

# **A NOVEL TECHNIQUE TO DETERMINE RETINAL TEMPLATE FOR PERSONAL AUTHENTICATION**

A report submitted in partial  
fulfillment of the requirements for the degree of  
Bachelor of Technology  
in

**Computer Science & Engineering**

by

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## CERTIFICATE

This is to certify that the project report entitled “**A NOVEL TECHNIQUE TO DETERMINE RETINAL TEMPLATE FOR PERSONAL AUTHENTICATION**”, submitted by **Sushmita Goswami(Registration No: 121040110118 of 2012-2013)** and **Suchismita Goswami (Registration No: 121040110241 of 2012-2013)** students of **INSTITUTE OF ENGINEERING & MANAGEMENT**, in fulfillment of requirement for the degree of **Bachelor of Computer Science & Engineering** is a genuine work carried out by them under the supervision and guidance of **Prof. Nilanjana Dutta Roy** during the academic session of 2012-2016. The content of this report has not been submitted to any other University or Institute for the award of any other degree.

We are glad to inform that the work is entirely original and the performance is found to be satisfactory.

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## **ABSTRACT**

Biometrics is the development of statistical and mathematical methods applicable to data analysis problems in the biological sciences. It is a new method of verifying authenticity. Biometrics uses biological traits or behavioral characteristics to identify an individual. A Biometrics system is actually a pattern recognition system that utilizes various patterns like iris patterns, retina patterns and biological traits like fingerprints, facial geometry, voice recognition and hand recognition etc. What makes Biometrics really attractive is the fact that the various security codes like the passwords and the PIN can be interchanged between people but the physiological traits can't be.

The current applications of Biometric authentication are Entry control, ATM's and Government programs. The most obvious use of biometrics for network security is for secure workstation logons for a workstation connected to a network. The main use of Biometric network security will be to replace the current password system. The most popular biometric authentication scheme employed for the last few years has been Iris Recognition. Many companies are adding biometric authentication features to their products for e.g. Key ware Technologies LBV (Layered biometrics verification) Internet toolkit provides high-level security to e-commerce applications. This toolkit finds use in the area of Internet Banking.

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Last but not the least, we would like to extend our warm regards to our families and peers who have kept supporting us and always had faith in our work.

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# CHAPTER 1. INTRODUCTION

## 1.1 OBJECTIVE

The objective of this project is to make an autonomous biometric security system which can be used to prevent attacks in various sensitive areas like airport, banks, passport system etc. Traditional authentication systems which use identification id, a password and many more is highly prone to risk. Emerging technologies demand for more reliable and comfortable user authentication methods. Automated biometric systems for personal authentication is among these newly adopted techniques. Biometric reorganization technology relies upon the physical characteristics of individual such as fingerprint, palm print etc. All of these technologies suffer from interference because of dirtiness, roughness or injury of the organs to be used for authentication purpose. Hence these are not stable and accurate. Retinal biometrics, being considered as one of the most reliable biometrics among all, are majorly used when the issue of very high security arises. Mostly, the biometric parameter employed for the retinal authentication is its vessel configuration, acquired through retinal digital fundus images of human eye, because of its uniqueness for each individual. With the rapid growth of retinal biometrics for authentication, searching an efficient feature is essentially important and challenging task for faster and safer execution. Thus using the unique biometric features of the retinal images we will generate a template which will be used as the main authentication key for this autonomous security. Existing systems are time consuming process, takes minimum 15 seconds time to adjust camera with human eye. It's not accepted. Moreover, one cannot move their head. Images captured from different angles may lead to even authentication failure. In the proposed system this problem can be resolved as the relative features of different biometric parameters of retinal image have been considered.

## 1.2 SCOPE:

The problem that this system is going to solve is described as follows-

- **Airport** :- Today's passenger and cabin baggage security screening works, but at great cost to authorities, to the airline industry, and to passengers. Given the predicted growth in air travel, continuously evolving security threats, and passengers being increasingly dissatisfied with queues and intrusive measures. Moreover carry-on-items of the passengers are checked through dual-energy X-ray system, but the checking of the identity of travellers is done by checking a photo ID, such as a driver's license, passport etc. Simply taking a look at a photo ID isn't enough. In the proposed system travellers do not need to carry any smart card with him/her and the entire system would work without intervention of any security guard. This system can seek to deliver strengthened security, Increased operational efficiency, Improved passenger experience etc.
- **Banks**:- In banking system usually the account number or pin number and the signature is used for enabling security measures. The fraudster then uses this information to carry out fraudulent transactions in countries where chip and PIN technology is not supported. The fraudster may also use this information in transactions where the card doesn't have to be physically seen by the retailer or merchant. For example, when shopping online. Proposed system provides another security layer in addition to the existing measures to prevent this spoofing and skimming attacks. The use of biometrics in banking can be used because of its potential as a predominant method of identifying themselves to access banking services such as branch banking, online banking, ATM networks, and mobile banking.

- **Passport**:- The duplicate passport problem can also be resolved through this proposed system.
- **Terrorist Attack**:- Now-a-days it is very much common that prisoners sometimes fled away from prison .If some facial changes takes place due to plastic surgery it become very difficult to identify though that person is suspiciously caught again for his behaviour.
- Proposed system can be used to provide biometric security to the homeowners.
- **Medical Analysis**:- This System can be used for earlier detection of PDR(Proliferative Diabetic Retinopathy).

### 1.3 ORGANIZATION

CHAPTER 1. INTRODUCTION: Gives a brief introduction on what is being done and why this topic has been chosen.

CHAPTER 2. BACKGROUND : In this section we shall discuss a literature survey of projects done on similar topics and how the authors tried to achieve their objective.

CHAPTER 3. PROPOSED FRAMEWORK: In this section , the method of how to go about the entire technique is described.

CHAPTER 4.EXPERIMENTAL RESULTS AND ANALYSIS : This section produces a report of how our framework is performing.

CHAPTER 5. CONCLUSION: The limitation of our framework and future scope of the work i.e. where and how we can improve this technique to make it more suitable.

## CHAPTER 2 .BACKGROUND

### 2.1 BASIC CONCEPT OF BIOMETRIC TEMPLATE GENERATION

Biometric system is essentially a pattern recognition system which recognizes a user by determining the authenticity of a specific physiological or behavioral characteristic possessed by the user. Several important issues must be considered in designing a practical biometric system. First, a user must be enrolled in the system so that his biometric template can be captured. This template is securely stored in a central database or a smart card issued to the user. The template is retrieved when an individual needs to be identified. Depending on the context, a biometric system can operate either in a verification (authentication) or an identification mode.

#### Verification Vs Identification:

There are two different ways to resolve a person's identity: verification and identification. Verification (Am I whom I claim I am?) involves confirming or denying a person's claimed identity. In identification, one has to establish a person's identity (Who am I?). Each one of these approaches has its own complexities and could probably be solved best by a certain biometric system.

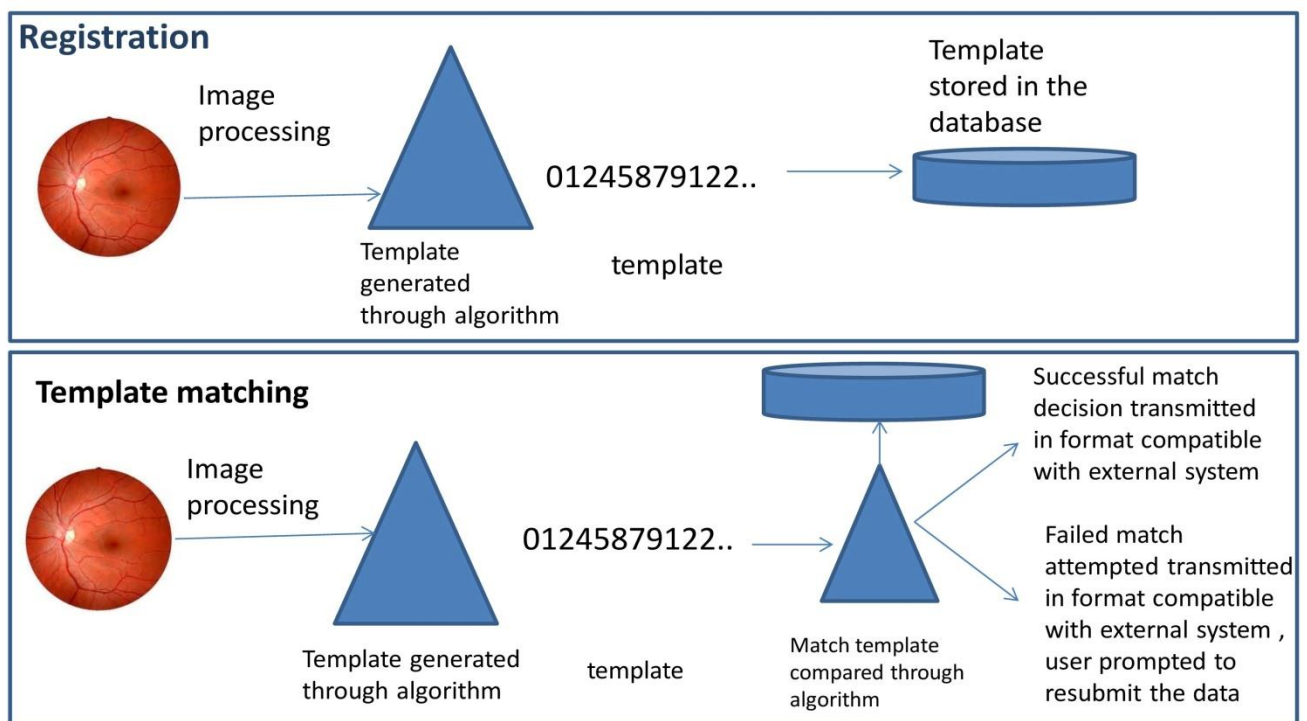


Figure 1: image showing the block diagram of the system

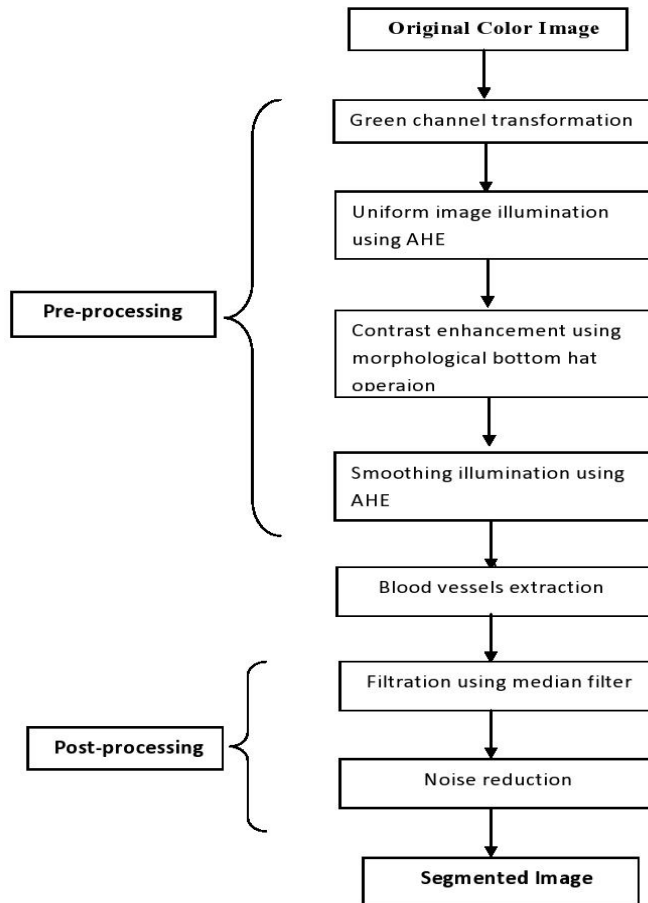
## 2.2 RELATED LITERATURE REVIEW:

Alauddin Bhuiyan, Tien Wong et al. in their paper named A NEW AND EFFICIENT METHOD FOR AUTOMATIC OPTIC DISC DETECTION USING GEOMETRICAL FEATURES, they presented a method for OD detection which is based on image global intensity levels, OD size and shape analysis. According to them, firstly the OD is the brightest part on the image and hence they had approximated its pixel intensity values by analyzing the histogram. Secondly, OD is more or less circular shaped and they have specified its size within a particular range for any person. Sourav Saha, Nilanjana Dutta Roy et al. [2] have proposed a novel method for automatic detection of bifurcation points in retinal fundus-images. They have focused on determining the potential bifurcation points by analyzing local neighborhood connectivity around junction points on blood-vessels. Tracking-based approaches utilize a profile model to incrementally step along and segment a vessel. Vessel tracking a one-dimensional matched filter fell with a given threshold. The tracking method was driven by a fuzzy model of a one-dimensional vessel profile [3]. One drawback to these approaches is their dependence upon methods for locating the starting points, which must always be either at the optic nerve or at subsequently detected branch points. Many image processing methods proposed for retinal vessels extraction [4] [5] [6] [7] [8]. Optimized Gabor filters with local entropy thresholding had been used in those approaches for segmentation of the blood vessels in the retinal images. The drawback of those segmentation methodology is that Optimized Gabor filter methods often produce false positive detections and fail to detect vessel of different widths. Also detection process much more complicated when retinal image abnormal condition. G. Kavitha MIT, S. Ramakrishnan et. al. in their paper named “Identification and analysis of macula in retinal images using Ant Colony Optimization based hybrid method” has presented a method of localization of macula in which the fundus retinal images are subjected to ant colony optimization (ACO) based method to identify optic disc (OD) and Otsu method to further analyze the macula. Parameters such as radius of optic disc and distance between the centers of the optic disc and macula are used as indices for evaluation.

## CHAPTER 3. PROPOSED METHODS

### 3.1 SEGMENTATION OF BLOOD VESSELS

#### 3.1.1 BLOCK DIAGRAM



#### 3.1.2 ALGORITHM

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**Algorithm 1:** Segmentation of blood vessels from retinal fundus image

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Input : RGB Retinal Image.

Output: Segmented Image of blood vessel.

Step1: RGB image is converted into Green channel.

Step2: Boundary of the previously obtained green channel image is being removed.

Step 3: Contrast of the image is enhanced by contrast-limited adaptive histogram equalization .

Step 4: Then morphological "bottom hat" operation is performed with structuring element of size 8X8.

Step 5: The image obtained after preprocessing is converted to binary image using threshold

value obtained by Otsu's method of thresholding.

Step 6: Median filter is used to remove salt & paper noise from previously obtained image.

Step 7: Next, smaller object is removed and final segmented blood vessel is obtained.

