20MCA24C - DIGITAL IMAGE PROCESSING

UNIT I

INTRODUCTION

FACULTY

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Year	Subject Title	Semester	Sub. Code
2020 - 2021 Onwards	DIGITAL IMAGE PROCESSING	II	20MCA24C

Objective: To study the various concepts, methods and algorithms of digital image processing such as image transformation, image enhancement, image restoration, image compression and Segmentation techniques

UNIT – Introduction: What is Digital image processing – the origin of DIP – Examples of fields that use DIP – Fundamentals steps in DIP – Components of an image processing system. Digital Image Fundamentals: Elements of Visual perception – Light and the electromagnetic spectrum – Image sensing and acquisition – Image sampling and Quantization – Some Basic relationship between Pixels.

UNIT – II Image Enhancement in the Spatial Domain: Background – some basic Gray level Transformations – Histogram Processing – Enhancement using Arithmetic / Logic operations – Basics of spatial filtering – Smoothing spatial filters – Sharpening spatial filters.

UNIT – III *Color Image Processing: Color Fundamentals-Color Models-Pseudocolor Image Processing- Color transformations-Smoothing and Sharpening-Color Segmentation-Noise in Color Images*

UNIT – IV *Morphological Image processing: Preliminaries-Dilation and Erosion-Opening and Closing-The Hit-or-Miss Transformation-Some Basic Morphological Algorithms. Image Segmentation: Detection and Discontinuities – Edge Linking and Boundary detection – Thresholding – Region- Based segmentation – Segmentation by Morphological watersheds.*

UNIT – V *Image Processing with OpenCV-Python: Introduction to OpenCV-Python-OpenCV GUI-Basic operations on Images-Arithmetic operations on Images – Image Processing in OpenCV: Changing Color Spaces- Geometric Transformation of Images – Smoothing Images – Morphological Transformations – Image Gradients-Edge Detection – Contours – Histograms.*

TEXT BOOKS

1.Rafael C. Gonzalez, Richard E. Woods, "Digital Image Processing", Second Edition, PHI/Pearson
2.Education.Alexander M., Abid K., "OpenCV-Python Tutorials", 2017.

REFERENCE BOOKS

1 .B. Chanda, D. Dutta Majumder, "Digital Image Processing and Analysis", PHI, 2003.

2. Nick Efford, "Digital Image Processing a practical introducing using Java", Pearson Education, 2004.

Course Outcomes	Statements
CO1	Remember the fundamental concepts of Image Processing
CO2	Explain different Image enhancement techniques
CO3	Understand and review image transforms
CO4	Analyze the basic algorithms used for image processing &image compression with morphological image processing.
CO5	Understand Image processing applications in python

What is Image ?

- An image is a spatial representation of a two-dimensional or three-dimensional scene.
- An image is an array, or a matrix pixels (picture elements) arranged in columns and rows.

WHY.....digital image processing...???

- Interest in digital image processing methods stems from two principal application areas:

1. Improvement of pictorial information for human interpretation

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

What Is Digital Image Processing?

DIP Definition:

A Discipline in Which Both the Input and Output of a Process are Images.

What Is Digital Image ?

- An image may be defined as a two-dimensional function, **f(x, y)**, where **x** and **y** are spatial (plane) 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.

- **Digital Image:**

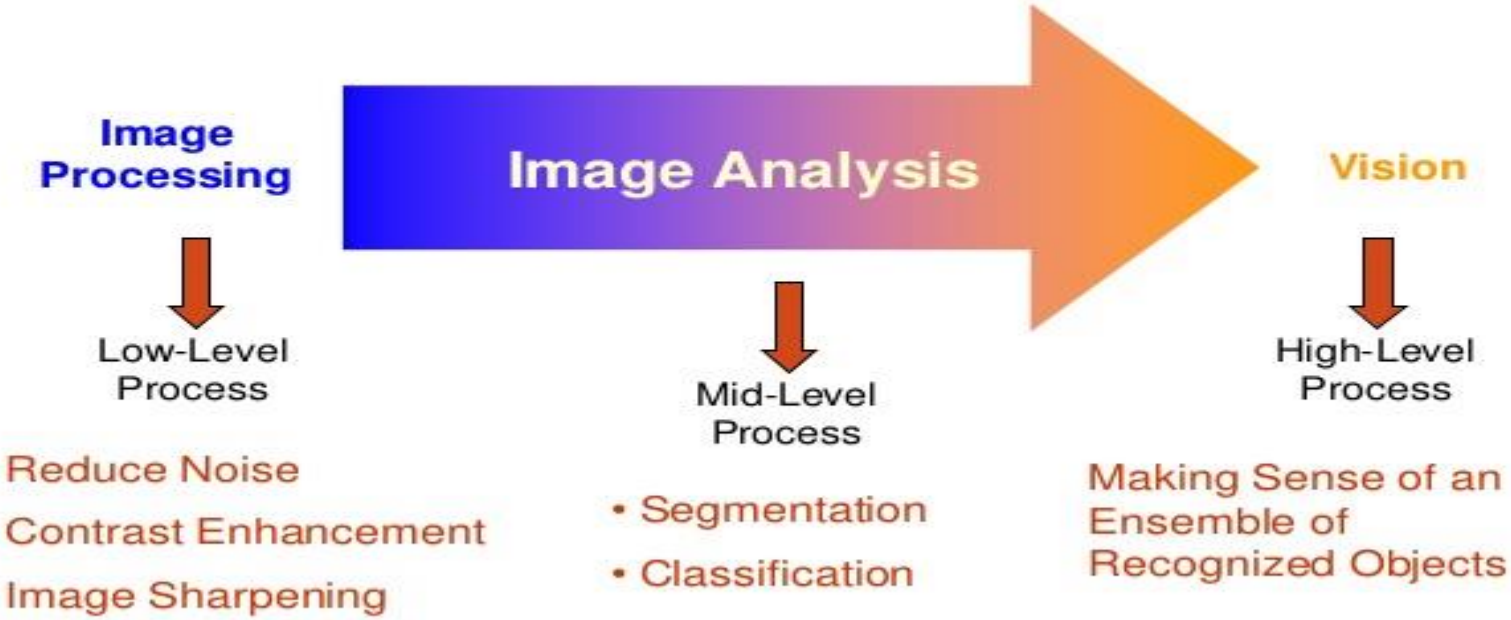
  When x, y and the intensity values of f are all finite, discrete quantities, we call the image a digital image.

- **Color Image:**

$$f(x, y) = \begin{bmatrix} r(x, y) \\ g(x, y) \\ b(x, y) \end{bmatrix}$$

The field of digital image processing refers to processing digital images by means of a digital computer.

What Is Digital Image Processing?



Origins of Digital Image Processing

- One of the first applications of digital images was in the newspaper industry, when pictures were first sent by submarine cable between London and New York.
- Introduction of the Bartlane cable picture transmission system in the early 1920s reduced the time required to transport a picture across the Atlantic from more than a week to less than three hours.

A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces.

FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. (McFarlane.)

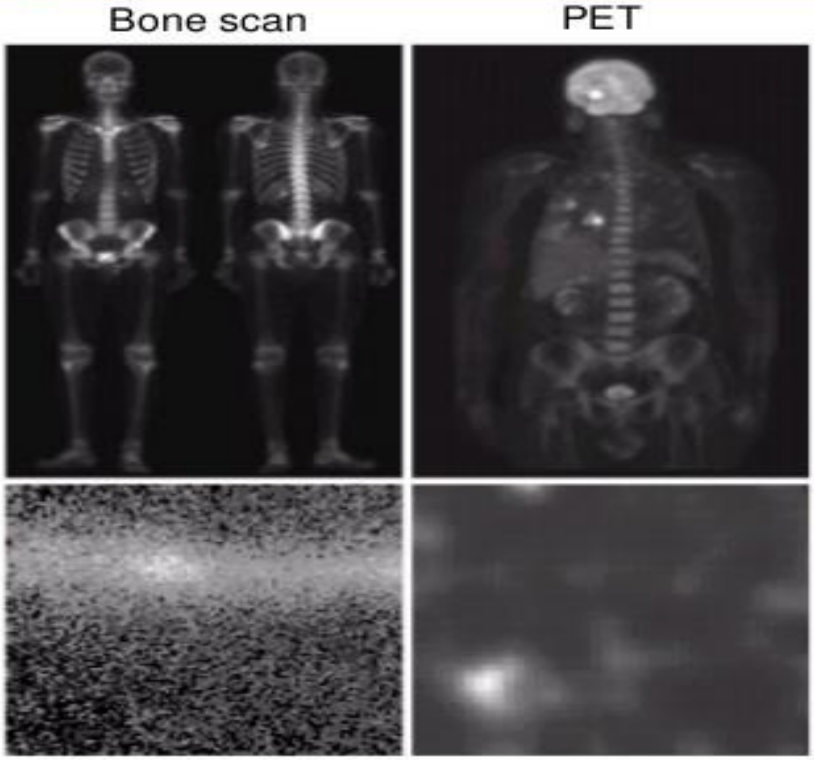
Fields that Use Digital Image Processing

- Today, there is almost no area of technical endeavor that is not impacted in some way by digital image processing.

- Gamma-Ray Imaging
- X-Ray Imaging
- Imaging in the Ultraviolet Band
- Imaging in the Visible and Infrared Bands
- Imaging in the Microwave Band
- Imaging in the Radio Band

Gamma-Ray Imaging

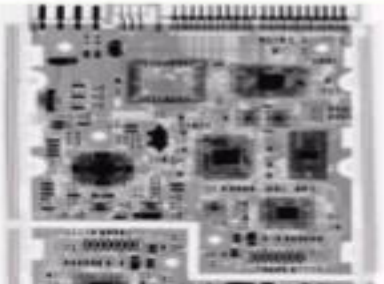
- Major uses of imaging based on gamma rays include nuclear medicine.
- In nuclear medicine, the approach is to inject a patient with a radioactive isotope that emits gamma rays as it decays.
- Images are produced from the emissions collected by gamma ray detectors.



