MRI Brain Image Segmentation Using Edge detection and Morphological Operators

Navpreet Kaur, Er. Harmandeep Singh

Department of Computer Engineering, University College of Engineering
Punjabi University, Patiala

[1]navpreet.walia12@gmail.com
[2]harmanjhajj@yahoo.co.in

Abstract **- Image segmentation plays a pivotal role in medical imaging. Medical Image Segmentation is used for locating diseases like tumors and other pathologies, measuring tissue volumes, face recognition, etc. Edge detection is one of the ways to extract more information from MRI brain images. In this paper, a comparative study is done on various edge-based segmentation algorithms namely, Canny, Sobel, Roberts, Prewitts, LoG and Zerocrossing. A performance evaluation is performed using parameters like computation time, segmented area on these algorithms. Morphological operations are done as a post-processing step to simplify the image data, preserving their shape characteristics and eliminate irregularities. Qualitative and quantitative analysis reveals that Zerocrossing technique consumes maximum time but also provide maximum segmented area. Roberts consumes least computation time and provide clear and better segmentation results.**

Keywords **– Image Segmentation, Edge detection, MRI, Segmented Area.**

I. INTRODUCTION

Today is the age of information technology and image processing is a rapidly growing area of information technology. Digital image processing is a subfield of digital signal processing. An image may be defined as a two-dimensional function f(x, y). Where x and y are spatial (plane) coordinates, and the amplitude of f at any pair of coordinates (x, y) is called the intensity or gray level of the image at that point. When x, y and the amplitude values of f are all finite discrete quantities, we call the image as digital image. The field of digital image processing refers to processing digital images by means of a digital computer. A digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are referred to as picture elements, image elements, pels, and pixels. Pixel is the term most widely used to denote the elements of a digital image [HYPERLINK \l "RCG04" 1] .

Medical Image segmentation is a critical step that often dictates the outcome of the entire clinical or research analysis. It greatly facilitates visualization and manipulation of specific structures. The field of medical image segmentation has undergone revolutionary advances over of the past two decades. New medical imaging technologies have provided doctors powerful techniques to probe the structure, function, and pathology of the human body2]**}**.

Magnetic resonance imaging (MRI) is an important diagnostic imaging technique to obtain high quality brain images in both clinical and research areas. Magnetic Resonance Image (MRI) is a visualization image with a detailed internal structure of any object. In extracting the ventricle, the brain, and brain tumors in magnetic resonance imaging (MRI) is often highly challenging due to the convoluted shape, blurred boundaries, inhomogeneous intensity distribution, background noise, and low intensity contrast between adjacent brain tissues[4].

Edge detection is one of the ways to extract more information from magnetic resonance images. Edge detection reduces the amount of data and filters out useless information, while protecting the important structural properties in an image. Edge detection refers to the process of identifying and locating sharp discontinuities in an image [5]. The discontinuities are abrupt changes in pixel intensity which characterize boundaries of objects in a scene.

The complexity of human brain structure mandates the use of computerized approaches derived from computer vision, image analysis, and applied mathematics fields to extract brain data. Successful algorithms in segmenting anatomic structures in neuroimages can help researchers, physicians, and neurosurgeons to investigate and diagnose the structure and function of the brain in both health and disease. But these researchers, physicians, and neurosurgeons encounter problem when they have to study these different algorithms separately and applying those algorithms to get best result. This is very much time-consuming and difficult task to apply one by one and yet don’t know which is correct and best. Usually, medical brain image has complex appearance due to the complicated anatomic structure. Medical expertise is required to understand and interpret the image, hence because of this inability about selecting the segmentation algorithm which could meet the clinicians’ needs. , this research paper is done. In this paper, edge detection techniques are explored. A comparative study is done on various segmentation algorithms and performance evaluation is performed using parameters like computation time, segmented area on these algorithms. Morphology is used as a post-processing step in all techniques for better segmentation results.

