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Forest fire detection and prediction using Internet of things

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Abstract: *Forest fires pose a serious threat to ecologically sound forests and environmental protection Also, loss of life and considerable natural individual properties, adding hundreds of houses and thousands of hectares of wilderness 80% of fire-related costs could have been avoided if the fire had been discovered sooner. Forest fires become worse and can be detected and forecast with IoT-based NodeMCU. The study is an honest attempt to comprehend the current system, studying various factors affecting forest fires. We tried to make it smarter with thehelp of IoT technology by linking the entire monitoring process to a cloud server. It has been utilized to identify forestfires in extensive surveys. The goal of this research is to look into the losses and damage caused by wildfires, both natural and human-induced and fire detection techniques. The major goal of this research is to anticipate how a firewill progress by monitoring temperature, humidity, and other factors.*

***Key Word**: Forest; Fire; NodeMCU; Sensors*

I. Introduction

Forest fires, weather natural or man-made, are a common occurrence in various regions of the world. Endangered locations are mainly found in the temperature regions, when pluviometry is high enough to maintain a large amount of vegetation, but summers are excessively dry and hot, resulting in the dangerous fuel load. The number and severity of these disasters will rise as a result of global warming. Wildland fires burn not only thousands of hectares of forest each season, it affects assets, properties, and public facilities. Furthermore, civilians and firemen are in danger, with an annual death toll of thousands of people. Despite recent advancements in the development of wildfire suppression, disaster response capability, including warning systems and improved real-time data exchange at all the stages of forest monitoring systems, remains a priority. In the fight against wildfires, technological improvements will become a major driver of change. Latest advancements in IC technologies, particularly forest fire detection systems, are already having a significant influence. Although satellite imagery-based systems exist, they are not utilized in real-time application on forests, because of their slow scan cycle, high cost and low resolution. Other methods based on short-range pictures have been proposed, such as optical, infrared, or thermal imaging. These methods, however, are extremely sensitive to outliers, such as direct sunshine, a lack of light, or smoke. They are prone to false alarm as well. The use of radio acoustic sounding to estimate in forest environments, metrological flow or temperature pattern are important profiles in forest regions has also been proposed. Also, it is costly (use of radars and an auditory source is necessary), and is susceptible to interfering like changes in wind direction.

II. Material And Methodology

The device's first stage is to detect the occurrence of any fire inside the specified area. An electric transducer, LM35 temperature sensor, humidity sensor, LDR sensor, soil moisture sensor, and other sensors are used to do this. The transducers send a signal to the electrical circuit whenever any reason causes a fire. The electric circuit is turned on and begins processing the information as soon as a signal from the fire sensing devices is received. A warning light and an alarm are turned on. The entire sensor data set was uploaded to an open-source cloud platform. We will visualize the data in that cloud- live updated data. If the scenario exceeds the predefined values.
HARDWARE

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RF Module (Receiver and Transmitter)

- Node MCU (Micro-controller unit)
- Smoke Sensor
- LM 35
- Soil moisture Sensor
- PCB
- Humidity Sensor DHT11
- Transformer
- Voltage Regulator
- Ultrasonic range Sensor
- LDR Sensor
- Capacitor
- Diode
- Relay
- Transistor
- Resistor
- Wiring
- Plug pin

List of sensors used

1. LM35 Temperature sensor
2. DHT11 Humidity sensor
3. LDR sensor
4. Ultrasonic range sensor
5. Soil moisture sensor
6. Smoke sensor
7. NodeMCU (Node Micro-controller unit)

In the current system, robots are used to extinguish fires, however robots have their own set of benefits and drawback. We use multiple sensors to identify and monitor forest fires in this system, which is then sent to an IoT cloud. If the sensors receiving values are more than the predefined values in the cloud, the user will receive an email. Continuous monitoring and uploading of data to the Thing Talk cloud is possible.

The “Forest fire detection and prediction over IoT” system is made up of various sensors and components
LM 35 - Uses for temperature variation
DHT 11 - Use for moisture value detection
Soil moisture –use to detect the moisture of the ground
LDR - Use to detect the variation in light
Ultrasonic - Use to detect the distance

Using many sensors, we are able to identify and monitor forest fires in this system. The signals and measurements obtained by these sensors will be sent to center, which will use computer vision and pattern to recognize and identify fire using threshold values which are predefined, temperature and humidity values, and an analysis. When it is detected, an alarm is activated, along an alert message that includes the sensor data and a prediction of the fire at the specific location.

