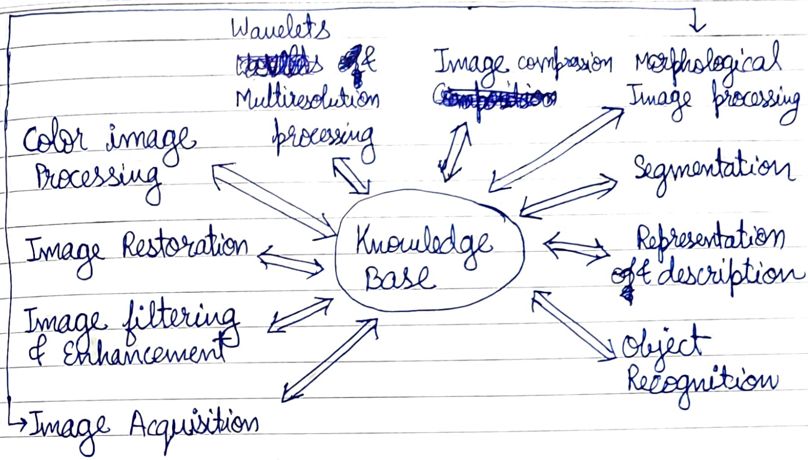
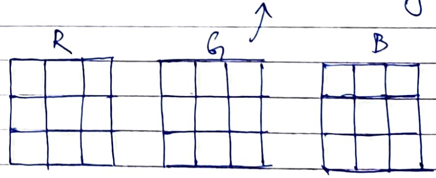


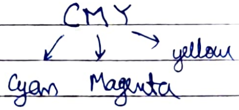
JPG → Joint Photography Group.
JPEG → Joint Photography Expert Group.

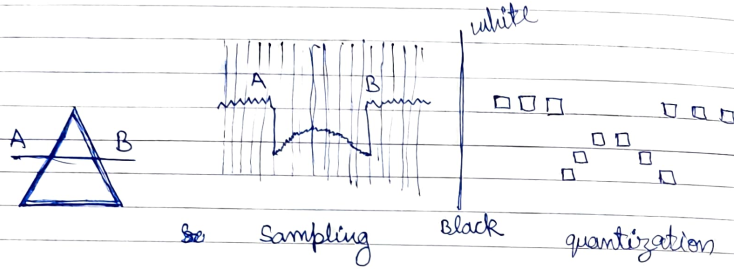
Digital images are represented in the form of their pixel intensity.

Green channel of any image has maximum information about the image.

Range of greyscale is 0-255 [2^8]







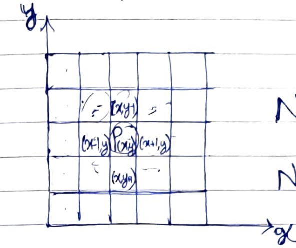
Digitization of coordinate value is called sampling.

Digitization of amplitude value is called quantization.

If we want to convert any image into digital form then we need to perform sampling and quantization.

After converting the image into digital form it only contains pixel and intensity values.

→ Relationship between pixels



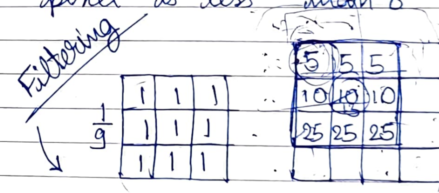
left, right, top, bottom pixels

$N_4(P) = \{(x+1,y), (x-1,y), (x,y+1), (x,y-1)\}$

$N_D(p) = \{(x+1,y+1), (x+1,y-1), (x-1,y+1), (x-1,y-1)\}$

$N_8(p) = N_4(p) \cup N_D(p)$ diagonal neighbouring pixels

In case a pixel belongs to border of a particular image then their neighbouring pixel is less than 8



Kernel or filter will always be in 3x3, 5x5 or in other words odd number as we need center pixel

Average the intensity of window elements.

$= \frac{40}{3} = 13.333$ select 13

Set the new intensity as the value of centere pixel of the window.

Here only center pixel is changing which is not what we want.

In order to overcome this problem we do padding of the image which ultimately helps us to cover every pixel of the actual (or original image). For example we can do zero padding or mirror padding and then apply the mask.
replicating

→ Adjacency, Connectivity, Region and Boundary.

Assume 'V' set of intensity value used to define adjacency. In a grayscale image we have,

$$V = \{0, 1, \text{—}, 255\}$$

Three types of adjacency :

a) Four adjacency (adjecent)
b) 8 adjecent
c) m adjecent

- 4 adjecency :-

Two pixels p and q with values from V are 4-adjecent if q is in the set $N_4(p)$.

- 8- adjecent :-

Two pixels p and q with values from V are 8-adjecent if q is in the set of $N_8(p)$.

- m- adjecency :-

Two pixels p and q with values from V are m-adjecent if;

i) q is in $N_4(p)$, or.

ii) q is in $N_8(p)$ and set $N_4(p) \cap N_4(q)$ has no pixels whose value are from V.

