KLS Vishwanathrao Deshpande Institute of Technology

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

University / Model Question Paper Scheme & Solution

Faculty Name	:	Prof. Pavitra M. B / Prof. Plasin D
Course Name	:	Digital Image Processing
Course Code	:	BEC613C
Year of Question Paper	:	2025 June - July
Date of Submission	:	05/02/2026

Faculty Member HoD Dean (Acad.)

Head of the Department
Dept. of Electronic & Communication Engg
KLS V.D.I.T., HALIYAL (U.K.)

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CBCS SCHEME

USN | | | | | | | | | | |

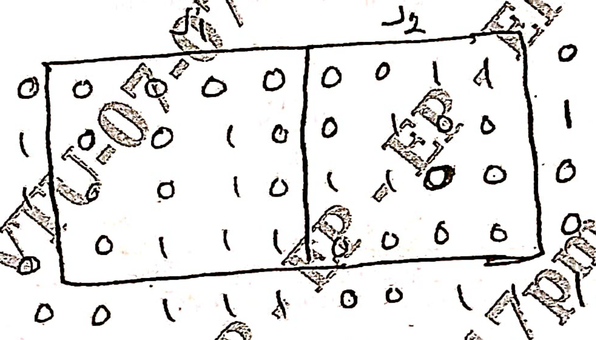
BEC/BTE/BVL613C

Sixth Semester B.E./B.Tech. Degree Examination, June/July 2025

Digital Image Processing

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2.. M : Marks , L: Bloom's level , C: Course outcomes.

		Module – 1	M	L	C
Q.1	a.	Explain the fundamental steps in Digital Image Processing.	10	L2	CO1
	b.	Consider the 2 image subsets, S_1 and S_2 shown below. For V = {1}, determine whether these subsets are 4 – adjacent, 8 – adjacent and m-adjacent. 	10	L3	CO1
		OR			
Q.2	a.	Explain the components of a general purpose image processing system.	10	L2	CO1
	b.	Consider the image segment shown below. Let V = {2, 3, 4}. Find the lengths of the shortest 4-, 8-, and m-paths between p and q. 3 4 1 2 0 0 1 0 4 2 (q) 2 2 3 1 4 (p) 3 0 4 2 1 1 2 0 3 4	10	L3	CO1
		Module – 2			
Q.3	a.	Justify that DCT is a fast transform.	10	L3	CO1
	b.	Find the 2D – DFT of the following image. Matrix $U = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$	10	L3	CO2
		OR			
Q.4	a.	Justify that Haar Transform can be implemented in O(N) operations.	10	L3	CO2
	b.	Find the - DCT of x(n) = { 1, 2, 1,4}	10	L3	CO2
		Module – 3			
Q.5	a.	Describe image negative and logarithmic transformations.	10	L1	CO3

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	b.	Assuming continuous intensity values, an image has the intensity pdf, $P_r(r)=\begin{cases}\frac{2r}{(L-1)^2}, & 0\le r\le L-1\\ 0 & \text{else where}\end{cases}$ Find the transformation function that would produce an image whose intensity pdf is, $P_z(z)=\begin{cases}\frac{3z^2}{(L-1)^3}, & 0\le z\le L-1\\ 0 & \text{else where}\end{cases}$	10	L3	CO3
		OR			
Q.6	a.	Explain piecewise – linear transformation functions used in image enhancement.	10	L2	CO3
	b.	Find histogram linearization of the following image segment. $\begin{bmatrix}4&4&4&4&4\\3&4&5&4&3\\3&5&5&5&3\\3&4&5&4&3\\4&4&4&4&4\end{bmatrix}$	10	L3	CO3
		Module – 4			
Q.7	a.	Describe image smoothing filters in frequency – domain.	10	L1	CO4
	b.	Explain pseudo colour Image Processing.	10	L2	CO4
		OR			
Q.8	a.	Explain Image sharpening filters in frequency – domain.	10	L2	CO4
	b.	Describe homomorphic filtering in detail.	10	L1	CO4
		Module – 5			
Q.9	a.	Describe a model for image degradation /restoration process.	10	L1	CO5
	b.	Explain some important noise pdfs.	10	L2	CO5
		OR			
Q.10	a.	Explain 4 order – statistics filters used in image restoration.	10	L2	CO5
	b.	Describe 4 mean filters used in image restoration.	10	L1	CO5

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MODULE-01

Q1a) Explain the fundamental steps in digital Image processing.

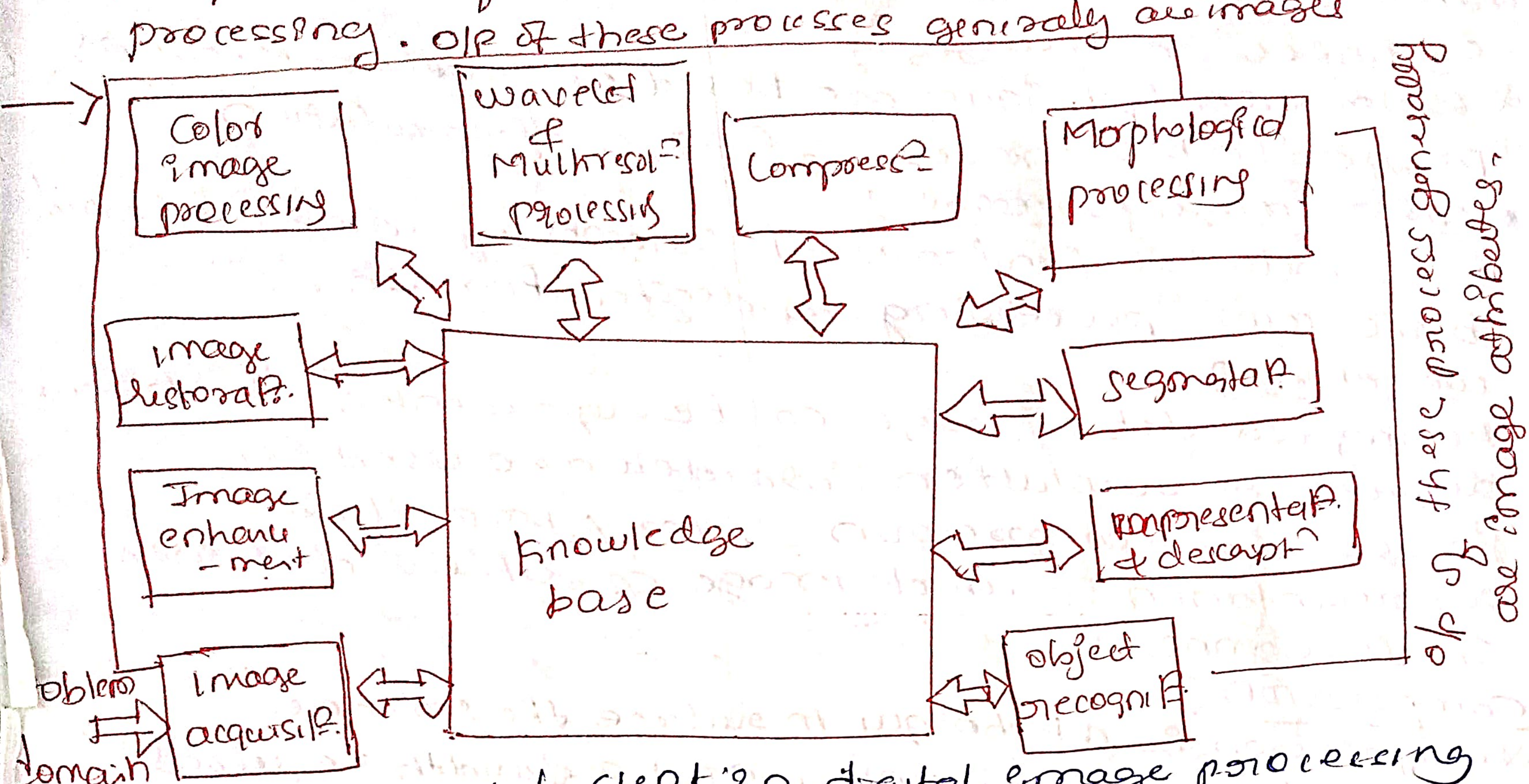

fig: Fundamental steps in digital image processing

Image Acquisition :

* It gives information about how to acquire image i.e. image origin.
* Image acquisition stage involves preprocessing such as scaling. Scaling is reducing or increasing the physical size of image by changing the number of pixels.
* Image acquisition gives the image in digital form.

