Study and Comparison of Edge Detection Algorithms

Shashidhar Ram Joshi
Institute of Engineering
Pulchowk Campus, Nepal
srjoshi@ioe.edu.np

Roshan koju
Institute of Engineering
Pulchowk Campus, Nepal
ko_rosh@yahoo.com

Abstract

Edge characterizes boundaries. If the edges of images could be identified accurately, all of the objects can be located and basic parameters such as area, perimeter and shape can be measured. This paper proposes fusion of Haar wavelet and Prewitt operator and compares its performance with frequently used gradient edge detection algorithms and canny edge detection method in different conditions. Canny edge detection algorithm is implemented with adaptive parameters. Software programs for all edge detectors are developed in visual C#.net. It has been shown that canny edge detection algorithm with adaptive parameters performs better in almost all conditions in comparison to other operators in the expense of its execution time.

Keywords: edge detection, Haar wavelet, canny edge detection, noise, gradient operators

1. Introduction

An edge of an image is jump in intensity. An ideal edge is the set of connected pixels each of which is located at an orthogonal step transition in grey level. But in practice edges are more closely modeled as having ramp like profile [1].

Numbers of edge detectors are developed each year. An edge detection operations is a neighborhood operation which determines the extent to which each pixels neighborhood can be portioned by simple arc passing through the pixel where pixel in neighborhood on one side of the arc have one predominant value and pixels in other side of arc have different predominant value.

Thus the goal of edge detection is to mark the points in digital image at which the luminous intensity changes sharply. However, not all edges involve a step change in intensity. Effects such as refraction or poor focus can result in objects with boundaries defined by gradual change in intensity. So, there are problems of false edge detection, missing true edges, edge localization, high computational time and problem due to noise.

Therefore our objective is to compare various edge detection algorithms and analyze the performance of various techniques in different condition.

2. Related works

Raman and Sohel evaluated the performance of Prewitt edge detector for noisy image and concluded that Prewitt detector cannot be used in practical images which are generally corrupted with Gaussian noise, salt and pepper noise and speckle type of noise. However, they demonstrated that Prewitt edge detector works quite well for digital images with poisson noise. [2]

Raman and Himanshu performed various experiments on classical operators and Canny edge detection algorithm. They discussed the advantages and disadvantages of these algorithms. They showed that Canny's edge detection algorithm is computationally more expensive compared to Sobel, Prewitt and Robert's operator. However, the Canny's edge detection algorithm performs better than all these operators under almost all scenarios. Similar conclusion was also derived by Heath and et al. [3]
Mohamed Roushdy applied morphological filter on noisy image. He noticed that morphological filter is more important as an initial process in edge detection for noisy image and concluded that morphological filter is equally efficient as Canny's edge detection algorithm.[4]

978-1-4673-2590-5/12/$31.00 ©2012 IEEE

Stephane Mallat has worked much more in wavelet transform for edge detection. Mallat has described method of finding edges through wavelet transforms. He goes on to describe a method of recovering complete images using only edges. Hanhang tong and et al used wavelet transform for blur detection in digital images. They concluded that wavelet transform is efficient and effective for blur images.[5]

Similarly NM Nandhita and et al have shown that wavelet based Sobel and Prewitt edge detectors provide better results by removing noise and results are analyzed subjectively. It is multiscale edge detection property of wavelet that has helped in removing noise.[6]

Jianjia pan has found that fusion of Canny edge detection algorithm with wavelet transform works excessively well. According to pan's experiment's result the fusion method not only helps to detect edge of image with noise free effectively but also enhance the image edge's details and locates edge accurately.[7]

Wnagluo have shown that classical edge detectors failed to perform in colony images due to noisy nature of remotely sensed data but the Canny edge detector performed best both visually and quantitatively.[8]

3. Edge detection operators

3.1 Gradient operators

Classical gradient edge detectors are based on the principal of matching local image segments with specific edge patterns. This method detects edges by looking for maximum and minimum in the first derivative (gradient) of the image. When the gradient is above the threshold there is object in the image. As regarding to image f(x,y), the gradient of point (x, y) is defined as [9]

$$\nabla f(x,y) = \begin{bmatrix} Gx & Gy \end{bmatrix} = \begin{vmatrix} df/dx & df/dy \end{vmatrix} \quad (1)$$

The weight of the vector is

$$\nabla f = mag(\nabla f) = \left[Gx2 + Gy2\right]1/2 \quad (2)$$

And its direction as

$$\phi(x,y) = \arctan(Gy/Gx) \quad (3)$$

The popular edge detection operators are Roberts, Sobel, Prewitt, Frei-Chen. They are all defined on a 3 x 3 pattern grid, so they are efficient and easy to apply. The general mask structure is:

W(-1,-1)	W(-1,0)	W(1,0)
W(0,-1)	W(0,0)	W(0,1)
W(1,-1)	W(1,0)	W(1,1)

Fig: 3.1 General mask for convolution

These patterns are represented as filters. From function point of view, filters are discrete operators of directional derivatives. Gradient of every pixel of image is calculated using above three equations.

