REVA UNIVERSITY

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Approved by AICTE, COA and BCI, New Delhi

LECTURE :1.1

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School of C&IT

INTRODUCTION TO COMPUTER VISION

VISION
Vision is most powerful scene
Which allows as to interact with
world without physical
Contact.

COMPUTER VISION

What is computer vision?

It is field of computer science the objective is to build a machine so that it can be interpret and process image and video just like human eyes does.

or

Computer vision is a field of artificial intelligence (AI) that **enables computers and systems to derive meaningful information from digital images, videos** and other visual inputs and take actions or make recommendations based on that information.

COMPUTER VISION?

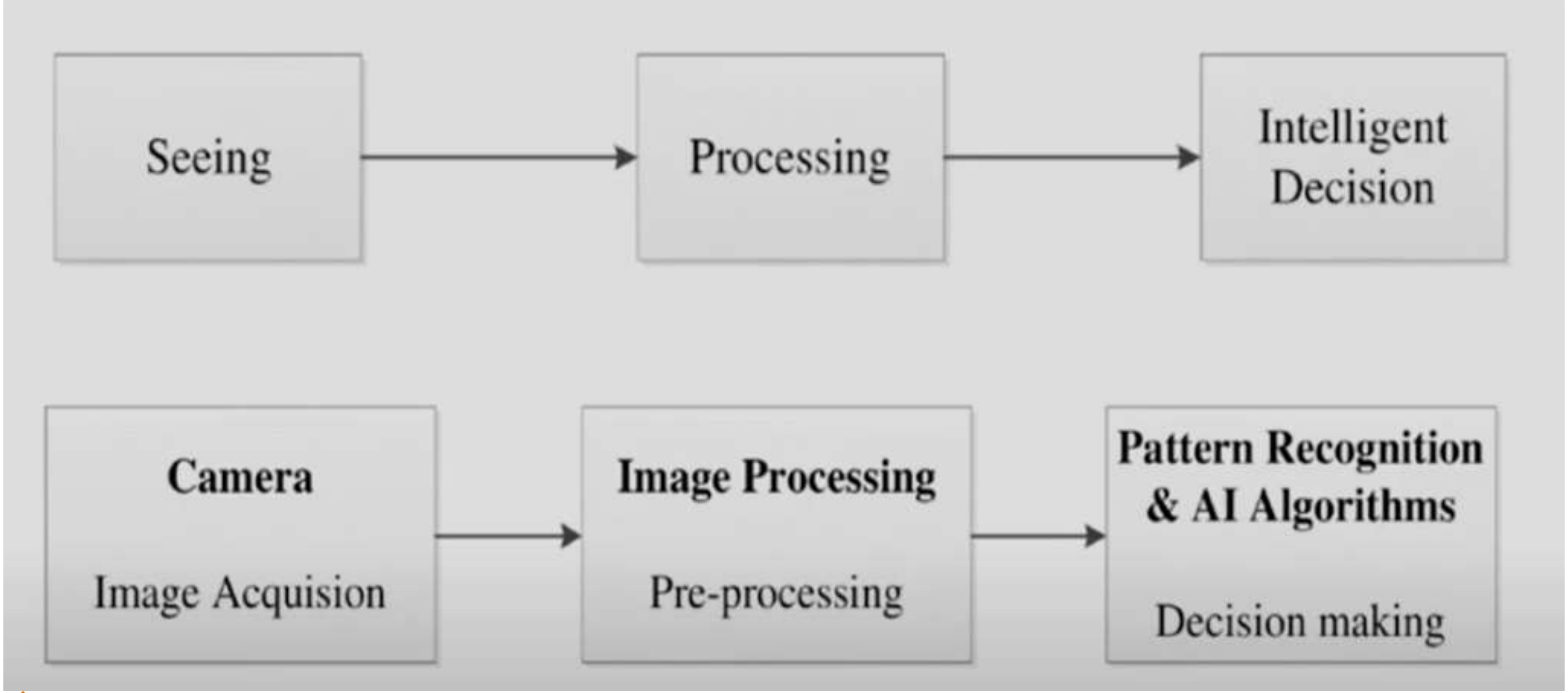
1. Building

Machines that can see

Machines that interact with world

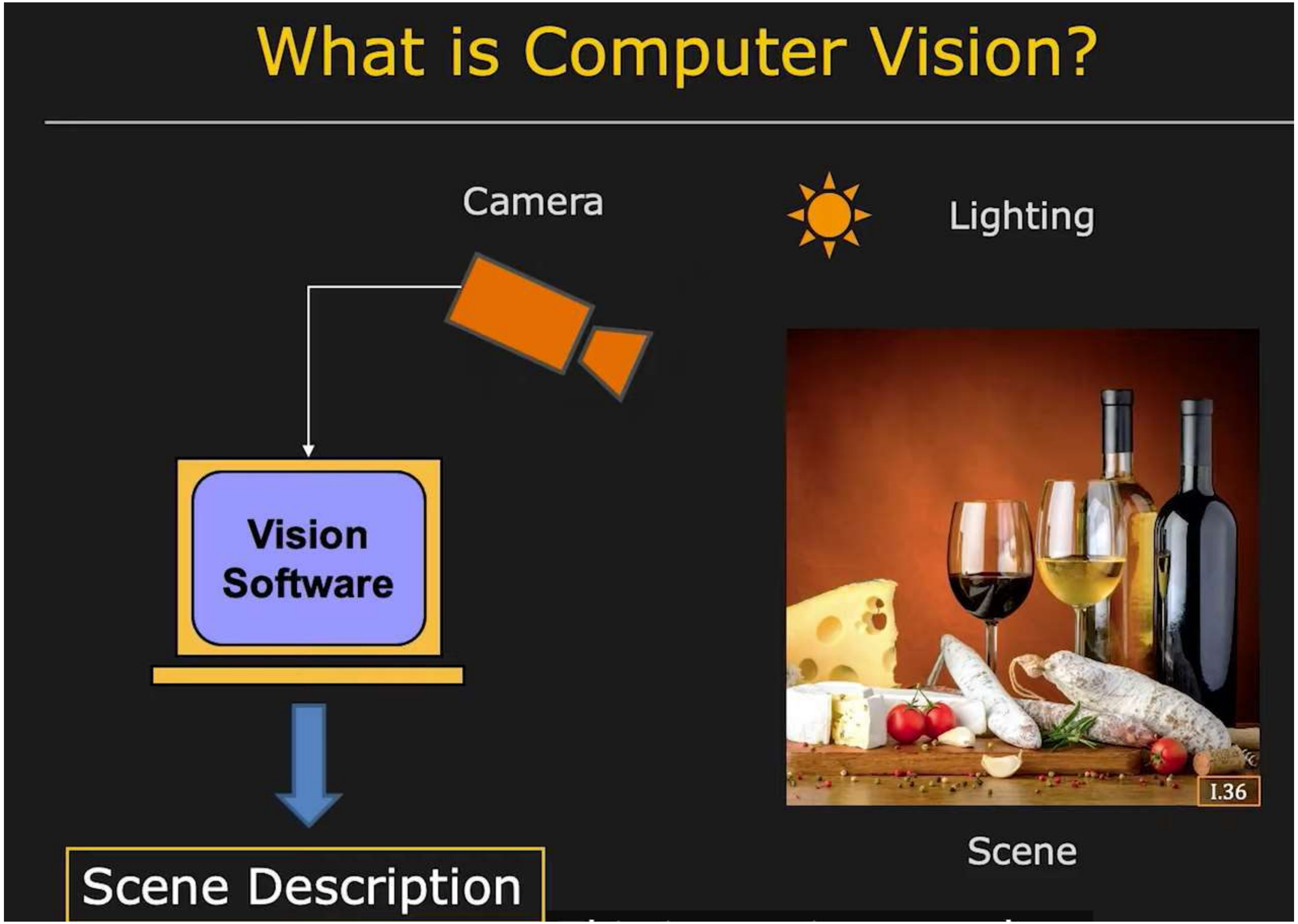
Input is digital image and videos

Most importantly computer vision system can be designed to surpass the capability of human vision and extract information about the world that we human cannot perceive.


Seeing
Processing
Intelligent Decision
Camera
Image Acquision
Image Processing
Pre-processing
Pattern Recognition & AI Algorithms
Decision making

What is Computer Vision..... ?

- Computer Vision
  - Input : Image — Output : Interpretation
    - Image analysis, Image Interpretation, Scene understanding.
- Image Processing
  - Input : Image — Output : Image
    - Image recovery, reconstruction, filtering, compression, visualization.
- Computer Graphics
  - Input: Scene representation — Output: Image


What is Computer Vision?
Camera
Lighting
Vision Software
Scene Description
Scene
I.36

UNIT -1

What Is Digital Image Processing? ,
The Origins of Digital Image Processing
Examples of fields that use digital image processing

Fundamental Steps in Digital Image Processing
Components of an Image Processing System
Image Sampling and Quantization
Basic Concepts in Sampling and Quantization
Representing Digital Images
Spatial and Gray-Level Resolution
Aliasing and Moiré Patterns
Zooming and Shrinking Digital Images
Some Basic Relationships Between Pixels
Neighbours of a Pixel
Adjacency, Connectivity, Regions, and Boundaries
Distance Measures
Image Operations on a Pixel Basis

Image Sensing and Acquisition

Image Acquisition Using a Single Sensor

Image Acquisition Using Sensor Strips

Image Acquisition Using Sensor Arrays

A Simple Image Formation Model

1. *Image Enhancement in the Frequency Domain*

Introduction to the Fourier Transform and the Frequency Domain

Smoothing Frequency-Domain Filters

Sharpening Frequency Domain Filters

Homomorphic Filtering

WHAT IS DIGITAL IMAGE PROCESSING?

- Digital
  - Image
    - Processing

Processing of Image which are digital in nature by a Digital Computer.

Motivation….

IMAGE

- Image is a representation of something or someone. Examples are any drawing, painting, photograph etc.
- Images are very powerful tool in communication.
- It may be black & white or color.

PURPOSE OF DIGITAL IMAGE PROCESSING

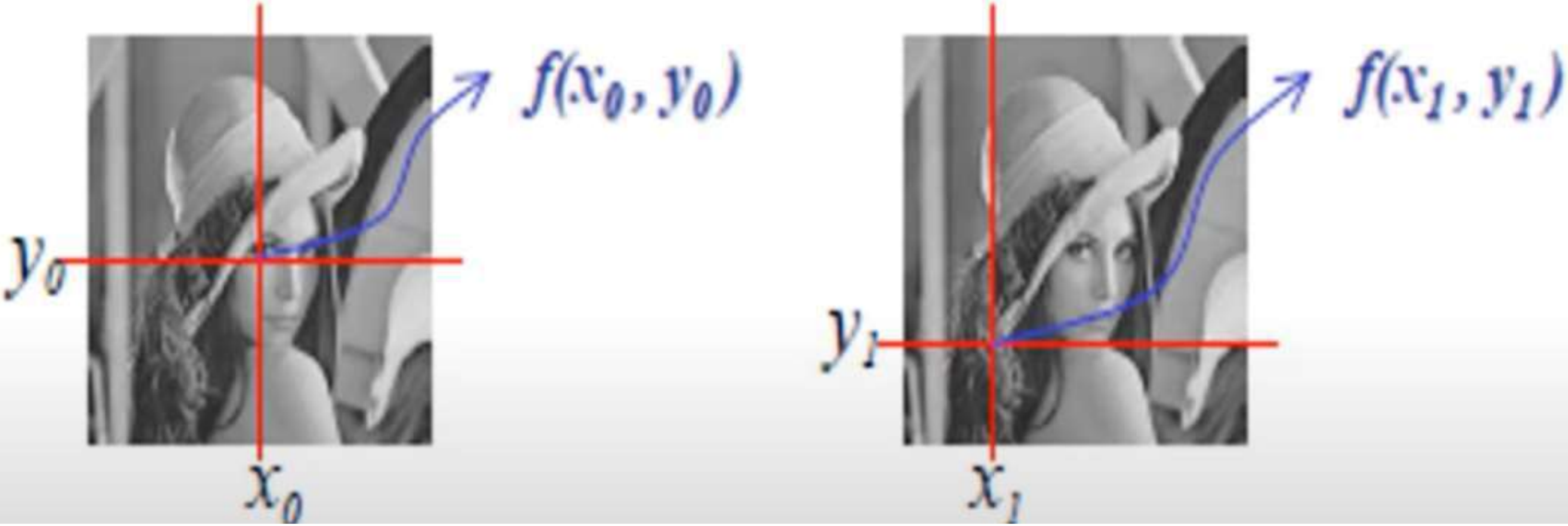
divided into 5 groups.

