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Digital image Processing :-

(I) An image can be defined as a two-dimensional funⁿ. $F(x,y)$ where x and y are spatial coordinates and 'F' is amplitude of these Coordinates.

amplitude is also called as intensity or gray level of the image.

(II) when (x,y) and intensity value of 'F' are finite (Discrete Quantities) be call the image a digital image.

Checkboard Effect :-

if the resolution is decreased too much, the checkerboard effect can Occurs.

Intensity Level Resolution :-

(I) Intensity level resolution refers to the number of intensity levels used to represent the image.

(II) The more intensity level used, the finer the level of detail discernable in an image.

(III) Intensity level resolution is usually given in terms of the no. of bits used to store each intensity level.

$F(x,y) \rightarrow 200\ (10,50)$

$F \rightarrow$ intensity value

$(x,y) \rightarrow$ Coordinate value

no. of bits	no. of intensity levels	Examples
1	2	0,1
2	4	00, 01, 10, 11
4	16	0000, 0101, 1111
8	256	00110011, 01010101
16	65.536	1010101010101010

Pixel → Coordinates → intensity Value.

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Digital image P refers to processing digital image by means of a digital computer.

Digital image is composed of a finite no. of elements each of which has a particular location and value. these elements are called piture element, image element or pixels element.

Application of Digital Image Processing :-

1) Quality improvement of an image.
2) Noise reduction of an image.
3) Content enhancement
   → Contrast enhancement
   → Deblurring
4) Remote Sensing
5) Medical imaging → identification of Brain tumor
   → Cancer detection.
6) GIS → Geographic information System
7) wheather forecasting
8) Astronomy
9) Artistic Effects
10) Image Compression (Ex: whatsapp)

var_dump

74 '75'

Quantization And Digitization :-

1) An image may be continous with respect to x, y coordination and also an amplitude.
2) To convert it to digital from we have to Sample the funⁿ in both coordinates and in amplitudes.
3) Digitalization the coordinates values is Called Sampling
4) Digitizing the amplitude Values is Called Quantization.

Intensity value
OR
amplitude value
OR
Gray value

identify the values → Digitization.

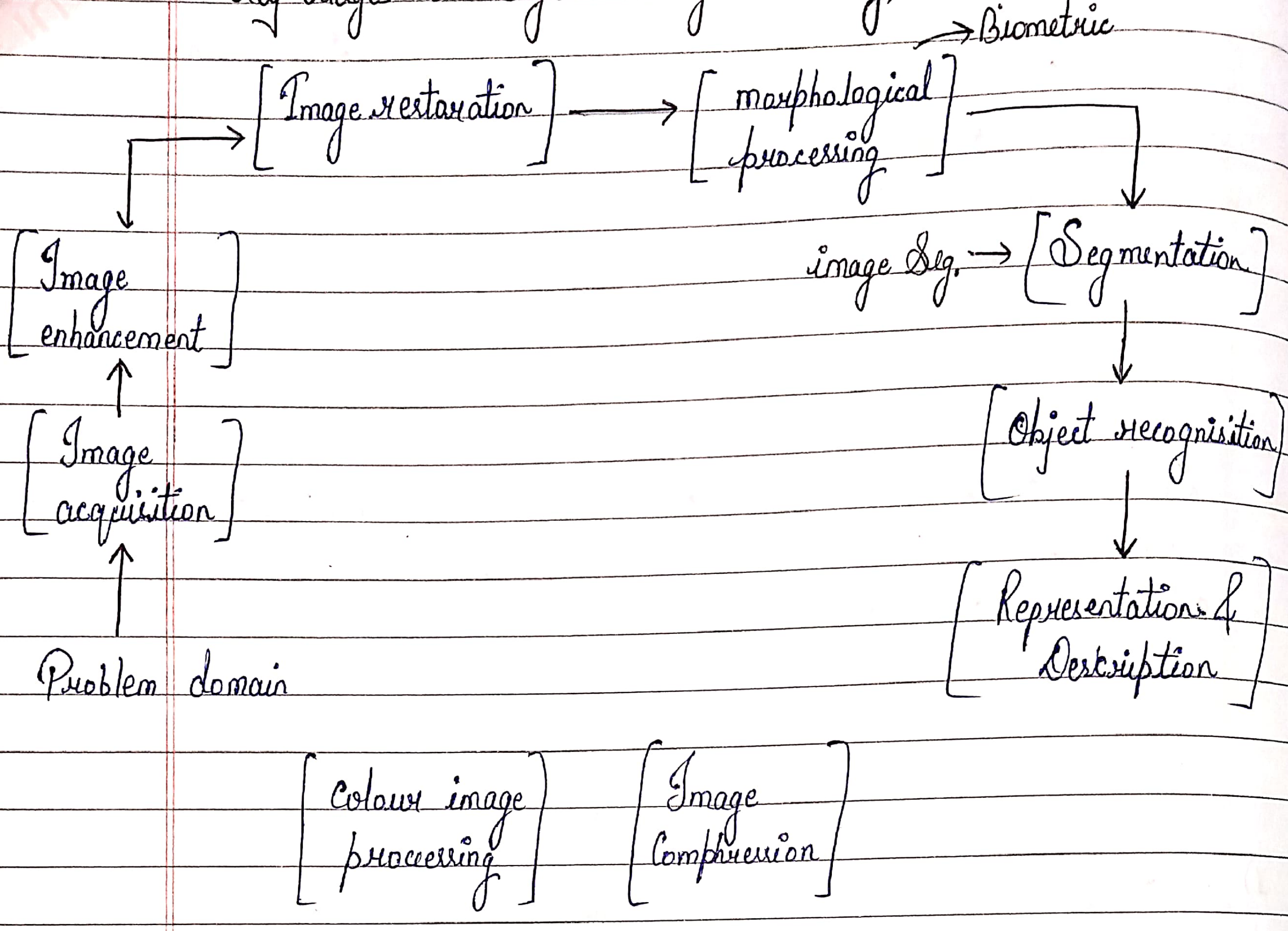
Computer Vision :-

Deals with the development of theoretical and algorithmic basis by which useful information about the 3D world can be automatically extracted and analyzed from a Single or multiple 2D images of the world.

Application :-

1) Industrial inspection / Quality control
2) Surveillance and Security.
3) Face recognisation
4) Gesture recognisation
5) Space application
6) Medical image analysis
7) Autonomous Vehicles
8) Virtual reality and much more.
9) Application in agriculture (Fruits & Vegetables classification)

Key stages in Digital image Processing :-



Histogram Processing :-

→ Basic for numerous spatial domain processing technique.
→ Used effectively for image enhancement.
→ information inherent in histograms also used in image Compression and Segmentation.
→ Histogram is a discrete fun^n formed by counting the no. of pixels that has a certain gray level in the image.
→ popular tool for real time image processing.

Quality Enhanced → histogram processing

① no. of pixels
② Bits representation in each pixels
③ gray level frequency

{pixels = R×C.}

for. clarity → if each intensity will be equalized.

0 – 255

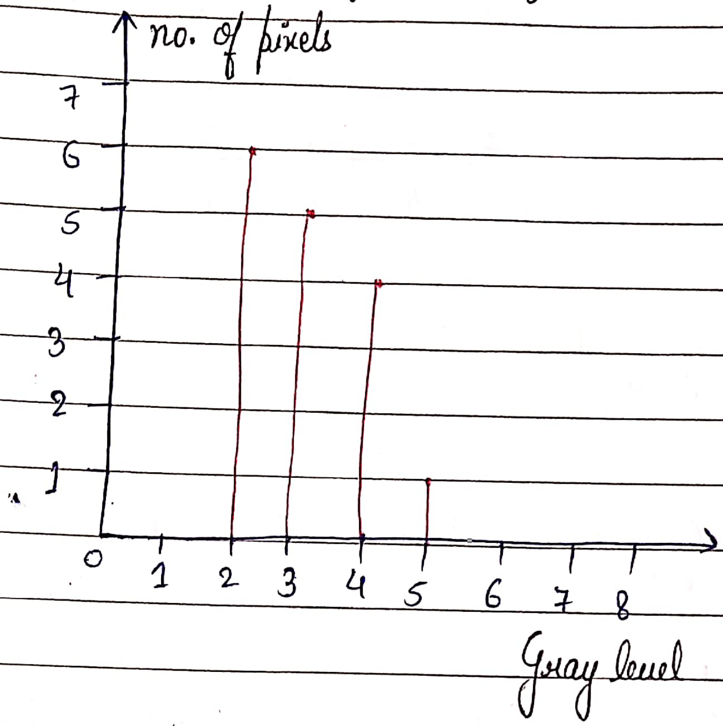
Que→ Consider an image of size 4X4 where the gray scale of these pixels can vary from 0 to 9 find out the histogram of the image ?

