# Introduction

- One picture is worth more than ten thousand words.

## What is digital Image?

- Digital image is a representation of a ~~two~~ 2D image as a finite set of digital values called pitcture Elements or pixels.

Two task of Image Processing:-

- Improvement of pictorial information for human interpretation
- Processing of image data for storage, transmission and representation for autonomous machine perception.

Digital Representation →

2D function $f(x, y) \rightarrow$ finite discrete quantities.

Image Processing to Computer Vision, We can divide Process into 3 parts

| Low-level Process | Mid level process | High Level process. |
|---|---|---|
| i/p → Image<br>o/p → Image | i/p → Input<br>o/p → Attributes. | i/p → Attribute<br>o/p → Understanding. |
| Ex:- Noise Removal, image sharpending. | Ex:- object Recognition, Segmentation | Ex:- navigation, Scene Understanding. |

till here course.

# History of Image Processing.

Early 1920s → Image were transferred by submarine cable between London and New York.

## Example of fields Use DIP.

- Image Enhancement → quality improvement technique.
  → Noise Removal

- Hubble Telescope
- Artistic Effects → moview.
- Medicine → MRI
- Geographic Information systems.
- Number plate Recognition for speed cameras/ automated toll systems.
- figerprint Recognition.
- Human Computer Iterface
  - face recognition
  - Gesture Recognition.
- Document verification / Handling.
- Signature Verification.
- Traffic Monitoring.

# Key stages in DIP.

Image Restoration → Morphological Processing → Segmentation

improving the appearance of image

Clear Image

Noise removal.

and. OR. NOT.

Image Enhancement

manipulating image → so result is more suitable.

division of image

Object Recognition

identification

Image Acquisition → Capture Image. → digitized image

Preprocessing scaling.

Problem Domain.

Representation & Description

Color Image Processing

Image Compression.

divided into parts. more accurate more good segmentation recognition

smaller region division.

reducing the storage required to save the image

Color image processing

Wavelets and multiresoultion Processing

Compression

Morphological processing

Image Restoration

↑

Image enhancement

↑

Problem Domain

Knowledge Used.

tools for extracting image components that are useful in representation and description of the shape.

Segmentation

Representation & description

Object Recognition.

feature selection quantitative value.

assigning label to image

Image Enhancement → Histogram equalization

→ Noise Removal using a Wiener fi

→ Linear contrast adjustment

- Median filtering

- Unsharp mask filtering.

- Constrast - limited adaptive histogram equalization

- Decorrelation stretch.

Image Restoration - Median filter

- Adaptive filter

- Linear filter

- Wiener filter

Morphological processing - Erosion and dilation

- opening

- Closing

- hit and miss transform

- Skeleton and propagation

Segmentation - Thresolding

- Clustering

- Histogram based method.

- Compression based method.

# Object Recognition

→ Templete matching
- Color based
- Active and passive
- shape based

## Components of Image Processing:

Network — for data transmission.

Computer — Our PC.

Image display — graphic display card. goggles used to watch 3D movies.

Mass storage — 1024×1024 pixel, 1 1M. size
- → short term
- → online storage
- Archival storage.

Hardcopy — printer, heat sensitive device

Image processing software
↓
- specialized modules that perform specific task
- code - editor

specialized image processing Hardware
- front-end subsystem
- speed

Image sensors
- elements: physical device
- digitizer - convert that into digital form.

Problem domain.

# Types of Image Representation

## Binary image

- simplest type of image.
- 2 values: 0, 1.
- only one binary digit to represent a pixel.
- Used for general shape or outline.

Ex:- OCR - optical Character recognition.

- generated using thresold operation

above thresold convert into 1 or 0.

Whole Black or white.

## gray scale Image

- monochrome - image
- only one color.
- they do not contain any information about color.
- Normal grayscale image contain 8 bits/pixel data which have 256 different gray levels.
- medical/astronomy also used 12 or 16 bits/pixel.

## Color image

- 3-band monochrome image., each band contain a different color
- Color image contain gray level info. in each spectral band.
- Images are Represented in RGB (Red, Green, Blue)
- and each color image has 24 bits/pixels. means 8 bits for each band - RGB.

## multispectral image.

## Multispectral images

- this image contein the information outside the normal human perceptual range.
- May include – infrared
  - ultraviolet
  - x-ray
  - acoustic.
  - radar data

## ⇒ 8 bit color format.

- 8 bit color is used to storing image info. in file of an image in computer's memory or
- each pixel Represent → one byte - 8 bit.
- Range 0-255

3 Red
G- 3- Green
2- Blue

0 127 255
↑ black ↑ gray. ↑ white

- 8-bit formate = grayscale image.
- Used by UNIX os.
- formate of these image is PGM (Portable Gray map).
- format not supported by default in windows.
- You want image viewer or processing tool to view this matlab.

