Implementation of an IoT-Based LPG Gas Leak Detection System Using Sugeno Fuzzy Logic

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***Abstract* - LPG leaks can cause fire and explosion, so an early detection system is required to provide rapid warning. This study implements an Internet of Things (IoT)-based LPG gas leak detection system using Sugeno fuzzy logic. The system uses an MQ-6 sensor to detect LPG, a DHT22 sensor to measure temperature, and an infrared flame sensor to detect fire. Temperature and gas data are processed by an ESP32 to classify conditions as Safe, Alert, or Danger and to control an exhaust fan and buzzer. Testing showed DHT22 readings of 31.4–32.0 °C when not cooking and 33.5–36.2 °C while cooking, while MQ-6 readings were 890–1200 ADC and 1300–1900 ADC, respectively. Nine fuzzy input combinations produced the intended classifications. Manual Sugeno calculations yielded outputs of 0, 50, and 100 for Safe, Alert, and Danger, respectively, consistent with the system. Monitoring was also available in real time through Blynk.**

Keywords: *Blynk, Fuzzy Sugeno, IoT, LPG Gas Leak, MQ-6*

I. INTRODUCTION

Liquefied Petroleum Gas (LPG) is widely used as a household fuel because it is practical and relatively efficient. However, LPG contains flammable hydrocarbons, so leakage can create a serious fire and explosion risk. Previous studies have developed LPG leak detectors using MQ-series gas sensors, microcontrollers, fuzzy logic, and Internet-based monitoring, demonstrating the importance of early detection and remote warning [1]–[5].

Recent systems have increasingly combined MQ-6 sensing with ESP32 or other network-capable controllers, fire sensors, and remote notification. For example, MQ-6-based systems have been integrated with IoT dashboards, automatic actuators, and fire detection, while fuzzy methods have been used to classify uncertain gas and temperature conditions [6]–[10]. These approaches show that a multi-parameter system can provide more informative decisions than a single fixed gas threshold.

Recent studies also demonstrate the effectiveness of integrated LPG safety systems. Arifin and Prasetyo developed an LPG gas leak detection system using MQ-6 and DHT22 sensors with automatic buzzer and fan responses [11]. Ahmed and Primajaya designed an ESP32- and MQ2-based IoT early warning system with Blynk notifications and reported rapid response and high detection accuracy [12]. Wicaksana and Hirzan proposed an IoT-based gas and air-temperature monitoring system using MQ6, DHT22, a fire sensor, and fuzzy logic with automatic fan, buzzer, and Telegram warnings [13]. Shaputra et al. implemented an MQ-6 and ESP32-based LPG detector with automatic actuator control and smartphone notification [14]. Husny et al. developed an IoT-based LPG monitoring and early fire-warning system using MQ-6 and a fire sensor, with real-time hazard information accessible through a smartphone [15]. These studies support the use of gas sensing, temperature or fire detection, fuzzy logic, microcontrollers, and IoT monitoring as complementary approaches for improving LPG safety.

This study develops an integrated LPG leak detection system using an MQ-6 gas sensor, DHT22 temperature sensor, infrared flame sensor, ESP32, exhaust fan, buzzer, Blynk, Raspberry Pi, and webcam. Sugeno fuzzy logic is applied to temperature and gas concentration to determine Safe, Alert, and Danger conditions, while the flame sensor operates independently as an additional fire-safety layer. The system is intended to detect hazardous conditions, provide automatic local responses, and support real-time remote monitoring.

II. METHOD

A. System Architecture

The proposed system consists of three main sensing inputs and two processing paths. The MQ-6 provides an analog gas signal and the DHT22 provides temperature data to the ESP32. These two variables are processed by Sugeno fuzzy logic. The infrared flame sensor provides a digital fire signal and is handled independently from the fuzzy inference. When fire is detected, the system activates the buzzer and turns the exhaust fan off as a safety response. The ESP32 also communicates sensor values and system status to Blynk through Wi-Fi. A Raspberry Pi connected to a webcam provides visual monitoring of the kitchen environment.

