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The Study of Current IoT Techniques Used in Plant Disease Detection

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Abstract

Plant diseases significantly affect global agricultural productivity and food security. Conventional disease detection techniques rely heavily on manual inspection, which is labor-intensive, time-consuming, and prone to subjectivity. The emergence of the Internet of Things (IoT) has enabled real-time monitoring of plant health and automated disease detection using interconnected sensors, imaging devices, and intelligent data processing frameworks. This paper presents a systematic review of current IoT techniques used in plant disease detection, focusing on sensor technologies, communication protocols, data processing platforms, and machine learning integration. A structured review methodology is adopted to analyze recent literature, and comparative tables are provided to highlight the strengths and limitations of existing systems. The study demonstrates that integrating IoT with artificial intelligence significantly improves detection accuracy, response time, and sustainability in precision agriculture.

1. Introduction

Agriculture remains the backbone of many economies worldwide; however, crop diseases continue to pose a major threat to food security and farmer livelihoods. Early disease detection and timely intervention are essential to minimize yield losses and reduce excessive pesticide usage. Traditional disease detection methods rely on visual inspection by agricultural experts, which is often costly, slow, and impractical for large-scale farming operations.

The Internet of Things (IoT) provides a promising alternative by enabling interconnected networks of sensors, cameras, and computing devices to collect and analyze plant and environmental data in real time. Advances in low-power sensing technologies, wireless communication, and cloud–edge computing architectures have made IoT-based plant disease detection systems more efficient, scalable, and accurate. This paper reviews recent IoT techniques used in plant disease detection and evaluates their effectiveness through a comparative analysis of existing approaches.

2. Review Methodology

To ensure a structured and unbiased review, a systematic methodology was followed.

2.1 Search Strategy

Relevant literature was collected from well-known scientific databases and digital libraries, including:

- IEEE Xplore
- ScienceDirect
- SpringerLink
- MDPI
- Google Scholar

Search queries included combinations of keywords such as “IoT-based plant disease detection,” “smart agriculture,” “sensor-based crop monitoring," "deep learning for plant disease," and "precision farming systems."

2.2 Inclusion and Exclusion Criteria

Inclusion Criteria:

- Studies published between 2019 and 2025
- Research focusing on IoT-enabled plant disease detection
- Papers integrating sensors, imaging systems, and AI/ML techniques
- Peer-reviewed journal articles and reputed conference papers

Exclusion Criteria:

- Studies not involving IoT components
- Non-agricultural disease detection systems
- Non-English publications and incomplete manuscripts

2.3 Review Process

Initially, over 120 articles were identified. After removing duplicates and applying inclusion criteria, 42 relevant papers were shortlisted. From these, 18 key studies were selected for detailed qualitative and comparative analysis based on system architecture, accuracy, scalability, and implementation feasibility.

3. Related Work

Several studies have explored the integration of IoT and artificial intelligence for plant disease detection. Rawat [1] demonstrated an IoT-based real-time disease monitoring system using environmental sensors to capture microclimatic conditions influencing disease outbreaks. Nguyen et al. [2] proposed edge-IoT devices combined with deep learning to reduce latency and cloud dependency.

Singh et al. [8] and Khan et al. [12] focused on continuous environmental monitoring using sensor networks, while Selvaraj et al. [7] and Narayanan et al. [13] emphasized AI-powered image-based disease classification using convolutional neural networks. Recent studies [14–18] introduced improved deep learning architectures, transfer learning, and hybrid sensor–image models to enhance robustness and early detection accuracy.

4. Background And Motivation

4.1 Importance of Plant Disease Detection

Plant diseases negatively impact crop yield, nutritional quality, and farmer income. Late detection often results in rapid disease spread and excessive chemical treatments. Early disease detection enables:

- Improved crop yield and quality
- Efficient use of water and fertilizers
- Reduced pesticide application
- Enhanced environmental sustainability

IoT-based disease detection systems support real-time monitoring and informed decision-making, making them essential for modern agriculture.

