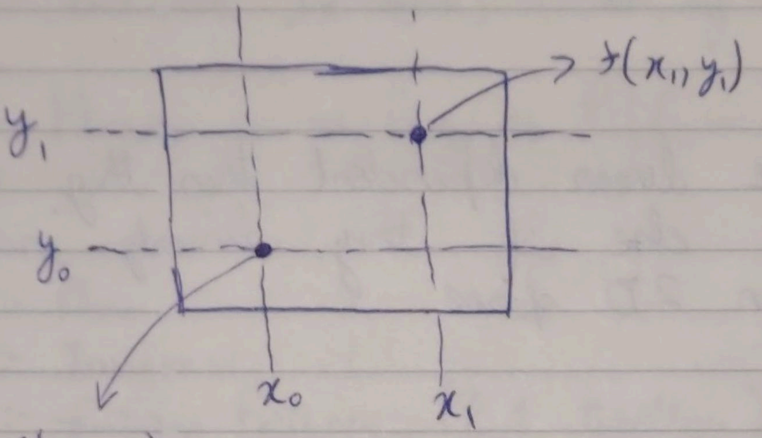
Digital Image Processing

~~Image~~ : Image $\rightarrow$ 2 D function $f(x,y)$



$f(x_0, y_0) \Longrightarrow$ Amplitude corresponds to Intensity level at that point.

Digital Image Processing :- Processing of Digital Images via Digital Computers.

<u>Types of DIP</u>:

(i) Low level process :-

$$\text{Img} \longrightarrow \boxed{\text{DIP}} \longrightarrow \text{Img}$$ (Denoising, Filters)

ii) Middle Level Process

Img $\longrightarrow$ $\boxed{\text{DIP}}$ $\longrightarrow$ attributes (Segmentation)

iii) High level process

attributes $\longrightarrow$ $\boxed{\text{DIP}}$ $\longrightarrow$ making sense

(Face expression detection)

Fundamental Steps in DIP:

Outputs are "Images":

- Image Acquisition (Collecting an image is the first step)
- Image Enhancement (Changing ~~resolution~~ saturation, depends person to person)
- Image Restoration (Restoring degraded images)
- Color Image Processing
- Wavelets and Multi resolution Processing
- Compression (Reducing storage space required to save an image)
- Morphological Processing (Extracting Useful components of image)

Outputs are 'attributes':

- Segmentation
- Representation and Description
- Object Recognition

Basic relation b/w pixels in Digital Image Processing

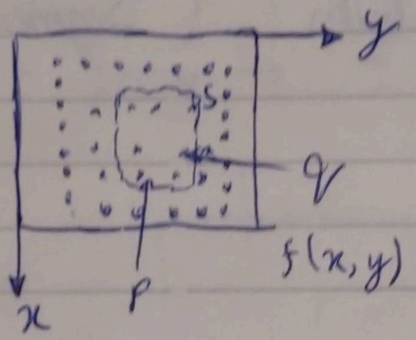


Image → $f(x, y)$

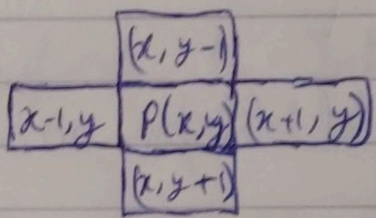
S → Subset of Pixels

q, p → particular ~~axis~~ pixels

4-Neighbours [$N_4(p)$]

2 ~~Horizontal~~ Vertical

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



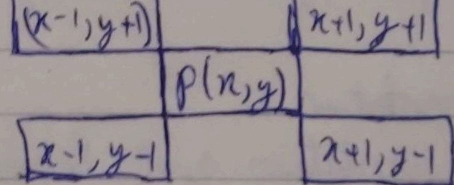
2 ~~Vertical~~ Horizontal

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

$\therefore$, $N_4(p) = (x, y-1), (x, y+1), (x-1, y), (x+1, y)$

Diagonal Neighbours

$N_D(p) = (x+1, y+1), (x-1, y-1),$
$(x-1, y+1), (x+1, y-1)$



8-Neighbour [$N_8(P)$]

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

$$N_8(P) = N_D(P) + N_4(P)$$

Connectivity / Adjacent relationship

- 4-adjacency → Along straight line
- 8-adjacency → Along diagonal
- m-adjacency [mixed adjacency]

$$\begin{matrix} 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \end{matrix}$$

→ 8-adjacency

→ 4-adjacency

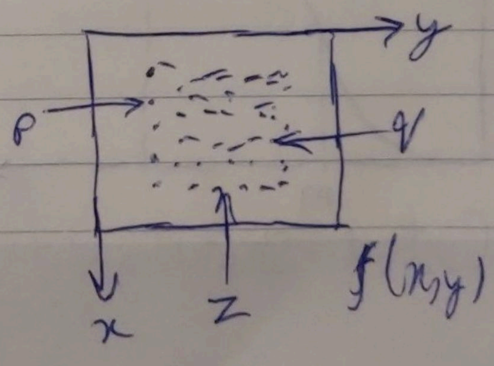
Binary Image

Gray Scale image
[0-255] range

Values for relation :- [0-10]

Distance Measure

Image → $f(x,y)$



Introduction to Image Enhancement using Spatial domain

Image Enhancement is a process to improve the quality of an image.

