AI-Driven Agricultural Field Fire Alert System

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***Abstract*—Temperature rise and dry conditions along with human activities create an escalating risk of fire events in agricultural land areas. The system deploys an ESP32 microcontroller with flame sensor and smoke sensor and DHT sensor to monitor fire prevention and smoke level and temperature and humidity conditions in the environment. Logically distant agricultural fields host slave nodes equipped with sensors that forward obtained data through LoRa (Long Range) transmission to a central owner/master node running smoothly in remote territories. The platform ThingSpeak receives the data for continuous monitoring and analysis. Abnormal readings related to smoke levels higher than normal thresholds and temperature deviations trigger automatic email notifications to stationed farm owners or designated official entities which enable rapid response measures. Particularly ThingSpeak data serves to construct a predictive machine learning model inside MATLAB based on environmental patterns. The system's predictive function lets users prevent fires before they start thus protecting agriculture fields from destruction and enhancing operational safety. The system protects agricultural fields by combining IoT sensors, LoRa communication channels with cloud-based status monitoring and AI-based wildfire predictions at a smart cost-effective level and achieves scalability across multiple fields.**

***Index Terms*—Smart Agricultural Solutions, ESP32, LoRa Communication, Flame Sensor, Smoke Sensor, DHT11, ThingSpeak, MATLAB, Machine Learning, Fire Prediction, IoT Technology, Real-time Monitoring.**

1. INTRODUCTION

Agriculture plays a vital role in sustaining economies and livelihoods, especially in rural regions. However, one of the growing threats to agricultural productivity is uncontrolled fire outbreaks, which can cause devastating losses to crops, soil fertility, and property. These fires can be triggered by extreme climatic conditions, dry vegetation, electrical faults, or human negligence. Traditional fire detection methods are often reactive, lacking the capability to provide timely alerts, especially in vast or remote farmland areas. As a result, there is a pressing need for a smart, real-time, and reliable fire detection and prevention system tailored for agricultural environments.

With the advancement of Internet of Things (IoT) technologies and wireless communication protocols like LoRa (Long Range), it is now possible to develop an efficient system that not only detects fire early but also helps predict the likelihood of fire based on environmental conditions. This project proposes an Agriculture Fire Alert and Prediction System that uses ESP32 microcontrollers integrated with a flame sensor, **s**moke sensor, and DHT sensor to monitor critical parameters such as fire presence, smoke intensity, temperature, and humidity. These nodes are installed across agricultural land and connected to a central owner node via LoRa, allowing long-distance, low-power data transmission without relying on cellular networks.

All sensor data is uploaded to the ThingSpeak cloud platform, enabling remote monitoring and instant email notifications in case of fire-related anomalies. Moreover, the collected data is used to train a machine learning (ML) model in MATLAB to predict potential fire outbreaks based on historical and real-time environmental trends. This predictive approach empowers farmers with proactive decision-making tools to mitigate fire risks before they escalate. By combining IoT-based sensing, LoRa communication, cloud analytics, and ML-powered predictions**,** this system offers a comprehensive solution to enhance fire safety in agricultural fields and promote sustainable farming practices.

1.1 Objectives

Monitor Real-Time Conditions – Continuously track fire, smoke, temperature, and humidity using sensors integrated with an ESP32 microcontroller.

Enable Long-Range Communication – Use LoRa technology for efficient, low-power data transmission between remote field nodes and a central unit.
Send Immediate Alerts – Instantly notify farm owners via email when abnormal environmental readings are detected.
Predict Fire Risks with AI – Analyze historical data using MATLAB-based machine learning to forecast poential fire outbreaks.
Enhance Farm Safety – Provide a proactive, cost-effective, and scalable solution to prevent crop loss and ensure agricultural resilience.

