MRI image segmentation based on new fuzzy c-means algorithm

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Abstract
The fuzzy c-means clustering algorithm is one of the most important procedures of unsupervised clustering. It had always involved inadequacy for the necessity of determining the initial quantities and lack of ways on theoretical bases for choosing it, in view of the fact that in fuzzy c-means algorithm like unlinear optimizing procedures of initial quantities(like the cluster number and initial center and membership matrix) is efficient in convergence of this algorithm. So, if these quantities are not selected correctly for a noisy data, this algorithm will stop in local minimum. Therefore this algorithm becomes limit. This work develops a specific method to construct the initial cluster center to construct initial membership to clusters in order to improve the strength of the clusters. The algorithm is realized by incorporating the spatial neighborhood information to calculate the initial cluster center. So this paper finds a reasonable way to get the initial cluster center to initialized membership matrix. The new FCM are tested on a set of dataset and then the application to the segmentation of real MRI image is presented and compared with the results obtained using FCM.

Keywords: fuzzy c-means; initial cluster center; initial membership matrix; spatial neighborhood information; MRI

I. INTRODUCTION

Magnetic Resonance Imaging (MRI) is a noninvasive method for imaging internal tissues and organs. The problems of image segmentation (the identification and quantitation of tissues and organs) of MRI images have been described extensively in the literature and many algorithms have been developed in an attempt to solve the problems. One of the goals of segmentation of MRI images is to determine the volumes of organs, tissues and lesions present in a given patient. These volumes, and the changes in these volumes over time, may aid in the diagnosis, prognosis and treatment planning of patients under investigation.

Image segmentation plays a major role in the field of biomedical applications. The segmentation technique is widely used by the radiologists to segment the input medical image into meaningful regions [1, 2, 3, and 4]. The specific application of this technique is to detect the tumor region by segmenting the abnormal MR input image. The size of the tumor region can be tracked using these techniques which aid the radiologists in treatment planning. The primitive techniques are based on manual segmentation which is a time consuming process besides being susceptible to human errors. Several automated techniques have been developed which removes the drawbacks of manual segmentation.

An image can be represented in various feature spaces, and the FCM algorithm classifies the image by grouping similar data points in the feature space into clusters. This clustering is achieved by iteratively minimizing a cost function that is dependent on the distance of the pixels to the cluster centers in the feature domain. The pixels on an image are highly correlated, i.e., the pixels in the immediate neighborhood possess nearly the same feature data. Therefore, the spatial relationship of neighboring pixels is an important characteristic that can be of great aid in the segmentation algorithm.

In the unsupervised clustering method FCM by Bezedek the initial membership matrix for initialized clusters generated by randomly. The initial membership matrix does not depend on samples of data sets in FCM and other unsupervised methods, simples some grade(in between 0 and 1) given to elements of clusters using random choice. It means the total value of grades of one sample in all clusters may be equal to one, but it is not meaning that some approximate membership grade given to the element in particular cluster according to the strength of element belongs to that cluster.

The organization of the paper is as follows: In section II, traditional fuzzy c-means algorithm is introduced. In section III, we obtain the fuzzy c - means cluster segmentation algorithm based on initial cluster center and initial membership matrix. The experimental comparisons are presented in section IV. Finally, in section V, we conclude and address the future work.

II.FCM CLUSTERING ALGORITHM

The FCM clustering algorithm was proposed by Bezdek ,which was an improved version of k-means algorithm [5]. It assigns pixels to each category by using fuzzy memberships. The algorithm is an iterative optimization that minimizes the cost function defined as follows:

$$J_{FCM} = \sum_{j=1}^{N} \sum_{i=1}^{c} u_{ij}{}^{m} \left| x_j - v_i \right|^2 \qquad (1)$$

Where X = {x1, x2,..., xn} $\subseteq R^p$ is the data set in the p-dimensional vector space, p is the number of data items, c is the number of clusters with 2 ≤ c ≤ n-1. V = {v1, v2... vc} is the c centers or prototypes of the clusters, vi is the p-dimension center of the cluster i. U = {μij} represents a fuzzy partition matrix with uij = ui (xj) is the degree of membership of xj in the ith cluster, xj is the jth of p-dimensional measured data. The fuzzy partition matrix satisfies:

$$\begin{aligned} & 0 \langle \sum_{j=1}^{n} u_{ij} \langle n \quad , \forall \ i \in \{1,......., \quad c\} \\ & \sum_{j=1}^{c} u_{ij} = 1 \quad , \forall \ j \in \{1,......., \quad n\} \\ & 0 \le U_{ij} \le 1 \quad , \quad \forall \ i, \ j \end{aligned} \qquad (2)$$

