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Overtaking Assistant System Based on Fuzzy Logic

Noor Cholis Basjaruddin[1,2*], Kuspriyanto[1], Didin Saefudin[2],
Edi Rakhman[2], Adin Mochammad Ramadlan[2]
[1] School of Electrical Engineering and Informatics, Bandung Institute of Technology
Jl. Ganesha no. 10, Bandung, Indonesia
[2] Department of Electrical Engineering, Politeknik Negeri Bandung
Jl. Gegerkalong Hilir, Ds.Ciwaruga Kotak Pos 1234 Bandung 40012, Phone: +62-22-2013789
*Corresponding author, e-mail: noorcholis@polban.ac.id

Abstract

Safety and comfort are two important aspects that must be achieved at the time of driving. The level of safety when driving can be improved by reducing driver (human) error. An auxiliary device is required by the driver to avoid an accident. Advanced Driver Assistance Systems (ADASs) are systems designed to help the driver in the driving process. The Overtaking Assistance System (OAS) is a subsystem of an ADAS that functions by assisting the driver in the overtaking process. This paper presents a decision-making system based on fuzzy logic for the OAS. The inputs in a decision-making system are the distance of the ego vehicle and the vehicle that will be overtaken as well as the distance of the ego vehicle and the vehicle in the other lane. The decisions involved in a decision-making system concern the vehicle performing the approaching, tailgating, and overtaking. The results from hardware simulation using a remote control car show that the decision-making system algorithm can work according to the design.

Keywords*: advanced driver assistance system, overtaking assistant system, fuzzy logic, overtaking decision making*

1. Introduction

Traffic safety is a global issue that has received a great deal of attention from various parties. Globally, 1.3 million people each year or 3,000 persons per day die as a result of traffic accidents. The WHO has published that deaths from traffic accidents are treated as one of the non-communicable diseases with the highest mortality level. By the year 2030 road traffic accidents are estimated to be the fifth most common cause of death in the world, after heart disease, strokes, emphysema, and other respiratory tract infections [1].

About 4-10% of all traffic accidents are caused by overtaking [2]. Sequentially from the most, the types of accident that occur through overtaking are a collision with a vehicle that is overtaking when someone is turning right, a collision with a vehicle from the opposite direction, a sideswipe crash while passing, and a collision while returning to the original lane [3].

Efforts are being made to reduce the number of traffic accidents involving fixing vehicles and improve infrastructure technologies as well as to increase the awareness and expertise of drivers. In terms of road transport, driver error contributes to 75% of all roadway crashes [4].

An Advanced Driver Assistance System (ADAS) or intelligent Driver Assistance System (IDAS) is an existing system in a vehicle that allows the driver to achieve their objectives with less stress, more safely, more comfortably, and efficiently in the pathway [5]. The ADAS is a development of the driver information system and driver warning system. Both these fields continue to be developed, among others, by using GPS as in [6]-[8]. ADAS development is inseparable from the concept of Integrated Human Machine Systems (IHMS) where the intelligent assistant system’s role is to help the operator to operate the machine [9].

ADAS can be grouped according to three phases of driving. [10]

a. Environment detection (recognition)
b. Decision making (judgment)
c. Implementation of the action (operation).

An example of an ADAS that helps in environment recognition is Lane Departure Warning (LDP). An example of decision making is the Overtaking Assistance System (OAS). Adaptive Cruise Control (ACC) is an example of the action phase.

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The OAS is a subsystem of the ADAS and functions by assisting the driver in the overtaking process. The transition between different levels of the OAS is shown in

Figure *1*. In the cooperative assistance system some assistance systems in different vehicles can work together by means of communication, such as the Vehicular Ad hoc NETwork (VANET). Some VANET research has been conducted by [11],[12].

