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An Automated Smart Embedded System on Fire Detection and Prevention for Ensuring Safety

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***Abstract*— One of the biggest issues for architects, planners, and landowners is house combustion. Singular sensors have been used in the case of a fire for a long time, but they cannot quantify the volume of fire to warn emergency service units. To resolve this problem, this research aims to develop an intelligent smart fire warning system that detects fires utilizing connected sensors and alerts property owners, emergency services. The current model is divided into three modules: Smoke Detection Module (SDM), which is responsible for detecting smoke to prevent unwanted incidents; Notification Send Module (NSM), which is responsible for creating an alert service to alert the closest support center and user; and Emergency Alarm Module (EAM), which is responsible for handling the emergency alarm schedule when a fire arises. The results prove that the device worked well, and it should be remembered that our proposal can be integrated into any kind of setting, such as a house, workplace, ship, or industry.**

Keywords—Automation, IoT, Embedded system, Arduino, Fire, Smoke detection, Breadboard, GSM SIM800L, Buzzer, Transistor

I. INTRODUCTION

Fires have been a severe problem in recent years [1], and they must be dealt with quickly and efficiently to prevent the destruction of lives and property [2]. When the controlled temperature reaches 50o C, it is called a fire condition. Personnel arriving for assistance in fire hazards in sensitive areas such as clinics, classrooms, and banks takes about 15 minutes [3]. According to estimates, there are 475,500 construction fires in the United States per year, resulting in 2,950 civilian fatalities, 12,775 civilian casualties, and $7.9 billion in property loss [4]. According to the National Fire Protection Association (NFPA), two-thirds of all house fires in the United States arise in homes with no functioning smoke detectors, alarms that have been neglected, or alarms that have been lost [5]. Fire alarms with proactive warnings placed in the right places could save lives and mitigate property damages [6], [7]. There are several different styles of fire alarms, such as heat detectors and smoke detectors, and learning about them will help you determine which model is best for your home or shop. When the temperature exceeds a certain amount, for example, heat detectors are a popular choice [8]. As a result, it's more suited to applications where a quick answer isn't expected or in environments where smoke alarms can't be mounted, such as frozen fields. Since the temperature increases steadily, heat detectors have a lower false alarm rate but are also slower to react. Through these shortcomings, smoke detectors seem to outperform heat detectors [9]. Smoke detectors are more able to locate fires when they launch. Smoke is generated when an object's energy is depleted due to the depletion of Carbon Dioxide (CO2) from heat [10]. Ionization, photoelectric, and hybrid smoke detectors are the three varieties. Instruments and calculation books should be used to learn more about each of these groups. We will focus on a short overview of ionization in this research. In a nutshell, ionization is a toxic substance that absorbs radiation from a blast. It reaches the ionization chamber, an air-filled area between two electrodes that allows a slow, steady current to flow between them. This style is ideal for fires that spread quickly, such as those triggered by bombs or collisions [11].

J.Lui *et al.* [12] have produced a technique that can conduct an area-wide segmentation in which color pixels can be identified in the picture and the fire region. YCbCr color space model and region-growing technology compare all unallowed adjacent pixels to the area is the approach used. The RGB color model and the background subtraction technique were used to be proposed by Punam *et al.* [13]. This technique offers two main benefits: computer load and quick processing modes, but the quality of the fire detected is significantly affected. A method that utilizes HSV and YCbCr color model with criteria to separately distinguish brightness from the background and ambient light was described in Jareerat *et al.* [14]. Wenhao and Hong *et al.* [15] have meanwhile explored the iterative adaptive threshold methods of extraction of flaming items. Tian Qiu *et al.* [16] suggested an approach that worked on border detection to identify a fire for a similar reason. The region between the thermal chemistry and the non-thermal reactions has been placed in this method by the fire. The result of this experiment indicates that the fire edge may be clearly and uninterruptedly observed. In contrast to Petro *et al.* [17] provided an algorithm in real-time that focuses on the subtraction technique of the backdrop. An algorithm based on detection and tracking was utilized to minimize false fire alarms, often employed using conventional electrical methods. In recent years IoT [18-27], machine learning [28-31] and artificial intelligence [32-33] did an excellent job of solving such types of problems. Machine learning [34-37] can assist in demystifying the hidden patterns in IoT data by evaluating large quantities of data using powerful algorithms. Machine learning inference [38-41] may augment or replace human operations with automated systems utilizing statistically determined actions in key activities. On

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the other hand, Artificial Intelligence (AI) [42-45] has affected today's main sectors worldwide. Due to numerous data gathering, analysis, and treatment improvements, AI has been especially prevalent in recent years. Strong Internet of Things [46-48] (IoT) connections and high-speed processors are essential players in strengthening these advances.

