



Project 1: Edge Detection

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Project Objective

ECEN-5283

Computer
Vision

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Project
Objective

Technical
Background

Results

Conclusion

Objectives

- ① Implement LoG, Canny and Matched Filter edge detection
- ② Apply them on 4 retinal images for blood vessel detection
- ③ Designing kernels for filtering

Tools, Input & Output

- ① **Python**, PyCharm IDE, Matplotlib, Numpy
- ② **Latex Beamer**, Sublime Text
- ③ **Input** Four retina image



Laplacian of Gaussian LoG

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- ① Laplacian is the 2D second order derivative

$$\text{LoG}(x, y) = \frac{1}{\pi\sigma^4} \left(\frac{x^2+y^2}{2\sigma^2} - 1 \right) e^{-\frac{x^2+y^2}{2\sigma^2}}$$

- ② LoG is the Laplacian applied to Gaussian

$$\text{LoG}(x, y; \sigma) = \Delta_{(x,y)} G(x, y; \sigma) =$$

$$\frac{\partial^2 G(x,y;\sigma)}{\partial x^2} + \frac{\partial^2 G(x,y;\sigma)}{\partial y^2} = \frac{1}{\pi\sigma^4} \left(\frac{x^2+y^2}{2\sigma^2} - 1 \right) e^{-\frac{x^2+y^2}{2\sigma^2}}.$$

- ③ Instead of calculating Gaussian then Laplacian the kernel is calculated into one single kernel

$$(K_{\nabla^2} * * (G_\sigma * * I)) = (K_{\nabla^2 * * G_\sigma}) * * I = (\nabla^2 G) * * I$$

- ④ Thresholding on Zero Crossing is applied to extract only the actual edges



- ➊ Estimate Gradient to find edges
 - ➋ $f_x = \frac{\delta f}{\delta x} = (K_{\nabla_x^2} * (G_x * I)) = (K_{\nabla_x^2 * G_x}) * I = (\nabla^2 G_x) * I$
 - ➌ $\Delta_{(x)} G(x; \sigma) = \frac{\partial^2 G}{\partial x^2} + \frac{\partial^2 G}{\partial y^2} = \frac{-x}{\pi \sigma^4} \left(\frac{x^2+y^2}{2\sigma^2} - 1 \right) e^{-\frac{x^2+y^2}{2\sigma^2}}$
 - ➍ $f_y = \frac{\delta f}{\delta y} = (K_{\nabla_y^2} * (G_y * I)) = (K_{\nabla_y^2 * G_x}) * I = (\nabla^2 G_y) * I$
 - ➎ $\Delta_{(y)} G(y; \sigma) = \frac{\partial^2 G}{\partial y^2} + \frac{\partial^2 G}{\partial x^2} = \frac{-y}{\pi \sigma^4} \left(\frac{x^2+y^2}{2\sigma^2} - 1 \right) e^{-\frac{x^2+y^2}{2\sigma^2}}$
 - ➏ Magnitude of the gradient can tell us whether it is an edge or not $\|\nabla f(x, y)\|_2 = \sqrt{f_x(x, y)^2 + f_y(x, y)^2}$
 - ➐ Orientation of the gradient tell us the orientation of the edge
- $$\tan(\theta(x, y)) = \frac{f_y(x, y)}{f_x(x, y)} \implies \theta(x, y) = \arctan \left(\frac{f_y(x, y)}{f_x(x, y)} \right)$$



Matched filter

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- Assumption is that cross section of an edge is Gaussian
- $G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{y^2}{2\sigma^2}}$ $m_0 \in [-x_0, x_0]$
- We define a group of filters $G(x, y)_{\theta 1} \dots G(x, y)_{\theta N}$
- Apply these kernel to image and fuse them
- We can then threshold the image to get binary image



Retinal Image Cock wise 1 to 4

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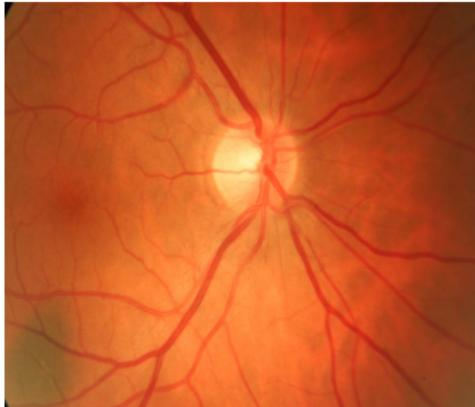
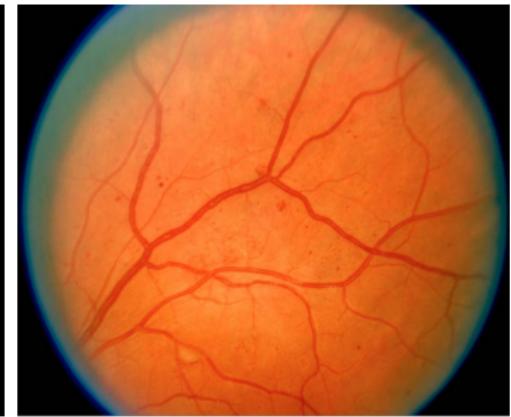
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For LoG

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$$K_2^* = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 2 & 1 & 0 \\ 1 & 2 & -16 & 2 & 1 \\ 0 & 1 & 2 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

$$K_3^* = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 2 & 1 & 0 & 0 \\ 0 & 1 & 1 & -3 & 1 & 1 & 0 \\ 1 & 2 & -3 & -12 & -3 & 2 & 1 \\ 0 & 1 & 1 & -3 & 1 & 1 & 0 \\ 0 & 0 & 1 & 2 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix}$$

K_3^* has been used for retina3.jpg and retina4.jpg for LoG while K_1^* for others.



For Canny

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$$f_x = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 2 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & -2 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$f_y = f_x^T$$

- Horizontal orientation
- ↗ Positive Slope orientation
- ↖ Negative Slope orientation
- ↑ Vertical orientation



For Match

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- $m_0 = -0.099$



Result and Contrast with Different Parameter

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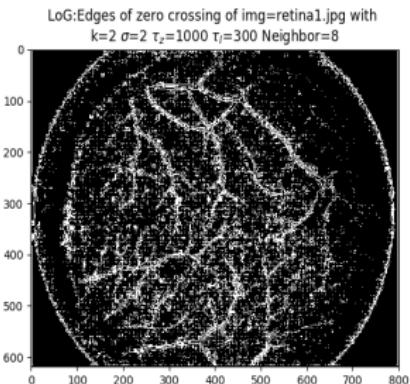
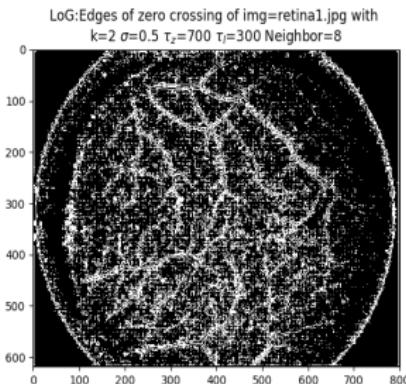
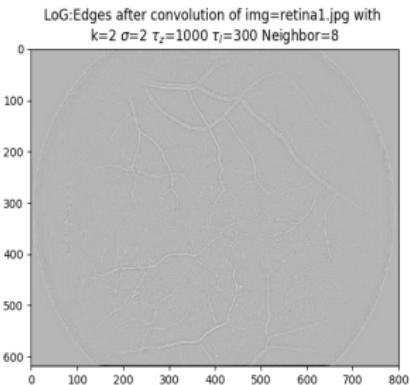
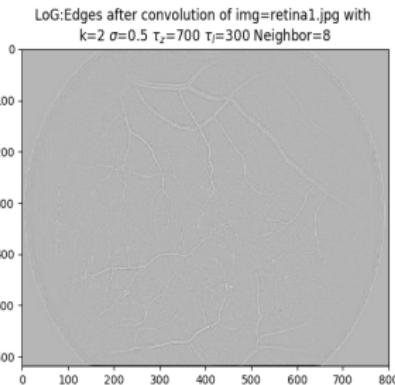
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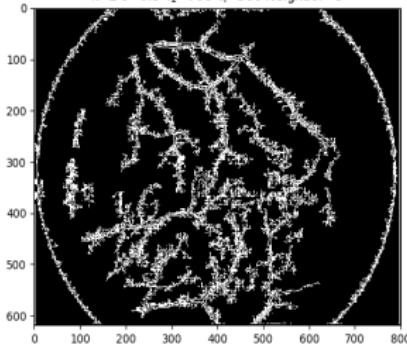
LoG