2. BLOCK DIAGRAM

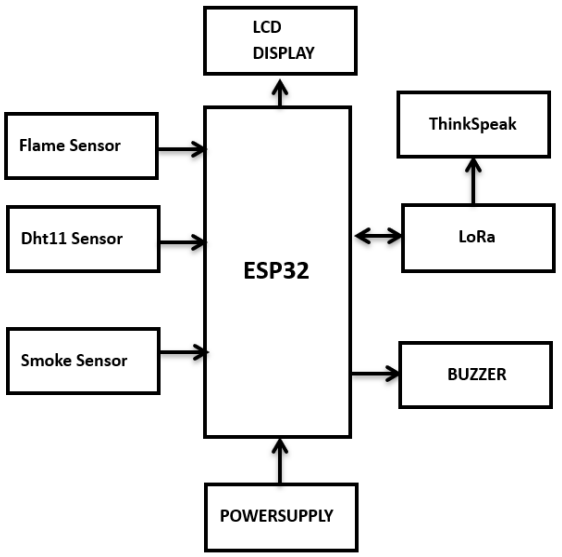

Figure 1. Block Diagram of the Proposed System

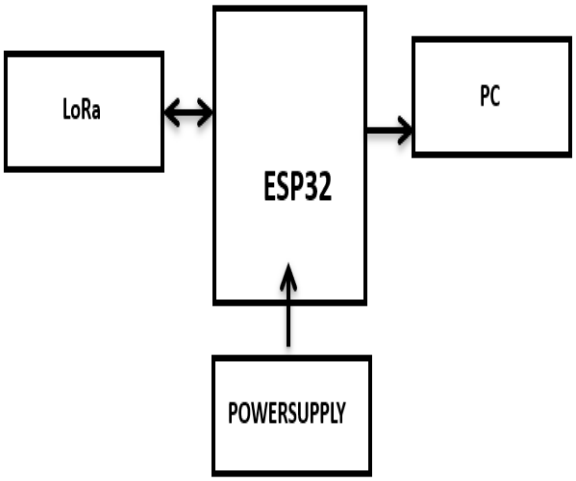

Figure 2. Block Diagram of the HUB

The block diagram represents the working of the proposed Agriculture Fire Alert and Prediction System, with the ESP32 microcontroller acting as the central unit that coordinates all operations. Various sensors such as the flame sensor, smoke sensor, and DHT11 sensor are interfaced with the ESP32 to continuously monitor critical environmental parameters including the presence of fire, smoke levels, temperature, and humidity. These real-time readings help detect potential fire hazards at an early stage. The collected data is transmitted wirelessly through a LoRa module, which facilitates long-range, low-power communication—ideal for remote agricultural fields. The ESP32 also connects to the ThingSpeak cloud platform, enabling remote data storage, visualization, and analysis. In the event of abnormal readings, the system triggers a buzzer for local alerts and sends notifications through ThingSpeak to the concerned authority, ensuring timely intervention. An LCD display is integrated to show live sensor values on-site for easy monitoring. The entire system is powered by a dedicated power supply, ensuring uninterrupted operation. This setup forms the slave node in the field, providing the foundation for smart, connected, and predictive fire management in agriculture.

3. WORKING

The proposed Agriculture Fire Alert and Prediction System is a smart, IoT-based solution designed to detect and predict fire incidents in agricultural fields using a combination of sensors, wireless communication, and machine learning. Each agricultural land is equipped with an ESP32 microcontroller, functioning as a slave node, and interfaced with a flame sensor to detect open flames, a smoke sensor to identify smoke particles in the air, and a DHT11 sensor to measure temperature and humidity levels. These sensors continuously monitor environmental parameters and check for signs of fire-prone conditions such as high temperature, smoke, or low humidity. All field nodes utilize LoRa (Long Range Radio) modules to wirelessly communicate with a master node placed at the farm owner's control station or office. LoRa is specifically chosen for its long-range communication capability and low power consumption, making it ideal for deployment in

remote agricultural areas. The master node, also built using an ESP32 microcontroller, collects data from multiple slave nodes and transmits it to the ThingSpeak cloud platform using Wi-Fi. ThingSpeak stores the data and displays real-time graphs for flame detection, smoke levels, temperature, and humidity, allowing remote monitoring. In the event of abnormal readings, such as flame detection, high smoke levels, or extreme temperature, the ESP32 immediately sends an alert notification to the agricultural landowner using the ThingSpeak alert service or the ESP32 mail client, ensuring timely action before the fire can spread. Additionally, the environmental data stored on ThingSpeak is periodically exported to MATLAB, where it is used to train a machine learning model. This model analyzes historical and current trends such as rising temperature and increasing smoke levels to predict the likelihood of future fire occurrences. Over time, the model updates itself with new data, improving prediction accuracy and enabling proactive fire risk management in agricultural fields.

