AUTOMATED FIRE RESCUE SYSTEM USING IOT FOR A CONFINED AREA

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ABSTRACT

Human and resource losses which are caused by fire accidents are irreplaceable. Each blaze begins with a flame and with time, it will turn into a fire which ruins its surrounding. In order to reduce the damage, the fire should be extinguished in its early stage. The particular study has aimed to develop an Automated Fire Rescue System to overcome this issue. It has focused on two main tasks: real-time surveillance of the confined area and automated alert passage to the predefined people. The system includes three main parts – sensor unit, transmission medium, and mobile application. Sensor unit is a combination of sensing subsystems and firebase act as the transmission medium in the system. Sensor unit of the system sends the readings of real-time surveillance to firebase. Each fresh reading is pushed and updated to the mobile application which is dedicated to fire brigadiers and the residential people of the area. The experimental results of the study showed that the Automated Fire-Rescue system was able to send the notifications in not more than 25 seconds.

Keywords: fire rescue system, sensor unit, transmission medium

1. INTRODUCTION

Fire accident is one of the most critical situations where the state of the surrounding turn to worse within a small time. Massive damages could arise to both lives and resources unless it is extinguished in its early stage. Preliminary surveys on the issue revealed that lack of efficiency in manual alert and request to the fire brigadiers is the major factor that delays the process of extinguishing.

The particular study is aimed to develop an Automated Fire Rescue System to overcome the above-mentioned issue. Moreover, it detects many factors, which are essential to the fire brigadiers, such as level of carbon monoxide, temperature, humidity level, and the location of fire occurrence. Analysis of temperature and humidity level is used to decide whether the location is a safe zone for human entrance. In addition to that, the system unlocks the entrance or exit of the confined area and keep a count on the number of people within the defined region.

Though the system is originally made of three parts as sensor unit, transmission medium, and mobile application, in order to produce a user- friendly product, the system is designed as a combination of two

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main sections: System Hardware and Mobile Application. Users have nothing to do with the system once it is engrained. In case of a fire, they will be alerted along with the relevant information by the system hardware through the mobile application.

2. RELATED WORK

Several researches have been undertaken so far for fire detection and extinguishment. Reinforcement in Information Technology and Computer Science have unzipped a vast list of mechanisms and techniques to accomplish the mentioned process in an accessible manner.

An Automatic Firefighting System (Adam, 2014) implements an early fire detection mechanism and communicates with its owners wirelessly over GSM network. It's capable of putting out fire by means of a firefighting pump and to justify the status of the indicator panel that provides visual feedback of the current status of the monitored environment at any given time.

Another research study explains about the hybrid suppression systems which propose a new fire suppression technology that is used to protect a variety of spaces ranges from machinery enclosures to computer server rooms. These new hybrid systems utilize both an inert gas (typically Nitregon) as well as a fine water mist to provide fire suppression and extinguishment more efficiently than stand alone inert gas or water mist system. (Gollner, 2014)

Spearpoint M.J focus on detecting the presence of fire in the fire detection (Spearpoint, 2007). Suitable technologies and prevailing methodologies are analyzed. Paper also elaborate the components of equipments that could be used for the process.

A fire Detection System Using Artificial Intelligence techniques (Kakde et.al,
2018) proposes a model which is capable of detecting fire in Real Time. Detection is done in the basis of color and controus and bounding boxes are used for the detection purpose. System is enhanced with Google Text to Speech recognition due to which is capable of generating the alert to when fire is detected.

3. METHODOLOGY

Functional flow within the system can be depicted as below:

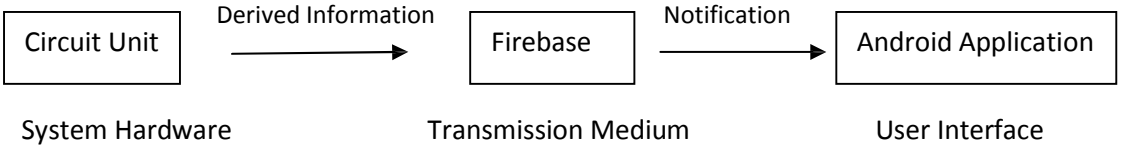

Figure 1. Functional Flow

With the power supply, the system starts to count and display the total number of people in the confined area at the entrance.