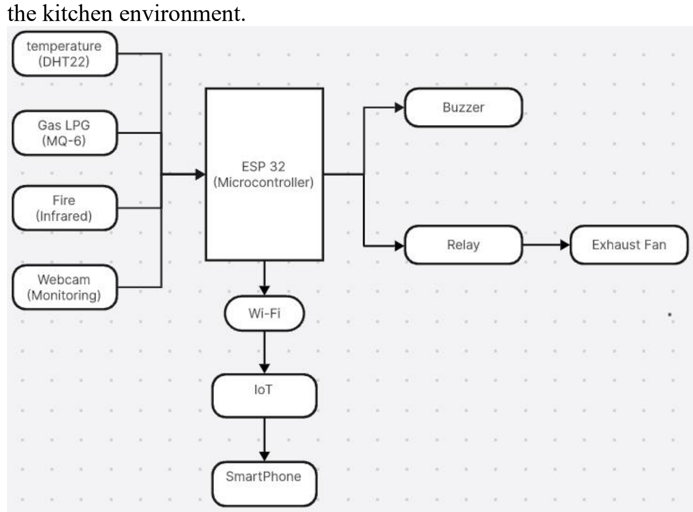

Figure 1. Block diagram of the proposed LPG leak detection system.

The physical arrangement places the MQ-6 and infrared flame sensor near the LPG cylinder area, while the DHT22 monitors room temperature. The exhaust fan is used to remove air from the kitchen, and the webcam provides visual observation. This arrangement follows the functional requirements described in the original task design.

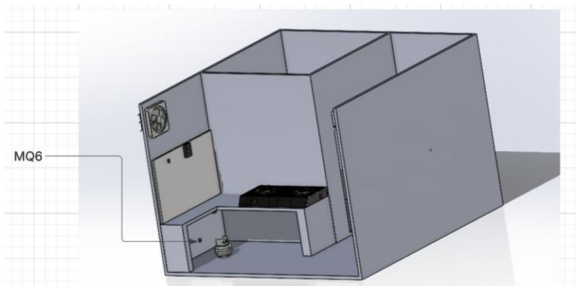

Figure 2. 3D design of the detection system.

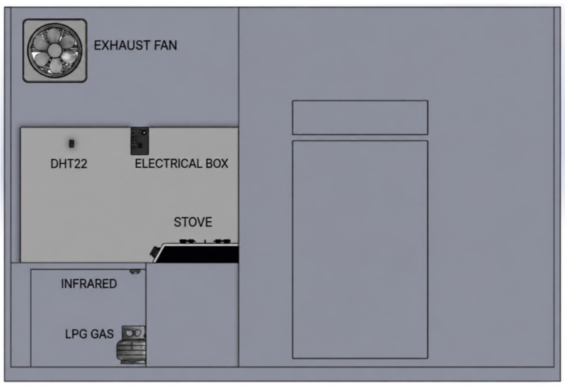

Figure 3. Layout of the kitchen test area and component placement.

B. *Sugeno Fuzzy Design*

The Sugeno fuzzy controller uses gas concentration from MQ-6 and temperature from DHT22 as its two crisp inputs. Each variable is divided into three fuzzy sets: Safe, Alert, and Danger. The ranges obtained from the experimental design are 890–1200 ADC, 1100–1600 ADC, and 1500–1900 ADC for gas; and 31.0–32.2 °C, 32.0–34.0 °C, and 33.8–36.0 °C for temperature. Overlap between adjacent sets allows gradual transitions between conditions.

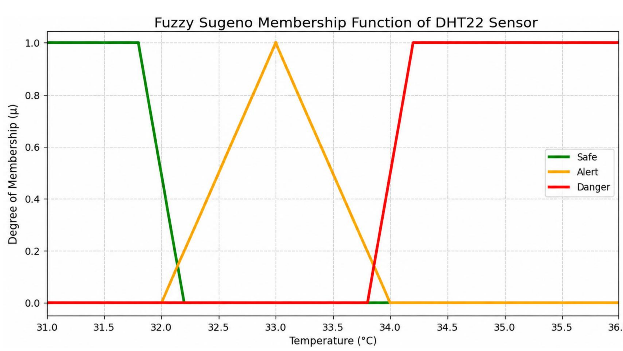

Figure 4. Membership functions for DHT22 temperature.

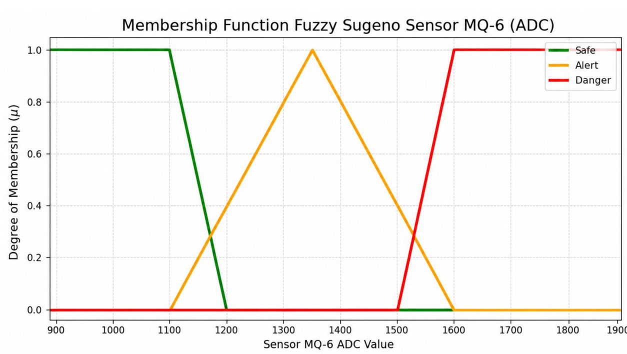

Figure 5. Membership functions for MQ-6 gas input.

