Images Segmentation Based on Fast Otsu Method Implementing on Various Edge Detection Operators

Hameed M. Abdul jabar
Amal J. Hatem
Taghreed A. Naji
Dept. of Physics, College of Education for Pure Science Ibn Al-Haitham,
University of Baghdad

Received in: 3 May 2015, Accepted in: 30 June 2015

Abstract

The present work aims to study the effect of using an automatic thresholding technique to convert the features edges of the images to binary images in order to split the object from its background, where the features edges of the sampled images obtained from first-order edge detection operators (Roberts, Prewitt and Sobel) and second-order edge detection operators (Laplacian operators). The optimum automatic threshold are calculated using fast Otsu method. The study is applied on a personal image (Roben) and a satellite image to study the compatibility of this procedure with two different kinds of images. The obtained results are discussed.

Keywords : Edge detection, image segmentation, and fast Otsu method.

Introduction

Image segmentation plays an important role in image analysis and computer vision systems. However, it is still considered being one of the most difficult and challenging tasks in image processing and object recognition, and determines the quality of results of the image analysis. It is the process of dividing an image into regions according to its characteristic e.g., color and objects present in the image. These regions are sets of pixels and have some meaningful information about object. As a result of image segmentation more meaningful image is obtained, that is easier to understand and easier to analyze [1 & 2].Segmentation can also be obtained through detection of edges of various regions, which normally tries to locate points of abrupt changes in gray level intensity values [3].

Edge detection is an important part of the digital image processing. The edge is the set of the pixel, whose surrounding gray is rapidly changing. The internal characteristics of the edge-dividing area are the same, while different areas have different characteristics. The edge is the basic characteristics of the image. There is a lot of information of the image in the edge. Edge detection is to extract the characteristics of discrete part by the difference in the image characteristics of the object, and then to determine the image area according to the closed edge. Edge detection is widely used in computer vision, image analysis, etc… [4].

Otsu Thresholding Method

Otsu's method is one of thresholding methods and frequently used in various field. This is used to automatically perform histogram shape-based image thresholding, or the reduction of a gray level image to a binary image. This method is characterized by its nonparametric and unsupervised nature of threshold selection by the discriminate measure of separately of the resultant classes in gray levels [1, 5 & 6]. The basic idea for Otsu method is to find the threshold that minimizes the weighted within-class variance.

The assumptions made in Otsu's model are [7]:

- Histogram (and the image) is bimodal.
- There is no use of spatial coherence, nor any other notion of object structure.
- Assumes stationary statistics, but can be modified to be locally adaptive.
- Assumes uniform illumination (implicitly), so the bimodal brightness behavior arises from object appearance differences only.

This paper has proposed a method that confirms a best threshold value through the fast Otsu method, which is used with four operators (Robert, Sobel, Prewitt and Laplacian) operators of edge detection.

The Operators of the Edge Detection

A number of edge detectors of first order and second order derivative edge detectors as Robert, Prewitt, Sobel and Laplacian respectively chosen to study the effect of the determination of a threshold depending on the different technique detectors.

- **First Order Derivative Edge Detection**

There are two fundamental methods for generating first-order derivative edge gradients. The first method involves generation of gradients in two orthogonal directions in an image; while the second utilizes a set of directional derivatives.

An edge in a continuous domain edge segment $I(x, y)$ can be detected by forming the continuous one-dimensional gradient $G(x, y)$. If the gradient is sufficiently large above some threshold value, an edge is deemed present. The gradient along the line normal to the edge slope can be computed in terms of the derivatives along orthogonal axes according the following [8]:

$$G_X(x,y) = \frac{\partial I(x,y)}{\partial x}, \; G_Y(x,y) = \frac{\partial I(x,y)}{\partial y} \quad \text{........(1)}$$

The row and column gradients can be computed by the convolution relationships:

$$G_X(\mathrm{x},\mathrm{y}) = I(x,y) \otimes H_X(x,y) \text{.............(2)}$$

$$G_Y(\mathrm{x},\mathrm{y}) = I(x,y) \otimes H_Y(x,y) \text{.............(3)}$$

Where $H_X(x, y)$ and $H_Y(x, y)$ are (3 × 3) row and column mask impulse response arrays. The edge magnitude and edge direction are found by the following formals [8 & 9]:

$$\text{Edge Magnitude} = \sqrt{G_X^2 + G_Y^2} \text{.............(4)}$$

$$\text{Edge Direction} = \tan^{-1}\left(\frac{G_X}{G_Y}\right) \text{ ....(5)}$$