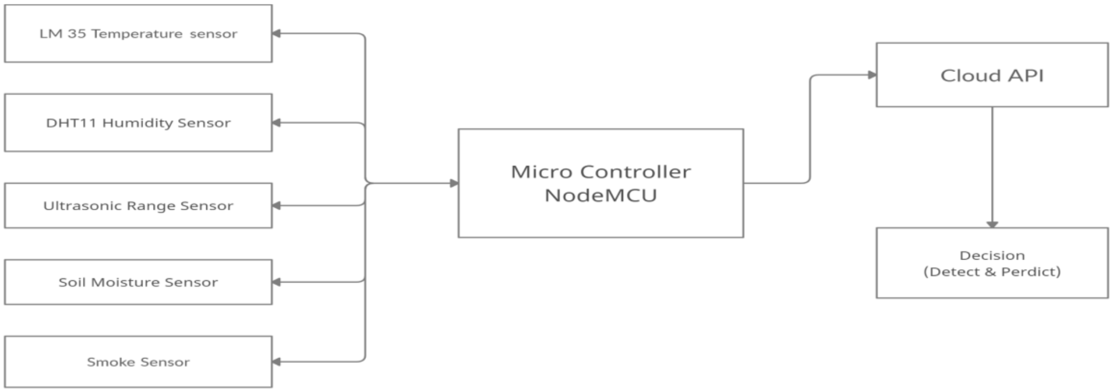

Figure1: Block diagram

III. Literature review

Lloret [1] from Spain brought forward a system with included setting up grid network of sensors merged with IP cameras. The sensors here detect the fire at the earliest and sends the signal back to the sink station. Which forwards the information to the IP cameras which provides live camera feed which can confirm the fire and avoid false alarm. Therefore, this report is totally based on the camera protocols, and the main concern with this picture transfers takes a lot of loads on the whole system as there is limitation of power and storage space in forests additionally these are in affective in rains and foggy weather and those can serve only in straight line of vision.

FireWxNet[2], is a system developed by Hartung et al which was put forward for its multiplayer ability, portability and wireless networks. It consists of a wireless set of sensors and web cameras to reveal fires at the earliest. It mainly focuses on the detection and understanding the pattern and other parameters and all the data along with the web cameras images are provided to the fire fighters for further work. It also employs directive radio towers and antennas installed on the higher grounds which keeps an eye on the environmental conditions.

Son [3], from South Korea initiated a concept which complies of similar wireless sensors along with integration to internet to detect fires. It uses a different routing technique called as Minimum (MCF) cost forwarding. It includes a table for routing every single node which enable it to locate or consider the shortest path to the sink. Their study includes general information on network architecture. The sensed parameter included temperature, humidity, and illuminations power sensors which further are sent to the base sink node. Which is sent to the gateway of the system which acts as interface between the application and the web database station which further performs necessary calculations to identify the change in humidity and temperature change than the daily or threshold values. It mainly focuses only on estimations.

Hefeeda and Bagheri [4] have devised an ingenious technique. They proposed an insightful technique, which totally depends on fire weather (FWI) index which takes credibility of possible ignition of fire and its rate of spread over a period of time, It works with the important data like moisture content of the forest soil and atmosphere, fuel codes further classified in three types, the litter fuel of 2 cm deep are classified under Fine Fuel Code, while others are at depth of 5 cm is considered as duff code and further above 10 cm is considered as drought code, It requires a lot of time before installation because consideration is made according to type of fuel code, majorly focusing on prediction of fire on basis of drought code rather than sensing.

In Pennsylvania, Conrad [5] built a system with GP projects after concluding that Pennsylvania alone loses 2554 acres of land every year due to forest fire which causes loss of human life as well as economic loss. They advised replacing current systems like towers, drones, Patrol teams etc. with their sensors and Global positioning devices. Their only motive towards this was to replace all currently used system with the latest system and more efficient systems they produce.

Aslan [6] advised a advanced and more efficient system with advanced sensor deployment techniques with deals with distance between set of sensors thus covering the whole area without any blind spots in the system. The whole cluster of sensors network is known as web. The transmission of signal between these clusters and nodes is in four steps: - initialize, period of free-risk, main threat of phase, and the hazard computation phase which depends on Humidity, temperature and other range value. And also allowing the clusters to interface with each other.

