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A Nonlinear Directional Derivative Scheme for Edge Detection

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ABSTRACT

In this paper, a new one-stage nonlinear directional derivative scheme has been proposed for edge detection. The directional edge detection method was applied to gray and color images. The results were compared to three well-known conventional edge detectors namely Canny, Prewitt, and Sobel. According to results, the directional derivative method is an efficient edge detection tool especially in capturing details.

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1. INTRODUCTION

Edge detection is an important topic in image processing. It has been particularly applied in feature extraction of images in biomedical and computer vision [1]-[6]. The main aim of an edge detection tool is to detect and localize edges of an image under investigation. Basically, it converts 2-D image into a set of curves. Canny [7] developed a linear edge detection method based on the first derivatives of an image. Canny method is referenced by many researchers as one of the best linear edge detector [8]. Perona and Malik proposed a nonlinear diffusion tool for edge detection [9]. Although, Perona and Malik reported that they used anisotropic diffusion model it should be named as isotropic due to their diffusivity coefficient is a scalar value. Laligant and Truchetet [10] presented a nonlinear derivative scheme based on the nonlinear combination of two polarized derivatives of $f(x, y)$. They reported that their new scheme is successful in localization, SNR improvement and very low computational cost. Edges are caused by variety of factors such as changes in lightning intensity, depth, and color. Change is measured by 1-dimensional derivative of the observing property

2. RESEARCH METHOD

Definition: If $\hat{\mathbf{n}}$ is a unit vector, then $\hat{\mathbf{n}}\text{-}\nabla f$ is called *directional derivative* of f in the direction $\hat{\mathbf{n}}$. The directional derivative gives the rate of the change of f in the direction $\hat{\mathbf{n}}$.

The basic edge detection methods based on gradient of $f(x, y)$ (i.e. ∇f) has been developed in 2-directions such as;

$$\nabla f = \frac{\partial f(x,y)}{\partial x}\mathbf{i} + \frac{\partial f(x,y)}{\partial y}\mathbf{j} \tag{1}$$

Since digital images consist of discrete cells, namely pixel, the change might be expressed using a finite difference scheme;

$$\frac{\partial f(x,y)}{\partial x} = \frac{f(x+h,y)-f(x,y)}{h} \tag{2}$$

On the pixel base, h can be 1 as its minimum. Similarly, the change in y-direction can be calculated as;

$$\frac{\partial f(x,y)}{\partial y} = f(x,y+1) - f(x,y) \tag{3}$$

Hence, the strength of an edge is proportional to the magnitude of the gradient;

$$\|\nabla f\| = \sqrt{(\frac{\partial f(x,y)}{\partial x})^2 + (\frac{\partial f(x,y)}{\partial y})^2} \tag{4}$$

Although, any pixel (except from the pixels lie outer frame) has eight neighbours, according to equations and only two neighbour-pixels have influence on edge detection algorithm. This might lead an inaccuracy in calculations.

In this study, a new nonlinear directional derivative (NLDD) scheme considering eight neighbours of a pixel has been proposed. Eight unit vectors, which are illustrated in Figure 1, can be expressed as;

$$\hat{\mathbf{n}}_k = \cos(k\frac{\pi}{4})\mathbf{i} + \sin(k\frac{\pi}{4})\mathbf{j}\ ;\ k = 1,2,...,8 \tag{5}$$

Therefore, the strength of an edge is proportional to the sum of the absolute of directional derivatives;

$$E(x,y) = \sum_{k=1}^{8} |\hat{\mathbf{n}}_\mathbf{k} \text{-} \nabla f(x,y)| \tag{6}$$

$E(x,y)$ should be thresholded to finalize the edge detection process.

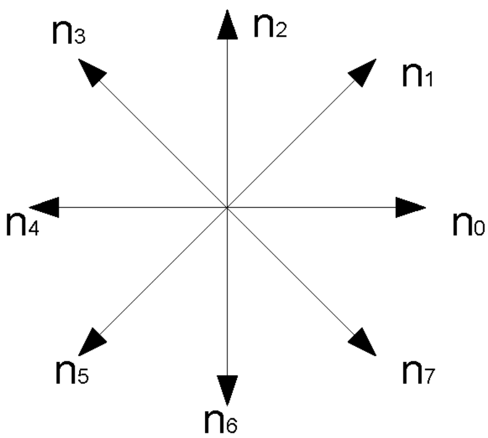

Figure 1. Direction vectors

3. RESULTS AND ANALYSIS

3.1. Testing

In literature, Pratt's figure of merit (PFOM) is commonly used to check the efficiency of the developed edge detection algorithm [11, 12]. It is computed as [13].

