# Extraction of the Retinal Blood Vessels and Detection of the Bifurcation Points

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## ABSTRACT
The changes in retinal blood vessels Structure and progression of diseases such as diabetes, hypertension and retinopathy of prematurity (ROP) has been the subject of several large scale clinical studies. Proposed algorithm for the detection and measurement of blood vessels of the retina and finding the bifurcation points of blood vessels is general enough that it can be applied to high resolution fundus photographs. 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. Minutiae techniques for finding bifurcation points of the extracted blood vessels. Performance of this algorithm is tested using the fundus image database ( 240 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 specificity for Saswade database , 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, Bifurcation Points 2D Median Filter.

## 1. INTRODUCTION
Proposed algorithm shows the blood vessels extraction and detection of the bifurcation points of the vessels. In this algorithm Image Processing techniques are used for extraction of the retinal blood vessels. Firstly preprocessing operation is performed on high resolution fundus images. Then 2D median filter is used for highlighting the blood vessel. For extraction of the blood vessels thresholding is used. for finding the bifurcation points of the blood vessels Minutiae techniques are performed. For observing the result images are taken from Dr. Manoj Saswade(240 images) and data base is formed, also images from online databases diaretdb0, diaretdb1 and Drive are used.

## 2. METHODOLOGY
Computer assisted diagnosis for various diseases are very common now a days and medical imaging is playing a vital role in such diagnosis. The proposed algorithm has 3 stages, shown in the figure 1. In first stage preprocessing is done. Blood vessels are highlighted and extracted in the second stage and in the third stage using thresholding technique and Skeletonazation bifurcation points are detected.

### 2.1 Preprocessing :
In this algorithm for enhancement of retinal blood vessels some Image Processing techniques are used. The Preprocessing is done to remove noise from the background and to enhance the image. In the first stage of preprocessing green channel is taken out, because green channel shows high intensity as compare to red and blue. Mathematical formula for finding green channel is shown in the equation 1. Green channel is taken out from RGB image because Green channel has high intensity as compared to Red and Blue. Fundus image and its equivalent green channel image are shown in the figure 2.

