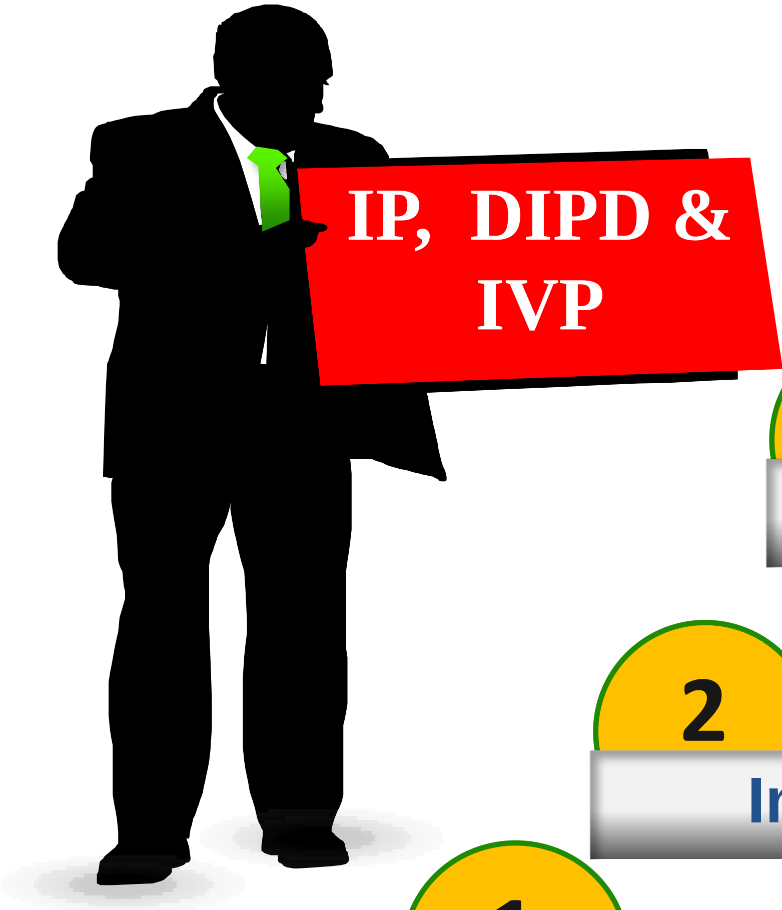

4 Image Transform

3 Image Segmentation

2 Image Enhancement

1 Image Fundamentals

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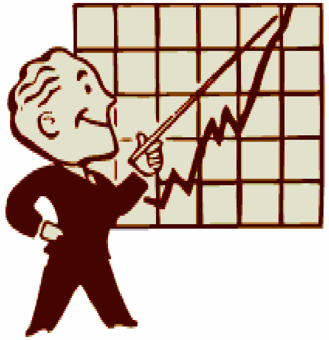

Image Processing - Comp

	TOPIC
1	Image Fundamentals
2	Image Enhancement
3	Image Segmentation
4	Image Transform
5	Image Compression
6	Binary Image Processing
7	

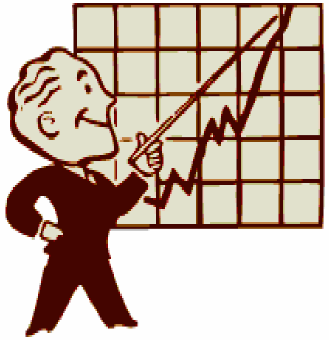

Image & Video Processing

	TOPIC
1	Image Fundamentals
2	Image Enhancement
3	Image Segmentation
4	Image Transform
5	Image Restoration
6	Video Formation
7	Motion Estimation

Image Enhancement

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Objective :

To process a given image so that the result is more suitable than the original image for a specific application.

[1] Image Enhancement using Zero Memory Point Operations

Let **r** denotes input image pixel value

and **s** denotes output image pixel value

Then $S = T(r)$

where **T** is any Spatial Domain Tx function.

Basic Gray Level Transformations using Zero Memory Point Operations

1. Contrast Stretching Transformations
2. Clipping and Thresholding
3. Digital Negative
4. LOG Transformation
5. Power Law Transformation
6. Intensity Level Slicing
7. Bit Level slicing

[1] Contrast Stretching Transformaton

(i) A Contrast Stretching Transformation function can be achieved by

- **Stretching** Dark range of input values into wider range of output values.
- **Shifting** Mid range of input values
- **Compressing** Bright range of input values.