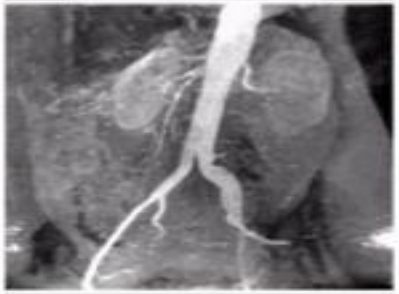
X-Ray Imaging

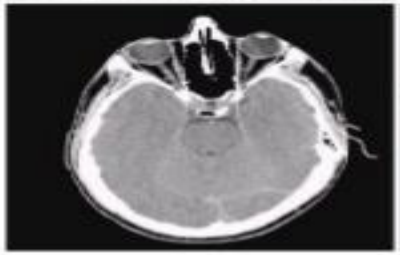
Chest X-Ray

PCB

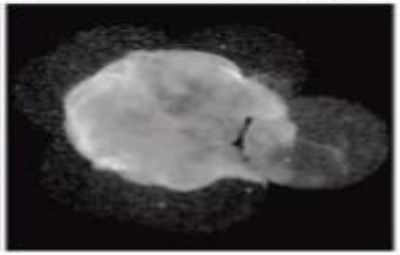


Angiogram





Head CT

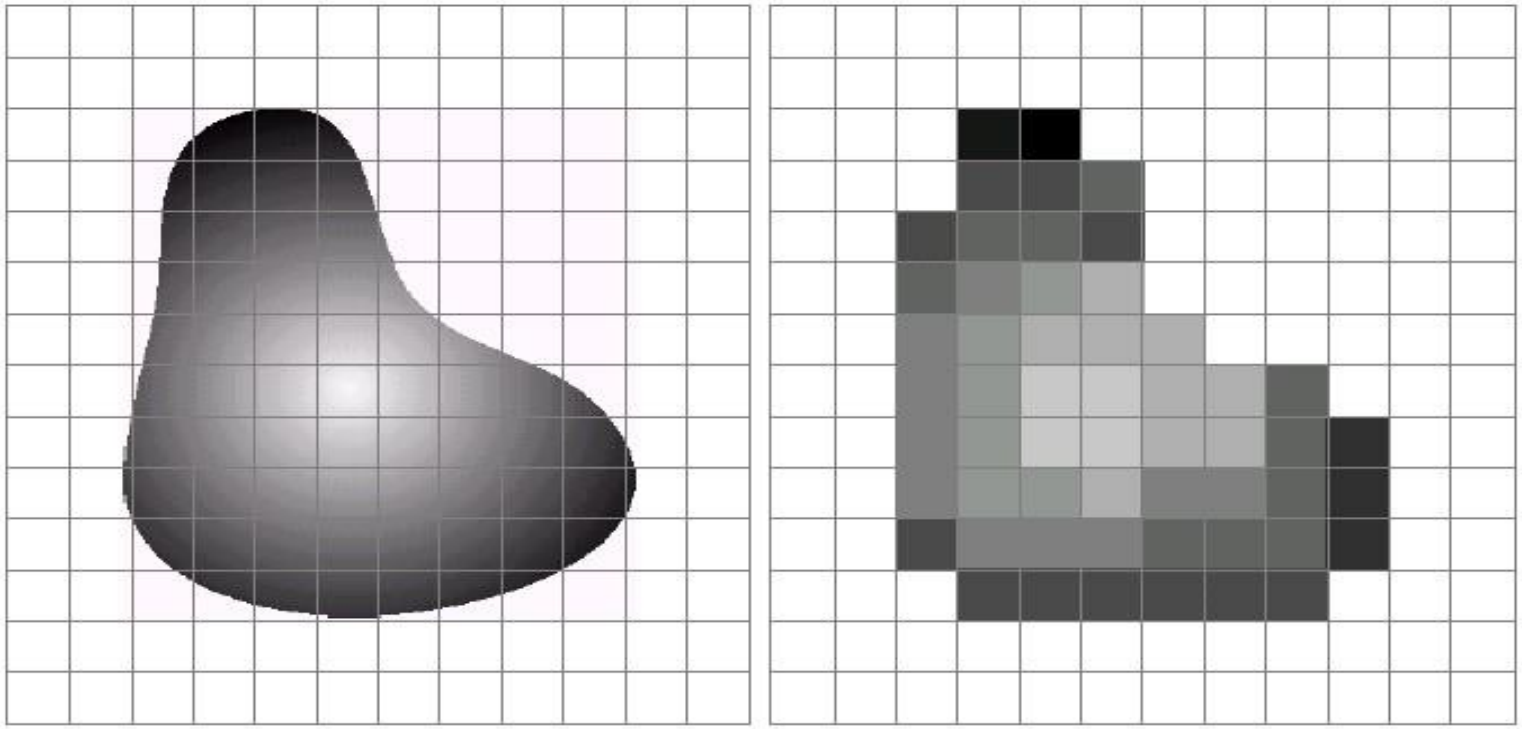


Cygnus loop

Digital Image

- Digital image composed of discrete pixels of digitally quantized brightness or intensities
- Numerical representation of image or picture is called digital image
- **Sampling** and **Quantization** process

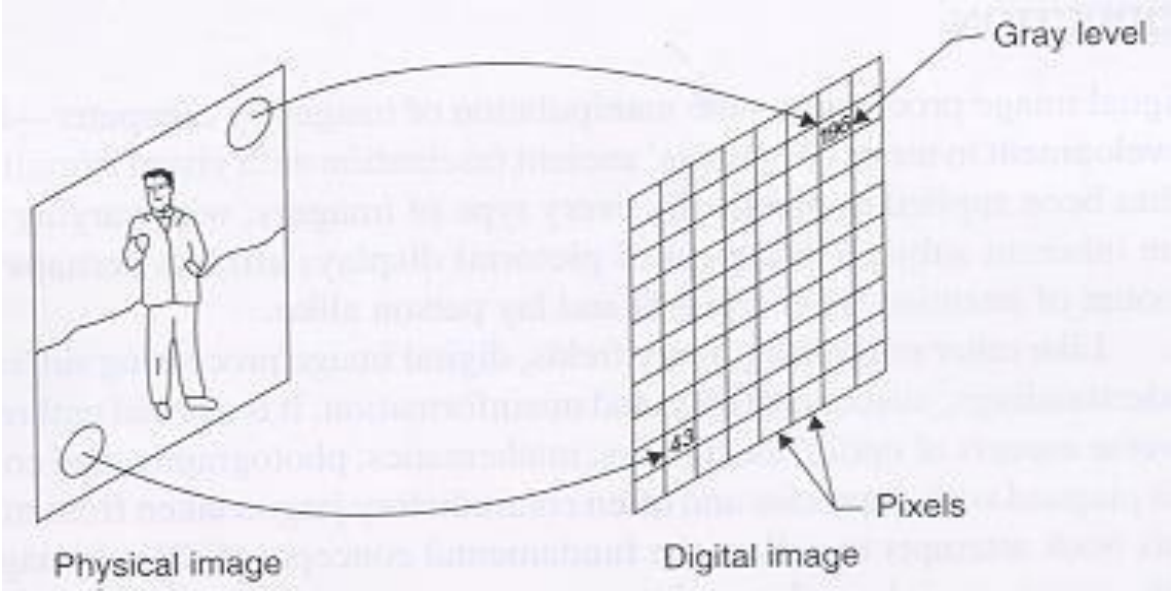
Sampling and Quantization



a b

FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

Sampling means digitizing co-ordinate



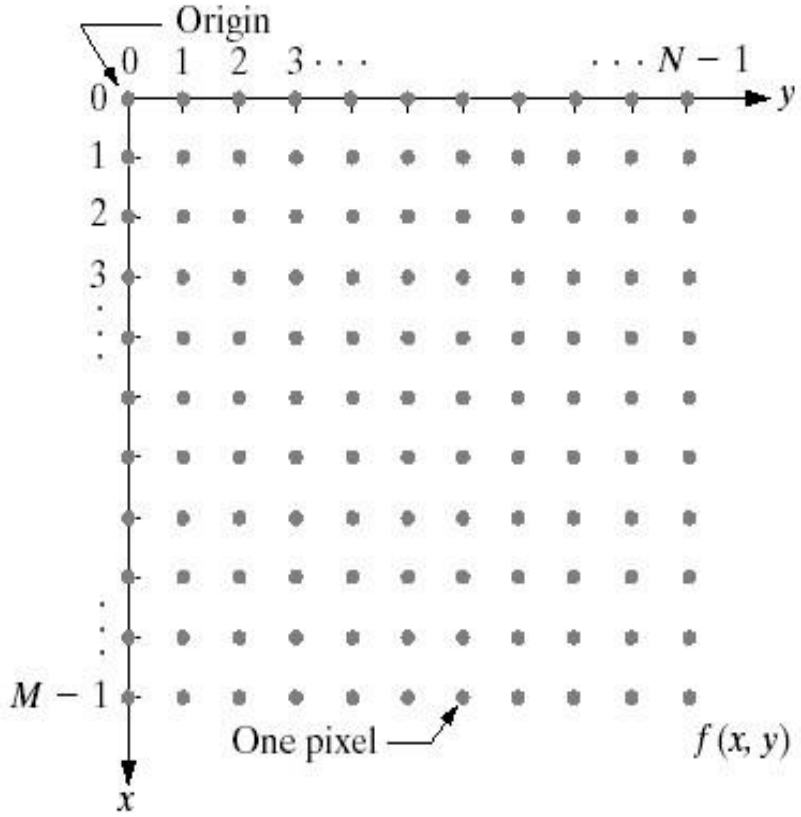
values

Quantization means digitizing amplitude values

2-bit binary image 4-bit gray image

Digital Image Representation

- An image is a function defined on a 2Dcoordinate f(x,y). The value of f(x,y) is the intensity.



