IMAGE PROCESSING

معالجه صور

INTRODUCTION IMAGE PROCESSING

“One picture is worth more than ten thousand words”

Anonymous

Image Processing , Image Analysis , Image Understanding

- Image Processing

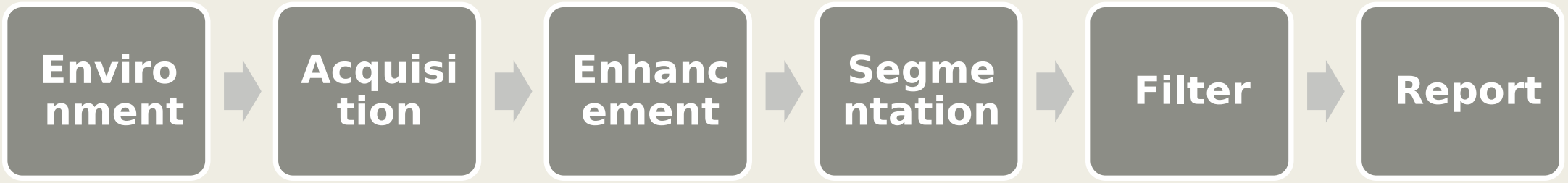
  image in →image out

- Image Analysis

  image in →measurements out

- Image Understanding

  image in →high-level description out


Enviro nment
Acquisi tion
Enhanc ement
Segme ntation
Filter
Report

Environment

Filed

Electronic spectrum

sound

Media

Indoor

Outdoor

Under water

Coordinate

الاسقاط(ثنائي, ثلاثي)

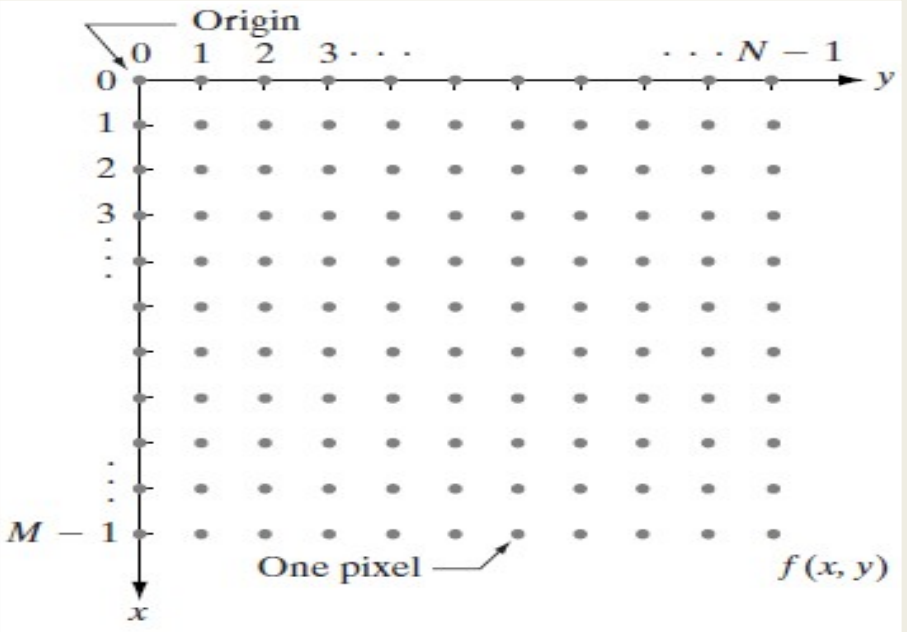
? What Is An image

- An image is a two-dimensional function, *f(x,y)*, where *x* and *y* are *spatial* (plane) coordinates, and the amplitude of *f(x,y)* at any pair of coordinates *(x, y)* is called the *intensity* or *gray level* of the image at the point *(x,y)*.

- Note: When x, y, and the amplitude values of *f* are all finite, discrete

? What Is A digital Image

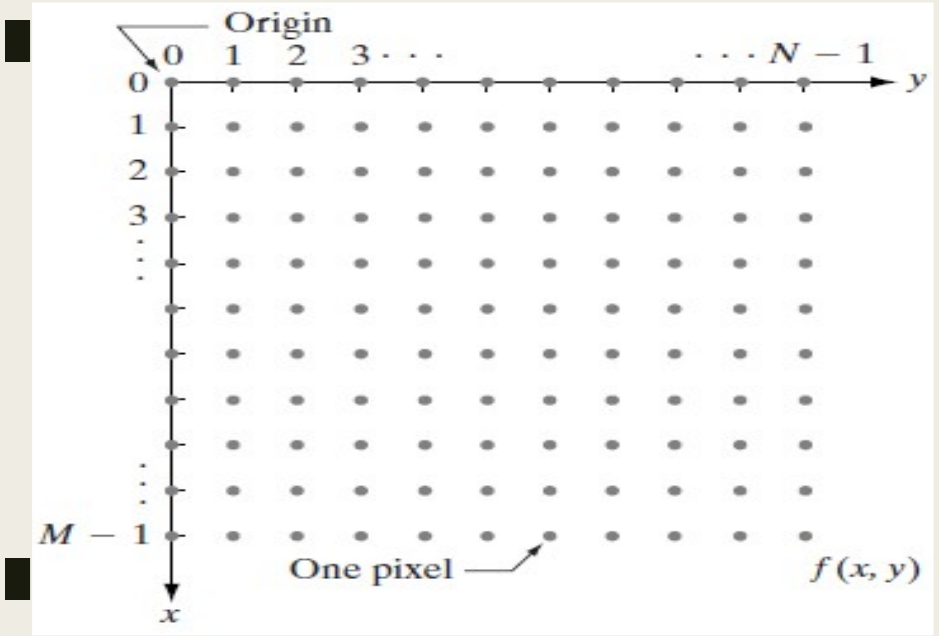
- A digital image is a two-dimensional matrix, f(M,N), where the value at the location (x,y) is called the intensity or gray level of the image at the point (x,y).
- So, the digital image is composed of a finite number of elements, each of which has a particular location and value.



The digital image elements are referred to *pels*, and *pixel*

? What Is A digital Image

- الصورة الرقمية عبارة عن مصفوفة ثنائية الأبعاد ، f(M,N), حيث تسمى القيمة في الموقع (x,y) الكثافة أو المستوى الرمادي للصورة عند النقطة (x,y).
- لذلك ، تتكون الصورة الرقمية من عدد محدود من العناصر ، لكل منها موقع وقيمة معينة.



? What Is A digital Image

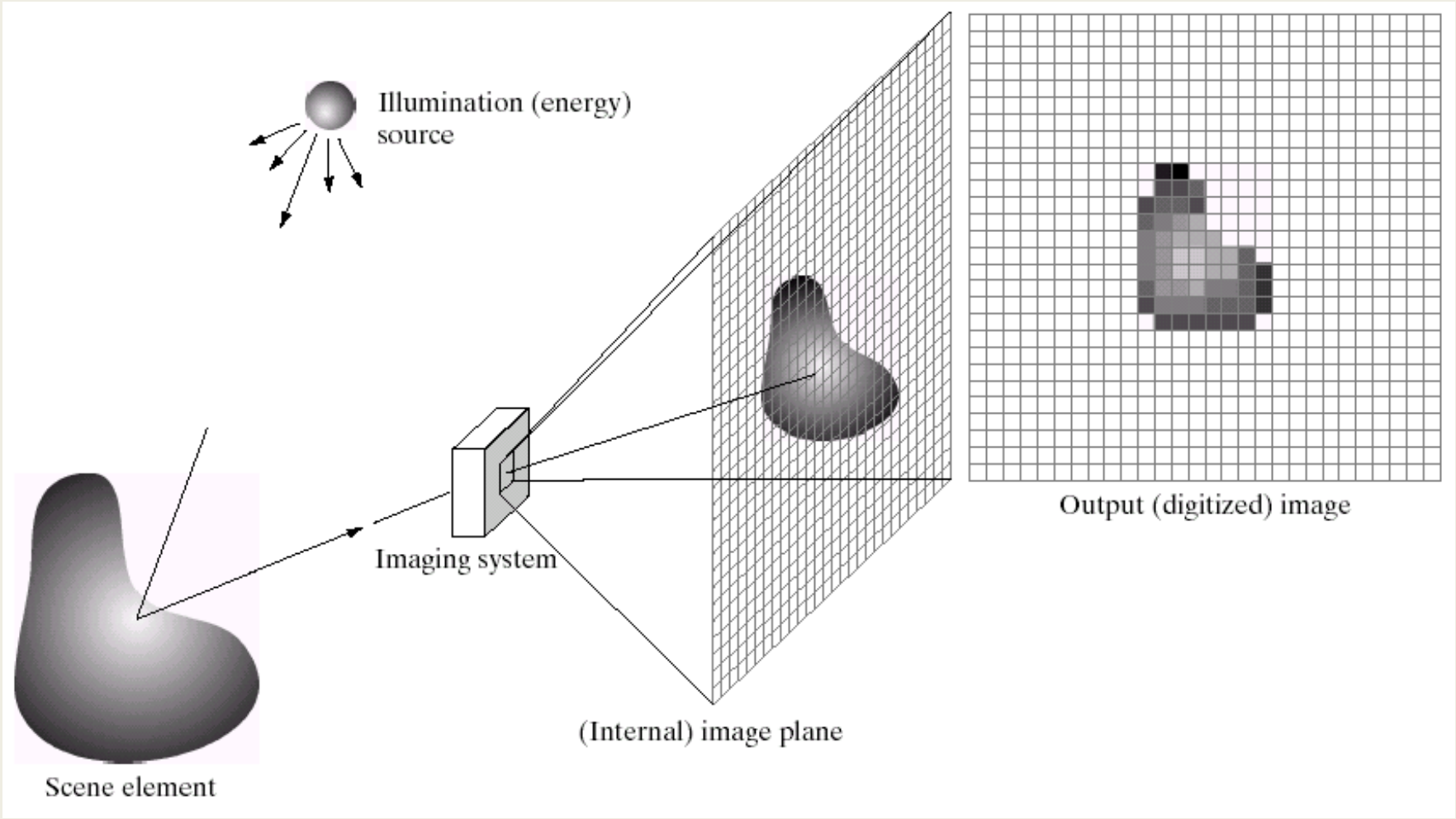
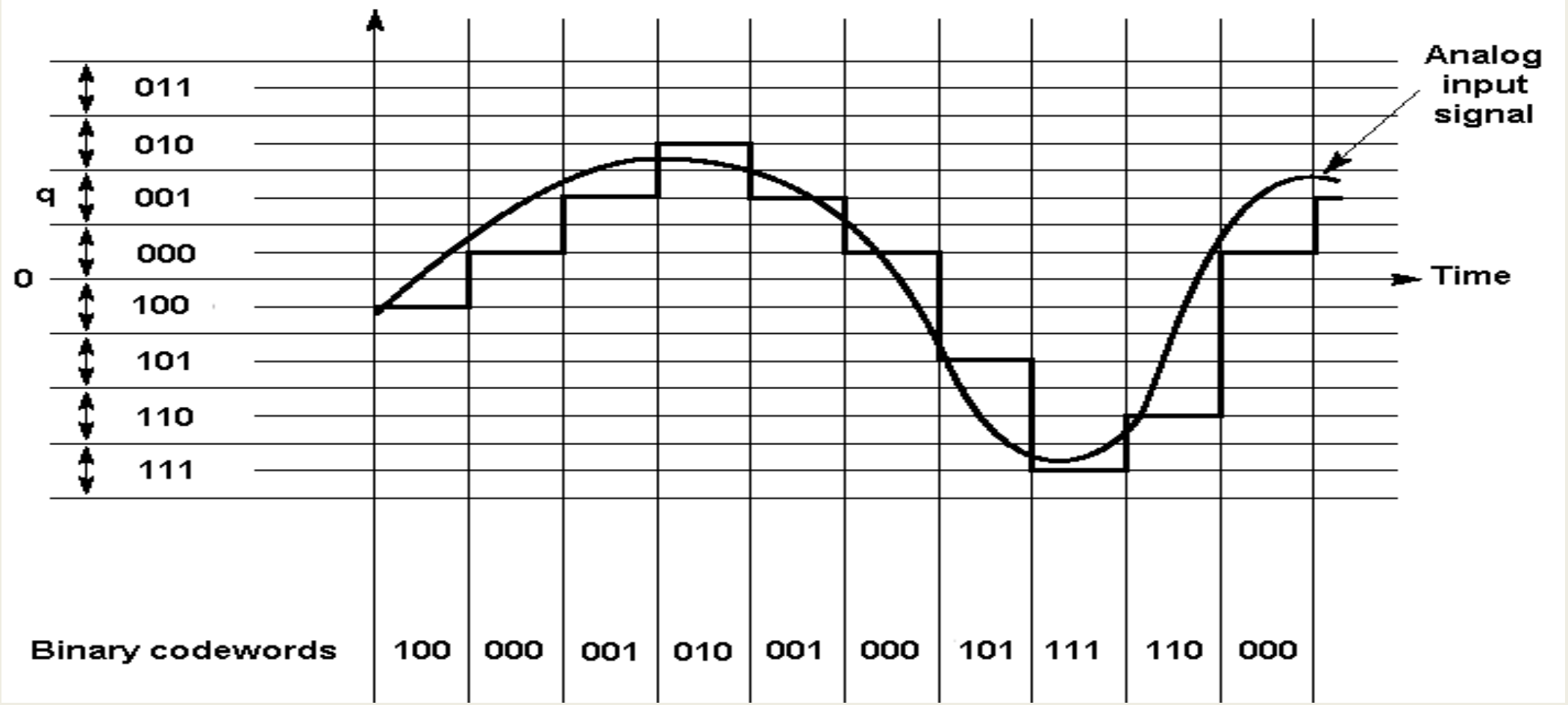


