Counter Measures for Early Detection of Fire within the Forest Using Hexagonal Based Neural Network Based Approach

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Abstract **- IoT provides mechanism to integrate various diverse components (Sensors) to work in synchronized way. A system of smart interconnected components can be used to monitor the abnormal situation where existing resources or infrastructure fails. This paper is intended to study to study the techniques and framework used to analyses the disasters such as floods, fire, earthquakes etc. the prime objective of this study is to examine the techniques associated with fire detection in considerably larger premises like forest. Fire detection system along with heat sensors are employed in this case. This work provides the neural network-based approach for the early detection of fire within the forest. It also provides comparative analysis of each technique to determine better approach that can be enhanced on the parameters of energy conservation and fault tolerance in future work.**

Index Terms **- IoT, Sensors, Disaster, Fault tolerance, fire alarm system.**

I.INTRODUCTION

Internet of Things (IoT) is the network of physical devices including sensors, actuators, and software and network connectivity. [1]IoT allow the object to be sensed and controlled remotely. It allows direct integration of physical world into the computer system causing enhanced performance in terms of accuracy. The cyber physical system is created using the application of IoT. The evaluation of Internet of Things greatly facilitates the diagnosis process of abnormal situations. [2] Suggest monitoring of records associated with patients is becoming possible with the utilization of IoT. In order to accomplish this task, [3][4]small IP based wireless sensor (Proximity sensors) is attached with the patient body. [5]propose sensor-based sensing application that helps in monitoring the psychological parameter like heart rate and blood pressure remotely and frequently. The record so obtained can be stored over the cloud so that patient record can be retrieved as and when required. The proposed work studies the applications of the IoT in the field of health care along with management policies used to enhance security of records stored within cloud. In addition, application of IoT can be used to monitor disaster management. [6], [7]In order to accomplish this sensor are in place for gathering the information about the smoke and heat. A fire alarm system has number of equipment's working together to detect abnormalities and warn people through audio and visual mechanisms as they detect smoke, fire and other critical situations. These fire alarm systems can also be activated manually. Alarms used within the fire alarm systems can be motorized bells or wall mounted horns. Frequency of alarms can be altered depending upon the area in which these systems are installed. IoT serves automatic extraction of information in the absence of infrastructure facilities or areas where human interaction is minimal.

II RELATED WORK

The existing literature provides framework for tackling the issues associated with fire detection over the remote area using the application of sensors over the given premises

Wireless sensor-based fire detection system proposed by [8]. In this literature nodes are distributed. Nodes with maximum energy are termed as monitoring nodes. The fire detection system detects the abnormal or intruder in terms of heat and flames. The fire detection system then gives the signal to the alarm system to show critical situations. Zigbee oriented fire monitoring system is used for the detection of abnormal situation within the area monitored.

Fire detection using ZigBee and GPRS system proposed by [9]. Forest fire detection using the zigbee and GPRS is handled through the said literature. Forest fire detection proposed through this literature includes algorithm detecting humidity and temperature change. The hardware circuitry of proposed solution is based on Arduino board with ATmega328 microcontroller, temperature sensor and humidity sensor along with ZigBee and GPRS modules.

Intelligent fire detection system is proposed by [10]. This literature presents a system in which dissipative fires as citrates, welding smoke etc. is eliminated using fusion algorithm. During the fire hazard SFF notifies the fire service and others by text messages and telephone calls. Along with ringing fire alarm it announces the fire affected locations and severity. To pre- vent fire from spreading it breaks electric circuits of the affected area, releases the extinguishing gas pointing to the exact fire locations. This paper presents how this system is built, components, and connection diagram and implementation logic.

Room temperature control using IoT and MQTT proposed by [11]. Amazon web service is considered for evaluation through message queue telemetry transportation. A broker is used in this case that senses the room temperature with the help of IoT. Threshold values are maintained which if violated alarm will blow. This alarm causes the monitoring of temperature within the room.

Fire detection system using the applications of IoT is proposed by [7]. This literature divides the entire fire detection system into three parts: first part involves detection of smoke. Second part involves detection and monitoring of flames and third part includes temperature monitoring. In case any of the above three cases are violated, alarm will be blown. An automatic wireless sensor network is considered in this case. The 'automatic' word in here signifies minimal human interaction. Once this system is in place, fire is detected and alarm is blown for safeguard of place and humans where it is installed.

