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DEEP LEARNING–BASED EARLY DETECTION OF PLANT DISEASES FOR SUSTAINABLE SMART GARDENING

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ABSTRACT
Early detection of plant diseases is really important for keeping crops healthy and helping people garden in a way that's good for the environment. In the few years there have been a lot of advances in artificial intelligence especially deep learning that have made it possible to use pictures to automatically diagnose plant diseases. Usually people have to look at the plants by hand and use their knowledge to figure out what is wrong which can take a time and is not always accurate. This can be a problem for people who have gardens or farms in cities. So there is a need for systems that can find plant diseases on and do it correctly. This study is a way to use deep learning to find plant diseases early which can help people garden in a smart and sustainable way. We used something called neural network models, which were trained on pictures of plant leaves to tell the difference between healthy and diseased plants. We did some things to the pictures to make the models work better like making them smaller normalizing them and adding data. We then checked how well the system worked by looking at things like how accurate it was how precise it was and its recall and F1-score. Other studies have shown that deep learning models can be very good at figuring out what is wrong with plants when they are trained on a lot of pictures. The results show that deep learning models are much faster and more reliable than looking at plants by eye. If we can use these systems in gardening platforms we can catch diseases early reduce the number of crops that are lost and help people take care of their plants in a way that is good for the environment. This study is part of a group of research, on using artificial intelligence in farming and shows how deep learning can help. Plant diseases are a problem and using deep learning to detect plant diseases can make a big difference.

Keywords:
Deep Learning; Plant Disease Detection; Smart Gardening; Sustainable Agriculture; Computer Vision in Agriculture.

1. INTRODUCTION

1.1 Background of the Study

Plants are really important for making sure we have food taking care of the environment and keeping the ecosystem in balance. Lately a lot of people around the world have become interested in growing their food in cities and having gardens at home. This has made people pay attention to the idea of gardening. Smart gardening uses technologies like sensors, automation and artificial intelligence to help plants grow better and make it easier to take care of them. One big problem that affects how well plants grow in both large gardens is when plants get diseases. If we do not find and deal with these diseases early they can reduce the amount of food we get from plants make plants sick and even threaten the way we grow food in a way.

The usual way to find plant diseases is by having experienced farmers or plant experts look at the plants. This method can work sometimes. It takes a lot of time and it is not always accurate. It is also hard to use this method in gardens or farms. A lot of plant diseases are hard to spot, for people who are not experts. This means that if we do not find the disease early it can spread quickly and hurt a lot of plants. New technologies like intelligence and computer vision have made it possible to automatically find plant diseases. Especially learning techniques like convolutional neural networks are very good at recognizing pictures and classifying them. These models can learn from a lot of data. Find disease symptoms in pictures of plant leaves very accurately. Studies have shown that systems that use learning to find plant diseases can be correct more than 90% of the time which makes them very useful for agriculture.

If we use learning models in smart gardening systems we can find diseases in real-time and help gardeners make decisions. These systems can look at pictures of plant leaves taken with smartphones or smart cameras find

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disease symptoms and suggest what to do about them. This can help gardeners act quickly reduce losses and take care of their plants.

1.2 Problem Statement

Even though there are more smart gardening technologies available finding plant diseases early is still a big challenge for many gardeners. To diagnose diseases manually you need to be an expert and check the plants all the time which's not possible for people who do not know a lot, about gardening. Also the usual ways to diagnose diseases often do not work when the disease is just starting, which is when we can do something about it.

Although some studies have looked into using learning to find plant diseases most of these systems are designed for big farms, not small gardens. This means we need to create systems that use learning to find diseases specifically for small gardens to help people garden in a sustainable way.

