CHAPTER - 1

DIGITAL IMAGE FUNDAMENTALS

In the past the cost of image processing was very high because the imaging sensors and computational equipments were very expensive and had only limited functions. As optics, imaging sensors and computational technology advanced, image processing is more commonly used in different areas.

1.1 What Is Digital Image Processing

An image can be defined as the variation of intensity in the space so, in image, intensity is the function of spatial co ordinates.

An image can be formally defined as a two-dimensional function $f(x,y)$ where x and y are spatial co-ordinates. The amplitude of f at any pair of co-ordinates (x, y) is called the intensity or gray level of the image at that point. For digital images x, y and the amplitude values of f are finite and discrete quantities. A digital image is composed by a finite number of elements called pixels. Each pixel has a particular location and value.

Image processing is a discipline in which both the input and output of a process are images. Computer vision use computers to emulate human vision including learning and being able to make inferences and take actions based on visual inputs. Computer vision uses Artificial Intelligence (A I). In Image Analysis its inputs are images, but its outputs are attributes extracted from these images (e.g., edges, contours and the identity of individual objects).

Applications of Image Processing

Image processing has many applications as eye is one of the most important sense organs, which is used for analysis and decision making. The following are the few image processing applications.

Medical Imaging

In medical science image processing plays an important role for detecting the abnormalities (diseases) in the human body.

Medical imaging helps in diagnosing diseases and also in analysis of body organs and tissues. Medical imaging incorporates.

Radiology : Radiology refers to examinations of the inner structure of opaque objects using X-rays or other penetrating radiation.

Radiology includes Images from X-rays, ultrasound, computed tomography (CT) Nuclear medicine, Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI).

X-rays Images

A beam of X-rays is projected towards the part of the body which has to be examined. According to the density and composition of the different areas of the body part, a position of X-rays are absorbed by the body. The X-rays that pass through the body are detected to give a 2D representation in terms of images.

Ultrasound Scanned images

Ultrasound frequency around (20,000 Hz) is projected on the organ, the waves travel through and reflected back where density differs. These reflections are detected and imaged, which will reveal details of the inner structure of the body organ to be examined.

Sonography is an ultrasound based diagnostic medical imaging used to vissualise muscles, tendons and many internal organs, to capture their size and structure.

Obstetric sonography is used during pregnancy to visualise fetus.

Computed Tomography (CT)

A 3D image of the inside of an organ can be generated using series of 2D X-ray images taken around a single axis of rotations. To diagnoise complex fractures CT scans can be used, especially ones around joints ligesmentous injuries and dislocations.

CT scans are used to diagonise head, lungs, pulmanory angiogram, Cardiac abdominal and - Pelvic.

PET and SPECT (Single Photon Emission Computed Tomography)

The gamma emitting radio esotope is injected into the blood stream of the patient. Gamma Camera is used to acquire 2D images of the blood nerves.

SPECT and PET can be used to analyse the functioning of Cardiac or brain.

Magnetic Resonance imaging (MRI)

MRI does not use any ionizing radiation. MRI uses powerful magnetic field, which makes the nuclei of the body to produce a rotating magnetic field detectable by the scanners. MRI is useful in imaging the brains, muscles, heart and cancers.

Digital infrared thermal imaging (DITI)

DITI camera is used to capture images called thermograms. DITI Cameras detect infrared radiation emitted by objects. The amount of radiation emitted by an object increases with temperature. So warm objects are easily visible in cool background. The thermograms will be

MRXEERAEB
BAE
MRXEERBAE

analysed by thermologists (Medical doctors trained in thermology) to detect breast cancer. Fever screening (i.e., H1N1). Monitoring healing process.

Electro encephalography (EEG)

EEG is the recording of electrical activity within nervous of the brain the diagnostic applications of EEG is in case of epilespy, coma, encephalopthies, brain death tumoss, stroke.

Electro Cardiography (ECG)

ECG is the measure of electrical activity of the heart over time captured. It is used to detect heart attack and heart related diseases.

Remote Sensing

Remote sensing is the gathering of information about an object, area or phenomenon without being in physical contact with it.

Images acquired by satellite are used in remote sensing i.e., tracking of earth resources, prediction of agricultural crops, urban growth, wheather forecasting flood control and fire control.

Astronomy

Image processing is used in astronomy to analyse the solar system and celestial bodies like moon, star and other planets.

Business

Digital image transmission helps in journalism. People from different countries can work together, using teleconferencing through which people can communicate seeing each other on the displays. Industries can be automated using digital image processing.

Entertainment

Digital Videos can be broadcasted and can be received by television. Videos can be transmitted through internet in you Tube. Video games are because of image processing.

Security and Survalence

Small target detection and tracking, missile guidance vehicle navigation wide area survelliance and automated aided target recognition can be done using image processing Biometric image processing for personal authentucation and identification.

Robotics

A Robot is an electromechanical machine which is guided by computer and electronic programing to emulate human behaviour. Camera and related network works as eyes for the robots.

Night Vision Infrared images

All objects emit a amount of black body radiation as a function of their temperature. The higher an object's temperature is, the more infrared radiation as black body radiation. A infrared camera can detect radiation and can be imaged. The intensity of these images depends on the temperature of the objects in the scene rather than visible light reflected by the objects. So even at night warm objects like warm blooded animals will be visible in the image.

1.2 Fundamental steps in image processing

Fundamentals steps in image processing is as shown in Fig. 1.1.

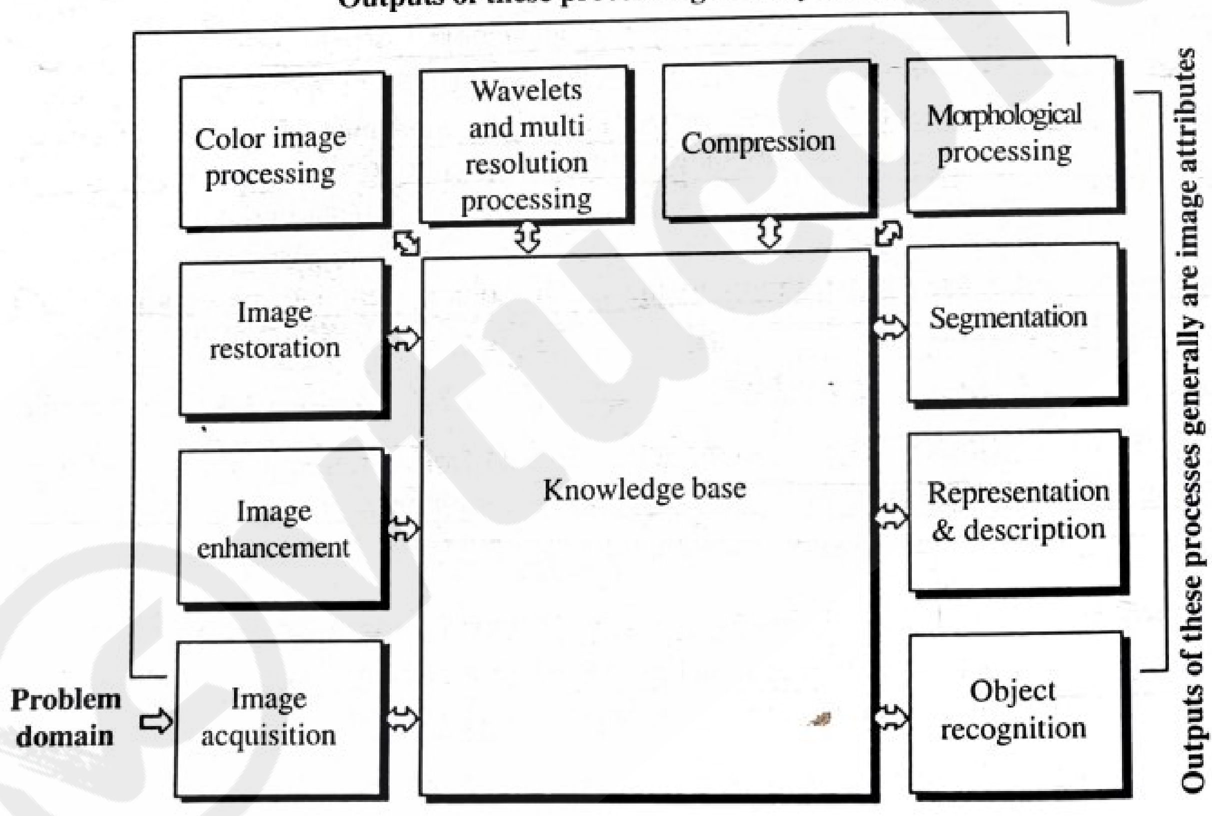


Fig. 1.1 : Fundamental steps in digital image processing

Image Acquisition : It gives information about how to acquire an image i.e., about image origin. Image acquisition stage involves preprocessing such as scaling. Scaling is reducing or increasing the physical size of the image by changing the number of pixels. Image acquisition gives the image in digital form.