The fuzzy inference uses the minimum operator for the AND connective. For a rule with temperature membership μT and gas membership μG, the firing strength is:

$$\alpha_i = \min(\mu T(x), \mu G(y)) \quad (1)$$

Each rule produces a constant Sugeno output. The final crisp output is obtained using the weighted average:

$$Z = \Sigma(\alpha_i z_i) / \Sigma\alpha_i \quad (2)$$

The output constants are 0 for Safe, 50 for Alert, and 100 for Danger. The nine rules used in the system are shown in Table I. The flame sensor is excluded from fuzzy inference because it provides a digital fire/no-fire decision and is implemented as an independent safety mechanism.

Table 1. FUZZY RULE BASE

Rule	Temperature	Gas	Output
1	Safe	Safe	Safe
2	Safe	Alert	Alert
3	Safe	Danger	Danger
4	Alert	Safe	Alert
5	Alert	Alert	Alert
6	Alert	Danger	Danger
7	Danger	Safe	Danger
8	Danger	Alert	Danger
9	Danger	Danger	Danger

C. *Experimental Procedure*

Testing was conducted in a kitchen environment. DHT22 performance was evaluated by comparing its readings with a digital thermometer under non-cooking and cooking conditions. MQ-6 was first observed in normal air and then during cooking to determine practical ADC ranges. The infrared flame sensor was tested with and without flame to verify its effect on the exhaust fan and buzzer. Finally, nine combinations of temperature and gas categories were tested to evaluate the fuzzy controller and actuator responses.

III. RESULT AND DISCUSSION

A. *Temperature and Gas Sensor Results*

Under non-cooking conditions, DHT22 readings ranged from 31.4 to 32.0 °C, while the reference thermometer ranged from 29.1 to 29.7 °C. The mean readings were 31.62 °C and 29.32 °C, respectively, with a constant difference of approximately 2.3 °C. During cooking, DHT22 readings increased from 33.5 to 36.2 °C, while the thermometer ranged from 30.0 to 31.3 °C. The corresponding mean values were 35.04 °C and 30.69 °C. The increase in temperature provided a useful second parameter for distinguishing normal room conditions from cooking-related conditions.

Table 2. DHT22 TEST RESULTS

Condition	DHT22 (°C)	Reference (°C)	Observed difference
Not cooking	31.4–32.0	29.1–29.7	2.3 °C
Cooking	33.5–36.2	30.0–31.3	3.5–4.9 °C

MQ-6 readings were 890, 990, and 1200 ADC when the kitchen was not being used for cooking. During cooking, the measured values increased to 1300, 1400, 1600, and 1900 ADC. These observations were used to define the Safe, Alert, and Danger fuzzy ranges and to support the classification process.

Table 3. MQ-6 TEST RESULTS

Condition	MQ-6 observations (ADC)	Fuzzy interpretation
Not cooking	890, 990, 1200	Safe range
Cooking	1300, 1400, 1600, 1900	Alert to Danger range

B. *Flame Sensor and Integrated System Response*

The flame sensor operated independently from the fuzzy controller. When flame was detected, the exhaust fan was turned OFF and the buzzer was turned ON, producing the Danger Fire response. When no flame was detected, the exhaust fan was ON and the buzzer was OFF.

This independent path provides an additional safety response when fire is present, regardless of the fuzzy gas-temperature classification.

Table 4. FLAME SENSOR RESPONSE

Flame condition	Exhaust fan	Buzzer	System status
Flame detected	OFF	ON	Danger Fire
No flame detected	ON	OFF	Normal

C. *Fuzzy System Test*

Nine combinations of temperature and gas categories were evaluated. The system produced Safe for the Safe-Safe combination, Alert for combinations such as Safe-Alert and Alert-Alert, and Danger when the rule base indicated a high-risk condition. The observed outputs followed the designed nine-rule mapping. In the Danger state, the exhaust fan and buzzer were activated; in the Alert state, the exhaust fan was activated while the buzzer remained off.