Conard and his colleagues were now working to configure GPS based portable device and radio wave sensors, which works on a set of temperature values by transmitting signals. Each device is assigned with unique identity code to make the system more efficiently. Their goals are to install 12000 systems in 4 years. After sensing the fire, the signal is sent to the GPS module which displays the exact fore location on the base station.

It was very expensive because of manual installation of sensor clusters and GPS and calibration GPS consumes more energy thus life of nodes is less. Each module is configured according to the countries forest and is unique,

Some researchers used these models or developed their own modules based on these systems additionally developing maps to merge with those and analyze behaviour of fire at any possible time assisting the forest fighting officers to find the best way of distinguishing fire. This is to detect the fire at early stage and limiting the losses caused by the minimum time.

Hongye [7] developed a smart system-based structure in Mongolia which is distributed into monitoring, data acquisition and decision making to fire proofing systems Monitoring gives the rapid and exact location of fire at the quickest on the map which is converted into 3D maps using photos form the place and used in together for fire simulation. The only con about the system is its complex construction despite being highly logical. Ngai et al. [8] create a global reliability-centric architecture for activity reporting in wireless networks that may be used to identify forest fires. They assess the accuracy, relevance, and validity of the provided data in environmental activity detection systems. They offer a delay-aware data communication protocol and a computation technique for selecting relevant data.

Wenning [9] offers a proactive disaster detection routing approach in wireless communication. The system was introduced in order to be aware of a node’s risk of demolition and to be willing to change routes if a sensor node destroyed. If a perceived phenomenon signals a potential failure danger, the method also alters the routing condition.

Garc[10] describes a simulation platform that may build a fire model by evaluating data from sensor nodes and integrating it with certain regional required data about the immediate landscape. This study is unique and it takes used of the topography of the area.

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By clustering characteristics such For the last 30 years, weather forecast offices and 40 weather observation stations have measured seasonal mean temperature and seasonal precipitation, South Korea is divided into 16 eco-regions. Gangwon is a forested and hilly region in northeastern South Korea. Yongpyong and Alpensia are two ski resorts. A major forest fire broke out in YangYang and Kosung in the Gangwon-do coastal ecoregion, destroying 300hectares. Flames are sparked by the fire created by the updraft. Flying sparks catch fire, such as pine cones, branches,and bark, and fly in the direction of the fire movement. Flying sparks reached a height of 1.5 to 2 kilometers. Forest fires are difficult to manage and cause significant environmental harm. In burned areas, around 3.4 tons of soil are lostevery hectare. The soil loss takes at least 3-4 years to recover. When forests are harmed by fires, it takes roughly 40 to 50 years for the ecology to recover Data taken from various resources for year 2010-2018.

Table no1: Forest Fire occurrence in South Korea

Year	Count	Area	Damage	Accumulated average	Cost ($1000)
2010	460	3947	9.1	195,071	9125
2011	265	1041	3.8	44092	2,567
2012	317	478	1.6	6378	665
2013	729	25943	35.14	1,373,502	65,241
2014	258	969	7.5	33458	2727
2015	231	1465	0.6	324196	8945
2016	266	149	2.9	2555	298
2017	478	1580	4.2	52859	4096
2018	512	2067	4.0	113,840	7,526

Table no2: Forest Fire occurrence Season wise in South Korea.

Seasons	Mean for 5-years	Year range					
	Count of Fires	Section (%)	2011	2012	2013	2014	2015
Total	360	100	265	317	729	258	231
Spring	223	63	167	206	437	167	143
Summer	4	1	2	4	7	3	3
Autumn	24	6	12	24	42	19	18
Winter	109	30	84	83	243	69	67

Except for August, when the peninsula has an oceanic climate, the peninsula has a continental climate. Summers have a wet monsoon environment that is hot and humid with frequent rain showers, but winters are chilly and dry. Seasonal variation and subtle but evident, with spring and fall seasons being shorter than summer and winter.

Because the spring and fall season are drier than the summer and winter, forest fires are more prevalent in Korea. Which include a lot of rain and a lot of snow. South Korea's Forest fire prevention seasons are 15th of February to 15th of May in spring and 1st of November to 15th of December in fall and early winter.

