Blood Vessel Segmentation In Fundus Images And Detection Of Glaucoma

LekshmiShyam
Dept of Electronics and Communication
SreeChitraThirunal College Of Engineering
Thiruvananthapuram,Kerala
lekshmishyam92@gmail.com

Kumar G S
Dept of Electronics and Communication
SreeChitraThirunal College Of Engineering
Thiruvananthapuram,Kerala
kumar.sasidharan@gmail.com

***Abstract*—Blood vessel segmentation of fundus images has obtained considerable importance during the past few years since it facilitates the early detection of eye diseases.A method based on high pass filtering and morphological operation is introduced in the proposed method for vessel segmentation. The blood vessel segmentation in turn helpsto provide a method for the detection of Glaucoma. In many of the earlier detection methods, analysis of cup to disc ratio is performed. But here the glaucoma is detected by means of ISNT ratio. The analysis is performed on Glaucomatous and normal eye. Ten images of each are collected from the database and ISNT ratio is calculated on each. The advantage of the method is that by calculating the area of blood vessels in each of the four quadrant of the eye, glaucoma can be detected with less complexity in a simpler manner.**

***Index Terms*—Blood vessel segmentation, fundus image, morphological operation, ISNT ratio, High pass filtering**

I. INTRODUCTION

Examination of blood vessels in the eye is an important toolin detecting various eye diseases in medical field.This task becomes difficult due to the presence of bright and dark lesions in fundus images.The fundus of the eye is the interior surface of the eye opposite the lens and includes the retina, optic disc, macula, fovea and posterior pole.The blood vessels in the fundus image should be segmented and analyzed to get an idea of the disease affecting the eye like glaucoma and diabetic retinopathy.These diseases in turn lead to blindness.Blindness is a growing problem all over the world.If these diseases can be detected earlier, then blindness can be prevented at the earliest.Here comes the importance of blood vessel segmentation.For the segmentation process we mainly use the green channel.The main advantage of the proposed method is that the blood vessel is segmented from two pre-processed image. Glaucomais a complicated disease that eventually leads to blindness. Glaucoma patients have an elevated intraocular pressure.In glaucoma affected patients, the blood vessels are narrower than normal. Thus calculation of the area of the segmented blood vessels enables the detection of glaucomaSegmentation of blood vessels plays an important role in the early detection of diseases.Several approaches have been presented earlier.One of the earlier methods was based on morphological reconstruction is used forsegmentation [1].Morphology is the technique that is used for the analysis and processing of images based on morphological characteristics.The pre-processing in the paper contains three main steps namely preprocessingphase, vessel centerline detection phase and finally vessel segmentation phase.The preprocessing is done for background normalization and vessel enhancement.Vessel centerline detection phase provides appropriate candidates by making use of Gaussian filter.The vessel segmentation involves a vessel filling by region growing process.Another method is based onmoment invariant based features are extracted for the classification[3].The preprocessing stage involves a morphological opening for filtering the green channel,background homogenization for shade correction and vessel enhancement.Vessel enhancement is performed by Top hat transformation.After the preprocessingstage,gray level and moment invariant based features are extracted and each pixel is classified by a neural network classifier. An ensemble classification for segmentation involves analyzing the orientation of the gradient vector field for localizing the blood vessels [3].Orientationanalysis is followed by morphological transformation. This is performedbecause the tophat transformation will enhance all the vessels eliminating the bright regions.Next edge detection is performed by multiscaleGabor filter.The classification is done by an ensemble classifier. This is primarily used to improve the prediction accuracy as it is based on multiple classifiers. Most of the segmentation algorithms are classified as supervised and unsupervised.Multiscale vessel segmentation methods that uses neighborhood analysis and gradient-based information for determining the vessel

pixels is an unsupervised method [4],[5]. The unsupervised methods are mainly computationally complex.

Glaucoma is a disease which causes damages to the optic nerves. The main characteristics of glaucoma are an elevated intra ocular pressure.The number of blood vessels is more and it is narrower in this case.Glaucoma detection in [6] is based on the calculation of ISNT. By calculating the area of the blood vessels in the ISNT quadrant, Glaucoma can be detected.The ISNT rule is such that the area of the blood vessels in the segments follow inferior>superior>nasal>temporal.Each quadrant is filtered by a mask. For each quadrant, a mask will be generated. Initially any one of the mask is generated.Then the mask is rotated 90 degree each time and is used on a binary blood vessel segmented image to obtain the area covered by the blood vessel in each quadrant.The ratio of the blood vessel area covered by inferior and superior regions to area covered by nasal and temporal regions is taken.The ratio is lower for glaucomatous eye.

