

# DIGITAL IMAGE PROCESSING

## UNIT – 1

### **Why do we need Image Processing?**

- To improve the Pictorial information for human interpretation
  - 1) Noise Filtering
  - 2) Content Enhancement
    - a) Contrast enhancement
    - b) Deblurring
  - 3) Remote Sensing
- Processing of image data for storage, transmission and representation for autonomous machine perception

### **What is Image?**

An image is 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 intensity or gray level of the image at that point. *When  $x, y$  and the intensity values of ' $f$ ' are all finite, discrete quantities then the image is called Digital Image*

**Analog Image-** An analog image is mathematically represented as a continuous range of values that give the position and intensity.

**Digitization** –it's the process of transforming images such as analog image into digital image or digital data.

### **PIXELS:**

A digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are called Picture elements or Image elements, pels and **Pixels**.

### **What is Digital Image Processing?**

Digital image processing is a method to perform some operations on an image. In order to get an enhanced image or to extract some useful information from it. It is a type of signal processing in which input is an image and output may be image or characteristics / features associated with that image.

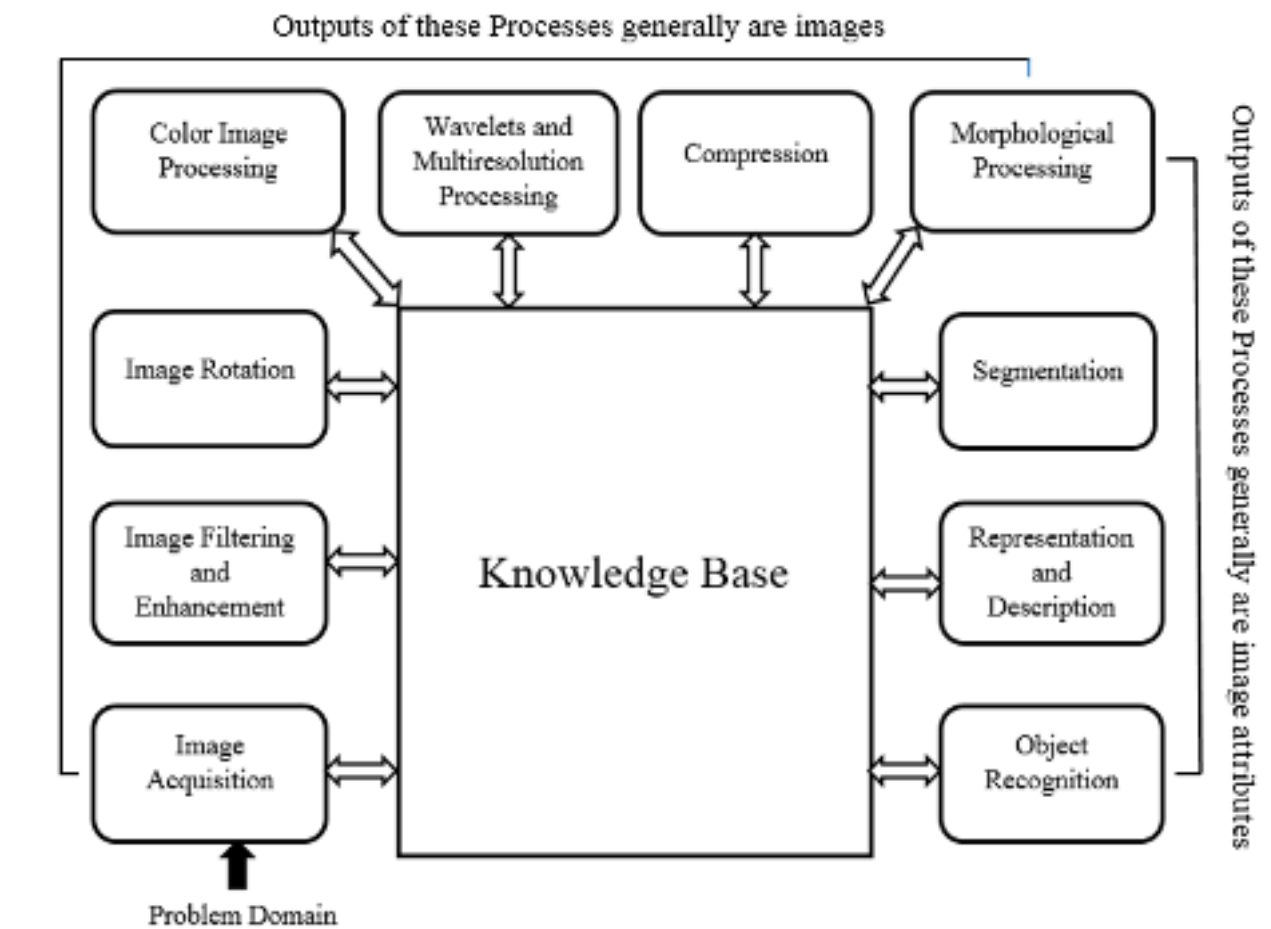
(or)

Digital image processing is defined as the process of analyzing and manipulating images using computer

### **The main advantage of DIP:**

- It allows wide range of algorithms to be applied to the input data.
- It avoids noise and signals distortion problems.

## 1.1 Fundamentals of Digital Imaging:



### 1.1.1 Image Acquisition:

Image acquisition is the process of acquiring or getting an image. The entire processing has been done on images so that, the images are first needed to be loaded to the digital computer. Eg: Digital camera, Scanner...etc.,

### 1.1.2 Image Enhancement:

Image enhancement techniques have been widely used in many applications of image processing, where the subjective quality of image is important for human interpretation. *Image enhancement is the process of manipulating an image so that the result is more suitable than the original for a specific application.*

- It accentuates or sharpens image features such as edges boundaries or contrast to make a graphic display more helpful for display and analysis.

