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An Extensive Study on Disease Prediction in Mango Trees Using Computer Vision

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ABSTRACT

Mango belongs to the Family Anacardiaceous, is also known as the king of fruits is India's most important commercial fruit crop. Due to its wide production, it's susceptible to many factors that affect its production. Microbes like fungi, bacteria, parasites, algae cause diseases in Mangoes in all phases of its growth, starting from its initial stage of seedling till the consumption of fruits. The diseases are capable of manifesting themselves as several kinds of rot, dieback, mildew, necrosis, scab, blotch, anthracnose, stem bleeding, wilt, spots, canker, sooty mold, and malformation. Diseases in plants cause major production loss as well as economic loss. Hence, it is most important that the plants are analyzed before taking effective control actions. This survey paper analyses the various computer vision techniques used to identify and predict the diseases that affect the mango trees.

Keywords

Mango Disease; Deep learning; Disease Prediction; Computer Vision.

Introduction

In India, agriculture performs a substantial part in feeding both human and cattle populations worldwide. A unique feature of Mango is that it is easily cultivable as it can adapt to any factors like climate, soil and place. It plays a pivotal role as the chief supplementary diet in many countries where the consumption is vast in tropical areas such as America, Africa. Mango contributes around 18.1 percent of India's total GDP in the agricultural sector. India is the largest producer of Mangoes as it is considered an essential agricultural product and contributes around 52.63 percent of the total world production rate. Regardless of all this, the mango cultivators are facing many dire challenges leading to a negative growth rate. Countless factors affect mangoes' production, ranging from bacterial, fungal diseases, or factors like climate changes, soil infertility. However, the major reason for this downturn is the farmers' difficulty in determining the diseases that affect the mango trees. Microbes like fungi, bacteria, parasites, algae cause diseases in Mangoes in all phases of its growth, starting from its initial stage of seedling till the consumption of fruits. Other kinds of diseases are also caused by nutritional deficiencies and unknown etiologies [1]. Mango fruit disorders are ailments caused by some external factors that result in some form of physical damage like blemishes appearing on the surface of the fruit. This declines the quality and lowers the cost. The diseases are capable of manifesting themselves as several kinds of necrosis, mildew, rot, stem bleeding, wild, sooty mold, and malformations. Figure 1 lists the microbial diseases which affect the mango trees and figure 2 lists the nutrient deficient diseases observed in mango trees.

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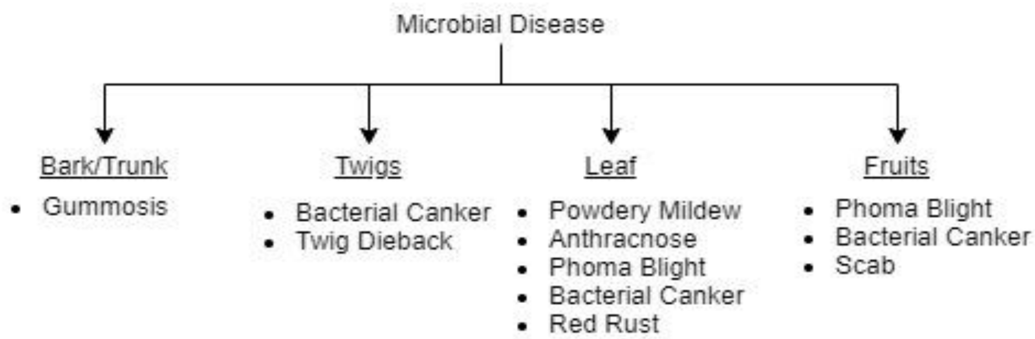