3 such functions can be defined for a color image, each represents onecolor component

Digital image can be represented as a matrix.

Digital Image Representation

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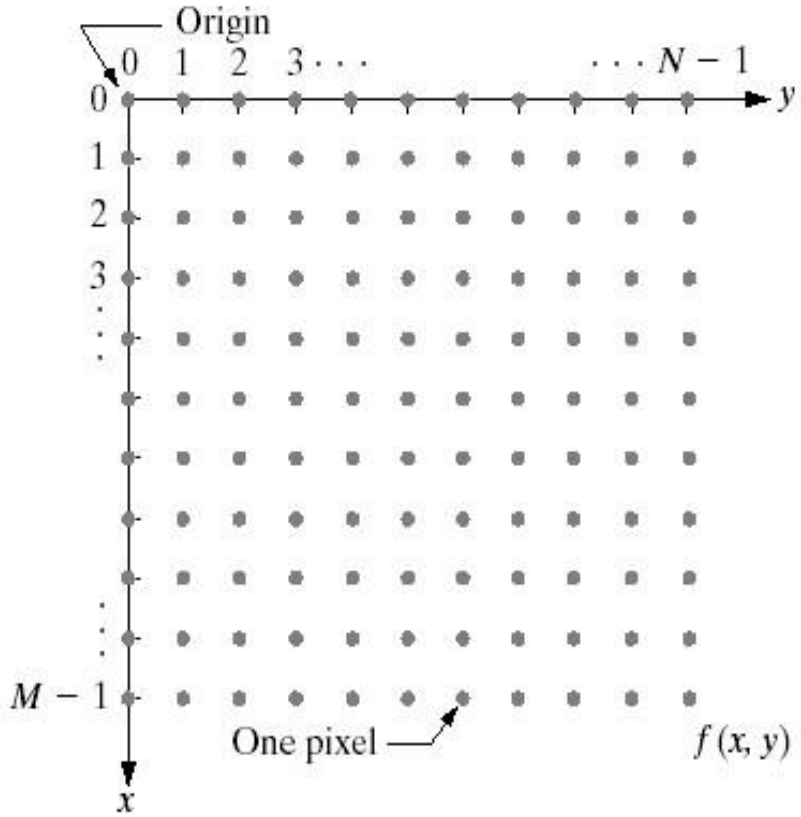


- 3 such functions can be defined for a color image, each represents onecolor component
- Digital image can be represented as a matrix.

Spatial and Gray Level Resolution

Spatial resolution

- Number of samples per unit length or area
- DPI: dots per inch specifies the size of an individual pixel
- If image size is kept constant, the size of pixel will affect spatial resolution

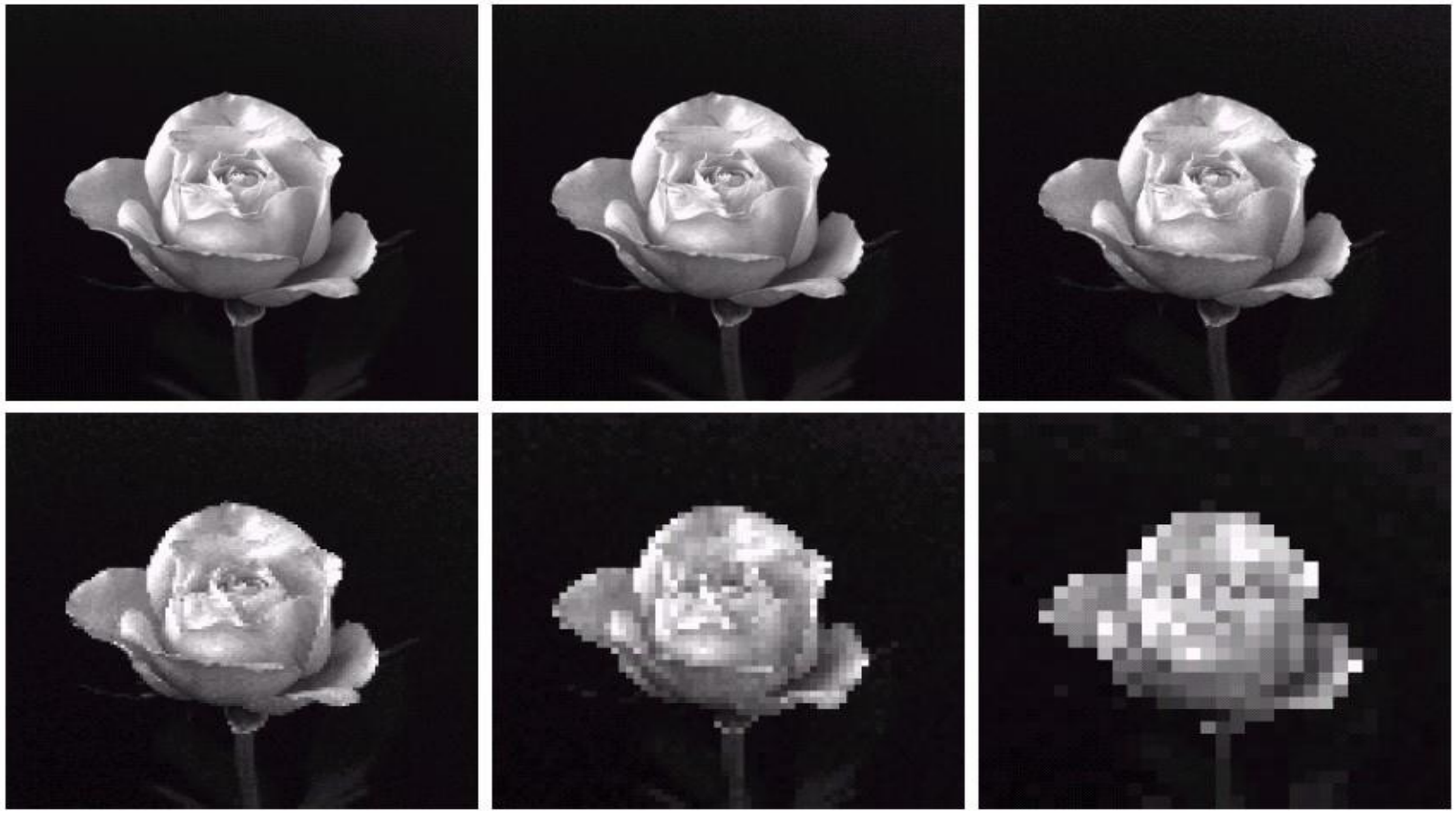
Gray level resolution

- Number of bits per pixel usually 8 bits
- Color image has 3 image planes to yield 8 x 3 = 24 bits/pixel
- Too few levels may cause false contour

Same Pixel Size and Different Image sizes

FIGURE 2.19 A 1024 × 1024, 8-bit image subsampled down to size 32 × 32 pixels. The number of allowable gray levels was kept at 256.

Different Pixel Sizes and Same Image size

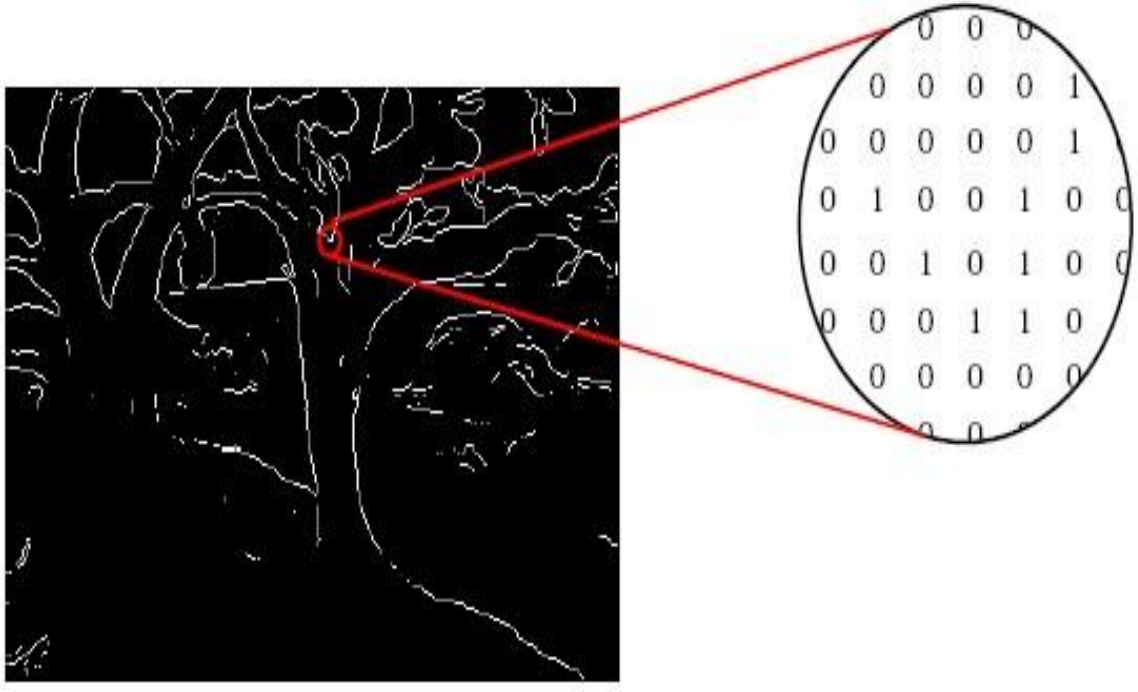


a b c
d e f

FIGURE 2.20 (a) 1024 × 1024, 8-bit image. (b) 512 × 512 image resampled into 1024 × 1024 pixels by row and column duplication. (c) through (f) 256 × 256, 128 × 128, 64 × 64, and 32 × 32 images resampled into 1024 × 1024 pixels.

