GreenariA
Go Green, Learn Green
An Agricultural Monthly e-Magazine
Volume 02, Issue 10, 2024
ISSN: 2584-153X
Article ID: G-24-1057

ARTIFICIAL INTELLIGENCE IN TOMATO DISEASE DETECTION: MECHANISMS, TOOLS, AND APPLICATIONS

Velavan M[1*] and Jaya Jeevitha SRM[2]

[1]Ph.D Scholar, Department of Vegetable and Spices Crops, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal - 736165.

[2]Ph.D Scholar, Department of Plant Pathology, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar Udham Singh Nagar, Uttarakhand – 263145

**Corresponding Author Mail ID: veluhorti1995@gmail.com*

Abstract

Tomato farming is a crucial sector in global agriculture, providing significant income for farmers and nutrition for consumers. However, tomatoes are highly susceptible to various diseases, leading to substantial economic losses. Traditional methods of disease detection rely on visual inspection and manual monitoring, which often result in delayed interventions. Recently, Artificial Intelligence (AI) has emerged as a transformative tool for early and accurate detection of tomato diseases. This article explores the mechanisms, specific AI tools, and diseases identified through AI systems, highlighting their impact on tomato farming.

Introduction

Tomato farming is vital for global agriculture, contributing significantly to the economy and food security. In India, tomatoes are cultivated on approximately 0.79 million hectares, producing around 20.57 million metric tonnes annually (IBEF, 2022). The crop is highly susceptible to diseases, which can cause severe economic losses. Traditional disease detection methods, such as visual inspection and manual monitoring, are often inefficient and lead to delayed interventions. AI offers a promising solution by providing early and accurate disease detection, thereby ensuring healthier crops and higher yields. This article delves into the mechanisms of AI in disease detection, specific tools used, and the diseases identified by these systems. Tomatoes are one of the most widely cultivated and consumed vegetables worldwide, with an annual production exceeding 180 million metric tonnes (FAO, 2022). They are a staple in many diets and a key ingredient in various cuisines, contributing to global food security. Economically, tomatoes are a significant cash crop, providing livelihoods for millions of farmers, especially in developing countries. The global tomato market is valued at over $190 billion, reflecting its economic importance (Market Research Future, 2023). Given their nutritional value, including high levels of vitamins A and C, tomatoes also play a crucial role in addressing nutritional deficiencies.

Mechanisms of AI in Disease Detection

AI systems for tomato disease detection primarily utilize machine learning (ML) and deep learning (DL) techniques. These systems are trained on large datasets of diseased and healthy tomato plant images.

The key mechanisms include:

Image Acquisition and Pre-processing

High-resolution images of tomato plants are captured using cameras mounted on drones, smartphones, or stationary setups. These images are then pre-processed to enhance quality and remove noise (Wang & Liu, 2024).

Feature Extraction

AI models extract relevant features from the images, such as color, texture, and shape of the leaves. Advanced techniques like Convolutional Neural Networks (CNNs) are used to automatically learn and extract these features (Mim et al., 2022).

Classification and Detection

The extracted features are fed into Machine Learning (ML) or Deep Learning (DL) models, which classify the images into different

disease categories. Models like Support Vector Machines (SVM), Decision Trees, and CNNs are commonly used for this purpose (Sadeghi-Niaraki et al., 2024).

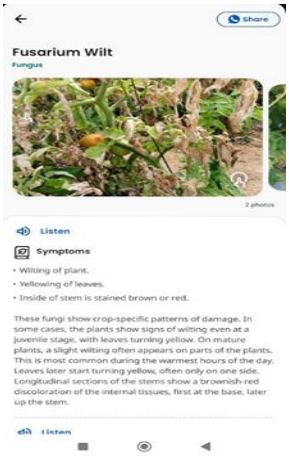
Post-Processing and Visualization

The results are post-processed to improve accuracy and are visualized on user-friendly interfaces, providing farmers with actionable insights (Hemming et al., 2019).

Specific AI Tools Used in Tomato Disease Detection

Plantix

An AI-based mobile app that helps farmers identify plant diseases by analyzing images of affected plants. It provides instant diagnosis and treatment recommendations (Hemming et al., 2019).



