



# Project 1: Edge Detection

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February 20, 2018



# 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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Project  
Objective

Technical  
Background

Results

Conclusion

- 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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Project  
Objective

Technical  
Background

Results

Conclusion

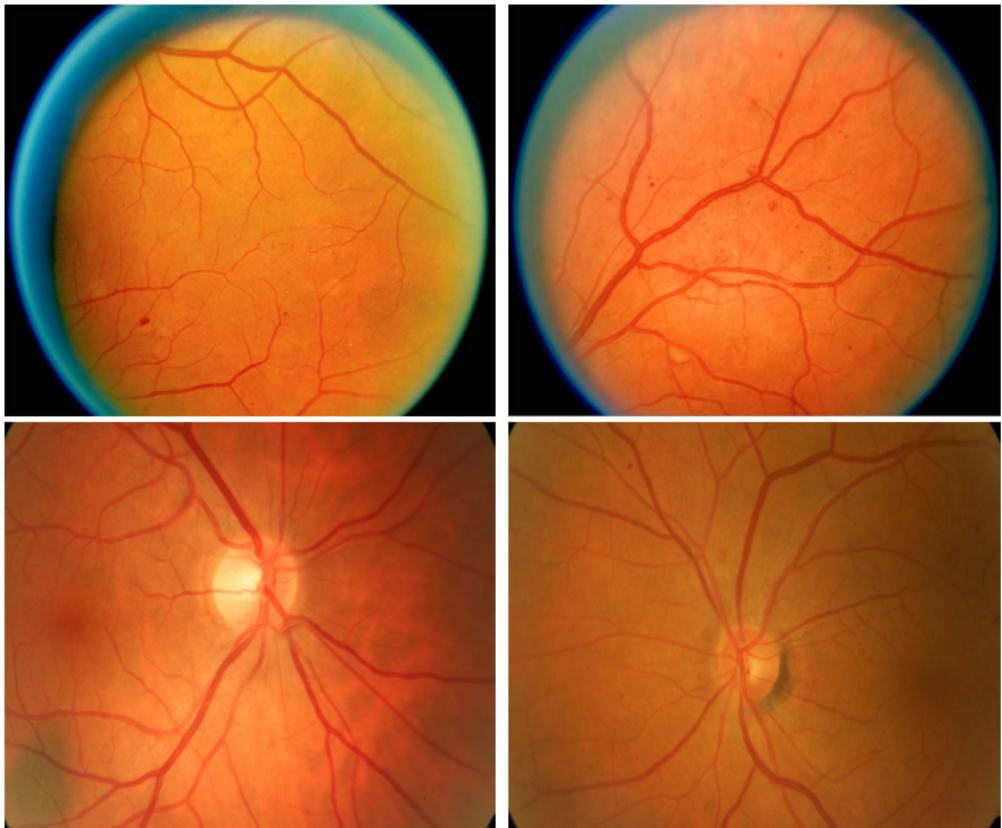
- Assumption is that cross section of an edge is Gaussian
- $G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{y^2}{2\sigma^2}}$        $m_0 \in [-x_0, x_0]$
- We define a group of filters  $G(x, y)_{\theta 1} \dots G(x, y)_{\theta N}$
- Apply these kernel to image and fuse them
- We can then threshold the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



# LoG: Retinal Image Cock wise 1 to 4

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Project  
Objective  
Technical  
Background  
Results  
LoG  
Canny  
Matched Filter  
Conclusion





# For LoG

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Vision

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Project  
Objective

Technical  
Background

Results

LoG

Canny

Matched Filter

Conclusion

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

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

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



# For Canny

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Project  
Objective

Technical  
Background

Results

LoG

Canny

Matched Filter

Conclusion

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

$$f_y = f_x^T$$

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



# Result and Contrast with Different Parameter

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Computer  
Vision

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Project  
Objective

Technical  
Background

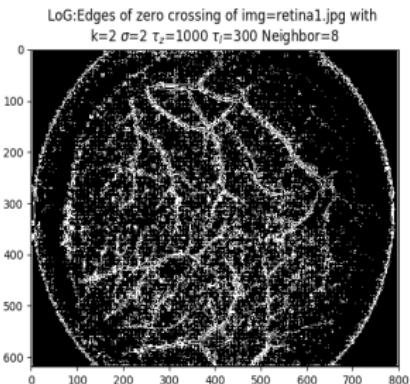
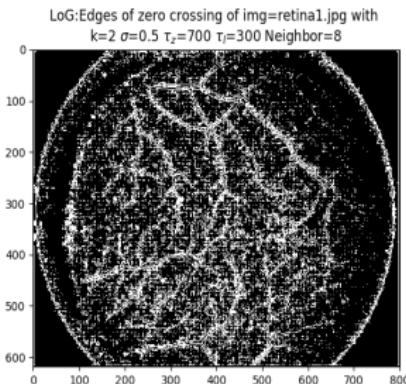
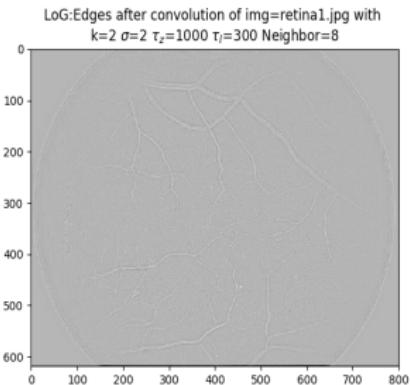
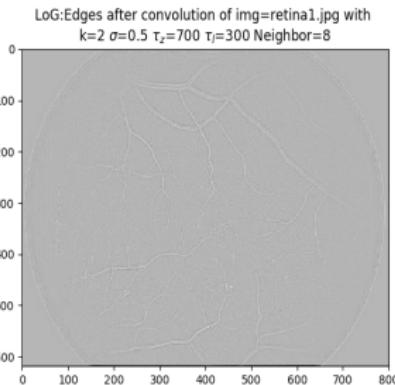
Results

LoG

Canny

Matched Filter

Conclusion





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ECEN-5283

Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

Results

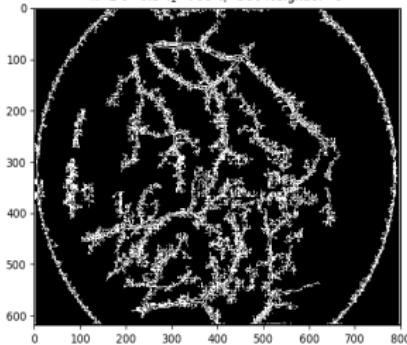
LoG

Canny

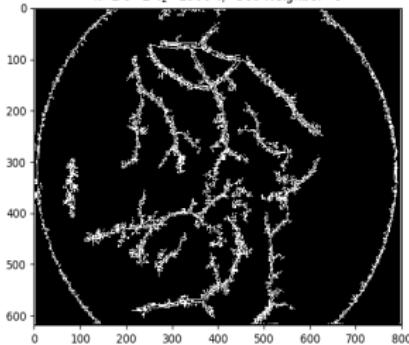
Matched Filter

Conclusion

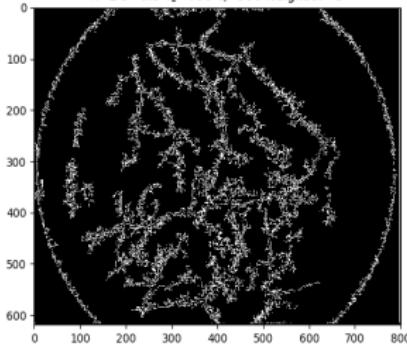
LoG: After Length Filtering of img=retina1.jpg with  
 $k=2 \sigma=0.5 \tau_2=700 \tau_1=300$  Neighbor=8



