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A Practical Implementation Fire Monitoring Systems Using Fuzzy Methods

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Abstract

Fires are serious disasters that require effective monitoring or control systems to identify risks and respond quickly. In this study, observations were made on the A Practical Implementation Fire Monitoring Systems Using Fuzzy Methods using temperature input from DHT22 sensors, smoke from MQ-2 sensors, and fire history as evaluation variables. The system will classify the temperature as "low", "medium", or "high", smoke as "low", "medium", "concentrated", as well as the history of fires categorized as "low", "medium", "high". The input will be processed using fuzzy logic to generate recommended actions, the actions are classified into "evacuate", "stay away from the area", or "wait for instructions". The implementation of the monitoring system uses the Arduino UNO platform as its base, then the DHT22 temperature sensor, and the MQ-2 smoke sensor to detect fire conditions. Then the test results from the monitoring system will provide recommendations related to more accurate and responsive actions based on actual conditions at the fire site.

Keywords: Arduino UNO, DHT22, Fire, Fuzzy Logic, MQ-2.

INTRODUCTION

Fire is one of the disasters that caused great losses, both in terms of material and soul. These disasters are often triggered by a number of factors, including electrical short circuits, human error, cigarette butts, gas leaks, negligence in turning off the stove, and natural factors (Alifah et al., 2023). According to the Indonesian National Standard (SNI), a fire occurs when a material reaches a critical temperature and reacts chemically with oxygen to cause heat, flame, light, smoke, steam, carbon monoxide, carbon dioxide or other products (Hafiz & Candra, 2021). Fire hazards can vary from mild to high levels, depending on their ability to spread fire, which in turn affects the level of damage it may cause. Mild fire hazards are characterized by a low and slow burning ability, often not significantly threatening life or the environment. Meanwhile, a moderate fire hazard has a sufficient amount of material to burn and can cause a fire to spread rapidly at a moderate level. Fires like these are usually local and can be managed quite well. On the other hand, high or severe fire hazards involve large amounts of flammable materials, generate high heat, and have the potential to seriously damage the environment and threaten lives (M. Rahman, 2021).

The causes of fires are very diverse, ranging from electrical short circuits, human negligence, to natural factors such as lightning, earthquakes, volcanic eruptions, and droughts. Fires can be triggered by various sources of fire, not only from direct sources of fire but also from human activities that do not directly produce fire. Human factors that often cause fires include negligence such as poor electrical installation, use of cooking utensils, as well as behaviors such as starting a fire near flammable fuels or using electrical equipment beyond a safe capacity (Geografi, 2016). The diverse causes of fires, both human and natural, indicate the need for an effective monitoring system.

In general, fires are detected after they have grown, causing delays in response from firefighters. This is due to the lack of detection devices and blackout control systems that work automatically (Yanuar et al., 2019). Therefore, this study aims to develop a more responsive fire monitoring system using fuzzy logic. Fuzzy logic, which is part of soft computing, is able to handle uncertainty in data by providing partial truths (Supriyadi & Subagja, 2020). Fuzzy logic is a method of reasoning that handles uncertainty and ambiguity in data. This is very suitable if applied to fire monitoring systems because fire conditions can be dynamic and unpredictable. A term is categorized as "fuzzy" if it cannot be defined definitely or definitively, thus requiring classification. Fuzzy logic is a great approach for mapping input space into output space (Sari, 2021).

Over the past few years, fire detection has become a significant issue as it results in serious damage, including loss of human life (Saeed et al., 2018). In this research, we will use fuzzy logic to improve fire detection accuracy, reduce response delays, and provide smarter solutions regarding actions to take in the event of a fire.

Fuzzy logic is an evolution of Boolean logic that introduces the idea of partial truth. While classical logic says that everything can be represented binarily (0 or 1, black or white, yes or no), fuzzy logic replaces boolean truth with varying degrees of truth. For those who are not familiar with the concept of fuzzy logic, you may find that it is very complex and confusing. However, once a person starts learning it, they will be intrigued and fascinated by the concept. Fuzzy logic is considered the "new old logic" because, although its modern methods have only been developed in recent years, the basic concept of fuzzy abstraction has been around for a long time (Nasution, 2020).

The use of fuzzy logic is easiest to do with the MATLAB programming language that can simulate fuzzy systems, with the results of analysis in the form of graphical signals characteristic of oscilloscopes (Putra et al., 2018). MATLAB, short for Matrix Laboratory, was originally developed by the University of New Mexico and Stanford University in 1970. This software was originally used for numerical analysis, linear algebra, and matrix theory (Kastina & Silalahi, 2016). MATLAB is a high-level language specifically designed to deal with computer engineering problems. MATLAB integrates computing, visualization, and programming into easy-to-use models, allowing problems and their solutions to be expressed in familiar mathematical notation (M Syariffudien Zuhrie, Nur Kholis, Nurhayati, 2021). MATLAB provides a variety of tools that facilitate the learning and implementation of various specialized technologies. Some of the areas in which the toolkit is available in MATLAB include fuzzy logic, control systems, and signal processing (Munawaroh, 2019).