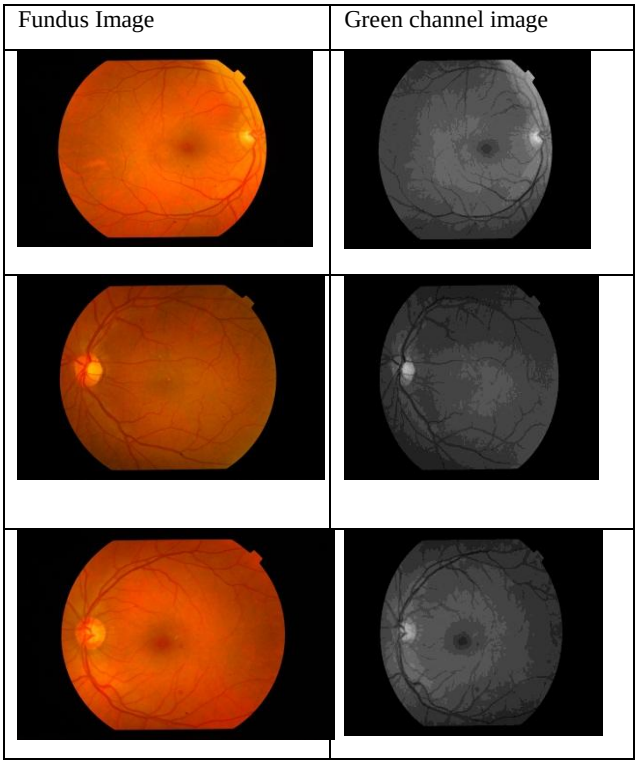


**Figure 2: Fundus image and green channel image**

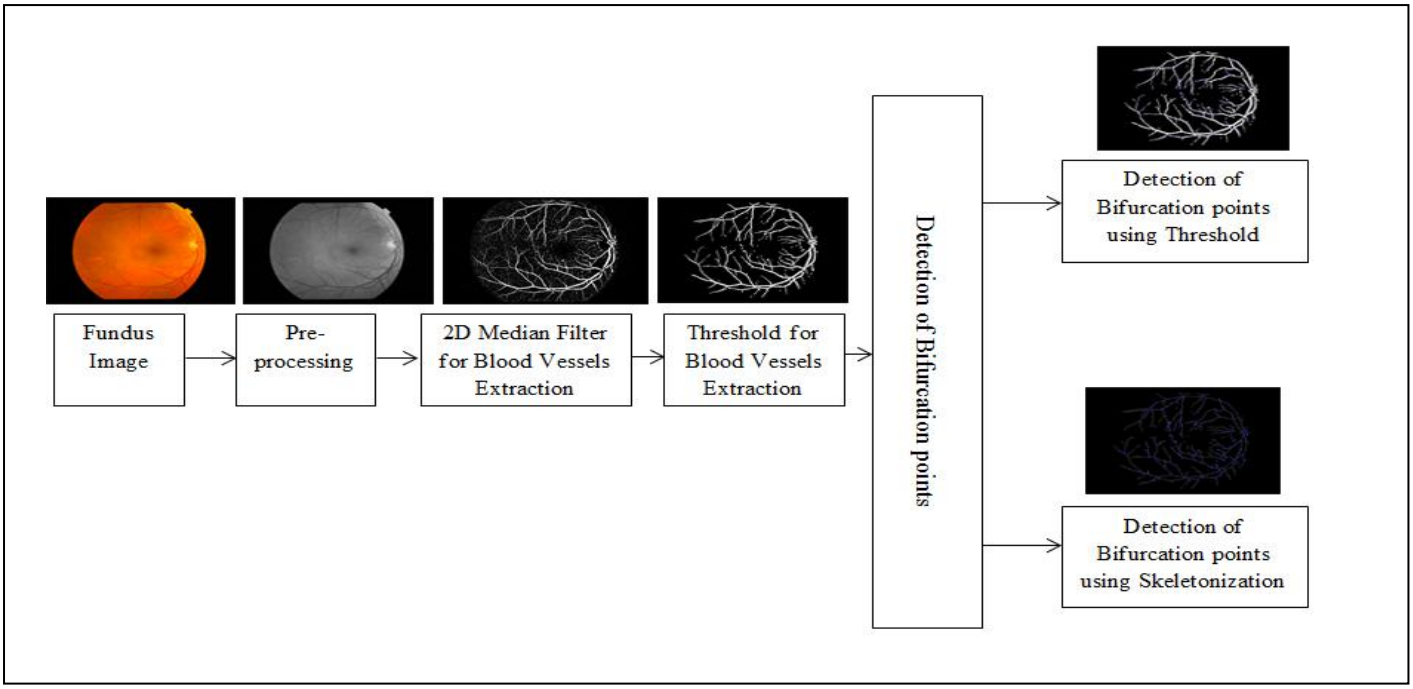


**Figure 1: Flow chart for proposed algorithm of Extraction of the Retinal Blood Vessels and Detection of the Bifurcation Points**

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

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 the complement function is used for enhancing the blood vessels of the retina.

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

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

Then Histogram equalization function is used 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, the Morphological structuring element is used for highlighting the blood vessels of the retina.