A.Comparison of Various Techniques Associated with Fire Detection

The comparative analysis of various fire detection system mechanisms using the application of IoT is considered for evaluation through qualitative analysis as

TABLE I. FIRE DETECTION AND MONITORING SYSTEM: QUALITATIVE ANALYSIS

Title	Technique	Sensors	Merit	Demerit
Efficient Cluster head selection for WSN[12]	High energy node selection for cluster head to conserve energy and reduce packet drop	Advanced and normal nodes considered as sensors	Packet drop ration in transfer of packets reduces greatly	Fault tolerance is not considered
IoT Middleware: A Survey on Issues and Enabling Technologies [13]	Survey of techniques used within IoT for performance enhancement	--------	Comprehensive mechanism for comparison of techniques is presented. Applications of IoT in the field of forest fire detection is presented	Fault tolerance and energy efficiency is missing
Fire Monitoring System for Fire Detection Using ZigBee and GPRS System[9]	Zigbee and GPRS	Fire, Flame and smoke sensors	GPRS enabled mechanism is presented providing on the go information to the user about abnormal situations.	Fault tolerance and energy efficiency is missing.
An Intelligent Fire Detection and Mitigation System Safe from Fire (SFF)[10]	Self-controlled fire extinguisher mechanism	Actuators, Fire, smoke and flame sensors	The suggested mechanism not only monitor the fire but also suggest the mechanism to control the abnormal situation	Fault tolerance and energy efficiency if missing in this literature

III PROBLEM DEFINITION

From the literature the fire alarm system used in the existing literature does not use any energy conservation mechanism. The energy conservation mechanism can ensure better detection process, but this is not the case in existing literature. The problems are listed as under

- Secure transmission of data from controller to secure is missing
- Sensor energy conservation mechanism is missing.
- Lifetime of the sensors is limited, and hence crucial time could be lost and forest could be completely burnt.
- Idle sensor identification is missing.

IV. PROPOSED MODEL

The proposed layered architecture is shown in figure for detecting Fire on Forests. It comprises of three layers i.e. Data Accumulation layer, Data pre-processing layer and Cloud layer. In the proposed model, data Accumulation layer is used to collect the data from various sensors i.e. heat sensors, smoke sensors, temperature sensors, gas sensors and flame sensors. The energy efficient mechanism employed with in forest area consists of sensors and cluster nodes. Hexagonal representation allows all the aspects of data to be analyzed and no missing values appear within the collected data. In data pre-processing layer, In cloud layer, Gathered information is transferred over the cloud through the topology used to connect the cluster head with the cloud is commonly this topology is wireless. Information received by the cloud and stored at the data Centre's within cloud system. Cloud users can access the information entering valid username and password. Valid users get the information about the abnormal situation and alarm is blown if necessary. Each layer of the proposed model is described as follows.

A. DATA ACCUMULATION LAYER

Data accumulation layer is responsible for gathering the information from the various sensors i.e. heat sensors, smoke sensors, temperature sensors, gas sensors and flame sensors. In data accumulation layer, Energy efficient mechanism employed within forest area consists of sensors and cluster nodes. Cluster nodes are selected on the basis of maximum energy. All the sensors transfer the gathered Information towards the cluster nodes also known as cluster head. Sensor presently not gathering data is at sleep. So energy is conserved. In the entire system network area is isolated into various square segments, which makes the cluster appropriation more uniform and to some degree diminish the vitality utilization. In any case, the conveyance of cluster territory depends on hypothetical esteem, causing the diverse size of territories. Along these lines, the more remote separation between cluster head and clustering individuals will make the inter cluster head hubs expend more vitality. It proposed isolating the whole remote sensors organize into various square zones with each segment appointing with a cluster head. In the meantime, it ought to be guaranteed that the separation between the cluster head and hubs can't surpass the limit d 0, with the goal that the correspondence utilization between the individuals from the cluster and the cluster hubs can be kept up at a low level. Gathered information is transferred over the cloud through the topology used to connect the cluster head with the cloud is commonly this topology is wireless. Hexagonal representation allows all the aspects of data to be analyzed and no missing values appear within the collected data. Collected information is used within the fire detection system for predicting abnormalities. There exist components associated with such a system. The collected information through the IoT enabled system is fed into the fire or abnormality detection system. The microcontroller through the threshold value comparison detects the abnormality and sets the alarm to on or off state.