In order to achieve this goal, we will integrate the DHT22 temperature sensor and MQ-2 gas sensor on the Arduino UNO microcontroller. DHT22 sensors are used to detect air temperature and relative humidity, while MQ-2 sensors are used to detect harmful gases. Arduino UNO will act as the brain of the fire monitoring system, controlling and processing data from both sensors to determine the action to be taken in the event of a fire.

The DHT22 sensor is a digital sensor for measuring relative humidity and temperature. DHT22 uses capacitors and thermistors to detect surrounding air conditions and generate signals via data pins. This sensor is considered to have high reading accuracy, judging from the speed in acquiring data and its compact design, as well as its affordable price when compared to conventional temperature and humidity measuring devices such as thermohygrometer (Arif, 2023).

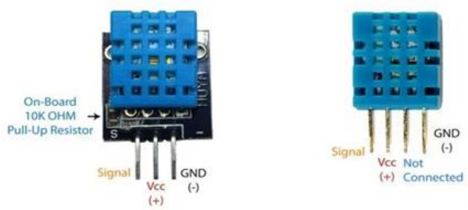

Figure 1. DHT22 Sensor

The relative humidity and temperature digital sensor, referred to as DHT22 Figure 1. DHT22 Sensor, relies on capacitors and thermistors to evaluate surrounding air conditions. The signal obtained from this sensor is transmitted through the data pin. DHT22 is known to have high reading accuracy, characterized by fast response in acquiring data and small size. In addition, this sensor is available at an affordable price, making it an attractive option when compared to other thermohygrometer devices (Puspasari et al., 2020).

The DHT22 sensor has the ability to measure air temperature and humidity simultaneously. Also known as AM2302, this sensor has a similar function to the DHT11 sensor, but with certain advantages. Unlike the DHT11, the DHT22 produces output in the form of digital signals that can be directly processed by an 8-bit microcontroller. This results in more accurate and precise measurements. In addition, DHT22 has a wider temperature and humidity measurement range than DHT11. This sensor is also capable of transmitting signal output through cables up to 20 meters, so it is very flexible in its placement (Siswanto et al., 2019).

Then, in addition to the DHT22 temperature sensor, the proposed monitoring system also involves the use of MQ-2 gas sensors. MQ-2 sensors are commonly used to detect harmful gases such as methane, propane, carbon monoxide, and smoke. This sensor has the ability to convey analog signals that can be processed by a microcontroller. MQ-2 gas sensors are a type of metal oxide (MOS) semiconductor sensor, also known as chemiresistor, because their detection relies on changes in the resistance of the sensor material when exposed to a specific gas. Through a voltage divider circuit, the sensor can measure the concentration of detected gases. The resistance of the MQ-2 sensor increases with the increase in the concentration of gases it detects (Suryana, 2021).

Figure 2. MQ-2 Sensor

The MQ-2 sensor (Figure 2) is a gas sensor designed to detect the presence of carbon monoxide. These sensors have high sensitivity and quick response to environmental changes. The output of this sensor is an analog signal, and for its operation, MQ-2 requires a voltage of 5 V DC. The resistance of this sensor will change with the presence of gas, and the output of this sensor is connected to the Analog pin on the Arduino microcontroller to be displayed in the form of a digital signal (Mauludin et al., 2014). The MQ-2 sensor is a gas sensor that detects the presence of smoke and flammable gases with concentrations of 200 ppm to 10,000 ppm such as alcohol, H2 (hydrogen), LPG, CH4 (methane), CO (carbon monoxide), smoke (smoke) and propane. This sensor only works optimally in closed rooms (Garonga et al., 2021).

In the monitoring system proposed in this study, the use of Arduino UNO is very relevant to integrate DHT22 sensors and MQ-2 sensors. Arduino UNO works as a microcontroller to control and also process data from both sensors. In this series of systems, Arduino UNO will function as the brain of the fire monitoring system, Arduino UNO will be connected to both sensors through the *available input/output* pins. Arduino UNO will read data from both sensors, then process the data to determine what action to take if a fire is detected.