→ To highlight important details.
→ To remove noise.

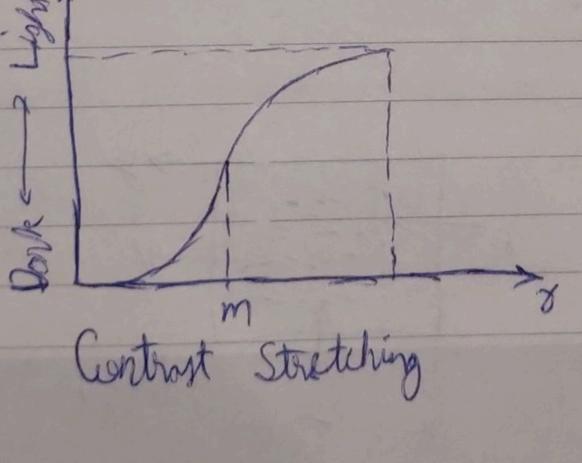
Methods of Image Enhancement

1) Spatial domain : Directly manipulation of pixel values.

2) Frequency domain : Modifying the Fourier Transform of Image.

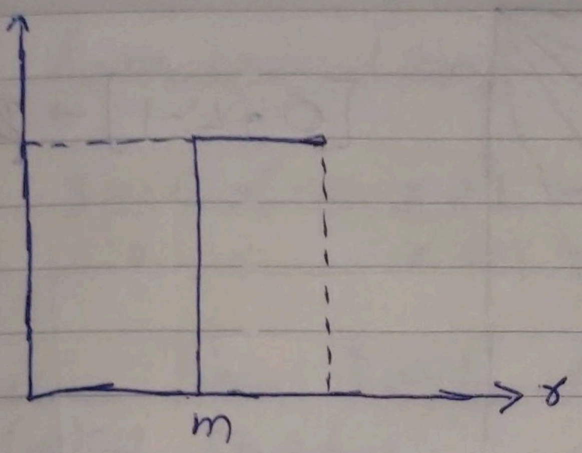
3) Combination method :- Combination of First two methods.

Example of Spatial domain,



Contrast Stretching

Pixels with values above 'm' will be brighten and values below 'm' will darken.
The contrast will ↑.



Binary Image

Point Processing

Basic Intensity Transformation Function

$s = T(r)$ $r \rightarrow$ Pixel value

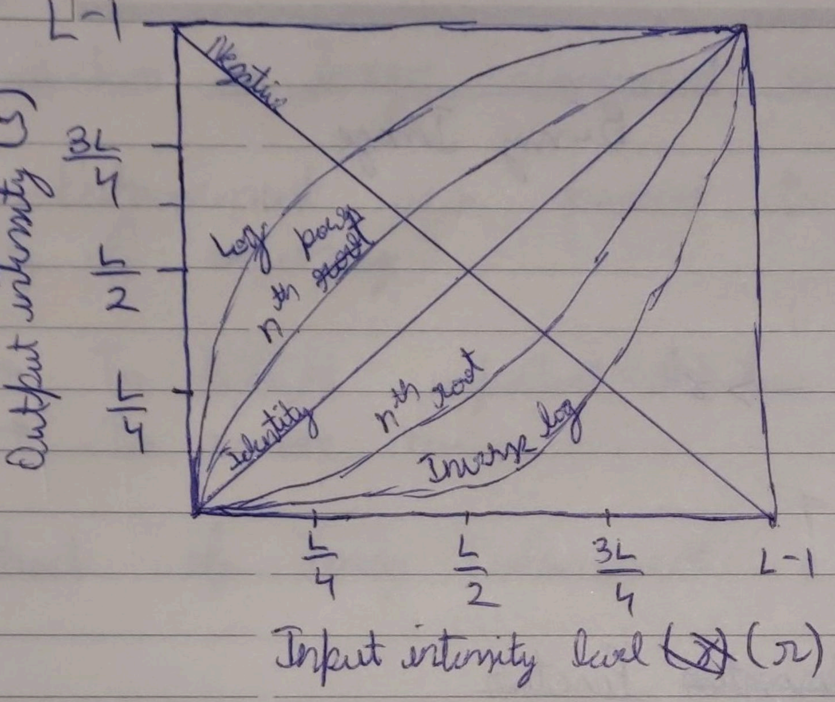
$s \rightarrow$ Value of pixel after transformation T