Naturally occurring wildfires: -
Lightning is the most common source of naturally occurring wildfires. Depending on the situation, there are also flames caused by volcanic eruptions, asteroids, and coal deposits.
Human caused wildfire: -
Wildfires started by humans might be unintentional, purposeful (arson), or the result of neglect. Wildfires caused by human activity account for around 80% of all wildfires that occurs in Country each year

Table No. 3: Causes of Forest fire

Reasons	Specific reasons	Other
Lightening (natural cause)	Thunderstorms	When a certain reason is unknown or does not appear on the list of specified causes, another known or unknown is chosen.
Smoking	Cigarette, and matchsticks or lighters, cigars	
Using fire	Burning debris, slash piles, etc.	
Railroads	Railroad work, Exhaust, brakes	
Delinquents	Fireworks	
Incendiary	Illegal or unauthorized, Arson, etc.	
Campfire	Warming, Bonfire,	

The following are the most commonly used fire detection and suppression tactics utilized by authorities:

1. Watch towers
2. Spotter planes
3. Lightning detectors
4. Optical smoke detector
5. Drone inbuilt with infrared camera
6. Optical sensor and digital camera
7. Weather Station report
8. Water tanker
9. Satellite based tracking system
10. Controlled Burning
11. Estimation of fuel and moisture content

Detection and monitoring systems include community outreach disclosure reporting of fires, ground support personnel, public aircraft, and operations and maintenance detection systems using aerial surveillance, fire spires, electronic flash detectors, and fully automated detection systems. In recent years, a variety of solutions for identifying out-of-control fires have been exhibited and implemented. The most common use of a video surveillance system is to identify wildfires. Thesignificant false alarm rate of these devices was due to climatic factors, such as fog, shadows, clean particles, mountain ranges obscuring the line of vision, and so on. The cameras are unable to include the land's topography into their positioning computations.

Best Current system Exists: Existing satellite-based forest fire monitoring have major limitations, resulting in a failure to suppress forest fires quickly and effectively. The following are some of the drawbacks of a method that is direct visual of fires in Low earth orbit (LEO)or geostationary (GEO): Because the Geo and Leo satellites are orbiting nearly 36,6693 kilometers above the earth's surface, it may be hard to provide complete or even intermittent satellite coverage. Flames generate optical and infrared (heat) radiation that may be too faint for a satellite to observe in their early stages, before they spread across a broad region

IV. Theory and Working

Steps Involved in The Process:

● Employing Sensors to act as a data collection center: - Temperature and smoke sensors are used, and they should be put at particular distances so that they kept on the complete forest area with the goal of identifying the onset of temperature and carbon dioxide (CO_2) gas levels are disturbing the forest. The data or the flag will be sent to the microcontroller by these sensors. All of these will sense variation and react natural in the event of a disaster. Fresh Developments in the field of pre-programmed beginning devices use cameras and computer computations to look at the visual impacts of flame and development in a way that current discovery instruments cannot. In a real scenario, a number of such sensors should be used, each of which should be situated at specified distances in orderto keep an eye on the entire forest environment.

● Gathering of information from the NodeMCU: The information acquired and recognized by the temperature, gas, and other sensors and send to the micro-controller unit NodeMCU in the transmission circuit. The controller then performs the tailored activity for it before passing the data to the transmitter.

● Transmitting the data by the transmitter: When transmitter receives the data from the control point that is controller. It sends a certain range where the station is very much enhanced to used. The micro-controller unit that is Node MCU is the heart of the circuit equipment. it enables the complete operation of the entire circuit, in this case the transmitter circuit.

● Acceptance of the data by the receiving station: The recipient receives the information from the transmitter circuit and transfers data to the controller IC of the attached NodeMCU, which is mounted in a computerized frame in the beneficiary circuit, allowing the controller to execute changed activities like temperature and CO_2 level checking for flame identification.

● Display of temperature and humidity level and other sensing levels.: - It is possible to construct a page in the privately built system with the assistance of switch when the temperature and CO_2 data source is produced in the IC of the receiving circuits NodeMCU, which is changed with various library components of the ethernet cloak interfacing. A caution that has also been added to encourage the fire security group to find the vulnerable area as quickly as feasible. This fire alarm circuit will sound an alarm only whenthe temperature levels exceed the stated threshold

