A Review on Digital Image Processing Techniques for Automatic Detection, Quantification and Identification of Plant Diseases

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ABSTRACT
This paper presents a study of different methods based on digital image processing techniques for detection, quantification and identification of plant diseases. Diseases can affect at any part of plant i.e. root, stem, leaf, fruit etc. This paper includes only those methods in which leaves were affected by diseases. Disease symptoms must be visible on leaves. Identification of the plant diseases is a very vital process to avoid the losses in both quality and quantity of crops in agricultural production system. It is very tough job to monitor the plant diseases manually. Manual plant disease monitoring system needs more processing time and expertize in the plant disease. So a fast, automatic and accurate approach to identify the plant diseases is needed. Hence, image processing techniques are used for the detection, quantification and identification of plant diseases because these techniques are fast, automatic and accurate. Disease detection by image processing techniques includes the main steps like image acquisition, image pre-processing, image segmentation, feature extraction and identification of disease.

General Terms
Digital Image Processing, Computer Vision

Keywords
Plant diseases; image processing; image segmentation

1. INTRODUCTION
Agricultural production system is a consequence of a complex interaction of soil, water, seed, fertilizer and agro chemicals. Therefore, ideal management of all these inputs is important for the sustainability of this complex system. The focus on improving the productivity without bearing in mind the ecological impacts has resulted in adverse effects on environment. However, productivity enhancement can also be achieved in a sustainable manner without any adverse consequences to environment.

In India, approximately 50% of the population is employed in agriculture industry and share of agriculture in Indian GDP is about 15% [1]. The crop losses due to pests and diseases are approximately assessed to be ranging from 10% to 30% of crop production. If average crop losses of 20% are considered, and the present gross value of our agriculture produce is considered as Rs. 7 Lakh Crore, the loss comes to Rs. 1,40,000 Crore, which is colossal. Even if we could save 50% by using plant protection, it will add Rs. 70,000 Crore additional income to the farmer and the country. Different types of direct and indirect damages due to the plant diseases such as reduced quantity and quality of crop and increased production cost [2]. When the crops are affected by pests and diseases, there is a huge decrease in yield. Mostly diseases are seen on the leaves of the plant. Therefore disease identification of leaves of plant and finding out the percentage of the disease incidence are major key factors for successful cultivation of crops [3].

Therefore, to minimize such losses, it is necessary to understand the classification of plant diseases. Disease can be defined as the result of interaction between causal agent pathogen, host plant and suitable environment as shown in Fig 1.

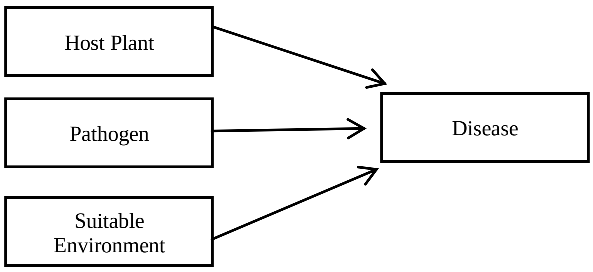

Fig. 1. Necessary Factors for Causing plant Diseases

Generally, the plant is affected by diseases, pests, unfavorable conditions and nutrition deficiency. The symptoms and the losses caused by these diseases and pests are different and their life cycles are also different hence the adopted control measure are also completely different. Plant diseases are mainly originated by parasitic and non-parasitic causes.

Parasitic Causes: These include various types of micro-organisms structure. Major plant diseases are encountered by these casual agents such as Bacteria, fungi and viruses. Symptoms of the diseased plant may include a change in color, shape, texture or function of the plant as it responds to the pathogen.

Fungi: Fungal body contains small threadlike structures known as 'mycelium'. They grow extremely fast and in a few days produce numerous microscopic seed like reproductive structures known as 'spores' under suitable conditions. Insects/Pests, rain, wind and irrigation water etc. easily transport these spores from infected plants to healthy plants and hence these are responsible for rapid transmission of the disease. Most of the severe plant diseases of various crops are caused mainly by different species of fungi. These diseases are the reason for great economic losses. The common symptoms of these diseases are as leaf spots, mildews, rots, rusts, wilts, anthracnose, white mold etc.

