Image: are represented as matrix of pixels where each pixel has value corresponding to its intensity / color.

colors are RGB, CMYK, HSV ... etc

Image Acquisition: its process of capturing an image using sensors like cameras or scanners.

Sampling:

process of converting a continous Signal such as an image into Discrete time signal by capturing image at discrete intervals..

Working:

i. Continous Image: a real-world scene or an analog image that has continous intensity values

Image Acquisition (x): process of capturing an image using sensor such as camera, or scanner.

Quantization: is process of mapping large set of input values to a smaller-set.

- It involve converting continous range of pixel intensity values into discrete levels

Working:

1. Intensity Levels:
- continous intensity values of sampled image are divided into Discrete Levels..

ex: 8-bit image can have 256 discrete intensity val's

2. Quantization Error: It is diff b/n actual continous values and Quantized value.... this error can introduce ARTIFACTS in the image especially in areas w/ smooth gradients...

3. Bit Depth: It is No of bits used to represent each pixel's intensity value

- higher bit depth allows for more intensity levels. & finer gradiation of errors

Histogram (A*)

→ It's a graphical representation wlc represents No of times a particular Grey-level has occured in an image

→ it's Graph in wlc x-axis represents Graylevels and y-axis represents No of pixels for each Gray-Level

→ probability of occurance of any pixel w its Amplitude is use to draw in image histogram.

→ It's defined as ff:

$\boxed{h(r_k) = n_k}$ where $r_k = k^{th}$ grey-level of n_k = No of pixels w Grey-level r_k and $k = 0, 1, 2 \cdots m-1$

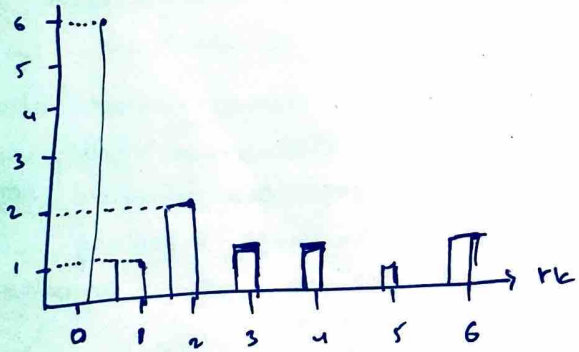
Example :

0	0	0	0
0	1	2	3
0	2	4	6

→ in the above table r_k = 0, 1, 2, 3, 4, 6 and n_k = is No of times that Grey value has occured.

∴

r_k =	0	1	2	3	4	5	6
n_k =	6	1	2	1	1	0	1



⇒ Histogram tells us the Dif B/n Average Grey-level of an object and its Surrounding.

→ Curves as useful image statistics wlc is helpful for thresholding, segmentation etc

Applications of Histogram:

- tells about image contrast
- mostly used in thresholding, to separate contrasting objects from the Background.
- indicates if clipping is a problem in image
- used where intensity levels are modified or processed.

HISTOGRAM EQUALIZATION

HE: is a point operation that maps an input image onto a new output image such that there are almost Equal numbers of pixels at each Gray-level in output.

∴ it can be used for contrast enhancement.....

this is done by adjusting probability density function (PDF) of Histogram of original image so that PDF spreads Equally..

then ff transformation is used:

$$\boxed{S = T(r),\ 0 \le r \le 1}$$

Histogram Equalization is done by the ff Transformation:

$$S_k = T(r_k) = \sum_{j=0}^{k} p_r(r_j),\ k = 0, \ldots N-1$$

Steps of Histogram Equalization or Algorithm

1./ Find histogram of input image by making table of r_k and n_k

2./ For each input level find cumulative sum.

3./ Divide cumulative sum by total No. of pixels (n).

4./ multiply each value result to the mxm Gray-level pixel value ; if 8 :. = 7

5./ Round-off to Nearest integer value to Find "S_k"

6./ map input value r_k to output level S_k using 1st and Last row of the table.

7./ Formulate New image $g(x,y)$ By replacing each level of $f(x,y)$ by the new table

8./ Draw input & output Histograms.

