

IOT Based Smart Disaster Monitoring System for Mountain Regions

D.Deekshitha¹, P. Gopika², A. Riythvika³, Dr. P. Rajkumar⁴,
Dr. R. ShobaRani⁵, Dr. F. Jerald⁶

^{1,2,3,4}Department of Artificial Intelligence, Dr. M.G.R. Educational and Research Institute, Chennai
600095, India.

Abstract

The environmental worth of mountain areas is constantly growing, but the susceptibility to natural disasters including forest fires and landslides are rapidly rising because of the impact of climate change, deforestation and more active people. Traditional disaster detection systems frequently fail to be valuable in distant and rugged areas, as these are based on either human eye inspection or satellite surveillance, which has a low level of accuracy and a slow response. The proposed paper is an IoT-based smart disaster monitoring system to detect forest fires and landslides in mountainous areas in real-time and provide an early warning. The offered system combines several sensors such as temperature and gas sensors to detect the fire, MEMS sensor detecting the vibrations or land shifts on the ground, and a soil moisture sensor to determine the level of ground saturation rates related to the landslide risks. Data of sensors are sent wirelessly to a central monitoring unit where the data is continuously analyzed. When the abnormal conditions are detected, early warning messages are communicated to the local authorities via cloud based system. The proposed system can enhance disaster preparedness, improve response time, and minimize risks to human life, infrastructure, and biodiversity in disaster-prone mountainous regions because it will integrate fire and landslide monitoring into a single framework to enhance disaster preparedness.

Keywords: Internet of Things (IoT), Disaster Monitoring, Forest Fire Detection, Landslide Detection, MEMS Sensor, Environmental Monitoring.

I. INTRODUCTION

The role of the mountain regions is crucial in ensuring the existence of environmental balance and highly diverse biodiversity. Nevertheless, climate change, deforestation, irregular rainfall patterns, and the growing human activity are predisposing these territories to natural disasters (forest fires and landslides) more and more. Forest fires are disastrous ecologically, wildlife is killed and trees are destroyed, not to mention air pollution, and landslides endanger human life, infrastructure, and transport networks, particularly in hilly and inaccessible regions.

To reduce the impact of these catastrophes, it is important to detect them early and provide early warnings. The traditional systems of control largely depend on the manual surveillance or the analysis of historical data or the satellite-based surveillance systems. Even though satellite tracking has a broad coverage area, it is usually characterized by a slow rate of data collection, high prices, and low accuracy in forested and mountainous areas. Manual surveillance is time consuming, inaccurate and not reliable enough to be used

24/7 in remote areas. The recent achievements in the Internet of Things (IoT) have allowed creating low-cost and real-time monitoring systems based on the interconnected sensors and wireless communication technologies. IoT-based solutions have the ability to provide continuous data gathering, remote access, and quick response and are therefore extremely applicable to the disaster monitoring applications.

In this paper, the author will suggest a smart disaster monitoring system based on iOS and Internet of Things to detect forest fires and landslides at the early stages in a mountainous area. The system combines temperature sensor, gas sensor to detect fire related conditions, MEMS sensor to detect ground vibration, and soil moisture sensor to detect ground saturation that is related to landslides. Furthermore, the system will have an automated water pumping system that will put off fire in its early stages by spraying water when the abnormal fire conditions are observed.

Analysis of experiments was done in open room and closed room to check the performance of the proposed system. The temperature sensor measured temperature at about 70 °C in open conditions and 70 °C in closed conditions. The gas sensor was able to read approximately 50 in the open spaces and 67 in the closed spaces. The soil moisture sensor registered the values close to 50, which denotes average saturation of the ground. The range of the MEMS sensor was between 1 cm and 2 cm. The distance sensor detected an average distance of approximately 3 cm distance in the two settings whereas the system response time in the two environments took an average of 2.34 seconds to 4.33 seconds. These findings indicate that the suggested system can easily identify abnormal changes and give timely alerts. Wireless data transfer is used to send sensor information to a main monitoring station and subject it to real-time analysis. The abnormal conditions are monitored, which sends early warning signals to the local authorities using cloud-based or GSM communication systems. At the same time, the automatic water pump is turned on in order to suppress and limit the dissemination of the fire before it takes serious forms.

