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Plant Disease Detection Techniques: A Survey

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Abstract

The main difficulty faced in image processing is to detect the disease of plants. There are four phases in which plant disease is detected such as pre-processing, segmentation, feature extraction and classification. In the pre-processing stage, the contrast of the input image is de-noised or increased. The points which are not visible are highlighted; the PNSR (peak signal noise ratio) is maximized and the magnitude signal error value of the image is mitigated in this stage. The second stage is the segmentation. There are two kinds of segmentation methods: threshold and region-based segmentation. The various type of feature selection algorithms are used for the feature extraction. The various schemes which are already proposed for the plant disease detection are reviewed in this paper.

Keywords

Plant disease, Feature extraction, Segmentation, Classification

1.Introduction

1.1 Plant Disease Detection

The presence of plant diseases negatively affects the production of farming goods. In agricultural crops, leaves act significantly for offering information related to the amount and nature of horticultural yield. The productivity of food is affected due to various factors including climate changes, occurrence of weed and soil infertility. Another factor that has a great impact on the productivity of food is the occurrence of disease in plant and leaf due to which progress of various agricultural products are affected. If these infections or bacteria are not detected in plants consequently, the utilization of pesticide or fungicide is done inadequately. Thus, plant diseases are taken into consideration by the scientific community, with a focus on the biological attributes of diseases [1].

Precision farming makes the implementation of the most advanced technology in order to optimize the decision-making. The experts and biological review often conduct the visual assessments using the plant diagnosis at the time of their necessity. But this technique consumes much time and it is not cost effective. To overcome these concerns, research into the appliance of image processing methodologies for plant disease detection has become a trending research subject. The general process of using traditional image recognition processing technology to identify plant diseases include image acquisition, image processing, feature extraction, and identification & classification. Detecting plant disorders in early stage provides a base to effectively preventing and controlling plant diseases, and they give major contribution in the management and decision-making of farming production. In recent years, the identification of plant disease has been an important issue. The detection of diseases in plant is required with the help of advanced and intelligent methods for dealing with these issues [2].

1.1.1 Plant Disease Detection using Image Processing

For plant disease identification based on plant leaves, the basis of plant classification mainly includes three: leaf shape, color and texture [3]. Because the color of most leaves will change gradually over time, the classification of leaf color will be subject to time constraints. However, the shape characteristics of leaves in different periods are similar, generally only size changes, and different leaf contours are different, making it one of the main symbols of plant identification. Compared with color and shape, the texture veins of leaves have more stable characteristics, and the texture veins of different leaves differ greatly. As a plant identification standard, it is easier to distinguish the types of plants. The basis of image recognition is to extract the target features to be recognized in the image. The recognition process is mainly divided into four steps [4]: image pre-processing, image segmentation, image feature extraction and image classification as shown in Figure 1.

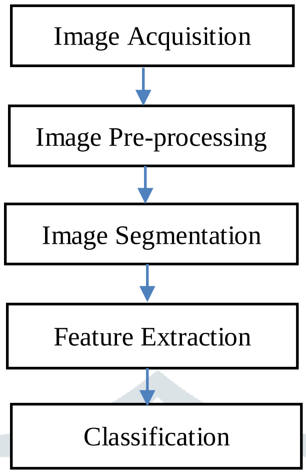

Figure 1: Plant Disease Detection based on Image Processing

All steps involved in plant disease detection based on image processing have been described below:

a.Image Acquisition: This task is concerned with the acquirement of different plant imagery from different datasets. One such dataset is 'The PlantVilllage Dataset'. It is an open-access repository containing 54,323 images in total. Multiple classes are selected per specie. The images are generally captured in controlled environmental conditions. This might lead to model bias. A test dataset comprising a number of images can be obtained from Google as well to access this. These images comprise supplementary plant anatomy, in-field background data and variable disease stages [5].

