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A Flaming Ions and Fire Accident Detection and Notification System: Imperative to Learning C-Programming Language

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Abstract: Fire is a threat to lives and properties when no proactive measure is engaged towards curbing the occurrence. Fire occurs whenever there is a complete reaction of combustible fuel, heat and oxygen. The students require technological skills for digitally-based society. This paper presented an automated flaming ions–fire detection and notification system that detected a combustible flaming ion before fire occurs, alerted the relevant authority using Short Message Service (SMS) through Global System for Mobile Communication (GSM) modem for urgent attention and imparted students with relevant skills in designing and implementation of automated systems. The developed system was continuously scanning for detection of combustible flaming ions by the sensors in its vicinity. The relevant authority not available within the surroundings as well as people within the neighbourhood was alerted for fast response before the fire incidence. The developed system had a response mean-time of 3.55s in detecting flaming ions before the occurrence of fire. The flaming ions were detected at the mean-time of 3.55seconds prior to the fire occurrence from the tested materials. It was remarked by the users that a prompt detection of flaming ions could prompt response from fire fighters and prevent any damages from fire incidence and principally, the students in the field of Computer Science were imparted with computational skills in designing and implementing a detection and notification system.

Index Terms: Flaming Ions, Fire Accident, Detection, Notification System and Learning.

1. Introduction

Nowadays, securing public's properties and specifically, the educational facilities against fire is becoming more important as many institutions had lost valuable properties. Fire disaster is a great threat to lives and properties that occurs unexpectedly. Regrettably, fire could cause death [19, 22] when there is no measure to prevent its occurrence. Fire is a swift and self-sustaining oxidation development that occurs from the progression of light and heat in different intensities [14]. Fire occurs when no proactive measures to tackle the occurrence are ignored. Smoke is a chemical compound comprises hydrogen, carbon-monoxide (CO) and oxygen (O_2). The detection of flaming ions for the occurrence of fire solely depends on electrically charged particles (ions) from fuel, heat and oxygen. The invisible electrically-charged particles can be detected with the detection of ions that cause a fire. This chemical reaction results to fire accidents at ignition temperature, causing provoking damages to life and properties. Fire has been rated as a threat to human and all other creatures creeping on land [8]. In [15], fire occurrence could be predicted. The earlier combustible flaming ions are detected, the faster it would be for the relevant authority and firefighters to respond. In [11], the consequences of fire outbreak included economic losses, injuries to human lives and environmental disasters such as destruction of infrastructural facilities. Early detection of combustible flaming ions for a fast response can save lives and valuable valued properties.

The flaming ions and fire detection and notification system sends an alarm when the fire is about to occur and helps to quickly take steps to fight and reduce the fire damage. Wireless sensor network has become the most important technology in environmental monitoring in recent years. The surveillance of institutions through sensors and the prevention of problems via accurate prediction are of vital importance for the safety of these areas and other valuable properties within the neighbourhood [1]. The damages of properties and even death of inhabitants of the fire-affected building were major identified problems that necessitated for this research. In this modern age, automated systems could be used for early detection of fire occurrence [17].

The future-leaders (students) needed to be practically equipped with the relevant knowledge and skills on programming towards designing and implementing a flaming ions and fire accident detection and notification system at homes and offices. The teaching that is based on practical would improve the effectiveness of learning at all levels of

education. A practical-based programming course would stimulate the students' interests in learning, enhances the overall academic performance of the students and national development [16]. This research attempted to enhance the acquisition of programming skills in designing and implementing a highly combustible flaming ions and fire accident detection and notification system. Furthermore, the objectives of this research were to design, develop, test and evaluate a flaming ion and fire detection and notification system.

The existing systems on fire detection and notification were developed using WiFi, radio frequency (RF) and remote sensing technologies that had limited geographical area of coverage for communication. This restricted the relevant authority or firefighter to have fast access to information on fire incidence. A fire detection system was also developed using a fuzzy logic technique. The detection of fire of a fuzzy-based system was on the degree of elements of fire present for damages or destruction of lives and properties. A low degree of fire elements could still cause a fire outbreak when there is a delay in communication to the relevant authority. Instead, a proactive measure in the detection of flaming ions was engaged in this research to avoid delay in communication that could eventually cause fire before the arrival of the firefighter. This research would enhance the detection time for a fast response from the relevant authority and firefighters as ionization technique of detection remains the best among the combination and photoelectric techniques [20, 21]

2. Research Motivation

In January 2017, there was an inferno in FCT College of Education, Zuba that affected a whole building of twelve (12) offices. All valuable items and confidential documents were blazed beyond repair. Till today, the building is yet to be renovated leading to forceful relocation of the occupants to another building. The relocation has resulted in office congestion in the new location. The consequences of the congestion are poor concentration on academic work, poor ventilation, psychological and social imbalance among other challenges. Figure 1 shows the photograph of the burnt building.