Image enhancement :

* Enhancement technique is used to bring out detail that is obscured (unclear) or simply to highlight certain features of interest in an image.
* Enhancement is subjective process. Mathematical tools are used for enhancing the image

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Image Restoration :

* Restoration means getting back something.
* Image Restoration is a objective process. It is removal of noise in image.
* Restoration techniques are based on mathematical or probabilistic models of image degradation.

* Color image processing :

* This includes fundamental concepts of color model and basic color processing in digital domain.

wavelets :

* using wavelets image can be represented in various degrees of resolution. wavelets are used in image data compression & for pyramidal representation in which image is subdivided into small regions.

Compression :

* compression is a technique to reduce the storage required to save an image or bandwidth required to transmit.
* compression is useful in internet which has to send significant pictorial content.
* JPEG images are compressed images.

Morphological processing :

* Morphological images processing deals with tools for extracting image components that are useful in representation and description of shapes.
* It begins a transition from process that o/p image to process that o/p image attributes.

Segmentation :

* It is partition an image into its constituent parts or objects.
* autonomous segmentation or rugged segmentation leads to object segmentation or identification.

Representation & Description :

* segmentation gives usually raw pixel data constituting either the boundary of region or all the points in the region itself.
* Boundary representation is suitable when the focus is on external shape.
* Regional representation is appropriate when the focus is only a part of solution for transforming raw data into a form of suitable for subsequent computers processing.

Recognition :

* It is process that assigns a label to an object based on its description.

Knowledge base :

* A knowledge base is a special kind of data base for knowledge management.
* Knowledge data base it gives knowledge about the problem domain in image processing system.
* It also guides the operation of each processing module.
* It also controls the interaction b/w modules.

Q 1b) Consider 2 images subsets, S1 & S2 shown below. For V = {1}, determine whether these subsets are 4-adjacent, 8-adjacent & m-adjacent

S_1					S_2				
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
0	0	1	1	1	0	0	1	1	1

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(a) S_1 & S_2 are not 4-connected because q is not in the set $N_4(p)$

(b) S_1 & S_2 are 8-connected because q is in set $N_8(p)$

(c) S_1 & S_2 are m-connected because

(i) q is in $N_D(p)$

(ii) The set $N_4(p) \cap N_4(q)$ is empty.

Q 2a) Explain the components of a general purpose image processing system.

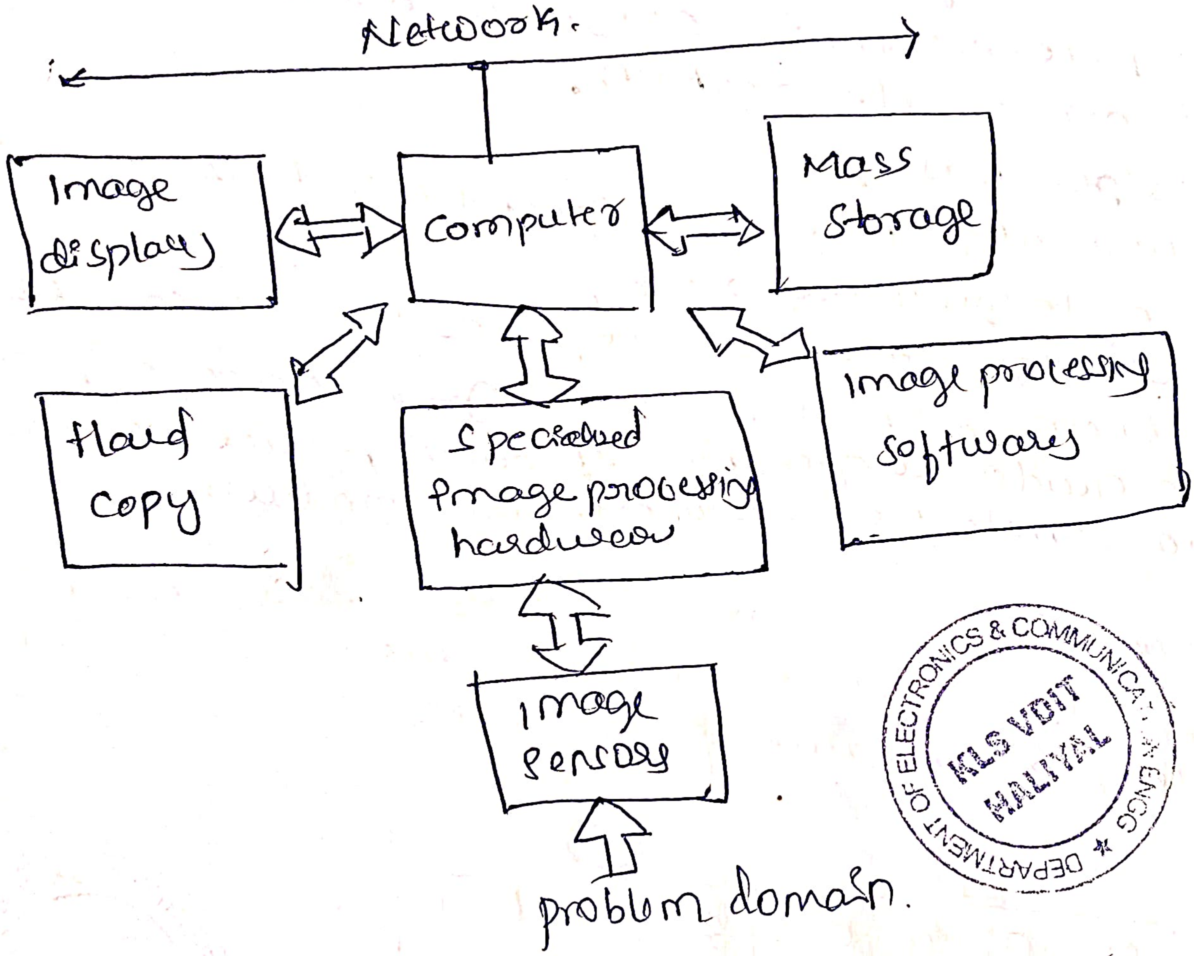

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Image Sensor :

* Image sensors is a physical device that is sensitive to energy radiated by the object that we wish to image.
* In digital video camera, the sensors produces an electrical o/p proportional to light intensity.

Ex: CCD (Charge couple device), photodiodes etc.

Specialized Image processing hardware :
* usually consists of digitizers, a device converting o/p of the physical sensing device into digital form, plus hardware that performs primitive operations such as ALU
* One example how ALU is used in averaging images as quickly as they are digitized, for the purpose of noise reduction.
* This type of hardware is called front end subsystem.
* This unit perform functions that require fast data throughputs that the typical main computer cannot handle.

