IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-6, Issue-5, May 2018 E-ISSN: 2347-2693

Analysis of Diabetic Retinopathy Based on Texture Properties of Retinal Images

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Available online at: www.ijcseonline.org

Accepted: 21/May/2018, Published: 21/May/20182018

Abstract— Diabetic retinopathy is the prime cause of vision loss in diabetic patients. It is caused by the damage of retinal blood vessels due to prolonged diabetes. This paper investigates on some image processing operations to extract blood vessels taking five feature set based on texture properties of images for the analysis of diabetic retinopathy. The proposed method stands out prominent in terms of specificity and accuracy.

Keywords- *diabetic retinopathy, sensitivity, specificity, accuracy, fundus image*

I. INTRODUCTION

The effect of diabetes in the eye is called diabetic retinopathy which can lead to partial or even complete loss of vision. Diabetes occurs when the pancreas does not secrete enough amount of insulin. The blood supply in all the layers of retina is done with the help of micro blood vessels. When a large amount of glucose gathers in blood, the blood vessels start reacting because of insufficient distribution of oxygen to cells. The blockage in these vessels leads to severe eye injury. The first signs of diabetic retinopathy are called microaneurysms. It swells the blood vessels. Microaneurysm detection in the early stage can reduce the degree of blindness. Other symptoms are appearance of exudates as well as abnormal growth of blood vessels. Exudates are yellow coloured lipid substances of leakage from damaged capillaries, with different shapes and brightness in different locations of the retina [1]. Diabetic retinopathy has four different stages [2]:

- Mild Non-Proliferative: Microaneurysms may occur at this stage. In the blood vessels of the retina, small areas of balloon-like swelling occur.
- Moderate Non-Proliferative: Some blood vessels that nourish the retina are blocked leading to bleeding and development of cotton wool spots.
- Severe Non-Proliferative: Many more blood vessels are blocked thus depriving several areas of the retina with the blood supply. Hence, these areas of the retina send signals so that it can grow new blood vessels for nourishment.
- Proliferative: This is the advanced stage where the signals send by the retina for nourishment trigger the growth of new blood vessels. These blood vessels are abnormal and fragile and grow along the retina and surface of the vitreous gel that fills the inside of the eye. These new blood vessels have thin and fragile walls that leak blood which can cause severe partial vision loss or total blindness.

Here, we have proposed a feature extraction method with the help of five feature set which is formulated for the automatic diabetes recognition system. We have captured the blood vessels which can later be fed to a neural network environment for the classification purpose.

Chapter II contains a brief description of the human eye. Chapter III contains the material being used. Chapter IV contains the performance evaluation parameters. Chapter V gives the tabulated list of related works. Chapter VI describes the design and implementation of the proposed algorithm. Chapter VII gives the result and comparison of our algorithm. Chapter VIII contains the conclusion and future work.

II. HUMAN EYE

The working of a human eye is somewhat similar to a camera. The optic nerve plays the vital role for visual information which is encoded and transmitted to the brain. In figure 1, a cross sectional view of the human eye is shown. In our work, retina plays the most important role. The retina is the internal part of the eye. The blood vessels present in the retina is used for the recognition of different types of eye diseases mainly diabetic retinopathy. Figure 2 shows the illustration of various features on a typical diabetic retinopathy image.

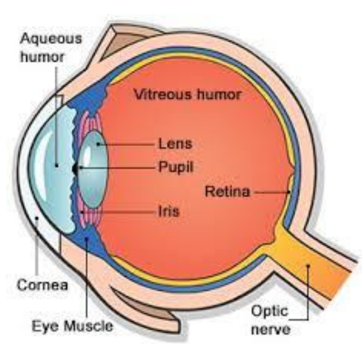


Figure1. Cross-sectional view of human eye [taken from Wikimedia Commons (NIH National Eye Institute)]