b. Image Pre-processing:Image pre-processing plays a vital role in deciding the performance of a model. It is quite challenging to differentiate viral, bacterial, and fungal disorders, and generally, an overlap of symptoms appears. These signs can be any quantifiable variation in color, shape, or function which occurs as the plant reacts to the pathogen. This criticality might be overcome by using RGB images. It generates clear, denoised images which may take more time than the greyscale image to train.Different pre-processing tasks are considered in order to make an object or image noise-free. The leaf image is cropped in image clipping to obtain an inclined region of the image. Smoothing filter is used for image smoothing. The popular image filtering schemes are discussed as below:

- Adaptive Median filter: The corrupted pixels are not distinguished from the normal pixels using median filter and it is its main problem [6]. The Adaptive Median filter is carried out to deal with this limitation. When a pixel is differentiated from its surrounding pixels according to its structure and properties that pixel is regarded as noisy pixel. The medians values are assigned at the place of noisy pixels. The noise classification test is surpassed by these medians that are acquired from neighbourhood.
- Aplha-Trimmed Mean Filter: All the pixels in the kernel are obtained equal affect even the noisy pixel by applying mean filter. This is the main limitation of mean filter. The distribution of pixel is performed prior to take the mean in trimming and some areas of the greatest and smallest values are also eliminated to get rid of this limitation. The mean and median filters are integrated in Alpha-Trimmed Mean filter.
- Gaussian Filter: The current pixel obtains more significance and the weight is tempered when the distance is varied in terms of Gaussian distribution by the Gaussian filter. The edges are preserved by using this filter. The two phases are comprised in the working principle of this filter. The filtering of centre pixel is done in the first phase and the weight of this pixel is multiplied with all the pixels. All these pixels are divided so a new pixel is developed. This process is performed in horizontal direction. After it, this process is repeated in vertical direction. The image which is arranged in horizontal manner, now controlled in vertical manner. In this way, the absolute image is developed [7].

c. Image Segmentation: Image segmentation is to segment the recognized image into several sub-regions. The features of each region have obvious differences, and the internal features of each region have certain similarities. The existing image segmentation methods mainly include edge-based segmentation, threshold-based segmentation and region-based segmentation.

- Edge-based segmentation: The method based on edge segmentation is to segment the image by detecting the region where the gray value of the pixel changes suddenly, or where the texture structure changes suddenly. Roberts Differential Detection Operator is a method of using local difference to find the edge of an image [8]. Its basic principle is that any pair of difference in the vertical direction can be regarded as the approximate value of the gradient. In practice, the difference between two adjacent pixels in the diagonal direction is often used to replace the approximate value of the gradient. The formula is as follows:

$$g(x,y) = \{[f(x+1,y+1) - f(x,y)]^2 + [f(x+1,y) - f(x,y+1)]^2\}^{\frac{1}{2}} \ldots\ldots (1)$$

In Formula 1, (x, y) is a point in the image, f (x, y) is the input image, and g (x, y) is the output image. Because the calculation of square and square root requires a large amount of calculation, the absolute value is usually used to replace it, then formula (1) can be expressed as:

$$g(x,y) \approx |f(x+1,y+1) - f(x.y)| + |f(x+1,y) - f(x,y+1)| \ldots\ldots (2)$$

By setting a threshold value TH, if g (x, y) is greater than TH, that the pixels corresponding to the (x, y) is the step edge points [9].

- Threshold segmentation: The main principle of threshold segmentation method is based on the difference of gray features between different target regions in the image. Image threshold segmentation is a traditional image segmentation method, which has the characteristics of simple implementation, small amount of calculation and stable performance. It is especially suitable for the image whose gray value of pixels in the target region and background region is not in the same range. Therefore, it has become a widely used technology in the field of image segmentation.
- Region segmentation: The region segmentation method can be divided into two parts: the region growing method and the splitting merging method. The principle of the region growing method is to gather pixels with the same or similar attributes to form a region. The region growing method saves the division process compared with the splitting merging method, and the splitting merging method can carry on the characteristic judgment and the region merging in the larger region [10].

