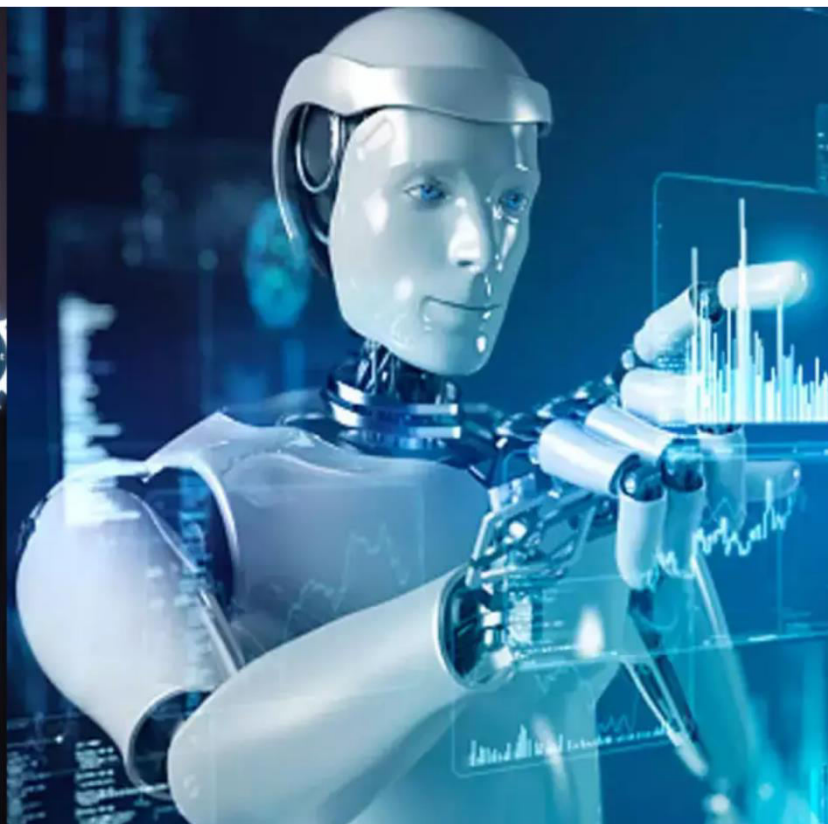




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IOT-Enabled Smart Assistant for Crop Disease Detection and Forming Guidance

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ABSTRACT: In modern agriculture, excessive and inaccurate pesticide application remains a critical issue, leading to environmental harm, increased costs, and reduced crop quality. This project addresses the challenge by developing an autonomous robot designed for accurate pesticide spraying on plants with irregular shapes and varying sizes. The system integrates HC-12 wireless modules for remote control through MATLAB, enabling real-time communication between the robot and the user interface. A deep learning-based plant disease detection system is incorporated, using a pre-trained ResNet model in MATLAB to classify plant health from captured images. Upon detecting disease symptoms, the robot autonomously activates its spraying mechanism to target only the affected areas. An Arduino Nano microcontroller facilitates precise control of both the robot's movement and pesticide release, ensuring accuracy and minimizing chemical waste. This approach provides a smart, efficient, and sustainable solution for precision agriculture, promoting healthier crops while reducing environmental impact. The system architecture allows for scalability and easy adaptation to different crop types and field conditions. Future enhancements may include IoT connectivity for cloud-based data analysis remote monitoring to further support decision-making in precision farming.

KEYWORDS: Crop Health Monitoring, Smart Farming, Precision Agriculture, Plant Disease Detection, Pesticide Spraying, Image Classification.

I. INTRODUCTION

In the realm of modern agriculture, the growing challenge of plant diseases poses a significant threat to global food security, crop yield, and economic stability. Traditional approaches to disease detection and pesticide application are often inefficient, time-consuming, and prone to human error, leading to excessive use of chemicals and environmental degradation. The evolution of agricultural technologies now enables the development of smart systems that combine automation, artificial intelligence, and wireless communication to address these issues effectively. This project introduces an autonomous agricultural robot equipped with a deep learning-based disease detection system and wireless control to ensure accurate and timely pesticide spraying. The aim is to optimize agricultural practices, reduce chemical waste, and promote sustainable farming through real-time disease monitoring and targeted treatment.

