Adaptive Cruise Control based Motor Acceleration Control using Fuzzy Logic Methods

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***Abstract* –The paper presents a method for adaptive cruise control based motor acceleration control. On the long-distance driving, using vehicles that have a risk for accidents. One of these accidents is collisions between vehicles in front of them which can cause multiple collisions. With the help of the ACC feature, it can reduce the occurrence of these accidents which are caused by the driver's fatigue and weather conditions on long-distance trips. By using the Fuzzy adaptive cruise control system, it is successful in adjusting the acceleration set on the fuzzy system, and with the help of the GUI it can make it easier for the operator to set the appropriate acceleration.**

Keywords: Fuzzy logic, motor acceleration, GUI, Cruise Control

I. INTRODUCTION

Four-wheeled vehicles are a mode of transportation that is widely used by people for their daily lives; many people choose four-wheeled vehicles or private cars because they are more affordable, practical, and faster. On highways or toll roads, vehicles move at a relatively constant speed, so a feature has been developed to make it easier for the driver to adjust the gas pedal so that the speed remains constant. The system is the Cruise Control System (CCS) or speed control system, this feature is also very helpful for the driver to reduce fatigue in changing the speed of the vehicle over long distances [1].

The CCS system is based on automatically controlling the accelerator pedal position. To control it, the driver needs to press a button so that the CCS system can be activated at a predetermined speed [10]. When the CCS feature is activated, the driver no longer needs to step on the gas pedal and the vehicle will drive constantly at the speed that has been set on the CCS feature [9]. In addition, the CCS feature can be useful in saving fuel because the engine speed is stable so that fuel is more efficient. The cruise control system has drawbacks, namely the system cannot reduce speed automatically when there is a dangerous condition and cannot detect vehicles in front of them that are slower or are stopping [14].

From these deficiencies, the Adaptive Cruise Control (ACC) system was created, which is a combination of the collision avoidance system and the CCS system. The ACC system is able to control the speed of the motorbike by adding acceleration and reducing acceleration and can adjust the safe distance to the vehicle in front of it [11]. This system is connected directly to the electric control unit and motor driver [5].

On long-distance trips using a vehicle has a large risk of accidents; one of these accidents is a collision between the vehicles in front of it which can cause multiple collisions. With the help of the ACC feature, it can reduce the occurrence of these accidents which are caused by the driver's fatigue and weather conditions on long-distance trips [12].

Algorithm and sensor programming are two important aspects of adaptive cruise control. This research develops an ACC system with a fuzzy logic method that regulates the speed, distance, and force exerted by the driving motor.

II. METHODS

A. Advanced Driver Assistance System (ADAS)

Advanced Driver Assistance System (ADAS) is an autonomous electronic system that functions to improve the safety and security of drivers while driving. ADAS is an integrated electronic control system, where the control is classified based on the sensors used in the sensing system. The sensing system is a type of control that learns and makes decisions from the input of the surrounding environment. Figure 2.1 is an ADAS feature classification based on the sensors used in vehicles, and Figure 2.2 is an ADAS classification diagram based on the sensor used.

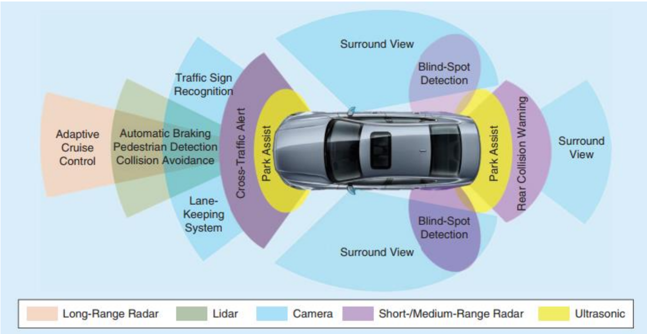

Fig. 1. Classification of ADAS Features on Vehicles

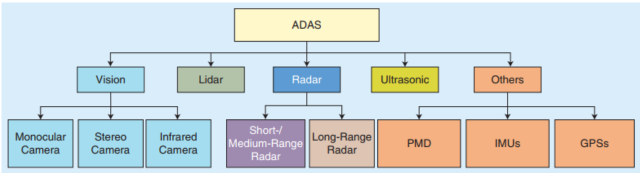

Fig. 2. ADAS Classification Based on Sensors Used

B. *Cruise Control*

The Cruise Control System is a technology that is on vehicles that function to maintain a constant speed without the need to step on the brake and gas pedals, the presence of a cruise control allows the vehicle to run constantly at a speed that has been set by the driver [6], [15].