Figure 3. Arduino UNO

Arduino Uno is a microcontroller board based on ATmega328 (datasheet). This board is equipped with 14 digital input/output pins, of which 6 of them can be used as PWM outputs, as well as 6 analog input pins. A 16 MHz crystal oscillator, USB connection, power jack, ICSP header, and reset button are also included in the Arduino Uno hardware features (Pradana Eka et al., 2023). Arduino Uno can support microcontrollers and can be connected with a computer via a USB cable. Arduino has a number of advantages compared to other microcontrollers. Besides being open source, Arduino also has its own programming language that uses C language (Saputra et al., 2016). Arduino UNO has a Static Random Access Memory (SRAM) of 2 KB, which is used to store data, and flash memory of 32 KB to store programs. In addition, Arduino UNO is also equipped with erasable programming memory (EEPROM) to store programs (Almeida et al., 2016).

Thus, the integration of the DHT22 temperature sensor and MQ-2 gas sensor on the Arduino UNO is a strategic step to improve the efficiency and responsiveness of the fire monitoring system. The application of fuzzy logic in this study is expected to make a significant contribution in reducing the impact of material losses and fatalities due to fire, while increasing effectiveness in responding to fire events.

METHODS

Research Location and Time

On February 19, 2024, research was conducted at the Bogor City Fire Department. The research commenced at 9:00 a.m. and concluded at 12:00 p.m. Data for this study were collected through direct interviews with experienced firefighters and literature review related to fire incidents and their management. The aim of this research is to understand temperature, smoke levels, and the fire history in that area. Consequently, it is expected that appropriate actions can be recommended based on the analysis of these parameters. Additionally, the study will also involve the application of fuzzy logic as a method for data analysis and decision-making to enhance the efficiency of fire response in the future.

Method of Collecting Data and Data Analysis Method

Fuzzy logic was first introduced by Lotfi A. Zadeh of the University of California in June 1965 (M. A. Rahman, 2013). This theory states that the degree of membership of a set element includes not only 0 and 1, but also includes a "gray" area between 0 and 1 (Yulianti & Wijaya, 2014). In building fuzzy systems, several inference methods are known, including the Tsukomoto Method, the Mamdani Method, and the Sugeno Method. For the design of the fire monitoring system in Bogor City, the Mamdani Method is used (Jayanti & Hartati, 2012).

The Mamdani method, often referred to as the Max-Min method, was introduced by Ebrahim Mamdani in 1975. To obtain the output, 4 stages are required (Vinsensia & Utami, 2018):

1. Formation of fuzzy repertoire
   In the Mamdani Method, input and output variables are divided into one or more fuzzy sets. The use of fuzzy sets allows representation of uncertainty and complexity in such systems. For example, when measuring temperature, sets such as "cold," "medium," and "hot" can be formed that represent a specific temperature range (Arifah et al., 2017).

2. Application function implications
   The implication function used in the Mamdani method is minimum (min). After forming a fuzzy set, the next step is to apply the implication function to relate the rules that connect inputs to outputs.
3. The composition of the rules
   The rule composition process involves combining the implication results of various applicable rules to produce more accurate output values based on the inputs provided. For example, if there are two fuzzy rules that contribute to a "high" output, then the output value will be taken from the maximum value of both contributions.
4. Affirmation (defuzzification)
   After obtaining the result of the composition of the rules, the fuzzy value needs to be converted into a firm value (defuzzification). This process involves choosing a method for calculating the firm value of fuzzy results, such as Composite Moment (centroid) or Mean of Maximum (MOM) (Much Junaidi, Eko Setiawan, 2005).

This research implements DHT22 temperature sensor and MQ-2 gas sensor to detect fire conditions, then integrates them into Arduino UNO platform as the main microcontroller. Arduino UNO reads, processes data, and makes decisions based on Mamdani's fuzzy rules. The validity of the research results is guaranteed by careful training of fuzzy sets and the application of proven fuzzy rules, referring to the early work of Ebrahim Mamdani in 1975.

The research process began with observation of fire conditions, data collection using DHT22 temperature sensors and MQ-2 gas sensors connected to Arduino UNO, and analysis of fire history in Bogor City. The study was conducted in a controlled environment that mirrored the fire situation, with adequate research time to obtain significant data. The presence of researchers during data collection and implementation of the system, as well as the use of high-quality sensors, guarantees the validity of the data. Overall, this study aims to develop a reactive fire monitoring system with the Mamdani method which is expected to provide accurate action recommendations based on actual conditions at the fire site. In determining action recommendations in the event of a fire using Fuzzy Mamdani's logic, here is a flowchart for the process of determining action recommendations in the event of a fire.

