IMAGE PROCESSING

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ASSIGNMENT-1

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Q.1] Explain the process of Histogram equalization for a given image having gray levels between [0,9] perform Histogram Equalization.

Ans Histogram Equalization is an approach to enhance a given image. The idea is to design a transformation $T(\cdot)$ such that the gray values in the output are uniformly distributed in [0, 1].

Step1: For image with distinct gray values compute:

$$P_{in}(r_k) = \frac{n_k}{n} \qquad 0 \le r_k \le 1 \qquad 0 \le K \le L-1$$

L = Total no. of gray levels
n_k = No. of pixels with gray value r_k
n = total no. of pixels.

Step2: Based on CDF compute the discrete version:

$$S_k = T(r_k) = (L-1) \sum_{0}^{k} P_{in}(r_j) \qquad 0 \le k \le L-1$$

- Input:

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

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Gray Level	0	1	2	3	4	5	6	7	8
No. of pixels	0	0	6	5	4	1	0	0	0

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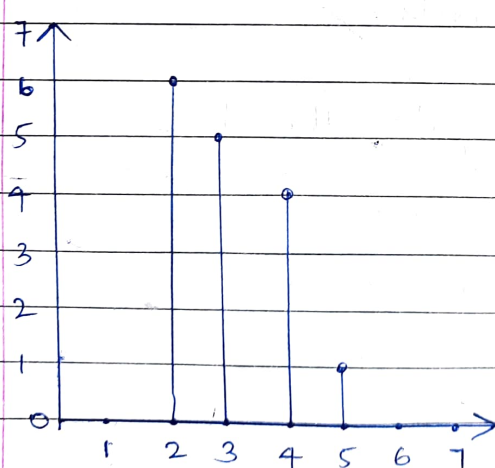
K	r_K	n_K	$P(r_K) = \frac{n_K}{n}$	$S_K = (L-1)\sum_{0}^{K} P_{in}(r_j)$	S_K
0	0	0	0	$0 \times 7 = 0$	0
1	1/8	0	0	$0 \times 7 = 0$	0
2	2/8	6	0.37	$0.37 \times 7 = 2.59$	3
3	3/8	5	0.31	$0.68 \times 7 = 4.76$	5
4	4/8	4	0.25	$0.93 \times 7 = 6.51$	7
5	5/8	1	0.062	$0.993 \times 7 = 6.94$	7
6	6/8	0	0	$0.992 \times 7 = 6.94$	7
7	7/8	0	0	$0.992 \times 7 = 6.94$	7
8	1	0	0	$0.992 \times 7 = 6.94$	7

$n = 16$

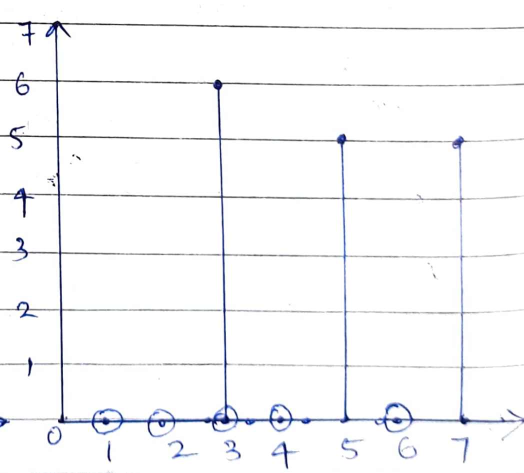
Gray level	0	3	5	7
No. of pixels	0	6	5	5

→ Histogram of Input & Output images

Input:



Output:



Output Image:

3	5	5	3
7	3	7	5
5	3	5	7
3	7	3	7

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Q.2] Explain smoothening & sharpening filters in spatial domain

Ans. Smoothening Spatial filters are used for blurring and noise reduction.

- Blurring is used as a pre processing step for removal of small details from an image prior to object extraction. Noise reduction can be accomplished by blurring.