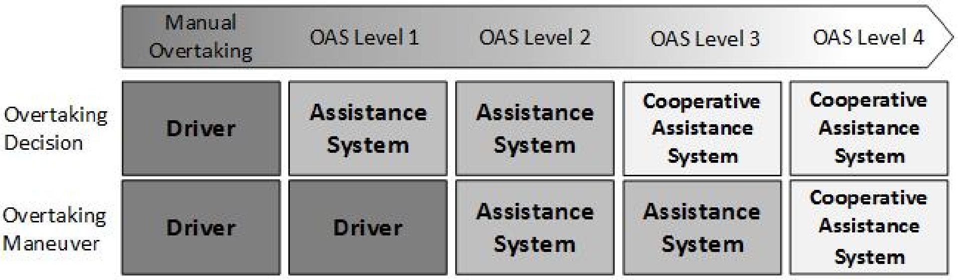

Figure 1. Transition between different levels of OAS

In general, research on the OAS includes the development of part of the decision making system, as carried out by [13] and [14], as well as development of the OAS for autonomous overtaking, as in [15],[16]. Some of the methods used in the development of the OAS include, among others, fuzzy logic (for example, [17]-[19]), reinforcement learning (for example, [20],[21]), and model predictive control (for example, [22]). Radar and lidar sensors are two commonly items used in the OAS. Currently, a vision-based OAS has also been developed (for example, [23],[24]).

Research to develop the OAS, among others, has been conducted by the Continental Corporation in cooperation with the Technical University Darmstadt (TU Darmstadt), along with the Research on Overtaking and Advanced Driver Assistance Systems (ROADAS) by TU Delft, and the University of Porto in Portugal.

Development of the OAS will be the basis for the development of driverless vehicles, like Google Car. It is estimated that by 2020 driverless vehicles will be marketed by car manufacturers such as BMW, Nissan, Toyota, Ford, and Mercedes.

2. Research Method

The OAS based on fuzzy logic is developed with due regard to overtaking on unidirectional and bidirectional roads. In certain situations the overtaking manoeuvre cannot be performed. Therefore, this study also takes note of pending/delayed overtaking.

2.1. Overtaking manoeuvre

The overtaking strategy that is used as a reference in the development of the OAS in this study is normal/accelerative. The normal strategy in overtaking is mostly used by the driver [25],[26]. The strategy can be divided into approaching, tailgating, lane changing, passing, and lane returning.

Overtaking on a unidirectional road is illustrated in

Figure 2. Car A (the ego car/vehicle) will overtake car B, while car C is in the right lane. The process will begin with car A approaching car B. If lane changing is not possible then car A will tailgate. Car A will change to the right lane if the situation allows (if the distance to cars B and C is enough), and also the speed of car B is still acceptable for overtaking. At the time of passing car A's speed will increase so that it is higher than the speed of car B. The final stage of overtaking is returning to the lane again.

Figure 3 shows the process of overtaking on a bidirectional road. On a bidirectional road, car C runs in the opposite direction to cars A and B. The overtaking manoeuvre on a bidirectional road is more dangerous than overtaking on a unidirectional road because a delay in the passing stage will result in a collision with car C.