The suggested system will provide an affordable and unified response capable of improving disaster preparedness and reducing the response time, as well as minimizing the loss of life, property, and ecological resources.

II. LITERATURE SURVEY

Wireless Sensor Networks (WSNs) have been popularly researched as a suitable and low power method in early disaster warning in remote and environmentally sensitive areas. Anuradha et al. [1] introduce a WSN system on the detection of a forest fire at its early stages with distributed sensor nodes, gateway nodes and a base station to continuously monitor the environment in real time. Their research reveals the significance of temperature and gas/smoke sensors and infrared sensors to enhance both fire detection accuracy and false alarms. Another point the authors make is the lack of radio propagation in forests and the evaluation of the different communication technologies, in which it is found that energy efficient network design and optimal positioning of sensors are essential to ensure reliability during the long term deployment.

Most current research has undertaken enhanced IoT-based landslide monitoring and early warning systems sensing architecture. Indukala et al. [2] suggest an IoT-based microseismic sensing system with geophone sensors to record low-frequency ground vibrations that are related to slope instability. They combine edge computing and cloud computing in their system to process real-time data and provide predictive analysis. Field tests in landslide-prone areas in the Himalayas prove the usefulness of the system in forecasting early seismic signals, but also point to the problem of false alarms, as well as power maintenance in remote areas.

Bagwari et al. [3] reports in depth review of sensor based and LoRaWAN enabled architecture to landslide monitoring in an IoT framework. The research divides the methods of monitoring landslides into remote sensing methods and ground-based WSN.

Although remote sensing has large spatial coverage, the authors observe its drawbacks in the cost and intermittency of data. On the other hand, terrestrial WSNs allow real-time observation over a long period with sensors like MEMS acceleration sensors, soil moisture sensors, and tilt sensors. The review also highlights the potential of multi-sensor fusion and the use of LPWAN technologies especially the LoRaWAN in attaining scalable and energy efficient monitoring systems.

Thirugnanam et al. [4] provide an in-depth review of IoT-based multi-sensor system used in landslide monitoring and prevention. Their work points to the fact that landslides are multi-parameter phenomena which depend on rainfall, soil moisture, pore-water pressure, and seismic activity, and thus it cannot be done with single-sensor approaches. This paper reports on the incorporation of MEMS sensor, rain sensors, soil moisture sensors and wireless sensor networks with cloud computing-based analytics to provide real-time monitoring and advance warning. The authors also highlight how edge computing can be beneficial in the reduction of latency and enhancement of the decision accuracy of disaster monitoring systems.

With respect to the forest fire detection, Dharmesh et al. [5] introduce FireWatch, an IoT-centric fire detection system that uses the LoRa communication to transmit data with low power and long distances. The system combines the three sensors (temperature, humidity, and flame) with an Arduino processor and forwards the data to Things Network (TTN) which sends the data to the cloud-based environments to be visualized at any specific time and generate alerts. Experimental data show dependable real-time monitoring and threshold based alerting, which can be used to detect fire in a large scale and remote setting early. Future improvements, including AI-based analytics and incorporation of other sensors to enhance scalability of the system are also addressed in the study. After examining the literature reviews, it can be said that the currently available systems are mainly designed to either detect forest fires or to monitor landslides as single solutions. This brings out the necessity to have a unified IoT-based disaster monitoring system that would be able to monitor and record various hazards simultaneously with multi-sensor data, real-time communications, and early warning systems, especially in mountainous areas that are prone to disasters.

III. SYSTEM ARCHITECTURE

Fig. 1 shows the system architecture of the proposed Smart Disaster Monitoring System IoT-Based in Mountain Regions. The system will be configured to keep an eye on the environmental conditions in hilly and mountainous areas and send timely notifications in case of a disaster like fire, leakage of gases, landslides, and abnormalities in soil moisture levels.

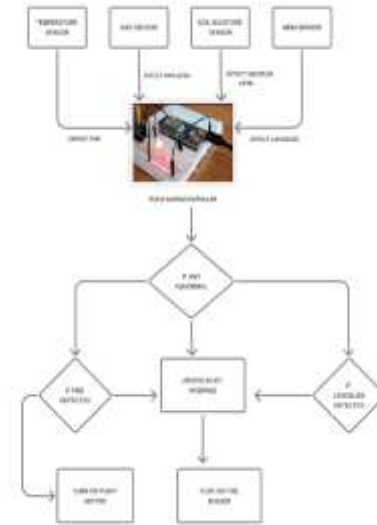


Fig. 1: Overall architecture

The proposed architecture has three major layers including: Sensing Layer, Processing and Control Layer, and Application Layer.