Figure 1. Microbial diseases affecting mango trees

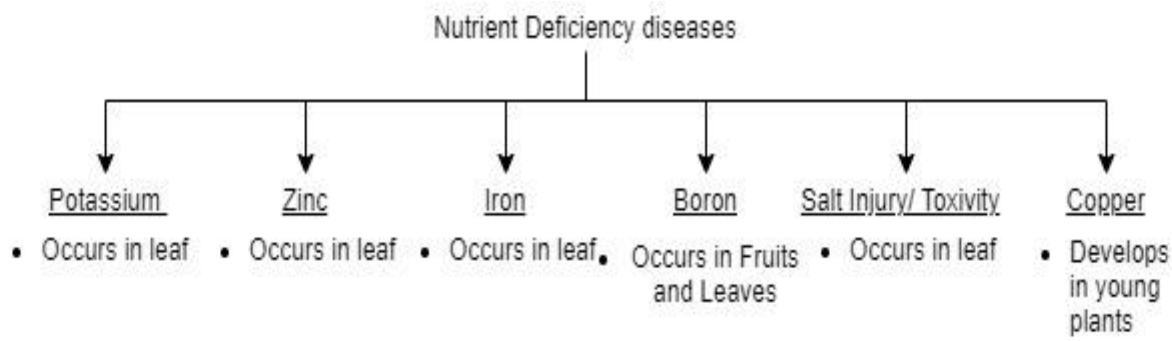

Figure 2. Nutrient deficient diseases observed in mango trees

If the mangoes are affected by these diseases, it will heavily impact productivity and reflect on the cost. Bacterial canker, anthracnose, blacktip, dieback, mildew, malformation, sooty mold, and phoma blight are of major concern to India's cultivators. The only effective method of reducing losses from most mango diseases is by prevention. Therefore, it is very crucial to identify the diseases in the early stages to safeguard the trees and prevent any economic losses and increase crop productivity for the farmers. This survey paper discusses and compares the various computer vision techniques used for detecting and identifying the various diseases that occur in Mango trees.

Literature Review

Mustafa Merchant et al. [1] presented a clustering methodology [1] to detect nutrient deficiencies in mango trees by extracting, comparing RGB and texture characteristics of mango leaf images captured by a high-definition camera. Preprocessing techniques like contract enhancement and rescaling is done for better feature extraction. By using the k means clustering algorithm, the leaves are categorizing into healthy or diseased leaves, which are further categorized as Potassium, Iron, Nitrogen, Copper deficient. This algorithm can help in early detection of deficiency and help the farmers to take countermeasures to minimize the risk of plants' unhealthy growth. Implementing machine learning methodologies with computer vision techniques like pattern recognition, classification, and object extraction has proved to be an efficient solution for early plant disease prediction. Hence UdayPratap Singh et al. [2] proposed a contemporary model named "Multilayer Convolution Neural Network" [2], which classifies the mango leaf images as healthy or infected with Anthracnose fungal disease. The performance of this system is compared

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with approaches like Radial basis function Neural network, Particle swarm optimization, Support Vector Machine. The high performance of the proposed work is justified by achieving an accuracy rate of 97.13% and is also computationally efficient and straightforward.

The concept of early disease detection is done by identifying small blobs on the plant images that can be identified only using higher resolution images using an “Artificial Neural Network model”. Tan Nhat Pham et al. [3] uses a "wrapper-based feature selection approach" called Adaptive Particle-Grey Wolf metaheuristic for feature selection. The chosen features are sent as inputs for the model, and when compared with the other CNN architectures like ResNet-50, AlexNet, and VGG16, the proposed approach achieved an accuracy rate of 89.14%.Among all the CNN architectures, AlexNet architecture has a high recall and precision values. In this extensive survey [4] of classification of diseases between AlexNet and CNN performed by Sunayana Arya et al. [4], it is concluded that AlexNet architecture's performance is better in terms of the dataset used. Compared with other pre-trained CNN architectures like DenseNet, GoogleNet, SqueezeNet, RestNet, and VGGNet in terms of the whole system, the AlexNet architecture model performs really well.

Arivazhagan S et al. [5] proposed a "deep learning-based" approach that automates the detection of Mango leaf diseases such as Leaf Gall, Anthracnose, Leaf Webber, Alternaria leaf spots, Leaf burn of Mangoes. The presented methodology [5] is trained using 600 images with 100 images per diseases classification class and tested using 600 images accounting for 1200 plant leaf images. The system achieved an accuracy rate of 96.67% for detecting the leaf diseases in mango plants by justifying the feasibility of real-time application usage. B Prakash et al. [6] proposed a system that uses the BPNN technique for segmentation purposes. By using K-means clustering technique, the classification process is performed. The complication in manual detection and identification of mango leaf disease is resolved using the proposed Back Propagation Neural Network model. This proposed methodology is tested with a different number of clusters, test datasets that constructs a mango leaf disease identification and control prediction system with the best performance having an accuracy of 94%.

MeenakshiSood et al. proposed an algorithm [7] that identifies the diseases affecting the capsicum and classifies them as healthy or infected, having bacterial or fungal diseases like anthracnose or bacterial canker. These disease symptoms are detectable by inspecting the plants’ parts, like either the stem or leaves. The extraction of features like the infected region on the leaf is done by k means clustering and classification by Decision Tree, Linear Discriminant, K-Nearest Neighbor, and Support vector classifiers with KNN and SVM, giving the best results with an accuracy of 100%.
By considering a pre-trained model trained from the ImageNet dataset, this transfer learning approach is followed for the proposed system called INC-VGGNet [8] for detection of diseased plant leaf images. This proposed approach by Junde Chena et al. [8] presented a substantial performance improvement by achieving a validation accuracy of 92% when compared to other state-of-the-art approaches like DenseNet-201, ResNet-50, Inception V3. This deep learning architecture, when experimented with PlantVillage dataset, proved the efficiency in the detection and also the validity of the proposed approach.

Detection of disease is done in this methodology proposed by Swetha K et al. [9] is by identifying the affected lesion areas by anthracnose using a thresholding segmentation technique

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by taking intensity, size of the spots into consideration. The intensity of the spots has been considered as a parameter to predict the percent of infected areas in many existing algorithms. Along with features like Thresholding, the area and perimeter of the affected parts are also considered, resulting in a more accurate calculation of the affected area because of the combination of these features.Md. Rasel Mia et al. [10] proposed the "neural network ensemble model" for mango leaves disease detection, which helps identify diseases efficiently instead of the manual method. This method [10] contemplates detecting mango leaf diseases, like "Dag disease", "Golmachi", "Moricha disease", "Shutimold", using machine learning by supervising different leaf types symptoms. Images of disease-infected leaves are collected, and training data is produced using the classification technique. The proposed model is capable of classifying the examined disease with a combined average accuracy of 80% (average of accuracies of all diseases) and help in early detection of disease and treating the infected plant with necessary treatments and thus increasing the production of mangoes.

A convolutional neural network model approach [11] proposed by Konstantinos P. Ferentinos is developed for plant disease detection and diagnosis using plant leaves dataset through many “deep learning methodologies”. Several other CNN model architectures like AlexNet, GoogLeNet are trained, with VGG Convolutional neural network reaching a success rate of 99.53% in identifying the corresponding combination (or healthy plant). Based on that high level of performance, it becomes evident that convolutional neural networks are highly suitable for the automated detection and diagnosis of plant diseases by analyzing simple plant leaf images.Parul Sharma et al. [12] proposed a work investigating a potential solution of overfitting by comparing the performance of two models in which one was trained with segmented images of plant leaves(S-CNN), and the second one was trained with full images(F-CNN). When the S-CNN model is tested on unseen data with ten disease classes, the accuracy rate doubled to 98.6% compared with the model's performance of F-CNN. This research work paved to be an exemplary automated application for non-experts for timely detection of plant leaf diseases.

Typically Computer Vision (CV) based works span across several domains [17-27] and CV will be used for tree disease prediction as well. An outstanding solution for early disease detection in plants is by incorporating computer vision and image processing techniques. Kien Trang et al. [13] proposed a deep neural network model, an image-based disease identification method of mango leaf diseases using the Plant Village dataset. Images are pre-processed using various pre-processing techniques like rescaling, contrast enhancement, and center alignment. The concept of Transfer Learning is incorporated for training the neural network model. This results in a significant advantage in the learning process resulting in the accuracy rate of the model to 88.46%, that is comparatively greater than the other architecture models like MobileNetv2, AlexNet, Inceptionv3.

Materials and Methods

General approach for plant disease detection

A large dataset is generally needed to train and test a deep learning model to analyze and compare each model’s performances. The PlantVillage Dataset [15] is a publicly available dataset that consists of around 20,000 images of healthy and diseased plant leaf images like bacterial spot, early blight, leaf mold, target spots in plants like Tomatoes, Potatoes, Pepper Bell. Few

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research papers have used customized datasets consisting of images captured using a high-resolution camera. It also consists of both healthy and infected leaf images of diseases like Anthracnose, Powdery Mildew, Dag, Golmachi, and various others, which occur in plants like Mango, Capsicum, and citrus fruits. Either of these datasets or both are used to train their deep learning model and test the efficiency of their trained model. Figure 3 describes the steps involved in detection of plant leaf disease.

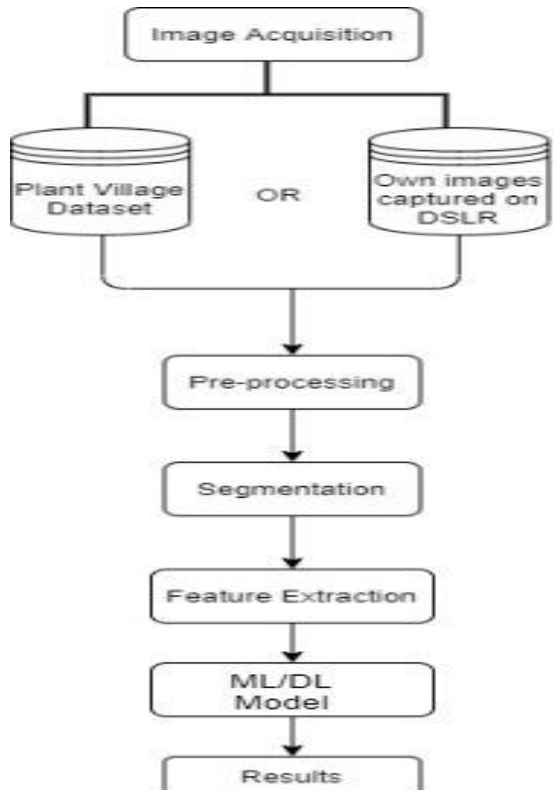

Figure 3. General approach towards detection of plant disease

Image pre-processing and segmentation

Pre-processing refers to the raw data's transformations before it is fed to the machine learning or deep learning algorithm. Image pre-processing performs operations on images at the lowest level of abstraction, aiming to improve the image data by suppressing unnecessary distortions and enhancing features crucial for future processes. As the images in these datasets are in distinct formats with varying resolution and quality, it is essential to pre-process them in the dataset. There is a wide range of pre-processing techniques available. Techniques like contrast enhancement, rescaling, resizing, angle rotation, vertical or horizontal flipping, and conversion of RGB to Grayscale are performed on the images. The most commonly used contrast enhancement technique is the histogram equalization method, which enhances the image's contrast using the image's histogram. The images in the dataset are also converted into Grayscale images or HSI images as required. For rescaling or resizing, the central crop method is made of use, and the images are resized to a specific dimension according to the dataset and the objective of their proposed system. RGB Additionally, images are processed using a Gaussian filter, removing noise and other unwanted features in the images.

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Partitioning or segmentation is generally done to obtain the region of interest. For plant leaf disease identification, segmentation is done by obtaining the area where the leaf is affected by the disease. All segmentation techniques can be approached from two basic segmentation approaches, i.e., region-based or edge-based approaches or cluster-based approaches. K-means clustering is one of the most commonly used clustering approaches used for the segmentation process for dividing data into k number of clusters. This clustering methodology basically groups the points which are situated at small distances from the central centroid point. The thresholding method is another critical segmentation technique which is capable of blurring unnecessary data and highlights the hidden features in the dataset.Data augmentation is performed on the image dataset to increment the dataset's size by augmenting it with varied copies of the existing data present in the dataset. This process acts as a stabilizer to reduce overfitting when the training process is done. Perspective, intensity, and affine transformation are some commonly performed transformation techniques.

Feature Extraction

To reduce the number of dimensions in the dataset, the feature extraction process is performed by converting the available data into a reduced form of manageable data. The most important characteristic of these datasets is that they have many variables in which few might not be needed for training and may require many computing resources to process. Feature extraction helps identify the best features from the datasets by selecting and combining them into essential features, thus effectively reducing the amount of data as optimized feature extraction is the fundamental step to effective model development. Feature extraction differs for each system. General dimensionality reduction techniques used are Independent component analysis, Kernel PCA, Latent semantic analysis, Partial least squares, and multifactor dimensionality reduction. The criteria for selecting depends on the redundancy and relevance of the features. Depending on these aspects, Yu et al. [17] have defined the feature subset into four types, namely the "noisy & irrelevant", "redundant & weakly relevant", "weakly relevant and non-redundant" and "strongly-relevant".

RGB and texture features are essential features that play a vital role in disease prediction in leaves as clustering [1] is done based on it. Other prominent features like contrast, energy, entropy, homogeneity is extracted for disease prediction [7]. With the obtained values, a feature dataset is created for the classification process. For infected area calculation in leaves, features like intensity, area, parameters are also considered [10]. The number of features is directly proportional to the size of the hypothesis space, i.e., as the number of features increases, the search space's size is also increased. “Gabor Wavelet Transform (GWT)” and “Gray Level Cooccurrence Matrix (GLCM)” [10] can also be used for feature extraction. [13]

Training and Testing

The dataset used is generally divided into training and the testing set. The splitting is usually done randomly, but when using the generalized splitting ratio, the resulting model would be trained well and will achieve a high-performance accuracy. Most of the datasets used in the proposed systems are split in a ratio of 80:20, where the training set would consist of 80% of the total images, and the remaining 20% will be used for testing. Another commonly used testing

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ratio is 70:30, where 70% of the images are trained, and the remaining images are used for testing. The model trained and tested using the 70:30 ratio does not significantly differ from that of the model trained and tested using the 80:20 ratio. The validation set is part of the training set is used to finetuning the model by parameter selection.

Some Machine Learning Methods

Support Vector Machine: "Support Vector Machine", a classifier and a regressor, is a supervised learning method that determines the classes which are associated with the known classes. However, it is widely used in classification problems because of its high performance. Hyperplanes are called decision boundaries as they help in classifying the data points. The SVM's primary function is to check for that hyperplane that can distinguish between the two classes.
Artificial Neural Networks: "Artificial Neural Network" is a learning system constructed on many simple elements, called artificial neurons or perceptron. The neuron is capable of making simple decision and sharing the data to other neurons which are interlinked with each other. ANN follows the concept of backpropagation for learning and to produce more accurate results by adjusting weights of the neurons.

Convolutional Neural Network: A "Convolutional Neural network" is a neural network architecture based on the concept of "convolution operations". The CNN [16] converts an image into a feature vector based on pixel definition. Advanced vision-based algorithms for solving complex-based problems can be constructed using CNN. AlexNet, VGG-Net, GoogLeNet are CNN architectures developed to handle challenges faced by the general CNN approach.

Backpropagation Neural Network: Backpropagation is the essence of neural net training, which is commonly used to train neural networks. It is an algorithmic method of fine-tuning the network weights depending on the rate of error obtained in each of iteration. Backpropagation is a classic approach used for training artificial neural networks by adjusting neuron's weights so that the results are closer to the known weights.

Related works on disease prediction using Machine Learning

K-Means clustering algorithm is used on the dataset containing RGB and texture feature values as this is unlabeled data. This technique will put each of the samples in a particular cluster [1], which denotes a class of deficiency of the sampled leaf. This methodology helps in the easy clustering of diseased leaves belonging to a particular class. Hybrid approaches [9] are also employed to detect an infected area in the leaf, which improves the classification process. Classification algorithms like Support Vector Machine [7] [10], K NearestNeighbor [7], Decision Tree are also employed for the classification of a leaf into healthy or diseased. Among these algorithms, Support Vector Machine gives the best results. Many CNN architectures like AlexNet, VGGNet, GoogLeNet have played a vital role and efficient role in disease detection in plants. Each of these architectures' efficiency is tested with different datasets, with VGGNet producing the greatest accuracy of 99.53% in this comparative study [11] with AlexNet, GoogLeNet using a self-acquired dataset. INC-VGGN [8] is a network model generated by using an auxiliary structure. It consists of a pre-trained module, and additionally, few layers are changed by inserting new layers in the CNN model. The main concept is that the pre-trained

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model is used as a basic feature extractor, whereas the newly added layers act as a high dimensional feature extractor that is responsible for classification.