Image Enhancement : Enhancement technique is used to bring out detail that is obscured (unclear) or simply to highlight certain features of interest in an image. Enhancement is subjective process. Mathematical tools are used for enhancing the image.

Image Restoration : Restoration means getting something back. Image restoration is a objective process. Image restoration is removal of noise in the image. Restoration techniques are based on mathematical or probabilistic models of image degradation.

Color Image Processing : This includes fundamental concept of color mode and basic color processing in digital domain.

Wavelets : Using wavelets images can be represented in various degrees of resolution (multi resolution) Wavelets are used in image data compression and for pyramidal representation in which image is subdivided into smaller regions.

Compression : Compression is a technique used to reduce the storage required to save an image or the band width required to transmitt. Compression is useful in internet which has to send significant pictorial content. JPEG image files are compressed images.

Morphological Processing : Morphological image processing deals with tools for extracting image components that are useful in representation and description of shapes. Morphological processing begins a transition from process that output image to process that output image attributes.

Segmentation : Segmentation procedures partition an image into its constituent parts or objects. Autonomous segmentation or rugged segmentation leads to object identification.

Representation and Description : Segmentation gives usually raw pixel data constituting either the boundary of a region or all the points in the region itself. Boundary representation is suitable when the focus is on external shape. Regional representation is appropriate when the focus is on internal characteristics such as texture. Choosing a representation is only a part of solution for transforming raw data into a form suitable for subsequent computers processing. Description also called feature selection deals with extracting attributes that result in some quantitative information to identify objects.

Recognition : Recognition is a process that assigns a label to an object based on its description.

Knowledge base : A knowledge base is a special kind of data base for knowledge management. Knowledge data base gives knowledge about the problem domain in image processing system. It also guides the operation of each processing module. It also controls the interaction between modules.

1.3 Components of the Image Processing System

Large scale image processing systems are sold for massive imaging application such as satellite image processing, Medical image processing. Components of the Image Processing System is as shown in Fig. 1.2.

Image Sensors : Image Sensor is a physical device that is sensitive to the energy radiated by the object that we wish to image. In digital video camera, the sensors produce an electrical output proportional to light intensity, example CCD (Charge Couple Device), Photodiodes etc.,

Specialized Image Processing Hardware : Usually consists of the digitizer, a device for converting the output of the physical sensing device into digital form, plus hardware that performs primitive operations such as ALU. One example how an ALU is used is in averaging images as quickly as

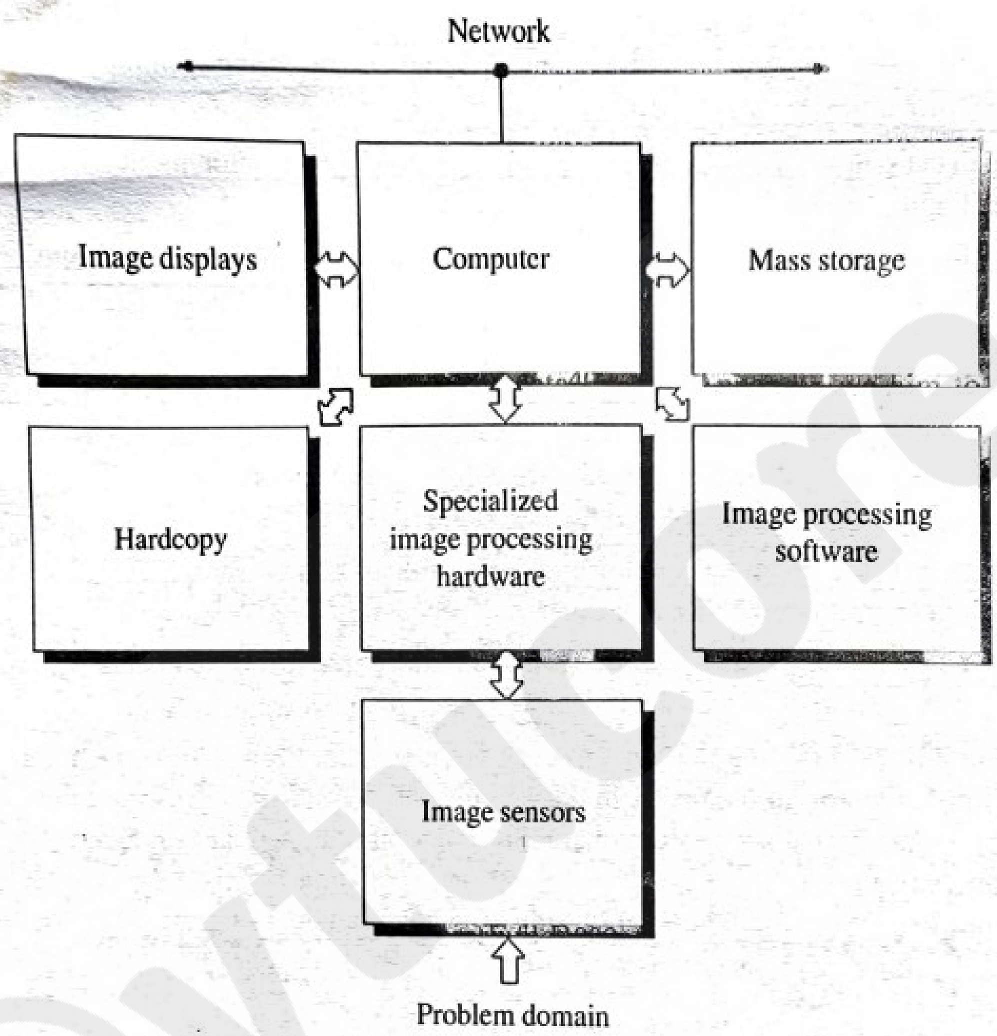


Fig. 1.2 : Components of a general purpose image processing system

they are digitized, for the purpose of noise reduction. This type of hardware is called front end subsystem. This unit perform functions that require fast data throughputs that the typical main computers cannot handle.

Computer : Image processing requires intensive processing capability as it has to handle large data. So computer to super computer is required.

Software : It Consists of specialized modules that perform specific task such as enhancing the image or filtering the image for restoration. More sophisticated software packages allow the integration of these specialized modules for user friendly and general purpose software commands from at least one computer language.

Mass Storage : This capability is a must in image processing application. Usually image processing system deals with thousands or even millions of images. Each uncompressed image may be take (24 μ bytes for 1 Mb image)Digital storage system for image processing falls into three major categories.

1. Short term storage for use during processing.

   Computer memory can be short term storage

2. On-line storage for relatively fast call.

   The key factor characterizing on line storage is frequent access to the stored image.

3. Archival storage characterized by infrequent Acess.

   Magnetic tapes and optical disks.

Image Displays : Displays are part of the computer system. In some cases it is necessary to have stereo display (3D).

Hard copy : Laser printer, optical and CD-ROM disks.

Networking : The key factor in image transmission is bandwidth.

1.4 Elements of visual perception

Human intuition and analysis play a central role in the choice of one technique verses another in image processing and this choice often is based on subjective visual judgements.

1.4.1 Structure of the Human eye

The eye is nearly a sphere with an average diameter of approximately 20mm. Three membranes enclose the eye as shown in Fig. 1.3.

1. The cornea and sclera outer cover
2. The choroid
3. The retina

Cornea is tough transparent tissue that covers the anterior surface of the eye. Continuous with the cornea the sclera is an opaque membrane that encloses the remainder of the optic globe. The choroid directly lies below the sclera with a network of blood vessels, as the major source of nutrition to the eye. At its anterior extreme the choroid is divided into the ciliary body and the iris diaphragm. The iris contracts and expands to control the amount of light that enters the eye. The front of the iris contains visible pigment of the eye, where as the back contains a black pigment. The lens is made up of concentric layers of fibrous cells and is suspended by ciliary fibers. Lens contains 60 to 70% water, about 6% fat and more protein than any other tissue in the eye. The lens absorbs approximately 8% of the visible light spectrum. The innermost membrane of the eye is the retina.

When the eye is properly focused, the reflected light from an objects outside the eye is imaged on the Retina. The light receptions are distributed over the surface of the retina. There are two classes of receptors: cones and rods. The cones in each eye number between 6 and 7 million. The cones are located primarily in the central portion of the retina called the fovea and are highly sensitive to color. Muscles controlling the eye rotate the eye ball untill the image of the object of interest falls on the fovea. Cone vision is called photopic or bright light vision. The number of rods are 75 to 150 million are distributed over the retinal surface. Humans can resolve fine details with cones largely because each one is connected to its own nerve end. Rods give a general overall picture of the field of view as several rods are connected to a single nerve end. Rods are not involved in colour vision and are sensitive to low levels of illumination. This phenomenon is known as scotopic or dimlight vision. The region with no receptors are called Blind spot.

