International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING

ISSN:2147-6799 www.ijisae.org Original Research Paper

Intelligent Traffic System for Ambulance Using Fuzzy Control System

Nur Iksan[1], Eva Faza Sabela*[2], Subiyanto[3] , Muhammad Harlanu[4]

Submitted: 10/09/2022 **Accepted:** 20/12/2022

Abstract: Congestion is a seemingly endless problem as vehicle increase is not followed by road width increase. One of the serious problems caused by congestion is ambulance delays in taking patients to the hospital, potentially causing dead on arrival. Therefore, an automatic traffic control system is needed to minimize the dead on arrival rate by prioritizing emergency vehicles, preventing them from being stuck in the traffic light congestion, and helping them to transport the patients faster to receive medical care. The present study designs an intelligent traffic light control system for ambulances using Fuzzy Control System. This traffic light control system was designed for a four-legged intersection using RFID to detect the ambulance load and an infrared sensor to detect the road condition based on the number of vehicles at the intersection. Values from RFID and infrared sensor are used as Fuzzy control system input to obtain the priority value of each lane. The priority value is then transmitted to ESP 32 server to turn the light green on the lane to be passed by the ambulance. If there is one line that has a priority value of 11 and line three has a priority value of 85, then the system will turn green on lane three. So it can be said that overall system performance is 100% optimally successful. This study proves that the fuzzy control system is the right method for determining priorities when a collision occurs between emergency vehicles.

Keywords: *Fuzzy Control System, RFID, Emergency Vehicle, Sensor Infrared, Traffic Light Control*

1. Introduction

United Nations report that Indonesia was the 4th most populous country in the world in 2021 with a 276,361,788 population, which keeps growing yearly. Population increase is associated with the number of motor vehicles [1]. In other words, the population increase in Indonesia will likely lead to increased vehicles. Indonesia Statistics (2019) reports that there were 133 million vehicle units in the country. The country's increasing vehicle number is not followed by the increased road width, causing significant traffic volume increase and congestion.

Congestion has brought various impacts, including ambulance delays in transporting patients to hospitals, eventually causing dead on arrival-- a condition in which a patient passes away before arriving at the hospital. According to the Head of the Ministry of Health's Crisis Center, dr. Budy Sylvna, 70% of death in Indonesia occurs before patients arrive in hospitals (dead on arrival/DOA), and 30% of death occurs after receiving medical assistance in the hospital. A 70% DOA may be accounted for by various factors, including traffic congestion. An ambulance transporting a patient to the hospital may be stuck in the traffic light, prevented from taking the patient on time.

In this regard, it is necessary to minimize the DOA rate by addressing the potential causes. Issues on the increasing number of vehicles could be addressed by increasing the road capacity. However, thorough social, economic, and environmental considerations should be made. Meanwhile, the rigid traffic light system could be engineered to adjust the traffic volume. By applying intelligent traffic lights, a traffic light could be set to adjust to the presence of emergency vehicles [2]. This could be done by implementing Fuzzy Control System in a traffic light by calculating the priority value. In this manner, a traffic light may generate a better decision as Fuzzy Control System is proven suitable for most real-life problems, including traffic light control.

Fuzzy logic has been used to control traffic lights due to its easy-to-understand, simple, and flexible concept, tolerance to inaccurate data, and natural language basis[3]. Mamdani Method is one of the fuzzy inference methods used to solve problems related to traffic optimization[4].

The intelligent traffic light control system for ambulances using Fuzzy logic constitutes the implementation of RFID for prioritized vehicles and improving traffic light responses [5]. Vehicle priority could be set by installing an RFID reader in the intersection and installing the RFID tag on the priority vehicle, i.e., ambulances. In this manner, vehicles with an RFID tag that passes the RFID reader may be detected as an input to identify the ambulance load. After identifying the load, the system reads the road condition through infrared sensors installed at each intersection. The ambulance load and road condition are input for the Fuzzy control system to obtain the priority value according to the rule base. The priority value is transmitted to the ESP server to control the traffic light by turning the traffic light passed by the vehicle with RFID to green.

Electrical Eng., Universitas Negeri Semarang – 50229, Indonesia
ORCID ID : 0000-0001-7028-5273
2 Electrical Eng., Universitas Negeri Semarang – 50229, Indonesia
ORCID ID : 0000-0002-4071-0694
3Electrical Eng., Universitas Negeri Semarang – 50229, Indonesia
ORCID ID : 0000-0001-5890-7017
4Electrical Eng., Universitas Negeri Semarang – 50229, Indonesia
ORCID ID : -
** Corresponding Author Email: vfaza33@students.unnes.ac.id*

2. Related Works

The traffic light control system in Indonesia still works conventionally and cannot prioritize emergency vehicles. Therefore, it is necessary to have an automatic traffic control system to prioritize emergency vehicles, as stipulated in article 134 Law no. 22 of 2009 on Traffic and Transportation concerning priority vehicles on the road [6].

The first issue to address is to find the appropriate method for managing wait time at the traffic light at an intersection to prevent a traffic jam. In order to solve traffic jam problems, the traffic light system should be set to have automatic wait time based on the lane's vehicle density using a sensor. The sensor is placed on every roadside and connected to a microcontroller that controls the traffic system during congestion. The microcontroller decides when to change traffic light settings based on information sent by the sensor [7]. Hence, it is necessary to apply fuzzy technology in controlling the traffic control system since it is capable of transforming the human thinking process into an algorithm using several mathematic models [8]. The fuzzy method is reported to be able to reduce waiting time. A study using the fuzzy method reports that it could reduce traffic congestion and minimize the amount of time wasted by green lights on the empty road, eventually reducing fuel consumption and air and noise pollution. [9]. Mamdani fuzzy rule-based model implementation may improve the operation of an application program[10].

