UNIT I
INTRODUCTION

Digital image processing, Examples of fields that use digital image processing, fundamental steps in digital image processing, components of image processing system, Image sensing and Acquisition, sampling and quantization , basic relationships between pixels.

1.1 Digital image processing

- 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 pairof coordinates (x, y) is called the *intensity* or *gray level* of the image at that point.
- When x, y, and the amplitude values of f are all finite, discrete quantities, we call the image a *digital image* .
- The field of digital image processing refers to processing digital images bymeans of a digital computer.
- A digital image is composed of a finite number of elements, each of which has a particular location and value.
- These elements are referred to as picture elements, image elements, pels,and pixels.
- *Pixel* is the term most widely used to denote the elements of a digital image.
- There is one useful paradigm is to consider three types of computerized processes : low-, mid-, and high-level processes.
- **Low level processes** involve primitive operations such as image preprocessing to reduce noise, contrast enhancement, and image sharpening. A low-level process is characterized by the fact that both its inputs and outputs are images.
- **Mid-level processing** on images involves tasks such as segmentation (partitioning an image into regions or objects), description of thoseobjects to reduce them to a form suitable for computer processing, and classification (recognition) of individual objects. A mid -level process is characterized by the fact that its inputs generally are images, but its outputs are attributes extracted from those images (e.g., edges, contours, and the identity of individual objects).
- **higher -level processing** involves "making sense" of an ensemble of recognized objects, as in image analysis, and, at the far end of the continuum, performing the cogn itive functions normally associated with vision and, in addition, encompasses processes that extract attributes from images, up to and including the recognition of individual objects.

1.2 Examples of fields that use digital image processing

- The image processing applications can categorize images according totheir source (e.g., visual, X -ray, and so on).
- The principal energy source for images in use today is the electromagnetic energy spectrum.
- Other important sources of energy include acoustic, ultrasonic, andelectronic (in the form of electron beams used in electron microscopy).

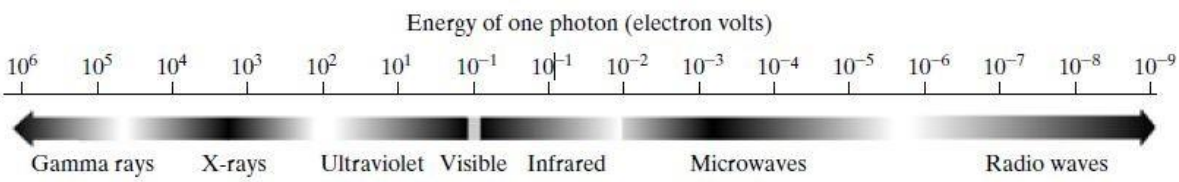


Fig 1.2 : Electromagnetic spectrum

1.2.1 Gamma -Ray Imaging:

- Major uses of imaging based on gamma rays include nuclear medicine and astronomical observations.
- 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. Figure 1. 2.1(a) shows an image of a complete bone scan obtained by using gamma-ray imaging. Images of this sort are used to locate sites of bone pathology, such as infections or tumors.
- Figure 1. 2.1(b) shows another major modality of nuclear imaging called positron emission tomography (PET).
- The principle is the same as with X -ray tomography. However, instead of using an external source of X -ray energy, the patient is given a radioactive isotope that emits positrons as it decays. When a positron meets an electron, both are annihilated and two gamma rays are given

off. These are detected and a tomographic image is created using the basic principles of tomography. The image shown in Fig. 1.2.1(b) is one sample of a sequence that constitutes a 3 -D rendition of the patient. This image shows a tumor in the brain and one in the lung, easily visible as small white masses.

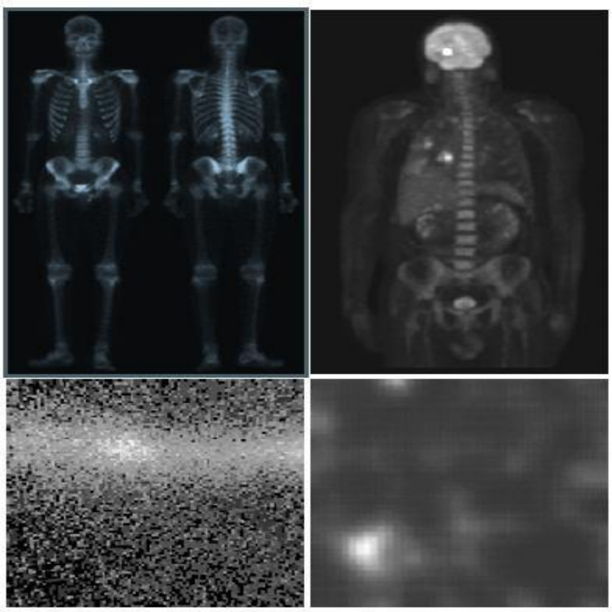


Fig 1.2.1: Examples of gamma -ray imaging

1.2.2 X-ray Imaging:

- X-rays for medical and industrial imaging are generated using an X -ray tube, which is a vacuum tube with a cathode and anode.
- The cathode is heated, ca using free electrons to be released. These electrons flow at high speed to the positively charged anode. When the electrons strike a nucleus, energy is released in the form of X -ray radiation.

- The energy (penetrating power) of the X -rays is controlled by a voltage applied across the anode, and the number of X -rays is controlled by a current applied to the filament in the cathode
- Figure 1.2.2(a) shows a familiar chest X -ray generated simply by placing the patient between an X -ray source and a film sensitive to X-ray energy. The intensity of the X - rays is modified by absorption as they pass through the patient, and the resulting energy falling on the film develops it, much in the same way that light develops photographic film.
- In digital radiography, digital images are obtained by one of two methods: (1) by digitizing X-ray films; or (2) by having the X -rays that pass throughthe patient fall directly onto devices (such as a phosphor screen) that convert X-rays to light. The light signal in turn is captured by a light- sensitive digitizing system.
- Angiography is another major application in an area called contrast enhancement radiography. This procedure is used to obtain images (called angiograms) of blood vessels.
- A catheter (a small, flexible, hollow tube) is inserted, for example, into an artery or vein in the groin. The catheter is threaded into the blood vessel and guided to the area to be studied. When the catheter reaches the site under investigation, an X -ray contrast medium is injected through the catheter. This enhances contrast of the blood vessels and enables the radiologist to see any irregularities or blockages.
- Figure 1.2.2(b) shows an example of an aortic angiogram. The catheter can be seen being inserted into the large blood vessel on the lower l eft ofthe picture. Note the high contrast of the large vessel as the contrastmedium flows up in the direction of the kidneys, which are also visible in the image.
- Techniques similar to the ones just discussed, but generally involvinghigher energy X - rays, are applicable in industrial processes. Figure

1.2.2(d) shows an X -ray image of an electronic circuit board. Such images, representative of literally hundreds of industrial applications of X-rays, are used to examine circuit boards for flaws in manufacturing, such as missing components or broken traces.

