Unit - 2

Spatial filters

Filter - filter is a process that removes some unwanted components detail in image.

⇒ Types of filters -

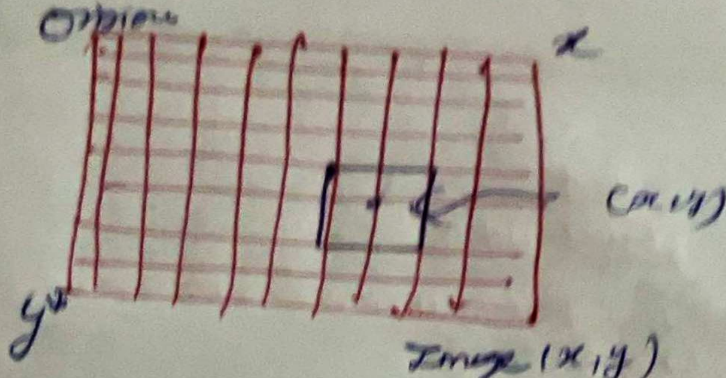
- Spatial Domain filters
- Frequency Domain filters

(1) Spatial Domain filters - The technique is used directly on pixels of an images. mask is usually considered to be added in size so that it has specific center pixel. This mask is moved on the image such that the center of the mask traverses all image pixels.

* The concept of mask is also known as spatial filtering. mask is type of filter which performs operation directly on the image. The filter mask is also known as convolution mask.

* To apply a mask on an image, filter mask is moved point to point on the image.

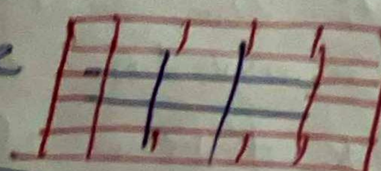
* Neighbourhoods are mostly a rectangle around a center pixel
* Any size rectangle and any shape filter are possible



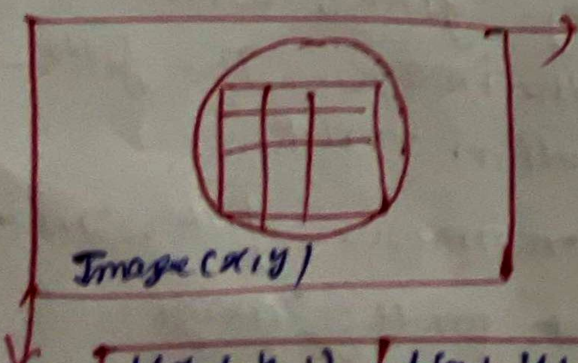

**Spatial filter** - The spatial filter is just moving the filter mask from point to point in an image. The filter mask may be 3X3 mask or 5X5 mask or to be 7X7 mask.

**Example**

3X3 mask in a 5X5 image



## Mechanism of Spatial Filtering




Mask coefficients

| | | |
|---|---|---|
| W (-1,-1) | W (-1,0) | W (-1,1) |
| W (0,-1) | W (0,0) | W (0,1) |
| W (1,-1) | W (1,0) | W (1,1) |

| | | |
|---|---|---|
| f(x-1, y-1) | f(x-1, y) | f(x-1, y+1) |
| f(x, y-1) | f(x, y) | f(x, y-1) |
| f(x+1, y-1) | f(x+1, y) | f(x+1, y+1) |

Pixels of image section under mask.

Types of Spatial filter on the basis of Linearity.

i) Linear spatial filter - Each pixel in an image can be replaced with constant value then it is called as linear spatial filter

ii) Non-Linear Spatial Filter. Each pixel in an image can not be replaced with constant value is called as non-linear.

Spatial Correlation and Convolution - Correlation is moving the filter over the image find the sum of products in each location. Convolution process is s as correlation but the filter is first rotate b degree.

General Classification of Spatial filters

1) Smoothing Spatial filter
2) Sharpening Spatial filter

① Smoothening Spatial filter – Smoothing filter is used for blurring and noise reduction in the image.

Types of smoothing filters

→ a) mean filter – Simply the average of pixels contained in the neighborhood of filter mask. Types of mean filter – Averging filter & weighted filter.

