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II Module 2

★ **Digital Image processing** focuses on two major tasks :-

① Improvement of pictorial information for human interpretation.

② Processing of image data for storage, transmission & representation for autonomous machine ~~preparation~~ perception

★ Key stages of DIP.

① Image Acquisition.
② Image Enhancement
③ Image Restoration.
④ Morphological Processing.
⑤ Segmentation.
⑥ Object Recognition.
⑦ Representation & Description.
⑧ Image Compression.
⑨ Colour Image Processing.

★ Digital Image Types.

① Intensity Image (Gray Scale level)

② RGB Image

③ Binary Image (1 → white ; 0 → black)

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☆ Relationship of Pixels

$x-1, y-1$	$x, y-1$	$x+1, y-1$
$x-1, y$	x, y	$x+1, y$
$x-1, y+1$	$x, y+1$	$x+1, y+1$

☆ Mathematical Operations on Image.

1. Addition
2. Subtraction
3. Multiplication.
4. Division.

☆ Aspect Ratio = $\dfrac{\text{Width of the image (R)}}{\text{Height (C)}}$

Baud Rate ⟹ It is a common measure to transmit digital data and is defined as number of bits transmitted per second.

Time taken = $\dfrac{N}{\text{Baud Rate}}$

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☆ Image Enhancement

Objective :- Improve the interpetability of the information present in images for human viewers.

Enhancement algorithm is one that yields a better-quality image which can be done by either suppressing the noise or increasing the image contrast.

Classified into :-

① Spatial Domain method - operates directly on pixels or raw data.

② Transform Domain Method - operates on the Fourier transform of an image and then transforms it back to the spatial domain.

☆ Image Enhancement in Spatial Domain.

Deals with manipulation of pixels values and can be broadly classified into :-

1] Point operation - one to one mapping

2] Mask operation - mask is a small matrix & operates on neighbourhood of pixels.

3] Global operation - Frequency domain operations.

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★ Point Operation Techniques:

1] Image Negative or Digital Negative.

Inverse transformation reverses light & dark.
Application :- X-ray image.

$$\boxed{s = (L-1) - r}$$

s → new image pixels
r → old image pixels.

⟹
For an 8 BPP image $2^8 = 256 = L$.

$s = (256-1) - r$
$s = 255 - r$

Eg:-

$$\begin{matrix} 4 & 3 & 5 & 2 \\ 3 & 6 & 4 & 6 \\ 2 & 2 & 6 & 5 \\ 7 & 6 & 4 & 1 \end{matrix}$$

$2^3 = 8 = L = L-1 = 7$

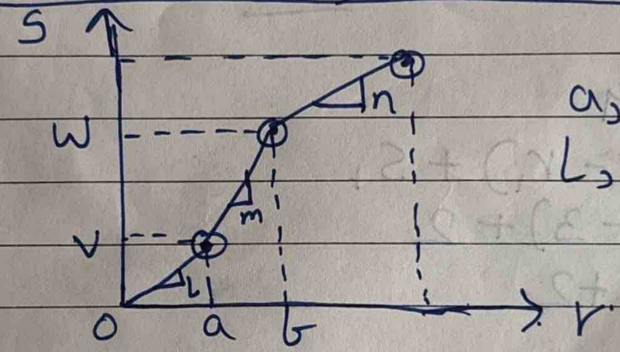
$s = (L-1) - r$

$$\therefore \boxed{\begin{matrix} 3 & 4 & 2 & 5 \\ 4 & 1 & 3 & 1 \\ 5 & 5 & 1 & 2 \\ 0 & 1 & 3 & 6 \end{matrix}} \Rightarrow \text{Digital Negative.}$$

2] Contrast Stretching

Increases the contrast of the image by making dark portions darker & brighter portions brighter. Contrast adjustment is done by scaling all the pixels of image by a constant k

$$\boxed{\begin{aligned} s &= Lr & 0 \le r < a \\ &= m(r-a)+v & a \le r < b \\ &= n(r-b)+w & b \le r < L-1 \end{aligned}}$$

