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A Simple, Low-cost, Efficient and Smart Consumer Gas Leakage Detection System

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ABSTRACTS

Liquefied Petroleum Gas is used for a wide range of both domestic and industrial purposes. Its use has seen a significant increase over the years. Unfortunately, there have also been many casualties resulting from gas explosions in recent times. Often, there is a news report of a gas explosion occurring somewhere, whether at home, in the marketplace or in an industry. Although these accidental explosions are sometimes beyond human control, some are due to ignorance, negligence, or improper care of gas cylinders. Most explosions are caused by undetected gas leakages which are then set off to explode with the slightest ignition. Apart from explosions, fires at homes can also be caused by gas leakages. This usually results in serious injuries, loss of property and even sometimes, loss of lives. This project seeks to provide a smart, budget friendly and easy to use gas leakage detector system, a better alternative to relying on the natural way of using the nose, which may fail and in effect, incur undesirable consequences. The system employs an MQ2 sensor interfaced with an ESP8266 Wi-Fi module for sensing the gas in the atmosphere and displaying an alert message on the lcd. The Wi-Fi in combination with the microcontroller module acts as the transmission and processing unit, allowing for communication over wireless medium. This way, a user can receive notifications on a mobile device depending on changes the hardware system detects in the atmosphere. There is also a buzzer to alert nearby persons by sound so that they can take the necessary precautions and actions.

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1. INTRODUCTION

In May 2021, a survey conducted by Doris Dokua revealed that 267 fire outbreaks were registered in the Greater Accra region of Ghana alone. Domestic fires were the most prevalent source of outbreaks, having 108 occurrences, with electrical installations being the next at 48, and the others being either bush fires, vehicular fires, institutional fires, or fires from burning refuse and others (Addai, et al., 2016). Fire is an oxidation process that occurs rapidly and is usually accompanied by the evolution of heat and light in varying intensities. Four components are thought to be necessary for fire to start: fuel, an igniting source, an oxidizing agent (typically ambient oxygen), and a reaction mechanism. The most frequent causes of flames include flammable gases used for cooking in houses, furniture, clothing, solvents like kerosene and gasoline used in daily activities, and combustible dusts like toner used in offices and starch sold in markets (Doris, 2020). Liquefied Petroleum Gas, LPG, is a flammable mixture of hydrocarbon gases, most commonly propane, butane, and propylene (Raslavičius et al., 2014). It is a colourless and doorless gas widely used in the domestic setting for a variety of purposes, mostly being cooking, and other times, as fuel for vehicles. To allow portability and mobility, LPG must be placed under pressure to be transported as a liquid, since it occupies much less volume as a liquid and is hence transported in gas cylinders. When this pressure is released, such as when the nozzle on a gas cylinder is open, the liquid becomes gas again (Murshed et al., 2021). LPG has a wide array of uses, which vary from domestic to industrial. It is used as fuel for vehicles, it is used for cooking, used as a refrigerant, used as chemical feedstock, used for drying processes in agriculture and industrial solution heating, and is also used to produce electrical energy by running turbines (Checkley et al., 2021). Despite the benefits LPG provides, there are dreadful consequences if certain measurable quantities of the gas can be detected in the atmosphere. LPG serves the average person well usually as fuel but fails sometimes. According to a study conducted by The Zebra in 2020, the top three causes of house fires are cooking, heating equipment and electrical malfunction, with cooking alone contributing to 50% of all fires. Each year, there is an average of 358,300 home-based fires, causing nearly 12 billion dollars in damage (Tylor, 2020). Statistics from the Ghana national fire service suggests that domestic fire outbreaks are peaking, with the highest in 2019 and 2020. The domestic fire incidents from January to October represented 39.63 per cent and 35.67 per cent of total fire outbreaks in both years respectively (News Desk Report, 2021).

Most house fires in Ghana are caused either by LPG explosion or leakage. LPG is colourless and odourless. Its nature makes it difficult to perceive by sight or by smell alone in the case of a leakage which poses danger to everyday users, hence the need for a monitoring device to reduce the risk of harm. This paper seeks to prevent the occurrences of fires and explosions owing to undetected gas leakages by providing a smart gas detection system for consumers. This will be done by incorporating software and hardware components to build a gas leakage detector which is cost effective and efficient in detection of gas leakages and the presence of fires. The system is also efficient with alerting users in case of gas or flame detection and is integrated with a mobile application for constant monitoring of the hardware system.

