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Development of a leakage detection and alert system for liquefied petroleum gas via a mobile application

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ABSTRACT

Nowadays, ensuring the comfort and safety of house users is a top priority, and this may be accomplished by implementing smart technology to lead a convenient and safe life. Leakage of liquefied petroleum gas (LPG), which is mostly utilized in the home kitchen for cooking, is one of the frequent risks. Using a gas sensing device, a gas control system, and wireless communication units, the goal of this study is to create an LPG gas leakage warning and management system to prevent the gas from exploding by detecting the leak. When LPG gas is brought near the sensor, it detects the leakage and the buzzer is activated by activating the audio-visual alarm and closing the gas cylinder valve. The system also generates alert messages and sends them to the fire station when the LPG gas leakage has reached a critical level. Testing results of the proposed LPG leakage system show a satisfactory performance of the developed device with a quick response to LPG gas leakage. In addition, powerful audio and visual alarms are activated. An immediate message was sent to homeowners and the fire station department regarding the leakage incident to prevent the risk of gas leakage.

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1. INTRODUCTION

Currently, technology is employed in almost every aspect of daily life to guarantee the comfort and safety of house users, reflecting the high convenience of contemporary lifestyles [1], [2]. The daily use of various accessible technologies to assist users in executing duties smoothly and effectively [3], [4]. One of the main goals is to keep people secure and comfortable in their homes. The majority of people's time is spent at home. Their houses serve as both accommodation and a place to store their necessities. Apartments that accommodate their demands and make everyday chores easier are sought after by many. As a result, these residences need safeguards against any threats. This is accomplished by the use of technology and the integration of monitoring systems, smart devices, and sensors to foresee possible risks. Residents feel more confident and trusting when these techniques are used. These techniques, which guarantee comfort at home, have become essential to modern living.

The implementation of new technologies realized different tools in smart homes to achieve comfortable living, as well as ensuring hazard-free homes [5]. Smart home technologies automate various features of the home environment, integrating devices and sensors to produce a more convenient, efficient, and safe human living space through their ability to monitor and mitigate potential hazards [6]. In addition, the use of smart home advanced technologies systems offers the capability to monitor and control, allowing homeowners to remotely manage their home utilizing smartphones and other special-purpose control devices [7].

The development of various controllers with user-friendly interfaces facilitates the advancement of highly efficient control systems [8], [9]. A computer is primarily used for control based on different algorithm techniques, such as machine learning, for the accurate prediction of code smells [10]. Rapid advances in science and technology offer advantages for adopting integrated embedded microcontrollers in industrial operations [11], [12]. Moreover, the need for such microcontrollers to be implemented in medical applications, in which they mostly require a high level of precision and accuracy [4], [13]. An example of such highly risky conditions is the treatment of patients in the quarantined rooms during the COVID-19 pandemic [14], [15].

Among the common household dangers is the leakage of liquefied petroleum gas (LPG), which is used in kitchens for cooking [16], [17]. Therefore, this issue could be addressed through the integration of gas sensors to detect the leak of LPG gas that could cause risks of fires, explosions, in addition to health hazards in home users [18], [19]. The sensors could monitor the surrounding air quality to capture any leaks of LPG [20]. In addition, once a leakage hazard is detected, an action is to be taken to mitigate this hazard, including an automated alarm, cutting off the gas supply, and calling for emergency services [21], [22].

Gas leakage causes various accidents [23] and may sometimes lead to disasters [24], property losses, and human injuries [25]. The number of deaths due to gas cylinder explosions has increased in recent years [26], [27]. The causes of such explosions are corrosion in worn valves and gas regulators. Also, the misuse and lack of maintenance of old gas cylinders increase these risks [28]. To avoid these risks, we must have a system to detect and warn of such risks [27], [29]. In addition to avoiding financial losses and protecting society members [30]–[32].

The basic structure of LPG is hydrocarbons containing three or four carbon atoms. The natural components of LPG are propane (C_3H_8), butane (C_4H_{10}), and other hydrocarbons in small concentrations. The other hydrocarbon components of LPG depend on the sources of the LPG and how it is produced [33]. One of the main sources of urban non-methane hydrocarbons (NMHCs) in the air is unburned LPG leaks. Reducing LPG leaks helps to improve the quality of the local air [34]. In order to successfully stop similar occurrences from happening again, a LPG disaster was examined using a straightforward systematic incident analysis tool. In order to capture common cause-and-effect patterns that arise anytime systematic event analysis is applied to the way accidents occur [23].

Hazardous toxic gases such as nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), LPG, hydrocarbon gases, silicones (S_i), hydrocarbons, alcohols, methane (CH_4), hexane, and benzene, must have a system responsible for monitoring and controlling them and environmental conditions, such as temperature and relative humidity to prevent potential accidents due to the danger of these gases. Although the toxic gas is not poisonous, it can pose a serious risk if it leaks [35]. If the LPG leaks, its vapors could be moved for long distances along the ground by where they can be collected in drains or basements cylinders that can explode due to fire [36]. As well, LPG leak has a health impact which can cause cold burns to the skin, and it can act as an asphyxiant at high concentrations [19], [37]. As the hydrocarbons and other chemicals of the LPG cause very long sleep and also cause an irritated respiratory tract, nose, and eyes [38]–[40].

In this paper, a gas leak monitoring and warning system is designed and implemented to reduce casualties and losses. This system is effective, automatic, and sensitive to detect cooking gas LPG leakage. The proposed automatic system uses a smartphone and Arduino Uno microcontroller to communicate through a mobile application with the home residents' phones to alert them and send the location coordinates to the civil defense department for assistance. Additionally, the system activates a visual and audible alarm for the residents of the area. As well as the ability to sense gas leakage, close the gas source valve, and activate the kitchen hood to get rid of the leaking gas in the home.