Computer : Image processing requires intensive processing capability as it has to handle large data.
So compared to super computer is required.

Software : It consists of specialized modules that perform specific task such as enhancing the image or filtering the image for restoration.
* More sophisticated software packages allow the integration of these specialized modules for user friendly & general purpose software commands from at least one computer language.

Mass storage :
* This capability is a must in image processing application.
* Usually image processing system deals with thousands or millions of images.
* Each uncompressed image may be take (2^24 bytes for 1Mb image) Digital storage system for image processing falls into three major categories.
(1) Short term storage for use during processing.
Computer memory can be short term storage
(2) On-line storage for relatively fast call
On line storage is frequent access
The key characterizing ~~by~~ on the storage image.
(3) Archival storage characterized by infrequent access.
Magnetic tapes & optical disks

Image Displays : Displays are parts of computer system.
* In some cases it is necessary to have stereo display (3D).
Hard copy : Laser printers, optical & CD-ROM disks.
Networking : The key factor in image transmission is bandwidth.

Q2b) Consider the image segment shown below :
Let V = {2, 3, 4}, find the lengths of shortest 4-, 8-, & m- paths b/w p & q.

	3	4	1	2	0
	0	1	0	4	2 (q)
	2	2	3	1	4
(p)	3	0	4	2	1
	1	2	0	3	4

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→ 1. Shortest 4-path (d4)
→ (3,0) → (2,0) → (2,1) → (2,2) → (1,2) → (1,3)
* Pixel value → 3 → 2 → 2 → 3 → 3 → 4 → 2
Length - 6
Logic : All values belong to V. we cannot take diagonals

2. Shortest 8-path (d8)
→ 8 connectivity allows, horizontal, vertical & Diagonal moves
* pixel value → 3 → 2 → 3 → 4 → 2
Logic : Since diagonal neighbors are allowed & their values are in V, we take the most direct route.
→ length = 4

3. Shortest m-path (mixed connectivity)
* diagonal move b/w p & q is allowed only if their common 4-neighbors are not in V.
→ length : 5
path (3→0) → (2,0) → (2,1) → (2,2) → (1,2) → (1,3)

MODULE 02

Q3a) Justify that DCT is a fast transform

→ The cosine transform is a fast transform.
The cosine transform of a vector of N elements can be calculated in $O(N \log_2 N)$ operation via an N point FFT.
To show this we define a new sequence $\tilde{u}(n)$ by reordering the even & odd elements of $u(n)$ as

$$\left.\begin{aligned} \tilde{u}(n) &= u(2n) \\ \tilde{u}(N-n-1) &= u(2n+1) \end{aligned}\right\}, \quad 0 \le n \le \left[\frac{N}{2}\right] - 1 \quad — (1)$$

→ split the summation term into 2 eqn even & odd terms.

$$v(k) = \alpha(k)\left\{ \sum_{n=0}^{(N/2)-1} u(2n) \cos\left[\frac{\pi(4n+1)k}{2N}\right] + \sum_{n=0}^{(N/2)-1} u(2n+1) \cos\left[\frac{\pi(4n+3)k}{2N}\right]\right\} \quad — (2)$$

$$= \alpha(k)\left\{ \sum_{n=0}^{(N/2)-1} \tilde{u}(n) \cos\left[\frac{\pi(4n+1)k}{2N}\right] + \sum_{n=0}^{(N/2)-1} \tilde{u}(N-n-1) \cos\left[\frac{\pi(4N+3)k}{2N}\right]\right\} \quad — (3)$$

Changing the index of summation in second term to $n' = N-n-1$ & combining term we obtain.

$$v(k) = \alpha(k) \sum_{n=0}^{N-1} \tilde{u}(n) \cos\left[\frac{\pi(4n+1)k}{2N}\right] \quad — (4)$$

$$= Re\left[\alpha(k) e^{-j\pi k/2N} \sum_{n=0}^{N-1} \tilde{u}(n) e^{-j2\pi kn/N}\right] \quad — (5)$$

$$= Re\left[\alpha(k) W_{2N}^{k/2}\, DFT\{\tilde{u}(n)\}_N\right] \quad — (6)$$

For inverse cosine transform

$$u(2n) = \tilde{u}(2n) \triangleq Re\left[\sum_{k=0}^{N-1} [\alpha(k) v(k) e^{j\pi k/2N}] e^{j2\pi nk/N}\right] \quad — (7)$$

$$0 \le n \le \left(\frac{N}{2}\right) - 1 \quad — (8)$$

odd points are obtained

$$u(2n+1) = \tilde{u}(2N-1-n) \qquad 0 \le n \le (N/2) \quad — (9)$$

We can also obtain the inverse DCT in $O(N \log N)$ operat.

* cosine transform has excellent energy compaction for highly correlated data.

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* The basic vectors for cosine transform (that is rows of C) are eigen vectors of symmetric tridiagonal matrix Q_c. defined as

$$Q_c = \begin{bmatrix} 1 & -\alpha & -\alpha & 0 \\ -\alpha & -\alpha & 1 & \\ & & 1 & -\alpha \\ 0 & & & \\ & & -\alpha & 1-\alpha \end{bmatrix}$$

~~Q2b) Consider the image segment shown below. let $V = \{1,2\}$~~

Q3b) Find the 2D-DFT of following image

Matrix $U = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$

$\rightarrow f(m,n) = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$

$F(k,l) = \text{kernel} \times f(m,n) \times \text{kernel}^T$

The kernel or basis of FT for $N=4$ is

$$\begin{array}{cc} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix} & \begin{array}{c} 0 \\ 2 \\ 3 \\ 1 \end{array} \end{array}$$

$$F(k,l) = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix}$$

$$= \begin{bmatrix} 4 & 4 & 4 & 4 \\ 1-j-1+j & 1-j-1+j & 1-j-1+j & 1-j-1+j \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix}$$

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$$\begin{bmatrix} 16 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

OR

Q40: Justify that Haar Transform can be implemented in O(n) operation.

→ Haar Transform: Haar Transform is based on Haar functions $h_u(x)$ defined over continuous, half open interval $x \in \{0, 1\}$

$u \in$ Integer, for $u > 0$ decomposed as

$$U = 2^p + q$$

p is the largest power of 2 contained in U and q is the remainder,

$$q = 2^p - u$$

Haar Basis function:

$$h_u(x) = \begin{cases} 1 & u = 0 \;\&\; 0 \le x \le 1 \\ 2^{p/2} & u > 0 \text{ and } q/2^p \le x < (q+0.5)/2^p \\ -2^{p/2} & u > 0 \;\&\; (q+0.5)/2^p \le x < (q+1)/2^p \\ 0 & \text{otherwise.} \end{cases}$$

It is the simplest of wavelet transform. Cross multiplies function against the Haar wavelet with various shifts and stretches.

Similar to Fourier Transform. Cross Multiplies a function against sinewave with two phases and many stretches.

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Transformation matrix :

$$H_N = \begin{bmatrix} h_0(0/N) & h_0(1/N) & \cdots & h_0((N-1)/N) \\ h_1(0/N) & h_1(1/N) & & \\ & & \ddots & \\ h_{N-1}(0/N) & \cdots & \cdots & h_{N-1}((N-1)/N) \end{bmatrix}$$

where $N = 2^n$

∴ Resulting transformation matrix

$$A_H = \frac{1}{\sqrt{N}} H_N$$

If $N=2$

$$A_H = \frac{1}{\sqrt{2}} \begin{bmatrix} h_0(0) & h_0(1/2) \\ h_1(0) & h_1(1/2) \end{bmatrix}$$

$$= \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

Assumed values

U	P	q
1	0	0
2	1	0
3	1	1

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when U is zero ie '0', $h_u(x)$ is independent of p and q.

