International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Multiresolution Bio-Medical Image Segmentation using Fuzzy C-Means Clustering

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Abstract*: *Fuzzy c-means clustering is a popular image segmentation technique, in which a single pixel belongs to multiple clusters, with varying degree of membership. The main drawback of this method is it sensitive to noise. This method can be improved by incorporating multiresolution stationary wavelet analysis. In this paper we develop a robust image segmentation method using Fuzzy c-means clustering and wavelet transform. The experimental result shows that the proposed method is more accurate than the Fuzzy c-means clustering.

Keywords: Fuzzy c-means clustering, segmentation, Stationary Wavelet Transform

I. INTRODUCTION

Image segmentation is a vital step in almost all image processing applications. Segmentation is a process of dividing an image into regions, in which pixels in a region are similar based on criterion considered for segmentation [1]. Image processing is broadly classified into three categories viz, i) Manual segmentation, in which image pixels are divided into regions manually, the major drawback of this technique is it consumes more time when an image consists of large number of pixels. ii) Semi-automatic, in this method starting points or seeds are identified manually and then it uses seed points to segment images. iii) Automatic or unsupervised Segmentation, in this method it segments an image without intervention of human.

The basic idea used in otsu's [2] segmentation is intensity thresholding, in this method the threshold value is calculated using histogram of the image and then the threshold value is used to separate the object from the background. The major drawback of this method is it ignores the spatial information of the pixels to segment the image. Edge detection segmentation [3] methods detect edges of the objects based on the illuminating patterns. These methods require post processing as these identifies only edges of the object.

Manuscript published on November 30, 2019.
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Region growing segmentation [4] techniques uses seed points as an initial points then the region are grown by comparing all unallocated pixel to the segmented image. In this method the seed points has to be identified manually or it has to be passed as the one of the input. The segmented outputs are sensitive to the selection of the seed points. Region split and merge is opposite to region growing in which first the image is divided into regions and then the region are merged based on the predefined criterions such as color intensity, energy of the pixel etc.

Vincent and Soille [5] proposed a watershed segmentation algorithm which watersheds are built in the places where water from different basins unites. The process ends when the water reaches the maximum peak of the relief, but this method suffers from over segmentation. Clustering algorithms like K-means and fuzzy c-means (FCM) [6] segmentation techniques require some prior knowledge to determine initial parameters, but the selection of initial parameters usually influences the clustering result greatly.

II. STATIONARY WAVELET TRANSFORM (SWT)

SWT is an extension of the Discrete Wavelet Transform [7]. It does not uses down sampling; the lengths of the decimated coefficients and the image are equal. In SWT instead of down sampling, filters are modified at each level by padding zeroes. The rows of the image are first convoluted by low pass and high pass filter, and then the outputs are again filtered column wise by low pass and high pass filter to obtain LL, LH, HL, HH bands. The LL band is called approximation coefficients, which contain most of the image information. LH, HL, HH bands are collectively called detailed coefficients. The detailed coefficients contain high frequency information and noise.

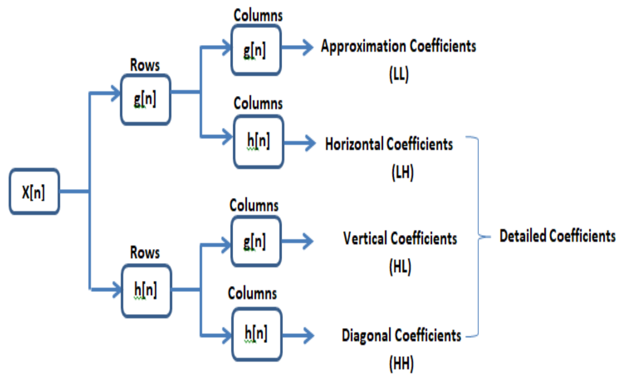

Fig (1): SWT Analysis filter bank

Fig (1) shows the first level decomposition of the image by SWT. In second level, the approximation coefficients of the first level are decomposed to get second level coefficients and so on.

The reconstruction is done by synthesis filter as shown in fig (2).

