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Chap 1 Digital Image Processing Systems

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What is DIP?

An image may be defined as a two-dimensional function f(x,y) where x and y are spatial (plane) co-ordinates & the amplitude of f at any pair of co-ordinate (x,y) is called the "intensity" or "gray level" of the image at that point.

When x, y & the amplitude values of f are finite discrete quantities, we call the image a digital image.

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

A digital image is composed of a finite number elements, each of which has a location and value.

These elements are referred to as picture elements, pels and pixels.

Elements of Digital image processing:

Large-scale image processing systems still are being sold for massive imaging applications, such as processing of satelite images. the trend continues toward miniaturizing & blending of general-purpose small computers with specialized image processing hardware.

Below fig shows the basic elements comprising a typical general purpose system used for digital image processing.

The function of each element is as follows.

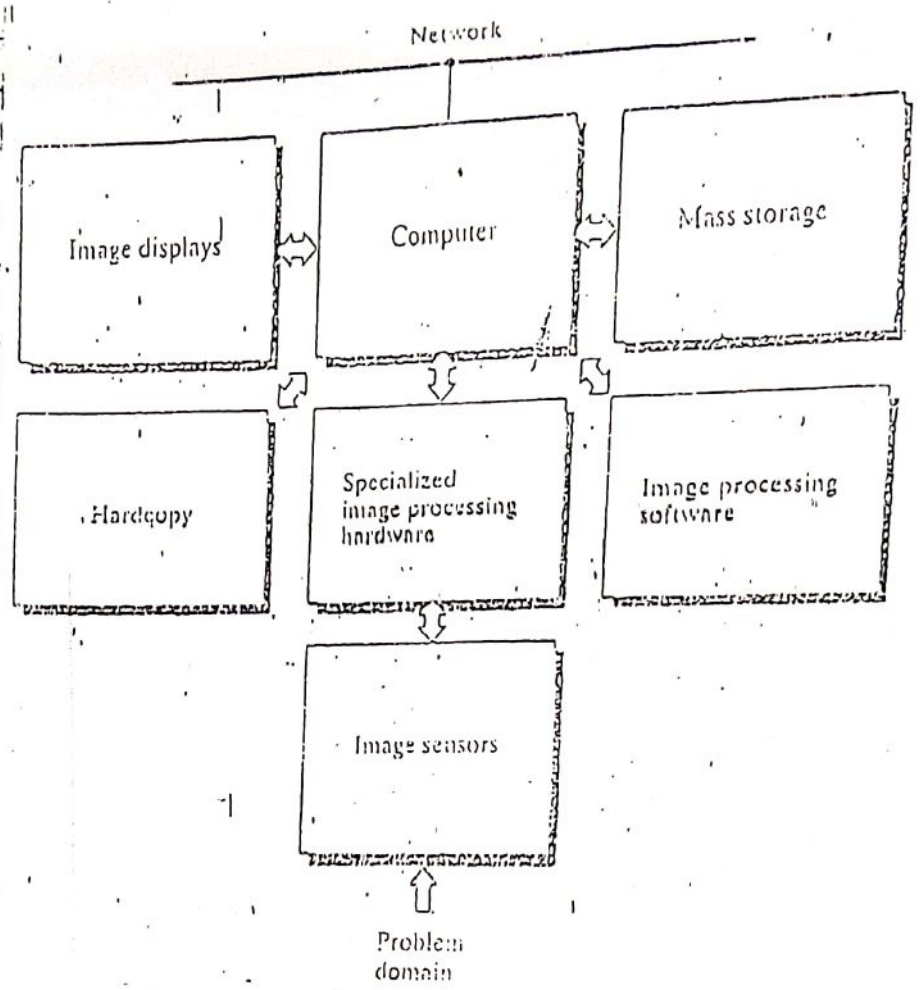


FIGURE 1.2... Components of a general-purpose image processing system.

The function of each element is as follows:

1) Image Sensors: With reference to sensing, two elements are required to acquire digital images. The first is physical device i.e. 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 physical sensing device into digital form.

ex: In a digital video camera, the sensors produce a electrical output proportional to light intensity; the digitizer converts these output to digital data.

2] Specialized image processing Hardware :→

It usually consis of the digitizer plus H/w that performs other primitive operations, such as an arithametic logic unit (ALU), which performs arithametic & logical operations in parallel on entire images.

ex: How an ALU is used is in averaging images as quickly as they are digitized, for the purpose of noise reduction.

This type of H/w sometimes is called a "front end subsystem", & its most distinguishing characteristic is speed.

3] Computer :

The computer in an image processing system is a general-purpose system & can range from a PC to a supercomputer. In dedicated applications, sometimes specially designed computer's are used to achieve a required level of performance.

4] Software :

S/w 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.

5] Mass Storage Capability :

It 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 1 megabytes of storage space.

If the image is not compressed when dealing with thousands, or even millions of images, providing adequate storage in an image processing system can be a challenge.

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 recall &
3) Archival storage - characterized by infrequent access.

One method for providing short-term storage is computer memory. Another is by specialized boards, called frame buffers, that store one more images and can be accessed rapidly.

On-line storage generally takes the form of magnetic disks or optical media storage. archival storage is characterized by massive storage requirements but infrequent need for access.

6) Image display :

Image display in use today are mainly color flat screen TV monitors. monitors are driven by the o/p of image & graphics display cards that are an integral part of the computer system.

7) Hardcopy :

Hardcopy devices for recording images include laser printers, film cameras, heat sensitive devices, inkjet units, & digital units, such as optical and CD-Rom disks. Film provide the highest possible resolution, but paper is the obivious medium of choice for written materials.

