

Fuzzy-Based Gas Leakage Detection System Using Arduino Microcontroller

Olusola Theophilus Faboya

Department of Computing and Information Science, Bamidele Olumilua University of Education, Science and Technology,
Ikere-Ekiti, Nigeria

E-mail: faboya.olusola@bouesti.edu.ng

Abstract - This paper examines an important safety issue related to gas leakages in residential, commercial, and industrial environments. Despite the advancements in gas leakage detection research, numerous challenges, including false alarms, mobility and communication issues, and the need for continuous power supply, have constrained their usefulness and user-friendliness. To address these problems, a cost-effective system that integrates a fuzzy logic framework into the Arduino microcontroller is presented to enhance the accuracy of sensor data interpretation and minimise false positives. The proposed system employs an MQ2 gas sensor connected to an Arduino microcontroller for real-time gas concentration monitoring. The fuzzy logic systems component enhances the management of uncertainty and imprecision in the system's decision-making process. This enables the system to accurately differentiate between noise and hazardous leakages. The results of the experiments showed high precision, reliability, and efficiency in gas detection. The integration of sensors with fuzzy intelligent processing on an affordable microcontroller presented a comprehensive solution for proactive and cost-effective gas safety management. This combined approach not only enhances leak detection but also helps create safer environments where gas safety is critical through instant SMS notification and email messages for quick action.

Keywords: Gas Leakage, Arduino microcontroller, Fuzzy Logic System, MQ sensor.

I. INTRODUCTION

Gas leakage poses a serious safety hazard in environments including residential, commercial, and industrial settings. The increasing incidence of gas leakage-related disasters underscores the critical need for effective and timely detection systems, especially given the increasing occurrences of fire accidents caused by Liquefied Petroleum Gas (LPG) leaks (Deepika *et al.*, 2024). The unintentional release of highly flammable gases such as methane, propane, and carbon monoxide compounds has resulted in severe consequences, including fire outbreaks, explosions, and health risks (Baballe,

2021). Most of these gases are odourless and colourless, making early detection difficult and increasing the likelihood of dangerous accumulations before intervention. However, several earlier methods have been used in gas leakage detection, including the colourmetric tubes, catalytic combustion, and an electrochemical sensor that uses electrodes to detect changes in gas concentrations. These methods are not only limited in sensitivity due to potential interference, but they also have high-cost maintenance requirements.

Modern gas detection systems often employ more advanced technologies such as Arduino microcontrollers for data processing, MQ series gas sensors, and other components for easy communication (Bharsakade *et al.*, 2024; Hasan *et al.*, 2024; Sharma & Jagtap, 2021). Several studies have leveraged these technologies to deploy low-cost systems with better performance. Their systems use MQ series gas sensors because of their high sensitivity to combustion gases like LPG, propane, and methane, combined with Arduino microcontrollers (e.g., Arduino Uno or NANO) for efficient data acquisition and processing (Anthony & Alan-lodam, 2024; Hasan *et al.*, 2024). However, the systems still face challenges such as false alarms, limited prompt communication to the remote users, and mobility problems. Particularly, the systems rely on conventional threshold-based detection methods to determine the gas concentration level. However, most often, environmental noise affects the sensor's accurate readings and hence, promotes false positives that limit the system's reliability.

In this paper, an Arduino microcontroller-based gas leakage detection system with a fuzzy logic framework is proposed to provide real-time monitoring and immediate alerts in gas leakage cases. The proposed system aims to address the limitations of conventional threshold-based detection methods through fuzzy logic systems. The incorporation of fuzzy logic systems will enable the system to handle imprecise and uncertain sensor inputs more effectively, hence improving the system's accuracy in identifying hazardous gas concentrations.

The remainder of this paper is as follows: Section 2 presents a review of related work on gas leakage detection studies. The methodology adopted in the paper is presented in Section 3, while the system implementation and testing are detailed in Section 4. The discussion and conclusions are presented in Section 5.

