Fundamentals of Spatial Filtering:

Spatial filtering is one of the principle tools used in the field of digital image processing for a broad spectrum of applications. The name 'filter' is borrowed from frequency domain processing, where 'filtering' refers to accepting or rejecting certain frequency components.

For example, a filter that passes low frequencies is called lowpass filter. The effect produced by low pass filter is to ~~smooth~~ blur or smooth an image.

The mechanics of spatial filtering:

A spatial filter consists of (i) a neighbourhood pixel and (ii) a predefined operation that is performed on the image pixels encompassed or mapped by the neighborhood.

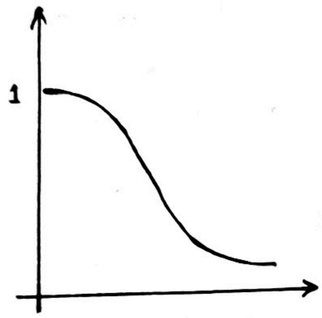
If the operation performed on the image pixels is linear, then the filter is called a linear spatial filter. Otherwise the filter is non-linear.

Filtering creates a new pixel at the same location as of original image but in the new image. A filtered image is generated as the filter visits each pixel in the input image.

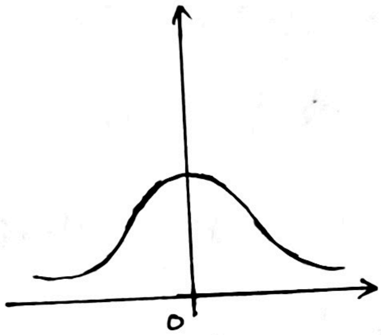
Linear filters:

Linear filters are based on the concepts of impulse response function and transfer function. There are mainly three types of linear filters,

i) Lowpass filter: These type of filters eleminate high frequencies, resulting in the removal of edges and sharpness in images, thus blurring or smoothing the overall image.

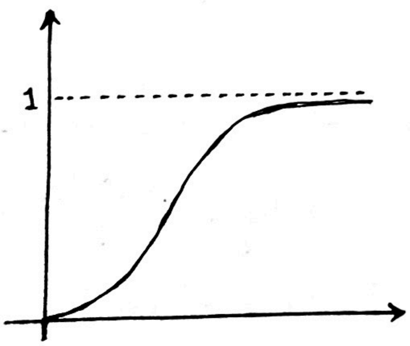


Frequency domain low-pass filter

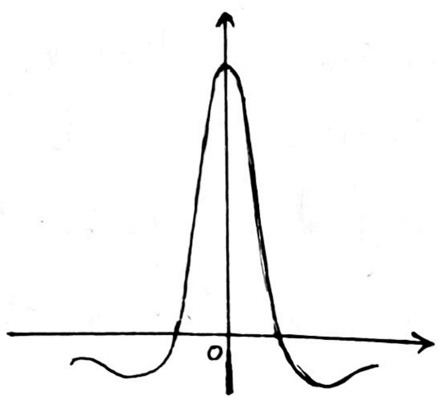


Spatial domain lowpass filter

ii) Highpass filter: These type of filters eleminate low frequencies, resulting in sharper images (i.e the edges of the image are more pronounced.

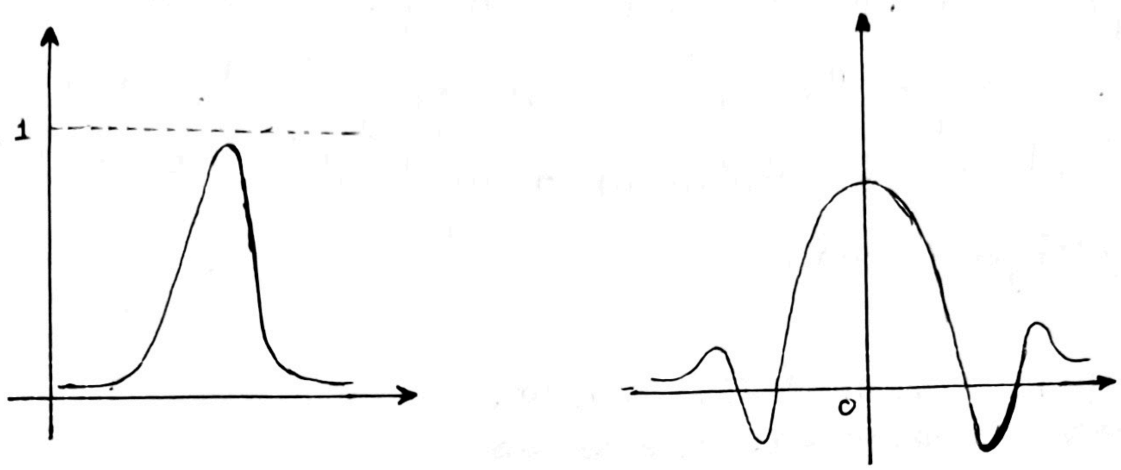


Frequency domain Highpass filter



Spatial domain Highpass filter

iii) Bandpass filter: These type of filters are a combination of lowpass and highpass filters. They are mostly used for image restoration rather than image enhancement.



Frequency Domain bandpass filter

Spatial Domain bandpass filter

A linear filter operates on an M×N neighborhood, defined by M×N mask co-efficient. These co-efficients are used in a sum that is calculated for each pixel at location (x, y) in the input image.

$$\boxed{R = w_1 z_1 + w_2 z_2 + w_3 z_3 + \cdots + w_n z_n}$$

Where, n is the number of co-efficients in the mask, $z_1, z_2, z_3, \ldots, z_n$ are the gray-level of the pixels under the mask, $w_1, w_2, w_3, \ldots, w_n$ are the co-efficients (also called weights) of the mask and R is the response of the linear mask. This is done for each pixel in the input image, thus the mask is moved from pixel-to-pixel.

Nonlinear filters:

These filters operates also on some neighborhood of every pixel at location (x, y), however, the non-linearity is expressed in the computation of R which can now be for example the maximum gray-level, the median gray-level or the minimum gray-level of all the pixel in the neighborhood.

Generating Spatial filter masks:

Generating an $m \times n$ linear spatial filter requires that it specify $m \times n$ mask co-efficients. These co-efficients are selected based on what the filter is supposed to do.

For example:

To replace the pixels in an image by the average intensity of a 3×3 neighborhood centered on those pixels, the average value at any location (x, y) in the image is the sum of the nine intensity values in the 3×3 neighborhood centered on (x, y) divided by 9. Let z_i, $1 \leq i \leq 9$, denotes these intensities. Then,

$$\boxed{R = \frac{1}{9} \sum_{i=1}^{9} z_i}$$

In some applications we have a continuous function of two variables, and the objective is to obtain a spatial filter mask based on that function.

For example:

A Gaussian function of two variables has the basic form,

$$\boxed{h(x,y) = e^{-\frac{x^2+y^2}{2\sigma^2}}}$$

Where,

σ is the standard deviation, the co-ordinates x and y are integers. To generate a 3x3 filter mask from this function, we sample it about its center.

Generating a 'nonlinear' filter requires that we specify the size of a neighborhood and the operation(s) to be performed on the image pixels contained in the neighborhood.

For example:

A 5x5, max filter centered at an arbitary point (x,y) of an image obtains the maximum intensity value of the 25 pixels and assigns that value to location (x,y) in the processed image.