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An Embedded System of Dedicated and Real-time Fire Detector and Locator Technology as an Interactive Response Mechanism in Fire Occurrences

Sheila Abaya[1a], Ejay Cabico[1b], Jonah Domingo[1c]
[1]Dept. Computer Studies and Systems
[1]University of the East
[1]Caloocan City, Philippines
[a]sheila_abaya@yahoo.com.ph,[b]ejaycabico@yahoo.com,
[c]jonahdomingo1211@yahoo.com

[1d]Rommel Diaz, [1e]Hiro Kojima, [1f]Ronel Rivera
[1]Dept. of Computer Studies and Systems
[1]University of the East
[1]Caloocan City, Philippines
[d]rommeldiaz08@yahoo.com,[e]hiroakikojima.hk@gmail.com
[f]nel_rivera18@yahoo.com

Abstract— **Fire alarm system is considered as one of the most essential mechanisms for safety against fire. In fact, most structural buildings especially the commercial ones are required by law to be equipped with this technology. The Bureau of Fire Protection (BFP) in the Philippines have recorded a total of 12,301 fire incidents in the year 2013, in the year 2014 there were 15,897 and in January 2015 a total of 1,848 incidents have transpired. Out of these incidents, 244 lives were lost in 2013 and 263 in 2014. Aside from the lives that were taken, these destructive killer fires also caused a lot of homeless individuals that have brought property damage to 5.5B in 2013, 3.3M in 2014 and 411M since January 2015. In spite of the figures, the BFP is still implementing measures that foster safety and fire prevention in whatever structural setup you are living or staying in. This information has motivated the development of an embedded technology of detecting and locating fire occurrence for possible deployment in the BFP agencies or fire stations in the country to provide immediate response and actions in mitigating fire incidents. The proposed system structure is an integration of sensors, microcontrollers and wireless sending of data. Homes, offices, schools or any building structure equipped with this technology will be an implementing measure in reducing the occurrence of destructive and killer fires.**

Keywords—fire detector and locator sensors; distributed control system; wireless transfer of data; embedded technology; Arduino; GSM Module;

I. INTRODUCTION

Fire under control can be very useful to the society, but a fire that goes out of one's control can create a massive destruction to property and even sacrifice lives. It can also cause impairment in the social and economic stability of the society and the country as well. In the Philippines, the Bureau of Fire Protection or also known as the BFP is the sole government agency mandated to protect lives and properties against destructive and killer fires. This entity delivers public awareness on life safety and fire prevention to preserve the lives and wealth of every individual and also tasked to provide several measures and ways to lessen fire accidents and one of these methods is the installation of fire alarms at home, offices, schools or structural buildings. Currently, the agency is implementing a manual way of detecting and locating fire in which most of the time, delays in emergency rescue is at far but implementing an automatic fire detector and locator system will save or rather alleviate the loss of lives and properties at all times. The technology of fire detector embedded with fire locator mechanisms designed and dedicated to recognize smoke and temperature caused by fire is wirelessly connected with the main fire control alarm technology and a pre-designed interactive mapping system installed in the BFP agency or fire stations will provide fire fighters with real-time information that will inform and notify the BFP persons of a fire incident and the exact location of fire.

II. MOTIVATION OF RESEARCH PROJECT

In the current setting, the BFP station is equipped with a bell that alarms whenever a confirmed caller informs the agency of a fire incident in a certain location. Confirming a fire incident and checking the exact location and address of the fire incident usually takes 5-7 minutes response time for the fire fighters of BFP to act and be sent to the alleged fire incident because the agency does not have a fire locator technology where they can easily detect the location of fire. A delayed reaction in a disaster just like in fire accident can cause a lot of harm not just in the properties but also in the safety of the society.