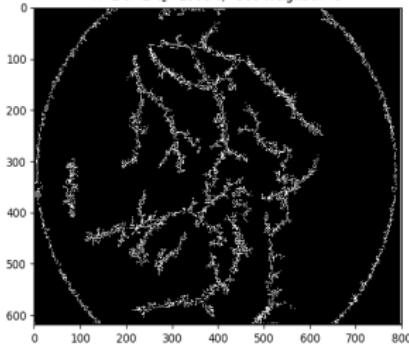
LoG: After Length Filtering of img=retina1.jpg with  
 $k=2 \sigma=2 \tau_2=1000 \tau_1=300$  Neighbor=8



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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ECEN-5283

Computer  
Vision

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Project  
Objective

Technical  
Background

Results

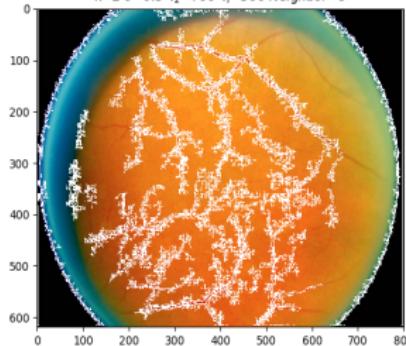
LoG

Canny

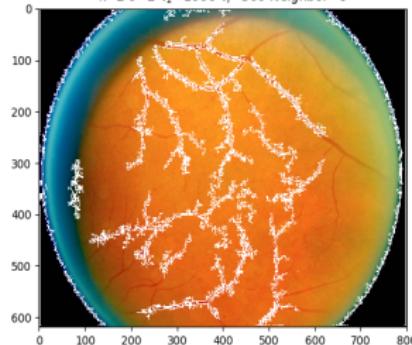
Matched Filter

Conclusion

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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ECEN-5283  
Computer  
Vision  
S M Al Mahi

Project  
Objective

Technical  
Background

Results

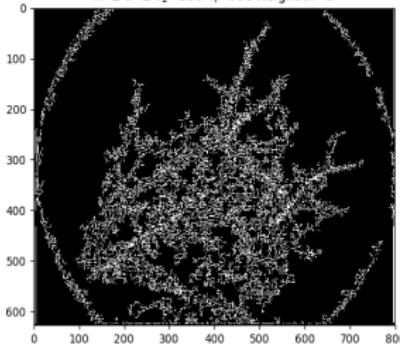
LoG

Canny

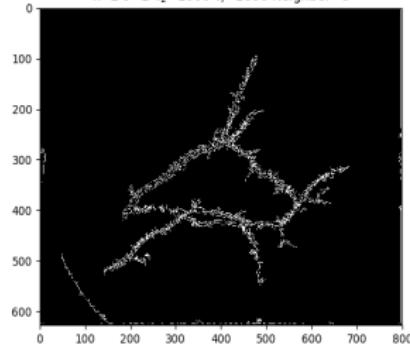
Matched Filter

Conclusion

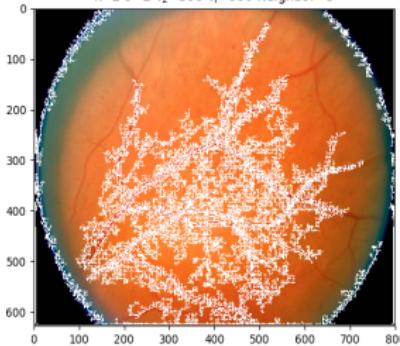
LoG: After Thinning of img=retina2.jpg with  
 $k=2 \sigma=2 \tau_z=300 \tau_l=600$  Neighbor=8



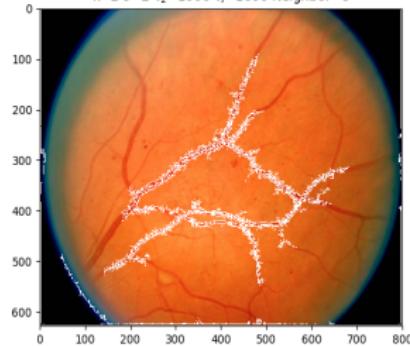
LoG: After Thinning of img=retina2.jpg with  
 $k=2 \sigma=2 \tau_z=1000 \tau_l=1000$  Neighbor=8



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





# Result and Contrast with Different Parameter

ECEN-5283  
Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

Results

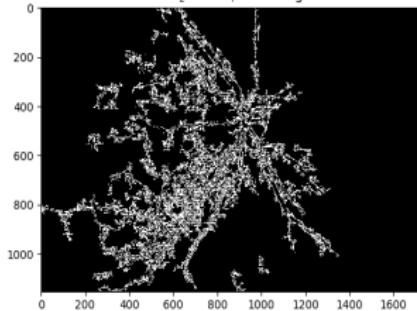
LoG

Canny

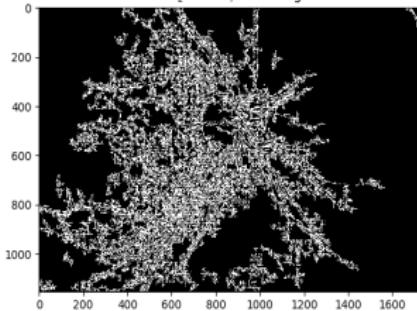
Matched Filter

Conclusion

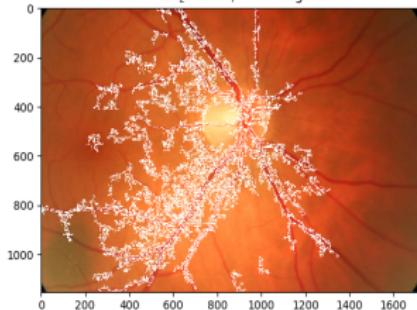
LoG: After Length Filtering of img=retina3.jpg with  
 $k=3 \sigma=1 \tau_z=150 \tau_l=800$  Neighbor=4



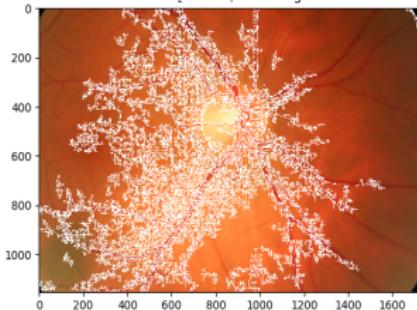
LoG: After Length Filtering of img=retina3.jpg with  
 $k=3 \sigma=1 \tau_z=100 \tau_l=800$  Neighbor=4



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





# Result and Contrast with Different Parameter

ECEN-5283  
Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

Results

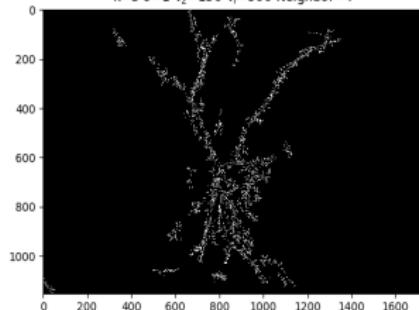
LoG

Canny

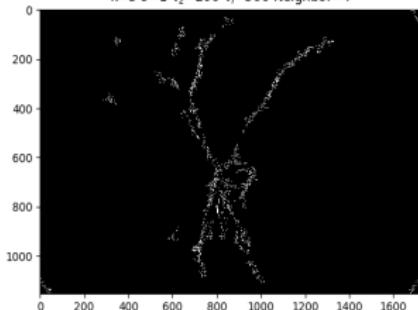
Matched Filter

Conclusion

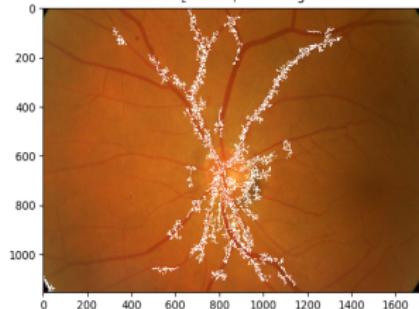
LoG: After Thinning of img=retina4.jpg with  
 $k=3 \sigma=1 \tau_2=150 \tau_1=800$  Neighbor=4



