Forest Fire Early Detection Using Machine Learning and IoT

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Abstract

Forest fires significantly threaten ecosystems, wildlife, and human lives. Rapid detection and a timely response are crucial in mitigating the devastating effects of these fires. In recent years, advancements in technology, specifically Machine Learning (ML) and the Internet of Things (IoT), have shown promising potential in improving forest fire detection systems. The proposed system leverages a network of IoT devices, including temperature and humidity sensors, smoke detectors, fire sensor, soil moisture sensor, and sound sensor strategically placed in forested areas. These devices continuously monitor environmental conditions and capture real-time data. The collected data is transmitted wirelessly to a central server, where ML algorithms process and analyse it to detect potential fire incidents. Machine Learning algorithms, such as Random Forest algorithms, decision tree algorithms, and support vector machine algorithms, are employed to develop predictive models using historical data. These models uncover patterns and correlations between environmental elements and fire occurrences, enabling accurate fire risk assessment. The system can adapt and improve its predictive capabilities over time by continually updating the models with real-time data. After gathering the data from the forest, the trained machine learning algorithm analyses it, and based on model training, a prediction is made as to whether or not a fire will break out. This paper presents an overview of the machine learning and IoT technologies used in early fire warning systems and provides an extensive survey of the machine learning algorithms employed for detecting forest fires.

Keywords: Forest fire, Machine Learning, decision tree algorithms, Internet of Things (IoT), Sensor, Random Forest algorithms, trained machine learning model, support vector machine algorithms.

Introduction

India frequently experiences forest fires, especially during the summer. According to ISFR (2015), montane temperate, semi-evergreen, and evergreen forests are significantly less susceptible to severe fires than many other types of forests, particularly dry deciduous forests. Over 36% of India's forest land is susceptible to regular forest fires, according to estimates. Only 4% of India's forest cover, according to ISFR 2019, is classified as severely fire-prone, while 6% of the country's forest cover is also classified as such. Numerous fires of all sizes and intensities decimate large tracts of forest every year. According to data from the forest inventory, there have been no large fires in 35.71 per cent of India's forests. On the other hand, fires only infrequently threaten the remaining 54.45% of woods, while they are moderately threatened by 7.49% of them and strongly threatened by 2.40% of them. Forest fires destroy important forest resources every year, including carbon that has been sequestered in the biomass, which has a detrimental impact on the flow of goods and services from forests.[1]

Even though they can occur spontaneously in a variety of habitats, forest fires can be very dangerous to people, property, and natural wealth. These fires are typically started by lightning or human error in uncontrolled situations. A wildfire fuelled by dry vegetation could spread swiftly and widely across significant areas in the event of favourable weather. It may take days to contain and extinguish a wildfire, and forest firefighters regularly lose their lives in the process. Smoke from wildfires and air pollution are dangerous to human health, but they may also badly damage or destroy houses and businesses. Protecting homes and communities from the threat of wildfires needs a catastrophe response plan and a fire prevention policy programme.

However, the development of early-warning systems with sufficient accuracy is now possible thanks to machine learning and the Internet of Things (IoT)-based technology solutions. It is thought that an effective method for reaching this goal is to use the necessary sensors to monitor changes in humidity, temperature as well as to find smoke and fire. [2]. These metrics' gathered data might be kept and then utilized to create ML models that can predict the chance of a fire starting. By examining data from prior fires, we may create models that forecast how a certain fire would evolve under particular circumstances. Firefighters and other emergency responders will find built-in fire databases to be a useful tool in fighting wildfires successfully. It might also make it possible to locate areas where wildfires are more prone to start, allowing for the implementation of protective measures.

Literature Survey

Uchechukwu C. Wejinya, George Mitri, George E. Sakr and Imad H. Elhajj presented a paper titled "Artificial Intelligence for Forest Fire Prediction" at the 2010 IEEE/ASME International Conference on Advanced Intelligent Mechatronics in Montréal, Canada, from July 6 to 9. This study offered a method for forecasting the threat of forest fires. The results demonstrate that it is possible to assess how dangerous forest fires are with a limited amount of data. [3]

"Predicting burned areas of forest fires: an artificial intelligence approach," by Mauro Castelli, Leonardo Vanneschi, and Ales Popovic. 2015 Fire Ecology: In this demonstration, they showed a revolutionary intelligent GP-based method for analysing burnt regions. The main objective was to develop a system that could calculate the amount of land that would be lost in a forest fire. The experimental findings showed that geometric semantic genetic programming performs better because of the short MAE. [4]