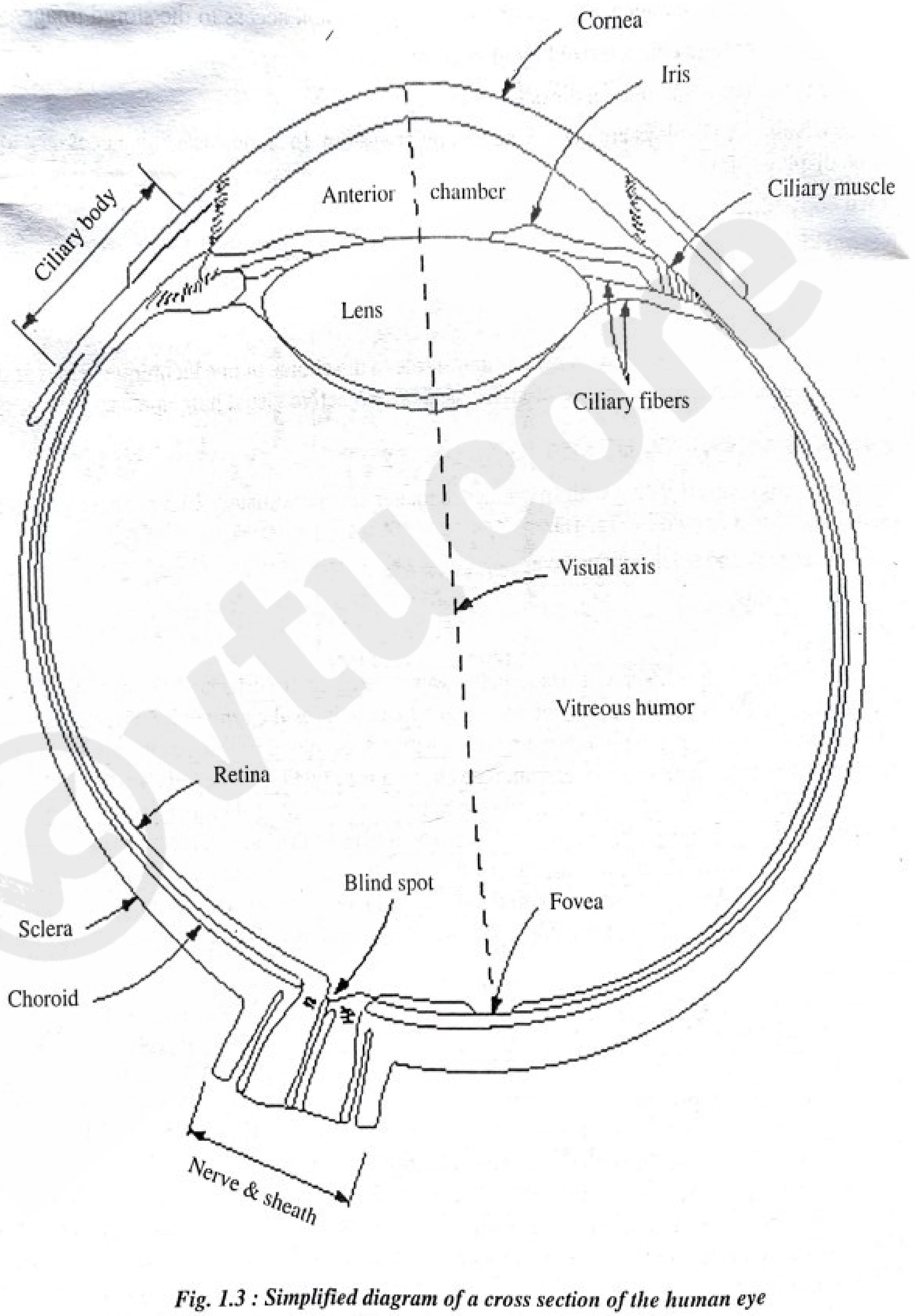


Fig. 1.3 : Simplified diagram of a cross section of the human eye

1.4.2 Image Formation In The Eye

The lens of the eye is flexible. The shape of the lens is controlled by tension in the fibers of the ciliary body. To focus on distant objects the controlling muscle cause the lens to be relatively flattened. Similarly there muscles allow the lens to become thicker in order to focus on objects near the eye. The distance between the center of the lens and the retina (focal length) varies from approximately 17mm to about 14mm. For example the observer is looking at a tree 14m high at a distance of 100m. If h is the height in mm of that object in the retinal image the geometry fields as shown in the Fig. 1.4.

$$15/100 = h/17$$

$$h = 2.55 \text{ mm}$$

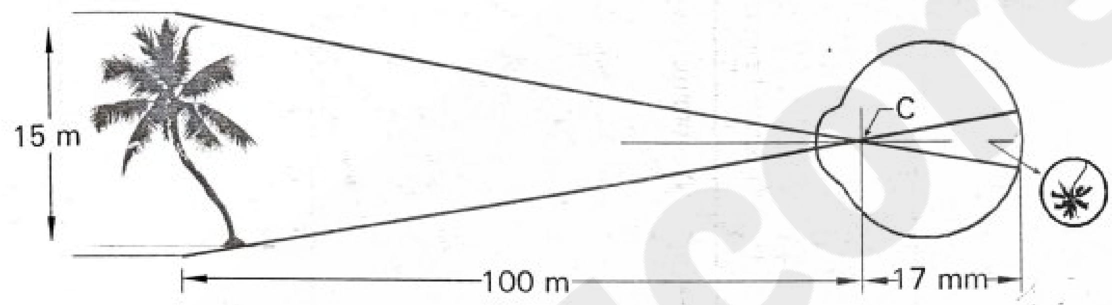


Fig. 1.4 : Graphical representation of the eye looking at a tree. Point C is the optical center of the lens

1.4.3 Brightness Adaptation and Discrimination

Digital image is displayed as a discrete set of intensities, the eye's ability to discriminate between different intensity levels is an important considerations in presenting Image processing results. Experimental evidence indicates that subjective brightness (intensity as perceived by the human visual system) is a logarithmic function of the light intensity incident on the eye. Fig. 1.5 plot of light intensity versus subjective brightness. The long solid curve represents the range of intensities to which the visual system can adapt. The visual system cannot operate over such a range simultaneously. It accomplishes this large variation by changes in its overall sensitivity, a phenomenon known as brightness adaptation. The total range of distinct intensity levels it can discriminate simultaneously is small. The short intersecting curve represents the range of subjective brightness that the eye can perceive when adapted to the level B_a. This range is restricted having a level B_b at and below which all stimuli are perceived as in distinguishable black.

