CBCS SCHEME

USN 2VD19EC406 **18EC733**

Seventh Semester B.E. Degree Examination, Feb./Mar. 2022
Digital Image Processing

Time: 3 hrs. Max. Marks: 100

Note: ***Answer any FIVE full questions, choosing ONE full question from each module.***

Module-1

1 a. Explain with block diagram the fundamental steps used in digital image processing. **(10 Marks)**

b. Explain the image acquisition using sensor strips and sensor arrays. **(10 Marks)**

OR

2 a. What is digital image processing? Explain the applications of image processing. **(06 Marks)**

b. With the help of neat diagram, explain the components of a general purpose image processing system. **(08 Marks)**

c. How image is formed in eye? Explain visual perception of eye. **(06 Marks)**

Module-2

3 a. Explain the process of image sampling and quantization in the digital image formulation. **(08 Marks)**

b. With necessary graphs explain the log and power law transformation used for spatial image enhancement. **(08 Marks)**

c. Compute the lengths of the shortest 4, 8 and M path between p and q in the image segment shown in Table Q3(c) by considering $v = \{2, 3, 4\}$.

	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	

Table Q3(c) **(04 Marks)**

OR

4 a. Explain the adjacency, connectivity, regions and boundaries between pixels with examples. **(10 Marks)**

b. What do you mean by histogram processing? Explain histogram equalization. **(10 Marks)**

Module-3

5 a. Explain smoothing of images in frequency domain using ideal, Butterworth and Gaussian low pass filter. **(12 Marks)**

b. Explain the properties of 2-dimensional DFT. **(08 Marks)**

OR

6 a. Explain the basic steps of filtering in frequency domain. Explain one method of sharpening frequency domain filters. **(10 Marks)**

b. Discuss the homomorphic filtering approach for image enhancement. **(10 Marks)**

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-4

7 a. Explain the importance of image restoration process in image processing with the basic model diagram. Explain any four noise probability density functions. (10 Marks)

b. Explain Weiner filtering and inverse filtering in image processing. (10 Marks)

OR

8 a. Explain the following methods to estimate the degradation function, used in image restoration.
   i) Estimation by image observation
   ii) Estimation by experiment
   iii) Mathematic modelling. (10 Marks)

b. Discuss the importance of adaptive filters in image restoration system highlight its working of adaptive median filter. (10 Marks)

Module-5

9 a. Explain the following morphological operations :
   i) Erosion
   ii) Dilation
   iii) Opening
   iv) Closing. (12 Marks)

b. Explain the RGB color model. (08 Marks)

OR

10 a. What is pseudo color image processing? Explain intensity slicing as applied to pseudo color image processing. (10 Marks)

b. Explain HSI color model and conversion from HSI to RGB colors. (10 Marks)

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Subject: Digital Image Processing

Subject code: 18EC733

Sem : 7

Year : 2022

29/3/2022

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30.08.2022

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AY: 2021-22

Department: E&C
Subject with Sub. Code: Digital Image Processing-18EC733 Semester / Division: 7 /A&B
Name of Faculty: Prof. Plasin Francis Dias

Q.No.	Solution and Scheme	Marks
1 a)	Fundamental steps used in digital image processing classification of DIP: List + Block Diagram + Explanation • Methods whose input and output are images. • Methods whose input may be images, but outputs are attributes. → 1) Image Acquisition : It is the first processing step in the image processing. It is as simple as, given an image that is already in digital form. It involves, processing such as scaling 2) Image enhencement: It is among the simplest and most appealing areas of digital image processing the idea behind this is to bring out details that are not clearly expressed or simply to highlight certain features of interest in image. 3) Image restoration: It deals with improving the appearance of an image. It is objective approach. It is based on mathematical or probabilistic models of image processing 4) Color Image processing: It is an area that is gaining importance because of the use of digital images over the internet. It deals with color models and their implementation. 5) Wavelets and multiresolution processing: These are the foundation for representing images in various degree of resolution.	4 + 6 10 M

Q.No.	Solution and Scheme	Marks

6) Compression: It deals with techniques reducing the storage required to save an image or the bandwidth required to transmit it over the network. The two major approaches are lossless compression and lossy compression.

7) Morphological processing
It deals with tools for extracting image components that are useful in the representation and description of shape and boundary of objects.

8) Representation and Description: It follows the o/p of segmentation step that is raw pixel data, constituting either boundary of an image or points in the region. In both cases converting the data to a form suitable for computer processing is necessary.

9) Recognition: It is the process that assigns label to an object based on its descriptors.

Knowledge base: It is about a problem domain coded into an image processing system in the form of knowledge base.

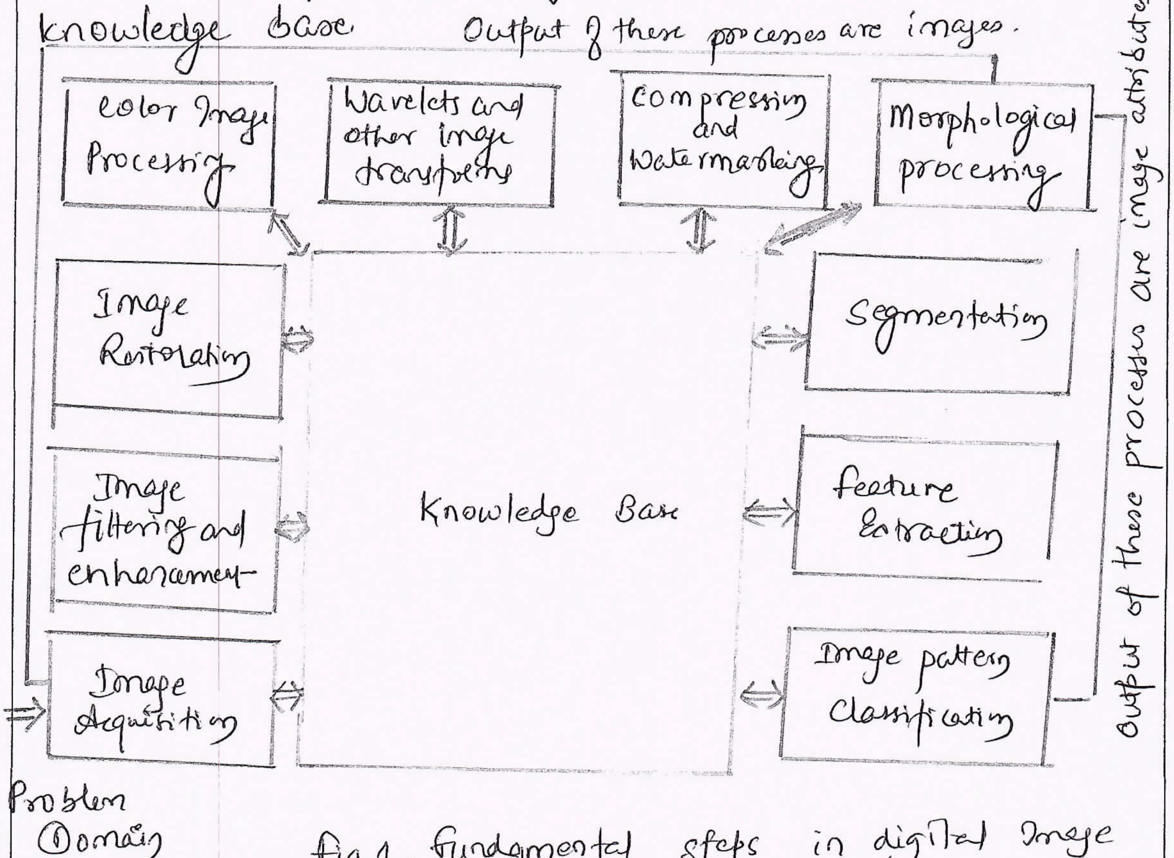


Fig 1. Fundamental steps in digital Image processing

Q.No.	Solution and Scheme	Marks
1 b)	Image Acquisition using sensor strips and sensor arrays.	

Sensors are used to transform illumination energy into digital images. Sensors are three types. i) Single Imaging sensor ii) Line sensor iii) Array sensor.

