ELL715
Assignment 7 Report

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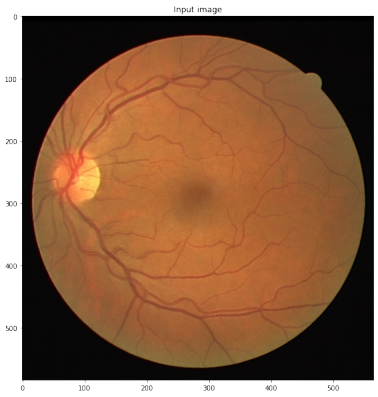
1 Original Image

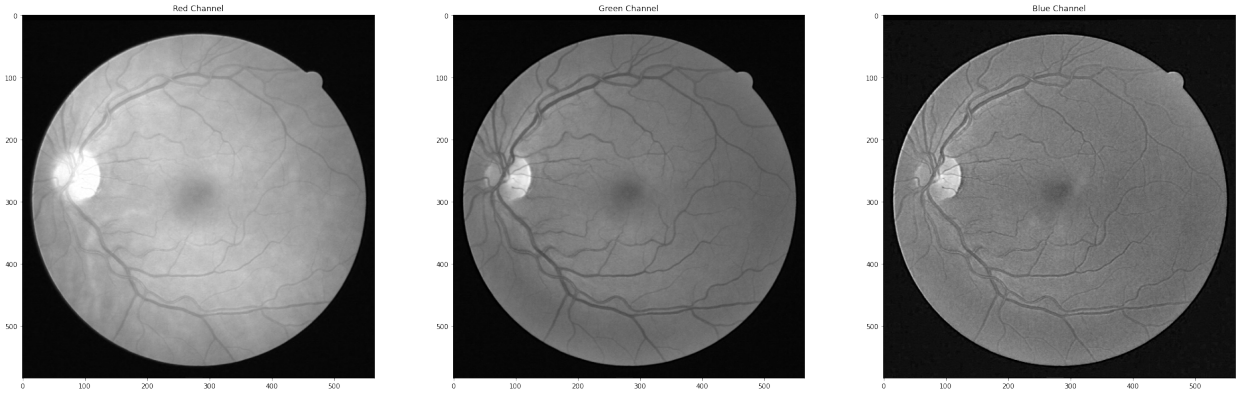
Unless otherwise stated, all the results shown in this document correspond the input image below:



2 Extracting Optic Disk

2.1 Channel Extraction

The image has three channels: R, G and B.



(a) Red Channel (b) Green Channel (c) Blue Channel

Figure 1: Images showing different channels corresponding to the input image

For extraction/removal of optic disk, we choose the blue channel, because it provides us with a better contrast between the optic disk and other components of the image.

2.2 CLAHE

After this, we applied contrast limited adaptive histogram equalization (CLAHE) on the blue channel to adjust the non-uniform illumination. The output of the same is:

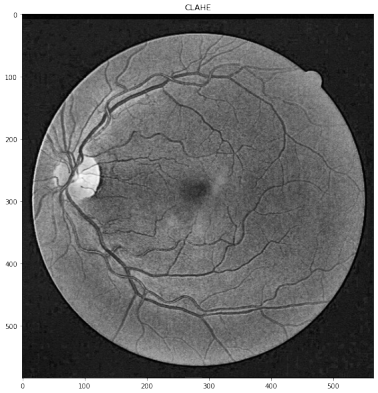


Figure 2: Output of applying CLAHE on blue channel

2.3 Smoothing

Then, we applied Median Filtering ($5 * 5$ blocks) to the CLAHE output, since it's noisy and causes issues in further steps if not resolved now itself. The output of the same is:

