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Detection and Counting the Microaneurysms using Image Processing Techniques

Manjiri B. Patwari
Institute of Management Studies & Information Technology,Vivekanand College Campus, Aurangabad MS (India)

Ramesh R. Manza
Dept of CS and IT, Dr. B. A. M. University, Aurangabad MS (India)

Yogesh M. Rajput
Dept of CS and IT, Dr. B. A. M. University, Aurangabad MS (India)

Manoj Saswade
Director, "Saswade Eye Clinic", Aurangabad MS (India)

Neha Deshpande
Director, Guruprasad Netra Rugnalaya pvt. ltd, Aurangabad MS (India)

ABSTRACT
In this paper, we present an algorithm for the detection and counting of the Diabetic retinopathy lesion 'Microaneurysms' by using image processing techniques. Processed fundus Image is able to display the lesions which otherwise are visible only after angiography. This algorithm processes through following steps 1) Preprocessing operations on high resolution fundus images 2) For detecting the Microaneurysms , Morphological operation on high resolution fundus images along with some enhancement techniques like histogram equalization and intensity transformation function.3) Segmentation for finding boundaries of the extracted Microaneurysms. Performance of this algorithm is tested using the fundus image database(245 images) taken from Dr. Manoj Saswade, Dr.Neha Deshpande This algorithm achieves accuracy of 96% with 0.92 sensitivity and 0 specificity for Saswade database, and also used statistical techniques.

Keywords
Microaneurysms, Morphological operations.

1. INTRODUCTION
Retinopathy is the general name given to diseases of the retina[1]. The principal problem of the retina caused by diabetes involves the very fine blood vessels which nourish the nerve tissue. High blood sugar causes these vessels to become damaged and then leak fluid and fatty material into the nerve tissue of the retina[2]. Microaneurysms are the first clinically detected lesions. It is Tiny swelling in the wall of a blood vessel. It appears in the retinal capillaries as a small, round, red spot. They are located in the inner nuclear layer of the retina. Microaneurysms are a tiny area of blood lengthened from an artery or vein in the back of the eye. These protrusions may open and leak blood into the retinal tissue surrounding it. Any form of vascular disease or high blood pressure may contribute to a retinal Microaneurysms; however the most common cause is diabetes mellitus[3]. As Microaneuisms are clinically first detected lesions, if diagnosed earlier can help early treatment. Proposed algorithm achieves detection and counting of Microaneurysms at early stage which otherwise is only possible through angiography. Because whenever lesions are not visible through fundus image, Dr. Recommends angiography. In this algorithm we have used the Image Processing techniques for enhancement and detection of Microaneurysms. For detection Morphological operations are performed[5] and for classification receiver operating characteristic curve is used[13]. In the beginning preprocessing operation is performed the on high resolution fundus images for enhancing the fine details. Then 2D median filter is used for removing the noise of the image. For extraction of the Microaneurysms, threshold function is performed. Lastly Segmentation is done for detecting boundaries of Microaneurysms. This algorithm is tested using 245 live fundus images from the database which is formed with the images given by Dr. Manoj Saswade and Dr. Neha

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. Image processing techniques can help in detection and counting the Microaneurysms. 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. Microaneurysms are highlighted and detected in the second stage and in the third stage Microaneurysms are extracted using threshold and segmentation technique is applied for boundaries to detect Microaneurysms.

2.1 PREPROCESSING:
The Preprocessing is done to remove noise from the background and to enhance the image[4]. We have taken out green channel, because green channel shows high intensity as compare to red and blue. 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[4].

In the green channel all minute details of image can be viewed. Using red channels only boundary is visible, and in blue channel image shows lots of noise. Due to these reasons green channel is used in the proposed system.

