Calculation of Retinal Blood vessels Tortuosity by using Image processing Techniques and Statistical Techniques

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ABSTRACT

In this paper, we present an algorithm for the classification and calculation of retinal blood vessels parameters. And calculate Tortuosity of extracted retinal blood vessels. The algorithm proceeds through three main steps 1. preprocessing operations on high resolution fundus images 2. For retinal vessel extraction, simple vessel segmentation techniques formulated in the language of 2D Median Filter 3. Segmentation for finding boundaries of the extracted blood vessels. Performance of this algorithm is tested using the fundus image database(245 images) taken from Dr. Manoj Saswade, Dr.Neha Deshpande and online available databases diaretdb0, diaretdb1 and DRIVE. This algorithm achieves accuracy of 96% with 0.92 sensitivity and 0 specificityfor Saswade detabase , for diaretdb0 accuracy 95% with 0.95 sensitivity and 0 specificity, for diaretdb1 accuracy 96% with 0.96 sensitivity and 0 specificity, and for DRIVE database 98% accuracy with 0.98 sensitivity and 0 specificity.

Keywords - **Blood Vessels, 2D Median Filter, Tortuosity.**

1. INTRODUCTION

Proposed algorithm shows classification and calculation of retinal blood vessels tortuosity. In this algorithm we have used the Image Processing techniques for extraction of the retinal blood vessels and then classification and calculations of retinal blood vessels Touristy, Tortuosity is early symptom of Diabetic retinopathy. Firstly we have performed the preprocessing operation on high resolution fundus images. We have used 2D median filter for highlighting the blood vessel. For extraction of the blood vessels we have performed threshold function. Segmentation for detecting boundaries. For observing the result we have taken the images and formed a database from Dr. Manoj Saswade and Dr. Neha Despande (245 images), images from online databases diaretdb0, diaretdb1 and DRIVE.

2. METHODOLOGY

Image processing techniques can help in extractions of blood vessels. The proposed algorithm has 3 stages, shown in the figure 1. In first stage preprocessing is done to remove the background noise from input fundus image. Blood vessels are highlighted and extracted in the second stage and in the third stage using segmentation technique boundaries are detected.

2.1 PREPROCESSING:

The Preprocessing is done to remove noise from the background and to enhance the image. We have taken out green channel, because green channel shows high intensity as compare to red and blue. shown in figure 2.

