Skull Stripping on Brain MR Images Using Priori Knowledge

Muhammet Üsame ÖZİÇ, Yüksel ÖZBAY, Ahmet Hakan EKMEKCİ, and Ali Sami KIVRAK

***Abstract*—**Skull Stripping is a process which separates brain tissue and non-brain tissue structures in magnetic resonance (MR) brain images. This process is a first step to make some transactions relating to MR images like as inhomogeneity correction, analysis of cortical structure, cortical surface reconstruction, cortical thickness estimation, tissue classification, image registration, shape quantification, identification of brain parts. This study uses a different method for skull stripping on MR images. MR images were obtained Selcuk University Medicine Faculty. Firstly, DICOM images were converted to the Nifti format. Then MR stack was segmented gray matter (GM), white matter (WM) and cerebrospinal fluid (CSF) by means of Statistical Parametric Mapping (SPM). These segmented brain regions were used priori knowledge. GM, WM and CSF were summed for making skull stripping mask. Noise pixels were removed on mask by using image processing techniques. Then the mask was converted to binary format. The last form of binary mask was used to extract brain tissue by multiplying original MR images. The proposed method was compared with Brain Extraction Tool (BET) in implemented MRIcro software. The results has been shown that the proposed method was more effective than BET method to skull stripping on real data.

***Keywords*—**Magnetic Resonance Imaging, Skull Stripping, Image Processing, Statistical Parametric Mapping, Priori Knowledge

I. Introduction

Magnetic Resonance Imaging (MRI) is a effective tool for diagnosis and treatments in medical applications. MRI can take three-dimensional images from three orientations which is axial, sagittal, coronal planes and can take high resolution images. Before analyzing MR images, several preprocessing techniques such as inhomogeneity correction, analysis of

cortical structure, cortical surface reconstruction, cortical thickness estimation, tissues, classification, image registration, shape quantification, identification of brain parts must make. Many of these tecniques are being used skull stripping methods to eliminate non-brain tissues as a first step. An error that made the first step will be affect subsequent preprocessing methods. Therefore, skull stripping is an important step to analysis of brain MR images [2]. Radiologists usually analyze this images manually. As mentioned previously, the removal of the non- brain tissues are an important step for analyzing MR images and for using several preprocessing techniques. This step removes non-brain tissues regions on MR images such as scalp, skull, fat, eyes, neck, optical nerves etc [3][4].

Many of skull stripping techniques have been proposed in the literature. Studies usually have been used morphological operators, image processing techniques, deformable modes, knowledge based models and priori probability. The popular brain extraction algorithms are The FMRIB Software Library FSL's Brain Extraction Tool [5], improved geometric active contour model [3], Brain Surface Extractor [6], method by using region labeling and morphological operations [4] AFNI's 3d Intracranial [7], FreeSurfer's MRI Watershed [8], using morphological filters and fuzzy C-means Segmentation [9], Model-based Level Sets (MLS) [10], Exbrain [11], using Brain Extraction Tool (BET) in implemented MRIcro software [17] , Simon Fraser University [12], hybrid methods like as Minneapolis Consensus Strip [13], Brain Extraction Meta Algorithm [14], Hybrid Watershed Algorithm [15], segmentation, registration and morphological operators [16]. The proposed method were compared with only BET method previously mentioned methods [17].

The proposed method has used WM, GM and CSF three brain section as a priori knowledge to skull stripping by using SPM software [19]. This paper is organized as follows: Section II reports methodology of skull stripping process. Six stages used the proposed method explain step by step in detail. Section III experimental results is given to be used 20 cross-sectional real MR images. At the same time, after extracting brain tissues, non-brain tissues that remained are given. The results of the proposed method are compared with BET implemented in MRIcro software. Section IV the results of experiment were evaluated.

II. Methodology

The proposed skull stripping method consists of six steps. This steps have been applied all of MR images as a stack for the all MR images. Figure 1 shows the process flow of our proposed method.

