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AI-Integrated Plant Disease Scanning Applications: A Systematic Literature Review

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ABSTRACT.

The evolution of digital technology has revolutionized the modern agricultural landscape, gradually incorporating the detection and management of plant diseases. In this work, we aimed to provide a systematic review addressing the state-of-the-art regarding the application of plant disease scanning embedded in artificial intelligence, subsistent from the newest literature as possible. The literature reviews from multiple sources revealed that Big Data and machine learning algorithms like Convolutional Neural Network (CNN) enhance the efficiency of plant disease identification. It has also been proven that integrated scanning systems in combination with the Internet of Things are able to monitor the conditions of plants in real time and provide accurate management recommendations. The integration of AI, IoT, and data analytics provide smart plant to achieve faster, effective, and accurate plant health management data mining through machine-learning methods.

Keywords: AI, plant, machine learning, scan, agriculture, plant, disease

1. Introduction

Agriculture is one of the most important pillars for food security and economic self-sufficiency of a country. A literature search from different sources revealed that big data [1] and machine learning algorithms such as Convolutional Neural Network [2] can be utilized to enhance the efficiency of plant disease identity. Integrated scanning systems linked with the Internet of Things have also been shown to be able to monitor the condition of plants in real-time and give accurate management recommendations. AI, IoT and data analytics integration presents opportunities for faster, more efficient and accurate management of plant health. [3] [4] demonstrate early detection of plant diseases using machine learning and AI. Pest and Plant Disease control is one of the Biggest Contributors to Increasing agricultural productivity. The amount of something due to plant disease attacks can amount to billions of dollars per annum[5]. Digital technology has enabled many increasingly accurate and efficient mechanisms to address challenges in the management of plant diseases. Over conventional methods, image processing, and machine learning techniques based on Artificial intelligence have been demonstrated capable of identifying

plant diseases with a higher degree of accuracy. Although the use of big data [1] provides new approaches for more effective management in agriculture, its application in public services has not been sufficiently optimized for the discovery of plant diseases. Big data is not only about big data volumes in agriculture but also data velocity, variety, and veracity. Data is collected, analysed and the information is extracted to implement big data in a successful manner to derive plant disease detection. Conventional methods are limited in their speed and accuracy and this, along with a growing demand for improved plant disease management, has necessitated the development of more advanced plant disease detection technologies [7]. Deep learning and computer vision-based AI technologies hold great promise in this area. Notably, deep learning enables machines to learn from large volumes of data and identify the complex relationships between features found in plant diseases [8]. Plant disease detection using computer vision is a technique used to visually identify the symptoms of diseases visually. The combination of AI tech and IoT allows for monitoring the status of a plant over time, which is essential for early identification and efficient and exact management of diseases. An AI and IoT based pest warning system[9[10]

Furthermore, the development of big data platforms in the agricultural field [11] also contributes to the improvement of plant disease detection and management capabilities. These platforms enable the integration of data from various sources, including image data, environmental data, and plant genetic data, for more comprehensive analysis. [12] demonstrates the great potential of big data analysis in agriculture for achieving smarter agriculture

2. Methodology

Although many studies have been conducted on the application of digital technology in plant disease detection, comprehensive reviews that integrate various cutting-edge approaches, especially those focused on practical field applications, are still limited. Much research has focused on the development of AI models and algorithms [13] [14] [15], but lacks discussion on the overall system integration, including hardware, software, and supporting infrastructure. [16] mentions the potential of AGI to bridge the gap between AI models and practical field applications.

In-depth analysis of the potential, challenges, and implementation recommendations for AI-integrated plant disease scanning applications, particularly in the context of existing agricultural systems, is needed to drive wider technology adoption in the agricultural sector. [17] emphasizes the importance of automating leaf disease detection using AI and IoT. However, [18] highlights the challenges in improving the accuracy of sensor-based plant disease measurements. [19] also discusses the opportunities and challenges in plant disease recognition using deep learning with limited and imperfect datasets. [20] shows how remote sensing can complement plant disease monitoring on a larger scale. [21] discusses plant disease sensing and large-scale plant-pathogen interaction studies. [22] offers a solution for real-time detection of post-harvest grape diseases using a lightweight CNN model. [23] discusses an API for plant disease detection and recognition using computer vision.

Further research is also needed to evaluate the effectiveness and efficiency of AI-integrated plant disease scanning systems in various environmental conditions and plant types.

Aspects such as scalability, ease of use, and implementation costs also need to be considered so that this technology can be widely accessed and adopted by farmers.

