ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School of Electrical and Computing

Department of computer science and Engineering

Introduction to Computer Vision Assignment I

Smoothing and Sharpening frequency domain

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Frequency Domain Filters

Frequency domain filters are used to modify the amplitude and frequency characteristics of signals, controlling the dynamics and level of detail. Smoothing filters reduce noise and improve the signal quality by eliminating lower frequency components while sharpening filters boost certain frequencies within a signal and enhance its detail. Frequency domain filtering is very useful for audio processing, image processing, and many other applications that require manipulating signals. By utilizing the frequency domain, a more accurate characterization of the signal can be achieved and further modifications can be applied.

These filters are typically digital and utilize Fast Fourier Transforms (FFTs) to transform the signal into the frequency domain and then various mathematical functions to analyze, filter, or modify the resulting frequencies. Frequency Domain Filters can be used for a variety of tasks, such as noise removal and signal enhancement.

Frequency domain filters differ from those in the spatial domain, as they focus on the image's frequency components instead. Smoothing and sharpening are the two most common operations for frequency-domain filters, which can be used to modify the amplitude and frequency of an image, allowing for more precise modifications to be applied.

The operations of filters in frequency domain involve modifying the amplitude and frequency characteristics of signals by either smoothing out or amplifying certain frequencies. Low pass filters are used to reduce noise, blur images and eliminate lower frequency components, while high pass filters are used to sharpen images, preserve edges and transitions and reduce noise. Frequency domain filtering is a useful tool for signal processing, as it can provide a more accurate characterization of the signal allowing for further detailed modifications in both the frequency and amplitude dimensions.

There are 3 types of Frequency domain filters

1. Low pass filters
2. High pass filters
3. Band pass filters

Smoothing frequency domain filters

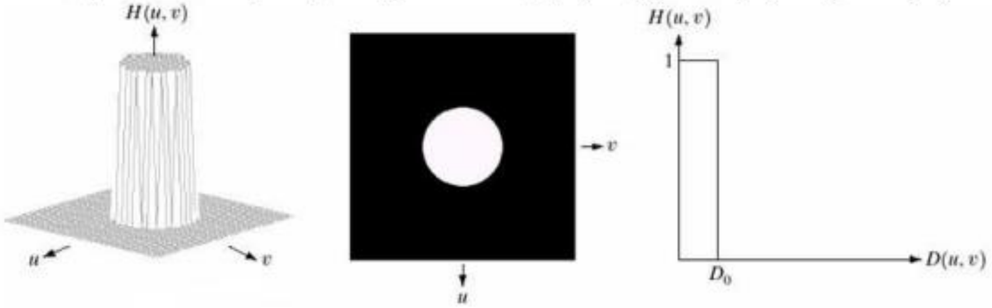
Low pass filters: are a complement of high pass filters and are used to smoothen an image by removing or attenuating the higher frequency components that are above the selected cut-off frequency and passing signals that are lower than the cut-off frequency.

Common applications of low pass filters include suppressing noise, removing sharp edges and transitions, and blurring images. By using low pass filters, signals can be filtered out at certain frequencies, allowing other signals to dominate an image.

The transfer function of this filter is:

$$H(u, v) = \begin{cases} 1 & \text{if } D(u, v) <= D_0 \\ 0 & \text{if } D(u, v) > D_0 \end{cases}$$

Where D_0 is cutoff frequency and given as $D(u, v) = \sqrt{(u - M/2)^2 + (v - N/2)^2}$

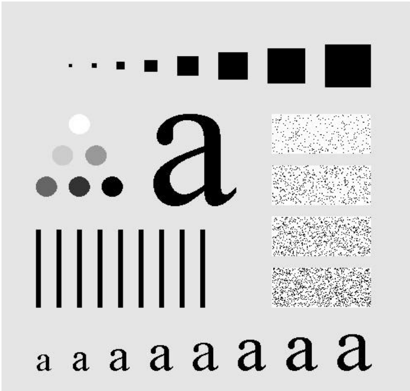


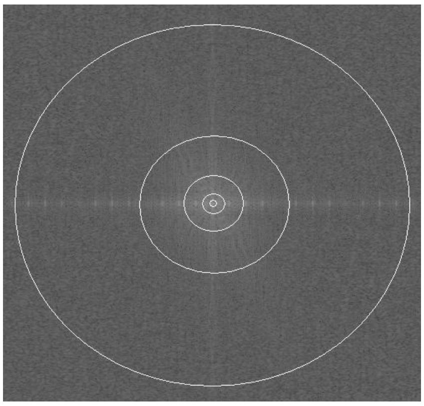
Here is an example of a low pass filtered image

a) Original Image

b) Low pass filtered image

The next figure shows a gray image with its Fourier spectrum. The circles superimposed on the spectrum represent cutoff frequencies 5, 15, 30, 80 and 23

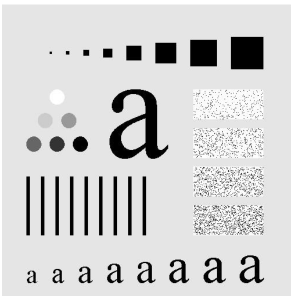




a)Original Image   b) Its Fourier Spectrum

We can see the following effects of low pass filter in the next images :

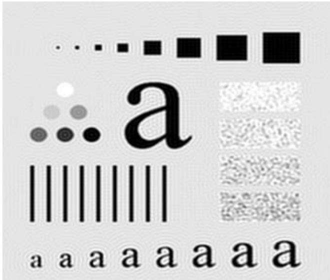
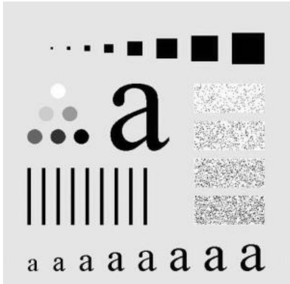
1. Blurring effect which decreases as the cutoff frequency increases.
2. Ringing effect which becomes finer (i.e. decreases) as the cutoff frequency increases

a) 

b) 

c) 

d)  e)

 f) 

- In the above figure, a shows the original image and b-f shows results of ILPF with cutoff frequencies 5, 15, 30, 80 and 230 respectively.