- Visualization – Observe the objects that are not visible
- Image sharpening and restoration – To create a better image
- Image retrieval – Seek for the image of interest
- Measurement of pattern – Measures different objects in an image
- Image Recognition – Separate, the objects in an image.

Often an image is defined as a two-dimensional function, f(x, y).

- where x and y are spatial (plane) coordinates

- the amplitude of f at any pair of coordinates (x, y) is called the intensity or gray level of the image at that point.



Pixel intensity value

↑

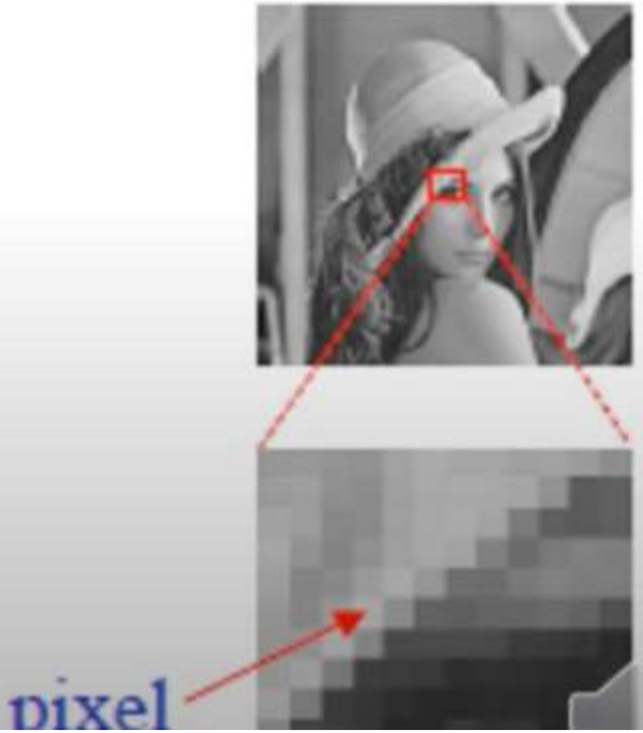
f(1,1) = 103

DIGITAL IMAGE

•Digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are referred to as:

- **picture elements**
- **image elements**
- **Pels**
- **pixels**

Pixel is the most widely used term.



THE ORIGINS OF DIGITAL IMAGE PROCESSING

the first applications of digital images was in the newspaper industry, when pictures were first sent by submarine cable between London and New York

Bartlane cable picture transmission system in the early 1920s reduced the time required to transport a picture across the Atlantic from more than a week to less than three hours.

reproduced on a tele- graph printer fitted with typefaces simulating a halftone pattern.

This method was abandoned toward the end of 1921

And developed photo- graphic reproduction made from tapes

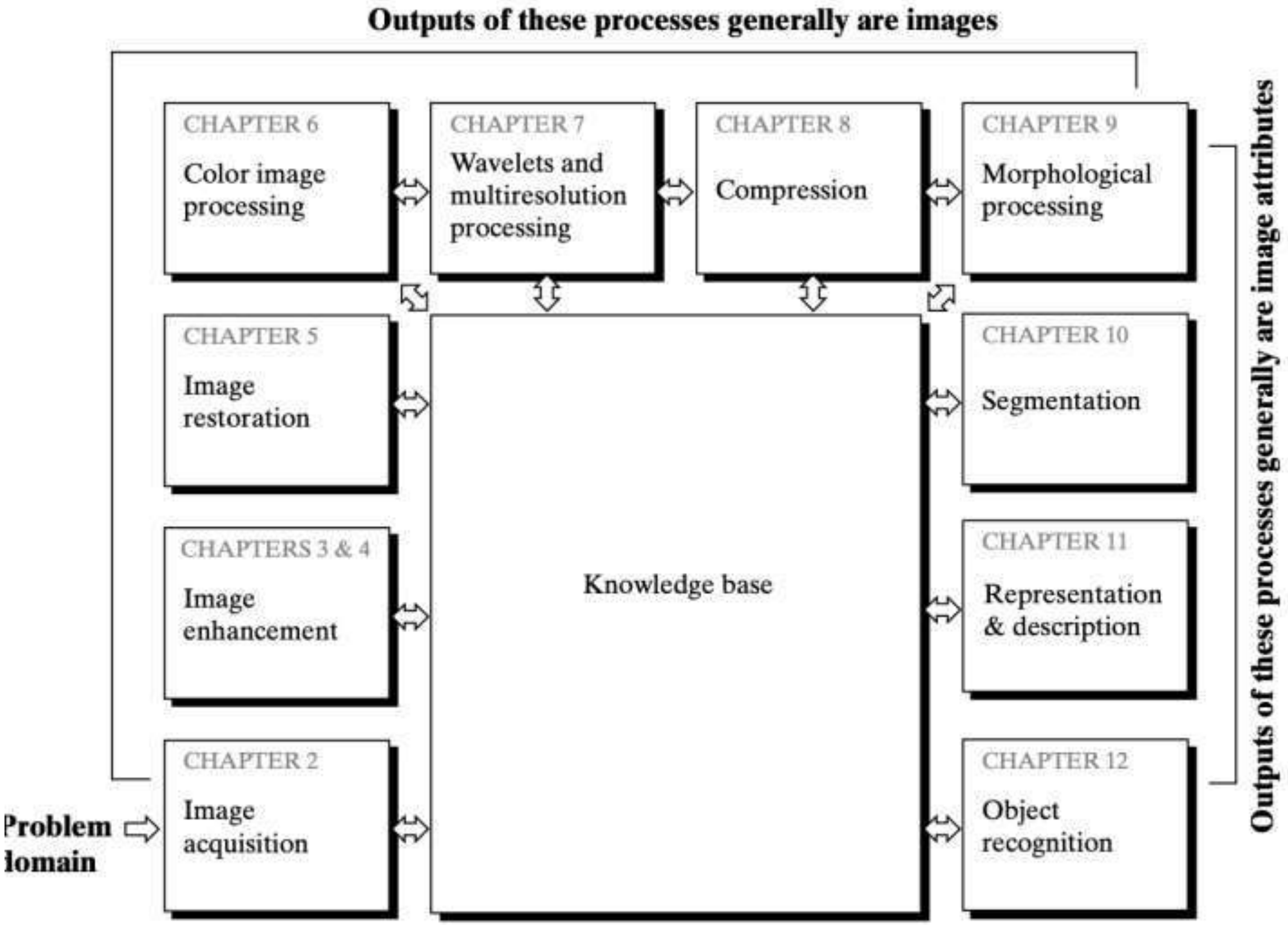
THE ORIGINS OF DIGITAL IMAGE PROCESSING

Specialized printing equipment coded pictures for cable transmission and then reconstructed them at the receiving end

Digital image processing techniques began in the late 1960s and early 1970s to be used in medical imaging, remote Earth resource observations and astronomy.

- The early Bartlane systems were capable of coding images in five distinct levels of gray. This capability was increased to 15 levels in 1929.

FUNDAMENTAL STEPS IN DIGITAL IMAGE PROCESSING



Fundamental Steps in Digital Image Processing

Image Acquisition: This is the fundamental step of digital image processing. This step involves pre-processing such as scaling etc.

Image Enhancement: To determine, image enhancement is the most straightforward and most appealing areas of image processing. The idea behind an enhancement technique is to deliver the information that is obscure or simply to highlight the particular features of interest in an image. Such as changing brightness and contrast etc.

Image Restoration: As a matter of fact, image restoration is a field which deals with enhancing the image appearance. Unlike enhancement, which is subjective and the image restoration is objective. In fact, the restoration technique which tends to depend on mathematical or probabilistic models of image degradation..

Image Restoration

1. **Original Image** → $f(x,y)$
2. **Enhanced Image** → $g(x,y)=T(f(x,y))$
3. **Degraded Image** → $h(x,y)=H(x,y)*f(x,y)+n(x,y)$
4. **Restored Image** → $f\hat{}(x,y)=R(h(x,y))$

FUNDAMENTAL STEPS IN DIGITAL IMAGE PROCESSING

- **Wavelets and Multiresolution Processing** : Wavelets are the basis for representing images in several degrees of resolution. At the same time, images can divide into smaller regions for pyramidal representation and data compression.
- **Color Image Processing**: It includes color modelling and processing in a digital domain etc.
- **Morphological Processing**: it deals with extracting image components that are useful in description and representation of the shape
- **Compression** : In fact, the compression deals with techniques are useful for reducing the storage required to save an image or the bandwidth from transmitting it.
- **Segmentation:** Segmentation procedures partition an image into its constituent parts or an object. The autonomous segmentation is the primary complex tasks in digital image processing trends.

FUNDAMENTAL STEPS IN DIGITAL IMAGE PROCESSING

- **Description and Representation** : Description and representation follow the output of a segmentation stage, that is usually is raw pixel data. At the same time, choosing an observation is only part of the solution for converting raw data into the form that is useful for subsequent digital signal processing projects. It deals with extracting attributes which result in some quantitative details of interest or is fundamental for differentiating one class of objects from another
- **Knowledge Base** : As a matter of fact, knowledge will be as easy as detailing regions of an image where the details of interest are known to be located.

COMPONENTS OF AN IMAGE PROCESSING SYSTEM

Sensing: two elements are required to acquire digital images. The first is a physical device that is sensitive to the energy radiated by the object we wish to image. The second, called a *digitizer*, is a device for converting the output of the physical sensing device into digital form.

Specialized image processing hardware: usually consists of the digitizer just mentioned, plus hardware that performs other primitive operations, such as an arithmetic logic unit (ALU), which performs arithmetic and logical operations in parallel on entire images. One example of how an ALU is used is in averaging images as quickly as they are digitized, for the purpose of noise reduction.

The *computer* in an image processing system is a general-purpose computer and can range from a PC to a supercomputer.

COMPONENTS OF AN IMAGE PROCESSING SYSTEM

Software for image processing consists of specialized modules that perform specific tasks.

Mass storage capability is a must in image processing applications

(1) short- term storage for use during processing, (2) online storage for relatively fast recall, and (3) archival storage, characterized by infrequent access

Image displays in use today are mainly color (preferably flat screen) TV monitors. Monitors are driven by the outputs of image and graphics display cards that are an integral part of the computer system.

Hardcopy devices for recording images include laser printers, film cam- eras, heat-sensitive devices, inkjet units, and digital units, such as optical and CD-ROM disks.