TABLE II: VARIABLES OF IOT RELATED PROPOSED SYSTEM

S. No.	Forest fire Related Phenomena	Measured Variables	IoT Technology Used	Types
1	Heat	Rate of heat Rise	Heat Sensors	Thermistor, Liner sensors
2	Smoke	Particulates	Smoke Sensors	Optical smoke sensor, Ionization smoke sensor

3	Temperature	Rate of temperature Rise	Temperature Sensors	Thermocouples, Infrared sensors, RTD
4	Gas	Gases like carbon monoxide	Gas Sensors	Gas detector, Carbon monoxide sensor
5	Flames	Light of fire	Flame Sensors	Optical Detectors, IR Detectors

B. DATA PRE-PROCESSING LAYER:

Data pre-processing layer is a data mining technique which converts raw data into usable information so that accurate information is used. The task performed in this model are collecting data through sensors, pre-processing and filtering collected data, communicating with the cloud and sending only necessary data and monitoring power consumption of Iot devices. Sometimes our data may be not correct, incomplete or inconsistent in some manner as well as can contain errors. So these issues can be resolved by using data pre-processing. In data pre-processing, data is cleansed such as filled up the missing values, removing of data inconsistency and smoothening the noisy data.

C. CATEGORIZATION LAYER

The categorization layer is used for collecting data from sensors. The collected data include fire related dataset, environmental dataset, location dataset, topological dataset and historical dataset. The description of dataset is described below:

1) Fire Related Dataset: The collected information through the IoT enabled system is fed into the fire or abnormality detection system. Information is partitioned into two categories. First category indicates that smoke and heat intensity levels are beyond the threshold value causing the alarm to blow and second situation indicates the normal in range smoke and fire values. Gas sensors used to detect the gas emission due to the application of fire within the prescribed premises. Gases like carbon dioxide, carbon monoxide etc. are detected along with the intensities associated with these gases. The emission of gases corresponding to comparison within the accompanied threshold which if exceeded alarm blows off.

2) Environmental Dataset: The attributes of environmental dataset are Temperature, Relative Humidity, Wind, Rain and Area. These dataset considers the information about outside temperature, outside relative humidity, outside wind speed, outside rain and total burned area.

3) Location Dataset: Location data set indicates the location specific attributes. The Longitude indicates an Angular description of location, Latitude indicates the geographical position specifying east or west location, Name of place from where notification is generated, Address of location, and Milestone indicates a nearby famous location.

4) Topological dataset: Topological analysis is conducted to determine complex behavior among the entities. Data storage indicates the size of data to be stored, certain is actual data and uncertain is approximate data, Topology indicates subsets used to obtain large dataset, Missing value indicates dataset with or without problems.

5) Historical dataset: The attributes of historical dataset are Sensors deployed indicates the sensors used to record information, Region covered indicates an area on which sensors are deployed, Temperature indicates sensors range for heat monitoring, Moisture levels indicates the soil moisture level and Wind indicates the wind speed for examining the fire density.

D. CLOUD LAYER

Cloud layer is used to store and process the data. Information received by the cloud and stored at the data centers within cloud system. Cloud users can access the information entering valid username and password. The cloud layer is used to process the data. The data is received by the cloud system and check the threshold value that the smoke or fire intensity levels are beyond the threshold or more and set the alarm to on or off state. If the threshold value is more, causing the alarm to blow. Only valid users get the information about the abnormal situation and alarm is blown if necessary. The emails will be sent to the concerned users. But in order to receive the emails login is must in cloud.

