An Improved Automated Fire Detection and Prompt Management System for Buildings

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Abstract - **The effects of fire disasters have constant negative impacts on humans and their dependable such air, water, environment and property. Fire disaster has brought about numerous injuries, loss of lives and destruction of valuables like documents, monies, and property. Some of these losses were due to panics and stampeding. These effects were usually as a result of lack of early fire detection and proper management for easy awareness, evacuation of humans and property, and fire extinguishing. Having known the causes and effects of fire outbreaks, this paper focused on developing an improved fire detection and management system using different technologies such as Arduino Uno microcontroller, gas-leakage senor, smoke sensor, flame sensor, Global System for Mobile (GSM) module, buzzer, MP3 module, and liquid crystal display (LCD) device. The developed fire detection and management system was able to detect and report early signs like gas leakage and high concentration of smoke that could lead to fire outbreak, and flames of fire. The system provided means of alerting both the house owner(s) or caretaker(s) and occupants of the building at different situations for immediate actions, and also provided clear directives through voice prompts on the best alternative exit routes for easy evacuation. Hence, this fire system can be utilized for providing maximum reduction of fire outbreaks and their costly effects.**

keywords - **Fire disaster, Fire detection and management, Fire system, Arduino Uno, MP3 module, and Flame sensor.**

I. INTRODUCTION

The continuous needs and quests for newer technologies and improved standard of living have brought and shall continue to bring about numerous changes more especially in our day-to-day actions and reactions in residential, social and commercial areas. Different researches and studies have shown that every technology has its own hazard or risk that must be controlled or addressed properly. The needs for better living have brought about various kinds of building, lighting, cooking, learning, safety, management and several other technologies which in some cases can cause more harm than good if not properly utilized. Some of these technologies more especially the lighting and cooking technologies have made fire hazard a recurrent incident in our homes, markets, industries and offices. Though all the available technologies were invented or developed to improve our standard of living, but the safety of lives and property must be given the highest priority when utilizing these technologies.

According to [1], the Federal Fire Service statistics has it that despite loss of lives, goods and property worth over five billion naira (#5,000,000,000,) were lost to various incidents of inferno across Nigeria between the year of 2013 and 2018. In the report of [2], fire hazard has really affected Nigerians in various ways resulting to inflation of prices, increase in crime rate, and loss of lives and property. The report accounted that four thousand five hundred and forty one (4,541) calls were received by the Federal Fire Service between year 2019 and year 2021, a total number of sixty eight (68) fire incidents including thirty one (31) market-fire incidents occurred in eighteen (18) months which led to over 79 deaths and destruction of goods and property worth billions of naira. In the fire incident that occurred in Kastina Central Market, about two thousand six hundred and sixty eight persons lost their means of income. The report also indicated that Lagos and Anambra were the two topmost fire disaster affected States in Nigeria. According to [3], United States of America's National Fire Data Center has it that between 2013 and 2015, about 17% and 20% of the fire incidents' death in residential buildings resulted from escape difficulties and egress issues respectively. [4] opined that a total number of one hundred and fourteen (114) fire incidents that resulted to fifteen (15) deaths and loss of property was recorded in Anambra State of Nigeria in the year 2021.

Scholars have shown that fire disaster has affected various economies of the world negatively and shall continue to cause several losses to mankind if appropriate technologies and techniques are not being employed in fire incident reporting and management targeted at providing efficient means of ensuring maximum safety of lives and property. Hence, the serious need for improving methods of fire hazard management for safety of lives and property. Studies have shown that smart home technology is the current technology being utilized in providing several home management services such as automation of lighting devices, home appliances, water pumping, intruder detection, gas-leakage detection and fire hazard detection. Most of these smart home technologies are microcontroller-based with various response or incident-reporting methods such as activation of an alarm or beeps, sending of text messages to specified phone number(s), activation of voice prompt in any desired language, displaying of messages on a digital display board. In the case of fire hazard monitoring and control, an efficient management system can be designed to integrate two or more of these incident-reporting methods. Hence, this paper presents an improved microcontroller-based fire disaster management system that combines multiple technologies for early fire disaster detection and management.