⇒

2	3	3	2
4	2	4	3
3	2	3	5
2	4	2	4

4X4 image
R X C

Gray Scale = [0, 9]

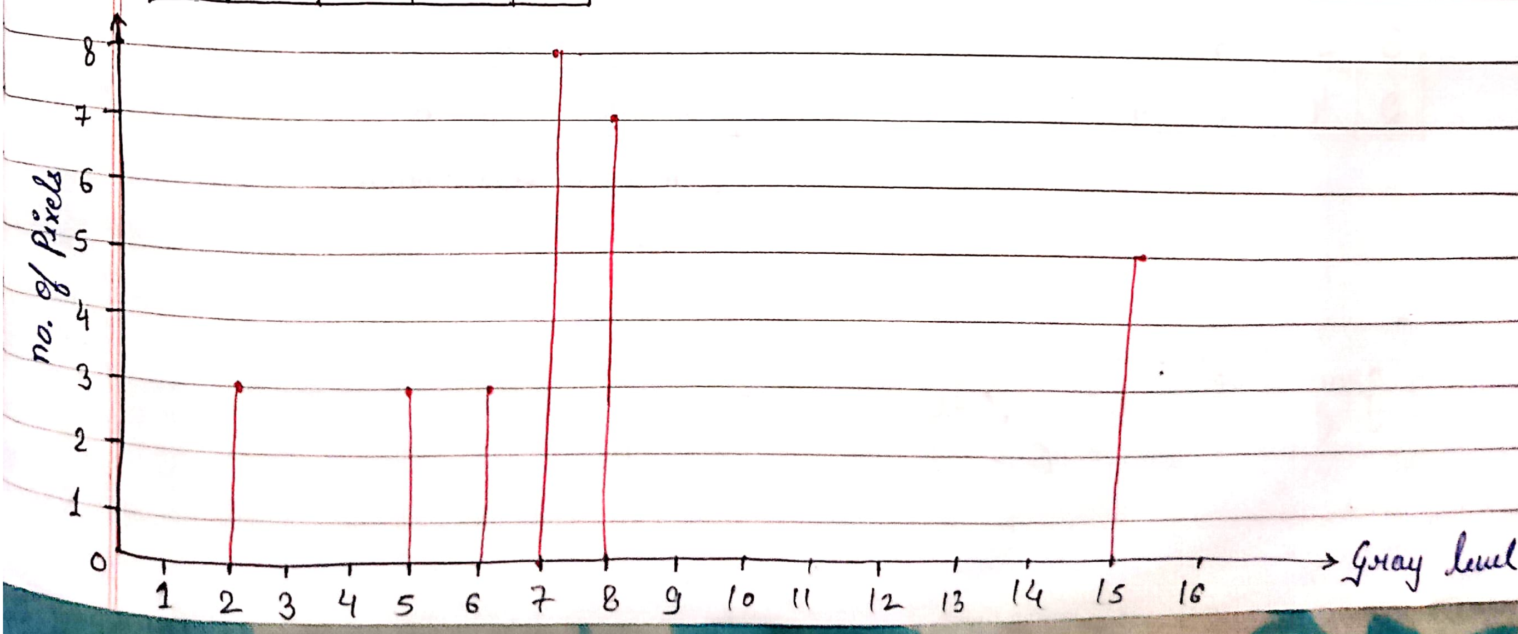


Que→ Consider the following image of size 5X6 where the generate histogram of the image ?

⇒

5	5	5	2	2
7	7	8	2	15
7	7	2	8	15
7	7	6	8	15
7	7	8	6	15
8	8	6	8	15

5X6 image



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Que ⇒ Generate histogram Equalization for the above Question?

⇒

2	3	3	2
4	2	4	3
3	2	3	5
2	4	2	4

4X4 image

Gray Scale = [0,9]

Gray level (r)	0	1	2	3	4	5	6	7	8	9
no. of pixels	0	0	6	5	4	1	0	0	0	0
$\sum_{j=0}^{k} n_j$	0	0	6	11	15	16	16	16	16	16
$\sum_{j=0}^{k} \frac{n_j}{n}$	0	0	$\frac{6}{16}$	$\frac{11}{16}$	$\frac{15}{16}$	$\frac{16}{16}$	$\frac{16}{16}$	$\frac{16}{16}$	$\frac{16}{16}$	$\frac{16}{16}$
$9 \times \sum_{j=0}^{k} \frac{n_j}{n}$	0	0	3.3 $\simeq 3$	6.1 $\simeq 6$	8.4 $\simeq 8$	9	9	9	9	9

$\frac{16}{16} \rightarrow$ size (RXC)

9 → gray level

2	3	3	2
4	2	4	3
3	2	3	5
2	4	2	4

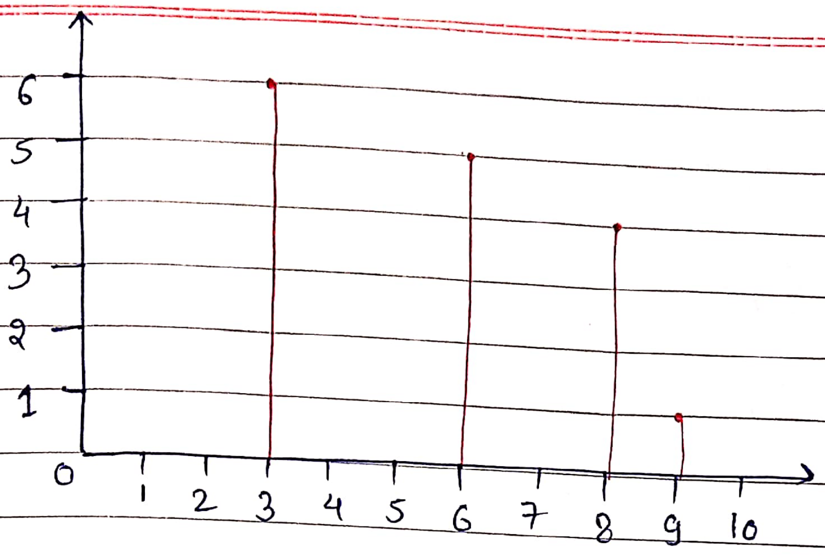
$\xrightarrow{\text{Replace}}$

3	6	6	3
8	3	8	6
6	3	6	9
3	8	3	8

Equalized histogram

{gray level = [0 -- n]}

n → G.L

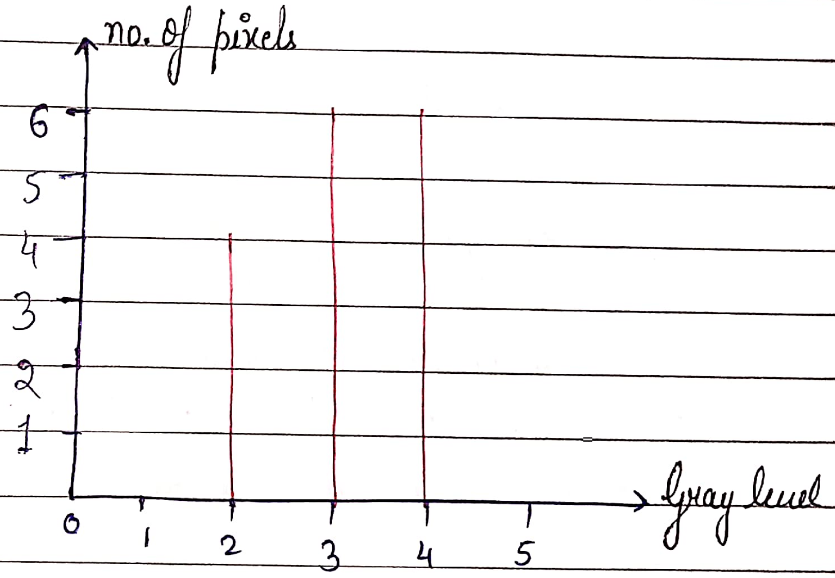


histogram Equalized.

Que→ Consider the histogram & histogram Equalization? Gray Scale 0 to 9 ?