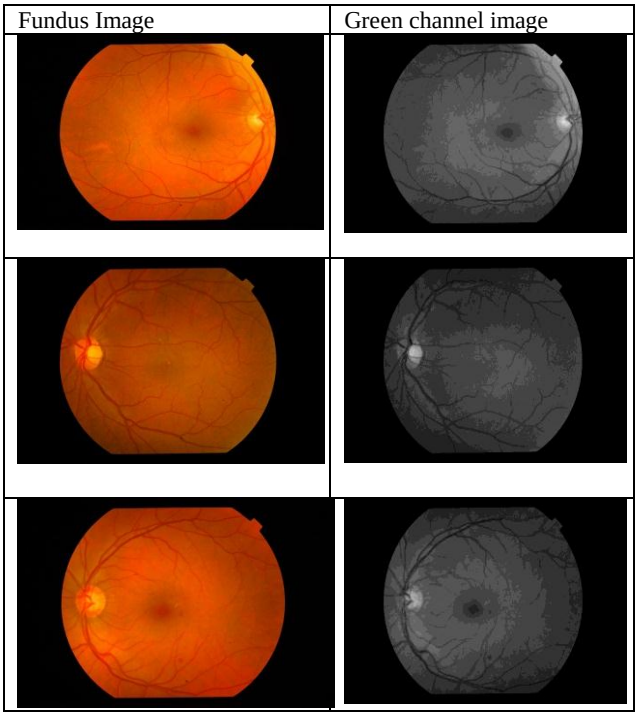

Figure 2: Fundus image and green channel image

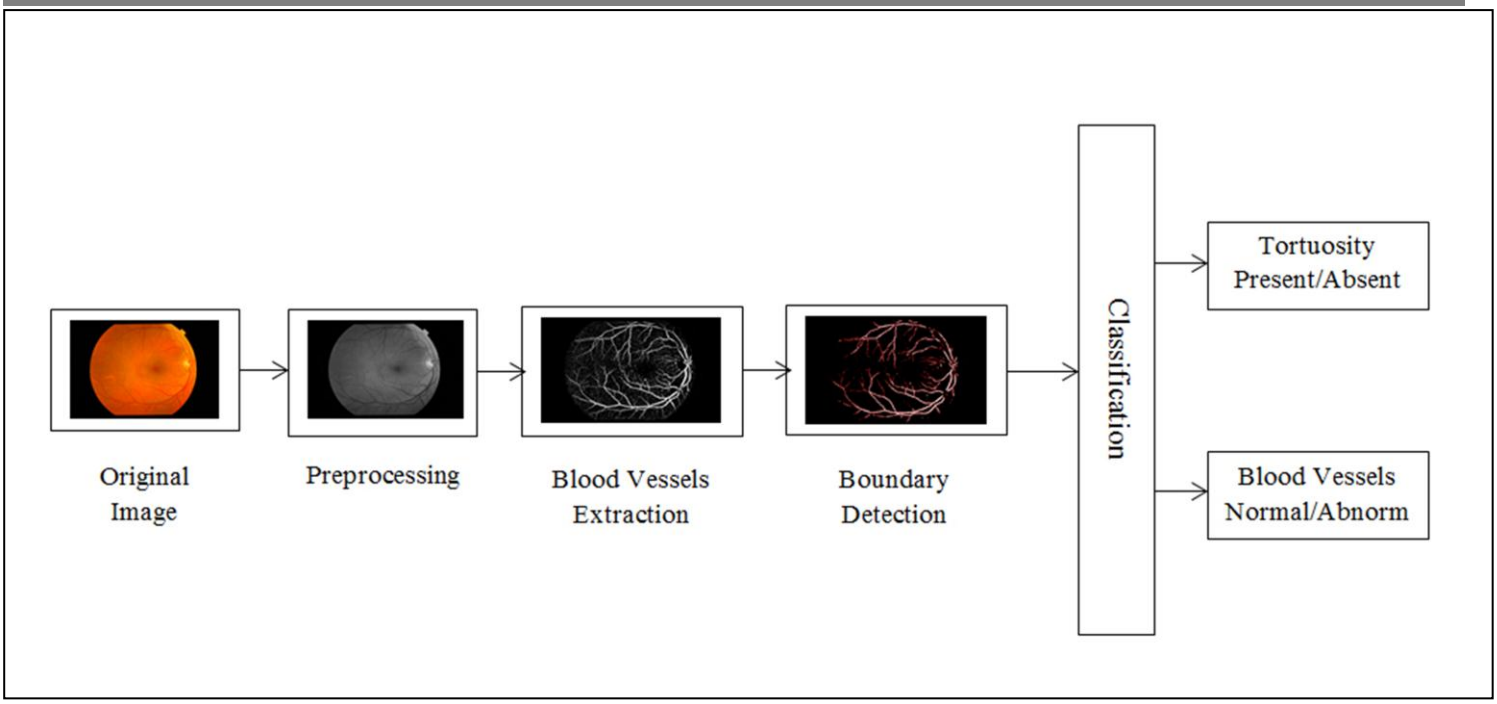

Figure 1: Flow chart for proposed algorithm of Classification and calculation of retinal blood vessels Tortuosity

Mathematical formula for finding green channel is as follows

$$g = \frac{G}{(R + G + B)} \qquad (1)$$

Here g is a Green channel and R, G and B are Red, Green and Blue respectively.

2.2 BLOOD VESSELS

2.2.1 Blood Vessels Enhancement

Then we have use the complement function for enhancing the blood vessels o the retina.

$$A^c = \{\omega \mid \omega \notin A\} \qquad (2)$$

Here A^c is a complement, ω is the element of A, ∉ stands for not an element of A and A is set.

Then we have use Histogram equalization function for enhancing the complementary image.

$$h(v) = \text{round}\left(\frac{cdf(v) - cdf_{min}}{(M \times N) - cdf_{min}} \times (L - 1)\right) \qquad (3)$$

Here cdf_{min} is the minimum value of the cumulative distribution function, M × N gives the image's number of pixels and L is the number of grey levels.

As shown in the figure 3, we have use the Morphological structuring element for highlighting the blood vessels of the retina.