2. RELATED WORKS

LPG consists of a mixture of propane and butane produced by Walter Snelling in the year 1910. This gas is a highly flammable chemical compound that is odourless and is heavier than air (Noku et al., 2021). The undetectable yet flammable nature of this gas makes it very dangerous to accommodate in the home; yet it is very common in many Ghanaian homes and industries serving various purposes because of its economic benefits. An odorant such as ethane oil is added to allow for natural detection by the average user, yet this gas is still not easily detectable by many at certain concentrations which renders it unreliable. With regular use, gas cylinders and pipes reach a point of wear and tear, leaving the gas prone to leakage, which is why these systems require constant monitoring.

N. Evalina and Azis H designed a system consisting of the ATMega 8 microcontroller, an MQ 6 sensor and a buzzer. It was a simple, cost-effective system designed to detect the leakage of LPG gas and to alert people by the sound of the loud buzzer (Evalina & Azis, 2020). Noku et al proposed a design of an automatic gas leakage detector with a control system and auto power trip. The control system included a gas valve for cutting supply of gas and was also responsible for shutting down electrical systems to avoid sparks which could lead to a fire. K. R. Katole et al in 2019; proposed a system that employed the MQ 4 sensor for methane gas detection, the MQ 2 sensor for LPG leakage detection, and the MQ 7 sensor for the detection of carbon monoxide. This system generally performed gas leakage detection and alerted people by displaying a message on an LCD screen stating the specific gas detected. In any case of gas leakage, people had to rely on their nose if they were far from the LCD and could not read what was displayed which is not the best safety mechanism applicable in this area (Katole et al., 2019). E. Jebamalar et al worked on a simple system which involved the use of the MQ 6 sensor interfaced with a microcontroller which generally performed gas leakage detection, and then alerted people around by activating the buzzer so that they could take the necessary precautions (Leavline et al., 2017).

Syeda Bushra Shahewaz et al proposed a system using Arduino Uno. This system employed three different gas leakage detectors planted at different parts of a building to cover more area. These gas leakage detectors were all linked to the same microcontroller and displayed messages on an LCD screen when gas is detected in a particular zone, specifying where. It also used a buzzer and a GSM module to alert people by sound and by SMS respectively (Shahewaz & Prasad, 2020). Hitendra et al designed a system that involved the use of a PIC microcontroller and an MQ 6 sensor. It was basically responsible for detecting gas leakages and for sensing extreme temperatures which gives a clue that there may be a fire (Rawat et al., 2014). A. Y. Nasir et al presented an alternative approach to develop a device that can automatically detect and control gas leakages and monitor temperature in vulnerable areas. The system detects the leakage of LPG using a gas sensor and then also monitors the temperature using a temperature sensor. When the LPG concentration in the air exceeds a certain level, the gas sensor senses the gas leakage and the output of the sensor goes LOW, the system then opens the exit windows, and then uses a GSM module for an alert about the gas leakage. Also, when the temperature of the environment exceeds a certain limit, it then turns ON the LED (indicator) and makes an alarm sound through the buzzer. An LCD displays the current temperature and gas leakage status in degree Celsius and PPM respectively (Nasir et al., 2019).

Rhonnel S. Paculanan and Israel Carino proposed a system to detect the presence of LPG leakage as a part of a safety system. Apart from alarm by sound, an SMS alert would be sent to inform the authorized person of the leakage and the solenoid valve of the gas container will be triggered to shut down the gas supply to prevent any harmful effects due to gas leakage. Essentially, a gas sensor was used to monitor the LPG if the gas leak reached beyond the normal level. This proposed leak detection system would then trigger the sound alarm. There was also a survey conducted on 75 people to know whether most people who use LPG are household members or employees of companies (Paculanan & Carino, 2019).

