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Anintegrated Iot Based Approach Enabled In UAV for the Early Prediction of Forest Fires

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ABSTRACT

Forests are habitats to millions of Biotic and Abioticfactors, It support numerous ecosystems and helps in maintain the ecological balance of the planet. However, the forest fires can cause significant property damage and loss of both human and animal life.It creates great impact on the resource ,economy and environment of the region. Forest fires wiped out the resources and heritage of the forest in a short span time. This paper proposes anintegrated approach of Internet of Things ,wireless sensor networks and Image processing bydesigninghybrid Unmanned Aerial Vehicle(UAV)to forest fire detection system.This forest fire detection system make use of UAVs to track and observe the changes in various environmental parameters includes temperature, humidity and soil moisture which in turn responsible for woodland fires.

Keywords—Unmanned Aerial Vehicles (UAVs) , Internet of Things (IoT), Sensors, cloud computing, Forest fires and image processing

1.Introduction

Forests cover 31 percent of the global land areaand serve as reserves for the genes of biodiversity .Good forest management system always strengthens resilience and combat against global warming. Each year the intensity and number of forest fires also increasing in great numbers. However, the fires can cause significant property damage and loss of both human and animal life. The bushfires that burnt across southeastern Australia's temperate forests in the 2019-20 fire seasons were unprecedented in their scale, intensity and impacts. It has been termed as Australia's Black Summer [19].The fires burnt an estimated 46 million acres destroyed over 5,900 buildings (including 2,779 homes) and killed at least 34 people Nearly three billion terrestrial vertebrates alone – the vast majority being reptiles – were affected and some endangered species were driven to extinction.At its peak, air quality dropped to hazardous levels in all southern and eastern states [3]

Another devastating wildfire in the Amazon rainforest broke out in January 2019. Nearly 906,000 hectares of land was burned in the 2019 Amazon rainforest wildfires [31]. In 2018, nearly 9 million acres were burned in the US alone. Uncontrolled fires often started accidentally by people, rampage and decimate forests.There were an average of 67,000 wildfires annually and an average of 7.0 million acresburned annually over the past 10 years.

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It is stated that due to climatic changes and extreme weather conditions contributing to the ferocity of the fires with hotter, drier conditions making the country's fire season longer and much more dangerous. .They pose a threat not only to the forest heritage but also to the entire regime to flora and fauna also disturbs the bio-diversity, ecology and environment of aregion.
Therefore forest fire management system plays an important role in preserving the entire forest area which acts as a biological community for biotic as well as abiotic factors over thereEven though several methods of prediction has been deployed an followed wildfire threatens human life and cause many resources to become extinct.[26]

This research contributes and supports in controlling the wild fires and also provides a method for its early detection and prevention in order to curtail its destructive impact.The harmonious coalescence of Internet of Things (IoT), Cloud Computing (CC), EdgeComputing and Wireless Sensor Networks (WSN) are synergistically deployed. Basic parameters taken in concern while developing the detection system for wildfires is as follows:

- Human interference should be less
- Cost effective
- Quick detection of forest fire
- Day/Night surveillance
- Wide coverage Range
- Low energy consumption

Considering the above listed requirements we proposed an architecture of hybrid UAV based forest fire Detection system shown in (Fig 1.1).It comprises of an unmanned aerial vehicle(UAVs) deployed with temperature, smoke and humid sensors fire detection.Technologies like WPAN, WLAN,RFID, Wi-Fi,Zigbee, 3G/4G remote sensors also used to generate data about environmentalconditions.
The structure of proposed system is as follows:

(1) Monitoring the maximum coverage range in the forest using hybrid UAV based forest fire controlling system
(2) Forest fire detection with the utilization of the sensors used.
(3) Collecting the real-time information about various environmental parameters like temperature, humidity, light intensity, and smoke through IoT devices.
(4) Validation of the wild fire
(5) Generation of an alert and warning messageduring high wildfire vulnerability levels
(6) Prediction the future fire explosion
(7) Protection of wild animals by finding animal dense zone.

