Object Detection System in Blind Spot Dump Truck Area Using Fuzzy Logic with Sugeno Method

Nenny Anggraini
Department of Informatics
Faculty of Science and Technology
State Islamic University of Syarif Hidayatullah Jakarta
Jakarta, Indonesia
nenny.anggraini@uinjkt.ac.id

Muhamad Vicky
Department of Informatics
Faculty of Science and Technology State
State Islamic University of Syarif Hidayatullah Jakarta
Jakarta, Indonesia
muhamad.vicky16@mhs.uinjkt.ac.id

Imam Marzuki Shofi
Department of Informatics
Faculty of Science and Technology State
State Islamic University of Syarif Hidayatullah Jakarta
Jakarta, Indonesia
imam@uinjkt.ac.id

Luh Kesuma Wardhani
Department of Informatics
Faculty of Science and Technology
State Islamic University of Syarif Hidayatullah Jakarta
Jakarta, Indonesia
luhkesuma@uinjkt.ac.id

Nashrul Hakiem
Department of Informatics
Faculty of Science and Technology
State Islamic University of Syarif Hidayatullah Jakarta
Jakarta, Indonesia
hakiem@uinjkt.ac.id

Tabah Rosyadi
Department of Informatics
Faculty of Science and Technology
State Islamic University of Syarif Hidayatullah Jakarta
Jakarta, Indonesia
tabah.rosyadi@uinjkt.ac.id

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***Abstract*— Dump Truck has an area that cannot be seen by the drivers, which is called the blind spot area. The reason is the construction of the vehicle, the bigger the vehicle, the bigger the blind spot. Based on the literature, fuzzy logic with the Sugeno method can provide decisions/reasoning that are easier for humans to understand. In this research, an object detection system was developed in the blind spot dump truck area using Fuzzy Logic with the Sugeno method. This object detection system uses 5 ultrasonic sensors as a detection device (input), as well as a buzzer and LED as a warning (output). Based on the results of research that has been tested using white-box testing, each existing test case has been tested and validated. With the closest testing distance of 2 cm, and the farthest distance from detection is 300 cm, and testing on black-box testing at the user level is under the function with a value of 100%.**

Keywords— Fuzzy Logic, Sugeno Method, Blind Spot, Dump Truck, LED, Buzzer, Blackbox Testing, Whitebox Testing.

I. INTRODUCTION

A dump truck is a vehicle used to transport materials such as sand, gravel, or soil for construction purposes. the contents of the cargo area filled by a loader such as a backhoe, while to unload the load, this heavy equipment can work alone by lifting the body using hydraulic technology[1]. According to Jusri Pulubuhu, Founder and Training Director of Jakarta Defensive Driving Consulting (JDDC), there is a dangerous area for dump trucks and other vehicles, namely blind spots. Blind spots are areas around the vehicle, which fail to be seen or are obstructed from being seen by the driver. One of the causes of blind spots is vehicle construction, the bigger the vehicle, the bigger the blind spot. Every vehicle has a blind spot, including motorbikes. The biggest blind spot of a dump truck is on the back because it is blocked by cargo and cannot see it through the rearview mirror like in a passenger car[2].

There have been several cases of accidents that have occurred due to blind spots, such as what happened in 2018, in the West Jakarta area, where a motorbike rider was run over when he was about to overtake a dump truck[2]. According to Kristono, there are not many accidents caused by dump trucks, even data from the National Police Corps show that the "giant" vehicles are relatively less involved in accidents that cause death. This is because the vehicles causing the most accidents are still motorbikes with a total of 35,980 accidents until the second quarter of 2019. Meanwhile, trucks are in third place in the second quarter of 2019 with 3,700 accidents. However, even a few accidents caused by dump trucks usually have a massive impact on motorcycle accidents[3].

An interview was conducted with the truck driver. According to him, for the object detection device in the blind spot, some have used it, especially in large companies, but it is still not enough, because the output is only a real-time video on the screen, and usually there is no reminder in the form of a sound like an alarm. From these factors, to meet safety needs, it is necessary to have a device that can provide a warning in the form of a sound such as an alarm. There are several blind spot detector products on the market, including the "Car Blind Spot Assist For Chevrolet Captiva Parking Sensor Car" this tool has been traded through the online shop Tokopedia[4] with the price of Rp. 451,000 / sensor. It uses to detect blind spots on the car and also helps to park the car. However, based on observations, the authors still have not found a similar product for the dump truck.