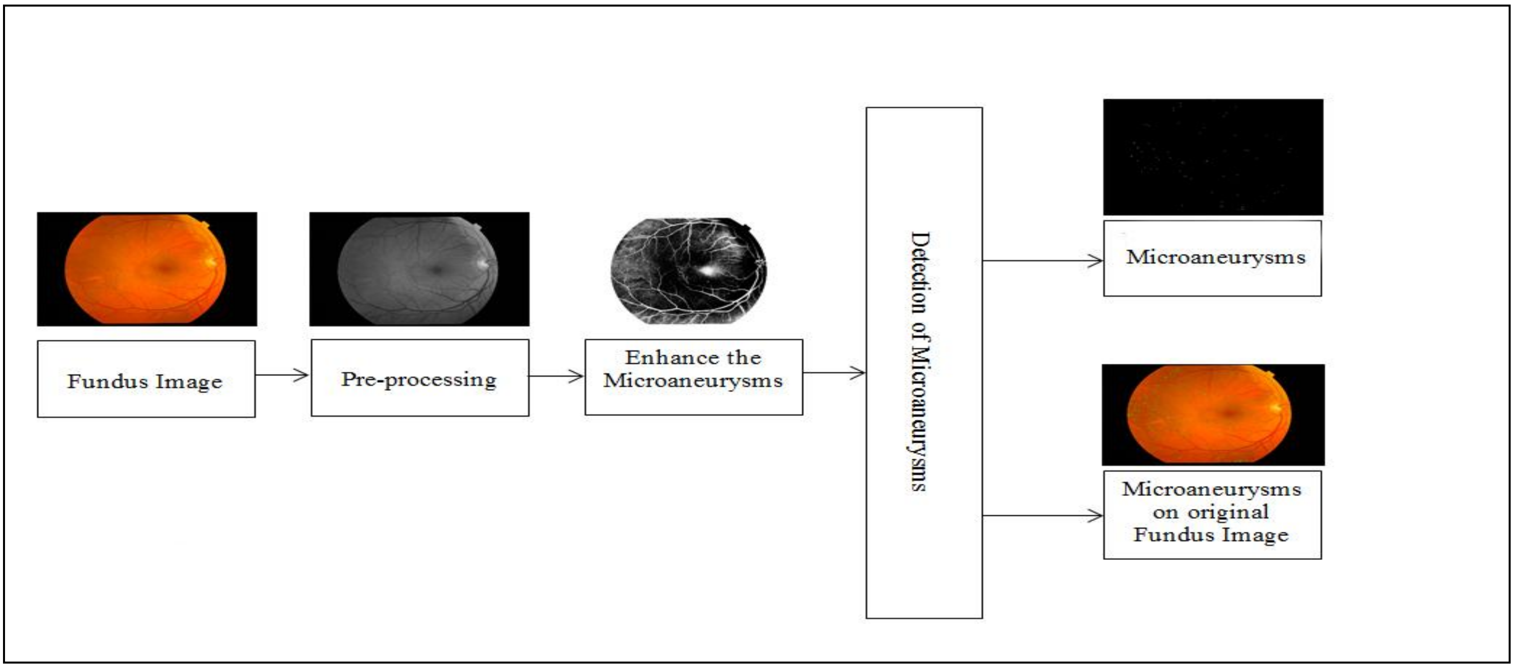

Figure 1: Flow chart for proposed algorithm of Detecting and Counting the Microaneurysms