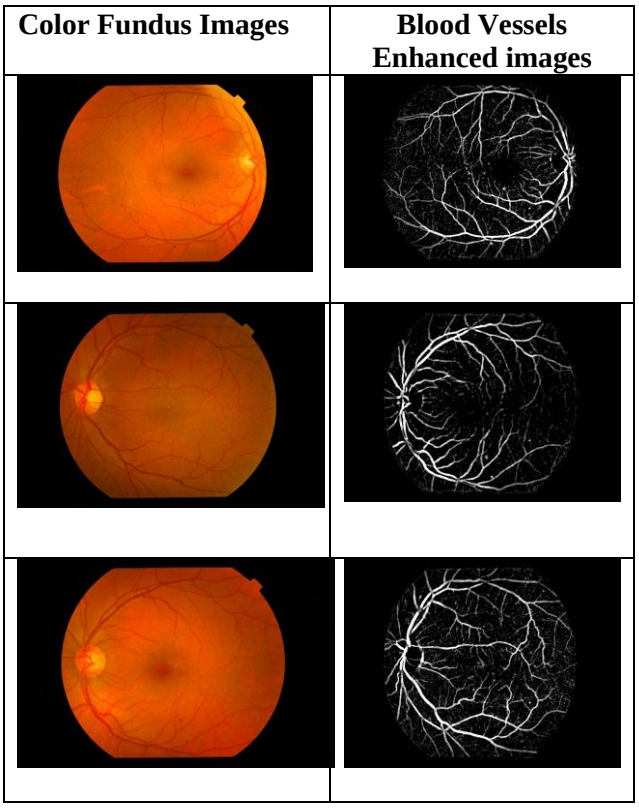

Figure 3: Fundus image and Blood vessels Enhanced images

2.2.2 Blood Vessels Extraction

$$I_{dilated}(i,j) = \max_{f(n,m)=true} I(i+n, j+m) \qquad (4)$$

$$I_{eroded}(i,j) = \min_{f(n,m)=true} I(i+n, j+m) \qquad (5)$$

We have use the Morphological open function for thickening the retinal blood vessels.

$$A \circ B = (A \ominus B) \oplus B \qquad (6)$$

Here $A \circ B$ is morphological opening, $\ominus$ is Erosion and $\oplus$ is Dilation.

We have used 2D median filter for highlighting and removing noise from the Morphological open function.

$$y[m,n] = \text{median}\{x[i,j], (i,j) \in \omega\} \qquad (7)$$

Here ω Represents a neighborhood centered around location(m,n) in the image.

Then we have use the Threshold function for extracting the retinal blood vessels, result images are shown in the figure 4.

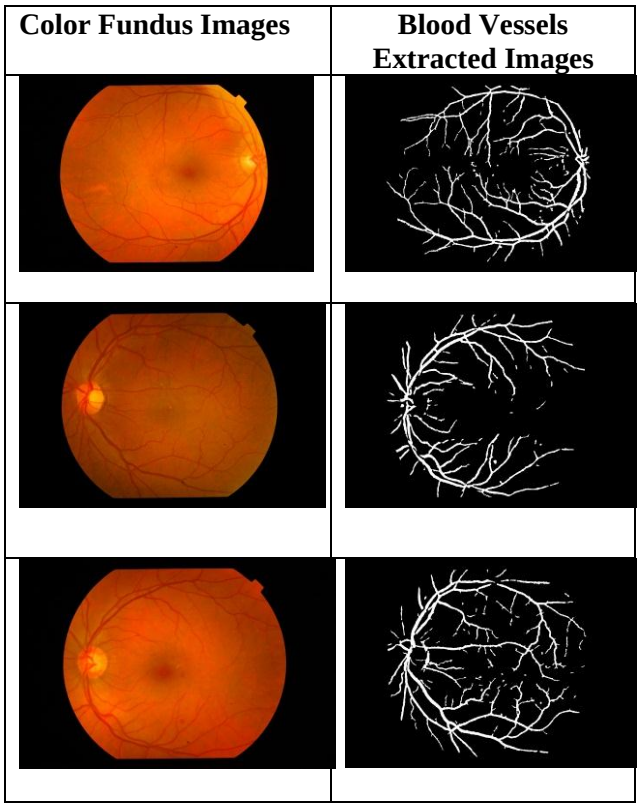

Figure 4: Fundus images and Images obtained using Threshold to Extract Blood Vessels

2.3 Detection of Boundaries using segmentation

The segment label $c(\vec{x}) = k$ for a pixel $\vec{x}$ is the k which maximizes the ownership of $\vec{F}(\vec{x})$ in the MoG model M. That is,

$$c(\vec{x}) = \arg max_k \left[\frac{\pi_k g\left(\vec{F}(\vec{x}) | \vec{m}_k, \Sigma_k\right)}{p\left(\left(\vec{F}(\vec{x}) | M\right)\right.} \right] \qquad (8)$$