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

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

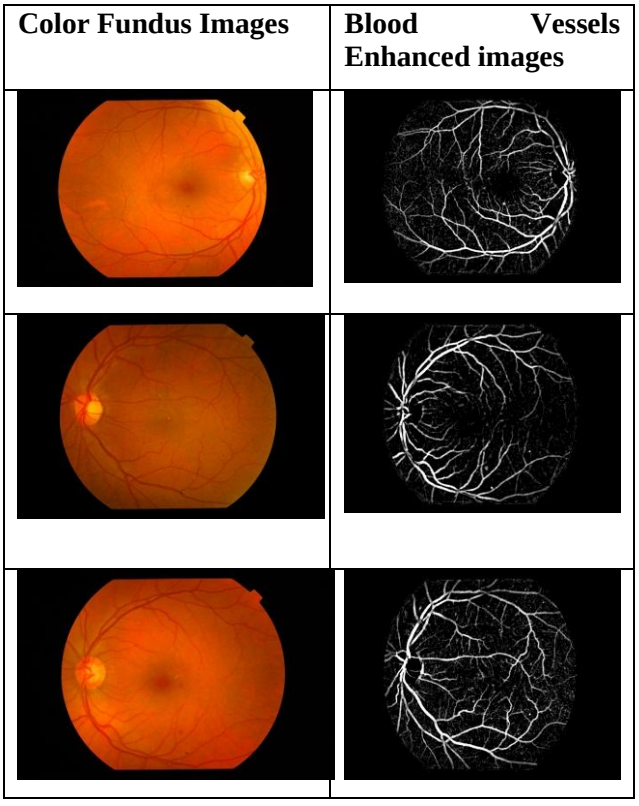


**Figure 3: Fundus image and Blood vessels Enhanced images**

The Morphological open function is used 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.

After Dilation 2D median filter is used 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 $\omega$ Represents a neighborhood centered around location(m,n) in the image.

Threshold function is used for extracting the retinal blood vessels, result images are shown in the figure 4.

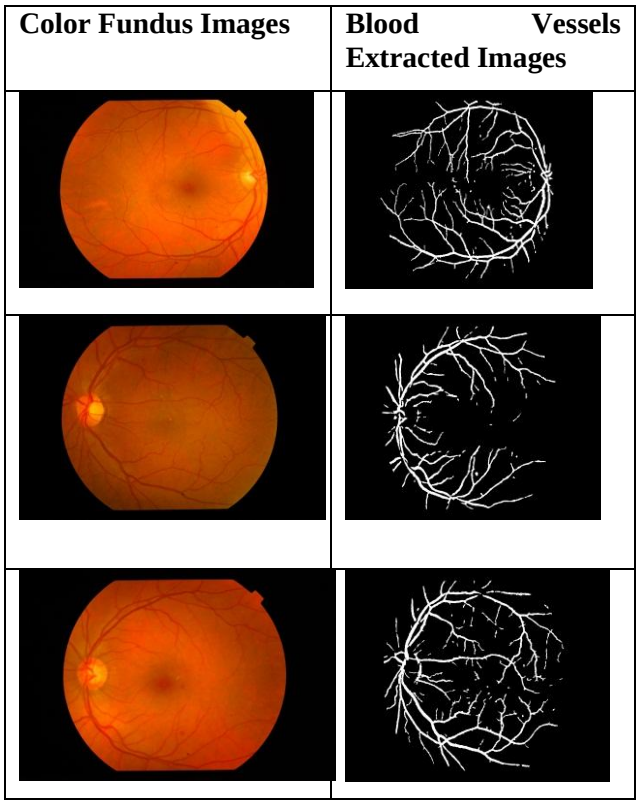


**Figure 4: Fundus images and Images obtained using Threshold to Extract Blood Vessels**

## 2.3 Detection of Bifurcation Point

### 2.3.1 Using Threshold

Bifurcation points are detected by applying threshold, images are shown in the figure 5.

$$T = \frac{1}{2}(m1 + m2) \quad (8)$$

Here m1 & m2 are the Intensity Values.

