SPATIALPYRAMID MATCHING APPROACH FOR IDENTIFICATION OF COTTON LEAF DISEASES THROUGH OPTIMIZED TRAINING DATASET

Kapil Prashar[1], Dr. Rajneesh Talwar[2], Dr.Chander Kant[3]

[1] *Research Scholar, I.K. Gujral Punjab Technical University, Kapurthala Road, Jalandhar, Punjab*

[2] *Principal, CGC Group of Colleges, Jhanjeri, Mohali, Punjab*

[3] *Department of Computer Applications, Kurukshetra University, Kurukshetra*

ABSTRACT

*The cotton leaf disease detection is the process of detecting disease by analyzing their visual properties. The visual properties extraction process from the images is known as the feature extraction. The feature extraction process can be done using the various feature descriptors like SIFT, SURF or other most suitable candidate. The feature descriptors are then passed to the classifier for the evaluation of the feature. The classifier is the algorithm, which is used to classify the feature on the basis of its similarity with the training dataset. The training dataset is the collection of features previously extracted from the known objects (the leaves with specific disease in this case). The leaves with disease are classified on the basis of their similarity with the training dataset of disease samples previously described by the feature descriptors. In this paper, our aim is to solve the cotton disease detection problem using the image processing techniques automatically from the input image. The disease classification will primarily based upon the visibility of the disease on the cotton leaves, which further can be used for the identification using the classifier. The proposed model implementation would be done using the MATLAB simulator and the proposed model results would be obtained in the form of the accuracy, precision, recall, elapsed time and many other similar parameters***.**

Keywords

Cotton disease classification, disease verification, leaf borne disease classification, disease feature descriptor, SIFT, SURF, vector classifier.

1. INTRODUCTION

Agriculture has played the most significant role in the economic development of most of the developing countries including India. The Cotton crop is largely found in North India. There are various types of diseases which have adversely affected the productivity of cotton crop during the last few years. Need of the hour is disease recognition and its classification. The approach of this work is to create such an expert system which may be at a central location but accessible to the farmers in the way of sending images to the central expert system and getting the information about the disease and its remedies. In this approach, the human experts will provide the expertise to identify the diseases. The computer expert will use this knowledge to create a training set which will be applied to images to ensure that the disease can be recognized with sufficient amount of accuracy. The Algorithm for the pattern matching will be optimized for the purpose of earliest recognition of the disease with acceptable accuracy levels at the fastest possible pace.

Fig 1 Leaf Curl Disease

Fig 2 Leaf Curl Disease

Fig 3 Anthracnose

Fig 4 Leaf Curl Disease

Fig 5 Bacterial Blight

Fig 6 Bacterial Blight

Fig 7 Fusarium Wilt

Fig 8 Fusarium Wilt

Fig 9 Grey Mildew

The above shown Fig 1, 2, 3, 4, 5, 6, 7, 8 and 9 are the graphical representation of different diseases infecting Cotton leaf. Automatic detection of cotton leaf diseases is an important research topic as it may prove beneficial in monitoring large field of crops, and thus automatically detect diseases from symptoms that appear on plant leaves.

Thus automatic detection of plant disease with the help of image processing technique provides more accurate and robot guidance for disease management in least possible time. Comparatively, visual identification is less accurate and time consuming.

2. REVIEW OF LITERATURE

Ole Mathis Opstad Kruse et al. [1] evaluated the performance of four classification methods in identifying pixels representing injured areas on the leaf surfaces. Fit to a pattern MIA approach combined with $T^{2,}$ RSS statistics and Linear discriminant analysis supervised classification methods and K-means clustering unsupervised method was used.LDA method significantly outperformed three other classification methods in pixel identification with significantly higher accuracy, precision, true positive rate & F-score as well as significantly lower false positive rate and computation time. A true positive rate of 80% indicates that 20% of the injured pixels were falsely identified as healthy.

S. Arivazhagan et al. [2] focuses on recognition of plant leaf using machine learning techniques by using the Shape features, Vein Features, Color features/Moments, Texture Features & Zernike Moments.

