International Journal of Electrical and Computer Engineering (IJECE)
Vol. 4, No. 6, December 2014, pp. 944~951
ISSN: 2088-8708

Developing Adaptive Cruise Control Based on Fuzzy Logic Using Hardware Simulation

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Article Info

Article history:

Received Sep 22, 2014
Revised Oct 25, 2014
Accepted Nov 17, 2014

Keyword:

Adaptive cruise control
advanced driver assistance system
Fuzzy logic
Safe distance

ABSTRACT

Ride comfort on the highway often interrupted because drivers need to adjust the vehicle speed. Safe distance between vehicles should be maintained is the main reason. The situation of monotonous and high speed will increase the risk of accidents on highway. A device is required by the driver to adjust the vehicle speed during the long distance (cruise) driving on highway without neglecting the safety aspects. The device is known as Adaptive Cruise Control (ACC). The ACC is a subsystem of Advanced Driver Assistance Systems (ADASs) that serves to assist the driver during cruise driving. The working principle of the ACC is the vehicle speed set automatically so that the distance to the vehicle in front remains safe. This paper presents the development of fuzzy logic controller for ACC. The fuzzy inference method used in this study is Mamdani. The result from hardware simulation that using remote control car shows that the fuzzy logic controller can work according to the design.

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1. INTRODUCTION

On the highway the vehicle move at relatively constant speed. A system has been developed to assist the driver in maintaining speed in order to constant. The system is known as the cruise control system (CCS) or speed control system [1]. This system can reduce the driver's fatigue in adjusting the speed of the vehicle during the long distance (cruise) driving.

CCS works by using the principle of automatic control system on throttle position setting [2], [3]. Driver need to push a button when it will activate the CCS on a certain speed.When the CCS is activated then the vehicle will run at the desired speed without the driver needing to adjust the gas or brake pedal.The weakness of CCS was not able to automatically reduce speed when a dangerous situation such as a vehicle in front of him suddenly slows down or stop.

Adaptive Cruise Control (ACC) is a system that is a combination of CCS and collision avoidance system [4]. The ACC was known by several other names such as Active Cruise Control (BMW), Distronic ACC (Mercedes), and the Intelligent Cruise Control (Nissan).

One of the main causes of traffic accidents on highway was too close a distance of vehicle with another vehicle on the front him (*following too closely*) [5]. The *following too closely*is also known as Assured Clear Distance Ahead (ACDA).A refinement of the CCS into the ACC is expected to reduce the weakness of CCS especially when a vehicle *following too closely*.

In addition to maintaining speed, ACC was also designed to prevent rear-end collision caused due to *following too closely*. On the following too closely situation the distance between vehicles more close than a safe distance. This situation causes the driver can fail to control the vehicle to avoid collision when the vehicle in front suddenly slows down or stop.Adjustment the speed and distance of a vehicle and the ability to avoid the danger that made the ACC could ultimately improve driver comfort.

Algorithms and sensors are two aspects of concern to ACC researchers. Both aspects are important for the realization of the reliable ACC. The research of developing algorithm, among others, performed by [6], [7], and [8]. While the research that to develop the sensor is done by [9], [10], and [11].

Some vehicles that have been equipped with ACC include the BMW 5 and 6 series, the Audi A8, and the Lexus LS 430. Sensors on the ACC which is currently mounted on a vehicle are radar dan lidar [12]. The camera can also be used as a sensor in the ACC as developed by [13], [14], and [15]. The development of inter-vehicle communication such as VANET also allows developed for the realization of the ACC [16].

In addition to have been installed in a variety of vehicles, the ACC is also used for the realization of the driverless car are planned to be marketed around the year 2020 by the various car manufacturers such as BMW, Nissan, Toyota, Ford, and Mercedes.

2. RESEARCH METHOD

The working principle of the ACC is the vehicle's speed control automatically to maintain safe distance. Therefore it takes a sensor to detect speed and distance of vehicle in front of him.

In the following discussion of the naming used ego vehilce (EV) to name the vehicle equipped with the ACC and leading vehicle (LV) for vehicle in front of EV on the same lane.

2.1. Control System of ACC

Block diagram of ACC can be seen in Figure 1 [17]. Controllers at the ACC consists of two levels, namely low-level controller and high-level controller. Low-level controller in the form of closed-loop control systems with input and output speed. The desired speed is the result of processing from a high-level controller. The sensor used in low-level controller is the speed sensors on EV. While the actuators used are the brake and gas pedals.

