NEW WAVELET-BASED TECHNIQUES FOR EDGE DETECTION

YAHIA S. AL-HALABI, HESHAM JONDI ABD

Computer Science Department
Princess Sumaya University for Technology
Amman , AL-Jubaiha
Jordan
E-mail: yahia_1111@yahoo.com

ABSTRACT

Image segmentation and edge detection are of great interest in image processing prior to image recognition step. Segmentation process has an important application in Military, Biomedical, space, and environmental applications. In this paper, we applied the spatial domain methods, Thresholding and Edge based methods (Roberts operator, Sobel operator, Prewitt operator, and Laplacian operator). In this research, we found that using Fourier Transform in edge detection applications yields to a bad results and has a serious drawback. Wavelet transform plays a very important role in the image processing analysis, for its fine results when it is used in multi-resolution, multi-scale modeling. Unlike Discrete Cosine transforms or Fourier transforms, wavelet transform offers a natural decomposition of images at multiple resolutions. The resulting representation of wavelet transform provides an attractive tradeoff between spatial and frequency resolution where the human visual system can be better exploited. Also, wavelet transform reveals another important feature unfound in the conventional transforms in the sense that its basis function can be designed to exactly fit a given problem.. New two wavelet-based edge detection techniques have been presented in this paper. The first one is called RC-Algorithm and the second one is called RCD-Algorithm. These two techniques have proved better results than other old techniques. Edges extracted using RC-Algorithm and RCD-Algorithm, are sharpen more than edges extracted using other techniques. RCD-Algorithm gave better results than RC-Algorithm in most cases. The RC-Algorithm and RCD-Algorithm respond best even on low transitions. The RCD-Algorithm can handle noisier images better than other techniques.

Key-Words: - *Thresholding, Segmentation, Wavelet, Roberts operator, Sobel operator, Prewitt operator, and Laplacian operator, RC-Algorithm and RCD-Algorithm, Fourier Transform,*

1 Introduction

The term image, refers to a two-dimensional light intensity function $f(x,y)$,where x and y denote spatial coordinates and the value of f at any point (x,y) is proportional to the brightness (or gray level) of the image at that point [4]. A digital image is an image $f(x,y)$ that has been discretized both in spatial coordinates and brightness, A digital image can be considered as a matrix whose row and column indices identify a point in the image and the corresponding matrix element value identifies the gray level at that point. The elements of such a digital array are called image elements, picture elements, pixels, or pels. The last two being commonly used abbreviations of "picture elements" [4] Computer imaging is a fascinating and exciting to be involved in today. The advent of the information superhighway, which its ease of use via the World Wide Web, combined with the advances in computer power have brought the world into our offices and into our homes. One of the most interesting aspects of this information revolution is the ability to send and receive complex data that transcend ordinary written text. Visual information, transmitted in the form of digital image, is becoming a major method of communication in the modern age. Computer imaging can be defined as the acquisition and processing of visual information by computer [1]. The importance of computer imaging is derived from the fact that our primary sense is our visual sense. The information that can be conveyed in images has been known throughout the centuries to be extraordinary-one, picture is worth a thousand words. In Image processing, the input is an *image*, and the output is also an *image*. While in the computer vision, the input is an image and the output consists of information about the image itself that may be used by another process. Thus, the output will not be an image any more. Fig. 1 , illustrates a block diagram of computer vision process [2]. It is quite clear that image-processing techniques are always the first stage of computer vision, moreover, some times image processing algorithms are used as feature extraction algorithms in the first step of the image analysis procedures.

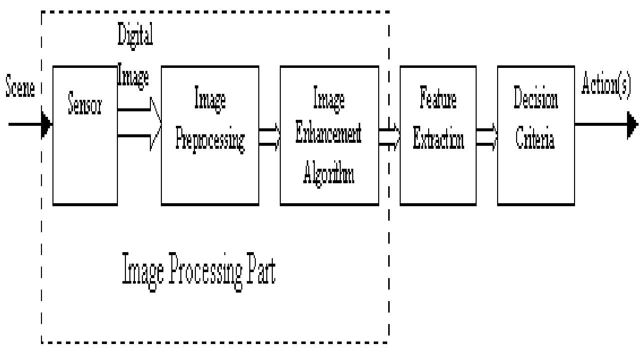


Fig. 1. Computer vision process.

This paper will discuss the different methods of segmentation and edge detection. The spatial domain methods used for the process of image segmentation and edge detection will be described in section 2. The new two edges detection techniques using wavelet transformation will be presented in section 3 .Comparison between the new techniques and the other known techniques, and an evaluation for the results, will be presented in section 4.

