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An Effective and Efficient Segmentation Method for Leaf Disease Detection using Spatial Fuzzy C Means Algorithm

M. Kannan[1] and R. Thangavel[2]
Research Scholar, Department of Electronics[1]
Principal, Department of Electronics[2]
SRMV College of Arts and Science, Bharathiar University, Coimbatore, India
kannanziskin@gmail.com[1]

Abstract: *One of the most significant industries, agriculture, is crucial to the socio-economic progress of a nation like India. In agriculture, maintaining crops and preventing illness are difficult undertakings. They need professional human resources for the job, but it is really tough to find an experienced person. Foliar diseases in turmeric plants often cause significant reduction in both quality and quantity and result in economic loss for turmeric products. This paper presents an efficient image segmentation method using Spatial Fuzzy C means algorithms (FCM) to improve the segmentation accuracy using turmeric plant leaf images. The proposed method utilizes the advantage of noise-robust nature and provides more information in segmentation process. Moreover, spatial FCM algorithm is employed to overcome the limitation of K means and fuzzy C means (FCM) algorithm. The benefit of the spatial FCM algorithm for image segmentation in the sense of low computation time and the advantages of spatial FCM algorithm in the sense of accuracy are considered. The challenging task of proposed spatial FCM algorithm for image segmentation performance are analysed and evaluated based on their parameter like MSE, PSNR and Accuracy.*

Keywords: Foliar Disease, Image Segmentation, Spatial FCM Algorithm, Accuracy.

I. INTRODUCTION

India is an agriculture based country wherein 70% of the population depends on agriculture. When pest and disease affect the crops, there will be a tremendous decrease in production. In most of the cases, pests or diseases are seen on the leaves or stems of the plant. Turmeric is the third largest spice produced by India and it accounts for about 80% of the world's production and 60% of world exports. The production and yield of turmeric may be affected due to several reasons, among which leaf diseases are primary. The various foliar diseases affect the turmeric, and those diseases are categorized as Leaf spot, Leaf blotch and Bacterial wilt as shown in fig.1. Depending on the severity of the leaf spot disease in the field, it can cause a loss in turmeric yield by 10% to 50%. Therefore, disease symptoms should be detected on time and relevant measures should be taken instantly to prevent further spread or progress of the disease. Hence, image processing plays a vital role in diseases detection and analysis.

(a) Leaf Spot (b) Leaf Blotch (c) Bacterial Wilt

Fig.1 Various images of turmeric foliar disease

The standard image segmentation techniques are threshold method, region based clustering, edge detection, partial differential equation, watershed method, ANN based technique, etc. During recent years, so many segmentation methods have been developed for leaf diseases detection but still it is necessary to improve the segmentation accuracy which makes the classifier to classify the leaf diseases accurately.

In this paper, we propose spatial FCM algorithm to improve the segmentation accuracy in leaf diseases detection system at the earliest. The approach of spatial FCM algorithm is to get the advantages of K means and FCM algorithm. The experimental results of proposed spatial FCM algorithm are evaluated and compared with the exiting methods based on the parameters like MSE, PSNR and accuracy. The next section deals with the clustering algorithm, proposed method and experimental results.

II. OVERVIEW OF IMAGE SEGMENTATION METHOD IN LEAF DISEASES DETECTION

Segmentation is the process of partitioning a digital image into multiple regions or objects and extracting meaningful region known as the region of interest (ROI). The level to which subdivision is carried depends on the problem being solved. Segmentation can be stopped when the region of interest in an application has been isolated. Segmentation accuracy determines the eventual success or failure of computerized analysis procedures. So care should be taken to pick an algorithm that performs the best for the given requirement.