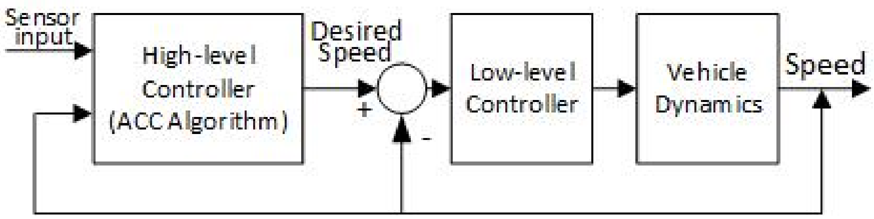

Figure 1. Block diagram of the ACC

The main concern in this study is the developinga high-level controller algorithm based on fuzzy logic. On the high-level controller there are two common configurations being used as can be seen in Figure 2 and Figure 3.

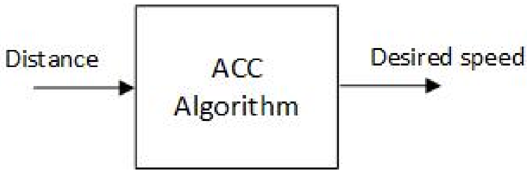

Figure 2.High-level controller of the ACC using single input

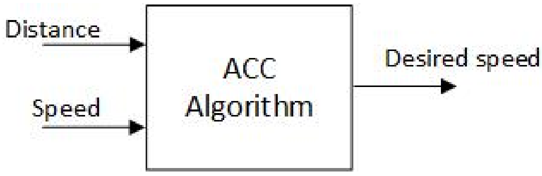

Figure 3. High-level controller of the ACC usingdouble inputs

At a high-level controllerusingsingle input, the desired speed is the result of processing the distance between EV and LV. This configuration has a weakness due to excessive in braking and accelerating. The second configuration uses two input which are distance and speed. Speed variables commonly used are speed of EV, speed of LV, and relative speed between EV and LV.

2.2. ACC Algorithm Based on Fuzzy Logic

Block diagram of a high-level controller on this study can be seen in Figure *4* [18]. Inputs of fuzzy logiccontrol are the distance and changeof distance between EV and LV are obtained from the distance sensor.Fuzzy inference engine is used in thissystem is Mamdani. The output of high-level controller is the desired speed. This speed value will be the set point for low-level controller.

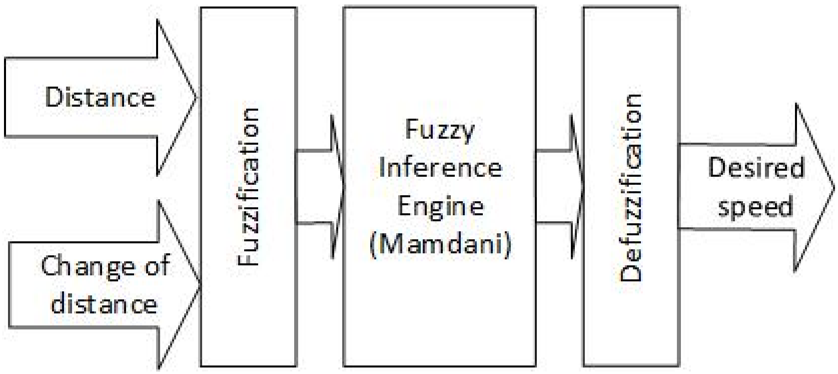

Figure 4. Block diagram of a high-level controller based on fuzzy logic

The membership function of inputsare shown in Figure *5* and Figure *6*. Membership function of distance input was divided into three regions which were near, medium, and far. While the membership function of change of distance input was divided into three regions which were small, medium, and big.

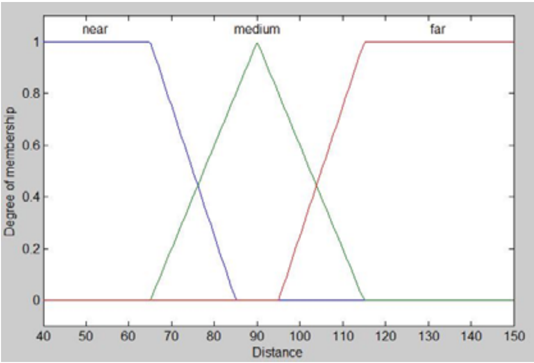

Figure 5. Membership function of distance

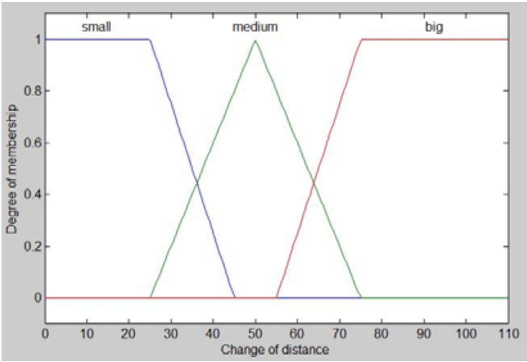

Figure 6. Membership function of change of distance

Figure 7 shows the membership function of output was divided into three regions which were slow, medium, and fast. As output variable are the values of PWM indicating the desired speed.The fuzzy rule base was used can be seen in Table *1*.

