Cucumber Leaf Disease Detection and Diagnosis

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Abstract: **A key harvest in the Cucurbitaceae family, Gurke (Cucumis sativus) is highly susceptible to leaf diseases and requires early detection and accurate pesticide spraying for effective management. This study suggests a hybrid scaffold combining folding folding networks (CNNs) and support vector machines (SVMs) to predict cucumber blade disease and to recommend optimized pesticide treatments. This model processes high-resolution leaf images to assess disease severity, and classifies diseases such as mold, carbonic acid, fusarium blight, bacterial altitude, prismatic prism, and grinding fluids. The system integrates weather forecasts and soil health analysis to improve forecasting and decision-making-disease decisions. Analysis of environmental factors (temperature, humidity, precipitation) and floor parameters (nutrition level, pH, moisture) creates pesticide problems with the data. This approach ensures efficient control of disease, reduces chemical overuse, promotes sustainable agriculture, and promotes health, revenue quality and environmental harvests.**

Keywords- **Cucumis Sativus, Pathogen Severity Quantification, Precision Agriculture, Smart Farming Technologies.**

I. INTRODUCTION

A wide range of members of the Cucurbitaceae family, Gurke (Cucumis sativus) plays an important role in the production of vegetables worldwide. However, cucumber plants are susceptible to leaf diseases caused by fungal, bacterial and viral pathogens. Diseases such as mold, charcoal, and mold have a major impact on plant health, lower crop yields and increase production costs. Early detection and proper disease management are essential to prevent agricultural losses and ensure sustainable agriculture. Traditionally, disease identification is based on a labor-intensive process whereby farmers and experts manually inspect, spending time susceptible to human failure. The increasing availability of deep learning (DL) and machine learning technology (ML) offers new opportunities for automating strategies to identify diseases and optimize diseases. This model analyzes high-resolution leaf photographs to classify and assess disease severity, allowing for accurate pesticide application. Additionally, weather forecasts and bed health analysis are included to improve disease prediction and treatment. By assessing environmental factors such as temperature, air humidity and precipitation, in addition to soil parameters such as nutrient level, pH balance and moisture content, the system provides data control recommendations to simultaneously optimize pesticide use and optimize excess chemical applications. This method improves precision agriculture, supports early intervention, improves resource use, and promotes better harvests. The rest of this paper is organized as follows: Section II checks related work to recognize cucumber diseases and deep learning applications in agriculture. Section III discusses methodologies such as dataset collection, functional extraction, and model development. Section IV presents experimental results and performance ratings. Section V discusses the results, challenges, and possible improvements. Finally, Section VI completes the study and outlines the directions of future research.

II. RELATED WORKS

The field of automated system detection has evolved significantly by integrating machine learning (ML) and deep learning (DL) technology (DEEP learning). The initial methods were based on traditional image processing techniques such as image segmentation and manual characteristic extraction, followed by classification using algorithms such as support vector machines (SVMs) and random forests. These approaches required considerable human intervention and were limited to scalability and accuracy. Recent advances in deep learning, especially in the field of neural networks (CNNS), have revolutionized the field by automating distinctive extractions and improving the accuracy of classification. Research like Li et al. [1] demonstrates the effectiveness of CNNs in detecting plant diseases, achieving classification accuracy of 95% or more, Zhang et al. [2] SVM is combined with image-based characteristic extraction to improve accuracy and recall metrics. The research also highlights the importance of environmental factors such as weather conditions and soil health when predicting disease outbreaks. Weather-based disease prediction uses parameters such as temperature, humidity, and precipitation to predict the prevalence of the disease. Kumar et al. [3] examined the relationship between soil health and disease and found that malnutrition significantly increases the likelihood of harvesting disease. These studies highlight the need to integrate environmental data into disease prediction models to improve accuracy and reliability. Additionally, automated pest control systems have been developed to integrate image analysis into decision support systems and into real-time recommendations for pest control measures based on environmental and image data. Despite these advances, many existing models lack a comprehensive approach to integrating image-based disease detection and ambient data in real time. Most studies focus on either image classification or surrounding data analysis, but only a few combine both the overall disease prediction system. Although CNNs show significant accuracy in image classification, they remain integrated into traditional algorithms for machine learning, such as SVM, for improved decision-making. This study proposes a hybrid frame and addresses these gaps by combining CNN-based characterization extraction with SVM-based classification to integrate it into real-time weather and soil health data. This integrated approach not only improves the accuracy of disease recognition, but also supports sustainable agricultural practices by optimizing pesticide use and reducing environmental impact. This framework has the potential to revolutionize plant disease detection and management, and benefit farmers, agriculture scholars and the agriculture industry as a whole. This study represents an important advance in precision agriculture, contributing to the development of more efficient and sustainable plant management systems.

