Implementation of Marker based Watershed Image Segmentation on Magnetic Resonance Imaging

Ayesha Khalid Khan, Gulistan Raja and Ahmad Khalil Khan

Department of Electrical Engineering, University of Engineering & Technology, Taxila, Pakistan
gulistan.raja@uettaxila.edu.pk

Abstract: Medical image segmentation is a prominent method to segment out specific regions of a given medical image. In this research paper we have implemented marker based watershed segmentation technique by applying different detection operators on MRI test images. The image is converted into grey scale and then its gradient magnitude image is found by different detection operators. The thresholded image is taken to show the image details in binary representation. The binary image is processed using marker based watershed technique for segmentation where different morphological operations are performed. Image parameters of the segmented image with respect to the input image in the optimum range are computed. The output shows the successful segmentation of different regions of the MRI. The results are evaluated on the basis of different image parameters namely Structural Similarity Index Measure (SSIM), Normalized-Cross Correlation (NCC), Mean Square Error (MSE) and Standard Deviation (SD). This technique has been implemented in the MATLAB 7.6.0(R2008a).

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Key words: Watershed, Detection operators, SSIM, NCC, MSE, SD

Introduction

Segmentation of a 2D medical image is performed to segment out different anatomical regions of interest for analysis. The particular diagnostic area has its own different properties which makes it more important than rest of the medical image. Segmentation techniques are used in medical imaging to segments out different regions of a medical image for investigation of its various parts for diagnosis. The characteristics on which segmentation is based on are colour, texture, intensity values and many more. Therefore from the medical point of view, segmentation techniques play vital role in the partition a medical image into specific sections of interest (Liu, 2011). Proper segmentation doesn't only provide valuable information to the clinicians but also to the patients for early surgery visualization and detection (Zhang, 2012). Literature review reveals there are some main methods of segmentation of images which are namely edge based segmentation, special theory based segmentation and region based segmentation.

This paper describes the implementation of marker based watershed technique which is based on region based segmentation. This technique is selected because of its efficiency to segment out different regions and it has shown optimum results for a given MRI image. The rest of the paper will give the overview of different segmentation techniques, working of marker based watershed segmentation technique, based on region based segmentation, with different detection methods and the output results of image parameters on MRI test image.

Overview of Segmentation Techniques

Some prominent segmentation techniques found in image segmentation are edge based, special theory based and region based segmentation. The tree structure of image segmentation types is shown in Figure 1.

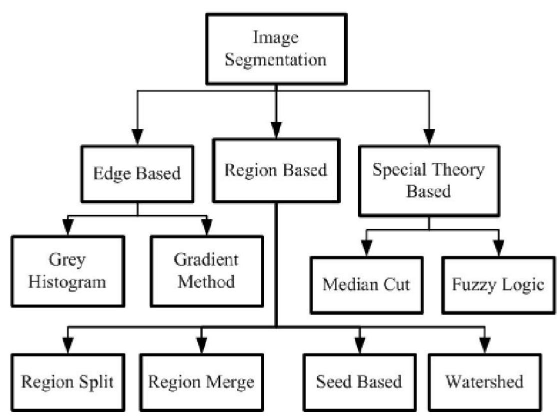

Figure 1 Types of Image Segmentation

In edge based segmentation linked pixels are present on the edges of different segments because of extreme discontinuities. The disadvantage of this method is that it is immensely influenced by the noise which may lead to faulty results like fake edges making the boundaries unacceptable for the detection (Whitey, 2007).

Special theory based segmentation is based on fuzzy clustering and neural network based segmentation. The drawback of this technique is the complexity in the attributes of the fuzzy members which makes this method more difficult to implement (Raja, 2009).

The third kind of segmentation technique used is region based segmentation, associated with an initial pixel point value and its corresponding similar pixels (Khalid, 2010). Region based segmentation can be further classified into further types which are seed dependent region augmenting type segmentation, region merging, region splitting and watershed segmentation.

In seed dependent region augmenting type segmentation, region augments based on the pixels alikeness. When a certain pixel having a certain property matches with its adjacent pixel of the same type, the region grows as long as the pixels encounter the pixels of different characteristics (Huilin 2011).

