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Plant Disease Detection using Machine Learning

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Abstract

Plants are essential for human life as they provide vigor and help mitigate the effects of global warming. Currently, various diseases like leaf spots, blights, rusts, mildews, leaf curling, discolouration, wilting, chlorosis, necrosis, stunted growth and premature leaf drop are affecting plants. These diseases considerably diminish crop yield and quality. Therefore, early revealing of plant diseases is significant in agriculture, as identifying them at a primary stage is important for effective disease management. This article aims to perceive plant leaf diseases using machine learning techniques such as CNN, Random Forest and ResNet-50, which afford faster, more precise and computerized disease finding from leaf images. CNN and ResNet-50 effectively extract composite image features for correct disease classification, while Random Forest provides stable forecasts with reduced over-fitting. These technologies provision early disease diagnosis, reduce pesticide usage and crop losses and support precision agriculture and sustainable farming practices.

Keywords: Convolutional Neural Network (CNN), Plant disease, Random forest, Resnet-50

Introduction

Plant diseases are an important threat to agricultural productivity, food security and farmers income around the world. Plant disease is an irregular illness that disrupts the regular growth, development or functioning of a plant. It may cause by pathogenic organisms such as fungi, bacteria, viruses and nematodes. Diseases that upset the leaves, which are the crucial organs responsible for photosynthesis, are called as plant leaf diseases. These conditions produce noticeable symptoms such as leaf spots, blights, rusts, mildews, curling, discoloration, wilting, chlorosis, necrosis, stunted growth and premature leaf drop. Because leaves show a crucial role in energy production, leaf diseases meaningfully reduce plant strength and finally lead to decreased crop yield. Traditional methods for finding these diseases depend largely on manual field inspections and professional knowledge. These processes are frequently time consuming, subjective and not simply available to small and marginal farmers. Delayed or inaccurate diagnoses can result in severe yield losses; extreme use of pesticide and higher production costs. With the upsurge of smart agriculture, plant disease detection has changed into a data driven and automated process. This is possible through the use of machine learning (ML), deep learning (DL), computer vision and environmental sensing technologies. These systems inspect crop images and agro climatic features like temperature, humidity, rainfall and pesticide use to spot diseases early, even before noticeable symptoms worsen. In smart agriculture platforms, sensing plant diseases serves as a defensive layer. It works alongside crop recommendations and yield predictions. By continuously monitoring crop health and environmental conditions, the system measures disease risk levels, classifies disease harshness and provides timely information for preventive or corrective actions. These aids farmers make informed decisions, use pesticides astutely and reduce crop losses. Automated plant disease detection supports sustainable farming by cutting down on worthless chemical use, improving crop quality and confirming efficient use of resources. Thus, plant disease detection systems are vigorous for turning traditional farming into precision agriculture. They help increase productivity, encourage environmental sustainability and boost resilience against climate change. This article aims

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to find the classification rules for agricultural crops using machine learning techniques.

Pathogen Factors

Disease causing agents comprise fungi (*e.g.*, rusts, mildews and blights), bacteria (*e.g.*, leaf spots and wilts), viruses (*e.g.*, mosaic diseases) and Nematodes are microscopic worms that injury plant roots and may also affect the leaves. These pathogens attack plant tissues and disrupt normal physiological processes, primary to disease development. Their movement and spread are sturdily influenced by environmental conditions such as high humidity, rainfall and temperature, which can favour pathogen development and infection. In addition, poor soil drainage, dense planting, improper irrigation practices, imbalanced pesticide use, poor field cleanliness and climate unpredictability can enhance pathogen survival, multiplication and transmission, thereby increasing the harshness of plant diseases.

Classification of Plant Diseases by Causal Agent

Plant diseases are commonly classified according to their causal agents, which can be broadly divided into non-infectious (abiotic) and infectious (biotic) disease-causing agents (Rana *et al.*, 2023).