II.METHOD AND MATERIALS

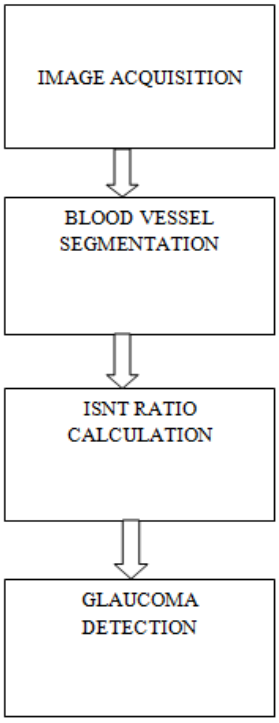

Fig.1 Block diagram for Glaucoma detection

The initial step in the glaucoma detection is the image acquisition. The images are obtained from the HRF data base which contains the images of Glaucomatous eyes. The second step is the blood vessel segmentation. The vessel regions are the intersecting regions between the binary images resulting from high pass filtering and morphological tophat reconstruction. The Glaucoma is detected by calculating the area of blood vessels in the four quadrants namely Inferior, Superior, Nasal and Temporal.

A.Data

1) STAREdataset contains twenty fundus images including their ground truth images. The images are captured by a fundus camera with 35 degree FOV (field of view) [7].

2) DRIVEdataset contains 40 images with 45◦ FOV including their ground truth image. This dataset is separated by its authors into a training set (DRIVE Train) and a test set (DRIVE Test) with 20 imagesin each set. The DRIVE Train set of images are annotated by one human observer [8].

3)HRF database which contains high resolution fundus images.The data base is publically available.

B.Blood vessel segmentation

The segmentation algorithm requires two pre-processed images. For the first pre-processed image, the green channel of the fundus image is required. The green channel extraction is the initial step. After the green channel is extracted, image enhancement is performed. Image enhancement involves contrast enhancement and vessel enhancement. Contrast is the difference between the maximum and minimum pixel intensities. Contrast enhancement increases the visibility of the image. Inorder to make the blood vessel clearer, each pixel value is squared and normalized in the range [0, 1]. This is an important process since squaring makes the vessels darker. The dark blood vessels are extracted from the enhanced image. First, a low pass filter is implemented by means of a median filter of size [25*25]. The blood vessels correspond to the high frequency components in the image. Inorder to obtain the high pass filtered image the low pass filtered image is subtracted from the enhanced image.This high-pass filtered image is thresholded to extract pixels less than 0. This is the first pre-processed image. For obtaining the second pre-processed image, red regions are extracted from the negative of the enhanced image.Next, 12 linear structuring elements are rotated through 15 degree to obtain the tophat reconstruction of the image. The tophat reconstruction is a morphological operation

that is used to extract the minute details from the image.The mean value of each pixel from the 12 images is the final reconstructed image. This is the second pre-processed image. Both the pre-processed images are thresholded to obtain the binary images. The regions common to the two images are the vessel regions.

C.Glaucoma detection

Glaucoma is a group of eye diseases which result in damage to the optic nerve and vision loss.The main characteristic of glaucoma is an elevated intra ocular pressure (IOP) and also the blood vessels get narrower .The numbers of blood vessels are more in glaucomatous eye. Glaucoma can be detected by calculating the ISNT ratio. The major
blood vessels are more concentrated in the nasal and temporal regions of the optic disc. The ISNT rule is such that the area of the blood vesselsin the four quadrants are Inferior>Superior>Nasal>Temporal.The initial step in glaucoma detection is the blood vessel segmentation. After the segmentation stage, the areas of the blood vessels in the four quadrants (ISNT) are calculated.For this a mask is used to filter one quadrant .The mask is rotated 90 degree each time and is used on a binary blood vessel image to obtain the area covered by the blood vessel in each quadrant. The ratio of the blood vessel area covered by inferior and superior regions to area covered by nasal and temporal regions is taken.The ratio is lower for glaucomatous case and higher for normal case.The algorithm for the proposed method is given below:

ALGORITHM I

1. Input image is selected from the database.

2. Contrast enhancement and vessel enhancement are performed on the green plane of the input image.

3. First a low pass filtering is done on the enhanced image using a median filter and then high pass filtered image is generated.

4. Negative of the enhanced image is taken.

5. Tophat reconstruction is performed on the negative of the image.

6. The region common to the high pass filtered image and tophat reconstructed image is taken as the vessel region.

7. Mask is generated to filter one quadrant.

8. Area occupied by the blood vessels and ISNT ratio are calculated.

III.RESULTS AND DISCUSSION

The important step in the glaucoma detection is the blood vessel segmentation. The vessel regions are the intersecting regions between the high pass filtered version and the tophat reconstructed images. The results are given in Fig.1. The proposed blood vessel segmentation is compared with a piecewise threshold probing based segmentation [9]. The performance of segmentation is compared in terms of sensitivity, specificity and accuracy. The formula for calculating the parameters are given in the TABLE 1.

