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Detection of plant leaf diseases using image segmentation and soft computing techniques

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ABSTRACT

Agricultural productivity is something on which economy highly depends. This is the one of the reasons that disease detection in plants plays an important role in agriculture field, as having disease in plants are quite natural. If proper care is not taken in this area then it causes serious effects on plants and due to which respective product quality, quantity or productivity is affected. For instance a disease named little leaf disease is a hazardous disease found in pine trees in United States. Detection of plant disease through some automatic technique is beneficial as it reduces a large work of monitoring in big farms of crops, and at very early stage itself it detects the symptoms of diseases i.e. when they appear on plant leaves. This paper presents an algorithm for image segmentation technique which is used for automatic detection and classification of plant leaf diseases. It also covers survey on different diseases classification techniques that can be used for plant leaf disease detection. Image segmentation, which is an important aspect for disease detection in plant leaf disease, is done by using genetic algorithm.

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1. Introduction

The agricultural land mass is more than just being a feeding sourcing in today's world. Indian economy is highly dependent of agricultural productivity. Therefore in field of agriculture, detection of disease in plants plays an important role. To detect a plant disease in very initial stage, use of automatic disease detection technique is beneficial. For instance a disease named little leaf disease is a hazardous disease found in pine trees in United States. The affected tree has a stunted growth and dies within 6 years. Its impact is found in Alabama, Georgia parts of Southern US. In such scenarios early detection could have been fruitful.

The existing method for plant disease detection is simply naked eye observation by experts through which identification and detection of plant diseases is done. For doing so, a large team of experts as well as continuous monitoring of plant is required, which costs very high when we do with large farms. At the same time, in some countries, farmers do not have proper facilities or even idea that they can contact to experts. Due to which consulting experts even cost high as well as time consuming too. In such conditions, the suggested technique proves to be beneficial in monitoring large fields of crops. Automatic detection of the diseases by just seeing the symptoms on the plant leaves makes it easier as well as cheaper. This also supports machine vision to provide image based automatic process control, inspection, and robot guidance [2,4,5].

Plant disease identification by visual way is more laborious task and at the same time, less accurate and can be done only

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in limited areas. Whereas if automatic detection technique is used it will take less efforts, less time and become more accurate. In plants, some general diseases seen are brown and yellow spots, early and late scorch, and others are fungal, viral and bacterial diseases. Image processing is used for measuring affected area of disease and to determine the difference in the color of the affected area [1,2,6].

Image segmentation is the process of separating or grouping an image into different parts. There are currently many different ways of performing image segmentation, ranging from the simple thresholding method to advanced color image segmentation methods. These parts normally correspond to something that humans can easily separate and view as individual objects. Computers have no means of intelligently recognizing objects, and so many different methods have been developed in order to segment images. The segmentation process is based on various features found in the image. This might be color information, boundaries or segment of an image [11,13]. We use Genetic algorithm for color image segmentation.

Evolutionary computing was first introduced in the 1960s by I. Rechenberg. His idea was then taken forward by other researchers. Sometimes evolutionary changes are small and appear insignificant at first glance, but they play a part in natural selection and the survival of the species. Examples of natural selections are

1. The warrior ants in Africa are probably one of the most impressive examples of adaptation. Within any single colony, ants emit a chemical signal that lets the others know they all belong to the same compound. Or, put more simply, a signal that says, "Don't attack me, we're all family." However, warrior ants have learned how to imitate the signal from a different colony. So if a group of warrior ants attacks a colony, they will be able to imitate that colony's signal. As a result, the workers in the colony will continue on, now under the direction of new masters, without ever realizing an invasion has taken place.
2. All rat snakes have similar diets, are excellent climbers and kill by constriction. They all have the same reaction when startled (they remain motionless), and will avoid confrontation whenever possible. Some will bite if threatened, although they are non-venomous. However, rat snakes come in a wide variety of colours, from yellow striped to black to orange to greenish. This is because rat snakes are found all over the Eastern and Midwestern states, and are subjected to all types of weather and terrain. Rat snakes are common in urban areas, but they can also be found in wooded areas, mountains or coastal regions. As a result, rat snakes have had to adapt to their local environments in an effort to avoid detection and hunt more effectively.

