n=2
IP

MODULE :- 2

Digital Image Formation

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⇨ **A Simple Image Model** :- To be suitable for computer processing, an image $f(x,y)$ must be digitalized both spatially and in amplitude.

* Digitizing of the co-ordinates are called 'Sampling'.
* Digitizing of the amplitude is called grey-level (quantization.

$$f(x,y) = i(x,y)\, r(x,y)$$

: $f(x,y)$ = intensity at the point (x,y)

:- $i(x,y)$ = illumination at the point (x,y)
= (the amount of source illumination incident on the scene).

$r(x,y)$ = reflectance/transmissivity at the point (x,y) - (the amount of source illumination reflected/transmitted by the objects).

where $0 < i(x,y) < \infty$ and $0 < r(x,y) < 1$.

(Low) ↑ limit of (i) (High) ↑ Low limit of (r) ↑ High

Geometric Model – Basic [Transformation]

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Spartial Domain :-

▷ **Gray-level Transformation :-**

- The grey level or grey value indicates the brightness level of a pixel.

* All Image processing techniques focused on gray level transformation as it operates directly on pixels. The

8 bit image also called as greyscale. limit $2^8 = [0-255]$

And in histogram, horizontal axis spans from 0 to 255, and the vertical axis depends on the No. of pixel in the image

Simple enhancement formula :- $\boxed{S = T * r}$

where; T is transformation
r; is the value of pixel (i/p),
S; is pixel value before & after process (o/p)

- Let;

$$\Rightarrow \begin{Bmatrix} r = f(x,y) \\ S = g(x,y) \end{Bmatrix}$$

'r' and 'S' are used to denote gray levels of 'f' and 'g' at (x,y).

⇒ **Three Types of Transformation :-**

1). Linear 2). Logarithmic
3). Power-law

Image Processing

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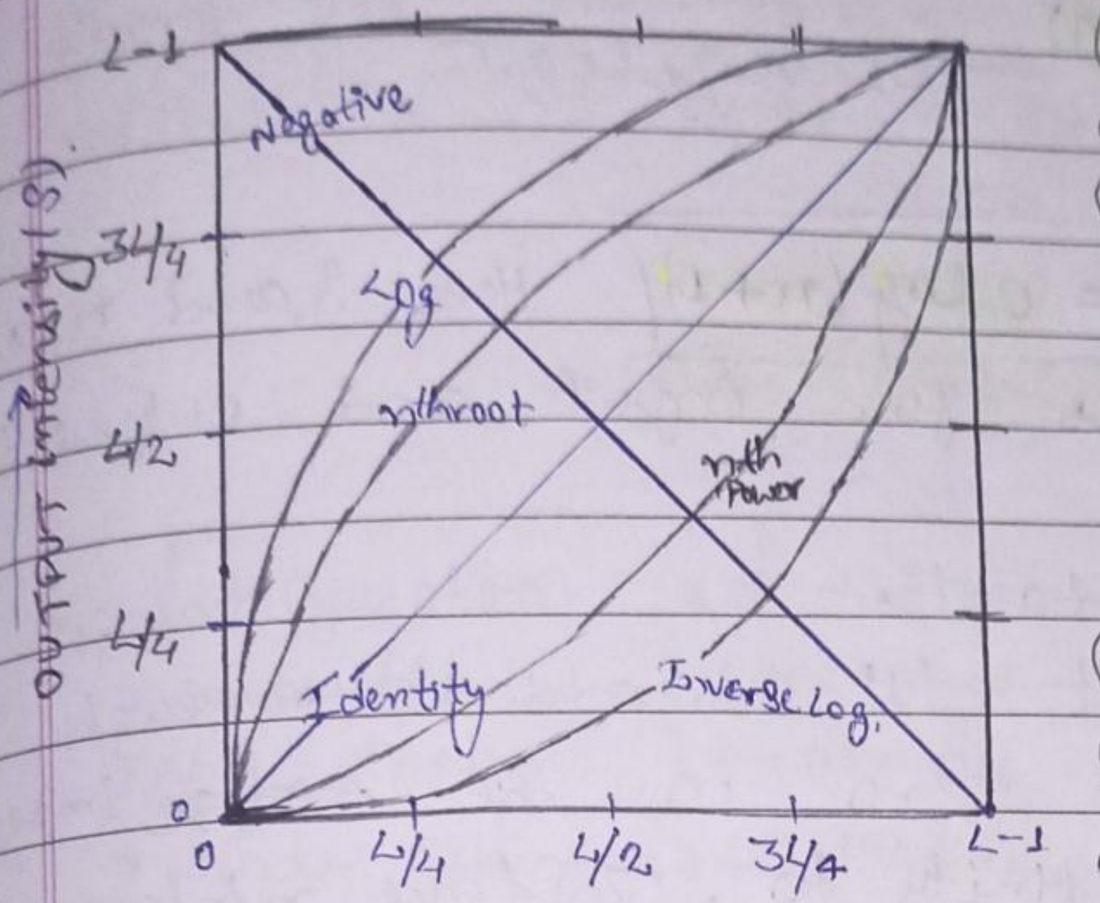
overall graph:-