Bader Farhan Alshammari and Muhammad Tajammal Chughtai in their paper outlined an industrial monitoring system design using the Internet of Things (IoT). Here, the gas sensor (MQ-5) - captured information which is posted into a data cloud. The sensor detects the leakage of gas under most atmospheric conditions. All the components are controlled by an Arduino (UNO-1) that acts as a central processor unit in the setup. As soon as a gas leakage is detected by the sensor, the alarm is raised using a buzzer. This alarm is supported by an LCD to display the location of leakage, alert the observer, and automatically activate the exhaust fan in the particular section to extract leaked gas from the enclosed space to prevent potential ignition and fire hazards (Alshammari & Chughtai, 2020). In a paper by Mohammad Monirujjaman Khan, an MQ6 semiconductor sensor is used to detect LPG gas. Sensitive material of the MQ-6 gas sensor is SnO_2, which has lower conductivity in clean air. When the target combustible gas exists, the sensor conductivity increases along with the rising gas concentration. The MQ6 gas sensor has a high sensitivity to Propane, Butane and LPG, and response to Natural gas. The sensor could be used to detect different combustible gasses, especially Methane; it has a low cost and is suitable for different applications. The MQ-6 can detect gas concentrations anywhere from 200 to 10,000 ppm. The sensor's output is an analog resistance. When the sensor detects gas in the atmosphere, it will give digital output 1 and if gas is not detected the sensor will give digital output 0. Arduino will receive the sensor output as digital input. If the sensor output is high, then the buzzer will start tuning along with the LCD that will show that "Gas detected: Yes". If the sensor output is low then buzzer will not be tuning, and the LCD will show that "Gas detected: No". The buzzer consists of several switches or sensors connected to control unit that determines which button was pushed or whether a preset time has lapsed, and usually illuminates a light on the appreciate button or control panel and sounds a warning in the form of a continuous or intermittent buzzing or beeping sound (Khan, 2020). MoVasudev Yadav in his project sought to add a little twist to the usual gas detection module by introducing a stepper motor also in addition to the normal LPG Gas leakage detectors which helps in turning off the switch when there is an emergency in our absence. The sensor used here has excellent sensitivity combined with a quick response time. The sensor can also sense iso butane, propane, LNG, and cigarette smoke. The report also outlines a background into the area of 8051 microcontroller and mobile communication, how they are interfaced to each other, and AT commands set used in communication (Yadav et al., 2016). Ba Thanh Nguyen, Anh Vu Nguyen designed a gas leakage detection and monitoring system which included an Arduino Mega 2560, an MQ-2 sensor, a SIM800L module, an ESP8266 Node MCU module, an LM2596 module, a LCD, and a buzzer. An allowable limit of gas sensed in the atmosphere was set. If the gas level exceeds 20% of the allowable limit, the system is triggered, data is displayed on the lcd showing that gas leakage has been detected, and the sim alarm clock calls the phone number set before the gas exceeds the limit. Data is also posted to thingsspeak.com every 15 seconds to ensure constant gas monitoring (Nguyen & Nguyen, 2020). Rahul Gupta et al designed a system with an AT Mega 328 microcontroller interfaced with two stepper motor IC (ULN 2003A), buzzer, LCD (Liquid crystal display), GSM module and RF link. Upon gas leakage detection, the system is triggered, and the buzzer activates simultaneously with a message displayed on liquid crystal display screen, and the GSM module is activated, which sends warning SMS to the user. The stepper motor IC (ULN 2003A) drives the stepper motor attached to it causing the main power to go off (Gupta, 2018). Arun Raj et al, designed a PIC 16F877A microcontroller with an operating frequency of 20 MHz. It was interfaced with a gas sensor, weight sensor (Load CellL6D), GSM module (SIMCOM 300), and display(s). It was a simple-to-use LPG sensor, suitable for sensing LPG concentrations in the air. The load cell acts as a passive transducer or sensor for converting applied force into electrical signals. This was used to check the available gas level. This system gives a fully automated approach towards the gas booking along with gas leakage detection. Real time weight measurement of the gas and its display on LCD makes it an efficient home security system (Raj & Athul, 2015).

Designed a gas leakage detection system interfacing an AT Mega 328p microcontroller with an MQ 6 gas sensor, an lcd, a stepper motor, and a buzzer

(Pooja, 2020). This functioned as an effective gas leakage monitoring system which simultaneously displayed a message on lcd while sending a message to a specific mobile number using the GSM and activating the buzzer to sound an alarm when gas was detected in the atmosphere. There was also a reset button available for resetting the system to its former state after the gas leakage has been fixed (Imade et al., 2018) used the IoT technology to make a Gas Leakage Detector for society which will have Smart Alerting techniques involving sending text messages to the concerned authority and an ability to perform data analytics on sensor readings. The primary objective was to propose the gas leakage system for society where each flat has a gas leakage detector hardware. This will detect the harmful gases in the environment and send an alert to the society member through alarm and sending notification. Proposed a solution to this problem by building a device utilizing sensors connected to the Node MCU (Sudha & Prasad, 2020). The device performs area monitoring continuously. The gas sensor provides data to Node MCU, and then the results are displayed as a warning to the user via an Android-based smart-phone device. Other than LPG gas, Air conditioner and refrigerator leaked gases are also harmful in the home. Using this device, users will be able to prevent accidents that occur due to harmful gas leaks so that accidents can be avoided.