Research Objectives

The purpose of this study is to conduct a systematic literature review of their application in the process of scanning plants integrated with artificial intelligence techniques. The particular objectives are: This study will perform a systematic literature review of the use of plant disease scanning combined with artificial intelligence. The specific objectives are: 1. To identify and evaluate the state-of-the-art AI technologies applied for plant disease detection, including image processing, machine learning, and deep learning. 2. Examine the potentials, challenges, and recommendations for the AI-integrated plant disease scanning systems for their possible field application. 3. Insights into the future research and development direction of AI-based plant disease scanning technology

Research Questions

Based on the research objectives above, the research questions for this study are as follows:

1. What AI technologies have been used for plant disease detection, and what is their performance and potential for further development?
2. What are the challenges and recommendations for implementing AI-integrated plant disease scanning systems, particularly in the practical context of the agricultural sector?
3. What is the future development direction of AI-based plant disease scanning technology, and what research opportunities are still open?
4. What AI technologies have been used for plant disease detection, and what is their performance and potential for further development?
5. What are the challenges and recommendations for implementing AI-integrated plant disease scanning systems, particularly in the practical context of the agricultural sector?
6. What is the future development direction of AI-based plant disease scanning technology, and what research opportunities are still open?

3. Results and Discussion

1. What AI technologies have been used for plant disease detection, and what is their performance and potential for further development?
   Various AI technologies have been used for plant disease detection, including: [24]

   1) Computer vision and digital image processing: These methods utilize machine learning and deep learning algorithms to identify visual patterns that indicate diseases on plant leaves, stems, or fruits [25]. Disease recognition accuracy can reach over 90% in good dataset conditions. [23] [26]

2) Machine learning: Models such as Support Vector Machine, Random Forest, and Logistic Regression have been used to classify plant diseases based on morphological, spectral, or textural features of the plants. [26]
3) Deep learning: Convolutional architectures like CNN have shown excellent capabilities in detecting plant diseases through digital image analysis [26] [27] [23].

While these technologies show promising performance, the main challenge is the need for large and diverse datasets to train the models effectively.

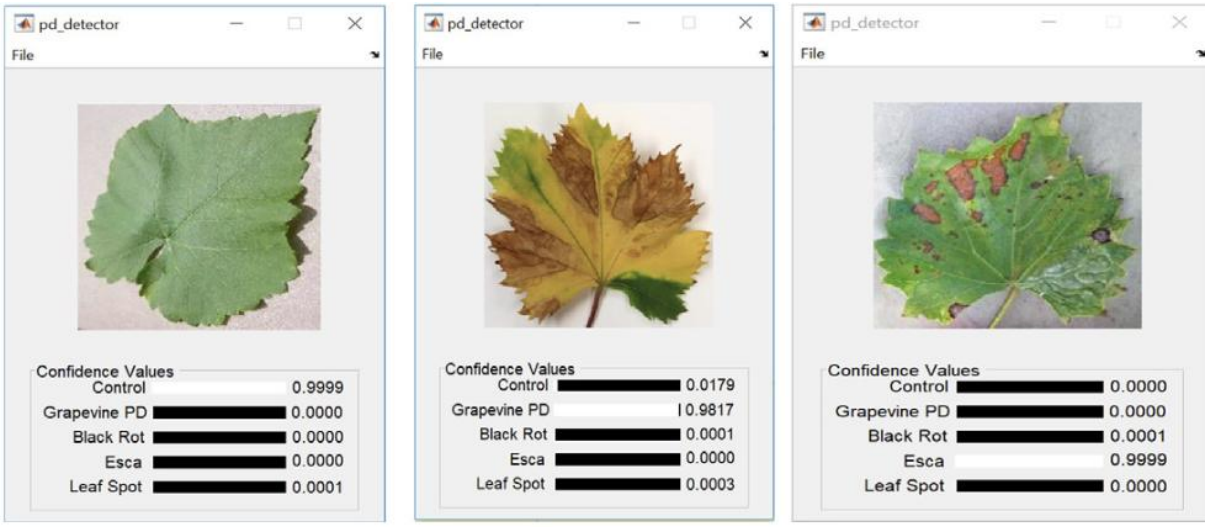

Figure 1. Example of a program that results from image capture ready to be sent to a machine learning server.