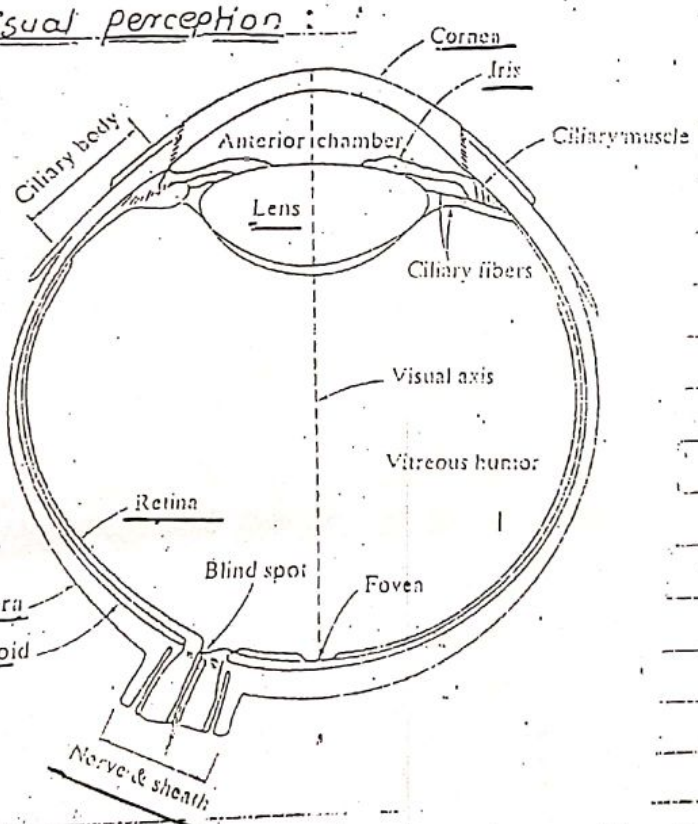
8] Networking:

Networking is almost a default function in an computer system in use today. Because of the largest amount of data interest in image processing applications, the key considerations in image transmission is bandwidth.

Elements of Visual perception:

- Structure of Human Eye

pupil (पुतली)
dilatation



Above fig shows a simplified horizontal cross section of the human eye. The eye is nearly a sphere, with an average diameter of approximately 20 mm. Three membranes enclose the eyes:

- The cornea and scllera outer cover
- The choroid
- The retina

The cornea is a tough transparent tissue that covers the anterior surface of the eye continous with the cornea, the sclera is an opaque (अपारदर्शक) membrane that encloses the remainder of the optic globe.

The choroid lies directly below the sclera. This membrane contains a network of blood vessels that serve as the major source of nuitrition to the eye.

The choroid coat is heavily pigmented & hence helps to reduce the amout of extraneous light enterring the eye & the backscatter within the optic globe.

At it's anterior extreme, the choroid is divided into the ciliary body and the iris, the iris contracts or expands to control the amount of light that enters the eye.

The central opening (छेद) of the iris (the pupil) varies in diameter from approximately 2 to 8 mm

The lens is made up of concentric layes of fibrous cells and is suspended by fibers that attach to the cillary body. It contains 60 to 70 % water, about 6 % fat and more protein than any other tissue in the eye

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The lens is colored by a slightly yellow pigmentation that increases with age.

The innermost membrane of the eye is the retina which lines the inside of the wall's entirer posterior portion.

When the eye is properly focused, light from an object outside the eye is imaged on the retina.

Pattern vision is afforded by the distribution of discrete light receptors over the surface of the retina.

There are two classes of receptors: Cones & rods.

The cones in each eye number between 6 to 7 million. They are located primarily in the central portion of the retina is called the "fovea", and are highly sensitive to color.

Cone vision is called photopic or bright-light vision.

The number of rods is much large: some 75 to 150 millions are distributed over the retinal surface.

Rods serve to give a general, overall picture of the field of view. They are not involved in color vision and are sensitive to low levels of illumination.

ex: Objects that appear brightly colored in day light when seen by moonlight appear as colorless forms because only the rods are simulated. This phenomenon is knows as scotopic or dim-light vision.

- Image formation in the eye.

In an ordinary photographic camera, the lens has a fixed focal length, and focusing at various distances is achieved by varying the distance bet-ween the lens and the imaging plane, where the film is located.

In the human eye, the converse is true; the distance between the lens and the imging regio (the retina) is fixed, and the local length needed to achievere proper focus is obtained by varying the shape of the lens.

The distance between the center of the lens and the retina along the visual axis is appro-ximately 17 mm.

The range of focal lengths is approximately 14 mm to 17 mm; the ~~later~~ latter taking place when the eye is relaxed and focused at distances greater than about 3 m.

The geometry in below fig. illustrates how to obtain the dimensions of an image formed on the retina.

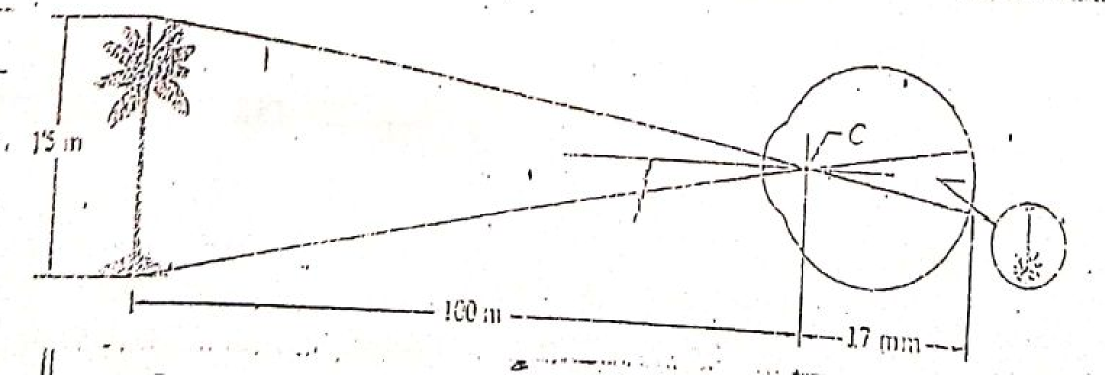

FIGURE 2.3 Graphical representation of the eye looking at a palm tree. Point C is the optical center of the lens.