The basic operation and the functionality of the proposed system are demonstrated in Figure 1. The operation block diagram illustrates the system flow from one activity to another. The control flow from one operation to another is well described. This flow can be sequential, branched, or concurrent. It captures the dynamic behavior of the system used to show the message flow from one activity to another. The system controller turns on the right devices that will take the necessary steps to stop any possible hazard and produce the necessary warnings and alerts based on the precise inputs that have been captured from the primary sensors.

This paper presents the development of an LPG leak detection and alert system, with a detailed explanation. The following sections describe the implementation of the LPG monitoring system, as well as a description of the main components and functions of the proposed system. The functional testing, operation, and validation of the proposed design are also presented.

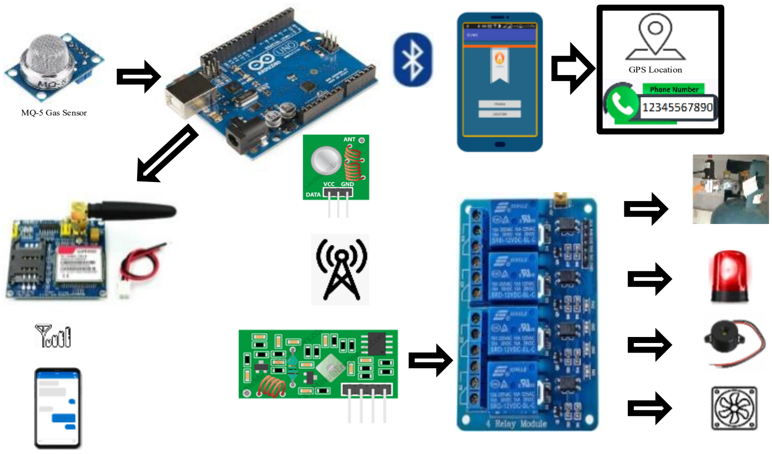

Figure 1. LPG leak detection system block diagram

2. SYSTEM HARDWARE DESCRIPTION

The primary hardware elements of the suggested system will be illustrated in this section. These components are integrated into both parts of the proposed LPG leak warning system. The first part of the project is mainly composed of the Arduino, a global system for mobile (GSM) module, and the sensor, which is powered by the Arduino board. The second part uses wireless communication radio frequency (RF) composed of (encoder, Bluetooth, and RF) are powered from the battery. The Bluetooth module connects the Arduino with the mobile application to input the user data, phone number, and the GPS coordinates. The second part, which is powered from a 12 V lithium battery, mainly includes the (relay, decoder, and RF) components that supply a 5 V DC from the voltage regulator. The RF works on linking the two parts with each other wirelessly, using a frequency of 330 MHz. An encoder is used to encryption the data between two pieces of the RF, to avoid exposure to outside influences. The RF receiver receives the signal from the RF in the first part and then passes it to the decoder for decoding, and activates the outputs of the relay circuit. The Arduino controller processes the value coming from the input to determine the output of the system as result in the solenoid valve, LED, buzzer, and alert SMS.

2.1. Arduino Uno

The proposed LPG gas leakage detection utilized the Arduino Uno microcontroller as the main controller for the operations on the system. The Arduino Uno is mainly based on the ATmega328P controller. As shown in Figure 2, it has 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, and a USB connection.

2.2. Solenoid valve

A solenoid valve is shown in Figure 3, which is basically an electromechanical-operated valve. These valves are widely used to control the flow of fluids or gases through the release of cut off the flow of fluid or gas in the system. Solenoid valves are advantageous in their fast response, high reliability, long life, simple control, and compact design.

Figure 2. Arduino Uno

Figure 3. Solenoid valve

2.3. Global services mobile module

The proposed LPG gas leakage detection utilized a GSM communication module, as shown in Figure 4, to send the warning messages to the homeowner and the civil defense department. The GSM is a digital mobile telephony system that digitizes and compresses the data. It operates at either the 900 MHz or 1,800 MHz frequency band. The GSM and other technologies are part of the evolution of wireless mobile telecommunications.

2.4. Bluetooth module

The HC-05 or HC-06 Bluetooth module is shown in Figure 5. This module is used to wirelessly communicate between the Arduino and the mobile phone. The data sending and receiving can be achieved within a range of 10 meters. The Bluetooth module has a standard 2-pin universal asynchronous receiver/transmitter (UART) connection (Tx and Rx) to easily connect to an Arduino microcontroller board. The module is used in LPG gas leakage detection to ensure real-time communication between the system controller and the smartphone mobile application.

2.5. Radio frequency module

An RF module, as shown in Figure 6, is a small electronic device used to transmit and/or receive radio signals wirelessly between two devices. In many applications, the choice is RF communication technology because it does not require a line of sight to communicate. The RF communications incorporate a transmitter/receiver with various bands of carrier frequencies. The module is used in LPG gas leakage detection to ensure real-time communication between the two parts in the system.

Figure 4. GSM module

Figure 5. HC-06 Bluetooth module

Figure 6. RF module

2.6. Mini siren alarm

Figure 7 is an illustration of the tiny siren alarm model TL7. A flashing alarm light and an audible alarm driver are both included in this alarm module, which is mounted on a panel. A flashing alert light and an audible alarm were generated by the Mini-siren in the event that the LPG gas leakage detection system identified a leak of LPG gas.

2.7. Gas sensor

The proposed gas leakage warning system (GLWS) utilizes an MQ-5 sensor module, which is shown in Figure 8. This module is a sensitive component, as the resistance of the sensitive component changes as the concentration of the target gas changes. They are used in gas leakage detecting equipment for detecting gases such as LPG, natural gas, and town gas. These sensor modules have advantages in their ability to avoid the noise related to alcohol, cooking fumes, and cigarette smoke during their operation.

