Smart Emergency Response Interface for Fire Detection

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***Abstract*-As a contribution to human safety and survival, the design, operation and experimental implementation of a fire detection system with a smart audio-visual emergency response interface is presented. This paper describes how real-time scientific data and instructions can be relayed to multiple computer devices in the case of a fire emergency. The experimental results showing the effectiveness and reliability of the system are reported.**

Keywords-Fire Detection, Temperature Monitoring; Data Acquisition; Cloud dashboard; Audio-visual; Graphical Interface; Emergency Response; Evacuation

I. Introduction

The safety of people and their assets against fires is of paramount importance. The reliability of today's fire safety measures within buildings can still be improved. Smoke detectors have an average success rate of about fifty per cent in preventing fire damages, injuries and deaths [1].In some environments, smoke detectors alone are not suitable neither effective. Such environments generally contain various airborne particulates in excess, such as dust and moisture. These environments include industrial building complexes such as warehouses, storage and manufacturing facilities. It becomes best to monitor temperatures using heat detection systems.

Furthermore, most fire outbreaks require immediate and ordered evacuation processes. The normal procedure involves the recognition of the fire alarm sound and an instinctive evacuation response often aided by exit route signs. In worse-case scenarios, smoke inhibits visibility and those trying to escape [2]. Evacuees are rarely convinced on whether they are moving away or towards the fire. In addition, fire men in their attempt to perform a rescue are also never certain of the intensity and spread of the fire within a building. In these dilemmas an audible and visual smart-form of guidance would save lives [3].

In light of technological advancements, this work introduces a real-time multipoint temperature monitoring system with an immediate audio-visual emergency response interface aimed at enhancing fire detection and the evacuation procedure.

II. Experimental Setup

A. Design

The system involves two sequential stages: First, fire detection and then the emergency response interface. Fire detection is achieved through accurate temperature monitoring of the rooms within a building using multiple sensors. Secondly, the emergency response interface which is linked to the monitoring stage is finally performed through computer devices. The following are the main tools required:

- Thermistors – temperature sensors
- NI USB 6009 – data acquisition device
- Labview – data processing and actuation computer software

The flowchart, in figure 1, shows the design layout. Sensors are distributed within the rooms or sections of the building and are named: S1, S2, S3, S4, S5, S6, S7 and S8.

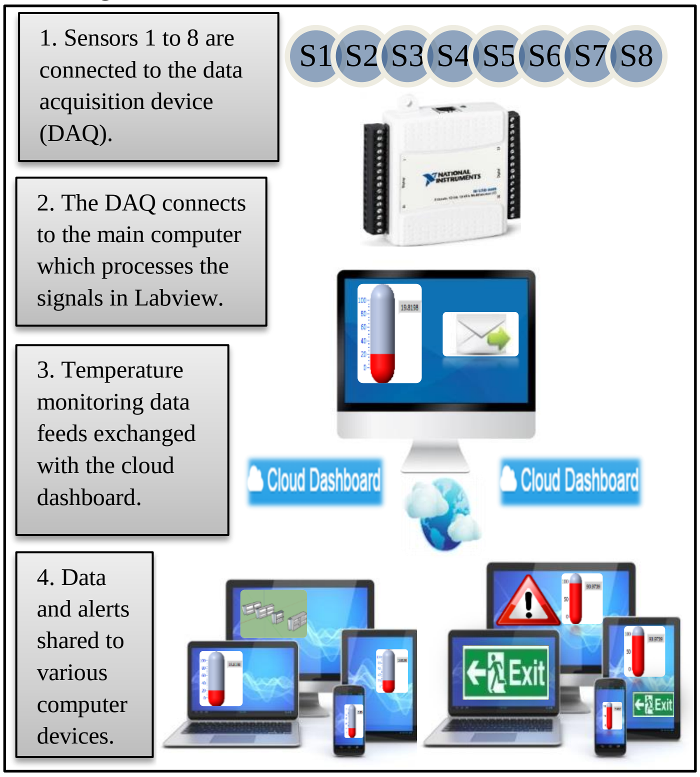

Fig 1. System flowchart.