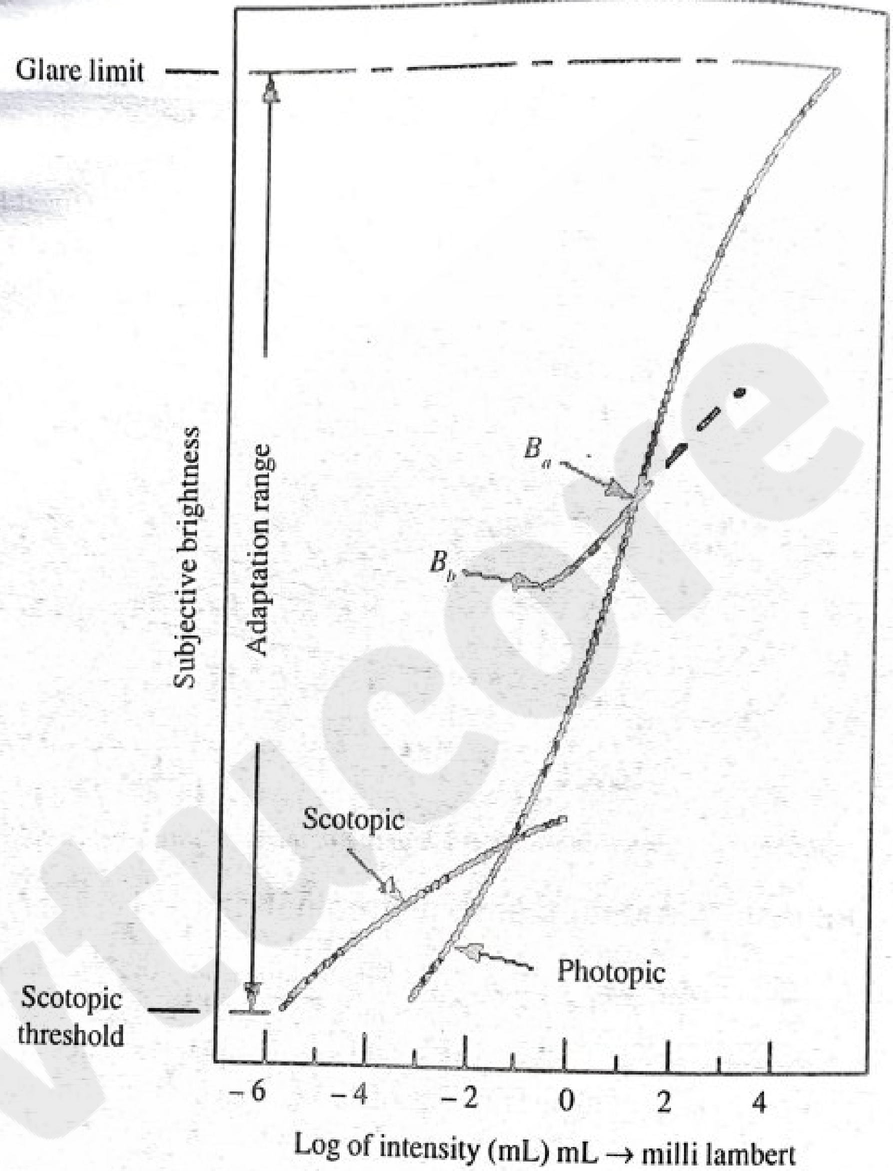


Fig. 1.5 : Log of the intensity versus subjective brightness shown for a particular adaptation level

A classic experiment used to determine the capability of the human visual system for brightness discrimination. The experiment consists of having a subject look at a flat, uniformly illuminated area large enough to occupy the entre field of view. The flat area is a opaque glass, that is illuminated from behind by a light source whose intensity (I) can be varied as shown in the Fig. 1.6. To this field

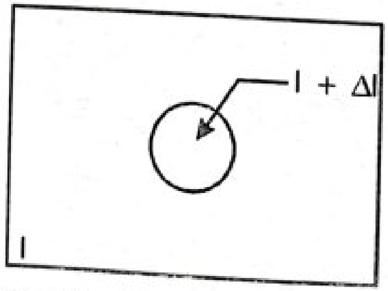


Fig. 1.6 : Experimental setup for determination of brightness discrimination in human eye

is added an increment of illumination ΔI, in the form of a short duration flash that appears as a circle in the center of the uniformly illuminated field. If ΔI is not bright enough, the subject says "no" indicating no perceivable change. As ΔI gets stronger the subject may give a positive response of "yes" indicating a perceived change. The quantity ΔIc/I where ΔIc is the increment of illumination with back ground illuminate I, is called the "weber ratio". A small value of ΔIc/I means that a small % change in intensity is discriminable.

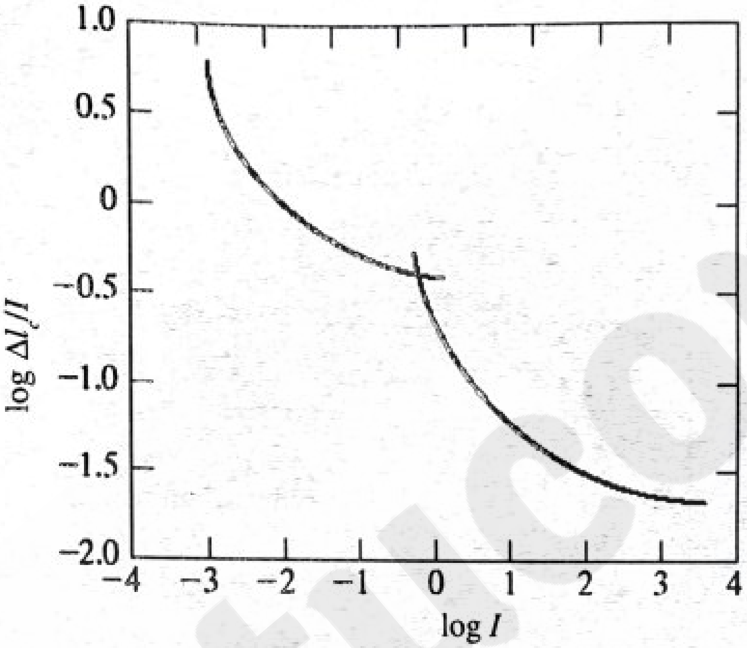


Fig. 1.7 : Typical weber ratio function of intensity

Fig. 1.7 is a plot of log ΔIc/Ic verses log I. This curve shows that brightness discrimination is poor at low levels of illumination. The two branches in the curve, reflect the fact that the low levels of illumination is due to rods where as highlevels is a function of cones.

Two phenomena demonstrate that perceived brightness is not a simple function of intensity. The first is called Mach bands as shown in Fig. 1.8. Mach bands is based on the fact that the visual system tends to perceive less brightness or more brightness around the boundary of regions of different intensities to undershoot or overshoot around the boundary of regions of different intensities.

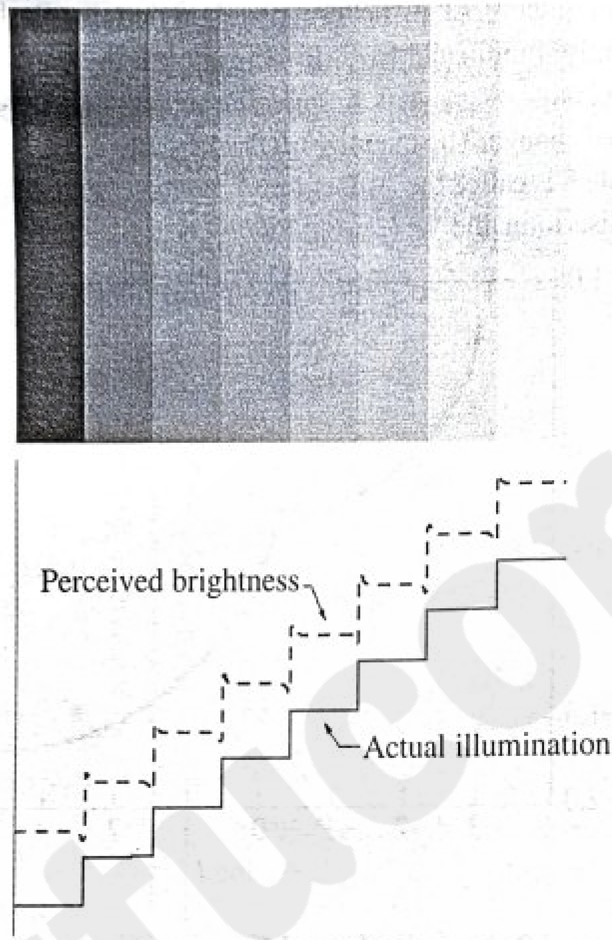


Fig. 1.8 : Mach bands

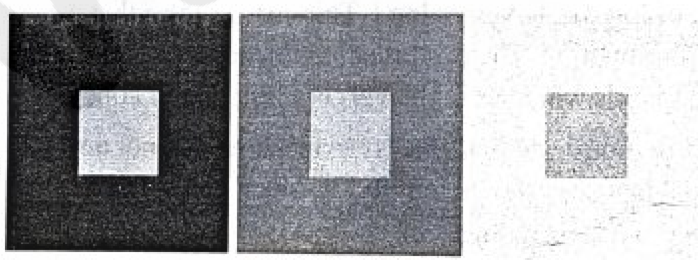


Fig. 1.9 : Simultanious contrast

Whenever there is a sudden change in intensity from low to high for example consider the first two bands at the edge of the intensity transition the border of the low intensity region (black) appears to be more darker and the border of the higher intensity appears to be more lighter.

The second is called simultaneous contrast. Simultaneous contrast is related to the fact that the regions perceived brightness does not depend simply on its intensity but also on its back ground. Fig. 1.9 shows the illustration. In Fig. 1.9 the centre square is of equal bringhtness in all the images, but the first one appears to be more lighter than the rest of the two.