A. Kansal, Y. Singh, N. Kumar, and V. Mohindru presented the paper "Detection of forest fires using machine learning techniques: A Perspective" at the 2015 Waknaghat Third International Conference on Image Information Processing (ICIIP). Regression and dataset partitioning are used in the method for detecting fire proposed in this paper. The method achieves a low root mean square error and low R-squared. This approach might be used to deal with similar tragedies in the future. A number of modifications could improve the model's performance. [5]

L. Yu, N. Wang, and X. Meng published Real-time Forest Fire Detection Using Wireless Sensor Networks in Wireless Communications, Networking, and Mobile Computing in Volume 2 of the 2005 International Conference on IEEE. In this example, ensemble learning is applied at each cluster head. SVM, a supervised machine learning method, is used at the base station with a polynomial kernel function. Temperature, humidity, carbon monoxide, and carbon dioxide may all be measured using the installed sensors. Clustered streams can produce data in tabular or clustered formats. Following that square mistake, fire is then identified using the SVM. This approach might be used to deal with similar tragedies in the future. A number of modifications could improve the model's performance. [6]

Technique for Sensor-Based Detection

Detecting physical quantities and converting them into a signal that can be interpreted by a viewer or piece of equipment is what a sensor does. A sensor, which monitors several environmental factors, is one of the most important tools we use to detect forest fires. One of the easiest methods to spot a forest fire early is by using sensors. There are several ways to spot a forest fire, including temperature, humidity, smoke, sound, and soil moisture.

The most common kind of sensor for forest fire detection is a temperature sensor. Hot spots, or places where the temperature is much greater than the surroundings, can be found using them. By-products of flames or burning embers might result in hot areas.

Sensors that measure humidity can potentially be used to spot forest fires. A fire may spread more readily in extremely dry air. Firefighters can determine how dry the environment is and whether or not a fire is likely to spread by assessing the humidity.

Sensors that measure CO and CO2 can be used to find smoke. A key fire signal is a smoke. These sensors can alert firefighters to the presence of a fire in advance.

Sound sensors can be employed to identify fire sounds. It may be possible to locate a fire with this.

The moisture level of the soil may be determined using soil moisture sensors. The probability of a fire spreading may be estimated using this information.

Machine Learning

There are several ways that machines may learn. Machine learning is a subfield of artificial intelligence that focuses on designing as well as developing algorithms that can learn from and anticipate input. Artificial intelligence is used by some machines, while machine learning is used by others. To find patterns in data and forecast the future, machine learning algorithms can be utilised.

Computers can be trained to learn from data using machine learning, rather than having to be explicitly programmed to do so. It entails exposing computers to big data sets and allowing them the discretion to independently search for patterns and correlations. To do this, a various type of algorithms can be utilised, such as artificial neural networks, random forest, decision trees, and state vector machine.

1) Random Forest
   During the training phase, the Random Forest technique builds many decision trees. The ultimate choice is made by the random forest using the majority decision of the trees. An action plan can be selected using a decision tree, a diagram in the form of a tree. The decision event or action is represented by each branch of the tree. Multiple trees are used in random forests to lower the danger of overfitting. Training takes less time. It operates effectively with a huge database and has great accuracy. It generates extremely accurate predictions for vast datasets. If a significant amount of the data is missing, accuracy can still be maintained.

2) State vector machine

Support vector machines, or SVMs, are machine learning methods used in regression and classification tasks. SVMs are an effective machine learning technique for classifying, regressing, and identifying outliers. By classifying fresh data points into one of the predetermined categories, an SVM classifier builds a model. Consequently, it can be categorised as a binary linear non-probabilistic classifier. Linear classification tasks are compatible with SVMs. When applying the kernel technique, SVMs can successfully do non-linear classification in addition to linear classification. This allows for implicit mapping of the inputs into high-dimensional feature spaces.

3) Decision tree

One of the numerous algorithms that utilise the idea of supervised learning is the Decision Tree algorithm. Both use cases based on regression and those based on classification may be resolved using this approach. In general, it performs incredibly well for classification-based tasks and generates datasets with a tree-based structure. Since it bases its conclusions mostly on a small number of things that it considers to be important, this algorithm is somewhat similar to how individuals think when making judgements in real life. The algorithm's decision-making process is simple to comprehend thanks to its tree-like layout.

