Chapter 3: Intensity Transformations & Spatial Filtering

Origin42

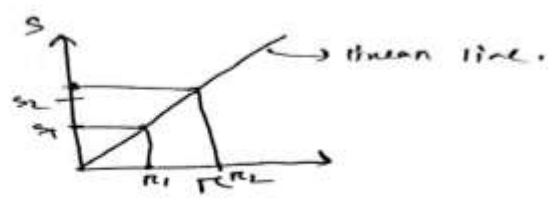
Question 2. [Marks: 13]

a) The locations of two points (r1, s1) and (r2, s2) control the shape of transformation function in Piecewise Linear Transformation. Now illustrate the relation between (r1,s1) and (r2,s2) for [5]

i. Linear Identity function. [1]
ii. Thresholding function. [2]
iii. Contrast Stretching function. [2]

2.a. Solution: **[Rafi-148]**

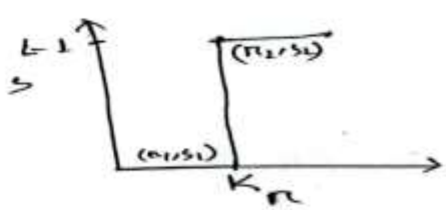
(i) When $r_1 = s_1$ and $r_2 = s_2$, its behaved like linear identity function.



(ii) Thresholding:

$(r_1, s_1) = (K, 0)$

$(r_2, s_2) = (K, L-1)$



(iii) Contrast streaching:

$(r_1, s_1) = (r_{min}, 0)$

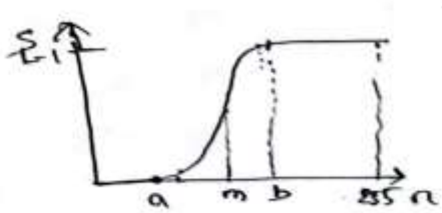
$(r_2, s_2) = (r_{max}, L-1)$

Assume

$r_{min} = a$

$r_{max} = b$

m = contrast streach point



b)	Consider a 4x4 image with 5-bit gray values [(11,10,12,7),(6,8,7,7),(5,6,11,11),(9,9,7,7)]: i. Calculate the histogram of image. [1] ii. Compute and sketch the normalized histogram of the image. [2] iii. Compute and sketch the equalize histogram of the image. [4] iv. Sketch the transformation curve. [1] (L-1)xCDF	[8]

2.b. Solution:
45.correction
Pdf (Nk/n) where n = (14??) total no. of pixel

Question 1. [Marks: 18]

a)	i. Explain with an example how a spatial filter affect an image. [2] ii. Suppose we have a 3x3 image as [(2, 5, 8), (5, 1, 3), (4, 7, 2)]. Now if we apply an average filter on this image of size 3x3 and zero padding is considered, what would be the filtered output image? [4] iii. Explain why the output of applying a median filter preserves more edge sharpness in compared to that of applying an average filter. [3]	[9]

1.a. .i. Solution:
45 ch3
Sharpening spatial filters seek to highlight fine detail. Remove blurring from images Highlight edges Useful for emphasizing transitions in image intensity

1.a. .ii. Solution:

1.a. .iii. Solution:

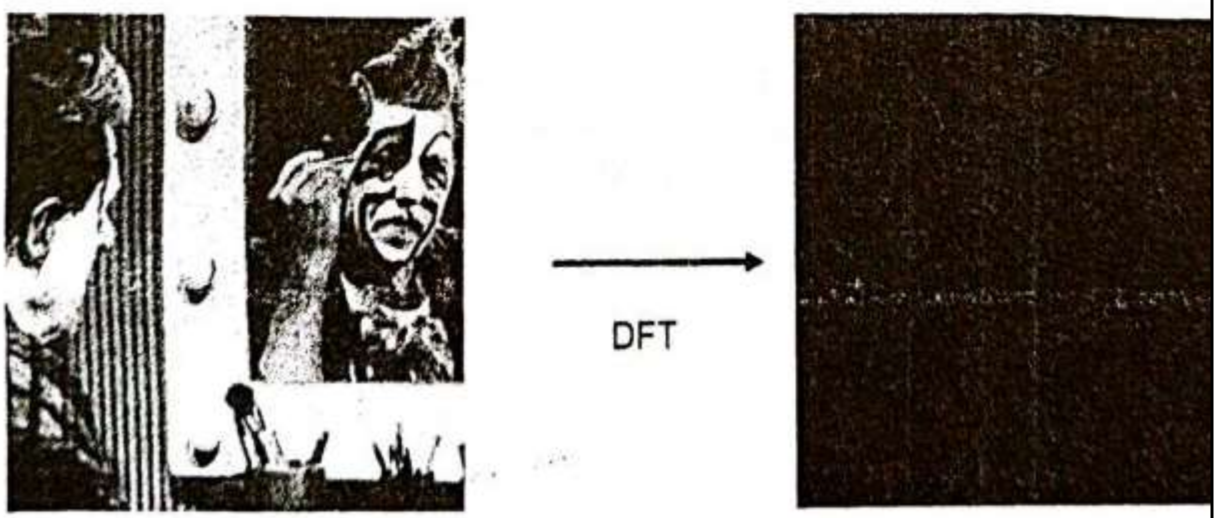
Enigma41

Question 1. [Marks: 14]

a) Suppose you have taken a photo of your grandmother. In that photo, you noticed s wrinkles on your grandmother's skin. You need to reduce the wrinkles from the p with no ringing effect. Which frequency domain filter will you use? Mention the f name and justify your answer. Also, define the filter function H(u, v) in the freque domain with appropriate figures. Besides, describe the reason for the ringing effec

Solution: Rabab 039
Mean filter. Median diye noise remove hoy. Wrinkle toh ar noise/grain na. So, smoothing mean filter dewa lagbe. Weighted mean o dewa jay i guess (?).

b) Describe the basic steps for filtering in the frequency domain. Explain why maximum frequency of spatial domain is 0.5. Consider the following image wit DFT. Only DC value is visible in the spectrum. Explain why? Also, discuss the solu of this problem.



Solution: ~ chap 4 (077)
Out of syllabus**

Question 3. [Marks: 14]

a) Consider Enigma.png is a 4x4 image with 5-bit gray values. **[8]**

16	30	8	10
25	1	12	0
6	13	9	5
19	14	29	4

i. What is histogram? Calculate the histogram of Enigma.png. [2]
ii. Compute and sketch the normalized histogram of the image. [2]
iii. Compute and sketch the equalize histogram of the image. [3]
iv. Sketch the transformation curve. [1]

3.a. Solution: 024

(i)

Histogram: In Statistics, Histogram is a graphical representation showing a visual impression of the distribution of data.

