SMART AGRO-BOT: AI-POWERED REAL-TIME CROP DISEASE DETECTION AND SMART PESTICIDE SPRAYER

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Introduction:

Agricultural is the backbone of many economies, playing a crucial role in ensuring food security and economic development. However, farmers face numerous challenges, one of the most critical being the early and accurate detection of crop diseases. Traditional methods of disease identification rely heavily on manual inspection, which is time-consuming, labor-intensive and often inaccurate, especially across large farmlands.

To address these limitations, the integration of Artificial Intelligence (AI) and robotics offers a modern, efficient solution. This project, titled *SMART AGRO-BOT: AI-Powered Real-Time Crop Disease Detection and Smart Pesticide Sprayer*, aims to transform traditional farming practices through automation and intelligent decision-making. The core objective is to develop an autonomous robot equipped with a camera and AI models capable of analyzing crop images in real time to detect diseases and assess their severity.

By leveraging deep learning models like VGGNet16 and ResNet50, the system classifies crops as healthy or diseased and determines the appropriate level of pesticide spray. The robot uses a 16x2 LCD to simulate pesticide application based on severity levels and navigates the field autonomously using motor drivers and pre-set boundary detection.

This project not only minimizes pesticide overuse but also reduces labor dependency and promotes eco-friendly, data-driven agriculture. The SMART AGRO-BOT demonstrates a scalable, sustainable, and practical solution for the future of precision farming, ultimately contributing to increased yield, cost savings, and better environmental stewardship.

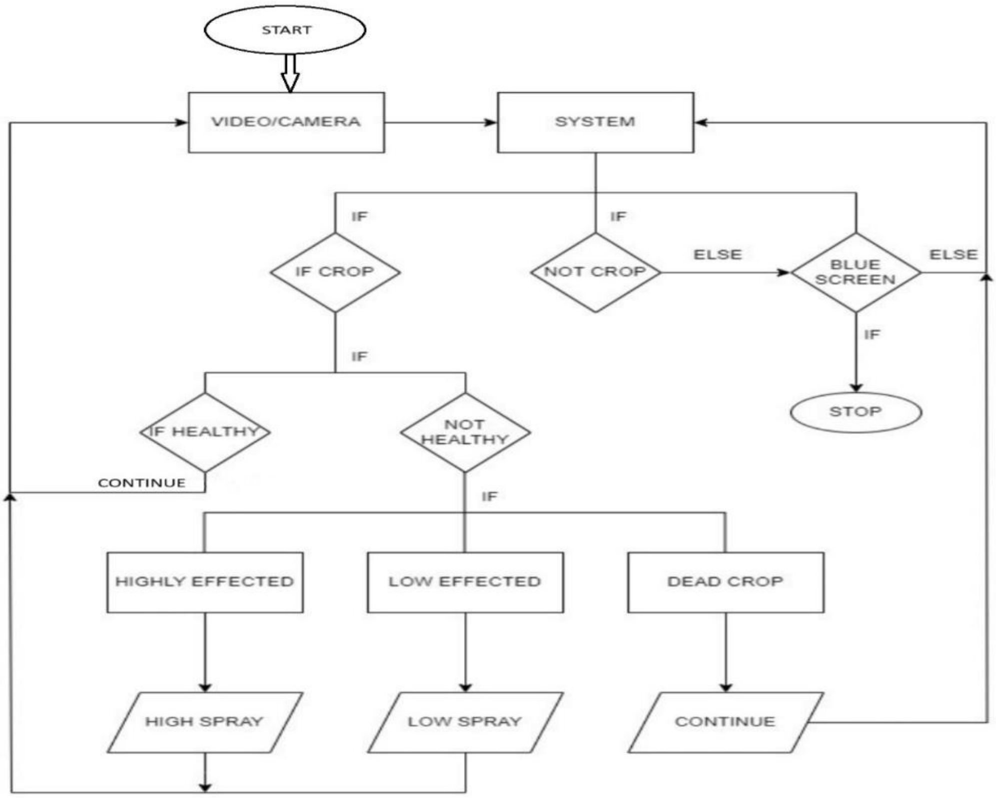

Figure 1: The Dataflow Diagram

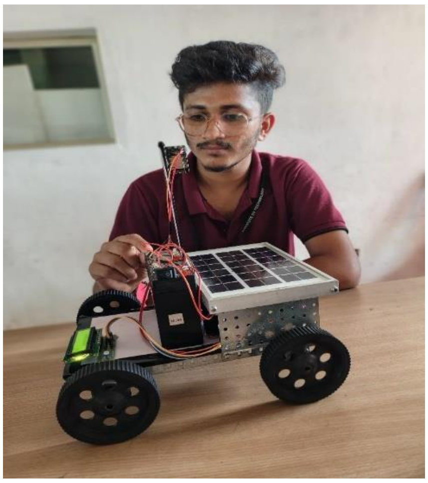

Figure 2: Smart Agrobot

Objectives:

- To develop an autonomous robotic system capable of real-time crop disease detection using AI and computer vision.
- To classify the severity of detected diseases into Healthy, Low, or High categories using deep learning models like VGGNet16 and ResNet50.
- To simulate appropriate pesticide levels based on disease severity, ensuring optimal chemical usage.
- To reduce human intervention and labor costs in the crop monitoring and spraying process.
- To enhance the efficiency, accuracy, and sustainability of agricultural practices through precision farming.
- To demonstrate a scalable prototype that can be further developed for real-world agricultural applications.

Methodology:

The SMART AGRO-BOT project integrates machine learning, embedded systems, and robotic automation to create a real-time crop disease detection and pesticide recommendation system. The entire process is divided into hardware setup, software development, and AI model integration.

1. Hardware Implementation:

The robot is built using an ESP32 WROOM microcontroller, which controls all operations including movement, image capture, and signal processing. An ESP32-CAM module is mounted on the robot to capture live images of crop leaves while navigating through the field. The robot is equipped with four DC motors driven by an L298N motor driver, allowing it to move autonomously in a straight path. A 16x2 LCD screen is used to display real-time feedback such as disease classification and pesticide level. A blue mat placed at the field's end serves as a visual boundary marker; when detected, the robot reverses its path.

2. Software and AI Model Design:

The image data captured by the ESP32-CAM is processed using Python-based models developed in TensorFlow and OpenCV. Two convolutional neural networks — VGGNet16 and ResNet50 — are used for classifying the health condition of the crops into categories: Healthy, Low Diseased, and High Diseased. The model is trained using a curated dataset of plant leaf images with various diseases. Preprocessing techniques such as resizing, normalization, and augmentation are applied to enhance model performance.

3. Disease Classification and Response Simulation:

After classification, the robot simulates the appropriate pesticide spraying level using the LCD display. Healthy plants prompt no action, while low and high disease severities trigger messages indicating 50% and 100% pesticide levels, respectively. This helps visualize a precision spraying mechanism without actually dispersing chemicals during prototyping.

4. Automation and Navigation:

The robot operates independently, using pre-programmed logic for forward motion, image capture intervals, and reaction based on image classification results. Upon reaching the blue mat, the robot automatically turns around and repeats the process in the opposite direction.

Result and Conclusion:

The SMART AGRO-BOT system was successfully developed and tested in a controlled environment. The robot was able to navigate autonomously, capture images in real time, and classify crop health using pre-trained deep learning models. The ResNet50 model achieved an accuracy of approximately 90% in disease detection, outperforming VGGNet16 in classification consistency. The system effectively identified healthy crops, low-level infections, and severely diseased plants, and responded accordingly by displaying the simulated pesticide spray levels (50% for low, 100% for high) on the LCD display.

The robot was also able to detect the blue mat boundary accurately and reverse direction without manual intervention, proving the efficiency of its automation and navigation logic. Graphs such as accuracy/loss curves and confusion matrices were generated during model training, and clearly showed the robustness of the AI models in handling the classification tasks. Feature maps from early convolutional layers further illustrated how the system identifies leaf patterns to distinguish health status.

In conclusion, the SMART AGRO-BOT demonstrates how artificial intelligence combined with robotics can revolutionize traditional farming. It reduces labor dependency, promotes precise pesticide usage, and lays the foundation for sustainable, smart agriculture. The system is scalable and can be adapted for more complex tasks such as multi-crop detection, real spraying, and remote farm monitoring in future iterations.

Future Scope:

The future scope of this project includes:

1. Integration of an actual pesticide spraying system to replace the current simulation.
2. Deployment of IoT modules for remote monitoring and real-time data access.
3. Implementation of GPS for accurate navigation and coverage in large farm areas.
4. Extension of the AI model to support multiple crop types and diseases.
5. Development of a user-friendly mobile application for farmers to control and monitor the bot.
6. Use of solar-powered modules to enhance energy efficiency and sustainability.
7. Cloud integration for storing crop health data and generating predictive analytics.
8. Improved classification models with better generalization under diverse field conditions.
9. Industrial collaboration to refine and scale the prototype for commercial use.
10. Exploration of autonomous recharging and docking stations to support long-term deployment.