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Detection of Alzheimer Disease in Human MRI Head Scans Using Spatial Fuzzy Clustering with Level Set Method

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Abstract

Alzheimer Disease (AD) is one of the brain related disease that occur due to aging. It affects the brain, degenerate and kills the brain cells therefore causes the shrinkage in the brain tissues. The detection of AD in brain images is very crucial in present times. In this paper, we proposed a method for detecting the Alzheimer disease in MRI human head scans by segmenting the WM and GM using Spatial Fuzzy Clustering Method (SFCM). This proposed method is a two-tier process, the Tier1 consists of brain portion extraction using skull stripping method and the segmentation of White Matter (WM) and Gray Matter (GM) using SFCM with level set method is processed in Tier2. The WM and GM are further analyzed to detect Alzheimer disease in MR brain images. Moreover, our method is evaluated by the similarity measures such as Jaccard (J) and Dice (D) to assess the efficiency.

Keywords:

Alzheimer Disease;
Spatial Fuzzy Clustering with Level Set Method;
Magnet Resonance Imaging.

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1. Introduction

Alzheimer Disease (AD) is most commanly known brain disorder that incorporates the symptoms of dementia. As AD is a progressive disease that gets severe over the time and parts of brain are damaged. As there is no standard treatment for AD, the neccesity of accurate diagnozing process should be adopted. The image segmentation plays a vital role in diagnozing processes and anlzying diseases like AD. Magnetic Resonance Imaging (MRI) is one of the widly used imaging modality that uses a magnetic field and radio waves to capture the pictures of the inner organs. There are many segmentation methods are available in the literature [1-3]. In this paper, we proposed a segmentaion method to detect the brain tissue in AD affected MRI head scans. Some of the notable Fuzzy clustering based segmentation methods are presented as follows. Shasidhar et al. [4] proposed a modification in the traditional FCM to detect the tumor part in MRI images. The modification in the cluster center and membership value updating creterion yeilds better results than the traditional FCM method for segmenting the tumor region. The performance evaluation of clustering in brain tissue segmentation is done in [5] and the role of two methods that Adaptive K-Means (AKM) and Fast Fuzzy Clustering method (FFCM) in tissue segmentation process is assessed in [6]. The brain tissue segmention using spherical brain mapping through the stastiscal characteristics of the tissues is presented in [7].

Basavaraj et al., [8] proposed a brain MRI segmentation which performed with the combination of Modified Fuzzy Clustering Method (MFCM) clustering algorithm and level set method for normal brain MRI. An initial segmentation is done by MFCM and a level set based approach is done in next stage. Zhang et al, [9] proposed a novel level set approach to simultaneous tissue segmentation and bias correction of MR images. The level set evolution process is used to achieve the tissue segmentation and for bias correction simultanously. Tembhekar et al., [10] developed a Spatial K-Fuzzy Clustering Method (SKFCM) for image segmentation. This algorithm gave an approximate boundary and then applying level set after clustering yields the exact boundary of WM, GM and CSF. Therefore, the AD is detected and the exact location is identified. The level set approch for image segmentation is proposed in [11]. A simple method to detect AD in MR brain images by segmenting the white matter and gray matter from normal and abnormal brain image was developed in [12]. This method was successful in segmenting the brain tissues using FFCM method. In this paper, we used SFCM with level set method to segment the WM and GM from given input brain image. The comparision is taken between the segmented WM and GM with the WM and GM of the normal brain. The irregularity in the structure of these tissues represents the shrinkage in the brain tissue. By quantifying this reduction, we can identify whether the brain is affected by AD or not. The remaining part of the paper is organized as follows: In section 2, the methodological detail of our proposed methods is presented. The results and discussion are given in section 3 and we conclude the paper in section 4.

2. Methodology

We have proposed an image segmentation method for the brain MRI images for detection of brain tissues using combination of SFCM and level set method. A cluster can be known as a group of pixels with similar features and it is an unsupervised classification technique. Spatial fuzzy clustering algorithm for segmenting the MRI image with level set method is implemented as following. The overall flowchart of the proposed method is shown in the Figure 1.