Diagram + Explanation — 4 + 6 = 10M

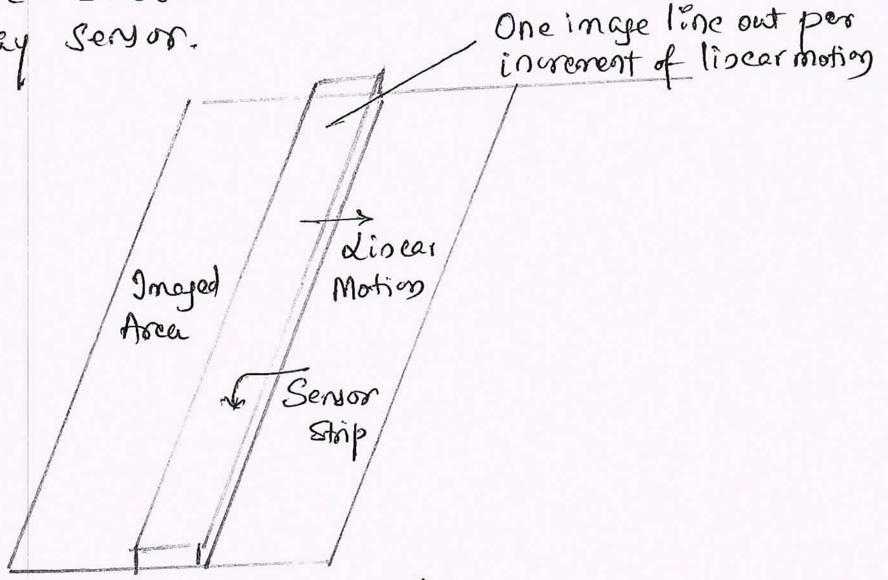
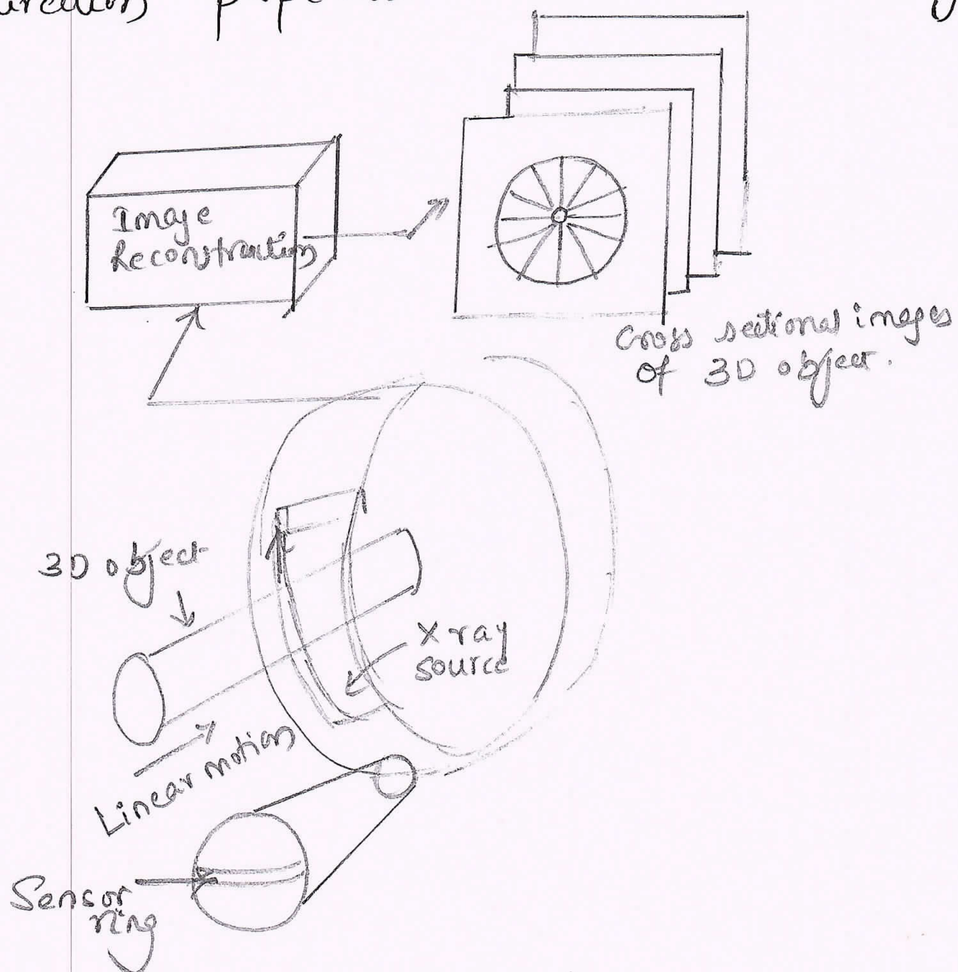


fig. @ Linear sensor strip.

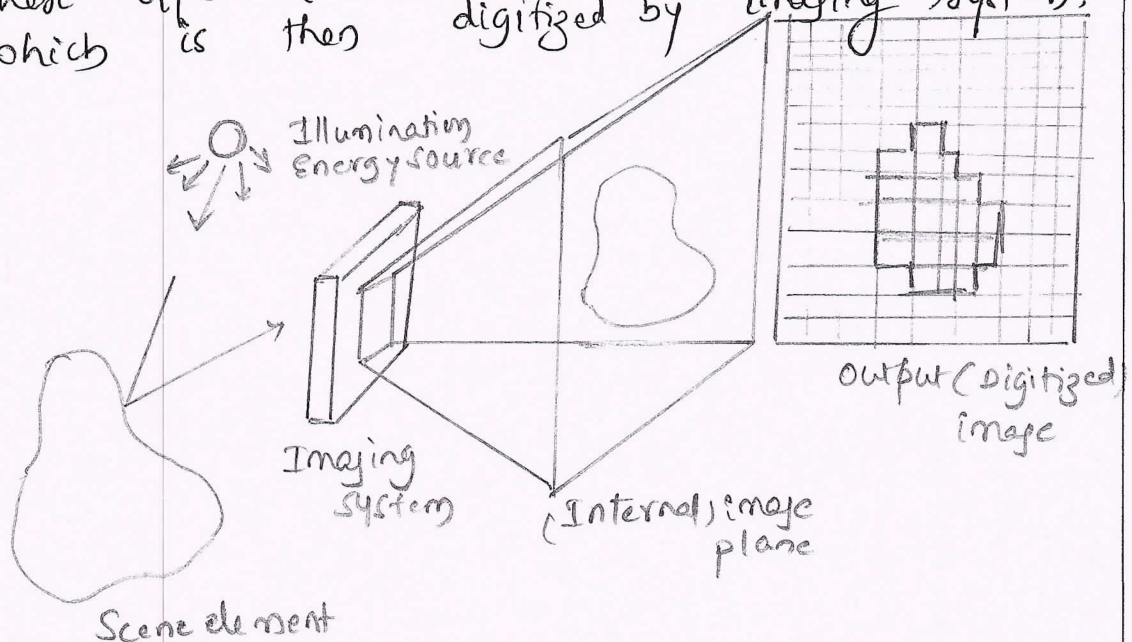
• Strip provides imaging elements in one direction
• Motion perpendicular to the strip provides imaging in the other direction. These arrangement is used in flat bed scanners. In line sensors are used in airborne imaging applications. Solid State arrays are composed of discrete silicon imaging elements called photosites that have a voltage output proportional to the intensity of the incident light.
• Two transfer gates used to clock the contents of the imaging elements into transport registers. An output gate used to clock the contents of the transport registers into an amplifier. The amplifier outputs a voltage signal proportional to the contents of the row of photosites. Sensor strips mounted in a ring configuration are used in medical and industrial imaging to obtain cross sectional (slice) images of 3D objects.

9

Q.No.	Solution and Scheme	Marks
	A rotating X ray source provides illumination and the portions the sensors opposite the source collect the X ray energy that pass through the object. A 3D digital volume consisting of stacked images is generated as the object is moved in a direction perpendicular to the sensor ring.	
		
	Image Acquisition Using Sensor Arrays. Electromagnetic and ultrasonic sensing devices are arranged in an array format. Typical sensor for digital camera is a CCD array. Charge coupled are arrays are similar to line scan sensors, except that the photosites are arranged in a matrix form and gate/transport register combination separates columns of photosites. Energy from an illumination source being reflected from scene element is represented in fig 1.	

Q.No.	Solution and Scheme	Marks

Imaging system collect the incoming energy & focus it onto an image plane. If the illumination is light, the front end of the imaging system is a lens, which project the viewed scene onto the lens focal plane. The sensor array, which is coincident with the focal plane, produces output proportional to the integral of the light received at each sensor. Digital and analog circuitry sweeps these o/ps & converts them to a video signal, which is then digitized by imaging system.



2 @ Digital Image processing and application of image processing

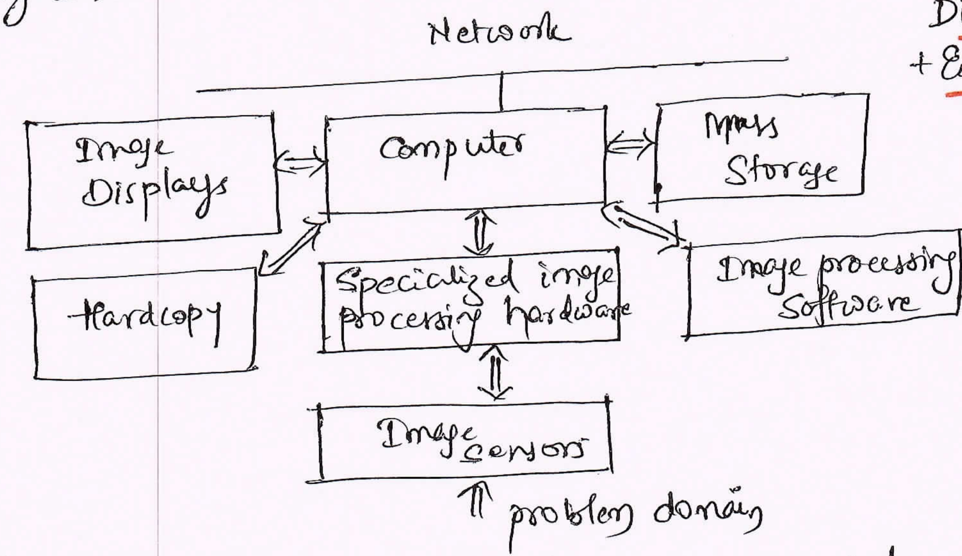
Definition + Applications list — 2 + 4 = 6M

Digital image processing is the use of computer algorithms to perform image processing on digital images. It refers to processing digital images by means of a digital computer. Digital image composed of finite number of elements called pixels or pels which has particular location and value.

Image Processing Applications:

- Medical Imaging
- Remote Earth resources observations
- Astronomy

Q.No.	Solution and Scheme	Marks
	• Computerized Axial Tomography (CAT)	
	Image processing are used in contract enhancement or code the intensity into color.	
	• X-Ray, Industrial, Medicine, Biological sciences.	
	• To study pollution pattern from aerial and satellite imagery.	
	Image enhancement and restoration are used to process degraded images of unrecoverable objects.	
	• Archeology – Image restoration	
	• Physics – Electron microscopy	
	• Astronomy, biology, nuclear medicine, law enforcement, defense, industrial application	
2 (b)	Components of a General purpose image processing System.	Diagram 3 + Explanation + 5 = 8 M



For sensing two elements are required to acquire digital images. The first is physical device that is sensitive to the energy radiated by the object. The second one is called digitizer, which is device to convert the o/p of the physical sensing device into digital form.

Specialized image processing hardware consists of digitizer plus hardware that performs other primitive operations such as arithmetic logic unit (ALU), that performs arithmetic & logical operations.

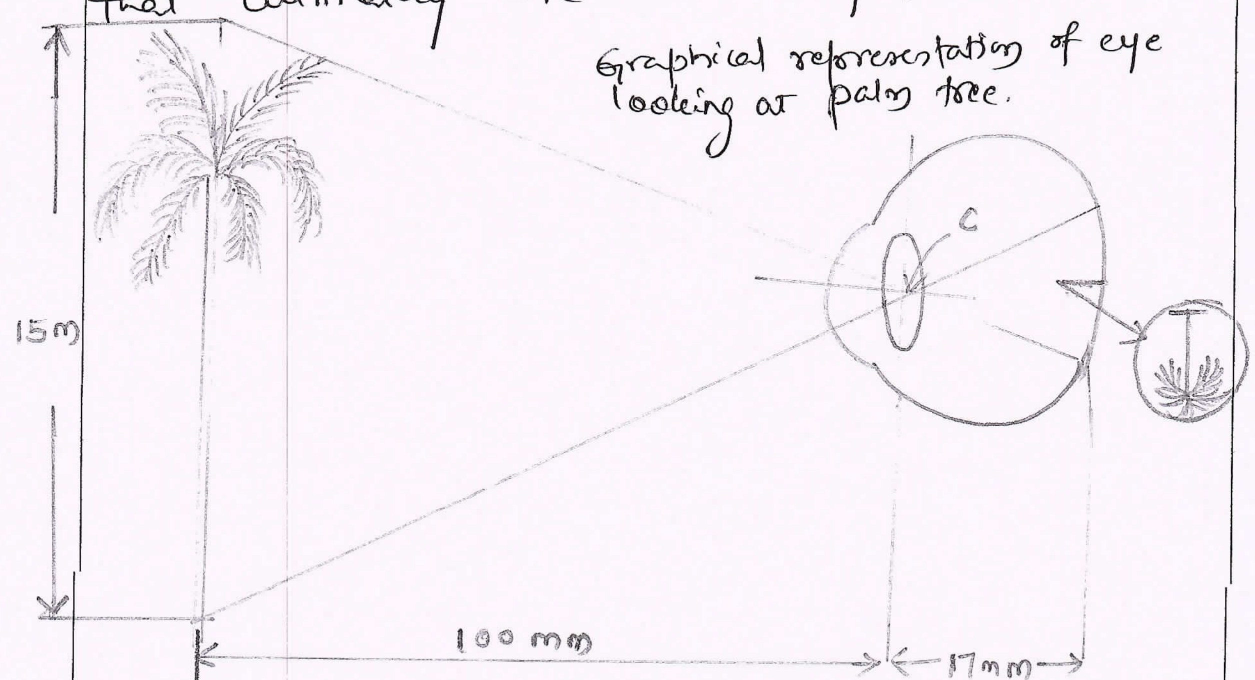
Q.No.	Solution and Scheme	Marks
	This type of hardware is called front end subsystem. This unit performs functions that require fast data throughputs. Computer in an image processing system is a general purpose computer and can range from PC to a super computer. Software for image processing consists of specialized modules that perform specific tasks. A well designed package includes capability for the user to write code, that as a minimum utilizes the specialized modules. Mass storage capability is a must in image processing applications. Digital storage for image processing applications falls into 3 categories. 1) short term storage for use during processing. 2) Online storage for relatively fast recall. 3) Archival storage, characterized by infrequent access. storage is measured in K bytes, M bytes, G bytes and T bytes. Method of providing short term storage is computer memory. An another is specialized boards called frame buffers, that store one or more images & can be accessed rapidly. Online storage takes the form of magnetic disks or optical media storage. Image displays are mainly color TV (flat screen) monitors. Monitors are driven by the outputs of image and graphics display cards, that are an integral part of the computer system. Hardcopy devices for recording images include laser printers, film cameras, heat sensitive devices, inkjet units and digital units, such as optical and CDROM disks. Networking is default function in any computer systems. The large amount of data is inherent in image processing applications. The key consideration in image transmission is bandwidth.	

Q.No.	Solution and Scheme	Marks
2 (c)	Image formation in eye and visual perception of eye	Diagram + Explanation: 3 + 3 = 6 M

In human eye distance between the lens and the imaging region (retina) is fixed and the focal length needed to achieve proper focus is obtained by varying the shape of the lens, The fibers in the ciliary body accomplish this by flattening or thickening the lens for distant or near objects respectively. The distance between the centre of the lens and retina along the axis is approximately 17 mm, The range of focal lengths is approximately 14 mm to 17 mm.

Example: A person looking at a tree 15 m high at a distance 100 m. Let h denote the height of that object in the retinal image, the geometry yields $15/100 = h/17$ or $h = 2.5$ mm.

Retinal image is focused primarily on the region of the fovea. Perception then takes place by the relative excitation of light receptors, which transform radiant energy into electrical impulses that ultimately are decoded by the brain.



c is the focal centre of the lens.

Q.No.	Solution and Scheme	Marks
3 (a)	Image Sampling and Quantization in the digital image formulation.	
		Definition 2 + Diagram + 3 + Explanation + 3 8 M

To create digital image, conversion of sensed data into a digital format is needed. This requires sampling and quantization.

fig (1a) shows continuous image f, to be converted to digital form. Image may be continuous with respect to the x and y coordinates and also in amplitude. To digitize sample the function in both coordinates and also in amplitude.

Digitizing the coordinate values is called sampling.
Digitizing the amplitude values is called quantization.

One dimensional function fig (1b) is a plot of amplitude (intensity level) values of the continuous image along the line segment AB in fig (1a). To sample the function, take equally spaced samples along line AB as shown in fig (1c). The vertical gray bar depicts the intensity values scale divided into eight discrete intervals, ranging from black to white. The vertical tick marks indicate the specific value assigned to each of the eight intensity intervals. The continuous intensity levels are quantized by assigning one of the eight values to each sample, depending on the vertical proximity of sample to a vertical tick mark. The digital samples resulting from both sampling and quantization are shown as white square in fig (1d).

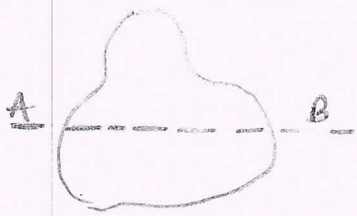


fig (1a)

fig (1b)

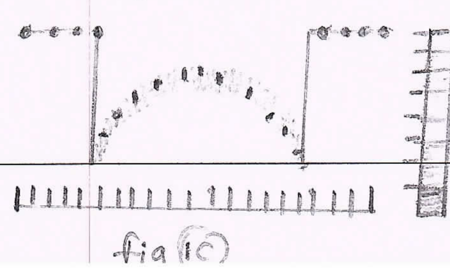


fig (1c)

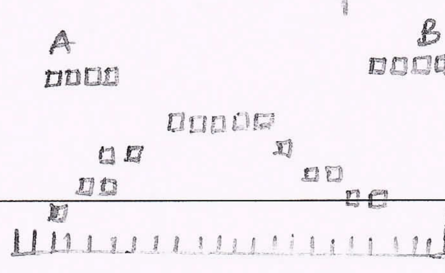


fig (1d)

9

Q.No.	Solution and Scheme	Marks
3(b)	Log and Power Law transformation used for spatial image enhancement.	Diagram 2 + Equation 2 + Explanation 4 = 8M

Log transformation:

General form $s = c\log(1+r)$ —— ①

where c is constant

Assume $r \geq 0$. The shape of the log curve shows that, this transformation maps a narrow range of low intensity values in the input into a wider range of output levels. Input levels in the range [0, L/4] map to output levels to the range [0, 3L/4]. The higher values of input levels are mapped to a narrower range in the output. Such transformation are used to expand the values of dark pixels in an image, while compressing the higher level values. The log function has the important characteristics, that it compresses the dynamic range of pixel values.

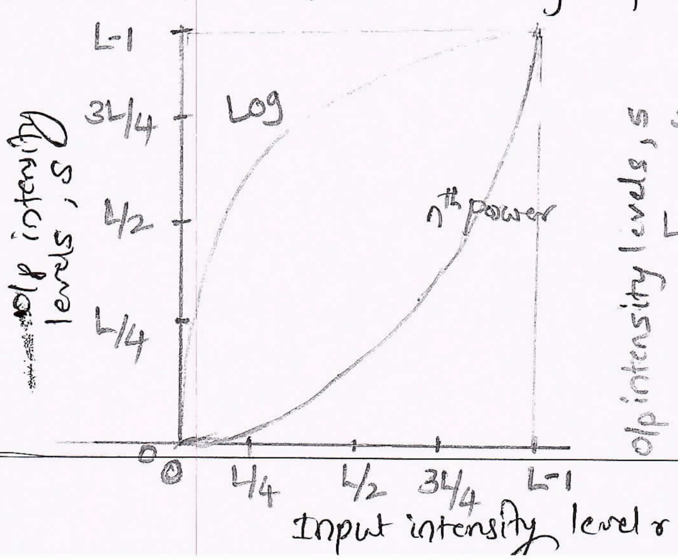
Ex: Fourier Spectrum.

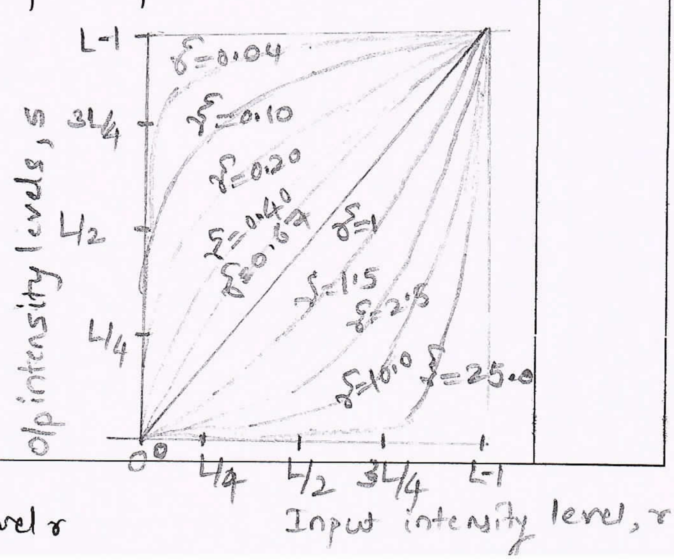
Power law (Gamma) Transformations

General form: $s = cr^{\gamma}$ —— ②

where c and γ are positive constants.

Equation ② is written as $s = c(r+\varepsilon)^{\gamma}$ to account for offsets. (measurable output when the input is zero). Power law curves with fractional values of γ map a narrow range of dark input values into a wider range of output values.





(10)

Q.No.	Solution and Scheme	Marks
3 c	Computing lengths of shortest 4, 8 and m path between p and q in the image segment.	path calculation + representation 3 + 1 = 4m

$V = \{2, 3, 4\}$

	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

(i) There is no 4 path between p and q, as none of the 4 neighbors of pixel q have from p.

(*)

	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

(ii) 8 Path length = 5

	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

(iii) m path length exist = 5

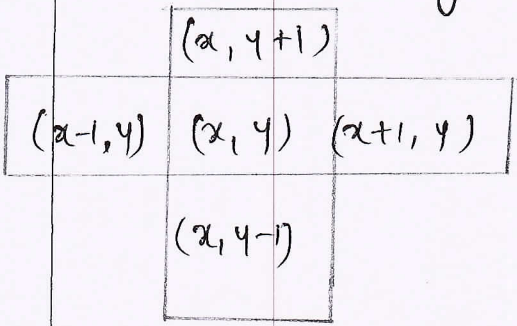
m path length = 5

3	4	1	2	0
0	1	0	4 →	2 (q)
2 →	2 →	3 ↗	1	4
3 ↑	0	4	2	1
1	2	0	3	4

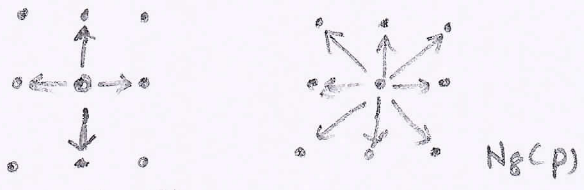
Q.No.	Solution and Scheme	Marks
4 (a)	Adjacency, connectivity, regions and boundaries between pixels with examples.	
	Let V be the set of intensity values used to define adjacency.	Def^n + Explanation Each term 2 × 4 = 8 + 2 = 10 m
	3 Types adjacency	
	i) 4 adjacency : Two pixels p & q with values from V are 4 adjacent if q is in the set $N_4(p)$.	
	(ii) 8 adjacency : Two pixels p and q with values from V are 8 adjacent if q is in the set $N_8(p)$	
	iii) m-adjacency (mixed adjacency) Two pixels p and q with values from V are m adjacent if, (i) q is in $N_4(p)$ or (ii) q is in $N_8(p)$ and the set $N_4(p) \cap N_4(q)$ has no pixels whose values are from V.	
	Connectivity: A digital path from pixel p to pixel q is a sequence of distinct pixels where the next pixels is adjacent to the previous one. Let S represent a subset of pixels in an image. Two pixels p & q are said to be connected in S if there exist a path between them consisting entirely of pixels in S.	
	Region: Let R be a subset of pixels in an image R is called region of the image if R is a connected set. Regions that are not adjacent are said to be disjoint.	
	Boundaries: The boundary (or border, or contour) of a region R is the set of points that are adjacent to points in the complement of R (the background) or the border of a region is	

Q.No.	Solution and Scheme	Marks

the set of pixels in the region that have at least one background neighbor.

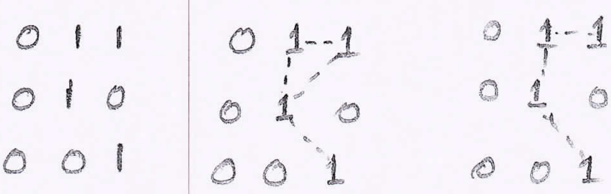


4 neighbourhood



$N_8(p) = N_4(p) \cup N_D(p)$

(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)



(a) Arrangement of Pixels (b) Pixels that are 8 adjacent (c) m-adjacency

4 (b) Histogram processing and Histogram equalization.

The Histogram of a digital image with intensity levels in the range [0, L-1] is a discrete function $h(r_k) = n_k$, where r_k is the k^{th} intensity value and n_k is the number of pixels in the image, with intensity r_k.

Definition 2
+ Equation + 4
+ Explanation + 4
10m

Normalized histogram is given by,

$p(r_k) = n_k / MN$, for $k = 0, 1, 2, \ldots L-1$

$p(r_k)$ is the estimate of the probability of occurrence of intensity level r_k in an image, The sum of all components of normalized histogram is equal to 1. Histogram are basis for spatial domain processing technique. Histogram manipulation can be used for image enhancement. Histograms plots how many times (frequency) each intensity value in image occurs.

Q.No.	Solution and Scheme	Marks

Histogram Equalization:

Let r denote intensities of an image to be processed, r is in the range $[0, L-1]$, with $r=0$ representing black and $r=L-1$ representing white,

$$s = T(r) \qquad 0 \le r \le L-1 \qquad \leftarrow \text{Transformation func}$$

Assume

(a) $T(r)$ is monotonically increasing function in the interval $0 \le r \le L-1$

(b) $0 \le T(r) \le L-1$ for $0 \le r \le L-1$

If $r = T^{-1}(s) \qquad 0 \le s \le L-1$

change condition (a) to (a') $T(r)$ is a strictly monotonically increasing function in the interval $0 \le r \le L-1$

Let $P_r(r)$ & $P_s(s)$ denote PDF of r and s.

PDF of the transformed (mapped) variable s can be obtained using

$$P_s(s) = P_r(r)\left|\frac{dr}{ds}\right|$$

$$s = T(r) = (L-1) = \int_0^r P_r(w) \cdot dw. \quad \text{—— (1)}$$

w is dummy variable of integration.

$$\frac{ds}{dr} = \frac{dT(r)}{dr}$$
$$= (L-1)\frac{d}{dr}\left[\int_0^r P_r(w) \cdot dw\right]$$
$$= (L-1)\,P_r(r)$$

$$P_s(s) = P_r(r) \cdot \left|\frac{dr}{ds}\right|$$
$$= P_r(r)\left|\frac{1}{(L-1)\,P_r(r)}\right|$$
$$= \frac{1}{L-1} \qquad 0 \le s \le L-1$$

$P_s(s)$ Uniform Probability density function

Suppose continuous values in an image have PDF

$$P_r(r) = \begin{cases} \frac{2r}{(L-1)^2} & \text{for } 0 \le r \le L-1 \\ 0 & \text{otherwise} \end{cases}$$

From (1)

$$s = T(r) = (L-1)\int_0^r P_r(w) \cdot dw = \frac{2}{L-1}\int_0^r w \cdot dw = \frac{r^2}{L-1}$$

Q.No.	Solution and Scheme	Marks

$$P_s(s) = P_r(r)\left|\frac{dr}{ds}\right| = \frac{2r}{(L-1)^2}\left|\left[\frac{ds}{dr}\right]^{-1}\right|$$

$$= \frac{2r}{(L-1)^2}\left|\left[\frac{d}{dr}\frac{r^2}{L-1}\right]^{-1}\right|$$

$$= \frac{2r}{(L-1)^2}\left|\frac{(L-1)}{2r}\right| = \frac{1}{L-1}$$

Probability of occurrence of intensity level r_k in a digital image approximated by,

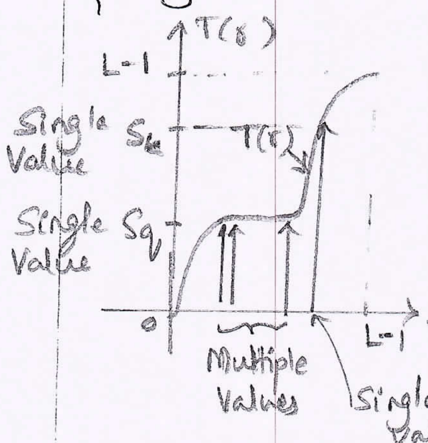
$$P_r(r_k) = \frac{n_k}{MN} \qquad k = 0, 1, 2, \cdots L-1$$

MN is the total number of pixels in the image.
n_k is the number of pixels that have intensity r_k
L is the number of possible intensity levels in the image.
$P_r(r_k)$ Vs r_k plot is called histogram.

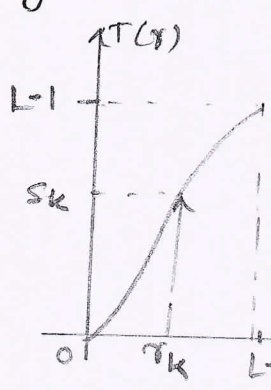
$$s_k = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j)$$

$$= \frac{L-1}{MN}\sum_{j=0}^{k} n_j \qquad k = 0, 1, 2 \cdots L-1$$

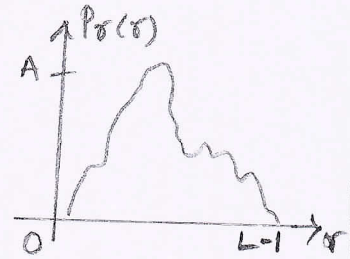
Processed output image is obtained by mapping each pixel in the input image with intensity r_k into a corresponding pixel with level s_k in the o/p image. Transformation (mapping) $T(r_k)$ is called histogram equalization or histogram linearization.



