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# Detection Of Plant Leaf Disease And Pesticide Sprinkling

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***Abstract**:* The growing global population has placed increasing demands on agricultural productivity, highlighting the need for advanced solutions to support maintainable food production. Predictable methods for detecting plant leaf diseases and applying pesticides are often laborious, slow, and prone to inefficiencies. This project presents an intelligent, automated system that combination of Machine Learning (ML) and Internet of Things (IoT) technologies for plant leaf disease detection and prescribed pesticide application. The system uses a robot controlled by an ESP32 Controller, DC motors, Zigbee module, Relay and Voltage Divider. A special ML model, trained using OpenCV and TensorFlow, can look at pictures of plant leaves and identify diseases with good accuracy. It can also check several images at once and sprinkling the pesticide by controlling the robot, which helps monitor big farms easily and more effective.

*Index Terms* - Machine Learning, Internet of Things, pesticide Sprinkler, Convolution Neural Network, ESP32.

## I. Introduction

Agriculture remains the backbone of our country, serving as the primary source of livelihood for a large part of the population. In India, majority of the workforce is engaged in farming, contributing significantly to the nation's GDP, exports, and overall food security. It also plays a key role in rural development and poverty reduction. However, recent lifestyle changes and growing customer demands have created new challenges for farmers. These include outdated farming methods, declining productivity, climate change impacts, soil degradation, shrinking farmland, poor market access, post-harvest losses, pest infestations, plant leaf diseases, labor shortages, and mounting debts.

Among these issues, plant leaf damage from pests and diseases is a major factor that lowers agricultural output. While chemical pesticide spraying is commonly used to manage pests, manual application is not only ineffective but also causes serious health risks such as respiratory illnesses, skin problems, and even cancer. Additionally, conventional pesticide sprayers often lack safety features to prevent misuse or theft, further increasing the risks to people and the environment.

To get over from these problems, our project introduces an advanced solution: a robotic pesticide spraying system integrated with machine learning-based plant leaf disease detection. This smart agricultural robot not only automates the spraying process. The main goals are to improve operational efficiency, reduce dependence on manual labor, cut down excessive pesticide use, and promote healthier plant growth. By making timely and accurate interventions possible, this system supports increased productivity and helps secure the food supply for our expanding population.

## II. Problem Statement

Traditional pesticide spraying techniques are inefficient and hazardous, leading to environmental pollution, health risks, and increased costs. The absence of real-time detection and selective pesticide application further exacerbates the problem. This project aims to develop a robotic solution that integrates disease detection using CNN algorithms and targeted pesticide spraying, ensuring efficiency and safety in pest management.

## III. Proposed System

This agricultural robot is designed using cost-effective components, making it a budget-friendly solution. It can be controlled using any smartphone equipped with a dedicated application. Through this IoT-based app, farmers can operate the pesticide spraying system remotely. The low-cost robotic vehicle aims to improve efficiency, enhance safety, and address labor shortages in the agricultural sector.

We have an TCP/UDP test tool application specifically to manage this spraying rover. The app first connects to the ESP32 module, which enables control over all the hardware components of the robot. Once connected to WIFI, the user can easily control the robot movement and spraying unit.

The robot is equipped with four DC motors, controlled by an L293D motor driver. The ESP32 module is interfaced with the motor driver and receives its power from a 12V battery. The motor driver regulates the rotation of the motors through phase connections managed by gate driver on the circuit and a servo motor is integrated into the system to control the sprayer mechanism. A servo motor is a type of actuator that offers precise control over angular or linear motion, including position, velocity, and acceleration.