Figure 1: Block Diagram

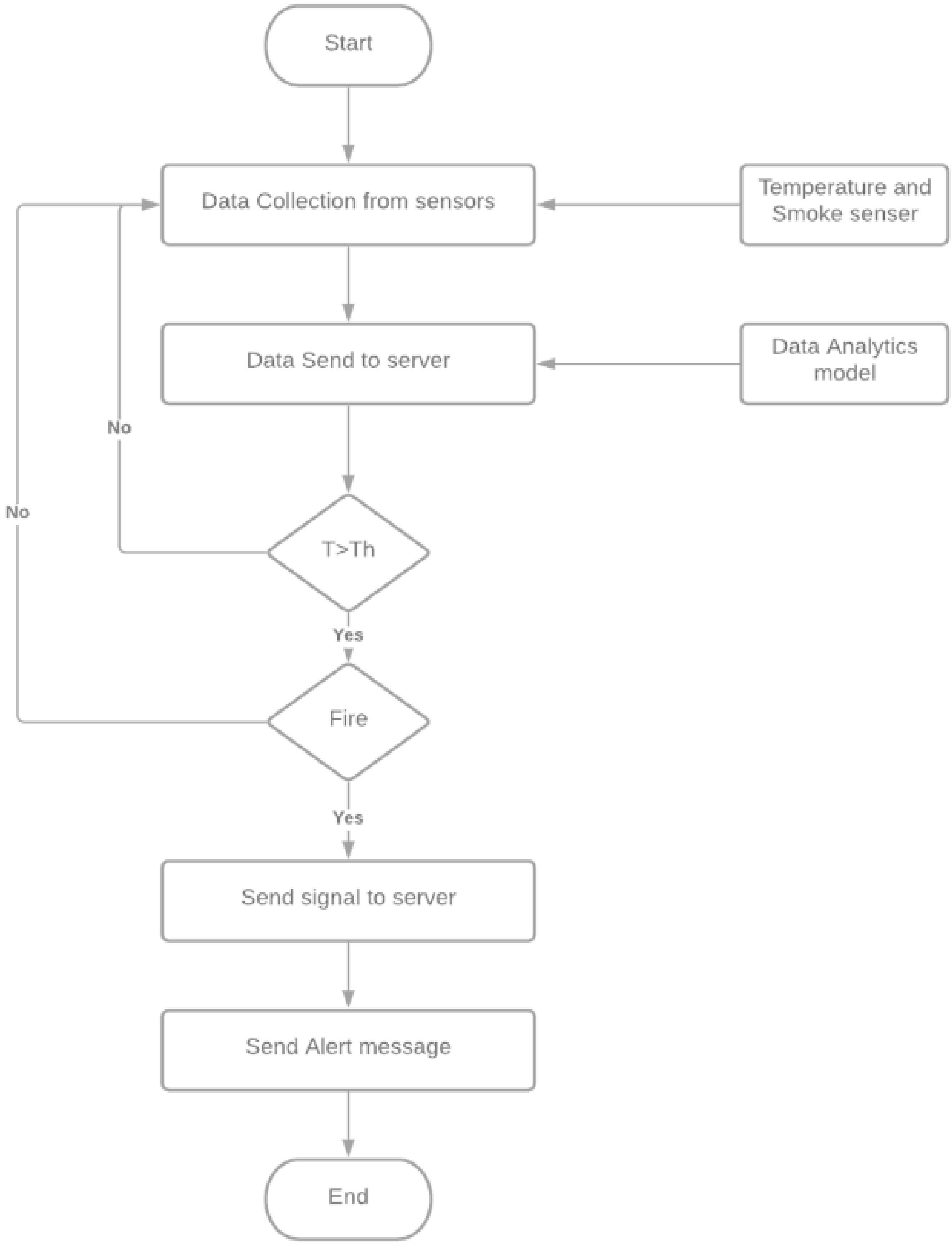

Figure2: Flow Chart of the system