1) Event classification

The classification procedure is based on FCM classifier. FCM (Fuzzy c mean) clustering algorithm is used in order to detect abnormal situation. Classes

are formed that are divided into four categories denoted with

Y={Extreme(y1),High(y2),intermediate(y3),low(y4)}

Each obtained data value is independent of other data values and may belong to one defined cluster. Threshold value is associated with each class forming the cluster. If Th1 is the minimum value and Th2 is the maximum value of class extreme (Y1) then obtained result from the data (d) lie in class Y1 if following inequality is satisfied

$$th1 < d \;\&\&\; th2 > d \; then \; class \; Y1]$$

Similar conditions can be defined for y2, y3 and y4 as

$$th3 < d \;\&\&\; th4 > d \; then \; class \; Y2$$

$$th5 < d \;\&\&\; th6 > d \; then \; class \; Y3$$

$$th7 < d \;\&\&\; th8 > d \; then \; class \; Y4$$

All of the above listed criteria's are defined to determine severity of situation. Class y4 is at low and class y1 is at high end of severity. Let $X = \{x_1, x_2, x_3 ..., x_n\}$ be the set of data points obtained though sensors detecting heat and fire also $V = \{v_1, v_2, v_3 ..., v_c\}$ be the set of centers. Algorithm defining FCM used for fire detection is given as under

Algorithm 1 Fuzzy C-means algorithm

1. Select clustering data set D, Custer centre(C) and termination conditions.
2. Select initial cluster centre $v=\{\boldsymbol{v_1}, \boldsymbol{v_2}, --, \boldsymbol{v_n}\}$
3. According to dataset D determine C_x.

$$\boldsymbol{C_x} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \frac{(\boldsymbol{x_k} - \boldsymbol{x})^{\boldsymbol{T}}(\boldsymbol{x_k} - \boldsymbol{x})}{\boldsymbol{n}\left|\left|\boldsymbol{x_k} - \boldsymbol{x}\right|\right|^2}$$

4. Determine maximum Eigen value $\sigma(C_x)$
5. If $\sigma(C_x)<0.5$ then $m<=\frac{1}{1-2\sigma(Cx)}$

   else

   $\sigma(C_x)>0.5$
6. Membership is updated at each iteration in FCM and when algorithm converges appropriate class to which data belongs is determined. This algorithm thus identified criticality of fire related information sensed.

2) Communication and Information sharing component

In cloud communication and information sharing is provided by cloud service provider. Login must be provided for establishing communication. The information detected by the sensors will be moved by the application of internet. For better performance redundant information fetched by the sensor has to be grouped with in the cluster for this purpose FCM clustering can be used.

3) Analysis and Predictive layer

This layer is critical in the detection and prevention of fire at forest area by observing the patterns of heat and moisture level observation. The observation is resulted by the use of artificial neural network. The predefined patterns are generally consistent which are observed through the sensors. In case patterns distorts indicating abnormal situation. In the considered environment forest area is considered having different longitude and latitude associated with them. The information will be gathered from the sensors and input to the predictive layer. The membership function is defined for determining classes which can be normal, intermediate or extreme. FCM determines the membership value and accordingly class is determined.

The steps involved in predictive layer include:

1. Monitor- monitoring is the process of deriving desired output from the prediction of situation. This process begins with the assigned input values; this value is predetermined value which depends upon the factor of each input attribute. These values include environmental and behavioural values like heat, humidity, soil, wind speed, number of trees etc. These attributes act as an input for neural network.

2. Learn- After monitoring stage, next step is learning where the errors generated by first Stages are minimized. It uses feed forward or backward Approach to handle the errors and then estimates the new calculated value with the faulted value.

3. Predict- When errors are minimized up to great extent then we can say that ANN as

Trained ANN. This ANN is used to predict the output in real time efficiently.

