Module 6
Digital Image Processing

Introduction

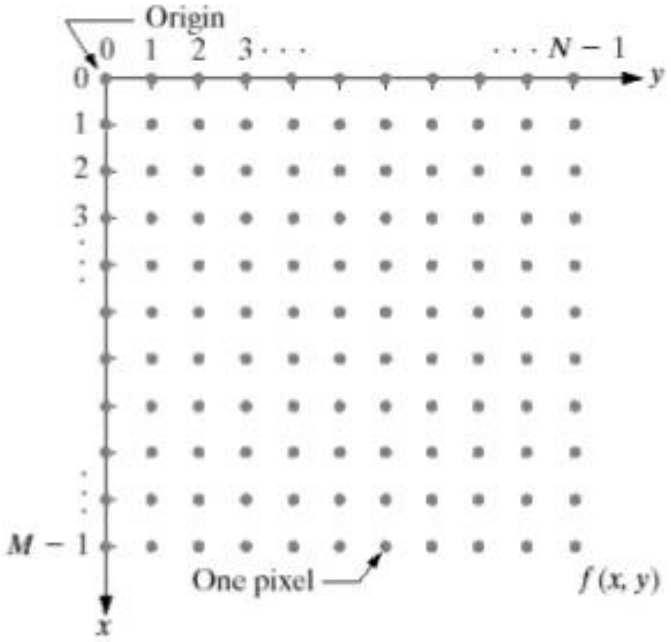
- Digital image processing deals with manipulation of digital images through a digital computer.
- Subfield of signals and systems but focus particularly on images.
- The input is a digital image, the system process that image, and gives an image or its characteristics as output.
- Eg: Adobe Photoshop.

Introduction

- Purpose of Image processing:
  - Visualization
  - Image sharpening and restoration
  - Image retrieval
  - Image recognition
  - Measurement of pattern

Digital Image

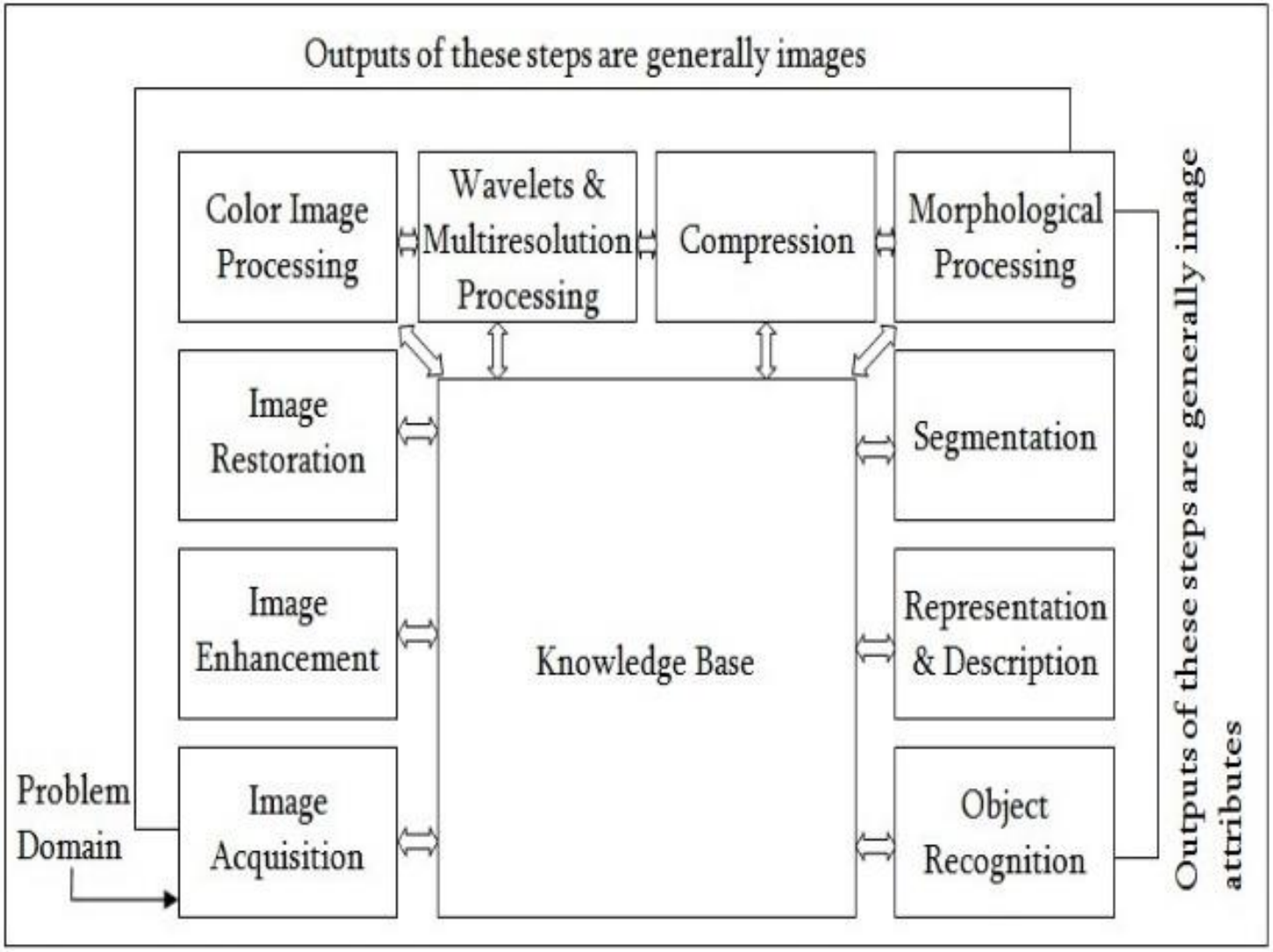
- A digital image is a representation of a two-dimensional image as a finite set of digital values
  - called picture elements or **pixels**.
- It is defined as a two dimensional function f(x, y) where x and y are spatial coordinates.
- The value of f(x, y) at any point gives the pixel value at that point of an image.