Figure 7. Mini siren alarm

Figure 8. Gas sensor (MQ-5)

3. METHOD

The designed prototype's main features are gas leak detection, warning, and taking the proper action related to the situation. An efficient and fast response microcontroller is required to continuously capture possible LPG gas leaks. This can be accomplished utilizing a device capable of sensing propane and butane gas in the surrounding air. When an LPG leakage occurs, the system senses the leak. Thereafter, a proper command is generated to automatically close the regulator valve to avoid more leakage from the gas cylinder. Simultaneously, a buzzer alarm and a rotating alarm light are activated, and a message is sent to the house owner and the civil defense department through the GSM.

The proposed device consists of two parts: the first part is placed in the area surrounding the gas supply. The second part is mounted on the gas cylinder before the gas regulator. Also, LPG leaks will quickly evaporate and form a relatively large cloud of gas, which will drop to the ground, as it is heavier than air. So, the proposed designed device consists of two parts: the first part is installed in the surrounding area based on specific standards, which could differ from one country to another [41]–[43]. The second part is installed on the gas cylinder before the regulator. The system is designed to be suitable for installation in all places with efficiency and sensitivity. Using a combination of sensors and remote communication technologies, an efficient system could be created to manage and alert people regarding the possibility of an LPG gas leak. The functions performed by the system's circuit include: acquiring sensor data, processing the input data, sending output signal to output modules, and responding based on the output.

An MQ-6 gas sensor measures the concentration of LPG, an Arduino Uno microcontroller processes the captured data, an electromechanical valve automatically stops the gas flow, an alarm and LED indicators provide visual and auditory alerts, and a GSM module allows wireless communication. The principles of the proposed system are to continuously check the surrounding area for LPG concentrations above a predetermined safety threshold. The microcontroller automatically closes the gas cylinder valve and sounds the alarm if a leak is found. A GSM notification will also be issued. The main flowchart of the system is shown in Figure 9.

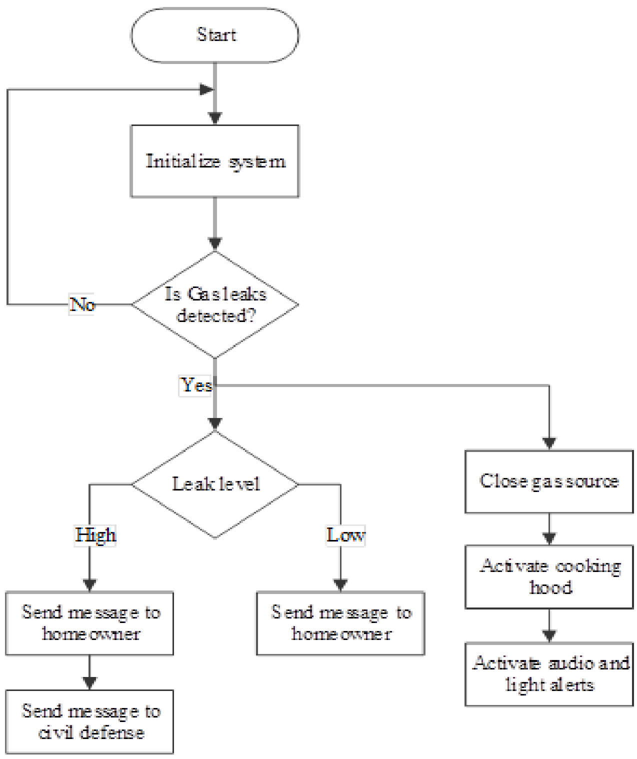

Figure 9. The GLWS flowchart diagram

The final assembled electronic circuit for the LPG system is shown in Figure 10. The first component of the system is the mobile application for entering user data; this component will be illustrated in the following section. The second component involves conducting a series of gas leak warnings, which also consists of two parts: the first portion will be placed in the gas-filled surroundings in accordance with certain requirements, and the second component will be placed on the gas cylinder prior to the gas regulator.

