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# White Matter and Gray Matter Segmentation in Brain MRI Images Using PSO Based Clustering Technique

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***Abstract***— Alzheimer's disease is one of the brain disorders caused due to shrinkage of brain tissues, particularly the White Matter and Grey Matter. Many imaging modalities are used to acquire the image of human brain, in order to diagnose the disorder. MRI is widely used technique to detect Alzheimer's disease. In this research work, we aimed to develop a computational method to quantify the brain tissue loss in MRI human head scans. In this proposed method, we used particle swam optimization (PSO) technique to find the optimal cluster centroids to segment the brain tissue. These segmented White Matter and Gray matter are further analysed to quantify the Alzheimer's disease. The output of this method is quantitatively and qualitatively evaluated by the similarity measures – Jaccard, and Dice based on the expert segmented results.

***Keywords***— Brain Tissue Segmentation, Clustering, Particle Swarm Optimization, MRI Images, Grey Matter and White Matter

## I. INTRODUCTION

Magnetic Resonance Imaging (MRI) uses magnetic field and radio waves to produce images of the organs which are present deep inside the body. MRI brain image segmentation is used to envisage the image in a meaningful and easiest way to inspect the different types of diseases such as Multiple Sclerosis, Alzheimer's diseases, and other brain related disorders. There are many segmentation methods available in the literature [1-3]. In general, segmentation techniques are broadly classified into following categories: Histogram based methods [4], Threshold based methods [5], Hybrid methods [6], Edge based methods [7], Region based methods [8], Cluster based methods [9] and Classification based methods [10]. In this paper, our aim is to segment and detect the brain tissue in MR brain images to detect Alzheimer's Disease (AD). AD creates problems in thinking, reasoning, behaviour and motor skills. It is caused due to the loss of neuronal cells, primarily cortical gray matter reduced to a great extent than white matter. Hippocampus of gray matter structure in the temporal lobe known to be affected the earliest stage of AD. Now a day, early detection of AD is a challenging task in the medical and research field.

In order to detect the AD, a method present in [11] performs spherical brain mapping by projecting the three dimensional MR brain images into a two-dimensional maps using different measures such as informative and statistical characteristics of the tissue. The sensitivity and exactness of structural features of brain regions were thoroughly studied for early diagnosis of AD in [12]. *Kannan et al* [13], proposed a novel FCM calculation for weighted tendency estimation and division of X-Ray images. They focus information technique keeping in mind the end goal to decrease the execution time of the proposed calculations. This proposed method delivered a great outcome, even in the cerebrum having poor homogeneities and different clamors. *Abinaya et al*[14] was developed enhanced image segmentation using PSO algorithm to segment brain tissues such as white matter, gray matter and CSF in brain MRI images. *Kalaiselvi et al.*, [15] have proposed an algorithm to initializes K-means segmentation automatically by the knowledge of MRI images and histogram processing. *Kaufman and Rousseeuw*[16] have proposed an algorithm to initialize the K-means segmentation manually by selecting the K-value. The first centroid is selected as the most centrally located instance and other centroids are taken as the higher numbered among the rest of data in the database. Which leads to limitation in the manual initialization of the number of cluster and the centroids [17][18]. *Sudipta et al.,[*19] developed a new concept which has been incorporated using level set methodology for the specific segmentation of brain tissue in MRI brain images. *Zhiguang Qin et al.*,[20] have proposed an algorithm to automatically segment the tissue of brain in MR images. The core idea behind this method is the mixed use of Gaussian Mixture Model and K-Means Algorithm (GKA). The brain tissue of MR images will be segmented into WM, GM and CSF by adopting the GKA method.

 

In this paper, we used PSO based clustering method to segment WM and GM in the given input brain images. The segmented WM and GM are compared against the WM and GM of the normal brain. The deviation in the structure of the brain tissue represents the contraction in the brain tissue. By quantify this reduction, we can identify that the brain is affected by AD. The remaining part of the paper is organized as follows: In section 2, the methodological detail of the proposed methods is given: the results and discussion is given in section 3 and the conclusion is given in section 4.

## II. METHODOLOGY

Alzheimer's Disease is caused due to some size decline in the brain tissues, so segmenting the brain tissue leads to identify the AD disease. Normally, segmenting a brain tissue from MRI head scan is a difficult task; therefore first we removed the skull from brain images. There are member of skull stripping methods are available in the literature. [21-22]. The overall flowchart of the proposed method given in Fig. 1.

