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To cite this article: I Rizianiza and D M Shoodiqin 2021 *J. Phys.: Conf. Ser.* **1833** 012005

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# Automatic braking system using fuzzy logic method

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**Abstract.** This research is design an autonomous car control system that can reduce the rate of traffic accident. Car prototype is designed by using Fuzzy Logic Control. Fuzzy logic is as main component of artificial intelligence has significantly influence the design controlled system. Fuzzy logic system is integrated with the arduino Mega 2560 microcontroller as the central control car prototype. In this paper, the Fuzzy logic used Mamdani method and 28 rule base. The fuzzy system was made based on fuzzy mechanism which are fuzzification, inference and defuzzification. Fuzzy logic has a variable input and output variables. Input variables used in this research is the distance between car and obstacle; the speed of car prototype and the output variable is the brake angle. The test is done with 5 variations of distance that is 100 cm, 125 cm, 150 cm, 175 cm, and 200 cm and two variations of speed that are 54 cm/s, and 63 cm/s. The test results showed that the prototype of the car was able to stop with a range of 22 cm - 35 cm from obstacle. The highest deceleration value at the speed of 63 cm/s is - 49.22 cm/s<sup>2</sup> and the accuracy of braking on a system that has been designed is between 99.91% -100%.

## 1. Introduction

According to global data on World Health Organization (WHO)'s on road safety status report in 2015, more than 1.2 million people die each year from traffic accidents, with millions more getting seriously injured. By the year 2020, the death toll in the world due to traffic accidents is predicted to reach 1.9 million if no real steps are taken to anticipate it. The causes of traffic accidents generally consist of three factors: human, vehicle, and environment. According to Directorate General Land of Transportation, human factor has the highest contribution reached 80-90%. As for the factors of vehicles and environmental factors have a sequential contribution of 5-10% and 10-20%.

For example the typical traffic accident is the car driving with high speed (more than 100km/ h), both of them installed Automatic Braking System (ABS). The main reason of the car accident is the car with high speed crossing through the water level, appearing "hydroplaning". While the speed is very high, the film even can make the car float, losing control and causes terrible traffic accident. If you braked at this moment, the car would slide and be out of direction[1].

The development of automotive technology in the field of advanced transportation requires the product of a vehicle has a good performance capability and has a high level of security for motorists. The development of automotive technology cannot be separated from the development carried out on vehicle automation system. Automation system plays a very important role in the development of automotive science and technology so as to help humans in minimizing the occurrence of human error in driving. One of the benefits of automation systems to reduce the level of accidents is by applying an automated control system that is capable of controlling automated braking on the vehicle so that the vehicle can avoid collisions when there is an object in front of it. The automatic braking system uses the



sensor on the front of the vehicle that serves as the object detector, so that automatic braking is done until the vehicle does not hit the detected object.

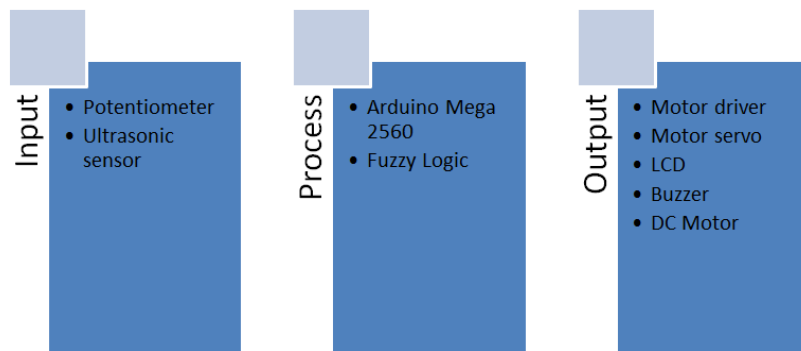
Fuzzy logic is one of the Artificial Intelligent. A fuzzy controller is an automatic controller, self-regulating mechanism that controls an object in accordance with a desired behavior. The object can be, for instance, a robot set to follow a certain path. A fuzzy controller acts or regulates by means of rules in a more or less natural language, based on the distinguishing feature. The rules are formulated by the human set of instructions. This is an intelligent control [2]. Fuzzy has three structures that are input, process, rule base, defuzzification, and output. The selection of membership function has many methods, such as two element comparison sort method, assignment method, fuzzy statistics method, etc [3]. The advantages of this control method come from the simple laws and low hardware requirement. Once the thresholds are determined, a basic control cycle can be achieved. Fuzzy controllers differ from model based controllers in that they encode heuristic knowledge [4].