Proposed an Internet of Things (IoT) based system that maintains track of several LPG cylinder-related factors and updates the user via a mobile application (Rohith, 2020). There are two sections to this project. The first part deals with the amount of gas still in the cylinder, which is calculated by a load cell sensor and continuously updated to the user's smartphone. An alert will be delivered to the user via the buzzer and a notification in the mobile app when the gas level is below the threshold value. Another component is the safety feature built into this home automation system, which notifies the user of a gas leak by both a buzzer and a mobile application when it is discovered. It alerts the user of a gas leak via a buzzer and a mobile application when it is found. Additionally, it turns off the gas regulator knob to halt additional leaks at their source. The gas valve can be turned on and off using the mobile application. The device is designed to serve as a stand for LPG cylinders.

3. METHOD

The method used for this is multi-faceted. The system is made up of several functional units that work together to provide the desired outcomes. These hardware and software components are incorporated into the system to carry out the smart gas leak detection functions. The system is visually represented here in the form of a system architecture, which depicts the system's expected functionality in general. Along with a flowchart outlining the logic of the system, it also includes a block diagram that illustrates how the hardware and software components work.

3.1. System Architecture

The general operating principles of the smart gas leakage detector are outlined in the system architecture in Fig. 1.

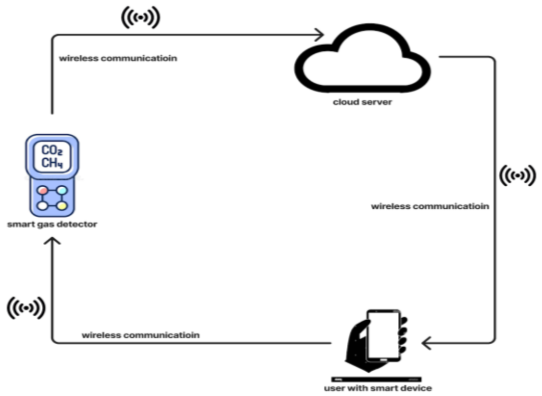
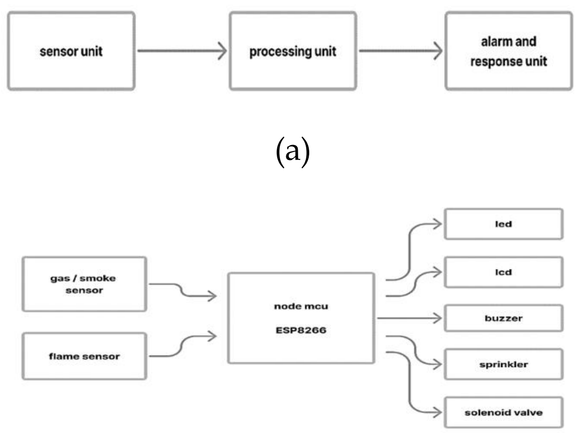


Fig. 1. System Architecture

It provides a visual representation of how the system works, outlining the various elements that must be recognized in the atmosphere, how the system handles detection, and how the user interacts with the system. The gas detector represents the whole system with the underlying components including sensors, a processor, alarms, and a Wi-Fi communication module. These components together makeup the hardware components of the system, collecting data from the environment and responding appropriately, by setting off an alarm and control system, and alerting the user through the mobile application. Data collected from the atmosphere by the sensors is constantly uploaded via wireless media to a website, thingspeak.com, which the mobile software application depends on for updates about the state of the system. The mobile software application can also be used to remotely control the hardware components of the system.

3.2. System Block Diagram

The smart gas detection system consists of three major units; the sensor unit, the processing unit and the alarm unit as depicted in Fig. 2a and 2b. As seen in Figures, the sensor unit consists of components including the gas and smoke sensor as well as the flame sensor. These components are constantly on the lookout for changes in the atmosphere with respect to smoke, flames, and LPG concentrations. The processing unit is the intelligent unit which consists of a processor which receives and interprets digital signals from the sensor unit. Based on what data is received, signals may be sent from this unit to trigger the alarm unit to alert people nearby to take precautions. The alarm and response unit are made up of the LCD, the LED, the buzzer, the sprinkler, and the solenoid valve. By transmitting signals that notify the user of the detection of gas in the environment as well as the risk of a fire occurring, these hardware components work together to engage the user's corporeal senses and enable the situation to be mitigated.



(a)

(b)

Fig. 2. System Block Diagrams

3.3. System Workflow

The system workflow shows the sequential stages that the gas sensor traverses to achieve its function of gas detection and alarming the user. The individual phases are as illustrated in Fig. 3, giving a graphical perspective of the logical flow of operations in the smart gas detector system. The system starts with the press of a button, which turns on the green led after which the sensors begin to compare atmospheric concentrations of gas with previously defined values. In case the values are detected to be higher than allowable concentrations, the solenoid valve is closed to obstruct the supply of gas while the red led is turned on. The buzzer is also turned on to sound an alarm, while the LCD displays a message indicating either gas detection or flame detection. If after a while, the concentrations as previously detected reduce to normal allowable levels, the system then resets and begins the process all over again. Notifications are also sent to a user via the system mobile software application.