Canny

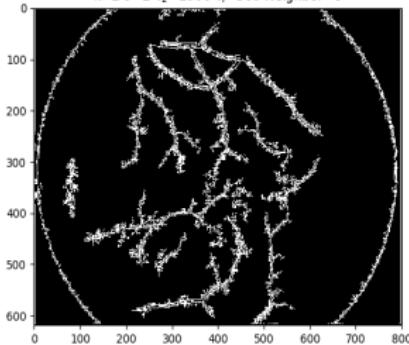
Matched Filter

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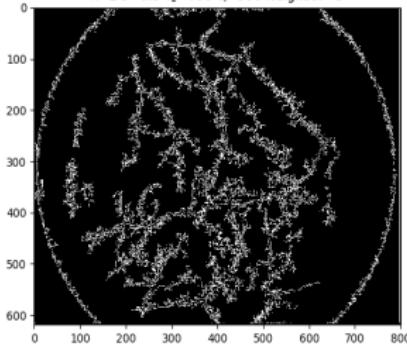
LoG: After Length Filtering of img=retina1.jpg with
 $k=2 \sigma=0.5 \tau_2=700 \tau_1=300$ Neighbor=8



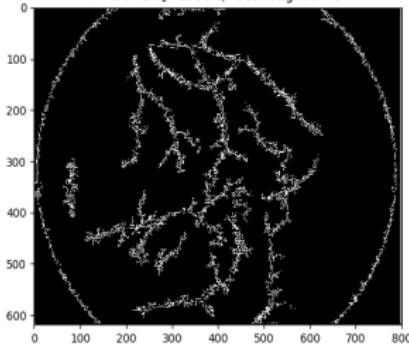
LoG: After Length Filtering of img=retina1.jpg with
 $k=2 \sigma=2 \tau_2=1000 \tau_1=300$ Neighbor=8



LoG: After Thinning of img=retina1.jpg with
 $k=2 \sigma=0.5 \tau_2=700 \tau_1=300$ Neighbor=8



LoG: After Thinning of img=retina1.jpg with
 $k=2 \sigma=2 \tau_2=1000 \tau_1=300$ Neighbor=8





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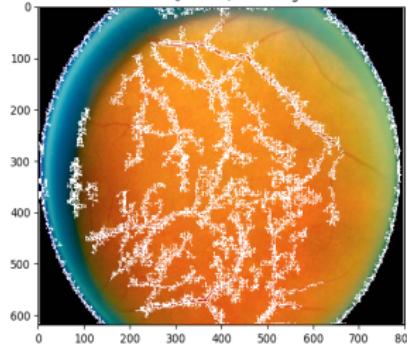
LoG

Canny

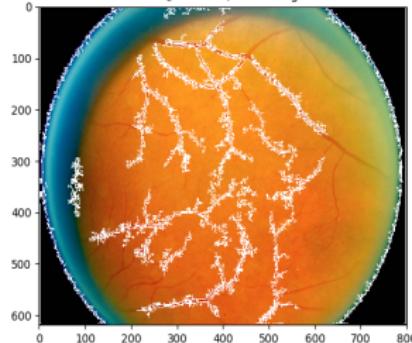
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LoG: After super imposeing of img=retina1.jpg with
 $k=2 \sigma=0.5 \tau_z=700 \tau_l=300$ Neighbor=8



LoG: After super imposeing of img=retina1.jpg with
 $k=2 \sigma=2 \tau_z=1000 \tau_l=300$ Neighbor=8





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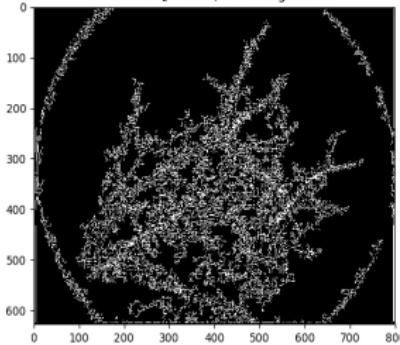
LoG

Canny

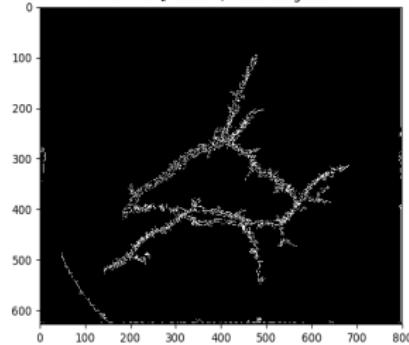
Matched Filter

Conclusion

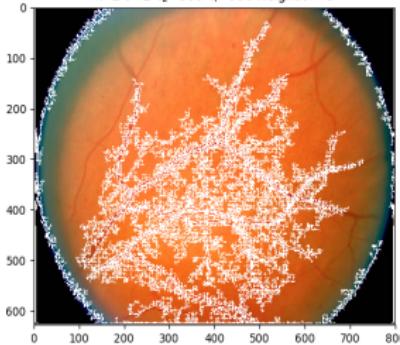
LoG: After Thinning of img=retina2.jpg with
 $k=2 \sigma=2 \tau_z=300 \tau_l=600$ Neighbor=8



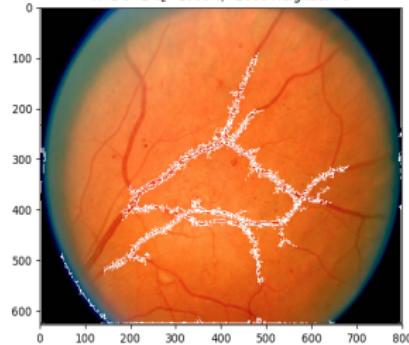
LoG: After Thinning of img=retina2.jpg with
 $k=2 \sigma=2 \tau_z=1000 \tau_l=1000$ Neighbor=8



LoG: After super imposeing of img=retina2.jpg with
 $k=2 \sigma=2 \tau_z=300 \tau_l=600$ Neighbor=8



LoG: After super imposeing of img=retina2.jpg with
 $k=2 \sigma=2 \tau_z=1000 \tau_l=1000$ Neighbor=8





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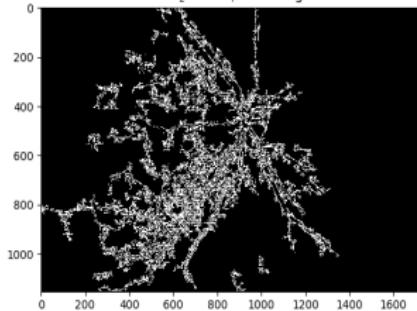
LoG

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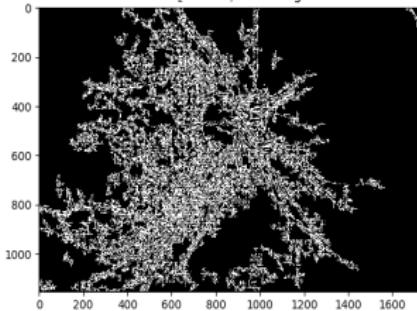
Matched Filter

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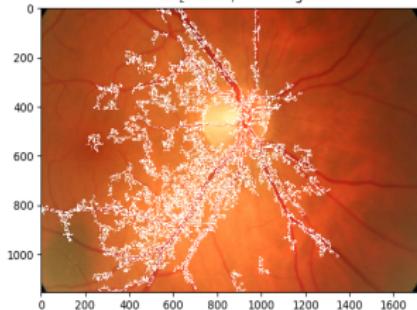
LoG: After Length Filtering of img=retina3.jpg with
 $k=3 \sigma=1 \tau_z=150 \tau_l=800$ Neighbor=4



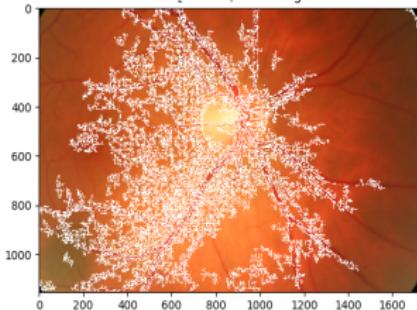
LoG: After Length Filtering of img=retina3.jpg with
 $k=3 \sigma=1 \tau_z=100 \tau_l=800$ Neighbor=4



LoG: After super imposeing of img=retina3.jpg with
 $k=3 \sigma=1 \tau_z=150 \tau_l=800$ Neighbor=4



LoG: After super imposeing of img=retina3.jpg with
 $k=3 \sigma=1 \tau_z=100 \tau_l=800$ Neighbor=4





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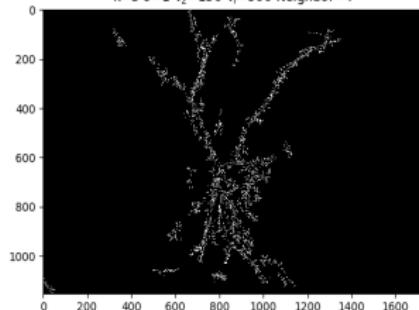
LoG

Canny

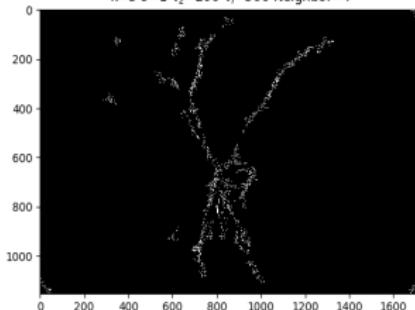
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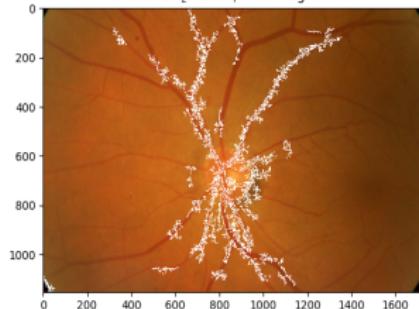
LoG: After Thinning of img=retina4.jpg with
 $k=3 \sigma=1 \tau_2=150 \tau_1=800$ Neighbor=4



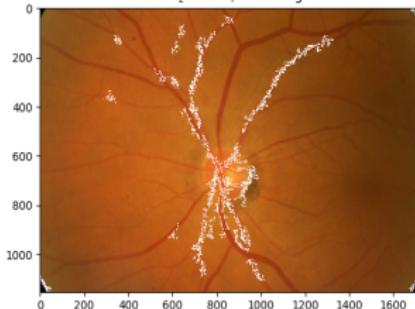
LoG: After Thinning of img=retina4.jpg with
 $k=3 \sigma=1 \tau_2=200 \tau_1=500$ Neighbor=4



LoG: After super imposeing of img=retina4.jpg with
 $k=3 \sigma=1 \tau_2=150 \tau_1=800$ Neighbor=4



LoG: After super imposeing of img=retina4.jpg with
 $k=3 \sigma=1 \tau_2=200 \tau_1=500$ Neighbor=4



Canny: Result and Contrast with Diff Param

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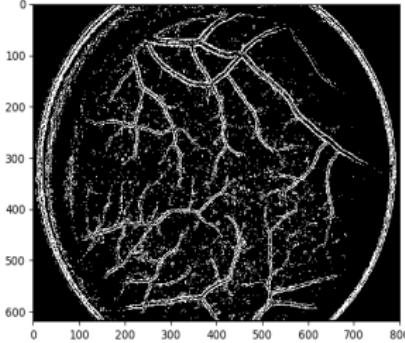
LoG

Canny

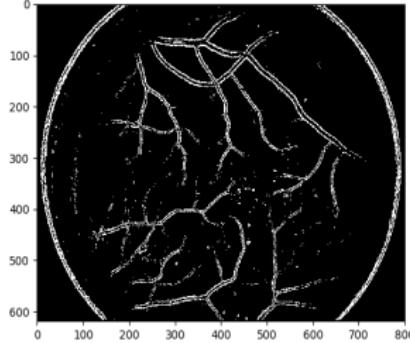
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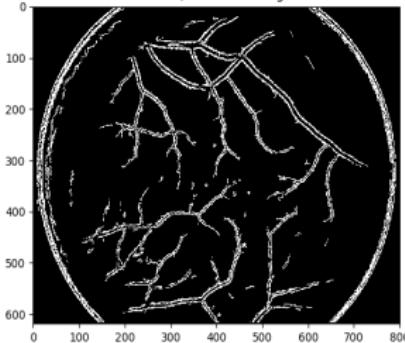
Canny: Non Max. Supression of retina1.jpg with
 $k=2 \sigma=0.5 T_1=30 N=30$ Neighbor=4



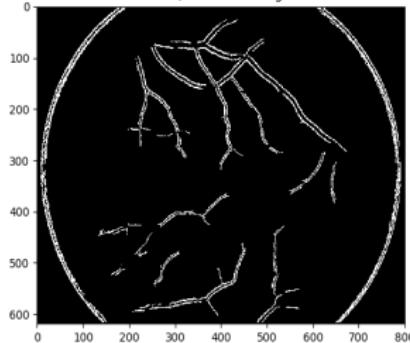
Canny: Non Max. Supression of retina1.jpg with
 $k=2 \sigma=2 T_1=50 N=50$ Neighbor=4



Canny: After Non Maximum Supression and Length Filter with of retina1.jpg w
 $k=2 \sigma=0.5 T_1=30 N=30$ Neighbor=4



Canny: After Non Maximum Supression and Length Filter with of retina1.jpg w
 $k=2 \sigma=2 T_1=50 N=50$ Neighbor=4





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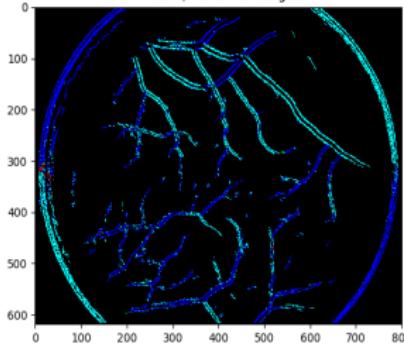
LoG

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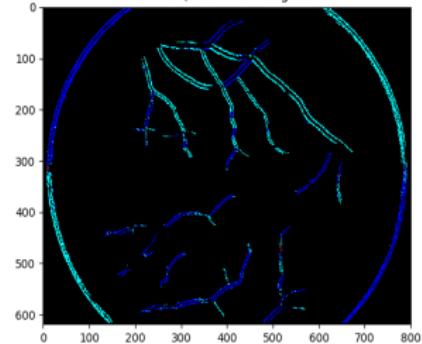
Matched Filter

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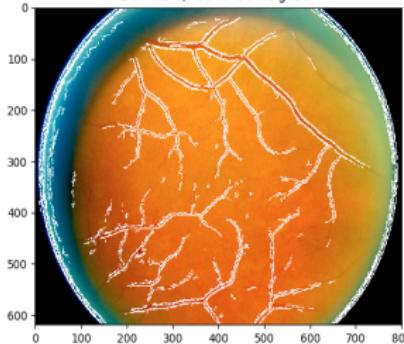
Canny: Edges orientation of retina1.jpg with
 $k=2 \sigma=0.5 \tau_1=30 N=30$ Neighbor=4



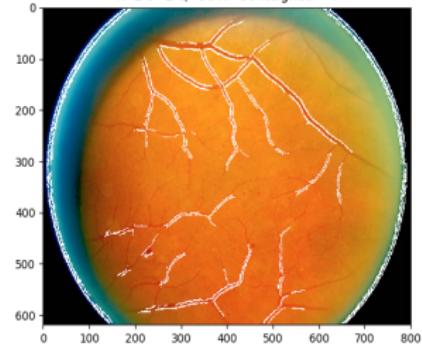
Canny: Edges orientation of retina1.jpg with
 $k=2 \sigma=2 \tau_1=50 N=50$ Neighbor=4



Canny: Edges Superimposed of retina1.jpg with
 $k=2 \sigma=0.5 \tau_1=30 N=30$ Neighbor=4



Canny: Edges Superimposed of retina1.jpg with
 $k=2 \sigma=2 \tau_1=50 N=50$ Neighbor=4





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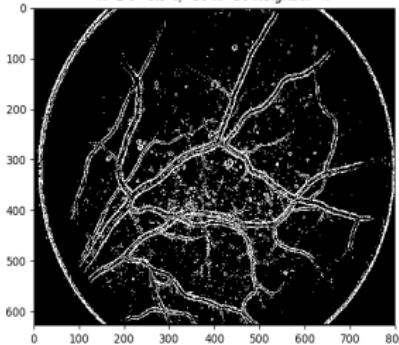
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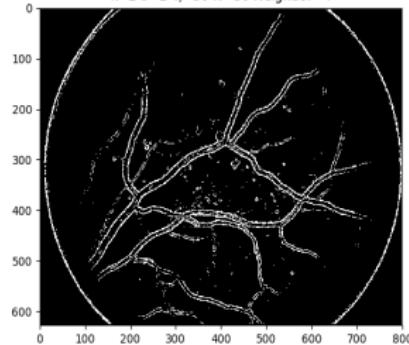
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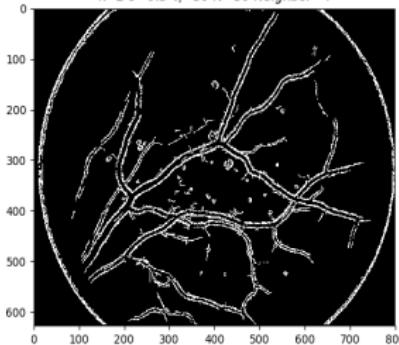
Canny: Non Max. Supression of retina2.jpg with
 $k=2 \sigma=0.5 \tau_1=30 N=30$ Neighbor=4



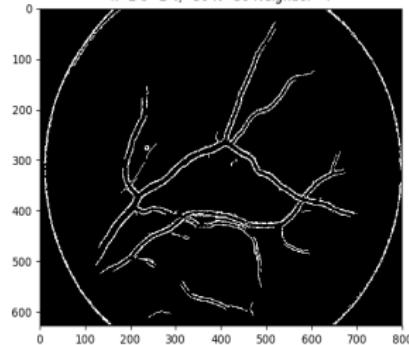
Canny: Non Max. Supression of retina2.jpg with
 $k=2 \sigma=2 \tau_1=50 N=50$ Neighbor=4



Canny: After Non Maximum Supression and Length Filter with of retina2.jpg w
 $k=2 \sigma=0.5 \tau_1=30 N=30$ Neighbor=4



Canny: After Non Maximum Supression and Length Filter with of retina2.jpg w
 $k=2 \sigma=2 \tau_1=50 N=50$ Neighbor=4

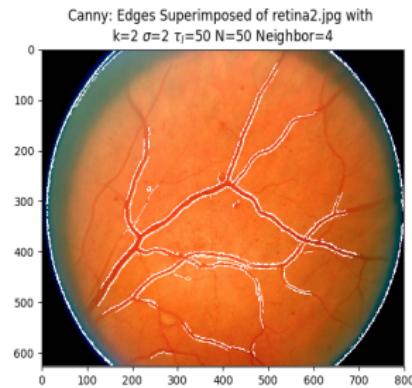
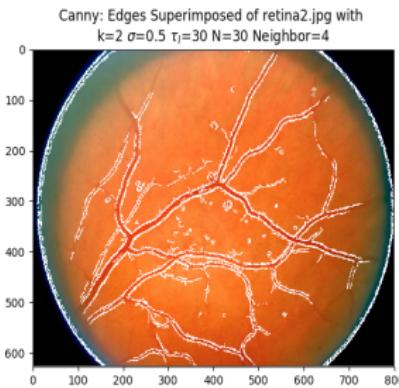
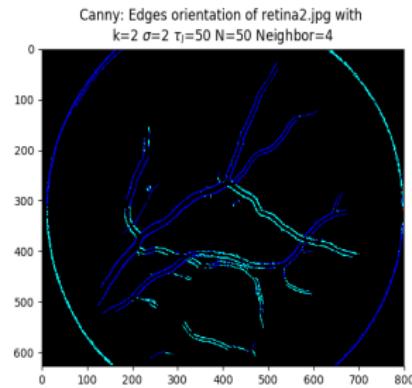
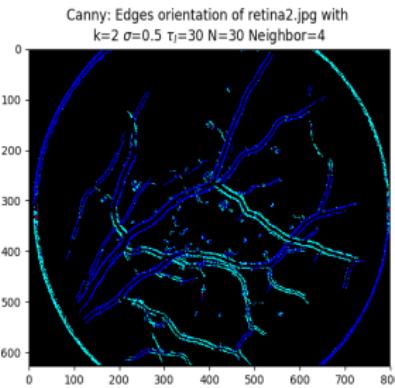




Canny: Result and Contrast

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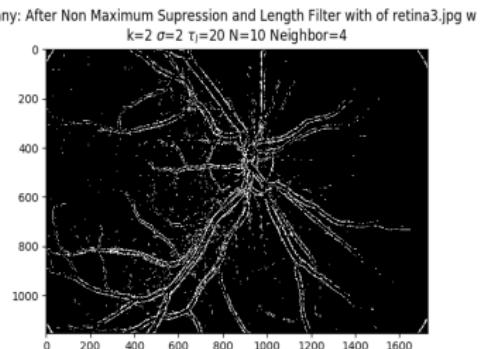
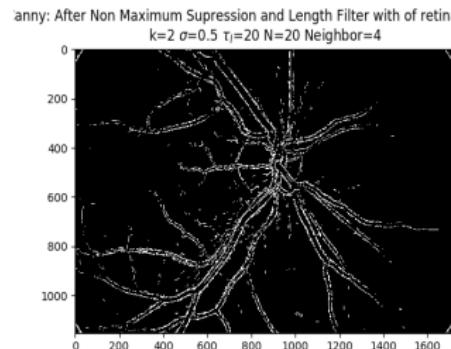
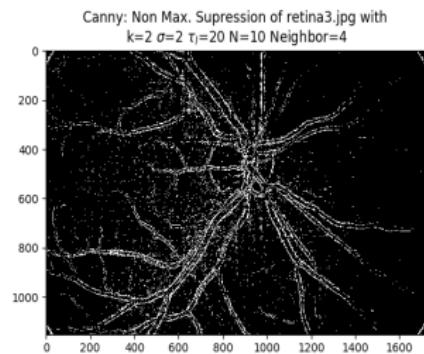
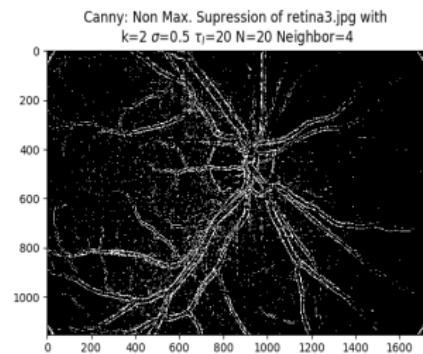
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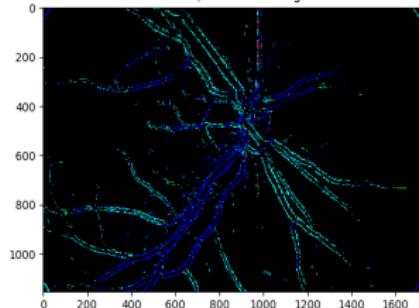
LoG

Canny

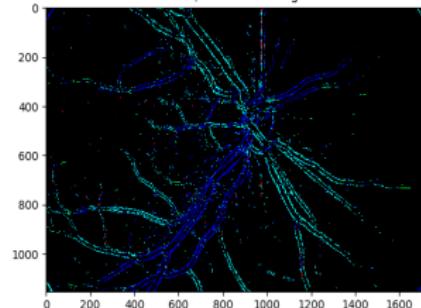
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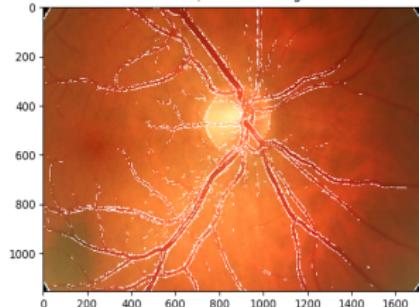
Canny: Edges orientation of retina3.jpg with
 $k=2 \sigma=0.5 \tau_l=20 N=20$ Neighbor=4



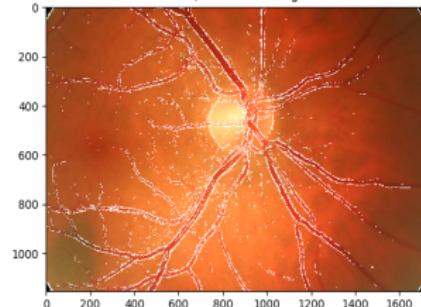
Canny: Edges orientation of retina3.jpg with
 $k=2 \sigma=2 \tau_l=20 N=10$ Neighbor=4



Canny: Edges Superimposed of retina3.jpg with
 $k=2 \sigma=0.5 \tau_l=20 N=20$ Neighbor=4



Canny: Edges Superimposed of retina3.jpg with
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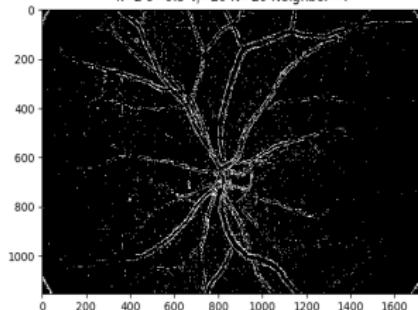
LoG

Canny

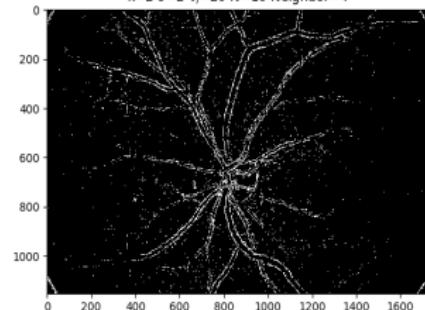
Matched Filter

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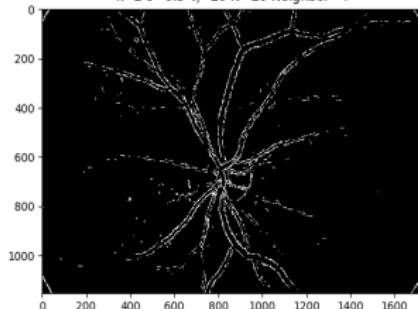
Canny: Non Max. Supression of retina4.jpg with
 $k=2 \sigma=0.5 \tau_1=20 N=20$ Neighbor=4



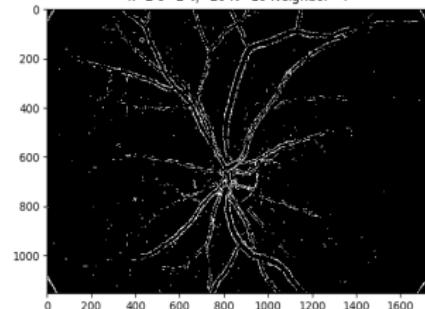
Canny: Non Max. Supression of retina4.jpg with
 $k=2 \sigma=2 \tau_1=20 N=10$ Neighbor=4



Canny: After Non Maximum Supression and Length Filter with of retina4.jpg w
 $k=2 \sigma=0.5 \tau_1=20 N=20$ Neighbor=4



Canny: After Non Maximum Supression and Length Filter with of retina4.jpg w
 $k=2 \sigma=2 \tau_1=20 N=10$ Neighbor=4





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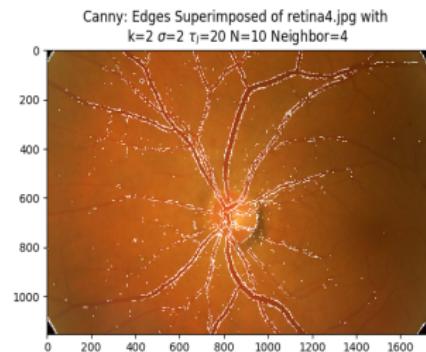
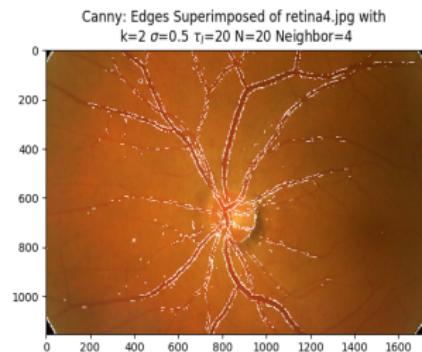
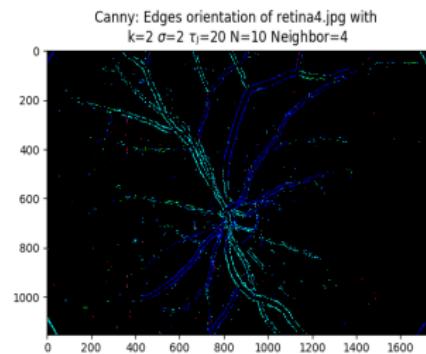
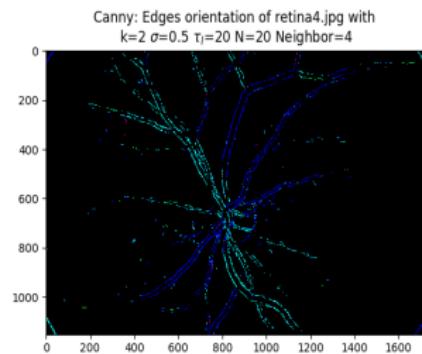
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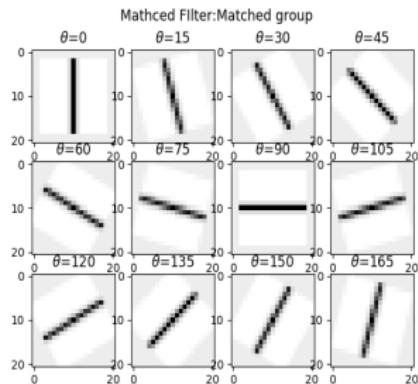
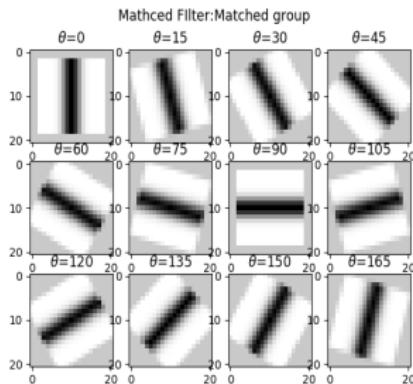
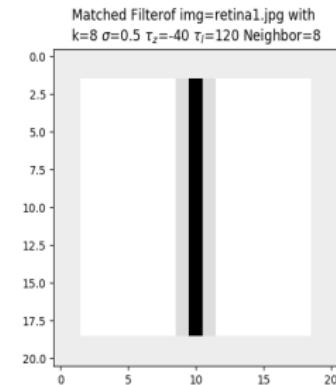
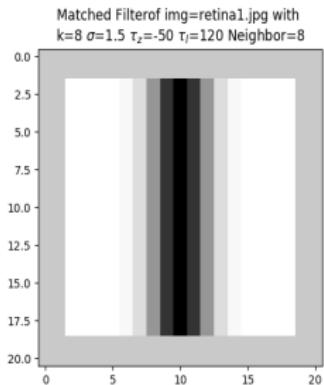
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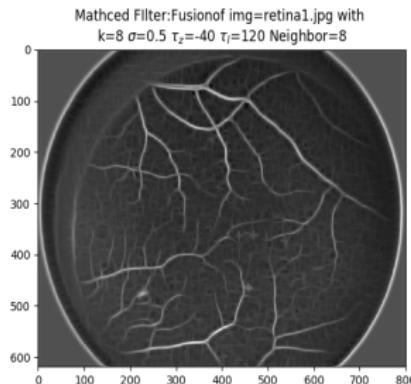
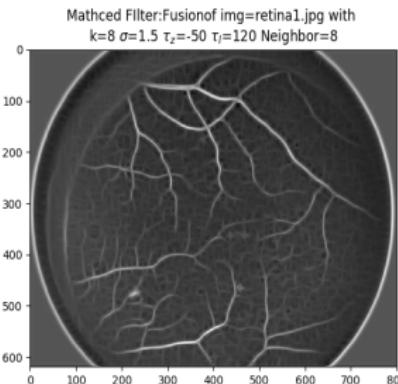
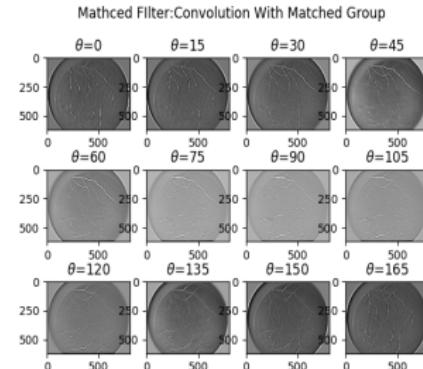
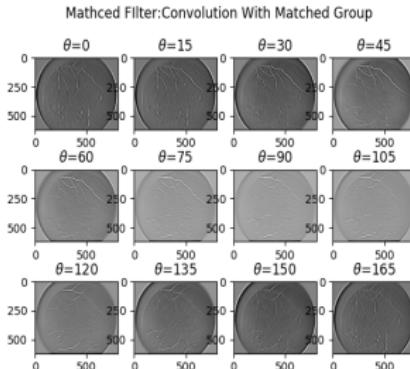




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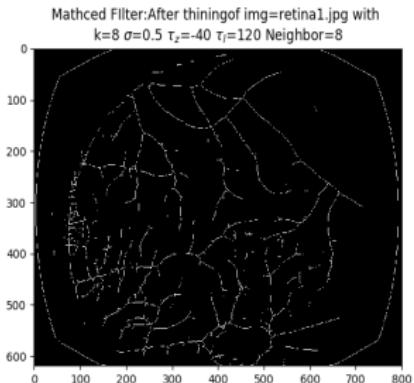
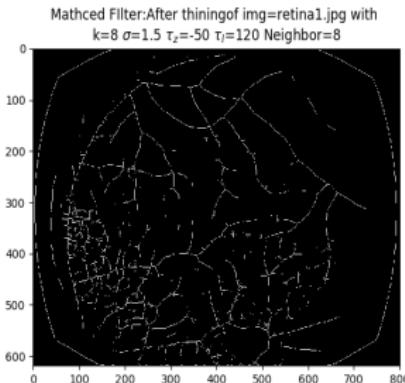
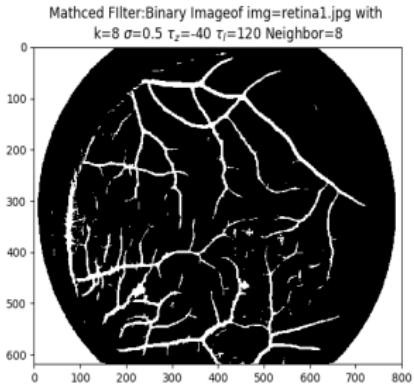
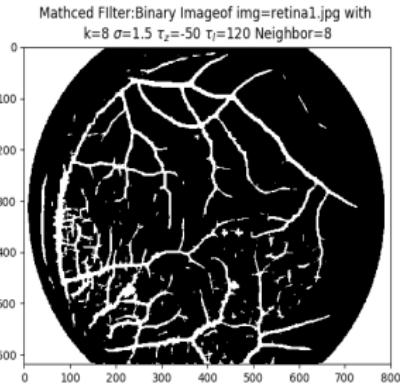




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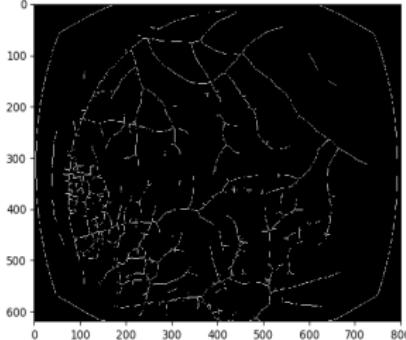
LoG

Canny

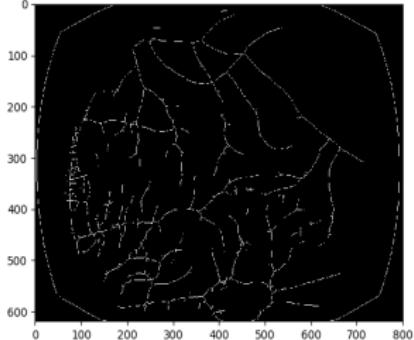
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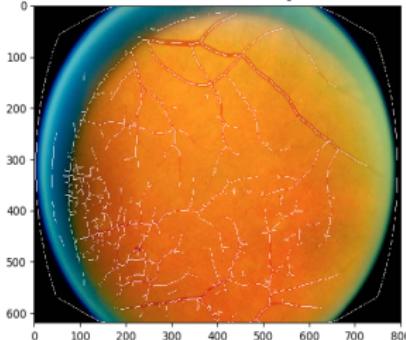
Matched Filter:Length Filtering of img=retina1.jpg with
 $k=8 \sigma=1.5 \tau_z=-50 \tau_l=120$ Neighbor=8



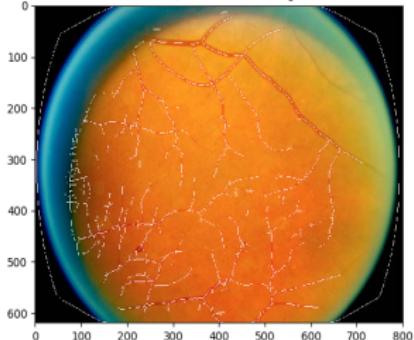
Matched Filter:Length Filtering of img=retina1.jpg with
 $k=8 \sigma=0.5 \tau_z=-40 \tau_l=120$ Neighbor=8



Matched Filter:Super Imposed of img=retina1.jpg with
 $k=8 \sigma=1.5 \tau_z=-50 \tau_l=120$ Neighbor=8



Matched Filter:Super Imposed of img=retina1.jpg with
 $k=8 \sigma=0.5 \tau_z=-40 \tau_l=120$ Neighbor=8

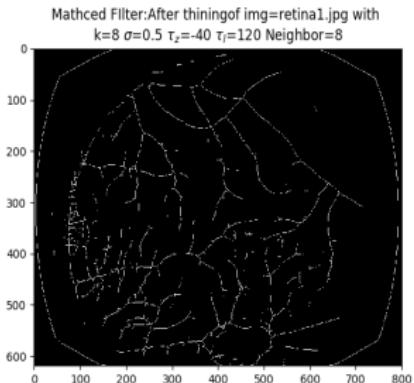
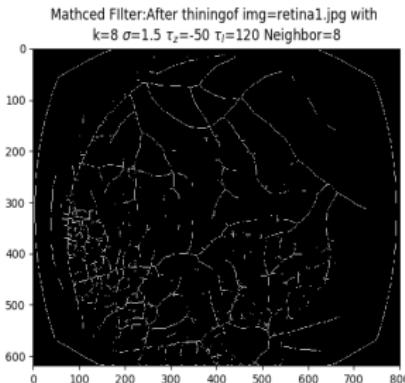
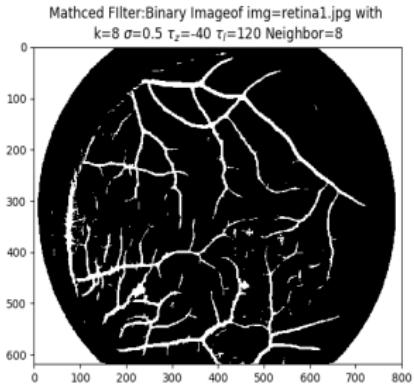
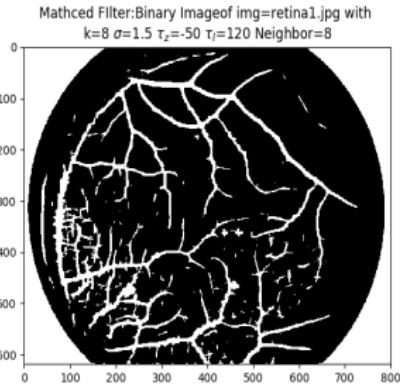




Match: Result and Contrast

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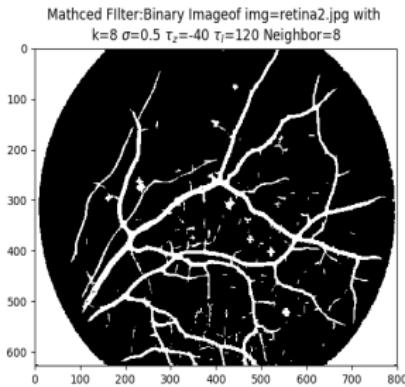
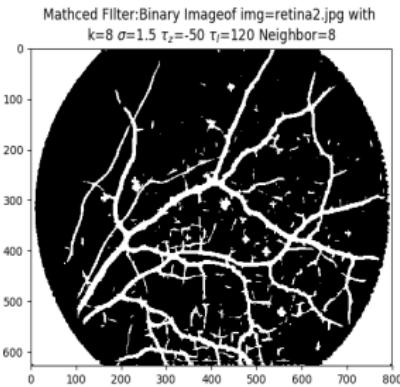
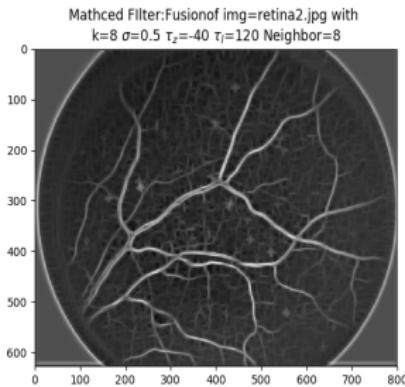
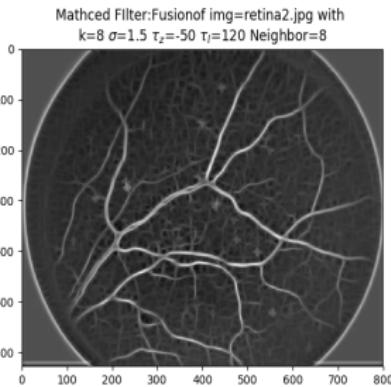
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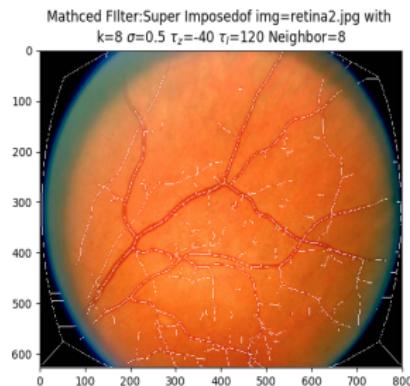
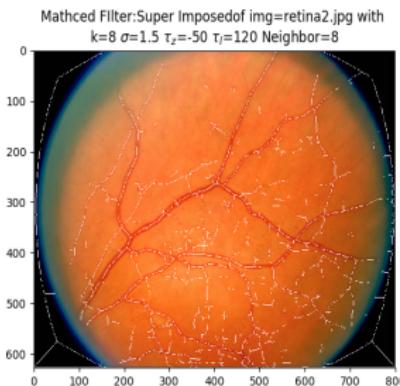
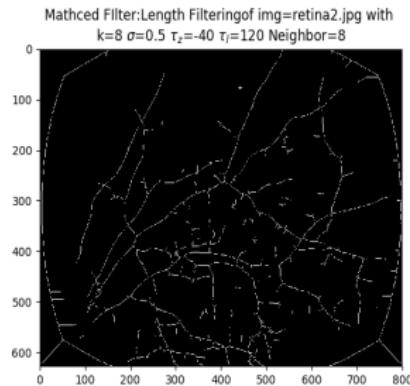
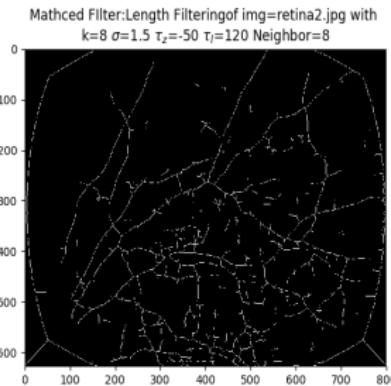
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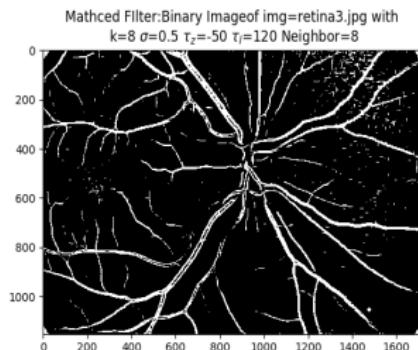
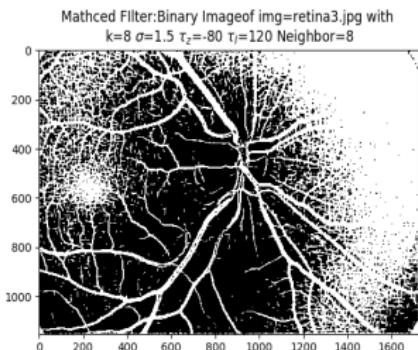
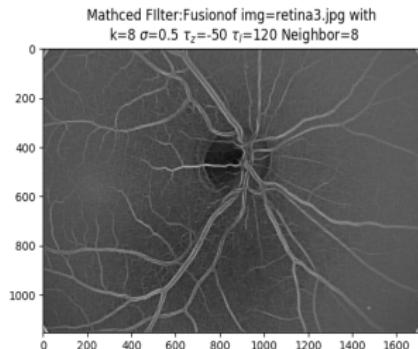
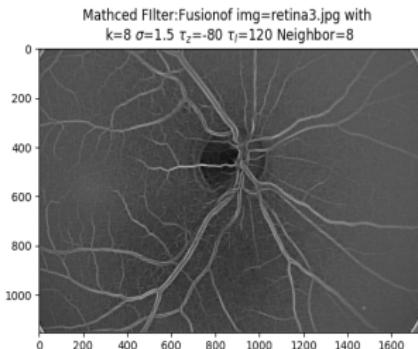
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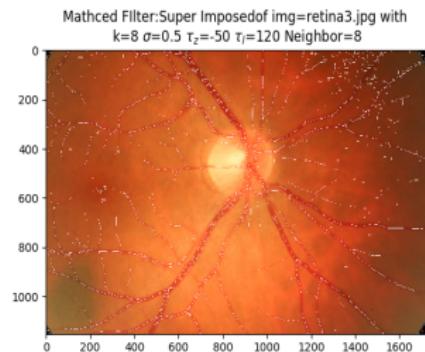
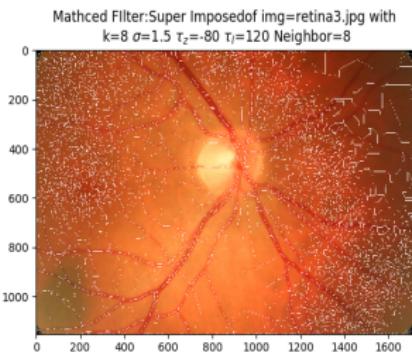
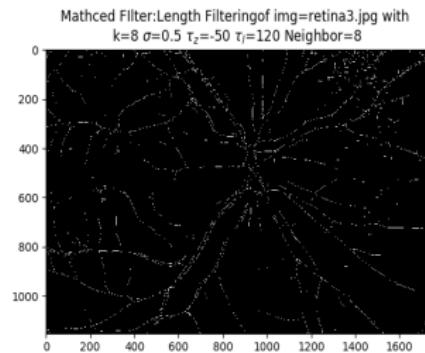
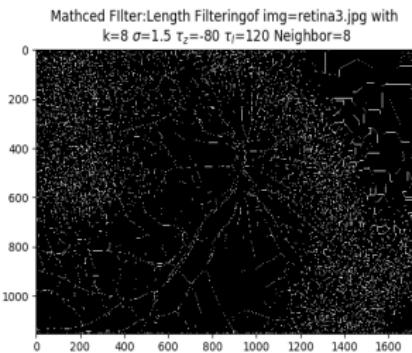
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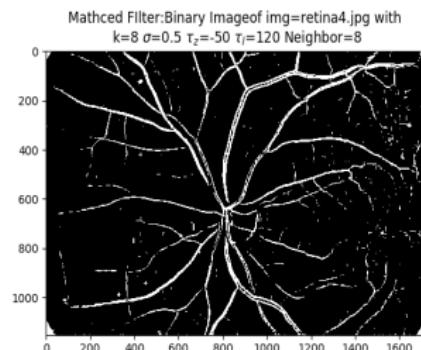
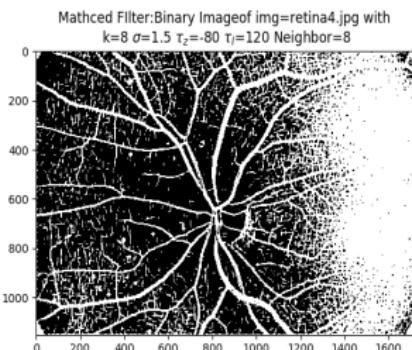
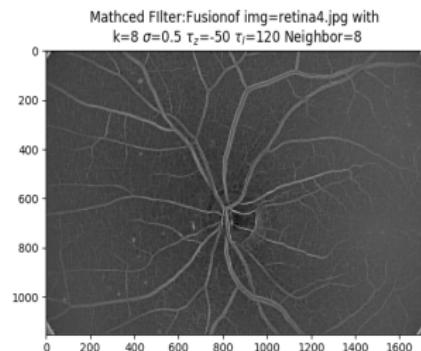
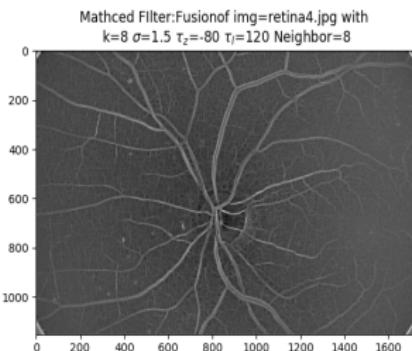
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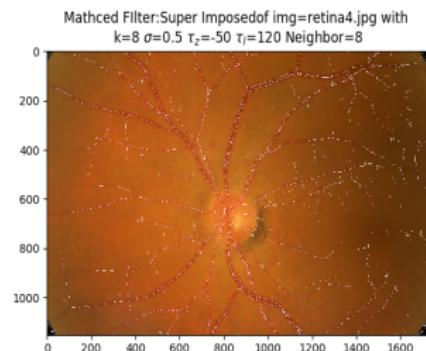
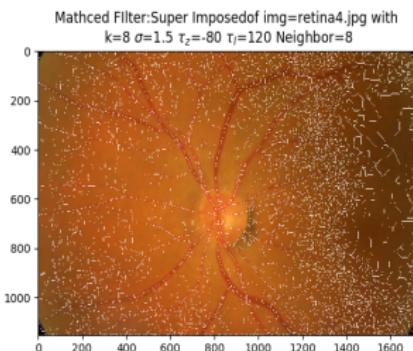
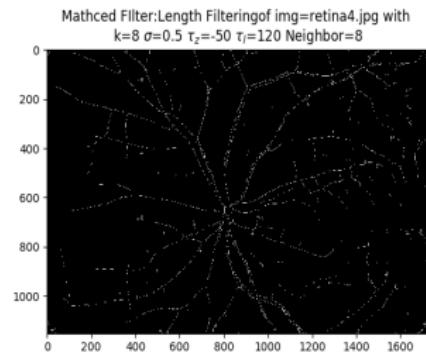
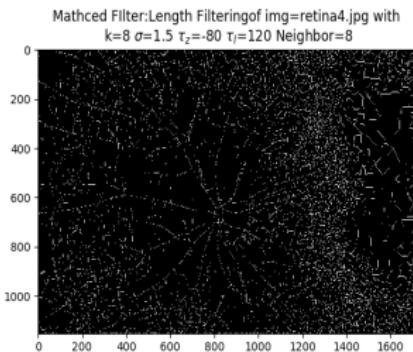
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Final Comparison