Eg,

	0	1	2	3	4
0	0	1	1	2	3
1	1	1	2	0	1
2	2	2	q_4 3	q_1 3	q_2 2
3	1	3	q_5 0	p 0	q_3 1
4	0	0	q_6 2	q_7 0	q_8 1

$V = \{0, 2, 3\}$
$N_4(p) = \{q_1, q_3, q_7, q_5\}$
$N_8(p) = \{q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8\}$
$N_D(p) = \{q_4, q_2, q_8, q_6\}$

$N_4(p) = \{(2,3), (3,4), (4,3)(3,2)\}$
$N_D(p) = \{(2,2), (4,4), (2,4)(4,2)\}$
$N_8(p) = \{(2,2), (2,3)(2,4), (3,4)(4,4), (4,3), (4,2), (3,2)\}$

	4 adjecent	8-adjecent	~~m-adj~~
p & q_1	~~4-adjecent~~ ✓	✓	
p & q_2	✗	✓	
p & q_3	✗	✗	
p & q_4	✗	✓	
p & q_5	✓	✓	
p & q_6	✗	✓	
p & q_7	✓	✓	
p & q_8	✗	✗	

Q: Is pixels p and q_1 are m-adjecent? (yes/no) ✓
— " — p and q_2 — " — (yes/no)
— " — p and q_3 — " — (yes/no)

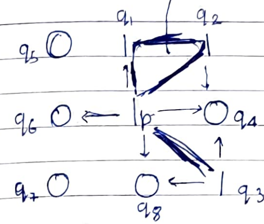
A: $N_4(p) = \{(2,3)(3,4),(4,3)(3,2)\}$
$N_4(q_2) = \{(1,4),(2,3),(3,4)\}$

$N_4(p) \cap N_4(q_2) = \{(2,3)(3,4)\}$
(3 , 1)

$N_4(q_3) = \{(3,3),(2,4),(4,4)\}$

$N_4(p) \cap N_4(q_3) = \phi$

Region of Interest

Q: 

p & q_1 4-Adj & m-Adj
p & q_2 8-Adj
p & q_3 8-Adj & m Adj

$V = \{1\}$

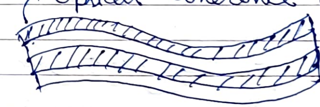
A: $N_4(p) \cap N_4(q_2) = \{q_1, q_4\}$
1 0

as $1 \in V$
thus not m-adj.

$N_4(p) \cap N_4(q_3) = \{q_4, q_8\}$
0 0

Since no element in the intersection set thus m-adj.

Optical coherence tomography (OCT)



Using adjency we can find the connectivity and hence the boundary or region of interest.

→ Distance, Euclidean distance, city block distance and chess-board distance

(x_2, y_2) q

(x_1, y_1) p

Euclidean [De] $= \sqrt{(x_1-x_2)^2 + (y_1-y_2)^2}$

City-block [D4] $= D_4(p,q) = |x_1 - x_2| + |y_1 - y_2|$

Chess-board [D8] $= D_8(p,q) = \max(|x_1 - x_1|, |y_1 - y_2|)$

If we get decimal values then consider upperside (~~not~~ if not mentioned)

Distance theorem: Distance between two points p and q must be ≥ 0.

Q: Write a short note on type of facial features used for face detection (or identification).

→ Point processing

↳ ~~Spacial~~ spatial domain
- → Point processing
- → Neighbourhood processing
  - ↓ define 4, 8, m neighbours
  - ↓ define adjacency matrix
  - ↓ define connectivity
  - ↓ if complete path the region
  - ↓ defined region
  - ↓ extract features
  - ↓ classify the image

In point processing we work with single pixel. It means if value of $g(x,y)$ depends on transformation function means.

$g(x,y) = T\, f(x,y)$, where $f(x,y)$ → intensity of pixel at (x,y) location.

Transformation function.

↓

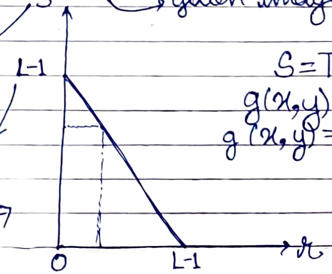
Point processing techniques :

1. Image negation
2. Image thresholding
3. Image clipping
4. Image contrast stretching
5. Bit plane slicing
6. Gray level slicing

* Image Negation → brighter to darker } kind of darker to brighter } image enhancement

Transformation function → $S = T(r)$ → given image

Modified image



$S = T(r) = L - 1 - r$

$g(x,y) = T\, f(x,y)$

$g(x,y) = (L-1) - f(x,y)$

Image negation for grey scale image

Q: Consider a given image of size 4 by 4,

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

What is the corresponding output negative image?

A: $L = 8$ → 3-bit image
as $L-1 = 7$. ⇒ $L = 8$

NEGATIVE IMAGE

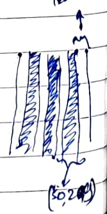
6	0	4	4
4	1	3	1
5	3	5	5
4	5	2	4

$g(x,y) = T\, f(x,y)$
$g(x,y) = (L-1) - f(x,y)$

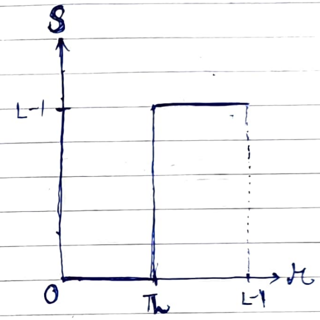
→ Image thresholding

Image thresholding is basically used for image segmentation.

Cropping / defining / highlighting Region of Interest.



Thresholding function, $S = \begin{cases} L-1 \; ; & r \geq Th \\ 0 \; ; & r < Th \end{cases}$



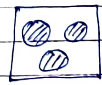
Q: What is the output of previous question if we apply thresholding with threshold value as 3?

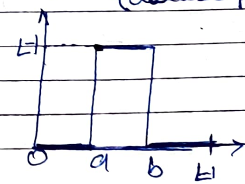
A:

0	7	7	7
7	7	7	7
0	7	0	0
7	0	7	7

→ Image clipping → Application image segmentation (disease prediction)

Intensity level slicing without background





intensity of the image

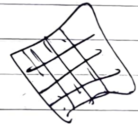
$$S = \begin{cases} L-1, & a \le I_z \le b \\ 0, & \text{otherwise} \end{cases}$$

Q: Apply image clipping to previous example with $a=2$ and $b=4$.