• When both our data and the data on which we make our predictions are continuous, regression is used.
• Classification is used when our data and the data on which we are basing our predictions are discrete (or categorical).

Internet of Things (IoT)- ThingSpeak

IoT cloud systems provide a comprehensive and centralised means of managing the connections and data of IoT devices. These platforms give businesses the ability to link IoT devices to different applications and data sources, as well as remotely monitor and control IoT devices. IoT cloud systems also provide services like analytics, data management, device management, and security [7]. An IoT analytics platform called ThingSpeak makes it possible to gather, display, and examine data from devices. It also enables the sending of commands to gadgets.

Methodology

Module for Data Collection and Communication

The sensor circuit which consists of all the required sensors is placed strategically in the forest. The following block diagram shows the architecture of the circuit.

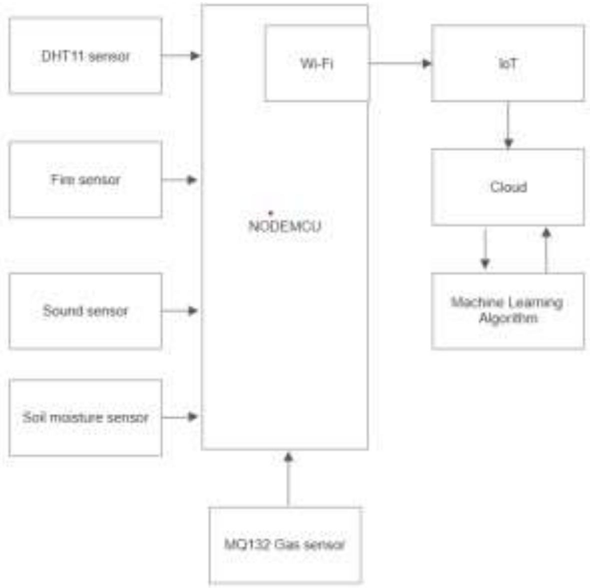


Figure 1: Block diagram of embedded circuit for data collection

The sensor nodes, once they have been installed, measure the elements of the forest environment, such as humidity, gases, and ambient temperature. Thingspeak, an IoT-based cloud analytics solution with the goal of storing sensed data through cloud channels, provides support for it. A sink node transmits field data to the cloud server for storage and in-the-moment processing. ThingSpeak's cloud analytics platform allows for the real-time collection, tracking, and archival of field data. Data may be retrieved whenever you need it and for any purpose. The cloud analytics platform ThingSpeak logs entries of ambient sensed variables every two to three minutes. By seeing the most recent entries in graphical form, the user at the control station may apply algorithms to connect the sensor network and controller. The data from each measurement is saved in a distinct field, and the channel ID denotes various field properties. Real-time environmental data is seen via the ThingSpeak channel on the Internet. Depending on the analysis, the user may at any moment change the field data and status. Using the ThingSpeak IoT analytics, numerous graphical charts for humidity, light intensity, gases, and ambient temperature have been created based on the data gathered.

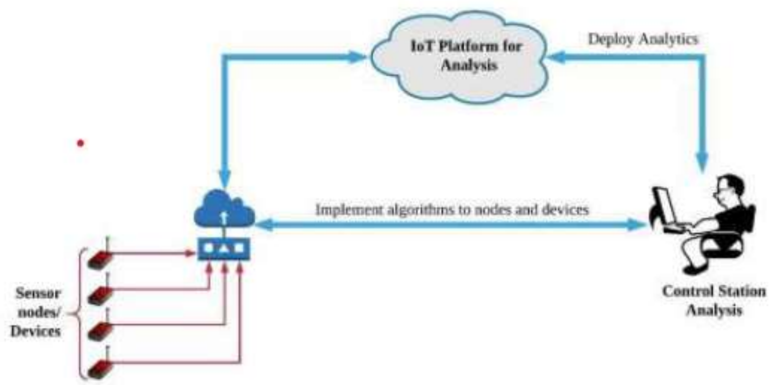
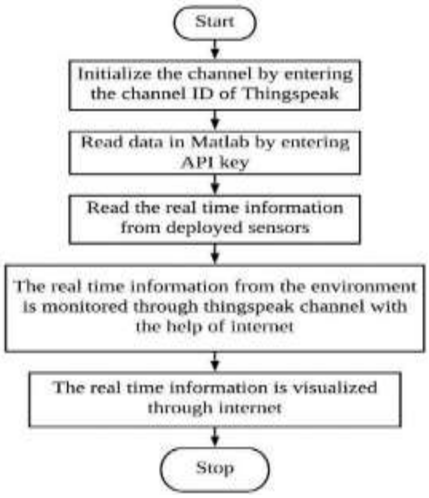


Figure 2: Data collection and storing using ThingSpeak cloud analytics platform

The flow process of the Thingspeak IoT platform is shown in the following.



