ISSN 2229-5518

Analysis of Diseased Leaf Images using Digital Image Processing Techniques and SVM Classifier and Disease Severity Measurements using Fuzzy Logic

Alakananda Mukherjee

Abstract— Potato constitutes one of the most widely grown crops in India. Productivity of potato decreases due to infections caused by various types of diseases on its fruit and leaf. Diseases are a major factor limiting crop production and they are often difficult to control. So, early detection of the plant diseases is critical to avoid losses in the yield and quality of the agricultural products. Studies of plant diseases have been widely researched to detect abnormality in plant growth using visually observable patterns on the plant. Plant monitoring and disease detection is needed to ensure sustainability in agriculture. However, it is usually very difficult to monitor the diseases manually as they require real-time as well as precise detection and without accurate disease diagnosis, proper control actions cannot be taken at the appropriate time. Digital Image processing techniques are commonly used for the detection of plant diseases which involves image acquisition, pre-processing, segmentation, feature extraction and classification techniques. The proposed method classifies two diseases (Early Blight and Late Blight) on potato leaf image samples, obtained from a publicly available plant image database called 'Plant Village'. Texture features are extracted using statistical Gray-Level Co-Occurrence Matrix (GLCM) and classification is done using Support Vector Machine (SVM). The proposed system can successfully detect and classify the examined diseases with an overall accuracy of 92%.This paper also includes a Disease Severity Estimation and Grading process employing Fuzzy Logic. Presently, plant pathologists mainly rely on naked eye prediction and disease scoring scale to grade diseases. But it is quite time consuming and erroneous, hence the need for automatic grading of diseases comes into play. The results are proved to be accurate and satisfactory in contrast with manual grading.

Index Terms— Plant Disease Detection, Digital Image Processing, K-Means Clustering, GLCM, SVM, Fuzzy Logic

1 Introduction

AGRICULTURE has played a key responsibility in the development of human civilization. More than 70% of the Indian population depends on agriculture. Any abnormal condition that injures the plant or leads it to function improperly is called as a disease. It is one of the crucial causes that reduces quantity and degrades quality of the agricultural products. Diseases are readily recognized by their symptoms. As plant diseases are inevitable, disease detection plays a major role in the field of Agriculture.So, proper disease control measures must be undertaken so that crop yield losses may be minimized.

Potato is one of the most significant food crops in the world. The diseases causing substantial yield loss in potato are caused by fungi *Phytophthora infestans* (late blight) and *Alternaria solani* (early blight). Early detection of these diseases can allow to take preventive measures and mitigate economic and production losses. Over the last decades, the most practiced approach for detection and identification of plant diseases is naked eye observation by experts. In this method experts are involved, who have the ability to detect the symptomatic changes in leaf, stem, or root characteristics. This method involves a lot of effort, takes long time and also not practical for the large fields and in most of the cases not very accurate. Overall, in many cases, this approach proves unfeasible due to the excessive processing time and also unavailability of experts at farms located in the remote areas.Hence, the introduction of image analysis software tools turns out to be an effective method for continuous monitoring of plant health status and early detection of plant diseases. As diseases leave some visible symptoms on the plants, particularly on leaves, disease detection can be performed by imaging analysis of those visible patterns on leaves. Thus imaging technique combined with machine learning offers a solution to the issue of agricultural productivity and ensures food security. So the objective of this work is to develop image processing and machine learning based effective and error-free disease detection system for plants.

2 Literature Survey

A lot of research has been done for the past few years on automatic detection of plant diseases using image processing, Machine Learning and Computer Vision techniques. Few of the related works are analyzed as follows.

In [3], R.Meena Prakash et al. proposed a method of detecting diseases in Citrus leaves using K-Means clustering as the segmentation algorithm.Extraction of four features: Contrast, Energy, Homogeneity, Correlation are done using GLCM method. Classification of the leaves are done using SVM algorithm to detect if the test input is diseased or healthy.Classification accuracy of 0.09 is obtained by training and testing 60 images of Citrus leaves. Pang et al proposed the method of automatic segmentation of crop leaf spot disease

- *Alakananda Mukherjee is currently pursuing Masters Degree (M.Tech.) program in Communication and Signal Processing Engineering (Dept. of ETCE) in Indian Institute of Engineering Science and Technology, Shibpur (IIEST), India.*
E-mail: alakananda357@gmail.com

images by integrating local threshold and seeded region growing in [4].