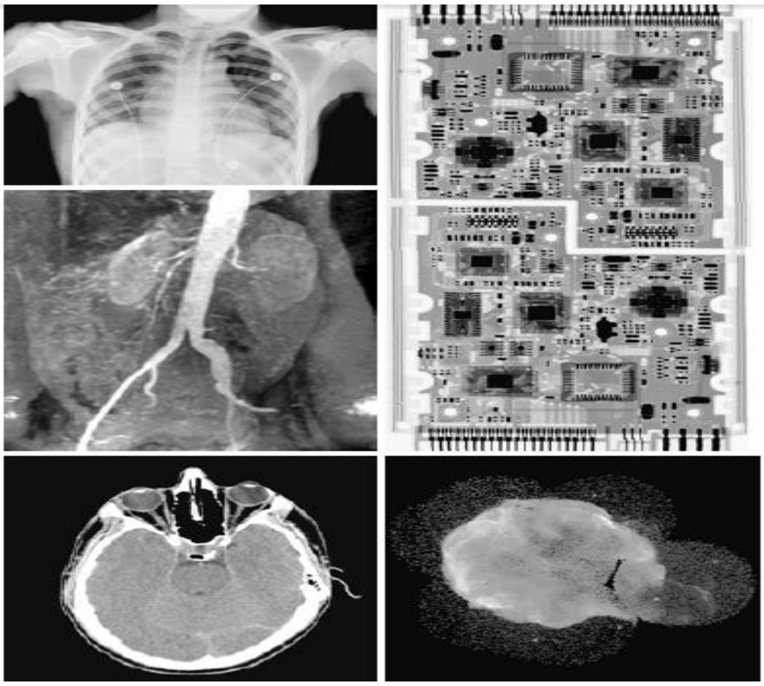


Fig 1.2.2 : Examples of X -ray imaging

1.2.3 Imaging in the Ultraviolet Band:

Applications of ultraviolet "light" are varied. They include lithography, industrial inspection, microscopy, lasers, biological imaging, and astronomical observations.

- Ultraviolet light is used in fluorescence microscopy. Fluorescence is a phenomenon discovered in the middle of the nineteenth century, when it was first observed that the mineral fluorspar fluoresces when ultravioletlight is directed upon it.

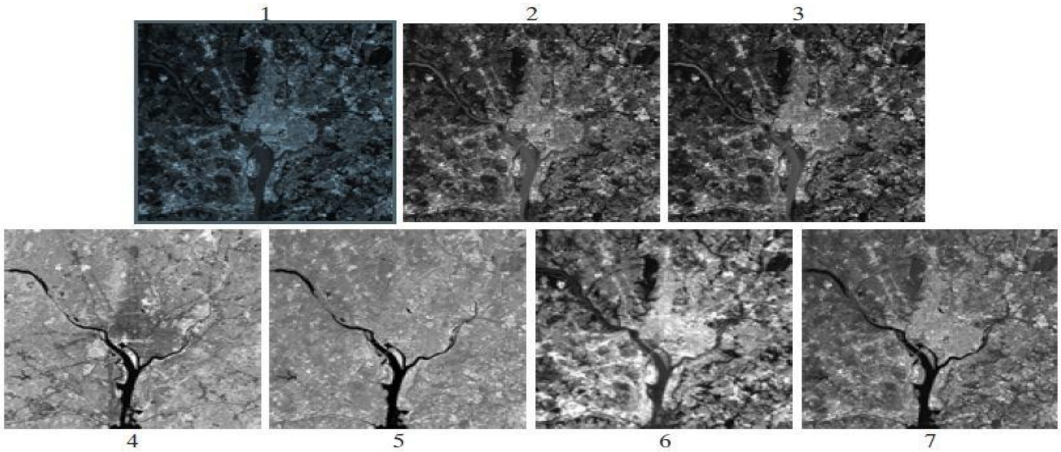
Imaging in the Visible and Infrared Bands:

Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

Table 1.1: Thematic bands in NASA's LANDSAT satellite

- Major area of visual processing is remote sensing, which usually includes several bands in the visual and infrared regions of the spectrum asshown in the figure 1.2.3

Fig 1.2.3: LANDSAT satellite images



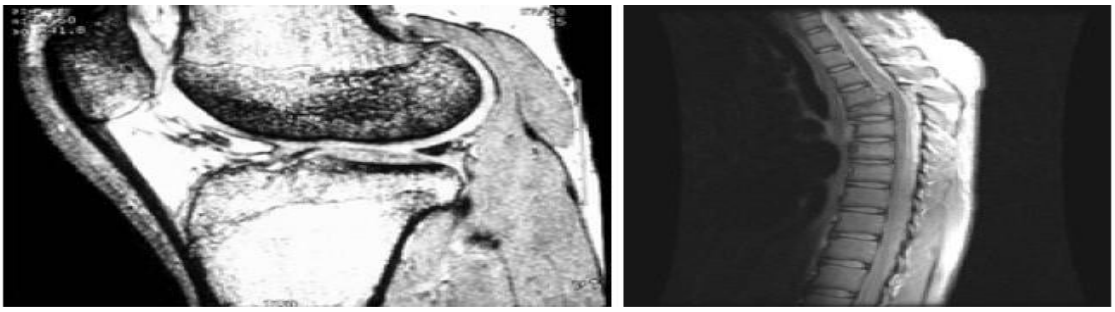
1.2.4 Imaging in the Microwave Band:

- The dominant application of imaging in the microwave band is radar. The unique feature of imaging radar is its ability to collect data over virtually any region at any time, regardless of weather or ambient lighting conditions.

- Some radar waves can penetrate clouds, and under certain conditionscan also see through vegetation, ice, and extremely dry sand.
- In many cases, radar is the only way to explore inaccessible regions ofthe Earth's surface. Imaging radar works like a flash camera in that it provides its own illumination (microwave pulses) to illuminate an area on the ground and take a snapshot image. Instead of a camera lens, radar uses an antenna and digital computer processing to record its images.
- In a radar image, one can see only the microwave energy that was reflected back toward the radar antenna.

1.2.5 Imaging in the Radio Band:

- The major applications of imaging in the radi o band are in medicine and astronomy.
- In medicine radio waves are used in magnetic resonance imaging (MRI). This technique places a patient in a powerful magnet and passes radio waves through his or her body in short pulses. Each pulse causes a responding pulse of radio waves to be emitted by the patient's tissues. The location from which these signals originate and their strength are determined by a computer, which produces a two -dimensional picture ofa section of the patient. MRI can produce pictures in any plane. Figure 1.2.5 shows MRI images of a human knee and spine.



a b

Fig 1.2.5: MRI images of a human

1.3 Fundamental St eps in Digital Image Processing

- Image acquisition is the first process shown in figure .
- The acquisition could be as simple as being given an image that is already in digital form. Generally, the image acquisition stage involves preprocessing, such as scaling.
- Image enhancement to bring out detail that is obscured, or simply to highlight certain features of interest in an image. A famil iar example of enhancement is when we increase the contrast of an image because “it looks better.” It is important to keep in mind that enhancement is a very subjective area of image processing.
- Image restoration subjective, image restoration is objective, in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image degradation. Enhancement, on the other hand, is based on human subjective preferences regarding what constitutes a “good” enhancement result.
- 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. Compression, as the na me implies, deals with techniques for reducing the storage required to save an image, or the bandwidth required to transmit it.
- 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. In general, autonomous segmentation is one of the most difficult tasks in digital image processing. A rugged segmentation procedure

brings the process a long way t oward successful solution of imagingproblems that require objects to be identified individually.