Genetic algorithms belong to the evolutionary algorithms which generate solutions for optimization problems. Algorithm begins with a set of solutions called population. Solutions from one population are chosen and then used to form a new population. This is done with the anticipation, that the new population will be enhanced than the old one. Solutions which are selected to form new solutions (offspring) are chosen according to their fitness – the more appropriate they are, the more probability they have to reproduce [12,14].

Some advantages of genetic algorithm are

- Genetic algorithm optimizes both variables efficiently, continuous or discrete.
- It searches from a large sampling of the cost surface.
- Large number of variables can be processed at the same time.
- It can optimize variables with highly complex cost surfaces.
- Gives a number of optimum solutions, not a single solution. So different image segmentation results can be obtained at the same time

The basic steps of genetic algorithm are as follows:

(1) [Start] Generate random population of n chromosomes (suitable solutions for the problem).
(2) [Fitness] Evaluate the fitness $f(x)$ of each chromosome x in the population.
(3) [New population] Create a new population by repeating following steps until the new population is complete.
    (a) [Selection] Select two parent chromosomes from a population according to their fitness (the better fitness, the bigger chance to be selected).
    (b) [Crossover] With a crossover probability cross over the parents to form a new offspring (children). If no crossover was performed, offspring is an exact copy of parents.
    (c) [Mutation] With a mutation probability mutate new offspring at each locus (position in chromosome).
    (d) [Accepting] Place new offspring in a new population.
(4) [Replace] Use new generated population for a further run of algorithm.
(5) [Test] If the end condition is satisfied, stop, and return the best solution in current population.
(6) [Loop] Go to step 2.

2. Literature review

Ghaiwat et al. presents survey on different classification techniques that can be used for plant leaf disease classification. For given test example, k-nearest-neighbor method is seems to be suitable as well as simplest of all algorithms for class prediction. If training data is not linearly separable then it is difficult to determine optimal parameters in SVM, which appears as one of its drawbacks [1].

Authors in paper [2] describe that there are mainly four steps in developed processing scheme, out of which, first one is, for the input RGB image, a color transformation structure is created, because this RGB is used for color generation and transformed or converted image of RGB, that is, HSI is used for color descriptor. In second step, by using threshold

value, green pixels are masked and removed. In third, by using pre-computed threshold level, removing of green pixels and masking is done for the useful segments that are extracted first in this step, while image is segmented. And in last or fourth main step the segmentation is done.

Mrunalini et al. [3] presents the technique to classify and identify the different disease through which plants are affected. In Indian Economy a Machine learning based recognition system will prove to be very useful as it saves efforts, money and time too. The approach given in this for feature set extraction is the color co-occurrence method. For automatic detection of diseases in leaves, neural networks are used. The approach proposed can significantly support an accurate detection of leaf, and seems to be important approach, in case of steam, and root diseases, putting fewer efforts in computation.

According to paper [4] disease identification process include some steps out of which four main steps are as follows: first, for the input RGB image, a color transformation structure is taken, and then using a specific threshold value, the green pixels are masked and removed, which is further followed by segmentation process, and for getting useful segments the texture statistics are computed. At last, classifier is used for the features that are extracted to classify the disease. The robustness of the proposed algorithm is proved by using experimental results of about 500 plant leaves in a database.

Kulkarni et al. presents a methodology for early and accurately plant diseases detection, using artificial neural network (ANN) and diverse image processing techniques. As the proposed approach is based on ANN classifier for classification and Gabor filter for feature extraction, it gives better results with a recognition rate of up to 91%. An ANN based classifier classifies different plant diseases and uses the combination of textures, color and features to recognize those diseases [5].

Authors present disease detection in Malus domestica through an effective method like K-mean clustering, texture and color analysis [6]. To classify and recognize different agriculture, it uses the texture and color features those generally

Table 1.1 – Analysis of various algorithms.