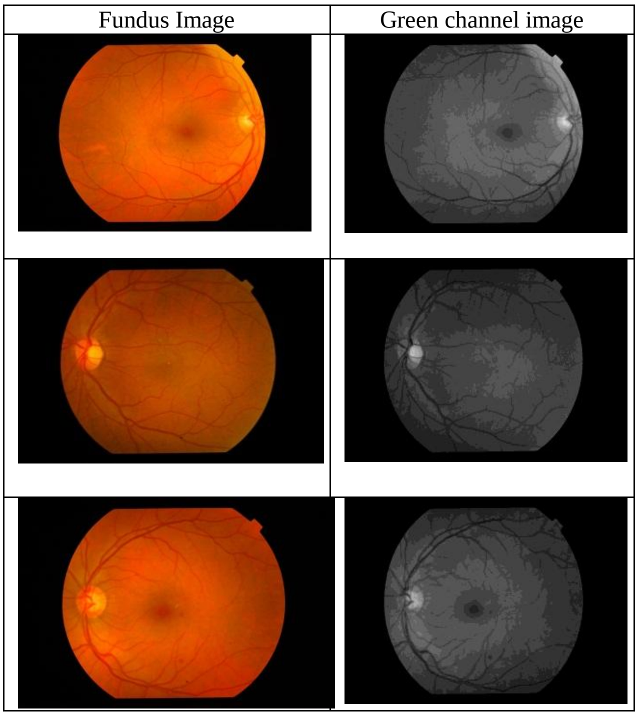

Figure 2: Fundus image and Green channel

2.2 Enhancement of Microaneurysms

2.2.1 Microaneurysms Enhancement

Then we have use the intensity transformation function for enhancing the Microaneurysms of the retina.

$$s = T(r) \qquad (2)$$

Then we have use Histogram equalization function for enhancing the intensity transformation 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, $M \times N$ gives the image's number of pixels and L is the number of grey levels.

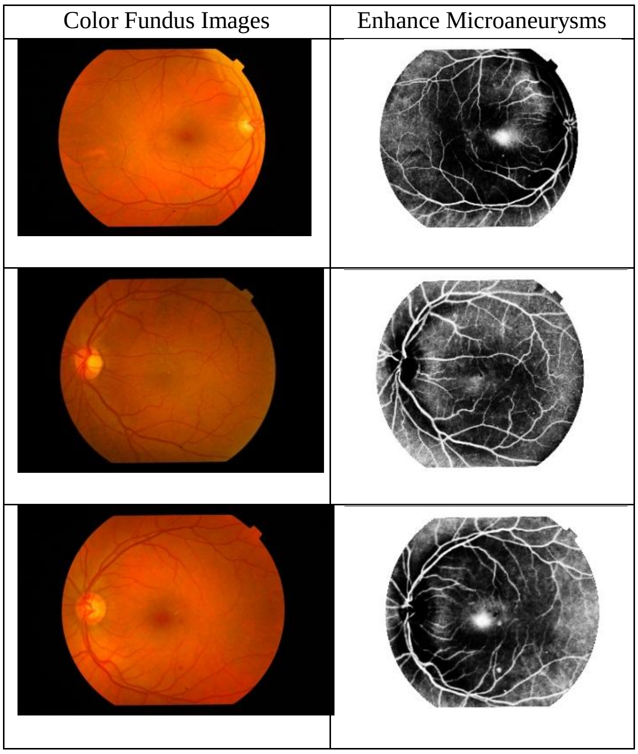

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Figure 3: Fundus image and Enhanced Microaneurysms images

In the above image 3, normal fundus images and enhanced Microaneurysms of the fundus images are shown.

2.2.2 Blood Vessels Extraction

2.2.2 Microaneurysms Extraction

Using Morphological Tophat

$$T_w(f) = f - f \circ b \qquad (4)$$

Where o denotes the opening operation

We have use the Morphological open function for thickening the Microaneurysms.

$$A \circ B = (A \ominus B) \oplus B \qquad (5)$$

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.

$$y[m,n] = \text{median}\{x[i,j], (i,j) \in \omega\} \qquad (6)$$

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

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

$$T = \frac{1}{2}(m1 + m2) \qquad (7)$$

Here m1 & m2 are the Intensity Values.