Image segmentation algorithms are generally based on two basic principles: discontinuity and similarity. The discontinuity principle is to extract regions that differ in properties such as intensity, color, texture or any other image statistics. In similarity principle image pixels are grouped into regions that are similar according to a set of predefined criteria. Thresholding, region growing and region splitting and merging are examples of similarity principle. The segmentation algorithms can be classified on the basis of the pixel similarity relationship with neighbouring pixel as (i) Contextual (region-based or global) algorithms, and (ii)Non-contextual(pixel-based or local)algorithms.

In region-based algorithms, the pixels are grouped based on some sort of similarity that exists between them. In pixel-based algorithm, the idea is to identify the discontinuities such as isolated lines and edges that are present in the image.

In plant leaf disease identification the following steps are followed.

1. Image is converted from RGB to HSI or gray scale image,
2. The infected areas of leaf are extracted by segmentation technique, and
3. From extracted part, texture features of a region are calculated and disease is identified by using classification technique.

There are many segmentation techniques such as Otsu Segmentation, Thresholding, K-Means clustering, Fuzzy C-Means clustering and unsupervised segmentation. Segmentation of diseased area of a plant leaf is the first step in disease detection and identification which plays a crucial role in agriculture research. This paper presents a spatial FCM algorithm for segmentation techniques that are used to segment diseased leaf of a turmeric plant more effectively at earlier stage.

III. ANALYSIS OF CLUSTERING ALGORITHM

Clustering is a technique for partitioning a group of images into disjoint subgroups. Images that are similar to each other group themselves into a single cluster. All the images in subgroup are similar to each other. At the same time, the images across the cluster are different. In image segmentation, clustering is used to provide the updated centriod value based on the distance between the objects.

This section describes some of the clustering techniques that are used to segment the infected area. The clustering techniques considered are, K-Means, FCM and Spatial FCM.

In this paper, the developed spatial FCM algorithm for the improvement of the image segmentation accuracy in leaf disease detection at earliest stage.

3.1 K-Means Clustering

K-Means is a hard clustering algorithm approach where the physical boundaries of cluster are well defined. In K-Means clustering algorithm the n objects or instances is classified into K clusters with initial centriods.

The K-Means objective function is;

$$J = \sum_{j=i}^{k} \sum_{i=1}^{n} \|x_i - c_j\|$$

where, K is the number of clusters.
C is the cluster centriod and x is the object.
Procedure for K-Means technique is

1. Initialize the centriod,
2. Find the distance between object and centriods,
3. Assign the object to the cluster with which distance is minimum,
4. Recalculate the new mean of the cluster, and
5. Repeat the step till a predefined threshold is met.

A. Advantage
Segmentation of an image is fast for image where the boundaries are well defined.

B. Disadvantage
The performance of the K-means algorithm depends on the initial positions of the cluster centers. This is an inherently iterative algorithm. And also, there is no guarantee about the convergence towards an optimum solution. The convergence centroids vary with different initial points.

3.2 Fuzzy C-Means Clustering
Fuzzy logic deals with the vagueness and imprecision present in the problem. The image in grey color has an ambiguity in brightness and darkness of a pixel. In segmentation problem, the image is first converted from RGB to HIS which has confusion in determining whether pixel is normal or infected. This kind of vagueness is known as spatial ambiguity. To solve this, image is considered as a fuzzy set. Fuzzy clustering obtains more reasonable results for vague cluster boundaries. In a fuzzy set, there is a degree of membership for every member. Value of membership lies between 0 and 1 and the sum of membership of each object is 1.Larger membership values indicates higher confidence to cluster.
Fuzzy C- Means objective function is

$$J = \sum_{I=1}^{C} \sum_{J=1}^{N} U_{ij}^{m} \left|X_i - C_j\right| 1 \leq m \leq a$$

where m is any real number greater than 1, c is number of clusters,
U_{ij}^{m} is the degree of membership of xi in the cluster j,
X_i-C_j is Euclidean distance between any data object and the centriod of jth cluster
Fuzzy C- means clustering algorithm is

1. Choose a number of clusters,
2. Assign randomly to each point in the coefficients for being in the clusters,
3. Repeat until the algorithm has convergence,
4. Compute the centriod for each cluster, and
5. For each point compute its co-efficient in the cluster.