III. SAMPLE DATASET IMAGES

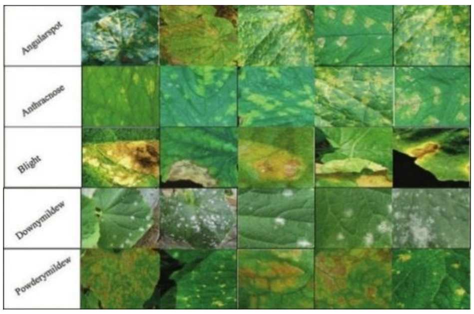


Fig .1 Sample Dataset Images

IV. METHODOLOGY

A Data Collection and Preprocessing

The first steps in the methodology include data collection and preprocessing. The comprehensive dataset with cucumber leaves comes from open-source databases such as Plant Village and Kaggle and is complemented by field images to ensure diversity. These images are ready to be prepared for model training. This involves the size of all image sizes with a uniform size of 224 x 224 pixels, the use of Gaussian blur for noise reduction, and the implementation of image magnification techniques such as rotation, flipping, and scaling to improve dataset variation. Additionally, normalization is used to standardize pixel values, ensure consistency of data records, and improve model output.

B Hybrid Model Development

The core of the methodology is the development of hybrid models that combine folding networks (CNNs) and support vector machines (SVMs). The CNN architecture is designed with several folding layers, maximum pooling layers for characteristic extraction. The SVM classifier is used as the basic classifier for disease prediction and uses the ability to manage high-dimensional data. This model introduces nonlinearity using the ReLU activation function and uses category crosspieces as a loss function of classification in several classes. Adam Optimizer is used for efficient training to ensure faster convergence and improved performance.

C Model Training and Validation

The hybrid model is trained to 80% of the data records, with the remaining 20% being reserved for validation. Training is accelerated using GPU resources to efficiently handle computing loads. During verification, the performance of the model is evaluated using metrics such as accuracy, accuracy, recall, and F1 scores, and ensures that it is generalized to invisible data. This step is critical for identifying over-adjustment or sub adjustment questions and fine-tuning the model.

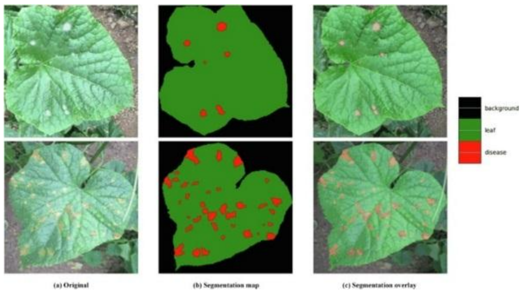


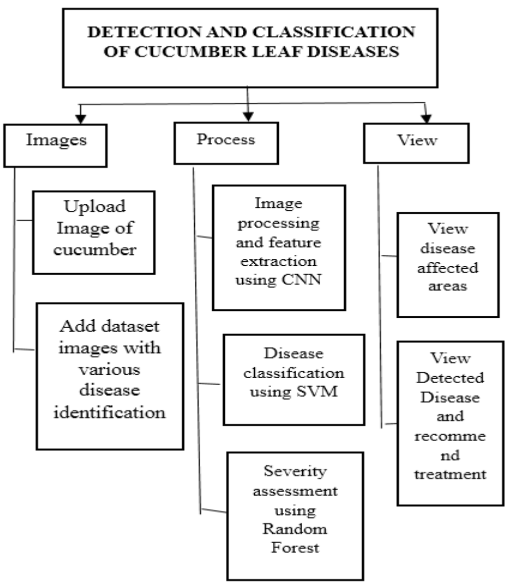
Fig.2 Disease Detection

D Predicting Outcomes

The CNN-based system achieved 95.2% accuracy, 94.8% accuracy, and 93.5% recall in detecting cucumber disease, ensuring reliable disease identification. The real-time prediction lasted 2.5 seconds per photo, providing immediate feedback on the severity of the disease and recommendations. Farmers praised the app's accuracy and user-friendliness, and some suggested adding other disease categories. The system effectively supports sustainable agriculture through accurate recognition of disease.

