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An Automated Fire Detection and Reporting System Based on AI and IoT Technologies

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Abstract- Most of the fires that engulf public facilities and cause more damage to properties usually happen after working hours or when people are asleep, implying that, humans play a central role in fire reporting. In this paper, a Location Based Smart Fire Reporting system capable of eliminating human involvement is proposed. The proposed system employs two technologies, namely, the Internet of Things (IoT) and Artificial Intelligence (AI). The AI looks at the integration of sensors with the Arduino Nano board that works in converting the analogue data into digital data for decision making. The IoT technology communicates the converted digital data to the appropriate authorities or users. The proposed system is made up of a GPS sensor, Arduino Nano micro-controller, two temperature sensors, Gas (MQ4) Sensor, smoke (MQ5) sensor and GSM SIM900 module. A test implementation of the proposed system was conducted and it came to light the system able to detect naked fire, flames, gas leaks and smoke; a Short Message Services (SMS) is also sent to the users/owners with the exact GPS location coordinates of the fire incident. Another functionality of the system is its ability to disconnect power supply to an affected building whenever, fire is detected. There are threshold values set for each sensor, above which triggered the beeper. The system takes averagely 3ms to send and deliver messages in stable cellular network area.

Keywords- Location Based, Smart Fire Reporting System, Arduino, internet of Things, Artificial Intelligence.

I. INTRODUCTION

Unwanted fires have caused the citizenry of Ghana a whole lot of damage over the years. Ghana National Fire Service (GNFS) as a state organization mandated for fire fighting in Ghana. It is commendable how the Ghana National Fire Service is committed to executing their mandate with the adoption of technology. The GNFS has an established control room in each fire station meant for attending to calls. A national toll free number (192) is made available to the public whereby the call is rooted to the nearest fire station for proximity and quick response. The aforementioned technologies still have human beings making the calls and the time spent in rooting a national call to a district/local fire station takes time which eventually cause delay in reporting fire [3].

However, with the introduction of Internet of Things (IoT) and Artificial Intelligence (AI), there is no doubt that the service is still behind technology. The conventional way of calling for fire has contributed to most lives and properties being lost, resulting from GNFS delay in arriving at the fire scene due to poor property addressing system in the country [10]. This cannot be blamed wholly on the GNFS because the addressing system is very poor and time interval property users/owners spend to reach out to the GNFS via phone is unacceptable [6]. Case study at GNFS, Tamale Metro Station, it was clear that most domestic fires that caused unprecedented damage occur when people are not home. Same can be attributed to commercial or industrial fires as well as bush fires. Implying that, almost all properties engulfed in serious fires happen when human beings are not available to put a phone call to the GNFS [10]. Published by the Ghana News Agency on 31st May, 2022, Ghana National fire service, recorded a total of 4,467 fire outbreak between the periods of January to June, 2021 with over Two (2) million prank calls.

Therefore, this paper proposes the design and implementation of a Location Based Smart Fire Reporting System by leveraging on Artificial Intelligence and Internet of Things technologies for real-time notification on occurrences of fire and as well as the Actual location of incidence of fire. The proposed system shall use sensors such as smoke sensors, fire flame sensors, GPS and temperature sensors. It shall also make use of Arduino microcontroller board and SIM900 with both hardware and software components. The rest of the paper is organised as follows: Section II presents the methods and tools employed to get the final system, Section III presents an analysis of a test implementation results of the proposed system whiles the paper is concluded in Section IV.

II. METHODOLOGY

This paper adopts the agile prototyping approach whereby individual components are assembled and tested [2]. The integration of all components of the systems and testing them follow same process in achieving the desired result. This discusses both the hardware and the software components of the proposed Location Based Smart Fire reporting system. Additionally, this makes use of IoT technologies taking into consideration sensors (smoke sensors, gas sensors, fire flame sensors, GPS sensors etc), Arduino microcontroller, buzzer and GSM SIM900A to report fire or potential fire timely [5].