→ Types of Smoothing filters:-

① Linear filter:- It is simply the average of the pixels contained in the neighbourhood of the filter mask. Eg: Average & weighted Avg. filter

② Order static filter:- They are non linear spatial filters. It is based on ordering the pixels contained in the image area encompassed by the filter. Eg: Median, min, max filter.

- Sharpening Spatial filters: They are used to highlight fine details in an image or to enhance details that has been blurred either in error or as a natural effect of any method of acquisition.

→ Foundation of sharpening filter

1-D : $\frac{\partial f}{\partial x} = f(x+1) - f(x)$

2nd order of 1-D : $\frac{\partial^2 f}{\partial x^2} = f(x+1) + f(x-1) - 2f(x)$

Gradient operator: $\nabla f = \frac{\partial f(x,y)}{\partial x \partial y} = \frac{\partial f(x,y)}{\partial x} + \frac{\partial f(x,y)}{\partial y}$

Laplacian Operator: $\nabla^2 f = \frac{\partial^2 f(x,y)}{\partial x^2} + \frac{\partial^2 f(x,y)}{\partial y^2}$

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

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

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

Q.3] Explain how arithmetic & logical operations are helpful in image enhancement.

Ans
- Addition, subtraction, multiplication, division comprise arithmetic operations while AND, OR, NOT makeup logical operations.
- They are often applied a preprocessing steps in image analysis in order to combine images in various ways.
- Addition – Used to create double exposures
  $$g(x,y) = f_1(x,y) + f_2(x,y)$$
- Subtraction – Used for finding changes in two images or to detect motion.
  $$g(x,y) = f_1(x,y) - f_2(x,y)$$
- Multiplication – Used to adjust brightness of an image.
  $$g(x,y) = f_1(x,y) \cdot f_2(x,y)$$
- Division – Used to adjust brightness of an image.
  $$g(x,y) = f_1(x,y) / f_2(x,y)$$

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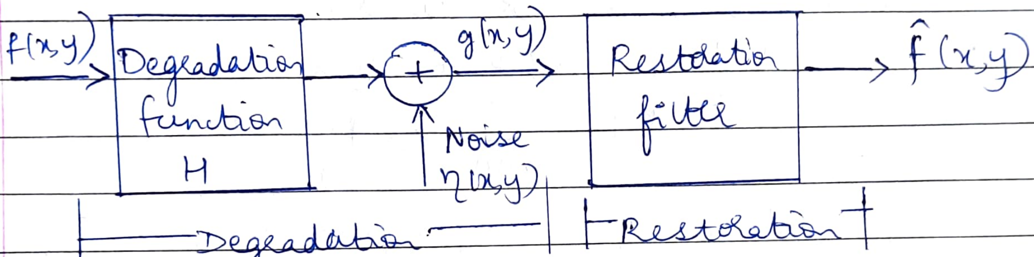
Q.4] What is image restoration? Explain the degradation model.

Ans• Image restoration attempts to restore images that have been degraded.

- It identifies the degradation process and attempt to reverse it.



- Degradation function along with some additive noise operates on f(x,y) to produce degraded image g(x,y)
- Given g(x,y) & some prior knowledge about the degradation function H & additive noise $\eta(x,y)$ objective of restoration is to obtain estimate $f'(x,y)$ of the original image.
- If H is linear position invariant process then degraded image in spatial domain is given by,

$$g(x,y) = \underbrace{h(x,y)}_{\text{Spatial rep. of } H} \underbrace{*}_{\text{Indicates convolution}} f(x,y) + \eta(x,y)$$

- Since convolution in spatial domain is multiplication in frequency domain

$$G(u,v) = H(u,v) \underbrace{\cdot}_{\text{Identity Operator.}} F(u,v) + N(u,v)$$

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Q.5] Explain image restoration in the presence of noise using spatial filtering.