A. Sensing Layer

The sensing layer will comprise of temperature, gas, soil moisture, MEMS and distance sensors that will detect real time environmental information. In the course of experimental testing, the readings were as follows: It was noted that the temperature sensor gave readings of 70C in the open air and 70C in the closed air which means that it is useful in monitoring the abnormal increase in heat in relation to fire. The gas sensor also responded to 50 in both conditions, and it indicates that the gas detector is stable to detect the gas. The soil moisture meter obtained a reading of between 50 which is a moderate level of ground saturation that applies in predicting landslides. The MEMS sensor was able to sense ground movement within the range of 1-2 cm with a 2cm movement to the right and 2cm movement to the left. These sensors keep on relaying data to central controller where they are further analysed.

B. Processing Layer

Processing layer is done with the help of ESP32 microcontroller which is the main control unit of the system. It captures sensor data, compares the values with previously established threshold values and detects abnormal environmental conditions. The response time of the system was 2.34 seconds to 4.33 seconds according to the environment conditions. In case of high temperature and gas, the system identifies the occurrence as a fire and automatically switches on a pump motor. In the same way, unusual soil moisture and vibration levels in the soils raise landslide warnings.

C. Application Layer

At the application layer, sensor data can be transmitted wirelessly over Wi-Fi/GSM to an internet of things platform on the cloud. The readings are presented in form of a web interface which can be monitored in real-time. In the case of abnormal conditions being detected, alert messages are sent to the relevant authorities. This stratified design guarantees key monitoring and fast reaction to even catastrophe management of mountainous areas.

IV. PROPOSED ALGORITHM

The disaster monitoring system proposed is an IoT-based system that runs on a threshold-based real-time detection system. The algorithm works with input of environmental sensors and categorizes events either as forest fire or landslide according to experimentally found values. Algorithm Intra: Forest Fire and Landslide Monitoring System IoT Based Working Flow.

A. System Initialization

The procedure starts with system start up. The microcontroller and sensors (temperature, gas, soil moisture, and vibration) are turned on. The modules of communication are also set to allow cloud connectivity

B. Real-Time Data Acquisition

Once it is initialized, the system keeps on receiving real-time environmental information on deployed sensors. These are sensors that keep track of important environmental parameters in regards to forest fires and landslides.

C. Data Preprocessing

The raw sensor data is processed into a more reliable form. This stage includes:

Noise filtering

Removal of invalid readings

Calibration adjustments

Data normalization

Preprocessing enhances the correct analysis and minimizes false alarms.

D. Threshold Evaluation

The acquired sensor values are processed and compared to preset threshold values. When the sensor values fall within the normal limits, the system goes back to continuous monitoring. When the sensor values are above the threshold values, the system will continue with analysis.

E. Correlation of Sensor

Values Sensor values are correlated to determine the relationship among them. E. Correlation of Sensor Values Sensor values are correlated to calculate the relationship between them. Abnormal readings are identified and thereafter, several sensor values are correlated to ensure the nature of the disaster. This minimizes false positives by authenticating mixed environmental factors as opposed to an individual parameter.

F. Forest Fire Detection

In case correlated values show:

High temperature

Low humidity

Smoke or toxic emissions.

The system recognizes a possible forest fire situation.

In this case:

The water pump is automatically triggered whereby it suppresses fire. Local alert is activated by a buzzer.

G. Landslide Detection

In case the sensor values are correlated and the values are:

High soil moisture

Abnormal vibration

Heavy rainfall conditions

The system detects a possible landslide situation.

In this case:

The alarm is sent on to alert the surrounding inhabitants.

Emergency warnings are ready.

H. Cloud Communication and Alert Generation.

Once either of the following disasters is identified:

The sensor data would be sent to the cloud server.

The data on the events is stored to be analyzed further.