COMPONENTS OF AN IMAGE PROCESSING SYSTEM

Networking is almost a default function in any computer system in use today. Because of the large amount of data inherent in image processing applications

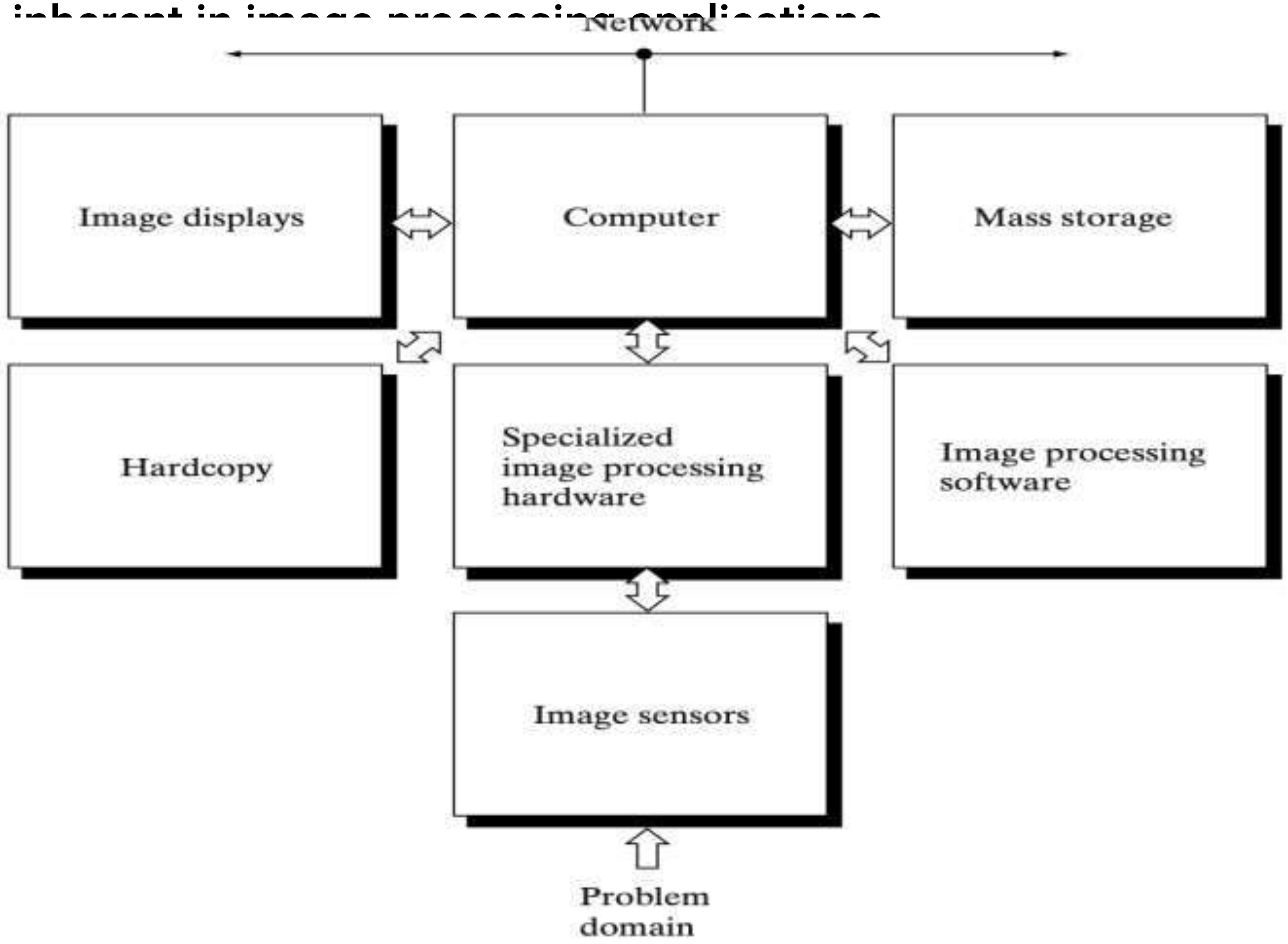


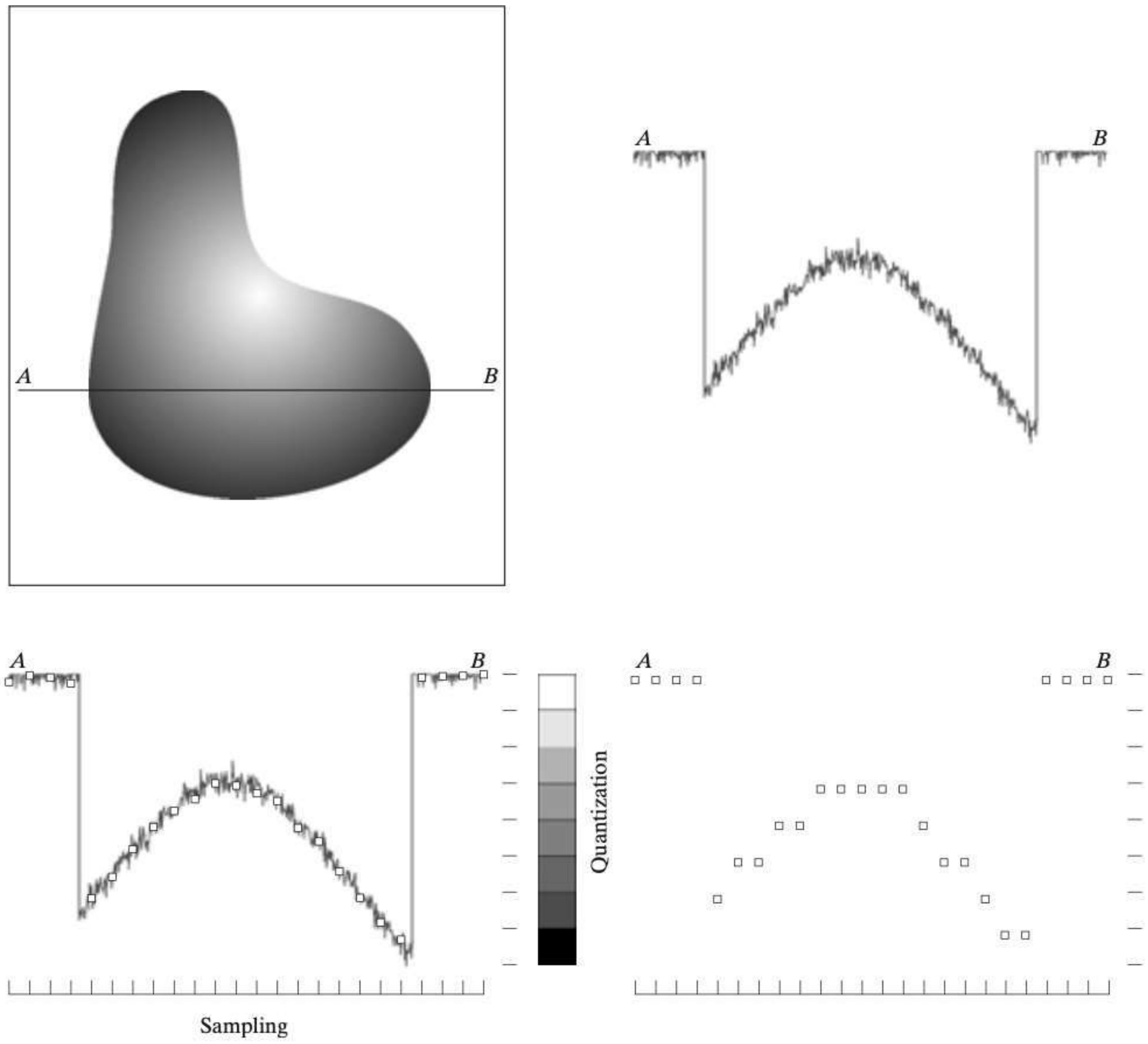
IMAGE SAMPLING AND QUANTIZATION

- objective is to to generate digital images from sensed data.
- we need to convert the continuous sensed data into digital form. This involves two processes: *sampling* and *quantization*.

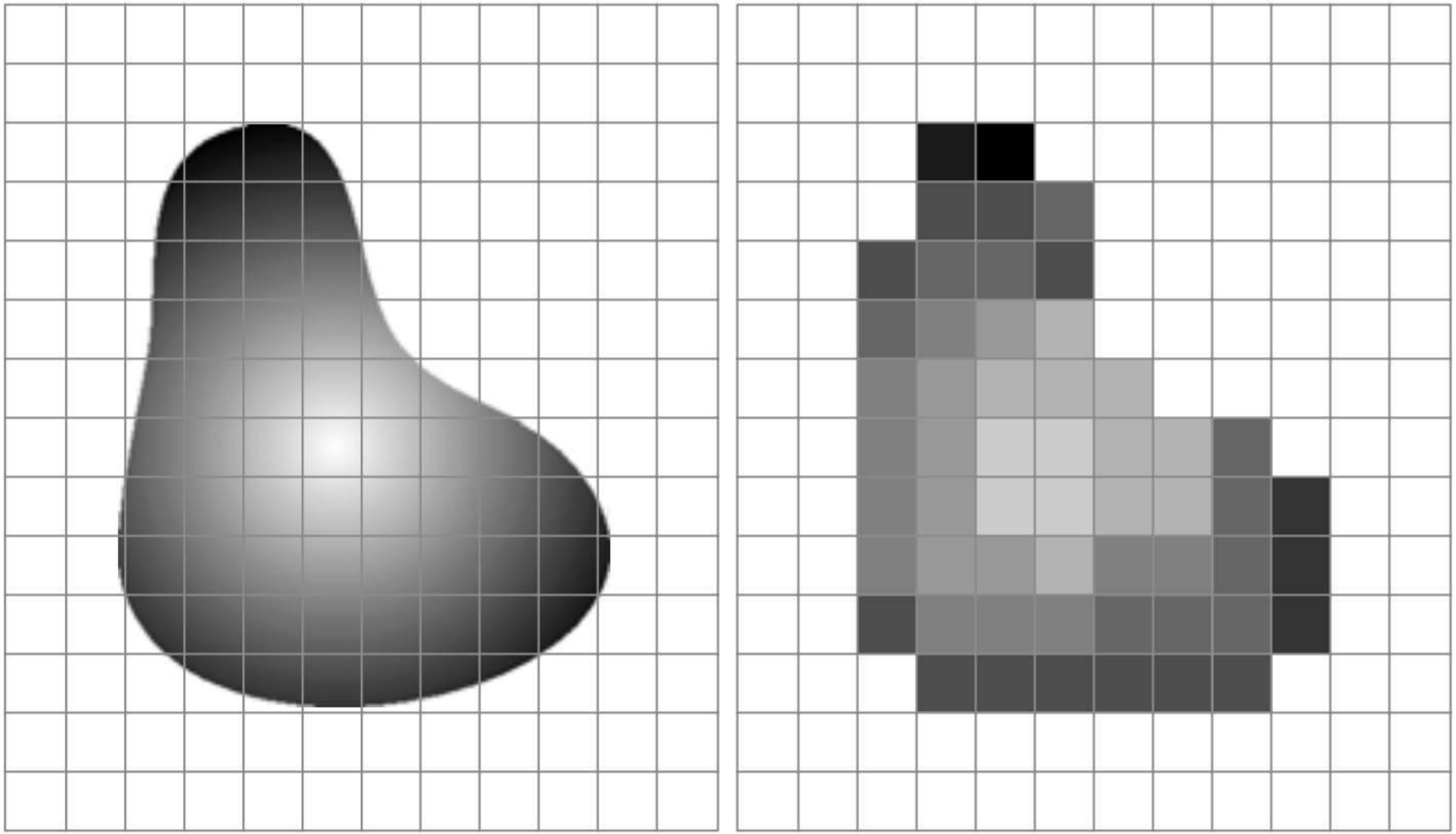
- output of most sensors is a continuous voltage waveform
- To create a digital image, we need to convert the continuous sensed data into digital form. This involves two processes: *sampling* and *quantization*.