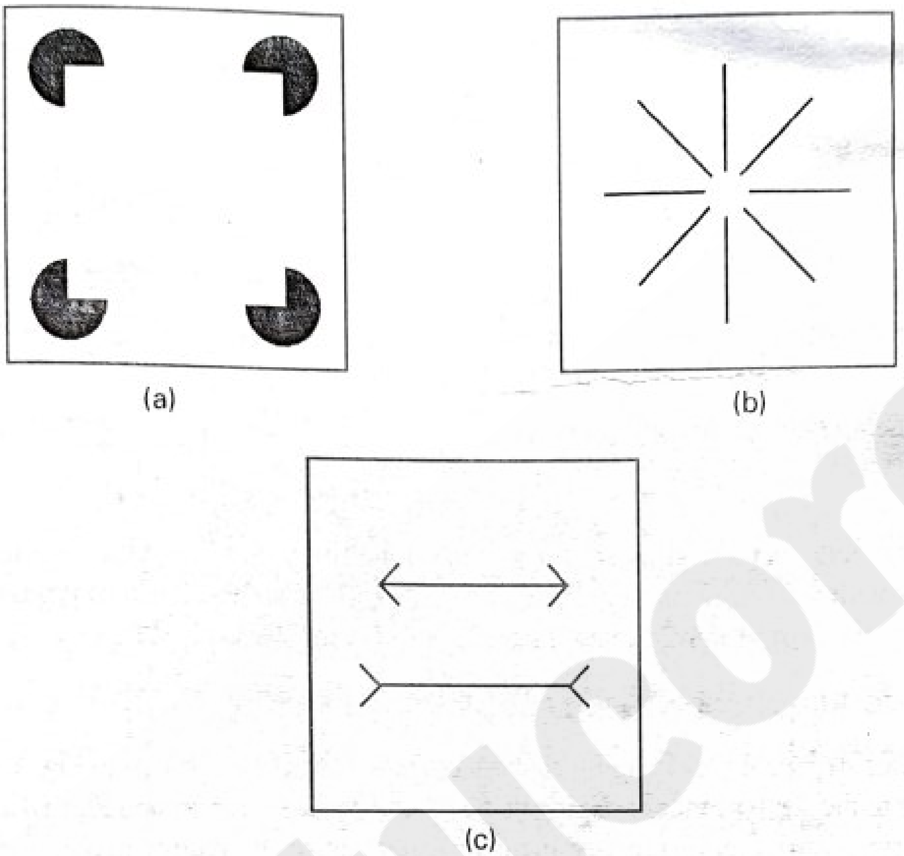


Fig. 1.10 : Some well known optical illusions

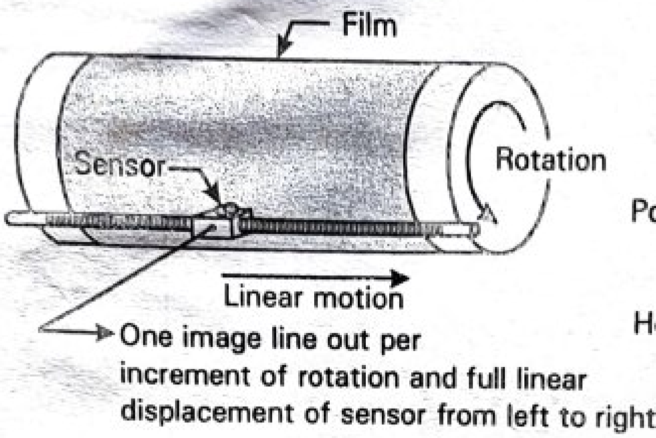
In optical illusions the eyes fill in non existing information as shown in Fig. 1.10. In Fig. 1.10 (a) a square seems to be existing between the circles, but there is no outlining of the square. Similarly a circle seems to be existing in the centre of the lines in the Fig. 1.10 (b). In the Fig. 1.10 (c) the two horizontal lines are of same length but one seems to be shorter than the other.

1.5 Image Sensing and Acquisition

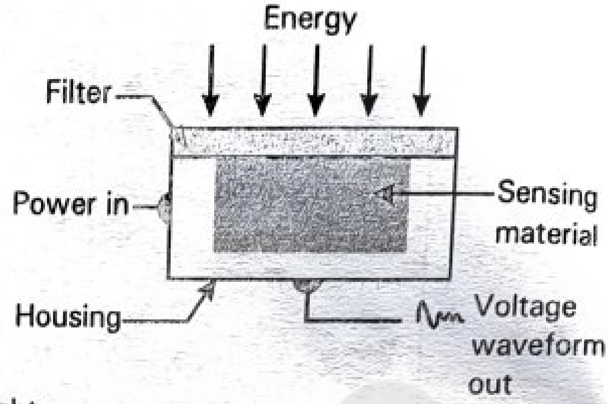
Images are generated by the combination of an "illumination" source and the reflection or absorption of energy from that source by the elements of the "scene" being imaged.

1.5.1 Image Acquisition using a single sensor

The sensor may be photo diode which is constructed of silicon materials and whose output voltage is proportional to light. The use of a filter in front of a sensor improves (selectivity selection of color essence in the image eg : greenish image) as shown in Fig. 1.11(b). In order to generate a 2 - D image using a single sensor as shown in the Fig. 1.11(a) there has to be relative displacement in both the x and y directions between the sensor and the area to be imaged. A film is mounted onto a drum whose mechanical rotation provides displacement in vertical direction. The single sensor is mounted on a lead screw that provides motion in the perpendicular direction. The mechanical motion can be controlled with high precision, this method is an inexpensive way to obtain high-resolution image but the disadvantage of this method is image acquisition takes more time and the



(a) Setup to image using single sensor



(b) Image sensor

Fig. 1.11 : Use of Single senser to generate to 2-D image

scene to be imaged has to be constant for a such a long time. Flat bed with a similar mechanical arrangements with the sensor moving in two linear directions are used. These types of mechanical digitizers sometimes are referred to as "microdensitometers".

1.5.2 Image Acquisition using sensor strips

The sensor strip provides imaging elements in one direction as shown in Fig. 1.13(a). Motion perpendicular to the strip provides imaging in the other direction as shown in Fig. 1.12. Sensor strips mounted in a ring configuration are used in medical and industrial imaging to obtain cross-sectional images of 3-*D* objects. A rotating *x* - ray source provides illumination and the portion of the sensors opposite the source collect the *x* - ray energy that pass through the object. The output of the sensors must be processed by reconstruction algorithm whose objective is to transform the sensed data into meaningful cross-sectional images.

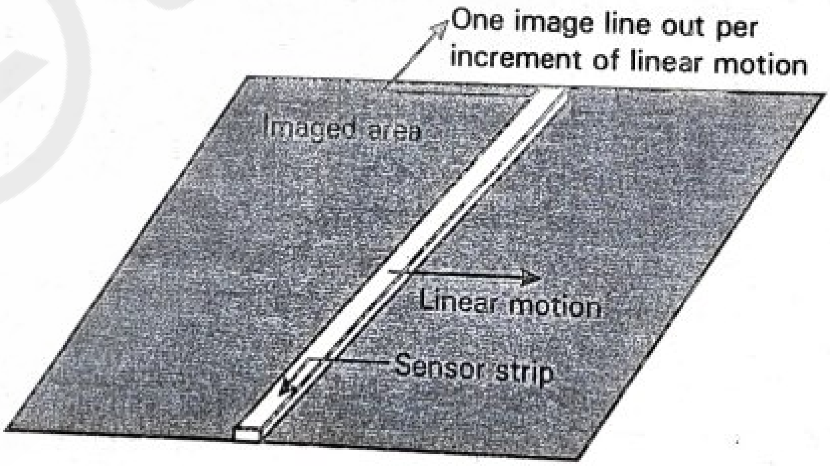
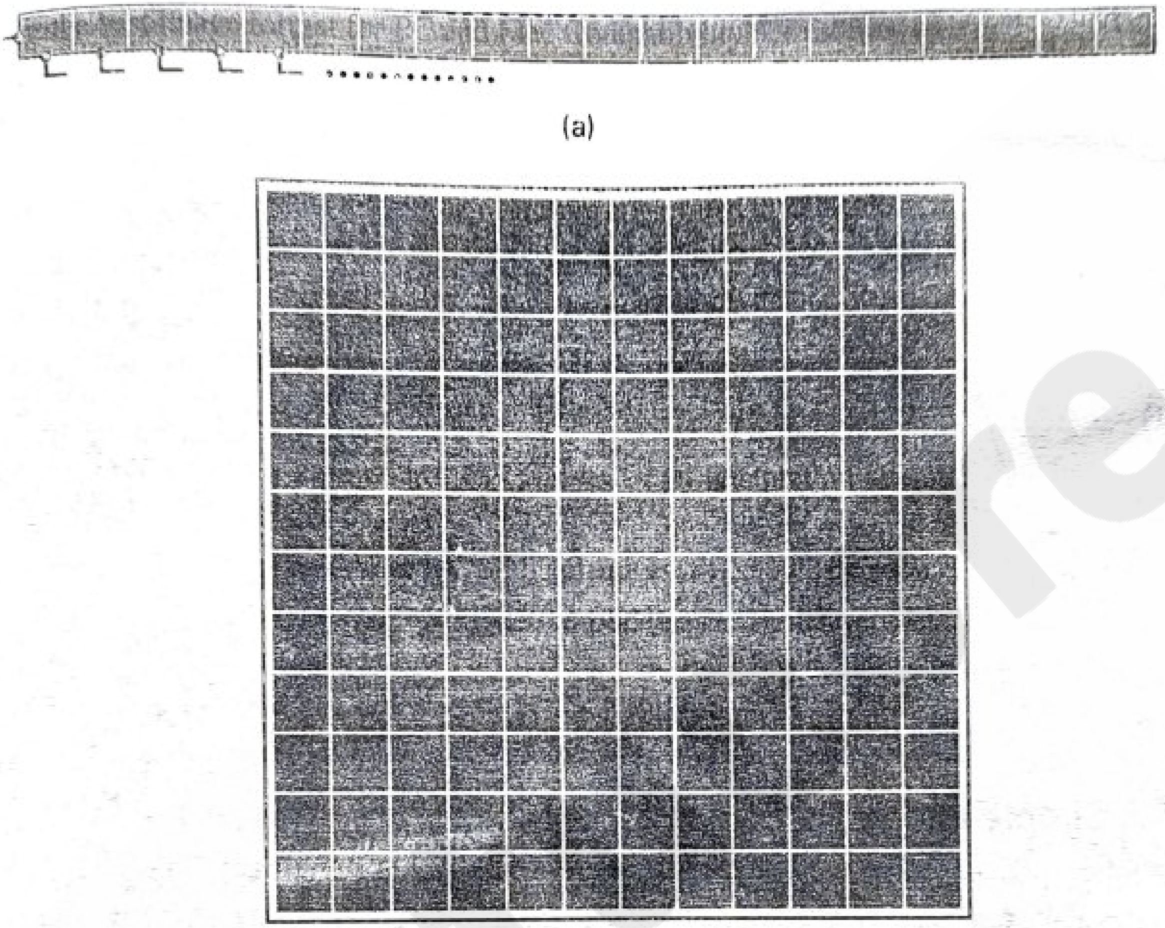


