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Mini project report

IOT based Forest Fire Detection System

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Abstract

Fire, as one of the world's biggest calamities, must be identified at the right moment before it can do significant damage to the atmosphere, living beings and resources. In one way or another, these renewable resources are very essential to mankind. Forest fires are the most common hazards in forests which lead to serious destruction of forest wealth, biodiversity, and natural habitat. According to a study, 75-80 percent of the various casualties caused by fire might have been prevented if the misfortune was detected quickly. Particularly in the case of a forest fire, this results in a significant loss to the environment and makes it extremely dangerous for the wildlife habitat. To avoid such losses, an automated system is needed that can provide early detection of any fire situation via any of the alarm systems. In order to achieve early detection, there are two most used traditional methods of human surveillance.

• Human observation

• Automation approach

Traditional methods of human surveillance are directly through human observation and through distant video surveillance. This requires 24/7 continuous monitoring. The automated fire alert detection system by which one can achieve surveillance through the automation approach of detection proposed in this project comprises three sensors, namely flame, temperature (DHT), and CO2 MQ135. These sensors detect a change in a measurable physical quantity and intimate the nearest fire-extinguishing station. Internet of Things (IoT) technology has brought a revolution to each and every field of common man’s life by making everything smart and intelligent. IoT refers to a network of things that make a self-configuring network. The development of IoT based Forest Fire Detection System will be helpful in mapping emergency plans and making them more effective during the occurrence of any disaster. In this project, the intention is to build a Forest fire detection system using IoT which would detect the fire and send an emergency alert to the Authority through IoT. Here a GSM/GPRS module is used to communicate with IoT servers.

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Introduction

A wildfire, forest fire, bushfire, wild-land fire or rural fire is an unplanned, uncontrolled fire in an area of combustible vegetation starting in rural and urban areas. Of late, forest fires have captured the attention of people worldwide. Over the last few years there have been devastating fires in the forests of South east Asia, Amazon and the Rocky Mountains of the USA. Such fires have not only led to threats to the biological diversity of these forests, but have also caused large-scale human suffering in neighboring lands, due to pollution of the environment. Forests play an important role in the global, ecological, environmental and recreational system. It greatly impacts the amount of greenhouse gasses, atmospheric carbon absorption, and reduces soil erosion. Forests contain many essential resources for human survival and social development that protect the balance of the Earth ecosystem. Forest fires are a recurrent phenomenon, natural or man-made, in many parts of the world. Global warming contributes to the increase in its number in recent years and the importance of these disasters. In this scenario, the frequency of forest fires has increased considerably due to climate change, human activities and other factors. The detection and monitoring of forest fires has become a global concern in forest fire prevention organizations. This system can monitor real-time related parameters, e.g., temperature, and relative humidity, and send the data immediately to the computer of the monitoring center. The fire alert system has low power utilization and quicker handling capacity at a lower cost and maintenance. The Forest fire detection system uses advanced technology which will help in tracing the forest fire in its initial stage. The development of IoT based Forest Fire Detection System will be helpful in mapping emergency plans and making them more effective during the occurrence of any disaster.

Problem statement

Lately, the world has seen many occurrences of wildfires which have caused a lot of damage to our biodiversity. These fires have caused damage to wildlife, human life, property, and the environment. It could be avoided if a robust system could be deployed in forest areas to detect the fire in its initial stage and alert the concerned authority to take appropriate and immediate action.

Hence our approach addresses the need for early detection of the forest fire before it spreads to a large scale and causes a number of casualties. As a result of this automated system, a lot of lives, as well as natural resources, could be saved. The approach ensures a more reliable and accurate result and is cost-effective at the same time

Brief solution

In this project, we will design an IOT based forest fire detection system. The working of the project is pretty simple: detect the fire and send an emergency alert to Authority through IoT. Many researchers came up with the solution by using various types of control and detection systems. It is a detection system equipped with a GPS navigation system and a flame sensor. As shown in the schematic block diagram below, the project consists of Flame sensor, DHT11 Sensor, MQ135 Sensor, Arduino Nano & SIM808 GSM/GPRS module as its primary components. The fire can be detected by the flame sensor which gives a digital output that corresponds to the fire status and is received by the Arduino Nano.

Arduino compares the signal and triggers the SIM808 in case of fire incidents. SIM808 is a compact module that allows GPRS transmission, send/receive SMS, and making voice calls. The SIM808 module has two antennas included on it. The first is for a ring antenna which can be soldered directly on the board and the other is meant for an external antenna. Through AT commands, SIM808 communicates with thingspeak server.

Components used

Hardware components

- Arduino UNO <<amazon links>>
- SIM808 GPS/GPRS/GSM Module
- Sensors-
    - Flame
    - DHT
    - CO_2 MQ135
- Buzzer, LEDs
- 9V- 1A Battery
- Breadboard
- 5 V DC power supply
- Jumper wires and cables.

Software components

- Arduino IDE (1.8.13)
- ThingSpeak Account (Cloud)
- Software Serial

Literature review

Numerous solutions have been proposed and implemented for this problem. Most common systems used in field work are video surveillance systems. Video cameras are sensitive to smoke only in the daytime. Fire sensitive cameras at night, using IR thermal imaging cameras for heat flux detecting and using backscattering of laser light, detect the smoke particles. This fire alert system has a few limitations because of environmental conditions like dust particles, mist, shadows and so on. Another method is automated picture capturing of fires in the forest.