Image Sampling and Quantization

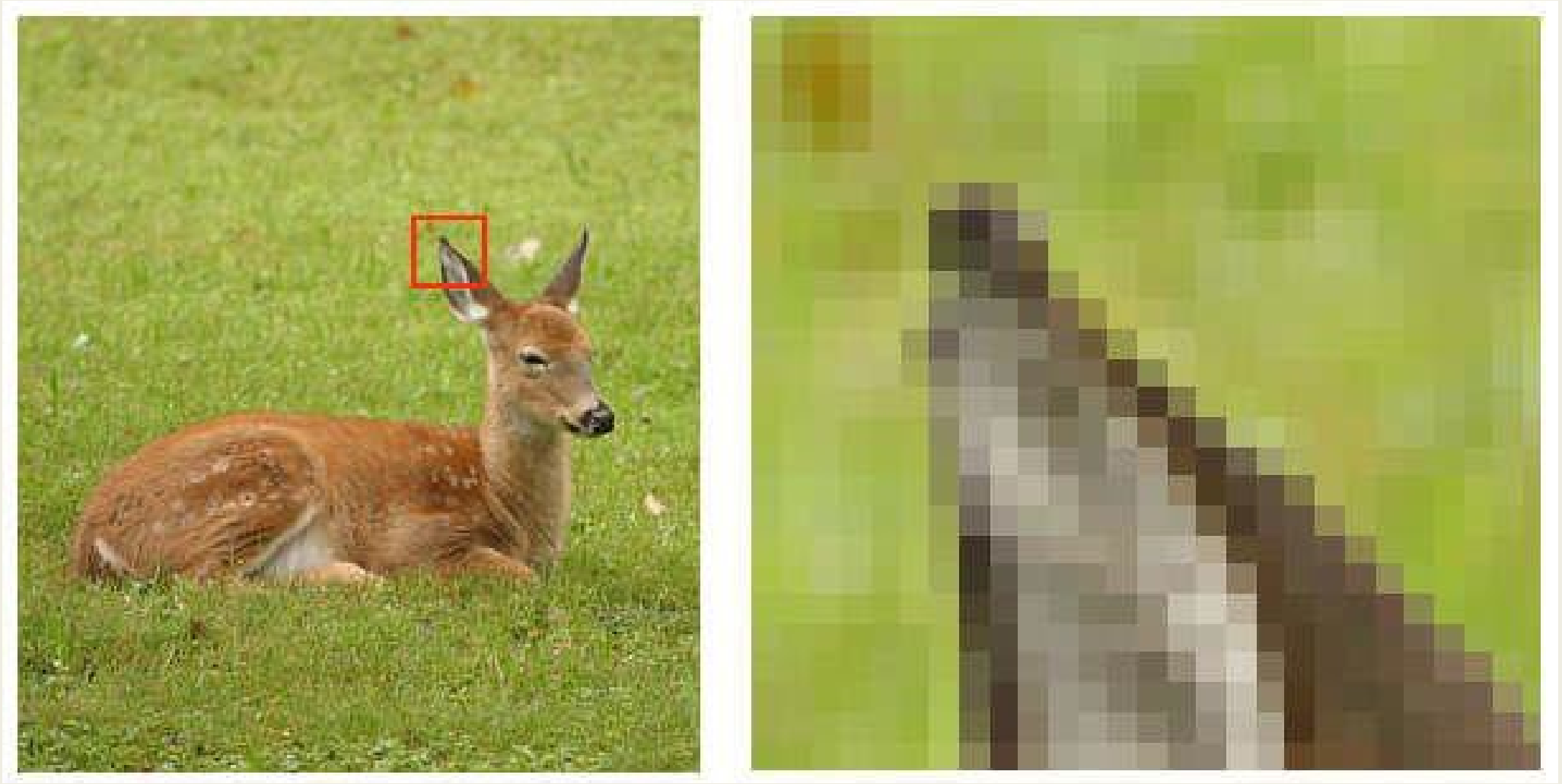
- An image may be continuous with respect to the x- and y-coordinates, and also in amplitude. To convert it to digital form, we have to sample the function in both coordinates and in amplitude.
- Digitizing the coordinate values is called *sampling*.
- Digitizing the amplitude values is called *quantization*.

How do we get a clearer picture?

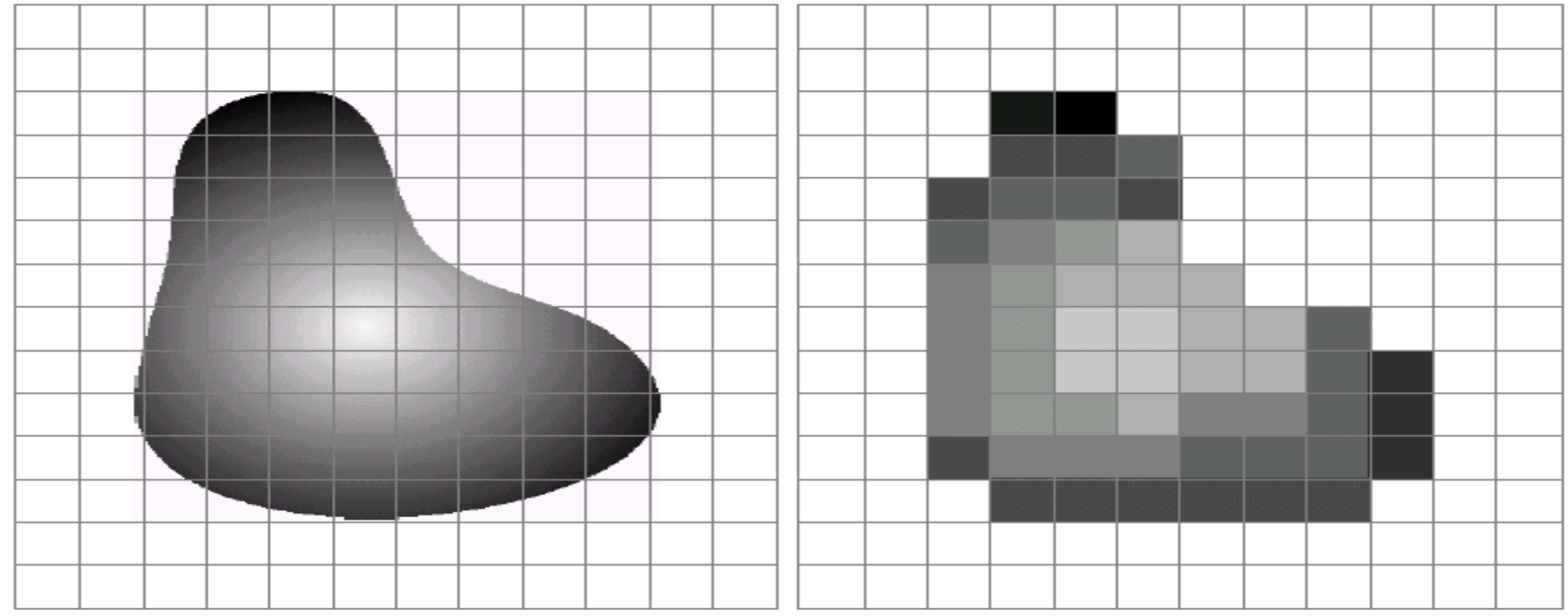
Sampling , quantization



? What Is A digital Image



? What Is A digital Image



What Is Digital Image ?Processing

- Digital image processing field, is a preprocessing step for other computerized processing fields such as computer vision and pattern recognition.
- In computer vision, the goal is to use computers to emulate human vision, including learning (understanding) and being able to make inferences and take actions based on visual inputs.

- مجال معالجة الصور الرقمية ، هو خطوة معالجة مسبقة لمجالات المعالجة المحوسبة الأخرى مثل رؤية الكمبيوتر والتعرف على الأنماط.
- في رؤية الكمبيوتر ، الهدف هو استخدام أجهزة الكمبيوتر لمحاكاة الرؤية البشرية ، بما في ذلك التعلم (الفهم) والقدرة على عمل الاستنتاجات واتخاذ الإجراءات بناءً على المدخلات المرئية.

Applications of Digital Image Processing

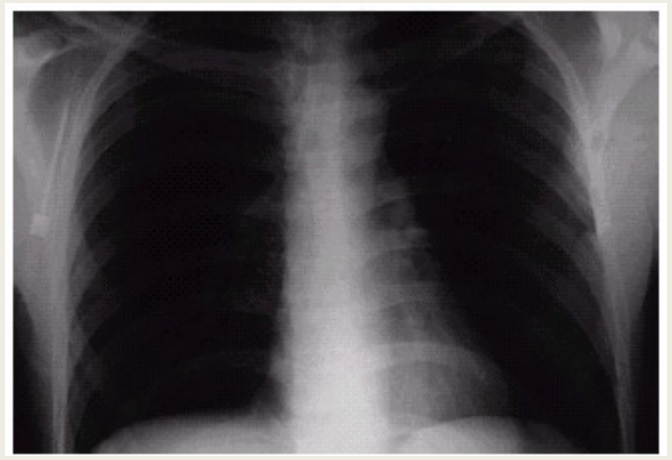
- Image sharpening and restoration

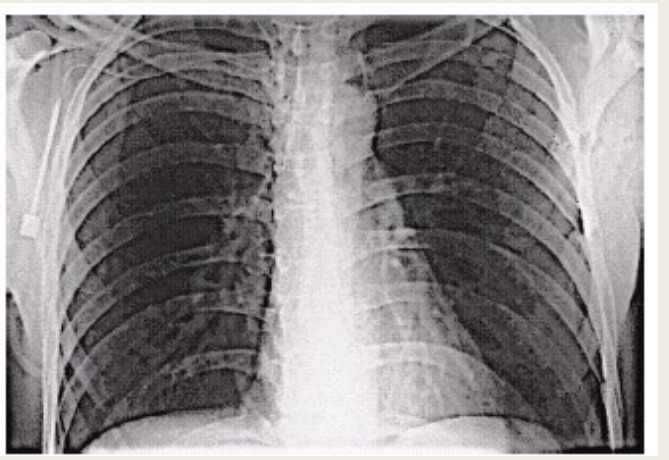
It refers to the process in which we can modify the look and feel of an image. It basically manipulates the images and achieves the desired output. It includes conversion, sharpening, blurring, detecting edges, retrieval, and recognition of images.

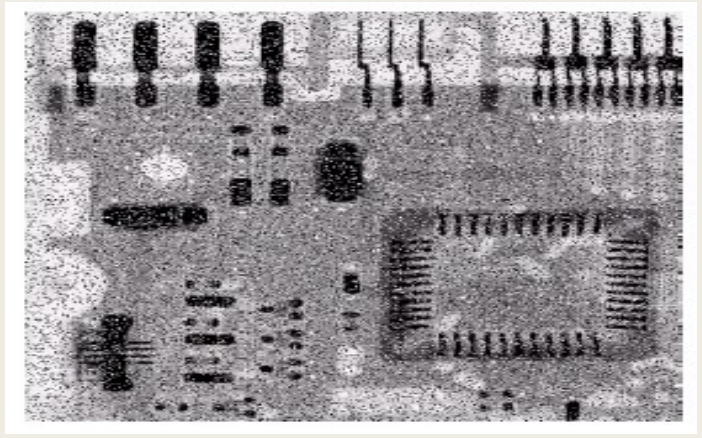
- 2) Medical field

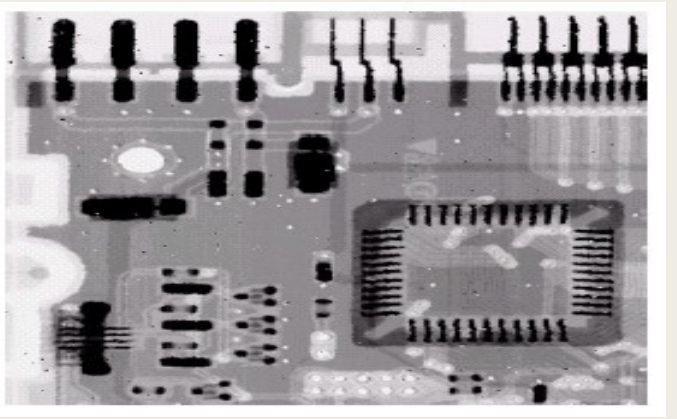
There are several applications under medical field which depends on the functioning of digital image processing .Gamma-ray imaging,X-Ray Imaging,Medical CT scan ,UV imaging