d. Feature Extraction: Image feature extraction is a key step in the three steps of image recognition. It refers to extracting the image information which is invariant by zooming, translation, scale transformation or illumination, and abstracting the image into some specific mathematical representation or vector description. Image feature extraction can be divided into global and local features according to the different extraction ranges. The global feature of an image refers to the representation of all the features describing the overall information of the image, such as the color feature, shape feature and texture feature of the image. Local features of an image refer to the partial features of an image within a specific region [11]. Following are the popular feature extraction algorithms

- FAST algorithm: The interest points in an image are verified using this algorithm. The Interest point is a pixel of an image that includes well defined positions. Its detection is possible. The content related to information is contained in every interest point and it can be reiterated among various images. The corner points are detected is the major aim of FAST algorithm as various real time frame rate applications have employed these points.
- SURF algorithm: The key points are extracted from the database as well as from the test images to register and identify the image using SURF algorithm. It is carried out as local object detector.

e. Image Classification: Image classification is often referred to the process of taking an input (such as image) and outputting a class or a probability that the input is a specific class. In plant disease detection, the main purpose of this step is to classify the input plant image as healthy or infectious. In case an image is detected as infectious, then some available approaches further classify it into a number of infections. Different researchers have introduced several ML algorithms over the years for the classification of images [12].

1.1.2 Machine Learning algorithms

Machine learning is an advancing domain of artificial intelligence which makes use of effectual adaptive techniques for pattern recognition in data. These techniques let the machine to adjust consequently by constructing a framework from example inputs for making data-oriented predictions or decisions, instead of implementing firmly static program instructions. There are two kinds of machine learning classifiers namely supervised or unsupervised on the basis of presence and absence of labelled data and the prediction is achieved from the dataset. The training data is deployed in the supervised learning for developing a function having training data which further has a pair of input vectors and outputs. The estimated distance amid the input-output instances is evaluated to train a dataset so that a classification algorithm is generated. After the completion of a trained system, this system assists in classifying the unknown examples into a learned class label. Different from the supervised learning, an unlabeled dataset is utilized and items are allocated to specific groups in unsupervised learning [13]. The process of assigning labels in the dataset is known as hyper-parameter tuning. Instead of predicting labels for some data item, the main objective of unsupervised learning is that the concealed clusters must be exposed in the dataset. The most common machine learning algorithms for plant disease detection are KNN, SVM, and ANN which are described as follow:

i. KNN (K Nearest Neighbor): K-NN is a machine learning algorithm based on instance. It is an algorithm that avoids all calculations after classification for lazy learning. The KNN algorithm is based on the concept that is that if a sample consists of k most similar neighbors in the feature space (that is, the nearest neighbor in the feature space), then the majority of samples be a member of a certain class, then the sample itself refers to this class. In general, classification task can use voting method, that is, the most visible category label in k samples is chosen as the prediction outcome [14]. The regression can be performed using averaging method, that is, the average of the actual values of k samples of the output label is used as the prediction outcome.

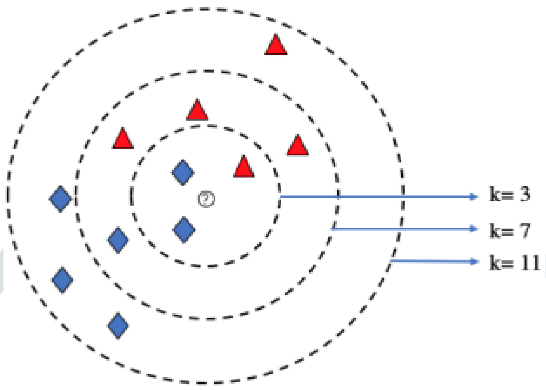

Figure 2: K-nearest Neighbor

A schematic diagram of K-NN (k-nearest neighbor) is represented in figure 2 in which k denotes a significant parameter. In case of diverse values of k, the classification results are found different. In figure, k = 3 defines that the sample judgment result is prismatic, k = 7 indicates that the judgment result of the sample is triangle and when k = 11 reveals that the judgment result of the sample is prismatic. With the utilization of various distance calculation techniques, distinct nearest neighbors are obtained due to which the results generated in classification are found diverse. The distance computation is supposed suitable to order to discover the KNNs [15].