A histogram of an image is a graphical representation of the distribution of pixel intensities

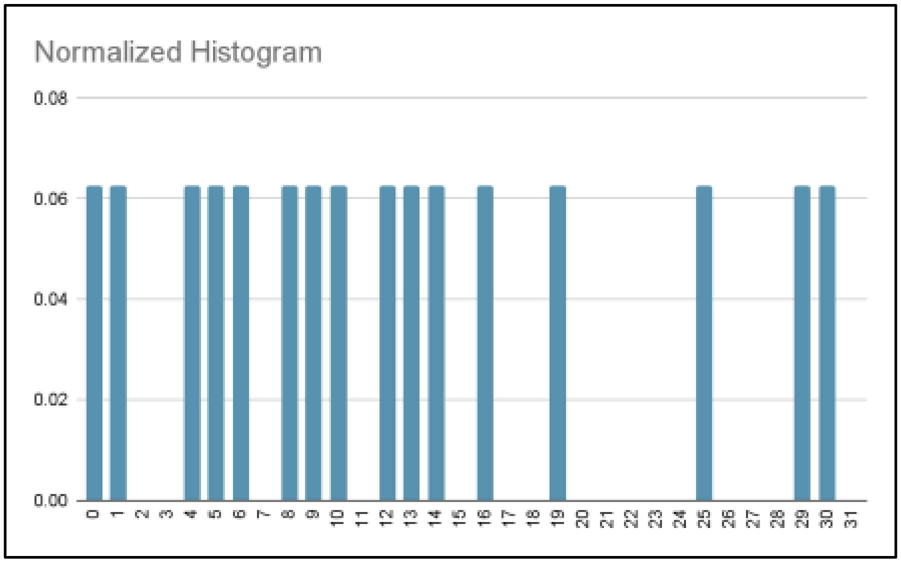
An Image Histogram is a type of histogram that acts as a graphical representation of the lightness/color distribution in a digital image. It plots the number of pixels for each value.

h(16)=1, h(30)=1, h(8)=1, h(10)=1, h(25)=1, h(1)=1, h(12)=1, h(0)=1,
h(6)=1, h(13)=1, h(9)=1, h(5)=1, h(19)=1, h(14)=1, h(29)=1, h(4)=1

(ii)

Total h(rk) = 16
Normalized values for histogram:
P(16)=P(30)=P(8)=P(10)=P(25)=P(1)=P(12)=P(0)=P(6)=P(13)=P(9)=P(5)=P(19)=P(14)=P(29)=P(4)=1/16 = 0.0625
Others, P(rk) = 0

For 5-bit gray value, bit range = 0 to (2^5 - 1) = 0 to 31



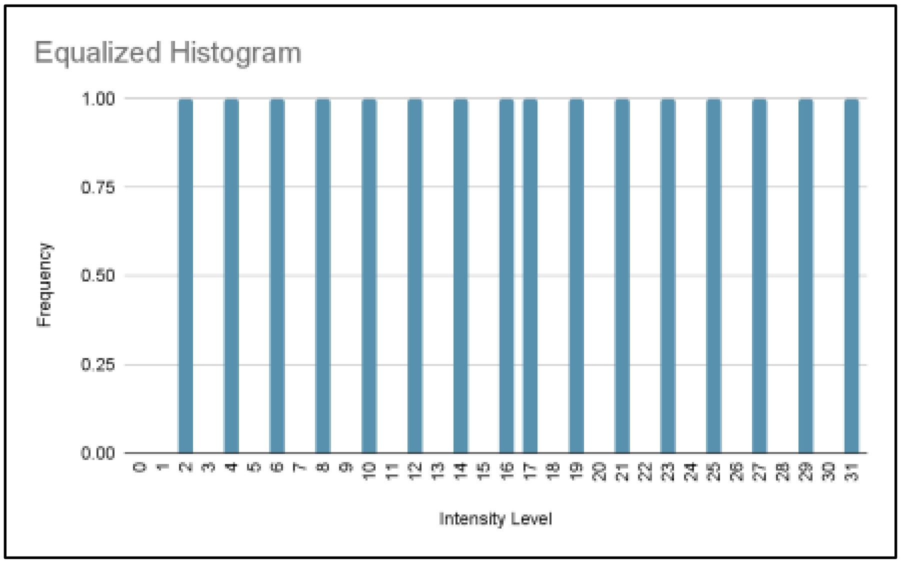
(iii)

What's the point of this type of sub-questions where I have to rewrite (i), (ii) again in (iii) !

For equalized histogram,

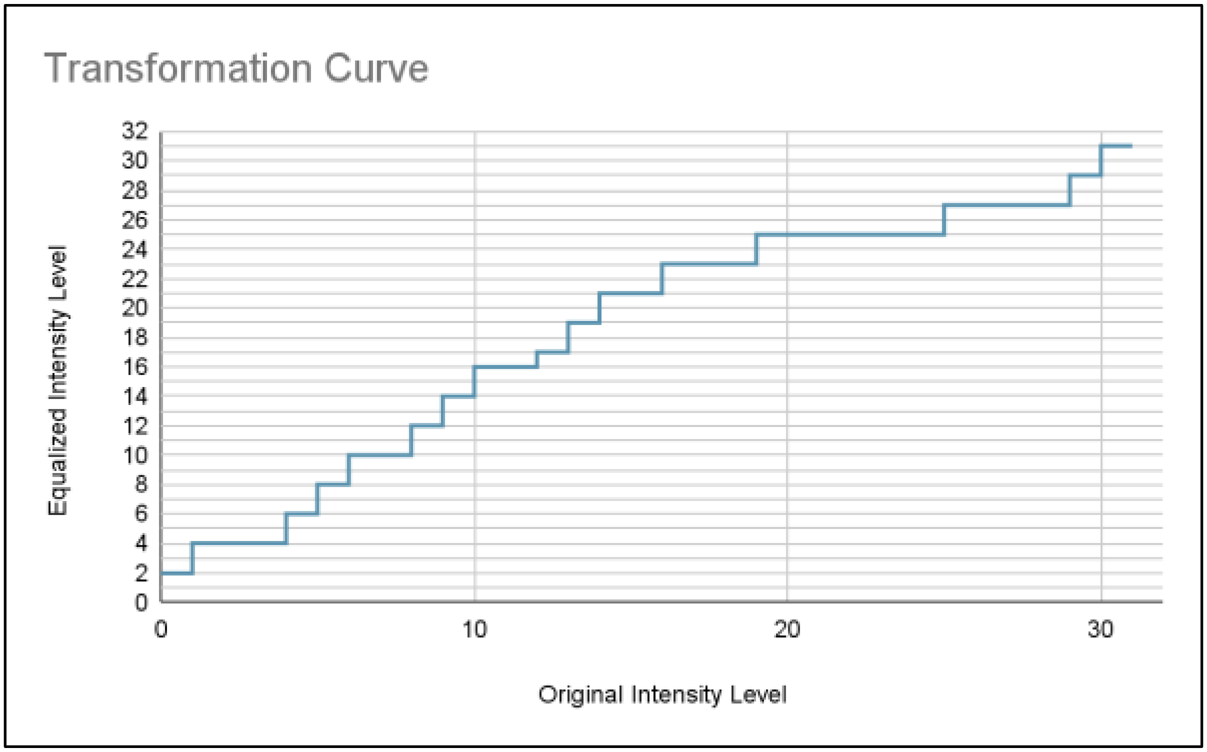
Intensity rk	Frequency h(rk)	PDF P(rk)	CDF	CDF x (L-1)	Roundoff sk
0	1	0.0625	1/16 =0.0625	1.9375	2
1	1	0.0625	2/16=0.125	3.875	4
2	0	0	0.125	3.875	4
3	0	0	0.125	3.875	4
4	1	0.0625	3/16=0.1875	5.8125	6
5	1	0.0625	0.25	7.75	8
6	1	0.0625	0.3125	9.6875	10
7	0	0	0.3125	9.6875	10
8	1	0.0625	0.375	11.625	12
9	1	0.0625	0.4375	13.5625	14
10	1	0.0625	0.5	15.5	16
11	0	0	0.5	15.5	16
12	1	0.0625	0.5625	17.4375	17
13	1	0.0625	0.625	19.375	19
14	1	0.0625	0.6875	21.3125	21
15	0	0	0.6875	21.3125	21
16	1	0.0625	0.75	23.25	23
17	0	0	0.75	23.25	23
18	0	0	0.75	23.25	23
19	1	0.0625	0.8125	25.1875	25
20	0	0	0.8125	25.1875	25

