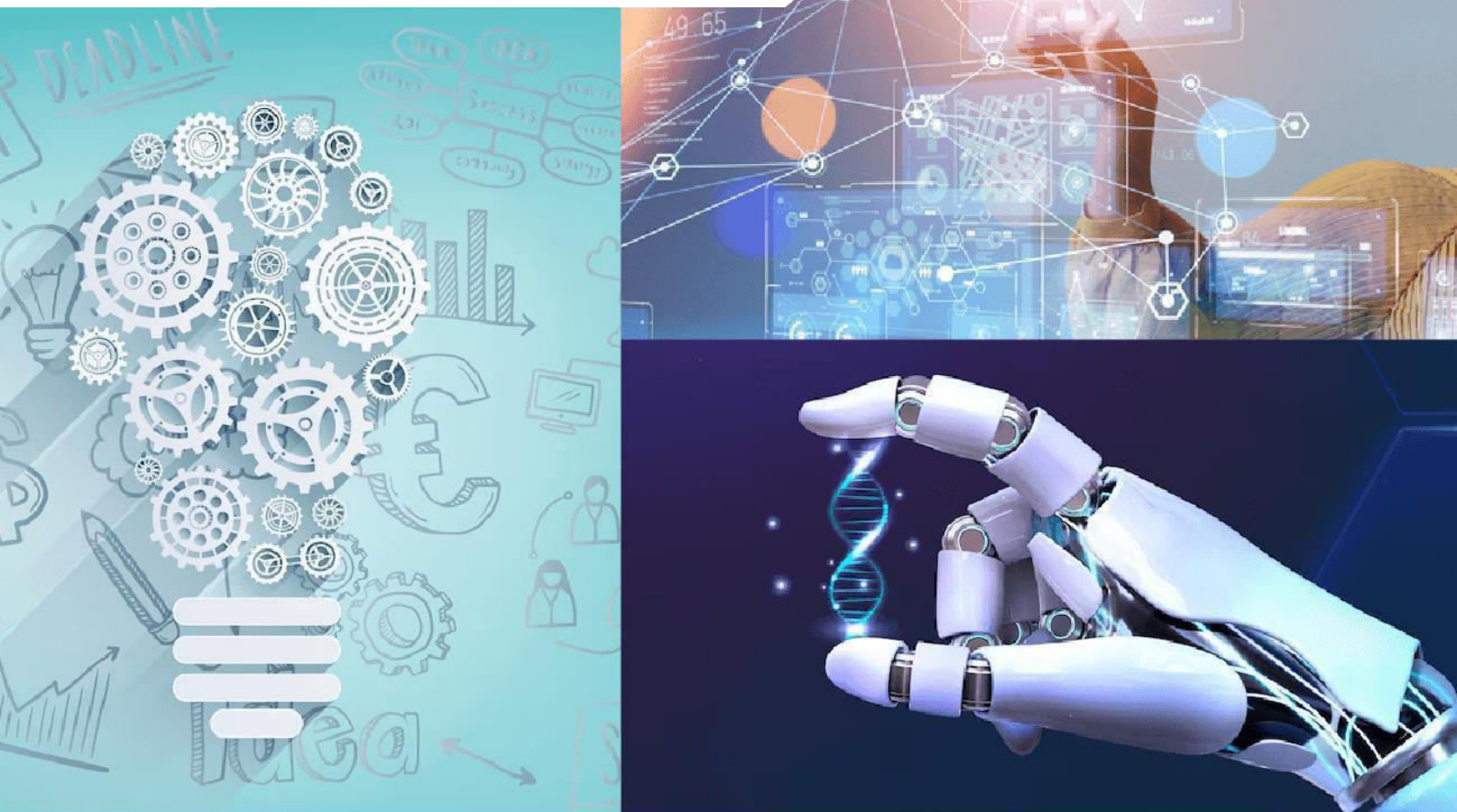




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A Deep Learning Approach for Disease Detection in Pomegranate Fruits Using a Hybrid Optimal Attention Capsule Network