- The enhancement doesn't increase the inherent information content of the data, but it increases the dynamic range of the chosen features so that they can be detected easily.
- The greatest difficulty in image enhancement is quantifying the criterion for enhancement and therefore, a large number of image enhancement techniques are empirical and require interactive procedures to obtain satisfactory results
- Image enhancement method can be based on either spatial or frequency domain techniques, some examples of image enhancement techniques are,
  - Point operations
  - Spatial operations
  - Transform operations
  - Pseudo coloring

In many applications (e.g., satellite imaging, medical imaging, astronomical imaging, poor-quality family portraits) the imaging system introduces a slight distortion. Often images are slightly blurred and image restoration aims at deblurring the image. However, image 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.*

$$g(x, y) = H[f(x, y) + \eta(x, y)] \quad \dots \dots \dots (1)$$

### 1.1.4 Color Image processing:

### **1.1.5 Wavelets:**

Wavelets is a powerful tool in image processing, *It's a mathematical function used for representing images in various degrees of resolution.* It was very useful in Image compression and removal of noise.

- 1) The wavelet compressed image can be as small as about 25% the size of the similar quality image
- 2) The wavelets are used to remove the noises present in the image with greater efficiency when compared to other filtering techniques

Wavelets can be combined using a reverse, shift, multiply and integrate techniques called convolution with portions of a known signal to extract information from the unknown signal.

### **1.1.6 Image Compression:**

*Image compression is a technique used for reducing the storage required to store/save an image or the bandwidth required to transmit an image.* Image compression algorithms are basically classified into

- 1) Lossy compression –loss of information's present in the image during compression
- 2) Lossless compression –no loss of information's present in the image during compression

Image compression algorithms may take advantage of visual perception and the statistical properties of image data to provide superior results compared with generic compression methods

### **1.1.7 Morphological Processing:**

Morphological processing is a tool for extracting image components that are useful in the representation and description of shape (extracting and describing image component regions)

### **1.1.8 Image Segmentation:**

Segmentation is the process of partitioning a digital image into multiple segments. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze.

- 1) Threshold based segmentation
- 2) Edge based segmentation
- 3) Region based segmentation
- 4) Clustering techniques
- 5) Matching

### **1.1.9 Representation and Description:**

**Representation-** *deals with compaction of segmented data into representation that facilitate the computation of descriptors*

**Description-** *deals with extracting attributes that result in some quantitative information of interest or basic for differentiating one class of objects from another*

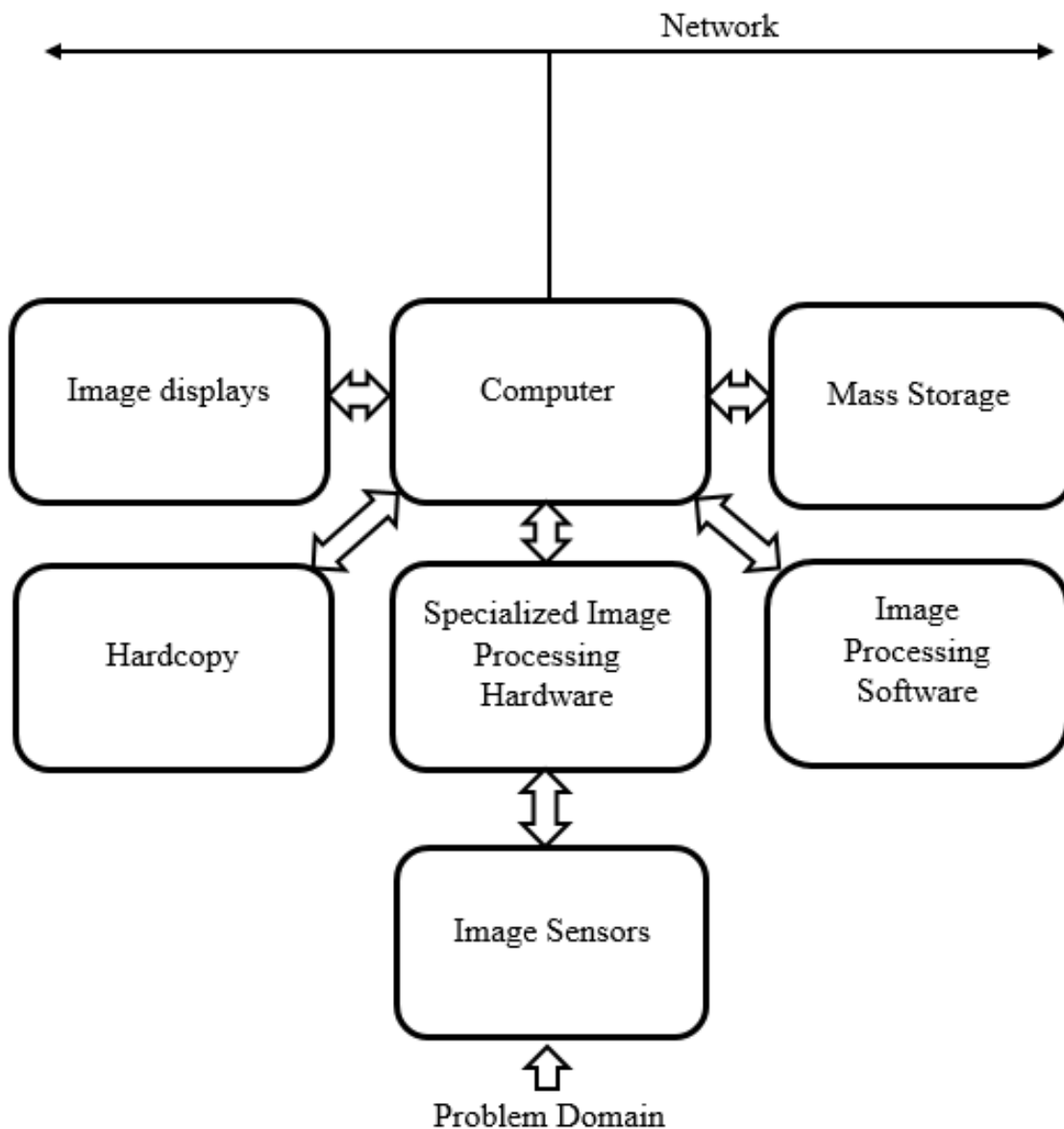
### 1.1.10 Object Recognition:

*Object recognition is the process that assigns a label to an object based on its descriptors*

### 1.1.11 Knowledge Base:

Knowledge about a problem domain is coded into an image processing system in the form of a knowledge data base. This knowledge may be as simple as detailing regions of an image where the information of interest is known to be located, thus limiting the search that has to be conducted in seeking that information.

