Automated retinal blood vessels extraction using Optimized Gabor filter

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Automated Retinal Blood Vessels Extraction Using Optimized Gabor Filter

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Abstract— **This paper presents a new automatic method to extract the retinal blood vessel under various normal or abnormal conditions. Extraction of blood vessels in retina is helpful for ophthalmologists to screen larger populations. The commonly used Gabor filter methods often produce false positive detections of blood vessels. We proposed a method for segmentation of blood vessels using Optimized Gabor filter as they tuned to the specific frequency and orientation. We have employed robust performance analysis to evaluate the accuracy. Our proposed Optimized Gabor filter demonstrated higher true positive rate and reduce false detection than existing various techniques in vessels extraction.**

Keywords-Retinal imaging, Optimized Gabor filter, Vessels extraction.

I. INTRODUCTION

Biomedical Image diagnostic processing has already become an important part of clinical routine. In the research or screening setting, large databases of retinal images may be automatically classified and managed more readily than labor-intensive observer-driven techniques. Automated diagnosis may also aid decision-making for optometrists. The greatest emphasis in automated diagnosis has unsurprisingly been given to the detection of diabetic retinopathy (DR). Diabetic retinopathy (DR) is a complication of diabetes and a leading cause of blindness. It occurs when diabetes damages the tiny blood vessels inside the retina, the light-sensitive tissue at the back of the eye.

DR is not a curable disease, laser photocoagulation can prevent major vision loss if detected early stages [2]. The employment of digital images for eye diseases diagnosis could be exploited for computerized early detection of DR. A system that could be used by non experts to filtrate cases of patients not affected by the disease, would reduce the specialists' workload, and increase the effectiveness of preventive protocols and early therapeutic treatments [3]. A WHO collaborative study projected that the global diabetic burden is expected to increase to 221 million people by 2010. However, treatment can prevent visual loss from sight-threatening retinopathy if detected early. Automated detection programs are able to exclude a large number of those patients who have no diabetic retinopathy, it will reduce the workload of the trained graders and thus reduce costs. Other benefits of an automated detection program include improved repeatability and immunity from fatigue.

Many image processing methods proposed for retinal vessel extraction [4] [5] [6] [7] [8] [9] [10]. In our literature is based on Optimized Gabor filter. Gabor filters have been widely applied to image processing and computer vision application problems such as face recognition and texture segmentation [8]. Gabor filter methods often produce false positive detections and fail to detect vessel of different widths. Also detection process much more complicated when retinal image abnormal condition. We have proposed a much robust and fast method of retinal blood vessel extraction using Optimized Gabor filter and introduce Optimized parameter.

II. PROPOSED VESSEL EXTRACTION METHOD

The proposed method uses the following steps: (1) Green channel extraction, (2) Adaptive histogram equalization, (3) Optimization Gabor filter, (4) Grayscale conversion, (5) Binary conversion, (6) Median & Length filter. Fig.1 shows the overall procedure of the proposed vessel extraction algorithm.

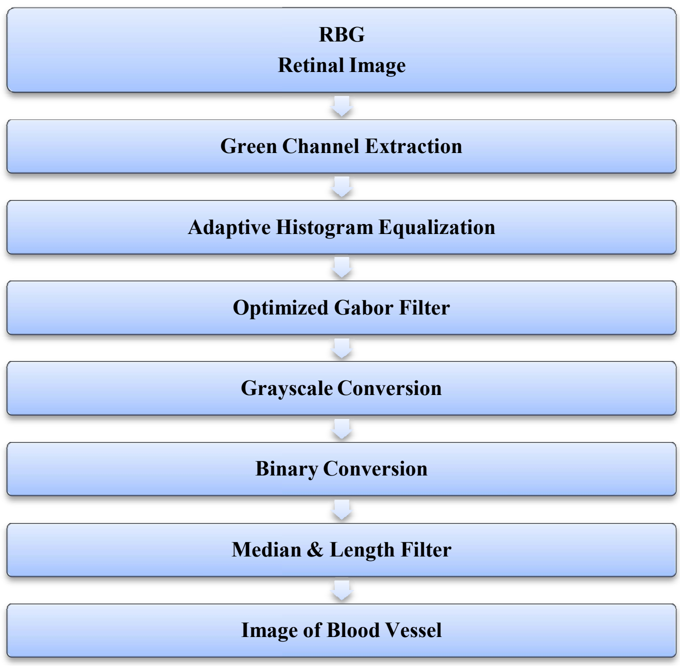

Fig.1. Proposed method of blood vessel extraction

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A. Preprocesing

Preprocessing is applied to eliminate the noises in the fundus image. Regarding the acquisition process, retinal images have often low contrast that cause to hardly detect the blood vessels. Our method is to improve the image dynamic range to prepare images for next step, detection the blood vessels, and attain to higher accuracy and precision of segmentation. Concerning our purpose, contrast enhancement, the green channel of colored retinal images is used, because compare to other channels it has the highest contrast [4]. Combining advantages of brightness in red channel decreasing the contrast between the abnormalities and the retinal background; this helps to reduce some responses from abnormalities which do not resemble any blood vessels that would otherwise decrease the performance of blood vessels segmentation methods. We used contrast-limited adaptive histogram equalization for enhancing the contrast of the green channel retinal image.