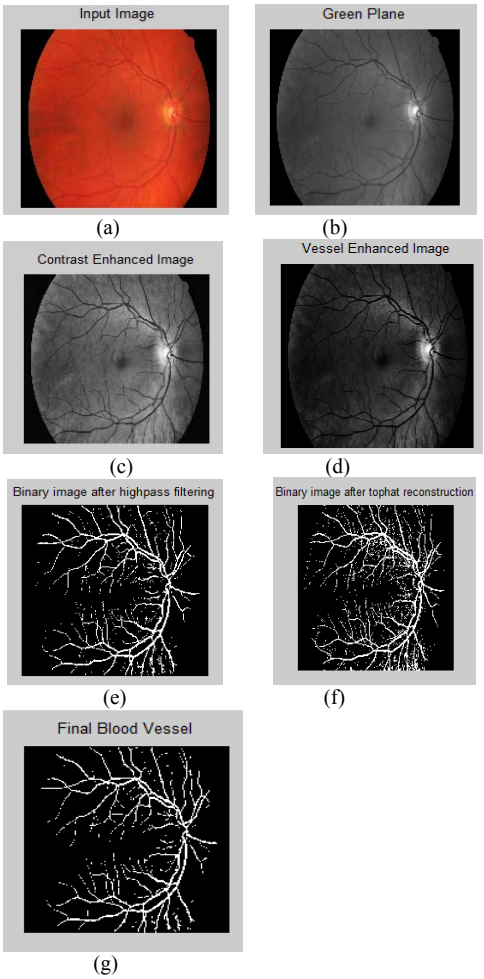

Fig.2 Proposed method of blood vessel segmentation a)Input image b)Green channel image c)Contrast enhanced image d)Vessel enhanced image e)High pass filtered image f)Tophat reconstructed image g)Final segmented image

The accuracy of the proposed segmentation method is about 0.931 with a sensitivity and specificity of 0.742 and 0.943 respectively. Whereas the method in [9] that utilizes the threshold probing has an accuracy of 0.927.

After the blood vessels are segmented, a mask of 512*512 size is generated. First a temporal mask is generated.Then it is rotated 90 degree each to obtain the superior,nasal and inferior .The blood vessels in the temporal, inferior, nasal and superior regions are obtained by making use of the respective masks

TABLE I. PERFORMANCE METRICS FOR BLOOD VESSEL SEGMENTATION

Measure	**Description**
Specificity	TP/(TP+FN)
Sensitivity	TN/(TN+FP)
Accuracy	(TP+TN)/(TP+TN+FP+FN)

TP=True Positive, TN= True Negative, FP=False Positive, FN=False Negative.

TABLE II. COMPARATIVE PERFORMANCE OF PROPOSED METHOD WITH EXISTING WORK ON THE STARE DATABASE

Method	**Sensitivity**	**Specificity**	**Accuracy**
Method in [9]	0.651	0.810	0.927
Proposed	0.742	0.943	0.931

The results of the blood vessels in the four quadrants are given below:

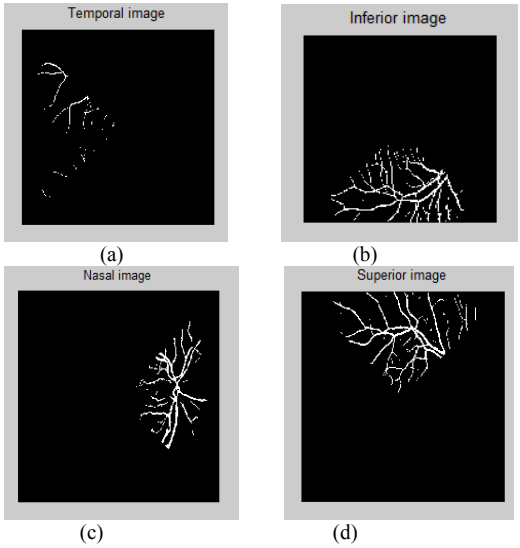

Fig.3 Blood vessels in the four quadrants a)Temporal image b)Inferior image c)Nasal image d)Superior image

The ISNT ratio is calculated by the following formula

ISNT ratio = (area of inferior blood vessel+ area of superior blood vessel)/(area of nasal blood vessel+area of temporal blood vessel) (1)

The images for the glaucoma affected patients are obtained from the HRF data base that is publically available. ISNT ratio of 10 images affected by glaucoma is analyzed. The ISNT ratios of healthy persons are given below:

TABLE III. ISNT RATIOS OF NORMAL PERSONS CALCULATED ON TEN IMAGES.