The project tries to resolve the following issues: a.) Unreliable detection of fire through calls - with the current system of BFP in relying only on phone calls that a fire incident is currently happening, they have to verify and validate first the information before responding to the report because chances are they could receive false information from unreliable source. b). Delay of notifications about occurrence of fire – since reported fire events have to be checked first before responding to the incident, it usually causes delay in rendering immediate emergency action to the alleged fire location, thus resulting to a massive destruction. c).Inability to

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detect fire – there is no way that BFP can immediately detect fire in certain place due to the absence of fire detection technology. d). Inability to speedily know the exact location of fire – the agency has no way of determining the exact point or location of fire which also hinders the fire fighters in providing a sudden response and action to the incident. These predicaments gave rise to the development of fire alarm technology system that will detect and locate the occurrence of fire thus will provide the agency specifically the nearest fire station a real-time and reliable information about the actual place of fire. With the implementation of the proposed technology, obstruction in detecting fire and determining the location of fire can easily be determined thereby resulting to an efficient and effective delivery of emergency action response to the public.

III. RELATED LITERATURE AND STUDIES

Several researches have been used and served as the foundation of this research project to push through. These studies have motivated the possible development and implementation of the available technologies that would help in disaster management such as fire incidents. In [1] research, it focused on the security and safety issues of the society today thereby resulting to the development of a real-time system through surveillance technology. Reference [10] is an article on smart homes security system, that buyers seek security through the combination of smoke-carbon monoxide alarm that links directly to a mobile phone which can alert the user of an emergency even if they are miles away. With [2] research, it provides technical information to aid in the development of guidelines and standards for the use of fire detection technologies for modern warehouse fire protection. It also consisted of the development of a fire hazard assessment system intended to provide insights into potential impact of early warning detection and notification with a goal of reducing the destruction of property. It was mentioned in the work of [3] that in developing a fire alarm system a smoke sensor and temperature sensor of separate product types belongs to a switch-based type. The combination of these types enables the system to give a comprehensive evaluation of the situation according to the temperature-gradient-rate and the law of smoke concentration change. Reference [4] developed a design and prototype in the implementation of fire detection and intelligent alarm system with the implementation of five circuits to compensate the proposed system operation which includes the Detection and Initiating Devices (DEADS), Notification Devices (NODES), Central Station Monitor (CSM), Annunciation Devices (ANODES) and the Suppression Circuitry. The prototype was evaluated based on the software quality characteristics defined in ISO 9126 and revealed the effectiveness of the practical application and development of the fire alarm system for an educational facility. Study of [5] dealt with wireless sensor networks and fusion information methods for forest fire detection wherein two algorithms were proposed. The first algorithm uses a threshold system and nodes equipped with temperature, humidity and light sensors and the second algorithm uses the Dempster-Shafer theory and assumes that nodes use temperature and humidity sensors. The research of [6] focused on the detection and early warning alert system through website and/or cell phones that alerts local subscribers of potential flood events. Several technologies were used such as detector, GSM module and microcontroller development board. The test was conducted to determine the efficiency of the proposed system by recording the time delay of the detection and found out that it is efficient and reliable enough to operate via wireless and that information could be readily available to the public**.** With the over growing number of Android users nowadays, it has been the focused on demand in the application of embedded systems such as mobile devices, camera and monitoring systems [12]. The GSM network is divided into three major systems such as switching system (SS), the base station system (BSS) and the operation and support system (OSS) and the GSM module is used to communicate with the user's mobile number [13].

IV. METHODOLOGY

The process flow of the proposed fire response mechanism shown on Fig. 1 starts with the smoke and temperature detector device that was installed in a structural building specifically in the "trial house". The chosen homeowner is within the proximity of the BFP station in the City. The device was set-up in a common place in a house which is considered as the prone area of a fire occurrence. Once an unexpected high degree of fire is detected, the device will send a signal to the microcontroller that will transfer codes to the GSM module serving as the receiver. The receiver device will then wirelessly send a notification to the pre-designed map located in the nearest fire station. The signal sent to the pre-designed map will trigger and turn ON the LED light placed in the pre-designed map which is an indication that there is a fire. The pre-designed map is the diagrammatic representation of an area of land showing the physical feature of the city covered by the BFP station. The map will serve as the guide of the BFP personnel particularly that of the fire fighters to easily locate the fire. With the real-time identification of the exact location of fire, delays in response will be avoided thus an immediate rescue and emergency services will be provided.