21	0	0	0.8125	25.1875	25
22	0	0	0.8125	25.1875	25
23	0	0	0.8125	25.1875	25
24	0	0	0.8125	25.1875	25
25	1	0.0625	0.875	27.125	27
26	0	0	0.875	27.125	27
27	0	0	0.875	27.125	27
28	0	0	0.875	27.125	27
29	1	0.0625	0.9375	29.0625	29
30	1	0.0625	1.0	31	31
31	0	0	1.0	31	31



(iv)

Transformation Curve:

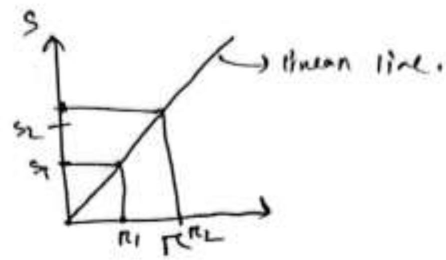


b) Contrast Stretching is one type of piecewise linear transformation function. In piecewise linear transformation the locations of points (r1, s1) and (r2, s2) control the shape of transformation function. Now illustrate the relation between (r1,s1) and (r2,s2) for **[6]**

i. Linear Identity [1]
ii. Thresholding [2]
iii. Contrast Stretching [3]

3.b. Solution:

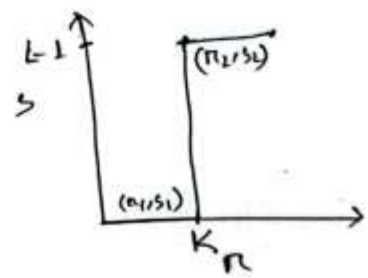
(i) When $r_1 = s_1$ and $r_2 = s_2$, its behaved like linear identity function.



(ii) Thresholding:

$(r_1, s_1) = (K, 0)$

$(r_2, s_2) = (K, L-1)$



(iii) Contrast streaching:

$(r_1, s_1) = (r_{min}, 0)$

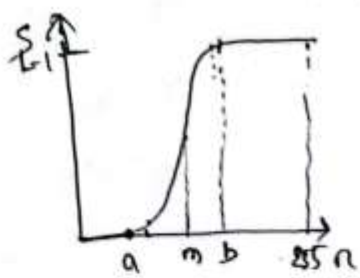
$(r_2, s_2) = (r_{max}, L-1)$

Assume

$r_{min} = a$

$r_{max} = b$

m = contrast streach point



Ans given Above

4.

4.b. Solution:
chapter 02

Recursive40

1.

a) What is histogram of an image? Describe the histogram e
9, 7, 7), (5, 6, 11, 11), (6, 8, 7, 7), (11, 10, 12, 7)} is a
Compute and sketch the equalize histogram of it.

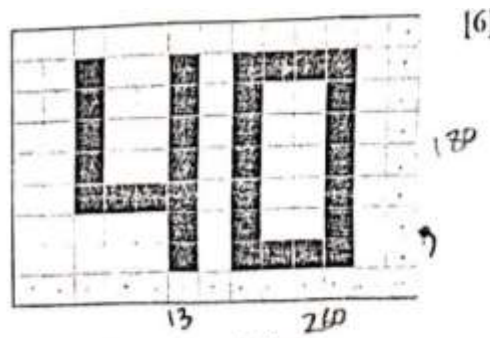
1.a. Solution:
45
Histogram is a graphical representation showing a visual impression of the distribution of data.
1. Find the frequency of each value represented on the horizontal axis of the histogram i.e. intensity in the case of an image.
2. Calculate the probability density function (PDF) for each intensity value.
3. After finding the PDF, calculate the cumulative density function (CDF) for each intensity's frequency.
4. The CDF value is in the range 0-1, so we multiply all CDF values by the largest value of intensity i.e. 255 or (L-1).
5. Round off the final values to integer values.

1.

b) Consider Recursive_40.bmp is a 180 × 260 binary image.

i. Calculate the histogram of Recursive_40.bmp.
ii. Calculate the bit size of Recursive_40.bmp.
iii. Describe how the histogram differ for the dark, bright, low contrast or high contrast image of the same scene.

[6]



Recursive_40.bmp

1.b. Solution: L = 2^2, For 2-bit gray value, bit range = 0 to (2^2 - 1) MxN=9x13

Given image is 9 x 13
Actual image is 180 x 260
So, every square(pixel) unit in the given image holds [(180/9) x (260/13)] = [20 x 20] pixels
Number of black pixels in given image = 32
So, number of black pixels in actual image = 32*(20x20) = 12,800
Number of white pixels in given image = ((9*13) - 32) = 85
So, number of white pixels in actual image =85 *(20 x 20) =23200

45.

Dark image Components of histogram are concentrated on the low side of the gray scale

Bright image Components of histogram are concentrated on the high side of the gray scale

Low contrast image Histogram is narrow and centered toward the middle of the gray scale

Histogram covers broad range of the gray scale and the distribution of pixels is not too far from uniform with very few vertical lines being much higher than the others

Question 4. [Marks: 14]

a) Define the Power Law intensity transformation function that enhance an image. What is gamma Correction? For a given image using power law transformation function, what will be the effect on output image: [8]

i. if $\gamma > 1$?
ii. if $\gamma < 1$? and
iii. if $\gamma = 1$?

Suppose, you have made a software which performs intensity transformation of a given image using power law transformation. In default setting, it uses $\gamma = 2.5$.

iv. Now if a user changes $\gamma = 5.0$, what will be the effect on the output image?
v. Repeat iv for $\gamma = 0.04$.

4.a. Solution: (Rafi-148)

The powerlaw transformation also called gamma transformation is a technique that uses a power law function to adjust the pixel value of an image.