Authors & year	Goals	Future perspective
[1] Savita N. Ghaiwat et al., Detection and classification of plant leaf diseases using image processing techniques: a review (2014)	Review of ANN, SVM, PNN, SELF ORG MAPS and fuzzy logic	In neural network it's difficult to understand structure of algorithm and to determine optimal parameters when training data is not linearly separable
[2] Prof. Sanjay B. et al., Agricultural plant leaf disease detection using image processing (2013)	Vision-based detection algorithm with masking the green-pixels and color co-occurrence method	NN's can be used to increase the recognition rate of classification process
[3] Mrunalini R. et al., An application of K-means clustering and artificial intelligence in pattern recognition for crop diseases (2011)	K-means clustering algorithm with neural networks for automatic detection of leaves diseases	Artificial neural network and fuzzy logic with other soft computing technique can be used to classify the crop diseases
[4] S. Arivazhagan et al., Detection of unhealthy region of plant leaves and classification of plant leaf diseases using texture features (2013)	Color co-occurrence method with SVM classifier	The training samples can be increased and shape feature and color feature along with the optimal features can be given as input condition of disease identification
[5] Anand H. Kulkarni et al., Applying image processing technique to detect plant diseases (2012)	Gabor filter for feature extraction and ANN classifier for classification	Recognition rate can be increased
[6] Sabah Bashir et al., Remote area plant disease detection using image processing (2012)	Texture segmentation by co-occurrence matrix method and K-means clustering technique	Bayes classifier, K-means clustering and principal component classifier can be used to classify various plant diseases
[7] Smita Naikwadi et al., Advances in image processing for detection of plant diseases (2013)	The color co-occurrence texture analysis method was developed through the use of spatial gray-level dependence matrices	Better result of detection can be obtained with the large database and advance feature of color extraction
[8] Sanjay B. Patil et al., Leaf disease severity measurement using image processing (2011)	Simple threshold and triangle thresholding segmentation methods	Nil
[9] Piyush Chaudhary et al., Color transform based approach for disease spot detection on plant leaf (2012)	Median filter is used for image smoothing and threshold can be calculated by applying Otsu method	Disease spot area can be computed for assessment of loss in agriculture crop. Disease can be classified by calculating dimensions of disease spot
[10] Arti N. Rathod et al., Image processing techniques for detection of leaf disease (2013)	Survey of different techniques for leaf disease detection	Development of hybrid algorithms & neural networks in order to increase the recognition rate of final classification process

appear in normal and affected areas. In coming days, for the purpose of classification K-means clustering, Bayes classifier and principal component classifier can also be used.

According to [7] histogram matching is used to identify plant disease. In plants, disease appears on leaf therefore the histogram matching is done on the basis of edge detection technique and color feature. Layers separation technique is used for the training process which includes the training of these samples which separate the layers of RGB image into red, green, and blue layers and edge detection technique which detecting edges of the layered images. Spatial Gray-level Dependence Matrices are used for developing the color co-occurrence texture analysis method. Analysis of various algorithms is given in Table 1.1.

Paper [8] presents the triangle threshold and simple threshold methods. These methods are used to lesion region area and segment the leaf area respectively. In final step, categorization of disease is done by calculating the quotient of leaf area and lesion area. According to the research done, the given method is fast and accurate for calculating leaf disease severity and leaf area calculation is done by using threshold segmentation.

Authors describe an algorithm for disease spot segmentation in plant leaf using image processing techniques [9]. In this paper, process of disease spot detection is done by comparing the effect of HSI, CIELAB, and YCbCr color space. For Image soothing Median filter is used. In final step, by applying Otsu method on color component, calculation of threshold can be done to find the disease spot. There is some noise because of background which is shown in the experimental result, camera flash and vein. CIELAB color model is used to remove that noise.

The state of art review of different methods for leaf disease detection using image processing techniques is presented in paper [10]. The existing methods studies are for increasing throughput and reduction subjectiveness which comes due to naked eye observation through which identification and detection of plant diseases is done.

