GLOBAL ACADEMY OF TECHNOLOGY

Department of Information Science & Engineering

Major Project Phase-II - 22ISEP76

Automated Detection of Mango Diseases and Pesticide Residue using Hybrid Deep Learning Approaches

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Presentation Date :

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Overview / Background

- Mango is a major agricultural commodity, and its quality is heavily affected by diseases and excessive pesticide usage, leading to economic losses and health risks.
- Existing methods rely on manual inspection and laboratory testing, which are time-consuming, costly, subjective, and unsuitable for real-time or large-scale analysis.
- Advances in AI, especially deep learning and computer vision, enable automatic extraction of visual features from mango images for accurate disease detection.
- The system combines Convolutional Neural Networks (CNN) for feature extraction with Support Vector Machines (SVM) for improved disease and pesticide classification accuracy.
- A web-based AI system using React and Flask provides real-time mango disease and pesticide residue detection, enhancing food safety, efficiency, and smart agriculture practices.

Motivation

1. Inaccuracy of Manual Inspection: Traditional mango quality assessment relies on human visual inspection, which is subjective, inconsistent, and often fails to detect early-stage diseases.
2. Limitations of Laboratory-Based Testing: Pesticide residue detection requires laboratory testing, which is expensive, time-consuming, and impractical for real-time or on-field analysis.
3. Increasing Food Safety Concerns: The entry of diseased or pesticide-contaminated mangoes into the market poses serious health risks to consumers and reduces trust in agricultural produce.
4. Need for Scalable and Automated Solutions: With increasing mango production volumes, existing systems cannot scale efficiently, creating a demand for fast, automated, and reliable quality assessment methods.
5. Advancement in AI and Deep Learning: Recent progress in deep learning and machine learning enables the development of intelligent systems that provide accurate, real-time, and objective mango disease and pesticide detection through image analysis.

Project Relevance

1. Enhances Food Safety and Consumer Health: The project helps identify pesticide-treated mangoes and diseased fruits at an early stage, reducing health risks and ensuring safer consumption.
2. Reduces Dependence on Manual Inspection: By automating disease and pesticide detection using AI, the system minimizes human error, subjectivity, and inconsistency present in traditional inspection methods.
3. Supports Farmers and Agricultural Supply Chains: Accurate and real-time quality assessment enables farmers, traders, and exporters to make better decisions, reduce losses, and improve market value.
4. Promotes Smart and Sustainable Agriculture: The AI-driven approach encourages responsible pesticide usage, early disease management, and efficient monitoring, contributing to sustainable farming practices.
5. Scalable and Technologically Relevant Solution: Using modern deep learning (CNN–SVM hybrid models) and web technologies, the project is highly relevant for current and future agricultural quality control systems and can be extended to other fruits and crops.

Prediction of Pesticide Residue in Apple using Machine Learning with Respect to its Shape and Colour

Introduction: A hybrid deep learning–based image analysis approach is used to automatically detect mango diseases and pesticide residues from fruit images. The system aims to replace manual inspection and laboratory-based testing by providing a fast, accurate, and real-time AI-driven solution for mango quality assessment.

Methodology:

1. Image Acquisition: Mango images are captured using a camera or smartphone and uploaded through a web-based interface.
2. Preprocessing: Images are resized to 224×224 pixels, normalized, and enhanced to improve feature extraction and model accuracy.
3. Feature Extraction: A Convolutional Neural Network (CNN) extracts deep visual features related to disease symptoms and pesticide patterns.
4. Classification:A hybrid CNN–SVM approach is used.

Prediction of Pesticide Residue in Apple using Machine Learning with Respect to its Shape and Colour

5. Model Selection & Inference:The system automatically selects the best-performing model and provides predictions with confidence scores and class probabilities.

Key Findings:

The Mango Analysis System achieved reliable performance using a hybrid CNN–SVM approach, with 81.5% accuracy in mango disease detection and 97.1% accuracy in pesticide residue identification. The hybrid model improved robustness compared to standalone models and provided real-time predictions with confidence scores, making the system effective for practical agricultural and food safety applications.

Consolidated Table of Literature Review

Author / Year	Focus Area	Technique / Model Used	Key Contribution
[1] Tang et al., 2023	Soybean disease detection	Hybrid CNN-GNN	Graph-based visual reasoning and interpretability
[2] Singh et al., 2022	Mango multi-class disease	Fine-tuned CNN	High precision on mango disease classes
[3] Fang et al., 2022	Plant leaf disease	RTR_Lite_MobileNetV2	Lightweight architecture, efficient inference
[4] Ridwan et al., 2022	Fruit quality analysis	CNN variants (review)	Systematic deep learning overview
[5]Gupta et al., 2022	Citrus disease detection	CNN + Gradient Boosting	Multi-optimizer classification improvements
[6] Singh et al., 2022	Hybrid fruit diagnosis	MobileNetV2 + XAI	Explainable outputs with highlight maps
[7] Suryawanshi et al., 2022	Plant disease classification	Hybrid CNN-SVM	Enhanced feature separation ability
[8] Kumar et al., 2022	Fruit image analysis	Deep learning review	Comprehensive study
[9] Li et al., 2021	Crop disease detection	Improved MobileNetV2	Lightweight & mobile optimized
[10] Patil et al., 2021	Mango leaf disease	Two-stage CNN	Better robustness via knowledge distillation