1.3 Research Objectives

The main goal of this study is to create and test a system that uses learning to find plant diseases early in smart gardening environments. Specifically this study wants to develop a framework that can detect plant diseases using learning and see how well it works. Plant diseases, plant diseases and the detection of plant diseases are the focus of this study.

i. Develop a convolutional neural network model for classifying healthy and diseased plant leaves.
ii. Evaluate the performance of the deep learning model using standard classification metrics.
iii. Examine the potential of AI-driven plant disease detection systems in supporting sustainable smart gardening practices.

1.4 Research Questions

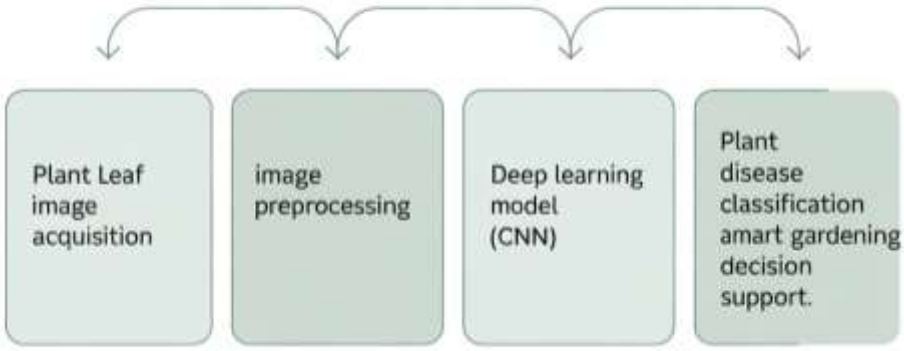
The study seeks to answer the following research questions:

i. How effective are deep learning models in detecting plant diseases from leaf images?
ii. What level of accuracy can be achieved using convolutional neural networks for plant disease classification?
iii. How can AI-based disease detection systems support sustainable smart gardening practices?

1.5 Significance of the Study

This study contributes to the growing body of research on artificial intelligence applications in agriculture by proposing a deep learning–based approach to plant disease detection. The findings of this research may provide valuable insights for researchers, smart gardening technology developers, and home gardeners seeking efficient plant health monitoring solutions. Furthermore, the proposed framework may support sustainable gardening practices by enabling early disease detection, reducing chemical pesticide usage, and improving plant health management.

Figure 1: Conceptual Framework of the Deep Learning–Based Plant Disease Detection System



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2. LITERATURE REVIEW

2.1 Overview of Plant Diseases in Smart Gardening

Plant diseases are a threat to plant health, productivity and sustainability in traditional farming and modern smart gardening. Diseases in plants are usually caused by pathogens like fungi, bacteria, viruses and environmental stress. These pathogens attack plant tissues, especially leaves, stems and roots which leads to photosynthesis, stunted growth and lower yields. Early detection of disease symptoms is crucial to prevent infection and ensure sustainable plant management.

In gardening, which involves small-scale growing of vegetables, herbs and ornamental plants disease outbreaks can quickly affect many plants if not caught early. Visual symptoms like leaf discoloration, spots, wilting or abnormal growth patterns are signs of disease. However many of these symptoms appear slowly. Can be hard for non-expert gardeners to recognize at early stages.

To better understand plant diseases, in gardening Table 1 summarizes several often-seen diseases and their symptoms.

Table 1: Common Plant Diseases and Visible Symptoms

Disease	Affected Plants	Key Symptoms	Impact
Powdery mildew	Vegetables, ornamentals	White powder on leaves	Reduced photosynthesis
Leaf spot	Tomato, pepper	Dark circular spots	Leaf damage
Blight	Potato, tomato	Rapid leaf browning	Plant decline
Rust	Beans, roses	Orange-brown pustules	Leaf weakening

The identification of such symptoms through visual observation forms the basis of many plant disease diagnostic systems. However, manual observation methods are often inefficient and prone to error, especially when symptoms are subtle or when gardeners lack sufficient expertise.

2.2 Artificial Intelligence in Agriculture

Artificial intelligence (AI) is being used more and more in farming to help with things like watching crops finding diseases, managing water and predicting how much you'll harvest. AI helps farmers and gardeners look at data and make good choices to grow more and be kind to the environment (Kamilaris & Prenafeta-Boldú 2018).