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ex: suppose that a person is looking at a tree 15m high at a distance of 100m.

Letting h denote the height of that object in the retinal image, the geometry of above fig yields

$$\frac{15}{100} = \frac{h}{17}$$

$h = 2.55$ mm.

Digital Image Representation:

An image defined as a two-dimensional function f(x, y), where x and y are spatial (plane) coordinates and amplitude of f at any pair of coordinates (x, y) is called the intensity of monochrome images.

An image may be continuous with respect to the x and y coordinates & also in amplitude converting such as image to digital form required that the coordinates as well as the amplitude should be digitized.

Digitizing the coordinate values is called sampling. Digitizing the amplitude values is called quantization.

When x, y and the amplitude values of f are all finite, discrete quantities, then image called as a digital images.

- Co-ordinate Conventions:

An image f(x, y) is a sampled then that resulting image has M rows and N columns, we say that the image is of size M X N.

The values of the coordinates (x, y) are descrete quantities

The image origin is defined to be at (x, y) = (0, 0). The next coordinate values along the first row of the image are (x, y) = (1, 1). It does not mean that these are the actual values of physical coordinates when the image was sampled.

fig (a) shows this coordinate convention x ranges from 0 to M-1 & y from 0 to N-1 in integer increments.

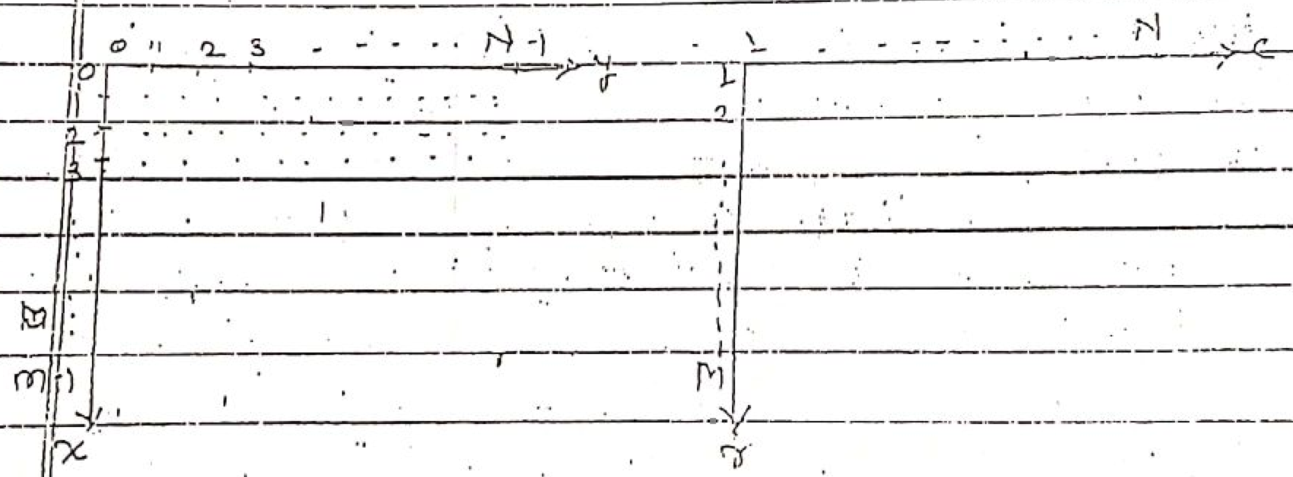

fig (a) coordinate conventions used in image processing books

fig (b) coordinate conventions used in image processing toolbox.

The cordinate conventions used in the toolbox to denote arrays is different in two minor ways first, instead of using (x, y) the toolbox uses the notation (r, c) to indicate rows & columns the first element of a co-ordinate tuple (a, b) refers to a row and the second to a column.

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The other difference is that the origin of the co-ordinate system is at $(r, c) = (1, 1)$, thus r ranges from 1 to M and c from 1 to N, in integer increments.

- Images as matrices:

The coordinate system in above fig. (a) lead to the following representation for a digitized image function:

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

The right side of this equation is a digital image by definition.

A digital image can be represented naturally as a MATLAB matrix.

$$f = \begin{bmatrix} f(1,1) & f(1,2) & \cdots & f(1, N) \\ f(2,1) & f(2,2) & \cdots & f(2, N) \\ \vdots & \vdots & & \vdots \\ f(M,1) & f(M,2) & \cdots & f(M, N) \end{bmatrix}$$

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Fundamental Steps in Digital Image processing

