives the real speed to whether it has maintained the speed set by the driver or has maintained the safe gap between the vehicles. Figure 3 shows the fuzzy controller that was used to implement the proposed AFCC.

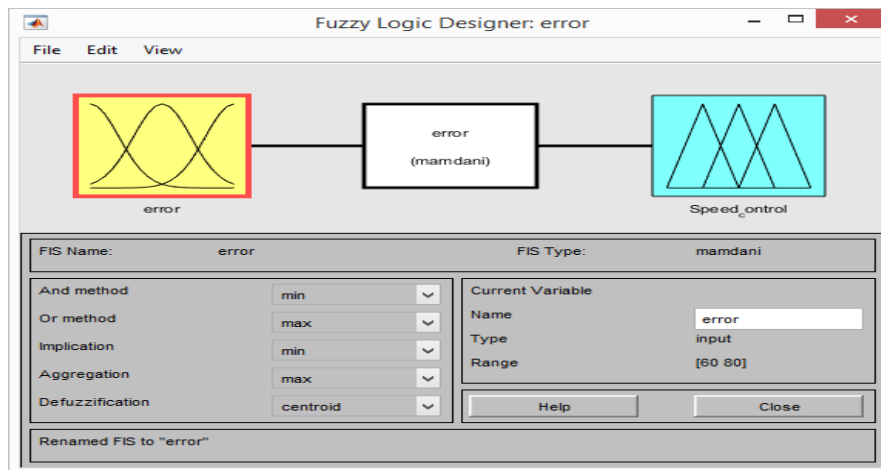


Figure 4. The fuzzy linguistic values used for the fuzzy input variable Error

The fuzzy input variable Error has five fuzzy linguistic values which are neg_small, neg, zero, positive, and positive_large. The fuzzy output variable Speed_control has five linguistic values which are neg_small, neg, zero, positive and large. Figure 4 shows the Matlab view for the fuzzy logic controller. The set time gap, the set distance and speed of the second vehicle can be calculated using the fuzzy controller.

V. Fuzzy Rule Base

The proposed fuzzy logic controller for the ACC will use ten fuzzy rules. The rules are as follow:

- Rule 1. If (error is neg_small) then (Speed_control is neg) (1)
- Rule 2. If (error is neg) then (Speed_control is zero) (1)
- Rule 3. If (error is zero) then (Speed_control is zero) (1)
- Rule 4. If (error is positive) then (Speed_control is positive) (1)
- Rule 5. If (error is positive_large) then (Speed_control is large) (1)
- Rule 6. If (error is positive_large) then (Speed_control is positive) (1)
- Rule 7. If (error is neg_small) then (Speed_control is neg) (1)

- Rule 8. If (error is neg) then (Speed_control is positive) (1)
- Rule 9. If (error is postivie) then (Speed_control is large) (1)
- Rule 10. If (error is positive_large) then (Speed_control is positive) (1)

Figure 5 shows the membership functions (linguistic values) for the fuzzy variable Error input which is the input for the vehicle to control the speed of the host (first) vehicle.

