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Segmentation of Brain Hemispheres in Magnetic Resonance Human Head Scans

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ABSTRACT

In this paper, we proposed an automatic algorithm for segmenting the left and right hemispheres of MR brain images using localized energy-based active contour method. We have tested our algorithm with the images obtained from IBSR brain datasets. For quantitative evaluation, we have computed Jaccard (J) and Dice (D) similarity measures. The experimental result show that this proposed algorithm produces better segmentation result compared to expert segmented result.

Keywords: Brain hemisphere segmentation, MRI brain image, active contour model.

1. INTRODUCTION

The magnetic resonance imaging (MRI) is a test that uses a magnetic field and pulse of radio wave energy to make pictures of organs and structures inside the body. In MRI brain image, a deep wrinkle divides the cerebrum into two halves, known as the left and right hemispheres. Usually, these two hemispheres look similar in shape but actually they are not identical and the functions associated with these two hemispheres are also slightly different. In general, right hemisphere is associated with creativity and the left is associated with logic abilities. Each hemisphere controls its unique set of activities or tasks [1]. The right brain is dominant for spatial abilities, face recognition, visual imagery and music. The left brain may be more dominant for calculations, math and logical abilities. The right hemisphere of the brain controls over muscles on the left side of the body and the left side of the brain controls over muscles on the right side of the body. Therefore, any damage to one side of the brain will affect the opposite side of the body. Segmentation is an important process in digital image processing which segment the image into several objects according to the user requirements [2], and it is an essential in medical image analysis. There are many segmentation technique are used in the medical field which help to detect and identify the disease clearly. Using the image processing technique, we can segment and analyze the differences and similarities between the hemisphere, brain compartment and intracranial structure to identify various brain abnormalities.

A new skull stripping method for magnetic resonance image of human head scans based on image contour was developed in [3]. In this method, they have used hybrid method to combine two or more method to produce good result. Zhao et al., [4] proposed hemisphere segmentation approaches based on mid - sagittal plane extraction or linear registration but for some brain images, it has produced inaccurate segmentation results because the brain are not always perfectly symmetric. Similar problem exists in free surfer [5] and Brain voyager [6], which apply two cutting planes, one separating the left and right hemispheres and other separating the cerebrum from the CB (Centre of Brain) and BS (Brain Surface). Brummer [7] developed a method to find the hemispheres based on the longitudinal fissure in the tomographic head images. Other methods were also proposed to segment the brain surface and other internal structure in MR brain images [8-11]. The method aiming for more accurate hemisphere/ compartmental segmentations can be based on the search of the segmentation surface between the hemisphere, usually by optimizing some cost function [12], nonlinear registration [13] or structure-reconstruction. Cerebral

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hemisphere segmentation using curve fitting was developed in [14]. Numerous brain segmentation methods are available in literature [15]. Liang et al., [16] defined that the boundary between the CHS (Cerebral Hemisphere) must lie within the interhemispheral fissure (IHF). IHF is deep cleft and a longitudinal fissure between the CH and is filled by CSF (Cerebral Spinal Fluid). In the following sections of this paper, the methodological details, results and discussion and the conclusions are given.

2. METHODOLOGY

Our algorithm uses localized energy based active contour model [17] to segment the left and right hemisphere of the MRI human brain images. The overall flowchart of the proposed method is given in Figure 1 and the process of segmenting the left and right hemisphere is illustrated in Figure 2. This proposed method first remove the skull from the input brain image as a preprocessing step. Because the hemispheres can be easily segmented only after removing the skull from the input brain image. There are many brain segmentation methods are available in the literature [18-23]. In this method, we used localized energy based active contour method to segment the brain from the MRI head scan image. The initial contour to evolve the active contour is defined by drawing a circle inside the brain area to segment the brain from MRI brain images and it is denoted by:

$$\text{Circle}\ (x_c, y_c, r) \tag{1}$$

where, x_c, the middle row of an image, y_c, is the middle column of the image, and r is the radius. In this method we assumed r = 30 for skull stripping. This value is assigned after experimenting our algorithm on several brain images. Given an input image I defined on the domain Ω with C as a closed initial curve which is defined in equation (1) as the zero level set of a signed distance function Ø, i.e., C ={x| Ø (x) = 0}. Then the interior of C defined by the approximation of soft Heaviside function as given below:

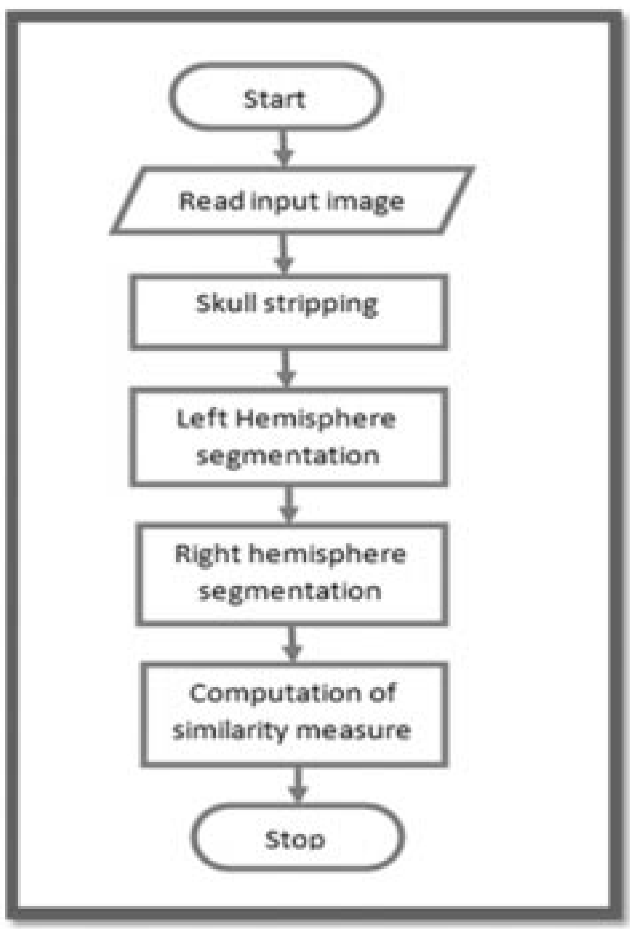

Figure 1: Flowchart of proposed method

$$HI\emptyset(x)\begin{cases}1, & \emptyset(x) < -\in \\ 0, & \emptyset(x) > \epsilon \\ \frac{1}{2}\{1+\frac{\emptyset}{\in}+\frac{1}{\pi}\sin\left(\pi\emptyset\frac{(x)}{\in}\right)\}, & Otherwise\end{cases} \tag{2}$$

Similarly, the exterior of C is defined as (1-HIØ (x)). To specify the area just around the curve, it will use the derivative of HIØ(x), a soft version of the Dirac delta.

$$\delta\emptyset(x)\begin{cases}1, & (x) = 0 \\ 0, & |\emptyset(x)| < \epsilon \\ \frac{1}{2\in}\{1+\cos\left(\pi\emptyset\frac{(x)}{\in}\right)\}, & Otherwise\end{cases} \tag{3}$$

It now introduce a second spatial variable y. Here, we will use x and y as independent spatial variables each representing a characteristics function in terms of a radius parameter R.

$$B(x,y) = \begin{cases}1, & \|x-y\| < r \\ 0, & Otherwise\end{cases} \tag{4}$$

It use B(x, y) to mask local regions. This function will be 1 when the point y is within a ball of radius r entered at x, and 0 otherwise. Based on the above equation (2) to (4), the skull portion is removed from the brain image. Because, as mentioned earlier, the hemisphere can be segmented with less effort when the skull is eliminated from the input brain image. Then the same procedure is applied to segment the left and right hemisphere.

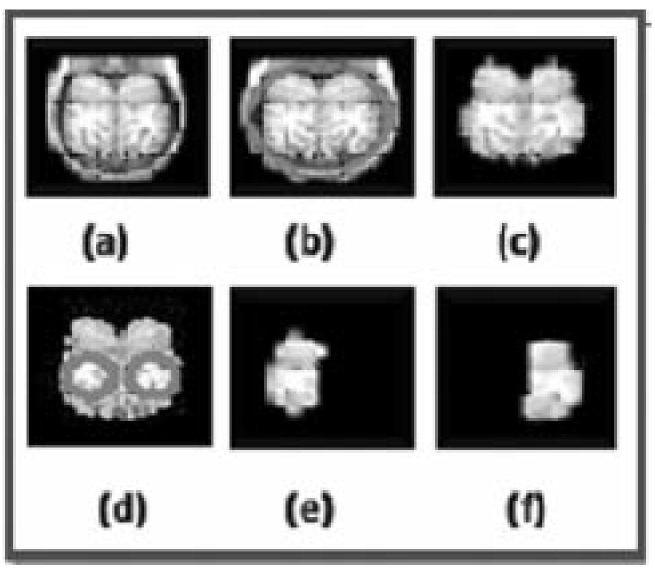

Figure 3: Skull stripping of MRI brain image; (a) Original image (b) Initial Mask (c) Skull stripped image (d) Initialization of left and right hemisphere (e) Segmented left hemisphere (f) Segmented right hemisphere.

In Figure 3, the original image is given in Figure 3(a), the initial mask is given in Figure 3(b), the skull stripped brain image is shown in Figure 3(c). In order to segment the left and right hemisphere, we need to find the initial contours of the left and right hemisphere. There, the two initial contours have been defined at the middle of the two halve of segmented brain image and it is illustrated in Figure 3(d). The segmented left and right hemisphere shown in Figure 3(e) and 3(f) respectively.