There are three types of Fuzzy Inference System are Mamdani, Sugeno and Tsukamoto. On one hand, Mamdani has more intuitive and the way it works is more like a human [5]. On the other hand, Fuzzy Inference System Mamdani has a problem in terms of computing. While the Sugeno method is more adaptive in terms of optimization, computing is more efficient especially in terms of nonlinear dynamic systems [6]. However, Mamdani still fast computing than others [7].

## 2. Design Automatic Braking System

### 2.1 Design Automatic Braking System

Automatic braking system design based on Arduino mega 2560 microcontroller by using fuzzy logic method divided into input, process and output. The workings of automated braking prototype of the car to be designed is when the input speed of the potentiometer is Pulse Width Modulation (PWM) and ultrasonic sensors detect the presence of obstacles with a certain distance, then automatically fuzzy logic integrated with arduino mega 2560 will process input from the sensor to determine the output of the braking angle on the prototype of the car.



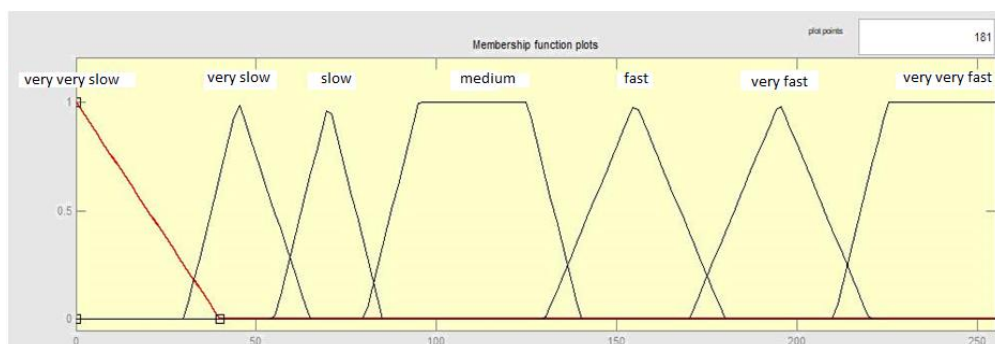
**Figure. 1** Block Diagram of Automatic Braking System

The design of an automatic braking system using the fuzzy logic method needs to determine the variables that can influence and become a reference for the final result. A variable is characteristics or values to determine the possibility of changing one thing to another. The variables divided into three, namely control variables, dependent variables and independent variables. The control variables are variables that are controlled or made constant so that the influence of the independent variable on the dependent variable is not influenced by external factors that are not examined. The control variable is determined to make it easier to work on the braking system design automatic braking. The control variable that has been determined is the distance to the emergency stop, where the prototype car must stop  $\geq 15$  cm to the obstacle. The selection of the emergency distance as the control variable is to avoid a collision between the prototype car and the obstacle, so that the prototype car always stops at a safe distance. The independent variable is a variable that affects the dependent variable. Treatment can take

the form of efforts made to be able to see the changes that occur in the dependent variable. The independent variable can also be said to be a variable that has an effect on the experiment. The independent variable in the design of an automatic braking system using the fuzzy logic method is the distance between the prototype car and the obstacle and the speed of the prototype car. The distance variation in the design of the automatic braking system is 100 cm, 125 cm, 150 cm, 175 cm, and 200 cm. The variations in the speed of the prototype cars are 100, 150, 200, and 255. The choice of distance and speed variations is adjusted to the predefined membership function range. The dependent variable is a variable whose value will change against certain factors. In general, experimental types of research seek only one type of independent variable that affects the dependent variable. The change in the value of the dependent variable will be proportional to the treatment given by the independent variable. The dependent variable in this study is the stopping distance, the deceleration value and the braking angle value of the prototype car.