⇒

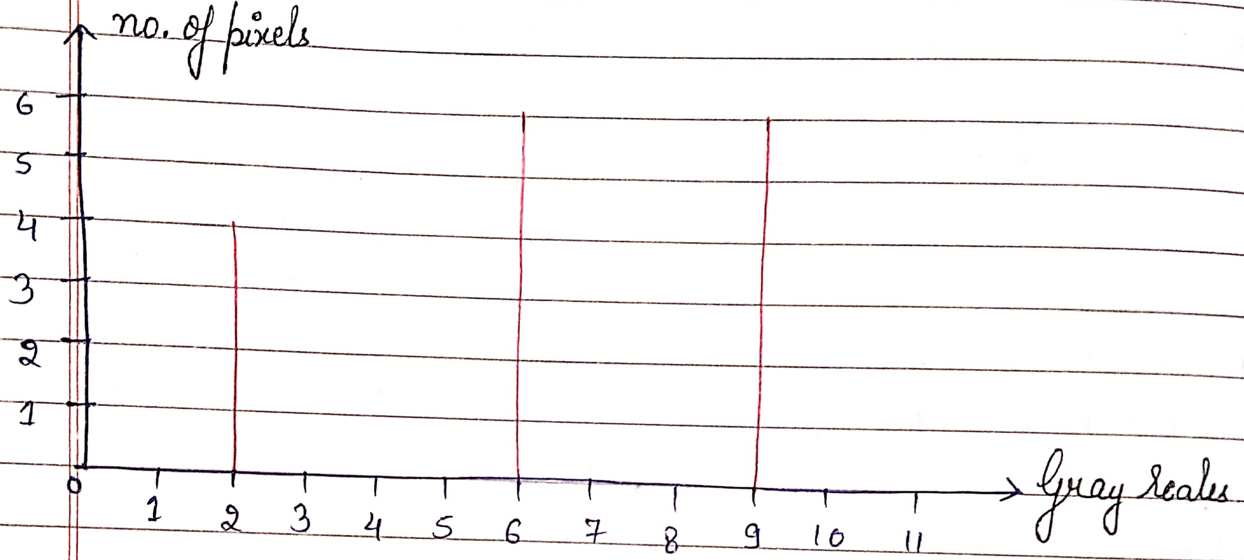
2	2	4	4
3	2	4	4
3	3	2	4
3	3	3	4



Gray level	0	1	2	3	4
no. of pixel	0	0	4	6	6
$\sum_{j=0}^{K} n_j$	0	0	4	10	16
$\sum_{j=0}^{K} \frac{n_j}{n}$	0	0	$\frac{4}{16}$	$\frac{10}{16}$	$\frac{16}{16}$
$9 \times \sum_{j=0}^{K} \frac{n_j}{n}$	0	0	2	6	9

2	2	9	9
6	2	9	9
6	6	2	9
6	6	6	9

histogram Equalized



Histogram Equalized

Que → ① Consider the following image & generate the histogram ?
② Convert the histogram into Equalized histogram where each pixel is represented by 4 bits ?

⇒

1	1	1	13	13
1	1	1	14	14
2	2	2	4	4
2	2	3	3	4
3	3	3	4	4

5×5 image

4×4 = 16

[0, 15] → gray level

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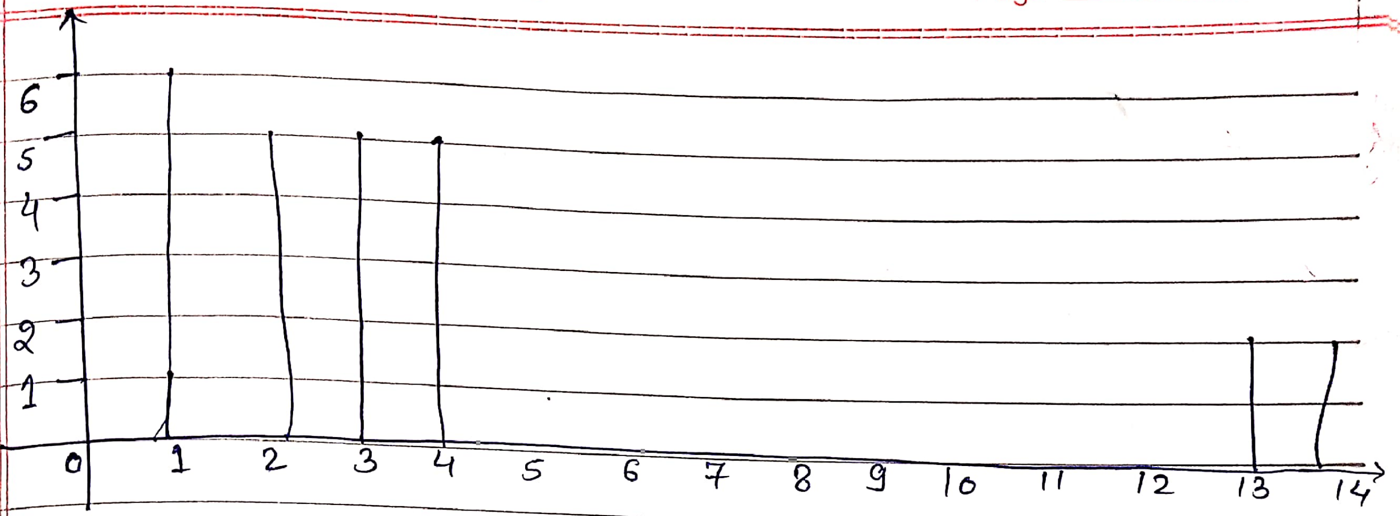
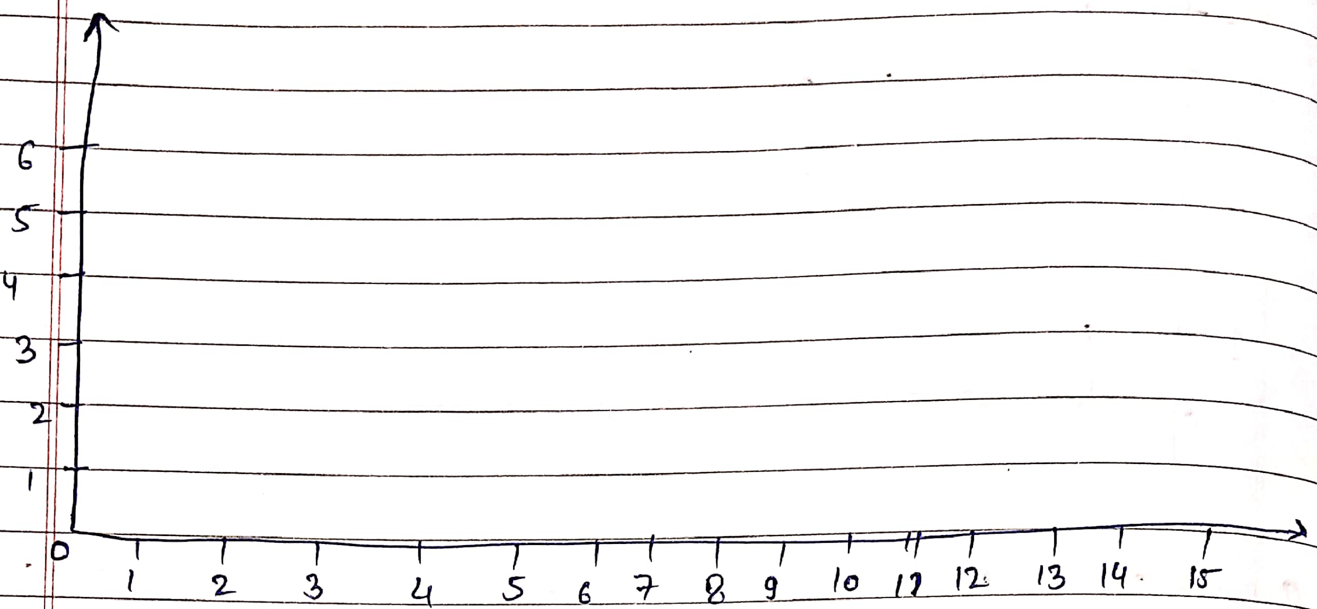


gray level →	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
no. of pixel →	0	6	5	5	5	0	0	0	0	0	0	0	0	2	2
$\sum_{j=0}^{K} n_j$ →	0	6	11	16	21	21	21	21	21	21	21	21	21	23	25
$\sum_{j=0}^{K} \frac{n_j}{n}$ →	0	$\frac{6}{25}$	$\frac{11}{25}$	$\frac{16}{25}$	$\frac{21}{25}$	$\frac{21}{25}$	$\frac{21}{25}$	$\frac{21}{25}$	$\frac{21}{25}$	$\frac{21}{25}$	$\frac{21}{25}$	$\frac{21}{25}$	$\frac{21}{25}$	$\frac{23}{25}$	$\frac{25}{25}$
$15 \times \sum_{j=0}^{K} \frac{n_j}{n}$ →	0	3.5 ≈ 4	6.6 ≈ 7	9.6 ≈ 10	12.6 ≈ 13	13	13	13	13	13	13	13	13	13.8 ≈ 14	15