(b) → Order Statistics filter – It is based on the ordering of the pixels contained in the image area encompassed by the filter.

i) Minimum filter – 0th percentile filter is the minimum filter. Select smallest value & replace the center by smallest value

ii) Maximum filter – 100th percentile filter is the maximum filter. Select the largest value within pixel value. replace center by large value

iii) Median filter – Each pixel in image is considered. sort the neighbouring pixel into order based upon intensity.

② Sharpening Spatial filter – also know as derivative filter, derivative.

It is based on first and second derivative.

i) First order derivative – must be zero in flat segment. must be non zero at the onset of gray level step.

ii) Second order derivative – must be zero in flat areas, must be zero at the onset and end of a ramp. must be zero along ramps. The approach uses the second order derivative for constructing filter mask.

Sharpening Spatial filter means removal of blurring and highlight the edges.

## frequency domain filters and its types –

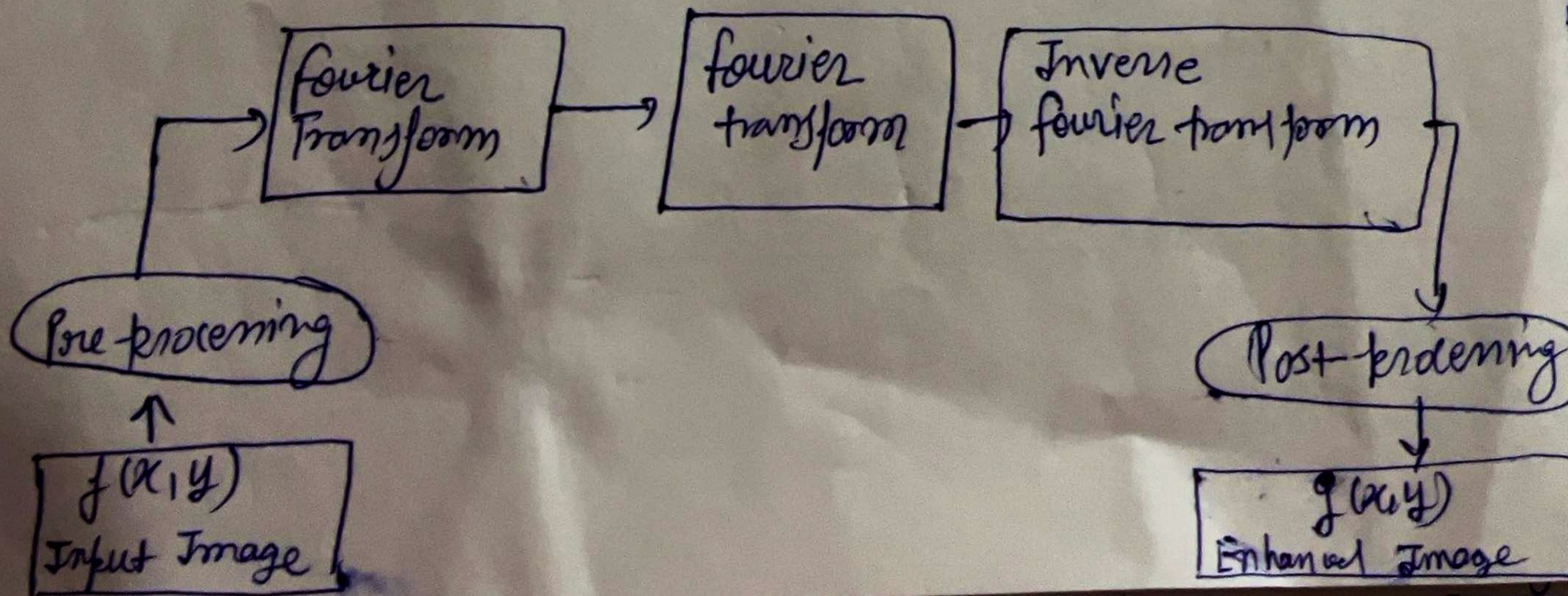
→ Frequency domain filters are used for smoothing & sharpening of image by removal of high or low frequency. ~~domain~~.

