A COMPREHENSIVE ANALYSIS OF EDGE DETECTORS IN SD-OCT IMAGES FOR GLAUCOMA DIAGNOSIS

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Abstract – *Glaucoma is a chronic eye disorder, associated with morphological changes to Optic Nerve Head (ONH), Retinal Nerve Fibre Layer (RNFL) and macular ganglion cell region. Spectral Domain-Optical Coherence Tomography (SD-OCT) is a high resolution, on-invasive imaging modality. Manifesting cross sectional region of retinal images, OCT increases the likelihood of diagnosing pre-perimetric Glaucoma. Segmentation of retinal boundaries offers objective quantification of progressive changes in optic nerve head. This article analyses the delineation of retinal boundaries using edge detection operators such as Canny, Prewitt, Roberts, Sobel, Laplacian of Gaussian, Kirsch compass mask and Robinson compass mask in a SD-OCT vivo healthy subject. Results demonstrated that kirsch compass mask outperforms other techniques in terms of different evaluation metrics such as Mean Square Error (MSE),Peak Signal to Noise Ratio (PSNR), Structural Similarity index(SSIM), Figure Of Merit (FOM), Performance Ratio (PR).Kirsch compass provides accurate and robust edge quality. Besides, Performance Ratio (PR) of Kirsch compass mask is extremely higher than other edge detection techniques resulting PR value of 15.2911.*

Key Words: Glaucoma, ONH, SD-OCT, MSE, PSNR, SSIM, FOM, PR.

1. INTRODUCTION

Glaucoma is a neurodegenerative ocular disease which is declared as the second leading cause of blindness according to WHO[2]. Malfunctioning of the retinal drainage system produces an Intra Ocular Pressure (IOP) in the eye can damages Optic Nerve Head (ONH)[5].Many imaging modalities are available to clinically diagnose the structural changes of ONH and monitor glaucoma..SD-OCT is an objective imaging technique which is used to spot structural changes in ONH and to localize the intra-retinal boundaries[6].

To assist the ophthalmologist in delineating different retinal layers as illustrated in Figure 1, automated segmentations have been proposed for clinically diagnosis of glaucoma. Edge detection operators plays a vital role in retinal layer segmentation based on discontinuities (changes in pixel intensity) of an image.[9]

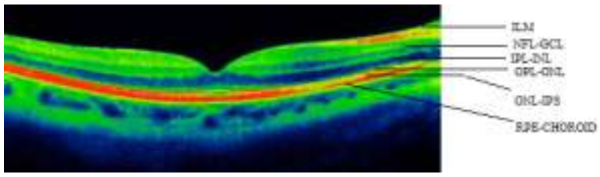

Figure 1. Intra retinal boundaries of Optic Nerve Head in an OCT image

Most commonly used edge detection operators are Canny, Prewitt, Roberts, Sobel, Laplacian Of Gaussian (LOG).So far, Canny operator provides an efficient outcome and occupies a significant role in edge detection.Here,we intended to include two more operators like Kirsch and Robinson compass mask for achieving better results in OCT boundary segmentation.

1.1 Motivation Justification

Though, various novel and hybrid segmentation algorithms been introduced, the key role of edge detecting operators in delineating high contrast edges are quick and easy. It is necessary to identify the best operating techniques since many are available in use. To motivate this, comparison of these edge detectors are performed here and an optimal result is justified based on appropriate metrics.

1.2 Outline of the Paper

The outline of the proposed system is shown in Figure 2.

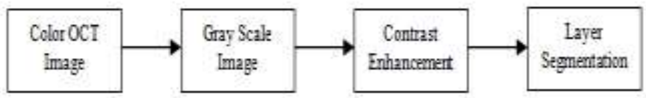

Figure 2. Outline of the proposed system.

1.2 Organization of the Paper

The remaining portion of the paper is structured as follows Section II comprises literature review, Section III describes methodologies, Section IV includes Performance analysis and Section V discuss conclusions.

