Digital image Processing

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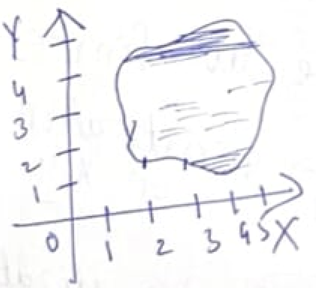
Unit-I

What is digital image processing :- An image may be defined as two-dimensional function $f(x,y)$ where x and y are coordinates and the amplitude of f at any pair of coordinates (x,y) is called the intensity or gray level of the image at that point. x, y, f are all finite, discrete quantities, the image is called digital image. Digital image processing refers to processing digital images by means of a digital computer using algorithm. Digital image is composed of a finite no. of elements, each of which has a particular location and value. These elements are called picture elements, image elements, pixels, pels.

$f(x,y)$ is intensity $\rightarrow$ 0-255

image can be represented in form of matrix.



$$f(x,y) = \begin{pmatrix} f(0,0) & f(0,1) & f(0,2) & \cdots \\ f(1,0) & f(1,1) & f(1,2) & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & & & \end{pmatrix}$$

→ Extracting of information from images is image processing.

→ Image acquisition ~~using~~ done using camera.

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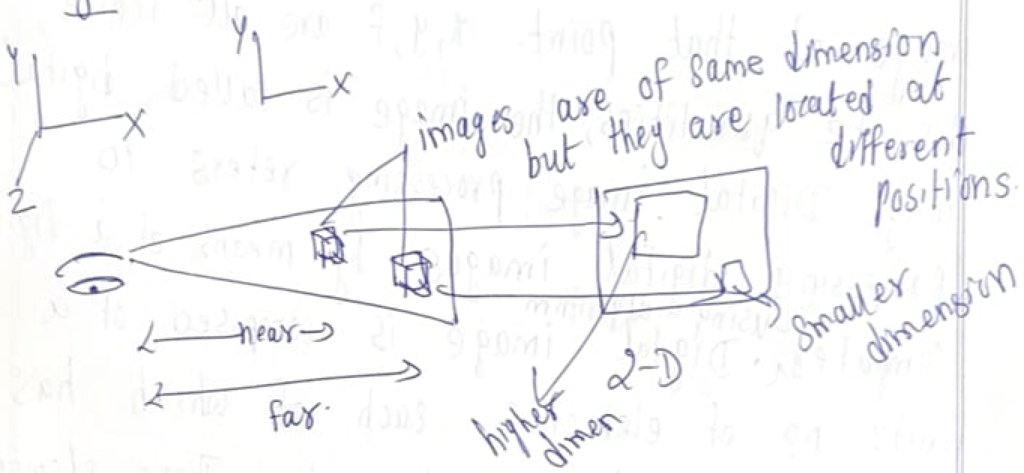
Motivation – ① Improvement of pictorial information for human interpretation

② processing of image data for storage, transmission, and representation for autonomous machine perception.

image – projection of 3D scene in 2D plane



Two types

→ Analog image – ~~f(x,y) has~~ continuous range of values representing position and intensity.
ex- image on the screen of a CRT monitor

→ digital image – x, y of f are all finite discrete quantities

Analog image to digital

[Analog image] → [Sampling] → discretization on x, y
↓
[quantization] → discretization on f
[digital image] ← [quantization]

In realworld, images are Analog. But for Storage and transmission images are stored in digital form.

Advantages –

① fast processing

② cost effective

③ effective storage

④ efficient transmission.

⑤ image manipulation.

Analog images are more precise compared to digital image. More Storage for Analog.

digital image processing – Analysis and manipulation of a digitized image, especially to improve its quality. or image processing is the process of transforming an image into digital form by means of computer (*)

Advantages – ① Humans are limited to the visual band of electromagnetic (EM) spectrum.

② But imaging machines covers almost the entire EM spectrum, ranging from gamma to radio waves.

③ operation on images generated by sources that humans are not capable to sense.

(*) to extract useful information.

3 types of computerized process

1. low-level process 2. Mid-level 3. high-level

low level – primitive operations such as image processing to reduce noise, contrast enhancement, image sharpening.

i/ps & o/ps are images.

Mid level – image segmentation, classification of individual objects.

i/ps are images, o/ps are attributes extracted from those images i.e edges, contours, identity of individual objects.

high level – making sense of ensemble recognized objects, in image analysis

Types of images – ① Binary image – 2 levels only
0 – black, 1 – White.