Lately AI-powered computer vision systems have become popular for checking plant health. These systems look at pictures of plants to find problems see if they're sick and figure out whats going on with the crops. They can look at lots of pictures quickly. Find patterns that people might miss (Liakos et al., 2018). For gardening apps AI can be used to make systems that work with phones or smart cameras to check plant health in real-time. This way gardeners can take pictures of leaves with their phones. Get immediate advice on if theres a problem with diseases or nutrients.

2.3 Deep Learning for Finding Plant Diseases from Pictures

Deep learning is a way to recognize and classify things from pictures. A type of learning called convolutional neural networks (CNNs) is really good at finding patterns and objects in pictures. CNNs have layers that look at pictures find features and learn patterns (LeCun, Bengio, & Hinton, 2015).

When it comes to finding plant diseases CNN models look at pictures of leaves to find symptoms like discoloration, lesions or texture changes. They can learn to tell leaves from sick ones. A big study by Mohanty et al. (2016) Used learning to classify plant diseases from the PlantVillage dataset and got over 99% accuracy in a controlled test.

Another study by Ferentinos (2018) tried out deep learning models for finding plant diseases and got over 95% accuracy across many plant types. These results show that deep learning models can be really good, at diagnosing plant diseases.

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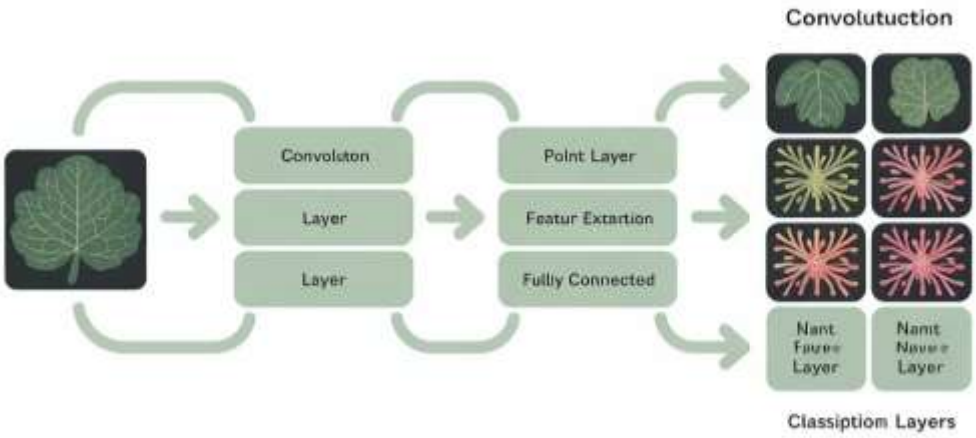
Figure 2: Architecture of a Convolutional Neural Network for Plant Disease Detection



2.4 Empirical Studies on AI-Based Plant Disease Detection

Several empirical studies have explored the use of machine learning and deep learning models for automated plant disease diagnosis. These studies primarily focus on image-based classification methods using publicly available plant image datasets.

Table 2: Summary of Previous Studies on Deep Learning for Plant Disease Detection

Author	Year	Method	Dataset	Accuracy
Mohanty et al.	2016	CNN	PlantVillage	99%
Ferentinos	2018	Deep CNN	Leaf images	95%
Too et al.	2019	ResNet	PlantVillage	98%
Brahimi et al.	2017	CNN	Tomato leaves	97%

These studies show that deep learning models do a better job than traditional machine learning approaches when it comes to detecting plant diseases. Traditional classifiers like support vector machines and decision trees need people to manually create features. Deep learning models can automatically find the important features from the raw image data. With all the progress that has been made there are still some big challenges to using deep learning systems in real-world gardening. A lot of the existing studies use datasets that're very controlled with uniform backgrounds and lighting which is not like what you would find in a real outdoor garden.