Major task of DIP

- Improvement of pictorial information for human interpretation.
- Processing of Image data for storage, transmission and representation .

Fundamental steps in image processing



Fundamental steps in image processing

1. Image acquisition

   Capture an image with the help of a sensor (Camera).

   Generally the image acquisition stage involves preprocessing such as scaling

2. Image enhancement

   Highlights the specific characteristics of an image.

   E.g.:- Changing brightness, contrast etc.

3. Image restoration-

Deals with improving the appearance of an image.

Image restoration is objective in the sense that the restoration techniques tend to be based on mathematical or probabilistic model of image degradation.

4. Color image processing-

Use the colour of the image to extract features of interest in an image

2 types are pseudo color image processing and full color image processing.

5. Wavelets and multi-resolution processing-

Wavelets are the foundation for representing images in various degree of resolution.

Images are subdivided into smaller regions for data compression

6. Compression

Deals with techniques for reducing the storage required to save an image or the bandwidth required to transmit it.

7. Morphological processing-

Deals with extracting image components that are useful in representation and description of shape for detection of boundaries.

8. Segmentation

Partition an image into its constituent parts or objects.

Used to separate objects from the image background

9. Representation and description

Always follow the output of segmentation stage, which usually is raw pixel data. It convert the image to a form suitable for computer processing.

- Boundary representation is appropriate when focus is on external shape characteristics.
- Regional representation is appropriate when focus is on internal properties.