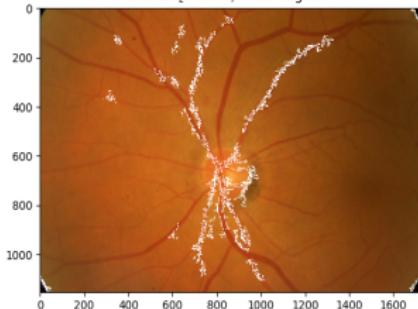
LoG: After Thinning of img=retina4.jpg with  
 $k=3 \sigma=1 \tau_2=200 \tau_1=500$  Neighbor=4



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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Computer

Vision

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Project  
Objective

Technical  
Background

Results

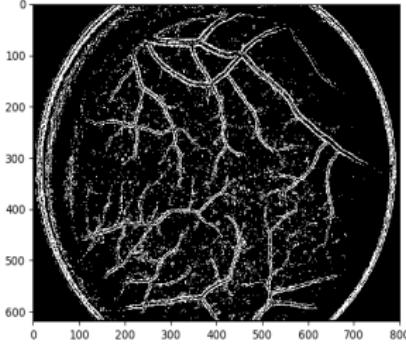
LoG

Canny

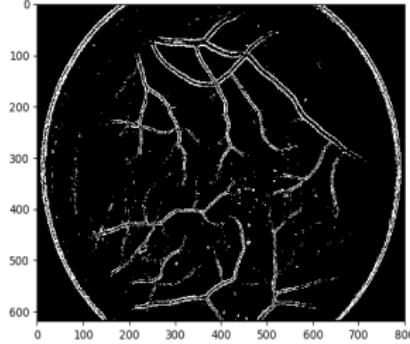
Matched Filter

Conclusion

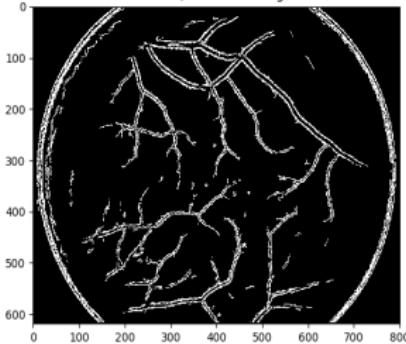
Canny: Non Max. Supression of retina1.jpg with  
 $k=2 \sigma=0.5 T_1=30 N=30$  Neighbor=4



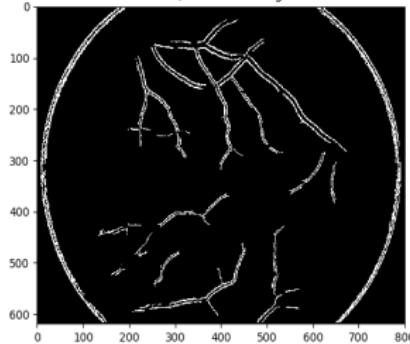
Canny: Non Max. Supression of retina1.jpg with  
 $k=2 \sigma=2 T_1=50 N=50$  Neighbor=4



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





# Canny: Result and Contrast

ECEN-5283

Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

Results

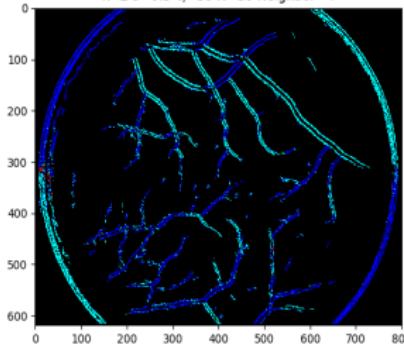
LoG

Canny

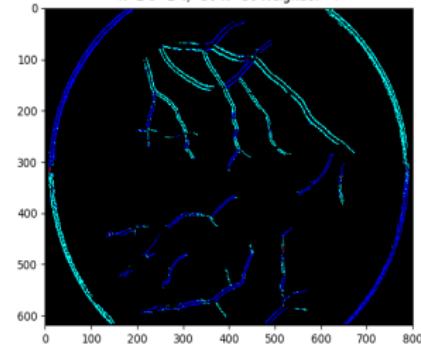
Matched Filter

Conclusion

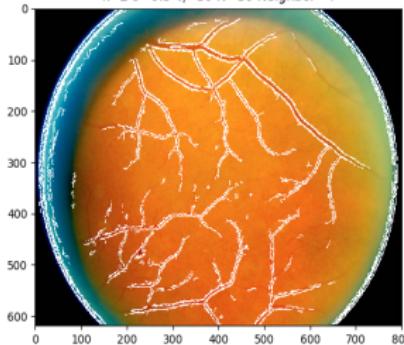
Canny: Edges orientation of retina1.jpg with  
 $k=2 \sigma=0.5 \tau_1=30 N=30$  Neighbor=4



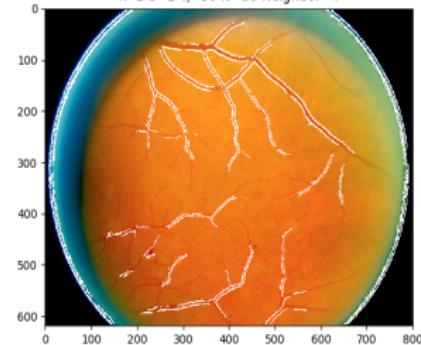
Canny: Edges orientation of retina1.jpg with  
 $k=2 \sigma=2 \tau_1=50 N=50$  Neighbor=4



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





# Canny: Result and Contrast

ECEN-5283

Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

Results

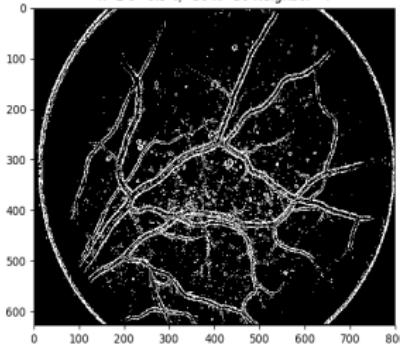
LoG

Canny

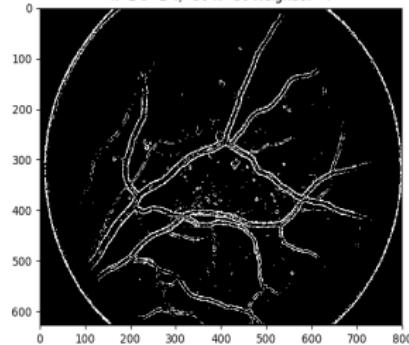
Matched Filter

Conclusion

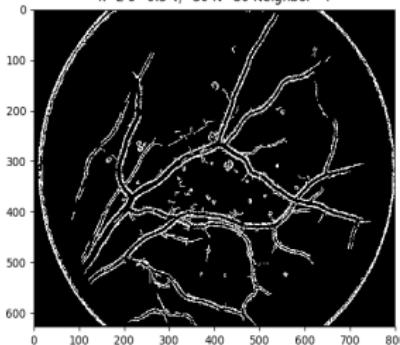
Canny: Non Max. Supression of retina2.jpg with  
 $k=2 \sigma=0.5 \tau_1=30 N=30$  Neighbor=4



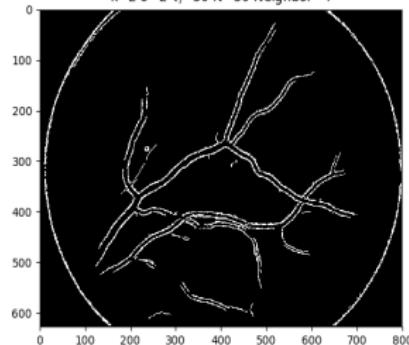
Canny: Non Max. Supression of retina2.jpg with  
 $k=2 \sigma=2 \tau_1=50 N=50$  Neighbor=4



