

## **MODULE-1**

### **DIGITAL IMAGE**

#### **INTRODUCTION**

The digital image processing deals with developing a digital system that performs operations on a digital image.

An image is nothing more than a two dimensional signal. It is defined by the mathematical function  $f(x,y)$  where  $x$  and  $y$  are the two co-ordinates horizontally and vertically and the amplitude of  $f$  at any pair of coordinate  $(x, y)$  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 image digital image processing refers to the processing of digital image by means of a digital computer.

A digital image is composed of a finite number of elements, each of which has a particular location and values of these elements are referred to as picture elements, image elements and pixels.

#### **Motivation and Perspective**

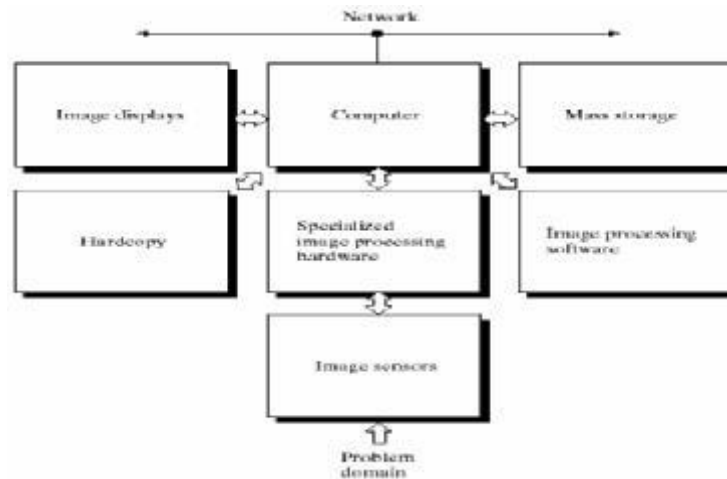
Digital image processing deals with manipulation of digital images through a digital computer. It is a subfield of signals and systems but focus particularly on images. DIP focuses on developing a computer system that is able to perform processing on an image. The input of that system is a digital image and the system process that image using efficient algorithms, and gives an image as an output. The most common example is Adobe Photoshop. It is one of the widely used applications for processing digital images.

#### **Applications**

Some of the major fields in which digital image processing is widely used are

1. Gamma Ray Imaging- Nuclear medicine and astronomical observations.
2. X-Ray imaging – X-rays of body.
3. Ultraviolet Band –Lithography, industrial inspection, microscopy, lasers.
4. Visual And Infrared Band – Remote sensing.
5. Microwave Band – Radar imaging.

## Components of Image Processing System



### i) Image Sensors

With reference to sensing, two elements are required to acquire digital image. The first is a physical device that is sensitive to the energy radiated by the object we wish to image and second is specialized image processing hardware.

### ii) Specialize image processing hardware –

It consists of the digitizer just mentioned, plus hardware that performs other primitive operations such as an arithmetic logic unit, which performs arithmetic such addition and subtraction and logical operations in parallel on images.

### iii) Computer

It is a general purpose computer and can range from a PC to a supercomputer depending on the application. In dedicated applications, sometimes specially designed computer are used to achieve a required level of performance

### iv) Software

It consist of specialized modules that perform specific tasks a well designed package also includes capability for the user to write code, as a minimum, utilizes the specialized module. More sophisticated software packages allow the integration of these modules.

### v) Mass storage

This capability is a must in image processing applications. An image of size 1024 x1024 pixels, in which the intensity of each pixel is an 8- bit quantity requires one megabytes of storage space if the image is not compressed. Image processing applications falls into three principal categories of storage

i) Short term storage for use during processing

ii) On line storage for relatively fast retrieval

iii) Archival storage such as magnetic tapes and disks

vi) Image displays

Image displays in use today are mainly color TV monitors. These monitors are driven by the outputs of image and graphics displays cards that are an integral part of computer system

vii) Hardcopy devices

The devices for recording image includes laser printers, film cameras, heat sensitive devices inkjet units and digital units such as optical and CD ROM disk. Films provide the highest possible resolution, but paper is the obvious medium of choice for written applications.

