An Efficient Automated System for Screening and Validation of Neovascularization caused by Diabetes in Retinal Images

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Abstract*—Neovascularisation (NV) is the serious Diabetic Retinopathy (DR) disease which causes disorder in the retinal blood vascularization due to the increase in diabetes ratio by growing new unwanted weak blood vessels over the optics disc(OD) or fovea region of the retina. Previously the evaluation of NV is done either in OD or in Fovea region of retina But our automated system aims in evaluating newly born vessels in both fovea and optic disc by using new methodology for screening of NV in entire retina by using SUSAN (Smallest Unvalued Segment Assimilating Nucleus) edge detector and line tracking algorithm for segmentation along with the classification using Support Vector Machine (SVM). These vessels are very thin to identify so pre-processing plays an important role which is done using unsharp masking, LOG (Laplacian of Gaussian) filter and high boost outlier filtering which gives better PSNR values than other pre-processing method.For segmentation, SUSAN edge detector detects the blood vascularisation with lower complexity and less computational time by extracting the features. Classification of NV is done using SVM which gives 100% specificity and 100% accuracy as compared to other method.Our proposed method helps in detecting NV at OD as well as in fovea along with the detection of the severity of disease.*

Keywords—*Fovea, Neovascularization, Optic Disc, Pre-Processing, SUSAN (Smallest Unvalued Segment Assimilating Nucleus) edge detector, SVM (Support Vector Machine) classifier***.**

I. INTRODUCTION (SIZE 10 & BOLD)

In the developed industrialized world diabetic retinopathy leads to the disease which can cause the visual disabilities [1]. Maximum percentages of people who suffer from DR are found in United

Kingdom where every person in the age between twelve and above are invited at least annually for retinal treatment using retinal photography [2]. Computer assisted automated system helps in accurate detection of DR which can also save time required for treatment [2]. Optic disc, fovea and blood vessels are the main components that can be affected by DR and any change in their structure shows the presence of injury in retina. The earliest stage of DR is NPDR. Which causes the small bulges in blood vessels, tiny spots of blood, swelling or thickening of macula? But PDR is advanced stage of DR in which retina supply blood to the closed area of blood vessels leading to the growth of newborn blood vessels, this proliferation of new vessels in retina is referred as Neovascularization. As the disease progresses these vessels can get damage and leak proteins or blood which in turn produces exudates .Further damage to retina can be surpass by early screening of NV. Lots of methods and techniques have been implemented for NV detection as presented in literature but still, detection of NV is very difficult because those newly grown vessels are very tiny to detect and appropriate segmentation technique which gives better accuracy needs to be developed [2].

Goatman *et al*., [1] describes an exhaustive set of 15 features which includes the vessel segment, the resulting vessel wall ramp and various tortuosity measures for detecting newly grown vessels on optic disc. Akram *et al*., [2] proposed a multilayered thresholding for segmentation of vessels and uses the classifier which is gaussian mixture model based with 5 dimensional feature set and features are set based upon intensity and gradient values. R.A.Welikala *et al*., [3] presents the vessel detection method which is simplified by removing the normal vasculature from vessel map. Vessel segmentation is approached by using standard line operator.

Hassan *et al*., [4] indicates the presence of new vessels with the help of two local features, one is the number of vessels i.e. Vessel count and another is area of vessels within small template. Zang *et al*., [5] proposed the technique which uses double sided thresholding with modified matched Filter he focused more on exudates to reduce its false response which may cause the local Densities on the

vessel segmented map and he reduces his false response to exudates by applying matched filtering.

Doaa Youssef *et al*., [6] basically work on the exudates detection but represents the new vessel detection method to improve the detection of exudates .Various characteristics of a retinal blood vessel such as its width range, intensities and orientations are considered for the purpose of selective segmentation. Optic disc detection is done using the common Hough transform technique.Optic disc extraction, detection of edge points and extraction of blood vessel tree are useful for blood vessel detection.

The work presented by R.J. Winder *et al*., [7] analyses and categorizes the literature in the field of digital imaging techniques in diabetic retinopathy during the period 1998 -2008. The studies included in his survey examined the use of novel computer algorithms to detect normal and pathological retinal features in DR. List of papers using the different pre-processing, segmentation, feature extraction algorithms are also provided in this survey Arturo Aquino *et al*., [8] stated that for automated diagnosis of various serious ophthalmic disease mainly Diabetic Retinopathy, Optic disc (OD) detection can be the major step. New template-based method of optic disc segmentation from retinal images is present. The circular optic disc boundary is obtained by the methodology that uses morphological and edge detection techniques followed by the Circular Hough Transform.