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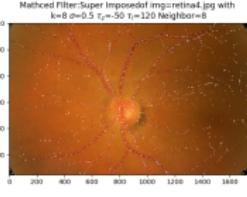
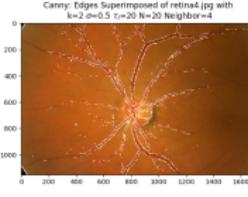
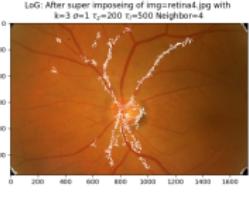
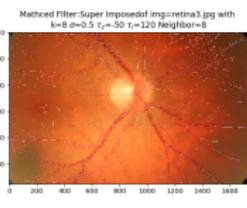
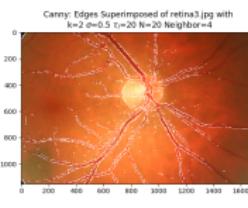
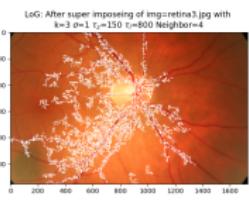
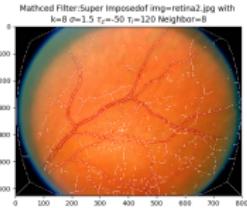
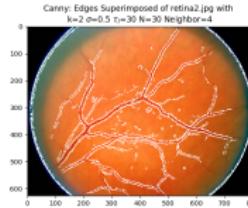
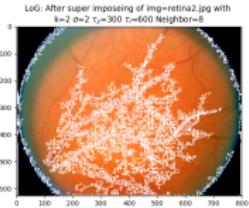
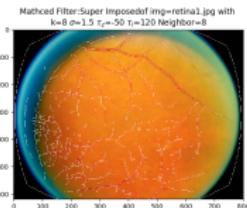
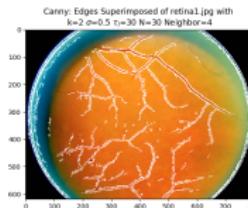
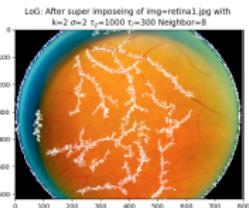
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- In this project, we have studied the Edge detection using LoG, Canny and Match filter Method
- LoG is simplistic in design and can but can not capture blood vessel rather captures the edges it is also spatial only does not give orientation information
- Canny gives spatial and orientation information. Besides there are some important criteria like signal to noise ratio, low false positive rate makes it attractive. However non Maximal Suppression can be time consuming.
- Matched filter gives more insight about the edge and better in detecting blood vessel. However manual design of filters may require efforts.



Additional Work

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- Developed my python implementation of Matlab BWLABEL
- My implementation can be found at LoG implementation py_bwlable
- py_bwlable is notoriously slow
- I figured out Matlab and skimage.measure.label uses bitwise optimization
- I had to use unofficial python package bwmorph_thin of BWMORPH as well