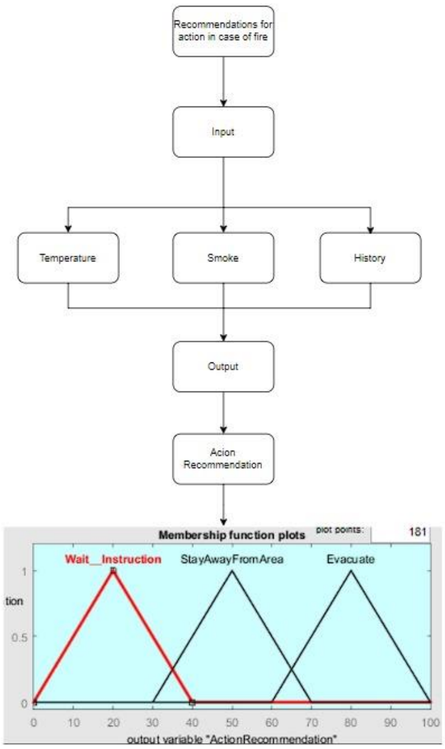

Figure 4. Action Recommendation Determination Flowchart

Based on the flowchart (Figure 4), in determining recommendations for action in the event of a fire, it requires three inputs, namely temperature, smoke and fire history, where the temperature unit is (℃). Then for the output itself, action recommendations consist of 3 parameters, namely Wait for Instructions, Stay Away from Areas, and Evacuate. To determine the recommendation for action, a fuzzy mamdani logic approach is used which will later go through several stages and also use the MATLAB application. This stage starts from determining the degree of membership, making rules, until later until the last stage, namely defuzzification.

RESULTS AND DISCUSSION

Fuzzy Group Formation

In the mamdani method, the input and output variables are divided into one or more fuzzy sets (Ekawati & Jannati, 2022). The division of input variables (temperature, smoke, and fire history) and output variables (action recommendations) into fuzzy sets is the process of grouping the values of these variables into categories that are not binary or firm, but rather more flexible and floating.

For temperature variables, we divide them into three fuzzy categories: "normal", "medium", and "high". This means that each temperature value detected by the sensor is valued 0 – 45 ℃ will be labeled "normal". If the temperature is worth 30 – 60 ℃ will be labeled medium, and if the temperature is worth 45 – 80 ℃ will be given a high label.

Table 1. Temperature Variable Input Membership Set

Temperature (℃)	
Parameters	**Set**
Normal	[0, 0, 30, 45]
Medium	[30, 45, 60]
High	[45, 60, 80, 80]

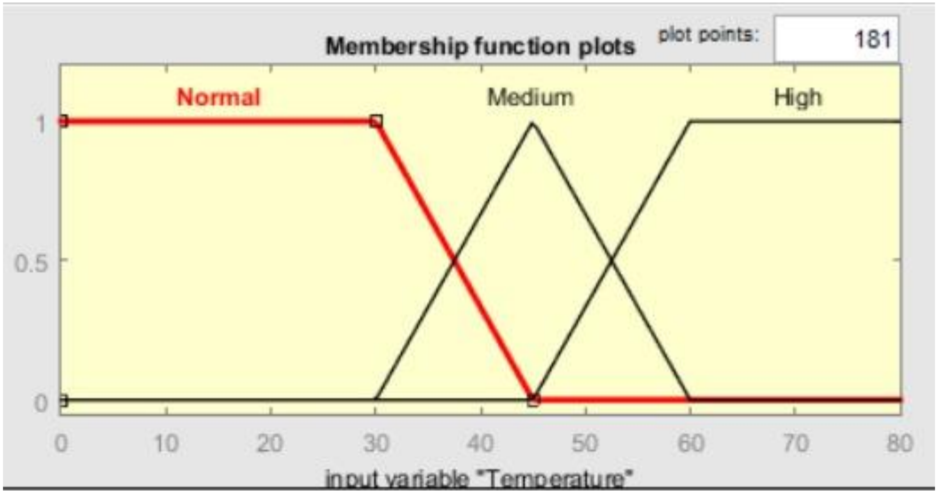

Figure 5. Temperature Variable Input Membership Set

The same applies to the smoke variable, where we divide it into "low", "medium", and "concentrated" to describe the level of smoke concentration detected. The parameter for this input is represented by a number, where for the parameter "bit" is valued 0 – 150, for the "current" parameter worth 50 – 250, and for concentrated parameters worth 200 – 400.

Table 2. Smoke Variable Input Membership Set

Smoke	
Parameters	**Set**
Low	[0, 0, 50, 150]
Medium	[50, 150, 250]
Concentrated	[200, 300, 400, 400]