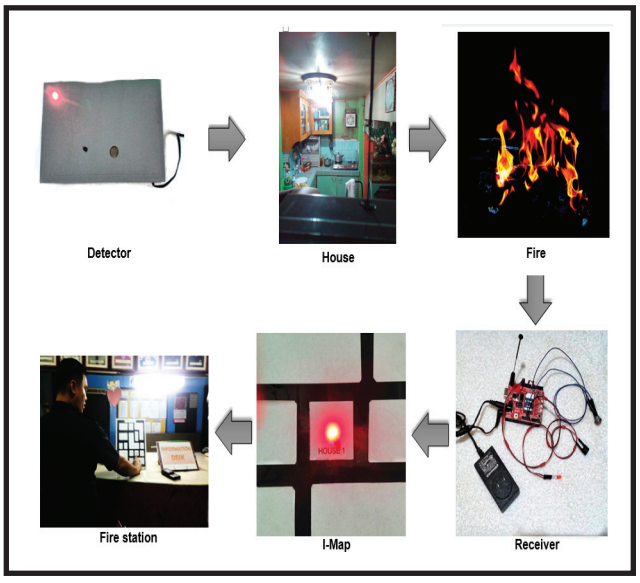

Fig. 1: Proposed process flow

A. Pseudo Code

Below is an excerpt of pseudo code applied in the detector device to send and receive signals.

- Pseudo code for sending signals:

1. Reading the input on analog pin 8 and read the input on analog pin A1 of the microcontroller
2. If the sensorValue detects greater than 500, the ledPin and buzzerPin will ON
3. The value will equal to 1 if the SmokeSensor detects greater than 500 which means true
4. The value will equal to zero if sensorValue detects greater than 500 which means false
5. If the SmokeSensor detects greater than 150, the ledPin and buzzerPin will ON
   The value will equal to 1 if the SmokeSensor detects greater than 150 which means true
6. The value will equal to zero if SmokeSensor detects less than 150 which means false
7. When the smoke and fire are both true, the ledpin and the BuzzerPin will turn ON

- Pseudo code for receiving signals:

1. Declare pin 13, 7 and 10 of the Arduino to be used for debugging purposes
2. Start the Arduino with a baud rate of 9600
3. Set Arduino and GSM to ON
4. Pos=sms.IsSMSPresent(SMS_UNREAD), save the messages in index
5. Display the position/index of the message
6. Get position/index, number of sender, and text message
7. Display the text on serial monitor
8. Set the sender's number
9. If the sender's number is the same as the registered number
10. The GSM set to received message "ON"
11. The ledpin will turn ON when GSM received message "ON"
12. The buzzerpin will turn ON when GSM received message "ON"

B. Hardware Component

Arduino is an open-source physical device that is used to develop stand-alone interactive objects that can be connected to software on the computer [11]. Fig. 2(a) presents the components of the smoke and fire detector device. (1) GSM module which transmit and decodes data from a cellular network establishing a communication between a cellular network and the computer, thus making the transmission of data unwired. (2) Arduino microcontroller executes the instructions of the program written in C-like Arduino language. The program is required to read the inputs and generate outputs. (3) Smoke sensor is tasked to detect smoke through the opto-electronic techniques and operates on the light scattering method. (4) Buzzer is used to provide means for audible identification of an alert or an emergency. (5) LED spot is used to provide light using the outright movement of electricity on the path of the semiconductor. The bulb signals that the device is capable of accepting and sending signals. (6) Mini breadboard houses the electronic circuits inside the detector device. (7) Flame sensor detects if a pilot light or the main flame is actually lit (8) and Adaptor is the device used to connect the detector device in the single main socket.

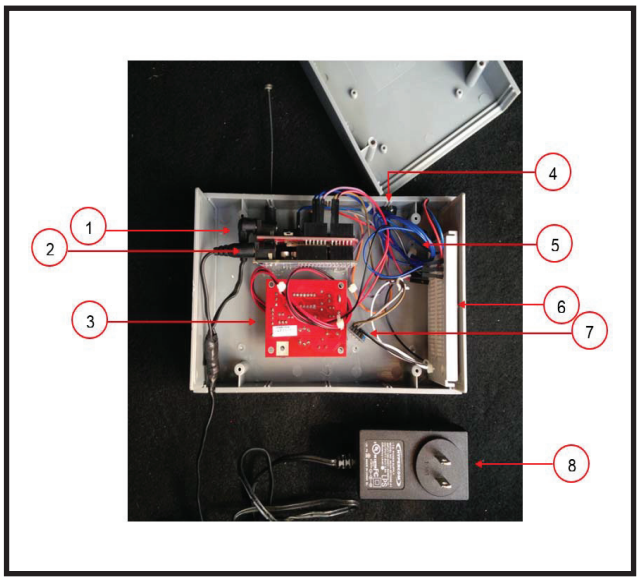

Fig. 2(a): Parts of the device detector

In Fig. 2(b), the receiver device has the following components: (1) GSM module, (2) Arduino Uno microcontroller, (3) adapter, (4) button that allows the fire officer to stop the alarm, (5) buzzer, and (6) LED light that is attached to pre-designed map. It is the LED that lights up a particular portion of the map after receiving a signal. This signal will provide fire fighters with real-time information about an occurrence and the exact location of fire, particularly the house in the city.

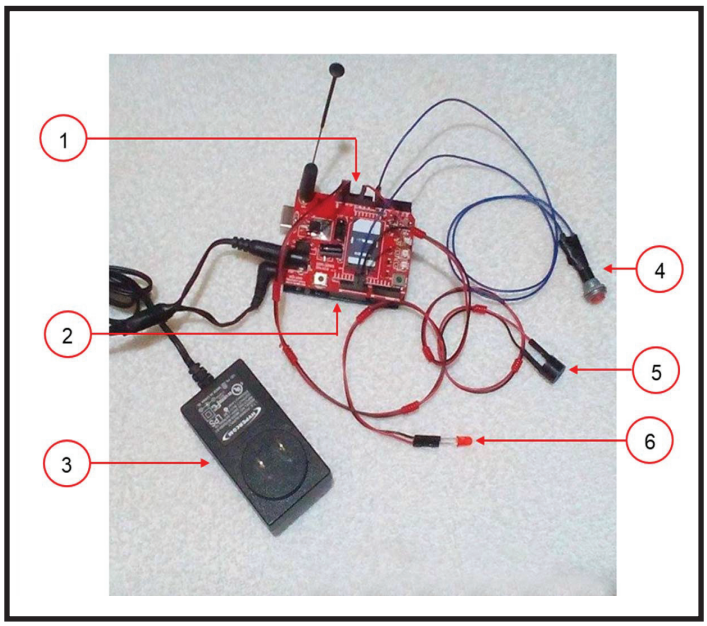

Fig. 2(b): Parts of the receiver device

C. Technology Set-Up

As shown on Fig. 1, the detector device that was installed in a particular house located within the proximity of the fire station was registered in the station and the house address was plotted in the pre-designed city map. On the other hand, the pre-designed city map was installed on the BFP station to be used as reference guide in determining fire location. The sensitivity detector device was tested by setting a small fire on the house and as expected, real-time response was received by the BFP station personnel. The pre-designed map LED was turned ON pointing to a particular location of the house and buzzer was turned ON that alarmed the fire fighters of a needed emergency response. The information that was provided by the pre-designed map is an indicator of a fire occurrence and that there is a need for a quick response and action.

