A Comprehensive Analysis of Edge Detectors in Fundus Images for Diabetic Retinopathy Diagnosis

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Abstract

Diabetic Retinopathy is an eye disorder that affects the people with diabetics. Diabetes for a prolonged time damages the blood vessels of retina and affects the vision of a person and leads to Diabetic retinopathy. The retinal fundus images of the patients are collected are by capturing the eye with digital fundus camera. This captures a photograph of the back of the eye. The raw retinal fundus images are hard to process. To enhance some features and to remove unwanted features Preprocessing is used and followed by feature extraction . This article analyses the extraction of retinal boundaries using various edge detection operators such as Canny, Prewitt, Roberts, Sobel, Laplacian of Gaussian, Kirsch compass mask and Robinson compass mask in fundus images. Edge detection is the process of identifying the boundaries of the objects in the image Results demonstrated that canny outperforms other techniques. Different evaluation metrics such as Mean Square Error (MSE),Peak Signal to Noise Ratio (PSNR), Entropy are analysed , Canny provides accurate edge quality.

Keyword - *Diabetic Retinopathy, fundus image, Preprocessing, Feature Extraction, Edge Detection Techniques.*

I. INTRODUCTION

Diabetic Retinopathy is an eye disease among people with diabetics which may lead to vision impairment. It causes loss of vision in 1.8 Million in 2015 people to 37 Million in 2040. Diabetic retinopathy arise due to damage to the tiny blood vessels in retina from the optic disk inside the eyes. Diabetic Retinopathy (DR) is classified into Non Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR). Based on the anomalies present in the retina the DR the stages can be identified.The anomalies such as micro-anourysms, hemorrhages, hard exudates, cotton wool spots develops at different stages of diabetic retinopathy.NPDR stage has mild, moderate and severe stage. PDR is an advanced stage in which the fluids sent by the retina for nourishment trigger the growth of new blood vessel that are abnormal and fragile.Initial stage has no vision problem, but with time and severity of diabetes it may lead to vision loss.DR can be treated in case of early detection.[1][2]

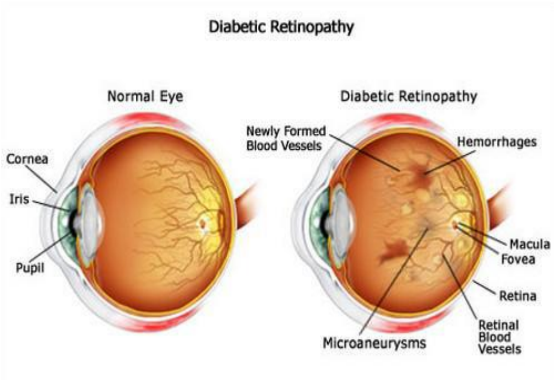
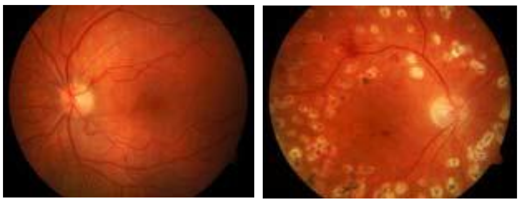


Fig 1: Normal Eye and DR affected eye

Fundus images can be used to diagnose DR. The raw retinal fundus images are hard to process. Preprocessing is used to enhance some features and to remove unwanted features. The acquired image is converted into gray scale image. Then processing is carried out to improve the quality of images.



a b
Fig. 2: Retinal fundus images of a normal b DR

Edge detection operators plays a vital role in feature extraction of retinal images based on discontinuities (changes in pixel intensity) of an image. Most commonly used edge detection operators are Canny, Prewitt, Roberts, Sobel, Laplacian Of Gaussian (LOG), Kirsch and Robinson compass mask.Among these, Canny operator provides an efficient outcome and gives better results. The outline of the proposed system is shown in Figure 2.

As there are various edge detection techniques are available and been introduced, to identify the best method, Comparision of different techniques are performed. Based on the metrices the result is concluded.