A. Advantages

1. In Fuzzy C-Means clustering each element is assigned to multiple clusters with certain degree of membership in the dataset. So it minimizes intra-cluster variance, and
2. FCM obtains more reasonable results where the boundaries are vague.

B. Disadvantages

1. Dependency on initial centriod,
2. Sensitivity to noise and outliners, and
3. Results depend on initial centriod.

To overcome the drawback of conventional FCM and K-Means clustering algorithm, sFCM clustering algorithm is developed.

IV. PROPOSED SPATIAL FUZZY C-MEANS CLUSTERING

4.1 Spatial Fuzzy C-Means Clustering

One of the important characteristics of an image is that neighboring pixels are highly correlated. In other words, these neighboring pixels possess similar feature values, and the probability that they belong to the same cluster is great. This spatial relationship is important in clustering, but it is not utilized in a standard FCM algorithm. To exploit the spatial information, a spatial function is defined as

$$h_{ij=}\sum_{k\in NB(x_j)} u_{ik}$$

where $NB(x_j)$ represents a square window centered on pixel x_j in the spatial domain. Just like the membership function, the spatial function h_{ij} represents the probability that pixel x_j belongs to ith cluster. The spatial function of a pixel for a cluster is large if the majority of its neighborhood belongs to the same clusters.

The spatial function is incorporated into membership function as follows:

$$u'_{ij} = {u_{ij}^{p} h_{ij}^{q}} \Big/ {\sum_{k=1}^{c} u_{kj}^{p} h_{kj}^{q}}$$

where p and q are parameters to control the relative importance of both functions. In a homogenous region, the spatial functions simply fortify the original membership, and the clustering result remains unchanged. However, for a noisy pixel, this formula reduces the weighting of a noisy cluster by the labels of its neighboring pixels. As a result, misclassified pixels from noisy regions or spurious blobs can easily be corrected. The spatial FCM with parameter p and q is denoted $sFCM_{p,q}$. Note that $sFCM_{1,0}$ is identical to the conventional FCM.

4.2 Median Filter

Median filtering is used as a noise removal in order to obtain a noise free image. After segmentation is done, the segmented image may still present some unwanted regions or noise. So, improve the quality of the image, the median filter is applied to the segmented image. We can use different neighborhood of $n \times n$. But generally, neighborhood of n=7 is used because large neighborhoods produce more severe smoothing.

V. EXPERIMENTAL RESULTS AND DISCUSSION

The efficiency of the proposed spatial FCM method for image segmentation to detect leaf diseases and the results are analysed and shown with various evaluation measures such as segmentation accuracy and the execution time with less iteration. To assess the quality of images, the parameters like MSE and PSNR are evaluated.

For a better segmentation algorithm, the MSE value, execution time must be less and PSNR value must be high. We showed our experimental results in Table.1, Table.2 and Table.3 for different Image set in Fig.2, Fig.3, and Fig.4 and compared our results with existing method with less MSE value, less execution time, less iteration, higher PSNR value and improved segmentation accuracy.

Moreover, the proposed method decides the initial cluster k value with decreased execution time of 4s for image 1with Iteration count 28, 5s for image 2 with iteration count 49 and 3s for image 3 with iteration count 31.

5.1 Segmentation Accuracy

Segmentation Accuracy is defined as the ratio of the total numbers of pixels inthe segmented area to the total number of pixels in the original image.

$$\textit{Segmentation Accuracy} = \frac{\textit{Total number of pixels in segmented infected leaf image}}{\textit{Total number of pixels in original leaf image}}$$

The graphical representation of Mean square error (MSE), Peak signal to noise ratio (PSNR) and Accuracy are shown in Fig.3, Fig.4, and Fig.5.