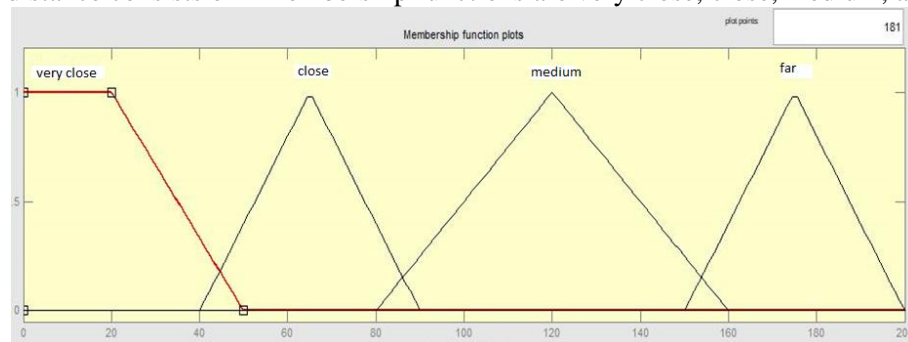
## 2.2 Fuzzy Logic System

In this research used fuzzy logic method mamdani. Fuzzy logic mamdani can be applied to automated braking systems according to the automated automated braking system control reference system with fuzzy mamdani inference system [8]. Fuzzy logic is used as an integrated braking control with arduino mega 2560 system device. In this fuzzy logic system there are 2 factors that influence the value of car prototype braking, the first is the distance of the car to the obstacle in front of the prototype of the car. The closer the car with the obstacle then it takes a great braking to avoid the occurrence of a collision. The second factor is the speed of the car, if the car drove at high speed then it takes great braking and when the car drove at low speed then braking generated on the fuzzy logic system will be low. Based on the main factors are obtained 2 input variables that will be used on the fuzzy logic system, the distance and speed and output variabel on this system is the braking angle. Furthermore, the preparation of membership functions of input and output variables that have a very important role to present the problem. Membership function is a curve showing the mapping of data input points into their membership values that have intervals between 0 and 1. Variable speed consists of 7 membership functions are very very slow, very slow, slow, medium, fast, very fast, and very very fast. Speed is one of the most important and difficult task needs to be controlled while driving[4]. The membership function is the basis of fuzzy set theory, which comes in many forms including triangular, Gaussian, trapezoidal etc. The triangular among them is the most widely used one and its fuzzy set shows a linear distribution [9]. Determination of the membership function is based on system dynamics.



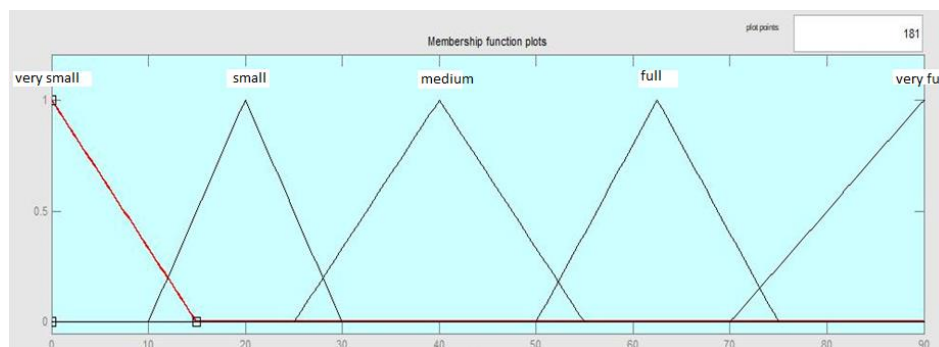
**Figure 2. Membership Function Speed**

Variable distance consists of 4 membership functions are very close, close, medium, and far.



**Figure 3.** Membership Function Distance

Braking variable consists of 5 membership functions are very small, small, medium, full, and very full.



**Figure 4.** Membership Function Braking

Arduino mega 2560 system is a circuit devoted to operate IC (Integrated Circuit) microcontroller. This microcontroller is used as a central control system on automatic braking. The Arduino mega 2560 has a Port I/O functioned to receive input from ultrasonic sensors and PWM values and outputs to motor driver, servo motors, LCD, and buzzer. The embedded fuzzy logic system to arduino mega 2560 is to implement input, process and output by incorporating fuzzy logic program into arduino mega 2560 microcontroller. Fuzzy logic program is created using software by determining input and output as needed. After that create a fuzzy rule to process the input so that it gets output on fuzzy logic system. After fuzzy logic programming is done, the next step is to insert fuzzy logic program into arduino mega 2560 microcontroller, so that automatic braking system can run. Fuzzy logic rules are used to process input and functions membership in order to obtain output as decision making [10]. This system uses 2 input variables and 28 rule bases are shown at Table 1.

