INDIAN INSTITUTE OF TECHNOLOGY
KHARAGPUR

IMAGE PROCESSING LABORATORY

A REPORT ON
EXPERIMENT 04

Frequency Filtering

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VISUAL INFORMATION AND EMBEDDED SYSTEMS

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Introduction

Frequency Filtering :

In this process, the image is first treated with Fourier transform, which is then multiplied with the filter function. This result is then converted back into the spatial domain. The filtering is done in Frequency Domain. Such filtering is utilised to smoothen a spatial image by attenuating high frequencies and also to enhance the edges by attenuating low frequencies.

The effect of the operator on an input image can be determined by the nature of the filter function chosen.

Low-pass Filter :

At the edges and sharp noise features in the spatial domain of an image, the intensity change is high. This contributes to the higher frequencies in the frequency domain of an image. Low-pass filter prevents the occurrence of frequencies higher than a set limit and thereby smoothens the image in spatial domain and removes sharp noise features.

High-pass Filter :

High-pass filter prevents the occurrence of frequencies lower than a set limit. This results in retaining the sharp details and edges and simultaneously suppressing all the features with little intensity changes. This filter can hence be used for edge detection.

Ideal Low/High-pass Filter :

In an ideal Low/High-pass Filter, all the frequencies higher/lower than a set limit are prevented respectively. The filter function has a rectangular graph shape.

Gaussian Filter :

In this filter, the filter function is of the shape of a gaussian curve. This sees to it that the frequency coefficients above or below the set limit are not cut abruptly, but they slowly disappear making the transition a smooth one. Gaussian low-pass filter attenuates frequencies away from the centre of the gaussian curve and gaussian high-pass filter attenuates frequencies near the centre of the gaussian curve.

$$X'_{uv} = X_{uv} e^{-\frac{\left(\frac{H}{2}-u\right)^2+\left(\frac{W}{2}-v\right)^2}{A^2}}$$

Gaussian Low-pass filter

$$X'_{uv} = X_{uv}\left(1-e^{-\frac{\left(\frac{H}{2}-u\right)^2+\left(\frac{W}{2}-v\right)^2}{A^2}}\right)$$

Gaussian High-pass filter

Butterworth Filter :

This is also a filter used for smoothening/sharpening. In a Buteerworth low-pass filter, the frequencies inside the radius of set limit are retained and the frequencies outside this radius are reduced gradually to reduce ringing effects. In a Buteerworth high-pass filter, the frequencies outside the radius of set limit are retained and the frequencies inside this radius are reduced gradually.

$$H(u,v) = \frac{1}{1+[D(u,v)/D_0]^{2n}}.$$

Butterworth Low-pass filter

$$H(u,v) = \frac{1}{1+[D_0/D(u,v)]^{2n}}$$

Butterworth High-pass filter

Algorithm

Problem Statement: Write C/C++ modular functions to perform the following operations on the 512 × 512 grayscale test images:

A. FFT2 (takes input image filename as the argument; gives 2D FFT coefficients as output)

B. IFFT2 (takes 2D FFT coefficients as input argument; gives the back-projected/ reconstructed image as output)

C. Perform Ideal, Gaussian, and Butterworth low-pass and high-pass filtering, taking cut-off frequency, D0, and image filename as input arguments respectively with Ideal_LPF, Ideal_HPF, Gaussian_LPF, Gaussian_HPF, Butterworth_LPF, Butterworth_HPF.

Display the (shifted) magnitude spectrums of the input, the filter and the filtered output. Make use of the tracker/slider function to 1) choose images, 2) filter types and 3) cut-off frequencies.

