F-ALERT: EARLY FIRE DETECTION USING MACHINE LEARNING TECHNIQUES

Nisarg Gupta, Prachi Deshpande, Jefferson Diaz, Siddharth Jangam, and Archana Shirke

ABSTRACT

Natural disasters have been causing havoc since time immemorial. Forest and rural fires are one of the main causes of environmental degradation. Wireless Sensor Networks (WSN) have been fruitful in monitoring areas remotely and detecting environmental changes. By incorporation of Data Mining and Machine Learning techniques, we can build a system for early detection of fire disasters. WSNs based on Internet of Things (IoT) helps us in remote monitoring over the internet and prediction of an event as Fire/No Fire. With multi-criteria detection, multiple attributes of a forest fire are sensed by different sensing units. The temporal data from the sensors is collected and various machine learning techniques are used to analyze the patterns of data and use them to develop classification and prediction models. Model construction is done based on available data whereas model updating and prediction is in the real-time scenario. According to the data fed from sensors onset of fire can be detected and so the warning can be raised and sent to the authorities. Early detection and prediction of fire hazards help in improving firefighting resource management and reducing the damage. Preventing wildfires will be helpful in protection of natural as well as the human habitat. It helps in addressing a wider spectrum of problems, such as situational awareness and real-time threat assessment using diverse streams of data

Index Terms *visually impaired people, recognize currency bills, the mobile phone, partial images, accuracy rate.*

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I. INTRODUCTION

Fires play an integral role in human lives, but if uncontrolled, can be disastrous. Burnable materials catch fire easily and spread rapidly degrading the environment. The first stage of fire is called as 'Surface Fire' and the latter stage is known as 'Crown Fire'. Crown fires are uncontrollable and damage the landscape. Although some safety measures have been employed, the accidents related to fire are ineluctable.

There are different systems that are used for the detection of domestic and forest fires. Various alarm systems are being used today for fire detection and warning purpose [1]. In this project, we focus on employing various machine learning techniques on a system based on wireless sensor networks. There are a number of advantages of using machine learning algorithms with WSNs. If we can successfully predict the

onset of the fire, a lot of damage will be reduced and environmental degradation will be decreased.

Many forest areas do not have fire alarm systems installed. Fire alarms are important because they can alert you before a tragedy happens. You can, therefore, stay prepared, take necessary actions and reduce any kind of loss that might occur. Our goal is to create a technique based on sensors which will help in detecting the forest fires in the early stages. As soon as the fire is detected an alarm will be generated thereby minimizing the loss of environment, property or human life. The machine learning techniques integrated with the sensors help in detection of fire without any human help, therefore no patrolling is required. The major advantage of sensors is that they are fast and accurate. Moreover, machine learning maximizes resource utilization and improves the performance of sensor networks.

We aim to evaluate the historical data and the natural events, predict the upcoming events based on acquired knowledge. Thus, the model will be capable of generating automatic warning signals whenever a dangerous situation arises, i.e., when fire or smoke is detected.

Since this project is based on experimentation, it is constrained by many parameters. Primarily within the stipulated time, the correct response needs to be generated and provided to the user. One of the major issues is noise. Since we are depending on wireless sensors for our data, it is possible that this data might not be clean and may contain noise. Proper and quick preprocessing is required for optimal results. Another issue is accuracy. There is a huge possibility that a false positive response will be generated and a fake warning may be issued. By parameter optimization, we can reduce these false-positives but not necessarily eliminate them. Also, the available computing power constraints the working of this system. The training and testing of models are compute-intensive tasks.

A. Overview

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions [2]. A WSN system incorporates a gateway that provides wireless connectivity back to the wired world and distributed nodes. Energy, memory, computation, and bandwidth are the main constraints of WSN. They are widely used in fields like Air Pollution Monitoring, Forest Fire Detection, Landslide Detection, Water Quality Monitoring etc.

Machine learning can be used to teach the computers to act like human beings without being hardcoded [3]. Supervised, unsupervised, and reinforcement learning. Form the three categories of machine learning. In supervised learning, class label is present for a certain data (training data) and needs to be predicted for unknown instances [4]. In unsupervised learning, there is no class label present and implicit relationships within given data need to be discovered. When learning involves some kind of feedback mechanism for each step then it is known as Reinforcement Learning. In this mechanism, there is no precise label or error message. In our project, we focus on the supervised learning techniques for fire detection based on historical data. Some supervised learning techniques are Decision Tree, Naïve Bayes, Support Vector Machine, Logistic Regression etc.