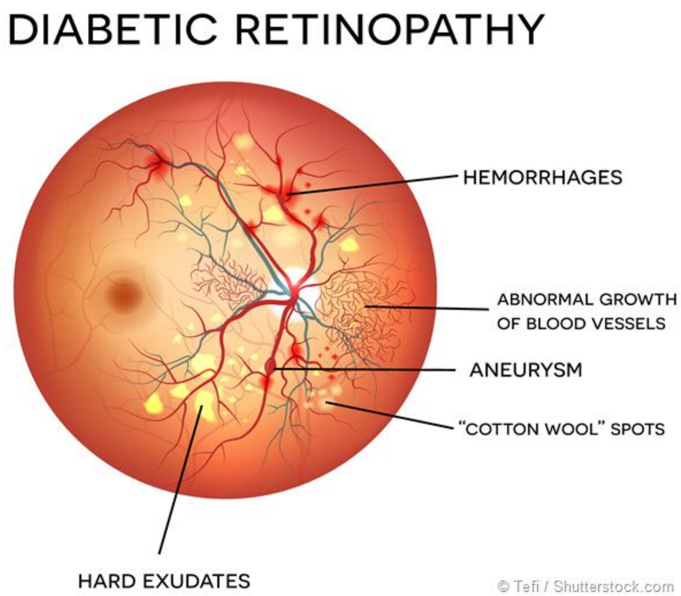


Figure2. Illustration of various features on a typical DR image [taken from News Medical Life Science

TABLE II. PERFORMANCE EVALUATION PARAMETERS

SL. NO.	PERFORMANCE PARAMETERS	FORMULA	DESCRIPTION
1	SENSITIVITY(SE)	$\frac{TP}{TP+FN}$	TRUE POSITIVE RATE
2	SPECIFICITY(SP)	$\frac{TN}{TN+FP}$	TRUE NEGATIVE RATE
3	ACCURACY(ACC)	$\frac{TP+TN}{TP+FP+FN+TN}$	THE DEGREE TO WHICH THE RESULT OF A MEASUREMENT CONFIRMS THE CORRECT VALUE OR A STANDARD
4	PEAK SIGNAL TO NOISE RATIO (PSNR)	$PSNR = 10 * \log_{10} \frac{MAX_I^{\,2}}{MSE}$, MAX_I is the maximum possible pixel value of the image and MSE is the mean square error	MEASURES QUALITY OF IMAGE

TABLE III. SOME RELATED WORKS

SL. NO.	AUTHORS/YEAR	TECHNIQUES	DATABASE	COLOUR SPACE	SENSITIVITY (%)	SPECIFICITY (%)	ACCURACY (%)
1	AMRUTKAR ET AL. [2] (2013)	VESSEL DETECTION BASED ON IMAGE SUBTRACTION AND THRESHOLDING	TOOK IMAGES FROM OPHTHALMOLOGIST	GREEN CHANNEL	-	-	-
2	RAJA ET AL. [3] (2015)	ANISOTROPIC DIFFUSION FILTER, THRESHOLDING & MORPHOLOGICAL OPERATIONS	DRIVE STARE	GREEN CHANNEL	93.99 93.6	98.37 98.96	98.03 95.94
3	NAYAK ET AL. [4]	CURVELET TRANSFORM, MORPHOLOGICAL THINNING	DRIVE STARE	GREEN CHANNEL	97.2 98.8	98.19 97.66	97.25 98.83

	(2013)	operation & Thresholding					
4	Wankhade et al. [5] (2016)	Segmentation, Canny Edge Detection	Took images using two cameras	Gray scale images	-	-	-
5	Shami et al. [6] (2014)	Morphological Operations & New Structuring Element	Nikookari Database obtained from Nikookari Ophthalmology Hospital, Tabriz, Iran	RGB	85.82	99.98	-
6	Hou [7] (2014)	Multidirectional Morphological transform, Rotating structuring element	DRIVE STARE	Green channel	73 73	96 96	94 93
7	Marin et al. [8] (2011)	Neural network	DRIVE STARE	Green channel	-	-	95 97
8	Yin et al. [9] (2014)	Clustering Technique based on Morphological features	DRIVE	Green channel	-	-	94
9	Fraz et al. [10] (2013)	Multiscale Line Detection Method, Gabor Filter	DRIVE STARE MESSIDOR	Gray scale	73 73 77	97 97 98	94 95 96
10	Nguyen et al. [11] (2012)	Vessel Segmentation based on Multiscale line detectors	DRIVE STARE	Green channel	-	-	94 93

III. Material

Images of the retina are taken with the help of a fundus camera which takes images of the internal surface of the retina. In the initial algorithm development stage, we have used images captured by a fundus camera with a 45 degree field of view taken at Omega Eye Clinic and Research Centre, Guwahati. The images were stored in TIFF (.tif) file format and the size of each image is 576 x 720. For the validation, we have used the images from DRIVE database.