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

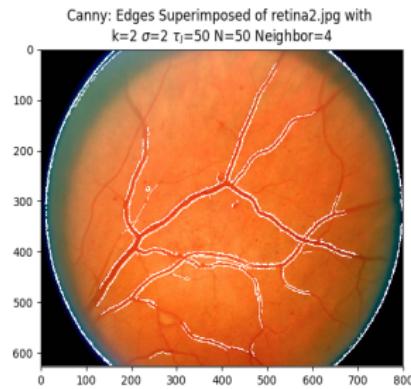
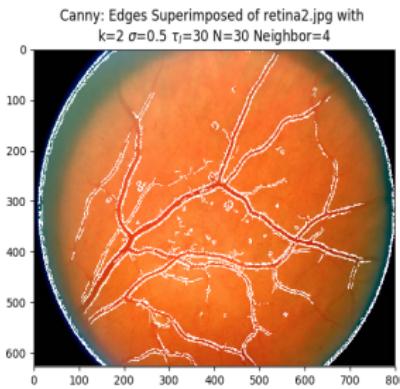
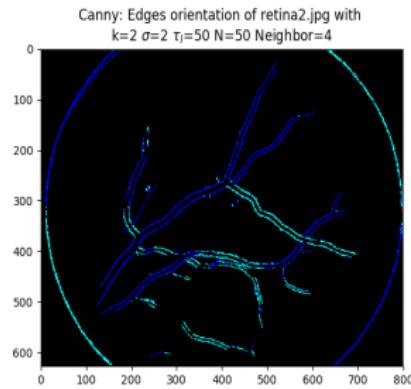
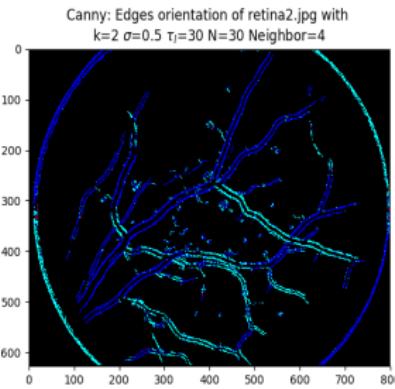




# Canny: Result and Contrast

ECEN-5283  
Computer  
Vision  
S M Al Mahi

Project  
Objective  
Technical  
Background  
Results  
LoG  
Canny  
Matched Filter  
Conclusion





# Canny: Result and Contrast

ECEN-5283  
Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

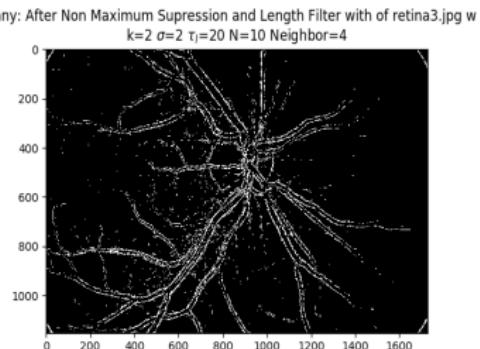
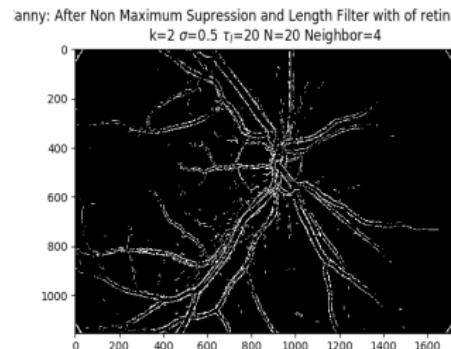
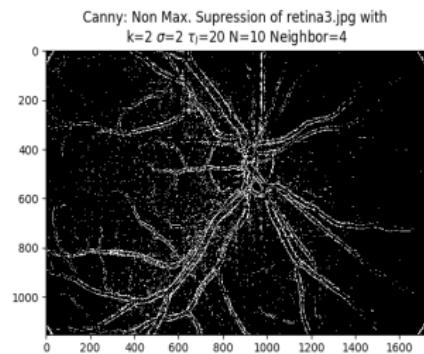
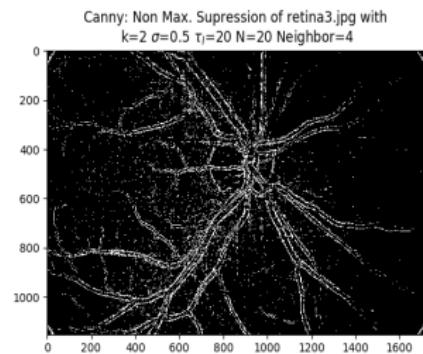
Results

LoG

Canny

Matched Filter

Conclusion





# Canny: Result and Contrast

ECEN-5283  
Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

Results

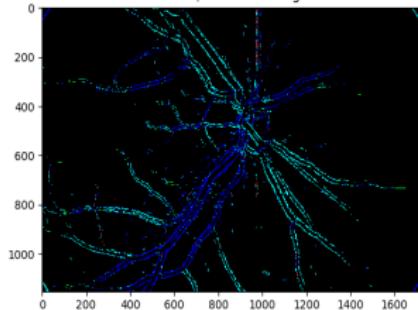
LoG

Canny

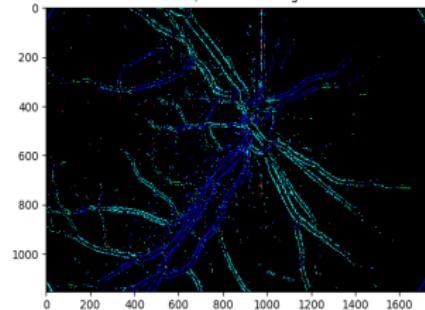
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Conclusion

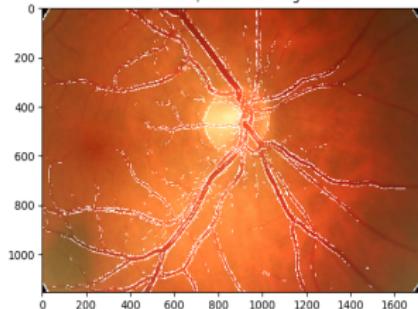
Canny: Edges orientation of retina3.jpg with  
 $k=2 \sigma=0.5 \tau_l=20 N=20$  Neighbor=4



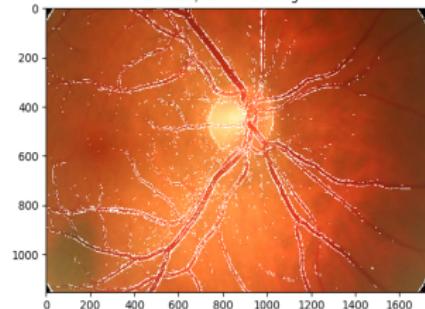
Canny: Edges orientation of retina3.jpg with  
 $k=2 \sigma=2 \tau_l=20 N=10$  Neighbor=4



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  
 $k=2 \sigma=2 \tau_l=20 N=10$  Neighbor=4