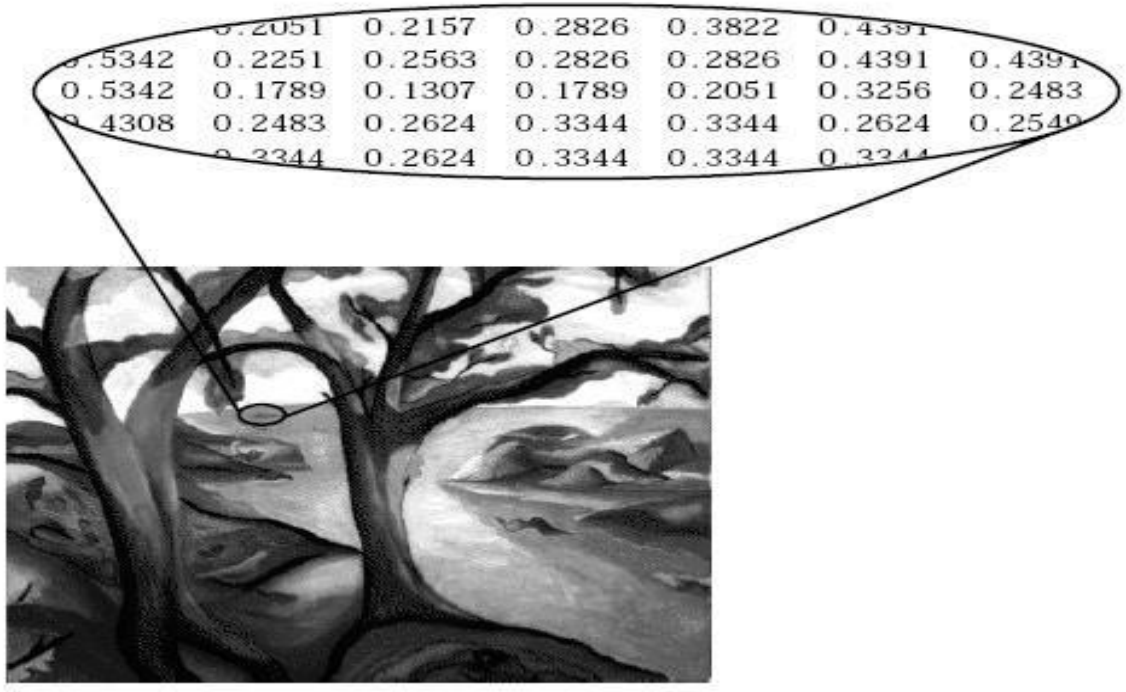
Digital Image Types

Binary image: Simplest type of images, which can take two values, typically black or white, or "0" or "1"



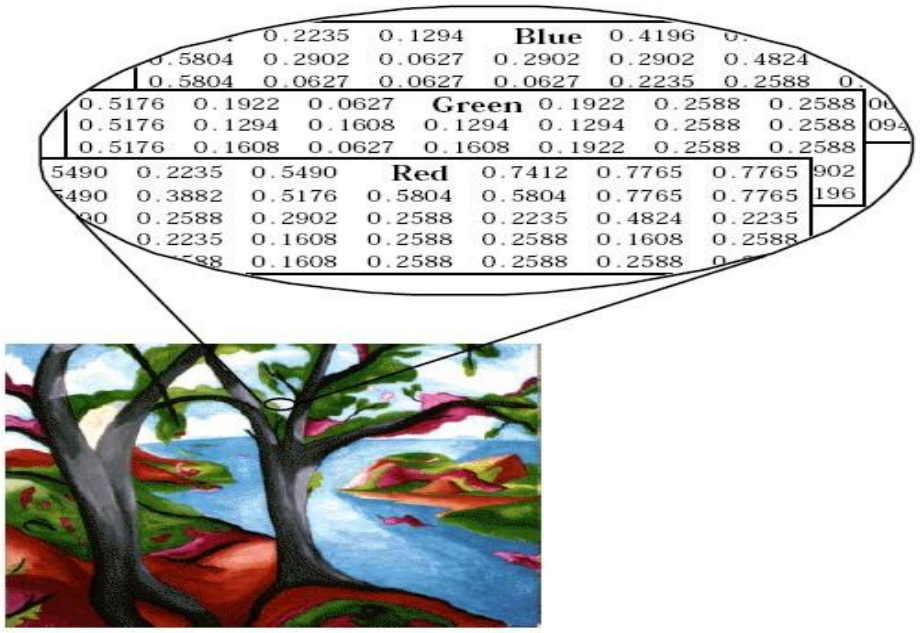
Digital Image Types

- Gray scale image: One-color or monochrome images that contains only brightness information and no color information



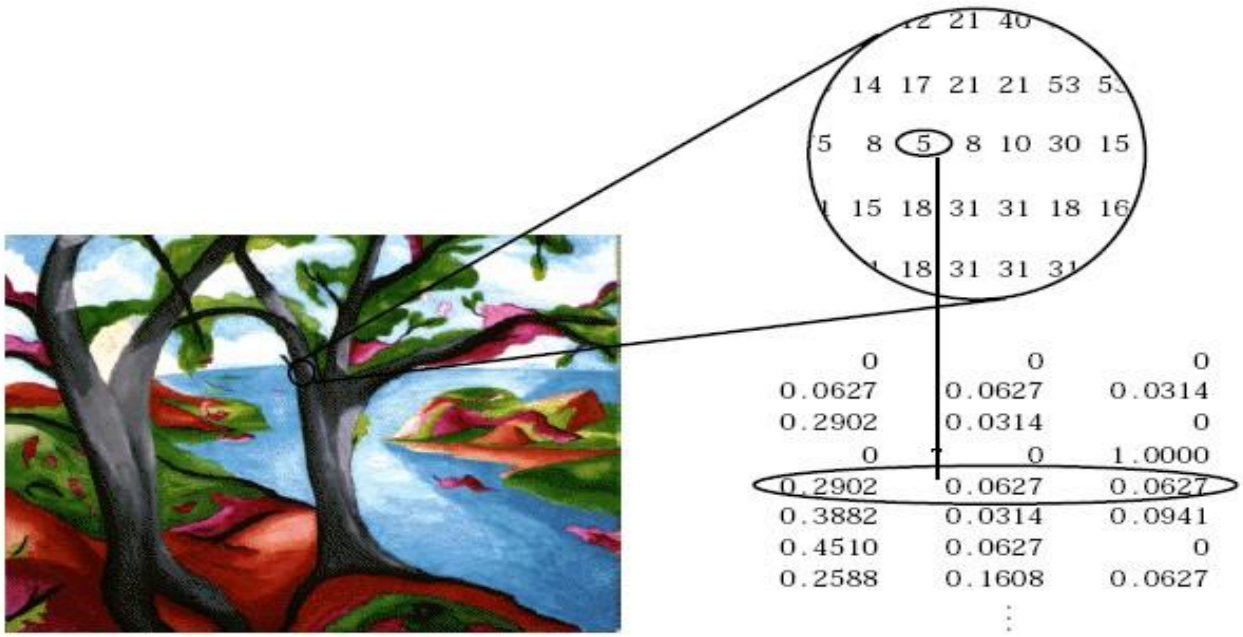
Digital Image Types

- Color image: 3 band monochrome images, where each band corresponds to a different color, typically red, blue and green or RGB



Digital Image Types

Indexedimage:Consists of an 2D Array and a colormap matrix. The pixel values in the array are direct indices into a colormap. The colormap matrix is an m-by-3 array of class double containing floatingpoint values in the range [0,1].