As technologies and problems develop, traffic engineering does not apply fuzzy to reduce wait-time at the intersection. Currently, various sensors are also added to increase the calculation accuracy of the fuzzy method. Input to the fuzzy logic controller could be taken from pictures from cameras installed on every road. The controller sets flexible green lights depending on the number of vehicles in each lane, preventing these vehicles from waiting too long at the traffic light [11].

However, another problem emerges when emergency vehicles pass an intersection. The fuzzy method could be used to determine the lane priority based on the number of queuing vehicles and the presence of emergency vehicles. It could also be used to determine the green signal duration. The system obtains the information from the monitoring module and real-time traffic information collection using wireless sensor network (WSN) [12]. A fuzzy rule base should consider the emergency to manipulate the traffic light into a green signal when an emergency vehicle passes[13].

In order to identify emergency vehicles like ambulance, an identification system is needed. Radio Frequency Identification (RFID) is one of the means to identify the presence of emergency vehicles in an intersection [14]. It could also detect the traffic flow by calculating the RFID tag reading in each vehicle and reduce vehicles' waiting time. [15]. It could also be used to detect stolen cars [16]. In addition to RFID, the infrared sensor could also be used to detect vehicle density in an intersection. Using an infrared sensor, a denser lane may be given higher priority and a longer green signal to expedite the traffic [17]. An Infrared sensor is installed to estimate traffic density by increasing the green light duration to reduce unnecessary queuing time when no vehicles are detected [18].

Based on the literature study, we propose an intelligent traffic light control system for ambulances using Fuzzy logic. It is a representation of Smart Traffic Light using the fuzzy method as the algorithm to manipulate the traffic light when a collision occurs involving two vehicle types and when there is no collision. Applying fuzzy method, it is expected that the traffic light could determine the priority following urgency between the hearse and ambulance. As in the previous study, the present study also applied RFID to detect ambulances in each intersection by installing an RFID tag on the ambulance and an RFID reader in each intersection. The RFID reader is used to identify the ambulance load. An infrared sensor was also installed in each intersection to detect road condition. The use of intelligent traffic lights is expected to detect the presence of emergency vehicles like ambulances, thus reducing the occurrence of Dead on Arriva [19].

3. Research Method

The present study uses fuzzy logic to design an intelligent traffic control system for ambulances. The object of the study was ambulance load type and road condition. This system may play an important role as it could manipulate traffic lights to prioritize ambulances using an infrared sensor, RFID, and fuzzy control system to prevent ambulances from being stuck in a traffic light. This study also considers the possibility of collision between two ambulances at the same time.

4.1 System Design Development

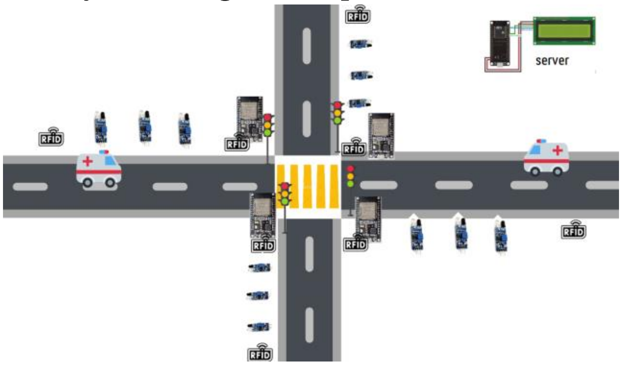

Figure 1. System Design Prototype

An intelligent traffic light system with a fuzzy logic algorithm is designed to prioritize emergency vehicles at the road lane by sending priority values to the server. The system determines a priority lane for ambulances based on the output value. The developed system consisted of an RFID tag installed on an ambulance and two RFID readers on the traffic light. One RFID is used to identify the ambulance loading and the second is used to restart the system after the ambulance passes. Three infrared sensors were used to identify quiet, crowded, and congested road conditions. The proposed system used fuzzy to determine the priority by considering ambulance, hearse, and road conditions. The data were used as the input to the fuzzy control system that determines the emergency vehicle priority. The ESP gateway transmits the priority value to the ESP server. The ESP server then manipulates the traffic light based on the priority value. The priority value is presented in LCD 16X2.

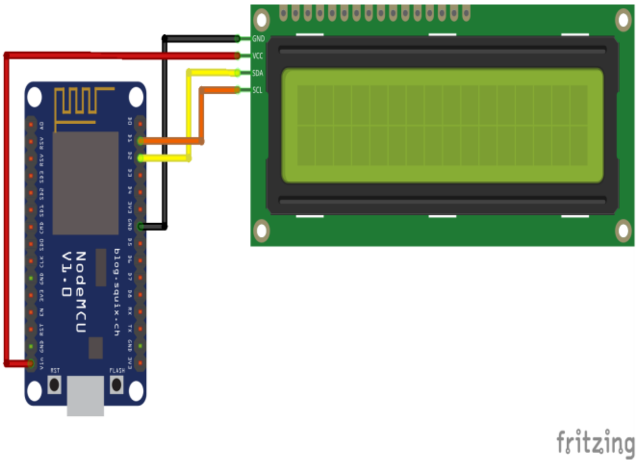

Figure 2. Hardware on Gateway Design

The hardware system prototype on the gateway is useful to determine the priority values when ambulance passes an intersection by combining I/O component of micro controller ESP 32, as displayed in Figure 2 and described in Table 1.