## 1.2 COMPONENTS OF IMAGE PROCESSING SYSTEM:



### **1.2.1 Image sensors:**

Image sensors are used to acquire a digital image, two elements are required to acquire a digital image

- 1) Physical device - It's sensitive to the energy radiated by the object we wish to image
- 2) Digitizer – A device for converting output of physical sensing device into digital form.

### **1.2.2 Image processing software:**

The software for image processing has specialized modules which perform specific tasks. Some software packages have the facility for the user to write code using the specialized modules  
Eg: MATLAB Software

### **1.2.3 Specialized image processing hardware:**

Image processing hardware performs mostly primitive operations such as an arithmetic logic unit(ALU), that performs arithmetic and logical operations in parallel on entire images. For example, ALU is used as averaging images as quickly as they are digitized for the purpose of noise reduction. This type of hardware sometimes is called a front-end subsystem, and its most distinguishing characteristic is speed.

### **1.2.4 Computer:**

The computer is an image processing system is a general purpose computer and can range from a PC to a supercomputer. In dedicated applications, sometimes custom computers are used to achieve a required level of performance. In these systems, almost any well-equipped PC-type machine is suitable for off-line image processing tasks.

### **1.2.5 Software:**

Software for image processing consists of specialized modules that perform specific tasks. A well designed package also induces the capability for the user to write a code that, as a minimum, utilizes the specialized modules. More sophisticated software packages allow the integration of those modules and general-purpose software commands from at least one computer language.

### **1.2.6 Mass Storage:**

Mass storage capability is a must in image processing applications. For example, an image size of 1024X1024 pixels, in which the intensity of each pixel is an 8-bit quantity, requires one megabyte of storage space. When dealing with thousands or even millions of images, providing an adequate storage for image processing can be a challenge. Digital storage for image processing applications falls into three principal categories

- 1) Short term storage – during processing (Computer memory or buffers)
- 2) On-line storage – for relatively fast recall (magnetic discs or optical-media storage)
- 3) Archival storage- infrequent access (magnetic discs or optical disks housed in “jukeboxes”)

### **1.2.7 Image Displays:**

Image displays are used for displaying images (eg; color TV monitors). Monitors are driven by the outputs of image and graphics display cards that are an integral part of the computer system. For image display applications, display cards are required and it's a part of the computer system.

### **1.2.8 Hardcopy:**

Hardcopy devices for recording images include laser printers, film cameras, heat-sensitive devices, inkjet units and digital units such as optical and CD-ROM disks. Film provides the highest possible resolution, but paper is the obvious medium of choice for written material. For presentations, images are displayed on film transparencies or in a digital medium if image projection equipment is used.

### **1.2.9 Networking:**

Networking is a default function in image processing application, because of the large amount of data inherent in image processing applications the key consideration in image transmission is bandwidth. In dedicated networks the bandwidth is not a problem, but communication with remote sites via the internet are not always as efficient. With the help of optical fibers and broadband technologies improving the results.

## **1.3ELEMENTS OF VISUAL PERCEPTION:**

Vision is the most advanced human sense. So images play the most important role in visual perception and also the human visual perception is very important because the selection of image processing techniques is based only on visual judgements.

### **STRUCTURE OF HUMAN EYE:**

The human eye is nearly in the shape of a sphere. Its average diameter is approximately 20mm. The eye, called the *optic globe* is enclosed by three membranes known as,

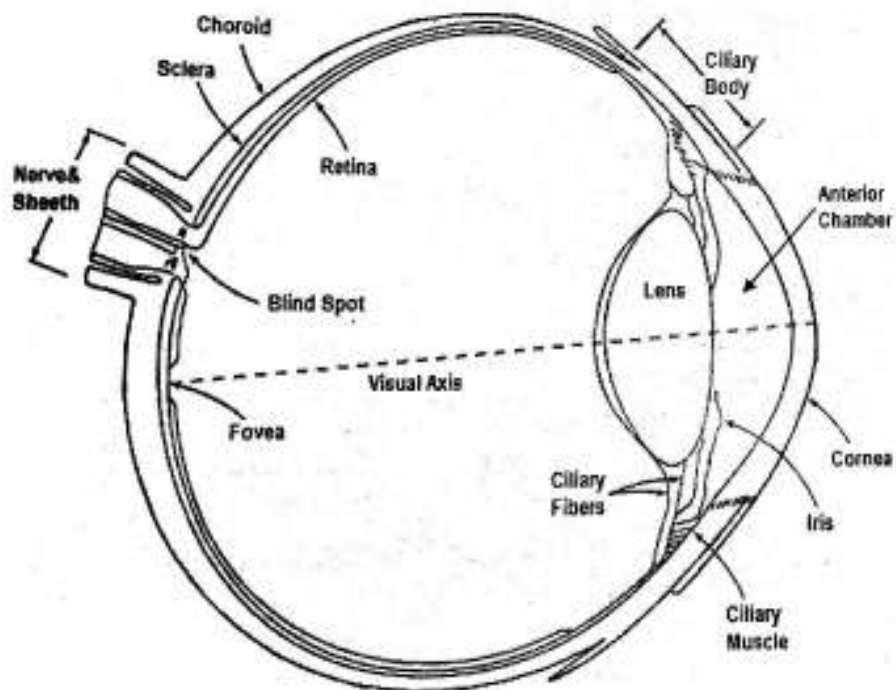
- 1) The Cornea and Sclera outer cover
- 2) The Choroid and
- 3) The Retina

#### **1.3.1 The Cornea and Sclera outer cover:**

- The **Cornea** is a tough, transparent tissue that covers the anterior (Front surface of the eye)
- The **Sclera** is an opaque (not Transparent) membrane that is continuous with the cornea and encloses the remaining portion of the eye.