$$\text{PFOM}=\frac{1}{\max(I_D, I_I)}\sum_{i=1}^{I_D}\frac{1}{1+\alpha d_i^2} \tag{7}$$

Where I_D is the number of detected edges, I_I is the number of actual edges, d_i denotes the distance from i^{th} actual edge to the corresponding detected edge, and α is a positive scaling constant usually set to $1/9$ as in Pratt's work. In equation (7), the value of PFOM lies between 0 and 1. The greater value of PFOM means the better algorithm. According to equation (7), the results obtained from the developed edge detector must be compared with the images on which the edges are exactly known. Therefore, to test the efficiency of the NLDD edge detection algorithm in this work, synthetic images are intentionally used. The performance of the NLDD scheme on the natural images is discussed in the next section. The synthetic images are created using Matlab (Mathworks, R2012a). The developed NLDD scheme is compared with Prewitt, Canny, and Sobel edge detectors at the threshold level of 0.2. The results are illustrated in Figure 2. The NLDD scheme shows more than 90% success referring to calculated PFOM values.

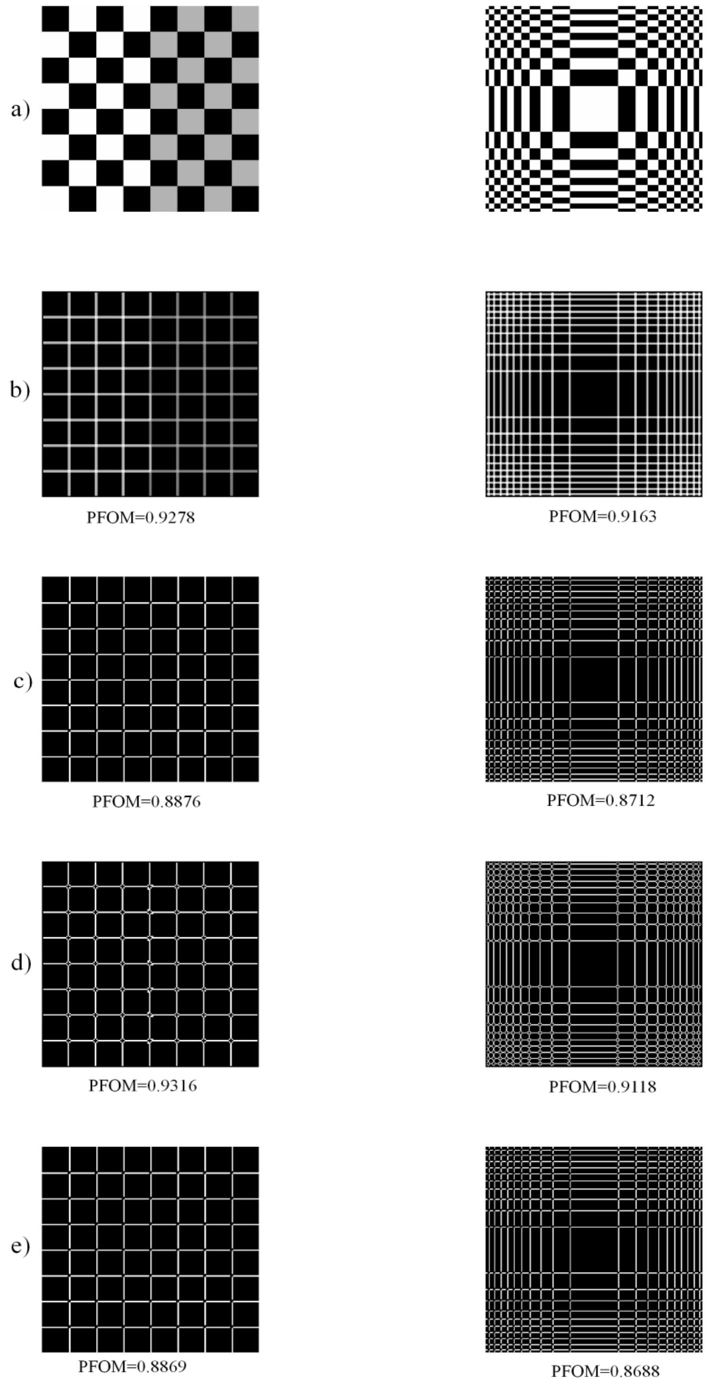

Figure 2. a) Syntetic images, b) NLDD, c) Prewitt, d) Canny, e) Sobel

Additionally, to carry out the noise sensivity of the NLDD scheme white Gaussian noises are added to the synthetic images. The results are shown in Figure 3. The values of PFOM decrease with the decrease of SNR coherently with the theoretical expectation.