B. Detection

Fire detection is achieved through temperature monitoring which is accomplished through the installation of heat detectors. The design of each heat detector involves the embedment of a thermistor on the edge of the surface of a 0.1m × 0.1m steel sheet using metallic epoxy. The sensitivity is enhanced by the large heat conductivity characteristic of the steel as well as the use of a silicon heat-transfer compound paste applied between the sheet and the thermistor. The relationship between the thermistor voltage and temperature, when connected in a voltage divider circuit, is given by the following formula [5]:

$$T = \left[\frac{1}{T_R} + \frac{1}{B}\ln\frac{RV}{R_R(V_{in}-V)}\right]^{-1} \quad (1)$$

Where T is the changing temperature, R is the thermistor resistance, R_R is the reference resistance, T_R is the reference temperature, B is Steinhart's constant, V_{in} is the system input voltage and V is the thermistor voltage. Multiple thermistors make up multiple heat detectors which are then distributed and installed as sensors.

All the sensors, bearing analog thermistor voltage signals, are connected to a single data acquisition device which converts all the analog signals to digital signals. These can then be processed through Labview. Labview is used to perform the interpretation and conversion of the signals to temperature.

For this experimental implementation, a data acquisition device accommodating eight channels is used. Suffice to say that, depending on the data acquisition device, the system can take an unlimited number of channels. After the processing of the digital signals, actual temperatures of the various rooms within the building are read simultaneously and in real-time. The actual temperatures along with important details are displayed on a graphical interface.

C. The Graphical Interface

The main graphical interface is a graphical representation of the real-time temperature using indicators. These indicators are built-in descriptive tools of Labview. They include digital displays, thermometer palettes and colour ramps. The same interface includes images of the rooms where the sensors are located as-well as a 3D representation of the building complex. This type of information is valuable to fire fighters.

The data is viewed on the screen display in real-time and shows the active operation of all the sensors simultaneously. When the temperatures rise in a particular room, the rise can be observed and tracked. When the temperatures exceed a pre-set **'danger'** temperature threshold, led indicators automatically pop-up on the screen with an alert message stating the possibility of a fire accident. This alert message is sent to safety personnel and the fire fighters station.

When rising temperatures exceed a higher pre-set **'fire detected'** temperature threshold, the fire alarm is triggered through activation signals relayed from the main monitoring computer. Alarm triggers are also sent to the cloud dashboard, which is a web interfacing tool. The cloud dashboard releases a trigger to all the computer devices registered to it, so as to override their active screen interfaces in order to show the emergency response screen interface. The emergency response interface is an audible report and evacuation guidance video that will show on the devices. The evacuation procedure presented on the devices is updated in real-time and designed to provide the best exit route leading away from the detected fire.

III. Operation

When temperatures within the monitored rooms of a building complex are normal, that is at room temperatures of approximately 23ºC, the only activity is the on-going monitoring of all room temperatures in real-time. Temperatures may fluctuate below the danger threshold temperature of approximately 25ºC for this experiment. When any temperature is detected to rise above this threshold, alert messages are sent by email from the main computer.

The fire alarm trigger for this experiment is set to go off when any temperature sensor reads 30°C or higher. Once triggered, the alarm stays on until the system is reset. Along with the alarm is the audio-visual emergency evacuation guiding media.

IV. Experimental Results

The analysis of a single temperature sensor, S8, reading ambient temperature over a collection of samples during a period of monitoring is presented in figure 2. The standard deviation was found to be 0.09866 which indicates that the sensor can read up to ±0.1°C of temperature change. The actual ambient temperature during the period of the experiment measured 23°C on a mercury-bulb thermometer. These measured results show a steady progression of the readings with minimal fluctuations about the mean temperature of 23.1°C.

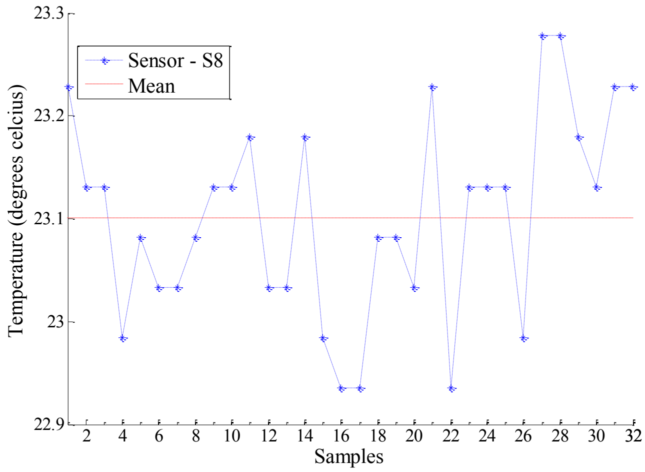

Fig 2. The response of a single sensor at ambient temperature.