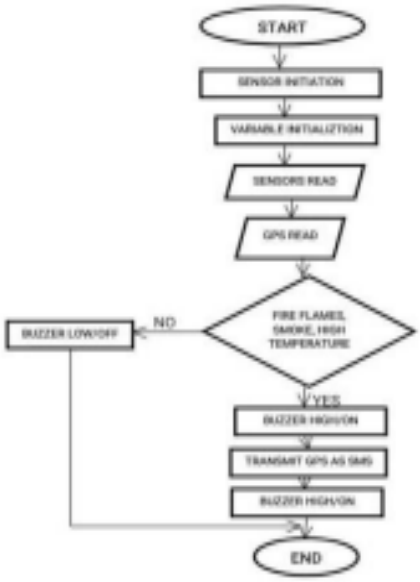

Fig 1. Flow Chart of the proposed system.

The sensors would be incorporated with the Arduino microcontroller to be fixed in a particular geographical location where the GPS sensor can read the current location of the device. This is to ensure that all the other sensors monitor the environmental conditions of where the device is located [9]. In an instance where gas, smoke, excessive high temperature or fire-flame is detected, the Arduino microcontroller simultaneously sends signals to the buzzer to alarm in the environment as well as a signal to the GSM Sim900 to transmit SMS with GPS coordinates to the nearest fire station for assistance [3].

Figure 1 is a flowchart representing the flow or the step by step operation of the proposed system. From the Figure (2) above, Arduino microcontroller serves as the central point of system where all the sensors are connected to [3]. The GSM Sim900A module is collected to Arduino microcontroller to enable call and SMS broadcast. The GSM Module is configured with the user's system and that of the fire service station's system. The sensors continuously read their environment and send the readings to the Arduino microcontroller. The microcontroller determines the impact of the data read, when the read information is above the pre-set values, then buzzer alarmed while SMS is transmitted. If values read are less, then it returns false, making the buzzer mute and no SMS would be sent [18].

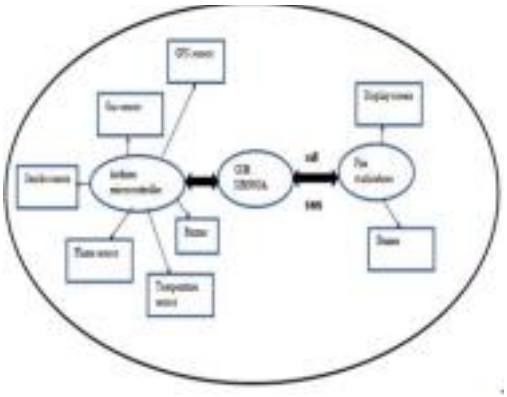

Fig 2. A Schematic Diagram of the Proposed Location Based Smart Fire Reporting System.

Figure 3 below shows the proposed circuit connection of the integrated system. All the components and units were individually configured for components testing purposes. Hence, Figure 3 represents the integration towards producing the desired results. All the components selected are guided by the selected objectives of this project.

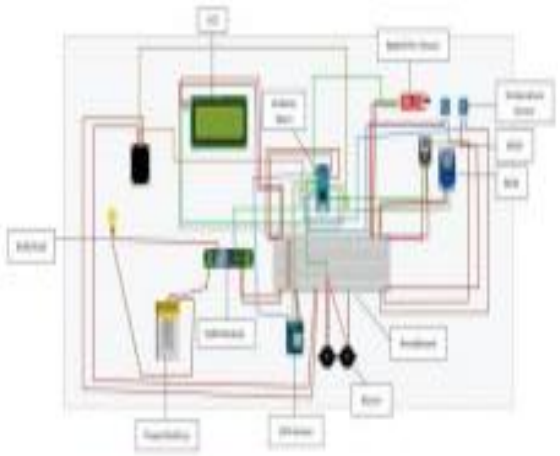

Fig 3. Full System Connection

As summarized in Table 1 is the components configurations. From Table 1, the digital pins of all components under consideration are configured with the digital pin of the Arduino Nano Board. All the analogue pins and the electronic components under consideration are configured with the analogue pin of the Arduino Nano, see [9] for more details. All the Ground (GND) pins of the components are configured with GND pin of the Arduino Nano. Finally, all the components required power to function and that their power (VCC) pins are configured with the Arduino Nano power (5V) pin [16] and [21].

Table 1. Full system Arduino Nano pin configuration and dependency library.

Component	Analog pin to Arduino Nano	Digital pin to Arduino Nano	VCC Pin to Arduino	Ground Pin to Arduino	Arduino Library
Sim900 GSM		Tx => D4 Rx => D3	VCC => 5V	GND => GND	SoftwareSerial
Neo 6M GPS		Tx => D13 Rx => D12	VCC => 5V	GND => GND	TinyGPS++ SoftwareSerial
Buzzer		VCC => D2		GND => GND	
20X4 LCD	SDA => A4 SCL => A5		VCC => 5V	GND => GND	LiquidCrystal_I2C
Flame Sensor		D0 => D6	VCC => 5V	GND => GND	
Relay		IN => D5	VCC => 5V	GND => GND	
DH11 (one)		S => D7	VCC => 5V	GND => GND	DHTesp
DHT11 (two)		S => D8	VCC => 5V	GND => GND	DHTesp
Gas Sensor (MQ4)	0 => A0	A	VCC => 5V	GND => GND	
Smoke Sensor (MQ5)	0 => A1	A	VCC => 5V	GND => GND	

1. Integrated System Test:
This is where all the sensors and other components mentioned above are being configured with the Arduino Nano micro-controller chip. This spelt out all the connections and integrated codes from all the components.

After successfully connecting all the components together with the Arduino Nano micro-controller as the hardware components of the system, the system required software in the form of a written instruction or codes to function. The hardware components alone cannot function until its corresponding code is run on it.

III. RESULTS AND DISCUSSION

Figure 4 below is the real physical design of the proposed system. This represents the physical result of the proposed system. All the components considered in the methodology are physically and electronically configured in Figure 4 as shown below.

Fig 4. The Complete Hardware System Design.

Figure 4 is the physical integration of components electronically with the Arduino Nano Micro-controller. This contains GSM SIM900, GPS Sensor, two Temperature Sensors, Gas (MQ4) sensor, and Smoke (MQ5) sensor. All the aforementioned sensors were configured with Arduino Nano micro-controller and integrated codes were ran on it. The initial proposal included the Electricity Company of Ghana (ECG) in the message broadcasting process to cut power supply to the area to prevent firefighters being electrocuted since water is a good conductor of electricity and an essential tool used in the fire fighting [1]. However, research is continues and meant to solve problems not to solve and create new problems. Why must a whole area be denied electricity because one house/property is on fire? Hence, this paper adopts the relay (automatic switching) to put power of a house/property off automatically in an event of fire. This was tested using relay and wall plug to demonstrate how power supply is curtailed in an even of fire.

First and foremost, the system itself needs power to function. For the purposes of effectiveness and safety, dry cells/battery was used [17]. Thus, the system should not use the same power that the facility is using or power from the same source or mains. This is not to say that, the system cannot be run using direct current from Electricity Company of Ghana (ECG). If the system uses the same power source with house, the main purpose of this project would be defeated, since power supply to the house would be cut off before the SMS is sent. In that case, cutting power supply to the house/property means cutting power supply to the system. It is against this background that this paper recommends dry cells/battery to be used and not same power source with building in question.

The system was tested using matches, mosquito coil and lighter to produced naked fire or fire flames, smoke and gas respectively. When any of these is sensed in the environment above the threshold values of the respective sensors, it is then seen as an anomaly, an SMS containing the detected value(s), and GPS location of the fire scene is transmitted to the proposed user. The SMS provided contains a link which when clicked, opens a Google map to show directions to the fire scene.

1. GPS Coordinates Notification via SMS:

Figure 5 below is a screenshot of SMS notification delivered by the system. This SMS contains the type of fire or the anomaly detected (gas, smoke, temperature or naked fire), the GPS coordinates and the Google map link. The Google Map link when clicked produces the directions in a form of a map and a live guide as to how to get to the fire scene.

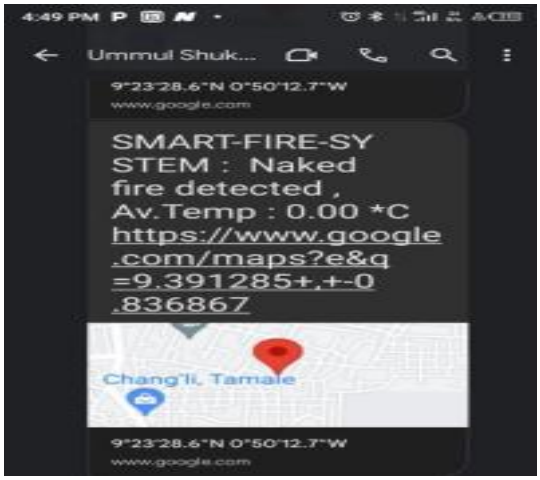

Fig 5. SMS Notification.

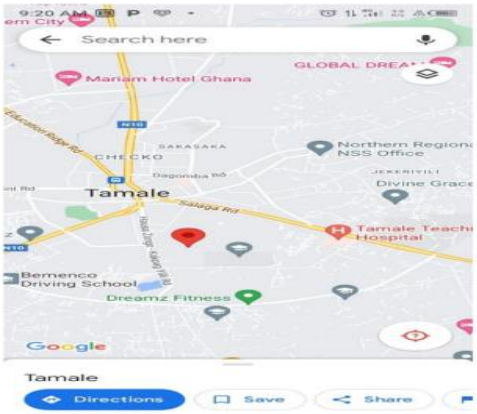

Fig 6. GPS Coordinates Notification.

Figure 6 above is a screenshot of the Google map directing to a tested fire scene where the Location Based Smart Fire Reporting System was tested.

As indicated earlier on, the sole purpose is to eliminate human involvement in fire reporting process whereby sensors are deployed to do the detection and reporting. This aim is achieved since the proposed system is able to detect fire or potential fire and report it to the appropriate authority and/or users. From the Figures (5 and 6) above, it is clear that the system successfully transmits messages containing the details of the fire including temperature and what is detected, whether it is smoke, gas or naked fire. These details arguably would further assist the Ghana National Fire Service (GNFS) to prepare adequately since the type and degree of fire is known in the report received. The GNFS eventually would become proactive in their mandate as a fire fighting institution. The Ghana National Fire Service need not roam in search of reported fire scene since the address of the fire spelt out and directions are given electronically. This system makes it possible to curb the issue of prank calls received by the Ghana National Fire Service.

2. Directions on Google map:

Figure 7 shows a screenshot of the directions experienced when the Google map link was clicked using smart phone and accessing the fire scene.

Fig 7. Detailed Google map direction.

Figure 7 and 8 further show how responsive Google map is when it comes to directions given. The distance between the GNFS and the fire scene is captured in the map and the best route to get there. The map detailed to the user/GNFS, the distance and time required to arrive at the fire scene. The user/GNFS is then prompted as and when they arrived at the fire scene. This proposed system would ensure timely intervention of the Ghana National Fire Service to save lives and properties.

The proposed Location Based Smart Fire Reporting System is a unique system and can stand the test of time. It is more efficient and resilient as compared to the already existing ones. The work in [2] presents closely

same system. However, their proposed system tied sensors together in a dependent manner. The reading in the temperature sensor had to rise above 35oC in order for the DHT11 to be triggered to operate. The proposed Location Based Smart Fire Reporting System built sensors independently and that the reading on one sensor does not depends on the data from another sensor.

Another similar project to the Location Based Smart Fire Reporting System is GPS Based Fire System by [8] In both case the fear of being electrocuted is still a possibility since both works, [2] and [8] failed to address power supply issue in the affected fire outbreak area. Unlike the proposed Location Based Smart Fire Reporting System, power supply is curtailed to an area, facility or building where there is a fire outbreak or potential fire outbreak using a relay (automatic switching).

While some of the literature reviewed tackled domestic fire, others tackled bush fire exclusively [5]-[15], [18]-[20]. Unlike our proposed system, it is universal and can be deployed in any part of the world. A Bush fire smart system does not necessarily need gas sensors and automatic switching, but domestic and industrial smart fire detection and reporting systems should incorporate that. Our proposed Location Based Smart Fire Reporting System is resilient, efficient and can be deployed in any environment.

IV. CONCLUSION

The paper presented the intricacies of the design and implementation of a Location Based Smart Fire reporting system with real-time notification of fire incidences. The proposed system incorporated five (5) sensors; for detecting naked fire, temperature, GPS, Gas and Smoke. It is also embedded with GSM SIM900 meant to connect the system with its users and relevant authorities. It also has a 2G supported SIM slot to accept SIMs from any network.

The System is environmentally friendly and causes no harm to its users and is easy to install and use, and does not require any serious training since majority of the proposed users use smart phones. Future work can look at ways by which similar systems are automated further to pre-set its own threshold values depending on the system pre-environmental reading and assessment. Also, system boards with enough memory to increase speed and efficiency should be considered.

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