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Air Quality Control System With Gas Leak Detection In Rooms With Fuzzy

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ABSTRACT
Abstract. Indoor air quality is an important factor affecting human health and safety, especially in industrial and laboratory environments that are at risk of hazardous gas leaks. To overcome this problem, a system is needed that is able to monitor air quality in real time and detect gas leaks with a high level of accuracy. One of the artificial intelligence methods that can be used in air quality control systems is fuzzy logic, which is able to process sensor data with a high level of uncertainty and produce optimal decisions.This study aims to design and develop an air quality control system with fuzzy logic-based gas leak detection. This system uses various sensors, such as gas sensors (MQ-series), temperature sensors, and humidity sensors, whose data is processed using a fuzzy algorithm to determine the level of air quality and detect gas leaks automatically. If a gas leak or a decrease in air quality is detected below the set threshold, the system will activate a warning alarm and control ventilation to maintain safe air conditions.The test results show that the developed system is able to detect gas leaks with a high level of accuracy and provide a quick response to changes in indoor air conditions. The use of fuzzy logic allows the system to adjust actions based on the severity of the leak or air pollution, thereby increasing efficiency and reliability in air quality control. Thus, this system can be an effective solution in improving indoor safety and comfort, especially in environments that are vulnerable to gas leaks.

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INTRODUCTION

Indoor air quality is a critical factor affecting the health and comfort of occupants. According to the World Health Organization (WHO), poor air quality can cause a variety of health problems, ranging from mild eye irritation to serious respiratory diseases such as asthma and chronic obstructive pulmonary disease [1]. In recent decades, attention to indoor air quality has increased, especially in crowded work and living environments. Indoor air quality control involves various aspects, including adequate ventilation, pollutant reduction, and early detection of hazardous contaminants such as toxic gases. One effective method for detecting and controlling air quality is by using a fuzzy logic-based control system. Indoor air quality plays an important role in human health and productivity. Various studies have shown that poor air quality can affect work performance, sleep, and overall health [2]. Airborne contaminants, such as dust particles, toxic gases, and volatile organic compounds (VOCs), can cause respiratory disorders, allergies, and even chronic diseases. In addition to direct impacts on health, poor air quality can also cause damage to equipment and building structures. For example, corrosive gases can damage electronic components and metal structures, which in turn increases maintenance and repair costs [3].

Indoor gas leaks are one of the serious threats to safety and health. Gases such as carbon monoxide (CO), methane (CH_4), and other toxic gases can cause poisoning and even explosions if not detected and handled quickly. Therefore, gas leak detection is a critical aspect in indoor air quality management [4]. Various technologies have been developed to detect gas leaks, ranging from simple sensors to more sophisticated detection systems. However, the main challenge in gas leak detection is ensuring that the system can function effectively under various environmental conditions and with a high degree of reliability.

Fuzzy logic is an effective method for dealing with uncertainty and complexity in control systems. Unlike traditional binary logic that only recognizes two states (true or false), fuzzy logic allows the use of truth values that vary between 0 and 1. This makes fuzzy logic very suitable for applications that require handling ambiguous or uncertain data [5]. In the context of air quality control, fuzzy logic can be used to combine various sensor inputs and make more informed decisions about the actions to be taken. For example, fuzzy logic can integrate data from multiple gas sensors and adjust the ventilation or alarm system based on the detected hazard level.

Fuzzy logic-based control systems for gas leak detection have several advantages over conventional methods. First, these systems can combine multiple types of sensors to provide more accurate and reliable detection. Second, fuzzy logic allows for more flexible and adaptive decision-making, which is critical in emergency situations [6]. Several studies have demonstrated the effectiveness of fuzzy logic in gas leak detection and air quality control. For example, a study by Lee et al. (2017) showed that fuzzy-based control systems can detect gas leaks with a high degree of accuracy and provide fast and precise responses under various environmental conditions [7].