There are several studies related to the creation of an object detection system in the blind spot dump truck area[5][6], such as in research by Adha, et al, producing an automatic turn signal system, and detection of blind spots on motorbikes using Arduino, in its implementation the turn signal will turn off automatically when it is finished turning. and also this system can detect objects in the motor blind spot with a distance of <= 144cm and can turn off the motor engine when it is on a 15-degree slope from the ground or falls[7]. Furthermore, the research of Heldiana, et al, produced a distance adjusting brake control on an electric car, in the process using the fuzzy logic method. By determining the input into 4 linguistic variables and 16 variables for the output[8].

Fuzzy Logic can be used to convey information from ambiguous data. There are several methods in fuzzy logic, namely; the Tsukamoto method, the Mamdani method, and

the Sugeno method[9]. Sugeno method is a decision-making method to determine the best alternative from some alternatives based on certain criteria. Criteria are usually in the form of measures, rules, or standards used in decision-making [10]. Fuzzy logic in this study is used to determine the decision of an object that is near, medium, or far from the dump truck.

Suardika, et al research stated that of the three methods owned by fuzzy logic, the Sugeno method has the smallest error value compared to other methods, so based on the results obtained the Sugeno method is best used in determining decisions[9]. From the results of the analysis, literature study, and interviews, the proposed solution based on the existing problems, the author makes a system that can detect objects in the blind spot area for dump trucks with the title of object detection systems in the blind spot dump truck area using fuzzy logic with the Sugeno method.

II. THEORY

A. *Object Detection*

According to Elisawati, object detection is a tool used to detect the distance of objects in front of the user[11]. And according to Riandi, et al. An object can be detected and its distance is known using a sensor. One of the sensors that can be used is the HC-SR04 ultrasonic sensor which can detect objects and can know the distance of the object, besides that the HC-SR04 ultrasonic sensor is the cheapest in its class[12].

B. *Fuzzy Logic*

Lutfi Zadeh is the person who first introduced fuzzy, in 1960 at the University of California Berkeley. Boolean logic does not have high accuracy, it only has 0 and 1, that's why this logic was created. A logic that has a level of fuzziness between true and false is a definition of fuzzy itself. between true or false is a value that is owned by fuzzy logic, which has a level of fuzziness. In fuzzy theory, a truth value and a false value have membership weights, because in fuzzy a value can be true and false at the same time. [10].

C. *Sugeno Method*

Takagi Sugeno Kang 1985 introduced a method called the Sugeno method which is one of the methods in fuzzy logic. In this method, a mathematical calculation is added as part of THEN to improve the weaknesses of pure fuzzy. The changes made have Weighted Average Values on the fuzzy IF-THEN rules. In Fuzzy Sugeno there is a weakness in the THEN section, with mathematical calculations can provide a natural framework for translating real human knowledge. [10][13].

III. RESEARCH METHODOLOGY

A. Method of collecting data

1. Primary data was used in the form of observations and interviews. In the observation stage which was carried out from December 2019 to February 2020, the researcher conducted observations of the systems that were already running on the dump truck and also the tools that were already circulating in the market or those already installed in the dump truck. And at the interview stage was conducted with a respondent who works as a dump truck driver who has experience as a dump truck driver for 6 years. The interview was conducted on January 11, 2020. The interview aims to determine the obstacles that the dump truck driver has with the blind spot object when driving.
2. Secondary data used is in the form of a literature study. At the literature study stage, the author looks for references related to research. Reference searches are carried out online via the internet, such as news portals and ebooks. After obtaining these references, various information needed in this study was selected.