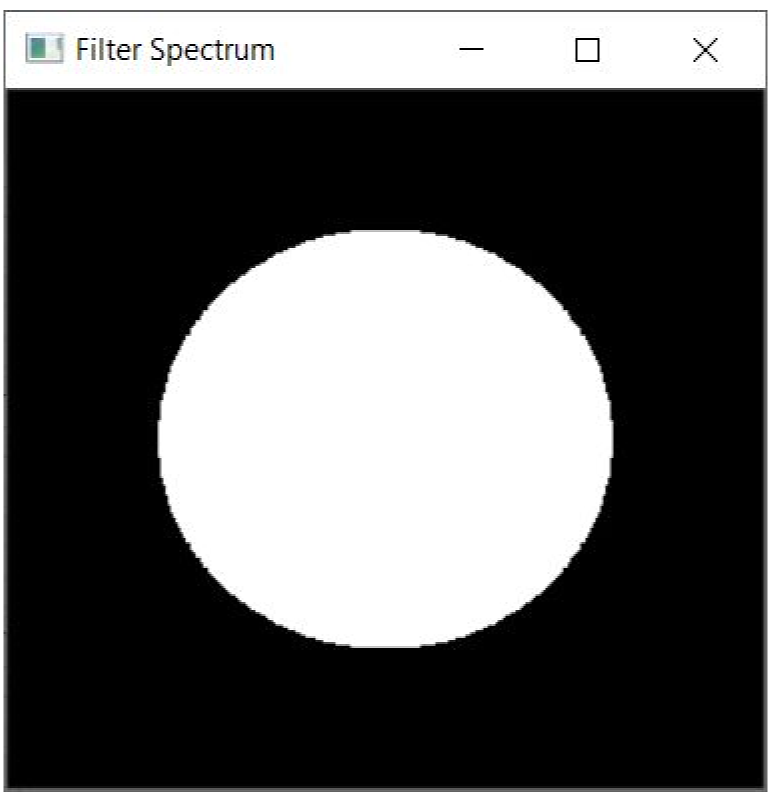
Functions:

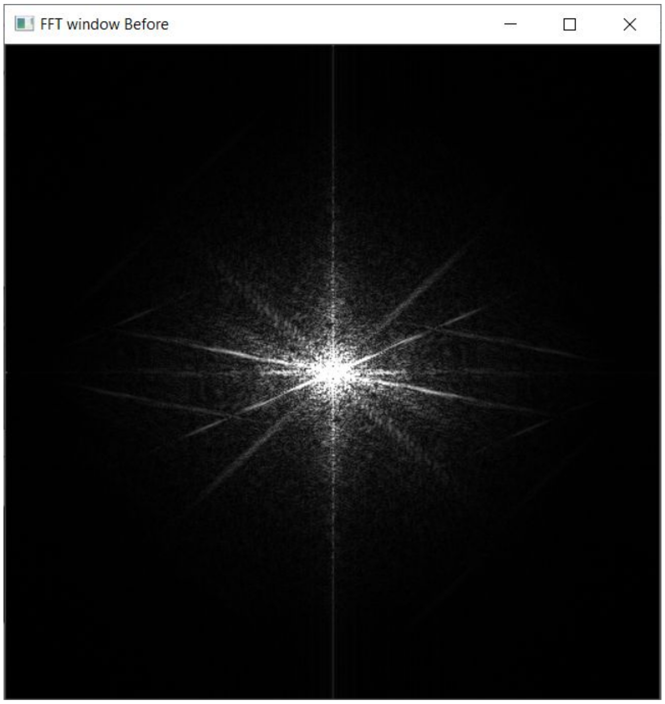
1. FFT2: FFT is performed on each row using divide and conquer strategy on the input image. This coefficient matrix is then transposed and again FFT is performed on the rows of the transposed matrix (originally the columns).
2. IFFT2: Similar to FFT2, IFFT is performed on the rows of the resultant matrix, transposed and then again IFFT is taken on the rows.
3. Apply Filter: Each filter function is created and applied according to the function selected using the slider.