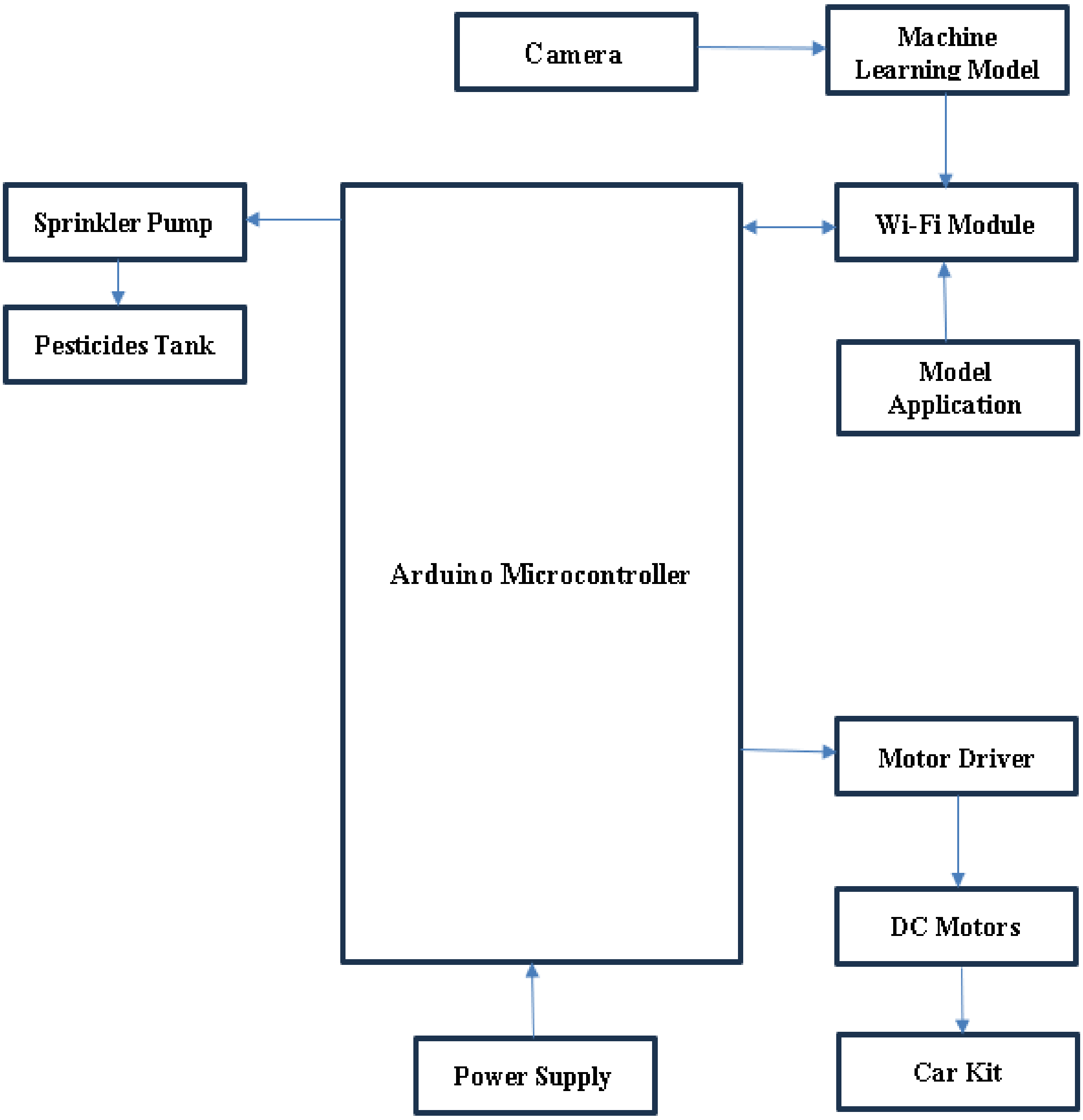


**Fig 1: System Architecture**

### SYSTEM COMPONENTS

- **Python**: Python is used as the core programming language for both developing the machine learning model and managing backend logic.

- **Flask:** Flask is a lightweight web framework in Python that is used for building the web interface and creating the backend API.

- **Machine Learning:** Machine learning forms the core of the application. Frameworks like TensorFlow and PyTorch are utilized for developing, training, and evaluating the model.