Q4b) Find the DCT of $x(n) = \{1, 2, 1, 4\}$.

→

for a sequence $x(n)$ of length N is given by

Type DCT - II formula

$$X(k) = 2 \sum_{n=0}^{N-1} x(n) \cos\left[\frac{\pi k (2n+1)}{2N}\right]$$

for $N = 4$, index k ranges from 0 to 3

To calculate $X(0)$

for $k = 0$, cosine term becomes $\cos(0) = 1$

$$\therefore X(0) = 2 \sum_{n=0}^{3} x(n) = 2(1+2+1+4) = 2(8) = 16.000$$

To calculate $X(1)$

for $K = 1$

$$X(1) = 2\left[1 \cdot \cos(\pi/8) + 2 \cdot \cos(3\pi/8) + 1 \cdot \cos(5\pi/8) + 4 \cdot \cos(7\pi/8)\right]$$

$\cos(\pi/8) \simeq 0.9239$

$\cos(3\pi/8) \simeq 0.3827$

$\cos(5\pi/8) \simeq -0.3827$

& $\cos(7\pi/8) \simeq -0.9239$

$$\therefore X[1] = 2[0.9239 + 0.7654 - 0.3827 - 3.6956]$$

$$= -4.778$$

To calculate $X(2)$

for $k = 2$,

$$X(2) = 2\left[1 \cdot \cos 2\pi/8 + 2 \cdot \cos \frac{6\pi}{8} + 1 \cdot \cos(10\pi/8) + 4 \cdot \cos(14\pi/8)\right]$$

$\cos(\pi/4) = 1/\sqrt{2} \simeq 0.7071$

$$X(2) = 2[0.7071 - 1.4142 - 0.7071 + 2.8284] = 2.828$$

To calculate $X(3)$

for $k = 3$

$$X(3) = 2\left[1 \cdot \cos(3\pi/8) + 2 \cdot \cos\left(\frac{9\pi}{8}\right) + 1 \cdot \cos\left(\frac{15\pi}{8}\right) + 4 \cos(21\pi/8)\right]$$

$$X(3) = 2[0.3827 - 1.8478 + 0.9239 - 1.5308]$$

$X(3) = -4.144$

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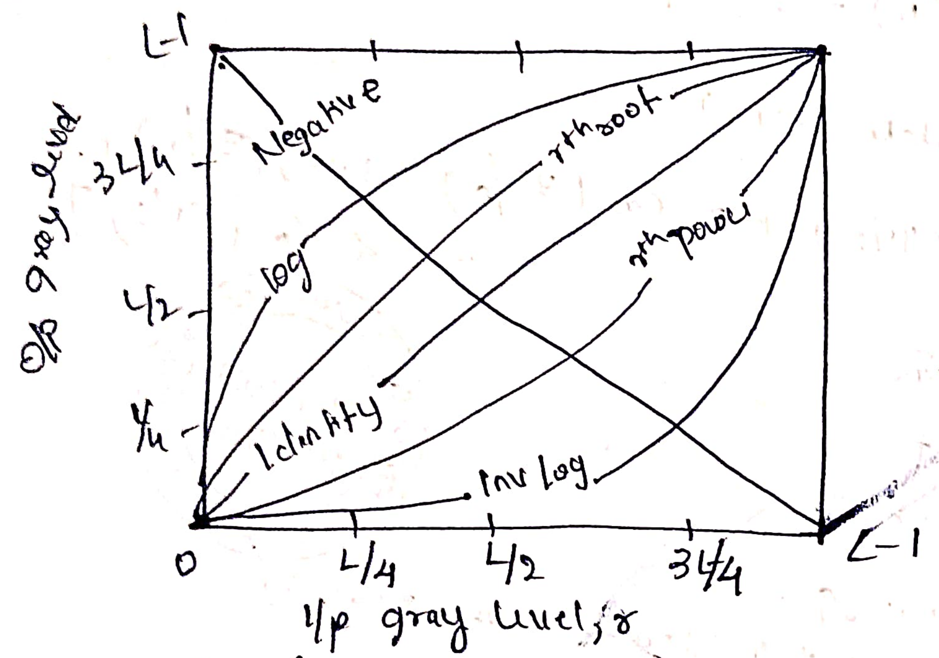
MODULE-03

Q5a) Describe image negative & Logarithmic transformation.

→ * The negative of an image with gray levels in the range [0, L-1] is obtained by using negative transformation.

$$s = L-1-r \quad \text{—— (1)}$$

* This type of processing is particularly suited for enhancing white or gray detail embedded in dark regions of an image especially when the black areas are dominant in size.



→ Log transformations:

* General form of the log transformation is

$$s = c\log(1+r)$$

where c is a constant & it is assumed that $r \geq 0$

* The shape of the log curve is as shown, that is transformation may narrow range of low gray level values in the input image into a wider range of o/p levels. Opposite is true for higher values of i/p levels.

* The use of transformation of this type expand the value of dark pixel in an image while compressing the higher gray level values.

Opposite is true for the inverse log transformation

Q5b) Assuming continuous intensity values, an image has the intensity pdf.

$$P_r(r) = \begin{cases} \frac{2r}{(L-1)^2}, & 0 \le r \le L-1 \\ 0 & \text{else where.} \end{cases}$$

Find the transformation that would produce an image whose intensity pdf is

$$P_z(z) = \begin{cases} \frac{3z^2}{(L-1)^3}, & 0 \le z \le L-1 \\ 0 & \text{else where.} \end{cases}$$

→ Histogram equalisation transformation

$$s = T(r) = (L-1)\int_0^r P_r(w)\,dw$$

$$= (L-1)\int_0^r \frac{2w}{(L-1)^2}\,dw$$

$$= \frac{2}{L-1}\int_0^r w\,dw = \frac{2}{L-1}\frac{w^2}{2}\Big|_0^r = \frac{r^2}{L-1}$$

$$s = T(r) = \frac{r^2}{(L-1)} \text{ ——— } (1) \qquad 0 \le s \le L-1$$

$$\therefore G(z) = (L-1)\int_0^z P_z(t)\,dt = (L-1)\int_0^z \frac{3t^2}{(L-1)^{3}}\,dt$$

$$= \frac{3}{(L-1)^2}\int_0^z P_z(t)\,dt = (L-1)\int_0^z \frac{3t^2}{(L-1)^{3}}\,dt$$

$$= \frac{3}{(L-1)^2}\int_0^z t^2\,dt = \frac{3}{(L-1)^2}\frac{t^3}{3}\Big|_0^z = \frac{z^3}{(L-1)^2}$$

$$G(z) = \frac{z^3}{(L-1)^2} \qquad 0 \le z \le L-1$$

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But $G(z) = s$

$\therefore s = \frac{z^3}{(L-1)^2}$

$z = [(L-1)^2 s]^{1/3}$

we can generate z's directly from the intensities r, of the i/p image.