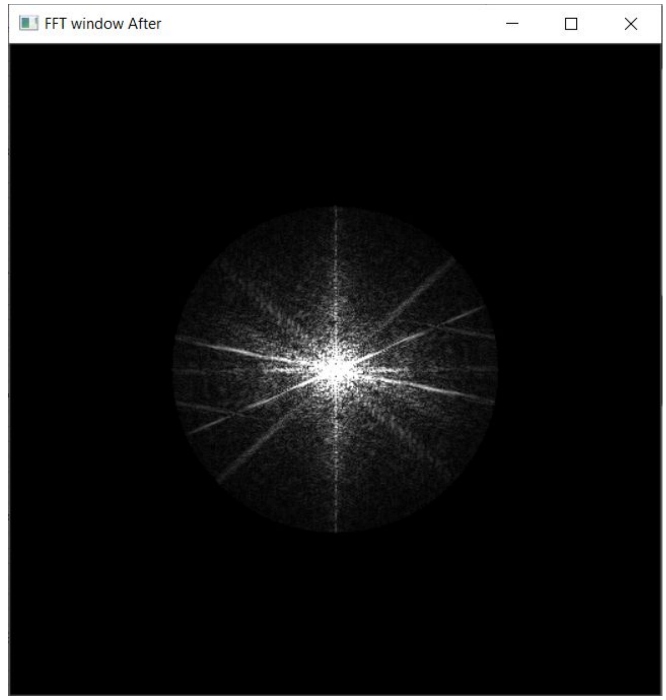
Results

Input Image

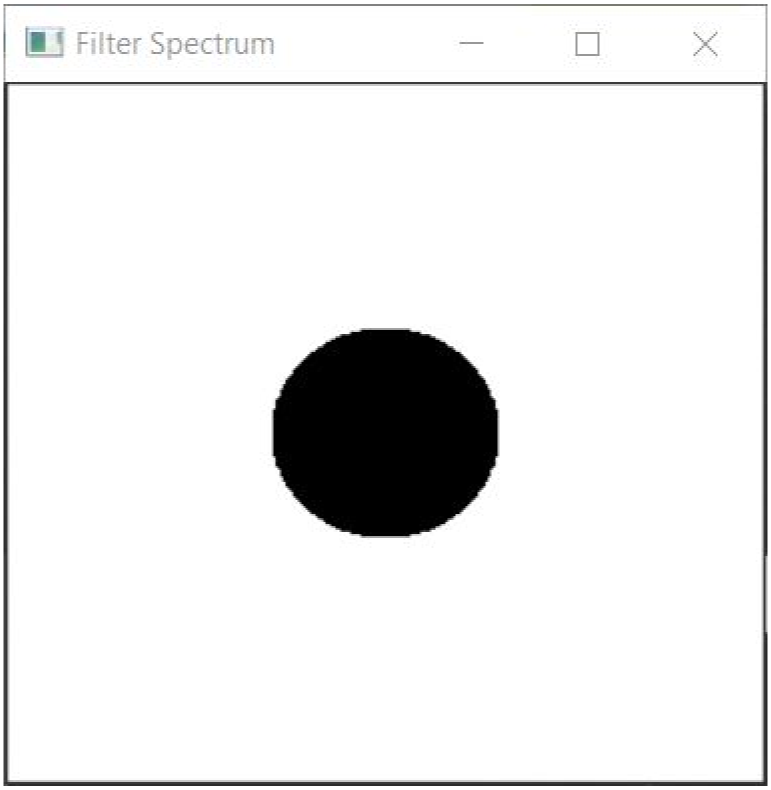
1. Ideal LPF (Cutoff Frequency = 0.3)