Firada rk hostala ku badel
Mid (SSK) (SK)

Image Enhancement :

- Process of improving quality of image so that resulting image is more suitable than the original image for a specific applications..
  - → this process enhances image features such as
    - Boundaries
    - edges or increasing image contrast for analysis purpose.
- ★ image enhancement can be done using following methods :
  1. Spatial domain method :
     - manipulation is done directly on pixels
  2. Frequency Domain method :
     - " " on Fourier transformed image

- There are 3- basic types of functions used for image Enhancement and those are :
  1- Linear — -ve Transform
  2- logarithmic — log- Transf
  3- power law

(#) NEGATIVE Transformation : (IT)

- Negative of Digital image is done by a Transformation function

o/p image $S = T(r) = (L-1) - r$ → gray level intensity

where "L" → number of gray levels (0-255)

→ in this Transformation Highest Gray level is mapped to lowest Gray level & vice-versa.

(#) this used for Displaying medical images

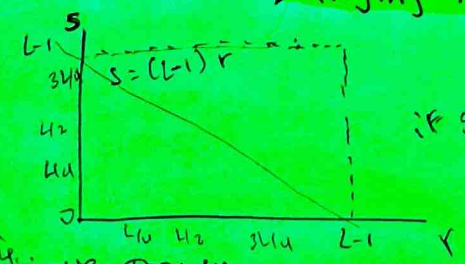


Fig.: -ve Transfn

Sol: xray

if $r=0$, $S=L-1$

$r=L-1$, $S=0$

(#) Log Transformation : (IT)

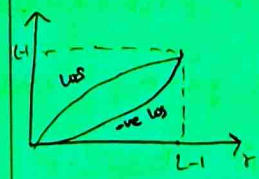
→ this is useful and applied when input gray Level intensity value has extremely Low- or high values that can be ↑es or ↓ed by $1 + \log(\text{intensity value})$

output Image (S) = $C * \log(1+r)$

where r → gray level intensity of image (input intensity level)

C → is constant and (C = 1)

and $\boxed{r \geq 0 \text{ , but } < 255}$ (r) (S) → o/p



Note: ammount of expansion or compression to be done in the image is fixed & cannot be changed.

(#) power-law Transformation : (intensity Trs)

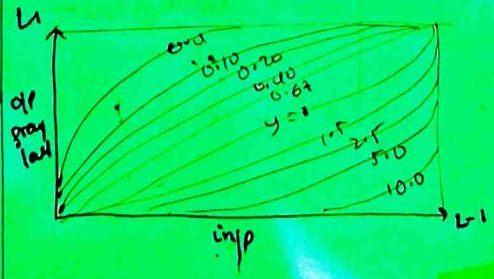
this has the basic form of

output I = $C \cdot (r)^{\gamma}$

where :- "C" and "γ" are +ve constant.

⇒ in this a narrow range of dark input values are mapped into wider range of output values. with the opposite is Being true for Large values of ($\gamma > 1$) ↳ Brighter region

⇒ Gamma function also has opposite effect when $\gamma < 1$, (→ darker region) if $C = \gamma = 1$ then power law Trans reduces to identity Trans



Intensity Transfn	Spatial filtering
$S = T(r)$	$g(x,y) = T[f(x,y)]$
S → o/p, r → i/p, T → operator	

Vector Representation of Linear filtering :

(i) Correlation

$R = k_1 z_1 + k_2 z_2 + \dots + k_{mn} \cdot z_{mn}$

$= \sum_{k=1}^{mn} k_k z_k$

$\boxed{k^T z}$

where

R → response of mask

k_k → coefficients of M×N f

z_k → corresponding image enc by filter

(ii) Convolution

rotate mask "180°"

∴ General 3×3 mask Equation

$R = k_1 z_1 + k_2 z_2 \dots + w_9 z_9$

$= \sum_{k=1}^{9} k_k z_k$

$\boxed{k^T z}$

w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

Fig.: represent of 3×3 f-m

⊛ SPATIAL Filtering

($S = T(r)$ — S → o/p, T → operator, r → input intensity → for intensity Trans)

It is a mask of rectangle type usually in size of odd-length. and this made to move on the image

→ we create New-image where GL-values of pixels are calculated values under the mask.

→ the values of mask are modified By function called Filter

→ if this filter function is a Linear function of all gray-level values in the mask then filter is called Linear filter else NON-linear.

⊕ the mechanism or process of spatial filtering is down below:

{ we deal in image itself enhancement are applied to image itself

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

→ filter coefficient

-1 → previous row/col

+1 → Next row/column

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

→ pixels of image section under filter

"$g(x,y) = T[f(x,y)]$" general formula

⊛ Fig: Spatial F' using 3x3 Filter mask.