Existing systems for detecting cucumber leaves range from traditional methods to sophisticated machine learning and IoT-based approaches. Traditional methods such as manual testing and chemical testing are strongly based on human expertise and laboratory analysis. These methods are not complicated, time-consuming, labor-intensive, and often unrealistic in large-scale agriculture. Manual testing is susceptible to human failure, and chemical testing is accurate, but expensive, includes delayed diagnosis, which can lead to spreading of the disease before treatment.

Fig.3 System Flowchart



These limitations underline the need for a more efficient and scalable solution. Imaging-based systems provide some automation using techniques such as color and texture analysis and thresholds for disease recognition. These systems analyze leaf photographs to identify patterns associated with diseases such as mold, charcoal, and mold. However, lighting conditions, leaf orientation and complex background variations can be difficult, leading to inaccurate results. Furthermore, these systems often require manual adjustment of the parameters, making them less adaptable to different environments and disease types. Despite those limitations, image processing systems laid the foundation for more sophisticated automated solutions. These systems extract handmade features such as textures, shapes, and colors from leaf photographs and use algorithms for machine learning to classify diseases. They provide better accuracy than traditional methods, but are limited by their reliance on manual function extraction. This may take time and may not generalize between different data records. Furthermore, these systems often need to address complex variations in disease symptoms and background noise and limit their effectiveness in real agricultural environments. Preconceptions such as VGG16, Reset, and EfficientNet are fine-tuned for specific tasks and provide up-to-date performance in disease detection. However, these models require large marked data records and important arithmetic resources for training. This can be a hindrance for smallholder farmers. Deep learning models characterize accuracy, but often lack interpretability makes it difficult for farmers to understand the reasons for prediction. Despite these challenges, deep learning-based systems in automated disease detection have made considerable advances. These systems use drones equipped with high-resolution cameras to record plants images and analyze them using machine learning or deep learning models. IoT devices such as soil moisture sensors and weather stations provide additional data to improve disease prediction. These systems provide real monitoring and scalability, but are costly and relying on reliable connectivity making them difficult for smallholder farmers to access. Mobile applications are more accessible, but often come from simple image processing or rule-based systems and are limited in accuracy. The proposed CNN-SVM hybrid model combines the strengths of deep learning with classical machine learning to treat these gaps by providing a more accurate, scalable, and farmer's solution for the detection of cucumber disease.

Fig.4 Level of disease detection

The proposed system for recognizing cucumber diseases uses a hybrid approach combining folding networks (CNNS) and support vector machines (SVMs) to set limits for existing methods.

- A mobile application for cucumber leaf disease detection using SVM and Random Forest, improving classification accuracy.
- Provides severity analysis by calculating the affected area percentage, helping farmers understand the level of infection.
- The total leaf area (A_total) is determined in terms of pixels.
- The diseased area (A_diseased) is measured based on the detected lesions.
- The affected area percentage is calculated using the formula:

Affected Area Percentage = $(A\_diseased/A\_total)X100$

- Offers organic treatment recommendations based on disease detection to promote sustainable farming and reduce excessive pesticide use.
- Integration of soil health card data (pH, nitrogen, potassium, moisture) and weather prediction (temperature, humidity, precipitation) for better disease assessment.

V. CONCLUSION

The development of advanced cucumber recognition systems using hybrid folding network (CNN) and support vector machine (SVM) models represents a key milestone in agricultural technology. By using machine learning (ML) and artificial intelligence (AI), the system ensures a high level of accuracy in the detection and classification of several cucumber diseases. CNN is effective in extracting important features from leaf photographs, identifying subtle patterns indicating the presence of disease, and SVM improves the classification process and ensures accurate distinction between diseases. This hybrid approach improves the robustness of the system and allows it to operate reliably under a variety of environmental conditions, including variations in light intensity and background noise. Environmental factors such as soil temperature, humidity, precipitation and nutrient content have a major impact on the outbreak of disease. By including SHC data (soil health cards) and real-time weather information, the system provides deeper insights into harvests and enables aggressive disease management. Farmers receive targeted recommendations for controlling disease. B. Use of fertilizer based on irrigation adaptation or soil condition. This reduces the chances of disease spreading. The ability to predict disease risk based on environmental conditions allows farmers to take precautions and ultimately improve harvest resilience. Traditional disease management practices often rely on excessive use of pesticides, leading to chemical residues of food, ground reduction and water pollution. This system mitigates such problems by providing accurate and disease-specific recommendations to ensure that pesticides are used only in optimal amounts as needed. This targeted approach helps farmers reduce chemical waste that reduces input costs and promotes environmentally friendly, sustainable agricultural practices. This contributes to healthier ecosystems and long-term agricultural productivity. The mobile app allows you to identify image recordings and illnesses in real time, provides interactive dashboards to monitor field conditions, and provides personalized warnings and recommendations based on weather and terrestrial data. With user-friendly surfaces, the application makes it easy for farmers with limited technical knowledge to navigate and use the system. With direct recognition of progressive disease, the system is introduced directly to farmers, improving their ability to make healthy decisions in real time and reduce reliance on traditional time-consuming diagnostic methods. From an economic perspective, disease detection can help detect diseases that reduce harvest losses and lead to increased farmer income and increased profitability. Targeted pesticide applications minimize unnecessary costs and ensure better use of resources. Environmental compatibility prevents the reduction in pesticides that prevent soil degradation, protects water sources from chemical contamination, and promotes biological diversity. With the support of sustainable agricultural practices, this system contributes to the long-term health of the agroecosystem. Socially, this system offers cheap and accessible agricultural technology. In particular, they support smallholder farmers who may lack resources for expensive solutions for disease management. By preventing crop failures on a large scale, the system increases nutritional safety and enhances agriculture sustainability. By combining modern machine learning techniques with real-world environmental data analysis, the system optimizes disease detection and management, ensuring increased productivity and sustainability. Integration into mobile applications makes disease detection more practical and efficient, enabling farmers with real-time research and recommendations. This system could provide economic, ecological and social benefits, revolutionize the management of agricultural diseases, and pave the way for a more sustainable, technologically progressive and resilient agroecosystem.