viii) Networking

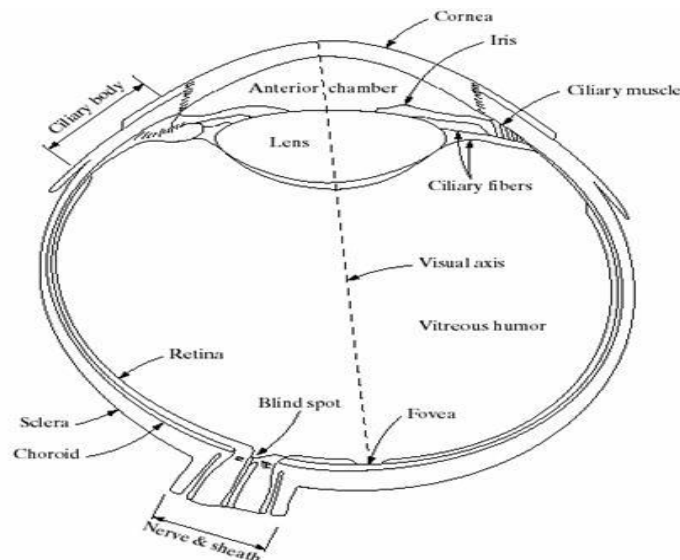
It is almost a default function in any computer system in use today because of the large amount of data inherent in image processing applications. The key consideration in image transmission bandwidth.

## Elements of Visual Perception

### Structure of the human Eye

The eye is nearly a sphere with average approximately 20 mm diameter. The eye is enclosed with three membranes

- a) The cornea and sclera: it is a tough, transparent tissue that covers the anterior surface of the eye. Rest of the optic globe is covered by the sclera
- b) The choroid: It contains a network of blood vessels that serve as the major source of nutrition to the eyes. It helps to reduce extraneous light entering in the eye  
It has two parts
  - (1) Iris Diaphragms- it contracts or expands to control the amount of light that enters the eyes.
  - (2) Ciliary body



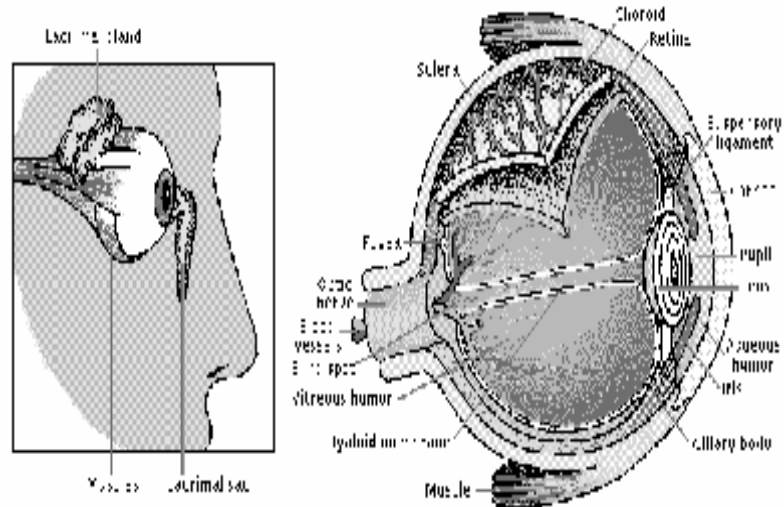
- c) Retina – it is innermost membrane of the eye. When the eye is properly focused, light from an object outside the eye is imaged on the retina. There are various light receptors over the surface of the retina

The two major classes of the receptors are-

- 1) cones- it is in the number about 6 to 7 million. These are located in the central portion of the retina called the fovea. These are highly sensitive to color. Human can resolve fine details with these cones because each one is connected to its own nerve end. Cone vision is called photopic or bright light vision

- 2) Rods – these are very much in number from 75 to 150 million and are distributed over the entire retinal surface. The large area of distribution and the fact that several rods are connected to a single nerve give a general overall picture of the field of view. They are not involved in the color vision and are sensitive to low level of illumination. Rod vision is called is scotopic or dim light vision.