Ans When there is noise present in an image then $g(x,y) = f(x,y) + \eta(x,y)$.
Spatial filtering can be done when only additive noise is present. The following techniques can be used:

(i) Mean filter: a] Arithmetic Mean

$$\hat{f}(x,y) = \frac{1}{mn} \sum_{(s,t) \in S_{xy}} g(s,t)$$

Results in smoothing effect of an image.

b] Geometric mean:

$$\hat{f}(x,y) = \left[\prod_{(s,t) \in S_{xy}} g(s,t) \right]^{1/mn}$$

c] Harmonic mean: $\hat{f}(x,y) = \dfrac{mn}{\sum_{(s,t) \in S_{xy}} 1/g(s,t)}$

d] Contra Harmonic mean: $\hat{f}(x,y) = \sum_{(s,t)} g(s,t)^{Q+1} \Big/ \sum_{(s,t)} g(s,t)^{Q}$

[ii] Order Statistics filter:

a] Median filter: $\hat{f}(x,y) = \underset{(s,t) \in S_{xy}}{\text{median}} \{ g(s,t) \}$

b] Max/Min filter: $\hat{f}(x,y) = \underset{(s,t) \in S_{xy}}{\max} \{ g(s,t) \}$

$\hat{f}(x,y) = \underset{(s,t)}{\min} \{ g(s,t) \}$

c] Mid point filter: $\hat{f}(x,y) = \frac{1}{2} \left[\underset{(s,t)}{\max} \{ g(s,t) \} + \underset{(s,t)}{\min} \{ g(s,t) \} \right]$

d] Alpha trimmed mean filter:

$$\hat{f}(x,y) = \frac{1}{mn-d} \sum_{(s,t) \in S_{xy}} g_r(s,t)$$

middle pixels $(mn-d)$

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[iii] Adaptive filters:

a] Adaptive local noise filter:

$$\hat{f}(x,y) = g(x,y) - \frac{\sigma_n^2}{\sigma_L^2}[g(x,y) - m_L]$$

b] Adaptive median filter:

Proposed for restoration of gray scale images that are corrupted by salt & pepper noise

Q.6] Describe periodic noise reduction using freq. domain filtering.

Ans.
- It is due to electromechanical inteference of during image acquisition.
- It can be done on periodic noise to reduce it using the following filters:

i] Bandreject filters: Remove/alternate a band of frequency

$$H(u,v) = \begin{cases} 1, & \text{if } D(u,v) < D_0 - W/2 \\ 0, & \text{if } D_0 - W/2 \le (D(u,v)) \le D_0 + W/2 \\ 1, & \text{if } D(u,v) > D_0 + W/2 \end{cases}$$

a] Butterworth bandreject filter:

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

b] Gaussian bandreject filter

$$H(u,v) = 1 - e^{-1/2\left[\frac{D^2(u,v) - D_0^2}{D(u,v)W}\right]^{2}}$$

ii] Bandpass filters: The goal is to isolate the noise pattern from image which can help simplify analysis of noise.

$$H_{bp}(u,v) = 1 - H_{br}(u,v)$$

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iii) Notch filters: They reject frequencies of predefined neighbours about a centre frequency.

$$H(u,v) = \begin{cases} 0, & \text{if } D_1(u,v) \le D_0 \text{ or } D_2(u,v) \le D_0 \\ 1, & \text{otherwise} \end{cases}$$

$$D_1(u,v) = \left[(u - M/2 - u_0)^2 + (v - N/2 - v_0)^2\right]^{1/2}$$

$$D_2(u,v) = \left[(u - M/2 + u_0)^2 + (v - N/2 + v_0)^2\right]^{1/2}$$

a) Butterworth notch filter:

$$H(u,v) = 1 / 1 + \left[\frac{D_0^2}{D_1(u,v)\,D_2(u,v)}\right]^n$$

b) Gaussian notch filter:

$$H(u,v) = 1 - e^{1/2\left[\frac{D_1(u,v)\,D_2(u,v)}{D_0^2}\right]}$$