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Patraraksha AI: An Offline-Enabled, Illumination-Adaptive Yolov8 Framework for Crop Disease Detection and Intelligent Treatment Guidance

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Abstract: ***Crop diseases significantly affect agricultural productivity and can lead to considerable economic losses when not identified at an early stage. To address this challenge, this paper presents PatraRaksha AI, an offline-enabled intelligent framework designed for crop disease detection and treatment guidance using artificial intelligence. The system employs the YOLOv8 object detection model to analyse uploaded leaf images and classify crop conditions into three categories: Healthy, Powdery Mildew, and Rust. A detection-level weighted-voting mechanism is incorporated to determine the final disease classification based on the model's detections. The framework operates locally, enabling disease identification without continuous internet connectivity. In addition to disease detection, it provides information about possible causes and severity, along with multilingual home-remedy recommendations to support farmers in understanding appropriate treatment options. An area-based dosage calculator is also integrated to estimate treatment quantities according to the specified land area. The system uses a FastAPI backend for image processing and prediction handling, while OpenCV and Pillow support image processing and the generation of annotated prediction outputs. By integrating offline disease diagnosis with multilingual and treatment-oriented agricultural assistance, PatraRaksha AI aims to provide an accessible decision-support solution for farmers and promote timely crop-health management. A separately developed illumination enhancement technique is also considered as a proposed extension to improve image visibility under varying lighting conditions, with integration and performance evaluation planned for future work.***

Keywords: ***PatraRaksha AI, Crop Disease Detection, YOLOv8, Deep Learning, Computer Vision, Offline Agricultural Assistance, Weighted Voting, Multilingual Treatment Recommendation.***

I. INTRODUCTION

Agriculture plays a vital role in ensuring food security and supporting the livelihoods of a large population. However, crop diseases remain a major challenge to agricultural productivity, as they can affect plant growth, reduce crop quality and cause significant economic losses. According to the Food and Agriculture Organization (FAO), plant pests and diseases account for the loss of up to 40% of global crop production every year [1]. Therefore, timely identification and appropriate management of crop diseases are essential for maintaining plant health and improving agricultural productivity. Traditional crop disease identification largely depends on visual inspection and the experience of farmers or agricultural experts. Although this approach is widely practised, identifying diseases at an early stage can be difficult, particularly when symptoms appear similar or are not clearly visible. The increasing use of artificial intelligence (AI), machine learning and computer vision has introduced new possibilities for automated plant disease detection. Deep learning models can analyse leaf images and identify disease-related patterns, reducing the need for manual examination. Among these approaches, object detection models such as YOLO have gained attention for their ability to identify and locate visual features within images. However, the reliability of image-based detection systems can be affected by variations in illumination, image quality, complex backgrounds and environmental conditions [2], [3].

Despite advances in automated disease detection, practical agricultural applications also face challenges related to internet connectivity and access to understandable treatment information. Systems that depend entirely on cloud-based processing may be difficult to access in areas with limited or unreliable internet connectivity. Furthermore, identifying a disease alone may not provide sufficient assistance to farmers, who may also require information about possible causes, disease severity and suitable treatment options. The availability of agricultural guidance in multiple languages and the ability to estimate treatment quantities according to land area can further support informed decision-making.

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To address these challenges, this paper presents PatraRaksha AI, an offline-enabled intelligent framework for crop disease detection and agricultural treatment guidance. The system uses the YOLOv8 object detection model to analyse uploaded leaf images and identify three crop conditions: Healthy, Powdery Mildew and Rust. A detection-level weighted-voting mechanism is incorporated to determine the final disease classification based on the detected regions and their confidence information. The system is designed to operate locally, allowing disease prediction without continuous internet connectivity. It also provides information about possible causes and severity, multilingual home-remedy recommendations and an area-based dosage calculator to estimate treatment quantities according to the specified land area.

The framework uses FastAPI for backend processing and API communication, while OpenCV and Pillow support image processing and the generation of annotated prediction images. A separately developed illumination enhancement technique is also considered as a proposed extension to improve the visibility of crop leaf images under varying lighting conditions. Its integration into the main detection pipeline and performance evaluation remain part of further development.

II. LITERATURE SURVEY

Recent developments in artificial intelligence, deep learning and computer vision have improved automated plant disease detection. Researchers have explored object detection, prediction aggregation, offline diagnosis, treatment recommendations and illumination-aware image processing. The following studies provide the foundation for PatraRaksha AI.

A. YOLO-Based Plant Disease Detection

Polly and Devi [4] proposed a plant disease detection system combining YOLOv8, DeepLabV3+, CNN and U-Net for disease identification, background removal, classification and damage segmentation. The system also provided severity assessment and remedy suggestions, demonstrating the potential of integrated deep learning techniques.

Nwaneto et al. [5] developed a YOLOv8-based system for detecting Taro Leaf Blight using field images collected in Nigeria and Ghana. The model achieved 85.7% mAP and was integrated into an Android application with a Web API. Unlike this disease-specific approach, PatraRaksha AI supports Healthy, Powdery Mildew and Rust categories.