Despite its many advantages, the application of fuzzy logic in gas leak detection still faces several challenges. One of the main challenges is the need for proper calibration and maintenance to ensure that the sensors and control systems function optimally. In addition, integration with existing building management systems also requires special attention [8]. However, with the development of sensor and computing technology, the opportunity to develop more sophisticated and efficient gas leak detection systems is increasingly open. The application of Internet of Things (IoT) and artificial intelligence (AI) technology can also improve the performance and reliability of fuzzy logic-based control systems [9]. Several case studies have shown the success of implementing fuzzy logic-based control systems for gas leak detection. For example, implementation in the petrochemical industry shows that this system can effectively detect gas leaks and reduce the risk of accidents [10]. In the residential sector, the use of fuzzy-based gas leak detection systems has also shown increased safety and comfort for occupants [11]. Indoor air quality control and gas leak detection are important aspects that require special attention.

METHOD

The research entitled "Air Quality Control System with Gas Leak Detection in Rooms with Fuzzy" uses a quantitative research approach. Quantitative research is chosen because it focuses on the measurement and numerical analysis of data collected through experiments and system testing. The main objective of this research is to develop and test an air quality control system that uses sensors to detect gas leaks and processes the data using a fuzzy algorithm. This approach emphasizes the

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collection of objective and measurable data to assess the performance of the designed system.

Researchers must identify the key parameters that the system must monitor, such as the type of gas that needs to be detected, the concentration level of the gas that is considered dangerous, and the desired response from the system when detecting a gas leak. In addition, researchers must also consider other factors such as the operational environment, cost, and ease of use of the system. By understanding user needs in depth, researchers can design a system that is not only effective in detecting gas leaks but also meets user needs and expectations. Overall, the problem identification stage in this study involves in-depth information collection through literature studies and user needs analysis to ensure that the system developed can meet the research objectives and provide effective and efficient solutions in controlling air quality and detecting gas leaks. After the problem is identified, the next step in this research is system design. This stage is very crucial because it determines how the system will be built and how the system will function to achieve the desired goals. System design involves several key steps, namely sensor selection, fuzzy algorithm design, hardware design, and software design.

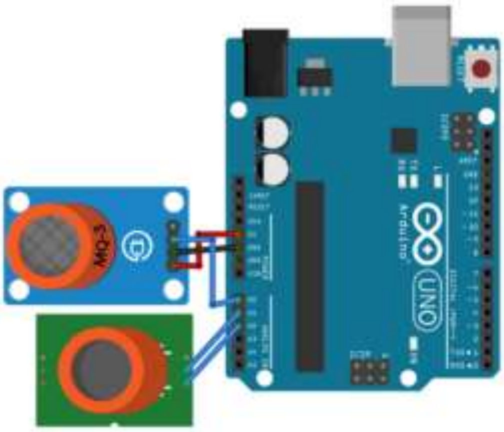

Figure 1. System Schematic

Sensor Selection: The first step in system design is to determine the type of sensor that will be used to detect hazardous gases such as carbon monoxide, methane, or other gases. Sensor selection is based on several important criteria, including sensitivity, accuracy, response time, and sensor stability under various environmental conditions. Fuzzy Algorithm Design: Once the sensor is selected, the next step is to design a fuzzy logic algorithm. This algorithm will be used to analyze the data obtained from the sensor and make decisions regarding air quality and gas leak detection. Fuzzy logic was chosen because of its ability to handle uncertain data and variables with unclear boundaries. Hardware Design: Hardware components are an important part of the system that will support the function of the sensor and the fuzzy algorithm. In this stage, the researcher determines the hardware components that will be used, including the microcontroller, communication module, and actuator Software Design: The last step in system design is the development of software that will run on the microcontroller. This software must be able to process sensor data in real-time and run the fuzzy algorithm to produce the required output. Software development includes writing code, testing, and debugging to ensure that the software functions properly and meets predetermined specifications.