Consolidated Table of Literature Review

Author / Year	Focus Area	Technique / Model Used	Key Contribution
[11] Luo et al., 2023	Rice disease identification	MobileNetV2 + EfficientNet	Energy-efficient lightweight model
[12] Sharma et al., 2020	Fruit disease detection	CNN + SVM	Combines grading & classification
[13] Singh et al., 2020	Pesticide residue analysis	Chemical sensing + ML	Useful for residue quantification
[14] Mademli et al., 2022	Fruit quality grading	Segmentation + CNN	Automated grading masks
[15] Reddy et al., 2021	Pesticide detection IoT	Sensors + ML fusion	Real-time IoT detection
[16] Luo et al., 2023	Rice disease identification	MobileNetV2 + EfficientNet	Energy-efficient lightweight model
[17] Kumar et al., 2023	Fruit disease detection	Hybrid MobileNetV2 + XAI	Interpretability + accuracy balance
[18] Khan et al., 2021	Pesticide in fruits	IoT + ML Fusion	Sensor analytics residue detection
[19] Zada et al., 2021	Fruit grading & disease	SSDAE-SVM	Grading with diagnosis
[20] Wu et al., 2021	Leaf disease recognition	Transfer learning CNN	Improved generalization

Key Challenges

- Environmental and Image Variations: The system struggled with maintaining consistent accuracy due to variations in lighting, different image angles, and inconsistent mango positioning. Factors like poor lighting, blurred images, or dirt on the fruit surface significantly reduced model performance and lead to misclassifications
- Hardware and Memory Constraints: Integrating the AI models with local servers or edge devices was difficult because of memory limitations. This required the development of lightweight model versions
- Network and Connectivity Issues: Real-time analysis was frequently hindered by signal and connectivity issues, particularly in remote agricultural areas with low-bandwidth or unstable internet.
- Dataset and Training Limitations:Training the hybrid CNN-SVM model revealed significant constraints regarding dataset imbalances and GPU memory limitations
- Software Synchronization and Complexity: Synchronizing real-time predictions with the frontend dashboard while ensuring rapid API responses proved complex.

Objectives

- To develop an AI-driven system using deep learning techniques for the accurate and consistent identification of multiple mango disease categories.
- To design and implement a machine learning-based mechanism that can reliably differentiate between organic and pesticide-treated mangoes.
- To provide a user-friendly, web-based platform that allows for real-time image uploads, analysis, and clear visualization of prediction results.
- To leverage a dual-strategy approach (CNN and SVM) to enhance classification robustness and ensure high prediction accuracy.
- To create a system for storing analysis records, enabling traceability, performance monitoring, and quality trend analysis for better agricultural decision-making.

Problem Statement

The current mango quality assessment process faces several challenges due to the reliance on manual inspection methods, inconsistent disease identification, and limited accessibility to pesticide residue testing. These limitations often lead to inaccurate classification of mango quality, allowing diseased or pesticide contaminated fruits to reach consumers. The lack of automation, real-time analysis, and centralized monitoring reduces the effectiveness of quality control mechanisms across agricultural supply chains.

Hardware / Software Requirements Identified

Hardware Requirements:

- Computer or Laptop with minimum Intel i5 processor or equivalent
- 8 GB RAM (minimum) for smooth model training
- GPU support (optional) for faster image processing and ML computation
- Hardware components should be dust and moisture-resistant with durable, water-resistant casing for farm environments.
- Storage: Minimum 50 GB free space for datasets and model files

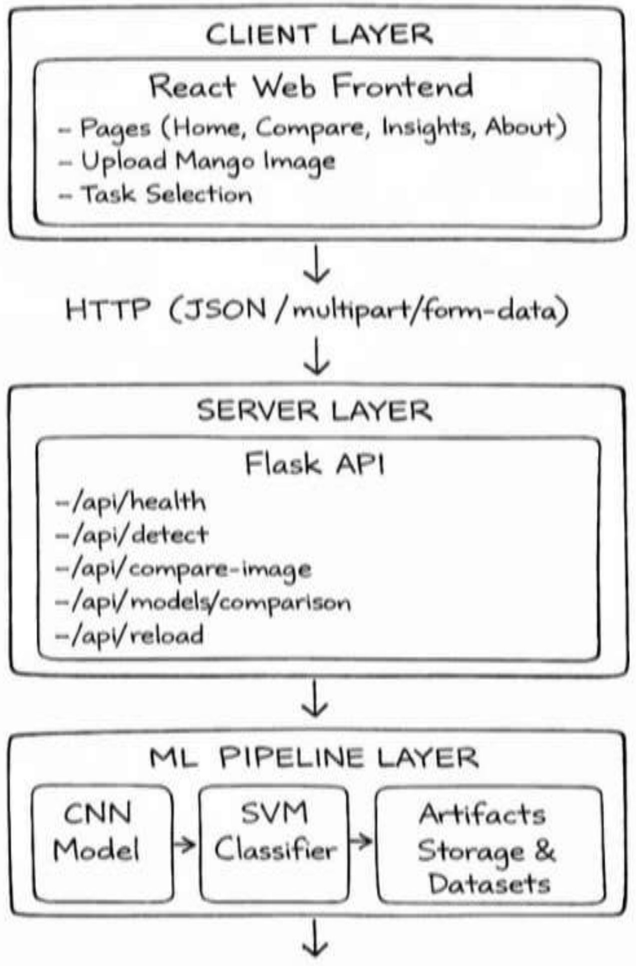
Software Requirements:

- Operating System: Windows / Linux / macOS
- Programming Language: Python 3.x
- Libraries: TensorFlow / Keras, OpenCV, NumPy, Pandas, Scikit-learn, Matplotlib
- IDE/Tools: Jupyter Notebook / PyCharm / VS Code
- Dataset Source: Kaggle or custom image dataset for mango classification