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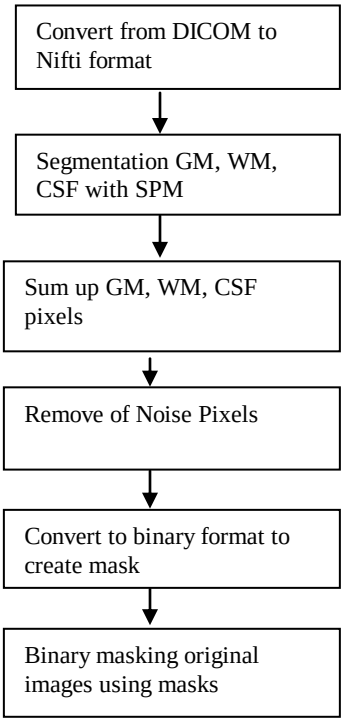


Fig.1 Process flow of the proposed method

MR data used our study were collected from Selcuk University Medicine Faulty. For images obtained were taken necessary ethic committee permission from Medicine Faculty Dean of Selcuk University. Technical features of MR stack are T1 weighted, 320*320 matrix size, 16 bit high resolution DICOM format and 20 cross-sectional images as a stack. MR data was influenced with Alzheimer disease [18]. As mentioned previous process flow figure describes step by step in detail.

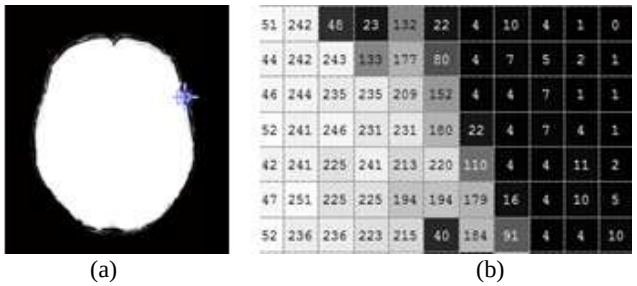
Step1. Digital Imaging and Communication in Medicine (DICOM) format has been used to obtain high resolution images in medical applications. This format is also used storing, sharing, printing, transmitting information as a standard in medical imaging [19]. We have to convert MR images from DICOM to The Neuroimaging Informatics Technology Initiative (Nifti) format for segmenting WM, GM and CSF. Because SPM supports this format to segment MR images. This converting process was made via SPM tools [19].

Step2. The brain consists of three main section which name is Gray Matter, White Matter, Cerebrospinal Fluid. Gray matter is located to external surface on white matter Cerebrospinal Fluid is a fluid uncolored and limpid where swam gray matter and white matter. One of popular segmentation methods GM, WM and CSF has been used Gaussian Mixture Model (GMM) and Bayesian Learning. This method is powered by Ashburner and Friston [1] and has been used via SPM tools. MR images that used were segmented via SPM tools as a stack [19]. Figure 2 shows that segmented brain sections GM, WM and CSF by means of GMM and Bayesian rules [1].

Fig.2 Respectively original MR, Gray Matter, White Matter, Cerebrospinal Fluid [1]

Step 3. Pixels belonging to GM, WM and CSF were summed up digitally. This is a necessary step for creating skull stripping mask.

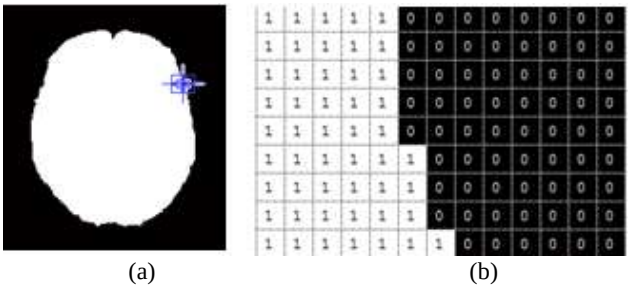
Step 4. GMM and Bayesian rule determines that each voxel belonging to which tissue. This rule assigns a value for each pixel that changed among 0-255 interval according to the probability of belonging tissue. This is a problem for the next step. Because some pixels doesn't contain information for tissues. For creating binary mask the next step, these pixels must remove from segmented images. Under 200 value pixels were removed all of the segmented images . Figure 3 shows that summed up GM, WM, CSF mask and value of pixels in blue rectangle.



(a) (b)

Fig.3 (a) GM,WM,CSF mask (b) Digital values of blue rectangle on mask

Step 5. After removed process of noise pixels, each pixels value was converted binary format to use binary masking for the next step. The aim of creating binary mask have been generated an image had got value of background 0 and foreground 1. Figure 4 shows that converted binary format mask and value of pixels in blue rectangle.