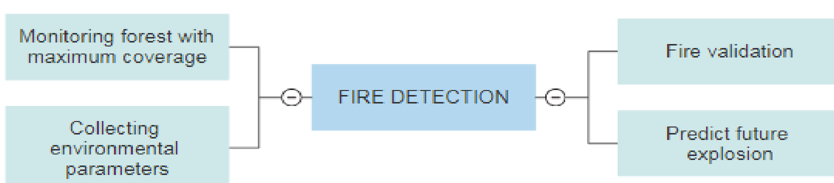

Fig 1.1 Fire detection method

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2.Literature Survey

Environmental parameters such as temperatures,humidity,light,intensity and smoke can be easily monitored with the utilization of sensors and allows access of Internet of things everywhere. since the cost of sensors available at low price it is easy to equipped with any kind of surveillance system to monitor abnormality.[1] As Sensor equipped systems predicts the incidents earlier it is important to utilize them in a challenging environment and deploying the sensors in an effective manner[5]

UAVs are utilized in predicting the forest fire and fight against them based on the settings incorporated.UAVs mounted with visual cameras and sensors are helpful in locating the danger zone as well helpful in calculating the burnt areas [16]. UAVs incorporated with the approach of internet of things and fuzzy interference systems is capable to predict fire incidences earlier and also alert the ground station along with sending direct alert messages to the smart phones [23] .Internet of things using smart sensors in fire prevention system. It gives the early alert to the user about the incident through the protocol in which the user is enabled [9]

In the traditional forest fire detectionmethods mechanical systems and manual handling with human resource required for monitoring the forests [27] .The traditionalfireprediction systems make use of satellite, fire watchtowers and wireless sensor networks for monitoring. In this method a person is there to monitor the forest area from the watch towers erected. If there is any abnormality or smoke observed alert has been created. In this method system processing, rehabilitation and restoration consumes time[7].For monitoring the environmental impacts over larger surface area sensor network has been deployed forobserving various environmental parameters such as temperature, humidity,smoke,soil moisture and other various events. A sensor network comprises of numerous sensors where individual sensor unit has three important division of processing which includes sensing,processing and storage unit. [13]. Most of the forest fires reported in the remote areas the traditional methods for monitoring of fires were not suited. It suits well for the plain areas. Recently deployed satellite systems having high accuracy towards prediction also not susceptible in case of poor signal areas[2]Due to the prevailing rainy and fog conditions in the forest areas sometime causes the generation of false alarms . In that case UAVs produces reliable monitoring in the quick duration and also generate accurate sampling of data .It also operated in low altitude regions and take the images in consecutive interval[4] .When compared to the traditional approaches UAVs more efficient in the perspective of surveillance .This methodology always performs efficiently than the existing remote sensing based techniques [25]

As UAVs responds in a short duration along with accurate data acquisition across various UAV sensor platforms is the added advantage to this methodology [21].As UAVs can cover the area with maximum range about 100000 m^2 efficiently it is highly recommended to detect the forest fire while the early methods monitoring and the confirmation takes long time which always leads incomplete results[24]. The UAVs can deployed with less expenditure and also provide efficient surveillance with wide area application. Because of the cost effectiveness large number of UAVs can be used for monitoring the wildfires. It can be equipped with all kind of digital cameras to capture and process the images[28].Multiple lens or multi camera can be used along with the UAVs equipped which generates the texture information of the targeted area. This

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method is user friendly approach the surveillance of smart cities as well which overcomes the drawback of low spatial resolution by satellite imaging [29].

One significant outcome of using UAVs that using multiple sources in several locations it consecutively updates the data for efficient early fire predictionand control[30] The UAVs equipped with IoT platform used face recognition from large altitudes which in turn reduces the energy consumption without any performance degradation [18]UAV's will play a crucial role in the Internet of Things (IoT) vision, and may even become key IoT enablers in various application domains (e.g., emergency management, precision agriculture, forest fire monitoring, architecture surveillance, goods transportations) [17]. It is mandate topredict and control wild fires prior to reaching an uncontrolled state. According to experts, a typical wildfire tends to double in size every few minutes while in high-wind conditions or extremely dry conditions, the rate of growth can be much greater. So it is important that while detecting the fire false alarm rate should be low for all the environmental conditions [12]. Utilization of resources should be optimized henceforth multirotor UAVs demonstrate increased agility and fault tolerance compared to fixed wing vehicles. However, multirotors are based on electric power sources with an average endurance of 10 to 50 minutes.It is also important that without endangering early detection is needed and accurate [6].