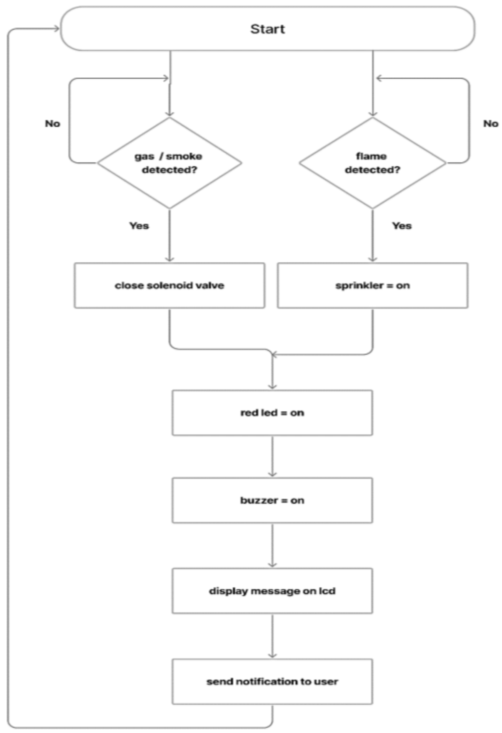


Fig. 3. System Workflow

3.4. System Hardware Prototype Design

The system hardware prototype was designed using modular method. The modules or hardware prototype components are illustrated in Fig. 4 and graphically and textually described in detail in table 1.

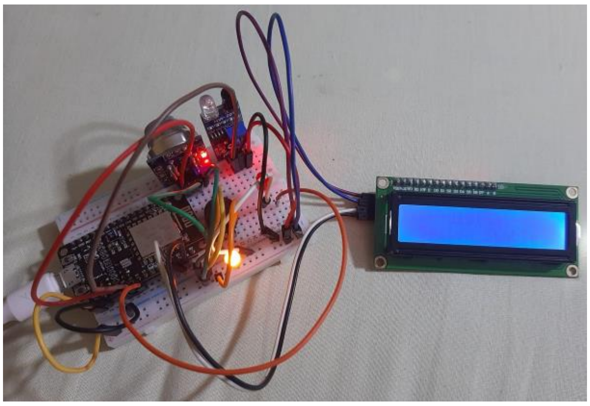


Fig. 4. System Hardware Prototype Design

Table 1. System Hardware Prototype Components and Description

Components	Image	Description
MQ-2 Gas Sensor		Gas sensors are devices that can detect the presence and concentration of various hazardous gases and vapours, such as toxic or explosive gases, volatile organic compounds (VOCs), humidity and odours (Mirzaei et al., 2018). A gas sensor uses specialized physical and chemical processes to transform the constituent parts and concentrations of various gases into conventional electrical signals. The MQ-2 sensor is sensitive to smoke, as well as other flammable gases including LPG, Butane, Propane, Methane, Alcohol, and hydrogen. It can be set to output values either in the form of analogue signals or digital signals which can be read with the analogue or digital inputs of the Arduino respectively.
Flame Sensor		A flame detector is a sensor designed to detect and respond to the presence of a flame allowing flame detection. The flame detector can often respond faster and more accurately than a smoke and heat detector due to the mechanisms it uses to detect the flame. This sensor is a short length of a thin metallic rod that creates a small current of electricity to confirm there is a fire burning. It can detect infrared light with wavelengths between 700nm and 1000nm. The far-infrared flame probe converts the infrared light detected into current changes. With a detection angle of 60 degrees, the integrated variable resistor allows for sensitivity adjustment. It has a working voltage ranging from 3.3 to 5.2 volts DC, and a digital output used to show whether a signal is present (https://create.arduino.cc).
Node MCU ESP8266		NodeMCU is an easy-to-use open-source platform built on the ESP8266 which is programmable with Arduino IDE or IUA languages. It allows things to be connected and data to be transferred over Wi-Fi. Additionally, it may address many of the project's requirements on its own by offering some