- **OpenCV:** OpenCV is used for image preprocessing tasks. This includes operations like converting images to grayscale, applying Canny edge detection, binary thresholding, sharpening, and other enhancements to prepare input for the model.

- **TensorFlow:** TensorFlow is a powerful open-source deep learning framework developed by Google. It is used to build and train the Convolutional Neural Network (CNN) model that classifies leaf diseases based on the processed images.

- **Web Development (HTML, CSS, JavaScript):** The user interface of the web application is created using standard web technologies.

- **SQLite3:** SQLite3 is a lightweight, embedded SQL database engine. It is used for managing user data such as registration and login credentials, and it stores the information locally in a file-based database.

- **Arduino IDE:** Arduino IDE is an open-source development environment used to write, compile, and upload code to Arduino boards.

- **IDE (Integrated Development Environment):** Various IDEs are used for efficient coding, debugging, and testing.

- **ESP32 Microcontroller:** The **ESP32** is a highly versatile and cost-effective microcontroller developed by Expressive Systems. It features dual-core processing power, built-in Wi-Fi, and Bluetooth capabilities, making it an ideal choice for Internet of Things (IoT) applications.

- **DC Motors:** DC motors are essential components in robotics, converting electrical energy into mechanical energy to produce rotation.

- **Motor Driver:** A motor driver acts as a bridge between the microcontroller and the DC motors.

- **Relay:** A relay is an electrically operated switch used to control high-voltage or high-current devices with a low-power signal.

- **Zigbee:** Zigbee is a low-power, low-data-rate wireless communication technology designed specifically for short-range communication in IoT networks.
- **Car Kit:** The robotic car kit provides the physical structure and mobility for the agricultural robot. It typically includes a chassis with pre-drilled holes for easy mounting of components like sensors, microcontrollers, cameras, and spray mechanisms.

- **Laptop:** The laptop plays a central role in the system by serving as the main interface for developing, training, and deploying the leaf disease detection model. It hosts the software backend (such as a Flask or Python application) that communicates with the microcontroller.

- **Smart Phone:** The smartphone serves as a remote-control unit in this system, offering portability and user-friendly interaction. Through a custom-built mobile app or a responsive web interface, users can issue commands to the robot for navigation.

## IV. WORKING METHODOLOGY

A. **Development of Machine Learning Model for Plant Leaf Disease Detection and Pesticide Prescription:** To enable pesticide identification in agriculture, a machine learning model is created and tested using pre-trained neural networks. The OpenCV, CNN model and TensorFlow is used for more efficiency in image classification tasks. After importing the necessary Python libraries like TensorFlow and OpenCV, CNN model was compiled for the classification task. The dataset, sourced from Kaggle, included images of both healthy and pest-infected leaves. Proper labeling was ensured to support supervised learning. Data augmentation techniques such as rotation, shifting, zooming, and flipping were applied to enhance the model's accuracy. The model was trained on the processed data and validated using a separate dataset. It was saved for future use, making it reusable for different plant leaf varieties. Testing was performed with images from multiple plant species such as tomato, cotton, papaya and banana plant leaf to ensure the model could generalize across various pests. With suitable datasets, the model can be trained to recognize diseases in any plant species.

B. **Design of a Mobile Agricultural Robot:** An agriculture robot has been developed to navigate agricultural fields using components such as an ESP32 Microcontroller board, robotic car kit, DC motors, motor drivers, and a rechargeable battery for power supply. The robot is programmed using the Arduino IDE and is wirelessly controlled via the TCP/UDP test tool android application. Selecting appropriate motors is crucial, as it depends on the required torque and load capacity, which is supported by the battery pack. The car kit acts as the mechanical base of the robot.

C. **Deployment of the Pesticide Spraying Mechanism:** Once a plant leaf disease is detected by the machine learning model, a ESP32 communication channel established over Wi-Fi using appropriate protocols triggers the spraying system. The pesticide spraying unit, equipped with a pumping mechanism, is activated to target the infected plant areas. The spraying nozzle length is adjustable, allowing it to accommodate different plant heights and density. This adaptability ensures accurate pesticide delivery based on the specific requirements of various plants.

