A NOVEL SKULL STRIPPING TOOL BASED ON MEAN SHIFT CLUSTERING AND MATHEMATICAL MORPHOLOGY

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ABSTRACT:

To obtain an image of human brain, the most popular imaging method is Magnetic Resonance Image (MRI). In order to diagnose brain related issues, physician requires skull stripped brain images. Skull stripping is the important task for correct medical diagnosis. A novel method that uses mean shift pixel clustering to segment the portion of human brain from T1 Weighted MRI scans is presented in this article. Morphological operations such as dilation and erosion operators have been applied to improve segmentation accuracy. Experiment results show this method can segment brain images very fast and has good segmentation results.

Keywords: MRI, Skull Stripping, Mean Shift Clustering, erosion, dilation.

1. INTRODUCTION

Human brain is the most complicated organ in human’s anatomy. The significant components of a human brain are white mater and grey mater, cerebro spinal fluid (CSF), meninges [1,2]. Computer based imaging techniques are used for visualizing brain image and its substructure accurately. MRI uses strong magnetic field and produces detailed brain images [3] which are clearer than other imaging modalities. Human brain is imaged through all three orientations such as Axial, Coronal, Sagittal [4-6]. Image acquisition helps to diagnose brain related issues. But for accurate diagnosis, brain segmentation is required. Manual segmentation process takes much time to segment even for a single volume and also sometimes it leads to erroneous one. So, there is a need for automatic skull stripping [7, 8] from MRI rise in medical field.

Skull stripping is the necessary work even for fetal brain segmentation [9], adult brain segmentation and further the segmented brain image is used for tissue classification, sub structure segmentation, volume rendering etc. [10-13]. Several research works are done for skull stripping [14-16] using region based, edge based and hybrid of both methods. All such existing works are having their own merits and demerits.

The region-based methods are intended to get the regions by using the spatial details of an image. Balan et al. [17] have developed a segmentation method which implements region-based approach. Histogram based analysis and morphological operations have been used to for the segmentation of brain and non-brain regions. Another region-based method proposed by Atkin & Mackiewich [18] make use of histogram analysis and non-linear anisotropic filter. In the successive step active contour is applied to find the brain boundary. A 3D skull-stripping automated method is proposed by Lemieux et al. [19]. Park & Lee [20] proposed a region growing method which initially selects a seed point and then grows by adding similar neighboring pixels and this process continues till the brain boundary.

S.A. Sadananathan et al. [21] intensity-based thresholding techniques followed by graph cuts. The method supports to eliminate thicken connectivity between brain surface and its surrounding non-brain surfaces. Brain Surface Extraction (BSE) method based on anisotropic diffusion filter was developed by Shattuck et al. [22] for skull stripping from MRI. Characteristics of this filter smoothes unnecessary gradient of MR signals in the input image. They have also applied an edge detection technique along with morphological operations to detect the brain boundary. Smith proposed a brain extraction technique (BET), which uses intensity-based histogram for
obtaining rough brain mask. A triangular tessellation is initialized inside the brain region and it is increased up to an edge of the brain.

A level set based method for the elimination of skull region from input MR images presented by Zhuang et al. [23]. The combination of watershed model and deformable surface model has been applied by Segonne et al. [24] to provide accurate skull stripping method. An atlas-based method for the segmentation of human brain proposed by Rehm et al.[25] in which the atlas is obtained using histogram of the input image and it is associated with BSE. A comparative analysis is done by Fennema-Notestine [26] on HWA, BET, BSE and found that HWA and BSE are more efficient and robust than any other methods for brain segmentation.

In this article, the brain and non-brain regions are extracted from T1-W MRI of human brain scans by the implementation of maximum entropy divergence. The PSO [27] method is initially applied to the input images to improve the quality of an image. To find the performance, the quantitative measures such as jaccard and dice are calculated. Section 2 gives the proposed method, results and discussion are explained in section 3 whereas section 4 gives the conclusion of the proposed work.

Proposed Method

The method consists of sequel of processes (Fig.1) which includes mean shift clustering, thresholding, erosion, LCC and dilation to segment brain from MRI.

**Mean shift clustering:**

Mean shift filter clusters [28,29] the brain image foredge-preserving and smoothing. Significant edges of the brain image might be detected easily after mean shift filtering. For a given input image (I), the filtering process is started from initial pixel intensity at (x₀,y₀). Then the neighboring pixels are determined and new center pixel is calculated based on the mean of the neighboring pixels intensity values. Next iteration is started with this new center pixel intensity (Fig.2) and this process is continued until mean value converge at a point. Finally, the last computed mean value is assigned to the initial pixel intensity. Mean shift clustering technique moves towards the direction where the maximum increase in the density gradient for the input image. Hence, this filter smoothens (Iₛ) the local brain structure and removing the background pixels.

**Threshold value detection and binary image:**

The surrounded brain pixels are suppressed and background pixels are removed in the first stage. In the second stage, threshold value is calculated using the gradient smoothened image (Iₛ). The popular Otsu method [30] is applied to calculate the optimal threshold value. In this method optimal threshold is obtained by using image separability condition which maximizes between the gray scale class variance. The optimum threshold (T) value is obtained as:
\[ T = \arg \max_{0 \leq t < L - 1} \sigma^2_B (t^*) \]  

where \( L \) is the gray levels and \( t^* \) is the intensity where \( \sigma^2_B \) is maximum.