According to [15] soft computing methods such as artificial neural networks (ANN), genetic programming, and fuzzy logic can be used as an alternative method for modeling complex behavior of materials such as graphene. These algorithms require input training data for solving problems. These computing methods generate meaningful solutions for complicated optimization problems based on the input. In many models feed-forward network of three layers can be used. Root-mean-square error method can be used to determine the number of neurons in hidden layer.

Tabu search is the meta heuristic search method which uses local search techniques used for mathematical optimization. Local searches pick up a solution to a problem which is potential and checks its immediate neighbors i.e. those solutions which are similar except for some minor details, with an intention of finding a better solution. Local search methods tend to get stuck in suboptimal regions or on plateaus where many solutions are equally fit. If any solution which is potential has been previously visited within a short duration or if it doesn't satisfies a rule, then it is marked as "tabu". By doing so, the algorithm doesn't consider that possibility repeated [24].

Genetic algorithms were used to evolve programs to perform certain tasks by John Koza in 1992. His method was known as "genetic programming" (GP). Genetic programming is considered to be the most famous for solving symbolic regression problems and is widely used for solving optimization problem. The working principle behind GP and GA are same but there lies a major difference between the two that GP gives solutions in terms of weighted sum of coefficients, whereas GA gives solutions represented by a number in binary or real form. Thus, we can say that GP is a structure optimization method whereas GA is a parameter optimization method. MGGP is the Genetic programming in which evolutionary stage is a combined set of several trees which are regressed using least squares method. We can use trial-and-error method for the effective implementation of MGGP [16,17,19].

Vijayaraghavan et al. in their work [18] stated that a support vector machine is a very potential AI method and can apply extensively to solve classification problems. The SVM which is used to solve regression problems is known as support vector regression (SVR). SVR is very popular among researchers for providing generalization ability to the solution model.

The manifestation of pathogens in plantations is the one of the most important cause of losses in many crops. Bernardes et al. give the method of the automatic classification of cotton diseases based on the feature extraction of foliar symptoms from digital images. For the feature extraction this method uses the energy of the wavelet transform and a SVM for the actual classification [20].

Ma et al., [21] makes a review on the current segmentation algorithms used for medical images. Algorithms mainly categories in three categories according to their main concepts: the first based on threshold, the second based on pattern recognition techniques and third one based on deformable models. In recent years the third category of algorithms are focused on deformable models as a result of intensive investigation. Some of the main applications of these algorithms are segmenting organs and tissues in pelvic cavity area. These are discussed through several preliminary experiments.

Authors in paper [22], classified an algorithm on the basis of the principal methodologies. Algorithms of each category are discussed and the important ideas, application fields, advantages and disadvantages of each category are summarized. Experiments that use these algorithms to segment the tissues and organs of the female pelvic cavity are to show their unique characteristics. In the last, the important guidelines for designing the segmentation algorithms of the pelvic cavity are proposed.

Tavares describes that the computational analysis of images is challenging due to tasks such as segmentation, extraction of representative features, matching, alignment, tracking, motion analysis, deformation estimation, and 3D reconstruction. In paper [23], the methods for processing and analyzing objects in images and their use in applications like medicine, biomechanics, engineering and materials sciences are proposed.

Limitation of existing work:

- The implementation still lacks in accuracy of result in some cases. More optimization is needed.

- Priori information is needed for segmentation.
- Database extension is needed in order to reach the more accuracy.
- Very few diseases have been covered. So, work needs to be extended to cover more diseases.
- The possible reasons that can lead to misclassifications can be as follows: disease symptoms varies from one plant to another, features optimization is needed, more training samples are needed in order to cover more cases and to predict the disease more accurately.

To remove these research gaps a new methodology for automatic detection as well as classification of plant leaf diseases using image segmentation has been proposed. The advantages of proposed algorithm are as follows:

1. Use of estimators for automatic Initialization of cluster centers so there is no need of user input at the time of segmentation.
2. The detection accuracy is enhanced with proposed algorithm.
3. Proposed method is fully automatic while existing methods require user input to select the best segmentation of input image.
4. It also provides environment friendly recovery measures of the identified disease.