The rest of the paper is in the same arrangement. The most rapid current developments in fire detection are discussed in this sector. Section II describes the analytical methodology for the construction of the whole system. Proposed System design and architecture have been discussed in Section III, and the result of the structure produced is examined in Section IV. Section V finishes with observation and deficiencies and plans for potential work.

II. Research Methodology

Develop a device to track or interpret the value (smoke) in a given environment's air and interpret the data for protection against unforeseen events. First, we must set up the embedded device on which the demonstration will be performed. Smoke SensorMQ2 continuously monitors the environment to sense large amounts of smoke; as smoke is combined with room air, the air becomes thicker. As a result, detecting smoke from the air for sensor formula is easy. Other gases may also be detected by this instrument (Like i-butane, nitrogen, gasoline, hydrogen, smoke). Through using a GSM SIM800L sensor, the system detects smoke and sends a warning message to the closest support center (such as a fire department) and an emergency phone number (a real person). We may programmatically insert any kind of help center number here.

In Fig. 1 we have shown the flowchart diagram of the proposed intelligent smart embedded system.

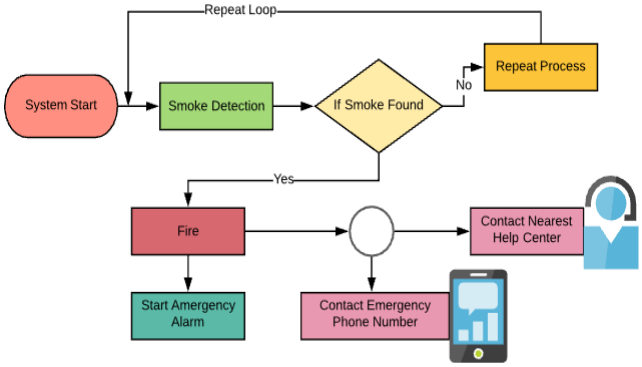


Fig. 1. Flowchart diagram of the proposed system.

III. System Design and Architecture

Our proposed system is composed of three (3) modules. Those are given below:

1. Smoke Detection Module (SDM).
2. Notification Send Module (NSM).
3. Emergency Alarm Module (EAM).

The overall circuit diagram of our proposed system as seen in Fig. 2, includes the Smoke Detection Module (SDM), Notification Send Module (NSM), and Emergency Alarm Module (EAM).

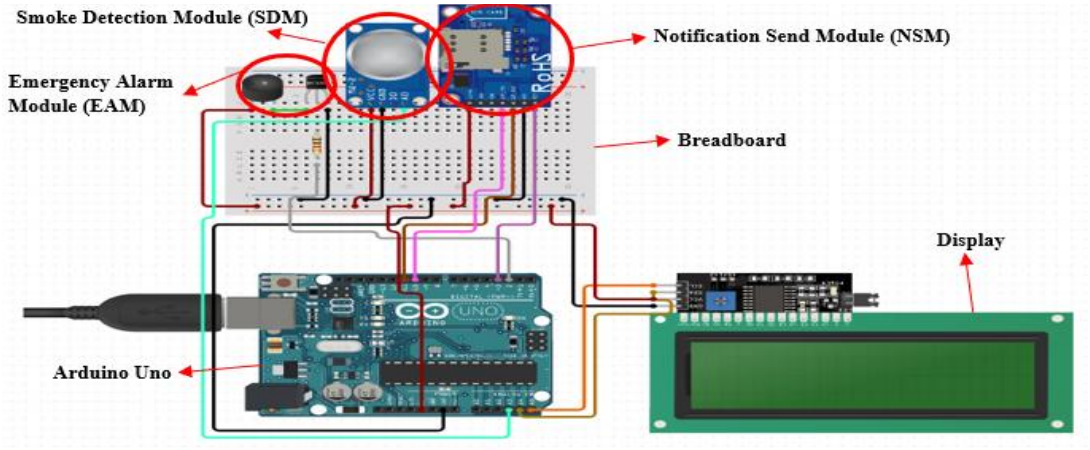


Fig. 2. Entire System Circuit Diagram.

