Blood Vessel Segmentation in Retinal Images Using Image Processing Techniques

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Abstract**—**Physical changes in the structure of retinal blood vessels are the major symptom of cardiovascular disease and diabetes. Detection of these diseases can be done by analyzing vascular features of retinal blood vessels. If detected in early stages, these diseases can undergo proper treatment whereas late detection of diabetes or cardiovascular disease makes it impossible to treat. Manual detection of variations in blood vessels features need expertise, is error prone and very costly, which led to the idea of automating this procedure. In this paper, an algorithm is proposed to efficiently and effectively detect the presence of disease from retinal fundus images. Green channel has been used in this study to extract the features as it contains detailed information of blood vessels than other channels. Morphological operations have been used to estimate the structure of retinal blood vessels and then rician denoise method is used to remove the noise. Segmentation is done by otsu thresholding method and post processing of segmented images is dine to smoothen the blood vessels. DRIVE and STARE datasets have been used to evaluate the performance of the proposed algorithm. Proposed algorithm has highest accuracy in segmentation process as compared to other techniques. This algorithm has the advantages of being fast, accurate, efficient, simple and thus can be adopted for segmenting retinal blood vessels from fundus images todetect diseases in early stages.

Keywords— *Diabetic Retinopathy, Segmentation, Blood Vessels, Image processing techniques*

I. INTRODUCTION

Diabetic Retinopathy (DR) is a major reason of losing the eye sight among the peoples in young age [1]. It does not mean all diabetic patients are visually weakened but due to the diabetes-mellitus most of the diabetic patients have the problem of improper vision. From various studies, it has been found that patients having diabetes and which are in the range of 10-15 years, 10% lose their eye sight and around 2% goes blind [2]. Also, the number of patients is expected to be doubled in 2030 as compared to number of patients in 2000. 171 million peoples were suffering from this problem since 2000 and it is suspected that there are 366 million patients who will suffer from DR in 2030. The major reason of this disease is the increase of glucose in blood which damages endothelium in blood vessels. At initial stage of DR only microaneurysms symptoms comes up but on later stages some other symptoms comes up like macular edema, neovascularization and hemorrhages and at final stage, due to retinal detachment the patient becomes blind. If this disease is identified at initial stages then we can prevent the patient from becoming blind and his vision can be improved. Also, the losing of eye sight is the starting symptom of the DR and if check up of eye fundus test for every diabetic patients is done after regular periods then DR can be identified at early stages and it can be cured [3]. But due to the lack of number of experts and large number of patients are not getting the treatment in proper way. Also, its treatment is highly expensive and it is a big financial problem. From last many years, with the help of Computer Aided Diagnosis systems many diseases are detected and prevented. CAD systems are helpful in reducing workload by removing that cases of patients which does not have DR and also in reducing the huge amount of cost of the tests which are done for detecting the disease.

The detection of the vessels from the vascular structure is the most important symptom for detecting DR in the patient by the automated DR diagnosis system. For evaluating the detection of vessels vascular tree segmentation is required as the previous step. Wrong information is removed by getting the right information of location of the blood vascular structure for diagnosing the hemorrhage and micro aneurysm. The vessels segmentation proves itself very useful. Also, vessels segmentation provides useful information for registering the multimodal images and for finding fundus features i.e. the fovea and the optic disc[4]–[6] .

Rest of the paper is structured as follows: Section 2 discusses the related work done in this field. Datasets used and methodology adapted are presented in Section 3 and Section 4 respectively. Section 5 gives the obtained results and their discussion is done. Finally, Section 6 concludes the paper.