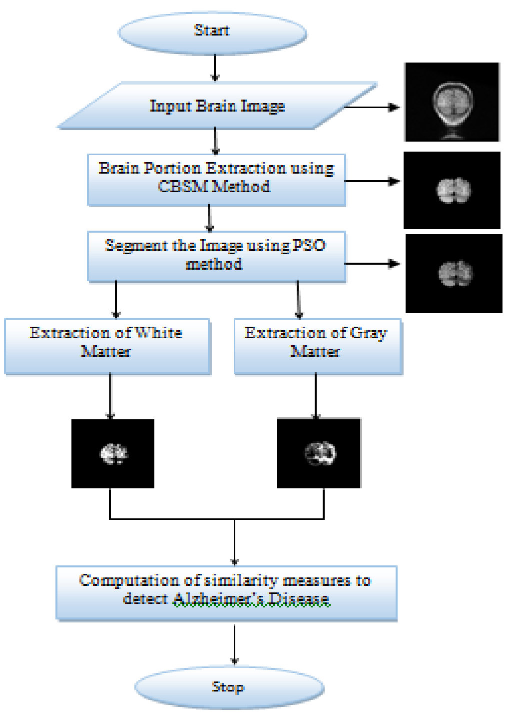


**Fig. 1: Flowchart of the proposed method**

In our method, we used Contour Based Brain Segmentation Method (CBSM) [18] to eliminate the skull from MRI images. Particle swarm optimizers (PSO) are population-based optimization algorithms modelled after the simulation of social behaviour of bird flocks [Kennedy, Eberhart,1995]. In a PSO system, a swarm of individuals (called particles) fly through the search space. Each particle represents a candidate solution to the optimization problem. The position of a particle is influenced by the best position visited by itself (i.e. its own experience) and the position of the best particle in its neighbourhood (i.e. the experience of neighbouring particles). The performance of each particle (i.e. how close the particle is from the global optimum) is measured using a fitness function that varies depending on the optimization problem. Each particle in the swarm is represented by the following characteristics:

$x_i$: The current position of the particle;
$v_i$: The current velocity of the particle;
$x_i$: The personal best position of the particle.

For each iteration of a PSO algorithm, the velocity vi update step is specified for each dimension j = 1.. $N_d$ where $N_d$ is the dimension of the problem. Hence, $v_{ij}$ represents the $j^{th}$ element of the velocity vector of the $i^{th}$ particle. Thus the velocity of particle i is updated using the following equations [20]:

$$v_{i,j}(t+1) = wv_{i,j}(t) + C_1 r_{1,j}(t)\left(y_{i,j}(t) - x_{i,j}(t)\right) + C_2 r_{2,j}(t)\left(\hat{y}_j(t) - x_{i,j}(t)\right) \quad (1)$$

where w is the inertia weight; C1 and C2 are the acceleration constants; and $r_{1,j}$ and $r_{2,j}$ are the position of particle i, $x_i$, which is then updated using the following equation [20]:

$$x_i(t+1) = x_i(t) + v_i(t+1) \quad (2)$$

We can define the fitness function as given in equation (3), the threshold value for which this function gives maximized fitness value is preferred and the fitness function is given by:

$$f(t) = F0 + F1 \quad (3)$$

**Algorithm of the PSO**

Initialize Swarm: $x_t^n$, $v_t^n$ , $\tilde{x}_t^n$, $\tilde{n}_t^n$, $\tilde{g}_t^n$
Loop:
For all the Particles
Evaluate the fitness $\varphi$ of each particle
Update: $x_t^n$, $\tilde{n}_t^n$, $\tilde{g}_t^n$
Update: $v_t^n$, $\tilde{x}_t^n$
End

The algorithm can be summarized as follow:

1) *Initialize:* Initialize the parameters and population with random position and velocities.
2) *Evaluation:* Evaluate the fitness value (the desired objective function) for each particle.
3) *Find the* $g_{best}$: If the fitness *value of particle i is* better than its best fitness value ($i.e. p_{best}$) in the history, then set current fitness value as the new $p_{best}$ to particle i.
4) *Find the* $g_{best}$: If any $p_{best}$ is updated and it is better than the current gbest, then set $g_{best}$ to the current value.
5) *Update position*: update velocity for each particle by applying Eqn (1) and (2).

 

### 2.1 MATERAL USED

To experiment and estimate the accuracy of our proposed methods, we have obtained brain images from the following datasets.

Dataset 1: Internet Brain Segmentation Repository (IBSR)

Dataset 2: KGS Hospital Scan Center at Madurai

**Dataset 1: Internet Brain Segmentation Repository (IBSR):**

The twenty volumes of T1- Weighted MR brain images obtained from IBSR [24] of the Center for Morphometric Analysis (CMA) at the Massachusetts General Hospitals are taken to be tested for proposed system. It contains MR brain volumes obtained from young-middle aged normal individuals. Each volume consists of T1-weighted 2D sequential coronal slices with dimensions of 256 x256 pixels. The number of slices ranges from 60 to 65 and the slice thickness is 3.1mm. Several volumes of the dataset had severe intensity in homogeneities caused by the non-uniformity of magnetic fields, radio frequency coils, and noise factors, therefore for the efficient performance comparison these volumes have been used in the existing methods.