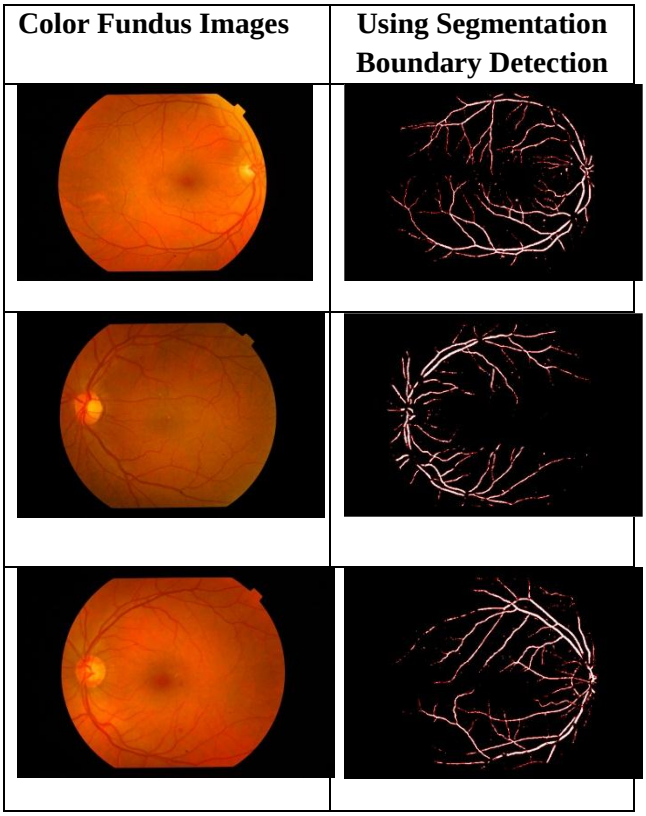

Figure 5: Fundus images and Images showing Boundaries

3. RESULT

For this algorithm we have designed one GUI in MATLAB, shown in the figure 6, for result analysis we have used Receiver Operating Characteristic Curve (ROC). ROC curve for Saswade database is shown in figure 7, this algorithm achieves a true positive rate of 96%, false positive rate of 0% and accuracy score 0.9202. Roc for Diaretdb0 this algorithm achieves a true positive rate of 95%, false positive rate of 0%, and accuracy score of 0.9514 as shown in figure 8, on diaretdb1 this algorithm achieves a true positive rate of 96%, false positive rate of 0%, and accuracy score of 0.9665 as shown in figure 9 and on DRIVE this algorithm achieves a true positive rate of 98%, false positive rate of 0%, and accuracy score of 0.9802 as shown in figure 10. Table 1 shows Performance Evaluation and table 2 shows accuracy.

Table 1: Performance Evaluation

Test Result	Present	Absent
Positive	True Positive (TP)	False Positive (FP)

Negative	True Negative (TN)	False Negative (FN)

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}} \quad (9)$$

$$\text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FN}} \quad (10)$$

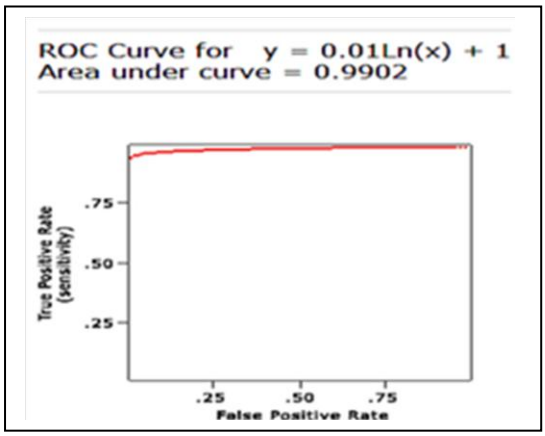

Figure 7: Receiver Operating Characteristics Curve Curve for Calculation of Retinal Blood vessels Tortuosity on online on Dr. Saswade's Image Database.