<u>Sub</u> for 3 to eqn & of z

$$z = \left[(L-1)^2 \cdot \frac{r^2}{(L-1)} \right]^{1/3}$$

$$= [(L-1) r^2]^{1/3}$$

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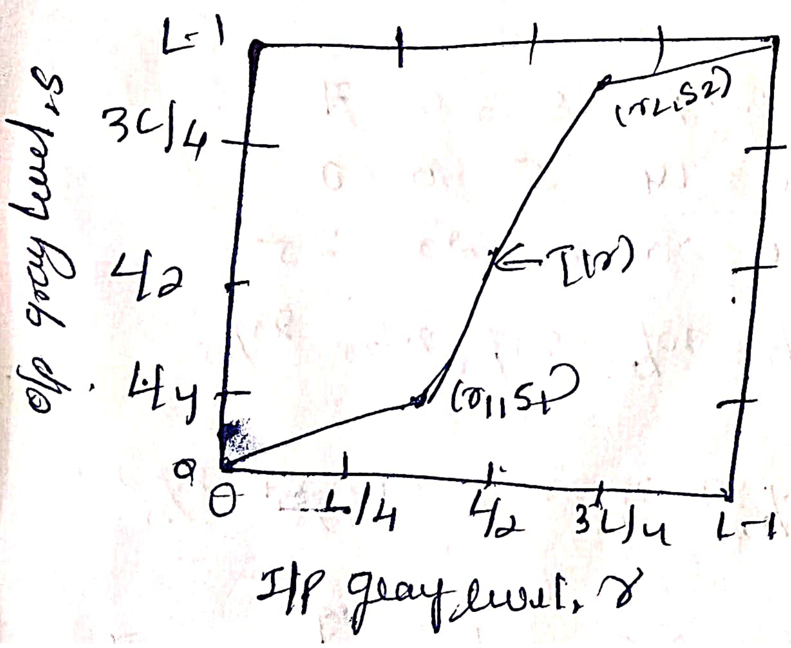
or

16a). Explain piecewise – linear transformation function used in image enhancement.

→ Contrast stretching:

* Low contrast images can result from poor illumination.
* Lack of dynamic range in the ~~range~~ image sensor or even wrong setting of a lens aperture during image acquisition.
* The idea behind the contrast stretching is to increase the dynamic range of the gray levels in the image being processed.
* The locations of points (r_1, s_1) & (r_2, s_2) control the shape of transformation functions.
* If $r_1 = s_1$ and $r_2 = s_2$, the transformation is a identity transformation, produces no change in gray levels.
* If $r_2 = s_2$ & $s_1 = 0$ & $s_2 = L-1$, the transformation becomes a thresholding function that creates a binary image (two gray level 0 & 1).
* In general $r_1 \le r_2$ & $s_1 \le s_2$, so that function is single valued & monotonically increasing.
* The input image gray levels b/w r_1 & r_2 will have a good stretch b/w s_1 & s_2 in the o/p image gray levels



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Q6b) Find histogram linearization of the following image segment.

$$\begin{bmatrix} 4 & 4 & 4 & 4 & 4 \\ 3 & 4 & 5 & 4 & 3 \\ 3 & 5 & 5 & 5 & 3 \\ 3 & 4 & 5 & 4 & 3 \\ 4 & 4 & 4 & 4 & 4 \end{bmatrix}$$

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max value is 5. so 3 bit to represent a pixel

The histogram of i/p image is.

Gray level	0	1	2	3	4	5	6	7
no. of pixel	0	0	0	6	14	5	0	0

Step I: compute the running sum of histogram values.

The running sum of histogram values is known as cumulative frequency distribution

Gray level	0	1	2	3	4	5	6	7
No. of pixel	0	0	0	6	14	5	0	0
Running sum	0	0	0	6	20	25	25	25

Step 2: Devide the running sum obtained in step I by the total no of pixels.

Total no of pixels = 25

Gray level	0	1	2	3	4	5	6	7
No. of pixels	0	0	0	6	14	5	0	0
Running sum	0	0	0	6	20	25	20	25
Running sum / Total No. of pixel	0/25	0/25	0/25	6/25	20/25	25/25	25/25	25/25
Mul by max level value	0/25 × 7	0/25 × 7	0/25 × 7	6/25 × 7	25/25 × 7	25/25 × 7	25/25 × 7	25/25 × 7
Histogram equ values	0	0	0	2	6	7	7	7

Step 3 : multiply the result obtained in step 2 by the max. gray-level value which is 7 in this case

& This case :
The result is then rounded to the closest Integer

Step 4 : Mapping of gray level by a one-to-one correspondence

$$\begin{bmatrix} 4 & 4 & 4 & 4 & 4 \\ 3 & 4 & 5 & 4 & 3 \\ 3 & 5 & 5 & 5 & 3 \\ 3 & 4 & 5 & 4 & 3 \\ 4 & 4 & 4 & 4 & 4 \end{bmatrix} \xrightarrow[\text{equalization}]{\text{Histogram}} \begin{bmatrix} 6 & 6 & 6 & 6 & 6 \\ 2 & 6 & 7 & 6 & 2 \\ 2 & 7 & 7 & 7 & 2 \\ 2 & 6 & 7 & 6 & 2 \\ 6 & 6 & 6 & 6 & 6 \end{bmatrix}$$

Original Image. Histogram Equalized image

MODULE - 04

Q7a) Describe Image smoothing filters in frequency-Domain

→ Edges & sharp transition — high frequency

Smoothing / blurring is achieved in freq domain by ~~att~~ attenuating high freq. Components in the transform of an image.

Basic model for filtering in freq domain

$G(u,v) = H(u,v) \cdot F(u,v)$

FT of the image.

$H(u,v)$ → filter freq to be selected so that it yields $G(u,v)$ by attenuation the high-freq of $F(u,v)$

3 types of Low pass filters

- Ideal —— sharp T.B
- Butterworth
- Gaussian —— Smooth TB

BW filter has filter order

↑ order → approaches ideal filter

↓ order → smooth form similar to Guassian filter

Ideal Low pass filter → $H(u,v) = \begin{cases} 1 & \text{if } D(u,v) \le D_0 \\ 0 & \text{if } D(u,v) > D_0 \end{cases}$

⇒ LoP filter → cuts off all high frequency components of F.T that are at a distance greater than D_0 from the origin of the centred transform

This is a 2-D Ideal LPF

$$H(u,v) = \begin{cases} 1 & \text{if } D(u,v) \le D_0 \\ 0 & \text{if } D(u,v) > D_0 \end{cases}$$

D_0 = specified non negative quantity.
Center of the rectangle is at $(M/2, N/2)$
Distance from any pt (u,v) to the center

$$D(u,v) = \sqrt{(u-M/2)^2 + (v-N/2)^2}$$

<u>Butterworth low pass filter</u>:

Transfer function of BLPF of order n & with cut off frequency at a distance D_0 from the origin

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

<u>Gaussian lowpass filter</u>:

$$H(u,v) = e^{-D^2(u,v)/2\sigma^2}$$

$\sigma \rightarrow$ measure of the spread of gaussian curve

Let $\sigma = D_0 \rightarrow$ so that we express the filter in a more familiar form

$$H(u,v) = e^{-D^2(u,v)/2D_0^2}$$

$D_0 \rightarrow$ cut off frequency.