# Canny: Result and Contrast

ECEN-5283

Computer

Vision

S M Al Mahi

Project  
Objective

Technical  
Background

Results

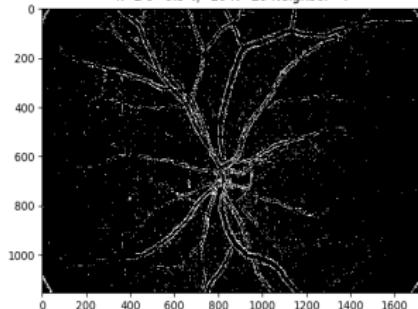
LoG

Canny

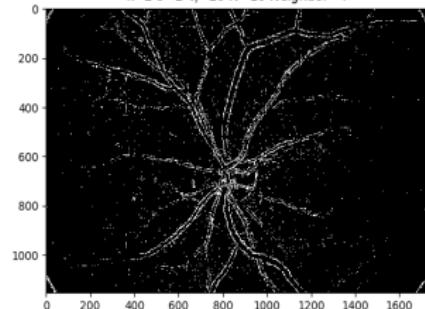
Matched Filter

Conclusion

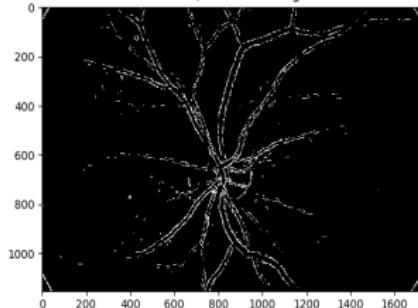
Canny: Non Max. Supression of retina4.jpg with  
 $k=2 \sigma=0.5 \tau_1=20 N=20$  Neighbor=4



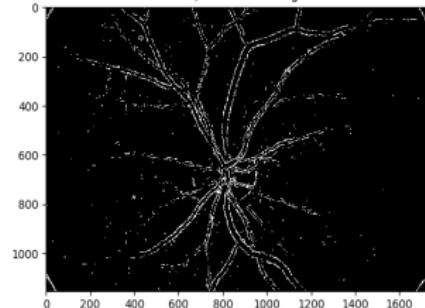
Canny: Non Max. Supression of retina4.jpg with  
 $k=2 \sigma=2 \tau_1=20 N=10$  Neighbor=4



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





# Canny: Result and Contrast

ECEN-5283  
Computer  
Vision

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Project  
Objective

Technical  
Background

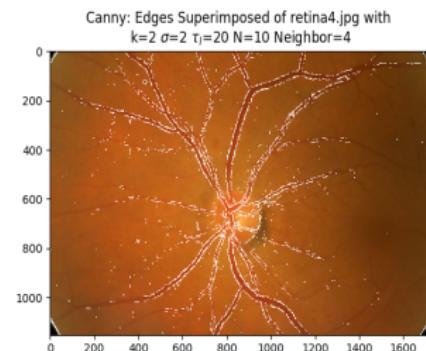
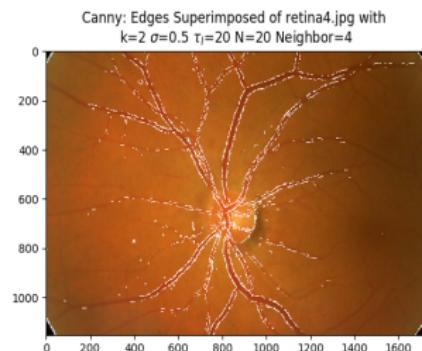
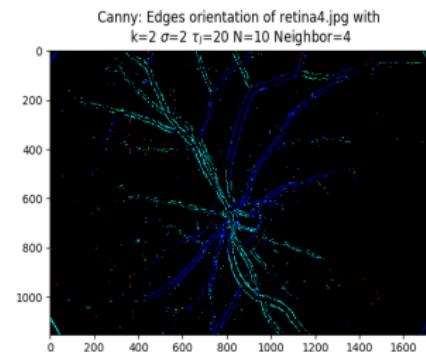
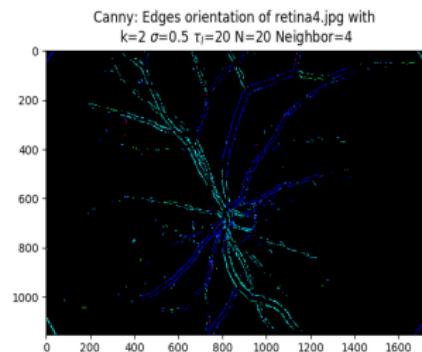
Results

LoG

Canny

Matched Filter

Conclusion





# Match: Result and Contrast

ECEN-5283  
Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

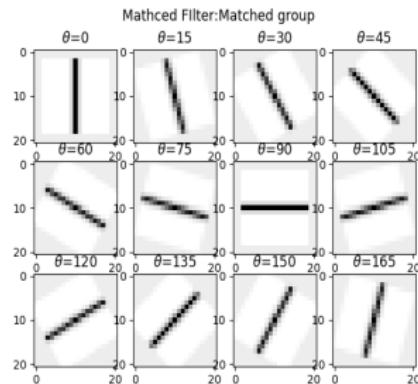
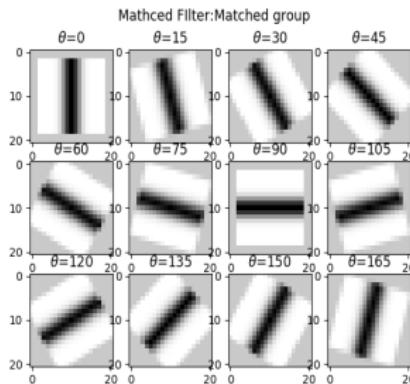
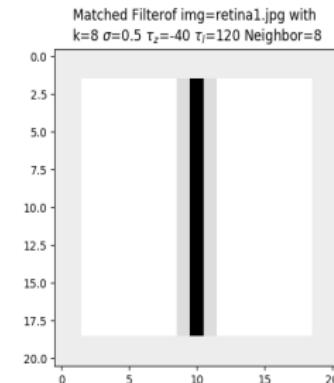
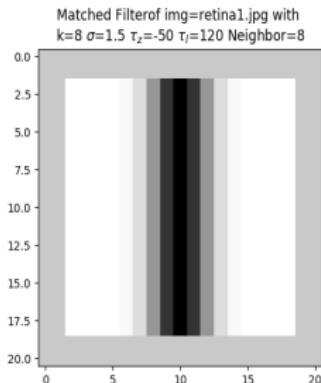
Results

LoG

Canny

Matched Filter

Conclusion

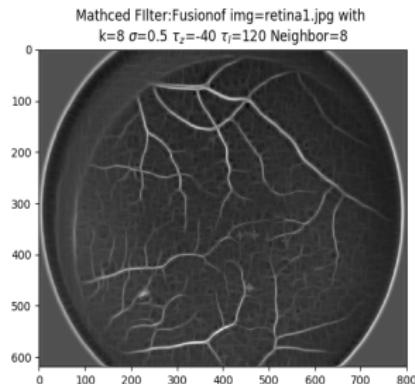
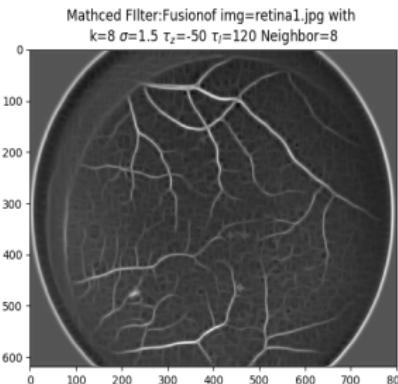
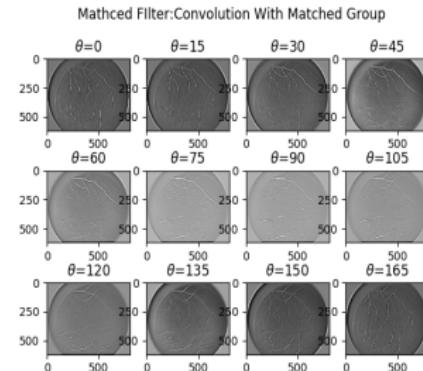
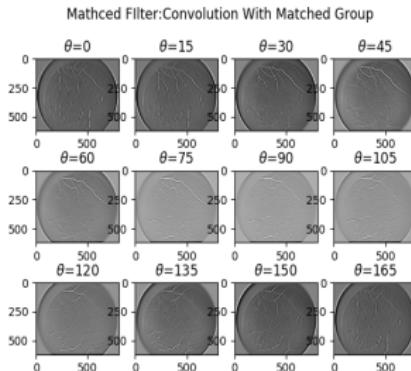