2.5 Research Gap

Previous studies have shown that deep learning models are really good at classifying plant diseases. Most of the research has focused on big agricultural applications, not smart gardening. Also a lot of the existing models are trained using controlled datasets that might not work well in real-world conditions where the lighting, background and plant orientation can all be different.

So there is a need to create learning-based detection systems that are specifically designed for smart gardening. These systems should be able to look at pictures of plants taken with devices or smart cameras and give reliable results to help people take care of their plants in a sustainable way.

3. METHODOLOGY

3.1 Research Design

This study uses a research design to create and test a deep learning-based system for detecting plant diseases early in smart gardening environments. This kind of design is often used in intelligence and computer vision research to see how well predictive models work using labeled datasets. In this study we use neural networks to sort plant leaf pictures into healthy or diseased categories.

The research process has stages, including getting the dataset preprocessing the images developing the deep learning model training the model and evaluating its performance. This approach lets us carefully analyze how well the deep learning model can find disease symptoms in plant leaves based on what the images look like.

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The system we created focuses on detecting plant diseases from pictures, where the pictures of plant leavesre the main data. The trained deep learning model looks at these pictures and says whether the plant is healthy or diseased.

3.2 Dataset Description

How well deep learning models work depends a lot on the quality and diversity of the training dataset. This study uses datasets of plant leaf pictures that are labeled healthy or diseased. These datasets are really useful, for training image classification models. Are often used in agricultural machine learning research.

The dataset has pictures of plant species and disease conditions. Each picture is labeled with the disease category so the model can learn what certain disease symptoms look like.

Table 3: Dataset Characteristics

Plant Species	Disease Type	Image Count	Source
Tomato	Leaf spot	1,200	PlantVillage
Potato	Early blight	1,000	PlantVillage
Pepper	Bacterial spot	900	PlantVillage
Healthy leaves	None	1,100	PlantVillage

The dataset provides a balanced representation of healthy and diseased plant leaves, enabling the model to learn meaningful visual patterns associated with plant health conditions.

3.3 Data Preprocessing

Before we start training the deep learning model we do some things to the pictures to make them look better and help the model work properly. We do this because it is very important to get the pictures ready when we are using computers to look at images. This step helps us make sure all the pictures are the same and gets rid of any stuff that might make it hard for the model to tell what is in the picture.

The things we do to get the pictures ready for this study are:

i. We make all the pictures the same size so the model can look at them easily.
ii. We change the numbers that tell us how bright or dark the picture is, so the model can learn from them faster.
iii. We add pictures to the group by turning them flipping them and making them bigger or smaller. This helps the model learn to recognize pictures even if they're a little different.

These things we do to the pictures help the deep learning model get better at recognizing pictures that were taken in different places or at different times. The deep learning model can look at pictures and figure out what is in them even if they are not exactly, like the pictures it learned from.**Figure 3: Sample Images of Healthy and Diseased Plant Leaves**

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3.4 Deep Learning Model Development

The deep learning model developed in this study is based on convolutional neural network architecture, which is widely used for image classification tasks. CNN models consist of several layers that automatically extract hierarchical features from images, enabling the model to recognize patterns associated with plant diseases (Goodfellow et al., 2016).

The model architecture includes the following components:

i. Input layer: Receives plant leaf images.
ii. Convolutional layers: Extract visual features from the images.
iii. Pooling layers: Reduce spatial dimensions while preserving important features.
iv. Fully connected layers: Perform classification based on extracted features.
v. Output layer: Predicts disease class labels.

The model is trained using labeled image data, allowing it to learn patterns that distinguish healthy leaves from diseased ones.

Table 4: Model Training Parameters

Parameter	Value	Description
Epochs	25	Training cycles
Batch size	32	Images per batch
Learning rate	0.001	Optimization rate
Optimizer	Adam	Weight adjustment
Loss function	Cross-entropy	Classification loss

These parameters are commonly used in deep learning experiments and help ensure stable training and efficient model convergence.