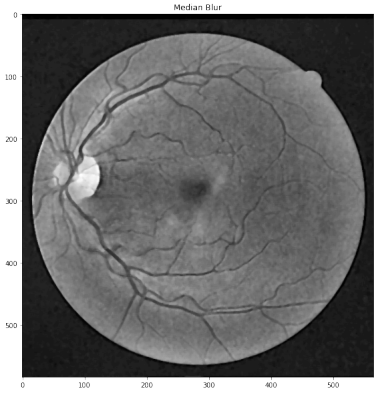


Figure 3: Output of applying median blur on CLAHE output

2.4 Opening

In the above figure, note that the optic disk has much higher intensity compared to the components in the image. The shown image is a grayscale image. The main effect of grayscale opening is to remove small, bright features from the image, while leaving the overall brightness unchanged. With that in mind, we perform opening on the above smoothed image with a disk kernel of radius 5 (an ellipse kernel of $(9, 9)$). The kernel used is:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

It should further increase the difference between the intensities of optic disk and non-disk regions. The output of the same is:

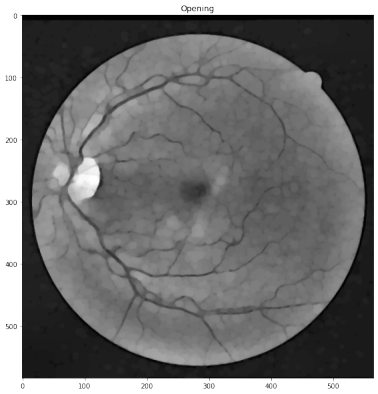


Figure 4: Output of opening on smoothed image with disk kernel of radius 5

2.5 Thresholding

Now, we perform binary thresholding with parameter 127 (all pixels with intensity less than or equal to 127 are assigned 0, and the rest are assigned 255). As should be evident in the image below, this gives us the required optic disk mask.

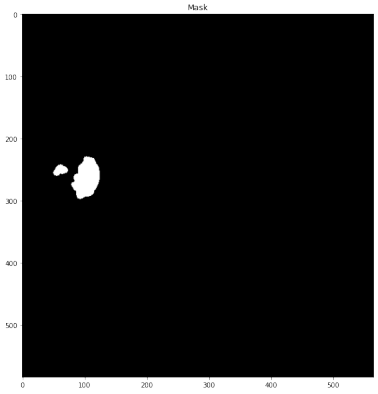
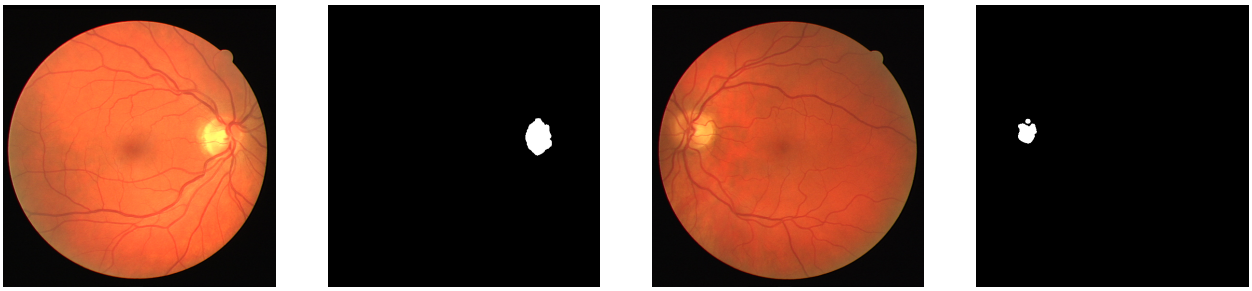
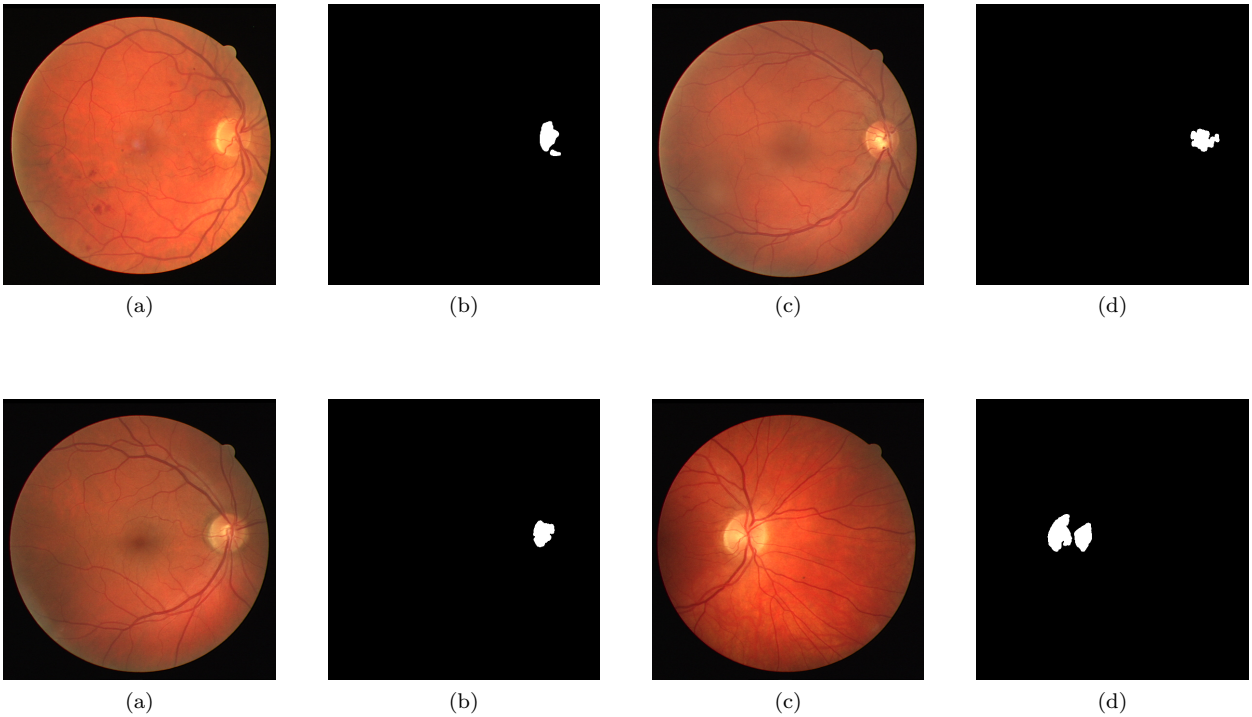


Figure 5: Output of thresholding the opening image

2.6 Additional Images: Extra Credit



(a) (b) (c) (d)



(a) (b) (c) (d)

(a) (b) (c) (d)

Figure 6: A few additional input images (a/c) and the corresponding mask for the optic disk obtained (b/d respectively)

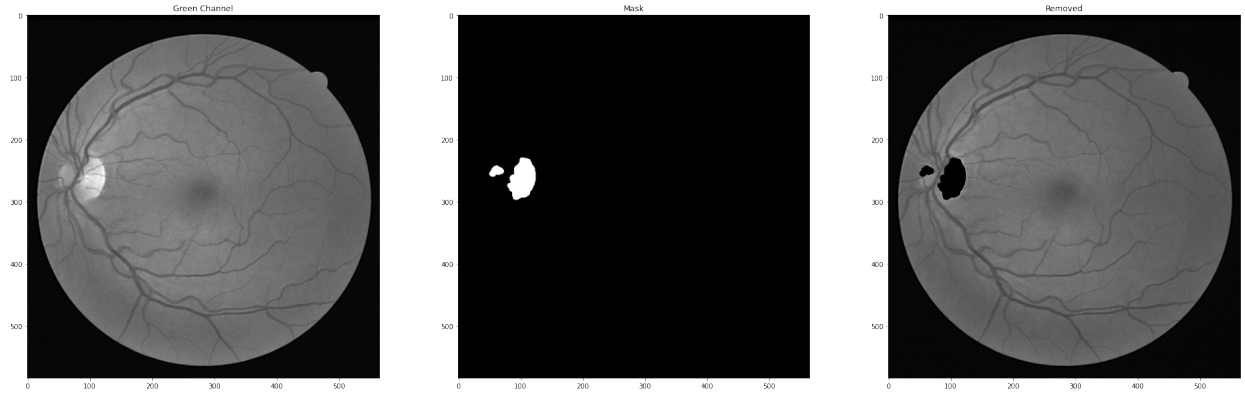
3 Vessel Map Segmentation

There are two approaches to this problem:

- In the first approach, we do not remove the optic disk, and use the green channel as-is.
- In the second approach, we first remove the optic disk, using the mask created in section 2, before proceeding with the same steps.