2. RELATED WORK

Su Luo [1] compared three edge detectors such as Canny, two-pass method, Edge flow technique to identify appropriate edge detector in OCT image segmentation. The author measures the performance of the algorithms using relevant metrics such as FOM, MLD, TPR, FPR and Accuracy and the two-pass method brings better results.

Shijian Lu [3] proposed a technique to delineate retinal layer boundaries. The OCT image is divided into vessel and non-vessel regions and then denoising using Bilateral and median filters. Using canny edge detector, five retinal layers are segmented accurately.

Zhijun Gao [4] proposed a method of intra retinal layers segmentation using Graph optimal approach. Initially, canny edge detector is utilized to detect the high contrast connected components. Accurate results are achieved because the canny detector provides better connected components for improving graph performance.

3. METHODOLOGY

3.1 Preprocessing

Working with colour images makes the task more complex, hence these colour images are first converted to Gray scale Images(GSI).Then contrast of GSI image is enhanced to boost the high intensity pixel along retinal boundaries[11]. Then edge detection operators are applied to discover the optimal resulting technique. The pre-processed output image is shown in Figure.3 (b, c).

3.2 Gradient Based Edge Detection Operators:

The edge detection operators like Sobel, Prewitt, Roberts, Kirsch compass mask are based on gradient information.

A. Sobel Operator

Sobel operator calculates approximate gradient vector of an image by focusing high spatial gradient of corresponding edges.[7] Maximum responds to horizontal and vertical edges using 3X3 convolution kernel mask with input image is given by

$$SG_x = \begin{vmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{vmatrix} \quad SG_y = \begin{vmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{vmatrix}$$

The gradient magnitude, G can be derived as

$$|G| = \sqrt{SG_x^2 + SG_y^2} = |SG_x| + |SG_y|$$

The angle of orientation to identify maximum edges is given as $\theta = \arctan\ (SG_x/SG_y)$

where ϴ is the angle to find direction.

When one kernel stays on this position, the other kernel is allowed to rotate in 90^0.The output of Sobel operator is shown in Figure 3 (d).

B.Prewitt Operator:

This operator identifies the presence of edges by evaluating the higher grey levels in an image with different kernels [7] and the convolution mask is

$$G_x = \begin{vmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{vmatrix} \quad G_y = \begin{vmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{vmatrix}$$

The gradient magnitude, G can be derived as

$$|G| = \sqrt{SG_x^2 + SG_y^2} = |SG_x| + |SG_y|$$

The output of prewitt operator is displayed in Figure3 (e).

C. Roberts Operator:

Roberts is a discrete operator. It can calculate 2D spatial gradient measurement of an image having two kernels, used to rotate one another by 90^0 [7].The horizontal and vertical convolution mask is given by

$$G_x = \begin{vmatrix} 1 & 0 \\ 0 & -1 \end{vmatrix} \quad G_y = \begin{vmatrix} 0 & 1 \\ -1 & 0 \end{vmatrix}$$

The angle of orientation is given as

$$\theta = \arctan\ (G_y/G_x) - 3\pi/4$$

where ϴ is the angle to find direction and it respond to 450 edges maximally. The output of Roberts operator is illustrated in Figure 3(f).

D. Kirsch compass mask:

Kirsch operator detects the edges with maximum strength in a fixed direction. Rotating along 450 in all eight directions like North (N), NorthWest (NW), South(S), SouthWest (SW), West (W), East (E), South East (SE), North East (NE)[10], the convolution mask with input image is given as

$$N = \begin{vmatrix} -3 & -3 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & 5 \end{vmatrix} \quad NW = \begin{vmatrix} -3 & 5 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & -3 \end{vmatrix}$$

$$W = \begin{vmatrix} 5 & 5 & 5 \\ -3 & 0 & -3 \\ -3 & -3 & -3 \end{vmatrix} \quad SW = \begin{vmatrix} 5 & 5 & -3 \\ 5 & 0 & -3 \\ -3 & -3 & -3 \end{vmatrix}$$

$$S = \begin{vmatrix} 5 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & -3 & -3 \end{vmatrix} \quad SE = \begin{vmatrix} -3 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & 5 & -3 \end{vmatrix}$$

$$E = \begin{vmatrix} -3 & -3 & -3 \\ -3 & 0 & -3 \\ 5 & 5 & 5 \end{vmatrix} \qquad NE = \begin{vmatrix} -3 & -3 & -3 \\ -3 & 0 & 5 \\ -3 & 5 & 5 \end{vmatrix}$$

The main advantage of kirsch filter is the efficiency of detecting maximum edges. The output of kirsch filter is depicted in Figure 3(g).

E. Laplacian of Gaussian (LoG):

Isotropic digital L0G kernels convolving input image is used to calculate Laplacian value[7]. The Laplacian of input image L(x, y) is given by

$$L(x, y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2}$$

LoG filter performs the following three step operations.

1. Exploits second order gradients of pixel intensity for an image.

2. Smoothening the image using Gaussian filter which can be defined by $\mathbf{LoG(x, y)} = \frac{1}{\pi}$

3. Apply Log. The convolution mask of LoG operator is

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix} \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

The output of LoG operator is shown in Figure 3(h).

3.3 OPTIMAL EDGE DETECTOR:

Canny operator and Robinson operator comes under the group of optimal edge detector.

A. Canny operator:

Canny operator is used to find optimized results on complex images. Canny operator has the potential of providing clear and better edge detection and good localization. The multistage process of canny operator is as follows.

1. Smoothening the image by Gaussian convolution.

2. Towards x and y direction, the convolution mask is used to compute gradient.

The gradient of the given image is

$$|G| = \sqrt{G_x^2 + G_y^2} = |G_x| + |G_y|$$

3. Compute the edges.

4. Trace the edges by finding edge direction as $\theta = \tan^{-1}(G_y/G_x)$, where ϴ is the angle of orientation.

5. Evaluating local maxima to find edges.

6. Concluding final edges by hysteresis method.

The output of canny operator is shown in figure 3(i).

B. Robinson Compass Mask:

Robinson is another method of derivative mask and it is also named as direction mask. By considering one mask and rotate it along 8 major compass directions, North(N), West(W), South(S), East(E), North West (NW), South West (SW),South East (SE), North East (NE)[10], the convolution mask of input image is

$$N = \begin{vmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{vmatrix} \qquad NW = \begin{vmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 2 \end{vmatrix}$$

$$W = \begin{vmatrix} 5 & 5 & -3 \\ 5 & 0 & -3 \\ -3 & -3 & -3 \end{vmatrix} \qquad SW = \begin{vmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & -1 \end{vmatrix}$$

$$S = \begin{vmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{vmatrix} \qquad SE = \begin{vmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{vmatrix}$$

$$E = \begin{vmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{vmatrix} \qquad NE = \begin{vmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{vmatrix}$$

These convolution masks focus on rapid change of pixels to detect high value edge point. Finally all the detected edge points are combined to form line of edges.

The output of Robinson compass mask is illustrated in figure 3(j).

4. EXPERIMENTAL RESULTS

***4.*1Performance Metrics:**

The performance metrics such as Mean Squared Error (MSE), Peak signal to Noise Ratio (PSNR), Structural Similarity Index (SSIM), Figure of Merit (FOM), and Performance Ratio (PR) are calculated to recognize which operator gives better outcome.

A. Mean Square Error (MSE):

MSE is the measure of loss of squared error in which the estimator fails to depict the more accurate information[8]. The formula for calculating MSE is as follows.

$$MSE = \frac{1}{MN}\sum[I_1(m, n) - I_2(m, n)]$$

M, N be the rows and columns of an image, I1 and I2 are the original and detected output image respectively.

B. Peak Signal to Noise Ratio (PSNR):

PSNR is used to measure the quality of reconstructed image by evaluating the ratio between maximum power of signal and power of noise[8]. It can be calculated as

$$PSNR = 10\log_{10}\left[\frac{\max(I)^2}{MSE}\right]$$

where max (I) is the maximum pixel value of input image and MSE is the Mean Square Error.

C. Structural Similarity Index (SSIM):

SSIM index is used to quantify the image quality by estimating the weighted combination of luminous, contrast changes and structural changes between the input and reconstructed image[8].

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

where μ_x, μ_y - average of x and y respectively,

σ_x^2, σ_y^2 - variance of x and y respectively,

σ_{xy} - covariance of x and y,

c1, c2 - two variables used to stabilize the equation.

D. Figure of Merit (FOM):

Figure of Merit is used to analyse the efficiency of the technique implemented[8].

$$FOM = \frac{1}{\max(N_a, N_d)}\sum_{i=1}^{N}\left[\frac{1}{1 + d\alpha^2}\right]$$

N_a is the detected edges, N_d is the Ideal edges is the distance; α is the penalty factor.

E. Performance Ratio:

Performance ratio is the measure of image quality[8]. It can be calculated as

$$PR = \frac{\text{True Edge Pixel}}{\text{False edge pixels identified as non} - \text{edges}}$$

4.2 PERFORMANCE EVALUATION

A healthy subject of OCT images is used to analyse the performance of different edge detecting operators. As a consequence, Performance Ratio of Kirsch compass mask is greater than other edge detection techniques which can yield value of 15.2911.In addition; Mean Square Error (MSE) of Kirsch compass mask is lower than others. Overall, Kirsch operator outperforms other techniques based on measurement like PSNR, SSIM and FOM.The result of edge detecting operators for a healthy subject is summarized in Table 1

Table1.Value of MSE, PSNR, SSIM, FOM, PR

	MSE	PSNR	SSIM	FOM	PR
Sobel	12147.97	7.3198	0.26649	0.02370	4.7648
Prewitt	12148.05	7.3197	0.26649	0.02368	4.7463
Roberts	12150.55	7.3188	0.26680	0.02370	4.0651
Kirsch	10880.06	7.7985	0.35284	0.21912	15.2911
LoG	12136.15	7.3240	0.26690	0.02382	9.6977
Canny	12137.38	7.3235	0.26772	0.02481	11.2555
Robinson	12134.81	7.3245	0.26801	0.21912	11.1779

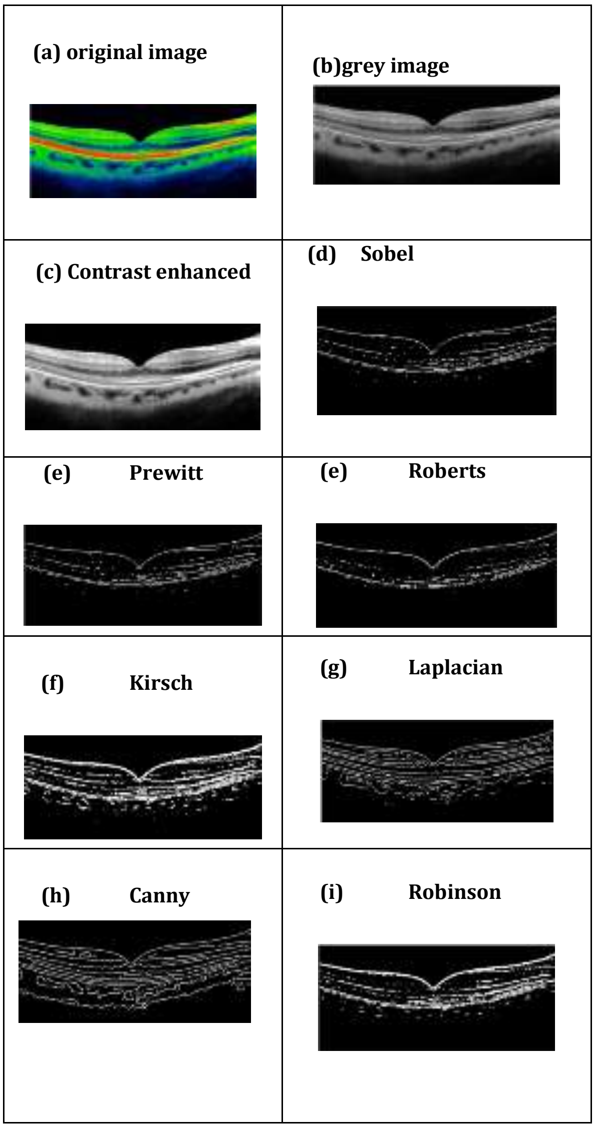

Figure 3.Output of different edge detecting operators.

5. CONCLUSION

The edge detection operators such as Sobel, Prewitt, Roberts, Kirsch, LoG, Canny and Robinson for extracting different retinal boundaries are compared in this paper. Quality assessment metrics like MSE, PSNR, SSIM, FOM, PR are evaluated. Considering all these factors, Performance of kirsch compass mask succeeds other techniques. Hence, the edge detecting operators can obtain optimal results in retinal layer extraction of high contrast connected edges.

REFERENCES

[1] J. Y. G. Z. a. A. Su Luo, Jing Yang, Qian Gao, Sheng Zhou, Chang'an A.Zhan, "The Edge Detectors suitable for Retinal OCT image segmentation," Journal of Health care Engineering, p. 13, 2017.

[2] Appaji M.AbhishekTos T.J.M.Berendschot ,Shyam Vasudeva Rao, "Segmentation and analysis of Retinal Layers(ILM & RPE) in Optical Coherence Tomography Images with Edema," IEEE conference on Bio medical Engineering and Sciences,Dec 2014.

[3] Shijian Lu,Carol Cheung,Jiang Liu,Hwee Ying Limm "Automated Layer Segmentation of Optical Coherence Tomography Images",IEEE Transactions on Biomedical Engineering,Vol.57,October 2010.

[4] Zhijun Gao,Wei Bu,Xiangqian Wu,Yalin Zheng, "Intra-retinal Layers Segmentation of Macular OCT Images Based on the Graph Optimal Approach," BioMedical Engineering and Informatics,IEEE 2016.

[5] Benjamin Michael Davis,Laura Crawley,Milena Pahlitzsch,Fatimah Javaid,"Glaucoma:the retina and Beyond," Acta Neuropathol,Springer 10.1007/s00401-016-1609-2, 2016.

[6] Surat Patanakanog,Teresa C.Chen,"Imaging Modality in Diagnosis and Monitoring of Glaucoma:Spectral Domain Optical Coherence Tomography," Diagnosis and monitoring of Glaucoma,Springer 10.1007/s40135-016-0108-x, 2016.

[7] Saket Bhardwaj,Ajay Mittal, "A Survey on Various Edge Detector Techniques , "Elsevier , 10.1016 /j .protcy.2012. 05.033, 2012.

[8] Diana Sadykova,Alex Pappachen James,"Quality Assessment Metrics for Edge Detection and Edge-aware Filtering: A Tutorial Review," January 2018.

[9] K.Bala Krishnan , Shiva Prakash Ranga , Nageswara Guptha, "A Survey on Different Edge Detection," Indian Journal of Science and Technology,Vol 10(4), January 2017.

[10] Rashmi, Mukesh Kumar, Rohini Saxena , "Algorithm and Technique on various edge detection : A survey ," Signal & Image Processing : An International Journal (SIPIJ), Vol.4, No.3, June 2013.

[11] Shahjun Nisha ,Ashika Parvin,Preservation of Historical Document Using EnhancemenTechniques,International journal of Trend in Research and Development,Vol 4(1),ISSN:2394-9333,Jan-Feb(2016).

BIOGRAPHIES

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