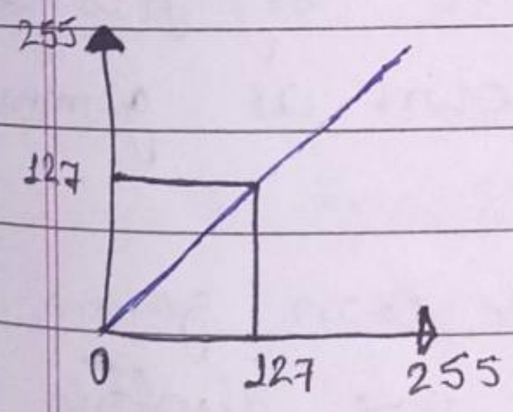
1. Linear
   - Identity
   - Negative

* Identity Transformation, each value of the input image is ~~subtracted~~ it is directly mapped to each other values of the output image.

~~from L-1 and then onto the output image.~~

* Negative Transform:- is the opposite of 'identity'

Here, each value of the input image is subtracted from L-1 and then it is mapped onto the output image.



Identity

Negative

Image Enhancement.

* 2. Logarithmic Transform → 1. Log. T.
→ 2. Inverse Log. T.

1. Formula :- $S = c \log(r+1)$ Here; S, and r are the pixels values for input and output img. And c. is constant.

⇒ We can see that "1" is added to each pixel intensity is zero in the ~~range~~ image then log(0) is infinity so, To have minimum value one is added.

