AN EFFICIENT SKULL STRIPPING ALGORITHM USING CONNECTED REGIONS AND MORPHOLOGICAL OPERATION

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ABSTRACT

Many diseases can be diagnosed by using segmentation and classification based on neural networks. The efficiency of the classification algorithm and the final output depends on the quality of input image. The input image may not have the fine qualities to produce a perfect output. In such scenario pre-processing plays an important role in the improvement of overall quality of the image. In this paper we propose various pre-processing steps that can be used in the framework for fully automatic tissue classification of Brain MR (Magnetic Resonance) images. Contrast enhancement and skull stripping are the pre-processing steps explained in this paper. A novel skull stripping algorithm is proposed and experimental results are illustrated. Skull stripping improves the efficiency in detecting tumors and other abnormalities in brain. The proposed skull stripping method is based on connected regions and mathematical morphology. Experiments are conducted on T1-weighted MR images obtained from radiopedia medical image database.

Keywords: skull stripping, connected regions, contrast limited adaptive histogram equalization (CLAHE), contrast enhancement, mathematical morphology.

INTRODUCTION

Brain MRI has been widely used in various medical applications that are helpful in detecting brain abnormalities such as brain tumor, cancer, multiple sclerosis, paralysis etc. Skull stripping is an important pre-processing step in brain image analysis. Skull stripping can be considered as one of the important pre-processing steps in brain image analysis. Skull stripping is the process of delineation and removal of non cerebral tissue region such as skull, scalp, meninges, vein etc. from the cerebrum. Misclassification of abnormal tissues can be avoided by removing the skull region. Variability in the anatomy of human brain, variable parameters of scanner, individual characteristics, complexity of human brain structure etc. are the various challenges faced by the skull stripping process. Various robust and efficient algorithms have been developed in order to reduce these artifacts. Skull stripping can be done using various methods such as region growing techniques, thresholding, mathematical morphology etc. A brief review on these methods will summarize the benefits and drawbacks of each one.

In region growing we need a seed pixel to start the process. The neighboring pixels of the starting seed are appended based on predefined criteria. Thus the region grows by appending the seed pixel with the neighbouring pixels that have similar properties as that of seed pixels. One of the major disadvantages of this method is that we have to select the seed regions manually. Another disadvantage of this method is the application of threshold value. That means a human supervision is required for implementing this method. In order to avoid this problem Park et al proposed an algorithm that selects seed regions automatically. The seed regions correspond to non brain and brain regions are selected by the algorithm. The major advantages are low noise, good contrast and homogeneity in intensity.

Thresholding is another method for skull stripping. This method is binary images created from grey level images by converting all pixels below a particular threshold value to zero and rest of the pixels to one. It is important to select an appropriate value for extracting different objects from the background. Non rational properties and simplicity of implementation makes thresholding algorithms very useful in image segmentation. But it is still difficult to select a robust threshold which can produce a good output for a wide set of images. We can subdue this problem by using double threshold method.

Morphological operations can be used for extracting components from an image. Mathematical morphology is widely used to separate the brain tissues from the surrounding and the dilution operation can be used to remove unwanted regions. The inputs to these types of operations are binary images. Morphological operations are simple and efficient for finding distance between pixels and extracting neighbourhood information during segmentation process. The major disadvantage is that, it requires binary image with objects and background regions.

METHODOLOGY

In this paper we introduce a novel algorithm for skull stripping. The method involves contrast limited adaptive histogram equalization (CLAHE), thresholding, finding the connected regions and morphological operation. Image enhancement and skull stripping are the two main operations in this method. The main advantages of this method are reduced computational complexity,
accuracy and flexibility. Detailed process flow of the proposed method is shown in Figure-1.

**Figure-1.** Process flow of proposed skull stripping method.

### A. Input Image

Input images are obtained from radiopedia.org, an open source medical image database. The image obtained from the database has been scaled down to reduce the computational complexity. Three types of images used as input are T1-weighted, T2-weighted and FLAIR (Fluid Attenuated Inversion Recovery). The images used here are axially oriented. Figure-2 shows the anatomy of cerebral and non cerebral tissues (skull region). The dataset consist of images from adults of age group 18 to 60.

**Figure-2.** Magnetic resonance image showing anatomy of human brain.

### B. Contrast Limited Adaptive Histogram Equalization (CLAHE)

Histogram represents the intensity distribution of pixels in an image. Histogram equalization is a method of contrast adjustment. By applying normal histogram equalization all intensity values have equal distribution over the image.

