Digital Image Processing Introduction UNIT-1

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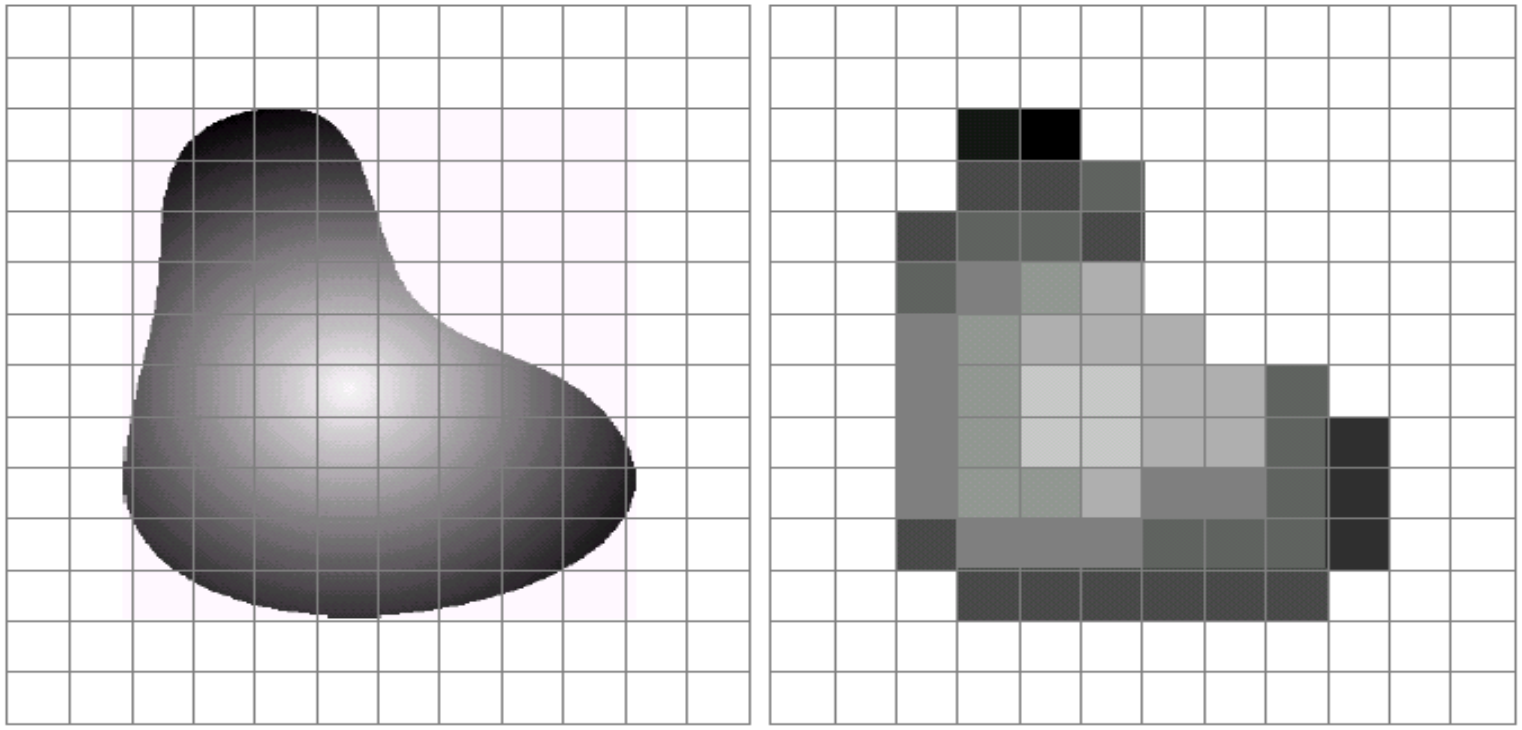
What is Image Processing?