3. Proposed methodology

Digital camera or similar devices are use to take images of leafs of different types, and then those are used to identify the affected area in leafs. Then different types of image-processing techniques are applied on them, to process those images, to get different and useful features needed for the purpose of analyzing later.

Algorithm written below illustrated the step by step approach for the proposed image recognition and segmentation processes:

(1) Image acquisition is the very first step that requires capturing an image with the help of a digital camera.
(2) Preprocessing of input image to improve the quality of image and to remove the undesired distortion from the image. Clipping of the leaf image is performed to get the interested image region and then image smoothing is done using the smoothing filter. To increase the contrast Image enhancement is also done.
(3) Mostly green colored pixels, in this step, are masked. In this, we computed a threshold value that is used for these pixels. Then in the following way mostly green pixels are masked: if pixel intensity of the green component is less than the pre-computed threshold value, then zero value is assigned to the red, green and blue components of the this pixel.
(4) In the infected clusters, inside the boundaries, remove the masked cells.
(5) Obtain the useful segments to classify the leaf diseases. Segment the components using genetic algorithm

For doing clustering appropriately, the search capability of GAs can be used, to set of unlabeled points in N-dimension into K clusters. On image data, we have applied the same idea in our proposed scheme. We have taken a color image of size $m \times n$ and every pixel has Red, Green and Blue components. Every chromosome shows a solution, which is a sequence of K cluster centers. Population is initialized in various rounds randomly and from existing chromosome best chromosome survives in each round for the next round processing.

In the first step of fitness computation the dataset of pixel is clustered according to nearest respective cluster centers such that each pixel x_i of color image is put into the respective cluster with cluster center z_j for $j = 1, 2, \ldots, K$ by the following equations

$$\text{If} \quad ||x_i - z_j|| < ||x_i - z_l||,$$

$$i = 1, 2, \ldots, m \times n, \quad l = 1, 2, \ldots, K, \text{ and } p \neq j.$$

In the further step new cluster centers are obtained by calculating the mean of each pixel of the assigned clusters. The new center of cluster Z_i is given by for the cluster C_i as:

$$Z_i(r, g, b) = \frac{1}{n_i} \sum_{xj \in c_i} (x_j(r, g, b)) \quad i = 1, 2, \ldots k \tag{1}$$

Now the fitness function is computed by calculating Euclidean distance between the pixels and their respective cluster by using following equations

$$M = \sum M_i \tag{2}$$

$$M_i = \sum_{x_j \in c_i} \left| (x_j(r, g, b) - z_i(r, g, b)) \right| \tag{3}$$

(6) Computing the features using color co-occurrence methodology

For feature extraction the method used is color co-occurrence method. It is the methodology in which both the texture and color of an image are considered, to come to the unique features, which shows that image.

Over the traditional gray-scale representation, in the visible light spectrum, the use of color image features provides an additional feature for image characteristic. There are three major mathematical processes in the color co-occurrence method. First, conversion of the RGB images of leaves is done into HIS color space representation. After completion of this process, to generate a color co-occurrence matrix, each pixel map is used, which results into three color co-occurrence matrices, one for each of H, S, I.

Features called as texture features, which include Local homogeneity, contrast, cluster shade, Energy, and cluster prominence are computed for the H image as given in Eqs. (4)–(7).

$$\text{CONTRAST} = \sum_{i,j=0}^{N-1} (i, j)^2 C(i, j) \tag{4}$$

$$\text{Energy} = \sum_{i,j=0}^{N-1} C(i.j)^2 \tag{5}$$

$$\text{Local Homogeneity} = \sum_{I,j=0}^{N-1} C(i, j)/(1 + (i - j)^2) \tag{6}$$

