Hazardous Gas Detection using Gas Sensors Arrays and Fuzzy-Based Classification

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Abstract: This paper presents hazardous gas detection using gas sensors arrays and fuzzy-based classification. This research is an automation of hazardous gas detection using electronic nose. Gases surround us could either hazard or benefit our health. Gas detection is an important issue, as humans should not breathe in hazardous gases in order to maintain their health. Hence, there must be an indicator to show the hazardous level of certain gases so that people can avoid and minimize the impact on their health. In this paper, hazardous gas detection is implemented by using gas sensor arrays and fuzzy-based classification. A classification for the electronic nose (e-nose) is developed in order to classify gases and determine the level of hazard of gases. The results found that e-nose system is able to differentiate hazardous level of chosen gases which are LP gas and CO gas.

Keywords: Hazardous gas, gas sensors, fuzzy classification.

I. INTRODUCTION

The main purpose of gas detection systems is to detect any gases in surrounding and measure accurate readings and then provide appropriate action to be taken by the people within that area. In Malaysia, there is no suitable system to detect gases that are considered hazardous to human health and flammable gases, which may lead to unexpected events such as fire or explosions if they are mixed with air in adequate amount. There are many gases that are hazardous, i.e. ammonia, chlorine, sulphur, carbon monoxide, to name a few. However in this research, the selected gases that need to be detected in the environment are carbon monoxide (CO) and liquefied petroleum gas (LPG). Hazardous gas detection will be implemented by using gas sensor arrays and fuzzy-based classification provides precise readings for the two gases as stated earlier. Based on the discussion above, electronic nose has been used in many fields especially in detecting gas at certain area, condition or environment. Many research has shown detection of gases using e-nose in many fields, and using various methods of classifications. By implementing fuzzy logic classification on the electronic nose system, the hazardous level of gases can be determined.

II.SYSTEM DESIGN

Electronic nose is an embedded-based system to help distinguish the hazardous level of gases by using the following mechanism; the e-nose sensor arrays will detect the gases surrounding the area, then the sensor arrays will respond in electrical signal form. Then, the value will be transmitted to the signal processing unit to perform the analysis of the sampling pattern in order to determine the hazardous level of the gases detected.

A. E-Nose System Description

The combination of e-nose hardware and the classification will generate precise output. The system will determine whether the gases are dangerous once the sensor arrays respond to them. After the digital signal from the sensor is sent to the microcontroller, it will be computed and the dangerous level of gases will be determined by using the developed classification method. The dangerous level will be displayed on the LCD monitor. There are few electronics parts that will be integrated in this system such as breadboard, LCD monitor and sensors in order to be functioned as gas detector.

B. Flowchart

Figure 1 shows the flow chart of the system. Based on the Figure 1, the e-nose system will be having a condition whereby if the detectable gas is not present, it will go to initial step. If the gas is present, it will respond and sends the digital signal to the microcontroller. Microcontroller then will compute the signal, by using the developed gas classification method, and then will determine the hazardous level of gas detected.

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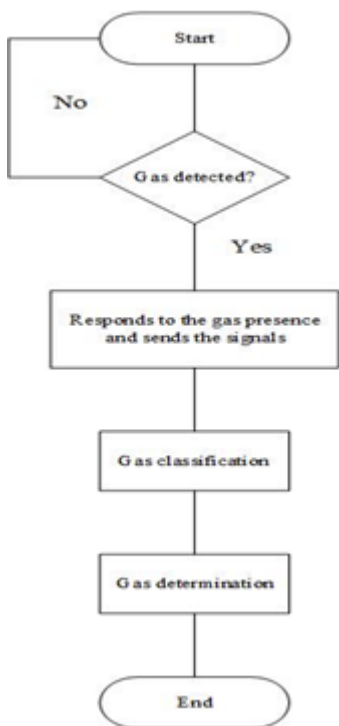
Figure 1: System flow chart