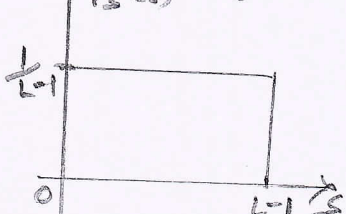
(a) Monotonically increasing function



(b) Strictly Monotonically increasing function



(c) Arbitrary PDF



(d) Uniform PDF

Q.No.	Solution and Scheme	Marks
5 ⓐ	Smoothing of images in frequency domain using Ideal Butterworth and Gaussian Low Pass filter	
	Smoothing (Blurring) is achieved in the frequency domain by high frequency attenuation that is by Low Pass filtering. — Diagram, Equation + Explanation of All three	3×4 = 12

Smoothing of images in frequency domain using Ideal Butterworth and Gaussian Low Pass filter

Smoothing (Blurring) is achieved in the frequency domain by high frequency attenuation that is by Low Pass filtering.

Types of Low Pass filters:

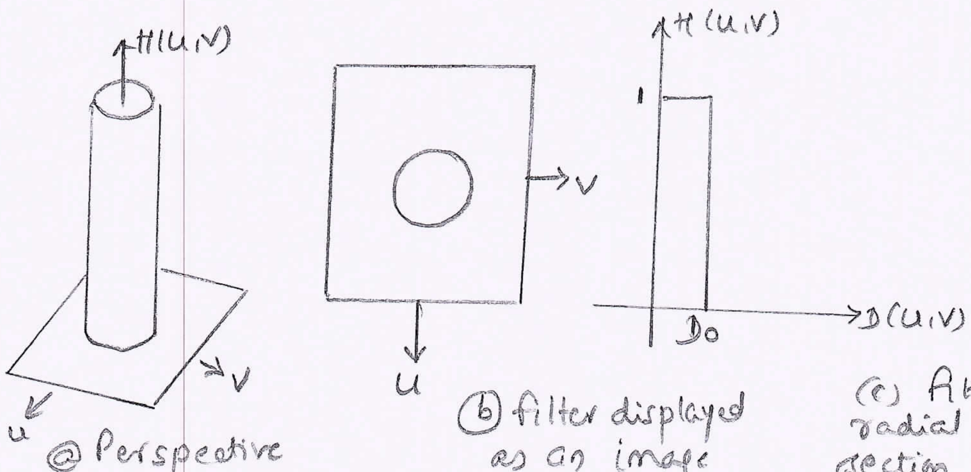
- → Ideal low Pass filter
- → Butterworth Low Pass filter
- → Gaussian Low Pass filter.

Transfer function of an ideal low pass filter

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

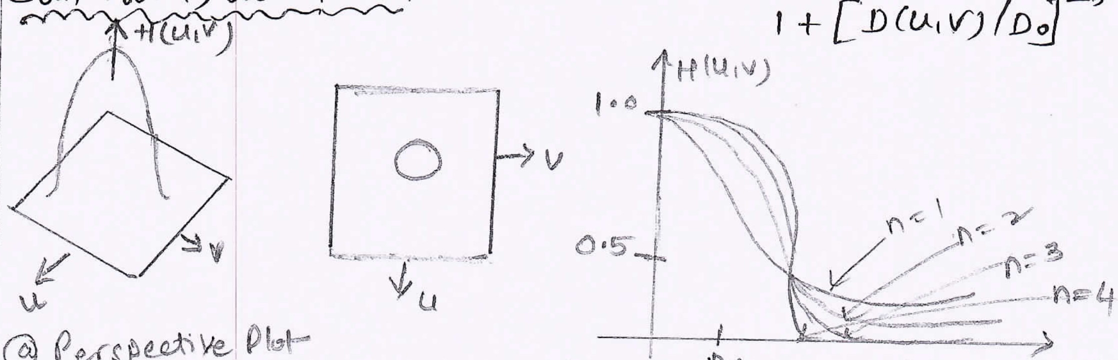
$D(u,v)$ the distance from point (u,v) to the center of their frequency rectangle.

$$D(u,v) = \left[(u - P/2)^2 + (v - Q/2)^2\right]^{1/2}$$



ⓐ Perspective Plot of low Pass filter Transferfunction
ⓑ filter displayed as an image
ⓒ Filter radial cross section.

Butterworth Low Pass filter: $H(u,v) = \dfrac{1}{1 + [D(u,v)/D_0]^{2n}}$



ⓐ Perspective Plot

Radial cross section order 1 to 4

Q.No.	Solution and Scheme	Marks

Gaussian Low Pass filters:-

Transfer function has the form $H(u,v) = e^{-D^2(u,v)/2\sigma^2}$

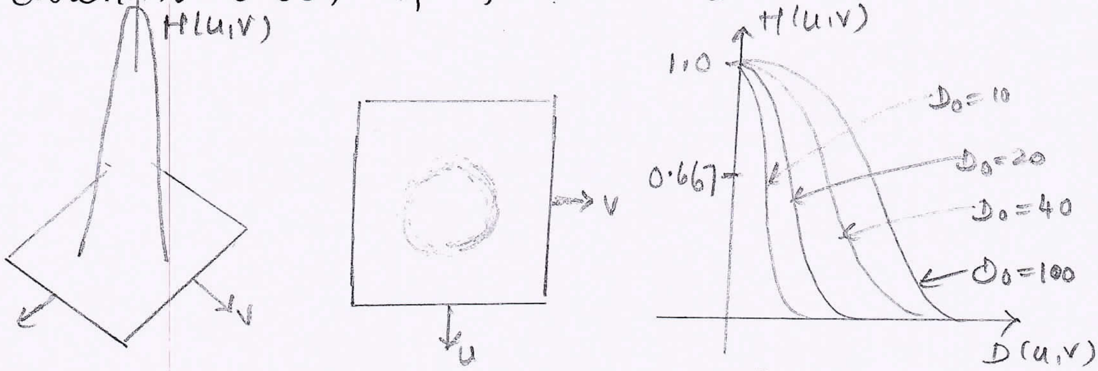
$\sigma \leftarrow$ measure of spread about the center.

Let $\sigma = D_0$

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

D_0 is the cutoff frequency

When $D(u,v) = D_0$ the GLPF transfer function is down to 0.607 of its maximum value 1.0.



(a) Perspective plot of a GLPF transfer function

(b) filter displayed as image

(c) filter radial cross section for various values of D_0.

5 (b) Properties of 2 dimensional DFT.

Suppose continuous function $f(t,z)$ is sampled to form a digital image $f(x,y)$ consisting of $M \times N$ samples taken in t and z direction. Let ΔT & ΔZ denote the separation between samples.

Explanation of 4 property — $4 \times 2 = 8$m

The separation between discrete frequency domain variables are given by

$$\Delta u = \frac{1}{M\Delta T}$$

$$\& \quad \Delta v = \frac{1}{N\Delta Z}$$

Separation between samples in the frequency domain are inversely proportional both to the spacing between spatial samples and the number of samples.

(17)

Q.No.	Solution and Scheme	Marks
	Translation and Rotation:	
	fourier transform pair satisfies the following translation properties.	
	$f(x,y)\,e^{j2\pi(u_0x/M+v_0y/N)} \Leftrightarrow F(u-u_0, v-v_0)$	
	and $f(x-x_0, y-y_0) \Leftrightarrow F(u,v)\,e^{-j2\pi(x_0u/M+y_0v/N)}$	
	Rotation Property:	
	Using the Polar co-ordinates $x=r\cos\theta$, $y=r\sin\theta$ $u=\omega\cos\varphi$ $v=\omega\sin\varphi$	
	results in the following transform pair,	
	$f(r,\theta+\theta_0) \Leftrightarrow F(\omega,\varphi+\theta_0)$	
	which indicates that rotating $f(x,y)$ by an angle θ_0 rotates $F(u,v)$ by the same angle.	
	Periodicity: 2D fourier transform and its inverse are periodic in the u and v directions.	
	$F(u,v) = F(u+k_1M, v) = F(u, v+k_2N)$	
	$= F(u+k_1M, v+k_2N)$	
	and	
	$f(x,y) = f(x+k_1M, y) = f(x, y+k_2N)$	
	$= f(x+k_1M, y+k_2N)$	
	k_1 & k_2 are integers.	
6 (a)	Basic steps of filtering in the frequency domain. One method of sharpening frequency domain filters.	
	1) Given an input image $f(x,y)$ of size $M\times N$, obtain the padding parameters P & Q. $P \geq 2M-1$ & $Q \geq 2N-1$. Select $P=2M$ & $Q=2N$.	5 to 6 Steps 5 Diagram + Explanation + 5 10 M
	2) Form a padded image $f_p(x,y)$ of size $P\times Q$ by appending necessary number of zeros to $f(x,y)$	

Q.No.	Solution and Scheme	Marks

3. Multiply $f_p(x,y)$ by $(-1)^{x+y}$ to centre its transform
4. compute the DFT, $F(u,v)$ of the image, from step 3
5. Generate a real symmetric filter function $H(u,v)$ of size $P \times Q$ with centre at coordinates $(P/2, Q/2)$. form the product $G(u,v) = H(u,v)F(u,v)$ using array multiplication. $G(i,k) = H(i,k)F(i,k)$
6. Obtain the processed image

$$g_p(x,y) = \{ real [\mathcal{F}^{-1}[G(u,v)]]\} (-1)^{x+y}$$

where real part is selected in order to ignore parasitic complex components resulting from computational inaccuracies and the subscript p indicates that the deal is with padded arrays.

7. Obtain the final processed result $g(x,y)$ by extracting $M \times N$ region from the top, left quadrant of $g_p(x,y)$

Image sharpening using frequency Domain filters.