4.2 Role of IoT in Agriculture

IoT connects physical devices such as sensors, cameras, and actuators with digital platforms for data collection and analysis. In agriculture, IoT supports:

- Soil and environmental monitoring
- Automated irrigation and fertilization
- Pest and disease surveillance
- Crop growth tracking

Machine learning models process sensor and image data to generate actionable insights, enabling precision farming and sustainable agricultural practices.

5. IOT System Components For Plant Disease Detection

5.1 Sensors

- **Temperature and Humidity Sensors:** Identify disease-favorable climatic conditions
- **Soil Moisture Sensors:** Detect excess moisture linked to fungal infections
- **Light Sensors:** Monitor chlorophyll activity and plant stress
- **Gas Sensors:** Detect volatile organic compounds (VOCs) emitted by diseased plants
- **Optical and Multispectral Cameras:** Capture visual symptoms for image-based analysis

5.2 Communication Technologies

Common communication protocols include:

- Wi-Fi
- LoRaWAN
- ZigBee
- Cellular networks (3G/4G/5G)

Each protocol offers trade-offs in terms of range, energy consumption, latency, and data rate.

5.3 Data Processing Platforms

- **Edge Computing:** Low latency, reduced bandwidth usage, real-time decisions
- **Cloud Computing:** Scalable storage and advanced analytics

Hybrid Architectures: Combine edge responsiveness with cloud scalability.

6. Machine Learning And Ai Integration

Traditional machine learning algorithms such as Support Vector Machines (SVM), Random

Forests, and K-Nearest Neighbors (KNN) rely on handcrafted features from sensor and image data. Deep learning models, particularly Convolutional Neural Networks (CNNs), automatically extract hierarchical features and provide superior performance in image-based disease classification. Transfer learning using pretrained models such as ResNet and Inception further improves accuracy and reduces training time, especially with limited datasets.

7. Summary Of Recent Iot-Based Approaches

Table 1. Summary of Key Prior Works in IoT-Based Plant Disease Detection

Author & Year	Approach	IoT Components	AI Technique	Key Contribution
Rawat (2024)	Sensor-based	Env. Sensors	Rule-based ML	Real-time monitoring
Nguyen et al. (2025)	Edge IoT	Sensors + Edge	CNN	Low-latency detection
Selvaraj et al. (2019)	Vision-based	Camera	CNN	High accuracy for banana diseases
Narayanan et al. (2022)	Hybrid	Sensors + Camera	Hybrid CNN	Robust disease classification
Sangeetha et al. (2023)	Vision-based	Camera	Deep CNN	Improved Panama wilt detection

8. Comparative Analysis Of Iot System Types

Table 2. Comparative Analysis of Reviewed IoT Systems

System Type	Accuracy	Latency	Scalability	Cost
Sensor-Only Systems	Moderate	Low	High	Low
Vision-Based Systems	High	Moderate	Medium	Medium
Hybrid IoT + AI Systems	Very High	Low	High	High

This comparison highlights the trade-offs between system complexity, cost, and detection performance.

9. Challenges And Implementation Issues

Battery-powered devices often face challenges due to high energy consumption, which can reduce operational lifespan and reliability. Connectivity is also limited in many rural and remote areas, making consistent data transmission difficult. In addition, large-scale data processing requirements demand significant computational resources, increasing system complexity. Real-time detection constraints further add to the challenge by requiring fast and accurate processing with minimal delay. Finally, high deployment and ongoing maintenance costs can make implementing and sustaining such systems expensive.

10. Future Trends

Emerging trends include the adoption of 5G networks for ultra-low latency communication, integration of UAVs and drones for aerial crop monitoring, and the use of federated learning to enhance data privacy while enabling collaborative model training across farms. These advancements are expected to further improve scalability, accuracy, and sustainability in smart agriculture.

11. Conclusion

IoT-based plant disease detection systems have revolutionized traditional agricultural practices by enabling early, automated, and accurate disease identification. While challenges related to energy efficiency, connectivity, and cost remain, ongoing advancements in sensors, communication protocols, and AI algorithms continue to enhance system performance. Future research should emphasize scalable deployment, low-power architectures, and seamless integration with farm management platforms to fully realize the potential of IoT-driven precision agriculture.

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