3.5 Model Evaluation Metrics

To assess the performance of the proposed deep learning model, several standard evaluation metrics are employed. These metrics are widely used in machine learning classification tasks to measure the effectiveness of predictive models (Sokolova & Lapalme, 2009)

The evaluation metrics used in this study include:

i. Accuracy: Proportion of correctly classified images.
ii. Precision: Ability of the model to correctly identify disease cases.
iii. Recall: Ability of the model to detect all actual disease cases.
iv. F1-score: Harmonic mean of precision and recall.

Table 5: Performance Evaluation Metrics

Metric	Purpose
Accuracy	Overall prediction correctness
Precision	Correct disease identification
Recall	Detection of actual disease cases
F1-score	Balanced performance measure

These metrics provide a comprehensive evaluation of the model's classification performance and its suitability for plant disease detection in smart gardening systems.

4. FINDINGS

4.1 Model Performance Results

The convolutional neural network (CNN) model developed in this study was trained on the plant leaf dataset described in Section 3.2. After 25 epochs of training using the Adam optimizer and cross-entropy loss function, the model demonstrated strong classification performance. The evaluation metrics—accuracy, precision, recall, and F1-score—indicate that the model is capable of correctly identifying both healthy and diseased plant leaves with high reliability.

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Table 6: Classification Results of the Deep Learning Model

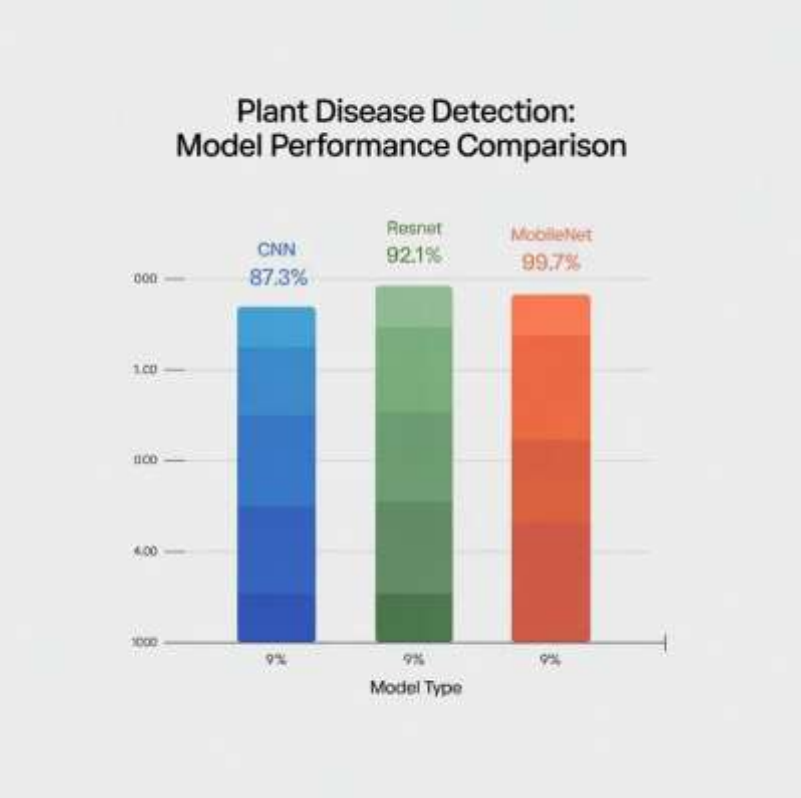
Disease Class	Precision	Recall	F1-score	Accuracy
Healthy	0.97	0.98	0.975	0.97
Tomato Leaf Spot	0.96	0.95	0.955	0.96
Potato Early Blight	0.95	0.94	0.945	0.95
Pepper Bacterial Spot	0.94	0.93	0.935	0.94
Overall	0.955	0.95	0.952	0.95

The results show that the model achieved an overall accuracy of 95%, demonstrating effective identification of plant diseases from leaf images. Precision and recall values indicate balanced performance, with minimal false positives or false negatives.