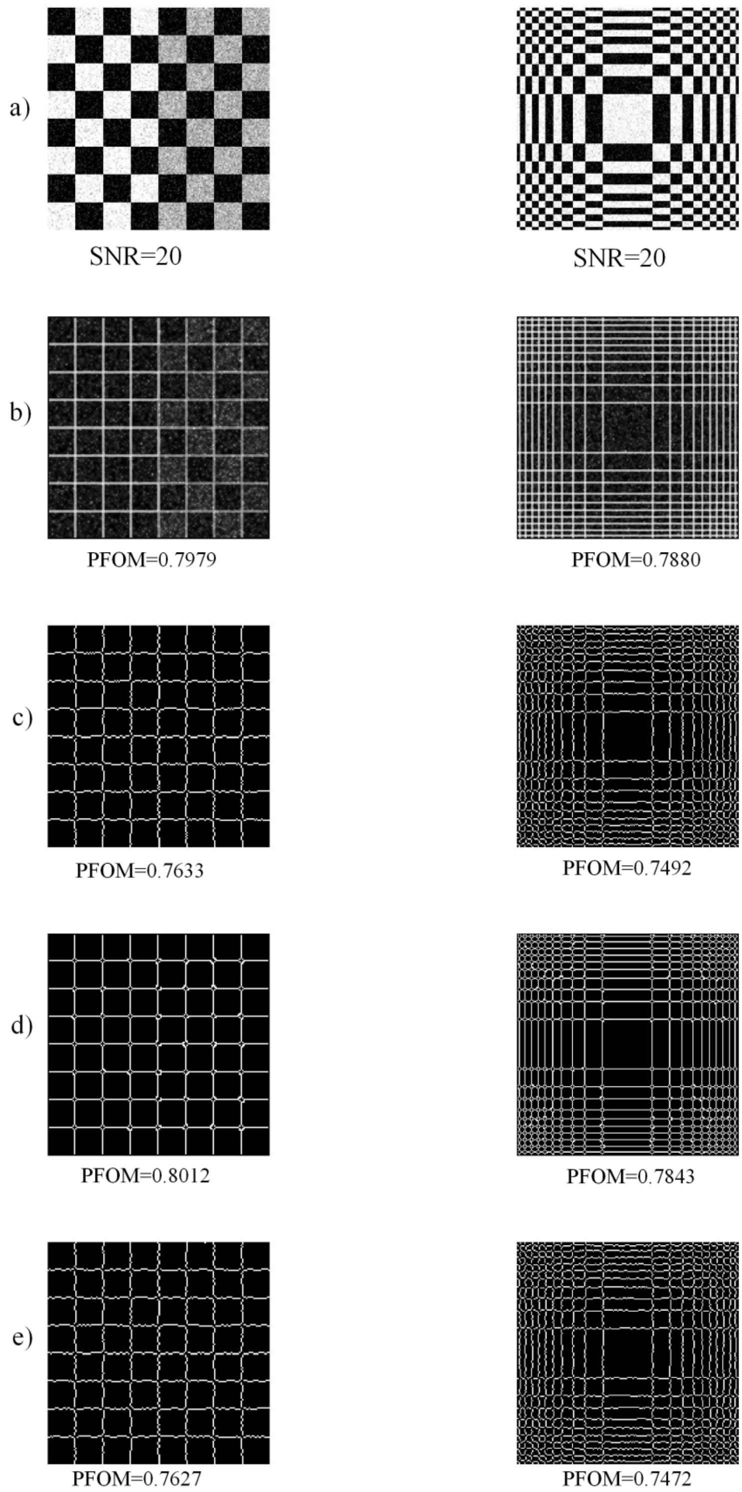

Figure 3. a) White Gaussian noise added syntetic images, b) NLDD, c) Prewitt, d) Canny, e) Sobel

3.2. NLDD Performance on Natural Images

3.2.1. Gray Image

A 512×512 pixel gray scale image, shown in Figure 4, has been used to check the efficiency of the directional derivative method. This image is obtained from ISIP database (http://sipi.usc.edu).