Table 1. Articles related to what AI technologies have been used for plant disease detection

Article	Author	Year	Topics	Main findings
[5]	Taranjeet Singh, K. Vinay Kumar, SS Bedi	2021	A Review on Artificial Intelligence Techniques for Disease Recognition in Plants	Farmers traditionally relied on experts or on their own experience to diagnose their crops' diseases. But the old crop monitoring is now be gradually superseded by the smart techniques which are more reliable, precise, swift and affordable than the former ones. This article highlights some researchers worldwide proposed techniques based on machine learning and image processing to classify diseases in plants and then follows with a discussion that can provide future research insight in this area.

[24]	Yiannis Ampatzidis	2018	Applications of Artificial Intelligence for Precision Agriculture	With advanced technologies in certain fields such as computer vision, mechatronics, artificial intelligence, and machine learning, it is now possible to develop and deploy remote sensing methods for identifying and managing plants, weeds, pests, and diseases. This paper elaborates the definition of artificial intelligence (Al) and machine learning and several examples showing the utilization of Al in agriculture.
[25]	Kurniawan Irfan Nauval, Sri Lestari	2022	Implementation of Potato Leaf Disease Object Detection with Convolutional Neutral Network Method	One use of digital image research in solving problems in this research is identifying diseases on potato plant leaves. This research aims to create a system that can help farmers or agricultural managers identify diseases on potato leaves by utilizing potato leaf image data.
[26]	Ruchika Sharma, Nagesh Kumar, Brij Bhushan Sharma	2022	Applications of Artificial Intelligence in Smart Agriculture: A Review	Research in the agriculture field poses numerous challenges related to soil properties, pest management, irrigation, post-harvest management, knowledge gap in farmers, and latest technology. Al can be a significant part of the solution to such challenges. This paper reviews comprehensive literature on artificial intelligence in context of advantages and disadvantages in managing disease, post-harvest crop management, soil properties and crop growth and management.

2. The main challenges in implementing AI-integrated plant disease scanning systems in the agricultural sector are:

1. Environmental and plant condition variability: Differences in soil type, climate, or plant growth stage can affect detection accuracy. AI systems need to be trained on representative data for various conditions to work effectively in the field. [28]

2. Data availability: Deep learning models require large and high-quality datasets for training. Collecting and labeling plant disease data can be expensive and time-consuming [29]. This challenge is exacerbated by a lack of standardization in data collection.

3. System integration: Integrating AI-based scanning systems with existing agricultural systems, including hardware, software, and supporting infrastructure, can be complex and challenging.

4. Accuracy and reliability: While AI promises high accuracy, the accuracy of AI models can be influenced by factors such as image quality, disease symptom variability, and lighting conditions. The system must be reliable and accurate across various conditions to be trusted by farmers.
5. Result interpretation: Interpreting AI scanning results and translating them into appropriate control actions requires specialized knowledge and skills. Farmers need to be trained to use these systems effectively.
6. Implementation cost: The hardware, software, and infrastructure required for implementing AI-based scanning systems can be expensive, especially for small-scale farmers.
7. Connectivity and infrastructure: AI-based scanning systems often require adequate internet connectivity and digital infrastructure, which may not be available in all agricultural areas.
8. Scalability: Deploying AI-based scanning systems at a large scale can be challenging, especially in areas with complex topography or limited access.
9. Data privacy and security: The use of agricultural data raises privacy and data security issues that need to be addressed.

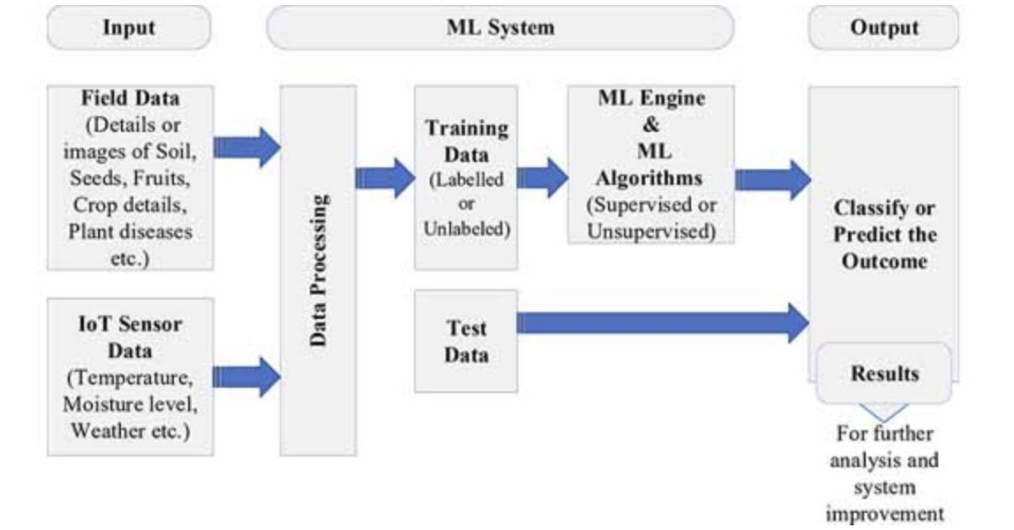

Figure 2 : The process of sending information data to the ML server for analysis and deciding on results