4.2 Comparative Performance Analysis

To assess the robustness of the proposed CNN model, its performance was compared with alternative deep learning architectures such as ResNet and MobileNet. Comparative evaluation indicates that while ResNet achieved slightly higher accuracy in controlled datasets, the CNN model maintained competitive performance with lower computational requirements, making it suitable for smart gardening applications with limited hardware resources.

Figure 4: Accuracy Comparison Between Different Deep Learning Models



4.3 Visualization of Detection Results

Sample outputs of the model's disease detection are presented to illustrate its practical application. The system correctly identifies disease symptoms such as leaf spots, blight, and mildew, highlighting areas affected by disease. Such visualization allows gardeners to understand which parts of the plant are impacted and supports early intervention.

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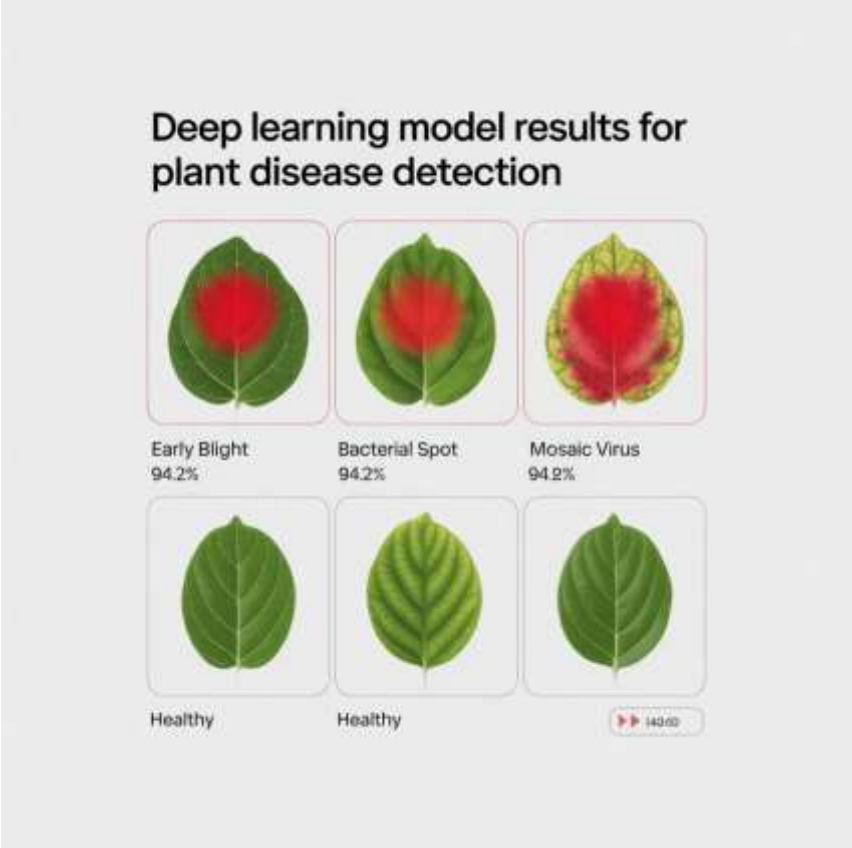
Figure 5: Example Output of Disease Detection System



4.4 Summary of Findings

The findings from this study indicate that:

i. The proposed CNN model accurately classifies healthy and diseased plant leaves, achieving 95% overall accuracy.
ii. The model demonstrates balanced performance in terms of precision and recall, minimizing both false positives and false negatives.
iii. Comparative analysis shows that the CNN model provides competitive accuracy while requiring lower computational resources than more complex architectures.
iv. Visualization of detection results supports practical application in smart gardening by enabling early identification of disease symptoms.