② gray scale image – 256 levels – numbered from 0 to 255. 0 – black, 127 – grey 255 – White
Size of pixel – 1 byte.

③ colored image – RGB (Red green blue)
R – 0 to 255 G – 0 to 255 B – 0 to 255
size – (3×1) byte.

Origins of digital image processing

1. first application of digital images was in news paper industry, when pictures were sent by submarine cable b/w London & Newyork.

2. With Introduction of Bartlane cable picture transmission system in early 1920's reduced the time required to transport a picture across the Atlantic from more than a week to less than 3 hours

3. Initial problems in improving the visual quality of early digital pictures were sometimes related to selection of printing procedures and the distribution of intensity levels.

   ex – digital picture produced in 1921 from a coded tape by a telegraph printer.

4. digital picture made in 1922 from a punch tape at the telegraph receiving terminal. Improvement in both tonal quality and in resolution.

5. Bartlane systems were capable of coding images in 5 distinct levels of gray improved to 15 levels in 1929.

   5 distinct → 5 tones

But, computers were not involved in their creation.

⑥ first computers powerful enough to carry out meaningful image processing tasks appeared in the early 1960

ex- first picture of moon by US Spacecraft in 1964.

⑦ In 1970, medical imaging - CAT (Computerised Axial Tomography) | CT scan - 3-D

④ X-Ray images

⑧ Remote earth resources - Weather forecast, crop production, disaster management.

⑨ Astronomy

⑩ Study of pollution patterns by geographers.

⑪ Restoring blurred images of Archeology.

⑫ Automatic character recognition.

⑬ Automatic processing of fingerprints.

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fundamental steps in digital image processing

It is helpful to divide the material of digital image processing into the two broad categories.

→ Methods whose i/p & o/p are images [1-7]

→ methods whose i/p are images but o/p are attributes extracted from those images. (8-10)

1. image acquisition :- it is the first process. It also involves preprocessing such as scaling. Scaling means resizing of an image (width × ht). Multiply each components by a scalar.

Uniform Scaling - Scalar Same for x, y.

non-uniform - Not same.

2. image enhancement - process of manipulating an image so that the result is more suitable than the original for a specific application.

Types - ① qualitative enhancement - refers to the modification of images to make it more appeal to human.

② quantitative enhancement - refer to the modification of information that an image carries.

ex - edge detection process. look is not a concern

Techniques - spatial domain, frequency domain, Combination.

③ image restoration :- reconstruct or recover an image from degraded image reconstruct using prior knowledge. Degradation occur due to camera lens, opening & closing of shutter.

$$f(x,y) \rightarrow \boxed{\begin{matrix}\text{degradation}\\ \text{function}\\ h(x,y)\end{matrix}} \rightarrow \underset{g(x,y)}{\overset{\eta(x,y)\downarrow}{\oplus}} \rightarrow \boxed{\begin{matrix}\text{Restoration}\\ \text{function}\end{matrix}} \rightarrow \hat{f}(x,y)$$

i/p image

$$g(x,y) = f(x,y) \underbrace{*}_{\text{convolution}} h(x,y) * \eta(x,y)$$

to remove this degradation we need to apply de-convolution (inverse).

④ color image processing :-

Motivation - ① easily identify an object in an color image.

② Human eye can identify 1000's of colours.

2 categories

→ full color - ex-TV

→

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⑤ Wavelets - representing images in various degrees of resolution.

⑥ Compression - techniques for reducing the storage required to save an image or bandwidth required to transmit.

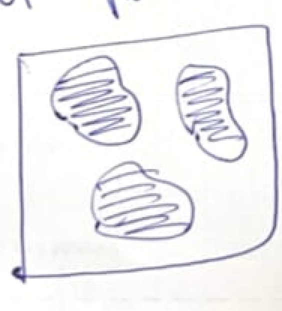
2 parts. → encoder performs compression
→ decoder performs decompression.

$f(x,y) \rightarrow$ [~~Source~~ encoder] $\rightarrow$ [Channel] $\rightarrow$ [Decoder] $\rightarrow f(x,y)$

⑦ Morphology - Related to shape & properties of objects. used for segmentation & feature extraction. Two operations erosion and dilation

dilation - process of expanding an image.
erosion - shrinking of an image.