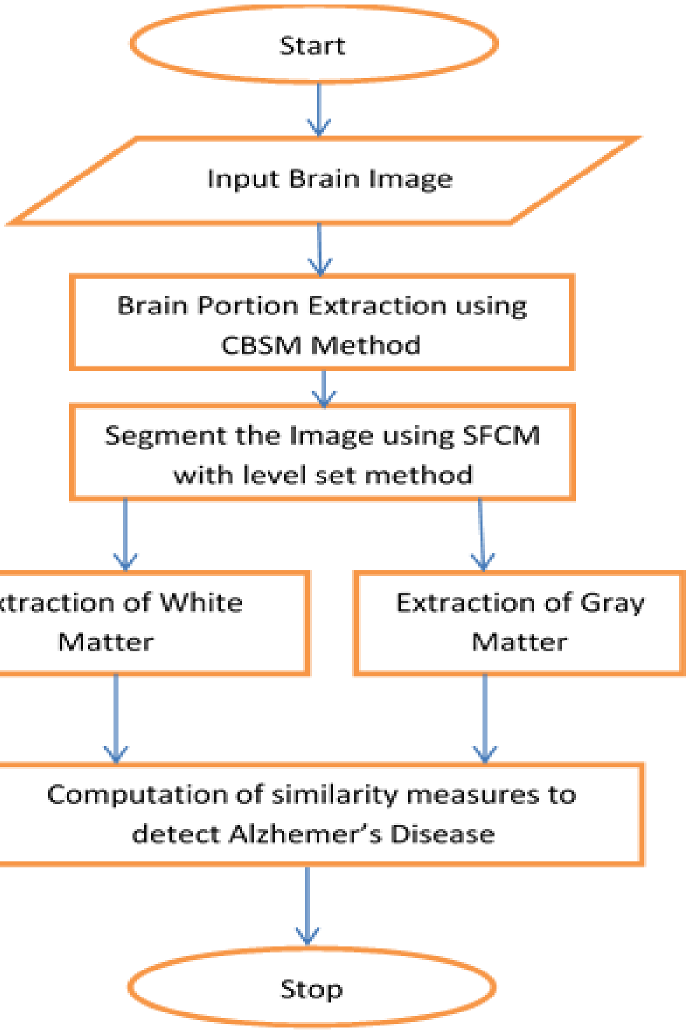

Figure 1. *Flowchart of Our Proposed Method*

The following steps illustrate our method as the sequence of steps.

Step1: Brain Portion Extraction

Normally, segmenting a brain tissue from MRI head scan is a difficult task. First, we have to remove the skull from brain MRI image to extract the brain portion. There are number of skull stripping methods are available in the literature [13]. In our method, we used Contour Based Brain Segmentation Method (CBSM) [14] to remove the skull from MRI images. The skull removed Brain image using CBSM is given in Figure 2(b) and Figure 3(b).

Step2: Segmentation of the Brain Tissues

After extracting the brain portion using CBSM method, the SFCM is used to segment the brain tissues such as WM and GM using spatial fuzzy clustering method that proposed in [15]. Clustering technique is used to segment White Matter (WM) and Gray Matter (GM) in the skull removed brain image. Although, FCM works well in many real-world applications but it cannot be applied to deal with spatial data directly, because of the special features in spatial clustering problems. The spatial parameter is combined with the fuzzy C-means clustering and it is defined as:

$$h_{ij} = \sum_{k \in w(x_j)} u_{ik} \quad (1)$$

where, $w(x_j)$ represents small square window function that centered on pixel x_j in spatial domain. The spatial function h_{ij} represents the probability that pixels x_j belongs to i^{th} cluster and the u_{ik} represents membership function.

The spatial fuzzy C-means have proved its superior than the FCM and some other recently proposed FCM based algorithms. Spatial fuzzy C-means method integrates spatial information, and the membership weighting of each cluster is corrected after the cluster distribution in the neighborhood is considered. The first pass is the same as that in standard FCM to calculate the membership function in the spectral domain. In the second pass, the membership information of each pixel is mapped to the spatial domain and the spatial function is computed from that.