C. System Design

The system was designed to contain a various components that fulfill the research purpose. Figure 2 shows the system design of e-nose system.
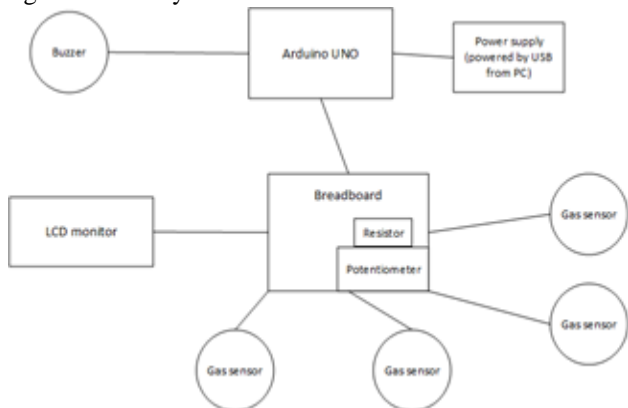

Figure 2: System design of electronic nose

Based on Figure 2, Arduino board will be powered by direct connection through USB cable or optionally, with batteries. Once it is powered on, the gas sensors needs to be placed in the area where the gases (CO and LPG) are present. For testing purpose, this process will be done inside a confined space. The gas sensors will react to the presence of the gases and the microcontroller will do its task as required. The output will be displayed on the LCD monitor.

III. IMPLEMENTATION

In this section, it will describe systematically on how to set up the e-nose system for the hardware as well as the testing and results from the fuzzy classifier.

A. Hardware Component Development

All the listed hardware components will be assembled and connected to the microcontroller board, which is the Arduino Uno. To develop the prototype device, the listed items which include Arduino Uno, Breadboard, Buzzer, Jumper wires, LCD monitor (20x4), MQ-6 gas sensor (LPG, propane gas), MQ-7 gas sensor (Carbon monoxide gas), Potentiometer, Resistor.

B. Classification
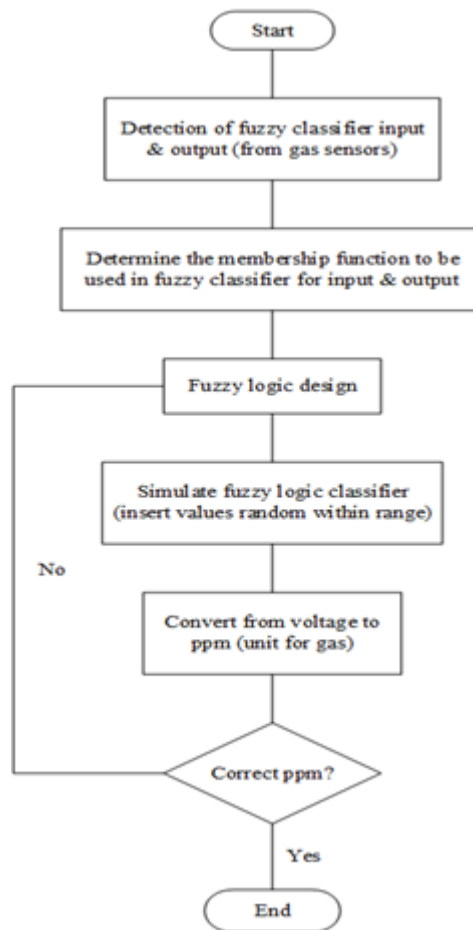
Figure 3 shows the flow chart of fuzzy logic designing.

Figure 3: Fuzzy Logic Designing Flow Chart

1. Fuzzification

Fuzzification is the process of changing a real scalar value into a fuzzy value. This process is achieved by using the different types of membership functions (fuzzifiers). The first step is to take the inputs from MQ-6 and MQ-7 sensors and determine the degree to which inputs belong to each of the fuzzy set.