### 1.3.2 The Choroid:

- The choroid is located directly below the sclera.
- It has a network of blood vessels which are the major nutrition source to eye. Slight injury to choroid can lead to severe eye damage as it causes restriction of blood flow.
- The outer cover of the choroid is heavily pigmented (colored). This reduces the amount of light entering the eye from outside and backscatter within the optical globe.
- The choroid is divided into two at its anterior extreme as,
  - 1) The Ciliary body
  - 2) The Iris Diaphragm



**FIG:***Human eye – cross section*

#### 1.3.2.1 The Iris Diaphragm

- It contracts and expands to control the amount of light enters the eye. The central opening of iris is known as **pupil**, whose diameter varies from **2 to 8 mm**.
- The front of the iris contains the visible pigment of the eye and the back has a black pigment.



### 1.3.2.2 Lens:

- The lens is made up of many layers of fibrous cells. Its suspended (hang up by the fibers attached to the ciliary body) and also it contains 60 to 70% water, 6% fat and more protein.

### 1.3.2.3 Cataracts:

- The lens is colored by a slightly yellow pigmentation. This coloring increases with age, which leads to clouding of lens. ***Excessive clouding*** of lens happens in extreme cases which is known as “Cataracts”.
- This leads to poor color discrimination and loss of clear vision

### 1.3.3 The Retina:

- The retina is a innermost layer or membrane of the eye. It covers the inside of the walls entire posterior (back portion).
- The central part of the retina is called ***fovea***, it's a circular indentation with a diameter of 1.5mm.
- **Light Receptors:** When the eye is properly focused, light from an object outside the eye is imaged on the retina. Light receptors provide this “pattern vision” to the eye. These receptors are distributed over the retina and these receptors are classified into two classes, known as
  - a) Cones
  - b) Rods

#### 1.3.3.1 Cones:

- In each eye there are ***6 to 7 million cones*** are present. They are highly sensitive to color and are located in the fovea
- Each cone is connected with its own nerve end. Therefore, humans can resolve fine details with the use of cones. Cone vision is called ***photopic or bright-light vision***

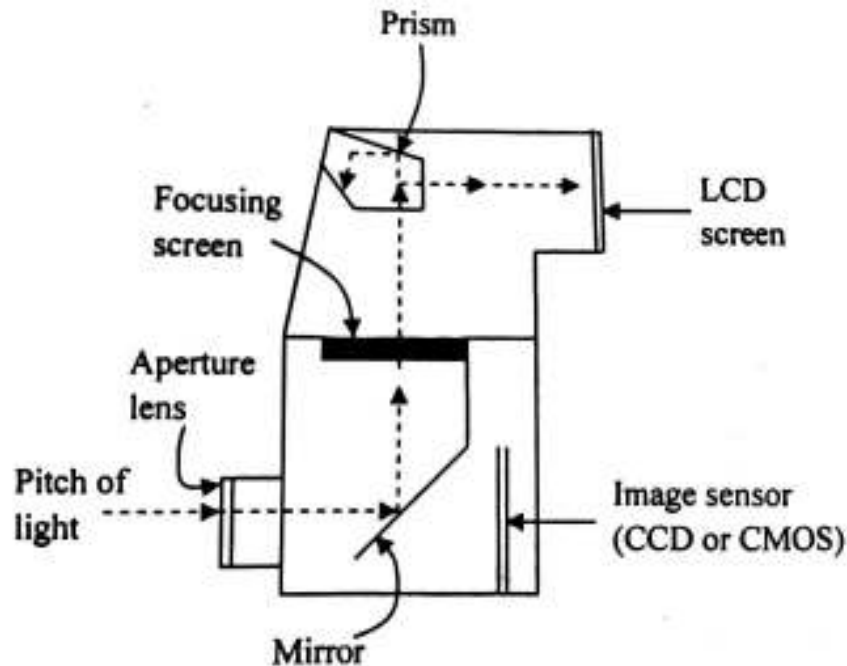
#### 1.3.3.2 Rods:

- The number of rods in each eye ranges from ***75 to 159 million***. They are sensitive to low level illumination (lightings and are not involved in color vision).
- Many number of rods are connected to a common, single nerve. Thus the amount of detail recognizable is less. Therefore, the rods provide only a general, overall picture of the field of view.
- Rods vision are called scotopic or dim-light vision (Due to stimulation of rods, the objects that appear with bright color in daylight, will appear colorless in moonlight. This phenomenon is called as “scotopic or dim-light vision”)

## 1.4 DIGITAL CAMERA:

A digital camera that produces digital images that can be stored in a computer, displayed on a screen and printed. The functioning of digital camera is very simple; it allows to take unlimited photographs.