Fig. 1. Burnt building of FCT College of Education, Zuba

The gaps in the recent pieces of literature were high electrical power consumption, low speed of data processing, limited areas of signal coverage by WIFI network and high responsive time [13]. It is on these identified problems that this research focused on the designing and implementation of a highly combustible flaming ions and fire accident detection and notification system, and to practically involved students towards the acquisition of relevant skills in the implementation.

3. Significance

The research would be significant in the following areas:

i. acquisition of hardware designing and implementation skills,
ii. mental creativity for human capacity enhancement,
iii. management of the limited building facilities for conducive teaching and learning environment,
iv. saving the cost of the buildings' renovation,
v. impartation of computational skills among students for self-reliance, and
vi. relevant for further scholarly investigation in the field of academic.

4. Objectives of the Research

This research aimed to design and implement highly combustible flaming ions and fire accident detection and notification system. Specifically, the objectives of this research included:

i. to design flaming ions and fire detection and notification system,
ii. to implement the designed flaming ions and fire detection and notification system, and
iii. to evaluate the developed system.

5. Literatures

Reference [2] developed a wireless fire sensor towards detection of gas, flame, the temperature, and humidity signals. The system detected a signal above a predefined threshold and sent a notification alarm message to the mobile users via a WiFi network. However, the operation of the proposed system by [2] used a WiFi network that has limited areas of signal coverage [6]. The developed system of [2] could not send the notification to the user in another geographical location and this weakness could eventually be led to uncontrollable fire incidence. Therefore, In case the user is not within the signal coverage, the problem of limited areas of signal coverage was tackled in this newly developed system by the integration of Subscriber Identity Module (SIM), SIM800 GSM modem for communication across larger areas even across the continents of the world.

Reference [4] designed and implemented a fire detector system. The system designed aimed to alert the distant property-owner efficiently and quickly by sending a short message (SMS) via GSM network. A linear integrated temperature sensor detected temperature beyond pre-set value whereas the semiconductor type sensor detected the presence of smoke or gas from fire hazards. The sensor units were connected via a common data line to ATMega8L AVR microcontroller. A SIM300CZ GSM kit based network module was used to send alert messages. However, the operation of the proposed system by [4] was on the use of ATMega8L AVR microcontroller that requires higher electrical power for operation and low speed of data processing [3] compared to the PIC16F877A microcontroller used for implementation of this research. This implies that the higher the power consumption, the higher the heat generate and the faster the microcontroller gets damaged. The damage of microcontroller results in a non-functional fire detection system. Also, high in room temperature as used in [4, 23] could falsely alert firefighter. Therefore, the problems of high power consumption, low speed of data processing, a longer lifespan and false alarm from high room-temperature devices were solved as the developed system sensitively detected flaming ions that could cause fire not temperature as a criterion for fire detection.

A fire detection and control system for automobiles using fuzzy logic was designed and implemented [5]. The automatic system consisted of flame sensors, temperature sensors, smoke sensors and a re-engineered mobile carbon dioxide air-conditioning unit for testing of a medium-sized physical car. On detecting fire, the system alerted the vehicle user by turning on the horn and hazard lights before extinguishing it by releasing carbon monoxide (CO) refrigerant gas at the fire location. The controller accomplished this using a fuzzy logic controller software designed and embedded on the Arduino Mega board. However, the operation of the proposed system was on the use of the fuzzy logic controller that deals with the degree or extent of the flame presence. Furthermore, the low speed of response and a high cost of purchasing a fuzzy logic controller were identified. Therefore, problems of a high cost of the fuzzy logic controller and low speed of response from relevant authority to take action against the occurrence of fire were solved in the developed flaming ions and fire detection and notification system. Significantly, the developed system dealt with the presence and detection of flaming ions not the degree of flame present for notification. This made the developed system to be more sophisticated and highly sensitive to the detection of fire occurrence.

