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Use of Artificial Intelligence in Crop Disease Detection and Management

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Abstract

The integration of artificial intelligence (AI) technologies in agriculture has revolutionized crop disease detection and management practices. Traditional methods of disease identification often rely on visual inspection by experts, which can be time-consuming, subjective, and prone to human error. AI-powered systems, particularly those utilizing machine learning algorithms and computer vision, offer promising solutions for early detection, accurate diagnosis, and effective management of crop diseases. This article examines the current applications, benefits, challenges, and future prospects of AI in crop disease detection and management, highlighting its potential to enhance agricultural productivity and food security.

Keywords: AI in Agriculture, Crop Disease Detection, Precision Farming, Machine Learning in Agriculture, Smart Farming Technologies

Introduction

Global food security faces unprecedented challenges due to increasing population, climate change, and the persistent threat of crop diseases. Plant diseases cause substantial economic losses worldwide, with estimates suggesting that they reduce global crop yields by 20-40% annually. Traditional disease management approaches often involve reactive measures that may be implemented too late to prevent significant damage. The emergence of artificial intelligence technologies presents an opportunity to transform crop disease management from reactive to proactive, enabling farmers to detect and address diseases before they cause irreversible harm.

Artificial intelligence encompasses various technologies including machine learning, deep learning, computer vision, and natural language processing. In the context of agriculture, these technologies can analyze vast amounts of data from multiple sources, including satellite imagery, drone surveillance, sensor networks, and smartphone cameras, to provide real-time insights into crop health and disease status.

Current Applications of AI in Crop Disease Detection

Computer Vision and Image Recognition

Computer vision represents one of the most successful applications of AI in crop disease detection. Deep learning algorithms, particularly convolutional neural networks (CNNs), have demonstrated remarkable accuracy in identifying diseases from digital images of plant leaves, stems, and fruits. These systems can process thousands of images rapidly, identifying subtle visual patterns that may be missed by human observers.

Several commercial platforms and mobile applications now utilize computer vision for disease detection. Farmers can capture images of affected plants using smartphones and receive instant diagnoses along with treatment recommendations. For example, systems have been developed to detect common diseases such as late blight in potatoes, bacterial leaf streak in rice, and powdery

mildew in various crops with accuracy rates exceeding 90%.

Remote Sensing and Satellite Imagery

AI algorithms can analyze multispectral and hyperspectral satellite imagery to detect disease outbreaks across large agricultural areas. These systems monitor vegetation indices, chlorophyll content, and other spectral signatures that change when plants are stressed or diseased. Machine learning models can identify patterns in spectral data that correlate with specific diseases, enabling early detection before visual symptoms become apparent.

Remote sensing applications are particularly valuable for large-scale farming operations and government agencies monitoring regional crop health. The technology allows for continuous surveillance of vast agricultural areas, providing early warning systems for potential disease outbreaks.

IoT Sensors and Environmental Monitoring

Internet of Things (IoT) sensors deployed in agricultural fields collect real-time data on environmental conditions such as temperature, humidity, soil moisture, and air quality. AI algorithms analyze this data to predict disease risk based on environmental factors that favor pathogen development and spread. For instance, machine learning models can predict the likelihood of fungal infections based on humidity levels and temperature patterns.

These predictive models enable farmers to implement preventive measures such as adjusting irrigation schedules, applying protective treatments, or modifying environmental conditions in controlled environments like greenhouses.

AI-Powered Disease Management Strategies

Precision Application of Treatments

AI systems can optimize the application of pesticides, fungicides, and other treatments by determining the precise locations, timing, and quantities needed. Machine learning algorithms analyze disease distribution patterns, environmental conditions, and crop characteristics to create customized treatment plans that maximize effectiveness while minimizing chemical usage.

Variable rate application systems guided by AI can apply treatments only where needed, reducing costs and environmental impact. This precision approach is particularly important in the context of integrated pest management and sustainable agriculture practices.

Predictive Analytics and Risk Assessment

Advanced AI models utilize historical data, weather patterns, crop varieties, and local conditions to predict disease outbreaks before they occur. These predictive systems enable farmers to take proactive measures such as applying preventive treatments, adjusting planting schedules, or selecting resistant varieties.