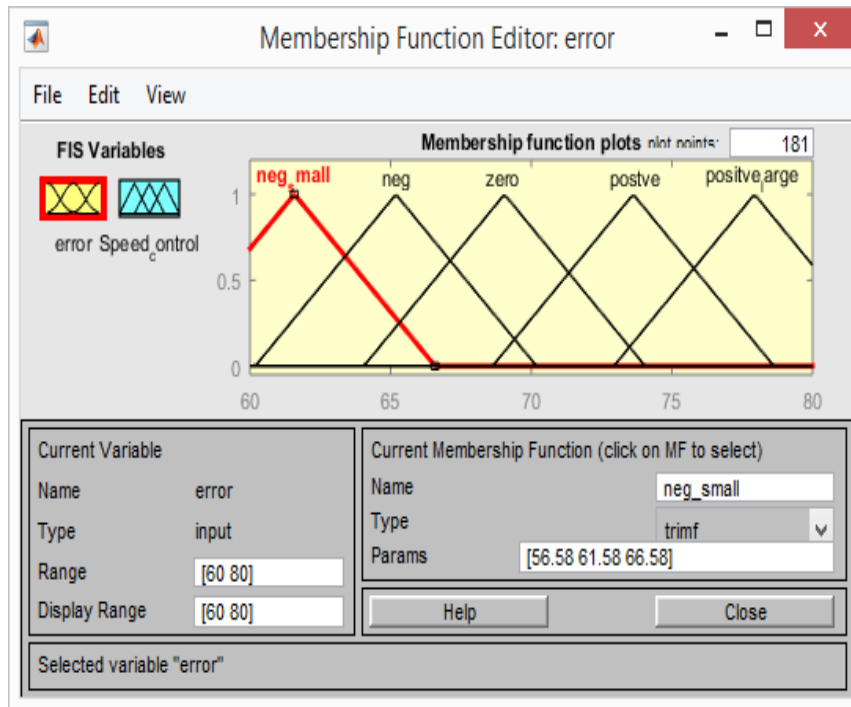


Figure 5. Fuzzy membership functions for the fuzzy input variable Error

Figure 6 shows the membership functions (linguistic values) for the fuzzy output variable Speed_control which is the speed control of the host (first) vehicle that maintains the speed according to the speed of the second vehicle.

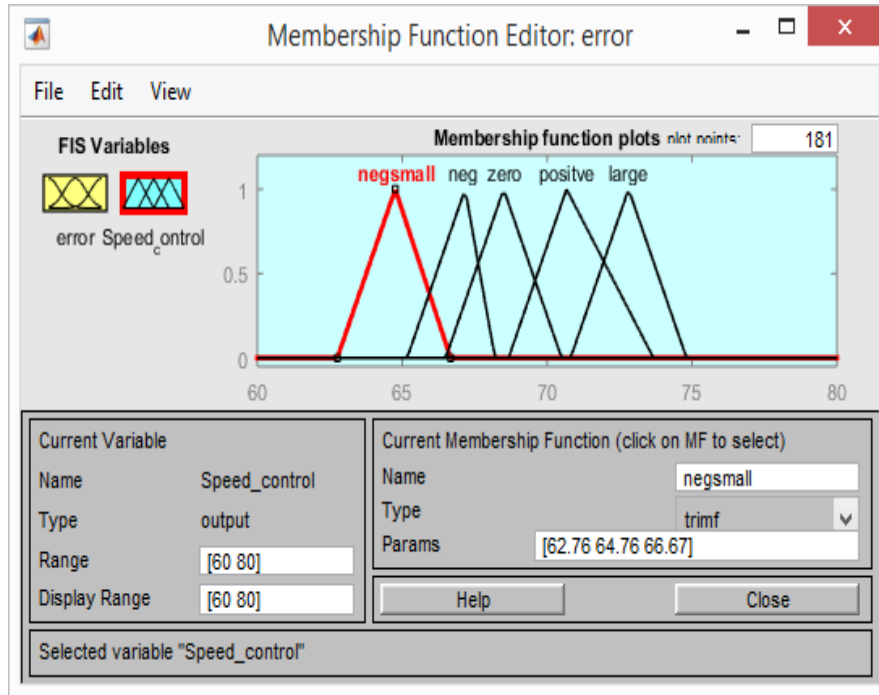


Figure 6. Fuzzy membership functions for the fuzzy output variable Speed_control

VI. Fuzzy rule viewer

Figure 7 shows the fuzzy rule viewer for the fuzzy input Error = 61.6 and producing the fuzzy output Speed_control = 68.7. This shows how to test the proposed fuzzy logic controller.