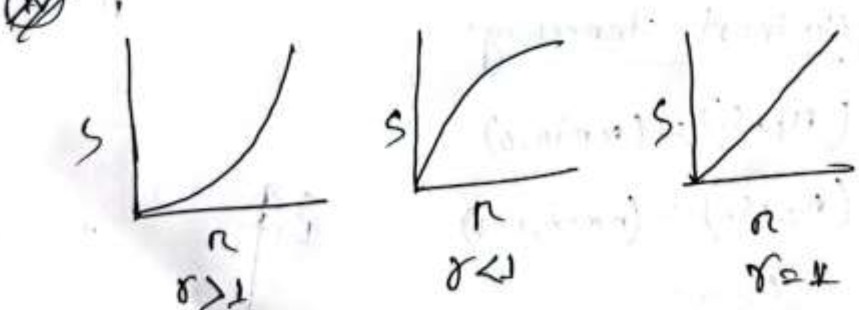
→ Gamma correction can be used to control the overall brightness of an image.

$$S = C \times r^{\gamma}$$

(i). $\gamma > 1$; behave like Inverse log Transformation function

(ii) $\gamma < 1$; " " logarithmic " "

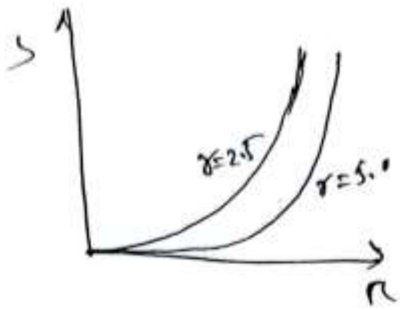
(iii) $\gamma = 1$; " " linear identity " "



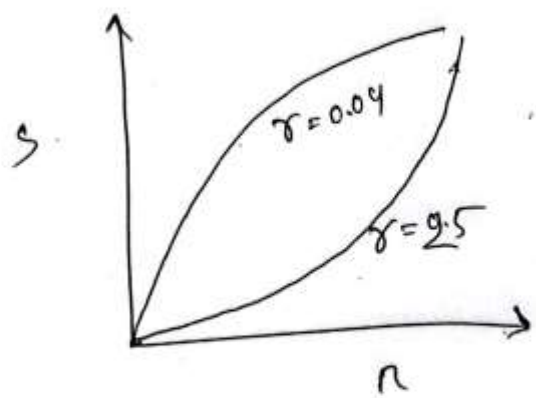
(iv) If we change $\gamma = 2.5$ to $\gamma = 0.5$ Dark portion of Image get more dark.

Iv . Dark pixel become more darker .

V. Dark pixel become more brighter.



(V) If we change γ = 2.5 to γ = 0.04. Dark portion of image get Bright. It behave like logarithmic Transformation function.



b) Define the Bit Plane Slicing method. What are the three main goals of bit plane slicing? [6]
Consider I = {(150, 60), (60, 210)} as a 2 X 2 image with 8-bit gray values.

i. Give 8 bit planes of I.
ii. Determine the reconstructed image using bit planes 8 and 7.

128 0
0 192

4.b. Solution: 039, 024

Bit plane slicing: Bit plane slicing is a method of representing an image with one or more bits of the byte used for each pixel. One can use only MSB to represent the pixel, which reduces the original gray level to a binary image.

The three main goals of bit plane slicing is:

- Converting a gray level image to a binary image.
- Representing an image with fewer bits and corresponding the image to a smaller size.
- Enhancing the image by focussing.

(i)

Given I,

Decimal	
150	60
60	210

=>

Binary	
10010110	00111100
00111100	11010010

So, 8 bit planes of I,

8th plane	
1	0
0	1

7th plane	
0	0
0	1

6th plane	
0	1
1	0

5th plane	
1	1
1	1

4th plane	
0	1
1	0

3rd plane	
1	1
1	0

2nd plane	
1	0
0	1

1st plane	
0	0
0	0

(ii)

Reconstructed image using bit plane 8 and 7 are,

8th plane			7th plane			Reconstructed Image	
1	0	+	0	0	=	1x2^(8-1)+0x2^(7-1) = 128	0x2^(8-1)+0x2^(7-1) = 0
0	1		0	1		0x2^(8-1)+0x2^(7-1) = 0	1x2^(8-1)+1x2^(7-1) = 192

Prototype39

3. b.

ii. What is the objective of sharpening spatial filters? The following figure shows a 3-bit image of size 5-by-5 in the square. Calculate the gradient magnitude and angle using **Sobel mask** at the highlighted center pixel. [3.5] **[6.5]**

5x5 Image

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

Solution: 024

Sharpening spatial filter objective:

- Remove blurring from images
- Highlight edges
- Useful for emphasizing transitions in image intensity

Calculation ...

SOBEL OPERATOR ULTA NEYA HOISE.

Highlighted center pixel values,

1	6	4
5	2	7
2	6	0

Using Sobel operator Gx,

1	6	4		-1	-2	-1		-1	-12	-4
5	2	7	X	0	0	0	=	0	0	0
2	6	0		1	2	1		2	12	0

Gx = -1-12-4+0+0+0+2+12+0 = -3

Using Sobel operator Gy,

1	6	4		-1	0	1		-1	0	4
5	2	7	X	-2	0	2	=	-10	0	14
2	6	0		-1	0	1		-2	0	0

Gy = -1+0+4-10+0+14-2+0+0 = 5

Gradient magnitude, G = |Gx| + |Gy| = 8
Angle, Theta = tan^(-1) (Gy/Gx) = -59.036

5.

b)	Figure presents the result of applying a filter to an image below. Now answer the following questions. i. What type of filter do you think was used? Justify your answer. ii. Propose at least one way to improve the result.	[3]

3

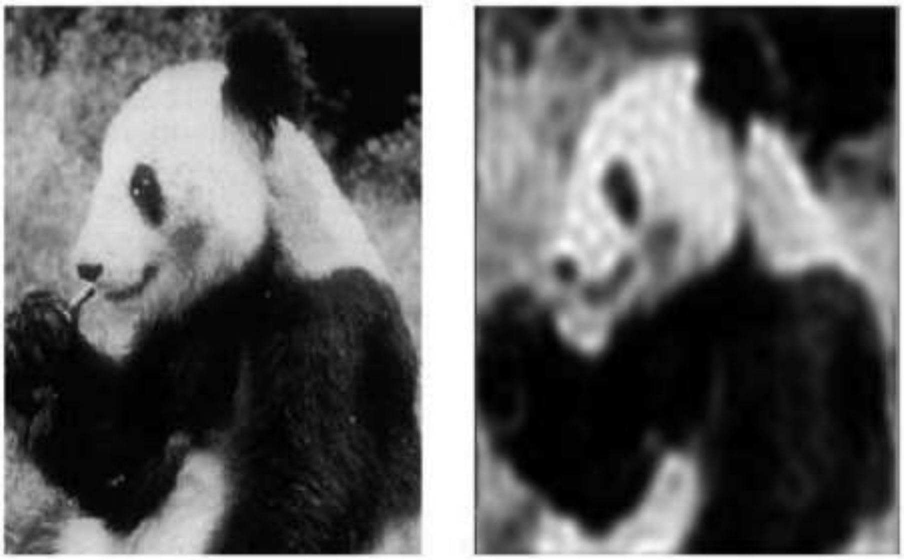


Figure: Image before filtering (left) and after filtering(right)

Solution: 🙂

6.

a)	An 8-bit digital image has a histogram where the gray levels are equally distributed in the range from 160 to 220 (uniform distribution). Sketch the new histograms and write the transformation functions for each of the following operations. Also, describe the produced effect on the image contrast and brightness. i. Calculation of the image negative. ii. Addition of 50 to all pixel gray levels. iii. Application of a threshold function with a threshold value of 128.	[6]

Solution:

b) Consider the spatial filter H given by **[3]**

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

Determine the maximum and minimum possible values that a pixel, to which this spatial filter is applied, can have. Do not apply any type of normalization.