BASIC CONCEPTS IN SAMPLING AND QUANTIZATION

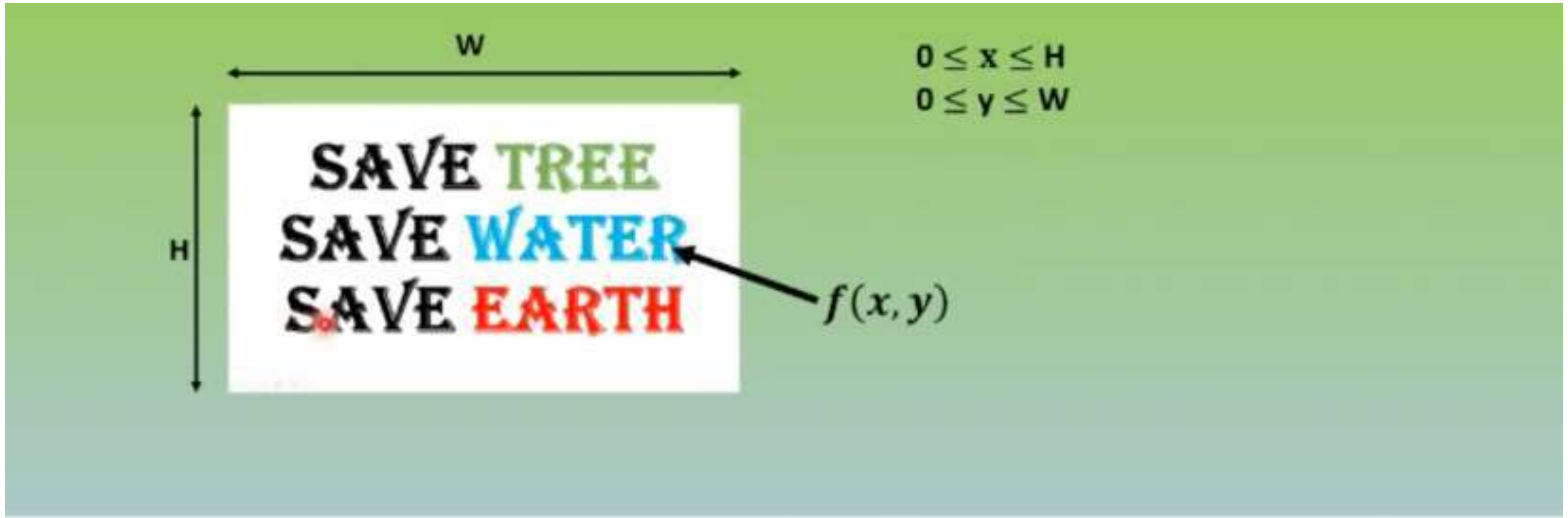
- The whole idea here is continuous image is converted into discrete image using spatial domain and quantization value
- The picture doesn’t look like discrete but it has lot of discrete values when you take pixel value which come from picture element we can see the discrimination
- Our digital cameras are color images i.e when images are color the values will be decide by RGB


A
B
A
B
A
B
Quantization
Sampling
A
B

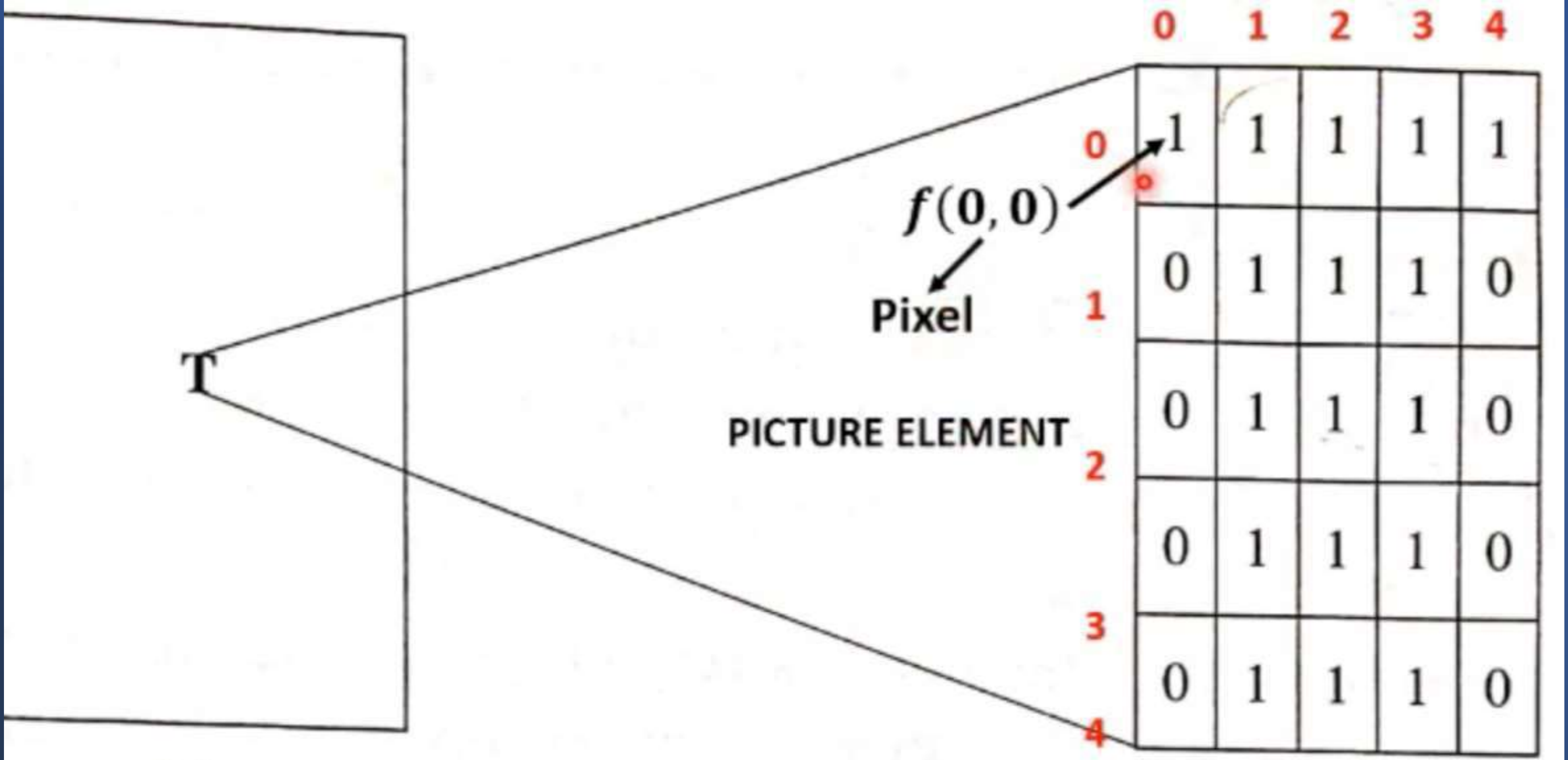
1. shows a continuous image, $f(x, y)$, that we want to convert to digi- tal form.



REPRESENTING DIGITAL IMAGES



$$f(x,y)=\begin{pmatrix} f(0,0) & f(0,1) & f(0,2) & \cdots & f(0,Y-1) \\ f(1,0) & f(1,1) & f(1,2) & \cdots & f(1,Y-1) \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ f(X-1,0) & f(X-1,1) & f(X-1,2) & \cdots & f(X-1,Y-1) \end{pmatrix}$$


T
f(0,0)
Pixel
PICTURE ELEMENT
0 1 2 3 4
0 1 2 3 4
1 1 1 1 1
0 1 1 1 0
0 1 1 1 0
0 1 1 1 0
0 1 1 1 0

(a)

(b)

'he number of rows in digital image is called vertical resolution.

'he no of columns is called horizontal resolution.

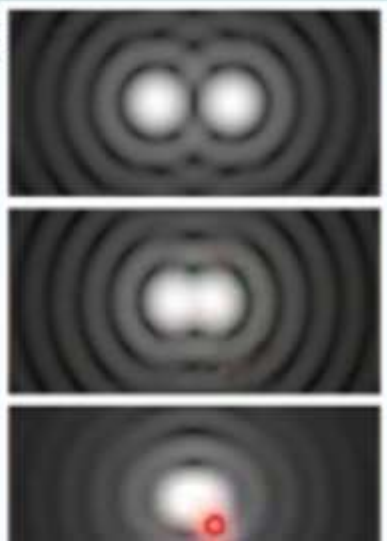
'he no of rows and column describe the dimension of image.

For example :- 256 X 256, 512 X 512

'esolution :-

It is ability of the imaging system to produce the smallest discern

tails, that is the smallest sized objects clearly, and differentiate it from ighbouring small object that are the image.



- Resolution depends on two parameters:-

1. The number of the pixels of image

2.The number of bits necessary for adequate intensity resolution(Bit depth).

- The no of pixels determine the quality of image. The total no of pixels that are present in the digital image is the no of rows multiplied by no of columns.
- Bit depth :-

In grey scale images pixels values can be between 0 and 255.

For this we can use 8 bit i.e

$$2^8 = 256$$

So, bit depth = 8

So, total no of necessary bit to represent the image =

$$\underbrace{(\text{No of rows X No of columns})}_{\text{No. of pixels}} \text{ X Bit depth}$$