Table 2: Shows Sensitivity, Specificity and Accuracy

Sr. No.	Database	Sensi-tivity	Speci-ficity	ROC	Accuracy
1	Saswade	0.92	0	0.9202	96%
2	Diaretdb0	0.95	0	0.9514	95%
3	Diaretdb1	0.96	0	0.9665	96%
4	DRIVE	0.98	0	0.9802	98%

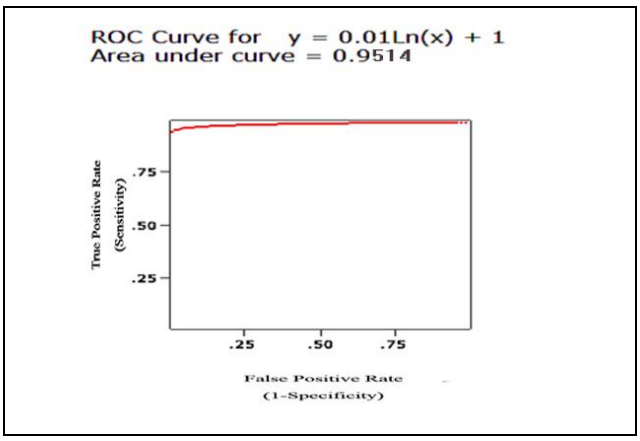

Figure 8: Receiver Operating Characteristics Curve for Calculation of Retinal Blood vessels Tortuosity on online on online available Database diaretdb0

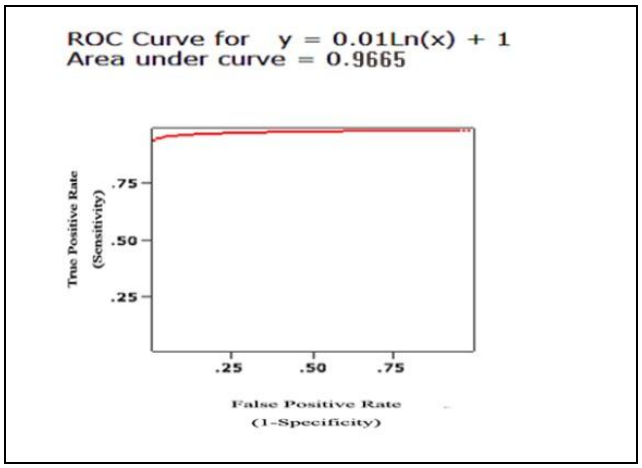

Figure 9: Receiver Operating Characteristics Curve for Classification and Calculation of Retinal Blood vessels Parameters on online available Database diaretdb1

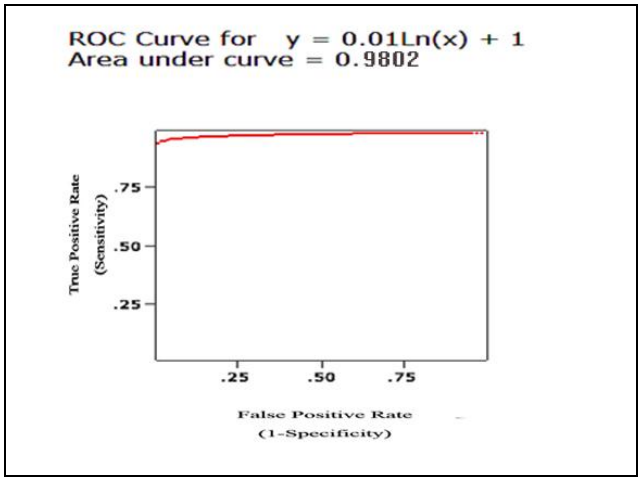

Figure 10: Receiver Operating Characteristics Curve for Calculation of Retinal Blood vessels Tortuosity on online available Database DRIVE

3.1 Statistical Techniques

For result analysis we also used statistical techniques like Mean, Standard deviation, correlation, Pearsons coefficient of correlation, Product moment correlation coefficient and Normalization and this statistical techniques gives the strong positive correlation and also Normalization gives the similar result like ground truth and proposed algorithm gives the similar outputs according to ophthalmologist. This statistical technique is one of the most important technique for result analysis, Table 3 show the sample images followed by its ground truth of tortuosity verses proposed algorithm tortuosity.

Table 3: Tortuosity ground truth verses Tortuosity on proposed algorithm

Sr. No	Fundus Image	Ground Truth	Proposed algorithm
1	1	3.8000	3.5
2	2	4	4
3	3	2.8284	2.8
4	4	3.3282	3.32
5	5	1.9415	1.415
6	6	3.4110	3.4110
7	7	1.9612	1.9612
8	8	1.7461	1.461
9	9	1.2500	1.2500
10	10	2.2993	2.2993
11	11	2.3684	2.684
12	12	0	0
13	13	2.2361	2.2361
14	14	2	2
15	15	3.1378	3.138
16	16	0	0
17	17	1.7219	1.7219
18	18	2.0580	2.050
19	19	1.1926	1.1926
20	20	14.1421	14.21