↑ in this "Filter mask" is moved from point to point of an image.

at any point (x,y) in the image the response $g(x,y)$ of the filter is sum of products of filter coefficients and corresponding image pixels in the area directly under the mask

↓

$$g(x,y) = w(-1,-1)\cdot f(x-1,y-1) + w(-1,0)\cdot f(x-1,y) \ldots\ldots + w(0,0)\cdot f(x,y) \ldots\ldots$$

∴ For MASK "MXN" we assume that $m = 2a+1$ & $n = 2b+1$ where a,b are integers.

So in General Linear Filtering of an image with size MXN with Filter mask "MXN" is Given By

$$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t)\, F(x+s, y+t)$$

where:

a,b → are integers specially odd integers b/c they have Clear Center point and easy located

es: 3x3, 5x5 .... etc.

$a = \frac{m-1}{2}$, $b = \frac{n-1}{2}$

SPATIAL Correlation & Convolution

[5 mask w example]

• Cor-relation: is process of moving a filter mask over the image and computing sum of products at each Location (mask weights & Integer of the neighbor elements = pixel) Same

Convolution: the mechanism is same except that filter is rotated first By 180°

example: correlation: [1-D correlation of filter w discrete unit impulse

mask/filter (w) = 12328

Function (origin) = 000 1 0000

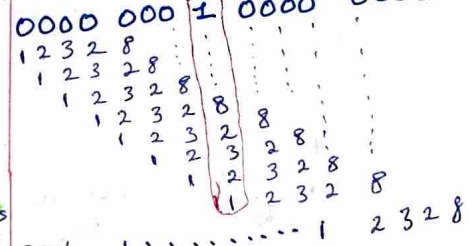
∴ f(w) = 5, and we need m-1 zeros on either side of m

⇒ f(w) = 5-1 ∴ f(w) = 4/11

0000 000 1 0000 0000

← zero-padding →

F=



∴ Full correlation result

000 82321 0000

∴ cropped CR = 08232100

Convolution Example:

⊛ process is same But first filter is rotated by 180°

F = 12328 rotated (F) = 82321

⊛ Starting position Alignment

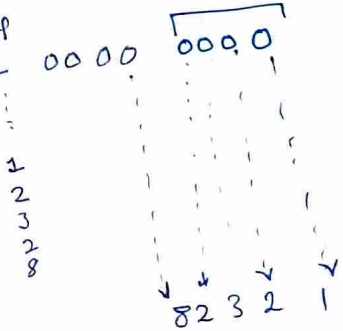
0 0 0 1 0000

82321

⊛ zero padding

0000 000 1 0000 0000

8232 1



⇒ Full convolution result

000 12328 0000

⇒ cropped convolution result

⊛ 01232800

Spatial Filtering

- Smoothing Filters
  - Linear f'
    - Averaging Filter
    - weighted Averaging Filter
  - Nonlinear f' (order statistics ranked)
    - Median filter
    - min / max filter
- Sharpening Filters
  - Linear Filters
    - Laplacian f's
    - 1st derivatives
    - 2nd ...
    - High Boost filter.

⊛ Smoothing Filters (Low pass Filters)

SF :- are used for Blurring and Noise Reduction

a) Blurring :-

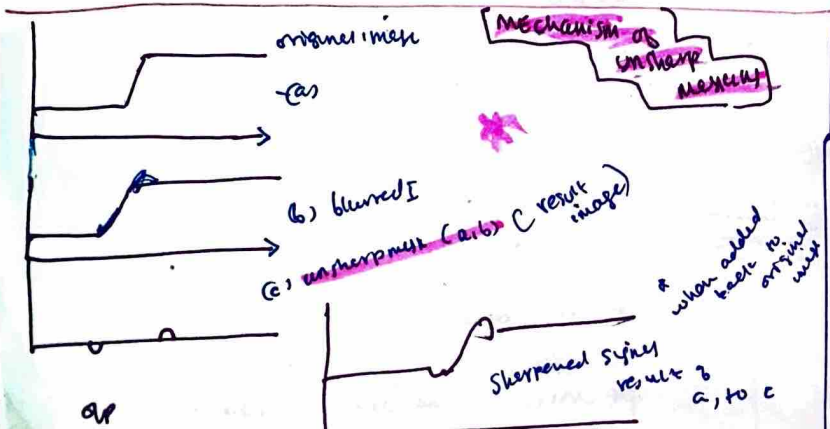
- used for preprocessing tasks such as removal of small details from an image prior to object extraction & to fill small gaps in lines or curves. Present in image

the output :-

- of smoothing linear filters is simply the average of pixels contained in the neighborhood of the filter mask.
- → they're also called Averaging / Lowpass Filters