Some Basic transformation function :-

(a) Linear [Negative & Identity]

(b) Logarithmic [Log and Inverse Log]

(c) Power law [n^{th} power & n^{th} root]



$[0, L-1] \Rightarrow$ Intensity range

a) <u>Image Negative</u>

Intensity level, $[0, L-1]$

$$s = L-1-r$$

b) Log transformation

$$s = c \log(1+r) \quad r \geq 0$$

$\hookrightarrow$ Scaling constant $= \dfrac{285}{\log(1+m)}$

$\hookrightarrow$ max. value pixel.

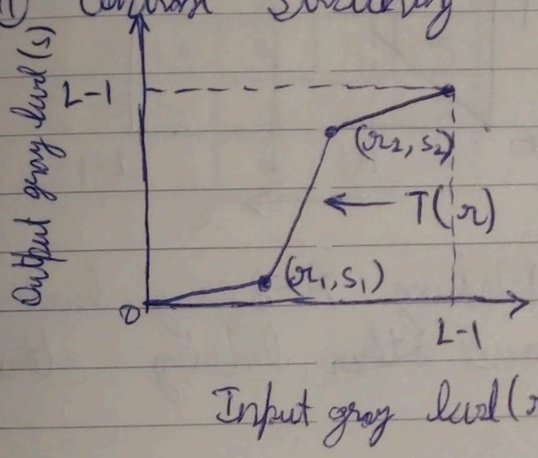
Q) Power Law (gamma correction)

$s = C r^{\gamma}$ $\quad \gamma > 1 \rightarrow n^{th}$ power

$\gamma < 1 \rightarrow n^{th}$ root

Piecewise Linear Transformation in Digital image processing

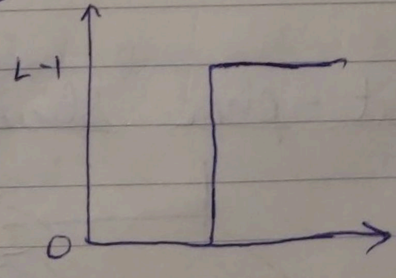
① Contrast Stretching



It makes
→ Dark portion, darker
→ Bright portion, brighter

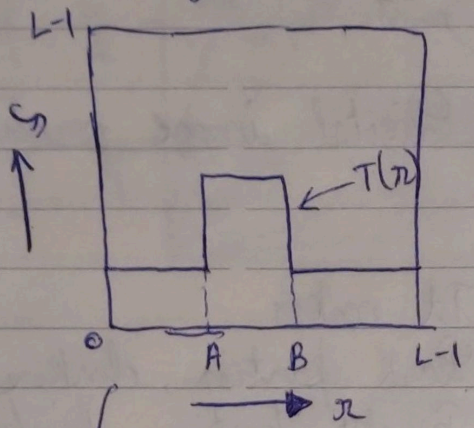
- If $r_1 = s_1$ and $r_2 = s_2 \Rightarrow$ Act as Linear transformation
- If $r_1 = r_2$, $s_1 = 0$ and $s_2 = L-1 \Rightarrow$ Thresholding
- Intermediate values (r_1, s_1) & (r_2, s_2) →

Various degrees of spread in gray levels.

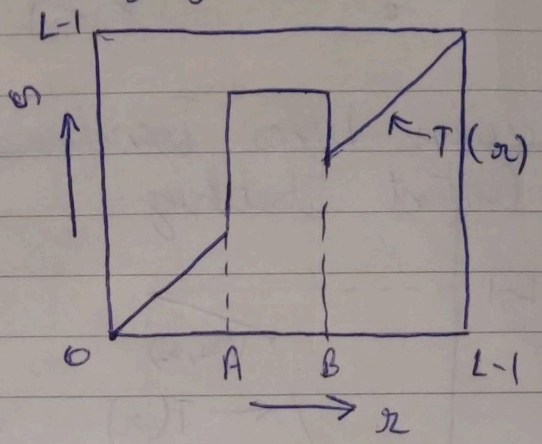


2) ~~G~~ Gray level Slicing :

→ Highlight Specific range of gray levels.