Mean

$$\text{Mean} = \frac{\text{Sum of all elements}}{\text{Total No of elements}} \qquad (11)$$

$$\text{Mean (X)} = \frac{584.0626}{204} = 2.8$$

$$\text{Mean (Y)} = \frac{581.9304}{204} = 2.848039216$$

Variance

$$\text{Variance} = \frac{\sum(x - \bar{X})}{N} \qquad (12)$$

$$\text{Variance} = \frac{\sum(x - \bar{X})}{N} = \frac{0.0626}{204} = 3.0867$$

$$\text{Variance} = \frac{\sum(y - \bar{Y})}{N} = \frac{0.9304}{204} = 0.0046$$

Standard Deviation

$$\text{Standard Deviation} = \sqrt{\text{Variance}(x)} \qquad (13)$$

Standard Deviation (x): $\sqrt{\text{Variance}(x)} = \sqrt{3.0867} = 1.75$

Standard Deviation (y): $\sqrt{\text{Variance}(y)} = \sqrt{0.0046} = 0.067$

Correlation

$$s = \frac{1}{N-1}\sum_{i=1}^{n}(x_i - \bar{X})(y_i - \bar{Y}) \qquad (14)$$

$$S = \frac{1}{204}(0.0626)(0.9304)$$

$$S = \frac{1}{204}(0.058)$$

$$s = 2.855050$$

Pearsons coefficient of correlation

$$r_{xy} = \frac{\sum xy}{N\sigma_x\sigma_y} \qquad (15)$$

Where,

xy = 2759.9579 N = 204,

$\sigma_x = 1.75$ $\sigma_y = 0.067$

$$r_{xy} = \frac{2759.9579}{204\ X\ 1.75\ X\ 0.067} = \frac{2759.9579}{23.919} = 115.38$$

Product moment correlation coefficient

N = 204 $\sum y = 581.93$

$\sum x = 584.06$ $\sum y^2 = 338642.52$

$\sum x^2 = 341126.08$ $\sum xy = 2759.95$

$$S_{xy} = \sum xy - (\sum x \sum y \div N)$$

$$= 2759.95 - (584.06 \times 581.93 \div 204)$$

$$= 2759.95 - (1666.08)$$

$$= 1093.87$$

$$S_{xx} = \sum xx - (\sum x \sum x \div N)$$

$$= 2766.55 - (584.06 \times 584.06 \div 204)$$

$$= 2766.55 - (341126.08 \div 204)$$

$$= 2766.55 - (1672.18)$$

$$= 1094.37$$

$$S_{yy} = \sum yy - (\sum y \sum y \div N)$$

$$= 2756.98 - (581.93 \times 581.93 \div 204)$$

$$= 2756.98 - (338642.52 \div 204)$$

$$= 2756.98 - (1660.01)$$

$$= 1096.97$$

$$r = \frac{S_{xy}}{\sqrt{S_{xx}\, S_{yy}}} = \frac{1093.87}{\sqrt{1094.37 \times 1096.97}} = \frac{1093.87}{1095.66}$$

$$= 0.99$$

$$= 1$$

Therefore, the Product moment correlation coefficient has the strong positive correlation. Hence it is prove that the proposed algorithm is correctly done. Following figures 11 and 12 shows the normalization graph over the ground truth and proposed algorithm for tortuosity. In this graph near about all values are same that why it is proving that the proposed system for retinal blood vessels is correctly done.