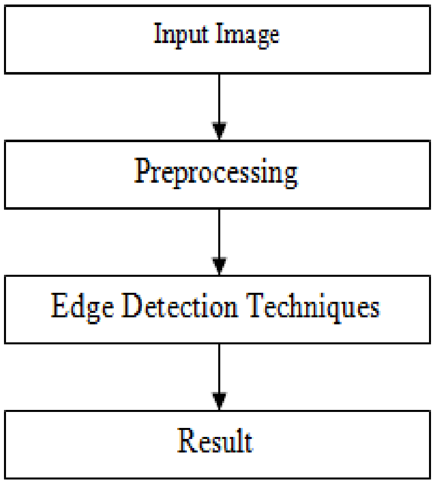


Fig 3: Block diagram of proposed system

A. Motivation Justification

The main role of edge detecting operators in delineating high contrast edges are quick and easy. As there are many techniques ,it is needed to identify the best technique. To motivate this, comparison of different edge detectors are performed and an optimal result is justified based on attained metrics.

B. Organisation Of The Paper

The paper continues as follows Section II comprises literature review, Section III describes methodologies, Section IV contains Performance analysis and Section V discuss conclusions.

II. RELATED WORK

[5]Anjali A Kunghatkar, M.S.Panse proposed a method to detect abnormalities in the fundus image. Canny’s edge detector is used for feature extraction.Supprt vector machine is used for classification of DR.

[6] DU Ning, LI Yafen implemented morphological processing techniques and texture analysis methods on the fundus images to detect the features such as area of blood vessels,, hard exudates and the contrast and homogeneity.

[7] May Phu Paing, Somsak Choomchuay proposed a system to automatically detect ang claasify the severity of DR,The lesions are extracted and features such as area, perimeter, and count from lesions are used to classify the stages and artificial neural network is used.

III. METHODOLOGY

A. Input Image

Fundus images are used in the proposed method to extract features for diagnosis of DR.

B. PreProcessing

Working with color images makes the task difficult in image processing, so the color images are converted to Gray scale Images(GSI).Then contrast of GSI image is enhanced to boost the high intensity pixel along retinal boundaries. Contrast Limited Adaptive Histogram (CLACHE) is used to enhance the GSI Image. The preprocessed output image is shown in Table 2.

C. Edge Detection Techniques

Different edge detection operators like Sobel, Prewitt, Roberts, Kirsch compass mask are based on gradient information and Canny operator and Robinson operator comes under the group of optimal edge detector are applied to discover the optimal resulting technique from the enhanced image. [10][11]

1. Gradient Based Edge Detection Operators:

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

1.1 Sobel Operator:

This is also known as sobel Feldman operator. It calculates approximate gradient vector of an image by focusing high spatial gradient of corresponding edges. Maximum responds to horizontal and vertical edges using 3X3 convolution kernel mask with input image to detect the edge and is given by

$$SG_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad SG_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

Gx is used to find out the gradient in x axis. Gy is used to find out the gradient in y axis.

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.

1.2 Prewitt Operator:

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

$$SG_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad SG_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

The gradient magnitude, G can be derived as

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

1.3 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 900.The horizontal and vertical convolution mask is given by

$$G_x = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \qquad G_y = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}$$

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.

1.4 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), the convolution mask with input image is given as

$$N = \begin{bmatrix} -3 & -3 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & 5 \end{bmatrix} \qquad NW = \begin{bmatrix} -3 & 5 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & -3 \end{bmatrix}$$

$$W = \begin{bmatrix} 5 & 5 & 5 \\ -3 & 0 & -3 \\ -3 & -3 & -3 \end{bmatrix} \qquad SW = \begin{bmatrix} 5 & 5 & -3 \\ 5 & 0 & -3 \\ -3 & -3 & -3 \end{bmatrix}$$

$$S = \begin{bmatrix} 5 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & -3 & -3 \end{bmatrix} \qquad SE = \begin{bmatrix} -3 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & 5 & -3 \end{bmatrix}$$

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

The main advantage of kirsch filter is the efficiency of detecting maximum edges.