Bacteria: These are microscopic organisms with their profiles varying from oval to round or short rods. Some bacteria have long, whip-like structures called "flagella" that they use for movement. They do not produce reproductive structures as in fungi but the bacterial cells themselves split from one to two, from two to four and so on. Their transmission commonly occurs by water, insects, seeds etc. The common symptoms of these diseases are as leaf spots with yellow halo, wilts, canker and blight.

Viruses: They are ultra-microscopic organism. They are so tiny that they can only be seen with a very powerful microscope called an electron microscope and they are so simple that they are technically not considered alive. These organisms do not consume any food and do not grow in size and number such as in fungi and bacteria microorganisms. They live only inside the living individual cells of plants or animal tissues. The common symptoms of viral diseases include such as chlorosis, mosaic, curling, dwarfing, crinkling and sometimes leaf spots.

Non Parasitic causes – These diseases are caused by some unfavorable conditions related to nutrition deficiency, soil moisture, climate, water, sunlight, harmful chemicals toxicity, etc.

Image processing techniques are those methods which convert an image into digital form and perform some operations on it, in order to get an enhanced image or to extract some useful information from it and to recognize the individual objects. The techniques which are used for this purpose are called image processing techniques [6].

2. LITERATURE REVIEW

Mohammed El-Helly et al. [8] proposed an approach for integrating image analysis technique into diagnostic expert system. A diagnostic model was used to manage cucumber crop. According to this approach, an expert system finds out the diseases of user observation. In order to diagnose a disorder from a leaf image, five image processing phases are used: image acquisition, enhancement, and segmentation, feature extraction and classification. Images were captured using a high resolution color camera and auto focus illumination light. Firstly they transformed the defected RGB image to the HSI color space then analyzed the histogram intensity channel then increased the contrast of the image. Fuzzy C Means (FCM) segmentation is used in this approach. The inputs of this FCM algorithm are no. of clusters and degree of fuzziness. Based on experiment with these parameters they have shown that the optimal cluster no. is 4 and degree of fuzziness is 2. Features are extracted corresponding to the color characteristics of the spots such as the mean of the red, green and blue channel and other features corresponding to morphological characteristics such as length of principal axes, eccentricity, diameter, compactness and euler's number. Finally classification is done by Artificial Neural Network. The proposed approach has greatly reduced error prone dialogue between system and user and achieved 88.8 % accuracy on average.

Kim et al. [9] proposed a method by using color texture features for detecting orange diseases. In this approach, they used leaves of oranges. A color microscopic imaging system was designed to collect RGB images from orange leaves with normal and seven common diseased conditions i.e. green islands, greening blotchy mottle, iron deficiency, manganese deficiency, zinc deficiency, young flush leaves. Firstly region of interest (ROI) was selected by user. Then ROI was converted from RGB color space to HSI color space. Spatial Gray Level Dependence Matrices (SGDM) were calculated for Hue, Saturation and Intensity channel of ROI. They extracted total of 39 texture features from Spatial Gray Level Dependence Matrices (SGDM) of hue, saturation and intensity. Algorithms for selecting useful texture features were developed by using stepwise discriminant analysis. They developed four models i.e. HSI_39, HSI_15, HS_10 and I_11. Classification was done by minimum distance classifier. The model using 15 selected HSI texture features got the best classification accuracy (95.6%), which recommended that it would be best to use a reduced hue, saturation and intensity texture feature set to differentiate orange diseases. The HSI_15 model, I_11 and HSI_39 models achieved classification accuracy 95.6%, 81.11% and 95.6% respectively.

Bauer et al. [10] developed algorithms for the automatic classification of leaf diseases based on stereo and high resolution multispectral images. Leaves of sugar beet were used in this method. Sugar beet leaves might be infected by several diseases. In controlled light laboratory environment, They collected stereo images of single sugar beet leaves by RGB and multispectral cameras. The leaves were either healthy or infected from diseases such as rusts, powdery mildew and Cercospora leaf spot. They generated 3-D models of the leaves to fuse information from the two cameras. Classification is done by k-nearest neighbour and an adaptive Bayes method. The classification accuracy achieved were 91% for Cercospora leaf spots and 86% for rust disease.