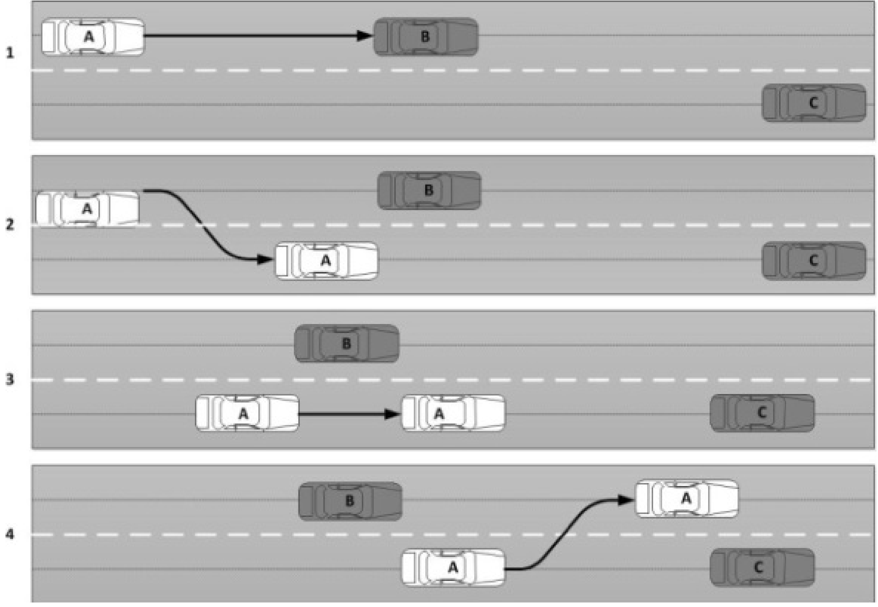

Figure 2. Overtaking on unidirectional road

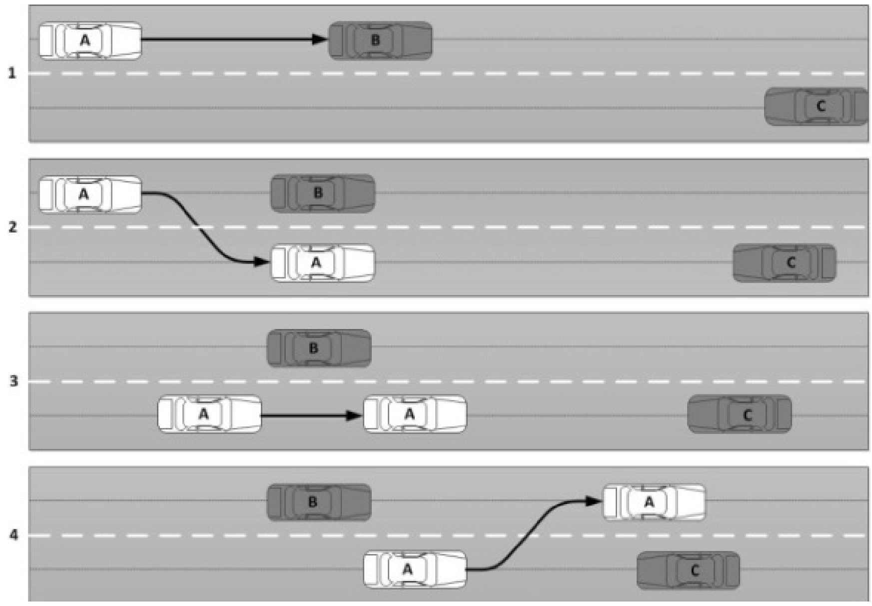

Figure 3. Overtaking on bidirectional road

2.2. Overtaking decision making

Decision making in the overtaking process is carried out in the approaching stage or during the tailgating stage. Improper decision making will possibly result in a collision when lane changing, passing, or lane returning.

A collision when lane changing is due to lack of attention to speed or/and distance of car B. A collision in the passing stage and when lane returning is due to lack of attention to the speed or/and distance of cars B and C.

Two variables that must be considered in the development of the OAS decision-making system is the speed and distance. In this study, the speeds of cars B and C are considered fixed so that only the distance is considered. A restriction when considering this problem is due to the limited sensors that are used in the simulation.

2.3. Overtaking decision making based on fuzzy Logic

The decision-making system based on fuzzy logic is designed in this study using the Mamdani method. Input membership functions at the OAS are the distance of car A and car B (distance1) and the distance of car A and car C (distance2).

Figure *4* and

Figure *5* show the membership functions of distance1 and distance2.

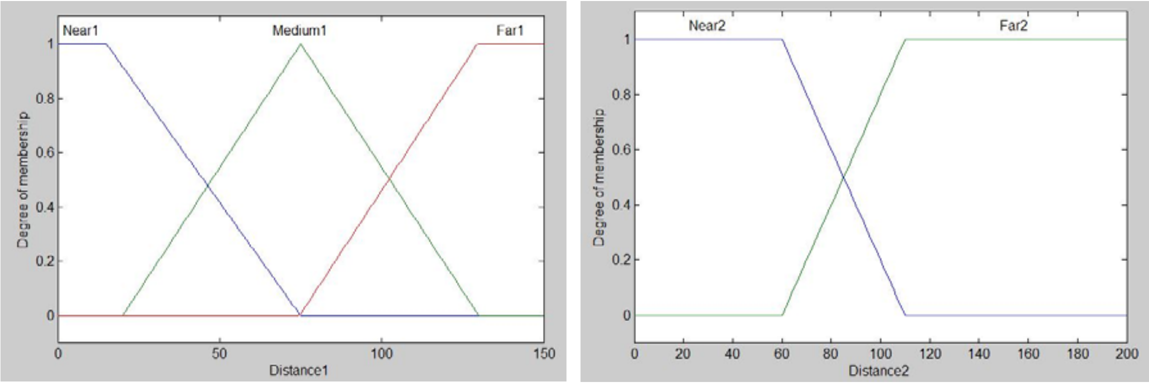

Figure 4. Membership function of distance1 Figure 5. Membership function of distance2

Figure 6 shows the output membership function the values of which are from 0 to 3 and are divided into three types, namely approaching, tailgating, and overtaking. The rules base used in the decision-making system can be seen in Table 1.