1.5 Laplacian of Gaussian (LoG):

LOG is Laplacian Of Gaussian. Marr and Hildreth proposed the method of zero-crossing of Log. Isotropic digital L0G kernels convolving input image is used to calculate Laplacian value. 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 has 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 $\text{LoG}(x, y) = \frac{1}{\pi}$

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

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

2. Optimal Edge Detector:

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

2.1 Canny operator:

It was developed by John.F.Canny in 1986. It applies Gaussian filter to reduce the noise. For thinning the edge non maximum suppression applied and applying the double threshold method to connect or link the edge pixels**.** 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. To find edges local maxima Evaluating.

6. final edges Concluded by hysteresis method.

2.2 Robinson Operator

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), NorthEast (NE), the convolution mask of input image is

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

$$W = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & -1 \end{bmatrix} \qquad SW = \begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix}$$

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

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

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.

IV. EXPERIMENTAL RESULTS

A. Performance Metrics

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

1. Peak Signal To Noise Ratio (PSNR)

It is the evaluation standard of the reconstructed image quality, is the most wanted feature. PSNR is measured in the decibels (dB) and it is given by

$$PSNR = 10\log (255 / 2\ MSE)$$

Where the value 255 is the maximum possible value that can be attained by the image signal. Mean square error is defined as where M*N is the size of the original image. Higher the PSNR value betters the reconstructed image.

2. Mean Square Error (MSE)

The average squared difference between the reference signal and distorted signal is called as the mean square error. It can be easily calculated by adding up the squared difference pixel-by-pixel and dividing by the total pixel count. Let m x n is a noise free monochrome image I, and K is defined as the noisy approximation. Then the mean square error between these two signals is defined as:

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

3. Entropy

For a given PDF p, entropy Ent[p] is computed. In general, the entropy is a useful tool to measure the richness of the details in the output image.

$$Ent[p] = -\Sigma k = 0\ (k)\log 2\ p\ (k)$$

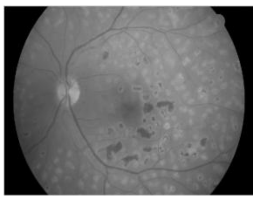
TABLE I

VALUES OF PSNR, MSE, ENTROPY

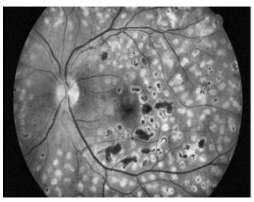
	PSNR	MSE	Entropy
Sobel	7.1621	12597.15	0.1959
Prewitt	7.1621	12597.22	0.1943
Roberts	7.1613	12599.35	0.1487
Kirsch	7.1145	12735.99	0.1002
LoG	7.1662	12585.31	0.3792
Canny	7.1692	12576.62	0.5104
Robinson	7.1629	12594.76	0.2486

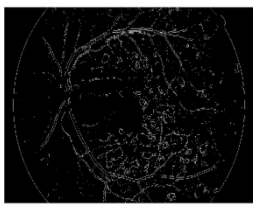
B. Performance Evaluation

a

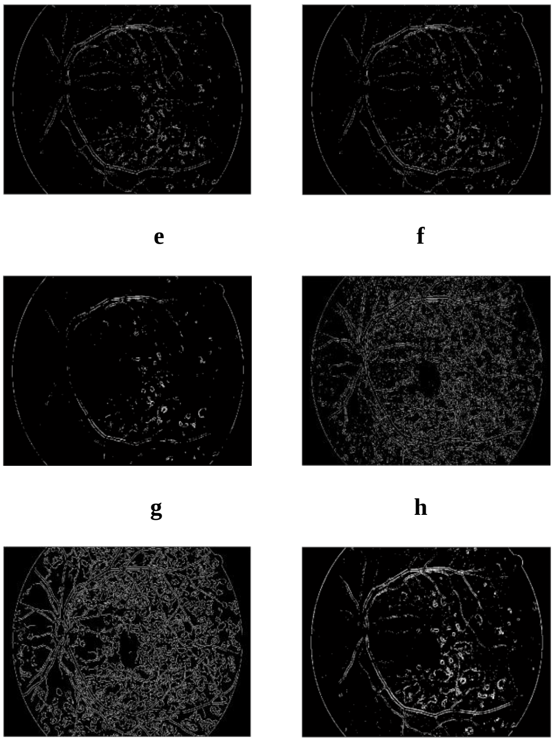


b





c d



i j

Fig 4: a. Input Image, b. GSI, c. CLACHE, d. Sobel, e. Prewitt, f. Roberts, g. Kirch, h. LOG, i. Canny, j. Robinson

V. CONCLUSION

In this paper different edge detection techniques like Sobel, Prewitt, Roberts, Kirsch, LoG, Canny and Robinson for extracting different retinal boundaries are compared for retinal fundus image. The image quality obtained after applying these algorithms is assessed with metrics. These metrics include Peak Signal To Noise Ratio (PSNR), and Mean Square Error (MSE). From the results Canny edge detection succeeds because it has higher PSNR, Entropy and Lower MSE value. Hence, the edge detecting operators can obtain optimal results in feature extraction of high contrast connected edges.

REFERENCES

[1] Swati gupta and Karandikar,"Diagonosis of diabetic retinopathy using machine learning", Journal of Research and development, 2015

[2] Sarni Suhaila Rahim, Vasile Palade, Chrisina Jayne, Andreas Holzinger, James Shuttle worth, "Detection of Diabetic Retinopathy and Masculopathy in Eye Fundus Images using Fuzzy Image Processing", Springer International Publishing Switzerland 2015, Y.Guo et al. (Eds.): BIH 2015 , LNAI 9250, pp.379-388, 2015

[3] Jeline Devadhas and R. Binisha, "Early Diagonosis of Diabetic Retinopathy by the Detection of Microaneurysms in Fundus Images", ICTACT Journal On Image and Video Processing , ISSN: 0976-9102, Volume:08, Issue: 04

[4] G. Prabavathi, Dr.K.Mahesh, "Automated Analysis of Microaneurysm Detection of Diabetic Retinopathy", International Journal for Modern Trends in Science and Technology, ISSN: 2455-3778, Volume:03, Issue No: 05, May 2017

[5] Anjali A Kunghatkar, M.S.Panse. "Detection of Lesions and classification of Diabettic Retinopathy", International Journal of scientific research in science and technology, vol 4, Issue 8, ISSN 2395-6011.

[6] DU Ning, LI Yafen, "Automated Identofication of Diabetic Retinopathy stages using Support Vector Machine ", Proceedings of the 32nd Chinese control conference, July 26-28,20123, Xi'an, China.

[7] May Phu Paing, Somsak Choomchuay, "Detection of Lesions and classification of Diabettic Retinopathy using fundus images", The 2016 Biomedical Engineering International Conference, 978-1-5090-3940-1/16/$31.00, 2016 IEEE

[8] Salman Sayed, Dr. Vandana Inamdar, Sangram Kapre, " Detection of Diabetic Retinopathy usimg Image Processing and Machine Learning", International Journal of Innovative Research in Science, Engineering and Technology, ISSN: 2319-8753, Vol.6, Issue 1, January 2017

[9] Khan Abdul Mukhtar Khan, "Detection of Digital Image Processing A Survey", International Journal of Research in Computer Application and Robotics",ISSN 2320-7345 Vol.6 Issue 1, Pg:13-19, January 2018

[10] A.Nagoor Meeral, S.Shajun nisha, "A Comprehensive Analysis Of Edge Detectors In Sd-Oct Images For Glaucoma Diagnosis", International Research journal of Engineering and Technology, vol. 6, no. 3, pp. 252-256, 2019.

[11] "Survey Of Various Edge Detection Techniques Over Brain MRI", International Journal of trends in research and development , vol 4(1), ISSN 2394-9333, Jan-Feb 2016