**Table 1.** Rule Base

Distance	Speed						
	Very very slow	Very Slor	Slow	Medium	Fast	Very Fast	Very Very Fast
Very close	Small	Small	Medium	Full	Very Full	Very Full	Very Full
Close	Very Small	Small	Small	Medium	Medium	Full	Very Full
Medium	Very Small	Very Small	Small	Small	Small	Small	Small
Far	Very Small	Very Small	Very Small	Very Small	Small	Small	Small

### 3. Result

Prior to retrieval of data from prototype cars that have been designed, tested the proximity sensor and speed as input on the automatic braking system. Speed testing is done by measuring the Pulse Width Modulation (PWM) value as the speed input on the automatic braking system. The PWM value will be converted to cm/s by the IR sensor. So get the value of each tire speed on the prototype car. The IR sensor measurements are shown in Table 2.

**Table 2.** IR Sensor Measurement

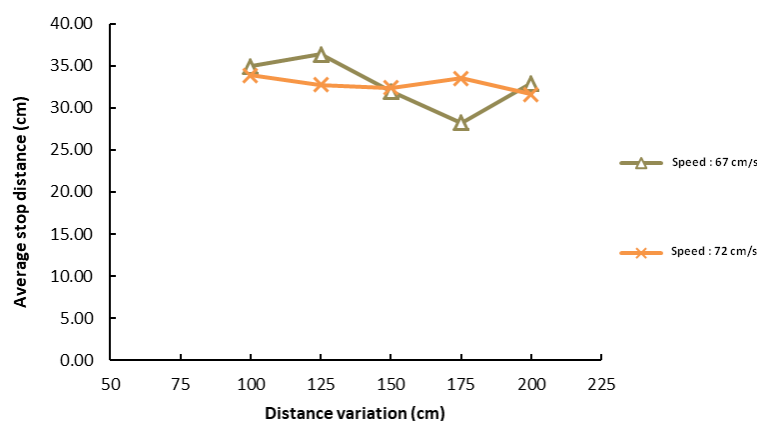
PWM Value	IR Sensor Measurement
200	67 cm/s
255	72 cm/s

Distance testing is done by using ultrasonic sensor HC SR-04 as the distance detector between prototypes of car with obstacle. The results of distance measurements using ultrasonic sensors are shown in Table 3.

**Table 3.** Ultrasonic Sensor Distance Measurement

Ultrasonic Sensor Measurement	Manual
10 cm	10 cm
25.05 cm	25 cm
50.03 cm	50 cm
75 cm	75 cm
100.01 cm	100 cm
125 cm	125 cm
150 cm	150 cm
175.4 cm	175 cm
200 cm	200 cm

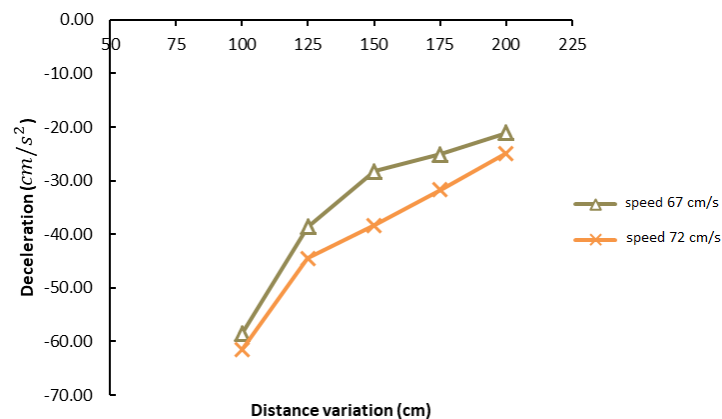
Figure 5 is a graph of the relationship between the average stopping distance of the prototype car against the variation of distance and speed.



**Figure 5.** Average Stop Distance

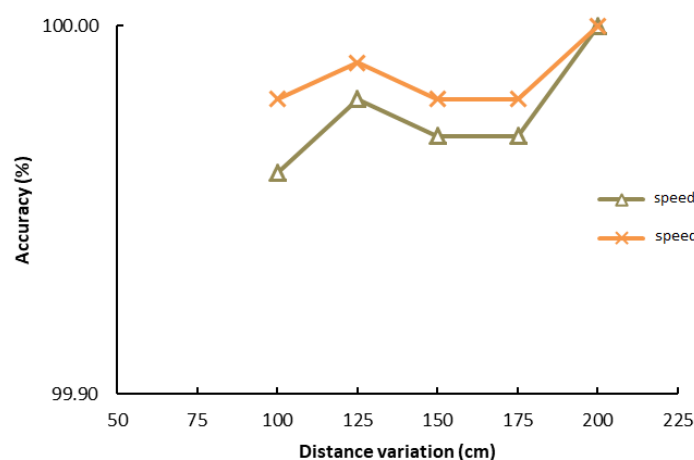
Figure 5 shows that the stop distance at each test fluctuates, with a range of between 28 cm-36 cm. The difference in stopping distance across all tests is not due to the variation in distance and speed but

