Wireless Forest Fire Detection and Control System

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Abstract: **Forest fires pose a real threat to human lives, ecological systems and properties. Hundreds of millions of hectares are destroyed by wildfires each year and over 200,000 forest fires happen every year around the world. Forest fires destroy a total area of 3.5 to 4.5 million km². Unfortunately, Forest fire is usually only noticed when it has already spread over a large area, making it difficult to control and sometimes making stoppage impossible at times. The result is devastating loss and irreversible damage to the environment and atmosphere (30%of carbon dioxide (CO2) in the atmosphere comes from forest fires), in addition to irreversible damage to the environment (huge amounts of smoke and carbon dioxide (CO2) in the atmosphere). Fire outbreaks have a starting period of about 3 to 5 minutes which is the ideal time to detect it and put it out after which it might get out of control. This means that timely identification of potential fire outbreak sources is critical to managing it. Most Forests are not fitted with fire detection devices owing to lack of awareness, inefficiencies, ineffectiveness and high costs. This project seeks to design and model a prototype of a simple and efficient wireless forest fire detection and control system. This project applied rapid prototype methodology for development of the prototype.**

Keywords: Forest Fire, Arduino microcontroller, GSM, GPS

1. INTRODUCTION

A forest is a large area which is usually dominated by trees. Forests cover 31 percent of the world's land surface, just over 4 billion hectares. (One hectare = 2.47 acres.) [1] They provide a range of ecosystem services including aiding in regulating climate, mitigating natural hazards such as floods. Studies have shown that forests induce rainfall as such when forests are cut or destroyed by forest fires it can lead to drought. The latter, which has been a research interest for many years. Forest fires always start by one of two ways - naturally caused or human caused. Natural fires are generally started by lightning, with a very small percentage started by spontaneous combustion of dry fuel such as sawdust and leaves. Human-caused fires can be due to any number of reasons including smoking, recreation and equipment. Human-caused fires constitute the greater percentage of forest fires in our forests, but natural fires constitute the great majority of the total area burned. This is because human-caused fires are usually detected early in their duration, and therefore they are usually contained easily. Natural fires, on the other hand, can burn for hours before being detected by firefighting authorities.[2]

Forest fire detection systems are gaining a lot of attention because of the continual threat it poses to both economic properties and public safety.[3] Thousands of forest fires occur every year across the globe and this causes disasters which are beyond measure and description. Apart from causing tragic loss of lives and valuable natural and individual properties including thousands of hectares of forest and hundreds of houses, it has become a serious threat to healthy grown forests and protection of the environment. There is a huge amount of very well studied solutions available out there for testing or even ready for use to resolve this problem. However, it is hard to apply these systems in large open areas for a variety of reasons like high cost, energy usage and inefficiencies by the various technologies. The most overlooked aspect of fighting forest fires is communication. It is important that the authorities be notified immediately when a fire occurs. A fire which is detected in its early stages will be much easier to extinguish than one that has been burning for some time but has only just been discovered due of lack of communication. This paper presents a novel approach in detecting forest fires and ensures that prompt notifications are sent to the proper authorities for action to be taken.

2. SYSTEM DESIGN

2.1 Functional Requirements

Functional requirements explain what has to be done by the prototype and specify the capabilities that the solution must offer. This is done by identifying the necessary task or activity that should be accomplished. They include:

1. The prototype should read analog gas, smoke and flame data from the environment.
2. The prototype should convert the sensor data into digital form.
3. The prototype should send a text alert and sound the buzzer during an smoke or flame detection.
4. The prototype should the sound buzzer and sends a text notification with GPS coordinates to relevant parties if a fire accident occurs.

2.2 Non-functional requirement

Non-functional requirements are requirements that specify criteria that can be used to judge the operation of a system, rather than specific behavior. The key non-functional requirements identified for the prototype are security, performance, availability and reliability.[4]

2.3 System Architecture and Circuit

The proposed system consists of an MQ2 sensor which senses the presence of smoke which is usually the staring phase of forest fires. It also consists of a flame sensor for flame detection, a GSM module for sending fire alerts and a GPS module for sending forest fire locations. Embedded into the system is a piezoelectric buzzer which produces sound when there is an incidence of forest fire. The Arduino Nano microcontroller serves as the brain behind the system with all other components connected to it. The Arduino Nano microcontroller converts the analog values from the sensors and converts them into digital values.