3.Existing methodology

Satellite based methodology produces high false alarming rate due to scanning of poor quality images during cloudy days[20.]One of the existing systems is the KNIME model which predicts the burnt area by forest fires. It allows users toinspect the results, models[11]. However, it doesn't suggestany preventive measures.Rothermelmodel [22] is a predictive fire modeling based approach generating exact values of some fire properties (e.g. spread rate)only if the exact values of initial data are known. Those data are not usually available for direct measurements. Vector models predict fire spreads according toa well-defined growth law. They also depend onthe accuracy of the initial data. Fractal and wave extensions ofvector models [8] less depend on the accuracy of observations, but they are more computationally intensive, so they cannot beused in real-time.

Cellular automata models [10] depend on theconstant conditions of weather, fuels, and topography, whichreally vary spatially and temporally. So, the predictive firemodeling approach is not suitable for forest fire control in real time. Online forest fire monitoringusing remote sensing techniques [30]. The forest fire monitoringdepends on real-time computation of theevolution of the most important parameters related to the firepropagation based on the online observations. All knownapproaches to the forest fire monitoring have their drawbacks. For example, ground-based systems, which use static cameras [15.], highly expensive. Mannedaircraft [30] is large and expensive, they depend on the weatherconditions and require the presence of aerodromes.

4. Proposed methodology

The proposed methodology aims to deploy more number of hybrid UAVs across large landscape of forest area for monitoring all types environmental parameters includes Temperature, humidity, Light, Smoke, Soil moisture,etc.

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The hardware deployment of hybrid UAV and working procedure of the proposed architecture is explained in sections 4.1 and 4.2.Satellite based monitoring is the traditional method to predict the wildfires but it cannot predict the future explosion .Based on weather and temperature statistics satellite system helps in the deployment of UAVs for monitor the forest area with maximum coverage and predict the explosion earlier with the help of sensors used in the hybrid UAV

4.1 Hardware Deployment of hybrid UAV

In this methodology UAVs equipped with various sensors and digital cameras. They are utilized to sense and provide the 3D visual effect which helps in identifying the wildfire earlier. The architecture diagram of the proposed methodology is shown in fig 4.4.

Sensors

1. Temperature sensors(LM35) used to detect the environment condition and checks any heating interrupt happens .It is easily interfaced with all types of microcontroller that has ADC or Arduino .This sensor is used to measure the temperature from -55°C to 150°C.It is very much useful in monitoring the forest environment. (Figure 4.1-(A))
2. Humidity sensors(DHT11) measures the humidity in its environment and it can be integrated to all the systems based on the size and requirements. This sensor converts the measured value into its corresponding electrical signal .this sensor acts as temperature sensor as well. It measures temperature from 0°C to 50°C and humidity from 20% to 90% with an accuracy of ±1°C and ±1%.(Figure 4.1(D))
3. Accelerometer sensor measures the acceleration forces acting on an object, in order to locate the position and monitor the animals movement this sensor is used.(Figure 4.1(E))
4. Soil moisture sensor measures soil moisture based on the changes in electrical conductivity of the earth (**soil** resistance increases with drought). The sensor is having two electrodes where the electrical resistance is calculated.A comparator produces the digital output when the threshold value is exceeded.(Figure4.1(B))
5. LDR sensor is a light dependent resistor measures the light energy from narrow range includes infra red to ultraviolet range. it produces the output signal that shows the light intensity of above mentioned spectrum .(Figure 4.1(C))

6. Ultrasonic sensor measures the distance of the targeted object using ultrasonic sound waves where it converts emitted sound signal in to an electrical signal. It is mainly used to detect the animal movement during forestfires(Figure 4.1(F))

7. Arduino uno
   Arduino Uno is an outstanding open source microcontroller board which has 14 digital I/O pins with 6 analog I/O pins programmable with Arduino IDE .It can be charged by the USB cable or by an external 9-volt battery, and it accepts voltages between 7 and 20 volt(Figure 4.1-(G))