1. Non-Infectious Disease-Causing Agents

Non-infectious plant diseases are caused by unfavourable environmental or physiological factors somewhat than living organisms and they are not communicable from one plant to another. Common causes contain nutrient deficiencies or toxicities (*e.g.*, nitrogen deficiency, excess salts), temperature stress (frost injury, heat stress), water stress (drought or water-logging), chemical injury (overuse of pesticides or fertilizers), air pollution (ozone, sulphur dioxide), soil pH unevenness and poor soil structure or compaction.

2. Infectious Disease-Causing Agents

Living organisms cause contagious plant diseases and can spread from one plant to another through air, water, soil, insects or farming tools. Main infectious agents include fungi, bacteria, viruses, nematodes and phytoplasmas. Some plant viruses are microscopic contagious agents that require a living host to multiply. They are usually transmitted by insects (vectors) such as aphids, whiteflies, thrips, mites, jassids *etc*. Their characteristics includes they cannot live independently. They cause systemic infections. Some common viral diseases include mosaic rice ragged stunt virus, rice grassy stunt virus, chilli leaf curl and bhindi yellow vein mosaic (YVM) *etc*. Another disease-causing agent caused by fungi, they are the most common and destructive plant disease agents. They succeed in warm and humid environments and attack leaves, stems, roots and fruits. Their features include they produce spores for reproduction. They spread through air, water, soil and seeds. They frequently cause visible symptoms on leaves. Common fungal diseases include rusts, powdery mildew, downy mildew, leaf spot and blight.

Plant Disease Detection Techniques

1. Convolutional Neural Network (CNN)

It is widely used for automatic plant disease verdict from leaf images due to its capability to study complex visual patterns. The technique involves several key steps (Shelar *et al.*, 2022).

a) Input Layer: The input to a CNN is an image, usually represented as a matrix of pixel values (RGB or grayscale). Images are resized and normalized before being served into the network.

b) Convolution Layer: Applies filters (kernels) that glide over the image. Each filter extracts indigenous features like edges, textures and shapes. It produces feature maps highlighting significant patterns connected to diseases.

Mathematical operation:

$$\text{Convolution} = (\text{Input Image} \times \text{Filter}) + \text{Bias}$$

c) Activation Function (ReLU): Rectified Linear Unit (ReLU) introduces non-linearity. It converts negative values to zero and keeps affirmative values unchanged. It helps the network acquire complex patterns efficiently.

d) Pooling Layer: It reduces the longitudinal size of feature maps. Max pooling is regularly used to retain dominant features. It reduces computation and avoids over-fitting.

e) Fully Connected Layer: It flattens the pooled feature maps into a single vector. It connects learned features to the output cover. It performs high-level cognitive and decision-making.

f) Output Layer: It uses Softmax (for multi-class classification) or Sigmoid (for binary classification). It produces class possibilities (*e.g.*, healthy leaf, fungal disease, viral disease).

g) Training Process: It uses back-propagation and gradient descent to reduce loss. The model updates weights iteratively to advance accuracy.

Benefits of Convolutional Neural Network (CNN)

a) High Accuracy: CNN is automatically identifying important image features, leading to more accurate disease detection.

b) Automated Feature Extraction: Save time and minimise errors by eliminating the essential for manual feature selection.

c) Fast Detection: CNNs quickly analyse images for real-time diagnosis.

d) Early Detection: Identifies diseases at early stages to inhibit crop loss.

e) Scalability: Handles huge datasets and increases with more data.

f) Adaptability: Can be retrained for different crops and diseases.

g) Reduced Human Intervention: Less dependence on experts.

h) Easy Integration: Can be used in mobile apps and smart farming tools.

i) Improved Productivity: Helps in improved disease management and higher yield (Figure 1).