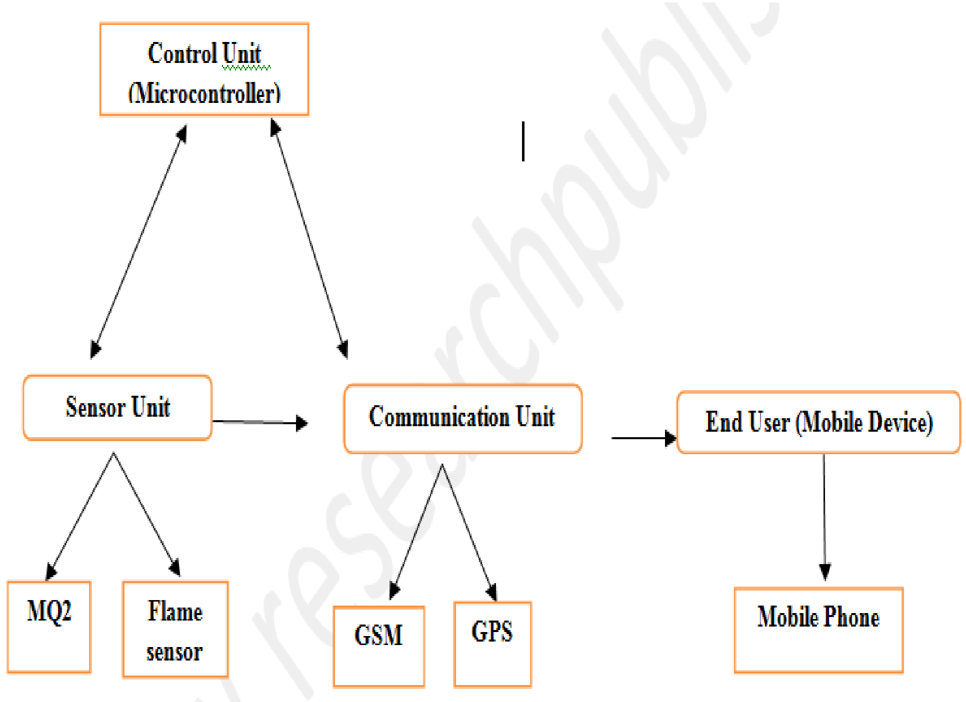

Fig.1 Block Diagram of Proposed System

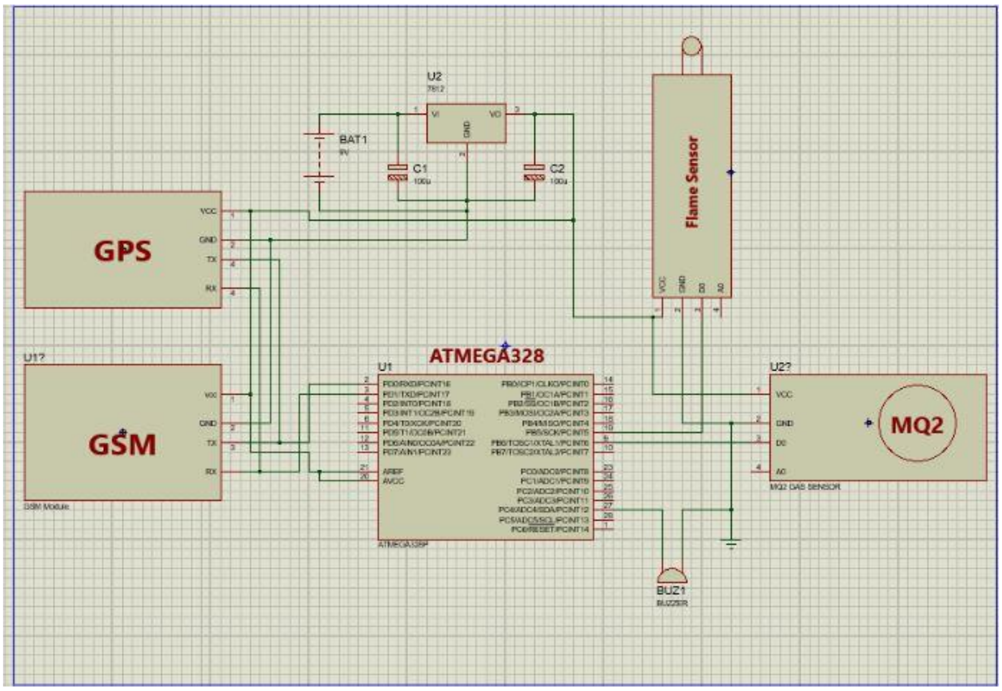

Fig. 2 Circuit Diagram

2.4 System Sequence

The sequence diagram below is used to show the interactions between the objects of the proposed system in the sequential order that they occur. It is a depiction of how the fire detection device captures data from the sensors. The end users receive notifications when positive fire identification is made by the device.