PYQ :-

explain Image Smoothing and Sharpening in Fr



Averaging Filter :- (mean filter)

Process :-

⊛ { we replace value of every pixel in an image by the Average / arithmetic mean of Gray levels in the neighborhood which is defined by filter mask.

Advantage :-

→ very small irrelevant areas of image are removed

Disadvantage :-

→ we may loose edges / sharp information of an image... is blur

example $\frac{1}{9} \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$ } 3x3 Filter for Averaging

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

Weighted Averaging Filter :- ex :- $\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} \times \frac{1}{16}$

Filtering on 'MxN' image with weighted Averaging Filter of size 'mxn' is given by ff

$$g(x,y) = \sum_{s=-a}^{a} \sum_{s=-b}^{b} w(s,t)\, f(x+s, y+t)$$

$$\hookrightarrow \sum_{s=-a}^{a} \sum_{s=b}^{b} w(s,t)$$

[NON Linear Filters] Smoothing Spatial f's

why ↳ It's used when we require a response of filtering based on the ordering or Ranking of pixels (answers nonlinear repo lin weight)

⊕ MEDIAN filter :- (dhanda ka kaisa)

ex :- {10, 15, 20, 15, 100, 20, 15}
sort 10, 15, 15, 15, 20, 20, 100 }

process :- (First sort pixel elements)

→ { replaces value of pixel by median of intensity levels in the neighbor hood. of that pixel

ADV :-

→ provides less Blurring than Linear SF's of similar size

Note :- in 3x3 NBH median is 5th largest, 5x5 NBH median is 13th largest ... such

⊕ max/min Filter :-

as median filter can represent 50th percentile of ranked set of pixels, we may also want to represent the 100th & 0th percentile also.

max filter :- $g(x,y) = \max\{z_k, k=1 \dots 2 \dots mn\}$

- is a filter that's using 100th percentile of ranked set of pixels
- It is usefull for finding brightest point of an image

min filter :- $g(x,y) = \min\{z_k = k=1,2 \dots mn\}$

→ is a filter that's using 0th percentile of ranked set of pixels

→ usefull for finding darkest point of an image

Image Sharpening in Spatial Filters (★★D)

ISh :- is done to enhance highlight fine details and edges on image

•) It is the reverse of smoothing process b/c :-

Smoothing (blurring) = Average of NBH pixels
≃ integration of pixels

But

Sharpening = Derivatives of pixels

Types of Derivatives :- → 1st order
→ 2nd order.

App's used in
- Electronic printing
- medical imaging
- industrial insps
- autonomous guide in military systems.

⊕ 1st order derivatives :-

can be represented by $\frac{\partial F}{\partial x} = f(x+1) - f(x)$ (For 1-D; next intensity; current intensity)

or

$\frac{\partial F}{\partial x} = \frac{df}{dx}$ and $\frac{\partial F}{\partial y} = \frac{df}{dy}$

⊕ IS-SF :- used to highlight transition in intensities

→ its reverse process of image ~~smoothing~~ sharpening

where sharpening :- enhance blurred image

⊕ FOD-properties :-

- Should be zero at area of constant Gray levels (intensity) / Plateau segments of image.
- must be Non-zero along ramps. onset of ramps
- must be Non-zero at the onset Gray-levels (intensity) step.

2nd order Derivatives

can be represented By :- $\frac{\partial^2 F}{\partial x^2} = f(x+1) + f(x-1) - 2f(x)$

Properties :-

- must be zero at constant Areas
  - Non-zero at onset & end of an intensity step
  - zero along ramps & constant slope.