The parameter m is a weighting exponent on each fuzzy membership and determines the amount of fuzziness of the resulting classification; it is a fixed number greater than one. The objective function JFCM can be minimized under the Constraint of U. specifically, taking of JFCM with respect to uij and vi and zeroing then respectively, tow necessary but not sufficient conditions for JFCM to be at its local extreme will be as the following:

$$\begin{aligned} & U_{ij} = \sum_{k=1}^{c} \left(\frac{\left\| x_j - v_i \right\|}{\left\| x_j - v_k \right\|} \right)^{\frac{-2}{m-1}} \\ & for\, i = 1,2,.....c \quad and \quad for\ j = 1,2,......,n \end{aligned} \qquad (3)$$

$$V_i = \frac{\sum_{j=1}^{n} (u_{ij})^m x_j}{\sum_{j=1}^{n} (u_{ij})^m} \qquad for\ i = 1,2,.....\ c \qquad (4)$$

Although FCM is a very useful clustering method, its memberships do not always correspond well to the degree of belonging of the data, and may be inaccurate in a noisy environment, because the real data unavoidably involves some noises.

III. A NEW FUZZY C-MEAN CLUSTERING FOR INITIALIZED CLUSTER CENTER

In this section we try to introduce or initialize a particular way to construct initial cluster center based on samples of data set. 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 [6, 7]. In order to make initial cluster center we use a square window centered on pixel x_j in the spatial domain to obtain a dissimilarity of samples in the square window. We need the dissimilarity of samples of data sets, commonly there are many distance function used to find the dissimilarity, but in this paper we use the Euclidean distance measure between the central pixel in each window and neighborhood of this pixel. The 3×3 window was used throughout this work.

In the new proposed algorithm, the initial cluster center has been constructed in the following way. Let c be the number of cluster, c=2… (n/2), where n is the total of pixels in the data set.

The initial cluster center is constructed using the following equation:

$$Vi = dissimilarities\{H(Xj)\} \qquad for\ i = 1,......,n \qquad (5)$$

Where H (xj) represents a square window centered on pixel xj in the spatial domain. Then we obtain the max, min and mean of the dissimilarities for Vi. The initial cluster center initialized According Eq. (5).

NEW FUZZY C-MEANS ALGORITHM APPROACH IS GIVEN BELOW:

1. selects the dataset
2. find the dissimilarity of elements in the data set using square window
3. select the number of cluster
4. initialized the cluster center using Eq. (5)
5. initialized the membership matrices using Eq. (3)
6. Calculated the cluster center using Eq. (2)
7. Update the membership matrices using Eq. (3)
8. Stop the iteration if the algorithm satisfy the $\|V_{new} - V_{old}\| \langle \varepsilon$.
9. otherwise, goto step 5

IV. EXPERIMENTAL RESULTS

To evaluate a fuzzy partition, a measure for the goodness of separation into groups is needed.In order to obtain a quantitative comparison, two types of cluster validity functions, fuzzy partition and feature structure, are often used to evaluate the performance of clustering in different clustering methods. The representative functions for the fuzzy partition are partition coefficient Vpc [8] and partition entropy Vpe [9]. They are defined as follows:

$$\mathrm{V_{pc}}(U) = \frac{1}{n}(\sum_{K=1}^{n}\sum_{i=1}^{c} u_{ik}^2) \qquad (6)$$

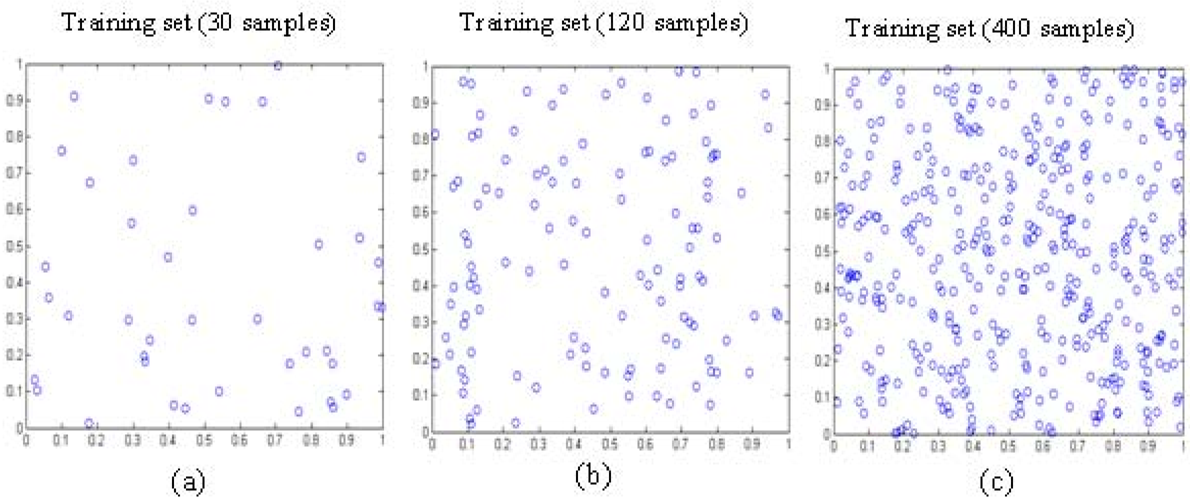
$$\mathrm{V_{pe}}(U) = -\frac{1}{n}(\sum_{K=1}^{n}\sum_{i=1}^{c} u_{ik} \log u_{ik}) \qquad (7)$$