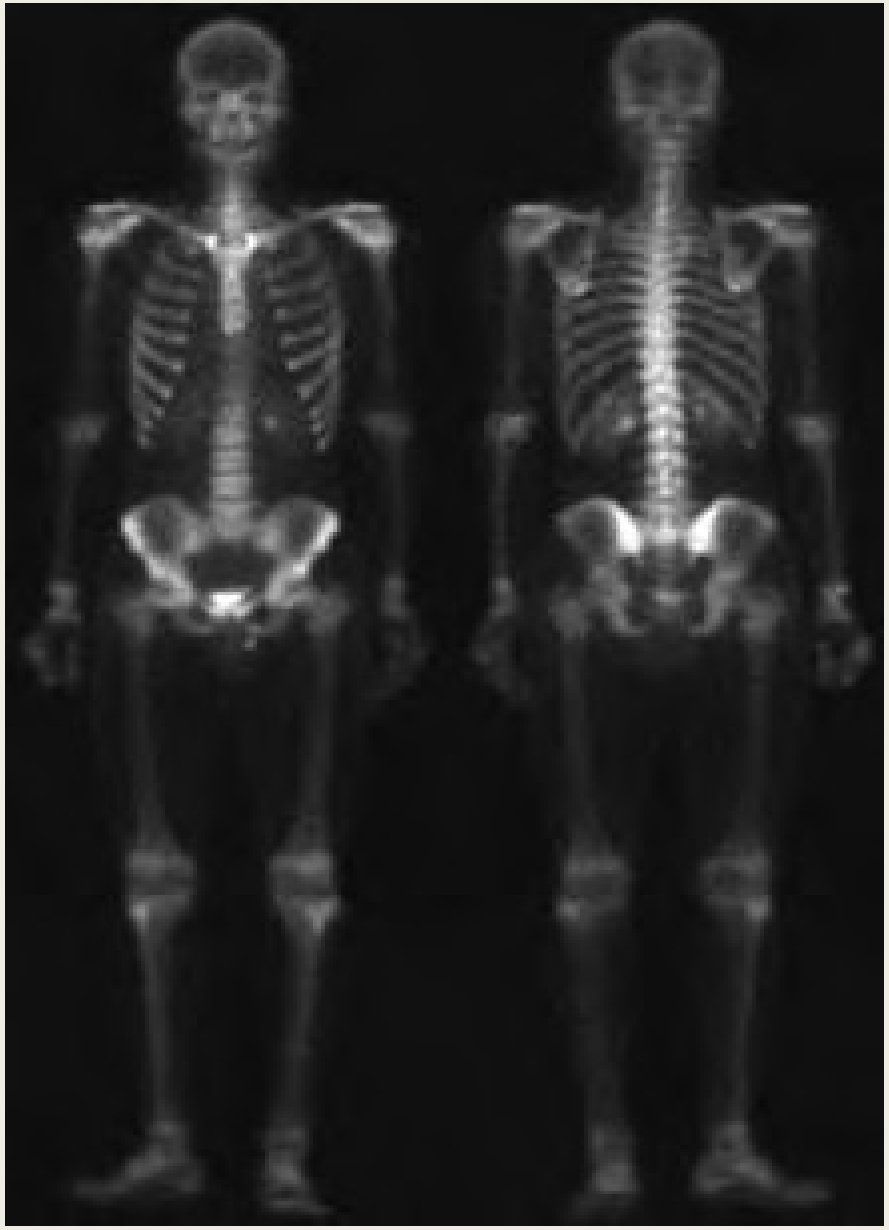
- 3) Robot vision

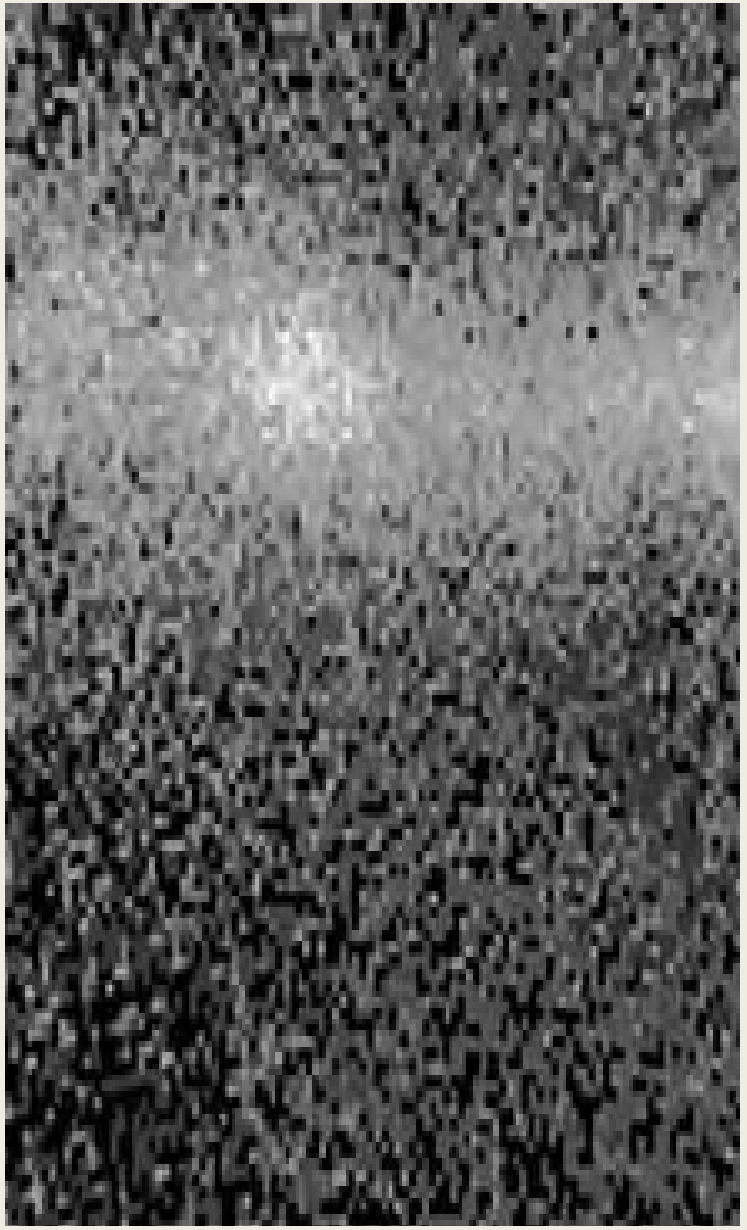












Applications of Digital Image Processing

- 4) Pattern recognition

It involves the study of image processing, it is also combined with artificial intelligence such that computer-aided diagnosis, handwriting recognition and image recognition can be easily implemented. Now a days, image processing is used for pattern recognition.

- 5)Video processing

It is also one of the applications of digital image processing. A collection of frames or pictures are arranged in such a way that it makes the fast movement of pictures. It involves frame rate conversion, motion detection, noise reduction and color space conversion etc.

,.Cont

- There are no clear-cut boundaries in the continuum from image processing at one end to computer vision at the other.
- So, we can consider three types of computerized processes in this continuum: low-, mid-, and high-level processes

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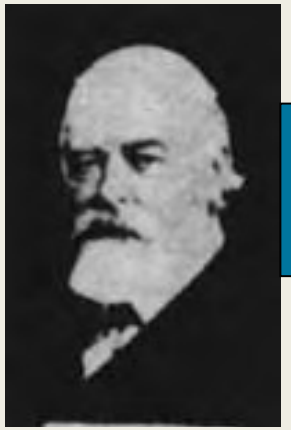
- Low-level processes involve primitive operations such as noise reducing, contrast enhancement, and image sharpening.
- Mid-level processing on images involves tasks such as segmentation, description of those objects to reduce them to a form suitable for computer processing.
- Higher-level processing involves “making sense” of an ensemble of recognized objects, as in image analysis, and, at the far end of the continuum, performing the cognitive functions.

The Origins of Digital Image Processing

- One of the first applications of digital images was in the newspaper industry, when pictures were first sent by submarine cable between Lond

- produced in 1921 (telegraph)
- five distinct levels of gray

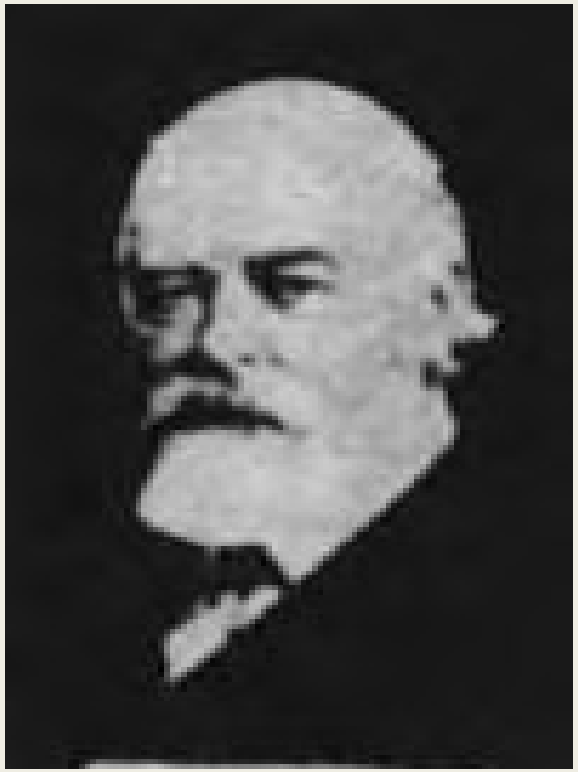


- produced in 1922 (telegraph)
- after the signals had crossed the Atlantic twice

- produced in 1929 (telegraph)
- 15 distinct levels of gray

The Origins of Digital Image Processing

The history of *digital image processing* is intimately tied to the development of the digital computer



,.Cont

- The first computers powerful enough to carry out meaningful image processing tasks appeared in the early 1960s.

- In 1964 when pictures of the moon transmitted by Ranger 7.
- processed by a computer to correct various types of image distortion inherent in the on-board television camera.

- ي عام 1964، قامت مركبة رينجر 7 بالتقاط ونقل صور للقمر. تم التقاط هذه الصور باستخدام كاميرا تلفزيونية موجودة على متن المركبة. ومع ذلك، كانت الصور التي تم استلامها من رينجر 7 تعاني من أنواع مختلفة من التشوهات في الصورة ناتجة عن عيوب الكاميرا وأخطاء النقل.
- لتصحيح هذه التشوهات وتحسين جودة الصور، تم استخدام تقنيات معالجة الصور عن طريق الحاسوب. تم تحويل الصور إلى تنسيق رقمي وإدخالها إلى نظام حاسوبي، حيث تم استخدام خوارزميات وبرامج لأداء تصحيح وتحسين الصور.

Image Types

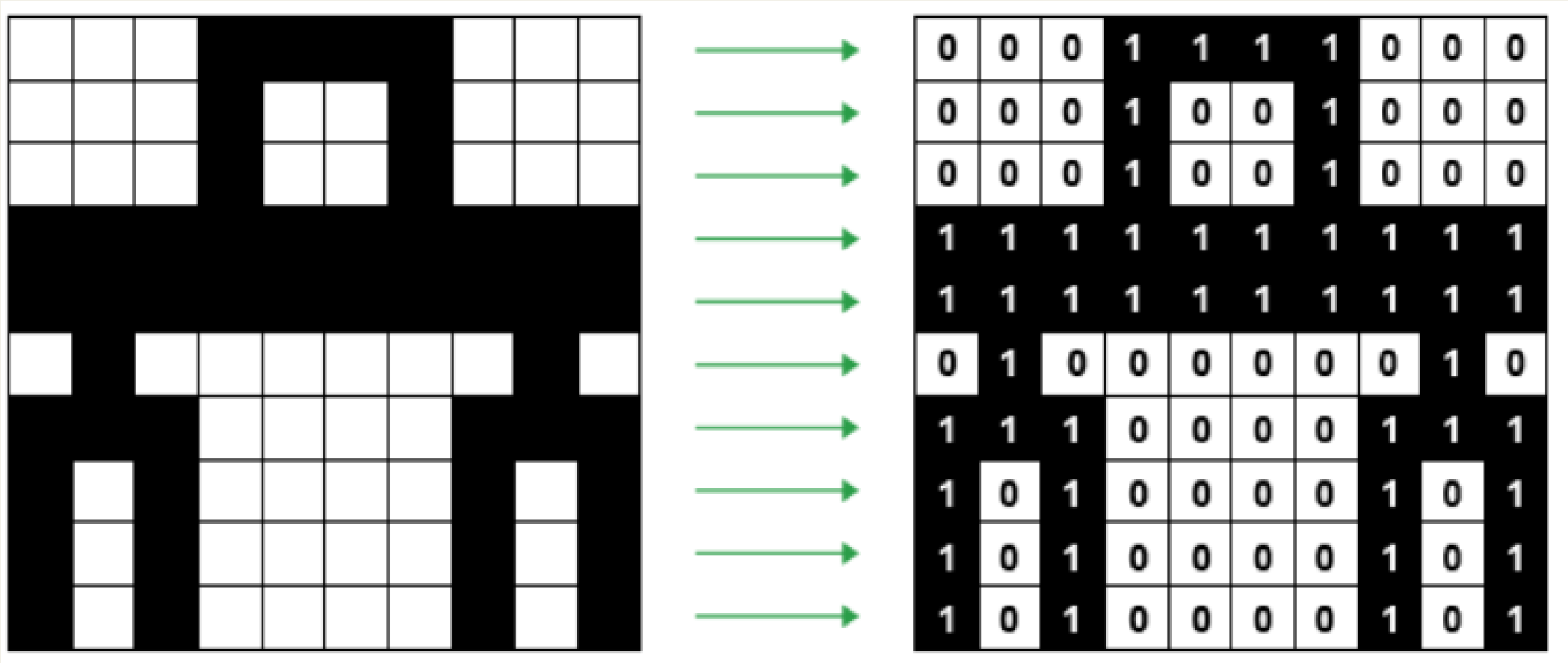
Image types according to color :

1-color RGB

2-Binary

3-gray

Binary image



gray image

0	2	15	0	0	11	10	0	0	0	0	9	9	0	0	0	
0	0	0	4	60	157	236	255	255	177	95	61	32	0	0	25	
0	10	16	119	238	255	244	245	243	250	249	255	222	103	10	0	
0	14	170	255	255	244	254	255	253	245	255	249	253	251	124	1	
2	98	255	228	255	251	254	211	141	116	122	215	251	238	255	49	
13	217	243	255	155	33	226	52	2	0	10	13	232	255	255	36	
16	229	252	254	49	12	0	0	7	7	0	70	237	252	235	62	
6	141	245	255	212	25	11	9	3	0	115	236	243	255	137	0	
0	87	252	250	248	215	60	0	1	121	252	255	248	144	6	0	
0	13	113	255	255	245	255	182	181	248	252	242	208	36	0	19	
1	0	5	117	251	255	241	255	247	255	241	162	17	0	7	0	
0	0	0	4	58	251	255	246	254	253	255	120	11	0	1	0	
0	0	4	97	255	255	255	248	252	255	244	255	182	10	0	4	
0	22	206	252	246	251	241	100	24	113	255	245	255	194	9	0	
0	111	255	242	255	158	24	0	0	6	39	255	232	230	56	0	
0	218	251	250	137	7	11	0	0	0	2	62	255	250	125	3	
0	173	255	255	101	9	20	0	13	3	13	182	251	245	61	0	
0	107	251	241	255	230	98	55	19	118	217	248	253	255	52	4	
0	18	146	250	255	247	255	255	255	249	255	240	255	129	0	5	
0	0	23	113	215	255	250	248	255	255	248	248	118	14	12	0	
0	0	6	1	0	52	153	233	255	252	147	37	0	0	4	1	
0	0	5	5	0	0	0	0	0	14	1	0	6	6	0	0	

RGB Image

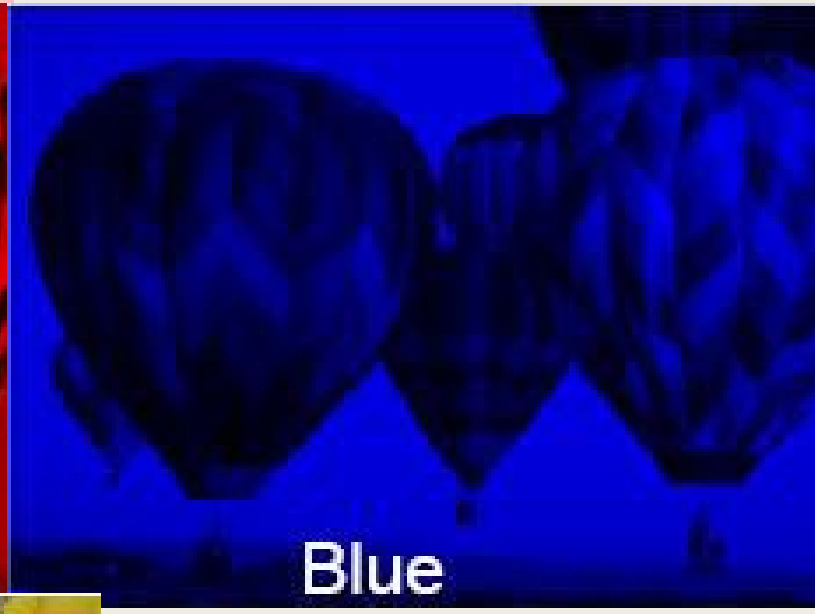


Image Types

Image types according to energy source:

1- Electromagnetic energy spectrum images(الصور الخاصة بطيف الطاقة الكهرومغناطيسية هي صور تلتقط مجموعة متنوعة من الموجات أو الترددات من طيف الطاقة الكهرومغناطيسية. يشمل طيف الطاقة الكهرومغناطيسية مجموعة واسعة من الطاقة، بدءًا من الموجات الراديوية ذات التردد المنخفض إلى الأشعة الغاما ذات الطاقة العالية.)