Table 1 Hardware Gateway line in ESP 32

No.	Component Pin	ESP32 Pin destination	GPIO
1	RC522 SDA	G5, G2	GPIO 5 & 2
2	RC522 SCK	618	GPIO 18
3	RC522 MOSI	G23	GPIO 23
4	RC522 MISO	G19	GPIO 19
5	RC522 GND	GND	GND
6	RC522 RST	G4	GPIO 4
7	RC522 3.3V	3.3V	3.3V
8	OLED GND	GND	GND
9	OLED VCC	3.3V	3.3V
10	LCD SDA	G22	GPIO 22
11	LCD SCL	G24	GPIO 24
12	LED GND	GND	GND
13	LED RED	G13	GPIO 13
14	LED YELLOW	G12	GPIO 12
15	LED GREEN	G14	GPIO14
16	IR OUT	G27, G26,G25	GPIO 27,26,25
17	IR GND	GND	GND
18	IR VCC	V5	V5

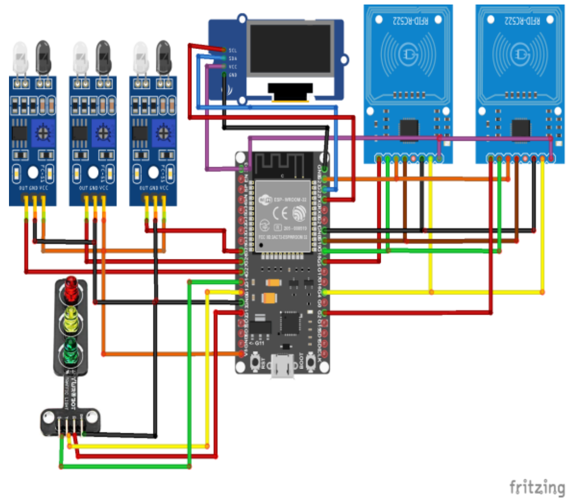

Figure 3. Hardware on Server Design

Server hardware was also designed to manipulate the traffic light after receiving the priority value sent by the gateway. Figure 3 presents the combination of I/O component on the micro controller ESP 32, which is presented in Table 2.

Table 2 Hardware Gateway line in ESP 32

No.	Component Pin	ESP85266 Pin destination	GPIO
1	SDA	D1	GPIO 4
2	SCL	D2	GPIO 5
3	VCC	VIN	VIN
4	GND	GND	GND

4.2 Flowchart System

The flowchart is designed to illustrate the system's process. When an emergency vehicle passes, the server will manipulate the traffic light to be passed by the emergency vehicle. The flowchart also shows how the system manipulate the traffic light during collision at the intersection.

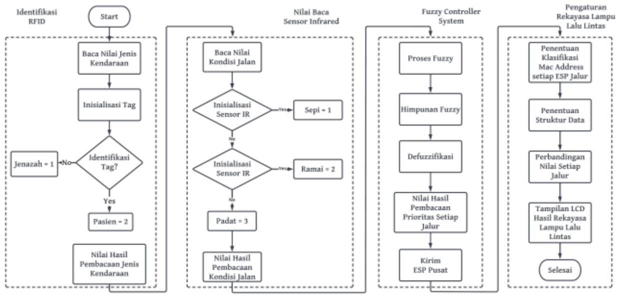

Figure 4. Flowchart System

Figure 4 presents how the system works when an ambulance passes an intersection. First, RFID will detect the ambulance load. Hearse will given score 1 while ambulance will be given score 2. After that, the infrared sensor will read the road condition based on three categorizations: quiet is scored 1, crowded is scored 2, and congested is scored 3. The infrared sensor reading and RFID results are input to be fuzzified to generate lane priority value. This value is presented in LCD 16x2 and used by the server to manipulate the traffic light. The designed system is able to make priority for each gateway in an intersection when collision occurs (two ambulance in different lanes at the intersection at the same time) based on the lane priority value on gateway.

4.3 Priority-Making

Fuzzy Control System is commonly used because the reasoning of fuzzy controller is similar to a traffic police [20]. In this study, fuzzy was used to determine the priority value. The first stage is fuzzification, i.e., a process that turn crisp value to fuzzy value. The fuzzy input included vehicle type and road condition membership functions, while the output was the priority.

