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Improved the accuracy of IOT based LPG leakage detection system with early fire prediction and smart alert

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Abstract:
Safety is of utmost importance in the realm of smart cities, smart homes, and industries. Among the various safety measures implemented in a smart city, the detection of gas leakage and the prevention of mass fires are crucial for safeguarding lives and valuable assets. This research paper introduces a novel system that not only detects gas leakage but also provides early predictions of fire outbreaks. Unlike the conventional gas leakage detectors available in the market, which only alert when the gas concentration reaches a high level, our system utilizes fuzzy logic, environmental temperature, and humidity to accurately detect gas concentration levels and predict early fire symptoms. By employing the Internet of Things (IoT) approach, this system promptly sends notifications and sensor readings to the relevant individuals, enabling them to take immediate action and prevent extensive damage.

Keywords: Classification model, Data Mining, Feature selection algorithms, Fuzzy logic and Internal and External factors

1. Introduction

The Internet of Things (IoT) makes our life easy by automating most of the tasks that are related to our everyday life. Safety is the most important thing for Industries, smart cities or vehicles. By automating the task, IoT also extends and enhances our existing safety standard. Currently, extensively gas cylinders are being used in homes, industries, and vehicles. Due to the weakness of our safety system, often we see people dying in the gas cylinder blast. In Bangladesh (a developing country), besides the huge use of industry, more than 44% of the stove use LPG gas. In 2017-2018, the number of gas bottles that were destroyed as a result of gas leakage.

Sometimes it can create a mishap and horrible situation. The increase of the concentration level of certain gasses can prove to be extremely dangerous. After exceeding the concentration level of gasses, it might be lethal for public health. Our existing safe-ty standard is not enough to prevent this hazardous situation.

To take control of this situation, in this paper we presented a new system for detecting gas leakage and detection of early fire symptoms using the MQ-2 gas sensor module that is capable of detecting the LPG, H2, CH4, CO, Alcohol, and Propane [2]. In this system, we also used temperature and humidity sensors to measure the fire symptom [3] [4]. Our Gas leakage detector is capable of detecting the early fire symptom using comparison analysis on sensor readings and our predefined test data. For this analysis process, the fuzzy logic is used. Fuzzy logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1. It is employed to handle the concept of partial truth, where the truth value may range between completely true and completely false [5].

This system is not only capable of detecting the gas leakage but also it can alert about harmful gasses through the audible system and also send the notification to the concerned person through the email and SMS. Our gas leakage detector sends the sensors reading to the cloud for further analysis through the Wi-Fi module. For real-time monitoring, we used a mobile app which was directly connected to the cloud via API.

This system is smart enough to prevent a massive fire. When exceeding the concentration level of gasses and the system detects the fire symptom then the system automatically cuts-off the electricity line and notify the security in charge of preventing the massive fire.

2. Literature Review

Already there are many gas leakage detectors available in the market, but they all are traditional gas detectors that only can detect gas leakage depending on the gas sensor and alert the people through the audio-visual system, which sometimes creates a false alarm. Gas detectors could be characterized in many categories on the basis of what type of gas they can detect and how they can respond.

Here is the statistical data of Accidents Related to gas cylinder blast in Bangladesh (2015-2019) [1] shown in the figure 1. The data presented in Table 1 illustrates further details regarding fire incidents between 2021 and 2023, indicating a progressive decline in leaky gas incidents alongside a continuous increase in the total number of fire-related occurrences.

Table 1: Statistics of fire incidents from 2021 to 2023

Year	Total fire incident	Leaky gas	LPG cylinder & broiler explosion	Smoking fires	Short circuit	Death	Injured
2023	27624	770	125	4904	9813	102	281
2022	24102	795	94	3878	9275	58	377
2021	21601	789	105	3179	7955	219	570

N.B: Fire incidents from 1996 to 2023: - 5376 incidents in 1996: - 27624 incidents in 2023
Source: *Fire Service*