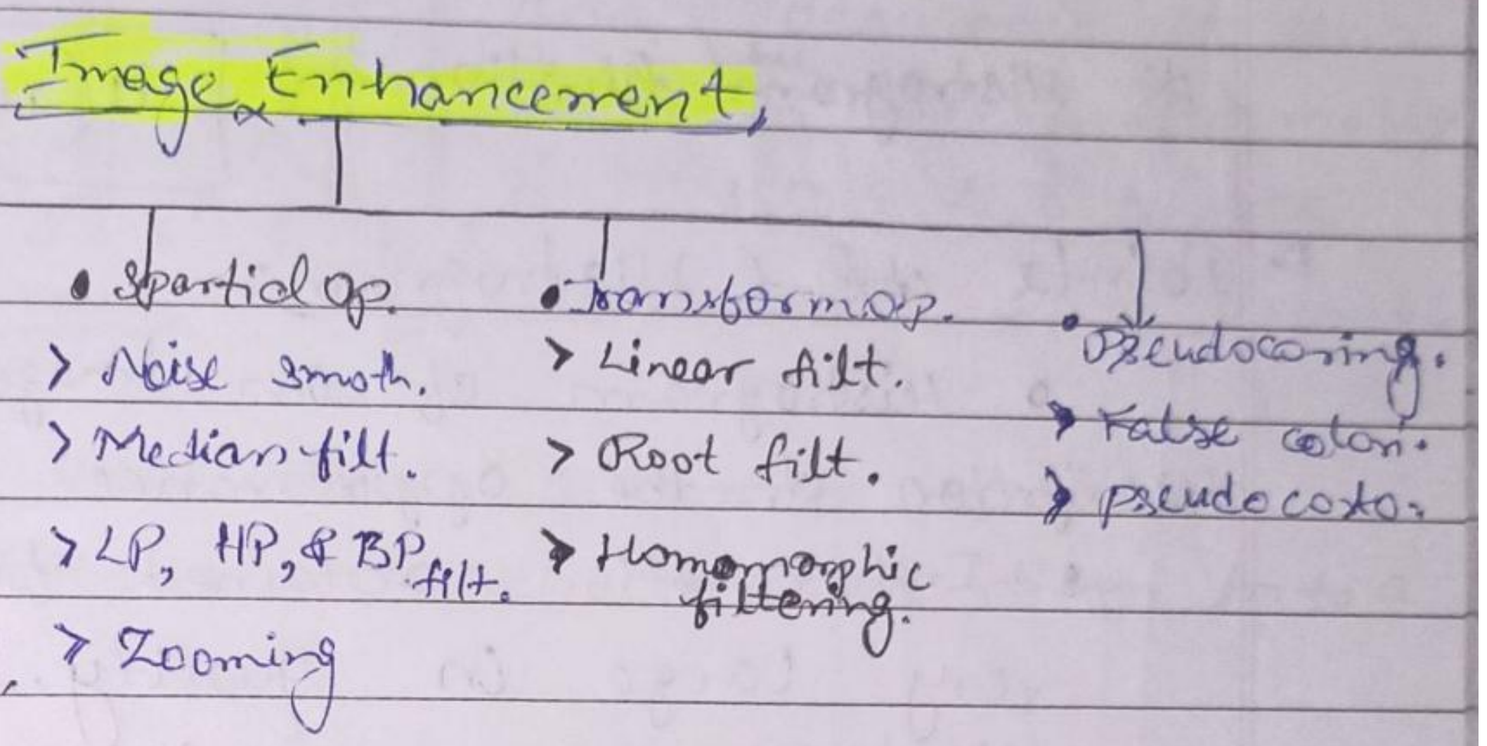
3. Power-Law Transformation :- It is of Two types of transformation n^{th} power Transform and nth root transformation

* Formula ⇒ $S = cr^{\gamma}$; (cr^{γ}) Here γ is gamma by which this transformation is known as gamma Transformation.

All display devices have their own gamma correction. That is why images are displayed at different intensity.

* These Transformation are used for enhancing images.

△ There are two types of Image Enhancement.
methods :- 1. Spartial Domain 2). Frequency domain



4. Spartial Technique are ~~defined~~ performed on the image plane, and they directly manipulate the pixel of the image.

△ operations are formulated :- $g(x,y) = T[f(x,y)]$
where g is the o/p image, f is the input ~~input~~ image, T is operation.

* Spartial domain further two types :-
  - point Op. (Linear)
  - Spartial op. (non-linear)

2). Frequency Domain enhances an image by following complex linear operators.

$$G(w_1, w_2) = F(w_1, w_2)\, H(w_1, w_2).$$

Histogram :-

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▲ The histogram of a digital - image with gray levels in the range $[0, L-1]$ is a discrete function.

* Histogram function :- $\boxed{H(r_k) = n_k}$

▷ Points about Histogram :-

- Histogram of an image provides a global description of the appearance of an image.
- Information obtained from histogram is very large in quality.
- Histogram of an image represents the relative frequency of occurence of various gray levels in an image.

Examples :-

(1) $\begin{bmatrix} 3 & 6 & 6 & 8 \\ 5 & 3 & 1 & 4 \\ 8 & 6 & 5 & 1 \\ 4 & 8 & 2 & 3 \end{bmatrix}$ → This image Matrix contains the pixel values at (i, j). position in the given x-y plane which is the 2D image with gray - levels.