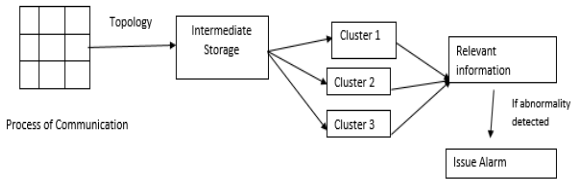

Fig 1: Proposed model of fire detection

Algorithm 2

1. Get the values from the IOT sensors and store it within appropriate variables to be inputted to the input layer.

2. Initialize Heat= 0
3. Compare heat [i+1] with the heat emitted at previous instance.
4. Present heat [i+1] to the input layer for deciding membership
5. Compare fire dataset values with the obtained result to decide criticality of the situation
6. Compare historical dataset values with the obtained result to decide criticality of the situation
7. Compare topological dataset values with the obtained result to decide criticality of the situation
8. Communicate the information to the cloud

TABLE III: KEY POINTS USED WITHIN PROPOSED SYSTEM

Basic Info	Forest Area 1	Forest Area 2	Forest Area 3	Forest Area 4
Longitude	38.567	37.465	36.986	35.863
Latitude	77.534	75.777	72.666	71.278
No. of Trees	1000	984	999	927
Soil Type	Dry	Fertile	Wet	Dry
Rain	Yes	Yes	No	No
Heat	3	4	2	5

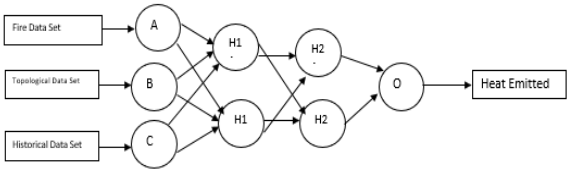

Fig 2: Neural Network Layer for the detection of extreme conditions of Fire.

E. Cloud Storage

Cloud storage is a model of information storage in which the computerized information is put away in consistent pools, the physical storage traverses numerous servers (and frequently areas), and the physical condition is normally possessed and overseen by a facilitating organization. These cloud storage suppliers are in charge of keeping the information available. Cloud storage administrations might be gotten to through a co-found cloud PC benefit, a web benefit application programming interface (API) or by applications that use the API, for example, cloud work area storage, a cloud storage passage or web-based substance administration frameworks. Here we utilize cloud for storing the information sensed by the sensor like longitude, latitude and milestone of the locations. Degree of intenseness in the area where fire detected is also stored along with the controller information. Controller related information is critical since controlling fire is in the hands of controller. It provides user the ability to do data analytics and sensor data visualization that we get from sensor data.