Fig. 3. Illustration of Cruise Control

The Adaptive *Cruise Control* (ACC) system is part of the *cruise control* that can be used in electric-powered vehicles in an electric vehicle. In this study, the aim is to apply a radar sensor to detect distances on an *intelligent cruise control* that will be embedded in electric vehicles. Radar sensors are generally widely used for *parking assistance* so that parked vehicles do not hit nearby objects and warn the driver if the vehicle is approaching an object in front of or behind the vehicle.

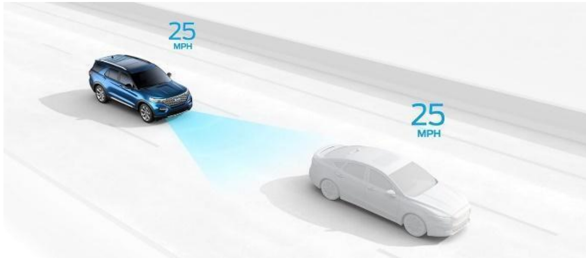

Fig. 4. Adaptive Cruise Control on Cars

C. *Fuzzy Logic*

Fuzzy Logic is a form of logic that has a truth variable value in numbers between 0 and 1. Fuzzy logic can also be used as a way to map an input area into an output area). A fuzzy system is a system based on rules (knowledge) built by a collection of IF-THEN rules.

In a fuzzy system, there is a membership function which is a curve that represents the mapping of input data into membership levels that have a value between 0 and 1. The most frequently used curves to represent input data values are the triangle curve and trapezoidal curve.

A fuzzy inference system (FIS) basically defines a nonlinear mapping from a vector of input data to a scalar output using fuzzy rules. The mapping process involves input/output membership functions, FL operators, fuzzy if-then rules, output set aggregation, and defuzzification. FIS with multiple outputs can be thought of as a collection of independent multi-input, single-output systems. The general model of a fuzzy inference system (FIS) is shown in Figure 5. FIS maps sharp inputs to sharp outputs. It can be seen from the figure that FIS consists of four components: fuzzifier, inference engine, rule base, and defuzzifier. The rule base contains linguistic rules provided by experts. It is also possible to extract rules from numeric data. Once the rules are defined, FIS can be seen as a system that maps input vectors to output vectors.

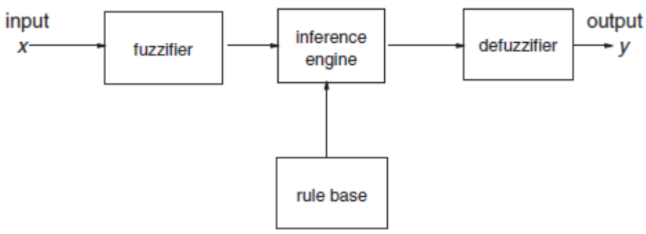

Fig. 5. Block diagram in FIS

The method used in this study is in the form of work steps and a series of activities, which can be seen in Figure 6 below.

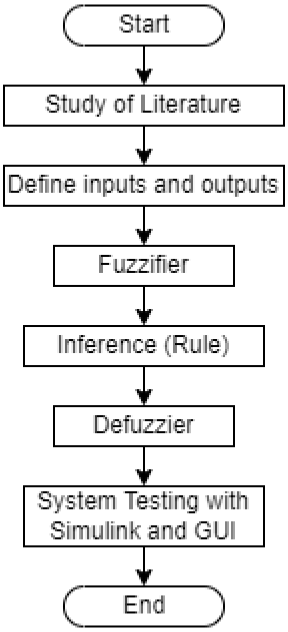

Fig. 6. Method Flowchart

D. *Inputs and Output*

In Figure 7, it is known that there are two inputs, namely distance and speed, wherein the adaptive cruise control. These parameters are very important to regulate the acceleration of the motorbike. The fuzzy Mamdani method is used because the fuzzy inference system is used to draw the best conclusions or decisions in uncertain problems [7].

The process of making decisions using the Mamdani method is carried out through stages, namely the formation of fuzzy, application of implication functions, the composition of rules, and defuzzification. Using the Mamdani method has the advantage of being more detailed in paying attention to the conditions that will occur for each fuzzy area.