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

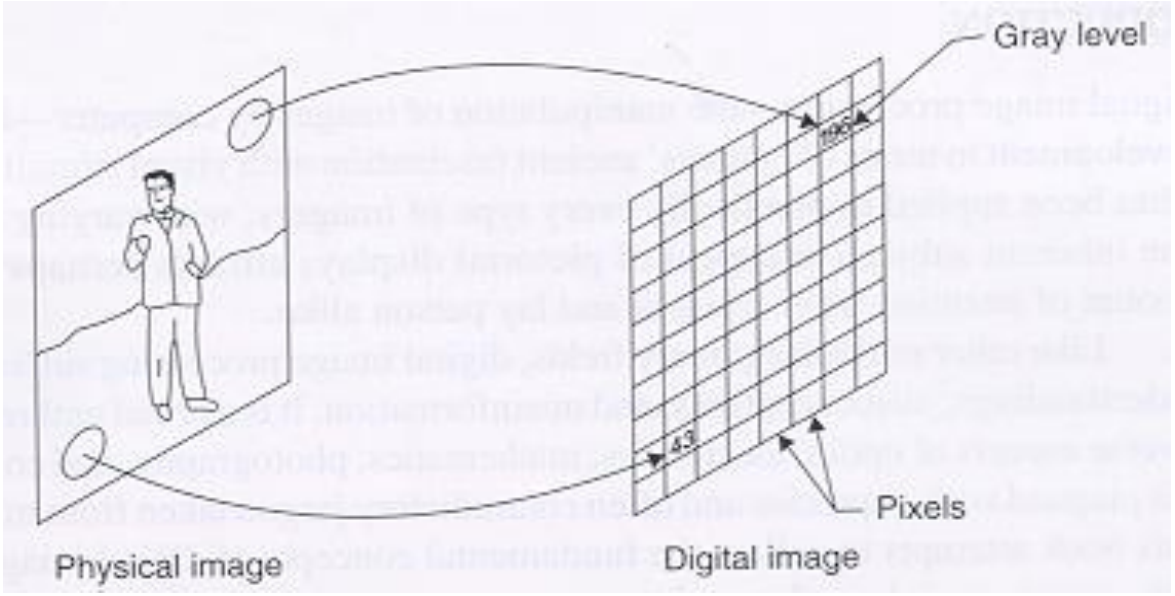
Sampling and Quantization



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



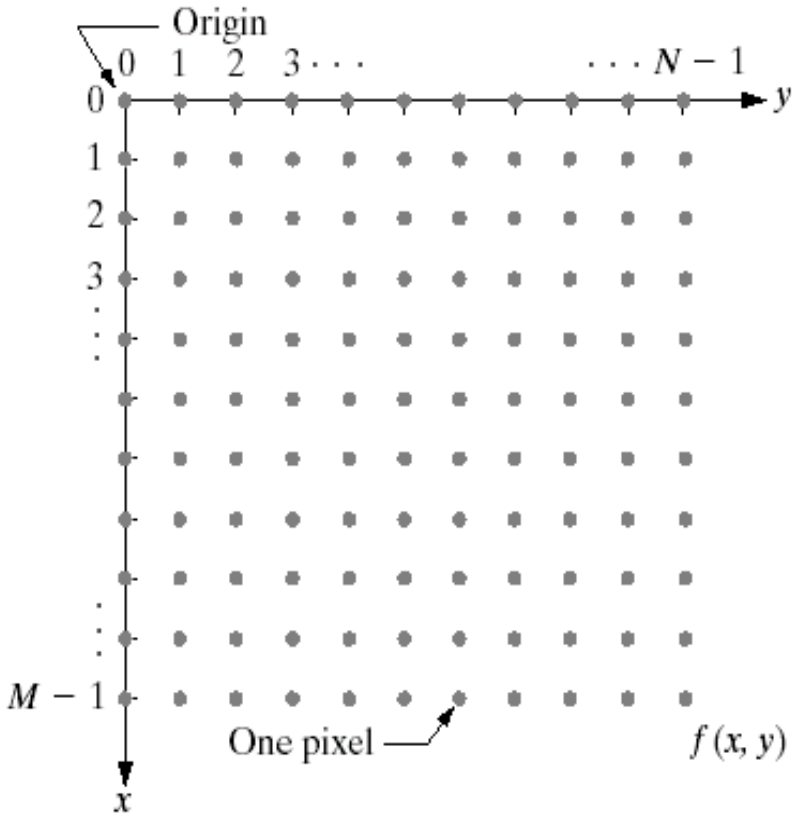
2-bit binary image

Quantization means digitizing amplitude values

4-bit gray image

Digital Image Representation

- ✓ *An image is a function defined on a 2D coordinate f(x,y). The value of f(x,y) is the intensity.*
- ✓ *3 such functions can be defined for a color image, each represents one color component*
- ✓ *Digital image can be represented as a matrix.*



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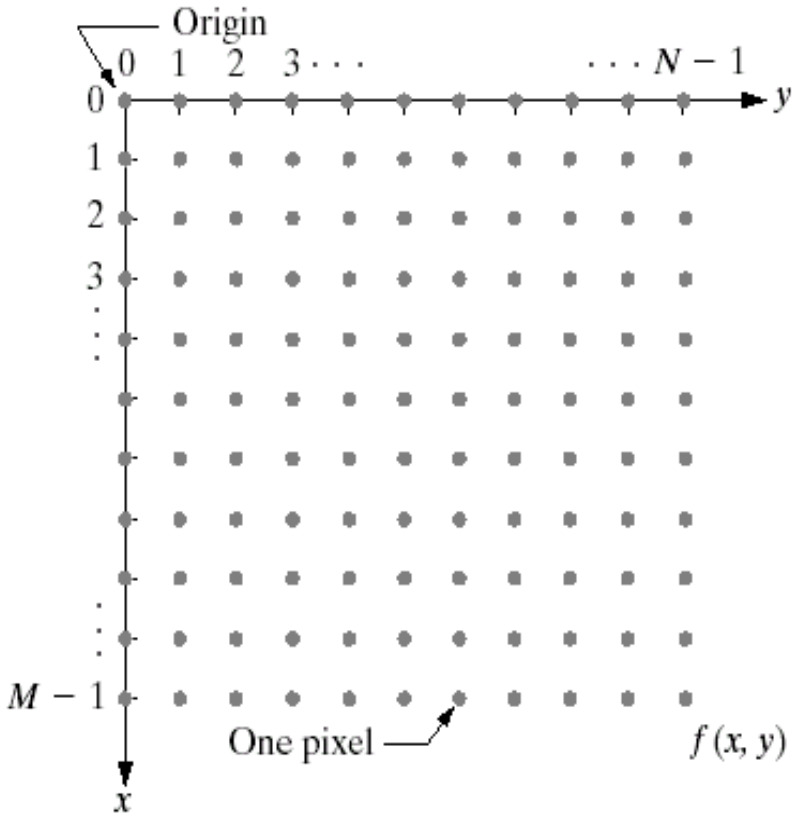