2 SPATIAL DOMAIN METHOD

Thresholding is particularly, useful region approach for scenes containing solid objects resting upon a contrasting background [2],[3],[5]. All methods in this approach depend on Gray-level Histogram, which can be defined as a function showing, for each gray level, the number of pixels in the image that have that gray level. The abscissa is gray level and the ordinate is frequency of occurrence (number of pixels) [4],[6],[9].

In fixed Thresholding**,** one assumes that the objects have pixel values, which are generally different from the background. A binary output image, that containing only 0's (background) and 1's (objects), may be created by applying the threshold [8],[9],

$$g(x,y)=\begin{cases}1 & if\ f(x,y)>T\\ 0 & if\ f(x,y)\le T\end{cases} \quad (1)$$

where T is a specified thresholding value.

Automatic or semi-automatic methods for finding the thresholds are available in [4],[6]. Thresholds may be defined between peaks in the one-dimensional histogram. For example, combine peaks that are close together, or combine peaks for which the ratio of the minimum of the two peaks is sufficiently small.

2.1 Edge based Methods

An edge is the boundary between two regions with relatively distinct gray-level properties. Several methods are known for edge detection as the next sections show. The Sobel edge detection operation [4] extracts all of edges in an image, regardless of direction. Sobel operation has the advantage of providing both a differencing and smoothing effect. The Sobel mask is defined as shown in Fig.2.

Z1	*Z2*	*Z3*
Z4	*Z5*	*Z6*
Z7	*Z8*	*Z9*

3x3 image region

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

Mask used to compute G_x

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

Mask used to compute G_y

Fig. 2. *Sobel* Operators.

It is implemented as the sum of two directional edge enhancement operations. The resulting image appears as an unidirectional outline of the objects in the original image. Constant brightness regions become black, while changing brightness regions become highlighted. Derivative may be implemented in digital form in several ways. However, the *Sobel operators* have the advantage of providing both a differencing and a smoothing effect. Because derivatives enhance noise, the smoothing effect is particularly attractive feature of the Sobel operators (Gonzalez *et al*., 1993). From Fig. 2, derivatives based on the Sobel operator masks are shown in equation (1) and equation (2) below:

$$G_x=(z_7+2z_8+z_9)-(z_1+2z_2+z_3) \qquad (1)$$

$$G_y=(z_3+2z_6+z_9)-(z_1+2z_4+z_7) \qquad (2)$$

The z's are the gray levels of the pixels overlapped by the masks at any location in an image. Computation of the gradient at the location of the center of the masks then utilizes Equation (3) or (4), which gives one value of the gradient.

$$\nabla f = mag(\nabla F) = \left[G_x^2 + G_y^2\right]^{1/2} = \left[\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2\right]^{1/2}$$

(3)

Which is equivalent to:

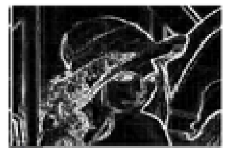
$$\nabla f \approx |G_x| + |G_y| \qquad (4)$$

To get the next value, the masks are moved to the next pixel location and the procedure is repeated. Thus, after the procedure has been completed for all possible locations, the result is a gradient image of the same size as the original. The following Algorithm shows the main features of *Sobel* edge detection . As usual, mask operations on the border of an image are implemented by using the appropriate partial neighborhoods.

Applying this mask on Lina image is shown in Fig. 3 – Fig. 5 below. Fig.3, shows the result of computing $|G_x|$ with the mask. Thus the strongest response produced by $|G_x|$ is expected to be on edges perpendicular to the x axis. This result is obvious in Fig. 4 which shows strong responses along horizontal edges. Note also the relative lack of response along vertical edges. The reverse situation occurs upon computation of $|G_y|$, as shown in Fig. 4. Combining these results via using Eq. 4, yields to the gradient image shown in Fig. 5.

Original Image

Case-1



Case-2

Fig. 3. Lena image. Result of applying the mask to obtain G_x; (Case-1) result of using the mask in Equation (5) to obtain G_y; (Case-2) complete gradient image obtained by using Equation 4.