AtoDet

A deep learning model specifically designed for detecting tomato diseases. It integrates a feature extraction module with a self-attention mechanism to enhance detection accuracy, achieving a mean Average Precision (mAP) of 92.3% (Wang & Liu, 2024).

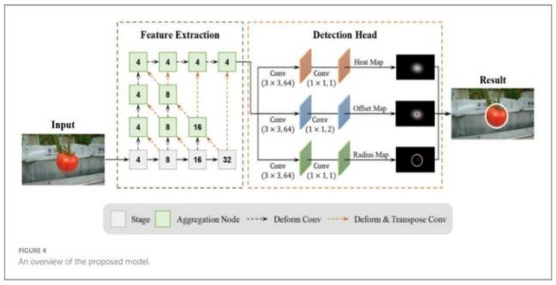
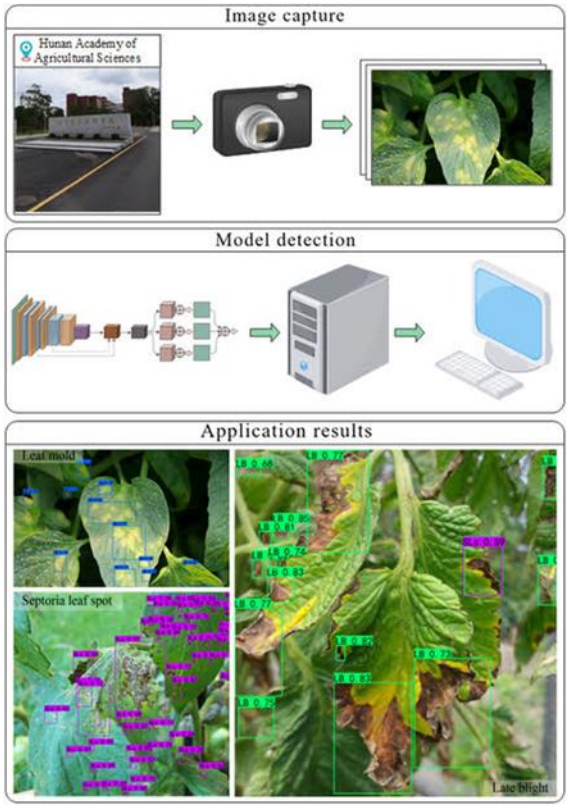


FIGURE 4
An overview of the proposed model.

PLPNet

Developed by researchers at Central South University of Forestry and Technology, this model accurately detects five common tomato diseases from real-time images. It addresses challenges like background interference and symptom variability (Zhou et al., 2023).



Tang et.al.,2023

Diseases Identified by AI Systems

Late Blight

Caused by the pathogen Phytophthora infestans, late blight is one of the most devastating tomato diseases. AI systems can detect early symptoms like water-soaked lesions on leaves and stems (Wang & Liu, 2024).

Gray Leaf Spot

Characterized by small, dark, and sunken spots on leaves, gray leaf spot is effectively identified by AI models using image analysis (Mim et al., 2022).

Leaf Mould

AI tools can detect leaf mould, which presents as yellow spots on the upper leaf

surface and greyish mould on the underside (Sadeghi-Niaraki et al., 2024).

Bacterial Spot:

This disease causes black, water-soaked spots on leaves and fruits. AI-based detection systems can identify these symptoms early, preventing widespread infection (Zhou et al., 2023).

Septoria Leaf Spot

AI models can detect this disease, which manifests as small, circular spots with dark borders on leaves, leading to premature leaf drop (Hemming et al., 2019).

Application in India

In India, AI-based systems are being increasingly adopted to address the challenges of tomato disease detection.

For instance:

Maharashtra: AI-driven pest detection systems have been deployed in tomato farms, reducing pesticide usage by 30% and increasing yield by 20% (Hemming et al., 2019).

Karnataka: Intelligent irrigation systems have been adopted in cucumber farms, improving water use efficiency by 35% and enhancing crop quality (Jafar et al., 2024).