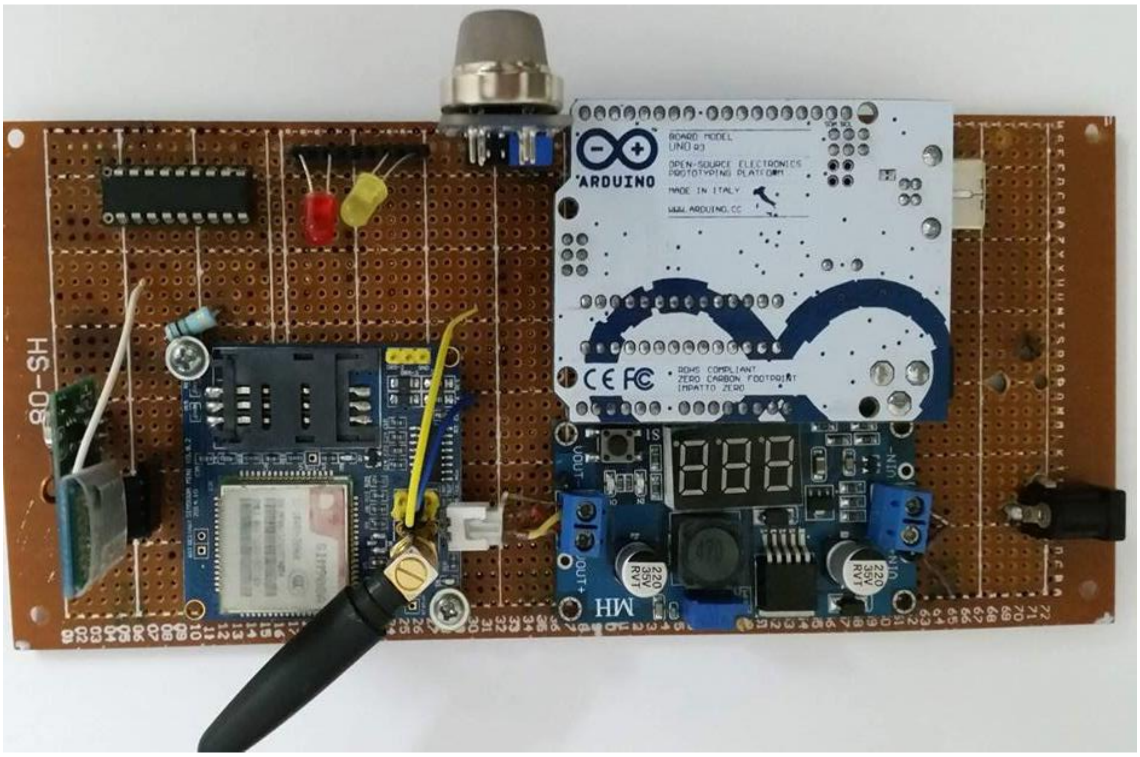

Figure 10. The assembled LPG leakage detection system's main electronic circuit

4. SOFTWARE AND PROGRAMMING

This part will cover the software design, programming techniques utilized in the development of programming, and the system diagrams in the gas leakage system. An electronic development board, incorporating both hardware and software, is designed to offer free software and an open-source interactive panel for constructing smart circuits, facilitating ease of use. Through sensors, the Arduino microcontroller interacts with the surroundings and influences them by controlling lights, engines, and other electronic components. The Arduino electronic board contains a programmable microcontroller, made of controllers ATMEGA8 and TMEGA168, programmed through the Arduino IDE software. Android Studio is a new IDE and launched recently by Google's Android operating system. It is designed to provide new tools to develop applications and provide an alternative to the Eclipse IDE, which is easier to use and more sophisticated. It provides developers with an integrated package of tools that help them develop their applications for various devices and screens more easily.

To send the setup data from the user to the system hardware through the mobile application, the user must log in to the developed application. Once the user has entered their name and password, the application will check their mobile device's Bluetooth service. If it is turned off, the app will ask them to turn it on. If they agree, it will then ask them to write down their phone number and click a button to send it to the Arduino via Bluetooth. To send the coordinates location from the user to the system hardware through the mobile application, the user must log in to the application. When the user enters the correct name and password, the application will check the Bluetooth service and GPS on the mobile. If it is turned off, the app will ask the user to allow it to turn it on, then the app will take the coordinates and send them to the Arduino.

When the voltage of the gas sensor exceeds 0.07 volts, this indicates a gas leak. The voltage on pin 11 of the Arduino board rises, and the buzzer, LED, valve, and kitchen hood light up. An alert is also sent to the homeowner. When the voltage of the gas sensor exceeds 1.0 volts, this indicates a continued gas leak. The voltage on pin 11 of the Arduino board rises, and the buzzer, LED, valve, and kitchen hood light up. An alert is also sent to the homeowner and the civil defense department, indicating a very high risk. The flowchart illustrates the functionality of the proposed LPG leakage detector system, as shown in Figure 11.

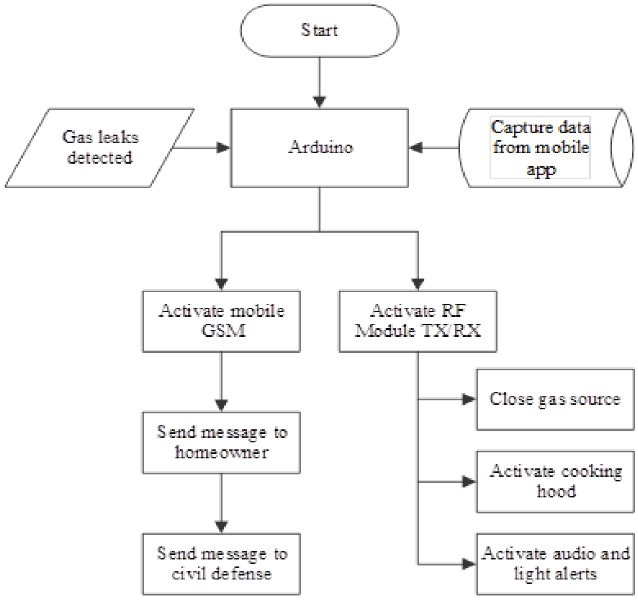

Figure 11. Functionality flowchart of the LPG detector and its smartphone application

5. RESULTS

The project components, including electronic circuits, sensors, and output devices, were assembled and installed. The microcontroller was also programmed, and the mobile application was developed. Several tests were then conducted to validate the functionality of the proposed system. This section presents some of the experiments and their results.

5.1. Test 1: GLWS system login

In this test, the input instructions for a correct user name and password are to be inserted. Upon successful login, the resulting output is a message of “user exists”. The results reveal the conclusion of a successful test. Figure 12 shows the successful user login result on the GLWS system mobile application.