**1.4.1 Working Principle:** The basic mechanism of digital camera is the technology of converting analog information to digital information. As the smallest unit of an image called a pixel consists of 1's and 0's a digital image is composed of such a string of 1's and 0's



**FIG:**Working of Digital Camera

In a digital camera there are some silicon chips containing *light sensitive sensors*. These sensors gather light that comes into the camera through the aperture and then convert the data into electrical impulses. These impulses are actually the information about the images. Thus the light is converted into electrons by these sensors and each light sensitive spot on the sensor determines the brightness of the image. But digital cameras have three separate sensors: **Red, Green and Blue**. These three colors are combined in different ratios to form a full color space

### **1.4.2 Exposure to Light:**

*Exposure is the duration for which the shutter in a digital camera remains open to allow the light to enter through the aperture.* Exposure of the aperture determines how much light will reach the sensor. Also shutter speed or exposure can be controlled manually or can be automatically. The higher the shutter speed, the lesser the light will reach the sensor and vice versa. In order to take picture in *bright light*, exposure should be less as more light will blur the image and if in *dark*, exposure should be more in order to allow more light to reach sensors

### 1.4.3 Focus:

In digital camera focusing helps an image to have better clarity. The focus is based the quality of the lens, because the lens of the camera controls the way of the light is directed towards the sensors. By using a combination of lenses, distance image can be magnified for a better picture.

### 1.4.4 Photo Storage – Memory:

Digital camera has an internal memory chip that is used to store images that are captured. Internal chips can be supplemented by a removable memory chip for extended storage space. The memory chip stores the digital information about an image that has been collected within the camera. The storage space required is directly proportional to the size of the image.

### 1.4.3 Resolutions:

Resolution is defined as the *amount of detail present in an image*. In digital camera resolutions determines the amount of detail it can capture. Each digital camera has its own particular resolution. If the resolution of the camera is high, the depth, the clarity and minute details of the picture will be better. eg: 256 x 256 or 4064 x 2704 pixels

## **1.5 IMAGE THROUGH SCANNER:**

A scanner is a device that is used for producing an exact digital image replica of a photo, text written in paper, or even an object. This digital image can be saved as a file to your computer and can be used to alter/enhance the image or apply it to the web.

### 1.5.1 Types of Scanners:

- **Drum Scanners** - This scanner is mainly used in the publishing industry. The technology used behind the scanning is called a photomultiplier tube (PMT).
- **Flatbed scanners** - Flatbed scanner is the most commonly used scanning machine nowadays. They are also called desktop scanners. They use Charge-coupled device (CCD) to scan the object
- **Hand-Held Scanners** - to scan documents by dragging the scanner across the surface of the document. This scanning will be effective only if with a steady hand technique, or else the image may seem distorted
- **Film Scanners** – to scan positive and negative photographic images. The film will be inserted into the carrier. It will be moved with a stepper motor and the scanning process will be done with a CCD sensor

### 1.5.2 Working of Flatbed Scanner

Charge-coupled device [CCD] is used in flat bed scanner. A CCD sensor is used to capture the light from the scanner and then convert it into the proportional electrons. The charge developed will be more if the intensity of light that hits on the sensor is more

*Any flatbed scanner will have the following devices.*

- Charge-coupled device (CCD) array
- Scan head
- Stepper motor
- Lens
- Power supply
- Control circuitry
- Interface ports
- Mirrors
- Glass plate
- Lamp
- Filters
- Stabilizer bar
- Belt
- Cover

**Glass plate, Cover:**

A scanner consists of a flat transparent glass bed under which the CCD sensors, lamp, lenses, filters and also mirrors are fixed. The document has to be placed on the glass bed. There will also be a cover to close the scanner. This cover may either be white or black in color. This color helps in providing uniformity in the background. This uniformity will help the scanner software to determine the size of the document to be scanned.

**Lamp:**

The lamp brightens up the text to be scanned. Most scanners use a cold cathode fluorescent lamp (CCFL).

**Stepper Motor:**

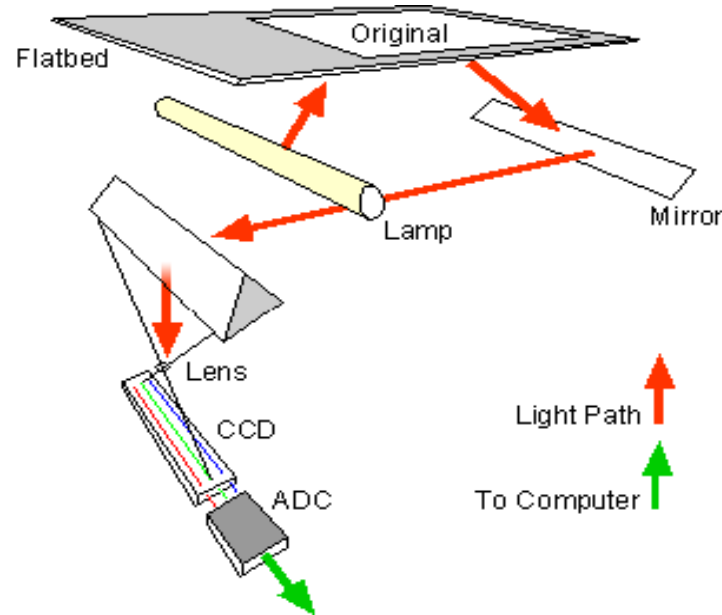
A stepper motor under the scanner moves the scanner head from one end to the other. The movement will be slow and is controlled by a belt.

**Scan Head, CCD, Lens, Stabilize bar:**

The scanner head consists of the mirrors, lens, CCD sensors and also the filter. The scan head moves parallel to the glass bed and that too in a constant path. As deviation may occur in its motion, a stabilizer bar will be provided to compromise it. The scan head moves from one end of the machine to the other. When it has reached the other end the scanning of the document has been completed. For some scanners, a two-way scan is used in which the scan head has to reach its original position to ensure a complete scan.

As the scan head moves under the glass bed, the light from the lamp hits the document and is reflected back with the help of mirrors angled to one another. According to the design of the device there may be either 2-way mirrors or 3-way mirrors. The mirrors will be angled in

such a way that the reflected image will be hitting a smaller surface. In the end, the image will reach a lens which passes it through a filter and causes the image to be focussed on CCD sensors. The CCD sensors convert the light to electrical signals according to its intensity.