→ Frequency domains filters are different from spatial domain filters as it basically focuses on the frequency of the images.

→ Basic difference between frequency domain & spatial domain

| Spatial domain | frequency domain |
| --- | --- |
| → Direct manipulation of image pixels. | – manipulation of Fourier transform or wavelet transform of an image |

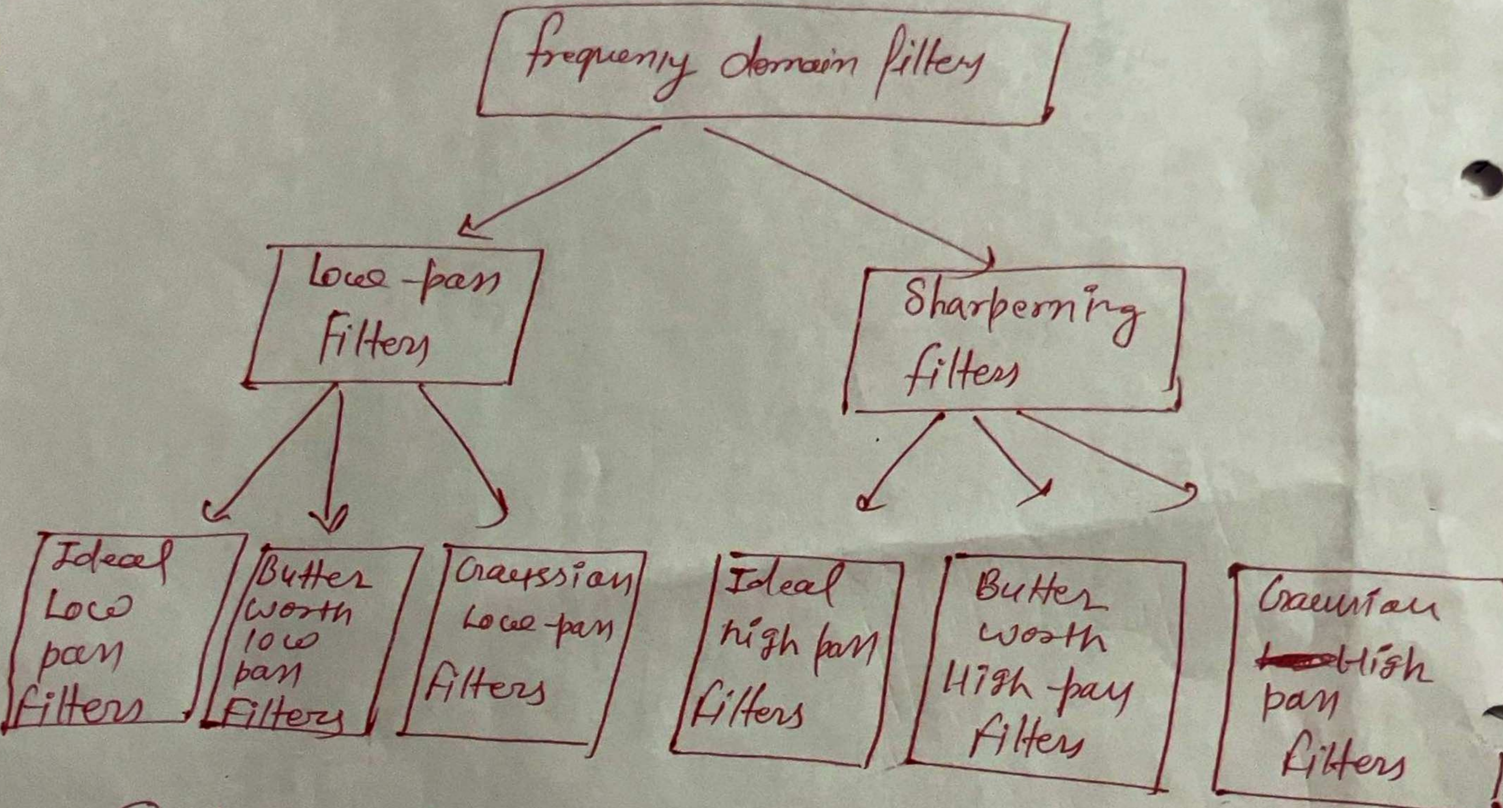
## frequency domain filtering steps –



→ It is basically done for two basic operation — Smoothening & Sharpening

→ frequency filters are broadly classified into two categories -

1. Low-pass filters/ Smoothning filters
2. High-pass filters/ Sharpening filters




1. Low-pass filters - Low pass filters is the type of frequency domain filter that is used for smoothning an image. It rejects high-frequency components and preserves the low-frequency components.

2. High-pass filters - High pass filter is the type of frequency domain filter that is used for sharpening the image. It rejects the low-frequency components and preserves the high-frequency components.

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## Types of High pass filters

① **Ideal Highpass filter in image processing** — In this of image processing. Ideal Highpass filter is used for image sharpening. It removes low-frequency components and preserve high-frequency components.

→ It can be determined by following relation—

$$H_{HP}(u,v) = 1 - H_{LP}(u,v)$$

where,

$H_{HP}(u,v)$ — transfer function of highpass filter

$H_{LP}(u,v)$ — is the transfer function of the corresponding lowpass filter.

~~The effective~~

IHPF can be specified by

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

$D_0$ = positive integer

This $D_0$ is cut off frequency between $H(u,v) = 1$ and $H(u,v) = 0$, so this is termed as cutoff frequency $D(u,v)$

② **Butterworth highpass filters** — used for image sharpening in frequency domain.

It can be determined using the relation—

$$H_{HP}(u,v) = 1 - H_{LP}(u,v)$$

where,

$H_{HP}(u,v)$

is the transfer function of the highpass filter

$H_{LP}(u,v)$

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

$D_0$ = positive constant and transition point between $H(u,v)=1$ & $H(u,v)=0$ (cutoff frequency)