Some benchmark databases which are freely available for the assessment of algorithms are DRIVE, STARE, MESSIDOR etc.

IV. Performance Parameters

The performances are tested based on certain evaluation parameters which are listed in Table II.

V. Related Works

Some of the related works are listed in Table III.

VI. Design and implementation of the proposed techniques

Here, we have proposed an important feature extraction method for blood vessels extraction with the aim of using it in the automatic detection of diabetes from the retinal images. The overall block diagram of feature extraction is shown in figure 3.

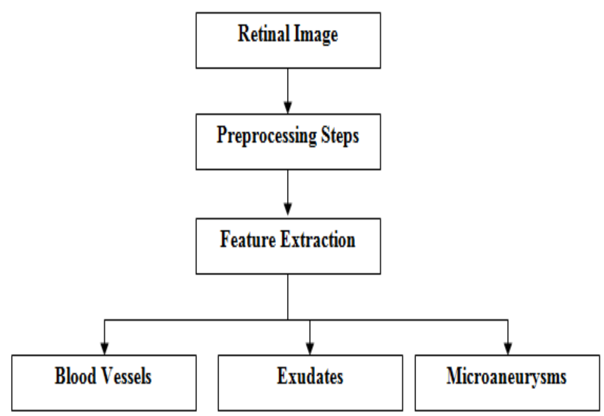


Figure3. Block diagram of feature extraction

A. *Morphological Image Processing*

Morphological image processing is a collection of non-linear operations related to shape or morphology of features in an image. Morphological techniques probe an image with a small shape or template called a structuring element. The structuring element is positioned at all possible locations in the image and it is compared with the corresponding neighbourhood of pixels. The structuring element is a small binary image, a matrix of pixels each with a value of zero or one. Figure 4 shows different shaped structuring elements.

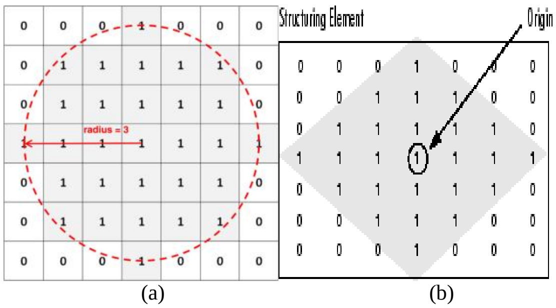
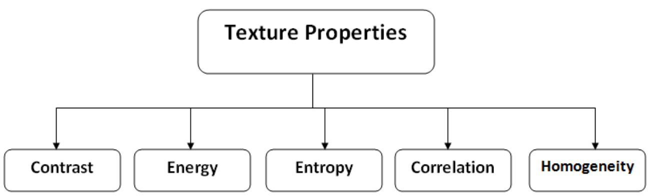


Figure 4: Structuring elements with R=3
(a) Disk shaped [taken from Researchgate]
(b) Diamond [taken from Mathworks Documentation]

B. *Texture Properties:*

Texture analysis gives the description of an image in terms of variations in the pixel intensities or gray level.



Gray-Level Co-occurrence Matrix (GLCM) is the computation of the frequency of each pixel pair occurring for different combinations of pixel brightness values in an image. The function "graycomatrix" is used to create the GLCM of the grayscale image. It calculates how often the pixel with value i of the gray level occurs horizontally adjacent to another pixel with value j. Each element (i,j) in the GLCM represents frequent of occurrence. The function "graycoprops" normalizes the GLCM so that the sum of its elements is equal to 1. It calculates the statistics as specified in the property.

