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Fuzzy C-Means Based Automated Technique for Hippocampus Segmentation

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***Abstract*—** Evaluation of the Hippocampus structure is extremely important step regarding the precaution, detection as well as identification of numerous brain upheavals owing to the implication of the complex structural changes of the HC in those disorders. In this paper, a new hybrid method for segmenting the HC from MRI brain images is introduced by using clustering method Fuzzy C-Means which is very sensitive to noise. So prior to segmentation, pre-processing is done to make the image free of noise as well as with prominent Region of Interest. To segment HC, image features are computed to validate the slice to identify whether it comprises of Hippocampus or not. Enhancement techniques based on morphological operations and filters are applied to make a image clear. Finally FCM clustering method is used to get the HC from binary image. The result of the above said procedure ideally extracts the hippocampus. For Quantitative analysis of proposed method Dice and Jaccard parameters are used.

***Keywords*—** Alzheimer's disease, segmentation, FCM clustering, hippocampus, image features

I. INTRODUCTION

Brain comprises of three tissues white matter(WM), gray matter(GM) and cerebrospinal fluids(CSF) important for detection of various neurological disorders. A neuro disoder that destroys brain cells connection will result in dementia such as Alzheimer Disease(AD), epilepsy, schizophrenia, and other neuro generated disorders. Any sign of memory loss creates a problem in performing daily activities and become a cause of death if it is not noticed on early stage. A disorder that destroy brain cells connection will result in memory loss(Alzheimer) & affect the Hippocampus .

The HC is the main area affected by AD. There is a shrinkage in this region which is one of the biomarker found in the early stage and can help to control the effect of AD. HCis the part of medial temporal lobe associated with memory, interlocking by C shaped structure: CornuAmmonis and Dentate Gyrus. For detection of Alzheimer hippocampal atrophy is examined by using different medical imaging techniques like Magnetic Resonance Imaging, Computed Tomography, and Positron Emission Tomography.

To diagnose AD disease, an image of MRI of HC is used . MRI is noninvasive diagnostic tool based on nuclear MR phenomenon used to visualize soft tissue of the brain as well as internal structure in detecting brain abnormalities. It is very hard to discriminate the boundaries between hippocampus and other brain sructures in clinical MRI images. So a simple approach is proposed to segment HC accurately. A lot of time and effort is needed to segment HC from brain MRI by the physician. Development of automated /semi-automated method can minimize the physician work.

II. RELATED WORK

In literature several automatic and semi-automatic segmentations have been proposed [1]. Pallavi Purohitet al presented a new efficient approach towards K-means clustering algorithm. They have proposed a method for generating the cluster centre by reducing the mean square error of the final cluster without large increment in the execution time. It reduced the means square error without sacrificing the execution time. Many comparisons have been done and concluded that accuracy is more for dense dataset rather than sparse dataset. G.L.N.Murthy et al [2] have proposed a particularly edge based FCM clustering algorithms for detection of AD and segmentation Of HC with region growing technique from coronal section. K-MEANS and FCM [3] are the most popular examples of the clustering methods that are used for segmentation of AD from PET scan brain images. However, performance of segmentation is sensible to cluster centres and numbers, which are difficult to identify directly and prior by human beings.

In [4], a deformable model with low level processing technique is used to segment HC. In [5], Hippocampus segmentation is carried out by using FCM to find out WM, GM, CSF and pixel counting method for calculating the volume of these tissues. In [6], the author proposed an algorithm for segmentation that follows smoothing the border of HC using morphological filters, Otsu for determining rough HC region, binary dilation to specify refined Hippocampus boundary and connected component analysis (CCA) to get HC.

In [7] Fuzzy rules with morphological operations are used to extract fine HC. In [8-9] level set with region growing and Artificial neural network segmentation algorithm are used to get HC from T2 weighted 2D axial brain MRI. Somasundaram et al[10-12] have proposed an approach to segment HC from multiple slices by using prior shape model with region growing and discussed a method based on two step for segmentation of HC with approximate location of HC. Image is converted in to binary by using Riddler Calvard method and in the last CCA is applied for segmentation of HC.