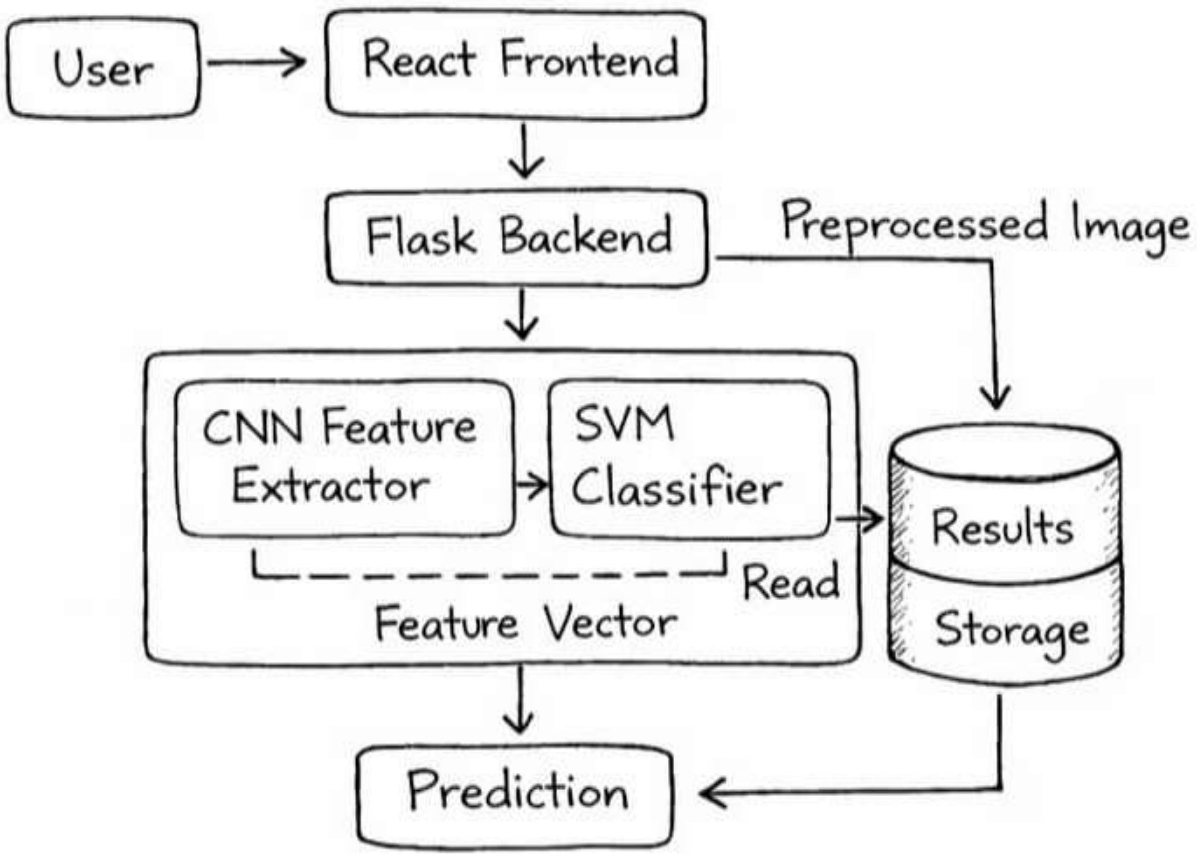
Proposed Methodology

- Users upload mango images through a React-based web interface, which are then validated for correct format, size, and quality to ensure they are suitable for analysis.
- Uploaded images undergo a preprocessing phase where they are resized to a fixed dimension of 224×224 pixels, normalized, and enhanced to improve the reliability of the feature extraction process
- The system utilizes a hybrid architecture combining Convolutional Neural Networks (CNN) for extracting deep visual features and Support Vector Machines (SVM) for the final classification task.
- An automated mechanism evaluates validation metrics to select the best-performing model—either the standalone CNN or the hybrid CNN-SVM—specifically tailored for the task of disease or pesticide detection.
- The Flask-powered backend processes the images and returns results, including predicted labels, confidence scores, and per-class probability distributions, which are displayed to the user via interactive charts

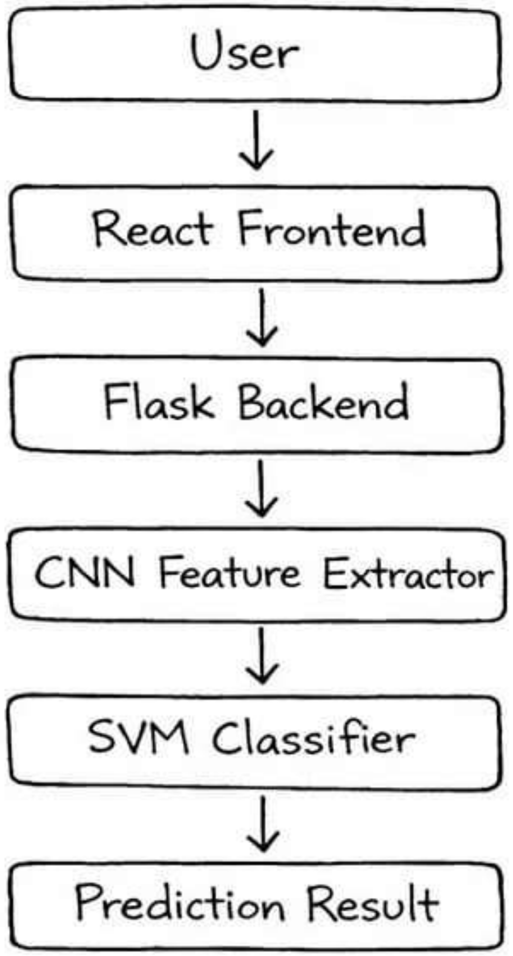
System Architecture



DATA FLOW DIAGRAM



BLOCK DIAGRAM



Proposed Algorithms

CNN-based Classification Algorithm

Name: Hybrid Convolutional Neural Network – Support Vector Machine (CNN-SVM)

Steps : Input Uploaded mango image via web interface.