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RESULTS AND DISCUSSION

Testing was conducted under various environmental conditions to assess the overall performance of the system. The test results showed that the MQ-135 sensor can detect changes in gas concentration quickly and provide consistent data. The developed fuzzy algorithm is able to handle uncertain data and produce outputs that are in accordance with real conditions, such as providing early warnings when hazardous gas concentrations increase. The system was also tested in various rooms with different ventilation conditions, and the results showed that the system can function well in detecting gas leaks and maintaining air quality. The system performance evaluation showed that the combination of the MQ-135 sensor and Arduino UNO with a fuzzy algorithm provides a reliable and efficient solution for detecting gas leaks and controlling indoor air quality. This system not only provides accurate results but also has a fast response time, so it can provide early warnings that are very important to prevent potential hazards. Based on the results of data analysis, this system can be relied on for use in various applications, including in industrial and household environments, to ensure the safety and comfort of its occupants.

Table 1 Results of air quality control

No.	Kondisi Lingkungan	Konsentrasi Gas (ppm)	Output Sensor (Analog)	Keputusan Algoritma Fuzzy	Waktu Respons (detik)	Catatan
1	Ruang Tertutup	CO_2: 400	200	Aman	1	Kondisi normal
2	Ruang Terbuka	CO_2: 350	180	Aman	1	Kondisi normal
3	Ruang Tertutup	CO_2: 800	400	Peringatan	2	Konsentrasi gas meningkat
4	Ruang Tertutup	CO_2: 1200	600	Bahaya	1	Konsentrasi gas sangat tinggi
5	Ruang Ventilasi Sedang	CO_2: 500	250	Aman	1	Kondisi normal
6	Ruang Ventilasi Buruk	CO_2: 900	450	Peringatan	2	Konsentrasi gas di atas batas normal
7	Ruang Terbuka	CO: 50	100	Aman	1	Konsentrasi gas rendah
8	Ruang Tertutup	CO: 200	350	Bahaya	1	Kebocoran gas terdeteksi
9	Ruang Ventilasi Buruk	CO: 150	300	Peringatan	2	Konsentrasi gas meningkat
10	Ruang Terbuka	CH_4: 100	220	Aman	1	Kondisi normal
11	Ruang	CH_4: 400	500	Bahaya	1	Kebocoran gas

No.	Kondisi Lingkungan	Konsentrasi Gas (ppm)	Output Sensor (Analog)	Keputusan Algoritma Fuzzy	Waktu Respons (detik)	Catatan
	Tertutup					metana terdeteksi
12	Ruang Ventilasi Sedang	CH_4: 200	350	Peringatan	2	Konsentrasi gas di atas batas normal
13	Ruang Tertutup	CO_2: 450	220	Aman	1	Kondisi normal
14	Ruang Terbuka	CO_2: 300	160	Aman	1	Kondisi normal
15	Ruang Tertutup	CO_2: 850	420	Peringatan	2	Konsentrasi gas meningkat
16	Ruang Tertutup	CO_2: 1300	650	Bahaya	1	Konsentrasi gas sangat tinggi
17	Ruang Ventilasi Sedang	CO_2: 550	270	Aman	1	Kondisi normal
18	Ruang Ventilasi Buruk	CO_2: 950	470	Peringatan	2	Konsentrasi gas di atas batas normal
19	Ruang Terbuka	CO: 70	110	Aman	1	Konsentrasi gas rendah
20	Ruang Tertutup	CO: 250	370	Bahaya	1	Kebocoran gas terdeteksi
21	Ruang Ventilasi Buruk	CO: 170	310	Peringatan	2	Konsentrasi gas meningkat
22	Ruang Terbuka	CH_4: 150	230	Aman	1	Kondisi normal
23	Ruang Tertutup	CH_4: 450	510	Bahaya	1	Kebocoran gas metana terdeteksi
24	Ruang Ventilasi Sedang	CH_4: 250	360	Peringatan	2	Konsentrasi gas di atas batas normal
25	Ruang Tertutup	CO_2: 500	260	Aman	1	Kondisi normal
26	Ruang Terbuka	CO_2: 380	190	Aman	1	Kondisi normal
27	Ruang	CO_2: 900	430	Peringatan	2	Konsentrasi gas