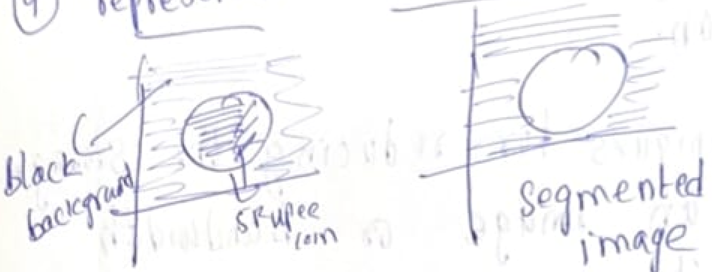
⑧ image segmentation:- it is the process of partitioning image into multiple regions



2 Methods
1. discontinuity - isolated point, line detection, edge detection.
2. Similarity - thresholding, region growing, region split.

Components of an imag...

(9) representation and description



Segmented image should be represented in a computer.

→ Boundary based

→ region based.

description – describe the properties of segmented image.

→ Boundary descriptor

→ Regional descriptor.

(10) Recognition – it is the process that assign a label to an object based on its descriptor
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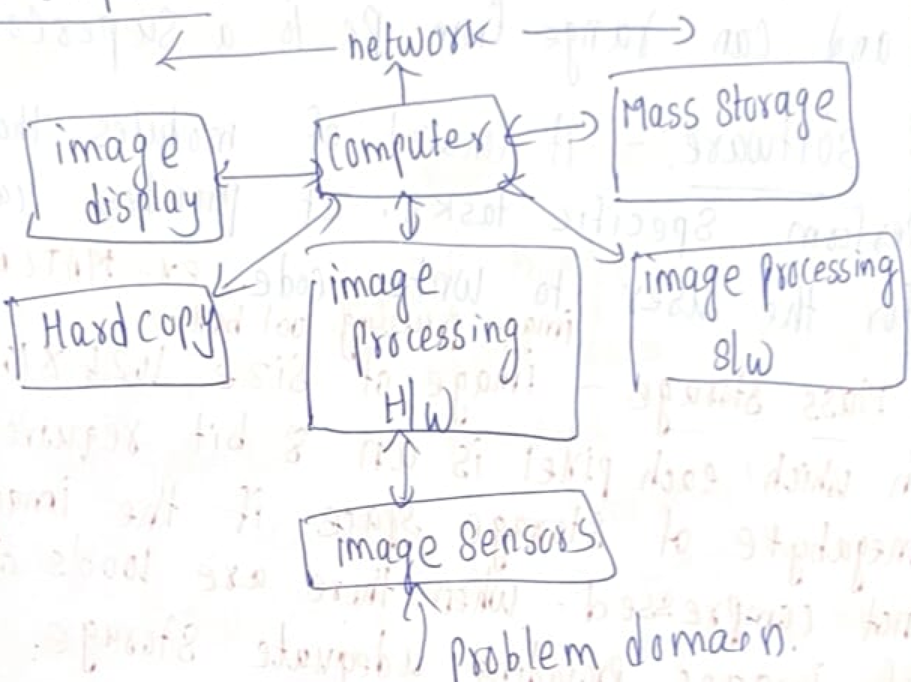
Components of an image processing system

Image Processing System is the combination of the different elements involved in the digital image processing. It is the processing of an image by means of a digital computer. It uses different computer algorithms to perform image processing on the digital images.

8 Components.



① image Sensor:- image acquisition is the process of capturing digital images using various devices and sensors. Two elements are required to acquire digital images. The first is a physical device that is sensitive to the energy radiated by the object we wish to ~~chang~~ image. The second is digitizer, is a device for converting the o/p of the physical sensing device into digital form.

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(2) image processing H/W :- Consists of digitizer, plus H/w that performs primitive operations, i.e ALU that performs arithmetic and logical operations on images. It is also called front-end subsytem. This unit performs functions that require fast data throughputs.

(3) Computer :- it is a general purpose computer and can range from PC to a supercomputer.

(4) software :- it consist of modules that perform specific tasks. It provides capability for the user to write code. ex- MATLAB image processing tool box.

(5) Mass storage - image of size 1024 X 1024 pixels, in which each pixel is an 8 bit, requires one megabyte of storage space if the image is not compressed. When there are 1000's or millions of images providing adequate storage.

3 types of storages.

→ Short term storage during processing - computer memory

→ online storage - Magnetic disks, optical storage

→ frequent access.

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3. archival storage - infrequent access.
(5) large storage - optical disks, magnetic tapes ~~juked in~~ packed in juke boxes.

(6) image display - TV screens, monitors to display processed images.

(7) Hard copy devices - for recording images ex- laser printers, CD-ROM disks.

(8) network - when image is transmitted it requires large bandwidth.