Table 5. COMBINATION FUZZY SYSTEM TEST

No.	Temperature	Gas	Output	Fan	Buzzer
1	Safe 31.2 °C	Safe 1076 ADC	Safe	OFF	OFF
2	Safe 31.1 °C	Alert 1224 ADC	Alert	ON	OFF
3	Safe 31.0 °C	Danger 1617 ADC	Danger	ON	ON
4	Alert 32.9 °C	Safe 1162 ADC	Alert	ON	OFF
5	Alert 32.4 °C	Alert 1323 ADC	Alert	ON	OFF
6	Alert 33.6 °C	Danger 1741 ADC	Danger	ON	ON
7	Danger 34.1 °C	Safe 1150 ADC	Danger	ON	ON
8	Danger 34.4 °C	Alert 1253 ADC	Danger	ON	ON
9	Danger 34.2 °C	Danger 1529 ADC	Danger	ON	ON

D. *Manual Sugeno Validation*

Manual calculations were performed using representative Safe, Alert, and Danger test data. For the Safe case, the input was 31.2 °C and 1076 ADC. The reported membership degrees were 0.833 for temperature and 0.400 for gas, giving a firing strength of 0.400 and a final output of 0. For the Alert case, 32.4 °C and 1323 ADC produced membership degrees of 0.400 and 0.892, respectively; the selected Rule 5 generated an output of 50. For the Danger case, 34.2 °C and 1529 ADC produced membership degrees of 0.182 and 0.073 in the Danger sets, while Rule 9 produced an output of 100.

Table 6. MANUAL SUGENO VALIDATION

Condition	Temperature	Gas	Representative firing strength	Sugeno output
Safe	31.2 °C	1076 ADC	0.400	0
Alert	32.4 °C	1323 ADC	0.400	50
Danger	34.2 °C	1529 ADC	0.073	100

The manual results were consistent with the implemented ESP32 controller: 0 corresponded to Safe, 50 to Alert, and 100 to Danger. This agreement indicates that the fuzzification, MIN-based inference, and weighted-average defuzzification were implemented consistently with the designed rule base. The result also confirms that the fuzzy controller can translate continuous gas and temperature readings into three actionable risk levels.

E. *IoT Monitoring*

The Blynk dashboard was configured to display sensor readings, system status, and risk information in real time. The monitoring interface provides remote access through a smartphone or web interface, while the webcam connected to the Raspberry Pi provides visual observation of the kitchen. The combination of numerical sensor information, automatic actuator response, notification, and visual monitoring extends the system beyond a standalone local alarm.

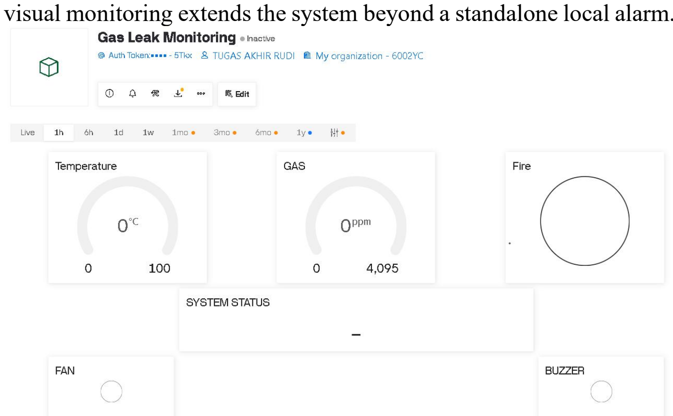

Figure 6. Blynk monitoring dashboard on the web.

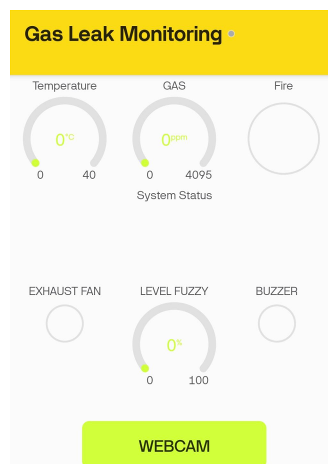

Figure 7. Blynk monitoring dashboard on the Handphone

IV. CONCLUSION

An IoT-based LPG gas leak detection system using MQ-6, DHT22, infrared flame sensing, ESP32, Sugeno fuzzy logic, exhaust fan, buzzer, Blynk, Raspberry Pi, and webcam was successfully implemented and tested. DHT22 readings ranged from 31.4–32.0 °C without cooking and 33.5–36.2 °C during cooking, while MQ-6 readings ranged from 890–1200 ADC and 1300–1900 ADC, respectively. Nine fuzzy combinations produced the intended Safe, Alert, and Danger classifications. Manual Sugeno validation produced outputs of 0, 50, and 100 for the three conditions and matched the system decisions. The flame sensor also provided an independent fire-safety response by turning the fan off and buzzer on when flame was detected. Real-time monitoring through Blynk and visual monitoring through the webcam further supported remote observation. Future work should test the system under more varied ventilation and environmental conditions and consider additional notification channels and image processing for automatic fire or smoke detection.

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