The optimal threshold value \( T \) is applied on \( I_s \), to obtain binary image \( I_B \). The binary image \( I_B \) contains brain mask as the largest component. This largest region is extracted in the subsequent process.

**Mathematical Morphology and Largest Connected Component (LCC)**

Morphological erosion is applied on the binary image \( I_B \) to erode the pixels in non-brain portions like skull, CSF, scalp and meninges. As given in [31], the operation of morphological erosion with structuring element, \( S \) can be calculated as:

\[ I_E = I_B \ominus S \]  

However, the resultant binary image with brain tissue is still included in the neck region. Hence, LCC is applied to extract brain region \( I_{lcc} \) alone. Morphological dilation is then applied to enhance the boundary of brain portions which are eliminated in the previous step. The final brain mask \( I_{br} \) is obtained by applying the mathematical morphology dilation[30] using same structuring element \( S \) as:

\[ I_{br} = I_{lcc} \ominus S \]  

Using \( I_{br} \), the portion of brain is extracted from the original input image \( I \).

**Materials Used**

Five volumes of MRI T1-Weighted coronal datasets of five volumes are collected from IBSR [32]. The slice thickness is 3.0mm and are of 256X256 pixel in size. All volumes are collected with manually segmented ground truth images available at IBSR.

**Results and Discussion**

The results of various steps of the algorithm are given in Fig.3. The results are compared with manually segmented images to validate qualitatively and quantitatively.

![Fig.3 Results of proposed method (a) Input image (b) Smoothened image using mean shift clustering (c) Binary image (d) Eroded image (e) Rough brain using LCC (f) Dilated image (g) Extracted brain](image-url)

For qualitative comparison the result of the method is compared with popular brain segmented methods BET [14] and BSE [22]. Fig. 4 shows randomly selected input image and the results obtained by manual segmented, BET, BSE and proposed method respectively.
<table>
<thead>
<tr>
<th>Slice No.</th>
<th>Original</th>
<th>Manual</th>
<th>BET</th>
<th>BSE</th>
<th>Proposed method</th>
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The results of the proposed method given in Fig. 4 shows that the method produced better segmented region than popular existing BET and BSE. BET has provided under segmented brain region whereas BSE has provided over segmented brain region. But the method produced accurate segmented brain portion for all input slices.

For quantitative comparison, Jaccard [33] and Dice [34-36] are calculated for the measurements between the manually segmented results and results of proposed method. J and D values are also calculated for results of BET and BSE and furnished in Table 1.

<table>
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<tr>
<th>Volume Label</th>
<th>JACCARD</th>
<th>DICE</th>
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<tr>
<td></td>
<td>Proposed</td>
<td>BET</td>
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<tr>
<td>1_24</td>
<td>0.971385</td>
<td>0.7581</td>
</tr>
<tr>
<td>2_4</td>
<td>0.978119</td>
<td>0.8078</td>
</tr>
<tr>
<td>4_8</td>
<td>0.967805</td>
<td>0.8281</td>
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<tr>
<td>5_8</td>
<td>0.955582</td>
<td>0.7716</td>
</tr>
<tr>
<td>6_10</td>
<td>0.95172</td>
<td>0.6666</td>
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<tr>
<td>Avg.</td>
<td>0.964922</td>
<td>0.76644</td>
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J and D are calculated as:

\[ J(A,B) = \frac{A \cap B}{A \cup B} \]  
\[ D(A,B) = \frac{2|A \cap B|}{|A| + |B|} \]

where A and B are results of two methods. In the case, A is the result obtained by ground truth and B is the result obtained by the method. If J and D produce 1, it shows that the segmented brain region by the proposed method is overlapped with manually segmented result. If J and D produce 0, it shows that completely non overlap with gold standard images. Table 1 demonstrates that the proposed technique accurately overlaps with manual segmented results for the given dataset and existing methods failed to overlap for all slices. Hence the method produces J, 0.9649 and D, 0.9744. J value of BET method for same five volumes is 0.76644 and for BSE is 0.83122. Dice similarity for BET and BSE are 0.86658, 0.9048 respectively. Fig.5 and Fig.6 illustrates the average results of Jaccard and Dice of five volumes for proposed, BET and BSE methods, where horizontal axis represents the volume label and vertical axis represents the similarity measurement.
II. CONCLUSION

Skull stripping is the primary requirement for brain image analysis. In this work, the method applied for skull stripping is based on mean shift clustering. Thresholding technique provides binary image which removes low intensity pixel and erosion removes border portions of the components in the binary image. Since, brain is the only largest connected structure in the binary image. Further, it is obtained and dilation is applied to regain brain pixels which are removed in the previous stage. Thus, finally brain mask is obtained to extract brain portion from the given input image. Experimental results show that the method effectively removes non brain regions and extracts only brain portion by keeping original brain pixels.

REFERENCES


32. International Brain Segmentation Repository(IBSR), Center for Morphometric Analysis Massachusetts General Hospital, CNY-6, Building 149, 13th Street, Charleston, MA, 02129-USA.


