Recent Modifications in FCM algorithm for Image Segmentation

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Abstract— **Image Segmentation is one of the important areas of image processing. It helps in getting more focused analysis of targeted area in image. It can be done using many algorithms. FCM is one of the algorithm and is based on clustering method. FCM algorithm is popularized with a lot of modifications. In this paper, we will see the modifications in FCM algorithms.**

IndexTerms— **Image Segmentation, FCM, Image Processing, Modification.**
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I. INTRODUCTION

Fuzzy C-means (FCM) algorithm is clustering based algorithm. Clustering is the grouping of similar kind of data. These grouping are then used for image segmentation. There are basically two types of clustering i.e., fuzzy and hard clustering. In fuzzy clustering every point of the image is related to every group based on some membership value. The value of membership varies from 0 to 1 [1].

Fuzzy C-means (FCM) clustering algorithm is a partition-based clustering algorithm where each pixel in the image has a membership value, associated to each cluster, ranging between 0 and 1. This membership value measures how much the pixel belongs to that particular cluster. It is an iterative partitioning method that produces ideal c-partitions and cluster centers which are centroids. The FCM algorithm minimizes generalized function 'J' and is calculated as follows,

$$J = \sum_{i=1}^{n} \sum_{j=1}^{k} (\mu_{ij})^m \| X_i - C_j \|^2 \qquad (1)$$

Where X= {X_1, X_2, X_3…X_N} be the pixels in an image, n is the number of pixels, C_j is the center of cluster j, k is the number of clusters, μ_{ij} is the degree of membership of X_i in the cluster j, m is the weighting exponent where m ϵ [1, ∞]. Let V= {V_1, V_2…V_K} be the set of cluster centers then the detailed FCM algorithm is as given below,

1. Randomly select k cluster centers.
2. Create a random fuzzy membership u_{ij} such that the sum of all membership function is unity. i.e.,

$$\sum_{j=1}^{C} \mu_{ij} = 1 \qquad (2)$$

3. Compute each cluster centroid V_i

$$V_i = \frac{\sum_{j=1}^{N} (\mu_{ij})^k X_j}{\sum_{j=1}^{N} (\mu_{ij})^k} \qquad (3)$$

4. Update the membership matrix $U^{(k)}$ to $U^{(k+1)}$ using $U^{(k+1)} = [\mu^{(k+1)}{}_{ij}]$

$$\mu_{ij} = \frac{1}{\sum_{M=1}^{C} \frac{\| X_j - C_i \|}{\| X_j - C_m \|^{(\frac{2}{K-1})}}} \qquad (4)$$

Where, ni is the number of pixels belonging to the cluster of centroid C_i and X_j is the pixels belonged to cluster C_i.
5. If $\| U^{(k)} - U^{(k+1)} \| <$ Threshold then stop, otherwise return to step 3.

The above calculated parameters are used in the objective function of FCM. Hence the portioning is taking place with the help of FCM [2].

The time complexity of the algorithm is O(N) where N is the number of pixels in the image. However, the FCM algorithm suffers from several disadvantages; such as priori specification of number of clusters, huge execution time due to its iterative nature and Different choice of μ_{ij} leads to different local minima 'J', which could lead to poor results.

II. MODIFICATIONS IN FCM ALGORITHMS:

The poor results have been corrected with the help of modified FCM algorithms. The three important modified FCM algorithms are as described below:

II A. Bias field corrected Fuzzy C-means (BCFCM)

In this modified fuzzy C-means algorithm, the objective function is the sum of standard FCM objective and an addition term involves the effect of neighbor term around x_k. The objective function for Bias field corrected Fuzzy C-means (BCFCM) is as follows:

$$J_m = \sum_{i=1}^{c} \sum_{k=1}^{N} u_{ik}^p \|x_k - v_i\|^2 + \frac{\alpha}{N_r} \sum_{i=1}^{c} \sum_{k=1}^{N} u_{ik}^p \left(\sum_{x_r \in N_k} \|x_k - v_i\|^2 \right)$$

Here J_m is the objective function for Bias field corrected Fuzzy C-means (BCFCM), c is no of pixels and N is the no of clusters, k representing the cluster number, p is the weighting exponent where $p \in [1, \infty]$.

where N_k shows the group of neighbours which are present in a window around x_k and N_r represents the number of elements of N_k. The variable alpha controls the impact of the neighbours term [3].

