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Cotton Plant Diseases Detection Using Various Classification and Segmentation Techniques – A Survey

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Abstract

Cotton is a prominentcash crop that is cultivated throughout the world majorly for its fibrous fruit known as the boll. Botanically named as Gossypium Hirsutum, cotton is a shrub that belongs to the family Malvaceae. It plays a phenomenal role in the textile industry over and above many other markets too. Like other plants, cotton plants are vulnerable to a variety of pathogenic attacks. This paper describes about the list of diseases that affects the cotton plant and the various segmentation and classification techniques that are employed to detect those diseases along with the pros and cons, accuracy of each technique.

Keywords: *Cotton, Disease Detection, Segmentation, Classification.*

1. Introduction

The significance of cotton can be understood from its name 'white gold' and 'king of fibres'[1].It is this plant that occupies 2.5% of the world's plantable land area[2]. It is not only a fibre yielding crop but also a plant from which we can extract oil and much more. The cotton chain almost involves 150 countries and 100 million families[3]. Due to its colossal need and consumption, it is not surprising that it is grown in huge acres of farm. Being a plant, it is very common that it is open to many plant ailments. It could be due to both living and non-living causative agents[4]. Since it is cultivated in massive areas it is not possible to supervise it manually. It needs tremendous man power supply and even then, the primary symptoms are microscopic and restricted to human vision[5]. Through human supervision, it is not possible to detect the stage of attack and its severity.

All the parts of the plant including the root, stem, flower, bud, leaves and fruits are infected. The primary part of infection in the cotton plant is leaf[3]. The cotton fruit called as the boll, is the primary product of concern. Pathogenic attacks to this part of the plant is usually rare and leaves are the first line of receivers. But as we all know, leaves serve the major purpose of photosynthesis which is the main source of nutrition to the plant[6]. Hence any attack to the leaves will eventually affect the production of such plants and sometimes if the disease goes undiagnosed it is also possible for the loss of life of the same plant. Therefore for any plant to yield good results, strength of the leaves is very important.The common diseases that have so far been found is majorly classified into four categories. They are bacterial, fungal, parasitic and viral infections as shown in Fig 1.

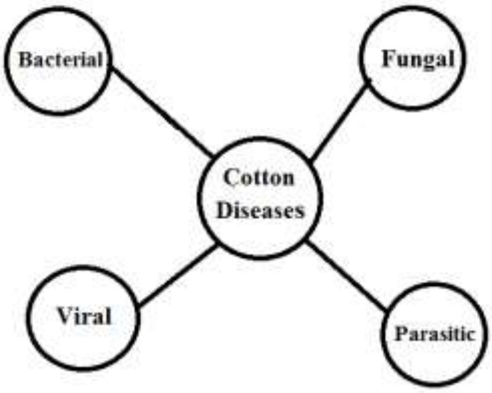

Fig 1. Types of cotton diseases.

Different types of diseases that could possibly affect the cotton plant and its parts are listed in Table1.

Table 1: Types of Cotton Diseases

Name of the disease	Disease Type	Causing agent	Symptoms	Management	Sample image
Bacterial blight of cotton	Bacterial	Xanthomonas citri	Small brown spots on the surface of leaf which may blend leading to leaf collapse.	Proper field sanitation and clearing crop residue into soil after harvesting can reduce the emergence.	
Crown gall	Bacterial	Agrobacterium tumefaciens	Galls are found onthe roots, twigs branches and as they enlarge, they become hard and woody.	It can be avoided by controlling root insects and nematodes, cutting away large galls and practicing five-year rotation of plants.	
Anthracnose	Fungal	Glomerella gossypii	Small, reddish spots on leaves are seen and when they grow the stem girdles, causing seedlings to die.	Seed treatment with 3 grams of Thiram or Spraying copper oxychloride (0.25%) or Zineb (0.25%) will help to control.	
Fusarium wilt	Fungal	Fusarium oxysporum	The vascular parts becomecolourless which can be seen by cutting it.	Using disease-free seed; plant varieties with higher resistance to such Fusarium diseases will give good results.	

