International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 01, January-2016

Smart Fire Warning System

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Abstract **- Protection from fire is vital. A system for protecting people from leaking gas and fire is crucial for residences and industries. Most existing fire protection systems work by signalling with words or an alarm, which does not attract the attention of people who are away from the incident site. Hence, a smart fire warning system is needed that is able to overcome this limitation. In this paper, a smart fire warning system is presented that sends an alert message containing the location coordinates of the fire to the nearest fire station and the owner. A detailed study on existing fire security systems was conducted, and a system was designed and implemented considering their limitations. A prototype of the system has been implemented and tested under different conditions. The results show that the proposed smart fire warning system accurately detects the onset of fire and responds quickly and reliably. The reliability index of the system is found to be 93%, which is considered acceptable for normal domestic applications.**

Keywords: Fire warning, Microcontroller, Smoke sensor, GPS, GSM.

1. INTRODUCTION

In many incidents, fire hazards have become recurrent and destructive and have caused significant disasters. With the rapid development of urban construction, the probability of the occurrence of fire has increased considerably (Shajadul et al., 2009). Early detection and early warnings are important for promptly extinguishing a fire, avoiding casualties and property loss. Therefore, intelligent and smart fire warning and security systems are essential.

Home and industrial security aspects continue to change and security is an important feature in modern houses. The new and emerging concept of smart homes offers convenient and safe environments for occupants. Conventional security systems keep homeowners and their property safe from fire by raising an alarm (Al-Ali, 2012).

However, a smart fire warning system offers many more benefits. In this paper, we mainly focus on the security of homes and industries when people are away and on industrial areas away from cities if a fire occurs at night. The system sends the location coordinates (longitude and latitude) using Global Positioning System (GPS) and sends an alert message to a fire or police and to other predefined telephone numbers. The location coordinates in the message received at the fire or police stations help in quickly navigating to the site using a map application like Google maps. The communication method of traditional fire alarm systems mostly involves radio tracking. The data transmission distance is short, transmission reliability is low, system maintenance is difficult, and the cost is high (Khondker et al., 2009). Compared with the traditional communication method, the proposed smart fire warning system is designed with an intelligent fire alarm system using a microcontroller and can achieve intelligent fire detection.

The system uses smoke sensors to determine the onset of a fire hazard which sends a control signal to the microcontroller. The microcontroller receives the location information via a GPS modem connected to it, and using the Global System for Mobile Communication (GSM) modem it sends the message containing the longitude and latitude information. The microcontroller also sends a signal to the alarm. The microcontroller, which is the heart of the smart fire warning system, controls all operations involved in an emergency situation. The proposed system could be the best alternative for saving lives and reducing property losses in the event of a fire.

2. RELATED WORK

Jayashri and Arvind designed a system that uses a multi-sensor-based fire detection (MSbFD) algorithm with two fire parameters (temperature and optical smoke density). These two parameters were chosen since ionization systems may become increasingly difficult to apply because of the environmental regulations being imposed on them. The evaluation and processing of the sensor signals are carried out using Fuzzy Logic (Jayashri & Arvind, 2013).

According to Lee and Mok (Lee & Mok, 2007), the purpose of a fire alarm system is to detect a fire at an early stage. An important point is that the alarm is provided to cause the operator to respond. If the operator does not notice an alarm, then the alarm system has failed. An alarm system must also result in a positive response from the operator (Shajadul et al., 2009).

Le Bodic and Gwenael (Le Bodic & Gwenael, 2005) have proposed a network environment integrating wire and wireless communication in which a fire control database with a five-layer structure (data source, data persistence, domain, controller/mediator, presentation) is established. This is critical for resolving the cooperative control problem in a quick-response fire control system.

The systems reviewed above use expensive components, are complex in nature and require experts for their operation. The objective of this work is to design and develop a low-cost, simple, reliable, efficient, fast, and smart fire warning system that overcomes most of the drawbacks in conventional fire security systems.

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3. METHODOLOGY

This project is divided into four phases: research, design, development, and analysis. The steps involved are illustrated in Figure 1.

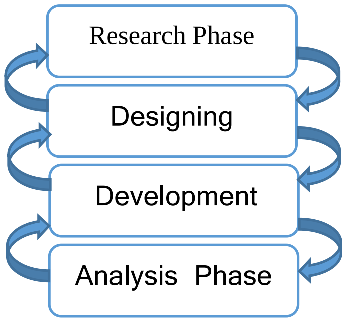

Figure 1 System development phases

4. REQUIREMENTS ANALYSIS AND DESIGN

This section analyses the requirements of the system in general and the requirements from a user's point of view. This analysis helps to meet user requirements. To collect use opinions, the following questions were asked to 15 selected people through individual personal interviews:

a. What do you think about the effectiveness of existing fire warning systems?
b. What features do you expect in a smart fire warning system?
c. What do you think the maximum cost of a smart fire warning system should be?
d. Do you think that information on the location of a fire is important for quick action?