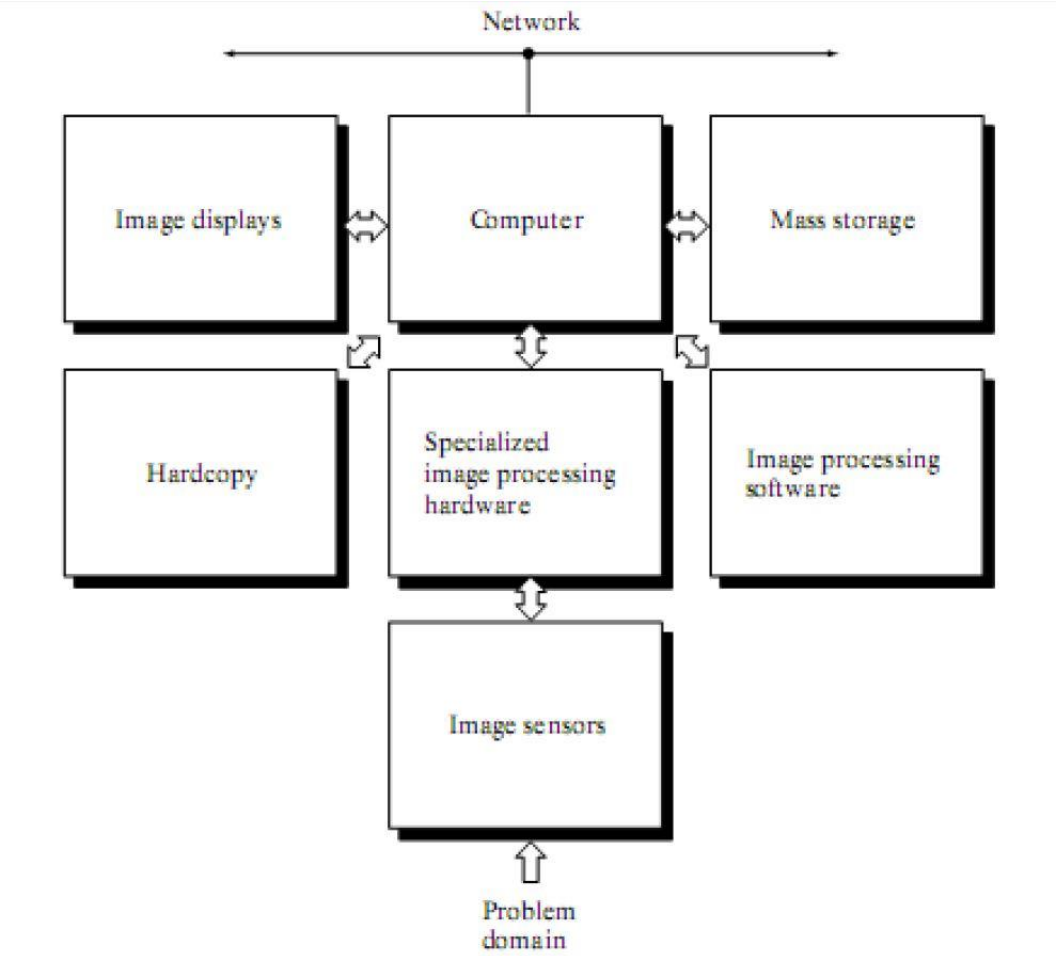
Description, also called feature selection deals with extracting attribute that result in some quantitative information of interest or are basic for differentiating one class from another.

10. Recognition

Process that assigns label to an object based on its descriptors.

Such as "flower"

Components of Image Processing System



Components of Image Processing System

- Image sensors are used for image acquisition.
  - A physical device that produce an electrical output proportional to light intensity.
  - Then a digitizer convert this into a digital form
- Specialized image processing hardware
  - consist of a digitizer which converts output from sensor into digital form and a hardware that performs primitive operations (such as ALU).
- The computer can range from a PC to a supercomputer.
- Software for image processing
  - consist of specialized modules that can perform various tasks. Eg: Photoshop, MATLAB etc
- Mass storage is needed for image processing.
  - An image of size 1024*1024 pixels requires one megabyte of storage space.

Components of Image Processing System

- Image displays can be color TV monitors.
- Hardcopy devices for recording images include laser-printers, film cameras etc
- Networking is needed to connect various components.

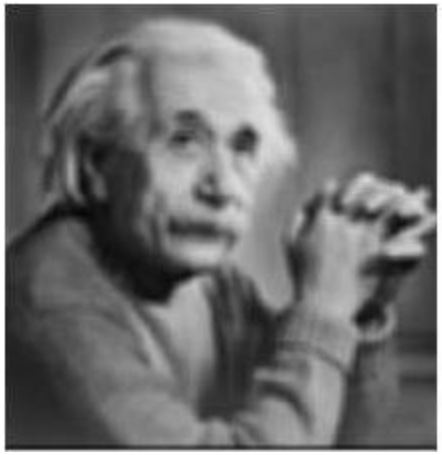
Applications

- Image sharpening and restoration
- Medical field
- Remote sensing
- Law Enforcement
- Human Computer Interface

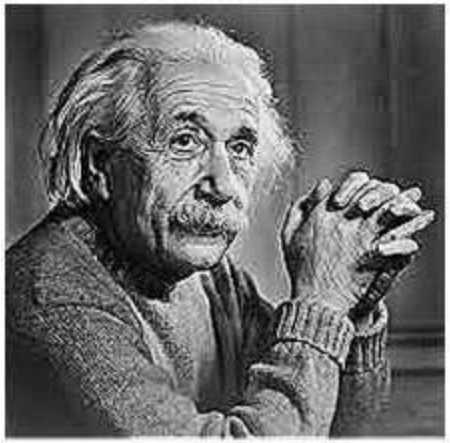
Image sharpening and restoration

- Image sharpening and restoration refers here to process images that have been captured from the modern camera to make them a better image or to manipulate those images in way to achieve desired result.