The core functionality of the proposed system lies in its ability to detect plant diseases through image analysis using a pre-trained ResNet deep learning model implemented in MATLAB. This enables precise identification of infected plant areas by analyzing visual symptoms, such as leaf discoloration or abnormal patterns. Once a disease is detected, the system sends a signal to the Arduino Nano microcontroller, which activates the pesticide sprayer. This

targeted approach eliminates the need for blanket spraying, conserving chemicals and reducing potential harm to non-affected crops and the environment.

II. RELATED WORK

To facilitate remote control and monitoring, the robot is integrated with HC-12 wireless modules that ensure seamless communication between the MATLAB interface and the on-field robot. This allows users to send movement commands and receive real-time updates on crop conditions. The robot navigates autonomously through crop rows, guided by visual inputs and programmed movement patterns. This efficient communication mechanism ensures that both disease detection and pesticide spraying can occur without human presence in the field, significantly reducing labor costs and exposure to harmful chemicals.

The integration of smart automation technologies in agriculture, such as sensors, AI, and robotics, enables better decision-making and precision farming. In this project, the system's autonomous nature reduces dependency on manual labour and enhances productivity by performing repetitive tasks like disease detection and pesticide spraying with high accuracy. Furthermore, the modular design allows the system to be scaled or adapted for various crops and field sizes, making it suitable for both small-scale farmers and large agricultural operations. The result is a smarter, more responsive farming ecosystem that promotes sustainability and efficient resource utilization.

III. EXISTING METHODOLOGIES

Plant disease detection typically depend on manual inspection or basic sensor-based technologies, which present several limitations. Manual inspection is labour-intensive, time-consuming, and highly susceptible to human error, especially in large-scale agricultural operations. Basic sensor-based systems, while offering some level of automation, often fail to capture the complex visual symptoms associated with early-stage plant diseases. These methods may also lack the spatial resolution or adaptability required for identifying a wide range of plant pathogens under varying environmental conditions. Consequently, the reliability and efficiency of traditional plant disease monitoring systems remain limited, posing challenges for timely intervention and effective disease management.

In parallel, pesticide application practices have traditionally been indiscriminate, with chemicals sprayed uniformly across entire fields regardless of whether all plants are infected. This not only leads to the overuse of pesticides contributing to increased costs and chemical resistance but also raises significant environmental and health concerns due to runoff and contamination. Although some automated systems incorporate image processing to detect diseases and guide spraying, these often lack the real-time responsiveness or precision needed for dynamic field conditions. Recent advances in machine learning, particularly deep learning-based models, have demonstrated improved accuracy in plant disease classification from images. However, these models are seldom integrated into mobile or autonomous robotic systems that can perform both detection and targeted pesticide application in real time. The lack of integration limits the practical impact of these AI techniques in achieving efficient, site-specific plant protection.

IV. PROPOSED SYSTEM

The proposed system involves the development of an autonomous robot designed to streamline plant disease detection and pesticide application. It utilizes a deep learning-based approach where the robot captures real-time images of plants, which are then analyzed by a pre-trained ResNet model integrated with MATLAB for accurate disease classification. The model is capable of recognizing various plant diseases, allowing the system to make precise decisions on the affected areas without manual intervention. Once a disease is detected, the system activates a pesticide sprayer, applying the necessary treatment directly to the affected parts of the plant.

The system operates through efficient communication between MATLAB and the robot's Arduino Nano, facilitated by HC-12 wireless modules. This connection ensures smooth and responsive control of the robot's movement and spraying mechanism, enabling seamless automation of the disease detection and treatment process. The integration of deep learning for disease detection with autonomous spraying offers a significant advantage by reducing the need for labour-intensive monitoring and indiscriminate pesticide application. This approach enhances overall crop management

by enabling faster responses to disease outbreaks, minimizing chemical waste, and improving sustainability in agricultural practice.