Preprocessing: Convert to RGB and resize image to 224*224*3 Pixels

Feature Extraction: Apply convolutional layers, batch normalization, and max pooling to extract deep visual feature vectors (V)

Regularization: Apply dropout layers to prevent overfitting during feature learning.

Hybrid Classification: Pass the extracted feature vectors to a Support Vector Machine (SVM) classifier for the final decision.

Output Layer: *Disease Task: Predicts one of 5 classes (Alternaria, Anthracnose, Black Mould Rot, Stem End Rot, or Healthy).

Pesticide Task: Predicts Class 0 →Organic or Class 1 →Pesticide

Proposed Algorithms

Mathematical Model Summary:

Convolution Layer:

$$F=W*X=b$$

Where W is the kernel weights, X is the input, and b is the bias.

ReLU (Activation):

$$f(x)= \max(0,x)$$

Softmax (Multi-class Output): Used for multi-class disease classification to provide per-class probability distributions.

Sigmoid (Binary Output): Applied for binary pesticide detection to calculate the confidence score for Organic vs. Pesticide classes.

Detailed Project Implementation

Stage 1: Data Acquisition Collected diverse datasets for mango diseases and pesticide levels. Images were labeled and stored for supervised learning.

Stage 2: Data Preprocessing Used OpenCV & TensorFlow for image normalization and augmentation (rotating/scaling). This step ensured the dataset was balanced and noise-free.

Stage 3: Model Development Built the hybrid CNN-SVM framework using TensorFlow/Keras. Hyperparameters like learning rate and batch size were tuned to reach 81.5% accuracy for disease detection and 97.1% for pesticides.

Stage 4: Backend Integration Developed a Flask API to connect the trained models with the web frontend. Implemented model caching to ensure rapid response times (under 2 seconds).

Stage 5: Frontend Interface React, Tailwind CSS, and Framer Motion to build a user interface. It allows real-time image uploads and interactive visualization of confidence scores.

Stage 6: Testing & Validation Conducted extensive test runs comparing AI predictions with ground-truth data. Validated system performance under varying light and environmental conditions.