D. Technology Evaluation Criteria

The proposed technology was evaluated based on ISO 9126 criteria which is the international standard for evaluating software quality. The framework of software quality model has the quality characteristics of: Functionality, Reliability, Usability, Efficiency, Maintainability and Portability to establish the technology acceptability as a response mechanism in fire occurrence. The **functionality** identifies the purpose of the technology that it provides. It focuses on the relationship of the proposed technology with the intended users of the application. The **reliability** defines the ability of the application to handle and withstand failures. It is the capacity of the system to maintain its service provision under defined conditions. The **usability** focused on the learnability of the application and how well a technology can be used by the intended users. **Efficiency** focused on the essential issue of performance based on the attributes of response and processing times and the throughput rate of the application. The **maintainability** factor is referenced as supportability. It is impacted by the code readability or complexity and modularization. It is the ability to verify the system through its testability feature. The **portability** attribute has the sub characteristic of adaptability. It refers to how well an application can adopt to the changes in its environment.

The mean result for each criterion was computed to determine the users' acceptability level of the proposed technology. Table 1 was used as reference to measure the mean rating scale for every software quality factor which will determine whether the proposed response mechanism is acceptable or not.

TABLE I. EVALUATION SCALE

Range of Mean Result	Evaluation Rating
4.0 – 3.01	Highly Accepted
3.0 – 2.01	Moderately Accepted
2.0 – 1.01	Fairly Accepted
1.0 and below	Not Accepted

V. RESULTS

The research project was initially demonstrated to and evaluated by the Bureau of Fire Protection personnel: Chief of Operations, Fire Safety Enforcement, Fire Safety Inspector, Fire Safety Education, Services Clerk, and Operations Crew/EMS Crew with the participation of a chosen homeowner which served as the "trial house" and some technical people for the maintainability aspect of the proposed technology. Sub-characteristics per software quality model factor were used such as: ***Functionality*** – (a)Running the technology immediately after turning it on and (b) Immediately detecting the heat and smoke to trigger the alarm, ***Reliability*** – Capability of the proposed technology to provide accurate and trustworthy information of the exact location of fire to the fire station personnel when met with software and hardware failures, ***Usability*** – (a) Functionalities of the application can easily be understood by the users and (b) the ease-of-use can be achieved in terms of human interaction, ***Efficiency*** – The useful work performed by the proposed technology to achieve the research project objective, ***Maintainability*** – (a) Easiness in identifying the root cause of system faults and failures, (b)An effortless verification of system change or testing and (b) The uncomplicated way of modifying the system when there is a need for some alterations and ***Portability*** – Proper adaption of the device into the location where it will be installed both in the BFP station and into the household.

Presented on Table 2 is the mean result for every criterion used. It was shown on the table that each mean for the quality characteristic falls in the range of 3.50 – 4.00 which is interpreted as "Highly Accepted" based on Evaluating Rating of Evaluation Scale. Based on the result, it revealed the acceptability aspect of the proposed fire detector and locator technology to the intended beneficiaries and the probable implementation of the fire response mechanism technology to several BFP agencies or fire stations.

TABLE II. MEAN RESULT

Criteria	Mean	Descriptive Rating
Functionality	3.75	Highly Accepted
Portability	3.75	Highly Accepted
Reliability	4.00	Highly Accepted
Efficiency	3.50	Highly Accepted
Usability	3.93	Highly Accepted

VI. CONCLUSION

With the proper implementation and integration of the current technologies, the proposed fire response mechanism will help in cases of emergency that would provide real-time information to prevent or mitigate the loss of lives and properties. Through the introduction of the proposed mechanism, the firemen specifically, will be provided with the needed and timely information about the location of fire and that they can immediately respond to the public needs thereby

preventing injuries, deaths and property destruction from fires. The centralized installation of the new mechanism in different BFP fire stations all over the city will enable these stations to communicate effectively and be informed of the fire occurrence and location, thus providing an efficient service to the society adhering to the BFP's doctrine of life preservation in cases of emergency, disaster and calamity. It is recommended in the future development of the project that the Interactive Map can be linked into a desktop PC that when the alarm is triggered, the PC will display the smoke optical density, temperature values that will identify the degree or level of fire**.**

Acknowledgment

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