Smooth transition from 0 to 1 to reduce ringing artifacts.

③ Gaussian high pass filters —

The Gaussian high pass filter is given as :

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

Example

① Results of Gaussian high pass filters with $D_0 = 15$ → Light Image

② Results of Gaussian high pass filter with $D_0 = 30$ → Dark Image rotation—

→ Butterworth low pass filter - To eliminiate ringing effect we have to remove the sharp cut off ~~is~~ in frequency domain, so Butterworth filter are used to they remove the ringing effect but up to a certain limit. Let us know discuss the filter and what happens if we modify some values in the filter

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

Where $D_0$ = cut off frequency given as an input by user and

$n$ = order of filter.

$$D(u,v) = \sqrt{\left[(u-M/2)^2 + (v-N/2)^2\right]}$$

where $M \times N$ is matrix

for a particular code and image the 2-D filter and filter with frequency response are given below -

⇒ Gaussian Low pass filter -

→ The disadvantage of Butterworth low ~~filter~~ pass filter are removed in Gaussian filter i.e no ringing effect at all

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

- Butterworth low pass filters - To eliminate ringing

→ Ideal Lowpass filter in Image processing - In the field of Image processing, Ideal Lowpass filters is used to image smoothing in frequency domain. It removes high-frequency noise from digital image and preserves low-frequency domain.
It can be defined by -

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

$D_0$ = positive constant
$D_0$ is the transition point between $H(U,V) = 1$ and $H(U,V) = 0$, so this is termed as cutoff frequency.
$D(U,V)$ is the Euclidean Distance from any point $(U,V)$ to the origion of the frequency plane i.e. -

$$D(u,v) = \sqrt{(u^2 + v^2)}$$

Approach - ① Input read image
② saving the size of i/p image in pixels
③ Get the fourier Transform of the Input Image
④ Assign the Cutoff frequency $D_0$.
⑤ Designing filter - ideal low pass filter
⑥ Convolution between the fourier transform input Image and the filtering mask
⑦ Take inverse transform of convoluted image.
⑧ Display the resultant image as output.