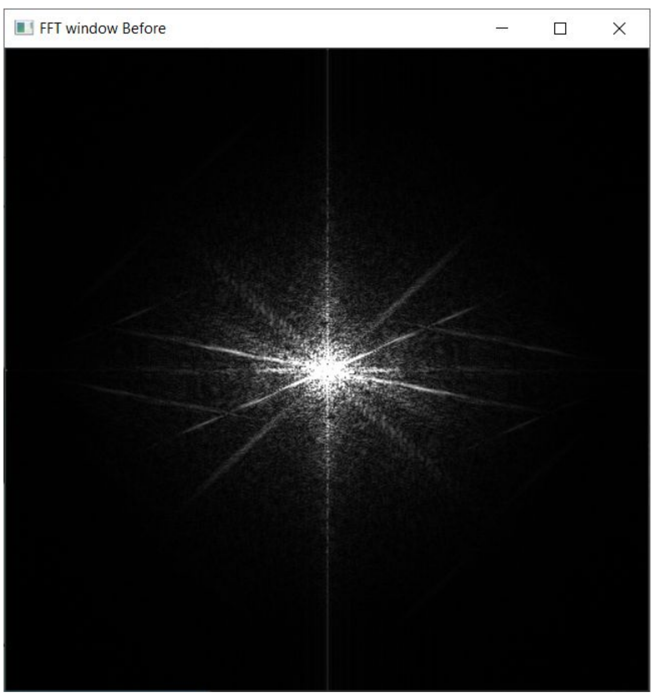


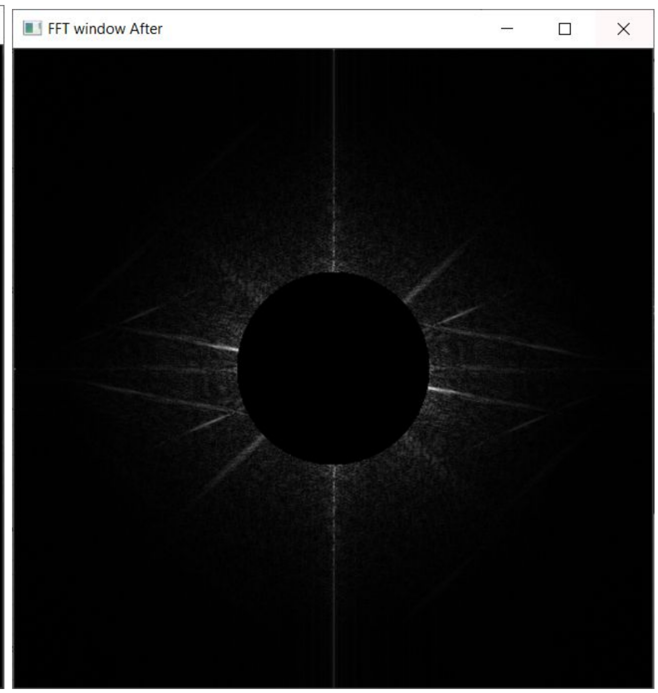




2. Ideal HPF (Cutoff Frequency : 0.2)

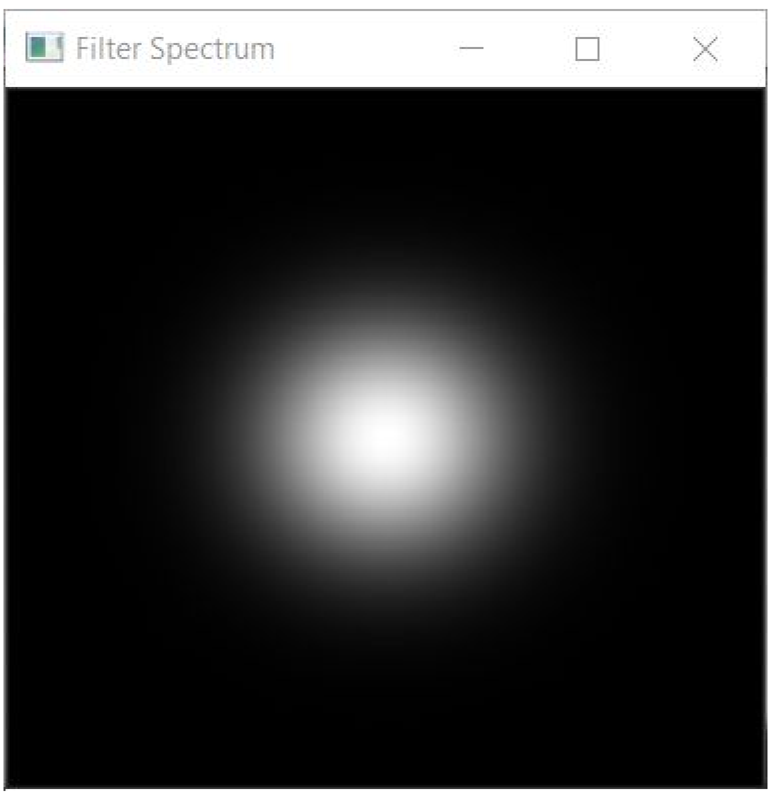


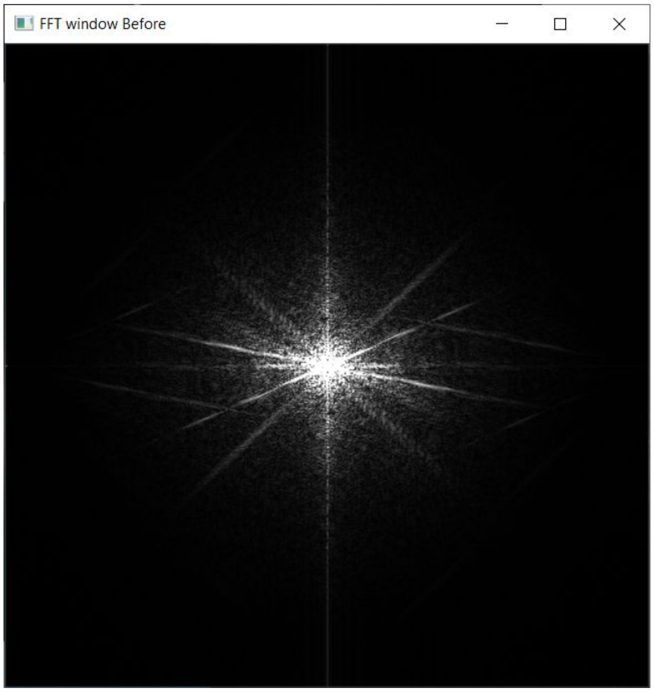




3. Gaussian LPF (Sigma Value: 0.5)

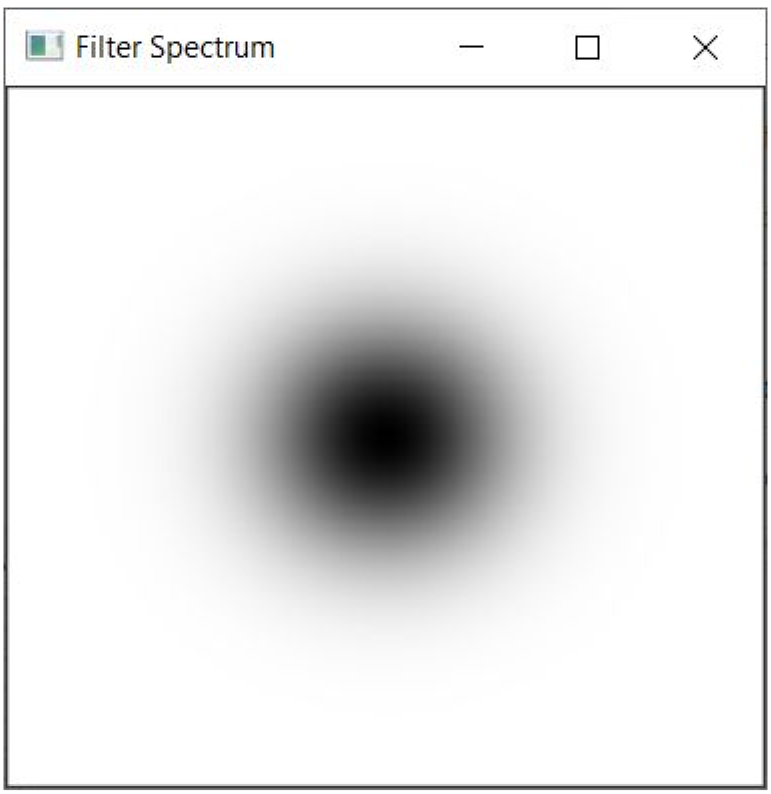

Output Image

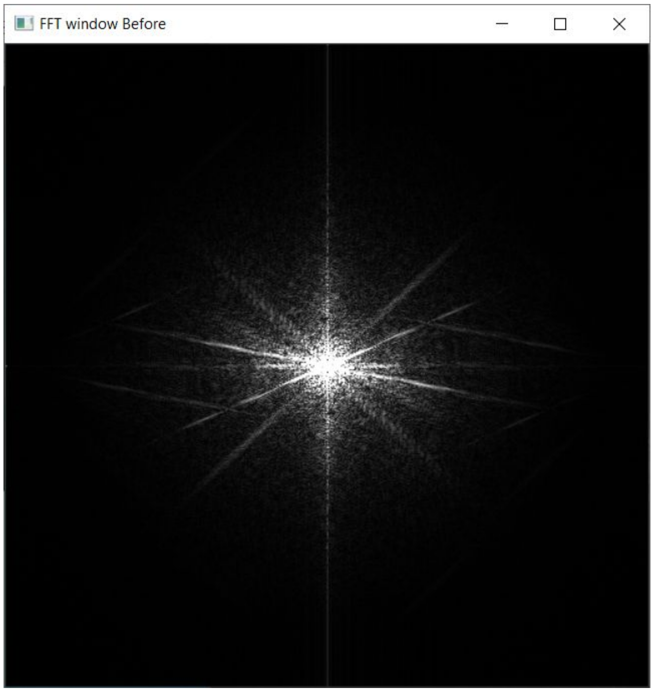

Filter Spectrum

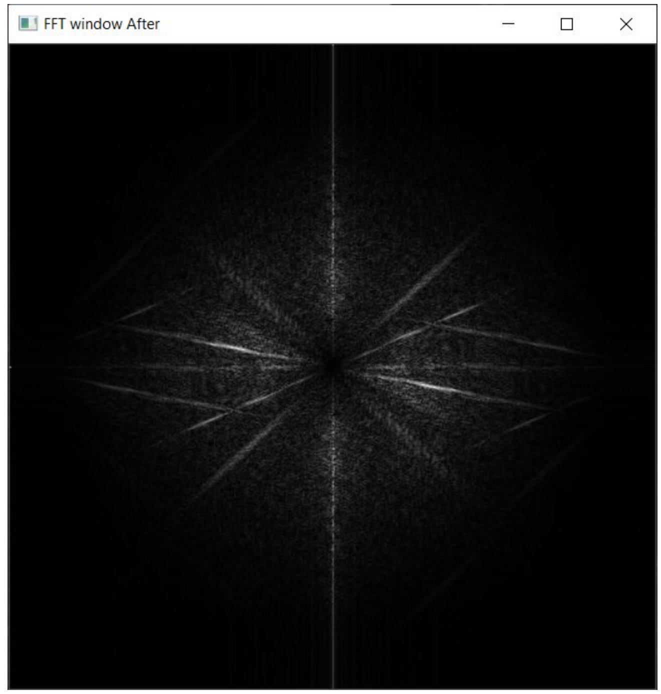


4. Gaussian HPF (Sigma Value: 0.5)