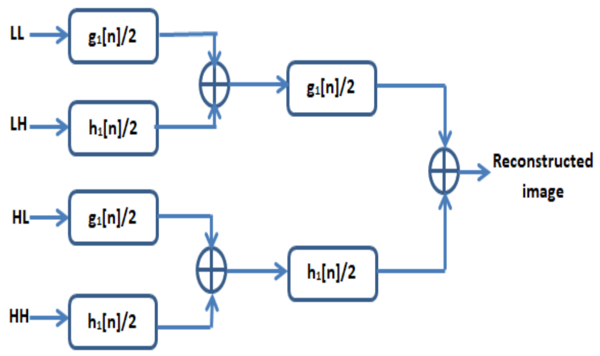

Fig (2): SWT synthesis filter bank

III. FUZZY C-MEANS CLUSTERING

J. C. Dunn [8] proposes FCM algorithm for detecting compact well-separated cluster and it is upgraded by Bezdex [9]. It divides the data point into groups called clusters, in which a data point can belongs to several clusters with different degree of membership in the range [0, 1]. It is an iterative optimization of the objective function. For a an image I={z(I,j), 0<i≤M,0<j≤N} with M*N number of pixels or data points is to be clustered into K clusters, the fuzzy c-means optimization function is given by,

$$J(X,Y)=\sum_{i,j}\sum_{c=0}^{k-1}(\mu_c(i,j))^m(d_c(i,j))^2 \qquad (1)$$

where, X=[μ_c(i,j)] is the fuzzy clustering matrix, Y={Y_0,Y_1,Y_2,….Y_{c-1}} denotes the set of clustering centers. μ_c(I,j) is the membership of the data point z(I,j) in the C^{th} cluster, m is the constant used to control the fuzziness of the resulting partitions, D_c(I,j) is the Euclidian distance of the data point z(I,j) from the C^{th} cluster.

The probability of a data point belonging to a certain cluster depends on the distance of the data point from the centroid of a cluster and it is denoted by membership value. When a data point is closer to a centroid of the cluster then it is assigned with a high membership value and cost function is minimized. The data point which is far from the centroid is assigned with a low membership value.

In FCM, first the number of clusters K (2≤K<M*N), and initial values of fuzzy clustering matrix are assigned. Then the clustering centers Yc and fuzzy clustering matrix X(i,j) are updated using (2), and (3) respectively. The process is repeated until the coefficients change between two iterations is no more than ε,

$$Y_c=\frac{\sum_{i,j}\mu_c(i,j)^m z(i,j)}{\sum_{i,j}\mu_k(i,j)^m} \qquad (2)$$

$$X_c(i,j)=\frac{1}{\sum_{p=0}^{K-1}\left(\frac{d_c(i,j)}{d_p(i,j)}\right)^{2/(m-1)}} \qquad (3)$$

IV. PROPOSED METHOD

When an image is contaminated by noise, the intensity of the affected pixel is altered. The FCM technique clusters the pixels based on the objective function which uses the intensity and distance between the pixels to group the pixels into clusters. So the noise in the image may mislead the FCM clustering. In the proposed method employs SWT to remove noise from the image. The detailed coefficients of the SWT contain noise, so these coefficients are masked and the FCM is applied to the approximation coefficients only. In the proposed method 2 level SWT is used.

The flow chart of the proposed method is shown in fig.1. The original image is first segmented by FCM and also it is decomposed into two levels SWT. The detailed coefficients of each level are masked to zero. Then the approximation coefficients of each level of SWT are subjected to FCM and the IDWT is applied.

The Segmented images obtained by direct segmentation of the image by FCM F_0(x,y), first level approximation image F_1(x,y) and second level approximation image F_2(x,y) are fused using the following criterion.

1. If F_0(x,y)=F_1(x,y)=F_2(x,y) then the segmented image F(x,y)=F_0(x,y)
2. If F1(x,y)=F2(x,y)≠F0(x,y) then F(x,y)=F1(x,y)
3. If F_1(x,y)≠F_2(x,y) then F(x,y)=F0(x,y)

The condition two ensures that no pixel of the image is mistakenly assigned to any cluster k, while the approximation coefficients of level one two belongs to same cluster. The criterion three ensures when F0, F1 and F2 all different then the segmented image is replaced by F0, since it may be due to edges which is removed while masking detailed coefficients.

V. RESULTS AND DISCUSSION

A. Experimental setup

The proposed method is executed in MATLAB and the results are compared with FCM technique. An image consists of shapes like star, circle; rhombus etc. is used to analyze the results of proposed method. The cell images and the corresponding ground truth images are obtained from UCSB center for Bio-image Informatics. The proposed method is compared with FCM segmentation in terms of accuracy and Dice co-efficient.

B. Performance matrices

- **Accuracy**

  It gives the percentage pixels of the image which are correctly classified. Accuracy of the segmentation technique is given by

$$Accuracy=\frac{TP+TN}{TP+TN+FP+FN}\times 100 \qquad (4)$$

Where, TP represents a pixel that is correctly predicted to belong to the given class and TN is the pixel that is correctly identified as not belonging to the given class. FN is the pixel that is wrongly predicted to belong to the given class and FN is the wrongly predicted pixel that is not belonging to the given class.