2. RELATED WORK

Fire alarm systems have been on the market for a long time. These alarms are either activated using some detection mechanism or may also be activated manually. Automatic actuated devices function by detecting the physical changes associated with fire like heat detector, flame detector etc.

Satellite-based systems are one of the prominent fire detection systems. MODIS (Moderate Resolution Imaging Spectroradiometer) [5, 15] and AVHRR (Advanced Very High-Resolution Radiometer) [6] are satellite-based monitoring systems. Factors like terrain, time, weather, light reflections and smoke from legitimate industrial or social activities limit the usability of these systems.

Another system for fire detection is the Wireless sensor networks (WSN). They have limited power, computational capabilities, and memory. Still, WSNs present a flexible, low cost and highly efficient technology that can be used for fire detection [7]. Sensor nodes that are deployed in the forest, collect data such as temperature or humidity or gas concentration etc. and send it to the base station where the data is analyzed. In some of the embedded devices, traditional algorithms based on pattern matching have been adapted. In such approach, data is gathered from many multifunctional sensors after which they are matched with previous data. Mapping of patterns of the event is important for detection in WSN.

WSN Designers have to address the issues related to data aggregation, data reliability, localization, node clustering, energy-aware routing, events scheduling, fault detection and security [8]. Machine Learning is important in WSN application for various reasons. It helps in developing an adaptive sensor system that can operate in harsh and dynamic environments. Robust machine learning algorithms are able to calibrate themselves to newly acquired knowledge in unreachable and dangerous locations. WSN applications come with minimum data coverage requirements that have to be fulfilled with limited resources. ML methods can be efficiently used to discover hidden correlations in sensor data and also propose a sensor deployment scheme for maximum data coverage.

The limitations of using Machine Learning include:

- There is a trade-off between algorithm's computational requirements and learned model's accuracy. Higher the required accuracy, the higher will be computational requirements, and the higher energy consumption.
- Learning by example requires large datasets and there is limited control over the knowledge formulation process.

Research has been done regarding various approaches for fire detection. Techniques like regression, Support Vector Machines (SVM), Neural Networks, Naïve Bayes Classifier, Decision Tree Induction, fuzzy logic, wireless image processing camera system etc. are studied and tested for fire detection.

There are four steps for machine learning procedure:

- Feature selection and output labeling
- Sample collection

- Offline training and
- Online classification

Feature selection is the method of choosing the most significant parameter, which will help to describe the problem easily. The parameters are chosen in such a way that maximum variability in the model is explained by them. According to the knowledge of experts in output labeling method, the outputs are classified. In sample collection, data is gathered for training and are collected in a database. The third step is offline training in which classification is done between two or more solutions. Online classification is different from offline because offline is done by keeping a backend server but in online, only learning overhead is considered.

In one of the approaches [9], it is shown how regression works best for detection of forest fires with high accuracy by dividing the dataset. It considers four parameters like rain, wind, temperature and relative humidity and predicts burnt area in which majority of occurrences were there. The performance of the overall task is calculated by Mean Absolute Deviation (MAD) and Root Mean Squared Error (RMSE).

One of the approaches implemented in [10] is using Naive Bayes. Naïve Bayes classifier is easy to implement, with probability calculation being the most time-consuming part. For higher accuracy, data can be divided into some intervals and count the data frequency within that interval. The prediction accuracy for Fires is 100% and Noise is 99.26% in this approach.

In one of the hybrid approaches, K-means clustering is combined with neural network and other classifiers [11]. Data aggregation is performed on normalized multi-dimensional fire datasets to remove the redundant data.

An energy efficient method involves three phases namely Clustering, Routing and Fire Detection [7]. Distributed clustering algorithm based on neighborhood information, helps in this approach by providing low computational complexity and high accuracy. Prediction of fire using classification techniques of data mining is done at the member node level, discarding normal values and transmitting only abnormal values to the cluster-head.

Distributed Event Detection is studied in approach [12]. Every individual sensor performs event detection using its own decision tree-based classifier and the events are aggregated by a voter running reputation-based voting.