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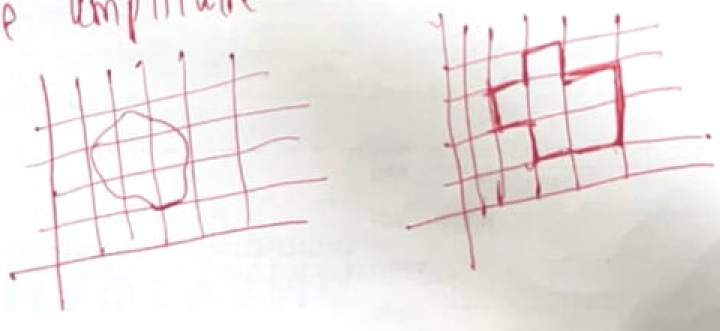
Image Sampling and quantization

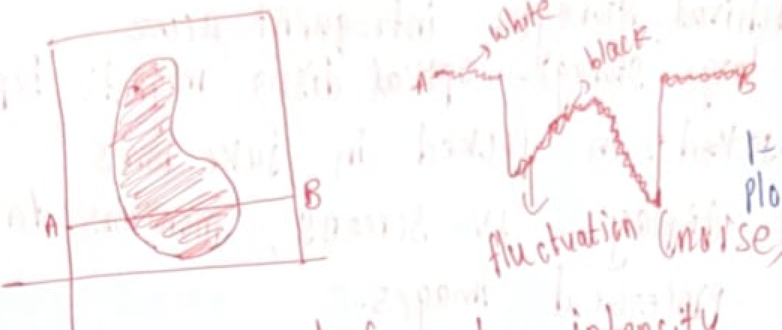
To create a digital image, we need to convert continuous sensed data into digital form. This involves 2 processes

→ Sampling → x-axis → coordinates

→ quantization → y-axis → amplitude

Sampling - image is continuous w.r.to x-coordinates, y-coordinates, amplitude. To convert into digital form, we've to sample the function in both coordinates and its amplitude. digitizing Digitizing the coordinates is called sampling. Digitizing the amplitude values is called quantization.

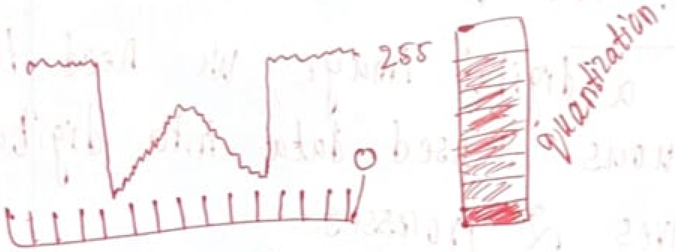




1-d function
Plot of amplitude along line AB

We can have different intensity
black (0) – low intensity, grey – slightly higher intensity, blue – medium intensity, white – very high intensity (255).

→ divide the x-coordinate into equal parts is called Sampling.



Sampling

Sampling the analog signal mean instantaneously measuring

digital scan line.

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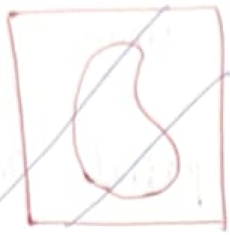


The one-dimensional function is a plot of amplitude of the continuous image along the line segment AB. Random variations are due to ~~to~~ image noise. To sample this, take equally spaced samples along line AB. Spatial location of each sample is indicated by a vertical tick mark in the bottom part of the fig. Samples are shown as small white squares. The set of these discrete locations gives the sampled function. Intensity values also must be converted into discrete quantities. Intensity scale is divided into eight discrete intervals, ranging from black to white. Vertical tick marks indicate the specific value assigned to each of the 8 intensity intervals.

Starting at the top of the image and carrying out this procedure line by line produces 2-D digital image.

Representing digital images

let $f(s,t)$ is a continuous image function of 2 continuous variables s & t. continuous Image is converted into digital image using sampling and quantization. i.e $f(x,y)$

$x \rightarrow$ rows $\quad y \rightarrow 0,1 \ldots n-1$ columns

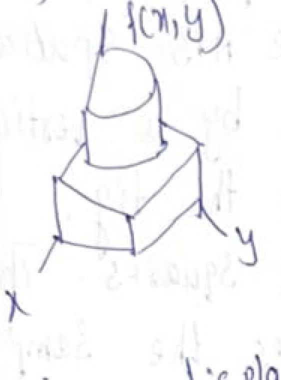
$0,1 \ldots m-1$

3 ways to represent digital image

1. image plotted as surface

3 axis - x & y represent spatial coordinates

f(x,y) is 3rd axis.