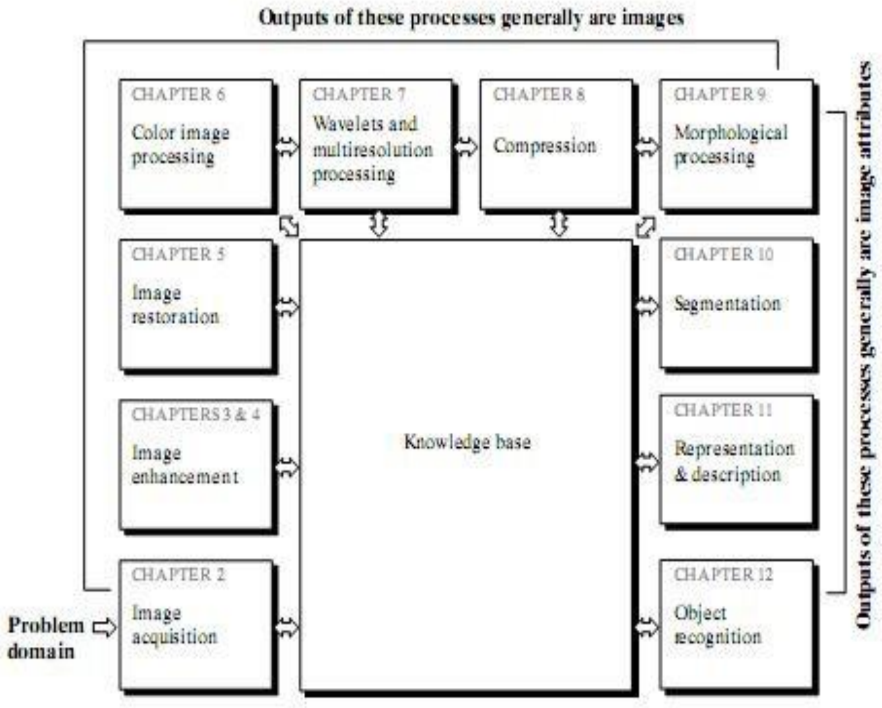


Fig 1.3 : Fundamental steps in Digital Image Processing

- Representation and description almost always follow the output of a segmentation stage, which usua lly is raw pixel data, constituting either the boundary of a region (i.e., the set of pixels separating one image region from another) or all the points in the region itself. The first decision that must be made is whether the data should be represented as a boundary or as a complete region. 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 textu re or skeletal shape. Description, also called feature selection, deals with extracting attributes that result in some quantitative information of interest or are basic fordifferentiating one class of objects from another.

- Recognition is the process that assigns a label (e.g., “vehicle”) to an object based on its descriptors.

1.4 Component s of an Image Processing System

- Figure 3 shows the basic components used for digital image processing.
- With reference to sensing, two elements are required to acquire digital images. The first is a physical device that is sensitive to the energy radiated by the object we wish to image. The second, called a digitizer, is a device for converting the output of the physical sensing device into digital form.
- Specialized ima ge processing hardware usually consists of the digitizer just mentioned, plus hardware that performs other primitive operations, such as an arithmetic logic unit (ALU), which performs arithmetic and logical operations in parallel on entire images. One exam ple of how an ALU is used is in averaging images as quickly as they are digitized, for the purpose of noise reduction.
- The computer in an image processing system is a general -purposecomputer and can range from a PC to a supercomputer.
- Software for image processing consists of specialized modules that perform specific tasks. A well-designed package also includes the capability for the user to write 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.

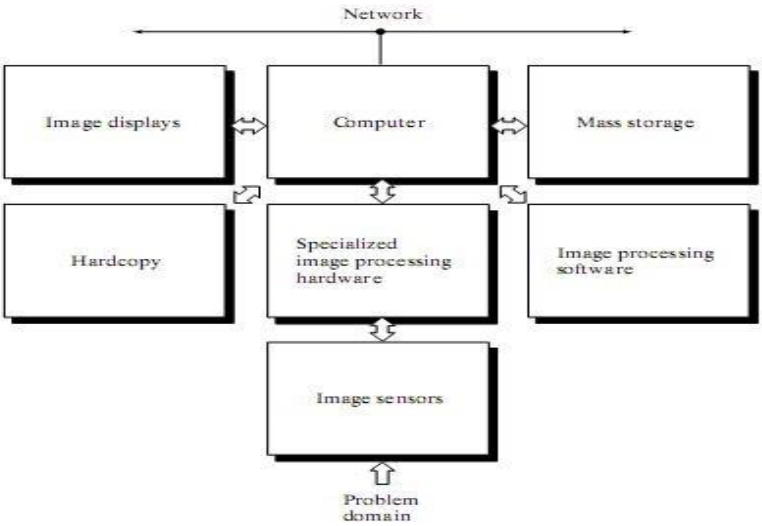


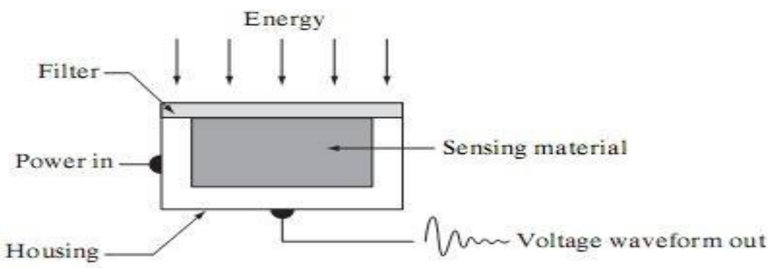
Fig 1.4.1 : Components of a general purpose Image Processing System

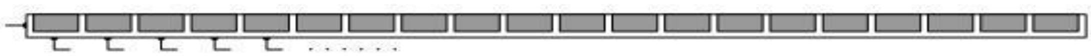
- Mass storage capability is a must in image processing applications. An image of size 1024*1024 pixels, in which the intensity of each pixel is an 8-bit quantity, requires one megabyte of storage space if the image is notcompressed.
- Digital storage for image processing applications falls into three principal categories:
    (1) short-term storage for use during processing,
    (2) on-line storage for relatively fast re -call, and
    (3) archival storage, characterized by infrequent access.
- Image displays in use today are mainly color (preferably flat screen) TV monitors. Monitors are driven by the outputs of image and graphics display cards that are an integral part of the computer system.
- 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.