The inputs are listed as below:

1st sensor: MQ-6 □ Voltage = fuzzy set [LOW, MEDIUM, HIGH], range [0-5]

2nd sensor: MQ-7 □ Voltage = fuzzy set [LOW, MEDIUM, HIGH], range [0-5]

3rd sensor: MQ-6 □ Voltage = fuzzy set [LOW, MEDIUM, HIGH], range [0-5]

4th sensor: MQ-7 □ Voltage = fuzzy set [LOW, MEDIUM, HIGH], range [0-5]

The output is listed as below:
Result: Level = {SAFE, LESS SAFE, DANGERUS}, range {0-800}

2. Fuzzy Rules

The next step is to use the inputs from all three sensors and apply them to the antecedents of the fuzzy rules. The 'AND' operation is used to obtain a single value that represents the result of the antecedent evaluation. This number is then applied to the consequence membership function. Table 1 – 3 shows all 81 rules belong to the system.

Table 1: Fuzzy Rules (Rule 1 - 27)

Number of Rules	1st Sensor (MQ-6)	2nd Sensor (MQ-7)	3rd Sensor (MQ-6)	4th Sensor (MQ-7)	Result
1	LOW	LOW	LOW	LOW	SAFE
2	LOW	LOW	LOW	MEDIUM	SAFE
3	LOW	LOW	LOW	HIGH	SAFE
4	LOW	LOW	MEDIUM	LOW	SAFE
5	LOW	LOW	MEDIUM	MEDIUM	SAFE
6	LOW	LOW	MEDIUM	HIGH	SAFE
7	LOW	LOW	HIGH	LOW	SAFE
8	LOW	LOW	HIGH	MEDIUM	LESS SAFE
9	LOW	LOW	HIGH	HIGH	DANGEROUS
10	LOW	MEDIUM	LOW	LOW	SAFE
11	LOW	MEDIUM	LOW	MEDIUM	SAFE
12	LOW	MEDIUM	LOW	HIGH	LESS SAFE
13	LOW	MEDIUM	MEDIUM	LOW	SAFE
14	LOW	MEDIUM	MEDIUM	MEDIUM	LESS SAFE
15	LOW	MEDIUM	MEDIUM	HIGH	LESS SAFE
16	LOW	MEDIUM	HIGH	LOW	SAFE
17	LOW	MEDIUM	HIGH	MEDIUM	LESS SAFE
18	LOW	MEDIUM	HIGH	HIGH	DANGEROUS
19	LOW	HIGH	LOW	LOW	SAFE
20	LOW	HIGH	LOW	MEDIUM	SAFE
21	LOW	HIGH	LOW	HIGH	DANGEROUS
22	LOW	HIGH	MEDIUM	LOW	LESS SAFE
23	LOW	HIGH	MEDIUM	MEDIUM	LESS SAFE
24	LOW	HIGH	MEDIUM	HIGH	DANGEROUS
25	LOW	HIGH	HIGH	LOW	DANGEROUS
26	LOW	HIGH	HIGH	MEDIUM	DANGEROUS
27	LOW	HIGH	HIGH	HIGH	DANGEROUS

Table 2: Fuzzy Rules (Rule 28 - 54)