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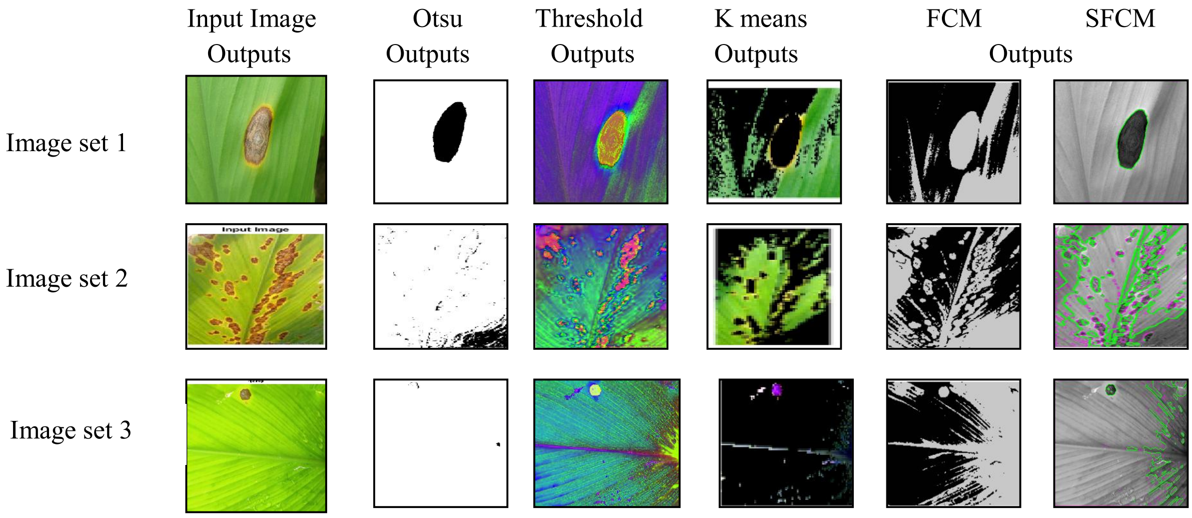
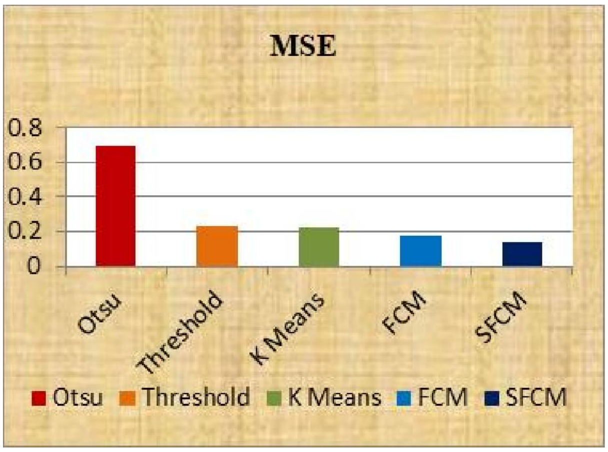


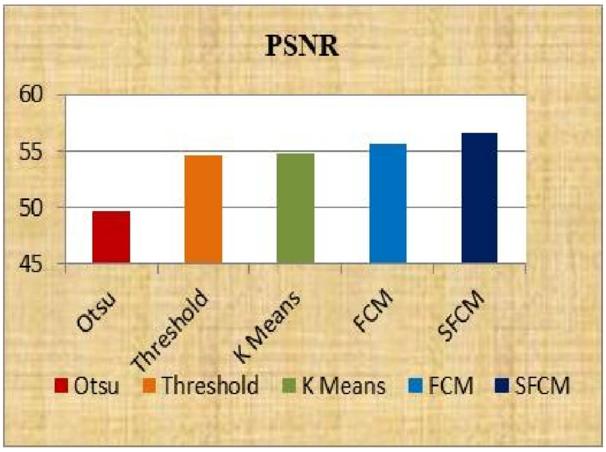
Figure 2: various segmentation results of turmeric leaf Various segmentation results of disease affected turmeric leaf for different existing and proposed algorithm as shown in fig.2.