Capturing can be done by the cameras which are placed on top of towers. A motor was introduced to give a coverage view on the forest and for its movement (Basu et al., 2018). Captured pictures are processed using program or MATLAB simulation and matching with references taken at the beginning stage. This alert system has a limitation of false caution rate and visual cameras installed on towers are of high cost. Another method of fire detection is by using satellite systems. The base station collects the information sent by satellite and runs an algorithm to recognize the facts (Basu et al.,2018). The raw data of satellites are processed and then the Advanced Very High-Resolution Radiometer instrument is utilized to recognize hotspots. In South Korea, a forest fire surveillance system was proposed by using wireless sensor networks. Wireless sensor networks detect humidity and application analyses the collected information (Hariyanwal et al., 2013; Kumar et al., 2017).

In this methodology, there is some loss of information during communication. By using a temperature sensor and GPS modem, forest fire detection can be possible (Basu et al., 2018). Here, temperature sensors collected data were sent to the base station by both primary and main antennas (Alahi et al., 2017). The continuous power supply was difficult for too many antennas and sensors. In addition to the above limitations, climatic changes may affect the system. In research done by Zhang et al. (2009), Pirbhulal et al. (2017), and Alahi et al. (2017) an ad hoc network using cluster topology for forest fire forecasting model was used to predict fire-prone areas.

It was concluded that WSNs have greater advantages. In another research done by Demin et al. (2014), sensors were deployed and the weather data were collected. This data was used to calculate and prevent forest fires. In these researches, there was no real-time forest fire monitoring, only the data were collected and fire prone areas were predicted. Libelium (Solobera, 2010) developed a wasp mote that has four sensors for measuring gases, temperature, and humidity. It gives early warnings and consumes very less energy.

Shunyang X. Du, J. Yongping and W. Riming, Realization of Home Remote Control Network Based on Zigbee (2007), et al. deal with the design of remote monitoring and control systems. The system consists of a real-time home monitoring subsystem and a light control sub-system. A home server with a home camera caters to home status through video to the client.

A program that analyzes satellite data in near real-time and converts information into instant messages and email alerts to track forest fires. ICIMOD helped design a system that uses satellite data to monitor and assess the damage of forest fires and then automatically sends SMS messages and emails to district forest officers and rangers so they are better able to monitor the growth and direction of a fire and alert populations when there may be a need to evacuate, L.N.Wang, et al. (avoid fire accidents on running trains using ZigBee wsn) proposed this system to avoid fire in running trains. When the fire is noticed in any compartment, the temperature sensor senses the fire by the difference between the coach temperature and the critical temperature.

- Surapong Surit, Watchara Chatwiriya proposed a method to detect fire by smoke detection in video. This approach is based on digital image processing approach with static and dynamic characteristic analysis.
- Akshata & Bhosale proposed another method where Local Binary Pattern acts as a base for fire detection and Wavelet Decomposition is used to detect fire. Pixel level analysis is required in this method.
- Libelium (Solobera, 2010) developed a wasp mote which has four sensors for measuring gases temperature and humidity.
- Terradas, J. and PiÃ±ol et al. (2009) [2] has conferred this system because the wireless web based system has numerous applications in real time system. A program that analyses satellite data in near real time and converts information into instant messages and email alerts to track forest fires.

Implementations

Input Implementation

1. **Arduino UNO**: The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc.[2][3] The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits.[1] The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable.[4] It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts

2. **SIM808 GPS/GPRS/GSM Module**: SIM808 module is a GSM and GPS two-in-one function module. It is based on the latest GSM/GPS module SIM808 from SIMCOM, supports GSM/GPRS Quad-Band network and combines GPS technology for satellite navigation.
   It features ultra-low power consumption in sleep mode and integrated with charging circuit for Li-Ion batteries, that make it get a super long standby time and convenient for projects that use rechargeable Li-Ion battery. It has high GPS receive sensitivity with 22 tracking and 66 acquisition receiver channels. Besides, it also supports A-GPS that available for indoor localization.
   The module is controlled by AT command via UART and supports 3.3V and 5V logical level.
3. **Sensors:**

   - **Flame:** A sensor which is most sensitive to a normal light is known as a flame sensor. That's why this sensor module is used in flame alarms. This sensor detects flame otherwise wavelength within the range of 760 nm – 1100 nm from the light source. This sensor can be easily damaged by high temperatures. So, this sensor can be placed at a certain distance from the flame. The flame detection can be done from a 100cm distance and the detection angle will be 600. The output of this sensor is an analog signal or digital signal. These sensors are used in firefighting robots like flame alarms.
   - **DHT:** DHT stands for Digital Humidity and Temperature. The DHT sensor is a low-cost digital sensor for sensing temperature and humidity. This sensor can be easily interfaced with any microcontroller such as Arduino, or Raspberry Pi to measure humidity and temperature instantaneously.
   - **CO2 MQ135:** MQ-135 is a gas sensor that is sensitive to CO2. The change in CO2 levels changes the resistance of the sensor which results in a change in the output of the sensor. The output generated from the sensor is fed to Analog Input to the Arduino board (In my case Arduino Uno).