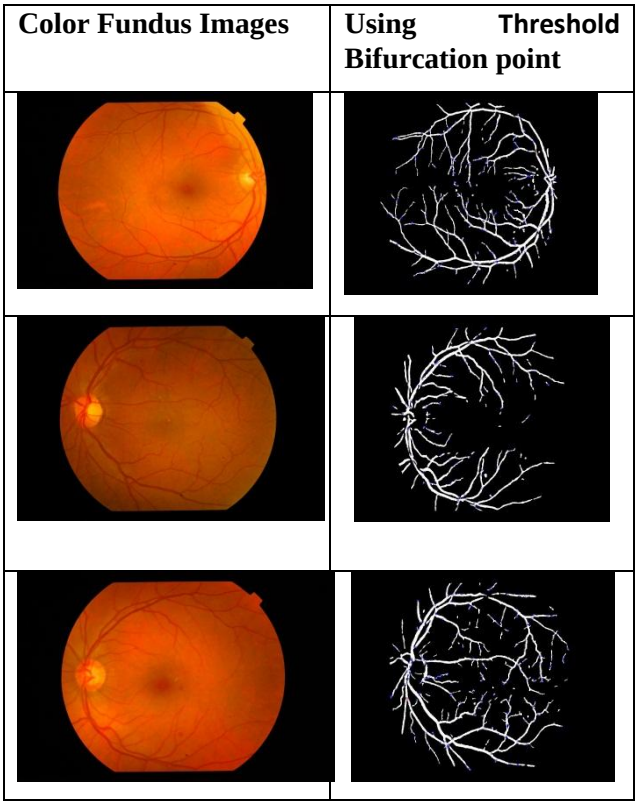


**Figure 5: Fundus images and Images showing bifurcation points obtained using Threshold**

### 2.3.2 Using Skeletonization

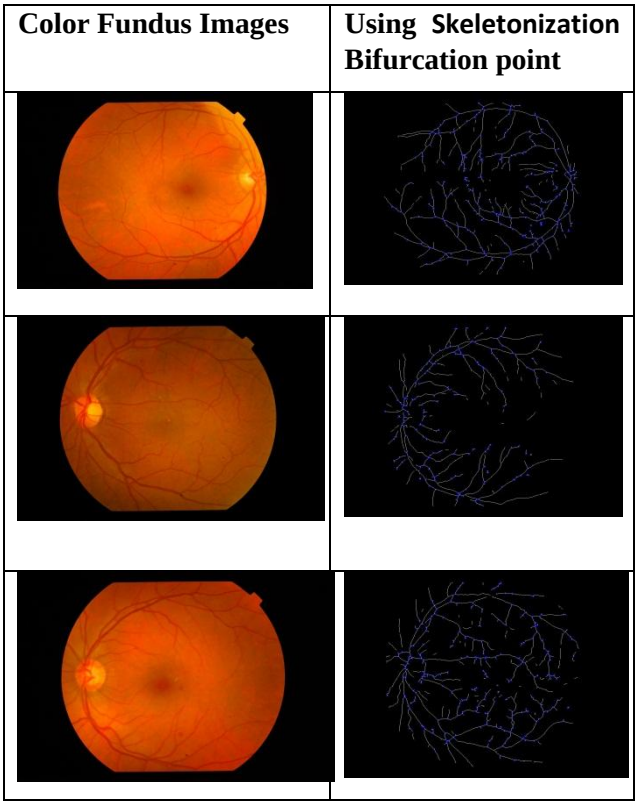


**Figure 6: Fundus images and Images showing bifurcation points obtained using Skeletonization**

$$S(X) = \bigcup_{P>0} \bigcap_{\mu>0} [(X \ominus \rho B) - (X \ominus \rho B) \circ \mu \bar{B}] \quad (9)$$

Result images obtained after Skeletonization are shown in figure 6.

## 3. RESULT

For this algorithm GUI is designed in MATLAB, as shown in the figure 7, for result analysis Receiver Operating Characteristic Curve (ROC) is used. ROC curve for Saswade database is shown in figure 8, 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 9, 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 10 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 11. 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) |

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}} \quad (10)$$

$$\text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FN}} \quad (11)$$

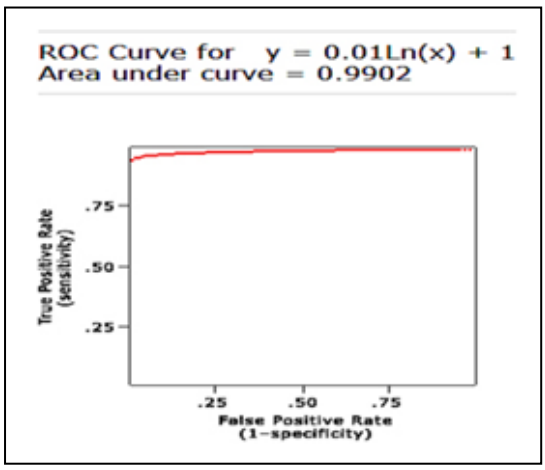


**Figure 8: Receiver Operating Characteristics Curve for blood vessel extraction and detecting bifurcation points of vessels on Dr. Saswade's Image Database.**

