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Fire Early Warning System in a Room Using Fuzzy Logic Tsukamoto Inference Method Based on Internet of Things

Farhan Assidiqi[1]*, Ilham Gading SP[2], and Muhammad Fikri[3]

[1,2]Program Studi Teknik Elektro, Telkom University, Bandung, Jawa Barat, 40257, Indonesia

[2]Department of Information Management and Computer Science, National Dong Hwa University, Hualien County, 974 Taiwan

E-Mail: farhanassidiqi@student.telkomuniversity.ac.id

Abstract: Fire incidents are among the most common disasters worldwide and frequently result in significant economic losses, property damage, environmental degradation, and loss of human life. In Indonesia, the number of fire incidents increased in 2023, highlighting the need for more effective fire prevention and early detection mechanisms. Many conventional fire detection systems are limited in their ability to provide real-time monitoring and rapid notification, which can delay emergency response efforts and increase the severity of fire-related losses. Therefore, the development of intelligent and automated fire early warning systems has become increasingly important. This research aims to design and implement an indoor fire early warning system by integrating Internet of Things (IoT) technology with fuzzy logic techniques. The proposed system utilizes a flame sensor to detect the presence of fire and an MQ-2 sensor to monitor smoke concentration levels. An ESP32 microcontroller functions as the central processing unit, collecting sensor data, processing information, and transmitting results to users. To improve decision-making accuracy under uncertain environmental conditions, the Tsukamoto fuzzy logic method is employed to determine the level of fire risk based on sensor inputs. The system is equipped with a real-time notification feature that automatically sends warning alerts through the Telegram application whenever potential fire hazards are detected. In addition, sensor readings and fire status information can be monitored remotely through a web-based platform. Experimental results demonstrate that the proposed system effectively detects fire and smoke conditions while providing timely alerts. The integration of IoT and fuzzy logic enables rapid response and supports proactive fire management, thereby reducing potential losses and enhancing indoor safety.

Keywords: Fire, Early Warning System, Fuzzy Logic, IoT, Flame Sensor, MQ-2 Sensor, ESP32, Telegram, Website Monitoring

1. INTRODUCTION

Fire is one of the most common disasters that cause significant losses, both in terms of material and human lives. In Indonesia, fire incidents by 2023 show a significant upward trend, highlighting the importance of effective prevention solutions. The main cause of fires is often attributed to human negligence, and these fires tend to occur in homes that are unattended by the occupants[1]. Given the complexity and variety of fire causes, a multidisciplinary approach is required to develop a comprehensive prevention strategy. In addition, the shift towards urbanization and population growth in densely populated areas increases the risk of fire occurrence, making fire management an issue that cannot be ignored in urban planning and infrastructure development. In dealing with this problem, this research aims to design an indoor fire early warning system that utilizes Internet of Things (IoT) technology by integrating fuzzy logic methods. The system uses fire and smoke sensors as the main inputs, where fuzzy logic with Tsukamoto inference method is used to determine the fire danger level. The IoT integration enables fast and efficient data transmission, so that information about potential fires can be immediately known and responded to. The system is also equipped with a messaging application via Telegram and a web-based monitoring application to send alert messages to users. The study also recognized the importance of educating the public on fire prevention. Therefore, in addition to technical development, the study also proposes the development of an educational program aimed at raising public awareness about fire prevention measures and safety protocols. By combining technological solutions and educational efforts, it is expected to reduce the frequency of fire incidents and minimize the losses incurred. This approach offers a proactive solution to fire risk management, which is much needed amidst the increasing incidence of fires in Indonesia.

2. LITERATURE REVIEW

Research that has been conducted by [1] which is entitled Designing a Fire Detection System Based on IOT and SMS Gateway. In the PTPN IX area which is in the highlands with hilly land contours, forest fires often occur which are difficult to overcome due to lack of information. Therefore, a system is needed that can send data from remote sensors. Data is sent using IoT technology, with Arduino connected to temperature, smoke, fire, and temperature sensors, and connected to the internet via SIM 900. The use of IoT in data transmission speeds up the process of sending fire information, so that fires can be recognized more quickly. The old system takes up to about 30 minutes to handle fires, while the new system developed by the author only takes a few minutes (≤5 minutes) to inform related parties. In addition, forest conditions can be monitored at any time because this system works in real-time [2].