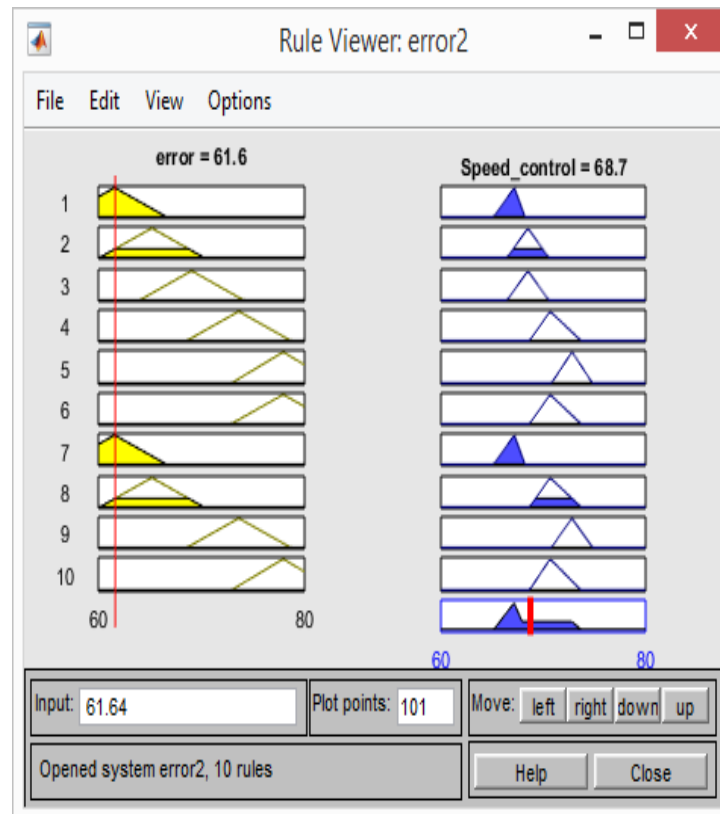


Figure 7. The fuzzy rule viewer

VII. Simulation Results

After designing and modelling the proposed fuzzy logic controller for the ACC, then results were plotted as shown in figure 8. This simulation also contains both the fuzzy and non-fuzzy simulation results. Figure 8 shows the first result for the fuzzy adaptive cruise controller. Figure 9 shows the result for the non-fuzzy cruise controller. Other figures will show the output results of the AFCC with error radar signal for both fuzzy and non-fuzzy cruise control systems.