Leaf spot	Fungal	Alternaria macrospora	A hole like appearance on the leaves is seen which develops a concentric pattern.	Providing plants with adequate potassium and application of 0.2% Mancozeb or Copper oxychloride at the startingstage will manageit.	
Root rot	Fungal	Thielaviopsis basicola	Roots decay and rot. Such roots can be easily pulled out.	Mixed cropping with legumes and disinfecting the soil with 0.1% Carbendazim will prove to be useful.	
Boll rot	Fungal	Ascochyta gossypii	Small black dotscover the entire bolls. Such infected bolls fall prematurely.	Optimum spacing and applying Fenvalerate 75 g + Copper oxychloride 0.2% at 15 days interval should be useful.	
Leaf curl and roll	Viral	Cotton leaf curl virus (CLCuV)	Infected leaves curl upward along with vein thickening. Such plants are stunted.	Protecting seedlings from whiteflies and immediately removing infected plants will help.	
Cotton aphids	Parasitic	Aphis gossypii	Green or yellow color small insects sit on the underside of leaves and stems.	Insecticidal soaps and neem oil are usually the best method of control	
Cotton bollworm	Parasitic	Helicoverpa zea	Holes are found in bases of bolls and insect are found around holes.	Appropriate chemical treatment may be required for control or sometimes Entrust SC will help.	

2 Disease Detection using Image Processing

Earlier days, the farmer would run with a specimen of the infected part to an agro specialist or seek help from a local pesticider for a temporary relief. Both are time consuming and won't offer a proper solution. Even a small disease can propogate throughout the field and can affect both the quality and quantity of the yield. It is said that a disease can discontinuitiesreduce the production till 25% . Hence it becomes very much essential that a disease is properly diagnosed that too in an early stage so that further spread can be stopped.

Unlike those days, plant diseases are not restricted to only a few well known ones, but new specimens keep arising due to the evolution of science[7]. The first part that is to be disease riden is the backside of the leaf which is not usually a visible part to human eyes. Turning every leaf back and forth and checking for any abnormality is not feasible. Also plants can be affected due to nutritional deficiency, uneven climatic conditions, soil pollution and more factors which do not need pesticides[8]. It is likely that the farmer mistakes a magnesium deficient leaf to be an infected one[9]. There is also the chance of joint attack of two or more diseases to the same plant which will cause chaos to the farmer[10].

These problems are to be addressed better as cotton serves as a raw material for many industries and any such reduction in the process will lead to huge economical losses both to the farmer and the nation as a whole[11]. In a nation like India where agriculture forms the backbone of the economy and contributes to 17% of the GDP[6] and being the major exporter of cotton to other countries, it is of utmost importance that we take up the assistance of technology. This requires a computer aided solution which often comes in the format of image processing. This is how image processing and its algorithms enter the agricultural scene[12].

This can be achieved easily nowadays as all are carrying a smart phone with them. The image that the farmer captures from the farm directly in order to send it to the agro adviser will definitely be corrupted because of uneven illumination, shadowing agents and overlapping of leaves[8]. Also the farmer is not going to use any good graded cameras and often he will be a moderate user of the smart phone. Therefore a specialist cannot expect a proper image without any occlusions in it. Therefore it becomes necessarythat the image is properly segmented and only the vital features that is needed for disease detection from the cluttered image is extracted. Further from the extracted features, using a classifier we can detect the disease[13]. The flowchart for the above said process is given below in Fig 2.

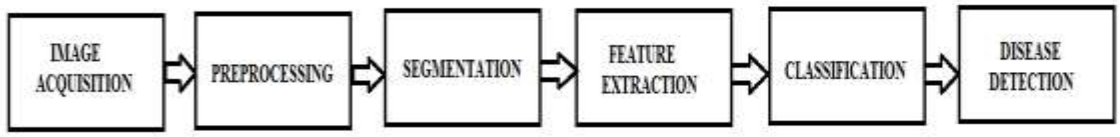

Fig 2. Cotton plant disease detection flowchart

3 Image Segmentation

Image segmentation is nothing but the process of splitting a digital image into multiple image segments or regions for a simplerrepresentation of the image or to convert it into something that is easier for the computer to analyze[14]. Segmentation algorithms can broadly be classified into threshold based segmentation, edge based segmentation, region based segmentation clustering based segmentation, artificial neural network based segmentation and watershed based segmentation.

K-Means

K-Means clustering is an algorithm that is used to segment the area of interest from its background[15]. It partitions the given data into K-clusters based on K-centroids. The goal of this algorithm is to find fewstrong groups based on some kind of similarity where number of groups are represented by K.