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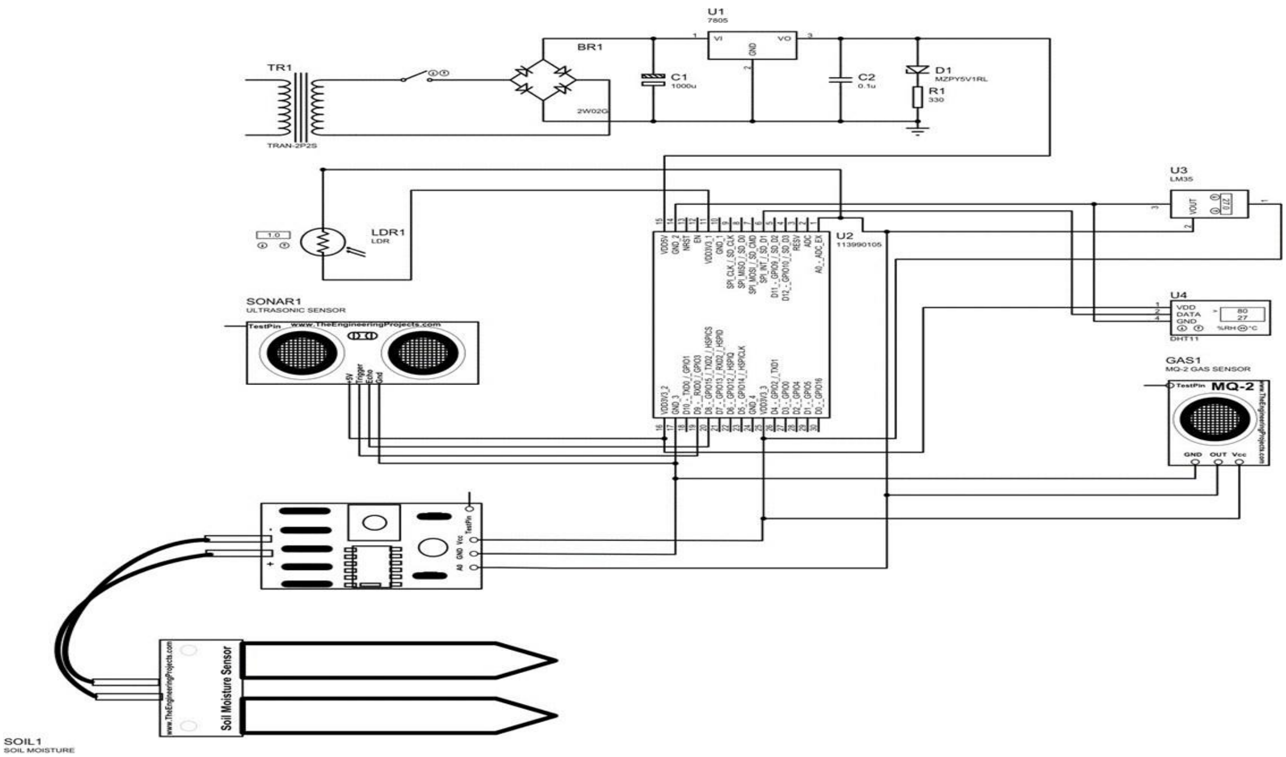