Dipika Gadriye, Gopichand Khandale *et al*., [9] uses neural network to do pre-processing with the help of Gray level 2D feature based vessel extraction .This methodology is evaluated on DRIVE database and proved to be superior than rule based methods. Morphological opening and image enhancement is performed to identify micro-aneurysms in an image. A MATLAB implementation of the complete algorithm is developed and tests suggest that the diagnosis in an image can be estimated in shorter time. To classify the images, thresholding is applied to the classification results.

The technique proposed in Ahmad Fadzil M Hani *et al*., [10] represents the noise detection algorithm in retinal fundus images. Since the tiny retinal vessels needs to analyze for diagnosing the retinal diseases of the eye but due to presence of noise this vessels are difficult to analyze. Time domain constraint estimator is proposed to reduce the noise and is characterized in terms of PSNR (signal to noise ratio).The image details as well as contrast of an image is maintained while removing noise.

Myself *et al*., in [11] reviewed and analyzed the automated techniques with the optimized algorithms and also the methodologies used for the detection of the early and advance stages of the retinal diseases caused by diabetes along with the severity of the disease. The proposed work also gave the information of available public data set on which algorithms are tested and trained.

2. PROPOSED METHOD

The block diagram of proposed methodology shown in figure (1) is an automated system for enhancement and segmentation of newly grown retinal blood vessels. The pre-processing technique is applied to remove noise from image and to enhance it. Input to the system are colored RGB retinal images since green channel of an image gives better contrast between background pixels and vessel pixels so the whole system is designed to work on the green channel image. Before vessel segmentation they need to be enhancing because these vessels are very thin and in this system we have used Laplacian of Gaussian, Unsharp masking and high boost outlier filtering for enhancement purpose. Later then with the help of SUSAN edge detector segmentation is done based on the appropriate threshold value. Then line tracking algorithm is applied for feature extraction of optic disc and fovea. Line tracking algorithm gives the total number of vessel density in on the basis of which we can conclude that whether the retina contains new vessels or not. Before doing this image acquisition is an important part of the system. Following figure shows the complete methodology block of proposed system

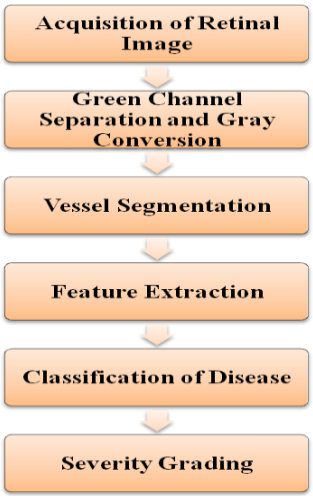


Figure1: Proposed Methodology block diagram

2.1 ACQUISITION OF RETINAL IMAGES

Including the retinal data in the form of digital retinal images before processing it is called as acquisition of retinal images which is in the RGB format. To improve the processing speed these images are resized into half of the size of original image. The original size of retinal fundus image available publically is 1500*1152 pixels. DRIVE (Digital Retinal Images for Vessel Extraction) database obtained from the public database is used. All imagesin DRIVE database are digitized using a Cannon CR5 non-mydriatic 3CCD camera with a 45 degree field of view. Also the database collected from ophthalmologist Dr.Anil Gedam,Sanket Eye Hospital,Nagpur,has been used.

2.2 PRE-PROCESSING

The objective of pre-processing is to unstay any artefacts that occur while the process of retinal image acquisition. Tiny retinal vessels need to be analysed for Diagnosing retinal eye diseases. But digital colour fundus images are pest by the problem of low and varied contrast. Further plagued by noise retinal vasculature is very difficult to be analysed Therefore, it is necessary to perform pre-processing of images. Basically enhancement is done for an out of focus image to sharpen it and de-blurring, edge highlighting, improving image contrast and removing noise as shown in figure (1)and the evaluation of the results are displayed in table 1.The pre-processing stages include Sharpening of the image which highlights the edges of blood vessels by measuring the variation in the intensity change.It involves spatial differentions.This is done by superimposing laplacian output on the original image,either by adding or substracting the laplacian output from the original image.Thus the high frequency components are reduced.the laplacian output is given by the equation (1)

$$L(x,y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \quad (1)$$

where L(x,y)is the Laplacian of an image highlighting pixel intensity values I(x,y) .The laplacian operator helps in enhancing the rapid intensity changes for edge detection.