Spatial and Gray Level Resolution

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

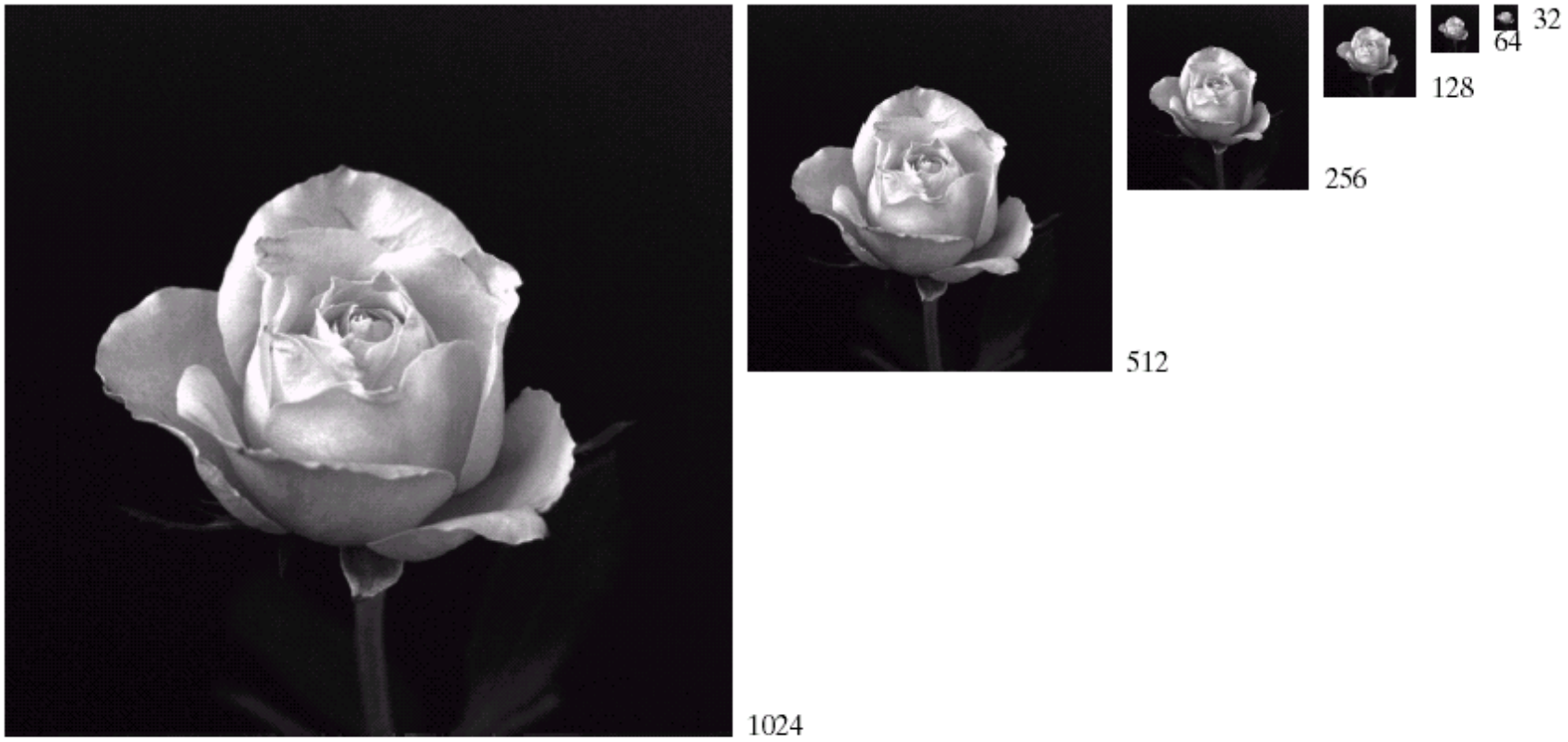


FIGURE 2.19 A 1024 × 1024, 8-bit image subsampled down to size 32 × 32 pixels. The number of allowable gray levels was kept at 256.

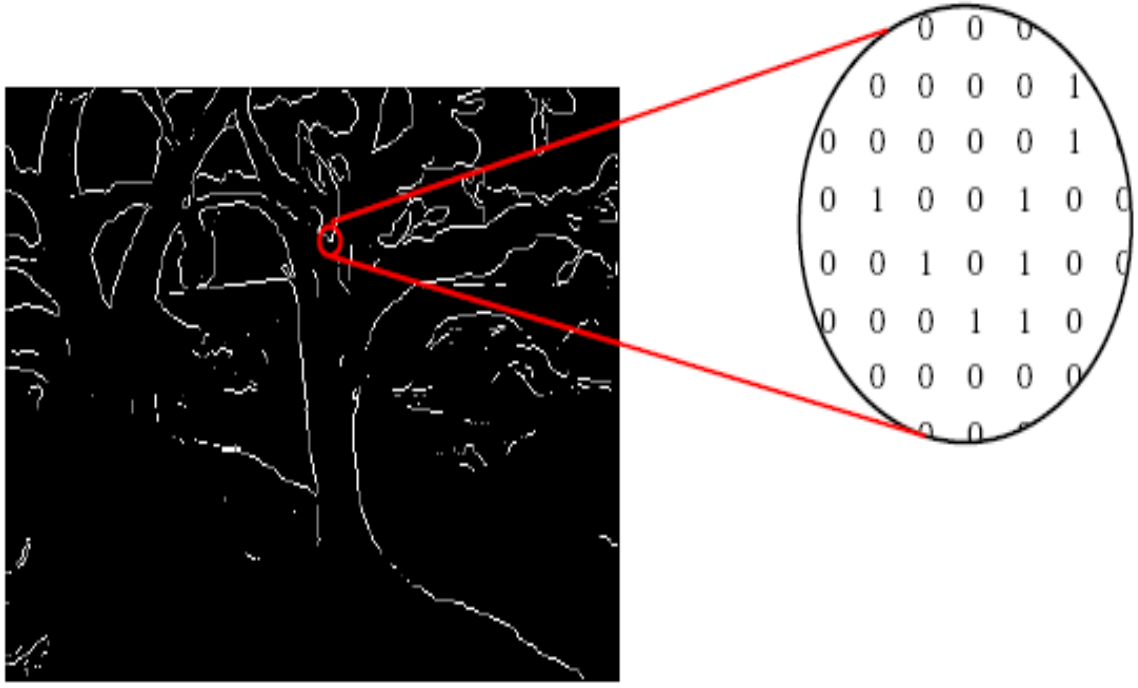
Different Pixel Sizes and Same Image size

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.