◉ There is two - ways to plot a Histogram of an image :-

** Method 1) In this method, the x-axis has grey levels / Intensity values and the y- axis has the number of pixel in each grey level. The Histogram value representation of the above image (2) is :-

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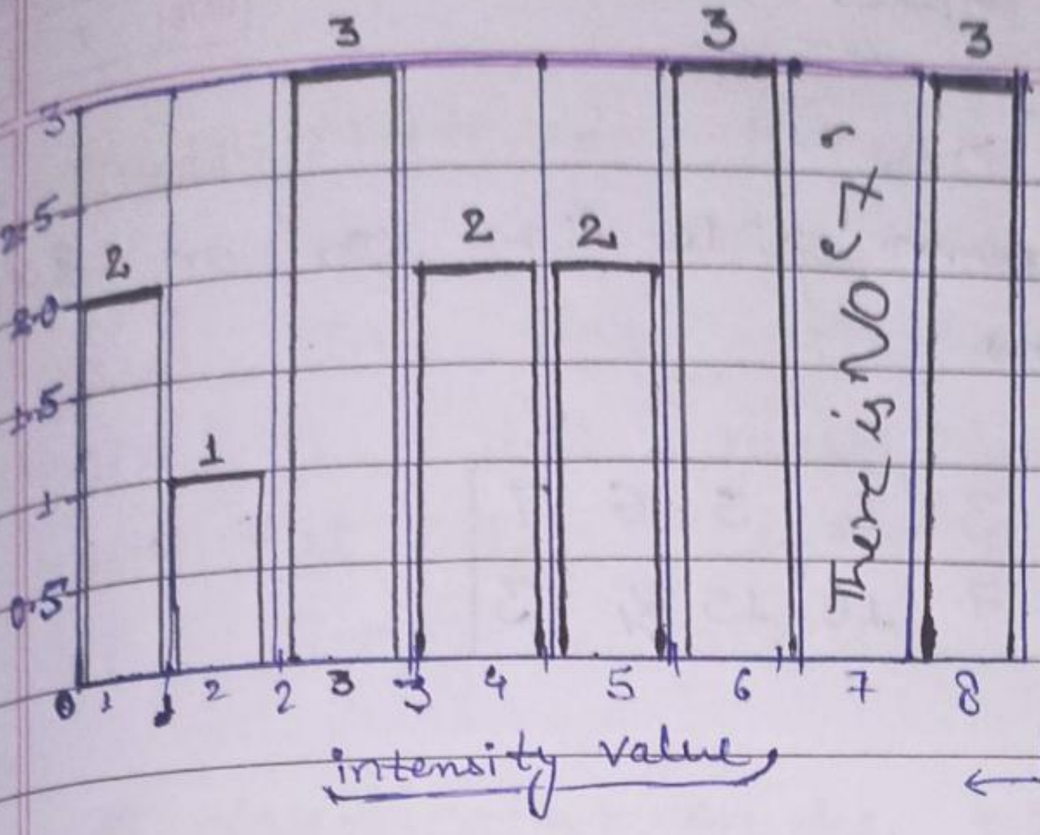
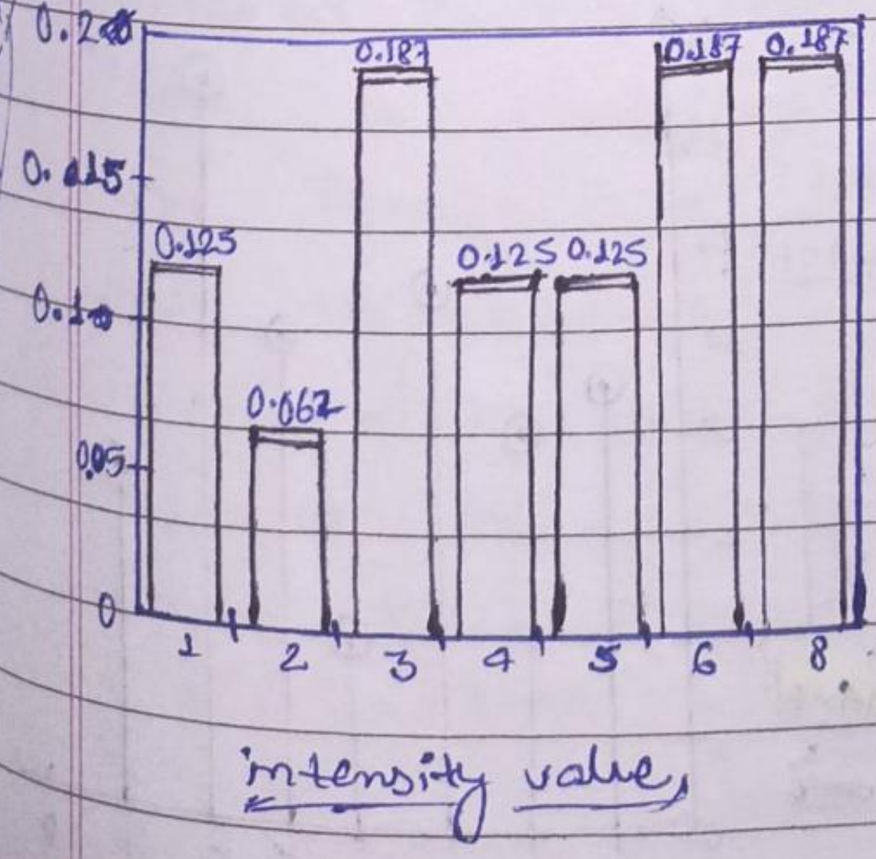