Unsharp Masking AND High Boost Filtering (Smart ☆'s) 2.5m

Unsharp masking :-

the sharpened image is generated by SUBSTRACTING Blurred or lowpass f/sharp smoothed image from Original image

process of unsharp masking contain FF :- steps :-

i :- blur the original image

ii :- Substract Blurred image from original image
d/t result is called mask ★

iii) ADD substracted mask to original image

$g_{mask}(x,y) = f(x,y) - \bar{F}(x,y)$

MASK = $g_{mask}(x,y)$ and $F(x,y) \rightarrow$ original image
$\bar{F}(x,y) \rightarrow$ blurred image

⇒ then we add weighted portion of mask back to original image

$g(x,y) = F(x,y) + k * g_{mask}(x,y)$

when

$k=1$, we have unsharp masking

$k>1$, process is called Highboost filtering

$k<1$, it decomphasizes contribution of unsharp masking.
↳ is frequency emphasizing filtering

NOTE :- the sharpened image generated By Unsharp masking has average Background intensity when Near to Black, B/c sharpening is a Highpass filter operation.
But eliminates component zero frequency
Solution to this is to add part image to the filtered image

- Why it is necessary to convert images from spatial domain to frequency domain

Some of the reasons are following:

(a) Analysis of frequency components:

- It enables representation of images in terms of frequency domain
  - ex: low frequencies represent smooth areas while high frequencies represent edges & fine details.
- allows effective filtering operations techniques like noise removal & image sharpening

(b) image compression

- concentrate image energy into fewer coefficients which enables data reduction
- allows for efficient storage by keeping only significant | important coefficients..
- used for image compression algorithm like JPEG

(c) Efficient image processing operations:

- Simplifies operations like convolution through convolution theorem
- helps feature extraction for tasks such as object rec

(d) Noise Reduction

- makes easy to separate signal from noise in FD
- enables more effective noise reduction techniques.

SPATIAL Domain	Frequency Domain
• Directly on pixels of the image are performed the operation	• original image is 1st converted in transform domain

Frequency Domain process:

$$F(x,y) \xleftrightarrow{DFT} F(u,v) \quad \text{--- (1)}$$

$$F(u,v) \xleftrightarrow{I\text{-}DFT} F(x,y) \quad \text{--- (2)}$$

the 2-D discrete fourier transform (DFT) is given by

$$F(u,v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) \cos\left(\frac{2\pi ux}{M}\right) - j \sin\left(\frac{2\pi vy}{N}\right)$$

↳ discrete image of M×N sample.

>> Taking common

$$2\text{-}D \rightarrow F(u,v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} e^{-2\pi\left(\frac{ux}{M} + \frac{vy}{N}\right)} \quad \text{--- (1)}$$

↳ FD variables

$$1\text{-}D \rightarrow F(u,v) = \ldots e^{-2\pi(ux+vy)m}$$

For Inverse DFT: equation will be:-

$$F(x,y) \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} F(u,v) \, e^{-2\pi(ux+vy)m} \quad \text{--- (2)}$$

Magnitude Equation is used to calculate funcy $u(u,v)$ & (x,y) as pf:

$$MAG(F(u,v)) \Rightarrow |F(u,v)|^2 \Leftarrow R^2(u,v) + I^2(u,v)$$

Fourier Series

States that a function $F(t)$ of continous variable 't' is periodic with period 'T' and can be represented By sums of sines and cosines multiplied by Appropriate coefficients.

→ this sum is known as fourier series.

$$f(t) = \sum_{n=-\infty}^{\infty} C_n \, e^{J \frac{2\pi n}{T} t}$$

where

$$C_n = \frac{1}{T} \int_{-T/2}^{T/2} f(t) \, e^{-J \frac{2\pi n}{T} t} \, dt$$

for $n = 0, \pm 1, \pm 2 \ldots$

Impulses And Their Shifting Property :- δ !!

a unit impulse of a continous variable 't' Located at '$t=0$' is defined as

$$\delta(t) = \begin{cases} \infty & \text{if } t = 0 \\ 0 & \text{if } t \neq 0 \end{cases}$$

(•) an impulse has shifting property w.r.t integration is:-

$$\int_{-\infty}^{\infty} f(t) \, \delta(t) \, dt = f(0)$$

provided that $f(t)$ is continous at $t=0$

Shifting property involves an impulse located at an arbitrary point 't', denoted By $\delta(t-t_0)$ in this case shp becomes following :-

$$\int_{-\infty}^{\infty} f(t) \, \delta(t - t_0) \, dt = f(t_0)$$

Let 'x' represent Discrete variable then the unit discrete impulse $\delta(x)$ is defined as