Solution:

c) Consider the original and processed image given in Figure below. Explain, which is the most likely processing from the list below to give this result? **[3.5]**

i. Edge detection by a Laplacian operator.

ii. Median filtering followed by an edge detection.

iii. Edge detection followed by a median filtering.

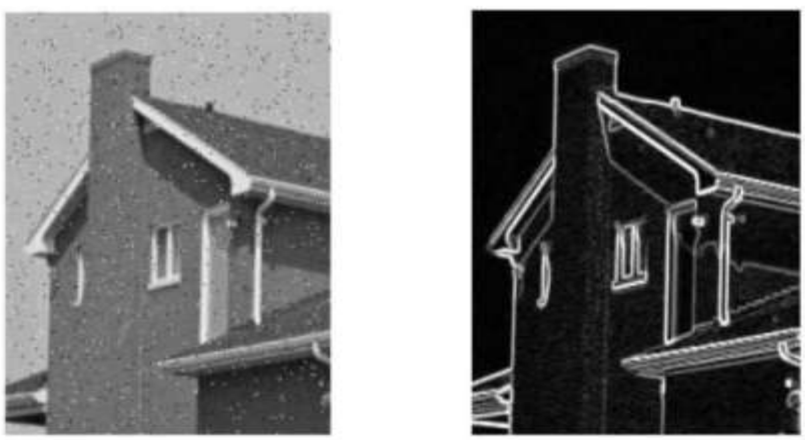


Figure: Original image (left) and processed image (right)

Solution:

Return38

2.

a) Define median filter. "Median filtering is much better suited than averaging for the removal of salt-and-pepper noise"- justify the statement.	**[2]**

Solution:

• No new pixel values introduced
• Never replace with largest or smallest value
• Removes spikes: good for impulse, salt & pepper noise
• Non-linear filter

b) i) Derive the following Laplace filter mask. **[5]**

1	1	1
1	-8	1
1	1	1

ii) Apply the following **Laplace** on the highlighted pixel as shown in below.
iii) Apply the following **Laplace 2nd derivative** on the highlighted pixel as shown in below.
iv) Apply a **3 × 3 Mean filter** on the highlighted pixel as shown in below.
v) Apply a **3 × 3 Median filter** on the highlighted pixel as shown in below.

0	−1	0
−1	4	−1
0	−1	0

153	157	156	153	155
159	156	158	156	159
155	158	**154**	156	160
154	157	158	160	160
157	157	157	156	155

Solution: Rabab 039

(iii) If we include the 8-neighbors of an image, the second derivative can be given by,

$\nabla^2 f = \partial^2 f/\partial x^2 + \partial^2 f/\partial y^2 + \partial^2 f/\partial xy + \partial^2 f/\partial yx$
$= [f(x+1,y)+f(x-1,y) - 2f(x,y)] + [f(x,y+1)+f(x,y-1) - 2f(x,y)] + [f(x+1,y+1)+f(x-1,y-1) - 2f(x,y)] + [f(x+1,y-1)+f(x-1,y+1) - 2f(x,y)]$
$= [f(x+1,y)+f(x-1,y) + f(x,y+1)+f(x,y-1) + f(x+1,y+1)+f(x-1,y-1) + f(x+1,y-1)+f(x-1,y+1)] - 8f(x,y)$

Writing in two dimensional matrix, it can be given as:

1	1	1

1	-8	1
1	1	1

(i)

0	-1	0
-1	4	-1
0	-1	0

153	157	156	153	155
159	156	158	156	159
155	158	**154**	156	160
154	157	158	160	160
157	157	157	156	155

Step 1:

154*4 – 158- 156-158-158 = -14

So the value after filter = **-14**

We call the resultant image: **sharpened image.**

Step 2:

Filtered image=original + sharpened image

The value in the filtered image=154-14 =130

156	158	156
158	130	156
157	158	160

(iii)

1	1	1
1	-8	1
1	1	1

153	157	156	153	155
159	156	158	156	159
155	158	**154**	156	160
154	157	158	160	160
157	157	157	156	155

156	158	156
158	127	156
157	158	160

Step 1:

154*(-8) + 156*1 + 158*1 + 156*1 + 158*1 + 156*1 + 157*1 + 158*1 + 160*1 = 17

So, the value after filter = **17**. We call the resultant image: **sharpened image.**

Step 2:

Filtered image = Original - sharpened image [∵ For $w_5<0$, $g(x,y) = f(x,y) - \nabla^2 f$]

= 154 - 17 = 127

(iv)

Applying 3x3 mean, the kernel would be:

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

Applying the filter, the value of the center pixel would be = (156+158+156+158+154+156+157+158+160)/9 = 1,413/9 = 157

So, the new image will be:

156	158	156
158	157	156
157	158	160

(v)

Sorting all the pixels in the 3x3 area around the highlighted pixel, we get,
[154, 156, 156, 156, **157**, 158, 158, 158, 160].
Here, the median is 157. So, the new image will be:

156	158	156
158	157	156
157	158	160

c) The histogram of an image is shown in Table 1. Show the histogram table for a desired image where the number of pixel distribution will be in reverse order of the original image. **[5]**

Table 1

Gray Levels (r)	2	18	33	58	67	96	114	152	184	206	220	245
No. of pixels	43	11	47	31	27	49	71	21	14	52	24	10

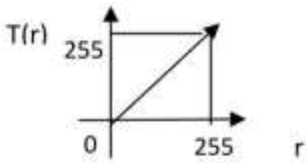
Sketch the normalize histograms of the original and desired images. What will be the output after applying histogram equalization process on the original image (Table 1)? Show your calculations.

Solution:

3.

a) The following figure illustrates the intensity transformation, T(r) = r. **[2]**

3



Now illustrate and explain the following intensity transformation functions:
i) T(r) = r + 100
ii) T(r) = r × 10

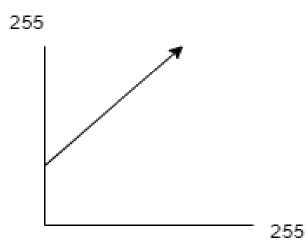
Solution: Rabab 039
(i) For T(r) = r + 100, the y-intercept will be at 100 i.e. every output pixel's intensity will be 100 more than that of the corresponding input pixel. It is a Linear transformation.

(ii) For T(r) = r x 10, the slope will be at 10 times steeper i.e. every output pixel's intensity will be 10 times that of the corresponding input pixel. It is a Linear transformation.