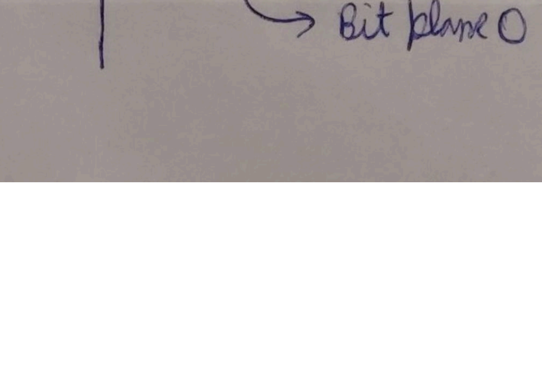
Making A-B gray level brighter and other darker



Making A-B gray level brighter and ~~other~~ leaving other as it is.

A-B ⇒ Region of interest

3) Bit-plane Slicing



A 8 bit image consist of 8 bit planes.

Usually, top 4 bit plane contains significant data.

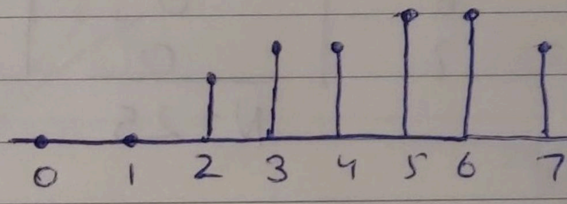
Useful in image compression.

Histogram Equalization → Image Enhancement

→ Representation → Frequency of occurrence of various gray levels.

6	6	7	7	6
5	2	2	3	4
3	3	4	4	5
5	7	3	6	2
7	6	5	5	4

Value Frequency
0 → 0
1 → 0
2 → 3
3 → 4
4 → 4
5 → 5
6 → 5
7 → 4



Histogram of the image

→ Useful for manipulating Contrast & Brightness

Example,

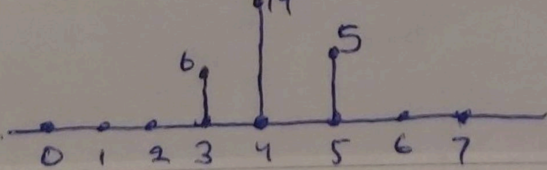
4	4	4	4	4
3	4	5	4	3
3	5	5	5	3
3	4	5	4	3
4	4	4	4	4

Highest gray value 5

to represent it we need, $2^{3} = 8$ [0-7]
3 bits

Gray levels	0	1	2	3	4	5	6	7
No of Pixel	0	0	0	6	14	5	0	0

Image histogram



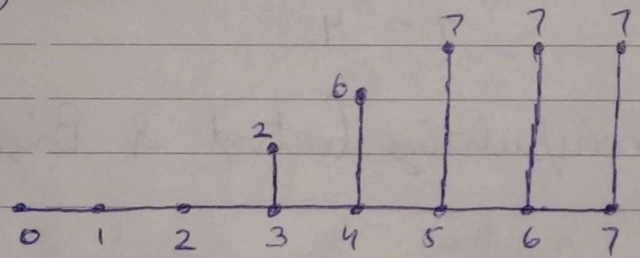
8 bits
[0-7]

Gray Level	no. of pixels n_k	PDF = n_k/N	CDF = S_k	$S_k \times 7$	Histogram equalization level
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	6	6/25 = 0.24	0.24	1.68	2
4	14	14/25 = 0.56	0.8	5.6	6
5	5	5/25 = 0.2	1	7	7
6	0	0	1	7	7
7	0	0	1	7	7

N = 25

Output

New histogram



Now in the previous image the previous pixels will be replaced by :-

$3 \rightarrow 2$

$4 \rightarrow 6$

$5 \rightarrow 7$

$6 \rightarrow 7$

$7 \rightarrow 7$

New image :-

6	6	6	6	6
2	6	7	6	2
2	7	7	7	2
2	6	7	6	2
6	6	6	6	6

Histogram Matching of Digital Image

→ Histogram equalization is not applicable in some cases.

So, Histogram matching (or) Histogram Specification is useful

New processed image is generated on the basis of Specified histogram.

Order Statistics filters in digital Image processing

→ Non linear spatial filters

→ It orders the pixels of the image

→ Replacing the center pixel value with value determined by ranking result.

1. Median filter

→ Replaces the central value of a pixel by the median of gray level.

