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ORIGINAL ARTICLE

Artificial Intelligence Approach For Fire Monitoring and Warning System Design

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ABSTRACT – Fire alarm system consist of several type of sensors that works togeher in order to detect a fire breakouts. But the systems itself consist of errors especially detecting smoke which sometimes could not lead to a potential fire breakouts instead causing a false alarm. Moreover, vision cameras are expensive to be installed and it takes a lot amount of money for maintenance alone. This causes many household does not equip with such devices making fire breakouts to be inevitable. In this research, the aim of this is to create a system that is cheap and could detect a potential fire before it could even happen by applying Fuzzy logic technique. By adding an Artificial Intelligence in a fire monitoring and warning systems, This could reduce error and predict the right event that could lead to a fire breakouts. With this, many household especially in Malaysia could have the safety to overcome this.

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INTRODUCTION

Organizations that deal with security systems provide items such as intruder alarm and fire alarm systems. The fire and intruder alarm systems that have been built by these firms are highly complex, costly and both do not come together in one system. These systems demand extra maintenance work which can only be carried out by the authorised corporate staff and creates delay with rise in costs. [1] The various solutions of home-based Fire Monitoring and Warning System (FMWS) are of two categories; smoke alarm and vision-based Camera systems. The first one, smoke alarm is not trustworthy while the second one, vision-based camera systems are excessively pricey. For underdeveloped nations, there is need of affordable and reporduceable solutions that may also be given on financial basis. [2]

In Malaysia, devices such as smoke alarm and vision-based Camera systems are rarely used on modern or old houses. Apartments or condominium have smoke alarm installed for an early prevention and detection in case of a fire breakouts. High buildings have a greater risk of fire due to the structure, height, and many more. Fire hazards and unintentional fires are commonly occurred every year. Based on statistics on fire breakouts, Malaysia, in the year 2019, a total of 50,720 fire breakouts occurred which is the second highest cases compared to the year of 2014 with a total of 54,540 fire breakouts cases [3].

The cooking area in houses have a very high chances for the fire source to begin. Between the year of 2000 and 2011, the number of fatalities in south Africa grew form close to 200 to about 500. These figures do not include the injuries sustained in those years as a result of fires, making it an extremely serious issue in the nation [4].

METHODOLOGY

Data analysis method

The rule is set based on the fuzzy inference system (FIS). 3 fuzzy subset is set for the rules which is gas, smoke, and temperature. This 3 FIS will determine the outcome of a potential fire outbreak. The membership function for all 3 is set from Low, Mid, and High. The inference engine which is used for this research is Mamdani fuzzy inference systems. The advantage of using Mamdani fuzzy inference systems is that it is well, suited to human input, more interpretable rule base, widespread acceptance and intuitive [5].

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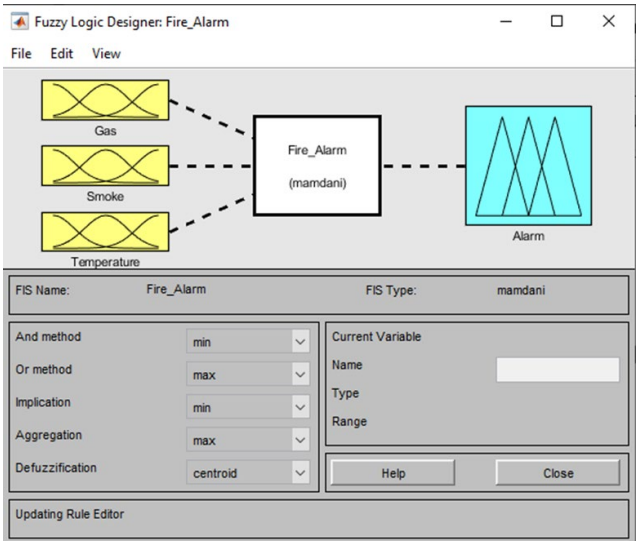

Figure 1. Fuzzy logic designer for Fire alarm system.

A total of 54-rule is created to test out whether this rule could determine the right outcome and reduce false alarm. A total of 27 rule is created for Fire detection and another 27 more rule is created for Pre-detection of fire. The fuzzy set is form based on the membership value for every variable which is needed to be assigned interval of [0 1]. A triangle function or trapezoidal function is used to define the function of membership.