- Networking is almost a default function in any computer system in use today. Because of the large amount of data inherent in image processing applications, the key consideration in image transmission is bandwidth.

1.5 Image Sensing and Acquisiti on

- An image is a combination of an "illumination" source and the reflection or absorption of energy from that source by the elements of the "scene" being imaged.
- Depending on the nature of the source, illumination energy is reflected from, or transmitted through, objects.
- In some applications, the reflected or transmitted energy is focused onto a photo converter (e.g., a phosphor screen), which converts the energy into visible light. Electron microscopy and some applications of gamma imaging use this appr oach.
- Figure shows the three principal sensor arrangements used to transform illumination energy into digital images. The idea is simple: Incoming energy is transformed into a voltage by the combination of input electrical power and sensor material that is responsive to the particular type of energy being detected. The output voltage waveform is the response of the sensor(s), and a digital quantity is obtained from each sensor by digitizing its response.





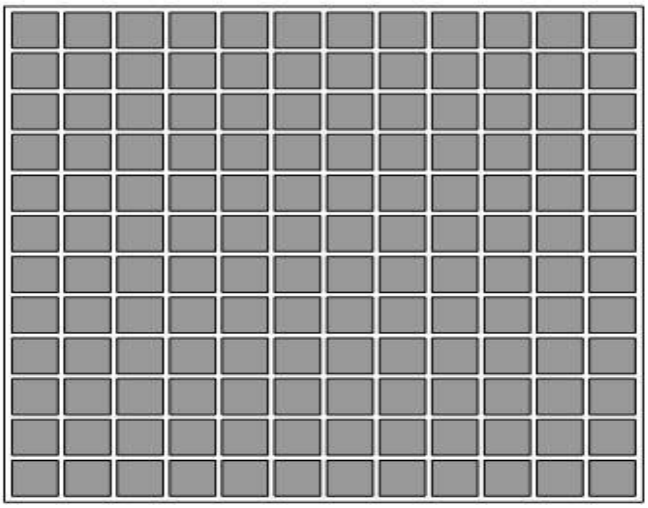


Fig 1.5.1: (a) Single imaging Sensor (b) Line sensor (c) Array sensor(1) Image Acquisition Using a Single Sensor:

- Figure 1.5.1 (a) shows the components of a single sensor. The mostfamiliar sensor of this type is the photodiode, which is constructed of silicon materials and whose output voltage waveform i s proportional tolight. The use of a filter in front of a sensor improves selectivity. For example, a green (pass) filter in front of a light sensor favors light in the green band of the color spectrum.
- The sensor output will be stronger for green light than for other components in the visible spectrum.

- In order to generate a 2 -D image using a single sensor, there has to be relative displacements in both the x - and y-directions between the sensor and the area to be imaged.
- Figure shows an arrangement use d in high-precision scanning, where a film negative is mounted onto a drum whose mechanical rotation provides displacement in one dimension. The single sensor is mounted on a lead screw that provides motion in the perpendicular direction. Since mechanical motion can be controlled with high precision, this method is an inexpensive (but slow) way to obtain high -resolution images. Other similar mechanical arrangements use a flat bed, with the sensor moving in two linear directions. These types of mechanical digitizers sometimes are referred to as microdensitometers.

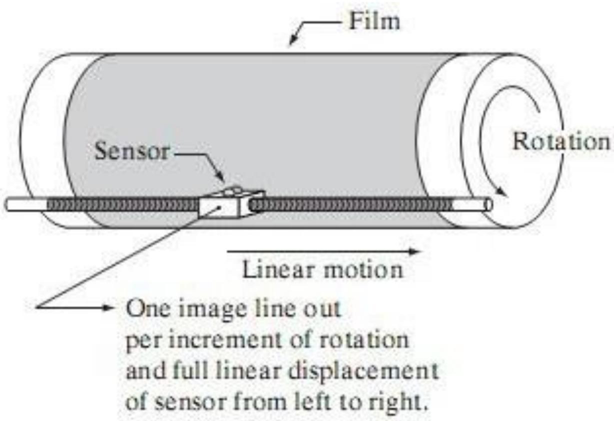


Fig 1.5.2: Combining a single sensor with motion to generate a 2 -D image

(2) Image Acquisition Using Sensor Strips:

- A geometry that is used much more frequently than single sensors consists of an in-line arrangement of sensors in the form of a sensor strip, as Fig. 1.5.1 (b) shows.
- The strip provides imaging elements in one direction. Motion perpendicular to the strip provides imaging in the other direction, as

shown in Fig. 1.5.3 (a).This is the type of arrangement used in most flatbed scanners.

- Sensor strips mounted in a ring configuration are used in medical and industrial imaging to obtain cross-sectional ("slice") images of 3-D objects, as Fig. 1.5.3 (b) shows.
- A rotating X-ray source provides illumination and the portion of the sensors opposite the source collect the X-ray energy that pass throughthe object(the sensors obviously have to be sensitive to X-rayenergy). This is the basis for medical and industrial computerized axial tomography (CAT). It is important to note that the output of the sensors must be processed by reconstruction algorithms whose objective is to transform the sensed data into meaningful cross-sectional images asshown in Fig. 1.5.3 (b).

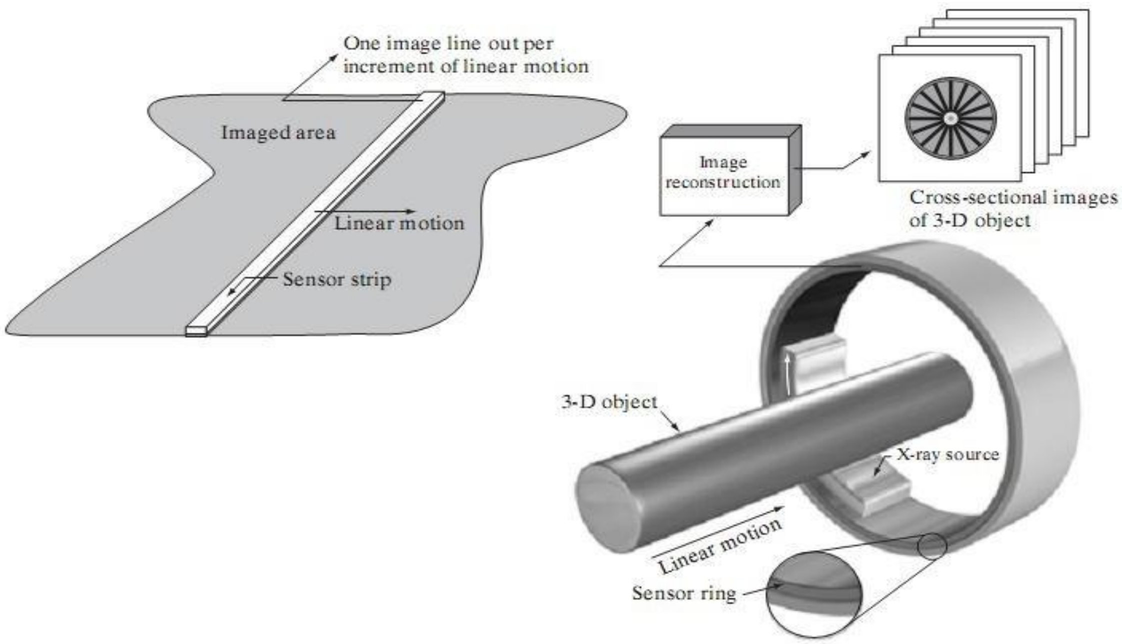


Fig 1.5 .3 :(a) Image acquisition using a linear sensor strip (b) Imageacquisition using a circular sensor strip.

