SEGMENTATION OF RETINAL VASCULATURE USING CONTOURLET ENHANCEMENT FOR EARLY DETECTION OF DIABETIC RETINOPATHY

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CERTIFICATION OF APPROVAL

SEGMENTATION OF RETINAL VASCULATURE USING CONTOURLET ENHANCEMENT FOR EARLY DETECTION OF DIABETIC RETINAPTHY

by

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Approved:

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Signature: .....

Name: AHMAD ALIFF B. ABD GHANI

ABSTRACT

Diabetic Retinopathy (DR) is a common problem among diabetic patient and one of the most leading causes for blindness. This eye disease results from changes or damage in eye blood vessels. The blood vessel may swell and leak fluid or abnormal new blood vessels grow on the surface of the retina. Without early detection and treatment this disease can cause permanent blindness to the patient. An image processing technique is required to analyze and interpret retina image (fundus) to examine the retina blood vessel to determine the severity of DR and any other eye disease. Detection of retina vasculature is achieved by image enhancement using contourlet transform or enhancement. In this project we use contourlet transform rather than wavelet transform because the contourlet transform was proven to require less number of coefficient compared to wavelet and contourlet also have the ability to detect directional signal. The enhanced blood vessel will be extract by BottomHat. This transformation works by isolating dark object on light surrounding. Last step is to perform vessel reconstruction. This step must be done to cover BottomHat weakness by causing blood vessel intersection point weakly being highlighted. Final input image of this reconstruction is a binary image. Overall algorithm takes just 3-4 minutes depending on size of image and variable coefficient such as region growing threshold and contourlet threshold.

ACKNOWLEDGMENT

Final Project has been such a challenging yet satisfying experience for me as the author myself. First of all, I am grateful for Al-Mighty for giving me the opportunity and strength to finish this course. I would like to show my sincere appreciation to the project supervisor, Pn Lila Iznita Izhar and Dr Aamir Saeed Malik for helping me throughout this project. I would also like to express my gratitude to my colleagues who had helped me giving ideas and support me accomplish this project. I would also love to mention my deep appreciation towards Department of Electrical & Electronic Engineering of Universiti Teknologi PETRONAS for their research facility. Also not forgotten to all researchers which their early project helps contributing the succes of this final year project. Last but not least, I would like to thank my family for their support in helping me to keep focus and being responsible in order to finish his project.

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ABBREVIATIONS

DR	Diabetic Retinopathy
FOZ	Foveal Avascular Zone
FA	Fluorescein angiogram
SE	Structuring Elements
SRG	Seed Region Growing
GRG	Gradient Region Growing

CHAPTER 1
INTRODUCTION

1.1 Background of Studies

Medical image enhancement has been an area of studies for a long time. Researches nowadays aimed to improve image enhancement system to produce much higher quality image. As the time grows, the needs for precise and accurate image processing system has increase in order to avoid any machine or human error in determining the symptom of a disease so doctors can interpret the level of infection. This is very important to avoid any fatal mistake by giving wrong treatment or advice to the patient.

Diabetic eye disease refers to a group of eye problems that people with diabetes may face as a complication of diabetes [2], in this case of studies we will focus on one of the eye problem that is Diabetic Retinopathy (DR). There are two cases in DR one is where the blood vessel swell and leak fluid. The other one is where abnormal blood vessels grow on the surface of retina. Retina is an area in the eye that is sensitive of light, a healthy retina was required to produce good image [2]. In Malaysia, about 30% of the diagnosed diabetic population in 1996 has retinopathy and each year the 1% developed sight threatening retinopathy [3]. It is believed that visual loss resulting from DR can be prevented by a periodic medical check up this can reduce the number of blindness in diabetic patient by 50% [4]. Prevention is better than cure is the best phrase in this situation considering the cost for blind person to see again using latest technology compared to early treatment cost of the disease [5].

1.2 Problem Statement

Analyzing and interpreting fundus image is necessary and important to diagnostic procedure in ophthalmology. Width changes of blood vessel in retina can be indicative or DR risk[2]. Image of these blood vessels in retina must be as accurate as possible to avoid diagnostic mistake. Early stage of DR such as non-proliferative DR and proliferative DR causes enlargement of foveal avascular zone (FAZ) resulting from loss of capillaries in the perifoveal capillary network. We need to determine and analyze FAZ because early detection may prevent the progress of the disease and save the patient from blindness. Ophthalmologists currently have to compare sets of fundus image taken from the patient with gold standard image in order to measure the level of enlargement of FAZ. A good image enhancement algorithm is needed to enhance the low contrast image and to identify a very small thickness of blood vessel in the eye. The system will provide image that is clear and accurate in order to easily interpret the level of DR patient currently in. This system also aims to reduce the operational cost because it does not require an ophthalmologist to perform the grading. Second is reducing fundus image screening time by interpreting DR feature effectively. Third increase the accuracy of the grading by using computer to process the fundus image.

1.3 Objective

This project objective is to produce a system to monitor and grading DR based on fundus image. There are three approaches in order to achieve the objective, 1) Enhancement of blood vessel using contourlet transform 2) Segmentation of blood vessel. 3) Reconstruction of blood vessel.

1.4 Scope of Work

This project mainly based on digital image processing where a series of program or algorithm will be written to extract and reconstruct fundus image in order to analyze FAZ. This system must be sensitive enough to detect thin blood vessel such as capillaries with width of 1 pixel. The imaging function used to process image range from image conversion, smoothing operation, geometrical operation, contourlet transform, noise removal and region growing. This image processing tool is built using MATLAB 7 image processing toolbox.

CHAPTER 2
LITERATURE REVIEW

2.1 Diabetic Retinopathy

Diabetic retinopathy is caused by complications of diabetes mellitus that cause damage to the retina, which can eventually lead to blindness. It is an ocular manifestation of systemic disease which affects up to 80% of all patients who have had diabetes for 10 years or more. Despite these intimidating statistics, research indicates that at least 90% of these new cases could be reduced if there was proper and vigilant treatment and monitoring of the eyes [8]. Figure 1 shows eye cross section.

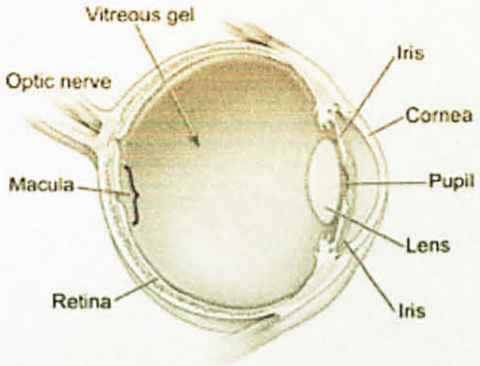


Figure 1: Eye cross section

Analyzing fundus image can be quite time consuming because of blood vessel to background is blurry and relatively low contrast. However this can be overcome with a technique that injects the patient eye with dye called Fluorescent angiogram (FA) and this dye will flow inside eye blood vessel.

So any disease that damage the blood vessel can be located with special camera that highlight the dye's flow pattern [9]. This method however has downside or side effect to the users. The patient will experience sensitive to light about 3 hours after the procedure. The skin also will turn to pale yellow result from dye injected and eventually will wears off in two days [10].

By using computer image processing the patient does not have to risk any side effect from injecting foreign substance into their eyes. Cades and Donho established a new system called curvelet transform that has optimal approximation for 2D piecewise smooth function but this type of method use polar coordinate so processing a discrete image can be problematic. Symptoms of diabetic retinopathy include:

- Blurred vision and gradual vision loss
- Floaters
- Shadows or missing areas of vision
- Difficulty seeing at nighttime

Many people with early diabetic retinopathy have no symptoms before major bleeding occurs in the eye. This is why everyone with diabetes should have regular eye exams [16]. In figure 2 below shows normal vision is on the right and diabetic retinopathy patient vision is on the left.

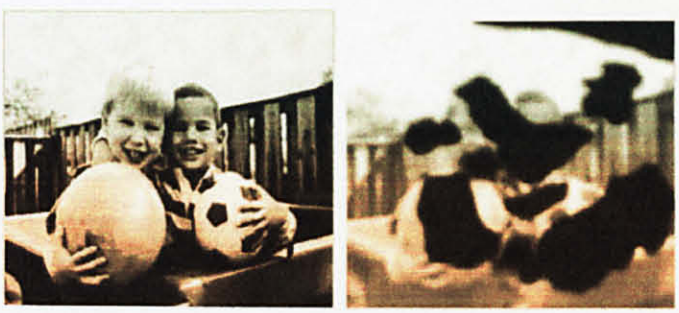


Figure 2: Normal and DR patient vision

2.2 Enhancement Method

2.2.1 Wavelet Enhancement

Wavelet-based image enhancement is not only being applied to increase the visualization of the image but it is also improving the error for accuracy in biomedical pattern recognition. This statement has been proved by Qiang Wu, Yu Ping Wang, Zhongming Liu, Teihan Chen and Kenneth R. Castleman [11].

2.2.2 Contourlet Enhancement

More accurate and friendly method was then been introduced by M. N. Do and M. Veterli[7] which is called contourlet transform. This method defines on rectangular coordinate so it can offer multiresolution and directional image processing [7]. Contourlet transform based on an efficient two-dimensional multiscale and directional filter bank that can deal effectively with images that have smooth contours[directional multiscale]. All natural images display this property. After some study that has been carried out, we found that wavelets in 2-D are good at isolating the discontinuities at edges point, but it will not see the smoothness along the contour[directional]. The wavelet was proven to be good to be used in medical image enhancement but in order to improve the image it should be based on local, directional and multiresolution expansion. Let us take a look and compare image coefficients obtain when using wavelet in figure 3 and contourlet method in figure 4.

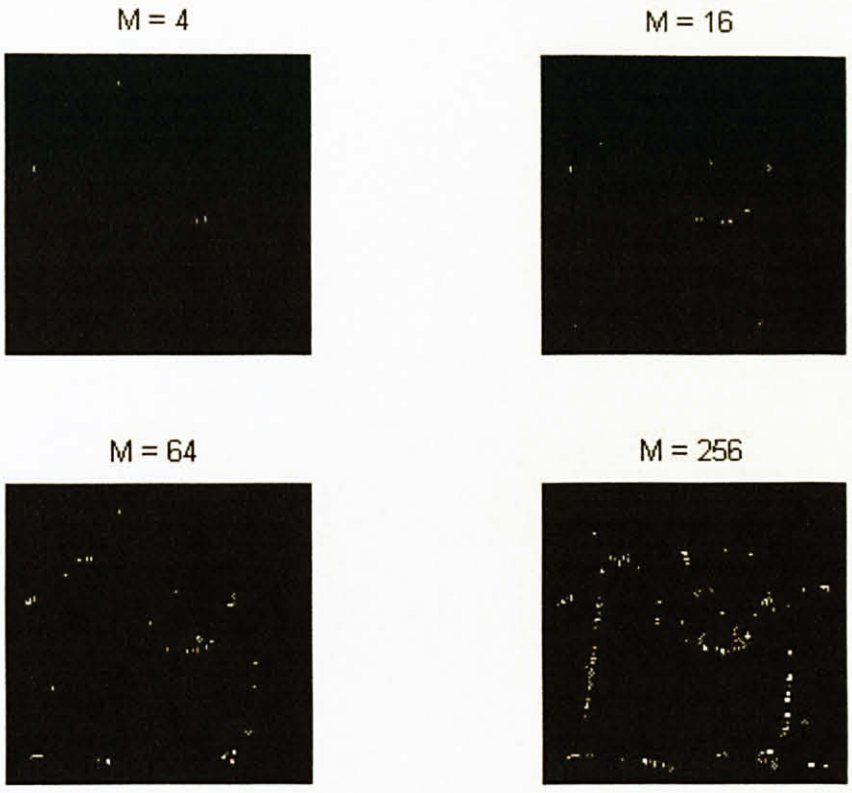


Figure 3: Wavelet coefficient

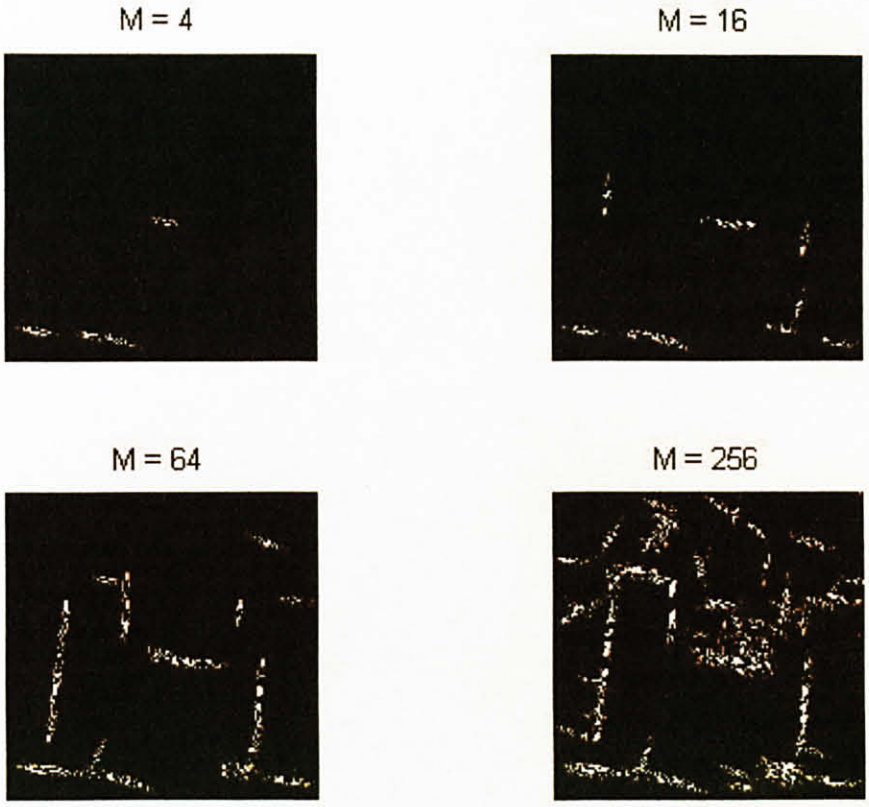


Figure 4: Contourlet coefficient

Where M is the maximum number of coefficient. From the two pictures above we can clearly see that contourlet can produce much significant data with the same number of coefficient compared to wavelet because the contourlet has the ability to capturing data direction.

CHAPTER 3
METHODOLOGY

3.1 Procedure Identification

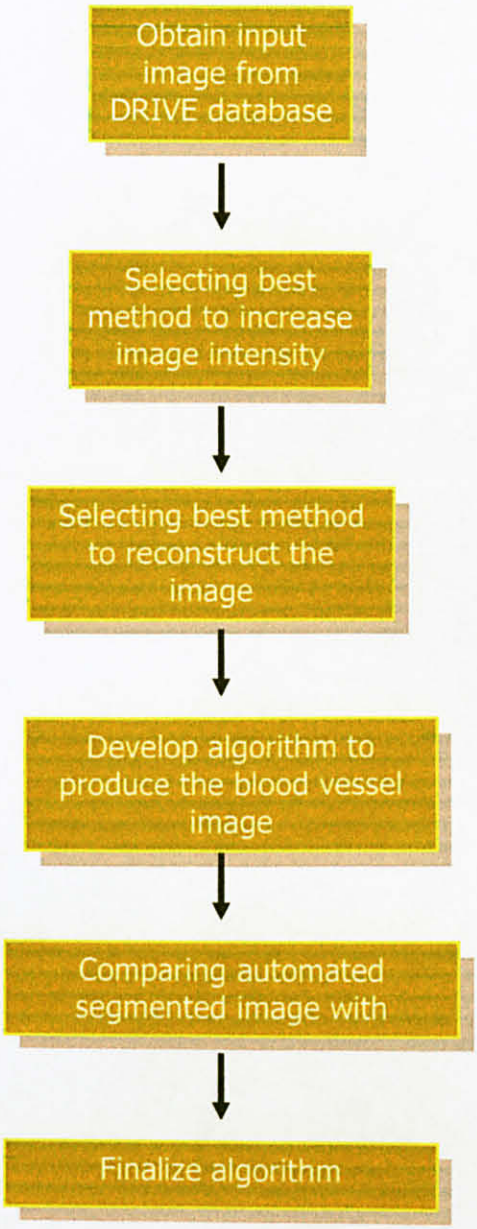


Figure 5: Methodology

3.2 Input Image

The input image was downloaded from DRIVE database [1]. This database specifically established to comparative study on segmentation of retinal blood vessel. The photographs for the DRIVE database were obtained from a diabetic retinopathy screening program in The Netherlands. The screening population consisted of 400 diabetic subjects between 25-90 years of age. Forty photographs have been randomly selected, 33 do not show any sign of diabetic retinopathy and 7 show signs of mild early diabetic retinopathy. Each image has been JPEG compressed.

The images were acquired using a Canon CR5 non-mydriatic 3CCD camera with a 45 degree field of view (FOV). Each image was captured using 8 bits per color plane at 768 by 584 pixels. The FOV of each image is circular with a diameter of approximately 540 pixels. For this database, the images have been cropped around the FOV. For each image, a mask image is provided that delineates the FOV.

The set of 40 images has been divided into a training and a test set, both containing 20 images. 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. All human observers that manually segmented the vasculature were instructed and trained by an experienced ophthalmologist. They were asked to mark all pixels for which they were for at least 70% certain that they were vessel. [1]

3.3 Method to Increase Image Intensity

The most popular method to perform image contrast enhancement is known as CLAHE, short for contrast-limited adaptive histogram equalization.

This method differs from ordinary histogram equalization in the respect that the adaptive method computes several histograms and uses them to redistribute the intensity values of the image where ordinary histogram equalization simply uses a single histogram to perform intensity enhancement for an entire image.

So, adaptive histogram equalization is considered an image enhancement technique to improving an image's contrast, bringing out more detail in the image. However, this method produces significant level of noise. CLAHE was generally developed in order to counter this noise amplification problem. [15]

Contourlet enhancement on the other hand is not only able to enhance the contrast of the image but at the same time reduces the noise that resulted during enhancement. This method also has important characteristic that is very useful to perform image enhancement on natural image. This characteristic called multidirectional and can produce much more accurate output image.

The number of directional filter bank decomposition levels is doubled at every other finer scale and is equal to 5 at the finest scale. Note that in this case, both the wavelets and contourlet share the same details subspace Wj. The different between wavelets and contourlet transform is that wavelet is represent by only three direction, whereas the contourlet is represent by redundant frame with many more direction. The figure 6 shows the subband coefficient of input image. The white parts in the image represent coefficient with higher value and the black represent coefficient that is lower. In this example we only decomposed the image into two pyramidal level, which than decomposed into four and eight directional subband.

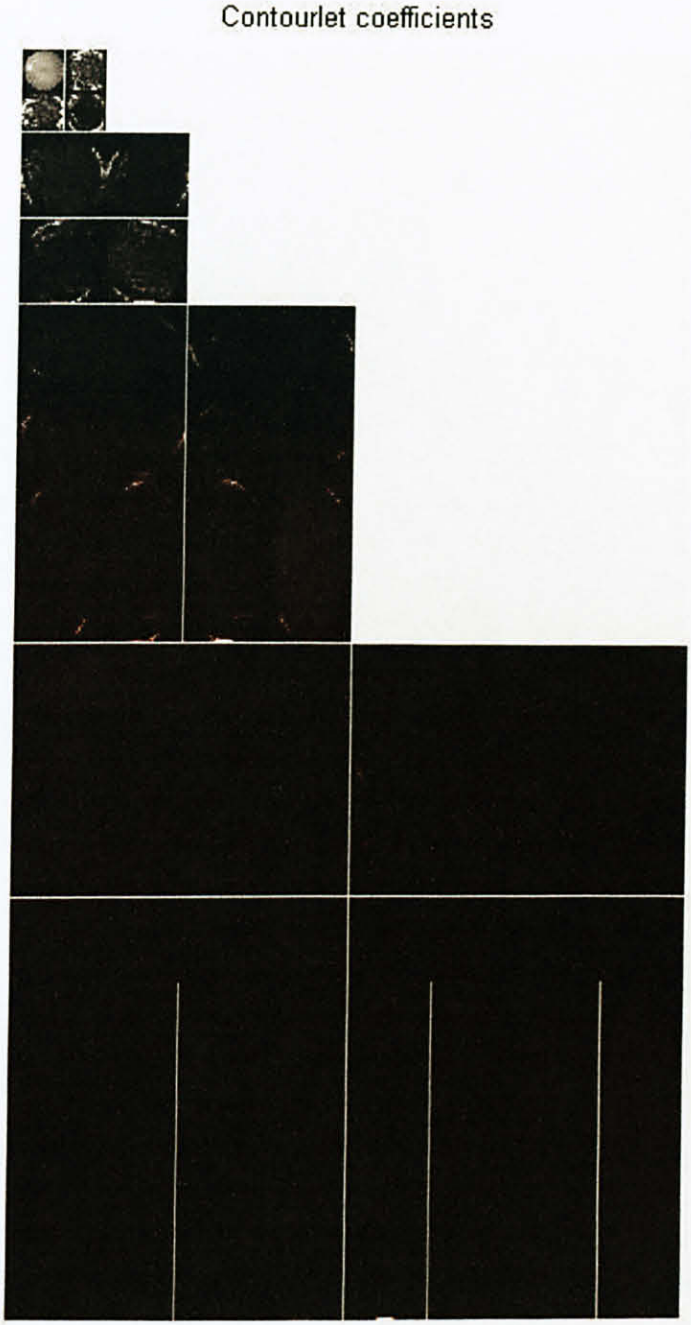


Figure 6: Contourlet subband coefficient

3.4 Method to extract blood vessel

Bottom-hat transform can be used to isolate dark objects on light surrounding. When bottom-hat method is applied to an image with background darker than the object, the background can be extracted [3]. The Bottom Hat module performs a dilation routine where it grows the current white image, followed by shrinking the current white image which is also known as erosion and then subtracts with the original image. Dilation followed by erosion will connect objects close to each other.

Subtracting the original will result in the display of just the connection points between close objects, it is defined as;

$$BottomHat(I, B) = (I \bullet B) - I \tag{1}$$

Closed image is made up by dilation followed by erosion. Dilation is a technique that allows object to grow and contributing in filling small hole and connecting object if some disjoint exist. Erosion on the other hand in general is a process of shrinking object by eroding their boundaries. Closed image can be defined as equation below;

$$A \bullet B = (A \oplus B) \otimes B \tag{2}$$

3.5 Method to Reconstruct the Blood Vessel

Seeded region growing, that is introduced by Adams and Bischof, is robust, rapid and free of tuning parameters. These characteristics allow implementation of a very good algorithm which could be applied to large variety of images. Seeded region growing algorithm is very attractive for semantic image segmentation by involving high level of knowledge of image components in the seed selection procedure. However, the SRG algorithm also suffers from the problems of pixel sorting orders for labeling and automated seed selection. An

obvious way to improve the SRG algorithm is to provide more effective pixel labeling technique and automate the process of seed selection. In this project we will focus on seeded region growing.

Seeded region growing approach to image segmentation is to segment an image into regions with respect to a set of q seeds. Given the set of seeds, $S_1, S_2, ..., S_q$, each step of SRG involves one additional pixel to one of the seed sets. These initial seeds are further replaced by the centroids of these generated homogeneous regions, $R_1, R_2, ..., R_q$, by involving the additional pixels step by step. The pixels in the same region are labeled by the same symbol and the pixels in variant region are labeled by different symbols. All these labeled pixel called allocated pixels, and the others are called unallocated pixels. Let H be the set of all unallocated pixels which are adjacent to at least one of the labeled region.

$$H = \left\{ (x,y) \notin \bigcup_{i=1}^{q} R_i \mid N(x,y) \cap \bigcup_{i=1}^{q} R_i \neq 0 \right\} \tag{3}$$

Where N(x,y) is the second order neighborhood of the pixel (x,y) as shown in table 1 below.

For the unlabeled pixel $(x,y) \in H, N(x,y)$ meets just one of the labeled image region R_i and define $\varphi(x,y) \in \{1,2,...,q\}$ to be that index such that $N(x,y) \cap R_{\varphi(x,y)} \neq 0$.

Table 1: The second order neighborhood of testing pixel at (x,y)

(x-1,y-1)	(x,y-1)	(x+1,y-1)
(x-1,y)	(x,y)	(x+1,y)
(x-1,x+1)	(x,y+1)	(x+1,y+1)

If $N(x, y)$ meets two or more of the labeled regions, $\varphi(x, y)$ takes a value of i such that $N(x, y)$ meets R_i and $\varphi(x, y, R_i)$ minimized.

$$\varphi(x, y) = \min_{(x,y)\in H} \left\{ \delta(x, y, R_i) \mid j \in \{1, ..., q\} \right\} \quad (4)$$

These seeded region growing procedures is repeated until all pixels in the image have been allocated to the corresponding regions [13].

3.6 Tools and Equipments

a. MATLAB

b. DRIVE database fundus image

CHAPTER 4

RESULT AND DISCUSSION

4.1 Process Identification

Image processing systems propose steps and processes shown by the following block diagram in figure 7 below.

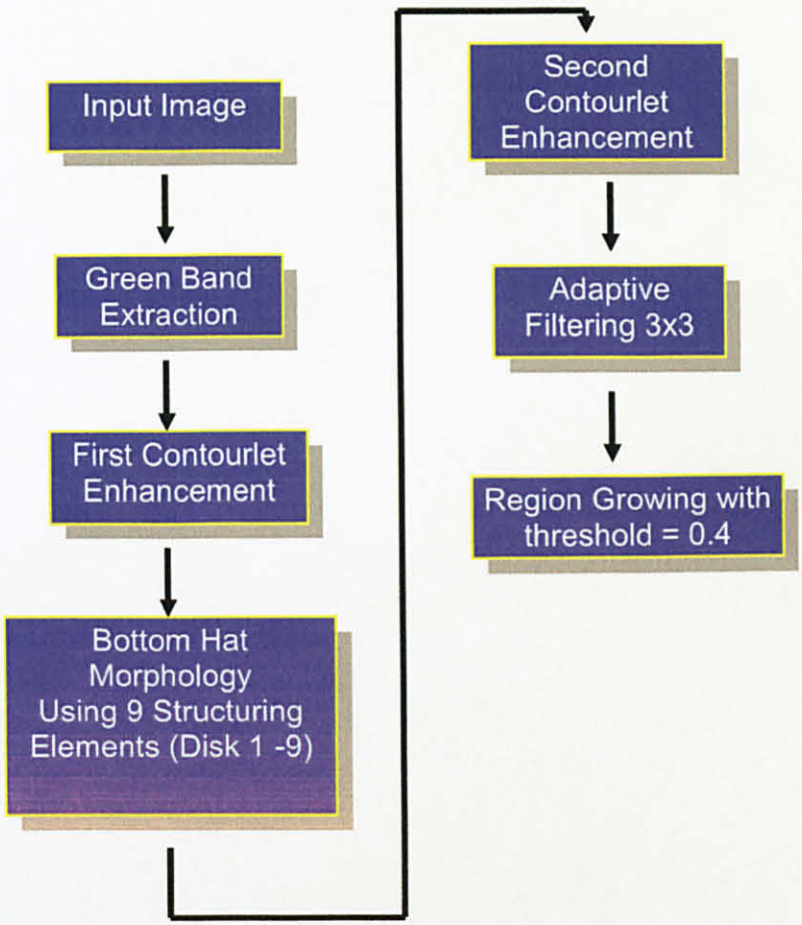


Figure 7: Block diagram of processing program.

4.1.1 DRIVE Database

This project will make use of newly available DRIVE database to carry out program simulation test. The example of fundus image provided in the DRIVE database was captured using 8-bits per color plane with resolution of 565 x 584 pixels as shown in figure 8.

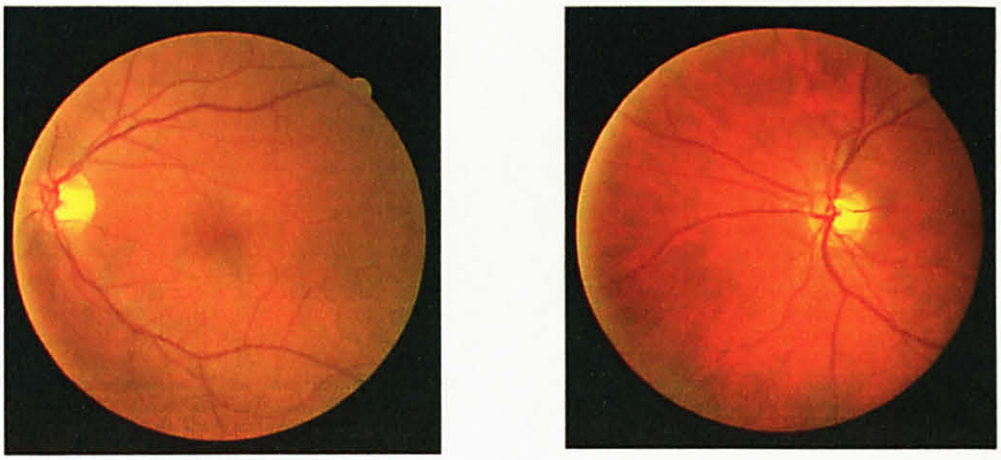


Figure 8: Original image

4.1.2 Green band Conversion

Images are usually in RGB (Red, Green and Blue) color space in most imaging application. Fundus image can be converted to 2D image to reduce computer processing time, thus allowing the examination process much faster. Number of patient that can be examine daily will increase. When processing such an easy task, regular computer can do the task and there is no need for a very high performance computer. Hence, this can reduce the cost. RGB image can be converted to grayscale image where the components can be defined as below;

$$Y=0.3R+0.59G+0.11B \quad (5)$$

From the equation we know that the brightness or intensity of a grayscale image is mostly being influenced by green band, please refer to figure 9.