(iii) Mathematically,

It is defined as **S= T(r)**

where T is Contrast Stretching Tx function such that,

$$S = \begin{bmatrix} \alpha r & 0 \le r \le a \\ S_1 + \beta(r-a) & a < r \le b \\ S_2 + \gamma(r-b) & b < r \le L-1 \end{bmatrix}$$

Q1

Obtain the gray level transformation function that :

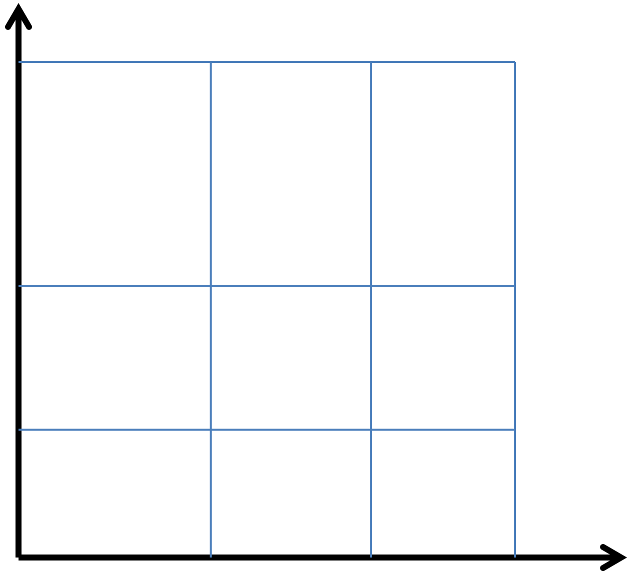
- **Stretches** gray scale range [0, 10] into [0, 15]
- **Shifts** the range [10,20] to [15,25] and
- **Compresses** the range [20,30] into [25,30].

A Contrast Stretching Tx function is given by,

$$S = \begin{bmatrix} \alpha r & 0 \le r \le a \\ S_1 + \beta(r-a) & a < r \le b \\ S_2 + \gamma(r-b) & b < r \le L-1 \end{bmatrix}$$

Q2 Apply the following Tx function on the image F and obtain new image.

$$F = \begin{bmatrix} 7 & 12 & 2 & 3 & 4 \\ 10 & 15 & 1 & 6 & 7 \\ 12 & 4 & 6 & 15 & 12 \\ 8 & 2 & 7 & 15 & 2 \\ 11 & 13 & 3 & 3 & 5 \end{bmatrix}$$



A Contrast Stretching Tx function is given by,

$$S = \begin{bmatrix} \alpha r & 0 \le r \le a \\ S_1 + \beta(r-a) & a < r \le b \\ S_2 + \gamma(r-b) & b < r \le L-1 \end{bmatrix}$$

By substituting we get,

$$S = \begin{bmatrix} 0.5r & 0 \le r \le 8 \\ S_1 + \beta(r-a) & a < r \le b \\ S_2 + \gamma(r-b) & b < r \le L-1 \end{bmatrix}$$

By substituting we get,

$$S = \begin{bmatrix} 0.5\,r & 0 \le r \le 8 \\ 4 + (r - 8) & 8 < r \le 12 \\ S_2 + \gamma\,(r - b) & b < r \le L - 1 \end{bmatrix}$$

By substituting we get,

$$S = \begin{bmatrix} 0.5\,r & 0 \le r \le 8 \\ r-4 & 8 < r \le 12 \\ 8+2.33(r-12) & 12 < r \le 15 \end{bmatrix}$$

$$F = \begin{bmatrix} 7 & 12 & 2 & 3 & 4 \\ 10 & 15 & 1 & 6 & 7 \\ 12 & 4 & 6 & 15 & 12 \\ 8 & 2 & 7 & 15 & 2 \\ 11 & 13 & 3 & 3 & 5 \end{bmatrix}$$

[2] Clipping and Thresholding

(i) It is a special case of Contrast Stretching Tx function.

(ii) A Contrast Stretching Tx function is given by,

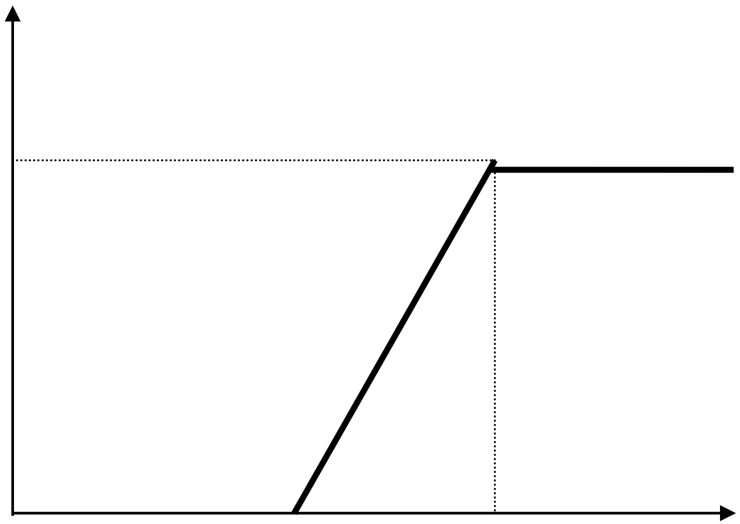
$$S = \begin{bmatrix} \alpha r & 0 \le r \le a \\ S_1 + \beta(r-a) & a < r \le b \\ S_2 + \gamma(r-b) & b < r \le L-1 \end{bmatrix}$$

Q3 Given Image A and Transformation Function.