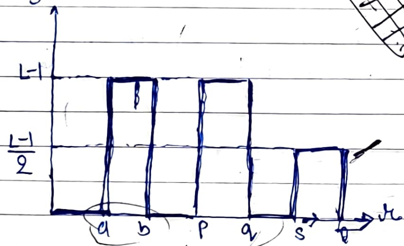
A:

0	0	7	7
7	0	7	0
7	7	7	7
7	7	0	7

$L-1 = 8 \Rightarrow L = 7$
$a=2$ and $b=4$



→



→ Bit-plane slicing

~~No. of planes~~ {No. of intensity levels} will decide no. of planes as,

No. of planes = no. of bits required to represent the max. intensity levels.

001 —

3

001	111	011	011
011	101	100	101
010	100	010	011
011	011	101	011

→ greyscale

MSB 2^2

0	1	0	0
0	1	1	1
0	1	0	0
0	0	1	0

bitmap

2^1

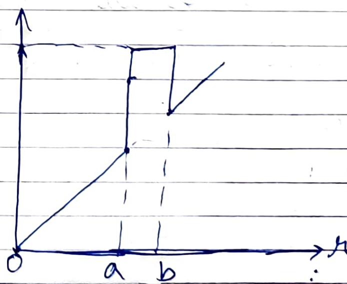
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1

2^0 LSB

1	1	1	1
1	1	0	1
0	0	0	1
1	1	1	1

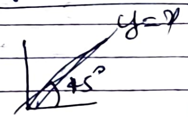
Three bit planes

To combine these images (bit planes) to get back the original greyscale image we have to perform the ~~addition~~ conversion of binary to decimal number based on MSB and LSB.



Intensity level slicing with background

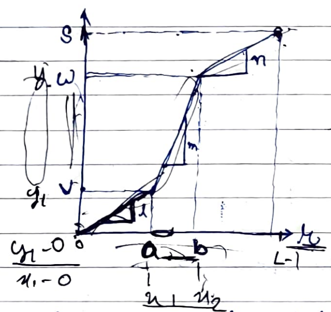
$$S = \begin{cases} L-1, & a \le r \le b \\ r, & \text{otherwise} \end{cases}$$



$\frac{y_2 - y_1}{x_2 - x_1}$

~~contrast stretching~~

→ Contrast Stretching



$s = l \cdot r$ if $0 \le r \le a$

$s = m(r-a)+v$ if $a < r \le b$

$s = n(r-b)+w$ if $b < r \le L-1$

where l, m, n ~~and~~ are the slope

$l \,\&\, n < 1$

$m > 1$

Many times when low contrast images due to poor illuminance or due to wrong setting of lens aperture. ~~obtain~~ It is required to enhance the image by using contrast stretch.

Q:

7	12	2	3
10	15	1	1
12	4	6	15
8	2	7	15

$v = 4$

$w = 8$

$a = 8$

$b = 12$

then find the output image

$\frac{7}{3} \times (15-12)$

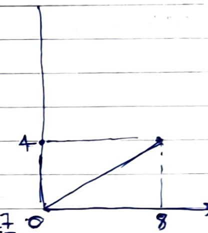
$7 + 8$

3 contrast stretching

A: $l = \frac{4}{8} = \frac{1}{2}$

$m = \frac{12-8}{8-4} = 1$

$n = \frac{15-8}{15-12} = \frac{7}{3}$



3.5	8	1	1.5
6	15	0.5	0.5
8	2	3	15
4	1	3.5	15

≡

4	8	1	2
6	15	1	1
8	2	3	15
4	1	4	15

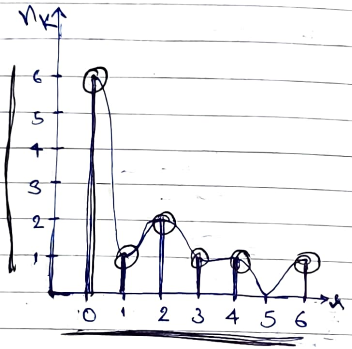
Take the significant digit and round off.

Exam: multilevel contrast stretching using graph.

→ Histogram

0	0	0	0
0	1	2	3
0	2	4	6

6 → 110

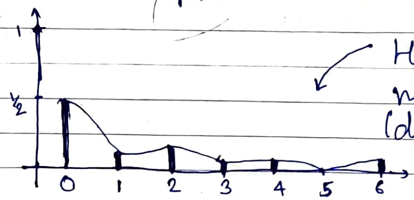


$$p(r_k) = \frac{n_k}{N}$$

N → Total number of pixel in the image

$p(r_k)$ → probability of occurance of gray level r_k

r_k	0	1	2	3	4	5	6
f	6	1	2	1	1	0	1
$p(r_k)$	6/12	1/12	2/12	1/12	1/12	0/12	1/12



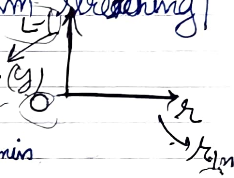
Histogram normalization (done by calculating probability)

If we normalize the histogram then quality of image may improve.

$$y = \frac{y_2 - y_1}{x_2 - x_1}(x - x_1) + c$$

$\frac{y_2 - y_1}{x_2 - x_1} \rightarrow m$ $\quad y = mx + c$

(1) → ~~Histogram equalization~~ / Histogram stretching / Linear stretching

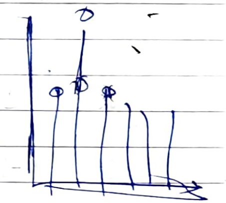


$$S = T(r) = \frac{S_{max} - S_{min}}{r_{max} - r_{min}}(r - r_{min}) + S_{min}$$

This will give us histogram equalized image.