(a) (b)

Fig 4 (a) Mask converted binary format (b) Digital values of blue rectangle on mask

Step 6. Masks occurred previous step and original MR images were multiplied on this step to obtain brain tissues. Regions multiplied by zero on original MR images assign

zero value, regions multiplied by one protect its previous value. Because 0 is swallowed element and 1 is ineffective element in multiply process. Result of multiply process have been came out region of interest (ROI) MR images. These six steps were applied all of MR images as a stack. Figure 5 shows that flow process proposed method as a image.

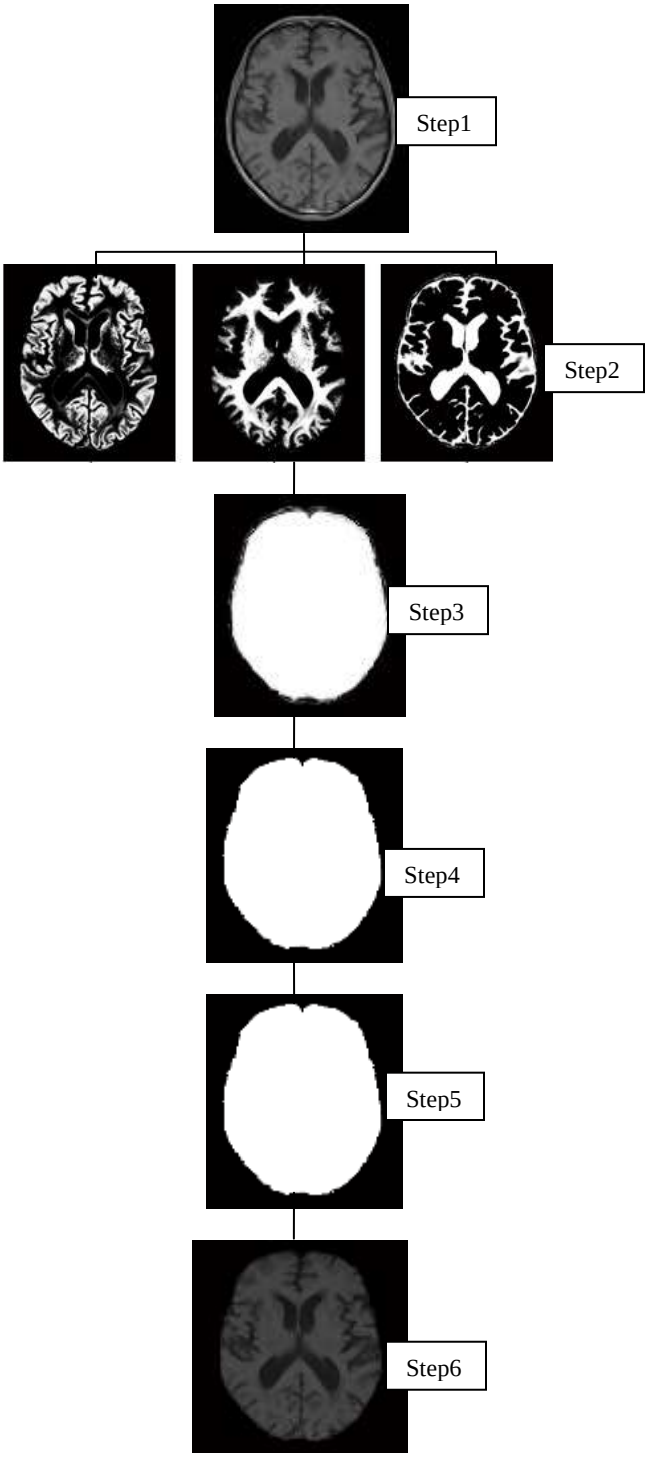


Fig.5 Respectively six steps to skull stripping

III. EXPERIMENTAL RESULTS

The proposed method has been applied 20 cross-sectional images to extract brain tissues. This method results were compared with BET method implemented in MRIcro software. Figure 6 shows that taken original images from Medicine Faculty, Figure 7 shows that results of BET skull stripping method, figure 8 shows that results of the proposed skull stripping method, figure 9 shows that occurred non-brain tissues the proposed skull stripping method.