Electro Magnetic Spectrum

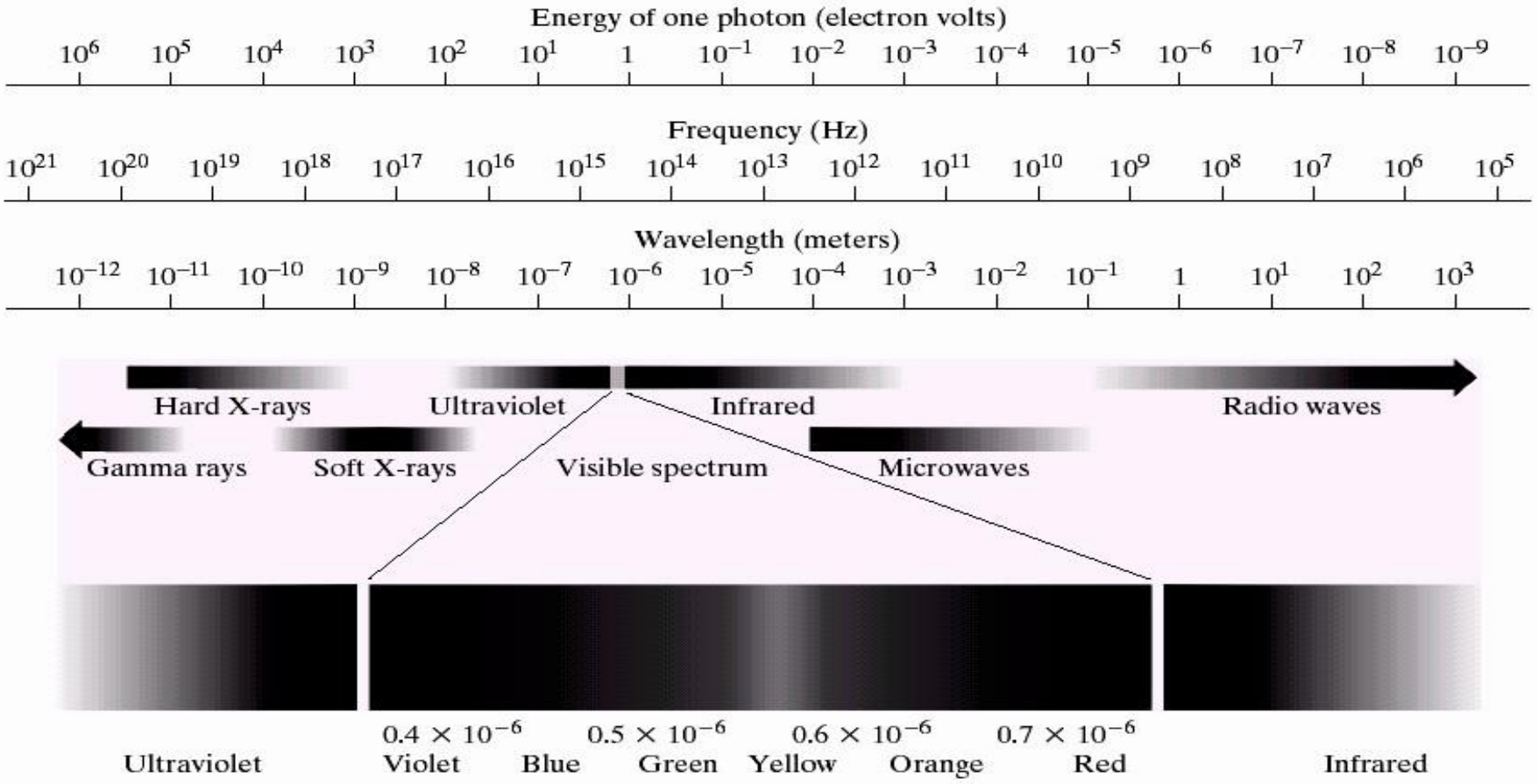
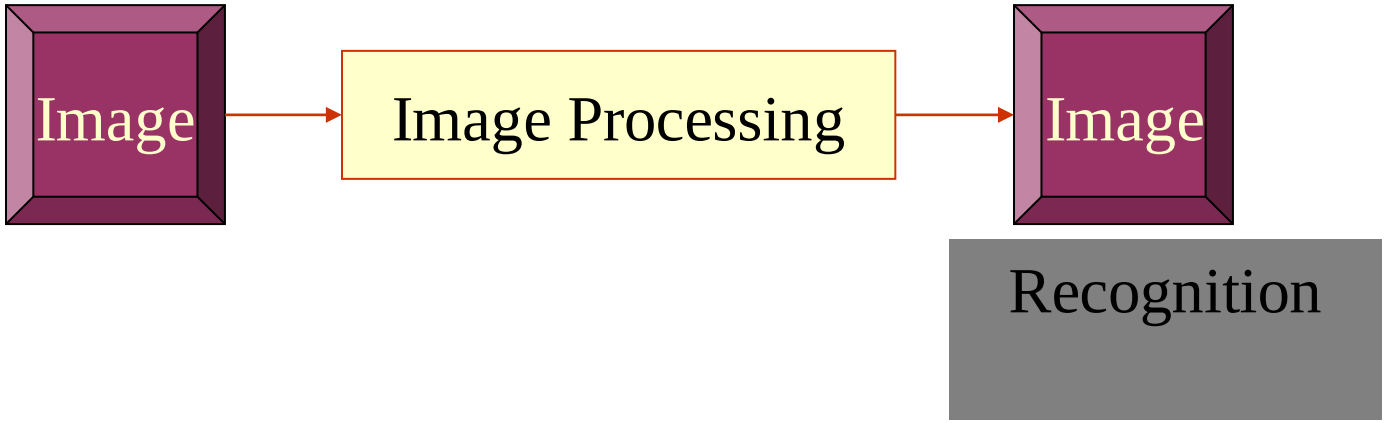


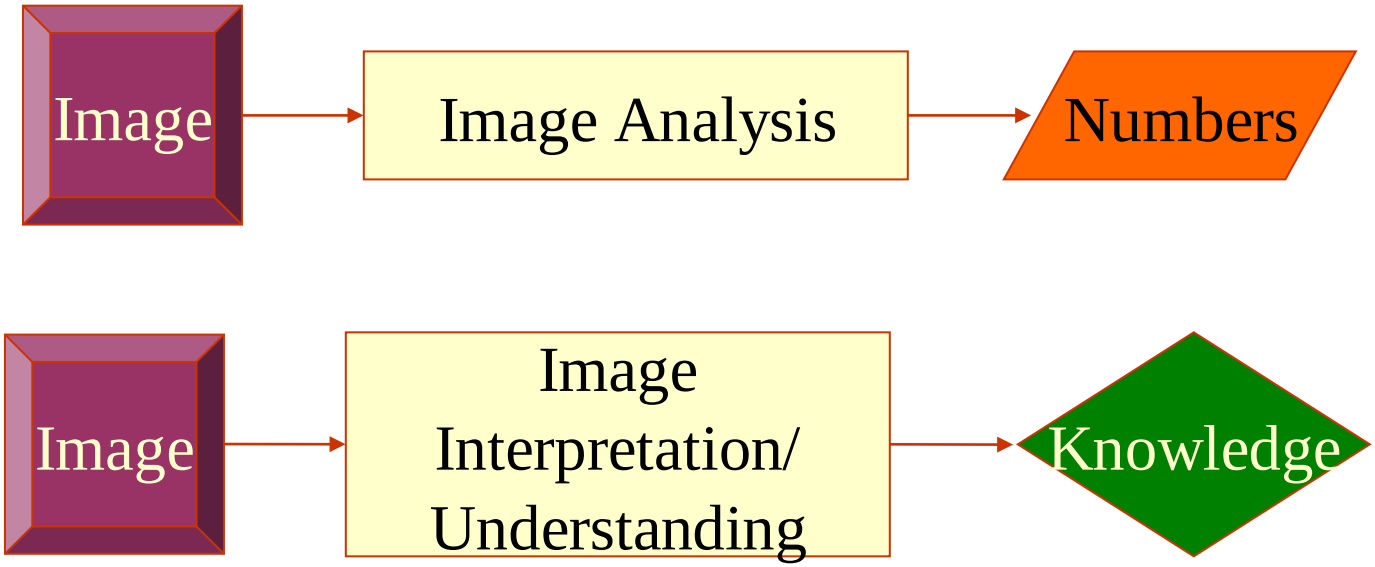
FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

Digital Image Processing

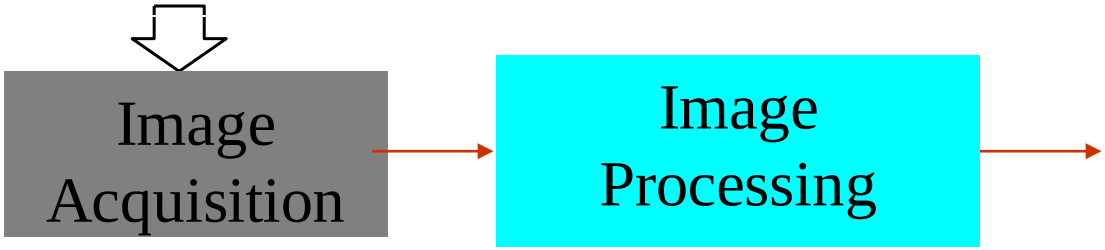
- Processing digital images by means of digital computer
- Computer-based manipulation and interpretation of digital images.



Computer Vision and Image Processing



Object



Why need DIP?

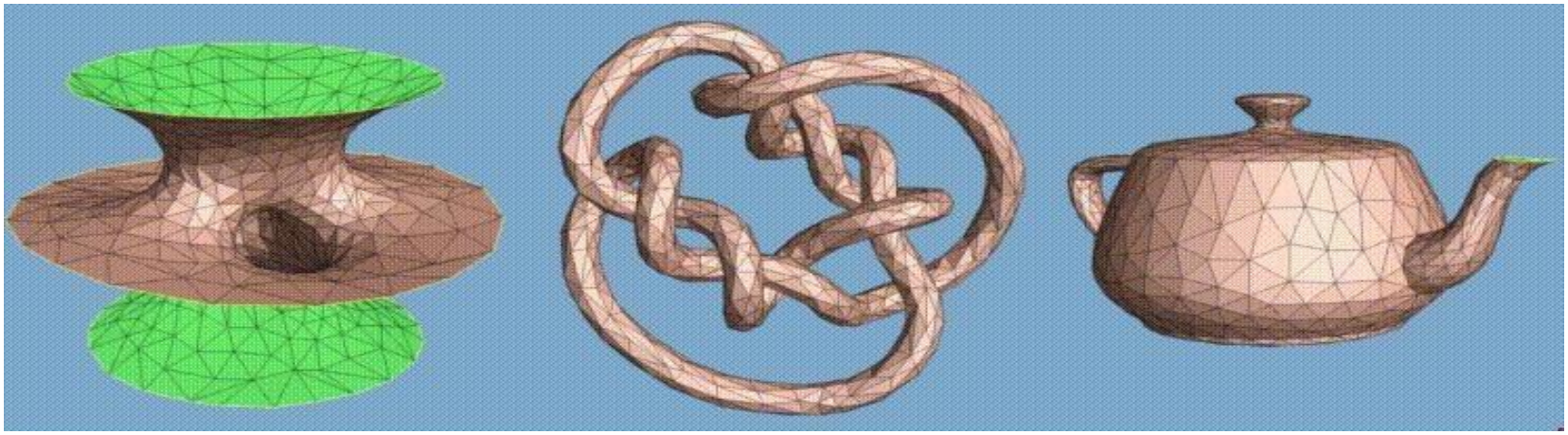
- One picture worth 1000 words!
- Support visual communication
- Facilitate inspection, diagnosis of complex systems like Human body, Manufacturing
- Entertainment
- Keep record, history
- Managing multimedia information
- Security, monitoring, watermarking, etc