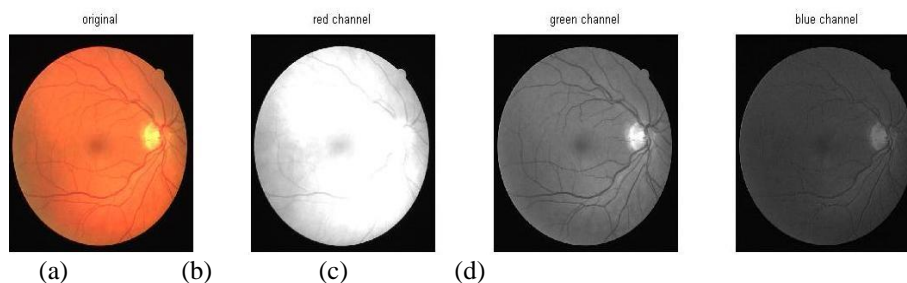
### 3.1.3 EXPLANATION

#### 1. Preprocessing:

The retinal images have non uniform illumination of the background due to the presence of vitreous humor, which is a transparent gel that fills the interior of the eye. The blood vessels have varying thickness and contrast due to which the darker vessels (thick vessels) can be easily detected which it is difficult to extract the vessels having poor contrast (thin vessels). So it is desirable to have high contrast between the retinal blood vessels and retinal background whilst there should be low contrast between retinal background and retinal abnormalities so that the blood vessel tree appears as dark structure in brighter background in the images. Hence preprocessing is applied to the original retinal image in order to eliminate these anomalies to prepare the image for the next steps of segmentation algorithm for detection of the blood vessels to higher accuracy.

The preprocessing stage of the proposed algorithm is splitted into 5 steps. Steps are described as follows -

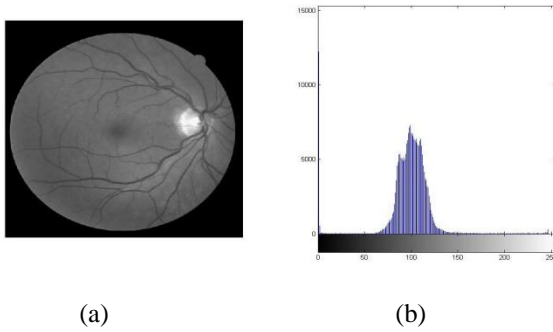
1.1 **Channel Conversion**:- The input image is a color (RGB) image. The red channel is the brightest color channel and has low contrast. The green channel provides the best vessel background contrast of the RGB representation. So the green channel of the image is extracted from the original RGB retinal images. Please refer Figure 2:



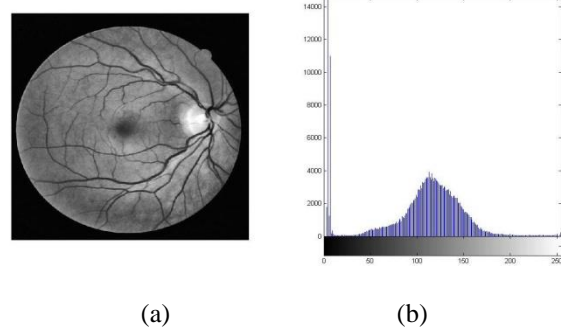
**Figure 2**(a):original RGB image,(b)red channel image,(c)green channel image,(d)blue channel image(left to right)

1.2 **Boundary Removal** :- In this step the outer border of the green component of the image is removed by suppressing the structures that are lighter than the surroundings and that are connected to the image border.

1.3 **Blood Vessel Enhancement** :- Fundus images have background intensity variation due to non uniform illumination which may deteriorate the segmentation result. Due to this non uniformity in the image background pixels may have their gray levels higher than the vessel pixels. So in this phase global thresholding techniques cannot be applied due to the various gray levels in different areas in the image and noisy unconnected regions appeared as false vessels. Hence Contrast-limited adaptive histogram equalization is applied for enhancing the contrast of the green channel retinal image to redistribute the lightness value of the image. This enhancement operation is performed on the small regions of the image, instead of the entire image and thus contrast of every smaller region is enhanced. Please refer Figure 3(a), Figure 3(b), Figure 4(a) and Figure 4(b),



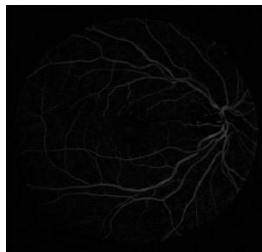
**Figure 3(a):** green channel image, (b) its Histogram



**Figure 4(a)** AHE filtered image (b) its histogram,

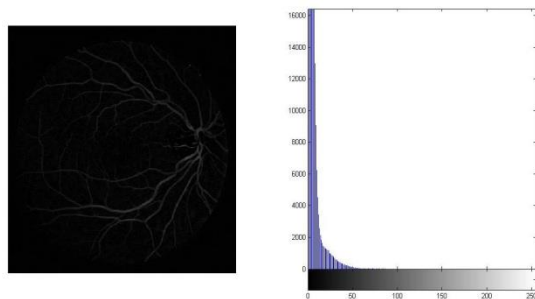
This step helps to reduce some responses from abnormalities which do not resemble any blood vessels that would otherwise decrease the performance of blood vessels segmentation method.

**1.4 Morphological Transformation:-** As in some cases blood vessels appeared as part of the background in a binary image due to the less intensity difference between blood vessels and image background , morphological bottom hat operation is performed in order to improve the contrast with a disk shaped structuring element of size 8x8.the shape and the size of the structuring element is set according to the image structure that are to be extracted. Bottom-hat filtering subtracts the input image from the result of performing a morphological closing operation on the image. Closing operation is defined s dilation(Max filter) followed by erosion(Min filter).Please refer Figure 5.

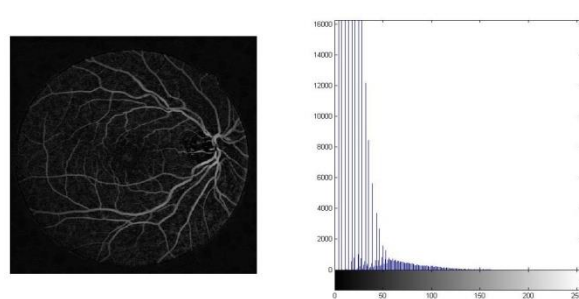


**Figure 5:**showing image after morphological bottom hat operation

**1.5 Smoothing Illumination:-**The image produced after the bottom hat operation has poor contrast. Hence In order to improve the contrast again contrast-limited adaptive histogram equalization is applied so that the image is well prepared for thresholding and segementation stage.Please refer Figure 6 ,Figure 7.



**Figure 6:**image after bottom hat& its histogram



**Figure 7:**contrast enhanced image & its histogram

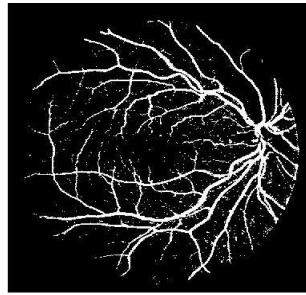


**2. Blood Vessels Segmentation:-** Preprocessing step has enhanced the contrast of the original image. Hence after enhancing the signal of the blood vessels which is lying in the range below the threshold value, the image is thresholded using the OTSU algorithm keeping the information below the threshold value and giving the rest of the image the same value as the threshold. Thus cluster based algorithm is used to perform clustering based image thresholding and the preprocessed gray scale image is reduced into the binary image. Please refer Figure 8.

Otsu's method is used to automatically perform clustering based image thresholding to reduce the gray level image into the binary image. In Otsu's method threshold value is used which minimizes the intra-class variation, defined as a weighted sum of variances of the two classes.

$$\sigma_w^2(t) = \omega_0(t) \sigma_0^2(t) + \omega_1(t) \sigma_1^2(t) \quad (1)$$

Weights  $\omega_{0,1}$  are the probabilities of the two classes separated by a threshold  $t$  and  $\sigma_{0,1}^2$  are variances of these two classes[11].

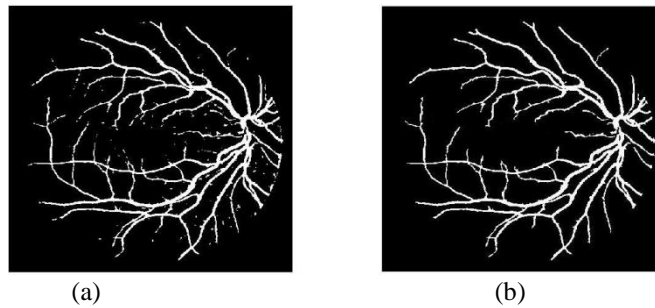


*Figure8:showing extracted blood vessels after applying Otsu's method of thresholding*

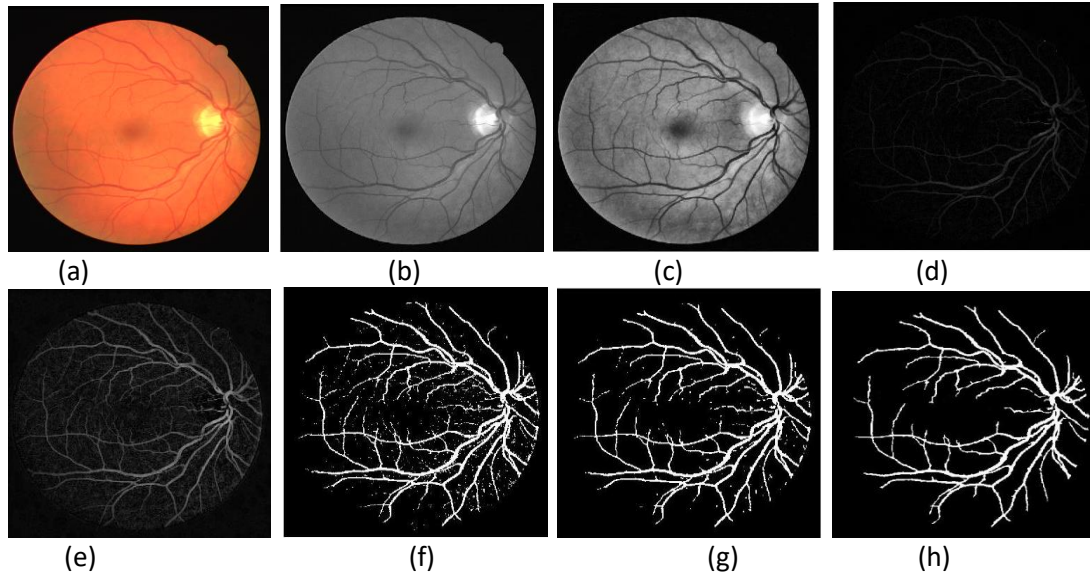
### 3. Post Processing:-

**3.1 Noise Removal :-** The image obtained by previous stages contain salt & paper noise. Hence a 2-D median filter with 3-by-3 neighborhood size is applied to obtain a clear image with a minimum extent of the noise of the green channel. Each output pixel contains the median value in a 3-by-3 neighborhood around the corresponding pixel in the input image. Please refer Figure 9(a).

Next, all the small connected components that have fewer than 35 white pixels around it within the 8x8 connectivity are removed from the previously processed image to get the final segmented image. Please refer Figure 9(b).



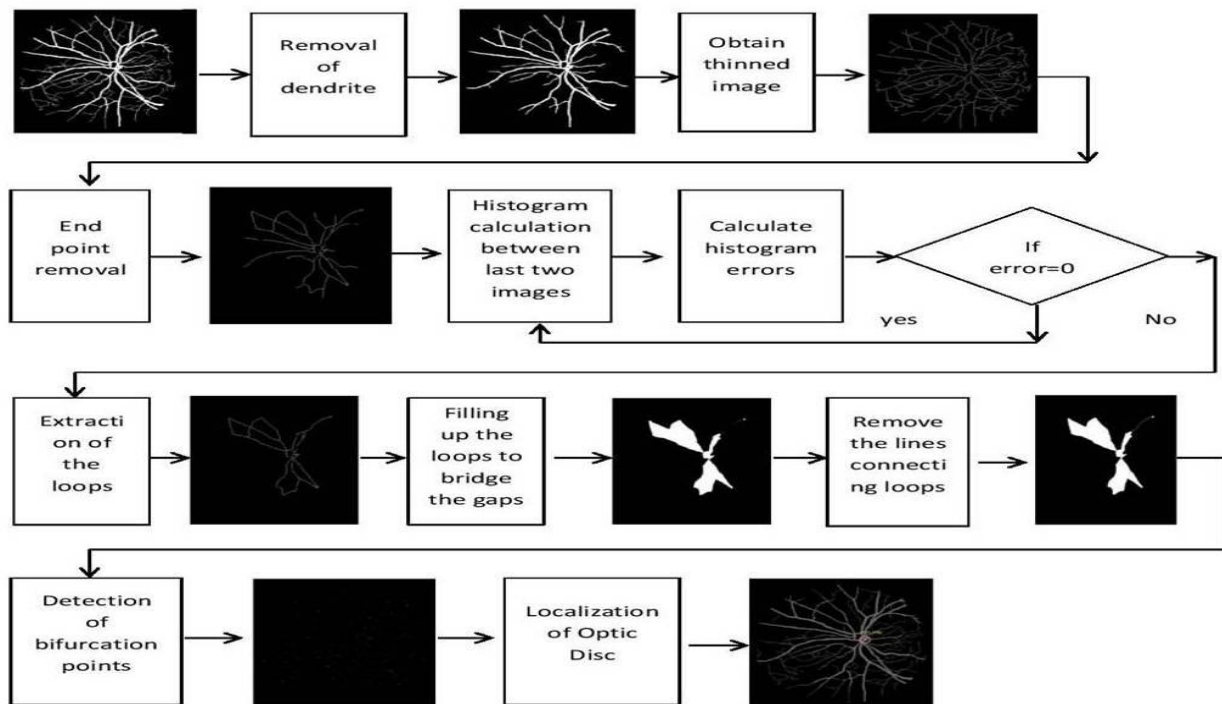
*Figure9 (a) Median filtered image ,(b) segmented image after noise removal*



**Figure 10:** (a) Original RGB image, (b) green channel image, (c) AHE filtered image, (d) after performing bottom hat operation, (e) contrast enhanced image, (f) extracted blood vessels by Otsu's thresholding, (g) median filtered image, (h) segmented image after removing noise

## 3.2 LOCALIZATION OF OPTIC DISC CENTRE:

### 3.2.1 BLOCK DIAGRAM



### 3.2.2 EXPLANATION

#### Proposed Algorithm of Localization of optic disc:-

It has been statistically found from the thinned images, that the overlapping of major blood vessels near optic disc area again forms polygonal loop like structures. We are emphasizing on this loop structure by considering them as the key feature to locate the optic disc in this algorithm. But overlapping of the dendrites may also generate loops which carries redundant information. So removing dendrites is an essential task to keep the loops near the optic disc intact.