II. RELATED WORK

A considerable number of gas leakage studies have been carried out to offer solutions to hazardous incidents due to gas leakages in the environment. Mahalingam *et al.* (2017) designed a cost-effective automatic alarming system that detects LPG leakage in residential and commercial premises. The system utilises a gas sensor that complies with UK occupational and health standards and emphasises the importance of safety in domestic and commercial environments. Priya *et al.* (2017) developed an embedded system for gas cylinder maintenance. This system includes a GSM and PIC module, a leakage detection module, and protection circuitry. The system not only detects gas leakage but also sends SMS alerts and monitors cylinder weight through a load cell, enhancing safety and user awareness. Sunithaa *et al.* (2017) designed a wireless LPG leakage monitoring system for home safety. Their system detects gas leakage, activates an alarm, sends SMS alerts, switches on an exhaust fan, and shuts off the LPG valve to prevent explosions. The design showcases the versatility of microcontroller applications in gas detection technologies. Furthermore, several studies have focused on developing low-cost systems that provide both audio and visual alerts in local dialects. (Selvakumar and Kumar, 2020; Bhuiyan and Hossain, 2020; Sharma and Patel, 2020; Baballe *et al.*, 2021). These studies emphasise the importance of accessibility and immediate notification in hazardous situations. Kim and Park (2020) proposed a wireless gas leak detection system that incorporates advanced data analytics to improve accuracy and efficiency, using machine learning algorithms. The work illustrates the growing trend of utilising artificial intelligence in safety systems.

There are growing studies on the use of Arduino microcontrollers for real-time monitoring of gas leakages. This is due to its high sensitivity to combustible gases like LPG, propane, methane, and others. Selvakumar and Kumar (2020) presented a low-cost gas leak detection system using an Arduino board and an MQ-6 gas sensor to detect LPG, propane, and methane gases. The system provides both audible and visual warnings and highlights the accessibility of gas detection technology for broader applications. Bhuiyan and Hossain (2020) developed a microcontroller-based gas leak detection system that detects leaks and sends alerts to remote locations via a GSM module. A microcontroller-based

system that utilises an MQ-6 gas sensor to detect LPG leakage with an integrated alarm unit for both audible and visual indications was developed by Jolhe *et al.* (2017). Zhang *et al.* (2020) proposed a real-time gas leak detection system for underground coal mines, integrating various sensors, wireless communications, and data analysis technologies to enhance accuracy and efficiency. This innovation is particularly significant for high-risk environments like mining. Sharma and Patel (2020) designed a wireless gas leak detection and alarm system using an MQ-6 gas sensor, Arduino Uno microcontroller, and NRF24L01 wireless module. The system showcased the integration of IoT in safety systems. Pandey and Gupta (2020) developed a gas leak detection and warning system employing an Arduino and GSM module, where a gas sensor detects leakage and sends a warning message to the user's mobile phone. These works exemplify the practical application of technologies in enhancing safety. Baballe *et al.* (2021), developed an automatic gas leakage monitoring system that uses the MQ-5 sensor for detecting LPG leakage. The system was designed to sound an alarm by means of a buzzer and send messages to the registered mobile numbers with the help of the GSM module. Deepika *et al.* (2024) In their work, presented an IoT-based gas leak detection system using a gas sensor and microcontroller with cloud computing infrastructure to enable real-time remote monitoring of gas leakages. The main feature of their system is its interoperability and integration with existing infrastructure and protocols. A cost-effective, user-friendly, and advanced Fire and Gas Detection System using an Arduino microcontroller and an MQ2 gas sensor was developed for gas and fire detection (Bharsakade *et al.*, 2024). The system was designed to find applications in diverse settings, capable of detecting an extensive array of gases and flames from various sources such as wood, paper, and plastics.

The studies reviewed in the paper, and numerous other studies, contributed to the evolving field of gas leakage detection systems. They highlighted the integration of advanced technologies and the need for continuous innovation to enhance safety in various applications. Despite the advancements, these systems still face challenges in accuracy and precision due to environmental noise included in the sensor's readings. The integration of machine learning algorithms and IoT platforms in some contemporary designs has enhanced sensor accuracy, enabled real-time monitoring from remote locations, and offered a comprehensive solution to mitigate risks associated with gas and fire incidents. There are still concerns about uncertainty and imprecision in the input data, as well as the overall expenses of the associated components for the sophisticated systems. This can limit reliability, user-friendliness, and continued development of cost-effective solutions for low-income users.

