A Survey on Medical Image Segmentation Using Fuzzy Clustering

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Abstract **In medical domain image segmentation is very challenging field because of poor resolution and limited contrast. The conventional segmentation techniques and thresholding methods which are predominantly used suffers from limitations because of heavy dependence on user interaction. These techniques cannot capture the uncertainties prevalent in an image. The detoriation of performance further takes place when the images are corrupted by outliers, noise and other artifacts. This paper aims at doing a survey on different types of segmentation method based on fuzzy c means clustering for segmenting vertebral from magnetic resonance image owing to its unsupervised form of learning. The main motive is to address the drawbacks of conventional FCM, all the objective functions of the conventional FCM approaches have been modified and the spatial information has been in corporate in the objective function of the standard FCM.**

Keywords: Segmentation, Spine, Clustering, Fuzzy C-Mean, Membership Function, Spatial probability.

I. INTRODUCTION

The fundamental building block in image analysis tool kit is the image segmentation. Medical image segmentation is a tedious process where the images are mostly affected by the noise. Its a difficult task to automate segmentation process of medical images as they are complex and does not contain any simple linear characteristics features. Moreover the results of the segmentation algorithm is highly affected due to intensity inhomogeneity and volume effect specially in case of MRI(magnetic resonance images).The detection of spine geometry and proper localisation and labelling enhances the diagnostic output of a physician.[1]

Most complex load bearing structure in entire human body is the spine. It consists of 26 irregular bones which are connected in such a way to provide a curved and flexible structure. degenerated disc and spinal stenosis. The partitioning of an image into uniform and non-overlapping regions based on some likeliness is done by the technique of segmentation [6]. This technique is applied on various applications one of which is medical image processing. The two basic properties of Image segmentation is Firstly, intensity values which involves various discontinuity which results in sudden changes in the intensity edges and Secondly, similarity which is partitioning any digital image into regions with some pre-defined likeness criterion. In recent years much interest have been generated in the field of image analysis. So are the various segmentation techniques.

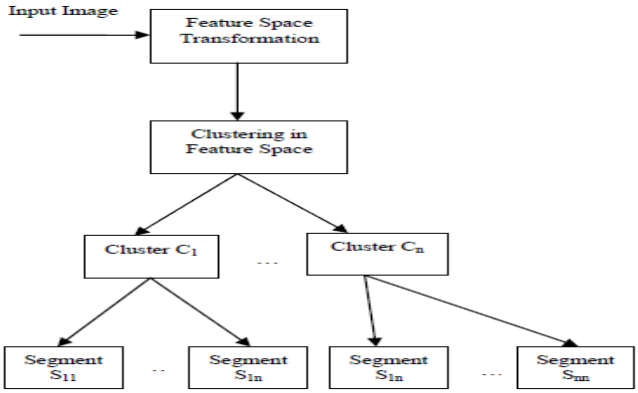

Fig. 1 Segmentation Using Clustering

II. LITRATURE SURVEY

Various approaches and huge literature are present for information extraction from an image and partitioning it into different regions but some how all of these suffer from one or the other drawbacks whether in terms of time complexities or accuracy. Due to non-sharp boundaries of the clusters of an image all the techniques other than fuzzy results in some abnormalities in the segmented part, on contrary we find fuzzy segmentation methods to be more trust worthy when it comes to segmentation of image. The images in the real world consists of some noise so segmentation of such images results in fuzzy regions. Clustering methods use some information like pixel location in space and the brightness which cannot separate regions of the image consisting similar pixel intensities by only taking their pixel intensity into account. The objective function of fuzzy algorithms include FCM(Fuzzy C-Means) algorithm, Gaussian Mixture Decomposition (GMD) algorithm, Gustafson-Kessel algorithm (GK), Adaptive Fuzzy-C varieties (AFC) algorithm, Fuzzy C-Shell (FCS) algorithm, Fuzzy C-Varieties (FCV) algorithm, Fuzzy C-Rings algorithm, Fuzzy C-Quadric Shells (FCQS) algorithm, Fuzzy C-Spherical Shells (FCSS) algorithm, Fuzzy C- Rectangular Shells (FCRS) algorithms etc. Among all of the above mentioned clustering methods FCM is the most common technique for segmentation of image due to its robustness against uncertainty which helps to save more information than other hard clustering approaches. Dunn first introduced FCM and Bezdek further modified it later. FCM divides pixels into different classes by the help of fuzzy membership function. Lets consider an image with N pixels which is to be grouped into C clusters/groups, X =(x_1,x_2, …..x_N), then iterative minimization of the following objective functions is given by FCM as:

$$J= \sum_{j=1}^{N}\sum_{i=1}^{C} u_{ij}^{m} \| x_j - v_i \|^2 \qquad (1)$$

where u_{ij} is the membership of x_j pixel of the i^{th} cluster, i^{th} cluster center is given by v_i , the fuzziness of the resulting partition which lies between $1< m \leq \infty$ and norm metric ||.|| which is controlled by the fuzzifier m. Generally the Euclidean distance between the centre of the i^{th} cluster v_i and the pixel x_j is used as the norm metric [10]. The centres of the clusters and the membership function are given as :

$$u_{ij} = \frac{1}{\sum_{k=1}^{c}\left(\frac{\| x_j - v_i \|}{\| x_j - v_i \|}\right)^{2/(m-1)}} \qquad (2)$$

$$vi = \frac{\sum_{j=1}^{N} u_{ij}^{m} x_j}{\sum_{j=1}^{N} u_{ij}^{m}} \qquad (3)$$

Initialization of the cluster centers can be done either by the approximation methods or by random initialization. FCM does not integrate spatial information which make them sensitive to noise and other artifacts for images with noise. Due to the distribution of pixel intensity which is the main concept behind FCM cluster distribution, it becomes sensitive to variation of intensity and object geometry[9]. An image pre-processing step which is been followed by FCM in order to overcome its drawback is mentioned [11, 12]. Many other algorithms have also been proposed so as to make FCM more robust which can be broadly classified into two main categories: First one is clustering algorithm with spatial constraints implementation [7] and the Second one is Introduction of dissimilarity index which is insensitive to variations in intensity in the FCM objective function. Spatial information has been incorporated in the original FCM algorithm in order to improve accuracy in segmentation has gained enough importance. A generalized Spatial Fuzzy C-Mean clustering algorithm (GSFCM) have been developed by Huynh Van Lung and Jong-Myon Kim for segmentation of MRI of brain. Generalized Spatial FCM utilizes the given attributes of the pixels and local spatial information weighted equally to neighbors which is based on their distance attributes. Its seen that GSFCM outperforms Conventional FCM. Experimental results shows the capability of this algorithm for extracting the skin lesion border efficiently. A generalized Spatial Fuzzy C-Mean clustering algorithm (GSFCM) have been developed by Huynh Van Lung and

Jong-Myon Kim for segmentation of MRI of brain. Generalized Spatial FCM utilizes the given attributes of the pixels and local spatial information weighted equally to neighbors which is based on their distance attributes. Its seen that GSFCM outperforms Conventional FCM. Mean shift based FCM for the extraction of skin lesions is developed by Huiyu Zhou *et al*. [14]. An enhanced segmentation technique have been proposed by Ruoyu Du and Hyo Jong Lee [13] which is applicable on sigma filter to vary neighboring pixels of targets. The proposed system shows a FCM based method to segment vertebral bodies (VB) with morphological post processing. Also the VB's are labelled which can reduce the burden of radiologist while classifying the degenerations involved.

III. FUZZY CLUSTERING METHODOLOGIES FOR IMAGE SEGMENTATION

In this section we present a review of various image segmentation techniques using fuzzy clustering recently proposed in the literature.

A. Robust segmentation for Noisy Medical Images Using Fuzzy Clustering with Spatial Probability

A robust segmentation technique that exploit histogram based FCM algorithm for the segmentation of medical imagesS. Zulaikha Beevi and M. Mohammed Sathik [2] have been developed. The noise is first removed from the images by the algorithm and then segmentation is been performed. Denoising is performed by the Sparse 3D transform-domain collaborative filtering. Then initialization of the parameters of the FCM is done by Histogram to avoid convergence in local minima. Spatial probability is been incorporated in the objective function in order to strengthen the robustness of algorithm against noise. In the given segmentation methodology, two types of spatial information are inserted in the membership function of FCM. This approach converges more quickly than the conventional FCM and attains fair segmentation accuracy apart from disturbance levels. Covergence of the given approach is faster than the conventional FCM and attains reliable segmentation accuracy apart from noise levels.

B. Fuzzy Logic Information C-Means (FLICM) Clustering Algorithm

Krindis and Chatzis [3] developed Fuzzy Logic v Information C-Means Clustering (FLICM) algorithm in order to overcome the drawbacks in algorithms presently available in the previous systems [16], [17] and [18]. FLICM introduces a new factor in objective function of FCM and the new factor G_{ki} has following characteristics:

1) This incorporates local spatial and gray level information in a fuzzy way in order to preserve robustness and noise insensitiveness.

2) It also controls the influence of the adjacent pixels depending on their distance from middle pixel.

3) It uses the original image as input so as to avoid pre-processing steps to preserve image details.

4) It is free from parameter selection of any type. This new novel fuzzy factor is defined mathematically.

$$G_{ki} = \sum_{\substack{j \in Ni \\ i \neq j}} \frac{1}{d_{ij}+1}(1-\mu_{kj})^m \| xj - vk \|^2 \qquad (4)$$

where λ^{th} pixel is the local window center e.g, 3*3, k is reference cluster and λ^{th} pixel belongs to the set of neighbors which falls into a window around λ^{th} pixel (N_i), d_{ij} is Euclidean distance between pixels j and i [3]. The factor G_{ki} is free from any control parameter for balancing noise and image detail. The stability between image details and noise is automatically attained by the fuzziness of image pixel. The factor G_{ki} formulates the influence of the pixels within the local window, so that it can change flexibly according to their distance from the middle pixel by using Euclidean distance which is d_{ij}. It is important that the factor G_{ki} shows the damping extent of the neighbors with the spatial distances from the central pixel [3]. The value of G_{ki} can change adaptively with diverse spatial locations or distances from the middle pixel [3]. This is used in the objective function of the enhanced FCM algorithm as:

$$j_m = \sum_{i=1}^{N}\sum_{k=1}^{C}[u_{ki}{}^m \| xi - vk \|^2 + G_{ki}] \quad (5)$$

There are two essential conditions for J_m to be at its local minimum extreme with respect to u_{ki} and v_k which are defined as:

$$u_{ki} = \frac{1}{\sum_{j=1}^{C}\left(\frac{\| xi - vk \|^2 + G_{ki}}{\| xi - vj \|^2 + G_{ji}}\right)^{1/m-1}} \quad (6)$$

$$v_k = \frac{\sum_{i=1}^{N} u_{ki}{}^m x_i}{\sum_{i=1}^{N} u_{ki}{}^m} \quad (7)$$

Later the convergence defuzzification of partition matrix U is performed using maximum membership method as

$C_i = \arg_K\{\max\{u_{ki}\}\}$; k =1,2,....., c

C. *Novel Fuzzy C-Means Clustering Algorithm (NFCM)*

Kann an *et al*. [4] have proposed a Novel Fuzzy C-Means Algorithm (NFCM) for intensity in homogeneities or weighted bias estimation and segmentation of T1-T2 Brain MRI images of same patient. They also presented a center knowledge method [4] to reduce the running time of the algorithm. The Center A distance table is than created so as to show the distance between the elements within each group. The Maximum distance between the groups is computed and finally a mean value is calculated. The objective function J is been modified for the said problem in [5] as follows:

$$j_m = \sum_{i=1}^{C}\sum_{k=1}^{n}\mu_{ik}{}^m[\alpha d_{ik}{}^2 + \delta(d_{ik}{}^*)^2] + \frac{n}{c}[1 - \sum_{i=1}^{C}\mu_{ik}{}^m] \quad (8)$$

Where

$$d_{ik}{}^2 = \| x_k - v_i \|^2 \quad \text{And} \quad d_{ik}{}^* = \| x_k + \varepsilon - b_k - v_i \|^2 \quad (9)$$

$$\varepsilon \in (0,1) \text{ And } \alpha, \delta > 0$$

Objective function is further minimized by employing same approach as in conventional FCM. J_m is differentiated with respect to $i_k\,\mu$,v_i and b_k and is than set equal to zero, to get estimators for U, V and b. These estimators are then used for designing an algorithm to calculate tissue class and bias class.