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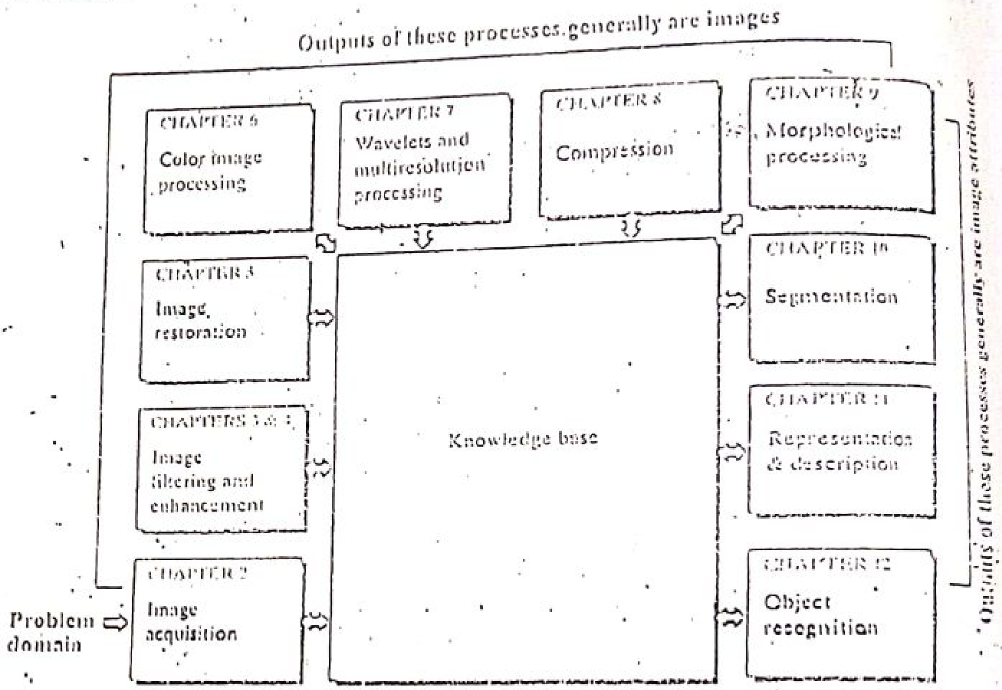
FIGURE 1.23 Fundamental steps in digital image processing. The chapter(s) indicated in the boxes is where the material described in the box is discussed.



1) **Image acquisition :**

Image acquisition is the first processes, as shown in above fig. acquisition could be as simple as being given as image that is already in digital form. Image acquisition stage involves preprocessing such as scaling.

2) **Image Enhancement :**

It is the process of manipulating an image so that the result is more suitable than the original for a specific application. It is applicable for some specific applications

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not for all applications.

ex: A method that is quite useful for enhancing X-ra images may not be the best approach for enhancin satelite images taken in the infrared band of the electromagnetic spectrum. when an image is processed for visual interpretation, the viewer is the ultimate judge of How well a particular method works.

3) Image Restoration:

It 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 technique tend to be based on mathematical or probabilistic models of image degradation.

4) Color image processing:

It is an area that has been gaining in importance because of the significant increase in the use of digital images over the internet.

Color image processing is motivated by two principall factors, first color is a powerful descriptor that often simplifies object identification and extraction from a scene. second, humans can discern thousands of color shades and intesities compared to about only two dozen shades of gray

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5) Wavelets and multiresolution processing :

Wavelets are the foundation for representing images in various degrees of resolution. If both small and large objects of low and high-contrast objects are present simultaneously, it can be advantegous to study them at several resolutions. This is the fundamentals motivation for multiresolution processing.

6) Compression :

As the name implies, deals with techniques for reducing the storage required to save an image, or the bandwidth required to transmit it. Image compression is familiar to most users of computers in the form of image file extensions, such as the jpg file extension used in the JPEG image compression standard.

7) Morphological processing :

It deals with tools for extracting image components that are useful in the representation & description of shape.

The language of mathematical morphology is set theory. As such, morphology offers a unified and powerful approach to numerous image processing problems. sets in mathematical morphology represent objects in an image.

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ex: The set of all white pixels in a binary image is a complete morphological description of the image.

8) Segmentation :

Segmentation procedures partition an image into its constituent parts or objects. A rugged 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.

9) Representation and description :

It almost always follows the output of a segmentation stage, which usually is raw pixel data, constituting either the boundary of a region or all the points in the region itself.

In either case, converting the data to a form suitable for computer processing is necessary. The first decision that must be made is whether the data should be represented as a boundary or as a computer region.

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

10) Object Recognition :

Recognition is the process that assigns a label (ex. "vehicle") to an object based on its descriptors.

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Knowledge Base :

Knowledge about a problem domain is coded into an image processing system in the form of a knowledge database. 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.

Light and the Electromagnetic Spectrum :

