Sri Lanka Institute of Information Technology

Internet of Things and Big Data Analytics - IT4021

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FireShield 360 - An Integrated IoT and Machine Learning Approach to Wildfire Prevention

2025_05

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Git Hub Link –https://github.com/IOTBDA2025/iot-data-collection-and-analysis-project-2025_05

Batch: Year 4 Semester 2 (Data Science)

Declaration

We declare that this project report or part of it was not a copy of a document done by any organization, university, other institute, or a previous student project group at SLIIT and was not copied from the internet or other sources.

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1. Background

1.1 Introduction

Wildfires have emerged as a growing global threat, fueled by global warming, prolonged droughts, and human activities. In California alone in 2020, over 4 million acres of land were engulfed by wildfires that resulted in billions of dollars' worth of losses and claimed countless lives [1]. Traditional detection techniques using satellite imagery and manning patrols cannot keep pace with this new risk [2]. Satellite systems, with repeat visits of hours, too frequently detect fires too late, while human observation is limited by visibility, man power, and logistics. These constraints highlight the critical need for an automatic real-time detection system that can sense wildfires at their very beginning in order to prevent widespread loss.

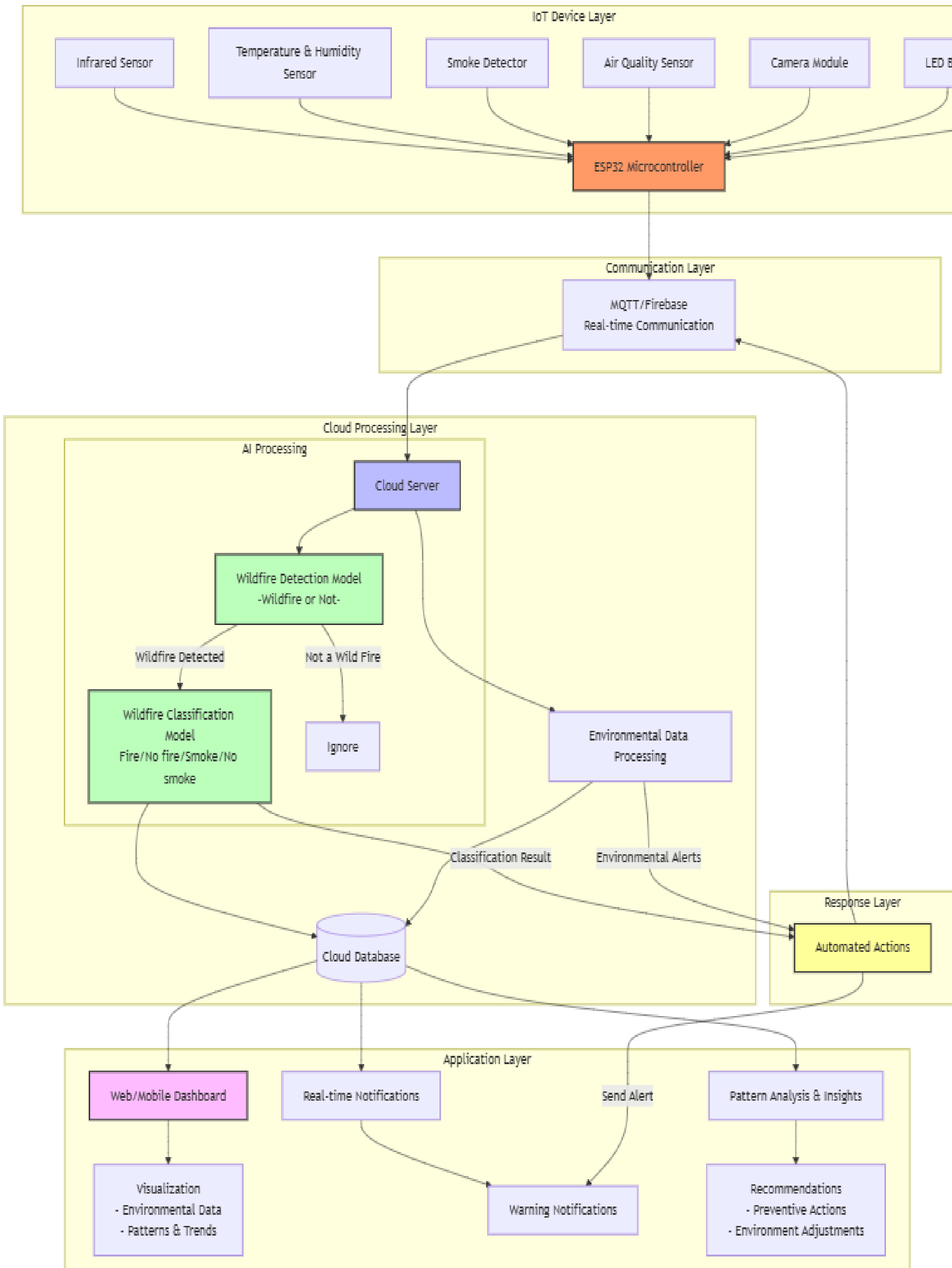
‘FireShield 360’ rises to this challenge through the form of an advanced system of wildfire prevention relying on the potential of Internet of Things (IoT) technology and advanced Machine Learning (ML). Contrary to older techniques, FireShield 360 utilizes a collection of IoT sensors—temperature, humidity, infrared radiation, smoke, and air quality—paired with a camera module in the vulnerable areas for scanning environmental situations round-the-clock. Upon detecting a fire or smoke, the system triggers immediate local alarm through a red LED light and buzzer for immediate alert in ranger stations or camps. It also informs the authorities through an instantaneous Node-RED dashboard in real-time, bringing down response time from hours to minutes. All the information is stored historically to facilitate AI-powered predictive analysis and support long-term wildfire prevention campaigns. FireShield 360 is an affordable, preventative means of limiting the devastating impact wildfires can have on communities and ecosystems.

