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Advanced Fire Alarm System (A-FAST) As a Tool for Early Fire Detection and Reliable Response Mechanism

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***Abstract* - Fire responses have only been limited to sprinkler systems, and recent projects have been focused on IoT-based fire response systems. This project aimed to develop an advanced tool for fire safety that includes the detection of gas and flame coupled with an SMS and call function to notify homeowners and emergency services providers. This project used ten (10) components: Arduino MEGA 2560 Rev3, Breadboard, MB102 Power Supply Module, IR Flame Sensor, MQ7 Gas Sensor, GSM SIM900A, LED lights (green and red), Piezoelectric Buzzer, 16 x 2 LCD Display, and jumper wires. The project used Arduino MEGA 2560 Rev3 to collect data from the sensors connected to the board for proper functioning. The presence of gas and flame were detected with the help of the IR flame sensor and MQ7 gas sensor. The users were able to determine the effectivity of the sensors through the LEDs, the LCD, and the buzzer. These components all indicate the presence of gas or flame. The project also allowed respective contact numbers to be notified by the system using text and phone calls through the GSM SIM900A. Through the series of experimentations and implementation of the projects, findings revealed that the Advanced Fire Alarm System (A-FAST) as a Tool for Early Fire Detection and Reliable Responsible Mechanism was highly reliable, useful, and effective.**

Keywords: Advanced Fire Alarm System, Fire Detection, Response Mechanism, Tool.

I. INTRODUCTION

Fire is unpredictably destructive. It is harmful and unwanted. Fire has helped human society evolve since the beginning. It is used to cook and warm and deter predators. Spreading fires are uncontrollable. It can disrupt people's lives and livelihoods. Philippines fires kill people and destroy property every year. The Bureau of Fire Protection (2022) reported that fires in the Philippines rose by 13 percent compared to 2022's first two months in the previous year. 2,103 fires were reported in January and February, up to 12.9% from 1,863 in 2021. Despite preventative measures and quarterly fire drills, fire incidents keep rising, requiring more efficient solutions. [1].

A fire detection method for commercial and residential spaces is a fundamental requirement for reducing the loss of personal property caused by natural and manufactured fires. With the progression of technology, people have continued to produce and enhance fire safety. Existing tools such as fire alarms and sprinkler systems result from technological advancements [2].Existing fire alarm systems are typically limited to notifying people in the immediate vicinity and cannot communicate situational details to rescue services. Moreover, current fire alarm systems are incapable of communicating with anyone outside. If an emergency personnel does not enter the building, they will be unable to determine how far the fire has spread. A homeowner who is not present in his burning home cannot determine its status outside the structure. Catastrophic losses of life and property may occur before a fire hazard is identified and eliminated. As a result, emergency services frequently respond with a delay [3].

Delays in responding to fires can result in losing human life or property. Most fire cases occurred in private residences [4]. Because of its type of activities, a house is a vulnerable object to fire. In a house fire, human safety is a critical element that must be considered and emphasized. As a result, occupants of disaster-affected homes must receive information in early warnings when a fire occurs, allowing them to evacuate on their own. It is vital to send information about the fire location to the fire department in order for them to have easier access to details about the situation. Leaning closer to a more tech-savvy generation, we can use technology to continue improving our present solutions to everyday life dilemmas. There have been recent innovations in IoT-based fire alarms, remote alarm systems, and wireless sensor networks, but they are all deemed complicated and costly. As a result, a dependable and responsive system and straightforward, quick to implement, and cost-effective system is needed [5].

Several efforts have been put recently into designing systems that can detect and control fire outbreaks. The SMS

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Based Fire Alarm and Detection System design is embedded with a GSM module that sends messages to the homeowners and fire service personnel. When the sensors detect fire or gas, the Arduino activates the GSM Module, which sends SMS, the alarm system, and the servo motors. The study aimed to detect a fire and commence fire suppression; a servo motor (SG-90) is needed to raise a firebox filled with flame-resistant materials, delaying the fire's growth until emergency responders respond. However, the problem is that the servo motor operates at a 170 degrees angle, which means it cannot reduce fire spread as effectively as a pump motor [3].