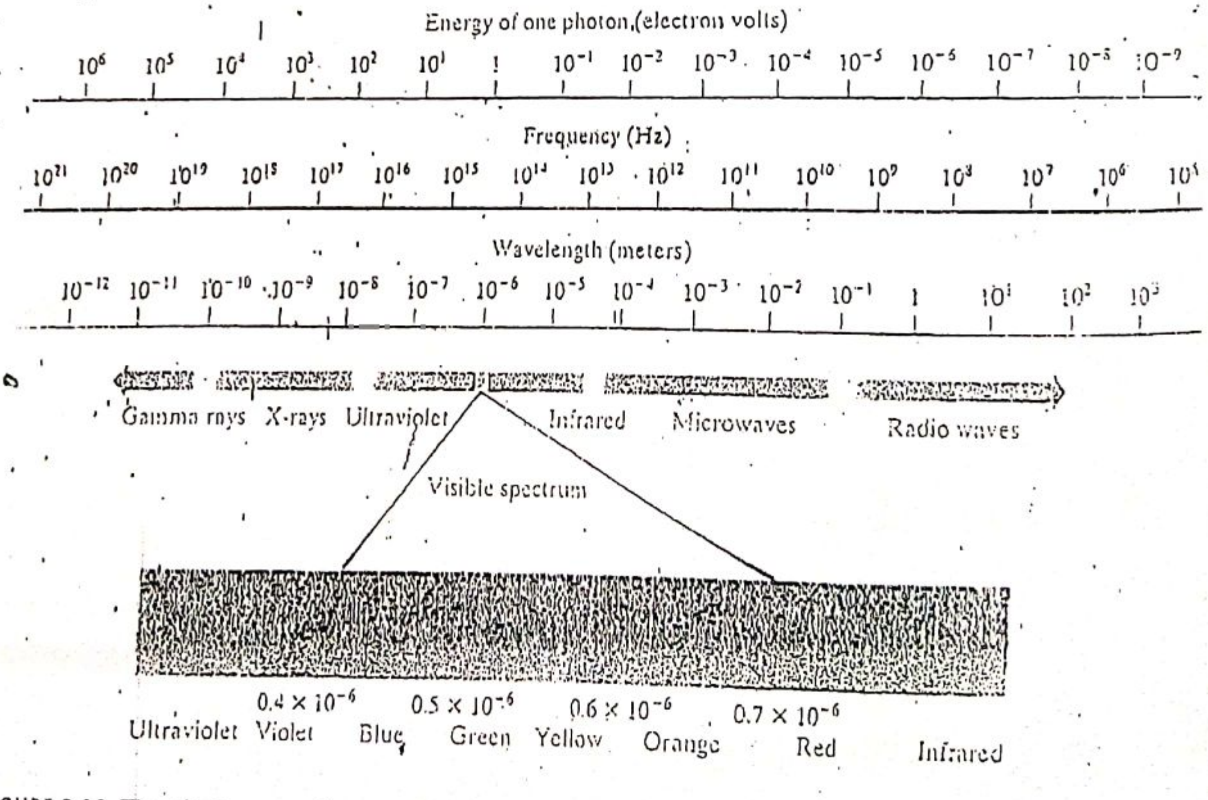

FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

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- Sir Issac Newton discovered that when a beam of sunlight is passed through a glass prism, the emerging beam of light is not white but consists instead of a continuous spectrum of colors ranging from violet at one end to red at the other.

As above fig shows, the range of colors we perceive in visible light represents a very small portion of the electromagnetic spectrum.

On one end of the spectrum are radio waves with wavelengths billions of times longer than those of visible light.

On the other end of the spectrum are gamma rays with wavelengths millions of times smaller than those of visible light.

The electromagnetic spectrum can be expressed in terms of wavelength, frequency, or energy.

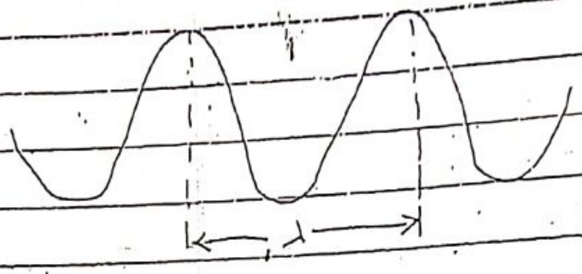
Wavelength (λ) and frequency (v) are related by the expression.

$$\lambda = \frac{c}{v} \quad \text{——} (1)$$

where c is the speed of light (2.998×10^8 m/s). The units of wavelengths are meters, with the terms microns (denoted μm and equal to 10^{-6} m) and nanometers (denoted nm & equal to 10^{-9} m) being used just as frequently.

Frequency is measured in Hertz (Hz), with one Hertz being equal to one cycle of a sinusoidal

A common used unit of energy is the electron-volt



graphical representation of one wavelength.

Electromagnetic waves can be visualized as propagating sinusoidal waves the wavelength is shown in above fig.

Each bundle of energy is called a photon. Energy is proportional to frequency, so the higher-frequency (shorter wavelength). electro-magnetic phenomena carray more energy per photon.

Radio waves have photons with low energies, microwaves have more energy that radio waves infrared still more, then visible, ultravioled, x-rays, and finally gamma rays, the most energetic of all. This is the reason why gamma rays are so dangerous to living organisms.

Light is a particular type of electromagnetic radiation that can be sensed by the human eye.

The visible (color) spectrum is shown expanded in above fig. for the purpose of discussion

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The Visible band of the electromagnetic spectrum spans the range from approximately 0.43 µm (violet) to about 0.79 µm (red)

For Convenience, the color spectrum is divided into six broad regions: violet, blue, green, yellow, orange & red.

The colors that humans perceive in an object are determined by the nature of the light reflected from the object.

Light that is void of color is called monochrome light, the term gray level is used commonly to denote monochromatic intensity

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Image Sensing and Acquisition:

Most of the images in which we are interested are generated by the Combination of a "illumination" source and the reflection or absorption of energy from that Source by the elements of the "scene" being imaged.

ex: the illumination may originate from a source of electromagetic energy such as radar, infrared, or x-ray system.

Depending upon 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 converted (ex. a phospher screen), which converts the enery into visible light.

ex: Electron microscopy & gamma imaging

Below fig shows the three principal sensor arrangements used to transform illumination energy into digital images.

Incoming energy is transformed into a voltage. 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 and a digital quantity is obtained from each Sensor by digitizing its response.