A.H.Kulkarni et al. [3] proposed the algorithm by using easy way to extract features like Shape, Vein, color, texture features which are combined with Zernike movements.

The improvement was on feature extraction techniques that include Zernike movements and the dual stage learning algorithm for training the classifier namely Radial basis function neural network. The dual stage learning Algorithm for training the classifier namely Radial basis function neural network was adopted. 32 different leaf types were used to recognize the input leaf from Flavia dataset.

Findings: Zernike moments from order 2 to 10 along with 5 shape features, mean of colors, standard deviation of colors, skewness of colors, 16 texture features, 3 vein features resulted in the highest accuracy of 93.82 %.By incorporating the Zernike moments for feature description is a feasible alternative for classifying structural complex images.

Qinghai He et al. [4] applied several algorithms like Image enhancement, image filtering which suit for cotton leaf processing. Three different color models namely RGB, HSI & YCbCr were implemented for extracting the damaged image from cotton leaf images. The results indicate that YCbCr was the best color model. The damaged ratio caused by diseases of each color model are RGB color model (81.60%), HIS color model(43.15%) and YCbCr Color model (58.40%).The damage ratio caused by pests of each color model are RGB color model(5.29%), HIS color model(4.90%), YCbCr color model(5.93%).

P.Revathi et al. [5] developed an advanced computing technology to help the farmer to take superior decision about many aspects of crop developed process. Suitable evaluation & diagnosis of Foliar crop disease is very critical for the increased production. The technological strategies have been expressed using mobile captured symptoms of cotton leaf spot images and categorized the diseases using neural network. The classifier is being trained to achieve intelligent farming, including early detection of disease in the groves, selective fungicide application etc. The work is based on Image edge segmentation techniques in which the captured images are processed for enrichment first. Then R,G,B color feature image segmentation is carried out to get target disease spots. Image features such as boundary, shape, color and texture are extracted for the disease spots to recognize diseases and control the pest recommendation.

Yinmao Song et al. [6] described the feature extraction methods of crop disease based on computer image processing technology in detail. The characteristics of crop diseases are complexity and variability due to wide range of crop diseases, in addition to severity of diseases. The crop disease should be analyzed and effectively identified according to the screening and representative characteristics parameter values based on color, texture and shape.

Prof. Sanjay B. Dhaygude and Nitin P.Kumbhar in the paper “Agricultural plant leaf diseases detection using image processing” worked on the texture feature of plant. The texture features of infected leaf are compared to the texture features of normal leaf. The developed processing consists of four main steps, first the color transformation structure for input RGB image is created, then RGB image is converted to HIS because RGB is for color generation and HIS for color descriptor. Then green pixels are masked and removed using specific threshold value, then the image is segmented and useful segments are extracted, finally the texture statics is computed using spatial Gray Level Dependence Matrices (SGDM) [7].

Haiguang Wang at el.[8] suggested that plant disease identification based on image processing could quickly and accurately provide useful information for the prediction and control of plant diseases.In this study, 21 color features, 4 shape features, and 25 texture features were extracted from the images of two kinds of wheat diseases wheat stripe rust and wheat leaf rust and two kinds of grape diseases grape downey mildew and grape powdery mildew. Principal component analysis was performed for reducing dimensions in feature data processing, and then neural networks including back propagation networks, radial basis function neural networks, generalized regression networks and probabilistic neural networks were used as classifiers to identify wheat and grape diseases respectively. The results showed that these neural networks could be used for image recognition of these diseases based on reducing dimensions using PCA and acceptable fitting accuracies and prediction accuracies could be obtained.

Anand Kulkarni and Ashwin Patil et. al.[9] in the paper titled “Applying image processing technique to detect plant diseases” developed good classification based system for plant diseases. The Gabor filter is used for segmentation and artificial neural network is used for classification of diseases.

Artificial neural network based classifier is adopted which uses the combination of color and texture features to recognize and classify different plant diseases. Experimental results showed that classification performance by ANN taking feature set is better with accuracy 91%.