I. Surveillance and Avertive Measures of the Resume.

After alert generation:

This system is automatically reinstated to monitor.

Prevention measures are activated to evacuation warnings, emergency response planning, or automated mitigation measures.

J. Termination

This will take place in a circuit until the system is manually terminated. The algorithm provides the round-the-clock monitoring of the environment and a quick disaster response.



Fig. 2: Working Flow

VI. EXPERIMENTAL RESULT AND DISCUSSION

The implementational performance of the proposed disaster monitoring system developed through IoT was tested experimentally to examine the individual sensor performance and the system reaction in general. The experiments were done in closed area and open area environments to study sensor behavior in controlled environmental conditions. The system kept on monitoring the environmental parameters at the temperature, gas, soil moisture, MEMS and distance sensors. Table 1 shows the results of the experimental setup. The temperature sensor read values near 70 o C during the analysis that means the sensor can identify abnormal heating conditions which can cause forest fires. In the same vein, the gas sensor indicated values of about 50, which is the sure indication of good detection of smoke and poisonous gases during combustion.

The sensor of soil moisture registered an answer of around 50, which indicates moderate levels of soil saturation that are related to landslides. The MEMS sensor was able to detect floor movements ranging between 1 cm and 2 cm, which proves that the sensor is effective in detecting the presence of vibrations in the environment

Table 1: Working Of Sensors In Open And Close Environment

S.NO	TEMPERATURE SENSOR			GAS SENSOR		SOIL SENSOR		MEMS
	TEMP(SEC)	TEMP (%)	TEMP DIST(CM)	GAS (SEC)	GAS RANGE	SOIL (SEC)	SOIL RANGE	
1	3.44	99	1.5	2.17	1	2.51	71	3.80
2	3.50	98	3	2.20	2	2.76	72	0.8
3	2.90	99	2	3.01	3	1.65	70	1.57
4	1.00	99	1	3.02	2.5	2.04	71	2.64
5	2.77	93	4	2.25	3.2	2.96	72	5.04
6	2.48	98	2.5	2.50	2.5	2.10	60	3.40
7	1.39	96	5	2.01	1.1	1.50	84	3.69
8	2.17	93	3.5	2.20	3.1	3.02	55	2.60
9	1.39	86	4.5	2.75	3.5	2.50	70	3.40
10	6.68	98	3.8	2.85	3.6	2.80	75	1.56
11	4.25	97	2.8	2.65	3.3	2.35	73	2.85
12	3.12	94	4.2	2.70	3.4	1.88	68	3.12
13	5.46	96	3.1	2.75	3.5	2.64	72	1.94
14	2.05	92	4.7	2.80	3.6	2.12	69	4.26
15	7.18	98	2.2	2.85	3.2	2.95	74	2.36
16	4.63	95	3.6	2.90	3.4	1.74	66	3.51
17	3.74	94	3.2	2.95	3.6	2.41	71	2.09
18	6.12	92	4.6	3.00	3.1	2.08	67	4.83
19	2.33	97	2.9	3.05	3.3	2.77	75	2.36
20	7.05	90	4.8	3.10	3.5	1.93	70	3.15
21	4.18	95	3.7	2.05	1.1	2.58	73	2.09
22	1.92	98	2.1	2.10	1.4	2.16	69	4.15
23	5.63	93	4.1	2.20	1.9	3.05	76	3.28
24	2.48	96	3.0	2.28	2.2	1.82	65	1.88
25	6.44	91	4.5	2.48	2.5	2.47	72	2.97
26	3.29	94	3.4	2.58	2.8	2.69	74	3.74

The experiment was repeated 30 times and 4 erroneous readings were eliminated and there were 26 valid observations. The stability and consistency of the sensors used in the proposed disaster monitoring system were assessed by the use of statistical analysis of the value of the sample standard deviation (n - 1).The standard deviation was computed by use f:

$$SD = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n - 1}}$$

where
 x_i = observed values,
 \bar{x} = mean value,
 n = 26 valid samples.

A. Temperature Sensor Performance

Parameter	Mean	Standard Deviation
Temp Sec	3.80	1.84
Temp %	95.15	3.30
Temp Distance (cm)	3.39	1.07

The temperature sensor demonstrates congruent results with a considerable variation, which means that it is capable of reliable detection.

