Skull Stripping and Automatic Segmentation of Brain MRI Using Seed Growth and Threshold Techniques

Shanthi K. J[1] , Dr. M. Sasi Kumar[2]

[1] Assistant Professor , Dept. of Electronics & Comm. Sree Chitra Thirunal College Of Engg.,

[2]Professor , Dept. of Electronics & Comm. Marian Engg. College,

University of Kerala, Thiruvananthapuram

Abstract: Segmentation of human brain from MRI scan slices without human intervention is the objective of this paper. A simple and accurate method is developed for extracting the brain tissues from the T1 weighted MR Images. The DICOM images are used for segmenting. A hybrid of threshold and seed growth techniques are used in classifying the brain tissues into White matter (WM), Gray matter (GM) and Cerebrospinal Fluid (CSF).

1. Introduction

Brain Segmentation is an area which has attracted researchers immensely. Brain segmentation has potential applications in diagnosing many ailments.

i. Segmentation of human brain images helps in analyzing the volumetric changes. Different neural disorders affect the volume of different cranial tissues within the brain. Segmentation and volumetric analysis is applied in diagnosing neural disorders like multiple sclerosis, stroke and Alzheimer's disease. Diagnosing these disorders need very accurate determination of volumetric changes of White matter, Gray matter and CSF.

ii. Segmentation helps in determining lesion growth and early detection of tumor [7].

iii. Segmentation also helps in planning neurosurgery.

In this paper we have considered 3D Magnetic Resonance Imaging, as this offers many advantages in imaging soft tissues over other imaging modalities. T1 weighted axial MR Images are used as T1 weighted images have best resolution.

2. Existing Techniques

There are semi automatic segmentation methods and fully automatic methods to replace the time intensive manual segmentation. Segmentation is based both on conventional image processing techniques and fuzzy and neural networks. An overview of the different technologies developed and applied for brain segmentation is listed here:

1. Threshold determination and classifying the regions based on the threshold value is one of the primitive methods that is commonly applied.

2. Edges can be determined between the different regions using many of the edge determination techniques [1]. Smoothing filters can also be used to preserve the details inside the region.

3. Many works are presented using Fuzzy classification methods with Fuzzy K means and FCM algorithms [9] and [10] .

4. Neural network methods are also applied [10] and [12].

5. Neuro-fuzzy algorithms are also developed for image classification in general [13].

Very little effort has been made to compare the existing techniques [2].

We have used automatic threshold value determination for the different tissues from the histogram and combined this with the 2D region growing method to segment the cranial tissues.

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3. Segmentation Method

Segmentation refers to the process of extracting features of interest from images. Regions of interest within an image will have certain characteristic properties like intensity or texture constant. And these characteristic properties will be significantly different in the neighbourhood. An image can be sliced into multiple regions, providing a clear computer vision into localized regions. Brain MRI segmentation aims at extracting the brain tissues WM, GM and CSF from the MRI pictures.

Our approach to the segmentation problem can be categorized as shown in fig.1

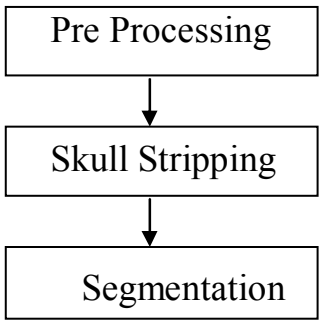

Fig.1 overview of classification

3.1. Pre processing

Pre processing forms an important step in all image processing applications. The high frequency noise induced in the image can be effectively removed using filters. Different mask sizes can be used to implement low pass filters. We used low pass filter to remove any high frequency noise speckles present in the image. The raw MRI image is first passed through a Low Pass Filter to be used for segmentation.

3.2. Skull stripping

The MRI picture has both the skull and the brain tissues. To segment the brain, the brain tissues which are of interest need to be extracted from the original image. The surrounding skull tissues are removed from the MR Image to achieve this. This process of removing the skull tissues is termed as Skull Stripping. Many skull stripping methods are employed [3] and [4].

The main feature of our algorithm is that we have exploited the anatomy of the brain to strip the skull and segment the tissues. Our algorithm becomes totally automatic as all the intensity values are automatically determined from the histogram. The simplicity of the algorithm is that the intensity values of the image are used to help stripping and no shape model is defined for the skull unlike [4].