III. METHODOLOGY

A system development approach was adopted in this paper. Hardware and software components were integrated into the design of a functional prototype of the gas leakage detection system.

The components include the gas sensor (MQ-2) for detecting and measuring gas concentrations in an environment. The Microcontroller (Arduino Uno) serves as the central processing unit that receives sensor data and executes control commands. The wi-Fi Module (ESP82-01) enables internet connectivity for real-time data transmission and remote notifications on the handheld device. The alarm system provides an immediate local alert when gas concentration or leakage is detected.

System Architecture

The system architecture is shown in Figure 1:

The software components of the system include the Arduino IDE for programming the microcontroller and the fuzzy logic library implementation.

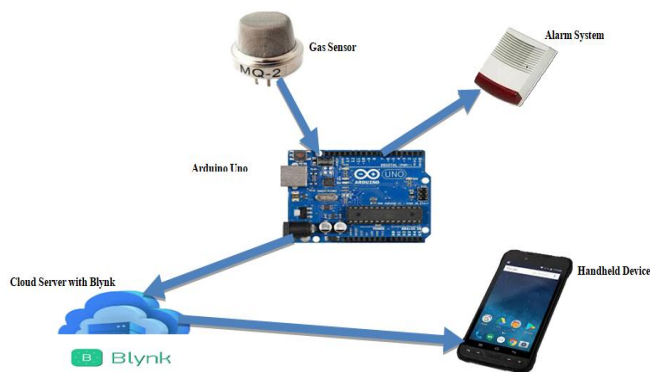


Figure 1: Gas Detection System Architecture

The fuzzy system component is incorporated to ensure the reliability of the readings by addressing the inherent uncertainties and imprecision associated with the input data as a result of the influence of environmental factors and sensor fluctuations. Leveraging fuzzy systems, the leakage system effectively manages the complexities of real-world conditions, thereby enhancing its accuracy and reliability. The Blynk IoT Platform connects the Arduino to the cloud to facilitate real-time monitoring and remote notifications. The next subsection explains the system design workflow.

System Design and Workflow

The operational workflow of the gas leakage detection system is provided in the flowchart in Figure 2:

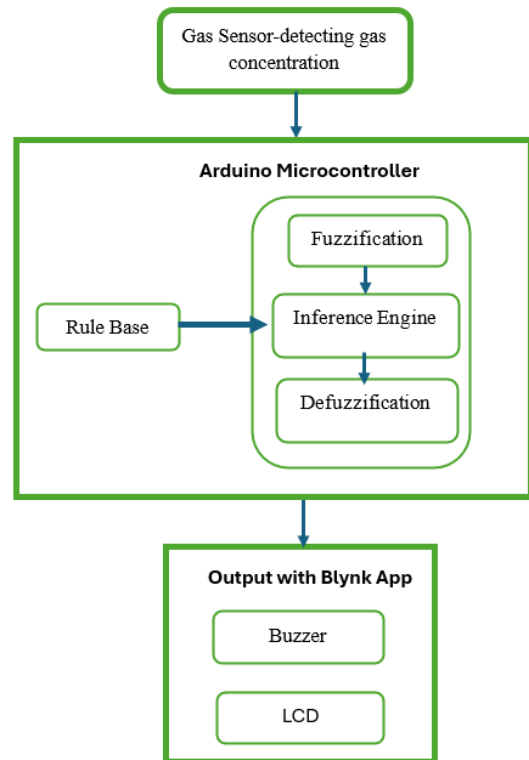


Figure 2: System Workflow

The device powers on, and the microcontroller initialises the connected components. The sensor calibration is performed during the initialisation phase to ensure accurate gas-level readings, and the gas sensors continuously monitor ambient air to collect environmental data. It sends the collected analogue signal to the Arduino microcontroller, which in turn processes it, converts it into digital values, and transmits the sensor data to the fuzzy logic components of the system. Practically, sensor reading is often affected by noise in the form of environmental conditions, including heat, humidity, or variations in sensor performance over time. To mitigate these challenges, the fuzzy logic system was incorporated to handle uncertainty and vague information. The output from the fuzzy system determines the action to be sent to a cloud-based IoT platform.