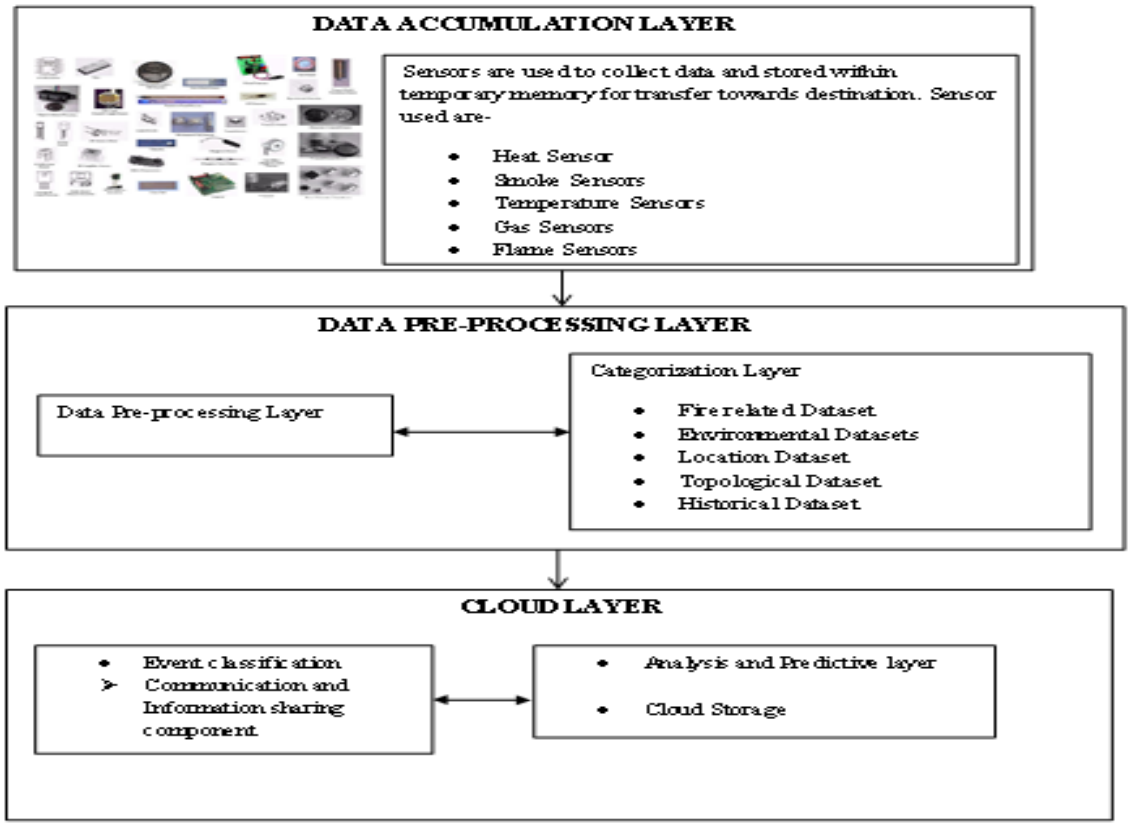

Fig 3: Data pre-processing and other layers of proposed model.

IV.PERFORMANCE ANALYSIS AND RESULTS

The proposed system generates the result in terms of classification accuracy and execution time. The mechanism applied ensures that fast detection of fire and classification accuracy is also improved. Pre-processing mechanism removes the noise if any from the real time dataset. Fuzzy c means mechanism with hexagonal system is used for improvement of result. The result in terms of execution time is given as under.

Dataset	Execution time(ms) Existing	Execution time(ms)Proposed
Heat and smoke offline	8	6
Real time dataset	10	6
Random	9	5

The comparison of existing and proposed model in terms of plot is given as under

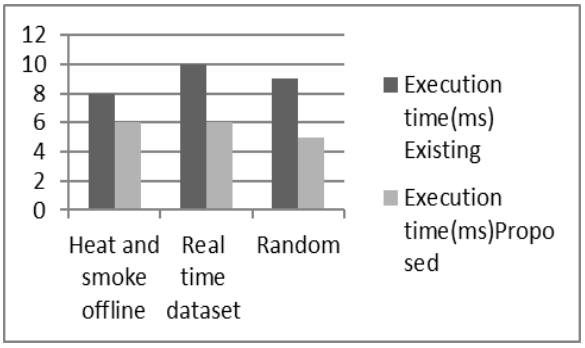

Fig 4: Comparison of execution time

The classification accuracy of the proposed system is also improved. The classification accuracy parameter indicates that how accurate our system is in detecting the heat and smoke. The result in terms of classification accuracy is given as under

Dataset	Classification Accuracy Existing	Classification Accuracy proposed
Heat and smoke offline	85	90
Real Time dataset	86	91
Random	84	91

TABLE V: CLASSIFICATION ACCURACY OF EXISTING AND PROPOSED SYSTEM

The classification accuracy plot is given within the fig 5. The result is improved by significant margin.

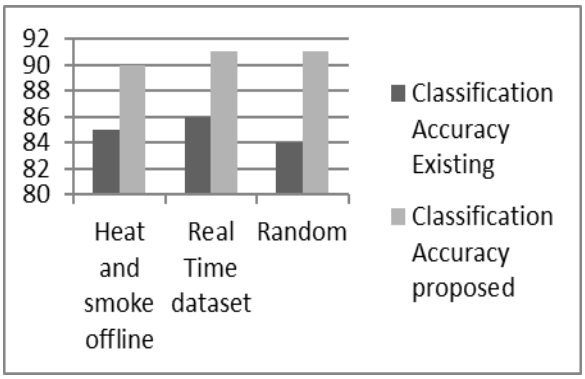

Figure 5: Classification accuracy comparison

The improved result in terms of classification accuracy and execution time proves worth of study.

V.CONCLUSION AND FUTURE SCOPE

The neural network-based approach along with missing value handling achieves higher classification accuracy. The existing approach does not achieve fire and smoke detection at early stage since hexagonal system was not employed. The mechanism achieves the classification accuracy in the range of 90% and existing system achieve the accuracy in the range of 85%. The execution time in the proposed approach is also least in the proposed system. The future work with the proposed system could include large real time data and mode based pre-processing mechanism.

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