## 16 bit color format :-

- also known as high color format.
- 65536 - different color shades.
- Used in Microsoft.
- 16 bit Color format

| | | | |
|---|---|---|---|
| 16 bit Color format | Red | format. | - 5 bits |
| | Green | | - 6 bits. |
| | Blue | | - 5 bits. |

Why one more in green only?

- in all 3 color green color is soothing to eyes.

## 24 bit color format :-

- true color format.
- 24 bit

| | | |
|---|---|---|
| 24 bit | Red | - 8 bit |
| | Blue | - 8 bit |
| | green. | - 8 bit. |

- 16 777 216 Colors.
- Most common used format.
- PPM (Portable pixMap) - format → Linux Unix
- BMP (BitMap) - format - Windows.

# Concepts of Bits per Pixel.

- BBP → Bits per pixel. → is used to denote the no. of bits per pixels.

formula for no. of color. $2^{BBP}$

| Bits per pixel | No. of color |
|---|---|
| 1 bpp | 2 |
| 2 bpp | 4 |
| 3 bpp | 8 |
| 4 bpp | 16. |

Shades = No. of colors = $2^{bpp}$

## Image size

= rows * Col * bpp → bits per pixel.

Ex: Rows = 3000
Col. → 1687
shades → 256. = $2^8$

Size = 3000 * 1687 * 8
= 40488000 bits.

into byte
$= \frac{40488000}{8}$
= 5061000 byte.

into kilo byte
$= \frac{5061000}{1024} = 4942$ kb

into Mega byte = $\frac{4942}{1024} = 4$ Mb.

Ex: Rows → 1024

Col → 1024

256 Shades. $= 2^8$

size of image $= 1024 * 1024 * 8$

$= 8388608$ bits.

in byte $= \dfrac{8388608}{8} = 1048576$ bytes.

kilo byte $= \dfrac{1048576}{1024} = 1024$ kb

Mega byte $= \dfrac{1024}{1024} = 1$ mb.

## (*) Color Code Conversion

- Binary Color format
  - Black
  - White.
- gray color ~~Mod~~ format
- RGB Color format.
- CMYK Model. Color
  - black.
  - Cyan
  - Magenta
  - Yellow

Binary Color Model → Black. RGB (0, 0, 0)

White RGB (255, 255, 255)

RGB Color model → Red. RGB (255, 0, 0).

Green RGB (0, 255, 0)

Blue ~~RBG~~ RGB. (0, 0, 255)

Gray Color model → Gray RGB (128, 128, 128)

CMYK Color Model. → Cyan - RGB (0, 255, 255)

Magenta - RGB (255, 0, 255)

Yellow - RGB (255, 255, 0)

black - RGB (0, 0, 0)

Conversion :→

16 | 127
8

① RGB to Hex code

Ex: (255, 255, 255)

16 | 255 | 15
15

→ #FFFFFF

Black → (0, 0, 0) → #00 00 00.

gray → (127, 127, 127) → # ~~7F7F7F~~ 7F7F7F
(128, 128, 128) → # 808080.

Red → (255, 0, 0) → #FF0000

Blue → (0, 0, 255) → # 0000FF

Cyan →

ex – (190, 121, 163) → # BE79A3.

② Hex code to RGB :—

#FFFFFF

FF

1111 1111

255

code

# Gray scale to RGB Conversion

## ① Average method:-

take Average of all 3 colors

$$(R+G+B)/3$$

② **Advantage:**

- easy and simplest

**disadvantage:**

- image turned to be a black image.
  not gray image.

because → every color have different wavelength and different contribution to the formation of an image.

## ② Weighted Method or Luminosity method:-

red → more wavelength
green → Less

→ but give soothing effect to eyes.

red value ↓ green ↑

Blue center between.

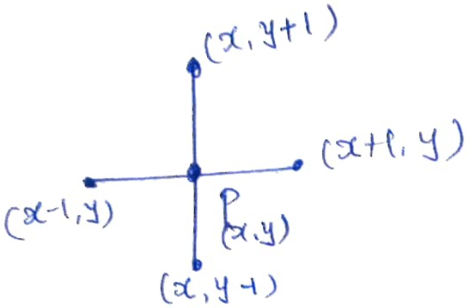
$$X = (0.3 * R) + (0.59 * G) + (0.11 * B)$$

30% Red, 59% Green, 11% Blue.