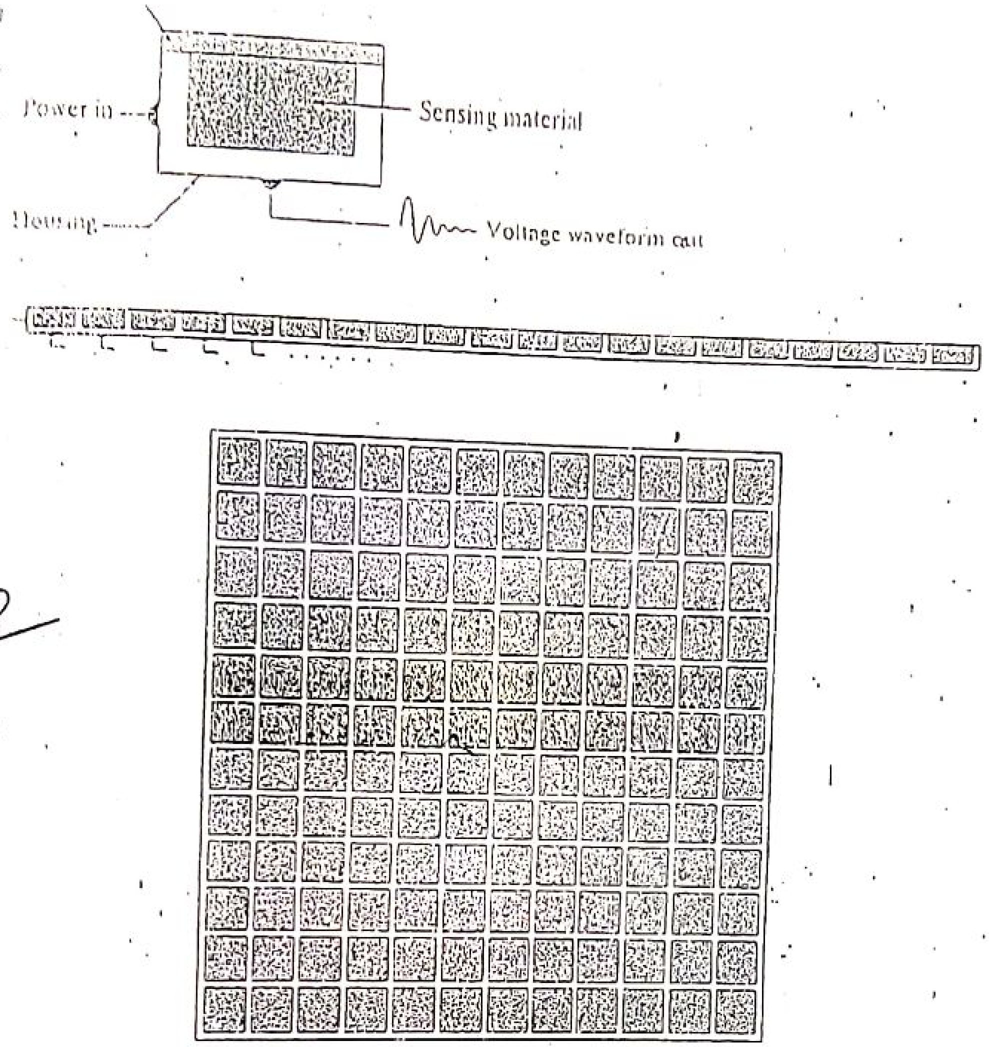

FIGURE 2.12
(a) Single imaging sensor.
(b) Line sensor.
(c) Array sensor.

IMP

Image Acquisition using a single sensor:

Above fig (a) shows the components of a single sensor perhaps the most familiar sensor of this type is the photodiode which is constructed of silicon materials and whose output voltage waveform is proportional to light.

The use of a filter in front of a sensor improves selectivity.

ex:- a green filter in front of a light sensor favors light in the green band of the color spectrum.

In order to generate a 2-D image using a single sensor, there has to be relative displacements in both both the x and y direction between the sensor & ~~over~~ the area to be imaged.

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Below fig. shows an arrangement used in high precision scanning., where a film negative is mounted onto a drum whose mechanical rotation provides a displacement in one dimension. a single sensor is mounted on a lead screw that provides motion in the perpendicular direction.

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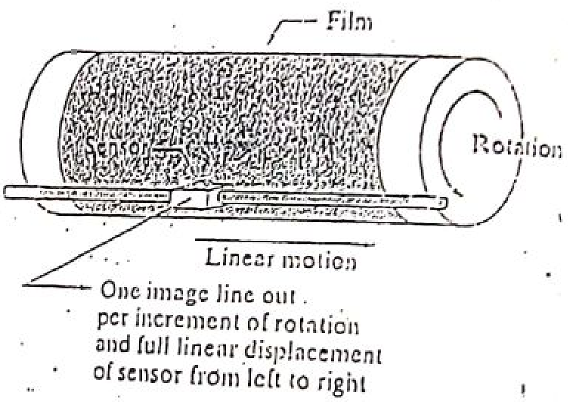


FIGURE 2.13 Combining a single sensor with motion to generate a 2-D image.

- Image Acquisition using Sensor strips :

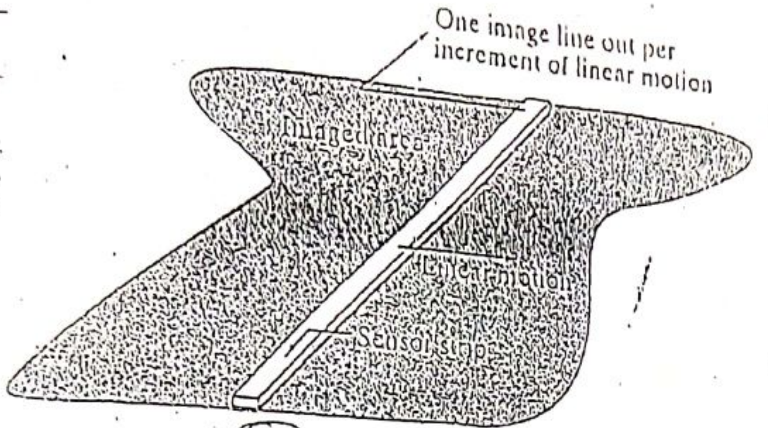
A geometry that is used much more frequently than single sensors consists of an in-line arrangement of sensors in the form of a sensor strip. as show in above fig 2.12 (b).

The strip provides imaging elements in one direction.

