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Early detection of leaf diseases in Beans crop using Image Processing and Mobile Computing techniques

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Abstract

Bean is one of the widely grown crop in the world. This crop is easily prone to various diseases such as Alternaria alternata, Bacterial blight, Cercospora yellow spot and Red spider Mite. Among these diseases, spider mites are most dangerous and widely occurring disease, hence this paper mainly aims at classification and identification of spider mite disease caused by spider mite. These diseases cause damage to the plants by feeding on green content of leaf leading to aging and earliest fruitless end of the crop.

In the existing situation farmer identify symptoms of the diseases by his vision, but he cannot differentiate types of the disease at its earliest stage of development. To know type of disease farmer need to get guidance from the expert which is time and cost fetching process. In order to control disease, it should be detected at its primary stage of development and pesticide is sprayed to the diseased plants. If the growth of disease extends its earliest stage of development, it cannot be controlled easily.

In order to solve the problems faced by the existing system, a novel automated computer vision based system is proposed for classification and early detection of diseases on bean crop using image processing and sending diseased information to the farmer using mobile computing. The experiment is conducted over 400 images on the underside surface of leaves of bean crop. The Precision, Recall, Error Rate and Average Accuracy obtained by the proposed system in detecting red spider mite disease are 73.6%, 81.2%, 15% and 84% respectively.

Keywords: Spider Mite, Bean, Alternaria Alternata, Bacterial Blight, Cercospora Leaf Spot.

I. INTRODUCTION

Agriculture plays a prominent role in the development of the country's economy. To improve agriculture, advance techniques should be used and implemented in farming. One such technique is early detection of leaf diseases in bean crop using image processing and mobile computing. It is an important research performed to provide benefits to the farmer by detecting symptoms of the disease large fields [1] very rapidly and accurately.

In India, beans crop covers an area of 2.07 lakh hectares with an annual production of about 58.2 lakh tons indicating high priority of crop production. Beans also dominates the top list of vegetables used for consumption in India. However, this crop is threatened by various diseases like Alternaria alternata, Bacterial blight, Cercospora yellow spot and Red spider mite. Among these diseases red spider mite is more terrific and occurs widely in the bean crop. Hence this paper mainly deals with the detection of spider mite disease in early and later stages.

Spider mites are very little, crawling, microscopic and wingless disease causing pathogens. They get increased in population by multiplying themselves in colonies. They can spread from one agricultural field to another through the air. The experiment is conducted on the Don breed of bean crop. Don breed of bean crop takes 5 to 6 days for germination of seed and 35 to 45 days to transfer into the preliminary stage of growth. Red spider mite is expected to occur at this preliminary stage of growth, hence the robot car is allowed to capture images of the underside surface of leaves of bean crop at this stage.

Robot car is used in agriculture to save manpower. The use of automated robot car can detect disease at an early stage and can reduce up to 70% waste use of crop pesticide. Red spider mite needed to be identified within 5 to 8 days of the span of occurrence to control the disease completely. If it extends the preliminary stage of occurrence that is more than 8 to 12 days, then the disease cannot be controlled easily. Prevention is better than cure, so we make early detection. If the disease is not detected at its initial stage of development would lead to death of the entire plant. In the existing system farmer identify diseases through naked eye observation.

Problems faced by the farmer for detecting disease in the existing system are as follows.

- Farmer identifies the symptoms of diseases manually through his vision, but he finds difficulty in detecting the type of the disease.
- To know type of disease, farmer is supposed to get guidance from experts which is time consuming and the cost fetching process [1].
- Early disease detection is not possible. If growth of disease exceeds its primary stage, then it will defoliate and destroy complete crop leading to loss in terms

of yield, labor and time to the farmer.

In order to solve the problems faced by existing system automated disease detection system is introduced by the proposed model. Proposed model enables computer vision based automatic inspection, classification and detection of diseases using image processing and mobile computing.

The main contributions of our proposed model are:-

- Design an automated remotely controlled robot car for capturing images of the underside surface of leaves of bean crop.
- Perform image processing activities on the captured images taken from the robot mobile camera to classify and detect diseases accurately.
- Send diseased information in the form of text message to the farmer using GSM (Global system for mobile communication) module.

A. *Related Work*

In recent times, digital image processing, image evaluation and device vision have been sharply advanced, such that they have come to be a vital part of a synthetic intelligence. Techniques of digital image processing had been applied extensively in various fields like industries, medicinal drug and agriculture. Efforts have been made by various researchers to adopt image processing techniques for detection of diseases in various agricultural crops are discussed below.

Sanjay et al., 2013 proposed a system for detection of disease on the leaf of a plant using Image Processing. This framework deals with steps of converting RGB into HIS [1], segmenting the image to get region of interest and finally extracting features from segmented part to detect a disease. This paper can efficiently detect diseases for uniformly colored image. But it cannot be applied for multicolor approaches consisting of disease segments for light gray, dark gray, yellow and brown colors. Mahesh et al., 2016 defined a method for detection of crop diseases using multiscaling technique [2]. Classification method used in this paper was found to be efficient in classifying small not trained datasets, but it cannot handle large trained datasets. Large datasets yield more training samples which would be time consuming to classify and detect diseased spot.