Mr.R.Aravindhan, Mrs.Mary Jojcy.A

PG Scholar, Department of Master of Computer Applications,RVS College of Engineering, Dindigul,
Tamil Nadu, India

Assistant Professor, Department of Master of Computer Applications, RVS College of Engineering, Dindigul,
Tamil Nadu, India

ABSTRACT: In 2022, the production rate of pomegranate is estimated at approximately 4.8 million metric tons. Unfortunately, these fruits are susceptible to many different kinds of diseases caused by bacterial, viral, and fungal infections. Such diseases can have a major negative impact on fruit quality, production, and the profitability of pomegranate cultivation. Nowadays, several machine learning and deep learning methods are used to identify pomegranate fruit diseases automatically and effectively. In post-harvest pomegranate fruit disease detection, deep learning has great potential to extract complex patterns and features from large datasets. This can improve disease identification accuracy, enabling more efficient disease control, lower crop losses, and better resource management. The proposed work introduces an intelligent deep learning-based approach for accurately detecting pomegranate diseases, begins with Improved Guided Image Filtering (Improved GIF) and resizing to pre-process fruit images, followed by feature extraction (shape, color, texture) using GLCM and GLRLM to streamline classification. Extracted features are then fed into a novel Hybrid Optimal Attention Capsule Network (Hybrid OACapsNet), which classifies the images as normal or diseased, conditions such as bacterial blight, heart rot, and scab. Our analysis indicates that the proposed classifier has a classification accuracy of 99.19 %, precision of 98.45 %, recall of 98.41 %, F1-score of 98.43 %, and specificity of 99.45 % compared to other techniques. So this approach offers a framework, which is a feasible solution for automated detection of diseases in fruits, thereby benefiting farmers and supporting their farming operations.

KEYWORDS: Deep Learning, Capsule Network(CapsNet), Pomegranate Diseases Detection, Attention Mechanism, Features Extraction, Computer Vision in Agriculture, Image Processing

I. INTRODUCTION

Pomegranate is a nutrient-rich fruit widely cultivated across the world. Despite its economic importance, its production is significantly affected by diseases such as bacterial blight, heart rot, and scab. These diseases reduce fruit quality and yield, leading to financial losses. Traditional disease detection methods rely on manual inspection, which is time-consuming and prone to errors. With the advancement of artificial intelligence, machine learning (ML) and deep learning (DL) techniques have been widely adopted for automated disease detection. Deep learning models, particularly convolutional neural networks (CNNs), have shown superior performance in image-based classification tasks. However, conventional CNNs face limitations in capturing spatial relationships and subtle features. To overcome these challenges, this work proposes a Hybrid Optimal Attention Capsule Network (OACapsNet), which improves feature representation and classification accuracy by integrating attention mechanisms and optimization algorithms.

II. EXISTING SYSTEM

The existing system for pomegranate disease detection mainly relies on manual inspection, traditional image processing techniques, and conventional machine learning algorithms. Farmers and agricultural experts identify diseases by observing visible symptoms such as spots, discoloration, and lesions on the fruit surface. Some automated approaches use handcrafted features like color, texture, and shape combined with classifiers such as Support Vector Machine (SVM), K-Nearest Neighbor (KNN), and Decision Trees. These methods often struggle to achieve high accuracy when disease symptoms vary in appearance and environmental conditions.

Disadvantages:

- Depends heavily on manual observation and expert knowledge.
- Time-consuming and labor-intensive process.
- Low detection accuracy for complex disease patterns.
- Sensitive to lighting, background noise, and image quality.
- Handcrafted features may fail to capture important disease characteristics.
- Limited ability to generalize to new disease variations.