Homogeneity is the measurement of the closeness of the distribution of elements in the GLCM to the GLCM diagonal and returns a value between 0 and 1. The homogeneity formula is as follows:

$$\sum_{i,j} \frac{p(i,j)}{1+|i-j|}$$

Contrast: Returns a measure of the intensity contrast between a pixel and its neighbour over the whole image. Range = [0 (size (GLCM,1)-1)^2]. The formula for contrast is as follows:

$$\sum_{i,j} |i-j|^2 \, p(i,j)$$

Correlation: Returns a measure of how correlated a pixel is to its neighbour over the whole image. Range = [-1 1]. Correlation is 1 or -1 for a perfectly positively or negatively correlated image. The formula for correlation is as follows:

$$\sum_{i,j} \frac{(i-\mu i)(j-\mu j)p(i,j)}{\sigma_i \sigma_j}$$

Energy: Returns the sum of squared elements in the GLCM. Range = [0 1]. The formula for energy is as follows:

$$\sum_{i,j} p(i,j)^2$$

Entropy is the statistical measure of the randomness of the grayscale image's texture. The green component of the image is applied with adaptive histogram equalization twice to enhance its contrast and texture. The function "entropy" is then used on the image which returns a scalar value. This represents the entropy of intensity for the image.

C. *Blood Vessel Detection:*

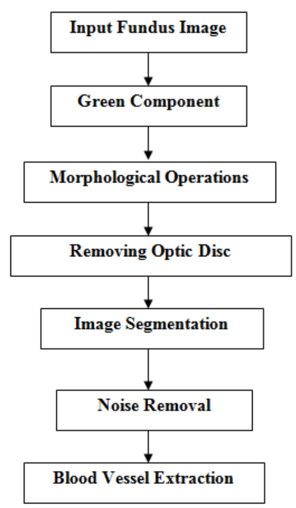


Figure5. Block diagram of blood vessel extraction

Figure 5 shows the block diagram of the proposed blood vessel extraction technique. The retinal image consists of three channels namely green, red and blue. Out of these three channels, green channel is considered best for blood vessel detection due to its high contrast between blood vessels and its background. The presence of blood vessels within the optic disc region may cause confusion due to incorrect detection of pixels belonging to blood vessels as optic disc. So, to detect the vessels accurately, the optic disc should be detected and eliminated from the retinal image. We complement the green component of the input retinal image and perform adaptive histogram equalization technique. Adaptive histogram equalization enhances the contrast of the image by transforming the values using Contrast Limited Adaptive Histogram Equalization (CLAHE). CLAHE operates on small regions in the image, called tiles, rather than the entire image. Each tile's contrast is enhanced and the neighbouring tiles are then combined using bilinear interpolation to eliminate artificially induced boundaries. We then apply the morphological opening operation using a structuring element. Using image subtraction we remove the optic disc from the retinal image. Next we convert the image to binary image and remove all small connected objects from the image.

Now, we convert the RGB fundus image to grayscale image and adjust the contrast. Using Canny's edge detection technique, we select the outline of the image. We next fill the outline and perform morphological erosion operation followed by dilation operation using a structuring element. We obtain the circular border of the image by subtraction operation. We then convert the numeric values to logical values. Next we find the area of the circular border and check if it is greater than a particular value. If it is greater than our border detection is wrong.

Next the grayscale contrast enhanced image is complemented and converted to binary black image. We perform morphological erosion operation followed by dilation operation using a structuring element and obtain the new circular border by subtraction operation. We convert numeric values to logical values and find the area of the new circular border.

Again, from the grayscale contrast enhanced image we take a single maximum column value and find the row & column indices that match the largest value. We take median value of row and column and prepare a suitable mask.

Lastly, we take adaptive histogram equalization of the green component of the image and convert it to binary image to get the segmented image for blood vessels. We then remove the small connected areas which are considered as noise. We add the mask with it to avoid the blood vessels at optic disc region for being removed. We then perform AND operation with the image obtained without optic disc in the initial stage to select the blood vessel area. Then we remove the borders to get the final blood vessels.