Figure 4. Original gray image

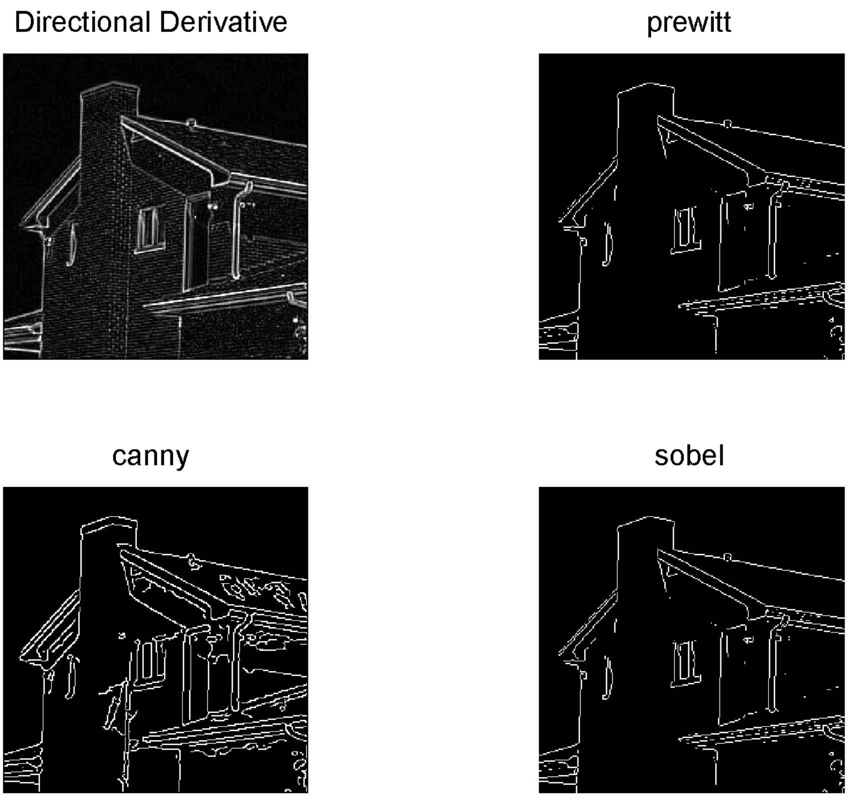

Figure 5. Comparison of directional derivative method using a gray image

The result of the directional derivative method and the results of Canny, Prewitt, and Sobel edge detectors are illustrated in Figure 5. Prewitt and Sobel supplied almost the same results. Canny edge detection tool resulted in more details. The directional derivative method presented the best result referring to capture the details of the image. For instance, bricks are visible only in the result of the directional derivative method. It should be noted that, the topic of the edge detection is very subjective. The efficiency of an edge detection tool may change from process to process. The needs and the questions of the person, who investigates the edge of an image, have the key role to determine which method is more appropriate to assign. The directional derivative method would be appropriate if the details had importance where the edge detection is used.