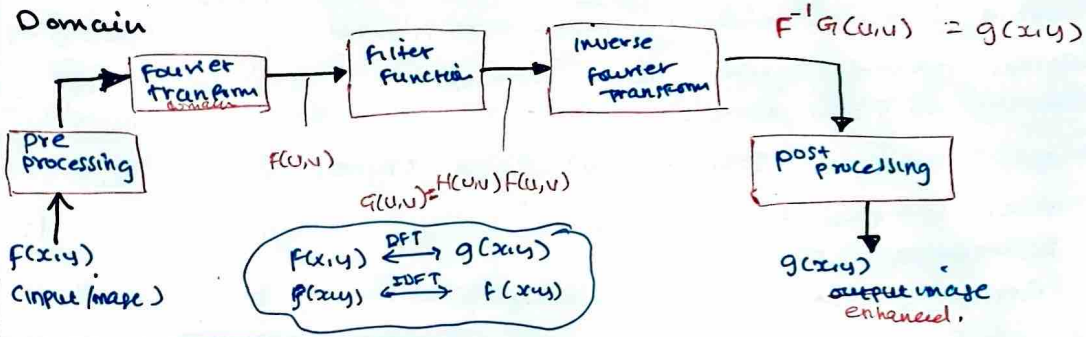
$$\delta(x) = \begin{cases} 1 & x = 0 \\ 0 & x \neq 0 \end{cases}$$

Impulse :- a distribution or Generalized Function

Shifting :- to separate a unit impulse of continous variable 't' located at $t=0$,

Frequency Domain Filtering (Steps 5m final Q's)

Filtering techniques in Frequency Domain are Based on modifying the Fourier Transform to achieve a specific Objecture / Requirement and then computing the inverse DFT to get us back to the image Domain



Steps followed while filtering in frequency domain :-

1) multiply input image $f(x,y)$ by $(-1)^{x+y}$ to center transform or to take image at its original posn after transfn
   - called pre-processing of the image
2) Now compute $F(u,v)$ i.e fourier transform of output of Step-1
3) Now for enhancement of the image multiply any filter wic is given. $(H(u,v))$ to the image so $G(u,v) = H(u,v) \cdot F(u,v)$
4) Now calculate Inverse DFT of image of Step-3 so that filtered image be $F^{-1}[G(u,v)] = g(x,y)$
5) Now to get back (Step-1) again Multiply image By $(-1)^{x+y}$ wich will shift center back to origin and finally that is the enhanced image wic is generated.

Smoothing Filters in Frequency Domain

- Smoothing is achieved in Frequency Domain By Dropping out / removing High Frequency components....

the Basic model for this filtering is:

$$G(u,v) = H(u,v) \cdot F(u,v)$$

where

$G(u,v) \rightarrow$ enhanced image

$H(u,v) \rightarrow$ is filter transform function

$F(u,v) \rightarrow$ is Fourier Transform of image to be filtered

- Smoothing removes Noise But introduce Blurring as side effect.

- Transform Function $H(u,v)$ is of 3 Types:-

1. Ideal low pass filter
2. Butterworth LPF
3. Gaussian LPF

Ideal Lowpass Filter :

It is defined By transfer function

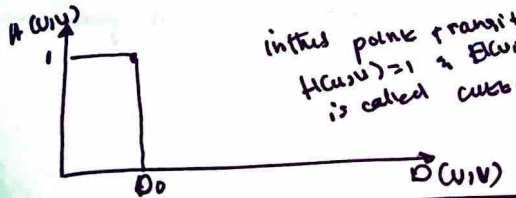
$$H(u,v) = \begin{cases} 1, & \text{if } D(u,v) \le D_0 \\ 0, & \text{if } D(u,v) > D_0 \end{cases}$$

where

$$D(u,v) = \left[\left(u - \frac{P}{2}\right)^2 + \left(v - \frac{Q}{2}\right)^2 \right]^{1/2}$$

and $D(u,v)$ is distance from point (u,v) to the center $\left(\frac{P}{2}, \frac{Q}{2}\right)$

the name Ideal indicates that All frequencies inside a circle radius "D_0" are passed without attenuation where as all frequencies outside the circle are completed attenuated / dropped.



in this point transition b/n $H(u,v) = 1$ & $H(u,v) = 0$ is called cutoff frequency.

where

$D_0 \rightarrow$ is cutoff frequency of filter

due to sharp cutoff ILP has ringing problem. • therefore cutting High frequency results in Blurring of image & effect on Noise of the image is reduced.