Tushar J.Haware, Ravindra D.Badgujar and Prashant G.Patil et. al. [10] in the paper titled “Crop disease detection using image segmentation” proposed an efficient algorithm with high clustering accuracy for detection of crop diseases. K-means clustering are used for segmentation and method for computed threshold value. Pixels with Zeros red, green and blue values and pixels on the boundary of the infected cluster are removed.

Kamaljot Singh Kailey and Gurjinder Singh Sahdra et. al. [11] in the paper titled “Content based image retrieval (CBIR) for identifying image based plan diseases” presents a method for identifying plant disease based on color, edge detection and histogram matching. This research is divided into two main phases. In the first phase, all the healthy and disease leaves are given input to MATLAB. Then RGB color component are separated into gray scale image and apply CANNY’s edge detection technique. After that histogram is plotted for each component of healthy and disease leaf image. In the second phase, the same process is repeated for testing leaf and the results are compared.

Viraj Gulhane et. al.[12] in the paper titled” Detection of diseases on cotton leaves and its possible diagnosis” gives the color image segmentation technique to extract the colour features of the cotton leaves. This technique provides easy way to extract the various features of diseased leaf of cotton image. After that the unsupervised network and back propagation neural network are applied to cluster the resulting color pixels and extract cotton leaf colour from diseases part of image respectively.

H.Al-Hiary, Bani-Ahmad, M-Reyalat and M.Braik et. al.[13] in the paper titled “Fast and accurate detection and classification of plant disease” developed more accurate and fast detection technique of plant disease. K-Means clustering and neural network have been formulated for clustering and classification of diseases that affect on plant leaf. They found that proposed approach, which can significantly support an accurate detection of leaf diseases in little computational effort.

Piyush Chaudhari, Anand K. Chaudhari, Dr. A.N.Cheeran and Sharda Godara et. al.[14] proposed an Algorithm for disease spot segmentation using Image processing technique in plant leaf. Color transform of RGB image can be used for better segmentation of disease spot. In this paper, they compared the effect of three different color space i.e. CIELAB, HIS & YbCr. Median filter is used for image smoothing. They found that CIELAB color model is better than other two models.

Dheeb Al Bashish, Malik Braik and Sulieman Bani Ahmad et. al. [15] in the paper titled “Detection and Classification of leaf diseases using K-mean based segmentation and neural network based classification” proposed detection model based neural network and they found that this model is very effective in recognizing leaf disease, while K-means clustering provides efficient result in segmentation RGB image.

Sanjay B.Patil and Dr. Shrikant K.Bodhe et. al.[16] in the paper titled “Leaf disease severity measurement using image processing” suggested the technique for disease detection in sugarcane leaves. In this paper, two thresholding methods are used for segmentation. Simple threshold segmentation is used to calculate leaf area but this method is not suitable for lesion area because of varying characteristic of the lesion region. So triangle threshold segmentation was used to achieve average accuracy of experiment to 98.60%.

A. Camargo at el. [17] in the paper titled “An image-processing based algorithm to automatically identify plant disease visual symptoms” described an image-processing based method that identifies the visual symptoms of plant diseases, from an analysis of coloured images.The processing algorithm starts by converting RGB image of the diseased plant or leaf, into the H, I3a and I3b colour transformations. The I3a and I3b transformations are developed from a modification of the original I1I2I3 colour transformation to meet the requirements of the plant disease data set.The transformed image is then segmented by analyzing the distribution of intensities in a histogram.

Di Cui et al. [18] described method for fast & accurate detection & classification of plant diseases. Authors used Otsu segmentation, K-means clustering & back propagation feed forward neural network for clustering and classification of diseases that affect on plant leaves.

Alexander A. Doudkin et.al. [19] in the paper titled “Three Level Neural Network for data clusterization on images of infected crop field” proposed neural network approach for segmentation of agricultural landed fields in remote sensing data.A neural network algorithm based on back propagation is used for segmentation of color images of crop field infected by diseases that change usual color of crops.

