Skull Stripping Methods and Tools

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Abstract- Skull Stripping aims to segment the brain tissue (cortex and cerebellum) from the skull and non-brain tissues in brain MR images. In this paper, a comparison evaluation of two widely used methods BET (Brain Extraction Tool) and BSE (Brain Surface Extraction) in brain image segmentation is presented. Performance analysis of segmentation methods integrated with the latest versions of FSL and BrainSuite is considered. Results obtained in this paper can be utilized to assist the users for selecting the appropriate method for brain tissue segmentation.

Keywords: *Segmentation, Brain Extraction Tool, Brain Surface Extraction, Magnetic Resonance Imaging.*

I. INTRODUCTION

Magnetic Resonance Imaging (MRI) is a non-invasive imaging technique that often is used for anatomical assessment of human brain structures. Due to its outstanding soft tissue contrast, detailed resolution and its non-invasive properties, MRI plays an important role in detection of neurodegenerative diseases. MRI provides detailed pictures of the brain and nerve tissues MRI scans are frequently used to evaluate the internal structures of the brain. Brain MRIs are not only used to discover tumours, infection and chronic diseases but also are now increasingly used in acute settings to look for bleeds and stroke [1].

In brain image MRI, segmentation of brain tissues is an important first step for numerous applications. Quantitative and qualitative studies of anatomical brain tissues and structures that have distinctive structural or functional properties usually relies on accurate segmentation of brain. Manual segmentation of brain tissues is reliable, but certainly hard and time-consuming. Moreover, it is highly dependent on large intra-and inter-observer variability that leads to degradation of credibility in the segmentation analysis. Therefore, there are strong demands to perform a reliable, reproducible, accurate and robust alternative automated segmentation of brain MR images as a prerequisite for the comprehensive brain analysis [2].

The segmentation of brain tissue from non-brain tissue in magnetic resonance images, commonly referred to as skull stripping, it is an important image processing step in many neuro-image studies. It is widely used in neuroimaging analysis application, such as registration; tissue classification; multi-modality image fusion; intersubject image comparisons; examination of the progression of brain disorders; monitoring the development or aging of the brain; and creating probabilistic atlases from large groups of subjects. At present, there are some methods and tools, which are most widely used in neuroimaging analysis. Skull stripping methods are classified into three types Intensity based, Morphology based, Deformable model based techniques [3].

Intensity based methods use intensity distribution functions to identify major brain tissues from MRI brain image. Each brain tissue is modeled as a modified normal distribution function. Morphological operations combine with thresholding or edge detection to extract image features and identify brain surfaces. Shattuck developed a tool called the brain surface extractor (BSE), which used a combination of edge detectors and morphological operators to skull stripping the brain images. Deform an active contour to fit the brain surface, which is identified using selected image characteristics. Brain extraction tool (BET) is an automated brain segmentation algorithm for MRI head scans, which was developed by Smith [4].

In this paper comparison evolution of two brain extraction tool is done. The remainder of this paper is organized as follows. Section II describe the brain extraction tools (BET and BSE) and software used for them. Section III describes the datasets and performance metrics that is used for evaluation. Section V explains the conclusion of paper by all the experiments evaluations.

II. BRAIN EXTRACTION TOOLS

There are two type of brain extraction tools used in neuro image analysis. These are Brain Extraction Tool and Brain Surface Extraction Tool

A. BET(Brain Extraction Tool)

BET employs a deformable model to fit the brain's surface using a set of "locally adaptive model forces". This method estimates the minimum and maximum intensity values for the brain image, a "centre of gravity" of the head image. The intensity histogram is processed to find "robust" lower and upper intensity values for the image, and a rough brain/non-brain threshold. The centre-of-gravity of the head image is found, along with the rough size of the head in the image. Next a triangular tessellation of a sphere's surface is initialized inside the brain, and allowed to slowly deform, one vertex at a time. If a suitably clean solution is not arrived then, this process is re-run with a higher smoothness constraint. Finally, the outer surface of the skull is estimated [5].

FMRIB's Software Library (FSL) as an integrated software package made by FMRIB Analysis Group is one of the most widely used library for neuroimage analyses. In this paper, FSLversion 4.1 is employed for the whole process of skull stripping by BET that eliminates all non-brain tissue automatically [6].

B. BSE(Brain Surface Extraction Tool)

BSE is an edge-based method, uses a sequence of anisotropic diffusion filtering, Marr-Hildreth edge detection, and morphological processing to segment the brain within whole head MRI.

The image is smoothed to reduce noise using anisotropic diffusion filtering. Thereafter edge detection (Marr-Hildreth edge detector) is applied to the smoothed image. Finally, the edge image is further processed to identify the largest connected region and to smooth the surface of this region. The largest remaining connected region is assumed to represent the brain. An additional dilation and erosion is performed to fill in surface pits and small holes [7].

Brain Suit-BrainSuite is the updated version of BSE (Brain Surface Extraction Software) and is specifically designed for the purpose of cortical surface extraction. BrainSuite is an integrated package which can be used for soft tissue, skull and scalp segmentation and for surface analysis and visualization [7].

III. DATASET AND PERFORMANCE METRICES

A. BrainWeb Simulated Datasets

The 3D MR images are provided by the BrainWeb Simulated Brain Database from the McGill University. In order to perform an evaluation on segmentation methods integrated in the presented software, they are tested on simulated MR images [8].

In this pre-computed simulated brain database (SBD), the parameter settings are fixed to 3 modalities, 5 slice thicknesses, 6 levels of noise, and 3 levels of intensity non-uniformity. Simulated MRI Volumes for Normal Brain have four different parameters Modality, Slice thickness, Noise, Intensity non-uniformity ("RF")[8].