**FIG:** *Working of Scanner*

The electrical signals will be converted into image format inside a computer. This reception may also differ according to the variation in the lens and filter design. A method called three pass scanning is commonly used in which each movement of the scan head from one end to another uses each composite color to be passed between the lens and the CCD sensors. After the three composite colors are scanned, the scanner software assembles the three filtered images into one single-color image.

There is also a single pass scanning method in which the image captured by the lens will be split into three pieces. These pieces will pass through any of the color composite filters. The output will then be given to the CCD sensors. Thus, the single-color image will be combined by the scanner

## **1.5 IMAGE SAMPLING AND QUANTIZATION:**

In order to become suitable for digital processing, an image function  $f(x,y)$  must be digitized both spatially and in amplitude. Typically, a frame grabber or digitizer is used to sample and quantize the analogue video signal. Hence in order to create an image which is digital, we need to convert continuous data into digital form. There are two steps in which it is done:

- Sampling
- Quantization

The sampling rate determines the spatial resolution of the digitized image, while the quantization level determines the number of grey levels in the digitized image. A magnitude of the sampled image is expressed as a digital value in image processing. The transition between continuous values of the image function and its digital equivalent is called quantization.

The number of quantization levels should be high enough for human perception of fine shading details in the image. The occurrence of false contours is the main problem in image which has been quantized with insufficient brightness levels.

- **Sampling:** *Process of digitizing the coordinate values is called sampling*
- **Quantization:** *Process of digitizing the amplitude values is called quantization*

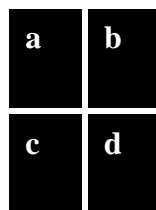
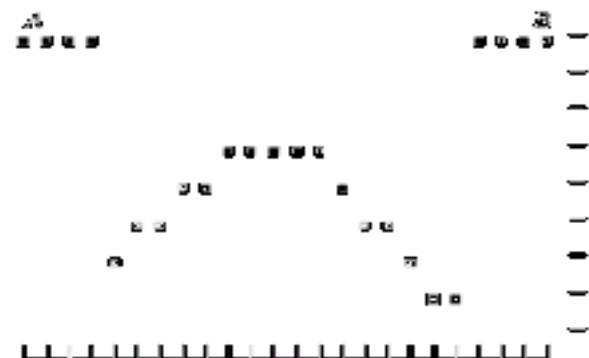
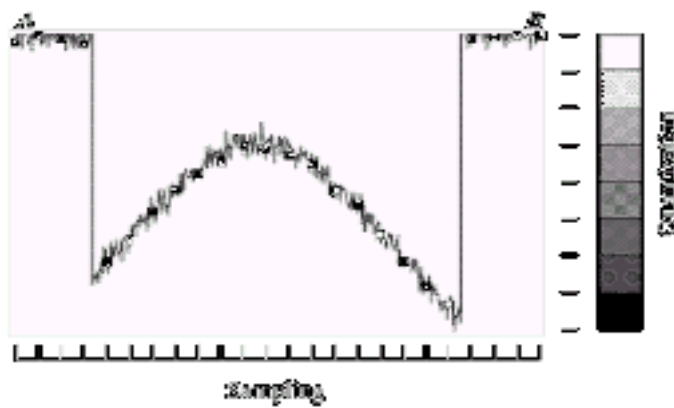
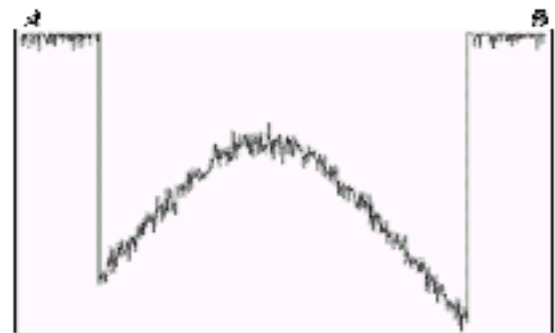
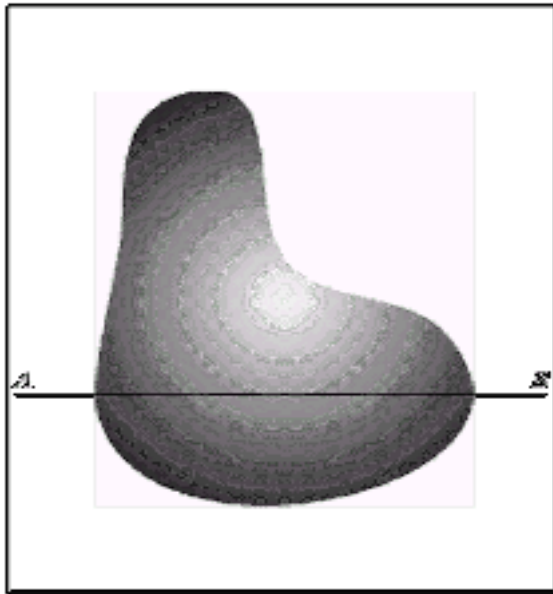
The Basic concepts of image sampling and quantization can be explained with the example given below.