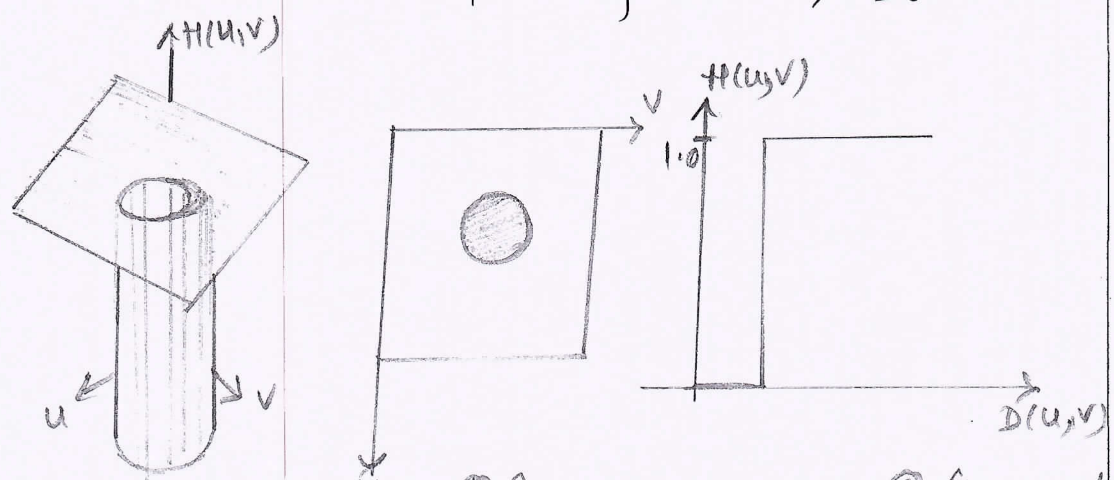
- Ideal high Pass filters
- Butter worth high Pass filter
- Gaussian High Pass filter

High Pass filter from low pass filter,

$$H_{HP}(u,v) = 1 - H_{LP}(u,v)$$

2D High Pass filter (IHPF) is defined as,

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



ⓐ Perspective plot ⓑ Image Representation ⓒ Cross section of IHPF

Q.No.	Solution and Scheme	Marks.

6 b) Homomorphic filtering approach for image enhancement.

Image $f(x,y)$ can be expressed as product of its illumination $i(x,y)$ and reflectance $r(x,y)$ components.

Equation 5 + Explanation 5 = 10M

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

Since, $\mathcal{F}[f(x,y)] \neq \mathcal{F}[i(x,y)]\, \mathcal{F}[r(x,y)]$

define,

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

then

$$\mathcal{F}\{z(x,y)\} = \mathcal{F}\{\ln f(x,y)\}$$
$$= \mathcal{F}\{\ln i(x,y)\} + \mathcal{F}\{\ln r(x,y)\}$$

or

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

where $F_i(u,v)$ and $F_r(u,v)$ are fourier transform of $\ln i(x,y)$ and $\ln r(x,y)$ respectively.

filter $Z(u,v)$ using filter $H(u,v)$

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

The filtered image in the spatial domain is

$$s(x,y) = \mathcal{F}^{-1}\{S(u,v)\}$$
$$= \mathcal{F}^{-1}\{H(u,v) F_i(u,v)\} + \mathcal{F}^{-1}\{H(u,v) F_i(u,v)\}$$

$$i'(x,y) = \mathcal{F}^{-1}\{H(u,v) F_i(u,v)\} \quad \text{——— (1)}$$

& $$r'(x,y) = \mathcal{F}^{-1}\{H(u,v) F_r(u,v)\} \quad \text{——— (2)}$$

Express eqn (1) in the form

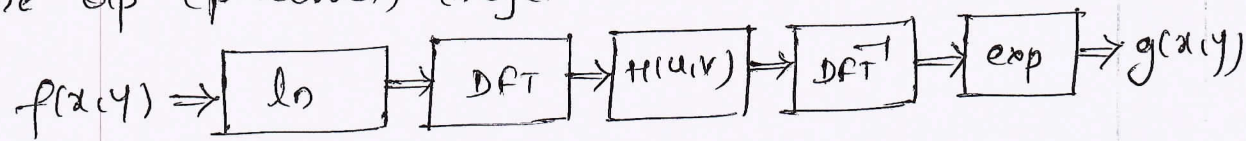
$$s(x,y) = i'(x,y) + r'(x,y)$$

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

where, $i_0(x,y) = e^{i'(x,y)}$

& $r_0(x,y) = e^{r'(x,y)}$

These are the illumination & reflectance components of the o/p (processed) image.

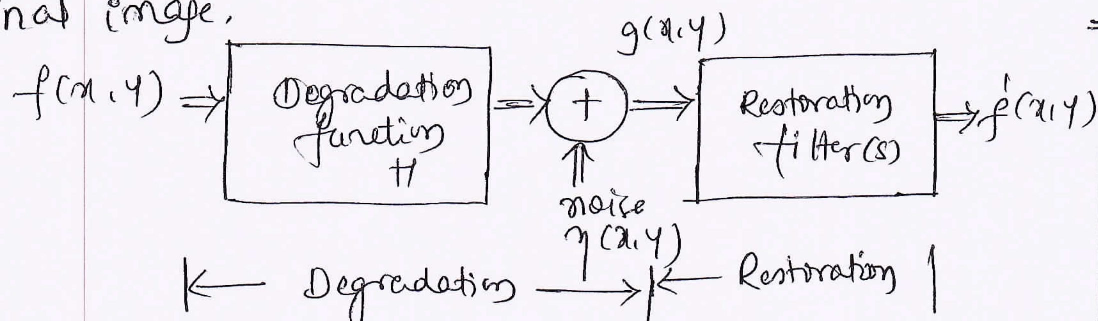


fig(1) summary of steps in homomorphic filtering

7 (a) Importance of Image restoration process and model diagram four noise probability density function

Block Diagram	2
+ Explanation + Graph.	4×2 = 8
	= 10M

The objective of restoration is to obtain an estimate $f'(x,y)$ of the original image.



fig(1) Model of image degradation and restoration process

degraded image in spatial domain

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

$h(x,y)$ is the spatial representation of degradation function

$*$ indicates convolution.

In frequency domain,

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

<u>Noise Models:</u> Noise in digital images arise during the image acquisition and/or transmission.

Noise PDF are, Gaussian Noise, Erlang (gamma) noise, Rayleigh Noise, Exponential noise.

PDF of Gaussian random variable z is given by,

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

$z \leftarrow$ intensity $\quad$ $\sigma \leftarrow$ standard deviation

$\bar{z} \leftarrow$ mean value of z $\quad$ $\sigma^2 \leftarrow$ Variance of z

Rayleigh Noise

PDF of Rayleigh Noise is given by

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

mean & variance are given by

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

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

Erlang Noise

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

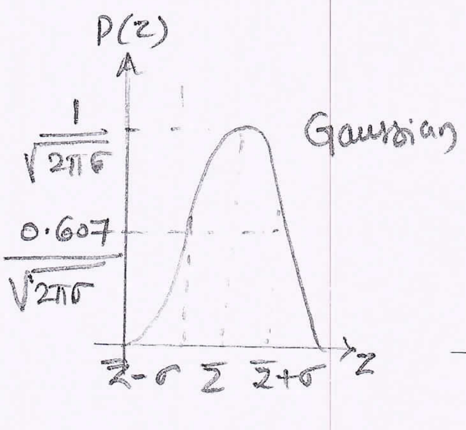
$$\bar{z} = b/a$$

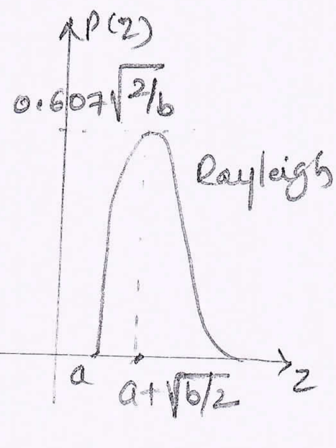
$$\sigma^2 = b/a^2$$

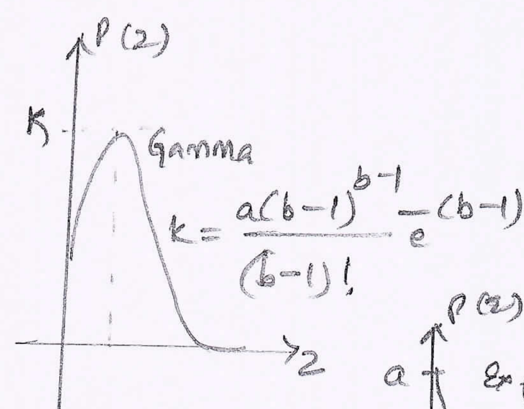
Exponential Noise

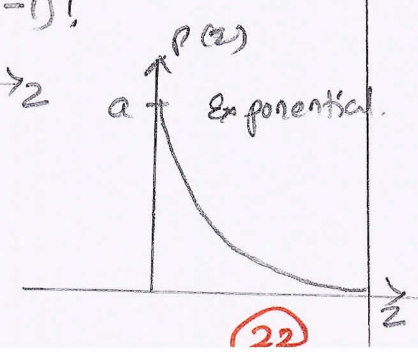
PDF is given by, $p(z) = \begin{cases} a e^{-az} & \text{for } z \geq 0 \\ 0 & \text{for } z < 0 \end{cases}$

$a > 0$, mean $\bar{z} = 1/a$, $\sigma^2 = 1/a^2$ //









Q.No.	Solution and Scheme	Marks
7 (b)	Wiener filtering and Inverse filtering in Image processing	
	Equation + Explanation for both	5 + 5 = 10M

Inverse filtering :-

Simplest approach to restoration is direct inverse filtering, which is an estimate $\hat{F}(u,v)$ of the transform of the original image by dividing the transform of the degraded image $G(u,v)$ by the degradation transfer function.

$$\hat{F}(u,v) = \frac{G(u,v)}{H(u,v)}$$

$$\hat{F}(u,v) = F(u,v) + \frac{N(u,v)}{H(u,v)}$$

where $G(u,v) = H(u,v)F(u,v)$

Points of Interest

- $N(u,v)$ is not known
- $N(u,v)/H(u,v)$ dominates the term $F(u,v)$ if degradation function is zero or small values.

Approach to get around the zero or small value problem is to limit the filter frequencies, to values near the origin.

Wiener filtering :-

Approach that incorporates both the degradation function and statistical characteristics of noise into the restoration process, is basic concept of Wiener filtering. Objective is to find an estimate $\hat{f}$ of the uncorrupted image f, such that mean square error between them is minimized.