Fig. 1.12 : Image aquisition using a linear sensor strips



(a)

(b)

Fig. 1.13 : (a) Linear Array sensors (b) Sensors in matrix forms

1.5.3 Image Acquisition using sensor Arrays

Numerous electromagnetic and some ultrasonic sensing devices frequently are arranged in a 2 - *D* array format as shown in Fig. 1.13(b). This is the predominant arrangement found in digital cameras with a CCD (Charge Coupled Devices) array. The response of each sensor is proportional to the integral of the light energy projected onto the surface of the sensor. Noise reduction is achieved by letting the sensor integrate the input light signal over minutes or even hours. Since the sensor array 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. Fig. 1.14 shows the energy from an illumination source being reflected from the scene element, the energy also could be transmitted through the scene elements as in X-rays. The first function performed by the imaging system is to collect the incoming energy and focus it into an image plane. If the illumination is light, the front end of the imaging system is a lens, which projects the viewed scene into 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 convert them to a voltage signal, which is then digitized by another section of the imaging system. The output is a digital image.

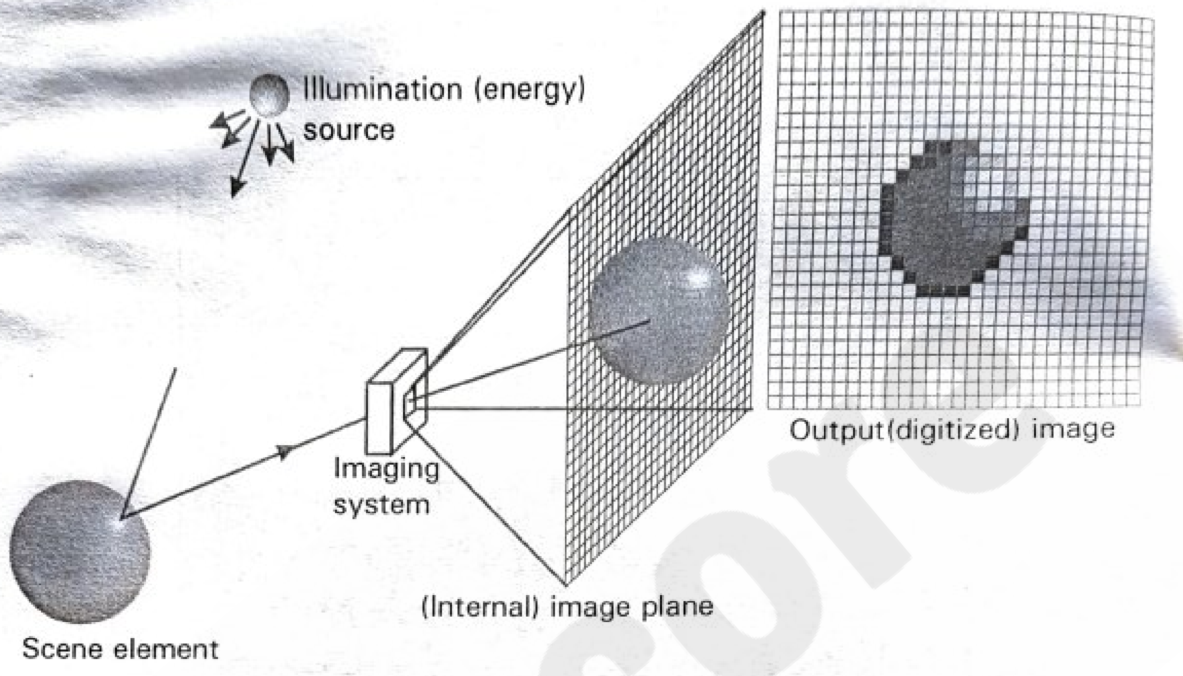


Fig. 1.14 : An example of the digital image acquisition process

1.6 A Simple Image Formation Model

Images are denoted by two-dimensional function of the form $f(x, y)$. The value or amplitud of f at spatial co-ordinate (x, y) is a positive scalar quantity whose physical meaning is determine by the source of the image. Monochromatic images said to span the gray scale. The value o $f(x, y)$ must be nonzero and finite.

$$0 < f(x, y) < \infty \qquad \text{---- (1.1}$$

The function $f(x, y)$ may be characterized by two components.

1. The amount of source illumination incident on the scene being viewed.
2. The amount of illumination reflected by the objects in the scene.

These are the illumination and reflectance components and are denoted by $i(x, y)$ and $r(x, y)$ respectively. The two functions combine as a product to form $f(x, y)$

$$f(x, y) = i(x, y)\, r(x, y) \qquad \text{---- (1.2)}$$

and

$$0 < i(x, y) < \infty \qquad \text{---- (1.3)}$$

$$0 < r(x, y) < 1 \qquad \text{---- (1.4)}$$

The reflectance is bounded by 0 (total absorption) and 1 (total reflectance).

On a clear day, the sun may produce 90,000 lm/m^2 of illumination on the surface of the earth. On a cloudy day, the illumination may be 10,000 lm/m^2. On a clear evening moon yields 0.1 lm/m^2 of illumination. In an office illumination will be 1000 lm/m^2. Similarly $r(x, y)$ is

0.01 for black velvet.

0.65 for stainless steel.

0.80 for flat-white wall paint.

0.90 for silver plated metal.

0.93 for snow.

The intensity of a monochrome image at any co-ordinates (x_0, y_0), the gray level (l) of the image at that point.

$$l = f(x_0, y_0) \qquad \text{---- (1.5)}$$

It is evident that l lies in the range

$$L_{min} \leq l < L_{max} \qquad \text{---- (1.6)}$$

In theory the only requirement on L_{min} is that it be positive and on L_{max} that it be finite.

In practice

$$L_{min} = i_{min}\, r_{min} \qquad \text{---- (1.7)}$$

$$L_{max} = i_{max}\, r_{max} \qquad \text{---- (1.8)}$$

The interval $[L_{min}\ L_{max}]$ is called the gray scale.

Common practice is to shift this interval numerically to the interval

$[0, L - 1]$

black White

All intermediate values are shades of gray varying from black to white.

1.7 Image Sampling and Quantization

Our objective is to generate digital images from sensed data. The output of most sensors is a continuous voltage waveform whose amplitude and spatial behaviour are related to number of photons sensed. Creating a digital image involves two processes.

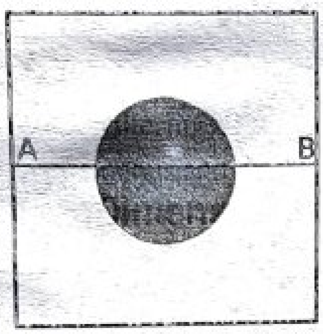
1. Sampling and
2. Quantization

1.7.1 Basic Concepts in Sampling and Quantization

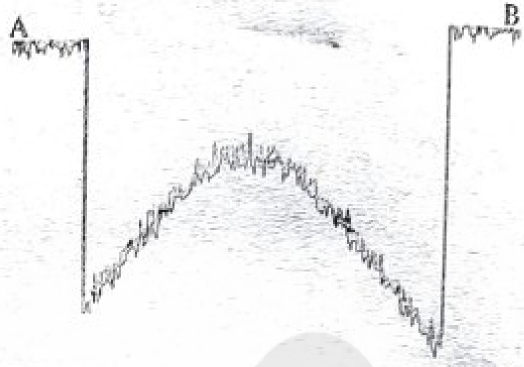
An image is continuous with respect to the x and y co-ordinates and also in amplitude. Digitizing the coordinate values is called sampling. Digitizing the amplitude values is called quantization.