J. G. A. Barbedo et al. proposed the method of semi-automatic segmentation of plant leaf disease symptoms in which the histograms of the H and color channels are manipulated [5, 6]. Different methods for automatic leaf image segmentation and disease identification have been proposed in literature [7-10]. Dhaygude et al. proposed agricultural plant leaf disease detection using image processing in which the texture statistics are computed from spatial gray-level dependence matrices (SGDM) [11].

In [12], Yao et al. proposed a method for detecting rice diseases using shape and colour texture features.Segmentation of diseased areas is done by performing Otsu's thresholding followed by edge detection by converting RGB colour space into two(y1,y2) colour functions.Diseased spot shape features are extracted using Minimum Enclosing Rectangle(MER) and texture features are obtained from GLCM.Three classification models are developed for three different combination of features by SVM algorithm using radial basis kernel function. In [13], authors detected different types of diseases in rice leaf. The classification of normal and diseased leaf is done using histogram plot. Both shape and color features are extracted using PCA method and color based grid moments respectively.

Kiran R. Gavhale et al. presented reviews and summarizes image processing techniques for several plant species that have been used for recognizing plant diseases. The major techniques for detection of plant diseases are: back propagation neural network (BPNN), Support Vector Machine (SVM), K-nearest neighbor (KNN), and Spatial Gray-level Dependence Matrices (SGDM). These techniques are used to analyse the healthy and diseased plants leaves [14]. Adhao Asmit Sarangdhar et al. designed an Android app system along with SVM classifier for recognition and classification of cotton leaves diseases such as Alternaria, Bacterial Blight, Cercospora, Gray mildew and Fusarium wilt, along with soil quality monitoring [15].

In [16], a Segmented Support Vector Machine (S-SVM) image processing algorithm is proposed to help to detect diseases in a Chilli plant. The S-SVM initially convert the image into a grayscale format using different clustering size before it is applied to the SVM for feature extractions.A comparison among different SVM Classifier models (Linear, Quadratic, Cubic,Fine Gaussian,Medium Gaussian, Coarse Gaussian SVMs) are done and it is obtained that quadratic SVM shows the best results with accuracy of about 90%.

This [17] survey paper describes plant disease identification using Machine Learning Approach and study in detail about various techniques for disease identification and classification techniques. Several advancements have been made to monitor and identify crop diseases, including RGB imaging, X-ray, ultrasound, and multispectral and hyperspectral technologies [18]. The method proposed by Macedo-Cruz et al. in [19] aimed to quantify the damage caused by frost in oat crops. First, the conversion from RGB to the L*a*b* color space is performed. The authors employed three different thresholding strategies: Otsu's method, Isodata algorithm, and fuzzy thresholding. The comparison of performance of classifiers support vector machine (SVM), random forest (RF) and artificial neural network (ANN) is performed on the same test dataset of potato leaves. From results, we observe ANN scores highest of 92% accuracy followed by SVM with 84%accuracy and RF with 79% accuracy [20].

3 Methodology

3.1 Dataset

The images of diseased potato leaves were obtained from a website named "PlantVillage" [22][23]. Total of 50 images are used in this paper. Out of which, 25 images, containing 9 Early Blight Diseased leaf images and 16 Late Blight Diseased leaf images, are used to train the classifier. Rest 25 miscellaneous images are used for testing. Ground Truth Images are obtained manually using Image Editing Tools.

Fig. 1. Late Blight and Early Blight diseased leaf samples

3.2 Image Pre-Processing

The image pre-processing is done on gathered images for improving the image quality. It removes the background noises and suppresses other undesired distortions. The input image is resized to 200*200 pixels and sharpened. Median Filtering Technique is used to reduce salt and pepper noises and speckles. Then, image contrast is enhanced using Contrast Limited Adaptive Histogram Equalization algorithm (CLAHE).

3.3 Image Segmentation

In this paper, Image Segmentation is done using K-Means Clustering Algorithm. K-means clustering is one of the unsupervised machine learning algorithms use to classify objects in the images or categorize datasets into groups. K-means clustering is an iterative, data-partitioning algorithm that assigns 'n' observations to exactly one of 'k' clusters defined by Centroids. Before clustering 'a' component is extracted from L*a*b space. By default, the MATLAB function 'kmeans' uses distance metric method of Sqeuclidean to compute point-to-cluster centroid distances which result in calculating the squared Euclidean distance and each centroid as the mean of the points in that cluster.
The equation below is used for the k-means clustering using

Sqeuclidean method:

$$d(x,c)=(x-c)(x-c)'$$

Trial and error method is used to find the best number of clusters or value of 'k'.When using high number of clusters, underfitting may result in the segmentation. While low numbers of clusters may result in overfitting.