Panagiotis Tzionas et. al. [20] presents design and implementation of an artificial vision system in paper “Plant leaves classification based on morphological feature and fuzzy surface selection technique” which extracts specific geometry and morphological features from plant leaves. In this paper, morphological features of leaves are used for plant classification and in the early diagnosis of certain plant diseases. The proposed system consists of an artificial vision system, a combination of image processing algorithms and feed forward neural network based classifier. A fuzzy surface selection technique for feature selection was used and the images with smallest distances are selected and sorted as matching images to the query.

3. PROBLEM FORMULATION

At present, identification of crop diseases is mainly done by manual methods and is highly subjective in nature depending upon the expertise of the expert and his availability for the purpose. The research Project being undertaken will allow the users (who may not be experts in the domain) to identify the cotton diseases at a very early stage by taking pictures of the diseased leaves and sending them to a farmer help center. Around 13 million hectares of area is under cotton crop in India, level of infection in the past 10 years, around 40% loss of cotton yield has been produced as a result of diseases, there is definite need of cost saving in terms of pesticides as well as yield through early identification and action, the health hazards due to heavy use of pesticides can be prevented, adverse effect of pesticides on crop yield & soil can be prevented.

The farmer help centers will have computers and the disease identification programs using this algorithm. This will result in saving a huge loss to the cotton crop all over India because there is no limit to the number of copies of the software being made available at required locations and their earliest identification. The basic methodology being used would be to scan the diseased leaves and the conversion of images into computer readable form (in terms of pixels).The original images have been provided by the domain experts with identification of diseases. The images of early attack of various diseases will be again put under the microscope and experts will identify the pattern. These patterns will be used to confirm that they are persistent in the images of diseased leaves at the later stages of disease. If there is no repetition of these patterns of disease at various stages of attack , then later patterns will be taken and included in the search algorithm so that the disease at any stage can be identified.

3.1 OVERVIEW ABOUT TECHNIQUES TO BE USED

3.1.1 FEATURE DESCRIPTORS

GIST- A typical GIST is computed over a complete image for the scene classification task. It falls in the global image descriptor category.

SIFT- The typical use of SIFT is to match the local regions in two images on the basis of their reconstruction, alignment or other similar. SIFT can be used for the purpose of identification of some specific objects by using BW (Bag of Words) model.

HOG- Histogram of Oriented Gradient (HOG) is used for object-recognition. It is based on computing edge-gradients. Typical HOG works in the sliding window fashion for object detection applications. HOG computes the complete image after dividing it into the smaller cells, called blocks. HOG can be used alongside SVM for feature detection using classification.

CENTRIST- CENTRIST (CENsus TRanform hISTogram) is a novel visual descriptor, which is more robust to illumination changes, gamma variation etc. as compared to GIST and SIFT. CENTRIST is histogram of Census Transform (CT) values. CT compares intensity value of a pixel with its neighboring pixels and assigns value 1 or 0 to those pixels. After that the decimal number corresponding to this sequence of 8 neighboring binary digits is computed and used as CT value of center pixel. This descriptor retains the local as well as global structure of the scene. However, there are several limitations of this descriptor. It is not invariant to rotation and scale changes. It also does not consider color information. Further it cannot be used for precise shape description.

3.1.2 FEATURE REPRESENTATION TECHNIQUES

Bag of words- Bag of words involves four steps:1) Detect point/region of interest 2) Compute local descriptor 3) Quantize local descriptors into words to form visual vocabulary

4) Find occurrences of these words in image for constructing BoW features. In first step, image features are detected by interest point detectors. These interest point detectors are used to detect distinctive features of image. Amongst the most popular detectors are Harris Laplace Detector, which is used to detect corner like structures. Difference of Gaussian (DoG) is also a well-known detector to detect blob-like structures. It is not only faster but also compact. Hessian-laplace has also been used in some of the previous works for scene classification. Another category of works are based on regular grids for feature detection. Image is partitioned into regular grids, then either dense or sparse features are computed over these grids. The next step is to compute local descriptors over interest points or regular grids. SIFT (scale invariant feature transform) is popular local descriptor. It is invariant to scale, space and orientation. PCA (principal component analysis) is often used in combination with SIFT to reduce the dimensionality. DoG interest point detector plus SIFT feature descriptor has proven to be good choice for scene classification techniques. The third step i.e. vector quantization is the most expensive step in this whole process of image representation. K-means clustering is often used to quantize the feature vectors to form words.