B. Weighted Prediction and Disease Classification

Muthulakshmi et al. [6] introduced a Weighted Ensemble based on Confidence Scores (WECS) using YOLOv8n, YOLOv8s and YOLOv8m for potato leaf disease classification. Their approach achieved 96.3% global mAP, 99.9% precision and 89.6% recall. While their method combines multiple YOLOv8 variants, PatraRaksha AI uses detection-level weighted voting to determine the final prediction from a trained model's detection outputs.

C. Offline Plant Disease Detection and Treatment Recommendations

Suresh et al. [7] developed an offline plant disease detection application using MobileNetV3-Large and TensorFlow Lite. Trained on 19,606 images across six classes, it achieved 94.4% test accuracy and provided treatment recommendations in English and Tamil. Similarly, Haider et al. [8] combined YOLOv8 with GPT-3.5 and LangChain for mulberry disease detection and treatment guidance using 1,417 field images covering four diseases and healthy leaves. These studies highlight the importance of accessible agricultural recommendations. PatraRaksha AI differs by providing locally available multilingual remedy information, possible causes and area-based dosage calculation without relying on an external language model.

D. Illumination-Aware Plant Disease Diagnosis

Li et al. [3] proposed YOLO-Leaf for apple leaf disease detection using Dynamic Snake Convolution, BiFormer attention and an improved bounding-box regression method. The model achieved mAP@50 values of 93.88% and 95.69% on the FGVC7 and FGVC8 datasets, respectively, addressing challenges associated with complex visual conditions.

Ashraf et al. [9] introduced HFA-Net, an illumination-invariant plant disease diagnosis framework incorporating Illumination-Adaptive Contrast Enhancement (IACE) using CLAHE and Adaptive Gamma Correction (AGC). It achieved accuracy values of 96.03%, 92.95% and 93.07% under normal, dark and bright illumination conditions, respectively. These studies establish the importance of illumination handling in agricultural image analysis and provide a research basis for the separately developed illumination enhancement module considered for integration into PatraRaksha AI.

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E. Research Gap and Motivation

Existing studies address plant disease detection, prediction aggregation, offline diagnosis, treatment recommendations and illumination handling through different approaches. However, there remains scope to combine these capabilities into a locally executable agricultural assistance system. PatraRaksha AI addresses this need through YOLOv8-based detection, detection-level weighted voting, disease information, multilingual home remedies and area-based dosage calculation. The separately developed illumination enhancement technique further motivates an extension to improve image visibility under varying lighting conditions, followed by integration and performance evaluation.

III.PROPOSED METHODOLOGY

The proposed PatraRaksha AI framework is designed to identify crop diseases from leaf images and provide agricultural treatment guidance. It combines image processing, YOLOv8-based object detection, detection-level weighted voting and rule-based recommendations. The system uses a locally available trained model to support disease prediction without requiring continuous internet connectivity. The methodology consists of the following stages.

A. Image Acquisition

The process begins when the user uploads a crop leaf image through the application interface. The FastAPI backend receives the image through the prediction endpoint, validates it and prepares it for further processing.

B. Image Preprocessing

The uploaded image undergoes initial preprocessing before disease detection. Pillow is used to decode the image and correct its orientation using EXIF information, while OpenCV supports image processing and annotation operations.

C. Crop Disease Detection Using YOLOv8

The preprocessed image is passed to the trained YOLOv8 model, loaded from the best.pt weight file. The model identifies three categories: Healthy, Powdery Mildew and Rust. For each detected region, it generates a predicted class, bounding-box coordinates and a confidence score.

D. Detection-Level Weighted Voting

A detection-level weighted-voting mechanism considers the detected classes and their associated confidence scores to determine the final predicted crop condition. The resulting classification is used to retrieve the corresponding disease information and treatment guidance.

E. Disease Information and Severity Assessment

Based on the final prediction, the system provides relevant disease information, including possible causes and severity details. This information is retrieved from predefined recommendation data to help users understand the identified crop condition.

F. Multilingual Home Remedy Recommendation

The system provides home-remedy information in multiple languages through a rule-based recommendation module. Relevant remedies are retrieved from predefined Python dictionaries and formatted using the remedy-processing function according to the identified disease category.

G. Area-Based Dosage Calculation

An area-based dosage calculator estimates the required treatment quantity according to the land area entered by the user. The calculation follows the system's predefined logic, helping users estimate treatment quantities for their agricultural land. The results should be interpreted according to applicable crop-specific and product-specific instructions.

H. Image Annotation and Result Generation

OpenCV annotates detected regions with bounding boxes and prediction information. The annotated image is converted into JPEG format and encoded using Base64 for inclusion in the API response. FastAPI returns a JSON response containing the prediction, confidence information, severity, possible causes, remedy recommendations and other relevant results.

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I. Offline Execution

PatraRaksha AI supports local execution using the trained YOLOv8 model, processing components and predefined recommendation data. This enables core disease detection and recommendation operations without continuous internet connectivity, provided the required software, model files and data are available locally.