The steps in the algorithm are given below:

1. Choose *k* initial cluster centers (centroid).
2. Compute point-to-cluster-centroid distances of all observations to each centroid. The Euclidean distance is the straight-line distance between two pixels and is given as follows:

$$\text{Euclidean Distance}=\sqrt{((x1 - x2)^2 + (y1 - y2)^2)}$$

3. Assign each observation to the cluster with the closest centroid.
4. Compute the mean of the observations in each cluster to obtain *k* new centroid locations.
5. Repeat steps 2 through 4 until there is no change in the cluster assignments or the maximum number of iterations is reached.

3.4 Feature Extraction

After segmentation, different features are extracted with the help of a matrix, generated from the image samples. Gray-Level Co-Occurrence Matrix (GLCM) is the statistical method of investigating texture which considers the spatial relationship of pixels [15]. The GLCM functions characterize the texture of images by computing the spatial relationship among the pixels in the images. The statistical measures are extracted from this matrix. In the creation of GLCMs, an array of offsets which describe pixel relationships of varying direction and distance have to be specified.
Let P_{ij} represent the (i, j)th entry in the normalized GLCM. N represents the number of distinct gray levels in the quantized image. In this paper, after the generation of GLCM, total of 13 features are extracted from the diseased leaf images to train the classifier for further processing.

Contrast measures intensity contrast of a pixel and its neighburing pixel over the entire image. If the image is constant, contrast is equal to 0. The equation of the contrast is as follows:

$$\text{Contrast}=\sum_{i,j=0}^{N-1}(P_{ij})\,(i-j)^2$$

Energy is a measure of uniformity with squared elements summation in the GLCM. Range is in between 0 and 1. Energy is 1 for a constant image. The equation of the energy is given by equation:

$$\text{Energy}=\sum_{i,j=0}^{N-1}(P_{ij})^2$$

Homogeneity measures the similarity among the pixels. Its range is between 0 and 1. Homogeneity is 1 for a diagonal GLCM. The equation of the Homogeneity is as follows:

$$\text{Homogeneity}=\sum_{i,j=0}^{N-1}[(P_{ij})^2/(1+(i-j)^2)]$$

Correlation measures how correlated a pixel is to its neighborhood. Its range is in between -1 and

$$\text{Correlation}=\sum_{i,j=0}^{N-1}[P_{ij}\{(i-\mu)\,(j-\mu)/\sigma^2\}]$$

Apart from these features other statistical features are obtained using basic equations, such as, Mean, Standard deviation, Entropy,RMS,Variance,Smoothness, Kurtosis, Skewness and Inverse Difference Moment(IDM).
The **mean** color intensity is calculated by using following formula:

$$\text{Mean}= (1/N).x_i$$

Where x_i is the pixel intensity and N is the total number of pixels.
The computed **variance** has the ability of measuring the variability.

$$\text{Variance}= (1/N).\sum_{i=1}^{N}(x_i - x')^2$$

The **skewness** for each block is calculated by:

$$\text{Skewness}= [(1/N).\sum_{i=1}^{N}(x_i - x')^3]/ [(1/N).\sum_{i=1}^{N}(x_i - x')^2]^{(3/2)}$$

Inverse Difference Moment of order 2 is given by:

$$\text{IDM}= \sum_i\sum_j 1/ (1+ (i- j)^2)\, P(i,j,d,\theta)$$

Entropy is given as:

$$\text{Entropy}= \sum_i\sum_j P(i,j,d,\theta)\log(P(i,j,d,\theta))$$

3.5 Image Classification

Support Vector Machine is a kernel-based supervised learning algorithm used as a classification tool, which was put forward by Vapnik in 90s' [21]. The training algorithm of SVM maximizes the margin between the training data and class boundary. The resulting decision function depends only on the training data called *support vectors*, which are closest to the decision boundary as shown in fig.2. It is effective in high dimensional space where number of dimensions is greater than the number of training data. SVM transforms data from input space into a high-dimensional feature space using kernel function. Nonlinear data can also be separated using hyper plane in high dimensional space. The computational complexity is reduced by kernel Hilbert space (RKHS).