(3) Image Acquisition Using Sensor Arrays:

- Figure 1.5.1 (c) shows individual sensors arranged in the form of a 2 -D array. Numerous electromagnetic and some ultrasonic sensing devices frequently are arranged in an array format.
- A typical sensor for these cameras is a CCD array, which can be manufactured with a broad range of sensing properties and can be packaged in rugged arrays of 4000 * 4000 elements or more.
- CCD sensors are used widely in digital cameras and other light sensing instruments. The response of each sensor is proportional to the integral of the light energy projected onto the surface of the sensor, a property that is used in astronomical and other applications requiring low noise images.
- The sensor array shown in Fig. 1.5.4 (c) is two dimensional, its key advantage is that a complete image can be obtained by focusing the energy pattern onto the surface of the array.
- The first function performed by the imaging system shown in Fig1. 5.4 (c)is to collect the incoming energy and focus it onto an image plane.
- If the illumination is light, the front end of the imaging system is a lens, which projects the viewed scene onto the lens focal plane. The sensor array, which is coincident with the focal plane, produces outputs proportional to the integral of the light received at each sensor.
- Digital and analog circuitry sweep these outputs and converts them to a video signal, which is then digitized by another sectio n of the imaging system. The output is a digital image, as shown diagrammatically in Fig.
  1.5.4 (e).

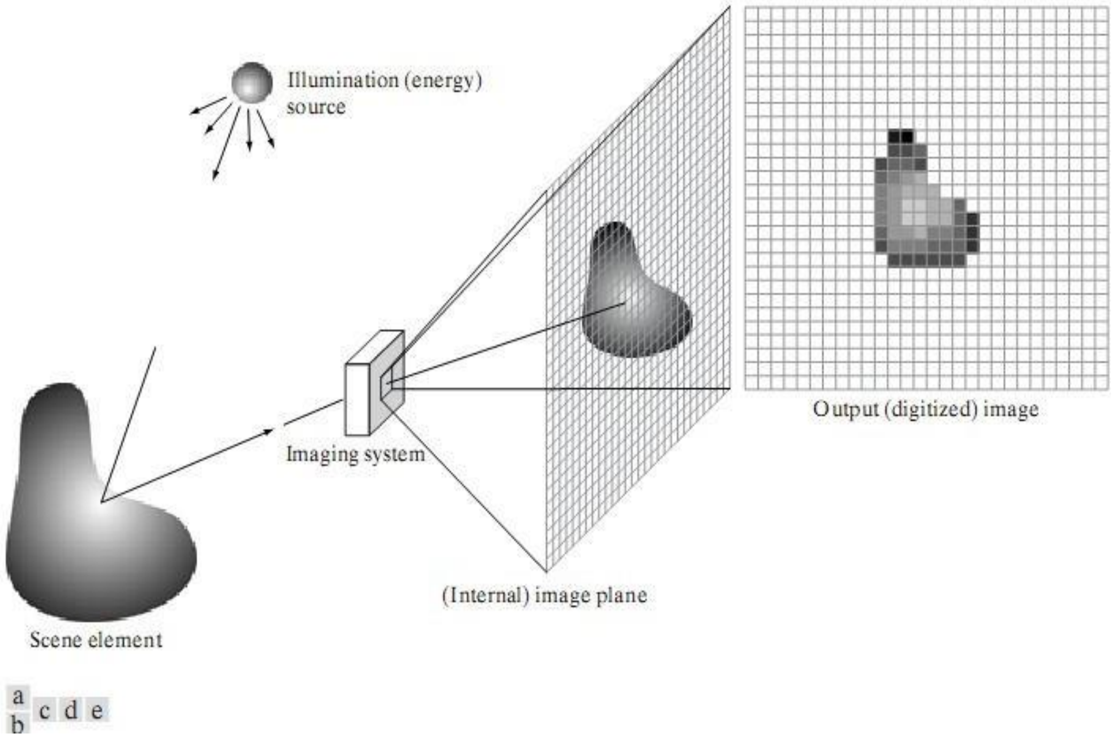


Fig1. 5.4 : An example of the digital image acquisition process (a) Energy ("illumination") source (b) An element of a scene (c) Imaging system (d)Projection of the scene onto the image plane (e) Digitized image

1.6 Image Sampling and Quantization

- The output of most sensors is a continuous voltage waveform whose amplitude and spatial behavior are related to the physical phenomenonbeing sensed. To create a digital image, we need to convert the continuous sensed data into digital form. This involves two processes: sampling and quantization.

Basic Concepts in Sampling and Quantization:

- The basic idea behind sampling and quantization is illustrated in figure . Figure (a) shows a continuous image, f(x, y), that we want to convert to digital form. An image may be continuous with respect to the x - and y-coordinates, and also in amplitude.

- To convert it to digital form, we have to sample the function in both coordinates and in amplitude.
- Digitizing the coordinate values is called *sampling* .
- Digitizing the amplitude values is called *quantization* .
- The one-dimensional function shown in Fig. (b) is a plot of amplitude (gray level) values of the continuous image along the line segment AB in Fig.(a).The random variations are due to image noise.
- To sample this function, we take equally spaced samples along line AB,as shown in Fig. (c).The location of each sample is given by a vertical tick mark in the bottom part of the f igure. The samples are shown as small white squares superimposed on the function.
- The right side of Fig. (c) shows the gray -level scale divided into eight discrete levels, ranging from black to white. The vertical tick marks indicate the specific value as signed to each of the eight gray levels. The continuous gray levels are quantized simply by assigning one of the eight discrete gray levels to each sample. The assignment is made depending on the vertical proximity of a sample to a vertical tick mark. The digital samples resulting from both sampling an d quantization are shown in Fig 1.6.1 (d). Starting at the top of the image and carrying out this procedure line by line produces a two-dimensional digital image.
- When an image is generated by a single sensing element combined withmechanical motion, the output of the sensor is quantized in the manner described above.
- The sampling is accomplished by selecting the number of individualmechanical increments at which we activate the sensor to collect data.
- Mechanical motion can be made very exact so, in principle; there isalmost no limit as to how fine we can sample an image.

- When a sensing strip is used for image acquisition, the number of sensors in the strip establishes the sampling limitations in one image direction. Mechanical motion in the other direction can be controlled more accurately, but it makes little sense to try to achieve sampling density in one direction that exceeds the sampling limits established by the number of sensors in the other.
- Quantization of the sensor outputs completes the process of generating adigital image.

