Digital Image and Video Processing

CASE:CONDUCT INVESTIGATIONS ON IMAGE SHARPENING IN FREQUENCY DOMAIN. USE GAUSSIAN AND BUTTERWORTH FILTERS AND EVALUATE THE PERFORMANCE OF THESE FILTERS USING SUBJECTIVE AND OBJECTIVE METRICS. PROVIDE VALID CONCLUSIONS AT THE END

Submitted by

S. Sri Krishna Kirthi: 1602-19-735-049

Ch. Manoj Kumar: 1602-19-735-020

Department of Electronics and Communication Engineering

Vasavi College of Engineering

(Private Un-aided Non-minority Autonomous Institution)

ACCREDITED BY NAAC WITH 'A++' GRAD

Affiliated to Osmania University and Approved by AICTE.

Team Charter

Goal: To perform sharpening using Butterworth and Gaussian filters on multiple images and analyse the suitable filtering technique among them.

Name	Roll Number	Role	Activities carried
S. Sri Krishna Kirthi	1602-19-735-049	Team Leader	literature Survey, Butterworth High pass filtering
Ch. Manoj Kumar	1602-19-735-020	Member	Gaussian High pass filtering, Subjective & Objective Metrics

Starting Date: 25/11/2022

Ending Date: 9/12/2022

S.S.K. Kirthi

S. Sri Krishna Kirthi

Ch. Manoj

Ch. Manoj Kumar

Contents

1.Introduction

Image processing can be defined as analysis of picture using techniques that can basically identify region of interest from all those images in bitmappedgraphic format that have been scanned or captured with digital camera. Image enhancement refers to the process of highlighting certain information of an image, as well as weakening or removing any unnecessary information according to specific needs. For example, eliminating noise, revealing blurred details, and adjusting levels to highlight features of an image.

Image enhancement techniques can be divided into two broad categories:

- **Spatial domain** — It includes enhancement of the image by dividing an image into uniform pixels according to the spatial coordinates with a particular resolution. The spatial domain methods perform operations on pixels directly.
- **Frequency domain** — It includes enhancement obtained by applying the Fourier transform to the spatial domain. In the frequency domain, pixels are operated in groups as well as indirectly.

Types of spatial domain operator:

- Point operation (intensity transformation) - Point operations refer to running the same conversion operation for each pixel in a grayscale image. The transformation is based on the original pixel and is independent of its location or neighbouring pixels.
- Spatial filter (or mask, kernel) - The output value depends on the values of f(x,y) and its neighbourhood.

In the frequency domain methods, the image is first transferred in to frequency domain. It means that, the Fourier transform of the image is computed first.

Applications of image enhancement

- Deblur images
- Contrast adjustment
- Brighten an image
- Smooth and sharpen

Image smoothing is a digital image processing technique that reduces and suppresses image noises. Commonly seen smoothing filters include average smoothing, Gaussian smoothing, and adaptive smoothing. Image sharpening filters highlight edges by removing blur

- Noise removal

Noises are introduced to images at the point of capture from cameras, printing, or during transmission. In terms of image processing, noises can be identified with a variance of intensity from its neighbour pixels. There are various types of noises. For example, Gaussian noise changes each pixel by a (usually) small amount, and salt-and-pepper noise (impulse noise) randomly scatters white or black pixels over the image. Noise removal techniques reduce the visibility of noises by smoothing the image using linear or non-linear filters.

- Grayscale image histogram equalization

Histogram equalization refers to the transformation where an output image has approximately the same number of pixels at each gray level, i.e., the histogram of the output is uniformly distributed.

Image enhancement techniques can be applied to restore the contents of old documents. Very often the old documents used for storing valuable information suffers from severe background damage. Few examples of background damages are varying contrast, ancient document age and the documents have degraded over time due to storage conditions and the quality of the written parchment. Image processing offers a few techniques to make these documents readable.

2.Literature Survey

Swathi Devangan and Anup Kumar Sharma **[1]** devised an image sharpening algorithm that can be applied in frequency domain of an image by use of Gaussian high pass filter and Butterworth high pass filter. Butterworth filters of different orders are compared with ideal and gaussian filters. The ringing effect caused due to use of ideal filters is noticed and rectified with Butterworth and Gaussian filters.