The *Prewitt Operator* extracts the north, northeast, east, southeast, south, southwest, west, or northwest edges in an image. The resulting image appears as a directional outline of the objects in the original image. Constant brightness regions become black and changing brightness regions become highlighted. The *Prewitt gradient operator* is more immune to image noise than the *shift* and *difference* operation, and provides stronger directional edge discrimination. The mask coefficients add to 0. The eight directional masks are:

1 1 1 1 1 1 -1 1 1 -1 -1 1

1 -2 1 -1 -2 1 -1 -2 1 -1 -2 1

-1 -1 -1 -1 -1 1 -1 1 1 1 1 1

N mask NE mask E mask SE mask

-1 -1 -1 1 -1 -1 1 1 -1 1 1 1 1 -2
1 1 -2 -1 1 -2 -1 1 -2 -1 1 1 1 1
1 1 1 1 -1 1 -1 -1

S mask SW mask W mask NW mask

The results of applying these masks on Lena image are shown in Fig. 6.

Lena testing image.

(a) *Prewitt* nothern direction

(b) Northeastern gradient.

(c) Eastern gradient.

(d) Southeastern gradient.

(e) Southern gradient.

(f) Southwestern gradient.

(g) Western gradient

(h) Northwestern gradient.

Fig. 6. Application of the 8 orientations masks of
Fig. 6. Application of the 8 orientations masks of
Prewitt Operator on Lena testing image.

3 THE NEW WAVELET-BASED EDGE DETECTION TECHNIQUES

In this section, we will present a new two Wavelet-based edge detection techniques. Both techniques depend on the following:

- The high-pass filter which is used to represent the differences between points, or it is called "details".
- Edge detection can be extracted depending on the difference between each pixel and its neighbors.
- In both techniques, we apply the convolution process between the signal (image data) and the high-pass filter. The results of the convolution will be used without down-sampling.

3.1 Row and Column (RC) Convolution Algorithm

Input: ***WT*** represents the used Wavelet type.
IM as a two-dimensional gray scale image.
R represents the number of rows in the in ***IM***.
C represents the number of columns in ***IM***.
Output: ***EM*** as a two-dimensional image, in which the edges are extracted.

The Process:
Begin
1) **HI_D** = **HPD_Filter**(***WT***);
% The **HI_D** holds the value of a high-pass decomposition filter for a specific wavelet type in ***WT*** %
2) For each row in ***IM***, do the following
RDiff = **Convolution** (**HI_D**, ***IM***(*i*, **:**));
% **RDiff** is a two-dimensional matrix that represents the differences between pixels in each row%
IM(*i*, **:**), *i* represents the row number (i.e. its value will be between 1 to ***R***). "**:**" Sign means to include all columns in the same row.
Convolution, is a function returns the result of the convolution process between the high-pass filter and the row image data.
3) For each column in ***IM***, do the following
CDiff = **Convolution** (**HI_D**, ***IM***(**:**, *j*));
% **CDiff** is a two-dimensional matrix that represents the differences between pixels in each column%
IM(**:**, *j*), "**:**" Sign means to include all rows in the same column *j*. *j* values will vary between 1 and ***C*** %
4) ***EM*** = |**RDiff** (*i*, *j*))| + |**CDiff** (*i*, *j*))| where $1 \leq i \leq R$ and $1 \leq j \leq C$.
% ***EM*** holds the result of the magnitude of a vector that includes **RDiff** and **CDiff** values%
5) ***EM*** = **Scale**(***EM***);
% **Scale**, is a function returns ***EM*** matrix, where each value in this matrix is be between 0 and 1 %
6) Threshold(***EM***)
% Thresholding (Section 3.2) can be used to extract the most important pixels which represent the edges %

End of Algorithm.

3.2 Row, Column and Diagonal Convolution (RCD) Algorithm

Input: ***WT*** represents the used Wavelet type.
IM as a two-dimensional gray scale image.
R represents the number of rows in the in ***IM***.
C represents the number of columns in ***IM***.
Output: ***EM*** as a two-dimensional image, in which the edges are extracted.

The Process:
Begin
1) **HI_D** = **HPD_Filter**(***WT***);
% The **HI_D** holds the value of a high-pass decomposition filter for a specific wavelet type in ***WT*** %

2) For each row in ***IM***, do the following
RDiff = **Convolution** (**HI_D**, ***IM***(*i*, **:**));
% **RDiff** is a two-dimensional matrix that represents the differences between pixels in each row%
IM(*i*, **:**), *i* represents the row number (i.e. its value will be between 1 to ***R***). "**:**" Sign means to include all columns in the same row.
Convolution, is a function returns the result of the convolution process between the high-pass filter and the row image data. %
3) For each column in ***IM***, do the following
CDiff = **Convolution** (**HI_D**, ***IM***(**:**, *j*));
% **CDiff** is a two-dimensional matrix that represents the differences between pixels in each column%
IM(**:**, *j*), "**:**" Sign means to include all rows in the same column *j*. *j* value will be between 1 to ***C***%