Advantages:

- Simple implementation
- It can be scaled to large data sets.
- It is easily adaptable to new examples.
- Clusters of different shapes such as elliptical clusters can also be used.

Disadvantages:

- The number of clustersi.e K should be defined in advance
- The algorithm takes a back seat while handling noisy data and outliers.

Fuzzy

Fuzzy clustering is a form of segmentation algorithm in which each data can belong to one or more clusters.Such algorithms have proven to be a very important tool for image processing in segmenting the objects of interest from the given image[16].

Advantages:

- It is very easy to understand.
- It is capable of providing effective solutions to complex problems.

- The algorithm can be modified easily in order to improve the performance.

Disadvantages:
- Defining rules and membership functions is a difficult task.
- Since the algorithm is based on assumptions, the results may not be widely accepted.

Otsu Thresholding

Otsu's method, named after its founder Nobuyuki Otsu is yet another segmentation approach that is used to perform thresholding andarrive at a threshold value that splits the needed pixels alone based on their intensity into foreground and background classes[17].

Advantages:
- Simple and fast calculation
- The process is not affected by brightness and contrast of images
- It is one of the segmentation technique which gives satisfactory results.

Disadvantages:
- It does not perform well when the histogram has a shallow valley.
- It performs badly where heavy noise is found.
- When the lighting is not proper and the object size is small, accuracy reduces drastically.

Edge Detection

Edge detection is a far and wide used segmentation technique for finding the edges ofneeded objects within a image by detecting breaks in brightness. It uses a variety of operators such as Canny, Sobel, Robert, Prewitt, Gradient and Laplacian[18].

Advantages:
- It greatly reduces the data and information in the image.
- The main advantage of edge detection is its simplicity.
- Approximate gradient calculation is another advantage.

Disadvantages:
- Computational complexity is high.
- It heavily consumes time.
- The major disadvantage is the signal to noise ratio.

4 Image Classification

Image classification is the procedure of classifying segments and groupidentical pixels based on their similarity measure[19]. Image classification algorithms can be broadly divided into two categories namely Supervised and unsupervised image classification techniques.

Support vector machines (SVM)

It is a very potentand flexible supervised classification algorithmwhich has its own unique way of implementation as compared to other algorithms. They are truly popular because of the ability to handle multiple and continuous variables. The backbone of this algorithm sits on the kernel function that is opted for use. Linear, Gaussian and Polynomial kernel are the ones often used[20].

Advantages:
- It works well when two classes are clearly separated.
- SVM is effective even in conditions where there are more dimensions than samples.
- It is a memory efficient algorithm.

Disadvantages:
- It is not suitable when the dataset is large.
- It has reduced accuracy in case of noisy data or overlapped classes.

Artificial Neural Networks(ANN)
Artificial Neural Networks is aclassification algorithm which is inspired by biological neural networks[21]. It consists of a system of interconnected nodes that are functionally comparable to biological neurons. The connections between these nodes have weights by altering which the network is able to estimate the desired function.

Advantages:
- This method of segmentation issturdy enough to noise.
- It evaluates fast even though the training period may be lengthy.
- They work excellently with numeric values

Disadvantages:
- ANN is equipment dependent as they require parallel processing systems.
- As there is no proper rule to define the structure of such networks, a right structure can be achieved through trial and error basis only.

K-Nearest Neighbor(KNN)
K-Nearest Neighbor is a classification method used in image processing which has *k* training examples in the data set. This algorithm works by finding the distance between feature vectors and classifies the dataset based on the distance function which is usually Euclidean or Manhattan[22].

Advantages:
- No Training is required for this algorithm.
- New data can be added at any time of the process
- Implementation is quite easy.

\Disadvantages:
- It requires low dimensions of data.
- The algorithm is very much sensitive to noise.

DECISION TREE
Decision tree, a widspread tool for classification is a tree like structure where the topmost node is the root, underlying nodes are branches and final nodes are leaves. Each node has an individual label[23]. It works by classifyingdata by ranking them down the tree from the root to the appropriate leaf node.

Advantages:
- It requires less effort for data training and preprocessing.
- Scaling and normalization of data is not a must.
- It is easy to explain and understand the result outcome.
- It handles missing data well.

Disadvantage:
- Data is not modifiable once the classification process begins because it will alter the entire tree structure.
- It takes more time when compared to other models and is complex also.
- It is not suitable for continuous values of data.