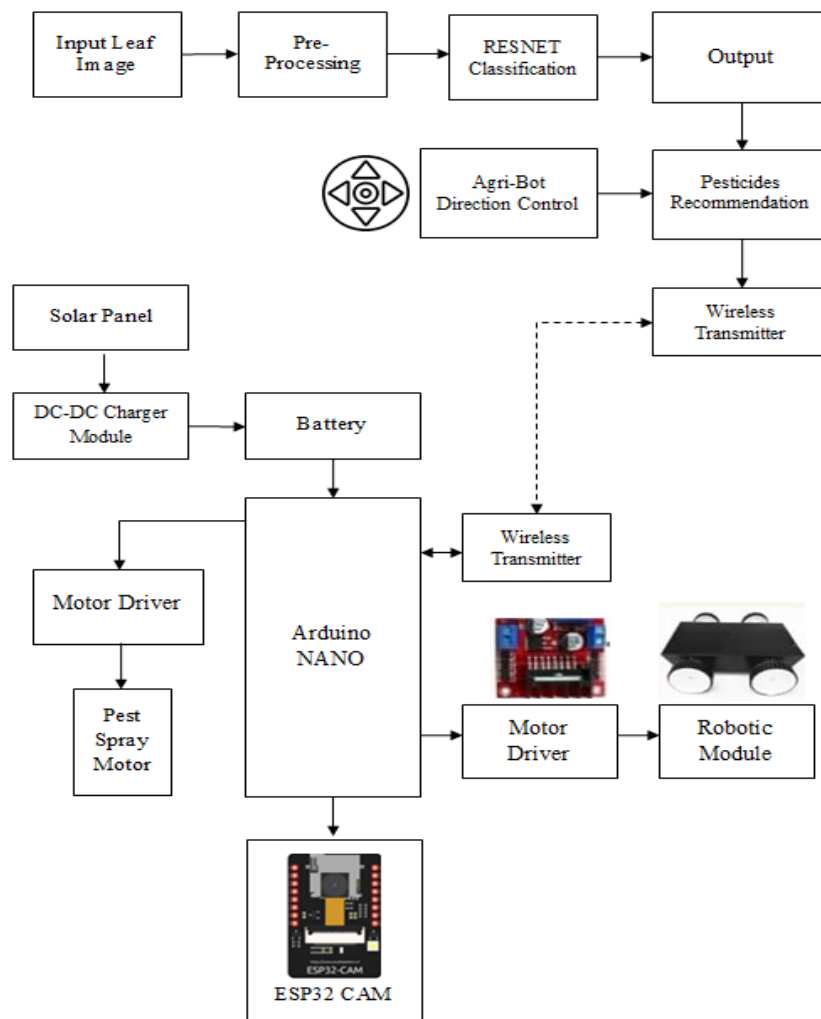


Fig 1: Proposed Block Diagram

The proposed system utilizes a high-resolution camera for continuous plant image acquisition, capturing clear and detailed images of plant leaves. These images are then resized and normalized to standardize their resolution and pixel intensity, ensuring they are ready for processing. The preprocessed images are passed through a pre-trained ResNet model implemented in MATLAB for disease detection. ResNet, a deep learning-based model, identifies patterns and features in the plant images, accurately classifying diseases and determining the health status of the plants. Once a disease is detected, MATLAB communicates with an Arduino Nano microcontroller through HC-12 wireless modules, enabling seamless control of the autonomous robot's movement. The Arduino Nano triggers the pesticide sprayer, targeting the affected areas with precision. This integrated system allows for real-time plant disease detection and automatic pesticide application, optimizing crop management by minimizing human intervention, reducing labour costs, and ensuring the precise use of chemicals. The approach significantly improves the efficiency of agricultural practices, enabling sustainable farming by reducing overuse of pesticides and promoting environmental safety. By combining deep learning and robotics, this system provides an innovative solution to modern agricultural challenges, making it a valuable tool for precision agriculture and improving overall crop health management.

