Automated System for Green House Agriculture with ML Fertility Advisior

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ABSTRACT— **In modern agriculture, precise monitoring and control of greenhouse environmental parameters are essential for optimal plant growth and productivity. Traditionally, this requires manual checks and labor-intensive processes, which are prone to inefficiency and human error. To address these challenges, we propose an IoT-based greenhouse monitoring and automation system that incorporates Machine Learning to enhance crop yield. The system's hardware includes the DHT11 sensor for measuring temperature and humidity, the MQ2 gas sensor for detecting harmful gases, and a soil moisture sensor to monitor water requirements. Data from these sensors is transmitted to an ESP32 microcontroller, which processes the information to automate irrigation. Based on the soil moisture levels, an irrigation motor is activated, ensuring precise water distribution. All sensor data is sent to Google Sheets for remote access, allowing real-time monitoring of greenhouse conditions. On the software side, a Windows application, PlantPulse, was developed for remote monitoring and control. The application provides a user-friendly interface for viewing sensor data and includes a machine learning model that recommends suitable fertilizers. The model analyzes soil type, temperature, humidity, and plant growth milestones to offer tailored fertilizer suggestions. This minimizes human intervention while maintaining optimal growing conditions, reducing operational costs, and improving agricultural efficiency. By combining IoT, automation, and machine learning, this project provides a comprehensive solution for modern agriculture, optimizing resource use, enhancing sustainability, and improving the productivity of greenhouse operations.**

I. INTRODUCTION

Greenhouses play a crucial role in modern agriculture, offering an environment where crops can thrive by protecting them from external weather conditions. This controlled space allows for year-round cultivation of diverse crops, contributing to higher yields and better quality produce. However, traditional greenhouse management remains a labor-intensive process, often requiring constant human oversight, which can lead to inefficiencies and challenges in maintaining ideal growth conditions. To overcome these challenges, the integration of IoT-based monitoring systems and automation offers a promising solution. By using sensors and machine learning, greenhouse conditions such as temperature, humidity, soil moisture, and harmful gases can be continuously monitored and controlled. This not only reduces the need for manual intervention but also optimizes resource use, ensuring a more efficient and sustainable agricultural process. The goal is to enhance crop yield and quality, making greenhouse farming more productive and less resource- intensive.

1.1 OBJECTIVE

The primary objective of this project is to develop a comprehensive, IoT- driven greenhouse monitoring and automation platform that leverages machine learning to optimize plant care and resource use. To achieve this, we employ DHT11, MQ2, and capacitive soil moisture sensors to continuously track key environmental parameters— temperature, humidity, soil moisture, and the presence of harmful gases— while an ESP32 microcontroller handles real-time data acquisition, automated irrigation control, and seamless wireless transmission of readings to Google Sheets. Complementing the hardware, we have created PlantPulse, a user-friendly Windows application that provides remote monitoring, visualization of live sensor data, and manual override of actuators when needed. At the core of the system's intelligence is a Random Forest-based fertilizer recommendation engine: by analyzing inputs such as soil type, temperature, humidity, and plant growth stage, it suggests tailored nutrient formulations to promote optimal development. Altogether, this integrated solution minimizes manual intervention and resource wastage, lowers operational costs, and drives higher, more consistent crop yields—fostering a more sustainable model of greenhouse agriculture.

1.2 MACHINE LEARNING & IOT

Our platform unites IoT sensing and supervised learning to provide real- time, automated greenhouse control. An ESP32 samples DHT11, MQ2, and soil moisture sensors and uploads the data to Google Sheets, where PlantPulse retrieves and visualizes live metrics before triggering actions like irrigation or venting. At the same time, a pre- trained Random Forest model—refined through preprocessing, SMOTE balancing, and GridSearchCV tuning—analyzes soil type, temperature, humidity, and growth stage to deliver tailored fertilizer recommendations. Tested via cross-validation and on a hold-out set, this streamlined pipeline achieves 92% accuracy, precision, and recall, ensuring dependable, data-driven nutrient guidance under changing greenhouse conditions.

1.3 ADVANTAGES

Real-Time Monitoring: Our system continuously captures temperature, humidity, soil moisture, and harmful gas levels, enabling immediate detection of any deviations from optimal conditions and rapid corrective action to protect plant health. Automation of Greenhouse Operations: By linking soil moisture readings and other sensor data directly to actuators (such as irrigation pumps and ventilation systems), the platform automates routine tasks, significantly reducing manual labor while ensuring precise, timely adjustments that conserve water and energy.