The T1 weighted axial images show a distinct region of separation between the surrounding tissues and the brain tissues. This makes it simple to look for this change in the intensity level and strip off this part. To make the algorithm more robust we have sampled the background pixels and determined the mean intensity value. The mean intensity of the darker background was determined on either side separately, any pixel value more than the mean value detects the beginning of the outer ring of the skull. The entire image was scanned row by row on either side. Entering the outer ring, the inner ring which is the darker region inside the skull is again checked. The pixel inside this region is checked for its darker neighbourhood. Once this region is found all the pixels in that row till this pixel are darkened. And the search begins with the next row. For skull stripping we have reduced the computation time by stopping the search for skull tissues, once the darker region is encountered. This process was repeated from both right and left side of the image. This removes the skull effectively and leaves the brain tissues along with the Dura.

Dura Removal: After the skull being removed the Dura is left with the brain tissues. We removed the Dura by setting a threshold value relative to WM and GM. Dura was removed scanning from left, right, top and bottom. The scanning was not allowed deeper into the brain tissue as this would remove the CSF inside the ventricles. Thus at this stage we were left with only WM, GM and CSF inside the ventricles.

With the skull tissues and the Dura being removed we are left with only the tissues of our interest.

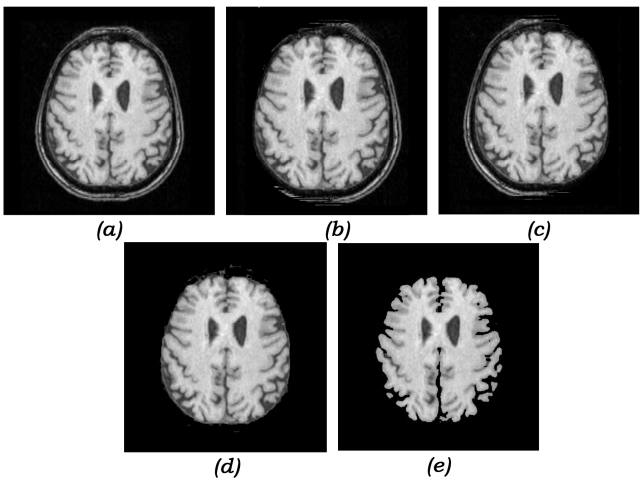

fig.2: Showing different stages of skull stripping
a. Original image b & c Partially stripped d. Skull removed e. Dura removed

3.3 Segmentation of Brain Tissues

a. Histogram Analysis

Once the brain tissues were extracted from the MR Image after skull stripping, segmentation of the brain tissue into three different classes of interest White Matter, Gray Matter and Cerebrospinal Fluid was carried out. We have made use of threshold application and seed region growing techniques. A 3D seed growing method looking for 26 adjacent pixels is developed in [5]. We have used the global histogram of the picture to automatically segment the tissues. For choosing the seed values and applying the threshold limits from the histogram, we have made use of the prior knowledge that the brightest region of the pixels in the skull stripped image represents WM and a predefined margin is fixed for GM from that of WM. This characteristic remains same from image to image though the pixel values might itself change. These values are detected for every slice from the histogram. Thus the human intervention is not called for in deciding the seed value.

b. Segmenting White Matter

Histogram regional maximum value was used for picking up pixels representing WM. A small offset was given to the regional maximum to decide the seed value for the WM. All the WM pixels were segmented using region growing choosing the four point neighbourhood connectivity. First the pixels with the white matter seed value are set to 1 in a mask. Now, we define a pixel to be white matter if it has an intensity greater than the seed value and is four point connected to any pixel whose corresponding pixel in the mask is set to 1. If the condition is satisfied, the pixel corresponding to this point in the mask is set to 1.This process is continued for a predefined number of iterations. After the WM mask is grown completely, we used image arithmetic [6] between the two images i.e with the skull stripped image and the WM mask to extract WM.

c. Segmenting Gray Matter

Segmentation in the previous step removes White Matter. This leaves the skull with Gray Matter and CSF. The Gray Matter pixels appear less brighter than the White Matter pixels. The GM pixels are detected giving an offset from the WM intensity values. We grow the mask for Gray pixels by setting pixels with the Gray Matter threshold value to 1 in the mask. Now, we follow the same seed growing method looking for the four point neighbourhood connectivity and extract the GM. The mask developed for GM combined with the skull stripped and segmented WM is used to separate GM.

d. Segmenting Cerebrospinal Fluid (CSF).

After successfully segmenting the WM and GM and removing them from the skull stripped image. CSF is segmented from the skull stripped image without seed growing. Only image arithmetic is used to extract CSF.

The different stages in which segmentation is carried out is outlined in the following flowchart.