Weizheng et al. [11] developed an accurate and fast new method based on digital image processing for quantification of plant diseases. They tested their solution on soybean leaves affected with gray spot disease. In this method, infected leaves were placedt on a white background paper; the optical axis of digital camera was perpendicular to the leaf plane to capture images. Leaf is segmented by Otsu method in gray channel. In the HSI color system H component is selected to segment disease spot to minimize the illumination and the vein effects. After that the disease spot regions are segmented by using Sobel operator to detect the disease spot edges and applied the operations such as region fill, morphology open operation in H component. Finally, plant diseases are quantified by calculating the quotient of disease spot areas and leaf areas.

Dheeb al Bashish et al. [12] proposed a method for detection and classification of leaf diseases. They investigated their solution on five diseases which affect on the plants i.e. Early Scorch, Late Scorch, Cottony Mold, Ashen Mold, and Tiny Whiteness. They did not mention the plant types used in their method. This method included four main phases; in the first phase they created a device independent color space transformation from the RGB leaf image. In the second phase, images are segmented using K-means clustering technique, this segmentation technique is used to divide the leaf image into four clusters in which one or more clusters contain the disease. In the third phase, they calculated the texture features for the segmented infected cluster. Features are extracted by Color Co-occurrence Method (CCM). It is a method in which the color and the texture features of an image are measured. Finally in the fourth phase the extracted features are feed in a pre-trained neural network. This method detected and classified diseases successfully with a precision around 93%.

H.Al-Hiary et al. [13] developed a method for automatic detection and classification of plant leaf diseases. The proposed method is an enhancement to the method in [12] as it provided high accuracy and faster solution. This method was also tested on five diseases which affect on the plants; they are: Early scorch, Cottony mold, Ashen mold, Late scorch, and Tiny whiteness. The proposed method consists of four main phases as in [12]. The new two steps are added successively after the segmentation phase. These are the identification and masking of green color pixels. The developed method successfully detected and classified the examined diseases with a precision between 83% and 94%, and achieved 20% speedup over the approach proposed in [12].

Kulkarni et al. [14] also proposed a methodology for early and accurate plant diseases detection using different image processing techniques and artificial neural network (ANN). Pomegranate leaves, stems and fruits were taken in this method. The work begins with the collection of images by digital camera. Images are filtered and segmented by using Gabor filter. Then, color and texture features are selected from the segmented image. Then in last step, artificial neural network (ANN) is trained by selecting the features that could differentiate the healthy and diseased samples correctly. Experimental results presented that the accuracy of this method is around 91%.

Shrivastava et al. [22] proposed a fully automatic disease detection and level estimation system based on color image sensing and processing for six diseases namely Rust, Sudden Death Syndrome, Bacterial Blight, Brown Spot, Downy Mildew and Frog Eye of soybean plant. In this method, Images have been collected by low resolution mobile camera and then converted the image from RGB color space to YCBCR color space after that Some new parameters such as Disease- Severity-Index (DSI), Infection-Per Region (IPR), and Disease-Level-Parameter (DLP) for measuring the disease severity level and disease classification have been formulated.

Majumdar et al. [23] proposed a new method based on integrated digital image analysis system for detection, recognition and diagnosis of rust disease in wheat leaves. This method include three main phases i.e. Image Analyzer, Feature Extraction and the classifier phase. The function of the image analyzer phase is to transform color image to gray image based on HSI color space. In second phase, Fuzzy C means clustering has been used for feature extraction. Then in the last phase, Multi layered perceptron has been used for detection and classification of wheat leave diseases. The accuracy rate of this classifier is 97% for disease detection and 85% for disease identification.

Vipinadas et al.[24] proposed a system that identifies the Black sigatoka and Panama wilt disease of banana fruit. In this method, The RGB image is first changed into YCBCR color space and the gray scale image is obtained by using ‘Y’ component. The next step is to apply adaptive contrast map to improve the leaf diseased portions. Then image is transformed into binary image using a threshold. The disease detection and quantification has been done using ANFIS classifier. Finally, classifiers comparison has been performed using confusion matrix.

