Detection of Vascular Tree in Retinal Images

[1]Vinayak Tambralli, [2]Karthik M

[1]Pursuing M.Tech in Digital Communication, [2]Pursuing M.Tech in Electronics
[1]Department of Electronics and Communication Engineering,
[1]B.M.S. College of Engineering, Bengaluru, India

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Abstract **- Patients with diabetes are more likely to have eye problems such as cataracts and glaucoma, but the diseases will affect on the retina is the main problem to vision. Diabetic retinopathy is one of the major causes of human abnormalities or even blindness. Early detection of such an abnormality can provide proper treatment and most of the visual loss can be prevented. The algorithm is to detect blood vessels. The blood vessels and exudates are extracted by matched filtering, local entropy thresholding, length filtering, and vascular intersection detection.**

Index Terms **- Blood vessels, Gray scale conversion, Length filtering, Local entropy thresholding, Matched filtering, Retinal image, Vascular intersection detection.**

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I. INTRODUCTION

Images of retina show the inner surface of the eye and help to observe the irregularities in the eye including blood vessels. Appearance of blood vessels is complex and has low contrast hence manual detection of the blood vessels is difficult [1]. To detect the blood vessels, various segmentation methods have been proposed. The segmentation use contrast between blood vessels and its neighboring background. Segmentation of vascular tree will be the most suitable representation of the the image registration applications because of following three reasons: 1) it maps the whole retina; 2) in some diseases it does move; 3) it contains enough information for the localization of some anchor points. An efficient threshold technique was proposed in [3] where matched filter response (MFR) image is used for mapping of the vascular tree. A set of criteria is tested to determine the threshold of the probe region and to decide if the area being probed is a blood vessel. Since the MFR image is probed in a spatially adaptive way. Different thresholds can be applied throughout the image for mapping blood vessels.

II. PROPOSED ALGORITHM

The proposed algorithm consists of five steps. First step is to convert colour image to gray scale image. We apply matched filter to enhance the blood vessels because blood vessels have lower reflectance. Matched filter results in generation of MFR image. To distinguish between vessels segments and background in MFR image entropy threshold scheme is used. A length filtering technique is used to remove misclassified pixels. Vascular intersection detection is performed by window based probing process. The algorithm flow is depicted in fig.1.
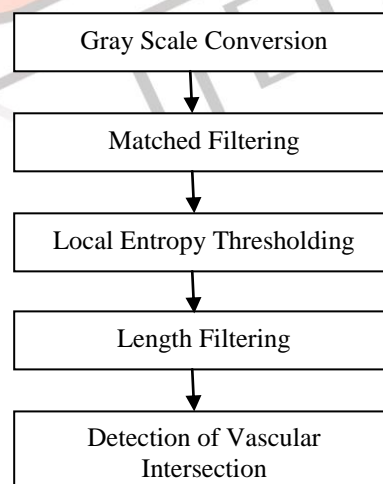

Fig.1 Flow of Proposed Algorithm

III. GRAY SCALE CONVERSION

In the gray scale images, the value of each pixel is a sample that carries only intensity information. Fig.2 shows the retinal image and fig.3 gray scale result.
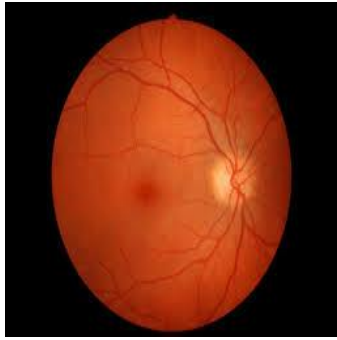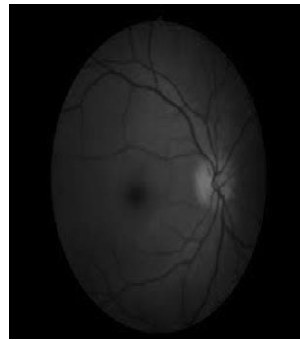
Fig.2 Retinal Image

Fig.3 Gray Scale Image

IV. MATCHED FILTERING

The gray level information of cross section of the blood vessels can be approximated to Gaussian shaped curve. Match filtering is used to detect piecewise linear segments of blood vessels in retinal images. Usually blood vessels have low contrast; two dimensional matched filter kernel is designed to convolve with original image in order to enhance the blood vessels. The matched filter kernel is expressed as (1). The direction of the vessel is assumed to be along y axis. Because vessel may take any angles, so kernel needs to be rotated for all possible angles. A 16x15 pixel kernel is applied for convolving with fundus image and only the maximum response at each pixel is retained.

$$f(x, y) = -\exp\left(-x^2/2\sigma^2\right), for \mid y \mid \leq L/2 \quad \ldots\ldots\ldots\ldots \quad (1)$$

Where L is the length of the segment for which the vessel is assumed to have fixed orientation. Fig.4 shows the matched filter result.
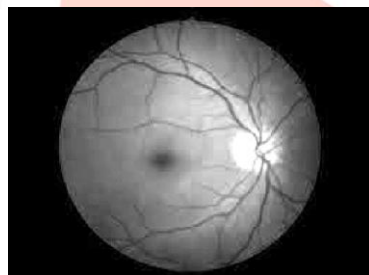