**Input:-** Segmented binary image

**Output:-** Center of the Optic Disc

Step 1. Removing the dendrites from the segmented image .

Step 2.The morphological thinning operation is performed on the segmented fundus image to get a thinned image .

Step 3. [End points removed] Within an iterative loop, all the end points are removed from the thinned image by checking its all eight neighborhood pixels to be off . And every time the new image is being compared with the previous one obtained from the early iteration by calculating the difference of the histogram of the two images.

If this difference is then two images are exactly equal and no further removal of endpoint is required.

Step 4. After the loop structure is found the thinned lines connecting the loop structures are removed and then the loops are filled up by using matlab defined 'imfill' operation.

Step 5. Now the distance between all the bifurcation points from the loop structure are calculated. Then the bifurcation points having minimum distance from the loop structure among all, are found as the bifurcations nearer to the optic disc.

Step 6. For each of the previously obtained bifurcation at the end of Step 5, no of bifurcation points around it is calculated. And the bifurcation point which is having the maximum no of bifurcation points around it, is considered as the root pixel.

Step 7. Then the no of blood vessels around the optic disc is calculated.

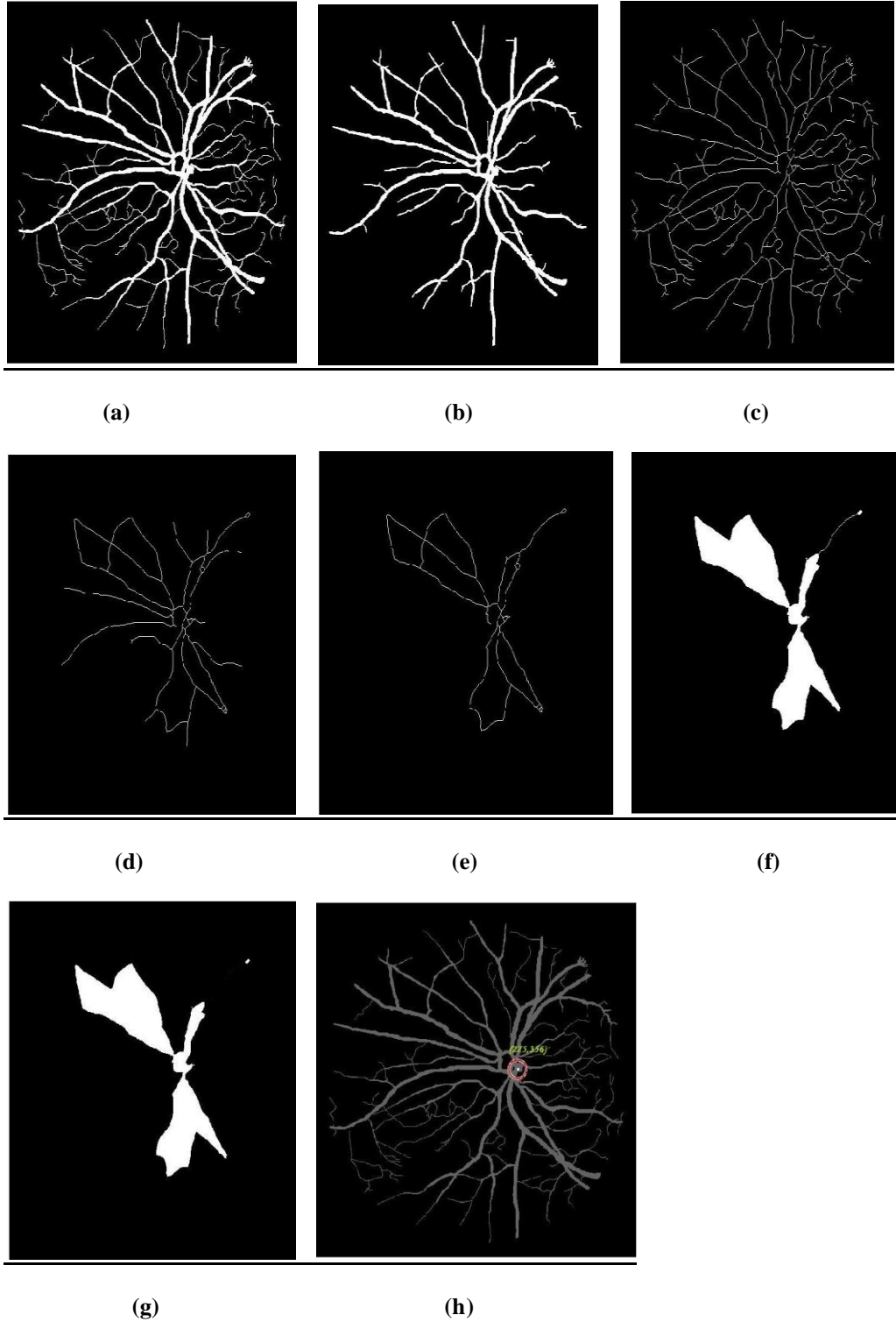
### **3.2.3 COMPLEXITY ANALYSIS(OPTIC DISC LOCALIZATION):-**

While Finding the center of the optic disc, we have first of all found out the branchpoint which is done in  $O(n)$  time, then the removal of terminal until the loop is found is also done in  $O(n)$  time. The distance between a single bifurcation point to the loop is found in  $O(n)$  times. So if there is  $n$  no of bifurcation points then for all these points, the algorithm would work with time complexity of  $O(n^2)$ . Next we have considered only those bifurcation points nearer to the optic disc which drastically reduces the complexity of the algorithm. And finally calculation of no of branchpoints around each of this bifurcation point will be done in  $O(n)$  times.

So time complexity for this algorithm is  $O(n^2)$ . Apart from this there would be obvious need of  $O(n^2)$  amount of time while scanning the entire image for processing.

And as there is no additional space or storage requirement So Constant space complexity.

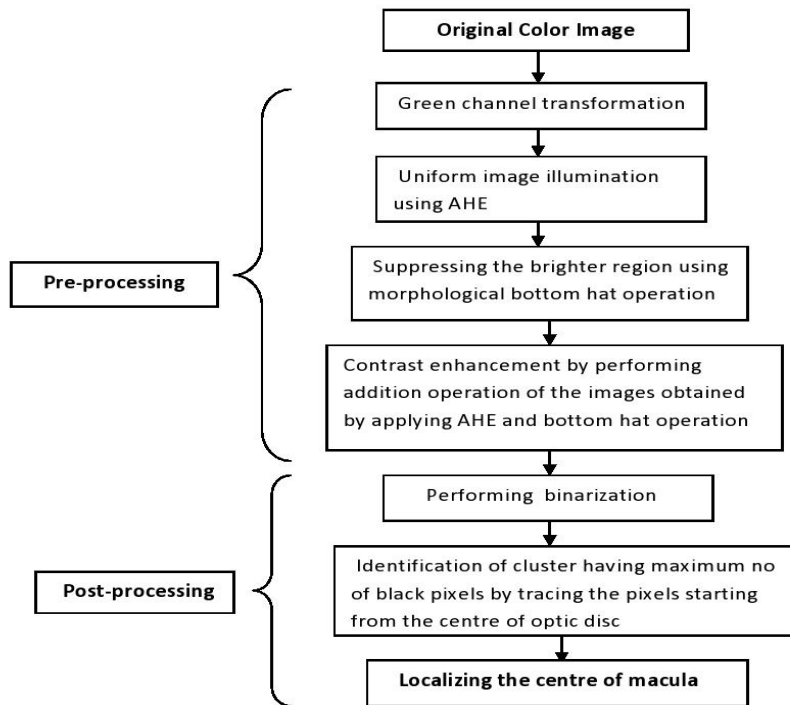
**Detected center point of the optic disc of the drive image :-**



**Figure. 11.** (a) segmented fundus image (b) image after removing the dendrites (c) Thinned image obtained after applying morphological function (d) Image after a few iteration (e) after extracting the loops in the image (f) after applying imfill function to bridge the holes (g) after removing lines connecting the loops (h) optic disc located

### 3.3 IDENTIFICATION OF THE CENTER OF THE MACULA:

#### 3.3.1.BLOCK DIAGRAM :



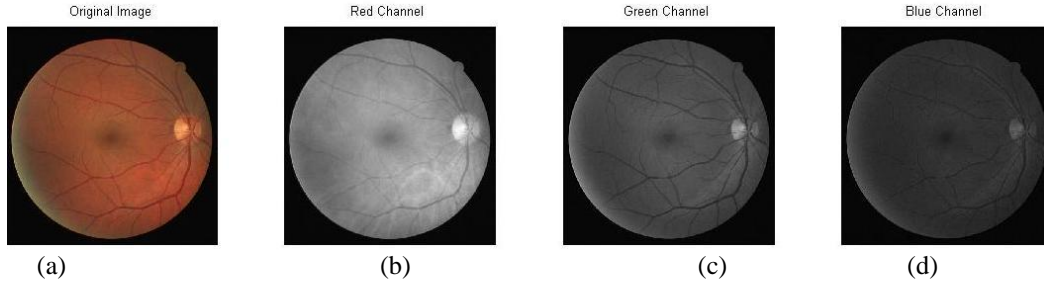
#### 3.3.2.EXPLANATION

##### Proposed Algorithm of localization of the macula

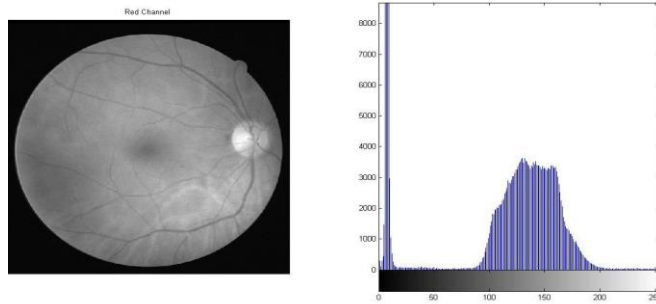
Proposed method of detection of macula in the color retinal image has been divided into two stages: 1)Pre-processing 2) Detection of macula .

**1.Pre-processing :** Pre-processing steps of the proposed algorithm has been divided into five stags

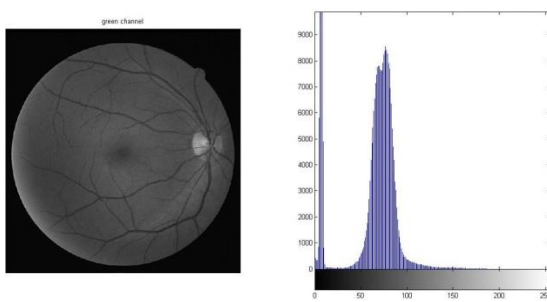
1.1 **Channel Conversion:-** The input image is a color (RGB) image. The red channel is the brightest color channel and has low contrast. The green channel provides the best vessel background contrast of the RGB representation.. So the green channel of the image is extracted from the original RGB retinal images. Please refer Figure12.Images of the three channels and its histogram is shown in Figure13.



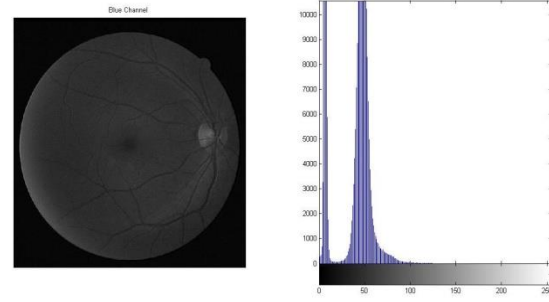
**Figure12(a):original RGB image,(b)red channel image,(c)green channel image,(d)blue channel image(left to right)**



**Figure 13. (a) Red channel image and its histogram**

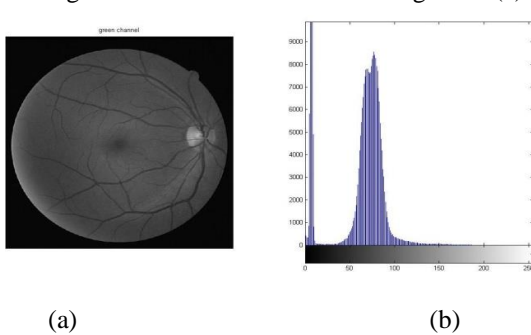


**Figure13(b) Green channel image and its histogram**

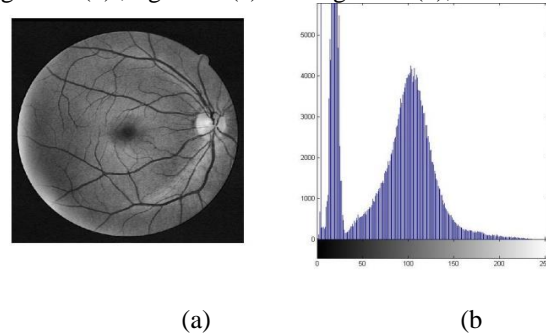


**Figure13(c) Blue channel image and its histogram**

**1.2 uniform the illumination of the image** :- Fundus images has background intensity variation due to non uniform illumination which may deteriorate the segmentation result . Due this non uniformity in the image Background pixels may have their gray levels higher than the vessel pixels. So in this phase global thresholding techniques cannot be applied due to the various gray levels in different areas in the image and noisy unconnected regions appeared as false vessels Hence Contrast-limited adaptive histogram equalization is applied for enhancing the contrast of the green channel retinal image to redistribute the lightness value of the image .This enhancement operation is performed on the small regions of the image , instead of the entire image and thus contrast of every smaller region is enhanced .Please refer Figure 14(a) ,Figure 14(b) ,Figure 15(a) and Figure 15(b),

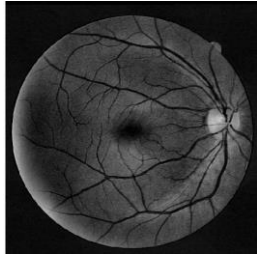


**Figure 14(a): green channel image, (b) its Histogram**



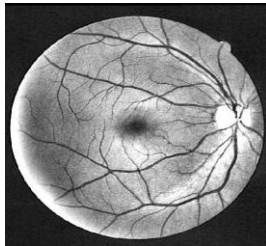
**Figure 15(a) AHE filtered image (b) its histogram,**

**1.3 Morphological Transformation:** This pre-processing stage consists on generating a new vessel-enhanced image, which proves more suitable for further detection of macula. Vessel enhancement is performed by applying the morphological Top-Hat transformation where is a morphological opening operation using a disc of 50 pixels in radius. Thus, while bright retinal structures are removed (i.e., optic disc, possible presence of exudates or reflection artifacts), the darker structures remaining after the opening operation become enhanced (i.e., blood vessels, macula ,fovea, or hemorrhages).Please refer Figure 16. The top-hat transformation is difference between an input image and its opening.



