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AI Based Intelligent Spraying Robot

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Abstract: *Agriculture remains a fundamental sector for global food security; however, plant diseases significantly reduce crop yield and quality. Conventional disease detection techniques rely on manual inspection, which is time-consuming, labor-intensive, and often inaccurate, leading to excessive pesticide usage and increased production costs. To address these challenges, this paper presents the design and implementation of an intelligent Agribot system for real-time plant disease detection and targeted pesticide spraying.*

The proposed system integrates an ESP32 microcontroller with an ESP32-CAM module to capture leaf images in real time. A lightweight machine learning model is employed to classify plant leaves as healthy or diseased. Based on the classification results, the ESP32 automatically controls a pesticide spray pump through a relay module, ensuring selective and precise chemical application. The robot's mobility is managed using an L298N motor driver, enabling efficient navigation across agricultural fields. A 12V battery powers the system, while a buck converter regulates voltage for safe and stable operation of electronic components.

The selective spraying mechanism significantly reduces pesticide wastage, minimizes environmental impact, and lowers operational costs for farmers. The proposed Agribot system demonstrates an effective integration of embedded systems, artificial intelligence, and IoT technologies to enable precision agriculture and promote sustainable farming practices. Experimental results indicate improved accuracy in disease detection and efficient pesticide utilization compared to traditional methods.

Keywords: *Agriculture*

I. INTRODUCTION

Agriculture is the backbone of many economies and plays a crucial role in ensuring food security for the growing global population. However, crop productivity is significantly affected by various factors, among which plant diseases are one of the major challenges. Early detection and proper treatment of plant diseases are essential to prevent crop loss and maintain agricultural sustainability. Traditional methods of disease detection rely heavily on manual inspection by farmers or experts, which is time-consuming, labor-intensive, and often inaccurate due to human error and lack of expertise.

With the advancement of technology, the integration of Artificial Intelligence (AI), Internet of Things (IoT), and embedded systems has opened new possibilities in modern agriculture. Smart farming techniques are increasingly being adopted to improve efficiency, reduce labor dependency, and optimize resource utilization. In particular, machine learning-based image processing techniques have shown promising results in identifying plant diseases at an early stage using leaf images.

This paper proposes an Agribot, an intelligent robotic system designed for real-time plant disease detection and automated pesticide spraying. The system utilizes an ESP32 microcontroller integrated with an ESP32-CAM module to capture images of plant leaves. These images are analyzed using a lightweight machine learning model to classify them as healthy or diseased. Based on the classification results, the system automatically activates a pesticide spray mechanism using a relay-controlled pump, ensuring targeted application only where required.

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In addition to disease detection, the Agribot is equipped with a motorized platform controlled by an L298N motor driver, allowing it to navigate through agricultural fields efficiently. The system is powered by a 12V battery, with a buck converter used for voltage regulation to ensure stable operation of all electronic components. This approach not only reduces pesticide wastage but also minimizes environmental pollution and operational costs.

The proposed system aims to provide a low-cost, portable, and efficient solution for small and medium-scale farmers. By combining AI-based disease detection with automated spraying, the Agribot contributes to precision agriculture and promotes sustainable farming practices.

II. LITERATURE SURVEY

Recent advancements in smart agriculture have focused on integrating Artificial Intelligence (AI), Internet of Things (IoT), and robotics to improve plant disease detection and crop management.

Several researchers have proposed AI-based systems for automatic plant disease detection. A study presented an AI-powered system using Convolutional Neural Networks (CNN) for real-time disease identification and targeted pesticide spraying, which significantly reduces chemical usage and improves crop productivity . Similarly, deep learning models such as YOLO have been widely used for accurate and fast disease detection, achieving high precision and enabling real-time applications in agriculture .

IoT-based approaches have also gained popularity in modern farming. A system using ESP32-CAM and machine learning was developed to capture plant images and detect diseases through cloud-based processing, reducing manual effort and improving yield quality . Another IoT-based crop monitoring system integrates ESP32-CAM with AI and cloud platforms like Blynk to provide real-time disease detection and environmental monitoring .