Module for Machine Learning Model Training and Testing

The dataset is exported from ThingSpeak as a CSV (comma-separated values) format file after the data has been gathered. A dataset is a organised collection of data. It frequently has several variables, each with a unique set of values. Other types of data, like subsets, hierarchies, or networks, may also be present in a dataset; these are typically used to represent real time events, systems, or objects [3]. Datasets on forest fires are crucial for determining the scope of the issue and for developing efficient mitigating measures. These databases can assist in providing information on the causes, location, magnitude, and severity of, forest fires. There are several different forms for forest fire datasets, including tabular (which contains information like sensor data gathered).[8]

The Dataset is then given to a machine learning algorithm to be analysed and to train the model to be able to understand the pattern behind the data from which the predictability of forest fire is possible.

Training data and testing data are separated from the dataset. The machine learning algorithm is taught using the training data to produce a trained model. After training the model it is now required to undergo testing to obtain the accuracy of the algorithm. [9]

<u>Result and Discussion</u>

In the Thingspeak the following output is shown, where each sensor data is shown in graphical form. Here we can observe the observations from 22nd may till 5th June 2023.

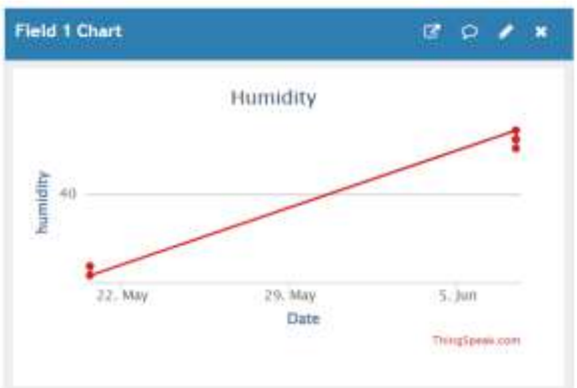


Figure 3: Thingspeak sensor data analysis

After calculating the accuracy of the algorithms the result is shown below.

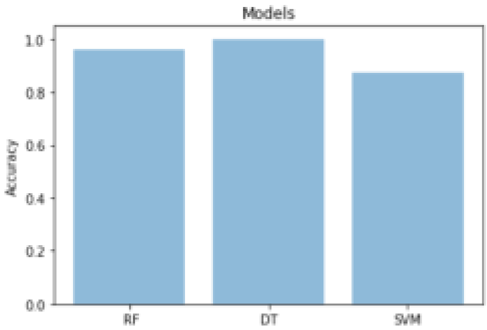


Figure 4: Random Forest, Decision trees, State vector Machine algorithms accuracy compared

Random forest and state vector machine algorithms are on par with each other in terms of predictability and accuracy.

Finally, Random forest algorithm is chosen for training the machine learning model and it is used to predict the forest fire.

0 - means forest fire not predicted

```
In [42]: test_vector = np.reshape(np.asarray([62,31.8,1024,1,0,1]),(1,6))
         p = int(classifier.predict(test_vector)[0])
         #  fire not predicted =0
         #  fire predicted=1
         p
Out[42]: 0
```

1- means forest fire predicted

```
In [43]: test_vector = np.reshape(np.asarray([37,42.4,194.0,0,1,1]),(1,6))
         p = int(classifier.predict(test_vector)[0])
         #  fire not predicted =0
         #  fire predicted=1
         p
Out[43]: 1
```

Figure: The final result of whether the fire will occur or not based on real-time data

Conclusion and Future Scope

For this research, a thorough assessment of the academic literature is conducted in order to identify and predict forest fires using IoT and machine learning. Temperature, humidity, and CO are the most often used characteristics to identify and detect forest fires, according to data analysis using a machine learning algorithm.

Also, as far as future scope is concerned, it is very cost-effective and can enhance the survivability of the forest also this system can work 24/7 sensing real-time data compared to the usage of UAVs or drones which cannot be operated throughout the day.

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