The absent of reciprocators is called blind spot



### Image Formation in the Eye

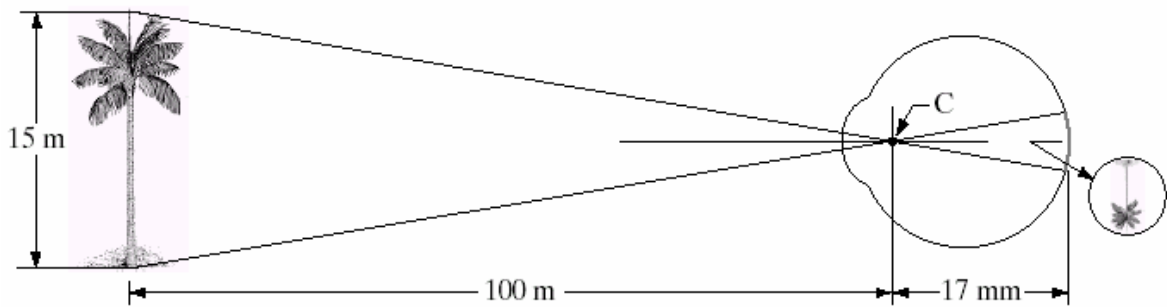
The major difference between the lens of the eye and an ordinary optical lens is that the former is flexible.

The shape of the lens of the eye is controlled by tension in the fibers of the ciliary body. To focus on the distant object the controlling muscles allow the lens to become thinner in order to focus on object near the eye it becomes relatively flattened.

The distance between the center of the lens and the retina is called the focal length and it varies from 17mm to 14mm as the refractive power of the lens increases from its minimum to its maximum.

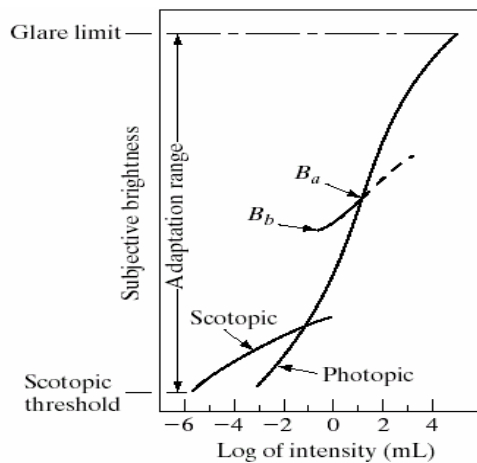
When the eye focuses on an object farther away than about 3m. the lens exhibits its lowest refractive power. When the eye focuses on a nearby object. The lens is most strongly refractive.

The retinal image is reflected primarily in the area of the fovea. Perception then takes place by the relative excitation of light receptors, which transform radiant energy into electrical impulses that are ultimately decoded by the brain.



## Brightness Adaption and Discrimination

Digital image are displayed as a discrete set of intensities. The range of light intensity levels to which the human visual system can adopt is enormous- on the order of  $10^{10}$  from scotopic threshold to the glare limit. Experimental evidences indicate that subjective brightness is a logarithmic function of the light intensity incident on the eye.

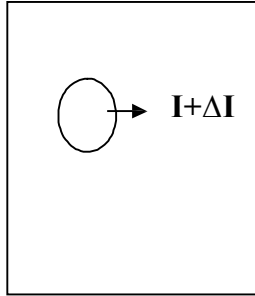


The curve represents the range of intensities to which the visual system can adopt. But the visual system cannot operate over such a dynamic range simultaneously. Rather, it is accomplished by change in its overall sensitivity called brightness adaptation.

For any given set of conditions, the current sensitivity level to which of the visual system is called brightness adoption level,  $B_a$  in the curve. The small intersecting curve represents the range of subjective brightness that the eye can perceive when adapted to this level. It is restricted at level  $B_b$ , at and below which all stimuli are perceived as indistinguishable blacks. The upper portion of the curve is not actually restricted, while simply raise the adaptation level higher than  $B_a$ .

The ability of the eye to discriminate between change in light intensity at any specific adaptation level is also of considerable interest.

Take a flat, uniformly illuminated area large enough to occupy the entire field of view of the subject. It may be a diffuser such as an opaque glass, that is illuminated from behind by a light source whose intensity,  $I$  can be varied. To this field is added an increment of illumination  $\Delta I$  in the form of a short duration flash that appears as circle in the center of the uniformly illuminated field. If  $\Delta I$  is not bright enough, the subject cannot see any perceivable changes.



