AGROBOT: AN ML BASED AUTONOMOUS SYSTEM FOR TREE HEALTH MONITORING AND TARGETED PESTICIDE SPRAYING IN ARECANUT PLANTATION

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Keywords:

Arecanut Plantation, Machine Learning, Sustainable Agriculture, Plant disease Detection, Image Processing, IoT, AI-Based Decision Making.

Introduction:

AgroBot is an intelligent system designed to help farmers monitor the health of arecanut trees in a smarter way. It combines sensors, cameras, and machine learning to detect diseases early and reduce manual effort. Instead of spraying pesticides everywhere, AgroBot identifies affected areas and applies treatment only where needed, saving cost and protecting the environment. By using automation and data-driven decisions, AgroBot improves crop productivity, reduces waste, and supports sustainable farming practices in a practical and efficient way.

AgroBot works by moving through the plantation using a controlled navigation system. It is equipped with cameras and sensors to capture real-time images and environmental data from arecanut trees. The collected data is processed using a machine learning model to detect signs of disease or stress. When an affected area is identified, the bot activates a targeted spraying mechanism to apply pesticides only where needed. This reduces chemical usage and prevents wastage. The system can also send updates to farmers, helping them monitor crop health remotely. Overall, AgroBot automates detection and treatment, making farming more efficient and precise.

Objectives:

1. To build a robot that can safely climb arecanut trees using a segmented design with gripping arms and motor coordination. It will move up and down the trees automatically without human help.
2. The robot will use sensors and smart tracking to detect obstacles, stay centered on the tree, and navigate through the tree on its own.
3. An automatic pesticide spraying system that will adjust the spray based on the tree's height, ensuring accurate and efficient application.
4. The robot will collect data and use machine learning to identify unhealthy trees, spraying only where needed to reduce chemical use and improve crop health.

Methodology:

System Architecture:

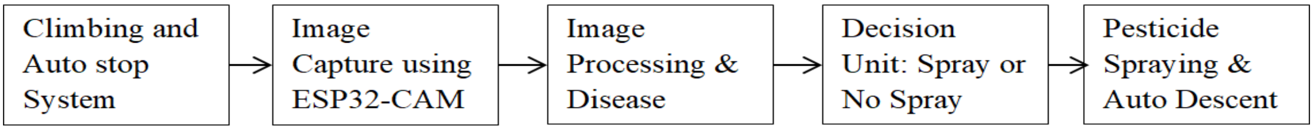

Figure 1: System Architecture of the Bot

The diagram 1 illustrates the complete operational workflow of the AgroBot system. It begins with tree climbing and automatic stopping, followed by image capture using ESP32-CAM.The captured image undergoes processing for disease detection, leading to a decision to spray or not, and finally the robot performs pesticide spraying and auto-descent.

- Climbing and Auto Stop System

  The robot climbs the arecanut tree using a gripping mechanism that ensures stability on smooth surfaces. It automatically stops at a predefined height for safe and accurate inspection.
- Image Capture using ESP32-CAM

  Once stopped, the ESP32-CAM captures clear images of leaves and nut clusters. These images act as input for detecting plant health and diseases.
- Image Processing & Disease Detection

  The captured images are analyzed using a machine learning model to identify disease symptoms like spots or discoloration. The system determines whether the plant is healthy or infected.

- Decision Unit (Spray or No Spray)
  Based on analysis, the system decides whether pesticide spraying is required. It avoids unnecessary spraying, reducing cost and environmental impact.
- Pesticide Spraying & Auto Descent
  If disease is detected, targeted spraying is performed on affected areas only.

  After completion, the robot safely descends, completing the operation efficiently.