The above image (1) has 1, 2, 3, 4, 5, 6 & 8. as the intensity values and occurence of each intensity value in the image matrix is 2, 1, 3, 2, 2, 3 and 3 respectively. So according to intensity value and occurence of that particular intensity we mapped them into a Graph.

* Method 2:- In this method, the x-axis represents the grey level, while the y-axis represents the 'probability of occurence of that grey level'.

* Probability fun $\boxed{P(r_k) = \frac{n_k}{n}}$

Now, we can create a histogram graph for each pixel and corresponding occurence probability.



@ Below table shows the probability of each intensity level of an pixel.

Intensity/Gray lev.	Occurence of intensity/Gray (or No of pixel)	Probability
1	2	0.125
2	1	0.0625
3	3	0.1875
4	2	0.125
5	2	0.125
6	3	0.1875
8	3	0.1875

Now

Spartial Filtering & it's types

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* Spartial Filtering is used directly on pixels of an image. 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 transverses all image pixels.

* classification on the basis OF Inearity, There is Two :-
  1. Linear Spartial
  2. Non-Linear Spartial.

⇒ General classification :-

- Smoothing, Spartial filter – It is Used for blurring and noise reduction in the image Blurring is pre-processing steps for removal Of Small details and Noise Reduction is accomplished by blurring.

Smoothing Spartial filter → 1. Linear filter (mean filter)
                            → 2. Order statistics (Non-Linear).

*Mean filter :- Linear Spartial filter is simply the average of the pixels contained in the neighborhood of the filter mask. The idea is replacing the value of every pixel in an image by the average of the grey levels in the neighborhood define by the filter mask.

(i) Averaging filter : It is used in reduction of the details in image. All co-efficients are equal.

(ii) weighted averaging filter, - In this, pixels are multiplied by different ——

co-efficient. Center pixel is multiplied by a higher value than average filters.

* **Order Statistics filter** :- It is based on the ordering the pixels contained in the image area encompassed by the filter. It replaces the value of the center pixel with the value determined by the ranking result. Edges are better preserved in this filtering.

⇨ Types of order statistics ⇦

(i) **Minimum filter** :- 0th percentile filter is the min. filter. The value of the center is replaced by the "smallest value" in the window

(ii) **Maximum filter** :- 100th percentile filter is max filter. The value of the center is replaced by the "largest value" in windows.

(iii) **Median Filter** :- Each pixel in the image is considered. First neighboring pixels is "replaced by the median of the list"

** **Shorpening Spartial Filter** :- It is also known as Derivative Filter. The purpose of the this filter is just opposite of the Smoothing Filter. Its main focus in on the removal of blurring and highlight the edges. It is based on the first & second order derivative.

* First order derivative :- ~~It is at~~

- Must be zero in flat segments.
- Must be non-zero at the onset of a gray-level step.
- Must be non-zero along ramps.