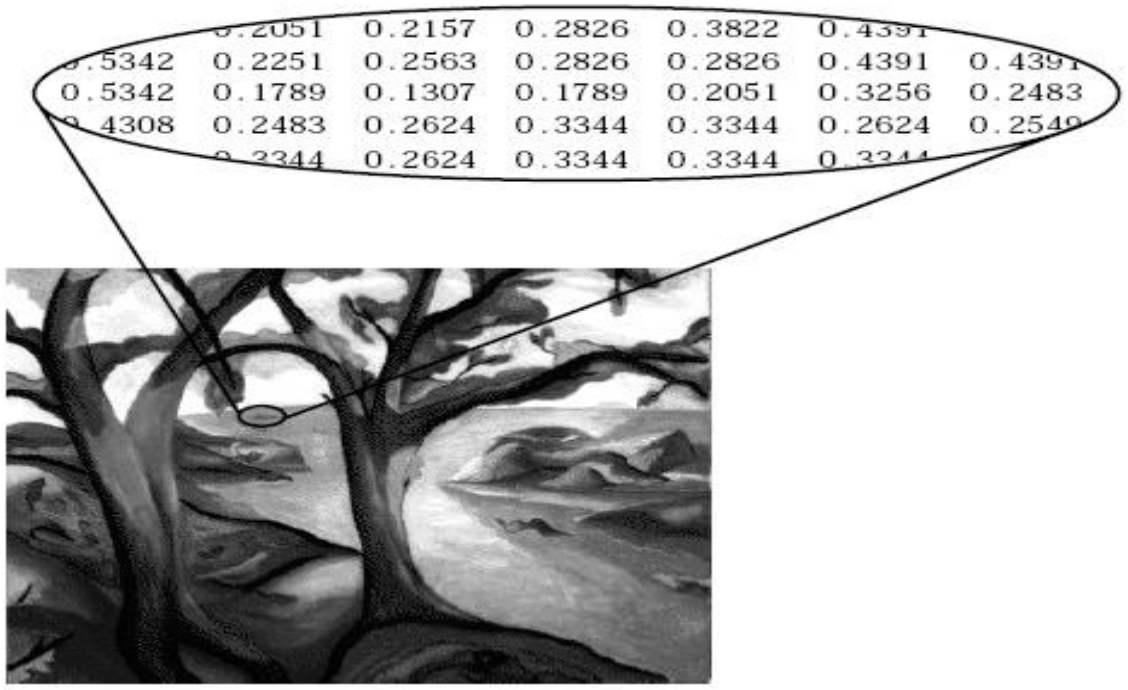
Digital Image Types

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



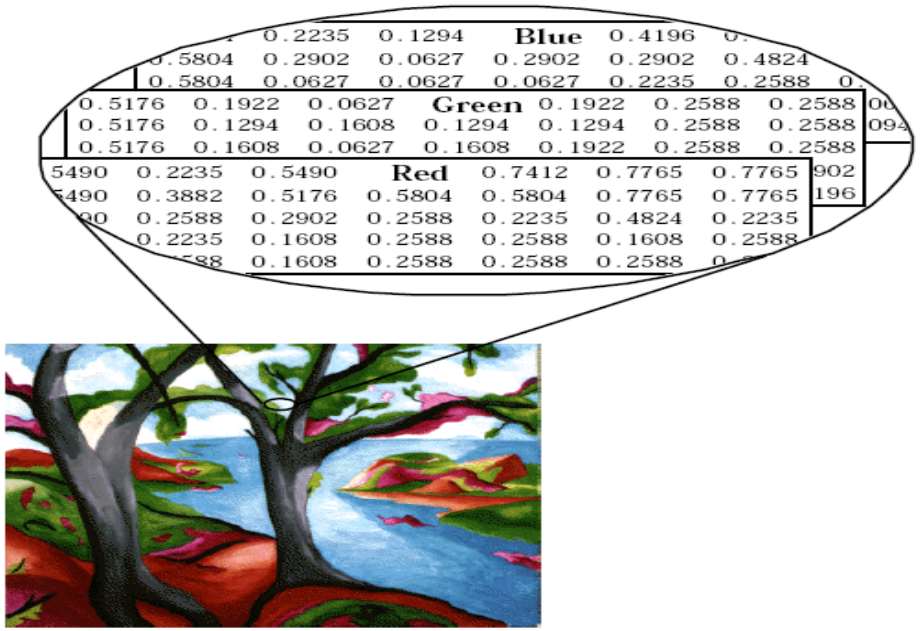
Digital Image Types

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



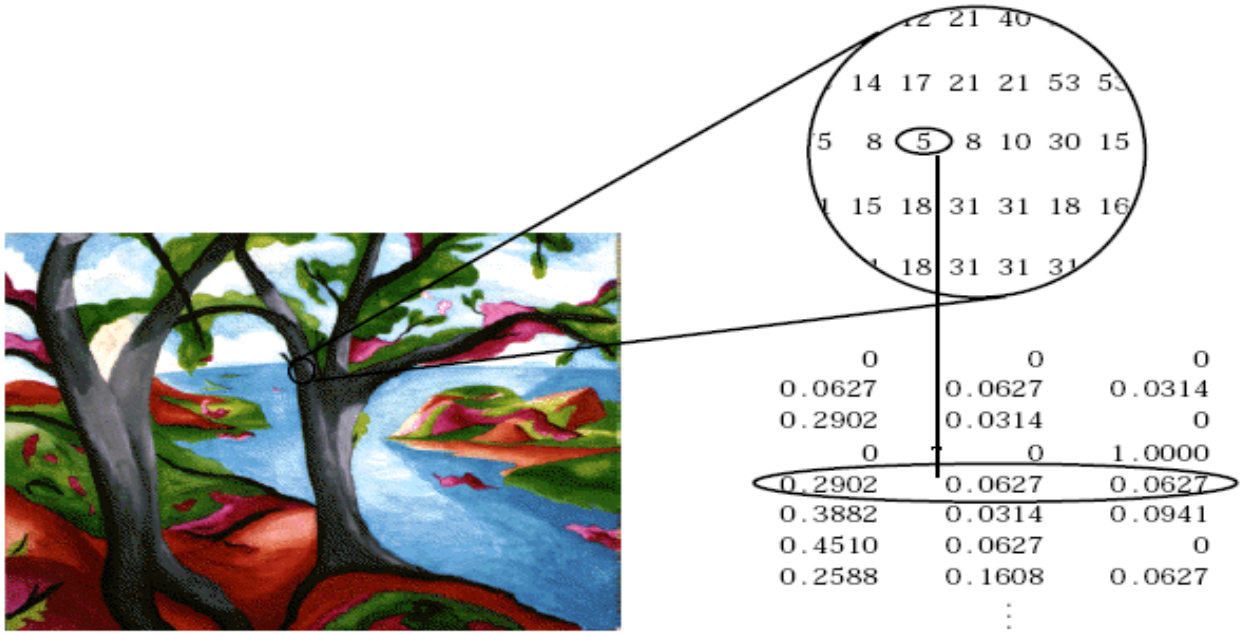
Digital Image Types

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



Digital Image Types

Indexed image: 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 floating-point values in the range [0,1].