II. LITERATURE

Chaudhuri et al. [7] was done the intial work for detecting and segmenting the blood vessels. In this work gray level values are taken in perpendicular direction of blood vessels and calculated before processing the segmentation phase in which mean filter is applied for enhancing the image.12 directions within range of 0° to 180° are selected of 15° equal distance for detecting the orientation of blood vessels. Ayala et al. [8] has presented procedure for detecting and segmenting blood vessels from the retinal images on the basis of a fuzzy rule. In this work before segmentation low level reprocessing phase is processed for enhancing the images, so that light and thin blood vessels can be easily detected. Al-Rawi et al. [9] was proposed an improved and better method for detection and segmentation of blood vessel over the method also proposed. In this proposed method improvement of optimal tuning parameters was done and after that this approach was applied on 20 various images from DRIVE dataset. Soares et al.[10] has proposed a new approach for detecting and segmenting the blood vessels by using a wavelet transformation. In this proposed work, 2-D MW Transformation method is used as it is well known for selecting orientation by doing optimal variability and frequency tuning. Chang et al. [14] has proposed a method on the basis of edge and line detector (RBVSLE) for detecting and segmenting the retinal blood vessels so that classification rate of vessel pixels gets improved. For improving the classification rate, two thresholds values were selected and if pixel intensity value stays in between the range of threshold values, then pixel is classified as vessel pixel, otherwise it is classified as non-vessel. Akram et al.[11] has proposed a method for detecting and blood vessels segmentation on basis of wavelet based enhancement. As right information of blood vessels pixels is not obtained from the corrupted or noise image, so in this work enhancement of image is done to easily extract the blood vessel pixels. Cinsdikici and Avdin [12] has proposed a new method for segmenting the blood vessels on basis of an Ant Colony algorithm. In this work, in preprocessing phase contrast enhancements techniques are applied on the image and some morphological operations are performed on the image. Xu and Luo [13] has proposed a different approach on the basis of vector machine classifier for the segmentation blood vessels. At initial stage, a green channel from retinal image is selected and then for enhancing the image normalization is done. After that morphological operations are performed on images for removing the optical disk and then segmentation of thick blood vessel is done by applying an adaptive thresholding method. Lupascu et al. [14] has introduced a new technique for segmenting blood vessels by using Feature-Based AdaBoost Classifier. In this proposed work, for enhancing images and removing noise different filters were used like Gaussian filter, matched filter and Gabor filters. By using intensity features like gradient, direction and mean curvatures edges and ridges were calculated. Sun et al.[15] has proposed a new approach for segmenting retinal blood vessels on basis of watershed transformation. In the proposed work, for detecting background image multi scale nonlinear morphological operators were used. Then a contrast normalized image is obtained by subtracting the detected background from the original image. Fuzzy morphological operations are used for processing the contrast normalized image. Marin et al.[16] has proposed a new supervised method for detection and segmentation of blood vessel using neural network. In this work, in preprocessing step vessel reflex problems and illumination are removed from the image. Then Gaussian kernel is used for smoothening of noise. After that for enhancement of image hat transformation technique on basis of morphological operations was used and 7 features were extracted. In which 5 features are selected on the basis of gray level features and rest 2 features are the Invariant Hu Moment features. Onkaew et al.[17] has proposed a new method for blood vessels segmentation from retinal images on basis of gradient orientation method. At initial stage, in this work calculation of gradient vectors was done for x and y direction by using the derivative operators. After that normalization was done for fast processing. Gradient vectors depend on the features. Vector will converge if features are darker than the background and they can diverge if features are brighter. Ocbagir et al.[18] has given a new approach for segmentation and detection of retinal blood vessels by applying a rule based Star Networked Pixel Tracking algorithm. In this work for enhancing some adaptive histogram equalization techniques and morphological operations are applied on the image. Then by using the median filter noise was removed. Then for performing classification a pixel by pixel method is used. Mehrotra et al.[19] has introduced an approach for segmentation of blood vessels on basis of Kohonen Clustering Network. At initial stage of the proposed work, by using Novel Edge Preserving Filter and Gaussian filter noises like impulse and Gaussian noise are removed from the image and then for removing the improper illumination equalization method was used. Bhatia et al.[20] has proposed a different and new technique for the segmenting blood vessels and it is an efficient supervised method. In this method, at initial stage green channel is selected from retinal image captured by the fundus camera, which makes the segmentation and detection of vessels easy by showing best contrast combination between back ground and blood vessels than other two channels.

III. DATASETS

Before In this work DRIVE and STARE datasets are used for the detection and segmentation of blood vessels from retinal images. In both datasets, images are separated into testing and training classes. Images of training class include ground truth information where manual segmentation is done by experts. Images of testing class are used for testing the validity of the presented system.

DRIVE Dataset

Images of Drive dataset for diabetic retinopathy were obtained from a screening program which was held in Netherlands[21]. In this dataset, 453 subjects were there and out of 40 images, 7 images were suffering from pathologies like hemorrhages and epithelium change. Images are divided into testing and training sets. View field masks for both data sets are also taken. Testing set is further divided into sub sets X and Y. Sample of DRIVE datasets are shown in Figure 3.1.

STARE Dataset

It contains collection of retinal fundus images which was manually segmented by 2 observers[22]. One out of two segmented 10.4% vessel pixels but other segmented 14.9% vessel pixels. The difference of the segmented pixels shows that the second observer segmented more blood vessels than the first observer. Figure 3.2 shows samples of healthy and unhealthy eyes.