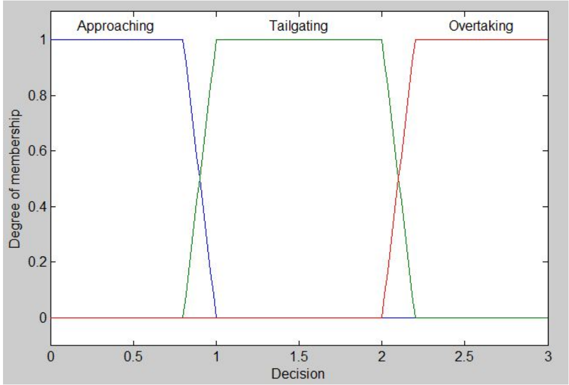

Figure 6. Membership function of output

Table 1. Rules base

		Distance2	
		Near2	Far2
Distance1	Near1	Tailgating	Tailgating
	Medium1	Tailgating	Overtaking
	Far1	Approaching	Approaching

The results of the decision-making system design using Matlab software can be seen in Figure 7.

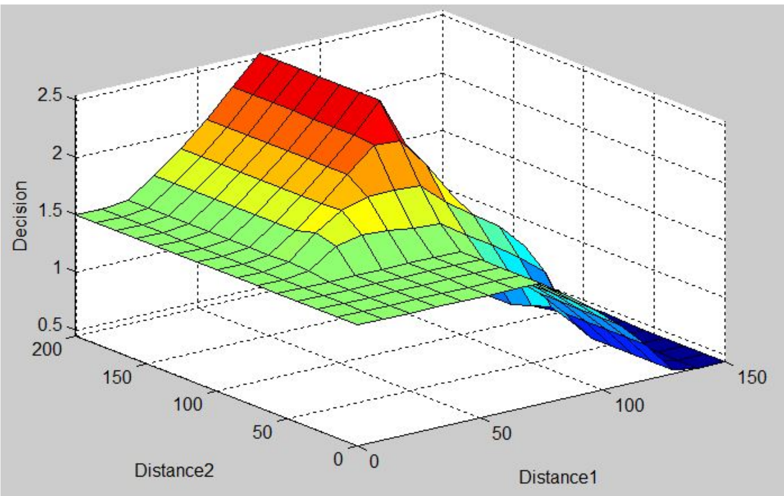

Figure 7. The relationship of input and output

2.4. Hardware simulation

The block diagram of the OAS hardware simulation is shown in Figure 8. OAS hardware simulation is built using a remote control car, as shown in *Figure 9* [27]. In the hardware simulation used two ultrasonic sensors are mounted on the front and side of the car. The sensor on the front is used to measure the distance to the car in front of the ego car, while a sensor on the side of the car is used to measure the distance to the car in the other lane.

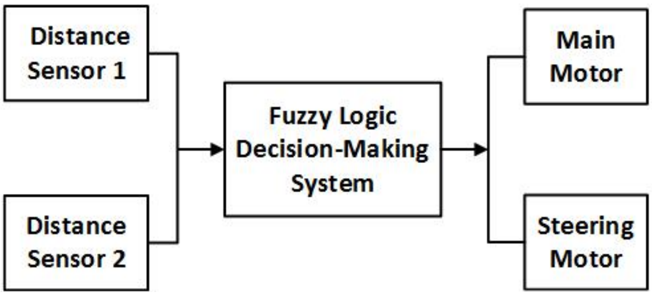

Figure 8. Block diagram of OAS hardware simulation

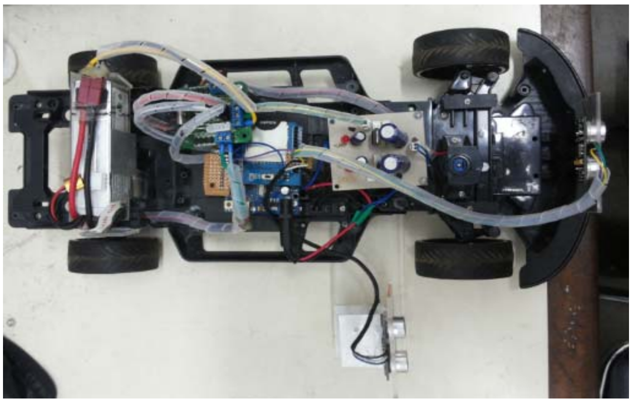

Figure 9. Remote control car

The microcontroller system that is used to control a remote control car and to implement the algorithm for decision-making system is the Arduino Uno R3. The ATmega328 microcontroller-based systems and library functions for fuzzy logic-based control can be added. The inference method used in the library functions is the Min-Max Mamdani method with the centre of the area for the defuzzification process.