Electro Magnetic Spectrum

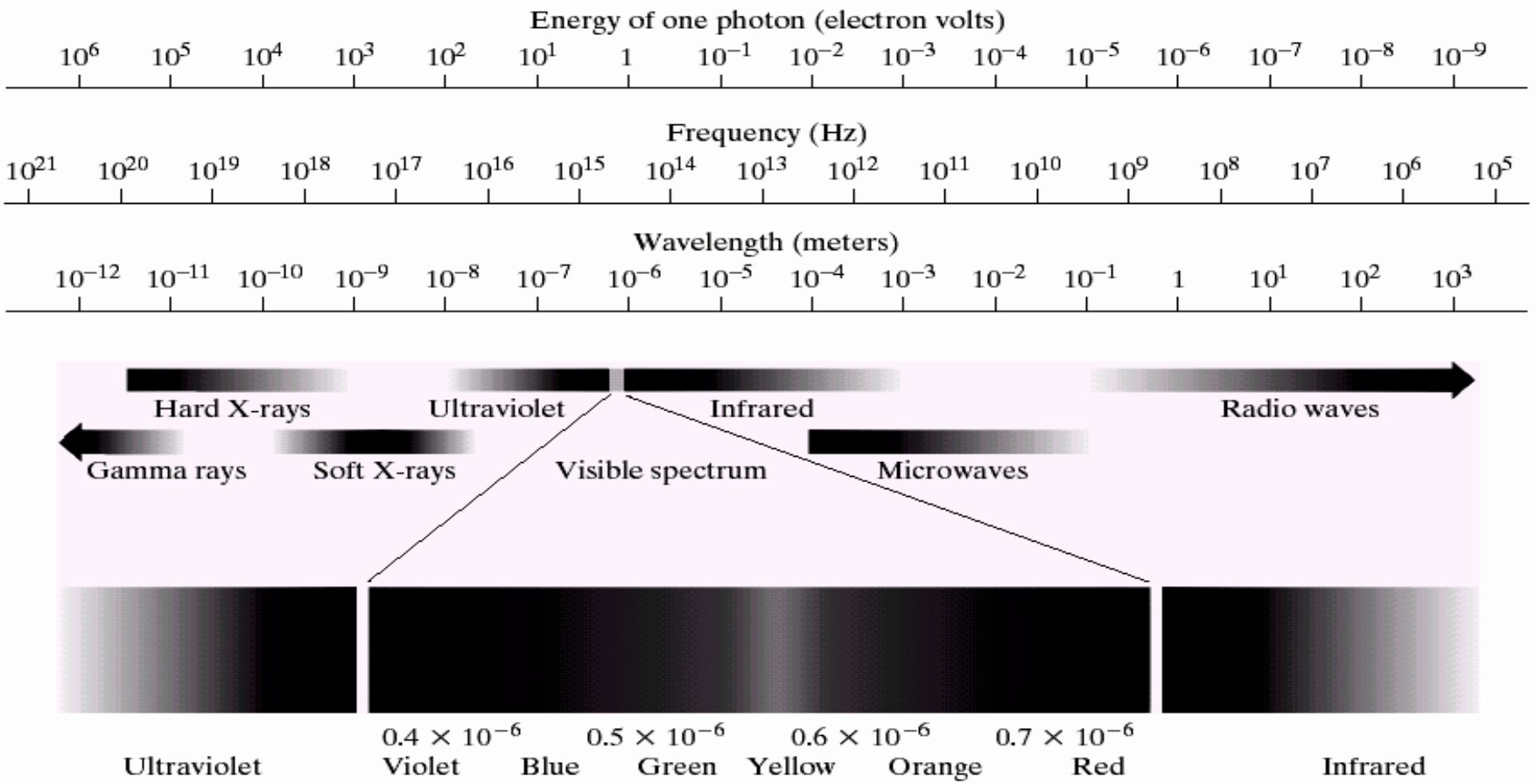
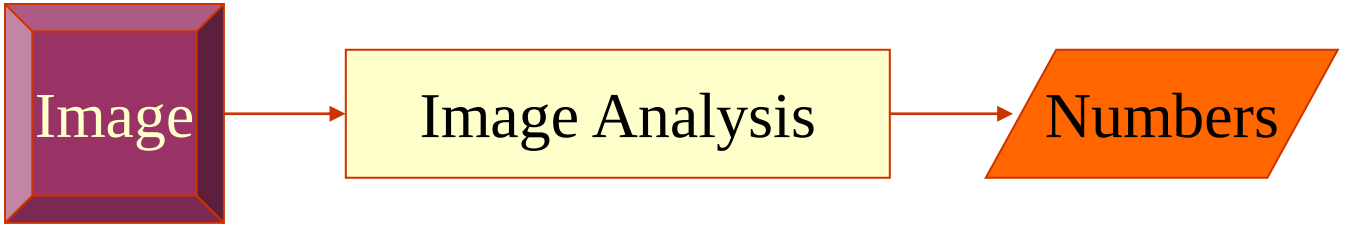


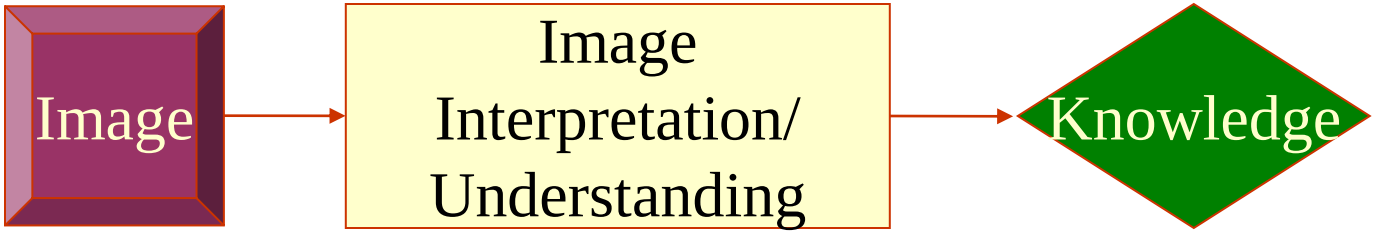
FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