IJSER

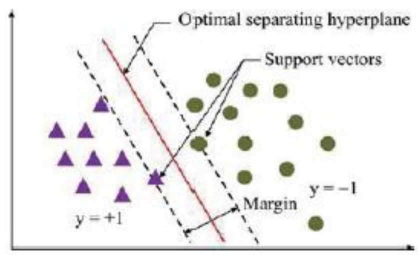

Fig.2. Support Vector Machine Classification Algorithm

The feature vector is given as input to the classifier. The feature vectors of the database images are divided into training and testing vectors. The classifier trains on the training set and applies it to classify the testing set. The hyper plane tries to divide, one class containing the target training vector which is labeled as +1, and the other class containing the training vectors which is labeled as −1. The performance of the classifier is measured by comparing the predicted labels and actual values. A number of applications showed that SVM holds the better classification ability in dealing with small sample, nonlinearity and high dimensionality pattern recognition. Linear Support Vector Machine (LSVM) is used for classification of leaf disease.
If points are linearly separable, the function of this surface is estimated by

$$f(x)= \mathrm{sgn} \left(\sum_{i=1}^{n} \alpha_i^* y_i (x_i . x) +b^*\right) \qquad (x_i,y_i)\in R^N \times\{-1,1\}$$

Where α_i^* is a Lagrange multiplier, b* is the bias and training data (x_i, y_j).
If the classes cannot be linearly separable, the function of this surface is given by

$$f(x)= \mathrm{sgn} \left(\sum_{i=1}^{n} \alpha_i^* y_i\, k(x,y) +b^*\right)$$

where k(x, y) is a kernel function.
Some commonly used kernel functions were defined as follows:
The linear kernel function-
$k(x, y)= x .y$
The polynomial kernel function-
$k(x, y)= (1+x .y)^q$, q =1,2,..., N
The radial basis kernel function-
$k(x, y)= \exp(-|| x -y ||)^2$

3.6 Disease Severity Estimation using Fuzzy Logic

Presently, the plant pathologists mainly rely on naked eye predictions and a disease scoring scale to grade the diseases on leaves. There are some problems associated with this manual grading. Diseases are inevitable in plants, so when a plant gets affected by a disease, a treatment advisory is required to cure the disease. Chemical pesticides are commonly used to cure the diseases.

But, excessive use of pesticides for plant disease treatment increases costs and raises the danger of toxic residue levels on agricultural products. As pesticides are among the highest components in the production costs of field crops and have been identified as a major contributor to groundwater contamination; their use must be minimized. This requires that the disease must be identified accurately along with the stage in which the disease is; so that only a proper quantity of pesticide can be used for the treatment.
Presently, the plant pathologists rely on disease scoring scale to grade the disease using the table below:

TABLE 1
TABLE FOR MANUAL GRADING OF DISEASES

Percent Infection	Disease Grade
1-20	0
20-40	1
40-60	2
60-80	3
80-100	4

It is observed that the grade of the disease is assigned based on the percent-infection i.e., if the infection percentage is 5 then the grade is estimated as 0. The problem here is that even if the percent-infection is 2 or 19 the grade remains 0 only. To overcome this problem machine vision is inculcated into agriculture to get the accurate grade of the diseases.

Fuzzy Logic, which was first introduced by Lotfi Zadeh (1965), is used to handle uncertainty, ambiguity and vagueness in a system. It provides a means of translating qualitative and imprecise information into quantitative (linguistic) terms. It is considered one of the approaches for Artificial Intelligence, where the intelligent behavior is achieved by creating fuzzy classes of some parameters. Fuzzy rule-based model, as shown, have a simple structure & consist of four major components:

1. A Fuzzification module, which translates crisp inputs (classical measurements) into fuzzy values through linguistic variables.
2. An if-then fuzzy rule base, which consists of a set of conditioned fuzzy propositions.
3. An inference method, which applies fuzzy reasoning mechanism to obtain outputs i.e., carries out the computation using fuzzy rules).
4. De-fuzzification.