Robotics has further enhanced automation in agriculture. A smart agricultural robot integrated with image processing techniques can detect plant diseases and perform targeted pesticide spraying, reducing human labor and improving efficiency . Additionally, robotic systems combined with deep learning models such as MobileNetV2 have demonstrated the ability to perform real-time disease detection and localized treatment in agricultural fields .

Recent research also highlights the importance of lightweight and edge-based AI models. Systems using ESP32-CAM with on-device CNN models enable offline disease detection, making them suitable for rural areas with limited internet connectivity . Moreover, advanced deep learning architectures such as MobileNet, Vision Transformers, and hybrid models have improved classification accuracy while maintaining low computational cost .

Despite these advancements, some limitations still exist, including high computational requirements, dependency on internet connectivity, and challenges in real-field conditions such as lighting variations and background noise. Therefore, there is a need for a low- cost, efficient, and portable system that combines real-time disease detection with automated pesticide spraying.

The proposed Agribot addresses these gaps by integrating ESP32- based edge computing, machine learning, and robotic automation to provide an efficient and practical solution for precision agriculture.

III. PROPOSED METHODOLOGY

The proposed Agribot system is designed to perform real-time plant disease detection and targeted pesticide spraying by integrating embedded systems, machine learning, and robotic automation. The overall methodology consists of image acquisition, disease classification, decision-making, and actuation environmental pollution and operational costs.

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V. PROPOSED METHODOLOGY

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A. System Overview

The system is built around an ESP32 microcontroller, which acts as the central processing unit. An ESP32-CAM module is used to capture images of plant leaves. These images are processed using a lightweight machine learning model to detect diseases. Based on the classification output, the system controls a pesticide spray mechanism through a relay module. The robot is mounted on a mobile platform driven by DC motors controlled via an L298N motor driver.

B. Image Acquisition

The ESP32-CAM continuously captures images of plant leaves as the robot moves through the agricultural field. The camera is positioned such that it can clearly focus on leaf surfaces. Proper lighting conditions are considered to improve image quality and detection accuracy.

C. Image Processing and Classification

Captured images are processed using a pre-trained machine learning model. The steps involved are:

Image Preprocessing – resizing, normalization, and noise reduction Feature Extraction – identifying patterns such as color, texture, and spots

Classification – categorizing leaves into:

Healthy Diseased

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A lightweight model (such as CNN or MobileNet) is used to ensure fast processing and compatibility with embedded systems.

D. Decision-Making Mechanism

The classification result is sent to the ESP32 controller. Based on the output:
If the plant is healthy, no action is taken
If the plant is diseased, the system triggers the spraying mechanism This ensures selective and efficient use of pesticides.

E. Automated Spraying System

A relay module is used to control a pesticide pump. When a diseased plant is detected:
ESP32 sends a signal to the relay Relay activates the pump
Pesticide is sprayed directly on the affected plant
This targeted spraying reduces chemical wastage and environmental impact.

F. Robot Navigation

The Agribot is equipped with DC motors controlled by an L298N motor driver. The movement includes:
Forward and backward motion Left and right turning
The robot navigates through crop rows either manually or through pre- programmed control logic.

G. Power Supply System

The system is powered by a 12V battery. A buck converter is used to step down the voltage to required levels (5V/3.3V) for ESP32, camera module, and other components, ensuring safe and stable operation.

H. Overall Workflow

Robot moves through field ESP32-CAM captures leaf image Image processed using ML model
Disease detected (healthy/diseased) ESP32 makes decision
Relay activates pump (if diseased) Targeted pesticide spraying performed