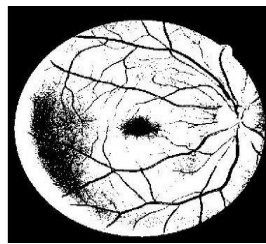
**Figure 16:** *image obtained after tophat operation*

**1.4 Contrast enhancement:** This stage increases the contrast of the image by performing addition operation of the image obtained after previous stage with the image obtained after adaptive histogram equalization. Thus, the lighter structures(background) remaining after the addition operation become enhanced. Please refer figure 17.



**Figure 17:** *image obtained after contrast enhancement*

**2 . Binarization of the preprocessed image:** The preprocessed image is thresholded using the OTSU's method keeping the information below the threshold value and giving the rest of the image the same value as the threshold. Thus cluster based algorithm is used to perform clustering based image thresholding and the preprocessed gray scale image is reduced into the binary image. please refer figure 18.

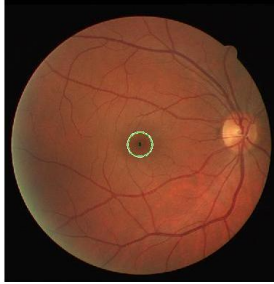


**Figure 18:** *image obtained after binarization.*

**3. Detection of macula:** After detection of the optic disc in the retinal fundus image a window of threshold size has been considered around it to remove this region from the pre-processed binary image. This will remove the false detection of the dark region nearest to the optic disc as macula. Next, from the extreme end of this rectangle towards macula, binary image Is traced horizontally upto a threshold distance towards other end along the x co-ordinate of the centre of the optic disc by considering an window of size 50X50 to find the cluster with maximum black pixels



count. After localizing this high density region , each pixel in this region is checked by considering a window of size 30X30 to find the pixel having maximum no of neighboring black pixels around it . This pixel is considered as the centre of the macula. Please refer figure 19.



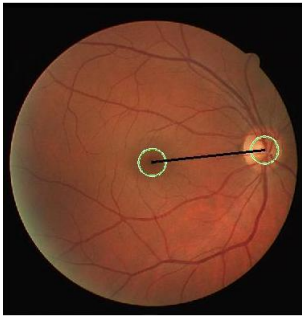
**Figure 19:**image showing macula and its center after detection.

**Algorithm :Calculation of the distance between centre of optic disc and that of macula:**

If the centre of optic disc is (x, y) and the centre of the macula is (s, t), then the distance between them is defined by

$$De= \sqrt{(x - s)^2 + (y - t)^2} \quad (2)$$

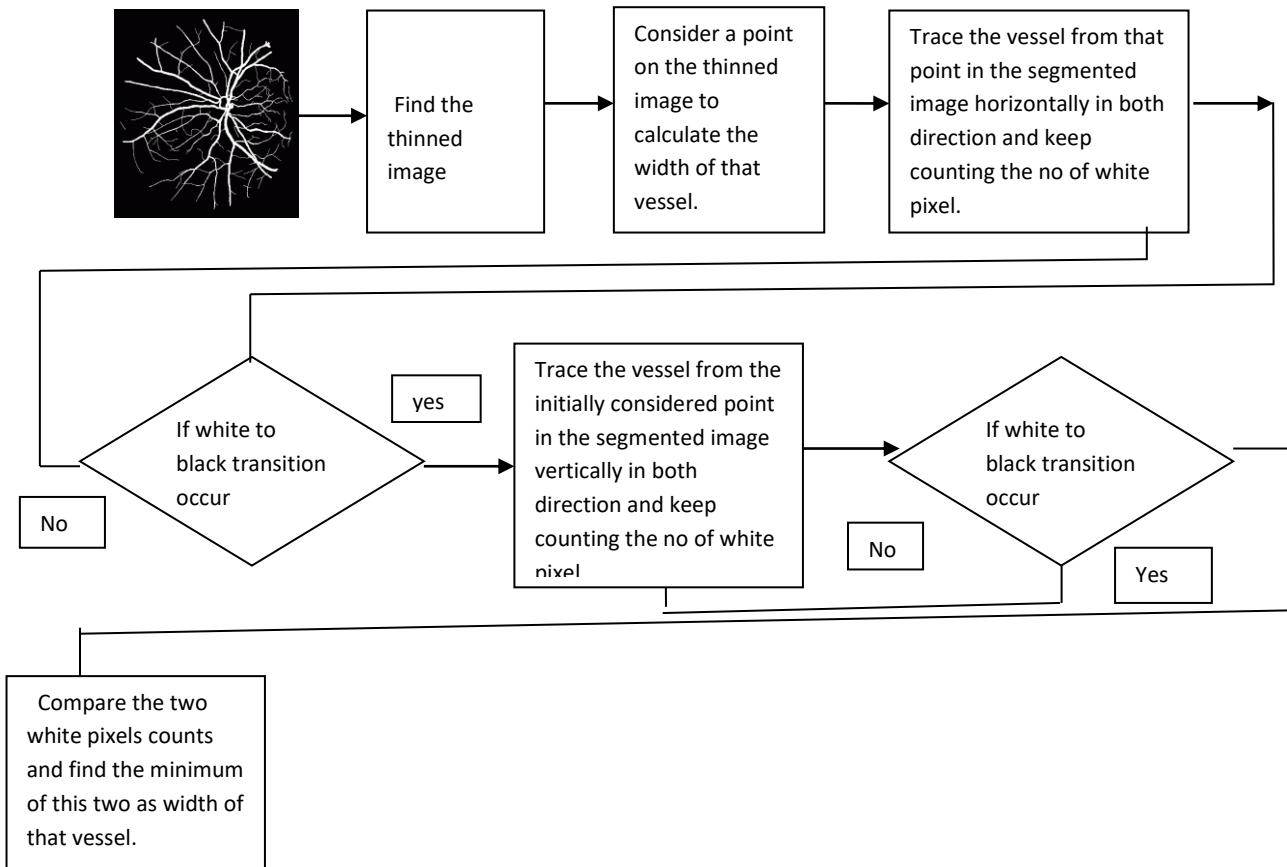
Please refer Figure 20.



**Figure 20.** Showing the distance between macula and optic disc center

## 3.4 CALCULATION OF WIDTH OF THE RETINAL BLOOD VESSELS:

### 3.4.1 BLOCK DIAGRAM



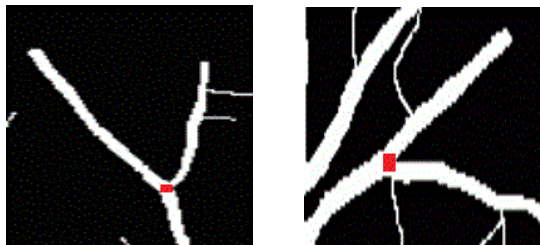
### 3.4.2 EXPLANATION

#### Proposed Algorithm of width calculation of the retinal blood vessel:

The algorithm is being described over here as a cumulative .

Step 1.The algorithm starts with the segmented image as its input.

Step 2. Anatomically, there are two possible scenarios of the vessels exist which are emanating out of the Optic Disc, please refer Figure 21



**Figure 21:** The tendency of the nerve is to move along (a) vertical direction (b) horizontal direction .

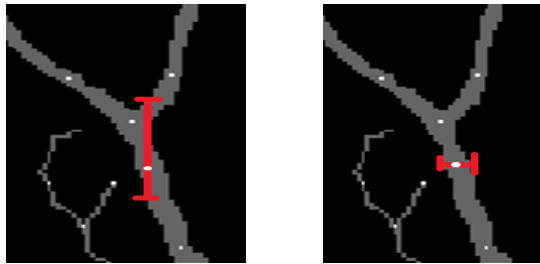
i.e., either they tend to move along the horizontal direction, or they are prone to the vertical direction.

So, to measure the width of any vessel at any point, careful steps has been taken about the directions and this could be done unerringly by comparing the number of white pixels along the vertical direction with the number of white pixel in the horizontal one. Then the minimum count of these two will be considered as the width of the present vessels at that point. Hence to calculate the width of the vessel first of all we are taking the thinned image of the original segmented image and then a point on the vessel at a certain distance around the optic disc in the thinned image is taken. For a single point on every nerves around the optic disc following steps are applied.

Step 2.1. Start tracing the vessel horizontally by counting the number of white pixel until a transition takes place from white to black pixel. The same process is repeated for both the left and right directions from that point in the original segmented image, see figure 22(a).

Step 2.2. Then, vertical tracing is done again by counting number of white pixels until a transition takes place from white to black pixel. The process continues for both the upward and downward directions from that point in the original segmented image. Please refer see figure 22(b).

Step 2.3. Then, the minimum count between horizontal and vertical directions is being selected as the width of the specified vessel .



**Figure 22:** Comparing this two count and as count along vertical direction count along horizontal direction hence we can predict that tendency of the nerve is along the vertical direction .so the width of the nerve at that point is equal to the count along the horizontal direction (a) Counting the no of pixel While moving along the vertical direction i.e. upward and downward direction from the point (b) Counting the no of pixel While moving along the horizontal direction i.e. along left and right from the point .

### Complexity Analysis:

While calculating the width of the vessel ,we are moving in left and right direction horizontally until a white to black transition occur and similarly in vertical directions also . Both the cases , it consumes linear amount of time , i.e., the above algorithm results into a time complexity of  $O(n)$ . Apart from this there would be obvious need of  $O(n^2)$  amount of time while scanning the entire image for processing. And as there is no additional space or storage are required, we conclude the space complexity as constant.

### **3.4.3.1 CALCULATION OF RATIO OF WIDTH OF CHILD VESSELS TO THE WIDTH OF THE PARENT VESSEL**

---

#### **3.4.3.1.1 ALGORITHM**

---

Ensure:

```
nv ← number of pixels in vertical direction
nh ← number of pixels in horizontal direction
nv ← 0
nh ← 0
width ← total width of vessel
width ← 0
parent ← width of the parent vessel
child1 ← width of one child vessel
child2 ← width of another child vessel
for each bifurcation point do mark three distinct point on the three branches around it
    for each of these points on the respective three branches do
        repeat move along the upward vertical direction
            nv ← nv + 1
        and move along the downward vertical direction also
            nv ← nv + 1
        until white to black transitions occur

        repeat move along the left horizontal direction
            nh ← nh + 1
        and move along the right horizontal direction
            nh ← nh + 1
        until white to black transitions occur
        if nv > nh then
            width :← nh
        else
            width :← nv
        end if
    end for
    calculate ratio1 :← parent/child1
    calculate ratio2 :← parent/child2
end for
```

#### **3.4.3.1.2 EXPLANATION**

The bifurcation points ensure stability and are not subject to any change even when prone to diseases. Identifying these points, our algorithm attempts to find the ratio of the width of a parent vessel with its corresponding child vessels at the bifurcation points. Experimental results prove that this ratio lies in the range of 1.1-1.8

### **3.4.3.2 COMPUTATION OF TOTAL NO OF MAJOR BLOOD VESSELS**

---

#### **3.4.3.2.1 ALGORITHM: COUNTING NUMBER OF BLOOD VESSELS AROUND OPTIC DISC**

---

Ensure

```

count ← total number of blood vessels around optic disc
consider a 50x50 window around the optic disc
repeat
for each pixel along the window border
if a white pixel is found then
repeat
move along the border of the window by one pixel
until white to black transition occur
count ← count+1
else
move along the border of the window by one pixel
end if
end for
until all the pixels along the four border of the specified window is traversed

```

---

### 3.4.3.2.2 EXPLANATION

Different parameters like accuracy, specificity, sensitivity are defined in order to compare the results from the algorithm with the segmentation of other algorithms. To compute this parameters one of the fundamental steps is calculating number of blood vessels detected by the algorithm so that it can be compared with the gold standard images. Moreover counting no of blood vessels around optic disc helps in diagnosis of PDR. Hence counting number of blood vessels around the optic disc would serve our purpose. Please refer Algorithm 2 for counting number of blood vessels around the optic disc and table 1 for the number of blood vessels detected by the algorithm applied on the DRIVE database.

### 3.4.3.3 DISTANCE BETWEEN TWO COSECTUIVE BLOOD VESSELS AROUND OPTIC DISC

Distance between the consecutive blood vessels is measured which helps in identification of PDR at very earlier stage. an odd sized window around it is fixed keeping the center pixel of the window as the detected Optic Disc. While scanning this window clockwise, the vessel locations are pointed and a counter is getting increased to keep track of the number of vessels. Then the distance between each consecutive vessels are calculated by Euclidean Distance measurement.

If the initial location is (x,y) and final points are (s,t), then the distance between them is defined by

$$De = \sqrt{(x-s)^2 + (y-t)^2} \quad (3)$$

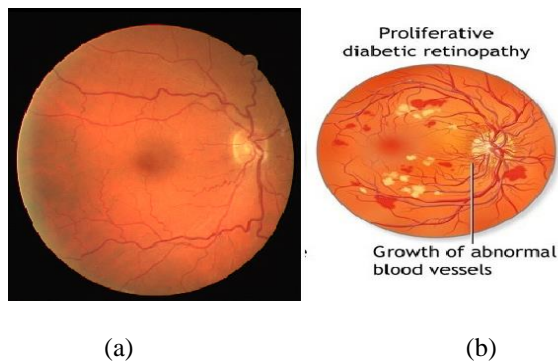
Total distance is again a cumulative distance of all the vessels emanating out from the OD.  
It is defined by

$$\text{Total distance} = \sum_{i=1}^n \text{vessels}_i \quad (4)$$

where n is the maximum number of blood vessels.