Fuzzy Logic System Components

The digital sensor readings serve as input to the fuzzy logic system, which handles threshold detection. The fuzzy logic multivalued system allows for gradual transitions without sharp or distinct boundaries.

(a) Fuzzification

The first step involves converting crisp sensor readings into fuzzy values represented with qualitative categories such as low, medium, or high gas concentrations. In this work, a sensor reading of 35 parts per million (ppm) is considered

“medium”, while a reading of 60 ppm is considered “high”. The rate of change of leakage is also fuzzified using linguistic variables, such as slow, moderate, and fast rates. The output is defined using variables: safe, warning, and danger. This transformation allows the system to interpret data in a way that reflects the inherent uncertainties of gas detection, thereby reducing the likelihood of false alarms.

Triangular membership functions were adopted due to their overlapping regions that ensure smooth transitions between states. Also, they are computationally efficient, simple, and suitable for real-time embedded systems like Arduino.

The membership function is defined by three parameters (a,b,c)

Where:

a = left point (i.e., start of triangle)

b = peak of the membership (i.e., the maximum point)

c = right point (i.e., end of triangle)

and given by the equation

$$\mu(x) = \begin{cases} 0 & x \leq a \\ \frac{x-a}{b-a} & a < x \leq b \\ \frac{c-x}{c-b} & b < x < c \\ 0 & x \geq c \end{cases}$$

(b) Rule-Based

The set of predefined rules shown below is used to make decisions on the concentrations of gas, the rate of flow, and the environmental conditions.

Each rule is expressed as:

$$R_i: \mu_{Risk}(y) = \min(\mu_{Gas}(x), \mu_{Rate}(z))$$

Where:

$$\mu_{Gas}(x) = \text{membership of Gas}$$

$$\mu_{Rate}(z) = \text{membership of Rate}$$

The rules are:

Rule 1: IF Gas is Low AND Rate is Slow, THEN Risk is Safe

Rule 2: IF Gas is Low AND Rate is Moderate, THEN Risk is Safe

Rule 3: IF Gas is Low AND Rate is Fast, THEN Risk is Warning

Rule 4: IF Gas is Medium AND Rate is Slow, THEN Risk is Warning

Rule 5: IF Gas is Medium AND Rate is Moderate, THEN Risk is Warning

Rule 6: IF Gas is MEDIUM AND Rate is Fast, THEN Risk is Danger

Rule 7: IF Gas is High AND Rate is Slow, THEN Risk is Warning

Rule 8: IF Gas is High AND Rate is Moderate, THEN Risk is Danger

Rule 9: IF Gas is High AND Rate is High, THEN Risk is Danger

(c) Inference Engine

The actual decisions from the rule-based system are made at the inference engine, where the rules are evaluated based on the combined fuzzy inputs, and the output is determined according to the rules.

(d) Defuzzification Process

The fuzzy output from the process is converted back into a crisp value, the value that triggers corresponding operations.

Real-time Monitoring and Notification

The output from the processed data is transmitted through the Blynk platform and the cloud (HTTP connection) to the mobile devices for real-time monitoring.

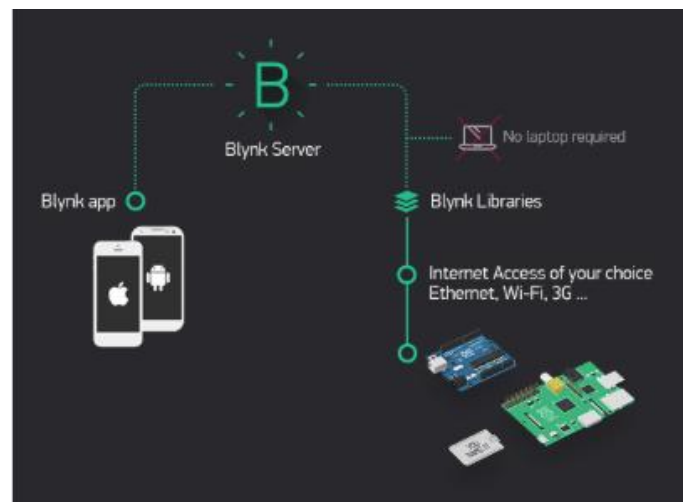


Figure 3: Blynk App Connection

This setup enables real-time gas leak detection, with users receiving notifications on their mobile devices. When the gas concentration level is low, i.e., when it does not necessitate an alert, the system pauses and resumes normal monitoring.