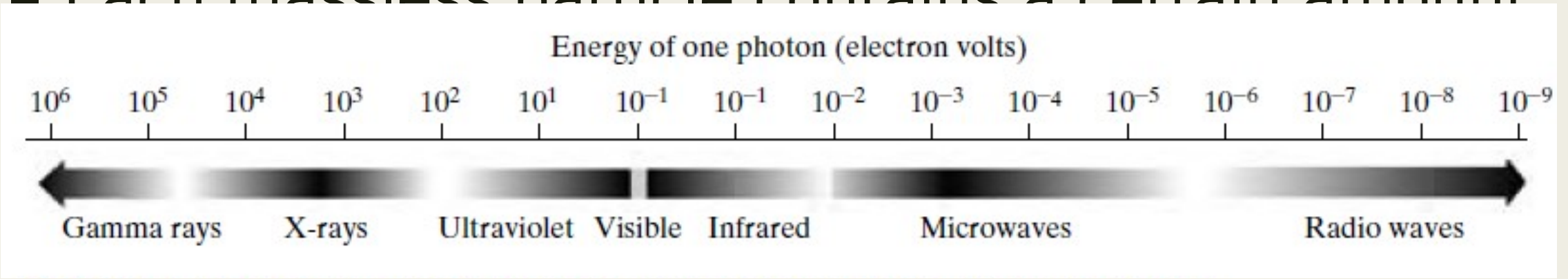
2- Acoustic & ultrasonic images(الصور الطبية التي تتم إنشاؤها باستخدام الموجات فوق الصوتية. تستخدم هذه التقنية الموجات فوق الصوتية لإنشاء صور داخلية للأنسجة والأعضاء في الجسم.)

3- Electronic images(الصور الإلكترونية هي صور تم إنشاؤها أو تخزينها بواسطة أجهزة إلكترونية وتكنولوجيا الحوسبة.)

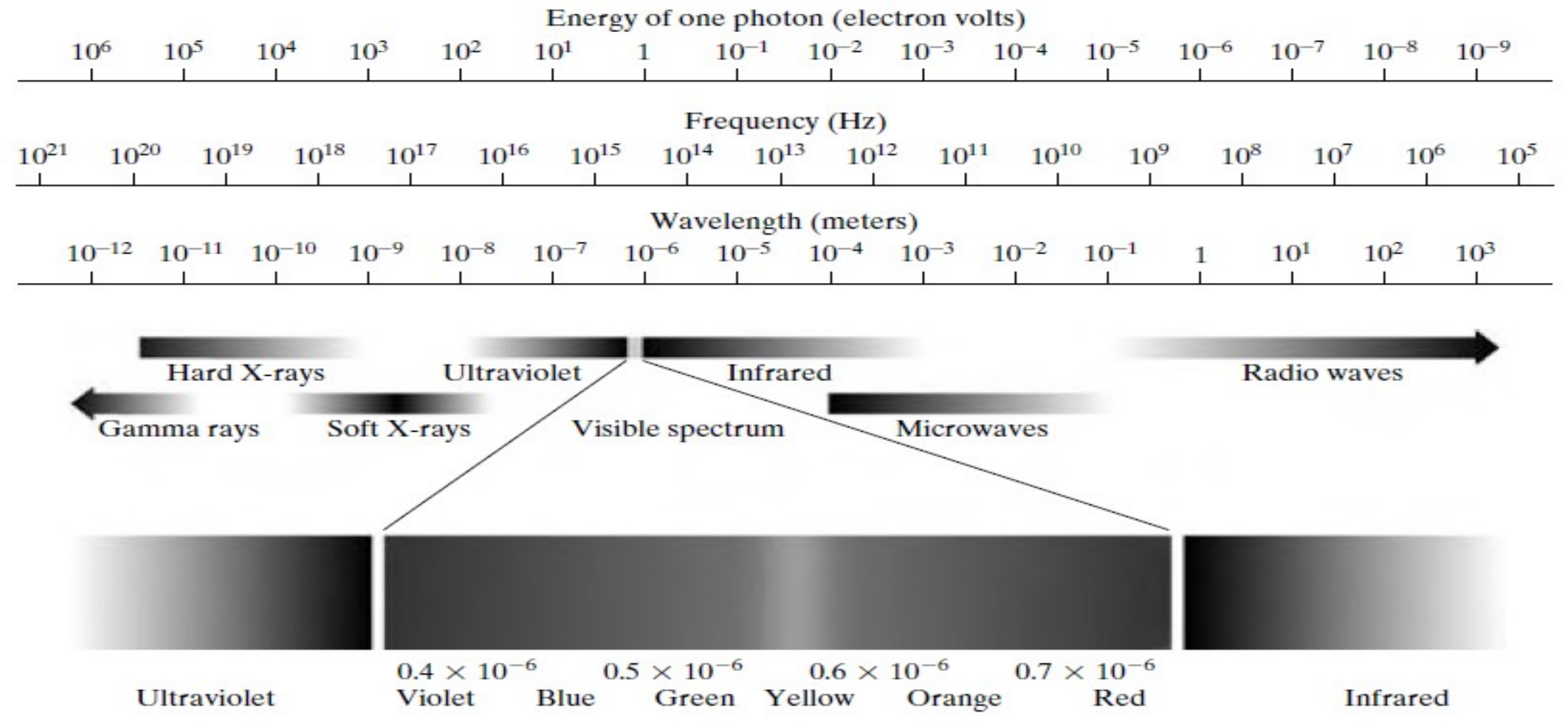
4- Computer modeling images (الرسام)

Electromagnetic spectrum (EM)

- Electromagnetic waves are sinusoidal waves of varying wavelengths, or are a stream of massless particles, each traveling in a wavelike pattern and moving at the speed of light.
- Each massless particle contains a certain amount



Electromagnetic (EM)

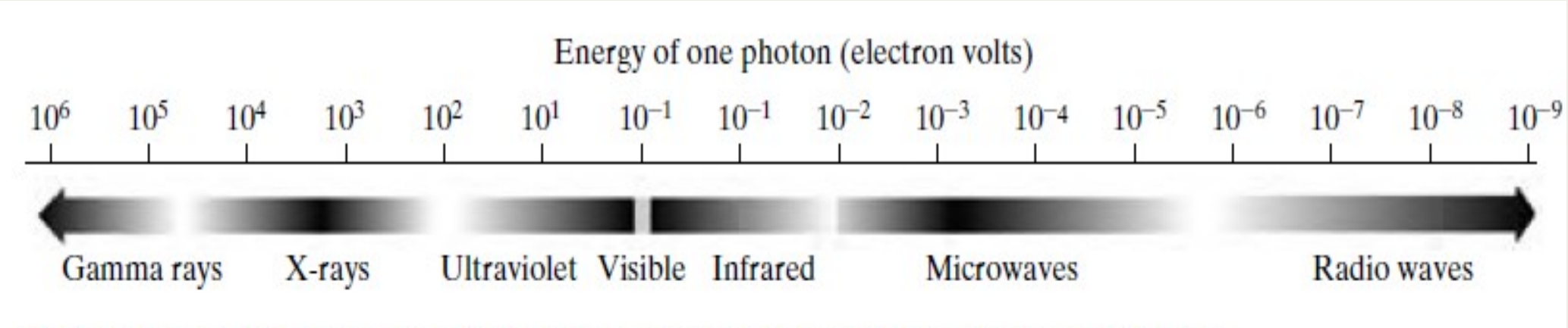


light

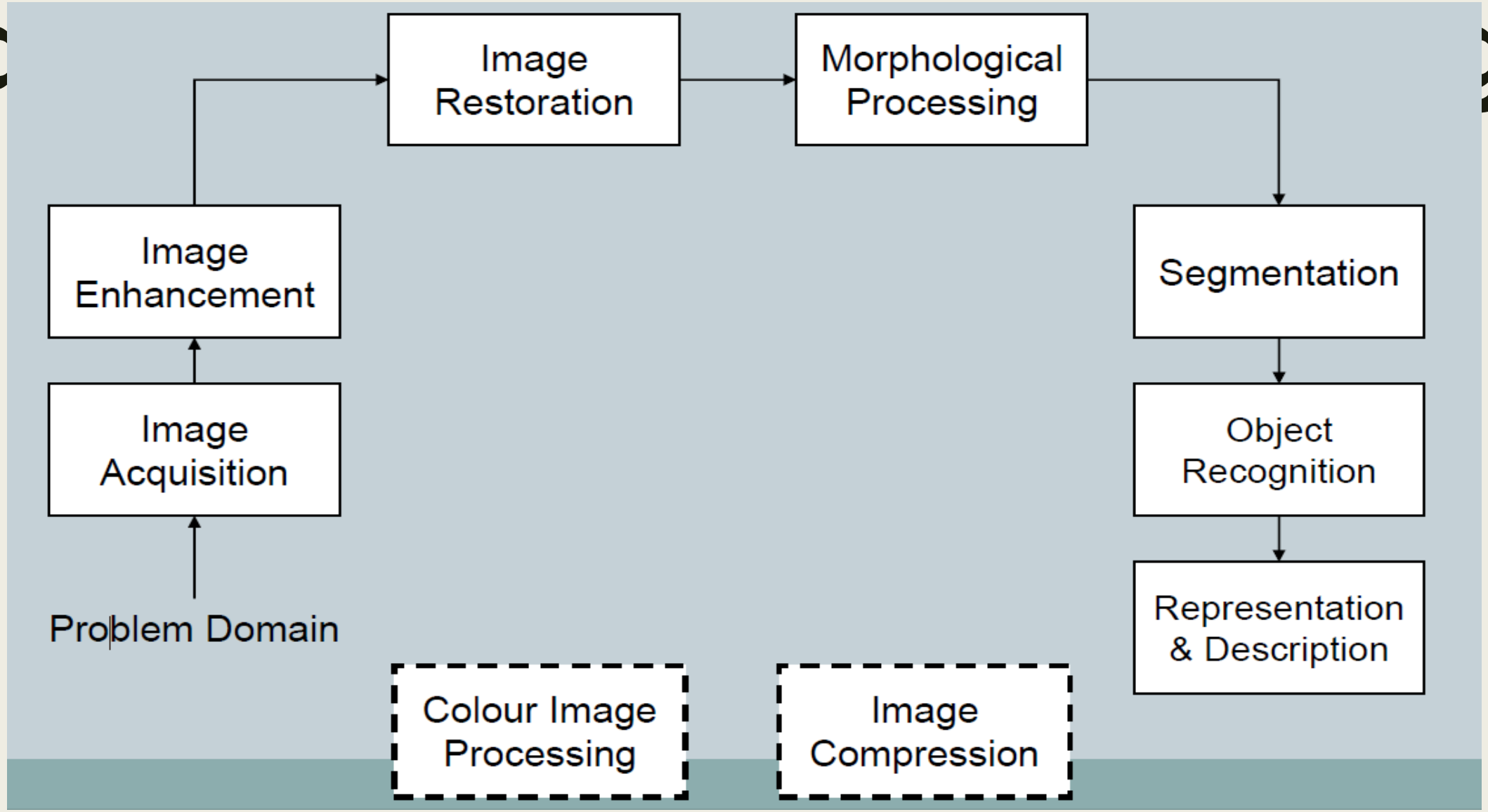
- Light is a form of electromagnetic radiation that is visible to the human eye and can travel through both vacuum and material mediums. It is part of the electromagnetic spectrum, which includes various types of radiation such as infrared, ultraviolet, X-rays, and gamma rays

.micron (violet) to about 0.79 micron (red) 0.43

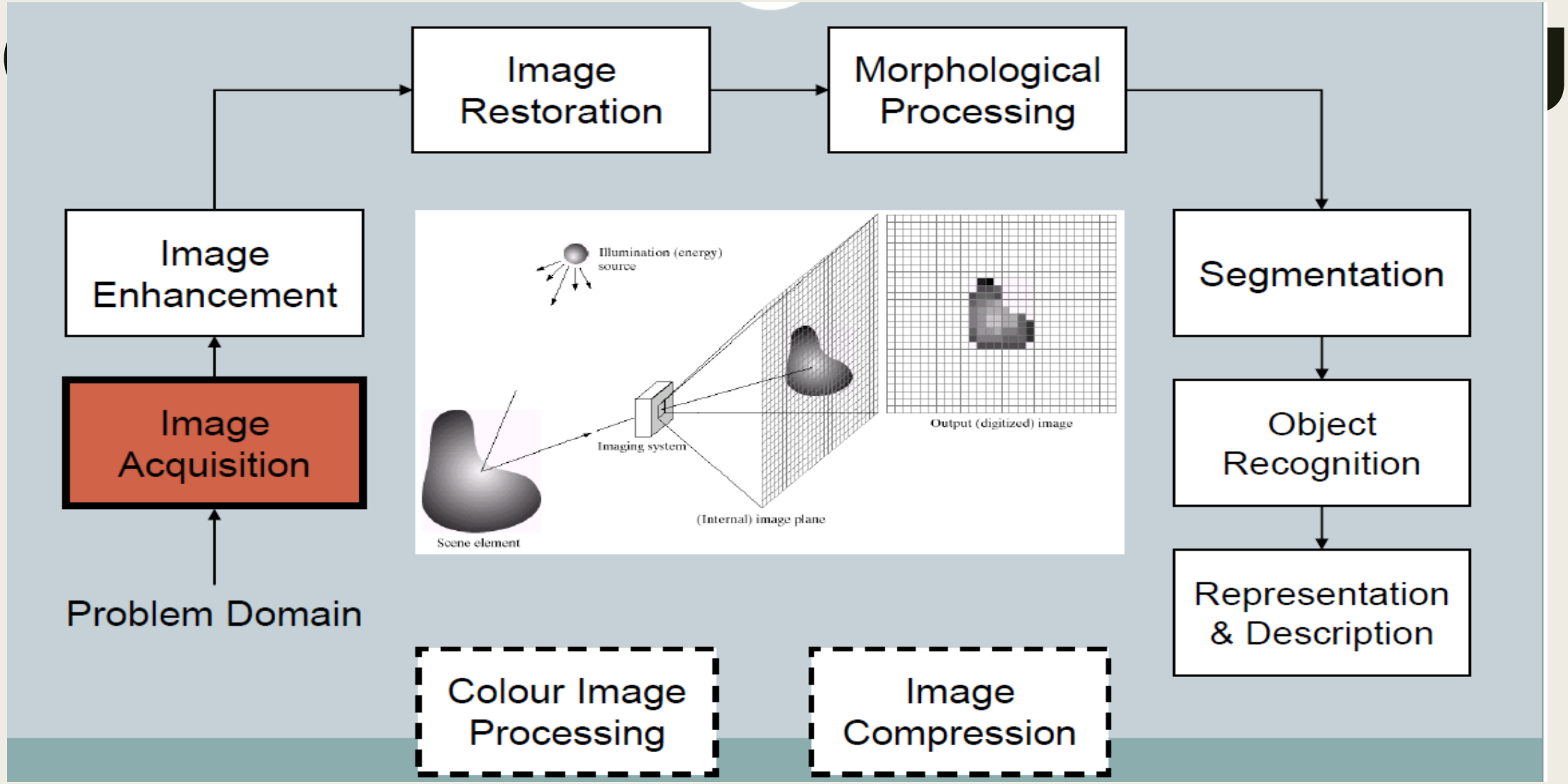
violet, blue, green, yellow, orange, and red