Project Flow:

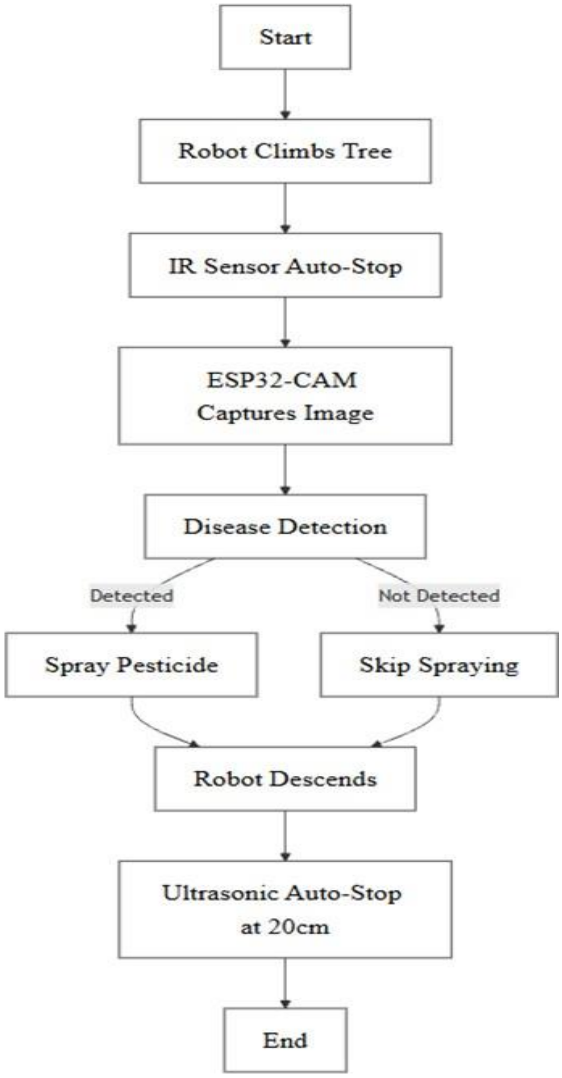

Figure 2 : Flowchart of the AgroBot's Disease Detection and Spraying Operation.

The flowchart illustrates the working process of AgroBot, beginning with the robot climbing the tree and stopping automatically using an IR sensor. The ESP32-CAM captures an image, and the system performs disease detection. Based on the result, the robot either sprays pesticide or skips spraying. Finally, the robot descends and stops automatically at 20 cm using an ultrasonic sensor.

Hardware Structure of the Bot:

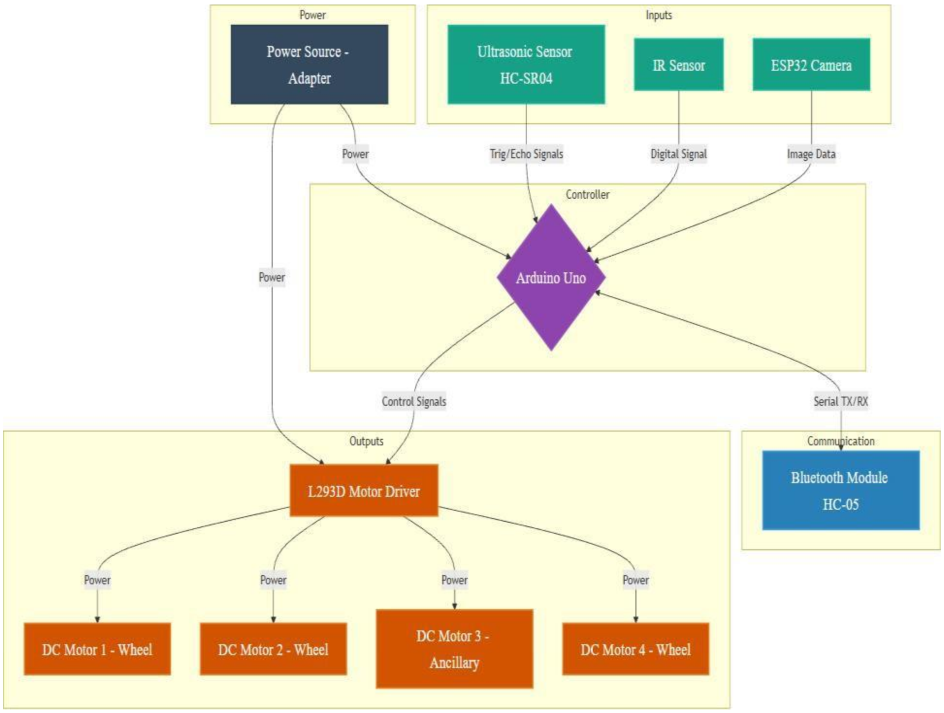

Figure 3: **Block Diagram of the Agrobot System Architecture.**

1. Power: An external Power Source/Adapter supplies electricity to the entire system.
2. Inputs (Sensors): Various sensors provide data to the controller:
   - Ultrasonic Sensor (HC-SR04): Provides distance data (Trig/Echo Signals) for proximity sensing and automated stopping.
   - IR Sensor: Provides a Digital Signal for specific detection and auto-stop.
   - ESP32 Camera: Supplies Image Data for the disease detection system.
3. Controller: The Arduino Uno serves as the central processing unit, receiving input signals, executing the control logic, and sending control commands.
4. Outputs (Actuators): The L293D Motor Driver receives control signals from the Arduino and manages power flow to the three DC Motors (two for wheels/climbing and one for an ancillary function, likely spraying).
5. Communication: The Bluetooth Module HC-05 handles wireless Serial TX/RX communication, allowing for external control or data transmission.

Software Architecture:

1. Data Ingestion & Validation Layer:

   This layer checks the input image format and quality before processing. It ensures only valid images (jpg/png) are used to avoid system errors.

2. Pre-Processing & Transformation Layer:

   The image is resized, normalized, and cleaned to match model requirements. This converts it into a proper format (tensor) for accurate analysis.
3. Inference Engine (ResNet-50):

   A deep learning model extracts features like color, texture, and disease patterns. It uses pre-trained knowledge to identify complex plant conditions.
4. Feature Extraction Process:

   Initial layers detect basic features like edges and shapes, while deeper layers identify disease-specific patterns. The output is a feature map representing the image.
5. Classification & Decision Layer

   The system converts features into probabilities and predicts whether the plant is healthy or diseased. Based on this, it provides a final decision or action.

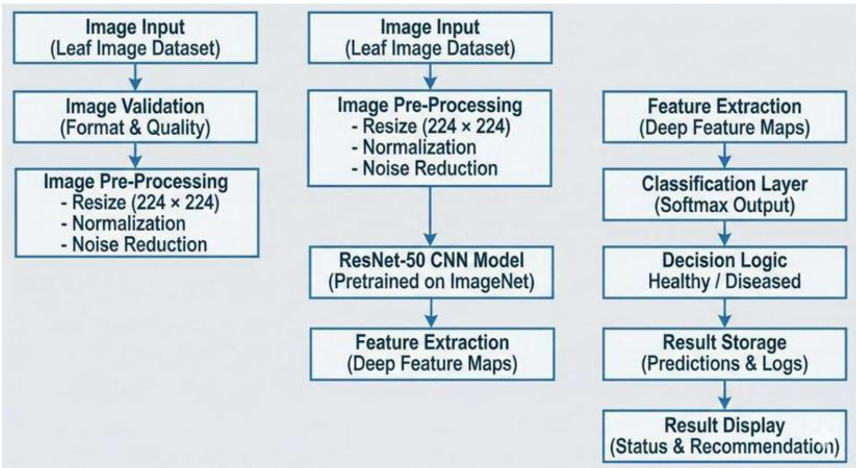

Figure 4: AgroBot Disease Detection Software Architecture

Algorithm:

Convolutional Neural Network:

A Convolutional Neural Network (CNN) is a deep learning model used for image analysis and pattern recognition. In the AgroBot system, CNN is used to process images of arecanut leaves captured by the camera. It automatically extracts important features such as edges, textures, color variations, and disease patterns without manual intervention. CNN consists of layers like convolution, pooling, and fully connected layers, which help in identifying whether the plant is healthy or affected by disease. This makes the system efficient in detecting early symptoms and improving crop monitoring.