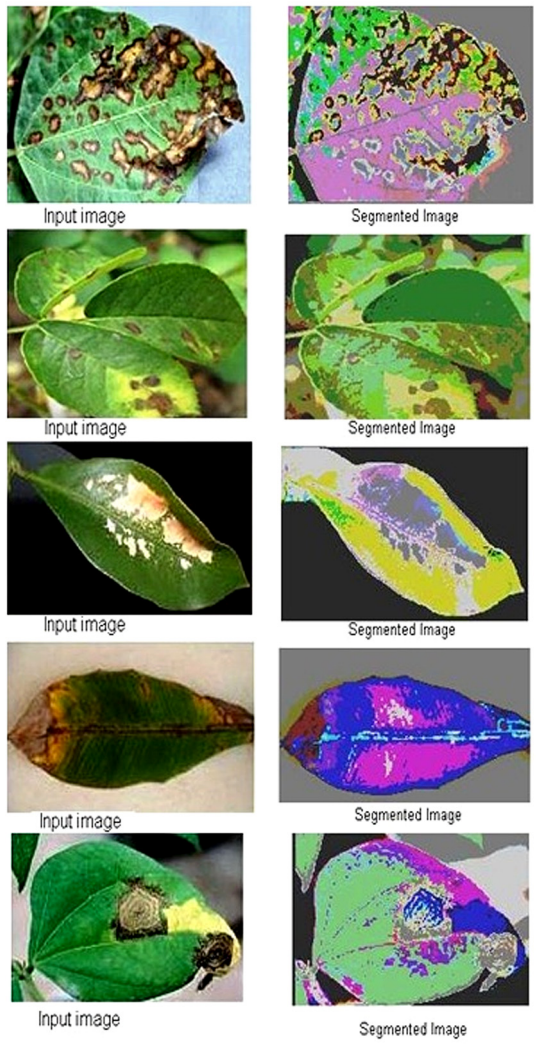

Fig. 1 – Input and output images.

$$\text{Entropy} = -\sum_{i,j=0}^{N-1} C(i.j)\log C(i.j) \quad (7)$$

(7) Classification of disease

In this phase of classification, extraction and comparison of the co-occurrence features for the leaves with the corresponding feature values are stored in the feature dataset. First, the Minimum Distance Criterion and then SVM classifier are used to done the classification. The measurement of success of classification is done by using the classification gain and following Eq. (8) is used for calculation:

$$\text{Gain } (\%) = \text{number of correct classification}/\text{Total no of test images} * 100 \quad (8)$$

4. Results

All the experiments are performed in MATLAB. For input data disease, samples of plant leaves like rose with bacterial disease, beans leaf with bacterial disease, lemon leaf with Sun burn disease, banana leaf with early scorch disease and fungal disease in beans leaf are considered. Fig. 1 shows the original images which are followed by output segmented images. Segmented image can be classified into different plant diseases. Fig. 2 shows the input and output image where input image is a banana leaf with early scorch disease and output image shows the classification of disease using feature extraction method.

In the same manner classification of diseases of other input plant leafs are shown in Figs. 3–6.

The co-occurrence features are calculated after mapping the R, G, B components of the input image to the thresholded images. The co-occurrence features for the leaves are extracted and compared with the corresponding feature values that are stored in the feature library. The classification is first done using the Minimum Distance Criterion with K-Mean Clustering and shows its efficiency with accuracy of 86.54%. The detection accuracy is improved to 93.63% by proposed algorithm. In the second phase classification is done using SVM classifier and shows its efficiency with accuracy of 95.71%. Now the detection accuracy is improved to 95.71% by SVM with proposed algorithm. The training and the testing sets for each type of leaf along with their detection accuracy is shown in Table 1.2 and Fig. 7. From the results it can be seen that the detection accuracy is enhanced by SVM with proposed algorithm compared to other approaches reported in [4,5,7].

The numbers of leaf disease samples that were classified into five classes of leaf disease using proposed algorithm are shown in Table 1.3 and Fig. 8. From the results it can be seen that only few samples from Frog eye leaf spot and bacterial leaf spot leaves were misclassified. Only two leafs with bacterial leaf spot disease are classified as frog eye leaf spot and one frog eye leaf spot is classify as bacterial leaf spot.