4	4	4	14	14
4	4	4	15	15
7	7	7	13	13
7	7	10	10	13
10	10	10	13	13

→ Equilized histogram



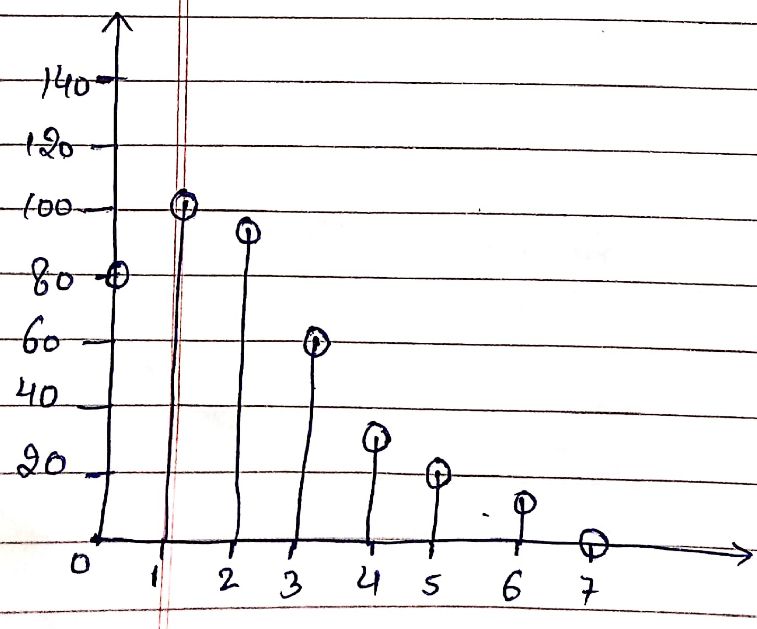
Que → Consider the histogram 1 of table 1 & histogram 2 of table 2 & convert of match of histogram 1 according to histogram 2 ?

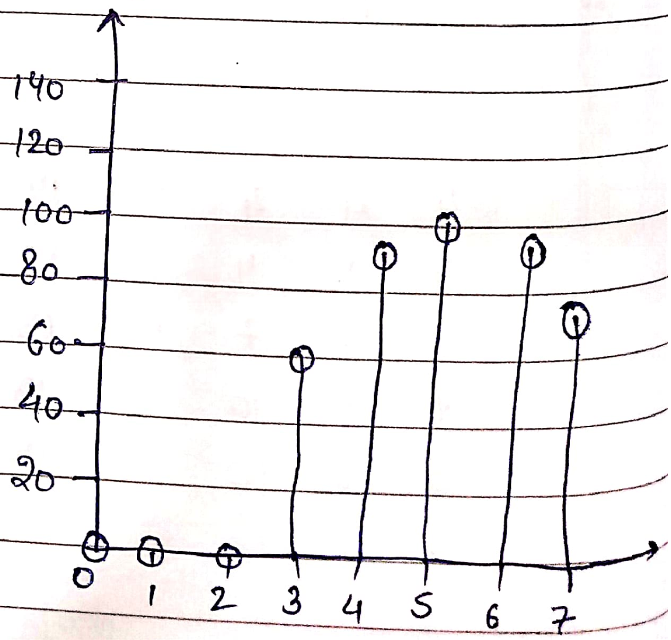
→ ①

G.L	0	1	2	3	4	5	6	7	
Pixels	80	100	90	60	30	20	10	0	— I
	1	3	5	6	6	7	7	7	— II
				90		30			

②

Gray level	0	1	2	3	4	5	6	7	— I
Pixels	0	0	0	60	90	100	80	70	
	0	0	0	1	2	4	6	7	— II





Que – Given histogram (a) & (b), modify histogram (a) as given by histogram (b)

(a)

Gray level	0	1	2	3	4	5	6	7
no. of pixels	790	1023	850	656	329	245	122	81

(b)

gray level	0	1	2	3	4	5	6	7
no. of pixels	0	0	0	614	819	1230	819	614

(a) →

g.L	0	1	2	3	4	5	6	7
no. of pixel	790	1023	850	656	329	245	122	81
$\sum_{K=0} n_j$	790	1813	2663	3319	3648	3893	4015	4096
$\sum_{K=0} \frac{n_j}{n}$	0.19	3.0	4.5	5.6	6.2	6.6	6.8	7
$7 \times \sum_{K=0} \frac{n_j}{n}$	0.19x7 ≃ 1.3 = 1	3.0 ≃ 3	4.5 ≃ 5	5.6 ≃ 6	6.2 ≃ 6	7	7	7
				985		448		

(b)

g.L	0	1	2	3	4	5	6	7
no. of pixels	0	0	0	614	819	1230	819	614
$\sum_{K=0} n_j$	0	0	0	614	1433	2663	3482	4096
$\sum_{K=0} \frac{n_j}{n}$	0	0	0	1.0	~~0~~ 2.44	4.5	5.9	7
$7 \times \sum_{K=0} \frac{n_j}{n}$	0	0	0	1.0 ≃ 1	~~0~~ 2.4 ≃ 2	4.55 ≃ 5	6	7

Equalize histogram (b)

gray level		Round off
0	$\longrightarrow$	0
1	$\longrightarrow$	0
2	$\longrightarrow$	0
3	$\longrightarrow$	1
4	$\longrightarrow$	2
5	$\longrightarrow$	5
6	$\longrightarrow$	6
7	$\longrightarrow$	7

~~gray l~~ Equalize histogram (a)

Round off		new nk
1	$\longrightarrow$	790.
2 → 3	$\longrightarrow$	1023
5	$\longrightarrow$	850
6		
6	$\longrightarrow$	985
7		
7	$\longrightarrow$	448
7		

$0 \longrightarrow 0$

$1 \longrightarrow 0$

$2 \longrightarrow 0$

$3 \longrightarrow 790$

$4 \longrightarrow 1023$

$5 \longrightarrow 850$

$6 \longrightarrow 985$

$7 \longrightarrow 448$

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Spatial resolution → it is the Smallest discernible details in an image.
→ MXN pixels

Gray-level Resolution →
it is the Smallest discernible change in the gray level of an image
→ L-Levels.

{ L-level digital image of Size MXN }

when the no. of pixels in an image is reduced keeping the no. of gray levels in the images const., fine checkerboard patterns are found at the edges of the image the effect is called is the checkerboard effect.

False-contouring → when the no. of gray-levels in the image is low, the foreground details of the image merge with the background details of the image, causing ~~rig~~ ridge like structure, this degradation phenomenon is known as false-contouring.

Que → consider the following image and identify the m adjacent path from p to q. , V = {1}

(i)

0	1	1
0	1	0
0	0	1

P

Q

m-adjacent path = 3

(ii)

p

1	0	0	0
1	1	0	0
1	1	1	1
1	0	1	1

Q

{ diagonally avoid }

m-adjacent path = 6

Date Types of adjacency. :- Page

4-adjacency → Two pixels p & q with values from V are 4 adjacent if q is in the set $N_4(p)$.

8-adjacency → two ~~ae~~ pixels p & q with values from V are 8-adjacency if q is in the set $N_8(p)$.

m-adjacency (mixed adjacency) → Two pixels p & q with values from V are m-adjacent if

(a) q is in the set $N_4(p)$, or
(b) q is in the $N_D(p)$ and the set $N_4(p) \cap (N_4(q))$ has no pixels whose values are from V.

Mixed adjacency is a modification of 8-adjacency. it is used to eliminate ambiguities that many arise when 8-adjacency is used.

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1) The discretization of image data in spatial coordinates is known as Sampling.

2) The number of bits required to store a 1024 X 512 image with 512 gray shades is $b = 2^n \times 2^n \times m \Rightarrow 1024 \times 512 \times 9$ bits
$= 2^{10} \times 2^9 \times 9 \Rightarrow \boxed{4718592}$

no. of rows   no. of col.   bit represent each pixels.

3) The smallest discernible change in the gray level of an image is called its gray level resolution

4) when the no. of pixels in an image is reduced keeping the no. of gray levels in the image constant, we observe checkerboard effect

5) when the no. of gray-levels in the image is low, the foreground details of the image merge with the background details of the image, causing ridge with like structure. this degradation phenomenon is known as False Contouring.

Que Consider two image subsets S_1 & S_2 as shown in the following figure. For $V = \{0\}$ determine wheather the regions are :-
1) 4-adjacent 2) 8-adjacent 3) m-adjacent.