The next stage in pre-processing used is the Unsharp Masking which preserve the high pass components of the images.It is done by firstly smoothing the input image f(x,y) with the mean filter of kernel 3x3 and subtracting it from original image.

$$g(x,y) = f(x,y) - f_{smooth}(x,y)$$

where $f_{smooth}(x,y)$ is a smoothed version of $f(x,y)$ (2)

$$f_{sharp}(x,y) = f(x,y) + k * g(x,y) \quad (3)$$

Where g(x,y) is the unsharp masking output of the input image f(x,y).

Thirdly,to preserve the low pass components along with the high pass components high boosting filter is used.

$$I_{highboost} = AI_{highboost} + I_{highpass} \quad (4)$$

Image enhancement results can be verified by calculating peak signal to noise ratio which is given by equation (2).

$$RMSE = \sqrt{\frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}[y(m,n) - x(m,n)]^2} \quad (5)$$

$$PSNR = 20log_{10}\left(\frac{256}{RMSE}\right) \quad (6)$$

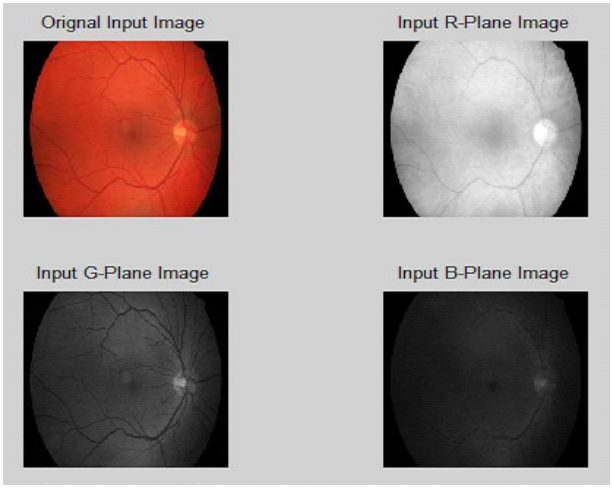


Figure 2: Input image and corresponding red, green and blue plane images

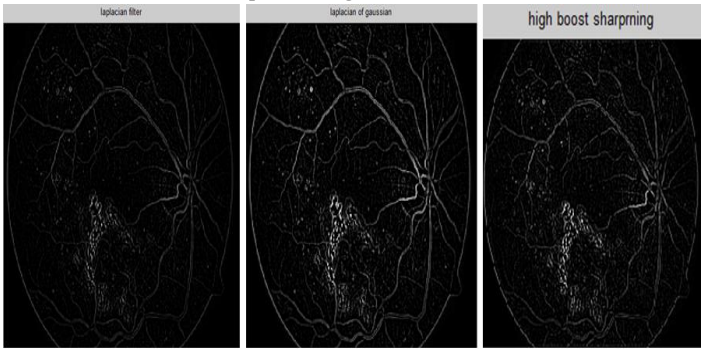


Figure 3: (a). Laplacian filtered image (b). Laplacian of Gaussian filtered image (c). High boost filtered image

Table I: PSNR values of original image and preprocessed enhanced image

Data	Original image PSNR(db)	Processed image PSNR(db)
Image-1	15.35db	33.55db
Image-2	17.53db	33.71db
Image-3	16.36db	33.13db
Image-4	14.48db	32.99db
Image-5	13.70db	32.84db

2.3 SUSAN EDGE DETECTOR

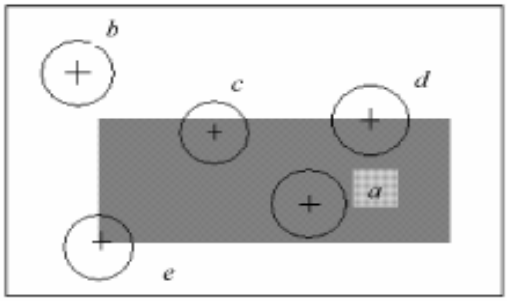


Figure3: Basic principle of SUSAN detector[12]