B. Systems Development Method

In developing this system, using the Prototyping method. The reason the authors use this method is that it is suitable for developing a tool in a short processing time. There are 5 stages of prototyping[14] namely:

1. Communication.
   At this stage, direct discussions are held with experts and dump truck drivers to find out an overview of the system needed, which can then be used as material for consideration in building the needed system.
2. Requirements Gathering.
   At this stage, it explains what the system requirements are, which includes defining the scope, analyzing the running system, analyzing the proposed system, analyzing system functional requirements, and analyzing software and hardware. Which is described as follows:
   a. Define the Scope
      The scope of this research is a dump truck driver or a company that has a dump truck. The object detection system proposed provides a feature that can detect objects in the dump truck's blind spot, namely the left, right, front and rear sides, by providing a notification on the truck dashboard via a box that contains an LED and a buzzer[15] that will light up and sound when there is an object close to the area of the blind spot.
   b. Analysis of the Blind Spot Dump Truck
      On the front side, to the right, the driver can still clearly see the object in front of him, but if the object is on the left, it is quite difficult to see the object (blind spot). On the backside, all the blind spots are not visible. On the left and right, the distance <100 cm can still be seen with the help of the mirror, but the rest cannot be seen.
   c. Object Detection Range Analysis Based on Ultrasonic Specifications HC-SR04
      Based on the results of the literature study conducted, it was determined that the angle that could be detected by the ultrasonic HC-SR04 was 15º.
   d. Current System Analysis
      Based on the analysis that has been done, the system that has been running so far can be seen in Figures 1 & 2.

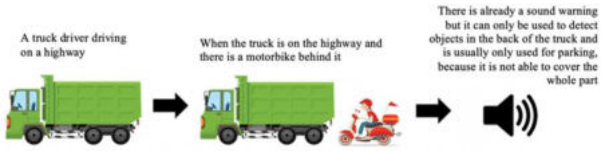


Fig 1. Current System 1

In the picture above the dump truck driver is on the road, and there is a motorbike rider behind him, the buzzer sounds, but when apart from that position, the buzzer does not sound.

Fig 2. Current System 2

In the picture above, the running system is almost the same as the running system in Figure 1, the difference is in the output. Figure 1 is output in the form of sound, while Figure 2 is output in the form of video.

e. Proposed System Analysis

In this study, it was concluded that the dump truck driver considered that no system could detect objects in each blind spot (left, right, front and rear) of the vehicle and make him know if there were objects in the blind spot. As one solution to this problem, we propose an object detection system in the blind spot dump truck area using fuzzy logic with the Sugeno method. The following is system proposal can be seen in Figure 3.

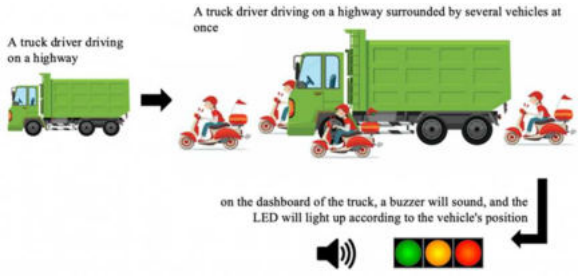


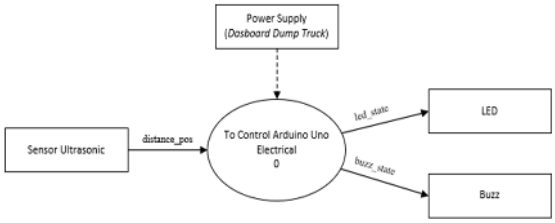
Fig 3. Proposed System

shows the user's activity while driving using a system or object detection device in the blind spot area using fuzzy logic with the Sugeno method. The user turns on the tool on the dashboard, and when an object is detected in the blind spot, the LED indicator and buzzer will light up according to the object's position. If the object is in range, more than 2-3 meters, it will light green light, if it is more than 1-2 meters it will light up a yellow light, and if it is under one meter it will light up a red light, accompanied by an alarm sound from the buzzer.

f. Functional Requirements Analysis

At this stage, an analysis of the functional requirements of the system is carried out. The need for the main function of the object detection system/tool on the blind spot dump truck will be presented in the Context Diagram (CD), Data Flow Diagram (DFD), Control Flow Diagram (CFD), and State Transition Diagram (STD). The following is the process in the Context Diagram.

Fig 4. Context Diagram



The figure above shows data through external input that goes into the Arduino Uno system process, the data comes from one external input, namely the ultrasonic sensor. After the system receives it, the data is processed to produce output data to the LED and buzzer.

g. Hardware Requirements Analysis

In making the object detection system in this blind spot dump truck. Some hardware or hardware is required. Namely Arduino Uno, ultrasonic sensor, buzzer, and LED.

h. Software Requirements Analysis

In addition to the hardware that has been mentioned, the software is also needed to support hardware performance so that it runs as expected. The following software is needed in making an object detection system in the blind spot dump truck area. Arduino Uno IDE, Fritzing, Microsoft Visio, Adobe Illustrator.