→ Excellent noise reduction

→ Less blurring

→ Effective for <u>Impulse Noise</u>

↓

Salt & pepper noise

10	20	20
20	15	20
20	25	100

⟹

10	20	20
20	20	20
20	25	100

Median

10, 15, 20, 20, 20, 20, 20, 25, 100

2. <u>Max. filter</u> :-

→ Finding the brightest point (Replacing with highest value in above case)

3.) Min. filter :-

→ Finding darkest point. (Replacing with min. value)

Image Sharpening in Digital Image Processing

- Highlight the finite details or to enhance details
- Image Blurring $\Rightarrow$ Integration and Pixel Averaging

Sharpening $\rightarrow$ "spatial Differentiation"

First order derivative :- $\frac{\delta F}{\delta x} = f(x+1) - f(x)$

Second order derivative :- $\frac{\delta^2 F}{\delta x^2} = f(x+1) + f(x-1) - 2f(x)$

Effects:

First order derivative :-
- Thicker edges
- Gray level step

Second order derivative :-
- Fine details
- Double response at step changes

Laplacian Filter : Use of 2nd order derivative for Enhancement

$$\Delta^2 f = \frac{\delta^2 f}{\delta x^2} + \frac{\delta^2 f}{\delta y^2}$$

In x- direction

$$\frac{\delta^2 f}{\delta x^2} = f(x+1,y) + f(x-1,y) - 2f(x,y)$$

In y- direction

$$\frac{\delta^2 f}{\delta y^2} = f(x,y+1) + f(x,y-1) - 2f(x,y)$$

$$\therefore \Delta^2 f = \left[f(x+1,y) + f(x-1,y) + f(x,y+1) + f(x,y-1) \right] - 4f(x,y)$$

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

$\longrightarrow$

0	1	0
1	-4	1
0	1	0

Image enhancement in frequency domain

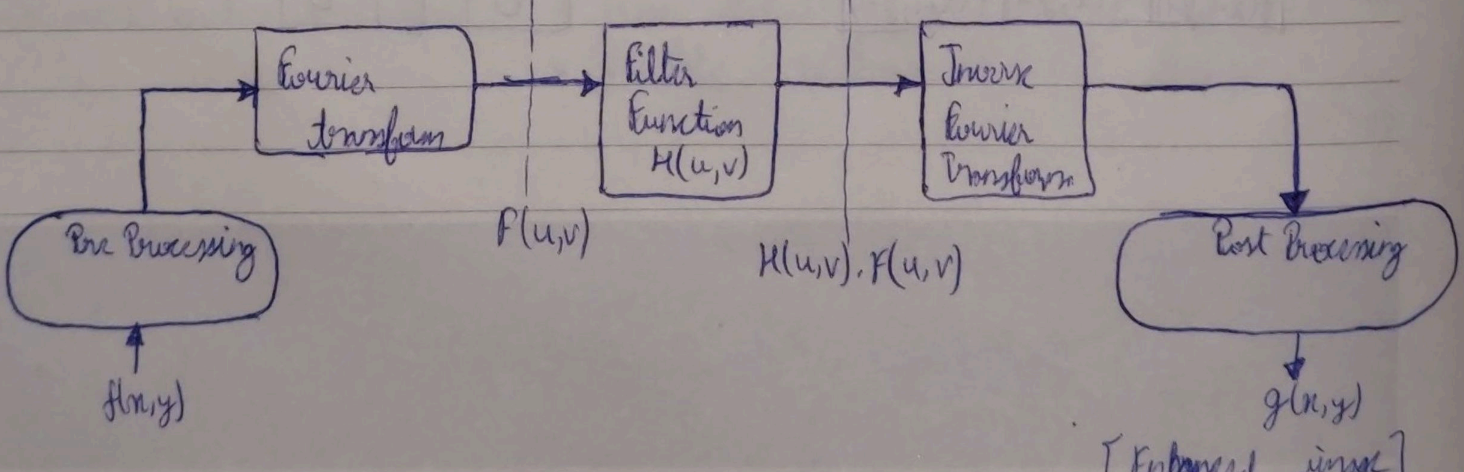
- Image is converted from spatial domain to frequency domain and then processed.
- Inverse transform is applied to bring back into spatial domain.
- Change is made on whole image instead of pixel by pixel.

Types of Filters :-

i) Low Pass filters :- It only keeps low ~~pass~~ frequency components.
Useful for Smoothening (Blurring)

ii) High Pass ~~P~~ filter :- It only keeps high frequency components.
Useful for Sharpening.

Steps for filtering in Frequency domain



1.) Image $f(x,y)$ of size $m \times n$ (Data Acquisition)

2.) $f(x,y)\,(-1)^{x+y}$ (Pre processing)

3) $F(u,v) \longrightarrow$ F.T of $f(x,y)$ [Converting to frequency domain].

4) $H(u,v) \longrightarrow$ Filter in frequency domain.

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

5) $g(x,y) = \text{Inverse}(G(u,v))$