SUSAN stands for smallest unvalued segment assimilating nucleus was introduced in 1995 [12] and it performed well even in presence of noise because it does not use image derivatives. Its basic principle is based on the pixels similarity with its neighbour pixel gray value.Figure(3) represent its basic principle in which circular templates carries information about image pixels around a given point. USAN area is shown by dark region and it is maximum at flat region, it becomes half at the edges and become very less at the corner of image. The weight or area of USAN region is calculated by following equation (3)[12].

$$n(ro) = \sum_r compare(r, ro) \tag{7}$$

$$comapre(r, ro) = \begin{cases} 1 \; if \; |I(r) - I(ro)| \leq t \\ 0 \; if \; |I(r) - I(ro)| > t \end{cases} \tag{8}$$

Where compare(r, r0) is function of pixel belongs to the USAN region within the template. *I(r0)are the* gray value of the nucleus within the mask. *I(r) as a* gray value for other random pixel in the mask, t is a threshold value of gray pixels. Then every pixels edge strength is computed using the mathematical formula[12]:

$$response(ro) = \begin{cases} g - n(ro) if \; n(ro) < g \\ 0 \; otherwise \end{cases} \tag{9}$$

Above formula shows the comparison between number of pixels in USAN region ad geometric threshold value which is fixe at $3n_{max}/4$, where n_{max} is the highest value of number of pixels containing in USAN region. This edge response given by eq.5 will be larger as the SUSAN area is smaller. After edge response calculation the direction which is perpendicular to the edge is required for image to be suppressed. Direction of the edge which is being examined depends on its type either inter pixel or intra-pixel. In case of inter-pixel if the area of USAN is large than diameter of USAN template and its centre of gravity lies more than one pixel fron nucleus then its centre of gravity is defined by[12]:

$$Centre\ of\ Gravity(ro) = \sum_r r\ compare(r, ro) \Big/ \sum_r compare(r, ro) \tag{10}$$

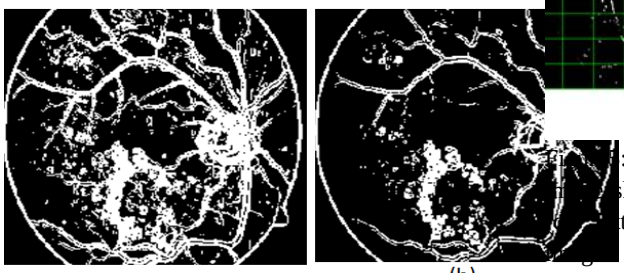
And the required direction is calculated by $ro - Centre\ if\ Gravity(ro)$. In case of intra-pixel if centre of gravity lays less than one pixel from nucleus and its area is less than diameter of USAN template then edge orientation is obtained by the ratio of following equation[12]s.

$$\overline{(x - xo)^2} = \sum_r (x - xo)^2 compare(r, ro) \tag{11}$$

$$\overline{(y - yo)^2} = \sum_r (y - yo)^2 compare(r, ro) \tag{12}$$

- Firstly one circular mask is placed around the centre pixel or nucleus in the image.
- Then the number of pixels having similar brightness to the centre pixel within the mask are computed using equation (4), this will define the USAN area.
- Edge strength image is then obtained by subtracting this area from geometric threshold value using eq.(5)

- Then apply moment calculations to USAN for finding edge orientations.
- The results of the algorithm using different thresholds are shown in figure 4.

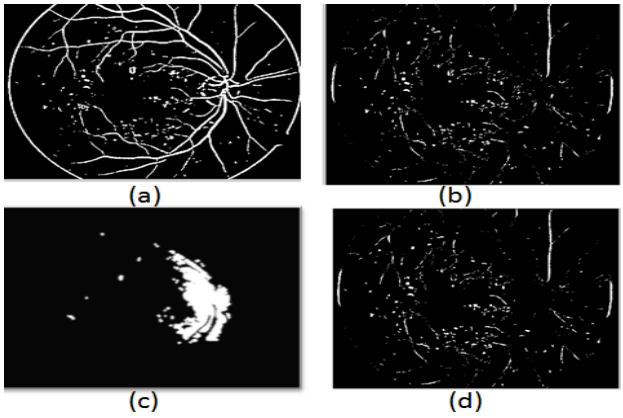


(a) (b)