Blurred image



Sharp image



Edges

Medical Field

- Imaging is a vital component in medical field
- Like MRI, CT-scan, X-Ray etc

Remote sensing

- Images captured by satellites are to be analyzed
- Used in fields of Weather, Forestry, Agriculture, Biodiversity

Law Enforcement

- Number plate recognition for speed cameras
- Finger print recognition
- Enhancement of CCTV footages

Human Computer Interface

- Face recognition
- Gesture recognition

Basic Relationships between Pixels

Basic Relationships between Pixels

- Neighbourhood
- Adjacency
- Connectivity
- Paths
- Regions and boundaries

Neighbours of a Pixel

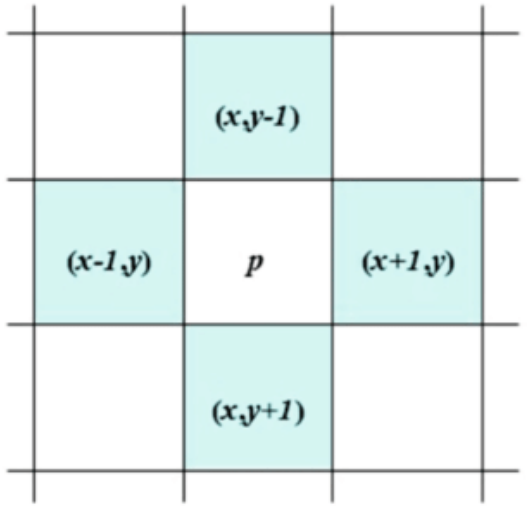
- The neighbourhood of a pixel is the collection of pixels which surround it.
- Required for operations such as morphology, edge detection, median filter, etc.

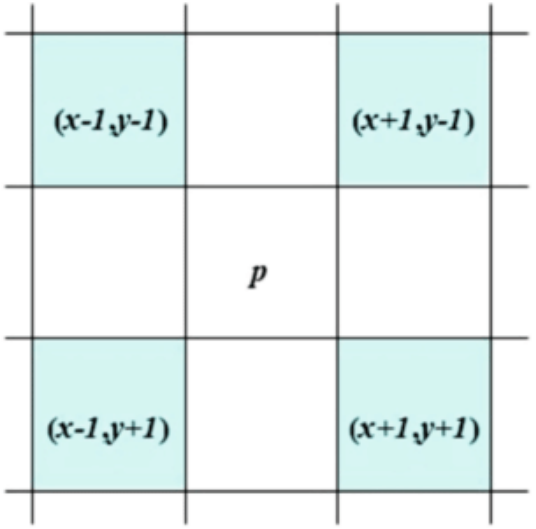
x−1,y−1	x−1,y	x−1,y+1
x,y−1	x,y	x,y+1
x+1,y−1	x+1,y	x+1,y+1

Neighbours of a Pixel

1. 4-neighbours: $N_4(p)$
   - Considers only vertical and horizontal neighbours
   - Each of them is at a unit distance from P.