### 3.5 DETECTION OF PROLIFERATIVE DIABETICS RETINOPATHY(PDR)

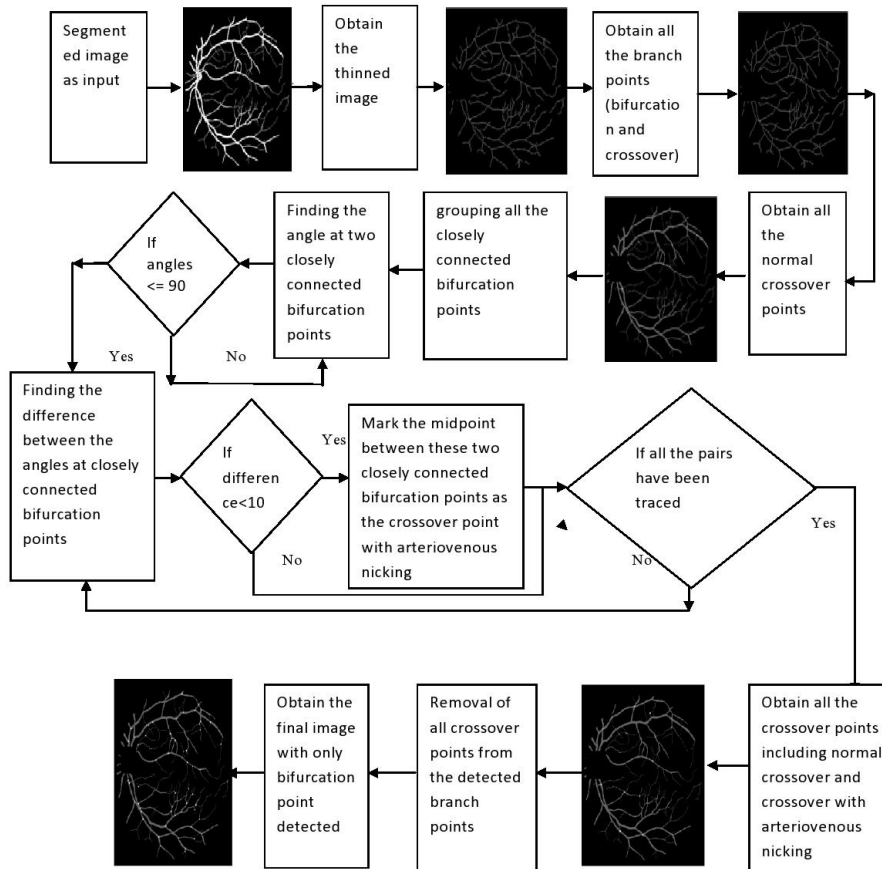
Additionally, biometric template based on this feature would be robust enough to fight against even the situation of Proliferative Diabetic Retinopathy (PDR) where newly generated, tiny fragile vessels interrupt the authentication process. At the advanced stage of Proliferative Diabetic Retinopathy, signal sent by the retina triggers the development of new fragile blood vessels that proliferate in the retina and the vitreous, which is a transparent gel that fills the interior of the eye, please refer Figure23. As these new vessels are not normal in nature, they can rupture and bleed, causing hemorrhages in the retina or vitreous. Scar tissue can develop and can tug at the retina, causing further damage or even retinal detachment .This algorithm can be used to find the width of the vessel around the optic disc which may be intended in diagnosing of PDR. Lot of variations in the width of the blood vessels around optic disc indicates the probability of generation of fragile nerves due to PDR.



**Figure23:** (a) normal retinal image (b) retinal image effected due to PDR

## 3.6 IDENTIFICATION OF DISTINCT BIFURCATION AND CROSSOVER POINTS

### 3.6.1 Block Diagram:



### 3.6.2 ALGORITHM

Algorithm 1 Bifurcation point calculation

Ensure:

points  $\leftarrow$  detected branch points bifurcation

points  $\leftarrow$  detected bifurcation points

diff  $\leftarrow$  difference between the angles at two close bifurcation points do skeletonization of the segmented image for each detected branch points

do count the no of neighboring pixels including the chosen one by considering a small rectangular window surrounding it

if count == 5 then

mark the branch point as normal crossover and remove the point from detected branch points

end if

end for

find the closely connected bifurcation points from the remaining detected branch points and group them individually

for each detected closely connected bifurcation pair

```

do find the angle at two close bifurcation points and mark as 1 and 2
if  $\alpha_1 < 90$  and  $\alpha_2 < 90$  then
    diff = abs( $\alpha_1 - \alpha_2$ )
else if diff  $\leq 10$  then
    mark the midpoint of the two closely connected bifurcation points generated due to arteriovenous nicking as a
    single crossover that is represented by two closely connected bifurcation points in the skeleton image
    end if
end for

```

---

### 3.6.3 EXPLANATION

#### Proposed algorithm of identification of distinct bifurcation points:

Step 1. This algorithm starts with the segmented images from DRIVE database as its input.

Step 2. The segmented images are being thinned by using a standard morpho- logical thinning function of Matlab. Then all the branch points of the thinned images are calculated using another morphological function 'bwmorph' along with the operation 'branchpoints'. The term branch point includes both the bi- furcation and the crossover points.

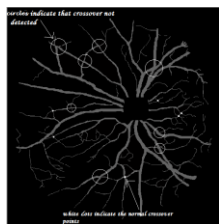
Step 2.1. These crossover points are basically of two categories, one is the normal one and another is a false situation which is often detected as bifur- cation point due to arteriovenous nicking occurs at the crossover points. Please refer the figure 3.

Step 3. Next, all the crossover points are needed here to be removed using the following steps.

Step 3.1. A  $3 \times 3$  window is being considered to traverse around each selected branch point. The window is then scanned to find out the total number of neighborhood white pixels surrounding the branch point.

Step 3.2. If this count gives a number which is equal to a predefined threshold value five including that branch point pixel, this pixel is marked as a normal crossover point then. At the end, all the normal cross over points have been successfully detected as shown in the following figure 24.

Step 3.3. The term arteriovenous is the junction where two very close



**Figure 24** Detected normal crossover points vessels meet and creates a troublesome situation.

This exceptional situation of- ten arises in the skeleton image and always there is a common probable scenario to identify this junction as two very close bifurcation points together. However, this process may lead to a false detection of real scenario as two bifurcation points also as shown the figure 25 where the two bifurcation points are really close in nature. With a hope to get a better solution here and to differentiate between true crossovers from spurious results, another geometrical features of each detected crossover are analyzed along with notion of two closely connected bifurcation points.



Step 3.3.1. The intersection angles formed by the two vessels at the crossing are  $\alpha_1$  and  $\alpha_2$  shown in the following figure 26.

Step 3.3.2. Then all the closed bifurcation points are detected and grouped together.

Step 3.3.3. Finally, for each group of two closely connected bifurcation points, the bifurcation angles are calculated as  $\alpha_1$  and  $\alpha_2$ . It has been



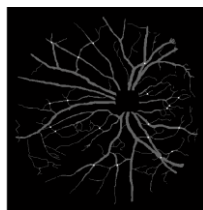
*Figure. 25. Showing arteriovenous nicking*

observed that when a crossover appears as two closed bifurcation points in the skeleton image due to the thinning process, the two angles formed by the two segments i.e. vessels associated with each bifurcation point represent the acute angles of the intersection. Hence,  $\alpha_1$  and  $\alpha_2$  values of a true crossover should be less than a certain threshold. And also from statistical analysis it has been found that if the difference between  $\alpha_1$  and  $\alpha_2$  are less than a predefined threshold 10, then this two closed bifurcation points can be considered as a single crossover point.

error:=difference between  $\alpha_1$  and  $\alpha_2 = (\alpha_1 - \alpha_2)$  if (error  $\leq 10$ ) then two closed bifurcation points is detected as a single crossover point. then, mid point of these two closed bifurcation points is considered as a single crossover point as shown in the following figure 26.



*Figure. 26. Mid point of two closely connected bifurcation points detected as a single crossover point*

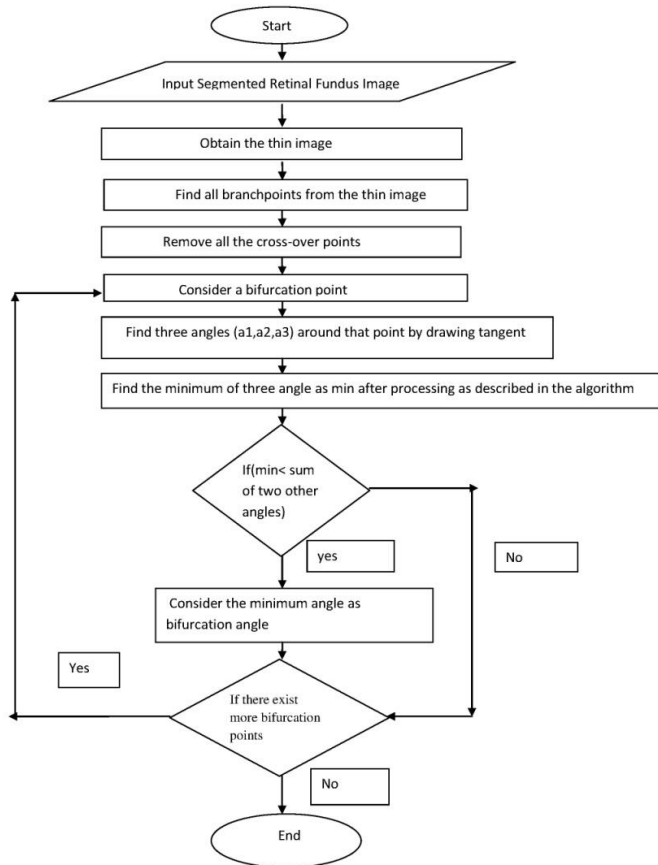


*Figure. 27 All the crossover points detected through the above steps*

Step 4. Then the result sets are found after the crossover points has been detected. In the evaluation process, all crossovers which fall within the optic disk are excluded from evaluation. In addition, the very small tiny vessels may cause some errors while calculating the no of crossover points from a fundus image which are negligible.

## 3.7 CALCULATION OF BIFURCATION ANGLE:

### 3.7.1 BLOCK DIAGRAM:



### 3.7.1 EXPLANATION

**Objective :** is to find out the three angle around each bifurcation point on the segmented input image and specifically the bifurcation angle.

Segmented image was taken as input image. All the branchpoints were found out from the segmented image using matlab defined function `bwmorph` with operation 'branchpoint' after morphological thinning operation has been performed on the segmented input image.

In the next step, all crossover points including false crossover points from previously found branchpoints were removed .

Hence only the bifurcation points have been almost correctly obtained from the input image.

In the next step , three angle around each bifurcation points were calculated using the following steps:

For each bifurcation point, in order to find three angle it is required to draw three tangent one along parent nerve and other two along the child nerve respectively.

Now, in order to draw three tangents , three points one on the parent nerve and other two on the child nerve are found out respectively using the following steps:

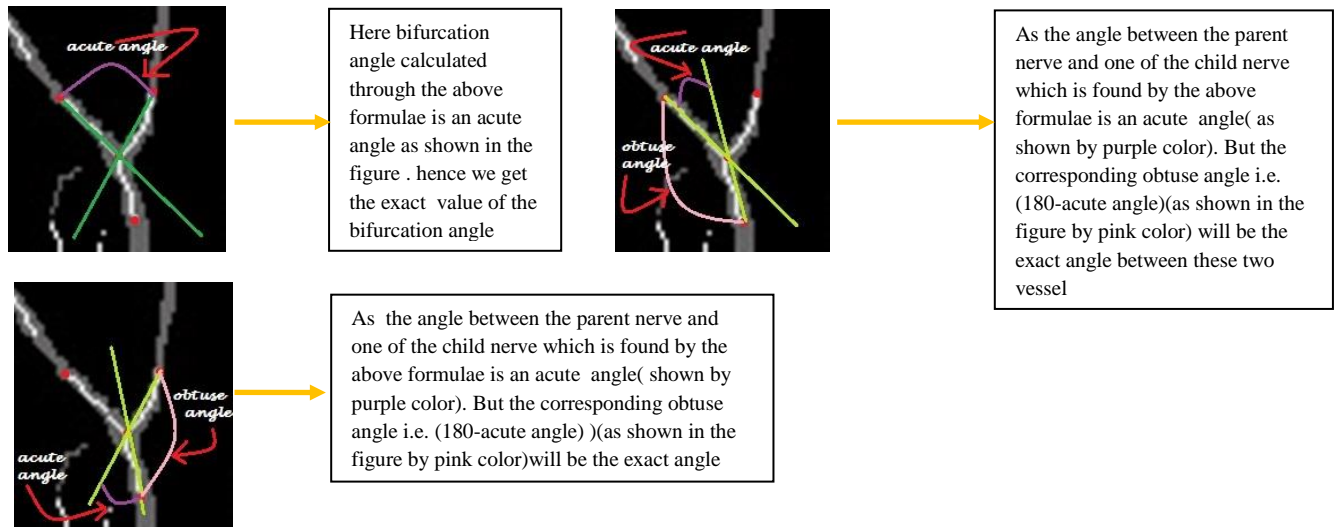
#### Steps :

Thinned image of the input segmented image was obtained with the help of matlab defined function `bwmorph` with the operation 'thinning'.

Around each bifurcation point , in the thinned image a 3X3 window is taken and whenever a white pixel is found , that pixel is being made as the current pixel to find the next neighborhood pixel , at the same time the previously traversed pixel in the thinned image is removed to indicate that this pixel has been traversed. This process is repeated until 18 pixel from the bifurcation point has been traversed for both three branches. Result will give one distinct point on each of the parent nerve and both the child nerves generated from the bifurcation point.

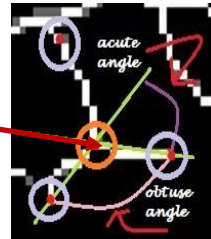
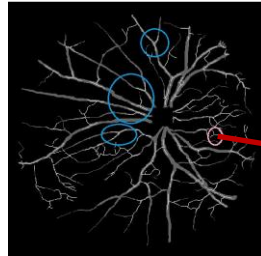
Thus, three distinct point were found out and three tangent were drawn along the three branches using the formulae  $m = \tan\theta = (y_1 - y_2)/(x_1 - x_2)$  where  $(x_1, y_1)$  is the bifurcation point and  $(x_2, y_2)$  is one of the three point found by the previous algorithm and  $m$  is the gradient of the tangent.

Then the angle between three angle were calculated using the formulae  $\theta = \tan^{-1}((m_1 - m_2)/(1 + m_1 * m_2))$  where  $\theta$  is the angle of two tangent,  $m_1$  and  $m_2$  are the gradient of two tangent respectively.

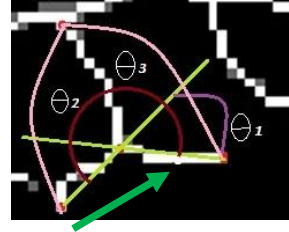


Hence, by using above formulae for finding the angle, three acute angles will be always obtained such that bifurcation angle will be > other two angle as shown in the figure .hence first of all the absolute value of the three angles were calculated .Then the maximum acute angle was considered as the bifurcation point( $\theta_1$ ). Next for other two angles , say  $\theta_2$  and  $\theta_3$  corresponding obtuse angles are found i.e.  $\Theta_2 = 180 - \theta_2$  and  $\Theta_3 = 180 - \theta_3$ . Hence the minimum of these three angle is the bifurcation angle and it satisfies the rule i.e.  $(\theta_1 < \theta_2 + \theta_3)$

### FOR DISTORTED BIFURCATION ANGLE:



$$(\theta_1 + \theta_2 + \theta_3) < 360$$



value of the bifurcation angle is calculated by the above formulae will be the acute angle (shown by purple color in the figure 5) between the two child nerve. Now sum of the three angles ( $\theta_1 + \theta_2 + \theta_3$ ) which are calculated by the above procedure (as shown in the figure : 6 with maroon color) is not equal 360 . hence we can conclude that it is a distorted bifurcation point .