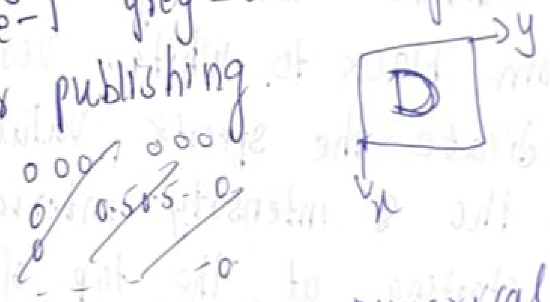


for complex image this representation is difficult.

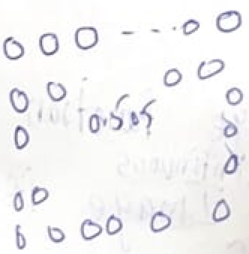
② image displayed as visual intensity array

it would appear on a monitor or TV screens.

It has 3 discrete intensity levels - white, black and grey. Black-0 white-1 grey-0.5. They are used in printers or publishing.



③ Numerical array - it contains numerical values. This is mostly used in processing.



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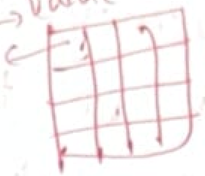
Basic relationships between pixels

image is denoted as $f(x,y)$. f is pixel

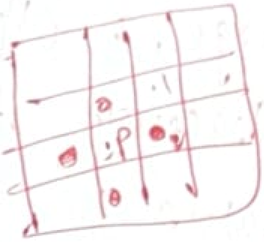
x, y are spatial coordinates.

$(0,0) \rightarrow$ value at this position is called pixel.



Neighbors of a pixel:-

Pixel p at coordinates (x,y) has four horizontal and vertical neighbors.



$p(x,y)$

$N_4(p)$ $x-1 \rightarrow$ previous row

$x+1 \rightarrow$ Next "

$y-1 \rightarrow$ previous row

$y+1 \rightarrow$ Next column

4 coordinates are

$N_4(p) = (x+1, y), \ (x-1, y) \ (x, y+1) \ (x, y-1)$

$\cancel{\{P, Q, R, S\}}$ $\{q, r, s, t\}$

diagonal nbr of p

$N_d(p) = (x+1, y+1) \ (x+1, y-1) \ (x-1, y+1), \ (x-1, y-1)$

8 nbrs of p – $N_4(p) \cup N_d(p) = N_8(p)$

$N_8(p) = \{q, r, s, t, 1, 2, 3, 4\}$

Adjacency, Connectivity, region and boundary

Adjacency - Two pixels that are nbrs & have the same gray level

Let V be the set of intensity values used to define adjacency. In binary image; V = {1} refer to adjacency of pixels with value 1.

0	1	1 q
0	1 p	0
0	0	1

binary image 2 - intensity values - 0, 1

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

$N_4(p) = \{b, d, q, q\}$

a 0	b 1	c
d 0	1 p	1 q
0	0 q	1

{b, q} are 4-adj to p

y			
y+1	(x-1, y+1)	(x, y+1)	(x+1, y+1)
y	(x-1, y)	(x, y)	(x+1, y)
y-1	(x-1, y-1)	(x, y-1)	(x+1, y-1)
	x-1	x	x+1

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4-distance - city block distance

$D_4(p,q) = |x-s| + |y-t|$

(*1) a pixel having a D_4 distance from (x,y) (center pt) $\le r$ from a diamond centered at (x,y).

		2		
	2	1	2	
2	1	0 (p)	1 (q)	2
	2	1	2	
		2		

(*1)

(*) the distance two pixels will depend on the values of the pixels along the path as well as the values of their nbrs.

$d_4(p,q) = 1$ q is 4-distance of p

q should be in 4-nbrs of p.

8-distance - chess board distance.

$d_8(p,q) = \max(|x-s|, |y-t|)$

dm - distance :- distance b/w 2 pts is defined as the shortest m-path b/w the pts.

p, p_2, p_4 as 1, $p_1, p_3 = 0$ or 1 (*) $V = \{1\}$

adjacency of pixels value

ex-

	p_3	p_4
p_1	p_2	
p		

① if p_1 & p_3 are 0.

m-path distance b/w p & p_4 is 2.

	0	1
0	1	
1		

② if p_1 ~~p_3~~ $=1$

	0	1
1	1	
1		

$p\,p_1 p_2 p_4 = 3$

③ if $p_3 = 1$ $p_1 = 0$

	0	1	1
	1	
1		

$p\,p_2\,p_3\,p_4 = 3$

④ p_1 & $p_3 = 1$

$p\,p_1\,p_2\,p_3\,p_4 = 4$.