In the Smoke Detection Module (SDM), the sensor detects a high volume of smoke from the environment. If the sensor detects a high rate of smoke in the atmosphere, the value is sent to Arduino. The suggested method then processes the data and sends a warning message to emergency contacts and the closest aid center. This module is done with a MQ2 smoke sensor. The MQ2 Smoke Sensor module may also be used to identify gas leakage. Gases such as LPG, i-butane, nitrogen, gasoline, hydrogen, smoke, among others, can be observed. Because of its fast reaction time. The MQ2 sensor will be connected to an Arduino Uno and a breadboard. MQ2 sensor, Breadboard, and Arduino Uno Pin MQ2 5V to Bus POS, MQ2 GND to Bus GND, and MQ2 AOUT to Arduino Uno A3 have been integrated.

The circuit diagram of the Smoke Detection Module (SDM) is shown in Fig. 3.

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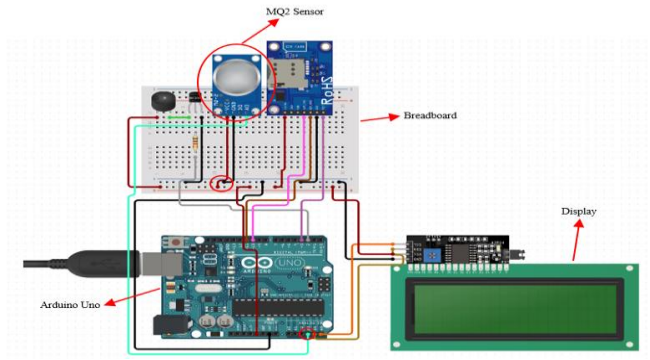


Fig. 3. Smoke Detection Module (SDM).

In our proposed framework [18], the Notification Send Module (NSM) is critical and decisive. Its role is to warn the closest support center and to deliver an alert note to an emergency contact (such as a homeowner). This module is built with a Quadband GPRS-GSM SIM800L. If high-rate smoke is detected, it sends a warning notice to the emergency contact and support center, along with an emergency message. With a quad-band antenna, the SIM800L is a lightweight quad-band GSM/GPRS device. A valid SIM card may be used to make phone calls, send text messages, and access the internet. The Quadband GPRS-GSM SIM800L can link directly to the Arduino Uno through the breadboard. SIM 800L Module, Arduino Uno 3, and breadboard SIM 800L 5V to Bus POS, SIM 800L TX to Arduino Uno 10, SIM 800L RX to Arduino Uno 11, SIM 800L GND to Bus GND, and SIM 800L RST to Arduino Uno 3.

Fig. 4 shows the circuit diagram for the Notification Send Module (NSM).

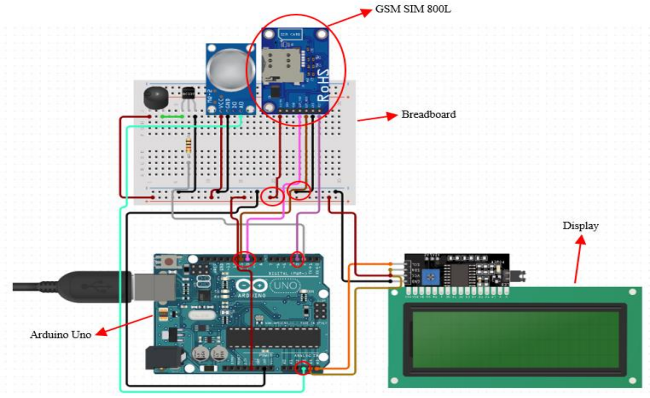


Fig. 4. Notification Send Module (NSM).

The Emergency Alarm Module (EAM) is in control of activating the alarm. As the smoke sensor senses smoke, the proposed integrated circuit would enable the alarm and switch on the red light to warn everyone. This module was created with Buzzer. This is a tiny buzzer that makes a very loud 2KHz beep signal. The buzzer will be connected to the breadboard, the NPN BC337 transistor, and the Arduino Uno. Buzzer, breadboard, transformer, and Arduino Uno pin Buzzer POS to Bus POS, Buzzer neg to TSBC337 C, TSBC337 E to Bus GND, and 1k ohm Resistor con 0 to Arduino Uno 2.

A circuit diagram depicting the usage of an Emergency Alarm Module (EAM) as shown in Fig. 5.