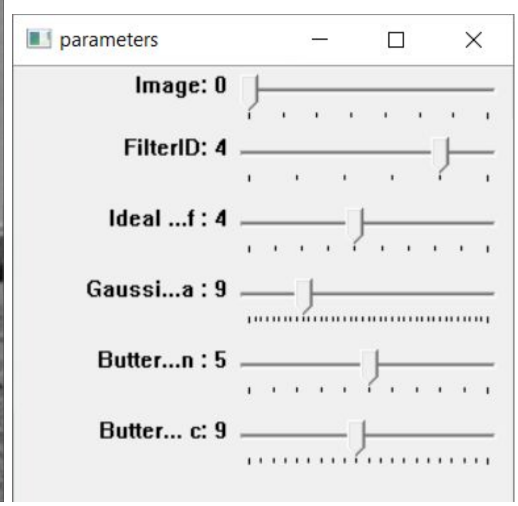

Output Image

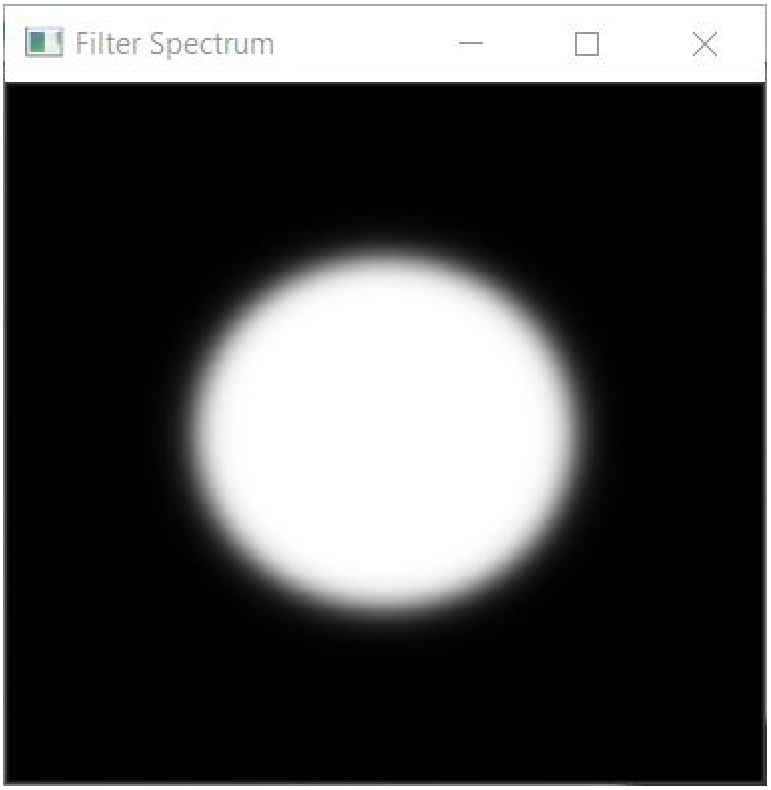

Filter Spectrum

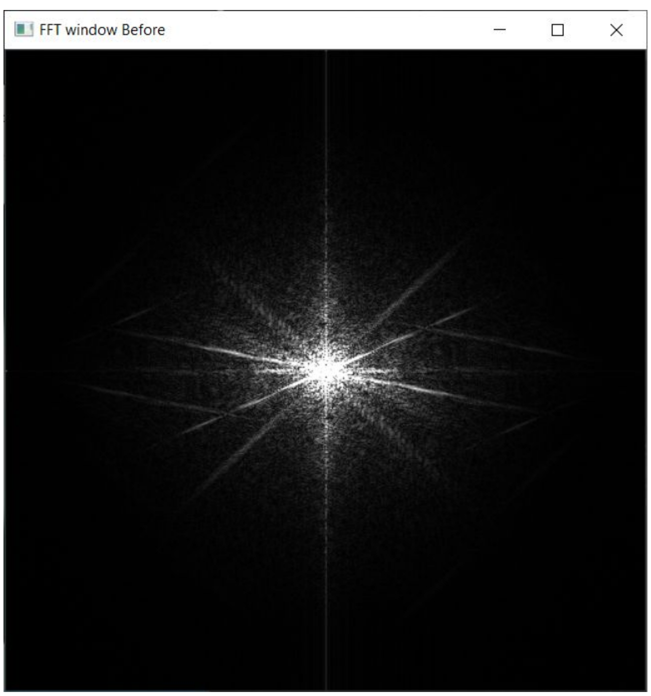


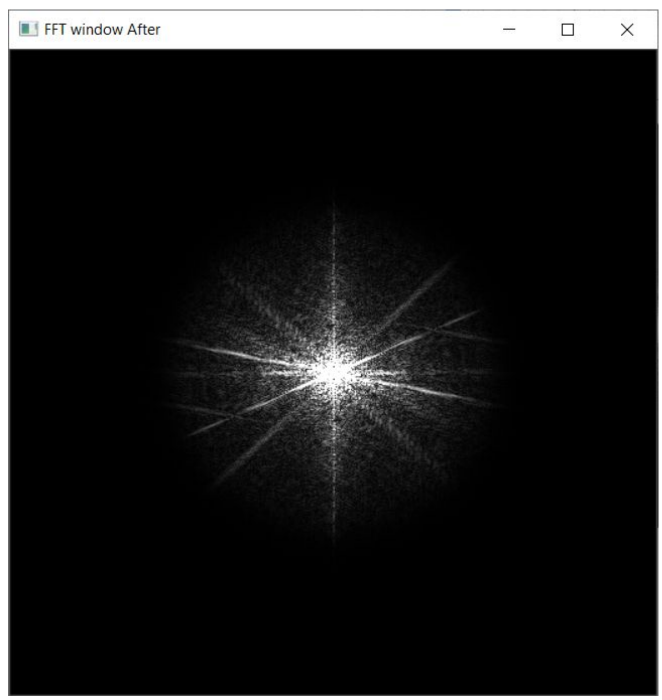


5. Butterworth LPF (order = 0.5)



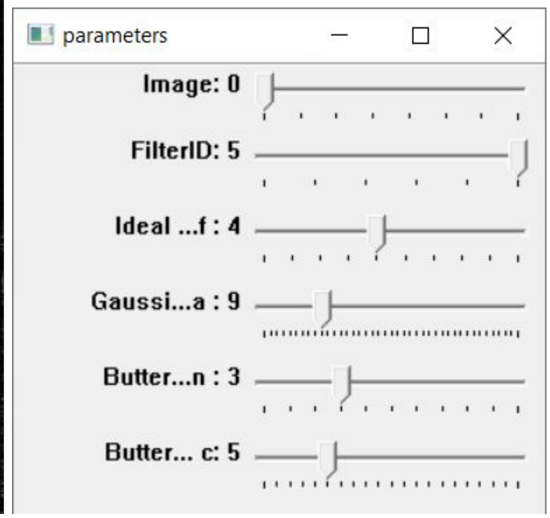






6. Butterworth HPF (order: 0.3)


Output Image


parameters
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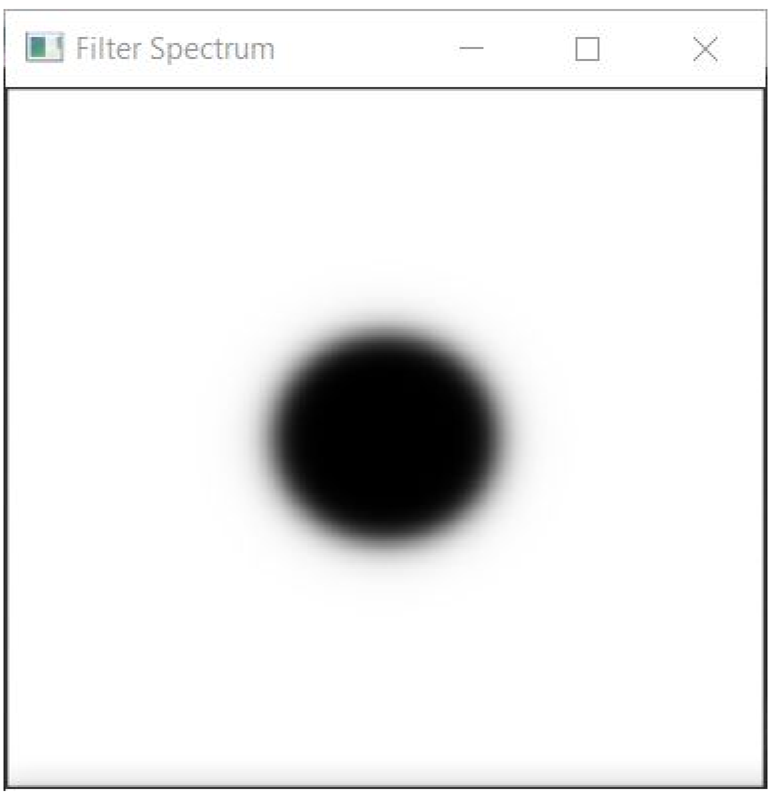
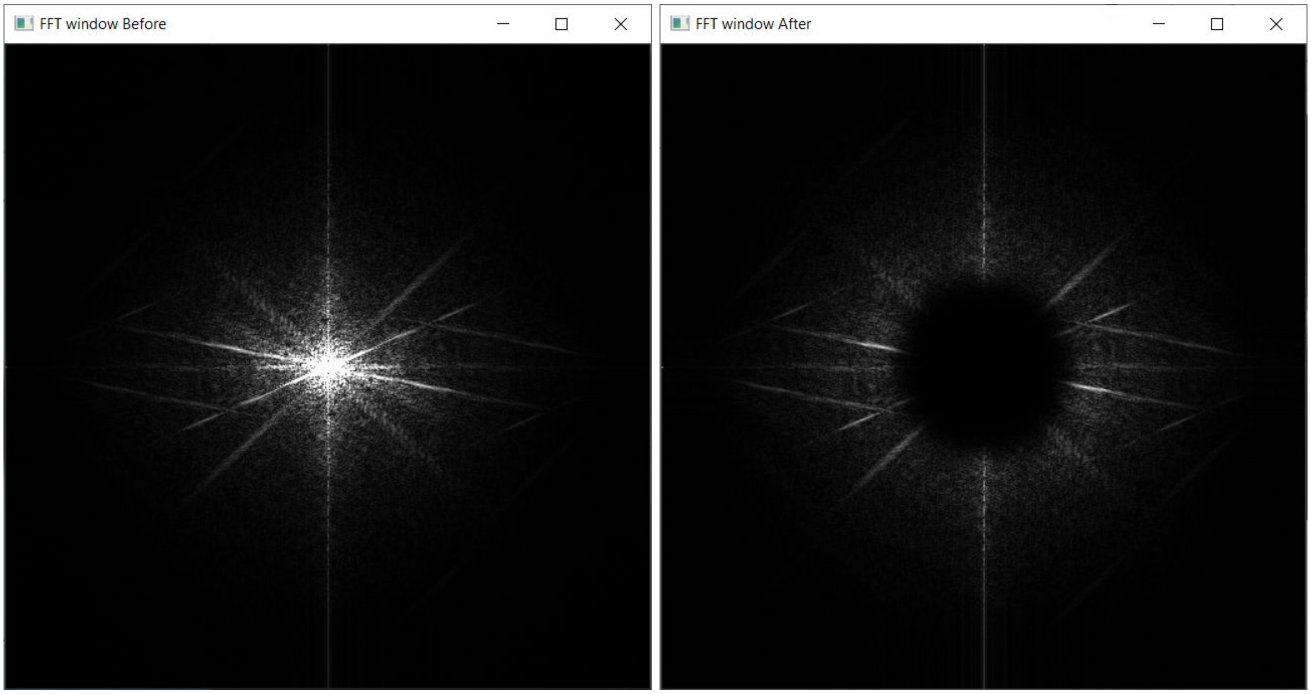
FilterID: 5
Ideal ...f : 4
Gaussi...a : 9
Butter...n : 3
Butter... c: 5


Filter Spectrum



Analysis

1. Smoothening and sharpening are the key utilisation features of Frequency domain filters.
2. Frequency domain filtering basically focuses on the frequency of the images. For example, in an ideal low-pass filter we can remove high frequency components easily. Thus they are easier for filtering operations.
3. In the spatial domain, we deal with images as they are. The value of the pixels of the image changes with respect to scene. Whereas in frequency domain, we deal with the rate at which the pixel values are changing in spatial domain. Hence frequency filtering is more computationally expensive than the spatial filters
4. It is because of the requirement of fourier transform and inverse fourier transform. Thus they are used only in case we can’t create a mask in the spatial domain for an operation.
5. Ideal filters suffer from ringing (Gibbs) phenomenon. It means some similar to oscillation response are observed in the output. It is due to the non-continuous nature of the filter.
6. Butterworth and Gaussian filters are used to avoid ringing effects in ideal filters which occur due to discontinuity in filter response, as they are continuous. The parameters (like σ or order) decide how close they are to the ideal filters by affecting the slope in the transition band.