Both fuzzy algorithms and level set methods are general purpose computational model that can be applied to problems of any dimensions. A new fuzzy level set algorithm is proposed for automated medical image segmentation. Our algorithm automates the initialization and parameter configuration of the level set segmentation using Fuzzy clustering. It employs FCM with spatial constraints to determine the approximate contours of interest in an image. The objective function is derived from spatial fuzzy clustering directly. The level set function will automatically slow down the evolution and will become totally dependent on the smoothing term. The segmented WM and GM for a sample image are shown in the images of Figure.2 and Figure.3.

Step 3: Compute the Similarity measures using Jaccard and Dice

To evaluate the shrinkage of WM and GM in brain image, we used the similarity measures Jaccard (J) and Dice (D). It compares the segmented WM and GM in AD affected brain image with corresponding normal brain image.

The Jaccard similarity is given by

$$J(s1, s2) = \frac{|S1 \cap S2|}{|S1 \cup S2|} \tag{2}$$

The Dice is similarity is given by

$$D(s1, s2) = \frac{2\,|S1 \cap S2|}{|S1|+|S2|} \tag{3}$$

where, S1 represents the total pixels of the WM and GM images obtained in the AD affected brain image and S2 represents the segmented WM and GM in the comparable normal brain image. Using this resultant value of similarity measures J and D, we can analyze the brain images which are affected by AD. Based on the values of J and D, we can determine whether the brain is affected or not.

3. Results and Disscussion

The segmentation process for a selected normal and AD-affected brain slices are shown in Figure 2. and Figure 3.

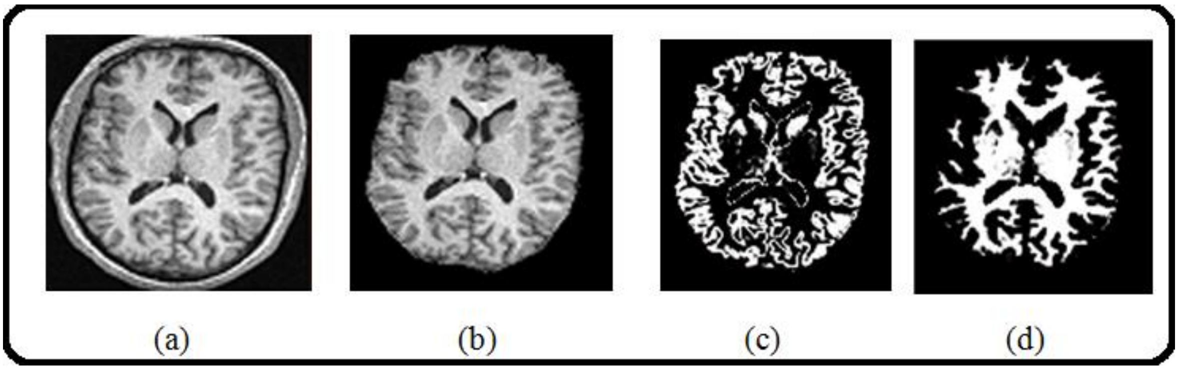

Figure 2. *Segmentation process for the Normal brain by our proposed method: (a) Original image (b) Skull removed image (c) Segmented Gray Matter (d) Segmented White Matter*

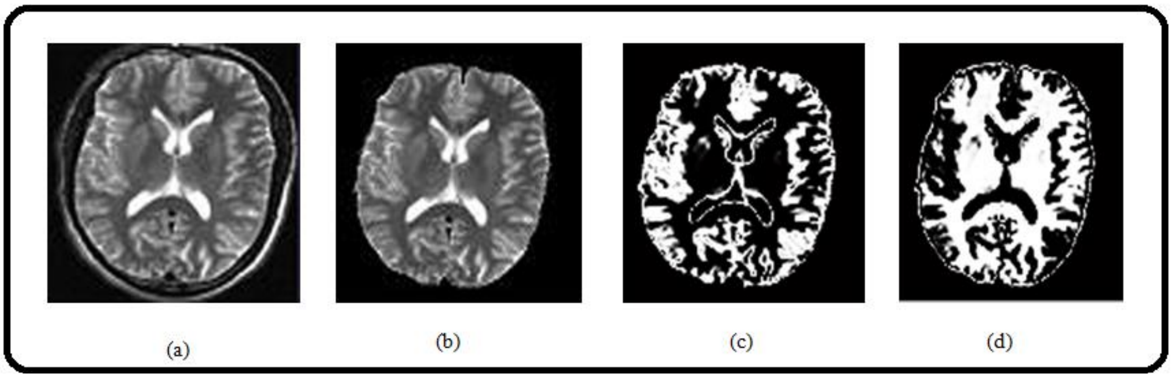

Figure 3. *Segmentation process for the AD-affected brain by our proposed method: (a) Original image (b) Skull removed image (c) Segmented Gray Matter (d) Segmented White Matter*