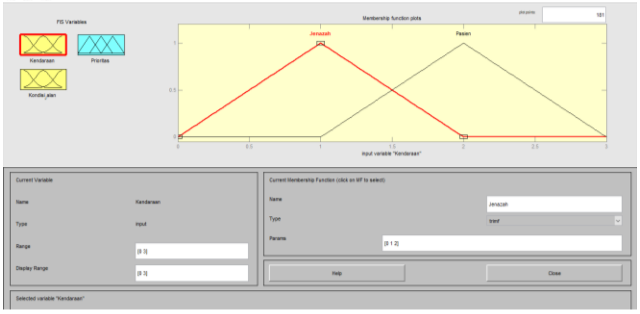

Figure 5. Membership Function: Vehicle Types

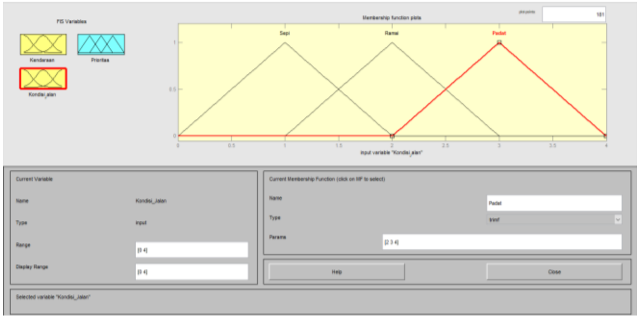

Figure 6. Membership Function: Road condition

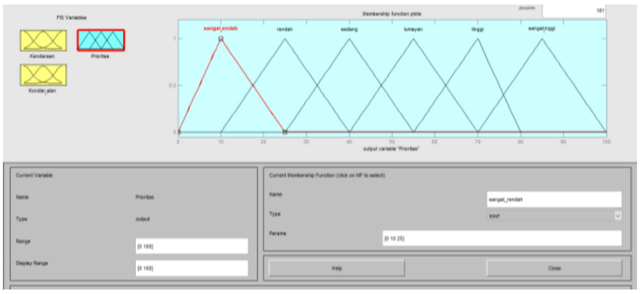

Figure 7. Membership Function: Priority

Once the fuzzification process is done, the fuzzification result is organized based on the rule base to ensure its output fits the design. This process is known as inference. In this system, the controller may increase or decrease the system output to make it fits the set point, thus the controller will take actions to adjust to the output Figure 8 presents the fuzzy rule base used in this study.

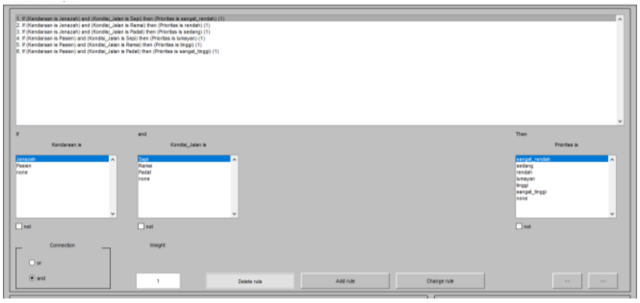

Figure 8. Fuzzy Rule Base

The last step in fuzzy logic system is the defuzzification process. In this step, the data input to fuzzy set is turned into crisp value using operator AND. The next step is to determine the predicate by looking for the lowest value in each combination. The following figure 9 displays the defuzzification

Figure 9. Defuzzification

4. Result and Discussion

This study attempts to find out the system performance and accuracy in manipulating traffic based on the priority. The system performance is evaluated based on several aspects: lane priority, fuzzy value, and traffic light manipulation. These aspects are analyzed in a descriptive quantitative manner.

Prior to the test, a scenario was made. Using the scenario, the program is tested, whether or not it works as expected and to see the system performance in each scenario. In the test scenario, several conditions are used to evaluate the system performance.

The test scenario was divided into three parts: lane priority, which is done to test the system performance in calculating lane priority according to the given condition; fuzzy value test, which is done to test the system response performance and to see the fuzzy control system condition, its stability and effectiveness; and central light manipulation, which is done to test the system performance in organizing and manipulating the traffic light to be passed by emergency vehicles.

4.1 Scenario Priority Estimation

In the priority estimation test, the system was tested for its performance in determining emergency vehicle (ambulance) priority using fuzzy control system of each test scenario. It is also done to see the fuzzy control system performance in determining priority scenario, the infrared sensor performance in reading the road condition, and the RFID performance in identifying ambulance loads. In each test, various conditions were applied.

Three types of test were performed:

1. RFID performance test in determining ambulance load
2. Infrared sensor performance test in reading road condition;

3. And Lane priority estimation

4.1.1 RFID Performance Test

RFID performance test was performance to evaluate the RFID performance in identifying ambulance load, i.e., whether or not RFID identifies the ambulance correctly according to the input.
In each test, various conditions were applied. The conditions in each test also vary in each scenario. RFID performance is considered successful if it could detect hearse (value 1) and ambulance (value 2).
The research result is presented in Figure 10, while the RFID performance test result is presented in Table 4.

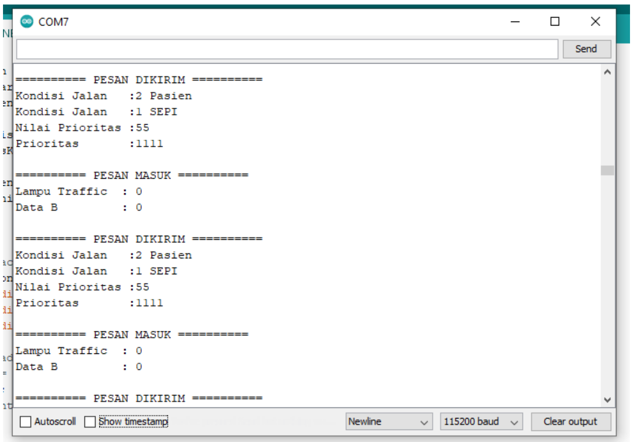

Figure 10. Serial Monitoring RFID Performance Test

Table 3. RFID Performance Test

	RFID Tag Identification Test				Description
	Lane 1	**Lane 2**	**Lane 3**	**Lane 4**	
1st	Hearse	-	-	-	Correct
2nd	Patient	-	-	-	Correct
3rd	-	Hearse	-	-	Correct
4th	-	Patient	-	-	Correct
5th	-	-	Hearse	-	Correct
6th	-	-	Patient	-	Correct
7th	-	-	-	Hearse	Correct
8th	-	-	-	Patient	Correct
9th	Hearse	-	Hearse	-	Correct
10th	-	Hearse	-	Hearse	Correct
11th	Hearse	Patient	-	-	Correct
12th	-	-	Patient	Hearse	Correct
13th	Hearse	Patient	-	Hearse	Correct
14th	Patient	-	Hearse	Patient	Correct

After conducting 14 tests with 2 vehicle types on each lane at an intersection, the result shows that RFID is able to identify the ambulance load. The RFID installed in each lane at the intersection worked optimally with a 100% success rate.

4.1.2 Infrared Sensor Performance Test

The infrared Sensor Performance Test was conducted to see the infrared sensor performance in reading the road condition, i.e., whether or not the sensor could correctly read the road condition according to the input.
In each test, various conditions were applied. The conditions in each test also vary in each scenario. The performance is considered successful if the infrared sensor managed to read according to the given parameter. The road condition parameter value was the sum of sensor IR1 + sensor IR2 + sensor IR3. The quiet road condition was scored 1+0+0 (= 1), crowded road condition was scored 1+1+0 (=2), and congested road condition was scored 1+1+1 (=3).

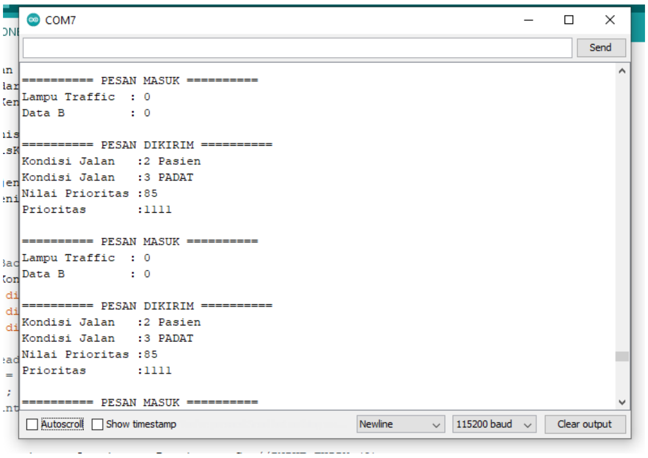

Figure 11. Serial Monitoring Infrared Sensoe Performance Test

Figure 11 presents the result of infrared sensor test. As shown in the figure, the infrared sensor is able to read a quiet road condition. In order to see the system performance, several tests were performed.

Table 4. Infrared Sensor Performance Test

Lane	**Sensor IR1 reading value**	**Sensor IR2 reading value**	**Sensor IR3 reading value**	**Total**	**Desc.**
Lane 1	1	0	0	1	Quiet
Lane 2	0	1	0	1	Quiet
Lane 3	0	0	1	1	Quiet
Lane 4	1	0	0	1	Quiet
Lane 1	1	1	0	2	Crowded
Lane 2	0	1	1	2	Crowded
Lane 3	1	0	1	2	Crowded
Lane 4	1	1	0	2	Crowded
Lane 1	1	1	1	3	Congested
Lane 2	1	1	1	3	Congested
Lane 3	1	1	1	3	Congested
Lane 4	1	1	1	3	Congested

Table 4 presents the result of test scenario with 12 tests in each lane at an intersection. The result shows that the infrared sensor is able to read the condition accurately with 100% success rate.

The quiet, crowded, and congested road was scored 1, 2, and 3, respectively.

4.1.3 Lane Priority Estimation Test

The next step was to test the fuzzy control system in making lane priority. The test aimed to see whether or not the priority value meets the expectation. This test also evaluate the ESP gateway performance in transmitting priority value to ESP server.

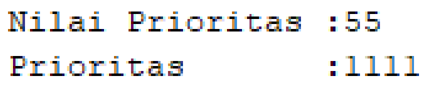

Figure 12. Result Lane Priority Estimation Test

Figure 12 presents the serial monitoring of Arduino IDE. As shown in the figure, the system is able to determine the priority value based on road condition and vehicle type inputs. It shows that ambulance with patients (value 2) was passing a lane at an intersection with a quiet road condition (value 1) was given a priority score of 55, meaning that the lane was prioritized.

Table 5. Lane priority estimation

Lane No.	Lane Ambulance	Road Condition	Priority Value	Description Prioritized Tourism Destination
Lane 1	Hearse	Quiet	11	Very Low
		Crowded	25	Low
		Congested	40	Moderate
	Patient	Quiet	55	Quite
		Crowded	70	High
		Congested	85	Very high
Lane 2	Hearse	Quiet	11	Very Low
		Crowded	25	Low
		Congested	40	Moderate
	Patient	Quiet	55	Quite
		Crowded	70	High
		Congested	85	Very high
Lane 3	Hearse	Quiet	11	Very Low
		Crowded	25	Low
		Congested	40	Moderate
	Patient	Quiet	55	Quite
		Crowded	70	High
		Congested	85	Very high
Lane 4	Hearse	Quiet	11	Very Low
		Crowded	25	Low
		Congested	40	Moderate
	Patient	Quiet	55	Quite
		Crowded	70	High
		Congested	85	Very high

Table 5 presents the serial test with 24 tests in each lane at an intersection. The result shows that the system manages to estimate lane priority for ambulance according to the fuzzy control system input in various conditions. Thus, it could be concluded that the system performance in making the priority value has been optimal with 100% accuracy.

4.2 Fuzzy Value Test Scenario

The system's fuzzy value test was performed to evaluate the condition of fuzzy control system, its stability and effectiveness. The test aimed to identify any fuzzy error in the system (ESP) using fuzzy on matlab.

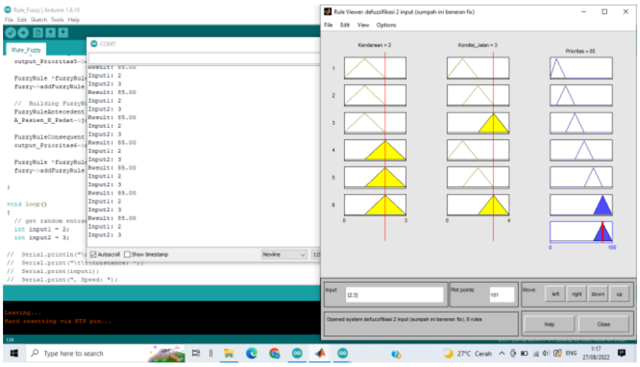

Figure 13. Comparison between Fuzzy result on Matlab and Arduino IDE.

Figure 13 presents the comparison of matlab and arduino IDE fuzzy result after six tests with two vehicle types (hearse is scored 1, while ambulance is scored 2) and road condition (quiet, crowded, and congested conditions are scored 1,2, and 3, respectively). The comparison result is presented in Table 6.

Table 6. Fuzzy Value Performance Comparison

ESP32 Vehicle types	ESP32 Road Condition	ESP32 Priority	MATLAB Vehicle types	MATLAB Road Condition	MATLAB Priority	Error fuzzy
1	1	11.67%	1	1	11.7%	0.03%
1	2	25%	1	2	25%	0%
1	3	40%	1	3	40%	0%
2	1	55%	2	1	55%	0%
2	2	70%	2	2	70%	0%
2	3	85%	2	3	85%	0%

The test result found no error fuzzy in matlab with only 0.03% difference. In other words, the system calculates the priority value according to the fuzzy in matlab.

4.3 Traffic Control System

This test evaluated the ESP server performance in controlling the traffic signals at the intersection when collision occurs, after receiving priority value from each ESP-gateway. The test was performed using the priority value sent to the server by ESP-gateway. Two conditions were applied. The first condition involves two different vehicle types (hearse and ambulance) at an intersection. The second condition involves the same vehicle conditions in the same road condition.

Two types of test were performed:

1. Traffic light control when there is only one emergency vehicle to pass at the intersection (no collision)
2. Traffic light control when there are two emergency vehicles to pass at the intersection (collision)

4.3.1 Traffic Scenario Test whitout Collision

The first traffic scenario test involves one emergency vehicle to pass at the intersection (no collision). Two test conditions were applied for hearse and ambulance with three road conditions (quiet, crowded, and congested condition)

Figure 14 Traffic Light Control
(No Collision)

Figure 15 LCD Display during Traffic light control

Figure 14 presents the traffic light control when only one emergency vehicle at the intersection. The test result showed that the system managed to control the traffic light by turning it into green for ambulance to pass. The LCD also displays the lane priority value and status. The LCD display during traffic light control is illustrated in figure 15.

Table 7. Traffic Light Control Test (no collision)

Test	Vehicle Types	Priority Value Lane 1	Lane 2	Lane 3	Lane 4	Traffic Light Control
1	Hearse	11				Lane 1 Green
2	Hearse		25			Lane 2 Green
3	Hearse			40		Lane 3 Green
4	Patient				55	Lane 4 Green
5	Patient			70		Lane 3 Green
6	Patient		85			Lane 4 Green

As shown in Table 7, after six trials, the system exhibits 100% optimal performance in controlling traffic light at the lane to be passed by the ambulance.

4.3.2 Traffic Scenario Test with Collision

The second scenario involves two different vehicle types that pass at the intersection, meaning that a collision should be addressed. The collision was divided into two scenarios:

1. Two different vehicle types in different road condition
2. Two same vehicle types in different road condition

Scenario 1:

Two different vehicle types in different road conditions. This scenario involves a condition where there are two different emergency vehicles (i.e., hearse and ambulance) in different road condition at the same time at an intersection.

Figures 16 and 17 displays a scenario when hearse and ambulance pass an intersection. The server will control the traffic light according to the priority value sent by lane gateway. As shown in the figure above, traffic light in lane 1 is turned into green because it has higher priority value than the combination of lanes 2,3, and 4. The priority value was 85 > 55+0+0, meaning that an ambulance transporting a patient is passing lane 1 with a quiet road condition, while hearse is passing lane 2 with a quiet road condition. Several tests were performed to ensure the accuracy. Table 8 presents the test result.

Figure 16 LCD Display during collision
With ambulance and hearse

Figure 17. Traffic Light Manipulation During Collision With Ambulance And Hearse

After conducting four tests with two different vehicle types and different road conditions, it could be concluded that the system exhibited 100% optimal performance in controlling the traffic light according to the priority value sent by lane gateway. As shown in the table above, the crowded lane 2 passed by ambulance was given priority value of 70, while the crowded lane 4 passed by a hearse was given priority value of 25. Thus, lane 2 is prioritized as its value is higher than lanes 1,3, and 4 combined.

Scenario 2:

Two different vehicle types in the same road condition. This scenario involves a condition where there are two different emergency vehicles (i.e., Hearse hearse and ambulance) in different road condition at the same time at an intersection.

Controlling traffic light when there are two different vehicle types at different lane may be easier, given the different urgency. The problem arise when there is a collision involving the same emergency vehicles, which one should be prioritized.

Figure 18 LCD Display during collision involving the same vehicle types

Figure 19 Traffic Light Control During Collision Involving The Same Vehicle Types

Figures 18 and 19 illustrate a scenario involving two vehicles of the same type at an intersection. The server will control the traffic light according to the priority value sent by lane gateway.

Vehicle Types				Priority Value				Traffic Light Control
J1	J2	J3	J4	J1	J2	J3	J4	
Hearse	-	Patient	-	11	-	55	-	Lane 3 Green
-	Patient	-	Hearse	-	70	-	25	Lane 2 Green
Patient	-	Hearse	-	70	-	40	-	Lane 1 Green
-	Hearse	-	Patient	-	40	-	85	Lane 4 Green

Table 8. Traffic Light Control During Collision Involving Two Different Vehicle Types

As shown in the figure above, traffic light in lane 3 is turned into green because it has higher priority value than the value of lanes 1,2, and 4 combined. The priority value was 70 > 55+0+0, meaning that an ambulance transporting a patient is passing the crowded lane 3, while another ambulance is passing the crowded lane 2. Several tests were performed to ensure the system accuracy. Table 10 presents the test result.

Table 9. Traffic light control during collision involving the same vehicle types.

Test	Vehicle Types	Priority Value Lane 1	Lane 2	Lane 3	Lane 4	Traffic Light Control
1	Hearse	11	-	25	-	Lane 3 Green
2	Hearse	-	25	-	40	Lane 4 Green
3	Patient	70	-	55	-	Lane 1 Green
4	Patient	-	85	-	70	Lane 2 Green

After conducting four tests involving two same vehicles in different road condition at the same time at an intersection, the system was proven to be able to control the traffic light during collision involving the same vehicle types. Since the collision involves the same vehicle types, the system calculates several different conditions, including the different road condition. In other words, in this scenario, the different road conditions account for different priority values.

As shown in Table 9, the third test involves a scenario where two ambulances pass two different lane at an intersection. Lane 1 was given priority value of 70, while lane 3 was given priority value of 55, meaning that lane 1 is prioritized.

4.4 General Scenario Test Analysis

Based on a series of test results, the system exhibited an optimal performance. The RFID was proven to be able to accurately detect the ambulance load by giving score 1 for hearse and 2 for ambulance with patient. The infrared sensor was also accurate in reading a road condition, where it gave score 1 for quiet road, 2 for crowded road, and 3 for congested road.

The ESP gateway performance in determining priority value in various road conditions is also optimal, showing that the fuzzy control system is capable of handling the priority value quickly

Based on the two test scenarios, the system was proven capable of controlling traffic light according to priority values sent by ESP gateway at the intersection quickly. The test demonstrated that lane 3 with priority value of 85 was prioritized over another lane with priority value of 11 by turning the traffic light into green in lane 3.

In other words, the system was 100% optimal. This study proved that fuzzy control system is a suitable method for determining priority during collision of emergency vehicles. However, the scenario tests revealed that the system could only handle two types of collision with different road conditions.

5. Conclusion

Following the test and analysis of the traffic light control system for ambulance using fuzzy logic, several conclusions are drawn as follows:

1. The intelligent traffic control system using fuzzy control system method was found to have a 95% success rate in controlling traffic light both in collision (involving two emergency vehicles) and there is no collision (involving only one emergency vehicle) at an intersection at the same time.
2. The system begins with identifying ambulance load using RFID and reading road condition using infrared sensor, which serve as values input to the fuzzy control system to obtain a priority value as a reference for traffic light control.
3. ESP-gateway in each lane is capable of transmitting the priority value to ESP server quickly and accurately, with 11 for very low priority, 25 for low priority, 40 for medium priority, 55 for quite high priority, 70 for high priority, and 85 as very high priority. Likewise, ESP server is able to receive the data accurately to be used for controlling the traffic light by turning the traffic light into green for a lane to be passed by an ambulance or hearse.
4. The fuzzy control system could only handle two types of collision in different road conditions. The developed system has not been able to handle various collisions at an intersection involving same road condition and same vehicle types.

6. References

[1] A. Khoirul, “128166-ID-faktor-faktor-yang-mempengaruhi-pertumbu,” *Fakt. Fakt. Yang Mempengaruhi Pertumbuhan Kendaraan Bermotor Roda Du*, vol. 4, pp. 1106–1120, 2017.

[2] A. N. A. Yusuf, A. S. Arifin, and F. Y. Zulkifli, “Recent development of smart traffic lights,” *IAES Int. J. Artif. Intell.*, vol. 10, no. 1, pp. 224–233, 2021, doi: 10.11591/ijai.v10.i1.pp224-233.

[3] M. Maslim, B. Y. Dwiandiyanta, and N. Viany Susilo, “Implementasi Metode Logika Fuzzy dalam Pembangunan Sistem Optimalisasi Lampu Lalu Lintas,” *J. Buana Inform.*, vol. 9, no. 1, pp. 11–20, 2018, doi: 10.24002/jbi.v9i1.1661.

[4] R. P. Prasetya, “Implementasi Fuzzy Mamdani Pada Lampu Lalu Lintas Secara Adaptif Untuk Meminimalkan Waktu Tunggu Pengguna Jalan,” *J. Mnemon.*, vol. 3, no. 1, pp. 24–29, 2020, doi: 10.36040/mnemonic.v3i1.2526.

[5] O. Avatefipour and F. Sadry, “Traffic Management System Using IoT Technology - A Comparative Review,” *IEEE Int. Conf. Electro Inf. Technol.*, vol. 2018-May, pp. 1041–1047, 2018, doi: 10.1109/EIT.2018.8500246.

[6] Dewan Perwakilan Rakyat, “UNDANG-UNDANG REPUBLIK INDONESIA NOMOR 22 TAHUN 2009 TENTANG LALU LINTAS DAN ANGKUTAN JALAN,” Jakarta, 2009. [Online]. Available: ???

[7] Skm. K.Priyadharshini, “Automatic Traffic Control System Based on the Vehicular Density,” *Int. Res. J. Eng. Technol.*, vol. 06, no. 04, pp. 1–3, 2019.

[8] S. Mohanaselvi and B. Shanpriya, “Application of fuzzy logic to control traffic signals,” *AIP Conf. Proc.*, vol. 2112, no. June, 2019, doi: 10.1063/1.5112230.

[9] J. ALAM, M. K. PANDEY, and H. AHMED, “Intellegent Traffic Light Control System for Isolated Intersection Using Fuzzy Logic,” *Conf. Adv. Commun. Control Syst. 2013*, vol. 2013, no. July 2015, pp. 209–215, 2013.

[10] D. Karyaningsih and R. Rizky, “Implementation of Fuzzy Mamdani Method for Traffic Lights Smart City in Rangkasbitung, Lebak Regency, Banten Province (Case Study of the Traffic Light T-junction, Cibadak, By Pas Sukarno Hatta Street),” *J. KomtekInfo*, vol. 7, no. 3, pp. 176–185, 2020, doi: 10.35134/komtekinfo.v7i3.78.

[11] A. Chabchoub, A. Hamouda, S. Al-Ahmadi, and A. Cherif, “Intelligent Traffic Light Controller using Fuzzy Logic and Image Processing,” *Int. J. Adv. Comput. Sci. Appl.*, vol. 12, no. 4, pp. 396–399, 2021, doi: 10.14569/IJACSA.2021.0120450.

[12] M. Shelke, A. Malhotra, and P. N. Mahalle, “Fuzzy priority based intelligent traffic congestion control and emergency vehicle management using congestion-aware routing algorithm,” *J. Ambient Intell. Humaniz. Comput.*, no. 0123456789, 2019, doi: 10.1007/s12652-019-01523-8.

[13] R. Jimenez-Moreno, J. E. M. Baquero, and L. A. R. Umana, “Ambulance detection for smart traffic light applications with fuzzy controller,” *Int. J. Electr. Comput. Eng.*, vol. 12, no. 5, pp. 4876–4882, 2022, doi: 10.11591/ijece.v12i5.pp4876-4882.

[14] S. Antonov, “Smart traffic control system for ambulance,” no. March, pp. 457–460, 2017.

[15] Kumar P, Priya L, and A. Sathya, “Smart Traffic Light System for Emergency Ambulance Using IoT,” vol. 25, no. 3, pp. 8655–8662, 2021, [Online]. Available: http://annalsofrscb.ro

[16] P. Devi and S. Anila, “Intelligent Ambulance with Automatic Traffic Control,” *2020 Int. Conf. Comput. Inf. Technol. ICCIT 2020*, pp. 374–377, 2020, doi: 10.1109/ICCIT-144147971.2020.9213796.

[17] S. Parekh, N. Dhami, S. Patel, and J. Undavia, “Traffic signal automation through iot by sensing and detecting traffic intensity through ir sensors,” *Smart Innov. Syst. Technol.*, vol. 106, pp. 53–65, 2019, doi: 10.1007/978-981-13-1742-2_6.

[18] B. Ghazal, K. Elkhatib, K. Chahine, and M. Kherfan, “Smart traffic light control system,” *2016 3rd Int. Conf. Electr. Electron. Comput. Eng. their Appl. EECEA 2016*, pp. 140–145, 2016, doi: 10.1109/EECEA.2016.7470780.

[19] M. I. Mahali, B. Wulandari, E. Marpanaji, U. Rochayati, S. A. Dewanto, and N. Hasanah, "Smart traffic light based on IoT and mBaaS using high priority vehicles method," *Int. Conf. Electr. Eng. Comput. Sci. Informatics*, vol. 2018-Octob, no. 22, pp. 703–707, 2018, doi: 10.1109/EECSI.2018.8752694.

[20] K. K. Tan, M. Khalid, and R. Yusof, "Intelligent traffic lights control by fuzzy logic," *Malaysian J. Comput. Sci.*, vol. 9, no. 2, pp. 29–35, 1996.