Implementation of components

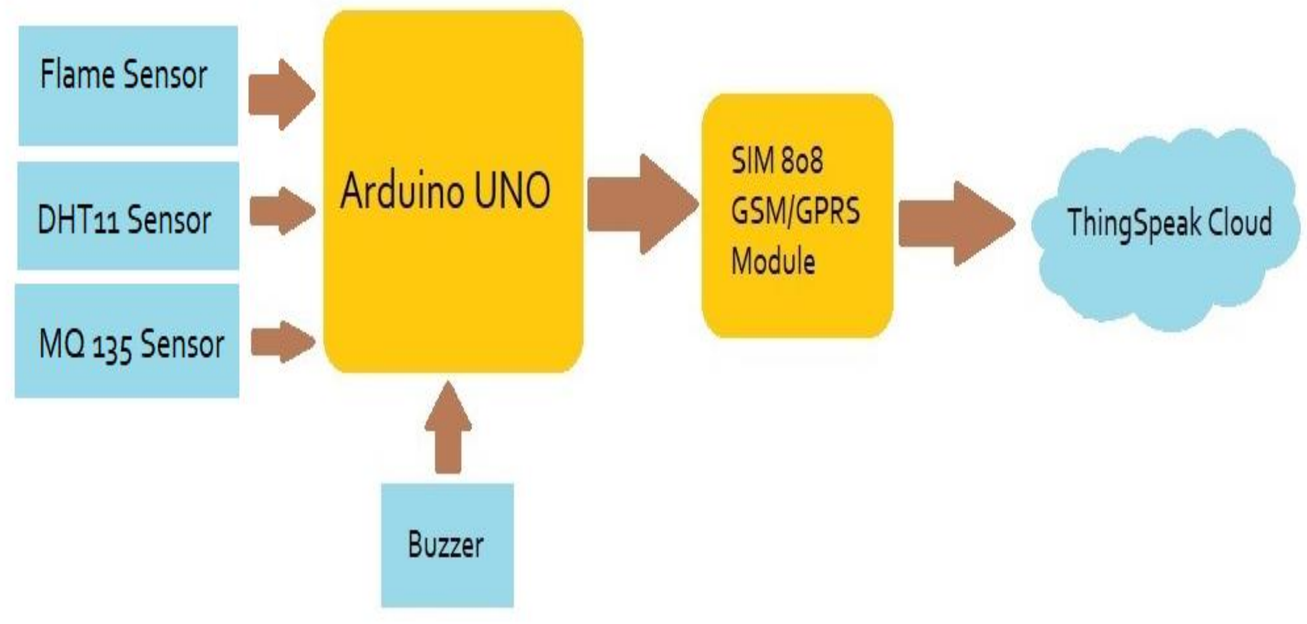
The Working procedure are as follows:

1. Connect the Flame sensor, DHT sensor and the CO2 sensor to the microcontroller (Arduino UNO) using Jumper wires and breadboard.
2. Also connect SIM808 module via Logic shifting resistors.
3. Connect the buzzer and LEDs for the alarming system.
4. Supply DC current (9V-1A) to SIM808 module to power it on.
5. 5V DC external supply is given to Arduino UNO for the working of UNO and the sensors.
6. After successful integration of hardware, Arduino IDE is used to code those components.
7. Cloud platform needs to be set up, where the real-time data will be received.

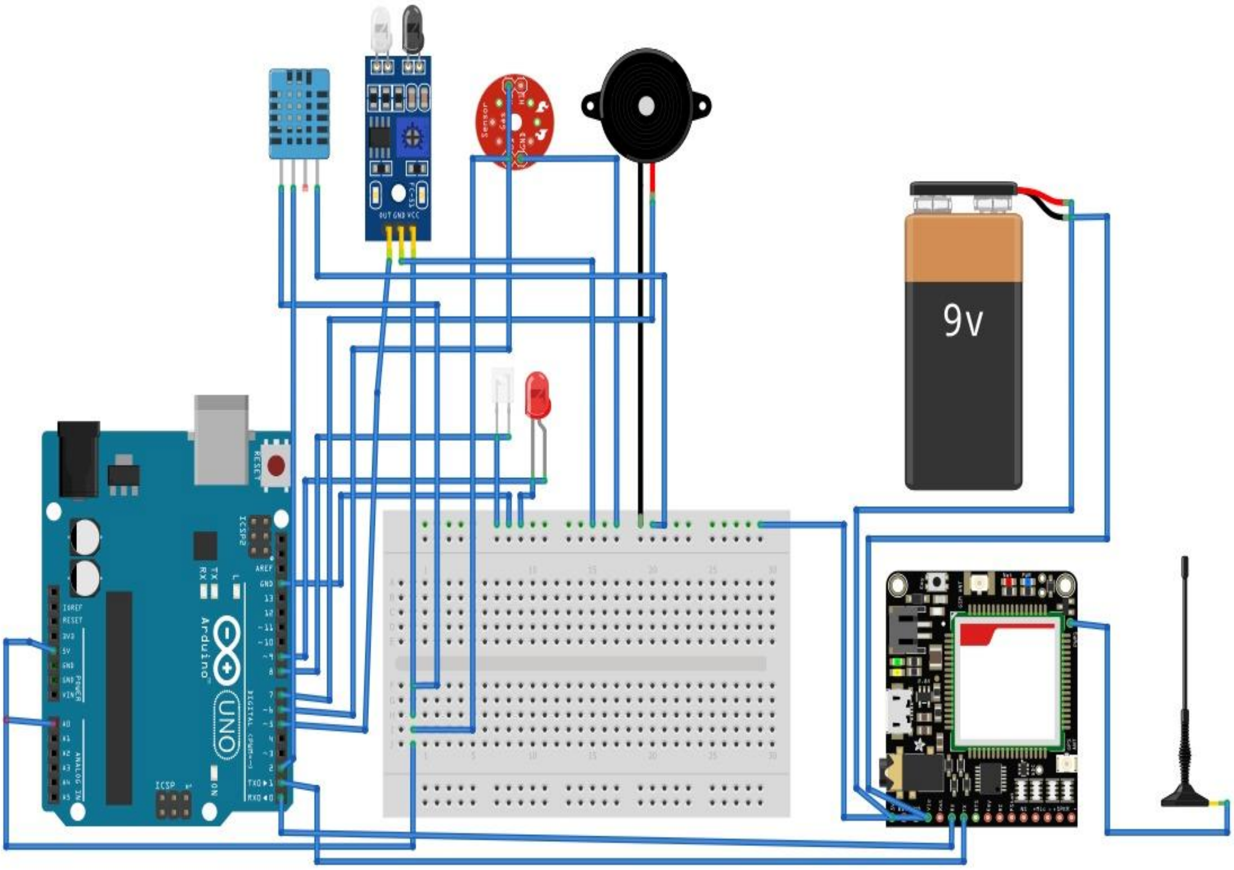
Once all the data is received, the intensity of the fire will be estimated and the level of the wild fire will be determined.