The one dimensional function shown in Fig. 1.15(b) is a plot of amplitude values corresponding to intensity of the continuous image along the line segment AB in Fig. 1.15(a)

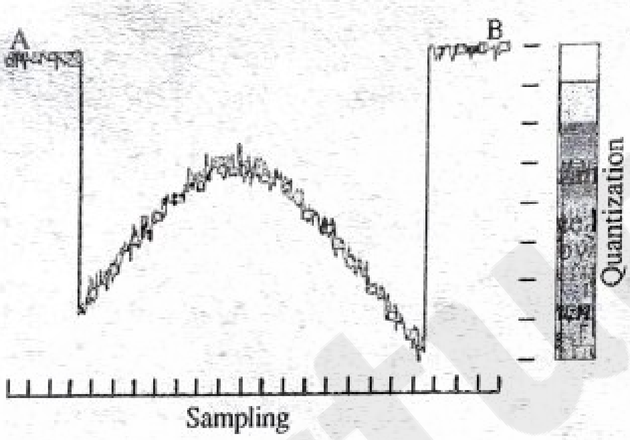
To sample this function, we take equally spaced samples along the line AB. The location of each sample is given by a vertical tick mark in the bottom part of the Fig. 1.15(c). The set of these discrete locations gives the sampled function. In order to form a digital function the gray level value of these samples must be converted (quantized) into discrete quantities. The gray scale is divided into eight levels ranging from black to white. The vertical tick marks indicate the specific value assigned to each of the samples from eight gray levels. Now, the continuous gray levels are



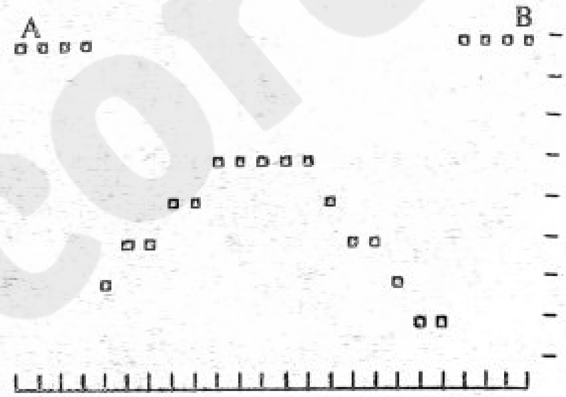
(a) Continuous image



(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

Fig. 1.15 : Generating a digital image

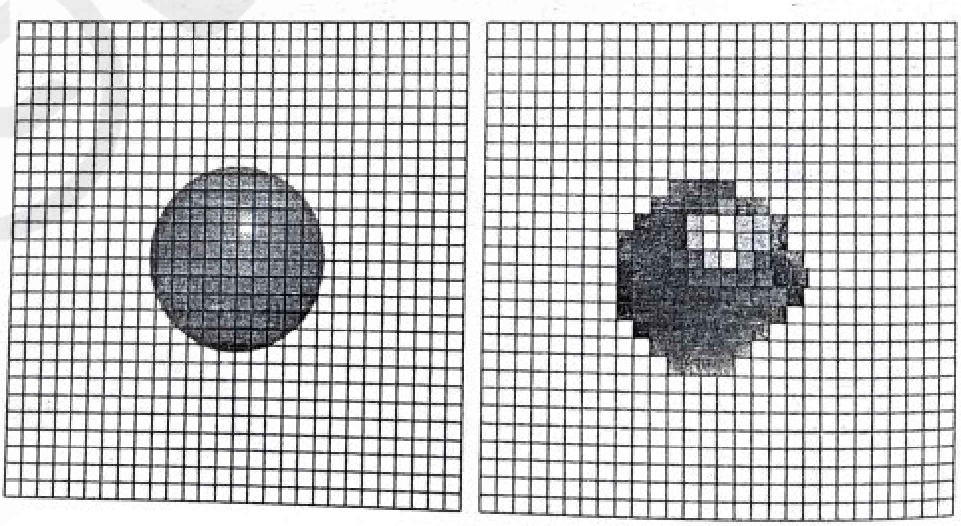
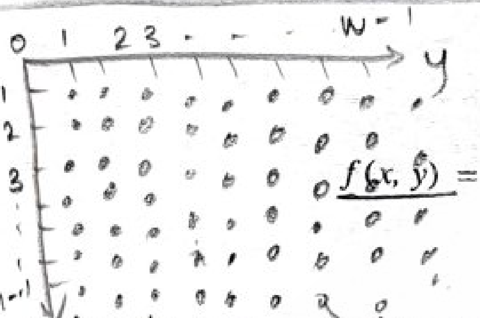


Fig. 1.16 : Digital image obtained after sampling and qualitization

quantized simply by assigning one of the eight discrete gray levels to each sample as shown in Fig.1.5 (d). Starting at the top of the image and carrying out this procedure line by line produces a two-dimensional digital image as shown in the Fig. 1.16. In practice the method of sampling is determined by the sensor arrangement used to generate the image. Clearly, the quality of a digital image is determined by the number of samples and discrete gray levels used in sampling and quantization.

1.7.2 Representing Digital Images

The result of sampling and quantization is a matrix of real numbers. Assume that an image $f(x, y)$ is sampled so that the resulting digital image has M rows and N columns. The complete $M \times N$ digital image is represented in the following matrix form.



$$f(x, y) = \begin{bmatrix} f(0,0) & f(0,1)\ldots & f(0, N-1) \\ f(0,1) & f(1,1)\ldots & f(1, N-1) \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ f(M-1,0) & f(M-1,1) & f(M-1, N-1) \end{bmatrix} \qquad \text{---- (1.9)}$$

co-ordinate convention used to represent all one pixel

Each element of this matrix array is called an image element or pixel. The sampling process may be viewed as partitioning the xy plane into a grid. The $f(x, y)$ is a digital image if (x, y) are integers and f is a function that assigns a gray-level value to each distinct pair of co-ordinates (x, y). This digitization process requires decisions about values for M, N and for the number L, of discrete gray levels allowed for each pixel. Due to processing, storage and sampling hardware consideration, the number of gray levels typically is an integer power of 2

$$L = 2^K \qquad \text{---- (1.10)}$$

We assume that the discrete levels are equally spaced and that they are integers in the interval $[0, L-1]$.

The number, b of bits required to store a digitized image is $b = M \times N \times K$

When $M = N$ this equation becomes

$$b = N^2 K \qquad \text{---- (1.11)}$$

1.7.3 Spatial and Gray-level Resolution

Fig. 1.17 : A 1024 × 1024 image subsampled down to 32 × 32 with number of grey levels kept 256

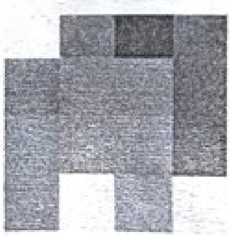
(a) 1024 × 1024,8-bit image

(b) 512 × 512 image resampled into 1024 × 1024 pixels, 8-bit image.

(c) 256 × 256 image resampled into 1024 × 1024 pixels, 8-bit image.

(d) 128 × 128 image resampled into 1024 × 1024 pixels, 8-bit image.

(e) 64 × 64 image resampled into 1024 × 1024 pixels, 8-bit image.



(f) 32 × 32 image resampled into 1024 × 1024 pixels, 8-bit image.

Fig. 1.18 : Resized Images of Fig. 1.17

Sampling is the principal factor determining the "Spatial resolution" of an image. Spatial resolution is the smallest detail in an image. Consider a chart with vertical lines of width W, with the space between the lines also having width W. Thus the width of the line pair is $2W$. There are 1/2W line pairs per unit distance, which are clearly visible.

Definition of Resolution : The number of smallest discernible line pairs per unit distance. Gray level resolution is the smallest discernible change in gray level. The number of gray levels is usually an integer power of 2. The most common number is 8 bits. Consider an L-level digital image of size $M \times N$. This image has a spatial resolution of $M \times N$ pixels and a gray level resolution of L levels.

Spatial resolution is explained using the images in the Fig. 1.17. This image is of size 1024×1024 whose gray levels are represented by 8 bit, (256 gray levels). Other image shown in Fig. 1.17 is of size 512×512 image is obtained from 1024×1024, by deleting every other row and column. Similarly 256×256 image is generated by deleting every other row and column from 512×512 image. Similarly 128×128, 64×64 and 32×32 images are created. It is difficult to see the effect of reduction in number of pixels in an image because of dimensional proportions between various image pixel densities.