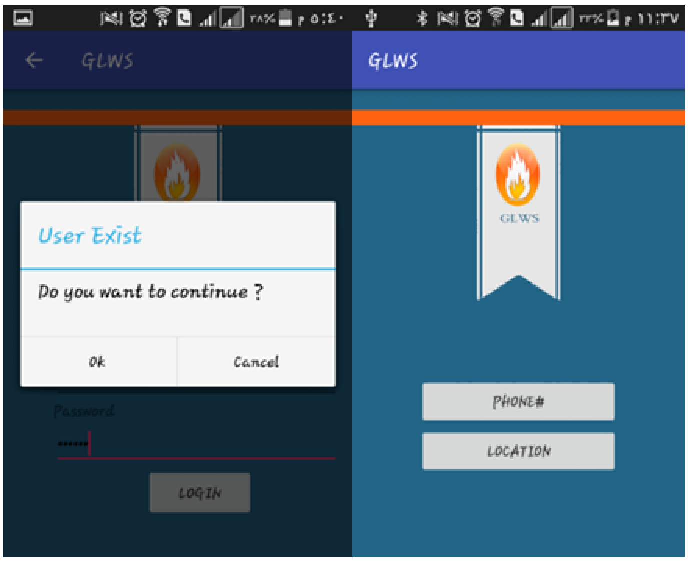

Figure 12. User login

5.2. Test 2: sending phone number

Testing the phone numbers to which the GLWS will send emergency alert messages. As shown in Figure 13, the input instructions inserted are the phone number, and the mobile Bluetooth service is activated. The intended output is the phone number sending and the activation of the Bluetooth connection. The test results show successful operation and evaluation for sending warning messages.

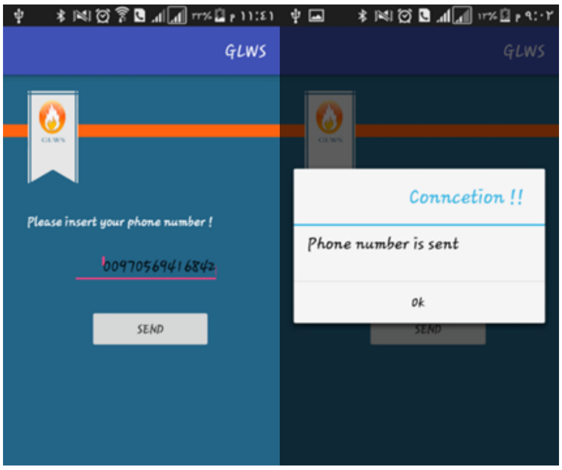

Figure 13. Sending the phone number

5.3. Test 3: coordinates sending

The aim of this test is to send the coordinates of the home location at which the LPG leakage detection system is installed. In order to provide warnings on the location of the home that had LPG leakage identified, the GLWS system made use of the input instructions of user details, as well as the GPS location system and Bluetooth communication service. The outcome of this test is the successful connection to the GPS service and the successful capturing of the location coordinates by which will be sent civil defense department. Figure 14 shows the successful test outcomes.

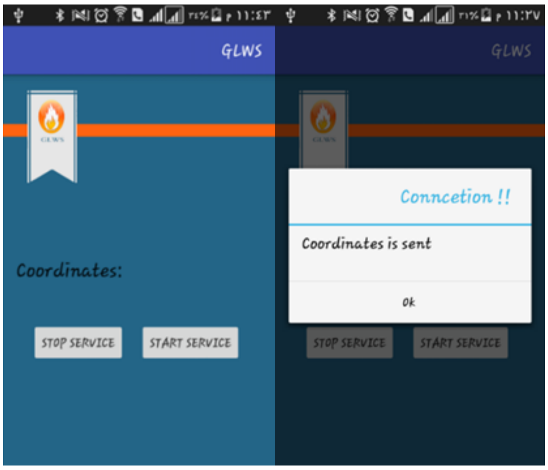

Figure 14. Sending coordinates

5.4. Test 4: no LPG leakage

This test examines the condition of LPG gas leakage without detecting any leaks. There was no LPG gas present around the MQ sensor during this test. The GLWS system's outcome is based on sensor data showing no signs of gas leaking. Additionally, the blue LED output lighting is turned on. The solenoid valve is open and allowing the LPG gas to pass through in its typical state. In light of this, there are no alert masses generated.

5.5. Test 5: LPG small leakage

In this test, a small amount of LPG leakage will be checked to verify how the gas performs. The GLWS system confirms a minor LPG gas leak when the MQ-5 gas sensor output value reaches 0.0009 V. Consequently, the orange and yellow LEDs are turned on, and the blue LED is turned off. The solenoid valve is also securely closed. In addition to turning on the audible alarm, the homeowner receives an SMS message. The message was successfully sent, as seen in Figure 15.

5.6. Test 6: LPG leakage

Examining the significant amount of LPG gas leak is the primary objective of this test. The output value of the MQ-5 gas sensor will be raised to 0.1 V. This captured value is used by the GLWS system to confirm a significant LPG gas leak. Consequently, the orange and yellow LEDs are on while the blue LED is off. The solenoid valve is closed tightly. The kitchen hood is also turned on, the GLWS system activates the visual and audible alert, and the location coordinates are included in the alarm message sent to the homeowner and civil defense department. Figure 16 illustrates the successful transmission of the message.

According to test results, the proposed gas leak warning system operated satisfactorily. The primary constraint of the technology is the usage of Bluetooth connection, which may be impacted by barriers and restricted distance. Nevertheless, this has no effect on the system's ability to function at home. Other communication technologies, including RF communication modules, could be used to overcome this problem. Table 1 presents the main features of the proposed GLWS in comparison with other commercial systems available in the market.