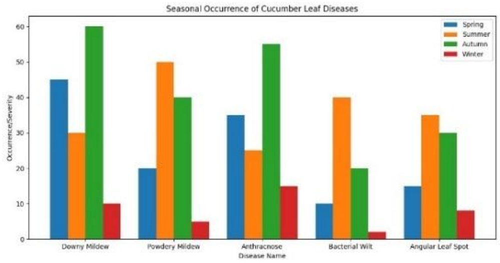


Fig.5 Bar chart for seasonal Occurrence of Cucumber Leaf Diseases

The data record and include a wide spectrum of leaf photographs from various environmental conditions, geographical locations and disease variations. A wider range of data records improve model accuracy and adaptability, ensuring effectiveness in a variety of agricultural environments. Furthermore, we consider advances in deep learning models to improve disease classification and possibly integrate the more demanding architecture of neuronal networks to improve characteristic extraction and computational efficiency. Another important aspect of future development is the improvements in mobile use to improve user-friendly, accessibility, and real time processing capabilities. Efforts have been made to support several languages, offline features and cloud-based synchronization. This means farmers all over the world, including remote worlds, can benefit from the system. The system can be expanded by integrating into smarter agricultural technologies such as IoT-based soil monitoring and drones that are supported by drones to support a wider range of plant and agricultural conditions. Ultimately, the project highlights the potential for technological transformation in agriculture and demonstrates how machine learning and practical data analysis can revolutionize traditional agricultural practices. By promoting precision agriculture and sustainable disease management, it contributes to increased yields, reduced environmental impacts, and improved nutritional safety. As agricultural technology continues to advance, the project paves the way for more intelligent, more efficient, and more environmentally contracted agricultural practices, ensuring more sustainable and food safety.

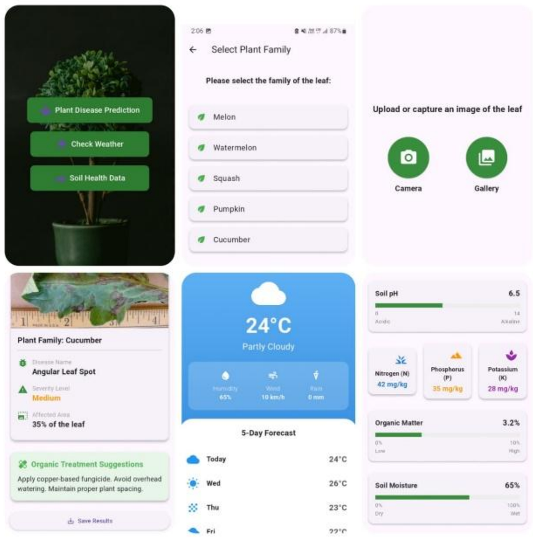


Fig.5 Output for Cucumber Leaf Disease Detection and Management System

This system was tested on several system samples from various regions with high accuracy in disease prediction and severity classification. Predictive models suggest suitable organic treatments to effectively identify plant diseases from images, classify severity levels, and minimize the use of chemical pesticides. Through the provision of targeted strategies for disease management, this system will help promote sustainable agricultural practices and reduce harvest losses.

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