1. Roberts Operator

The Roberts operator marks edge points only; it does not return any information about the edge orientation. It is the simplest edge detection operator and works best with binary images. The mask of this operator is defined as [10]:

$$H_X = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}, \; H_Y = \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$$

There are two forms of the Robert edge detection, The first is by using eq.(4) and the second is by using the sum of the absolute value of its gradients as follows [10].

$$\mathrm{G}(\mathrm{x},\mathrm{y}) = |G_X((\mathrm{x},\mathrm{y}))| + |G_Y((\mathrm{x},\mathrm{y}))| \text{.............(6)}$$

Roberts's operator differs from the rest first order derivative edge detection operators in the calculation of the orientation of the image gradient, which is [11]:

$$\text{Edge Direction} = \tan^{-1}\left(\frac{G_X^2}{G_Y^2}\right) + \frac{\pi}{4} \text{.............(7)}$$

2. Prewitt Operator

The Prewitt has introduced a (3 × 3) pixel edge gradient operator described by the pixel numbering convention. The reason that the Prewitt operator visually appears to be better delineate object edges than the Roberts operator which is attributable to their larger size, which provides averaging of small luminance fluctuations. The mask of this operator is defined as [8 & 9]:

$$H_X = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}, \; H_Y = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

Each of these masks are convolute with the image. The edge magnitude and edge direction, are defined in eq. (4 & 5) [8 & 9].

3. Sobel Operator

The Sobel edge detection masks look for edge in both the horizontal and vertical direction and then combine this information into signal metric. The masks are as follows [11].

$$H_X = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}, \quad H_Y = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

Each of these masks is convolute with the image. The edge magnitude and edge direction, are defined in eq. (4 & 5).

The Sobel edge detector operator differs from the Prewitt edge detector operator in the values of the north, south, east and west pixels that are doubled. The motivation for this weighting is to give equal importance to each pixel in terms of its contribution to the spatial gradient [8].

- **Second Order Derivative Edge Detection**

Second-order derivative edge detection technique employs some forms of spatial second-order differentiation to accentuate edges. An edge is marked if a significant spatial change occurs in the second derivative [8]. Two of the Laplacian edge detection masks are considered.

1. Laplacian operator

The Laplacian operators described here by the two Laplacian masks that follow represent different approximations of the Laplacian operator. Unlike compass masks, the Laplacian masks are rotationally symmetric which means edges at all orientations contribute to the result. They are applied by selecting one mask and convolving it with the image. The sign of the result from two adjacent pixel locations provides directional information, and tell us which side of the edge is brighter [9].

$$L_1 = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}, \quad L_2 = \begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}$$

Test Images

The scene that is used in this research is Al-Ramadi city, which is located in Al-Anbar provenience of the Iraq region, and it covers (581.72) km^2 west of Baghdad. Geographic location of AL-Ramadi region was shown in Fig. (1). The available scene was TM exposure at March 04, 1990,This region lies between latitudes 33° 27' 21.44" N to 33° 14' 14.05" N and longitudes 43° 29' 17.91" E to 43° 44' 36.64" E. This region represents Alluvial Plain; the hot desert climate prevails in the sedimentary plain and the western plateau. It contains some vegetation cover, many soil and rock erosion noticed. Robin image is used also as a standard image.

Methodological Approach

For the edge detection operators that are adopted in this research, the following steps are performed to apply the 1D fast Otsu thresholding method:

1- Chose the test image.
2- Apply various edge detection operators (Robert, Sobel, Prewitt, and Laplacian), to find the edge detection of the image using 3×3 slide window.

3- Apply the 1D Fast Otsu method on the product image of step 2, to calculate the best threshold value for each operator.
4- Apply the threshold values on the product images of the step 2 to produce the final binary images.

Results and Discussions

In order to study the fast Otsu method as an automatic thresholding method to create binary images, the fast Otsu method had been implemented and applied on the test images (Robin and Al-Ramadi region).