		of the most crucial microcontroller functionalities, like GPIO, PWM, ADC, and others, having an internal antenna, and containing 13 GPIO pins, 10 PWM channels, I2C, SPI, ADC, UART, and 1-Wire.
LCD		A liquid crystal display is a flat panel display or other electronically modulated optical device that uses the light modulating properties of liquid crystals combined with polarizers. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in colour or monochrome (Liu & Abbatt, 2021). The LCD in this system displays messages to alert the user about the status of the system.
LED		A light emitting diode is a semiconductor diode which emits light when a voltage is applied to it. The LEDs in this design are responsible for representing the status of the system. The green LED lights up when the system is turned on, while the red one only lights up when the system detects either gas, smoke, or flames.
Buzzer		A buzzer or beeper is a mechanical, electrochemical, or piezoelectric audio signaling device. Types of buzzers and beepers include alarm devices, timers, train, and confirmation of user input such as a mouse click or a keystroke (Siregar & Qurniawati, 2022; Gustov & Levina, 2021). The buzzer comes as an extra component for sending alarm signals to people within hearing distance.
Sprinkler		A fire sprinkler system is a straightforward yet essential active part of the fire protection system in a residential or commercial building. The system, which is installed inside walls or ceilings, consists of sprinkler heads, a water source, and a pipe system for water distribution. The sprinkler automatically releases water when a fire is detected; smoke does not cause it to do so. A fire detection and suppression system both detects and suppresses the fire. Sprinkler systems have

		been in use since Hiram Stevens Maxim invented them in the late 19th century. They are currently widely utilized, with more than 40 million sprinkler heads installed annually. In most systems, water is kept under pressure in a system of pipes that runs throughout a structure.
Solenoid Valve Controller		The definition of a solenoid valve is an electro-mechanical valve that is commonly used to control the flow of liquid or gas. In most flow control applications, it is necessary to start or stop the flow in the circuit to control the fluids in the system. An electronically operated solenoid valve is usually used for this purpose. By being solenoid actuated, solenoid valves can be positioned in remote locations and may be conveniently controlled by simple electrical switches. Solenoid valves are the most frequently used control elements in fluidics. They are commonly used to shut off, release, dose, distribute or mix fluids. For that reason, they are found in many application areas. Solenoids generally offer fast and safe switching, long service life, high reliability, low control power and compact design.

3.5. System Mobile Software Application

The gas detection system can be remotely observed at any time and from any location by a user via the mobile application. The requirements for the mobile software application were influenced by the project's objectives. Through the smartphone application, a connection between the hardware system and the user is made possible. This section covers the functional and non-functional requirements for the mobile software application. It also provides a use case and activity diagrams, as well as a few application views. Some of the development tools used are discussed as well.

3.5.1. Software System Functional Requirements

The functional requirement of the mobile software application provides a thorough explanation of what it should be able to achieve. The user needs and other requirements that the user may not directly interact with are presented in this section. The functional specifications for the mobile software application are listed.

- It should provide a login functionality to the user which authenticates the user when they allow the application to access email.

- It should display a dashboard to a successfully logged in user.
- The dashboard shows the gas concentration and a progress circle updated in real-time indicating gas percentages in the atmosphere.
- It should have buttons for directly controlling the hardware components.
- It should display previous events on a history page.
- It should provide a logout functionality to allow users to logout of the application

3.5.2. System Software Non-Functional Requirements

The features of the mobile software application are not specifically related to the non-functional requirements. Nevertheless, they are important because they highlight how simple it is for users to interact with the software. The non-functional requirements for the mobile software application are:

- Performance: This is a measure of how quickly the mobile application reacts to user input. The mobile application must be able to display measured data from the gas sensor in real-time with the least amount of lag time possible.
- Security: As a measure to enforce security, only users who are logged in will be able to access the software application.
- Ease of use: The user-friendly interface of the mobile software application makes using and navigating intuitive. It will be used to closely monitor readings from the gas sensor.

3.6. System Use Cases

The system use cases are illustrated in the form of diagrams in Fig.5. The use case diagram of the system provides a visual representation of the relationship that exists between actors - internal or external entities that interact with the system - and the system. The two actors in the system are the server, which provides real-time updates of measurements taken from the sensors in the gas detector.