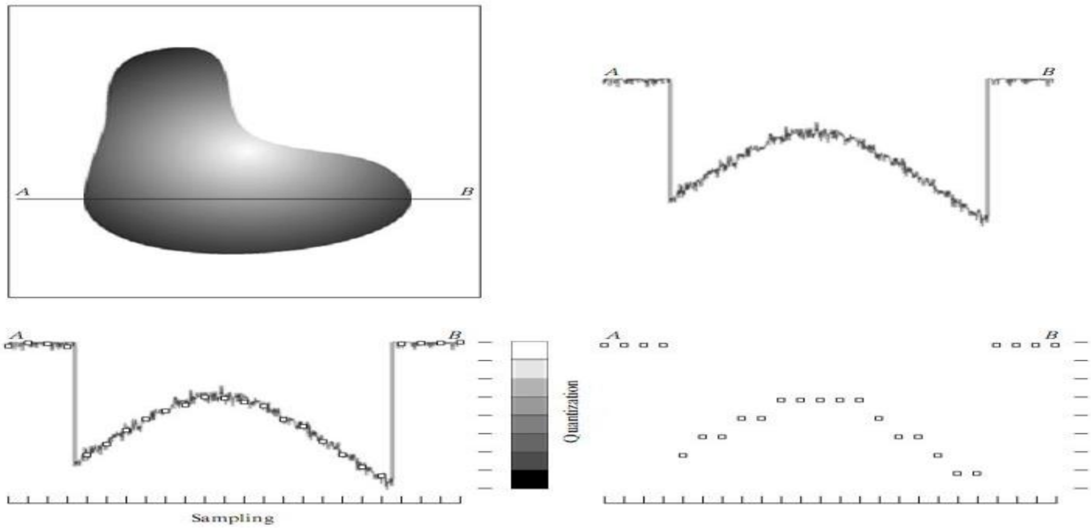


Fig 1.6.1: Generating a digital image (a) Continuous image (b) A scan line from A to Bin the continuous image, used to illustrate the concepts of sampling and quantization (c) Sampling and quantization. (d) Digital scan line

- When a sensing array is used for image acquisition, there is no motion and the number of sensors in the array establishes the limits of sampling in both directions. Figure 6.2 illustrates this concept. Figure 1.6.1(a) shows a continuous image projected onto the plane of an array sensor. Figure 1.6.2(b) shows the image after sampling and quantization.

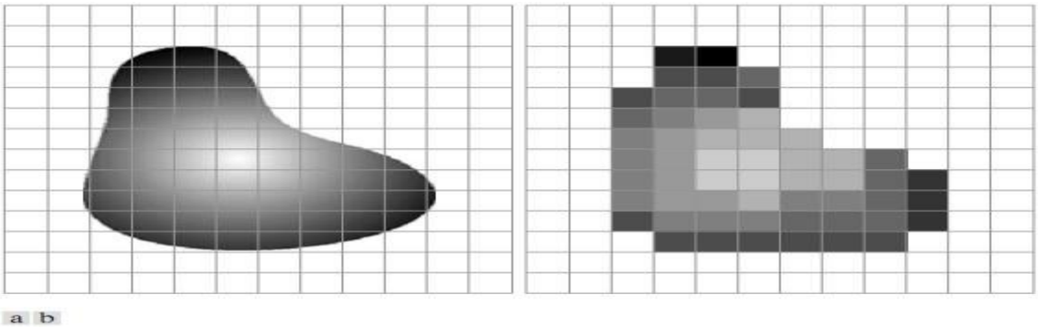


Fig1 .6.2. (a) Continuos image projected onto a sensor array (b) Result ofimage sampling and quantization.

Representing Digital Images:

- We will use two principal ways to represent digital images. Assume that an image f(x, y) is sampled so that the resulting digital image has M rows and N columns. The values of the coordinates (x, y) now become discrete quantities.
- Thus, the values of the coordinates at the origin are (x, y) = (0, 0). The next coordinate values along the first row of the image are represented as(x, y) = (0, 1). It is important to keep in mind that the notation (0, 1) is used to signify the second sample along the first row. It does not mean that these are the actual values of physical coordinates when the image was sampled. Figure 1 shows the coordinate convention used. 7397022122

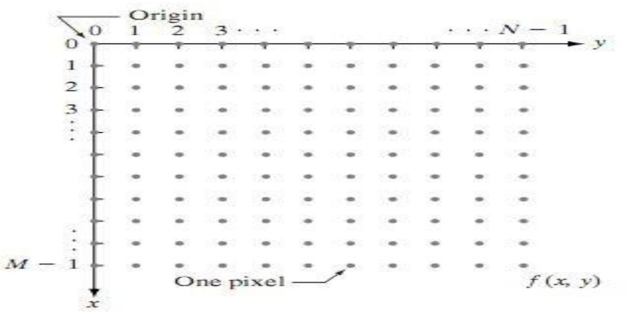


Fig1.6.3: Coordinate convention used to represent digita l images

- The notation introduced in the preceding paragraph allows us to writethe complete M*N digital image in the following compact matrix form.

$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}.$$

- The right side of this equation is by definition a digital image. Each element of this matrix array is called an image element, picture element, pixel, or pel.

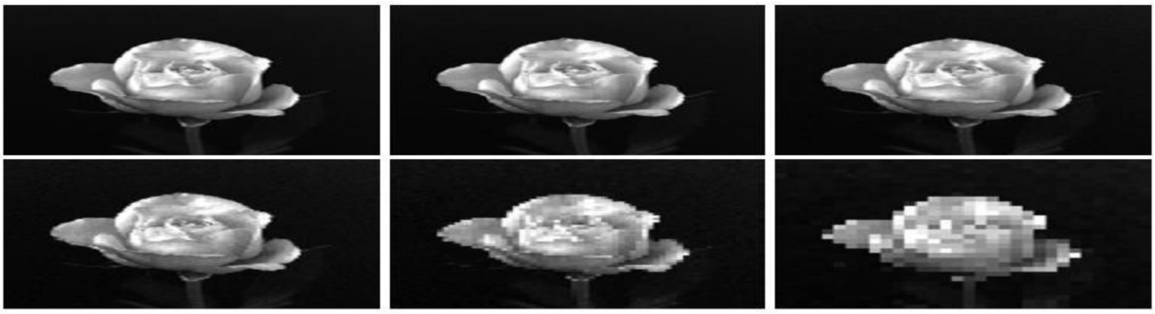
Spatial and Gray -Level Resolution:

- Sampling is the principal factor determining the spatial resolution of animage.
- Spatial resolution is the smallest discernible detail in an image.
- Suppose that we construct a chart with vertical lines of width W, withthe space between the lines also having width W.A line pair consists ofone such line and its adjacent space. Thus, the width of a line pair is 2W, and there are 1/2Wline pairs per unit distance.
- Gray-level resolution similarly refers to the smallest discernible changein gray level.