This study was performed using 64-bit computer platform of core 2 Due 2.2 GHz processor and MATLAB version 2009. From the results of applying the fast Otsu method as thresholding method which deprecated in fig. (1 & 2), the following points can be noticed:

1- Calculating the threshold value for the adopted edge detection operators, give an efficient way to find the thresholding value.
2- The thresholding via Otsu was able to recognize the main edges of the objects in the image and eliminate the minor edge due to the fain details that disruption on the main edge.
3- For the ordinary image, the Prewitt, Sobel and Robert edge detection operators were compatible with the automatic thresholding via Otsu.
4- For the satellite image, the Prewitt and Sobel edge detection operators were compatible with the automatic thresholding via Otsu.
5- The Laplacian incompatible with the automatic thresholding via Otsu are due to the weak edges (faint) that produce.

Conclusions

According to the results the use of fast Otsu method to calculate the thresholding value for the operators Prewitt, Sobel are recommended for both ordinary images and satellite images for its ability to separate the main edges from the minor edge, which make it easier to separate the main object from the background.

For Robert edge detection operator and the Laplacian edge detector masks are recommended to be used with the automatic thresholding of Otsu with satellite image only.

References

1-Zhang, J. and Hu, J. (2008), Image segmentation based on 2D Otsu method with histogram analysis, IEEE, International conference on computer sciences and software engineering: 105.
2-Saif, J. A.; Al-Kubati, A. A.; Hazaa, A. S. and Al-Moraish, M. (2012), Image Segmentation Using Edge Detection and Thresholding, The 13th International Arab Conference On Information Technology ACIT, Dec. (10-13).
3-Pal, N. R.and Pal, S. K. (1993), A review on image segmentation techniques, Pattern Recognition, 26 (9):1277-1294.
4-Zhou, P.; Ye, W.; Xia, Y. and Wang, Q. (2011), An Improved Canny Algorithm for Edge Detection, 7(5), 1516-1523.

5- Naji, T. A. (2012), The Effect of Window Size Changing on Satellite Image Segmentation Using 2D Fast Otsu Method, Ibn Al-Haitham Journal for Pure & Applied Science, 25(1):143-152.

6-Otsu, N. (1979), A Threshold Selection Method from Gray-Level Histograms, IEEE Transactions on System, Man, and Cybernetics, SMC-9 (1), January.

7- Priyadharshini,K.S.(2012)Research and Analysis on Segmentation and Thresholding Techniques, International Journal of Engineering Research &Technology (IJERT), 10 (1):1-8.

8-Pratt W. K. (2007), Digital image processing, 4rd edition, John Wiley & Sons, Inc., (Chapter 15).

9-Conzalez, R. C.and Woods, R. E.(2002), Digital Image Processing, Second Edition, Prentice Hall.

10-Solomon, C. and Breckon, T. (2011), Fundamentals of Digital Image Processing: A Practical Approach with Examples in Matlab, John Wiley & Sons, (Chapter 4).

11-Scott, E. (1998), Computer vision and Image Processing: A Practical Approach Using CVIP tool, Prentice Hall PTR, A Simon & Schuster company.

Table :(1) Threshold Values of the Operators Images via Fast Otsu Method for Robin Image

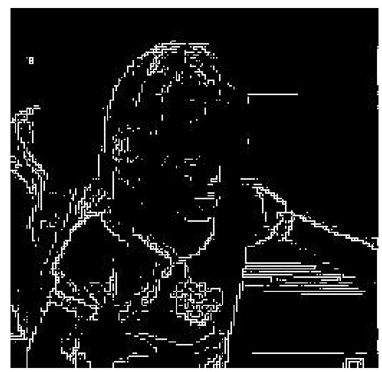
Threshold Values of Operators	Edge Line Detection Operators				
	Soblel Operator	Prewitt Operator	Robert Operator	Laplacian Operator	
				Mask_1	Mask_2
	53	53	47	52	34

Table :(2) Threshold Values of the Operators Images via Fast Otsu Method for Al-Ramadi Image

Threshold Values of Operators	Edge Line Detection Operators				
	Soblel Operator	Prewitt Operator	Robert Operator	Laplacian Operator	
				Mask_1	Mask_2
	45	53	32	53	53