Computer Graphics

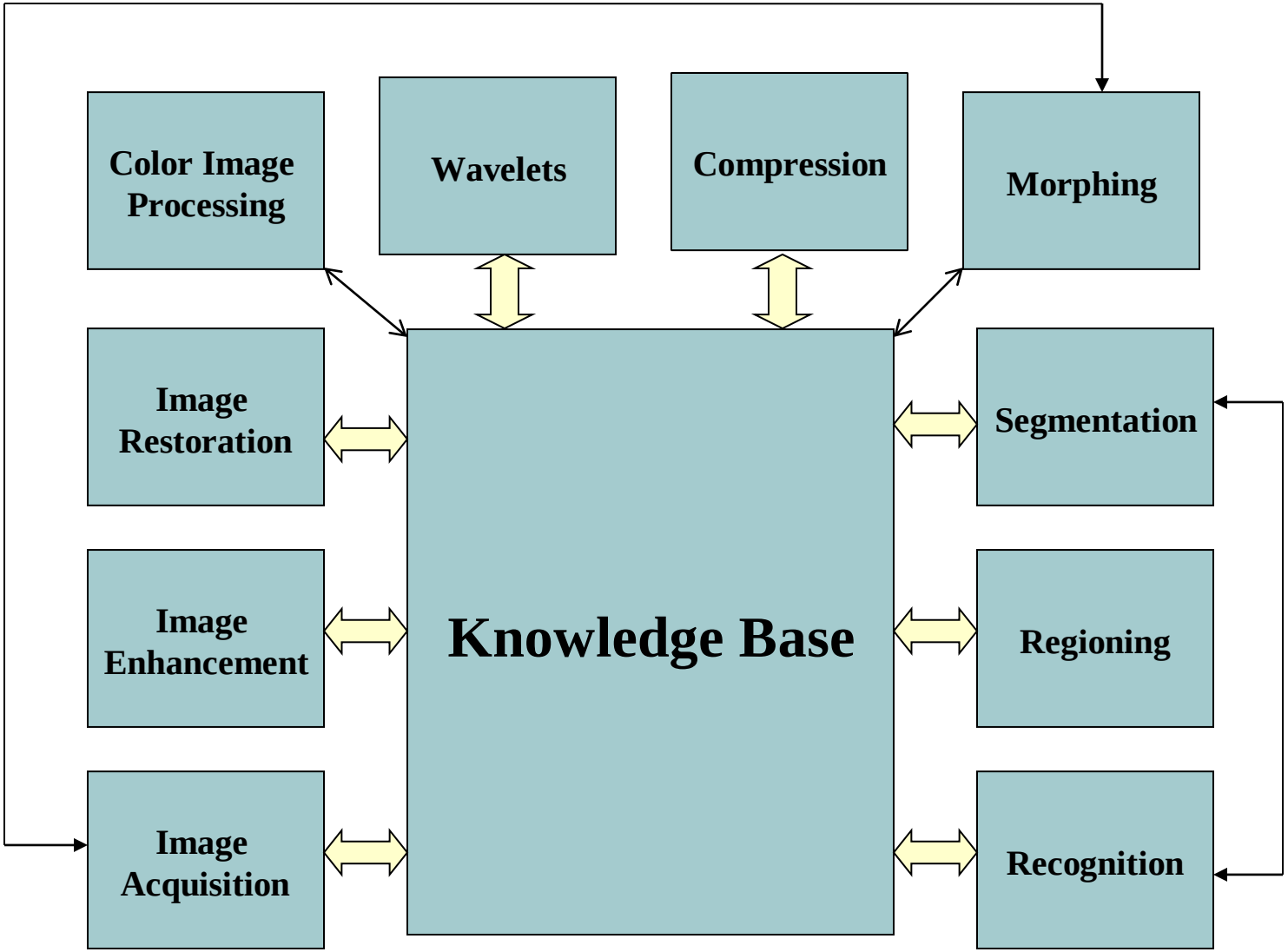
A methodology of creating images using a computer

Input


Computer
Graphics
3-D Model
2-D Image

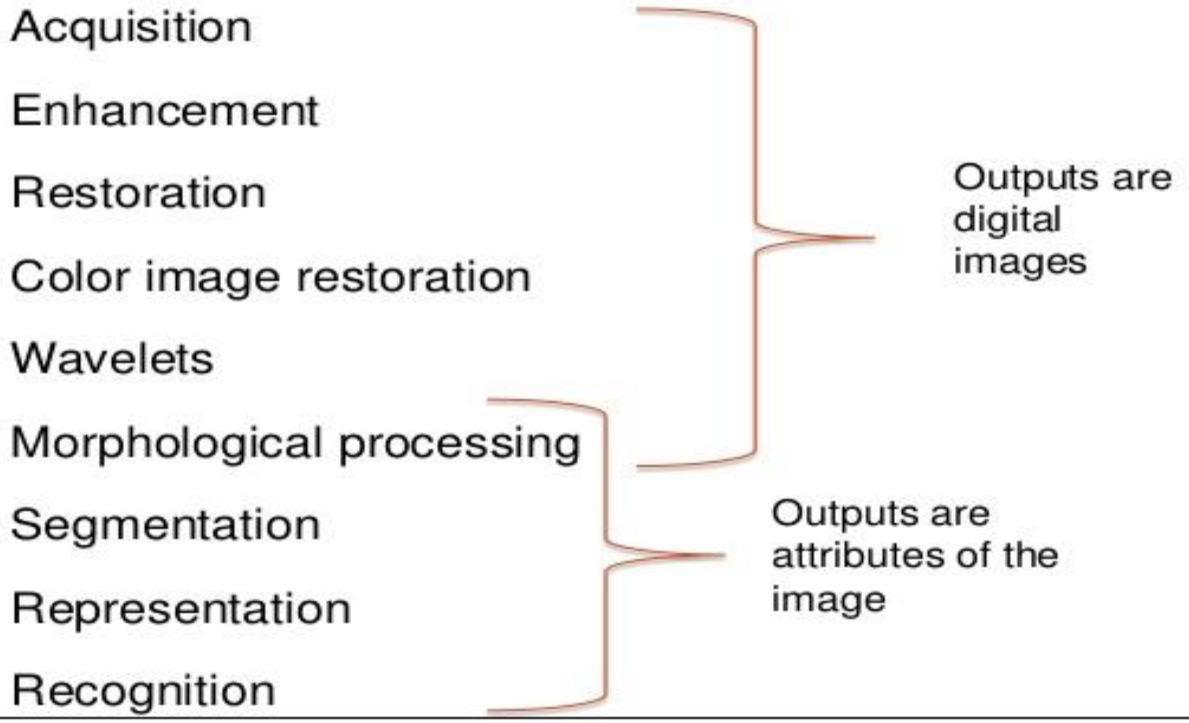


Basic Steps in Image Processing


Color Image Processing
Wavelets
Compression
Morphing
Image Restoration
Knowledge Base
Segmentation
Image Enhancement
Regioning
Image Acquisition
Recognition

Fundamental Steps in Digital Image Processing

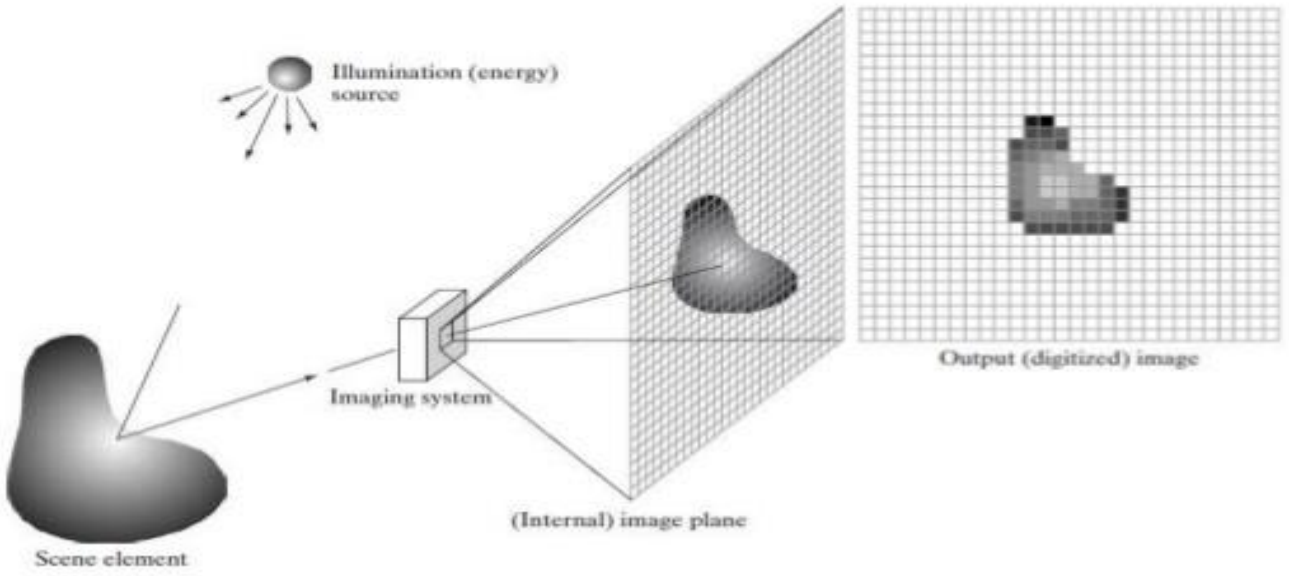
Essential steps when processing digital images:



Fundamental Steps in Digital Image Processing

- ***Image acquisition*** is the first process.

  Generally, the image acquisition stage involves preprocessing, such as scaling.