II. EDGE DETECTION TECHNIQUES

Edge detection has major feature for image analysis. These features are used by advanced computer vision algorithms. Edge detection is used for object detection which serves various applications like medical image processing, biometrics etc. There are many edge detection techniques in the literature for image segmentation [3]. The most commonly used discontinuity based edge detection techniques are reviewed in this section.

A. Sobel operator

Sobel algorithms work using a mathematical procedure called convolution and commonly analyse derivatives or second derivatives of the digital numbers over space. We move the Sobel kernels over a particular pixel in the MRI image. Then we calculate a new value. The sobel convolution kernels are designed to respond to edges vertically and horizontally. These masks are each convolved with the image. We calculate horizontal and vertical gradient (G*x* and G*y*), then we combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient.

-1	-2	-1
0	0	0
+1	+2	+1

G_x

-1	0	+1
-2	0	+2
-1	0	+1

G_y

We use these numbers to compute the edge magnitude which given by:

$$|G| = \sqrt{Gx^2 + Gy^2}$$

Typically, an approximate magnitude is computed using:

$$|G|=|Gx|+|Gy|$$

which is much faster to compute.

The angle of orientation of the edge (relative to the pixel grid) giving rise to the spatial gradient is given by:

$$t= \arctan(Gy /Gx)$$

B. Robert's cross operator

The Roberts Cross operator performs a simple, quick to compute, 2-D spatial gradient measurement on an image. Robert's edge detection technique is the most basic of all the techniques. This method emphasizes regions of high spatial frequency which often correspond to edges. ount of noise that that of other filters.

-1	0
0	+1

G_x

0	-1
+1	0

G_y

These kernels are designed to respond maximally to edges running at 45° to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these *Gx* and *Gy*). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient.

The gradient magnitude is given by:

$$|G| = \sqrt{Gx^2 + Gy^2}$$

although typically, an approximate magnitude is computed using:

$$|G|=|Gx|+|Gy|$$

which is much faster to compute.

The angle of orientation of the edge giving rise to the spatial gradient (relative to the pixel grid orientation) is given by:

$$q = \arctan(Gy /Gx) - 3p / 4$$

C. Prewitt's operator

The Prewitt method finds edges using the Prewitt approximation to the derivative. Prewitt is a method of edge detection in image processing which calculates the maximum response of a set of convolution kernels to find the local edge orientation for each pixel. Prewitt operator is similar to the Sobel operator and is used for detecting vertical and horizontal edges in images. To estimate the magnitude and orientation of an edge Prewitt is a correct way. This gradient based edge detector is estimated in the 3x3 neighborhood for eight directions. All the eight convolution masks are calculated. One complication mask is then selected, namely with the purpose of the largest module.

-1	-1	-1
0	0	0
+1	+1	+1

G_x

-1	0	+1
-1	0	+1
-1	0	+1

G_y

Prewitt detection is slightly simpler to implement computationally than the Sobel detection, but it tends to produce somewhat noisier results.

D. Laplacian of Gaussian

The Laplacian of Gaussian method finds edges by looking for zero crossings after filtering image with a Laplacian of Gaussian filter. The Laplacian is a 2-D isotropic measure of the 2nd spatial derivative of an image. The Laplacian of an image highlights regions of rapid intensity change and is therefore often used for edge detection. The Laplacian is often applied to an image that has first been smoothed with something approximating a Gaussian Smoothing filter in order to reduce its sensitivity to noise. The operator normally takes a single gray level image as input and produces another gray level image as output.

In digital images, to calculated the Laplacian value is also by using the templates. The basic requirement on the templates is that the center pixel corresponding coefficient should be positive number, but the coefficient adjacent pixels of the center pixel should be negative number and their sum should be zero.