on the performance of the components of the prototype of the car that responds to the servo motor response to any change in the output value of the fuzzy logic and the readings of the distance value by the ultrasonic sensor. Servo motors as actuators of automated braking systems have a vital role in determining the success of automobile prototype testing, to improve the response of servo motors to check the battery supply voltage to the servo motor periodically. The standard voltage of the servo motor is 6.4 volts. The test results show prototype car can stop with distance more than 15 cm to obstacle, so testing of car prototype in this research have success rate equal to 100%. Figure 6 is a graph of deceleration of prototype car testing results against variations in distance and speed.



**Figure 6.** Deceleration of Prototype Car

Figure 6 there is a tendency that the higher the speed of the prototype of the car, the greater the resulting slowdown. At a speed of 72 cm/s the resulting slowdown of any distance variation is greater than the other velocity values with the same distance variation. Theoretically the value of deceleration is influenced by 2 variables, the first is the time it takes the prototype of the car from running to stop and the second is the initial speed of the prototype car. The longer it takes to stop the speed of the prototype of the car, the smaller the retarding value. The value of the prototype deceleration of the car is related to the fuzzy logic system that is designed as the input value processor and produces the output of a braking angle. The greater the angle of braking results fuzzy logic output, then the value of prototype deceleration of the car the greater. The deceleration results in all tests that have been performed show that the fuzzy system is designed to run well, so the value of the prototype deceleration of the car is directly proportional to the output of processed fuzzy logic in the form of braking angle. Figure 7 is a graph of braking accuracy of test results and software calculations.



**Figure 7.** Braking Accuracy



Figure 7 shows the accuracy of braking at all variations of speed and distance between 99.96% - 100%. Maximum percentage of braking error of 0.22% at speed of 67 cm/s and the initial distance of 100 cm. The occurrence of braking error on this system is due to the reading of distance value as fuzzy logic input on prototype of car is decimal number two behind coma, whereas at software calculation distance value is decimal number one behind coma so brake angle output value slightly different. In the software calculation if the decimal value of two behind the comma is entered, software will automatically do the rounding to a decimal number one behind the comma. The automated braking system using the fuzzy logic method in this study runs well so that it has an accuracy value close to 100% in all tests. Compare with previous study that discuss about antilock brake system, the fuzzy logic have error and error rate as input variables and percentage of braking as a output variable. The simulation of automatic braking system controller based on fuzzy logic, whether brake time or brake distance are all achieve a great control effect, guarantee the steady of braking, the fitness of brake efficiency, and the requirements of national safety specifications for vehicles operating on roads. When the brake time within 0.5 second, slip rate increase rapidly, vehicle speed decrease quickly as time goes on, while the slip rate is up to about 20%, slip rate change constantly and vehicle speed keep on decreasing as the increase of brake time [1].

#### 4. Conclusion

The prototype of the car is able to stop outside the emergency range with a range of 28 cm - 36 cm to obstacle. There is a difference in the stopping distance of the prototype of the car on each test, this is due to the responsiveness of the servo motor to the fuzzy logic output value. Variations in speed and distance provide a tendency to decelerate the prototype of the car, the higher the speed as well as the distance between the prototype of the car and the near obstacle, the greater the resulting slowdown, and vice versa. The highest deceleration value at the speed of 72 cm/s and the initial distance of 100 cm i.e.  $-61.53 \text{ cm/s}^2$ . The accuracy of this system braking value is between 99.96% - 100% and the maximum percentage of braking error of 0.22%, the occurrence of error due to difference in the distance value of the prototype of the car with software, so the brake angle value is slightly different. We already have a prototype electric car to apply automatic braking system. Future work will focus on monitoring the automatic braking system. In addition, future work will explore the extent to which the stability of the control system is designed to create an electric car as expected.

#### Acknowledgments

This article is funded by research grant of Lembaga Penelitian dan Pengabdian kepada Masyarakat Institut Teknologi Kalimantan in 2020.

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