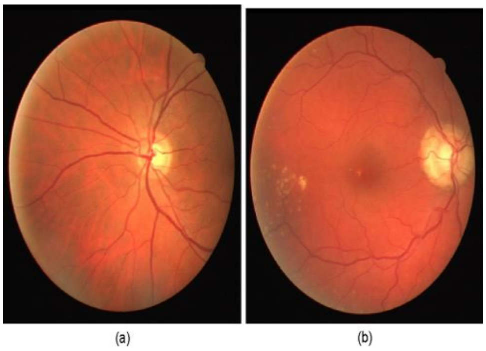


Fig.3.1 DRIVE: (a) Eye image of healthy person, (b) Eye image of diabetic patient

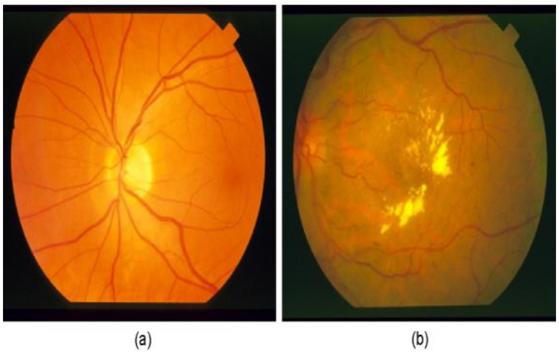


Fig.3.2 STARE: (a) Eye image of healthy person, (b) Eye image of diabetic patient

IV. METHODOLOGY

After The evaluation of proposed algorithm is validated by performing it on the two retinal image datasets, which are called as DRIVE and STARE datasets. In the research field of segmenting the blood vessels from retinal images both datasets are favorably considered by many researchers for performance testing of the applied algorithms. DRIVE dataset contains 40 colored retinal images and STARE dataset contains 20 colored retinal images. Images of the datasets are categorized into two sets: testing and training set. Hand labeling of vessels has been done in both datasets by two different experts. In this work, first expert's labeling is considered as ground truth for evaluating performance and second expert's labeling is used for algorithm evaluation against first expert labeling for analysis of the performance.
The proposed algorithm is executed on the system having Intel core I7 processor of 1.43 GHz speed and 8 GB RAM with MATLAB 2010 application software installed on it.

A. Image Acquisition

In DRIVE dataset, there are total 40 colored retinal images taken by using a fundus camera Canon CR5. The images taken from the camera are saved in the TIFF format with resolution of 768*584 pixels. The view field of camera is considered at 45˚. In images of Set X, 3,960,532 pixels are labeled as non-vessel pixels and 577,649 pixels are labeled as vessels pixels. In images of set Y, 3,981,611 pixels are taken as non-vessel pixels and 556,532 pixels are taken as vessel pixels.

In STARE dataset, there are total 20 colored retinal images and taken by using a TopCon TRV-50 camera. The images taken from the camera are saved in the PPM format with resolution of 700*605 pixels. The view field of the camera is considered at 35˚. There are total 10 images that contain pathology disease. The observed diameter of FOV is 650*500 pixels approximately.

B. Vascular Structure Extraction

For extracting the blood vessel structure from retinal images as described in the design phase the following procedure has been followed. First of all, out of the RGB components of the retinal image a green channel is selected. Then the background retinal image is estimated. For getting the vascular structure image background retinal image would be subtracted from the original retinal image. The implementation step of vascular structure extraction is discussed in detail:

Green Channel Selection

In this step, a green channel is selected from the input colored retinal image. The input retina image is taken by using fundus camera. Every color channel of the camera gives information about pathological and anatomical structures of retina. Green channel contains information of higher contrast between background and vessels than other channels so this channel is selected for representing the vascular structure of eye images and also in existing works this channel is favorably considered for the segmentation of vessels. Therefore, the green channel is favorably taken for vascular structure segmentation. Figure 4.1 shows the RGB components of a colored retinal image.