The LoG of an image f(x,y) is a second order derivative defined as,

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

It has two effects, it smoothes the image and it computes the Laplacian, whch yields a double edge image. Locating edges then consists of finding the zero crossings between the double edges. The digital implementation of the Laplacian function is usually made through the mask below:

0	-1	0
-1	4	-1
0	-1	0

G_x G_y

The LoG (`Laplacian of Gaussian') kernel can be pre-calculated in advance so only one convolution needs to be performed at run-time on the image.

E. Zerocrossing

The zero-cross method finds edges by looking for zero crossings after filtering I with a filter you specify. Zero crossing use the second derivative and it includes Laplacian operator. It is having fixed characteristics in all directions but draw-back is that it is sensitive to noise.

F. Canny Edge Detection Algorithm

The Canny method finds edges by looking for local maxima of the gradient of Image. The gradient is calculated using the derivative of a Gaussian filter. The method uses two thresholds, to detect strong and weak edges, and includes the weak edges in the output only if they are connected to strong edges. This method is therefore less likely than the others to be fooled by noise, and more likely to detect true weak edges.

III. MORPHOLOGICAL OPERATIONS

The morphology refers to the study of forms and structures. Elimination of any obstacles and noise from the image is the primary function of the morphological operators. Morphological processing is a tool for extraction or modifying information on the shape and structure of the objects within an image [3]. Following morphology operators are used in this paper:

1. *Erosion* - Erosion is an operation that increases the size of background objects in binary image.
2. *Dilation* - Dilation is used to create outline of features in an image. In binary images, dilation is an operation that increases the size of foreground objects generally taken as white pixel.
3. *Opening* **-** An opening operation consists of erosion followed by dilation with the same structuring element.
4. *Closing* **-** A closing operation consists of a dilation followed by erosion with the same structuring element.

IV. PROCEDURE

Brain is a very complex organ. Even well trained surgeons face difficulties in determining the exact size of the diseases. This is critical as the surrounding normal cells should not get affected. Medical expertise is required to understand and interpret the image; hence because of this inability about selecting the segmentation algorithm which could meet the clinicians' needs, this paper is done.

-1	-1	-1
-1	8	-1
-1	-1	-1

In this research paper, an attempt is done to compare various edge detection techniques using morphological operators. MRI brain image is taken and converted into grayscale image. Edge detection technique is applied. Morphological element is generated and morphological tools are applied. After implementing morphological operations, a layout is created which is multiplied with input image generating results. Parameters like time and area segmented are calculated and evaluation is done from the segmentation. This method is repeated for all other techniques of edge detection.

- *Performance Measures*

i. Computation Time

Computation time is defined as the amount of time required to segment an image. It returns the total CPU time (in seconds) used by MATLAB application from the time it was started. It is basically elapsed CPU time.

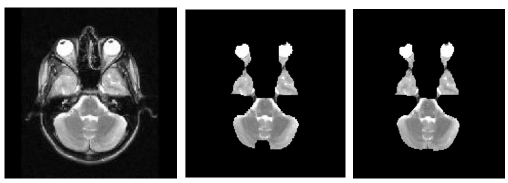
ii. Segemented Area

Segmented area is defined as the maximum area which is segmented from original MRI brain image.

- *Results*

Six MRI brain images have been selected for verifying the validity of presented method. All the images were brain disease images and comparative results are defined using the performance indices Computation Time and Segmented Area.

The presented method result both the qualitative and quantitative of the images. A comparison in the qualitative analysis of MRI brain images is shown in Fig. 1 and Fig. 2.