Since, it is a distorted bifurcation point (i.e. bifurcation angle  $> 90$ ) as shown in figure 6 , in order to find out the exact bifurcation angle corresponding obtuse angle ( as shown in the figure:5) between two child nerve is to be taken i.e. (180-acute angle)

Hence, according to the previous analysis sum of the three angle ( $\theta_1 + \theta_2 + \theta_3$ ) is not equal to 360 then it indicate that the bifurcation angle which was taken by the previous process is an acute angle , but in real corresponding obtuse angle is the exact bifurcation angle . Distortion in bifurcation point causes the above scenario as shown in figure . hence 180-(bifurcation angle found previously) will be the actual bifurcation angle. Hence the minimum of these three angle is the bifurcation angle and it satisfies the rule i.e. ( $\theta_1 < \theta_2 + \theta_3$ ). This bifurcation points can be recognized as distorted bifurcation too.

## 3.8 GENERATION OF BIOMETRIC TEMPLATE

Retinal biometrics, being considered as one of the most reliable biometrics among all , using the unique biometric features of the retinal image , we have generated a 96 bytes template which will used as the main authentication key for proposed biometric security system.

Image captured from different angle may lead to even authentication failure. In the proposed system this problem can be resolved as the relative features of different biometric parameters of retinal images will be considered.

**A 96 bytes template has been generated by extracting following different features from the retinal colored image.**

- Relative distance between center of the optic disc and macula
- Distinct bifurcation points
- Bifurcation angle at every distinct bifurcation points

All this features have been concatenated to generate the secured 96 bytes template.

## 4. EXPERIMENTAL RESULT AND ANALYSIS

### 4.1 EXPERIMENTAL SETUP

To evaluate the performance of the proposed system experiments have been conducted base on the DRIVE[2] and VARIA[3] database. The photographs for the DRIVE database were obtained from a diabetic retinopathy screening program in The Netherlands. Each image was captured using 8 bits per color plane at 768 by 584 pixels. For the training images, a single manual segmentation of the vasculature is available. For the test cases, two manual segmentations are available; one is used as gold standard, the other one can be used to compare computer generated segmentations with those of an independent human observer. The VARIA database is a set of retinal images used for authentication purposes. The database currently includes 233 images, from 139 different individuals. The images are optic disc centered with a resolution of 768x584[3].

### 4.2 PERFORMANCE EVALUATION METRIC

**Evaluation Parameter:** To evaluate the proposed algorithm manually following parameters are defined in order to compare the results from the algorithm with other algorithms.

- **TP (true positive):** This refers to the pixels of the blood vessels that are correctly recognized by the algorithm. Let TP denotes the number of true positives.
- **FP (false positive):** This refers to the pixels of the blood vessels that are incorrectly recognized as positive pixels by the algorithm. Let FP denotes the number of false positive.
- **TN (true negative):** This refers to the pixels of the blood vessels that are correctly discarded by the algorithm. Let TN denotes the number of true negative.
- **FN (false negative):** This refers to the positive pixels of the blood vessels that were mislabeled as negative pixels by the proposed algorithm. Let FN denotes the number of false negative.

**TPR, FPR, TNR and FNR** are the other parameters which are also used in evaluation process are defined as follows.

- **TPR (true positive rate):** It is the ratio of the true positives to all pixels belonging to blood vessels. This is also called **SENSITIVITY**.

$$\begin{aligned}\text{Sensitivity} &= (\text{Number of true positive}) / (\text{Number of true positives} + \text{Number of false negative}) \\ &= TP/P \\ &= (TP) / (TP+FN)\end{aligned}\tag{4}$$

- **TNR (true negative rate):** It is the ratio of the false positives to all the pixels that do not belong to the blood vessels. This is also known as **SPECIFICITY**.

$$\begin{aligned}\text{Specificity} &= (\text{Number of true negatives}) / (\text{Number of true negatives} + \text{Number of false positives}) \\ &= TN/N \\ &= (TN) / (TN+FP)\end{aligned}\tag{5}$$

- **FPR (false positive rate):** It is the ratio of false positive to all the pixels that do not belong to the blood vessels. This is also known as fall-out.

$$\begin{aligned}\text{Fall-out} &= (\text{Number of false positive}) / (\text{Number of true negatives} + \text{Number of false positives}) \\ &= FP/N \\ &= FP / (TN+FP)\end{aligned}\tag{6}$$

- **FNR (false negative rate):** It is the ratio of false negative to all the pixels belonging to the blood vessels.

$$\begin{aligned}\text{FNR} &= (\text{Number of false negative}) / (\text{Number of true positives} + \text{Number of false negative}) \\ &= \text{FN}/\text{P} \\ &= \text{FN}/(\text{TP}+\text{FN})\end{aligned}\tag{7}$$

Using the above parameters, accuracy of the proposed algorithm has been calculated.

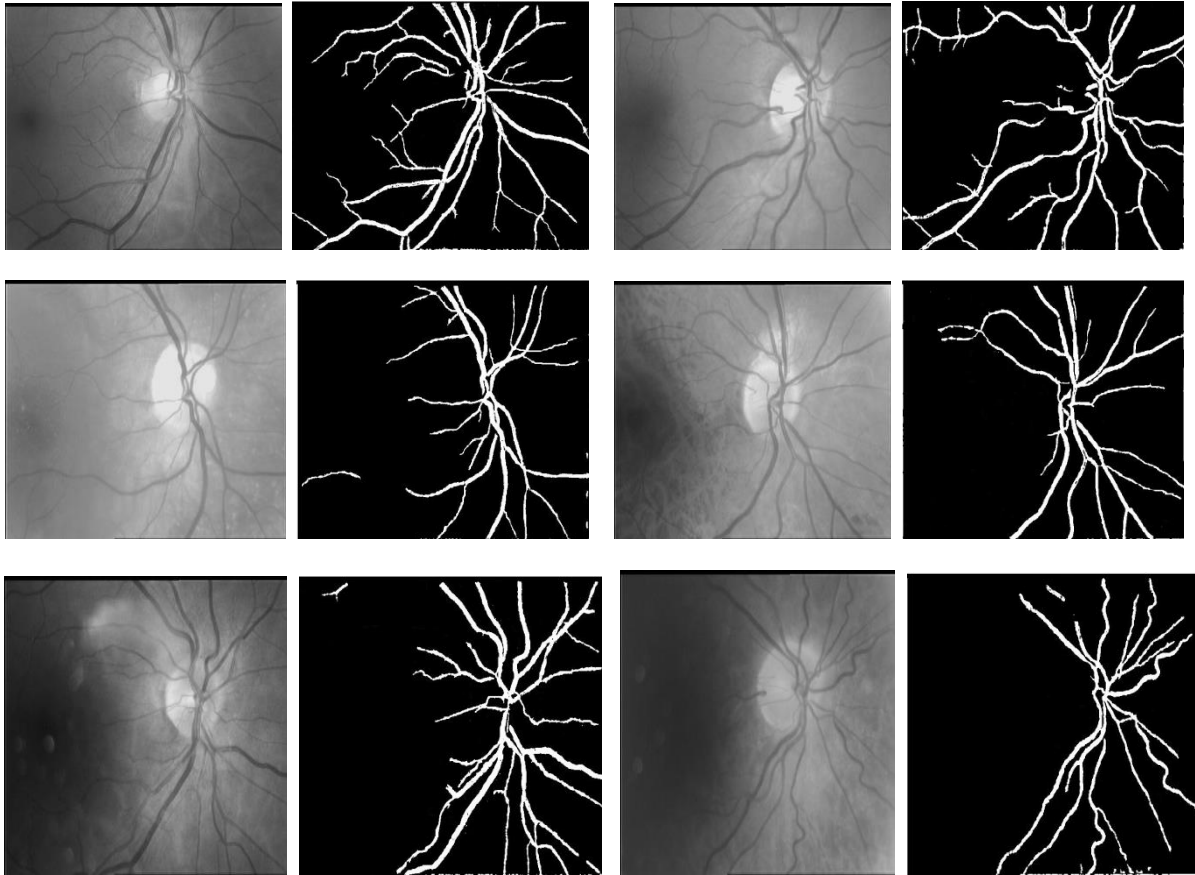
- **Accuracy:** it is a description of systematic errors, a measure of statistical bias. Accuracy of the algorithm is defined as

$$\begin{aligned}\text{Accuracy (ACC)} &= (\sum \text{True Positive} + \sum \text{True Negative}) / \text{Total population} \\ &= (\text{TP} + \text{TN}) / (\text{TP} + \text{FN} + \text{TN} + \text{FP})\end{aligned}\tag{8}$$

## 4.3 RESULTS:

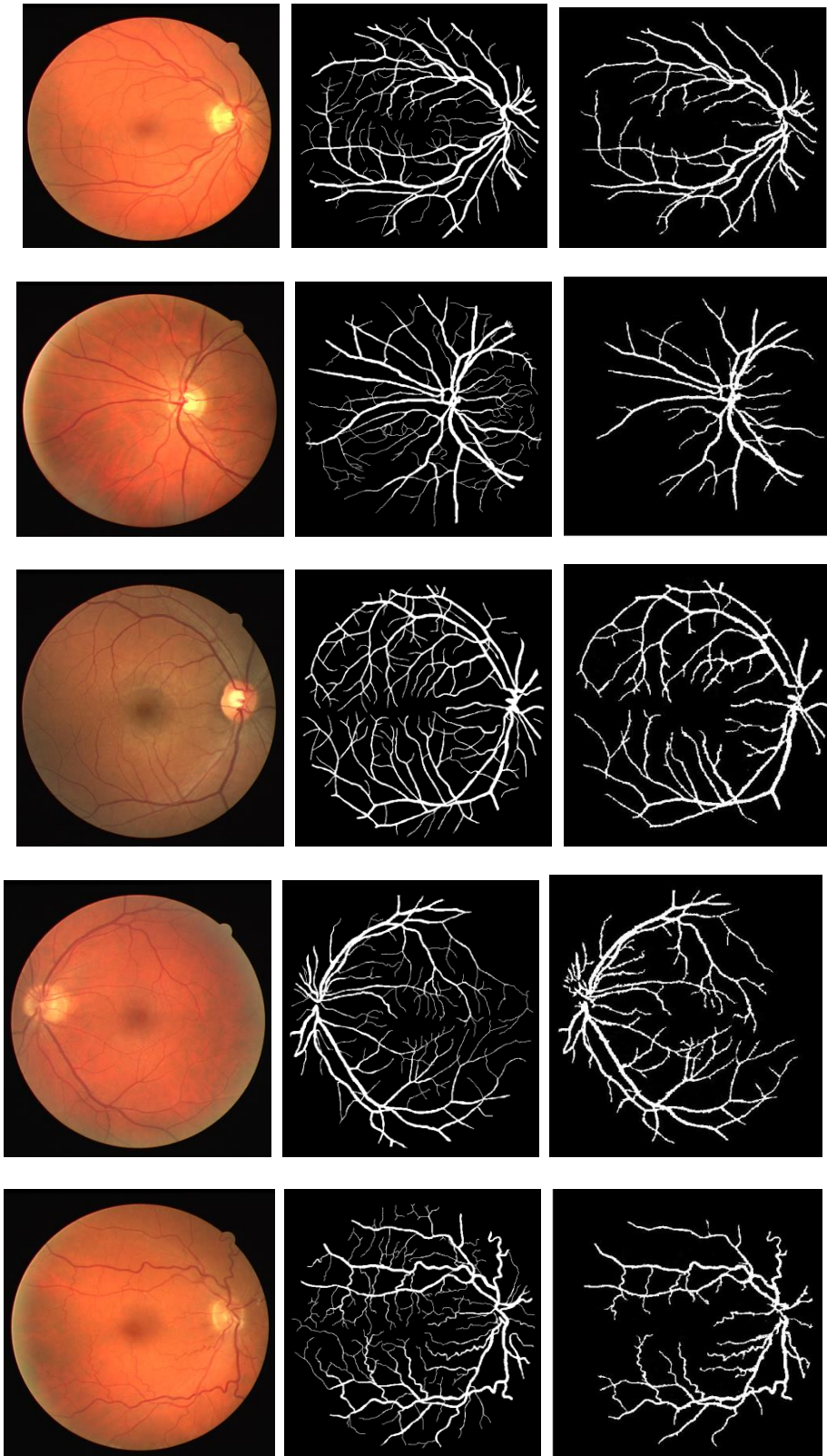
### 4.3.1 RESULTS OF BLOOD VESSELS SEGMENTATION