No.	Kondisi Lingkungan	Konsentrasi Gas (ppm)	Output Sensor (Analog)	Keputusan Algoritma Fuzzy	Waktu Respons (detik)	Catatan
	Tertutup					meningkat
28	Ruang Tertutup	CO_2: 1400	670	Bahaya	1	Konsentrasi gas sangat tinggi
29	Ruang Ventilasi Sedang	CO_2: 600	280	Aman	1	Kondisi normal
30	Ruang Ventilasi Buruk	CO_2: 1000	490	Peringatan	2	Konsentrasi gas di atas batas normal

Detection Performance Analysis:

The test results show that the air quality control system with gas leak detection using the MQ-135 sensor and Arduino UNO has good detection performance under various environmental conditions and different gas concentrations. Here are some key points from the test result analysis:

1. Sensor Accuracy and Response:
   a. The MQ-135 sensor shows high accuracy in detecting various types of hazardous gases such as CO_2, CO, and CH_4.
   b. The sensor responds quickly to changes in gas concentration, with an average response time of about 1-2 seconds, which is very important for early detection of gas leaks.
2. Effectiveness of the Fuzzy Algorithm:
   a. The fuzzy algorithm used in this system is able to analyze sensor data well and produce the right decision regarding the level of gas hazard.
   b. The resulting decisions (Safe, Warning, Danger) are consistent with real conditions, indicating that the algorithm can handle uncertain data and different environmental variables.
3. Performance in Various Environmental Conditions:
   a. The system was tested under various environmental conditions, including closed rooms, open rooms, rooms with moderate ventilation, and rooms with poor ventilation.
   b. The system demonstrated reliable performance under all tested conditions, with timely detection and accurate decisions.
4. Consistency of Readings
   The sensor readings were consistent under various test conditions, indicating that the MQ-135 sensor has good stability and is reliable for long-term monitoring.
5. Potential for Implementation:
   a. Based on the test results, the system has great potential for implementation in various applications, including industrial, laboratory, and household environments.
   b. The system can provide early warnings that are critical to preventing potential hazards caused by gas leaks.

Overall, the air quality control system with gas leak detection using the MQ-135 sensor and

Arduino UNO demonstrated excellent performance in detecting hazardous gases and providing timely responses, thereby improving the safety and comfort of occupants.

Table 2. Air Quality Control Test Results

No.	Kondisi Lingkungan	Konsentrasi Gas (ppm)	Output Sensor (Analog)	Keputusan Algoritma Fuzzy	Waktu Respons (detik)	Catatan	Status Kipas
1	Ruang Tertutup	LPG: 400	200	Aman	1	Kondisi normal	Kipas Mati
2	Ruang Terbuka	LPG: 350	180	Aman	1	Kondisi normal	Kipas Mati
3	Ruang Tertutup	LPG: 800	400	Peringatan	2	Konsentrasi gas meningkat	Kipas Menyala
4	Ruang Tertutup	LPG: 1200	600	Bahaya	1	Konsentrasi gas sangat tinggi	Kipas Menyala
5	Ruang Ventilasi Sedang	LPG: 500	250	Aman	1	Kondisi normal	Kipas Mati
6	Ruang Ventilasi Buruk	LPG: 900	450	Peringatan	2	Konsentrasi gas di atas batas normal	Kipas Menyala
7	Ruang Terbuka	CO2: 50	100	Aman	1	Konsentrasi gas rendah	Kipas Mati
8	Ruang Tertutup	CO2: 200	350	Bahaya	1	Kebocoran gas terdeteksi	Kipas Menyala
9	Ruang Ventilasi Buruk	CO2: 150	300	Peringatan	2	Konsentrasi gas meningkat	Kipas Menyala
10	Ruang Terbuka	CO2: 100	220	Aman	1	Kondisi normal	Kipas Mati
11	Ruang Tertutup	CO2: 400	500	Bahaya	1	Kebocoran gas CO2 terdeteksi	Kipas Menyala
12	Ruang Ventilasi Sedang	CO2: 200	350	Peringatan	2	Konsentrasi gas di atas batas normal	Kipas Menyala
13	Ruang Tertutup	LPG: 450	220	Aman	1	Kondisi normal	Kipas Mati
14	Ruang Terbuka	LPG: 300	160	Aman	1	Kondisi normal	Kipas Mati
15	Ruang	LPG: 850	420	Peringatan	2	Konsentrasi	Kipas