Research conducted by [3] is the design of an IoT-based fire detection tool. Fire is a tragedy that cannot be predicted and is not wanted by the community. Fires are often uncontrollable when the fire is already large, threatening and disrupting people's lives. Fires can be caused by natural, non-natural, or human intentional factors, resulting in loss of life, environmental damage, property loss, and psychological impact. Urban areas with high population density are particularly vulnerable to fires. Given the impact, a fire detection system is needed that can detect fire in the house and reduce the impact caused. This research uses the IR Flame sensor to detect fire in the house. The IR Flame sensor detects flames with wavelengths between 760 nm - 1100 nm, using infrared as a transducer. Node MCU is used to send notifications via Telegram. The system is designed with two IR Flame sensors in one room for optimal fire detection. The test results show that the system is able to provide accurate fire location data and information via Telegram. Telegram has a channel feature that can add more than 3000 members to receive fire information, as well as integration with Google Maps to determine the distance between channel members and the location of the fire. This system also uses a buzzer as an alarm simulation to speed up fire handling [3].

Research conducted by Sari is a Fire Detection Tool Using SMS. Lately, there have been frequent fires caused by human negligence. Fires are difficult to predict and the lack of information about fires can be fatal to the safety of life and property. With technological advances, we can minimize the risk of fire by designing an early fire detection device. This tool uses temperature and smoke sensors to detect fires quickly and send information through alarms and SMS gateways. The main component of this tool is Arduino Uno, which functions as the brain of the fire detection system. The DHT11 temperature sensor detects the temperature, and if the temperature exceeds normal limits, an alert notification will be sent via SMS gateway. In addition, the MQ2 smoke sensor detects smoke, and a buzzer will sound as a warning alarm [4].

This research develops a fire detection system in vehicles using microcontrollers and IoT. This system uses Arduino Node MCU ESP8266 as the control center, fire sensors for fire detection, Telegram application to send fire incident messages, and NEO-6 GPS module for location tracking. This system provides direct notification to vehicle owners with text messages such as "Sensor 1 detected a high fire, immediately contact the fire department" [5].

In a study entitled Fire Monitoring and Detection System based on fuzzy logic and Real-time Database. Fire is a disaster that occurs due to human negligence; therefore, a system is needed that can detect fires in real-time online. By using several sensors that measure fire and temperature in the room, fuzzy logic calculations are then carried out and monitored in real-time on an online website [6].

The tool is made using fuzzy logic in it as a decision-making tool by performing the Tsukamoto inference method [7] Fuzzy logic is the basic concept of a fuzzy system that can be used to perform calculations on an input variable based on its ambiguity value. Fuzzy logic has membership degrees in the range 0 to 1, indicating the extent to which a value is true or false. This is an appropriate method for mapping input space to output space and producing continuous values [7] Which fuzzy logic also belongs to the Soft Computing section which is based on fuzzy set theory. The basic concept lies in the use of membership degrees to determine the presence of an element in the set. The degree of membership, known as the membership function, is the key in fuzzy logic reasoning [8]. Then fuzzy logic is placed in esp32 as the processing brain of the device [9] which receives input from the flame sensor to detect fire [10] and also the MQ-2 sensor as a smoke detector [11] which is the input variable in this study.

In this study also uses a buzzer as a notification in audio form [12] and also LCD for notification in visual form [13]. And all circuits are connected to the breadboard [14] and arranged in an electronic box. To do programming in this study, researchers used the Arduino IDE as a compiler and used the C++ language [15][16]. And also, can do monitoring and get notifications via website and telegram [17][18].