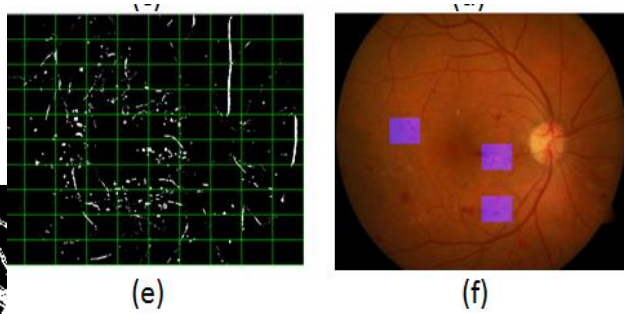
Figure4: a. SUSAN edge detection with threshold value=5.85 b. SUSAN edge detection with threshold value=9

2.4 FEATURE EXTRACTION

To trace the line of the image we used Line Tracking Method using different angular orientation and diameter. By utilizing the image histogram, the pixel area boundaries will be determined to be tracked by the threshold value corresponding to the frequency of the intensity image. Tracking of the image area is done earlier before initialisation process using pixel neighbourhood with direction and a predetermined diameter. By calculating the value of the weight of each pixel neighbours, it will be selected the pixels that have the greatest weight and the value exceeds a predetermined threshold weight. Re-initialisation of early pixel is done if the condition is not satisfied.If there is one that meets the pixel, the pixel is marked as a line pixel by providing trust value of "1", while the other pixels set to "0" as shown in figure (5). Furthermore, this process is repeated until all of the pixel area is completed tracking.



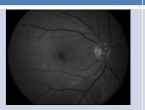
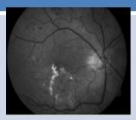
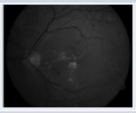
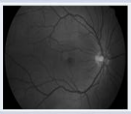
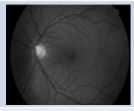
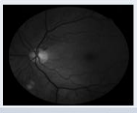
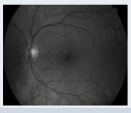
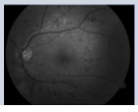
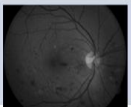
(a) (b) (c) (d)



(e) (f)

: (a). Line tracked blood vessels (b). Residual showing thin vessels (c). High intensity region traction of high intensity region from residual (e). Block division of (d) (f). Final result image showing new blood vessel region

Table II: Comparison of vessel density of normal eye and affected eye

Normal eye	Vessel density	Affected eye	Vessel density
	187468		302733
	71519		275113
	108435		264060
	124040		237557
	159738		202894

From the above table II we can conclude that the normal eye has vessels density is less as compared to the NV affected eye as the new blood vascularization is grown in the normal eye blood vascularistion. Thats why,we choose the blood vessel density as the main feature for the detection of NV in our proposed work.

2.5 SVM CLASSIFICATION

SVM classification is based on the concept of dividing the hyper plane to preeminent classify the two classes by increasing distance between them. After applying all the processing stages on the image dataset , its validation parameters are calculated by using TP, TN,FP, FN values. The proposed method segmentation results showed the better accuracy with the ground truth segmented outcome[11].

$$\text{Specificity}=TN/(TN+FP) \quad (13)$$

Accuracy = (TP+TN)/(TP+FN+TN+FP)) (14)

Sensitivity =TP/(TP+FN)) (15)

True Positive refers to the correctly detected blood vessels pixels True Negative refers to the correctly detected background pixels. False Positive refers to the wrongly detected blood vessel pixels. False negative refers to the wrongly detected background pixels