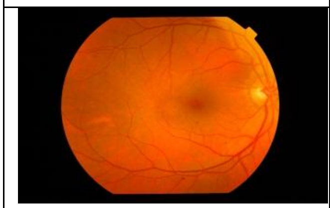
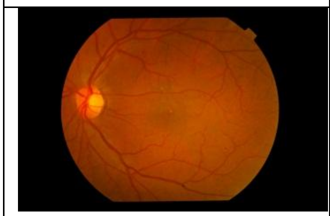
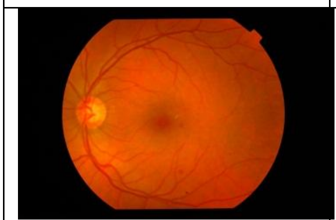
Color Fundus Images	Microaneurysms
	
	
	

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,

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

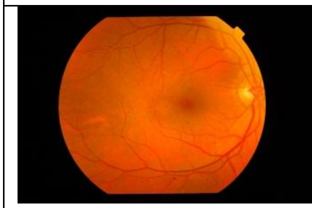
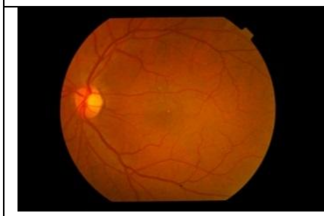
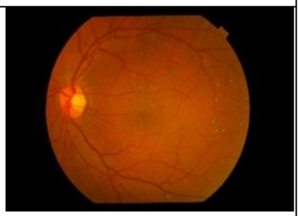
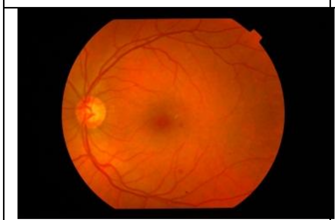
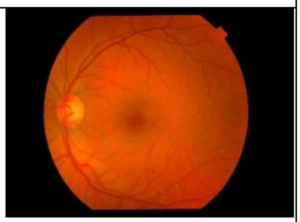
Color Fundus Images	Microaneurysms on Original Image
	
	
	

Figure 5: Fundus images and Images showing Boundaries

3. RESULT

For this algorithm we have designed one GUI in MATLAB with the help of image processing techniques like histogram equalization, intensity transformation,etc 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. Table 1 shows Performance Evaluation and table 2 shows accuracy. And also used statistical techniques for result analysis, total we have 204 high resolution fundus images followed by 204 angiographic images from Dr. Manoj Saswade and Dr. Neha Deshpande. Table 2 shows images followed by its Microaneurysms count.

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Table 1: Performance Evaluation

Test Result	Present	Absent
Positive	True Positive (TP)	False Positive (FP)
Negative	True Negative (TN)	False Negative (FN)

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

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

Where, TP = True Positive, TN = True Negative

FP = False Positive, FN = False Negative

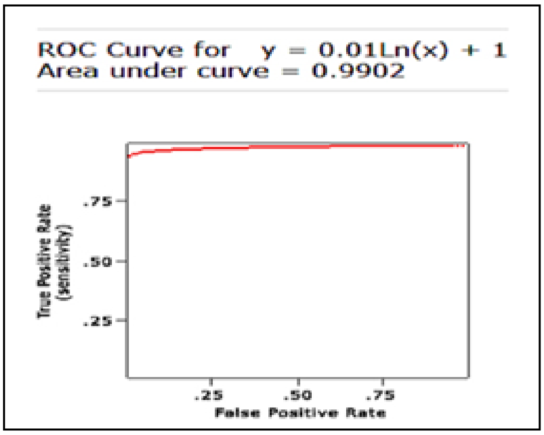

Figure 7: Receiver Operating Characteristics Curve

3.1 Statistical techniques

Table 2: Microaneurysms Readings[14]

Sr No	High Resolution Fundus Image Number	Microane-urysms Visible Through Process Image	Angiography Image number	Microaneu - rysms visible on Angiography image
1	1	4	2	4
2	3	12	4	12
3	5	6	6	6
4	7	18	8	18
5	9	6	10	6
6	11	14	12	14
7	13	8	14	8
8	15	1	16	1
9	17	6	18	6
10	19	3	20	3
11	21	23	22	23
12	23	4	24	4
13	25	13	26	13
14	27	11	28	11
15	29	4	30	4
16	31	4	32	4
17	33	7	34	7
18	35	2	36	2
19	37	13	38	13
20	39	15	40	15
21	41	2	42	2