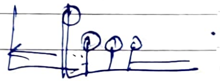
(2)

GL	0	1	2	3	4	5	6	7
old : f	0	3	8	13	19	20	13	5



→ Methods :

1) Histogram stretching
2) Histogram equalization
3) Histogram ~~generalization~~ specification
4) Histogram generalization



Q:

GL	0	1	2	3	4	5	6	7
f_{old}	0	3	8	13	19	20	13	5
~~f_{new}~~	~~0~~	~~0~~	~~3~~	~~8~~	~~13~~	~~19~~	~~13~~	~~5~~
St f_{new}	3	8	13	0	19	20	13	5

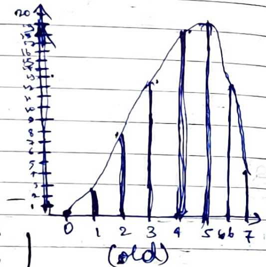
Total pixels = 81 (9×9)

$$S = \frac{S_{max} - S_{min}}{r_{max} - r_{min}}(r - r_{min}) + S_{min}$$

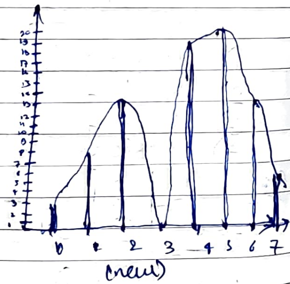
$$S = \frac{7-0}{7-1}(r-1) + 0 \Rightarrow S = \boxed{\frac{7}{6}(r-1)}$$

$S = \frac{7}{6}(r-1)$

$S(0) = -7/6 = -1.17 \simeq 0$
$S(1) = 0$
$S(2) = 7/6 = 1.17 \simeq 1$
$S(3) = 14/6 \simeq 2.33 \simeq 2$
$S(4) = 37/2 = 3.5 \simeq 4$
$S(5) = 28/6 = 4.67 \simeq 5$
$S(6) = 35/6 = 5.84 \simeq 6$
$S(7) = 42/6 = 7$



r	s	round-off (s)
0	-1.17	0
1	0	0
2	1.17	1
3	2.33	2
4	3.5	4
5	4.67	5
6	5.84	6
7	7	7



exam imp

For sake of understanding the take simple probability

(2) Histogram equalisation

This can be any kind of distribution

GL	n_k (freq^n)	$p(k) = \frac{n_k}{N}$ (PDF)	CDF ($S_k = \sum p$)	$S_k * (L-1)$	Round-off
0	0	0.0	0.0	0.0	0
1	3	3/81=0.037	0.037	0.259	0
2	8	8/81=0.098	0.135	0.945	1
3	13	13/81=0.160	0.295	2.065	2
4	19	19/81=0.235	0.530	3.710	4
5	20	20/81=0.248	0.778	5.446	5
6	13	13/81=0.160	0.938	6.559	7
7	5	5/81=0.062	1	7.000	7
	$\Sigma n_k = 81$	$\Sigma p(k) = 1$			

GL	0	1	2	3	4	5	6	7
fold	0	3	8	13	19	20	13	5
fnew	3	8	13	0	19	20	0	18

(3) Histogram specification

Exam IMP

First equalize the given two images after that we perform the mapping of the equalized images.

Q:

GL	GLA	GLB	GLF
0	1	0	?
1	2	0	
2	2	0	
3	3	0	
4	5	2	
5	6	4	
6	7	6	
7	7	7	

I_A

GL	0	1	2	3	4	5	6	7
freq	8	10	10	2	12	16	4	2

I_B

GL	0	1	2	3	4	5	6	7
freq	0	0	0	0	20	20	16	8

ImageA

S_k

GL	freq	p(k)	CDF=ΣP	(L-1)ΣP	Roundoff
0	8	8/64			1
1	10	10/64			2
2	10	10/64			3
3	2	2/64			3
4	12	12/64			5
5	16	16/64			6
6	4	4/64			7
7	2	2/64			7

GL	freq	p(k)	CDF	(L-1)ΣP	Round off
0	0	0/64			0
1	0	0/64			0
2	0	0/64			0
3	0	0/64			0
4	20	20/64			2
5	20	20/64			4
6	16	16/64			6
7	8	8/64			7

Actual image

Reference image

GL	Round off A	Round off B	GLF
0	1	0	4
1	2	0	4
2	3	0	5
3	3	0	5
4	5	$\boxed{2}$	6
5	6	4	6
6	7	6	7
7	7	7	7

final image

$\boxed{GL_B >= GL_A}$

GL	0	1	2	3	4	5	6	7
freq	0	0	0	0	18	12	28	6

Q: Maybe 3 reference image are given in the question (EXAM)

- **Neighbourhood Processing (Spacial Filter)**

Neighbourhood Processing

- Smooth filter
  - Linear filter
    - Averaging filter
    - Weight average filter
  - Non-linear filter (order-statistics)
    - (i) Median filter
    - (ii) Max-Min filter
- Sharpening filter
  - Linear filter
    - ① Laplacian filter
    - ② I^{st} derivative filter
    - ③ High boost filter

Smoothing filter are used for reducing the blurring and noise.

Sharpening spacial filter highlights the fine detail that has been blurred and in both cases we use either mask or kernal or window or template.

1. How to design a kernal?
2. How to generate a kernal?
3. What is the characteristic of kernal?

4x4 we need to do the average but this might cause the problem and borders might ~~not to~~ be blurred. Thats why we take 3x3 or 5x5 or ___ so that we get a center pixel.