- **Dice co-efficient**

  Dice co-efficient [10] is used to measure similarity between segmented image and the ground truth. It is given by,

$$DC = \frac{2|M \cap N|}{|M|+|N|} \qquad (5)$$

C. Comparisons

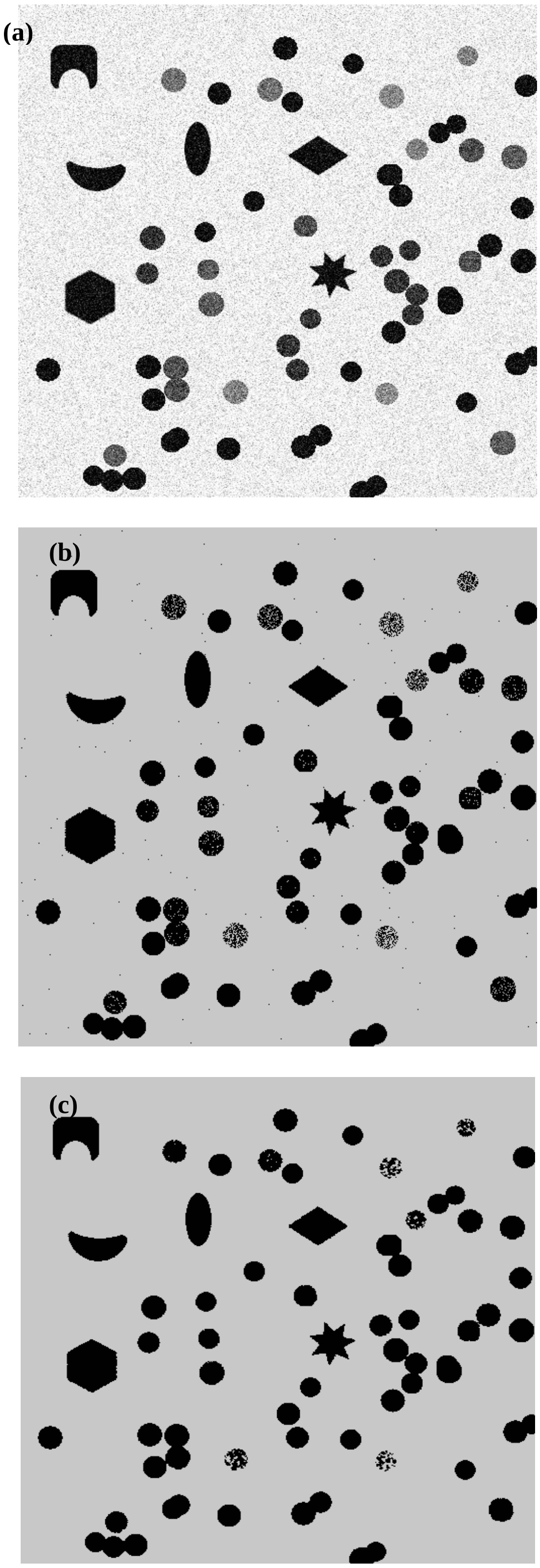

Fig (3): a) Noisy image with noise SNR=30, image segmented by b) FCM c) Proposed method

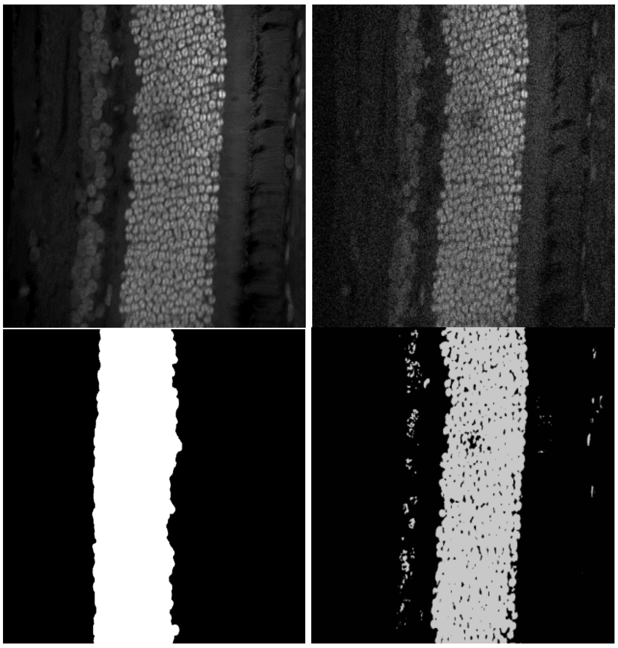

Fig (4): Cell image-1 a) original image b) image contaminated by noise SNR=30 c) Ground truth image d) Segmented by proposed method