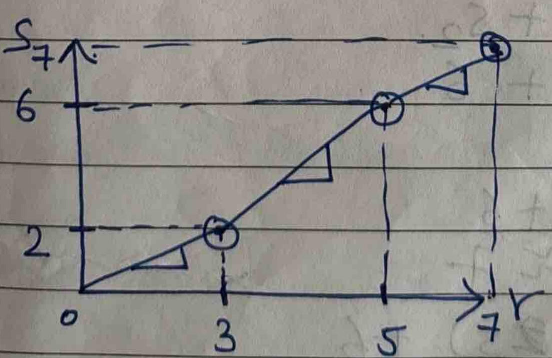


a, b, v, w $\rightarrow$ Given.
L, m, n & slopes.

Eg:-

$$\begin{matrix} 4 & 3 & 5 & 2 \\ 3 & 6 & 4 & 6 \\ 2 & 2 & 6 & 5 \\ 7 & 6 & 4 & 1. \end{matrix}$$

$r_1 = 3 \quad r_2 = 5$
$s_1 = 2 \quad s_2 = 6.$



$\cancel{L = \frac{3-0}{2-0}} =$

$L = \frac{y_2 - y_1}{x_2 - x_1} = \frac{2-0}{3-0} = \underline{0.66}$

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$$m = \frac{6-2}{5-3} = \frac{4}{2} = \underline{2}$$

$$n = \frac{7-6}{7-5} = \frac{1}{2} = 0.5$$

For ~~r~~ 0, 1, 2

$s = l \times r$

$\underline{s_0} = 0.66 \times 0 = \cancel{0.66}\ \underline{0}$

$\underline{s_1} = 0.66 \times 1 = \underline{0.66} \approx 1$

$\underline{s_2} = 0.66 \times 2 = \underline{1.32} \approx 1$

For 3, 4

$s = m(r - r_1) + s_1$

$s_3 = 2(3-3) + 2$

$= 2(0) + 2$

$\underline{s_3 = 2}$

$s_4 = 2(4-3) + 2$

$\underline{s_4 = 4}$

For 5, 6, 7

$s = n(r - r_2) + s_2$

$s_5 = 0.5(5-5) + 6$

$\underline{s_5 = 6}$

$s_6 = 0.5(6-5) + 6$

$\underline{s_6 = 6.5} \approx 7$

$s_7 = 0.5(7 - \cancel{2}5) + 6$

$\underline{s_7 = 7}$

Image:-

4	2	6	1
2	7	4	7
1	1	7	6
7	7	4	1

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3] Thresholding.

Extreme contrast stretching.

$$S = \begin{cases} L-1 & ; \; r \geq T \\ 0 & ; \; r < T \end{cases}$$

T = threshold value.

Example :-

$$\begin{matrix} 4 & 3 & 5 & 2 \\ 3 & 6 & 4 & 6 \\ 2 & 2 & 6 & 5 \\ 7 & 6 & 4 & 1 \end{matrix}$$

$T = 4.$
$L = 8$
$L-1 = 7$

New Image :-

$$\begin{matrix} 7 & 0 & 7 & 0 \\ 0 & 7 & 7 & 7 \\ 0 & 0 & 7 & 7 \\ 7 & 7 & 7 & 0 \end{matrix}$$

4] Gray Level Slicing (Intensity Slicing).

Useful for highlighting features in an image.
Thresholding splits gray level into two parts

Without bg

$S = L-1 \quad a \leq r \leq b$
$S = 0 \quad$ otherwise

With bg.

$S = L-1$
$S = r$

Example :-

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

$a = 3$
$b = 5$
$L - 1 = 8 - 1 = 7$

With background :-

$s = L-1$ for $3, 4, 5$
$s = r$ for $0, 1, 2, 6, 7$.