$D_0 \rightarrow$ is chosen where most of frequency component of interest are passed, while unnecessary components are eliminated.

$P, Q \rightarrow$ are called "padded parameters" w/c will add extra "0's" outside the image

if $P = Q = 1 \rightarrow$ one line of zeros are added

$P = Q = 2 \rightarrow$ two " " and so on.

when "P, Q" are linear Transformation of Batchwise processing then total Energy of image space could be represented as power Transform image

$$P_T = \sum_{u=0}^{P-1} \sum_{v=0}^{Q-1} p(u,v) \quad \text{where } u = 0 \cdots P-1, \; v = 0 \cdots Q-1$$

Butterworth LPF

→ It doesnot have a sharp transition B/n Pass band & stop band.

→ It's more suitable for Image smoothing and doesnot make Ringing problem for low order ~~frequency~~ filters. ~~H(u,v)~~

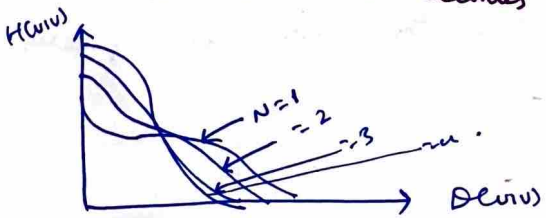
- The Transform function of BLPF with order of 'n' & cutoff frequency with Distance 'D_0' from origin is Defined as.

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

where $D(u,v) = D(u,v)$ of lowpass filter

For $n = 1 \rightarrow$ transition is very smooth and has No ringing problem but as filter order increases it goes towards Ideal LPF.

For $n = 2 \rightarrow$ ringing can't be seen ~~prob~~ properly but as $n \rightarrow$ increases it becomes more significant...



GAUSSIAN LPF

→ It has smooth transition b/n passband & stop band.

→ It does not have any ringing problem but only blurring is visible. and as cutoff ~~filtering~~ frequency increases then blurring decreases.

• The transfer function of G-LPF is given by $H(U,V) = e^{-D^2(U,V)/2\sigma^2}$

where σ → spread / dispersion of G-filter curve

larger values of 'σ' → larger cutoff frequency.

if $\sigma = D_0$ then $H(U,V) = e^{-D^2(U,V)/2D_0^2}$

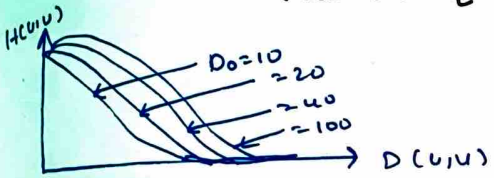


Image sharpening using frequency domain

→ Sharpening of image means enhancing blurring information, edges, and details of the image

• Sharpening filters are high pass filters which blocking attenuates low frequency components without disturbing high fc. (allowing H fc)

• The transfer function of High pass filter is given by:

$$\boxed{H_{hp}(U,V) = 1 - H_{Lp}(U,V)}$$

where H_{Lp} → transfer function of Lowpass filter.

→ It performs reverse operation of Lowpass filter

HPF
- ideal HPF
- Butterworth HPF (order wise.)
- Gaussian HPF

IDEAL HPF

• I-HPF attenuates / blocks all frequency components inside "D0" radius and allows all frequencies outside the circle (D0) of the radius D0.

The 2-D transfer function of Ideal HPF can be given as:

$$H(U,V) = \begin{cases} 0, & D(U,V) \le D_0 \\ 1, & D(U,V) > D_0 \end{cases}$$

where D_0 → is cutoff frequency measured from origin P/2, Q/2

$D(U,V)$ → distance from the center of frequency rectangle.

• Appln:- used in sharpening of image in fo.