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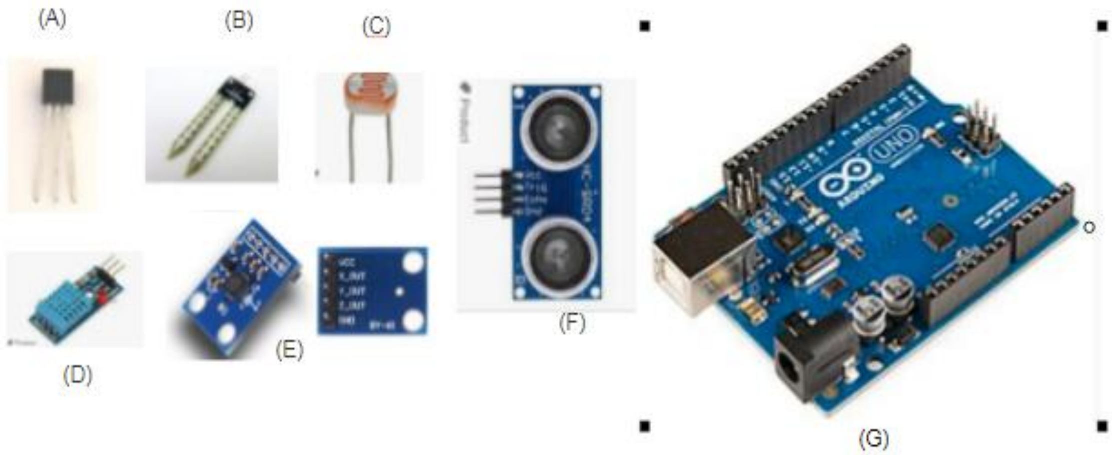

Figure4.1 Sensors

In order to build an integrated sensor system with UAVs, the parametersconsidered for detecting forest fires are temperature, humidity, soil moisture, light intensity. Sudden changes in these parameters can result in forest fires. The sensors are connected with Arduino microcontroller shown in Figure 4.2.It enables the system to sense and the value keeps on recording .Recorded value send to ThingSpeak during alert situations.

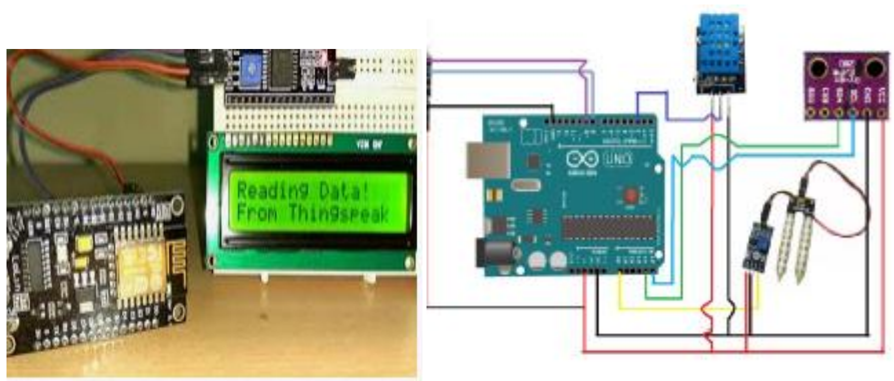

Figure 4.2 Circuit Diagram

The first phase of our implementation starts with the monitoring of forest with maximum coverage range using UAVs and it takes the images continuously .Sensors equipped with the system also continuosly sense for the abnormality with the help of all the sensors.

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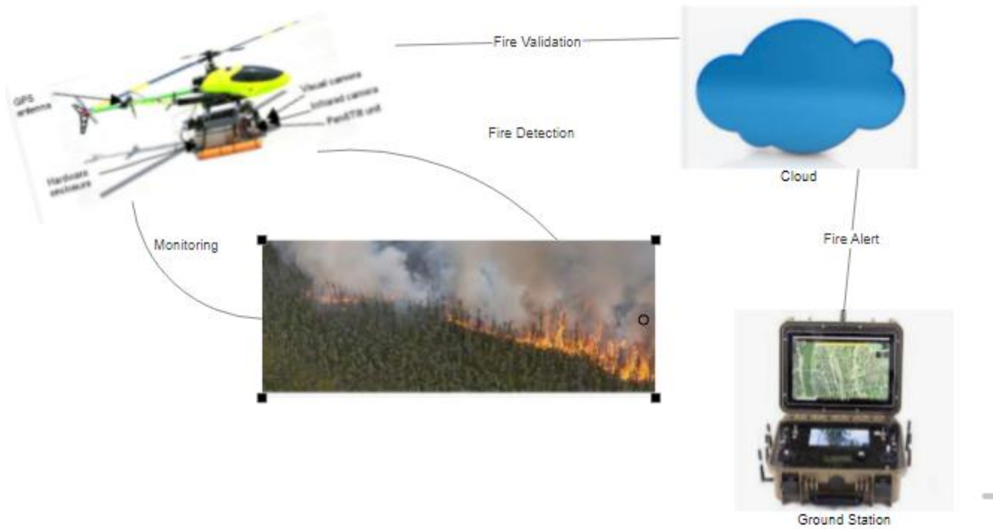