Moreover, situational awareness helps initial rescuers, especially incident commanders, analyze dynamic onsite events and make smart choices. An industry-proposed approach includes an LM35 fire sensor, a GSM module, a PIC microprocessor, a recording device, and firefighting equipment. The PIC microcontroller performs four operations under critical conditions. It automatically performs prevention and control actions, saving workers' lives in accidents. Automatic speech recorders operate fire extinguishers. GSM is installed to send real-time regional data to the company's IP address [5]. Likewise, a Factory Security System with a smoke sensor, GSM mobile and sound module design was created. The Model of the leakage system was validated with Propane gas near the gas sensor and candle flame near the flame sensor. MQ-6 (LPG Gas Sensor) gas and fire sensors send signals to the microcontroller (Arduino Uno 328). The microcontroller sends a signal to external devices. SMS is sent when a gas leak is detected. The system has no device to control gas leakage, so if a fire breaks out, the necessary device to extinguish the fire is not included, potentially resulting in property loss [6].

Furthermore, in pursuit of offering solutions to the unpredicted fire problem, another intelligent smoke alarm system with a wireless sensor network using ZigBee was created, an affordable, low-power IoT network technology. The system includes smoke detection, wireless connectivity, intelligent identification, and data visualization modules. A smoke alarm module has the following benefits. First, smoke information categorization reduces alarm errors. Second, smoke modeling helps users understand air quality. These wireless networks boost alarm accuracy and reliability [7].However, their approach has the disadvantage of being extremely costly and challenging to build [8].The heat flux sensor (HFS) can be deemed a sufficiently effective technology for detecting fires at an early stage. To determine the intensity of thermal radiation, the device employs a photovoltaic cell. The digitized value is then used to find the radiation source's location. This allows, among other things, to utilize the gadget to locate fire coordinates so that a robotized fire complex may successfully extinguish it. As a result of the effort, an upgraded heat flux sensor was provided, which can work in a wider temperature range and have a faster response time [9].

In fact, another project focused on fire detection and an automatic fire extinguisher system was built, but not for buildings and residential areas. The project mainly focused on gas station fires. An automated fire extinguisher system should be able to detect the fire's location and extinguish it before it spreads. The Arduino IDE project framework uses ultrasonic, infrared, and thermal sensors to distinguish barriers and fires. Infrared flame sensor, radio frequency sensor, and MQ7 sensor detect heat/flame, carbon monoxide, and mobile phone frequency. MQ7 was used because it is easy to use and install and detects CO in the air. It can detect 20-2000ppm CO-gas anywhere. MQ7 is a monoxide-susceptible carbon-intensive compound with a long life cycle. This project is operational based on its performance and capability [10].

Meanwhile, as our generation and environment go more high-tech as years pass by, researchers have also created more innovative and more highly technological ways to achieve early fire detection and suppression. Traditional fire-detection systems can be upgraded with vision-based technologies to build fire prevention in societies using technological innovations such as digital cameras, human-computer interaction, intelligent systems, and machine learning. The created design of a fire detector that reliably identifies even little sparks and raises an alert in less than 8 seconds of a fire breaking was a promising model. A unique machine learning algorithm was constructed to recognize fire zones using an upgraded You Only Look Once (YOLO) v4network. The network was customized to run on the Banana Pi M3 board to reduce the processing time of CPU and GPU tools. The suggested method effectively spotted and reported disastrous fires with speed and precision in various weather environments, sunny or rainy, day or night [11].

Finally, in fire detection system design, it is equally important to check how air affects smoke and flame sensors in this current project. Researchers must read Ambient Air Quality Standards for Suspended Particles to understand its properties. Specifying measuring methods for assessing and achieving compliance is an integral part of creating a National Ambient Air Quality Standard. Compliance samples are often used to identify sources, evaluate control efficacy, and determine pollution-health links [12]. Before establishing a monitoring methodology, a thorough understanding of sampling and analysis technologies and a cost analysis are needed. This evaluation analyzes concerns with measuring standard compliance, describes present and future methods and their limits, and determines how well existing technology can meet short and long-term needs.