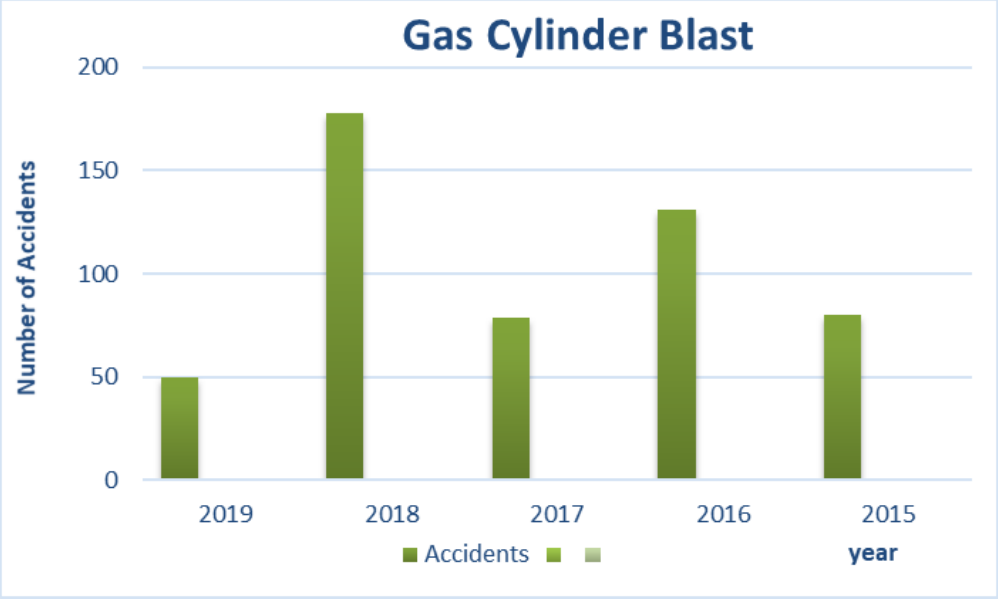

Figure 1: Statistics of Accidents Related to Gas Cylinder Blast in Bangladesh (2015-2019)

We have studied some gas detection devices which are available in the market and the description of those devices are given below:

- Handheld EGD01: This device Deliver high-sensitivity and adjustable wide variety gas detection availability. But the system has no IoT integration and smart notification system [12].

- EG-NGD050: This device can detect LPG and natural gasses. Also, this device can communicate with mobile devices. But the device has no multiple sensors [12].

- Amprobe GSD600: This is a portable gas detector for detecting gasses such as methane and butane. It has only an audible alert system [12].

All the above devices are traditional which has some limitations. However, our device will overcome these limitations and it will be more accurate and cost effective.

3. Methodology

In our proposed system we used a gas sensor with temperature and humidity sensor to precise the accurate result and we have used predefined test data to reduce the false alarm which proves the device is more reliable. Below the materials list that we have been used in our gas leakage detection system:

- Arduino mega (ATMEGA328): A microcontroller board that comes preprogrammed with a boot loader that allows uploading new code to it without the use of an external hardware programmer. The Arduino Uno can be programmed with the Arduino software IDE [6]. The gas sensor, temperature sensor and humidity sensor are connected to this board for processing the sensor readings according to the uploaded program. The GSM module and NodeMCU Wi-Fi module are also connected to this board for uploading and providing the information to the specified user through the internet and sending the SMS notification through the GSM bandwidth.
- Gas sensor: For detecting the gas leakage in our system we used MQ2 gas sensor of the MQ-X family which is capable of detecting the LPG (liquid petroleum gas), H2, CO (carbon monoxide), Methane, propane etc. this sensor can detect the concentration level of Combustible gasses.

- Temperature and Humidity sensor: It is important to reduce the false alarm, to measure the environment temperature and humidity, because fire not only depends on gas leakage, it is also very much related to temperature and humidity. To calculate the temperature and humidity we used a DHT11 sensor which is able to detect the temperature and humidity.

- GSM Module: The SIM900A delivers GSM/GPRS 900/1800 MHz performance for voice, SMS, data and fax in a small form factor and with low power consumption [7]. This GSM module in our system is being used for sending text messages to the regarding person or organization.

- Wi-Fi module: The Wi-Fi module allows the Arduino to connect with the internet. For this internet communication, we used NodeMCU V3 which is based on the Wi-Fi module esp8266. The NodeMCU is a standalone board with a processing unit and input output pin. In this system NodeMCU communicates via Tx, Rx pin [13].

3.1 Processing Steps

To execute this research, we have followed some scientific rules. The theory and data of this research is dependent on some test data that has been done by means of constitution. We have reached to the conclusion/result of our research by following the steps below:

- We have used the MQ-2 gas sensor to detect gas leakage, which can identify LPG, Methane, propane, butane accurately. The surface of the sensor which is called filtering mask is made of a net of steel, so that only gassy components can be detected and can increase precision and SnO2 sheet is used inside the sensor to identify a specific gas using voltage variation.

- As a temperature and humidity sensor, we have used DHT 11 sensor of DHT X series, which can pick out temperature and humidity correctly and give digital output [8].

- MQ-2 gas sensor compares every single value with the threshold voltage of the sensor to know if there is any gas leakage [9]. Threshold value is dependent on the sensor behavior and the structure of the gas. LPG, CO, Smoke concentration threshold is shown in the table below (table: 2,3,4):

Table 2: LPG Concentration Threshold Level

Level	LPG (ppm)
Low	0-1000
Medium	1001-5000
High	5000<
None	0<, <10

Table 3: CO Concentration Threshold Level

CO (ppm)	Level
<50	Low
51 - 100	Normal
100 - 200	Medium
200<	High

Table 4: Smoke Concentration Threshold Level

Smoke (ppm)	Level
<10	Normal
7500<	Fire
1000<	Smoked
4500<	Caution

The Average of LPG data from the above table, CO and Smoke is used as input of the microcontroller.

- Collecting the temperature and humidity data from the environment, it is categorized as shown in the table below (table: 5 and 6) and sent to the microcontroller along with the MQ-2 sensor data to compare with the test data.