B. Proposed Optimized Gabor Filter

In our algorithm Optimized Gabor filter is used for detecting the blood vessel in retinal image. The Gabor Filters are a set of orientation and frequency sensitive band pass filters which have the optimal localization in both the frequency contents of the patterns [8]. The Optimized Gabor filter kernels are sinusoids modulated.

$$\sigma_x = k \tag{1}$$

$$\sigma_y = \frac{\sigma_x}{\gamma} \tag{2}$$

$$x_\theta = x\cos\theta + y\sin\theta \tag{3}$$

$$y_\theta = -x\sin\theta + y\cos\theta \tag{4}$$

$$g_\theta(x,y) = \exp\{-\frac{1}{2}(\frac{x^2{}_\theta}{\sigma_x} + \frac{y^2{}_\theta}{\sigma_y})\}\cos(2\pi fx) \tag{5}$$

Where,

σ_x: Standard deviation of Gaussian in x direction along the filter that determines the bandwidth of the filter.

σ_y : Standard deviation of Gaussian across the filter that control the orientation selectivity of the filter.

f : Central frequency of pass band.

θ: Orientation of the filter, an angle of zero gives a filter responds to vertical feature.

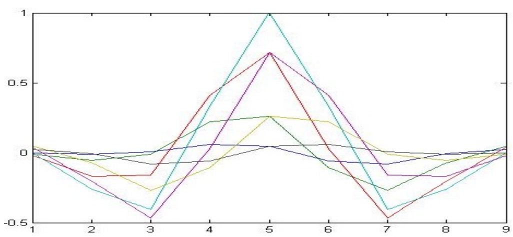

Fig. 2. Optimization (9×7) matrix of Gabor Filter

Proposed Optimized Gabor filter function

$$\hat{g}_\theta(x,y) = \exp\{-\frac{1}{2}(\frac{x^2{}_\theta}{\sigma_x} + \frac{y^2{}_\theta\gamma^2}{\sigma_y})\}\cos(\frac{2\pi}{\lambda}x_\theta + \psi) \tag{6}$$

The Optimization Gabor filter kernel (9×7 matrix) is rotated in different rotations with the Optimized parameters set as follows

$$\sigma_x \in [3.91, 4], \lambda \in [5.1, 5.3], \gamma \in [1.2, 1.4]$$

$$\sigma_x = 3.91$$

$$\lambda = 5.1$$

$$\gamma = 1.3$$

$$\psi = 2\pi$$

σ_x is required so that the shapes of the filter are invariant to the scale. The width of the vessels is found to lie within a range of 2-14 pixels (40-200μm). Here, λ and γ values maintain false positive rate. ψ always 360^0 or (2π) rotation phase in this method. The optimized parameters are to be derived by taking into account of size of the lines structures to be detected. Only six optimized Gabor filters with different orientations (0 to 360^0 intervals of sixty degrees) are used to convolve with the preprocessing image. The magnitude of each response is retained and combined to generate the result image.

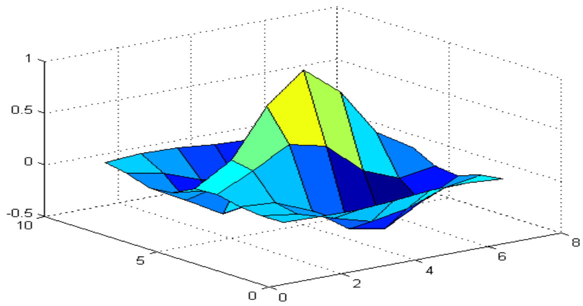

Fig.3. Optimized Gabor filter response in 60^0

Fig.4. Typical retinal image

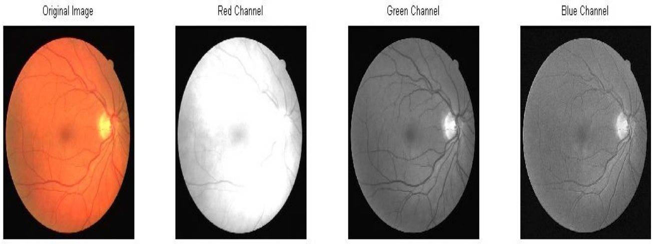

Fig.5. Original image with extraction channels

C. *Gray Scale & Binary Conversion*

In this study Optimized Gabor response image is converted to gray scale and gray scale is also converted to binary image [21].