Except for continuous updating of the headcount, the system remains constant in its initial state until the existence of fire is detected.

The operation of the system begins with the activation of a fire alarm. With the detection of fire, the system unlocks the entrance of the room and classify the strength of fire by measuring the temperature. Finally, the system sends a notification which includes all the above records to the android application.

Therefore, implementation of the system followed the same order – system hardware, firebase, and Android application.

4. SYSTEM HARDWARE

System Hardware is developed with the traditional approach of prototyping. As it attempts to reduce inherent project risk by breaking the project into smaller segments, it is identified as a suitable approach for the system (Selecting A Development Approach, 2008). System design is divided into five subsystems, each of which performs a separate set of processes.

- Fire Detect and Alert System
- Safe Zone Declaring System
- Headcount System
- Door Unlocking System
- Location Detecting System

System Hardware is developed by integrating all the subsystems together. The output of fire detection and alert system is programmed to be sent as the input for the other subsystems. Results of each subsystem are finalized as a statement and combination of statements are pushed to firebase.

a. Fire Detect and Alert System

The first and foremost function, which is performed by the system, is fire detection. One of the following two conditions is verified to finalize a fire occurrence.

- Flame value should be lower than the threshold value of 100.
- Carbon Monoxide (CO) limit exceeds the threshold value of 250.

In order to measure the flame value and carbon monoxide limit of the confined area, the system is designed with Arduino Uno, KY026 flame sensor and MQ7 gas sensor. Additionally, a buzzer is attached to alert the surrounding. Above mentioned threshold values for both flame and gas sensors are finalized through the preliminary studies and the experimental test results.

Table I shows the experimental test results of carbon monoxide readings. As all the readings are recorded above 250 in the presence of a smoke, it is finalized as threshold value for CO limit.

Table 1. Gas Sensor Readings in the Presence of Smoke

Day	At 10 am	At 12 pm	At 2 pm	At 4 pm	At 6 pm
1	256	260	333	275	333
2	256	260	326	278	326
3	258	260	356	283	356
4	259	262	405	285	405
5	261	264	434	290	434
6	263	264	437	290	441
7	264	265	454	291	454
8	264	265	465	296	465
9	264	267	475	296	475
10	265	267	478	298	481
11	267	267	484	300	484
12	268	268	485	305	492

Table 2. Flame Sensor Readings

Turn	Sensor 1 (f1)	Sensor 2 (f2)	Sensor 3 (f3)	Sensor 4 (f4)
1	98	99	90	98
2	97	95	91	95
3	95	97	95	96
4	98	90	89	90
5	87	89	86	98
6	99	98	84	90
7	92	93	90	94
8	96	94	93	93
9	94	90	90	94
10	92	91	95	90

Experimental test results of flame sensor readings are recorded in Table II. Flame values of all four sensors at the presence of fire during various times of a day are shown there. Average of maximum flame values which are recorded by each sensor is chosen as the threshold value for fire.

Threshold value = (Sum of maximum flame sensor readings) / 4

= (f1+f2+f3+f4) / 4

= (99+99+95+98)/4

= 97.75

Placement of the components is the other important factor that should be considered regarding the system. Though the gas sensor is attached in the top middle of the area, the performance of the flame sensor shows more effective when it is placed on the corner of the area. Detection area of an individual flame sensor in two different placements are shown in figure 2 (Flame Sensor FS-5000E Istruction Mnual).