Block diagram/Flow chart

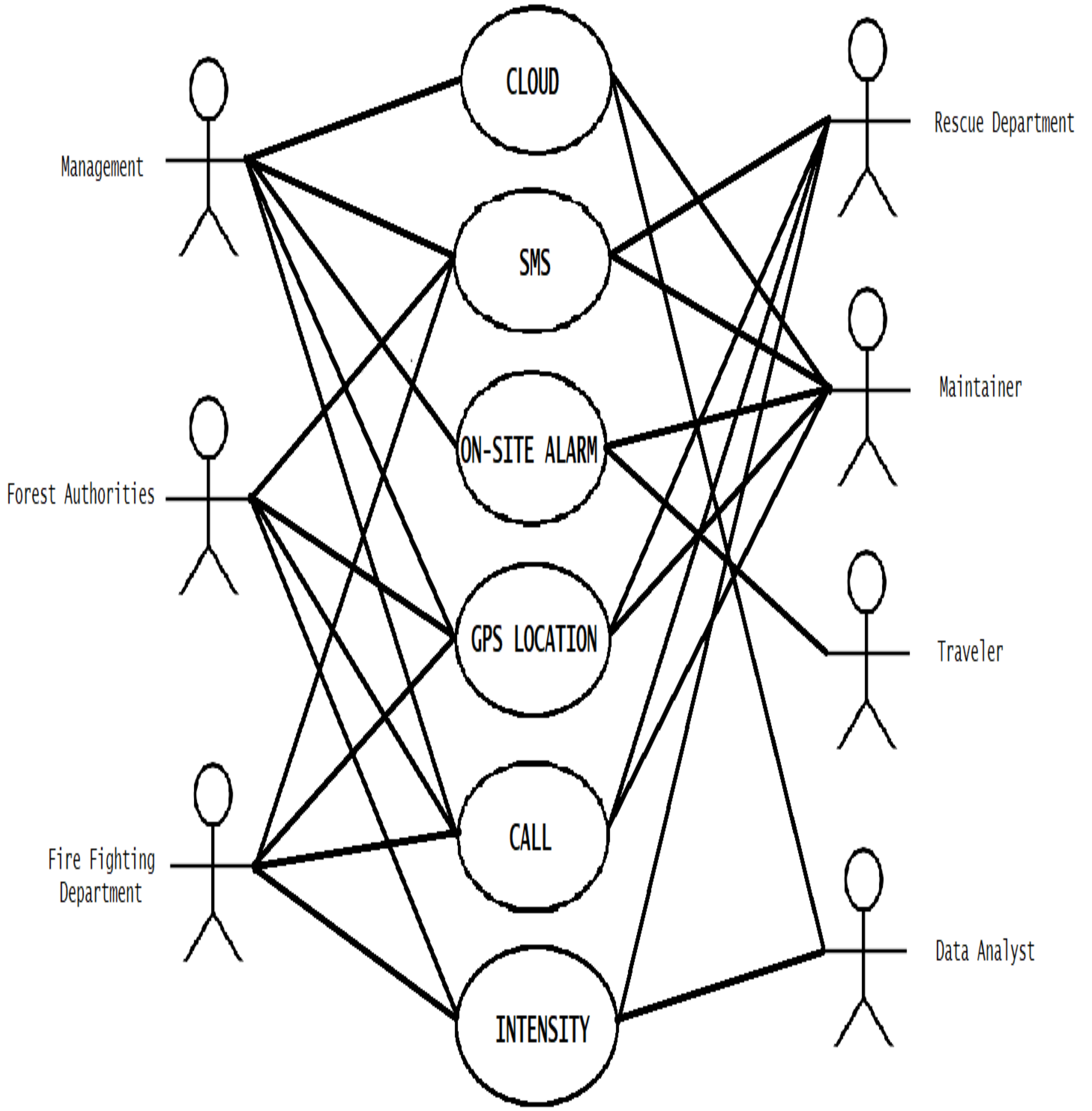
The diagrammatic representation for project is as follows:



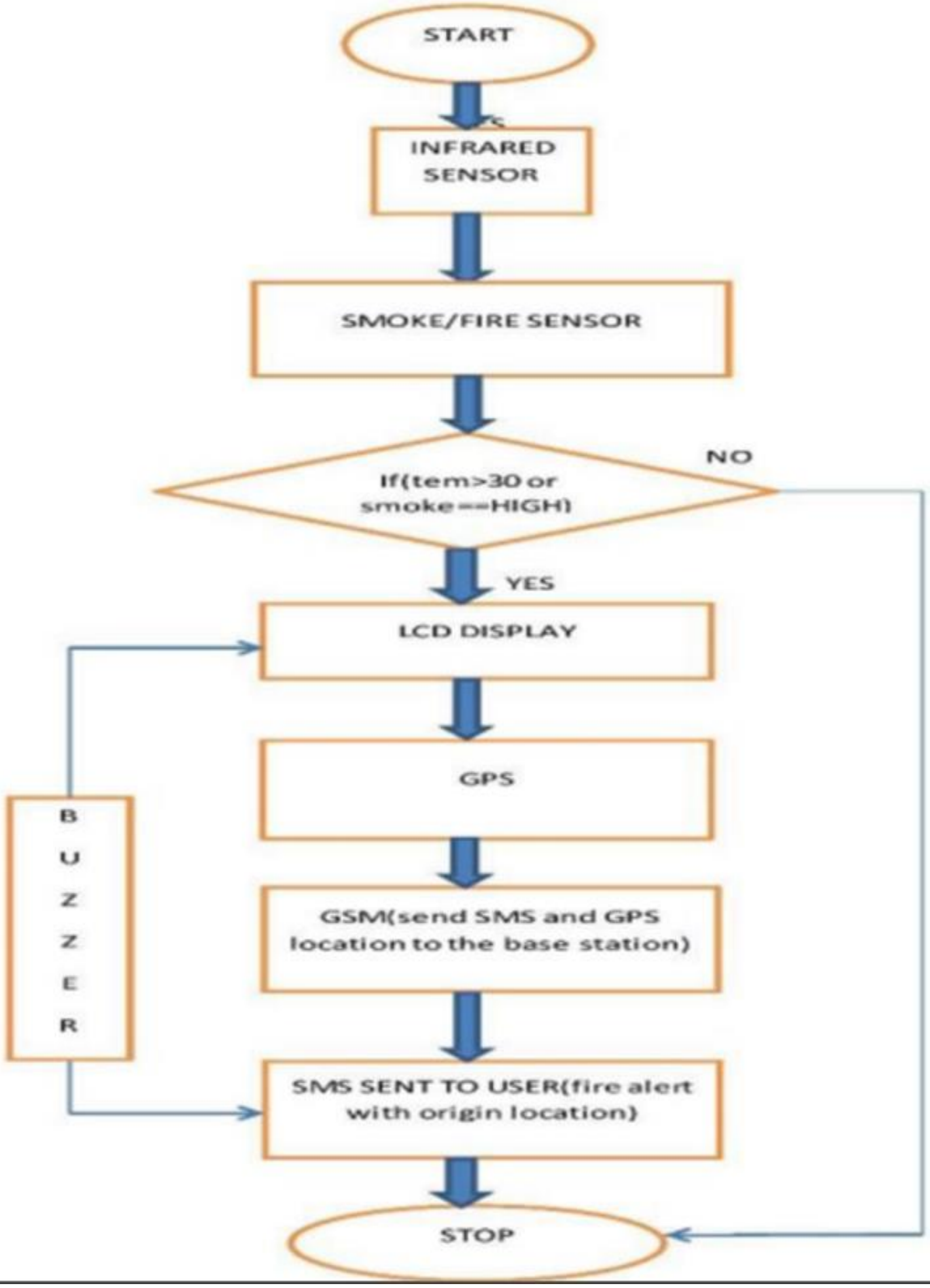
Architecture Diagram



Use-Case Diagram



Flow chart Diagram



After successful completion of hardware as per the above circuit diagram, the IoT platform needs to be set up, where the real-time data will be received. Here Thingspeak is used to store the parameters and show them in GUI.

For setting up the Thingspeak account follow the steps below:

○ First, go to https://thingspeak.com/ and create a new free Mathworks account if you don't have a Mathworks account before.

○ Sign in to Thingspeak using your credentials and click on "New Channel".

Now fill up the details of the project like Name, Field names, etc. Then click on "Save channel".

○ Record the Credentials

○ Select the created channel and record the following credentials.

○ Channel ID, which is at the top of the channel view.

○ Write API key, which can be found on the API Keys tab of your channel view.

○ Add widgets to your GUI

○ Click on "Add Widgets" and add four appropriate widgets like gauges, numeric displays, and indicators. In my case, I have taken the Indicator for Fire Alert. Select appropriate field names for each widget.

Innovation

The already existing system or the system that has been used currently in detecting forest fire is not efficient enough to detect the fire in the initial stage. It can detect only when the fire is widely affecting the forest. This caused many damages. But the cost of these devices is very high. These are not making use of the IOT that is the main disadvantage of these systems. If it makes use of the IOT it can detect and warn the fire in the early stages. Thus, in this project, the main focus is to detect the fire in the early stages and creates a high-pitched ringing sound or alarm that ranges up to 3 km to help save the wildlife and the humans present around the affected area. On detection, it also immediately intimates the nearest fire extinguishing office by sending a pre-recorded message via call indicating the occurrence of fire followed by an SMS which will be sent to the officer-in-charge which will contain the GPS location or the coordinates of the place of occurrence of fire. In the next step, the details of the damage including the temperature readings will be uploaded to a cloud platform for future analysis

1. **Determining the Fire Intensity:**

The extent of a forest fire is classified into 3 stages:

1. Ignition (Low)
2. Growth (Medium)
3. Fully Developed (High)

Byram's formula:

$I = H\,w\,R$ ***Equation 1***

where:

I = fireline intensity (kW m^{-1})

H = heat yield of the fuel consumed (kJ kg^{-1})

w = amount of fuel consumed (kg m^{-2})

R = forward rate of spread of the fire (m s^{-1})

Proposed Formula:

We know that,

- Intensity is directly proportional to Temperature.
- Intensity is directly proportional to the Concentration of CO_2 present in the air.
- Intensity is inversely proportional to the Relative Humidity of the atmosphere.