Ghulam et al., 2016 introduced an advanced system for detection of plant disease. This paper aims at the design and development of image processing based software for automatic classification and detection of disease in plants. In this paper detection of the disease is done on two distinct classes of disease like scorch and spot [3]. Algorithms are designed for segmentation, feature extraction, classification and detection of disease. One of the drawbacks of the technique used in this paper is that it can be implemented only in controlled laboratory condition. It has good adaptability for different color spaces, but it yields poor segmentation results on the tested images.

Megha et al., 2017 implemented a method for plant disease identification using the FCM (fuzzy C-means) clustering technique. Segmentation is done by using FCM clustering technique [4]. Features are extracted from affected regions and passed to the SVM (support vendor machine) classifier for classification. The combination of classifier technique is used in this paper can classify diseases efficiently, but takes more processing time. Hence main drawback of this paper is early detection of disease is not possible.

Vijay et al., 2015 implemented a method for detection of unhealthy region of plant leaves using image processing and genetic algorithm. Genetic algorithm [6] is the iteratively formed evolutionary algorithm for generating solutions to analytical problems. The algorithm begins with a set of solutions called a population. Solutions from one population are chosen and used to form a new population. This paper can extract features of the disease from the segmented part efficiently, but it takes more time to handle multiple iterations of the sample input. It has low execution speed since it takes more training time.

The proposed paper uses histogram equalization approach for image enhancement to get global contrast which can overcome light shades of sunlight. Enhanced image is segmented through feature based hybrid clustering approach of k-means and watershed algorithm. This hybrid segmentation approach yields good segmentation results in detecting diseased part. Features are extracted from the segmented part using PCA (principal component analysis) and final classification is performed by using SVM classification. SVM yields good classification performance in classifying diseases. The method used in proposed paper is automated for performing all processing activities, so it can be used for early detection of diseases.

This paper is organized as follows: In section 2. The proposed methodology is defined with model diagram and flowchart. In section 3. Experimental results are shown with tools, segmentation and classification performance measures. In section 4. The conclusion is described and finally in the last section acknowledgement and references are defined.

II. PROPOSED METHODOLOGY

The proposed model aims in the design and development of an automated system for early detection of diseases on bean crop and send diseased information to the farmer. This technique gives an evident path for classification and identification of various diseases in bean crop. There are five main steps implemented in the detection of bean leaf diseases as shown in Fig. 1.

The first step in this approach is to capture the images of the underside surface of leaves of bean crop with uniform background. A mobile camera with 5 megapixel and above resolution is used for capturing the images of the leaf of the bean crop. Capturing of images from the mobile camera is controlled remotely by means of Bluetooth module. Bluetooth module is connected between mobile and the robot car. Mobile with Bluetooth module is placed on a robot car as shown in Fig. 2.

Robot car is the mobile vehicle consisting of four wheels and two DC motors, These DC motors require 12 volts for operation. It has 30 RPM, moving capability and requires 12 volt battery to run. Robot car is controlled remotely by means of Zigbee module. Mobile camera is faced in the upward direction on robot car. The crop field consists of a number of rows, robot car will move in between these rows. The robot car runs in between these rows because there are no ups & downs in this area. Images captured from the mobile camera are sent to MATLAB installed host through a Wi-Fi module for performing image processing activities.