Reference [9] developed a wireless smoke detection system based on radio frequency (RTFQ2) of 433MHz and other electronic components such as resistors, transistors, and HT-12D decoder. The system was tested at 70 metre distance for indoor and a positive response was recorded. However, the system failed at outdoor experiment with distance greater than 250 metres. The problem of [9] was the RF limited transmission capacity which has consequences on the diffraction, reflection, and attenuation properties of radio wave. In this research, uninterrupted transmission was achieved through the use of GSM technology which allows data communication through walls, ceilings and long-range of transmission was accomplished even outside the geographical location of fire.

Reference [10] developed a smoke detection system using ATmega328 microcontroller, buzzer, 12VDC voltage regulator, 1N4007 diode, relays, resistors and other relevant electronic components. A notification of fire incidence was achieved by a decibel buzzer. How would a fire fighter or authorized personnel who is not within the vicinity of fire incidence receive an emergency notification where the sound of buzzer has limited traveling capacity? The short range of sound wave of buzzer for notification restricted fast response from the fire fighter who is not present for urgent action against fire outbreak.

A fire detection system of [12] had 11 detectors, 3 repeaters which is economical expensive and worked at frequency of 433MHz for real-time surveillance of fire incidences. A GSM technology with higher frequency of 1,900

MHz was used for data communication between the fire detector and the mobile phone of a fire fighter or authorized personnel. In addition, the detector presented in this paper was cheaper when compared to Reference [12] because one flaming ions sensor, MQ-6 LPG CNG and one fire sensor TFD-1332 were used for implementation that detected the presence of flaming ions and possibility of fire outbreak.

Reference [18] used internet-based approach to develop a fire detection and notification system. However, the Internet of Things (IoT) used in [18] had a higher rate of Denial-of-Service (DoS) attacks than the digital cellular technologies used in this research.

6. Methodology

The methodology of this research involved hardware design and software development.

6.1. Hardware Design

The developed fire detection system had seven (7) functional modules: the power supply, flaming ions sensor, fire sensor, controller, buzzer, display and GSM module. Figures 2 and 3 showed an overview and functional diagram of the developed system.