The NNR (nearest neighbor rule) is a theoretical foundation of K-NN classifier. For a scenario, suppose x be a point for which a label is assigned and the point nearer to x has to be investigated and suppose it as$y$. The possible error is obtained from the NNR in case y is labeled similar to x and it is expressed in the given equation.

$$P^* \leq P \leq P^* \left(2 - \frac{c}{c-1} P^*\right) \ldots \ldots . (3)$$

In this equation, P^* denotes the Bayes error rate, c illustrates the number of classes and P is utilized to show the error rate of the nearest neighbor [16]. In case of enormous number of points, the error rate of the nearest neighbor is found less that twice the Bayes error rate. In case of minor error of the best possible optimal assignment, twice that error is also small. When the number of data points is present in huge amount, the probability that label of x and $y$are similar is very high. In the given equation, the nearest neighbor algorithm is relatively simple. Therefore, its error rate is no more than twice the error rate of the Bayesian optimal classifier.

ii. Support Vector Machine (SVM): SVM is one of the most popular machine learning algorithms. This algorithm is inspired from the idea of statistical learning. SVM has gained wide-ranging fame as a classification algorithm because of its exclusive benefits in managing issues with small samples, nonlinear and high dimensional data sets. It is also possible to use this algorithm for analyzing data, identifying patterns, and performing regression analysis. SVM performs non-linear mapping. This algorithm applies the implicit mapping of the internal product kernel function to the high dimensional space to deal with the issue of original data space which is linearly indivisible to a great extent. SVM is referred as a second-class classifier model. Its standard model is described as the linear classifier with the highest interval in feature space, which means the learning approach of SVM focusses on to maximizing the interval [17].

In the data space, hyperplanes are classified by defining the spatial classification model of points. Initially, equation 1 is used to define the classification function:

$$f(x) = w^t x + b \ldots . . (4)$$

In equation 1, the parameters of the hyperplane to be determined are stored in w^t, while b represents the bias. Many may support vectors may be required to determine the t, w parameters which in turn are used to determine the classification of the hyperplane. Generally, the accuracy of the classification prediction can be defined as a distance from a point to the hyperplane [18]. SVM aims to make this distance maximum. In real time, linear inseparable examples generally occur. Hence, mapping of data features to a high-dimensional space is essential. A linear inseparable mapping at high-dimensional space may increase the size, making it difficult to compute. This issue can be solved using the kernel function.

The kernel function is measured at lower dimensions before converting to a higher dimensional space, and a substantial classification effect is defined at this location. This approach may prevent complex calculations once this transformation is performed. In contrast to other kernel functions, lesser number of parameters are required by Gaussian kernel function and it also shows more flexibility. Hence, following Gaussian kernel function is used for mitigating the inseparable issues [19]:

$$K(x, x_i) = exp\left(-\frac{\|x - x_i\|}{2\sigma^2}\right) \ldots . (5)$$

An SVM is generally applied to process data noise with stack variables as noise contaminates data.

iii. Artificial Neural Networks: Endeavours to artificially reproduce the biological cycles that give rise to intelligent conduct concluded in the building of ANN. ANN is a numerical or computational model that depends on natural neural organizations. It comprises of an interconnected set of counterfeit neurons which performs the data processing through a connectionist way to calculation. Much of the time, ANN is a versatile framework that changes its structure dependent on outer or inside data that courses through the network during the learning stage. In more useful terms, neural networks are non-linear statistical information instruments to model data. They can be utilized for the modelling of intricate connections among input and outputs or to discovers patterns in data. ANN is a nearby replica of the natural sensory system [20]. In this model, a neuron multiplies the inputs by loads, computes the total, and implements a threshold. The outcome of this calculation would then be communicated to ensuing neurons. Fundamentally, the ANN has been summed up to:

$$y_i = \left(\sum_k w_{ik}\, x_k + \mu_i\right) \ldots . (6)$$

In this expression, x_k represents inputs to the neuron I, while w_{ik} denotes weights associated with the inputs. Also, threshold (offset or bias), transfer function, and the output of the neuron are represented by μ_i, f (•), and y_i respectively. The transfer function f (•) may be linear, non-straight, piece-wise linear, sigmoidal, tangent hyperbolic and polynomial function. A portion of the renditions of ANN, contingent upon which algorithm is utilized at the summation stage, include: Probabilistic Neural Networks, Generalized Regression Neural Networks and Multi-Layer Perceptron Neural Networks. The most usually utilized learning algorithm of ANN is the Feed-Forward Back-propagation algorithm.