Fundamental Steps in Digital Image Processing

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

  There is no general "theory" of image enhancement.

  When an image is processed for visual interpretation, the viewer is the ultimate judge of how well a particular method works.

lack of contrast

image enhancement

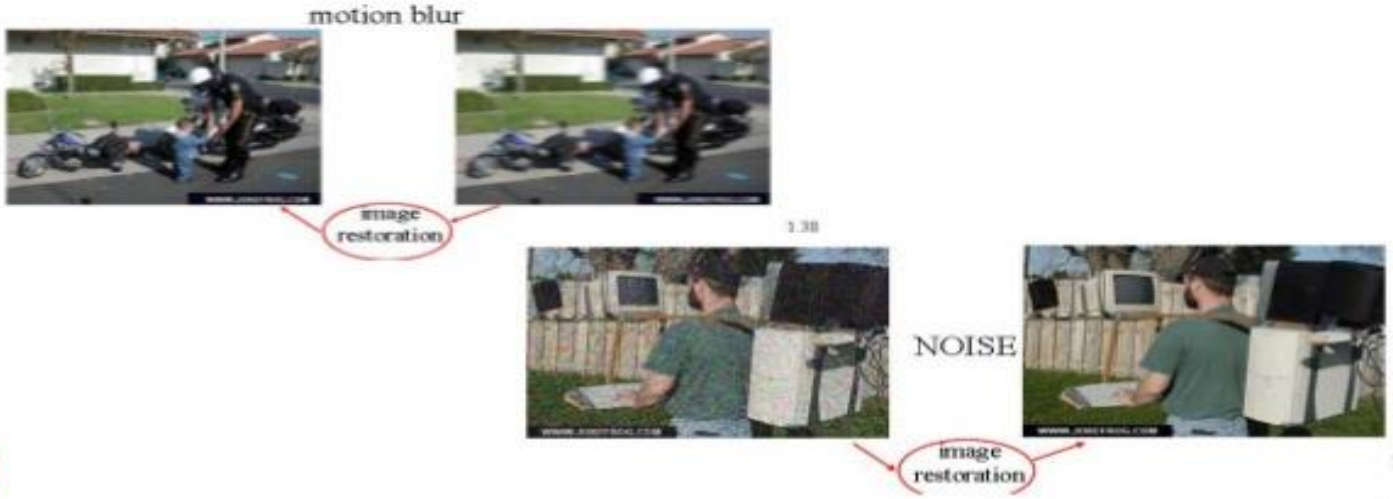
BLURRING

image enhancement

Fundamental Steps in Digital Image Processing

- ***Image Restoration*** is an area that also deals with improving the appearance of an image.

  However, unlike enhancement, which is subjective, image restoration is objective, in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image degradation.



Fundamental Steps in Digital Image Processing

- ***Color Image Processing*** is an area that has been gaining in importance because of the significant increase in the use of digital images over the Internet.

- ***Wavelets*** are the foundation for representing images in various degrees of resolution.

Fundamental Steps in Digital Image Processing

- ***Compression***, as the name implies, deals with techniques for reducing the storage required to save an image, or the bandwidth required to transmit it. This is true particularly in uses of the Internet.

Fundamental Steps in Digital Image Processing

- ***Morphological processing*** deals with tools for extracting image components that are useful in the representation and description of shape.

- ***Segmentation*** procedures partition an image into its constituent parts or objects.

  A segmentation procedure brings the process a long way toward successful solution of imaging problems that require objects to be identified individually.

  In general, the more accurate the segmentation, the more likely recognition is to succeed.

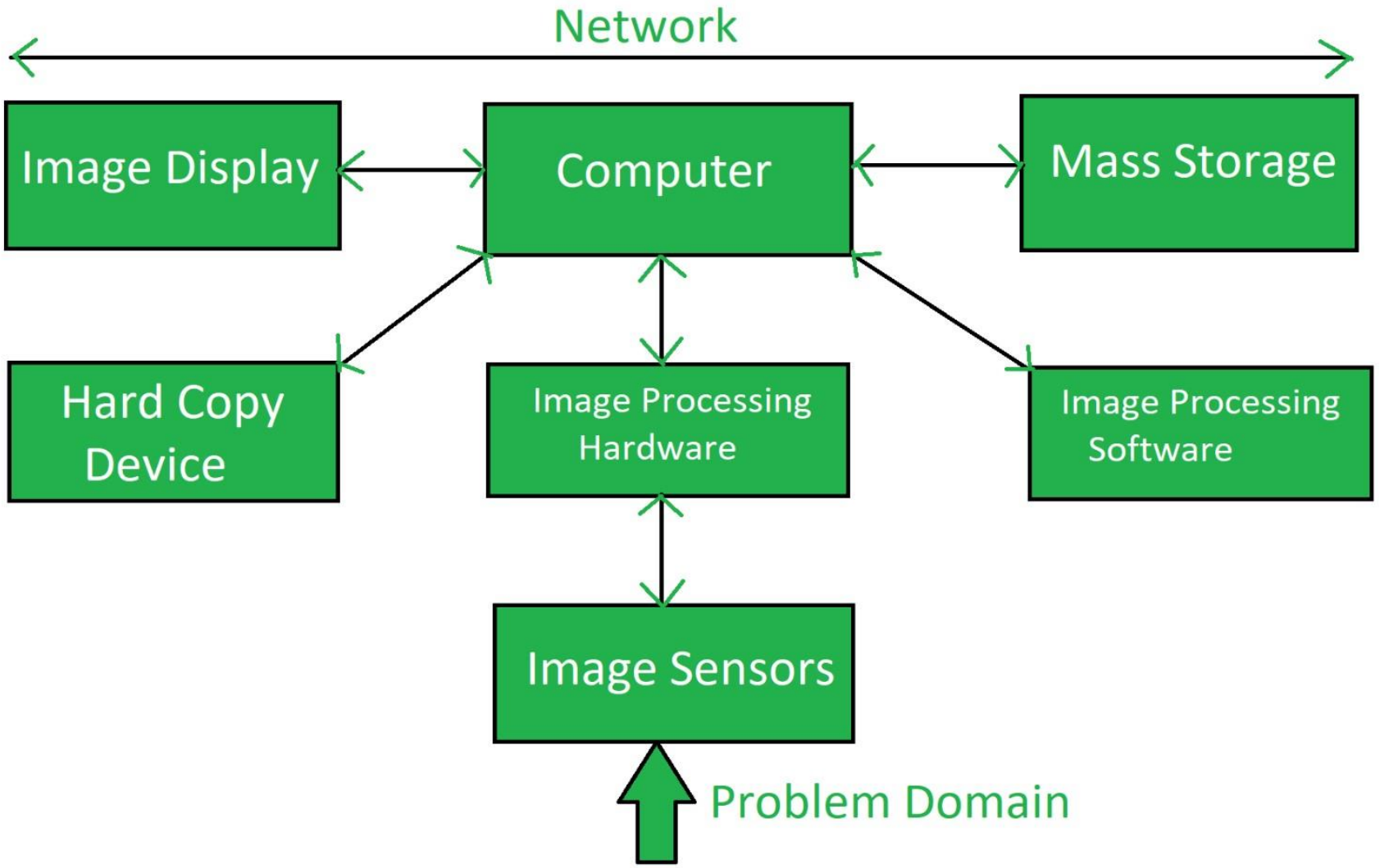
Fundamental Steps in Digital Image Processing

- **Representation and description** almost always follow the output of a segmentation stage, which usually is raw pixel data.
  - Boundary representation is appropriate when the focus is on external shape characteristics, such as corners and inflections.
  - Regional representation is appropriate when the focus is on internal properties, such as texture or skeletal shape.

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

- ***Recognition*** is the process that assigns a label (e.g., "vehicle") to an object based on its descriptors. Digital image processing with the development of methods for recognition of individual objects.

Components of DIP System


Network
Image Display
Computer
Mass Storage
Hard Copy Device
Image Processing Hardware
Image Processing Software
Image Sensors
Problem Domain

.....Components of DIP System

- **Image Sensors:**

  Image sensors senses the intensity, amplitude, co-ordinates and other features of the images and passes the result to the image processing hardware. It includes the problem domain.

- **Image Processing Hardware:**

  Image processing hardware is the dedicated hardware that is used to process the instructions obtained from the image sensors. It passes the result to general purpose computer.

.....Components of DIP System

- **Computer:**

  Computer used in the image processing system is the general purpose computer that is used by us in our daily life.

- **Image Processing Software:**

  Image processing software is the software that includes all the mechanisms and algorithms that are used in image processing system.

- **Mass Storage:**

  Mass storage stores the pixels of the images during the processing.

Components of DIP System(Contd…)

- **Hard Copy Device:**

  Once the image is processed then it is stored in the hard copy device.

- **Image Display:**

  It includes the monitor or display screen that displays the processed images.

- **Network:**

  Network is the connection of all the above elements of the image processing system.