The fuzzy Mamdani method is a method for drawing conclusions that are easy for humans to understand because it is most in line with human instincts. So using the Mamdani method will produce the best decision for a problem.

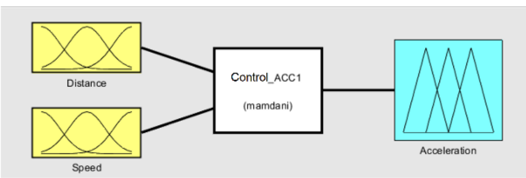

Fig. 7. Input and Output on the system

E. *Fuzzifier*

Fuzzifier is a stage that is used in mapping the values or values of variables in the real world within the area of fuzzy sets (*fuzzy sets*). The mapping is done using a function called the degree of membership (membership function). In the fuzzifier stage, there are three methods, namely, singleton fuzzifier, gaussian fuzzifier, and triangular fuzzifier [2].

$$\text{Singleton fuzzifier} \quad : \quad \mu A'(x) = \begin{cases} 1 & \text{if } x = x^* \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

$$\text{Gausian fuzzifier} \quad : \quad \mu A'(x) = e^{-\left(\frac{x_1 - x_1^*}{a_1}\right)^2} * \dots * e^{-\left(\frac{x_n - x_n^*}{a_n}\right)^2} \quad (2)$$

$$\text{Triangular fuzzifier} \quad : \quad \mu A'(x) = \begin{cases} \left(1 - \left(\frac{|x_1 - x_1^*|}{b_1}\right) * \dots * \left(\frac{|x_n - x_n^*|}{b_n}\right)\right) & \text{If } |x_n - x_n^*| \le b_i,\ i = 1,2,\dots,n \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

In Figure 8, it can be seen that there are degrees of membership in the form of close, medium, and far. Where the speed is divided into three fuzzy set areas.

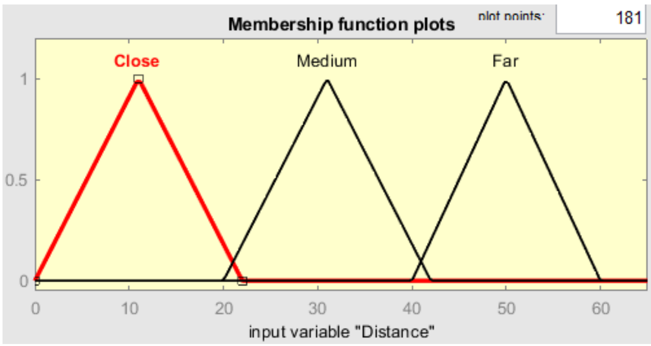

Fig. 8. Membership function of distance

The next membership is a function for speed where there are three degrees of membership namely slow, medium, and fast which can be seen in Figure 9.

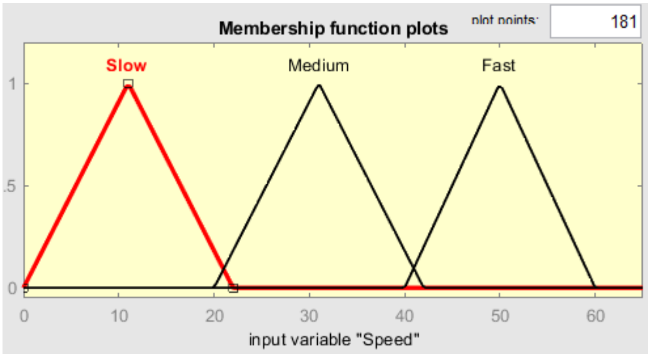

Fig. 9. Membership function of speed

Figure 10 explains that there are three degrees of membership, namely low, moderate, and high, where the degree of membership is used to accelerate the output of the fuzzy system..