1) Modality

Magnetic resonance (MR) is a dynamic and flexible technology that allows one to tailor the imaging study to the anatomic part of interest and to the disease process being studied. With its dependence on the more biologically variable parameters of proton density, longitudinal relaxation time (T1), and transverse relaxation time (T2)[8].

2) Slice thickness

Slice thickness for plane pixel sixe is 1mm [8].

3) Noise

The "percent noise" number represents the percent ratio of the standard deviation of the white Gaussian noise versus the signal for a reference tissue. 3% noise is added in database [8].

4) Intensity non-uniformity

For a 20% level, the multiplicative INU field has a range of values of 0.90 ... 1.10 over the brain area. For other INU levels, the field is linearly scaled accordingly [8].

B. Performance Metrices

In this paper, Dice coefficient and Jaccard coefficient are the two measures, which represent spatial overlap between two binary images. These metrics are commonly used measures and their values range between 0 (no overlap) and 1 (perfect agreement).

1) Jaccard Inde

The Jaccard coefficient measures similarity between sample sets, and is defined as the size of the intersection divided by the size of the union of the sample sets [9]:

$$J(\mathrm{A},\mathrm{B}) = \frac{|A \cap B|}{|A \cup B|} \quad (1)$$

2) Dice Index

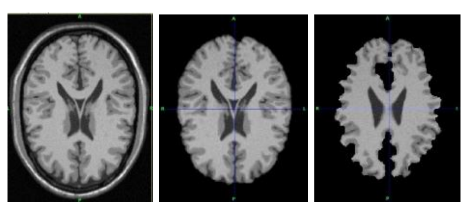
The Dice index is a statistic used for comparing the similarity of two samples. It was independently developed by the botanists Thorvald Sørensen and Lee Raymond Dice, who published in 1948 and 1945 respectively. Original formula was intended to be applied to presence/absence data[10], and is

$$D(\mathrm{A},\mathrm{B}) = \frac{2|A \cap B|}{|A| + |B|} \quad (2)$$

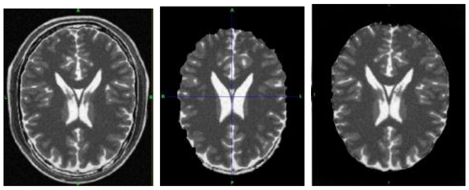
IV. RESULTS AND DISCUSSION

In first experiment, T1, T2 and weighted volumes with different levels of noise and non-uniformity are used as input of BSE and BET Tool. .Results in Fig I, II and III describe metrics for the following tests.

In this paper the manually segmented brain images as a Gold Standard for comparison. Illustrations of skull-stripping results are shown in Figure I ,II and III. Figure I and II axial section slice. The results of BET show that some of non-brain tissues are not skull stripped. According to parameters the results of BSE are near to ground truth.

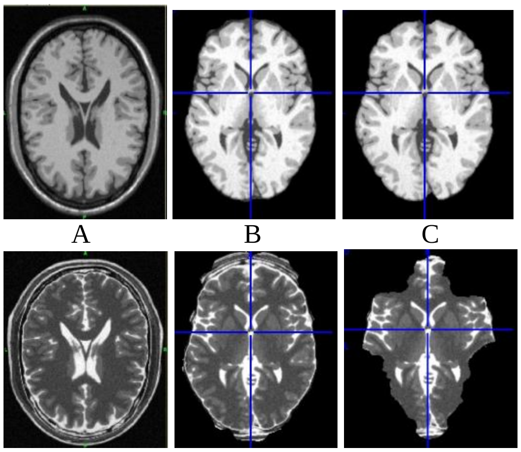


A B C



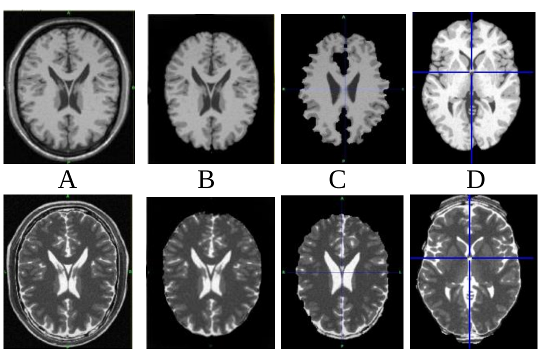
D E F

Fig. I Illustrations of skull-stripping result in axial section slice. Figure A is the Input data set(T1 weighted) B and C are result of BSE Tool for T1 weighted data. Figure D is Input data set(T2 weighted) E and F are results from BSE tool for T2 weighted data.



D E F

Fig. II Illustrations of skull-stripping results. Figure A is the Input data set (T1 weighted) B and C are result of BET Tool for T1 weighted data. Figure D is Input data set (T2 weighted) E and F are results from BET tool for T2 weighted data.



E F G H

Fig. III Illustrations comparison result of BET and BSE with manually stripped. Figure A and E shows the Input data set (T1,T2 weighted) , B and F are manually stripped results , C and G are result of BSE Tool for T1,T2 weighted data. Figure D and H are BET output results.

V. CONCLUSION

In this paper, a comprehensive comparison evaluation of two most widely used neuroimage analysis software was presented. This analyzed the MRI brain image such as axial - T1 weighted, T2-weighted, PD-weighted. Brain segmentation is widely used as a preliminary step in many MR image-processing methods. Different MRI data sets may be collected under various conditions. Under the quantitative comparison of the performance of Two Brain extraction Algorithm (BEAs) – Brain surface Extractor BSE, BET against the ‘‘Gold Standard’’ of manual brain extraction using MRI brain volumes, simulation. As the results of experiments over simulated datasets, BSE outperforms BET in segmentation of brain image.

VI. REFERENCES

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