Amit Shukla et al. (2014) **[2]** examined the performance of frequency domain filters. Quality of the images is assessed with quality analysis metrics like PSNR and MSE. This study considered Low pass, High pass and High boost filters of Gaussian and Butterworth filters for examination.

Shaikh etal.(2016) **[3]** implemented low-pass and high-pass filters in same cut off frequency. Through the results ideal filter gives better performance in both the smoothing and sharpening images. High-order Butterworth filter and Gaussian filters are also applied to remove the noise.

Bhopal et.al (2011) **[4]** discussed about frequency domain algorithm and proposed a technique to better noise removal in finger print images. New method produces 80-90 % of quality finger prints.

3.Image Sharpening

3.a Filtering

Removing unwanted frequencies from the image is called filtering. Filtering is an image enhancement technique performed to make the image appear better. It can be performed in spatial and frequency domain.

A filter that attenuates high frequencies while passing low frequencies is called low pass filter. They are used for smoothing. Whereas, a filter that does not affect high frequencies is called high pass filter. They are used for sharpening. Furthermore, band pass (band reject filter) work on specific frequencies bands and Notch filters work on specific frequencies.

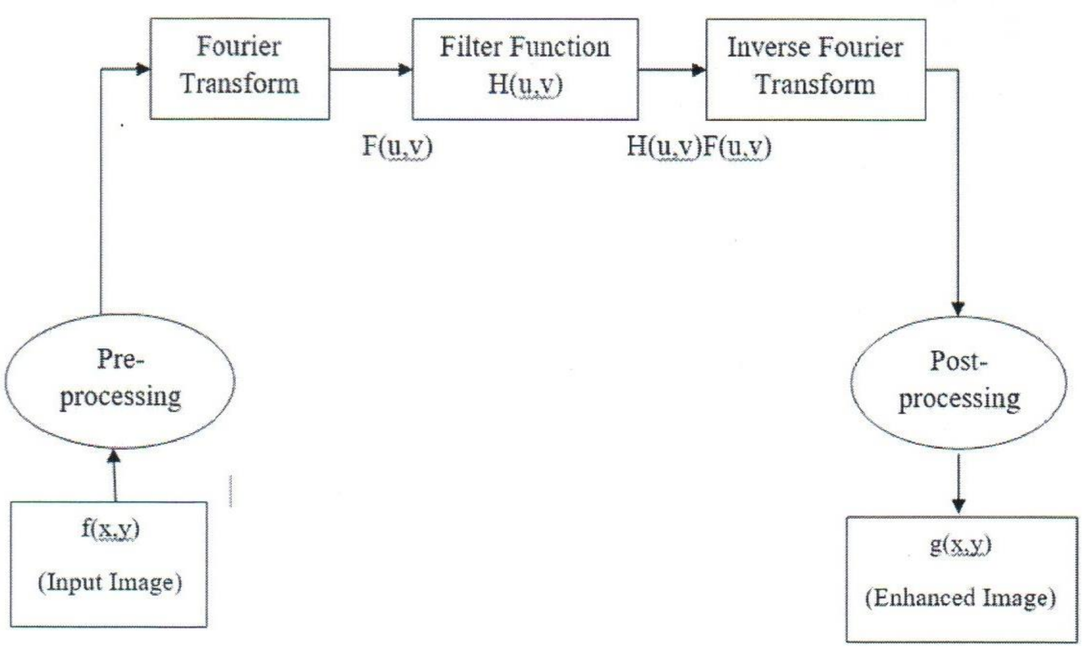
The two filters form a Fourier transform pair:

$$h(x, y) \Leftrightarrow H(u, v)$$

where h(x ,y) is the spatial kernel. Because this kernel can be obtained from the response of a frequency domain filter to an impulse, h(x ,y) sometimes is referred to as the impulse response of H(u,v).