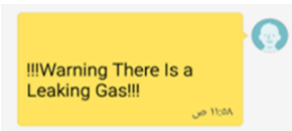

Figure 15. Alert message sent to homeowner

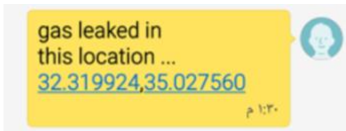

Figure 16. Alert message to the civil defense department

Table 1. Comparison of the proposed system with other commercial systems

	LPG gas leak detector [44]	UH home LPG gas leak detector [45]	Purposed GLWS
Working voltage	220 VAC/110 VAC; 12 VDC-20 VDC	AC 220 V~240 V DC 12~24 V	12 V DC voltage source 12 V DC rechargeable battery
Gas detection	Gas, LPG, H2	LPG gas	LPG gas
Solenoid valve	No.	Yes wired connected system	Yes wirelessly connected system
SMS messaging	No	No	Yes
Mobile application	No	No	Yes
Sensitivity	Medium	High	Medium
Responsible time	less than 3 s	less than 2 s	less than 4 s

The proposed system is seen to be advantageous in its ability to detect LPG gas leaks, control of gas cylinder solenoid valve, sensitivity, and its ability to send alerts via SMS communication system [46], [47]. Additionally, compared to other developed systems, the proposed system has the advantage of having numerous alarm levels regarding potential leaks, primarily the GSM messages, as well as the presence of an automatic valve to shut down the LPG gas supply and the developed mobile application tool [48]. Although the proposed system has been successful, there are still a few obstacles, including the short-range connectivity of the Bluetooth module and the fact that GSM alerts do not function effectively when the network coverage is poor. Additionally, the gas sensor may generate false positives due to the presence of regular cooking emissions, and the system currently lacks a reliable fallback power source. Future enhancements may involve the integration of Wi-Fi networks to enhance the durability and reliability of connections, the implementation of AI-based techniques to detect gas leakage prior to its occurrence, and an improvement of the device to detect different kinds of hazardous gases.

6. CONCLUSION

This research paper successfully implemented a system that serves the majority of the community, as many individuals work in different locations away from their families, who live in homes. The proposed system aims to provide superior protection for home residents from the effects of LPG leaks. A device was designed and developed to detect these leaks and shut off the gas supply to the stove from the cylinder. The developed system senses the leakage of LPG mixed with the surrounding air to prevent any potential explosion. It detects the leak and closes the cylinder valve. The proposed system also generates visual and observable warning signals to alert the home residents and the surrounding community. The system also sends text messages that can be used by the homeowner and local public safety authorities to alert them of any potential leak hazard. Test results of the proposed LPG leak detection system demonstrated satisfactory performance, with rapid response to LPG leaks, as audible and visual alarms are activated when an LPG leak occurs. A message was also sent to the homeowners and the civil defense department detailing the leak incident and location coordinates.

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Anees Abu Sneineh		✓				✓		✓	✓	✓	✓			✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT
Authors state no conflict of interest.

DATA AVAILABILITY
Data availability is not applicable to this paper as no new data were created or analyzed in this study.

REFERENCES
[1] D. A. Stephen, D. V. M. Sundari, D. B. Thayumanavar, D. R. K. Shakya, and D. E. Muthukumar, "Technology and its role in shaping the future of worklife balance," *Educational Administration: Theory and Practice*, vol. 30, no. 5, pp. 1045–1053, May 2024, doi: 10.53555/kuey.v30i5.3005.
[2] A. S. M. Al-Obaidi, A. Al-Qassar, A. R. Nasser, A. Alkhayyat, A. J. Humaidi, and I. K. Ibraheem, "Embedded design and implementation of mobile robot for surveillance applications," *Indonesian Journal of Science and Technology*, vol. 6, no. 2, pp. 427–440, May 2021, doi: 10.17509/ijost.v6i2.36275.
[3] A. A. El-Saleh, A. M. Sheikh, M. A. M. Albreem, and M. S. Honnurvali, "The internet of medical things (IoMT): opportunities and challenges," *Wireless Networks*, vol. 31, no. 1, pp. 327–344, Jan. 2025, doi: 10.1007/s11276-024-03764-8.
[4] W. A. Salah, M. A. M. Albreem, and B. A. Zneid, "Implementation of smart house digital applications for safety and health," *Journal of Engineering Science and Technology*, vol. 15, no. 4, pp. 2679–2695, 2020.
[5] A. Chakraborty, M. Islam, F. Shahriyar, S. Islam, H. U. Zaman, and M. Hasan, "Smart home system: a comprehensive review," *Journal of Electrical and Computer Engineering*, vol. 2023, pp. 1–30, Mar. 2023, doi: 10.1155/2023/7616683.

[6] A. A. Roslan and R. Baharom, “Advanced gas leakage, fire, and power supply failure monitoring system,” *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 17, no. 1, p. 222, Jan. 2020, doi: 10.11591/ijeecs.v17.i1.pp222-227.

[7] W. A. Salah, A. A. Sneineh, and A. A. A. Shabaneh, “Smartphone sensor-based development and implementation of a remotely controlled robot arm,” *Journal of Robotics and Control*, vol. 5, no. 4, 202AD, doi: 10.18196/jrc.v5i4.21987.

[8] W. A. Salah, B. A. Zneid, A. A. A. Aish, and M. Nofal, “Development of smart and portable controllable syringe pump system for medical applications,” *Journal of Engineering and Technological Sciences*, vol. 55, no. 3, pp. 300–312, Aug. 2023, doi: 10.5614/j.eng.technol.sci.2023.55.3.7.

[9] S. Tongsubanan and K. Kasemsarn, “Developing a design guideline for a user-friendly home energy-saving application that aligns with user-centered design (UCD) principles,” *International Journal of Human–Computer Interaction*, vol. 41, no. 12, pp. 7424–7446, Jun. 2025, doi: 10.1080/10447318.2024.2398324.

[10] N. A. A. Khleel and K. Nehéz, “Detection of code smells using machine learning techniques combined with data-balancing methods,” *International Journal of Advances in Intelligent Informatics*, vol. 9, no. 3, p. 402, Nov. 2023, doi: 10.26555/ijain.v9i3.981.