After Image Segmentation using K-Means Clustering Algorithm, the image showing the cluster containing disease spots is considered and converted into binary. It is used to calculate total disease area (AD).In image processing terminology, area of a binary image is the total number of *on* pixels in the image. Hence, the original resized image is converted to binary image

IJSER

such that the pixels corresponding to the leaf image are *on(* White). From this, total leaf area (AT) of the leaf is calculated. Once AT and AD are known, the percent-infection (PI) is calculated by applying the formula:

$$PI = (AD / AT) * 100$$

It has been observed that fuzzy logic can be inculcated effectively and efficiently in the agriculture domain covering a wide range of precision agriculture applications such as texture analysis, agriculture produce grading, effective use of herbicide sprayers in disease control etc. Hence, in the present work Fuzzy Logic (FL) is used for the purpose of disease grading.

Here, a Fuzzy Inference System (FIS) is developed for disease grading by referring to the disease scoring scale in the table as shown earlier. For FIS, for disease grading, input variable is Percent Infection and output variable is the corresponding Grade. Triangular membership functions are used to define the variables and certain fuzzy rules are set to grade the disease.

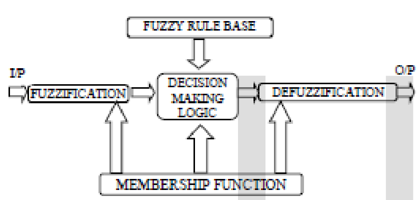

Fig.3. Fuzzy Logic Algorithm

IJSER

4 RESULTS AND DISCUSSIONS

The performance of image segmentation using K-Means Clustering algorithm is measured by calculating Accuracy, Sensitivity, Fmeasure, Precision, Dice index, Jaccard Index, Specificity. These parameters are calculated by comparing the segmented image with the Ground Truth, which is being created manually.

True Positive (TP) score is calculated using this equation

$$TP_i = [\sum_{j=1}^{Na} tp_i(j)] / [\sum_{j=1}^{Ne} tp\_ground\_truth_i(j)]$$

Where, Na is the total count of disease infected areas of leaf identified by our proposed system and Ne is the total count of disease infected areas of leaf in the ground truth.

tp_i and $tp\_ground\_truth_i$ denotes each disease infected area in the leaf our proposed system detects and in the ground truth respectively. It is nothing but the number of pixels correctly segmented as foreground in the image.

False Positive (FP) score is calculated using the equation shown below.

$$FP_i = [\sum_{j=1}^{Fa} fp_i(j)] / [\sum_{j=1}^{Fe} fp\_start_i(j)]$$

Where, Fa is total count of connected regions, the proposed system falsely identifies after all iterations and Fe is total count of connected regions, in the ground truth, as falsely detected. Fp_i and fp_start_i denotes each infected area detected by the algorithm and the ground truth marks respectively. It is basically the number of pixels falsely segmented as foreground in the image.

Similarly, True negative (TN) score is the number of pixels correctly detected as background and False negative (FN) is the pixels falsely detected as background in the segmented image.

These terms are validation metrics used for verifying quality of a segmented image. Assumptions are made of taking foreground as "white" pixels and background as "black" pixels in the ground truth. These metrics are then used to calculate sensitivity, specificity, accuracy and other parameters as:

1. **Sensitivity** (also called the true positive rate, recall, or probability of detection) measures the proportion of actual positives that are being correctly identified. This is calculated as

$$Sensitivity = TP/(TP+FN)$$

2. **Specificity** (also called the true negative rate) measures the proportion of actual negatives that are being correctly identified.This is calculated as

$$Specificity = TN/(TN+FP)$$

3. **Accuracy** is closeness of the measurements to a specific value. It is calculated as

$$Accuracy = (TP+TN)/(TP+TN+FN+FP)$$

4. **Precision** or positive predictive value is the closeness of the measurements to each other. It is calculated as

$$Precision = TP/ (TP+FP)$$

5. **Matthews's correlation coefficient** (MCC): The coefficient takes into account true and false positives and negatives and is generally regarded as a balanced measure which can be used even if the classes are of very different sizes. The MCC can be calculated directly from the confusion_matrix using the formula:

MCC= (TP*TN)(FP^FN)/sqrt[(TP+FP)(TP+FN)(N+FP)(TN+FN)]

6. **F-Measure** provides a single score that balances both the concerns of precision and recall in one number.

   F-Measure= 2*Precision*Recall/ (Precision+Recall)

7. **Dice Score** is a measure of how similar the objects are.It is the size of the overlap of the two segmentations divided by the total size of the two objects.