The common goal for smart fire warning systems is to provide full security from fire and gas leaks for the home or office at a low cost. The user requirements for the proposed fire warning system were drawn based on the outcome of the above interviews. The results indicated that the proposed system should have the following features:

i. The system should be highly sensitive and be able to detect any smoke or gas leak.
ii. The system should be able to know the exact coordinates of the location.
iii. The system should respond quickly.
iv. The system should be reliable and cost effective.

In addition, there are other equally important criteria that need to be satisfied for a fire warning system to be effective which are:

i. The information should be accurate and without any errors.
ii. The information should be clear and without delay.
iii. The system should be rendered for easy updates at any time.

Based on above requirements, it was concluded that the system should be reliable, affordable and user friendly. Most importantly, it must be highly robust, accurate, and secure. Figure 2 provides an overview of the proposed system.

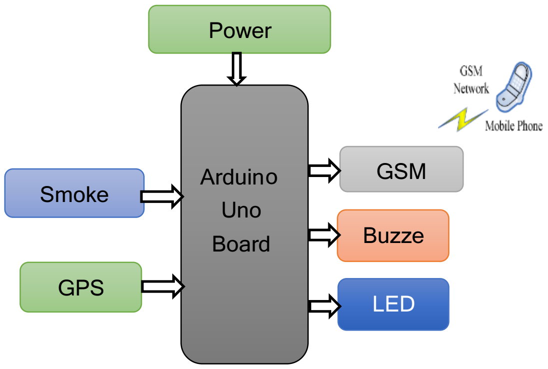

Figure 2 Block diagram of the system

4.1 Sensory Module

The fire and gas sensors used in this system sense the fire and send electrical signals as an input to the microcontroller**.**

4.2 Controller Module

The controller is the main part of the system where all the process flows are controlled according to the requirements. The Arduino Uno R3 platform with an ATmega328P microcontroller was selected which allows multitasking and is easier than other microcontrollers to setup and configure.

4.3 GPS and GSM Modems

The GPS provides geographical location by using a space-based satellite navigation system. The GSM modem allows the system to contact the GSM network by using a subscriber identification module (SIM) card. The GPS and GSM together help to send the details regarding the location of the fire to intended recipients.

5. SYSTEM IMPLEMENTATION

5.1 Hardware Implementation

When the device is turned ON, the microcontroller initiates the GPS module until it receives a good signal from GPS satellites. The GSM module sends a specified text message with the coordinates of the location to a pre-defined mobile number. The smoke detector detects both smoke and gas. When there is a sign of smoke or gas, this detector sends an analogue signal to the microcontroller, which converts the analogue signal into a digital signal. The microcontroller then calculates the level of the gas or smoke detected. If the level is greater than 200 ppm, the microcontroller executes the next operation.

When the GSM module operates, it looks for a good network carrier to send the message. Once the message is sent, an LED indicator is displayed. Then the output indicators (LED 1 and 2 and the buzzer) start working, and the mains power supply to the house or office is disconnected. This status continues until the system is reset.

5.2 Software Implementation

A number of software libraries were used that help the devices work together. In the GSM module, the libraries used are *SIM900.h* and *sms.h.* The first library is used to declare the GSM module and all its commands. The second library is used to declare all SMS commands within the

GSM module. A library, *TinyGPS.h*., is also included for the GPS module and enables the system to obtain all the data, such as location and timing, from the satellites. We used the *SoftwareSerial.h* library to show the results using serial ports. This library also has the capability to use many instructional functions and control statements, such as time delay, ports mode, serial print, digital control, and many others. The program starts by initialising the GPS module and obtains all data from the satellites, trying four at a time. The program then starts up the smoke sensor and keeps it running to detect any sign of gas or smoke. If the value obtained from the detector is greater than or equal to 200 ppm, then a fire alarm will come ON along with a flashing light, the power supply to the building will be disconnected, and the GSM module will be initialised. After initialisation of the GSM module, an SMS message is sent from the system to the preset mobile number. The system continues running, the fire alarm and flashing light stay on, and the power remains off until the user resets the system. Resetting the system will start the previous steps.

6. SYSTEM TESTING

First, all the hardware units of the system were tested for verification that they were working as expected. Then, each unit was interfaced with the microcontroller board and tested with the software. The testing of the system was not done as a whole; rather, each unit of the system was tested individually. After all the units were working correctly, the whole system was developed and tested to identify the problems and the bugs in the system.

6.1. Test Cases

To measure the reliability and effectiveness of the system, the prototype was tested thoroughly, and each test was repeated 10 times. The test was repeated to assess the system's performance in different cases and in different environments, such as home or office, to measure the reliability.