Roben Image

Robert Operator



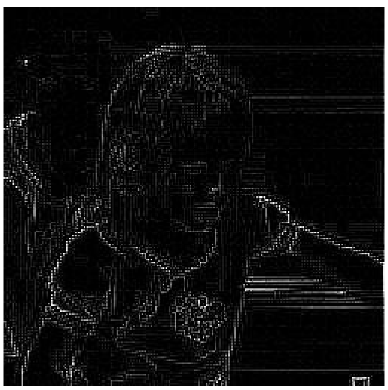
Robert Operator with Fast Otsu

Sobel Operator

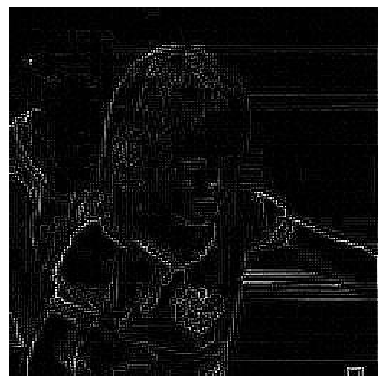
Sobel Operator with Fast Otsu

Prewitt Operator

Prewitt Operator with Fast Otsu Otsu

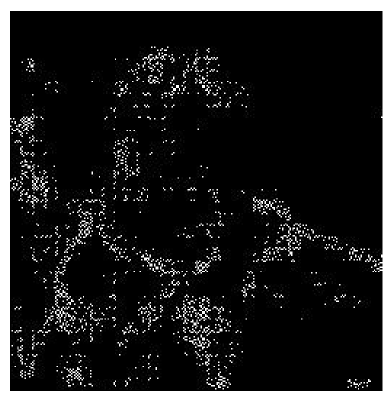


Laplacian _1 Operator



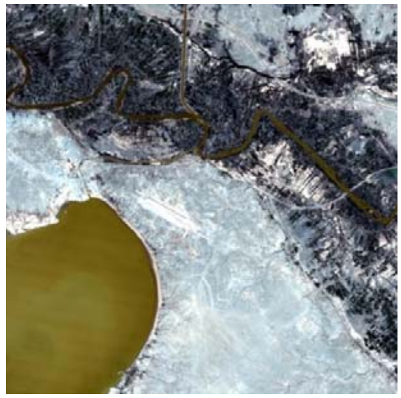
Laplacian _1 Operator with Fast Otsu

Laplacian _2 Operator

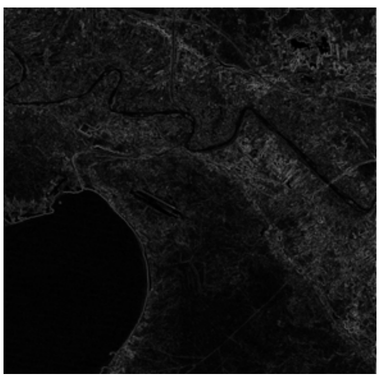


Laplacian _2 Operator with Fast Otsu

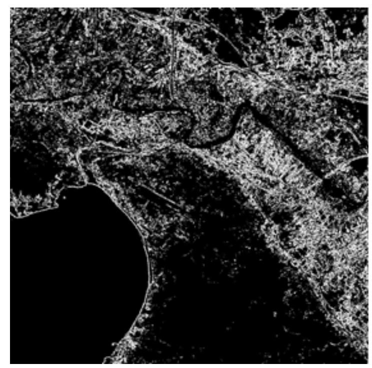
Figuer (1): Edge detection operators with and without thresholding using fast Otsu method for roben image