4)

Kernal 3x3

1	1	1
0	0	0
-1	-1	-1

I/P image

3	8	2	10	12
7	9	8	6	13
8	3	6	8	9
3	5	7	8	15
4	4	5	2	12

a) Apply median filter
b) Apply max filter
c) Apply min filter

a)

1	1	1	1	1	1	1
1	1	3	6	6	1	1
1	3	7	8	8	8	1
1	3	7	6	8	6	1
1	3	5	5	7	3	1
1	1	4	3	3	1	1
1	1	1	1	1	1	1

111237889

⇓

1	3	6	6	1
3	7	8	8	8
3	7	6	8	6
3	5	5	7	3
1	4	3	3	1

b)

1	1	1	1	1	1	1
1	9	9	10	13	13	1
1	9	9	10	13	13	1
1	9	9	9	15	15	1
1	8	8	8	15	15	1
1	5	7	7	15	15	1
1	1	1	1	1	1	1

⇒

Intensity of center pixel will increase or remain same as compared to neighbour pixel.

9	9	10	13	13
9	9	10	13	13
9	9	9	15	15
8	8	8	15	15
5	7	7	15	15

c)

1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	2	2	2	1	1
1	1	3	2	2	1	1
1	1	3	2	2	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1

⇒

1	1	1	1	1
1	2	2	2	1
1	3	2	2	1
1	3	2	2	1
1	1	1	1	1

(highlighting)

Although we are getting the boundary but image is completly changed using ~~min~~ 1 or 0 padding and apply min filter.

→ Larger mask size results in greater smoothing effect which results in more blurring because of information loss.

- **Averaging filter**

$$g(x,y) = \frac{\sum_{s=-a}^{a}\sum_{t=-b}^{b} w(s,t)\, f(x+s, y+t)}{\sum_{s=-a}^{a}\sum_{t=-b}^{b} w(s,t)}$$

averaging filter — we assume origin at center pixel.

$$\frac{1}{9}\begin{array}{|c|c|c|}\hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline\end{array} \qquad \frac{1}{16}\begin{array}{|c|c|c|}\hline 1 & 2 & 1 \\ \hline 2 & 4 & 2 \\ \hline 1 & 2 & 1 \\ \hline\end{array} \rightarrow \text{weighted averaging filter}$$

The values in mask (also called sub-image) are called coefficients rather than pixels.

Order-statistics filter. (Non-linear)

Order-statistics filters are nonlinear spatial filters whose response is based on ordering or ranking of pixels which are in the given domain of pixels.

→ **Derivative filters**

Ist order derivative
- one dimensional $f(x)$ x-direction
- 2-D second order derivatives

1D image

$$\frac{\partial f}{\partial x} = f(x+1) - f(x) \Rightarrow \begin{array}{|c|c|c|}\hline 0 & 0 & 0 \\ \hline 0 & -1 & 1 \\ \hline 0 & 0 & 0 \\ \hline\end{array}$$

$$\frac{\partial^2 f}{\partial x^2} = f(x+1) + f(x-1) - 2f(x) \Rightarrow \begin{array}{|c|c|c|}\hline 0 & 0 & 0 \\ \hline 1 & -2 & 1 \\ \hline 0 & 0 & 0 \\ \hline\end{array}$$

Laplacian derivative

$$\frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} = \nabla^2 f$$ → For 2D image.

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

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

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

$$\begin{array}{|c|c|c|}\hline & 1 & \\ \hline 1 & -4 & 1 \\ \hline & 1 & \\ \hline\end{array}$$ → Laplacian mask

Smoothing → integration → low pass filter

Sharpening → differentiation - change in intensity
High pass filter

Highlight ~~a~~ a transition in intensity is performed in sharpening.

Applications.

1. Electronic ~~paint~~ printing
2. Medical imaging
3. Autonomus guidance in military systems

Lapalsian and sharp masking

Property of 1st derivative :

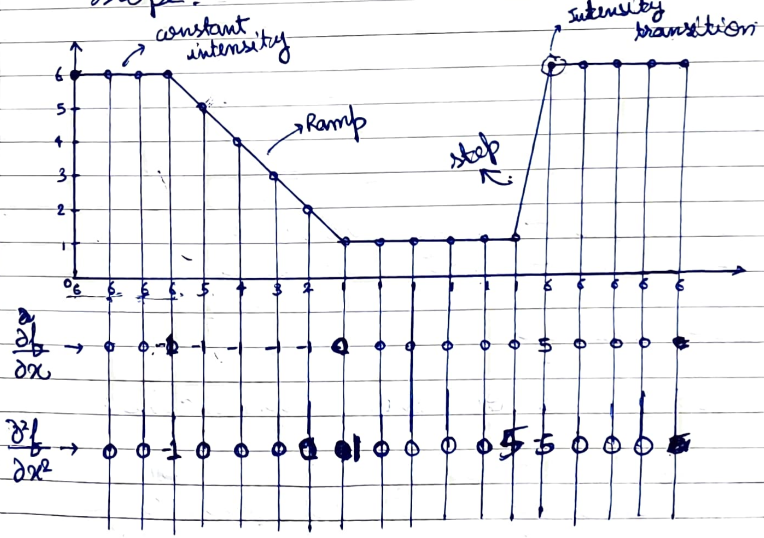
1. Must be 0 in area of constant intensity.
2. Must be non-zero at the onset of an intensity ~~state~~ step or ramp.