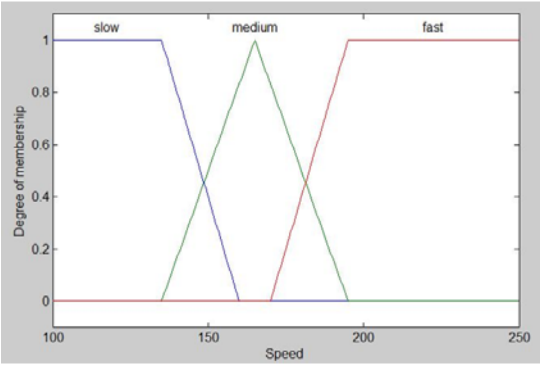

Figure 7. Membership function of output

Table 1. Fuzzy rule base

		Change of distance		
		small	medium	big
	near	slow	slow	slow
Distance	medium	medium	medium	slow
	far	fast	fast	medium

The graph of input and output relationship can be seen in Figure 8. The view of the Rule Viewer at low, medium, and fast speed can be seen in Figure 9 - Figure *11*. In Figure *9* it can be seen that when the distance between EV and LV *near* and change of distance is *small* then the speed is*slow*. EV will slow down so that the safedistance can be improved. When the distance between EV and LVis *far enough* (*medium*) and changes of distance is also *medium* then the speed of EV is*medium* so the EV will be located at a safe distance, see *Figure 10. In*

Figure *11* it can be seen that the speed of the EV will be high when the distance to LV is much greater than the safe distance. In this condition, the EV will try to approach the LV to a safe distance allowed.

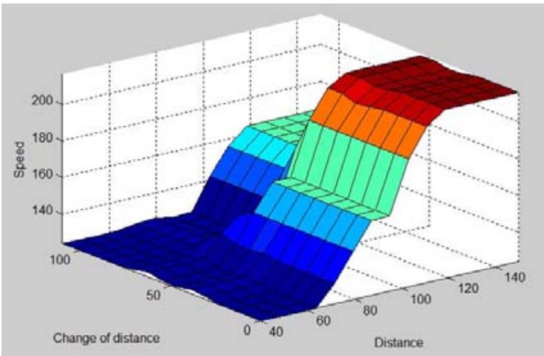

Figure 8. Graph ofinput and output relationship

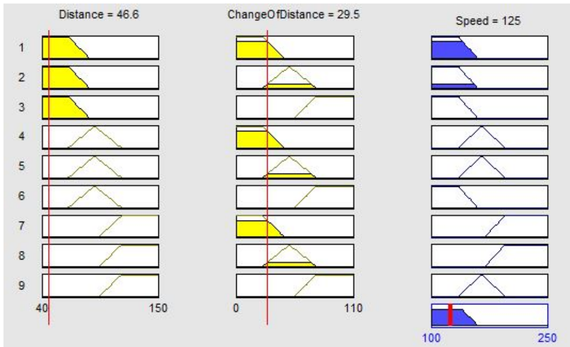

Figure 9. View of the Rule Viewer at low speed

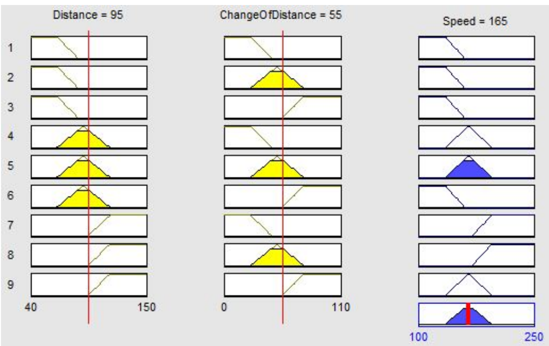

Figure 10. View of the Rule Viewer at medium speed

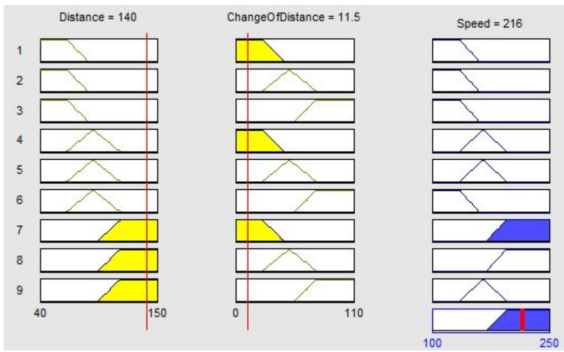

Figure 11. View of the Rule Viewer at fast speed

2.3. Hardware Simulation

Hardware simulation was built using the remote control car as shown in
Figure 12 *and*
Figure *13* [14]. On the hardware simulation in this study used an ultrasonic sensor that is mounted on the front side of the car. The sensors was used to measure distances LV from EV. The low-level of control on this study is simplified with open loop speed control system based on Pulse Width Modulation (PWM).