[11] L. Falaschetti, M. Beccerica, G. Biagetti, P. Crippa, M. Alessandrini, and C. Turchetti, “A lightweight CNN-based vision system for concrete crack detection on a low-power embedded microcontroller platform,” *Procedia Computer Science*, vol. 207, pp. 3948–3956, 2022, doi: 10.1016/j.procs.2022.09.457.

[12] P. Shrivastava *et al.*, “Low-cost microcontroller-enabled embedded system for assessing jute retting water quality parameter,” *Journal of Natural Fibers*, vol. 22, no. 1, Dec. 2025, doi: 10.1080/15440478.2025.2456648.

[13] W. A. Salah and A. A. Sneineh, “Development of pulse and blood pressure monitoring system,” in *2018 IEEE Symposium on Computer Applications & Industrial Electronics (ISCAIE)*, IEEE, Apr. 2018, pp. 37–42. doi: 10.1109/ISCAIE.2018.8405441.

[14] A. A. Shabaneh, S. Qaddomi, M. Hamda, A. A. Sneineh, and T. Punithavathi, “Automatic class attendance system using biometric facial recognition technique based on Raspberry Pi,” *Optica Pura y Aplicada*, vol. 56, no. 3, Sep. 2023, doi: 10.7149/OPA.56.3.51152.

[15] I. Rokhim, N. J. Ramadhan, and Z. Najakh, “CURe-Mi mobile manipulator robot for contact-less COVID-19 patients serving missions,” *IAES International Journal of Robotics and Automation (IJRA)*, vol. 12, no. 3, p. 262, Sep. 2023, doi: 10.11591/ijra.v12i3.pp262-273.

[16] B. Aamaas *et al.*, “Required knowledge for clean cooking transition: the case of Tanzania,” *Environmental Science & Policy*, vol. 160, p. 103834, Oct. 2024, doi: 10.1016/j.envsci.2024.103834.

[17] N. F. Abdullah and N. S. Abdullah, “Kitchen gas leakage control system,” *Research and Innovation in Technical and Vocational Education and Training*, vol. 1, no. 1, pp. 187–193, 2021.

[18] B. B. Didpaye and S. K. Nanda, “Automated unified system for LPG using microcontroller and GSM module-a Review,” *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 4, no. 1, pp. 209–212, Jan. 2015, doi: 10.17148/IJARCCE.2015.4145.

[19] H. Chandra *et al.*, “Preventing environmental and health problems due to LPG transport tank leaks: fatigue and crack behavior of heat-treated steel investigation,” *Cogent Engineering*, vol. 11, no. 1, Dec. 2024, doi: 10.1080/23311916.2024.2304491.

[20] B. D. Jolhe, P. A. Potdukhe, and N. S. Gawai, “Automatic LPG booking, leakage detection and real time gas measurement monitoring system,” *International Journal of Engineering Research & Technology*, vol. 2, no. 4, 2013.

[21] T. Soundarya, J. V. Anchitaalagammai, G. D. Priya, and S. S. K. Kumar, “C-Leakage: cylinder LPG gas leakage detection for home safety,” *IOSR Journal of Electronics and Communication Engineering*, vol. 9, no. 1, pp. 53–58, 2014, doi: 10.9790/2834-09165358.

[22] A. A. Olayiwola, O. M. Osifeko, K. A. Olaniyi, A. A. Oluwaleke, and O. F. Adizua, “Development of an IoT based smart gas leakage monitoring system,” *Scientia Africana,* vol. 24, no. 2, pp. 119–128, 2025, doi: 10.4314/sa.v24i2.13.

[23] Q. Jia, G. Fu, X. Xie, S. Hu, Y. Wu, and J. Li, “LPG leakage and explosion accident analysis based on a new SAA method,” *Journal of Loss Prevention in the Process Industries*, vol. 71, p. 104467, Jul. 2021, doi: 10.1016/j.jlp.2021.104467.

[24] Z. Liu, X. Li, R. Jiang, and B. Jia, “Evacuation traffic management under low visibility and toxic-gas leakage disasters,” *Journal of Transportation Engineering, Part A: Systems*, vol. 147, no. 1, Jan. 2021, doi: 10.1061/JTEPBS.0000472.

[25] G. Paliwal, K. Agrawal, R. K. Srivastava, and S. Sharma, “Domestic liquefied petroleum gas: are we using a kitchen bomb?,” *Burns*, vol. 40, no. 6, pp. 1219–1224, Sep. 2014, doi: 10.1016/j.burns.2013.12.023.

[26] B. F. Alshammari and M. T. Chughtai, “IoT gas leakage detector and warning generator,” *Engineering, Technology & Applied Science Research*, vol. 10, no. 4, pp. 6142–6146, Aug. 2020, doi: 10.48084/etasr.3712.

[27] A. J. Ishak, S. N. Mahmood, and A. -S. T. Hussain, “GSM based gas leak monitoring system,” *Periodicals of Engineering and Natural Sciences*, vol. 7, no. 2, p. 670, Jul. 2019, doi: 10.21533/pen.v7i2.529.

[28] D. T. Y. Shin *et al.*, “Advancements in gas reticulation system safety measures: a comprehensive development perspective,” *Journal of Achievements in Materials and Manufacturing Engineering*, vol. 122, no. 2, Mar. 2024, doi: 10.5604/01.3001.0054.5455.

[29] Q. Tan, M. Fu, Z. Wang, H. Yuan, and J. Sun, “A real-time early warning classification method for natural gas leakage based on random forest,” *Reliability Engineering & System Safety*, vol. 251, p. 110372, Nov. 2024, doi: 10.1016/j.ress.2024.110372.