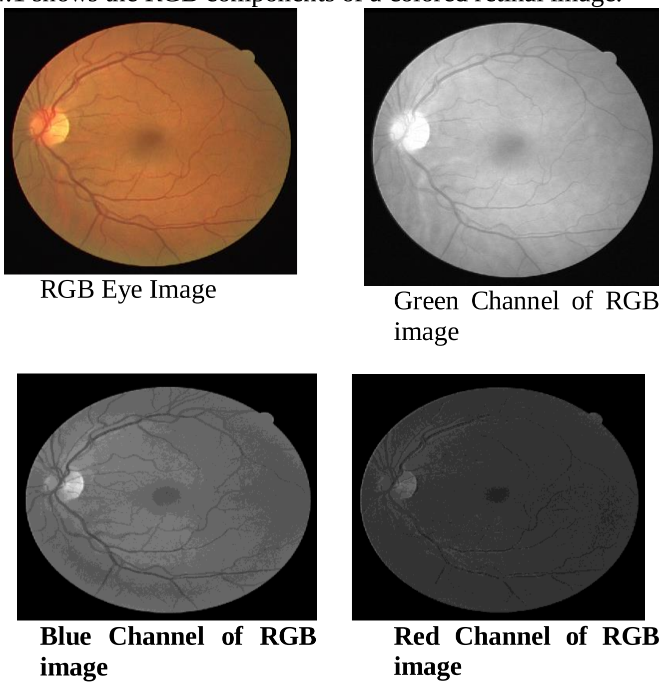
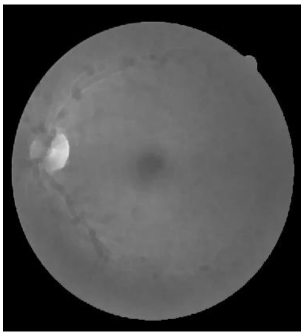


Fig.4.1: Fundus Retinal Image and its RGB channels

Background Estimation:
For estimating the background image morphological operations are used. In this work, closing morphological operation is used for estimating the background of retinal area of image. As closing operation suppress the structuring element more than the dark details. So, it will remove the present vessels in the retinal image for producing the background of retina area. In this step, size of structuring element is taken as the parametric value according to which the background estimation is done. If size of structuring element increases than the retinal image get more blurred and vice versa. Figure 4.2(a) shows the estimated background for retinal image from green channel.



a:Background estimation

b: Vascular structure

Fig.4.2: Vascular Structure Extraction

Vascular Structure Estimation:
Estimation of the vascular structure is done by evaluating the difference between estimated background and original retinal image. A Sample of blood vessel structure obtained from retinal image is shown below in Figure 4.2(b).

C. Segmentation

After estimating the vascular structure segmentation phase is performed. In this phase, for minimizing the non-uniform lighting problem image normalization is performed on the blood vessel segmented image.

Noise Removal
For removing the noise apply Rician De-Noise filter. By applying this filter image is also enhanced and the texture information is preserved. The values of parameters for the method are as follows: $a = 0.25,\ b = 2,\ c = 10\ and\ T = 0.5$. Values of the above parameters are selected on the basis of accuracy evaluation of different combination values of these parameters on individual datasets. The set of combination which produces highest accuracy is selected as the final one. Values of these parameters are fixed for all of the images of a dataset. The image produced after removing the noise from the segmented image of blood vessel structure is shown in Figure 4.3.

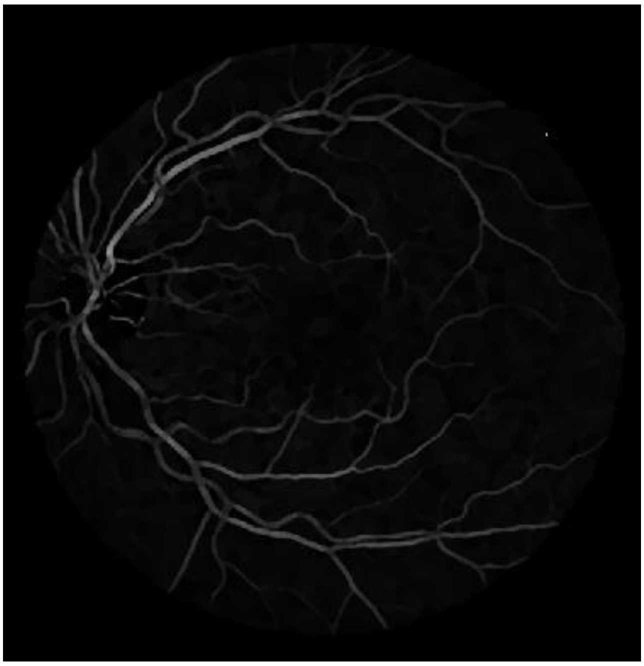


Fig.4.3: Noise Removal

Segmentation
In this work, segmentation is done by applying modified Phansalkar method on vascular structure of retinal images. Phansalkar method is modified to make it suitable for our problem by setting its thresholding technique to the global instead of the local. The thing is made by changing the size of search window from local to the whole image and after that threshold value is calculated and used for the segmentation of blood vessel structure. Figure 4.4 shows the segmented image with blood vessel structure.