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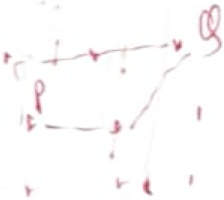
Regions that are not adjacent are said to be disjoint.

Boundary:- Suppose image contains K disjoint regions R_K $K = 1 \ldots K$, none of which touches the image border. R_U denote the union of all the K regions, $(R_U)^c$ denote complement. All points in R_u, foreground and all points in (R_u^c) is background of image.

Boundary of a region R is the set of points that are adjacent to points in the complement of R.

distance Measures:- for pixels P, q, Z with coordinates (x, y), (s, t) and (v, w). D is a distance metric

a) $D(P, q) \geq 0$, $D(P, q) = 0$ iff $P = q$



b) $D(P, q) = D(q, P)$

c) $D(P, Z) \leq D(P, q) + D(q, Z)$

Euclidean distance

$$D_e(P, q) = \sqrt{(x-s)^2 + (y-t)^2}$$

Connections should be unique path

- → 4-adjacency → Priority
- → 8-adjacency

```
0 1 1
0 1 0
0 1 1
```

Mixed adjacency is used to eliminate ambiguity.

Connectivity - 2 pixels are said to be connected if there exist a path. Path can be 4-adj or 8-adj.

```
0   1 1q
0 p 1 0
0   0 1
```

p, q there 2 path. We should prefer 4 adj.

Region: - ~~0 1 1~~ let R be a subset of pixels in an image. R is a region of the image if R is a connected set. Two regions R_i and R_j are said to be adjacent if their union forms a connected set.

```
0 1 1 }
0 1 0 } Ri
0 1 0 }
0 0 1 }
1 1 1 } Rj
1 1 1 }
```

8 adj :- Two pixels p and q with values from V are 8-adj if q is in set $N_8(p)$

$N_8(p) = \{a, b, c, d, e, f, g, h\}$

8 adj to p = {b, e, h}.

m-adj :- ① q is in $N_4(p)$

② q is in $N_D(p)$ and $N_4(p) \cap N_4(q)$ has no pixels whose values are from V.

4-adjacency

Binary image V={1}

0	1	0	1	8 adj
0	0	1	0	→ 4 adj
0	0	1	0	
1	0	0	0	

not connected.

gray scale

54	10	100	8	→ 8 adj
81	150	2	34	→ 4 adj
201	200	3	45	
7	70	147	56	

not adjac.

V = {1, 2, 3 - - 10}

m-adj - (mixed adj)

V={1}

0	1 — 1		0	1	1	0	1	1
0	1	0	0	1	0	0	1	0
0	1	1	0	0	1	0	0	1

Mathematical tools used in Digital image processing

1. Array VS Matrix operations
2. linear VS non-linear operations
3. Arithmetic operations
4. Basic set "
5. logical "
6. spatial "
7. vector of Matrix oprns.

Array VS Matrix operations

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \text{ and } \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$ (each image is represented in form matrix)

array product of two images is pixel by pixel

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} = \begin{bmatrix} a_{11}b_{11} & a_{12}b_{12} \\ a_{21}b_{21} & a_{22}b_{22} \end{bmatrix}$$

Matrix product

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} = \begin{bmatrix} a_{11}b_{11} + a_{12}b_{21} & a_{11}b_{12} + a_{12}b_{22} \\ a_{21}b_{11} + a_{22}b_{21} & a_{21}b_{12} + a_{22}b_{22} \end{bmatrix}$$

linear VS Nonlinear operations - important classification of an image processing is whether it is linear or non linear.

linear - Addition, Sub, Multiplication, division each pixel of on image

non-linear - Max, Min, Median, mode, mean

$H[f(x,y)] = g(x,y)$

H is said to be linear operator if

$H[a_i f_i(x,y) + a_j f_j(x,y)] = a\, H[f_i(x,y)] + a_j H[f_j(x,y)]$

$= a_i g_i(x,y) + a_j g_j(x,y)$

let H is the sum operator

$\Sigma [a_i f_i(x,y) + a_j f_j(x,y)]$

$= \Sigma a_i f_i(x,y) + \Sigma a_j f_j(x,y)$

$= a_i \Sigma f_i(x,y) + a_j \Sigma f_j(x,y)$

$= a_i g_i(x,y) + a_j g_j(x,y)$

ex- $\begin{bmatrix} 50 & 75 & 100 \\ 125 & 150 & 175 \\ 200 & 225 & 250 \end{bmatrix}$

linear operation by adding constant value 50 to each pixel

$\begin{pmatrix} 100 & 125 & 150 \\ 175 & 200 & 225 \\ 250 & 275 & 300 \end{pmatrix}$

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non-linear - Max operation → find maximum value of pixels in an image.