C. *System Building Stage*

Building a prototype is a temporary design of a system that is made as an initial stage before being converted into code. Before assembling it into a unified system, first, make a system design architecture scenario on a hardware circuit.

The authors created a block diagram for the entire object detection system in the blind spot dump truck area shown in the image below.

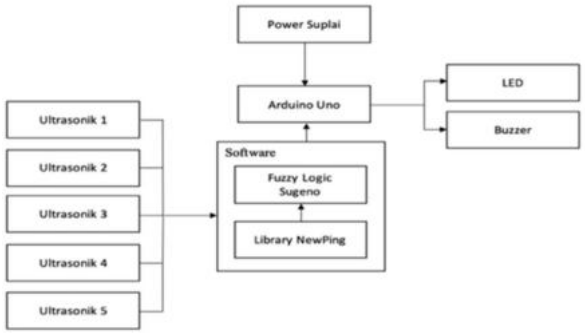


Fig 5. Block Diagram

If the ultrasonic sensor 1,2,3 sends data, the fuzzy logic process is ignored and is processed only by the NewPing library. And if ultrasonic 4 and 5 transmit the data, the NewPing and the fuzzy logic process will be carried out.

The following is a display of the object detection device in the blind spot dump truck area.

1. The Display of object detection tool on the dump truck's blind spot area
   Arrangement of hardware components and modules according to the schematic that has been made. Integration between modules is also carried out by referring to predetermined pin configurations. Here's a minimalist look at the main components.

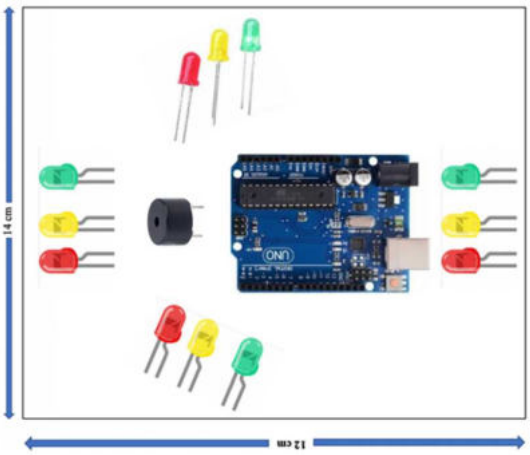


Fig 6. Composition of Components

2. The appearance of the tool after packaging
   There are two devices in this system, namely the main device and the supporting device. The main equipment is placed on the dump truck's dashboard and the supporting devices are placed at each predetermined point. Here's the picture.

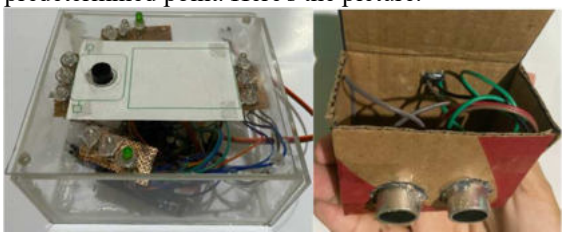


Fig 7. Display of The Device

D. Stage Encoding System

The next stage is coding the system. Refers to the analysis of the proposed system, which uses several hardware functions and libraries from the Arduino Uno[17] that must be programmed and connected to run as their function. The steps are:

1. Arduino Uno coding with ultrasonic, LED, and Buzzer.
2. Coding using the NewPing library and conditioning.
3. Fuzzy logic implementation coding using the Sugeno method.

   There are several code stages to implement Fuzzy logic using the Sugeno method. Which consists of several stages, namely:

   3.1 Fuzzy set formation

   There are 2 input variables in this study, namely ultrasonic sensor 4 and ultrasonic sensor 5. Each input variable is further divided into 3 fuzzy sets. A Fuzzy set is used to represent conditions in a fuzzy variable. From each obscure set that is formed, each of them has a domain whose value is contained in the universe of conversation and may be operated in an obscure set. The following is a table of the universe of fuzzy set talks[18].