Figure3: Circuit diagram

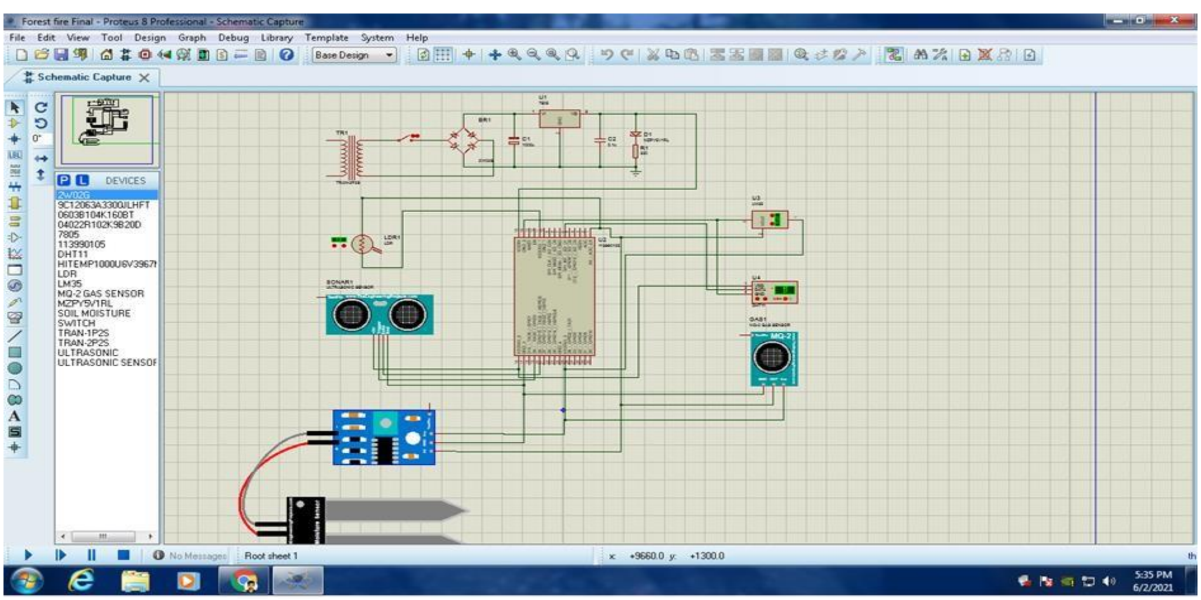

Figure4: Circuit diagram simulation

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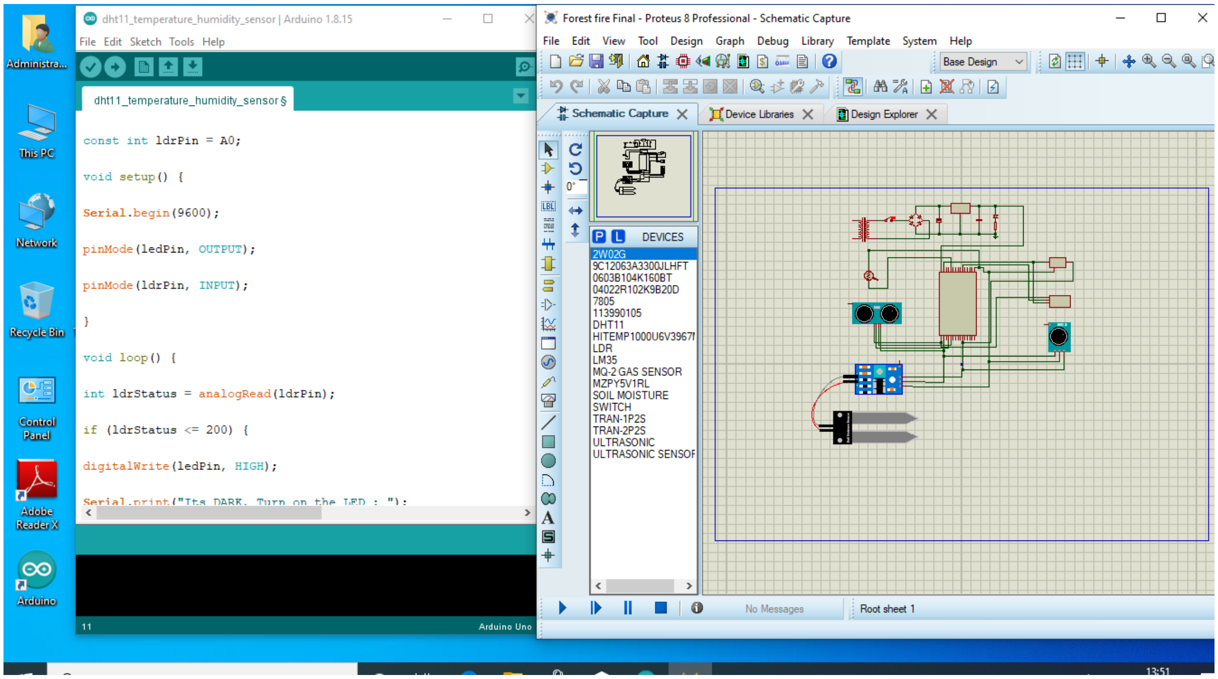