⇒ First order derivative in 1-D is given by :-

$$\boxed{f' = f(x+1) - f(x)}$$

* 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.

⇒ 2nd order derivative in 1-D is given

$$\boxed{f'' = f(x+1) + f(x-1) - 2f(x)}$$

HISTOGRAM – Question & Answers

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Q) ex:- Perform histogram equalization for the following image

$$f(x,y) = \begin{bmatrix} 1 & 2 & 1 & 1 & 1 \\ 2 & 5 & 3 & 5 & 2 \\ 2 & 5 & 5 & 5 & 2 \\ 2 & 5 & 3 & 5 & 2 \\ 1 & 1 & 1 & 2 & 1 \end{bmatrix}$$

:- max value = 5 (will be)

* we have to do histogram equalization

$2^0 = 1$
$2^1 = 2$
$2^2 = 4$
$2^3 = 8 > 5$

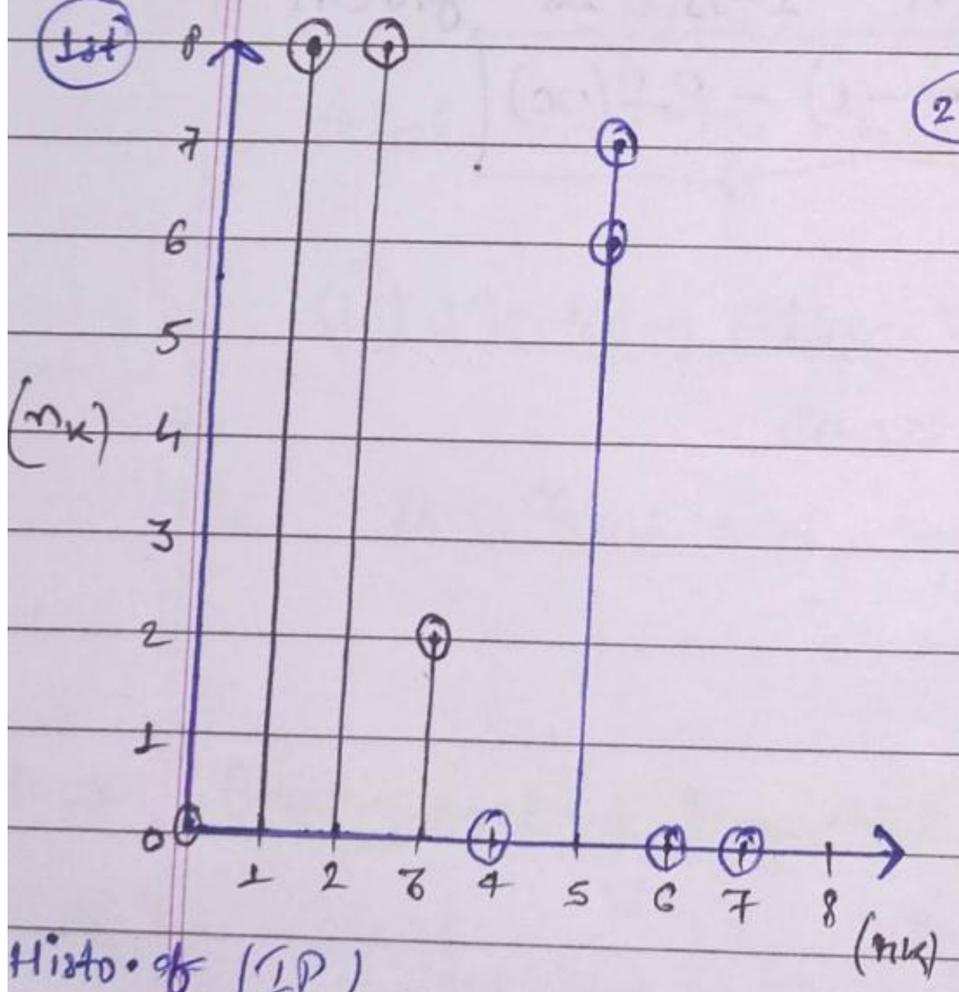
$L = 8$

* $[0 - L-1] = 0 - (8-1) = [7]$

* Gray level (r_k) 0 1 2 3 4 5 6 7
  No. of pixel (n_k) 0 8 8 2 0 7 0 0

▽ Histogram According to above value:-

(1st)