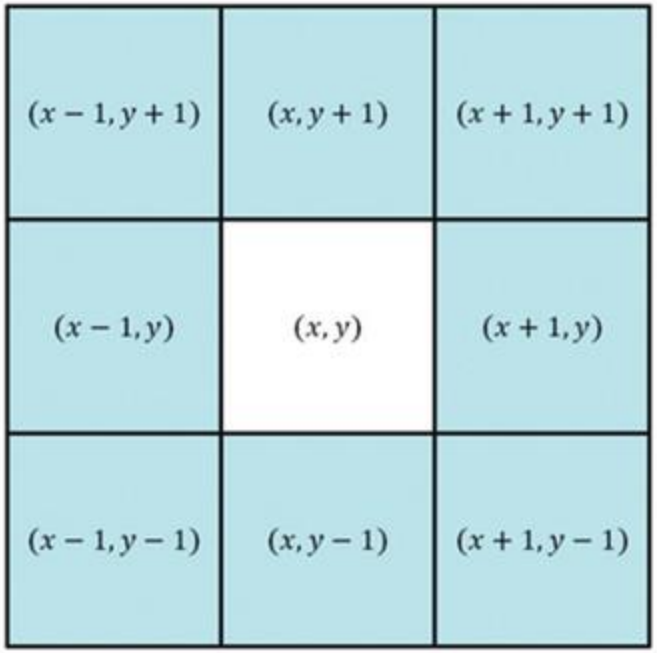
2. Diagonal neighbours: $N_D(p)$
   - Each of them are at Euclidean distance of 1.414 from P





Neighbours of a Pixel

3. 8-neighbours of p : $N_8(p)$
   - $N_4(p)$and $N_D(p)$ together are called 8-neighbors of p
   - $N_8 = N_4 \cup N_D$



Adjacency

- Two pixels are said to be adjacent if:
  i. Both of them are neighbours
  ii. Have similar properties (defined range of Gray scale values from V)
- Three types of adjacency:
  i. 4-adjacency
  ii. 8-adjacency
  iii. m-adjacency

Adjacency

- 4-adjacency: Two pixels p and q are 4-adjacent if
  i. Their values lies from V
  ii. q is in the set $N_4(p)$.

For the following image assume V=(1,2)

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

Adjacency

- 8-adjacency: Two pixels p and q are 8-adjacent if
  i. Their values lies from V
  ii. q is in the set $N_8(p)$.

For the following image assume V=(1,2)

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

Adjacency

- m-adjacency (mixed): Two pixels p and q are m-adjacent if
  i. Their values lies from V
  ii. q is in the set $N_4(p)$.

  OR

  q is in $N_D(p)$ and the set $N_4(p) \cap N_4(q)$ has no pixel whose values are from V (No intersection)

For the following image assume V=(1,2)

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

Path

- A digital path (or curve) from pixel p with coordinate (x,y) to pixel q with coordinate (s,t) is a sequence of distinct pixels with coordinates (x_0 , y_0), (x_1 , y_1), ..., (x_n , y_n), where

  $(x_0, y_0) = (x, y)$

  $(x_n, y_n) = (s, t)$

- (x_i , y_i) is adjacent pixel (x_{i-1}, y_{i-1}) for $1 \leq i \leq n$, n- length of the path.

- If $(x_0 , y_0) = (x_n , y_n)$:the path is closed path.

Path

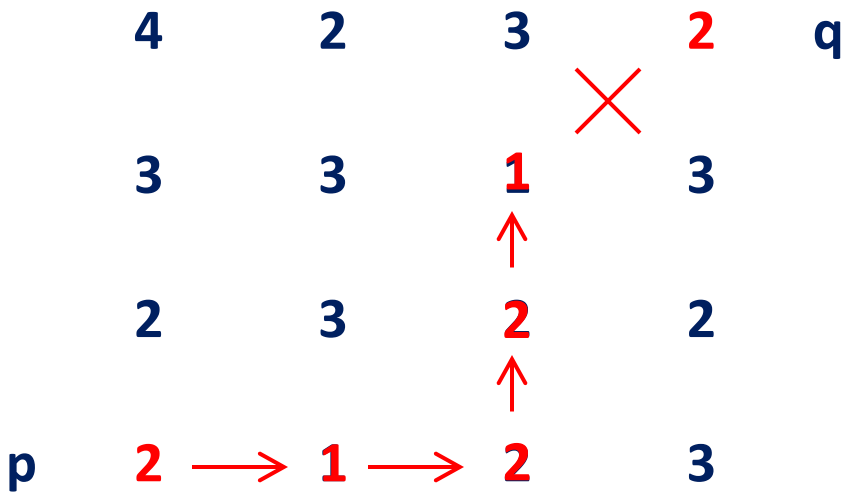
- Example:- Consider the image segment shown below. Compute length of the shortest-4, shortest-8 and shortest-m paths between pixels p & q where V = {1, 2}

