LPG Gas Leakage and Fire Alerting System using Anomaly Detection (Z-Score Analysis)

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Abstract: Home fires have been taking place frequently and the threat to human lives and properties is growing in recent years. Liquid petroleum gas (LPG) is highly inflammable and can burn even at some distance from the source of leakage. Most fire accidents are caused because of a poor-quality rubber tube or the regulator is not turned off when not in use. If the gas leakage can't be detected fast and no action is taken, may lead to explosion and cause severe damages to life and environment. Hence a gas leakage detector and a fire cautioning device is required in every kitchen. Fire detectors as we know play an imperative part in businesses, shopping centers, parking zones, etc. They offer assistance in identifying fire or smoke at an early stage and can offer assistance in saving lives. In this project, we're proposing a gas leakage and fire alert system through IoT using anomaly detection. The anomaly detection algorithm used in this project is Z-score analysis. This project includes several essential features like temperature detection and smoke rise in the given location. We may also identify the LPG gas leakage with both data in conjunction. We receive the warning by notification and telegram message if such a circumstance arises utilizing a Z-score analysis. The anomaly can be detected by evaluating the Z-score. The anomaly here means that the variable value (temperature or gas) goes beyond a defined range of values. The range of values computed are called thresholds or bounds (upper and lower bound). We only notice the warning of a fire with the upper bound. The message contains information on the occurrence of fire, smoke or gas leakage. We become acquainted with notification and telegram message. We also receive a web app link to regulate the buzzer to warn people.

KEYWORDS: Internet of Things (IoT), Anomaly Detection, Z-score Analysis

DOI of the Article: https://doi.org/10.46501/IJMTST0706057

Available online at: http://www.ijmtst.com/vol7issue06.html

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To Cite this Article: K. V.UshaRamani; ImrozeJahan and Mr. P. Anvesh. LPG Gas Leakage and Fire Alerting System using Anomaly Detection (Z-Score Analysis). *International Journal for Modern Trends in Science and Technology* 2021, *7*, 0706211, pp. 344-350. https://doi.org/10.46501/IJMTST0706057

Article Info. Received: 19 May 2021; Accepted: 18 June 2021; Published: 24 June 2021

INTRODUCTION

Gas leakage can be very deadly leading to both human loss and materialistic loss. It's physical properties like toxicity, flammability increases the risk of explosion, firing and even suffocation or poisoning. The number of incidents due to the explosion of gas cylinders has been increasing in the recent years. The Bhopal gas tragedy is one such tragic incident that is still impacting the lives of survivors and the surroundings. The LPG or propane is a flammable mixture of hydrocarbon gases and has some desirable qualities like high calorific value, less smoke and soot, impacting the environment in the most meagre ways possible hence making it a right fuel for applications like automobiles and transportation, industries, hostels and homes.

In homes, LPG and natural gas are mainly used as fuel for cooking purposes. Both of these fuels produce clean energy but when handled poorly can lead to problems like leakages and explosions. These gases are heavier than air and cannot disperse easily and leads to suffocation when inhaled. The reason for the explosion includes lack of maintenance of the gas cylinders, old valves, worn out cylinders and poor handling and lack of awareness. To avoid this problem, a system for detecting that LPG leakage needs to be developed. This can be done by employing various sensors and respective actuators for dealing with the aftermath.

Today, the security and safety of the people in the house using LPG are important. Therefore, the goal is to develop a system that can detect gas, smoke, and flame from the LPG cylinder and can notify the owner via text messages. The system can display also the detected value of sensors and can alarm the owner using a buzzer. This project is being executed using advanced technologies like the Internet of Things and Anomaly Detection algorithms.

Structure of paper

The paper is organized as follows: In Section 1, the introduction of the paper is provided along with thestructure, related work and objective of the project. In Section 2 is methodology where we discuss about anomaly detection. In Section 3 we have the complete information about software and hardware tools utilized in this project. Section 4 shares information about implementation of the said prototype. Section 5 showsthe prototype of the design proposedalong with the desired outputs that we've drawn from it. Section 6 tells us about the future scope and Section 7 concludes the paper with acknowledgement and references.

Related Work

This platform has conducted several research initiatives. Initially, only the on-site alarm proposed the gas leakage detection system. The evolution of the LPG and fire warning system is detailed in the following documents. In 2019 Nasir and their teammates did a project for gas leakage and temperature monitoring system [1]. This project offers a method for developing a device for detecting and controlling gas leaks and for monitoring temperature in sensitive locations. The system detects LPG leaking with a gas sensor from MQ6 and then measures temperature with a temperature sensor. The Gas sensor recognises gas leakage when the output of the sensor is LOW, the system opens the escape windows, and then uses a GSM module to notify you to the gas leakage. when the GSM module reaches a specific level. Also, when the ambient temperature reaches certain level, the LED is switched on and the buzzer alert is generated.