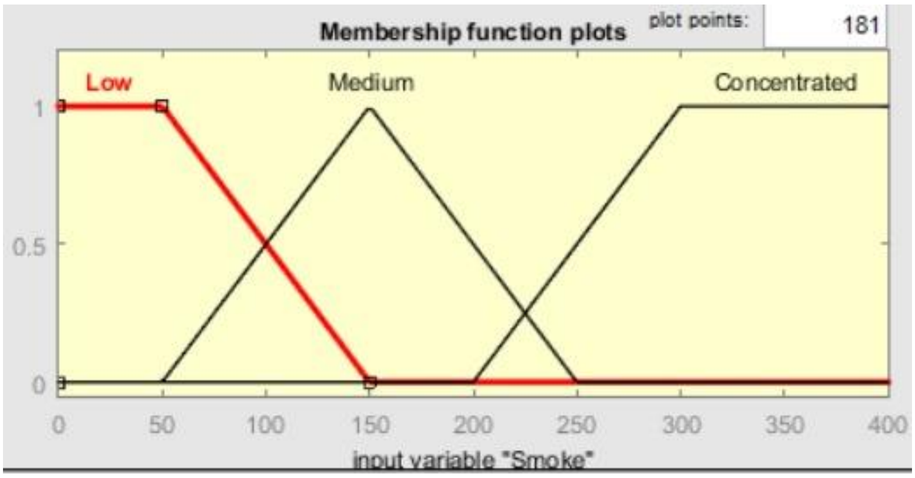

Figure 6. Smoke Variable Input Membership Set

The last input variable is fire history, this data is obtained from the website of the Central Bureau of Statistics of Bogor City, which is then processed to obtain the minimum value, maximum value and middle value from the existing data.

Table 3. Variable Input Membership Fire History

History	
Parameters	**Set**
Low	[0, 0, 5, 7]
Medium	[5, 10, 17]
High	[15, 18, 19, 19]

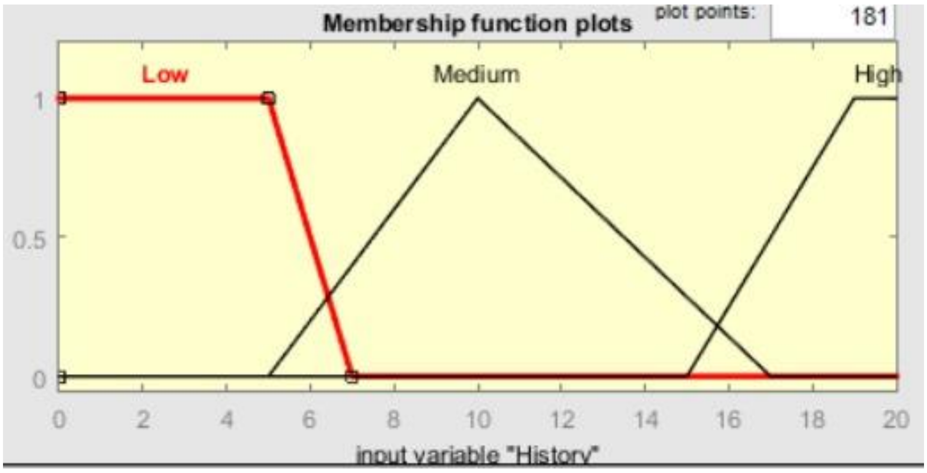

Figure 7. Variable Input Membership Fire History

As for the output variables, that is, action recommendations, they are also grouped into fuzzy sets. For example, we could have fuzzy sets for actions like "Evacuate", "Stay Away from Areas", and "Wait for Instructions". This means the system will provide action recommendations in the form of fuzzy categories appropriate to the detected fire conditions, enabling a more flexible and adaptive response to changing situations.

Table 4. Action Variable Output Membership Set

Action Recommendation	
Parameters	**Set**
Wait Instruction	[0, 20, 40]
Stay Away From Area	[30, 50, 70]
Evacuate	[60, 80, 100]