Region merging based segmentation is based on each single pixel representation. This method starts to segment out an image into small segments based on a specific condition. After defining the criteria all the regions which are according to the specific condition will be merged into each other and all the disjoint regions will be segmented separately (Ansari, 2007).

In region splitting, the basic idea is to split a given image into several disjoint regions. It is the inverse of region merging in which firstly the whole image is considered as a single region which doesn't satisfy a specific condition. The process continues until no further splitting takes place. The output results of this technique are different from the region merging method even if the same criterion is used (Zhang, 2007).

The above mentioned techniques are well suited for specific applications but they do have certain flaws in them. Seed dependent segmentation gives some errors in edges and boundaries. Split and merge shows erroneous results when intensity change takes place in pixels. On the other hand watershed segmentation has capability to segment out an image efficiently into its constituents, but it suffers from over-segmentation. This problem can be overcome by using the marker based technique with certain enhancements.

Watershed is actually a topographical term which is based on an analogy that if a drop of water falls from somewhere on a landscape, it will flow down towards the river or any other frame of water at the end no matter what happens. As shown in Figure 2, this frame of water in which the drop of water falls at the end is known as the catchment basin in jargon of watershed image segmentation (Wiley, 2008). There exists some point of local minima linked to every catchment basin, and each catchment basin is separated from another one by watershed lines or mainly known as watersheds. So the division of the landscape is achieved by properly segmented regions on the landscape by watershed lines separating the catchment basins based on respective local minima (Kaur, 2011).

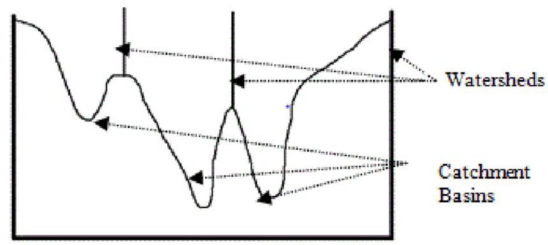

Figure 2 Two dimensional view of Watershed

Implementation of Marker based Watershed Segmentation

The five steps of implementation of marker based watershed segmentation are shown in the block diagram in Figure 3.

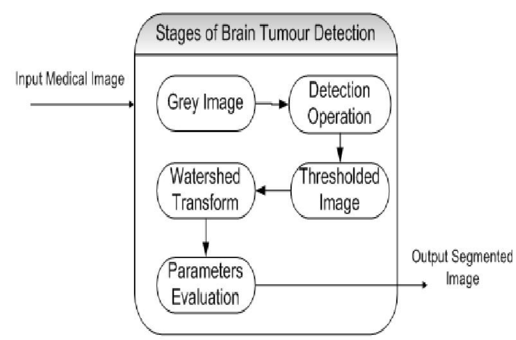

Figure 3 Stages of brain tumor detection

The five steps of the marker based watershed implementation are:

1. RGB to grey conversion
2. Gradient Operator
3. Thresholded Image
4. Watershed Transform
5. Parameter Evaluation

The first step involves the conversion of input RGB image into grey scale image. In 2nd step gradient magnitude of grey scale is found by using four detection operators which includes sobel, prewitt, LoG (Laplacian of Guassian) and kirsch operators. The output of gradient magnitude is then sent to 3rd step, where the threshold of the image is obtained to see the details of the input image in binary form. Now the marker based watershed is applied. This step can be better understood by considering a grey pixel value of an image. Let $B \subseteq D^2$, and suppose $f: B \rightarrow N$ is grey value of image with $t_{\min}$ and $t_{\max}$ are minimum and maximum values of f. There exist local minima for defined catchment basins. If U_t is the union of the all catchment basins then M_{t+1}, will be the new limit at $t+1$. This point can be called a new local minima or widening of the catchment basin in M_t. In other words M_{t+1}, is a new addition in territory of U_t. if Z_t represents all the minima having altitude t, $t \in [t_{\min}, t_{\max}]$, then above scenario can be described in equations as:

$$U_{t\min} = \{p \in B \mid f(p) = t_{\min}\} = M_{t\min}$$
$$U_{t+1} = Z_{t+1} \cup ID_{Mt+1}(U_t)$$

The segmented image will have the markers around different regions of the input image. At the end, various parameters are computed to check the performance of implementation.