J. Proposed Illumination-Aware Image Enhancement

An illumination-aware image enhancement module is considered as an additional research contribution to improve the visibility of leaf images captured under varying lighting conditions. Techniques such as Contrast Limited Adaptive Histogram Equalization (CLAHE), adaptive gamma correction and Retinex-based enhancement can be investigated to address low illumination, uneven brightness and shadows. The enhanced images can subsequently be processed by YOLOv8. Its effectiveness will be evaluated by comparing detection performance on original and enhanced images under different lighting conditions.

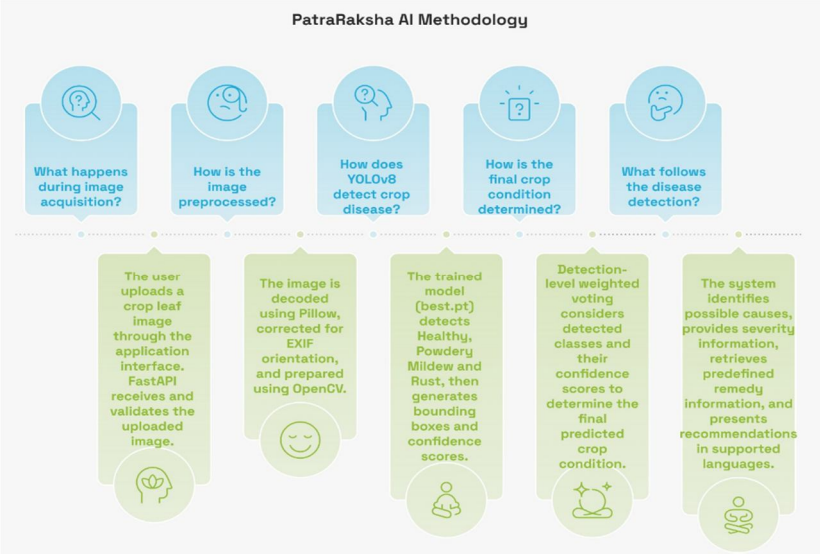

Fig. 1. Methodological Workflow of the Proposed PatraRaksha AI System.

IV. SYSTEM ARCHITECTURE

The system architecture of PatraRaksha AI consists of multiple interconnected components designed to perform crop disease detection and provide agricultural treatment guidance. The framework follows a modular architecture in which image acquisition, preprocessing, disease detection, prediction aggregation and recommendation generation are handled by separate functional modules. FastAPI acts as the backend framework responsible for receiving image inputs, coordinating processing operations and returning the prediction results.

A. Image Acquisition Module

The image acquisition module serves as the entry point of the system. Users provide crop leaf images through the application interface. The uploaded images are transmitted to the FastAPI backend through the prediction API endpoint. The backend validates the uploaded files and prepares them for further processing.

B. Image Processing Module

The image processing module prepares the uploaded images for disease identification. Pillow is used for image decoding and orientation correction, while OpenCV supports image processing and annotation operations. An illumination-aware image enhancement component is also proposed to investigate improvements in image visibility under varying lighting conditions.

C. Disease Detection Module

The disease detection module uses the trained YOLOv8 model stored in the best.pt file. The model analyses the input image and identifies the presence of crop conditions belonging to the supported classes: Healthy, Powdery Mildew and Rust. It generates detection information, including predicted classes, bounding-box coordinates and confidence scores.

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D. Weighted Voting Module

The weighted-voting module processes the detection outputs generated by YOLOv8 to determine the final crop condition. It considers the detected classes and their associated confidence information to aggregate the predictions. The resulting classification is passed to the recommendation module for retrieving the relevant disease information and treatment guidance.

E. Agricultural Recommendation Module

The agricultural recommendation module provides additional information based on the final disease classification. It retrieves predefined information about possible causes, severity and multilingual home remedies. The recommendation data is maintained using Python dictionaries and formatted before being included in the final response.

F. Area-Based Dosage Calculation Module

This module estimates the required treatment quantity based on the land area provided by the user. It processes the specified area using the configured calculation method and generates the corresponding dosage estimate. The output is intended to support treatment planning and should be interpreted according to the relevant agricultural product instructions.

G. Result Generation Module

The result generation module combines the outputs from the disease detection and recommendation components. OpenCV is used to draw bounding boxes and prediction labels on the detected image regions. The annotated image is converted into JPEG format and encoded using Base64. Finally, FastAPI generates a JSON response containing the disease prediction, confidence information, severity details, possible causes, treatment recommendations and other relevant outputs.

H. Local Execution and Offline Support

The system supports local execution through its locally available YOLOv8 model, processing libraries and recommendation data. This allows image analysis and the associated recommendation workflow to function without continuous internet connectivity, provided that the required application components are available locally. The modular architecture allows individual components to be maintained and extended independently.