(a) Obtain the new image.

(b) Plot Histogram of input & output Image

(c) Compare the histograms of I/O image.



$$F = \begin{bmatrix} 2 & 5 & 3 & 5 \\ 3 & 6 & 5 & 3 \\ 3 & 5 & 2 & 4 \\ 2 & 5 & 4 & 5 \end{bmatrix}$$

(c) Comparison of Input and Output image Histogram

1. Input Image has **limited pixel range** [2-6].
   So, input image has LOW contrast.
2. Input Image pixel range [2-6] is increased to
   [0-8] in the output image.
   Thus, Contrast of output image is improved.
3. Distribution of pixels is NOT uniform in both input
   and output image,

Q4

Convert the gray image to Binary Image.
Select appropriate value of threshold from the histogram.

$$F = \begin{bmatrix} 0 & 3 & 0 & 1 & 0 \\ 1 & 7 & 4 & 5 & 2 \\ 2 & 6 & 6 & 7 & 7 \\ 7 & 4 & 0 & 1 & 0 \\ 5 & 6 & 7 & 6 & 5 \end{bmatrix}$$

$$F = \begin{bmatrix} 0 & 3 & 0 & 1 & 0 \\ 1 & 7 & 4 & 5 & 2 \\ 2 & 6 & 6 & 7 & 7 \\ 7 & 4 & 0 & 1 & 0 \\ 5 & 6 & 7 & 6 & 5 \end{bmatrix}$$

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[3] Digital Negative

Negative Image is obtained by reverse scaling of gray levels of input image.

Application :

[1] To obtain negative prints of Photograph

[2] To display Medical Images

[4] LOG Transformation

(i) Mathematically,

LOG Transformation,

(i) **Enhances small magnitude input values** into wider range of output values

(ii) **Compresses large magnitude input values** into narrow range of output values.

Application :

To display Fourier Transformed Image,

[5] Power Law Transformation

(i) Mathematically,

Q5 For the image given below perform the operation

$$S = r^2$$

$$F = \begin{bmatrix} 2 & 3 & 10 \\ 4 & 6 & 10 \\ 7 & 1 & 3 \end{bmatrix}$$

Step-1 : Find Normalized Input Pixel values

$$\text{Normalized pixel value} = \frac{\text{Input pixel value}}{\text{Max Value}}$$

Step-3 : Find De-normalized output Pixel values

Denormalized = Power Law Tx MAX Value
Output value Value

Step-3 : Find De-normalized output Pixel values

Denormalized = Power Law Tx MAX Input value
Output value Value

[6] Intensity Level Slicing

Highlighting a specific range of input values is called Intensity Level Slicing.

[7] Bit Level Slicing

Highlighting a specific **bit** of input pixel values is called Bit Level Slicing.

Q6 For the input image F perform the following.

$$F = \begin{bmatrix} 4 & 2 & 3 & 0 \\ 1 & 3 & 5 & 7 \\ 5 & 3 & 2 & 1 \\ 2 & 4 & 6 & 7 \end{bmatrix}$$

Q 6 (a) Thresholding T = 4

$$F = \begin{bmatrix} 4 & 2 & 3 & 0 \\ 1 & 3 & 5 & 7 \\ 5 & 3 & 2 & 1 \\ 2 & 4 & 6 & 7 \end{bmatrix}$$

Q 6 (b) Intensity Level Slicing with background for $r_1 = 2$ and $r_2 = 5$

$$F = \begin{bmatrix} 4 & 2 & 3 & 0 \\ 1 & 3 & 5 & 7 \\ 5 & 3 & 2 & 1 \\ 2 & 4 & 6 & 7 \end{bmatrix}$$

Q6 (c) Bit Level Slicing for MSB and LSB planes.

$$F = \begin{bmatrix} 4 & 2 & 3 & 0 \\ 1 & 3 & 5 & 7 \\ 5 & 3 & 2 & 1 \\ 2 & 4 & 6 & 7 \end{bmatrix}$$

Q6 (d) Negation

$$F = \begin{bmatrix} 4 & 2 & 3 & 0 \\ 1 & 3 & 5 & 7 \\ 5 & 3 & 2 & 1 \\ 2 & 4 & 6 & 7 \end{bmatrix}$$

Image Enhancement by Histogram Processing :

(ii) Histogram of dark image, bright image and low contrast image is narrow.