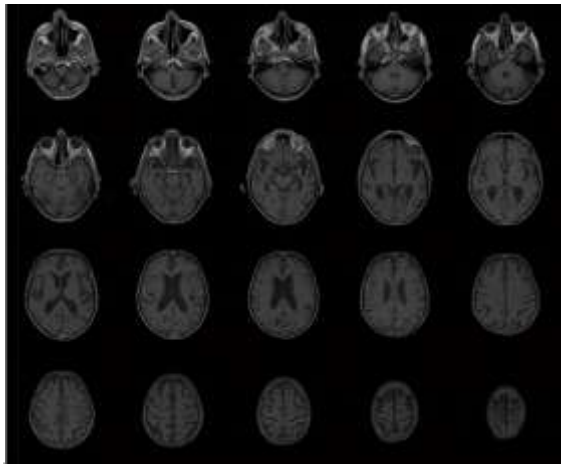


Fig.6 20 cross-sectional MR images taken from Medicine Faculty

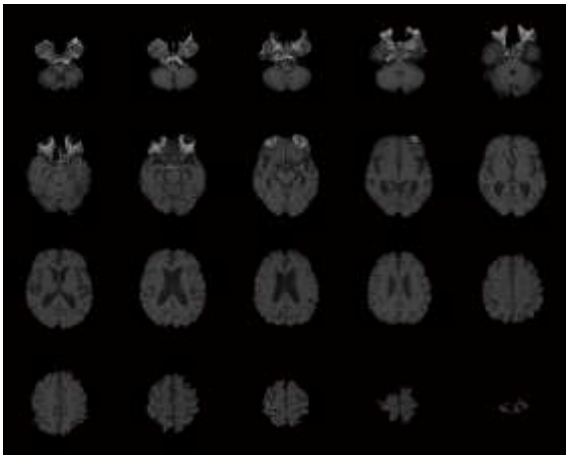


Fig.7 Skull stripping results using BET

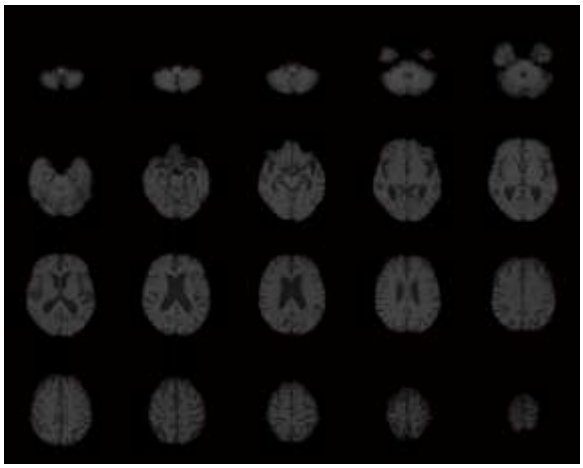


Fig.8 Skull Stripping results using the proposed method

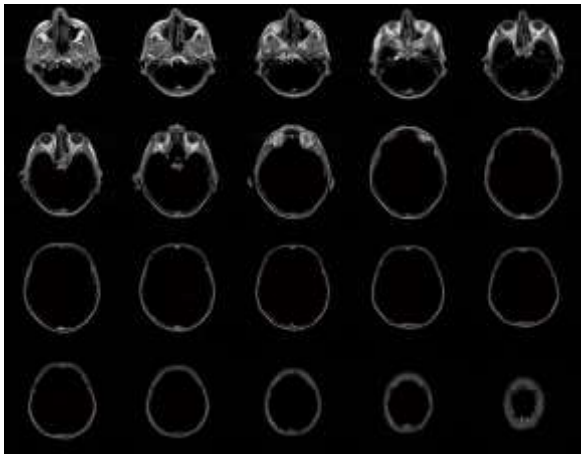


Fig. 9 Non-brain tissues removed the proposed method

IV. CONCLUSION

Experimental results show that the proposed method more effective than BET method to skull stripping on real images. When figure 7 compared with figure 8, it shown that figure 8 more better extraction brain tissues than figure 7. Especially, eyes and neck regions on MR images that extracted using BET have been remained on brain tissues . It is also seen that there are loss tissues the last three images in figure 7. Most studies usually have been used synthetic images while trying their methods. But daily life, real data are used to diagnose, treat and analysis any disease. Therefore, the proposed method is shown that it is more effective and robust skull stripping process than BET method while using real data shown previous figures.

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