**Table 2: Shows Sensitivity, Specificity and Accuracy**

| No. | Database | Sensitivity | Specificity | 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% |

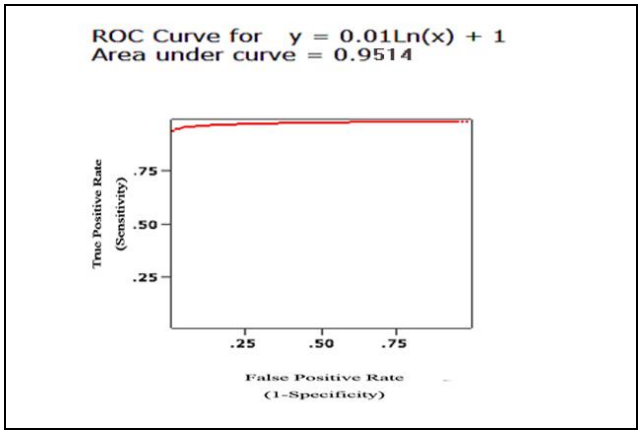


**Figure 9: Receiver Operating Characteristics Curve for blood vessel extraction and detecting bifurcation points of vessels on online available Database diaretdb0**

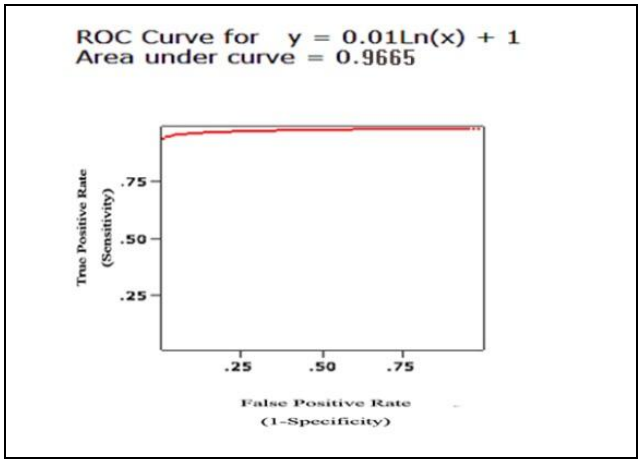


**Figure 10: Receiver Operating Characteristics Curve for blood vessel extraction and detecting bifurcation points of vessels on online available Database diaretdb1**

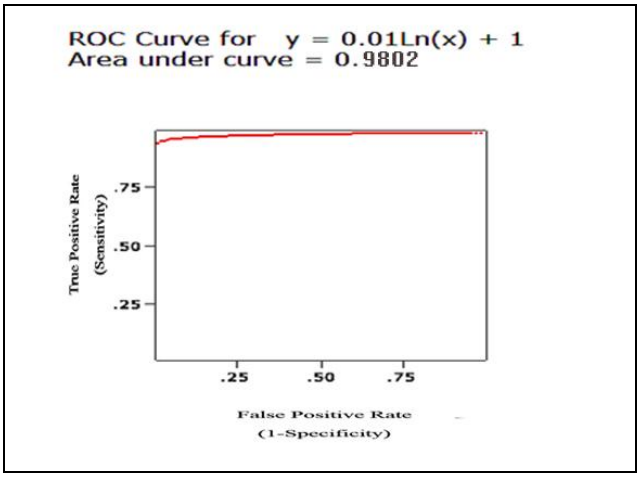


**Figure 11: Receiver Operating Characteristics Curve for blood vessel extraction and detecting bifurcation points of vessels on online available Database diaretdb1**

## 4. DISCUSSION

For this algorithm Image processing techniques are used. Initially Green channel from RGB image is taken out because Green channel has high intensity as compare to Red and Blue. On the green channel different operations are performed using functions like, Complement function to highlight the Green channeled image, Histogram equalization for enhancement of 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 Threshold function and for finding the bifurcation points of the blood vessels the minutiae techniques. For manipulating these techniques MATLAB 2012a is used and with the help of this tool one GUI is designed for retinal blood vessel the retinal blood vessels extraction and bifurcation point detection.