In this simulation we used a main motor and steering motor. The main motor is the motor that becomes the prime mover remote control car and its speed can be controlled. The steering motor is the motor that can be used to control the direction of the remote control car. Both motors are controlled using Pulse Width Modulation (PWM) signals. Important data obtained during the testing of the hardware simulator is stored in a Secure Digital (SD) memory card via the Arduino shield.

3. Results and Analysis

The scenario used in the testing of the hardware simulator is as follows.

1. Overtaking on a unidirectional road
2. Overtaking on a bidirectional road
3. Delayed overtaking.

In the test two other remote control cars are used, the speeds of which can be set according as required. The ego car or car A is the car that is equipped with the OAS, car B is the car that will be overtaken, and car C is the car in the other lane.

3.1. Overtaking on a unidirectional road

In this test cars A, B, and C are running in the same direction. Car A is behind car B and car C is in another lane. It is expected that the situation will allow car A to overtake car B while taking into consideration car C.

The test results show a success rate (safety index) of 90%. A graph that illustrates the relationship between distance1, distance2, the fuzzy output, and the speed can be seen in Figure 10.

At the beginning of the test in this scenario car A will approach car B. At this time when the output value of the decision-making system is less than 1 this means that car A is the one approaching. At 160 ms distance1 and distance2 allow the overtaking. At this time the OAS decision-making system output is worth more than 2. After overtaking sensor 1 will detect an object, or non car, and sensor 2 will detect car C.

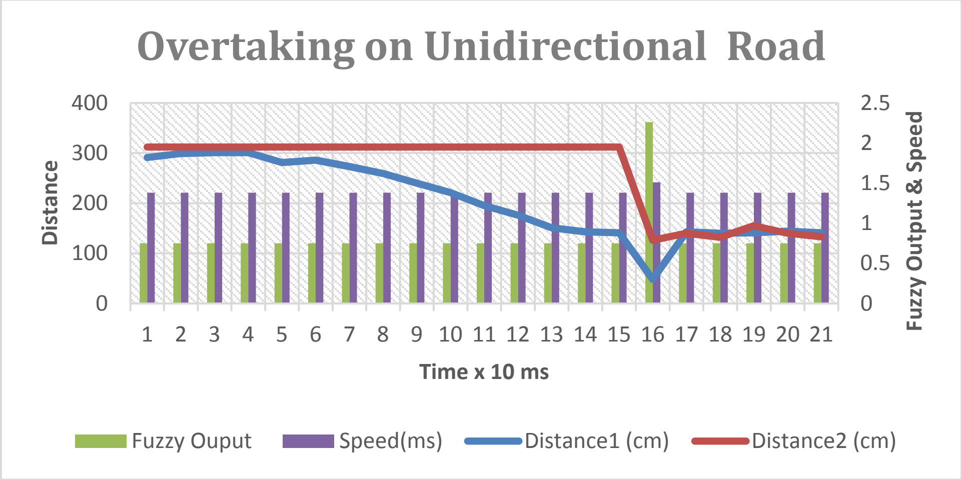

Figure 10. Test results of overtaking on unidirectional road

3.2. Overtaking on a bidirectional road

In this test cars A and B are running in the same direction, whereas car C is driving in the opposite direction in the right lane. It is expected that the situation will allow car A to overtake car B while considering car C.

The test results show a safety index of 80%. A graph that illustrates the relationship between distance1, distance2, the fuzzy output, and the speed can be seen in Figure 11.

In Figure 11 it can be seen that at the time at 80 ms the positions of cars A, B, and C allow overtaking. The decision-making system's output at this time is more than 2; this means car A is the one overtaking. When car A is passing car B, the sensor 1 detects car C (not car B) while sensor 2 detects objects other than cars.