S_1				S_2			
1	1	1	1	0	1	0	0
1	1	0	1	0	0	1	1
1	1	0	1	0	0	1	1
1	0	0	0	1	1	1	1

$V = \{0\}$ → check

✗ $N_4(P)$ → (0—0 ye same hone chahiye)

✓ $N_8(P)$ → (0 ke diagonal mai 0 hota condition). (diagonal or same)

✓ m-adjacency → (0—0, aur reverse mai 1—1, in diagonally too).

boundary pixels

region vale ques. mai boundary ke rows paas ke dekhte hai.

1	0
0	1

(both are diagonal)

diagonal   reversed

Que → Consider the following image & find out the distance of P to q by using this three formulas?

⇒

Pixel	Coordinate
P	(x, y)
q	(s, t)

✓ Euclidean distance between p & q

$$D_e(p,q) = \left[(x-s)^2 + (y-t)^2\right]^{1/2}$$

✓ City-block distance b/w P & q

$$D_4(p,q) = |x-s| + |y-t|$$

✓ chessboard distance b/w P & q

$$D_8(p,q) = \max(|x-s|, |y-t|)$$

P →

	(0,0)	(0,1)	(0,2)
(0,0)	0	0	1
(1,0)	1	1	0
(2,0)	1	1	0

→ 0

Euclidean distance →

(i) $P = (x, y) \quad (0,0)$

$q = (s, t) \quad (2,2)$

$$D_e(p,q) = \left[(0-2)^2 + (0-2)^2\right]^{1/2}$$

$$D_e(p,q) = [4+4]^{1/2}$$

$$D_e(p,q) = \sqrt{8} = 2\sqrt{2}$$

City-block →

(ii) $D_4(P,q) = |0-2| + |0-2|$

$2 + 2 = 4$

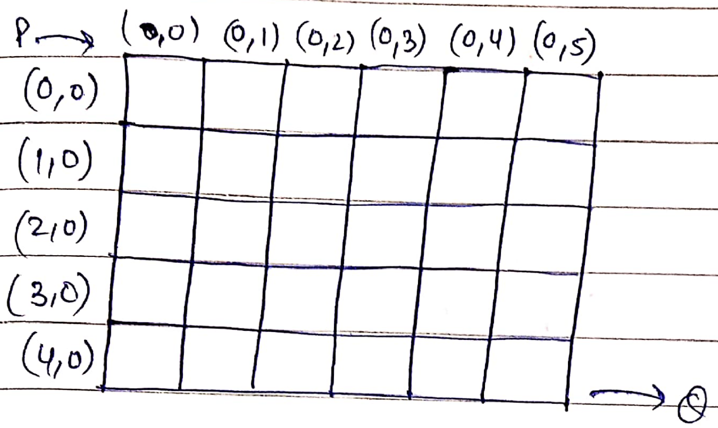
chessboard distance →

(iii) $D_8(P,q) = \max(2,2)$

$= 2$

Que → Consider the following image & find out the distance of p to q by using this three formulas?

⇒



$P = (x,y) \Rightarrow (0,0)$

$q = (s,t) \Rightarrow (4,5)$

(i) $D_e(P,q) = \left[(x-s)^2 + (y-t)^2\right]^{1/2}$

$\Rightarrow \left[(0-4)^2 + (0-5)^2\right]^{1/2}$

$\Rightarrow \left[16 + 25\right]^{1/2}$

$\Rightarrow \sqrt{41} = 6.4$

(ii) $D_4(P,q) = |0-4| + |0-5|$

$= 4+5$

$= 9$

(iii) $D_8(P,q) = \max\left(|0-4| ; |0-5|\right)$

$= \max(4,5)$

$= 5$

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Arithmetic operations on images :- (+, -, *, ÷)

Q→ Consider the following images A & B & perform all 4 airthemetic operations ?

⇒

A

$$\begin{bmatrix} 0 & 100 & 10 \\ 4 & 0 & 10 \\ 8 & 0 & 5 \end{bmatrix}$$

B

$$\begin{bmatrix} 10 & 100 & 5 \\ 2 & 0 & 0 \\ 0 & 10 & 10 \end{bmatrix}$$

i) Addition → used in image to reduce noise

Formula → $I(x,y) = \min(I1(x,y) + I2(x,y), I\max)$

$$\begin{bmatrix} 10 & 200 & 15 \\ 6 & 0 & 10 \\ 8 & 10 & 15 \end{bmatrix}$$

If addition cross 255 then, we have to write only 255.

ii) Subtraction → basic tool in medical language

Formula → $I(x,y) = \max(I1(x,y) - I2(x,y), I\min)$

$$\begin{bmatrix} 0 & 0 & 5 \\ 2 & 0 & 10 \\ 8 & 0 & 0 \end{bmatrix}$$

iii) Multiplication → to correct gray-level shading result from non-uniformities in illumination used to acquire the image.

$$\begin{bmatrix} 0 & \overset{\to 255}{10000} & 50 \\ 8 & 0 & 0 \\ 0 & 0 & 50 \end{bmatrix} \Rightarrow \begin{bmatrix} 0 & 255 & 50 \\ 8 & 0 & 0 \\ 0 & 0 & 50 \end{bmatrix}$$

Division $\rightarrow$ $I(x,y) = I_1(x,y) / I_2(x,y),\ I_2(x,y) <> 0$

$$\left\{ \begin{array}{l} \frac{0}{10} = 0 \\ \frac{10}{0} = 0 \\ \cdot \rightarrow \text{round off} \end{array} \right\} \begin{bmatrix} 0 & 1 & 2 \\ 2 & 0 & 0 \\ 0 & 0 & 1/2 \end{bmatrix} \qquad 1/2 \rightarrow 0.5 \rightarrow 0 \ (\text{round off}) \qquad \Rightarrow \begin{bmatrix} 0 & 1 & 2 \\ 2 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

Que → consider the following images A & B and perform all 4 arithmetic operations?

$\Rightarrow$

$$A = \begin{bmatrix} 200 & 100 & 50 \\ 10 & 0 & 1 \\ 20 & 30 & 50 \end{bmatrix} \qquad B = \begin{bmatrix} 100 & 200 & 0 \\ 0 & 0 & 100 \\ 100 & 60 & 100 \end{bmatrix}$$

Addition →

$$\begin{bmatrix} 255 & 255 & 50 \\ 10 & 0 & 101 \\ 120 & 90 & 150 \end{bmatrix}$$

multiplication →

$$\begin{bmatrix} 255 & 255 & 0 \\ 0 & 0 & 100 \\ 255 & 255 & 255 \end{bmatrix}$$

Subtraction →

$$\begin{bmatrix} 100 & 0 & 50 \\ 10 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

division →

$$\begin{bmatrix} 2 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

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Image Enhancement in spatial domain :-

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

Or in short

$$s = T(r)$$

T transforms the given image f(x,y) with another image g(x,y)

$$\left\{ f(x,y) \xrightarrow{T} g(x,y) \right\}$$

Three methods of Transformation :-

(1) Linear transformation → Image negative
(2) Non-linear transformations → Logarithmic transformation
Exponential transformation
(3) Piecewise-linear transformation → Contrast stretching
Gray-level slicing
Bit-plane slicing.

(Gray levels of the Original image is the range of [0, L-1], Then, the (-ve) of an image can be obtained)

(1) Image-negative → The negative of an image can be obtained by reversing the intensity levels, the expression for which is given by :

$$s = L-1-r.$$

This type of processing is suited for enhancing white or gray detail embedded in dark regions of an image, especially when black areas are dominant.

use of I.N.

Que → Consider the following image & calculate the image negative where each pixels is represented by 3 bits?

$2^3 \rightarrow 8 \rightarrow \{0-7\}$.

⇒

0	1	3
2	4	5
2	3	7

} → input image (r)

Output image (S) {Subtracted by 7}.

7	6	4
5	3	2
5	4	0

Que → Consider the following image & find Out the image (-ve), if each pixel is represented by 4 bits?

$2^4 \rightarrow \underset{L}{16}\ \{0-15\}$

⇒

9	15	14
0	10	1
2	12	3

} input image (r)

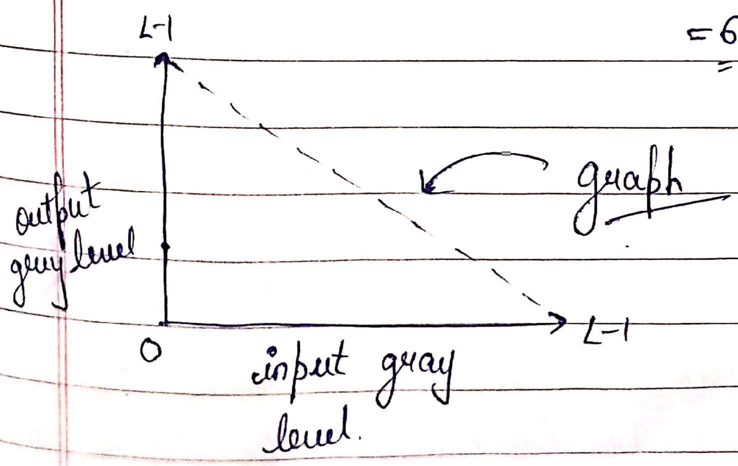
6	0	1
15	5	14
13	3	12

Output image (s)

$S = L-1-r$ {Subtracted by 15}

$15 - 9$

$= 6$



Que → Consider the image in fig. & find out the image negative where each pixel is represented by 3 bits?