In 2019 S. Jamadagni and team published a paper on a system that detects gas leakage and fire and then alerts the owner of the place through text message [2]. The project covers the evolution of Internet of Things design in the industrial monitoring system. The sensor utilised for the design is MQ-2, which detects gas leaks and fire sensors in any atmosphere as a compact and simple fire safety device. In gas sensor system, Raspberry pi plays a vital function such that all the components are interfaced to it. The watcher therefore noticed the changes from all around the planet. A gas detection system requires a constant monitoring of the environment. The system sends SMS to the user when the gases and smoke are detected then the user takes action accordingly.

In 2017 E. JebamalarLeavline and the team designed a portable LPG gas leakage detection as well as alerting system [3]. The system is run by the battery and is mobile. It also works with aerated power supply. For the latter instance, a bridge rectifier with a condenser filter was employed. A IC7805 regulator with a +5V controlled power supply supports a rectifier. The MQ-6 gas sensor is used for the detection of LPG. The gas sensor output is sent to LM358, where the threshold value for gas density is compared and extended using pre-determined potentiometers. The operational amplifier output fires the driver circuit for the LED and Buzzer when the voltage detected is higher than the predefined threshold value. The LED glows as a consequence and the buzzer is triggered.

Objectives

This project aims to tocreate LPG leakage and fire alerting system using Bolt Wi-Fi Module replacing the conventional GSM system,providing IoT capabilities to the project. To useAnomaly detection algorithm to detect any situation that is out of the pre-defined conditions.To use Bolt Cloud and third-party applications to alert the user through a message and to give an interactive platform to the user for controlling the buzzer at times of alert.

METHODOLOGY

Anomaly Detection

Anomaly Detection is the challenge of discovery in relation to anomalies within the data that do not match up to expected behaviour is one of discovering patterns. These patterns of non-consistency are commonly characterized in different applications as anomalies, bogus outskirts, disagreement with observations, exceptions, aberrations, surprises, particularities, or contaminants. Anomalies and outliers are the two most often used words in connection with anomaly detection.

Detection of abnormalities is widely used in a range of administrations and implementations, counting from bank card fraud, warranty bonds, cybersecurity intrusion detection, security-critical defect detection, and enemy military surveillance.

Data may contain abnormalities for a number of causes including malevolent behaviour, such as credit card fraud, cyber-intrusion, terrorist action, or a system disruption, but all the explanations share a similar feature that the analyst is interested in. An important element of anomaly identification is the "interest" or actual life significance of abnormalities.

Z-Score Analysis

Data objects that vary considerably from most data items are anomalies. The aim of detecting abnormalities is to discover such abnormalities, which have vital applications in broad fields, e.g., for detecting cyber security assaults, detecting fraudulent financial transactions, and detecting health problems. Z-score is a simplest computational algorithm that has capability of swiftly partitioning the data for additional scrutinization to determine whether they are apprehensive or not.

Z-scores (Z value) is the measure of standard deviations from the average of a score or a value (x). Z-score gauges data dispersion, in other terms. Theoretically, the value of Z-score (x) represents how much standard deviation is below or above the average population (μ). If the Z value is positive, the value or score (x) is greater than the mean. Also, if Z is a negative number, it implies that value (x) is lower than the mean.

Anomaly denotes a variable value (temperature of the environment and the gas concentration of the environment) that exceeds a specific range of values in this project. The value range is known as limits (upper bound and lower bound). These limits are determined with the values of the input, frame size and multiplication factor.

For the Z-score analysis, the frame size is the minimum input value and the multiplication factor defines the proximity of the limits to the input value curve. Basically, this functions to identify any rapid changes in sensor data when the temperature changes quickly or if this anomaly is observed in the gas quantity and the alert message is sent accordingly via telegram bot and a notification to the user's mobile through the integromat scenario.

The Mean formula:

$$Mn = \frac{\sum_{i=1}^{r} Vi}{r}$$

Fig. 1. The mean formula

The Z-score formula:

$$Zn = C * \sqrt{\frac{\sum_{i=1}^{r} (Vi - Mn)^2}{r}}$$

Fig. 2. The z-score formula

The bounds formulae:

$$Tn = Vi \pm Zn$$

Fig. 3. The bounds formulae

In the above equations, the variables mentioned are as follows.