PROPOSED SYSTEM

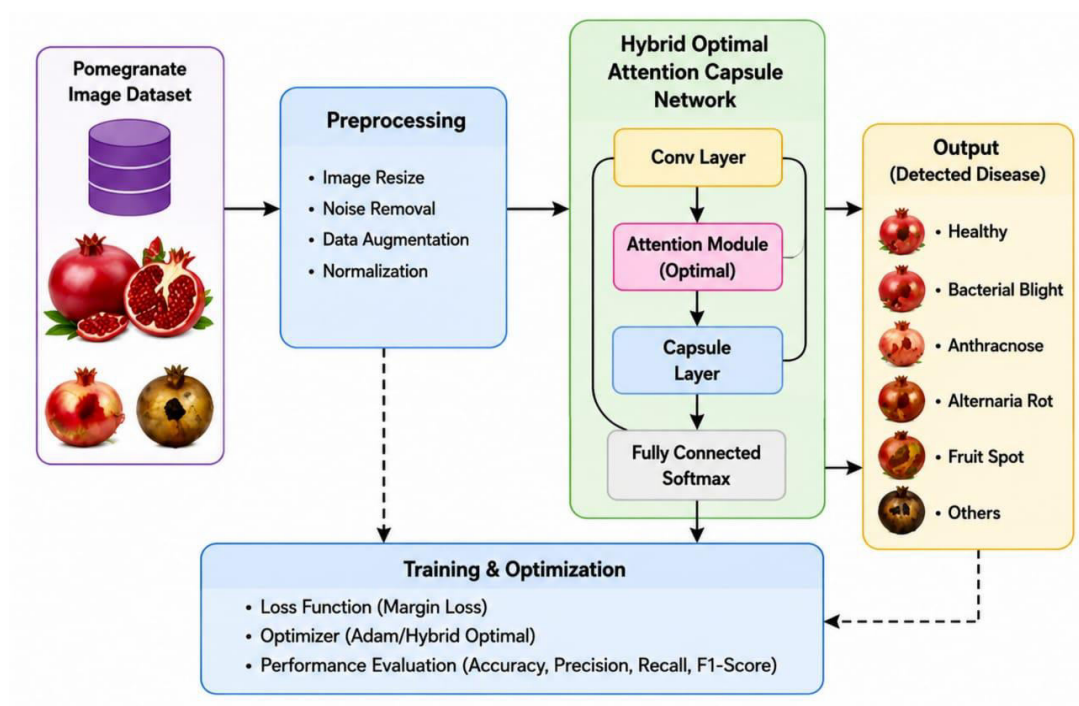
The proposed system utilizes a Hybrid Optimal Attention Capsule Network (HOACN) for automatic detection and classification of pomegranate fruit diseases. The system first performs image preprocessing and resizing to enhance image quality. Deep learning techniques are then used to extract relevant features from the images. The attention mechanism focuses on infected regions, while the capsule network preserves spatial relationships between disease features. An optimization algorithm further improves feature selection and classification performance. The model classifies pomegranate fruits into categories such as Alternaria, Anthracnose, Bacterial Blight, Cercospora, and Healthy fruit.

Advantages:

- High disease detection and classification accuracy.
- Automatic feature extraction without manual intervention.
- Attention mechanism focuses on important infected areas.
- Capsule networks preserve spatial and hierarchical feature information.
- Robust against variations in lighting, orientation, and image quality.
- Faster and more reliable disease diagnosis.
- Reduces crop losses through early disease detection.
- Supports precision agriculture and smart farming applications.

III. SYSTEM ARCHITECTURE

The proposed system automatically detects and classifies diseases in pomegranate fruits using a Hybrid Optimal Attention Capsule Network (HOACN). The architecture consists of several stages, including image acquisition, preprocessing, feature extraction, attention-based learning, capsule network classification, and result generation. The system improves disease detection accuracy by focusing on important infected regions and preserving spatial relationships between disease features.



IV. MODULE DESCRIPTION

1. Image Acquisition Module

The Image Acquisition Module is responsible for collecting pomegranate fruit images from different sources such as cameras, mobile devices, and online datasets. The captured images may contain healthy and diseased fruits under various environmental conditions. This module ensures that the input images are stored properly for further processing and analysis in the disease detection system.