(iii) Histogram Processing involves the modification of input image histogram to increase the dynamic range of gray values.

(iv) This improves the visual quality of image on display device.

[1] Histogram Equalization

(i) Histogram Equalization Tx increases dynamic range of gray levels of input image so that they are evenly distributed.

(ii) The histogram of the output image is almost uniform over the entire range of gray levels.

Q7 Given input image F, Apply Histogram Equalization Tx and obtain new image

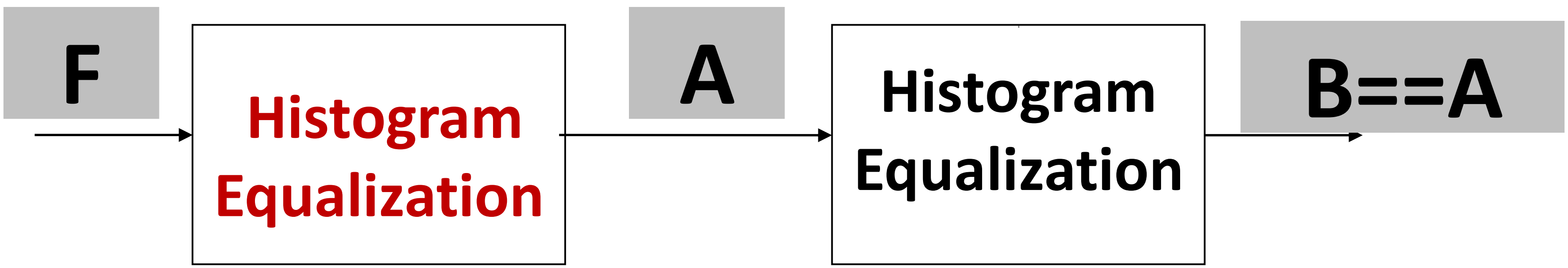
$F(x, y) = |x - y|$, for x, y = 0,1,2,3,4,5,6,7.

HE Tx is defined as

$$S_k = \sum_{j=0}^{k} P_r(r_j)$$


F
H.E. Tx
A

NOTE : Histogram Equalization Tx gives only one type of output image. By repeatedly applying HE there is NO change in the output image.



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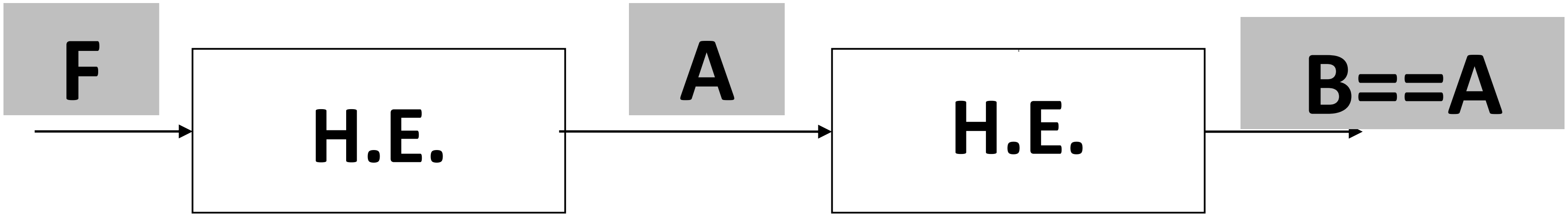
NOTE : HE Tx gives only one type of output image. By repeatedly applying HE there is NO change in the output image.



[2] Histogram Specification

(i) Histogram Specification Tx modifies histogram of input image as per the specified image histogram.

(ii) Histogram of the output image closely matches with the histogram of the specified image.

Q8 Histogram of Input Image A is given below.

(a) Modify the histogram A as given in histogram B.

(b) Plot the histogram of the Input and Output Image.