3.1 Channel Extraction

The green channel gives the best result in the contrast of blood vessels for extracting darker blood vessels on a bright background.
In approach 1, we use the green channel as-is.
In approach 2, we first extract the mask corresponding to the optic disk as explained in Section 2, and then use the green channel after removing the pixels present in the mask

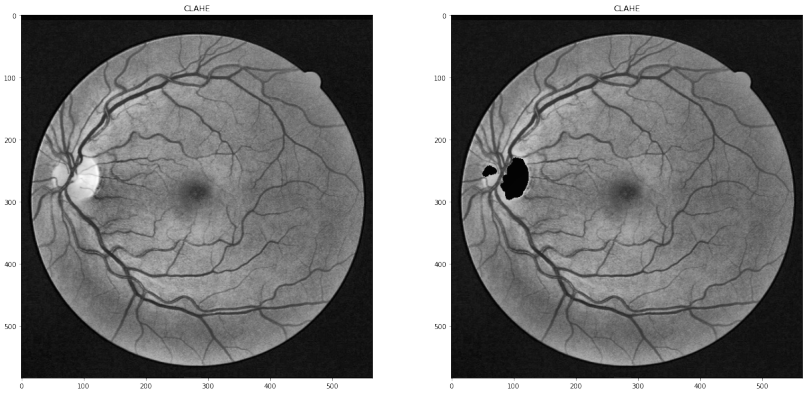


(a) Green channel (approach 1) (b) Optic Disk (c) Optic disk removed (approach 2)

Figure 7: Images showing the two distinct starting points

3.2 CLAHE

After this, we applied contrast limited adaptive histogram equalization (CLAHE) on the two distinct approaches based green channels to adjust the non-uniform illumination. The output of the same is:



(a) Approach 1 (b) Approach 2

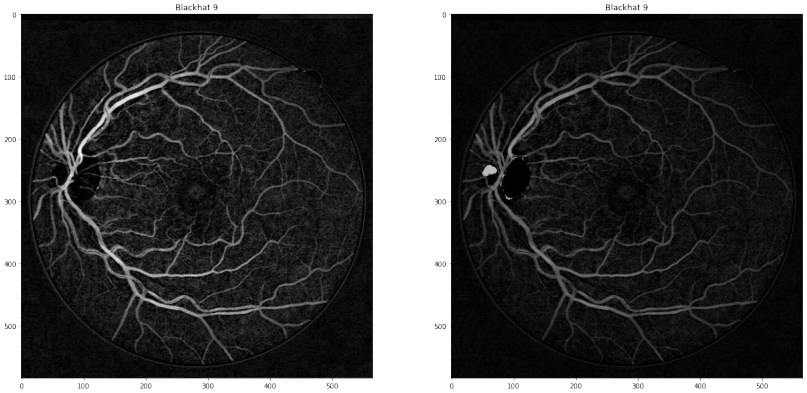
3.3 Smoothing

Then, we applied Gaussian Smoothing to the CLAHE output, since it's noisy and causes issues in further steps if not resolved now itself. The output of the same is:

(a) Approach 1 (b) Approach 2

3.4 Bottom hat transform

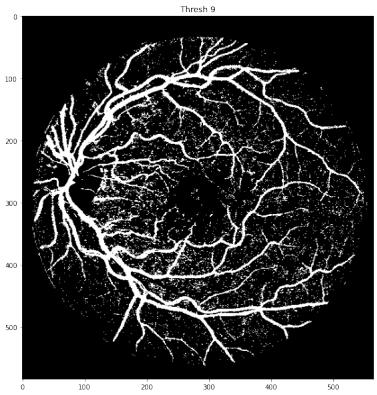
The bottom hat transform is used to enhance dark objects of interest in a bright background. That's exactly our case. The "black" blood vessels are in a "whitish" background. Thus, we then apply bottom hat transform on the smoothed image using a disk kernel of radius 9 (an ellipse kernel of $17 * 17$). The output of the same is:



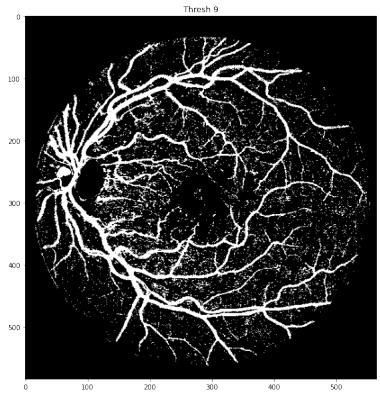
(a) Approach 1 (b) Approach 2

3.5 Thresholding

Now, we perform binary thresholding with parameter 30 (all pixels with intensity less than or equal to 30 are assigned 0, and the rest are assigned 255). As should be evident in the image below, this gives us the required vessel map (even though it is pretty noisy right now).



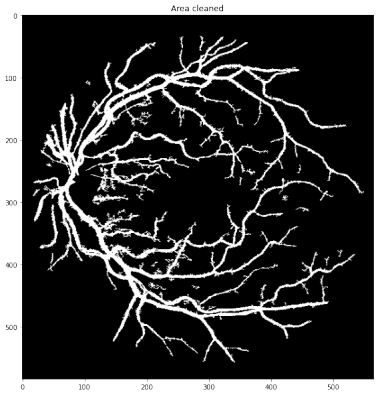
(a) Approach 1



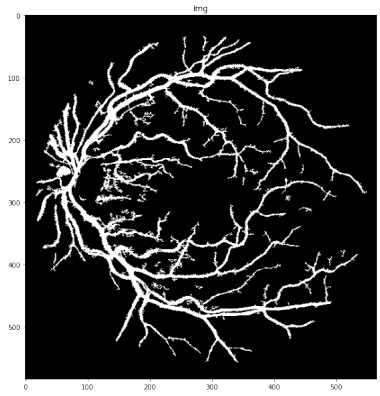
(b) Approach 2

3.6 Area-based cleaning

Now, note that in the above output, there are some isolated regions which are misclassified as vessel pixels. These misclassification can be removed by calculating the area of each connected region and considering that if the area is less than 25 (a hyper-parameter) then it can be marked as non-vessel, and hence removed. Output of applying above area-thresholding on the thresholding output:



(a) Approach 1



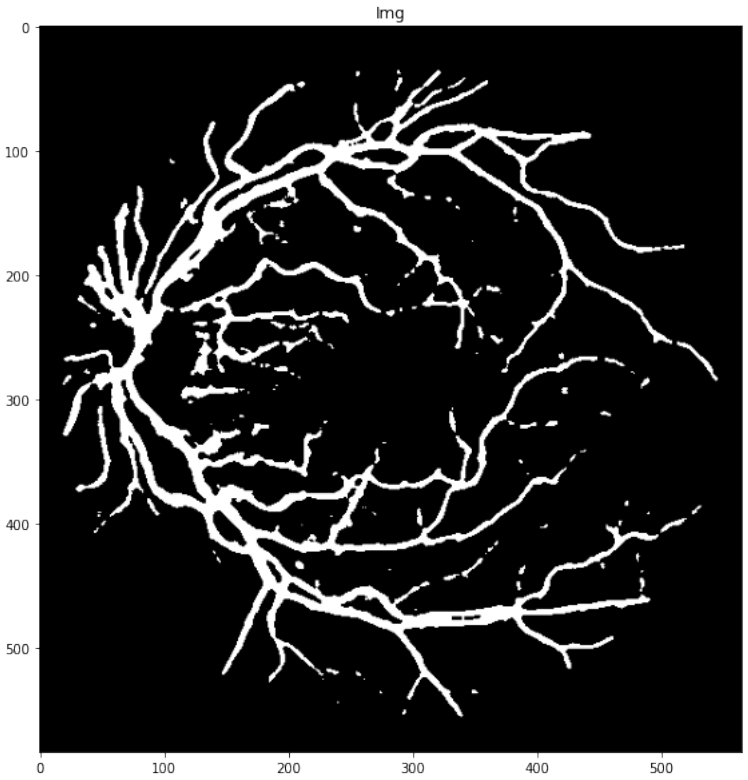
(b) Approach 2

3.7 Comparison

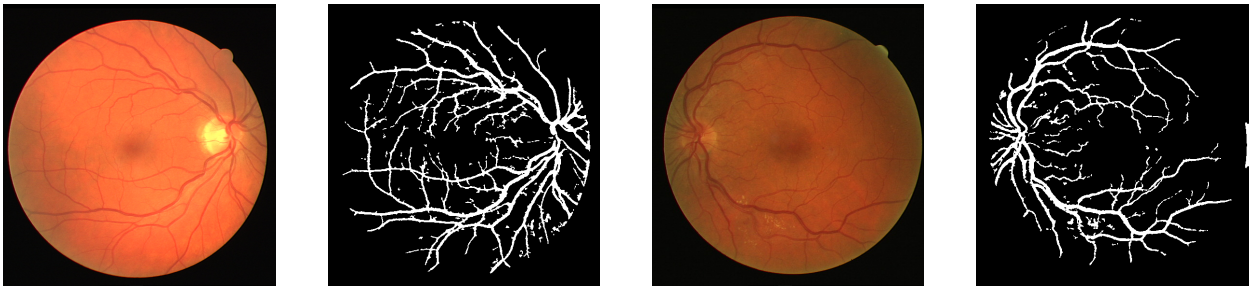
Since output corresponding to approach 2 is more noisy compared to approach 1 (around the optic disk region to be specific), we use approach 1, and proceed forward with this.

3.8 Hole filling

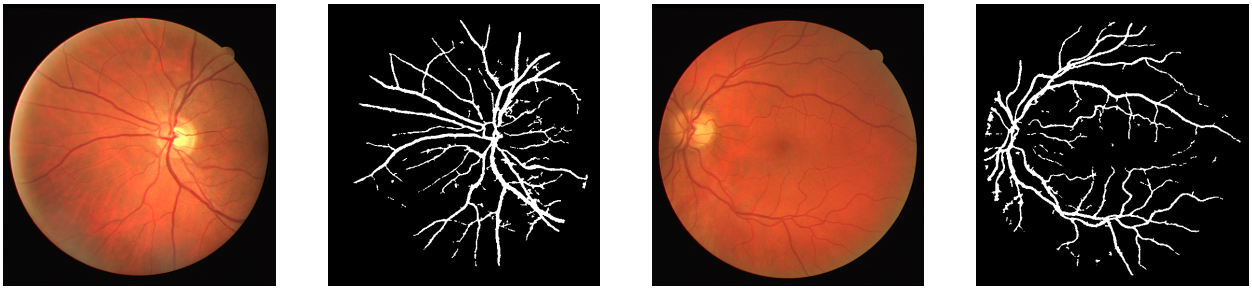
As the last step, we use median filtering with a $3 * 3$ block. It helps us solve both the problems: smoothing the vessel map by filling unwanted gaps (holes) and removing spurious branches in a single step. The final output is:



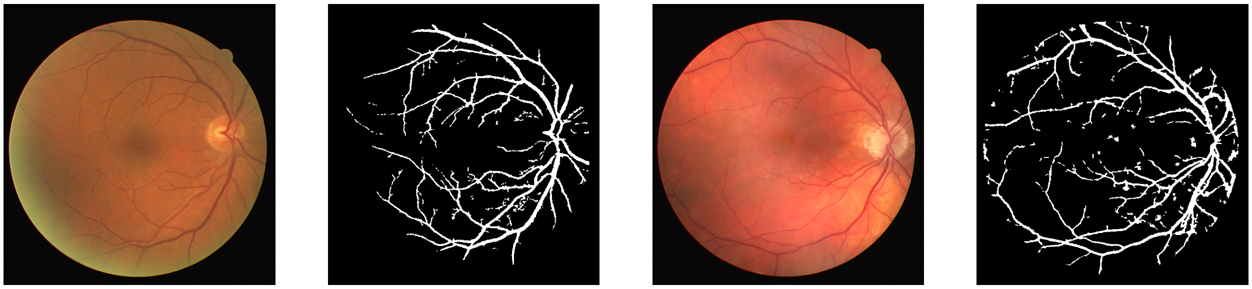
3.9 Additional Images: Extra Credits



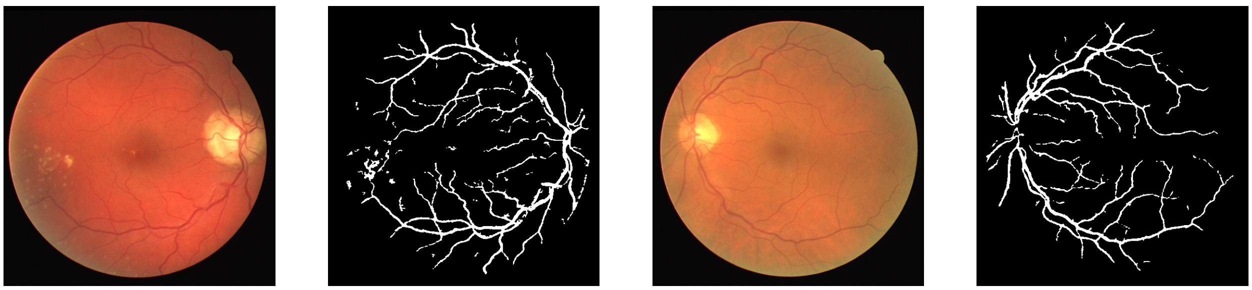
(a) (b) (c) (d)



(a) (b) (c) (d)

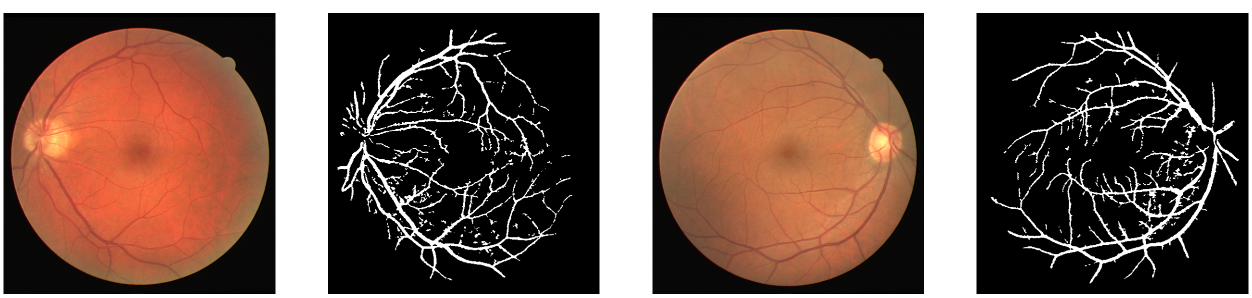


(a) (b) (c) (d)