7	7	7	2
7	6	7	6
2	2	$\cancel{3}$ 6	7
7	6	7	1

Without background :-

$s = L-1 = 7$ for $3, 4, 5$
$s = 0$ for $0, 1, 2, 6, 7$

7	7	7	0
7	0	7	6
0	0	0	7
0	0	7	0

5] **Bit Plane Slicing**

Useful for image compression
High order bits contain significant visual info
Lower order bits contain subtle details

Example :-

$$\begin{matrix} 1 & 2 & 0 \\ 4 & 3 & 2 \\ 7 & 5 & 2. \end{matrix}$$

7 is max grey level ; 3-bits are needed.

Binary Image :-

$$\begin{matrix} 001 & 010 & 000 \\ 100 & 011 & 010 \\ 111 & 101 & 010 \end{matrix}$$

LSB (Leftmost bit) :-

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

Centre /middle bit :-

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

MSB (Rightmost) bit :-

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

6] Dynamic Range Compression (Log Transformation)

Some pixel values are so high that low pixel values get overshadowed by them In order to see small value pixels Log Transformation is used.

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

c is constant

7] **Power Law Transformation**

Human perception of brightness is more sensitive to changes in dark as compared to bright

Any input signal, the output will be transformed by gamma (λ) because of non-linear intensity to voltage relationship of the display screen

$$1.8 \leq \lambda \leq 2.5$$

$$\boxed{s = c r^{\lambda}}$$

c is constant
λ is gamma value.

☆ **Neighbourhood Processing (Mask Operation)**

1] **Low Pass Averaging Filter.**

Low Pass Averaging filter is used to eliminate any noise present in the image. It preserves the smooth region in the image and removes the sharp variations leading to blurring effect.. Each pixel is replaced by a weighted average of its neighbourhood pixels.

3x3 mask $\rightarrow \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$

5x5 mask $\rightarrow \frac{1}{25}\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$

Similarly, for 7x7 . . .

<u>Example</u> :-

Iteration 1 I2 I3

Given :-
$$\begin{bmatrix} 10 & 10 & 10 & 10 & 10 & 10 & 10 & 10 \\ 10 & \boxed{10} & \boxed{10} & \boxed{10} & 10 & 10 & 10 & 10 \\ 10 & 10 & 10 & 10 & 10 & 10 & 10 & 10 \\ 10 & 10 & 10 & 10 & 10 & 10 & 10 & 10 \\ 50 & 50 & 50 & 50 & 50 & 50 & 50 & 50 \\ 50 & 50 & 50 & 50 & 50 & 50 & 50 & 50 \\ 50 & 50 & 50 & 50 & 50 & 50 & 50 & 50 \\ 50 & 50 & 50 & 50 & 50 & 50 & 50 & 50 \end{bmatrix}$$

Mask :- $\frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$

New Image :-
$$\begin{bmatrix} 10 & 10 & 10 & 10 & 10 & 10 & 10 & 10 \\ 10 & 10 & 10 & 10 & 10 & 10 & 10 & 10 \\ 10 & 10 & 10 & 10 & 10 & 10 & 10 & 10 \\ 23.33 & 23.33 & 23.33 & 23.33 & 23.33 & 23.33 & 23.33 & 23.33 \\ 36.6 & 36.6 & 36.6 & 36.6 & 36.6 & 36.6 & 36.6 & 36.6 \\ 50 & 50 & 50 & 50 & 50 & 50 & 50 & 50 \\ 50 & 50 & 50 & 50 & 50 & 50 & 50 & 50 \\ 50 & 50 & 50 & 50 & 50 & 50 & 50 & 50 \end{bmatrix}$$

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~~Iteration 1.~~

Limitations :-

→ Leads to blurring which affects feature localisation.

→ If avg ops applied to image corrupted by impluse noise then impulse noise is attenuated and diffused but not removed.

→ Single pixel with unrepresentative value can affect the mean value of the pixel.

2] Weighted Average Filter

Mask ⇒ $\frac{1}{16}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$

3] Median Filter.

Smoothens the image by utilising the median of the neighbourhood.