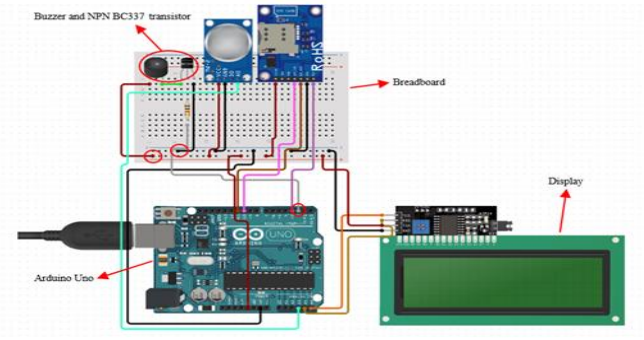


Fig. 5. Emergency Alarm Module (EAM).

IV. Implementation and Analysis

To build the proposed smart embedded fire safety system some hardware has been integrated. Arduino Uno R3, Breadboard, Smoke Gas Sensor - MQ-2, Quadband GPRS-GSM SIM800L, Buzzer, NPN BC337 Transistor, and LCD Display 20x4 12C are all necessary components.

All of these components have been combined in the design and development of the proposed embedded framework. The overall system diagram is seen in Fig. 6.

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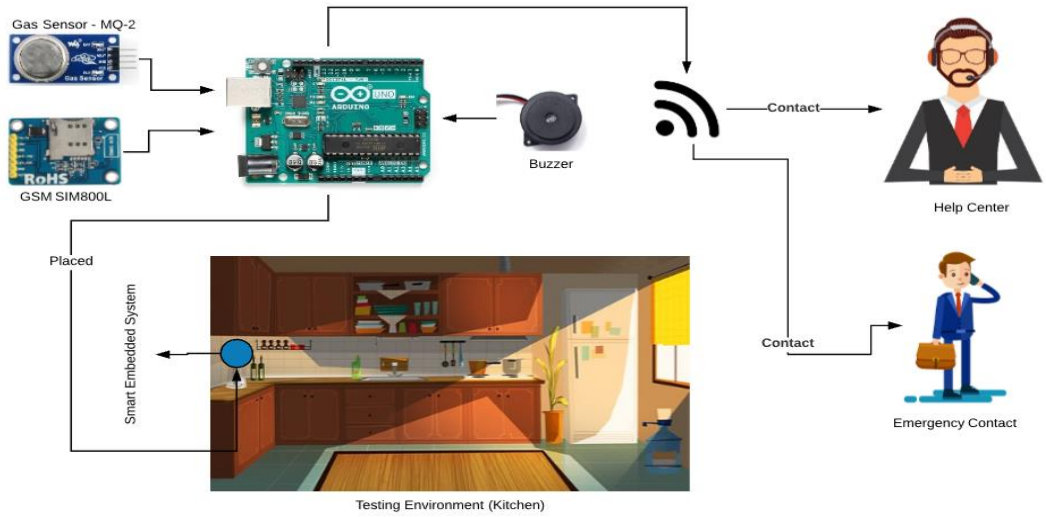


Fig. 6. The proposed intelligent smart embedded system diagram.

In general, 17 experiments are carried out to analyze the efficiency of the integrated smart embedded device. Our embedded device would be installed in a medium-sized kitchen design of around 110 square feet. The room was tightly sealed, and the temperature was 26 ° Celsius. To begin, we placed the device near a smoke-producing fire, around 1 m away from the flame. And we start counting down the device's response time. The device then took 0.312 seconds to identify the smoke, switch on the red led light with an emergency warning, and transmit warning messages to the designated phone numbers (See Fig. 8).

After that, in test step 2, we moved the device away from the flame to a distance of around 1.7 m, and it worked well. Similarly, we conducted 17 experiments in order to determine the device's maximum distance from the flames. We were concerned that the device might operate in every corner of the room. For the remaining 15 experiments, we gradually raise the gap between each stage; when the distance between each step increases, the system takes significantly longer to respond; we all know that when the fire burns anything, it takes at least a certain period of time for the smoke to be produced and blended with the environment. It takes time for the unit to penetrate the mixed smoke air as it is well removed from the flames. With a maximum distance of 9.5 meters, we had a maximum response time of 6.019 seconds. All of the experimental results (distance and response time) are collected by Arduino and integrated display.

In Table. I, we depicted the value that we have noted from the experiments.