Figure 12. Front view of hardware simulator

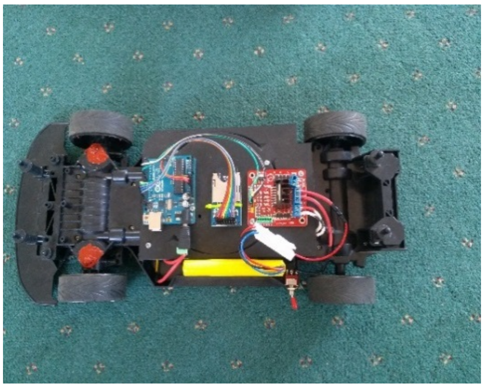

Figure 13. Top view of hardware simulator

Remote control car is controlled by using the Arduino Uno R3. This microcontroller system based on AT mega 328 and can be equipped withfuzzy logic library functions. The library functions use Min-Max Mamdani method for fuzzy logic inference system and the center of areafor defuzzification [19].

Importantdata during the testing was stored in Secure Digital (SD) memory card via Arduino shield.The data were then processed with software to get a graph of the system performance.

3. RESULTS AND ANALYSIS

On this hardware simulation the sensor linearity is very important. The testing of sensor linearity is done by running EV to an object. The test results can be seen in
Figure *14*.

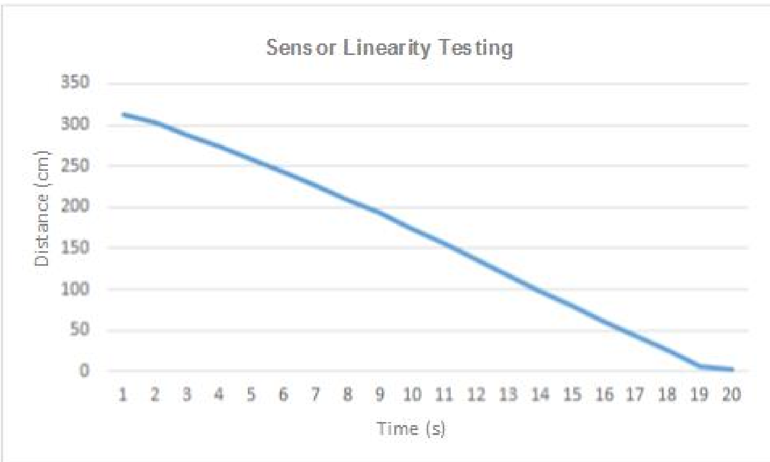

Figure 14. Sensor Linearity

ACC algorithm testing performed by the following two scenarios:

1. In front of EV given object is not a car that changed the distance

2. EV moves behind LV

The first test scenario has the objective to see the effect of distance on EV's speed setting. The test results can be seen in Figure 15.

Figure 15. ACC test data with a object non-car

The test results showed that the ACC algorithm respond well to any change in the distance. Any change in the distance will be followed by a change of EV's speed. Through this way a safe distance with the LV can be maintained. If the distance is too close (less than the safe distance) then the speed is reduced. Otherwise the speed EV gain if the distance is greater than the safe distance.

On the testing safe distance set to 40 cm, therefore if the distance is less than 40 cm then the speed will be reduced. Otherwise if a distance of over 40 cm then the speed will be increased.

The second test scenario has the objective to investigate the performance of the ACC under conditions similar to reality. Speed of LV was changed by a embedded softwarein the microcontroller system. The test results can be seen in Figure 16.

The test results showed that if the distance is more than safe distance, then speed of EV was increased. The testing also shows that the safe distance of 40 cm is maintained during the simulation.

Figure 16. ACCtest data with speed of LV changeable

4. CONCLUSION

The results of the study showed that the ACC high-level controller based on fuzzy logiccan work well. Improvements need to be made on the input or the output membership function in order to get optimal performance. In addition it needs to be fixed so that the vehicle's direction following the vehicle in front of him so that testing can be more accurate.The controller also need to be developed by adding speed as the inputso obtained better control performance.

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