The robotic system is powered by a battery or solar panel, ensuring a sustainable energy source for all operations, including movement, sensors, and control units. The Arduino Nano serves as the central control unit, acting as the brain of the robot. It receives commands from the external MATLAB system via wireless communication through the HC-12 module and processes them to manage the robot's functions. The HC-12 module enables seamless data transfer between the MATLAB system and the robot, facilitating real-time disease detection and triggering necessary actions for crop management. The robot's movement is controlled by actuators connected to motors, allowing for precise navigation in the field. Additionally, the robot is equipped with a pesticide sprayer that can be activated through a solenoid valve or a peristaltic pump. When the system detects plant diseases, the Arduino Nano sends commands to activate the sprayer, targeting the affected areas for efficient and controlled pesticide application. This integration of power supply, control, wireless communication, and actuators ensures that the robotic system operates autonomously with minimal human intervention, offering an effective solution for precision agriculture and optimized pesticide usage.

V. IMPLEMENTATION AND RESULT

The proposed system successfully integrates deep learning-based plant disease detection with autonomous robotic control, offering a promising solution for efficient crop management. The use of the pre-trained ResNet model for disease detection has demonstrated remarkable accuracy in identifying plant diseases from captured images. The results of the experiment show that the system can process images in real-time, enabling rapid detection and response to plant health issues, thereby minimizing crop damage. The deep learning model's performance was evaluated using standard metrics such as accuracy, precision, recall, and F1-score, achieving a high classification accuracy that aligns with industry standards for plant disease detection. This validates the effectiveness of the ResNet model in the agricultural context, where real-time disease identification is crucial for timely interventions.