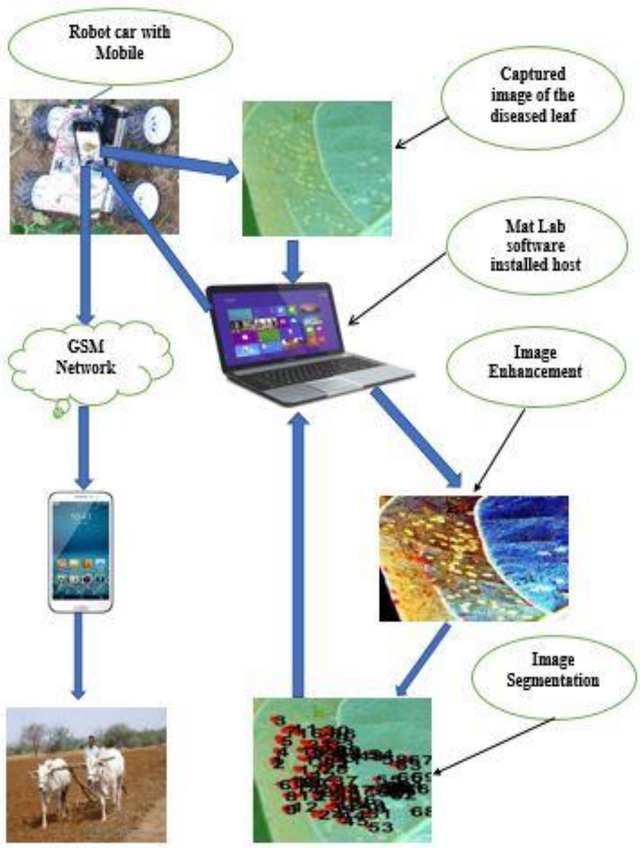


Fig. 1. Proposed model

Fig. 2. Robot car

Second step is to perform enhancement on the input image taken from the mobile camera using image processing techniques. Image enhancement can be through primary and secondary stages. Primary stage involves resizing of images into 256-256 pixel format to get uniform size, removing undesirable noise and converting RGB format of the input image into an HSV format to get HSV values. HSV color space defines a color vision for the image in terms of Hue and Saturation values. HSV values are then used in the code to determine the location of a specific object based on threshold values. The secondary stage involves histogram equalization to increase contrast or brightness of the input image.

Let A be a given image represented by a matrix of integer pixel intensities ranging from 0 to M – 1. Then normalized histogram for the image is given by Equation (1).

$$N(n) = \frac{number\ of\ pixels\ with\ intensity\ n}{total\ number\ of\ pixels} \quad (1)$$

Where, n is the intensity ranging from 0 to M – 1 and M is the number of possible intensities from 0 to 256.

The contrast of the image can be increased by using the formulae given by Equation (2).

$$I(x,y) = \frac{J(x,y) - Jmin}{Jmax - Jmin} \times 256 \quad (2)$$

Where, J (x, y) denotes the value of each pixel intensity, Jmin = 0 and Jmax = 256. After performing histogram equalization output image obtained is taken as enhanced image shown in Fig. 3.

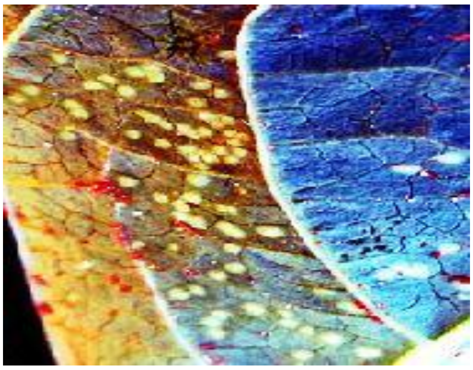


Fig. 3. Enhanced image of bean leaf

The third step is segmentation where the image is partitioned into discrete quantities of quality images with uniform background. This paper proposes a hybrid cluster based approach consisting of K-means and Watershed algorithm for segmenting an enhanced image to get desired region of interest. In general k-means clustering algorithm can segment pixels based on a set of features like size, shape and color. Segmentation is achieved by minimizing the sum of squares of distances between the objects and corresponding cluster. K-means algorithm does not yield the same result for each run as the resulting clusters is dependent on initial random assignments. K-means algorithm cannot handle empty clusters if no points are allocated to a cluster.

The proposed model solves the problems faced by k-means algorithm by splitting the image into different levels and sorting the pixels at each level in defining order. Maxima and minima are taken for all pixels of points. Central distance between different pixel coordinates is measured. Those pixel coordinates satisfy given condition are selected and remaining are neglected. Segmenting the region of interest as white pixels and remaining as black pixels. This cycle of the process is repeated for all pixel points at different levels to get desired region of interest that is diseased spot.

K-means algorithm is applied for segmenting images of the diseases alternaria alternata, bacterial blight and cercospora yellow spot only. Diseases with unique spots like a webbed spot of spider mite cannot be segmented using K- means algorithm. Segmentation of spider mite diseased image is performed by pointing out for regions of higher intensity gradients that divide neighbour point minima. Shade of the image is taken by marking values of different mask points. Proposed model uses matrix mask to scan the marker image to find null marker values and assign them to their intensity values as in the original image. Compare these values with neighbour pixel's intensity to assign them to one marker region. Disease spot is segmented by finding the difference in the intensity values of the region of the original and shaded image is as shown in Fig. 4. Steps involved in segmentation process are described using the following algorithm.

A. *Hybrid cluster based K-means and Watershed algorithm*

Input: Image I contain A = {A_1, A_2, A_3 ….A_n} pixels,
K= {K_1, K_2, K_3….K_n} clusters

Output: Segmented output image with desired region of Interest.

Begin

1. Split the enhanced image into multiple levels.

if (image with high intensity pixel gradient = null)

{

2. Sort the pixels in the order and assign them to any one of the clusters.
3. Compute the distance between the pixel and all centroids.
   C= {C_1, C_2, C_3….C_k} as $\sum_{i=1}^{k} \sum Aj\ |Aj - Ck|^2$
   Where, $Aj\ |Aj - Ck|^2$ denotes Euclidean normal form, C_k is mean of all pixels in K^{th} cluster and for all pixel A_j belongs to C_k.
4. Reassign the pixel A_i to the cluster C_i if its distance is less than or equal to the central euclidean distance calculated.
5. Repeat this until no reassignment is done.