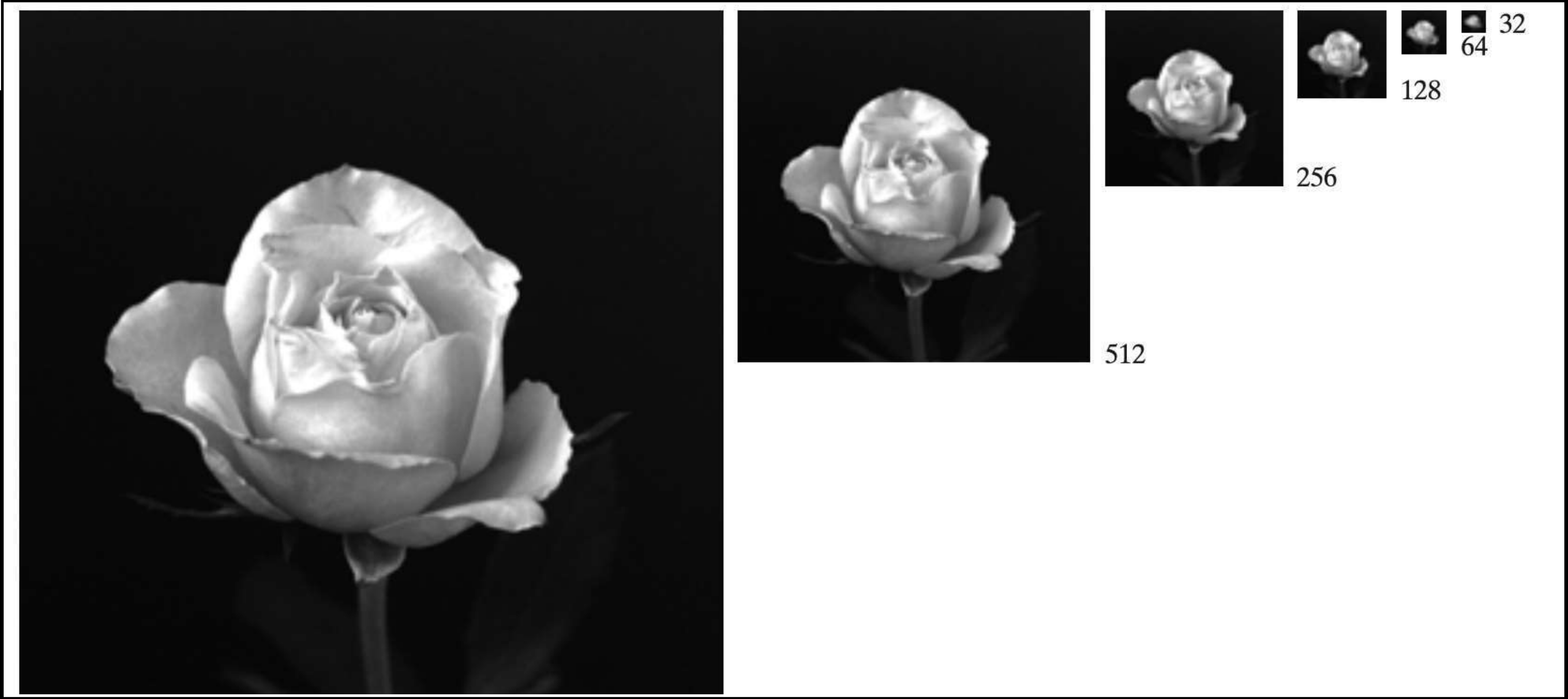
SPATIAL AND GRAY-LEVEL RESOLUTION

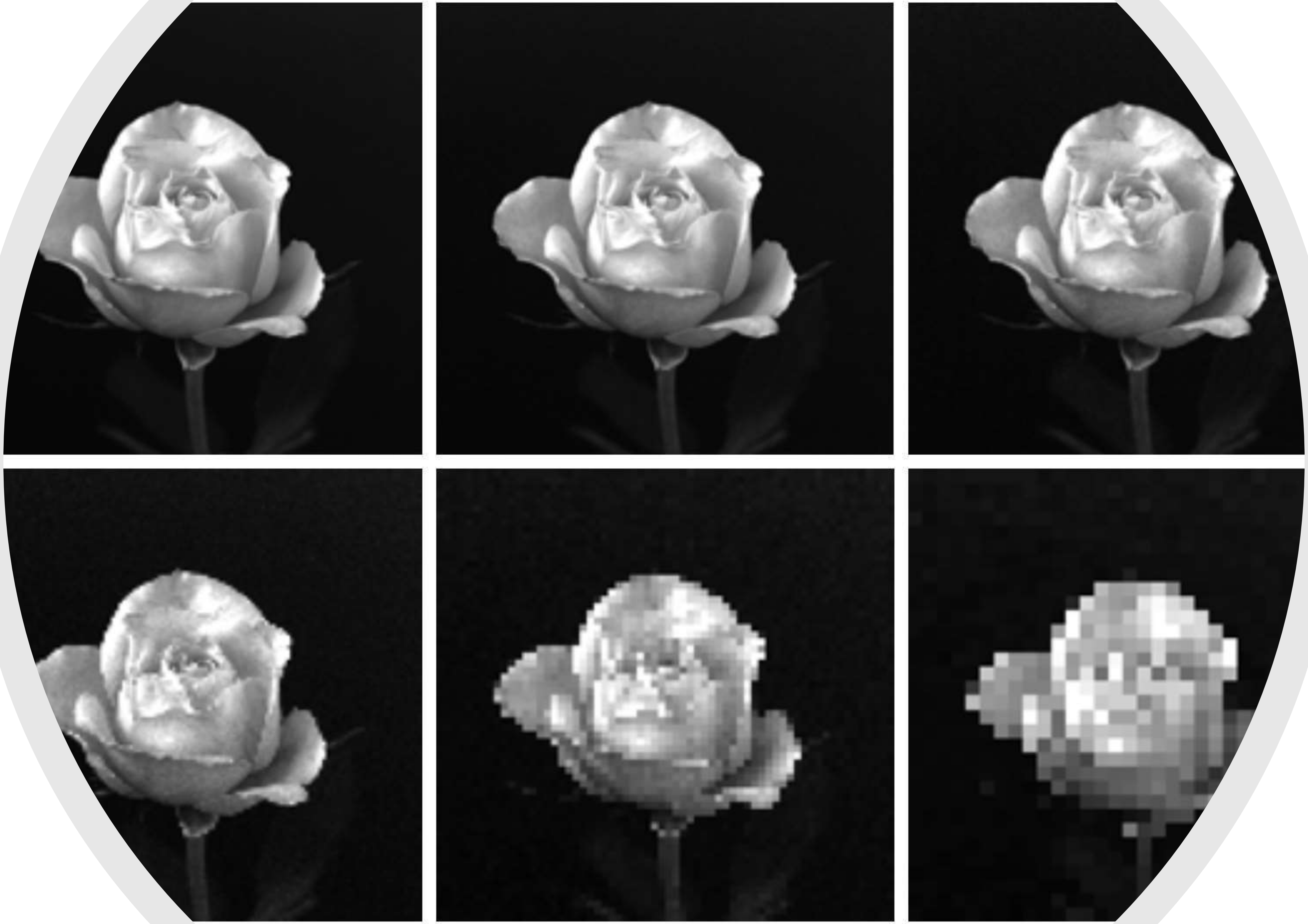
1. spatial resolution is the smallest discernible detail in an image

Or

spatial resolution as the number of independent pixels values per inch.

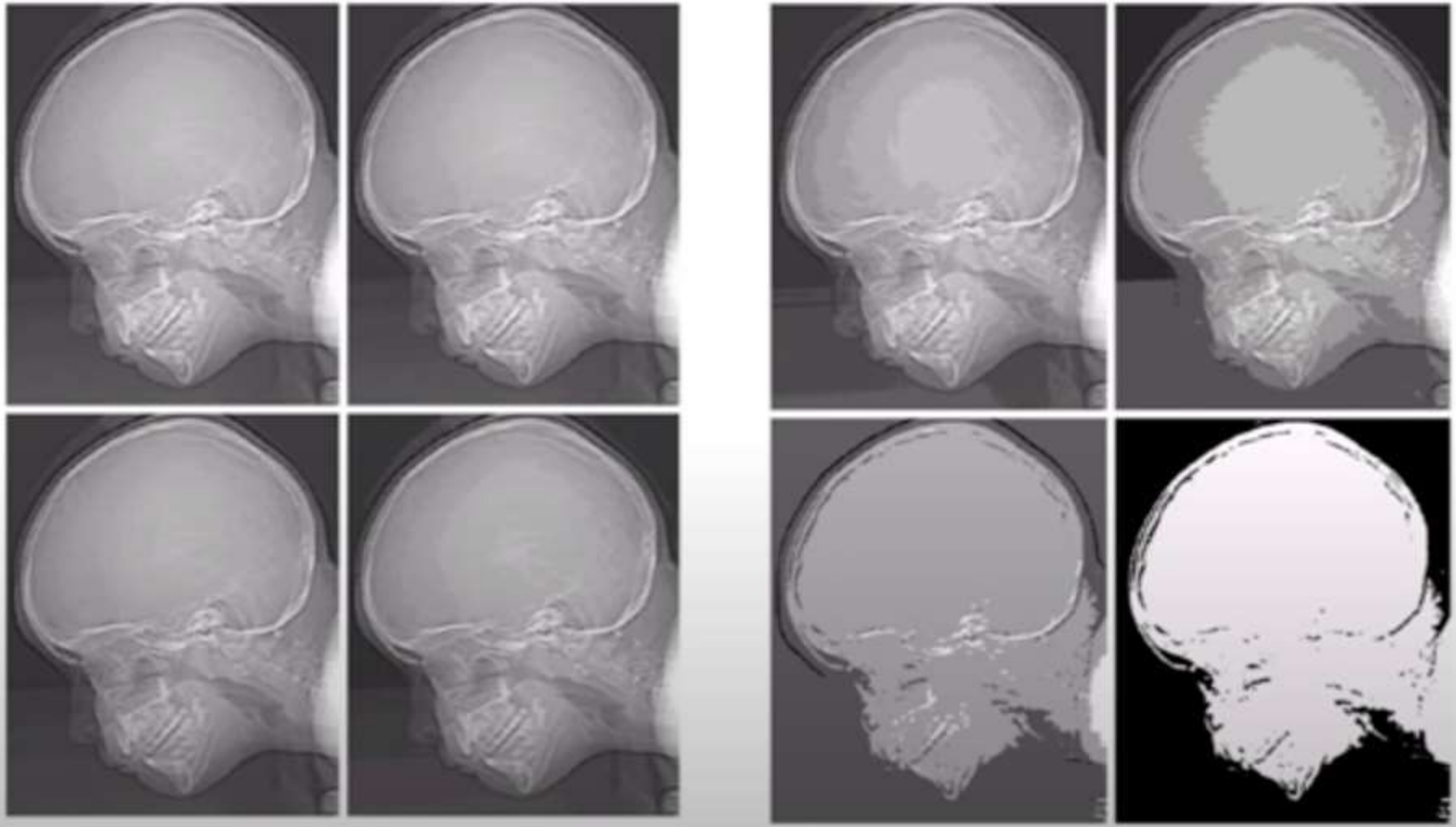
1. *Gray-level resolution* similarly refers to the smallest discernible change in gray level, or In short gray level resolution is equal to the number of bits per pixel.
2. digital image of size M*N
3. spatial resolution of M*N pixels
4. These are the resolutions which convert image into digital form it always indicates the number of pixels that is resolution of the image
5. image the days number of rows and columns in the image as shown in the example we are subsampling


512
256
128
64
32



Gray Level Resolution

- The number of gray levels; in integer images usually a power of 2
- $L = 2^k$



k = 8, 7, 6, 5 k = 4, 3, 2, 1

- Zooming simply means enlarging a picture in a sense that the details in the image became more visible and clear.

You can zoom something at two different steps.

- The first step includes zooming before taking an particular image. This is known as pre processing zoom. This zoom involves hardware and mechanical movement
- The second step is to zoom once an image has been captured. It is done through many different algorithms i which we manipulate pixels to zoom in the required portion.

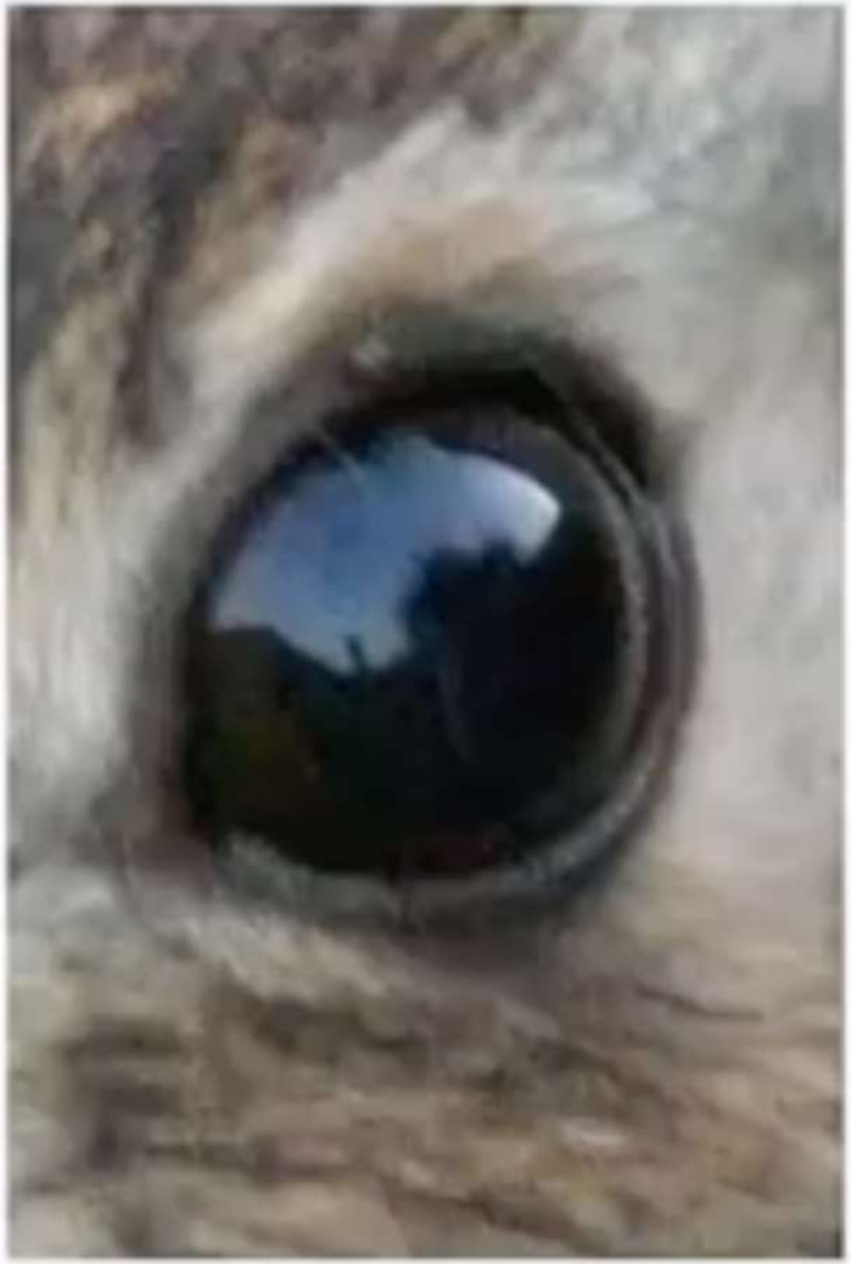
Optical Zoom:

The optical zoom is achieved using the movement of the lens of your camera. An optical zoom is actually a true zoom. The result of the optical zoom is far better then that of digital zoom.

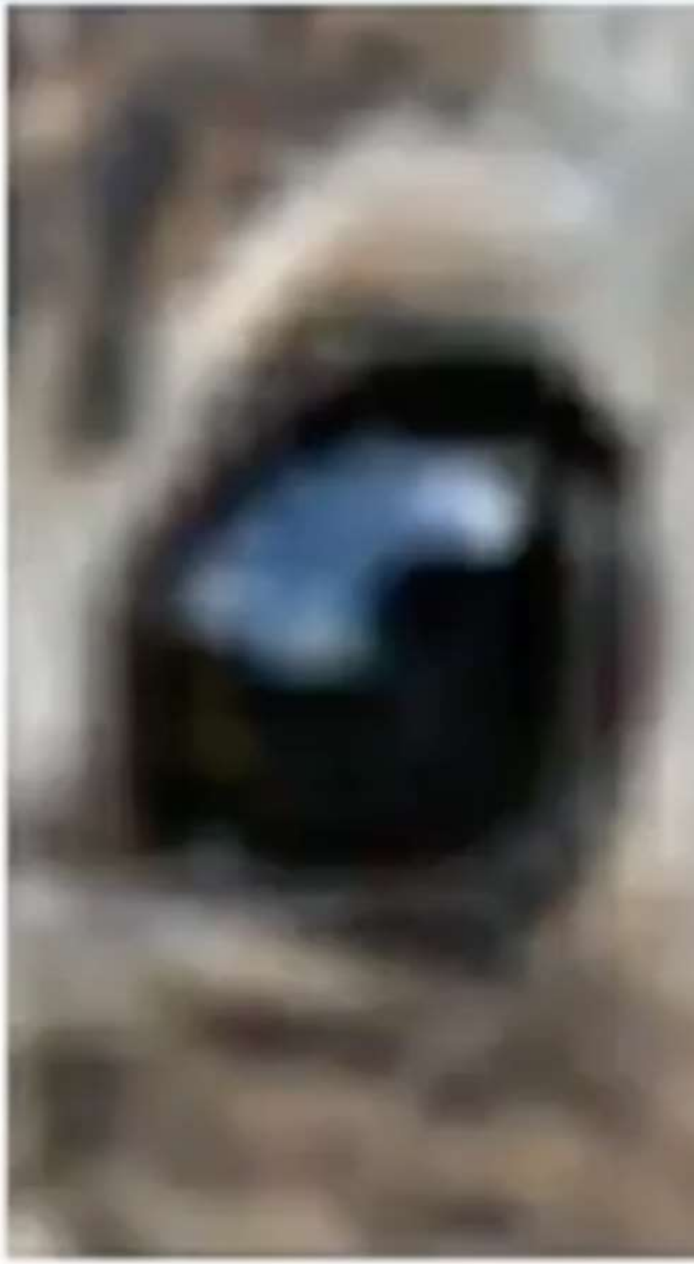
Digital Zoom:

Digital zoom is basically image processing within a camera. During a digital zoom, the center of the image is magnified and the edges of the picture got crop out. During a digital zoom, the pixels got expand , due to which the quality of the image is compromised.

ORIGINAL



OPTICAL ZOOM



DIGITAL ZOOM

2) zero order hold method

3) Zooming K times

Pixel replication

given image → given pixels ← New pixel

For Example

2×2 → Zoom it twise

→ image

$$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$$

2×2

Row wise zooming

$$\begin{bmatrix} 1 & 1 & 2 & 2 \\ 3 & 3 & 4 & 4 \end{bmatrix}$$

Column wise wise zooms

$$\begin{bmatrix} 1 & 1 & 2 & 2 \\ 1 & 1 & 2 & 2 \\ 3 & 3 & 4 & 4 \\ 3 & 3 & 4 & 4 \end{bmatrix}$$

4x4

Zero order hold

↳ adjacent elements from rows

$\begin{bmatrix} a & b \\ c & d \end{bmatrix}$

$\frac{a+b}{2} = Ans$

a Ans b

↳ $\frac{a+c}{2} = Ans$

a
Ans
c

For Example

$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$

row wise

$\begin{bmatrix} 1 & 1 & 2 \\ 3 & 3 & 4 \end{bmatrix}$

Column wise

$$\begin{bmatrix} 1 & 1 & 2 \\ 2 & 2 & 3 \\ 3 & 3 & 4 \end{bmatrix}$$

Zoom in max

$1+2/2 = 3/2 = 1.5 \Rightarrow 1$

$3+4/2 = 7/2 = 3.5 \Rightarrow 3$

K- times zooming

Example

$$\begin{bmatrix} 2 & 3 & 4 \\ 5 & 6 & 7 \end{bmatrix}$$

zooming factor = 3

no of values to be inserted is $k-1 = 3-1 \Rightarrow 2$

3, 4

$4-3=1$

$1/3 = 0.3$

$3+0.3 = 3.3$

$4+0.3 = 4.3$

Row wise zooming

let's take 1st two adject pixels ie 2 2 3

2	2	3	3	3	4	4
5	2	3	6	3	4	7

Now subtract $3-2=1$

Divide 1 by k

$1/3 = 0.3$ OP

Add op with the lower no

$2+0.3 = 2.3$

$\downarrow$

2

Add op with the higher 3

$3-0.3 = 2.7$

$\downarrow$

3

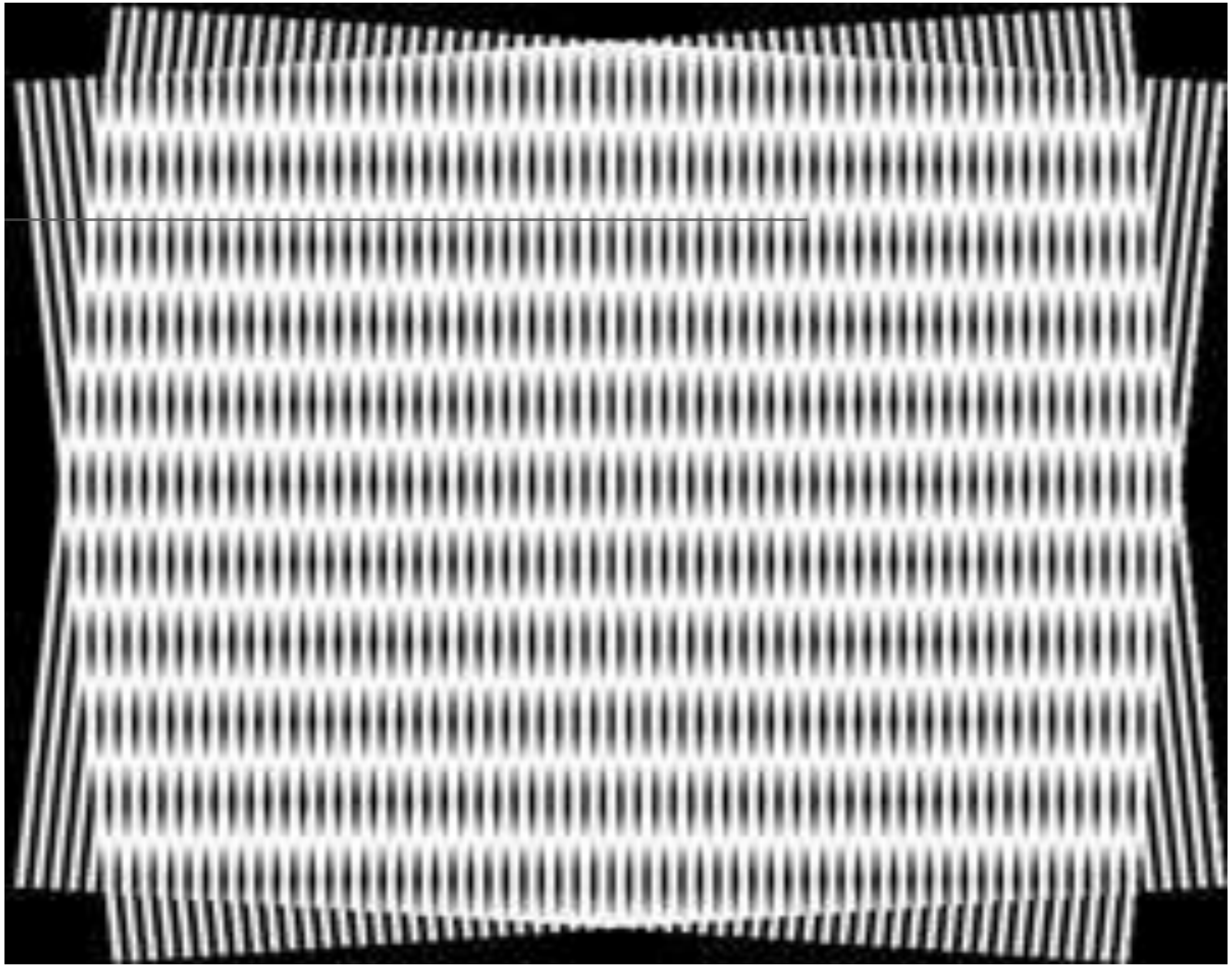
Zoom

Shrinking

$$\begin{bmatrix} 1 & 1 & 2 & 2 & 3 & 3 \\ 1 & 1 & 2 & 2 & 3 & 3 \\ 4 & 4 & 5 & 5 & 6 & 6 \\ 4 & 4 & 5 & 5 & 6 & 6 \\ 7 & 7 & 8 & 8 & 9 & 9 \\ 7 & 7 & 8 & 8 & 9 & 9 \end{bmatrix} \qquad \begin{bmatrix} 11 & 22 & 33 \\ 44 & 55 & 66 \\ 77 & 88 & \end{bmatrix}$$

ALIASING AND MOIRÉ PATTERNS

1. the Shannon sampling theorem
2. if the function is sampled at a rate equal to or greater than twice its highest frequency, it is possible to recover completely the original function from its samples. If the function is *undersampled*, then a phenomenon called *aliasing* corrupts the sampled image
3. The principal approach for reducing the aliasing effects on an image is to reduce its high-frequency com- ponents by blurring the image *prior* to sampling.
4. The effect of aliased frequencies can be seen under the right conditions in the form of so- called *Moiré patterns*†

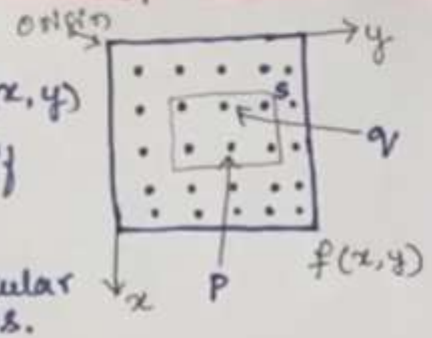


Basic Relationship between Pixels.