Table 1. First 10 rules of Fuzzy Logic Fire Detection

Rule	Gas	Smoke	Temperature	Alarm
1	LOW	LOW	LOW	FALSE
2	LOW	LOW	MID	POTENTIAL
3	LOW	LOW	HIGH	TRUE
4	LOW	MID	LOW	FALSE
5	LOW	MID	MID	POTENTIAL
6	LOW	MID	HIGH	TRUE
7	LOW	HIGH	LOW	FALSE
8	LOW	HIGH	MID	TRUE
9	LOW	HIGH	HIGH	TRUE
10	MID	LOW	LOW	FALSE

Membership Function Setup

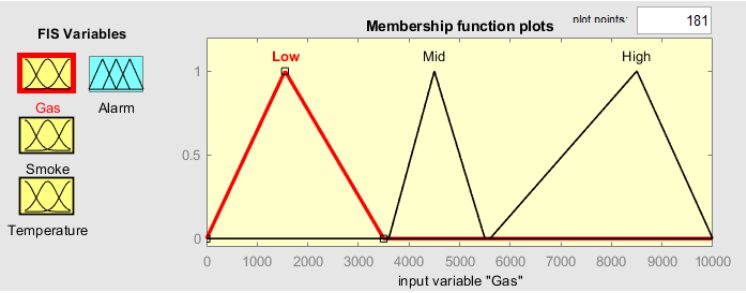

Figure 2. Membership function of Gas

In figure 2, there are 3 linguistic variables of Gas which is Low, Mid and High that are used and where the X-axis represents the value change of gas from 0 to 100% and Y-axis represents the degree of membership from 0 to 1. The value of gasses obtain is in ppm. The membership functions is also set according to the respective linguistic variables for smoke and Temperature. The calculation to obtained in percentage is callculated as follows for Gas and Smoke:

$$Percentage(Gas) = \left(\frac{ppm}{10000}\right) x100 \tag{1}$$

$$Percentage(Smoke) = \left(\frac{ppm}{10000}\right) x100 \tag{2}$$

As for temperatures, the X-axis represents the value change of temperature in Celsius from 0ºC to 100ºC and Y-axis represent the degree of membership from 0 to 1. The linguistic variable for Low is set from 0ºC to 30ºC, Mid is set from 31ºC to 55ºC and High is set from 56ºC to 100ºC. Normal rom temperature is considered to be around 23ºC to 26ºC in Malaysia. The temperature of a fire varies based on the source and kind of fire. Red flame temperatures vary from 525ºC to 1000ºC. The temperature of orange flames is between 1000ºC and 1200ºC. Blue flames with temperatures ranging from 2500ºC to 3000ºC ("What is the Temperature of Fire? | News – Target Fire Protection," 2022). For Fire detection, the current temperature is monitored. The detection will occur when the temperature reach the current target based on the linguistic variable set.

RESULTS AND DISCCUSION

Pre-detection data

Pre-detection data is considered to be the data before a fire incident could occurred. The prediction to detect an early outcome or a potential starting fire could prevent it from happening. In figure 3 shows the results for the first experiment which is for the pre-detection phase. In the rule viewer, the first column indicates the change rate of humidity (C.Rate_Humidity), the second column indicates the change rate of carbon dioxide (C.Rate_CO) and the third column indicates the change rate of temperature (C.Rate_Temperature). The last column indicates the output and reflects the probalities of fire pre-detection. The input data for each membership function is all based on table 2.