D. Post processing

In this section post processing steps are done for enhancing the performance of proposed approach for extracting the blood vascular structure from the earlier segmented retinal image.

In this step, for removing isolated and unwanted areas that does not belongs to the blood vessel structure an area filtering operation applied on the vascular structure image. This operation is achieved by using connected component analysis (CCA). In which all connected components are labeled by using 4-way or 8-way pixel connectivity scheme. Then all labeled components are calculated for classification as vessels or non-vessels components. The regions who have more area than *A* are vessels, else are non-vessels.

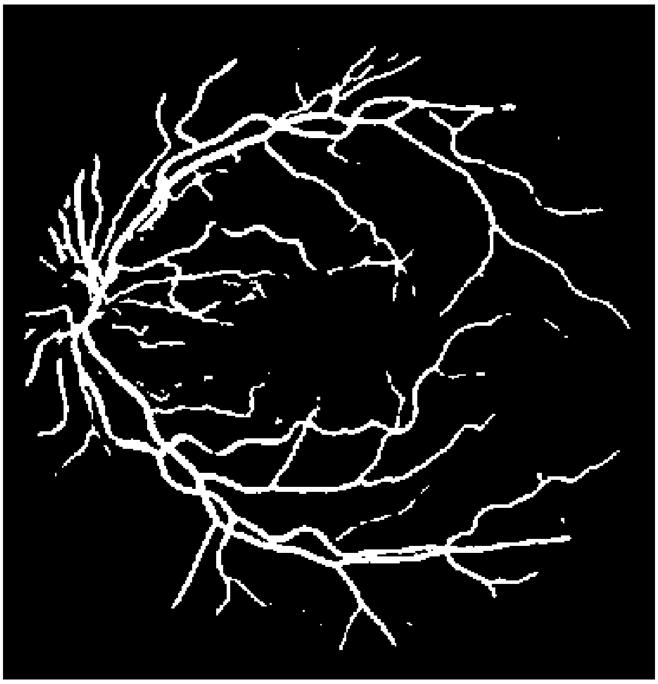


Fig.4.4: Segmented image

The second operation performed in post processing is the removal of spur pixels. Spur pixels are presented at edges of blood vessels and removed for improving the system performance.

Then after post processing the final segmentation of blood vascular image is done.

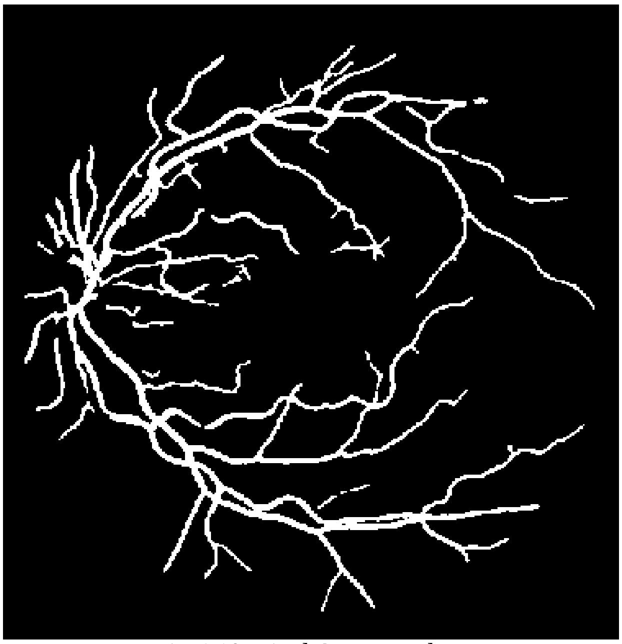


Fig.4.10: Final Segmented Image

V. RESULTS

The correct performance metrics selection plays an important role for the evaluation of the implemented method's performance and for validating the system. The parameters selected for performance evaluation of the proposed method are specificity, accuracy and sensitivity.

Sensitivity: Sensitivity is defined as the ratio of true positives which are identified correctly[21]. If the sensitivity is high, then the false positives will be less.

$$Sensitivity\ (S) = \frac{TP}{TP + FN} \times 100 \qquad (5.1)$$

$$= \frac{\text{number of true positive assessment}}{\text{number of all positive assessment}}$$

Where, FN stands for False Negative (i.e. to that subjects which are incorrectly identified according to their class) and TP stands for True positive (i.e. to that subjects which are correctly identified according to their class) [23].

Specificity: Specificity is defined as the ratio of the true negatives which are identified correctly[21]. The value of specificity tells the probability of a test to identify a class without taking the false-positive results.

$$Specificity = \frac{TN}{TN + FP} \times 100 \qquad (5.2)$$

$$= \frac{\text{number of true negative assessment}}{\text{number of all negative assessment}}$$

Where, TN stands for True Negative (i.e. to that subjects which are not belonging to the class and identified correctly) and FP stands for False Positive (i.e. to that subjects which are not belonging to the class and identified incorrectly) [23].

Accuracy: Accuracy is defined as ratio of true results, whether it is true negative or true positive [24].

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \times 100 \qquad (5.3)$$

$$= \frac{\text{Number of true correct assessments}}{\text{Number of all assessments}}$$

Table 5.1 shows the outputs of DRIVE dataset at disc size of 5 units. The values of specificity, accuracy and sensitivity have been shown for all the 20 images of DRIVE dataset. The highest values obtained for specificity and sensitivity are 99.21% and 81.34% respectively and 95.84% accuracy has been achieved for 19 number image of DRIVE dataset.

Table 5.1: Performance Metrics for Drive Dataset at Disk Size 5

Image No.	SE	SP	ACC
1	0.7515	0.9763	0.9469
2	0.7671	0.9815	0.9494
3	0.6841	0.9770	0.9343
4	0.6519	0.9898	0.9448
5	0.6386	0.9902	0.9425
6	0.6225	0.9875	0.9360
7	0.6792	0.9768	0.9374
8	0.6409	0.9840	0.9409
9	0.5679	0.9921	0.9423
10	0.6935	0.9825	0.9480
11	0.6667	0.9808	0.9401

12	0.6666	0.9834	0.9437
13	0.6304	0.9868	0.9362
14	0.7243	0.9809	0.9506
15	0.7542	0.9649	0.9430
16	0.6440	0.9844	0.9399
17	0.6686	0.9790	0.9407
18	0.7180	0.9744	0.9450
19	0.8134	0.9783	0.9584
20	0.7256	0.9761	0.9494

Table 5.2 shows the output of STARE dataset. The values of specificity, accuracy and sensitivity have been shown for all the 20 images of STARE dataset. The highest values obtained for specificity and sensitivity are 99.42% and 86.85% respectively and 96.57% accuracy has been achieved for 18 number image of STARE dataset.

Table 5.2: Performance Metrics for Stare Dataset at Disk Size 5

Image No.	SE	SP	ACC
1	0.6485	0.9514	0.9184
2	0.5933	0.9406	0.9086
3	0.7515	0.9532	0.9368
4	0.4444	0.9917	0.9351
5	0.7207	0.9693	0.9387
6	0.8341	0.9692	0.9574
7	0.8576	0.9651	0.9533
8	0.8229	0.9666	0.9519
9	0.8512	0.9667	0.9543
10	0.8174	0.9625	0.9465
11	0.8172	0.9678	0.9531
12	0.8685	0.9704	0.9596
13	0.7981	0.9656	0.9451
14	0.7854	0.9687	0.9459
15	0.6992	0.9739	0.9416
16	0.6011	0.9835	0.9331
17	0.7432	0.9853	0.9556
18	0.5832	0.9942	0.9657
19	0.6503	0.9853	0.9656
20	0.5360	0.9710	0.9314

VI. CONCLUSION

The proposed method is proved as an enhanced technique for the detection and segmentation of blood vascular structures from retinal images which were taken by using fundus camera. In this proposed method, thresholding methods and basic morphological operations are applied for extracting out the blood vessel structure and segmentation of blood vessels is done by using green channel from colored retinal image. Before segmentation noise is removed from images by using Rician Denoise technique. The proposed method is evaluated on two favorable datasets of retinal images, named as STARE and DRIVE dataset. Then Specificity, Accuracy and Sensitivity performance metrics are used for evaluating the results and perform well than other well known methods and gives better and comparable results. Best results are calculated from both datasets at disk size five (5). The proposed system proves itself simple, robust and effective. Due to fast implementation of the proposed method it is suitable to integrate the proposed method in pre-screening systems so that detection of DR early stages is possible.

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