## ★. Basic Relationship Between Pixels.

### ① Neighbors of a pixel:-

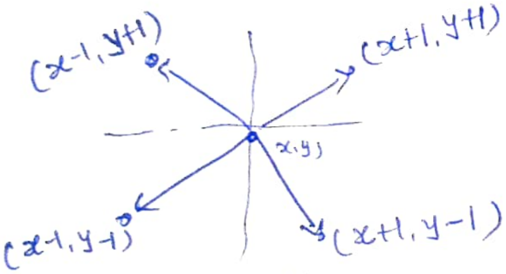
- P - pixel at coordinates $(x, y)$ has four horizontal and vertical Neighbors




$N_4(P)$

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

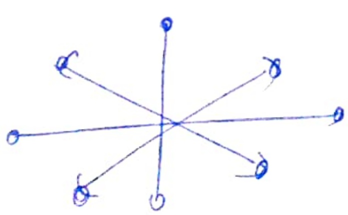
- Diagonal Neighbors.




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

$N_D(P)$

- 8 - Neighbors of P



$N_8(P) = N_4(P) + N_D(P)$

$N_8(P)$

## ② Adjancency :- Two pixels that are neighbours and have the same gray level are adjacent

V be the set of intensity values used to defined adjancency.

0 to 255 values.

→ 4-adjancency :- $4 : N_4(P)$

Two pixel p and q with values V are 4-Adjacent if q is in the set $N_4(P)$

Binary image

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

$V = \{1\}$

Gray-Scale image.

$$\begin{matrix} 54 & 10 & 100 & 8 \\ 81 & 150 & 2 & 34 \\ 201 & 200 & 3 & 45 \\ 7 & 70 & 147 & 56 \end{matrix}$$

$V = \{1, 2, 3 \dots 10\}$

→ 8 Adjancency :- $N_D(P)$

Two pixel p and q with values V are 8-Adjacent if q is in the set $N_8(P)$

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

$V = \{1\}$

Not connected.

$$\begin{matrix} 54 & 10 & 100 & 8 \\ 81 & 150 & 2 & 34 \\ 201 & 200 & 3 & 45 \\ 7 & 70 & 147 & 56 \end{matrix}$$

$V = \{1, 2, 3 \dots 10\}$

Not adjacency
Not connected.

→ m-adjancency :- (mixed)

Two pixel p and q with values V are m-adjacent if

(i) q is in set of $N_4(P)$ OR

(ii) q is in the set of $N_D(P)$ and set $N_4(P) \cap N_4(q)$ has no pixels whose values are from V

(means → when one element can connected by 4-adacency. → Priority to 4-adacency path 8-adacency)

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

①

$V = \{1\}$

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

②

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

③

So, unique path

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

↓

m-adjacency.

## Connected in S :-

p pixel → $(x_0, y_0)$

q pixel → $(x_n, y_n)$

Said to be connected in S if there exists a path

$(x_0, y_0)$ $(x_1, y_1)$ ... $(x_n, y_n)$

every set of pixel are called as connected components of S.

## Distance Measure :-

p → (x, y)

q → (s, t)

z → (u, v)

distance → a) $D(p, q) \geq 0$ [if $(p \neq q)$]

$D(p, q) = 0$ if $p = q$.

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

c) $D(p, z) \leq D(p, q) + D(q, z)$

The following are the different Distance measures :-

a) Euclidean distance.

$$D_e(P,Q) = \left[ (x-s)^2 + (y-t)^2 \right]^{1/2}$$

b) City Block distance

$$D_4(P,Q) = |x-s| + |y-t|$$

$$\begin{array}{ccccc} & & 3 & & \\ & 3 & 2 & 3 & \\ 3 & 2 & 1 & 2 & \\ 2 & 1 & 0 & 1 & 2 \\ & 2 & 1 & 2 & \end{array}$$

(4-adjacency)

c) Chess Board Distance:-

$$D_8(P,Q) = \max(|x-s|, |y-t|)$$

$$\begin{array}{ccccc} 2 & 2 & 2 & 2 & 2 \\ 2 & 1 & 1 & 1 & 2 \\ 2 & 1 & 0 & 1 & 2 \\ 2 & 1 & 1 & 1 & 2 \\ 2 & 2 & 2 & 2 & 2 \end{array}$$

(8-adjacency)

d) $D_m$ distance:-

- It is defined as the shortest m-path between the points.
- This distance between 2 pixels depends on the values of the pixels along the path as well as the value of their neighbours

P (x, y) ...... q (s, t)

Values depends on (x, y), (s, t) and neighbours of the whole path.