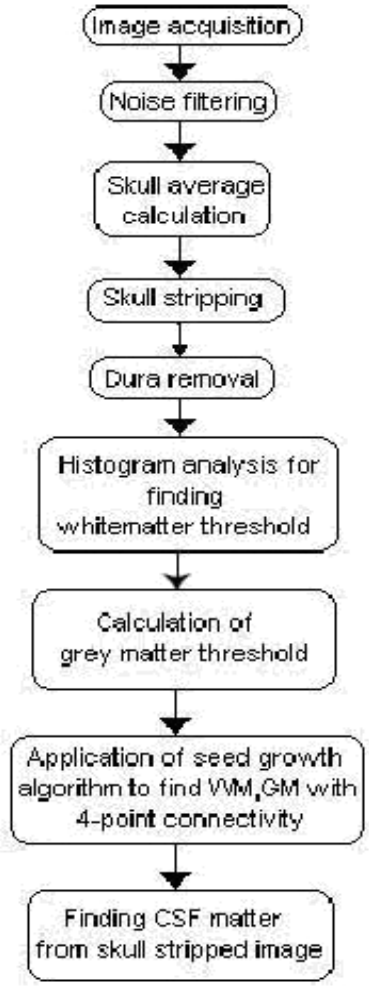

fig.3: Detailed Flowchart

TEST RESULTS

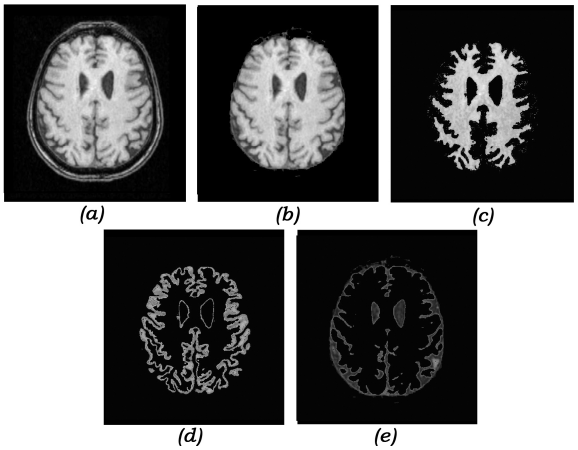

fig. 4. Segmentation of brain tissues of mid MRI slices, slice No. 44. a. Original image, b. Skull stripped c. Segmented WM d. Segmented GM e. Segmented CSF

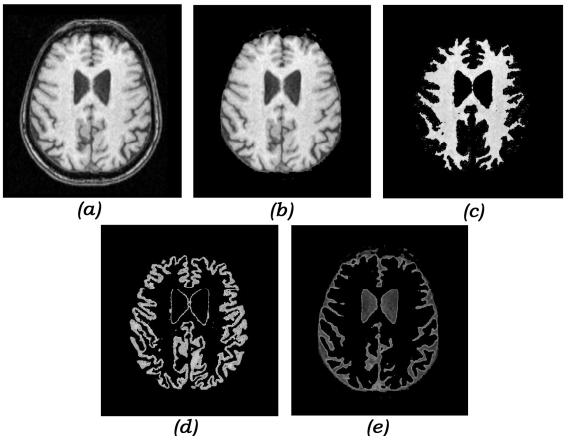

fig. 5 MRI Slice 46 (size of the ventricles larger) a.Original image, b. Skull stripped c. Segmented WM d.Segmented GM e. Segmented CSF

Conclusion: Segmentation using our algorithm gave good results. The high frequency speckles in the images are removed. The algorithm is mathematically simple as it involves only intensity based manipulations and scanning for

particular intensity values. The seed values are automatically chosen and a preset margin is defined between tissues. We have allowed a smaller variation in the intensity values so that intra intensity variations within a class of tissues is addressed. All these make our algorithm completely automatic.

The number of iterations used in seed growing is lesser compared to the iterations in fuzzy classification. The algorithm does not require that the picture be positioned at the center in the background. Our algorithm can be improved by checking for the 3 dimensional connectivity of the tissues between the adjacent slices. The intensity values passed from the histogram peak and the variations of the intensity values between WM, GM and CSF considered in our algorithm gave good results. Our algorithm shows slight under segmentation for CSF. We ran our algorithm on many mid slices of T1 weighted axial images in DICOM format. We chose mid slices as the ventricles are more prominent in these slices.The results are shown in fig. 4 and 5 for two different slices. The results were confirmed by a neurologist. Our algorithm is implemented in MATLAB on Pentium machines. The C code can be easily written in a matter of few days by expert programmers.

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