Image → $f(x,y)$

S → Subset of Pixels

q, P → Particular pixels.



4- Neighbors [$N_4(P)$]

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

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

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

$\therefore N_4(P) = (x, y-1), (x, y+1), (x-1, y), (x+1, y)$

Diagonal Neighbours [$N_D(P)$]

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

$N_D(P) = (x+1, y-1), (x-1, y-1), (x-1, y+1), (x+1, y+1)$

8 neighbour [$N_8(P)$]

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

Connectivity | Adjacent

1. 4-adjacency
2. 8-adjacency
3. m-adjacency [mixed-adjacency]

Binary Image

V = {1}

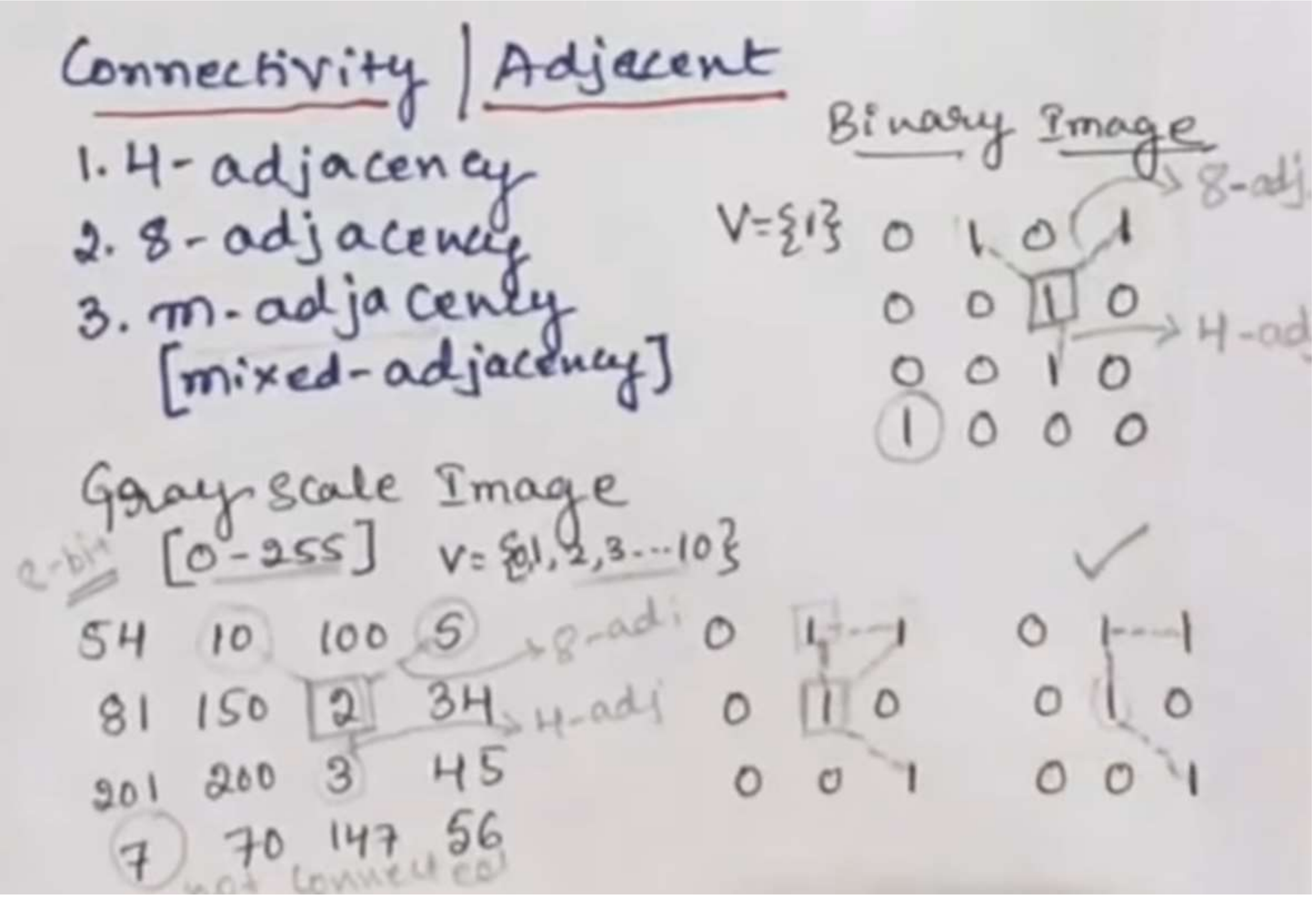
0	1	0	1
0	0	1	0
0	0	1	0
1	0	0	0

Gray Scale Image
[0 - 255] V = {1, 2, 3 ... 10}

54	10	100	5
81	150	2	34
201	200	3	45
7	70	147	56

0	1	1
0	1	0
0	0	1

0	1	1
0	1	0
0	0	1


Connectivity | Adjacent
1. 4-adjacency
2. 8-adjacency
3. m-adjacency
[mixed-adjacency]
Binary Image
V={1}
0 1 0 1
0 0 1 0
0 0 1 0
1 0 0 0
8-adj
4-adj
Gray scale Image
8-bit
[0-255]
V={0,1,2,3...10}
54 10 100 5
81 150 2 34
201 200 3 45
7 70 147 56
8-adj
4-adj
not connected
0 1 1
0 1 0
0 0 1
0 1 1
0 1 0
0 0 1

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

N_8 (p)

2.5.3 Distance Measures

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

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

The *Euclidean distance* between p and q is defined as

$$D_e(p, q) = \left[(x - s)^2 + (y - t)^2\right]^{\frac{1}{2}}. \tag{2.5-1}$$

For this distance measure, the pixels having a distance less than or equal to some value r from (x, y) are the points contained in a disk of radius r centered at (x, y).

The D_4 *distance* (also called *city-block distance*) between p and q is defined as

$$D_4(p, q) = |x - s| + |y - t|. \tag{2.5-2}$$

In this case, the pixels having a D_4 distance from (x, y) less than or equal to some value r form a diamond centered at (x, y). For example, the pixels with D_4 distance ≤ 2 from (x, y) (the center point) form the following contours of constant distance:

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

The D_8 *distance* (also called *chessboard distance*) between p and q is defined as

$$D_8(p, q) = \max(|x - s|, |y - t|). \tag{2.5-3}$$

In this case, the pixels with D_8 distance from (x, y) less than or equal to some value r form a square centered at (x, y). For example, the pixels with D_8 distance ≤ 2 from (x, y) (the center point) form the following contours of constant distance:

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

The pixels with $D_8 = 1$ are the 8-neighbors of (x, y).

- Image Acquisition:

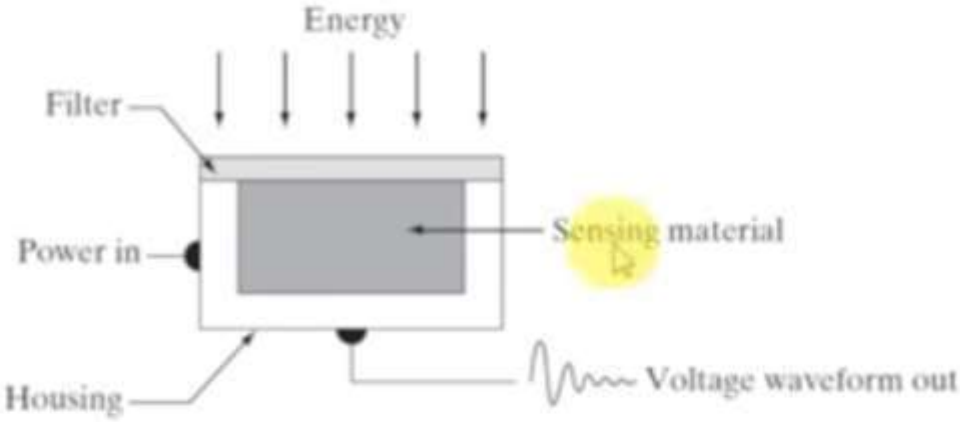
To deal with images and before analyzing them the most important thing is to capture the image. This is called as **Image Acquisition**.

There are 3 principal sensor arrangements (produce an electrical output proportional to light intensity).