2. Image Preprocessing Module

The Image Preprocessing Module enhances the quality of the acquired images before they are fed into the deep learning model. It performs operations such as image resizing, normalization, noise removal, filtering, and data augmentation. These preprocessing techniques help improve image clarity, reduce unwanted distortions, and increase the accuracy of disease detection by preparing standardized input data.

3. Feature Extraction Module

The Feature Extraction Module extracts important visual characteristics from the pre-processed pomegranate images. In the proposed system, convolution layers and attention mechanisms are used to identify significant disease-related features such as color variations, texture patterns, lesions, and infected regions. This module plays a crucial role in improving the learning capability of the model.

4. Hybrid Optimal Attention Capsule Network Module

The Hybrid Optimal Attention Capsule Network Module is the core component of the proposed system. It combines convolutional neural networks, attention mechanisms, and capsule networks to achieve efficient disease classification. The attention module focuses on important infected regions, while capsule layers preserve spatial relationships between features. This hybrid architecture improves classification accuracy and enhances the model's ability to detect multiple pomegranate diseases effectively.

5. Disease Classification Module

The Disease Classification Module predicts the category of the pomegranate fruit based on the extracted features. The trained deep learning model classifies the fruit into different disease categories such as bacterial blight, anthracnose, alternaria rot, fruit spot, or healthy fruit. The classification process is performed using fully connected layers and softmax activation functions to generate accurate prediction results.

6. Database Management Module

The Database Management Module stores image datasets, preprocessing outputs, trained model parameters, and disease prediction results. It maintains organized records of user uploads, detected diseases, confidence scores, and system logs. This module helps in efficient data retrieval, monitoring, and future analysis of disease detection performance.

7. Model Training and Optimization Module

The Model Training and Optimization Module trains the Hybrid Optimal Attention Capsule Network using labeled pomegranate fruit datasets. Optimization algorithms such as Adam optimizer and loss functions such as margin loss are applied to improve model learning and reduce classification errors. This module continuously updates model parameters to achieve better performance and higher prediction accuracy.

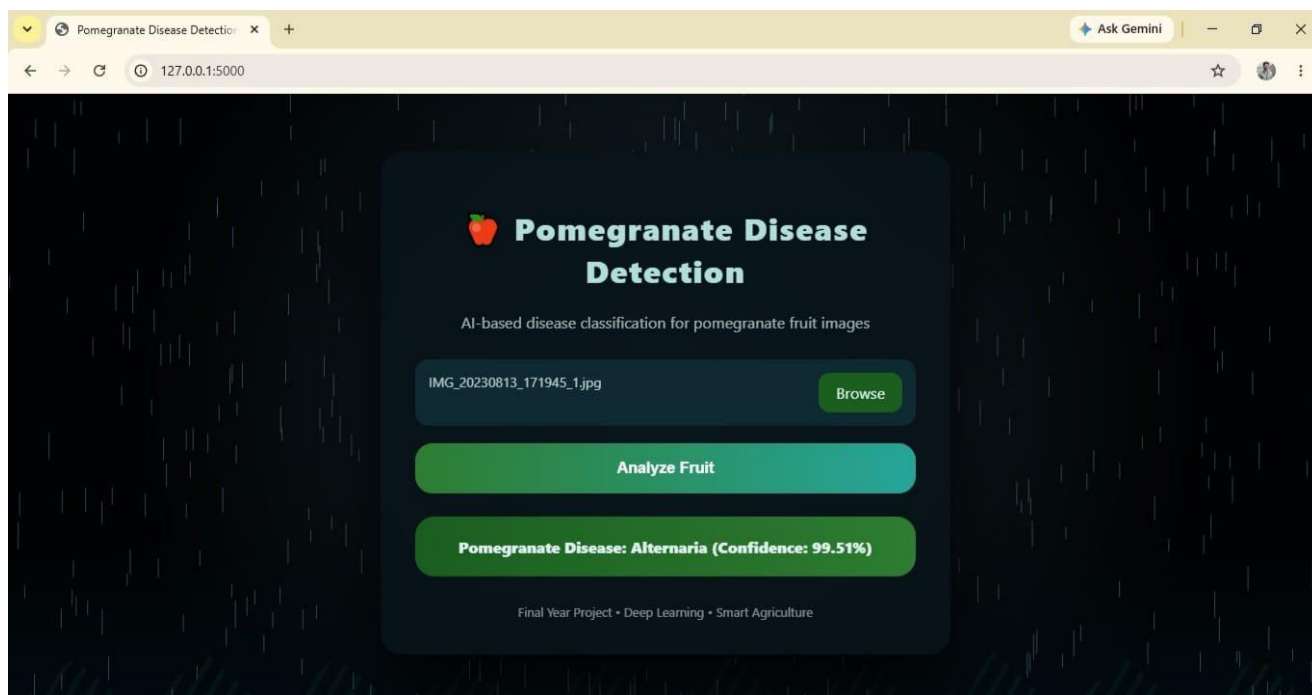
8. Performance Evaluation Module

The Performance Evaluation Module evaluates the effectiveness of the proposed disease detection system using different evaluation metrics such as accuracy, precision, recall, F1-score, and confusion matrix analysis. This module helps in analyzing the reliability and efficiency of the deep learning model for real-time disease prediction.