In general, Low pass filters are frequency-selective components that allow low-frequency signals to pass through while blocking high frequency components.

High pass filters: are commonly used in image processing to increase image sharpness and detail by preserving the edge details and suppressing low frequencies which produce a blur effect. These filters may also be used for reducing noise and increasing contrast in images.
The frequency-selective components of a high pass filter allow it to pass high frequencies while blocking low frequencies, resulting in a signal or image with more details. This is particularly useful when working with images that contain a large amount of noise or when dealing with images that require additional edge details.

The transfer function of this filter is:

$$H(u, v) = \begin{cases} 1 & D(u, v) <= D_0 \\ 0 & D(u, v) > D_0 \end{cases}$$

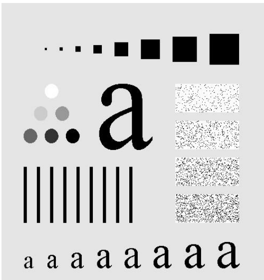
D0 is cutoff distance as before which is given as $D(u, v) = \sqrt{(u - M/2)^2 + (v - N/2)^2}$

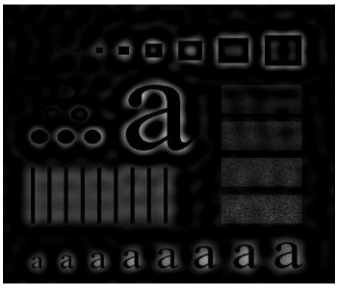
Here is an example of high pass filtered image

a) Original Image

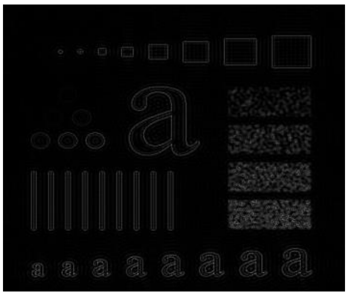
b) High pass filtered image

The figure below shows the results of applying IHPF with cutoff frequencies 15, 30, and 80.

a) 

b) 

c) 



d)

- In the above figure, a shows the original image and b-d shows results of IHPF with cutoff frequencies 15, 30, and 80 respectively.

The figure above shows the results of applying IHPF with cutoff frequencies 15, 30, and 80.

Band Pass filters

Band Pass Filters are filters that are designed to allow only a certain frequency range to pass, while blocking other frequencies. These filters typically utilize Fast

Fourier Transforms (FFTs) to transform the signal into the frequency domain and then various mathematical functions to analyze, filter, or modify the resulting frequencies. There are several types of band pass filters, including Butterworth and Chebyshev filters, which have their own characteristics in terms of frequency response and phase shift. Band pass filters are typically used in audio applications, such as speakers and musical instruments, and in signal processing applications such as noise removal.

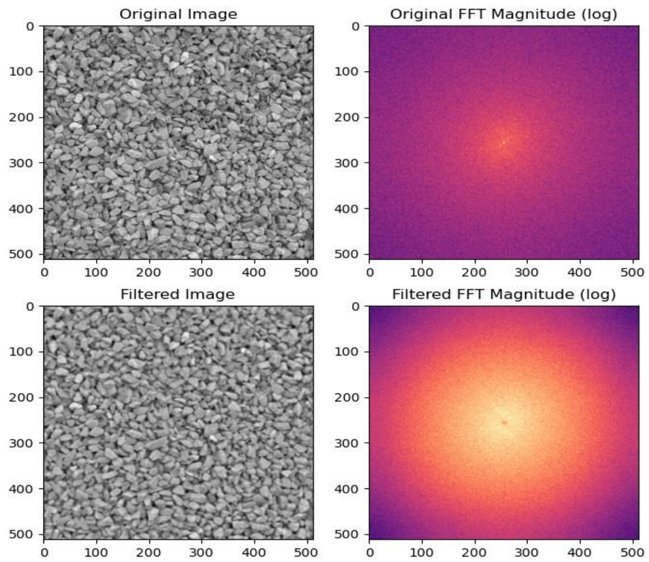


fig. band pass filter

Sharpening frequency domain filters

To sharpen frequency domain filters specifically, one must adjust the cut-off of the filter to boost or attenuate certain frequencies, usually within a specific range. This can be done using a variety of tools, including knobs, sliders, dials and graphical user interfaces. The resulting filter can be used in various signal processing applications to enhance the frequency range of a signal, or to limit it in order to reduce noise or distortion.

For any low pass filter there is a high pass filter.

The IHPF sets to zero all frequencies inside a circle of radius $D0$ while passing, without attenuation, all frequencies outside the circle.

(a) (b)

fig. using IHPF for image sharpening

References

1. https://www.cs.uoi.gr/~cnikou/Courses/Digital_Image_Processing/2011-2012/Chapter_04b_Frequency_Filtering_(Application)_2spp.pdf

2. https://www.mathworks.com/matlabcentral/fileexchange/46812-two-dimensionalgaussian-hi-pass-and-low-pass-image-filter

3. https://en.wikipedia.org/wiki/High-pass_filter