## V. RESULTS

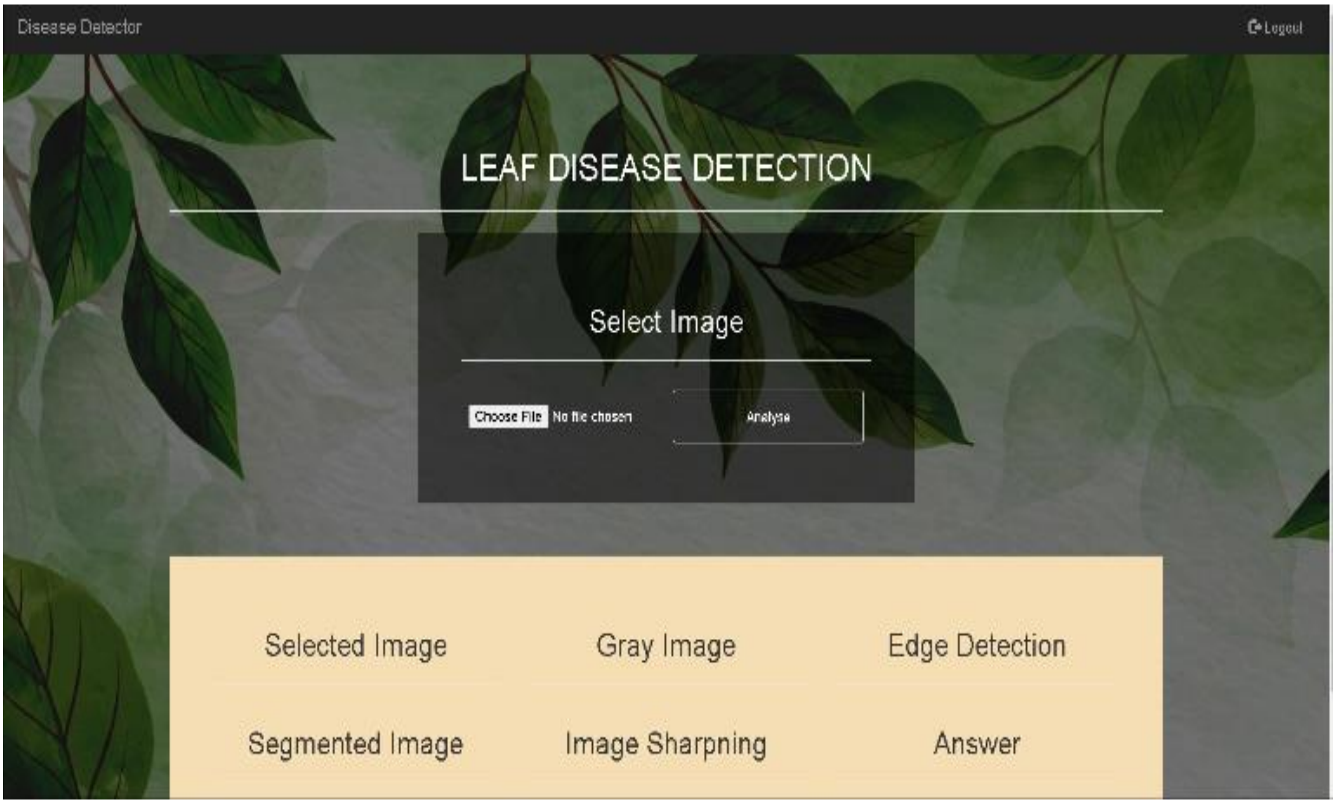


**Fig 2: App User Interface**

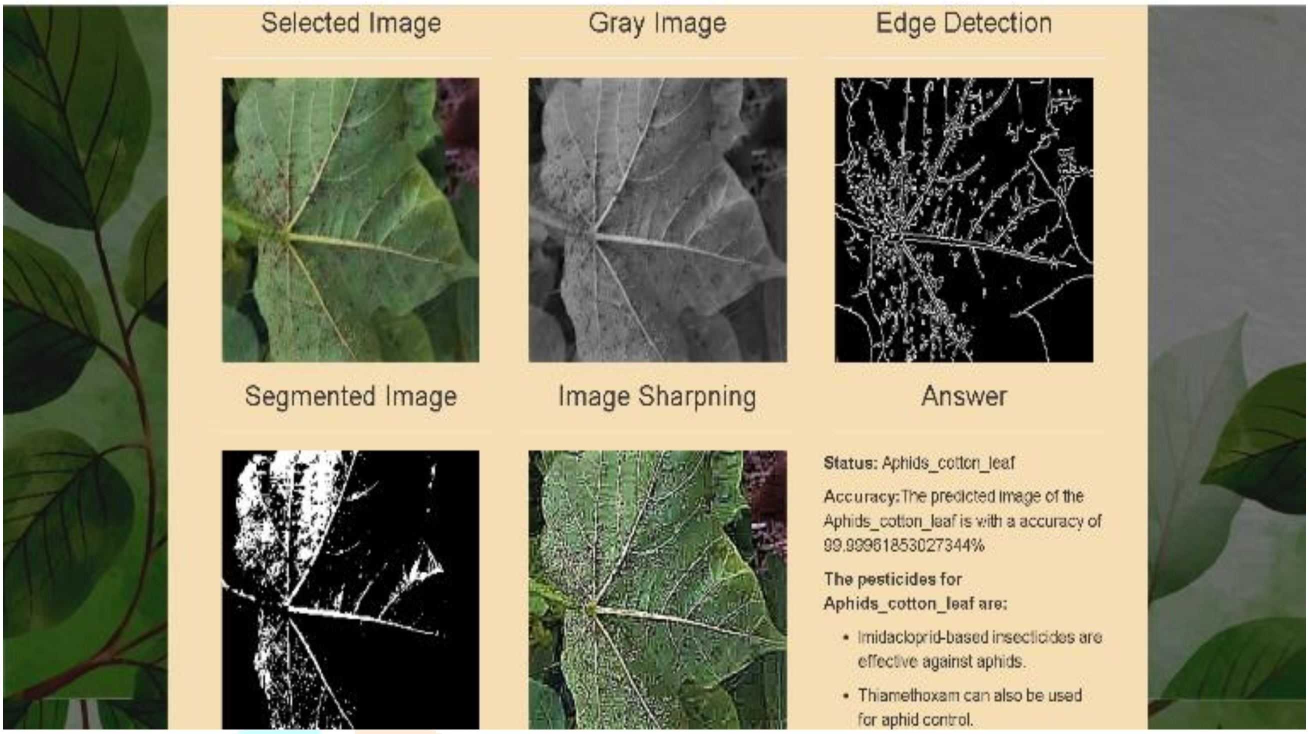


**Fig 3: Result Interface**

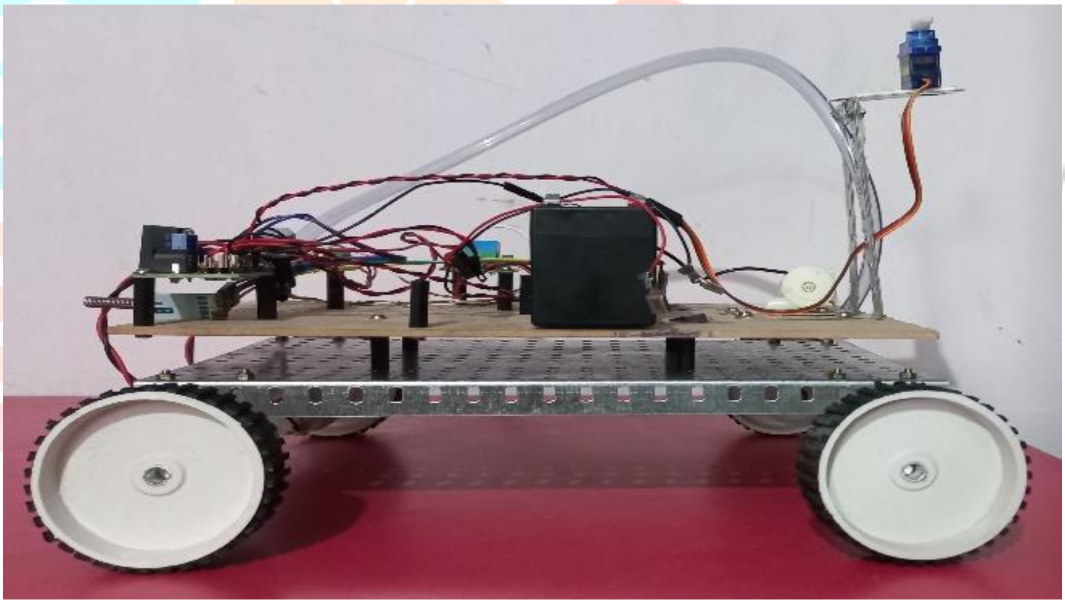

**Fig 4: Final Model**

The performance of the developed agricultural robot was tested through various experiments focused on key operational parameters. This included pest detection accuracy, pesticide spraying capability, mobility, and battery efficiency. The machine learning model functioned as intended by identifying pest-affected regions and triggering the spraying system via Wi-Fi to treat only those specific areas. The evaluation of the pesticide application involved two major criteria: the movement flexibility of the sprayer mechanism and the overall coverage provided by the spray system itself.

Although robotics has made significant progress, agricultural robots are still in the initial phases of real-world application and face numerous implementation barriers. Our research indicates that successful deployment of such robots depends not only on advanced technologies but also on reliable infrastructure support. The prototype we designed is powered by a 12V battery and utilizes two DC motors for mobility and a submersible pump for pesticide application. All of these components work together to support efficient and automated farming processes.