3.1.3 SPATIAL PYRAMID MATCHING

Spatial pyramid matching is another well-known representation based on incorporating spatial lay-out of feature by first partitioning the image into increasingly fine fixed sub-regions and then computing histogram of local-features on these local sub-regions. Basically, it is extension of BoW representation. The local features are computed over each fixed sub-region. The geometric correspondence between images is computed by using pyramid matching scheme. More specifically, an image is partitioned into regular grids at resolutions 0,1…L such that there are 2l cells in the grid at level l. Histogram intersection is used for finding number of matches between cells. Using clustering technique the feature vectors are quantized into M discrete types. The dimensionality of feature vector for L levels and M channels is MΣ4l= M*1/3*(4l+1-1).

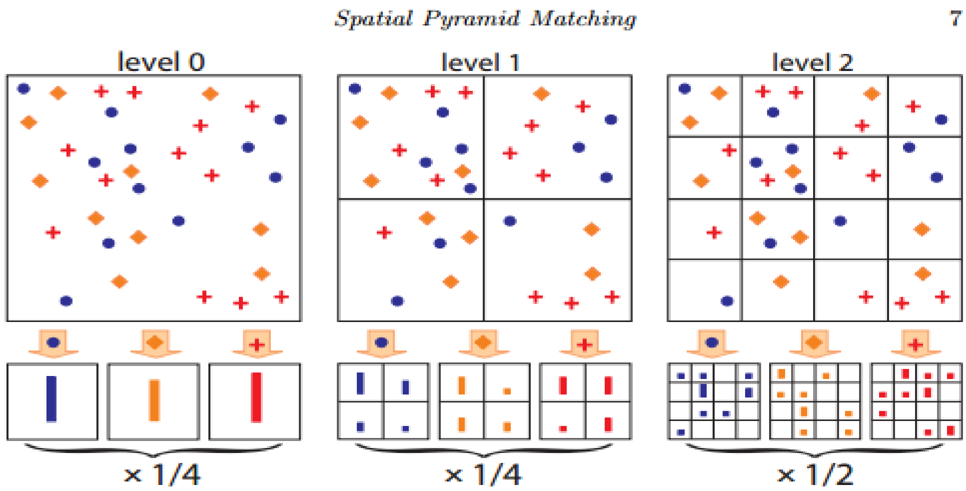


Fig. Spatial Pyramid Matching

3.1.4 OBJECT BANK REPRESENTATION

Object bank consists of a number of object detectors. Due to availability of a large number of detectors, it seems reasonable to use objects representation for scene classification. The latent SVM object detectors and texture classifier have been used for blobby objects and texture-based objects respectively. For a given image, several object detectors run on image. The image representation can be viewed as response of ―generalized object convolution‖. The dimensionality of representation is a point to be considered. For O object detectors at S detection scales and L spatial pyramid levels, the dimensionality is O*S*L. 200 object detectors have been used at 12 detection scales and 3 spatial pyramids. But this representation also works well with even modest number of object-detectors. Object-bank representation is useful representation in scenes cluttered with many objects, where GIST and SPM fail to distinguish scenes.