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Existing fire alarm systems can be modified and upgraded into systems that have more benefits and fewer drawbacks. There are still ways to produce a simple, cheap, but equally functional and reliable as an existing one.

1.1 Objective of the Project

This project generally aimed to create an Advanced Fire Alarm System (A-FAST) as a Tool for Early Fire Detection and Reliable Response Mechanism that is also sustainable, reliable, and cost-effective. Specifically, it sought to create a prototype model system and test its functionalities through a series of experiments with both hardware and software components.

1.2 Conceptual Design

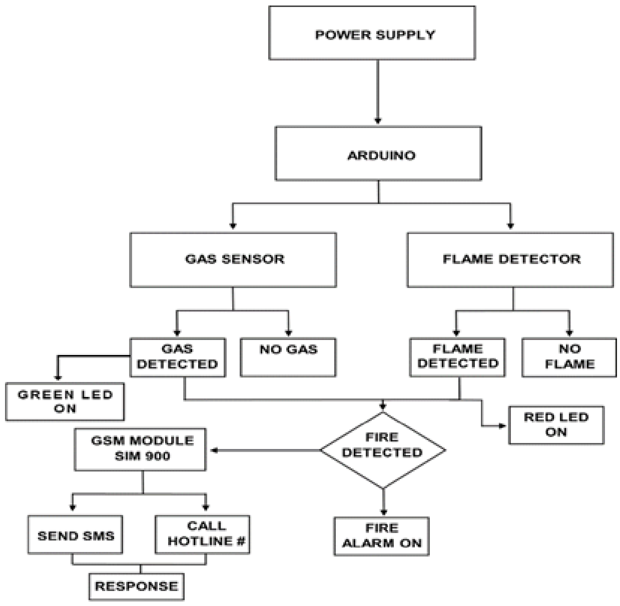

Figure 1: Conceptual Design of the Project

II. MATERIALS AND METHODS

Here you will find the utilized materials, system design, block diagram, and statistical analysis for the Project.

2.1 Materials

The hardware components used were carefully selected, evaluated, and tested for the output's validity and dependability to design the project. In order to achieve the desired system, sensors such as the IR Flame Sensor Module and the MQ-7 Gas sensor were utilized for Gas and Flame detection. Similarly, Piezoelectric Buzzer and Jumper wires were used for the physically sound alarm mechanism design. Additionally, Light-Emitting Diode (LED) was utilized as the Physical indicator of the system's Gas and Flame detections. Moreover, a 16x2 LCD was used to physically display the data gathered by the system for the user's convenience. To easily connect all the components, an MB102 breadboard was used. In order to make the design functional, an Arduino MEGA 2560 was used as the central processing unit of the system design; it interprets and transmits the signal to the respective components in order to execute the algorithm written as a series of Arduino-uploaded codes. An MB102 power supply module was utilized to provide adequate power to the entire design to make it more portable. A GSM SIM900A module was integrated into the design to make the response mechanism more reliable. This module enables the design system to send SMS messages and phone calls to Homeowners and emergency services hotline numbers for early notification of the fire's details, thereby making the response mechanisms more reliable and efficient.

2.2 System Design of the Project

The proposed system is an Advanced Fire Alarm System (A-FAST) as a Tool for Early Fire Detection and Reliable Response Mechanism. It requires two sensors: a smoke sensor and a fire sensor/flame detector. The sensors will be used to monitor and observe the presence of smoke and fire in an establishment, which will then be considered to determine if a fire is breaking out. A total of ten (10) hardware components will be used, namely; IR Flame Sensor, MB102 Solder less Breadboard, MB102 Power Supply Module, LED lights (Red and Green), Jumper Wires, Arduino MEGA 2560 Rev3, 16 x 2 LCD Display, Piezoelectric, GSM SIM900A, and MQ-7 Smoke Sensor. In this system, the Arduino MEGA 2560 Rev3 will serve as the main control center, making it the system's brain.