Table 1. Article related to Key challenges in implementing AI-integrated plant disease scanning systems in the agricultural sector

Artikel	Penulis	Tahun	Metode	Temuan Utama
[27]	Ersin Elbasi, Nour Mostafa, Zakwan Al-Arnaout, Aymen I	2022	Artificial Intelligence Technology in the Agricultural Sector: A Systematic Literature Review	Quality and safety of agricultural products is one of major concern in today's scenario. In earlier times farmers consults experts or use their own experience for identification of diseases in their crops but now days intelligent techniques are slowly replacing the monitoring of crops as they are more reliable, accurate, fast and economical in comparison to earlier techniques. This paper discusses few techniques based on machine learning and image processing that were presented by researchers all over the world for recognition of diseases in crops, later discussions are presented that can be helpful for improvements in this domain.

3. What is the future development direction of AI-based plant disease scanning technology, and what research opportunities are still open?
Based on the literature review, the future development direction of AI-based plant disease scanning technology includes:

1) Development of more accurate and robust deep learning algorithms: Deep learning models continue to experience rapid development, with increasingly sophisticated architectures and better generalization capabilities.
2) Integration of IoT sensors and robotics: Scanning systems will be increasingly integrated with IoT sensors, drones, and robots to enable more comprehensive data collection and faster response.
3) Utilization of multi-sensor and multimodal data: The use of multispectral, hyperspectral, thermal, or 3D imaging will improve disease detection accuracy.
4) Development of AI-based expert systems: These systems will integrate AI scanning capabilities with a broad knowledge base to provide more accurate disease diagnosis and control recommendations.

Some research opportunities that are still open include:

- Development of rich, standardized, and open plant disease datasets to support AI research in this field.
- Investigation of data augmentation techniques to improve the quality and diversity of training data.

- Exploration of transfer learning and active learning models to reduce the need for large labeled data.
- Development of disease scanning algorithms that can adapt quickly to environmental variability.

The application of AI technology, particularly computer vision and machine learning, has shown significant potential in early detection and classification of plant diseases [30] [31]. Various methods, such as digital image processing, machine learning, and deep learning, have been utilized to identify visual patterns that indicate disease symptoms on plants [24] [28].One example of its application is in the identification of leaf, stem, or fruit diseases of plants through digital image analysis. The very high accuracy of disease recognition, reaching over 90% in good dataset conditions, demonstrates the great potential of this technology [24] [28] [26].Additionally, machine learning models such as Support Vector Machine, Random Forest, and Logistic Regression have also been utilized to classify plant diseases based on the morphological, spectral, or textural features of the plants [24] [28].Deep learning with convolutional architectures like CNN has shown excellent capabilities in detecting plant diseases through digital image analysis. Although these technologies show promising performance, the main challenge is the need for large and diverse datasets to effectively train the models.Furthermore, the integration of AI-based scanning systems with existing agricultural infrastructure, such as IoT sensors, drones, and data analytics platforms, is also an interesting area to explore further.

4. Conclusion

So far the literature review demonstrates the greater potential of AI technology primarily computer vision and machine learning in diagnosing and classifying plant diseases at an earlier stage. Digital imaging processing, machine learning and deep learning are some of the techniques used to detect the visual patterns for disease appearance on the plants with higher level of accuracy. The technology can offer numerous solutions to address these challenges but there are still a couple of challenges that need to be overcome like large and diverse datasets needed to train algorithms as well as integration of the solutions with the existing agricultural infrastructure and processing of the scanning results by the farmers. Future Research Work − Development of plant disease datasets, data augmentation techniques, transfer learning & adaptive scanning algorithms are the promising areas of future research work. It is hoped that AI-integrated plant disease scanning applications can be used as an effective tool to reduce the threat of plant diseases by enabling farmers to identify and control plant diseases early, given the rapid growth of AI technology.

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