When fire incidents occur, the spread of fire flames along with the rise of ambient temperature often occurs rapidly within a few seconds [1]. In figure 3 the results of the simultaneous response of eight sensors to ambient temperature is shown. The results are acquired over an experimental period of 32 seconds. Sensor S7, in one of the building compartments, is subjected to heat. Its temperature reading rises from 22°C to 25°C within 15 seconds. According to the graph, the other sensors maintain steady temperature readings.

As the temperature of S7 crosses the set **‘danger’** temperature threshold of 25°C, alert messages are emailed successfully. During the next 10 seconds of the experiment, the temperature exceeds 30ºC. This is the set **‘fire detected’** temperature threshold that triggers the fire alarm.

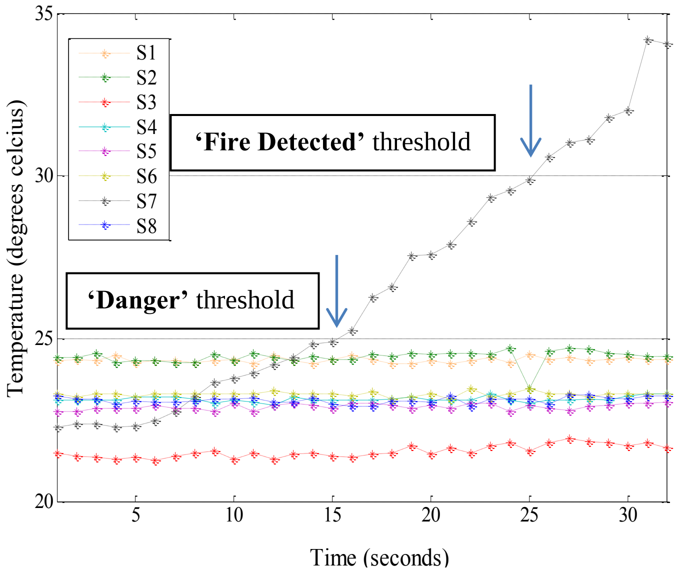

Fig 3. All the sensors with S7 exposed to heat.

After the triggering of sensor S7, a secondary response trigger is sent from the cloud dashboard to registered computer devices within the building in order to take over any current graphical interface activity and force the display of the emergency response audio-visual media.

The audio voicing, in the media, is portrayed in figure 4. It describes the location of the fire as well as the safety precautions to be taken as the evacuation proceeds.

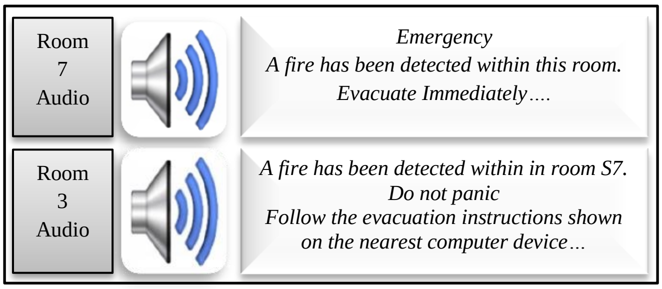

Fig 4. Audible emergency evacuation message.

The audio-visual emergency media displays the evacuation procedure and is viewed on the computer device. It is the actual representation of the exit paths through the building. The exit path is shown repeatedly with the aid of directional arrows and updating data. The media clearly shows the safest exit route away from the fire and leading to the outside of the building.

Fig 5. Audio-visual evacuation interface on computer devices.

V. Discussion

From the analysis of a single temperature sensor at ambient temperature, the reliability of the heat detector is affirmed. Any systematic error is adjustable within the programming environment. The standard deviation of 0.09866 is an acceptable value because it is small and implies a minimal deviation of any steady readings from the mean temperature over time.

The experiment also proves the independence of each heat detector. Figure 3 shows that when S7 was exposed to heat, all the other measured temperatures remained steady and unaffected by the temperature rise on S7. This confirms the real-time and simultaneous capability of monitoring multiple sensors.

The alert and emergency response actuations occurred at the set trigger thresholds. These thresholds are adjustable and can therefore be set according to the environmental and climatic conditions of any place.

Finally the audio-visual emergency response was successfully triggered providing clear, immediate and uninterrupted guidance of a safe evacuation process.

VI. Conclusion

The system proved smart and reliable with an accuracy of up to ±0.1°C in temperature monitoring. The experimental implementation was successfully performed.

Further developments to the sophistication and efficiency of the system include the design and development of compact multi-sensor (smoke, heat and heat differential) fire detectors, the development of smart safety software and mobile applications, enhancement of the evacuation algorithm and real-time GPS coordination.

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