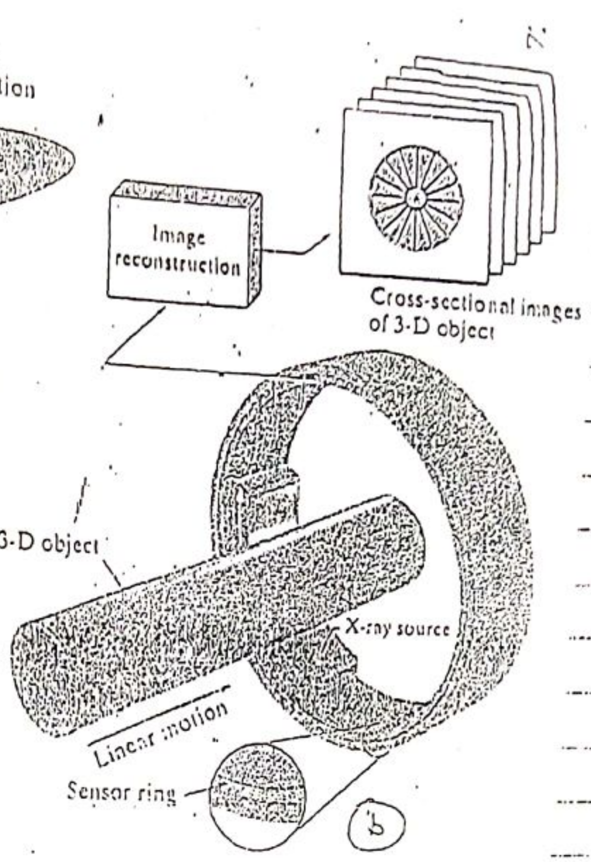
motion perpendicular to the strip provides imaging in the other direction. shown in below fig

- This is the type of arrangement used in most flat bed scanners. Sensing devices with 4000 or more in-line sensors are possible.

The Imaging strip one gives one line of an image at a time and the motion of the strip completes the other dimension of two-dimensional image.



(a)



(b)

(a) Image acquisition using a linear sensor strip
(b): Image acquisition using a circular sensor strip

Image acquisition using Sensor Arrays:

fig 2.12(c) shows individual sensors arranged in the form of 2D-array. Numerous electromagnetic and some ultrasonic sensing devices frequently are arranged in an array format. This is also predominant arrangement found in digital cameras. 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 element 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 a in~~

Because the sensor array in fig 2.12(c) is two dimensional, its key advantage is that a complete image ~~is that a~~ can be obtained by focusing the energy pattern onto the surface of the array.

I.mp.

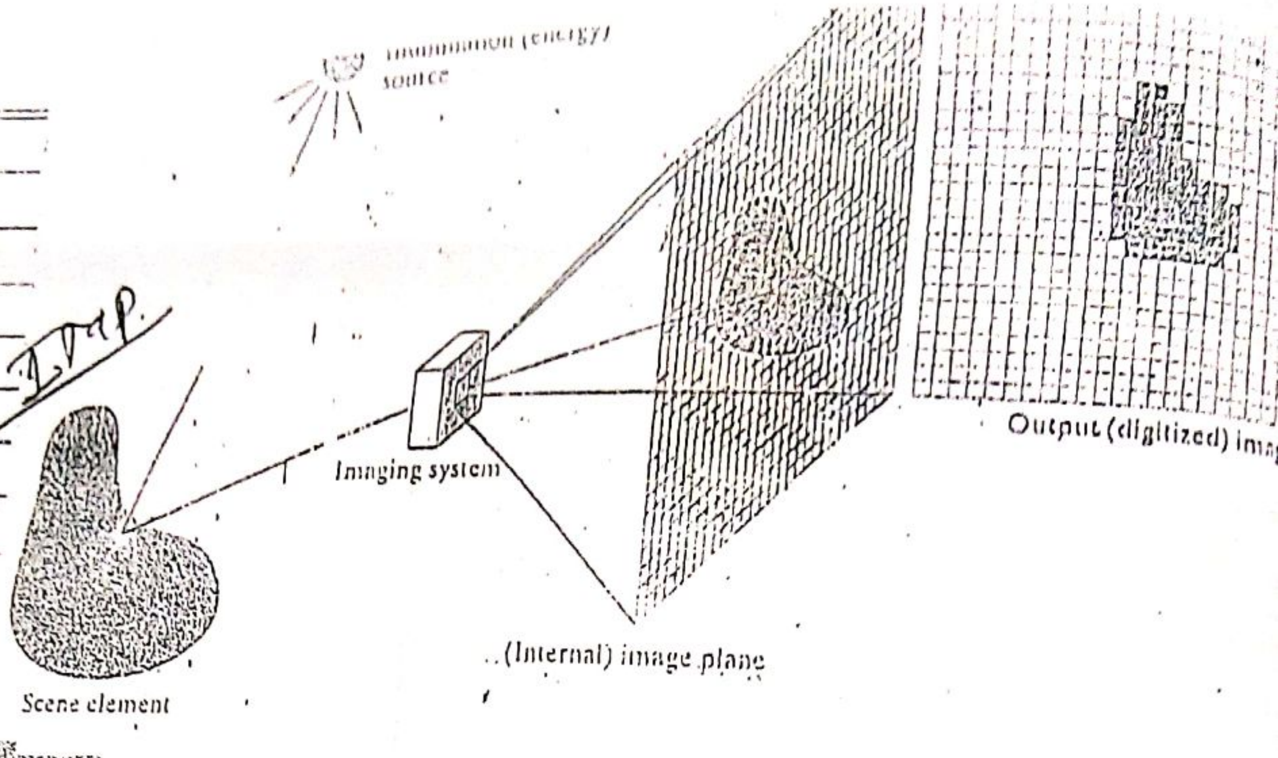


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized

The principal manner in which array sensors are used is shown in above fig.

This figure shows the energy from an illumina source being reflected from a scene element.

The first function performed by the imaging sys in fig (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 an optical lens that project the viewed scene onto the lens focal plane, as fig (d) shows.

The o/p is a digital image, as shown diagra-mmatically in fig (e).

Image Sampling and quantization :

There are numerous ways to acquire images, b... our objective in all is the same : to generate digit... images from sensed data.

The output of most sensors is a continous volta... waveform whose amplitude and spatial behaviour a... related to the physical phenomenon being sensed.

To create a digital image, we need to conve... the continuous sensed data into digital form. This involves two processes :

1] Sampling
2] quantization.

- Basic concepts in Sampling and quantization :

The basic idea behind sampling and quantization is illustrated in below fig.