Number of Rules	1st Sensor (MQ-6)	2nd Sensor (MQ-7)	3rd Sensor (MQ-6)	4th Sensor (MQ-7)	Result
28	MEDIUM	LOW	LOW	LOW	SAFE
29	MEDIUM	LOW	LOW	MEDIUM	SAFE
30	MEDIUM	LOW	LOW	HIGH	SAFE
31	MEDIUM	LOW	MEDIUM	LOW	SAFE
32	MEDIUM	LOW	MEDIUM	MEDIUM	LESS SAFE
33	MEDIUM	LOW	MEDIUM	HIGH	LESS SAFE
34	MEDIUM	LOW	HIGH	LOW	SAFE
35	MEDIUM	LOW	HIGH	MEDIUM	LESS SAFE
36	MEDIUM	LOW	HIGH	HIGH	DANGEROUS
37	MEDIUM	MEDIUM	LOW	LOW	SAFE
38	MEDIUM	MEDIUM	LOW	MEDIUM	SAFE
39	MEDIUM	MEDIUM	LOW	HIGH	LESS SAFE
40	MEDIUM	MEDIUM	MEDIUM	LOW	LESS SAFE
41	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LESS SAFE
42	MEDIUM	MEDIUM	MEDIUM	HIGH	LESS SAFE
43	MEDIUM	MEDIUM	HIGH	LOW	LESS SAFE
44	MEDIUM	MEDIUM	HIGH	MEDIUM	LESS SAFE
45	MEDIUM	MEDIUM	HIGH	HIGH	DANGEROUS
46	MEDIUM	HIGH	LOW	LOW	LESS SAFE
47	MEDIUM	HIGH	LOW	MEDIUM	DANGEROUS
48	MEDIUM	HIGH	LOW	HIGH	DANGEROUS
49	MEDIUM	HIGH	MEDIUM	LOW	LESS SAFE
50	MEDIUM	HIGH	MEDIUM	MEDIUM	DANGEROUS
51	MEDIUM	HIGH	MEDIUM	HIGH	DANGEROUS
52	MEDIUM	HIGH	HIGH	LOW	DANGEROUS
53	MEDIUM	HIGH	HIGH	MEDIUM	DANGEROUS
54	MEDIUM	HIGH	HIGH	HIGH	DANGEROUS

Table 3: Fuzzy Rules (Rule 55 - 81)

Number of Rules	1st Sensor (MQ-6)	2nd Sensor (MQ-7)	3rd Sensor (MQ-6)	4th Sensor (MQ-7)	Result
55	HIGH	LOW	LOW	LOW	SAFE
56	HIGH	LOW	LOW	MEDIUM	SAFE
57	HIGH	LOW	LOW	HIGH	DANGEROUS
58	HIGH	LOW	MEDIUM	LOW	LESS SAFE
59	HIGH	LOW	MEDIUM	MEDIUM	LESS SAFE
60	HIGH	LOW	MEDIUM	HIGH	DANGEROUS
61	HIGH	LOW	HIGH	LOW	DANGEROUS
62	HIGH	LOW	HIGH	MEDIUM	DANGEROUS
63	HIGH	LOW	HIGH	HIGH	DANGEROUS
64	HIGH	MEDIUM	LOW	LOW	SAFE
65	HIGH	MEDIUM	LOW	MEDIUM	LESS SAFE
66	HIGH	MEDIUM	LOW	HIGH	DANGEROUS
67	HIGH	MEDIUM	MEDIUM	LOW	LESS SAFE
68	HIGH	MEDIUM	MEDIUM	MEDIUM	LESS SAFE
69	HIGH	MEDIUM	MEDIUM	HIGH	DANGEROUS
70	HIGH	MEDIUM	HIGH	LOW	DANGEROUS
71	HIGH	MEDIUM	HIGH	MEDIUM	DANGEROUS
72	HIGH	MEDIUM	HIGH	HIGH	DANGEROUS
73	HIGH	HIGH	LOW	LOW	DANGEROUS
74	HIGH	HIGH	LOW	MEDIUM	DANGEROUS
75	HIGH	HIGH	LOW	HIGH	DANGEROUS
76	HIGH	HIGH	MEDIUM	LOW	DANGEROUS
77	HIGH	HIGH	MEDIUM	MEDIUM	DANGEROUS
78	HIGH	HIGH	MEDIUM	HIGH	DANGEROUS
79	HIGH	HIGH	HIGH	LOW	DANGEROUS
80	HIGH	HIGH	HIGH	MEDIUM	DANGEROUS
81	HIGH	HIGH	HIGH	HIGH	DANGEROUS

Once the codes have been uploaded to the Arduino, the e-nose system is tested by using LP gas and CO gas resource, which is from mini gas stove or lighter.