Table 5: Level According to Temperature

Temp	Level
<15°C - 20°C	Low
21°C - 26°C	Normal
27°C - 34°C	Medium
34°C< °C	High

Table 6: Level According to Humidity

Humidity	Level
<30%	Superdry
31% - 40%	Dry
41% - 60%	Comfort
61% - 70%	Humid

70%< %	Sticky

- The data from the MQ-2 sensor and the DHT-11 sensor are sent to the microcontroller as an input. Then the microcontroller makes comparison analysis between the previously given test data that has been done in our lab and the input data from the sensors and gives a specific output. According to the table below (table: 7) we have collected our test data and a fuzzy rule-based method is used for the comparison analysis [9] [10] [11].

Table 7: Smoke Concentration Threshold Level

LPG (ppm)	SMOKE (ppm)	CO (ppm)	Temp. (°C)	Hum. (%)	OUTPUT	
					Fire Appearance	Gas Detected
10	5	5	32	65	Normal	Normal
115	10	10	32	65	Normal	Normal
1025	10	85	31	65	Normal	Medium
1760	640	60	32	60	Smoke	Medium
1152	7582	64	28	80	Fire	Medium
5100	970	110	29	62	Smoke	High
5100	4760	93	29	61	Caution	High
2163	3200	2	35	60	Caution	Medium

By strictly changing the value of LPG and the ratio of temperature, and humidity, we have recorded several test values to identify the fire appearance break point.

When the fire appears, more changes in the value of CO and smoke is noticed comparatively. Because the value of CO and smoke increase when it catches fire. The chances of fire proportionally change with the value of CO and smoke.

Figure 2: The Test Data Collect by Using Square Shape Glass Box and Sensors

- Using a fuzzy logic microcontroller makes comparison analysis between the input and the test data and gives output through mobile apps as alarm or SMS [8].

- To store the sensor readings, firebase has been chosen as a real time database. Firebase is a cloud based real time database which is directed by Google. Android apps show the real time data of the sensors from the firebase database to the user.

- The device uses Wi-Fi communication system to send data to the apps and cloud. But if any problem occurs with the Wi-Fi communication, then the device uses the GSM module, associated with it, to

send SMS to the user to notify the latter. In this case the device doesn't send data gradually, but sends only when a reversal situation occurs. So that the charges of sending SMS can be minimized.

- As a general defense mechanism, the device uses a relay to cut off the electric line and switch on the adjusted fan to reduce the chances of catching fire/explosion.

3.2 System Architecture

In this part we will discuss the system architecture of our system. Fig-2 shows the block diagram of our system. The device is contained with the temperature sensor, Humidity sensor and MQ-2 sensor to collect the related data. The microcontroller will communicate with the sensor, collect the sensor data and compare the collected data with the given range of the parameters. After comparing, the device will save the process results in a database for further research. It also communicates with Wi-Fi and GSM modules to send the sensor data to the cloud and to the user via the android app required for the device. In case of any change in the value of the parameters, the device will give an alert via SMS along with related information.

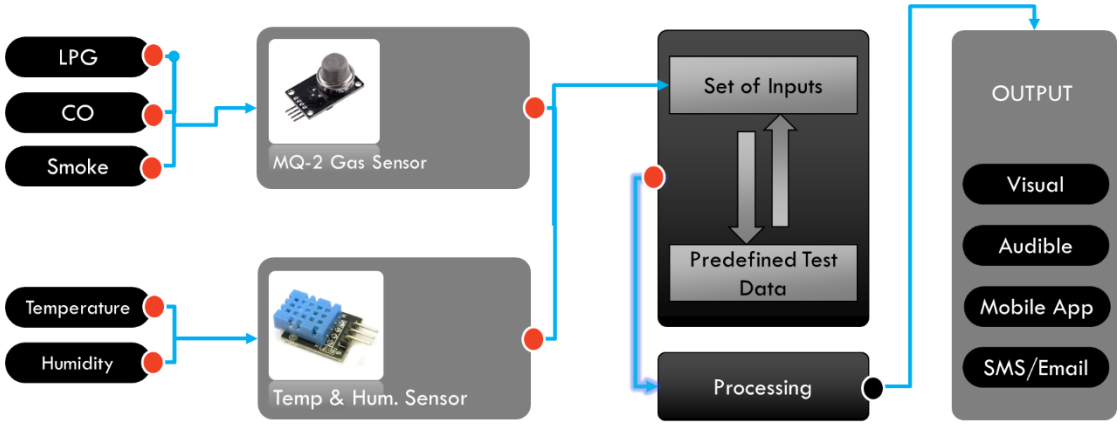

Figure 3: Block Diagram of System Architecture

3.3 Comparison and Improvement

We have compared our device experimentally with the devices that are available in the market nowadays and are being used and it has been noticed that our device is 20% more accurate than the available devices. Besides, our device is smarter and IoT enabled.

4. Results and Discussions

The result from this research is more accurate and better as expected than the available devices. We expect that the use of this device will reduce cylinder blasts and the damages occur due to gas cylinder blast and the use of sustainable technology will bring benefits.

5. Future Work

In future we will use artificial intelligence to make the device more self-contained. We will make the device an embedded system and make sure to install it easily.

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