}

Else {

6. Read the original image I and reconstruct it morphologically.
7. The complement of the reconstructed image taken is denoted by I_c.
8. To get minima, subtract original image I from complemented image I_c . Minima = I - I_c
9. Obtain marker pixel points from imposed minima.
10. Compute watershed transformation using marker pixel points.
11. Get the segmented diseased spot from the segmented image

}

end

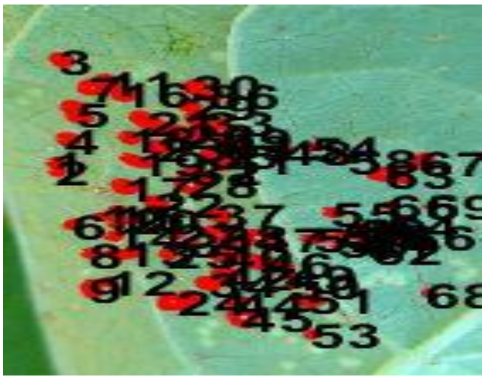


Fig. 4. Segmented Image of bean leaf

Mask of the image is tested for different values of hsv to find the diseased spot. Black and white area with high intensity is open to fill the detected spot is shown in Fig. 5. The region with white pixels is taken as desired region of interest.

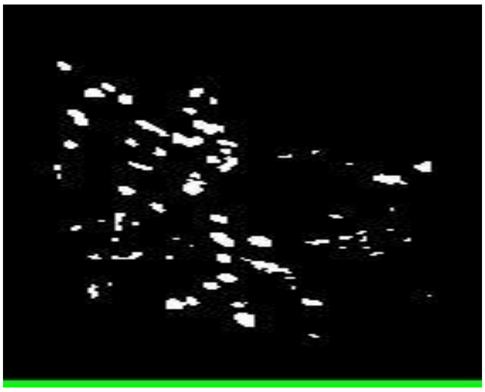


Fig. 5. Black and white image defining diseased spot

After performing image segmentation activities, features are extracted from the chosen region of interest. In this paper features are extracted based on color using PCA (Principal Component Analysis) method. PCA method is applied to the high dimensional transformation for getting high quality discriminant features. Segmented image contains low frequency and high frequency components. To extract features these components are to be displayed efficiently. It is done through wavelet transform technique.

In wavelet transform technique, coefficients are extracted from segmented input vectors. It uses four coefficients namely approximation coefficients, horizontal, vertical and diagonal coefficients. A parameter for size is calculated which also gives two more functions, matrix rescale and coefficient decimation. These intensity coefficients are used to classify different diseases. All the features of the image are not selected only accurate and useful features are selected. This method is known as “feature extraction” performed through PCA. Steps involved in the feature extraction process are as follows.

- Obtain the mean value of wavelet feature set.
- Subtract mean value from the original mean value to get component matrix.
- Calculate the co-variance matrix using the matrix obtained from the previous step.
- Calculate the eigenvectors and eigenvalues of the covariance matrix.
- Determine the new wavelet feature set.

The features obtained from these components are combined to form a feature vector which is given as input to the classifiers to classify various diseases in the leaf image.

Fourth step is to classify and detect red spider mite leaf disease using support vendor machine classification algorithm. SVM is one of the advanced trend in machine learning used for solving many pattern recognition problems. SVM mainly deals with two classes by maximizing or minimizing the margin from the hyperplane as shown in Fig. 6. The object samples close to the margin that are used to define the hyper plane are called as Support vectors. Depending on the way the given points are separated by hyperplane, the SVMs can be classified into linear SVM and non-linear SVM. Hyperplane is defined by positive and negative values. The mathematical formula for finding hyperplane is given by

$$(a.b) + c = +1(positive\ label) \quad (3)$$

$$(a.b) + c = -1(negative\ label) \quad (4)$$

$$(a.b) + c = 0(hyper\ plane) \quad (5)$$

Where, a, b and c are individual classes defining the hyperplane. The values of these classes are calculated by using linear algebra.

The proposed system uses multiclass classification to classify 6 different classes. Multiclass classification can be done by combining two or more two class SVMs by taking one to many or one to one combinations. For detection and classification, a training data set of 240 leaf images and testing dataset of 160 leaf images is taken into consideration. Classification is performed on the trained data set consisting six classes, namely Alternaria alternata, Bacterial blight, Cercospora yellow spot, Healthy leaves, Red spider late and Red spider mite early. Each of the classes has 40 leaf images and defined by their own specific features.