Machine Learning–Driven Fertilizer Recommendations: Embedded within the PlantPulse application is a Random Forest model that analyzes live environmental metrics and crop growth stages to suggest the most appropriate fertilizer formulation, improving nutrient uptake efficiency, boosting yields, and maintaining long-term soil vitality.

Support for Remote Agricultural Management: Farmers can monitor trends, receive alerts, and override controls from anywhere via the PlantPulse desktop interface. Leveraging Google Sheets for data storage keeps the setup lightweight and accessible even in rural or connectivity- limited areas, democratizing smart farming.

II. LITERATURE REVIEW

1. X. Xu et al., "Cucumber Flower Detection Based on YOLOv5s-SE7 Within Greenhouse Environments," IEEE Access, vol. 11, 2023.
2. M. Vernon et al., "A Survey of Modern Greenhouse Technologies and Practices for Commercial Cannabis Cultivation," IEEE Access, 2025.
3. J. U. M. Akbar et al., "A Comprehensive Review on Deep Learning Assisted Computer Vision Techniques for Smart Greenhouse Agriculture," IEEE Access, 2024.
4. Y. Wu et al., "Intelligent Agricultural Greenhouse Extraction Method Based on Multifeature Modeling," IEEE J. Sel. Topics Appl. Earth Observ., 2025.

III. EXISTING SYSTEM

There are several limitations in traditional greenhouse management systems, especially when it comes to ensuring efficient automation and environmental control. Greenhouses require continuous monitoring of factors like temperature, humidity, soil moisture, and air quality to promote healthy plant development. However, conventional methods heavily rely on manual labor and fixed routines, making them inefficient and error-prone. In many traditional setups, farmers or operators manually measure environmental conditions using basic tools like analog thermometers, hygrometers, and soil probes. Data collection is periodic, and decisions are often made based on estimated observations rather than real-time, accurate data. This manual system leads to delayed reactions to critical changes, such as sudden temperature spikes, drops in humidity, or dry soil conditions, which can severely affect crop health and yield. Similarly, irrigation systems in older greenhouses are typically set on fixed schedules without feedback from actual soil moisture levels. This results in either overwatering or under watering, leading to resource wastage and potential damage to plants. Gas detection for greenhouse air quality is often overlooked, leaving crops vulnerable to harmful pollutants that can go unnoticed until visible damage occurs. Moreover, fertilizer management in existing systems depends heavily on the farmer's judgment and manual soil condition assessments. There is no automation or intelligent recommendation for fertilizers based on real-time environmental data. Farmers must manually record conditions like soil type, temperature, and humidity and then cross-reference these with fertilizer guidelines, which can be time- 26 consuming and imprecise. This often results in poor fertilizer choices, harming crop health and reducing overall yield.

IV. PROPOSED SYSTEM

In the proposed system, a layered architecture unites sensor- driven IoT hardware with a streamlined data pipeline and an embedded machine learning engine to deliver end- to- end greenhouse automation . At the foundation lies a robust power supply—comprising a step- down transformer, bridge rectifier, voltage regulators (7805/7812), and smoothing capacitors—that feeds an array of environmental sensors. A DHT11 sensor continuously measures air temperature and relative humidity, an MQ2 module detects combustible and noxious gases, and a capacitive soil moisture probe monitors water content at root level. These analog and digital signals interface with an ESP32 microcontroller (via ADC, I²C, and GPIO), which not only polls the sensors at configurable intervals but also executes actuator control through an L298N dual H-bridge driver to operate a submersible pump for precision irrigation.