Thus, using the concept of Byram's Formula, we have extended the formula as follows:

I = [(T * C * k) / H] - 1.2

where,

T= Temperature (in degrees Celsius)

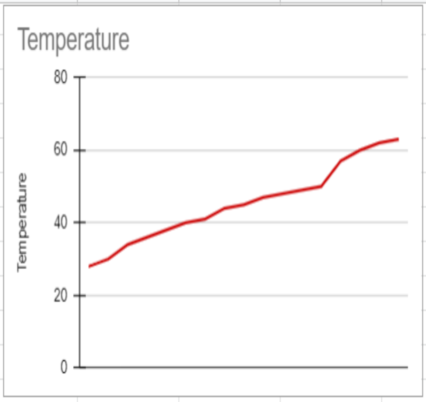
C= Concentration of CO_2 present in the air (in ppm)

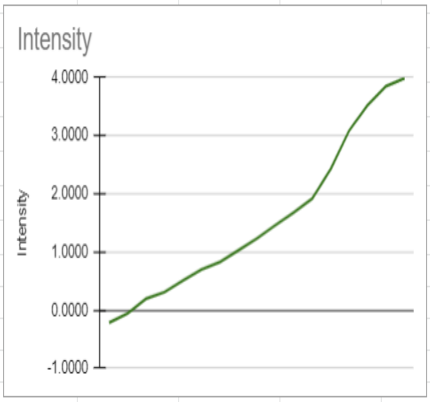
H= Relative humidity of the atmosphere (in RH)

k= proportionality constant

= 5.397×10^{-3} (RH per ppm per degree Celsius)

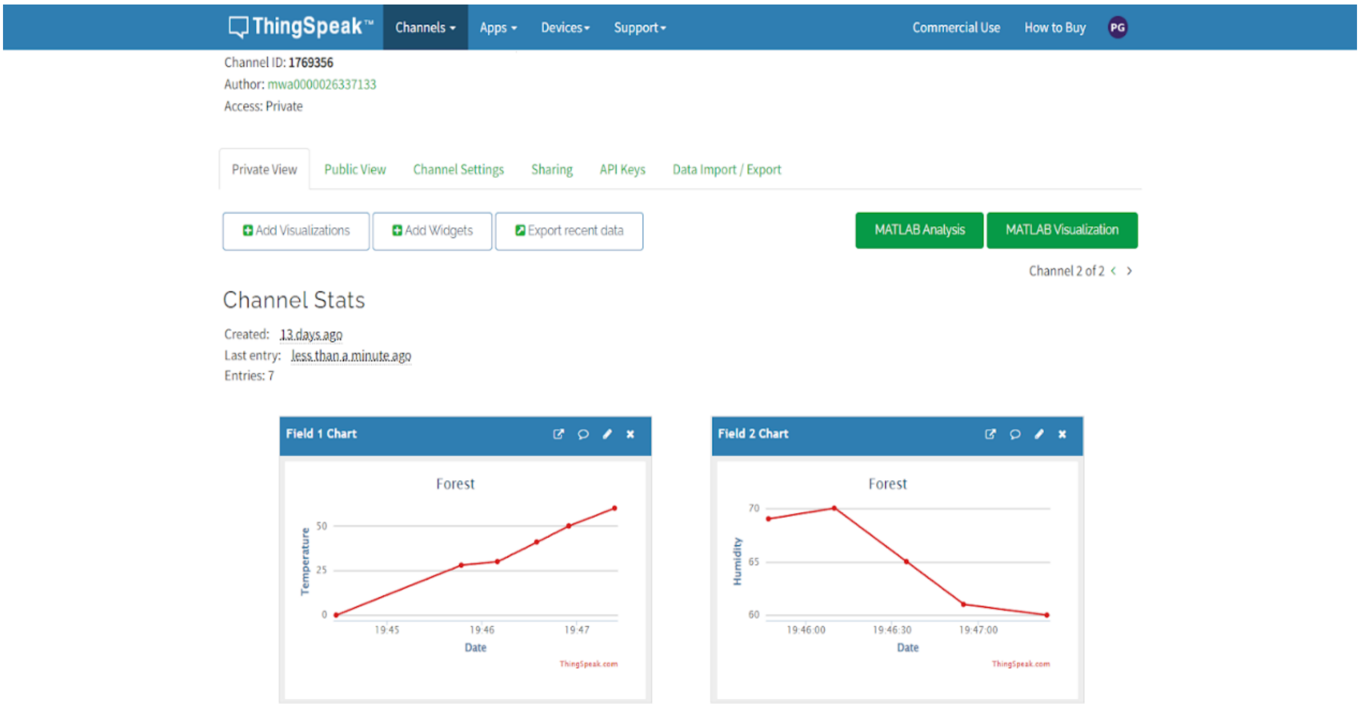
Data sheet for the Intensity of Forest Fire						
S.No	Humidity	Temperature	CO2 concentration	Intensity	Stage of forest fire	Level
1	69	28	450	-0.2145	0	No Fire
2	68	30	480	-0.0571	0	No Fire
3	67	34	510	0.1968	1	Ignition
4	67	36	520	0.3079	1	Ignition
5	66	38	550	0.5091	1	Ignition
6	66	40	580	0.6971	1	Ignition
7	65	41	595	0.8255	1	Ignition
8	64	44	600	1.0263	2	Growth
9	64	45	640	1.2287	2	Growth
10	63	47	660	1.4574	2	Growth
11	63	48	700	1.6784	2	Growth
12	62	49	730	1.9137	2	Growth
13	61	50	820	2.4275	3	Fully Developed
14	61	57	850	3.0866	3	Fully Developed
15	60	60	875	3.5224	3	Fully Developed
16	59	62	890	3.8476	3	Fully Developed
17	59	63	900	3.9866	3	Fully Developed