Vi = Input

r = Frame size

C = Multiplication factor

Mn = Mean calculated

Zn = Z-score calculated

Tn = Bounds

SOFTWARE AND HARDWARE REQUIREMENTS

Software

This project requires specific platforms to handle the sensors through their respective libraries, to connect the system to an internet memory storage, an interface to club all the platforms together and an interactive development environment (IDE) to deploy the code. There are many such platforms available to perform all the tasks. We have chosen the following platforms as per our convenience.

[1] Arduino IDE
[2] Bolt IoT Cloud
[3] Integromat
[4] Python IDE

Integromat is a tool for manual process automation without coding. It helps its clients to link apps and services together to interface them as a single platform. The Arduino IDE is an open-source programme used primarily for creating and compiling code for the Arduino Module It is easily available for operating systems such as MAC, Windows, and Linux and operates on the Java Platform, which has built-in functions and commands for debugging, editing, and compiling code in the environment. The Bolt Cloud is a key component in delivering IoT capabilities to the Bolt device. All Bolt devices automatically connect to the Bolt Cloud.

Hardware

The main motive of the project is to detect the gas and temperature parameters of the surroundings and to alert the premises in case of abnormality. In order to make that happen the following hardware components are employed.

[1] Arduino UNO
[2] Bolt Wi-Fi Module (ESP8266)
[3] LM35 Temperature sensor
[4] MQ6 Gas sensor
[5] Buzzer

Arduino is a free and open-source electronics platform with simple hardware and software. Arduino Uno is a microcontroller board based on ATmega328. ESP8266 is a low-cost, user-friendly gadget for providing internet access to the projects. Because the module can function as both an access point (which can establish a hotspot) and a station (which can connect to Wi-Fi), it can simply retrieve data and post it to the internet, making the Internet of Things as simple as feasible. It can also retrieve data from the internet using APIs, giving the project to access any information accessible on the internet.The MQ-6 gas sensor is used for the detection of LPG. LM35 is the temperature sensor.

WORKING

The gas sensor MQ6 and the temperature sensor LM35, always keep sensing the surroundings when the power is supplied to them. As they are connected to Arduino analog pins A0 and A1 they keep sending sensed values to Arduino. The Arduino serial transmitter, receiver pins are connected to bolt Wi-Fi module and the analogvalues at A0 and A1 are transmitted to the bolt cloud.

To use the bolt Wi-Fi module, first establish a bolt cloud account and then build a new product using the physical device's API key and device ID. Because the buzzer is attached to the bolt module in this project, the trigger has to be provided by the bolt module. To activate or disable the buzzer, an API is utilised. As a result of the user's actions, a web application with a user interactive platform is developed, with two buttons ON and OFF that are coupled with the bolt API of buzzer activation / deactivation. The buzzer is linked to the bolt module's pin 0 (power).

These URL are linked into buttons ON & OFF of a web application created. We used a web application prototype building app to create a simple web app with comfortable user interface. In this project whenever there is an abnormality, the system should send a message as well as an android notification to the user. The integration platform we used is Integromat. A scenario is created in Integromat, which takes an input from the program main.py. A webhook is assigned at the beginning of the route which takes the input directly from the program as the webhook URL is given inside the main program. We can identify three abnormalities using this project they are as follows.

- **Fire Alert:** Whenever the temperature is greater than 40°C, it is considered as a fire and the alert is created.
- **Gas Leakage Alert:** If the temperature is less than 40°C, but the gas ppm value is greater than 350, this is recognized as gas leakage and the alert is created.
- **Smoke Alert:** If the temperature is less than 40°C, gas value in ppm is less than 350 but greater than 220, it is considered as some smoke is present in the air and a smoke call warning is sent.

So, to route the messages according to the abnormality, instead of mentioning all that in a code, we attached a router to the webhook, which is then connected to message and notification sending applications. This router output routes are designed with filters which determine which route is the suitable route for the incoming alert.

Android is attached to all of the router outputs, which will send the notification to the user mobile phone. For sending messages to the user, Telegram bot is linked to the androids, in which is created using bot father to send the messages.

RESULTS & OUTPUTS

The prototype of the proposed system is as follows.