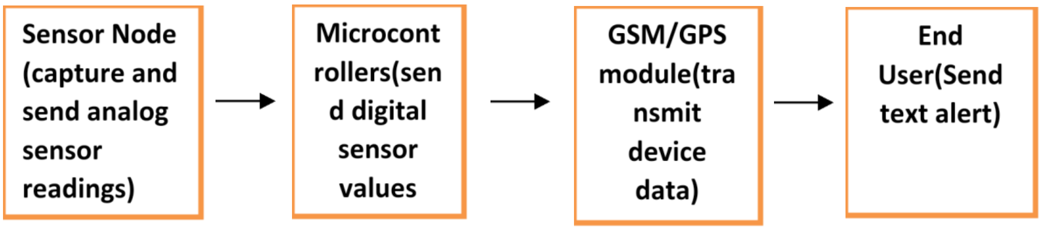

Fig. 3 Sequence Diagram

3. RESULTS AND DISCUSSION

3.1 Integration testing (System Testing)

This test was done on the integrated prototype to verify its combined functionality. A lighter and a piece of cloth were used. The lighter was used to produce the flame and heat while the piece of cloth was ignited and put out to produce smoke.

Table 1: Integrated Test Results

Smoke(ppm)	Flame(nm)	Fire Status	Expected Result
Low: 100	Low: 300	No Fire	No Fire
High: 326	800	Fire	Fire
Low: 180	749	No Fire	No Fire
High: 406	953	Fire	Fire
Low: 142	220	No Fire	No Fire
High: 440		Fire	Fire

3.2 Testing Against Known False Alarm Triggers.

The prototype was tested against some of the factors which triggers false alarms in smoke and thermal based fire detectors in a home setting. The known main triggers are chemical odours, steam, burning food, and cigarette.

Table 2: Test Requirement

Testing Requirement	
Trigger	Result
Cigarette	No false alarm
Steam	No false alarm
Chemical odors	No false alarm

3.3 Performance Testing

Performance testing was carried out to assess the notification service (Text alert) based on a speed metric. It was important for the prototype to send timely text SMS to the relevant parties once a fire was detected. The test was carried out with a stopwatch to record the amount of time taken between fire detection and the arrival of the alert to a mobile phone. There were 3 tests conducted and the results are as tabulated below.

Table 3: Performance Testing

Alert Name	Time before text arrived
Alert 1	Alert 1min 42 seconds
Alert 2	1 min and 15 seconds
Alert 3	1 min 3 Seconds
Average Time(In seconds)	61 seconds

3.4 Summary

To summarize, there are keys functionalities/techniques that were implemented to ensure the prototype was used to achieve its main objectives which was to reduce false alarm rates and its sub-objectives which were affordability and making fire detectors "smart". They are as follows:

i. Using Smoke and flame as parameters to detect fire.

ii. Combining both rate of rise in the smoke unit and a fixed smoke threshold as techniques to detect changes in smoke.

iii. Using GSM instead of Wi-Fi for sending text notifications.

3.5 Advantages of Proposed forest fire detection systems

The main advantage of installing this fire detection and alarm system is the early warning benefit. Early warning is important in effective fire safety because fires have the ability of occurring anytime and anywhere. Subsequently, this aids in:

i. Preservation of forests and wildlife.

ii. Allowing fire department personnel to respond promptly

4. CONCLUSION

There were numerous challenges that were identified relating to fire detection and response. The main challenge identified under fire detection were high false alarm rates by detection devices, lack of prompt communication to authorities and others being high cost of some fire detection devices and lack of sufficient awareness on the importance of installing these devices. The high false alarms rate especially by smoke sensors and heat/ thermal sensors came out as the major challenge. The researcher's main aim was to investigate the problem and afterwards develop a solution that solved the false alarm problem while considering the cost of the final product. To achieve this, the researcher laid his emphasis on using more than one percent from the environment during a fire outbreak. The researcher investigated extensively and identified three main precepts that formed or were emitted during a fire. They were smoke, heat and a flame. The research considered this aspect and embedded into the prototype sensors which are used to detect these parameters to aid in increasing accuracy in fire detection devices. Based on both secondary and primary data collected, a multi-sensor fire detection was implemented and tested accordingly. This gave rise to a 82% percent success rate and 18% false alarm rate based on 6 test cases of which only one failed. Stakeholders in fire department services should adopt the technique proposed in this research for fire detection as a stepping stone towards a faster response time to forest fire incidents. This will go a long way to save properties and lives. Secondary and Primary Data which was collected from the detection device also provides an opportunity for better reporting and data analysis which could help in the process of improving fire detection services especially in Ghana where there is insufficient recording and publishing of information relating to fire.

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