II. LITERATURE REVIEW

According [5], fire disaster has several great consequences on the natural environments. These consequences range from injuries, loss of lives and valuables to contamination of air, soil and water through the fire plume and its diffusion. [2] stated that the fire-hazard incident that occurred in Kastina Central market, Kastina State of Nigeria on 2nd March, 2021 burnt goods and property worth about nine hundred and two million one hundred thousand naira (#902,100,000.00) only, and six hundred and eight (608) shops. [6] worked on 'Assessment of Fire Safety Measures in Some Markets in Kaduna State, Nigeria'. The authors' goal was to evaluate fire safety procedures in marketplaces, which they accomplished by selecting two markets in Kaduna State. Within the research areas, a thorough investigation of structured interviews was done with well-informed administrators, shop owners, and architects. According to their findings, six out of twenty (30%) of respondents are familiar with standard fire safety precautions, whereas fourteen out of twenty (70%) are familiar with traditional procedures, indicating that effective steps to mitigate the consequences of fire in markets are lacking. Knowledge of fire and fire safety equipment, equipment accessibility, waste disposal, and traffic congestion are among these measures. As a result, architects and designers should create markets that adhere to fire safety standards in order to prevent the loss of life and property.

[7] opined that innovational science and technology have been employed constantly developing various systems that help in preventing fire disaster and its effect. The smart real-time detection system was designed with sensors meant to detect smoke and fire at early stage and immediately send signals to the controller board which in turns activate output signals to enable fire management. The fire system was built using Tensilica ESP 8266 processor and a Wi-Fi module for communication. [8] proposed a smart fire alarm system using Arduino Uno with three different modules; signal detectors, prompt communication, and execution modules. The fire system was designed to include temperature and flame sensors for detection, manual call point, Wi-Fi, alarm modules, and display unit for prompt information and communication, and water sprinklers for fire extinguishing. [9] designed a home fire detection system prototype with DS18B20 sensor (temperature sensor), MQ2 sensor (gas sensor), GSM module and buzzer interconnected on an Arduino Uno microcontroller that makes gas leakage and fire detection so easy for both house owner(s) and fire fighters. This system was meant to activate outputs such as sending of short message to already stored contact(s) and sounding of an alarm once the room gas concentration is at 220 ppm and/or room temperature is detected to be above 45°C. [10] proposed an ATMega 328p Arduino based fire detection and control system that has the capability of fire detection, switching off the power source, and minimize the fire intensity by spraying water. This was developed using an Arduino microcontroller to integrate 5v DC motor, DHT 11, buzzer, SIM8001 GSM module, and LCD device to enable efficiently operational procedures.

III. MATERIALS AND METHODS

This paper adopted different materials such as journal papers/articles, and national newspapers in its literature review and thereafter employ efficient system design, coding and integration methods in achieving the desired automated fire detection, reporting and management system. The literature review was done to obtain sufficient background knowledge and understanding about the causes and effects of fire outbreaks in both residential and nonresidential buildings. This actually provided clear understanding of most things that were needed for the design and integration of the fire management system. The system designs methods were done in parts; the first part was to identify all the needed components, the second part was to design each component for performance efficiency, and the final part of the methods was the use of an Arduino Uno microcontroller for the coding and integration of the various components, and also for the demonstration of the developed fire disaster management system. The construction of the fire detection and reporting system involved the use of a microcontroller board known as an Arduino Uno board, photoelectric/ionization sensor for smoke detection, and MQ2 sensor for gas-leakage detection, infrared optical sensor for open flame detection, buzzer/piezo for sound alarm, 16x2 LCD for displaying messages, SIM module for emergency contacts communication, and Mp3 module for audio announcement. The block diagram and the operational flowchart of the fire detection and management system are as shown in Figures 1 and 2 respectively.