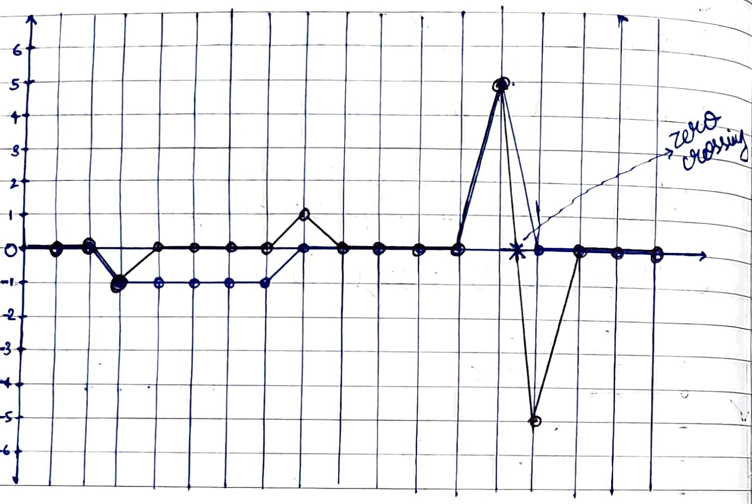
step → continuous constant increase; ramp → sudden change in intensity

3. Must be non-zero along the ramp.

Property of 2nd derivative :

1. Must be 0 in area of constant intensity.
2. Must be non zero at the onset and end of an intensity step or ramps.
3. Must be 0 along the ramp of constant slope.





Black line → second derivative
Blue line → first derivative

~~Zero crossings~~

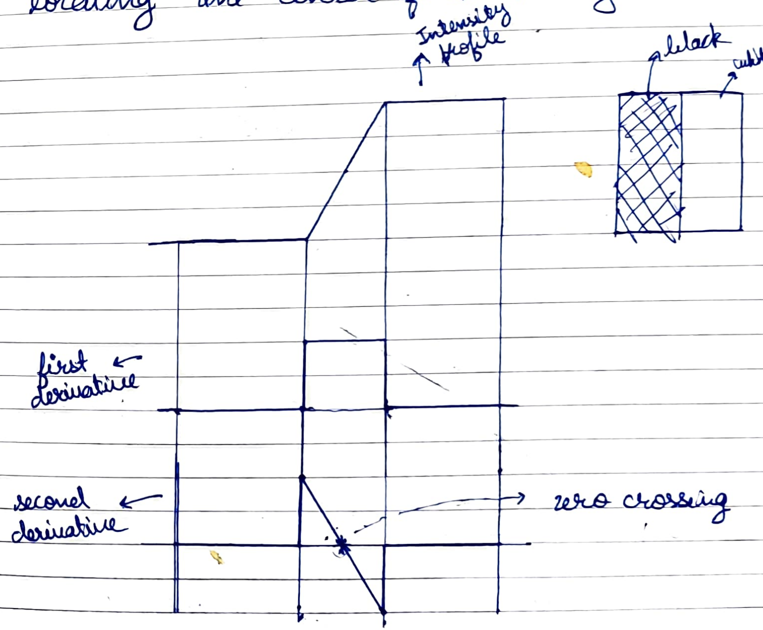
Observations of the above graphs:

1) The magnitude of first derivative can be used to detect the presence of an edge at a point in the image.

2) Sign of second derivative can be used to determine whether an edge pixel lie on the light or darker side of the edge.

3) In second derivative it produce two values for every edge in an image.

4) Its (second derivative) zero crossing can be used for locating the center of thick edges.



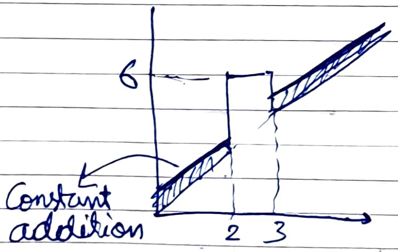
Quiz next thursday

Image operations are array operations, are done on a pixel-by-pixel basis. Array operations are different from matrix operations. For example, consider two images

$$F_1 = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \text{ and } F_2 = \begin{bmatrix} E & F \\ G & H \end{bmatrix}$$

Two images can be added in a direct manner.

$$g(x,y) = f_1(x,y) + f_2(x,y)$$



After adding constant contrast stretching may change or may not change the overall image.

~~Two~~ The image subtraction of two image can be done as follows.

$$g(x,y) = |f_1(x,y) - f_2(x,y)|$$

to avoid -ve values

Image division

$$g(x,y) = \frac{f_1(x,y)}{f_2(x,y)}$$

→ Logical Operations

1. AND/NAND
2. OR/NOR
3. EXOR/ENOR
4. Invert/Logical NOT

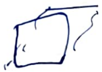
→ ~~Geometric~~ Geometric operation.

$$x' = x + \delta x$$
$$y' = y + \delta y$$

Scaling operation

$$x' = x \times S_x$$
$$y' = y \times S_y$$

$$[x', y'] = \begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix} [x, y]$$



probability

Entropy $H = -\sum_{i=1}^{n} P_i \log_2 P_i$

0	1	2	3	4	5	6	7
5	6	2	3	9	10	10	2

Find probability.

suppose total no. of pixels in image $= N$

$P_0 = \frac{5}{N}$, $P_2 = \frac{6}{N}$, ——

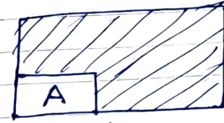
$$H = -\sum_{i=0}^{7} P_i \log_2 P_i$$

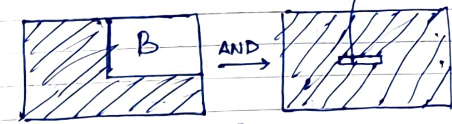
$$= -(P_0 \log_2 P_0 + P_1 \log_2 P_1 + \dots + P_7 \log_2 P_7)$$