Digital Image Processing

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

Computer Vision and Image Processing



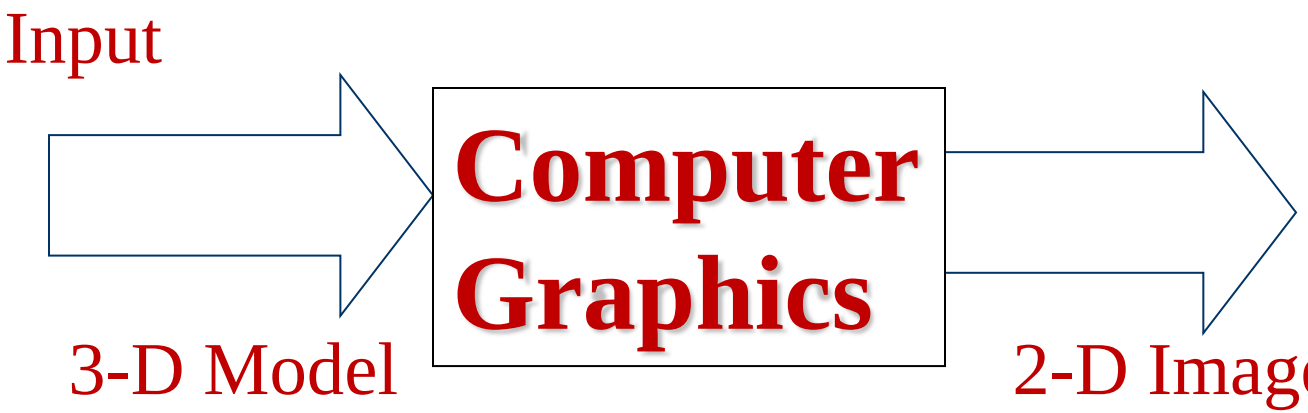


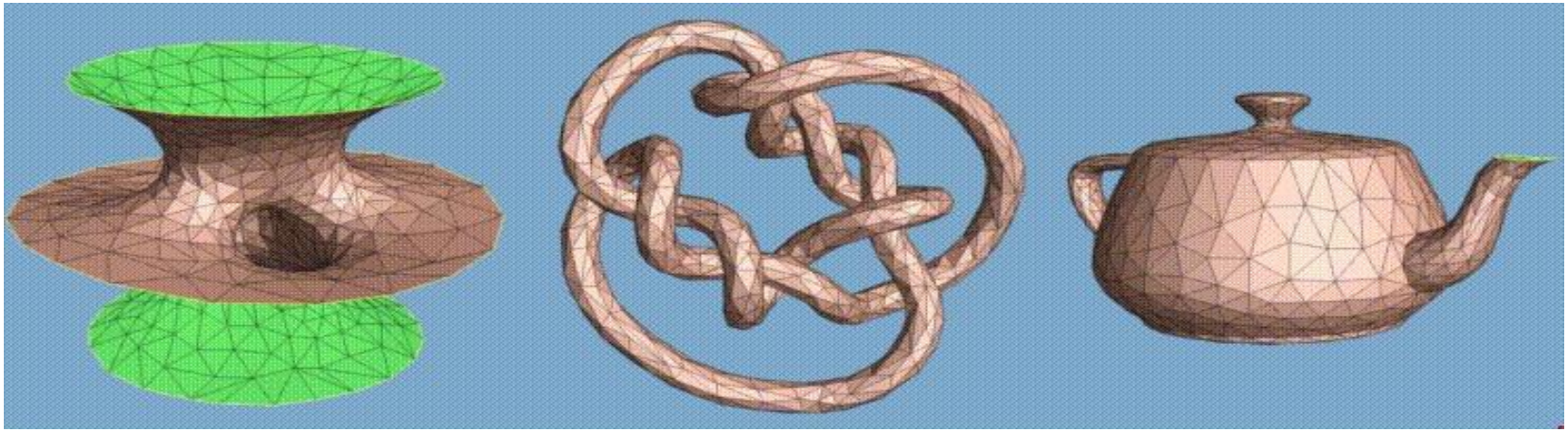
Why need DIP?