Thus the overall contrast will be enhanced. This may result in over contrast in particular regions of the image. To avoid this problem contrast limited adaptive histogram equalization (CLAHE) is used. CLAHE computes several histograms correspond to different sections in an image. These histograms are used to redistribute the luminance level of the image. The major advantage of this method is that we can improve the local contrast by selecting appropriate clip limit.

$$I_{c_{\text{out}}} = [I_{c_{\text{max}}} - I_{c_{\text{min}}}] \times F_k(I_{c_{\text{in}}}) + I_{c_{\min}}$$  \hspace{1cm} (1)

where,

- $I_{c_{\text{max}}}$ is the maximum allowed intensity,
- $I_{c_{\text{min}}}$ is the minimum allowed intensity,
- $I_{c_{\text{in}}}$ is the input intensity,
- $I_{c_{\text{out}}}$ is the equalized output intensity.

Probability density function (PDF) of a particular intensity level $I_k$ in the output is given by

$$f_k(I_k) = \frac{n_k}{N}$$  \hspace{1cm} (2)

Cumulative distribution function (CDF) of a particular intensity level $I_k$ in the output is given by

$$F_k(I_k) = \sum_{j=0}^{k} f(I_j)$$  \hspace{1cm} (3)

Where $n_k$ is the number of pixels with intensity level $I_k$ and $N$ is the total number of pixels.

### C. Thresholding

Thresholding is the process of converting the original image into a binary image. The values of the pixels will be converted to either level 0 or level 1 and there will not be any grey levels. For example, in an 8 bit image 0 is represented by (00)$_{16}$ and 1 is represented by (FF)$_{16}$. Threshold intensity level taken for experimental
purpose is 40 and this value was obtained using trial and error method. The pixels above intensity level 40 are considered as 1 and below 40 are considered as 0.

\[ F_{th}(x,y) = \begin{cases} 
1 & \text{if } I_k(x, y) \geq 40 \\
0 & \text{if } I_k(x, y) < 40
\end{cases} \] (4)

where, \( F_{th}(x,y) \) is the threshold image and \( I_k(x,y) \) is the intensity of pixels in the image and the value ranges from 0 to 255.

D. Connected regions

The threshold image is converted into N number of connected regions. Each of the connected regions is labeled using a number. Length of each connected regions is found out. Thus we get the largest connected region from a set of connected regions.

E. Preparing the mask

The largest connected region is obtained and the inside of this region is filled with holes. Thus we get a white shape same as that of the shape of the brain in a black background. This is a binary image which consists of only black region and white region.

Algorithm 1: Skull stripping using connected regions and morphological operation.

Step 1: Get the input image.
Step 2: Apply CLAHE for contrast enhancement.
Step 3: Apply threshold and convert into binary image.
Step 4: Find the connected regions.
Step 5: Find the largest connected region.
Step 6: Fill the largest connected region with holes.
Step 7: Get the complement of the image.
Step 8: Apply morphological dilation.
Step 9: Get the complement of the image.
Step 10: Multiply pixel-wise with the output of step 2.
Step 11: Get the skull stripped output image.

Figure-3. Proposed skull stripping algorithm.

After dilation the area of the black region reduces. The image thus obtained is again inverted and a white region in a black background is obtained. This is the required mask for skull stripping.

F. Applying the mask

The mask image is multiplied with the enhanced brain image (pixel-wise multiplication). Each pixel in the enhanced image is multiplied with the corresponding pixel in the mask. The output thus obtained is the skull stripped image.

EXPERIMENTAL RESULT

The input image is Magnetic resonance image (MRI) obtained from radiopedia medical database. Size of the image is 212 x 229. Since the algorithm is adapted to work on any image size, there is no need for image resizing. Contrast Limited Adaptive Histogram Equalization (CLAHE) is used for contrast enhancement. The input image, histogram of input image, histogram equalized image and the corresponding histogram is shown in Figure-4. By comparing the two histograms we can understand how the contrast level is enhanced.

In the next step the enhanced image is converted into threshold image of binary values. From the threshold image, connected regions are computed and are illustrated in Figure-5. Each connected regions will be assigned a length, so that the largest connected region can be found out.

Figure-4. (a) Input image, (b) Histogram of the input image, (c) Contrast enhanced image using CLAHE, (d) Histogram of the enhanced image.
In the mask preparation process the largest connected region is filled with holes and the image thus obtained is inverted. In the next step, the white region in the inverted image is dilated using a square structural element of size 3x3. The image thus obtained is inverted to get the mask image. The mask preparation steps are illustrated in Figure-6. The mask is applied to the enhanced input image to get skull stripped image which shows the details of brain region. The skull stripped image is shown in Figure-7 which has good contrast and displays the region of interest.

CONCLUSIONS

We have presented a skull stripping method that uses connected regions and morphological operation to segment the brain region from the input MR image. This algorithm exploits the dilation property of mathematical morphology to find the regions to be stripped off. We have evaluated our method on FLAIR, T1-weighted and T2-weighted MR images. The algorithm is very much effective in contrast enhancement, accuracy and speed of computation. The complexity of computing is very much reduced by using this algorithm. Future research work includes the incorporation of this algorithm in the framework for brain MRI segmentation and classification. Better results will be obtained by applying skull stripping during pre-processing.

REFERENCES