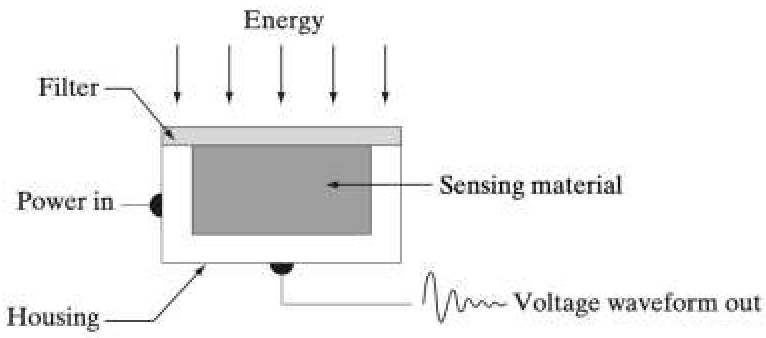
(i)Single imaging Sensor

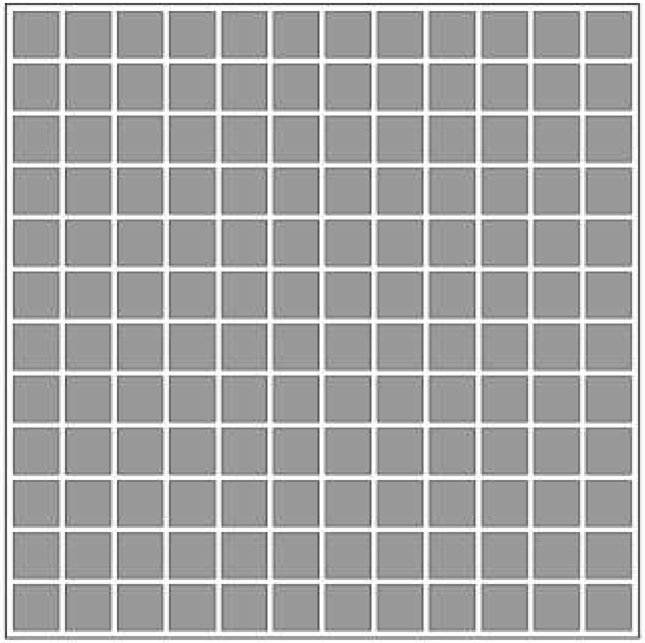
(ii)Line sensor

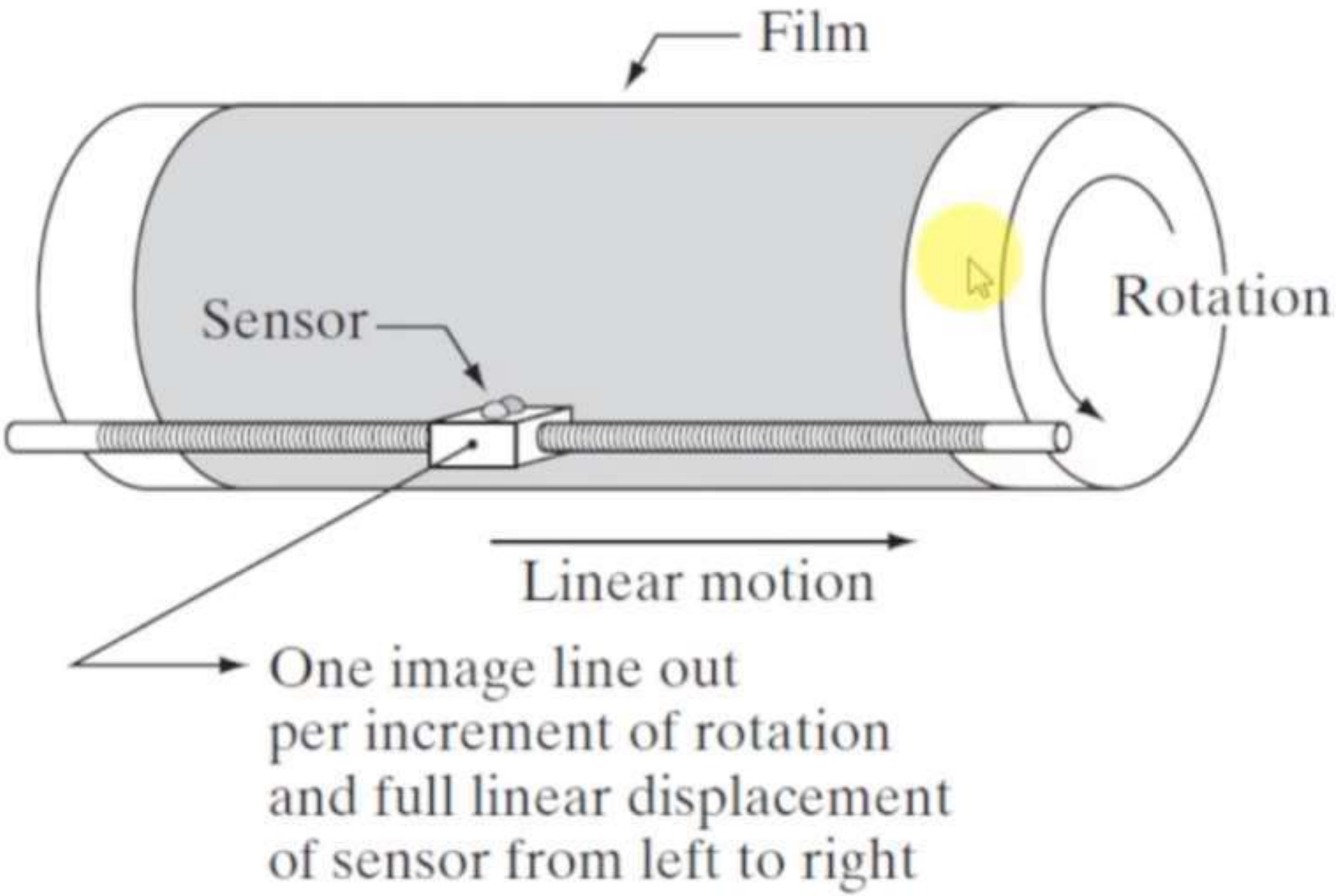
(iii)Array sensor

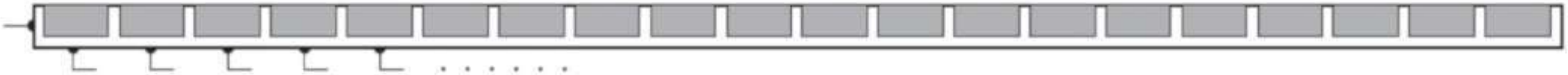


- Sensor of this type is the photodiode.
- The use of a filter in front of a sensor improves selectivity.
- In order to generate a 2-D image using a single sensor, there has to be relative displacements in both the *x*- and *y*-directions between the sensor and the area to be imaged.

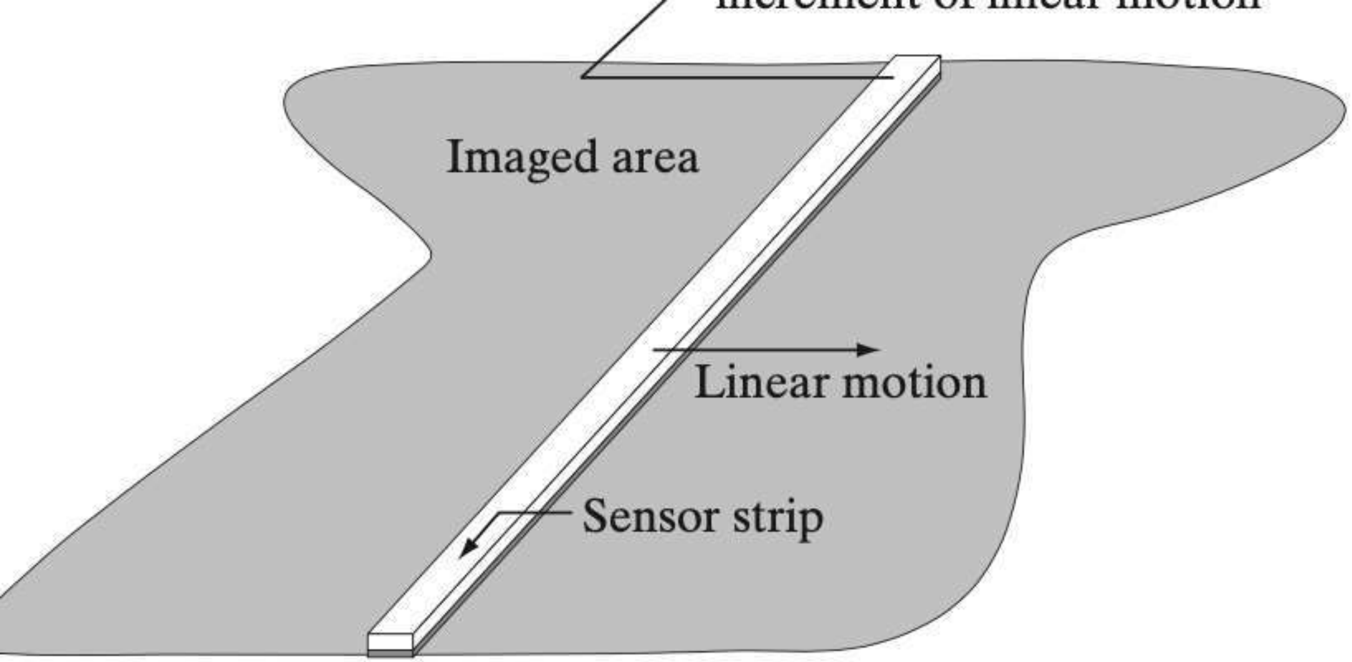

Energy
Filter
Power in
Sensing material
Housing
Voltage waveform out




Film
Sensor
Rotation
Linear motion
One image line out
per increment of rotation
and full linear displacement
of sensor from left to right



- 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 above.
- The strip provides imaging elements in one direction.
- Motion perpendicular to the strip provides imaging in the other direction.
- Sensor strips mounted in a ring configuration are used in medical and industrial imaging to obtain cross-sectional ("slice") images of 3-D objects.


Imaged area
Linear motion
Sensor strip

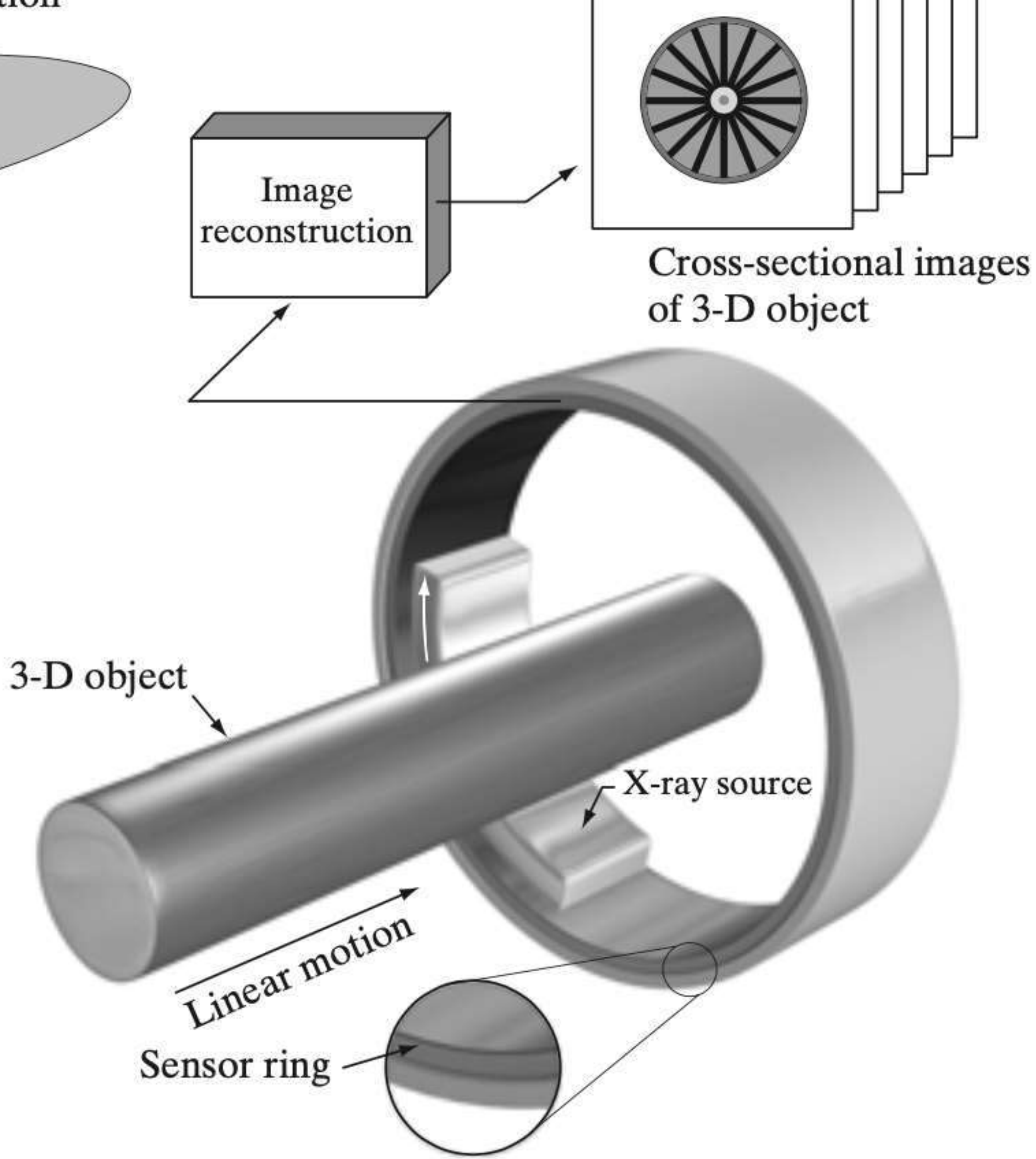


Image
reconstruction
Cross-sectional images
of 3-D object
3-D object
X-ray source
Linear motion
Sensor ring

- Figure shows individual sensors arranged in the form of a 2-D array.
- This is also the predominant arrangement found in digital cameras.
- A typical sensor for these cameras is a CCD array.
- Motion obviously is not necessary.