① Arrange all pixels in ascending order

② Median is sorted & chosen as the pixel value for processed image.

Example :-

$$\begin{bmatrix} 18 & 22 & 33 & 25 \\ 34 & 128 & 24 & 172 \\ 22 & 19 & 32 & 31 \end{bmatrix}$$

For pixel 128:

$$\begin{bmatrix} 18 & 22 & 33 & 25 \\ 34 & \boxed{128} & 24 & 172 \\ 22 & 19 & 32 & 31 \end{bmatrix}$$

Arrange them in ascending order.

$\cancel{18}$ $\cancel{19}$ $\cancel{22}$ $\cancel{22}$ 24 $\cancel{32}$ $\cancel{33}$ $\cancel{34}$ $\cancel{128}$

24 is the median.

For pixel 24.

$$\begin{bmatrix} 18 & 22 & 33 & 25 \\ 34 & 128 & \boxed{24} & 172 \\ 22 & 19 & 32 & 31 \end{bmatrix}$$

$\cancel{19}$ $\cancel{22}$ $\cancel{24}$ $\cancel{25}$ 31 $\cancel{32}$ $\cancel{33}$ $\cancel{128}$ $\cancel{172}$

31 is the median.

$\therefore$ New Image :- $\begin{bmatrix} 18 & 22 & 33 & 25 \\ 34 & 24 & 31 & 172 \\ 22 & 19 & 32 & 31 \end{bmatrix}$

Median Filter is effective to minimise Salt & pepper noise

4] <u>High pass Filtering</u>

Eliminates Low frequency regions while enhancing high frequency components

High pass image will have no background

Main aim is image sharpening to highlight fine details in the image.

Mask $\rightarrow$ $\frac{1}{9}\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$

Pixel values cannot be negative
$\therefore$ After calculation replace all negative values by 0.

5] <u>High Boost Filtering</u> (Retaining high frequency ~~or~~ and some low frequency components)

The input image is multiplied by an amplification factor A before subtracting the low-pass image

High Boost = $(A-1) \times f(m,n) + \text{High Pass}$

Mask $\rightarrow$ $\frac{1}{9}\begin{bmatrix} -1 & -1 & -1 \\ -1 & 9k-1 & -1 \\ -1 & -1 & -1 \end{bmatrix}$

☆ Zooming.

Helps to view fine details in the image
Simplest operation is Replication of pixels.

Example :-

1	2

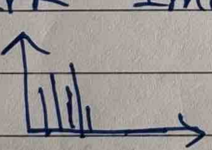
→

1	1	2	2
1	1	2	2

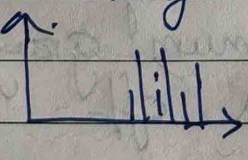
☆ Global operation.

Histogram ~~Equivalence~~ Modelling.

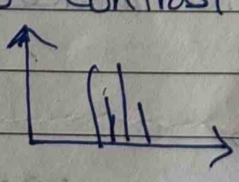
→ Dark Image → Histogram clustered towards lower gray level.



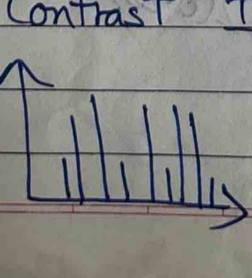
→ Bright Image → histogram clustered towards ~~low~~ higher gray level



→ Low Contrast Image → histogram not spread equally i.e narrow.



→ High Contrast Image → histogram has an equal spread



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1] Linear Stretching

$$S = \frac{S_{max} - S_{min}}{R_{max} - R_{min}} (R - R_{min}) + S_{min}$$

2] Histogram Equivalence.

	Gray levels.					
	No. of pixels					
①	Running Sum.					
②	① / Total No. of Pixels					
③	② * Max Gray level					

Steps :-

① Perform Running Sum.
② Divide ① by Total No. of Pixels.
③ Multiply ② by maximum gray level value & round off.

④ Map gray level value to make Histogram.
+0.54