⇒

r → (input image)

$$\begin{bmatrix} 2 & 3 & 0 \\ 1 & 7 & 6 \\ 2 & 1 & 7 \end{bmatrix}$$

3bit → 2^3 → 8 $\{0-7\}$
→ (L)

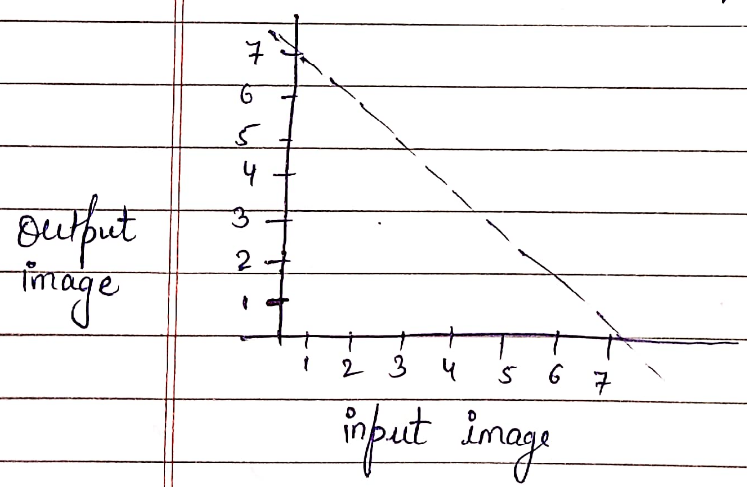
$S = L-1-r$.
(Output image)

$= 7-2 = 5$	$7-6 = 1$
$7-3 = 4$	$7-2 = 5$
$7-0 = 7$	$7-1 = 6$
$7-1 = 6$	$7-7 = 0$
$7-7 = 0$	

S → (output image)

$$\begin{bmatrix} 5 & 4 & 7 \\ 6 & 0 & 1 \\ 5 & 6 & 0 \end{bmatrix}$$

used in medical field.



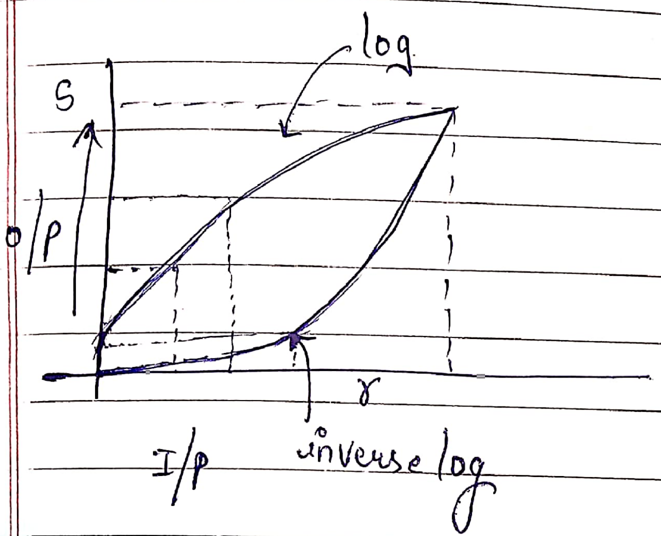
(2) **Log transformation :-**

General form :- $S = c\log(1+r)$
where C is a constant & $r \geq 0$.

This type of processing is used to expand the values of dark pixels in an image while compressing the higher level values.

$$\boxed{S = c \log(1+r)}$$

where, C is Constant & $r \geq 0$
S = output, r = input.



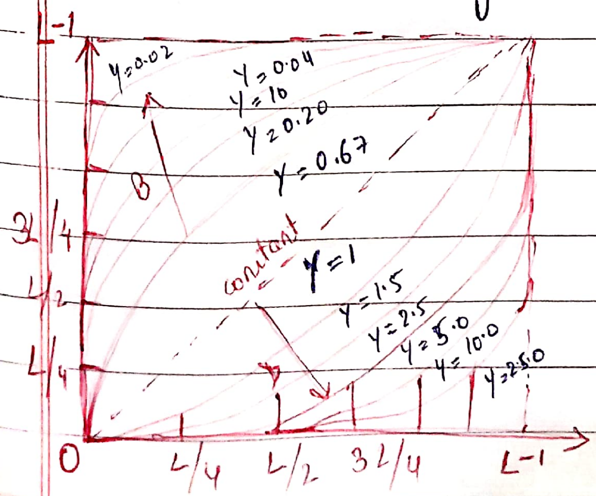
Darker → inverse log
Brighter → log

(3) Power law (Gamma) Transformation :-

$$\boxed{S = c r^{\gamma}}$$

where, c & γ are positive Constant

when $\gamma < 1$ → image become brighter
when $\gamma > 1$ → image become darker
when $\gamma = 1$ → image remains Constant.



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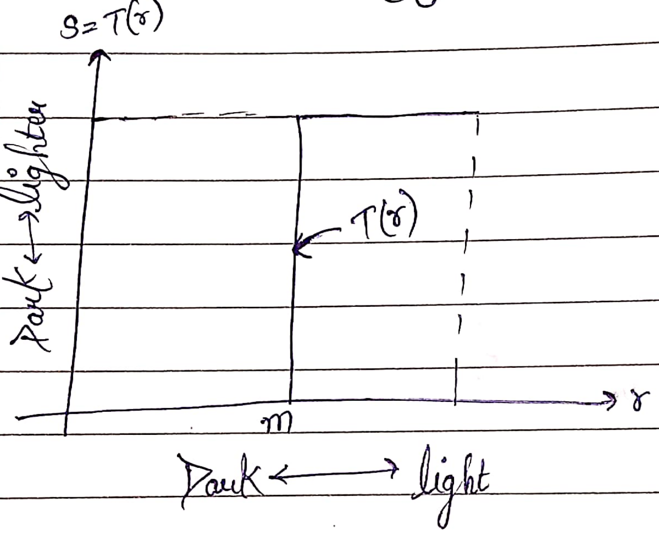
(4) **Contrast Stretching** :- Simplest of piecewise linear funⁿ.

Basic idea → to increase the dynamic range of the gray levels in the image being processed.

Thresholding function :- m = 'thresholding level'

$$s = \begin{cases} L-1 & \text{if } r > m \\ 0 & \text{otherwise} \end{cases}$$



Que → Consider the following image & perform Contrast streching where threshold level 'm' = 3 & each pixel is represented by 3 bits?

3 bits → 2^3 → 8 → L

{0 - 7}

↓

L-1

r

1	6	2
2	5	4
3	4	5

$m = 3$

$r > m$

$1 > 3 = 0$

$6 > 3 \rightarrow 7$

$2 > 3 \rightarrow 0$

$2 > 3 \rightarrow 0$

$5 > 3 \rightarrow 7$

$4 > 3 \rightarrow 7$

$3 > 3 \rightarrow 0$

$4 > 3 \rightarrow 7$

$5 > 3 \rightarrow 7$

s

0	7	0
0	7	7
0	7	7

Que→ Consider the following image in fig. where each pixel is represented by 3 bit. perform the contrast stretching using thresholding fun^n where threshold level is 3.