In this method, we used MRI brain images obtained from internet sources to implement our proposed method. Our method is evaluated by computing the similarity measures Jaccard (J) and Dice (D) as per the equations given in Eqns. (2) and (3). The five selected sample images from the normal and AD-affected brain images along with the segmentation result obtained by our proposed method are shown in Figure 4. and Figure 5. In Figure 4., tested original brain images are given in column1, the skull removed image by CBSM are given in column 2 and the segmented WM and GM are shown in column 3 and column 4 respectively.

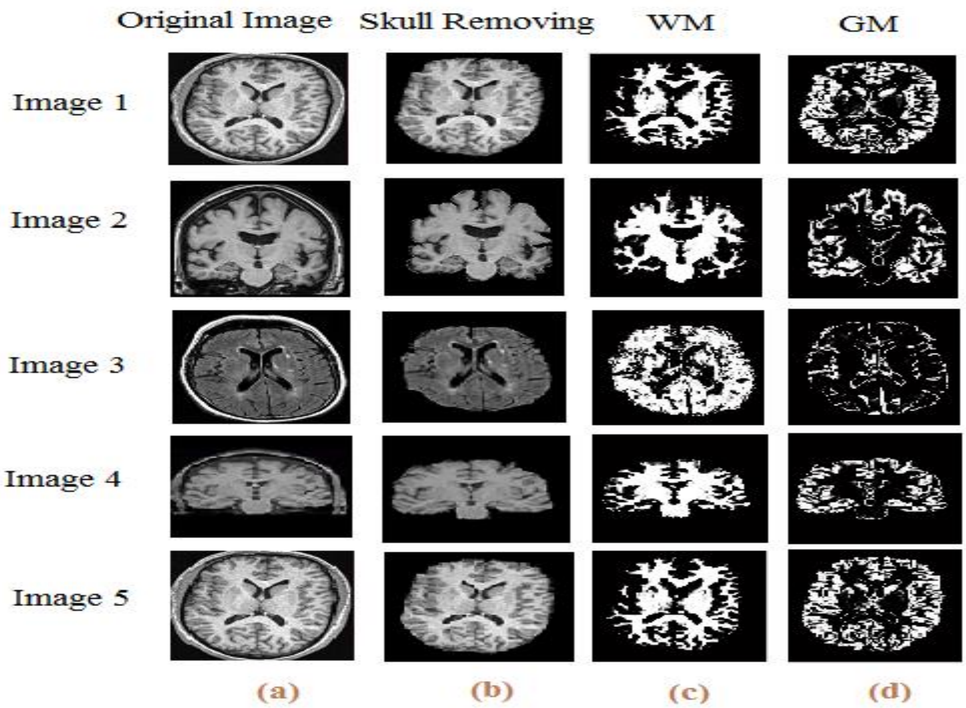

Figure 4. *Segmentation Result of Normal Brain (a) Original Image (b) Skull Removed Image (c) Segmented White Matter (d) Segmented Gray Matter*

The segmented results for selected images of abnormal brain by our proposed method are shown in Figure 5. The tested original abnormal brain images are given in column1, the skull removed image by CBSM are given in column 2 and the segmented WM and GM are shown in column 3 and column 4 respectively. The computed similarity measures Jaccard (J) and Dice (D) for the segmented WM and GM for the selected brain images that are given in Table. 1. Note that all the images expect the image 5 does not have similarity measure value of 1, which indicates that these images not having the similar gray and white matter patterns. Therefore, we can say that there is shrinkage on those brain tissues due to the occurrence of AD.