3.2 Canny edge detection algorithm

The Canny edge detection algorithm is also known as optimal edge detector. Canny edge detection algorithm based on three criterions [10]

I. Low error rate. It is important that edges occurring in the images should not be missed and that there be no responses to non edges.
II. Distance between the edge pixels and actual edge is to be at minimum.
III. Response to a single edge.

The algorithm runs in 6 separate steps:

1. Smoothing: Blurring of the image to remove noise
2. Finding gradients: The edges should be marked where the gradients of the image has magnitudes
3. Direction calculation: direction of edge should be calculated
4. Non maximum suppression: Only local maxima should be marked as edges
5. Double thresholding: Potential edges are determined by thresholding
6. Edge tracking by hysteresis: Final edges are determined by suppressing all edges that are not connected to very certain (strong) edge.

3.3 Haar based edge detection

The Haar wavelet is also the simplest possible wavelet. The Haar wavelet operates on data by calculating the sums and differences of adjacent elements.

After 2D Haar transformation of image, it is subjected for edge detection. After two dimensional frequency decomposition of wavelet transform, low frequency information can be decomposed low frequency area LL and high frequency area LH. High frequency area can be decomposed into low frequency area HL and high frequency components area HH. LL shows the smoothing image of the original image which consists of the most of the contents of original image. LH preserves the vertical edge details. HL preserves the horizontal edge details. HH preserves the diagonal details which ate influenced by noise greatly. This process is shown in figure below:

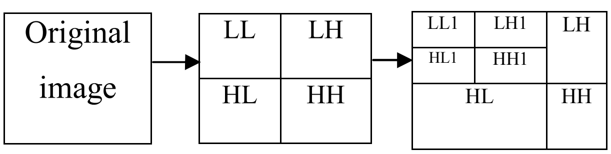

Fig 3.3: Image decomposition based on wavelet transforms

Though the edge extracted by wavelet transform can reduce the most of noise of image, the real edges of the image are also mixed with much noise, and especially HH areas are affected by noise greatly. Thus usually HH areas are discarded. Thus, LL area of transformed image is used to apply Prewitt edge operator.

Thus the step involved in fusion of Haar and Prewitt edge detection operator can be listed as follows:

1. Perform Haar transformation of given image
2. Select LL area of transformed image
3. Apply Prewitt edge operator to LL area

4 Experiments and results

4.1 Noise tolerance experiment:

We checked the performance of each edge detector in various degree of noise environment. Here we used Lena image for experiment. Noise is added into Lena image through Photoshop.

First the no noise image is passed through all edge detectors, corresponding SNR values are recorded. Then after, noise level is gradually increased 5% at each level up to 30% and those noisy images are passed through all edge detectors and corresponding SNR values are recorded. The edge images for noisy images are shown in figure 4.1 and 4.2 below.

The sample output of image and its treatment through six edge detectors is shown in following table 1:

Table 1: SNR values for noisy environment

	5%	**10%**	**15%**	**20%**	**25%**	**30%**
Robert	16.07	9.89	7.33	6.05	5.35	4.37
Sobel	14.82	14.09	12.28	8.7	4.92	1.64
Prewitt	18.85	18.49	17.37	15.03	11.69	8.41
Canny	19.43	20.38	20.06	20.04	19.4	18.99
Haar with Prewitt	7.16	3.1	1.96	0.66	0.15	0.1

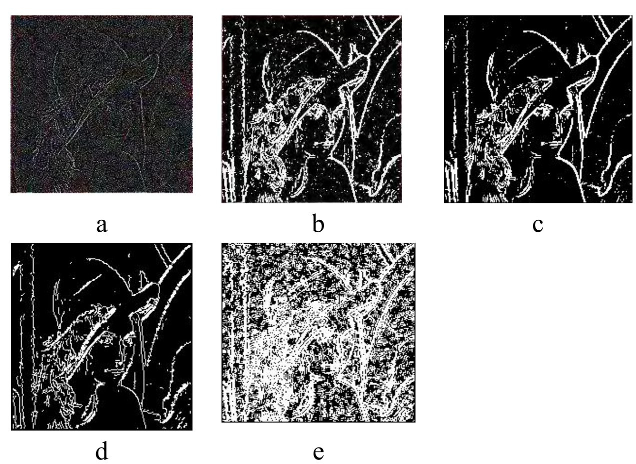

Fig 4.1: Edge images of Lena image noise added 15% obtained through a) Robert operator b) Sobel operator c) Prewitt operator d) canny operator e) Haar with Prewitt operator