TABLE I. FUZZY SET TALKING UNIVERSE

Functions	Variable Names	Fuzzy Set Name	Universe	Domain
Inputs	Ultrasonic 4	Low	[2, 300]	[2, 150]
		Medium		[100, 250]
		High		[200, 300]
	Ultrasonic 5	Low		[2, 150]
		Medium		[100, 250]
		High		[200, 300]
Outputs	Distance	Low		[2, 150]
		Medium		[100, 250]
		High		[200, 300]

After a membership function is created. The membership function is the mapping of data input points in a fuzzy set into the value or degree of membership which has an interval from 0 to 1. In this study, the membership function is obtained through the function approach. The function used is through the trapezoidal shape representation.

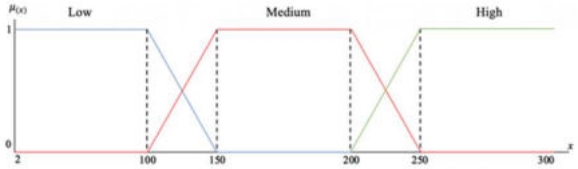


Fig 8. Ultrasonic Membership Functions I

Based on table 1, ultrasonic variables are divided into three fuzzy sets, namely near, medium, and far. To present the ultrasonic variable one, a curve in the shape of the left shoulder is used for the near variable, the trapezoid curve for the medium variable, and the right shoulder curve for the far variable. The x-axis is the input value for the ultrasonic variable one, while $\mu(x)$ is the membership degree value of the input value.

3.2 Application of the implications

Application of the implication function uses the MIN function

3.3 Composition of Rules

At this stage, the fuzzy rules will be created. Making fuzzy rules in determining output based on ultrasonic variables 4 and 5, using the Sugeno method. This rule is made to express the relationship between input and output so that it can be formed into 9 combinations of rules. The formation of rules resulting from the combination of each of these conditions is known as the decision rule. With concern to the MIN function, which is to take the minimum value of the two inputs. Each rule consists

of 2 antecedents with the operator used to connect the AND operator while the one that maps between the input and output is IF-THEN. So that the resulting table below:

TABLE II. RULES OF FUZZY

No		Ultrasonic 4		Ultrasonic 5		Output
R1	If	Near	And	Near	Then	Near
R2	If	Near	And	Medium	Then	Near
R3	If	Near	And	Far	Then	Near
R4	If	Medium	And	Near	Then	Near
R5	If	Medium	And	Medium	Then	Medium
R6	If	Medium	And	Far	Then	Medium
R7	If	Far	And	Near	Then	Near
R8	If	Far	And	Medium	Then	Medium
R9	If	Far	And	Far	Then	Far

3.4 Defuzzification

The method used for defuzzification is the weighted average, which calculates the average of all inputs.

E. System Testing Stage

After coding, the researchers tested the results of the system implementation. This test is carried out at the system testing level. And user acceptance test. The methods used in testing are white-box testing and black-box testing[19].

1. *White Box – Basis Path Testing*

In system testing using white-box testing is carried out to ensure that the source code used has been implemented correctly. The following is a graph of the test results:

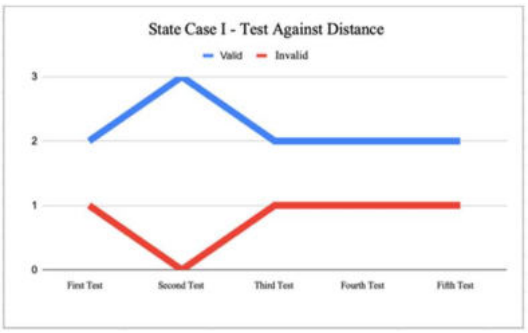


Fig 9. Chart Test Case I

Figure 9 shows a graph of the test result data on distance, it can be seen in the test graph that there is at least one in each test that is not validated, this happens because HC-SR04 ultrasonic is not able to detect the distance accurately. Meanwhile, the evaluation of each line of code has been evaluated as a whole.