Bayesian classifier
It is a graphical model that is based on Bayes' Theorem. It has a set of classes and works on the principle of conditional dependence among those classes[24,25]. It is a fast and highly scalable algorithm which is widely used in multi-class classification.

Advantages:
- It works quickly and hence saves the computational time.

- The assumption that is made about the dependence of features turns out to be true, then it can out-perform all the other models.
- It requires less data for training.

Disadvantages:

- It is not suitable for real time solutions.
- If assumptions go wrong, then the output accuracy will go down.

Table 2 presents the dataset, disease detected, image processing steps, techniques used, extracted features, accuracy reported by various authors from 2018 to 2022.

Table 2 : Detailed comparison of various techniques employed for study

S.No.	Name	Dataset	Disease Detected	Image Processing steps	Techniques Used	Extracted Features	Accuracy	Year
1.	Azath M. et. al.	2400 images	Bacterial blight, Leaf minor, Spider mites	Images' Sample Digitization, Data Preprocessing, Feature Extraction, Dataset Partitioning, Training with CNN, Classification	Convolution Neural Network	Color parameters	96.4 %	2021
2.	Rafael Faria Caldeira et. al.	60,659 images	Cotton Leaf Lesions	Image acquisition, Preprocessing, Attribute extraction, classification	Convolution Neural Network	Texture attributes	70%	2021
3.	Roberto Tarazia et. al.	Not specified	Cotton pathogens and pests	Genetical modification of cotton	Genome editing technologies, Plant-mediated RNAi technology	Cotton defense reactions	Not specified	2020
4.	Hari Krishnan et. al.	Camera acquired images	Cercospora leaf spot	Image Collection, Pre-processing, Segmentation, Feature Extraction, Classification	K-Means Clustering, Support vector machine	Color, Contrast	Not specified	2019
5.	Abirami Devaraj et. al.	Self captured images	Alternaria, Bacterial Blight, Cercospora leaf spot, Antracnose	Image Collection, Preprocessing, Segmentation, Feature Extraction, Classification	K-means, GLCM, Random forest	Not specified	Not specified	2019
6.	Santhosh Kumar. S et. al.	Not specified	Plant leaf diseases	Not specified	Not specified	Not specified	Not specified	2019
7.	M. Sheshikala et. al.	400 images	Cotton diseases.	Data Set Collection, Pre-processing, Feature Extraction, Training,	Convolution Neural Network	Not specified	91%	2020

				Testing				
8.	ZHANG Jian-hua et. al.	Cotton leaf images with single and complex backgrounds.	Cotton leaf diseases	Filtering, Define the canny gradient operator, Define the gaussian kernel function, Constructing energy function, Iterative operation to the end	Automatic image segmentation	Active contour model	Not specified	2018
9.	Kadem Shravan Kumar et. al.	245 cotton images	Cotton leaf diseases	Dataset collection, Preprocessing, Evaluation	Convolution Neural Network	Not specified	91%	2020
10.	Vijai Singh et. al.	Thermal, Hyperspectral, Fluorescence, Multispectral and 3D Images	Plant diseases	Image generation, Image processing algorithms, Classification.	SVM, K-means clustering, Deep learning, and K-NN.	Not specified	Not specified	2020
11.	Yogita K. Dubey et. al.	80 images	Alternaria, Bacterial Blight, White flies,	Image Collection, Preprocessing, Segmentation, Feature Extraction	Support Vector Machine	Roughness measure	94%	2018
12.	Minu Eliz Pothen et. al.	120 images	Bacterial leaf blight, Brown spot and Leaf smut disease	Image Collection, Preprocessing, Segmentation, Feature Extraction, Classification	Otsu's thresholding, Support Vector Machine	LBP and HOG feature descriptors	94.6 %	2020
13.	Mrs. Shruthi U et. al.	40 images	Grey Mildew disease	Image Collection, Preprocessing, Segmentation, Feature Extraction Classification	K-Nearest Neighbor algorithm	Colour, shape and texture features	82.5 %	2019
14.	Vibhor Kumar Vishnoi et. al.	270 images	Rootrot, Fusarium wilt	Image Collection, Preprocessing, Segmentation, Feature Extraction, Classification	Support Vector Machine, Fuzzy classifier	Edge with color and texture features	92%	2020