TABLE I: Image Quality Metrics and Charts

Image Quality Metrics – Image Set 1

METRICS	Otsu	Threshold	K Means	FCM	SFCM
MSE	0.70	0.23	0.22	0.18	0.14
PSNR	49.72	54.64	54.77	55.61	56.63
ACCURACY	74.90	80.60	38.58	57.56	98.12
ITERATION NO	33	34	35	06	28
TIME (S)	4s	3s	3s	3s	4s





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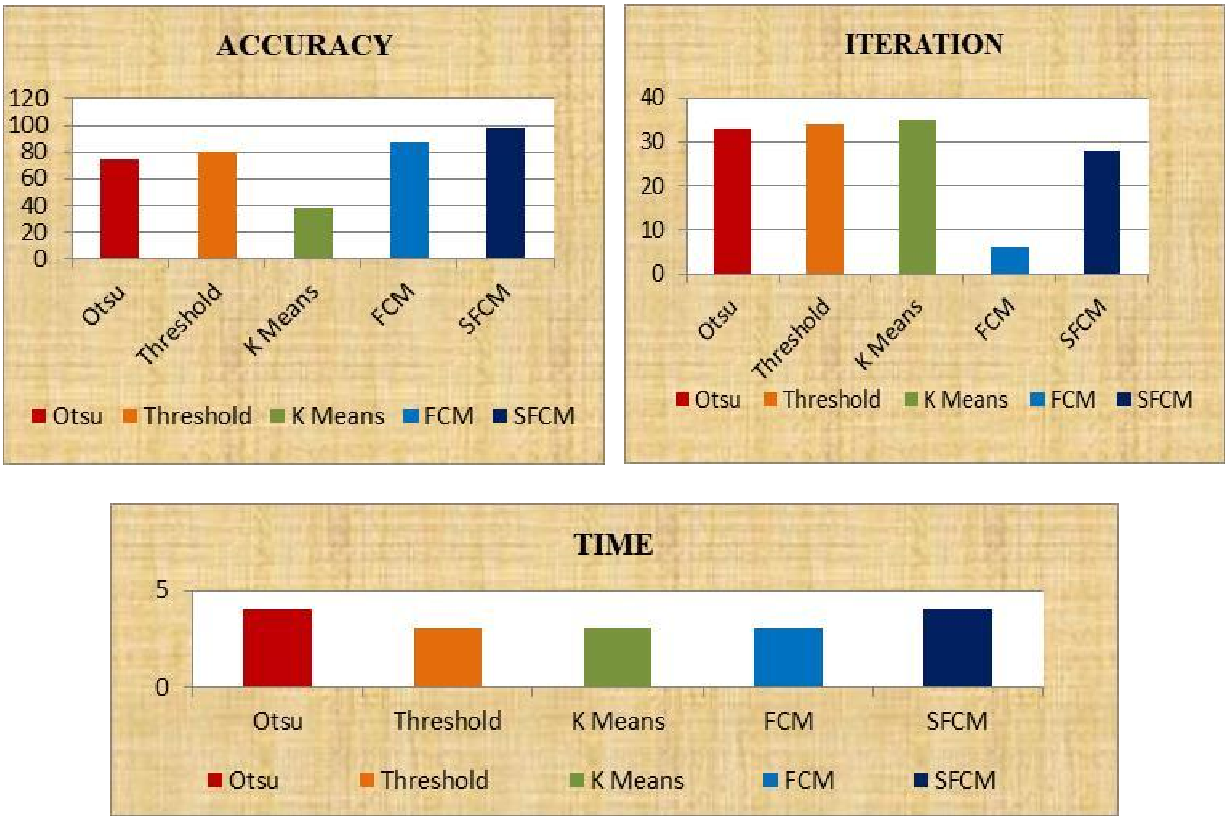
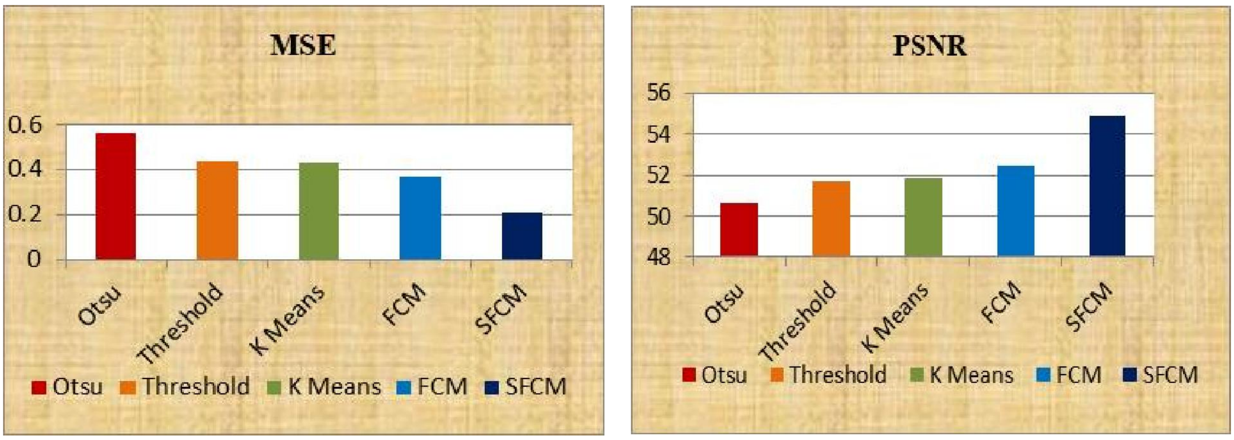
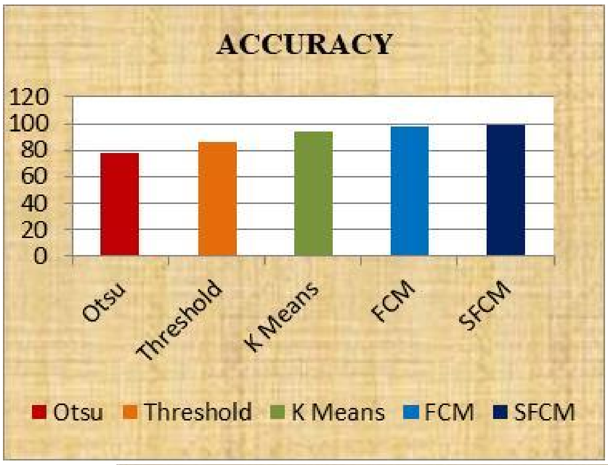