VII. EXPERIMENTAL RESULTS AND COMPARISONS

The performance of the proposed retinal blood vessel extraction algorithm is tested using MATLAB version 7.11.0 (R 2010b) with the help of a publicly available DRIVE database. The performance of the proposed blood vessel extraction results are analyzed with respect to the ground truth images. We have also extracted the blood vessels of the images taken from Omega Eye Clinic and Research Centre, Guwahati but could not evaluate the performance of those images due to the absence of ground truth images. Table IV summarize the results of this proposed work using DRIVE database. The proposed algorithm detects and segments the retinal blood vessels at an average specificity of 98.7% and accuracy of 98.6% respectively. The results obtained are compared with the other state of art in DRIVE dataset and tabulated in Table V. Table VI shows the texture properties of the images taken from Omega Eye Clinic and Research Centre, Guwahati.

TABLE IV. TABLE SHOWING AVERAGE SPECIFICITY AND ACCURACY USING DRIVE DATABASE

Database	Average Specificity	Average Accuracy
DRIVE	98.7%	98.6%

TABLE V. BLOOD VESSELS EXTRACTION RESULTS (DRIVE DATABASE)

Method	Year	Specificity (%)	Accuracy (%)
RAJA ET AL. [3]	2015	98.37	98.03
NAYAK ET AL. [4]	2013	98.19	97.25
HOU [7]	2014	96	94
MARIN ET AL. [8]	2011	-	95
YIN ET AL. [9]	2014	-	94
FRAZ ET AL. [10]	2013	97	94
NGUYEN ET AL. [11]	2012	-	94
PROPOSED METHOD	**2018**	**98.7**	**98.6**

TABLE VI. TEXTURE PROPERTIES

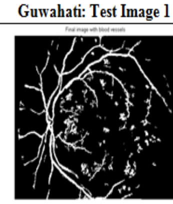
Feature	Omega Eye Clinic and Research Centre, Guwahati: Test Image 1	Omega Eye Clinic and Research Centre, Guwahati: Test Image 2
Blood Vessels	 Area=43315	 Area=43929
Correlation	0.9806	0.9711
Energy	0.2213	0.2613
Entropy	7.6862	7.6644
Homogeneity	0.9713	0.9719
Contrast	0.0576	0.0565

Figure 6 shows a set of images where a) the first image is the original input fundus image obtained from DRIVE database, b) the second one is the green component image, c) the third is the complemented image, d) the fourth image is the image obtained after removing optic disc, e) the fifth image is the image of outline border using Canny edge detection, f) the sixth image is the circular border image, g) the seventh image is the result of the AND operator showing the blood vessels with borders and h) the eighth image is the final image with blood vessels without borders.

Figure6 (a) Input Fundus Image (RGB)

Figure6 (b) Green Component Image

Figure6 (c) Complemented Image of Green Component

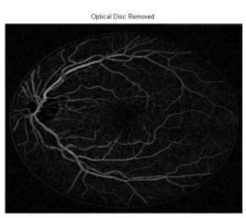


Figure6 (d) Image obtained after removing optic disc

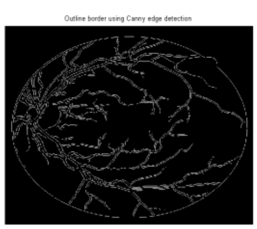


Figure6 (e) Outline border using Canny Edge Detection

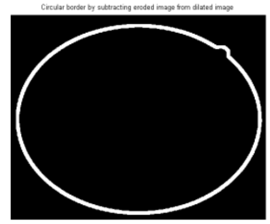


Figure6 (f) Circular Border

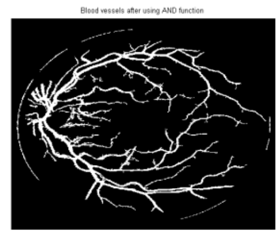


Figure6 (g) Blood vessels with borders

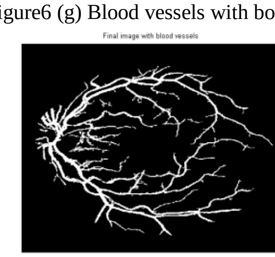


Figure6 (h) Final blood vessels

VIII. Conclusion

From experimental results, it can be concluded that the proposed method leads to fairly satisfactory results in terms of specificity and accuracy. This work can be further extended to extract microaneurysms and exudates from the retinal images. The extracted features can be fed to a neural network environment for proper classification and automatic detection of diabetic retinopathy.

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