3. METHODOLOGY

The method applied in this research is prototyping method. The prototyping method is a system development approach that involves prototyping to gain a deeper understanding of the expected system specifications, both in the context of software and hardware [19]. The stages of development described infigure 1that begin the process with the determination of system requirements. This is followed by the design of the system, which includes the creation of an initial prototype. Furthermore, the prototype is tested and modified based on the feedback received, so as to achieve greater accuracy in meeting the needs of the end user.

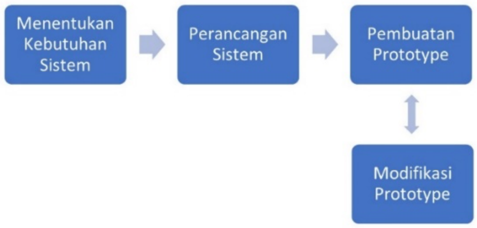

Figure 1. Process flow of the system.

3.1 Hardware Needs Analysis

The following are the advantages of system design:

Table 1. Specification of the hardware

No	Hardware	Sum	Function
1	ESP-32	1	Processing brain
2	Sensor *Flame*	1	as input of the fire distance value
3	Sensor MQ-2	1	as smoke value input
4	Cable Jumper	6 meters	as a link between the ESP-32 and the
5	LCD	1	as a uotput viewer
6	Buzzer	1	as audio output
7	LED RGB	1	as output
8	BOX	1	as a place where the network is organized
9	adaptor	1	as a power source

Based on the table above, the following are the tools needed in the design:

- ESP-32 is a microcontroller that is used as the processing brain in this system. These microcontrollers are in charge of receiving inputs from various sensors, processing data, and controlling the output based on that processing. The ESP-32 also supports Wi-Fi and Bluetooth connectivity, allowing the system to connect with other networks or devices.
- A flame sensor is a sensor used to detect the presence of fire. This sensor measures the light intensity of the flame and sends the value to the ESP-32 as input.
- The MQ-2 sensor is a gas sensor that detects the presence of smoke and flammable gases such as LPG, propane, methane, and others. This sensor sends smoke detection values to the ESP-32 as input.
- A 6-meter jumper cable is used to connect the various components in the circuit with the ESP-32. These cables ensure the flow of signals and electricity between components.
- LCD is used as a visual output viewer. This screen displays information from the ESP-32, such as sensor status, measured values, and other messages.
- The buzzer is used as an audio output. This buzzer provides an audible alert based on the conditions detected by the system, such as the presence of fire or smoke.
- RGB LEDs are used as additional visual outputs. These LEDs can illuminate in a variety of colors to provide a system status indication or visual alert.
- The box is used as a place to arrange all the components of the network. This box protects components from physical damage and makes the circuit tidier.
- Adapters are used as a power source for the system. This adapter provides the power required by the ESP-32 and other components for the system to operate.

3.2 Software Needs Analysis

In this study, the researcher used several software such as.

Table 2. Specification of the software

It	Software	Function
1	Arduino IDE	As a Code Compiler for Microcontrollers
2	Telegram	As a User Notification
3	Website	As a Monitoring System

Based on the table above, it is described as follows.

- Arduino IDE, which serves as a compiler for the code to be executed on the microcontroller. The Arduino IDE provides a complete and easy-to-use development environment, allowing users to write, compile, and upload code to an Arduino board. It is perfect for prototype and DIY projects thanks to its large user community and extensive support.
- Telegram, Telegram software is used as a notification tool for users. Telegram integration allows real-time messaging to users through bots or Telegram APIs. It takes advantage of Telegram's speed, security, and ease of use, making it ideal for applications that require quick responses or monitoring of certain circumstances.
- Website, which functions as a monitoring system. This website allows real-time monitoring of data from a microcontroller. An effective website should be responsive, easy to use, and accessible from a variety of devices, including phones and tablets. Using modern web technologies such as HTML5, CSS3, and bootstrap, as well as backends such as localhost, the website can display performance metrics, device status, and alerts in an interactive and user-friendly form.

3.2 Tool Design

Figure 2 below is a series of prototypes of a fire early warning system.