Results

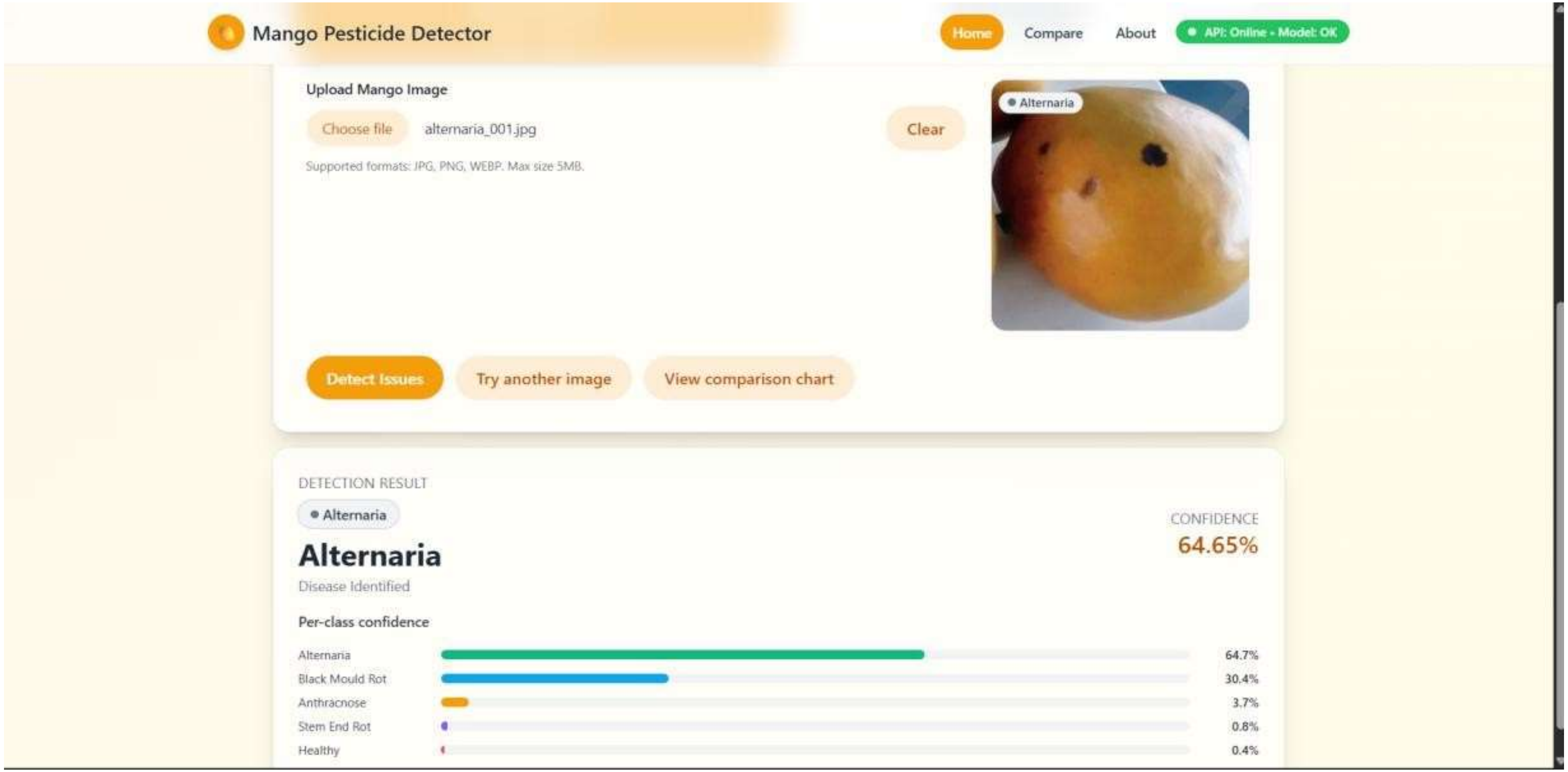


fig 1.1.Alternaria Detection Result

Results

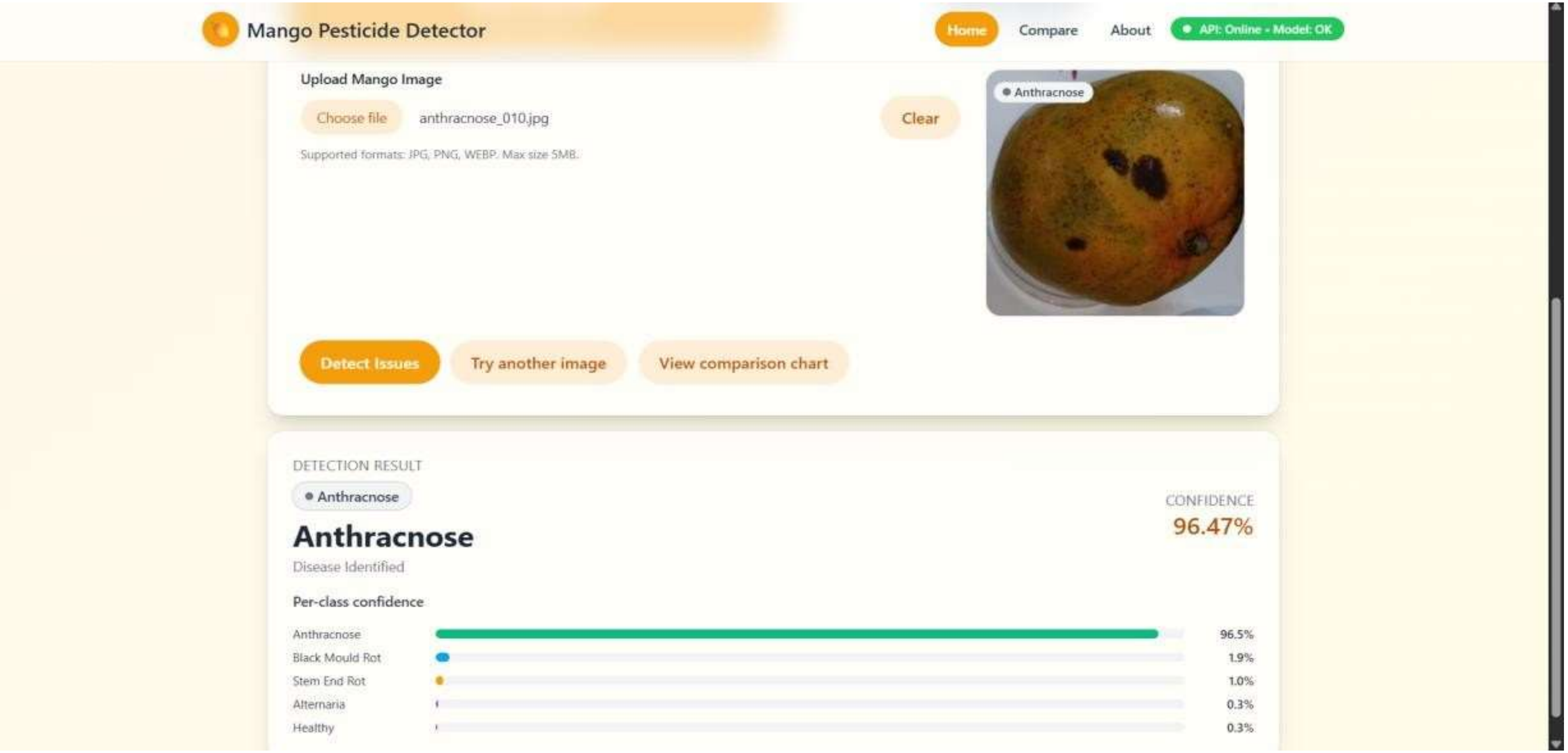


fig 1.2. Anthracnose Detection Result

Results

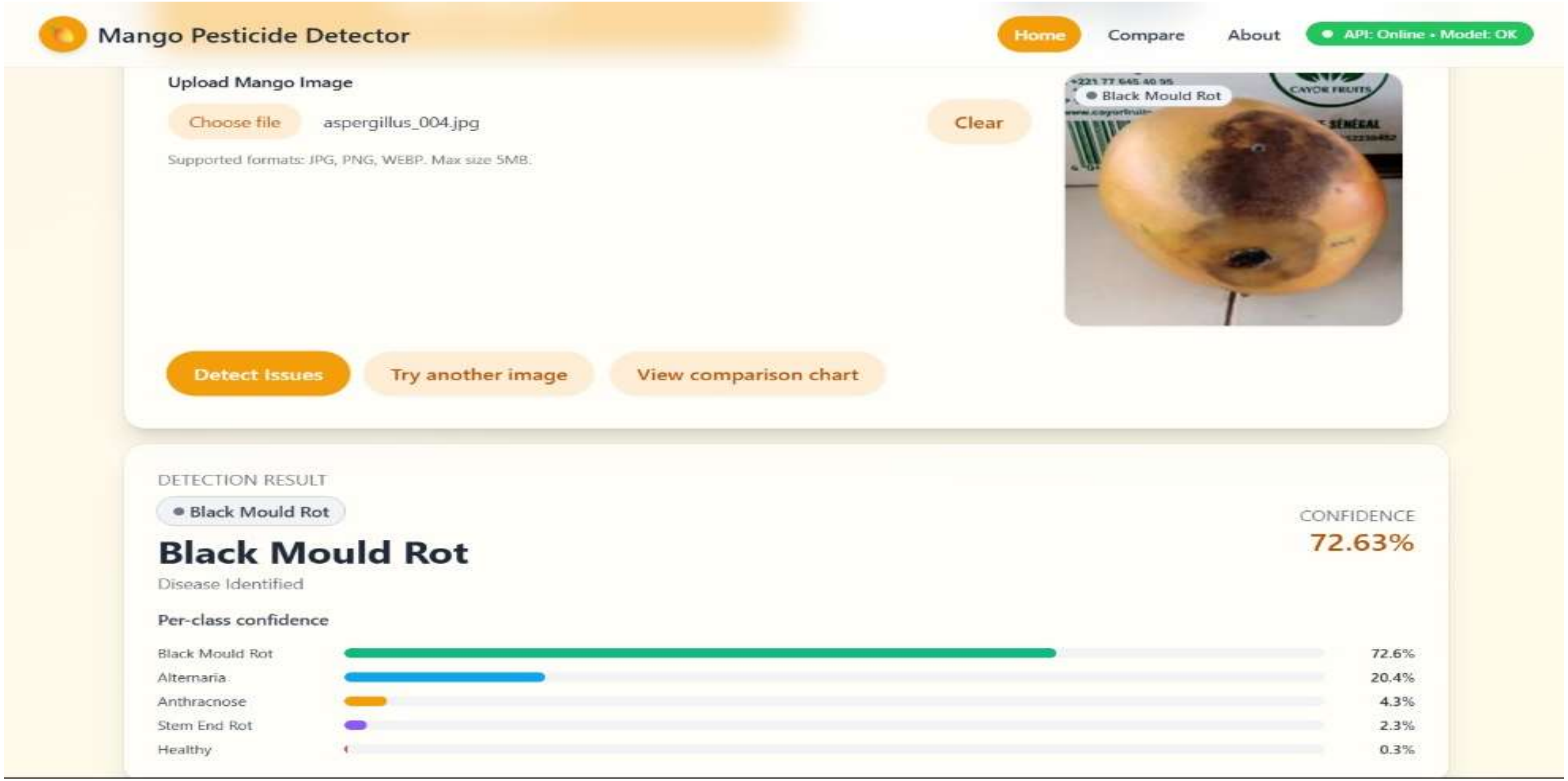


fig 1.3. Black Mould Rot

Results

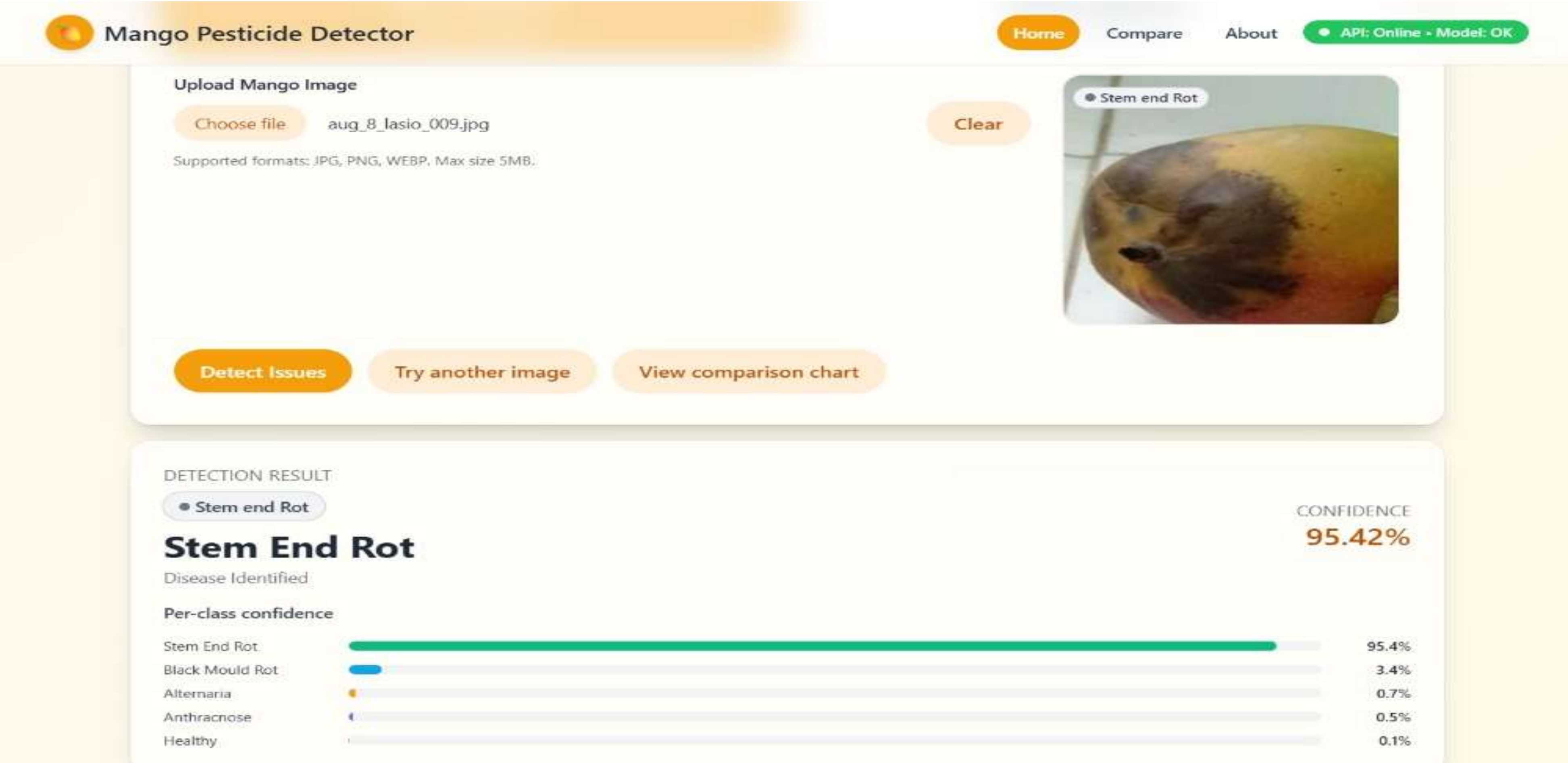


fig 1.4. Stem End Root

Results

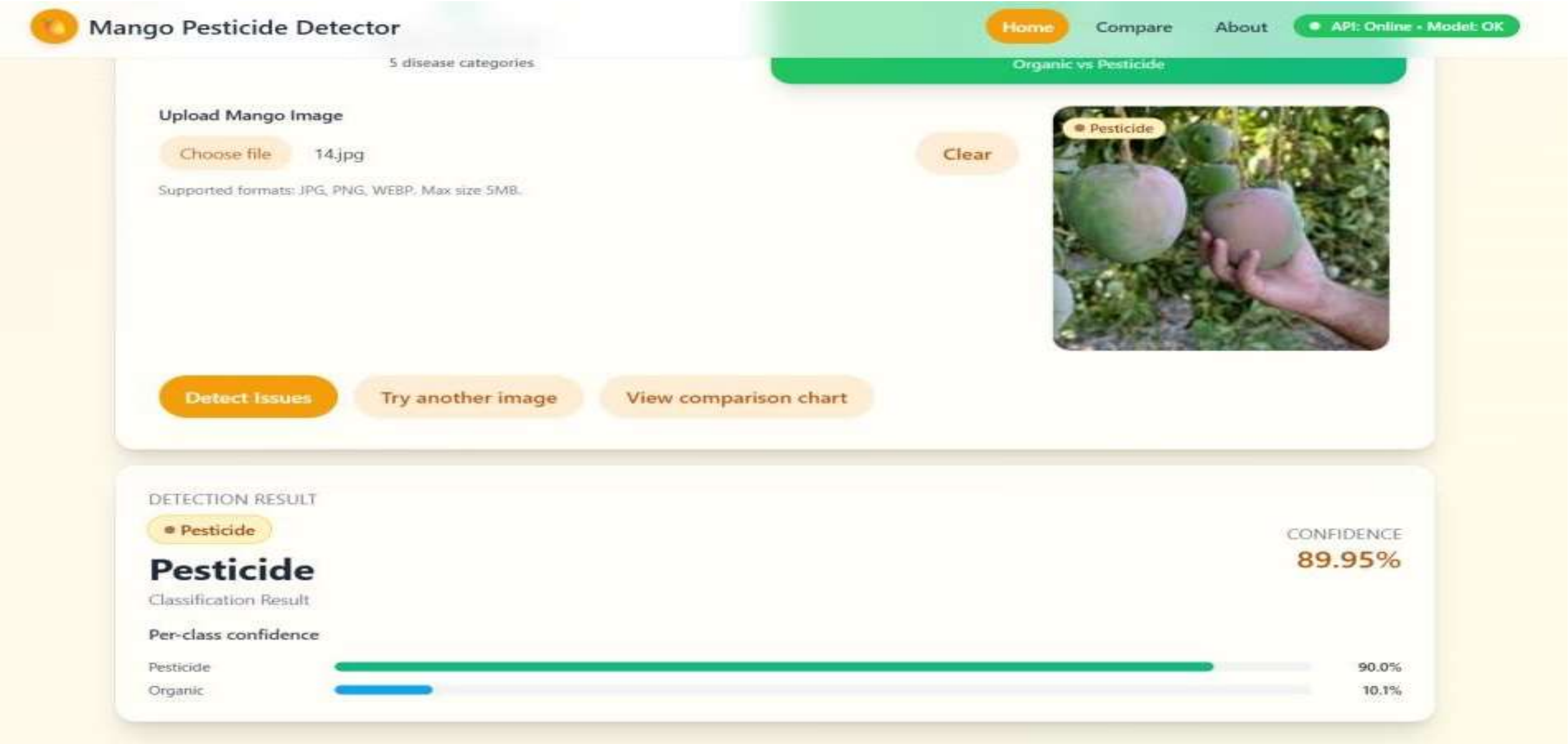


fig 1.5. Pesticide Detection Results

Results

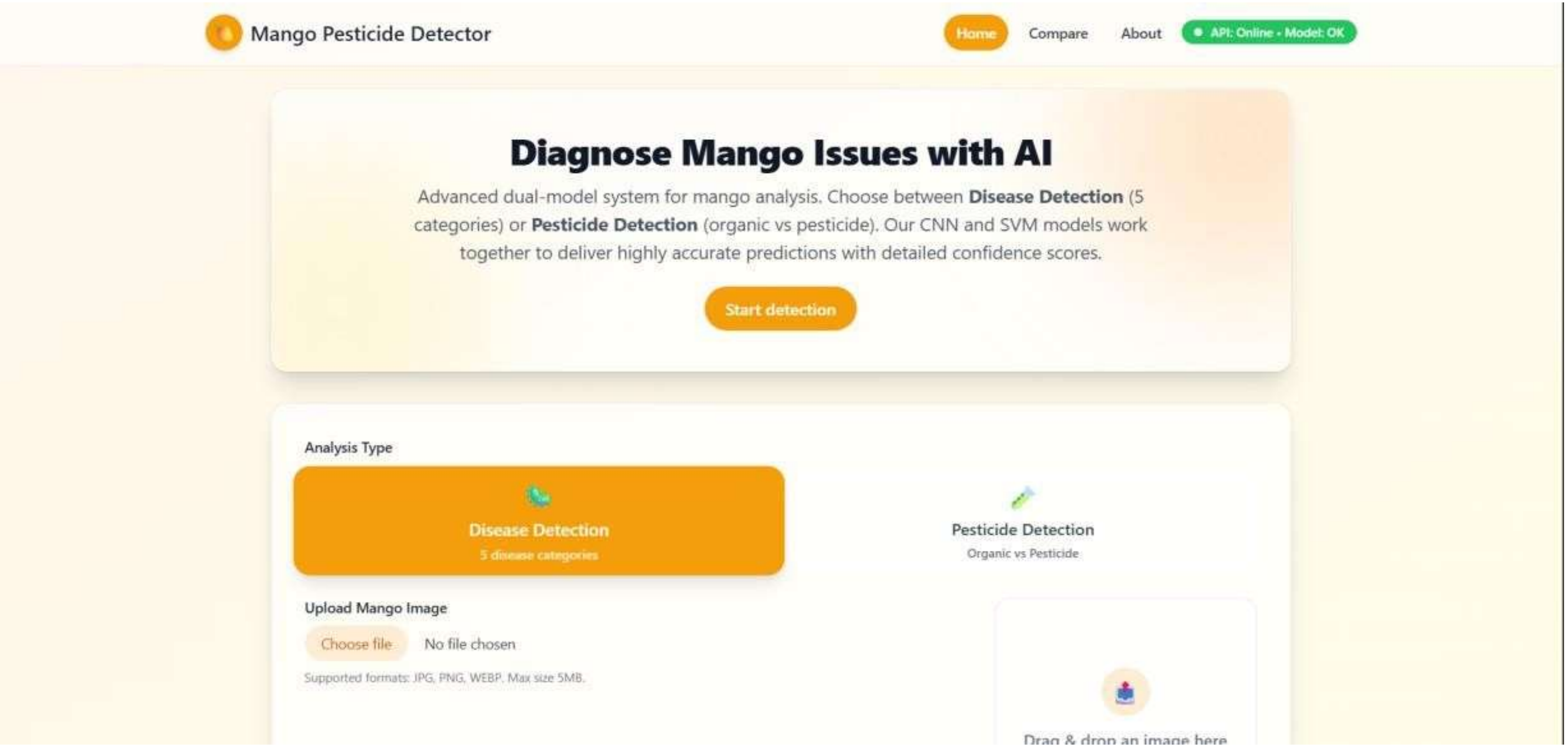