- 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

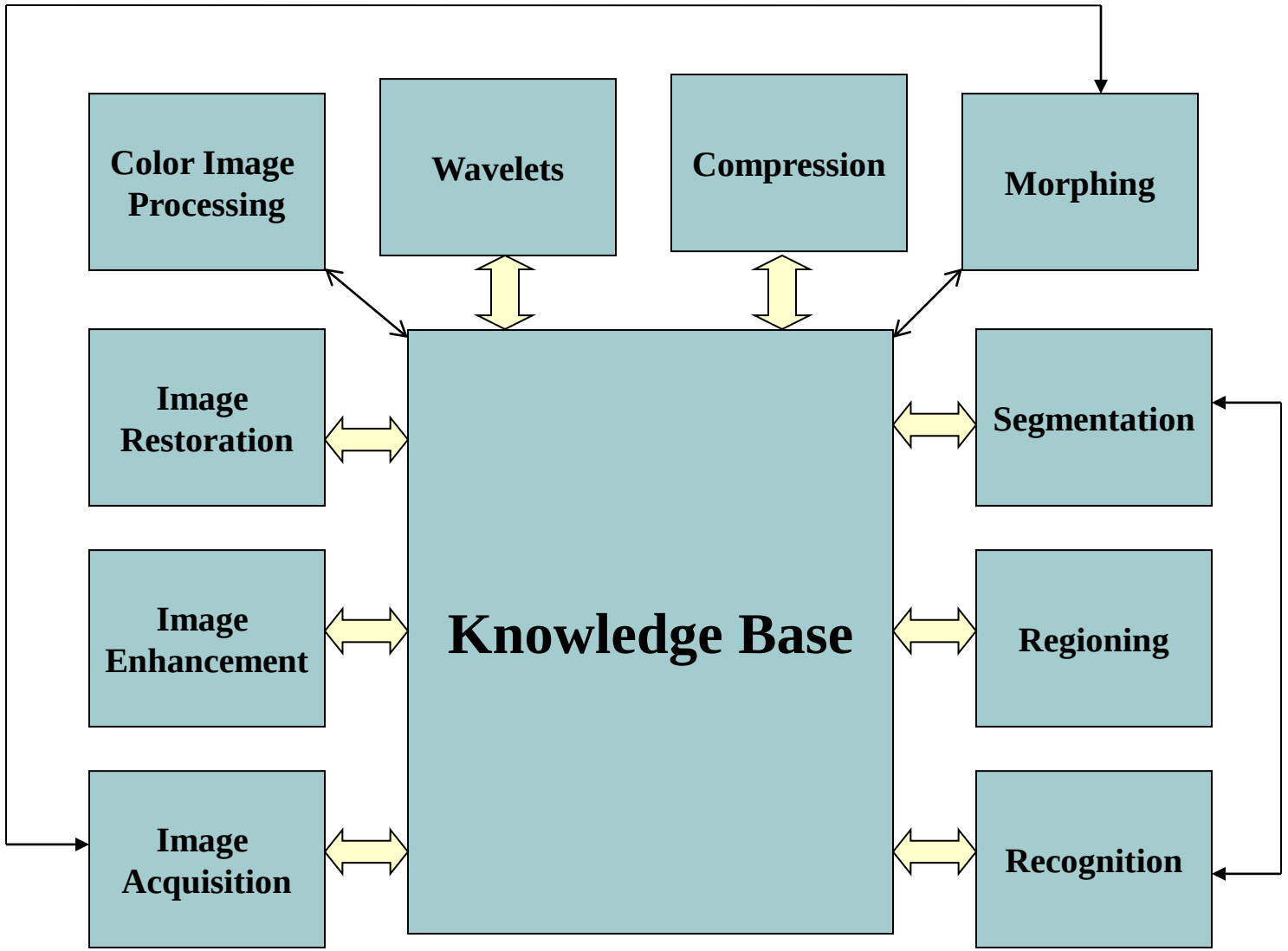
Computer Graphics

A methodology of creating images using a computer

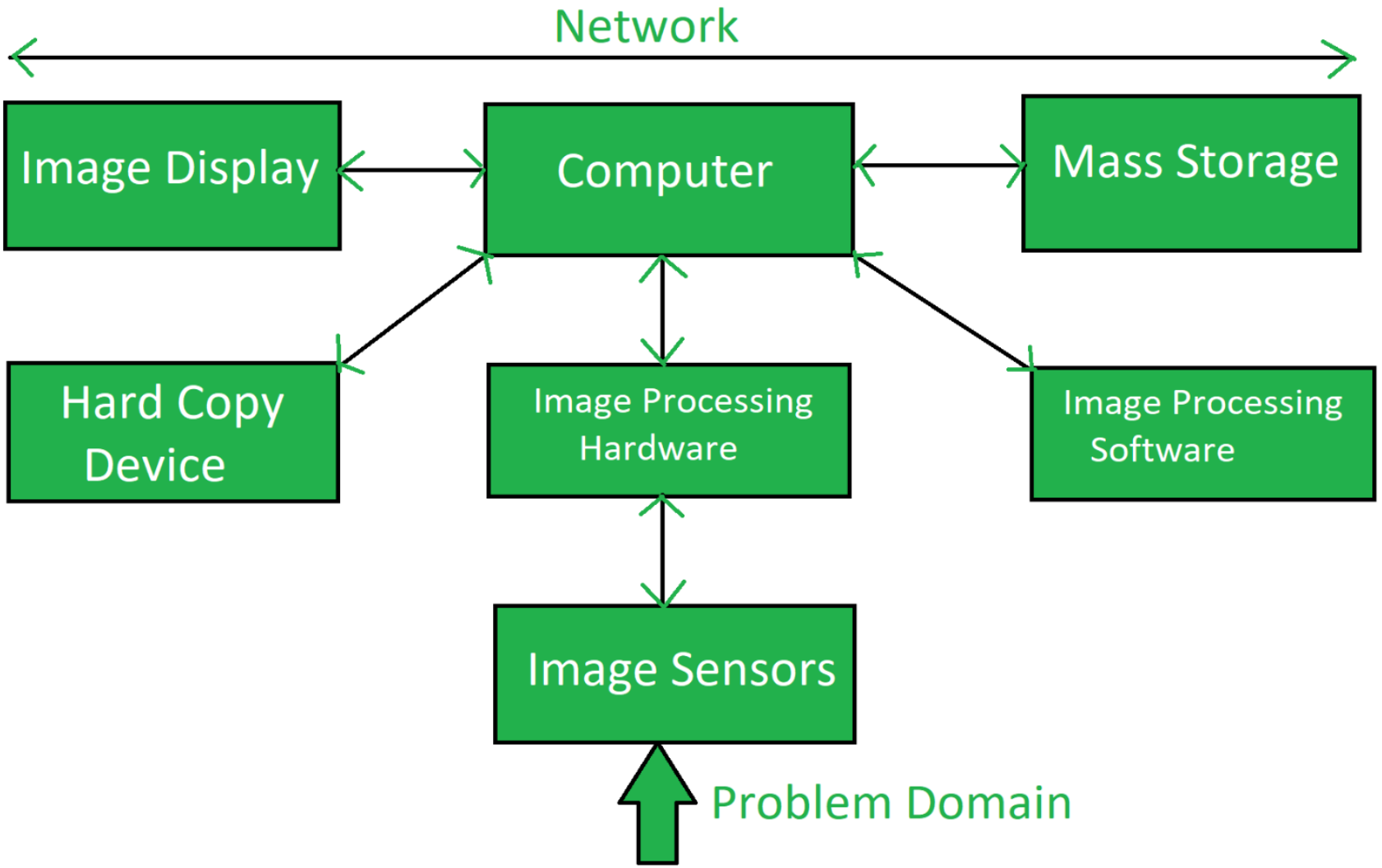




Basic Steps in Image Processing



Components of DIP System



…….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:**

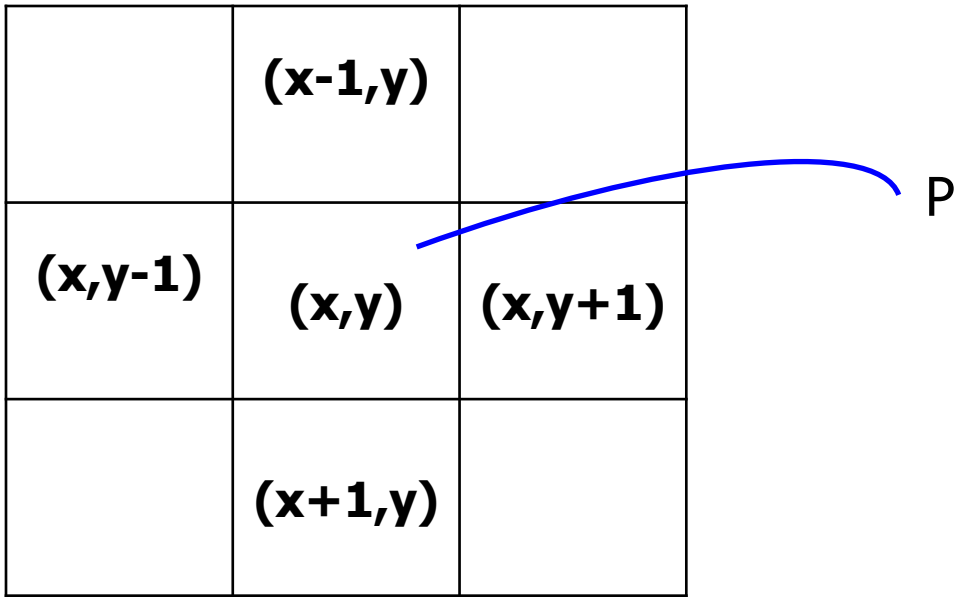
  Network is the connection of all the above elements of the image processing system.

Basic Relationships Between Pixels

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

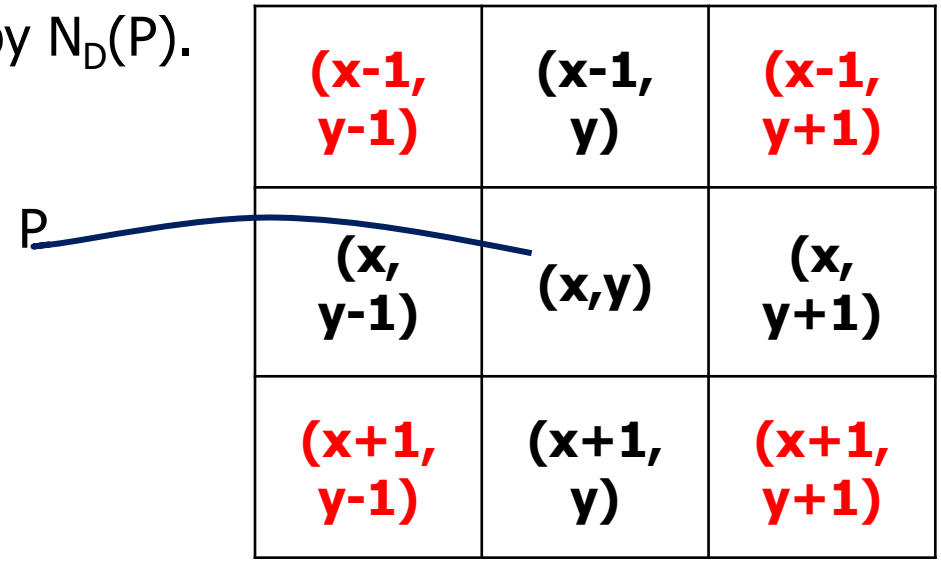
Neighbors of a Pixels

- 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….)

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

Adjacency

- Two pixels are connected if they are neighbors and their gray levels satisfy some specified criterion of similarity.
- ***For example***, 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 8-adjacent if q is in the set $N_8(p)$.

m-adjacency: Two pixels *p* and *q* with values from V are m-adjacent 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.

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