r

7	6	5
0	0	1
2	2	3

$m = 3$

3 bit → 2^3 → 8 {0 — 7}; 8 → L, 7 → L-1

$r > m$

~~7<~~ $7 > 3 = 7$ $2 > 3 = 0$

$6 > 3 = 7$ $2 > 3 = 0$

$5 > 3 = 7$ $3 > 3 = 0$

$0 > 3 = 0$

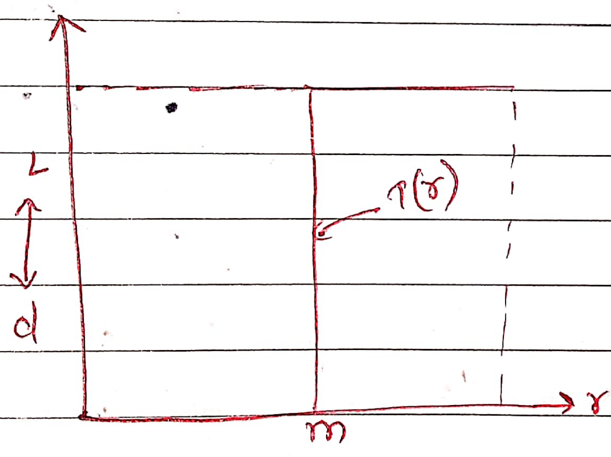
$0 > 3 = 0$

$1 > 3 = 0$

s

7	7	7
0	0	0
0	0	0

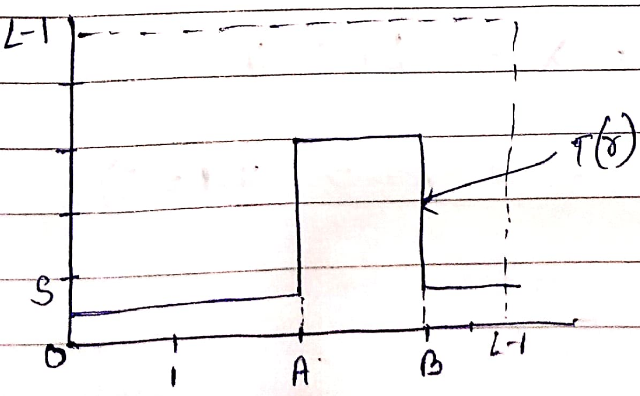
~~St~~: $S = T(r)$



d ⟷ L

(5) Gray level / Intensity - level slicing :-

it is used to highlight a specific range of gray values.



$$S = \begin{cases} L-1 & \text{if } n > r > m \ (A > r > B) \\ 0 & \text{otherwise} \end{cases}$$

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Que → Consider the image in fig & find out gray-level / Intensity-level slicing using the following funⁿ. where $n=5$ & $m=2$.

r

7	6	5
4	3	1
2	2	5

→

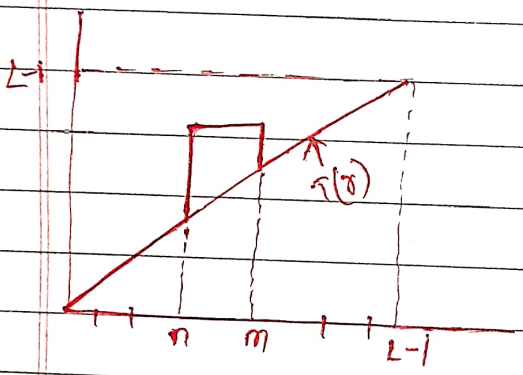
$n > r > m$

$5 > 7 > 2 = (X) \rightarrow 0$

$5 > 4 > 2 = (✓) \quad (7) \rightarrow (L-1)$

$$s = \begin{cases} L-1 & \text{if } n>r>m \\ 0 & \text{otherwise} \end{cases}$$

0	0	0
7	7	0
0	0	0



$$s = \begin{cases} L-1 & \text{if } n>r>m \\ r & \text{otherwise} \end{cases}$$

7	6	5
7	7	1
2	2	5

Que Consider the image in fig & find out gray-level / intensity-level slicing using the following funⁿ where $n=5$ & $m=2$.

$$s = \begin{cases} r-1 & \text{if } n>r>m \\ L-1 & \text{otherwise} \end{cases}$$

→

7	6	5
4	3	1
2	2	5

⇒

7	7	7
3	2	7
7	7	7

$\overset{5}{n} > 7 > 2 = X \rightarrow L-1 \Rightarrow 7.$

$5 > 4 > 2 = ✓ \rightarrow r-1 \rightarrow 4-1 = 3$

(6) Bit plane slicing → Extracts the information of a single bit plane. instead of highlighting gray-level ranges, highlighting the Contribution made to the total image appearance by specific bit might be desired.

Logical operations :-

Que→ Consider the two images & perform logical operation ?

0	0	1
0	1	1
0	1	0

Fig.1

1	0	1
1	0	1
1	1	0

Fig.2

0	0	1
0	0	1
0	1	0

And operation.

OR

0	0	0
0	1	1
1	0	1
1	1	1

1	0	1
1	1	1
1	1	0

OR operation

Que → perform logical NOT operation of an fig.1

⇒

1	1	0
1	0	0
1	0	1

Que→ Consider the image 1 & 2 and perform all 4 arithmetic operations?

10	120	180
50	60	0
0	20	80

img.1

80	200	220
0	0	0
100	50	20

img.2

addition →

90	255	255
50	60	0
100	70	100

$2^8 = 256$ (0, 255)

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Subtraction →

0	0	0
50	60	0
0	0	60

multiplication →

255	255	255
0	0	0
0	255	255

division →

0	0	0
0	0	0
0	0	4

Spatial filtering → Spatial filtering is the filtering operations that are performed directly on the pixels of an image.
if the operation performed on the image pixels is linear, then the filter is called a linear spatial filter.
Otherwise, the filter is a nonlinear spatial filter

Linear spatial filtering :- Two types :-
(1) Smoothing linear filter
(2) Order - statistics filter

(1) Smoothing Linear filters / Averageing filters / Lowpass filters :-

Linear spatial filter is simply the average of the pixels Contained in the neighbourhood of the filter mask.

Que → Consider the image 1. what will be the value of pixel (1, 1) if filtering is done using average filter of mean filter.

⇒

(1,1)

2	2	4	4
3	3	4	4
3	3	2	5
1	1	1	2

$\frac{1}{9} \times (2+2+4+3+3+4+3+3+2)$

$= \frac{26}{9} = 3$

2.8 ?

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Que what will be the new value of pixel (3,3), if smoothing is done using mean filter?

⇒ By using (zero) 0 padding.

	0	1	2	3	
0	2	2	4	4	
1	3	3	4	4	
2	3	3	2	5	0
3	1	1	1	2	0
			0	0	0

$\frac{1}{9} \times (2+5+1+2)$

$\frac{10}{9} = 1.1 = 1$

(Standard avg. smoothing linear filter)

Que - what will be the value of pixel (2,2) by appling mean filter?

	0	1	2	3
0	2	2	4	4
1	3	3	4	4
2	3	3	2	5
3	1	1	1	2

$\frac{1}{9} \times (3+4+4+3+2+5+1+1+2)$

$= \frac{25}{9} = 2.7 = 3$

Que Consider pixel (2,1) by appling mean filter?

	0	1	2	3
0	2	2	4	4
1	3	3	4	4
2	3	3	2	5
3	1	1	1	2

$\frac{1}{9} \times (3+3+4+3+3+2+1+1+1)$

$= \frac{21}{9} = 2.3 = 2$

weighted average linear filter :-

Que→ Consider the image & find Out the value at pixel (2,2) by applying weighted average filter by using (4,2,1).

(4,2,1)
mid, up & down, diagonal

1	2	1
2	4	2
1	2	1

(sum) 16

	0	1	2	3
0	2	3	6	4
1	2	4	5	4
2	3	5	2	3
3	4	5	5	5
4	6	2	2	2

$$\frac{4\times1 + 5\times2 + 4\times1 + 5\times2 + 2\times4 + 3\times2 + 5\times1 + 5\times2 + 5\times1}{16}$$

$$= \frac{62}{16} = 3.8 \simeq 4$$

Que→ find Out the value at pixel (1,1) by applying weighted average filter.

⇒ (1,1)

	0	1	2
0	2	3	6
1	2	4	5
2	3	5	2

$$\frac{2\times1 + 3\times2 + 6\times1 + 2\times2 + 4\times4 + 5\times2 + 3\times1 + 5\times2 + 2\times1}{16}$$

$$= \frac{59}{16} = 3.6 \simeq 4$$

Que → Find Out the value at pixel (2,1) by applying filter of weight (1,2,3).

1 → mid, 2 → up/down, 3 → diagonal

⇒ (2,1)

2	4	5
3	5	2
4	5	5

3	2	3
2	1	2
3	2	3

(Sum) 21

$$\frac{2\times3+4\times2+5\times3+3\times2+5\times1+2\times2+4\times3+5\times2+5\times3}{21}$$

$$\Rightarrow \frac{6+8+15+6+5+4+12+10+15}{21}$$

$$\Rightarrow \frac{81}{21} = 3.8 \simeq 4$$

Order-statistics filter :- Order statistics filters are non-linear spatial filters whose response is based on Ordering (ranking) the pixels. This is also known as median filter.

Que → Consider the figure, find Out the value at pixel (2,2) by applying median filter?

