

# Segmentation of the White Matter from the Brain fMRI Images

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**Abstract**— Segmentation of the white matter from the brain fMRI images for the study of brain activities and for the diagnosis for various brain related diseases caused by the changes and damages to regions of the brain continues on a manual time consuming segmentation technique. We present a solution for automatic segmentation of the brain fMRI images; the solution contains three steps which are pre-processing the raw images, threshold estimation using an Otsu's algorithm and finally performing the segmentation by binarization of the images based on the calculated threshold value.

**Index Terms**— brain, fMRI, grey matter, threshold, segmentation, white matter.

## I. INTRODUCTION

The fMRI stands for functional magnetic resonance imaging is an MRI procedure that measures brain activity by detecting associated changes in blood flow [1], unlike MRI images which gives only the structural aspects of the brain fMRI provides both the structural and the functional aspects of the brain. Hence this feature allows the physicians to study the functionalities of the brain as well as to diagnose the brain related diseases.

There are three parts in fMRI projections of which are grey matter [2] formed basically by neurons, white matter[3] formed by axon extremities with myelins, and cerebrospinal fluid, changes and damages in these regions can cause various diseases. The white matter segmentation from the brain images plays a major role in the study of brain activities, based on the distribution of the white matter in the brain it is possible to determine which part of the brain is more active while performing certain activities, for example brain activity study involves determining the structure and the distribution of the white matter when a person is happy, sad, watching TV, walking or performing other day to day activities etc. the white matter segmentation also enables in the diagnosis of the white matter diseases[4], MS(multiple sclerosis) and demyelinated diseases, minor cardiovascular diseases, neurologic damages, and blindness can be listed.

## II. LITERATURE SURVEY

The fMRI images can be taken in three views namely coronel, axial and sagittal. Each of these views typically contains 60 to 70 image slices. The current method of segmentation of the white matter from the brain fMRI images is done using a manual segmentation (hand segmentation), this method has the following disadvantages:

- Time consumption: It takes around 48 to 72 hours to manually segment the white matter from the gray matter of the brain fMRI images.
- Extra Labor: To manually segment the white matter from the gray matter of the brain fMRI images it requires a skilled labor with good training and experience
- Lots of paper work: As the process of segmentation is non reproducible. The entire process has to be repeated if the image is slightly changed or if there are minor errors in the process, hence requires a lot of paper work.

In order to analyze anatomical structure in 3D volume data, physicians need reliable segmentation methods. One of the most frequently addressed problems is the segmentation of MRI images of the human brain into gray matter and white matter.

In recent years several methods for this have been made available to the public, e.g. Freesurfer, slicer and SPM. All those methods rely on a registration of the analyzed imaged with pre-computed anatomical atlas providing a priori information about spatial distribution of the tissue types. The anatomical knowledge incorporated into the atlas allows high quality segmentation, even when structures are hard to distinguish visually. However, registration with an atlas is time consuming and might not find a globally optimal solution or even fail completely in the case of strong anatomical anomalies. In those cases physicians have to fall back and prone to inter-rater discrepancies.

In 2005 and 2006, a new atlas free brain segmentation method was shown to able to deliver results of similar quality to those produced by the established atlas based SPM method even in the case of images without anatomical anomalies. The method builds upon the 3D-CSC, a general segmentation

voxel images which partitions 3D images into gray value similar, spatially connected regions. In 2007, several improvements were introduced to 3D-CSC based segmentation of T1 weighted MRI images into white matter, gray matter and non brain which further enhance both reliability and quality while pertaining the computational complexity of the method. As no time consuming registration step is needed, the method is not only reliable, but also very fast

### I. PROPOSED SOLUTION

The fMRI brain images are captured using a fMRI scanner will be in the form of Digital Imaging and Communications in Medicine (DICOM) format, 60 image slices of a coronel view of the brain is used in our experiment, figure 1 shows a centre slice of typical fMRI brain image in a coronel view

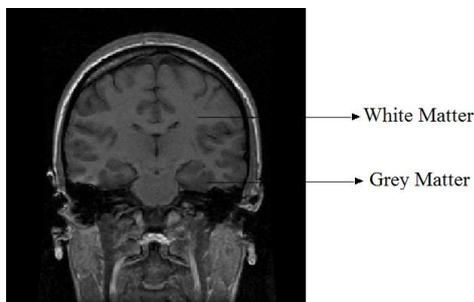


Fig. 1 A Brain fMRI image in coronel view showing white matter and grey matter

The main objective is to extract the white matter from the rest of the image so that end users can analyze the segmented result, the overall process of achieving this result and the flow of data is shown in the figure 2.