Figure4.3 UAVs Surveillance in Fire detection

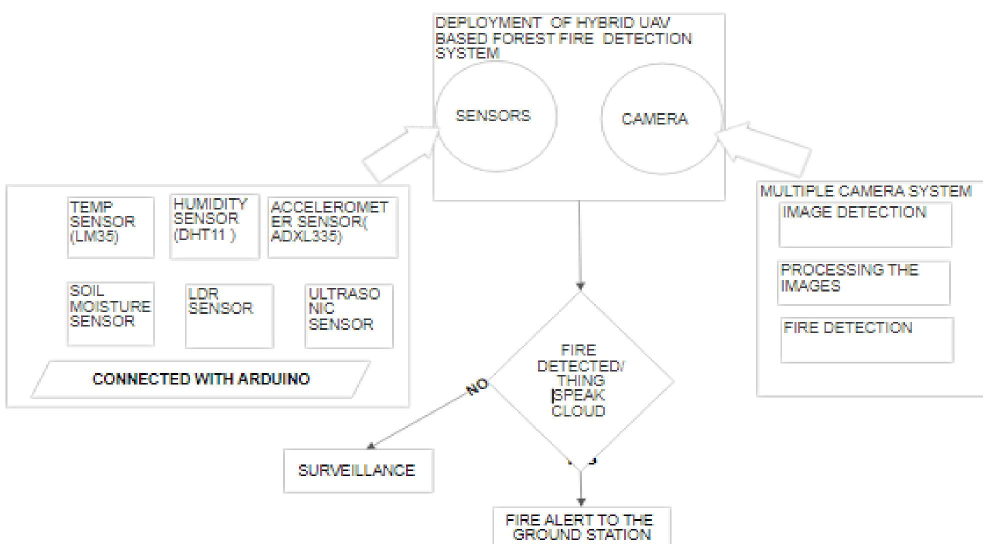

Figure 4.4 Architecture of the proposed methodology

Image Capturing Mechanism

This block holds multiple camera equipped with UAVs at various angles and computes the fire measurements individually ,all the camera process its own mechanism of capturing images ,preprocessing and categorizes the fire finally results from individual units are integrated and produce overall result of fire detection. The data fusion method adopted is based on Kalman Filtering, It implements temporal and spatial filtering techniques to cancel high-frequency fluctuations and local errors. This block also generates 3D views of the fire[14]

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Multi-Camera Forest-Fire Estimation

The aim is to assimilate all the fire measurements generated individuallyI from cameras with different perception capabilities. Bayesian Filters provide a well-founded mathematical framework for estimating the state of the system using observations in presence of noise: sensors are modeled as uncertain sources. Decentralized schemes require a strong communication infrastructure (with sufficient bandwidth and coverage) which is often inexistent in forestenvironments. In contrast, centralized schemes only require point-to-point communication between each camera station and the main processing station.

The basic diagram of the Recursive Bayesian Filter (RBF) used is shown in figure4.5 The input is *x*, the set of measurements obtained individually from each of the *N* cameras. The output of the block is the estimation of the state of the fire front at time *t*. The RBF requires one update model in order to perform short-term prediction of the evolution of the state and one observation model for each of the cameras used in the deployment. Inaccuracies in the prediction and noise in the observations should be taken into account. RBFs obtain an updated estimation of the state as a weighted average using the prediction of its next state as well as using a new measurement from the sensor. The purpose of this weighting is to give more trust to values with better (*i.e.*, smaller) estimated uncertainty. This process is repeated with every new measurement.