The algorithm steps of this proposed method in given below:

Algorithm: Hemisphere segmentation in MRI brain Images

Step 1:	Read the input brain image.
Step 2:	Define the initial mask
Step 3:	Remove the skull from input brain image using localized energy based active contour model.
Step 4:	Define the initial mask for the left and right hemisphere segmentation
Step 5:	Obtain the segmented left hemisphere
Step 6:	Obtain the segmented right hemisphere
Step 7:	Compute the similarity measures using segmented MRI brain image by expert segmented result

2.1. Brain Image Dataset used

We used 18 volume of MRI brain images obtained from IBSR [25] the Center for Morphometric Analysis (CMS) at Massachusetts General Hospital. This dataset contains 18 volume of T1-weighted MRI brain images along with expert segmented images. The image dimension is 256 x 256 pixels and the number of slice in each volume range from 1 to 120 slices.

2.2. Evaluation metrics

Similarity measures such as Jaccard (J) and Dice (D) were computed for quantitative evaluation of this proposed method. The equation for computing J and D values are given below:

The J similarity is given by:

$$J(s1,s2) = \frac{|S1 \cap S2|}{|S1 \cup S2|} \tag{5}$$

The D similarity is given by:

$$D(s1,s2) = \frac{2\,|S1 \cap S2|}{|S1|+|S2|} \tag{6}$$

where, S1 represents the total pixels of the image obtained by the proposed segmentation method and S2 represents the total pixels in the image obtained from ground truth image.

3. RESULTS AND DISCUSSION

In this method, we used images from IBSR [24] dataset to evaluate the performance of the proposed method. A quantitative evaluation also done by computing the similarity measures Jaccard (J) and Dice (D) as per the equations

Table 1
Computed Jaccard (J) and Dice (D) similarity measures for the images given in Figure 4.

Images	*Jacquard (J) similarity*		*Dice(D) similarity*	
	Left hemisphere	*Right hemisphere*	*Left hemisphere*	*Right hemisphere*
Image 1	0.6202	0.6051	0.7605	0.7619
Image 2	0.5284	0.5312	0.7645	0.7630
Image 3	0.5618	0.5772	0.7634	0.7612
Image 4	0.5405	0.5376	0.7656	0.7634
Image 5	0.5355	0.5291	0.7608	0.7637
Image 6	0.7313	0.7130	0.7619	0.7601
Image 7	0.7547	0.7030	0.7583	0.7608
Image 8	0.6483	0.6396	0.7597	0.7791

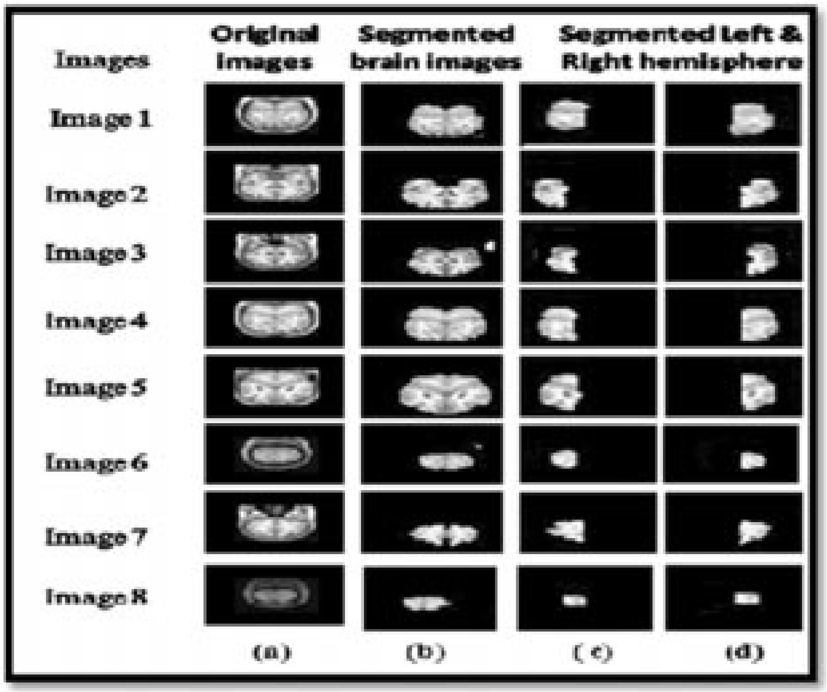

Figure 4: Hemisphere segmentation result by the proposed method; (a) Original image; (b) Skull stripped image; (c) Segmented left hemisphere (d) Segmented right hemisphere

given in Eq. (5) and (6). A selected sample images from the brain dataset along with the segmentation result by the proposed method are shown in Figure 4.

In Figure 4, the original brain image is given in column (a) and the segmented brain image are shown in column (b). The segmented left and right hemisphere by the proposed methods are given in Figure 4(c), and 4(d) respectively. We have also computed similarity measures J and D for quantitative result. The computed J and D value for the image shown in Figure 4 are given in Table 1. It is proved from Figure 4 and Table 1 is that the proposed hemisphere segmentation method efficiently segmented hemispheres from the brain images.

4. CONCLUSIONS

A simple method for automatic segmentation of hemispheres from MRI brain image is proposed in this paper. This method was successful in segmenting the brain hemispheres based on localized energy-based active contour method. The automatic segmentation of hemispheres may be used to quantify the neurological damage to brain images caused due to various brain related diseases. We would extend this method to find the symmetric and asymmetric bias in the brain images in order to detect brain related disorders.

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