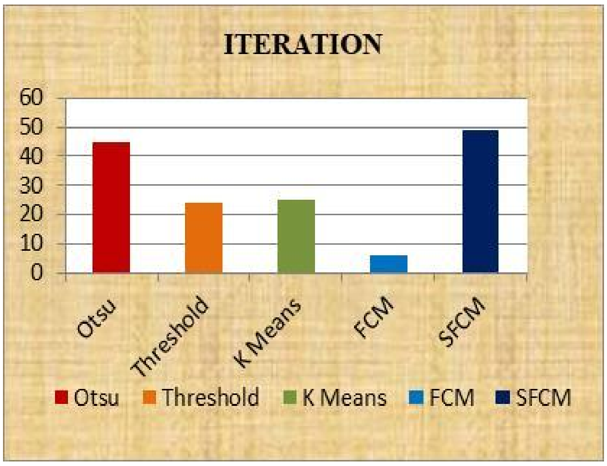
Figure 3: Image segmentation results of Image Set 1

TABLE III: Image Quality Metrics – Image Set 2

METRICS	Otsu	Threshold	KMeans	FCM	SFCM
MSE	0.56	0.44	0.43	0.37	0.21
PSNR	50.67	51.73	51.83	52.45	54.90
ACCURACY	77.80	85.49	94.47	97.86	98.64
ITERATION NO	45	24	25	06	49
TIME (S)	5s	9s	9s	3s	5s







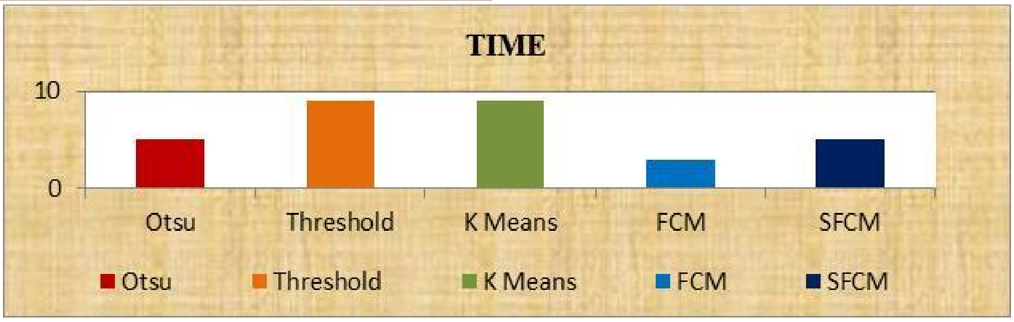
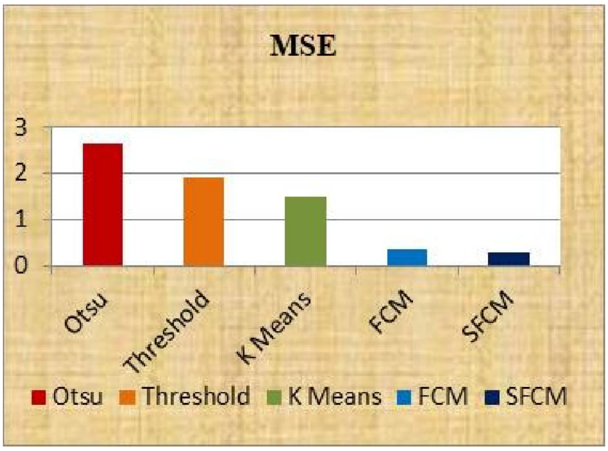
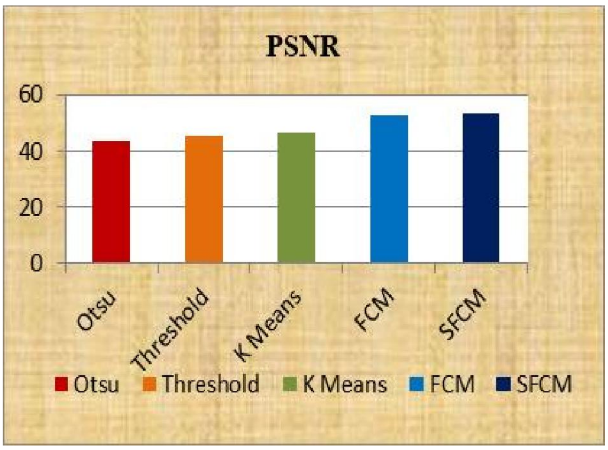


Figure 4: Image segmentation results of Image Set 2

TABLE IV: Image Quality Metrics – Image Set 3

METRICS	Otsu	Threshold	K Means	FCM	SFCM
MSE	2.64	1.90	1.50	0.35	0.29
PSNR	43.95	45.38	46.39	52.72	53.53
ACCURACY	63.69	76.22	84.28	85.20	96.28
ITERATION NO	31	40	41	06	31
TIME (S)	3s	3s	3s	3s	3s