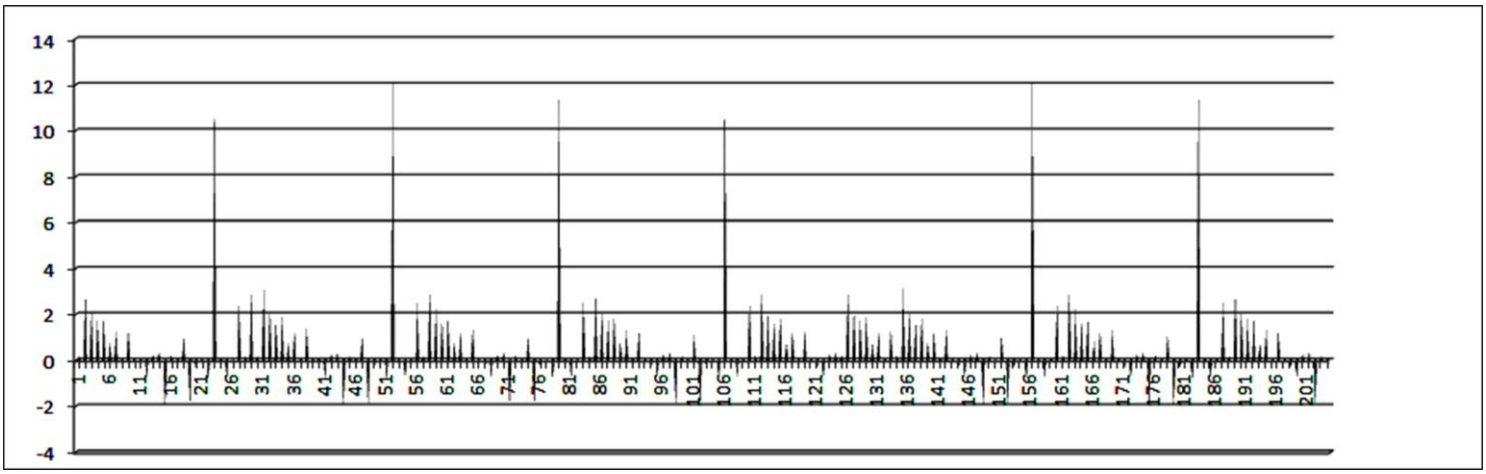

Figure 11: Normalization curve for Ground Truth

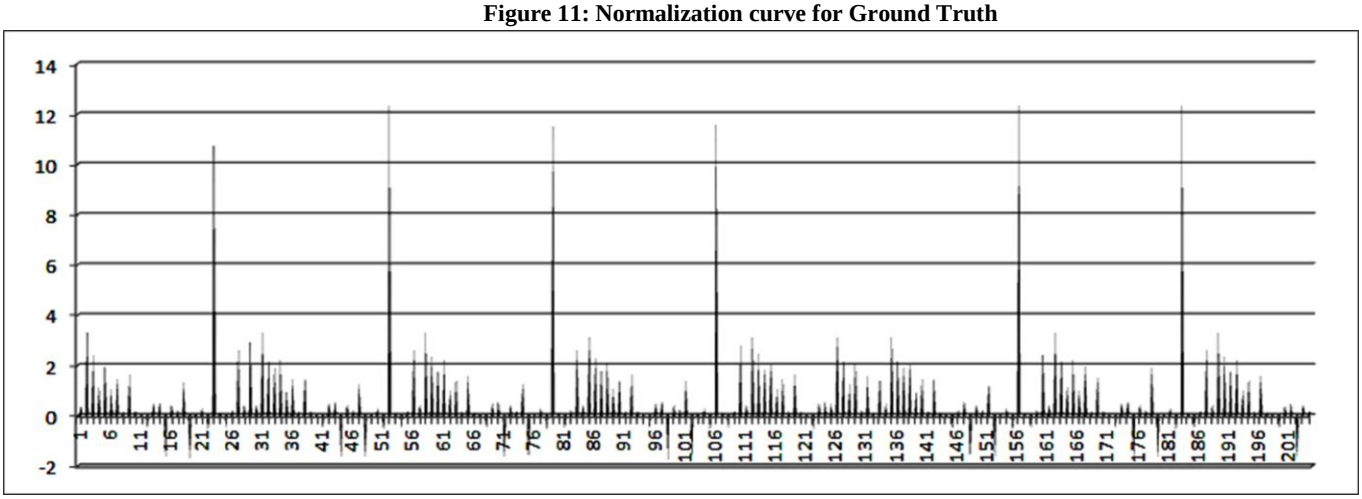

Figure 12: Normalization curve for proposed algorithm

4. DISCUSSION

For this algorithm we have used Image processing techniques like Green channel from RGB image because Green channel have high intensity as compare to Red and Blue, then Complement function for highlight the Green channeled image, Histogram equalization for enhancement for the complemented image, Morphological structuring element, Morphological opening for thickening the retinal blood vessels, 2D Median filter for removing noise, for extracting the retinal blood vessels performed Threshold function and for finding the bifurcation points of the blood vessels we have performed the minutiae techniques. For manipulating these techniques we have used MATLAB 2012a and with the help of this tool we have design one GUI for retinal blood vessel the retinal blood vessels extraction and bifurcation point detection. For result analysis we have used Receiver operating characteristic curve at the same time used statistical techniques and evaluate the result.