0	1	1
1	0	1
1	1	0

} XOR

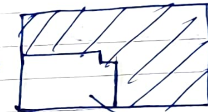
selected region is here

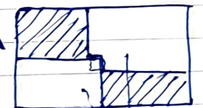




Or

A AND [NOT(B)] =

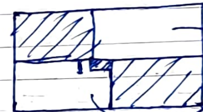




selected region is here

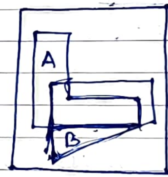
selected region is here

A XOR B =

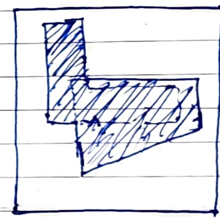


selected region is here

Ans

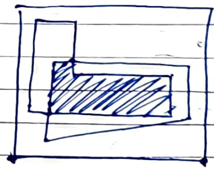


A∪B =

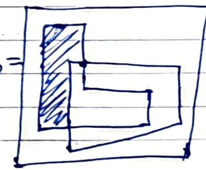


A∩B =

(AND)



A-B =



Convolution]
Corelation] difference of 180°

We will find sum of product of intensity

Padding → 0 or 1

Wrapping

Put the first and last row and column at the ~~last~~ new last and first row and column

4	8	9	4	8
3	1	2	3	1
7	5	6	7	5
4	8	9	4	8
3	1	2	3	1

Convolution means how image is closely related.

convolution = $M \cdot I$

Corelation = $M * I$

M → mask

I → given image

If the mask we have in corelation ~~cor~~ and rotate it by 180° ~~then we~~ ~~will and perform the operation we~~ we will get convolution.

5	4	9
5	4	9
5	4	9

horizontally 90° →

9	4	5
9	4	5
9	4	5

vertically 90° →

9	4	5
9	4	5
9	4	5

M_{conv} = 1 2 3 2 8

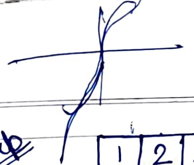
M_{cor} = 8 2 3 2 1

M_{conv} =

1	2	3
4	5	6
7	8	9

M_{cor} =

9	8	7
6	5	4
3	2	1



exp

1	2	2	3
3	2	4	1
1	3	3	2
4	1	1	3

Image

0	1	0
1	1	1
0	1	0

Mask.

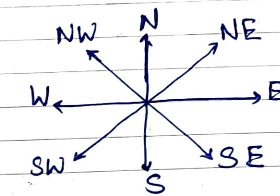
Apply wrapping then find the resultant image ~~of the~~ after convolution.

3	4	1	1	3	4
3	1	2	2	3	1
1	3	2	4	1	3
2	1	3	3	2	1
3	4	1	1	3	4
3	1	2	2	3	1

Edge detection

- Three types of basic edges →

(i) Horizontal
(ii) Vertical
(iii) Diagonal



- Masks :

Prewitt
Sobel
Robinson Compass Mask
Krisch Compass Mask
Laplacian Mask

1. Prewitt (Horizontal and vertical mask

gradient

G_y

-1	0	1
-1	0	1
-1	0	1

G_x

-1	-1	-1
0	0	0
1	1	1

gradient

$$\theta = \tan^{-1}\left(\frac{G_y}{G_x}\right)$$

$$|G| = \sqrt{G_x^2 + G_y^2}$$

2. Sobel Mask

$$G_y = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

$$G_x = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

3. Robinson Mask. (8 directional edges can be identified)

$$\cancel{G_y} = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \xrightarrow{45^\circ} \begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix} \xrightarrow{45^\circ}$$

N-direction mask   NE-direction mask

$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \xrightarrow{45^\circ} \begin{matrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{matrix} \xrightarrow{45^\circ} \begin{matrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{matrix} \xrightarrow{45^\circ}$$

E-direction mask   SE direction mask   S direction mask

$$\begin{matrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -2 \end{matrix} \xrightarrow{45^\circ} \begin{matrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{matrix} \xrightarrow{45^\circ} \begin{matrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{matrix}$$

SW direction mask   W direction mask   NW direction mask

4. Krisch mask (weights are adjusted)

$$\begin{matrix} -3 & -3 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & 5 \end{matrix} \xrightarrow{45^\circ} \begin{matrix} -3 & -3 & -3 \\ -3 & 0 & 5 \\ -3 & 5 & 5 \end{matrix} \xrightarrow{45^\circ} \begin{matrix} -3 & -3 & -3 \\ -3 & 0 & -3 \\ 5 & 5 & 5 \end{matrix} \xrightarrow{45^\circ}$$

N-direction   NE-direction   E-direction

$$\begin{matrix} -3 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & 5 & -3 \end{matrix} \xrightarrow{45^\circ} \begin{matrix} 5 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & -3 & -3 \end{matrix} \xrightarrow{45^\circ} \begin{matrix} 5 & 5 & -3 \\ 5 & 0 & -3 \\ -3 & -3 & -3 \end{matrix} \xrightarrow{45^\circ}$$

SE-direction   S-direction   SW direction

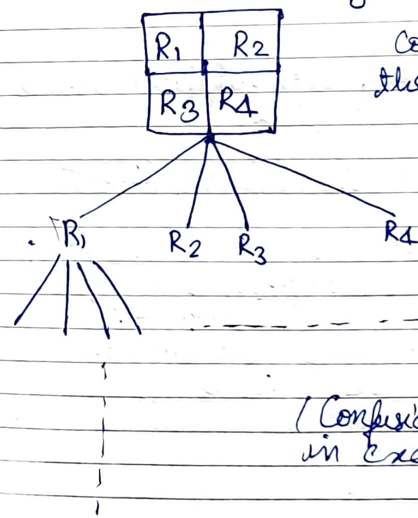
$$\begin{matrix} 5 & 5 & 5 \\ -3 & 0 & -3 \\ -3 & -3 & -3 \end{matrix} \xrightarrow{45^\circ} \begin{matrix} -3 & 5 & 5 \\ -3 & 0 & -3 \\ -3 & -3 & -3 \end{matrix}$$

W direction   NW direction

Step edges
Ramp edges
Line edges
Roof edges

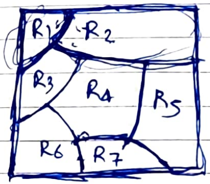
Segmentation
- Discontinuity based segmentation → different from each other based on certain feature
- Similarity based segmentation → based on certain feature/characteristics

Region Growing → Based on thresholding
Split and Merge → Divide the image in 4 regions.