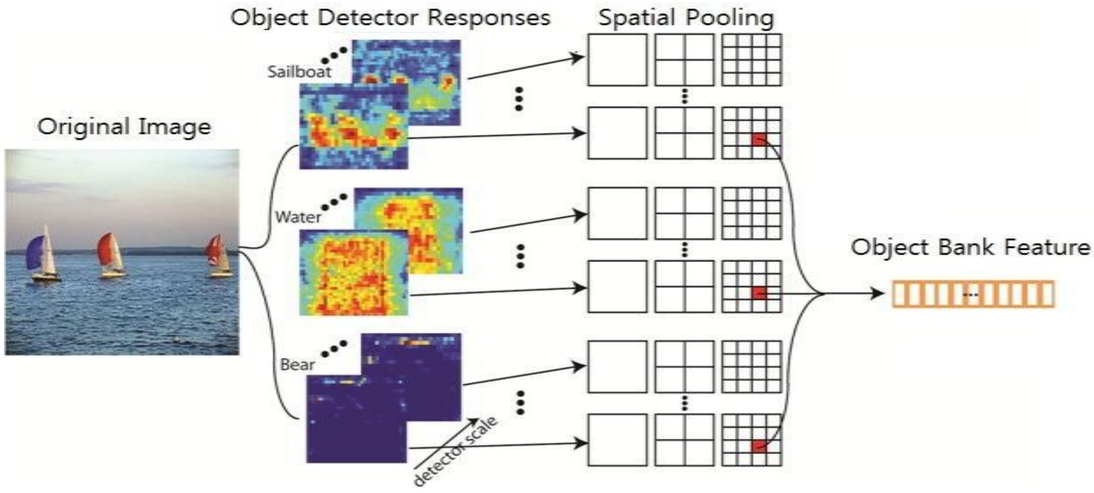


Fig. Object Detector Responses

3.2 CLASSIFIERS

3.2.1 SUPPORT VECTOR MACHINE

Support Vector machine (SVM) is a supervised learning based classifier. SVM is supervised machine learning approach specifically designed for pattern matching. SVMs construct a set of hyper-planes that separates the data points into two classes with maximal margin in high dimensional feature space. Mathematically, SVM learns a mapping **χ→ϒ** where **x € χ** represents the feature vector and **y € ϒ** represents scene category. The objective is to learn a function defined below, with function parameter α, given a set of training images **(x1, y1), (x2, y2)…(xn,yn). y=f(x,α) ---(3.1.4.1).** Once the mapping function is learnt, the classifier can render a category label for unobserved feature vector. According to the linear separability of data-points, SVM can be linear or non-linear. Non-linear SVM is an extension of linear SVM. It maps the non-linearly separable points to higher dimensional plane in which these can be linearly separable. Linear SVM- In case of non-linear SVM, the hyper plane is defined as given below **xi.w+b≥ +1, if yi=+1---(3.1.4.2) xi .w+b≤+1, if yi= -1---(3.1.4.3)** where **xi** denotes observed data points, w is normal vector, b is offset of hyper plane w.r.t. to origin and yi is target value.

Supports vectors are those data points that lie exactly on hyper plane and satisfy following equations: **xi .w+b= +1—(3.1.4.4) xi .w+b= -1---(3.1.4.5)**. This linear SVM is used for binary classification. For multiclass classification multiple one-vs-all linear SVMs can be used.

4. PROPOSED MODEL

The proposed model has been designed for cotton disease recognition by using the image processing techniques. The proposed model is a knowledge based system, which is built from the database available from the similar feature objects obtained from various scenarios. The proposed model has been designed to work with the obtained database, which is known as the knowledge and derive the knowledge-driven algorithms. The proposed model is consisted of three primary models: feature descriptor, feature representation and feature classification. The feature descriptor is the descriptor which extract and describes the feature, which is leaf borne disease in this case. There is a requirement of the feature descriptor, which can fetch the geometric shapes such as angular leaf curl (bacterial blight), leaf spot which is available in polygon shape (not defined shape for this fungal disease) etc. The feature descriptor must be capable to extract and describe the disease feature on the cotton leaf correctly. The feature descriptors are obtained from the leaf and then represented in the readable format for the classifier. The feature representation is the method which makes the feature descriptor validated for the feature classifier. The different types of classifiers understand different types of feature descriptors. For example, Support Vector Machine (SVM) and Relevance Vector Machine (RVM) understand the feature descriptor in the columns, whereas some of classifier process the matrix shaped feature descriptor. Feature representation method plays the important role in converting the feature descriptor in the classified supported format. The proposed model will be using the most adaptive feature descriptor out of the accurate and efficient existing options, such as GIST, SIFT, SURF, FREAK etc. The proposed model will utilize one or multiple (hybrid) feature descriptor in order to make it adaptable to fetch the various types of diseases from the images of cotton leaves. The proposed model will use the efficient vector machine for the classification purposes because of their efficient and accuracy results producing capability with the least response time in comparison with the bio-inspired classifiers such as neural network, etc. The proposed model will adaptable for the meta-heuristic data, which means it will be applicable over the data obtained from any source of the cotton plant leaf. In this model, the focus will be set upon the foliar diseases only. The foliar effects caused by the insects or pests will be also covered under this research to expand the reach of this system.