[30] A. Q. B. N. Azuwan, T. N. B. T. Yaakub, and A. B. A. Aziz, “Implementation of real time approach for early warning gas leakage detection,” in *2022 IEEE 12th Symposium on Computer Applications & Industrial Electronics (ISCAIE)*, IEEE, May 2022, pp. 317–321. doi: 10.1109/ISCAIE54458.2022.9794548.

[31] N. N. M. Noor and M. F. Lee, “LPG mass monitoring scale with automatic gas leakage detector system,” *Journal of Physics: Conference Series*, vol. 2312, no. 1, p. 012037, Aug. 2022, doi: 10.1088/1742-6596/2312/1/012037.

[32] D. Dey, S. Datta, S. Datta, S. Das, and T. Dutta, “IoT based LPG, smoke, and alcohol detection system with automatic power cut-off,” in *Recent Advances in Electrical and Electronic Engineering (ICSTE 2023)*, Springer, Singapore, 2024, pp. 289–300. doi: 10.1007/978-981-99-4713-3_28.

[33] M. Paczuski, M. Marchwiany, R. Pulawski, A. Pankowski, K. Kurpiel, and M. Przedlacki, “Liquefied petroleum gas (LPG) as a fuel for internal combustion engines,” in *Alternative Fuels, Technical and Environmental Conditions*, InTech, 2016. doi: 10.5772/61736.

[34] T. Chen, I. J. Simpson, D. R. Blake, and F. S. Rowland, “Impact of the leakage of liquefied petroleum gas (LPG) on Santiago air quality,” *Geophysical Research Letters*, vol. 28, no. 11, pp. 2193–2196, Jun. 2001, doi: 10.1029/2000GL012703.

[35] J. Praveenchandar *et al.*, “IoT-based harmful toxic gases monitoring and fault detection on the sensor dataset using deep learning techniques,” *Scientific Programming*, vol. 2022, pp. 1–11, Aug. 2022, doi: 10.1155/2022/7516328.

[36] A. B. Codjoe *et al.*, “Kitchen cooking burns: a real danger for adults and children in Ghana,” *Burns*, vol. 51, no. 4, pp. 107458, May 2025, doi: 10.1016/j.burns.2025.107458.

[37] C. Kypridemos *et al.*, "Health and climate impacts of scaling adoption of liquefied petroleum gas (LPG) for clean household cooking in cameroon: a modeling study," *Environmental Health Perspectives*, vol. 128, no. 4, Apr. 2020, doi: 10.1289/EHP4899.
[38] E. R, H. K, I. K, A. Alkarn, B. A, and E. A, "General and respiratory health of workers exposed to liquified petroleum gases in bottle-gas tubes factory," *Egyptian Journal of Occupational Medicine*, vol. 48, no. 2, pp. 25–39, May 2024, doi: 10.21608/ejom.2023.239490.1318.
[39] S. Liaqat, S. W. Hussain, K. Hussain, and F. Begum, "Indoor air quality and human health risk assessment in selected high-altitude villages of Gilgit-Baltistan, Pakistan," *Environmental Monitoring and Assessment*, vol. 197, no. 2, p. 187, Jan. 2025, doi: 10.1007/s10661-025-13642-1.
[40] K. Parvizi *et al.*, "Burden of headaches, eye irritation and respiratory symptoms among females stacking LPG with polluting cooking fuels: modelling from Peri-Urban Cameroon, Ghana, Kenya," *Energy Nexus*, vol. 14, p. 100304, Jul. 2024, doi: 10.1016/j.nexus.2024.100304.
[41] D. Hossain and D. K. Alasa, "Fire detection in gas-to-liquids processing facilities: challenges and innovations in early warning systems," *International Journal of Biological, Physical and Chemical Studies*, vol. 6, no. 2, pp. 07–13, Dec. 2024, doi: 10.32996/ijbpcs.2024.6.2.2.
[42] J. Chojnowski, "Safety in the use of car gas fuel installations," *Combustion Engines*, vol. 189, no. 2, pp. 3–9, Apr. 2022, doi: 10.19206/CE-142172.
[43] J. D. Miller, B. Crosley, and M. P. Bailey, "Gas detection as a risk mitigation technique," *Chemical Engineering (United States)*, vol. 125, no. 9, pp. 47–55, 2018.
[44] Trade India, "LPG gas leak detector for home use," Infocom Network Private Limited. Accessed: Jul. 15, 2024. [Online]. Available: https://www.tradeindia.com/products/lpg-gas-leak-detector-for-home-use-1098456.html
[45] United Honesty, "UH household gas leak detector with solenoid valve," Shenzhen Zhonghe United Technology Co.,Ltd. Accessed: Jul. 15, 2024. [Online]. Available: https://ycdpan.diytrade.com/sdm/847565/4/pd/12917640-2742394/UH_household_gas_leak_detector_with_solenoid_valve.html
[46] M. A. Rahman, H. Ahmed, and M. M. Hossain, "An integrated hardware prototype for monitoring gas leaks, fires, and remote control via mobile application," *International Journal of Advanced Computer Science and Applications*, vol. 13, no. 10, 2022, doi: 10.14569/IJACSA.2022.0131099.
[47] A. K. Srivastava, S. Thakur, A. Kumar, and A. Raj, "IoT based LPG cylinder monitoring system," in *2019 IEEE International Symposium on Smart Electronic Systems (iSES) (Formerly iNiS)*, IEEE, Dec. 2019, pp. 268–271. doi: 10.1109/iSES47678.2019.00066.
[48] B. Jena, S. K. Pradhan, R. Jha, S. Goel, and R. Sharma, "LPG gas leakage detection system using IoT," *Materials Today: Proceedings*, vol. 74, pp. 795–800, 2023, doi: 10.1016/j.matpr.2022.11.172.

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