(a) (b) (c)

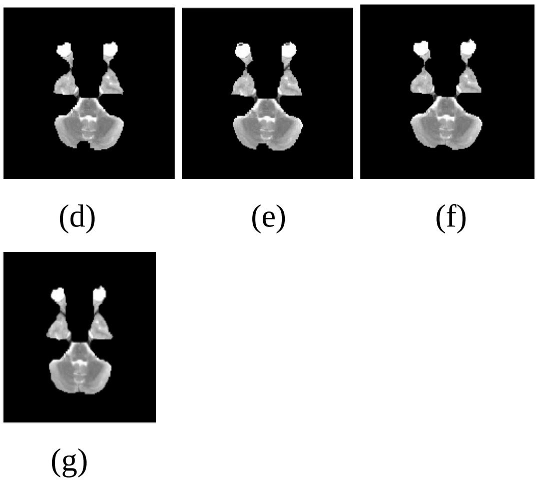


Fig. 1 Image Segmentation using (a) Original image (b) Sobel (c) Canny (d) LoG (e) Prewitt (f) Roberts (g) Zerocrossing edge detection techniques

The above figure illustrates brain parenchyma and orbital structures, scalp and calvesium has been removed. It can be useful for differentiating intra-axial masses from those scalp origin.

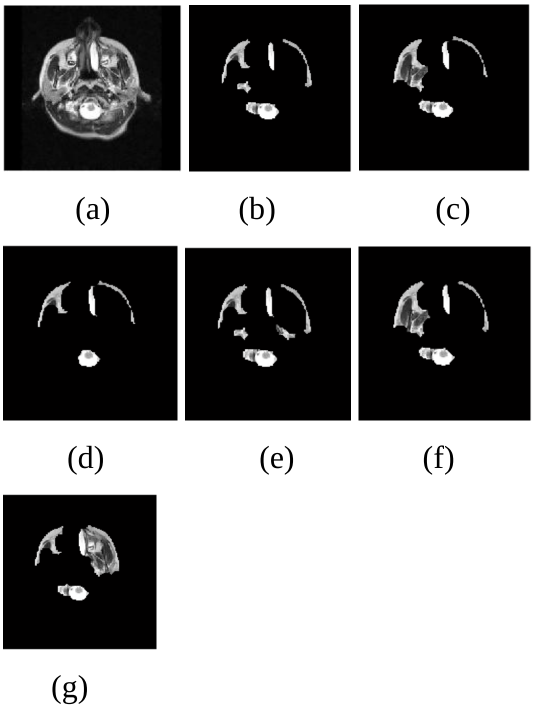


Fig. 2 Image Segmentation using (a) Original image (b) Sobel (c) Canny (d) LoG (e) Prewitt (f) Roberts (g) Zerocrossing edge detection techniques

The above figure illustrates left inferior turbinate mucosal hypertrophy disease in segmentation, also known as sinusitis. Roberts provide clear and best segmentation result for analysis.

The measured time in Fig. 3 reveals that Roberts consumes least time in segmentation whereas zerocrossing consumes maximum time. Sobel. Canny and LoG performance are equivalent wrt each other. Prewitt consumes less time compared to others except Roberts.

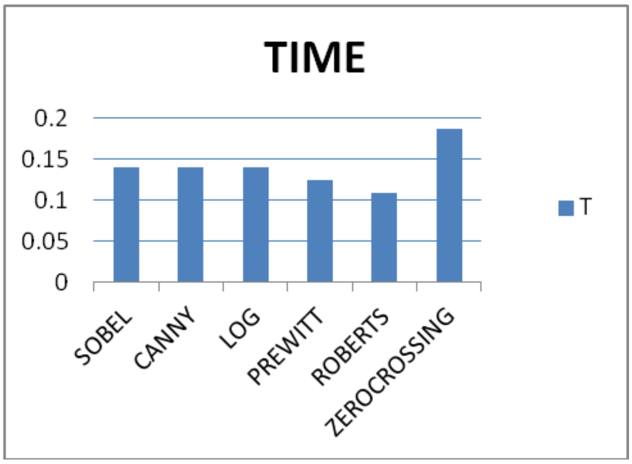


Fig. 3 Performance analysis based on Time

The measured Segmented Area in Fig. 4 reveals that Zerocrossing has maximum segmented area whereas LoG has minimum segmented area. The above figure depicts that Sobel, Prewitts and Roberts have equal segmented area. Out of which, Roberts consume less time and better segmentation. Hence, Roberts can be used for medical image segmentation.