### **Example:**

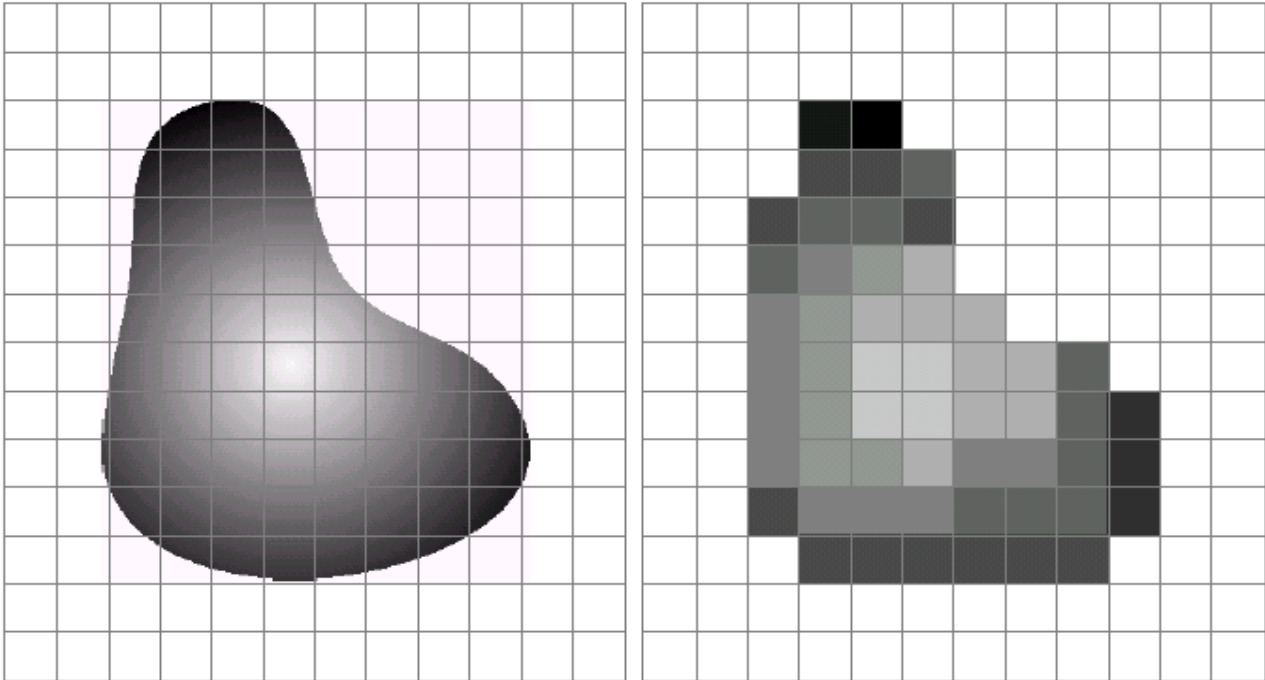
Consider a continuous image  $f(x,y)$  shown in figure (a) which is needed to be converted into digital form. Its gray level plot along line AB is given in figure (b). This image is continuous with respect to the x and y coordinates as well as in amplitude. i.e. gray level values. Therefore, to convert into digital form, both the coordinates and amplitude values should be sampled.

To sample this function, equally spaced samples are taken along the line AB. The samples are shown as small squares in figure (c). The set of these discrete locations give the sampled functions.

Even after sampling, the gray level values of the samples have a continuous range. Therefore, to make it discrete, the samples are needed to be quantized. For this purpose, a gray level scale shown at the figure (c) right side is used. It is divided into eight discrete levels, ranging from black to white. Now, by assigning one of the eight discrete gray levels to each sample, the continuous gray levels are quantized



Generating a digital image. (a) Continuous image. (b) A scaling line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.



a b

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

## **1.7 RELATIONSHIP BETWEEN PIXELS:**

A relation of pixels plays an important role in digital image processing. Where the pixels relations are used for finding the differences of images and also in its sub images.

### **1.7.1 Neighbors of a Pixel:**

A pixel,  $p$  can have three types of neighbors known as,

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

1. 4 – Neighbors,  $N_4(p)$
2. Diagonal Neighbors,  $N_D(p)$
3. 8 – Neighbors,  $N_8(p)$

#### **a. 4 - Neighbors, $N_4(p)$**

The neighbors of a pixel ' $p$ ' at coordinates  $(x, y)$  induces two horizontal and two vertical neighbors. The coordinate of these neighbors is given by,

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



Here, each pixel is at unit distance from  $(x,y)$  as shown in figure. If  $(x,y)$  is on the border of the image, some of the neighbors of pixel 'p' lie outside the digital image.

**b. Diagonal Neighbors,  $N_D(p)$**

The coordinates of the four diagonal neighbors of 'p' are given by

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

Here also, some of the neighbors lie outside the image if  $(x,y)$  is on the border of the image

**c. 8 - Neighbors,  $N_8(p)$**

The diagonal neighbors together with the 4-neighbors are called the 8-neighbors of the pixel 'p'. It's denoted by  $N_8(p)$ .

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

**1.7.2 Adjacency:**

Let  $\{V\}$  be the set of intensity values used to define adjacency. In a binary image  $V=\{1\}$  if we are referring to adjacency of pixels with value 1. In a gray-scale image, the idea is the same, but set  $\{V\}$  typically contains more elements. For example, in the adjacency of pixels with a range of possible intensity values 0 to 255, set  $V$  could be any subset of these 256 values. The adjacency has been classified into three types,

1. 4-Adjacency
2. 8-Adjacency
3. m-Adjacency (or) Mixed-Adjacency

Let  $\{V\}$  be the set of gray levels used to define adjacency

**a. 4-Adjacency**

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

**b. 8-Adjacency**

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

**c. m-Adjacency**

Mixed adjacency is a modification of 8-adjacency. It is used to remove the ambiguities present in 8-adjacency.

Two pixels p and q with values from  $\{V\}$  are m-adjacent if the following conditions are satisfied.

- 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  $V$ ).