ResNet – 50 Model:

ResNet-50 (Residual Network with 50 layers) is an advanced CNN architecture used in AgroBot for accurate disease detection. It uses a technique called skip connections, which helps in training deep networks without losing important information. In this project, ResNet-50 is used through transfer learning, where a pre-trained model (trained on ImageNet dataset) is adapted for arecanut disease classification. It analyzes complex features like leaf spots, discoloration, and infection patterns, providing high accuracy and reliable results for decision-making and targeted pesticide spraying.

Result and Conclusion:

Training Summary of ResNet – 50:

```
 Layer (type)                Output Shape              Param #
=================================================================
 resnet50 (Functional)       (None, 2048)              23587712

 flatten (Flatten)           (None, 2048)              0

 dense (Dense)               (None, 512)               1049088

 dense_1 (Dense)             (None, 15)                7695

=================================================================
Total params: 24644495 (94.01 MB)
Trainable params: 1056783 (4.03 MB)
Non-trainable params: 23587712 (89.98 MB)
_________________________________________________________________
Epoch 1/10
67/67 [==============================] - 214s 3s/step - loss: 0.3387 - accuracy: 0.8973 -
Epoch 2/10
67/67 [==============================] - 241s 3s/step - loss: 0.0180 - accuracy: 0.9967 -
Epoch 3/10
67/67 [==============================] - 255s 4s/step - loss: 0.0068 - accuracy: 0.9986 -
Epoch 4/10
```

Figure 5 : ResNet50-based Classification Model Training Results

The snippet shows the layered structure and training progress of the ResNet-50-based model. The model consists of the ResNet-50 backbone (non-trainable, 23,587,712 parameters) followed by a Flatten layer and two Dense layers, leading to a total of 24,644,495 parameters, of which 1,056,783 are trainable.

AgroBot Prototype Mounted on Arecanut Tree for Health Monitoring :

During the implementation and testing phase, AgroBot demonstrated reliable climbing and smooth operation on arecanut trees using its motor-based gripping mechanism, ensuring stable vertical movement without slipping. The integrated camera and sensors successfully captured real-time images and plant health data, which were processed to detect early signs of diseases and pest infections. Based on this analysis, the system performed targeted pesticide spraying only on affected areas, reducing unnecessary chemical usage. Field tests showed improved efficiency, enhanced farmer safety, and optimized pesticide application. Overall, AgroBot proved to be a practical, autonomous solution for precision farming, reducing labor, cost, and risk in plantations.

Figure 6 : Test Configuration: Vertical Climbing Trial on a Palm/Rough-Bark Tree.

Results:

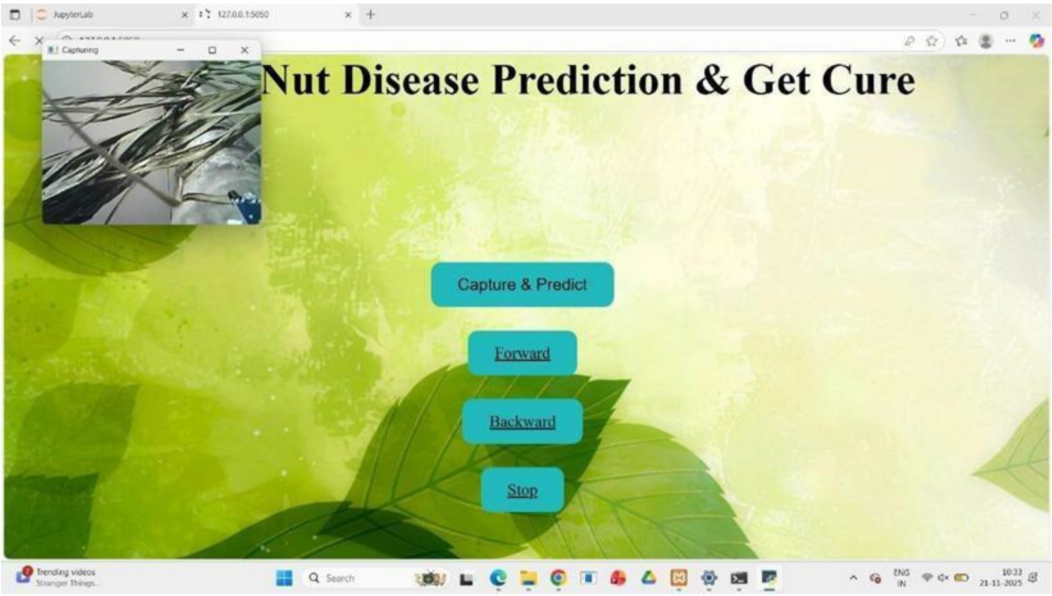

Figure 7 : Live Capturing Interface for the Leaf and Nut Disease Prediction and Cure system .