4) ***EM*** = |**RDiff** (*i*, *j*))| + |**CDiff** (*i*, *j*))| where $1 \leq i \leq R$ and $1 \leq j \leq C$.
% ***EM*** holds the result of the magnitude of a vector that includes **RDiff** and **CDiff** values %
5-) ***EM*** = **Scale**(***EM***);
% **Scale**, is a function returns ***EM*** matrix, where each value in this matrix is be between 0 and 1 %

6) Threshold(***EM***)
% Thresholding (Section 3.2) can be used to extract the most important pixels which represent the edge %

End of Algorithm.

4 RESULTS AND CONCLUSION

In this section, we will show the results obtained using different Edge Detection techniques. We used Roberts, Prewitt, Sobel, Laplacian, RC-Algorithm, and RCD-Algorithm. An evaluation of the results will be presented in the following section.

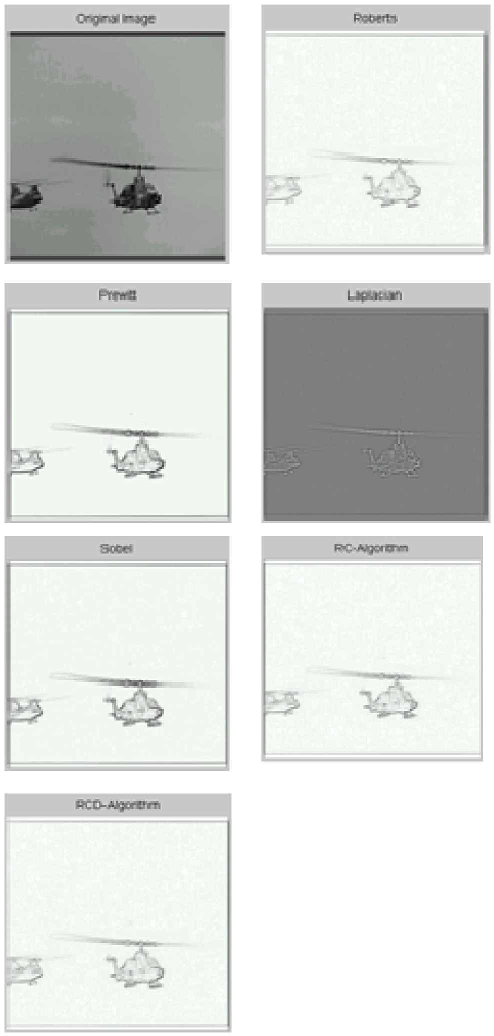
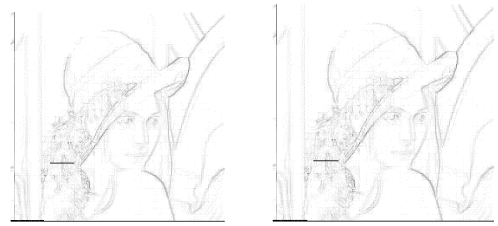


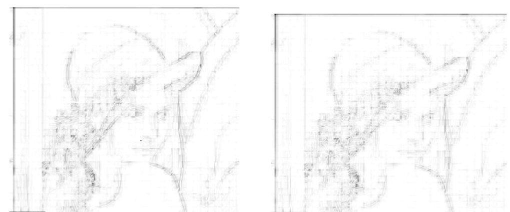
Fig. 7. Sample of the results obtained using different techniques for edge detection.

Fig. 8. shows the result of applying RC-Algorithm on Lena image, by using (a) ***WT*** = Haar Wavelet, (b) ***WT*** = DB2 Wavelet, (c) ***WT*** = DB3 Wavelet and (d) ***WT*** = DB4 Wavelet. It is clear that the most efficient results are extracted when ***WT*** = Haar Wavelet, this is because Haar wavelet is more strict on breakdown points [3]. For edge detection, breakdown points represent edges. Fig. 8. The results of applying RC-Algorithm on Lena image

Fig. 9 shows the results of applying RC-Algorithm (when ***WT*** = Haar Wavelet) on different images.