Error measure is defined as $e^2 = E\{(f-\hat{f})^2\}$

where $E\{\cdot\}$ is expected value of the argument.

$$\hat{F}(u,v) = \left[\frac{H^*(u,v)\,S_f(u,v)}{S_f(u,v)\,|H(u,v)|^2 + S_\eta(u,v)}\right]\cdot G(u,v)$$

Q.No.	Solution and Scheme	Marks

$$= \left[\frac{H^*(u,v)}{|H(u,v)|^2 + S_\eta(u,v)/S_f(u,v)} \right] \cdot G(u,v)$$

$$= \left[\frac{1}{H(u,v)} \frac{|H(u,v)|^2}{|H(u,v)|^2 + S_\eta(u,v)/S_f(u,v)} \right] \cdot G(u,v)$$

Wiener filter concept is proposed by N. Wiener in the year 1942. The filter is called minimum mean square error filter or the least square error filter.

8 (a) Methods of Estimation of Degradation function.

(i) Estimation by image observation. — Equation + Explanation: 4 + 6 = 10M

Suppose, degraded image is given without any knowledge about degradation function H, Assume image was degraded by linear position invariant process. One way to estimate H is to gather information from image itself.

Let observed subimage is denoted by $g_s(x,y)$.

Let processed subimage is denoted by $\hat{f}_s(x,y)$.

Assume effect of noise is negligible.

$$H_s(u,v) = \frac{G_s(u,v)}{\hat{F}_s(u,v)}$$

(ii) Estimation by Experimentation:

If equipment similar to the equipment used to acquire the degraded image is available, it is possible to obtain an accurate estimate of the degradation. Images similar to the degraded image can be acquired with various system settings until they are degraded as closely as possible to the image, to be restored. Obtain the impulse response of the degradation by imaging an impulse using the same system settings.

$$H(u,v) = \frac{G(u,v)}{A}$$

G(u,v) is the fourier transform, ~~A~~ is constant, describes the ~~strength of the impulse~~

Q.No.	Solution and Scheme	Marks

(iii) Estimation by modeling:

Degradation modeling can be accounted for environmental conditions, that cause degradations. Degradation model proposed by Hufnagel and Stanley is based on the physical characteristics of atmospheric turbulence. The model has the form,

$$H(u,v) = e^{-k(u^2+v^2)^{5/6}}$$

where k is a constant that depends on the nature of the turbulence. This equation has the same form as that of Gaussian low pass filter transfer function, with exception of 5/6 power in exponent.

8 (b) Importance of adaptive filters and adaptive median filter.

Algorithm 5
+explanation +5
10m

Adaptive filter behaviour changes based on the statistical characteristics of the image inside the filter region defined by the m×n rectangular neighborhood S_{xy}. Performance of adaptive filter is superior to other filters. Increased complexity is the price paid for the improved filtering power.

Adaptive Median filter:

The two types of adaptive filters are, Adaptive Local Noise Reduction filter and Adaptive Median filter.

Median filter $\hat{f}(x,y) = \underset{(r,c)\in S_{xy}}{\text{median}}\{g(r,c)\}$

performs well if the spatial density of the salt and pepper noise is low. ~~Adaptive~~ median filter handles noise with probabilities larger than these. Adaptive median filter preserves detail while simultaneously smoothing

Q.No.	Solution and Scheme	Marks
	non impulse noise. Adaptive median filter changes (increases) the size of S_{xy} during filtering, depending on certain conditions.	

Adaptive median filtering algorithm uses two processing levels, denoted as level A & level B, at each point (x, y):

Level A : If $Z_{min} < Z_{med} < Z_{max}$, go to level B
Else, increase the size of S_{xy}
If $S_{xy} \leq S_{max}$, repeat level A
Else, output Z_{med}

Level B : If $Z_{min} < Z_{xy} < Z_{max}$, output Z_{xy}
Else output Z_{med}.

where S_{xy} and S_{max} are odd positive integers greater than 1. Another option in the last step of level A is to output Z_{xy} instead of Z_{med}.

Z_{min} = minimum intensity value in S_{xy}
Z_{max} = Maximum intensity value in S_{xy}
Z_{med} = Median of intensity values in S_{xy}
Z_{xy} = Intensity at coordinates (x, y)
S_{max} = maximum allowed size of S_{xy}.

The Algorithm has 3 Principal objectives:

- To remove salt and pepper (impulse) noise, to provide smoothing of other noise that may not be impulsive and to reduce distortion, such as excessive thinning or thickening of object boundaries.

Q.No	Solution and Scheme	Marks
9 (a)	Morphological operations (i) Erosion (ii) Dilation	Diagram / Explanation + Equation of 4 operations 4×3M =12M

These operations are fundamental to morphological processing. Most of the morphological algorithms are based on these two primitive operations. Morphological expression are interms of structuring element and a set A, of foreground pixels or interms of structuring elements and an image I, that contains A.

With A & B as sets in Z^2

Erosion of A by B, denoted as $A \ominus B$, is defined as,

$$A \ominus B = \{ z \mid (B)_z \subseteq A \}$$

A is a set of foreground pixels, B is structuring element and z's are foreground values (1's).

Erosion of A by B is the set of all points z such that B, translated by z, is contained in A.

$$I \ominus B = \{ z \mid (B)_z \subseteq A \text{ and } A \subseteq I \} \cup \{ A^c \mid A^c \subseteq I \}$$

I is a rectangular array of foreground and background pixels.

~~Also~~,

$$A \ominus B = \{ z \mid (B)_z \cap A^c = \emptyset \}$$

Dilation:

With A and B as sets in Z^2, the dilation of A by B, denoted as $A \oplus B$, defined as

$$A \oplus B = \{ z \mid (\hat{B})_z \cap A \neq \emptyset \}$$

This is based on reflecting B about its origin & translating the reflection by z. The dilation of A by B then is the set of all displacements z such that the foreground elements of $\hat{B}$ overlap at least one element of A.

$$A \oplus B = \{ z \mid [(\hat{B})_z \cap A] \subseteq A \}$$

Q.No.	Solution and Scheme	Marks

iii) Opening and iv) closing

Dilation expands the components of a set and erosion shrinks it. Opening smoothes the contour of an object, breaks narrow isthmuses and eliminates thin protrusions. closing tends to smooth sections of contours. It fuses narrow breaks and long thin gulfs, eliminates small holes & fills gap in the contours

Opening of set A by structuring element B denoted $A \circ B$, defined as

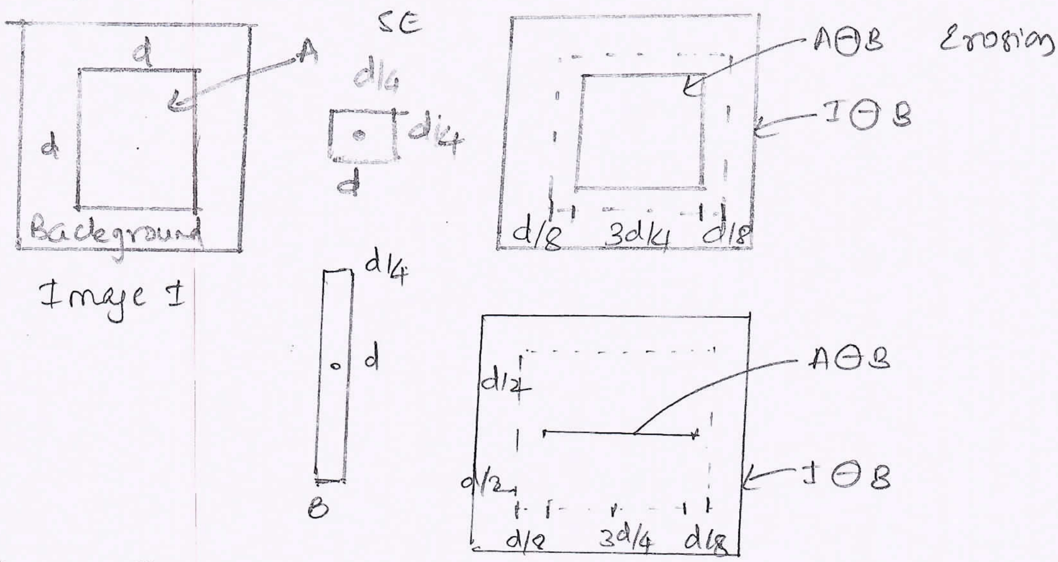
$$A \circ B = (A \ominus B) \oplus B$$

Opening A by B is the erosion of A by B followed by a dilation of the result by B.

||ly closing of set A by structuring element B denoted $A \bullet B$, is defined as

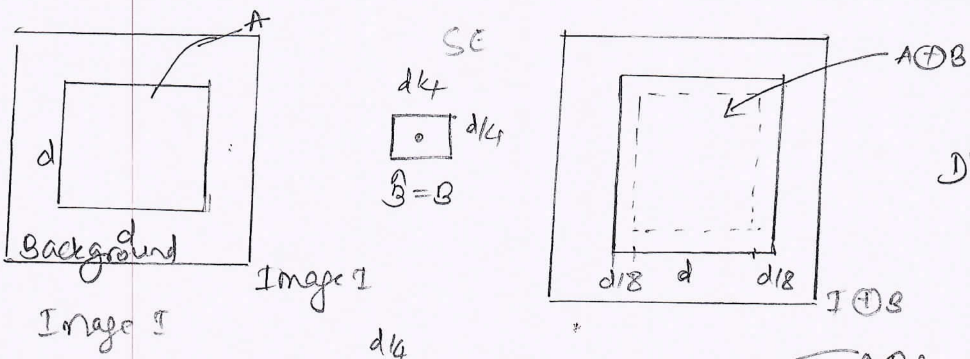
$$A \bullet B = (A \oplus B) \ominus B$$

closing of A by B is simply the dilation of A by B followed by erosion of the result by B.