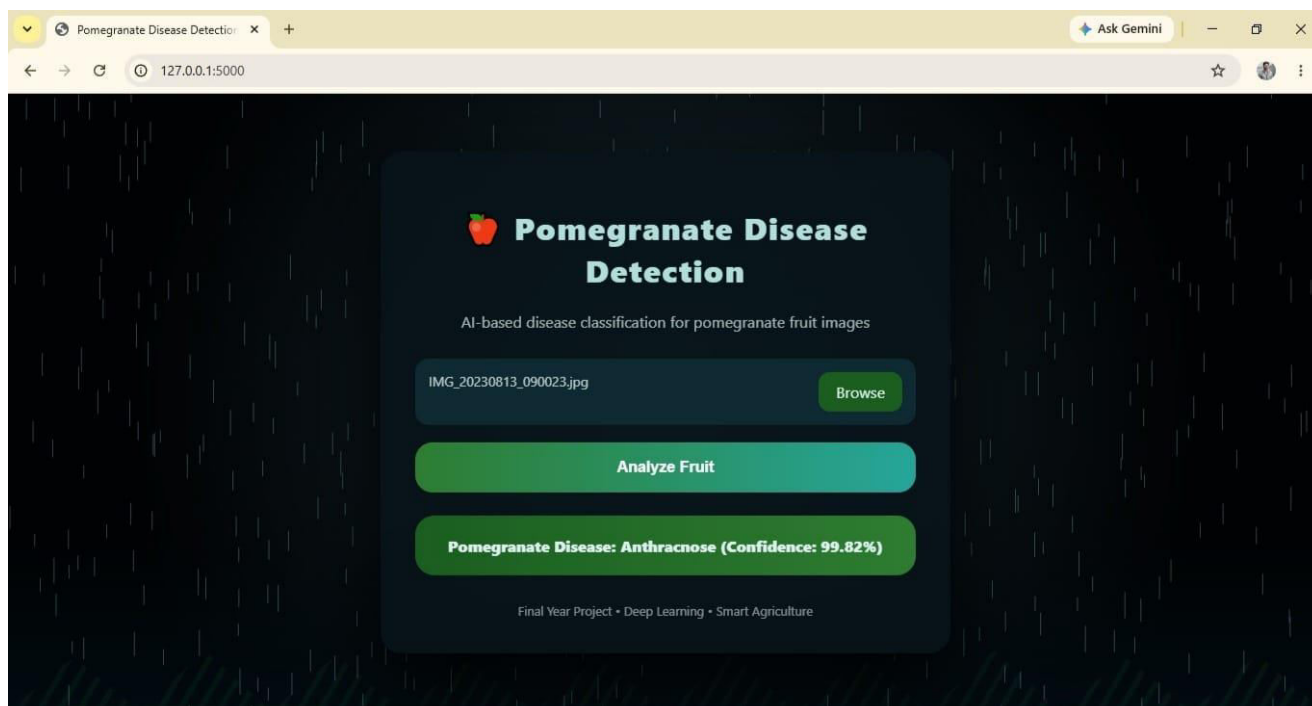
9. Result Visualization Module

The Result Visualization Module displays the final disease detection output to the user in an understandable format. It presents the predicted disease name, confidence score, and related information through graphs, reports, or visual indicators. This module helps agriculturists and researchers easily interpret the detection results for effective decision-making.