The following parameters were used to measure the reliability of the system:

1. Sensitivity of the smoke sensor
2. GSM response time
3. GPS response time

A new parameter, the 'reliability index' (RI), of the system was defined to analytically evaluate the reliability of the system. The RI is derived by giving different weights to each parameter measured according to its importance. The sensitivity of the smoke/gas sensor is the most important one because it identifies smoke and gas leaks that may be responsible for a fire. It also triggers the system and the fire alarm that will alert everybody in the vicinity. Hence, this parameter was given a weight of 50%. The highest priority is the safety of the people at the site. The response time of GSM was given a weight of 30%. The response time of the GPS was given a weight of 20% as it is the parameter of lowest importance.

The reliability of the system cannot be found directly because the operation of the system depends on many sensors and associated parameters. The RI (δ) of a sensor is defined as the product of the number of tests passed by that sensor (%) and the weight of the corresponding parameter.

$$\delta_{\text{reliability index}} = (\% \; of \; tests \; passed \; x \; parameter \; weight \,).$$

For example, if the smoke sensor passes 100% of the test, its RI is

100 × 0.5 = 50 %

The RI (δ) of the whole system is calculated by adding the RIs of the individual sensors.

7. RESULTS AND ANALYSIS

Table 1 Results of 10 tests done in a domestic environment

Parameters	Smoke Sensor	GSM Module	GPS Module
No. of tests applied	10	10	10
No. of tests passed	10	9	8
No. of tests failed	0	1	2
% of tests passed	100%	90%	80%
% of tests failed	0%	10%	20%
Reliability index	50 %	27 %	16 %

Table 1 shows the results of applying tests to each of the sensors (10 tests in a domestic and 10 in an office environment); however, the calculations and the results are shown only for the tests done in domestic environment. All the tests were passed by the smoke sensor (100%). The GSM module sent nine of 10 messages. The percentage of tests passed was 90%. The GPS module passed eight of 10 tests. The percentage of tests passed was 80%.

The overall reliability index value of 93% is very promising and is adequate for normal domestic applications.

The receiver at the fire or police station is a smartphone with the Google Maps application for navigation. Figure 3 shows a sample message received at the fire station.

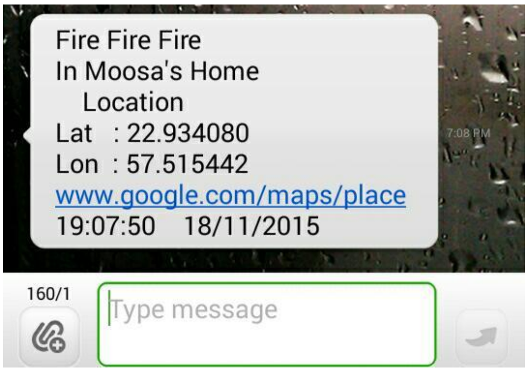

Figure 3 Sample message received at the fire station

International Journal of Engineering Research & Technology (IJERT)
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8. CONCLUSION

The objective of this project was to design and develop a simple, easy-to-use, reliable, efficient, fast, and automatic fire warning system that has a precise and quick notification mechanism. The developed smart fire warning system determines the location of a fire and sends a message containing the location coordinates to a preset mobile number. The system obtains location information using a GPS module and sends a short alert message using a GSM communication module. Appropriate sensors were used to detect smoke and gas leaks as the onset of fire.

A step-by-step approach was followed in the design of the system. The design was carried out based on the study and analysis of existing similar systems and user perceptions. A prototype of the system was implemented and tested in home and office environments. A new performance parameter called the Reliability Index was defined to measure the performance of the system. Several tests were conducted, and the results were analysed to ensure that the system produced the intended results. The test results showed that the RI of the system was 93%, which is considered acceptable for normal domestic applications. The system is user friendly, affordable and smart. Using GSM to send alert messages has the advantage of wide availability, good coverage, and being cost effective. As the cost of SMS messages continues to fall, the system will become easier to realise. It is therefore a good and cost-effective choice as a smart fire warning system.

The system has been implemented and tested, showing satisfactory performance. Although our system has many advantages, it could be improved further in the following ways:

a. Adding external antennae for the GPS module and GSM modules. This will ensure a strong signal, which will speed up the process of finding the network.
b. Adding more sensors, such as temperature and humidity, to make the system more efficient.
c. Link the system to a fire protection system to activate the same in the absence of an operator to extinguish the fire

9. ACKNOWLEDGMENTS

At the outset, we thank the almighty God for giving the strength and patience for successfully completing this project.

We would also like to thank the management of Caledonian College of Engineering, Oman for providing all the facilities and support for undertaking this project successfully.

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