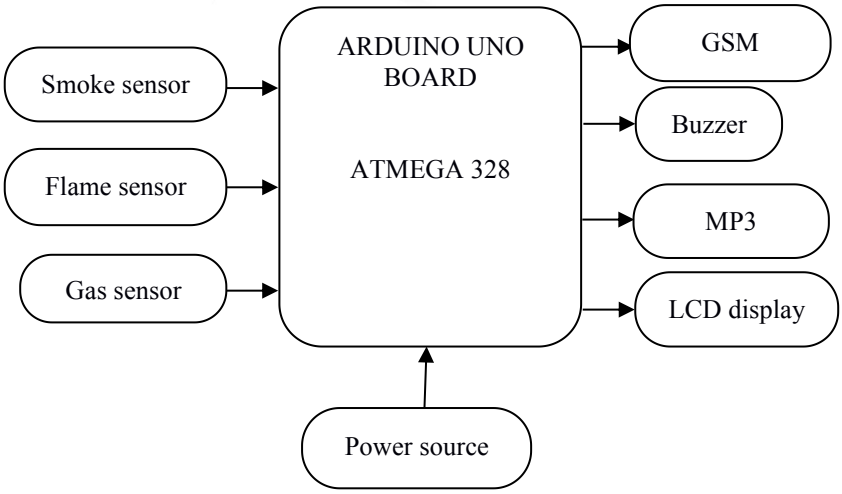

Figure 1: Block diagram of the fire detection and management system

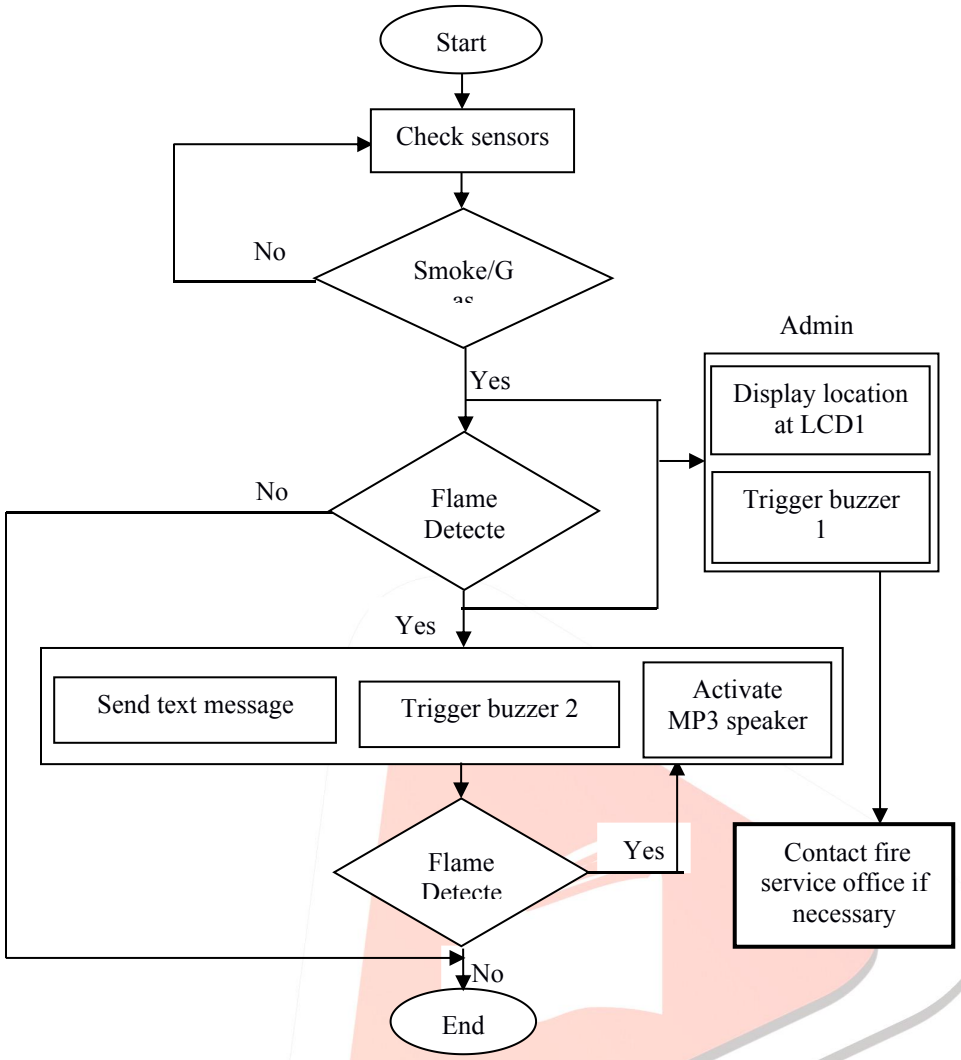

Figure 2: Flowchart of the fire detection and management system operational model