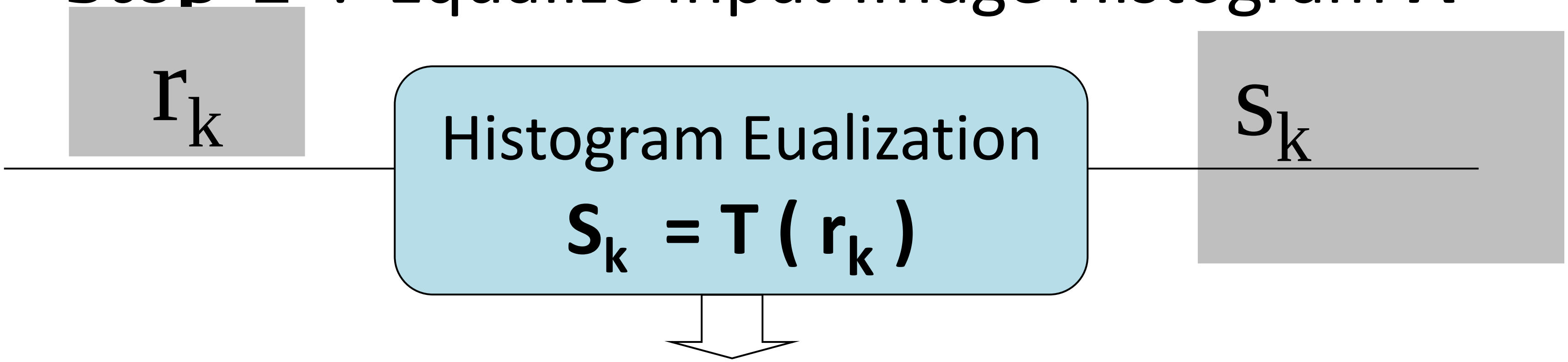
- Input Image Histogram (A) :

Gray Level r_k	0	1	2	3	4	5	6	7
No of Pixel N_{rK}	790	1023	850	656	329	245	122	81

- Specified Histogram (B) :

Gray Level Z_k	0	1	2	3	4	5	6	7
No of Pixel N_{ZK}	0	0	0	614	819	1230	819	614

- **Step-1** : Equalize Input Image Histogram **A**



$$S_k = \sum_{j=0}^{k} P_r(r_j)$$

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INPUT **rk**	Norm **rk**	Freq. Nr_k	PDF Pr	CDF S_k	Equalized Gray Value S_k
0	0	**790**	**0.192**	**0.192**	**1**
1	1/7	**1023**	**0.249**	**0.441**	**3**
2	2/7	**850**	**0.207**	**0.648**	**5**
3	3/7	**656**	**0.160**	**0.808**	**6**
4	4/7	**329**	**0.080**	**0.888**	**6**
5	5/7	**245**	**0.059**	**0.947**	**7**
6	6/7	**122**	**0.029**	**0.976**	**7**
7	1	**81**	**0.019**	**1**	**7**

- **Step-2** : Equalize Specified Histogram **B**

Z_k → Histogram Eualization **V_k = G (Zk)** → V_k

$$V_k = \sum_{j=0}^{k} P_r(z_j)$$

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INPUT **Zk**	Norm **Zk**	Freq. Nz_k	PDF Pr	CDF V_k	Equalized V_k
0	0	**0**			
1	1/7	**0**			
2	2/7	**0**			
3	3/7	**614**			
4	4/7	**819**			
5	5/7	**1230**			
6	6/7	**819**			
7	1	**614**			

INPUT **Zk**	Norm **Zk**	Freq. Nz_k	PDF Pr	CDF V_k	Denorm. V_k
0	0	**0**	**0**		
1	1/7	**0**	**0**		
2	2/7	**0**	**0**		
3	3/7	**614**	**0.150**		
4	4/7	**819**	**0.200**		
5	5/7	**1230**	**0.300**		
6	6/7	**819**	**0.200**		
7	1	**614**	**0.150**		

INPUT **Zk**	Norm **Zk**	Freq. Nz_k	PDF Pr	CDF V_k	Denorm. V_k
0	0	**0**	**0**	**0**	
1	1/7	**0**	**0**	**0**	
2	2/7	**0**	**0**	**0**	
3	3/7	**614**	**0.150**	**0.150**	
4	4/7	**819**	**0.200**	**0.350**	
5	5/7	**1230**	**0.300**	**0.650**	
6	6/7	**819**	**0.200**	**0.850**	
7	1	**614**	**0.150**	**1.00**	

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INPUT **Zk**	Norm **Zk**	Freq. Nz_k	PDF Pr	CDF V_k	Equalized V_k
0	0	**0**	**0**	**0**	**0**
1	1/7	**0**	**0**	**0**	**0**
2	2/7	**0**	**0**	**0**	**0**
3	3/7	**614**	**0.150**	**0.150**	**1**
4	4/7	**819**	**0.200**	**0.350**	**2**
5	5/7	**1230**	**0.300**	**0.650**	**5**
6	6/7	**819**	**0.200**	**0.850**	**6**
7	1	**614**	**0.150**	**1.00**	**7**

[3] Histogram Stretching

Histogram Stretching Tx increases the dynamic range of Gray values of input image **linearly.**

Q9 Frequency table of 3 bit input image is given below. Increase the dynamic range to [0 to 7] and find new image.