2. Integration of Cloud:

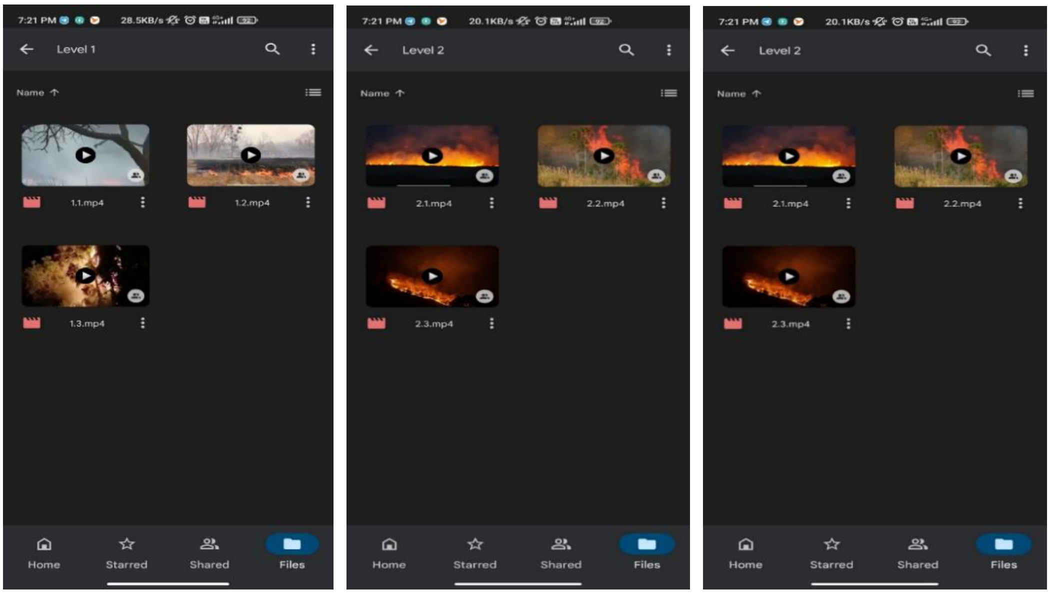
ThingSpeak, an open-source cloud is integrated with the device with the help of an API to visualize the data in a graphical format (line graph) and to understand the changes in the physical parameters during the incident.



3. Clips of the current state:

The authorities are informed about the current scenario at the site of the incident by an SMS containing a google drive link that has a few video clips.

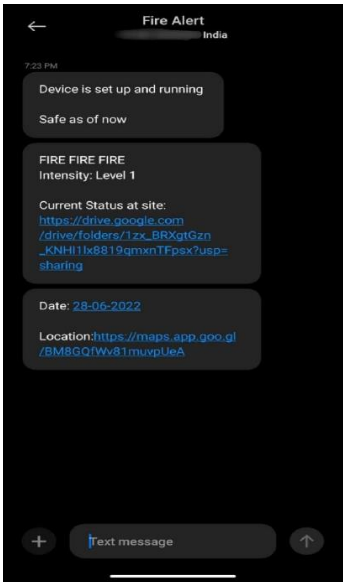
- Currently, we have uploaded pre-recorded videos in the drive.
- As a future scope, clips of 10 sec each showing the status of the scenario will be posted in the drive at regular intervals of time.

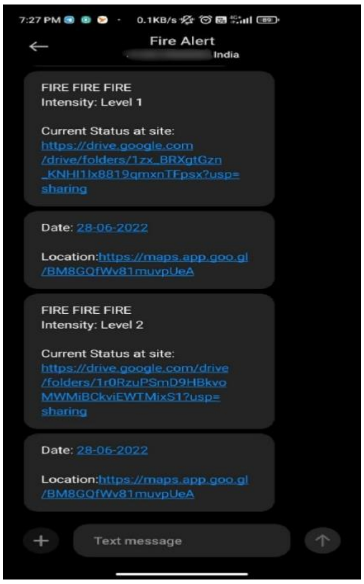


4.Intimating the Authorities:

Authorities are informed about the forest fire at the earliest.
It is done in 2 ways:

- **SMS**: A customized SMS is sent to the authority based on the intensity of the fire along with the date and location to ensure that appropriate measures will be taken.
- **Call**: As a precautionary measure in case there is a delay in sending or receiving the SMS, a call is given.





5.Buzzing the Alarm at the site:

As a matter of fact, all the animals (domestic or wild) and humans are hardwired by evolution to find loud noises frightening. Hence a high-frequency buzzing sound is generated when the fire breaks out which helps in creating a sense of alarm within them and evacuating the hotspots thus, saving many lives.

- For now, the buzzer is audible up to a range of 4 m.
- A future scope implementation would be to create an alarm with a range of about 4-6 km.

Output

Test Cases

Data sheet for the Intensity of Forest Fire						
S.No	Humidity	Temperature	CO2 concentration	Intensity	Stage of forest fir	Level
1	69	28	450	-0.2145	0	No Fire
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17	59	63	900	3.9866	3	Fully Developed