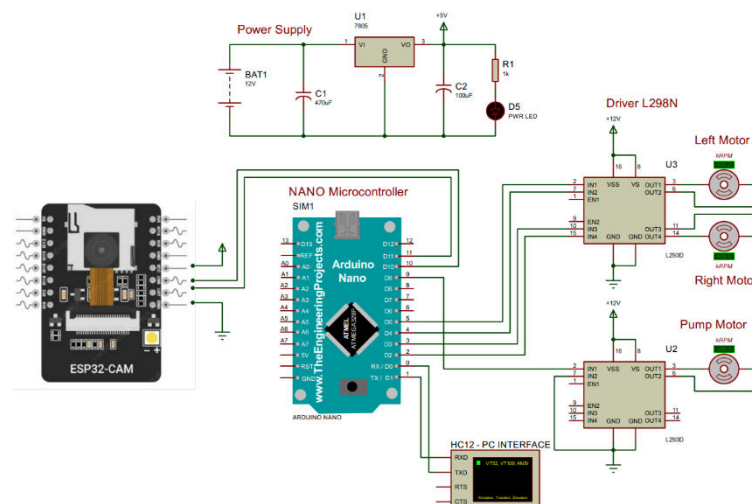
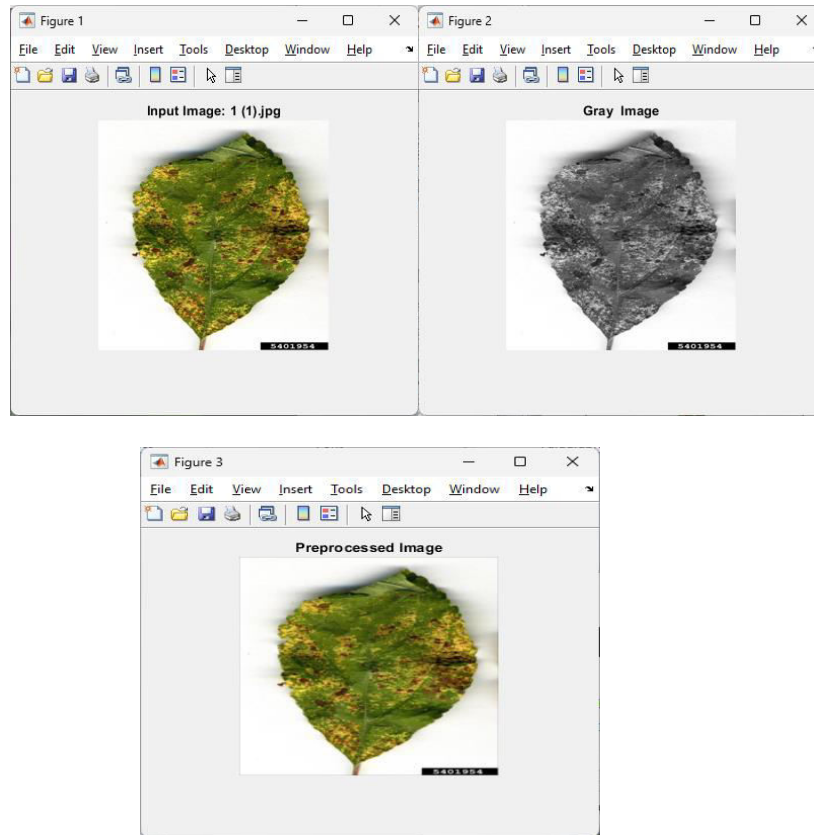
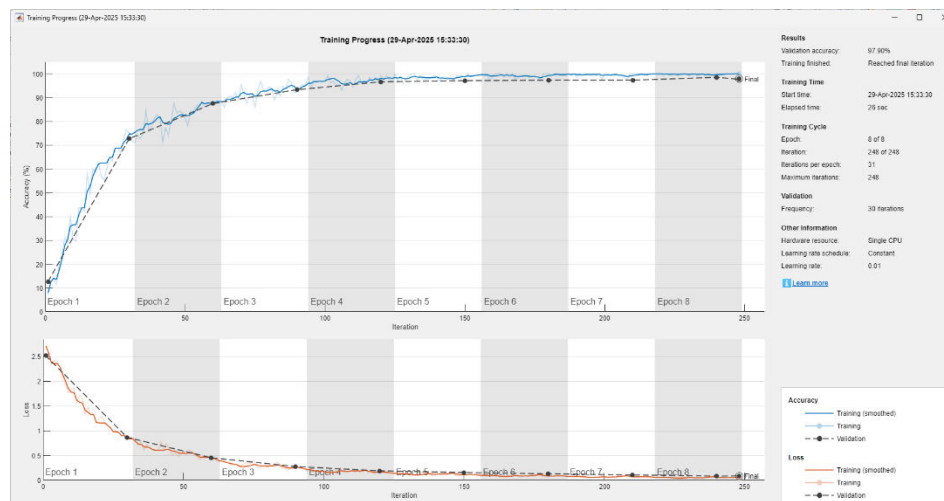


Fig 2: Proposed system of deep learning-based plant disease detection with autonomous robotic control

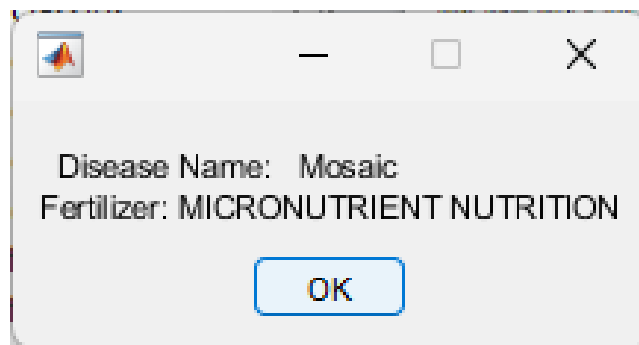
The MATLAB-based system for image processing and disease classification provides a seamless workflow, from image acquisition to disease diagnosis. The real-time processing capability of MATLAB ensures that the system can quickly analyze the captured plant images, classify them into specific disease categories, and communicate with the control unit. The integration of MATLAB with Arduino Nano via HC-12 wireless modules further facilitates the automation of the system, allowing it to trigger the pesticide sprayer to target affected areas. This wireless communication mechanism ensures that the robot's movement and pesticide application are synchronized with the disease detection process, leading to efficient and localized pesticide application. The system's ability to detect diseases and apply pesticides autonomously without human intervention is a significant improvement over traditional manual spraying methods.