Gray Level r_k	0	1	2	3	4	5	6	7
Frequency N_{rk}	100	90	85	70	0	0	0	0

Image Enhancement by Neighbourhood Processing : Spatial Filtering

(i) In Neighbourhood opération, Tx. function works on a **group of input pixel values**.

(ii) The Output pixel value at (x,y) position is obtained by **masking operation.**

Masking Operation : Consider a Digital Image F and 3x3 filter mask w as shown in fig below,,

$$F = \begin{bmatrix} & & \\ & & \\ & & \end{bmatrix} \qquad A = \begin{bmatrix} & & \\ & & \\ & & \end{bmatrix}$$

Spatial filter

$$w = \begin{bmatrix} w_1 & w_2 & w_3 \\ w_4 & w_5 & w_6 \\ w_7 & w_8 & w_9 \end{bmatrix}$$

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List of Spatial Filters

[I] Smoothing Linear Filters

eg Low Pass Averaging Filter, Weighted Average Filter, Trimmed Averaging Filter

[II] Smoothing Non-Linear Filters

Eg..Median, Max and Min Filter.

[III] Sharpening : First Order Derivative Filters

Eg. Robert, Prewit, Sobel and Fri-Chen filter

[IV] Sharpening Second Order Derivative Filters

Eg. Laplacian Filter, HPF and High Boost Filter

[I] Smoothing Linear Filters

(1) Low Pass Averaging Filter

(i) LPF attenuates High frequency Components and allows to pass LOW frequency components of the image.

(ii) LPF reduces the difference between neighbouring pixels by distributing it's energy using averaging technique.

(iii) LPF removes sharp transitions in the image.

- Sharp transitions are due to :

  (1) High frequency random Impulse Noise.

  (2) High frequency Edges of an object.

Consider a Digital Image F and LPF mask w as shown in fig below,,

$$F = \begin{bmatrix} Z_1 & Z_2 & Z_3 \\ Z_4 & Z_5 & Z_6 \\ Z_7 & Z_8 & Z_9 \end{bmatrix}$$

L P F

$A =$

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Consider a Digital Image F and LPF mask w as shown in fig below,,

$$F = \begin{array}{|c|c|c|} \hline Z_1 & Z_2 & Z_3 \\ \hline Z_4 & Z_5 & Z_6 \\ \hline Z_7 & Z_8 & Z_9 \\ \hline \end{array}$$

L P F

$$w = \begin{bmatrix} w_1 & w_2 & w_3 \\ w_4 & w_5 & w_6 \\ w_7 & w_8 & w_9 \end{bmatrix}$$

$A =$

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- All the pixels in the output image have almost same value.
- Thus High frequency Impulse noise is completely suppressed. This is desirable effect.

(2) Low Pass Weighted Averaging Filters

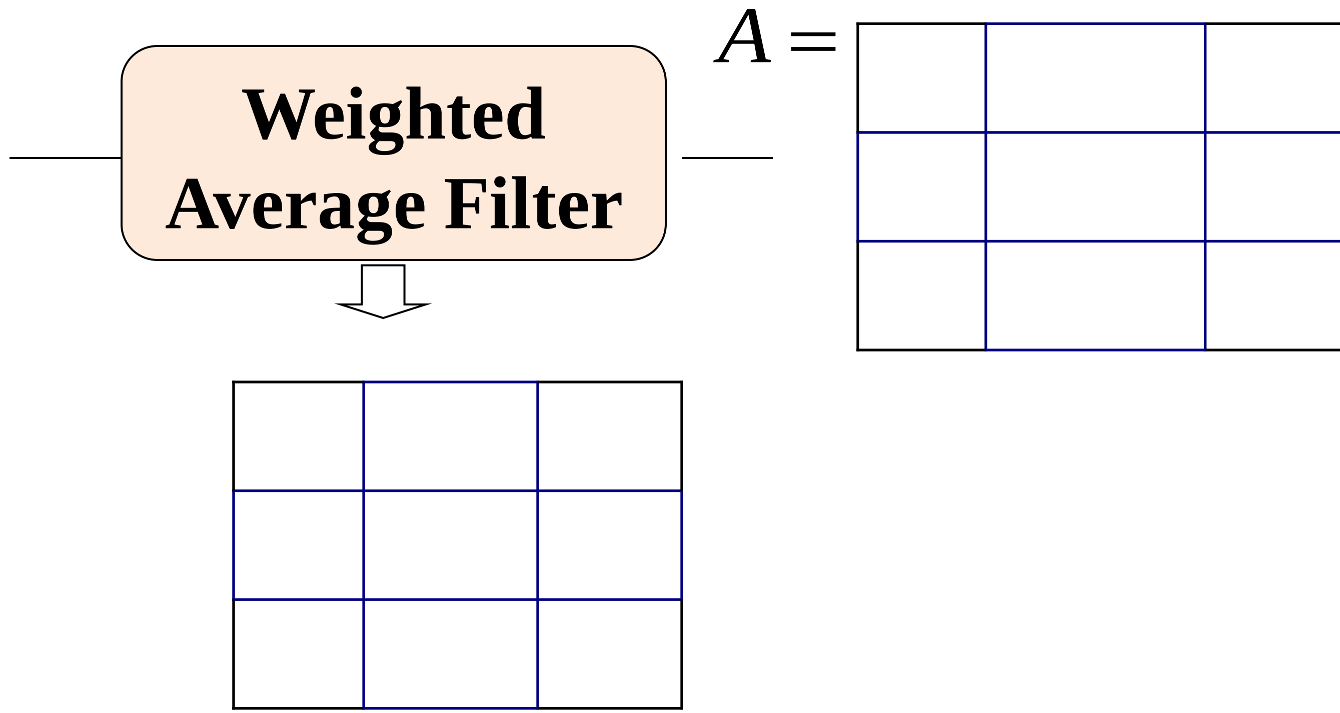
(i) In this filter, output pixel value at each (x,y) position is obtained by averaging the weighted neighbouring pixel values.