Mean

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

$$\text{Mean (X)} = \frac{2090}{204} = 10.25$$

$$\text{Mean (Y)} = \frac{2072}{204} = 10.15$$

Variance

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

$$\text{Variance} = \frac{\Sigma(x - \bar{X})}{N} = \frac{-0.0004}{204} = -1.97$$

$$\text{Variance} = \frac{\Sigma(y - \bar{Y})}{N} = \frac{0.00056}{204} = 2.75$$

Standard Deviation

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

$$\text{Standard Deviation (x): } \sqrt{\text{Variance(x)}} = \sqrt{1.97} = 1.40$$

$$\text{Standard Deviation (y): } \sqrt{\text{Variance(y)}} = \sqrt{2.75} = 1.65$$

Correlation

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

$$S = \frac{1}{204}(-0.0004)(0.00056)$$

$$S = \frac{1}{204}(-0.0004)(0.00056)$$

$$s = -0.000000224$$

Pearsons coefficient of correlation -

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

Where,

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$\mathrm{xy} = 31300$, $\mathrm{N} = 204$, $\sigma_x = 1.40$, $\sigma_y = 1.65$

$$r_{xy} = \frac{31300}{204 \text{ X } 1.40 \text{ X } 1.65} = \frac{31300}{471.24} = 66.24$$