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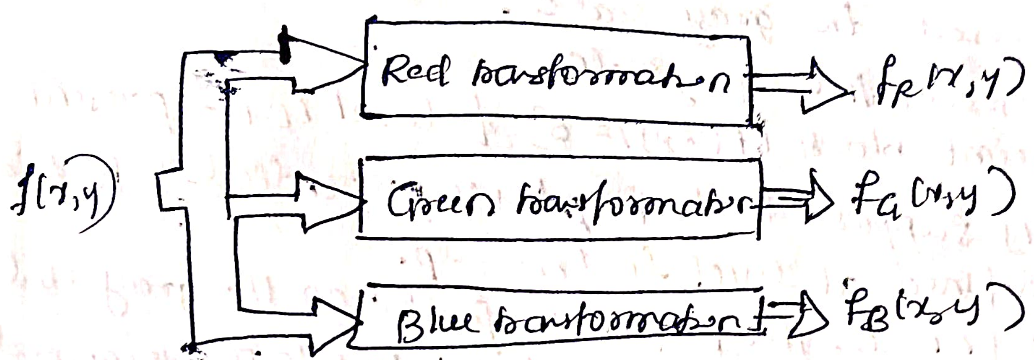
Q76) Explain pseudo colour Image Processing?

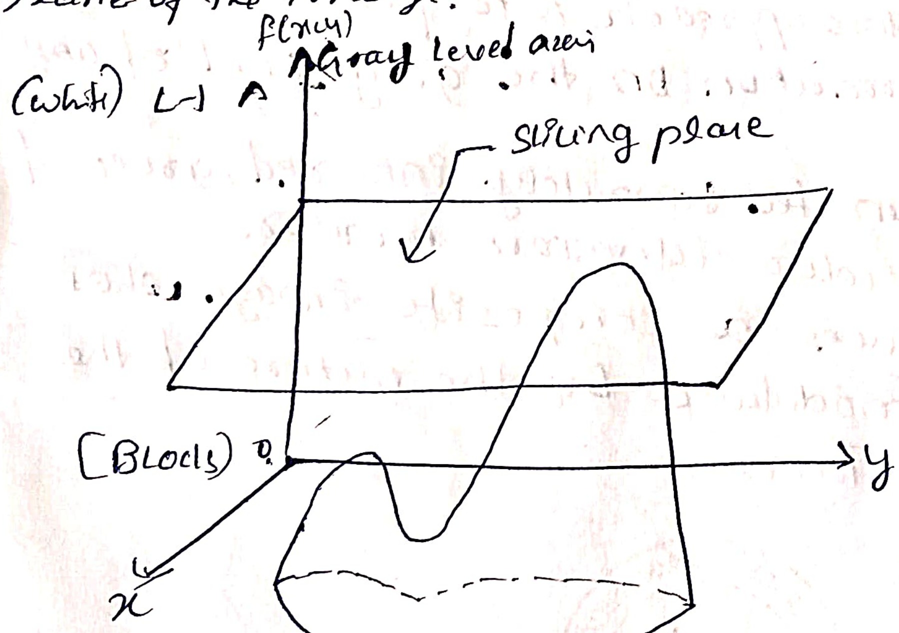
→ Pseudo color (also called false color) Image processing consists of assigning colors to gray values based on specified criterion.

* Function block diagram of pseudo colour image processing



→ Intensity slicing:

* The technique of intensity slicing and color coding is one of the simplest example of pseudocolor image processing.
* If image is interpreted as a 3-D function, the method can be viewed as one of the placing planes parallel to the co-ordinate plane of the image.



* If a different color is assigned to each side of plane many pixel whose gray level is above the plane will be ~~added with~~ coded with one colour, & any pixel below one plane will be coded with other.

level that lies one plane itself may be arbitrarily assigned one of the two colours.

* The whole result coloured image whose relative appearance can be controlled by moving the slicing plane up and down the gray-level axis.
* In general, the technique may be summarized as follows.
* Let [0, L-1] represent the gray scale.
* Let level l_0 represent the gray scale.
* Let level l_0 represent black $[f(x,y)=0]$ & level l_{L-1} represent white $[f(x,y)=L-1]$ suppose that P planes perpendicular to the intensity axis are defined at level $l_1, l_2, \ldots l_p$.

Assuming that $0 < P < L-1$, the P planes partition the gray scale into P+1 intervals $V_1, V_2 \ldots V_{P+1}$. Gray-level to color assignment are made according to the relation.

$$f(x,y) = C_k \text{ if } f(x,y) \in V_k.$$

* where C_k is color associated with k^{th} intensity interval V_k defined by the partition planes $l=k-1$ & $l=k$.

<u>Gray Level to Color transformation:</u>

* The idea underlying this approach is to perform three independent transformation on the gray level of any I/P pixel.
* The 3 results are then fed separately into red, green & blue channels of a color television monitor.
* This method produces a composite image whose color content is modulated by the nature of the transformation function.

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Or

Q8a) Explain image sharpening filters in frequency-domain.

→ The principal objective of sharpening is to highlight transitions in intensity

* Image sharpening finds applications in electronic printing & medical image, & also in industrial inspection & autonomous guidance in military system.
* Image blurring can be accomplished in the spatial domain by pixel averaging in a neighbourhood.
* Because averaging is analogous is integration.

Since sharpening is the reverse of smoothing, sharpening can be achieved by spatial differentiation

* The strength of the response of a derivative operator is proportional to the degree of intensity discontinuity of the image at the point at which the operator is applied.

Thus, image differentiation enhance edges & other discontinuities (such as noise) & deemphasizes area with slowly varying intensities. Sharpening filters are based on first & second order derivatives

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Q86) Describe Homomorphic filter in detail.

→ An image $f(x,y)$ can be expressed as the product of illumination & reflectance components:

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

* This eqn cannot be used directly to operate separately on the frequency components of illumination & reflectance because

$$F\{f(x,y)\} \neq F\{i(x,y)\}\,F\{r(x,y)\}.$$

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* Suppose we define

$$z(x,y) = \ln f(x,y)$$
$$= \ln i(x,y) + \ln r(x,y).$$

or

$$Z(u,v) = F_i(u,v) + F_r(u,v).$$

where $F_i(u,v)$ & $F_r(u,v)$ are Fourier Transforms.

* If we process $Z(u,v)$ by means of a filter function $H(u,v)$ then

$$S(u,v) = H(u,v)\,Z(u,v)$$
$$= H(u,v)F_i(u,v) + H(u,v)F_r(u,v).$$

$S(u,v)$ is Fourier transform of result.

* In spatial domain,

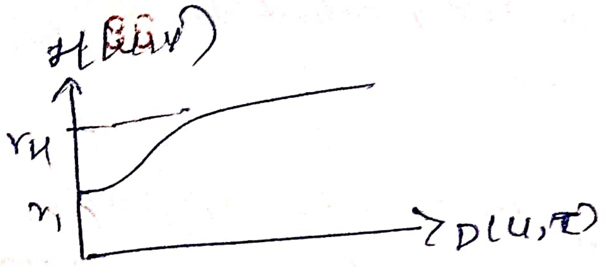
$$s(x,y) = F^{-1}\{S(u,v)\}$$
$$= F^{-1}\{H(u,v)F_i(u,v)\} + F^{-1}\{H(u,v)F_r(u,v)\}$$
$$= i'(x,y) + r'(x,y).$$

* $$g(x,y) = e^{s(x,y)} = e^{i'(x,y)}\,e^{r'(x,y)} = i_0(x,y)\,r_0(x,y).$$

$$f(x,y) \rightarrow \boxed{\ln} \rightarrow \boxed{DFT} \rightarrow \boxed{H(u,v)} \rightarrow \boxed{(DFT)^{-1}} \rightarrow \boxed{\exp} \rightarrow g(x,y)$$

Fig: Homomorphic filtering approach for image enhancement.

* The key to the approach is separation of illumination & reflectance components.
* The homomorphic filter funcn $H(u,v)$ can then operate on these components separately.
* Illumination component of an image is characterized by slow spatial variations, while reflectance components tends to vary abruptly, particularly at the junctions of dissimilar objects.