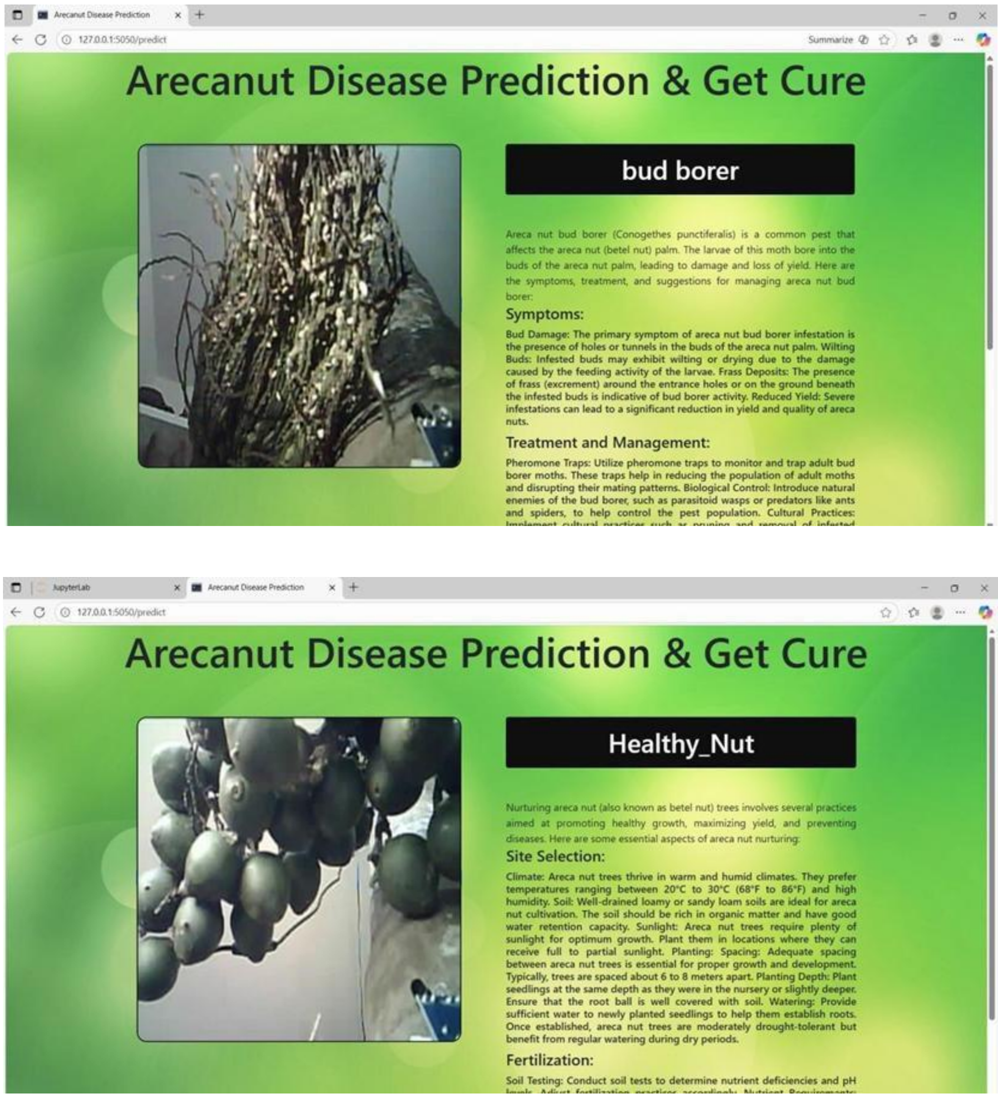

Figure 8: The above image shows predicted diseases

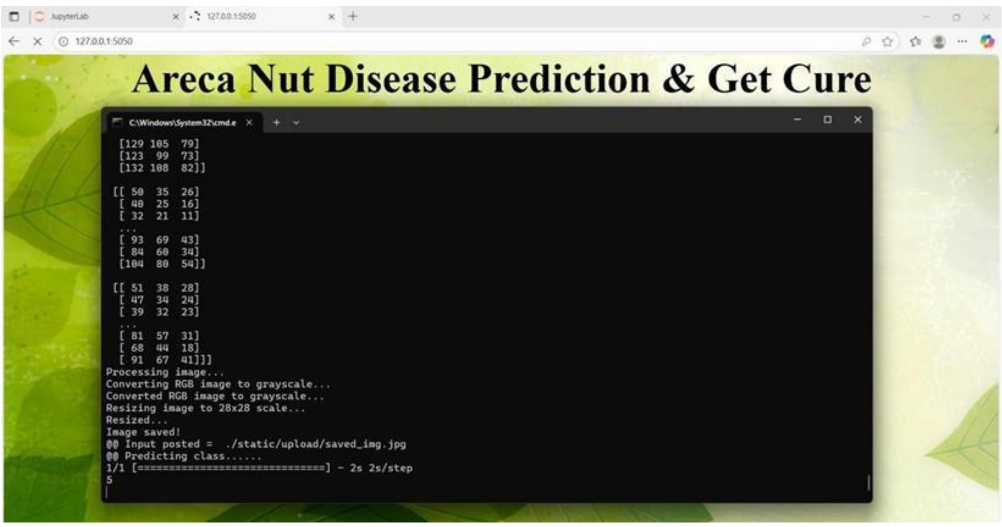

Figure 9: Backend console output detailing image preprocessing (grayscale conversion, resizing) and the initiation of the deep learning classification prediction.

Conclusion:

AgroBot can be improved with lightweight materials, stronger motors, and better gripping for smoother and safer climbing on arecanut trees. Wireless control through mobile apps, along with cloud storage and advanced image processing, can enable real-time disease detection and monitoring. The spraying system can be enhanced with automatic dosage control, multi-chemical usage, and uniform coverage based on plant condition. In the future, AI integration, GPS navigation, and solar power can make AgroBot fully autonomous, reducing labor and supporting sustainable farming practices.

References:

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Future Scope:

The future scope of this project includes:

1. AgroBot can be enhanced with lightweight materials, stronger motors, and better gripping systems for faster, safer movement on arecanut trees.
2. Integration of wireless control, mobile access, cloud storage, and advanced image processing will enable real-time disease detection and easy remote monitoring.
3. Features like automatic pesticide dosage, solar power, AI-based decision-making, GPS navigation, and autonomous operation will make AgroBot more efficient, scalable, and farmer-friendly.