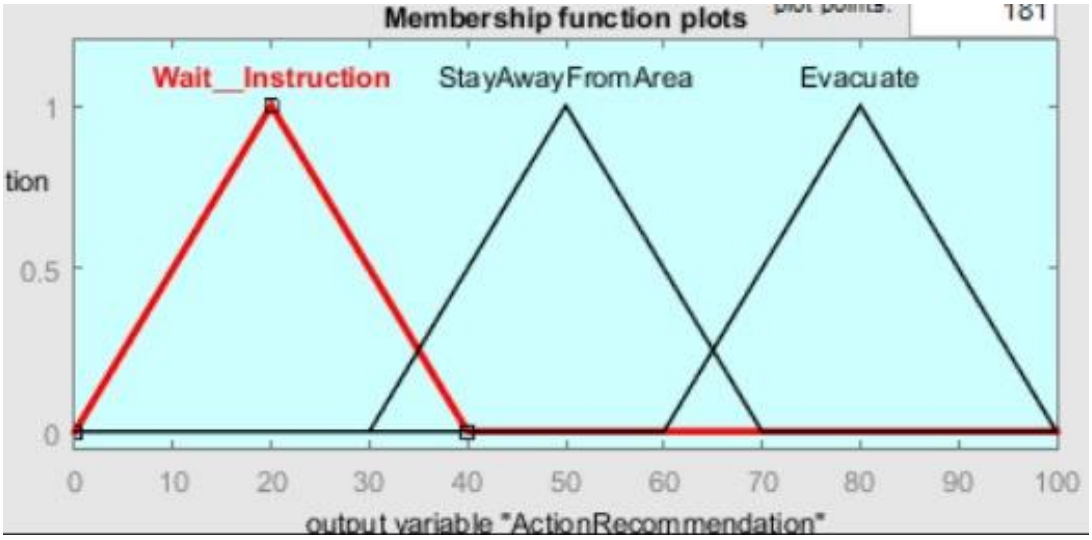

Figure 8. Action Variable Output Membership Set

Membership Association

This input membership set is made based on interview data and adjusted to graphs made in the MATLAB application which can later be used in calculating the level of steak doneness based on the range of each parameter to determine the value of the membership degree (µx). Here's the function data of the membership set input variable:

$$Fx(Temperature)\begin{cases} \mu Normal(x)\begin{cases} 1 & : x \leq 30 \\ \frac{45-x}{45-30} & : 30 \leq x \leq 45 \\ 0 & : x \geq 45 \end{cases} \\ \mu Medium(x)\begin{cases} 0 & : x \leq 30 \\ \frac{x-30}{45-30} & : 30 \leq x \leq 45 \\ \frac{60-x}{60-45} & : 45 \leq x \leq 60 \\ 0 & : x \geq 60 \end{cases} \\ \mu High(x)\begin{cases} 0 & : x \leq 45 \\ \frac{x-45}{60-45} & : 45 \leq x \leq 60 \\ 1 & : x \geq 60 \end{cases} \end{cases}$$

$$Fx(Smoke)\begin{cases} \mu Low(x)\begin{cases} 1 & : x \leq 50 \\ \frac{150-x}{150-50} & : 50 \leq x \leq 150 \\ 0 & : x \geq 150 \end{cases} \\ \mu Medium(x)\begin{cases} 0 & : x \leq 50 \\ \frac{x-50}{150-50} & : 50 \leq x \leq 150 \\ \frac{250-x}{250-150} & : 150 \leq x \leq 250 \\ 0 & : x \geq 250 \end{cases} \\ \mu Concentrated(x)\begin{cases} 0 & : x \leq 200 \\ \frac{x-200}{300-200} & : 200 \leq x \leq 300 \\ 1 & : x \geq 300 \end{cases} \end{cases}$$

$$Fx(History)\begin{cases}\mu Low(x)\begin{cases}1 & : x \le 5\\ \frac{x-5}{7-5} & : 5 \le x \le 7\\ 0 & : x \ge 7\end{cases}\\ \mu Medium(x)\begin{cases}0 & : x \le 50\\ \frac{x-5}{10-5} & : 5 \le x \le 10\\ \frac{17-x}{17-10} & : 17 \le x \le 10\\ 0 & : x \ge 17\end{cases}\\ \mu High(x)\begin{cases}0 & : x \le 15\\ \frac{x-15}{19-15} & : 15 \le x \le 19\\ 1 & : x \ge 19\end{cases}\end{cases}$$

Based on the membership set data we perform calculations to determine fire recommendation actions, with temperature 35℃ (being in the range of Normal parameters), valuable smoke 280 (is in the range of Concentrated parameters), and Narrated by 19 times (is within the range of the High parameter). From the experiment, a degree of membership was obtained (μx) from temperature 35℃ be 0,5, Membership Degrees (μx) from smoke worth 280 be 0,8, and the degree of membership history is valuable 19 be 1.

$$\mu_x\ Normal\ (35) = \frac{45-x}{45-30} = \frac{45-35}{45-30} = \frac{10}{15} = 0\ 66$$

$$\mu_y\ Concentrated\ (280) = \frac{x-200}{300-200} = \frac{280-200}{300-200} = \frac{80}{100} = 0\ 8$$

$$\mu_y\ Concentrated(280) = 1$$

Implication Function Application

When determining the contribution of each fuzzy rule to the final output in the Mamdani method, we use the minimum implication function between the fuzzy set of inputs and outputs. This means that in cases where there are multiple conflicting rules in providing action recommendations, the minimum value of the membership degree of each such rule will be selected as the final membership value for the output. Thus, the minimum implication functions as follows:

$$\begin{aligned}\mu_{R1} &= \min(\mu_{lx\ Normal}[35],\ \mu_{y\ Concentrated}[280],\ \mu_{z\ High}\ [19])\\ &= \min(0.66, 0.8\ , 1)\\ &= 0{,}66\end{aligned}$$

Composition of Rules

We set fuzzy rules based on the correlation between input and output variables. These rules define the actions to be taken based on a combination of temperature, smoke levels, and fire history.