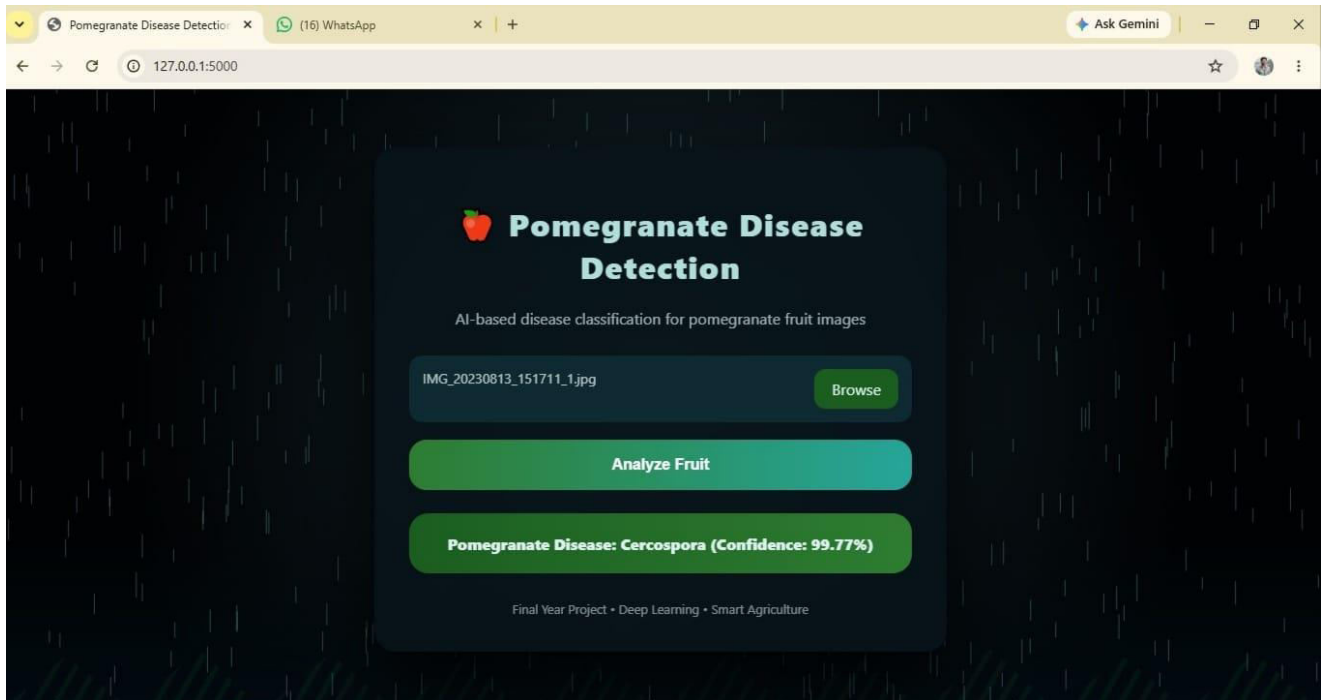
V. OUTPUT SCREENSHOTS



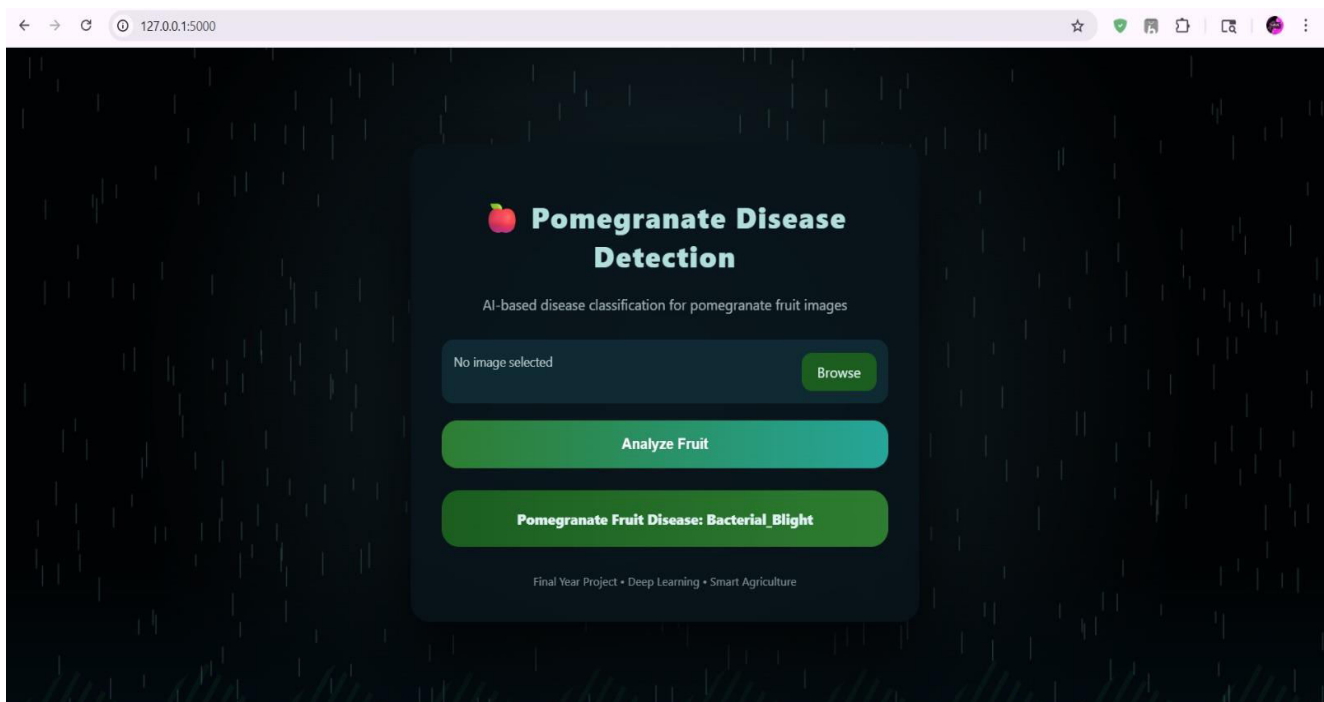
Alternaria Analyze Screen



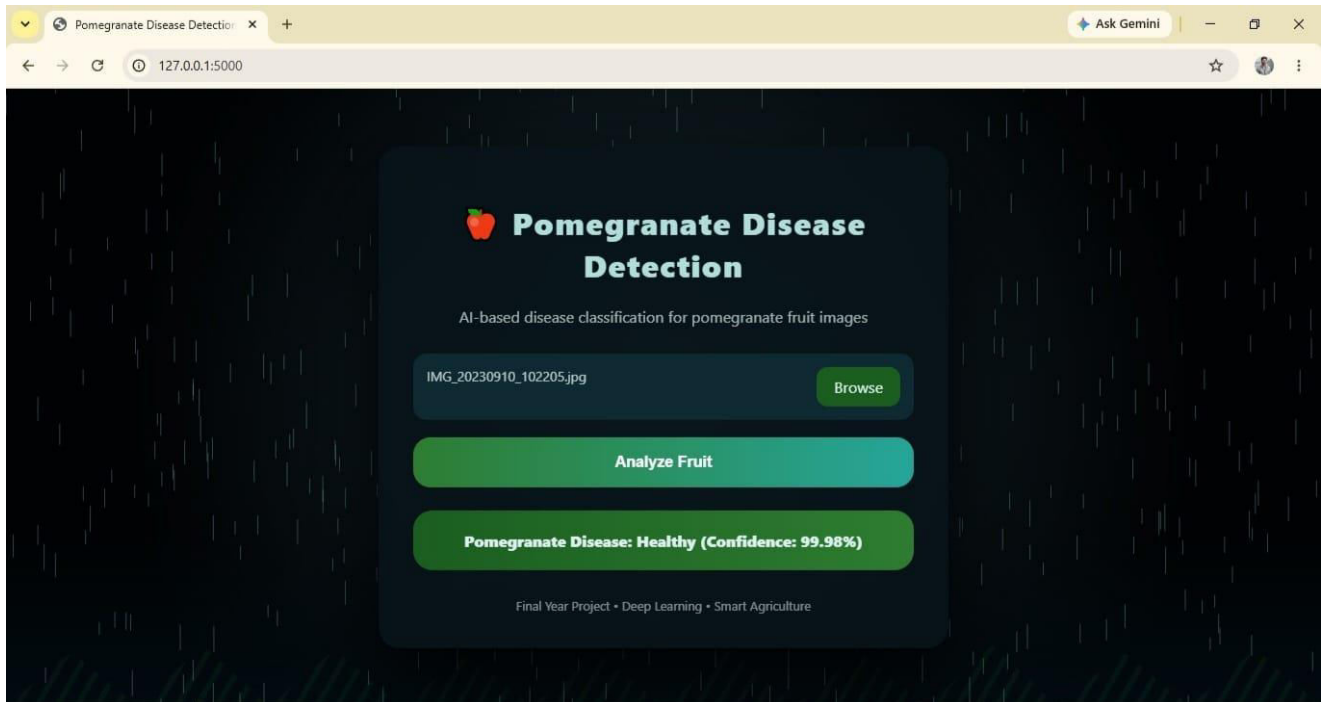
Anthracnose Analyze Screen



Cercospora Analyze Screen



Bacterial Blight Analyze Screen



Healthy Analyze Screen

VI. CONCLUSION

The proposed system combines image preprocessing, feature extraction, attention mechanisms, and capsule networks to accurately identify and classify various pomegranate diseases such as Alternaria, Anthracnose, Bacterial Blight, and Cercospora. The attention module helps the model focus on important disease-affected regions, while the capsule network preserves spatial relationships between features, resulting in improved classification performance. The experimental results demonstrate that the proposed approach achieves high accuracy, reliability, and robustness in disease detection compared to traditional machine learning and conventional deep learning methods.

The system effectively distinguishes between healthy and infected fruits, enabling early diagnosis and reducing the dependence on manual inspection. Furthermore, the automated detection process can assist farmers in taking timely preventive measures, thereby improving crop yield and fruit quality. The Hybrid Optimal Attention Capsule Network provides an efficient and intelligent solution for pomegranate disease detection. The proposed model contributes to the advancement of precision agriculture by offering a fast, accurate, and scalable disease diagnosis framework. Future enhancements can include real-time mobile deployment, larger datasets, and integration with IoT-based monitoring systems to further improve agricultural decision-making and disease management.

VII. FUTURE ENHANCEMENT

The proposed hybrid optimal attention capsule network for pomegranate fruit disease detection can be further enhanced in several ways to improve accuracy, scalability, and real-time applicability. Future work may focus on integrating advanced transformer-based deep learning models to achieve better feature extraction and disease classification performance.

The system can also be extended to detect multiple stages of disease severity and identify newly emerging infections in pomegranate fruits. Furthermore, optimization techniques can be applied to reduce computational complexity and make the model suitable for edge devices and smartphones. Explainable Artificial Intelligence (XAI) methods can also be integrated to improve the interpretability of the deep learning model and assist agricultural experts in understanding the decision-making process.

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