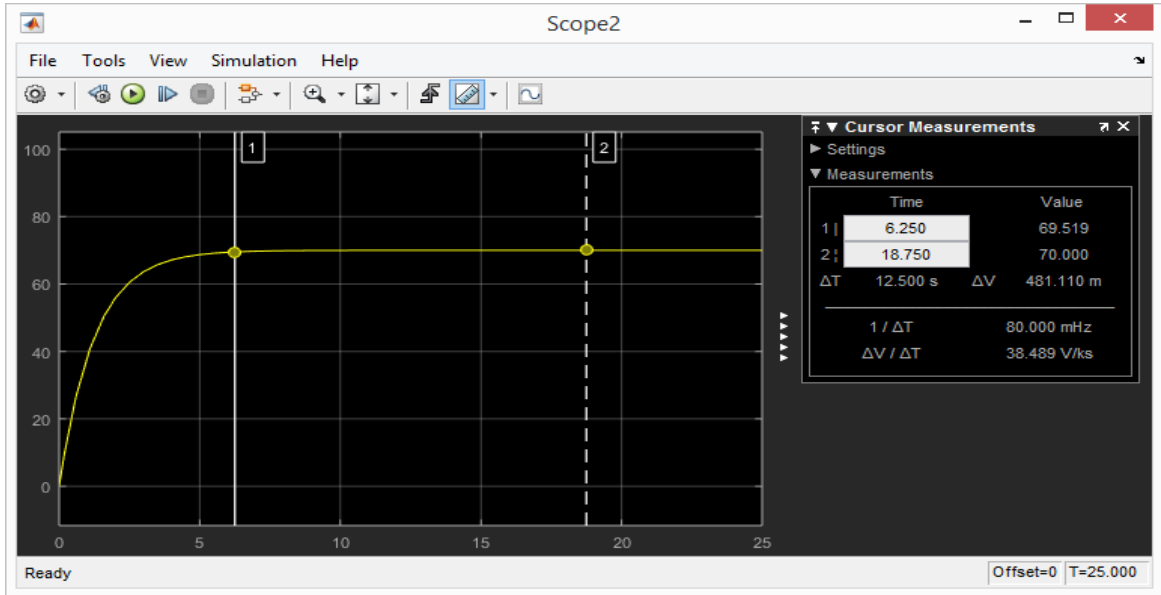


Figure 8. Fuzzy adaptive cruise control output

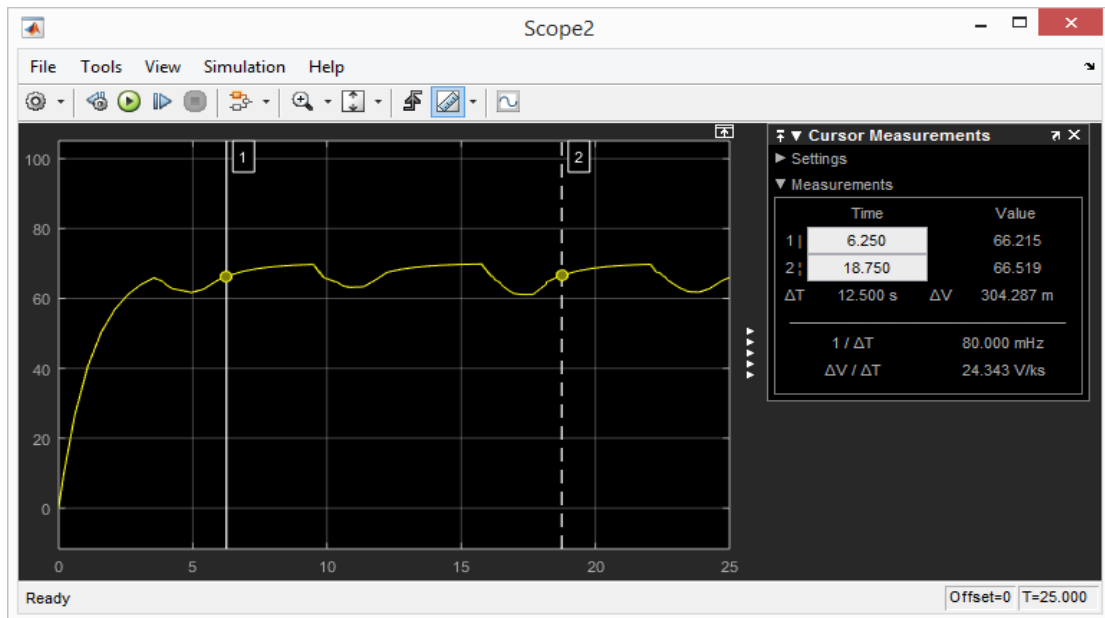


Figure 9. Non-fuzzy Adaptive cruise control output

From figures 8 and 9, it can be observed that the ACC with the fuzzy controller (AFCC) has given better results than the ordinary non-fuzzy one in maintaining a safe gap and a safe speed.

Figure 10 shows the output for the non-fuzzy ACC with the analog radar sensor. Figure 11 shows the output for the fuzzy ACC with analog radar sensor.