**Dataset 2: KGS Hospital Scan Center at Madurai**

The proposed method was tested with T2-Weighted MR brain images obtained from a popular scan center at Madurai. It contains MR brain volumes obtained from middle aged normal individuals. The three dimensional axial T2-Weighted spoiled gradient echo MRI Scans were performed on two different Imaging systems. The machine type is (Avanto) t2_trim_tra_dark_fluid_FIL_1. MR_CT_Scan system with the following parameters: TR=4.2ms, TE=99ms Flipangle=150 degree Slice Thickness=5mm.

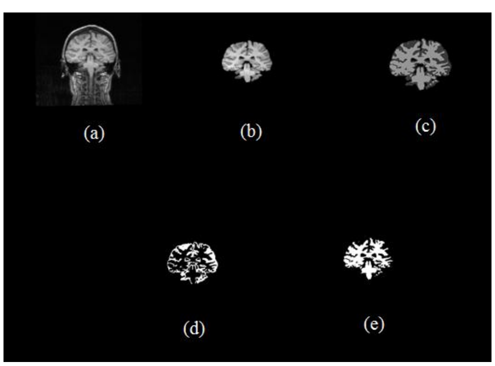


Figure 4: Segmentation process by proposed method for the images obtained from dataset-1; (a) Original Image (b) Skull Stripped Image (C) Segmented image by PSO Cluster technique (d) Segmented Gray Matter (e) Segmented White Matter

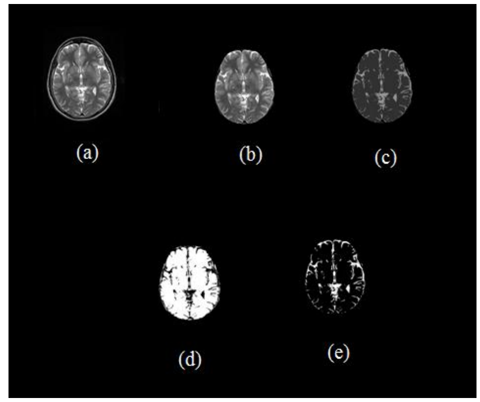


Figure 5: Segmentation process by proposed method for the images obtained from dataset-2;(a) Original Image (b) Skull Stripped Image (C) Segmented image by PSO Cluster technique (d) Segmented Gray Matter (e) Segmented White Matter

### 2.2 EVALUATION METRICS USED

The execution of the proposed technique is assessed utilizing the likeness measures Jaccard (J) and Dice (D). These metrics produce the result that lies between 0 and 1.

The Jaccard (J) coefficient [25] is also called Tanimoto coefficient, measures the similarity of two images. It is defined as the size of the intersection of the images divided by the size of their union and it is calculated by the formula given in Eqn. (4) as below:

$$J(s1, s2) = \frac{|s1 \cap s2|}{|s1 \cup s2|} \quad (4)$$

The index is zero if the two images are rambling that is they have no common pixels, and is one if they are the same. Higher numbers indicate better segmentation results.

The Dice (D) [26] coefficient also measures the image segmentation and it is calculated by the formula given in Eqn. (5).

$$D(s1,s2) = \frac{2|s1 \cap s2|}{|s1| + |s2|} \quad (5)$$

where, s1 represents the total pixels of the image obtained by the proposed segmentation method and s2 represents the total pixels in image, obtained from ground truth image. Overlap measure is defined for a given voxel class assignment as the sum of the number of voxels that both have the class assignment divided by the sum of voxels where either segmentation has the class assignment.

## III. RESULTS AND DISCUSSION

In this method, we used brain images obtained from dataset-1 and dataset-2 to evaluate the performance of the proposed method. The selected sample images from the brain datasets along with the segmentation results by the proposed method are shown in Fig. 6 and Fig. 7. In Fig. 6, the original brain images are given in column (a) and the segmented skull stripped segmented brain images are given in column (b) and

 

Segmentation using PSO is given in column (c), the segmented WM and GM are shown in column (d) and column (e) respectively. The computed similarity measures Jaccard (J) and Dice(D) using the Eqn (4) and (5) for the segmented WM and GM for the Dataset-1 brain images are shown in Fig 6 are given Table 1 and Dataset-2 brain images are shown in Fig 7 are given Table 2.