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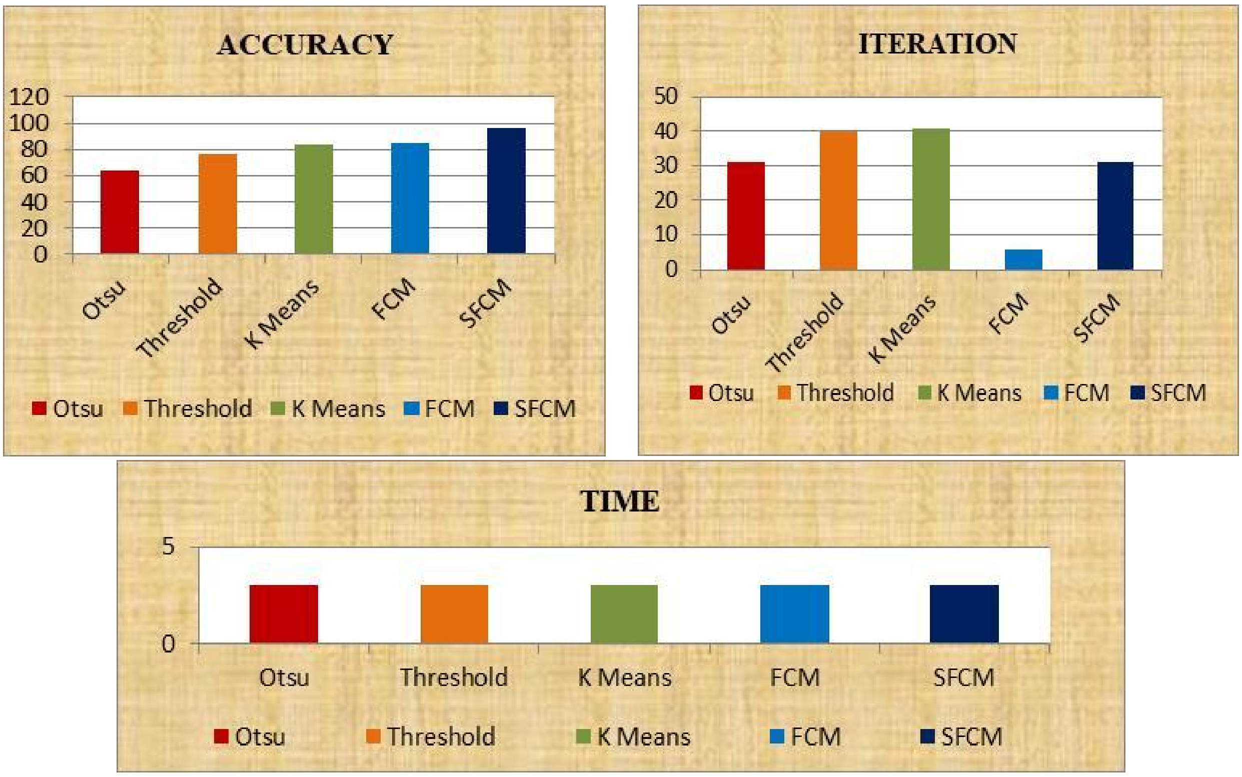

Figure 5: Image segmentation results of image set 3

VI. CONCLUSION

The performance of the proposed spatial FCM image segmentation method is compared with convention K means, Otsu and FCM algorithm based on the parameter measures like segmentation accuracy, execution time, MSE and PSNR value. From the experiments results, it is seen that the proposed spatial FCM has good image quality and proved that the proposed image segmentation algorithm is very effective which results in less MSE, higher PSNR value and improved segmentation accuracy to make classification of leaf diseases easier. From the results obtained, the spatial FCM segmentation algorithm provide 98.64% in terms of accuracy. This system is a robust system because the results are having the high percentage of accuracy and low percentage of error. In future, we can extend the work for feature extraction and classification of plant foliar diseases using hybrid algorithm.

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