There will also be two power sources. The primary power source will be the establishment's electrical power supply, while a power bank will be reserved in case of a power outage. When the sensors sense irregularities or changes in the environment, the Arduino MEGA 2560 Rev3 will analyze and process what the sensors have detected. Once the irregularities are classified as signs of a fire breakout, it will automatically activate the piezoelectric buzzer and operate the GSM module. The system will use the GSM module to send Short Message Service (SMS) to emergency services hotline numbers. These actions will be carried out simultaneously, delivering and ensuring real-time data and responses. In the prototype, there will be an LCD that will show the results from the analysis of the Arduino. Green and red LED lights will also be used to indicate whether or not the sensors have detected smoke or fire, or both. If gas or fire is detected, the red LED light will light up. If there is a presence of gas, the green LED will illuminate. If both sensors have detected fire and gas, both LED lights will ignite. However, no LED lights will light up if the sensors haven't detected any gas and/or fire.

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2.3 Block diagram

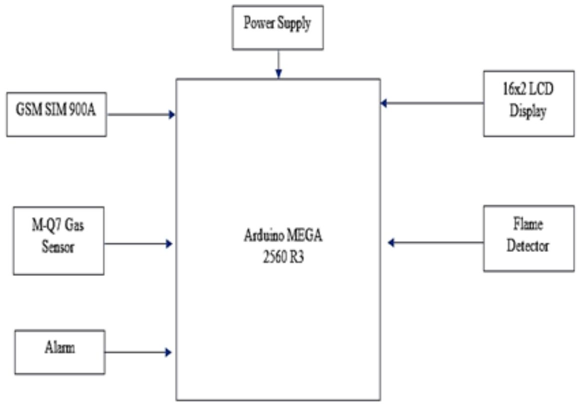

Figure 2: Block diagram of the project

2.4 Statistical Analysis

Several experimental tests were conducted to verify the accuracy and reliability of the design to collect the necessary data for this project. This project utilized descriptive statistics to analyze and interpret the experimental results. Mean was the primary descriptive statistic used to interpret the data collected. The study also used the serial plotter found in the Arduino software as the foundation of the data collection procedures; all data from the software were converted into statistical presentations such as graphs to make sense of the data. Specifically, graphs were used to analyze and interpret data to test the readability and functionality range of gas and flame sensors.

Five (5) trials were set up to test and determine the average range detected by the Gas Sensor, and the data from the series of trials were analyzed using Mean. Similarly, the Overall Mean was used to test and determine the GSM SIM900A module response time's average interval. The numerical data obtained from the series of trials and experiments conducted and the actual observations of the researchers during the study's implementation were utilized to interpret the data gathered.

III. RESULTS AND DISCUSSIONS

This section discusses the prototype design, the application of the project, and the hardware tests that were conducted to validate the sensor readings and performance. This section describes how the product reacts to specific data and how data is displayed. In the system, there are two analog sensors: flame and gas. The Arduino Mega 2560 and GSM Module SIM900A boards receive data from these sensors.

3.1 Prototype design of the Project

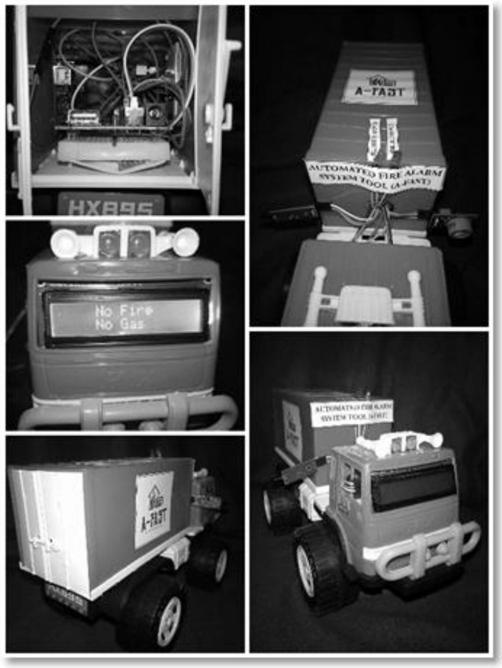

Figure 3: Prototype design

Shown in Fig.3 is the actual prototype design of the system. The researchers decided to frame their prototype as a fire truck toy, which would make their work more exquisite and marketable. The Arduino MEGA 2560 Rev3, the breadboard, and the GSM SIM900A module were kept inside the cargo box to keep the prototype neat and orderly. The LEDs connected to the breadboard were extended outside the cargo box using jumper wires for the visibility of the LEDs. The toy car's windshield was replaced with an LCD screen for an easy display view. The sensors, namely the flame and gas sensors, were taped in front of the cargo box. The buzzer was placed under the trailer. The jumper wires were taped together to ensure that every connection was distinguishable. The whole prototype design is automated. Once the sensors detect the presence of gas and flame, the system will automatically send out the data to respective components, the buzzer alarms, and the GSM sends out an SMS and a call.