Fig. 2 – Input and output image of banana leaf and output diseases is early scorch disease.

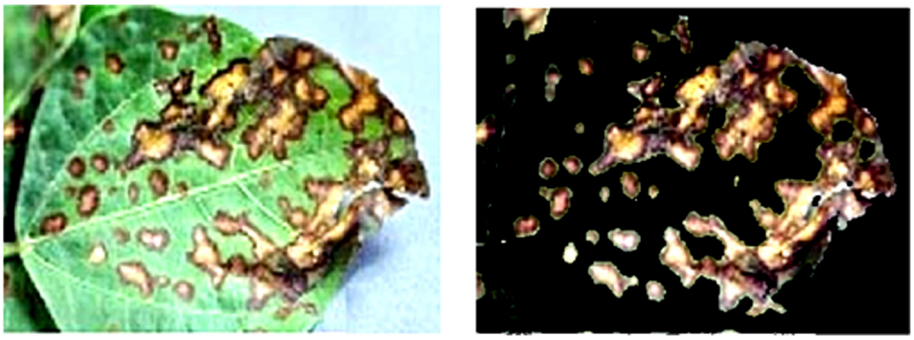

Fig. 3 – Input and output image of beans leaf and output diseases is bacterial leaf spot.

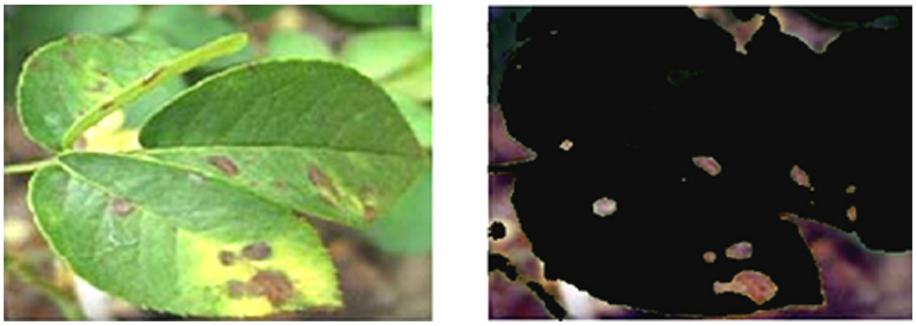

Fig. 4 – Input and output image of rose leaf and output diseases is bacterial leaf spot.

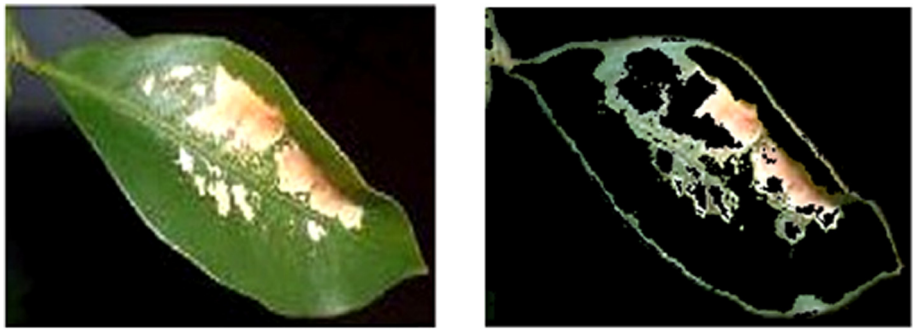

Fig. 5 – Input and output image of lemon leaf and output diseases is sun burn disease.

Fig. 6 – Input and output image of beans leaf and output diseases is fungal disease.

Table 1.2 – Comparison of results.