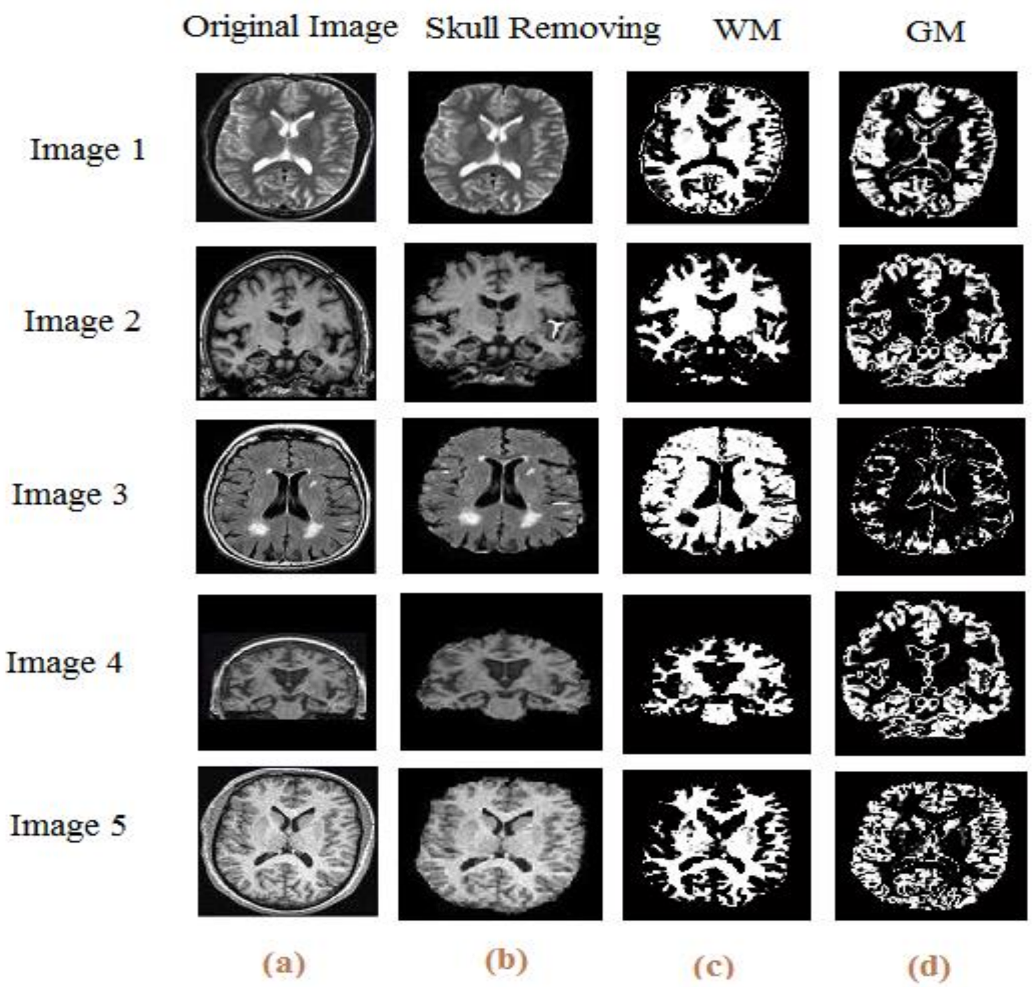

Figure 5. *Segmentation Result of AD-affected Brain (a) Original Image (b) Skull Removed image (c) Segmented White Matter (d) Segmented Gray Matter*

Table 1. Computed Similarity Measures of Our Proposed Method

Similarity Measures					
Images	JACCARD		DICE		REMARKS
	WM	**GM**	**WM**	**GM**	
Image 1	0.8217	0.8122	0.9021	0.8964	AD-affected
Image 2	0.8969	0.8451	0.9456	0.9160	AD-affected
Image 3	0.8921	0.8301	0.9430	0.9072	AD-affected
Image 4	0.9168	0.8858	0.9566	0.9394	AD-affected
Image 5	1	1	1	1	Normal

4. Conclusions

In this paper, a detection of AD in MR brain images by segmenting the white matter and gray matter is proposed. Our method results successful in segmenting the brain tissues using SFCM with level set method. The combination of SFCM with level set method to segment the WM and GM gives efficient results and it is very comparable to other existing methods. This automated segmentation of WM and GM may be used to quantify the neurological damage to brain images particularly in AD scenarios.

ACKNOWLEDGEMENT

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