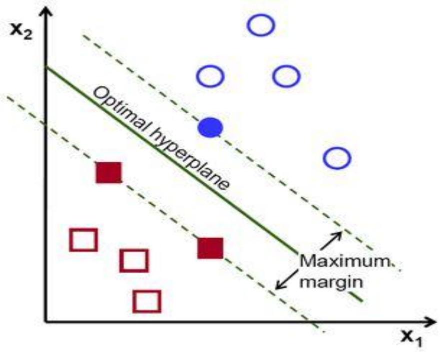


Fig. 6. Optimal seperating hyperplane of SVM

Binary tree representation of classification of six class dataset is shown in Fig. 7. Let n denotes number of classes, then discriminate function for dataset at training stage is given by $\frac{(n\times(n-1))}{2}$.

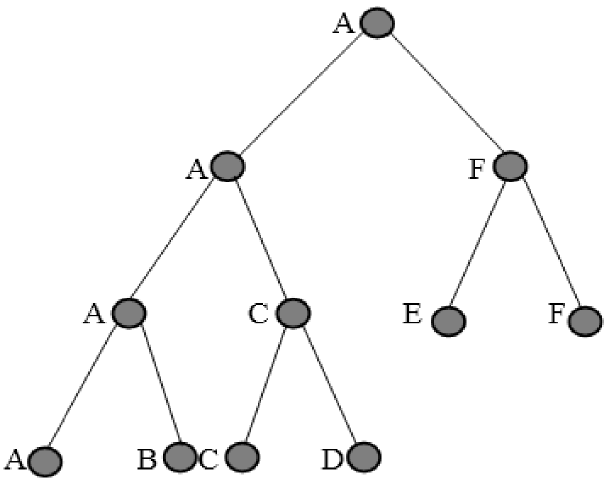


Fig. 7. Bottom up classification Diagram

Six classes A, B, C, D, E, F represents five different diseases like Alternaria alternata, Bacterial blight, Cercospora leaf Spot, Red spider mite late, Red spider mite early and Normal leaf respectively. Alternaria alternate can be identified by means of brown shade on the surface of the leaf. Bacterial blight is cut portion of the leaf caused by bacteria. Cercospora Leaf Spot is the occurrence of yellow spots on the surface of the leaf. The proposed system mainly deals with the detection of the red spider mite disease. It is detected based on the symptoms like white webbing spots at an early stage and red spots at a later stage on the surface of the leaf. Based on the features diseases are classified and detected.

Fifth step is to send diseased information to the farmer using GSM module. GSM module acts as an interface to send information between matlab host and mobile used by the farmer. An important characteristic underlying the design of image processing systems is the significant level of testing and experimentation that is normally required before arriving at an acceptable solution. The characteristic feature implies that the ability to formulate approaches and quickly prototype candidate solutions generally plays a major role in reducing the cost and time required to arrive at a viable system implementation.

The proposed model is represented by a flowchart as shown in Fig. 8.