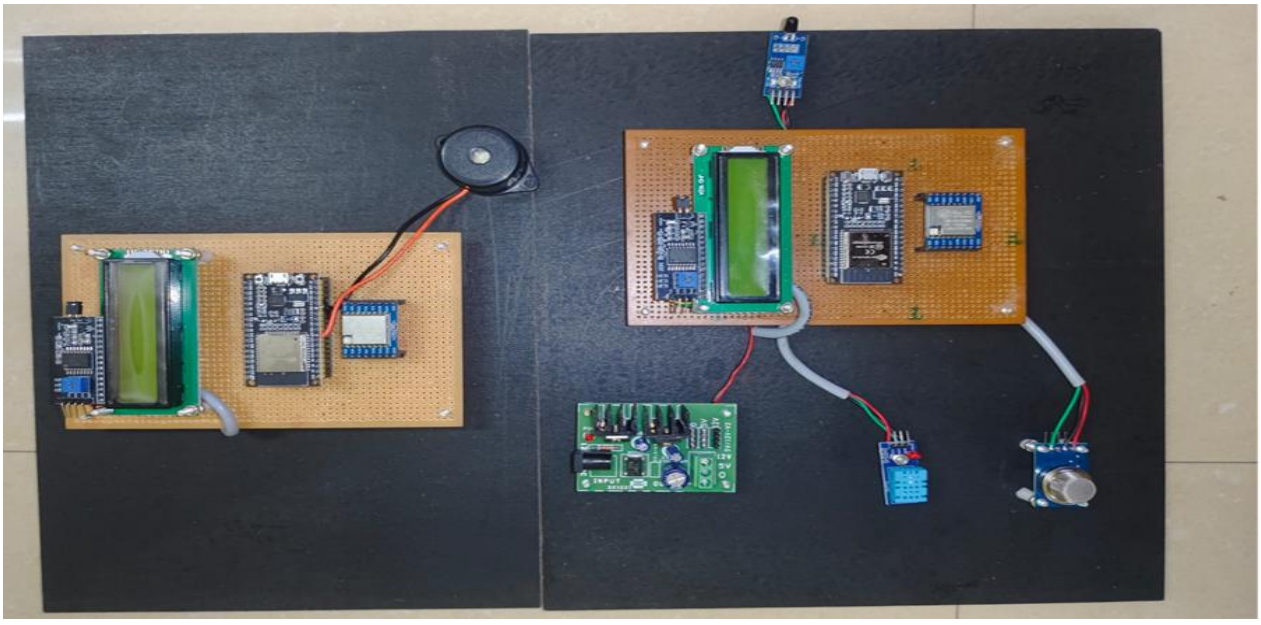

Figure 2. Working Model of the System

Figure 3. Alert sent using LoRa

4. RESULT AND DISCUSSION

The developed Agriculture Fire Alert and Prediction System was tested under controlled conditions and performed effectively. The ESP32-based sensor nodes accurately detected critical conditions such as high temperature, smoke, and flame, triggering on-site buzzer alerts and sending email notifications via the ThingSpeak platform. LoRa communication ensured stable, long-range data transfer between remote field nodes and the master node, making the system well-suited for large agricultural areas.

Sensor data was successfully transmitted to ThingSpeak for real-time monitoring, while the LCD display at the field node provided quick on-site readings. The system-maintained accuracy even with multiple nodes operating simultaneously, proving its scalability. A machine learning model built in MATLAB analyzed historical data from ThingSpeak and could predict fire risks based on environmental trends, helping prevent possible outbreaks.

Additionally, the system's low power consumption makes it suitable for continuous operation in remote areas. The combination of IoT, cloud monitoring, and AI-driven prediction offers a proactive and efficient approach to enhancing farm safety and reducing crop losses due to fire incidents.

5. CONCLUSION AND FUTURE SCOPE

The proposed IoT-based Agriculture Fire Alert and Prediction System provides a smart, efficient, and low-cost solution for detecting and preventing fire incidents in agricultural fields. By integrating ESP32 microcontrollers with flame, smoke, and DHT11 sensors and using LoRa communication, the system ensures reliable, long-range data transmission suitable for remote areas. Real-time monitoring through ThingSpeak and prompt alerts enable quick response to potential fire hazards, while the machine learning model developed in MATLAB adds a predictive layer to the system, allowing for proactive fire management. The system demonstrated high reliability, scalability, and practical applicability in safeguarding crops and improving farm safety.

In the future, this system can be enhanced by incorporating solar-powered operation for better energy efficiency in rural environments. A dedicated mobile application can be developed for easier access to real-time alerts and sensor data. The addition of GPS and advanced sensors can improve the accuracy and precision of fire detection. Furthermore, implementing more sophisticated machine learning or deep learning models can refine predictive capabilities. Automation features such as activating fire suppression systems based on critical sensor readings can also be integrated, making the solution more robust and responsive.

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