When computational speed, cost, and size are important parameters, spatial convolution filtering is well suited for small kernels using hardware and/or firmware. However, when working with general purpose machines, frequency-domain methods in which the DFT is computed using a fast Fourier transform (FFT) algorithm can be hundreds of times faster than using spatial convolution, depending on the size of the kernels used.

Below are the steps involved in filtering of an image in frequency domain.



The pre-processing stage of images may include image resizing, converting images to grayscale and image augmentation.Fourier transform will reflect the frequencies of periodic parts of the image. The required filter function is applied on it. By applying the inverse Fourier transform the undesired or unwanted frequencies can be removed and this is called masking or filtering. A filter is a matrix, and components of the filters usually vary from 0 to 1. If the component is 1, then the frequency is allowed to pass, if the component is 0 the frequency is tossed out.

A filter that attenuates high frequencies while passing low frequencies is called low pass filter. They are used for smoothing. Whereas, a filter that does not affect high frequencies is called high pass filter. They are used for sharpening. Furthermore, band pass (band reject filter) work on specific frequencies bands and Notch filters work on specific frequencies.

$$G(u,v)=F(u,v)\bullet H(u,v)$$ Multiplication in Frequency Domain

$$g(x,y)=f(x,y)*h(x,y)$$ Convolution in Time Domain

Correspondence between Filtering in the Spatial and Frequency Domain:

Convolution theorem: – The discrete convolution of two functions f(x,y) and h(x,y) of size MXN is defined as

$$f(x,y)*h(x,y)=\frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f(m,n)h(x-m,y-n)$$

Let F(u,v) and H(u,v) denote the Fourier transforms of f(x,y) and h(x,y), then

$$f(x,y)*h(x,y) \Leftrightarrow F(u,v)H(u,v)$$

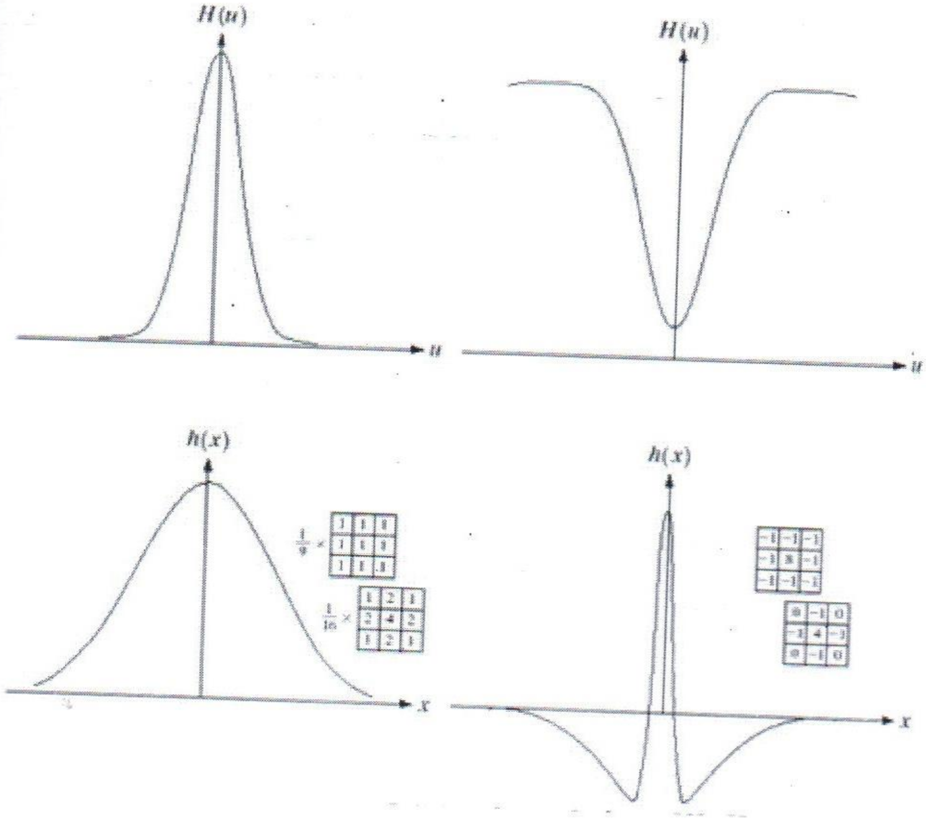
$$f(x,y)h(x,y) \Leftrightarrow F(u,v)*H(u,v)$$