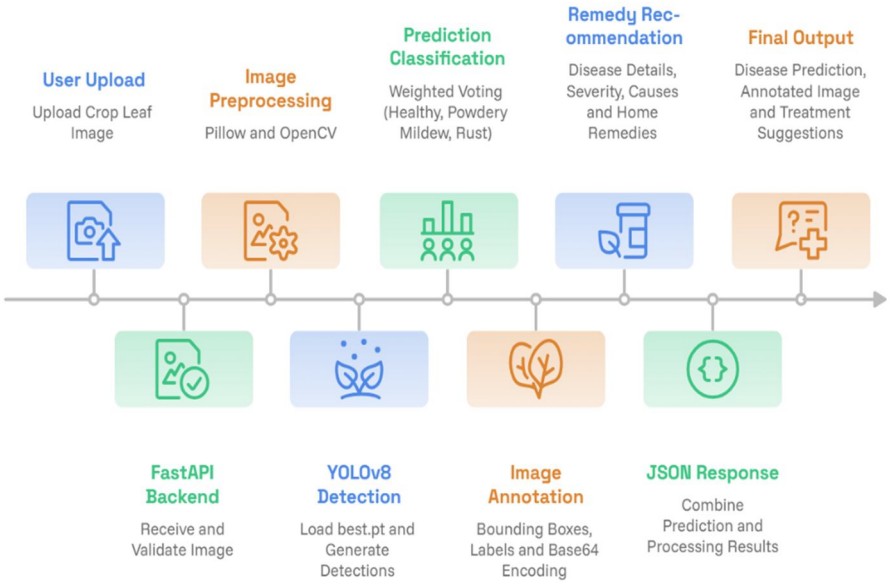

Fig. 2. System Architecture of the Proposed PatraRaksha AI Framework.

V. IMPLEMENTATION

The PatraRaksha AI framework is developed using Python and deep learning technologies to provide crop disease detection and agricultural treatment guidance. Its modular architecture separates image processing, disease prediction, recommendation generation and result handling. The trained YOLOv8 model is integrated with a FastAPI backend to process uploaded leaf images and generate prediction results.

A. Development Environment

Python is used as the primary programming language. FastAPI handles backend development, while Uvicorn runs the application as an ASGI server. Development and testing are performed in a Windows environment using the required Python libraries. Git is used for version control and project management.

B. YOLOv8 Model Integration

The trained YOLOv8 model is integrated using the Ultralytics framework. Its weights, stored in the best.pt file, are loaded during application initialization. The model identifies three categories: Healthy, Powdery Mildew and Rust, and generates detection outputs containing predicted classes, confidence scores and bounding-box coordinates.

C. Backend Development Using FastAPI

FastAPI manages image uploads, prediction requests and result delivery. The backend provides endpoints for application information, health monitoring and crop disease prediction. The prediction endpoint accepts images through multipart/form-data requests and processes them using the YOLOv8 model. Results are returned in JSON format, with interactive API documentation available through Swagger.

D. Image Processing and Annotation

Pillow handles image decoding and orientation correction, while OpenCV supports image processing and annotation. After prediction, bounding boxes and class labels are drawn on the image to highlight detected regions. The annotated image is converted into JPEG format and encoded using Base64 for inclusion in the API response.

E. Weighted Voting and Prediction Handling

The YOLOv8 detection outputs are processed through a detection-level weighted-voting mechanism. The detected classes and associated confidence information are considered to determine the final predicted crop condition. This prediction is then used to retrieve the corresponding disease information and recommendations.

F. Agricultural Recommendation and Dosage Calculation

Predefined Python dictionaries store information about possible disease causes and multilingual home remedies. The remedy-processing function retrieves and formats relevant information according to the final prediction. The area-based dosage calculator estimates treatment quantities using the land area entered by the user and the system's configured calculation logic.

G. Offline Execution

The application supports local execution using the trained YOLOv8 model, installed Python dependencies and locally available recommendation data. This enables core disease detection and recommendation operations without continuous internet connectivity, provided all required resources are available locally.

H. API Response Generation

The backend prepares a structured JSON response containing the final prediction, confidence information, severity details, possible causes, treatment recommendations and Base64-encoded annotated image. The response is returned to the application interface for presentation to the user.

I. Separately Developed Illumination Enhancement

An illumination enhancement technique has been developed separately to address variations in brightness and lighting conditions in crop leaf images. However, this technique has not yet been integrated into the main FastAPI and YOLOv8 application pipeline. Its integration and evaluation under different lighting conditions are considered further development of the proposed framework.

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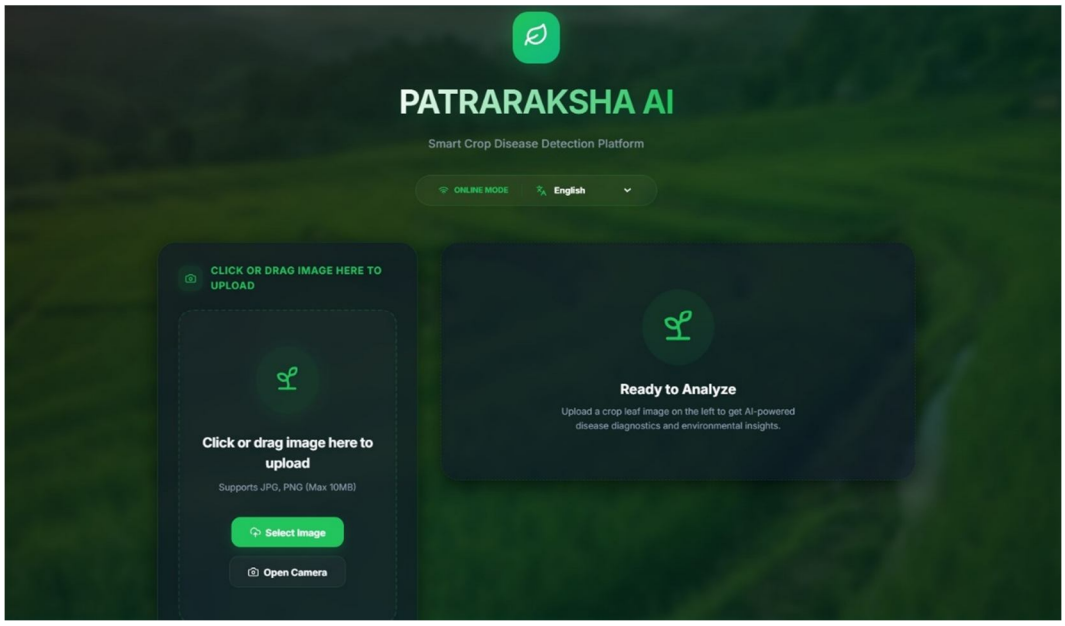