Fig.4 Matched filter result

V. LOCAL ENTROPY THRESHOLDING

In order to extract the vessel segments from background the MFR image should be processed by a proper thresholding scheme. Local entropy thresholding is an efficient thresholding algorithm which takes into account the spatial distribution of gray levels [5]. Two images with identical histograms but having different spatial distribution will result in different entropy and also have different thresholding values. The image F has co-occurrence matrix T= [tij] P*Q which gives the idea about transition of intensities between the adjacent pixels, indicating spatial structural information of an image. The co-occurance matrix T is P*Q in dimension. Depending upon the ways in which gray level i follow gray level j, different definitions of co-occurance matrix are possible. Consider an asymmetric co-occurance matrix which is horizontally right and have vertically lower transitions and defined as

$$t_{ij} = \sum_{l=1}^{P} \sum_{k=1}^{Q} \delta \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where, $\delta = 1$ if $f(l,k) = i, f(l,k+1) = j$
$$f(l,k) = i, f(l+1,k) = j$$
$\delta = 0$ otherwise

The probability co-occurance p_{ij} of gray levels i and j can be written as

(1)
$$p_{ij} = t_{ij} \Big/ \sum_{i} \sum_{j} t_{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

If s is a threshold ranging from 0 to L-1, then s can partition the co-occurance matrix into four quadrants. Namely A, B, C and D shown in fig.5.
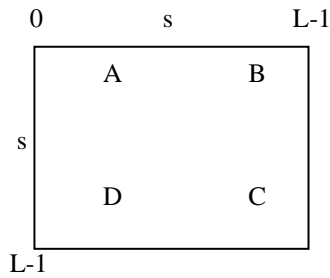
Fig.5. Quadrants of co-occurance matrix

Let us define P_A and P_C, considering first and third quadrant respectively.

$$p_A = \sum_{i=0}^{x}\sum_{j=0}^{x} p_{ij} \quad \text{.............................. (4)}$$

$$p_C = \sum_{i=x+1}^{L-1}\sum_{j=0}^{L-1} p_{ij} \quad \text{.............................. (5)}$$

Normalizing the probabilities within each individual quadrant, such that the all probabilities in each quadrant are equal to one. We get the cell probabilities defined as (6) and (7).

$$p_{ij}^{A} = \frac{p_{ij}}{p_A} = \frac{t_{ij} \Big/ \sum_{i=0}^{L-1}\sum_{j=0}^{L-1} t_{ij}}{\sum_{i=0}^{x}\sum_{j=0}^{x} t_{ij} \Big/ \sum_{i=0}^{L-1}\sum_{j=0}^{L-1} t_{ij}} = \frac{t_{ij}}{\sum_{i=0}^{x}\sum_{j=0}^{x} t_{ij}} \quad \text{.............................. (6)}$$

$$for, o \le i \le s, 0 \le j \le s$$

$$p_{ij}^{C} = \frac{t_{ij}}{\sum_{i=0}^{x}\sum_{j=0}^{x} t_{ij}} \quad \text{.............................. (7)}$$

$$for, s+1 \le i \le L-1, s+1 \le j \le L-1$$

The second order entropy of the object can be defined as

$$H_A^{(2)}(s) = -\frac{1}{2}\sum_{i=0}^{x}\sum_{j=0}^{x} p_{ij}^{A} \log_2 p_{ij}^{A} \quad \text{.............................. (8)}$$

$$H_C^{(2)}(s) = -\frac{1}{2}\sum_{i=x+1}^{L-1}\sum_{j=x+1}^{L-1} p_{ij}^{C} \log_2 p_{ij}^{C} \quad \text{.............................. (9)}$$

$$H_T^{(2)}(s) = H_A^{(2)}(s) + H_C^{(2)}(s) \quad \text{.............................. (10)}$$

And it is corresponding maximum gray level.

Fig.6 shows the result of local entropy thresholding where the vessel segments are extracted from the background.

Fig.6. image of local entropy thresholding

VI. LENGTH FILTERING

The local entropy threshold image still has some misclassified pixels. In order to produce clean and complete vascular tree structure, length filtering is used to remove isolated pixels by using the concept of connected pixels labeling. Connected regions correspond to individual objects. First we need to identify separate connected regions. Length filtering isolates the individual objects by using the eight connected neighborhood and label propagation.

VII. DETECTION OF VASCULAR INTERSECTION

Vascular intersections and crossovers are the most appropriate representation in registration process because they exist in every retinal image and do not move except in some diseases. If the vascular tree is one pixel wide, the ranching points can be detected and characterized efficiently. Morphological thinning is applied to the vascular tree in order to get one pixel wide vascular tree as shown in fig.7.
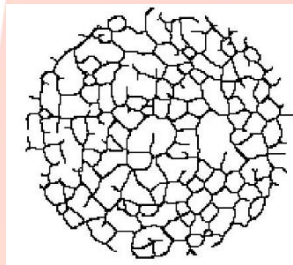

Fig.7. Resulted image

VIII. CONCLUSION

The proposed algorithm for automated blood vessel segmentation is effective to handle vessel images under different conditions with good accuracy and reliability for medical diagnosis. Visibility of vascular pattern is not good in retinal images; we have introduced an efficient algorithm for automatic detection of blood vessels in fundus images using local entropy thresholding. The proposed method has simple computation and accurate segmentation results. In future work, we want to improve the robustness of the algorithm by involving preprocessing and additional anatomical constraints to separate the lesions in the final vascular tree.

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