(ii) The **Weight** (i.e. Scaling factor) depends on the position of the neighbouring pixel with reference to the center pixel.

	Pixel Position	Weight
1	Center Pixel	
2	4 Directional Neighbour	
3	Diagonal Direction Neighbour	

Consider a Digital Image F and filter mask w as shown in fig below,,

$$F = \begin{array}{|c|c|c|} \hline Z_1 & Z_2 & Z_3 \\ \hline Z_4 & Z_5 & Z_6 \\ \hline Z_7 & Z_8 & Z_9 \\ \hline \end{array}$$



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[II] Smoothing Non-Linear Filters
[also called as ordered statistic filters]

Median Filter

(i) Medial filter is a Non-Linear ordered statistic filter.

(ii) Output pixel value at (x,y) position is obtained by selecting the median of neighbourhood of input pixel value.

* Median Filter ALGORITHM

(I) Arrange the pixels in the window either in Increasing order OR in Decreasing order.

(II) Select the middle value

(III) Replace the input pixel value by the selected median value in the output image.

Sharpening Derivative Filters

FILTER		
Smoothing filter		
Sharpening filter		

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[III] Sharpening First Order Derivative filters [also called as Gradient Filters]

Eg; Robert, Prewit, Sobel and Fri-chen filters

[IV] Sharpening Second Order Derivative filters

(1) Laplacian Filter

(2) High Pass Filter

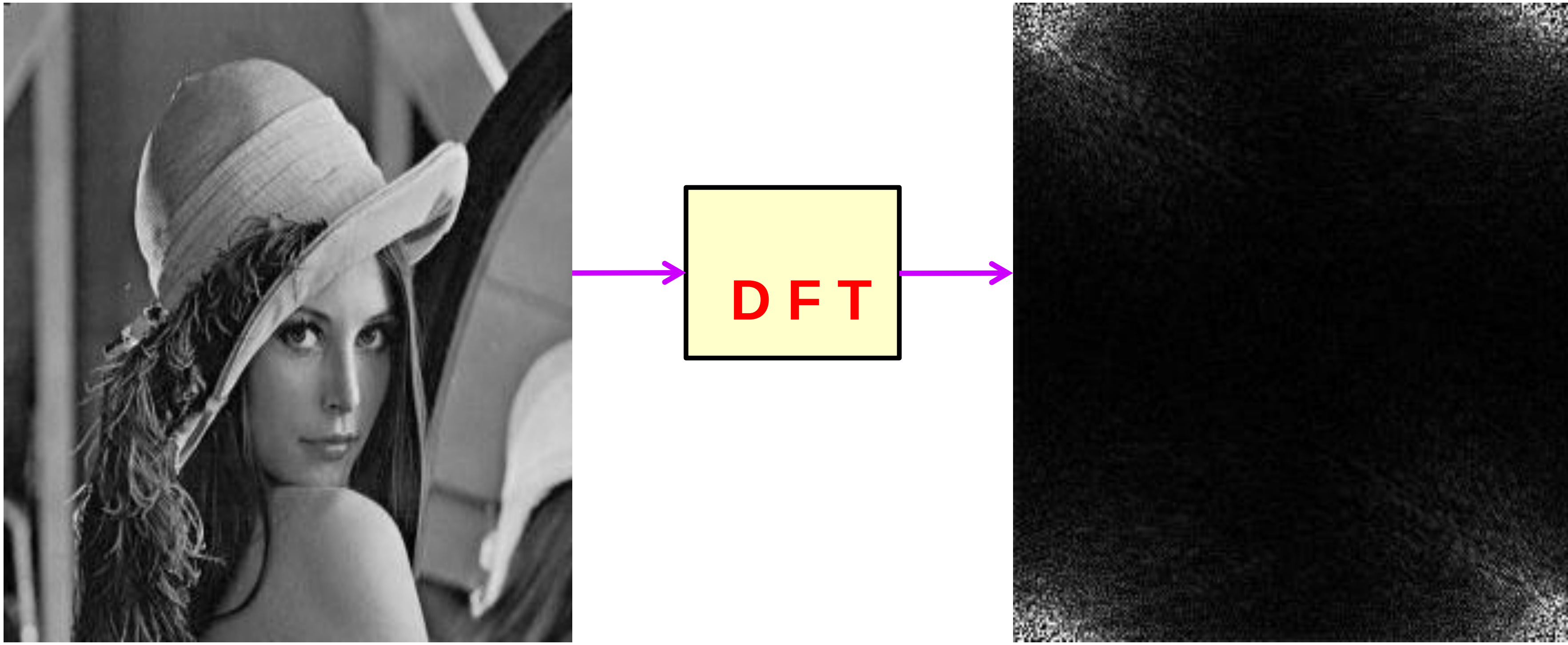
(i) HPF attenuates LOW frequency Components and allows to pass HIGH frequency components of the image.