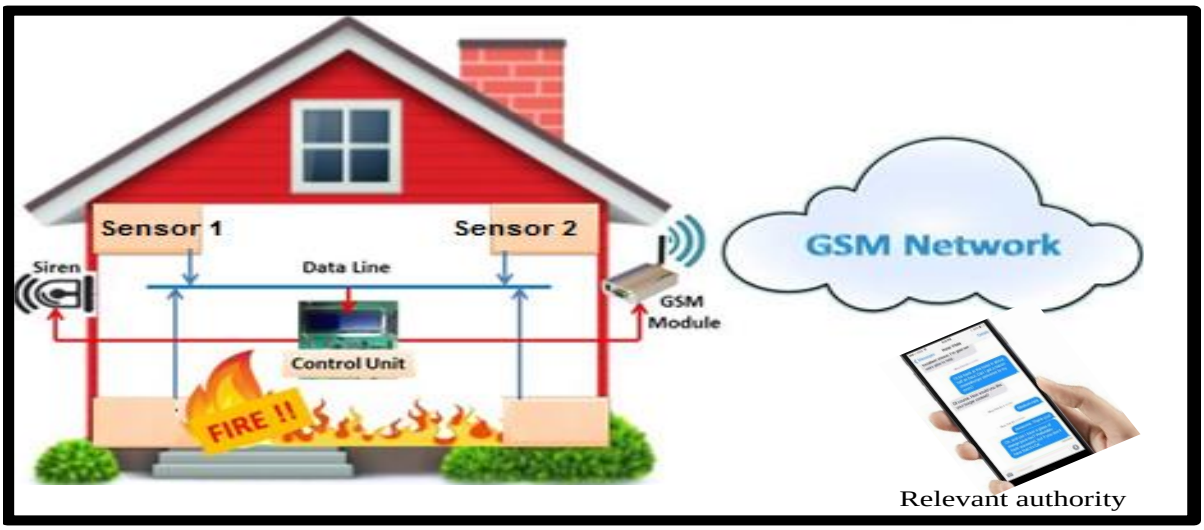

Fig. 2. Overview of the developed system

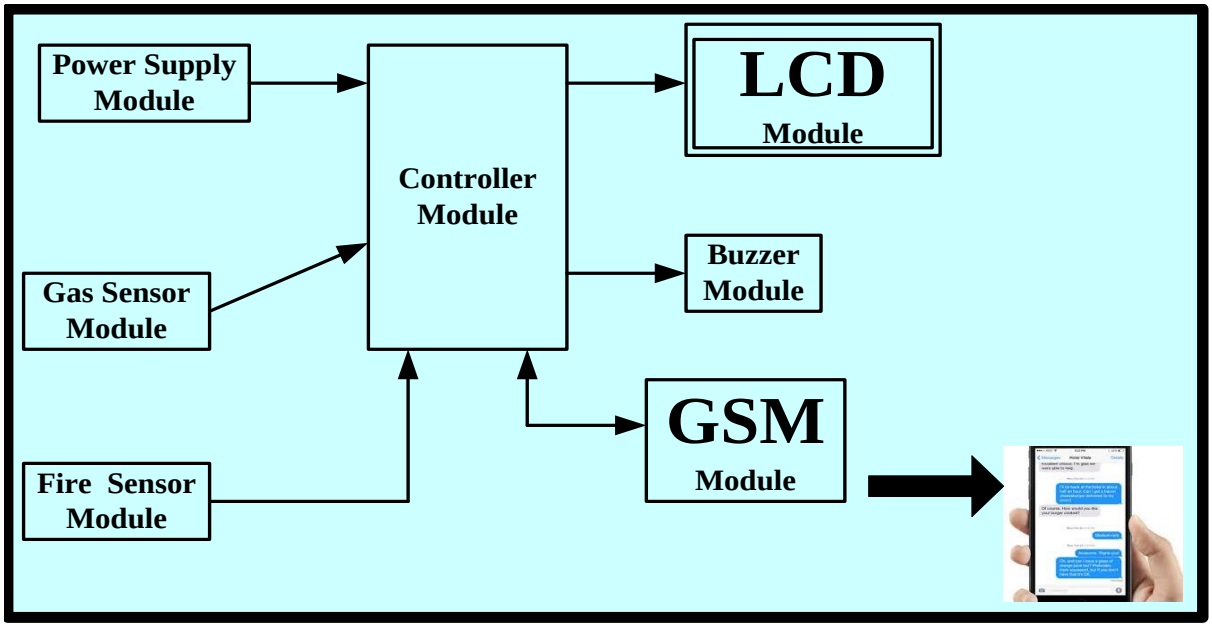

Fig. 3. Figure Block diagram of the developed system

A. Power Supply Module

The module supplied the required voltage to make the developed flaming ions detection system function.

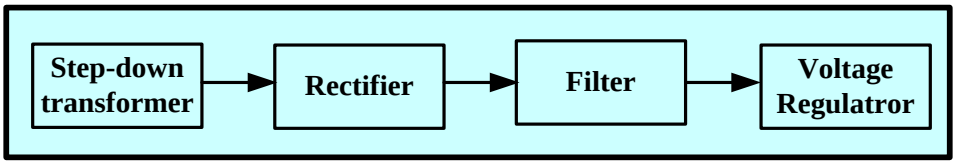

Fig. 4. Four-block representation of power supply

a. Transformer

A 240 V/12 V. 50Hz, a step-down transformer was used. The main function was to step down the input voltage supply to suit the requirements of the electronic components used in the implementation.

b. Rectifier

Four (4) diodes were used to convert the voltage into pulsating DC voltage.

c. Filter

The main function of a filter was to minimize the ripples contents of the rectifier output.

d. Voltage Regulator

A 7805 voltage regulator was used to achieve a constant positive output DC voltage of 5V.