D. *Median & Length Filter*

We used [3×3] size of median filter [21] reduce the salt & paper noise & length filter is used to remove isolated pixels by using concept of connectivity in binary image.

Fig.6. Green channel of the original image (*left*) and Adaptive histogram equalization image (*right*)

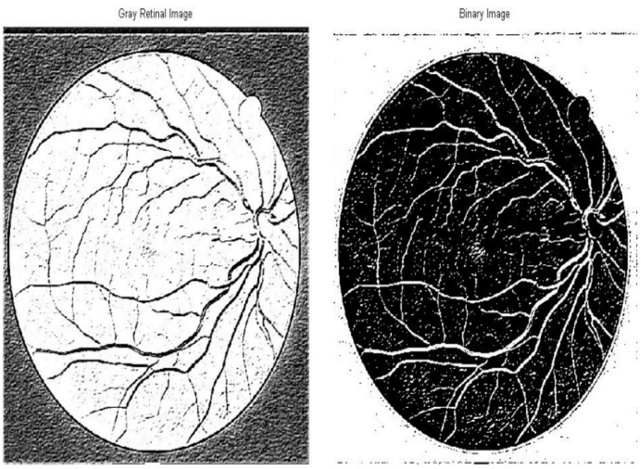

Fig.7. Gray retinal image (*left*) and Binary image (*right*)

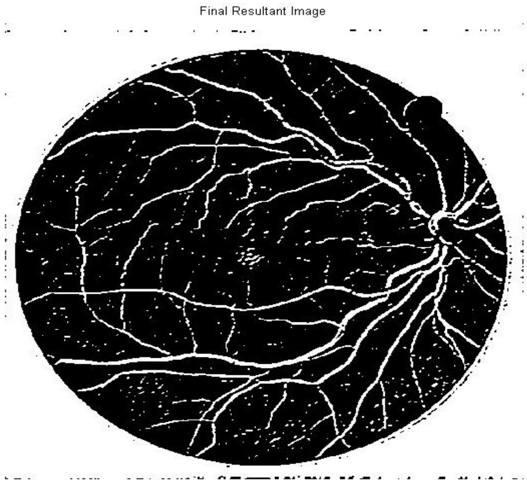

Fig.8.Final resultant image

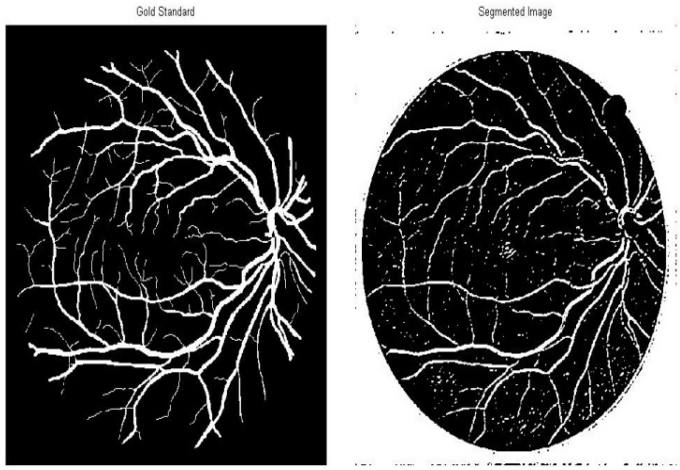

Fig.9. Gold standard (*left*) and Proposed segmented Image (*right*)

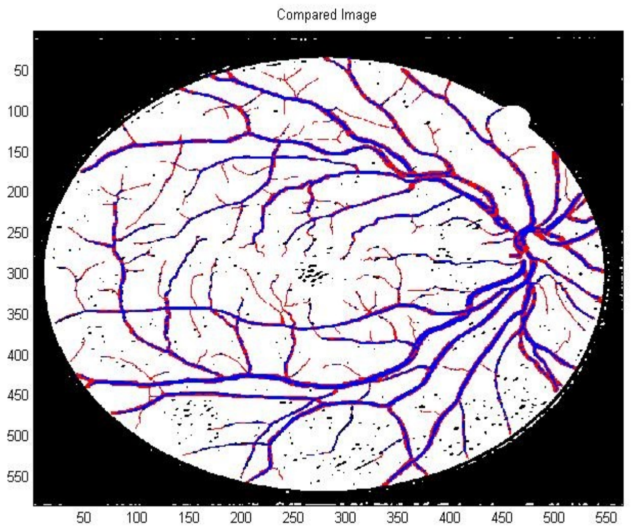

Fig.10. Compared image (Gold standard & Final resultant image)
[True Positive (TP) = Blue pixels, False Positive (FP) = Black pixels, False Negative (FN) = Red pixels, True Negative (TN) = White pixels]