15.	Usha Kumari et. al.	4564 Images	Grey-Mildew, Rust Foliar Fungal Disease	Image Collection, Preprocessing, Segmentation, Feature Extraction, Classification	K-means, Support Vector Machine, Artificial Neural Network	Contrast, Correlation, Energy, Mean, Standard Deviation, Entropy, Variance	SVM – 92.06% ANN – 85.1 %	2019
16.	Gyanesh Shrivastava	Digital camera or scanner	Plant Diseases	Image acquisition, Preprocessing, Segmentation, Feature Extraction, Classification	Support Vector Machine, Artificial Neural Network , K-Nearest Neighbors	Morphological feature extraction	SVM – 95.8 % ANN- 90.86% KNN- 85.28%	2021
17.	Zahid Iqbal et. al.	Not specified	Citrus plant diseases	Preprocessing, Segmentation, Feature Extraction, Classification	K-means, Support Vector Machine, Neural Network	Texture features	Not specified	2018
18.	Sandeep Kumar et. al.	110 samples	Blight, Narcosis, Alternaria, Grey mildew	Image acquisition, Preprocessing, Segmentation, Feature Extraction, Classification	Principal component analysis	Green (G) channel of RGB picture.	95%	2021
19.	Yin Min et. al.	560 images	Bacterial Blight and Cercospora Leaf Spot, Powdery Mildew and Rust	Image acquisition, Preprocessing, Segmentation, Feature Extraction, Classification	K-Means Clustering, Support vector machine	GLCM and LBP features	98.2 %	2018
20.	Jenifa et. al.	60 images	Fungal diseases	Image acquisition, Preprocessing, Masking, classification	Multi-SVM	Color	93.63%	2019
21.	Nikhil Shah et. al.	18 images	Cotton disease	Image acquisition, Preprocessing, Enhancement, Segmentation, Feature Extraction	Artificial Neural Network	RGB and HSV components	Not specified	2019
22.	Kapil Prashar et. al.	40 infected images	American Cotton leaf diseases	Label data, Extractfeatures, Train the classifier, Evaluate results	K-nearest Neighbor, support vector machine	GLCM and HOG	96%	2019
23.	Jayraj Chopda et. al.	Not specified	Wilt, Anthracnose	Acquire farming data using sensors, Push the collected data into Thingspeak server,	Decision tree classifier	Not specified	Not specified	2018

				Analyse the data using Decision Tree Classifier.				
24.	Bhagya M. Patil et. al.	Mendeley Data-Cotton Leaf Dataset.	Leaf diseases	Image acquisition, Preprocessing, Segmentation, Feature Extraction, Classification	Machine learning algorithms	Shape, color, and texture	Not specified	2021
25.	Li Dongyang et. al.	25 cotton plants	Arthropods	Sampling, Statistical analysis	Principal co-ordinates analysis	Diversity Index	Not specified	2022

Segmentation and Classification accuracies by implementing various techniques reported in literature are presented in Table 3 and Table 4 respectively.

Table 3: Segmentation Algorithm Accuracies

SEGMENTATION ALGORITHMS	
Name	**Accuracy**
K-means[17]	93%
Edge Detection[18]	98.1%
Fuzzy[16]	85%
Otsu Thresholding[17]	79.5%

Table 4: Classification Algorithm Accuracies

CLASSIFICATION ALGORITHMS	
Name	**Accuracy**
SVM[18]	98.46%
ANN[15]	92.5%
KNN[24]	96.76%
Decision Tree[18]	96.73%
Bayesian[17]	86%

5. Conclusion

As the world's population increases, the need for cotton as a raw material seems no bound. Hence there is a dire need to improve cotton yield to fulfill its surging demands. It is a wiser way to adopt modern concepts and techniques for sustainable cotton production. Apart from pesticidal and pathogenic attacks, poor soil health, improper nutrition management, deprived water quality and unpredictable climatic patterns are becoming big problems to cotton production. Management of plants and farms are more important than its production and harvesting parts are concerned.Site management using novel technologies like GPS, GIS, and remote sensing technologies will make the production process of cotton more effective. Genetically modified cotton that is resistant to such diseases is also a solution.This paper presents a wider view of cotton plant maladies and also discusses about the various segmentation and classification algorithms in detail.Each algorithm is specific and good in its own way and each might work differently for each disease. Using Table 2, Table 3 and Table 4 which portray the accuracies of each algorithm one can choose to pick up the right algorithm that will suit the problem.

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