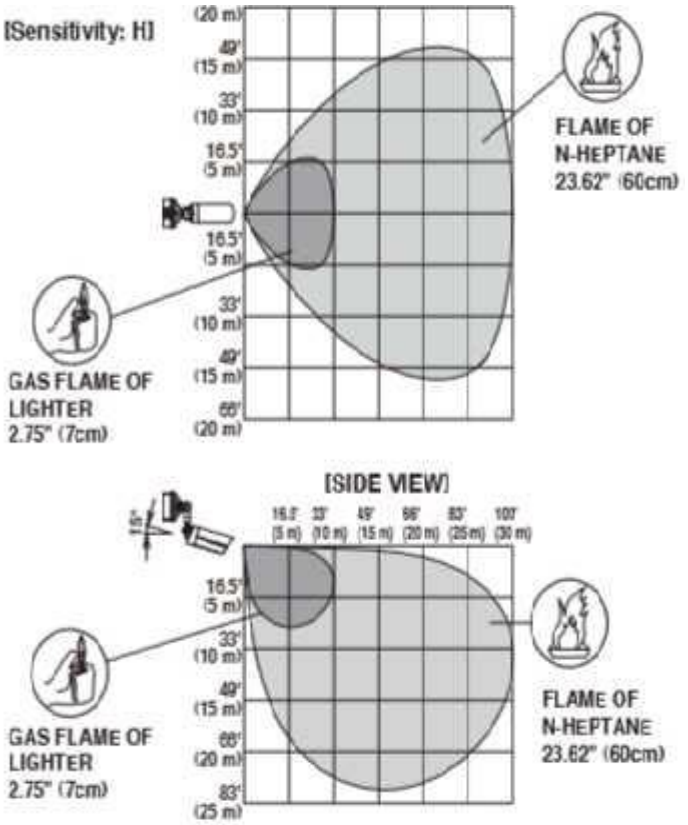

Figure 2. Detection Area of Flame Sensor

The feature of 0 – 60 degree detection is identified as the reason for the corner placement (SPOLOCNOST, n.d.). In order to increase efficiency, four flame sensors are fixed to the corners of confined regions as shown in figure 3.

As soon as a fire is detected, microcontroller release the command to activate the buzzer to alert the surrounding.

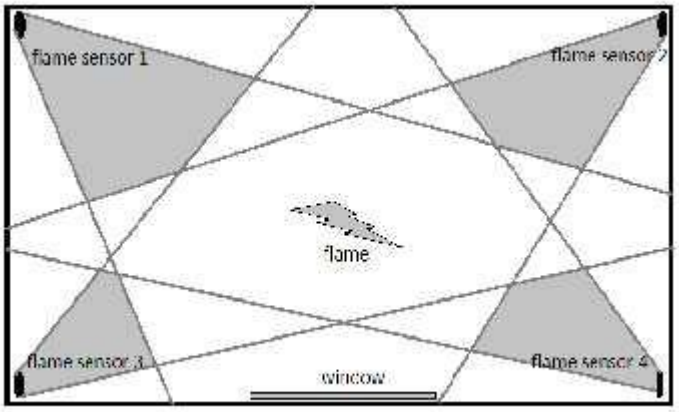

Figure 3. Placement of sensors on the system

b. Safe Zone Declaring System

Another main function which is performed by the system is declaring whether the confined area is a safe zone for human entrance. Temperature value and humidity level are the two key factors that are used to identify the safety of the surrounding. In order to be an area which is suitable for human entrance, the region should be maintained with room temperature and 55% – 65% relative humidity (B. & K.Nice)

Table 3. Zone Declarations

Zone Declaration	Display	Temperature (^{0}c)
Safe	Green	35 – 43
Danger	Blue	42 – 120
Critical	Red	119 <

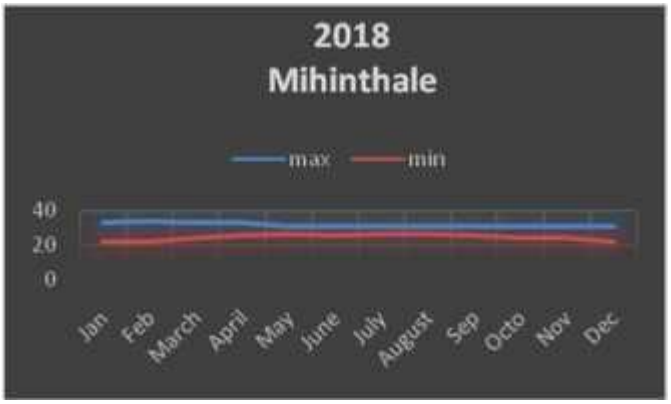

Figure 4. Experimental results for standard room temperature.

As the relative humidity shows a considerable decrement with temperature increment (B. & K.Nice, n.d.) (2016), the system is designed to monitor both temperature and humidity levels. Intervals between the values are defined according to the preliminary experimental results as shown in figure 4 and figure 5 (e-Bay, n.d.) Figure 5 depicts the humidity comfort levels (Weather Spark, n.d.)

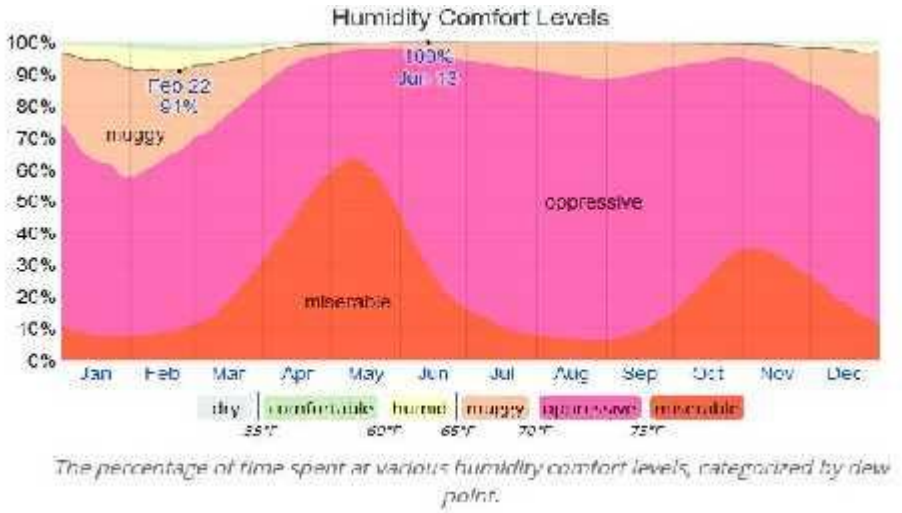

Figure 5. Humidity comfort levels (Weather Spark, n.d.)

c. Headcount System

Rescuing human lives is the utmost purpose at a fire accident. But finding the exact number of people trapped inside an area is not a simple task. Arduino mega, PIR sensors and ultrasonic sensors are used to track and count the number of people. Ultrasonic sensors are used to detect an obstacle and PIR sensors ensure the obstacle as a living being.

A couple of ultrasonic sensors and PIR sensors are attached to the top of both the internal and external interfaces of the entrance. When the internal sensor`s detection is followed by external sensor`s detection, the system considers it as an addition to human count and vice versa. Just as in the flame sensor, the placement of the PIR sensor plays a major role in the system. It must be fixed as the following in order to receive the most effective fixed results. (Fire Protection Engineering, 2008)

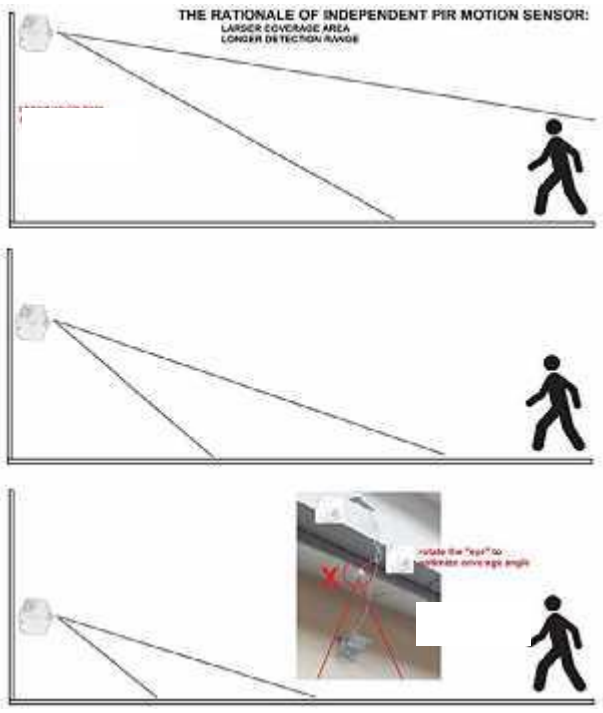

Figure.6 – Placement of PIR sensor

In addition to the features and functionalities, the system involved with two prominent assumptions – No living being except humans are allowed to the confined region and the entrance permits only one at a time.

d. Door Unlocking System

Another dilemma which arises during a fire is locked entrance or exits. Preliminary surveys on the issue have revealed that locked entrance or exits act as a cause for a dilemma during a fire. Therefore, the door of the confined area is connected to the system through a servo motor in a manner where the normal entry and exit is not disturbed.

Whenever fire is detected, the system checks the current condition of the door and release the command to unlock it automatically if the door is in a lock state. The current condition of the door (open or close) is checked through the following algorithm:

```
Begin
        Initialize lock to 1
          Initialize fire to 1
          Input flame value
          Loop
                  If fire detected
                                  Set fire to 1
                                    If lock equal to 1
                                      Unlock the door
                                                  Set lock to 0
          If fire not detected
                                  Set fire to 0
                                    If lock equal to 0
                                    Lock the door
                                                  Set lock to 1
End
```

e. Location Detection System

Location of fire is the initial factor that is needed by the fire rescue team. As the system mostly focuses on indoor locations SIM 900 GSM module along with an Arduino Mega is used to trace the location. With the detection of fire, GSM Module detects the longitude and the latitude coordinates of the relevant area.

5. TRANSMISSION MEDIUM

Firebase – Real time database was selected as the transmission medium by considering the following two factors.

Unlike Bluetooth, transmission medium should be able to transfer data to any distance. As the sensor readings should be updated to mobile application in a real-time manner, transmission medium should be able to tackle with real – time data.

All the detected data from the sensor unit is sent to firebase as four notifications – alert, temperature (zone variation), headcount and location. As firebase is a NoSQL database, all these detected data are stored as JSON files. When a fresh data arrives, it replaces the old ones on the file.

System Hardware is connected to firebase using a microcontroller Arduino Nodemcu esp8266. As soon as new data has arrived, it updates each fresh data to the mobile application.

6. ANDROID APPLICATION

As the purpose of the android application is to notify the user regarding an emergency situation, it is developed as a simple and user-friendly interface.

Android Studio and Java are used as front–end and back–end development tools during the process. The application does not focus on any other feature than the notification display and it is built with android version 4.4 (KitKat). It was designed

with an interface which contains four slots with each one displaying a different notification.

Android Application is connected to firebase through mobile data connections. Each slot in the interface is connected to a JSON file which receives the notifications from the circuit unit. It is programmed to push each new data to the relevant slot in the interface through the same data type variable.

7. EVALUATION

Once the prototype was integrated by connecting all the separate sections, it was sent through final experimental tests. Ensuring the time limits to complete the process in various conditions are in acceptable ranges is one of the major requirements of testing the system. To finalize the result, prototype was connected to various network connections and received the test results as shown below in table 5.

Through these experimental test results, it was deduced that "Automated Fire Rescue System Using IoT for a Confined area" is able to notify a user or a fire brigadier regarding a fire in no more than 25 seconds.

Table 5. Time Taken to Receive a Notification

Connection	Type	Time (s)
SLT_4G-116032	Private	11.76
ASPAC	Public	18.70
Applied	Public	23.91
Sanku-4G	Private	13.03
Dialog-4G	Private	10.64
Dialog (3G)	Mobile	12.82
Mobitel (4G)	Mobile	10.43

8. CONLUSION

Developed Automated Fire Rescue System detects a fire in its early stage without any human interaction and notify the fire rescue team in no more than 25 seconds.

9. HYPOTHESIS

- Power supply and network connection are constant to the system.
- As none of the safety techniques are applied to the system, performance of the system after a fire occurrence is not assured.
- All the preliminary studies and experimental results are collected through a prototype testing. Therefore, it should be scaled to relevant ratios during the implementation.

10. FUTURE WORK

For future development, headcount is planned to be developed without the mentioned assumptions. Moreover, it is planned to release CO2 extinguisher automatically when the headcount reaches zero.

11. ACKNOWLEDGEMENT

In developing our project throughout the time period, we guided by many respectable characters, who deserve greatest gratitude. We acknowledge our gratitude with a great respect to all the lecturers in Department of Computing, Faculty of Applied Sciences, Rajarata University of Sri Lanka

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