Product moment correlation coefficient -

N = 204 $\qquad \sum y = 0.00056$

$\sum x = -0.0004 \qquad \sum y^2 = 0.0000003136$

$\sum x^2 = -0.0008 \qquad \sum xy = 31300$

$$S_{xy} = \sum xy - \left(\sum x \sum y \div N\right) \qquad (16)$$

$$= 31300 - (-0.0004 \times 0.00056 \div 204)$$

$$= 31300 - (-0.00000224 \div 204)$$

$$= 31300 - (-1.99)$$

$$= 31301.99$$

$$S_{yy} = \sum yy - \left(\sum y \sum y \div N\right) \qquad (17)$$

$$= 31300 - (0.00056 \times 0.00056 \div 204)$$

$$= 31300 - (0.0000003136 \div 204)$$

$$= 31300 - (1.5473)$$

$$= 31298.45$$

$$S_{xx} = \sum xx - \left(\sum x \sum x \div N\right) \qquad (18)$$

$$= 31300 - (-0.0004 \times -0.0004 \div 204)$$

$$= 31300 - (-0.0008 \div 204)$$

$$= 31300 - (-3.93)$$

$$= 31303.93$$

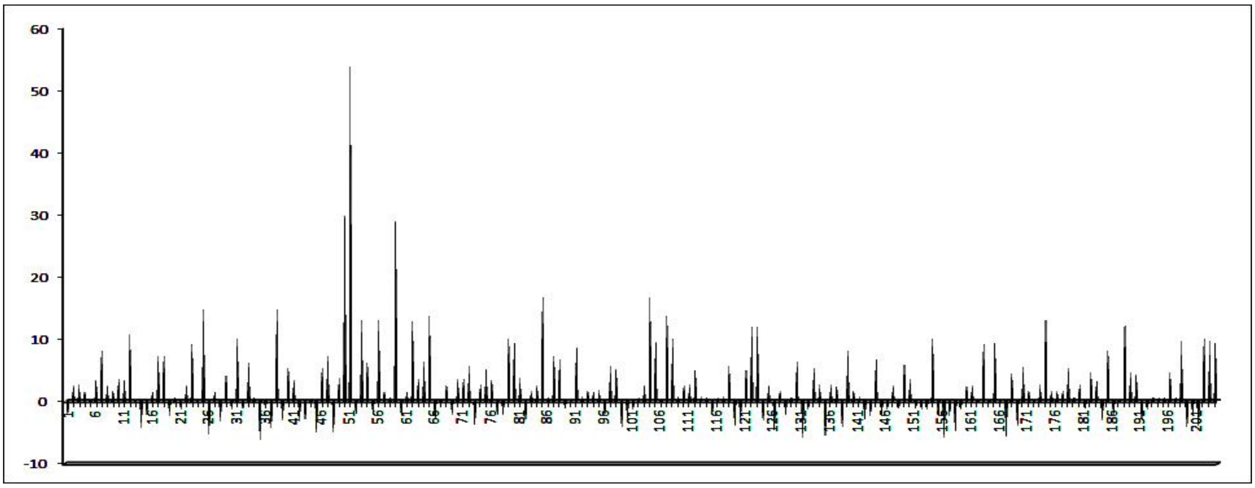

Figure 8: Normalization curve for processed high resolution fundus images

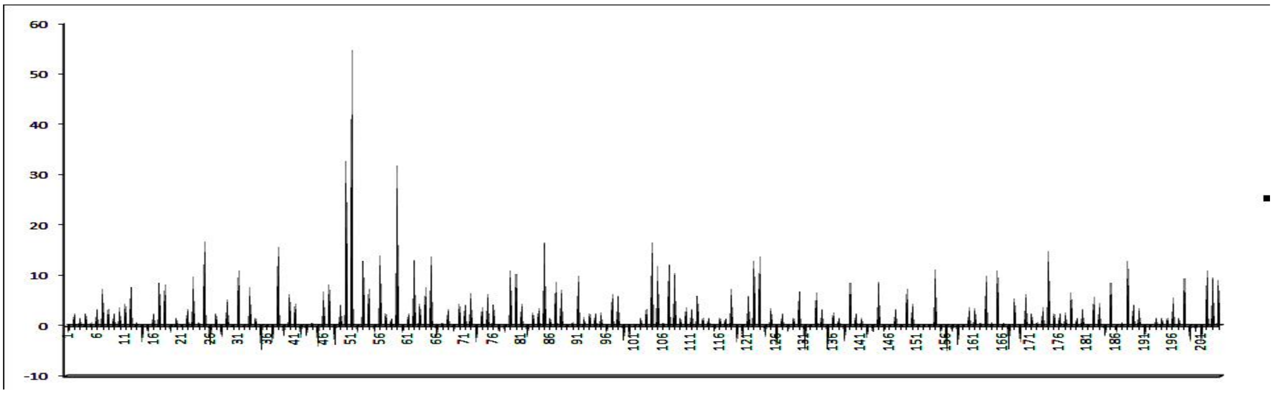

Figure 9: Normalization curve for Angiography images

$$r = \frac{S_{xy}}{\sqrt{S_{xx}\, S_{yy}}} \qquad (19)$$

$$r = \frac{S_{xy}}{\sqrt{S_{xx}\, S_{yy}}} = \frac{31301.99}{\sqrt{31303.93 \times 31298.45}} = \frac{31301.99}{31301.18}$$
$$= 1.01$$

Therefore, the Product moment correlation coefficient has the strong positive correlation among the 204 high resolution verse 204 angiographic images hence it is prove that the proposed is archives the same result as compare to angiographic images.

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 intensity transformation function for highlight the Green channeled image, Histogram equalization for enhancement for the intensity transformed image, 2D Median filter for removing noise, Morphological operation for detecting the Microaneurysms and Threshold function for extraction of Microaneurysms are used. At the end segmentation is done for pointing the Microaneurysms. For manipulating these techniques we have used MATLAB 2012a and with the help of this tool we have designed one GUI for detection and counting of Microaneurysms for result analysis we have used some statistical techniques like mean, variance, correlation, Pearsons coefficient correlation, Normalization is used and due result is strong positive we have achieve the same result as compare to angiography images according to ophthalmologist.

5. CONCLUSION

In this algorithm we have used Image processing techniques for detection and counting Microaneurysms. We have tested this algorithm using database from Dr. Manoj Saswade and Dr. Neha Deshpande. This algorithm for Saswade database achieves accuracy of 96% with 0.92 sensitivity and 0 specificity and also statistical techniques gives the strong positive results.