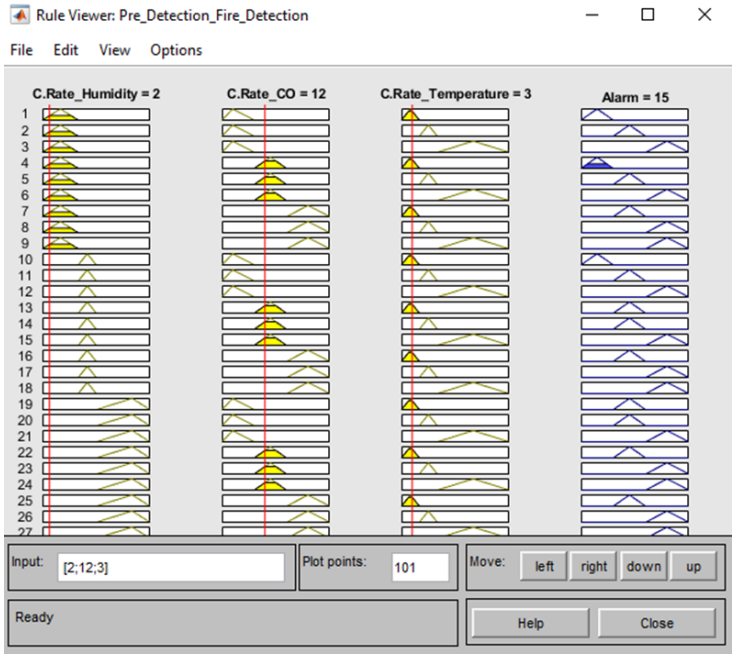

Figure 3. The Pre-Dectection chances of fire in experiment 1 using MATLAB Rule Viewer.

After running the simulation through MATLAB, the results are collected and is illustrated through table 2 which are the outcomes of experiment results.

Table 2. Pre-Detection Alarm outcomes of experiment results

No.	Change Rate of Humidity (%)	Change Rate of Carbon Dioxide (%)	Change Rate of Temperature (%)	Alarm Percentage (%)
1	2	12	3	15
2	4	15	10	50
3	20	9	21	50
4	3	8	10	50
5	9	24	25	80
6	28	25	20	80
7	20	13	15	80
8	8	17	29	80
9	3	20	10	50
10	27	19	23	80

Figure 4 shows the surface of viewer from MATLAB of change rate of Carbon Dioxide against Change rate of Temperature. The results shows that change rate of carbon dioxide and change rate of Temperature. The results shows that change rate of carbon dioxide and change rate of temperature have higher value in fire regions and the value is lower in region that has no fire.

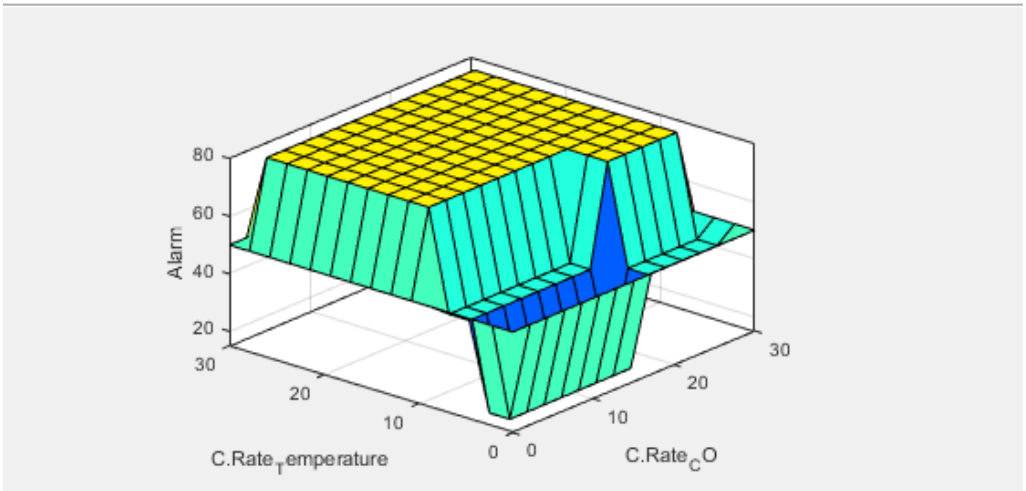

Figure 4. Surface viewer of Change Rate of Temperatures against Change Rate of Carbon dioxide in MATLAB.

Fire detection data

Fire detection data is considered to be the data during a fire incident occurred. According to the data obtained after conducting the simulation in MATLAB, the data is collected and organized into table 3. In figure 5 shows the results for the second experiment which is for the fire detection phase. In the rule viewer, the first column indicates the gas presents, the second column indicates the smoke presents and the third column indicates the temperature of surrounding. The last column indicates the output of alarm detecting the fire. The input data for each membership functions is based on table 3.