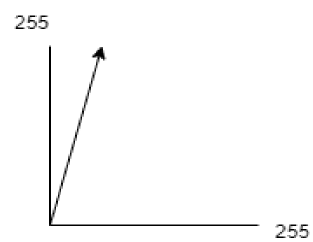
b) i) Explain a simple image enhancement technique that improves the contrast in an image by stretching the range of intensity values. **[5]**

3

ii) Define intensity transformation function T(r) for the Thresholding.



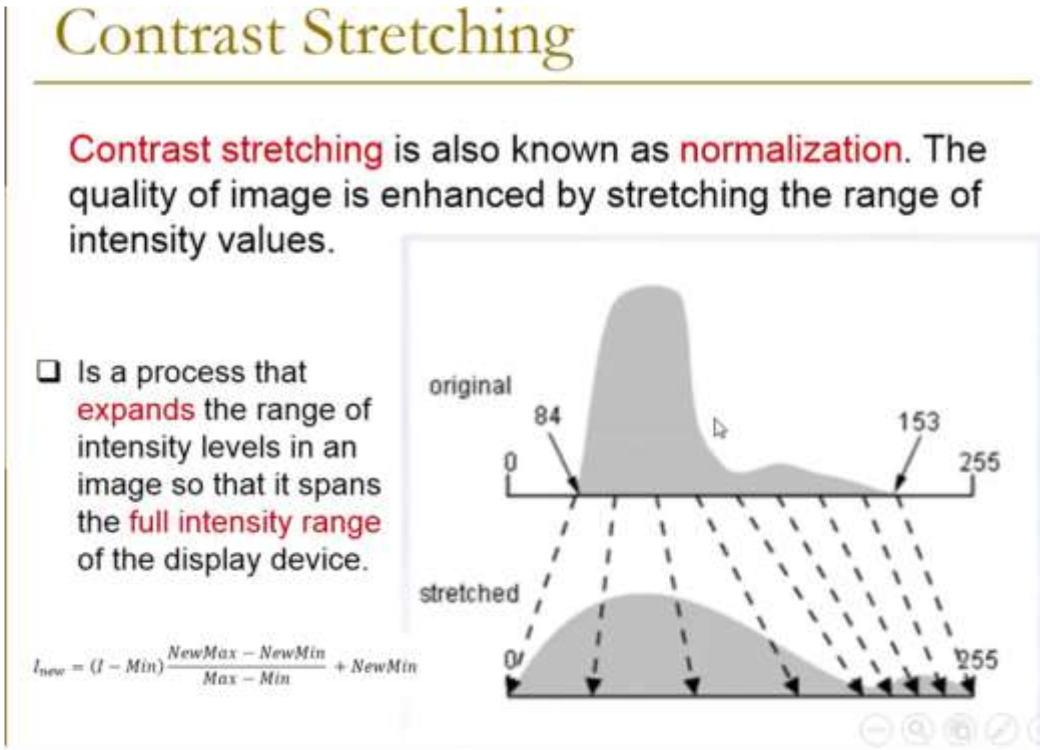
T(r) = r + 100



T(r) = r x 10

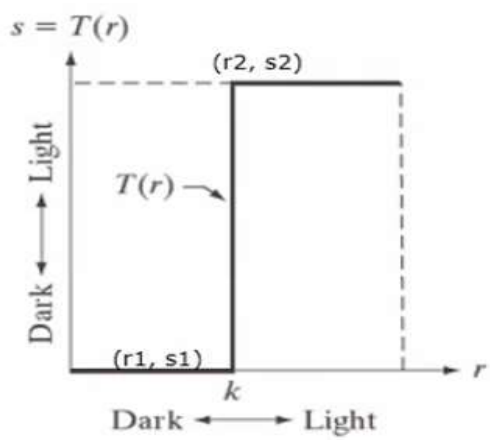
Solution: Rabab 039

(i)



(ii)

Thresholding is a form of contrast stretching which creates a binary image by introducing a threshold value at the midpoint of the original image's contrast. If the input pixel's value is equal to or greater than the threshold value, its new value will be L-1 (where L is the maximum gray level range of the input image), otherwise, it will be zero.



Thresholding:

c) Consider figure ***I*** as a 2 X 2 image with 8-bit gray values. **[5]**

3

i. Give 8 bit planes of ***I***.

ii. Determine the reconstructed image using bit planes 8 and 7.

120	60
60	250

I

Solution:

Malware37

3.

a) i. In the following image of Fig 3.1, you can find an **edge** labeled in the red region. Which form of discontinuity creates this kind of **edge**? [1] **[6]**

Fig 3.1

Fig 3.2

5	10	7	9
12	11	8	2
21	32	25	14
30	31	20	21

Fig 3.3

ii. To blur an image, can you use a linear filter? Justify your answer with an example. [1]

iii. Suppose we have a noisy image as in Fig 3.2. The type of noise in the image is called salt-and-pepper noise. What is the best way to denoise this image? Describe your process with explanation. [1]

iv. If we convolve an image with a 3x3 matrix as [0, 0, 0, 0, 0, 1, 0, 0, 0], what would be the relation between the original and modified image? [1]

v. How can you smooth an image? If you subtract your smoothed image from the original image, what will happen if we add the subtracted result back to the original image? [1]

vi. Sharpen the 4x4 image of Fig 3.3 using the second derivative operator and draw your output image (consider zero-padding for the border pixels). [1]

Solution:

45.
3. Median filter
4.image will be shifted towards left by 1 pixel

b) The histogram of an image is shown in Table 3.1. Show the histogram table for a desired image where the number of pixel distribution will be in reverse order of the original image. For example – there will be 43 pixels in gray level 2, 11 pixels in gray level 18, and vice-versa. **[4]**

Table 3.1

Gray Levels (r)	2	18	33	58	67	96	114	152	184	206	220	245
No. of pixels	10	24	52	14	21	71	49	27	31	47	11	43

Sketch the normalized histograms of the original and desired images. What will be the output after applying histogram equalization process on the original image (Table 3.1)?

Solution:

5.

b) Consider the two image subsets, S_1 and S_2, shown in the following figure. For $V = \{1\}$, determine whether these two subsets are (a) 4-adjacent, (b) 8-adjacent, or (c) m-adjacent. **[4]**

$$
\begin{array}{c|cccc|cccc|c}
 & & & S_1 & & & & S_2 & & \\
\cline{2-9}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\
1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 \\
1 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 0 & 0 \\
0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\
\cline{2-9}
\multicolumn{1}{c}{0} & 0 & 0 & 1 & \multicolumn{1}{c}{1} & 0 & 0 & 1 & \multicolumn{1}{c}{1} & 1
\end{array}
$$

Solution:

COREi36

1.

a) What is histogram of an image? Describe how the histogram differ for the dark, bright, low contrast or high contrast image of the same scene. [3] L-6 S-24,26

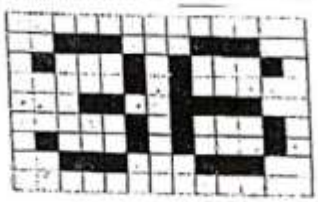
Solution: 019

A histogram of an image is a graphical representation of the distribution of pixel intensities or colors in the image. It consists of an x-axis representing possible intensity or color values and a y-axis representing the frequency of pixels with each value.