For example, a fuzzy rule can be made by example, if the temperature is normal and the level of dense smoke and a history of fire are high, then the recommendation of action is "evacuation". If the temperature is normal or the smoke level is moderate and the history of fires is moderate, then the recommended course of action is "Stay Away from Areas".

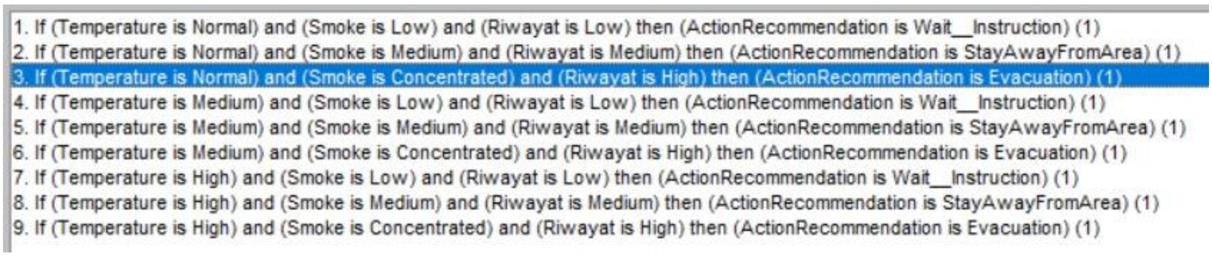

Figure 9. Fuzzy Rules

Defuzzification

The input of the defuzzification process is a fuzzy set resulting from the composition of the fuzzy rule, while the output is a number in the domain of the fuzzy set. Therefore, if a fuzzy set is given in a certain range, then its output must have a certain crisp value (Ilham & Fajri, 2020).

In practice, after a fuzzy logic system generates a fuzzy set of outputs based on predefined rules, we need to convert that fuzzy set into concrete values that can be used in decision making. The centroid defuzzification method does this by calculating the center of mass point of the fuzzy output set. This center of mass is the middle value of the entire fuzzy set, representing the most representative output value of the set.

In this defuzzification process, the first calculation is to determine the values of X1 and X2 from the data that has been calculated. The values of X1 and X2 are determined from the graph of the output variable based on the rules and parameters used. This calculation yields a value of X1 of 73,2 and X2 as big as 86,8, which is included in the output parameter "High", with the following calculation:

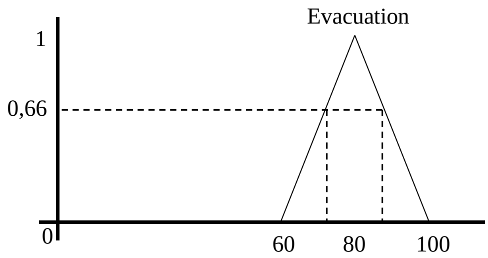

Figure 10. Defuzzification Results

$$\alpha = \frac{X_1 - 60}{80 - 60} \qquad \alpha = \frac{100 - X_2}{100 - 80}$$

$$0{,}66 = \frac{X_1 - 60}{20} \qquad 0{,}66 = \frac{100 - X_2}{20}$$

$$13{,}2 = X_1 - 60 \qquad 13{,}2 = 100 - X_2$$

$$X_1 = 73{,}2 \qquad X_2 = 86{,}8$$

Then from the results of the values X1 and X2 above, a membership set is formed on the output variable as follows:

$$Fx(a,b,c,\mathrm{d})\begin{cases} 0 & : x \leq 60 \\ \frac{x-60}{80-60} & : 60 \leq x \leq 73{,}2 \\ 0{,}66 & : 73{,}2 \leq x \leq 86{,}8 \\ \frac{100-x}{100-80} & : 86{,}8 \leq x \leq 100 \\ 0 & : x \geq 100 \end{cases}$$

After getting the membership set on the output variable, the next step is to calculate for the Set Moment, the calculation x is as follows:

$$x_1 = \frac{x - 60}{80 - 60} = \frac{x}{20} - \frac{60}{20} = 0.05x - 3$$

$$x_2 = 0.66$$

$$x_3 = \frac{100 - x}{100 - 80} = \frac{100}{20} - \frac{x}{20} = 5 - 0.05x$$

After obtaining the x value, calculate the Area and Moment of the Set. The calculation is as follows:

$$RA1 = \frac{(73{,}2 - 60)\ .\ 0{,}66}{2}$$
$$RA1 = 4{,}35$$

$$RA2 = (86{,}8 - 73{,}2)\ .\ 0{,}66$$
$$RA2 = 8{,}97$$

$$RA3 = \frac{(100-86{,}8)\ .\ 0{,}66}{2}$$
$$RA3 = 4{,}35$$

$$M1 = \int_{60}^{73{,}2} (0{,}05x - 3)x\ dx$$
$$= \int_{60}^{73{,}2} 0{,}05x^2 - 3x\ dx$$
$$= \int_{60}^{73{,}2} 0{,}016x^3 - 1{,}5x^2\ dx$$
$$M1 = 182{,}21$$