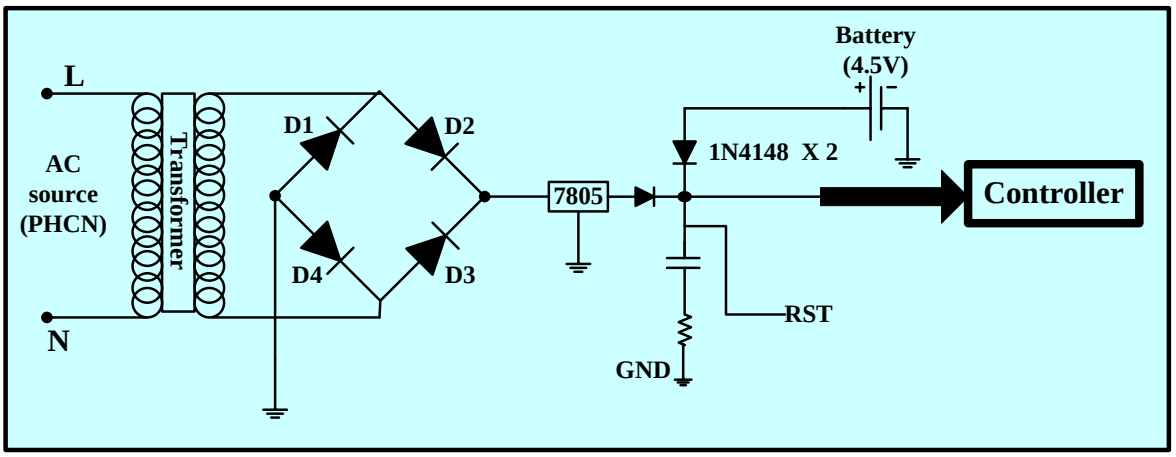

Fig. 5. A Regulated Power Supply

B. Flaming ions Sensor Module

The module sensed gas leakage through a flaming ions sensor, MQ-6 LPG CNG which was capable of detecting a wide range of gases including alcohol, carbon monoxide, hydrogen, isobutene, liquefied petroleum gas, methane, propane and smoke.

C. Fire Sensor Module

The module sensed smoke and send a signal to the GSM module for notification. A smoke detector is a device that senses smoke, typically as an indicator of fire.

D. Controller Module

This module comprised of PIC16F877A microcontroller that coordinated the activities of all other modules. The codes of the flaming ions and fire accident detection and notification were stored into the memory of the microcontroller for specific functions as programmed.

E. Buzzer Module

The module had a 30-120 VAC Warble Tone Piezo Buzzer 95dB to produce sound for the attention of anyone around the vicinity of the place where there was a possibility of fire incidence for intervention and rescue.

F. Display Module

The module had a JHD 162A liquid-crystal display (LCD) to display a message on the screen. The module displayed messages on the screen for the staff or relevant authority to see and respond. The room temperature was as well displayed for awareness.

G. GSM Module

The module had a Subscriber Identity Module (SIM) (STM32/SIM900A SIM800 GSM) modem for communication. Figure 6 showed a circuit diagram of the developed system. The GSM technology was used because, globally, an SMS could be sent and received in any GSM phone; it cheaper and readily avoidable by the poor citizens compared to internet-based communication mechanism.