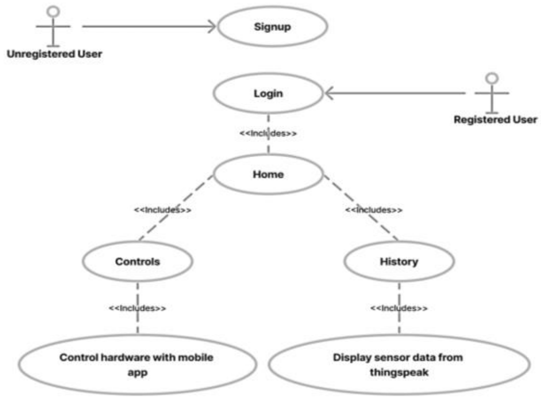


Fig. 5. System use case diagram

3.7. System Software Activity Diagram

The system software activity diagram is as depicted in Fig. 6. The activity diagram shows the possible activities of the mobile software application. When a registered user successfully logins in, the user is redirected to the home screen. If the user is not registered, they are redirected to the signup screen which allows a new user to get registered. From the home screen, a user can navigate either to the controls page or to the history page, and likewise from any of the other two pages. They can logout of the application at any time of convenience from any of the three screens. For an unsuccessful login, the user stays on the login screen so that they can try to login again.

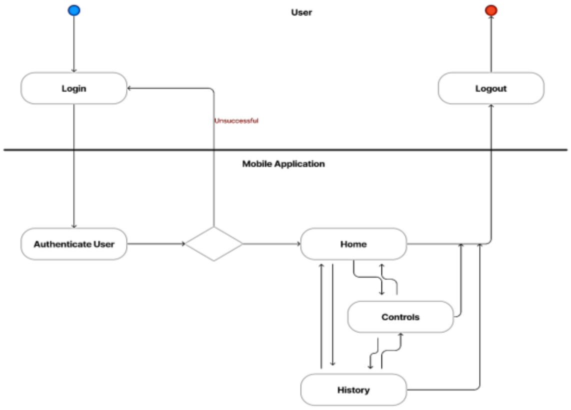
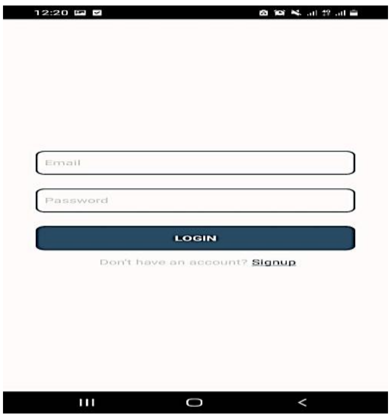


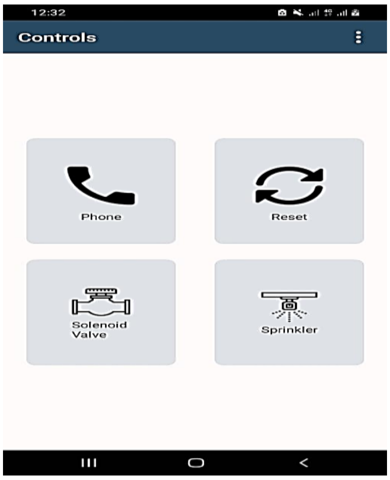
Fig. 6. System Software Activity Diagram

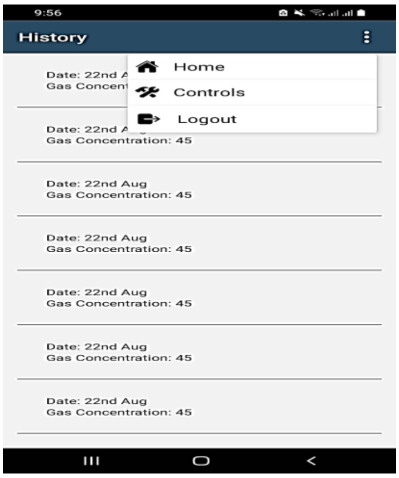
4. RESULTS AND DISCUSSION

Various tests were run to see if all functionalities were working as expected. Table 2 contains screen shoots, functionalities, and test results.

Table 2. System Software test and results

Task	Screen	Results
Signup		Unregistered users trying to login to the mobile application get redirected to the signup page. There, they are required to create an account using an email and a password. This allows them to access the functionality of the mobile application without obstruction. From here, they are redirected to the home page.
Login		On the login page, the mobile application verifies if a user has been registered, the user is verified; if found, the user is directed to the home screen. Verification is done with credentials used for registration on the signup page which include an email and a password. If an unregistered user tries to log in, they are redirected to the signup page where they can register with their preferred credentials.

Home		This screen is accessible only to authenticated users. The home page presents the user with the information they need about gas concentrations detected in the atmosphere, and if it is safe to be in that place. It represents gas concentrations visually using a progress circle and percentages.
Controls		The controls page consists of four buttons - phone, reset, solenoid valve and sprinkler. The phone button opens the user's phone application on their mobile device with an emergency number already dialled in so that they can quickly place a call for help. The reset button is engaged when a user wants to reset the hardware system. The solenoid valve button sends a command to have the solenoid valve connected to the gas cylinder triggered so that it shuts off gas supply. The sprinkler button is used to manually activate the sprinkler connected to the hardware system in case it fails to start automatically.