# Match: Result and Contrast

ECEN-5283  
Computer  
Vision  
S M Al Mahi

Project  
Objective  
Technical  
Background  
Results  
LoG  
Canny  
Matched Filter  
Conclusion

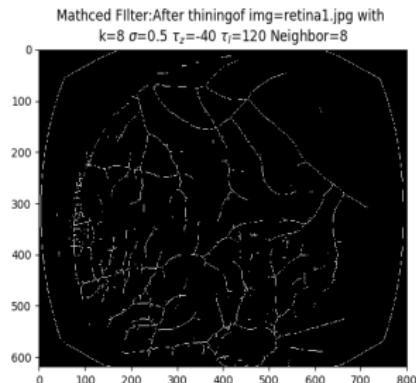
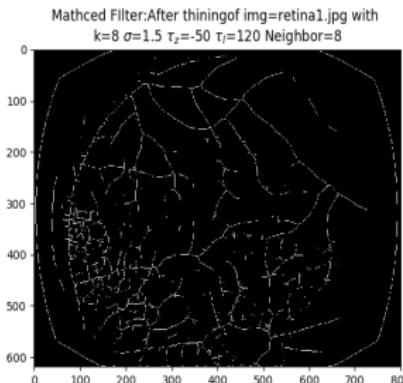
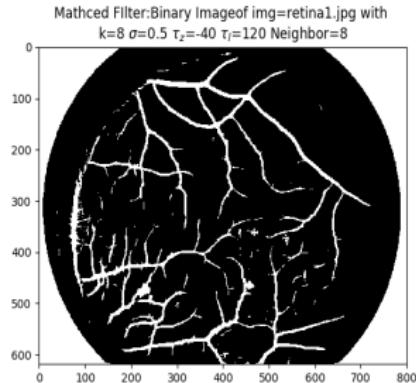
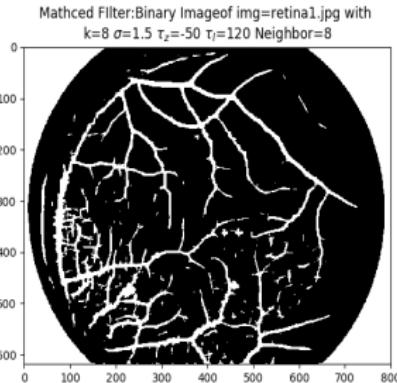




# Match: Result and Contrast

ECEN-5283  
Computer  
Vision  
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Project  
Objective  
Technical  
Background  
Results  
LoG  
Canny  
Matched Filter  
Conclusion





# Match: Result and Contrast

ECEN-5283

Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

Results

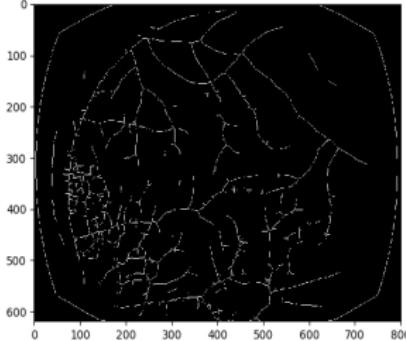
LoG

Canny

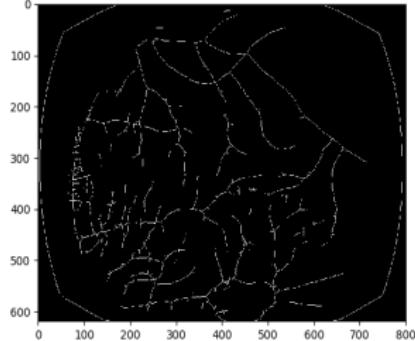
Matched Filter

Conclusion

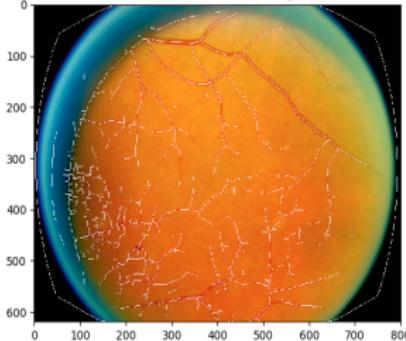
Matched Filter:Length Filtering of img=retina1.jpg with  
 $k=8 \sigma=1.5 \tau_2=-50 \tau_l=120$  Neighbor=8



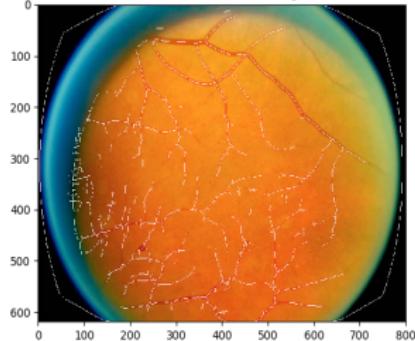
Matched Filter:Length Filtering of img=retina1.jpg with  
 $k=8 \sigma=0.5 \tau_2=-40 \tau_l=120$  Neighbor=8



Matched Filter:Super Imposed of img=retina1.jpg with  
 $k=8 \sigma=1.5 \tau_2=-50 \tau_l=120$  Neighbor=8



Matched Filter:Super Imposed of img=retina1.jpg with  
 $k=8 \sigma=0.5 \tau_2=-40 \tau_l=120$  Neighbor=8

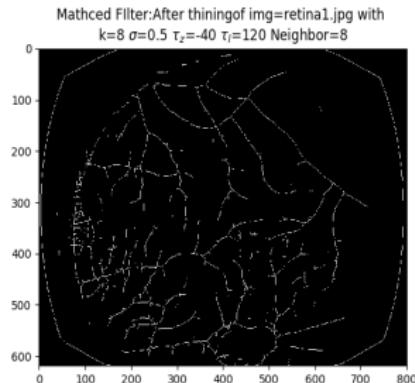
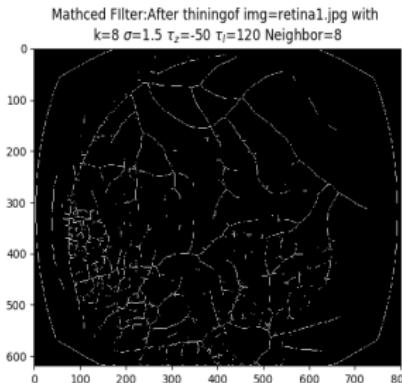
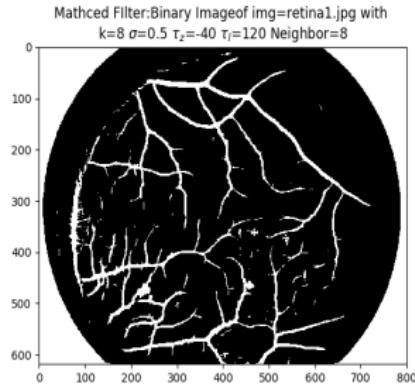
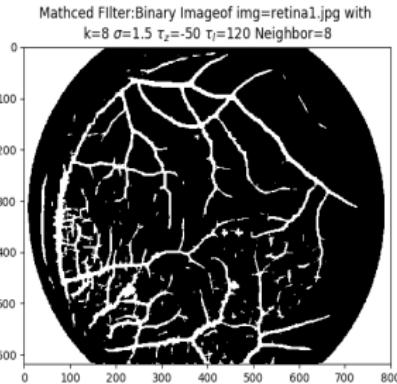




# Match: Result and Contrast

ECEN-5283  
Computer  
Vision  
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Project  
Objective  
Technical  
Background  
Results  
LoG  
Canny  
Matched Filter  
Conclusion





# Match: Result and Contrast

ECEN-5283  
Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

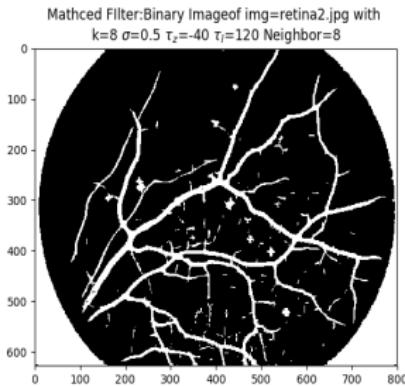
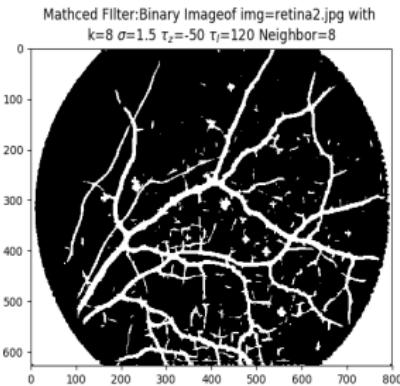
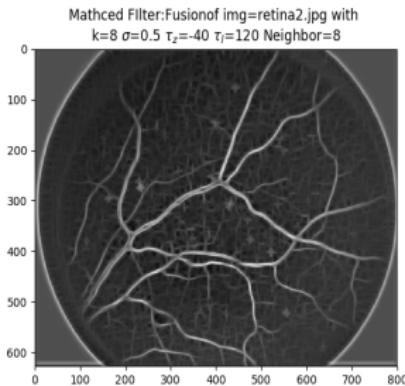
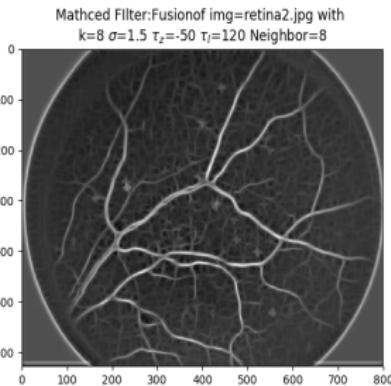
Results

LoG

Canny

Matched Filter

Conclusion





# Match: Result and Contrast

ECEN-5283  
Computer  
Vision  
S M Al Mahi

Project  
Objective

Technical  
Background

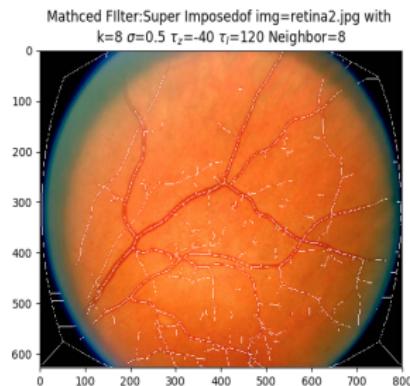
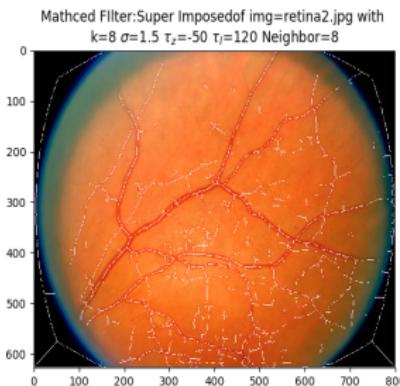
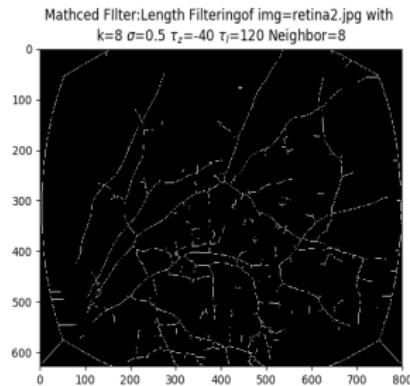
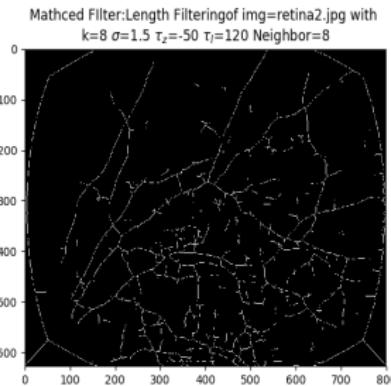
Results

LoG

Canny

Matched Filter

Conclusion





# Match: Result and Contrast

ECEN-5283  
Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

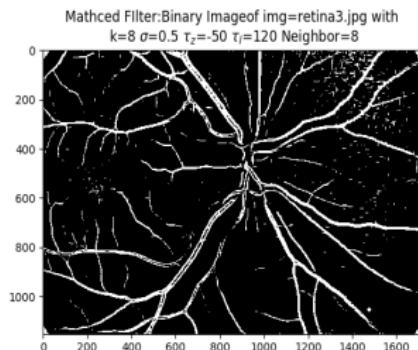
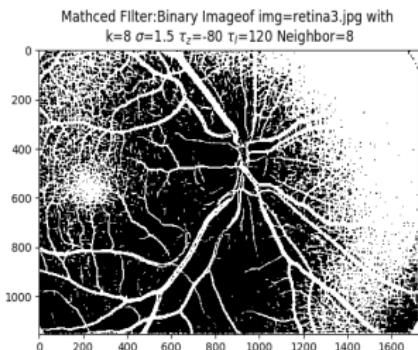
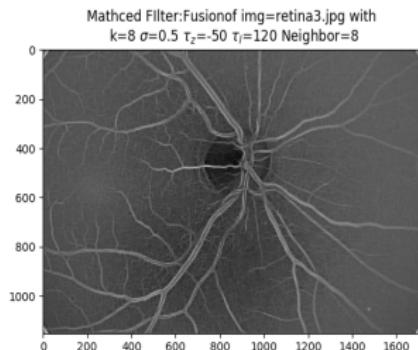
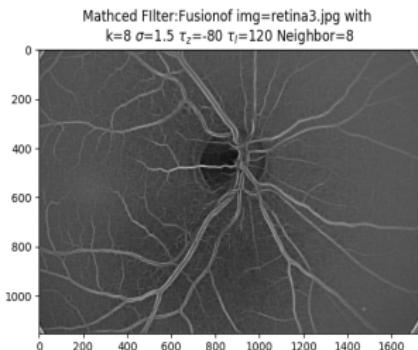
Results

LoG

Canny

Matched Filter

Conclusion





# Match: Result and Contrast

ECEN-5283  
Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

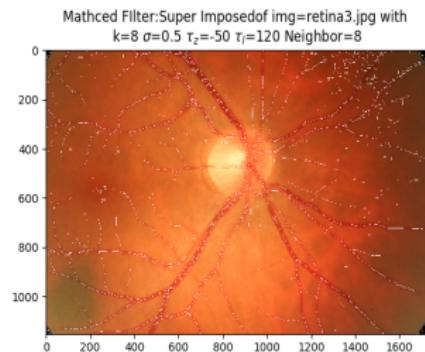
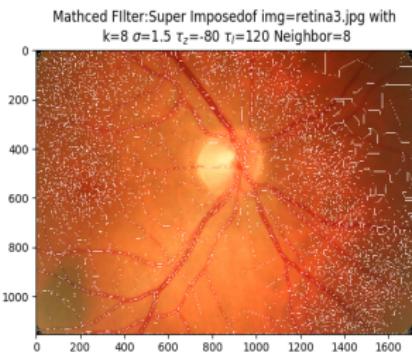
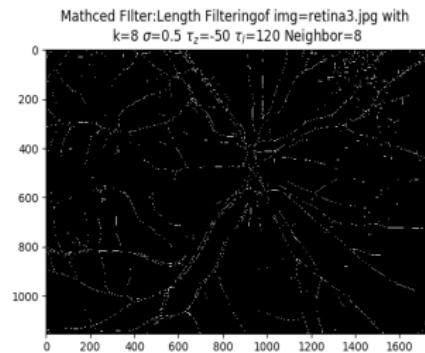
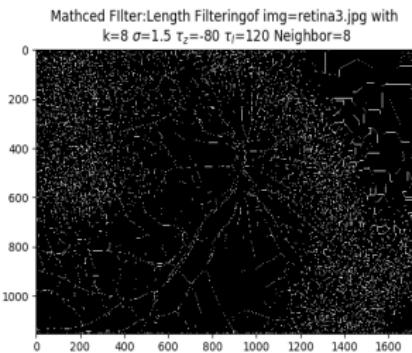
Results