The pests also cause the heavy losses along with the crop diseases; hence covering them becomes very important. The while fly has destroyed the whole cotton crop in Punjab in this year, which inspires us to include the pest damage, which can be studied from the foliar properties, will be covered under this research.

5. WORK METHODOLOGY

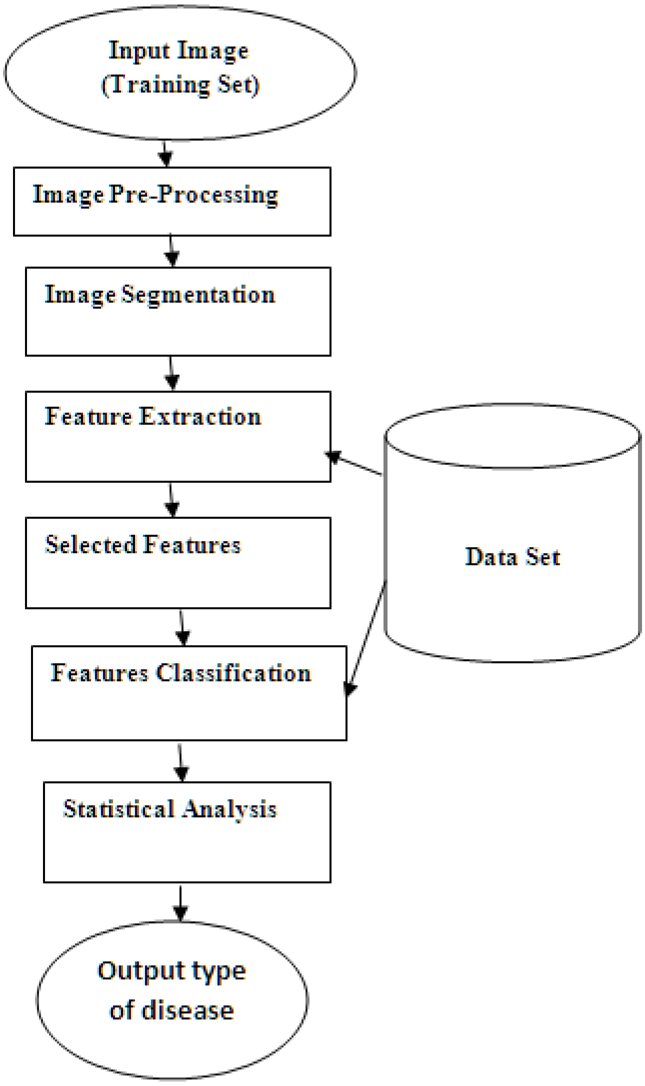
A known sample will be taken, scanned and digitized. This will contain the infected areas which will be physically marked to compare and identify a repetitive pattern which will be representative of the disease. This pattern will be used as training set. This training set will be used on different samples to arrive at the final training set. Once the training set is finalized, the pattern will be applied on unknown samples for identification of the disease. Fuzzy C Means (FCM) or OTSU technique will be adopted for segmentation of infected area of leaf. Zernike moments will be used to ensure that the results are not affected due to the angle at which input image is clicked. SIFT or SURF technique would be used to extract the features of the cotton disease from the infected area of the leaf. Support Vector Machine or KNN classifier would be used to classify the type & level of disease in the infected area of cotton leaf.