Fig. 3. Home Page of PatraRaksha AI

VI. RESULTS AND DISCUSSION

The developed PatraRaksha AI system provides an integrated approach to crop disease detection and treatment guidance. The system uses the YOLOv8 model to analyse uploaded leaf images and identify the crop condition as Healthy, Powdery Mildew, or Rust. Based on the detection results, the system generates relevant information to help users understand the identified condition and possible treatment options.

A. Crop Disease Detection Results

The YOLOv8 model processes the uploaded leaf image and generates predictions based on the trained disease categories. The system identifies the detected class and its corresponding confidence score. The detection-level weighted-voting mechanism is used to determine the final prediction from the available detection results.

The system supports three classification categories: Healthy, Powdery Mildew, and Rust. The prediction results are presented along with an annotated image that highlights the detected regions.

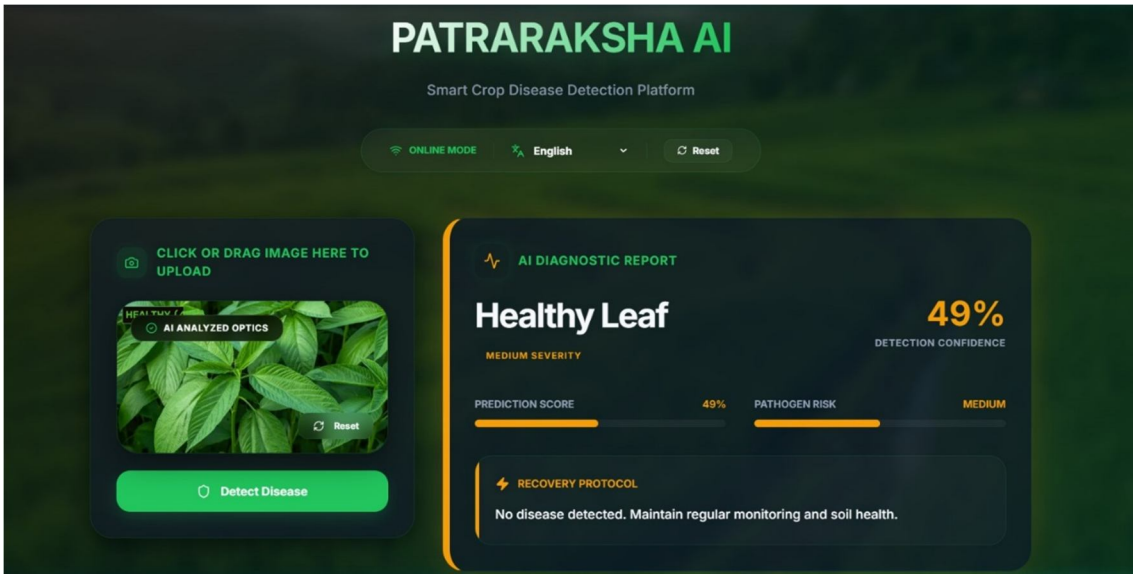

Fig. 4. Healthy Leaf Detection Result

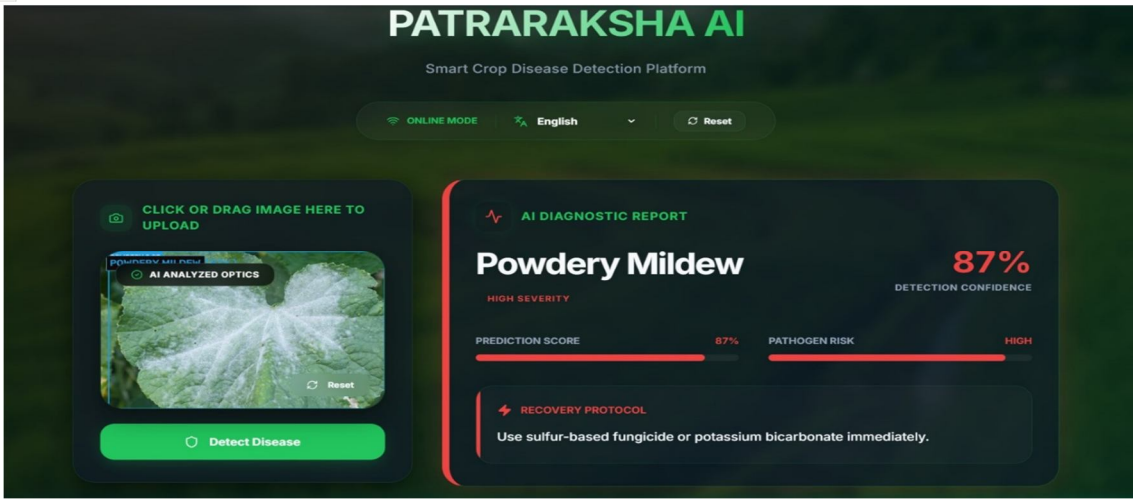

Fig. 5. Powdery Mildew Detection Result

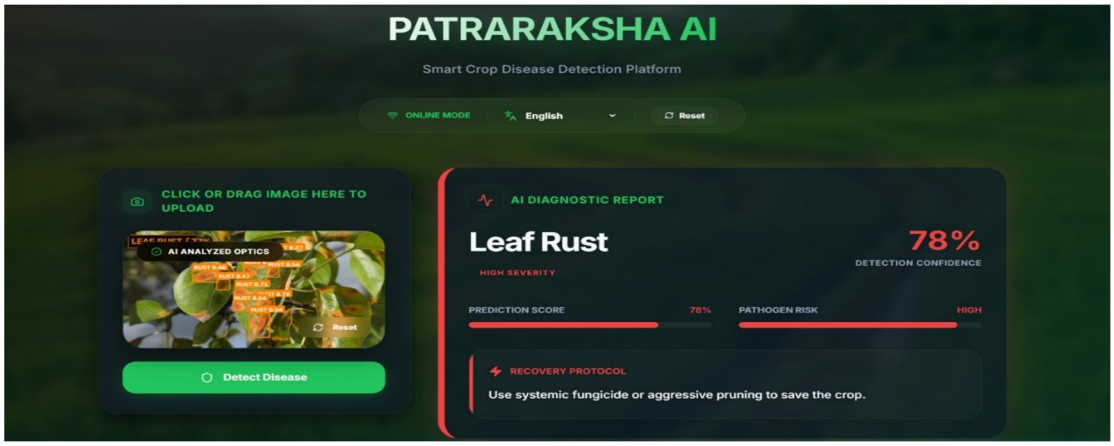

Fig. 6. Rust Detection Result

B. Disease Information and Treatment Guidance

After identifying the crop condition, PatraRaksha AI provides additional information about possible causes and disease severity. It also displays multilingual home-remedy recommendations to make the information easier for farmers to understand.

These recommendations are intended to support farmers in identifying possible treatment approaches. The information provided by the system should be considered decision-support guidance and not a replacement for professional agricultural advice.