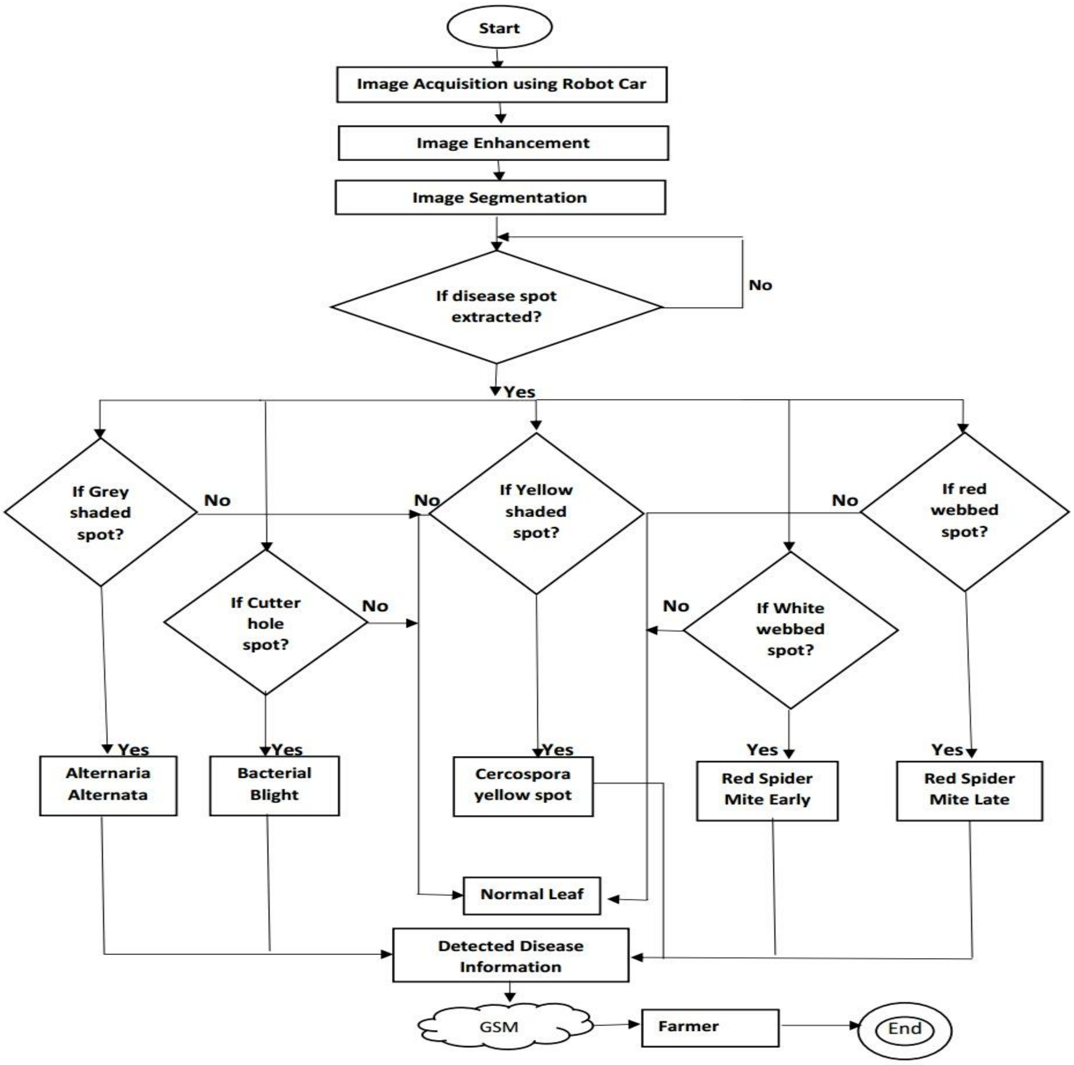


Fig. 8. Flowchart

III. EXPERIMENTAL RESULTS

The proposed system uses a robot car, Matlab host and GSM module as the components to build an automated system for leaf disease detection. The robot car includes mobile with camera of 5 megapixel and above resolution for capturing images of the leaf, RS232 motor driver to provide movements of the robot car, 80C51 microcontroller for controlling Robot Car, CC2500 RF ZigBee module for controlling robot car remotely and Bluetooth module for capturing images. MATLAB Host includes Intel (R) Core (TM) i5-3470 3.20GHz processor, 6GB RAM, 250GB hard disk, Windows 8 operating system, R2016b version matlab software and Keil uVision4 Software. GSM is used as an interface to send diseased information in the form of text message to the farmer.

Experimental setup for the proposed system can be done by placing mobile camera on the Robot car to capture images of leaf and send images to the matlab host for processing and detecting the disease. Diseased information is then sent to farmers through GSM module. Experimental setup of the proposed model is shown in Fig. 9.

Dataset consists of 400 images of leaves of Bean crop, Size of dataset is about 200MB and each image is about 500KB in size. In 400 images 60% of the images are used for training the dataset and 40% of the images for testing the dataset.

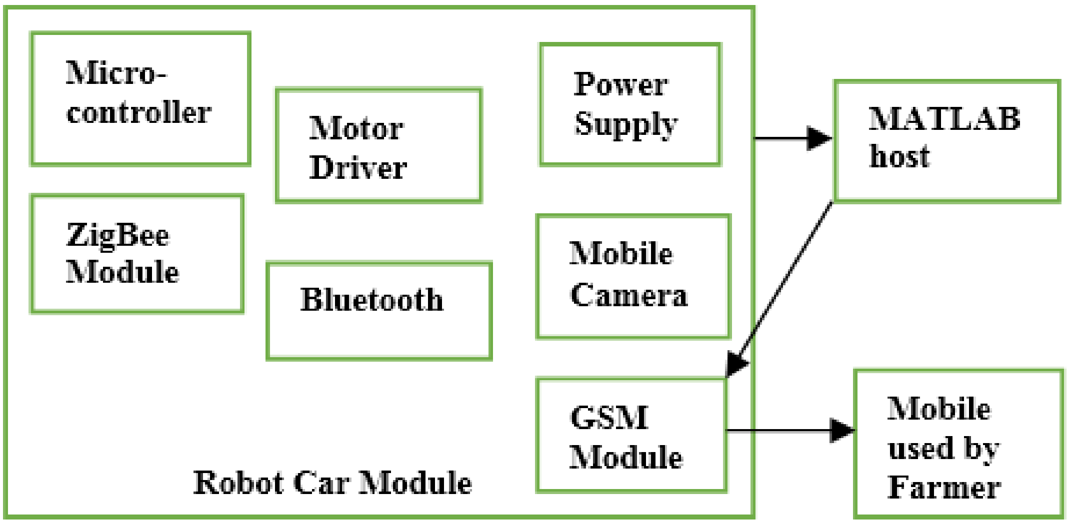


Fig. 9. Experiment setup diagram

The proposed system is represented to the user by means of graphical user interface as shown in Fig. 10.