	4	2	3	2 q
	3	3	1	3
	2	3	2	2
p	2	1	2	3

Path

- Example:- shortest-4 path

V = {1, 2}

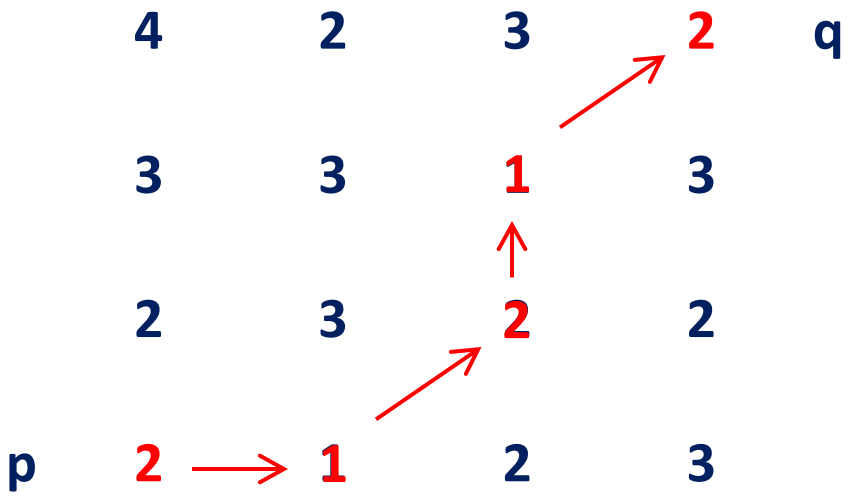


Path does not exist!

Path

- Example:- shortest-8 path

V = {1, 2}

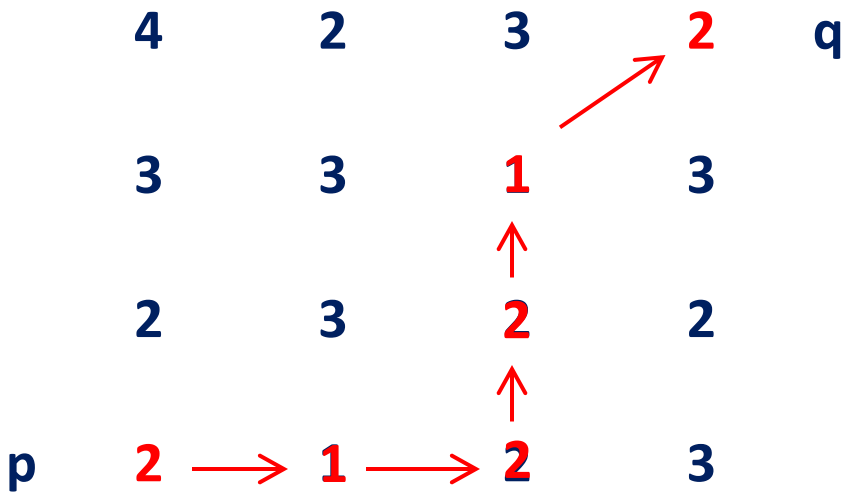


Shortest-8 Path = 4

Path

- Example:- shortest-m path

V = {1, 2}



Shortest-m Path = 5

Connectivity

- Let S represent a subset of pixels in an image, Two pixels p and q are said to be connected in S if there exists a path between them consisting entirely of pixels in S.
- For any pixel p in S, the set of pixels that are connected to it in S is called a connected component of S.

Region

- Let R be a subset of pixels in an image, we call R a region of the image if R is a connected set.
- We consider 4- and 8- adjacency when referring to regions.

0	**0**	**0**	**0**	**0**	**0**
0	**1**	**1**	**1**	**1**	**0**
0	**1**	**1**	**1**	**1**	**0**
0	**1**	**1**	**1**	**1**	**0**
0	**0**	**1**	**1**	**1**	**0**
0	**0**	**0**	**0**	**0**	**0**

Region

- Two regions Ri and Rj are said to be adjacent if their union form a connected set.
- Region that are not adjacent are said to be disjoint.

- Example: the two regions (of 1s) given, are adjacent only if 8-adjacany is used.

1	1	1	
1	0	1	Ri
0	1	0	
0	0	1	
1	1	1	Rj
1	1	1	

Boundary

- The boundary (also called border or contour) of a region R is the set of pixels in the region that have one or more neighbours that are not in R.

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