(ii) HPF image can be obtained by subtracting LPF image from the original image.

(3) High Boost Filter

(i) HBF image is obtained by subtracting LPF image from the scaled original image.

Q10 Show that High Boost Filter Image can be obtained by adding HPF image with the original Image.



- INPUT Image

- OUTPUT Image

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Image Enhancement in Frequency Domain

(1) Ideal LPF

$$H(u, v) = \begin{cases} 1 & \text{if} \quad D(u,v) \le D_o \\ 0 & \quad D(u,v) \succ D_o \end{cases}$$

Where

D_o : is a non-negative quantity (cutoff frequency)
D(u, v) : is the distance from point (u, v) to the origin of the frequency plane and

(b) **Butterworth LPF**

$$H(u, v) = \frac{1}{1+[D(u,v)/D_o]^{2N}}$$

--- (1) **Ideal HPF**

$$H(u, v) = \begin{cases} 0 & D(u,v) \le D_o \\ 1 & Oterwise \end{cases}$$

Where

D_o : is a cutoff frequency

(b) Butterworth HPF

$$H(u, v) = \frac{1}{1 + \left[\dfrac{D_o}{D(u,v)}\right]^{2N}}$$

THE HOMOMORPHIC FILTER

- In homomorphic filter, multiplicative noise is changed to an additive noise.

To attain this, the illumination reflectance model is used where the image is modeled as the product of illumination $i(x, y)$ and reflectance $r(x, y)$ components.

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

Where $0 < i(x, y) < \infty$ and

$0 < r(x, y) < 1$

(I) Take logarithm of gray level of the image at each pixel

Now, $\mathbf{f(x, y) = i(x, y) \quad r(x, y)}$

$$\ln [f(x, y)] = \ln [i(x, y)] + \ln [r(x, y)]$$

Let $f_1(x, y) = \ln [i(x, y)] + \ln [r(x, y)]$

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(II) Take DFT of $f_1(x, y)$ and then suppress the noise, by passing it through Filter.
Then take Inverse DFT of output of filter.

Now, $f_1 (x, y) = \ln [i (x, y)] + \ln [r (x, y)]$

By DFT,

$$\text{DFT} \{f_1(x, y) \} = \text{DFT} \{ \ln[I (x, y)] \} + \text{DFT}\{ \ln[r (x, y)] \}$$

$$F_1(u, v) = I(u, v) + R(u, v)$$

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$$F_2(u, v) = H(u, v)\, F_1(u, v)$$

$$F_2(u,v) = \mathbf{H(u, v)}\, \{\, \mathbf{I(u, v)} + \mathbf{R(u, v)} \,\}$$

$$F_2(u, v) = H(u, v)\, I(u, v) + H(u, v)\, R(u, v)$$

By Inverse DFT,

$$\mathbf{f_2(x, y) = i'(x, y) + r'(x, y)}$$

(III) Take antilog at every (x, y) and scale them to 0-255 to obtain the enhanced image $f_0(x, y)$

Now, $f_2(x, y) = I'(x, y) + r'(x, y)$

Let $f_0(x, y) = \text{Antilog}[f_2(x, y)]$

$= \exp[f_2(x, y)]$

$= \exp[i'(x, y) + r'(x, y)]$

$= \exp[i'(x, y)] \exp[r'(x, y)]$

$$f_0(x, y) = i_o(x, y)\ r_o(x, y)$$