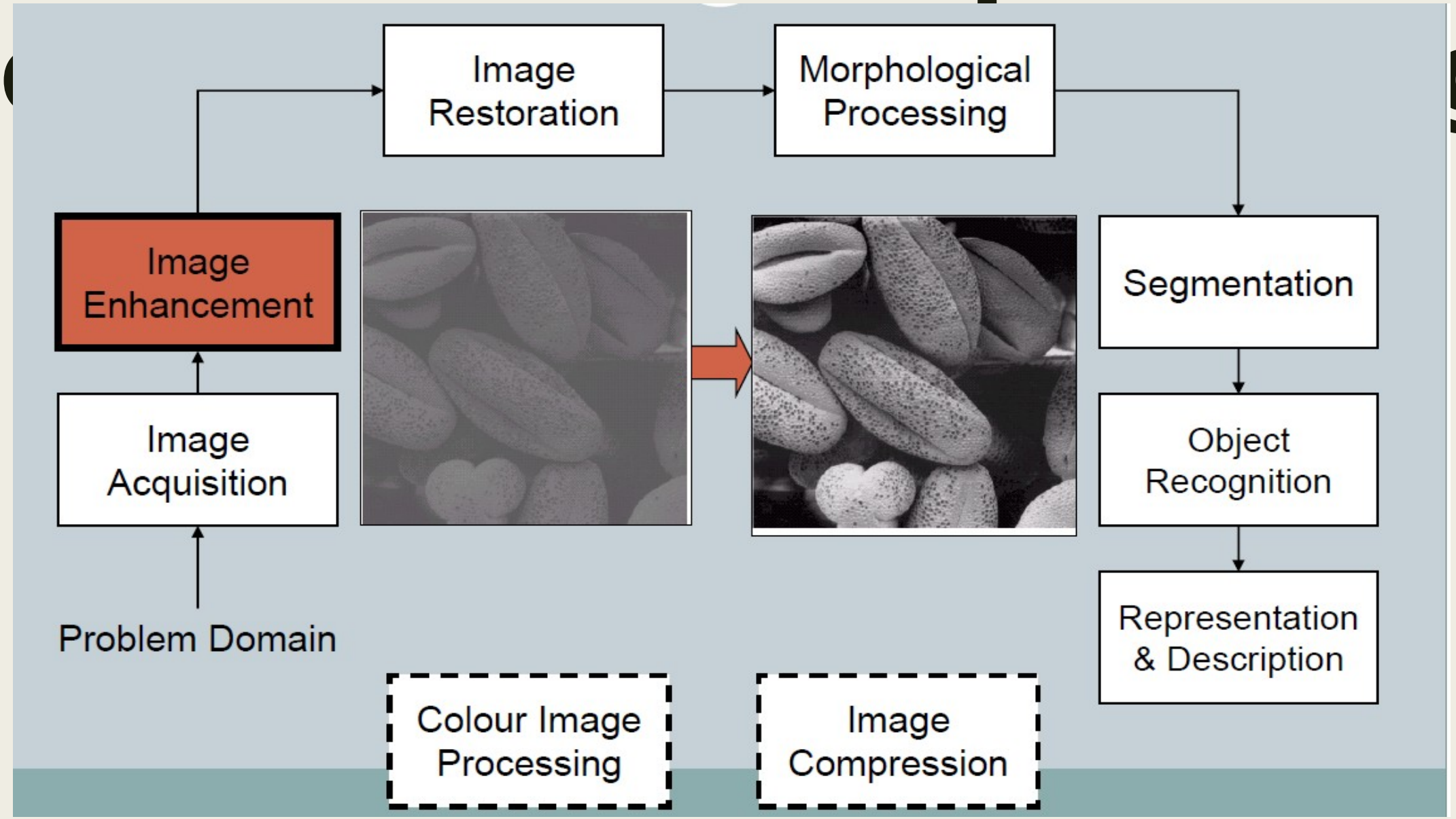
Fundamental steps in .c g



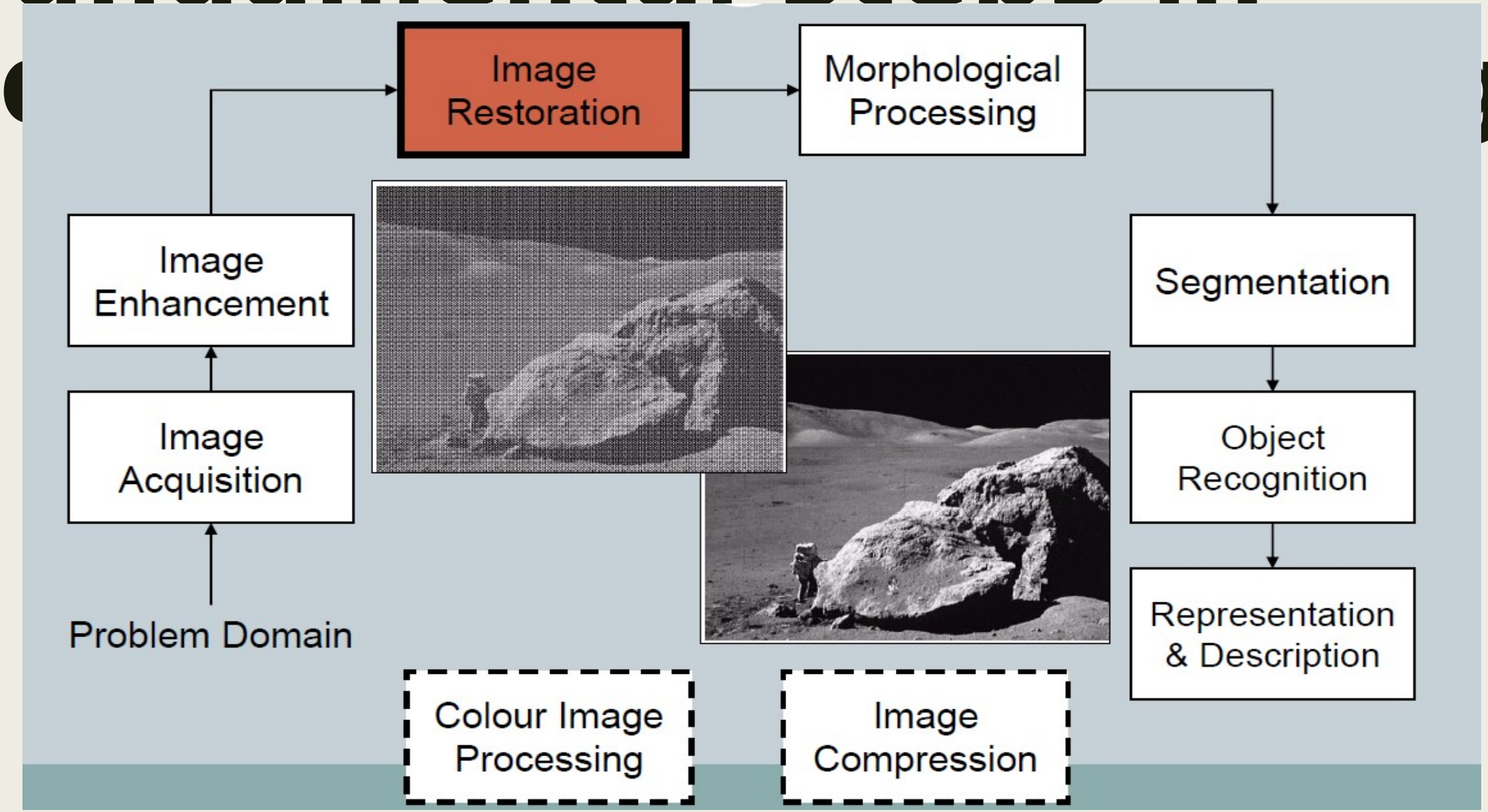
Fundamental steps in



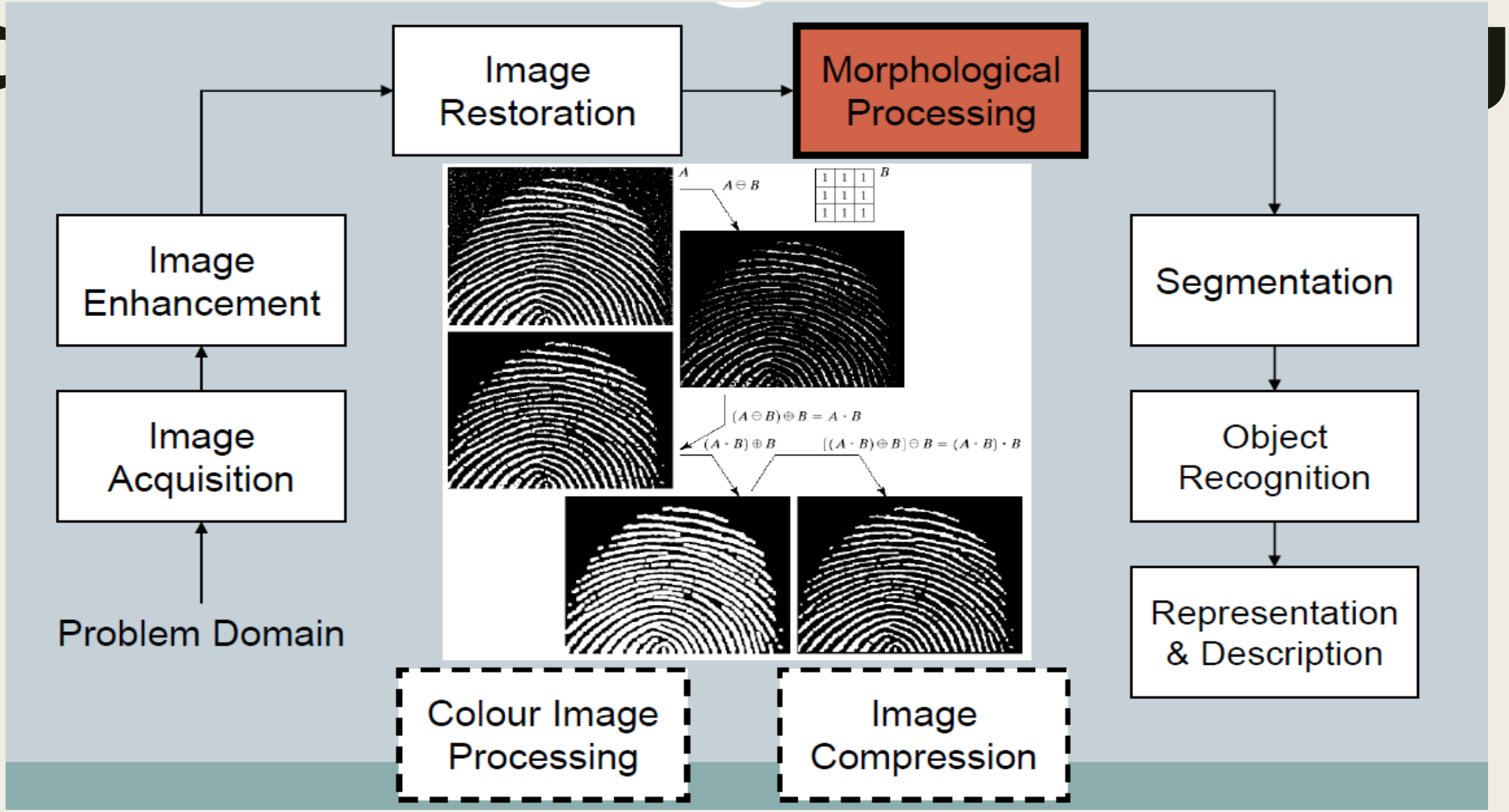
Fundamental steps in .g



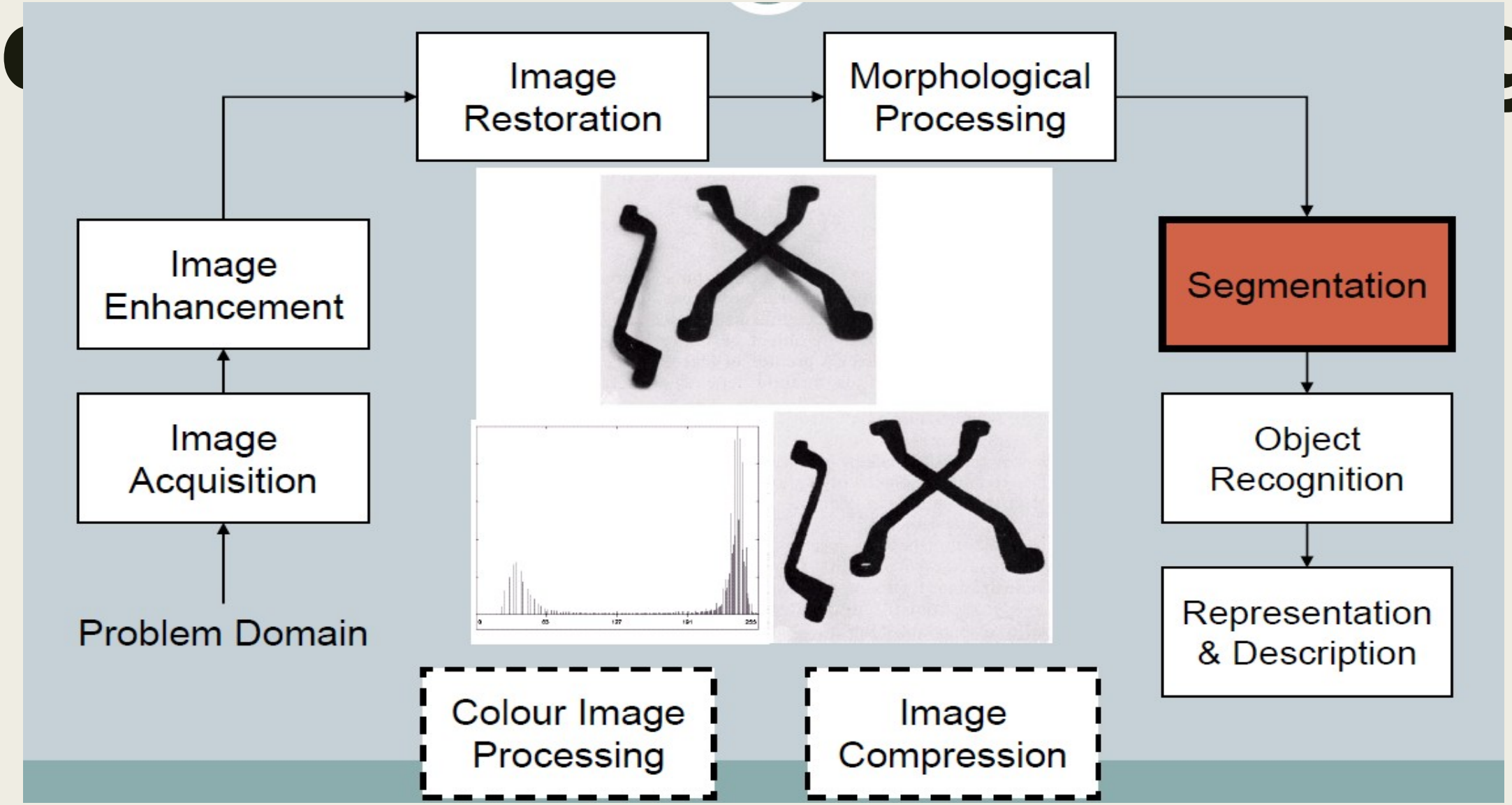
Fundamental steps in .g



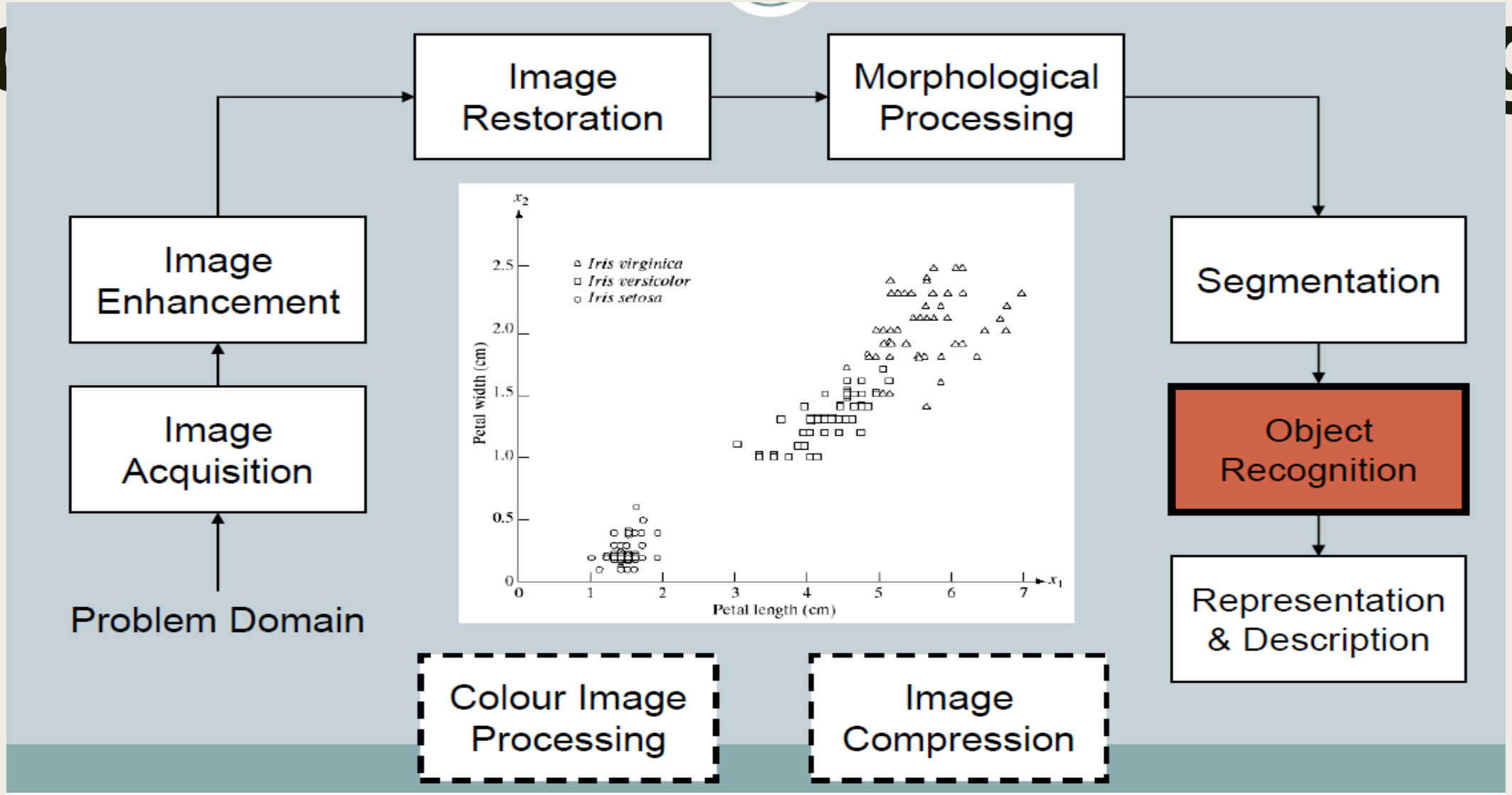
Fundamental steps in .c



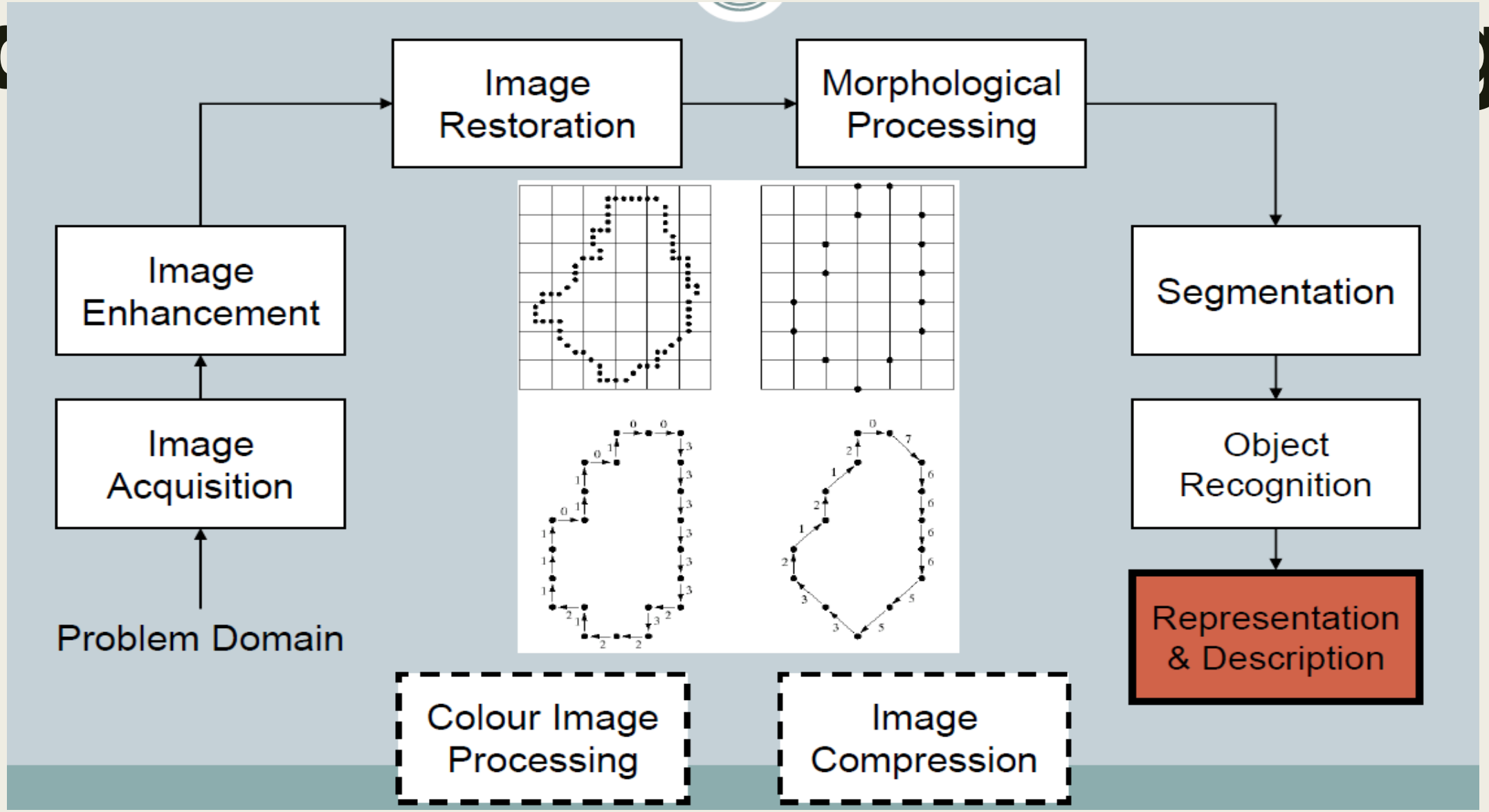
Fundamental steps in .g