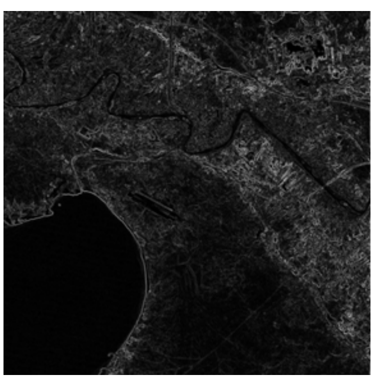
Al-Ramadi image



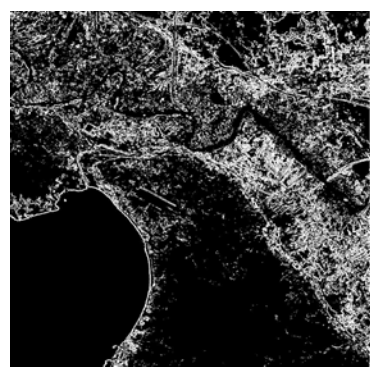
Robert Operator



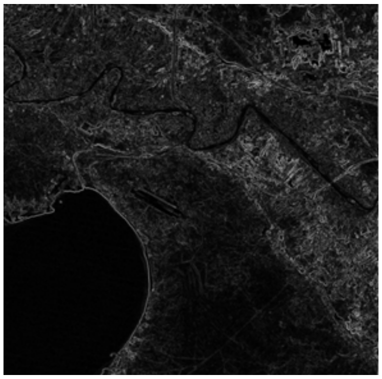
Robert Operator with Fast Otsu



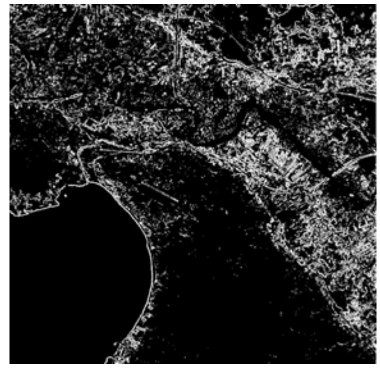
Sobel Operator



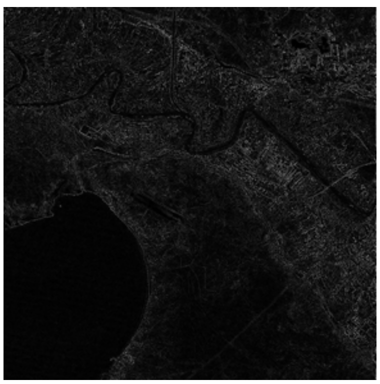
Sobel Operator with Fast Otsu



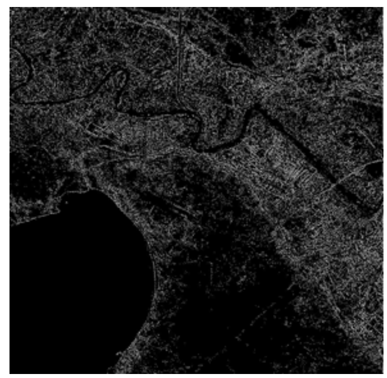
Prewitt Operator



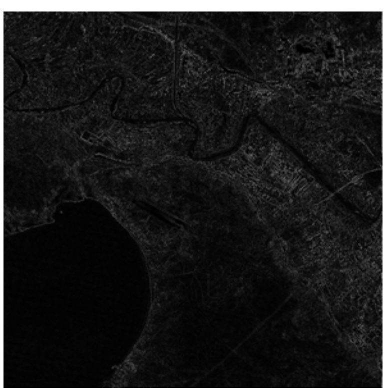
Prewitt Operator with Fast Otsu Otsu



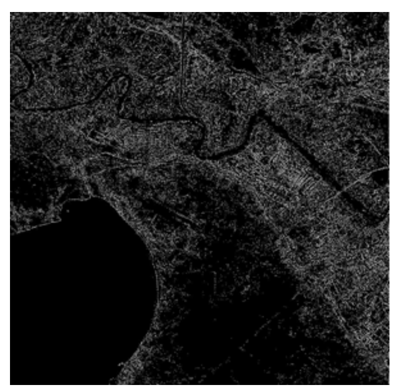
Laplacian _1 Operator



Laplacian _1 Operator with Fast Otsu



Laplacian _2 Operator



Laplacian _2 Operator with Fast Otsu

Figuer (2): Edge detection operators with and without thresholding using fast Otsu method for Al-Ramadi image

تقسيم الصور بالاستناد على تطبيق طريقة أوتسو السريعة على معاملات كشف الحواف المختلفة

حميد مجيد عبد الجبار
آمال جبار حاتم
تغريد عبد الحميد ناجي
قسم الفيزياء / كلية التربية للعلوم الصرفة -ابن الهيثم/ جامعة بغداد

استلم في: 3 ايار 2014، قبل في: 30 حزيران 2015

الخلاصة

يهدف العمل الحالي الى دراسة تأثير استخدام العتبة الالي لتحويل معلم الحواف للصور الى صور ثنائية لفصل الجسم عن خلفيته، حيث تم الحصول على معلم الحواف لعينات الصور بوساطة مؤثرات كشف الحواف من الدرجة الأولى (روبرت، بريوت، سوبل) ومؤثرات كشف الحواف من الدرجة الثانية (مؤثرات لابلاس). تم تطبيق هذه الدراسة على صورة شخصية (روبن) وصورة لقمر صناعي لدراسة توافق الطريقة مع نوعين مختلفين من الصور، وقد تم مناقشة النتائج.

الكلمات المفتاحية: كشف الحواف، تقسيم الصورة، طريقة أوتسو السريعة.