Figure 4: Serial Monitor Readings of the system

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The sensor readings presented on the serial monitor are illustrated in Fig. 4. The serial monitor readings were on the left when neither flame nor gas was detected. The gas concentration was also indicated. There was a change in the readings of the flame sensor, indicating "flame detected" on the right, compared to the left, which is essentially identical. A reading was taken using the lighter (source of fire) close to the flame sensor. In addition, the output of the GSM SIM900A was revealed. The content of the sent message and the contact number was displayed.

3.2 Serial Plotter Readings of the Project Design

Figure 5: Readings displayed on the serial plotter

As can be gleaned in Fig. 5 is the serial plotter that shows the gas sensor readings. The green line indicates the gas value. The higher the gas value, the more gas is detected. This means that gas is detected when the green line goes up to 100 and above.

3.3 Readings and Functionality Tests of the Flame Sensor

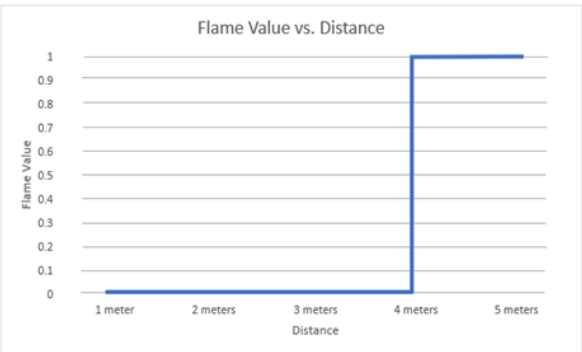

Figure 6: Graphical presentation of Flame Sensor Test

As demonstrated in Fig.6 is the results of testing the flame sensor. For the test, various distances were observed for five trials. The different distances observed are one meter, two meters, three meters, four meters, and five meters. A fire sensor's value begins at 1. This indicates that no fire is present. When the IR flame sensor detects a fire, its value will drop to 0, indicating the presence of a flame.

Moreover, for the first distance tested, the flame value is 0. This means that at one meter, the flame sensor can detect the presence of fire. From two meters to three meters up, the flame value remains 0, and the flame sensor can still detect the presence of fire. However, when the source of flame was four meters away from the sensor, the flame value went up to 1, which means the sensor could no longer detect the presence of fire. The same happened when the flame source was positioned five meters away from the sensor. The value remained 1, meaning there was no fire detected. This means that by increasing the distance of the fire source from the design, it will no longer be detected.

3.4 Readings and Functionality Tests of the Gas Sensor

Table 1: Gas Sensor Reading Test

Trials	Gas Value	Descriptive indication
Trial 1	31	No Gas
Trial 2	89	No Gas
Trial 3	102	Gas Detected
Trial 4	113	Gas Detected
Trial 5	145	Gas Detected

As shown in Table 1, the results of the five trials were conducted to test the functionality of the gas sensor. A lighter was used as a gas source to test the gas sensor. The gas value determines the presence or detection of gas. For the first trial, the gas value was 31, which indicated "no gas." For trial two, the gas value went up to 89, but no gas was detected again. For the third, fourth, and fifth trials, the gas values were 102, 113, and 145. These were indicated as "gas detected." These results suggest that gas was detected only when the value was 100 or higher; no gas was detected when the values were below 100. The function of the gas sensor is to determine the gas value in the surroundings. This functionality allowed the system to notify homeowners of possible gas leakage. This means that the analog sensor range must be met to detect the gas leak.