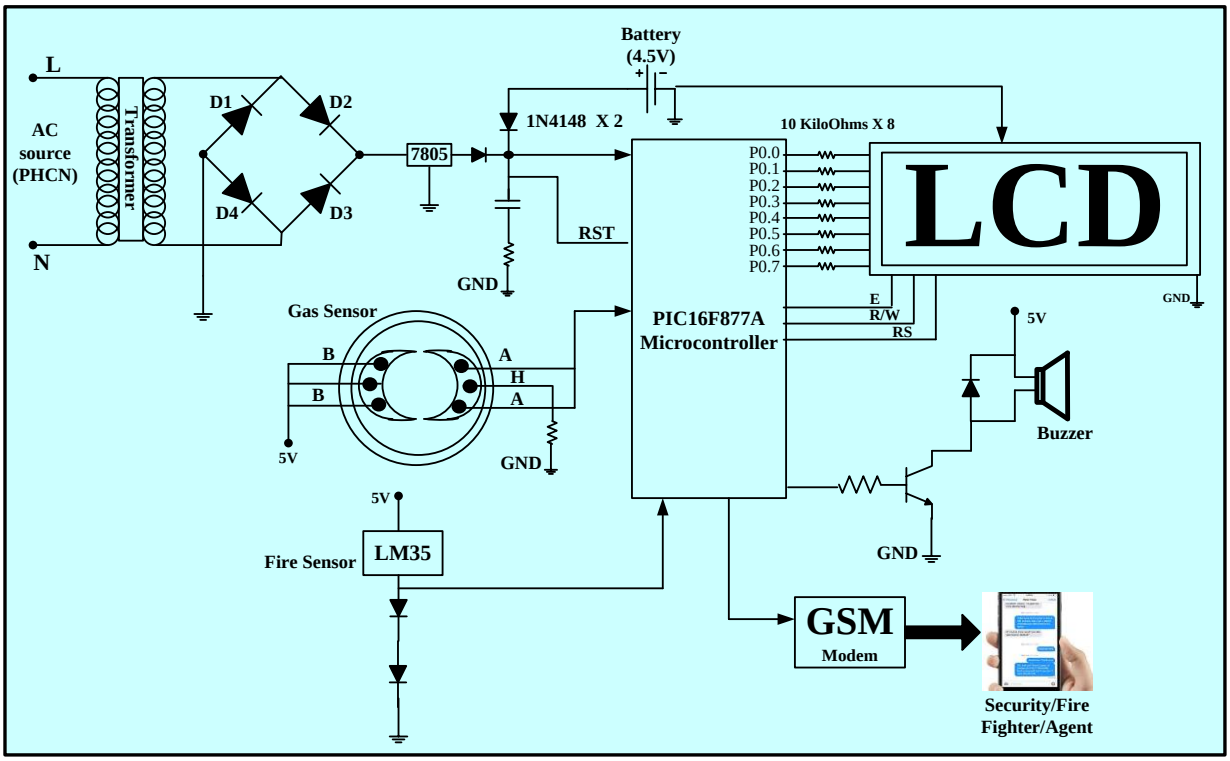

Fig. 6. Circuit diagram

6.2. Hardware Implementation

The major hardware components for implementation included: PIC16F877A microcontroller PCB, Breadboards, LEDs, transformer/adapter, push-button, HIH6130 temperature sensor, MQ-6 LPG CNG flaming ions sensor, warble tone piezo buzzer 95dB, SiMetrix 11.4 Simulator, PIC16F877A debugger, HD44780 Character LCD, STM32/SIM900A SIM800 GSM modem, crystal oscillators, capacitors, resistors, transistors, diodes and connecting wires. The components were connected and soldered as illustrated and simulated. Figure 7 illustrated the engagement of students in the designing and implementation of a flaming ions and fire detection and notification system.

Fig. 7. Students' involvement in the implementation

6.3. Software Development

The developed system was programmed in C-language. The C codes were edited using Crimson editor that is specifically designed PIC16F877A family of microcontrollers. The edited codes were transferred into Small Device C Compiler (SDCC) to compile the source codes into HEX CODES needed by the chip for proper execution. The last step in the software development involved the transferring of the HEX Codes into the chip and this was accomplished by inserting the microcontroller on the socket of PIC16F877A programmer connected to a computer for codes transfers.

Figure 8 shows a Unified Modeling Language (UML) diagram of a proposed flaming ions and fire accident detection and notification system. The UML diagram was used to model the proposed system functionalities and interactions with the administrator, relevant authority/fire fighter and vicinity personnel for prompt responses towards restricting the incidence of fire.