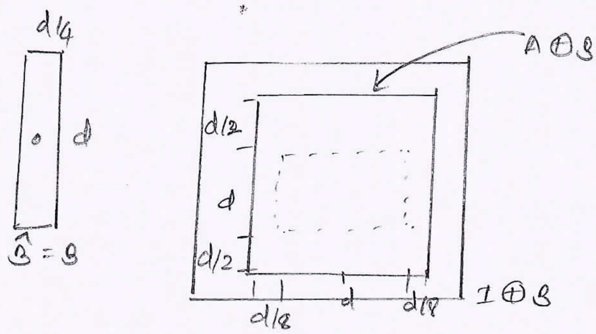


Fig(i) Erosion of A⊖B

Q.No.	Solution and Scheme	Marks

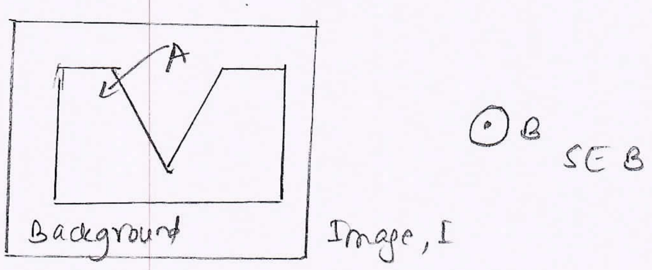


Dilation operation

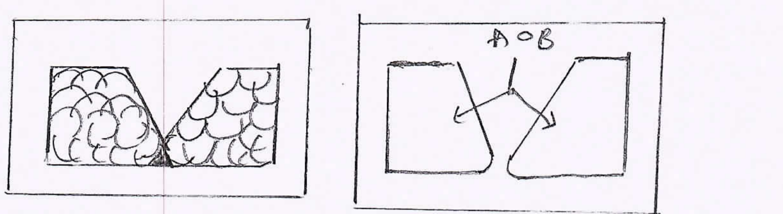


fig(2) Dilation of A by B

(iii)



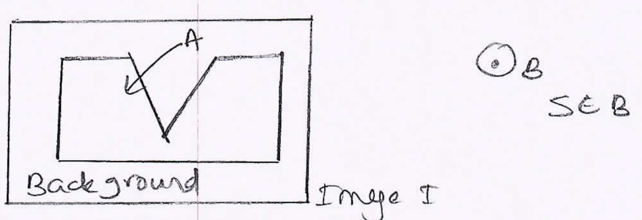
Opening Operation



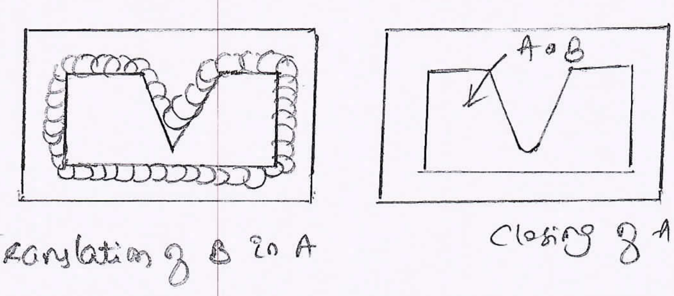
Translation of B contained in A

Opening of A by B.

(iv)



Closing Operation

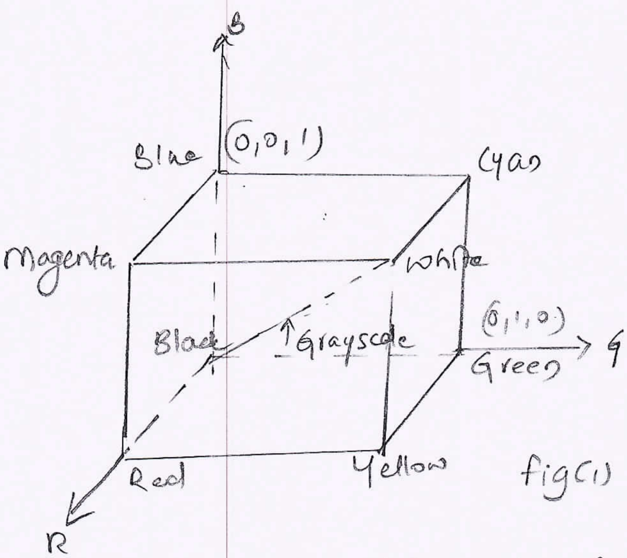


Translation of B in A

Closing of A by B

Q.No.	Solution and Scheme	Marks
9 (b)	RGB color model :	Diagram 4 + Explanation + 4 = 8M

Schematic of the RGB Color Cube



fig(1) Schematic of RGB model

In RGB color model, each color appear in its primary spectral components of red, green and blue. This model is based on Cartesian co-ordinate system. The color subspace of interest is shown in fig(1)
RGB primary values are at three corners, the secondary colors are cyan, magenta and yellow, are at three other corner. Black is at the origin and white is at the corner far from origin.

The grayscale (Points of equal RGB values) extends from black to white along the line joining these two points. The different colors in this model are points on or inside the cube and are defined by vectors extending from the origin, color values are normalized, so the cube in fig(1) is the unit cube. That is all values in R, G and B in this representation are assumed to be in the range [0, 1].

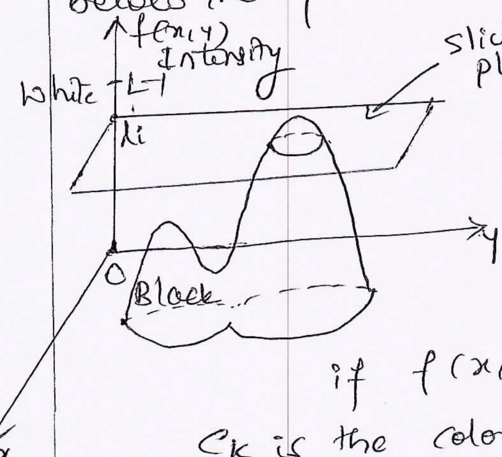
Image represented in RGB color model, consists of three component images one for each primary color. When fed into an RGB Monitor, these three images combine on the screen to produce a composite color image. The number of bits used to represent each pixel in RGB space is called the "pixel depth". The term full color image is used to denote a 24 bit RGB color image

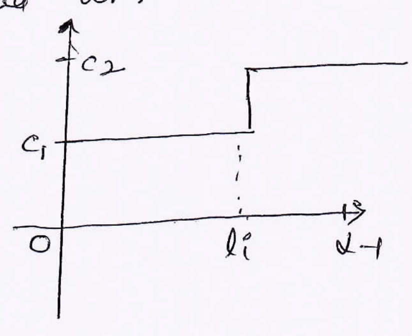
Q.No.	Solution and Scheme	Marks
10 (a)	Pseudo color image processing and intensity slicing applied to color image processing.	
	Pseudo color image processing is also called false color image processing. It consists of assigning colors to gray values based on a specified criterion. The term pseudo or false color is used to differentiate the process of assigning colors to achromatic images from the processes associated with true color images. The principal use of pseudocolor is for human visualization and interpretation of grayscale events in an image or sequence of images.	Defn + Diagram + Explanation = 2 + 3 + 5 = 10m

Intensity slicing and color coding

→ These are simplest and earliest examples of pseudocolor processing of digital images.

If an image is interpreted as a 3D function, method can be viewed as one of placing planes parallel to the coordinate plane of the image. Each plane then slices the function in the area of intersection. Fig(a) shows example of using plane at $f(x,y) = l_i$ to slice the image intensity function into two levels. If a different color is assigned to each side of the plane, any pixel whose intensity level is above the plane will be coded with one color and any pixel below the plane will be coded with the other.





if $f(x,y) \in I_k$, let $f(x,y) = c_k$.

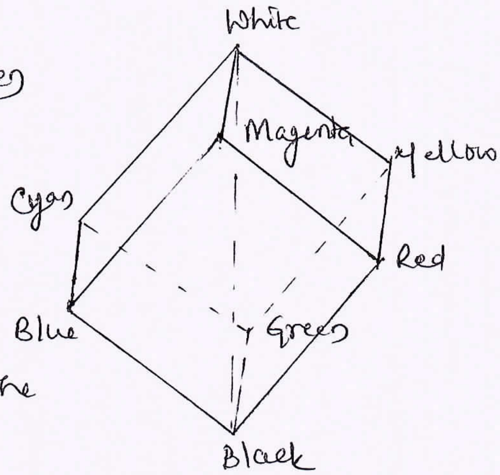
c_k is the color associated with the k^{th} intensity interval I_k, defined by the planes at $l = k-1$ & $l = k$.

Q.No.	Solution and Scheme	Marks
10 (b)	HSI Color model and HSI to RGB Colors.	

HSI (hue, saturation, intensity) color model decouples the intensity component from the color carrying information (hue and saturation) in a color image. HSI model is useful tool for developing image processing algorithms based on color descriptions that are natural and intuitive to humans.

Defn + Equation + Explanation: 2 + 4 + 4 = 10M

Conceptual relationships between RGB & HSI Color Model.



Converting colors from HSI to RGB.

Given values of HSI in the interval [0,1].

Multiplying H by 360°, which returns the hue to its original range of [0°, 360°]

RG sector: $(0° \le H < 120°)$

When H is in this sector, RGB components are given by the equations,

$$B = 1 - S$$

$$R = I\left[1 + \frac{S\cos H}{\cos(60° - H)}\right]$$

$$G = 3I - (R + B)$$

GB sector: $(120° \le H \le 240°)$

If the given value of H is in this sector, first subtract 120° from it.

$$H = H - 120°$$

RGB components are

$$R = I(1 - S)$$

$$G = I\left[1 + \frac{S\cos H}{\cos(60° - H)}\right]$$

$$B = 3I - (R + G)$$

Q.No.	Solution and Scheme	Marks
	BR sector: $(240^\circ \le H \le 360^\circ)$ If H is in this range, subtract 240° from it. $H = H - 240^\circ$ RGB components are $G = I(1-S)$ $B = I\left[1 + \frac{S\cos H}{\cos(60^\circ - H)}\right]$ $R = 3I - (G+B)$	