III. EXPERIMENTAL RESULTS

This paper, the software selected to perform the experiment is MATLAB 7.10.0.499 (R2010a). The retinal images were collected from the DRIVE database. The DRIVE database contains 20 color images of the retina with 565×585 pixels and 8 bits per color image [20]. The accuracy (A_{cc}) is calculated by the ratio of the number of correctly classified pixels to the total number of pixels in the image [22]. Our proposed method has 97.72% average accuracy. The sensitivity (S_e) represents the fraction of pixels correctly classified as vessel pixels, where the false positive defines the fraction of pixels erroneously classified as vessel pixels. Average sensitivity is 98.15%. The computational time of whole process of our method takes approximate 2 seconds for each retinal image.

TABLE I
VESSEL CLASSIFICATION

	Vessel Present	**Vessel Absent**
Vessel detected	True Positive (**TP**)	False Positive (**FP**)
Vessel not detected	False Negative (**FN**)	True Negative (**TN**)

$$A_{cc} = \frac{TP + TN}{TP + TN + FP + FN} \quad (7)$$

$$S_e = \frac{TP}{TP + FN} \quad (8)$$

TABLE II
PERFORMANCE RESULTS COMPARISON TO OTHER METHODS ON THE DRIVE DATABSE

Method	(A_{cc})
Chaudhuri et al.[3]	0.8773
Staal et al.[5]	0.9441
Jiang and Mojon [6]	0.8911
Niemeijer et al.[9]	0.9417
Mendonca et al. [10]	0.9463
Cinsdikici and Aydin [11]	0.9293
Proposed algorithm	**0.9772**

IV. CONCLUSION

In this study, we introduce Optimized Gabor filter & proposed a new automatic method to segmentation blood vessels in retinal image. Optimized Gabor filter demonstrated higher true positive rate and reduce false detection in retinal image. The performance of the proposed method is evaluated by comparing DRIVE database images [20]. This method average accuracy (A_{CC}) is 97.72% and sensitivity (S_e) is 98.15%. This method can be applied for image registration purpose to track the change in fundus images for monitoring diabetic retinopathy.

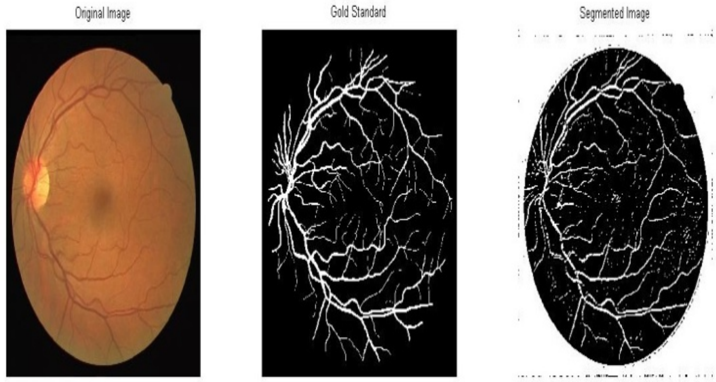

Fig.11. Original image (*left*), gold standard (*middle*), segmented [proposed] (*right*)

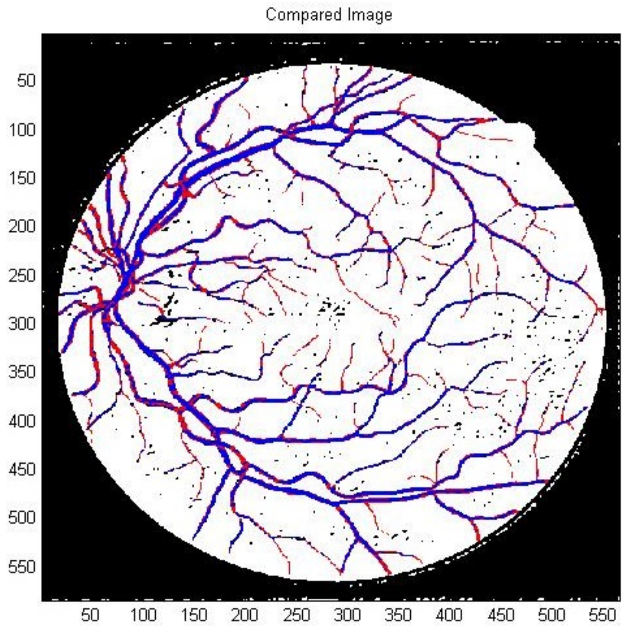

Fig.12.Compared result of gold standard & segmented image [proposed]) [True Positive (TP) = Blue pixels, False Positive (FP) = Black pixels, False Negative (FN) = Red pixels, True Negative (TN) = White pixels] s

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