   Dice = 2*TP/ (2*TP+FP+FN)

8. **Jaccard coefficient** measures similarity between finite sample sets, and is defined as the size of the intersection divided by the size of the union of the sample sets.

   Jaccard = Dice/ (2-Dice)

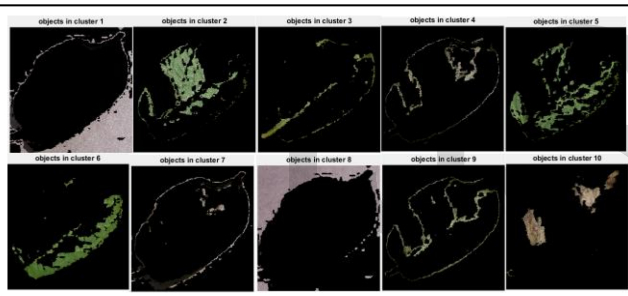

Fig.4. Late Blight diseased spot Segmentation results

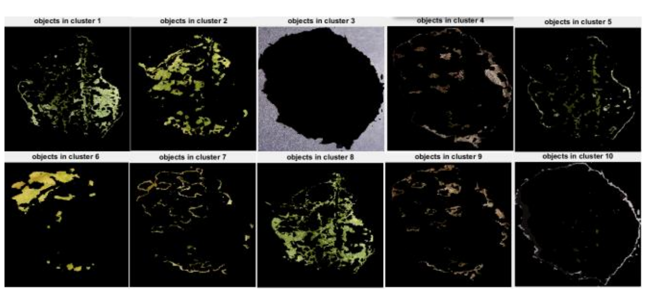

Fig.5. Early Blight diseased spot Segmentation results

TABLE 2
K-MEANS CLUSTERING SEGMENTATION ACCURACY MEASUREMENT

Parameters	Values
Accuracy	0.9159
Sensitivity	0.4562
Precision	0.5655
Fmeasure	0.5050
MCC	0.4628
Dice	0.5050
Jaccard	0.3378
Specificity	0.9636

Out of 50 images, 25 images are used for training and rest 25 images are used for testing the classifier (1:1). It is seen that out of 25 diseased leaf images, where there are 11 numbers of Early Blight Diseased leaf images and 14 numbers of Late Blight Diseased leaf images, 23 images are recognized correctly, leading to an overall accuracy of 92%.
The classification accuracy is calculated as:

Accuracy (%) = [Correctly Recognized Images/ Total Number of Test Images]*100

TABLE 3
SVM CLASSIFICATION ACCURACY MEASUREMENT

Diseased Classes	Percentage of accuracy of correct recognition
Early Blight Potato Leaf Disease	90.90%
Late Blight Potato Leaf Disease	92.85%

This paper proposed a Fuzzy Logic based model to measure the severity of disease in potato leaves and validated using two types of diseased potato leaves. The model estimated the flaw marks on the skin of the leaves and simulated disease severity based on population dynamics.

From the graphs, we can see that the grading of the two diseases corresponding to the percent-infections match the table 1. Unlike the results from grading manually (problem discussed), disease Grading using Fuzzy Logic gives accurate and precise results, corresponding to each individual percent- infection value.

IJSER

TABLE 4
AUTOMATIC ESTIMATION OF DISEASE GRADES

	Early-Blight diseased leaf sample	Late-Blight diseased leaf sample
Percent-Infection	30.2856	19.5603
Disease Grade	1.5114	0.9989

