Demarcation of Brain Tumor Using Modified Fuzzy C-Means

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ABSTRACT

The Demarcation and prediction of the area of the tumor have an important role in medical treatments of malignant tumors. This paper describes an application of Fuzzy set theory in medical image processing, namely brain tumor demarcation. Fuzzy C-Means is proved to be a good and efficient segmentation method. But the main disadvantage of this method is that it is highly sensitive to noise. In this paper a modified Fuzzy C-Means (MFCM) is proposed which is less sensitive to noise than state-of-the-art Fuzzy C-Means method. MFCM filters the image at the time of the segmentation of noisy Magnetic Resonance Imaging (MRI) images. This methodology is applied to the three MRI images of brain consisting tumors with different areas. The proposed method always`s results in better segmentations of brain tumors than conventional FCM. This method is applied efficiently for detection of contour and dimensions of a brain tumor.

Keywords - **MRI, Brain Tumor, Image Segmentation, Fuzzy C-means, Adaptive Filtering, Edge detection.**

I. INTRODUCTION

The diagnosis of human being has been improved significantly with the arrival of Computed Tomography (CT), Positron Emission Tomography (PET), and Magnetic Resonance Imaging (MRI). Medical imaging provides a reliable source of information of the human body to the clinician for use in fields like reparative surgery, radiotherapy treatment planning, stereotactic neurosurgery etc. Several new techniques have been devised to improve the biomedical research.

One of the important steps of image analysis is image segmentation. Image segmentation is the process of partitioning an image into its different constituent parts.

Fuzzy C-means is one of the widely used image segmentation method which retain more information than hard segmentation methods [2, 3, 4]. Fuzzy C-Means basically uses fuzzy pixel classification to segment an image. A hard segmentation method forces a pixel to belong exclusively in one cluster. But in Fuzzy C-Means a pixel is allowed to be in multiple clusters with varying degree of membership function. So FCM allows greater degree of flexibility than hard segmentation methods. Due to this advantage FCM has recently been used in medical images for various applications especially in MRI.

There are several Fuzzy pixel classification methods have been proposed for classification of MRI images. Mrs.Mamata S.Kalas implemented neuro-fuzzy logic for the classification of MRI images to detect cancer [5]. T.Logeswari and McKiernan has implemented Self Organizing Map (SOM) for medical image segmentation [6].According to their research segmentation has tow phases. In the first phase, the MRI brain images are acquired form patient database. In that film artifact and noise are removed. In the second phase the image segmentation is done. A new unsupervised method based on FCM has been proposed in this paper.

The main disadvantage of conventional FCM algorithm is that it is very sensitive to noise. As MRI images may contain noise, so FCM algorithm needs to be modified so that it can avoid misclassification in noisy images. In this paper a modified Fuzzy C-means algorithm is proposed which provides a better segmentation than state-of-the-art FCM segmentation method. However, Fuzzy C-means was proposed a long time ago. Lwarence et. Al [7] stated that the fuzzy algorithm exhibited sensitivity to the initial guess with regard to stability. In this paper a modified Fuzzy C-Means method is proposed which is inspired from Markov Random Field (MRF) which results in better segmentation in both noisy and noiseless brain MRI images.

Rest of this paper is organized as follows. In section II state-of –the-art Fuzzy C-Means algorithm is described. In section III the Modified Fuzzy C-means algorithm is presented. In section IV experimental results are shown. In section V some conclusions have been drawn.

II. FUZZY C-MEANS ALGORTIHM

Fuzzy C-Means method of clustering which allows a pixel to belong to two or more clusters provides greater flexibility than hard segmentation method. This method has been used in pattern recognition successfully. It is based on minimization of a objective function defined as follows:

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{C} \mu_{ij}^{\kappa} \left\| x_i - c_j \right\|^2 \text{ …….. (1)}$$

x_i is the ith of d-dimensional measured data , C_j is the d-dimensional cluster centre and $\|*\|$represents the norm expressing the similarity between any data to be measured and the center. μ_{ij} is the membership value of x_i in cluster j. C is the total number of clusters and N is the total data points.

κ *is* any value greater than 1 i.e. $\kappa \epsilon [2, \infty)$ .It was taken as 2 suggested by Bezdek [9].

Fuzzy partitioning is carried out through an iterative optimization of objective function shown above , with the update of membership μ_{ij} and the c_j cluster centers by :

$$\mu_{ij} = \frac{1}{\sum_{l=1}^{c} \left(\frac{D_{ij}}{D_{kj}} \right)^{\frac{2}{\kappa - 1}}} \text{ ……………….(2)}$$

$$C_j = \frac{\sum_{i=1}^{N} \mu_{ij}^{\kappa} . x_i}{\sum_{i=1}^{N} \mu_{ij}^{\kappa}} \text{ ……………….(3)}$$

The iteration will stop when

$$\max_{ij} \left\{ \left| \mu_{ij}^{(t+1)} - \mu_{ij}^{t} \right| \right\} < \varepsilon \text{ …………(4)}$$

Where ε is very small number lies between 0 and 1 i.e. $\varepsilon \epsilon [0,1]$.

Now $\mu_{ij} = \mu_i(x_j)$ where $1 \le j \le C$ and $1 \le i \le N$.

Where $0 \le \mu_{ij} \le 1 \ \forall \ i, j$. …………….(5)

$$\sum_{j=1}^{C} \mu_{ij} = 1 \ \forall \ i \text{ ……………….(6)}$$

In the equation (2) D_{ij} and D_{kj} can be calculated as follows:

$$D_{ij} = \left\| x_i - c_j \right\| \text{ ………………………(7)}$$

$$D_{kj} = \left\| x_k - c_j \right\| \text{ ……………………..(8)}$$

So the algorithm composed of the following steps :

1. Initialize $\Psi = [\mu_{ij}]$, $\Psi(0)$.
2. At t-step: calculate the center vectors $C(t) = [C_j]$ with $\Psi(t)$ using equation number (3).
3. Update $\Psi(t)$, $\Psi(t+1)$ using equation number (2).
4. If equation number (4) is satisfied the STOP, otherwise return to step 2.

Fuzzy C-Means algorithm has several advantages like a) it is unsupervised b) it distributes the membership values in a normalized fashion. However in unsupervised method it is not possible to predict ahead of time what type of cluster will emerge from the Fuzzy C-Means.

III. PROPOSED ALGORITHM

In the conventional Fuzzy C-Means algorithm for a pixel $x_i \epsilon I$ where I is the image, the clustering of x_i with class j depends on the membership value μ_{ij}. Now if we consider a noisy image, conventional fuzzy C-means does not have a method to overcome this problem. In the proposed method FCM has been modified to overcome the drawback associated with noisy images.

$$\xi_{ij} = \frac{\sum_{k \epsilon \ neighbours} \mu_{jk} * \zeta_{ik}}{\sum_{k \epsilon \ neighbours} \zeta_{ik}} \text{ ……………..(9)}$$

Now, $D_{ij} = D_{ij} \left(1 - \Delta * \left(\xi_{ij} \right) \right)$ ……………… (10)

In the proposed method D_{ij} is introduced as the resistance of pixel of pixel x_i to be clustered in class j. this resistance can be tolerated by the neighboring pixel x_k. This neighboring pixels work is such a manner that it decrease the pixel's resistance by a fraction that depends on the membership value of x_k with cluster j i.e. μ_{kj}. As the system converges when membership values reaches to its' meaningful value so this neighboring value will robustify the FCM algorithm.

In equation (10) Δ is a constant where $0 \le \Delta \le 1$. If Δ is equal to 0 then D_{ij} becomes $D_{ij} = D_{ij}$. Thus giving the conventional Fuzzy C-Means algorithm. If Δ is equal to 1 and μ_{ik} then from equation (10) becomes $D_{ij} = 0$. ζ_{ik} measures the proximity of pixel i to its neighbor pixel k. The proximity here is measured using relative distance between two pixels i.e. $\zeta_{ik} = \|i - k\|$.

So this algorithm considers the fact that each surrounding pixel tries to pull its neighbor toward its class without neglecting the effect of pixel itself. So this algorithm filters the image while segmenting. So this modified version of FCM gives better result in noisy image segmentation as well as normal image segmentation.

Now the procedure for the Modified Fuzzy C-Means can be summarized as follows :

Step1: The initial cluster centers are chosen randomly from the image dataset uniquely. Numbers of clusters is determined randomly.

Step2: Obtaining $D_{ij,}$ using new method, from which Ψ matrix can be calculated. As the non-descriptive initial centers would enlarge the processing time , we applied the neighboring effect after approaching the final centers.

Step3: This process continues until minimization of objective function offers.

Step4: After that defuzzification is performed in order to achieve crisp set. A pixel x_i would belong to cluster j iff , μ_{ij} is maximum than the membership values to other clusters.

IV. Implementations & Results

In order to see the effect of proposed algorithm a clean brain MRI image with tumor was taken. After segmenting by both Fuzzy C-Means and Modified Fuzzy C-means separately Prewitt edge detection [10, 11, 12] was performed to detect the edge of the tumor. Fig.1 shows the input clean brain MRI image. Fig.2 shows the segmented image by FCM algorithm using 5 clusters and Fig. 3 shows the segmented image by MFCM method using same number of clusters as FCM i.e. 5. In Fig.4,5 Prewitt edge detected images of Fig.2,3 are shown.

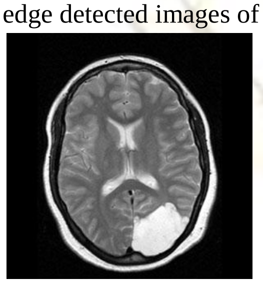


Fig. 1

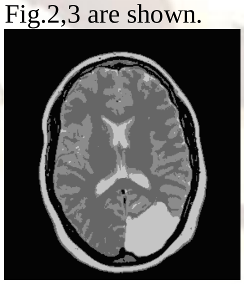


Fig.2

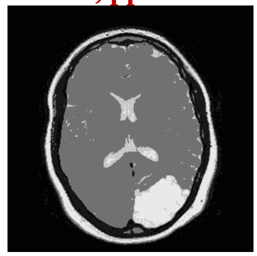


Fig.3

Fig.4

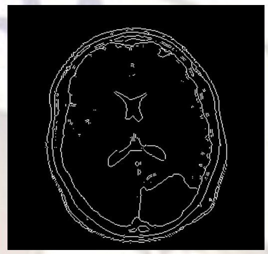


Fig.5

Fig. 1 represents the original noiseless input image of brain MRI consists of tumor. 2 &3 represent segmented image with FCM & MFCM. 4& 5 represent result of Prewitt detection.

If we compare Fig.4 and Fig.5 it can be easily seen that Fig.5 has better tumor boundary than Fig.4. So the proposed method gives better segmentation of tumor region than FCM.

Fig. 6, 7, 8,9,10 shown below is another results of FCM & MFCM as stated above.

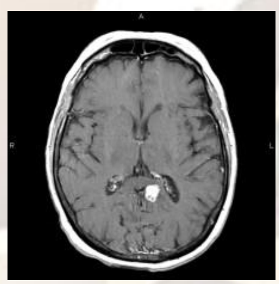


Fig.6

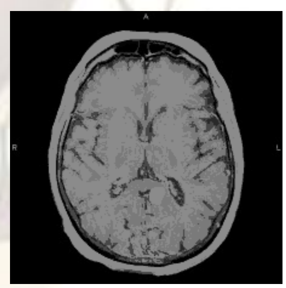


Fig.7

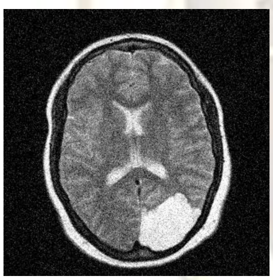
Fig.8 Fig.9

Fig.10

Fig. 6 represents the original noiseless input image of brain MRI consists of tumor. 7 &8 represent segmented image with FCM & MFCM. 9 & 10 represent result of Prewitt detection.

In fig.9 we can easily see that region of the tumor is not clear. In fig.10 it is easily seen that tumor region is well segmented by MFCM.

Now these methods have been tried on several noisy images. Gaussian white noise added with the fig.1. Resulting image is shown below. Also the segmented and Prewitt edge detected images are shown below:



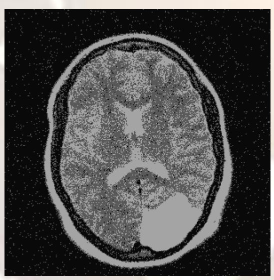
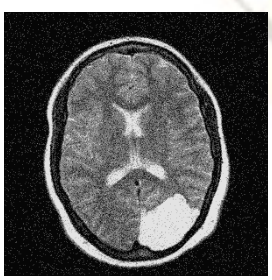


Fig.11 Fig.12



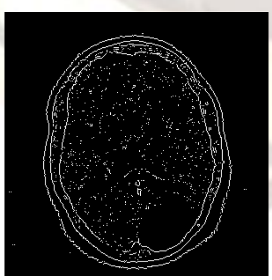


Fig.13 Fig.14

Fig.15

Fig.11 Noisy input image. Fig.12 & 13 segmented image of Fig.11 by FCM & MFCM respectively. Fig.14 & Fig. 15 Prewitt edge detected image of fig.12 & 13 respectively.

Several values of Δ has been tested. But $\Delta = 0.56$ gives the best result. So $\Delta = 0.56$ was kept through out the work. The value of $\kappa = 2$ was taken as suggested by Bezdek.

Area of the tumor region is calculated using the segmented image by proposed method. This result is shown in a tabular format. Each pixel in the image occupies 96dpi in both horizontal and vertical directions. So area of single pixel is $\frac{1}{96} * \frac{1}{96}$ square inch. This is converted into cm unit. The table of area of tumor in different images is shown below:

Table: 1

No of Image	Name of The Image	Area (cm^2)
1	Fig.1	1.7073
2	Fig.6	0.0826

V. Conclusion

In this paper a Modified Fuzzy C-Means method has been proposed to overcome the drawback with noisy images of the Fuzzy C-means. The adaptive filtering is also done while segmenting an image. The dimensions and area of the tumor can be calculated using proposed method neglecting the effect of noise. In this proposed method neighbors are used to enhance the clustering with the FCM which do not affect the edges. Thus tumor boundary can be easily understood. Finally, suggestion to the readers is that the application of the MFCM method to other abnormal medical image segmentation of noisy image cases will be the topic for further research.

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