Butterworth HPF :-

Transfer function of 2-D of BHPF of order 'n' & cutoff freq "D0"

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

n → order of filter

D0 → cutoff freq

• used to control sharpening effect depending on the order

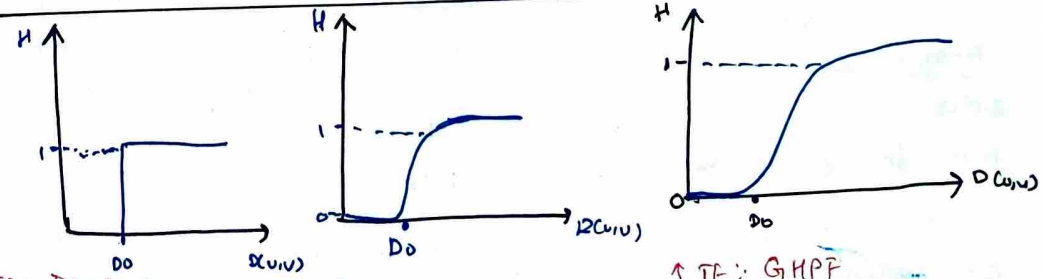
GAUSSIAN HPF

Transfer function :-

$$H(U,V) = 1 - e^{-\frac{D^2(U,V)}{2D_0^2}}$$

* The larger values of D0, the larger cutoff frequency.

→ It has smooth transition b/n passband & stop band near cutoff.



TF: Ideal HPF ↑ TF: BHPF ↑ TF: GHPF

Relationship b/n pixels

1→ Neighborhours
2→ Adjacency
3→ path
4- connectivity
5- Region
6- Boundary
7 Distance

① **NEIGHBOURS** :- in any image (F(x,y)). lets take a pixel (P) at coordinates of (x,y)

x-1, y-1	x, y-1	x+1, y-1
x-1, y	x, y (P)	x+1, y
x-1, y+1	x, y+1	x+1, y+1

then pixel (P) can have three (3) types of Neighbors

those are :- , 4, 8, & Diagonal

•) **4-Neighbors ($N_4(p)$)** →

→ 2-Horizontal & vertical

	x, y-1	
x-1, y	x, y (P)	x+1, y
	x, y+1	

•) **D-Neighbor ($N_D(P)$)** →

x-1, y-1		x+1, y-1
	x, y (P)	
-1, +1		+1, +1

•) **8-Neighbors ($N_8(P)$)**

→ N_4 and N_d together are called $N_8(P)$ →

Full image pixel (P)

② **ADJACENCY** :-

two pixels "p" and "q" can be adjacency under two conditions :- → Should be Neighbours

→ N_4 and N_8

→ mixed adjacency (m-A)

→ their gray level should be same.

(•) **4-Adjacency** ($N_4(P)$ w̄ same 'v' values)

2-pixel p' and q' w̄ values from 'v' are 4-A, if 'q' is in set of $N_4(P)$

(•) **8-A** :- p' and q' has same value inside 'v' and are connected through $N_8(P)$

→ if not set of V = [1, 2, 3, 4] they're not 8-A

(•) **M-A** :- → p' & q' both have value of set 'v' and

(i) q is $N_4(P)$

or

(ii) q is $N_D(P)$ and $N_4(P) \cap N_4(q)$ has no pixels whose value is in set of 'v'

③ **PATH** :- is a sequence of connected pixels such as (x,y) (x0,y0), (x1,y1) .... (u,v) where. path is b/n pixel 'p' having coordinates (x,y) & to pixel 'q' with (u,v).

•) Length of path is count of connected pixels.

•) if first and last pixels are same this called closed path ....

④ **CONNECTIVITY** :-

refers to relationship b/n pixels, 2-pixels are are connected if they are adjacent, and similarly two subsets are connected if some pixel in S_1 is adjacent to some pixel in S_2.

⑤ **REGION** :- [depend on adjacency levels] (group of subsets)

is set of pixels that are connected to e/o and have similar properties such as intensity or texture.

⑥ **Boundary** :- (it is edge of region)

→ are set of pixels that are adjacent to the region But Does not Belong to the Region

⑦ **DISTANCE** :-

- is a measure of separation b/n two pixels

-> it can be measured using diff metrics / formulas such as:-

→ Euclidean

→ manhattan.

→ it is used to find Nearest Neighbour of pixel or find distance b/n two Regions

(#) **Euclidean distance**

$$d_e(P,q) = \sqrt{(x-u)^2 + (y-v)^2}$$ where P (x,y) & (u,v)

(#) **4-Distance** (city distance → magnitude)

$$d_4(P,q) = \{|x-u| + |y-v|\}$$

(#) **8-Distance** (chessboard)

$$d_8(P,q) = \max\{|x-u| + |y-v|\}$$