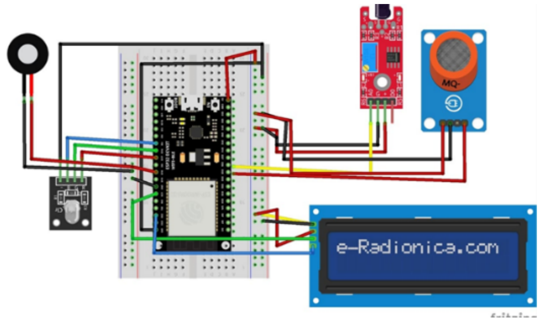

Figure 2. Hardware assembled for the system

Figure 2 above, you can see an overview of the series of fire early warning tools. The network in the picture above is explained as follows:

- The ESP32 microcontroller, located in the center of the image and serves as the data processing center of the various connected sensors. The ESP32 is known for its Wi-Fi and Bluetooth capabilities, which are very useful in IoT projects.

- Gas Sensor (MQ2), On the top right there is an MQ gas sensor which is used to detect the presence of certain gases in the environment. This sensor is connected to the ESP32 with a data, ground (GND) and VCC cable.

- LCD Display Module, At the bottom right, there is an LCD module that is used to display information such as measurement results from temperature, humidity, and gas sensors. This module is connected to the ESP32 with multiple data, ground (GND) and VCC cables.

- Buzzer, At the top left, there is a buzzer that is used to provide sound signals as alarms or notifications. This buzzer is connected to the ESP32 via a ground (GND) cable and a signal.

- Flame Sensor, At the bottom left, there is a flame sensor that is used to detect the presence of fire or flame. These flame sensors typically have three pins: data, ground (GND), and VCC. This sensor connects to the ESP32 to detect a fire or the presence of a fire source.

- Breadboard, Breadboard is used as a platform to connect all components with the ESP32. Connections between components are made using jumper cables that correspond to the pins on the ESP32.

4. RESULTS AND DISCUSSION

4.1 Fuzzy Tsukamoto Logic

Fuzzy logic is the basic concept of the fuzzy system which is used to perform calculations on input variables based on their obscurity values. Fuzzy logic has membership degrees in the range of 0 to 1, which indicates the extent to which a value is considered true or false. This is the proper method to map the input space to the output space and generate a continuous value. As part of Soft Computing, fuzzy logic is based on fuzzy set theory. The basic concept lies in the use of membership degrees to determine the existence of an element in a set. Membership degrees, or membership functions, are key in fuzzy logical reasoning. Tsukamoto's Fuzzy Logic method uses IF-THEN-shaped rules, where fuzzy sets are represented by monotonous membership functions. This method utilizes criteria and rules to determine the result. Fuzzy logic provides a tool that can transform linguistic control strategies derived from the human way of thinking into an automatic control system. The reasoning process in fuzzy logic can be seen in Figure 3 [7] [8].

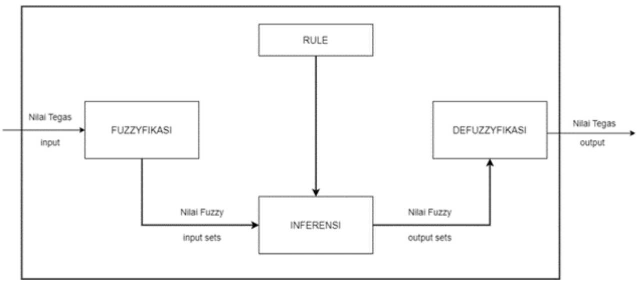

Figure 3. System flow diagram

In Tsukamoto's fuzzy logic, a membership function is a curve that describes how input data points are mapped into membership degrees with a value range between 0 and 1. Some of the functions of fuzzy membership are: [20]

4.1.1 Linear Representation

- The improvement curve describes how the set moves from a domain value with zero membership degrees to a domain value with a higher membership degree. This curve moves from left to right, towards the dominant value. An illustration of the improvement curve can be seen in Figure 4.