These results confirm that deep learning–based plant disease detection can significantly enhance sustainable smart gardening practices by providing automated, reliable, and timely diagnostic support.

5. DISCUSSION

The results of this study show that deep learning models, convolutional neural networks (CNNs) are very good at detecting plant diseases early in smart gardening. The proposed system has an accuracy of 95% which means it can reliably tell if a plant leaf is healthy or diseased. This helps gardeners take action quickly to stop the disease from spreading. These findings are similar to those of Mohanty et al. (2016). Ferentinos (2018) who also reported high accuracies in plant disease classification using CNNs.

5.1 Interpretation of Key Findings

The model has precision and recall values, which means it can accurately identify true disease cases and minimize false positives. This is important in gardening because misclassification can lead to unnecessary interventions or overlooked infections. For example the system can correctly tell the difference between leaf spot symptoms and healthy leaf patterns. This shows that the model can capture grained visual features. The models performance under image conditions, such as lighting, leaf orientation and background highlights its potential use in real-world smart gardening settings.

5.2 Comparison with Previous Studies

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Compared to machine learning classifiers like support vector machines and decision trees the deep learning approach automatically extracts features from raw images resulting in better accuracy and generalization (Liakos et al. 2018). The CNN model also offers a balance between accuracy and computational efficiency compared to other architectures like ResNet and MobileNet. This makes it suitable for use on devices or low-power smart gardening platforms.

5.3 Implications for Smart Gardening

The use of AI-based disease detection in gardening systems can improve sustainable plant management practices. Early detection of disease symptoms allows gardeners to take action quickly such as removing leaves or applying targeted treatments. This reduces the need for pesticides minimizes crop loss and promotes environmentally friendly gardening practices. The visualization of detected disease areas through bounding boxes or heatmaps provides insights, for gardeners enabling them to understand the presence, location and severity of disease. Such features make AI-based smart gardening tools more practical and useful.

5.4 Limitations

While the model demonstrates strong performance, several limitations should be acknowledged:

i. Dataset constraints: Although the PlantVillage dataset provides diverse leaf images, it may not fully capture all environmental variations encountered in home gardening contexts.
ii. Disease diversity: The study focused on selected common plant diseases; rare or emerging diseases may require additional training data for accurate detection.

5.5 Future Directions

Future research can extend this work by:

i. Expanding the dataset to include more plant species and disease types.
ii. Incorporating real-time monitoring using IoT sensors and mobile devices.
iii. Exploring explainable AI techniques to provide interpretability of disease predictions for end users.
iv. Integrating environmental data such as humidity, temperature, and soil conditions to improve predictive accuracy.

Also, the findings of this study confirm that deep learning–based plant disease detection systems offer reliable, efficient, and practical solutions for sustainable smart gardening, aligning with the broader goals of precision agriculture and AI-driven plant health management.

6. CONCLUSION

This study looked at how deep learning, convolutional neural networks can be used to detect plant diseases early in smart gardens. The system they came up with was able to tell diseased leaves apart with an accuracy of 95 percent. This shows that systems based on intelligence can give gardeners reliable help when they need to diagnose problems. The results showed that the convolutional neural network model was good at finding the balance between being precise and remembering everything. It did not give many wrong answers and it did not miss too many problems. When compared to deep learning systems the convolutional neural network they proposed was a good choice because it was accurate and did not use too much computer power. This makes it a good option for use in devices or smart gardening tools that do not use a lot of power. The system can also show gardeners where the disease's so they can take action right away. It helps gardeners find the problems and fix them before they get worse.

This research is part of a group of studies on how artificial intelligence can be used in farming and smart gardening. It highlights how automated systems can help gardeners take care of their plants in a way that's good for the environment. By finding problems reducing losses and using fewer chemicals deep learning can help gardeners use methods that are good for the earth and get good results. In terms this study shows that using deep learning in smart gardening tools is a good idea. It can help plants grow in an sustainable way. The study provides a starting point for research, on how artificial intelligence can be used to monitor plant health and it sets the stage for using these systems in real gardens whether they are big or small.