Kruse et al. [25] developed, compared and tested new methods for classifying individual pixels as healthy or injured from ozone pollutant of clover leaves. RGB images of the leaves were collected in controlled laboratory using a standard digital SLR camera. Features were selected based on different color and texture from the images. Four classification methods were evaluated namely K-means clustering, linear discriminant analysis (LDA), Fit to a Pattern Multivariate Image Analysis (FPM) combined with T2 statistics (FPM-T2) and Residual Sum of Squares statistics (FPM-RSS).The LDA classifier performed very well than the other three classifiers in pixel identification.

3. BASIC STEPS INVOLVED IN DETECTION, QUANTIFICATION AND IDENTIFICATION OF PLANT DISEASES

In this section, the basic steps for plant disease detection, quantification and classification using image processing are discussed as shown in Fig. 2

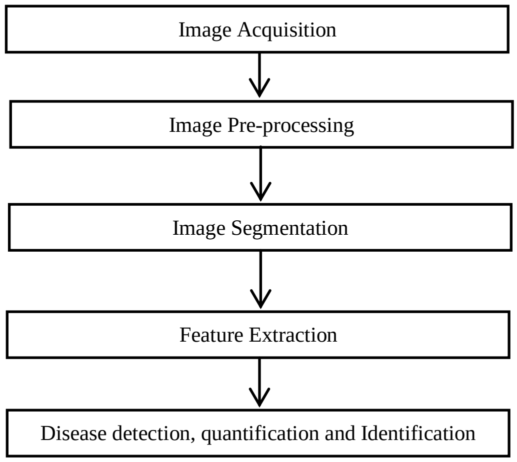

Fig. 2. Basic steps in disease detection

3.1 Image Acquisition

This is the first stage of any vision system. Image must be captured by a camera and transformed into a manageable entity. This process is known as image acquisition. Images have been collected by high resolution and low resolution digital cameras in visible bands in literature.

3.2 Image Pre-Processing

The goal of the preprocessing stage is to improve the quality of the acquired image. Possible algorithms during this stage include contrast improvement, brightness correction, noise removal and color space conversion.

3.3 Image Segmentation

Image segmentation is the first step and one of the most vital tasks of image analysis. It is used either to discriminate objects from their background or to divide an image into the related regions. It produces at its output a number of labeled regions or sub images [15]. In literature segmentation has been performed at two levels firstly segmenting the leaf from the rest of the original image and then segmenting leaf spots within the leaf. Automatic image segmentation is one of the most challenging tasks in a machine vision system. There are different methods used for image segmentation. K means clustering method has been used in [12]. Fuzzy c means segmentation has been used in [8, 23]. Otsu segmentation method has been utilized in [11, 22].

3.4 Feature Extraction

The purpose of the feature extraction phase is to reduce image data by measuring certain features or properties of each segmented region such as color, shape and texture [16].

In this step, pictorial information has been transformed into quantitative attributes. Different features were extracted from segmented image based on color, shape and texture as shown in Table 1.

3.5 Disease Detection, Quantification and identification

It is the last step of any image analysis system. The above described methods include not only disease detection but also disease severity and identification. There are very less methods which focus on only disease detection. Methods described in [11, 12, 24] are for disease quantification. The disease quantification may be done either by color and texture of the diseased spots or by estimating the area of diseased spots.

The disease classification techniques are the extension of the disease detection and quantification methods. All extracted features are feed into different type of classifier. Some popular classifiers are neural networks, support vector machines, fuzzy classifier, self-organizing maps, discriminant analysis and minimum distance classifier.