Imp: $D_4$ and $D_8$ Distance between p and q are independent of any path that might exist between the points because these distance involved only the co-ordinates of the points.

Q-1 An image segment is shown below let V be the set of gray level values used to define connectivity in the image compute $D_4$, $D_8$ and $D_m$ distance between pixels P and q for

V = {2, 3}

V = (2, 6)

| | | | | | |
|---|---|---|---|---|---|
| (0,0) (P) | 2 | 3 | 2 | 6 | 1 |
| | 6 | 2 | 3 | 6 | 2 |
| | 5 | 3 | 2 | 3 | 5 |
| | 2 | 4 | 3 | 5 | 2 |
| | 4 | 5 | 2 | 3 | 6 (q) (4,4) |

distance

Co-oordinates of $p(x,y) = (0,0)$

$q(s,t) = (4,4)$

$$D_4(P,Q) = |x-s| + |y-t|$$
$$= |0-4| + |0-4|$$
$$= |-4| + |-4|$$
$$= 4+4$$
$$= 8 \text{ units.}$$

$$D_8(P,Q) = \max(|x-s|, |y-t|)$$
$$= \max(|0-4|, |0-4|)$$
$$= \max(4, 4)$$
$$= 4 \text{ units.}$$

① $V = \{2, 3\}$

$D_m$.

$p = 2$, $q = 6$ → but in $V = \{2,3\}$ 6 is not included for making connections only 2,3 can include.

Also There is no path between p and q, as q (6) is not included in the set V.

② $V = \{2, 6\}$

Traverse 2 and 6 to reach.

There is no path between p and q.

| | | | | |
|---|---|---|---|---|
| (P) 2 | 3 | 2 | 6 | 1 |
| 6 | 2 | 3 | 6 | 2 |
| 5 | 3 | 2 | 3 | 5 |
| 2 | 4 | 3 | 5 | 2 |
| 4 | 5 | 2 | 3 | 6 (q) |

② Consider the following image segment. Compare $D_m$, $D_4$ and $D_8$ Distances between pixel p and q.

for $V = \{0,1\}$ where v is set of gray level class used to define connectivity. Repeat for $V = \{1,2\}$

| | | | |
|---|---|---|---|
| 3 | 1 | 2 | 1 (q) (3,3) |
| 0 | 2 | 0 | 2 |
| 1 | 2 | 1 | 1 |
| 1 (P) (0,0) | 0 | 1 | 2 |

co-ordinates of $p(x,y) = (0,0)$
$q(s,t) = (3,3)$

$D_4 = |x-s| + |y-t|$
$= |0-3| + |0-3|$
$= 3+3$
$= 6$ units

$D_8 = \max(|x-s| + (y-t))$
$= \max(|0-3|, |0-3|)$
$= \max(3,3)$
$= 3$ units.

① $V = \{0,1\}$

| | | | |
|---|---|---|---|
| 3 | 1 | 2 | 1 (q) |
| 0 | 2 | 0 | 2 |
| 1 | 2 | 1 | 1 |
| 1 (P) | 0 | 1 | 2 |

4-way

$D_m = 5$ units.

② $V = \{1,2\}$

| | | | |
|---|---|---|---|
| 3 | 1 | 2 | 1 (q) |
| 0 | 2 | 0 | 2 |
| 1 | 2 | 1 | 1 |
| 1 (P) | 0 | 1 | 2 |

units. 6 unit

both are not adjacent

$D_m = 6$ -(Shortest distance.)

(3). Compute the distance between two pixels using the three distances;

$q = (1,1)$

$p = (2,2)$

Euclidian Distance $= \left[(1-2)^2 + (1-2)^2\right]^{1/2}$

$= \text{sqrt}(2)$

$D_4$ (City Block distance) $= |1-2| + |1-2| = 2$

$D_8$ (chess board distance) $= \max(|1-2|, |1-2|) = 1.$

(4). Use city block distance to prove 4-neighbors?

| | 1 | 2 | 3 |
|---|---|---|---|
| 1 | | d | |
| 2 | a | p | c |
| 3 | | b | |

pixel A $= |2-2| + |1-2| = 1$

pixel B $= |3-2| + |2-2| = 1$

pixel C $= |2-2| + |2-3| = 1$

pixel D $= |1-2| + |2-2| = 1.$