The above mentioned BCFCM is suitable for the image segmentation of MRI images into gray and white matter. It has been observed that the above BCFCM is promising in do the image segmentation for the MRI images.

II B. A Novel Fuzzy C Means Algorithm (NFCM)

In this novel fuzzy C Means algorithm, three modifications have been proposed:

(i) Defining a new member grade function,

(ii) A new objective function and

(iii) to find a new distance formation.

Similar neighborhood pixels are grouped in order to utilize spatial information. This method involves modifications of distance calculations in neighborhoods of cluster centers.

$$d_{ij}^k = d_{ij}^{(E)} - t_k d_{ij}^{(C)},$$

here $d_{ij}^{(E)}$ is the Euclidean distance, $d_{ij}^{(C)}$ is the characteristic distance and it is defined as

$$d_{ij}^{(C)} = \sum_{t \in NB(j)} u_{it} p_{ij} \Big/ \sum_{k=1}^{c} \sum_{t \in NB(j)} u_{kt} p_{kj}$$

Where $p_{ij} = N_j^i / N_j,$ and N_j^i is the amount of pixels belonging to cluster i in the neighborhood of the pixel xj, and Nj is the amount of pixels in the neighborhood of the pixel x_j, c is the amount of cluster centers, p_{ij} is the factor of the neighborhood area, u_{ij} is the member grade as in (4), $NB(j)$ is the neighborhood area of xj's and the size of $NB(j)$ is $N \times N$, in our experiments, N is set to 3. t_k is defined as

$$t_k \sim \frac{1}{k^2} \Gamma(y_k),$$

Where $\Gamma(.)$ is the Gamma function,

$$y_k = \frac{k}{\max\_iter},$$

here max_iter is the maximum iteration and k is the number of iterations [4].

II C. Adaptive Fuzzy C-means Algorithm (AFCM)

The parameters are modified in the modified FCM to improve the segmentation results. In this method, a separate parameter $\alpha - \{\alpha_j\}_{i=1}^{N}$ is introduced. Here αi expresses the probability of pixel i being a noise point. This probability is characterized by its variance of grey levels in its neighbourhood, i.e.

$$\alpha_j = \sum_{j \in N_i} \exp \left(\frac{\|x_j - x_i\|^2}{\lambda_\alpha \max_{j \in N_i} \|x_j - x_i\|^2} \right) \Big/ N_R$$

where λ_α is a given parameter for controlling the scale, N_i and N_R still represent the corresponding neighborhood window and the number of pixels in it, $\|a\|$ is the Euclidean norm of vector a. Note that, here the central pixel i rather than neighborhood mean is the reference quality for obtaining the variance. In other words, bigger the difference between the central pixel and its surrounding ones is, more likely the pixel is a noise point.

On the basis of the measurement of local noise probability, the modified objective function as

$$J_{NDFCM} = \sum_{j=1}^{N} \sum_{k=1}^{c} u_{jk}^m \|[(1 - \alpha_j)\xi_j + \alpha_j x_j] - v_k\|^2$$

where ξ_i is the weighted mean and x_j is the mean of the corresponding neighborhood. Here α_i is the noise possibility that is computed according to above mentioned equation. It is worth mentioning that here x_j is computed in a bigger size neighborhood window for a better smoothing result [5].

III. COMPARATIVE ANALYSIS

The comparative analysis can be done on the above mentioned three modified FCM algorithms. The modification part of BCFCM and AFCM is the objective function whereas the distance calculation is modified for the NFCM. The NFCM images have shown improvement over the FCM images in context of partition coefficient (PC), partition entropy (PE), modification of the PC index (MPC), Xie and Beni Index (XB), PBMF Index etc. Out of the three mentioned algorithm, AFCM is showing best results for the noisy images.

IV. CONCLUSION

In this paper, three modified FCM algorithm methods are explained. Out of the above mentioned, it is concluded that the Adaptive FCM (AFCM) is having better results. So, AFCM is better for the practical implementation. It can also be conclude that the BCFCM is best suitable for the MRI images and for medical applications.

V. FUTURE SCOPE

There are many modified FCM algorithms for the image segmentation. But there is no generalized algorithm which is suitable for all kind of images. A particular method is best suitable for the particular kind of images. So there is a scope of introduce artificial intelligence in the FCM algorithm to make it generalized solution for the image segmentation.

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