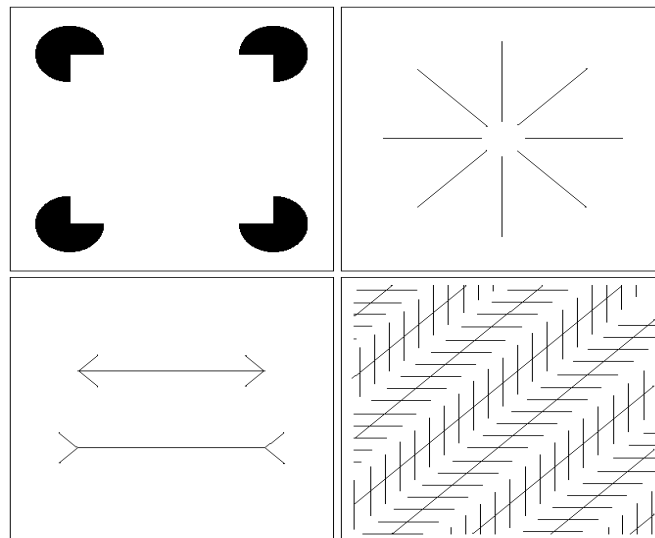
As  $\Delta I$  gets stronger the subject may indicate of a perceived change.  $\Delta I_c$  is the increment of illumination discernible 50% of the time with background illumination  $I$ . Now,  $\Delta I_c / I$  is called the Weber ratio.

Small value means that small percentage change in intensity is discernible representing “good” brightness discrimination.

Large value of Weber ratio means large percentage change in intensity is required representing “poor brightness discrimination”.

### Optical illusion

In this the eye fills the non existing information or wrongly pervious geometrical properties of objects.





#### iv) Color image processing

It is an area that is been gaining importance because of the use of digital images over the internet. Color image processing deals with basically color models and their implementation in image processing applications.

#### v) Wavelets and Multiresolution Processing

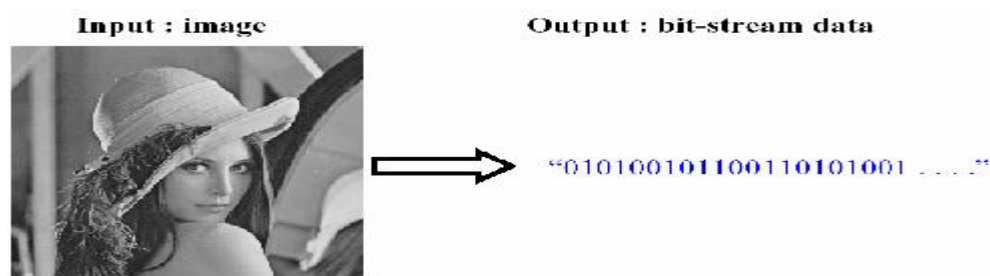
These are the foundation for representing image in various degrees of resolution



#### vi) Compression

It deals with techniques reducing the storage required to save an image, or the bandwidth required to transmit it over the network. It has two major approaches:

- a) Lossless Compression
- b) Lossy Compression



#### vii) Morphological processing

It deals with tools for extracting image components that are useful in the representation and description of shape and boundary of objects. It is majorly used in automated inspection applications.

#### viii) Representation and Description

It always follows the output of segmentation step that is, raw pixel data, constituting either the boundary of an image or points in the region itself. In either case converting the data to a form suitable for computer processing is necessary.

#### ix) Recognition

It is the process that assigns label to an object based on its descriptors. It is the last step of image processing which use artificial intelligence software.