$f_1 = \begin{bmatrix} 0 & 2 \\ 2 & 3 \end{bmatrix}$ $f_2 = \begin{bmatrix} 6 & 5 \\ 4 & 7 \end{bmatrix}$ $a_1 = +1$ $a_2 = -1$

LHS

$\max\left\{ 1 \begin{bmatrix} 0 & 2 \\ 2 & 3 \end{bmatrix} + (-1) \begin{bmatrix} 6 & 5 \\ 4 & 7 \end{bmatrix} \right\} = \max \begin{bmatrix} -6 & -3 \\ -2 & -4 \end{bmatrix} = -2$

RHS $(1) \max \begin{bmatrix} 0 & 2 \\ 2 & 3 \end{bmatrix} + (-1) \max \begin{bmatrix} 6 & 5 \\ 4 & 7 \end{bmatrix}$

$= (1) 3 + (-1) 7 = -4$

$LHS \neq RHS$.

∴ max operation is not linear.

Arithmetic operations:- b/w images are array operations carried out b/w corresponding pixel pairs.

$s(x,y) = f(x,y) + g(x,y)$

$d(x,y) = f(x,y) - g(x,y)$

$p(x,y) = f(x,y) \times g(x,y)$

$v(x,y) = f(x,y) \div g(x,y)$

$A = \begin{bmatrix} 50 & 75 \\ 100 & 125 \end{bmatrix}$ $B = \begin{bmatrix} 25 & 50 \\ 75 & 100 \end{bmatrix}$

$A+B = \begin{bmatrix} 75 & 125 \\ 175 & 225 \end{bmatrix}$ $A-B = \begin{bmatrix} 25 & 25 \\ 25 & 25 \end{bmatrix}$

$A*B = \begin{bmatrix} 1250 & 3750 \\ 7500 & 12500 \end{bmatrix}$ $A/B = \begin{bmatrix} 2 & 1.5 \\ 1.33 & 1.25 \end{bmatrix}$

1. if the result is a floating pt no, round off its value
2. if the result is above pixel range, select the max range value
3. if
4. if the result is infinity, write it as 0.

Addition

$$\begin{bmatrix} 0 & 100 & 10 \\ 4 & 0 & 10 \\ 8 & 0 & 5 \end{bmatrix} + \begin{bmatrix} 10 & 100 & 5 \\ 2 & 0 & 0 \\ 0 & 10 & 10 \end{bmatrix} = \begin{bmatrix} 10 & 200 & 15 \\ 6 & 0 & 10 \\ 8 & 10 & 15 \end{bmatrix}$$

Uses :- Addition of noisy images, for noisy reduction

-> image average

Subtraction = $\begin{bmatrix} 0 & 0 & 5 \\ 2 & 0 & 10 \\ 8 & 0 & 0 \end{bmatrix}$

-> enhancement

-> Medical imaging

Multiplication = $\begin{bmatrix} 0 & 255 & 50 \\ 8 & 0 & 0 \\ 0 & 0 & 50 \end{bmatrix}$

-> Shading correction

-> Masking or RoI

division – $\begin{bmatrix} 0 & 1 & 2 \\ 2 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$

Shading correction

logical operations – And, or, not – pixel by pixel

A	B	Y
0	0	0
0	1	0
1	0	1
1	1	1

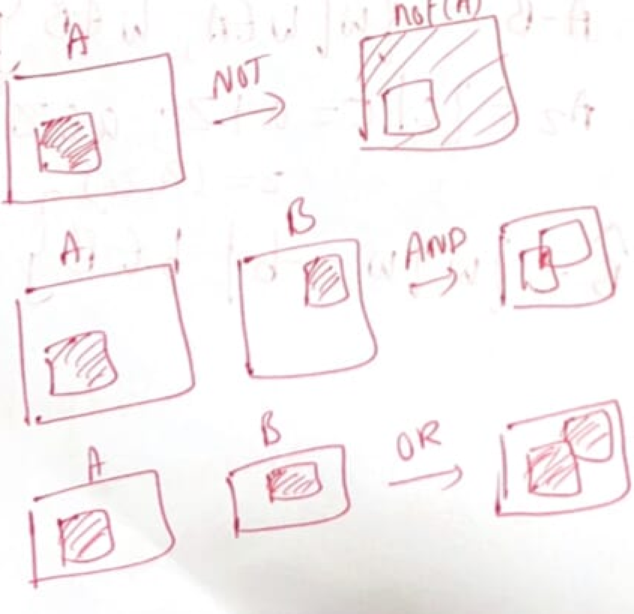
$$\overset{X}{\begin{bmatrix} 1 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 1 \end{bmatrix}} \text{ and } \overset{Y}{\begin{bmatrix} 0 & 1 & 0 \\ 1 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