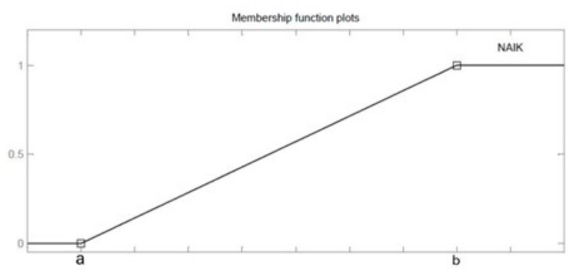

Figure 4. Fuzzy logic analogy in function membership

With a formula like:

$$\mu[x,a,b] = \begin{cases} \frac{x-a}{b-a}, a \le x \le b \\ 1, \quad x \ge b \\ 0, \quad x \le a \end{cases}$$

- The Decline Curve depicts a decrease in a set that starts from the value of the domain with the highest degree of membership on the left side, then moves down to the value of the domain with the lower degree of membership. An illustration of the decline curve can be seen in Figure 5 below.

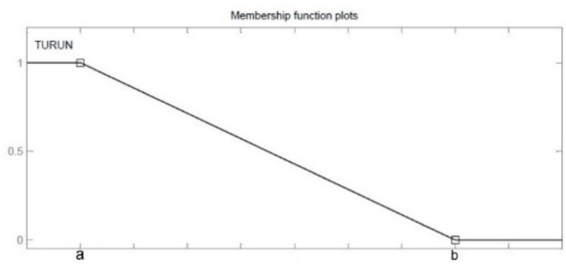

Figure 5. Fuzzy logic analogy in function plot

With the function formula:

$$\mu[x,a,b] = \begin{cases} \frac{b-x}{b-a}, a \le x \le b \\ 1, \ x \le a \\ 0, \ x \ge b \end{cases}$$

4.1.2 Triangle Representation

A triangular curve is basically a combination of 2 lines. A representation of the curve of the akita bus is seen in figure 6.

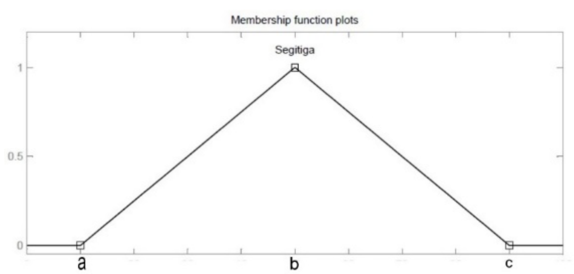

Figure 6. Fuzzy logic analogy in result

I. With the formula:

$$\mu[x,a,b] = \begin{cases} \frac{x-a}{b-a}, & a < x < b \\ \frac{c-x}{c-b}, & b < x < c \\ 0, & x \le a \text{ atau } x \ge c \end{cases}$$

In this study, fuzzy logic is used to determine the level of fire danger in the room. Fuzzy logic is applied to fire and smoke variables as an indicator of the existence of fire potential. The stages of fuzzy logic used in this study can be seen in the following Figure 7.

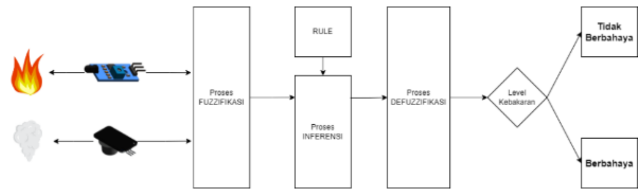

Figure 7. System block diagram

The process begins with the sensor reading the values from the distance of the flame and the thickness of the smoke. An Arduino fire sensor and an MQ2 sensor are used to obtain a dataset for each input variable. There are several parameters included in the study of the early warning system in the room. The parameters representing this study consist of fire and smoke, as described in the following table.

Table 3. Specification of the fuzzy Tsukamoto

Variable Inputs	Interval	Linguistic Variables
Api	[0, 3500]	Close [1, 600], Medium [550, 1000, 1200], Far [1200, 3000].
Asap	[0, 3500]	Thin [1000,1500], Medium [1300, 2100, 2600], thick [2500,3500].