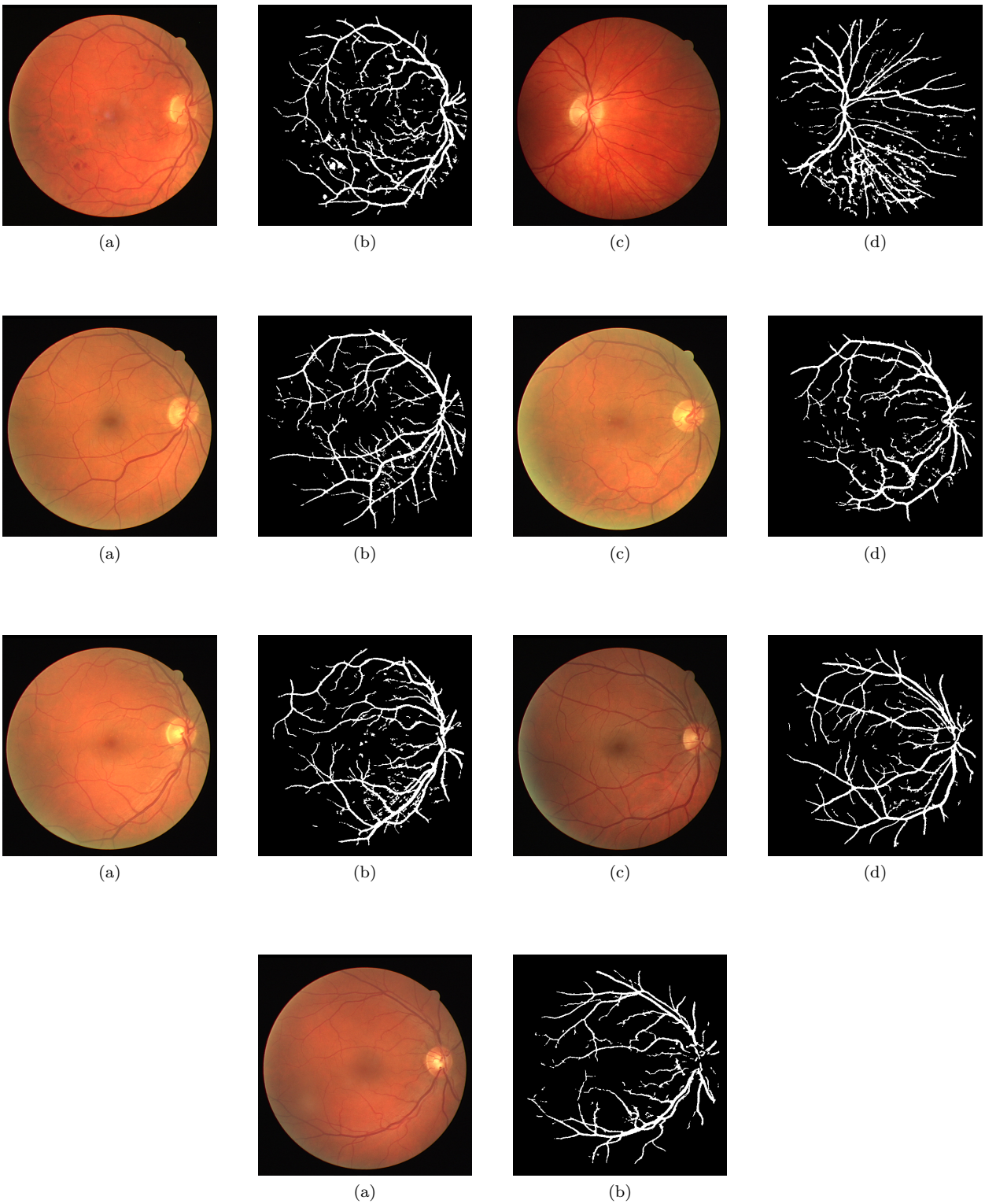


(a) (b) (c) (d)

(a) (b) (c) (d)



(a) (b) (c) (d)



(a) (b) (c) (d)

(a) (b) (c) (d)

(a) (b) (c) (d)

(a) (b)

Figure 8: a/c in the above figures represent input image, while b/d represent the corresponding output image (segmented vessel map)

4 Diameters

4.1 Diameter of thickest vessel

To find the thickest vessel we found the largest structuring element which gives zero output (black image) when we erode our image with it . We used circle as structuring element. Diameter of thickest vessel in terms of diameter of circle : 13

4.2 Diameter of thinnest vessel

To find the diameter of thinnest vessel we found the smallest structuring element which give non zero (black image) output .
Following steps are used to find the output

- Erode input image with the structuring element
- dilate eroded image with the structuring element
- intersection of original and dilated image
- difference of original and intersected image to get final output

Diameter of thinnest vessel in terms of diameter of circle : 1