In Fig. 1.18 all images with different pixel densities are shown with the same dimension so the effect of reduction in number of pixels in an image (reducing spatial resolution) can be seen. In 1024×1024 and 512×512 number much difference is not seen. But in 256×256 check board pattern is seen in borders in the image and they become pronounced in the 64×64 and 32×32 image.

Here we keep spatial resolution constant (number of pixels in an image) and reduce the gray level resolution by reducing the number of gray levels from 256 to 2 (2^K where K = 8 to 1) in integer power of 2.

Fig. 1.19 (a) is a 128×128 resolution with 256 gray levels (2^8). Similarly Fig. 1.19 (b) is with same spatial resolution (128×128) with 128 gray levels. Similarly Fig. 1.19 (c) is with 64 gray levels. The 256, 128, 64 level images are visually identical. The 32 level image shown in Fig. 1.19 (d) has very unnoticable set of very fine false edges in the areas of smooth gray levels (in the which hexagonal patches of the ball). This effect is pronounced in 16-8 levels images. This effect is called false contouring.

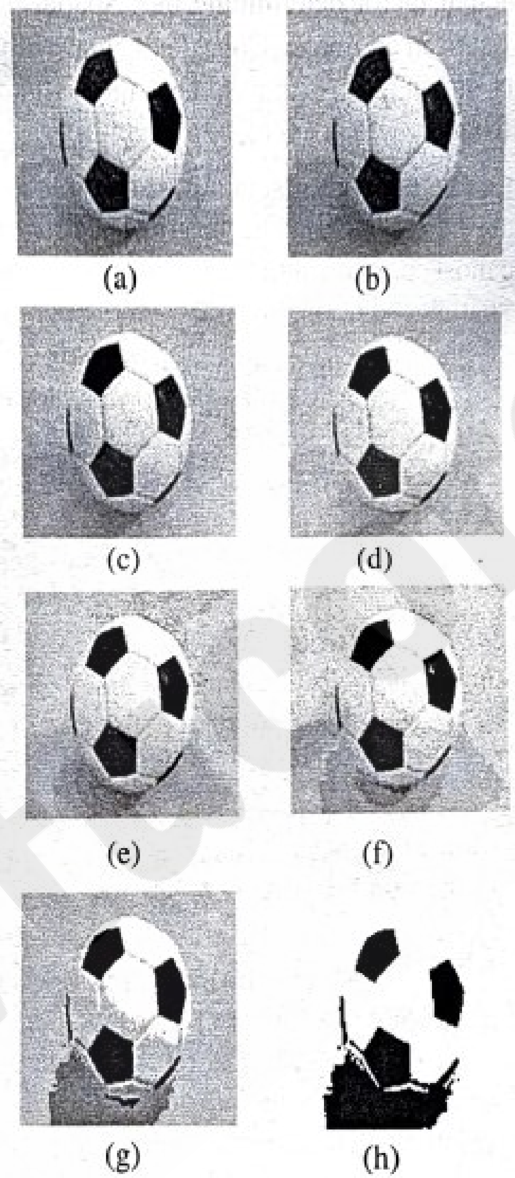


Fig. 1.19 : Images to show gray level resolution

Isopreference Curves

Isopreference curves are drawn in the N, K plane as shown in Fig. 1.21, where N is th number of pixels in the image with $M = N$. K is the number of gray levels. Each point in th N, K plane represents an image having values of N and K equal to the co ordinates of that poi Points lying on an isopreference curve correspond to images of equal subjective quality. For exampl the baby face image with $N = 230$ and $K = 4$ will have the same quality as the same image wi $N = 128$ and $K = 5$. The baby's face is representative of an image with relatively little detail a shown in Fig. 1.20(a). The picture of the flowers contains an inter mediate amount of detail a shown in Fig. 1.20(b). The picture of group of people contains more detail as shown in Fig. 1.20(c) The isopreference curves tended to become more vertical as the detail in the image increases.

(a) Image with a low level of detail

(b) Image with a medium level of detail

(c) Image with a relatively large amount of detail

Fig. 1.20 : Example images for Isopreference Curves

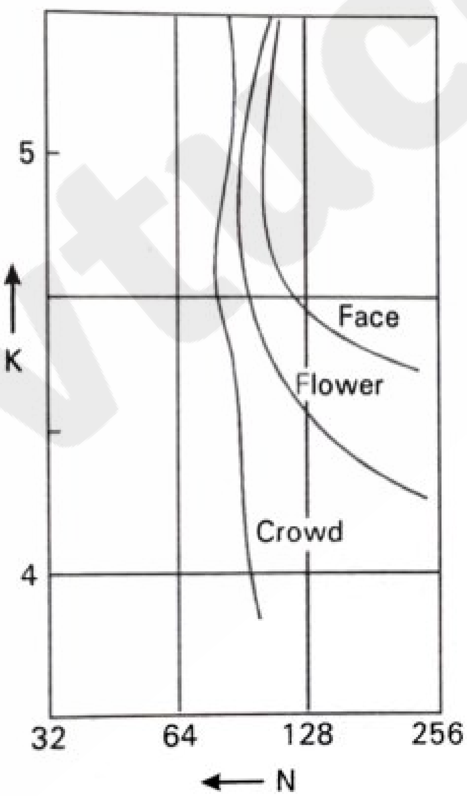


Fig. 1.21 : Isopreference Curves

1.7.4 Zooming and Shrinking Digital Images

Zooming may be viewed as oversampling. Shrinking may be viewed as undersampling.

Application of Zooming images

- If the image size one normally show images, is not in high enough resolution to grasp t details in the image. For example the image of a model wearing the designery costume, if o wants to view the in detail design and material of the costume one can zoom and get t details.

  Zooming is very critical in medical imaging to analyse the infected areas of the organ.

Application of Shrinking images

Shrinking of images can be used where many images are required to display on the sam screen and when fine details are not required.

Micro photocopy of the book is the result of shrinking scanning text images.

Zooming requires two steps:

1. The creation of new pixel locations.
2. Assignment of gray levels to these new locations.

Three methods for gray level assignment.

1. Nearest neighbor interpolation.
2. Pixel replication.
3. Bilinear interpolation.

Nearest neighbor interpolation : Suppose that we have an image of size 500×500 pixels and wa want to enlarge it 1.5 times to 750 × 750 pixels. Lay an imaginary 750 × 750 grid over the origina image. Obviously, the spacing in the grid would be less than one pixel. Closest pixel's gray level i assigned to the new pixels. Expand it to the original specified size to obtain the zoomed image.

Pixel replication : Pixel replication is applicable to increase the size of an image an integer number of times. For instance to double the size of the image. We can duplicate each coloumn and each row.

Bilinear Interpolation : This uses the four nearest neighbours of a point. Let (x', y') denote the coordinates of a point in the zoomed image and let $V(x', y')$ denote the gray level assigned to it. For bilinear interpolation, the assigned gray level is given by $V(x', y') = ax' + by' + cx'y' + d$, where the four coefficients are determined from the four equations in four unknowns that can be written using the four nearest neighbors of point (x', y').

(a) (b) (c)

Images zoomed from 128 × 128, 64 × 64 and 32 × 32 to 1024 × 1024 using nearest neighbor gray level interpolation

(d) (e) (f)

Images zoomed from 128 × 128, 64 × 64 and 32 × 32 to 1024 × 1024 using bilinear gray level interpolation

Fig. 1.22 : Image Zooming using nearest neighbor interpolation and bilinear interpolation methods

In Fig. 1.22 (a) (b) and (c) are the images zoomed from 128 × 128, 64 × 64, and 32 × 32 to 1024 × 1024 using nearest neighbor interpolation method. The equivalent results are shown in Fig. 1.22 (d) (e) (f) using bilinear interpolation. In 128 × 128 to 1024 × 1024 overall appearance is almost clear in both the methods but in 32 × 32 to 1024 × 1024 in nearest neighbor interpolation method checkerboard effect is seen and in bilinear interpolation there is severe blurring effect.

Shrinking the images follow the same methodology but with opposite operations.

1.8 Some Basic Relationships Between pixels

1.8.1 Neighbors of a pixel

4 - Neighbors [N_4 (P)]

A pixel P at Co ordinates (x, y) has four horizontal and vertical neighbors whose co ordinates are given by $(x + 1, y)$, $(x - 1, y)$, $(x, y + 1)$, $(x, y - 1)$

D - Neighbors [N_D (P)]

The four diagonal neighbors of P have co ordinates

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

8 - Neighbor [N_8 (P)]

The N_4 neighbors and N_D neighbors together are called 8 - neighbors

Adjacency, Connectivity, Regions and Boundaries.

To establish two pixels are connected they should be 4 - adjacency, 8 - adjacency or m - adjacency.