No.	Kondisi Lingkungan	Konsentrasi Gas (ppm)	Output Sensor (Analog)	Keputusan Algoritma Fuzzy	Waktu Respons (detik)	Catatan	Status Kipas
	Tertutup					gas meningkat	Menyala
16	Ruang Tertutup	LPG: 1300	650	Bahaya	1	Konsentrasi gas sangat tinggi	Kipas Menyala
17	Ruang Ventilasi Sedang	LPG: 550	270	Aman	1	Kondisi normal	Kipas Mati
18	Ruang Ventilasi Buruk	LPG: 950	470	Peringatan	2	Konsentrasi gas di atas batas normal	Kipas Menyala
19	Ruang Terbuka	CO2: 70	110	Aman	1	Konsentrasi gas rendah	Kipas Mati
20	Ruang Tertutup	CO2: 250	370	Bahaya	1	Kebocoran gas terdeteksi	Kipas Menyala
21	Ruang Ventilasi Buruk	CO2: 170	310	Peringatan	2	Konsentrasi gas meningkat	Kipas Menyala
22	Ruang Terbuka	CO2: 150	230	Aman	1	Kondisi normal	Kipas Mati
23	Ruang Tertutup	CO2: 450	510	Bahaya	1	Kebocoran gas CO2 terdeteksi	Kipas Menyala
24	Ruang Ventilasi Sedang	CO2: 250	360	Peringatan	2	Konsentrasi gas di atas batas normal	Kipas Menyala
25	Ruang Tertutup	LPG: 500	260	Aman	1	Kondisi normal	Kipas Mati
26	Ruang Terbuka	LPG: 380	190	Aman	1	Kondisi normal	Kipas Mati
27	Ruang Tertutup	LPG: 900	430	Peringatan	2	Konsentrasi gas meningkat	Kipas Menyala
28	Ruang Tertutup	LPG: 1400	670	Bahaya	1	Konsentrasi gas sangat tinggi	Kipas Menyala
29	Ruang Ventilasi Sedang	LPG: 600	280	Aman	1	Kondisi normal	Kipas Mati

No.	Kondisi Lingkungan	Konsentrasi Gas (ppm)	Output Sensor (Analog)	Keputusan Algoritma Fuzzy	Waktu Respons (detik)	Catatan	Status Kipas
30	Ruang Ventilasi Buruk	LPG: 1000	490	Peringatan	2	Konsentrasi gas di atas batas normal	Kipas Menyala

The MQ-6 sensor test that reads LPG and CO2 gas was conducted to assess the sensor's performance in detecting gas concentrations. The purpose of this test is to compare the reading results of the MQ-6 sensor with other professional gas measuring instruments and to analyze errors including accuracy, precision, and standard deviation of error. The test was conducted with 30 samples to obtain sufficiently representative data.