#### Knowledge base

Knowledge about a problem domain is coded into an image processing system in the form of a knowledge base. This knowledge may be as simple as detailing regions of an image where the information of the interest is known to be located. Thus limiting search that has to be conducted in seeking the information. The knowledge base also can be quite complex such interrelated list of all major possible defects in a materials inspection problems or an image database containing high resolution satellite images of a region in connection with change detection application



## A Simple Image Model

An image is denoted by a two dimensional function of the form  $f\{x, y\}$ . The value or amplitude of  $f$  at spatial coordinates  $\{x,y\}$  is a positive scalar quantity whose physical meaning is determined by the source of the image. When an image is generated by a physical process, its values are proportional to energy radiated by a physical source. As a consequence,  $f(x,y)$  must be nonzero and finite; that is  $0 < f(x,y) < \infty$

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

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

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

We call the intensity of a monochrome image at any coordinate  $(x,y)$  the gray level ( $l$ ) of the image at that point  $l = f(x, y)$ ,  $L_{\min} \leq l \leq L_{\max}$

$L_{\min}$  is to be positive and  $L_{\max}$  must be finite

$$L_{\min} = i_{\min} r_{\min}$$

$$L_{\max} = i_{\max} r_{\max}$$

The interval  $[L_{\min}, L_{\max}]$  is called gray scale. Common practice is to shift this interval numerically to the interval  $[0, L-1]$  where  $l=0$  is considered black and  $l=L-1$  is considered white on the gray scale. All intermediate values are shades of gray varying from black to white.

## Image Digitization

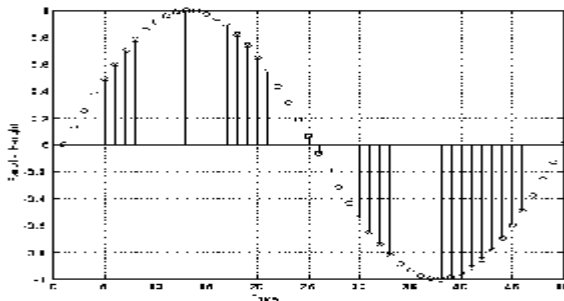
To create a digital image, we need to convert the continuous sensed data into digital form. This involves two processes – sampling and quantization. An image may be continuous with respect to the  $x$  and  $y$  coordinates and also in amplitude. To convert it into digital form we have to sample the function in both coordinates and in amplitudes.

**Digitalizing the coordinate values is called sampling**

**Digitalizing the amplitude values is called quantization**

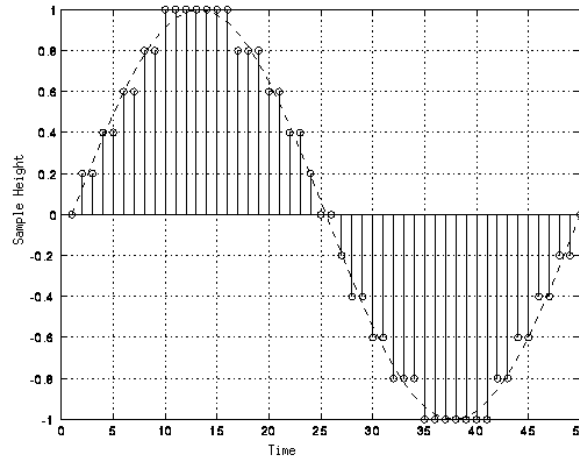
There is a continuous image along the line segment AB.

To sample this function, we take equally spaced samples along line AB. The location of each samples is given by a vertical tick back (mark) in the bottom part. The samples are shown as block squares superimposed on function the set of these discrete locations gives the sampled function.



In order to form a digital image, the gray level values must also be converted (quantized) into discrete quantities. So we divide the gray level scale into eight discrete levels ranging from black to white. The vertical tick mark assign the specific value assigned to each of the eight level values.

The continuous gray levels are quantized simply by assigning one of the eight discrete gray levels to each sample. The assignment it made depending on the vertical proximity of a simple to a vertical tick mark.

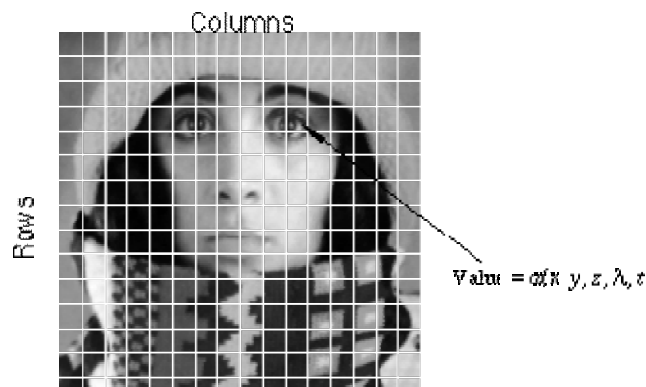


Starting at the top of the image and covering out this procedure line by line produces a two dimensional digital image.