$$h(x,y) \Leftrightarrow H(u,v)$$

The basic model for filtering in the frequency domain $G(u,v)=H(u,v)F(u,v)$

where F(u,v): the Fourier transform of the image to be sharpened

H(u,v): a filter transfer function



a b
c d

(a) Gaussian frequency domain lowpass filter.
(b) Gaussian frequency domain highpass filter.
(c) Corresponding lowpass spatial filter.
(d) Corresponding highpass spatial filter

Image sharpening can be achieved in the frequency domain by high-pass filtering, which attenuates low-frequencies components without disturbing high-frequencies in the Fourier transform.

$$H_{hp}(u,v)=1-H_{lp}(u,v)$$

3.b Butterworth High pass filtering

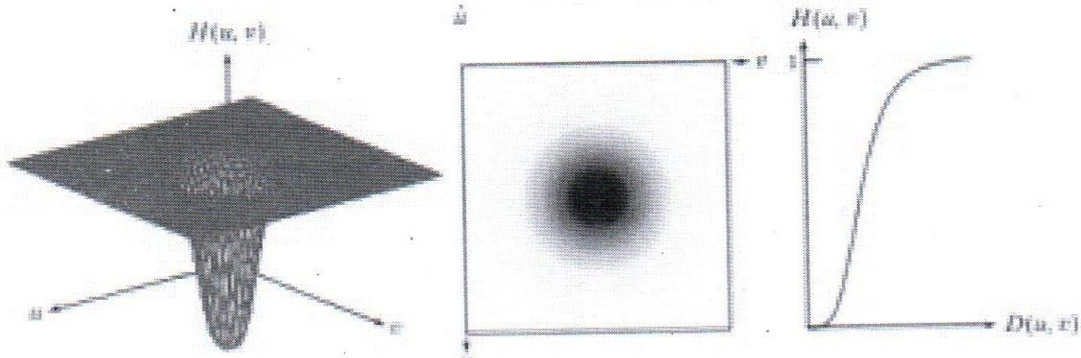
Butterworth Highpass Filter (BHPF) is used for image sharpening in the frequency domain. Image Sharpening is a technique to enhance the fine details and highlight the edges in a digital image. It removes low-frequency components from an image and preserves high-frequency components. This Butterworth highpass filter is the reverse operation of the Butterworth lowpass filter.

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

Where,

D_0 is a positive constant. BHPF passes all the frequencies greater than value without attenuation and cuts off all the frequencies less than it.

- This D_0 is the transition point between H(u, v) = 1 and H(u, v) = 0, so this is termed as ***cutoff frequency***. But instead of making a sharp cut-off (like Ideal Highpass filter), it introduces a smooth transition from 0 to 1 to reduce ringing artifacts.
- ***D(u,v)*** is the Euclidean Distance from any point (u, v) to the origin of the frequency plane, i.e $D(u,v) = \sqrt{(u^2 + v^2)}$



3.c Gaussian High pass filtering

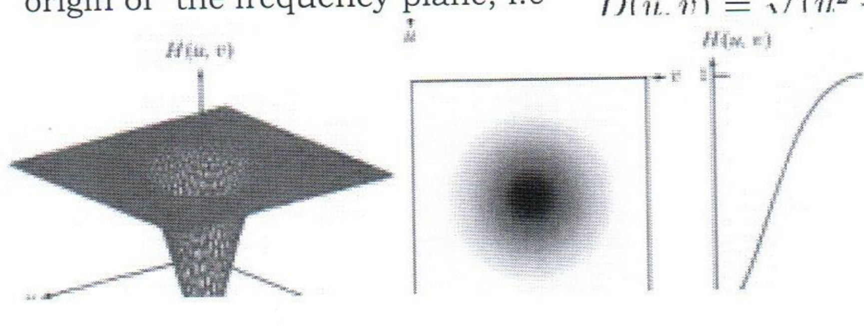
The transfer function of a Gaussian high pass filter (GHPF) is given by