Thereafter, the microcontroller was configured and programmed to detect and activate the alarm, Mp3 Shield and SIM Modules. In this design, two different buzzers were used for warning; "Buzzer 1" for the admin and "Buzzer 2" for everyone within the building. The fire system puts the responsibility of contacting the fire service office on the Admin or emergency contacts. This was designed knowing that it is not all smokes and gas leakages or flames that lead to fire outbreak. Hence, the Admin can manage all the low risk incidents when reported by the fire system. The power source contained in Figure 1 can either be a DC source or an AC source which must be converted to a DC voltage in order not to damage the Arduino Uno board that accepts a maximum DC voltage of 5V.

IV. RESULT

After the programming and integration of the various components of the fire detection and management system, it was observed that all the individual components were functioning properly as predefined. The various testing and results were obtained as shown in Table 1.

Table 1: Results of the testing performed

Components Tested	No. of Times Tested	Accuracy of the Results (%)
Gas sensor	15	100
Smoke sensor	18	100
Flame sensor	12	100
GSM module	12	100
Buzzer 1	45	100
Buzzer 2	12	100
MP3 module	12	100

The gas-leakage detection (MQ-2) and smoke detection (photoelectric/ionization) sensors were able to detect the presence of gas when released from a gas container and high concentration of smoke respectively, and thereafter triggered "buzzer 1" ON

for the Admin's notification only. The infrared optical sensor was able to detect open fire or flame which triggered both "Buzzer 1", "Buzzer 2" and MP3 speaker ON simultaneously for the notification of both the Admin and everyone within and around the building. The MP3 speaker was activated to provide audio announcement meant to guide everyone in the building on the appropriate exit route to follow. The fire detection incident was sent through GSM module to the admin/caretaker and already stored emergency contact(s) whose responsibility is to manage the fire either remotely or by contacting the fire fighters as the intensity of reported fire usually differs.

V. CONCLUSION

Fire outbreak is an unnatural disaster that usually occurs due to human/operational errors or substandard electrical or heat materials/appliances as well as leakage of inflammable substances. Typical causes of fire outbreaks are electrical appliance faults, cooking gas leakage, candle fire, human carelessness, and thunder strikes. Studies have shown that every fire outbreak that occurred in a residential building has resulted to loss of valuables; property, documents, or human lives; and that every fire outbreak that occurred in nonresidential building has resulted to enormous losses such as goods, property, lives, means of livelihood, and monies. Having known the effects of fire disasters in both residential and nonresidential buildings, this paper therefore provided an improved system for fire outbreak management termed an automated fire detection, reporting and management system. The fire system was developed using Arduino Uno board that provided platform for interfacing and integration of different components such as smoke sensor, gas-leakage sensor, flame sensor, LCD, MP3 module, GSM module, and buzzers.

An automated fire detection, reporting and management system is an improved fire disaster control system that when installed ensures maximum safety of lives and property within a building and its environs. This system provides early detection and reporting services which can be implemented by triggering the alarm system or sending short text messages to the appropriate persons and authorities for effective actions or reactions. In the case of large buildings with multiple exit routes, the automated fire detection and management system can as well provide prompt voice instructions or directives in a specific language(s) to avoid panic and stampeding but to properly guide the occupants on the best alternative exit routes.

This system provides modern methods and techniques for minimizing fire disaster response time to the barest minimum which in turn maximizes safety of lives, documents and property. This will also minimize the ripple effects of fire disaster such as loss of means of livelihood, emotional trauma, high blood pressure and untold hardship.

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