Risk assessment models can also help farmers make informed decisions about crop insurance, resource allocation, and market planning based on predicted disease pressure and potential yield impacts.

Decision Support Systems

AI-powered decision support systems integrate multiple data sources and analytical tools to provide comprehensive recommendations for disease management. These systems consider factors such as disease identification, severity

assessment, treatment options, economic thresholds, and environmental impacts to suggest optimal management strategies.

Such systems serve as valuable tools for both experienced farmers and agricultural extension services, providing evidence-based recommendations that improve decision-making quality and consistency.

Benefits and Advantages

The implementation of AI in crop disease detection and management offers numerous benefits that address longstanding challenges in agriculture. Early detection capabilities enable intervention before diseases reach epidemic proportions, significantly reducing crop losses and economic impacts. The speed and accuracy of AI systems surpass traditional diagnostic methods, allowing for rapid response to emerging threats.

Cost reduction represents another significant advantage, as AI systems can optimize resource utilization, reduce unnecessary pesticide applications, and minimize labor requirements for field scouting. The scalability of AI technologies makes advanced disease management accessible to farms of all sizes, democratizing access to sophisticated agricultural tools.

Furthermore, AI systems continuously learn and improve their performance through exposure to new data, adapting to emerging diseases, changing environmental conditions, and evolving agricultural practices. This adaptive capability ensures that the technology remains relevant and effective over time.

Challenges and Limitations

Despite its promising potential, the implementation of AI in crop disease detection faces several challenges. Data quality and availability remain significant obstacles, as AI systems require large datasets of high-quality images and environmental data for training and validation. Many regions lack the infrastructure and resources needed to collect and maintain such datasets.

Technical challenges include the need for robust algorithms that can perform accurately under varying field conditions, lighting situations, and image qualities. The diversity of crop varieties, disease manifestations, and environmental conditions creates complexity that current AI systems may struggle to handle comprehensively.

Economic barriers also limit adoption, particularly among smallholder farmers who may lack access to smartphones, internet connectivity, or the financial resources needed to implement AI-powered systems. The digital divide in rural areas compounds these challenges, limiting the reach of technological solutions.

Additionally, the lack of standardized protocols and validation procedures for AI-based diagnostic systems raises concerns about reliability and consistency across different regions and crops.

Future Prospects and Emerging Technologies

The future of AI in crop disease detection and management appears promising, with several emerging technologies poised to enhance current capabilities. Edge computing and improved mobile processors will enable more sophisticated AI algorithms to run directly on smartphones and field devices, reducing dependence on internet connectivity and

cloud computing resources.

Integration with robotics and autonomous systems will enable automated disease detection and treatment application, further reducing labor requirements and improving precision. Advances in sensor technology, including low-cost hyperspectral cameras and environmental sensors, will provide richer data for AI analysis.

The development of explainable AI systems will improve farmer confidence and adoption by providing transparent reasoning for diagnostic decisions and treatment recommendations. These systems will help users understand why specific recommendations are made, facilitating better decision-making and system trust.

Conclusion

Artificial intelligence represents a transformative technology for crop disease detection and management, offering solutions to longstanding challenges in agricultural productivity and sustainability. While current applications demonstrate significant promise, realizing the full potential of AI in agriculture requires addressing technical, economic, and social barriers that limit widespread adoption.

The continued development of AI technologies, combined with improvements in data collection infrastructure and farmer education, will likely drive increased adoption and effectiveness of these systems. As AI becomes more accessible and reliable, it has the potential to significantly contribute to global food security by reducing crop losses and enabling more sustainable agricultural practices.

Success in implementing AI for crop disease management will depend on collaborative efforts among researchers, technology developers, agricultural extension services, and farmers to ensure that these powerful tools are practical, affordable, and accessible to those who need them most. The integration of AI into existing agricultural systems represents not just a technological advancement, but a fundamental shift toward data-driven, precision agriculture that can better meet the challenges of feeding a growing global population.

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