Fig 1.6.4: A 1024*1024, 8 -bit image subsampled down to size 32*32 pixelsThe number of allowable gray levels was kept at 256

- The sub sampling was accomplished by del eting the appropriate number of rows and columns from the original image.
- For example, the 512*512 image was obtained by deleting every other row and column from the 1024*1024 image. The 256*256 image was generated by deleting every other row and column i n the 512*512 image, and so on. The number of allowed gray levels was kept at 256. These images show the dimensional proportions between various sampling densities, but their size differences make it difficult to see the effects resulting from a reduction in the number of samples. The simplest wayto compare these effects is to bring all the sub sampled images up to size 1024*1024 by row and column pixel replication. The results are shown in Figs. 7.2 (b) through (f).

Fig. 1.6.5 (a) 1024*1024, 8 -bit imag e (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



a b c
d e f

- Compare Fig. 1.6.5(a) with the 512*512 image in Fig. 1.6.5(b) and note that it is virtually impossible to tell these two images apart. The level of detail lost is simply too fine to be seen on the printed page at the scale in which these images are shown. Next, the 256*256 image in Fig. 1.6.5(c)shows a very slight fine checkerboard patte rn in the borders betweenflower petals and the black background. A slightly more pronounced graininess throughout the image also is beginning to appear. These effects are much more visible in the 128*128 image in Fig. 1.6.5(d), and they become pronounced in the 64*64 and 32*32 images in Figs. 1.6.5 (e) and (f), respectively.

- Another example is given below.

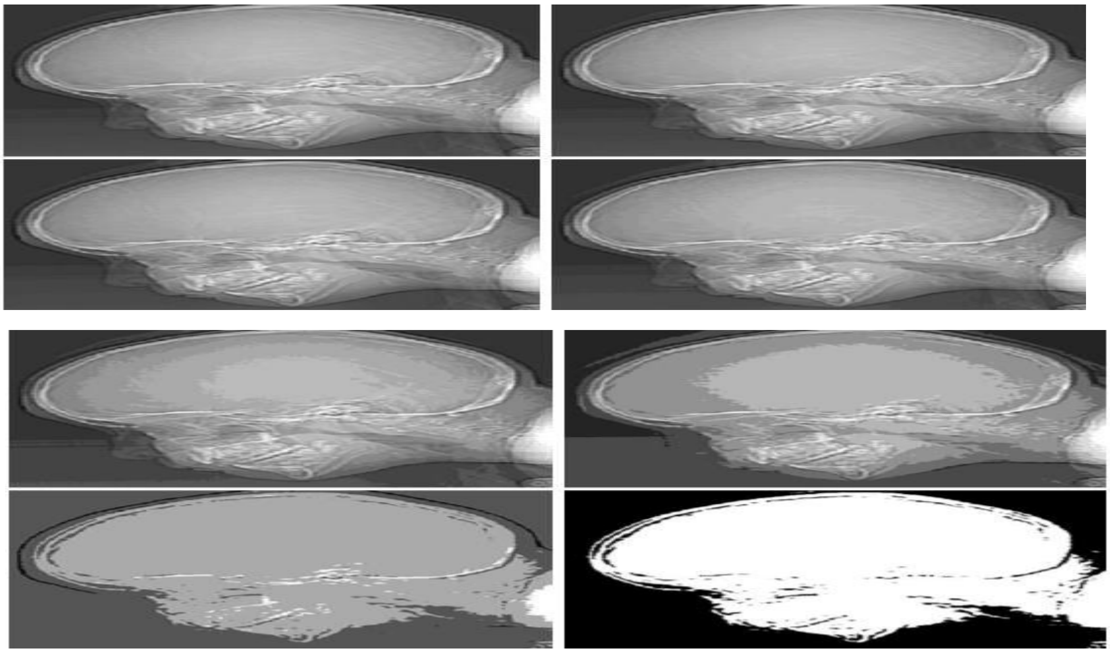


Fig. 1.6.6 (a) 452*374, 256 -level image (b) –(d) Image displayed in 128, 64,and 32 gray levels, while keeping the spatial resolution constant (e)–(g) Image displayed in 16, 8, 4, and 2 gray levels.

1.7 Basic relationships between pixels

Neighbors of a Pixel:

- A pixel p at coordinates (x, y) has four horizontal and vertical neighbors whose coordinates are given by (x+1, y), (x -1, y), (x, y+1), (x, y-1). This set of pixels, called the 4-neighbors of p, is denoted by N4 (p). Each pixel is a unit distance from (x, y), and some of the neighbors of p lie outside the digital image if (x, y) is on the border of the image.
- The four diagonal neighbors of p have coordinates (x+1, y+1), (x+1, y-1), (x-1, y+1), (x-1, y-1) and are denoted by ND (p). These points, together

with the 4-neighbors, are called the 8 -neighbors of p, denoted by N8 (p). As before, some of the points in ND (p) and N8 (p) fall outside the image if(x, y) is on the border of the image.

Connectivity:

- Connectivity between pixels is a fundamental concept that simplifies the definition of numerous digital image concepts, such as regions and boundaries.
- To establish if two pixels are connected, it must be determined if they are neighbors and if their gray levels satisfy a specified criterion of similarity (say, if their gray levels are equal). For instance, in a binary image with values 0 and 1, two pixels may be 4 -neighbors, but they are said to be connected only if they have the same value.
- Let V be the set of gray-level 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 gray-level values 0 to 255, set V could be any subset of these 256 values.

  We consider three types of adjacency

  a. 4-adjacency. Two pixels p and q with values from V are 4 -adjacent if qis in the set N4 (p).
  b. 8-adjacency. Two pixels p and q with values from V are 8 -adjacent if qis in the set N8 (p).
  c. m-adjacency (mixed adjacency).Two pixels p and q with values from Vare m-adjacent if
     i. q is in N4 (p), or
     ii. q is in ND (p) and the set has no pixels whose values are fromV.
- Mixed adjacency is a modification of 8 -adjacency. It is introduced to eliminate the ambiguities that often arise when 8 -adjacency is used.

- For example, consider the pixel arrangement shown in Fig. 1.7 (a) for V= {1}.The three pixels at the top of Fig.1.7 (b) show multiple (ambiguous) 8-adjacency, as indicated by the dashed lines.
- This ambiguity is removed by using m-adjacency, as shown in Fig. 1.7(c).Two image subsets S1 and S2 are adjacent if some pixel in S1 is adjacent to some pixel in S2. It is understood here and in the following definitions that adjacent means 4-, 8- , or m-adjacent.
- A (digital) path (or curve) from pixel p with coordinates (x, y) to pixel qwith coordinates (s, t) is a sequence of distinct pixels with coordinates

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

- Where $(x_0, y_0) = (x, y), (x_n, y_n) = (s, t)$,and Pixels (x_i, y_i) and (x_{i-1}, y_{i-1}) are adjacent for 1<=i<=n In this case, n is the length of the path. If (xo, yo) =(xn, yn), the path is a closed path. We can define 4 -, 8-, or m-paths depending on the type of adjacency specified. For example, the paths shown in Fig. 1.7(b) between the northeast and southeast points are 8 - paths, and the path in Fig. 1.7(c) is an m-path.
- 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 consistingentirely 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. If it only has one connected component, then set S is called a connected set.