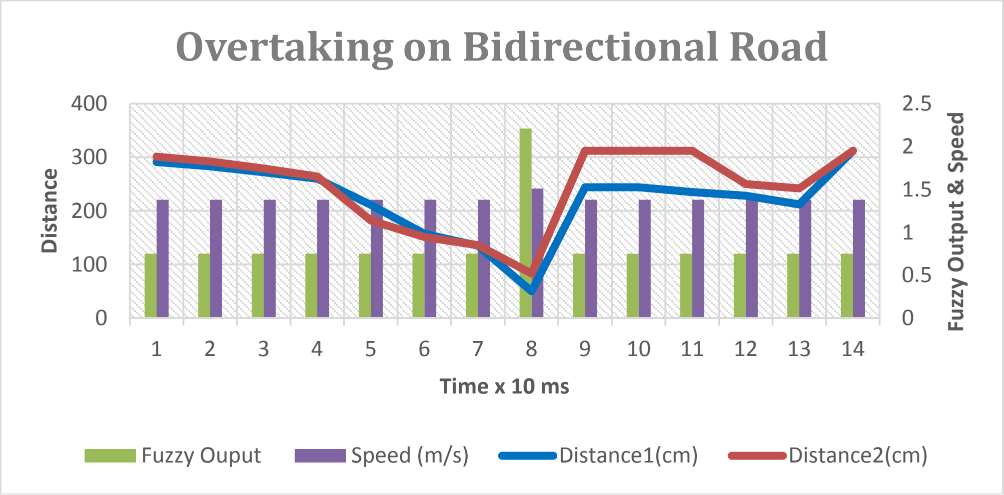

Figure 11. Test results of overtaking on bidirectional road

3.3. Overtaking delayed

In this test cars A and B are running in the same direction, whereas car C is driving in the opposite direction in the right lane. It is expected that the situation does not allow car A to overtake car B. The overtaking manoeuvre will be delayed by car A reducing its speed and then trailing (tailgating) car B. The test results can be seen in Figure 12.

At the beginning of the test, cars B and C are at a certain distance from car A. When the decision-making system's output is worth less than 1 this means that car A is in the approaching process. When car A is near to car B, overtaking still cannot be undertaken because car C is too close in distance. At this time the decision-making system's output value is between 1 and 2, which means the system is tailgating or delaying the overtaking. A delay in overtaking is executed by car A, which adopts a lower speed so it does not hit car B.

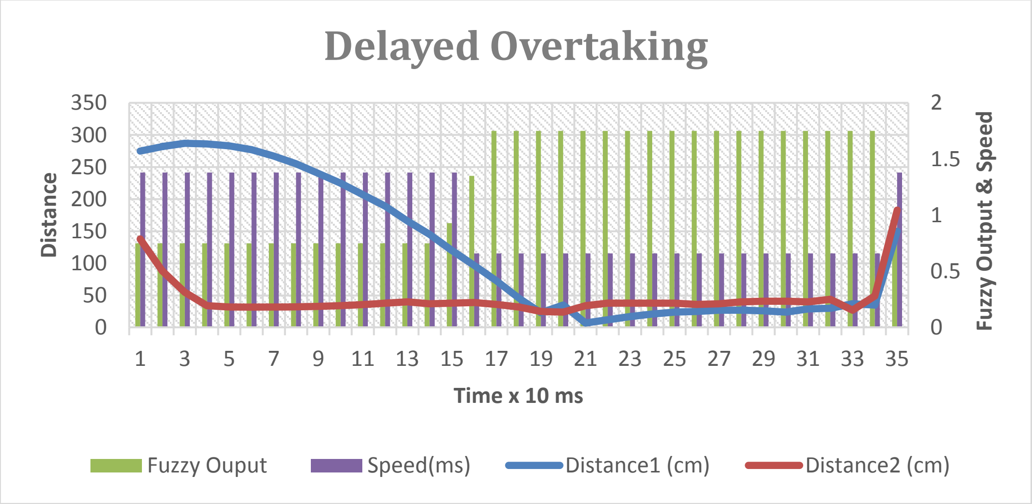

Figure 12. Test results of delayed overtaking

4. Conclusion

The results show that the decision-making system based on fuzzy logic can be applied to the OAS. Based on the test the safety index value of overtaking on a unidirectional road is 90% whereas on a bidirectional road it is 80%.

The algorithm developed also allows delayed overtaking if the situation does not allow the overtaking manoeuvre. The algorithm developed still needs to be enhanced, among other procedures, by adding the input variables for the cars' speeds.

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