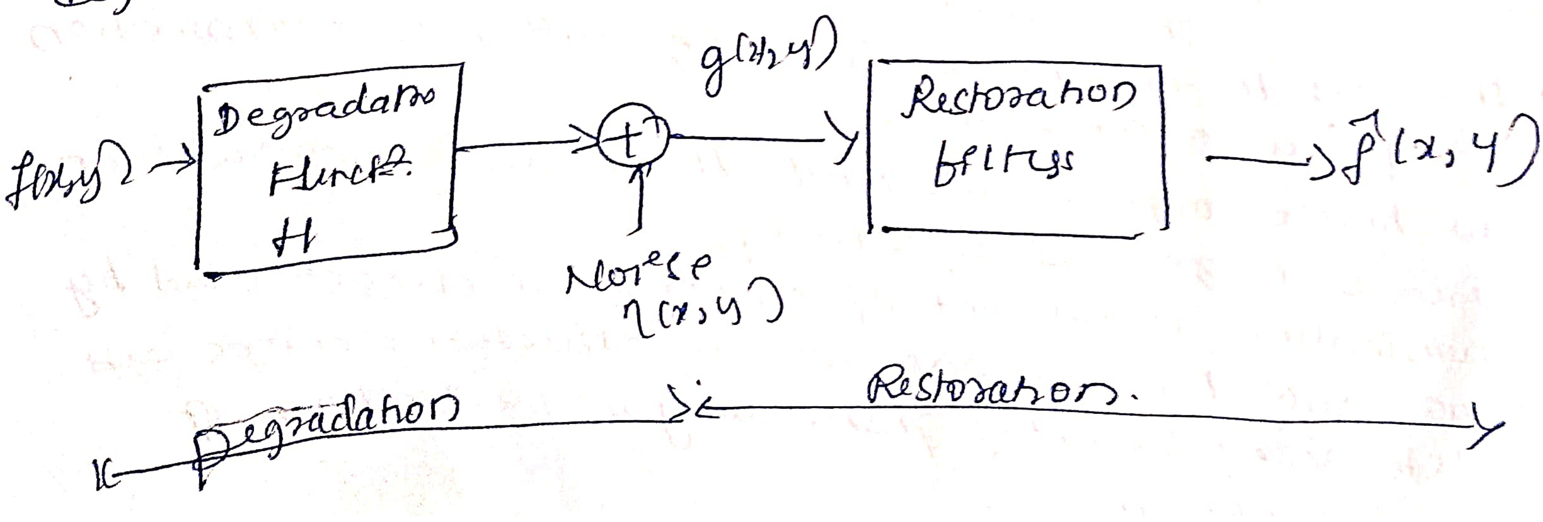


* fig shows cross section of such filter.
* if the parameters are choosen so that $\gamma_L < 1$ & $\gamma_H > 1$, the filter tends to decrease the contribution made by the low frequencies (illumination) & amplify the contribution made by high frequencies (reflectance).
* Net result is simultaneous dynamic range compression & contrast enhancement.
* $H(u,v) = (\gamma_H - \gamma_L)[1 - e^{-c(D^2(u,v)/D_0^2)}] + \gamma_L$
* Contrast c has been introduced to control sharpness of slope of filter function as it transitions b/w γ_L & γ_H
* This type filter is similar to the high-frequency emphasis filter.

module 05

Q9a) Describe a model for image degradation/restoration process.

→ Degradation process is modeled as a degradation function that together with an additive noise term operates on an i/p image f(x,y) to produce a degraded image g(x,y)



→ Given $g(x,y)$ with some knowledge of H & η the objective is to get an estimate $\hat{f}(x,y)$ of original image.

H → Linear, position-invariant process in spatial domain

$$g(x,y) = f(x,y) * h(x,y) + \eta(x,y)$$

in freq domain

$$G(u,v) = F(u,v) \cdot H(u,v) + N(u,v)$$

* Restoration is the process of noise only spatial filtering when the only degradation present in an image is noise. then

$$g(x,y) = f(x,y) + \eta(x,y)$$

& $G(u,v) = F(u,v) + N(u,v)$.

The noise terms are unknown, no subtracting them from $g(x,y)$ or $G(u,v)$ is not a realistic option.

* In case of periodic noise, it is possible to estimate $N(u,v)$ from spectrum of $G(u,v)$.

then $N(u,v)$ can be subtracted from $G(u,v)$ to obtain an estimate of original image.

* Spatial filtering is the method of choice in situation when only addition random noise is present.

Q6) Explain some important noise pdfs.

→ In signal processing & image processing, noise is modeled using probability density functions (PDFs) to represent the likelihood of different noise intensities occurring. Understanding these models is essential for designing filters that restore images or improve communication signals.

1. Gaussian Noise (Normal Distribution)

→ Guassian noise

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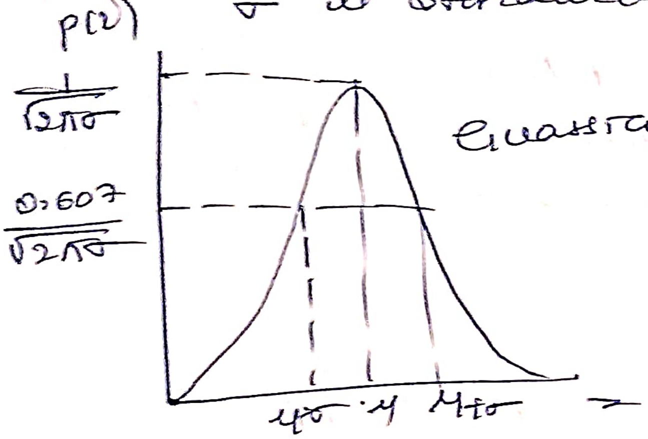
→ The PDF of Gaussian random variables is given by

$$p(z) = \frac{1}{\sqrt{2\pi}\sigma} e^{-(z-\mu)^2/2\sigma^2}$$

where z represents gray level

μ is mean of average value of z

σ is standard deviation



2. Rayleigh noise

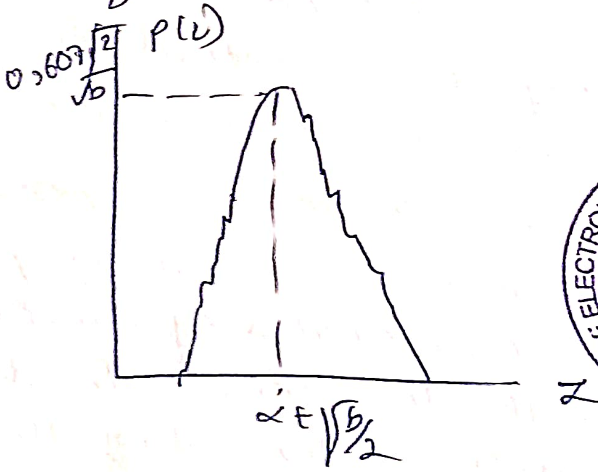
→ PDF of Rayleigh noise is given by

$$p(z) = \begin{cases} \frac{2}{b}(z-a)e^{-(z-a)^2/b} & \text{for } z \geq a \\ 0 & \text{for } z \leq a \end{cases}$$