Another notable methodology is the MCNN model named the Multilayer Convolutional Neural Network, which gives an accuracy of 97.13%. This has three max-pooling layers with two fully connected layers and softmax function in the final layer, with the overall model based on AlexNet architecture. There is a higher chance of reduced performance issued when the models are applied to unseen real-world images. S-CNN and F-CNN [12] use datasets with segmented images and full images, respectively, for training, where the S-CNN model's accuracy reached a rate of 98.6%. Other neural networks like Back Propagation Neural Network [6] and Residual Neural Network [13] are also employed for disease prediction, and the accuracy rate of these systems is 94% and 88.46%, respectively. Table 1 gives the details of the surveyed research papers.

Table 1. Machine Learning based works on plant disease prediction

Methodology Used	Plants	Disease	Dataset	Accuracy
K- means algorithm [1]	Mango	Nutrient Deficiency (Potassium, Phosphorous, Copper and Iron)	Self-acquired	-
Multilayer Convolutional Neural Network [2]	Mango	Anthracnose	Self-acquired, PlantVillage Dataset	97.13%
CNN, ANN [3]	Mango	Multiple	Self-acquired	ANN - 89.41%
CNN, AlexNet [4]	Potato and Mango	Anthracnose, Potato Early Blight	Self-acquired, PlantVillage Dataset	AlexNet -8.33% CNN – 90.85%
CNN [5]	Mango	Multiple	Self-acquired	CNN - 96.67%
BPNN [6]	Mango	Red Rust, Bacterial leaf spot	Self-acquired	BPNN - 94%
Tree, Linear Discriminant, KNN, SVM [7]	Capsicum	Multiple	Self-acquired	SVM-100% Tree- 98.4% KNN – 100% Linear Discriminant-98.4%
INC-VGGN [8]	Rice, Maize	Rice and Maize diseases	Self-acquired,	INC-VGGN - 92.00%

			PlantVillage Dataset	
Hybrid approach of thresholding and segmentation [9]	Mango	Anthracnose	Self-acquired	-
ANN with SVM [10]	Mango	Multiple	Self-acquired	SVM - 80.00%
AlexNet, AlexNetOWTBn, GoogLeNet, Overfeat, VGG [11]	Multiple	Multiple	PlantVillage Dataset	VGG - 99.53% AlexNet – 99.06% AlexNetOWTBn-99.44% GoogLeNet - 97.27% Overfeat - 98.96%
S-CNN, F-CNN [12]	Tomato	Multiple	PlantVillage Dataset, Images from Internet	S-CNN – 98.6%
RNN [13]	Mango	Anthracnose, gall midge, powdery mildew	Self-acquired, PlantVillage Dataset	88.46%

Conclusion and Future Work

The primary cause of damage and loss to the production yield is caused due to plant diseases, resulting in a catastrophic impact on food production safety. It may even lead to no harvest in severe cases. Thus, the application of plant disease identification is essential. In this work, the authors have done a survey of various algorithms, techniques, and models employed for plant disease identification and classification of healthy or diseased plant leaves using simple plant leaf images. The models' training is done using self-acquired images or the publicly available dataset PlantVillage dataset for this system. Based on our extensive study of Machine learning and Deep Learning models, we can conclude that using classification algorithms and Convolutional Neural Network models are highly suitable for this process. For the development of these kinds of models, our prime target should be used on the usage of real images of the plants in the training data. With the availability of better datasets, the high performance of these applications can be efficiently achieved. Future work will be directed towards developing a model to predict different types of diseases in mango tree.

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