As shown in the figure 2 the fMRI DICOM images are obtained from the fMRI scanner will be stored in the Medical information centre database, these data are obtained by the system to perform white matter segmentation which includes three steps preprocessing, threshold value estimation and finally performing the segmentation procedure based on the previously calculated threshold value, these three steps are in detail in the following sections. The segmented white matter binary image will be stored in the Medical information centre database and finally the segmented white matter is analyzed and examined by the physicians.

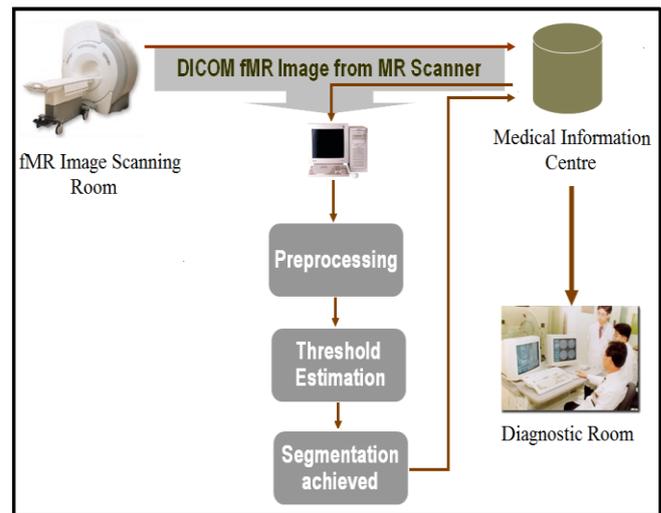


Fig. 2 A Brain analysis system architecture

#### A. Preprocessing

The fMRI images should be preprocessed to remove the noise before performing the segmentation operation. Figure 3 shows the result of the segmentation process without performing the preprocessing step.

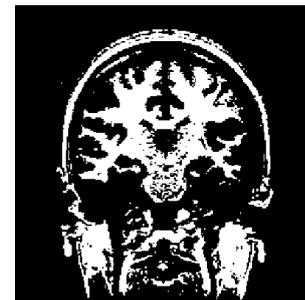


Fig. 3 Segmented result without preprocessing

As shown in figure 3 the segmented result contains noise in terms of background colour, skull bone, hard tissues, cerebrospinal fluid and air. The preprocessing step involves using a histogram based double thresholding technique to remove the noise particles and to obtain the only the soft tissue structure of the brain containing white matter and grey matter.

Figure 4 shows the histogram distribution for the image in figure 1, pixel count is taken in y-axis and the intensity is taken in the x-axis, the pixels that are bounded by the red rectangular box forms the soft brain tissues and the rest of the pixels outside the rectangular box are considered as noise and are removed by using a double thresholding technique [6].

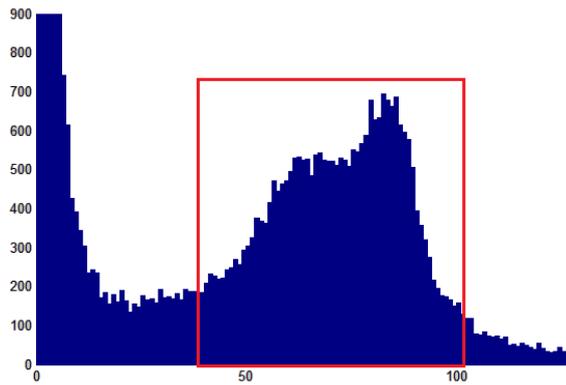


Fig.4 Histogram of the fMRI image showing pixels which forms the soft tissue of the brain