OR

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

NOT

$$X \rightarrow \begin{bmatrix} 0 & 0 & 1 \\ 1 & 1 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$



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Morphological operations – extructing image components – boundaries, skeletons.
used for preprocessing, post processing.
set theory → mathematical morphology

→ if $a = (a_1, a_2)$ → $a \in A$ → a is element of a

→ if a is not an element of A , $a \notin A$

→ $A \subseteq B$

→ $C = A \cup B$

→ $C = A \cap B$

→ disjoint – $A \cap B = \phi$

→ Complement $A^c = \{w \mid w \notin A\}$

→ difference $A - B = \{w \mid w \in A, w \notin B\}$

→ Translation – $A_z = \{c \mid c = a + z ; a \in z\}$
$z = (z_1, z_2)$

→ reflection – $\hat{B} = \{w \mid w = -b \mid b \in B\}$

Spatial operations - functions that create new spatial data from specified i/p data. They are performed directly on the pixels of a given image.

Spatial operation

- Single point operations
- neighbourhood operations
- geometric | geometrical operations Spatial oper

Single point operation - alter the values of its individuals pixels based on their intensity

$S = T(Z)$ →transform   Z is intensity of image

$f(x,y) = f(x,y)+3$

ex- NOT operation.

0 → 1

1 → 0

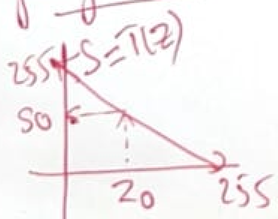
NOT

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

→

1	1	1	1	1	1	1

gray scale - image negative (255 - Z)
→ negative image



$Z = 0$ $S = 255$

$Z = 255$ $S = 0$, Max

$\boxed{T = N - f(Z)}$

Z → image

$Z_0 = 20$

$S = 255 - 20$

$S = 235$

Neighbourhood operations - The value of this pixel is determined by a specified operation involving the pixels in the i/p image with coordinates in S_{xy}

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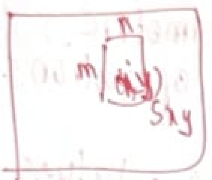

image f

value of this pixel is the avg value of the pixels in Sxy.

image g

ex- Averaging with neighbourhood of 3×3 grid.

Padding

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

6×7

$$g(x,y) = \frac{1}{mn}\sum f(r,c)$$

0	0	0
1	0	1
1	1	1

$$= \frac{1}{3\times3}[0+0+0+1+0+1+1+1+1]$$

$$= \left\lfloor \frac{5}{9} \right\rfloor = 0$$

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Geometric transformations (Rubber sheet transformation)

reshaped.
intensity interpolation.
Affine transform

A spatial transformation of coordinates

$$(x, y) = T\{(v, w)\}$$

→ intensity interpolation that assigns intensity values to the spatially transformed coordinates

$$(x, y) = T(v, w) = \left(\frac{v}{2}, \frac{w}{2}\right)$$

Affine Transform -

$$\begin{bmatrix} x & y & 1 \end{bmatrix} = \begin{bmatrix} v & w & 1 \end{bmatrix} \begin{bmatrix} t_{11} & t_{12} & 0 \\ t_{21} & t_{22} & 0 \\ t_{31} & t_{32} & 1 \end{bmatrix}$$

Probabilistic methods - treat image intensities as random quantities. let z_i, $i = 0, 1, \ldots L-1$ denote the values of all possible intensities in an $M \times N$ digital image. Probability $P(z_K)$ of intensity level z_K occuring in the image is

$$P(z_K) = \frac{n_K}{MN}$$

where n_K is no. of times z_K occur in the image

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

$z = \{1, 2, 3\}$

$P(z_1) = \frac{3}{12} = \frac{1}{4} = 25\%$

$P(z_2) = \frac{6}{12} \frac{1}{}$

$P(z_3) = \frac{1}{4}$

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