Fundamental steps in .g



Fundamental steps in .C g



Elements of Visual Perception

1.Structure of Eye

E

Retina:(2 receptors)

- *Cones (6 – 7 million)*بـــكسل الـجوالـل

- *Rods (*75 to 150 million)

**photopic* or bright-light vision

•*scotopic* or dim-light vision

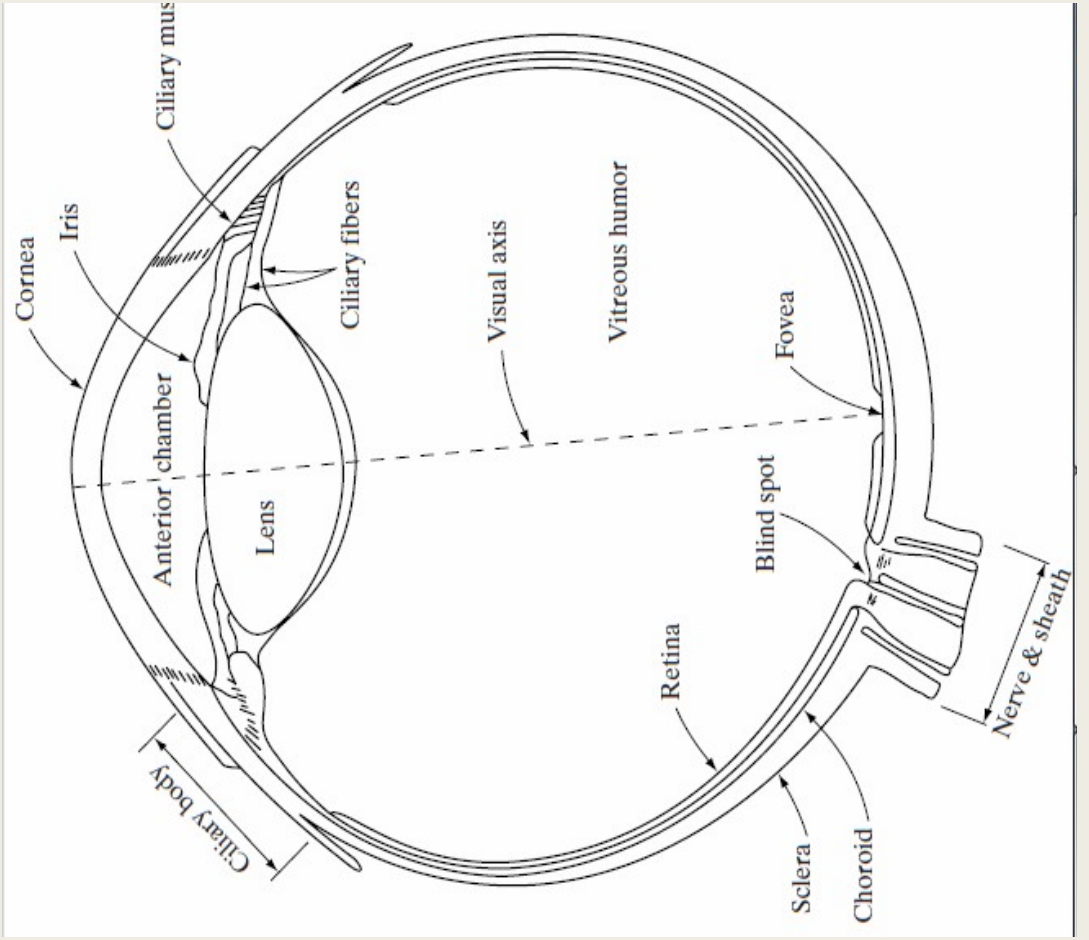
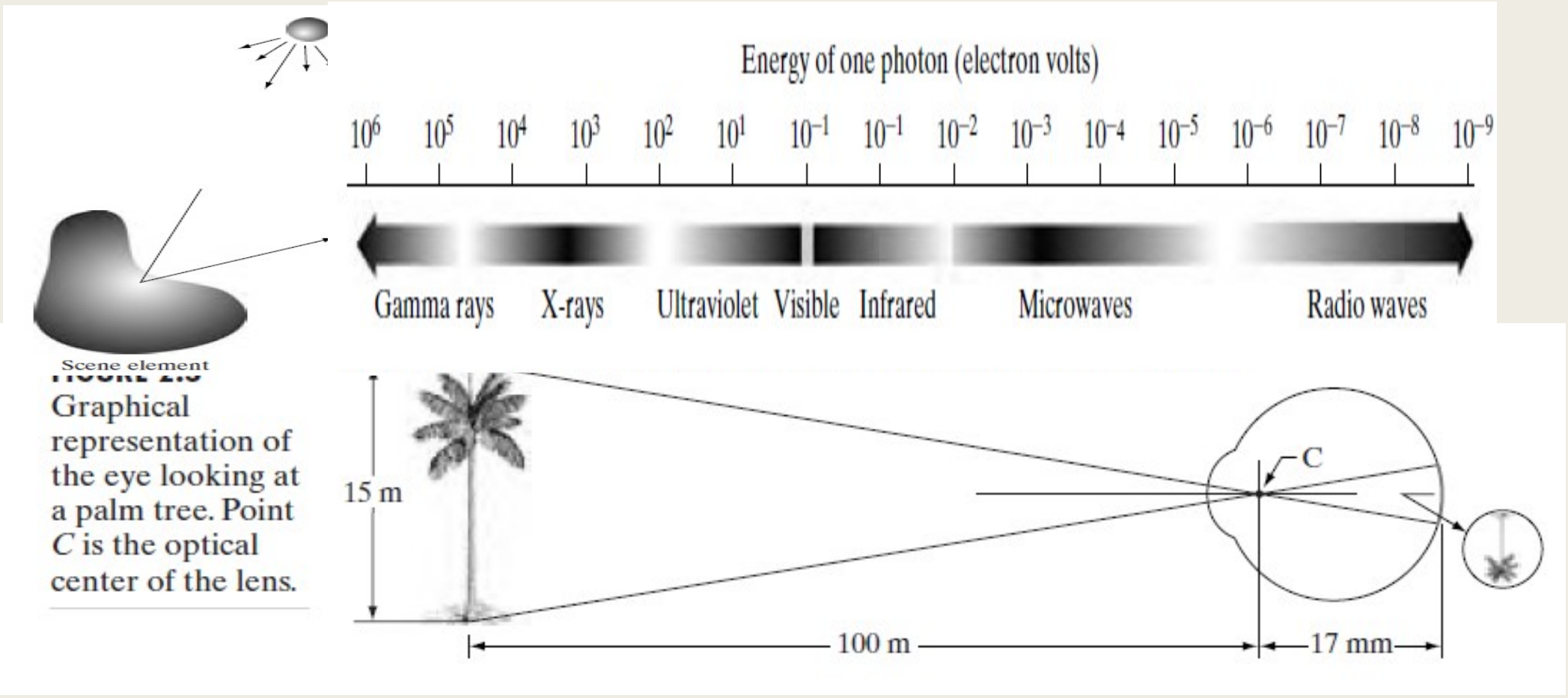
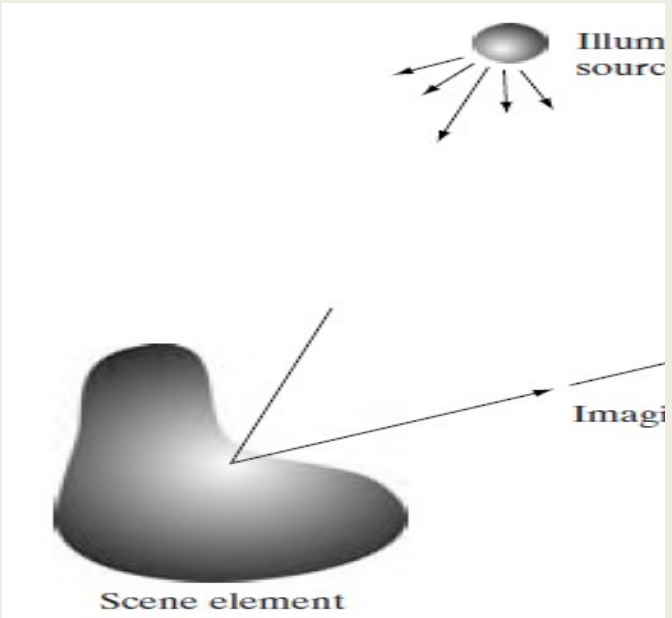