2. Literature Review

Fatma Marzougui, et.al (2020) suggested a computer method on the basis of DL (Deep Learning) systemsto detect theplant diseases in advance [21]. Thus, CNN (convolutional neural networks) calledResNet was adopted in this method. An augmented dataset that had images of normal and affected leaves was utilized for this method. The images were classified into two categories namely normal and affected. Anaconda 2019.10 was applied to deploy the suggested method and made its comparison with others. The outcomes depicted the superiority of the suggested method over the traditional methods.A CNN (convolutional neural networks) algorithm was introduced byMarwan Adnan Jasim, et.al (2020) for classifying and detecting the plant leaf diseases [22]. The classification of diseases occurred onplant leaf was done in twelve classes for diseases of diverse plants whose detection was done and 3 classes for healthy leaves. There were 20636 images of plants and their diseases extracted from the Plant Village dataset. The results demonstrated that the introduced algorithm provided the accuracy around 98.29% in training phase and 98.029% in testing phase. A CNN (Convolutional Neural Network) was projected by G. Madhulatha, et.al (2020) for classifying variousplant diseases from thePlant Village dataset [23]. The AlexNet model was utilized for differentiatingseveral kinds of diseases of the plant into 38 diverse classes. Also, an optimal solution was generated for detecting and recognizing the diseases in the plant. The results indicated thatthe projected algorithm provided the accuracy around 96.50%. A Convolutional Neural Network (CNN) model was investigated byAkshay Kumar, et.al (2019) for classifying the image so that the plant disease was detected [24]. The experiments were conducted on the investigated model in order to detect diseases intomato leaves.PlantVillage dataset that had 14,903 images taken from affected and healthy plant leaves was executed to train this model. The results revealed that the accuracy obtained from the investigated model was calculated 99.25%.A solution was presented by N Radha, et.al (2021) in order to monitor the plant and detect the plant disease in premature phase [25]. The Automated plant disease detection method was assisted in detecting the symptoms of diseases in advance in huge fields. This method was trained using CNN (Convolution Neural Network) to detect the plant diseases. A dataset that had several images of normal and infected leaves was applied. The presented solution yielded the accuracy up to 85% and negligible loss of 0.25. Monu Bhagat, et.al (2020) established a computationally efficient method for classifying the plant leaves as healthy or diseased and detecting the plant leaf diseases [26]. This method was planned on the basis of SVM (Support Vector Machine) and the Grid Search method was utilized to optimize this method. This method was assisted the framers in generating a significant technique to recognize thediseases accurately with least computational effort. The SVM algorithm provided the accuracy around 80% and the latter method offered 84%. The K-means clustering algorithm was developed by F.A. Princi Rani, et.al (2019) to detectand classify the leaf disease [27]. When, the image was segmented and classified, the color median filter was utilized. The segmentation process emphasized on transforming the RGB model intoL*a*b model. The extraction ofcolor texture attribute was done and the SVM (Support Vector Machine) algorithm utilized this attribute.MATLAB 2015a was utilized to construct these models. The results exhibited that the SVM algorithm provided the accuracy up to 95%. A SVM (Support Vector Machine) technique was intended bySelim Hossain, et.al (2018) for recognizing the diseases [28]. The classification process was executed to analyze 11 attributes. These attributes were deployed in discovering appropriate match for the disease every time while uploading an image into the SVM database. The intended algorithm yielded the accuracy of 90%. This algorithm was capable of enhancing the accuracy to detect and recognize the diseases occurred on plants for whichthe losses because of diseases of the leaf were mitigated and the overall productivity was improved. A ML (machine learning) technique called Random Forest was formulated byMeghana Govardhan, et.al (2019) for recognizing and classifying thetomato diseases [29]. The formulated technique was trained by pre-processing the images and extracting the attributes. This technique was efficient for diagnosing thetomato diseases including early blight, late blight, septoria leaf spots and pider mite. The results obtained in experimentation proved that all thetest images provided the suitable discrimination among the classes of images and the accuracy obtained from the formulated technique was counted 95%. An automatic system was designed byDebasish Das, et.al (2020) for detecting thedisease occurred on tomato leaf. This system emphasized on recognizing the infected region of leaf. First of all, the images were pre-processed for alleviating the noise available in the dataset. The significant texture attributes were extracted using Haralick algorithm. In the end, various ML models such as LR (logistic regression), RF (random forest) and SVM (Support Vector Machine) were implemented for classifying the extracted attributes from tomato leaf disease database. The promising outcomes were generated using SVM in comparison with other two algorithms.