Equal Gain Combiner (EGC) and K-nearest neighbor algorithm are used in approach [13]. Temporal data shipped from multiple sensors are combined into an equitable manner into one fused data using EGC algorithm. Then KNN algorithm is used to classify this data into one of the two clusters (‘fire’ or not ‘fire’). The proposed approach is as robust as CVR (CHAIR VARSHNEY RULE). Also, the execution time of decision simulation of CVR is heavier compared to that of KNN. This makes the approach better in terms of processing speed and reliability.

SVM based forest fire detection using static and dynamic features is proposed in [14]. Color based segmentation based on a video feed from the environment is used to obtain the flame regions in one image. A total of 11 static and 27 dynamic features including color distributions, texture parameters, shape roundness, flickering frequency etc. are used for classification Trained SVM is used to filter out the false candidates in these flame regions.

3. PROPOSED SYSTEM

This project requires training to be done before deploying. Using historical data, various machine learning techniques are applied for Model learning and validation. Accordingly, the model classifies the real-time data, predicting the chances of fire.

The Modules involved in Fire Detection System are as follows:

- Pre-processing module: The data acquired from sensors is sent to the pre-processing module. It performs thresholding, cleaning, transformation and any specific enhancements required for later employed algorithms.
- Classification module: Pre-processed data is then classified using machine learning algorithms using the classification module. According to the result, alerting and alarming is done to the respective authorities.
- User Interface module: A user interface for monitoring and supervision purposes is provided. It shows real-time statistics and reports.

The Working phases are as follows:

- Learning phase
  Using the historical data first we train the model using various machine learning algorithms. This involves training and validation and application of accuracy improvement techniques like bagging and boosting. Once the model is trained, it is exported and can be used for deployment purposes.
- Testing phase
  The system is exposed to the real-time data acquired either through cloud server or a local network. First, preprocessing is done in order to make the data suitable for algorithms to process. Cleaning is done to eliminate the noisy data followed by transformations and enhancements.

Then the data is subjected to machine learning algorithms which predict the chances of onset of fire. According to the prediction results, the concerned authorities are alerted and respective mitigation measures can be taken to prevent or limit the damage.

3.1 ARCHITECTURE DIAGRAM

Architecture Diagram for the system is shown in figure 1 below. It has following components:

- Heterogeneous WSN: A heterogeneous Wireless Sensor Networks consist of a network of different sensor linked to a base station. For fire detection we measure the environmental parameters using the sensors like temperature sensor, humidity sensor, Carbon Monoxide/ Carbon Dioxide sensors. Along with the sensor data, a visual feed is also sent to the base stations at timed instances.
- Data Acquisition: Data from multiple sensors is aggregated and some minor processing is done. We check the parameters for threshold values. If any of value exceeds the threshold then data is forwarded for classification