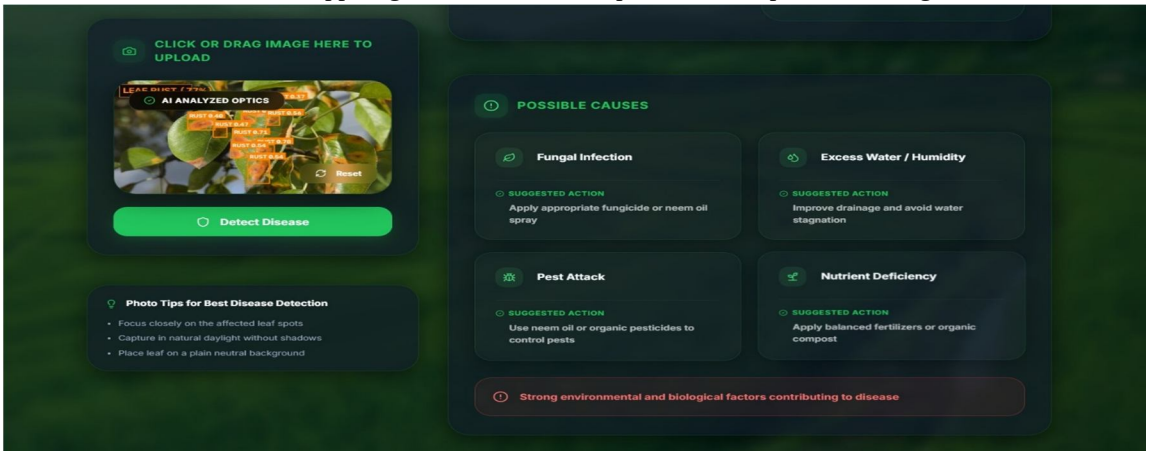

Fig. 7. Possible Causes of Identified Crop Disease

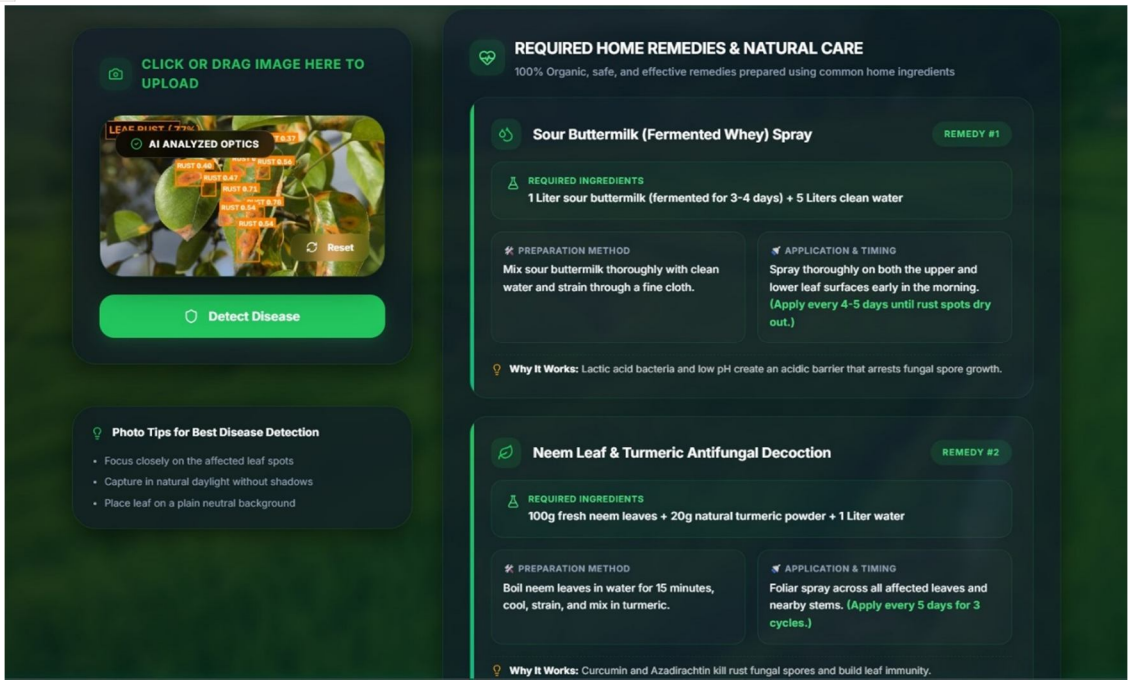

Fig. 8. Home-Remedy Recommendations

C. Area-Based Dosage Calculation

The system includes an area-based dosage calculator that estimates the required treatment quantity according to the land area entered by the user. This feature aims to make treatment recommendations more practical by considering the size of the affected agricultural land.

The calculated quantity depends on the dosage information and calculation rules configured in the application.

D. Offline Functionality

PatraRaksha AI is designed to perform its core disease-detection and recommendation operations locally without requiring continuous internet connectivity. This functionality is useful in agricultural areas where internet access may be limited or unreliable.

E. Discussion

The developed system combines crop disease detection with treatment-oriented information in a single application. Unlike a system that only identifies disease categories, PatraRaksha AI also provides possible causes, severity information, multilingual home remedies, and area-based dosage estimation.

The use of local execution supports accessibility in areas with limited internet connectivity. However, the reliability of the system depends on the quality and diversity of the training dataset, the performance of the trained model, and the accuracy of the configured treatment information.

Overall, PatraRaksha AI provides an integrated framework for crop disease detection and agricultural assistance.

VII. FUTURE SCOPE

PatraRaksha AI can be further improved by introducing additional features and advanced technologies to make crop disease detection more accurate, efficient, and accessible to farmers.

A. Integration and Evaluation of Illumination Enhancement