Table III: Comparison of ground truth images with proposed segmentation results

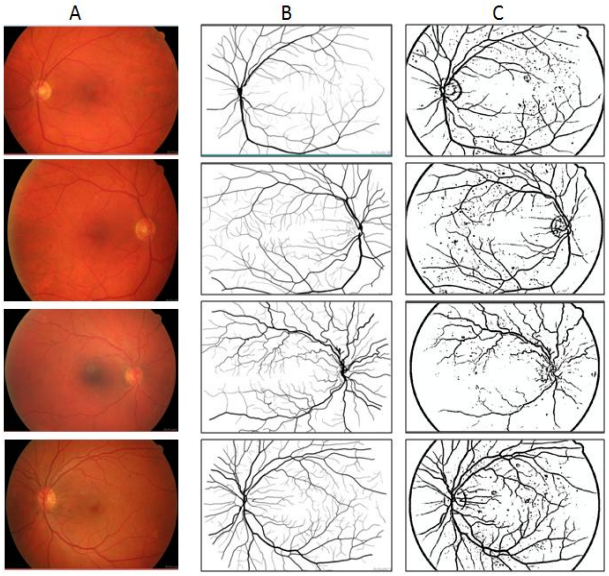


Table IV: Validation parameters for individual images in dataset using proposed methodology

Dataset images	Severity grading	Specificity(%)	Sensitivity(%)	Accuracy(%)
image1	Moderate	91.33	88.62	91.21
image2	Moderate	91.56	82.92	91.08
image3	Moderate	84.9	87.92	85.06
image4	Moderate	89.43	80.90	89.01
image5	Normal	92.34	88.87	92.15
Image6	Moderate	89.78	75.23	88.83
Image7	Normal	89.86	89.56	89.84
Image8	Normal	83.3	93.64	83.99
Image9	Moderate	94.06	66.67	92.39
Image10	Moderate	92.76	77.18	91.70
Image11	Moderate	91.94	84.17	91.35
Image12	Normal	92.63	76.91	91.70
Image13	Moderate	93.71	77.39	92.71
Image14	Moderate	85.80	89.46	86.05
Image15	Normal	83.63	92.82	84.17

Table V: Comparison of validation results

Reference	Validation		
	Specificity	*Sensitivity*	*Accuracy*
Goatman and et al.[1]	84.2%	85.9%	------
Usman Akram and et al. [2]	96.35%	98.93%	95.02%
Welikala and et al. [4]	94.4%	86.2%	------
Youssef and et al. [6]	100%	80%	------
R. Geetha Ramani and et al.[10]	100%	93.3%	96.67%
Hassan and et al. [3]	89.4%	63.9%	------
Proposed Technique	90%	100%	98.62%

3. RESULT

Decision support system is developed with the images obtained from DRIVE and STARE database. This database consists of 40 images of which 13 are affected and 18 are normal images. In this automated system retinal image features such as total density of vessels , optic disc area, circularity of optic disc ,mean value , standard deviation are use for classification purpose and to train the support system. Optic disc parameters are obtained by extracting optic disc from fovea and performing segmentation and extraction algorithm on it. Fig.1 shows the pre-processing results and table I consist of the PSNR values for pre-processing images. Fig4. shows the segmentation results with different threshold values. Fig.5 shows the feature extracted images and result image showing new vessels present in fovea by highlighting it with blue area. Density of total vessel is calculated for normal and affected images as shown in table II. Finally the disease is characterized and accuracy of system is compared with ground truth images .validation parameters are shown in table III,IV & V.

3.1 GUI RESULTS

Fundus image which is to be tested is taken as input image in diagnostic designed environment system with the help of MATLAB GUI command shown in Figure 6 (a),(b),(c).