#### 4.3.1.1 VARIA SEGMENTATION :

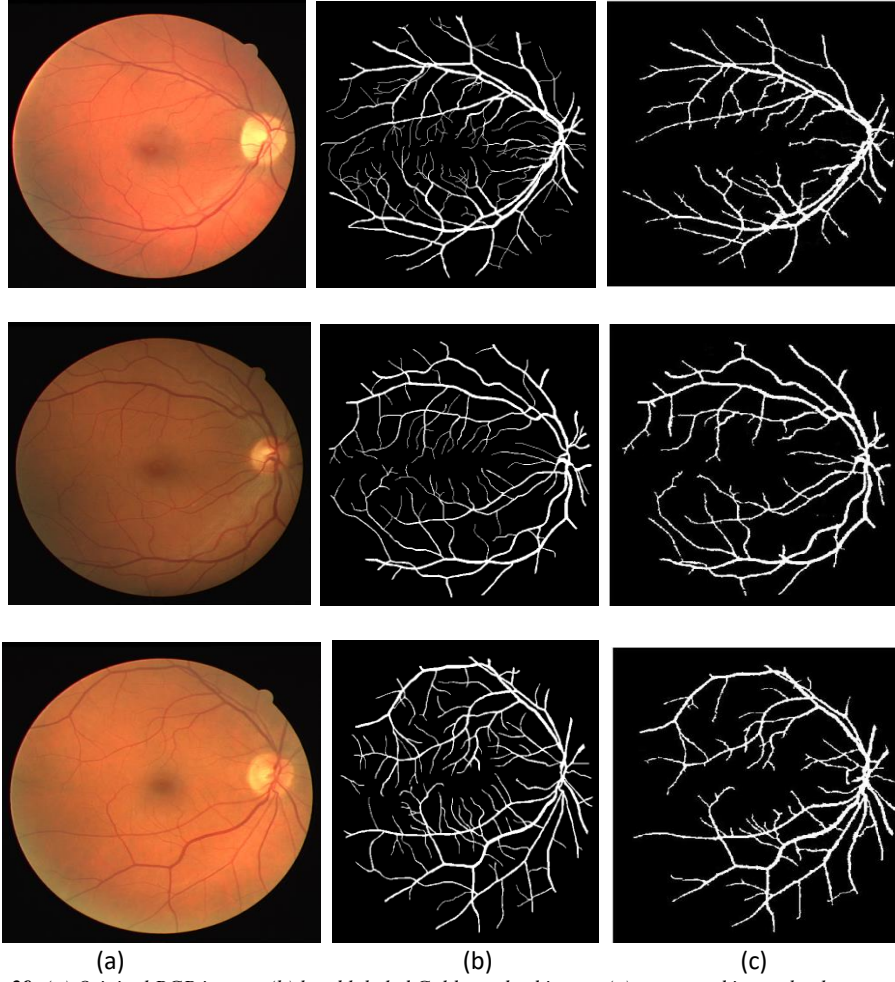


**Figure 28:** original gray scale image & its segmented image(image pair left to right)

#### 4.3.1.2 DRIVE SEGMENTATION :

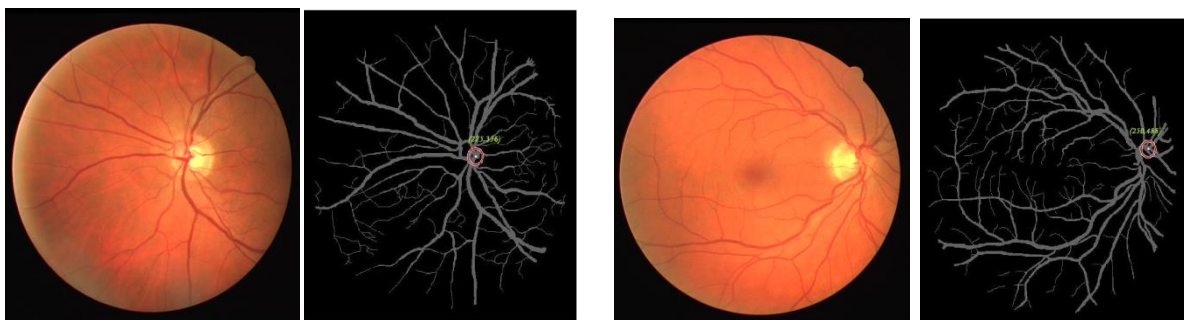




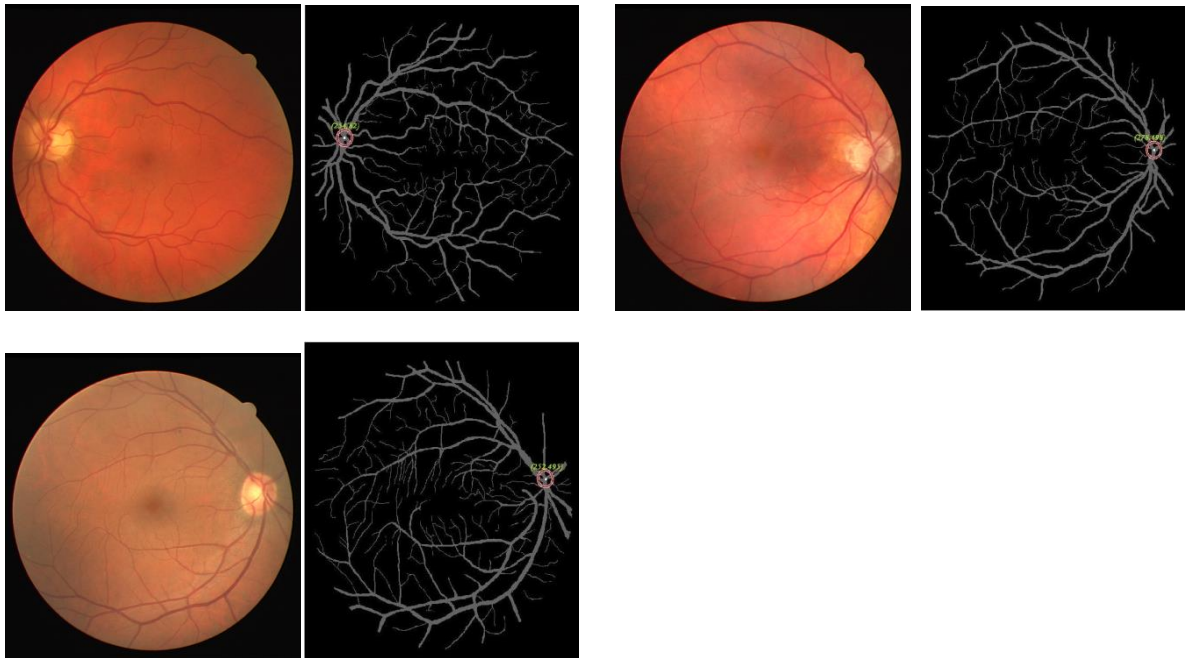


*Figure 29: (a) Original RGB image , (b) hand labeled Gold standard image, (c) segmented image by the proposed method*

#### 4.3.2 RESULTS OF LOCALIZATION OF OPTIC DISC

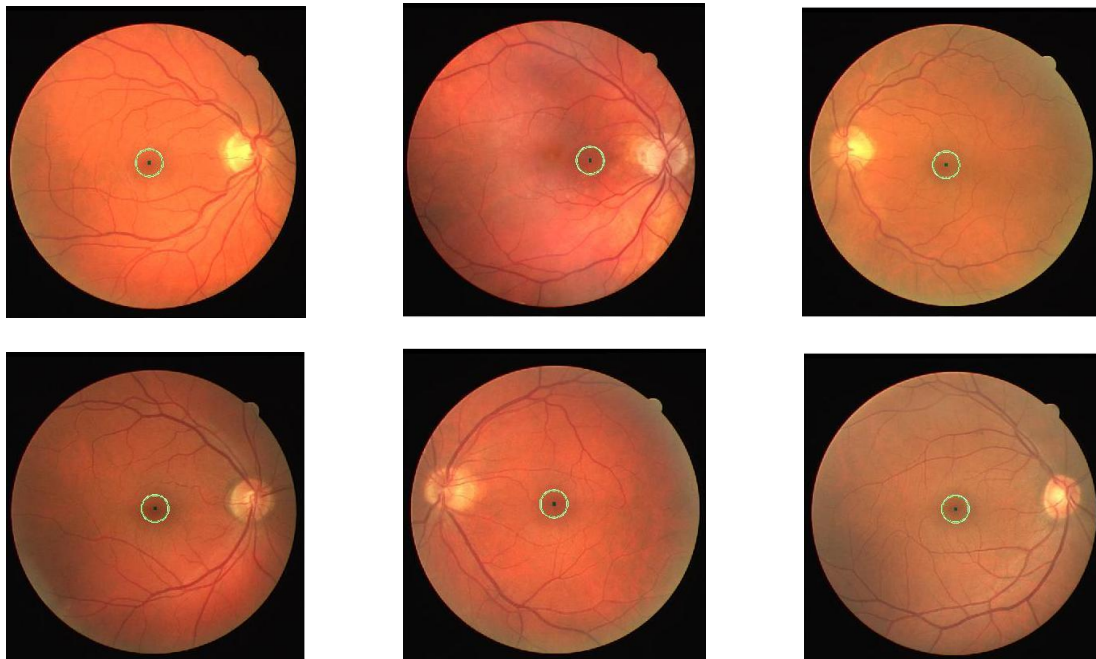






*Figure 30:(a) original rgb image,(b)image showing OD localized on segmented image.*

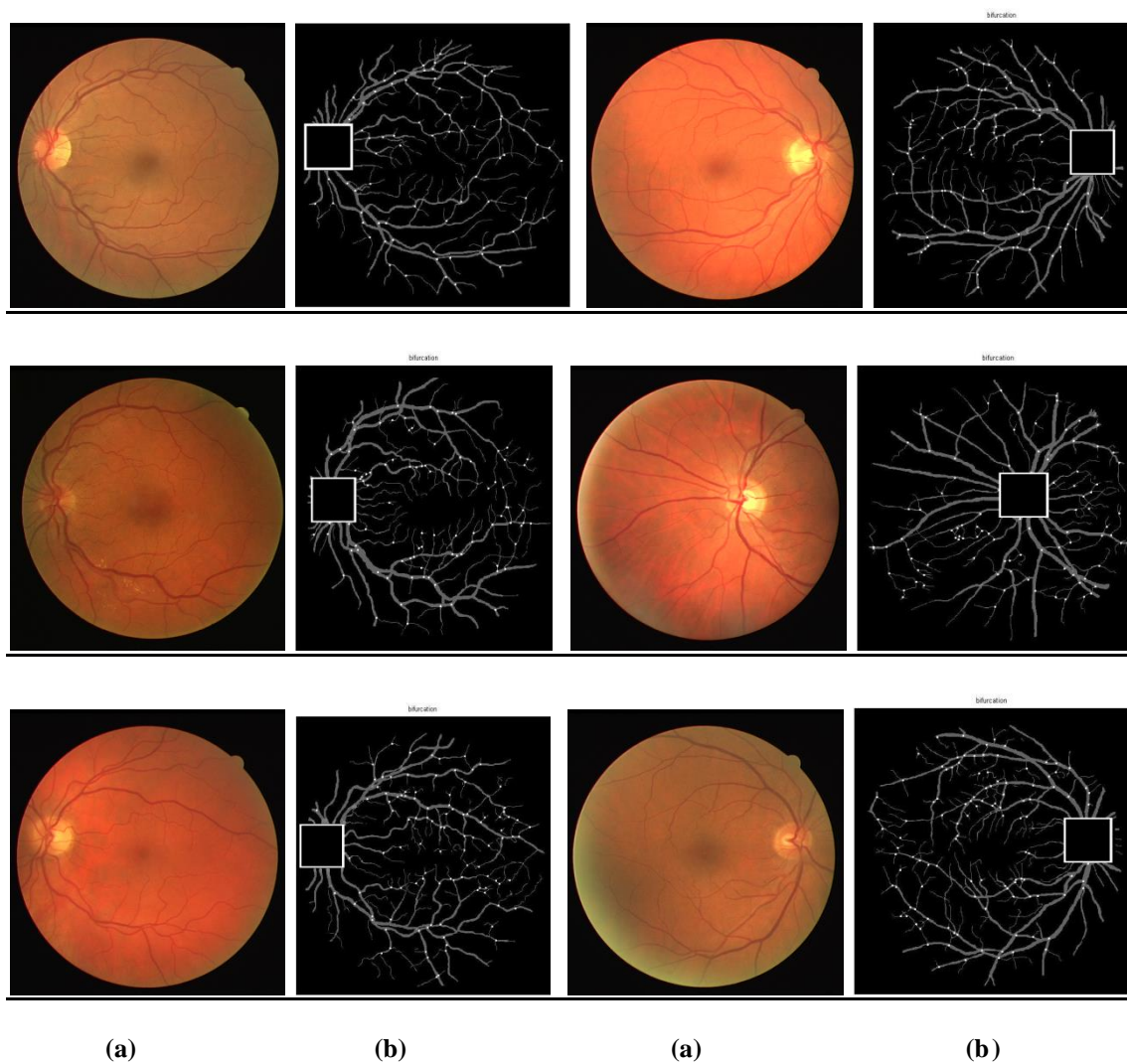
### 4.3.3 RESULTS OF MACULA





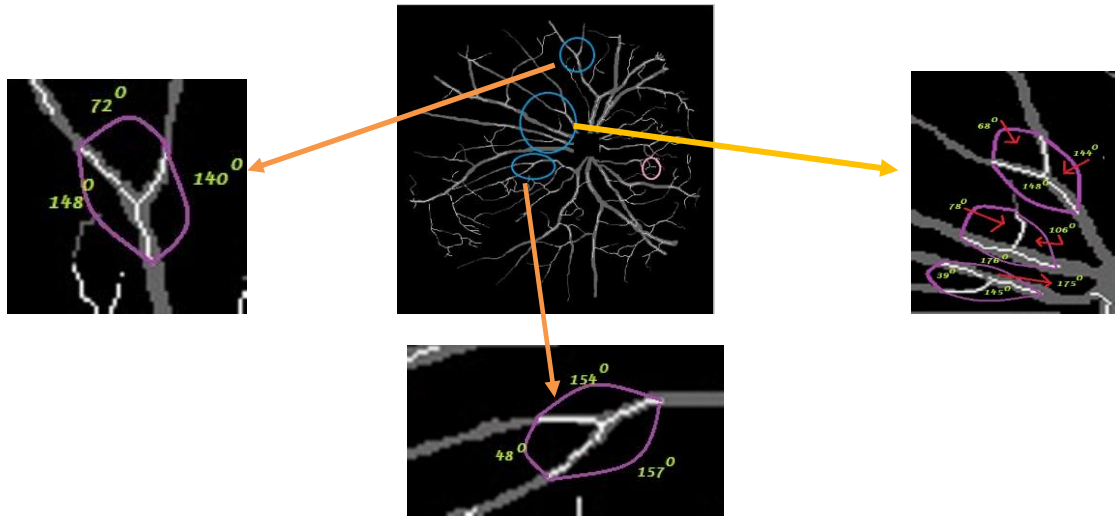
**Figure 31:**image showing localized macula in original rgb image.