Lagrange multiplier is used to perform the task of membership evaluation as follows [4]:

$$L_m = \sum_{i=1}^{C}\sum_{k=1}^{n}\mu_{ik}{}^m[\alpha d_{ik}{}^2 + \delta(d_{ik}{}^*)^2] + \frac{n}{c}[1 - \sum_{i=1}^{C}\mu_{ik}{}^m] + \lambda[1 - \sum_{i=1}^{C}\mu_{ik}] \quad (10)$$

L_m is then differentiated with respect to ik μ and is set to zero to compute $i_k\,\mu$ *.

D. *Improved Spatial Fuzzy C-Means Clustering Algorithm (ISFCM)*

Zulaikha et al. [5] have proposed an advanced Spatial Fuzzy C-Means algorithm. The histogram based FCM (HFCM) is used to initialize the input parameters for ISFCM as HFCM converges more rapidly since it clusters the histogram of the image instead of clustering the whole image [5]. The spatial neighborhood information is implemented into the standard FCM by apriori probability. The apriori probability is incorporated in order to show the spatial influence of neighboring pixels on the central pixel that is automatically decided in the fuzzy membership algorithm [5]. Apriori probability assigns a noise pixel to that cluster, whose members are majority in the pixels neighborhood and fuzzy spatial information is used so that pixel gets higher membership values when their neighboring pixels have high membership values with the corresponding cluster [5].

IV. PROPOSED SYSTEM

The previous section shows various methods of image segmentation using Fuzzy clustering which has been included in various segmentation processes to provide fruitful results so does our proposed system which uses the FCM for segmentation. In our proposed system input is T1 weighted Magnetic Resonance Image of spine which is initially smoothed using the edge preserving anisotropic diffusion filter. This pre-processing serves the dual purpose of removing inhomogeneity and as an enhancer as well which is then segmented by using Fuzzy C-Mean(FCM) clustering algorithm and the output which is got is the segmented

Vertebral image. The flow of the system can be better explained by the flow diagram below:

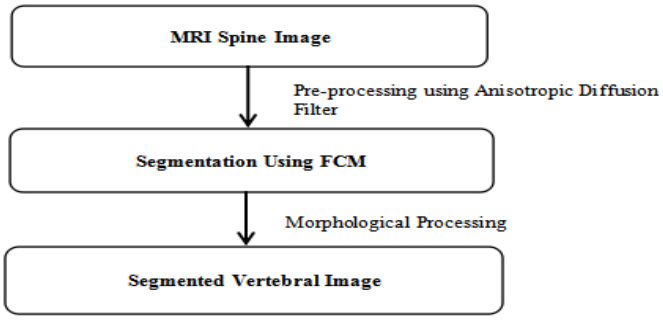

Fig. 2 Proposed System

V. CONCLUSION

Segmentation is an important step in advance image analysis and computer vision in both medical and general science, and also is an ongoing research area. The FCM algorithm which is used for segmentation of MRI spine image is observed to gives improved segmentation results. Further the incorporation of spatial information in to the objective function of standard FCM yields successful results for robust and effective image segmentation of noisy images [3, 4, 5] and the techniques like [4], ISFCM [5] and NFCM [4] can be applied to segment colored images. The techniques [2, 3 and 4] reviewed in this survey are applicable to analysis of MRI images and can be applied to other medical image types like CT and PET for better analysis. 3D volume of MR data based on segmentation using fuzzy clustering can be reconstructed and lesion volume can be analyzed quantitatively.

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