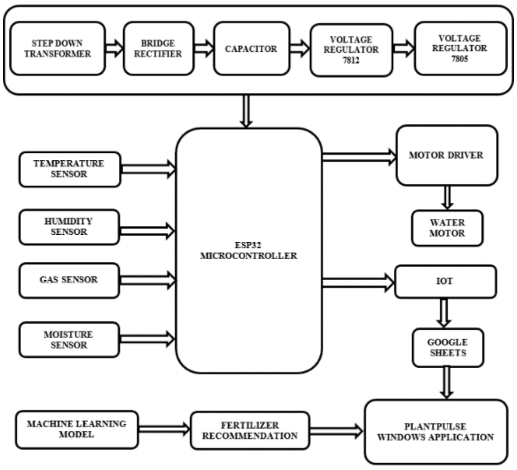

FIG 4. BLOCK DIAGRAM

Once gathered, sensor readings are packaged by the ESP32 and transmitted over Wi-Fi directly into a Google Sheets worksheet, effectively serving as a lightweight, cloud-less data lake. This approach eliminates the need for complex server infrastructure while ensuring farmers can access real-time and historical environmental logs from any location. The custom PlantPulse Windows application then periodically retrieves this data stream to render live dashboards, alert users to threshold breaches (e.g., low soil moisture or high gas concentration), and provide manual override controls for irrigation and ventilation systems. PlantPulse embeds a pre-trained Random Forest Classifier, serialized via joblib, to process a feature vector comprising encoded soil type, ambient temperature, relative humidity, and plant growth stage, delivering precise fertilizer recommendations. Developed offline using a curated Kaggle dataset, the model underwent comprehensive preprocessing— including missing value imputation, categorical encoding, SMOTE oversampling for class imbalance correction, and exhaustive hyperparameter tuning via GridSearchCV. Achieving 92% accuracy, precision, and recall in cross-validation and on a held-out test set, it ensures reliable, context-aware nutrient guidance in dynamic greenhouse conditions. This integrated framework significantly reduces manual intervention, optimizes water and fertilizer utilization, and empowers growers with data-driven insights.

V. RESULT

The Random Forest model demonstrated 92% accuracy, precision, and recall on the test set following SMOTE resampling and hyperparameter tuning, ensuring robust performance in fertilizer recommendation.

The automated irrigation system efficiently responded to soil moisture thresholds within seconds, while real-time data updates empowered timely decision-making for optimized resource utilization.

Additionally, PlantPulse's intuitive UI streamlined remote monitoring and fertilizer suggestions, significantly reducing operational overhead and enhancing user experience.

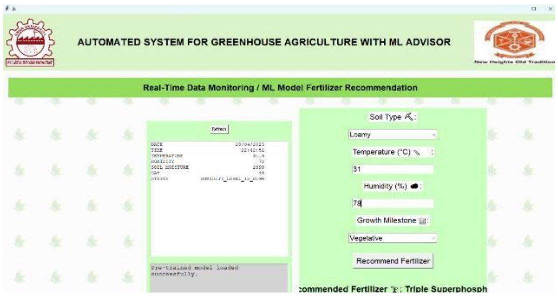

FIG 5.1 PLANTPULSE GUI

FIG 5.2 HARDWARE IMPLEMENTATION

VI. CONCLUSION

This work presents a fully integrated IoT- and machine learning- driven greenhouse monitoring and automation system that addresses the limitations of traditional, labor- intensive greenhouse management. By leveraging an ESP32 microcontroller to collect real-time sensor data on temperature, humidity, soil moisture, and gas levels—and by streaming these readings to Google Sheets—the platform provides continuous environmental visibility without complex cloud infrastructure. The PlantPulse desktop application not only visualizes live and historical trends but also embeds a Random Forest classifier to deliver data-drive fertilizer recommendations with 92% accuracy, precision, and recall. Automated irrigation and actuator control, triggered directly by sensor thresholds, reduce manual intervention, optimize water and energy use, and maintain ideal growth conditions. Collectively, these innovations yield a more sustainable, cost-effective, and scalable greenhouse solution capable of enhancing crop yield and quality.

VII. FUTURE ENHANCEMENT

To further enhance our greenhouse automation platform, we envision deploying the fertilizer recommendation model at the edge— either directly on the ESP32 or a dedicated device like NVIDIA Jetson Nano—to cut latency and enable offline operation; expanding our sensor array with PAR/light intensity, CO_2 , and leaf- wetness probes for a richer environmental dataset; developing predictive analytics using time-series models (e.g., LSTMs) and a rule-based alert system (SMS or push notifications) to forecast microclimate trends and disease risks; extending PlantPulse into cross-platform mobile and web applications with multi-user, role-based access for seamless collaboration; integrating renewable energy sources such as solar or wind to move toward a self-sustaining, off-grid system; and scaling the architecture to orchestrate multiple greenhouses from a centralized dashboard with comparative analytics and coordinated control for precision agriculture at the farm level.

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