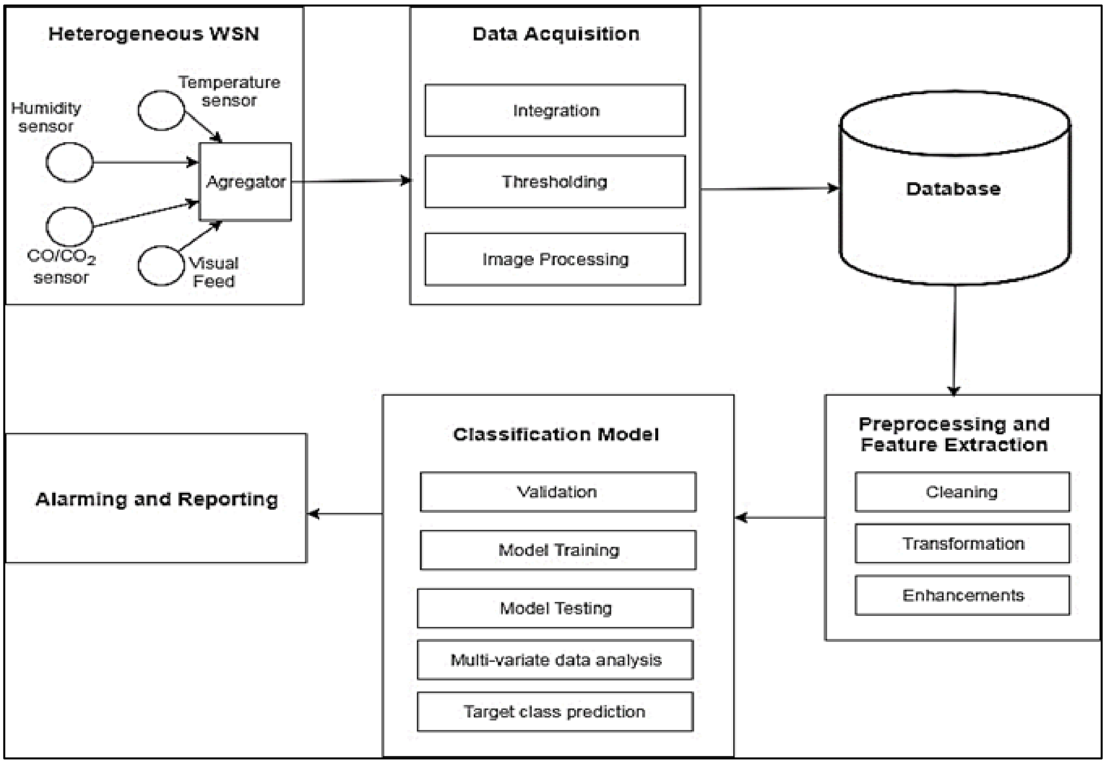

Figure 1: Architecture Block Diagram for F-Alert system

- Pre-processing and Feature Extraction: The data either stored at base station or cloud server is fetched and pre-processing is performed. This involves cleaning of data for removal of inaccurate/corrupt data. Along with cleaning we perform transformation and enhancements to make the data suitable and ready for classification algorithms.
- Classification Model: This is the heart of the system. First, using labelled data we undergo a model training phase via supervised learning strategy. Then data validation is used to check for the model accuracy and feasibility. Once the model has suitable accuracy, we can start the testing of model using unlabeled data. Multivariate data is fed as input and target class is predicted along with its probability.
- Alarming and Reporting: According to the predicted class, the system generates an alert and sends to the designated authorities along with information about severity of the situation.

Basic flowchart for the proposed system is shown in figure 2 below. After the system is trained properly using appropriate machine learning technique it is deployed for real-time testing. Data can be acquired from base station of wireless sensor networks or a cloud server over internet.
Since this data may contain noise and impurities, it needs to be preprocessed. Data is cleaned for removing noise and redundant information. Appropriate transformation and enhancements can be done to simplify and accelerate the usage of data in algorithms.

After preprocessing stage, we check for threshold values of parameters. In case all values are normal, there is no need of wasting energy and resources. But even if single parameter shows deviation above/below the threshold then we pass this data to the classification and/or prediction models.

Accordingly, the model determines the chances of fire and accordingly alarm is raised based on severity of situation. Once the concerned authorities are notified, appropriate mitigation measures can be taken to prevent widespread destruction.