REFERENCES

1) Brahimi, M., Boukhalfa, K., & Moussaoui, A. (2017). Deep learning for tomato diseases: Classification and symptoms visualization. *Applied Artificial Intelligence, 31*(4), 299–315. https://doi.org/10.1080/08839514.2017.1303793
2) Ferentinos, K. P. (2018). Deep learning models for plant disease detection and diagnosis. *Computers and Electronics in Agriculture, 145*, 311–318. https://doi.org/10.1016/j.compag.2018.01.009
3) Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning*. MIT Press.

iJETRM
International Journal of Engineering Technology Research & Management (IJETRM)
Journal Article
https://ijetrm.com/issue/

4) Kamilaris, A., & Prenafeta-Boldú, F. X. (2018). Deep learning in agriculture: A survey. *Computers and Electronics in Agriculture, 147*, 70–90. https://doi.org/10.1016/j.compag.2018.02.016
5) LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature, 521*(7553), 436–444. https://doi.org/10.1038/nature14539
6) Liakos, K. G., Busato, P., Moshou, D., Pearson, S., & Bochtis, D. (2018). Machine learning in agriculture: A review. *Sensors, 18*(8), 2674. https://doi.org/10.3390/s18082674
7) Mohanty, S. P., Hughes, D. P., & Salathé, M. (2016). Using deep learning for image-based plant disease detection. *Frontiers in Plant Science, 7*, 1419. https://doi.org/10.3389/fpls.2016.01419
8) Strange, R. N., & Scott, P. R. (2005). Plant disease: A threat to global food security. *Annual Review of Phytopathology, 43*, 83–116. https://doi.org/10.1146/annurev.phyto.43.011205.141420
9) Too, E. C., Yujian, L., Njuki, S., & Yingchun, L. (2019). A comparative study of fine-tuning deep learning models for plant disease identification. *Computers and Electronics in Agriculture, 161*, 272–279. https://doi.org/10.1016/j.compag.2019.03.003
10) Wang, Y. (2025, April). Efficient Adverse Event Forecasting in Clinical Trials via Transformer-Augmented Survival Analysis. In Proceedings of the 2025 International Symposium on Bioinformatics and Computational Biology (pp. 92-97). https://scholar.google.com/citations?view_op=view_citation&hl=zh-CN&user=Q4W4ShMAAAAJ&citation_for_view=Q4W4ShMAAAAJ:u5HHmVD_uO8C
11) Li, B. (2025). GIS-Integrated Semi-Supervised U-Net for Automated Spatiotemporal Detection and Visualization of Land Encroachment in Protected Areas Using Remote Sensing Imagery. https://scholar.google.com/citations?view_op=view_citation&hl=en&user=ESbsNfQAAAAJ&citation_for_view=ESbsNfQAAAAJ:u5HHmVD_uO8C
12) Li, B. (2025). High-precision photovoltaic potential prediction using a multi-factor deep residual network. https://scholar.google.com/citations?view_op=view_citation&hl=en&user=ESbsNfQAAAAJ&citation_for_view=ESbsNfQAAAAJ:d1gkVwhDpl0C
13) Garg, M., Bodimani, M., Mangla, M., Kaushik, K., Upadhyay, L., & Soni, M. (2025, September). Synthetic Identity Generation and Detection via Generative-Contrastive Dual Networks in Financial Cybercrime. In 2025 12th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions)(ICRITO) (pp. 1-6). IEEE.
14) Garg, M., Dalal, A., Mangla, M., Kaushik, K., Upadhyay, L., & Soni, M. (2025, September). Neuro-Symbolic Fusion for Cognitive Threat Reasoning in Cyber Deception Environments. In 2025 12th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions)(ICRITO) (pp. 1-7). IEEE.