1.2 Problem Statement

The increasing severity and frequency of wildfires necessitate innovative approaches in addition to traditional measures of detection. Satellite-based systems, while effective on a large spatial scale, lack the temporal response to capture incipient fires. Human observation, while effective at the urban location, is infeasible over remote forests due to logistical difficulties. Most modern automated systems currently lack the ability to integrate current data with archived analysis or to provide intelligent actionable information [3]. Not having real-time local alarms further delays response action, allowing for fire propagation. FireShield 360 tries to bridge all these gaps with an end-to-end, automated solution based on real-time detection, local alerts, and data-driven prevention.

2. Proposed Solution

2.1 System Architecture Diagram



2.2 System Architecture

FireShield 360 is an IoT and Machine Learning (ML)-based wildfire detection system that is designed to monitor environmental conditions and visual cues in real time. It integrates a sensor network, a camera module, and actuators (red bulb and buzzer) with an ESP32 microcontroller to provide both local and remote alerts. The system is constructed into five levels—IoT Device Level, Communication Level, AI Cloud Computing Level, Application Level, and Response Level—and ensure the early detection, speedy response, and actionable suggestions against preventing wildfire.

IoT Device Layer

At the heart of FireShield 360 is the IoT Device Layer, a collection of sensors, a camera module, and actuators controlled by an ESP32 microcontroller. The sensors—for temperature, humidity, infrared radiation, smoke, and air quality—continuously scan the environment inside high-risk zones [3]. When anomalies such as abnormal heat or smoke levels are detected, the camera module captures images of the affected area for analysis. Not only does the ESP32 microcontroller collect and analyze this data, but it also activates a red bulb and buzzer to provide immediate local visual and audible alarms, thereby warning personnel in the area of potential danger immediately.

Communication Layer

The Communication Layer ensures easy and effective transfer of the data from the IoT devices to the cloud. Sensor information is delivered in a persistent manner even in the event of bandwidth-constrained networks through MQTT, an efficient messaging protocol. Firebase also aids this by providing real-time synchronization and storage, where the data becomes accessible for analysis and alerting in real-time. The layer contributes significantly to the responsiveness and scalability of the system.

AI Cloud Processing Layer

At the AI Cloud Processing Layer, state-of-the-art deep learning models process the sensor data and images obtained to confirm the presence of wildfires. Either Convolutional Neural Networks (CNN), YOLO, ResNet-50 or a combination would be used for extracting deeper features to detect a fire or smoke in real time [3]. Collectively, these models allow accurate and timely detection with fewer false positives. All analytical results, along with the raw data, are stored in a MongoDB database for historical reasons and future predictive modeling.