Image Formation in the Eye



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

?What determines image quality



(Achromatic or *monochromatic) and chromatic* light.
Three basic quantities are used to describe the quality of a chromatic light source: radiance; luminance; and brightness.

Radiance

is the total amount of energy that flows from the light source, and it is usually measured in watts.

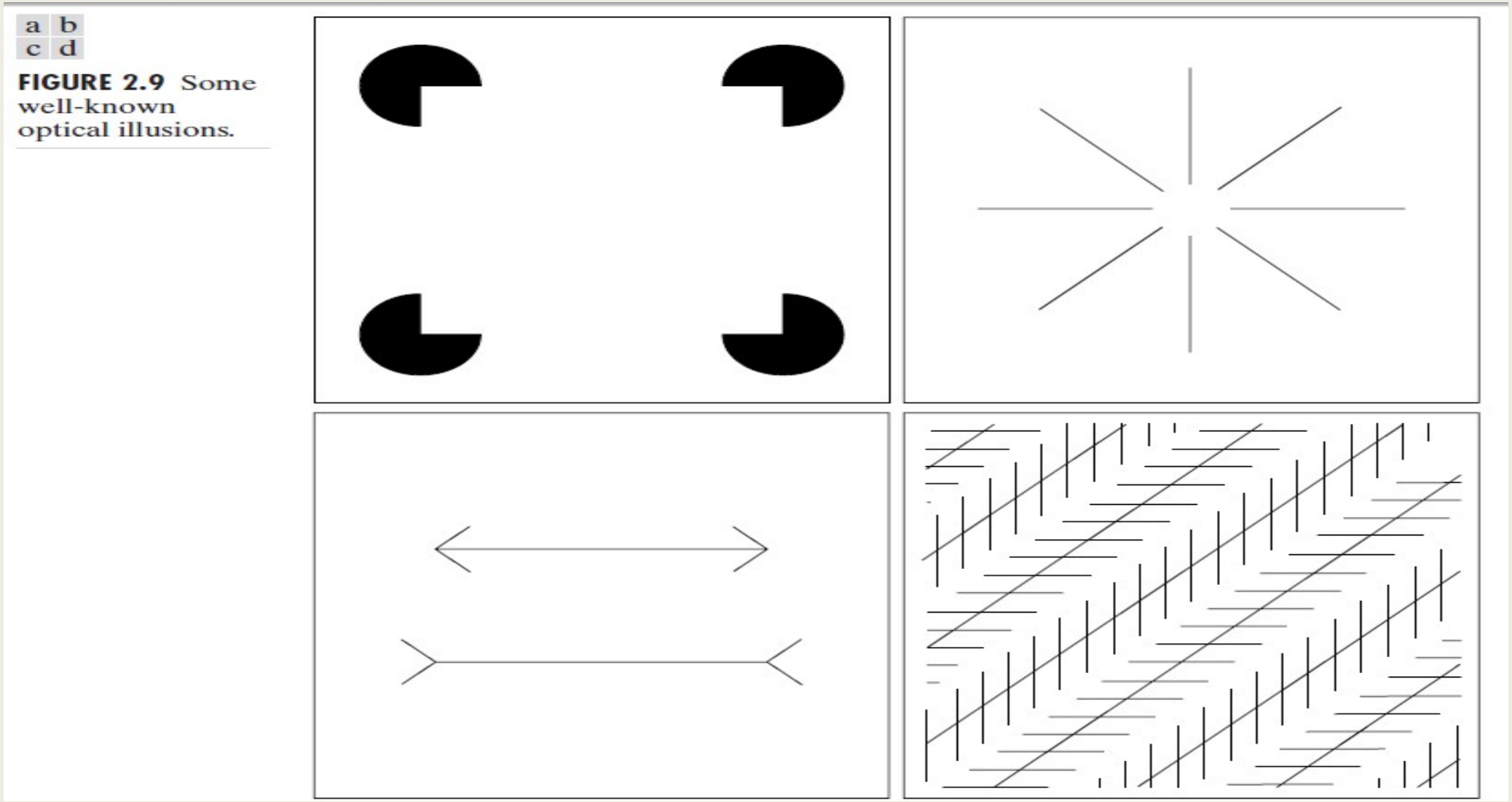
Luminance,

measured in lumens (lm), gives a measure of the amount of energy an observer *perceives* from a light source.

Brightness

Brightness is a subjective perception of light intensity by the human visual system. It is the attribute of visual perception that determines the subjective impression of how intense a light source or a surface appears. Brightness can be influenced by various factors, including the luminance of the light source or surface, the surrounding environment, and individual differences in visual perception. Brightness is often described using qualitative terms such as "bright," "dim," or "dull.«فـيالحاسوبفـاخذ تـدرج الـلونلـكلنـقطه

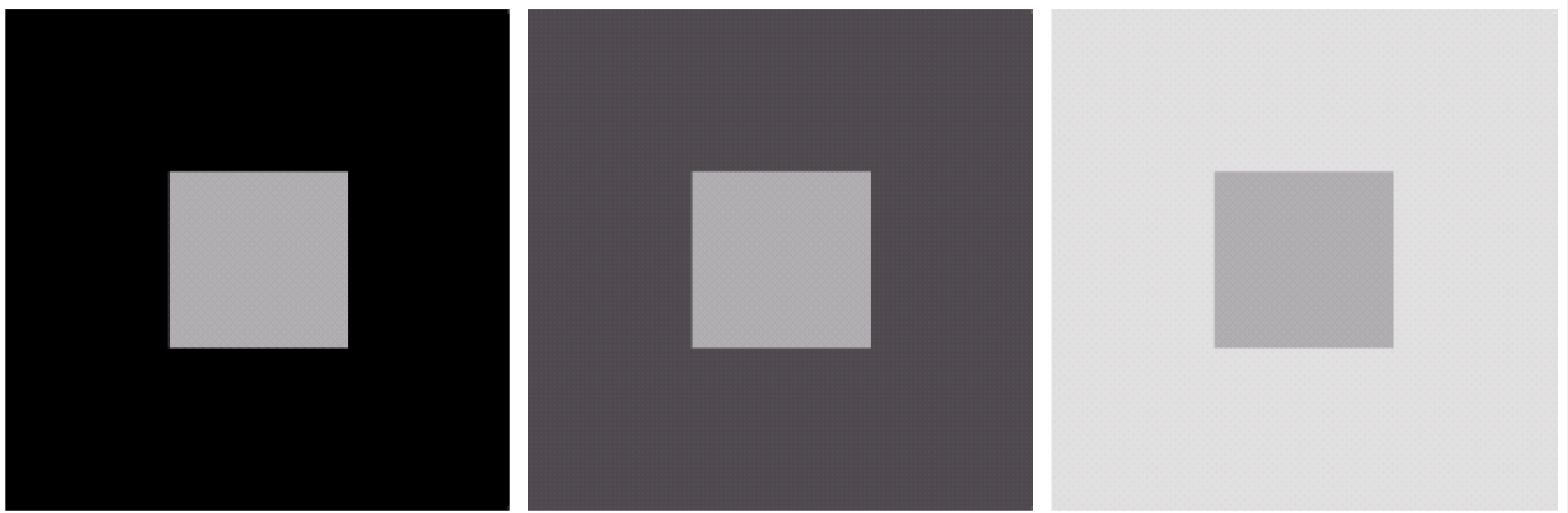
Some well known optical illusions
بـــعض الـخداع الـبصري الـمعروف



a b
c d

FIGURE 2.9 Some well-known optical illusions.

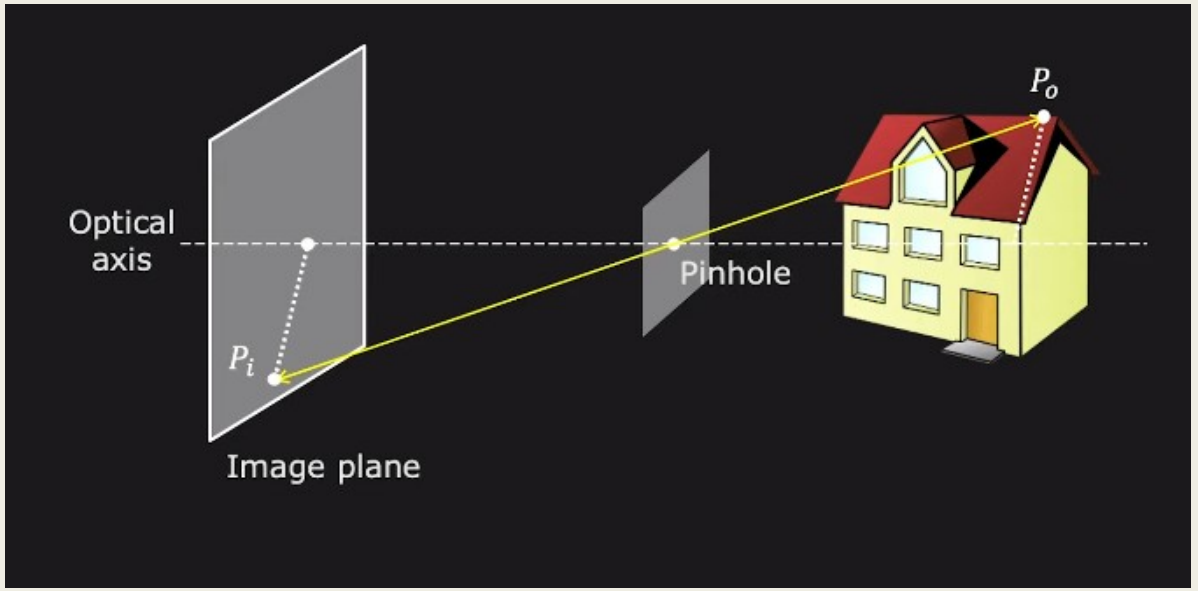
Some well known optical illusions *simultaneous contrast*