$$M2 = \int_{73{,}2}^{86{,}8} (0{,}66)x\ dx$$
$$= \int_{73{,}2}^{86{,}8} 0{,}66x\ dx$$
$$= \int_{73{,}2}^{86{,}8} 0{,}33x^2\ dx$$
$$M2 = 718.21$$

$$M3 = \int_{86{,}8}^{100} (5 - 0{,}05\ x)x\ dx$$
$$= \int_{86{,}8}^{100} 5x - 0{,}05x^2\ dx$$
$$= \int_{86{,}8}^{100} 2{,}5x^2 - 0{,}016x^3\ dx$$
$$M3 = 627\ .\ 95$$

From all the data obtained, namely Regional Area (RA) and Moments (M), is the Defuzzification process by dividing the total Moments by the total Regional Area. The following are the defuzzification stages:

$$Z^* = \frac{\sum M}{\sum RA}$$

$$Z^* = \frac{M1 + M2 + M3}{RA1 + RA2 + RA3}$$

$$Z^* = \frac{182.21 + 718.21 + 627.95}{4.25 + 8.97 + 4.35} = \frac{1528.37}{17.67}$$

$$Z^* = 86.49$$

From the results of the defuzzification process, the final value is obtained 86.49 which is the value on the output parameter "Evacuation" that is in the range 60-100. In this case, it proves that the calculations carried out are in accordance with the rules that have been used, namely "If the Room Temperature is Normal, Dense Smoke and High Fire History, then the recommended action is Evacuation.

Hardware

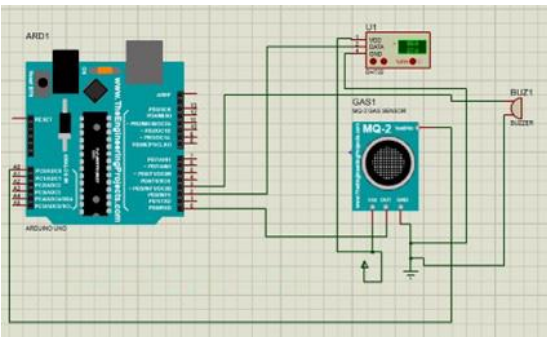

Figure 11. Schematic of the Fire Monitoring System Circuit

This connected fire monitoring system is made to detect fire smoke and monitor the temperature of the fire. The system integrates four main components: Arduino Uno, MQ-2 smoke sensor, DHT22 temperature and humidity sensor, and buzzer. This system aims to detect fire smoke and monitor the temperature of the fire. As a central control, the Arduino Uno can read data from sensors and set the output to the buzzer. The MQ-2 smoke sensor, which can be connected to analog pin A0 on the Arduino Uno, is used to detect smoke produced by fires and allows the system to measure smoke levels in the surrounding environment.

The system also has a DHT22 temperature sensor. It connects to digital pin 2 on the Arduino Uno and allows the system to monitor temperature changes in real-time. The buzzer connected to the digital pin 3 on the Arduino Uno can issue a sound alert when environmental conditions reach a certain threshold specified by its program. Overall, the system demonstrates how sensor and microcontroller technology can be used effectively to monitor and respond to environmental conditions. This system is used to detect fire smoke, temperature changes, as well as give sound alerts calling for evacuation measures. This shows that technology can improve environmental safety and well-being.

CONCLUSION

In this study, we successfully implemented a fire monitoring system that uses Mamdani's fuzzy logic to provide responsive action recommendations based on temperature conditions, smoke levels, and fire history. By dividing input and output variables into fuzzy sets, we can interpret sensor data in a more complex way, resulting in more adaptive and accurate action recommendations. The use of minimum implication functions in the fuzzy rule application process ensures that each rule makes a proportionate contribution to the final output, increasing the reliability of the system in providing action recommendations. We also managed to develop fuzzy rules that suit possible fire conditions, generating relevant and situationally appropriate action recommendations.

Through rigorous testing and the presence of researchers throughout the implementation process, we can ensure the reliability and validity of the developed fire monitoring system. Thus, the system can be relied upon to provide essential guidance in emergency fire situations, assist in informed decision making and ensure the safety of the community. However, we also recognize that Mamdani's fuzzy logic method has limitations, especially in the complexity of formulating fuzzy rules and the need for extensive training data. Therefore, we recommend future research to explore alternatives to fuzzy logic methods or even the development of hybrid systems that can improve the efficiency and accuracy of fire monitoring systems.

Thus, the A Practical Implementation Fire Monitoring Systems Using Fuzzy Methods offers an innovative and responsive approach in handling fire emergency situations, making a significant contribution to fire prevention and suppression efforts in Bogor City.

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