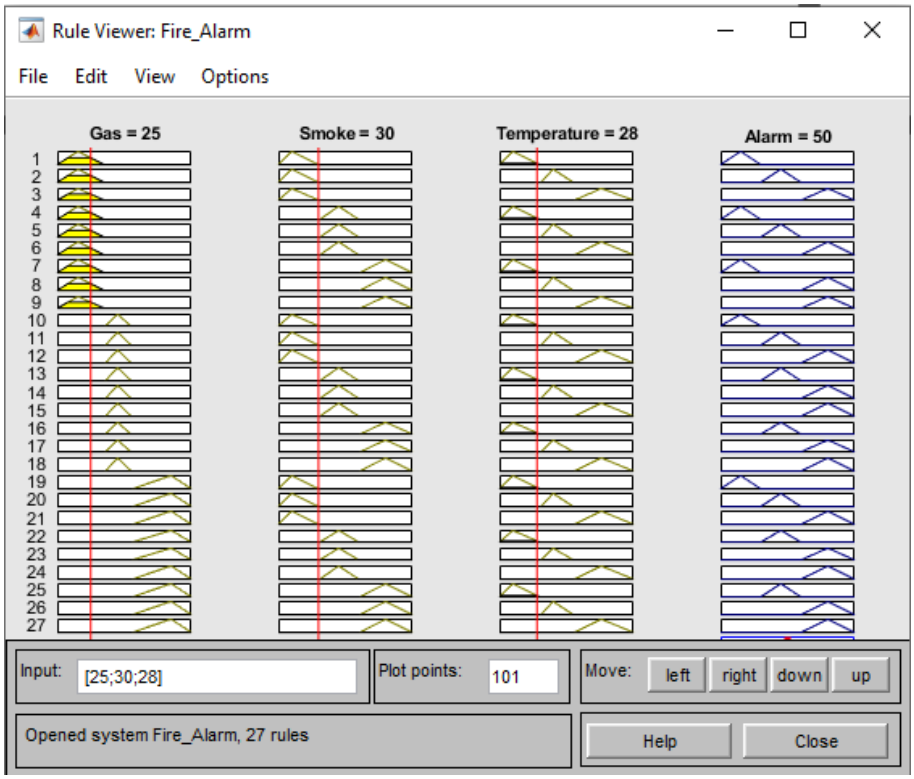

Figure 5. Fire Detection in experiment 2 using MATLAB Rule Viewer

After running the simulation in MATLAB, the results are collected and is illustrated through table 3 which are the outcomes of the simulation results.

Table 3. Fire detectio outcomes of simulation results.

No.	Gas	Smoke	Temperature	Alarm Percentage
1	25	30	28	50
2	10	50	20	15
3	40	68	45	80
4	89	90	89	80
5	29	38	51	45
6	31	52	43	45
7	32	43	60	80
8	29	81	78	80
9	10	2	18	15
10	72	18	30	50

Figure 6 shows the surface of viewer from MATLAB of Smoke against the temperature. The results shows that smoke and an increase in temperature have high value in fire region compared to region that has no fire.

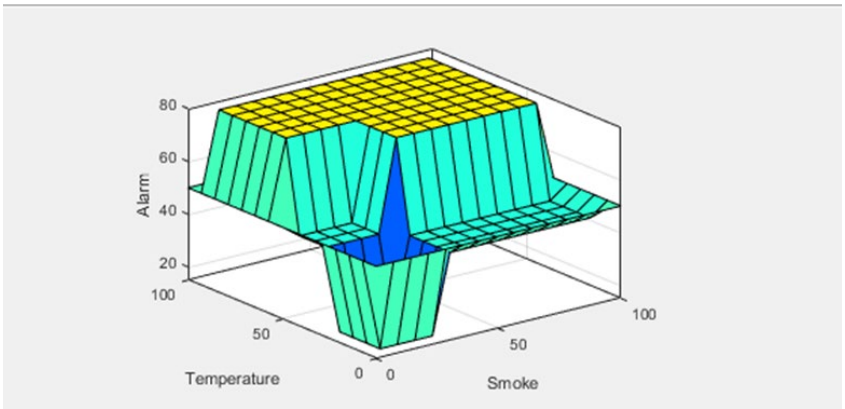

Figure 6. Surface viewer of Smoke against Temperatures in MATLAB.

CONCLUSION

In Conclusion, Fire monitoring and warning system that is implemented with fuzzy logic could be the key in preventing and creating cheaper safety option. This implementation could prevent and provide safety measure in every household especially in Malaysia where most smoke detectors are not installed. This method can be improved in the future as there are parts of technology is limited. Fuzzy logic algorithm can be improvised to ensure better understanding in reading and making better decision making.

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