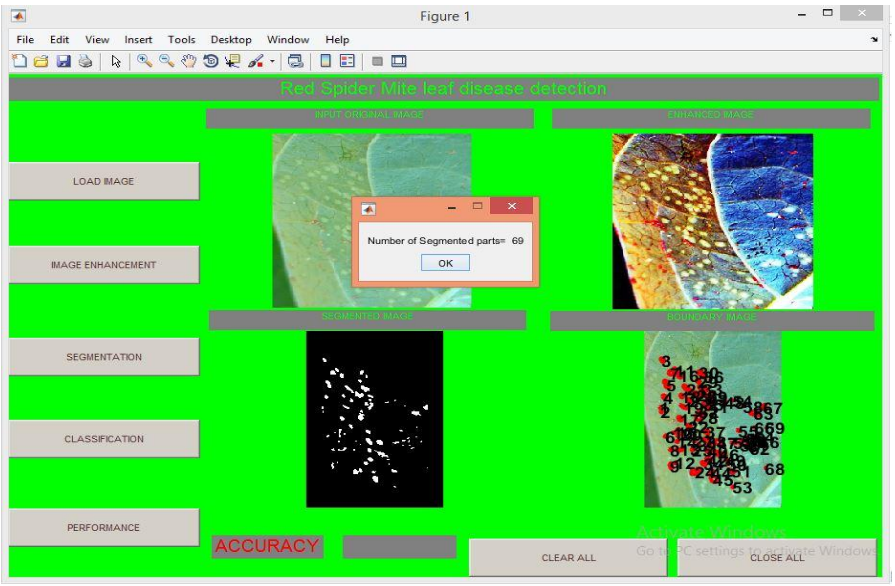


Fig. 10. Graphical User interface

The GUI provides a complete package for displaying image processing activities. It has various buttons to load image, enhance image, segment the image, classify the disease in the image and detect diseases in the image. On clicking "load" button it will ask to select images from the dataset. On clicking "Image enhancement" button it will perform image enhancement to increase contrast of the image. On clicking "segmentation" button it will perform segmentation on image to extract diseased part. Finally, on clicking "classification" button it will classify and detect different disease mentioned in below table. Performance can be measured through accuracy by pressing "performance" button on the GUI. Area of diseased part is found by converting segmented part into black and white image. The number of white pixels is counted to give the area of diseased part.

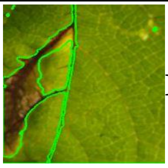
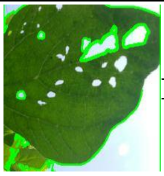
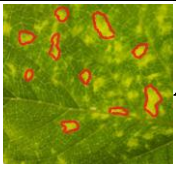
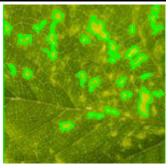
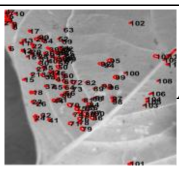
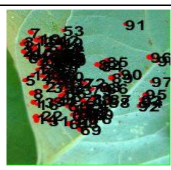
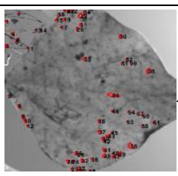
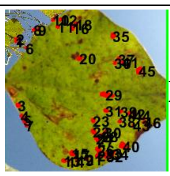
*A. **Segmentation measure***

Effectiveness of segmentation is calculated by using relative error as given in the Equation (6). Table. 1 gives the relative error of 5 diseased leaf image samples. Column 2 shows the actual segmentation of disease and column 3 gives segmentation done by the proposed system. Relative error is calculated for all the diseased leaf image samples.

$$\text{Relative error in } \% = \frac{(a-d)}{a} \times 100 \qquad (6)$$

Where, A is the actual diseased area measured in pixels and D is the diseased area of proposed system measured in pixels.

Table 1: Calculation of Relative Error

Sl. No	Name of the disease detected	Actual Segmentation	Segmentation by Proposed method	Relative Error in %
1	**Alternaria Alternata**	 **A = 39910**	 **D = 43360**	**8.64**
2	**Bacterial Blight**	 **A = 16780**	 **D = 19436**	**15.82**
3	**Cercospora Yellow Spot**	 **A = 44139**	 **D = 49998**	**13.27**
4	**Red Spider Mite Early**	 **A = 56791**	 **D =48574**	**14.468**
5	**Red Spider Mite Late**	 **A = 23676**	 **D = 17926**	**24.286**

Relative error yielded for the diseases Alternaria alternata, Bacterial blight, Cercospora yellow spot, Red spider mite early and Red spider mite late is 8.64%, 15.82%, 13.27%, 14.468% and 24.286% respectively. Alternaria alternata has lower relative error due to small change in intensity values. Red spider mite late has a higher relative error because of the large change in the number of pixels that is segmented area. Proposed system uses a hybrid approach of watershed and k-means algorithm, hence it is more efficient in segmenting the diseased part.