2. Random Forest

Random Forest is a machine learning algorithm mostly used for classification tasks, although it can also be applied to regression problems. It involves of a huge number of verdict trees that collectively form a "forest." Each decision tree is

trained on a dataset and makes its own forecast. The final output is determined by majority voting in classification or by averaging in regression. Random Forest decreases overfitting by combining the predictions of several trees, making it more consistent and precise than a single decision tree. It does capably on large datasets and provides better stability and correctness without requiring extensive data scaling. Additionally, the model maintains high correctness even when new data is added, thereby making it one of the utmost effective methods and extensively used machine learning algorithms nowadays.

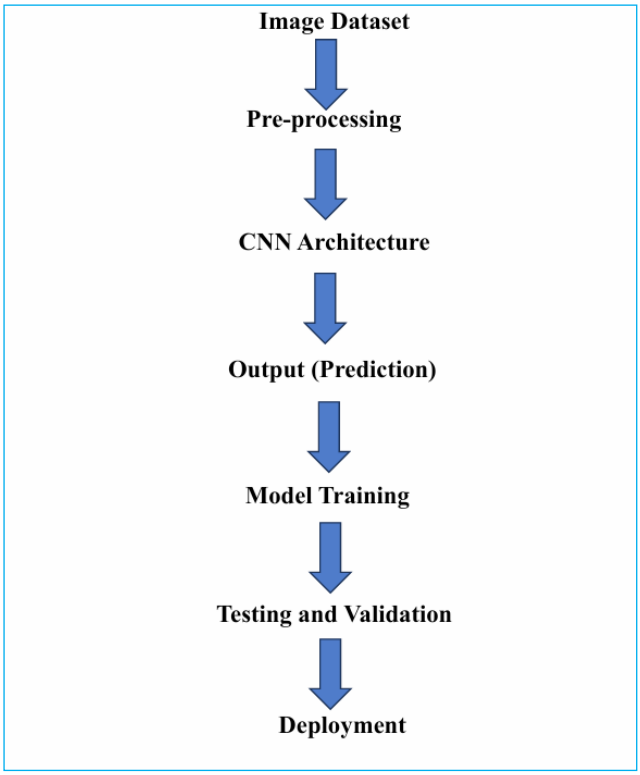

Figure 1: Plant Disease Detection using convolutional Neural Network

3. Resnet50

ResNet-50 is a deep CNN architecture comprising of 50 layers, developed by Microsoft Research in 2015. It is one of the most prevalent pre-trained deep learning models and is commonly used for image classification, object detection and plant disease detection through transfer learning techniques.

Advantages

a) Deep architecture with 50 layers enables actual extraction of complex image features.

b) Usages residual learning, which aids overcome the vanishing gradient problem in deep networks.

c) Broadly used as a pre-trained model for transfer learning, reducing training time and computational cost.

d) Performs well in plant disease identification and other agricultural image analysis applications.

e) More constant and effective compared to traditional CNN architectures.

Disadvantages

a) Requires high computational power and memory for training and implication.

b) Training can be time-consuming on huge datasets without GPU support.

c) The model is relatively complex and tough to interpret.

d) Large model size may not be fit for low-resource or mobile devices.

e) Performance is highly dependent on the quality and quantity of the training data.

f) Fine-tuning the model for specific applications may require technical expertise.

Conclusion

Exposure of plant disease using machine learning techniques has occurred as an effective tactic for improving modern agriculture. Traditional disease identification methods are frequently time-consuming, labor-intensive and dependent on expert knowledge, whereas automated systems offer faster, more correct and consistent diagnosis. Techniques such as Convolutional Neural Networks (CNN), Random Forest and ResNet-50 play an important role in detecting plant diseases from leaf images with high accuracy. Among these methods, CNN and ResNet-50 are effective in extracting complex image features and detecting diseases at early stages, while Random Forest offers stable and accurate classification with reduced overfitting. These technologies support precision agriculture by enabling timely disease management, reducing avoidable pesticide use, curtailing crop losses and improving crop productivity.

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