Figure 4: Welcome Screen

Figure 4 shows the welcome screen when the e-nose system is switched on.

Figure 5: 'Safe' Level Screen

Figure 5 shows the result which is "safe" when the gas sensors are tested with LP gas and/or CO gas with less than 30ppm and less than 5ppm respectively.

Figure 6: 'Less safe' Level Screen

Figure 6 shows the result which is "less safe" when the gas sensors are tested with LP gas and/or CO gas with more than 30ppm and more than 5ppm respectively.

Figure 7: 'Dangerous' Level Screen

IV. RESULTS AND DISCUSSION

Figure 7 shows the result which is "dangerous" when the gas sensors are tested with LP gas and/or CO gas when they reach more than 800ppm for LP gas and more than 50ppm for CO gas.
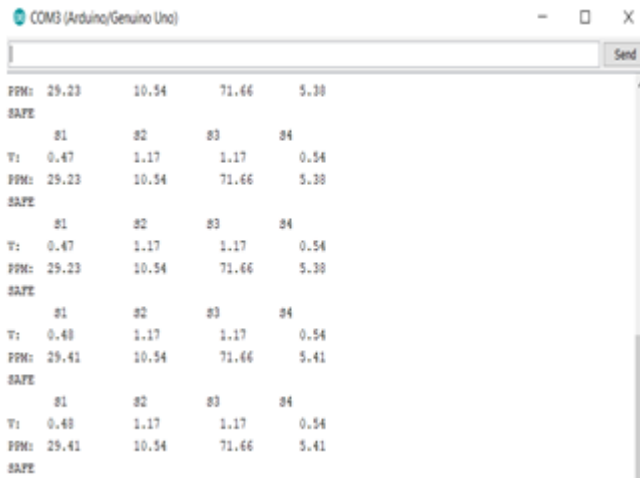

Figure 8: Serial Monitor Readings

Figure 8 shows the similar screen shown by the LCD monitor at serial monitor of Arduino IDE. The purpose of duplicating monitoring screen is to have a backup monitoring screen if the LCD monitor is not working.

In order to verify the classification and output of the e-nose system, the verification is done by comparing the gas of both LP and CO in ppm unit to values that have been set earlier in the research, which summarized in Table 4 and Table 5.

Table 4: Result for LP Gas

Value (ppm)	Classification result
Less than 30ppm	Safe
In between 30ppm & 800ppm	Less safe
More than 800ppm	Dangerous

Table 5: Result for CO Gas

Value (ppm)	Classification result
Less than 5ppm	Safe
In between 5ppm & 50ppm	Less safe
More than 50ppm	Dangerous

Based on the result, e-nose is able to determine the level of dangerous of chosen gases which are LP gas and CO gas..

V.CONCLUSION

This research achieves the objectives, which are to read several gases from the environment by using e-nose and to classify gas using classification method. Fuzzy logic application enables the system to get the optimum result. Based on the result, it is proven that e-nose system is a reliable device for human to use as the deciding factor for classifying hazardous gas in the environment. In the software part, integrating all four sensors at the same time consumed a longer time and can be considered one of the challenges. In order for them to work accurately, they need to be pre-heated for at least 30 minutes. Sometimes these sensors loss their sensitivities due to other factors such as wind. Other than that, adjusting the precise current to the LCD monitor is challenging. The LCD monitor has to be provided with explicit amount of voltage in order for it to work properly. For future improvement, other different gases can be detected by using this e-nose system such as ammonia gas, or even formaldehyde gas. Other than that, this e-nose system can be improved by having alerting functions such as by GSM module, or even a mobile application. To have a full and an almost perfect system, this e-nose system can be combined with a web-based system whereby all the data collected by the sensors can be stored in a database and they can be used for future reference for any research and development purpose.

VI. ACKNOWLEDGMENT

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DOI:10.35940/ijrte.B1194.0882S819

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