VI. SYSTEM ARCHITECTURE

The AI-Based Agri Robot is designed using a layered architecture that ensures modularity, efficient processing, and reliable field operation. At the sensing layer, an ESP32-CAM module captures real-time images of plant leaves as the robot navigates through the agricultural field. These images are forwarded to the processing layer, where a lightweight machine learning model analyzes leaf features such as color, texture, and visible disease patterns to classify them as healthy or diseased. The classification output is then transmitted to the control layer, where the ESP32 microcontroller executes predefined decision logic. If a plant is identified as diseased, the control unit activates the actuation layer, which consists of a relay module connected to a pesticide spray pump for targeted chemical application. Simultaneously, the mobility layer, driven by an L298N motor driver, manages the robot's movement, enabling forward motion and directional control within crop rows. The entire system is powered by a 12V battery, while a buck converter regulates voltage levels to ensure stable and safe operation of the ESP32, camera module, and other electronic components. This layered architecture provides a structured and efficient integration of sensing, processing, control, actuation, mobility, and power management functions for precision agriculture.

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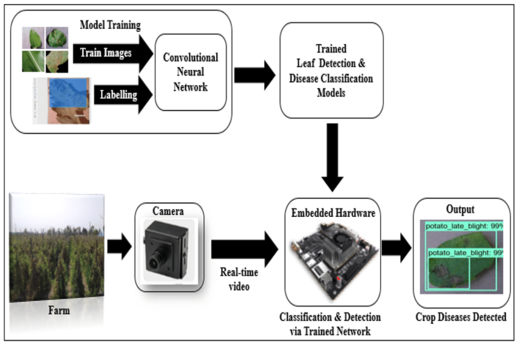

Fig. 3. Layered architecture diagram of AI-Based Agri Robot.

Functional Blocks Description

1. Image Acquisition Block

The ESP32-CAM captures real-time images of plant leaves. It acts as the input unit of the system.

2. Processing Block (AI Model)

The captured images are processed using a lightweight ML model. The model analyzes leaf features and classifies them as healthy or diseased.

3. Control Unit (ESP32)

The ESP32 receives the classification result.

It makes decisions based on programmed logic:

Healthy → No action

Diseased → Activate spraying system

4. Actuation Block (Relay + Pump)

A relay module is used as a switching device. When triggered, it turns ON the pesticide pump. Ensures targeted spraying only on infected plants.

5. Mobility Block (Motor Driver)

The L298N motor driver controls DC motors. Enables robot movement in agricultural fields:

Forward / Backward Left / Right

6. Power Supply Block

A 12V battery powers the entire system.

A buck converter regulates voltage for safe operation of ESP32 and other modules.

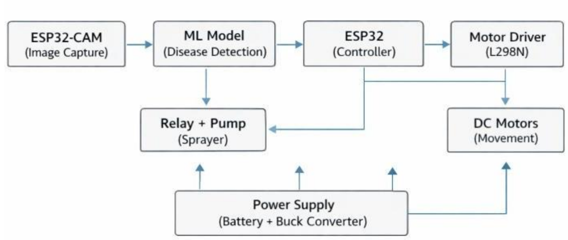

Fig. 4. Block diagram of AI-Based Agri Robot

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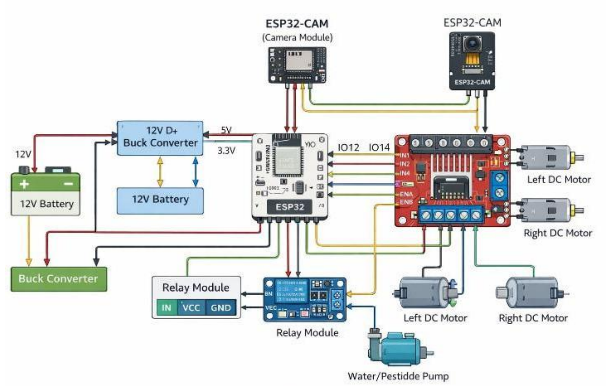
Circuit Diagram



Circuit Diagram

12V battery supplies power; buck converter gives 5V/3.3V to ESP32.

ESP32-CAM captures plant images and sends data for processing. ESP32 controls relay (pump) and L298N motor driver.

If disease detected → relay ON → pump sprays pesticide.

Motors move robot to next plant.

SOFTWARE IMPLEMENTATION

The software implementation of the proposed Agrirobot system integrates embedded programming and machine learning to enable real-time plant disease detection and automated control of the robot.