(2nd)

(b)

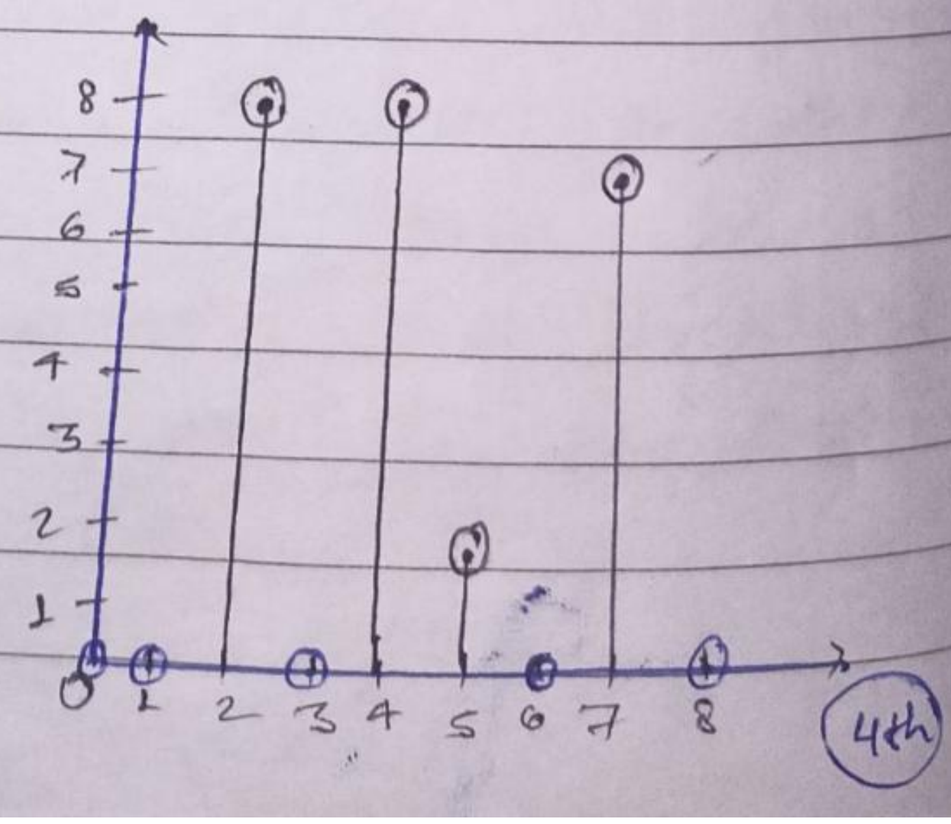
Gray level (r_k)	No. of pixel.	$(P_{r_k}) = n_k/n$	Sk COF	Sk x 7	Hist eq.
0	0	0	0	0	0
1	8	0.32	0.32	2.24	2
2	8	0.32	0.64	4.48	4
3	2	0.08	0.72	5.04	5
4	0	0	0.72	5.04	5
5	7	0.28	1	7	7
6	$n=25$	0	1	7	7
7		0	1	7	7

Histo. of (IP),

Gray level :-	0	2	4	5	7
No. of Pixel :-	0	8	8	2	7

optimized

(3rd)



Step (5) ⇒ Next page.

Gaussian Filter

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- A Gaussian Filter is a low pass filter used to reducing noise (high frequency components) and blurring noise region of image.

The filter is implemented as the odd sized Symmetric Kernel (DIP resion of a matrix) which is passed through each pixel of the region of interest to get the desired effect.

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

Where, (x, y) is coordinate(x, y)
Pi $(\pi) = 3.14$}.
'σ' → Standard deviation.

5th Step

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

input img.

→

2	4	2	2	2
4	7	5	7	4
4	7		7	4
4	7	5	7	4
2	2	2	4	1

output

Ans.