Here we make use of two threshold values  $threshold_1$  and  $threshold_2$  and then apply a thresholding operation as: A pixel becomes black if its value is lesser than  $threshold_1$  or greater than  $threshold_2$ , and will remain as it if the pixel value is found to be in-between  $threshold_1$  and  $threshold_2$ , for example let  $X$  be a pixel value whose value ranges from 0 to 255, then the following algorithm is applied

Algorithm preprocessing (input  $threshold_1$ , input  $threshold_2$ , input histogram)

```
{
if histogram is above  $threshold_1$ 
if histogram is below  $threshold_2$ 
return 1
else
return 0
}
```

In our experiment we have taken  $threshold_1$  as 40 and  $threshold_2$  as 100, the pixel values less than 40 are found to be a noise in the form of background colour, CSF and air, the pixel values greater than 100 are found to be a noise in the form of skull bone and hard tissue, the result after performing the preprocessing step by applying double thresholding is shown in figure 5.

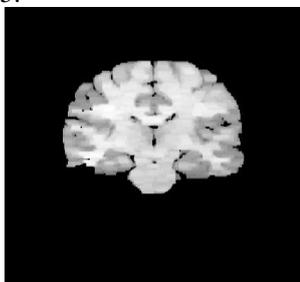


Fig. 5 Segmented result with preprocessing

### B. Threshold estimation

After obtaining the preprocessed data the next process involves the calculation of threshold value to perform the white matter segmentation from the rest of the image, the threshold value is obtained by using a global thresholding method called Otsu's algorithm [7]. Otsu's method selects the threshold by minimizing the within-class variance of the two groups of pixels separated by the thresholding operator. Here we briefly explain the calculation of threshold value

For more technical details, see [8]. The algorithm works as follows:

- Compute the normalized histogram of the input image. Denote the components of the histogram by  $P_i$ , for  $i = 40, 41, \dots, 100$ .
- Compute the cumulative sums,  $P_1(k)$ , for  $k = 40, 41, \dots, 100$ .
- Compute the cumulative means,  $m(k)$ , for  $k = 40, 41, \dots, 100$ .
- Compute the global intensity mean,  $m_G$ .
- Compute the between-class variance,  $\sigma_B^2(k)$ , for  $k = 40, 41, \dots, 100$ .
- Obtain the Otsu threshold  $k^*$ , as the value of  $k$  for which  $\sigma_B^2(k)$  is maximum. If the maximum is not unique, obtain  $k^*$  by averaging the values of  $k$  corresponding to the various maxima detected.
- Obtain the separability measure,  $\eta^*$  at  $k = k^*$ .

The obtained threshold value is then used to perform segmentation in the next step.

### C. Segmentation

The segmentation of the white matter from the rest of the brain image can be simply achieved by performing the binarization process based on the threshold value obtained from the previous step. All the pixels with the intensity values greater than the threshold value are made white and all the pixels with the intensity values lesser than the threshold value are made black, this process gives the structure of the white matter distribution in various regions of the brain, the binarization is performed as follows:

Let  $X$  be the pixel having intensity value ranging from 40 to 100, then let  $T$  be the threshold value obtained from previous step, The pixel value greater than  $T$  is changed to 1 and the pixel value lesser than  $T$  is converted to 0. The following algorithm is applied

Algorithm segmentation (input threshold, input histogram)

```
{
if histogram is above threshold
return 1
else
return 0
}
```

The segmentation result is shown in figure 6, the segmented result is of the white matter from the brain in a binary image format.



Fig. 6 Segmented result of the white matter from the rest of the brain

## I. CONCLUSION

The proposed solution is a simple technique used for an automatic segmentation of the white matter from the brain fMRI images; the experiment was conducted on all 3 views of single brain image with each view having 60 slides of data, the experiment has shown an accurate extraction of the white matter in all the three views. The segmented results are found to be useful in the study of brain as well as with the diagnosis of white matter related diseases.

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