A. Development Tools

Arduino IDE – for programming ESP32

Python – for machine learning model development TensorFlow/Keras – for training disease detection model OpenCV – for image processing

B. Working of Software

ESP32-CAM captures image of plant leaf Image is processed using trained ML model Model classifies leaf as healthy or diseased Result is sent to ESP32 controller

ESP32 takes action:

Diseased → Pump ON (spraying) Healthy → No action

Robot continues movement using motor driver

C. Control Logic

GPIO pins used to control:

Relay module (pump ON/OFF)

L298N motor driver (robot movement)

Simple IF-ELSE logic used for decision making

VII. RESULTS AND PERFORMANCE ANALYSIS

The proposed Agribot system was tested under controlled and semi- field conditions to evaluate its performance in plant disease detection and automated pesticide spraying. The results demonstrate the effectiveness of integrating machine learning with embedded systems for precision agriculture.

A. Disease Detection Accuracy

The machine learning model was tested using a dataset of plant leaf images. The system successfully classified leaves into healthy and diseased categories with high accuracy.

- Accuracy Achieved: ~90–95%
- Fast Processing Time: Real-time detection
- Reliable Performance under normal lighting conditions

B. Spraying Efficiency

The automated spraying mechanism was evaluated based on selective pesticide application.

- Spraying activated only for diseased plants
- Reduced unnecessary pesticide usage
- Uniform spraying achieved through pump system

C. Robot Navigation Performance

The mobility system using L298N motor driver showed stable movement:

- Smooth forward and turning motion
- Effective navigation in small crop rows
- Consistent speed and control

D. Power Consumption Analysis

- 12V battery provided sufficient backup for operation
- Buck converter ensured stable voltage supply
- Low power consumption due to efficient components

E. Comparative Analysis

Parameter	Traditional Method	Proposed Agribot System
Disease Detection	Manual, inaccurate	Automatic, ~90–95% accurate
Time Consumption	High	Low (Real-time)
Pesticide Usage	Excessive	Optimized (Selective)
Labor Requirement	High	Low
Cost Efficiency	Low	High

VIII. CONCLUSION AND FUTURE WORK

A. Conclusion

The proposed Agribot system presents an efficient and intelligent solution for real-time plant disease detection and targeted pesticide spraying. By integrating an ESP32 microcontroller, ESP32-CAM, and a lightweight machine learning model, the system successfully automates the process of monitoring crop health and applying pesticides only where necessary.

The implementation of this system reduces dependency on manual labor, minimizes human error, and significantly decreases excessive pesticide usage. The use of a motorized robotic platform enables smooth navigation across agricultural fields, while the relay-controlled spraying mechanism ensures precise and selective application.

Experimental results demonstrate that the system achieves high accuracy in disease detection and improves overall efficiency in crop management. Additionally, the Agribot is cost-effective, portable, and suitable for small and medium-scale farmers. The project highlights the potential of combining embedded systems, artificial intelligence, and IoT technologies to enable precision agriculture and promote sustainable farming practices.

A. Future Work

Although the proposed system provides effective results for plant disease detection, several improvements can be incorporated in future research to enhance its functionality and performance:

- Multi-Disease Detection:

Extend the current model to identify and classify multiple plant diseases rather than limiting the system to only healthy and diseased leaf detection.

• Cloud and IoT Integration:

Integrate the system with cloud platforms or IoT-based dashboards such as Blynk or Firebase to enable real-time monitoring, remote access, and mobile notifications.

• GPS-Based Navigation:

Incorporate GPS technology to support autonomous movement, field mapping, and location tracking during crop monitoring.

• Solar Power Integration:

Replace or supplement the existing battery system with solar panels to improve energy efficiency and support sustainable operation in agricultural fields.

• Advanced AI Models:

Employ more advanced deep learning architectures such as YOLO or MobileNet to achieve higher accuracy, faster processing, and improved real-time detection.

• Automatic Path Planning:

Implement intelligent path-planning algorithms with obstacle detection sensors to allow the system to move automatically and efficiently across the field.

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