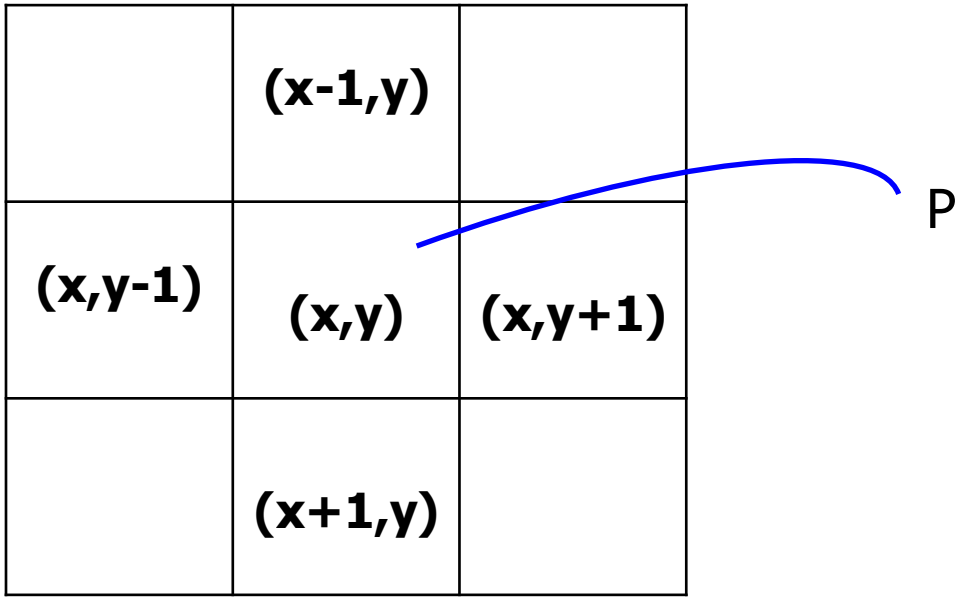
Basic Relationships Between Pixels

- Neighborhood
- Adjacency
- Connectivity
- Paths
- Regions and boundaries

Neighbors of a Pixels

- Any pixel p(x, y) has two vertical and two horizontal neighbors, given by (x+1, y), (x-1, y), (x, y+1), (x, y-1)

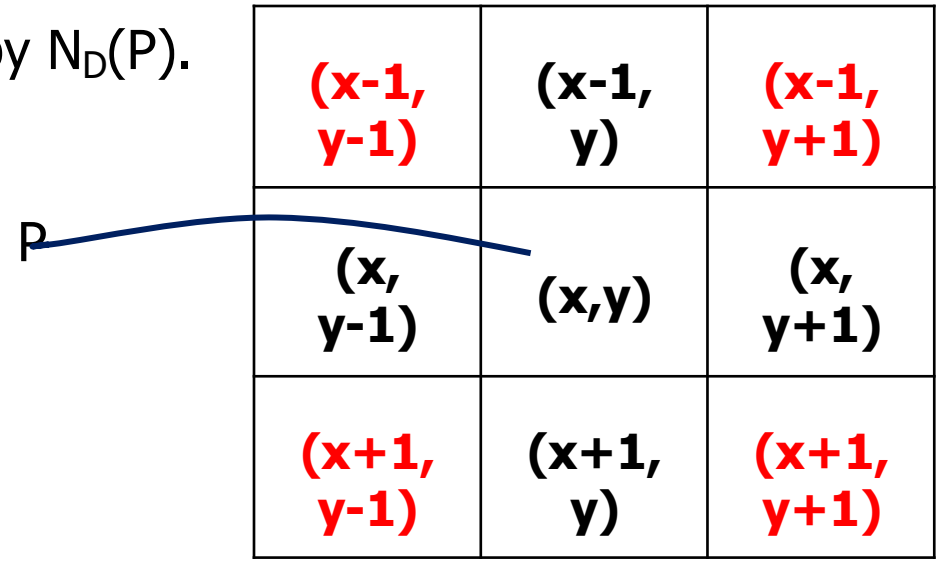
- This set of pixels are called the 4-neighbors of P, and is denoted by $N_4(P)$.
- Each of them are at a unit distance from P.



Neighbors of a Pixels(Contd….)

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

- This set is denoted by $N_D(P)$.



- The points $N_D(P)$ and $N_4(P)$ are together known as 8-neighbors of the point P, denoted by $N_8(P)$.
- Some of the points in the N_4, N_D and N_8 may fall outside image when P lies on the border of image.

- The four diagonal neighbors of p(x,y) are given by, (x+1, y+1), (x+1, y-1),

Adjacency

- Two pixels are connected if they are neighbors and their gray levels satisfy some specified criterion of similarity.
- **Forexample**, in a binary image two pixels are connected if they are 4-neighbors and have same value (0/1).
- Let V be set of gray levels values used to define adjacency.
- **4-adjacency:** Two pixels p and q with values from V are 4-adjacent if q is in the set $N_4(p)$.

Adjacency(Contd...)

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

m-adjacency: Two pixels p and q with values from V are madjacent if,

- q is in $N_4(p)$.
- q is in $N_D(p)$ and the set $[N_4(p) \cap N_4(q)]$ is empty (has no pixels whose values are from V).

Adjacency(Contd...)

Example : Consider following Image (I) and Vector V={1,2,3}

Find 4-adjacency, 8-adjacency and m-adjacency of each pixel. **4-adjacency**of pixel 0 at (1,1) is {(0,1),(1,2),(1,0)}

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

8-adjacencyof pixel 0 at (1,1) is {(0,1),(1,2),(1,0),(0,0),(0,2),(2,2) }

m-adjacency of pixel p at (1,1) is calculated as follows:

$N_4(p) = \{(0,1),(1,2),(1,0)\} = \{1,2,3\}$

$N_D(p) = \{(0,0),(0,2),(2,2)\} = \{2,2,1\}$

Adjacency (Contd...)

- Consider the neighbor pixel q at (1,2), where

$N_4(q) = \{(0,2),(1,3),(2,2)\} = \{2,3,1\}$

$[N_4(p) \cap N_4(q)] = \{(0,1),(1,2),(1,0)\} \cap \{(0,2),(1,3),(2,2)\}$

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

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

Connectivity

- To determine whether the pixels are adjacent in some sense.
- Let V be the set of gray-level values used to define connectivity; then Two pixels p, q that have values from the set V are:
  - 4-connected, if q is in the set $N_4(p)$
  - 8-connected, if q is in the set $N_8(p)$
  - m-connected, iff
    - q is in $N_4(p)$ or
    - q is in $N_D(p)$ and the set $[N_4(p) \cap N_4(q)]$ is empty

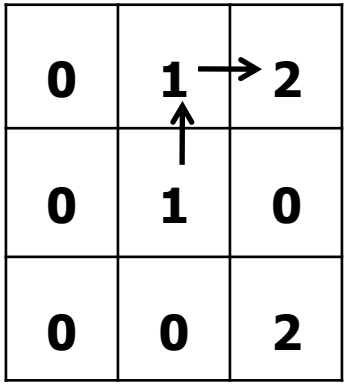
Connectivity (Contd...)

Example : Consider the following sample image pixel and vector

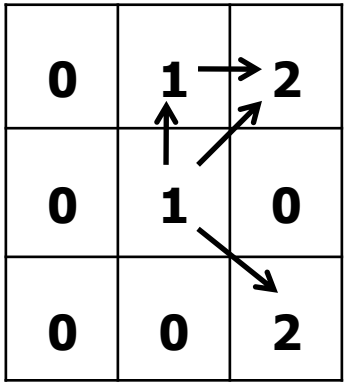
V={1,2}

0	1	2
0	1	0
0	0	2

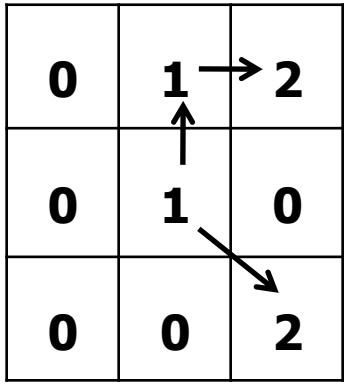
(a)



(b)



(c)



(d)

(a) Input

(b) 4-way Connected

(c) 8-way Connected

(d) m-way Connected

Connectivity

- To determine whether the pixels are adjacent in some sense.
- Let V be the set of gray-level values used to define connectivity; then Two pixels p, q that have values from the set V are:
  - 4-connected, if q is in the set $N_4(p)$
  - 8-connected, if q is in the set $N_8(p)$
  - m-connected, iff
    - q is in $N_4(p)$ or
    - q is in $N_D(p)$ and the set $[N_4(p) \cap N_4(q)]$ is empty

Paths & Path Length

- A path from pixel p with coordinate (x, y) to pixel q with coordinate (s, t) is a sequence of distinct pixels with coordinates:

$$(x_0, y_0), (x_1, y_1), (x_2, y) \ldots (x_n, y_n),$$

where $(x_0, y_0)=(x, y)$ and $(x_n, y_n)=(s, t)$;

(x_i, y_i) is adjacent to (x_{i-1}, y_{i-1})

- Here n is the length of the path.
- We can define 4-, 8-, and m-paths based on type of adjacency used.

Connected Components

- If p and q are pixels of an image subset S then p is **Connected**to q in S if there is a path from p to q consisting entirely of pixels in S.
- For every pixel p in S, the set of pixels in S that are connected to p is called a **Connected Component** of S.
- If S has only one connected component then S is called **Connected Set.**

Regions and Boundaries

- A subset R of pixels in an image is called a **Region**of the image if R is a connected set.
- The **Boundary**of the region R is the set of pixels in the region that have one or more neighbors that are not in R.
- If R happens to be entire Image?

Distance Measures

- Given pixels p, q and z with coordinates (x, y), (s, t), (u, v) respectively, the distance function D has following properties:

  a. $D(p, q) \geq 0$ [$D(p, q) = 0$, iff $p = q$]

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

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

Distance Measures (Contd...)

The following are the different Distance measures:

- Euclidean Distance :

$$D_E(p, q) = [(x-s)^2 + (y-t)^2]$$

- City Block Distance:

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

- Chess Board Distance:

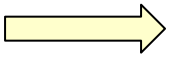
$$D_8(p, q) = \max(|x-s|, |y-t|)$$

Distance Measures *(Contd...)*

		2		
	2	1	2	
2	1	0	1	2
	2	1	2	
		2		

⟸ City-Block / D_4 Distance

Chess Board/ D_8 Distance



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

THANK YOU

THIS CONTENT IS TAKEN FROM THE TEXT BOOKS AND REFFERENCE BOOKS

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