The final outcome is a comprehensive robotic solution capable of detecting disease, pesticide and spraying pesticides accurately. This system integrates machine learning and IOT techniques for classification, ESP32 Microcontroller for robot movement and sprayer control. Users can operate the robot using an Android-based mobile app. Moreover, the spraying arm can be adjusted according to the height and needs of different c. If needed, users can source plant image datasets from platforms like Kaggle and train the model to suit specific agricultural requirements.

## VI.LIMITATIONS

1. **Dependency on Image Quality:** The accuracy and effectiveness of the disease detection model are highly dependent on the quality of the uploaded leaf images. Factors such as poor lighting, motion blur, low resolution, or incorrect focus can lead to inadequate feature extraction by the image processing and CNN model. As a result, this may cause misclassification or failure to detect the disease accurately, affecting the reliability of the system in real-world scenarios.

2. **Limited Disease Classes:** The current system has been trained only on a predefined set of plant disease categories. This means that it can only recognize diseases that are part of the training dataset. If a user uploads an image of a plant suffering from an uncommon or rare disease that was not included during training, the model may provide inaccurate or irrelevant results. This limits the system's capability in handling new or evolving diseases in agricultural fields.

3. **Hardware Cost and Maintenance:** Although the system is designed to be cost-effective in the long run, the initial setup cost of the robotic platform which includes components like DC motors, water pumps, a sprayer unit, motor drivers, and the ESP32 microcontroller can be significant, especially for small-scale farmers. Additionally, regular maintenance is required to ensure proper functioning of mechanical and electronic parts, which may add to operational costs over time.

4. **Limited Field Conditions:** The robot has been designed to work effectively in open or semi-structured fields, but it may encounter mobility challenges in uneven, muddy, or highly dense crop fields. Complex terrain, obstacles, or very tall and closely packed plants may hinder its movement and reduce the precision of the spraying mechanism. This makes the system less suitable for all types of agricultural environments.