For different types of images of the same scene:

1. Dark image has a left-shifted histogram with more low-intensity pixels.
2. Bright image has a right-shifted histogram with more high-intensity pixels.
3. Low-contrast image has a flatter histogram with less variation.
4. High-contrast image has a histogram with pronounced peaks and valleys, indicating a wide intensity range.

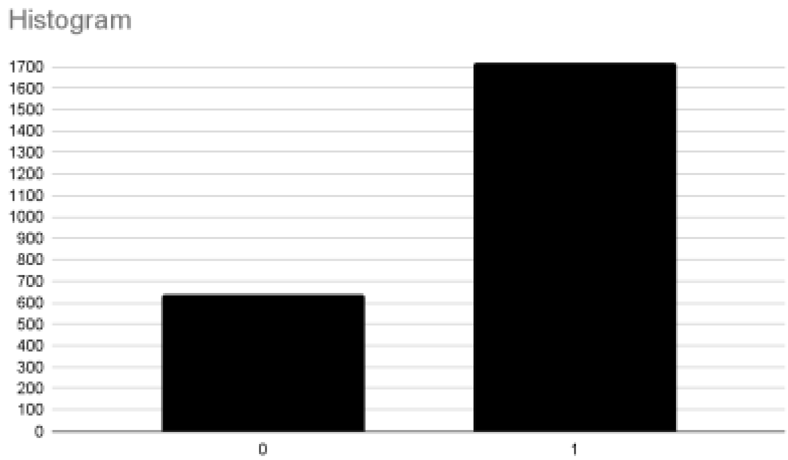
b) Consider *Corei_36.bmp* is a *180 × 260* binary image. [2]



i. Calculate the histogram of *Corei_36.bmp* and sketch it.

ii. Calculate the bit size of *Corei_36.bmp*. → কেমনে হবে?

Solution: (i) Rabab 039
Given image is 9 x 13
Actual image is 180 x 260
So, every square unit in the given image holds (180/9) or (260/13) = 20 pixels
Number of black pixels in given image = 31
So, number of black pixels in actual image = 31*20 = 620
Number of white pixels in given image = ((9*13) - 31) = 86
So, number of white pixels in actual image = 86*20 = 1720

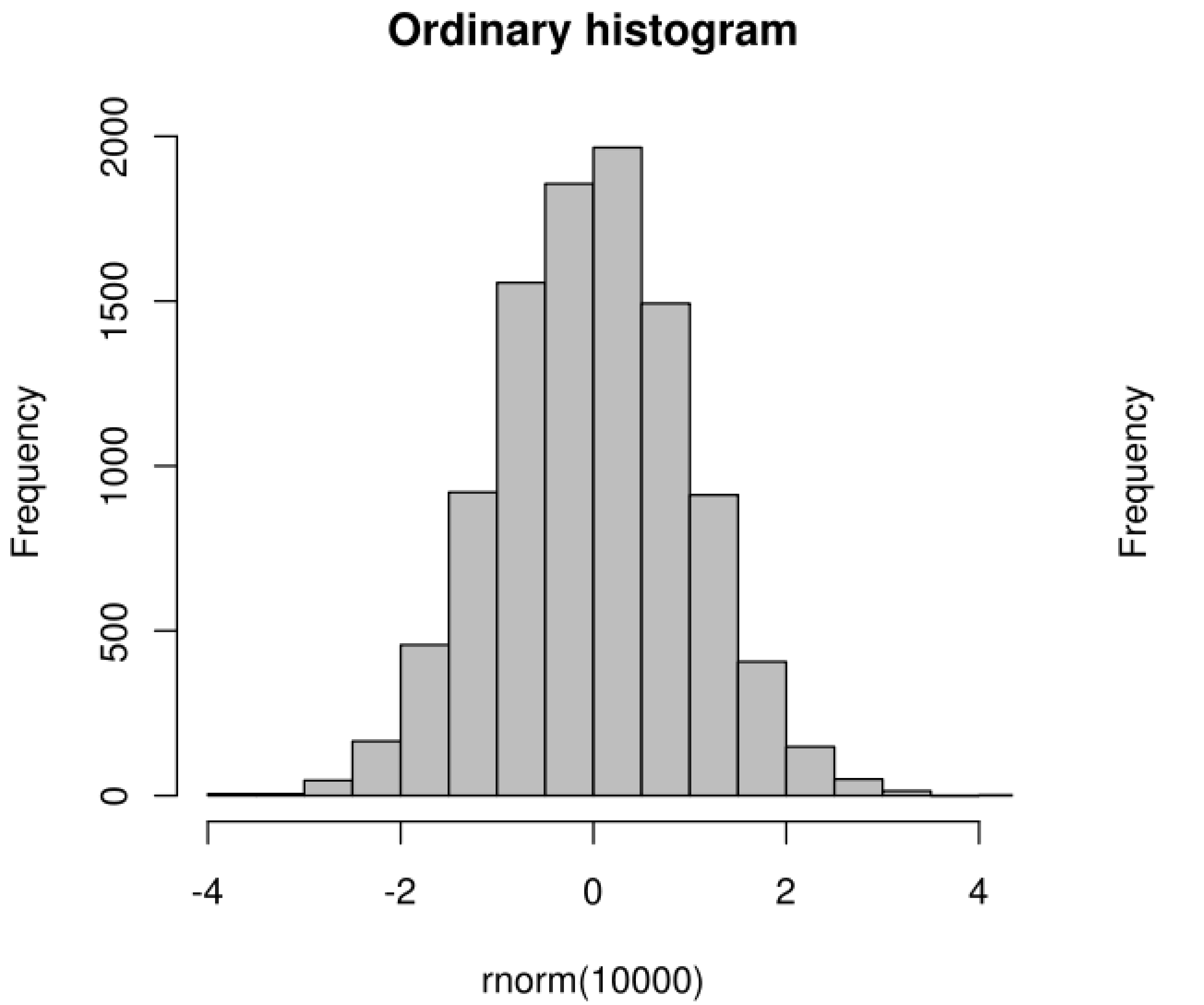


(ii)

c) What do you understand by cumulative histogram? Explain the histogram equalization algorithm. C-6 [3]

Solution: Sujon 49

A cumulative histogram is a histogram that has an additional line or curve that plots the cumulative frequency or relative frequency of the data on the vertical axis. The cumulative frequency is the sum of the frequencies of all the values less than or equal to a given value.



Swarna(061)

Histogram Equalization - Algorithm

1. Find the frequency of each value represented on the horizontal axis of the histogram i.e. intensity in the case of an image.
2. Calculate the probability density function (PDF) for each intensity value.
3. After finding the PDF, calculate the cumulative density function (CDF) for each intensity's frequency.
4. The CDF value is in the range 0-1, so we multiply all CDF values by the largest value of intensity i.e. 255 or (L-1).
5. Round off the final values to integer values.

d) Consider the histogram of an image as shown in following table. [6]

Gray levels (r)	0	1	2	3	4	5	6	7
No of pixels	790	1023	850	656	329	245	122	81

i) Compute and sketch the normalized histogram of it.

ii) Compute and sketch the equalize histogram of it.

iii) Show the mapping of the new gray level values into number of pixels.

iv) Plot the Histogram Equalization Transformation function.

v) Show that a second pass of histogram equalization (on the histogram equalized image) will produce exactly the same result.