⇒

	0	1	2	3
0	1	2	6	6
1	1	2	2	7
2	6	5	3	7
3	6	7	7	7
4	2	2	2	2

(2,2)

Ascending Order
2, 2, 3, 5, 7, 7, 7, 7, 7

median

median filter = 7

Max & Min filter :-

Max filter = 7, min filter = 2

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Que → Consider the following figure, find out the new value at pixel (3,1) by applying

(i) linear filter
(ii) weighted average filter (3,2,1)
(iii) median filter
(iv) min filter
(v) max filter

⇒

	0	1	2	3
0	1	2	6	6
1	1	2	2	7
2	6	5	3	7
3	6	7	7	7
4	2	2	2	2

(3,1)

⇒

6	5	3
6	7	7
2	2	2

(i) Linear filter :-

$$\frac{6+5+3+7+7+6+2+2+2}{9}$$

$$= \frac{40}{9} = 4.4 \approx 4$$

(ii) weighted average filter (3,2,1)

1	2	1
2	3	2
1	2	1

$\}$ 15

$$\frac{6\times1+5\times2+3\times1+6\times2+7\times3+7\times2+2\times1+2\times2+2\times1}{15}$$

$$= \frac{6+10+3+12+21+14+2+4+2}{15}$$

$$= \frac{74}{15} \Rightarrow 4.9 \approx 5$$

(iii) median filter :-

2, 2, 2, 3, 5, 6, 6, 7, 7 → median

median filter = 5

(iv) min filter ⇒ 2

(v) max filter ⇒ 7

Sharpening spatial filter :-

The objective of sharpening is to highlight fine detail in an image or to enhance detail that has been blurred.

First-Order Derivatives	Second-Order derivatives
⇒ $\frac{\partial f}{\partial x} = f(x+1) - f(x)$	⇒ $\frac{\partial^2 f}{\partial x^2} = f(x+1) + f(x-1) - 2f(x)$
⇒ Must be zero in areas of const. intensity	⇒ Must be zero in areas of const. intensity.
⇒ Must be non-zero at the onset of an intensity step & ramp.	⇒ Must be non-zero at the onset and end of a intensity step or ramp.
⇒ Must be non-zero along intensity ramps.	⇒ Must be zero along intensity ramps.

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Assignment Que :-

VII → For a 8X8 image as shown below, generate the linear Contrast stretched image with minimum gray level 0 and maximum gray level 7.

Note :- $\frac{r - r_{min}}{r_{max} - r_{min}} = \frac{s - s_{min}}{s_{max} - s_{min}}$

r (input image)

3	3	3	3	3	3	3	3
3	4	4	4	4	4	4	3
3	4	2	2	2	2	4	3
3	4	2	5	5	2	4	3
3	4	2	5	5	2	4	3
3	4	2	2	2	2	4	3
3	4	4	4	4	4	4	3
3	3	3	3	3	3	3	3

I → $\left[\frac{r - r_{min}}{r_{max} - r_{min}} = \frac{s - s_{min}}{s_{max} - s_{min}}\right]$

II → $\left[s = \frac{r - r_{min}}{r_{max} - r_{min}} (s_{max} - s_{min}) + \right.$

$s_{min} = 0$; $s_{max} = 7$

$r_{min} = 2$, $r_{max} = 5$

$\frac{r-2}{5-2} = \frac{s-0}{7-0}$

$s = \frac{7}{3}(r-2)$

$r = 2 \Rightarrow s = \frac{7}{3}(2-2)$

$s = 0$

$r = 3 \Rightarrow s = \frac{7}{3}(3-2)$

$s = \frac{7}{3} = 2.3 = 2$

Date $\left[S = \frac{r - r_{min}}{r_{max} - r_{min}} (S_{max} - S_{min}) + S_{min} \right]$ Page

$r = 4 \rightarrow \quad S = \frac{4-2}{5-2}(7-0)+0$

$S = \frac{2}{3} \times 7$

$S = \frac{14}{3} = 4.6$

$= 5$ //

$r = 5 \rightarrow \quad S = \frac{5-2}{5-2}(7-0) + 0$

$S = 1 \times 7 + 0$

$S = 7$ //

$r = 2, \quad S = 0$
$r = 3, \quad S = 2$ } → bright
$r = 4, \quad S = 5$
$r = 5, \quad S = 7$ } → darker.

$+ S_{min}]$

Que → VII For a 8×8 image as shown below, generate the linear Contrast stretched image with minimum gray level 7 and maximum gray level 15.

Note :- $\dfrac{r - r_{min}}{r_{max} - r_{min}} = \dfrac{s - s_{min}}{s_{max} - s_{min}}$

r:

3	3	3	3	3	3	3	3
3	4	4	4	4	4	4	3
3	4	2	2	2	2	4	3
3	4	2	5	5	2	4	3
3	4	2	5	5	2	4	3
3	4	2	2	2	2	4	3
3	4	4	4	4	4	4	3
3	3	3	3	3	3	3	3

$r_{min} = 2$ $s_{min} = 7$

$r_{max} = 5$ $s_{max} = 15$

$$\left[s = \frac{r - r_{min}}{r_{max} - r_{min}} (s_{max} - s_{min}) + s_{min} \right]$$

$r = 2 \rightarrow \dfrac{2-2}{5-2}(15-7) + 7$

$\dfrac{0}{3} \times 8 + 7 \Rightarrow \underline{7}$

$r = 3 \rightarrow \dfrac{3-2}{5-2}(15-7) + 7$

$\dfrac{1}{3} \times 8 + 7 \rightarrow 2.6 + 7$

$s = 3 + 7 = \underline{10}$

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$r=4 \rightarrow \quad \frac{4-2}{5-2}(15-7)+7$

$\frac{2}{3} \times 8+7$

$\frac{16}{3}+7$

$= 5.3+7$

$S = 5+7 = \underline{\underline{12}}$

$r=5 \rightarrow \quad \frac{5-2}{5-2}(15-7)+7$

$1 \times 8+7$

$S = 8+7 = 15$ //

$r=2$	$S=7$
$r=3$	$S=10$
$r=4$	$S=12$
$r=5$	$S=15$

Que → Assume a 6-bit gray scale image I and Consider the spatial filter H is given by.

$$H = \begin{bmatrix} -1 & -2 & 0 \\ -2 & 0 & 3 \\ 0 & 3 & 1 \end{bmatrix}$$

(a) Determine the maximum and minimum possible value that a pixel, to which this spatial filter is applied, Can have. do not apply any type of normalization.

$$\Rightarrow \quad H = \begin{bmatrix} -1 & -2 & 0 \\ -2 & 0 & 3 \\ 0 & 3 & 1 \end{bmatrix} \Rightarrow \quad 6\text{ bit} \Rightarrow 2^6 = 64 \; [0 - 63]$$

For minimum →

$$\begin{bmatrix} -1 & -2 & 0 \\ -2 & 0 & 3 \\ 0 & 3 & 1 \end{bmatrix} \longrightarrow \begin{bmatrix} 63 & 63 & 1 \\ 63 & 1 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

$$(-1 \times 63) + (-2 \times 63) + (-2 \times 63) = -315$$

For maximum →

$$\begin{bmatrix} -1 & -2 & 0 \\ -2 & 0 & 3 \\ 0 & 3 & 1 \end{bmatrix} \longrightarrow \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 63 \\ 1 & 63 & 63 \end{bmatrix}$$

$$(3 \times 63) + (3 \times 63) + (63 \times 1) \rightarrow 441$$

$\gamma_{min} = -315$

$\gamma_{max} = 441$

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(b) Propose a gray-level transformation function to ensure that any Output of this filter will be a standard 6-bits gray scale image?

$2^6 = 64$ [0-63]

$\Rightarrow$ $\gamma = \begin{bmatrix} -1 & -2 & 0 \\ -2 & 0 & 3 \\ 0 & 3 & 1 \end{bmatrix}$ $\quad \gamma_{min} = -315 \quad S_{min} = 0$

$\gamma_{max} = 441 \quad S_{max} = 63$

$$\boxed{S = \frac{\gamma - \gamma_{min}}{\gamma_{max} - \gamma_{min}} (S_{max} - S_{min}) + S_{min}}$$

$\gamma = -2, -1, 0, 1, 3$

$\gamma = -2 \longrightarrow S = \frac{(-2) - (-315)}{441 + 315} (63-0) + 0 \Rightarrow 24$

$\gamma = -1 \longrightarrow S = \frac{(-1) - (-315)}{441 + 315} (63-0) + 0 \Rightarrow 25$

$\gamma = 0 \longrightarrow S = \frac{(0) + 315}{441 + 315} (63-0) + 0 \Rightarrow 26$

$\gamma = 1 \longrightarrow S = \frac{1 + 315}{441 + 315} (63-0) + 0 \Rightarrow 26$

$\gamma = 3 \longrightarrow S = \frac{3 + 315}{441 + 315} (63-0) + 0 \Rightarrow 26.5 \simeq 26$