### Digital Image Definition

A digital image  $f[m,n]$  described in a 2D discrete space is derived from an analog image  $f(x,y)$  in a 2D continuous space through a sampling process that is frequently referred to as digitization. Some basic definitions associated with the digital image are described.

The 2D continuous image  $f(x,y)$  is divided into  $N$  rows and  $M$  columns. The intersection of a row and a column is termed a pixel. The value assigned to the integer coordinates  $[m,n]$  with  $\{m=0,1,2,\dots, M-1\}$  and  $\{n=0,1,2,\dots,N-1\}$  is  $f[m,n]$ . In fact, in most cases  $f(x,y)$  is actually a function of many variables including depth ( $d$ ), color ( $\mu$ ) and time ( $t$ ).



There are three types of computerized processes in the processing of image

- 1) Low level process- these involve primitive operations such as image processing to reduce noise, contrast enhancement and image sharpening. These kind of processes are characterized by fact the both inputs and output are images.
- 2) Mid level image processing - it involves tasks like segmentation, description of those objects to reduce them to a form suitable for computer processing, and classification of individual objects. The inputs to the process are generally images but outputs are attributes extracted from images.
- 3) High level processing – It involves “making sense” of an ensemble of recognized objects, as in image analysis, and performing the cognitive functions normally associated with vision.

### Representing Digital Images

The result of sampling and quantization is 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 values of the coordinates  $(x,y)$  now become discrete quantities thus the value of the coordinates at origin become  $(x,y) = (0,0)$  The next Coordinates value along the first signify the image along the first row. It does not mean that these are the actual values of physical coordinates when the image was sampled. Thus the right side of the matrix represents a digital element, pixel or pel. The matrix can be represented in the following form as well.

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

The sampling process may be viewed as partitioning the  $x$ - $y$  plane into a grid with the coordinates of the center of each grid being a pair of elements from the Cartesian products  $Z^2$  which is the set of all ordered pair of elements  $(Z_i, Z_j)$  with  $Z_i$  and  $Z_j$  being integers from  $Z$ .

Hence  $f(x,y)$  is a digital image if gray level (that is, a real number from the set of real number  $R$ ) to each distinct pair of coordinates  $(x,y)$ . This functional assignment is the quantization process. If the gray levels are also integers,  $Z$  replaces  $R$ , and a digital image become a 2D function whose coordinates and the amplitude value are integers.

Due to processing storage and hardware consideration, the number of gray levels typically is an integer power of 2.  $L=2^k$

Then, the number  $b$ , of bits required to store a digital image is

$$B=M *N* K$$

When  $M=N$  The equation become  $b=N^2*K$

When an image can have  $2^k$  gray levels, it is referred to as “ $k$ - bit” . An image with 256 possible gray levels is called an “8-bit image (because  $256=2^8$ ).

## Spatial and Gray Level Resolution

Spatial resolution is the smallest discernible details are an image. Suppose a chart can be constructed with vertical lines of width  $w$  with the space between the also having width  $W$ , so a line pair consists of one such line and its adjacent space thus. The width of the line pair is  $2w$  and there is  $1/2w$  line pair per unit distance resolution is simply the smallest number of discernible line pair unit distance.