The separately developed illumination enhancement technique can be integrated into the main PatraRaksha AI pipeline to improve the visibility of crop leaf images under varying lighting conditions. Further evaluation using original and enhanced images can help determine its effect on disease detection performance.

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B. Expansion of Crop Disease Categories

The system can be extended to support more crop types and a wider range of plant diseases. Training the model with a larger and more diverse dataset can improve its ability to identify different disease conditions.

C. Improved Disease Detection Accuracy

Advanced deep learning techniques and model optimisation methods can be explored to improve detection performance. Further evaluation using standard metrics such as precision, recall, F1-score, and mean Average Precision can help assess the model's effectiveness.

D. Mobile Application Development

A dedicated Android application can be developed to make PatraRaksha AI more accessible to farmers. The application can provide an easy-to-use interface for capturing leaf images and receiving disease predictions directly through mobile devices.

E. Advanced Multilingual Support

Support for additional regional languages can be introduced to make disease information and treatment recommendations understandable to farmers from different linguistic backgrounds. Voice-based interaction can also be added to improve accessibility for users with limited reading ability.

F. Weather-Based Disease Prediction

Weather information such as temperature, humidity, and rainfall can be integrated to identify environmental conditions that may favour the development of crop diseases. This can help provide early warnings and support preventive agricultural practices.

G. Improved Treatment Recommendations

The treatment recommendation module can be enhanced using verified agricultural databases and expert-approved guidelines. This can help provide more reliable treatment suggestions, appropriate dosage information, and crop-specific recommendations.