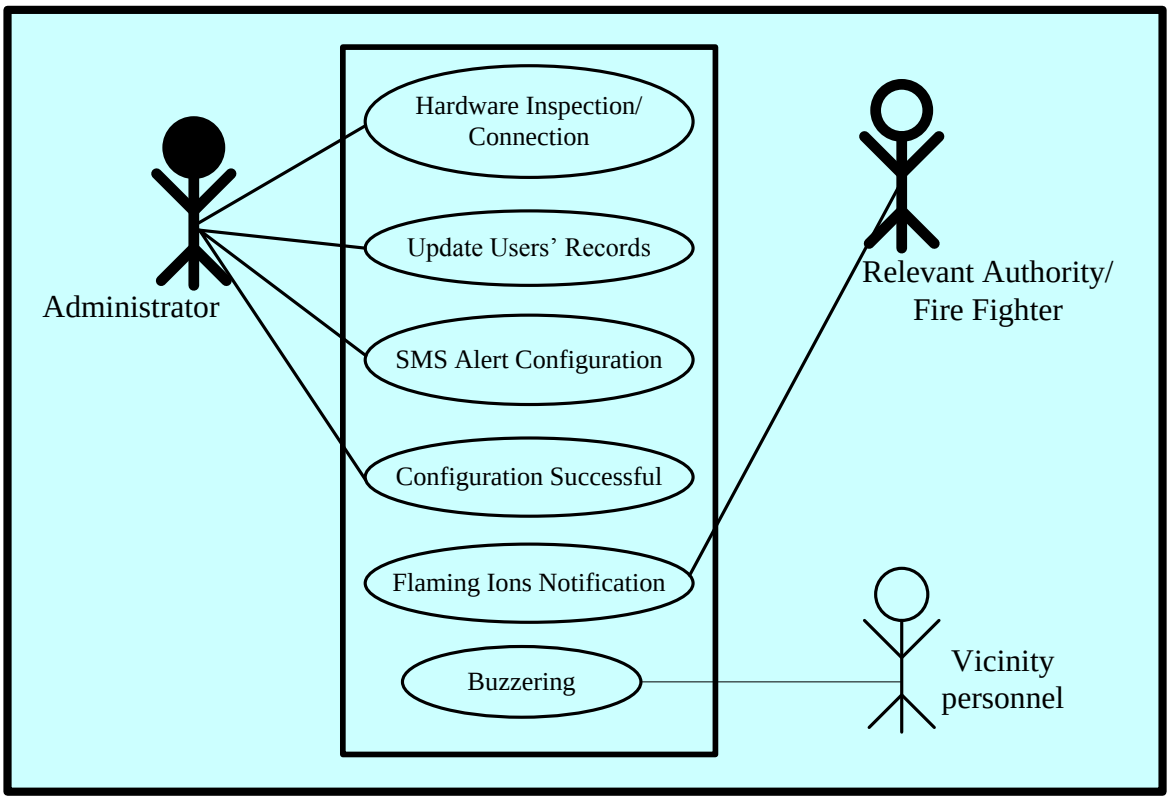

Fig. 8. UML diagram of proposed system

7. Experimental Results

The developed system was configured with an authorized mobile number as follows:

"CONFIG/ RECEIVER=+2348036572801&ALERT=ON"

The notification message of flaming ions detection could be switched off by replacing "ON" to "OFF" and a new mobile phone number could be updated by replacing "+2348036572801" with the new number. The inclusion of a country telecommunication code is important and must be included for the user to receive a notification at any geographical location worldwide.

The developed system was tested and the experimental outcomes/results of the research were illustrated in Tables 1 and 2, and graphically represented in Figures 9 and 10.

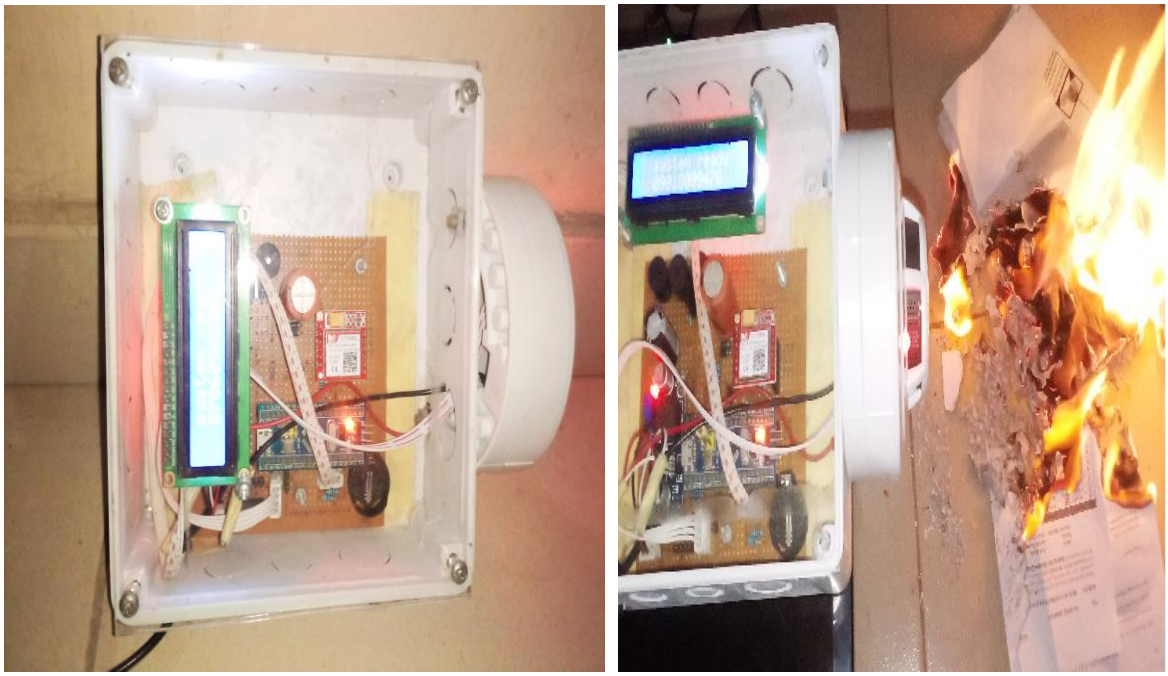

Fig. 9. Testing the flaming ions and fire detection system

Table 1. Experimental outcomes/results

Test case	Test event	Description of test	Outcome/result
01	Testing the system' modules	Each module of the developed system was tested to ascertain the specified functionalities	Each module responded according to the desired functions
02	Detecting of carbon-monoxide (CO)	The cylinder filled with carbon-monoxide (CO) was turn ON for combustible flaming ions detection and alert notification	The developed system detected the flaming ions and a notification of the presence of flaming ions was received by the relevant authority for urgent action
03	Setting materials on fire	Materials such as papers, woods, papers, plastics, wires and cellophane were set on fire for detection of flaming ions	The developed system detected combustible flaming ions and smoke, and notification of likelihood of fire incidence was received by the relevant authority for urgent action
04	Verification of SMS alert on the relevant authority mobile phones at different geographical places	The mobile phone of the relevant authority was checked for SMS on the fire incidence	The mobile phone received the SMS of fire occurrence at different geographical places