2.1 Comparison Table

Author	Technique Used	Dataset	Outcomes	Results and drawbacks
Fatma Marzougui, et al.	ResNet, a convolutional neural network	Anaconda 2019.10	The outcomes depicted the superiority of the suggested method over the traditional methods.	The accuracy is achieved upto 90 percent and it can be further improved to improve execution time
Marwan Adnan Jasim, et al.	Convolutional neural network (CNN)	Plant Village dataset	The results demonstrated that the introduced algorithm provided the accuracy around 98.29% in training phase and 98.029% in testing phase.	The technique can be further improved using RNN
G. Madhulatha, et al.	AlexNet architecture	Plant Village dataset	The results indicated thatthe projected algorithm provided the accuracy around 96.50%.	The models can be trained using other training sets
Akshay Kumar, et al.	Convolutional Neural Network (CNN)	PlantVillage dataset	The results revealed that the accuracy obtained from the investigated model was calculated 99.25%.	The model can be tested on other datasets
N Radha, et al.	Convolution Neural Network (CNN)	ImageNet	The presented solution yielded the accuracy up to 85% and negligible loss	The other parameters like precision and recall needs to be

			of 0.25.	considered
Monu Bhagat, et al.	Support Vector Machine, Grid Search technique	Kaggle	The SVM algorithm provided the accuracy around 80% and the latter method offered 84%.	The hybrid models needs to be designed to improve performance
F.A. Princi Rani, et al.	K-means clustering algorithm	MATLAB 2015a	The results exhibited that the SVM algorithm provided the accuracy up to 95%.	The technique of feature extraction needs to be apply
Selim Hossain, et al.	Support Vector Machine classifier (SVM)	SVM database	The intended algorithm yielded the accuracy of 90%. This algorithm was capable of enhancing the accuracy to detect and recognize the diseases occurred on plants	The models needs to validated with other classifiers
Meghana Govardhan, et al.	Random Forest	PlantVillage dataset	The results obtained in experimentation proved that all thetest images provided the suitable discrimination among the classes of images and the accuracy obtained from the formulated technique was counted 95%.	The technique can be improved using hybrid classification and also needs to be tested on other datasets
Debasish Das, et al.	LR (logistic regression), RF (random forest) and SVM (Support Vector Machine)	MATLAB	The promising outcomes were generated using SVM in comparison with other two algorithms.	The technique needs to be validated.

Conclusion

The plant disease detection models consist of four steps: pre-processing, segmentation, feature extraction and classification. The use of microscopes was quite popular in old times for the detection of plant diseases. However, every plant leaf can't be inspected individually in real-time. Therefore, a fast and consistent approach is devised for sensing the disease by means of remote sensing. Machine learning technique proves to be extremely proficient for detecting the disease at early stages according to their symptoms. The plant pathologists can make use of the digital image processing technology for the detection of plant diseases using digital images. The computer processing is employed for detecting the infections in leaves and fruits in cultivation. All methods based on digital image processing capture the digital images using a digital camera. It is concluded that major data is published in the conferences related to plant disease detection.

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