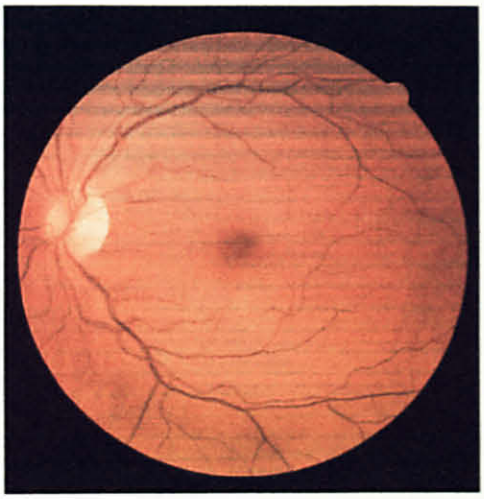


Figure (a)

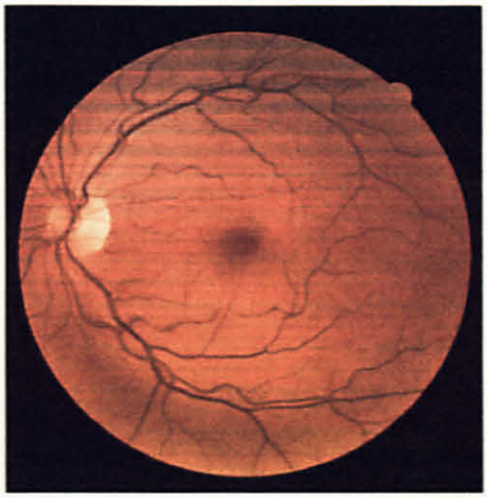
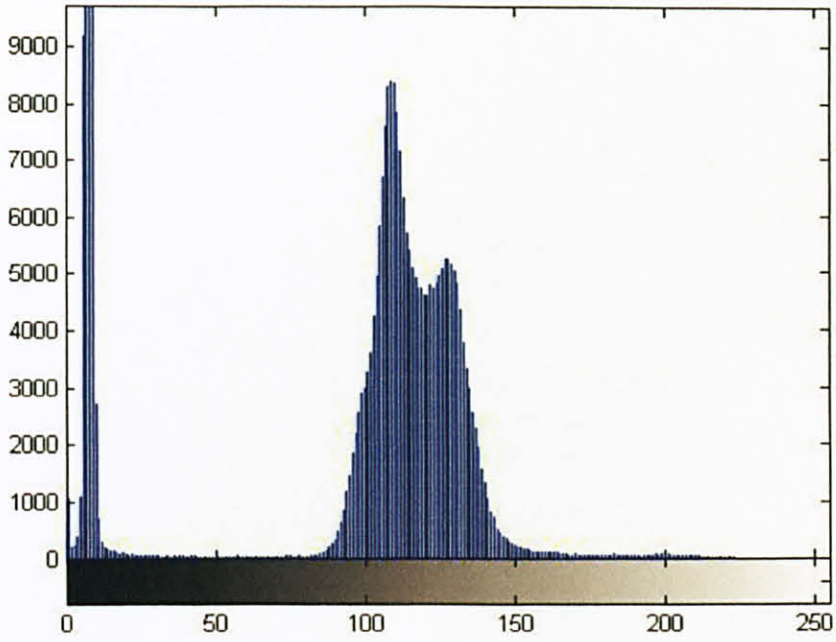


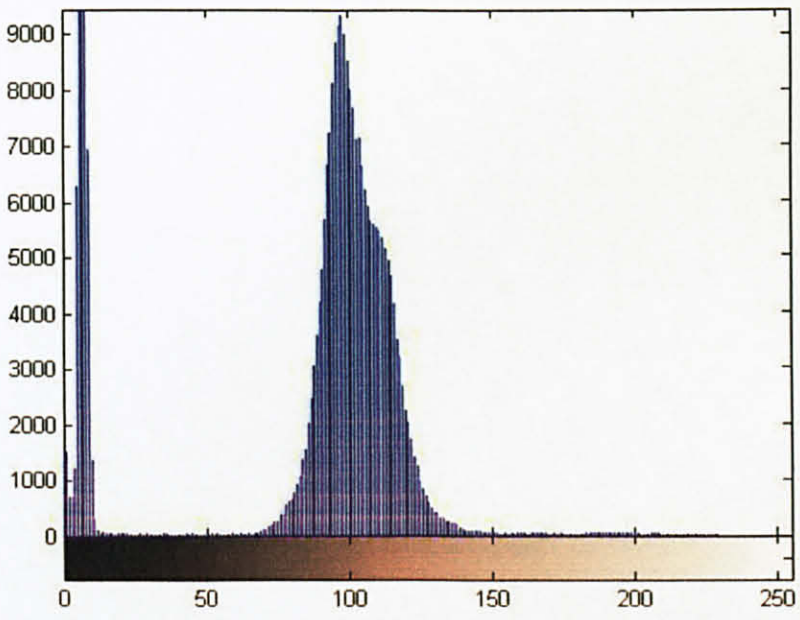
Figure (b)

Figure 9: (a) Grayscale image (b) Green band image

We select only the second layer of RGB image that is the green band. Greenband have the highest intensity level compared to the other 2 layers that is blue layer and red layer. In figure 10 shows the comparison of grayscale image and green band image intensity distribution.



(a)



(b)

Figure 10: (a) Intensity value of grayscale image, (b) intensity value of green band image

4.1.3 Contourlet Enhancement

Image then will be enhanced for more clarity using a method called contourlet transform developed by M. N. Do and M. Vetterli. This method is more effective than wavelet transform. This method reduces the number of coefficients and is able to capture directional data. This step will make use of the algorithm developed by M. N. Do and M. Vetterli to decompose the fundus image. After decomposing the image, a function developed by Ehsan Nezhadarya and Mohammad B. Shamsollahi [12] will be applied to enhance the image contrast. The enhancement function is descripted below;

$$E(u) = u \times sign(u) \times \tanh(bv) \times (1 + ce^{-v^2}) \tag{6}$$

Where,

$$v = \frac{2.5u}{tM} \tag{7}$$

Where u is coefficient amplitude in transform domain and M is the magnitude of the maximum coefficient amplitude. In this function, tM is a threshold which shows that the coefficient larger than this threshold will be linearly amplified. The parameter b and c determine the gain needed in each amplitude interval.

Figure 11 below shows the output of enhancement function when we set M=1,b=1,t=0.8 and c=1,2,3,4,5. Figures are plotted using MATLAB. This function works by making negative value more negative, vice versa.

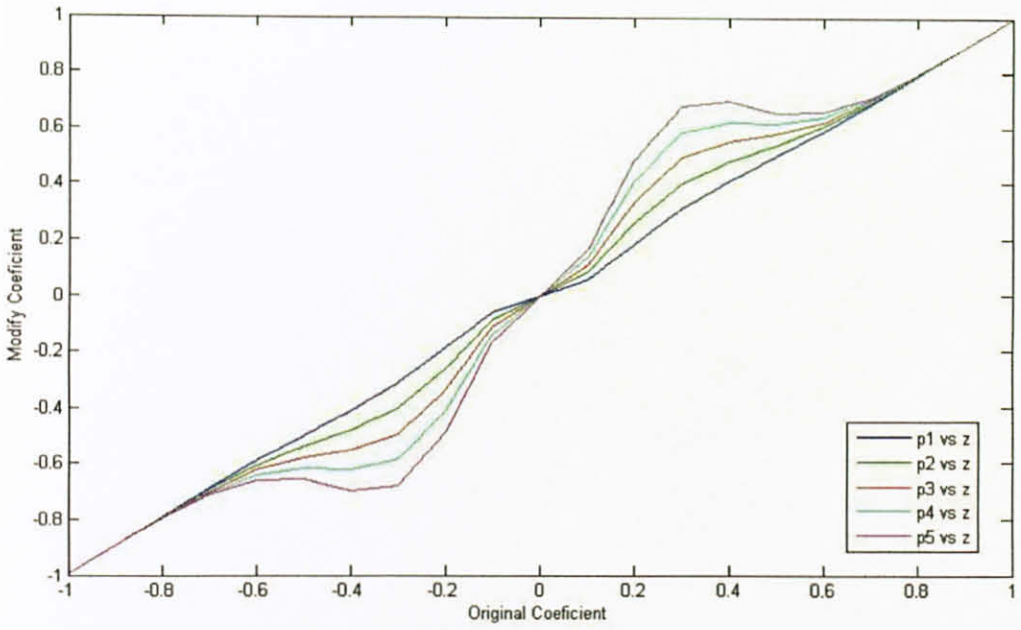


Figure 11: Output of the enhancement function

This step is required before any enhancement function can be applied to the image. This step is located in the contourlet transform method block as mentioned in the methodology part. The image will undergo a decomposition process then the enhancement function will be applied, lastly the image will be reconstructed back. The algorithm used is obtained from M. N. Do [7].

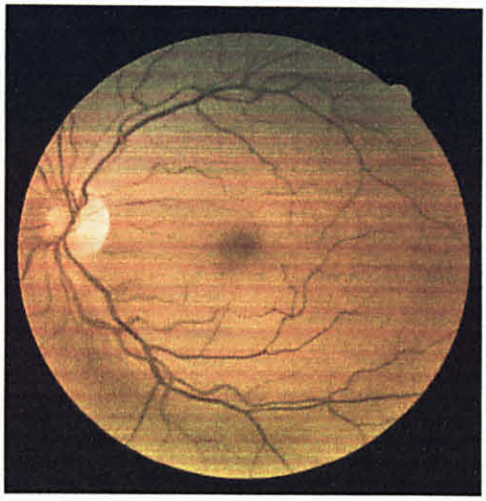


Figure 12: Input Image

Figure 12 above shows the input image that is fed into the algorithm. The image than will go through pyramidal directional decomposition filter bank and produce transform coefficient that will be use to boost the image. This algorithm source code is provided in the appendix.

Shown is figure 13 and 14 below is the image before and after contrast enhancement using contourlet transform. The enhancement function that has been discussed in the previous chapter will be utilized here. To obtain optimal enhancement the ranges of a is from 1 to 2.5, for b is from 1 to 3, and c is from 1 to 5 [6].

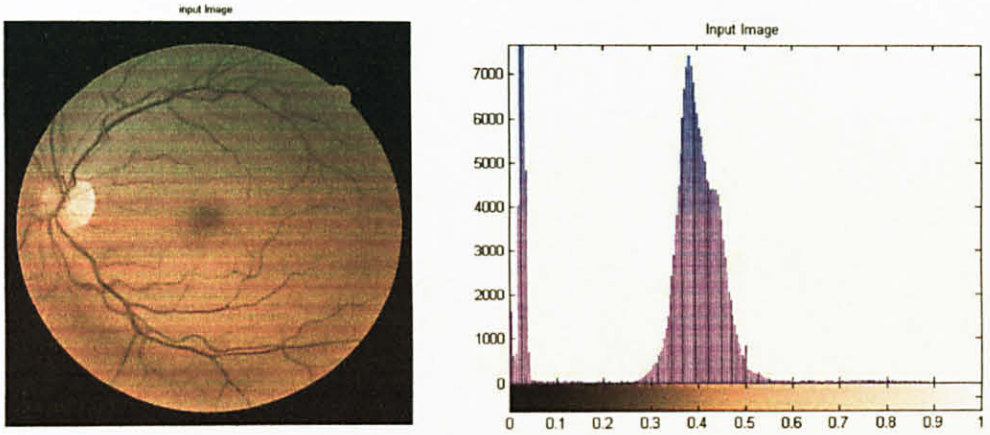


Figure 13: Image before enhancement

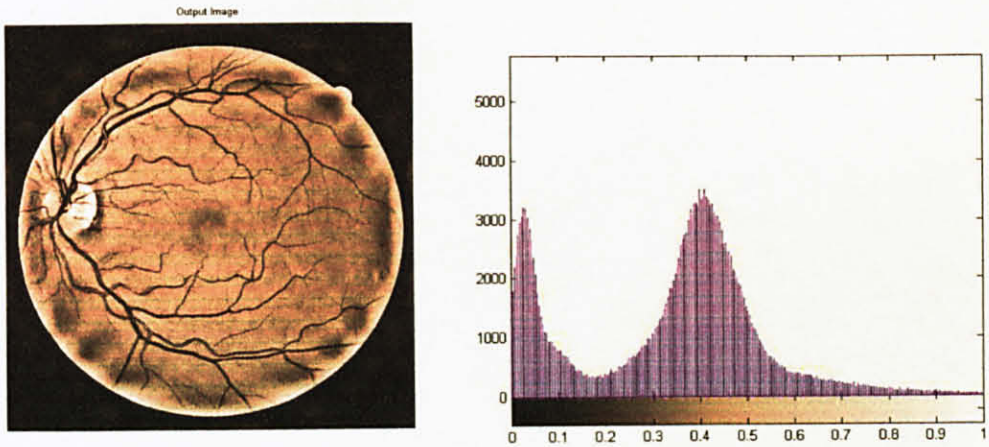
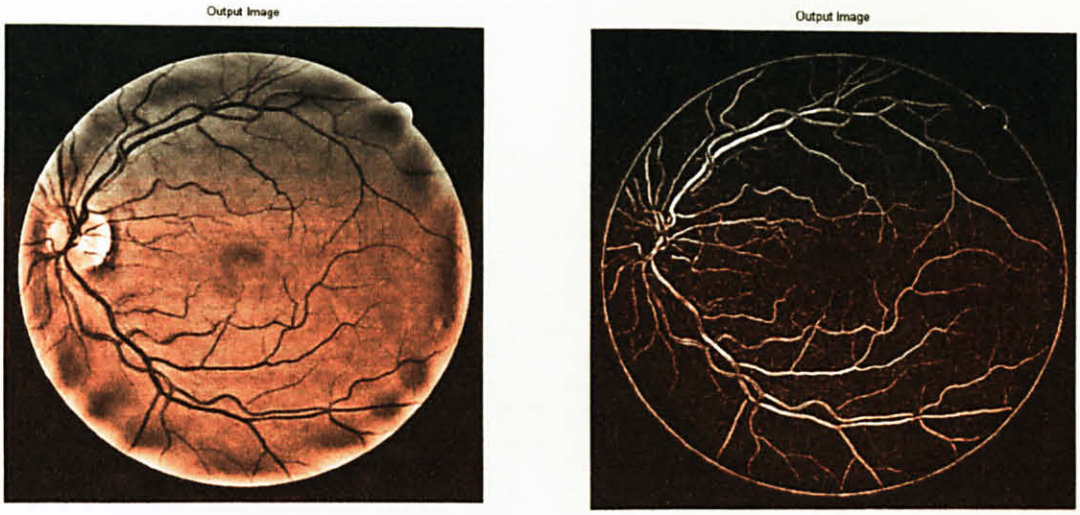


Figure 14: Image after enhancement with a=2,b=1 and c=3

4.1.4 BottomHat Transform

BottomHat transform was applied on the contourlet enhanced image to extract the retinal blood vessel. Figure 15 shows the image before and after BottomHat was applied. We use 7 structuring elements (SE) that is square with size varying from 2 to 8. The SE is a matrix with all value of one and having the specified size.



(a) (b)

Figure 15: (a) Before BottomHat, (b) After BottomHat

4.1.5 Noise Reduction

The need to reduce noise at the Bottom hat transformation output is a must. It is to help the step reconstruction method that is region growing to produce much more accurate image, and from observation we can say that the type of noise in the image of Bottom hat output is random noise. The suitable filter to do this noise elimination job is median filter or adaptive filter. Both filters were tested and the result is shown in figure 16 and 17 below. In figure 16 image is filtered using adaptive filter having size of 3 by 3 pixel and figure 17 image is filtered using median filter having size also 3 by 3 pixel and in figure 18 image without any noise reduction approaches.

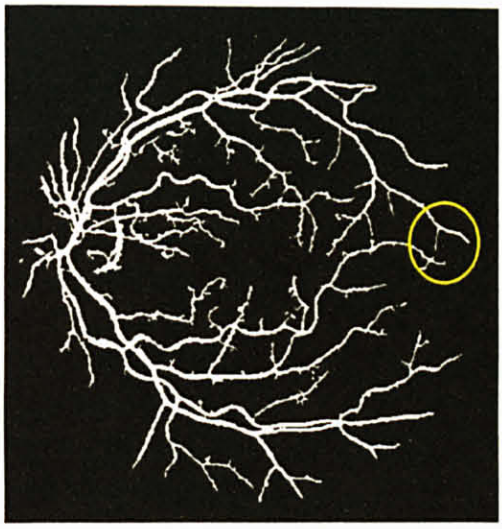


Figure 16: Using adaptive filtering 3x3

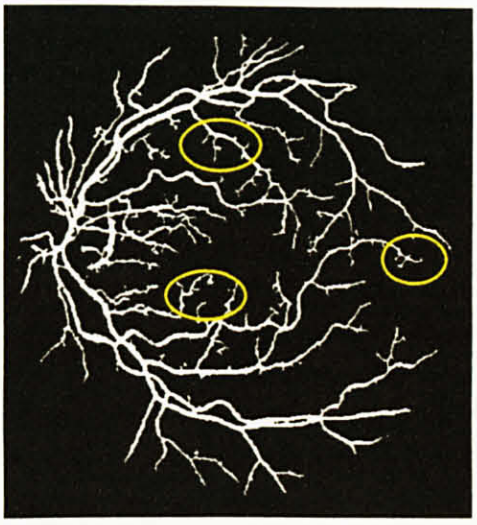


Figure 17: With median filtering

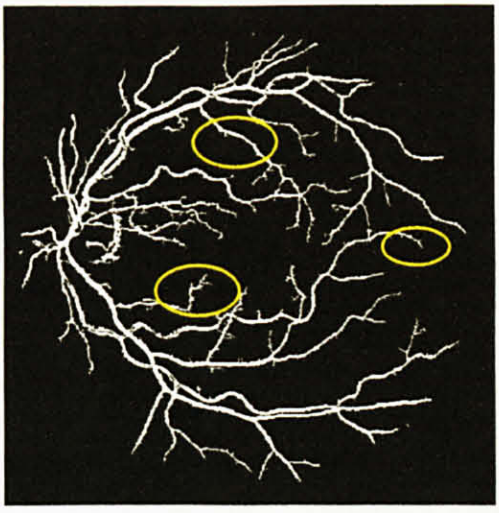


Figure 18: Without filtering

Using the images obtained, we compare both pictures with the manually segmented image. The image with adaptive filter has a similarity percentage 1.04% greater than the median filter image.

4.1.6 Blood Vessel Reconstruction using Seed Region Growing (SRG)

The weakness of Bottom Hat transformation is that the method is unable to capture intersection point between two or more blood vessel effectively. This weakness will produce not accurate image because when we observe the fundus image in figure 19, the intersection point mostly is at primary vessel. Here we consider a few of reconstruction techniques available to overcome this weakness.

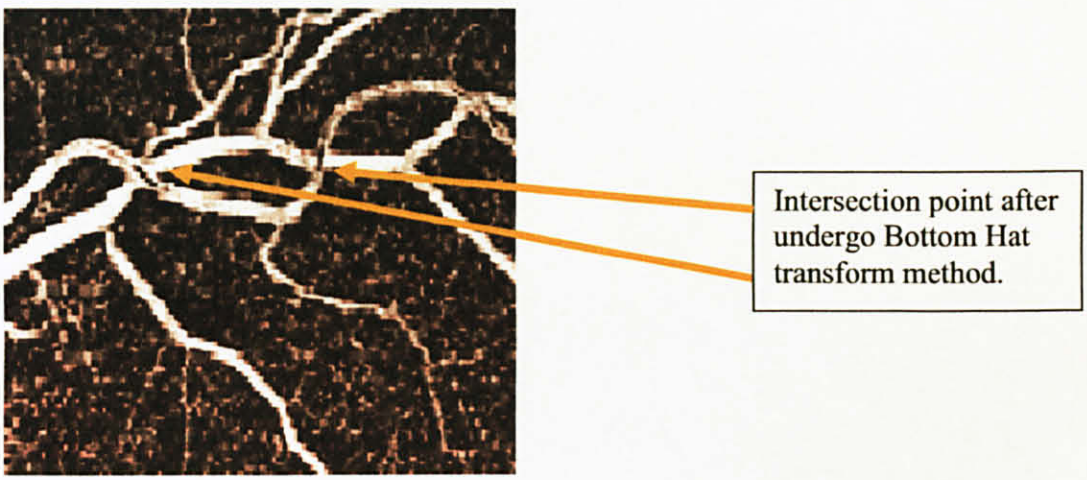


Figure 19: Blood vessel intersection point

Originally the Seed Region Growing (SRG) had developed to overcome the Bottom Hat technique and reconstruct the blood vessel. SRG algorithm also suffers from the problems of pixels sorting for labeling and making automated seed selection [13]. However there is potential approach to deal with this problem, by using automated seed selection algorithm we can maximize the SRG performance.

Later, a technique called Gradient Region Growing method was developed to improve the performance of SRG. The Region growing flow chart is shown in figure 20 below [5]. The enhanced image than will be reconstructed and converted into a binary image to simplify the processing.

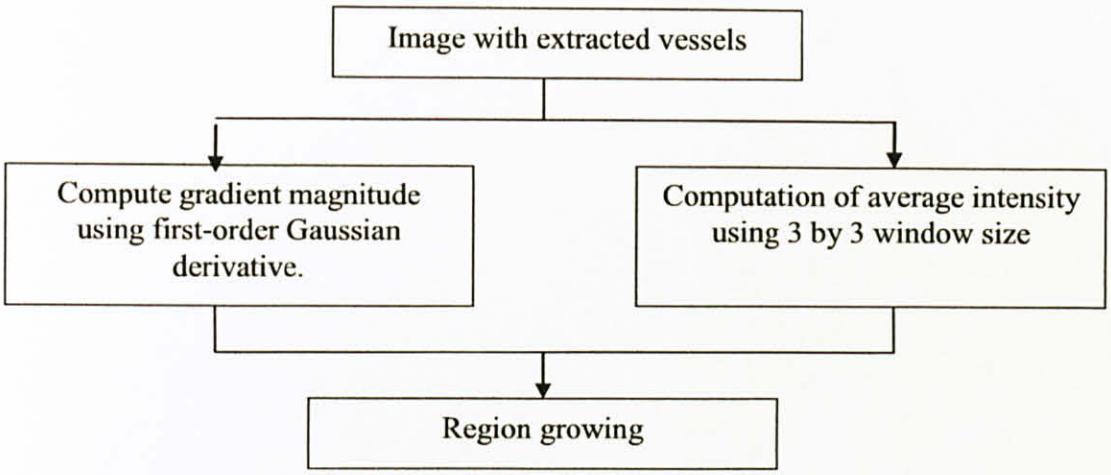


Figure 20: Flowchart of region growing process

There is also a new method to segment images called Edge based region growing [14]. In grey image segmentation, the object usually was found in non-uniform illumination. So, the segmentation will be poor by using intensity based algorithm. In this method there are two kinds of pixels, hot and cold. The two types of pixels are defined from these seeds simultaneously. The final output image is shown in figure 21 below.

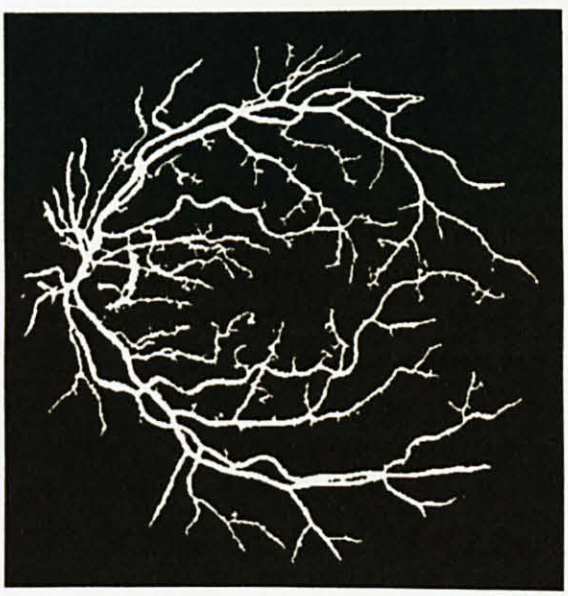


Figure 21: Reconstructed image using region growing

4.2 Comparing automated segmented image with manually segmented image

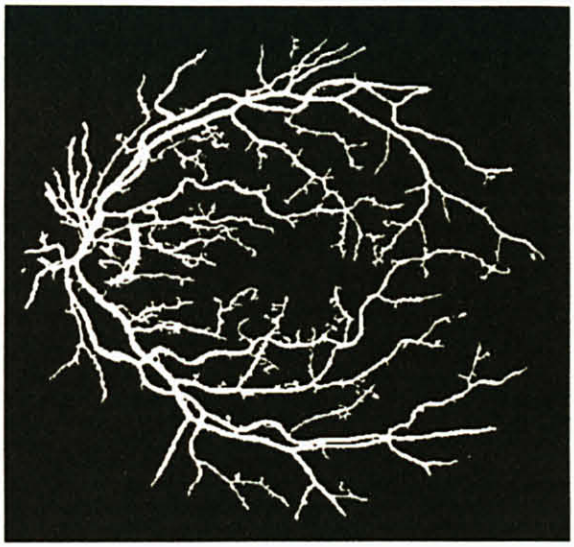


Figure 22: Automated segmented

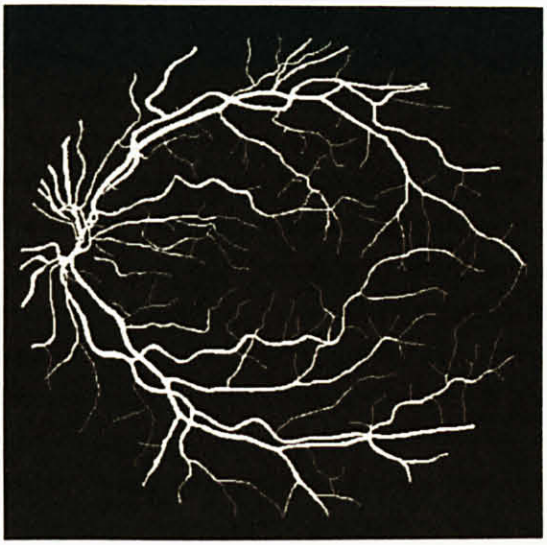


Figure 23: Manually segmented

Figure 22 is our automated segmented image, and figure 23 is the manually segmented image. For test purposes, we assume that manually segmented image is 100% correct, where as in the real condition, the ophthalmologist that produce this image is only 70% sure about the blood vessel pixels. So by comparing and counting the black and white pixel in both images we can come up with the error percentage of the automated segmented image. The data is presented in table 2 below;

Table 2: Comparison Data

Elements	Data
Total number of white pixel	28,848
Number of white pixel different	4,701
Total number of black pixel	301,112
Number of black pixel different	11,158
Percentage of white pixel error	16.2958%
Percentage of black pixel error	3.7056%
Percentage of overall pixel different	4.8063%

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

To determine the accuracy of the automated segmented image that was produced by our algorithm, we compare our image with the manually segmented image. Our automated image only 4.8063% different than the manually segmented image. Overall algorithm just take 3 to 4 minutes to complete, this can reduce the processing time to segment the blood vessel manually. In this project we used the contourlet enhancement two times to further increase the intensity of blood vessel, the first contourlet enhancement is to assist Bottom-hat to extract the blood vessel and the second enhancement is to assist blood vessel reconstruction using region growing. Because of the noise produce after Bottom-hat transformation we must use adaptive filter to remove the significant random noise that affecting the accuracy of our reconstruct image. Note that final output image is a binary image where 1 represents white (blood vessel) and 0 represent black (background). Because the use of SGR to reconstruct blood vessel, for an image other that the default, new seed coordinate must be input into the algorithm to perform image reconstruction.

5.2 Recommendation

It is recommended that the algorithm is tested with more real data to validate its performance.