$$H(u,v) = 1 - e^{-D^2(u,v)/2D_0^2}$$

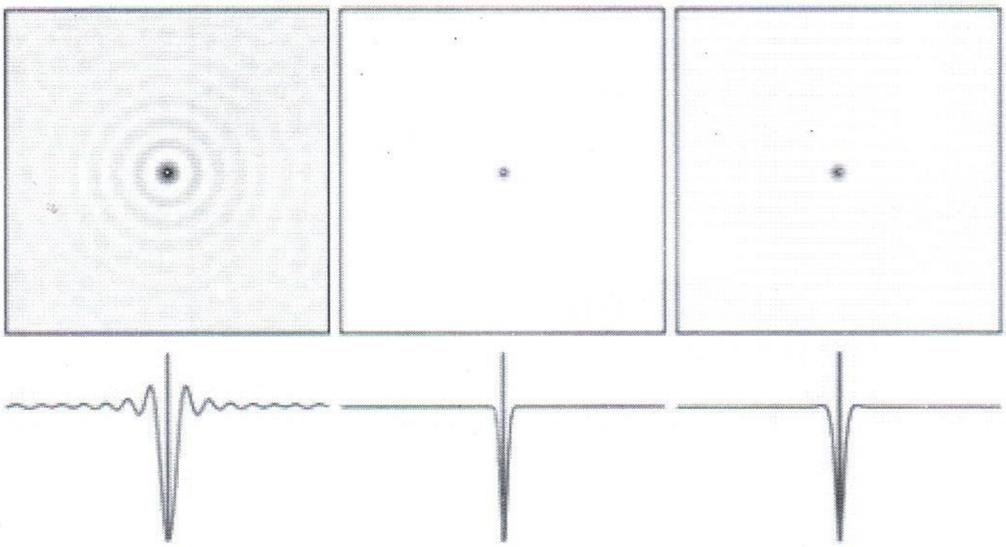
Where,

D_0 is a positive constant. BHPF passes all the frequencies greater than value without attenuation and cuts off all the frequencies less than it.

- This D_0 is the transition point between H(u, v) = 1 and H(u, v) = 0, so this is termed as ***cutoff frequency***. But instead of making a sharp cut-off (like Ideal Highpass filter), it introduces a smooth transition from 0 to 1 to reduce ringing artifacts.
- ***D(u,v)*** is the Euclidean Distance from any point (u, v) to the origin of the frequency plane, i.e $D(u,v) = \sqrt{(u^2 + v^2)}$



Comparison of Gaussian, Butterworth and Ideal high pass filters



a b c
d e f

FIGURE (a)–(c): Ideal, Gaussian, and Butterworth highpass spatial kernels obtained from IHPF, GHPF, and BHPF frequency-domain transfer functions. (The thin image borders are not part of the data.) (d)–(f): Horizontal intensity profiles through the centers of the kernels.

3.d Subjective and Objective Metrics

The most reliable method for assessing the quality of images is through subjective testing, since human observers are the ultimate users in most of the multimedia applications. In subjective testing a group of people are asked to give their opinion about the quality of each image. In order to perform a subjective image quality testing, several international standards are proposed which provide reliable results.

The following are the objective metrics we considered:

- Minimum Mean Square Error(MSE): It is a error measure which is defined as

$$e^2 = E\left\{\left(f - \hat{f}\right)^2\right\}$$

f is the original image, f^ is the smoothed image, E{.} is the expected value of the argument.

$$\text{MSE} = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left[f(x,y) - \hat{f}(x,y)\right]^2$$

M and N are the number of rows and columns in the input images.