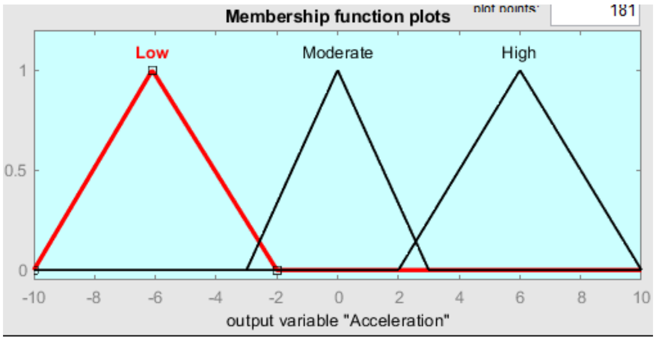

Fig. 10. Membership function of acceleration

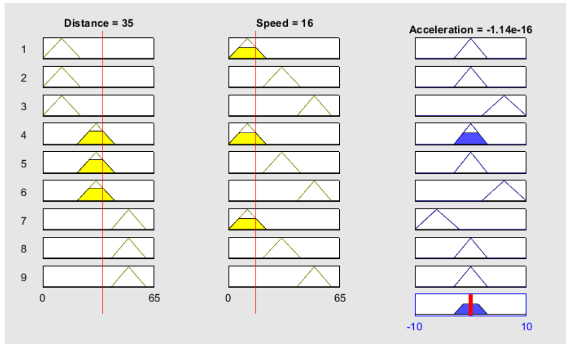

Fig. 11. View of the Rules

F. *Inference*

Tables 1 and 2 explain the fuzzy rules for the desired acceleration output using 9 rules, which can be seen in the table below. As for Table 2, it describes the linguistic function in the application of the configuration of the nine rules [3].

TABLE I. CONFIGURATION 9 RULES

Distance	**Speed**		
	S	M	F
C	M	M	L
M	M	M	L
F	H	M	M

TABLE II. CONFIGURATION DEFINITION OF LINGUISTIC

Linguistic	**Definition**
C	Close
M	Medium
F	Fast
S	Slow
L	Low
H	High

G. *Defuzzifier*

Defuzzifier is a stage whose job is to retrieve the results of fuzzy calculations (fuzzy sets) which are then used as variables according to their range in the real world. Similar to the fuzzifier, the defuzzifier also uses a membership function to map the set values in the fuzzy set into real variables. At this stage, there are three defuzzifier methods, namely [4]:

- Center of gravity defuzzifier, which is expressed in y*, which shows the center of the area covered by membership function B'
- Center average defuzzifier is a method for showing the average weight of the center point (center) of each membership function
- Maximum defuzzifier method uses the highest value as y*.

III. RESULT AND DISCUSSION

In Figure 12 show that the block diagram system in Simulink has two parameter blocks that function to enter speed and distance values, then these values are entered in the mux block, which will be sent to the fuzzy logic controller (FLC) and will display the acceleration value in the block. parameter.

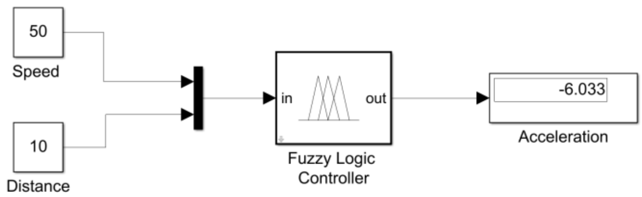

Fig. 12. Trial of the Simulink Fuzzy System

Meanwhile, Figure 13 shows the results of creating a GUI using Matlab, where the previously set fuzzy inference system (FIS) is entered into the GUI system so that when entering the input values for speed and distance then pressing the process button will produce acceleration output on the GUI, so that by using this system will make it easier for the operator to find out the appropriate value [8], [13].

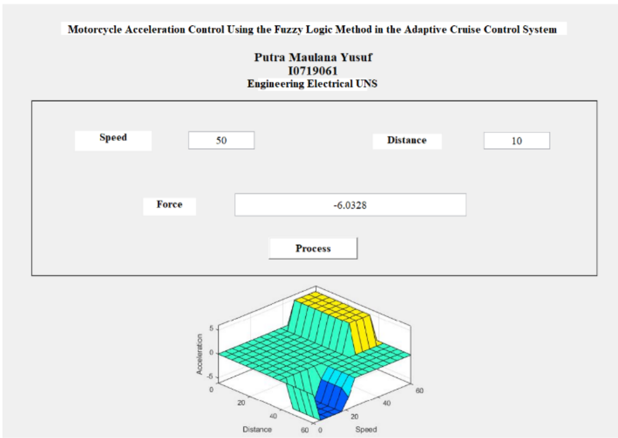

Fig. 13. GUI Results with Matlab

IV. CONCLUSION

In the experimental results using the fuzzy method, the adaptive cruise control system can be made well, as well as the Graphical User Interface, which is successful in retrieving fuzzy inference system data so that the GUI is able to work properly. For further research, it is necessary to calculate real acceleration with a safe distance and adjusted speed.

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