Table 3. Specification for the interval

0Close Variable	Interval	Linguistic Variables
Danger	[1,100]	Danger [1, 100].
No Danger	[1,100]	Harmless [1, 100].

The membership function of each set of fire variables is described and represented in Figure 8 below as follows.

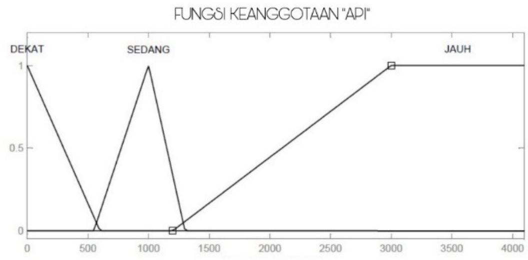

Figure 8. Summary of the fuzzy Tsukamoto logic fire

a. Near

$$\mu[x,a,b] = \begin{cases} \dfrac{600-x}{600-1}, a \le x \le b \\ 1, \quad x \le a \\ 0, \quad x \ge b \end{cases}$$

b. Keep

$$\mu[x,a,b] = \begin{cases} \dfrac{600-x}{600-1}, a \le x \le b \\ 1, \quad x \le a \\ 0, \quad x \ge b \end{cases}$$

c. Far

$$\mu[x,a,b] = \begin{cases} \dfrac{600-x}{600-1}, a \le x \le b \\ 1, \quad x \le a \\ 0, \quad x \ge b \end{cases}$$

The membership Function of each smoke variable set is described and represented in Figure 9.

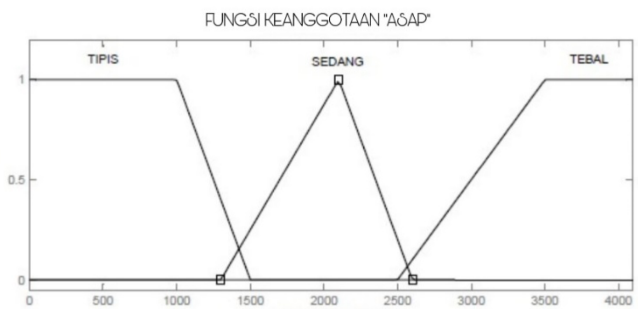

Figure 9. Summary of the fuzzy Tsukamoto logic smoke

a. Thin

$$\mu[x,a,b] = \begin{cases} \dfrac{1000-x}{1000-1500}, a \le x \le b \\ 1, \quad x \le a \\ 0, \quad x \ge b \end{cases}$$

b. Keep

$$\mu[x,a,b] = \begin{cases} \dfrac{x-1300}{2100-1300}, \quad a < x < b \\ \dfrac{2100-x}{2600-2100}, \quad b < x < c \\ 0, \quad x \le a \text{ atau } x \ge c \end{cases}$$

c. Thick

$$\mu[x,a,b] = \begin{cases} \dfrac{x-2500}{3500-2500}, a \le x \le b \\ 1, \quad x \ge b \\ 0, \quad x \le a \end{cases}$$

Based on the membership function above, 9 rules are further determined.

[R1] IF api JAUH and asap TIPIS THEN Tingkat_bahaya TIDAKBAHAYA.

[R2] IF the fire is FAR away and the smoke is MEDIUM THEN Tingkat_bahaya NO DANGER.

[R3] IF api JAUH and asap TEBAL THEN Tingkat_bahaya TIDAKBAHAYA.

[R4] IF api SEDANG and asap TIPIS THEN Tingkat_bahaya TidakBahaya.

[R5] IF api SEDANG and asap SEDANG THEN Tingkat_bahaya TIDAKBAHAYA.

[R6] IF api SEDANG and asap TEBAL THEN Tingkat_bahaya BAHAYA.

[R7] IF fire is NEAR, and smoke is THIN THEN Tingkat_bahaya NO DANGER.

[R8] IF fire is NEAR and smoke is MEDIUM THEN Tingkat_bahaya DANGER.