Table 2. Responsive times for different materials

Cases	Items burnt	Responsive time (s)
Case 1	Papers	2.27
Case 2	Plastics	4.01
Case 3	Woods	6.04
Case 4	Wires	3.09
Case 5	Cellophane	2.32
	Cluster time	3.55

The response mean-time of the developed system was approximately 3.55 seconds which was considered suitable for fast response by the relevant authority and fire fighters.

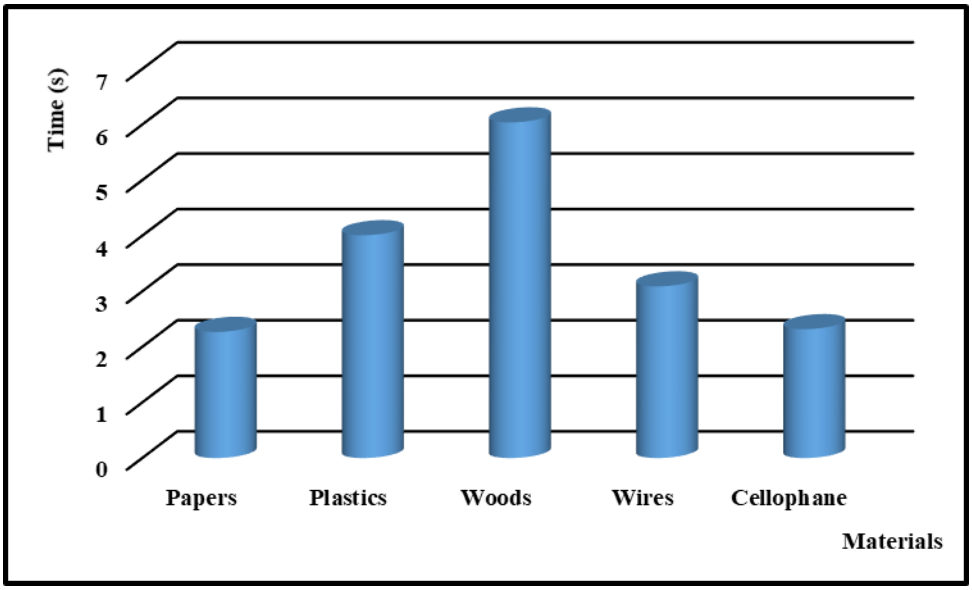

Fig. 10. Bar chart of responsive times for different materials

8. Conclusion

Fire is destructive that could cause damages to properties and even cause death to the lives of the individual. A proactive but technical measure is required to curtail the damages of fire incidence. Recently, a WiFi technology was used to implement a fire sensor which was not suitable for a relevant authority or fire fighter in a different geographical location and such system had a limited area of signal coverage. Other problems reviewed were diffraction, reflection, attenuation, short-distance, low speed of data processing, high power consumption, and false alarm from high room-temperature. In this research, an uninterrupted transmission of signal was accomplished with the use of GSM technology which allows data communication through walls, ceilings and long-range of transmission was accomplished even outside the geographical location of fire. The students in today education cannot be left out in the acquisition of computational skills for human capacity building and securing lives and properties through technology. This paper presented an implementation of a flaming ions and fire accident detection and notification system to provide students with knowledge of the c-programming language for the development of automated systems and self-reliance. Scientifically, a high level programming language was used to achieve the detection of flaming ions, SIM configuration, transmission, and reception of flaming signal in different geographical locations for fast response against fire occurrence. The developed system was tested with different materials such as wood, papers, and 3.55seconds was recorded as response mean-time to detect flaming ions and send a notification of likelihood of fire incidence to the relevant authority through a GSM module and buzzer within the vicinity of the detector. In conclusion, students were practical imparted with relevant computational skills and piece of information in this paper would be relevant for further scholarly investigation in the field of academic.

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