- Peak Signal To Noise Ratio(PSNR):

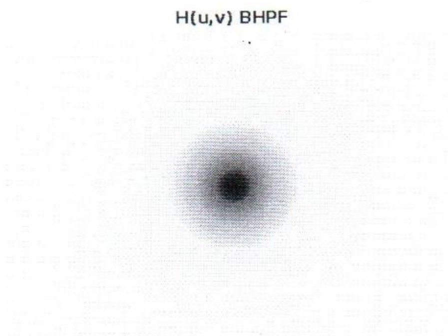
$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right)$$

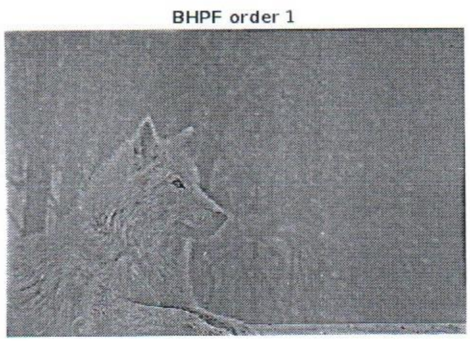
R is the maximum fluctuation in the input image data type

4.Experimental Results

1)D0=30

Butterworth high pass filter (n=1)

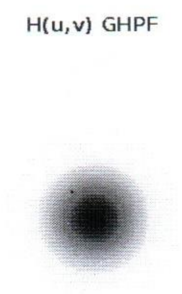




Mean Square Error(MSE) =760.92

Peak Signal to Noise Ratio (PSNR) = -38.81

Gaussian High pass filter

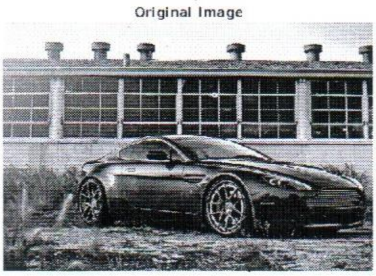


Mean Square Error(MSE) =767.42

Peak Signal to Noise Ratio (PSNR) = -38.85

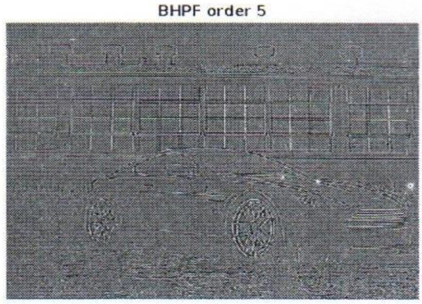
2)D0=70

Butterworth high pass filter(n=5):

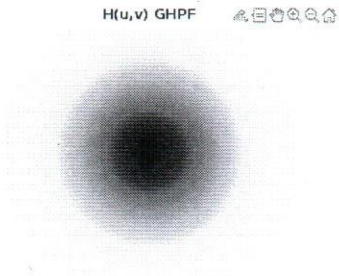


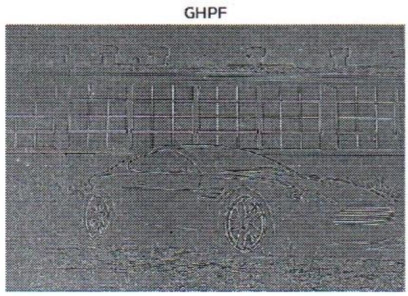
Mean Square Error(MSE) =209.43

Peak Signal to Noise Ratio (PSNR) = -43.21



Gaussian filter:





Mean Square Error(MSE) =207.78

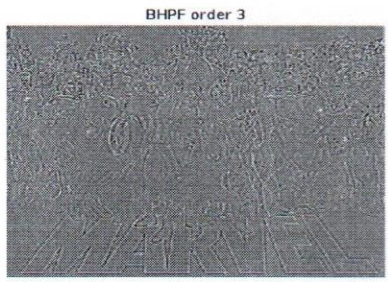
Peak Signal to Noise Ratio (PSNR) = -43.17

3) D0=50

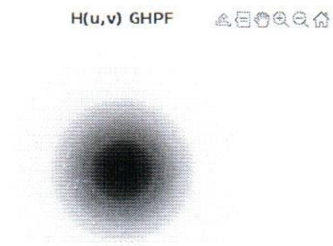
Butterworth high pass filter(n=3):