TABLE I. PROPOSED SYSTEM PERFORMANCE MEASUREMENT

No. of Test	Distance from Flame (m)	Response Time in Seconds	Status
1	1	0.312	Pass
2	1.7	0.590	Pass
3	2.3	1.201	Pass
4	2.8	1.483	Pass
5	3.2	1.599	Pass
6	3.9	2.151	Pass
7	4.4	2.495	Pass
8	4.9	3.108	Pass
9	5.2	3.339	Pass
10	5.8	4.012	Pass
11	6.2	4.319	Pass
12	6.9	4.415	Pass
13	7.4	4.590	Pass
14	7.9	5.162	Pass
15	8.5	5.309	Pass
16	9.0	5.624	Pass
17	9.5	6.019	Pass

For a clearer interpretation of the output, we showed the Graphically representation of Table I data in Fig.7. We can see that the device's overall efficiency is really good, and the trend line shows that response time increases as the distance increases.

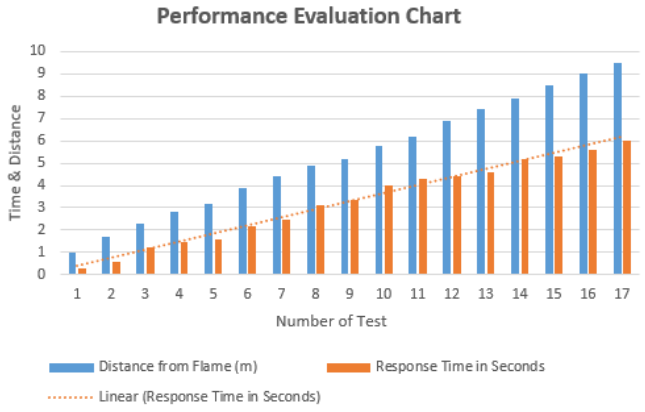


Fig. 7. Performance Evaluation Chart (Graphical representation of Table I data).

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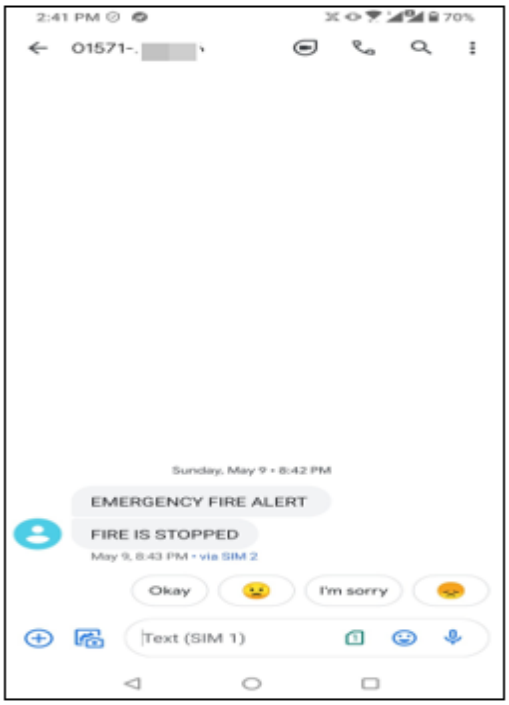


Fig. 8. Fire alert message by the proposed system.

The projected expense of the proposed system is shown in Table II. It depends on the industry, the region, and the demand. We tried to keep the cost as minimal as possible so that everyone would do it and be safe.

TABLE II. PROPOSED SYSTEM HARDWARE EXPENSE IN BD MARKET

Hardware Components	Price
Arduino UNO R3	450 tk
Breadboard	90 tk
Smoke Gas Sensor - MQ-2	120 tk
QuadBand GPRS-GSM SIM800L	900 tk
LCD Display 20x4 I2C	200 tk
Transistor - NPN BC337	20 tk
1K Ohm Resistor	5 tk
Wires	40 tk
Total	1825 tk

V. CONCLUSION

The model correctly identified the simulated fire after the setup was implemented, and an alert was transmitted over the Wi-Fi network. In order for the recipient to be alerted, the message was sent to the server. To warn people that they are present and to avoid explosions and fires, the warning sound (Buzzer) is triggered automatically. This smart system has a slew of protection advantages, including early fire warning and accident prevention. There will be no danger if the fire was put out within a certain period of time. To avoid explosions, the device may also be used in combination with machine intelligence, deep learning, and image processing. We may try to merge them in the future to produce the most useful outcomes.

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