[R9] IF api DEKAT and asap TEBAL THEN Tingkat_bahaya BAHAYA.

Suppose the sensor reads a fire value of 60 nm and smoke of 2670 ppm, then it can be calculated.

$$\mu\textbf{Api DEKAT}\ (60) = \frac{600-60}{600-1} = 0{,}901$$

μApi MEDIUM (60)=0

μApi NEAR (60)=0

µAsap THIN (3430)=0

µAsap MEDIUM (3430)=0

µAsap THICK (3430)=(3430-2500)/(3500-2500)= 0,93

Because it uses the "and" operator to resolve between variables, the value of $\alpha - prediket\ (\mu_i)$ of each rule is:

[R1] IF fire is FAR **and** smoke is **THIN THEN** Hazard_level is NOT DANGEROUS.

$$\mu_1 = min\{0;0\} = 0$$

[R2] IF fire is FAR **and** smoke is MIDDLE **THEN** Hazard_level is NOT DANGEROUS.

$$\mu_2 = min\{0;0\} = 0$$

[R3] IF fire is FAR **and** smoke is **THICK THEN** Hazard_level is NOT DANGEROUS.

$$\mu_3 = min\{0;0{,}93\} = 0$$

[R4] IF fire is MEDIUM **and** smoke is **THIN THEN** Danger_level is not Dangerous.

$$\mu_4 = min\{0;0\} = 0$$

[R5] IF fire is MEDIUM **and** smoke is MEDIUM **THEN** Hazard_level is NOT DANGEROUS.

$$\mu_5 = min\{0;0\} = 0$$

[R6] IF fire is MEDIUM **and** smoke is **THICK THEN** Hazard_level is DANGEROUS.

$$\mu_6 = min\{0;0{,}93\} = 0$$

[R7] IF fire is NEAR **and** smoke is **THIN THEN** Hazard_level is NOT DANGEROUS.

$$\mu_7 = min\{09;0\} = 0$$

[R8] IF fire is NEAR **and** smoke is MIDDLE **THEN** Hazard_level is DANGEROUS.

$$\mu_8 = min\{09;0\} = 0$$

[R9] IF fire is NEAR **and** smoke is **THICK THEN** Hazard_level is DANGEROUS.

$$\mu_9 = min\{09;0.93\} = 0{,}9$$

And here it can be calculated that the approximate of each rule on the hazard level variable, namely:

µtidak bahaya(z1)=b - (z1×(b-a))=100-(0×(100-1)) =100

µtidak bahaya(z2)=b - (z1×(b-a))=100-(0×(100-1)) =100

µtidak bahaya(z3)=b - (z1×(b-a))=100-(0×(100-1)) =100

µtidak bahaya(z4)=b - (z1×(b-a))=100-(0×(100-1)) =100

µtidak bahaya(z5)=b - (z1×(b-a))=100-(0×(100-1)) =100

µbahaya(z6)= a+(z1 ×(b-a)) = 1 + (0×(100-1)) =1

µtidak bahaya(z7)=b - (z1×(b-a))=100-(0×(100-1)) =100

µbahaya(z8)=a+(z1×(b-a))=1+(0×(100-1))=1

µbahaya(z9)=a+(z1×(b-a))=1+(0.9×(100-1)) = 90.25

So the definition is as follows:

Z=((µ_1.z1)+(µ_2.z2)+(µ_3.z3)+(µ_4.z4)+(µ_5.z5)+...+(µ_9.z9))/(µ_1+ µ_2+µ_3+µ_4+µ_5+µ_6+µ_7+µ_8+µ_18+)

Z =((0,9 × 90.25))/0,9 = 90,25

So, the danger level if the fire value is 60 and the smoke thickness is 3430 is 90.25, or the danger level is 90.25%. Basically, the Tsukamoto method applies monotone reasoning to each rule. While monotonic reasoning systems usually have only one rule, the Tsukamoto method consists of multiple rules.