5. CONCLUSION

In this algorithm we have used Image processing techniques for extracting the blood vessels of the retina and calculates the tortuosity values on extracted blood vessels. For performing these techniques we have used database from Dr. Manoj Saswade, Dr. Neha Deshpande and online available databases diaretdb0, diaretdb1 and DRIVE. This algorithm for Saswade database achieves accuracy of 96% with 0.92 sensitivity and 0 specificity, for diaretdb0 accuracy 95% sensitivity and specificity 0, accuracy 96% with 0.96 sensitivity and specificity 0 for diaretdb1, and for DRIVE 98% with 0.98 sensitivity and specificity 0 respectively. And used statistical techniques like mean, variance, correlation, normalization and so on.

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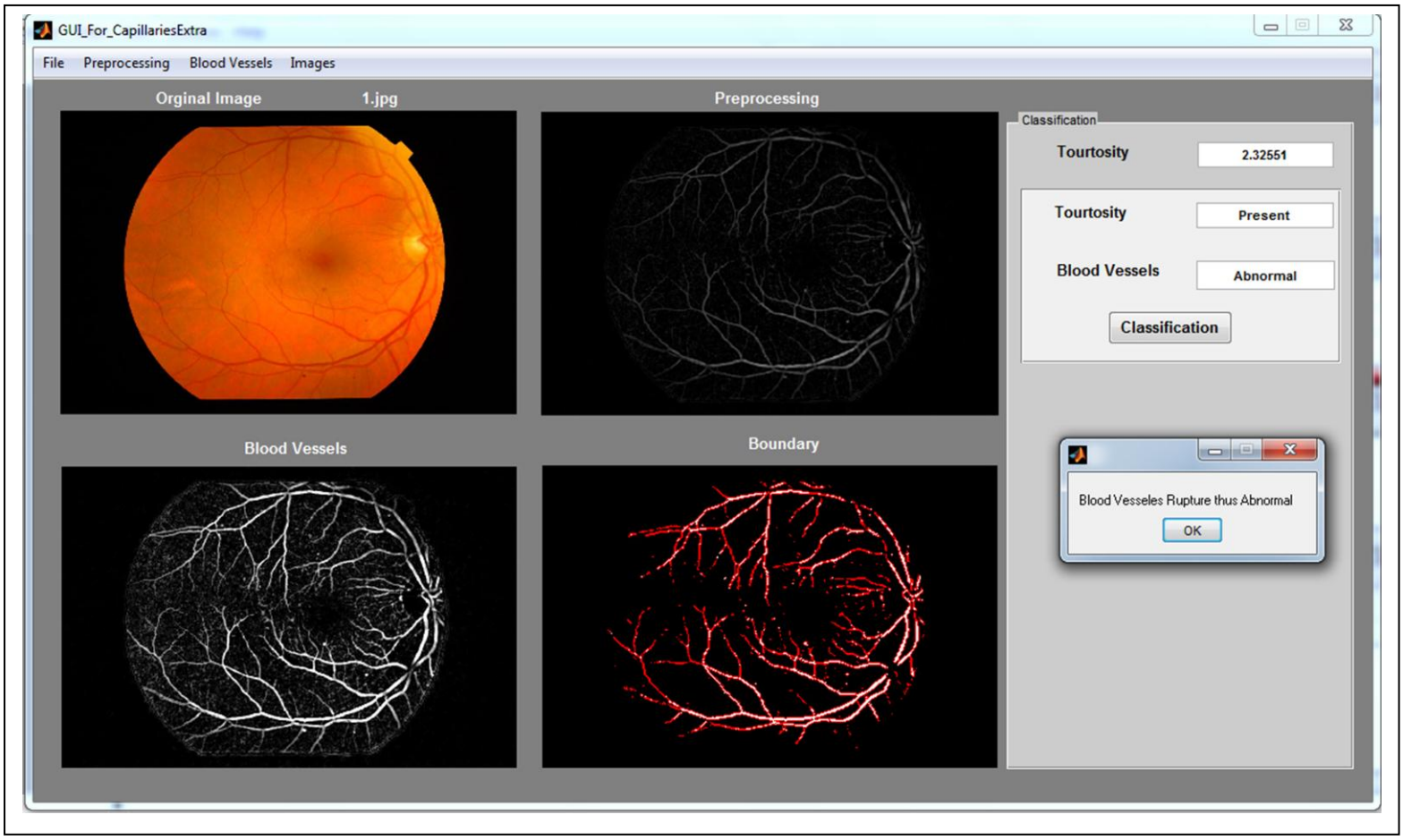

Figure 6: GUI for Calculation of Retinal Blood vessels Tortuosity