The idea of these validity functions is that the partition with fuzziness means better performance. As a result, the best clustering is achieved when the value Vpc is maximal or Vpe is minimal.

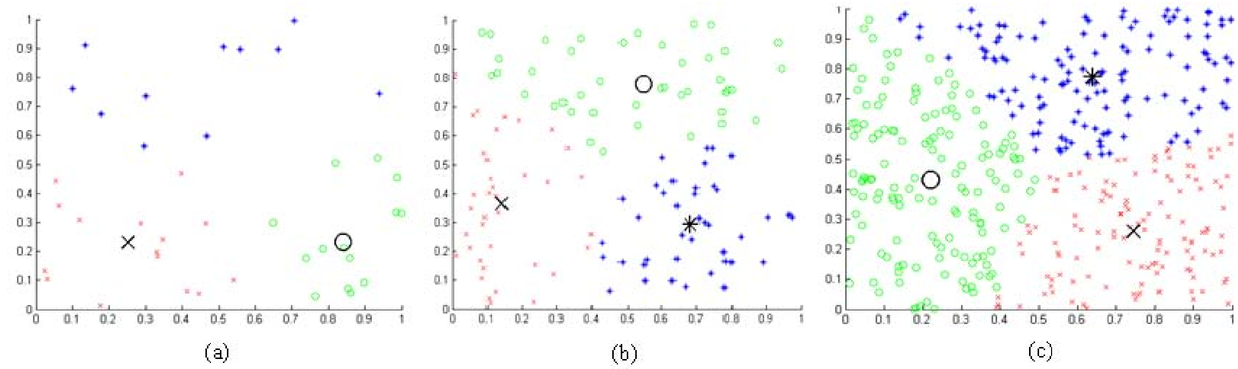
In order to verify the effectiveness of the proposed algorithm, we give some experiments using both artificial synthesized image and real image to compare the performance of the proposed algorithm with that of the standard FCM algorithm.

A. Demonstration of the new fuzzy c-means approach with training sets

To show the efficiency of new FCM we construct randomly three training set given in fig.1 (a-c). The first training set contained 40 samples, second training sets contained 120 samples and the training set third contained 400 samples. For demonstration purpose each training set divided into three clusters by using the procedure of FCM and new FCM. The results of these algorithms are shows in fig. 2(a-c). In this work we assume number of cluster is three, it does not mean that the three cluster of data sets are appropriated clusters.



FigureI (a) Training set1, (b) Training set2, (c) Training set3



FigureII experimental new FCM result on (a) Training set1, (b) Training set2, (c) Training set3

The values of partition coefficient Vpc and partition entropy Vpe and number of iteration in FCM procedure and the values of new FCM procedure for the same training sets given in table 1.

This paper had generated many training sets and compared the results between the procedure of FCM and new FCM. Many times the results are same by the procedure of both methods, but some cases the results by the procedure of new FCM are better than the results of FCM procedure, certainly not worser than the result of FCM.

TABLEI THE VALUSE OF PARTITION COEFFICIENT VPC AND PARTITION ENTROPY VPE AND NUMBER OF ITERATION IN THE TRAINING SETS 1-3 BY FCM AND NEW FCM

Training sets	Vpc	Vpe	Num. iter.
Training set1 by FCM	0/8529	0/1247	20
Training set1 by new FCM	0/8530	0/1247	12
Training set2 by FCM	0/7843	0/1691	36
Training set2 by new FCM	0.7845	0/1689	21
Training set2 by FCM	0/8062	0/1542	52
Training set3 by new FCM	0/8062	0/1542	33

B. Experimental result on real image

Fig.3a shows an MRI brain image with 256*256 pixels. The image degraded by the Salt-Pepper with noisy density d =0.02 and speckle noise is shown in Fig.3b and 3c, respectively.