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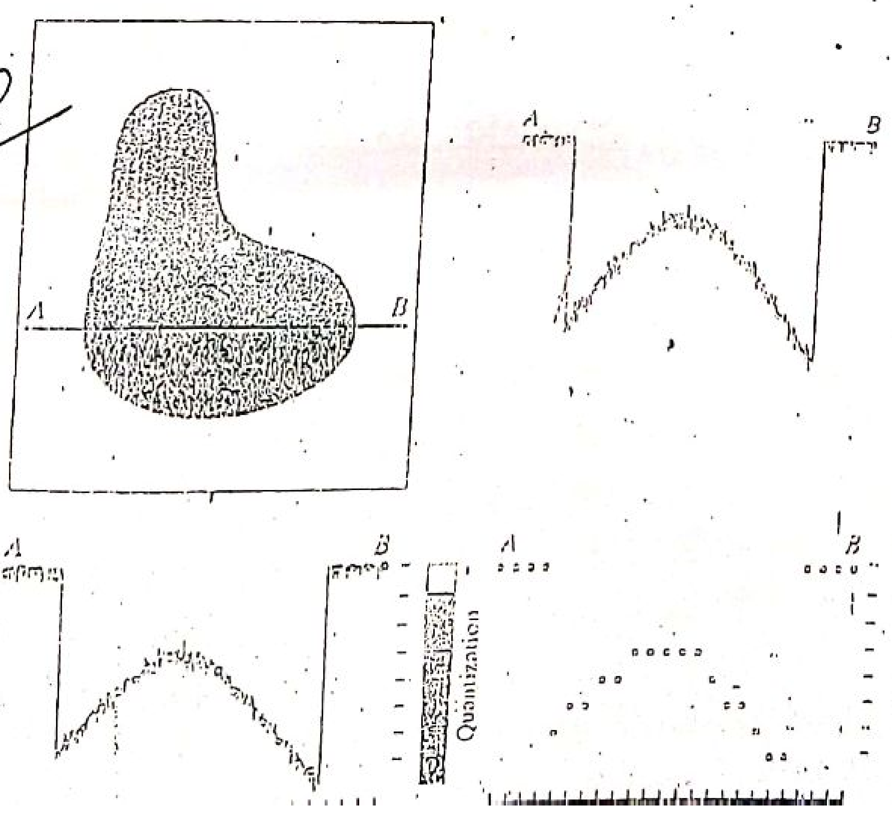

FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

Image Sampling and quantization :

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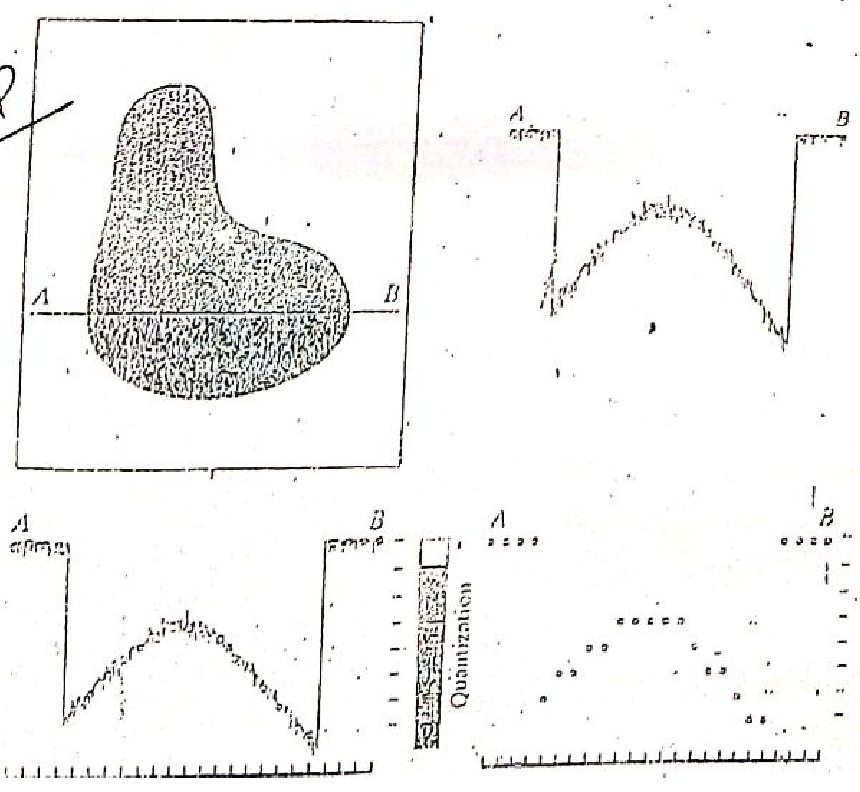

FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

above fig (a) shows a continous image f 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 in above fig (b) is a plot of amplitud (intensity level) values of the continuous image along the line segment AB in fig (a)

The random variation are due to image noise.

To sample this function, we take equally spaced sample along line AB shown in fig (c). The spatial location of each sample is indicated by a vertical tick mark in the bottom part of the fig. The set of these discrete locations gives the sampled function.

In order to form a digital function, the intensity values also, must be converted (quantized) into discrete quantities. The right side of the fig (c) shows the intensity scale ~~de~~ divided into eight descrete ~~quantities~~ intervals, ranging from black to white. The vertical tick marks indicate the specific value assigned to each of the eight intensity intervals.

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The Continous intensity levels are quantized by assign of the eight values to each sample.

The assignment is made depending on the vertic proximity of a sample to a vertical tick mark. The digital samples resulting from both sampling and quantization are shown in fig (d)

Starting at the top of the image and carrying out this procedure line by line produces a two-dimensi digital images as shown in below fig.

- Digital Image Representation:

Explain Digital Image Representation of second chapter here.