Application Layer

The Application Layer provides a Node-RED dashboard, which provides real-time data and control in an easy-to-use way. The authorities can see real-time plots of the sensor data, a heatmap of the high-risk area, and a timestamp and severity-based alert log. This will allow the authorities to make informed decisions within timely limits. This layer fills the gap between response in terms of action and data analysis.

Response Layer

The Response Layer triggers auto-responses on the confirmation of a wildfire. Locally, the ESP32 microcontroller activates the red bulb and buzzer to alert surrounding staff. Simultaneously, remote alerts are sent via the Node-RED dashboard to centralized command centers, thereby providing a concerted response. The dual-alarm system is designed to minimize response time and prevent severe harm [4].

FireShield 360 workflow is an integration of the aforementioned layers. The sensors continuously monitor the environmental parameters, and when two or more sensors exceed the threshold value, the camera module is triggered to capture images. The images are transmitted to the cloud via Google App Script, where the AI models confirm the occurrence of fire or smoke. Upon confirmation, the ESP32 turns on the local red bulb and buzzer, and remote alerts are transmitted through the cloud system. This end-to-end process offers early detection of wildfires and quick response.

Real-time monitoring is another very critical component of FireShield 360, and this is done through the Node-RED dashboard. It displays real-time plots of trends in air quality, smoke, humidity, and temperature in real time, which allows users to see environmental conditions in real time. A heatmap gives highest priority to regions of highest risk as per live feedback, and an alert log records all events, timestamp and severity level.

Historical analysis is possible through the existence of sensor readings, images, and analysis output are recorded in a MongoDB data store. It allows for capability to conduct trend analysis to identify recurring fire-hazard scenario, predictive model to forecast instances of maximum hazard, and optimization placement of the sensors based on past [5]. The proposed solution protects against persisting threats and shields against ensuing wildfires by evidence-based expertise.

System has full environmental record logs, including temperature and humidity trends, infrared heat trends, smoke and air quality readings, and time-stamped alarm images. The logs are invaluable for forensic analysis following an event and for real-time optimization of the detection algorithms and threshold parameters of the system. FireShield 360 offers actionable intelligence by the combination of AI-driven sensor data analysis and image processing. It offers immediate local alerts via the red bulb and buzzer, while remote alerts are offered via dashboard notification. It also offers predictive intelligence based on past trends in order to assist in preventive action, i.e., redistributing patrol units or fortifying firebreaks in areas of high intensity.

3. Member Contributions

Member 1 (IT21487484):
Member 1 has the task of hardware integration and IoT deployment, enable sensors (Infrared, Temperature & Humidity, Smoke, Air Quality, Camera Module) and red bulb and buzzer through the ESP32 Microcontroller. Setup MQTT and Firebase communication, conduct field testing to verify system reliability, and collaborate with Member 2 in synchronizing hardware with AI output.

Member 2 (IT21243226):
Member 2 deals with AI development and cloud management, designing and training or fine-tuning deep learning models (CNN, YOLO, ResNet-50) to detect wildfires. Setting up the cloud infrastructure, including MongoDB storage, and designing the Node-RED dashboard for real-time monitoring and alerts, working together with Member 1 to incorporate AI with hardware information.

4. List of Hardware

Sensors

- Infrared Sensor (MLX90614)
- Temperature & Humidity Sensor (DHT22)
- Smoke Detector (MQ-2)
- Air Quality Sensor (MQ-135)
- Camera Module (OV2640)

Actuators

- Buzzer
- Red LED Bulb

Other Devices

- ESP32 Microcontroller
- Breadboard
- Jumper Wires

5. Cost Breakdown

Hardware	**Cost (Rs/)**
ESP32 Microcontroller	1100.00
Infrared Sensor (MLX90614)	570.00
Temperature & Humidity Sensor (DHT22)	350.00
Smoke Detector (MQ-2)	480.00
Air Quality Sensor (MQ-135)	650.00
Camera Module (OV2640)	950.00
Buzzer	280.00
Red LED Bulbs	150.00
Breadboard	580.00
Jumper Wires	250.00
Total Cost	**5360.00**

6. References

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[2] Smith, J., & Brown, K. (2020). IoT-based wildfire detection and prevention systems: A comprehensive review. Journal of Environmental Monitoring, 15(4), 312–328

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[5] Silva, J., & Gomez, M. (2022). *Integrating AI and IoT for predictive wildfire management*. Proceedings of the International Conference on AI for Environmental Protection, 10(1), 87–101.