IV. IMPLEMENTATION AND TESTING

Experimental procedures were employed in this study to test the system's reliability and effectiveness with practical simulation of controlled environments and real-world scenarios in residential and industrial environments.

Two sets of tests were performed. The first set was conducted in a controlled environment where gas concentrations were manipulated systematically to enable proper evaluation of the system's response time and accuracy to various gas concentrations and other variables, and its ability to trigger alerts accurately. Figure 4 shows one of the gas sensor reading interfaces.

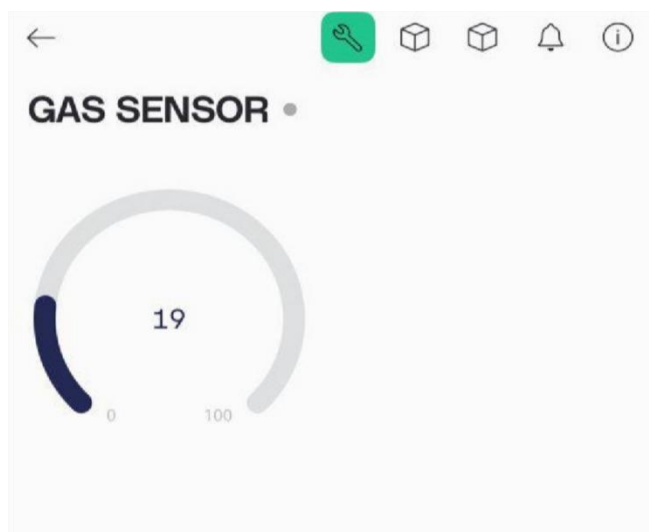


Figure 4: Gas Sensor Reading Interface

Results from the tests indicated that the system successfully detected gas concentrations within predefined ranges and activated alarms when necessary. For instance, when gas levels reach 60ppm, the system activates an alarm within seconds and alerts the user on the Blynk platform through the connected Wi-Fi and cloud. This demonstrates its capability for real-time monitoring.

The second series of tests involved deploying the system in real-world scenarios across both residential and industrial environments. This phase aimed at evaluating how well the system performed under varying environmental conditions that could affect sensor accuracy, such as temperature fluctuations and airflow variations.

V. RESULT AND DISCUSSION

The results obtained from the experiments in this study pointed to the effectiveness of the system's reliability in detecting gas presence at different concentrations and providing timely alerts through IoT connectivity. The proposed system also delivers notifications on the assigned mobile devices whenever gas levels exceed safety limits so as to allow for immediate action to mitigate potential hazards. Compared to Sharma and Patel (2020), who developed a WiFi connected notification delivery gas detection system with a threshold-based sensor, this proposed system delivered a more reliable gas leakage detection system that mitigates the effect of noise and environmental fluctuations and a reliable IoT-based communication module for better connectivity.

The improvements can be attributed to the integration of fuzzy systems to handle imprecision and uncertainty in input data associated with false alarms, and the use of a cloud-based Blynk module as the IoT for better connectivity that ameliorates the range barrier in wireless connectivity. The results underscore the importance of integrating advanced technologies such as IoT and fuzzy systems into the proposed system. The ability to continuously monitor gas levels and provide real-time alerts enhances safety measures across various environments.

VI. CONCLUSION

A reliable and intelligent gas leakage detection system capable of addressing the limitations of conventional threshold-based sensor reading approaches is discussed in this paper. The proposed system implements the fuzzy logic library on an Arduino microcontroller. The experimental results from the system demonstrated the effectiveness of the system in detecting gas presence across varying gas concentrations while also providing immediate feedback as alerts through an IoT-enabled framework. The integration of the fuzzy logic system significantly improved the system's ability to handle uncertainty and imprecision due to environmental noise, thereby reducing false alarms and enhancing reliability. The outcome of the experiments demonstrated the capability of the system to represent gas leakage scenarios appropriately with reduced cases of false alarm. The successful operation of this system not only enhances safety measures against potential gas leaks but also provides a foundation for future developments in gas detection technology.