4. COMPARATIVE TABLE SHOWING DIFFERENT WORK OF RESEARCHER

Table 1:Comparsion of different research methods

S. No.	Authors (year)	Plant Name	Diseases Name	Image Acquisition	Segmentation Method	Extracted Features	Classifier	Accuracy (%)
1	Mohammed El-Helly et al. [8] (2004)	Cucumber	Powdery Mildew, Leaf Miner, Downey Mildew	High resolution camera with illumination light	Fuzzy C-Means Segmentaion techniques	mean of the red, green and blue channel, length of principal axes, eccentricity, diameter, compactness and euler's number	Artificial Neural Network No of training images:250 Testing 50 For each disease	88.8
2	Weizheng et al. [11](2008)	Soybean	Gray Spots	Digital camera	Otsu Thesolding And Sobel operator in hue comonent	diseased leaf area divided by total leaf area	-	-
3	Kim et al.[9] (2009)	Orange	Young flush, Normal mature, Blotchy mottle, Green islands, Zinc deficiency ,iron deficiency ,manganes deficiency .	Microscopic imaging system	ROI was selected by user	Color Texture features & stepwise discriminant analysis	Discriminat analysis 60 sample for each class	85.56
4	Bauer et al. [10] (2011)	Sugar Beet	Rusts, Powdery mildew Cercospora beticola	High resolution multispectral camera and digital camera	Fusion of images of two cameras to develop 3d models	Features from fused images	k-nearest neighbour and an adaptive Bayes method 60images for each class	88.5
5	Dheeb Al Bashish[12] et al. (2011)	Not specified	Early Scorch, Cottony Mold, Ashen Mold, Late Scorch and Tiny Whiteness	Digital Camera	Device independent color transforamtaion structure And K means clustering	Color and texture based features	Back propagation neural network 32 samples for each class	93
6	Hiary et al.[13] (2011)	Not specified	Early Scorch, Cottony Mold, Ashen Mold, Late Scorch and Tiny	Digital Camera	Identification and masking of green color pixels	Color and texture based features	Back propagation neural network	95%

			Whiteness					
7	Kulkarni et al.[14] 2012	Pomegranate	Alterneria Anthracnose Bacterial blight	Digital camera	Conversion from RGB color Space to CIE L*A*B* color space	Gabor Filter	Back propagation neural network	91%
8	Shrivastava et al.[22] (2014)	Soybean	Rust, Bacterial blight, Brown spot, Downy mildew, Frog eye spot and Sudden death syndrome	Low resolution Mobile camera	Convert RGB color space to Ycb cr color space and normalize y component Bi level Segmentation in Y channel on threshold 170	Ratio of Infected Area (RIA): Lesion Color Index (LCI): Damage Severity Index (DSI):	-	-
9	Kruse et al.[25] 2014	Clover	Ozone Affected	Digital camera	Conversion from RGB color Space to CIE L*A*B* color space and Unfold of images	Color features of a pixel and its neighbouring pixels controlled by a Quadratic neighbourhood windows with sides w of an odd number of pixels usually in the range 3–49 pixels	Fit to a Pattern Multivariate Image Analysis (FPM-T^2) Residual Sum of Squares statistics (FPM-RSS), linear discriminant analysis (LDA) K-means clustering.	86% 85% 95% 93%
10	Majumdar et al. [23] 2015	Wheat	Rust	High resolution	Conversion from RGB color Space to HSI color space Fuzzy C means	Entropy Std deviation Corelation Homogenity Moments No of conneceted component	Multi layered Perceptron	Detection-97% Classification-85%
11	Vipinadas et al. [24] (2016)	Banana	Black sigatoka and Panama wilt	Video samples by mobile phone	Conversion from RGB color Space to YCBCR color space Not specified	Different features based on color Shape & texture	Support Vector Machine or ANFIS	100 % accuracy for ANFIS and 92% for SVM.

5. CONCLUSION AND FUTURE SCOPE

This paper presented a comprehensive survey for automatic detection, quantification and identification of plant diseases. This paper also discussed several Feature extraction and classification techniques for plant disease classification. It is clear from the above comparative review that no method gives a complete solution for all problems but this review helps to select the best method for disease identification in term of the segmentation algorithm and classifier. The performance of all methods is measured by its accuracy. From these methods, Researchers can accurately identify and classify various plant diseases using image processing techniques. Some papers of this area could not be reviewed to limit the paper length. For future work, these methods could be developed for other diseases and some new features could be extracted for achieving high accuracy.

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