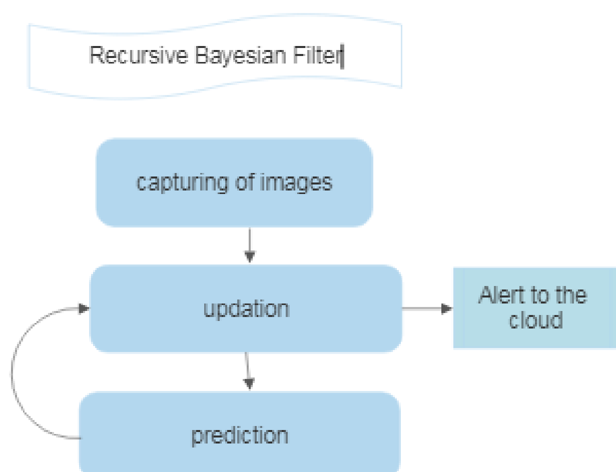

Figure 4.5**.** Diagram of the Recursive Bayesian Filter used.

All the images are validated on the UAV nodes only , the Cloud nodes are notified if an emergency situation is identified with high probability . The UAV nodes capture the images continuously within proper interval of time and executes the image classification service and sensors also sensing the data in a periodical manner. Evaluation takes place by edge computing mechanism.If any emergency situation is detected with high probability than a predefined threshold ,here threshold is set as notification by both sensors and camera deployed in UAV then this situation is intimated to the Cloud for further analysis and alert the ground station as shown in figure 4.3

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The sensor are connected to Arduino Uno. After this the esp8266-01 WIFI module is connected to the microcontroller.The entire setup is then attached to the UAVs. During its surveillance, initially the sensor records no data. As soon as the UAVscomes in the vicinity of a fire the sensors immediately catches the infrared radiations of the flames and records the intensityof the flames according to the distance of the UAV from the fire The recorded data is then sent to a cloud platform calledThingSpeak via the Esp8266-01 WIFI module On things speak the data is analyzed in a user friendly environment. Thedata is represented in the form of flame intensity with respect to the time. This represents that the UAVs has detected a fire and we canview its intensity.

Image capturing mechanism uses image processing using google API. There is an inbuilt camera module present in the UAVs. Oncapturing the image of the area under fire, UAVs sends the image for image processing. RBF isperformed using google API. By using this method intensity of the fire along with the nearbyobjects present is identified. With the help of this system we can identify whether people are trapped inside the building or the forest fire.This will help us to prioritize the area for rescue and prevent civilian casualties.

5.Results and Discussion

The result of proposed mechanism is executed well running system which gives a solution to our issue which we addressed. The proposed system developed that helpsus in the early detection and prediction of forest fires. All the sensors equipped with the hardware and software connected in our methodology are giving correct values .The sensors records the environment parameters and sending the values to the cloud Thingspeak .The cloud API is continuously displaying the current values in the form of a graph whichhelps us in continuous monitoring of the environment.Different graphs for different sensors used in our paper of early detection and prediction offires.The graphs shown below based on the recorded value of each sensor.