5. **Connectivity Requirement:** The system relies on stable Wi-Fi or Zigbee-based wireless communication between the web application and the robot's ESP32 controller. In remote or rural farming areas, where internet or wireless signal strength may be weak or inconsistent, maintaining a reliable connection could be difficult. Loss of connectivity may lead to delayed commands, failed operations, or limiting the system's usability in some locations.

## VII. ADVANTAGES

1. **Accurate Disease Detection:** The system utilizes a Convolutional Neural Network (CNN) model that has been trained on a large dataset of leaf images to detect and classify various plant diseases with high accuracy. This deep learning approach reduces the chances of human error during diagnosis and ensures consistent and reliable disease identification across multiple crop types. It helps in early detection, which is critical for effective disease control and crop management.

2. **Automated Pesticide Spraying:** Once a disease is detected, the system integrates with an ESP32-based robotic platform that is capable of autonomous movement within agricultural fields. This robot performs targeted pesticide spraying only on affected plants. By doing so, it eliminates the need to spray entire fields unnecessarily, which significantly reduces chemical usage, lowers costs, and promotes sustainable farming practices.

3. **Time and Labor Efficient:** The automation of both disease detection and pesticide spraying significantly reduces the need for manual intervention. Traditional methods require farmers to manually inspect crops and apply pesticides, which is time-consuming and labour-intensive. This system helps to save valuable time, minimizes dependence on manual labour, and allows farmers to manage larger areas with fewer resources.

4. **User-Friendly Interface:** The project includes a simple and intuitive web-based interface through which users can upload images of plant leaves. The interface displays the disease classification result along with a recommendation for the most appropriate pesticide. This ensures that the system can be used by individuals with minimal technical knowledge, making it accessible to a wide range of users including local farmers.

5. **Cost-Effective:** By implementing selective spraying, the system avoids the overuse of pesticides, which not only cuts down on chemical expenses but also optimizes resource utilization such as water and fuel. Additionally, the use of affordable hardware components like the ESP32 microcontroller and simple motors keeps the overall system cost low, making it suitable for small-scale and resource-limited farming environments.

## VIII. CONCLUSION

Agriculture continues to be the backbone of many economies, particularly in rural areas where it remains a primary occupation. However, with the growing population and increasing demand for food production, traditional farming methods often fall short in terms of efficiency, accuracy, and labour requirements. To address these challenges, the integration of technology into agriculture has become essential. One such innovative solution is the development of a multifunctional farming robot designed to simplify and automate various farming tasks, especially for small-scale farmers. This advanced agricultural robot is engineered to perform multiple operations such as water sprinkling, pesticide application, and leaf disease detection. By automating these labour-intensive processes, the robot not only reduces the physical workload for farmers but also enhances the precision and effectiveness of farming activities. It is equipped with navigation capabilities that allow it to move in all four directions forward, backward, left, and right enabling it to cover the field efficiently during operations.

A key highlight of this robot is its ability to detect plant leaf diseases. This is achieved through an image processing and classification system that captures real-time images of plant leaves and compares them with a database containing samples of both healthy and diseased leaves. Once an image is captured, it undergoes several stages of preprocessing using Python-based tools. Important features such as leaf colour, texture, and shape are extracted from the image, which are then analysed using a Convolutional Neural Network (CNN) algorithm.

The CNN model, trained on a labelled dataset of various plant diseases, effectively classifies the captured leaf as either healthy or infected. In the case of a detected disease, the robot goes a step further by alerting the farmer and providing a recommendation for the most suitable pesticide to treat the identified condition. This not only helps in early detection and prevention of disease spread but also ensures that only the necessary chemicals are applied, promoting sustainable farming practices. Communication between the robot's various modules—such as image processing, movement control, and spraying units—is facilitated using Zigbee, a low-power, wireless communication protocol well-suited for agricultural environments. A dedicated and reliable power supply is integrated into the system, allowing for continuous operation.

Overall, this agricultural robot offers an efficient and intelligent approach to managing farming tasks. It empowers farmers with the tools needed to maintain crop health, reduce input costs, and increase productivity. This system is especially beneficial for small-scale farms where manual labour is often limited and costly.

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