VII. FUTURE WORK

In future, the effectiveness and applicability of this system can be improved by engaging in a more rigorous testing of the systems in different environments that represent

diverse conditions that could be encountered in real-world as variation in humidity, airflow and even temperature can affect sensor accuracy. Furthermore, another model of gas sensor can be used to compare sensitivity and gas selectivity with this system. Lastly, further validation in large-scale real-world environments would also strengthen the system's robustness.

REFERENCES

- [1] Anthony, U. O., & Alan-Iodam, D. N. (2024). Development of a Mobile Liquefied Petroleum (MLP) Gas Leakage Alert System with Multilingual. *September*.
- [2] Baballe, A. (2021). *Review of Computer Engineering Research* AUTOMATIC GAS LEAKAGE MONITORING SYSTEM USING MQ-5 SENSOR Keyword s. 8(2), 64–75. <https://doi.org/10.18488/journal.76.2021.82.64.75>
- [3] Bharsakade, R., Khairnar, A., Khairnar, Y., Gulati, K., Kale, A., & Patil, D. K. (2024). Advanced Fire & Gas Detection System. *May*.
- [4] Deepika, B., Sivakami, S., Sneha, S., & Sujitha, B. (2024). Early Detection System for Gas Leakage and Fire in Smart Home Using IOT. 102, 102–108.
- [5] Hasan, M., Nobi, A., & Sharma, H. G. (2024). Design and Analysis of low-cost LPG (liquefied petroleum gas) detector. 1399–1403.
- [6] Sharma, L., & Jagtap, A. (2021). Gas leakage detection kit: At a low cost. *International Journal of Multidisciplinary Research and Growth Evaluation*, 2(3), 4–5.
- [7] Jolhe, R. R., Patil, R. C., & Jalgaonkar, R. (2017). Microcontroller-based gas leakage detector with an alarm system. *International Journal of Engineering Trends and Technology*, 45(2), 101-105.
- [8] Kim, P. J., & Park, H. J. (2020). Wireless gas leakage detector system with advanced data analytics. *International Journal of Advanced Computing*, 34(7), 231-243.
- [9] Mahalingam, T., Nisha, V., & Ramya, R. (2017). Cost-effective automatic alarm system for detecting liquefied petroleum gas (LPG) leakage. *Journal of Residential and Commercial Safety Systems*, 5(1), 25-30.
- [10] Pandey, S., & Gupta, R. (2020). Design of gas leak detection and warning system using GSM technology. *Journal of Advances in Computing and IoT Applications*, 7(6), 145- 152.
- [11] Priya, R., Rao, T., & Sharma, A. (2017). Embedded system for gas cylinder maintenance and leakage detection. *International Journal of Embedded Systems*, 10(4), 67-76.
- [12] Selvakumar, S., & Kumar, S. S. (2020). A low-cost gas leak detection system using an Arduino board and MQ-6 gas sensor. *International Journal of Affordable Safety Solutions*, 3(5), 89-95.
- [13] Sharma, M., & Patel, J. (2020). Wireless gas leak detection and alarm system using IoT. *Journal of Smart Systems and Networks*, 14(3), 56-64.
- [14] Sunithaa, R., Krishnan, K., & Rao, A. (2017). A wireless LPG leakage monitoring system for home safety. *Journal of Home and Commercial Safety Systems*, 12(1), 45-50.
- [15] Zhang, L., Chen, F., & Wang, X. (2020). Real-time gas leak detection for underground coal mines using IoT. *International Journal of Mining Safety Engineering*, 25(2), 109-120.

Citation of this Article:

Olusola Theophilus Faboya. (2026). Fuzzy-Based Gas Leakage Detection System Using Arduino Microcontroller. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 10(4), 432-437. Article DOI <https://doi.org/10.47001/IRJIET/2026.104059>