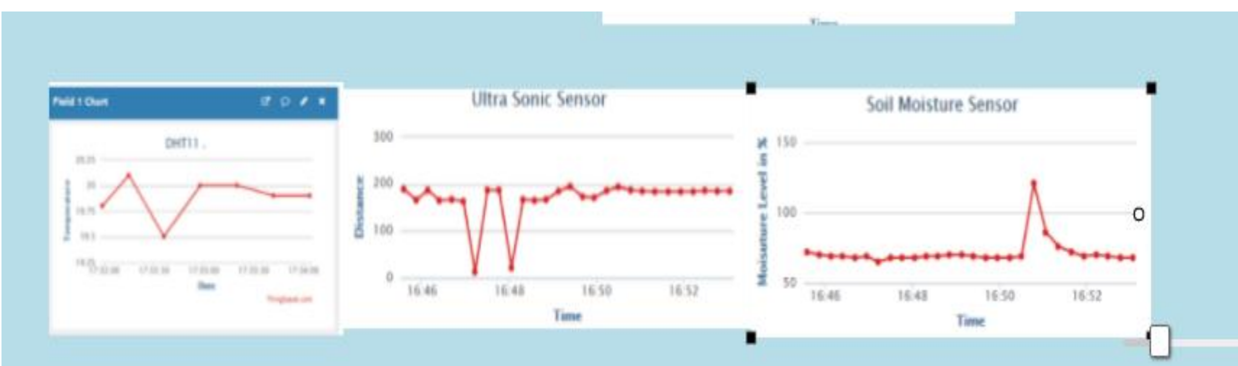

Figure 5.1 Graphs of DHT11,Ultra sonic sensor and Soil moisture sensor

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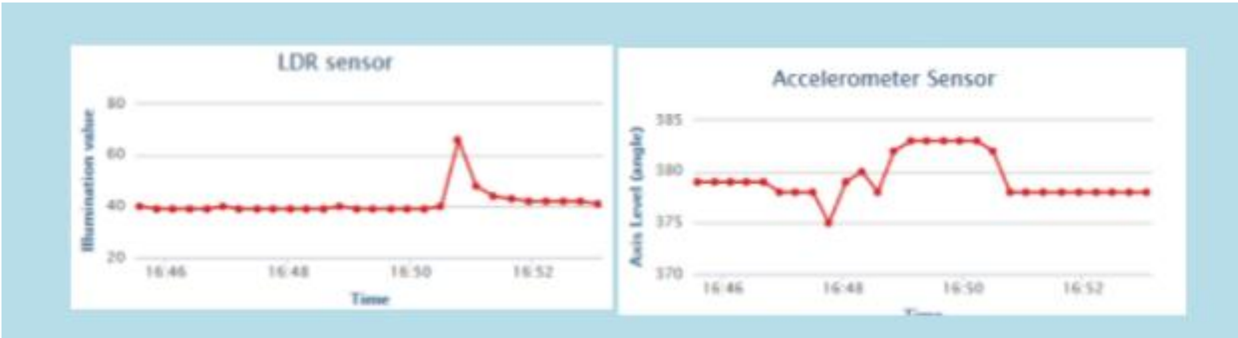

Figure 5.2 Graphs of LDR and Accelerometer sensor

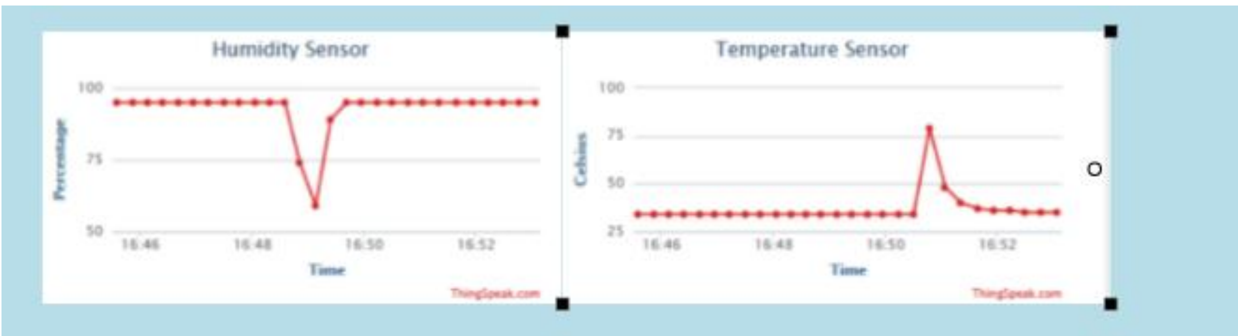

Figure 5.3 Graphs of Humidity and Temperature sensor

The threshold values of all the sensors used have been preset in cloud API.As soon as the present values exceed the preset values, an alert is alarmed to the ground station which gets information about the environmental conditions not being in the ideal state.An easy and continuous monitoring of the environmental conditions of forests can beachieved.Thus, the proposed methodology helps in detecting the forest fire earlier and alert also send to the ground station before the fire starts to spread and destruct the entire region.

6. Conclusion

This paper proposes an integrated approach of Internet of Things, Cloud Computing and Image processing for equipping the Unmanned Aerial Vehicle(UAV) for the early prediction of forest fires.Data recorded by means of all the sensors used are processed the Arduino Uno placed in various places. The result the proposed model is tested with ThingSpeak web interface and sensor data is recorded for testing of fire detection. The system processed the information and send alert to the ground

In future, we can develop this model to minimize the energy consumption of all sensors andidentify the presence of dense animal crowd and provide suitable technology to preserve them to avoidthe great destruction.

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