4.2 Design results

Software testing aims to evaluate the performance of the software that has been developed. Testing is carried out directly using the tools that have been designed, using predetermined test parameters. The output of this research is in the form of monitoring through the website and notification through the Telegram application. The implementation of this fire early warning system uses fuzzy logic with flame sensor and MQ-2 sensor as inputs. This system utilizes ESP 32 as the main processing unit. The processed data is sent to the website for monitoring purposes and also sends notifications via the Telegram application.

4.3 Software Testing Result

Software testing was utilized to evaluate a fire monitoring system that integrates fire and smoke sensors with a website and Telegram notifications. The system effectively displays real-time data such as fire levels, smoke density, and safety statuses, calculated through Tsukamoto fuzzy logic, on the monitoring website. Additionally, it sends timely Telegram alerts when there's a change in the fire status, ranging from 'safe' to 'check' or 'dangerous', thereby ensuring users are promptly informed to take necessary actions. This confirms the reliability and accuracy of the integrated sensors, microcontrollers, and IoT platform in managing and communicating fire safety conditions.

4.4 Hardware Test Result

System testing is conducted to verify the effectiveness and reliability of the developed design. During the testing process, a series of tests were repeated several times to ensure consistency and accuracy of results. The results obtained from these tests include quantitative data describing the performance of the system under different conditions, including the speed at which the system responds to changes in fire conditions, the accuracy in detecting and sending notifications, and the stability of the system during continuous operation. This analysis is essential to ensure that the system can operate effectively under real-world conditions.

Table 3. Results achieved from the testing

Fire	**Smoke**	**Fuzzy Result**	**Indicator**
4095	141	1.00	Safe
2064	129	52,48	Check
128	3979	79,01	Danger
703	849	66.34	Check
763	1710	53.14	Check
499	1055	83.31	Danger
4095	308	1.00	Safe

The designed fire detection system demonstrated significant effectiveness in providing early warning based on measurements of the internal conditions of the room. The flame sensor, which is designed to be sensitive to the light spectrum emitted by fire, and the MQ-2 sensor, which detects the concentration of smoke gas, operate synergistically to generate accurate data. This data is crucial to support the user's decision-making process. In addition, the system is equipped with local indicators on the device and integration with the Telegram platform and website for real-time monitoring. This integration gives users the ability to monitor room conditions continuously from any location.

5 CONCLUSION

Based on the analysis, design, and implementation conducted, several conclusions can be drawn:

1. Fire Warning System: This system employs a flame sensor as a fire detector and an MQ-2 sensor as a smoke detector, integrated with Tsukamoto fuzzy logic calculations. The ESP32 microcontroller is used as the data processor. Additionally, a website serves as the monitoring platform for rooms where fire is detected, and alert notifications are sent via Telegram. Overall, this system functions properly and efficiently in detecting fire and smoke.
2. Monitoring: The early fire warning system facilitates users in monitoring rooms detected with fire and smoke without the need for direct supervision. With notifications sent via Telegram and a monitoring display on the website, users can promptly recognize emergency conditions and take necessary actions remotely.
3. Fire Warning: Utilizing this fire and smoke detection system helps prevent greater losses in rooms where fire is detected. The early warning provided enables users and visitors to be alert and take necessary preventive measures before the fire spreads further.
4. Use of Tsukamoto Fuzzy Logic: Tsukamoto fuzzy logic is applied in this system to enhance accuracy and reliability in fire detection. The flame sensor and MQ-2 detect room conditions, and the data obtained is then processed using fuzzy logic calculations. This method allows the system to provide more precise judgments based on inputs from the flame and smoke sensors. Fuzzy logic handles uncertain data and offers a more refined and quantified output, translated into "Safe", "Check", or "Danger" status. This facilitates a faster and more accurate response to detected fire conditions.

Overall, the fire detection system effectively provides early warnings based on indoor conditions detected by the flame and MQ-2 sensors, processed through fuzzy calculations. The system not only delivers on-site visual and auditory alerts but also sends notifications via Telegram and updates data on the monitoring website in real-time, ensuring users are always informed about indoor environmental conditions.

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