mean & variance of the density are given by

$$\mu = a + \sqrt{\pi b/4}$$

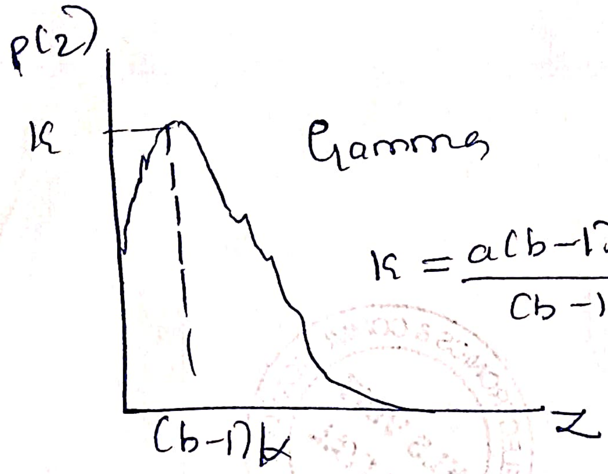
$$\sigma^2 = \frac{b(4-\pi)}{4}$$



3. Erlang (Gamma) Noise:

The PDF of erlang noise is given by

$$p(z) = \begin{cases} \frac{a^b z^{b-1}}{(b-1)!} e^{-az} & \text{for } z \geq 0 \\ 0 & \text{for } z < 0 \end{cases} \quad \text{—— (1)}$$



$$K = \frac{a(b-1)^{b-1}}{(b-1)!} e^{-(b-1)}$$

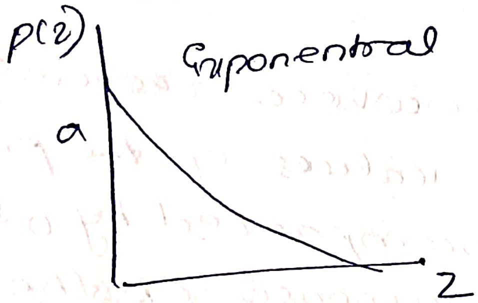
Exponential noise

$$p(z) = \begin{cases} a e^{-az} & \text{for } z \geq 0 \\ 0 & \text{for } z < 0 \end{cases}$$

where $a > 0$

The mean & variance of this density function are

$$\mu = \frac{1}{a} \quad \& \quad \sigma^2 = \frac{1}{a^2}$$

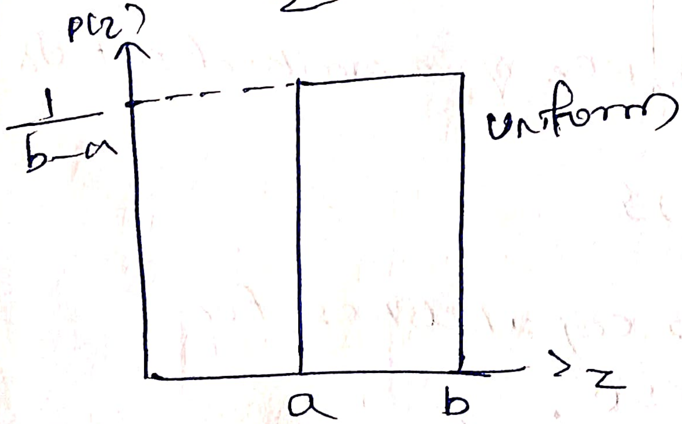


uniform noise

$$p(z) = \begin{cases} \frac{1}{b-a} & \text{if } a \leq z \leq b \\ 0 & \text{otherwise.} \end{cases}$$

mean & variances of this density are.

$$\mu = \frac{a+b}{2} \quad \& \quad \sigma^2 = \frac{(b-a)^2}{12}$$



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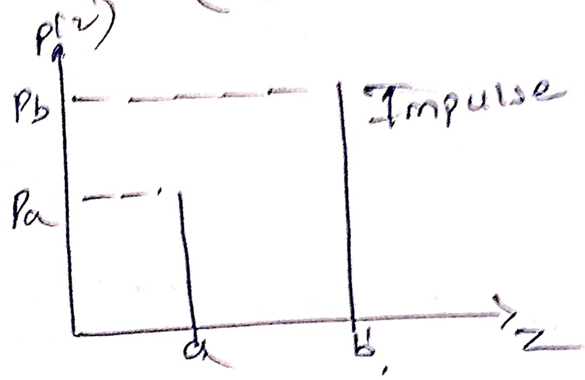
Impulse (Salt & pepper) noise

$$p(z) = \begin{cases} P_a & \text{for } z = a \\ P_b & \text{for } z = b \\ 0 & \text{otherwise} \end{cases}$$



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Or

Q.10 a) Explain 4-order-statistic filters used in image restoration.

→ Order static filters are spatial filters whose response is based on ordering (ranking) the values of the pixels contained in the image area encompassed by filter. Ranking result determines the response of the filter.

Median filter -

* In this method value of a pixel is replaced by median of the intensity levels in the neighbourhood of that pixel.
* median represent 50th percentile of a ranked set of numbers.

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

* It has excellent noise reduction capabilities for certain types of random noise.
* less blurring than linear smoothing filter of similar size

* It is effective in presence of both bipolar & unipolar noise.

Max & min filters

Max filters uses the 100th percentile of a ranked set of numbers

Max filters

$$\hat{f}(x,y) = \max_{(s,t)\in S_{x,y}} \{g(s,t)\}$$

* It is good for removing pepper noise present in the image.

Min filters : is 0th percentile of ranked set of numbers

Min filters

$$\hat{f}(x,y) = \min_{(s,t)\in S_{x,y}} \{g(s,t)\}$$

* It is good for removing salt noise present in the image

Midpoint filters :

* Midpoint filters computes b/w max & min values in the area encompassed by filters.

$$\hat{f}(x,y) = \frac{1}{2}\left[\max_{(s,t)\in S_{xy}} \{g(s,t)\} + \min_{(s,t)\in S_{xy}} \{g(s,t)\}\right]$$

* This filter combines order statistics & averaging filters. It works best for randomly distributed noise, like gaussian or uniform noise.

adaptive filter :

* The behaviour of adaptive filter changes based on statistical characteristics of the image inside the filter region defined by m×n rectangular window
* The performance is superior to that of mean filter or order statistic filters.
* Filter complexity is increased when filter is designed for improved filtering

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Q 10b) 32 Describe 4 mean filter used in image restoration

→ ① Arithmetic mean filter:

* This is the simplest of mean filter.
* Let Sxy represent the set of coordinates in rectangular subimage window of size m×n centred at pt(x,y)
* $\hat{f}(x,y) = \frac{1}{mn} \sum_{(s,t) \in S_{xy}} g(s,t)$.
* The value of the restored image $\hat{f}$ at pt(x,y) is arithmetic mean computed using the pixels in the region defined by Sxy
* This operation can be implemented using a spatial filter of size m×n in which all coefficients have value 1/mn.
* a mean filter smooths local variations in an image & noise is reduced as a result of blurring.

② Geometric mean filter

* an image restored using geometric mean filter is given by

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

Each restored pixel is given by product of the pixel in subimage window, raised to the power 1/mn
* a geometric mean filter achieves smoothing comparable to arithmetic mean filter but it tends to lose less image detail in process

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(3) Harmonic mean filters

* Harmonic mean filters operation is given by

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

* The harmonic mean filter works well for salt noise but fails for pepper noise.
* It does well also with other types of noise like gaussian noise

(4) Contra harmonic mean filters

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

Q order of filter

* This filter is well suited for eliminating the effects of salt & pepper noise

Q is +ve → eliminates pepper noise

Q is -ve → eliminates salt noise.

It cannot do both simultaneously.

* The contraharmonic filter reduces to the arithmetic mean filter if $Q=0$ & to the harmonic mean filter if $Q=-1$.

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