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Multisensory Fire Detection and Alerting System Using Fuzzy Logic

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ABSTRACT

This paper presents the design of a fuzzy logic based multisensory fire detection system and a web-based notification system. Recently, most fire detection systems working with the help of only smoke detectors. The problem is the lack of adequate alert and notifying mechanisms. A typical system relies on the physical presence of a human being to act on the alert. In developing countries, poor planning and addressing negatively affects the fire and rescue crew's response time. To address this problem, a fuzzy logic system was implemented using an Arduino development board with inputs from an MQ2 smoke sensor, a TMP102 temperature sensor, and a DFRobot flame sensor. The output of the detection system is sent over short message service (SMS) using a SIM900A global system for mobile communication (GSM) module to the web-based system and the house owner or caretaker in real-time. With access granted to the web-based system, the fire and rescue crew also get notified in real-time with location information. A comparison between the efficiency of the notification system employed by standard fire detectors and the multisensory remote-based notification approach adopted in this paper showed significant improvements in the form of timely detection, alerting, and response.

Keywords: Data Fusion, fire Detection, Fuzzy Logic, Microcontroller-Based, Real-Time, Web-Based.

I. INTRODUCTION

In India, every year about **25,000 persons die** due to fires and related causes. Female accounts for about **66%** of those killed in fire accidents. It is estimated that about **42 females and 21 males die every day in India due to fire.** According to the statistics released by the National Crime Records Bureau, fire accounts for about **5.9% (23,281)** of the total deaths reported due to natural and un-natural causes during the year 2012. Probably many of these deaths could have been prevented. No comprehensive data is available in India on the economic losses suffered on account of fires. However, according to one estimate the major losses reported by the Indian Insurance Companies in the year 2007-2008 indicate, that about **45% of the claims are due to fire losses**. According to another estimate about **Rs.1000 crores are lost every year due to fire.** Fire losses are reported both in industrial and non-industrial premises like hospitals, commercial complexes, educational institutions, assembly halls, hotels, residential buildings, etc… According to Fire Risk Survey (FRS) 2013, carried out by Pinkerton & Federation of Indian Chambers and Industry, in India**, fire accounted for 8.45% of the overall ranking of risks**. FRS also revealed that **fires has been rated as the 5th highest risk in industry in 2013.** Even though it is important to adhere to fire safety measures, putting in place early detection systems greatly mitigates the effects of fire outbreaks. This has led to a lot of novel contributions in the field of fire detection. The need to produce a more reliable fire detection system devoid of false alarms has led to the adoption of a multisensory approach. Unlike fire-detection approaches relying solely on smoke, this approach relies on the detection of more than one fire signature. Due to the effectiveness and efficiency of multisensory-based fire

detection systems, current research on fire detection is largely focused on developing better algorithms and processing techniques based on the data received from the sensors, thereby reducing false alarms. An emerging phenomenon in fire detection is the use of multiple parameters and sensors in the detection mechanism. The system employed an adaptive fuzzy classification system to automatically generate a rule base, based on data from the three sensors. Most existing fire detection systems automatically actuate an audible alert via a siren or a strobe light on detecting fire. Remote notification has been done traditionally using the public switched telephone network; however, GSM has been adopted due to its secure and reliable nature. This paper presents the design and development of a fuzzy logic based multisensory fire detection system with a real-time web-based alert notification system. The fuzzy logic approach to fire detection was adopted because it simplifies the fusion of data from the multiple sensors.

II. PROPOSED METHOD AND DESIGN

The fire detection system greatly depends on the sensors used and their ability to register accurately the fire signatures being monitored. The sensors were chosen based on detection range, size, and cost. The sensors are TMP102 Temperature Sensor, DFRobot Flame Sensor, and MQ2 Smoke Sensor. By adopting a multisensory approach, the need to fuse the data arises. Fuzzy logic provides an easy way of dealing with uncertain data from multiple sensors by aggregating these to make a decision. For instance, a crisp temperature value may be classified into cold, normal, or hot, a crisp flame value may be classified into far, not far or near, and a crisp smoke value may be classified into low, medium or high fuzzy set with a degree through fuzzification. This allows the use of the "IF THEN" rules defined in the rule base to make a decision. This fuzzy decision is then defuzzified into a crisp output value. For each sensor input (linguistic variable), three (3) fuzzy sets were created using grade, reverse grade, and triangular membership functions. The center of area defuzzification method was used to obtain the system output.

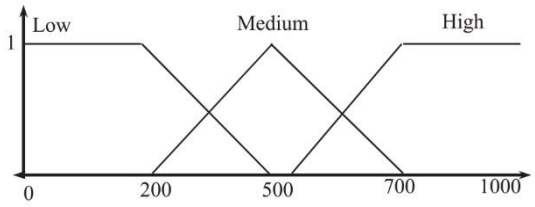

Figure 1. Fuzzy membership sets for smoke density.

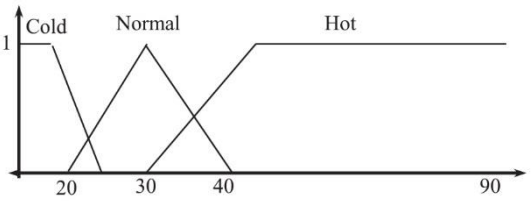

Figure 2. Fuzzy membership sets for ambient temperature.

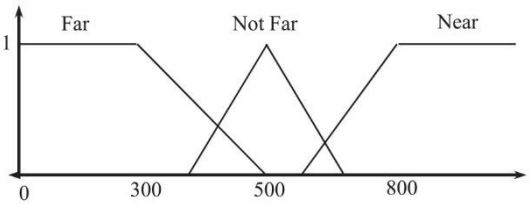

Figure 3. Fuzzy membership sets for flame intensity.

Three membership functions were chosen for each input. The size of the rule base of a fuzzy logic system is affected by its inputs and sets used. The ambient smoke density data from the smoke sensor were grouped into three fuzzy sets (low, medium, and high), which is shown in Figure 1. TheMQ2 sensor readings that are analog voltage levels are converted into digital data. Since the analog to digital converter (ADC) on board the Arduino has a 10bit resolution, possible sensor readings range from 0 to 1023. Figure 2 shows the fuzzy sets for the ambient temperature. The temperature sensor readings have been classified into cold, normal, and hot fuzzy sets. The range of possible values for the ambient temperature was set to 16^0C to 90^0C. The fuzzy membership sets for flame intensity that was measured using a DFRobot flame sensor are shown in Figure 3. This sensor relies on the UV radiation given off by flames. A large fire will

give off more UV radiation and vice versa. The sensor output is also affected by the proximity of the flame to the sensor. The data from the flame sensor also undergo ADC, thereby resulting in values from 0 to 1023. These values are the digital equivalent of the analog voltage values outputted by the sensor. The output fuzzy variable (status) shown in Figure 4 consists of three fuzzy sets. These include no fire, potential fire, and fire fuzzy sets. To determine the fire status (the output), crisp sensor readings of the ambient environment are fuzzified (assign to a fuzzy set with a certain degree of membership), and then these inputs are processed using the rule base shown in Figure 6. The fuzzy rules used are shown in Table I. The total number of rules adds up to 27.

When the three sensor inputs are supplied to the system, the inputs are then fuzzified using the various membership sets. The output of this process gives the fire status where a fire alert may be activated. Based on the output of the system, a fire event is either dispatched to the web-based notification system and house owner(s) or no action is taken. To establish a communication channel between the fire detection system and the web-based notification system, an SMS over GSM network was used. Figure 6 shows an overview system indicating the flow of information.

The device consists of a fire sensor suite, a microcontroller, and a GSM module. These two subsystems are interconnected using the GSM infrastructure via SMS. An API upcode is also send to the thingspeak server(Web-based notifying mechanism) with the help of GSM, which gives the time and location of the fire outbreaks in the thingspeak. An integral part of a fire detection system is its ability to notify people when a fire is detected. The notification also relays fire events to the fire and rescue service and the owner of the structure in real-time.

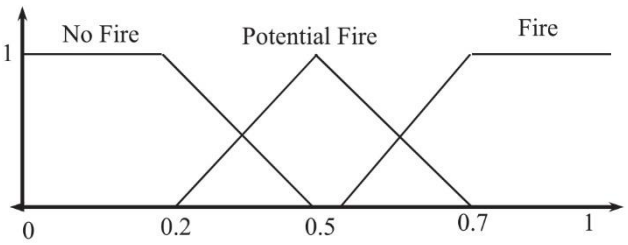

Figure 4. Fuzzy membership sets for fire status.

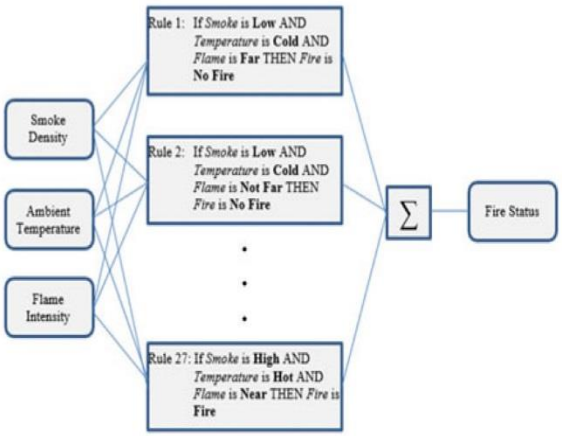

Figure 5. Fire detection fuzzy logic system.

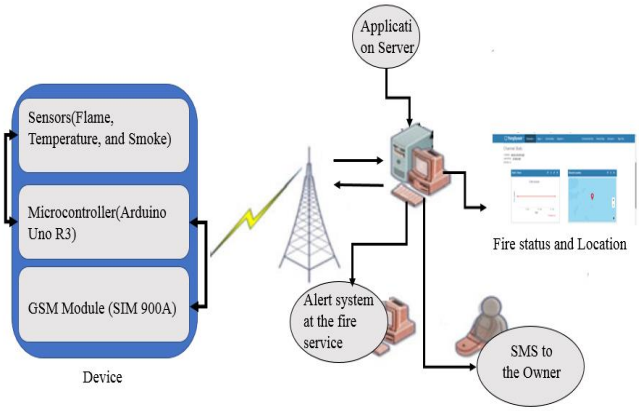

Figure 6. System architecture of multisensory fire detection and the notification system.

Table 1. Rules For Fire Status When Smoke Is Low

No.	Smoke	Temperature	Flame	Fire Status
1.	Low	Cold	Far	No fire
2.	Low	Cold	Not far	No fire
3.	Low	Cold	Near	Potential Fire
4.	Low	Normal	Far	No fire
5.	Low	Normal	Not far	No fire

6.	Low	Normal	Near	Potential Fire
7.	Low	Hot	Far	Potential Fire
8.	Low	Hot	Not far	Fire
9.	Low	Hot	Near	Fire
10.	Medium	Cold	Far	No fire
11.	Medium	Cold	Not far	Potential Fire
12.	Medium	Cold	Near	Fire
13.	Medium	Normal	Far	Potential Fire
14.	Medium	Normal	Not far	Potential Fire
15.	Medium	Normal	Near	Fire
16.	Medium	Hot	Far	Potential Fire
17.	Medium	Hot	Not far	Fire
18.	Medium	Hot	Near	Fire
19.	Hot	Cold	Far	Potential Fire
20.	Hot	Cold	Not far	Potential Fire
21.	Hot	Cold	Near	Fire
22.	Hot	Normal	Far	Potential Fire
23.	Hot	Normal	Not far	Fire
24.	Hot	Normal	Near	Fire
25.	Hot	Hot	Far	Fire
26.	Hot	Hot	Not far	Fire
27.	Hot	Hot	Near	Fire

A. System Requirements

The fire notification system is a web-based application used for remote monitoring and management of the fire detection devices. To increase the response time of the fire and rescue crew and house owners, real-time delivery of fire alerts was done using SMS. The navigational details of fire scene were send to the web-based application sever (thingspeak) using GSM. Table 2 shows the complete system components needed.

Table 2. System Components

Components	Description	Qty.
Power supply	Power supply for the fire detection system	1
Arduino Uno R3	Microcontroller board	1
GSM module	Quad-band GSM module from cooking hacks	1
Flame sensor	DFRobot flame sensor	1
MQ2 smoke sensor	Smoke sensor	1
Temperature sensor	TMP102 digital temperature sensor	1
Perforated board	10 cm×5 cm circuit board	1
SIM card	SIM card with airtime for sending SMS alerts	1
Connectors Wires	for connecting circuit components	300m
Plastic case	10 cm×6 cm	1
Internal GSM antenna	Internal GSM antenna	1

B. Design Considerations

An Arduino development board was used for the device because of its relative ease of programming and its suitability for rapid prototyping. The detection software for the device was programmed using Arduino. The detection module only interacts with the GSM module when an alert event is detected. A great feature of a fire detection system is its ability to feedback instantly of its state. This is a necessity when a fire is detected. The buzzer provided with the device ensures fire events result in audible feedback and remote alerts to whoever is concerned. Even though a simple alert on a fire outbreak would have sufficed, visualizing fire outbreaks using the location of the

device and providing useful information on the structure of fire provides more information. The choice of web-based application to perform the was informed by the cross-platform nature of web applications, remote access, and the ability to extend web applications easily through APIs, making them mobile device friendly.

III. SYSTEM IMPLEMENTATION PROCESS

This section outlines the implementation of the various sub systems. An overview of the fire detection system is shown

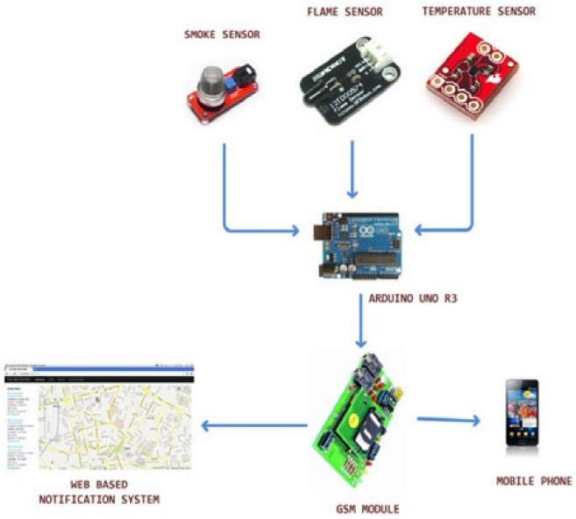

Figure 7. Fire detection subsystem implementation modules.

In Figure 7. This shows all the sensors interfaced with the microcontroller. A fuzzy logic system was implemented on the Arduino development board by using an embedded fuzzy logic library (eFLL). It is convenient to use the eFLL in this implementation because it is particularly optimized for constrained environments. The flowchart presented in Figure 8 shows the operation of the fire detection device. For a no fire output, the process is restarted. A potential fire output only leads to the activation of the buzzer. When the output is fire, the buzzer gets activated, an SMS alert is sent out and an API up code is also send to the thingspeak server. The thingspeak server gave a graphical representation showing time when the fire incident occurs and also show the location of the fire incident.

IV. RESULTS AND DISCUSSION

The smoke and flame sensors, being analog devices, rely on the ADC on board the Arduino to perform the conversion. The ADC on board the Arduino produces outputs from 0 to 1023. For the flame sensor a higher value of about 900 indicates a flame with high intensity and a lower value indicates a flame of low intensity or no flame for values below 200. The same principle applies to the smoke sensor: A higher value indicates high smoke obscuration and vice versa. With three output states of the fuzzy logic algorithm, fire alerts get activated only when either the potential fire state or fire state pertinence is high. The sample input values for fire and potential fire status is show in Table III. Unlike conventional fire detectors or single signature-based detection system, which operates by comparing the sensor output with a set threshold, but our multisensory approach makes a decision based on the weight of each input. This implies that the system is able to operate without necessarily relying on all signatures. This implies that the system is able to detect a flaming fire, which produces flame and heat with little or no smoke. This property of the system allows for a potential fire warning to be issued. The system should be ceiling mounted, so it will not trigger false alerts to burning candles under normal use but nonetheless remains sensitive.

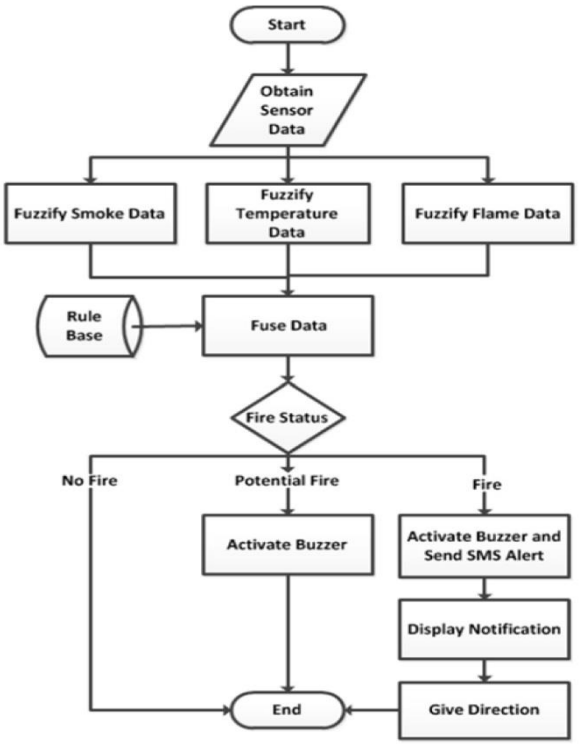

Figure 8. Fuzzy logic fire detection flow chart.

When the fire status triggered, SMS has been send to the owner or caretaker and also send API upcode to the thingspeak server with the help of GSM. The thingspeak website shows the time and location of the fire outbreak, which can be seen in Figure 9.

Table 3. Perfomance Of Fire Detection

Smoke	Flame	Temperature	Status
647.1ppm	0	83.31°C	Fire(0.708)
548.5ppm	918.49	28.93 °C	Potential fire (0.459)

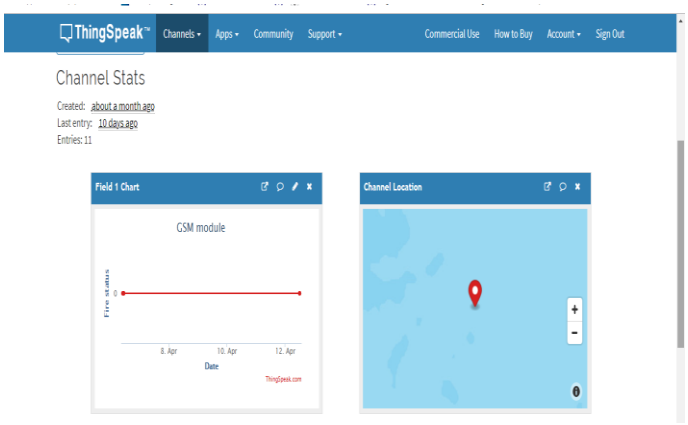

Figure 9. Screenshot of web-based notification system

V. CONCLUSION

Unlike the existing fire detectors, this system employs a multisensory approach whereby the outputs of three sensors sensing three different fire signature parameters (smoke, flame, temperature) contribute to the fire alert decision and hence produce a more reliable fire detection system devoid of false alarms. When a fire alert is detected, the system automatically reports them to owner(s) through SMS messaging on their cellphones. The system also provides a map-assisted navigation system to help locate the scene of a fire outbreak.

VI. REFERENCES

[1]. "Fire Statistics in India," [Online]. Available:https://factly.in/fire-accidents-caused-an-average-of-62-deaths-per-day-in-the-last-5-years/

[2]. "Smoke sensor MQ2," [Online]. Available: http:// www.cooking-hacks.com/index.php/electronic-brick-smoke-sensor- mq2.html

[3]. "TMP102 temperature sensor," [Online]. Available: http://www.cooking-hacks.com/index.php/digital-temperature-sensor-breakout-tmp102.html

[4]. "Flame sensor," [Online]. Available: http://www.cookinghacks.com/index.php/flame-sensor.html

[5]. "zerokol/eFLL," [Online]. Available: https://github. com/zerokol/eFLL

[6]. "Thingspeak Server," [Online]. Available: https://thingspeak.com/channels/718644