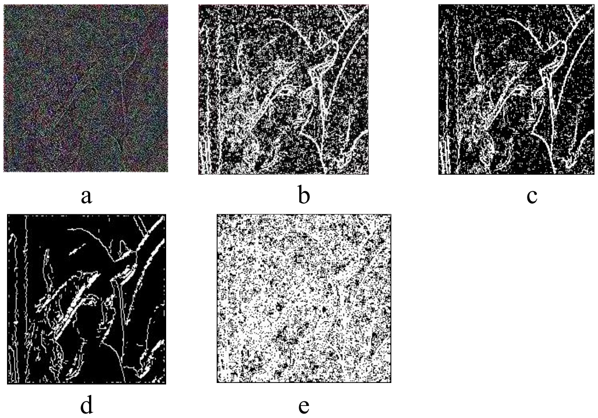

Fig 4.2: Edge images of Lena image noise added 25% through a) Robert operator b) sobel operator c) prewitt operator d) canny operator e) Haar with Prewitt operator

4.2 Blur tolerance experiment

In this experiment we use same Lena image for blur tolerance of each edge detectors. First image is made blur through Photoshop.

Then each blurred image is passed through each edge detector to check their performance in blurred environment. Figure 4.3 shows the performance of edge detectors in blurred environment. It shows that neither of edge detectors works better in blurred images. But comparatively, Canny based edge detector performs relatively better in comparison to other methods. Sobel and Prewitt performs very poor in such environments.

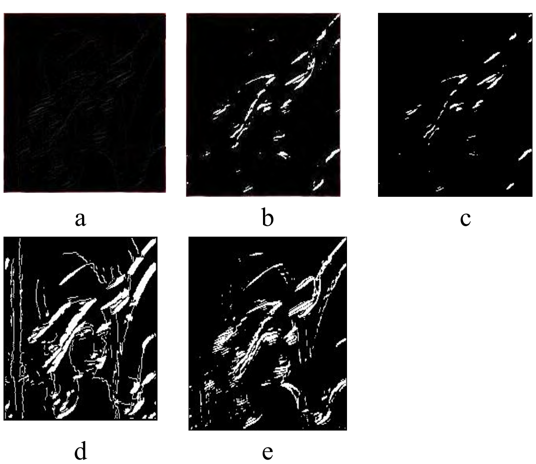

Fig 4.3: Edge images of Lena image motion blurred obtained through a) Robert operator b) sobel operator c) prewitt operator d) canny operator e) Haar with Prewitt operator

5 Conclusion

The performance proposed Haar based Prewitt Edge detection is compared with classical gradient operators and Canny edge detection. Haar based Prewitt method of edge detection does not perform better than classical edge detectors. It can perform better in blur condition. Canny edge detection algorithm is found to be better in noisy and blur condition but its results are highly dependent on adjustable parameters

References:

[1] R .C .Gonzalez, “Digital image processing*,”*

[2] Raman Maini, J.S Sohal, 2006, “Performance evaluation of Prewitt edge detector for noisy images”, *GVIP journal volume 6, issue 3*

[3] Raman Maini and Dr. Himanshu Aggarwal, 2006, “Study and comparison of various edge detection techniques”*,IJIP volume 3 issue*

[4] Mohamed Roushdy, 2006, “Comparative Study of edge detection algorithms applying on the grayscale noisy image using morphological filter”, *GVIP journal volume 6 issue 4*

[5] Hanghang tong and et al, “Blur detection for digital images wavelet transform”

[6]N.M. Nandhitha and et al, 2006, “A comparative study on the performance of the classical and wavelet based edge detection for image denoising on defective weld thermographs”, *Asia pacific conference on NDT*

[7] Jianjia pan,2008, “Edge detection combining wavelet transform and Canny operator based on fusion rules”

[8] Wang luo,2006, “Comparison for edge detection of colony images”, *Internaltional journal of*

computer science and network security volume 6 number 9A
[9] Jun li, 2003, “A wavelet approach to edge detection”, *Sam Houston University*
[10] Thomas moeslund,2009, “Canny edge detection