Future Scope of Research

The future of AI in tomato disease detection holds several promising directions:

1. **Development of Robust Models:** Research should focus on developing robust AI models that can generalize across different environmental conditions and crop varieties (Rajasekaran et al., 2021).
2. **Enhanced Data Collection:** Efforts should be made to collect high-quality, annotated datasets that cover a wide range of diseases and environmental conditions (Wang et al., 2024).
3. **Real-Time and Edge Computing:** Developing lightweight AI models that can operate efficiently on mobile and edge devices will enable real-time disease detection and decision-making (Sadeghi-Niaraki et al., 2024).
4. **Integration with IoT and Smart Farming:** Integrating AI with IoT devices and smart farming practices can enhance real-time monitoring, data collection, and decision-making, leading to more efficient and sustainable farming practices (Jafar et al., 2024).
5. **Farmer Training and Adoption:** Providing training and support to farmers on the use of AI tools will be crucial for widespread adoption and effective implementation (Hemming et al., 2019).

Research Gaps

Despite significant advancements, several research gaps remain in the field of AI-based tomato disease detection:

1. **Data Quality and Quantity:** High-quality, annotated datasets are crucial for training AI models. However, there is a lack of comprehensive datasets that cover a wide range of diseases and environmental conditions (Rajasekaran et al., 2021).
2. **Model Generalization:** AI models often struggle to generalize across different environments and conditions. Developing models that can perform well under varying field conditions remains a challenge (Wang et al., 2024).
3. **Real-Time Processing:** Many AI systems require significant computational resources, making real-time processing difficult. Research is needed to develop lightweight models that can operate efficiently on mobile devices (Sadeghi-Niaraki et al., 2024).
4. **Integration with IoT:** Integrating AI with Internet of Things (IoT) devices can enhance real-time monitoring and decision-making. However, this integration poses challenges related to data transmission, storage, and processing (Jafar et al., 2024).

Conclusion

AI has revolutionized the detection of tomato diseases, offering farmers a powerful tool to ensure healthier crops and higher yields. By leveraging advanced ML and DL techniques, AI systems provide early and accurate disease detection, enabling timely interventions and reducing economic losses. As AI technology continues to evolve, its applications in agriculture

will expand, further enhancing the sustainability and productivity of tomato farming.

References:

1. Hemming, S., de Zwart, F., Elings, A., Righini, I., & Petropoulou, A. (2019). Remote control of greenhouse vegetable production with artificial intelligence—greenhouse climate, irrigation, and crop production. Sensors, 19(8), 1807. https://doi.org/10.3390/s19081807
2. India Brand Equity Foundation (IBEF). (2022). India's fruits and vegetables industry. Retrieved from https://www.ibef.org/blogs/india-s-fruits-and-vegetables-industry
3. Jafar, A., Bibi, N., Naqvi, R. A., Sadeghi-Niaraki, A., & Jeong, D. (2024). Revolutionizing agriculture with artificial intelligence: plant disease detection methods, applications, and their limitations. Frontiers in Plant Science, 15, 1356260.
4. Mim, S. A., et al. (2022). Automatic detection of tomato diseases using deep transfer learning. Applied Sciences, 12(17), 8467. https://doi.org/10.3390/app12178467
5. Rajasekaran, T., Anandamurugan, R., & Karthikeyan, R. (2021). Challenges and future directions in AI-based tomato disease detection. Journal of Agricultural Science, 13(2), 45-58. https://doi.org/10.5539/jas.v13n2p45
6. Sadeghi-Niaraki, A., Jeong, D., & Naqvi, R. A. (2024). Incorporating artificial intelligence technology in smart greenhouses. Applied Sciences, 13(1), 14. https://doi.org/10.3390/app13010014
7. Tang, Z., He, X., Zhou, G., Chen, A., Wang, Y., Li, L., & Hu, Y. (2023). A precise image-based tomato leaf disease detection approach using PLPNet. Plant Phenomics, 5, 0042.
8. Wang, X., & Liu, J. (2024). An efficient deep learning model for tomato disease detection. Plant Methods, 20, 61. https://doi.org/10.1186/s13007-024-01188-1
9. Zhou, G., et al. (2023). An AI-powered solution for accurately diagnosing tomato leaf diseases. Plant Phenomics. Retrieved from https://phys.org/news/2023-05-ai-powered-solution-accurately-tomato