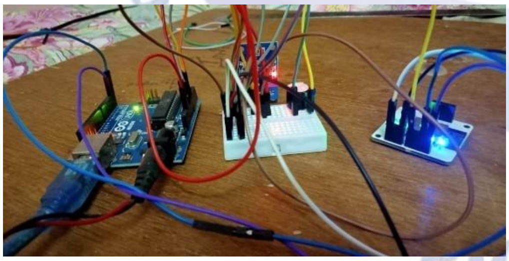


Fig. 4. Hardware connections

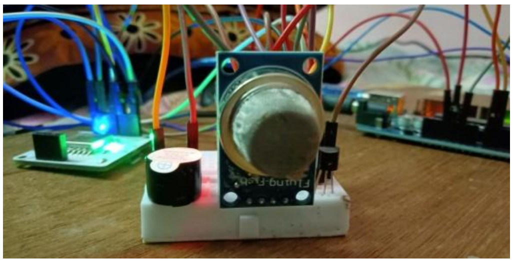


Fig. 5. Sensors and buzzer

The Integromat scenario is as follows.

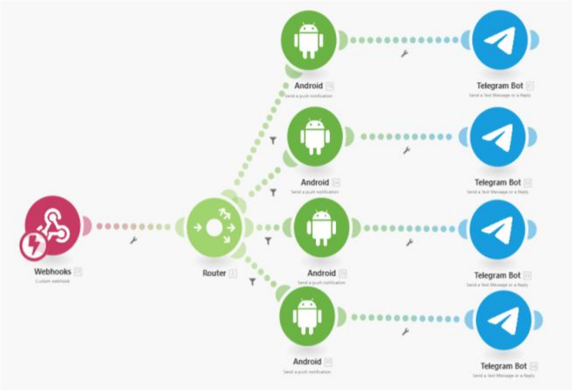
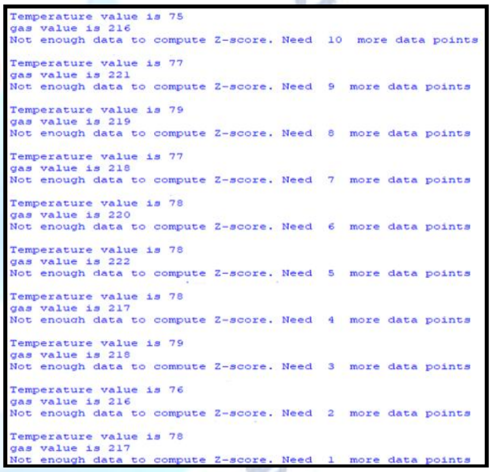


Fig. 6. Integromat Scenario

For identifying any abnormality in the given situation, the system needs to read enough values of the sensors to compute the z-score which can be set using r (frame size). For this, frame size is set to 10 i.e., it reads ten set of sensor values (each sensor) before proceeding with computation of z-score and checking for abnormalities.



```
Temperature value is 75
gas value is 216
Not enough data to compute Z-score. Need 10 more data points

Temperature value is 77
gas value is 221
Not enough data to compute Z-score. Need 9 more data points

Temperature value is 79
gas value is 219
Not enough data to compute Z-score. Need 8 more data points

Temperature value is 77
gas value is 218
Not enough data to compute Z-score. Need 7 more data points

Temperature value is 78
gas value is 220
Not enough data to compute Z-score. Need 6 more data points

Temperature value is 78
gas value is 222
Not enough data to compute Z-score. Need 5 more data points

Temperature value is 78
gas value is 217
Not enough data to compute Z-score. Need 4 more data points

Temperature value is 79
gas value is 218
Not enough data to compute Z-score. Need 3 more data points

Temperature value is 76
gas value is 216
Not enough data to compute Z-score. Need 2 more data points

Temperature value is 78
gas value is 217
Not enough data to compute Z-score. Need 1 more data points
```

Fig. 7. reading values for z-score

After getting enough data points, z-score is calculated. Then it keeps comparing the sum of sensor values of temperature and gas at that instant with the calculated upper bound value until there is an abnormality. If there is any kind of abnormality and the sum value exceeds bound value, the alert is sent to integromat.

When alert is received at the webhook, it cannot determine what alert it is. So, the information is passed on to the router which compares with each filter at each route and sends out to the suitable route.

The route filters designed are as follows:

- Temperature > 40°C– Fire Alert

- Temperature < 40⁰C, Gas > 350 – Gas Leakage
- Temperature < 40⁰C, 220 < Gas < 350 – Smoke Warning
- None of the above – Anonymous

Each route consists of android and telegram bot linked together to alert the users with respective notifications. Let's look at the output for gas leakage alert.

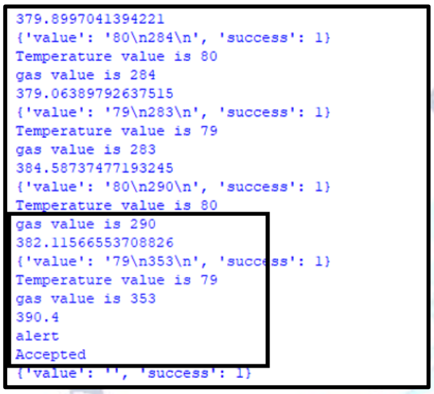


Fig. 8. output at python

The alert is sent to Integromat scenario to compare the sensor values and determine which type of alert it is.