Experimental Results

Experimentations are performed on Intel®Core™2 Duo P9400 2.40GHz processor with 2GB RAM and 64-bit operating system using MATLAB R2008a. The effectiveness of the algorithm is evaluated on the basis of different detection operators which are sobel, prewitt, LoG, and kirsch.

There are number of parameters used for determining the effectiveness of the implemented algorithm by using different detection operators. For this purpose, Normalized Cross-Correlation (NCC), Mean Square Error (MSE), Structural Similarity Index Measure (SSIM) and Euclidean distance of Standard Deviation (SD) of LBP images are used to check the imperceptibility and robustness.Table.1 shows the averaged values of four image parameters of 30 MRI test images by using different detection operators on watershed transform. It is clear that the value of the SSIM by using sobel, prewitt and kirsch operator shows better result than LoG. NCC for all the operators shows optimum result. MSE value is better by using the kirsch operator, and Euclidean Distance of Standard Deviation is minimum for kirsch operator.

Figure 4 Implementation of various operators on MRI Image (a) Input Image, (b) Operator (c) Thresholded Image, (d) Output Marker (e) LBP Image

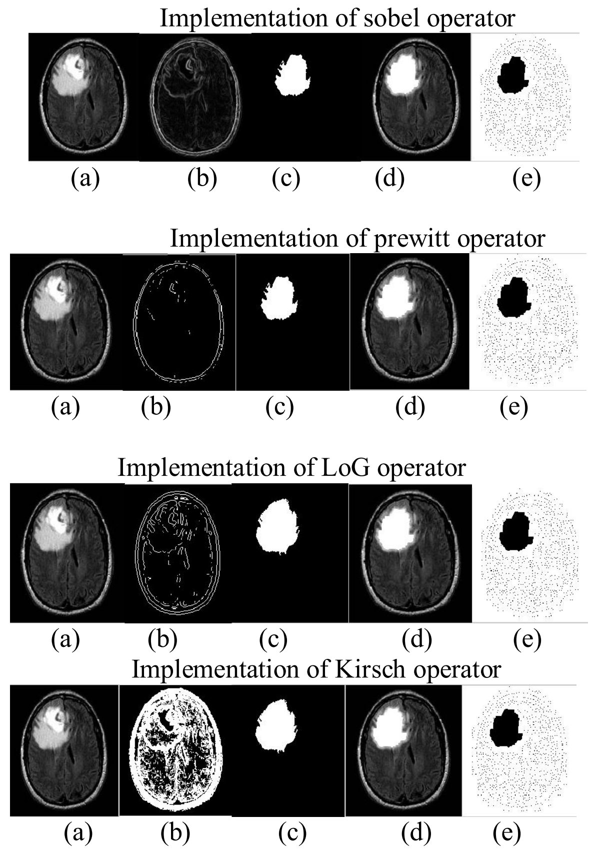

Table 1 Results of Different Operators

Detection techniques	SSIM	NCC	MSE	ED of SD
sobel	0.796	0.99	29	27.0
prewitt	0.733	0.98	34	27.6
LoG	0.634	0.87	39	27.4
kirsch	0.966	0.99	10	26.8

The results of four image operators on a MRI are shown in the Figure 4. Images (a) show the input MRI image. Images (b) are the gradient magnitude of an image. Images (c) are the thresholded images showing the brain tumour clearly. Results in (d) are output segmented image by applying marker based watershed transform. Images (e) are the local binary pattern (LBP) images of the output segmented image by using the respective operator images.

Conclusion

We have implemented various image processing operators in marker based image watershed segmentation on MRI images. The simulation results show that kirsch operator has effectively segmented out the region of interest with better SSIM, NCC, MSE and Euclidean distance of standard deviation in comparison to sobel, prewitt and LoG operator. This segmentation technique using Kirsch operator can be used by radiologists for diagnosis.

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