Figure5: Simulation and coding

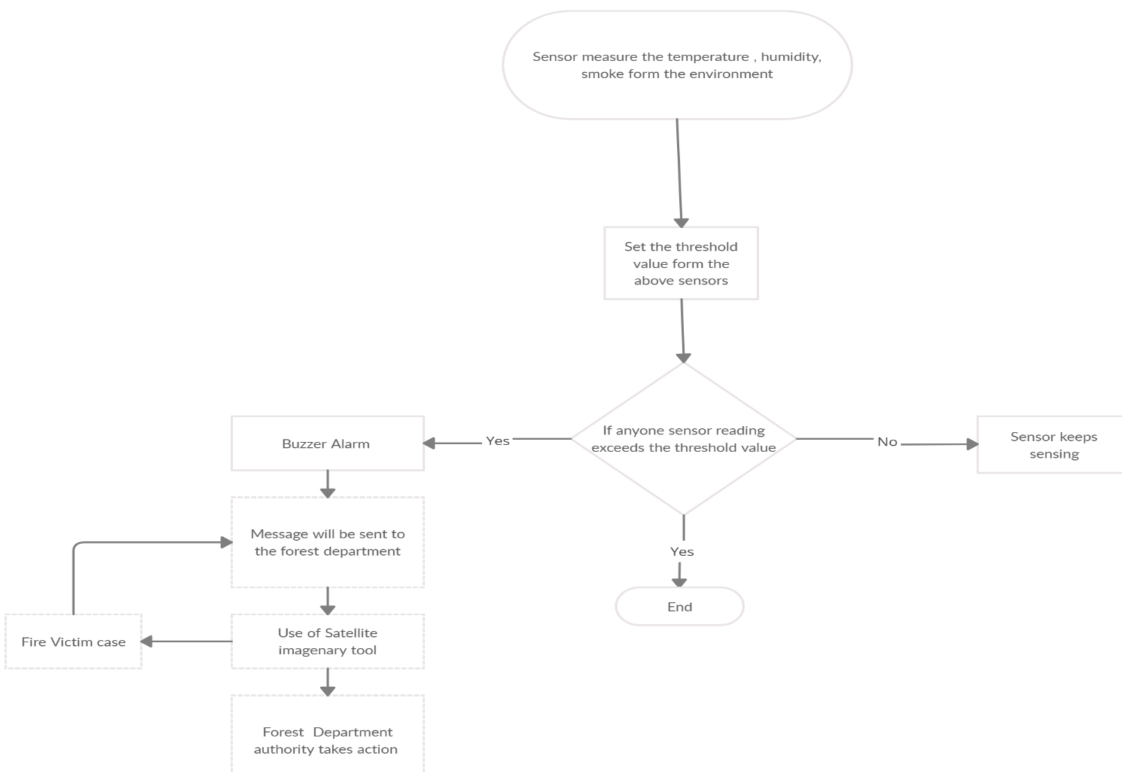

Figure6: Flow of the process

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Table no 4: Cost analysis of our proposed system

Sr. no	Part Description	QTY	Rate	Amount
1	NodeMCU	1	570	570
2	RF Module (Receiver and Transmitter)	1	700	110
3	Smoke Sensor	1	110	110
4	LM 35	1	240	240
5	Soil moisture Sensor	1	190	190
6	PCB	1	30	30
7	Humidity Sensor DHT11	1	205	205
8	Transformer	1	260	260
9	Voltage Regulator	1	21	21
10	Ultrasonic range Sensor	1	227	227
11	LDR Sensor	1	92	92
12	Capacitor	3	9	27
13	Diode	3	10	30
14	Relay	1	25	25
15	Transistor	1	8	8
16	Resistor	2	5	10
17	Wiring	2 meters	20	40
18	Plug Pin	3	10	30
19	Total			2225

Table no 5: Current fire detection techniques correlations

Human based system	**Satellite based system**	**Optical based system**	**Wireless based system**
over the past decade, mainly departments have been focused on "suppressing" their budget cuts and reorganizing them, allowing for a further increase in fuel level and thus providing a foundation for catastrophic fire	Any existing forest fire satellite observation suffer from severe constraints that result in failure of quick and precise forest fore control	In general, the frequency of false alarm caused by various dynamic phenomena such as wind turbines, sky covering by clouds, reflection and human activity should be minimized	Best forest fire detection solution available
The environmental impact is not a priority for them	There may no satellite coverage for the entire forest region or the coverage may be intermittent (not ongoing), with the scope of some area or area of the forest	such a technology provides only a viewing line where high trees or hill and mountain block the vision and where pictures for ignition cannot be provided	You can cover any area and your scalable network.
High risk of defective arms	Usually, a satellite has many different functions. Remote Sensing for board feature of the earth' surface so it is not cost-effective	Weather and vision at night reflect the performance of the camera	No tower or complicated communication connection are necessary
Free of cost	Very expensive	Expensive	Comparative lower

V. Conclusion

The key techniques to avoid extraordinary catastrophes and ecological and social legacy damage are early warning and prompt response to a fire outbreak. As a result, the most crucial objective in flame observation are quick and precise detection, as well as fire detection. It's a lot easier to put out a fire when you know where it started and when it's still in its early stages. Information on the progression of fire is also extremely useful for dealing with the fire at any stage. In light of this information, firefighting personnel may be directed to focus on putting out the fire before it spread to social heritage sites and extinguishing it as fast as possible using the required firefighting equipment and vehicles. The system is designed to use a open-source cloud platform to monitor forest fires. It is well-known among internetusers worldwide for leveraging transfer of the data to the cloud. Various values such as temperature, wetness, light intensity, humidity and other sensor data are shared to the cloud platform in this article. We use the cloud to monitor sensor data and send emails to the appropriate users based on the circumstances. As a result, the method offers several benefits. It is portable, cost-effective, and it satisfies the monitoring parameters via cloud.

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