Fig. 9. Gas leakage alert is detected

Telegram message and notification are sent to the user's mobile.

Fig. 10. Notification received

Fig. 11. Telegram message received

Along with the message a link is sent to the user providing access to a web app which in turn helps in triggering the buzzer to alert the premises.

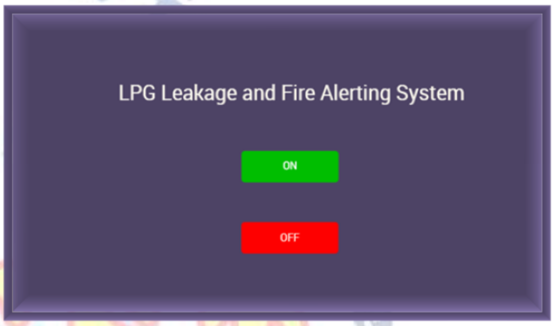


Fig. 12. Web app to control buzzer

We've linked bolt control APIs of pin 0 that is connected to the buzzer to the ON and OFF of the web app and we can operate the buttons on the interface provided accordingly.

Similarly, the same process is done by the system in case of both the fire alert and the smoke alert.

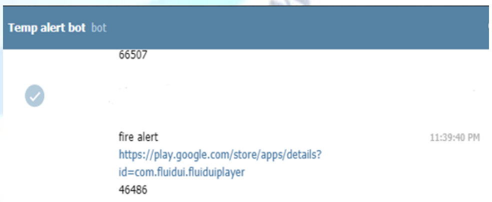


Fig. 13. Fire Alert message at telegram

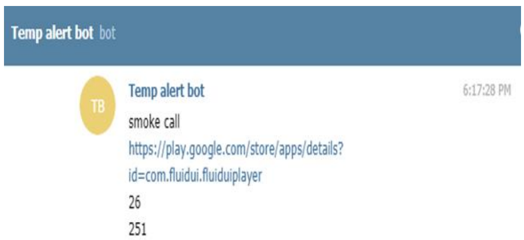


Fig. 14. Smoke alert message at telegram

FUTURE SCOPE

This project can be further improved by using machine learning algorithms to train a model for anomaly detection which helps to automate the process and also provide more accurate readings. The output operations of the system are currently limited to alerting through the buzzer and can be enhanced by can adding additional modules like a fanning system or a LED display. Systems like these needs to be developed and employed at a large scale to avoid the major disasters occurring due to small negligence.

CONCLUSION

LPG is being used more and more day by day. The safety of LPG users is an important consideration. Due to the cylindrical blast several individuals were burned alive. Most of them are dead. There is hence a public demand for the security system. The major purpose of this article is to create a system which can provide people with security at minimal cost. As the result, an LPG and fire alerting system has been designed and implemented. This system was devised to provide the required alerts and notifications under three conditions namely a fire alert for excessive temperature, LPG leakage alert and smoke alert when a particular range of gas values are crossed. The gas sensor MQ6 and temperature sensor LM35 were used to collect the data and further processing of the data was done through the Arduino. The Bolt Wi-Fi module provided the Internet of Things capabilities to the system by giving access to the data through the internet and the Bolt cloud.

A no code-based platform named Integromat was used to filter out the response from the system and categorize them to proceed with the telegram notifications. The use of the Integromat makes clubbing of the different platforms and androids much simplified, easier and also cost effective. The system outputs to a buzzer which can be controlled by the user through awebsite created for handling the on and off operation of the buzzer. All the scenarios have been tested and their respective outputs and results have been documented. The damage due to breaking out of fire or LPG leakage can be reduced to none when detected at the earliest stage. Hence, LPG leakage and fire alerting system should be made a basic necessity of every household.

ACKNOWLEDGMENT

Firstly, we are grateful to Sreenidhi Institute of Science and Technology for giving us the opportunity to work on this project. We are fortunate to have worked under the supervision of our guide Mr. P. Anvesh. His guidance and suggestions helped us a lot in this work. We are also thankful to Dr. Syed Jahangir Badashah for being the In Charge and Coordinator for this project and its reviews. We are also thankful to the HOD of Electronics and Communication Engineering [ECE], Dr. S. P. V. Subba Rao for giving permission and access to all the resources whatever needed in building this project.

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