Disease samples	No. of images used for training	No. of images used for testing	Detection accuracy/%		
			MDC with K mean	MDC with proposed algorithm	SVM with proposed algorithm
Banana	15	10	80.00	90.00	90.00
Beans	15	14	92.85	92.85	92.85
Lemon	15	10	90.00	100.00	100
Rose	15	12	83.33	91.66	100
	Overall accuracy		86.54	93.63	95.71

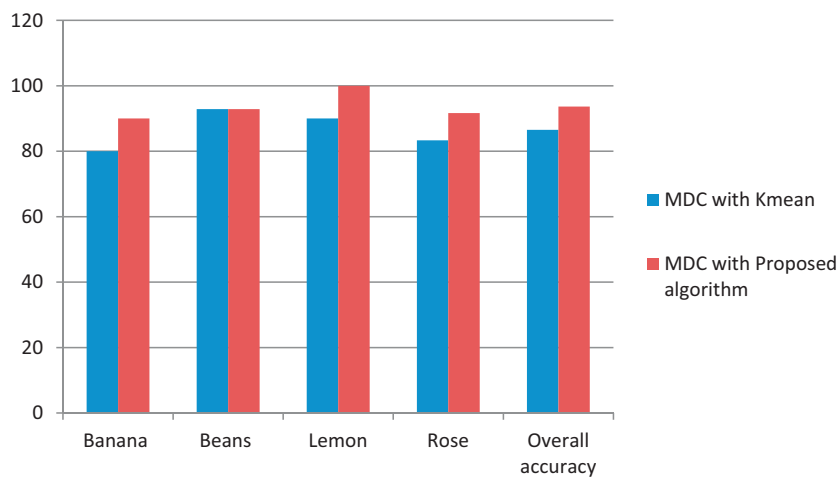

Fig. 7 – Comparison of results.

Table 1.3 – Classification results per class for proposed method.

Leaf disease	Bacterial leaf spot	Frog eye leaf spot	Sun burn disease	Fungal disease	Early scorch	Accuracy
Bacterial leaf spot	23	2	0	0	0	92
Frog eye leaf spot	1	24	0	0	0	96
Sun burn disease	0	0	25	0	0	100
Fungal disease	0	0	0	25	0	100
Early scorch	0	0	0	0	25	100
Average						97.6

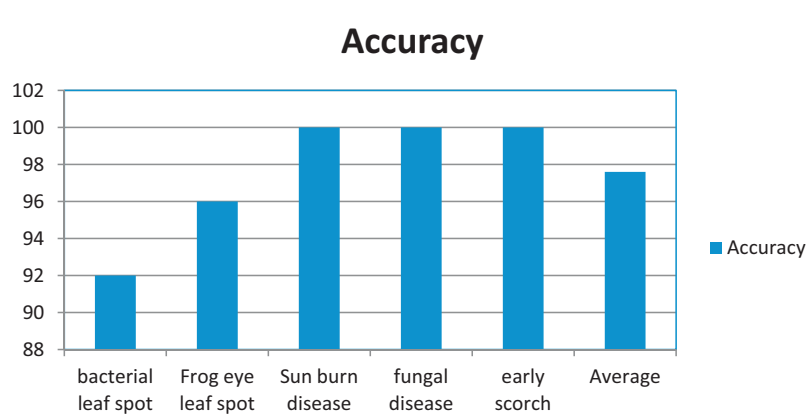

Fig. 8 – Classification results per class for proposed method.

The average accuracy of classification of proposed algorithm is 97.6 compared to 92.7 reported in [25].

5. Conclusion

This paper presents the survey on different diseases classification techniques used for plant leaf disease detection and an algorithm for image segmentation technique that can be used for automatic detection as well as classification of plant leaf diseases later. Banana, beans, jackfruit, lemon, mango, potato, tomato, and sapota are some of those ten species on which proposed algorithm is tested. Therefore, related diseases for these plants were taken for identification. With very less computational efforts the optimum results were obtained, which also shows the efficiency of proposed algorithm in recognition and classification of the leaf diseases. Another advantage of using this method is that the plant diseases can be identified at early stage or the initial stage. To improve recognition rate in classification process Artificial Neural Network, Bayes classifier, Fuzzy Logic and hybrid algorithms can also be used.

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