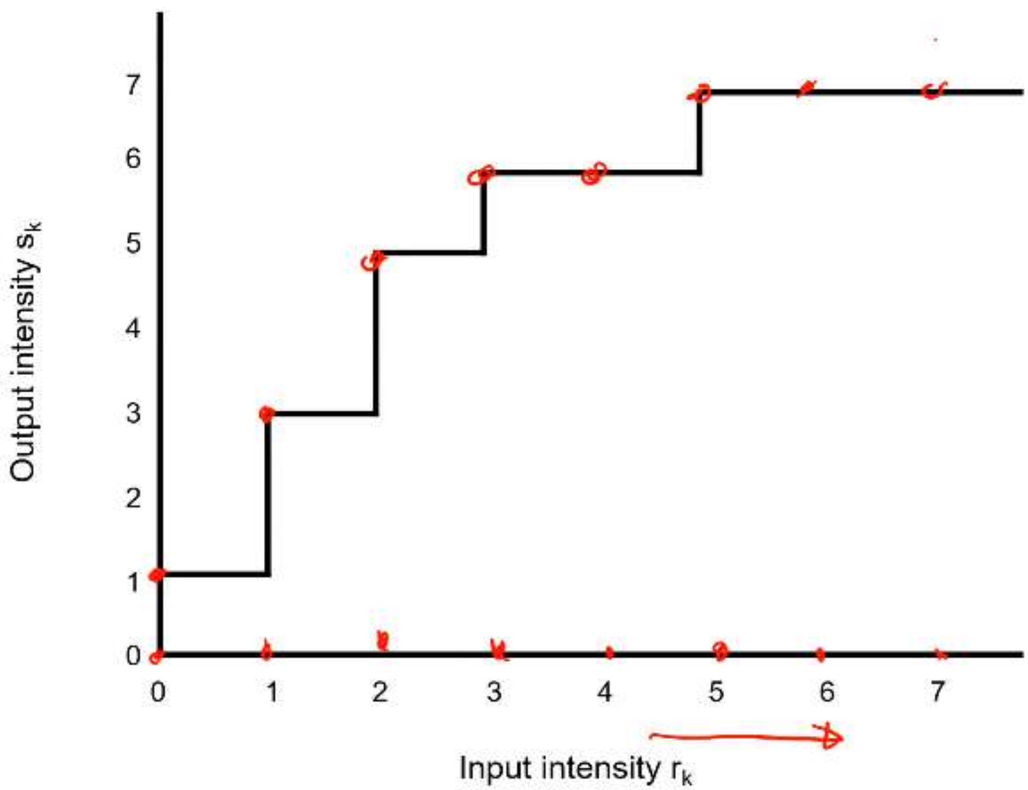
Solution:45
Normalize:
Total no of pixel nk = 4096 , P(rk) = N/nk
Bin Pos: 0 to 7
H(rk):
P(rk):

Problem: Equalize the given histogram of image below:.

Grey level (r)	0	1	2	3	4	5	6	7
Number of pixels	790	1023	850	656	329	245	122	81

Grey level r_k	Histogram $h(r_k)$ (Original image)	(CDF)	S_k = ((L-1) /MxN) x CDF	Rounding off S_k	No. of Pixels n_k (Output image)
0	790	790	1.35	1	790
1	1023	1813	3.09	3	1023
2	850	2663	4.55	5	850
3	656	3319	5.67	6	(656+329 =) 985
4	329	3648	6.23	6	
5	245	3893	6.65	7	(245+122+81=) 448
6	122	4015	6.86	7	
7	81	4096	7	7	

Histogram Equalization Transformation function



Histogram Equalization

Gray Levels (r_k)	No. of Pixels n_k	(PDF) $Pr(rk) = nk/n$	(CDF) $Sk = \sum Pk(rk)$	(L-1) Sk = 7 x Sk	Rounding off
0	790	0.19	0.19	1.33	1
1	1023	0.25	0.44	3.08	3
2	850	0.21	0.65	4.55	5
3	656	0.16	0.81	5.67	6
4	329	0.08	0.89	6.23	6
5	245	0.06	0.95	6.65	7
6	122	0.03	0.98	6.86	7
7	81	0.02	1	7	7
	n = 4096	**1**			

Equating Gray Levels to No. of Pixels:

0 -> 0
1 -> 790
2 -> 0
3 -> 1023
4 -> 0
5 -> 850
6 -> 985
7 -> 448

Total : 4096

Hence Verified!!!

2.

c) Find the number of bits required to store a 256 X 256 image with 32 gray levels. Write the expression to find the number of bits to store a digital image. [2]

Solution: 019

Number of Bits = Width x Height x Number of Gray Levels
= 256 x 256 x 5
= 327680 bits

d) Write the three major goals of image enhancement in spatial domain. Why do we need the processing in frequency domain where spatial domain is quite easy to understand? [4]

Solution:

5.

5. (a) Consider the following image: [5]

	0	1	2	3 (3,0)
0	3	1	2	1(a)
1	2	2	0	2
2	1	2	1	1
3	1(b)	0	1	2

(0,3)

Assume that $V = \{0,1\}$.

i) Does a 4 – path exists between a and b.

ii) Does a m – path exists between a and b.

(**Explain your answers**)

iii) Calculate the distances, D_4 = ?, D_8 = ?, D_e = ? for the point (a) & (b).

Solution:

7.

a) What does Mean or Box filter do? Design a weighted average filter mask where each of the 4-neighbor gets half of the weight and each of the diagonal neighbor gets one fourth of the weight of the center pixel. [4]

Solution:

b) The following figure shows [7]

A. a 3-bit image of size 5-by-5 in the square, with x and y coordinates specified,

B. a Laplacian filter and

3 C. a low-pass filter.

A

y \ x	0	1	2	3	4
0	3	7	6	2	0
1	2	4	6	1	1
2	4	7	2	5	4
3	3	0	6	2	1
4	5	7	5	1	2

B — Laplacian filter

0	1	0
1	-4	1
0	1	0

C — Low pass filter

0.01	0.1	0.01
0.10	0.56	0.10
0.01	0.1	0.01

Now find,

i. The output of a 3 × 3 mean filter.

ii. The output of a 3 × 3 median filter.

iii. The output of the 3 × 3 Laplacian filter shown above at (2,3).

iv. The output of the 3 × 3 low-pass filter shown above at (3,4).

[For dealing with edge pixels use zero padding and put zero at the border in the output image]

Solution:

c) Image enhancement using Laplacian involves the following two steps: [3]

3

i. Finding the Laplacian of an image using the following Laplacian mask,

0	1	0
1	-4	1
0	1	0

ii. Subtract the Laplacian result from the original image.

Now derive a filter mask, which reduces above two steps into a single filtering operation. L - 8

Solution: