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Survey on MR Image Segmentation Using Fuzzy C-Means Algorithm

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Abstract— ***an authentic and up to-date analysis in case of any disease is basic demand in the field of medical sciences as this might escalate the probability of endurance of a human. The role of image segmentation is important for most tasks demanding image analysis. Various image segmentation techniques are being utilized for diagnosis of medical images. However authentic segmentation of MRI (Medical Resonance Image) is of grave importance for exact analysis by computer assisted clinical apparatus. Our paper gives a survey of recent MRI segmentation approaches that uses FCM algorithm. In this paper, we have reviewed four MRI segmentation algorithms that are selected from literature survey. To overcome the flaws of traditional FCM, the reviewed methods have altered the objective function of traditional FCM and also unified its spatial information in the objective function.***

Keywords— ***MR image segmentation, clustering, fuzzy c-means, objective function, spatial information, KFCM, enhanced FCM, Kernelized FCM.***

I. Introduction

In terms of computer vision, image segmentation can be defined as a process of segregating or partitioning a digital image into multiple partitions or segments. A digital image is basically a numeric representation of a 2-D image. It purely depends upon the image resolution whether it is fixed or variable[i]. There are 2 types of digital image: vector type and raster type. The primary aim of segmentation is to elucidate or modify the image portrayal into something that is more elementary and understandable. Medical image segmentation partitions the image into specific groups like brain tumour, necrotic tumour and other types of tumour and it gives an apt analysis remedy by calibrating tissue volume and diagnosing brain tumour. As a result, this approach is vital diagnosis technique for early stage detection of brain tumour and MR image segmentation.

Clustering can be defined as organizing set of objects into disjoint sets called clusters [ii]. Clustering divides the data objects in such a manner that objects belonging to similar group have higher similarity than those data objects in other groups. Clustering belongs to unsupervised classification category. Classification is a process that accredits data objects to a group of class. Unsupervised refers to no supervision, i.e. clustering does not require any supervision training examples to classify the data objects. Hence a cluster can be defined as a set of objects which are homologous to themselvesbut are disparate with respect to the objects that belongs to alien clusters.

FCM is an unsupervised clustering method where each data object can belong to more than one cluster [iii]. It can be utilized to establish outstanding results in Magnetic Resonance image segmenting in a vigorous manner. FCM isprofitably implemented in various real world scenarios such as medical imaging, recognising the target, and image segmentation [iv]. Amongst all the applications mentioned before, fuzzy c-means has many advantages, because they are able to hold on to ample details of the original image than hard clustering algorithms. This paper is mainly confined to K-means, fuzzy c-means and Kernelized fuzzy c-means.

The rest of our paper is classified as follows: Section II contains the literature survey that reviews various segmentation algorithms adopted for MRI image segmentation. Sections II, III and IV gives methods, conclusion of our paper and future work proposed respectively.

II. Literature Survey

This section deals with literature survey of various MR image segmentation algorithms. Our primary aim focuses on advantages and disadvantages of the reviewed algorithms.

Dao- Qiang and Song-Can [i] have made an attempt to present a different algorithm for MR image segmentation (KFCM-Kernelized Fuzzy c-means) using fuzzy c-means by altering the objective function of fuzzy c-means algorithm via implementing kernel distance and also altering spatial information of membership functions. The basic idea involved in their algorithm is to portray the centres of all the clusters as a sum of linear combination of an implicit non-linear map. Along with this, they have also introduced a spatial constraint for KFCM. They have introduced spatial information in the form of penalty which replicates it’s works as a regulator and helps to label the pixel that is associated with its neighbourhood. Working as a regulator, the spatial constraint can alter the solution towards piecewise uniform labelling. This spatial constraint helps in image segmentation especially those that are corrupted by noise. Their approach implemented in a straight forward fashion to improvise the efficiency of conventional FCM methodologies.

Mohamed N. Ahmed [ii], presented BCFCM (Bias Corrected FCM), an algorithm for fuzzy c-means for MR image segmentation along with estimation of intensity heterogeneity using fuzzy logic. Due to faults or imperfect radio-frequency coils, a variable shading artefact that might occur in resultant segmented image thus producing noisy data. They have altered the objective function of conventional FCM algorithm by injecting a terminology that grants the labels of voxels to be determine by labels that are present in the immediate neighbourhood of thevoxel. This modification acts as a

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regularizer to bias the result towards piecewise-uniform labelling. This approach is useful for images corrupted with salt and pepper noise. The results showed that BCFCM has a faster convergence rate then FCM and produces better results as it compensates the noise through regularization term.

Pham [iii], presented 3-D AFCM (Adaptive FCM), an algorithm that is mainly designed to counter shading artifacts that might occur during image segmentation due to intensity heterogeneities using conventional FCM algorithm rendering noisy images. This algorithm is an augmentation of 2-D AFCM that has been proposed by authors in previous works. They have also introduced a spatial information in the form of penalty term, modifying the original objective function, to be spatially smoothed.

Nookalavenu [iv], presented NMKFCM (Novel Multiple-Kernel Fuzzy C-means), which is segmentation methodology that has spatial knowledge that introduces framework for image-segmentation flaws. This model has been proposed using tow Gaussian Kernels instead of a single kernel. The membership values are altered using their neighbours. The modified membership values are better, produce noiseless images and are more robust to noise than other image segmentation algorithms form FCM family. NMKFCM is applicable for images despoiled by Gaussian noise and salt and pepper noise.

Ramathilagamet. al[v], presented MRDCM-wBE (Modified Robust Fuzzy c-Means with weight Bias Estimation) algorithm. This is a modified and robust version of conventional FCM algorithm. Due to imperfect radio-frequency coils and faults related to image acquisition, intensity heterogeneity are endorsed in the segmented images. This defect has a huge impact during demarcation process when partitioning algorithms are utilized for segregating borders amid tissues in medical images. They have presented a model that has the capacity to deal with intensity heterogeneity and noisy images efficiently. Also, to decrease the cardinality of iterations, the suggested algorithm initialises the centres of clusters iteratively before the algorithm executes. The experimental results prove the superiority of the proposed algorithm.

Xia[vi] has presented MPFCM (Modified possibility fuzzy c-means clustering algorithm) to eliminate bias field. This algorithm is mainly utilized for corrupted MR images. To calculate the degree of heterogeneity, Xia has introduced a global intensity into the clustering algorithm and considers both the types of intensities i.e. local and global intensities to make sure that the blurring of derived bias field along with enhancing its accuracy. This approach is able tohandle local provisional information so as to enforce local spatial persistence, thus granting the elimination of alien data and resolving segregation ambiguity. Xia presented a flexible approach to gauge the values or weights for neighbourhood of each voxel in the image. The suggested approach beats the impact of noise effectively and also averts from image softening. Good initialization can lead to fewer number of iterations in this approach and can obtain results within few iterations. Numerous artificial and actual brain MR images are utilized to contrast the efficiency of the proposed MPFCM algorithm. Results depict that the suggested method is more efficient, vigorous and more precise for both 3D and 2D brain MR image segmentation.

Shan Shen et al. [vii] proposed IFCM (Improved FCM), a robust segmentation algorithm that is basically an extension of the conventional FCM algorithm to circumvent the significant amount of noise that occurs in the segmented images due to bad operator performance, equipment failure and properties of neighbouring voxels. In their proposed algorithm, an attraction based neighbourhood attraction is set to prevail amongst neighbouring voxel. This algorithm takes into account, the neighbourhood attraction directly. Three different categories of images were employed to compare the IFCM and FCM algorithm. Results showed that for square images, FCM could not outlay the noise degradation in segmented image, only IFCM was able to successful in segmenting the classes. For simulated MR images, IFCM proved its robustness by reducing noise significantly in the segmented images as compared to FCM algorithm. Finally for real MR images, IFCM proved its superiority by eliminating noise impact completely.

Stelios Krinidis et al. [viii] proposed FCLIM (fuzzy local information C-Means), a variant of FCM algorithm used for image clustering. This algorithm is a novel approach towards implementing local spatial and grey level information in a fuzzy fashion. FLICM can cover the drawbacks of FCM as well as improvise its clustering performance. In order to overcome the flaws of FCM algorithm, a new factor has been added so as to keep intact the robustness and noise insensitivity. FLICM provides immunity towards noise, retains image details, free of parameters and it can be implemented on the original image data set. Also this algorithm is not dependent on the type of noise added and therefore lack of prior knowledge of type of noise applied or present in the image won't matter and therefore this algorithm is the best choice for clustering analysis.

Maoguo et al. [ix], proposed KWFLICM (Kernel Fuzzy Local Information C-Means Clustering Algorithm) algorithm, which is an improvised version of FCLIM (Fuzzy Local Information C-Means Clustering Algorithm), for image segregation by adding a fuzzy element with weights and kernel distance. This algorithm utilizes a local coefficient of variation to reinstate spatial distance as local quantity. Also, this algorithm is more robust as compared to FCLIM. Motivation for this algorithm is basically to implement a trade-off weighted fuzzy term for robustly supervising the local spatial relations. In order to improvise FCLIM algorithm furthermore in countering noise, another novel element has been introduced in its objective function i.e. the kernel distance measure. Results show that on applying KWFCLIM algorithms on synthetic, natural and medical images, KWFCLIM algorithm's trade-off factor helped in denoising the images completely. Also it showed that the suggested algorithm erased roughly all the custom alien data that were added to images, thus achieving robust results.

Liao [x] suggested a fast kernel FCM (SFKFCM) clustering algorithm to advance the calculative productivity. The clustering process that is executed in a kernel space has very large time complexity. A fast SKFCM algorithm is proposed for MRI image partitioning, and altering intensity heterogeneities called bias field. This kernel approachcompletelyprojects the image data to a bigger dimensional kernel space to upgrade the divisibility of data and administer more capability for efficient segmentation of MRI data. Bias field rectifying and accelerated kernel clustering support one other in a loop and drastically lowered the time taken to complete the process of kernel clustering.

III. Material and Methodology

3.1 *K-Means Clustering*

K-means algorithm belongs to the elementary unsupervised category of algorithms that construes the famous problem of clustering. This algorithm starts off by placing k centroids in random location in high dimension vector space. Then we do the following steps iteratively:

Step1: Assuming there are K set of points X_1, X_2….. X_k and for k points there are k centroids C_1, C_2… C_K
Step2: Repeat till convergence

- Find the centre of cluster that is closest, C_j
- Now, appoint the point $X_j$to $C_j$cluster.

Step 3: Run a loop from j=1 to k, i,e, for every cluster:

- Update the cluster's new centre C_j. to the mean of all the points that are present in C_j

Step3: Stop when none of the cluster assignments change.

Lastly, this algorithm focuses ondiminishing the objective function. The objective function of the algorithm can be written as:

$$(\boldsymbol{U},\boldsymbol{V}) = \sum\sum \|Xi - Cj\|^2 \boldsymbol{nj}=\mathbf{1}\boldsymbol{ki}=\mathbf{1} (1)$$

Where ‖Xi −Cj‖ is the measure of distance amid any given Xi which is a data point and the cluster centroidCj.

3.2 *Fuzzy C-means Clustering*

Fuzzy means "of or relating to a form of set theory and logic in which predicates may have degrees of applicability, rather than simply being true or false." The main idea in Fuzzy C-means Clustering is the heterogeneoussegregation of the data that are assigned to the assembly of clusters.
Its main function is to minimize the following objective function:

$$J_m = \sum_{i=1}^{N}\sum_{j=1}^{C} u_{ij}^m \left\|x_i - c_j\right\|^2 , \quad 1 \le m < \infty \qquad (3)$$

Where m , degree of fuzzification, a real number greater than 1, and $\|x_i - c_j\|$ is the measure of distance amid the data set point and the cluster's centre along with $\sum \boldsymbol{Uik} = \mathbf{1ci}=\mathbf{1}$.

The FCM algorithm is composed of the following steps:
Step1: set U_{ij}=0.
Step2: At i^{th} step, determine the cluster's centre vectors using the formula: $C^{(k)}=[c_j]$ with $U^{(k)}$

- Use the formula:

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^m \cdot x_i}{\sum_{i=1}^{N} u_{ij}^m} \qquad (4)$$

)

- Use the formula for updating $U^{(k)}$to $U^{(k+1)}$

$$u_{ij} = \frac{1}{\sum_{k=1}^{C}\left(\frac{\left\|x_i - c_j\right\|}{\left\|x_i - c_k\right\|}\right)^{\frac{2}{m-1}}} \qquad (5)$$

Termination condition is given by $\| U^{(k+1)} - U^{(k)}\| < \varepsilon$ where ε is the termination point between 0 and 1.

3.3 *Kernelized Fuzzy C-means Algorithm*

The conventional FCM algorithm's objective function is given by:

$$J_m = \sum_{i=1}^{N}\sum_{j=1}^{C} u_{ij}^m \left\|x_i - c_j\right\|^2 . \qquad (6)$$

Where Uij is the membership function and ||Xi-Cj|| is the distance between data points and centroid of clusters.
The parameter m is the fuzzification factor that lies between 0 to1 and it calculates the degree of fuzziness in resultant data. During image assembling, the common feature adopted is the grey-scale value for a coloured image. Therefore the objective function of FCM is reduced when we take large values of Uij, that are employed to those voxels which have intensities closer to cluster's centre of the cluster and smallUij values are appointed when pixels are distant from the centre
.

3.4 *Enhanced K-means clustering algorithm*

Kernelized FCM has a drawback, that, for coloured image segmentation, the coloured image has to converted into grey scale image and then start segmenting. This drawback is covered by Enhanced Fuzzy c-means algorithm that enhances the segregation process for grey scale images. The linear weighted-sum image to accelerate this process is given by:

$$\varepsilon_k = (1/(1+\alpha))(x_k + (\alpha/N_R)\textstyle\sum_{j\in N_k} x_j), \quad (7)$$

Where ε_k denotes grey scale value of k^{th} pixel of image. The term x_k means neighbours, Nkmeans group of neighbours around $x_k$within certain window. Objective function of EnFCM is given by:

$$J_s = \sum_{i=1}^{c}\sum_{l=1}^{q}\gamma_l\,\mu_{il}\,(\varepsilon_l - \vartheta_i)^2 \quad (8),$$

Where Vi means prototype of cluster Ci, U_{il} is the grey scale value l w.r.t cluster Ci, q is the degree of grey levels in the input image, γ_l is the cardinality of pixels with grey value as l. We then take first order derivatives of J_s w.r.t to u_{il} and $\boldsymbol{v}i$, and equate them both to 0, we get its local extrema as follows:

$$\mu_{il} = \frac{(\xi_l - v_i)^{-\frac{2}{m-1}}}{\sum_{j=1}^{c}(\xi_l - v_j)^{-\frac{2}{m-1}}}, \quad (9)$$

$$V_i = \frac{\sum_{l=1}^{c}\gamma_l\mu_{il}^{m}\xi_l}{\sum_{l=1}^{q}\gamma_l\mu_{il}^{m}}, \quad (10)$$

The EnFcm algorithm can be written as follows:
Step 1. The degree c of these formulas ranges from 2 to Cmax
Step 2. Calculate the new image ε in using formula no. (7) in terms of ε_k.
Step 3. Alter the partition matrix via formula no. (9)
Step 4. Keep altering the formulas using (10).
Repeat step3-4 till the following criteria is satisfied: $|\,V_{new} - V_{old}\,| < \varepsilon$ where V=[v_1, $v_{2,\,....}$$v_c$]

IV. Conclusion

Image segmentation is alluring as well as of grave importance. Fuzzy C-Means, K-Means and Kernelized Fuzzy C-Means,Enhanced K-means clustering algorithms have been discussed and reviewed. After surveying these four methods, we can conclude that enhanced fuzzy c-means algorithm will be best suited for MRI image segmentation.

V. Future Work

In all, the clustering algorithm selects the initial centroids in arbitraryfashion. In future an advanced method for selecting or initialisingcentres of clustering methods is utilized. This algorithm depends on superlative distance measure function which is responsible for the process of detecting centres of clusters or the centroids. The future operationof these methods will be concentrating more on correlation of various distinct parameters like mean squared deviation (MSD), peak signal to noise ratio (PSNR) of the four algorithms K means, fuzzy c mean, Kernelized fuzzy c means , and Enhanced k means.

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