A Review of Clustering Methods for MRI Brain Image Segmentation in Presence of Intensity Inhomogenity

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Abstract **–** Image segmentation is an essential and indispensable step in medical image analysis. Medical image segmentation can help clinicians to differentiate and visualize organs and tissues, measure and compare the size of tissue or pathologies and also plan for surgery and other treatments. This paper makes a review on eight different segmentation algorithm based on clustering method which is used for brain MRI and also compares the performance of these segmentation methods in terms of misclassification rate and segmentation accuracy with 40% intensity non-uniformity (INU). The analysis shows that biased field c-means clustering method has an advantage over other standard fuzzy c- means approaches by providing improvement in computational time. But the limitation is that by using biased field c-means clustering method, misclassification error is slightly higher and segmentation accuracy is slighter lower than fuzzy c-means.. This paper also provides future directions to researchers in the area of MRI brain image segmentation.

Keywords: Image Segmentation, Magnetic resonance imaging, Intensity non-uniformity, Clustering.

I. Introduction

Image segmentation is one of the primary steps in image analysis for object identification. The main aim is to recognize homogeneous regions within an image as distinct and belonging to different objects. The segmentation process can be based on finding the maximum homogeneity in gray levels within the regions identified. The major role of segmentation is in the field of biomedical applications especially used for the detection of tumor in brain. The size of tumor region can be tracked using these techniques which aid the radiologist in treatment planning [1,2].

Methods for performing segmentation vary widely depending on the specific applications, imaging modalities and other factors. There are currently no single segmentation methods yields which produce acceptable result for medical images. Medical images mostly contain unknown noise [3], non-uniformity and complicated structure. Therefore, segmentation of medical images is a challenging task. Commonly used medical modalities are Computed tomography (CT), Ultrasound, X-ray and Magnetic resonance imaging (MRI), out of which MRI is a very popular medical imaging technique because of its high resolution and contrast. Besides all these good properties, MRI suffers from three considerable obstacles: noises, partial volume effect and intensity non-uniformity (INU), out of which intensity non-uniformity is the most important obstacles. In order to produce a correct segmentation of MR images the INU artifact needs to be modeled and compensated. INU has two different types of sources: those related to MRI device and those related to the imaged patient's shape, position and orientation [4]. The first type of source has efficient compensation and calibration methods, while the second type of INU artifacts are much more difficult to handle [5]. This paper deals with various clustering techniques of image segmentation based on intensity non-uniformity and not the method for reduction of intensity non-uniformity.

The rest of the paper is organized as follows: Section II presents principal methodologies on image segmentation using Fuzzy Clustering methods. Section III gives a comparative analysis of these segmentation approaches in terms of misclassification error and segmentation accuracy. The summary and conclusion are presented in section IV. Section V gives directions for future research work.

II. Image Segmentation

Image Segmentation is one of the most widespread means to classify correctly the pixels of an image in decision oriented applications. Image segmentation is a process of partitioning an image into different regions such that each region is homogeneous in nature. The level of subdivision depends on the problem being solved and segmentation stops once object of interest in the application has been isolated. Segmentation technique has variety of applications include computer vision, remote sensing, image analysis , geographical information system and most widely used application is in the field of medical image processing. This method provides richer information than that which exists in the original image. Thus, segmentation method is mostly preferred by radiologists to segment the input medical image into meaningful regions [6].

A. Clustering Methods

Clustering is one of the widely used image segmentation techniques and is a process of organizing the objects into groups based on its attributes. A cluster patterns are classified in such a way that samples of the same group are more similar to one another than samples belonging to different groups [7]. Similarity in a sample is determined by the distance measure, such a Euclidean distance. Medical images are always present in overlapping of gray-scale intensities for different tissues. Therefore, fuzzy clustering methods are particularly suitable for the segmentation of medical images [8].This paper describes various Clustering methods as Conventional Fuzzy C-means, Mni-Fuzzy C-means, Adaptive Fuzzy C-means, Multicontext Fuzzy Clustering, Adaptive Spatial Fuzzy C- Means, Fuzzy C-Means, Adaptation FCM to Bias Field.

Conventional Fuzzy C-means: In this method each class is assumed to have a uniform value as given by its centriod. Each data point is assumed to be independent of every other data point and spatial interaction between data points is not considered [9]. The estimation of partial volume cluster data is computed by measuring membership value at each voxel for a specified number of class [10]. It is a popular and effective clustering method which employs fuzzy partitioning such that a data point can belong to all groups with different membership grades between 0 and 1 [11] . But the main limitation of this method is that it is sensitive to noise which leads to unsatisfactory segmentation result and also information about spatial relationship is not considered.

Mni-Fuzzy C-means (Mni-Fcm): This is non-parametric non-uniformity normalization (N3) method which is used for correction of intensity non-uniformity in MR volumes. This method does not require a model for tissue intensities nor does it not rely on the segmentation of the volume into homogeneous regions. N3 can be controlled by two parameters, one by controlling the smoothness of the estimated non-uniformity and the other parameter is used to control the convergence rate and accuracy [12]. This method is used as preprocessing step and is applied at initial stage without prior knowledge of data analysis. Once bias field is reduce then followed by Fuzzy C- means segmentation method.

Adaptive Fuzzy C-means (AFCM): AFCM algorithm is designed for segmenting two dimensional (2D) as well as three dimensional (3D) scalar image which is corrupted by intensity inhomogeneity. When considering two dimensional (2D) image the algorithm is termed as Full Multigrid Adaptive FCM (FM-AFCM) and while considering three dimensional (3D) the term is Truncated multi grid Adaptive FCM (TM-AFCM). The advantage of this algorithm is that it automatically produces soft segmentation, robust to inhomogeneities and can compute smooth gain field based on all pixels in the image. But the main limitation of Full Multigrid Adaptive FCM algorithm is that the execution time is too slow and also this method is not applicable in considering volumetric acquisition where the inhomoginities are three dimensional in nature [13]. To overcome the limitation of FM-AFCM, Truncated multigrid AFCM (TM-AFCM) has been used where gain field yields a threefold improvement in computational speed without reducing segmentation accuracy [14,15]. The main limitation of AFCM method is that this algorithm provides very good segmentation result in the presence of inhomogeneity effect under the presence of low noise[16].But result deteriorate when noise increases.

Multicontext Fuzzy Clustering (MCFC): Multicontext Fuzzy Clustering algorithm include two parts, fuzzy clustering and information fusion. Multicontext Fuzzy Clustering method is used for classifying 2D and 3D MR data into tissues automatically, where multiple clustering contexts are generated for each pixel and fuzzy clustering is independently performed in each context to calculate the degree of membership of a pixel of each tissue class. To maintain the statistical reliability and spatial continuity of membership distribution, a fusion strategy is adopted to integrate the clustering outcomes from different contexts. The fusion result is taken as the final membership value of the pixel. Thus as a result computational load reduces which in turn increase in execution time [17].

Adaptive Spatial Fuzzy C- Means (ASFCM): This algorithm is based on fuzzy C-means that address both INU artifact and local spatial continuity. Local spatial continuity constrained is accounted by using dissimilarity index [18] that allows spatial interaction between image voxels and thus reduces the noise effect. To suppress the INU artifact, a multiplicative bias field MR image formation model is used. By modeling the multiplicative bias field as a stack of smoothing B - spline surface an efficient two stage algorithm has been used. In the first stage the bias field is estimated slice by slice, with no explicit coupling between adjacent slices of spline surface. In the second stage , previously computed spline coefficients is updated while taking into account the explicit coupling between adjacent spline surface resulting the regularization term. Finally, the spatial continuity constraint is taken into account in fuzzy objective function [9, 5].

FCM (Fuzzy C-Means): In case of conventional FCM the number of clusters is determined by operating index procedures to whole data to determine the number of clusters before starting fuzzy methods. This will consume much time for finding the suitable number of cluster and thus computational cost is quit high for large data sets. To overcome the shortcomings of conventional FCM, Fuzzy C- Means algorithm has been used where spatial information is incorporated into the membership function. In this method intra- cluster distance measure has been used which is simply the median distance between a point and its cluster center. The number of cluster increases automatically according to the value of intra- cluster , for example when the cluster is obtained, it uses this cluster to evaluate intra-cluster of the next cluster as input to the Fuzzy C- Means and so on, stops only when intra – cluster is smaller than a prescribed value[19]. The most important aspect of this algorithm is that appropriate number of clusters can be determined automatically. It is clear that Fuzzy C- Means algorithm can estimate correct tissues much more accurately than conventional Fuzzy C Means, thus segmentation accuracy has been improved [20].

Adaptation FCM to Bias Field: This algorithm reformulates the design of C-means Clustering based approach of intensity non-uniformity compensation. In this algorithm Fuzzy C-means method uses global information about pixel instead of individual consideration of pixel. Global information means pixels will assign to that clusters which is based on their intensities without considering the pixel position in the image. By using this technique the computational time reduces without causing any relevant change in segmentation accuracy. According to [21] it is proposed that this algorithm is highly compatible with various c-means clustering based intensity non-uniformity compensation technique.

III. *Quantitative evaluation of performance*

Segmentation algorithm can be evaluated on the basis of misclassification error and segmentation accuracy for 40% intensity non-uniformity

Intensity non-uniformity (INU) is defined as a spatially slow varying function that makes the pixels belonging to same tissue be observed with different intensity.

Misclassification error (MCR) is defined as the number of pixels misclassified by the algorithm divided by the total numbers of pixels in an image.

$$MCR = \frac{Number\ of\ pixel\ misclassified}{Total\ number\ of\ pixel}$$

Segmentation Accuracy (SA) is defined as number of correctly classified pixels by the algorithm divided by the total number of pixels in the image.

$$SA = \frac{Number\ of\ correctly\ classified\ pixel}{Total\ number\ of\ pixel}$$

Segmentation accuracy determines the eventual success or failure of computerized analysis procedures, and for this reason a considerable care is taken to improve the probability of accurate segmentation.

Table 1 summarizes comparison analysis of various segmentation methods with 40% levels of Intensity non-uniformity (INU).

Table 1: Error measures at 40%INU for different segmentation methods when applied on MR brain

Sr. No.	Author's Name	Year	Segmentation Method	MCR %	SA %
1	J.C. Bezdek [11]	1981	Conventional Fuzzy C-Means	9.016	90.984
2	D.L.Pham and J.L.Prince [13]	1998	Full Multigrid Adaptive Fuzzy C-Means	5.065	94.935
3	J.G.Sled et.al [12]	1998	MNI-FCM	5.625	94.375
4	D.L.Pham and J.L.Prince [14]	1999	Truncated Multigrid Adaptive Fuzzy C-Means	4.938	95.062
5	C.Zhu and T.Jiang [17]	2003	Multi context Fuzzy Clustering	4.290	95.710
6	A.W.C. Liew and H.Yan [9]	2003	Adaptive Spatial Fuzzy C-Means	3.832	96.168
7	M.Y.Siyal and L.Yu [20]	2005	Fuzzy C-Means	2.624	97.376
8	L.Szilagyi et.al [21]	2012	Adaption Fuzzy C-Means to bias field	2.630	97.370

It is observed from Table1 that lower the value of misclassified error higher will be the segmentation accuracy. Fuzzy C-Means gives lower misclassification error, thus better performance in terms of segmentation accuracy.

For 40% Intensity non-uniformity (INU) level Adaptation Fuzzy C-Means to bias field method shows an improvement of 70.8% over Conventional fuzzy c-means, 31.36% over Adaptive spatial fuzzy c-means, 38.69% over Multicontext fuzzy clustering, 46.73% over Truncated multigrid adaptive fuzzy c-means, 53.24% over MNI-FCM, 48.07 over Full multigrid adaptive fuzzyc-means.

If comparing fuzzy c-means and adaption fuzzy c-means to bias field, it is observed that fuzzy c- means is more accurate in terms of both misclassification error value and segmentation accuracy, but by using adaption fuzzy c-means method the computational time is reduce which is the main limitation of fuzzy c-means method.

IV. Conclusion

To understand the disease process at its early stage, it is important to perform qualitative evaluation of the medical data. Medical imaging process plays a vital role in early diagnosis. Applying Fuzzy C-means segmentation method in medical imaging can solve the problems in traditional methods for segmentation accuracy. This paper presents an exclusive survey on eight image segmentation methods related to clustering algorithm to intensity non- uniformity in MR brain images. The methods and validation approaches were classified according to various features such as misclassification rate and segmentation accuracy with 40% intensity non-uniformity. However, MR images always include an intensity non-uniformity caused by the RF coil in MRI acquisition, which may introduce unexpected intensity values of the pixels. This may cause an inaccurate segmentation. The biased field c-means clustering algorithm was developed to solve this problem. The processing time was reduced by using biased field c-means clustering over fuzzy c- means algorithm. But the limitation is that by using biased field c-means clustering method, misclassification error is slightly higher and segmentation accuracy is slighter lower than fuzzy c- means.

V. Future Scope

Following are the directions in which the researcher can work on image segmentation algorithm.

- Researchers can develop a method to strive towards improving the accuracy, precision and computation speed of the segmentation algorithms, while reducing the amount of mutual interactions.
- Researchers are suggested to deal segmentation algorithms with 3D volume, since MRI data is 3D in nature.
- Researchers can design segmentation algorithms which should be more robust even in the conditions of very noisy situation.
- Researchers can design a segmentation algorithm which should be evaluated for localized measurements, such as the impact on tumor boundary or volume determinations.
- Researchers can develop a context sensitive pre- filter for elimination of intensity non-uniformity artifacts, so that segmentation can be performed easily.

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