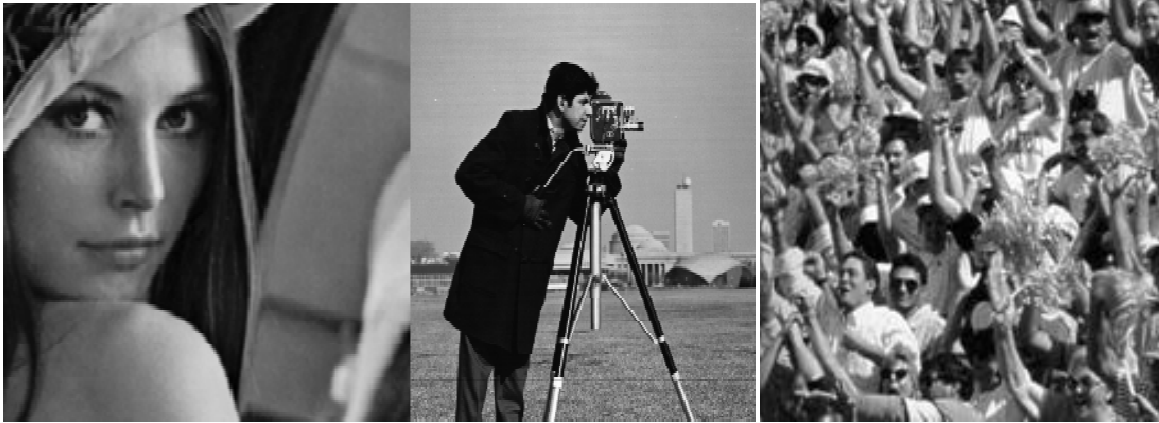
Gray levels resolution refers to smallest discernible change in gray levels.

Measuring discernible change in gray levels is a highly subjective process reducing the number of bits  $R$  while repairing the spatial resolution constant creates the problem of false contouring .it is caused by the use of an insufficient number of gray levels on the smooth areas of the digital image . It is called so because the rides resemble top graphics contours in a map. It is generally quite visible in image displayed using 16 or less uniformly spaced gray levels.

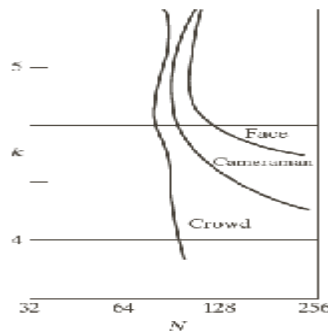


## Iso Preference Curves

To see the effect of varying  $N$  and  $R$  simultaneously. These pictures are taken having little, mid level and high level of details.



Different images were generated by varying  $N$  and  $k$  and observers were then asked to rank the results according to their subjective quality. Results were summarized in the form of iso-preference curves in the  $N$ - $k$  plane.



The iso-preference curve tends to shift right and upward but their shapes in each of the three image categories are shown in the figure. A shift up and right in the curve simply means large values for  $N$  and  $k$  which implies better picture quality.

The result shows that the iso-preference curve tends to become more vertical as the detail in the image increases. The result suggests that for an image with a large amount of details, only a few gray levels may be needed. For a fixed value of  $N$ , the perceived quality for this type of image is nearly independent of the number of gray levels used.

## Pixel Relationships

### Neighbors of a pixel

A pixel  $p$  at coordinate  $(x,y)$  has four horizontal and vertical neighbor whose coordinate can be given by

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

This set of pixel is called the 4-neighbours of  $p$  and is denoted by  $n_4(p)$ , Each pixel is at a unit distance from  $(x,y)$  and some of the neighbors of  $P$  lie outside the digital image or  $(x,y)$  is on the border of the image .

The four diagonal neighbor 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-neighbours are called 8 – neighbors of  $P$  denoted by  $n_8(p)$

### Adjacency

Let  $V$  be the set of gray-level values used to define adjacency in a binary image, if  $V=\{1\}$  we are referencing to adjacency of pixel with value. Three types of adjacency occurs

4- Adjacency – two pixel  $P$  and  $Q$  with value from  $V$  are 4–adjacency if  $A$  is in the set  $n_4(P)$

8- Adjacency – two pixel  $P$  and  $Q$  with value from  $V$  are 8–adjacency if  $A$  is in the set  $n_8(P)$

M-adjacency –two pixel  $P$  and  $Q$  with value from  $V$  are m– adjacency if

- $Q$  is in  $n_4(p)$  or
- $Q$  is in  $nd(p)$  and the set  $N_4(p) \cap N_4(q)$  has no pixel whose values are from  $V$

### Distance measures

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

$$D [p,q] \geq 0 \quad \{D[p,q] = 0 \text{ iff } p=q\}$$

$$D [p,q] = D [q,p] \text{ and}$$

$$D [p,q] \geq 0 \quad \{D[p,q]+D(q,z)\}$$

The Euclidean Distance between  $p$  and is defined as

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

The D4 Education Distance between  $p$  and is defined as

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