Fig. 1.7 (a) Arrangement of pixels; (b) pixels that are 8-adjacent (showndashed) to the center pixel; (c) m -adjacency

Distance Measures:

- For pixels p, q, and z, with coordinates (x, y), (s, t), and (v, w), respectively, D is a distance function or metric if

$$\begin{aligned}&\textbf{(a)}\ D(p,q) \geq 0 \quad (D(p,q) = 0 \quad \text{iff} \quad p = q),\\&\textbf{(b)}\ D(p,q) = D(q,p), \text{ and}\\&\textbf{(c)}\ D(p,z) \leq D(p,q) + D(q,z).\end{aligned}$$

- The Euclidean distance between p and q is defined as

$$D_e(p,q) = \left[(x-s)^2 + (y-t)^2\right]^{\frac{1}{2}}.$$

- For this distance measure, the pixels having a distance less than or equal to some value r from(x, y) are the points contained in a disk of radius r centered at (x, y).
- The **D4** distance (**also called city -block distance**) between p and q is defined as
- In this case, the pixels having a D4 distance from (x, y) less than or equal to some

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

value r form a diamond centered at (x, y). For example, the pixels with D4 distance ≤ 2 from (x, y) (the center point) form the following contours of constant distance:

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

- The pixels with D4 =1 are the 4-neighbors of (x, y).
- The **D8** distance (**also called chessboard distance**) between p and q is defined as
- In this case, the pixels with D8 distance from(x, y) less than or equal to some value r

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

form a square centered at (x, y). For example, the pixels with D8 distance ≤ 2 from(x, y) (the center point) form the following contours of constant 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

- The pixels with D8=1 are the 8 -neighbors of (x, y). Note that the D4 and D8 distances between p and q are independent of any paths that might exist between the points because these distances involve only the coordinates of the points.
- If we elect to consider m-adjacency, the distance between two points is defined as the shortest m -path between the points. In this case, the distance between two pixels will depend on the values of the pixels along the path, as well as the values of their neighbors. For instance, consider the following arrangement of pixels and assume that p, p2 , and p4 have value 1 and that p1 and p3 can have a value of 0 or 1:
- Suppose that we consider adjacency of pixels valued 1 (i.e. = {1}). If p1 and p3 are 0, the length of the shortest m -path (the Dm distance) between p and p4 is 2. If p1 is 1,

	p_3	p_4
p_1	p_2	
p		

then p2 and p will no longer be m - adjacent (see the definition of m -adjacency) and the length of the shortest m-path becomes 3 (the path goes through the points pp1p2p4).

UNIT -I

Assignment -Cum -Tutorial Questions

Section - A

Objective Questions

1. A pixel p at coordinates (x, y) has four horizontal and vertical neighbors whose coordinates are given by_________________________called the 4-neighbors of p [ ]

a. (x+1, y) b. (x-1, y) c.(x, y+1) d.(x, y-1) e.ALL

2. A pixel p at coordinates (x, y) has called the 8-neighbors of p if it has_________________ [ ]

a. Horizontal and vertical neighbors(x+1, y), (x -1, y), (x, y+1), (x, y-1)

b. Diagonal neighbors(x+1, y+1), (x+1, y -1), (x-1, y+1), (x-1, y-1)

c. Both A and B d. None of the above

3. Intensity levels in 8-bit image are [ ]
a. 128 b. 255 c. 256 d. 512

4. In bit plane slicing 8 bit image will have________________ number of planes. [ ]

a. 6 b. 7 c. 8 d. 9

5. A continuous image is digitised at________points. [ ]
a. Random b.vertex c.contour

6. The smallest discernible change in intensity level is called _____________ [ ]
a. Intensity Resolution b. Contour

c. Saturation d. Contrast

7. The difference is intensity between the highest and the lowest intensity levels in an image is [ ]

a. Noise b. Saturation c. Contrast

8. Which of the following is used for chest and dental scans? [ ]

a. Hard X-Rays b. Soft X-Rays
c. Radio waves d. Infrared Rays

9. In a binary image with values 0 and 1, two pixels may be 4-neighbors, but they are said to be connected only if they have the ___________value. [ ]

a. Same b. Different c. Both A and B d. none

10. Image enhancement and restoration are used to process [ ]

a. high resolution images b. degraded images

c. high quality images d. brighter images

11. Which one is not the area of digital image processing [ ]

a. law enforcement b.lithography

c. medicine d.voice calling

12. An image is a two dimensional function where x and y are [ ]

a. spatial coordinates b. frequency coordinates

c. time coordinates d. real coordinates

13. Which is the image processing related fields [ ]
a. medicines b. chemistry
c. neurobiology d. chemicals

14. Method in which images are input and attributes are output is called

a. low level processes b. high level processes [ ]

c. mid level processes d. edge level processes

Section – B

Descriptive Questions

1. What is meant by Digital Image Processing? Explain how digital images canbe represented?
2. Explain of Fields that Use Digital Image Processing.
3. What are the fundamental steps in Digital Image Processing?
4. What are the components of an Image Processing System?
5. Explain the process of image acquisition.
6. Explain about image sampling and quant ization process.
7. Define spatial and gray level resolution. Explain about isopreference curves.
8. Explain about Aliasing and Moire patterns.
9. Explain about the basic relationships and distance measures between pixelsin a digital image.
10. Calculate the 4 neig hbors of a pixel at coordinates p(2,3).
11. Calculate the resolution of an 1024X1024 image.
12. Find out 8 neighbors of a pixel at coordinates p(8,8).
13. Calculate the number of bits required to store an 128X128 image with 64gray levels.
14. Consider the two image subse ts, S1 and S2, shown in the following figure. For V={1}, determine whether these two subsets are (a) 4 -connect (b)8-connect or (c) m-adjacent.

	S_1				S_2				
0	0	0	0	0	0	0	1	1	0
1	0	0	1	0	0	1	0	0	1
1	0	0	1	0	1	1	0	0	0
0	0	1	1	1	0	0	0	0	0
0	0	1	1	1	0	0	1	1	1

15. Consider the image segment shown below, Let V={0,1} and compute the lengths of the shortest 4, 8, and m -path between p and q. if a particular path does not exist between these two points, explain why?

$$\begin{array}{rcccl} & 3 & 1 & 2 & 1\,(q) \\ & 2 & 2 & 0 & 2 \\ & 1 & 2 & 1 & 1 \\ (p) & 1 & 0 & 1 & 2 \end{array}$$

16. Compute for V = {1,2} with the same data in problem 6.

17. Calculate the (Euclidean) distance between points (2, -1) and (-2, 2).