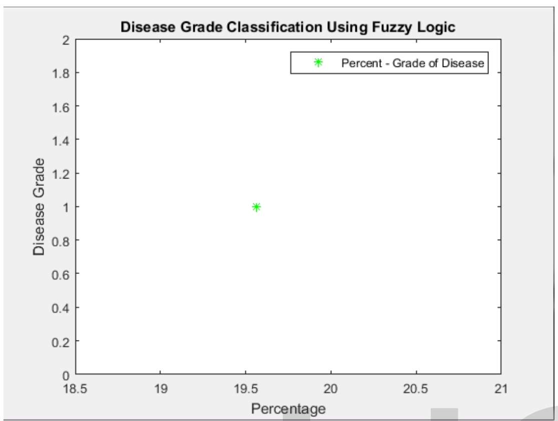

Fig.6. Late Blight Disease Grading

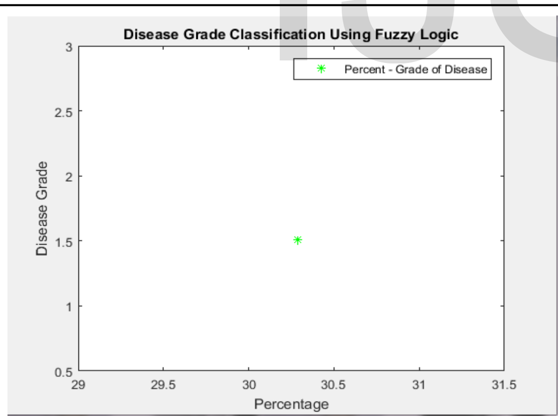

Fig.7. Early Blight Disease Grading

5 Conclusion

Automatic plant disease detection technique has many advantages over manual methods. It takes less effort, less time and is more accurate. Image processing is used for analyzing the affected area of leaves by extracting textural and colour features from the collected leaf image samples. In this paper, a method for classification and detection of leaf diseases is implemented, along with the measurements of disease severity. It is a MATLAB based system, which utilizes image processing and Machine Learning techniques for accurate identification of plant diseases.The segmentation of the diseased part is done using K-Means Clustering segmentation method. Plant diseases happen under natural conditions and their symptoms vary significantly for different types and at different stages of the diseases. Whether the image is segmented correctly or not determines the success or failure of the study. After that, GLCM texture features are extracted and classification is done using SVM. Features, such as color, and texture components are useful for pattern recognition, accurate and error free classification, are calculated.

The usage of image processing technology for plant disease grading eliminates the subjectivity of traditional classification methods and human-induced errors. Thus the estimation credibility is improved and accurate data are provided for disease studies. As it is realized in this paper, an approach to automatically grade the disease on plant leaves is very much essential in the present scenario. The Grading System built by Machine Vision and Fuzzy Logic is quite useful for grading the diseases. This kind of expert system is going to help pathologists as it overcomes almost all the disadvantages of manual grading in terms of complexity and time. The method is also convenient, which simply needs computers, digital cameras with the combination of necessary software programs to realize the disease grading steps.

The observed results through this experiment are found to be accurate, reliable and satisfactory and can be implemented for early disease detection of different agricultural products worldwide.

IJSER

References

[1] Rafael C. Gonzalez, Richard E. Woods: "Digital Image Processing",Third Edition, Eastern Economy Edition,Prentice-Hall Inc.

[2] Gonzalez,R,C: "Digital Image processing",4th International Edition,Pearson Publication,pp 120-180.

[3] R. M. Prakash, G. P. Saraswathy, G. Ramalakshmi, K. H. Mangaleswari and T. Kaviya, "Detection of leaf diseases and classification using digital image processing," 2017 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS), Coimbatore, 2017, pp. 1-4, doi: 10.1109/ICIIECS.2017.8275915.

[4] J. Pang, Z.-Y. Bai, J.-C. Lai, and S.-K. Li, "Automatic segmentation of crop leaf spot disease images by integrating local threshold and seeded region growing," 2011 International Conference on Image Analysis and Signal Processing, 2011.

[5] J. G. A. Barbedo, "A novel algorithm for semi-automatic segmentation of plant leaf disease symptoms using digital image processing," Tropical Plant Pathology, vol. 41, no. 4, pp. 210– 224, 2016.

[6] J. G. A. Barbedo, L. V. Koenigkan, and T. T. Santos, Identifying multiple plant diseases using digital image processing," Biosystems Engineering, vol. 147, pp. 104–116, 2016.

[7] J. Y. Bai and H. E. Ren, "An Algorithm of Leaf Image Segmentation Based on Color Features," Key Engineering Materials, vol. 474-476, pp. 846–851, 2011.

[8] N. Valliammal and S. S.n.geethalakshmi, "A Novel Approach for Plant Leaf Image Segmentation using Fuzzy Clustering," International Journal of Computer Applications, vol. 44, no. 13, pp. 10–20, 2012.

[9] L. Kaiyan, W. Junhui, C. Jie, and S. Huiping, "A Real Time Image Segmentation Approach for Crop Leaf," 2013 Fifth International Conference on Measuring Technology and Mechatronics Automation, 2013.