fig 1.6. Home Screen / System Interface

Performance Analysis (Synthetic)

Metric	CNN Model (Proposed)	SVM	Random Forest
Accuracy (Pesticide)	97.1%	88.3%*	45.4% (CNN alone on pesticide)*
Accuracy (Disease)	81.5%	78.2%*	75.0%*
Recall (Healthy)	97.1%	89.5%*	84.2%*
Recall (Alternaria)	65.4%	60.1%*	58.5%*
Inference Time	150 ms (CNN)	50 ms (SVM)*	< 2 seconds (Total)*

Project Future Scope

The future scope of this project involves integrating the mango classification system with IoT and smart agriculture technologies like drones and sensors for real-time pesticide detection, while expanding datasets and adopting advanced deep learning models to improve accuracy and accessibility through mobile or web applications.

Conclusion

The Mango Analysis System: AI-Powered Disease & Pesticide Detection was successfully designed, developed, and implemented as a comprehensive full-stack web application capable of performing automated mango quality assessment with remarkable efficiency. This system integrates a hybrid machine learning pipeline, combining the strengths of a Convolutional Neural Network (CNN) for feature extraction with a Support Vector Machine (SVM) for classification.

Papers Published

Status of the Literature Survey Paper : Submitted
Status of the Methodology Survey Paper : not Submitted

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