Human experts will ratify the findings of the computer. After this, the work will be done to improve the algorithm in terms of optimizing the size of training set and improving the speed of disease recognition. A similar approach will be used to identify other diseases of cotton crop. The algorithm will loop for including the recognition of other diseases on the same sample because it is likely that the crop may be affected by the multiple diseases at the same time. After recognition of all diseases, the computer expert system will generate a report identifying the disease(s) and remedies thereof.

Note:- The number of samples and the method of picking the samples for testing will be statistically designed and will depend upon the area of the crop.

The effort of the whole research would be to accurately identify the type of disease at as early stage as possible.

Fig. Flow Chart of Process



6. METHODOLOGY/PLANNING OF WORK

A sample of diseased leaf at an early stage will be put under microscope and manually scanned by the crop disease expert who will mark the repetitive patterns of disease. These diseased areas will be digitized and algorithm will be developed to optimize the size of the training set. The algorithm will be coded using MATLAB. The program will be used on different known diseased samples to ensure its accuracy and modified/improved to arrive at the final training set. After the training set has been identified for a particular disease, samples will be collected from the field for identification of the disease, the number of samples will be statistically designed so that the type of disease can be predicted with accuracy.

The end users will send the images of diseased leaves along with their addresses through mobile phones to the service centers (Kisan sewa centers). These images will be transferred to the computers along with the identity of the end user so that the final reports can be sent to the appropriate user. The pattern of various diseases will be tried on the unknown samples. An algorithm will be formulated such that it is efficient and accurate for identification of disease which will be tried on various samples. A masking technique will be used to filter out the non infected areas of the unknown digitized samples. Fuzzy C Means (FCM) or OTSU technique will be adopted for segmentation of infected area of leaf. By reducing the dimensions of the feature data extracted from the images of plant diseases using SIFT or SURF technique could reduce the running time of the algorithm and acceptable recognition results can be obtained. As stated in the introduction, plants are generally recognized using the shape of the leaf. For this reason they cannot be appropriately described with the help of regular shape descriptors like circularity, linearity and so on. That's why we adopt Zernike moments. These moments have higher space feature vector and are normally of order N. If additional order of moments is considered, then we achieve better the recognition probability. If an image is presumed to be an object, its descriptors are recognized as its feature vectors. In the end, Support Vector Machine or KNN will be applied to classify the disease and test the efficiency along with accuracy of the system in MATLAB. The program will be applied on unknown digitized samples for identification of the disease using the above training set for pattern and the program developed for the purpose on MATLAB.

Human experts will ratify the findings of the computer**.** After this, the work will be done to improve the algorithm in terms of optimizing the size of training set and improving the speed of disease recognition. A detailed map of the infected area denoting the combination of various pixels will be identified and will be used as a training set for checking the samples. An efficient algorithm will be developed so that the cotton leaf infection is identified at a fast pace.

A similar process will be used for other diseases of the crop and a total report of infection of the crop will be produced. A report generator will be used to pick up the data from the results of the program to create a report for the end user. The report will contain the types of diseases and detailed recommendations of the experts to control the diseases. The reports will have a capability of being modified from time to time so that the latest recommendations of experts in terms of technique & pesticides can be included.

7. CONCLUSION & FUTURE SCOPE

The Algorithm will help the end user to segregate the infected crop based on percentage of infection to take preventive measures at as early stage as possible. The algorithm will help in minimizing the use of pesticides thereby improving the environment and ecological balance. The proposed work has vast applications to help the Indian farmers in early identification of cotton crop diseases. The program can be converted into an executable form and distributed to various agricultural universities and Kisan Sewa centers so that the cotton crops can be saved with a huge benefit to the farmers and to the Indian economy. The research can be extended to identify the severity level of any disease on leaves, stems or roots. This will require further work in terms of measurement of area of leaf under attack and recognition of patterns of attack of disease on stems and depletion of root area. The program is likely to be used by other researchers for identification of other types of diseases in other crops along with identification of multiple cotton diseases on same cotton leaf.

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