B. Gas Sensor Performance

Parameter	Mean	Standard Deviation
Gas Sec	2.62	0.35
Gas Range	2.73	0.82

The gas sensor has a low variation meaning that the sensor has uniform sensing during successive experiments.

C. Soil Sensor Performance

Parameter	Mean	Standard Deviation
Soil Sec	2.37	0.43
Soil Range	71.12	6.08

The variability of the reading in the soil sensor is acceptable, which proves the validity of environmental monitoring.

D. MEMS Sensor Performance

Parameter	Mean	Standard Deviation
MEMS Sec	2.96	1.08

The MEMS sensor maintained stable response time across the trials.

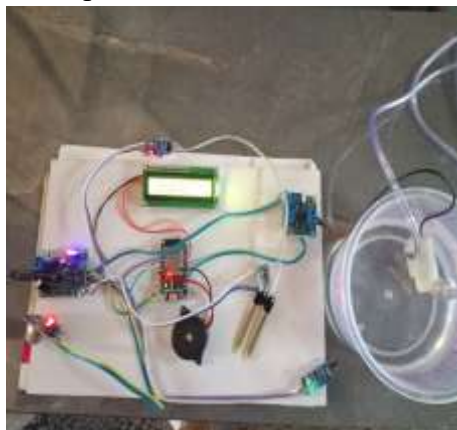


Fig.3: Device

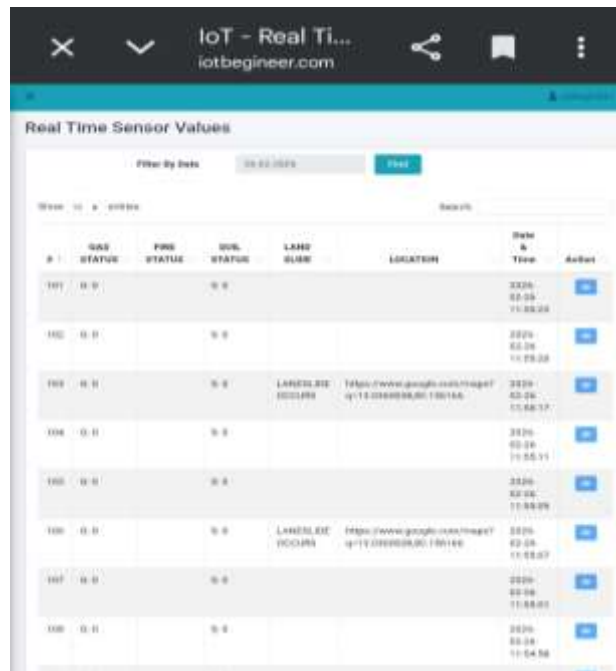


Fig.4: IOT Website

The total system response time was between 2.34 seconds and 4.33 seconds, which means that it is fast in responding to abnormal changes in the environment. The findings prove that the combination of different sensors increases detection accuracy and allows to provide the efficient early warning during monitoring forest fire and landslides.

VII. CONCLUSION

The paper has introduced an IoT-based smart disaster monitoring system that will be used to detect forest fire and landslides in mountainous areas early. Based on the suggested system, several sensors are involved such as temperature, gas, soil moisture, MEMS to be constantly aware of the environmental conditions and detect any calamity that can occur.

The implementation of the system was based on ESP32 microcontroller with wireless communication possibilities so that to send data in real time to cloud-based monitoring platform. Moreover, the automated system of water pumping was integrated that would prevent fire outbreak at the first stage and, consequently, decrease fire propagation and cause less harm to the environment.

System performance was evaluated through experimental analysis in an open environment as well as closed environment. The analysis showed that the sensors were successful in identification of abnormal environmental conditions, and the system reacted within a short period of time of around 2 to 4 seconds. The reliability and accuracy of disaster detection was enhanced by the incorporation of several sensing parameters.

The system proposed is cost-effective, scalable and efficient in real-time monitoring of the environment and disaster management. It can greatly decrease the response time and assist the authorities to act in time to stop serious devastation created by forest fires and landslides. The system may be further extended in future by adding more sensors, satellite communication, and machine learning methods to enhance the accuracy of the prediction and increase the accuracy of the system in large scale application in remote forests areas.

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