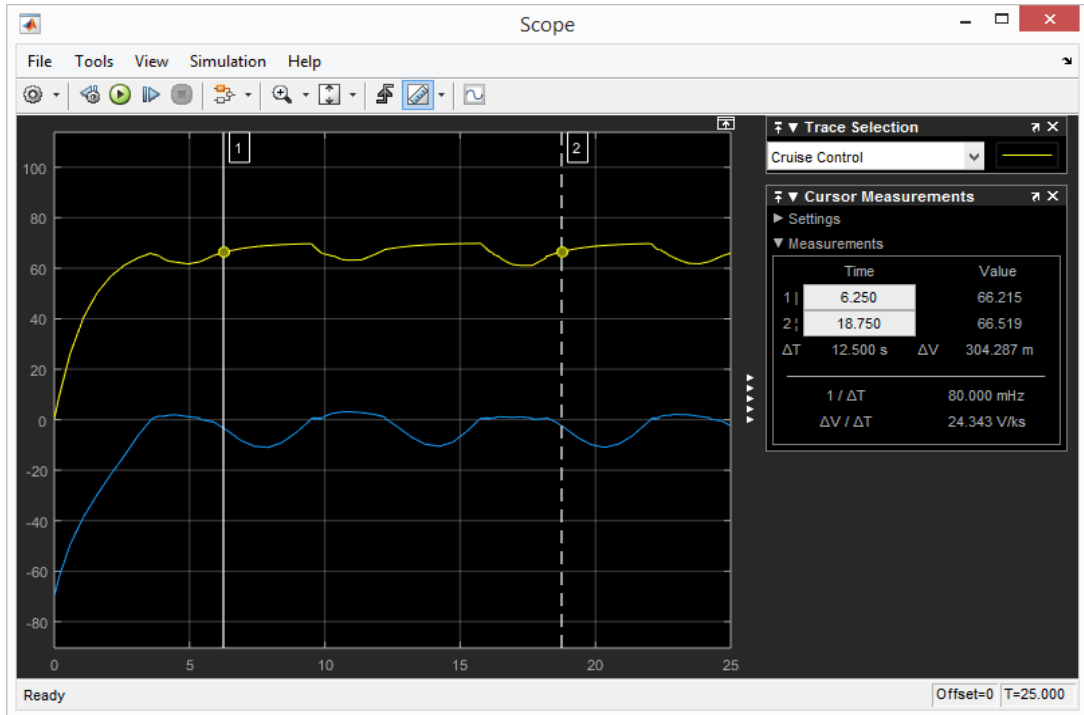


Figure 10. Non fuzzy with analog radar sensor and adaptive cruise control

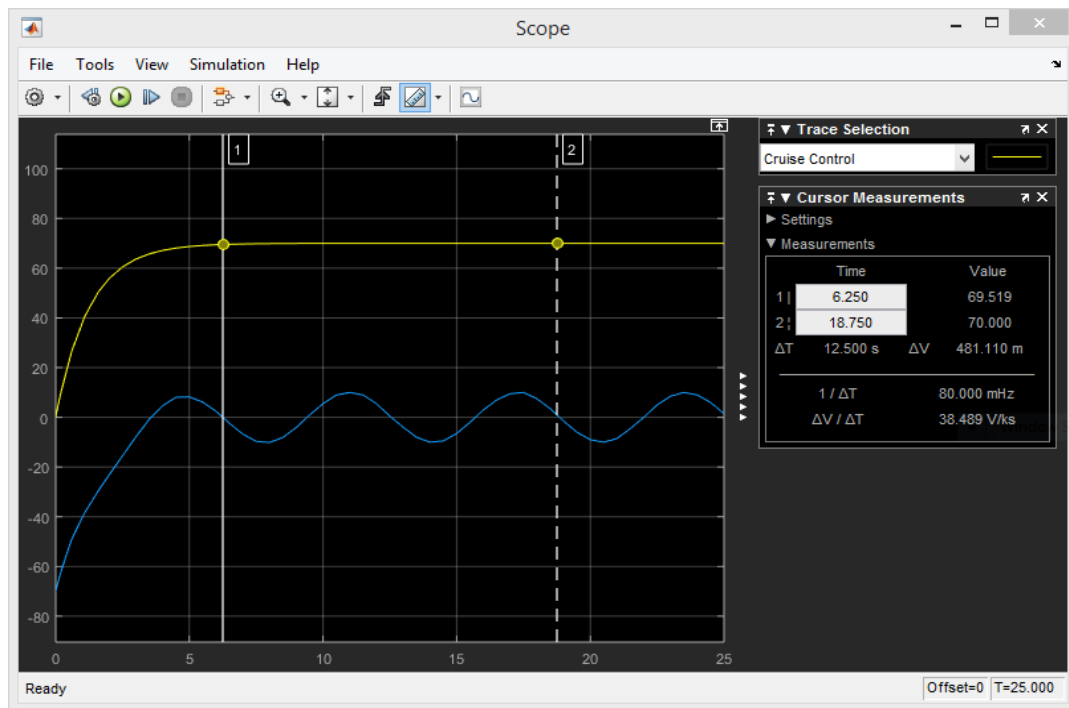


Figure 11. Fuzzy with analog radar sensor

Figures 11 and 12 shows clearly that the one with fuzzy controller (AFCC) has greater advantage in maintaining a safe distance and reaching the safe set speed without crashing into the second vehicle. The AFCC system makes the decision to follow the speed of the second vehicle or to maintain the set speed intelligently.

VIII. Conclusion

An adaptive fuzzy cruise control (AFCC) has been designed in this paper. The AFCC is capable of reaching the maximum speed that is set by the driver. It has many subsystems that plays major role in deciding the car speed. The AFCC used both the brake system and engine speed. The use of fuzzy in designing and modeling the presented AFCC is justifiable. The presented AFCC takes less time to calculate the given set time gap and set distance which makes driving more stable and safe.

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