Continuously divide the regions.

(Confusion matrix question in exam)



(i) $R_1 \cup \cdots \cup R_N = R$

(ii) $R_1 \cap R_i,\ i = 2 \text{ to } N = \phi$

(iii)

- <u>Region oriented segmentation</u>

Basic Formulation: R be a region describing the complete image and Let $R_1, R_2, \ldots, R_n$ are regions

① $\bigcup_{i=1}^{n} R_i = R \Rightarrow$ ~~Segm~~ Segmentation Process complete.

② R_i is connected regions. (4 or 8 connected)

③ $R_i \cap R_j \neq \phi$ for all i,j where $i \neq j$ (disjoint property)

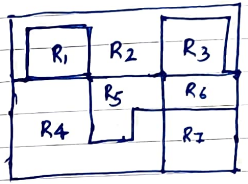
seed point

④ $P(R_i)$ = True → means all ~~population~~ properties P must be satisfied by all the pixels in the region R_i

→ Logical predicate over the points in set R_i

⑤ $P(R_i \cup R_j)$ = False for $i \neq j$

boundary representation



Seed point : ① Generally seed point is considered near to highest greylevel value. It gives less number of regions and less number of isolated regions.

② Seed point may be considered any pixel having grey level (generally we consider middle grey level)

③ In case if we select ~~a~~ seed point near to lowest greylevel value then it gives may ~~to~~ be to gives better ~~result~~ region. but depends on image quality.

Similarity function :

$$|f(x,y) - f(x',y')| < T \rightarrow \text{Threshold value}$$

$f(x,y)$ → Image point intensity

$f(x',y')$ → seed point intensity

T → multilevel, Local, Adaptive, Global

	S				

1	0	7	8	7
0	1	8	9	8
0	0	7	9	8
0	1	8	8	9
1	2	8	8	9

seed point $S_1 = 9$ $S_2 = 1$

Thresholding condition $T \leq 4$

Apply region growing technique

If seed value = 9

$|f(x,y) - f(x',y')| \equiv T \leq 4$

$|f(x,y) - 9| \leq 4$

possible intensity values = $\{5, 6, 7, 8, 9\}$

		X	X	X
		X	X	X
		X	X	X
		X	X	X
		X	X	X

If seed value = 1

$|f(x,y) - f(x',y')| \equiv T \leq 4$

$|f(x,y) - 1| \leq 4$

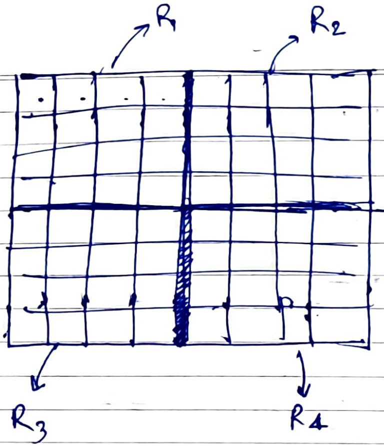
possible intensity values = $\{5, 4, 3, 2, 1, 0\}$

X	X			
X	X			
X	X			
X	X			
X	X			

6	5	6	6	7	7	6	6
6	7	6	7	5	5	4	7
6	6	4	4	3	2	5	6
5	4	5	4	2	3	4	6
0	3	2	3	3	2	4	7
0	0	0	0	2	2	5	6
1	1	0	1	0	3	4	4
1	0	1	0	2	3	5	4

Thresholding condition $T \leq 3$

$I_{max} - I_{min} \leq T$



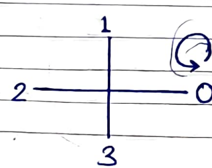
Region representation

- External Characteristics (Boundary)
  - Chain code
    - length
    - orientation
    - control
- Internal Characteristics (Pixels)
  - color
  - pattern
  - texture

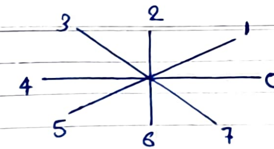
  } features

Boundary will be checked using 4 and 8 connectivity.

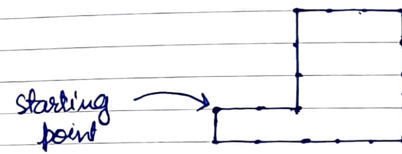
Criteria for 4-connected



Criteria for 8-connected



Translation and rotation invarient will have same chain code.



4 connected

0 0 0 1 1 1 0 0 0 3 3 3 3 3 2 2 2 2 2 1

Now we have to take the smallest integer value for the chain code by performing shifting.

0 0 0 1 1 1 0 0 0 3 3 3 3 3 2 2 2 2 2 1

0 0 3 0 0 1 0 0 1 0 0 0 0 1 0 0 0 0 1 01

Now we take the minimum integer formed from shifting.

0 0 0 0 1 0 0 0 0 0 1 1 0 0 3 0 0 1 0 0 1

This is rotation invariate