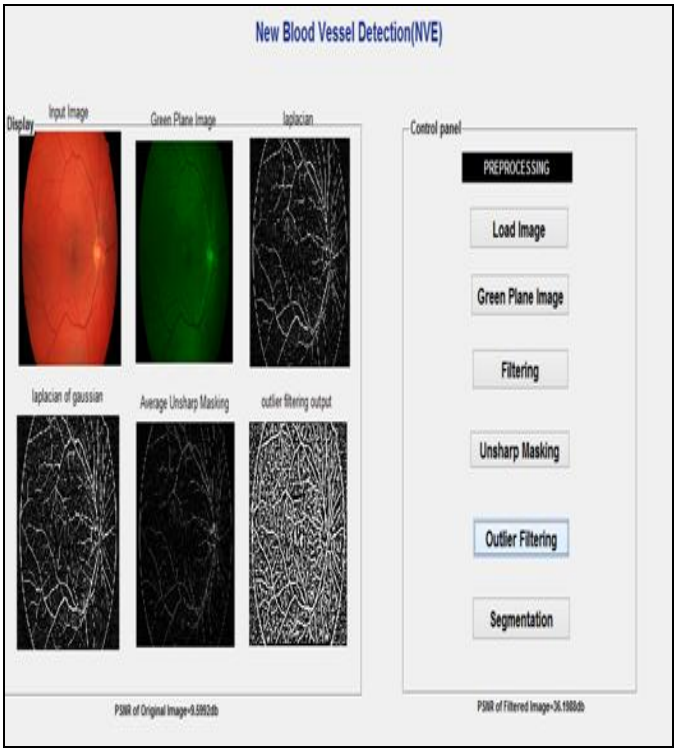


Figure 6: (a) Images Preprocessing GUI window

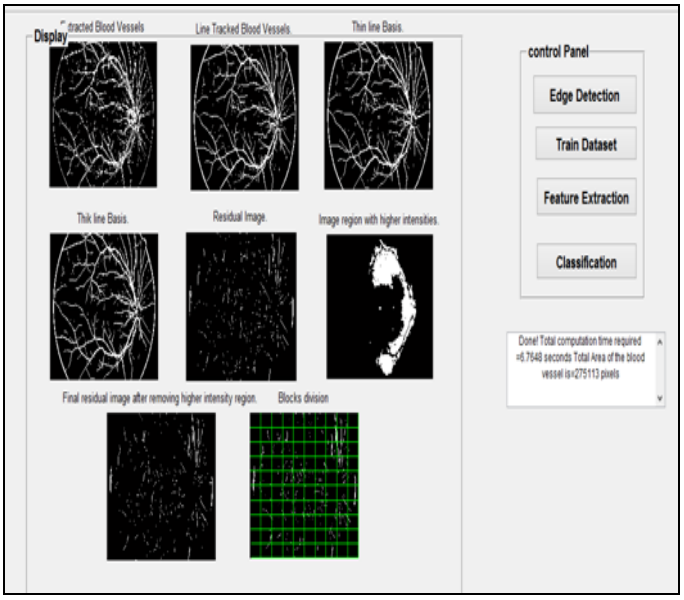


Figure 6: (b) Images Segmentation GUI window

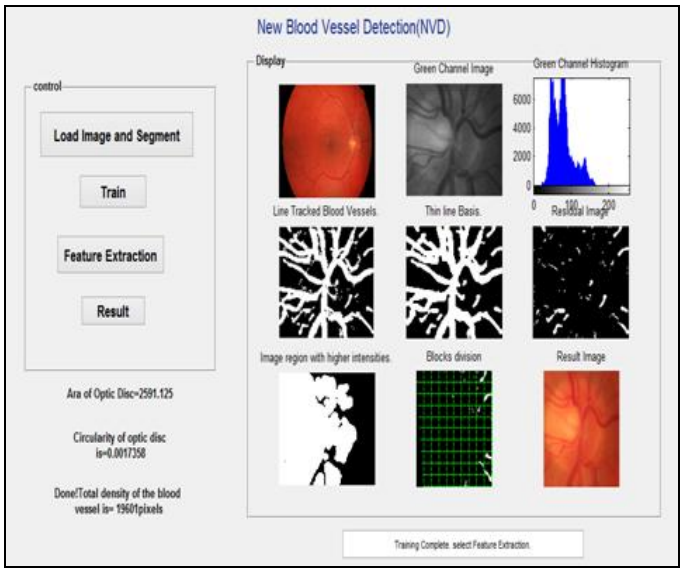


Figure 6: (c) Image for detection of new vessels on optic disc with GUI window

4. Discussion

This paper describes a novel technique for screening and validation of newly grown blood vessels. The main aim of this methodology is to characterized disease as normal, moderate, or severe. SUSAN edge detection and line tracking algorithms are very effective for automatically segmentation of blood vessels and performs best even in presence of noise. For segmentation, specific threshold is selected on which SUSAN gives better response and it can be handled with lower complexity and easy to implement. This system is capable of detecting new vessels on fovea and optic disc. Support Vector Machine gives excellent classification results on various testing samples. This system can be served as a secondary observer in clinical decision making.

5. ACKNOWLEDGEMENTS

The whole system is represented by graphical user interface (GUI) Using MATLAB13.1. Validation procedure of Neovascularization is performed on publically available dataset like DRIVE and STARE and also the database collected from ophthalmologist Dr.Anil Gedam,Sanket Eye Hospital,Nagpur,has been used.

Reference

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