H. Model Optimisation for Offline Usage

The YOLOv8 model can be further optimised using techniques such as quantisation and model compression. This can reduce computational requirements and improve inference speed, making the system suitable for devices with limited hardware resources.

By incorporating these improvements, PatraRaksha AI can be developed into a more comprehensive agricultural assistance platform that supports early disease identification, accessible treatment guidance, and better crop-health management.

VIII. CONCLUSION

PatraRaksha AI presents an intelligent and offline-enabled framework for crop disease detection and agricultural treatment guidance using deep learning and computer vision. The system employs YOLOv8 to identify crop conditions from leaf images and classify them into three categories: Healthy, Powdery Mildew and Rust. A detection-level weighted-voting mechanism is used to determine the final prediction from the model's detection results.

Beyond disease identification, the system provides information about possible causes and disease severity, along with multilingual home-remedy recommendations. The area-based dosage calculator helps estimate treatment quantities according to the land area specified by the user. FastAPI, OpenCV and Pillow support image processing, prediction handling and annotated result generation.

The offline functionality enables the core system operations without requiring continuous internet connectivity, making the framework useful in areas with limited network access. Further evaluation using diverse leaf images and additional disease categories can improve its reliability and practical applicability. Overall, PatraRaksha AI demonstrates the potential of artificial intelligence in providing accessible crop-health monitoring and supporting informed agricultural decisions.

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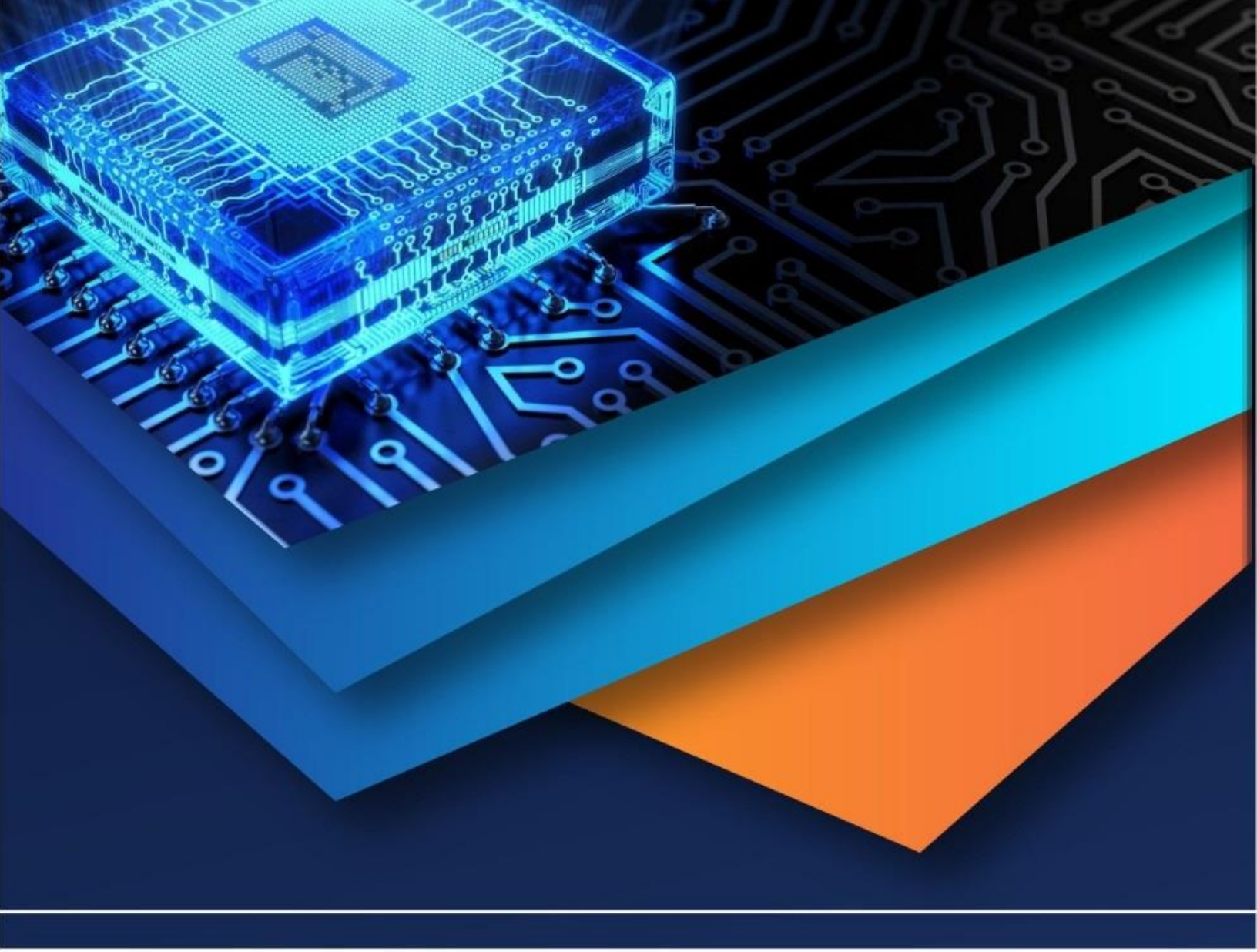

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