#### 4.3.4 RESULTS OF BIFURCATION POINTS



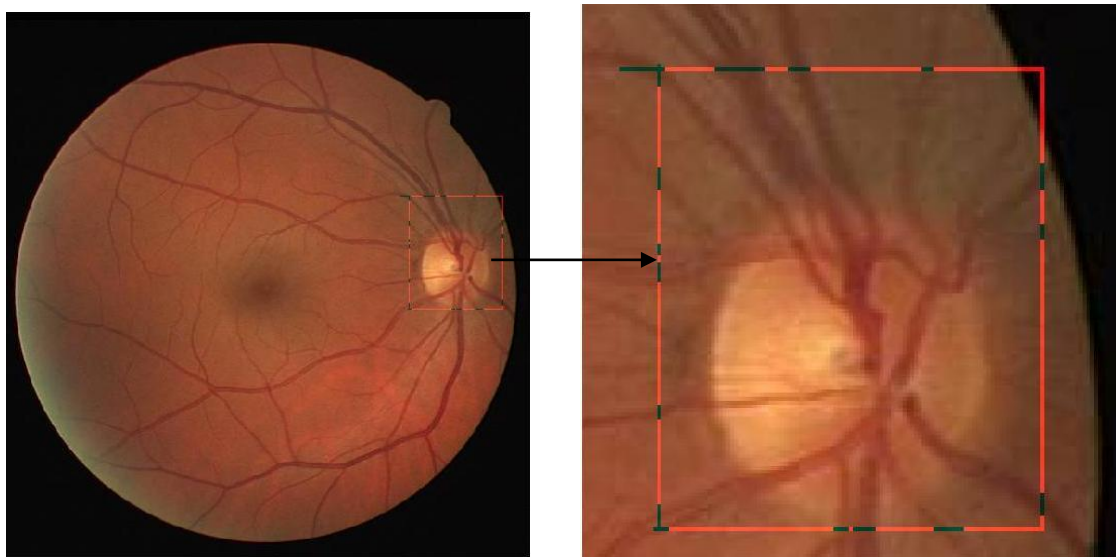
**Figure 32** (a) original rgb image,(b) image showing bifurcation point detected

#### 4.3.5 RESULTS OF BIFURCATION ANGLE



*Figure33 : image showing the all three angles including bifurcation angle at bifurcation point.*

#### 4.3.6 RESULTS OF NO OF MAJOR BLOOD VESSELS AROUND THE OPTIC DISC



*Figure 34 images showing the major blood vessels around the optic disc and distance between each consecutive blood vessels(vessel width is shown by green line and distance between the vessels is show by red line)*

## 4.3.7 DATABASE

### 4.3.7.1 DATABASE(CENTER OF OPTIC DISC OF THE IMAGES ON DRIVE DATABASE)

**TABLE 1**

image no	optic disk(X)	optic disk(Y)
1	268	80
2	250	488
3	289	82
4	275	356
5	265	67
6	277	465
7	278	498
8	258	493
9	264	77
10	267	498
11	264	58
12	275	70
13	249	507
14	283	483
15	253	212
16	274	478
17	256	474
18	249	503
19	258	486
20	268	493
21	264	54
22	255	466
23	269	424
24	287	480
25	250	469
26	249	75
27	263	495
28	250	488
29	277	506
30	281	504
31	260	367
32	286	494
33	253	365
34	264	370
35	293	75

36	250	401
37	292	503
38	250	502
39	269	82
40	282	478

#### 4.3.7.2 DATABASE(DISTANCE BETWEEN THE CENTRE OF THE OPTIC DISC AND MACULA CENTRE)

**TABLE2**

image No      optic disc centre      macula centre distance

1			(268,80)	(293,282)	203
2			(250,488)	(294,272)	220
3			(289, 82)	(293,291)	209
5			(265, 67)	(293,282)	217
6			(277, 465)	(294,288)	178
7			(278, 498)	(291,357)	140
8			(258, 493)	(303,286)	212
9			(264,77)	(298,282)	208
10			(267,498)	(295,285)	215
11			(264,58)	(291,281)	225

#### 4.3.7.3 LOCATION OF OPTIC DISC AND CALCULATION OF NO OF BLOOD VESSELS AROUND IT

##### 4.3.7.3.1 ( DRIVE DATABASE)

image no	optic disk	optic disk	vessel count
1	268	80	14
2	250	488	12
3	289	82	16
4	275	356	13
5	265	67	10
6	277	465	12
7	278	498	16
8	258	493	16
9	264	77	14
10	267	498	13
11	264	58	10
12	275	70	12
13	249	507	14
14	283	483	13
15	253	212	12

#### 4.3.7.3.2 (VARIA DATABASE)

imageno	optic disc(X)	optic disc(Y)	vessel count
1	258	465	16
2	272	565	15
3	327	543	12
4	313	442	8
6	255	543	8
7	289	488	15
13	279	458	16
14	303	548	10

#### 4.3.7.4 VESSEL WIDTH AROUND THE OPTIC DISC

##### 4.3.7.4.1 (DRIVE DATABASE):

TABLE 3

img	w1	w2	w3	w4	w5	w6	w7	w8	w9	w10
1	3	4	7	9	12	6	2	2	3	4
2	2	5	11	10	6	6	6	5	8	6
3	5	7	5	4	3	11	9	2	22	2
5	7	3	10	16	5	4	3	3	7	8
6	2	4	3	8	16	3	1	11	10	6

#### 4.3.7.4.2 (VARIA DATABASE):

**TABLE 4**

img no	w1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w11	w12	w13	w14
1	8	11	12	8	14	2	1	1						
3	3	5	2	5	2	12	4	3	16					
6	4	10	6	3	9	8	6	12	7					
9	7	11	5	12	13	9	12	15	26					
13	1	5	11	14	11	9	1	6	20	7	4	15	12	4
14	5	15	7	5	13	9	7	3						
19	2	7	3	8	8	15	10	8	7					

\* w stands for width of a vessel

#### 4.3.7.5 TEMPLATE(96 BYTES)

**TABLE 5**

IMAGE NO	TEMPLATE
1	822472056429849882648499404871002471081012488410324059104204771042411510524490109389117115226751
2	484248217493026060191287522188823937985242921022836011934881223005126207112136232931403294314333
3	712982198529510799186569935056101229541082636511618667118137771181841031201855812313011112527697
5	672662177725455102173491062346010922925110238117113233571143517212531078128193101131191771471692
6	470255186552246379303769622744962645898293871012137610121870101220651032199211139159112413191152
7	483252131732364381198608120411384346909240357100359661033176611733894131102941344528214036847144
11	632542214820876541899554200108572005566378506817127701732974396297539759784032180156278115572844
12	892631953525669702559089352889023262102269811213737713415277143147941463671081571434017011986176
16	491272199463065748317149315205031636601938365344146634537673444988211819837658983872410138253104
18	478278190704036871384997338695743577374363427823773782397980383948320457121407901461556415690861
22	471284190543204910332982128384881374916313910093155379721563809616821569169206101170385621722309
24	481287200612986665306197033067731833678248838015675833047792209809221162933205499331104100220102
26	742482134632372692444372240729738771104140631053299512529582155809317226981839789184275961873525
27	500283221382917655251851031629011819241201948134229881362161041439841162202701623375616718999183
28	486269198533019355265665925510261218118612215785195778733697923399094339711530386120252761213497
29	505289226803249694333131134477212028284129361771333575614738491624357019946282022779621345242192
30	469263185803606085365958626447983167010129851102305109104218461093106810944286112195461604166917
32	484262203109247731113679411637431117267531193821412028563123381512740165143125661574135619522310
33	466337986523993782225585316178831947933296398417801073109411536119122375391272417812837751137386
35	782662095220374862636089429459531380962568110317910810419289104269791053282510533089106122681072
37	510282225733515990141699042163912799212019090121189921223588912617088127351701291907134313371463

## 4.4 ANALYSIS

### 4.4.1 BLOOD VESSEL SEGEMENTATION

#### 4.4.1.1 PROPOSED METHOD(APPLIED ON DRIVE DATABASE)(TABLE 6)

Image sequence	Sensitivity	Accuracy (%)
1	0.944	97.44
2	0.985	98.50
4	1	97.23
12	0.944	96.44
16	1	96.11
19	0.933	96.33
22	0.9167	98.61
27	1	96.90
36	0.928	97.47
40	1	98.33
<b>Average</b>	<b>0.95897</b>	<b>97.33</b>

#### 4.4.1.2 COMPARISION WITH OTHER SEGMENTATION ALGORITHMS(TABLE 7)

Methodology	Sensitivity(TPR)	Accuracy (%)
Human Observer	0.7763	94.70
Mendonca et al. [4]	0.7344	94.63
Niemeije et al. [5]	0.7145	94.16
Proposed method	0.9589	97.33

### 4.4.2 DISTINCT BIFURCATION POINTS IDENTIFICATION

#### 4.4.2.1 PROPOSED METHOD(TABLE 8)

Parameters	Image 12	Image 26	Image 19	Image 3
Actual bifurcations present	73	64	42	84
Detected bifurcation points	75	63	42	83
Correctly detected points	73	63	41	83
Bifurcation points not detected	0	1	1	1
Incorrect	2	0	0	0
Sensitivity	1	1	.976	.988
Specificity	0	0	0	0
Acuuracy	97.33%	98.41%	97.6%	98.8%

#### 4.4.2.2 OVERALL PERFORMANCE OF BIFURCATION POINT DETECTION ALGORITHM(TABLE 9)

Database	Sensitivity	Specificity	ROC	Accuracy
DRIVE	0.98	0	0.9882	98.8%



## 5. CONCLUSION:

### 5.1 SUMMARY

A novel framework is proposed for autonomous biometric authentication system in which biometric retinal template is generated by extracting different unique features from the retina like optic disc center, centre of macula, bifurcation points, bifurcation angles etc. The performance of the proposed system is reasonably good and comparable with existing algorithms. We have proposed a novel method to detect the exact location of optic disc i.e., root pixel which will also be used as one of the unique biometric feature of the retinal image for the generation of template. An automatic and efficient detection of it plays a significant role for various reasons, like to locate other anatomical components in retinal images, for vessel tracking to diagnose many eye diseases even related to Diabetes and for registering the image for personal authentication. Also, the position of Optic Disc can be used as a reference length for measuring distances in retinal images, especially from the location of macula. Keeping the importance of finding Optic Disc in mind, we have taken an initiative to locate an exact point, probably the center of it within the white bright region called Optic Disc. This work will count and keep track of the number of normal vessels around the around the optic disc. In this way, we may define a general statistics of the number count of blood vessels in a healthy human eye. The width of the vessels around the optic disc has been calculated which will help the ophthalmologists for earlier detection of the PDR. In future, we will concentrate on finding out other biometric feature for the template generation. Detection of only bifurcation points in a fundus image is a challenging task in true sense. The purpose of the work aims to avoid numerous unnecessary hazards of appraising crossover points as one of the crucial feature for authentication. Most of the literature show the crossovers as their reliable authentication parameter. But in contrary, image capturing should always be from a fixed location and angle to avoid non-identification of the authentic source. Moreover, the patients suffers from diseases like hypertension, cardiovascular diseases and type II diabetes, often experience the change in crossover points of their retina which further increases the possibility of True Negative (TN) factor in authentication process. So to focus on only bifurcation point which is anatomically stable and never changes is an important issue. We have tried to accomplish this work successfully and acquired a satisfactory result. But, due to inadequacy of real data, we have done the experiments in an available database named DRIVE.

### 5.2 PUBLICATIONS

1. **TITLE:** “Extraction of distinct bifurcation points from retinal fundus image”  
**PUBLICATION:** Springer AISC Series  
**AUTHORS:** Nillanjana Dutta Roy, Dr. Arindam Biswas, Suchismita Goswami, Sushmita Goswami, Sohini De
2. **TITLE:** “Automatic measurement and analysis of vessel width in retinal fundus image”  
**PUBLICATION:** Springer AISC Series  
**AUTHORS:** Sushmita Goswami, Suchismita Goswami, Sohini De

### 5.3 LIMITATION & FUTURE WORKS

We plan to improve the accuracy, complexity, efficiency, execution time of the algorithms. We will try to publish papers on segmentation of the blood vessels, localization of the optic disc and localization of the macula. We will integrate this software with hardware to develop a secured biometric authentication system. We plan to continue testing of the existing modules for this domain as well as future development of our proposed framework to obtain more promising results.

## **Reference:**

1. Sourav Saha, 2 Nilanjana Dutta Roy, AUTOMATIC DETECTION OF BIFURCATION POINTS IN RETINAL FUNDUS-IMAGES , International Journal of Latest Research in Science and Technology , March - April (2013) , Volume 2, Issue 2 :Page No.105-108 .
2. The DRIVE database, Image sciences institute, university medical center utrecht, The Netherlands.  
<http://www.isi.uu.nl/Research/Databases/DRIVE/> last accessed on 7th July 2007.
3. VARIA Database, Department of Computer Science of the the University of Corua,  
<http://www.varpa.es/varia.html>
4. A New and Efficient Method for Automatic Optic Disc Detection Using Geometrical Features , World Congress on Medical Physics and Biomedical Engineering, September 7 - 12, 2009, Munich, Germany  
Volume 25/4 of the series IFMBE Proceedings pp 1131-1134, publication: Springer.
5. B. JL. "Photo physical Processes in Recent Medical Laser Developments". Lasers Med Sci., vol. 1, pp.47-66. 1986.
6. B. GM. "Lasers in Medicine and Surgery", JAMA, vol. 256, pp. 900-907, 1986
7. Toliaas YA, Panas SM. A fuzzy vessel tracking algorithm for retinal images based on fuzzy clustering. IEEE Trans Med Imaging 1998; 17:263-273
8. Mendonça AM, Campilho A. Segmentation of retinal blood vessels by combining the detection of centerlines and morphological reconstruction. IEEE Trans Med Imaging. 2006; 25(9):1200–1213. doi: 10.1109/TMI.2006.879955.
9. I. M. Ortega, C. Marino, M.G. Penedo, M. Blanco, F. Gonzalez, "Biometric authentication using digital retinal images", Proceedings of the 5th WSEAS International Conference on Applied Computer Science, Hangzhou, China, April 16-18, 2006 (pp 422-427)
10. C. Marino, M. G. Penedo, M. Penas, M. J. Carreira, F. Gonzalez, "Personal authentication using digital retinal images", Pattern Analysis and Applications, May 2006, Volume 9, Issue 1, pp 21-33
11. K. Saraswathi, B. Jayaram, Dr. R. Balasubramanian, "Retinal Biometrics based Authentication and Key Exchange System", International Journal of Computer Applications (0975 8887), Volume 19 No.1, April 2011
12. Alauddin Bhuiyan, Baikunth Nath, Joselito Chua and Kotagiri Ramamohanarao, "Automatic Detection of Vascular Bifurcations and Crossovers from Color Retinal Fundus Images", Third International IEEE Conference on Signal-Image Technologies and Internet-Based System, SITIS 2007, Shanghai, China, December 16-18, 2007, IEEE Computer Society 2007, ISBN 978-0-7695-3122-9
13. 4. A. Perez-Rovira, R. Cabido, E. Trucco, S.J. McKenna: "Robust Efficient Registration via Bifurcations and Elongated Elements Applied to Retinal Fluorescein Angiogram Sequences", In : Medical Imaging, IEEE Transactions, Volume:31
- 14 J. Hjek and M. Drahansk and R. Drozd: Extraction of Retina Features Based on Position of the Blood Vessel Bifurcation. In: 5th WSEAS International Conference on Applied Computer Science, pp. 422-427, Hangzhou, China (2006)
15. G. Kavitha ,S. Ramakrishnan: Identification and analysis of macula in retinal images using Ant Colony Optimization based hybrid method. In : Nature & Biologically Inspired Computing, 2009. NaBIC 2009. World Congress on, DOI:10.1109/NABIC.2009.5393783, pp. 1174 - 1177, ISBN:978-1-4244-5053-4, IEEE .