Image number	**ISNT ratio**
1	2.1423
2	2.4064
3	2.4149
4	1.9378
5	2.0355
6	2.0140
7	1.9418
8	2.2399
9	2.1186
10	2.4049

The ISNT ratios of glaucoma affected persons are given in the following table.

TABLE IV.ISNT RATIOS OF GLAUCOMA AFFECTED PEOPLE CALCULATED ON TEN IMAGES

Image number	**ISNT ratio**
1	1.8337
2	1.8108
3	1.7794
4	1.8111
5	1.6112
6	1.7146
7	1.8574
8	1.6520
9	1.7061
10	1.7788

The ISNT ratio is lower for glaucomatous eye and high for normal persons. From the analysis performed on 10 images, it is observed thatthe ISNT ratio for normal eye is 2.166 ± 0.19 and for Glaucoma eye is 1.755± 0.08.The number of blood vessels will be higher in the nasal region for glaucomatous eye. Therefore the blood vessels occupy more area in the nasal quadrant which makes the ISNT ratio lower for glaucomatous eye.

IV.CONCLUSION

The retinal images used for the proposed method is collected from STARE, DRIVE and HRF database. Glaucoma is a chronic eye disease which is the cause of irreversible blindness, and is predicted to affect around 80 million people by 2020.So it is important to detect glaucoma at the earliest to control it to a certain extent. Inorder to detect glaucoma, first the blood vessel has to be segmented.For this we proposed a segmentation algorithm. The algorithm is based on high pass filtering and tophat reconstruction. The segmentation method provides an accuracy of about 0.931. In this paper ISNT parameter is used for the detection of glaucoma.The analysis of the results show that the ratio will be in the range 2.166 ± 0.19 for normal persons and 1.755 ± 0.08 for Glaucoma effected patients. The proposed method provides a means to distinguish Glaucoma from normal eye.

REFERENCES

[1] A. Mendonca, and A. Campilho, "Segmentation of retinal blood vessels by combining the detection of centerlines andmorphological reconstruction," *IEEE Trans. Med. Imag.*, vol. 25, no. 9, pp. 1200–1213, Sep. 2006.

[2] D. Marin, A. Aquino, M. Gegundez-Arias, and J. Bravo, "A new supervised method for blood vessel segmentation in retinal images by using gray-level and moment invariants-based features," *IEEE Trans. Med.Imag.*, vol. 30, no. 1, pp. 146–158, Jan. 2011.

[3] M. Fraz, P. Remagnino, A. Hoppe, B. Uyyanonvara, A. Rudnicka, C. Owen, and S. Barman, "An ensemble classification-based approach applied to retinal blood vessel segmentation," *IEEE Trans. Biomed. Eng.*, vol. 59, no. 9, pp. 2538–2548, Sep. 2012.

[4] A. Budai, G. Michelson, and J. Hornegger, "Multiscale blood vessel segmentation in retinal fundus images," *Proc. Bildverarbeitungfr die Med.*, pp. 261–265, Mar. 2010.

[5] A. Budai, R. Bock, A. Maier, J. Hornegger, and G. Michelson, "Robust vessel segmentation in fundus images," *Int. J. Biomed.Imag.*, article 154860, 2013, doi: 10.1155/2013/154860.

[6] D.Jeyashree, .G.Sharmila and K.Ramasamy , " Combined Approach on Analysis of Retinal Blood Vessel Segmentation for Diabetic Retinopathy and Glaucoma Diagnosis", International Journal of Scientific & Engineering Research, Volume 5, Issue 5, May-2014.

[7] A. Hoover, V. Kouznetsova, and M. Goldbaum, "Locating blood vessels in retinal images by piecewise threshold probing of a matched filter response," *IEEE Trans. Med. Imag.*, vol. 19, no. 3, pp. 203–210, Mar. 2000.

[8] J. Staal, M. Abramoff,M. Niemeijer, M. Viergever, and B. van Ginneken,"Ridge-based vessel segmentation in color images of the retina," *IEEETrans. Med. Imag.*, vol. 23, no. 4, pp. 501–509, Apr. 2004.

[9] A. Hoover, V. Kouznetsova, and M. Goldbaum, "Locating blood vesselsin retinal images by piecewise threshold probing of a matched filter response,"*IEEE Trans. Med. Imag.*, vol. 19, no. 3, pp. 203–210, Mar. 2000.