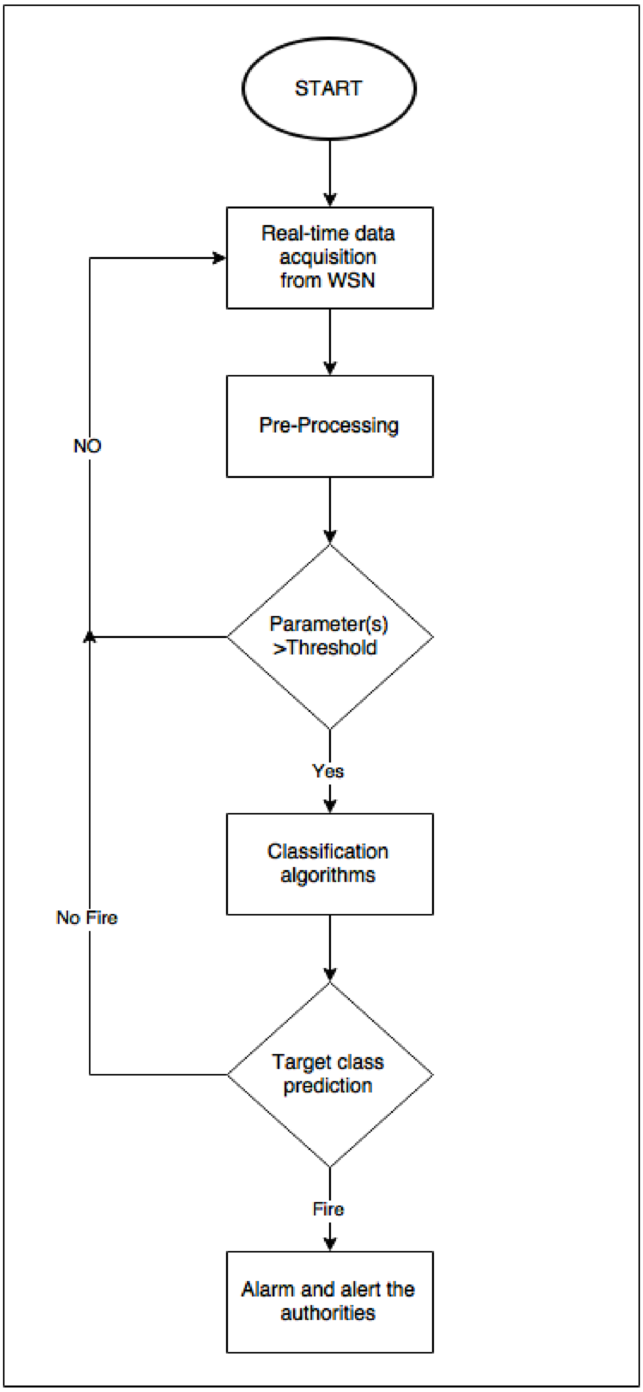

Figure 2: Flowchart for F-Alert system

4. EXPERIMENTAL RESULTS

Machine learning algorithms were tested on Orange data mining tool. A single node sensor unit with temperature, humidity, carbon monoxide sensor was used to collect data for training and testing purposes. Target variable fire_present was manually labelled as 0 or 1 according to fire presence.

Total 1441 instances were manually labelled and divided into two sets. 75% (1081 instances) were used for training purposes. Four machine learning algorithms for classification were tested: Support Vector Machine, Random Forest Classifier, Decision Tree Classifier and Neural Network (two hidden layers with 6 neurons each) were tested and evaluated using inbuilt evaluation module of Orange Tool.

Table 1: Evaluation Results for training data set

Algorithm	Area under ROC curve	Classification Accuracy	Precision	Recall
SVM	0.998	0.966	0.957	0.979
Random Forest	0.997	0.985	0.986	0.986
Decision Tree	0.989	0.980	0.982	0.979
Neural Network	0.995	0.961	0.960	0.966

The results of evaluation of training data set are shown in table 1. Area under ROC Curve, Classification Accuracy, Precision and Recall were recorded for the four machine learning algorithms.

For test dataset prediction module was used and accordingly compared with original labels. Table 2 shows the confusion matrix results for the test dataset prediction using the four classification algorithms.

Total instances : 360
Fire Present : 188
Fire Not Present : 172

True Positive : Fire present and predicted correctly.
False Positive : Fire not present, but predicted as present.
True Negative : Fire not present and predicted correctly.
False Negative : Fire present, but predicted as not present.

Table 2: Confusion Matrix

Algorithm	True Positive	False Positive	True Negative	False Negative
SVM	185	7	165	3
Random Forest	187	2	170	1
Decision Tree	183	3	169	5
Neural Network	186	9	163	2

5. APPLICATIONS

Fire detection systems can be installed at various locations susceptible to hazards. Fire prone areas need to have an efficient and fast mechanism to detect and alarm the required personnel. If the response time is minimized, then mitigation measures can prevent an onset of wide range disruption, reducing the damage and cost on rehabilitation.

The system is useful for following:

- Security Department
- Forest Safety Workers
- Organizations, Institutions, Hospitals, etc.
- Industrial plants

6. CONCLUSION

Adoption of machine learning improves the usability of Wireless Sensor Networks (WSN) in environmental analysis and monitoring. Efficiency and accuracy along with cost factor serve as key factors for the building of fire detection systems. In this project we understand the working of various machine learning techniques along with their advantages and limitations. According to evaluation factors appropriate choice can be made regarding the technique to be implemented. Also, a hybrid technique involving combination of algorithms can be suggested. This paper gives the idea about how combination of sensor data and prediction algorithms can be utilized to detect onset of fire and limit the damage caused to environment.

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