III. Proposed Method

Here we propose an automatic segmentation algorithm to segment the HC from the MRI brain slice. The rest of the paper is structured as follows. Section II, elaborates the methods and the materials. In section III, we have presented the results and discussion. Finally we have concluded in section IV.

A. Materials Used:

We have collected the data set for our work available in the Penn Hippocampus Atlas (PHA)[13]. PHA is a repository comprising of segmented as well as normalized MRI of the human hippocampus taken in high resolution from the post-mortem samples.

B. Methods:

This proposed technique is a generalized approach to segment the HC from the slices of Penn002L. The proposed technique is depicted in the flowchart shown in Figure.1. It consists of five stages. At the first stage, an input MRI slice is taken. (Figure.2)

On the second stage, input MRI slice is analysed to check if HC is present or not by manipulating the features related to shape based, intensity based and texture based like mean(μ), homogeneity(H), correlation(cor) and var(σ) .The mean(μ) value computes the level of intensity and texture of the image as:

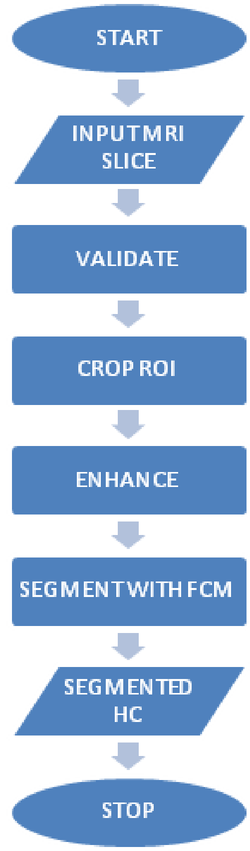


Figure. 1. Proposed Technique-Flowchart

Figure2. Input image

$$\mu = \sum_{x=0}^{M_g-1} x.p(x) \quad (1)$$

Where $p(x) = \frac{h(x)}{n \times m}$

where p(x) is the intensity of the image and n x,m is number of rows and columns. The Standard Deviation of image is calculated as

$$S.D(s) = \sqrt{\sum_{x=0}^{M_g-1} (1-\mu)^2 . p(x)} \quad (2)$$

The texture feature Energy (E) define homogeneity in an image is defined as

$$E = \sum_{x=0}^{M_g-1} \sum_{y=0}^{M_g-1} p(x,y)^2 \quad (3)$$

The measure of intensity variation between a pixel and neighbor pixel of the whole image is Contrast calculated as

$$con = \sum_{n=0}^{M_g-1} n^2 \sum_{x=0}^{M_g-1} \sum_{y=0}^{M_g-1} p(x,y)^2 \quad (4)$$

To measure the relation of pixel with its neighboring pixel correlation is calculated as:

$$corr = \frac{1}{s_m s_n} \sum_{x=0}^{M_g-1} \sum_{y=0}^{M_g-1} (x,y) p(x,y)^2 - \mu_m \mu_n \quad (5)$$

The values for the above said features are computed and compared with table 1 value, if the computed values lie in the range then HC is in the slice and considered for further processing otherwise it is discarded.

Table 1. Features of manually segmented hippocampus

Feature	Value	
	Minimum	*maximum*
Mean(μ)	218	235
S.D(S)	5.4	7.5
Corr(C)	0.9879	0.9947
Contrast(k)	0.0014	0.0154

On the third stage, crop only the required region of the image to minimize the time space complexities i.e the unwanted or outer part of slices that contain no useful information is removed by setting co-ordinate values of height and width of the slice and it is found that the value of coordinate (R_{min}= 100, R_{max}= 154, C_{min}= 40 and C_{max}= 124) enclose the HC completely on the slice which is defined by (HC_c) of the slice(HC) is :

$$HCc(x,y) = \begin{cases} HC(x,y), & Rowmin < x < Rowmax, \ Colmin < y < Colmax \\ 0, & otherwise \end{cases}$$