4-adjacency of pixel 0 at (1,1) is

{(0,1),(1,2),(1,0)}

8-adjacency of 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

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

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

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

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

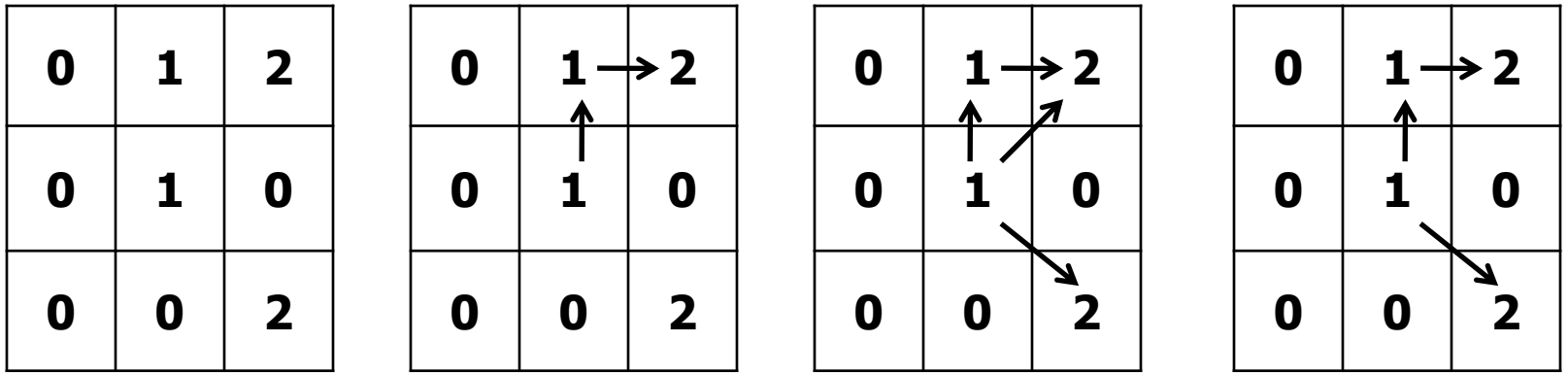
Connectivity

- 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}



(a) Input

(b) 4-way Connected

(c) 8-way Connected

(d) m-way Connected

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  - m-connected, iff
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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

References

- https://www.slideshare.net/CristinaPrezBenito/simultaneous-smoothing-and-sharpening-of-color-images.
- https://www.javatpoint.com/digital-image-processing-tutorial.
- https://www.tutorialspoint.com/dip/index.html.

TEXT BOOKS

1) Rafael C. Gonzalez, Richard E. Woods, "Digital Image Processing", Second Edition, PHI/Pearson Education.
2) 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.