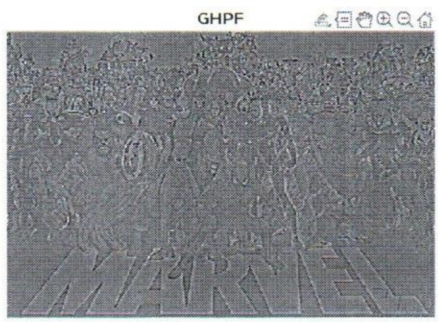
Mean Square Error(MSE) =18710

Peak Signal to Noise Ratio (PSNR) = -42.7207



Gaussian high pass filter:





Mean Square Error(MSE) =18542

Peak Signal to Noise Ratio (PSNR) = -42.681

5.Conclusion

As observed in experiment results, Butterworth high pass filter of higher order performs better sharpening than Gaussian high pass filter. A Gaussian High pass filter performs better sharpening than Butterworth high pass filter of order 1.

When Objective metrics are considered, MSE of Butterworth filter of higher order is more when compared to MSE of Gaussian filter. Higher the sharpening, higher the MSE.

PSNR of Butterworth high pass filter is less when compared to PSNR of Gaussian high pass filter which implies noise is more in Butterworth filter when compared to Gaussian filter.

The same results are observed for any test image.Butterworth filtering performs better sharpening of image than Gaussian filtering.

References

1. Baldonado, M., Chang, C.-C.K., Gravano, L., Paepcke, A.: The Stanford Digital Library Metadata Architecture. Int. J. Digit. Libr. 1 (1997) 108–121.
2. Bruce, K.B., Cardelli, L., Pierce, B.C.: Comparing Object Encodings. In: Abadi, M., Ito, T. (eds.): Theoretical Aspects of Computer Software. Lecture Notes in Computer Science, Vol. 1281. Springer-Verlag, Berlin Heidelberg New York (1997) 415–438.
3. van Leeuwen, J. (ed.): Computer Science Today. Recent Trends and Developments. Lecture Notes in Computer Science, Vol. 1000. Springer-Verlag, Berlin Heidelberg New York (1995).
4. Michalewicz, Z.: Genetic Algorithms + Data Structures = Evolution Programs. 3rd edn. Springer-Verlag, Berlin Heidelberg New York (1996).

Annexure: keep Code here

```
img=imread("237706.jpg");
i=rgb2gray(img);
figure
imshow(i)
title('Original Image')
[M, N]=size(i);

f=fft2(double(i));
D0=100;

u=0:(M-1);
idx=find(u>M/2);
u(idx)=u(idx)-M;

v=0:(N-1);
idy=find(v>N/2);
v(idy)=v(idy)-N;
[V, U]=meshgrid(v,u);
D=sqrt(U.^2+V.^2);

n=10;
H=1./(1+(D0./D).^(2*n));

G2=H.*f;
butterop=real(ifft2(double(G2)));
figure
imshow(abs(fftshift(H)));
title('H(u,v) BHPF')

figure
imshow(butterop,[]);
title('BHPF order 3')

H=1-exp(-(D.^2)./(2*(D0^2)));
G2=H.*f;
gop=real(ifft2(double(G2)));

figure
imshow(abs(fftshift(H)));
title('H(u,v) GHPF')

figure
imshow(gop,[]);
title('GHPF')


but=psnr(butterop,double(i))
gas=psnr(gop,double(i))

berr=immse(butterop,double(i))
gerr=immse(gop,double(i))
```

Assessment Sheet

A9 20

Criteria	Name 1 Roll Number 1	Name 2 Roll Number 2	Name 3 Roll Number 3
Able to Conduct investigations of complex problems (PO4)-2M	2	2	
Able to implement signal and image processing techniques for real time applications (PSO3)-2M	2	2	
Able to use Mat Lab (PO5)-2M	2	2	
Able to Follow Ethics (PO8) - 1M	1	1	
Individual and team work (PO9)-1M	1	1	
Communicationand proper report writing(PO10) -2M	1	1	
	9	9	

(Dr Kilari Veera Swamy)