B. Classification Performance

Multi-class classification performance of the proposed system can be measured using various metrics such as, Average accuracy, Error rate, Precision and Recall. Average accuracy is the average effectiveness of a classifier measured per class given by Equation (7). Error Rate is the classification error obtained per class given by

Equation (8). Precision is the fraction of relevant instances among retrieved instances of the image given by Equation (9). Recall is the fraction of relevant instances that have been retrieved over total relevant instances of the image given by Equation (10).

$$Average\ Accuracy = \frac{\sum_{i=1}^{n} \frac{tp_i + tn_i}{tp_i + fn_i + fp_i + tn_i}}{n} \quad (7)$$

$$Error\ Rate = \frac{\sum_{i=1}^{n} \frac{fp_i + fn_i}{tp_i + fn_i + fp_i + tn_i}}{n} \quad (8)$$

$$Precision = \frac{\sum_{i=1}^{n} tp_i}{\sum_{i=1}^{n}(tp_i + fp_i)} \quad (9)$$

$$Recall = \frac{\sum_{i=1}^{n} tp_i}{\sum_{i=1}^{n}(tp_i + fn_i)} \quad (10)$$

Where tp is true positive cases which are correctly classified, tn is true negative cases which are correctly classified, fp is false positive cases which are incorrectly classified and fn is false negative cases which are incorrectly classified.

Table. 2 is used for evaluating the classification performance of different diseases. Column 1 of the table gives different disease samples. Column 2, 3, 4 and 5 shows different possible cases for the classifier. Column 6, 7, 8 and 9 represents various metrics used by the classifier. Dataset consists of 400 images of the underside surface of leaves of bean crop. Out of 400 images, 240 images that is 60% of the images are used for training the dataset and remaining 160 images that is 40% of the images are used for testing the dataset. Classification is performed on this trained dataset consisting 240 images. 240 images are classified into six different classes, where each class consisting of 40 images. The proposed method yielded Precision, Recall, Error Rate and Average Accuracy of 73.6%, 81.2%, 15% and 84% respectively.

Table 2: Classification performance evaluation

Disease Sample	tp	tn	fp	fn	Precision in %	Recall in %	Error Rate in %	Accuracy in %
Alternia Alternatae	12	20	4	2	75	86	15	80
Bacterial Blight	12	26	2	2	85	86	10	90
Cercospora Yellow Spot	10	24	4	2	71	83	15	85
Red Spider mite early	8	26	4	2	66	80	15	85
Red Spider mite late	10	22	4	4	71	71	20	80
Average					**73.6**	**81.2**	**15**	**84**

Accuracy gained by the classifier is represented by a performance graph as shown in Fig. 11. Performance graph is plotted for Accuracy of disease detected in % versus different types of diseases.

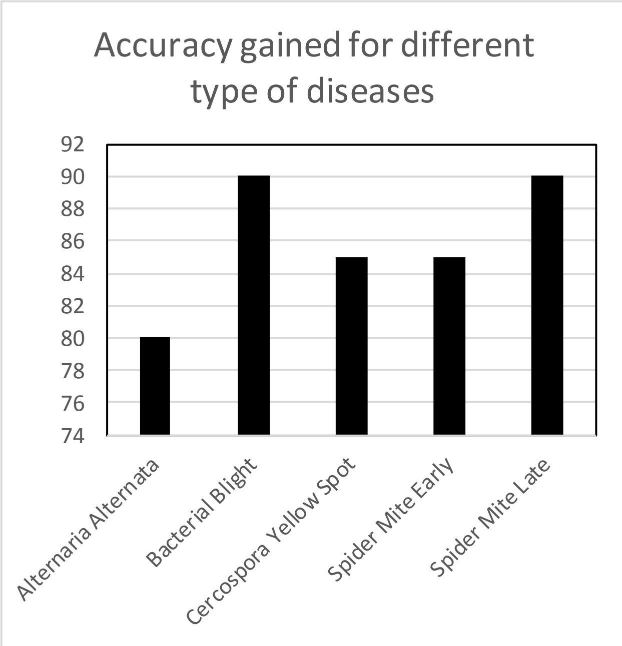


Fig. 11. Performance graph

Accuracy gained by diseases alternaria alternata, bacterial blight, cercospora yellow spot, red spider mite early and red spider mite late is 80%, 90%, 85%, 85% and 90% respectively. Total time taken for processing and detecting disease in the image is about 10 seconds.

IV. CONCLUSION

The proposed paper provides an automated computer vision based system for classification and detection of leaf diseases on bean crop using image processing and send diseased information to the farmer using mobile computing.

In proposing a system android mobile is placed on the robot car for capturing images of the underside surface of the leaves of bean crop. Captured images are made to undergo a set of pre-processing activities to get enhanced image. Enhanced image is segmented using hybrid approach of k-means and watershed algorithm to get desired region of interest that is diseased part. Features are extracted from the region of interest using PCA. Diseases are classified and detected based on the extracted features using an SVM classification algorithm. Finally diseased information is sent in the form of text message to the farmer using GSM module.

Average accuracy obtained by the proposed system in detecting the disease is 84%. Hence the proposed system helps the farmer by detecting the disease at an early stage and hence improves the crop yield.

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