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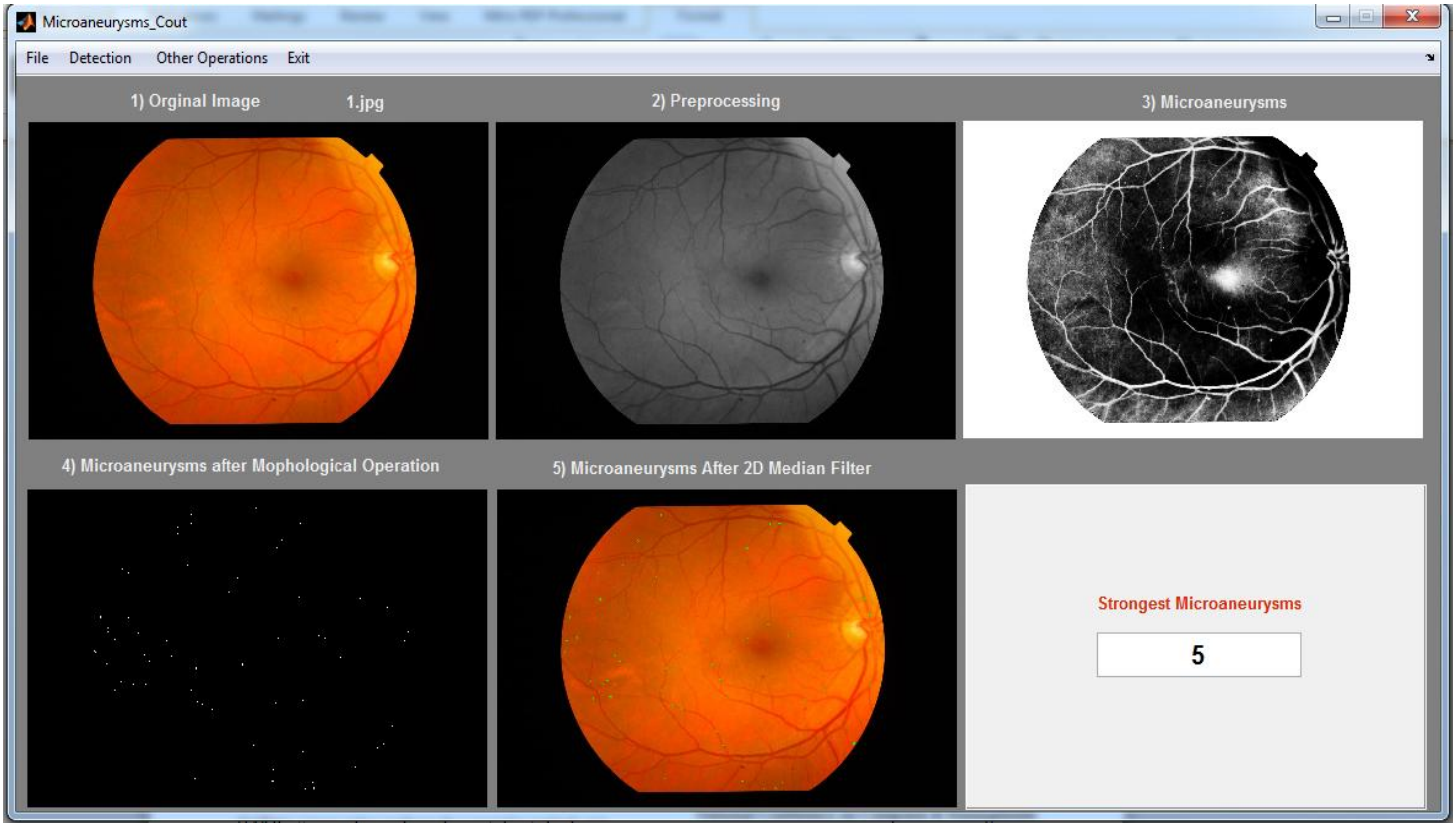

Figure 6: Graphical User Interface for detection and count the Microaneurysms