WT = Haar Wavele ***WT*** = DB2 Wavelet



WT = DB3 Wavelet ***WT*** = DB4 Wavelet

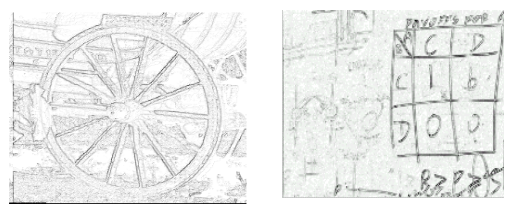


Fig. 9. The results of applying RC Algorithm on different image (wheel and blackboard) (when *WT* = Haar Wavelet).

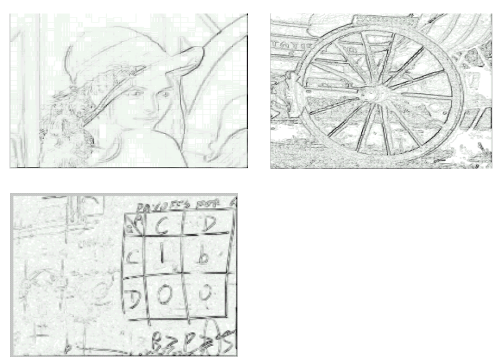


Fig. 10. The results of applying RCD Algorithm on different image (Lena, wheel and blackboard) (when *WT* = HaarWavelet).

As we previously mentioned in Section 3.3.4, the objective metrics are often of limited use in practical applications, so we will take a subjective look at the results of the edge detectors. The human visual system is still superior, by far, to any computer vision system that has yet been devised and is often used as the final judge in application development. From the previous results, we conclude the following:

1) Edges extracted using RC-Algorithm and RCD-Algorithm, are sharpen more than other edges extracted using other techniques. But it is clear that RCD-Algorithm gives better results than RC-Algorithm.

2) By using RC-Algorithm and RCD-Algorithm, we can easily make better distinction between objects in the image.

3) RC-Algorithm and RCD-Algorithm respond best even on low transitions.

4) RCD-Algorithm can handle noisier images better than other techniques.

REFERENCES:

[1]Abdou, I. E. and Pratt W. K., Quantitative Design and Evaluation of Enhancement Thresholding Edge Detectors, *Proc. IEEE*, 67(5), 1979, pp. 753-763**.**

[2] Aydin, T., Yemez, Y., Anarim, E. and Sankur, B., Multidirectional and multiscale Edge Detection via M-Band Wavelet Transform, *IEEE Trans. on Image Processing*, **5(9)**, 1996, pp. 1370-1377.

[3] Biajaoui, A., Rue, E. S., Wavelet& study of the Distance Universe, *Proc. IEEE*, 84(4), 1996,pp.670-679.

[4] Gonzalez, R. C. and Woods, R. E.,. *Digital Image Processing, 3st. Edition*. Addison-wesley Publishing Company, 2008,USA.

[5] Ryan, T. W., Sanders, L. D., Fisher, H. D. and Iverson, A. E., Image Compression by Texture Modeling in the Wavelet Domain, *IEEE Trans. on Image Processing*, **5(1)**, 1996, pp.26-36.

[6]Wilson, R., Multiresolution Image Modeling, *Electronic & Communication* 1997. 1997. *Journal*, 1997, pp. 90-96.

[7] José Miguel Buenaposada Biencinto, Luis Baumela Molina. Real-time tracking and estimation of plane pose, Proc. of International Conference on Pattern Recognition, IEEE. Quebec, August 2002,Vol II,.pp. 697-700.

[8] Vetterli, Martin (2009) Reproducible Research in Signal Processing - What, why, and how. IEEE Signal Processing Magazine, 26 (3). pp. 37-47.

[9] Han et al. Detecting objects in image sequences using rule-based control in an active contour model. IEEE Trans Biomed Eng. Vol 5, 2003, pp 705-710.

ABOUT THE AUTHOR:

Profesor Yahia AL-Halabi received his Ph.D Degree in Computer Science in 1982, from Clarkson University, Potsdam,NY, USA and his Ms.c degree in Numerical Simulation from the University of Jordan - Hashemite Kingdom of Jordan . Since 1982, he served as professor of computer Science, Chairman of the computer, Director of Computer Center Department at the University of Jordan, Dean Of faculty of Art and Sciences at Amman Private University, Dean of Faculty of Computer Studies at Arab Open University – Kuwait headquarter office. He joined Princess Sumaya University for Technology in 2005 and continues his research in image processing and simulation. Since September 2008-2010, he is appointed as Dean, King Hussein School for Information Technology at Princess Sumaya University for Technology. He is involved in many scientific organizations, locally and internationally and editor for many international research journals and member of accreditation and validation group for higher education in Jordan and abroad.