3.5 Readings and Functionality Tests of the GSM SIM900A Module

Table 2: GSM SIM900A Module Reading and Response Time Tests

COMPONENT		T1 (sec)	T2 (sec)	T3 (sec)	T4 (Sec)	T5 (sec)	Total	Mean
1.	Gas Sensor (SMS)	15	9	8	8	8	**48**	**9.6**
2.	Flame Sensor (SMS)	9	8	7	9	9	**42**	**8.4**
3.	Flame Sensor (Call)	15	14	17	17	19	**82**	**16.4**
Overall Total and Mean							**172**	**11.5**

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As revealed in Table 2, the results for testing the functionality of the GSM SIM900A module. The first test was for the gas sensor. This test only used the SMS messaging text function of the module, and only the house owner received the notification. For the first trial, the homeowner received the SMS text 15 seconds after the sensor had detected the flame. There was a 9-second interval between the time the flame was detected, and the message received for the second trial. For the third to last trial, the time interval was 8 seconds. The mean for the gas sensor SMS messaging test was 9.6 seconds.

Moreover, the second and third tests were performed with the flame sensor and used both the SMS messaging function and the call function of the module. Two tests were conducted, each of which was given five trials. The time interval between when the system processed the data and when the contact numbers received their notifications was measured in each trial. Trials 1, 4, and 5 for the flame sensor SMS text messaging took 9 seconds intervals, while trials 2 and 3 took 8 and 7 seconds, respectively. In terms of call, trials 1 to 5 took 15 sec, 14 sec, 17 sec, 17 sec, and 19 seconds for the emergency hotline number to receive the call, respectively. The first test for SMS text messages received a mean of 8.4 seconds, while the second test (call) received a mean of 16.4 seconds.

Furthermore, SMS text messaging for both the gas and flame sensors did not take long enough to occur. This means that homeowners and emergency hotline numbers can be notified through SMS text messaging in a short period of time. Therefore, they get to know about the fire incidence early. However, it took a while for the system to call the emergency hotline number. The last test received a mean of 43 seconds. Since the call option was only added to the system in case emergency providers missed out on the SMS sent, this time interval can still be considered. Meanwhile, the overall mean of 11.5 seconds corresponds to the overall response time of the design model, indicating that the Fire Alarm System is a dependable design that allows for information to be transmitted in less than a minute, which is an ideal time for rescuers to be notified and preceded with the rescue mechanisms.

Meanwhile, the functionality of the GSM module allows the owners and emergency providers to respond to fire occurrences as early as possible. This module's functionality was proven effective and has notified the contact numbers provided in the system.

IV. CONCLUSIONS

The Advanced Fire Alarm System (A-FAST) prototype and applications as a Tool for Early Fire Detection and Reliable Response Mechanism were highly effective, reliable, and useful for detecting fire and monitoring gas levels, transmitting useful information to the emergency providers of the house owners. Based on the series of experimental results, all of the hardware components, such as the sensors and microcontroller, were functional, while the software component developed for this project was effective in sending commands and receiving data from the project, as found out by the researchers in their series of experimental trials. As a result, it is then concluded that the Advanced Fire Alarm System (A-FAST) as a Tool for Early Fire Detection and Reliable Response Mechanism proved to be dependable and effective in monitoring and sending alerts to the house owners and emergency providers' hotline numbers; also, a sustainable, reliable, and cost-effective advanced fire alarm system was built effectively.

V. RECOMMENDATIONS

For the further development of this project, the researchers recommended the following:

1. Future researchers are encouraged to embrace and continue this research in order to further develop the system.
2. It is suggested to add more monitoring components such as an application system.
3. In order for the system to continue running and performing its duty in the event of a power loss, it is advised that a solar panel and a battery be incorporated.
4. For future research applications, more Arduino research-based initiatives should be investigated.
5. It is also recommended to install an automated voice alarm system for notification.
6. The addition of monitoring cameras is warmly recommended.
7. The addition of a Sprinkler System is highly recommended.

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Conducting a research study is a challenging endeavor. It requires time, money, and the assistance of other researchers. This research project was successful due to the assistance of brilliant minds and assisting hands. The researchers would like to thank them for their knowledge, ability, and scholarly suggestions for the realization of this research endeavor.

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