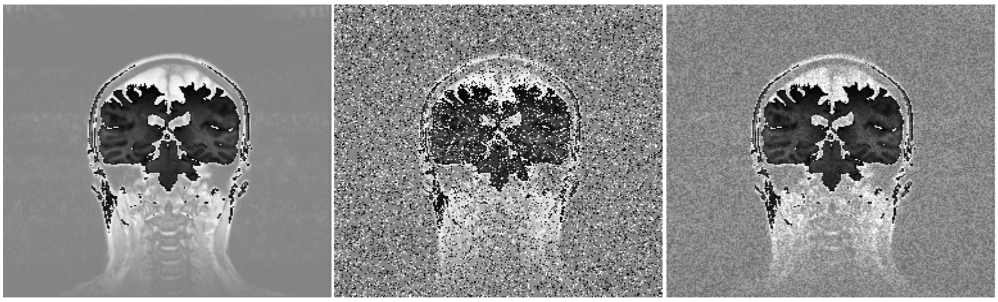
Figs. 4a-4b display the clustering results of the Salt-Pepper degraded image using the FCM and New-FCM, correspondingly, the clustering results on speckle degraded image were shown in Figs. 5a-5b.

Tables 2 tabulates the Vpc and Vpe and number of iteration of the two algorithms on two different noise degraded MRI images shown in Figs.6b and 6c, respectively [For c=3(num. of cluster)].

TABLEII COMPRESSION OF THE CLUSTERING RESULTS ON TWO KIND NOISE DEGRADED MRI IMAGE USING FCM AND NEW FCM ALGORITHMS [FOR C=3(NUM. OF CLUSTER)]

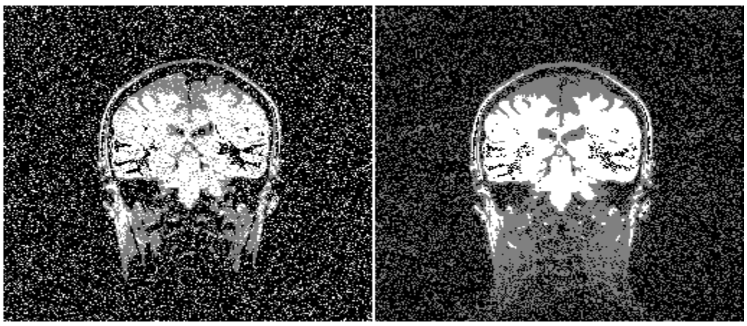
Noise type	Algorithm	Vpc	Vpe	Num. iter.
No noise	**FCM**	0/9367	0/0541	15
No noise	**New FCM**	0/9367	0/0541	10
Salt-pepper	**FCM**	0/9378	0/0527	11
Salt-pepper	**New FCM**	0/9380	0/0523	9
speckle	**FCM**	0/7826	0/1688	98
speckle	**New FCM**	0/7826	0/1688	59

Table 2 shows that our proposed algorithm improves significantly the performances of clustering both Salt-Pepper degraded image and speckle degraded image compare to the standard FCM algorithm.



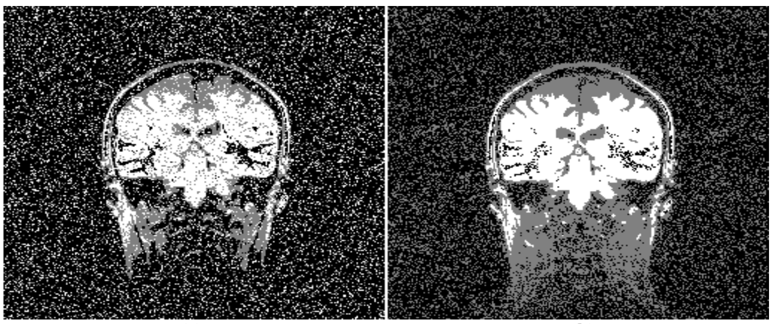
. (a) (b) (c)

FigureIII MRI image: (a) original image, (b) image degraded by Salt-Pepper noise, (c) image degraded by speckle noise



(a) (b)

FigureIV Comparison of segmentation results on MRI image which is corrupted by 2% Salt- Pepper noise. (a) FCM result (b) New FCM result



(a) (b)

FigureV Comparison of segmentation results on MRI image which is corrupted by speckle noise. (a) FCM result (b) New FCM result

V.CONCLUSION

The main drawback of the standard FCM for image segmentation is that the initial membership matrix for initialized clusters generated by randomly, and initial membership matrix does not depend on samples of data sets in FCM and other unsupervised methods, if initial cluster center and initial membership matrix are not selected correctly for a noisy data, this algorithm will stop in local minimum. Therefore, as mentioned in many literatures the standard FCM algorithm is sensitive to noise and a noisy pixel is always wrongly classified because of its abnormal feature.

In this paper we proposed a new algorithm called new Fuzzy c-means for segmentation of MR image. In this work we develop a specific method to construct the initial cluster center to construct initial membership to clusters in order to improve the strength of the clusters. The proposed algorithm has been tested with training data sets and results have compared with the results of FCM procedure to show the efficiency of new FCM.

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