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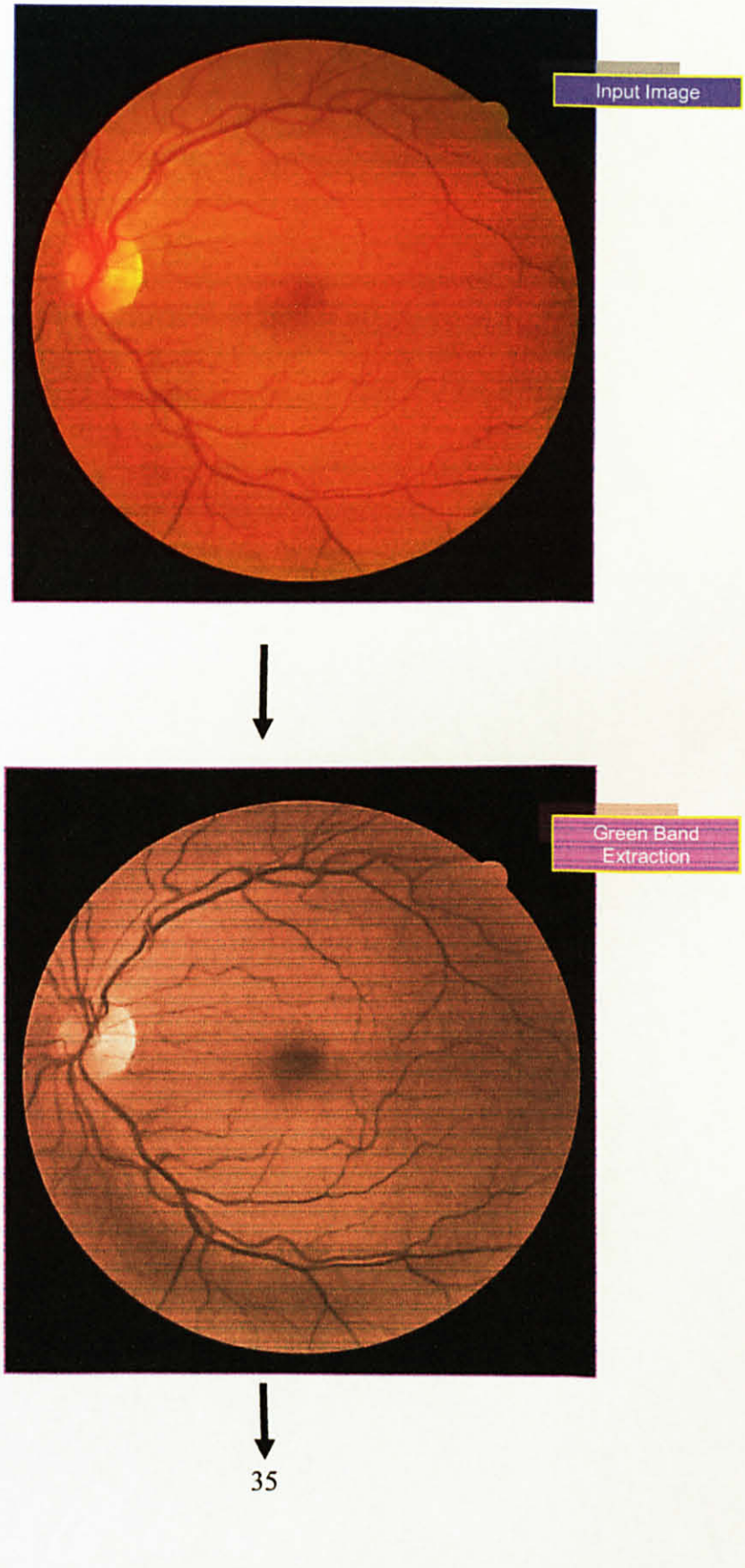
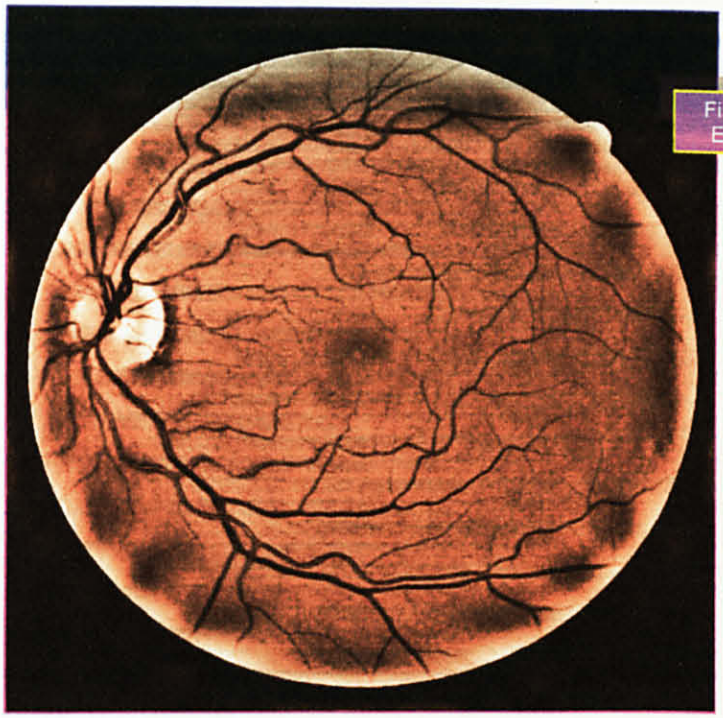
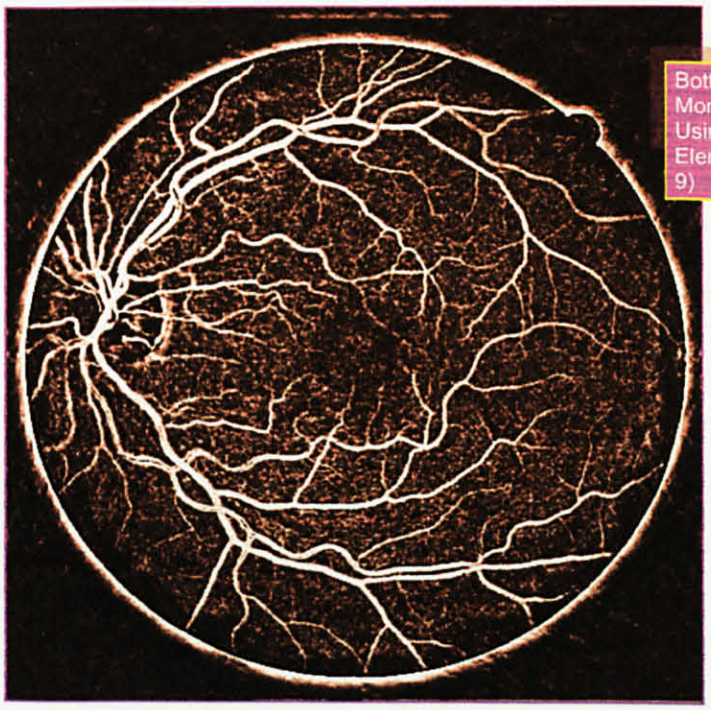
APPENDICES

Appendix A: Project Flow and Result

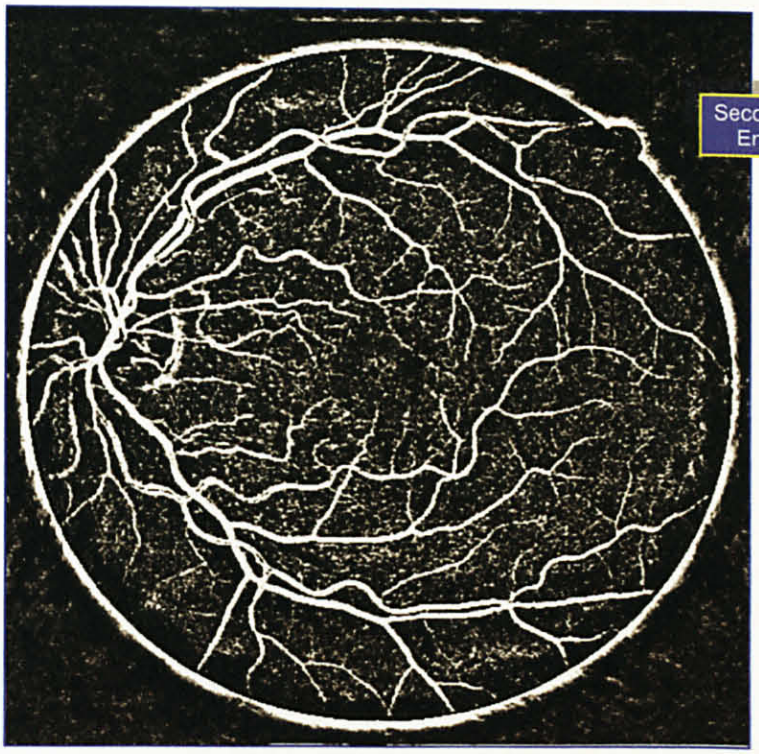




First Contourlet Enhancement



Bottom Hat Morphology Using 9 Structuring Elements (Disk 1 - 9)


Second Contourlet
Enhancement


Adaptive Filtering
3x3


Region Growing
with threshold =
0.4

Appendix B: Contrast enhancement function

```
function contourletout = ctransform(inraw)

im=imresize(inraw,[512 512],'bicubic');
ctres = 3.03;


im = double(im)/256;
pfilt='9-7';                % choose LP decomposition filter
dfilt='pkva';               % choose DFB decomposition filter
nlevs = [3,3,4,5,5];        % nlevs:vector of numbers of  directional filter bank
decomposition levels
                            % at each pyramidal level (from coarse to fine
                                % scale).


%assure the values of J and l(j)
[nlrow,nlcol] = size(nlevs);
kl=nlcol; % kl record the level of LP
for i=1:nlcol
    if nlevs(i) >= 2
       J = nlcol-i+1;
    break
    else i=i+1;
         J=0;
    end
end
if (J)
   for j=J:-1:1
       l(j) = nlevs(i);
       i=i+1;
   end
end
% Generate noisy image.
sig = std(im(:));
sigma = sig / 5;
sigmap=sigma^2;
%nim = im + sigma * randn(size(im));
%figure,imshow(nim);title('ÔëÉùÍ¼Ïñ');axis on;
%sigmaj = (4/3) * sigma *std(sqrt(nvar));
% Contourlet transform

     y = pdfbdec(im, pfilt, dfilt, nlevs);
t=.8;
b=1;
c=3;

wl = 0 ; %count the number of zero in nlevs,that is the    level of wavelet
decomposition
```

```
        for i=1:nlcol
            if nlevs(i)==0
            wl = wl+1;
            end
        end



    % if wl=1,y{1}is the lowpass image ,and y{2}is the  horizontal,vertical and
diagonally subbands


    %cope with the contourlet coefficients
     % cs is a parameter ranging from 1 to 5

    for j=1:J
        p=J+2-j+wl;
        for k=1:2^(l(j)-1)
             sigmaj=sigmap/std(y{p}{k}(:));       % essig is a function to
estimate the noise variance of this subband
            [m,n]=size(y{p}{k}); % the size of directional subbands of scale
2^j,direction k
            for f=1:m
               for g=1:n
                   i=0;
                   z=0;
                   for nu=1:2^(l(j)-1)
                        i=i+1;
                        z(i)=y{p}{nu}(f,g);
                   end
                   px=max(abs(z));   % the max coefficients of this subbands
                   pm=mean(z);

                %if  (px>=c*sigmaj)
                         v=3*y{p}{k}(f,g)/(t*px);

                          %   y{p}{k}(f,g)
=y{p}{k}(f,g)*sign(y{p}{k}(f,g))*tanh(b*v)*(1+c*exp(-v^2));
    nn =y{p}{k}(f,g)*sign(y{p}{k}(f,g))*tanh(b*v)*(ctres+c*exp(-v^2));
    y{p}{k}(f,g) = nn;
                %elseif  (px<c*sigmaj)
                    % y{p}{k}(f,g)=0 ;
                 % end
               end
            end
        end

        for k=2^(l(j)-1)+1:2^l(j)
            [m,n]=size(y{p}{k});
            sigmaj=sigmap/std(y{p}{k}(:));
```

```
                for f=1:m
                    for g=1:n
                        i=0;
                        for nu=2^(l(j)-1)+1:2^l(j)
                            i=i+1;
                            z(i)=y{p}{nu}(f,g);
                        end
                            px=max(abs(z));   % the max coefficients of this
subbands
                            pm=mean(z);
                           %if (px>=c*sigmaj)
                                 v=3*y{p}{k}(f,g)/(t*px);
                                %y{p}{k}(f,g)
=y{p}{k}(f,g)*sign(y{p}{k}(f,g))*tanh(b*v)*(1+c*exp(-v^2));
       nn =y{p}{k}(f,g)*sign(y{p}{k}(f,g))*tanh(b*v)*(ctres+c*exp(-v^2));
     y{p}{k}(f,g) = nn;
                          %elseif (px<c*sigmaj)
                            % y{p}{k}(f,g)=0 ;
                          %end
                    end
                end
            end
        end

     contourletout = pdfbrec( y, pfilt, dfilt ) ;% use the modified cofficients
to reconstruction
```