Basics of software testing

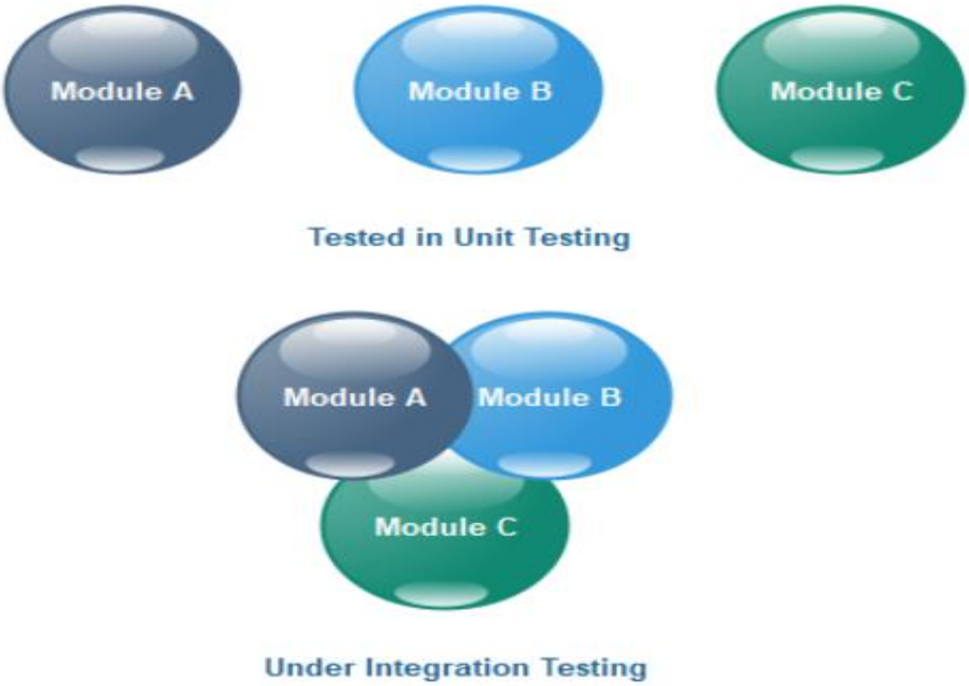
- **Smoke Testing** - smoke tests verify if the most important functionality is working. Detecting fire and determining the intensity was rigorously tested. **Smoke Testing** is a software testing process that determines whether the deployed software build is stable or not. Smoke testing is a confirmation for QA team to proceed with further software testing. It consists of a minimal set of tests run on each build to test software functionalities. Smoke testing is also known as “Build Verification Testing” or “Confidence Testing.”

- **Black box Testing** - Black box testing assesses a system solely from the outside, without the operator or tester knowing what is happening within the system to generate responses to test actions. **Black Box Testing** is a software testing method in which the functionalities of software applications are tested without having knowledge of internal code structure, implementation details and internal paths. Black Box Testing mainly focuses on input and output of software applications and it is entirely based on software requirements and specifications. It is also known as Behavioral Testing.

- **White box Testing** - White box testing is an approach that allows testers to inspect and verify the inner workings of a software system. Various paths, statements, conditions, and loops were closely examined. White box testing techniques analyse the internal structures the used data structures, internal design, code structure and the working of the software rather than just the functionality as in black box testing. It is also called glass box testing or clear box testing or structural testing.

- **Unit Testing** - Unit testing is a software development process in which the smallest testable parts of an application, called units, are individually and independently scrutinized for proper operation. Unit testing is a component of test-driven development (TDD), a pragmatic methodology that takes a meticulous approach to building a product by means of continual testing and revision. This testing method is also the first level of software testing, which is performed before other testing methods such as integration testing. Unit tests are typically isolated to ensure a unit does not rely on any external code or functions. Testing can be done manually but is often automated.

- **Integration testing (Bottom-up)** - A type of software testing in which the different units, modules, or components of a software application are tested as a combined entity. Integration testing is the second level of the software testing process that comes after unit testing. In this testing, units or individual components of the software are tested in a group. The focus of the integration testing level is to expose defects at the time of interaction between integrated components or units.



Output/Result

The output of the proposed system is as follows:

The fire and smoke sensors detect the respective elements and this initializes an alert and activates the system. This, in turn, sends the location, which is detected by the GPS module, with an alert message via SMS to the user with the help of the GSM module that has been incorporated into the system. Once the user receives the alert message, the required action can be taken to control and cease the fire.

The wireless transmission using RF, from one node to another node was experimented up to 1m. As there would not be any obstructions in the forest, the RF modules can work up to one meter efficiently. For GSM module to work properly, there should be a minimum network coverage to send an SMS with location. The nodes can be placed 1m away from each other, for maximum coverage of the forest area with minimum number of nodes and to perform with good efficiency. The fire and smoke sensors were tested up to 1m

Conclusion

Early cautioning and quick reaction to a fire breakout are the main approaches to dodge incredible misfortunes and natural and social legacy harms. Hence, the most critical objectives in flame observation are fast and solid identification and restriction of the fire. It is substantially less demanding to stifle a fire when the beginning area is known, and keeping in mind that it is in its beginning periods. Data about the advance of flame is likewise profoundly profitable for dealing with the fire amid every one of its stages. In light of this data, the fire battling staff can be guided on focus to hinder the fire before it achieves social legacy destinations and to smother it rapidly by using the required putting out fires' hardware and vehicles.

The improved system can be deployed for tenement appliances and in industries also. However, the system above is meant for sincere opinion news only. As a tomorrow aggravation, several-decision companies through the IOT landing are studying an object and the exploration is being done to effectuate this enormous toil.

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Future improvements/Scope of the project

In the future, we can develop this model to minimize the energy consumption of all sensors. Also, industrial sensors can be used for better range and accuracy. We can also install a wind sensor in the system which helps to determine the direction of the fire and the rate at which it will spread. Along with this, we can implement an automatic fire extinguisher system. As soon as a sensor detects a fire, the extinguisher gets activated

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    - **DOI:** 10.1109/ICSCAN.2019.8878808
    - **Conference Location:** Pondicherry, India
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    - **Volume**: 08
    - **Issue**: 04 | Apr 2021
    - **Authors**:
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