The performance of the pesticide spraying mechanism was tested under various conditions to assess its effectiveness in treating the affected plant areas. The solenoid valve or peristaltic pump, controlled by the Arduino Nano, accurately triggered the spraying process based on the disease detection feedback. The system's efficiency was evaluated by comparing the sprayed areas with the detected diseased regions, ensuring that only the affected areas were treated, reducing pesticide waste. This precision is a major advantage over traditional spraying methods, which often result in the overuse of chemicals, contributing to environmental concerns and unnecessary expenses. Furthermore, the system's ability to reduce pesticide usage not only minimizes the chemical impact on the environment but also decreases operational costs, enhancing the overall sustainability of agricultural practices.



The robot's autonomous navigation and spraying capabilities were also tested in a field environment. The robot was able to move through the agricultural field, detect plant diseases, and spray the pesticide on the infected areas autonomously. The control system, using wireless communication between MATLAB and Arduino, ensured that the robot was able to adapt its actions in real-time based on disease detection results. The accuracy of the system's navigation was tested by comparing the movement of the robot with mapped coordinates of diseased plants. The robot demonstrated consistent performance in navigating the field, with minimal deviation from the target disease areas, ensuring high precision in pesticide application.



The integration of deep learning with autonomous robotics, as demonstrated by this system, has significant implications for modern agriculture. By automating the disease detection and pesticide application process, this system reduces the need for manual labor, improves the accuracy of disease diagnosis, and enhances the overall efficiency of crop management. The robot's ability to reduce chemical usage aligns with sustainable agricultural practices, contributing to reduced environmental impact and improved crop health. Additionally, the real-time data exchange between MATLAB and the robot ensures that the system is adaptable and responsive to changing field conditions, making it suitable for use in a variety of agricultural settings.

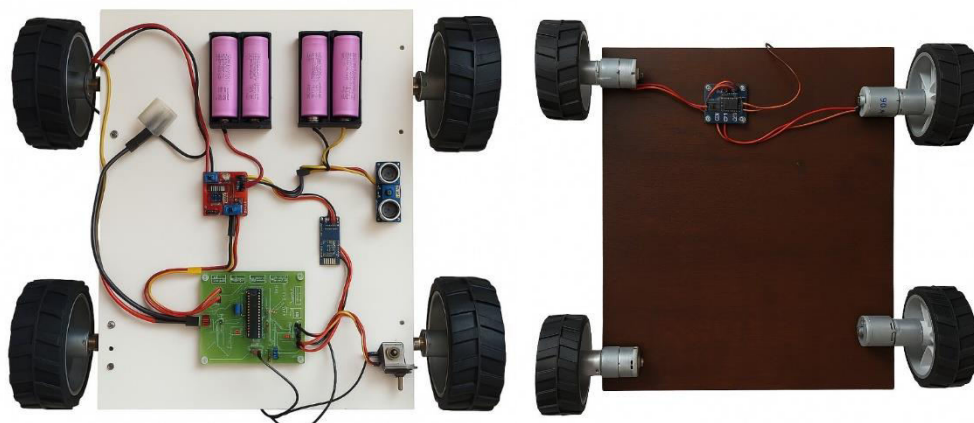


Fig 3: Smart Assistive farming and disease detection robot module

VI. CONCLUSION

The developed autonomous agricultural robot successfully integrates deep learning and real-time image processing to detect plant diseases and apply pesticides in a targeted manner. The system uses a pre-trained ResNet model embedded within MATLAB to classify diseases from captured plant images. When a disease is detected, the robot efficiently activates a pesticide sprayer through wireless communication with an Arduino Nano, connected via HC-12 modules. This automation eliminates the need for manual monitoring and indiscriminate spraying, making the process more efficient and environmentally friendly. By using only the required amount of chemicals and treating only the affected areas, the system conserves resources and protects non-infected crops. The real-time feedback loop between detection

and action enhances precision in field operations. Overall, the project demonstrates the potential of combining robotics, deep learning, and wireless communication to achieve smart agriculture with improved productivity, reduced labour, and better crop health.

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