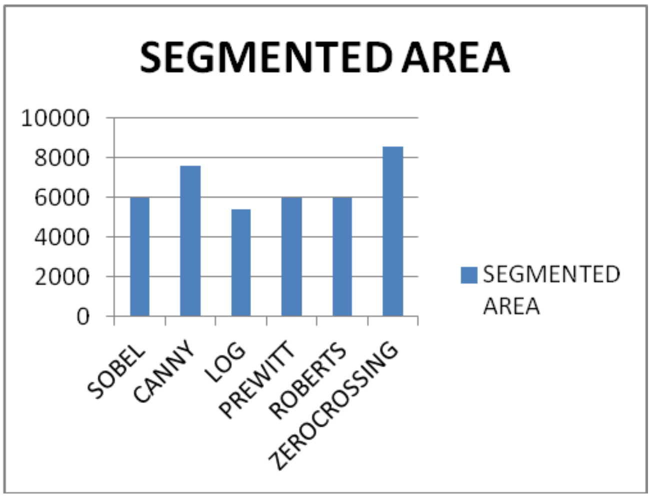


Fig. 4 Performance analysis based on Segmented Area

V. CONCLUSION

In the discipline of computer vision, image processing is a quickly moving field. Medical image segmentation algorithms play a vital role in numerous applications, such as the quantification of tissue volumes, diagnosis, localization of pathology, study of anatomical structure, treatment planning, and computer-integrated surgery.

There has been significant number of research in the field of medical image segmentation. In this paper, we proposed an algorithm which compares the different edge based segmentation techniques. The relative performance of various edge detection techniques is carried out with different MRI brain images by using MATLAB software. The performance is measured by Computation Time and Segmented Area. The measured time shows that Roberts consumes minimum time whereas Zerocrossing consumes maximum time. The measured Segmented Area shows that Log is having least area segmented whereas Zerocrossing is having maximum area segmented. It is observed from the results that Robert's edge detection technique is superior when compared to all other techniques as it is less time consuming and provides a clear and better segmentation results. This proposed algorithm is assessed from the radiologist, who results in positive as this dissertation helps in selecting the best segmentation method for the diagnosis, the treatment procedure and state of the brain in detection of diseases like tumour monitoring, inferior turbinate mucosal hypertrophy, etc.

ACKNOWLEDGEMENT

The authors are greatly indebted to Paramjit Singh Walia and Prof. Amteshwar Singh Jaggi who encouraged and appreciated us during the tough times of the research work.

REFERENCES

[1] Ehsan Nadernejad, Sara Sharifzadeh ,Hamid Hassanpour, "Edge Detection Techniques: Evaluations and Comparisons", Applied Mathematical Sciences, vol. 2, no. 31, pp. 1507 – 1520, 2008.

[2] D.J. Withey, Z.J. Koles, "Medical Image Segmentation: Methods and Software", Paper presented on Joint Meeting of the 6th International Symposium on Noninvasive Functional Source Imaging of the Brain and Heart and the International Conference on Functional Biomedical Imaging, pp. 140-143, 2007.

[3] K. Shri Sarika P. Sudha, "An Analysis of Edge Extraction for MRI Medical Images through Mathematical Morphological Operators Approaches", International Conference on Research Trends in Computer Technologies (ICRTCT), pp. 9-13, 2013.

[4] Kimmi Verma, Aru Mehrotra, Vijayeta Pandey, Shardendu Singh, "Image Processing Techniques for the Enhancement of Brain Tumor Patterns", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 2, no. 4, 1611-1615, 2013.

[5] Muthukrishnan.R and M.Radha, "Edge Detection Techniques for Image Segmentation" International Journal of Computer Science & Information Technology (IJCSIT), vol. 3, no. 6, pp. 259-267, 2011.