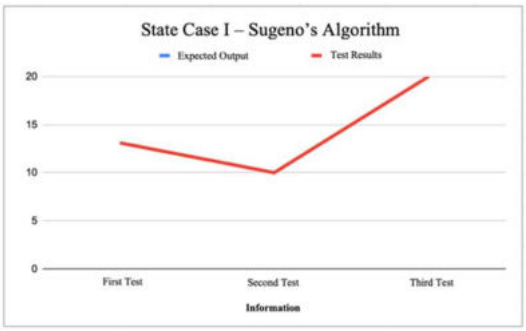


Fig 10. Chart Test Case II

Figure 10 shows a graph of the data from the Test Case II - Sugeno Algorithm test. It can be seen in the test results that the red line covers the blue line which means that the expected output and test results are the same. The expected output results are obtained by calculating manually using the Sugeno algorithm, while the test results are obtained from the system test results. Based on the results of the discussion, it is known that the Sugeno algorithm which is implemented in the code has run correctly.

2. *Black Box Testing – User Acceptance Test*

Based on tests carried out by dump truck drivers through user acceptance tests on the object detection system in the blind spot dump truck area, the data on the results of the functional testing is simplified in the following table.

TABLE III. RESULT OF UAT

Test Numbers	Features	Total Suitability Value/s	
		Yes	No
UAT-01A	Object Detection Function on Left Side	9	0
UAT-02A	Object Detection Function on Right Side	9	0
UAT-03A	Front Side Object Detection Function	9	0
UAT-04A	Back Side Object Detection Function	9	0

Based on table 3, the number of conformity scores obtained in this study is 36. While the level of conformity expected in this user acceptance test is the number of "yes" values plus the number of "no" values, the result is 36 + 0 = 36. Then the percentage level of the suitability of this application with the user is 100%.

IV. RESULT

Based on tests conducted by researchers using a simulation with a scale of 1: 5. The researcher made 3 scenarios, namely, with 20cm, 40cm, and 60cm with each scenario pulling the distance to the right and left, as much as the ultrasonic HC-SR04[20] can detect.

In the figure below, it can be seen that the ultrasonic detection ranges in reality and specifications differ. In fact, the ultrasonic sensor can detect up to 80 ° at 300cm. And on

the back, you can see if there are parts that are still not covered by the system created by the researcher.

And mounting on the back, pulling a distance of 15 cm from the edge to the center, following the farthest reach from the ultrasonic. The one is depicted below[21].

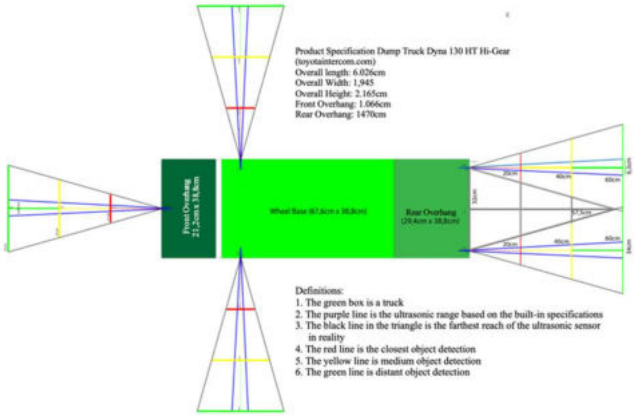


Fig 11. The Detection Range of Objects in Reality with A Scale Of 1: 5

V. Conclusion And Sugestion

A. Conclusions

Based on the results of the research and discussion in the previous chapter, it can be concluded that the object detection system in the blind spot dump truck area was successfully created by implementing the fuzzy algorithm, the Sugeno method, using the HC-SR04 ultrasonic sensor, buzzer, and LED to solve the dump truck driver problem. which requires an object detection device capable of covering the blind spot of the dump truck and capable of providing output in the form of a sound from the buzzer and flashing lights from the LED.

Based on the results of the test base path testing, which is divided into two state cases, namely testing the distance and the Sugeno algorithm, all tests carried out have been successfully validated in line of code, but from the ultrasonic itself, it is still not able to detect it accurately. And based on the results of user-level testing, the presentation of this tool's suitability level with the user is 100%.

B. Suggestions

After making an object detection system in the blind spot dump truck area using fuzzy logic with the Sugeno method, there are several suggestions for readers in the next developer. For example, adding on/off each side of the detection, adding or changing the type of ultrasonic sensor, which detects with a wider range and a high degree of accuracy, and finally separates the output on each side of the detection object.

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