### 1.7.3 Connectivity:

Two pixels  $p$  and  $q$  are said to be connected if

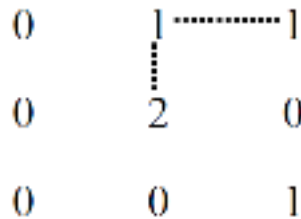
- they are neighbors and
- their gray levels satisfy a specified similarity criterion (E.g: if their gray levels are equal)

The connectivity has been classified into three types,

1. 4-Connectivity
2. 8-Connectivity
3. m-Connectivity (or) Mixed-Connectivity

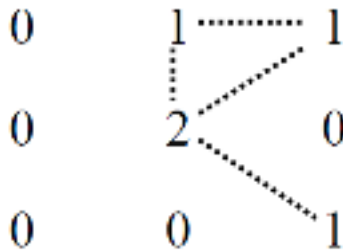
#### a. 4-Connectivity

Two pixels  $p$  and  $q$ , both having values from a set  $V$  are 4-connected if  $q$  is from the set  $N_4(p)$ .



#### b. 8-Connectivity

Two pixels  $p$  and  $q$ , both having values from a set  $V$  are 4-connected if  $q$  is from the set  $N_8(p)$ .



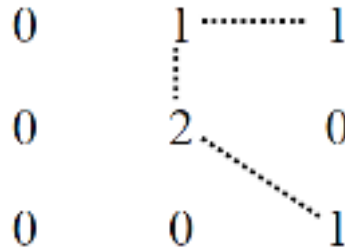
#### c. m-Connectivity

Mixed connectivity is a modification of 8-adjacency. It is used to remove the ambiguities present in 8-connectivity.

Two pixels  $p$  and  $q$  with values from  $\{V\}$  are m-connectivity if the following conditions are satisfied.

- $q$  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  $V$ ).



#### 1.7.4 Paths and Path length:

A path is also known as digital path or curve. A path from pixel,  $p$  with coordinates  $(x,y)$  to pixel  $q$  with coordinates  $(s,t)$  is defined as the sequence of different pixels with coordinates.

$$(X_0, Y_0), (X_1, Y_1), \dots, (X_n, Y_n)$$

Where,  $(X_0, Y_0) = (x, y)$  and  $(X_n, Y_n) = (s, t)$ ;  $(X_i, Y_i)$  and  $(X_{i-1}, Y_{i-1})$  are adjacent for  $1 \leq i \leq n$

- **Path Length:**

Path length is the number of pixels present in a path. It's is given by the value of 'n' here.

- **Closed Path:**

In a path, if  $(X_0, Y_0) = (X_n, Y_n)$  i.e. the first and last pixel are the same, it's known as a closed path

According to the adjacency present, paths can be classified as:

1. 4 – path
2. 8 – path
3. m – path

#### 1.7.5 Region, Boundary and Edges:

- In an image  $I$  of pixels, a subset  $R$  of pixels in an image  $I$  is called a Region of the image if  $R$  is a connected set.
- Boundary is also known as border or contour. 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  $R$  is an entire image, its boundary is defined as the set of pixels in the first and last rows and columns of the image.
- An edge can be defined as a set of contiguous pixel positions where an abrupt change of intensity (gray or color) values occur

### 1.7.6 Distance Measure:

Distance measures are used to determine the distance between two different pixels in a same image. Various distance measures are used to determine the distance between different pixels.

**Conditions:** Consider three pixels p, q and z, p has coordinates (x, y), q has coordinates (s, t) and z has coordinates (v, w). For these three pixels **D** is a **Distance function or metric** if

- $D(p, q) \geq 0$ , [ $D(p, q)=0$  if  $p = q$ ]
- $D(p, q) = D(q, p)$  and
- $D(p, z) \leq D(p, q) + D(q, z)$

#### Types:

- Euclidean Distance
- City – Block (or) D4 Distance
- Chessboard (or) D8 Distance
- Quasi-Euclidean Distance
- Dm Distance

- a. **Euclidean Distance:** The Euclidean distance is the straight-line distance between two pixels.

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

0	0	0
0	1	0
0	0	0

Image

1.41	1.0	1.41
1.0	0.0	1.0
1.41	1.0	1.41

Distance Transform

- b. **City – Distance:** The city block distance metric measures the path between the pixels based on a 4-connected neighborhood. Pixels whose edges touch are 1 unit apart; pixels diagonally touching are 2 units apart.

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

0	0	0
0	1	0
0	0	0

Image

2	1	2
1	0	1
2	1	2

Distance Transform

- c. **Chessboard Distance:** The chessboard distance metric measures the path between the pixels based on an 8-connected neighborhood. Pixels whose edges or corners touch are 1 unit apart

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

0	0	0
0	1	0
0	0	0

Image

1	1	1
1	0	1
1	1	1

Distance Transform

- d. **Quasi – Euclidean Distance:** The quasi-Euclidean metric measures the total Euclidean distance along a set of horizontal, vertical, and diagonal line segments.

$$D_{qe}(p, q) = \sqrt{2} \cdot \lfloor (x-s) + (y-t) \rfloor$$

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

Image

2.8	2.4	2.0	2.4	2.8
2.4	1.4	1.0	1.4	2.4
2.0	1.0	0	1.0	2.0
2.4	1.4	1.0	1.4	2.4
2.8	2.4	2.0	2.4	2.8

Distance Transform

## **1.8 CONCEPTS OF GRAYLEVELS:**

Gray level resolution refers to the predictable or deterministic change in the shades or levels of gray in an image. In short gray level resolution is equal to the number of bits per pixel. The number of different colors in an image is depends on the depth of color or bits per pixel.

The mathematical relation that can be established between gray level resolution and bits per pixel can be given as.

$$L = 2^k$$

In this equation L refers to number of gray levels. It can also be defined as the shades of gray. And k refers to bpp or bits per pixel. So the 2 raise to the power of bits per pixel is equal to the gray level resolution.

### **1.8.1 Gray level to binary conversion:**

#### **THRESHOLD METHOD**

The threshold method uses a threshold value which converts the grayscale image into binary image. The output image replaces all pixels in the input image with luminance greater than the threshold value with the value 1 (white) and replaces all other pixels with the value 0 (black).