The fourth stage involves enhancement to get a better result because HC has complex structure with various noise .To improve the quality of the image, enhancement is done by removing noise, sharpening the image or brightening the image (increase or decrease contrast). In the first stage of enhancement wiener2 filter is applied to reduce the noise. In the first stage of enhancement to improve the quality of the image wiener2filter and top hat operations are used to remove spotty or mismatched background with non-white background. Erosion and dilation are used to separate connected objects from the image to make the HC prominent.

After enhancing the image, the HC from the enhanced image is segmented by using FCM (clustering method given by Dunn & modified by Bezdek) algorithm. To get only HC from image, divide the set of data into clusters based on homogeneity and heterogeneity inside cluster data by initializing the following factors: number of Clusters, centroid, number of iterations, termination parameters, fuzziness factor, distance and membership values. Update the centroid, Find objective function. The following steps are used to get the desired result.

The image is converted in to set of data pixel H=(h_1,h_2,h_3,.......,h_N) in N data set and partitioned in to K(no. of cluster).find distance d_{ip}=(h_p-h_i) give the result how pixel (h_p)is far from the centroid of the cluster(h_i). Merbership of pixel(h_p) in the i^{th} cluster is represented as

$$\sum_{i=1}^{K} M_{ip} = 1 \ where \ p = 1 \quad (6)$$

Then calculate cluster centre as

$$h_i = \frac{\sum_{p=1}^{N} M_{ip}{}^q . h_p}{\sum_{p=1}^{N} M_{ip}{}^q} \quad (7)$$

Calculate and Update membership value (M_{ip}) by using distance(d_{ip})(distance of particular pixel and centroid of pixel.) as

$$M_{ip} = \sum_{j=1}^{K} \frac{1}{\left(\frac{\|(hp-hi)\|}{\|(hp-hi)\|}\right)^{2/q-1}} \quad (8)$$

The membership function and cluster center are updated with every iteration. The procedure terminate when given condition is satisfied:

$$\text{If} \quad \left\| U^{(k+1)} - U^{k} \right\| < V \tag{9}$$

FCM aim is to minimize the objective function

$$J_{HFCM} = \sum_{i=1}^{K} \sum_{p=1}^{N} M_{ip}{}^{q} \, d_{ip}{}^{2} \tag{10}$$

If $\left\| U^{(k+1)} - U^{k} \right\| < V$ is terminated.

IV. Results and Discussion

We carried out the experiments by applying our method on the slices available in the PHA. The segmented results for a sample slice are given in Fig.3. The database consists of Gold standard segmented data of manual segmentation.

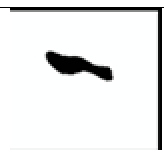
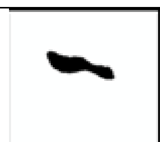
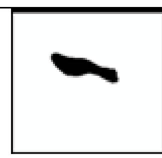
Slice No.	Manual Segmentation	Proposed Method	ITK – SNAP 2.4.0
Penn002L _01081			

Figure 3. Sample images of Segmented Results

The performance analysis of the proposed method is evaluated using various quantitative analysis parameters as presented in Table 2. The results show that our method is comparatively better than the automatic tool as well as closer to the manual segmentation.

Method	Metric						
	Jaccard J	*Dice D*	*Sensitivity S*	*Specificity Sp*	*Predictive accuracy PA*	*FPR*	*FNR*
ITK-SNAP	0.8029	0.8906	0.8481	0.9977	99.1762	0.0563	0.1519
Proposed	0.8892	0.9413	0.9102	0.9989	99.4845	0.0236	0.0898

V. Conclusion and Future Scope

Our method can work only for the specific data set of high resolution. In future we aimed at segmenting from some low resolution MRI brain images.

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