Appendix C: Main Function

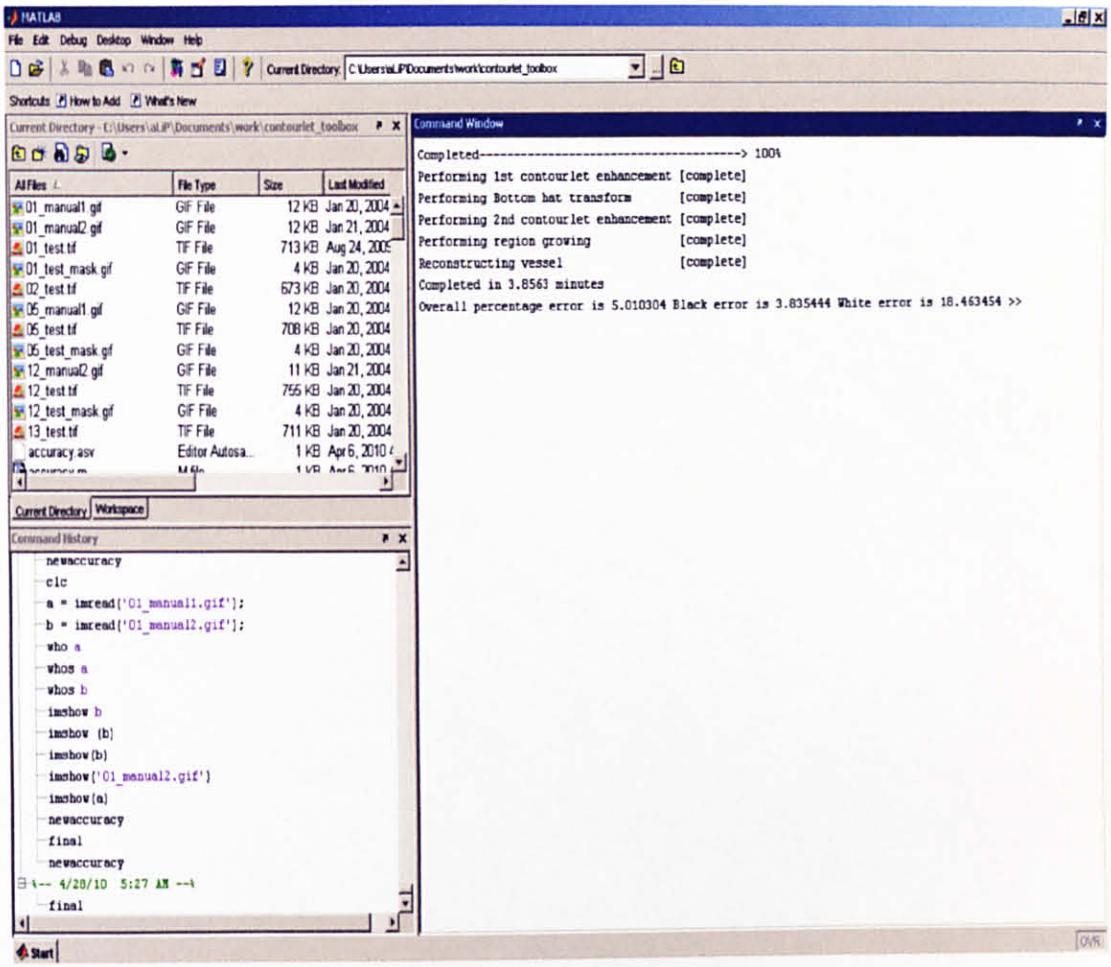
```
clc
clear all
time = cputime;

disp('Complete --->                                          15%')
disp('Performing 1st contourlet enhancement...')

iminput = imread('12_test.tif');
immask = imread('12_test_mask.gif');
imref = imread('12_manual2.gif');
ingreen=iminput(:,:,2);
imcontourlet = contourlettransform(ingreen);
%imwrite(imcontourlet,'contourlet1.tif')  %save image
clc
disp('Complete --------->                                    24%')
disp('Performing 1st contourlet enhancement [complete]')
disp('Performing Bottom hat transform...')

se(1) = strel('disk',1);
se(2) = strel('disk',2);
se(3) = strel('disk',3);
se(4) = strel('disk',4);
se(5) = strel('disk',5);
se(6) = strel('disk',6);
se(7) = strel('disk',7);
se(8) = strel('disk',8);
se(9) = strel('disk',10);
se(10) = strel('disk',11);
se(11) = strel('disk',12);
%se(10) = strel('square',19,150);
%se(11) = strel('square',12,180);
%se2 = strel('line',20,15);
imsum = 0;
for i = 1:8
bothat = imbothat(imcontourlet,se(i));
imsum = imsum + bothat;
end

%imfilt3 = wiener2(imsum,[2 2]);

imwrite(imsum, 'filt1.tif')  %save image

clc
disp('Complete -------------->                               37%')
disp('Performing 1st contourlet enhancement [complete]')
disp('Performing Bottom hat transform       [complete]')
disp('Performing 2nd contourlet enhancement...')
```

```
imsum2 = imread('filt1.tif');
%imfiltter = filter2(imsum2,[40,40]
imcontourlet2 = ctransform(imsum2);
%imwrite(imcontourlet2,'contourlet2.tif')  %save image
%imshow(imcontourlet2);
%delete filt1.tif
%imnonoise = wiener2(imsum,[2,2]);

%bothatim = imbothat(bothatim1,se2);
%imsnr = SNR(imrec,im)
%imsnr2 = SNR(nim,im)

%subplot(2,2,1),imshow(im);title('input Image');axis off;
%subplot(2,2,2),imshow(nim);title('input image');axis off;
%subplot(2,2,2),imhist(im);axis on;
%figure,imhist(im);axis on;
%figure,imhist(imrec);axis on;
%subplot(2,2,4),imhist(newim);axis on;
%subplot(2,2,4),imshow(bothatim);title('Output2 Image');axis off;
%subplot(2,2,4),imhist(bothatim);axis on;
%imshow(bothatim);title('Contourlet Image');axis off;
%PSNR(imbothat,im);
%figure,imshow(im);title('input Image');axis off;
%figure,imhist(im);title('Input Image');axis on;
%figure,imshow(imsum);title('Output Image');axis off;
%figure,imhist(imrec);title('Output Image');
imwrite(imcontourlet2, 'con2.tif')  %save image
imcon2 = imread('con2.tif');
clc
disp('Complete ---------------------------->           68%')
disp('Performing 1st contourlet enhancement [complete]')
disp('Performing Bottom hat transform       [complete]')
disp('Performing 2nd contourlet enhancement [complete]')
disp('Performing region growing...')

%imfilt = medfilt2(imcon2,[2 2]);
imfilt = wiener2(imcon2,[3 3]);
%imwrite(imfilt,'medfilt.tif')  %save image
im = im2double(imfilt);
tres=0.36;
x1=185;     %for 01_test.tif
%x1=533     %for 13_test.tif
y1=80;      %for 01_test.tif
%y1=292     %for 13_test.tif

x2=531;
y2=255;

clc
disp('Complete ------------------------------->      85%')
```

```
disp('Performing 1st contourlet enhancement [complete]')
disp('Performing Bottom hat transform       [complete]')
disp('Performing 2nd contourlet enhancement [complete]')
disp('Performing region growing             [complete]')
disp('Reconstructing vessel...')

J1 = regiongrowing(im,x1,y1,tres);

%J2 = regiongrowing(im,x2,y2,tres);

%J3 = regiongrowing(im,x3,y3,tres);

%J4 = regiongrowing(im,x4,y4,tres);

%J5 = regiongrowing(im,x5,y5,tres);

%J6 = regiongrowing(im,x6,y6,tres);

%J7 = regiongrowing(im,x7,y7,tres);


BW=J1;
%figure,imshow(I+J), title('I+J');

%figure,imshow(JJ), title('JJ');

imfinal=imresize(J1,[584 565],'bicubic');
imfinal1 = im2double(imfinal);
immask1 = im2double(immask);
%imallfinal = imfinal1 + ~immask1;
imminus = immask1-imfinal1;
vv = ~imminus+immask1;
minus = ~vv;
imm = imfinal1-minus;

imallfinal = medfilt2(imm,[3 3]);
imwrite(imallfinal,'reconstructedimage.tif')

%imcom = imread('reconstructedimage.tif');
imcom = imallfinal;

[result,berror,werror] = newaccuracy(imref,imcom);

%figure,imshow(imallfinal), title('Reconstruted image');

delete con2.tif;
time2 = (cputime -time)/60;
clc
disp('Completed------------------------------------> 100%')
disp('Performing 1st contourlet enhancement [complete]')
```

```
disp('Performing Bottom hat transform       [complete]')
disp('Performing 2nd contourlet enhancement [complete]')
disp('Performing region growing             [complete]')
disp('Reconstructing vessel                 [complete]')
fprintf('Completed in %.4f minutes\n',time2)
fprintf('Overall percentage error is %f %',result)
fprintf('Black error is %f %',berror)
fprintf('White error is %f %',werror)
imshow(imcom)
```

Appendix D: Matlab



Appendix E: Milestone
FYP 1

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic															
2	Preliminary Research Work															
3	Submission of Preliminary Report															
4	Seminar 1 (optional)															
5	Converting image to green band															
6	Image filtering and resizing															
7	Image enhancement															
8	Submission of Progress Report															
9	Seminar 2 (compulsory)															
10	Extracting blood vessel using Bottom-hat transformation															
11	Background removal and contrast stretching															
12	Submission of Interim Report Final Draft															
13	Oral Presentation															

FYP 2

	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
	Noise reduction															
	Submission of Progress Report 1															
	Vessel reconstruction															
	Submission of Progress Report 2															
	Vessel reconstruction															
	Poster Exhibition															
	Submission of Dissertation (soft bound)															
	Oral Presentation															
	Submission of Project Dissertation (Hard Bound)															