Table 1: Calculated Jaccard and Dice Value for the brain images in Figure 6.

| **Images** | **GM** | | **WM** | |
|---|---|---|---|---|
| | **Jaccard** | **Dice** | **Jaccard** | **Dice** |
| **Image _1** | 0.53 | 0.69 | 0.38 | 0.55 |
| **Image_2** | 0.71 | 0.83 | 0.64 | 0.78 |
| **Image_3** | 0.78 | 0.87 | 0.77 | 0.87 |
| **Image_4** | 0.63 | 0.78 | 0.65 | 0.79 |
| **Image_5** | 0.57 | 0.73 | 0.70 | 0.82 |
| **Image_6** | 0.57 | 0.72 | 0.69 | 0.81 |
| **Image_7** | 0.61 | 0.76 | 0.56 | 0.72 |
| **Image_8** | 0.70 | 0.82 | 0.62 | 0.76 |
| **Image_9** | 0.79 | 0.88 | 0.78 | 0.88 |
| **Image_10** | 0.71 | 0.83 | 0.63 | 0.77 |
| **Mean** | **0.660** | **0.792** | **0.642** | **0.776** |

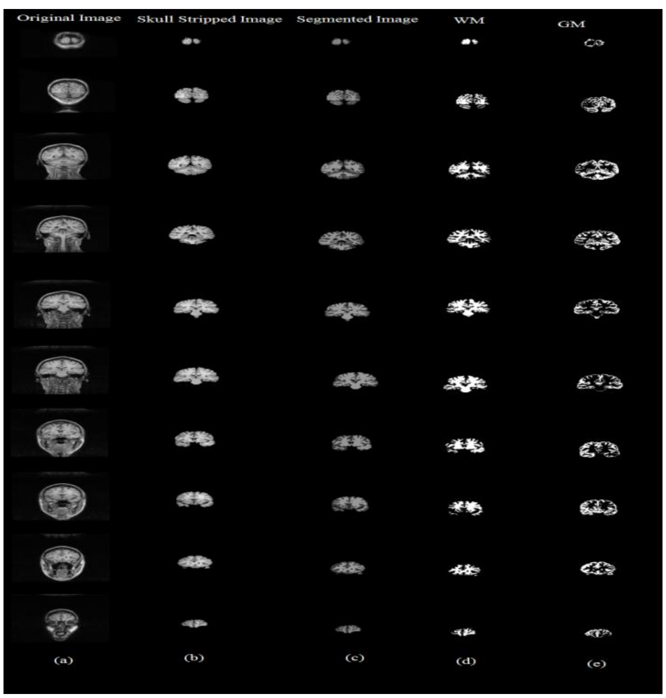


Figure 6: Segmentation process by proposed method for the images obtained from dataset-1; (a) Original Image (b) Skull Stripped Image (C) Segmented image by PSO Cluster technique (d) Segmented White Matter (e) Segmented Gray Matter

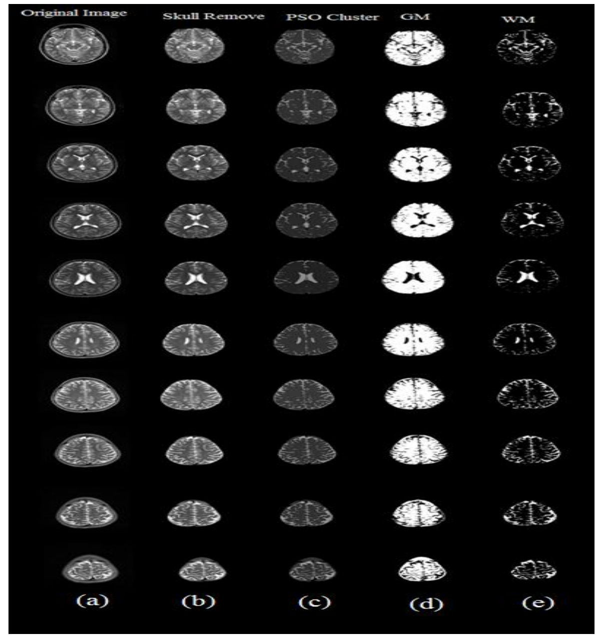


Figure 7: Segmentation process by proposed method for the images obtained from dataset-2;(a) Original Image (b) Skull Stripped Image (C) Segmented image by PSO Cluster technique (d) Segmented Gray Matter (e) Segmented White Matter

It is clearly observed that our proposed method accurately segments WM and GM from the brain image. The proposed method finds application in diagnosis of brain related disorders or diseases as a follow-up.

## IV. Conclusion and Future Scope

The brain tissue segmentation using PSO based clustering techniques was developed to detect AD in MR brain images. This proposed method was tested with images. collected from benchmark dataset (dataset1) and also on real time images (dataset 2) and found to produce better segmentation result on compared with the existing methods. This simple automatic segmentation of WM and GM may be used to quantify the neurological damage to brain affected with AD.

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