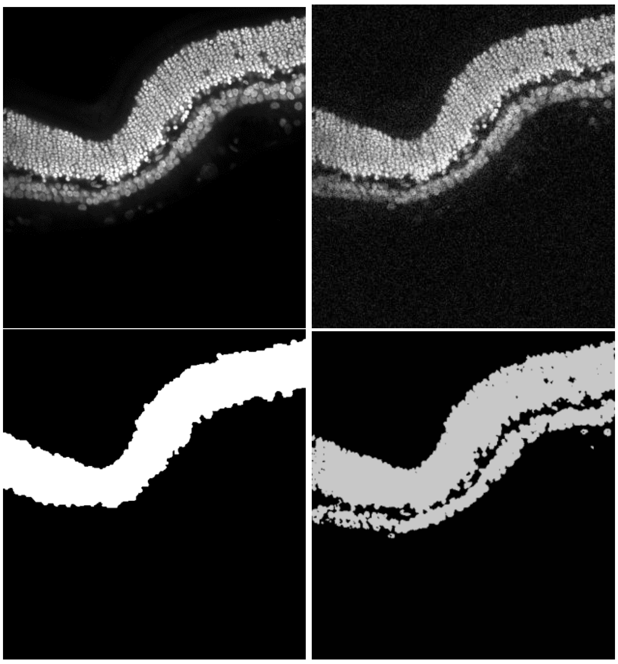

Fig (5): Cell image-2 a) original image b) image contaminated by noise SNR=30 c) Ground truth image d) Segmented by proposed method

To evaluate the efficiency of the segmented image it is compared with the FCM segmented image. It is observed that the image segmented by FCM classifies the pixel contaminated noise as identified class of pixels. Tab.1 compares the accuracy and Dice co-efficient of the proposed method with the FCM, and the results shows improvement in both accuracy and Dice co-efficient. The images segmented by proposed method have best segmented results in terms of accuracy and Dice co-efficient.

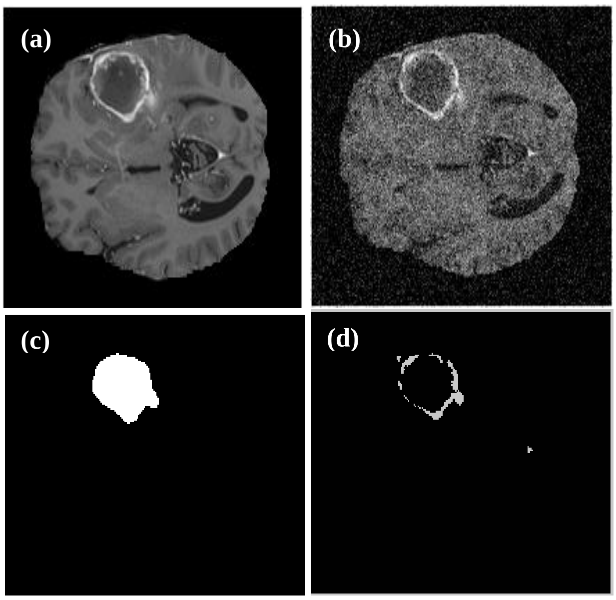

Fig (6): Brain MRI with tumor a) original image b) image contaminated by noise SNR=30 c) Ground truth image d) Segmented by proposed method

Table-I: Comparison of Accuracy scores of the segmented images

Image	Accuracy		Dice Co-efficient	
	FCM	**Proposed method**	**FEM**	**Proposed method**
Cell image1	79.04%	91.15%	0.6689	0.8340
Cell image2	92.13%	93.49%	0.7958	0.8324
MRI Brain tumor	97.05%	97.94%	0.9771	0.9839

VI. CONCLUSION

This paper presents a multiresolution FCM using stationary wavelet analysis. The conventional FCM is highly sensitive to noise. This drawback is eliminated by employing multiresolution SWT to segment images along with FCM. The experimental result shows that the proposed method improves the efficiency of the FCM segmentation in terms of accuracy and Dice-coefficient. The increase in accuracy is 12% in case of noise SNR=30 and increase in Dice coefficient is 0.1651.

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