## 5. CONCLUSION

In this algorithm Image processing techniques are used for extracting the blood vessels of the retina and detecting the bifurcation points of the extracted blood vessels. For performing these techniques database from Dr. Manoj Saswade, Dr. Neha Deshpande and online available databases diaretdb0, diaretdb1 *and* DRIVE are used. 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.

## 6. ACKNOWLEDGMENTS

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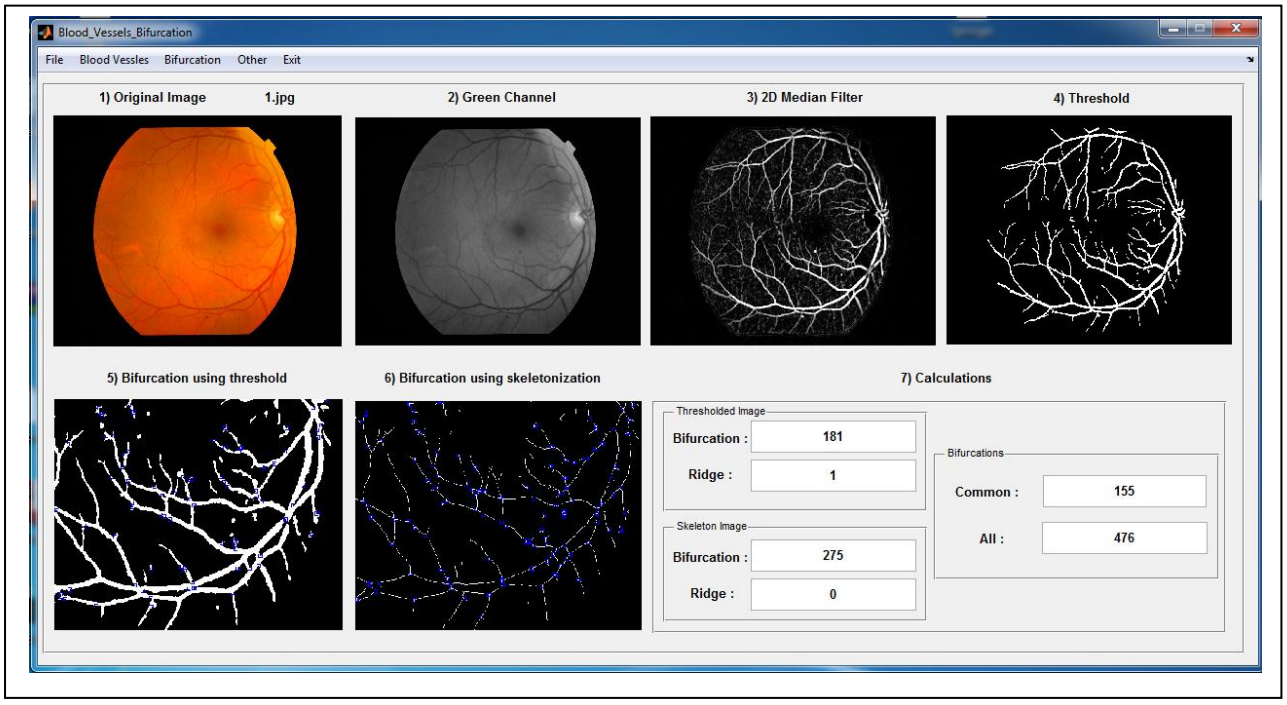


**Figure 7: GUI for Blood Vessels Extraction and Detection of Bifurcation Point**