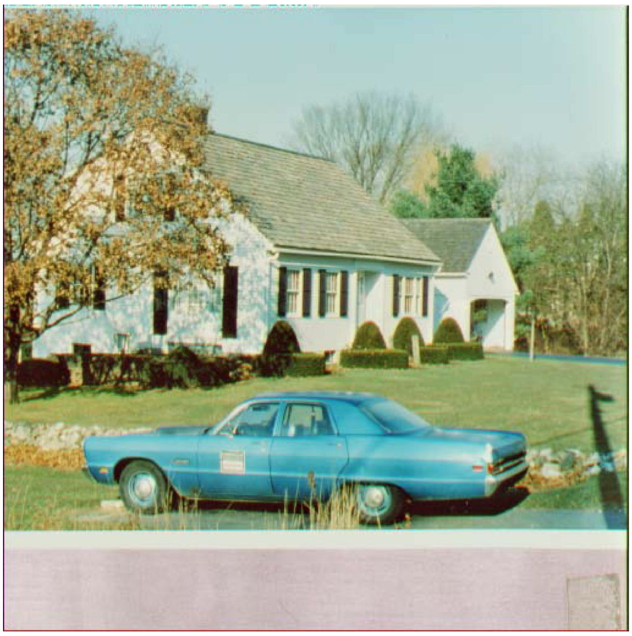

Figure 6. Original color image

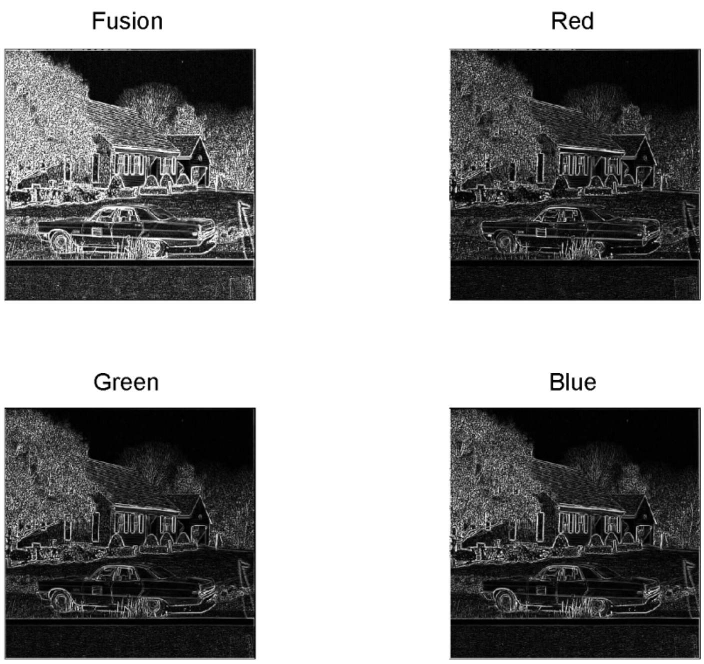

Figure 7. Red, green, blue, and fusion results of directional derivative method using a color image

3.2.2. Color Image

Color image edge detection is more complex than binary and gray images. Nevatia [14] published the first journal paper on color image edge detection. In literature, there are three ways to apply edge detection on color images such as fusion method, multi-dimensional gradient method and vector method. In this paper, the fusion method is adopted. According to fusion method, Red, Green and Blue components of a color image are separated; then edge detection procedure is applied for three times for each component. Finally, the results are fused to obtain one final edge map.

A 512×512 pixel color image, given in Figure 6, was used to perform the directional derivative method. It is taken from ISIP database (http://sipi.usc.edu). Firstly, RGB parts of the image were obtained; then the edges have been detected separately, and finally, the results were combined using fusion algorithm. According to the results illustrated in Figure 7, the directional derivative method is successful on edge detection of color images.

4. CONCLUSION

Edge detection has a particular place in image processing. Its application areas are wide-ranged such as biomedical, machine intelligence and computer vision. In this paper, a one-stage nonlinear directional derivative scheme for edge detection has been proposed. Syntetic images have been used to check the ability of the method. In addition, the developed scheme was applied to natural gray and color images.According to results, this method would be more appropriate for an edge detection process where the details are important.

REFERENCES

[1] T. Logeswari and M. Karnan, "An improved implementation of brain tumour detection using segmentation based on soft computing", *Journal of Cancer Research and Experimental Oncology*, Vol. 2, pp. 6 – 14, 2010.

[2] H. Gabor *et al.*,"Markov Chain Based Edge Detection Algorithm for Evaluation of Capillary Microscopic Images", In: *11th Mediterranean Conference on Medical and Biomedical Engineering and Computing*, Ljubljana, Slovenia: IFMBE Proceedings; 2007.

[3] A. Fedorov *et al.* , "Evaluation of Brain MRI Alignment with the Robust Hausdorff Distance Measures", In: *The 4th International Symposium on Visual Computing*, Las Vegas, Nevada: ISVC 2008; 2008.

[4] Z. Tu and S.C. Zu, " Image Segmentation by Data-Driven Markov Chain Monte Carlo", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 24, pp. 657 – 673, 2002.

[5] L. Caponetti *et al.*, "A Cooperative Agent Model for Edge Detection", *Turkish Journal of Electrical Engineering & Computer Sciences*, Vol. 5, pp. 147 – 154, 1997.

[6] A. Basturk and E. Gunay, " Efficient edge detection in digital images using a cellular neural network optimized by differential evolution algorithm", *Expert Systems with Applications*, Vol. 36, pp. 2645-2650, 2009.

[7] J. Canny, "A computational approach to edge detection", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 8, pp. 679 – 698, 1986.

[8] J. Weicker, "Anisotropic Diffusion in Image Processing", Stuttgart, Teubner-Verlag, 1998.

[9] P. Perona and J. Malik, "Scale-Space and Edge Detection Using Anisotropic Diffisuion", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 12, pp. 629 – 639, 1992.

[10] O. Laligant and F. Truchetet, "A Nonlinear Derivative Scheme Applied to Edge Detection", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 32, pp. 242 – 257, 2010.

[11] B. Chanda *et al.* "A Multi-Scale Morphologic Edge Detector", *Pattern Recognition*, Vol. 31, pp. 1469-1478, 1998.

[12] K.A. Panetta and E.J. Wharton, "Logarithmic Edge Detection with Applications", *Journal of Computers*, Vol.3, pp. 11-19, 2008.

[13] W.K. Pratt, "Digital Image Processing", New York, John Wiley & Sons, 1991.

[14] R. Nevatia, "A Color Edge Detector and Its Use in Scene Segmentation", *IEEE Transactions on Systems, Man and Cybernetics*. Vol. 7, pp. 820 – 826, 1977.

BIBLIOGRAPHY OF AUTHOR

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