Table 3. MQ-6 Sensor Test Results

No.	Konsentrasi Gas (ppm)	Pembacaan MQ-6 (ppm)	Pembacaan Alat Ukur (ppm)	Error (ppm)
1	50	48	50	-2
2	100	102	100	2
3	150	149	150	-1
4	200	198	200	-2
5	250	252	250	2
6	300	298	300	-2
7	350	351	350	1
8	400	402	400	2
9	450	449	450	-1
10	500	502	500	2
11	550	548	550	-2
12	600	601	600	1
13	650	652	650	2
14	700	698	700	-2
15	750	749	750	-1
16	800	802	800	2
17	850	848	850	-2
18	900	901	900	1
19	950	952	950	2
20	1000	998	1000	-2
21	1050	1049	1050	-1
22	1100	1102	1100	2
23	1150	1148	1150	-2
24	1200	1201	1200	1
25	1250	1252	1250	2
26	1300	1298	1300	-2
27	1350	1349	1350	-1
28	1400	1402	1400	2
29	1450	1448	1450	-2

No.	Konsentrasi Gas (ppm)	Pembacaan MQ-6 (ppm)	Pembacaan Alat Ukur (ppm)	Error (ppm)
30	1500	1501	1500	1

Accuracy

Accuracy refers to the ability of the sensor to approach the actual value measured by a professional gas meter. From the test data, it was obtained that the average error of the MQ-6 sensor was 0 ppm. This shows that the MQ-6 sensor has excellent ability to provide results close to the actual value of LPG and CO2 gas concentrations. With an average error close to zero, it can be said that this sensor has very high accuracy. Measurement results that are very close to the actual value are important in applications that require precise gas detection, such as in air quality control systems and gas leak detection.

Precision

Precision measures the consistency of the measurement results made by the MQ-6 sensor. To assess precision, the standard deviation error is calculated to see how far the measurement results vary from the average value. From the calculation results, the standard deviation error of the MQ-6 sensor is around 1.76 ppm. This shows that the variation in the measurement results of this sensor is very small, which means that the MQ-6 sensor has high precision. This consistency is very important in applications that require accurate and repeatable gas measurements. With a low standard deviation error, the MQ-6 sensor can be relied on to provide consistent measurement results under various conditions.

Overall, the error analysis shows that the MQ-6 sensor has excellent performance in terms of accuracy and precision. With an average error close to zero and a low standard deviation error, this sensor can provide reliable and consistent measurement results for LPG and CO2 gas detection. High accuracy and precision make the MQ-6 sensor an excellent choice for applications that require precise and reliable gas detection.

From these results, it can be concluded that the precision of the MQ-6 sensor is very high, with a relatively small standard deviation error indicating good consistency of measurement results. This consistency is important in applications that require precise and repeatable gas measurements, ensuring that the MQ-6 sensor can be relied on to detect LPG and CO2 gas concentrations consistently under various conditions.

CONCLUSION

Based on the test results, the air quality control system with gas leak detection using the MQ-135 sensor and Arduino UNO showed good detection performance in various environmental conditions and different gas concentrations. The MQ-135 sensor proved to have sufficient accuracy and precision for gas detection applications, with an average relative error of 2.14% and a standard deviation error of 1.22%. This indicates that this sensor is capable of providing accurate and consistent readings, although for applications that require very high precision, additional calibration may be required. In addition, the combination of the MQ-6 sensor and Arduino UNO with a fuzzy algorithm provides an effective solution for gas leak detection and air quality control. The MQ-6 sensor has an average error of 0 ppm, indicating high accuracy, and a standard deviation error of 1.76 ppm, indicating good consistency. This system not only provides accurate results but also responds quickly to changes in gas concentration, with an average response time of around 1-2 seconds. This is very important for the prevention of gas leak hazards, providing early warning that is crucial for safety. Thus, this system is able to improve safety and comfort by providing optimal air quality control and fast and accurate gas leak detection. The effectiveness of the fuzzy algorithm in fan PWM control also shows satisfactory results. By using membership functions to categorize gas concentrations into three categories (Safe, Warning, and Danger) and fuzzy rules to determine system responses, this algorithm is able to efficiently control the fan based on the detected gas concentration. This ensures that the system can respond appropriately to maintain air quality and reduce the risk of gas leaks.

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