<table>
<tr><td>History</td><td>
</td><td>The history page displays data about previous states of the system, relating them to specific dates. This is important for referencing, as it is crucial for a user to closely monitor changes in the system.</td></tr>
<tr><td>Navigation</td><td>
</td><td>The three dots at the upper right corner of the mobile application are responsible for navigation. Engaging that button on a page shows a drop-down menu with buttons that lead to the two other screens. There is a logout button as well, which allows a user to end their session in the mobile application.</td></tr>
</table>

Repeated testing was done to expose situations that obstructed proper functioning of the system. During testing, it was ensured that test vectors were kept within perceivable range so that the sensors could detect them to give desired results. The gas detector, which includes both gas and fire sensors, was successful in logging data from those sensors to thingspeak.com to generate a visualization of past activities. Table 3 contains a summary of various test vectors used during testing and how the system responded to them. In case the gas sensor detects gas in the atmosphere, the system must light a red LED, sound the buzzer, display a message on an LCD and send a notification to the user's mobile device. The same reaction was expected of the system when fire was detected, as well as when both gas and fire were detected. Using the table, a success rate of 91.67% was obtained, since the system failed during trial 8. The success rate was determined using equation (1).

$$\textit{Success rate} = (\textit{Success}/\textit{Number of trials}) \times 100\% \quad (1)$$

Figs. 7 and 8 show the visualization of gas sensor and fire sensor data recorded over time on thingspeak.com.

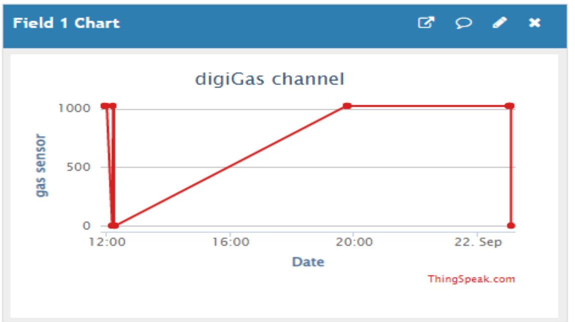


Fig. 7. System Gas Sensor per time

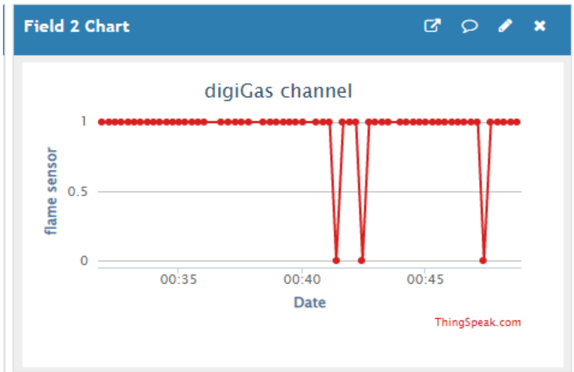


Fig. 8. System Fire Sensor per time

Table 3. System Response to Test Vectors

	Test Vector		System Response				
Test No.	Gas	Flame	LED	Buzzer	LCD	Notification	Remark
1	Yes	Yes	On	On	Message Printed	Sent	Success
2	Yes	No	On	On	Message Printed	Sent	Success
3	No	Yes	On	On	Message Printed	Sent	Success
4	No	No	Off	Off	Message Not Printed	Not sent	Success
5	Yes	Yes	On	On	Message Printed	Sent	Success
6	Yes	No	On	On	Message Printed	Sent	Success
7	No	Yes	On	On	Message Printed	Sent	Success
8	No	No	On	On	Message Printed	Sent	Fail
9	Yes	Yes	On	On	Message Printed	Sent	Success
10	Yes	No	On	On	Message Printed	Sent	Success
11	No	Yes	On	On	Message Printed	Sent	Success
12	No	No	Off	Off	Message Not Printed	Not Sent	Success

5. CONCLUSION

In this project, a gas detector system that operates collaboratively with a mobile application was designed to achieve domestic fire control. The design process of the cost-effective smart gas leakage detector system was illustrated, and after testing and evaluation, functionality was ascertained. Following findings made, it can be presumed that the number of residential fires may be significantly reduced because of the application of this method. It is recommendable for users to undertake the following for the system to be more efficient: An emergency ventilation control system should be employed, and an electrical power supply control system should be used. Instructing and training users on the dangers of using LPG and get users acquainted with fire safety measures to be taken whenever necessary.

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