LoG

Canny

Matched Filter

Conclusion





# Match: Result and Contrast

ECEN-5283  
Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

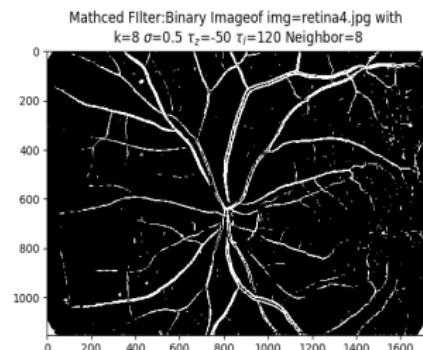
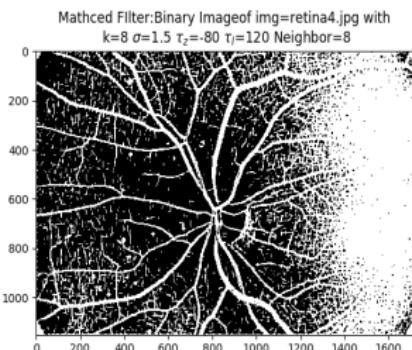
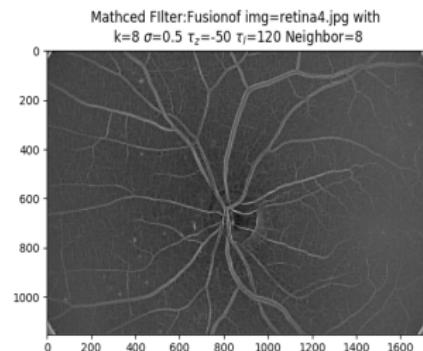
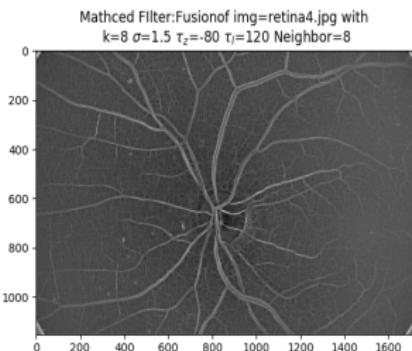
Results

LoG

Canny

Matched Filter

Conclusion





# Match: Result and Contrast

ECEN-5283  
Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

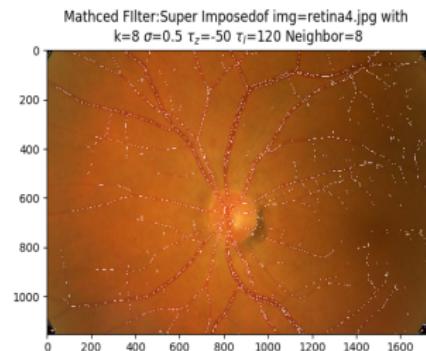
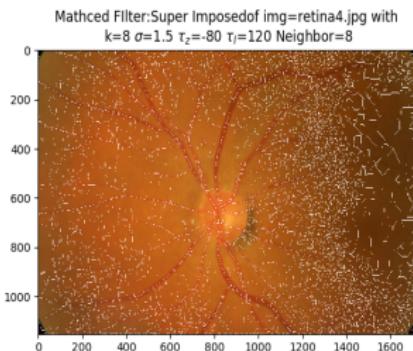
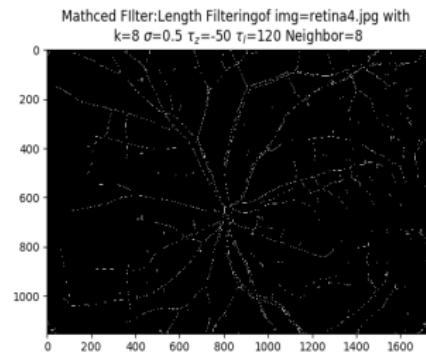
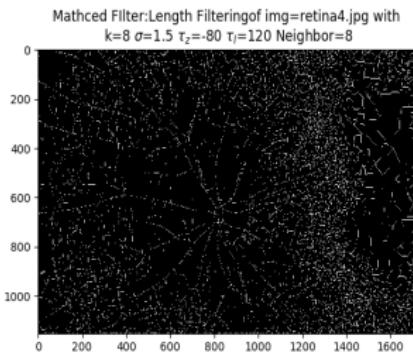
Results

LoG

Canny

Matched Filter

Conclusion





# Final Comparison

ECEN-5283  
Computer  
Vision

S M Al Mahi

Project  
Objective

Technical  
Background

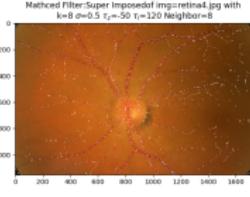
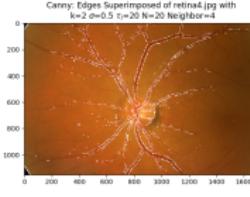
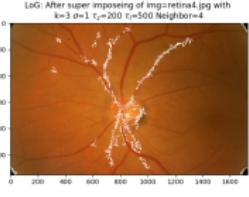
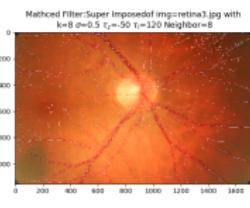
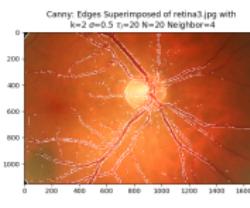
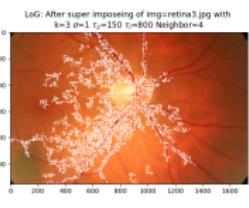
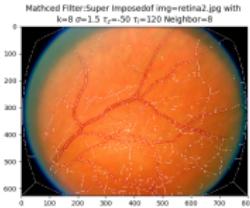
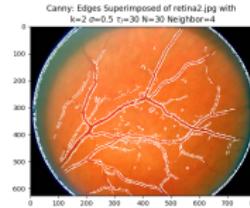
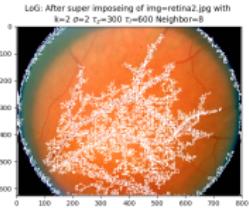
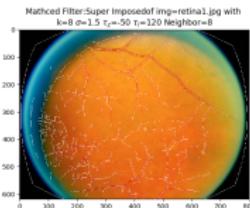
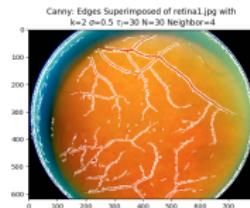
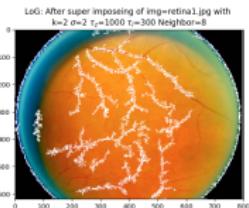
Results

LoG

Canny

Matched Filter

Conclusion





# Conclusion

ECEN-5283

Computer  
Vision

S M AI Mahi

Project  
Objective

Technical  
Background

Results

Conclusion

- 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.