[10] K. R. Gavhale, U. Gawande, and K. O. Hajari, “Unhealthy region of citrus leaf detection using image processing techniques,” International Conference for Convergence for Technology-2014, 2014.
[11] B. Dhaygude & P.Kumbhar, “Agricultural plant Leaf Disease Detection Using Image Processing”, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 2, no. 1, 2013, pp. 599-602.
[12] Q. Yao, Z. Guan, Y. Zhou, J. Tang, Y. Hu and B. Yang, "Application of Support Vector Machine for Detecting Rice Diseases Using Shape and Color Texture Features," 2009 International Conference on Engineering Computation, Hong Kong, 2009, pp. 79-83, doi: 10.1109/ICEC.2009.73.
[13] Suman T. and Dhruvakumar T., “Classification of paddy leaf diseases using shape and color features”, IJEEE, Volume 07, Issue 01, PP.239-250, Jan- June 2015.
[14] Kiran R. Gavhale, and U. Gawande, “An Overview of the Research on Plant Leaves Disease detection using Image Processing Techniques,” IOSR J. of Compu. Eng. (IOSRJCE), vol. 16, PP 10-16, Jan. 2014.
[15] Sarangdhar and V. Pawar, “Machine learning regression technique for cotton leaf disease detection and controlling using iot,” in Electronics, Communication and Aerospace Technology (ICECA), 2017 International conference of, vol. 2. IEEE, 2017, pp. 449–454.
[16] A. H. Bin Abdul Wahab, R. Zahari and T. H. Lim, "Detecting diseases in Chilli Plants Using K-Means Segmented Support Vector Machine," 2019 3rd International Conference on Imaging, Signal Processing and Communication (ICISPC), Singapore, 2019, pp. 57-61, doi: 10.1109/ICISPC.2019.8935722.
[17] J. Shirahatti, R. Patil and P. Akulwar, "A Survey Paper on Plant Disease Identification Using Machine Learning Approach," 2018 3rd International Conference on Communication and Electronics Systems (ICCES), Coimbatore, India, 2018, pp. 1171-1174, doi: 10.1109/CESYS.2018.8723881.
[18] Mirwaes Wahabzada, Anne-Katrin Mahlein, Christian Bauckhage, Ulrike Steiner, Erich Christian Oerke, Kristian Kersting, “Plant Phenotyping using Probabilistic Topic Models: Uncovering the Hyperspectral Language of Plants,” Scientific Reports 6, Nature, Article number: 22482, 2016.
[19] Macedo-Cruz A, Pajares G, Santos M, Villegas-Romero I., “Digital image sensor-based assessment of the status of oat (Avena sativa L.) crops after frost damage,” Sensors 11(6), 2011, pp. 6015–6036.
[20] Patil, Priyadarshini & Yaligar, Nagaratna & S M, Meena. (2017). Comparison of Performance of Classifiers - SVM, RF and ANN in Potato Blight Disease Detection Using Leaf Images. 1-5. 10.1109/ICCIC.2017.8524301.
[21] Vapnik,V., The Nature of Statistical Learning Theory. New York: Springer Verlag, 1995 .
[22] N. Otsu, “A threshold selection method from gray-level histogram,” IEEE Trans. Syst., Man and Cybern.,vol.9, no.1, Jan 1979, pp. 62-66
[23] https://www.kaggle.com/vipoooool/new-plant-diseases-dataset
[24] http://www.plantvillage.org/
[25] S. Weizheng, W. Yachun, C. Zhanliang and W. Hongda, "Grading Method of Leaf Spot Disease Based on Image Processing," 2008 International Conference on Computer Science and Software Engineering, Hubei, 2008, pp. 491-494, doi:10.1109/CSSE.2008.1649.
[26] S. K. Behera, L. Jena, A. K. Rath and P. K. Sethy, "Disease Classification and Grading of Orange Using Machine Learning and Fuzzy Logic," 2018 International Conference on Communication and Signal Processing (ICCSP), Chennai, 2018, pp. 0678-0682, doi: 10.1109/ICCSP.2018.8524415.
[27] Sanjeev S Sannakki, Vijay S Rajpurohit , V B Nargund , Arun Kumar R , Prema S Yallur, “Leaf Disease Grading by Machine Vision and Fuzzy Logic” , SEPT-OCT 2011, IJCTA, ISSN:2229-6093.

IJSER