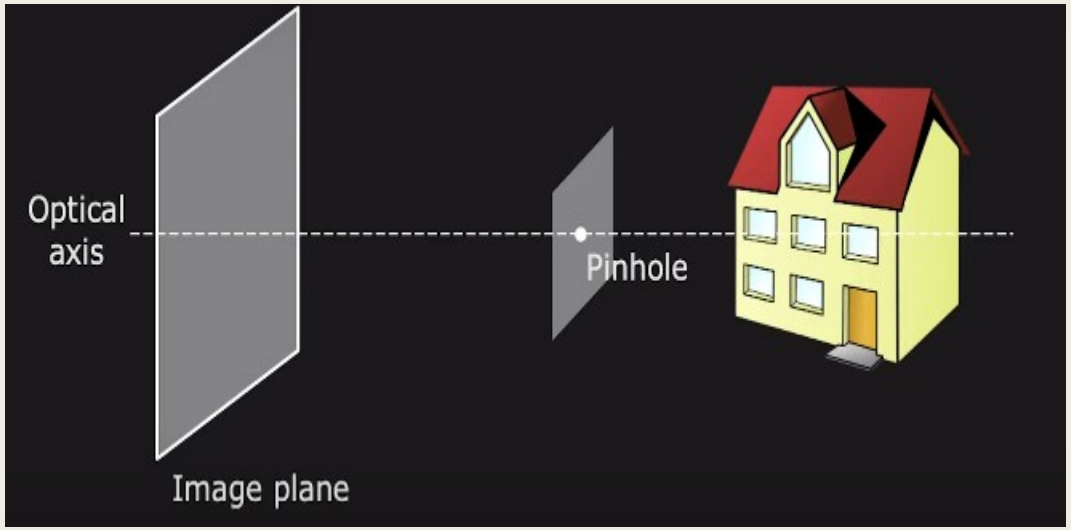


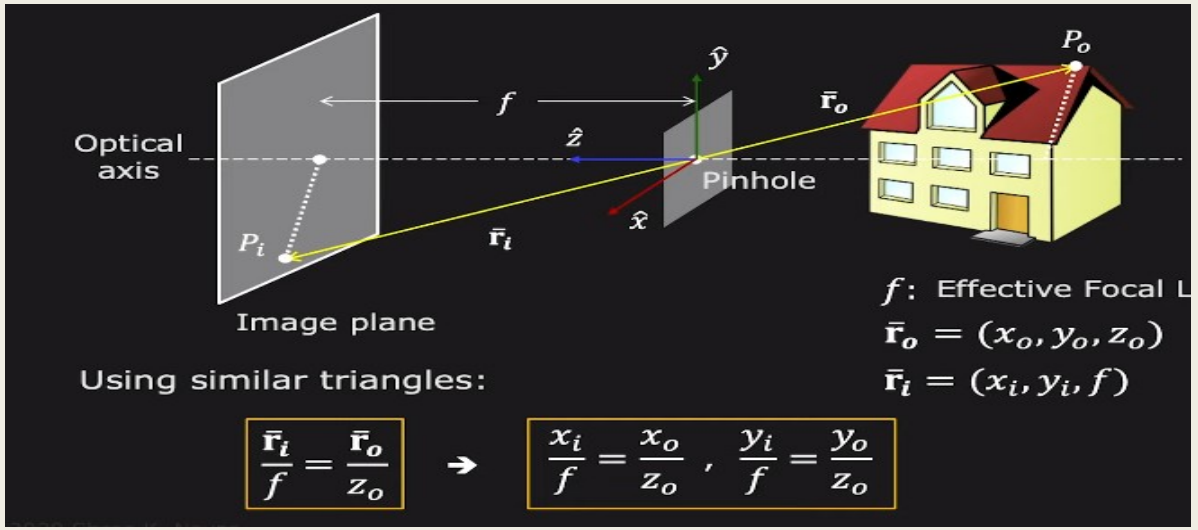
Next

- Image Sensing and Acquisition
  استشعار الصورة والحصول عليها

Pinhole projection





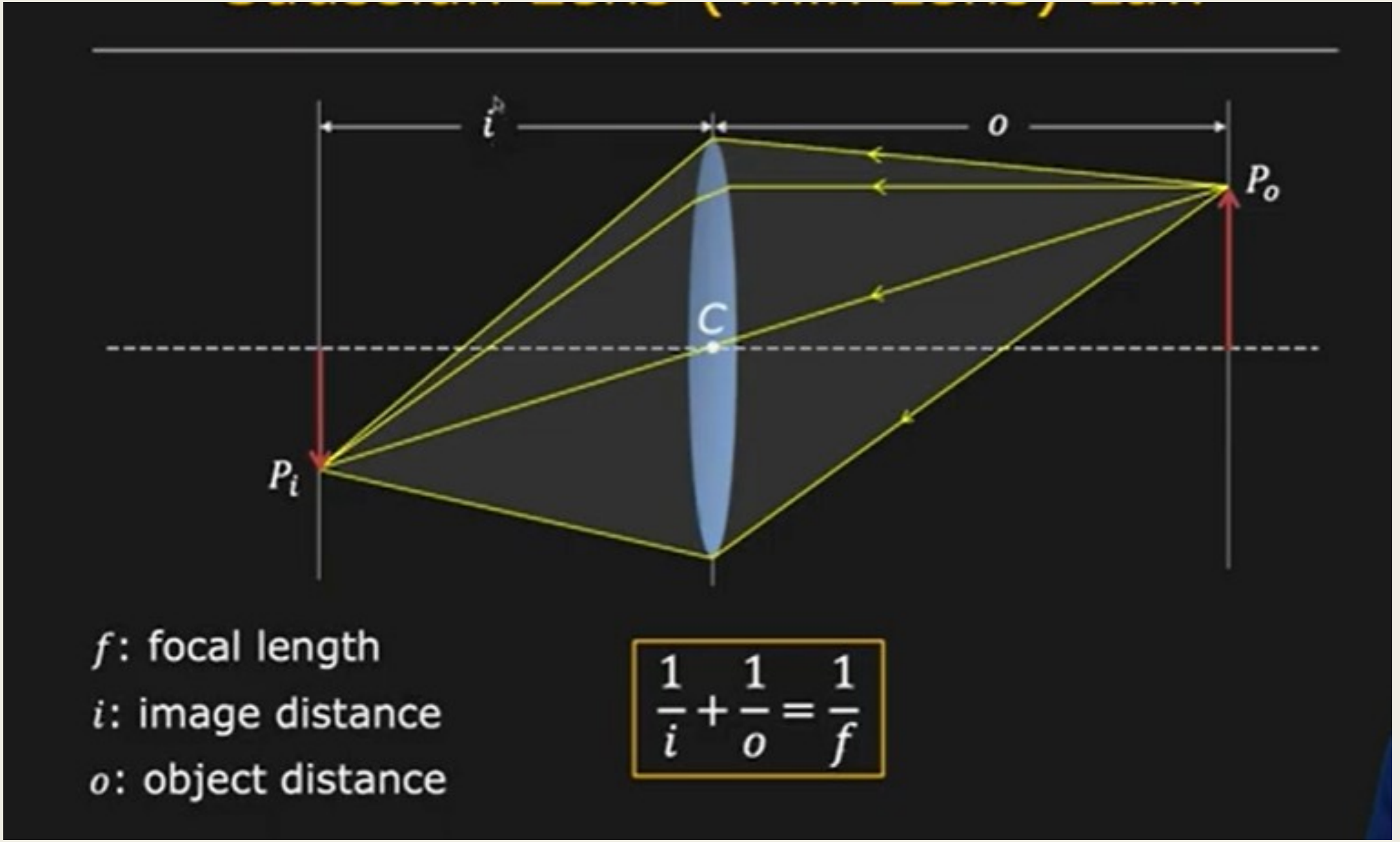


What is the Ideal Pinhole Size?

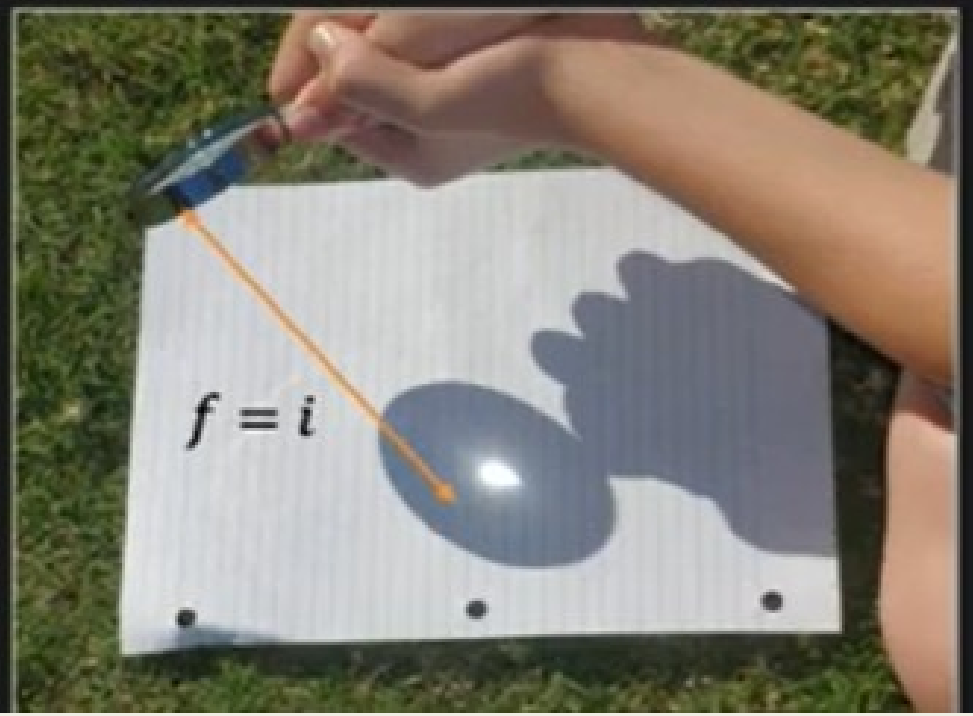
2 mm | 1 mm | 0.6 mm | 0.35 mm | 0.15 mm | 0.07 mm

Lenses

Same projection as pinhole, but gather more light!


i
o
P_o
C
P_i
f: focal length
i: image distance
o: object distance
$\frac{1}{i} + \frac{1}{o} = \frac{1}{f}$

$$\frac{1}{i}+\frac{1}{o}=\frac{1}{f} \quad \Rightarrow \quad \text{If } o=\infty, \text{ then } f=i$$



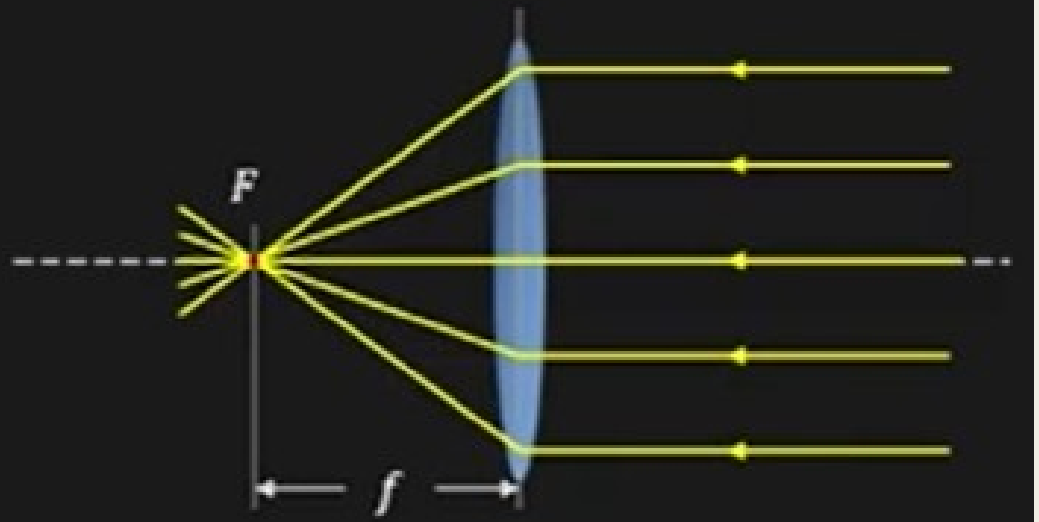


Image Sensing and Acquisition

Image Sensing and 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

Image Sensing and

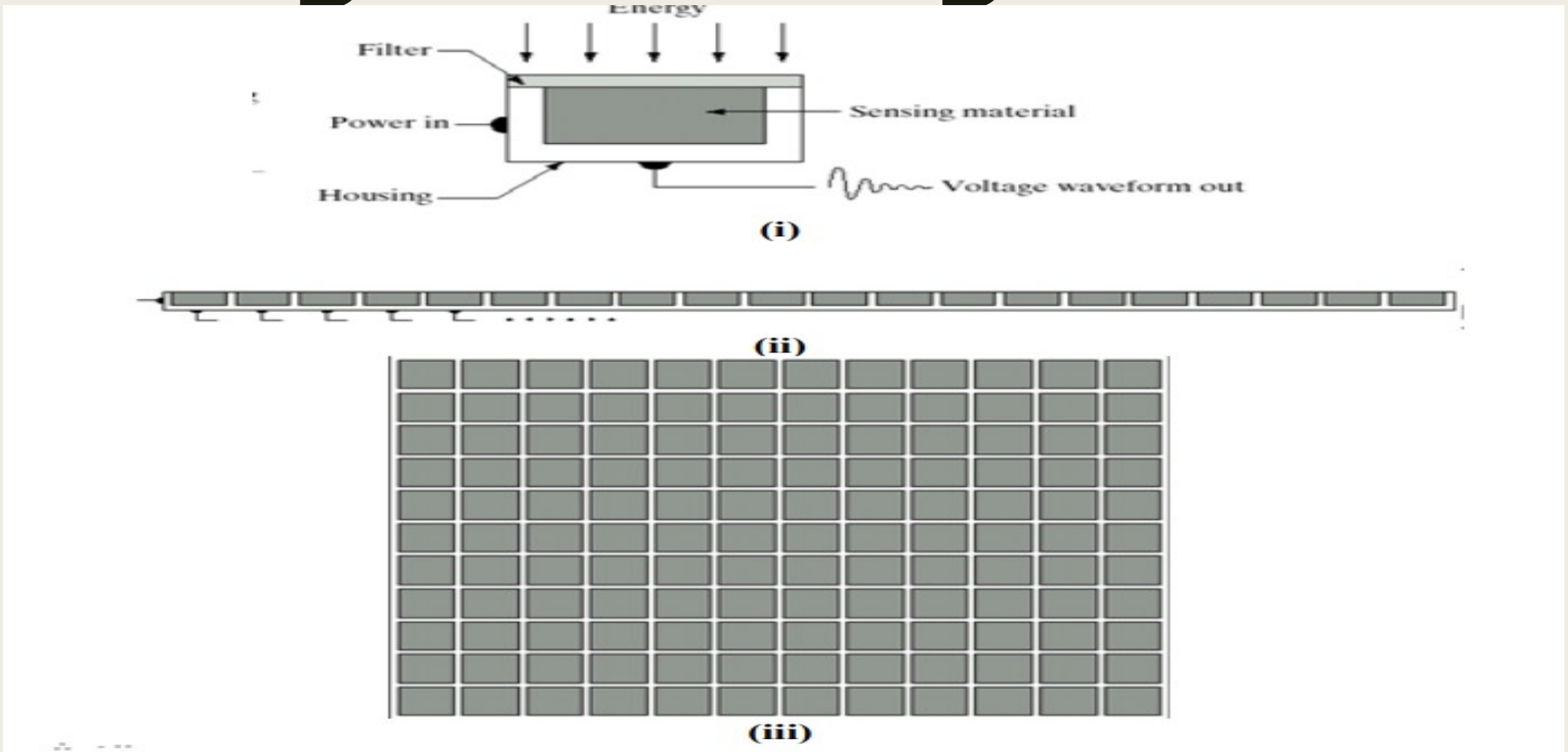


Fig: (i)Single image (ii)Sensor line sensor (iii)Array sensor

Image Sensing and Acquisition

Image Acquisition Using.1

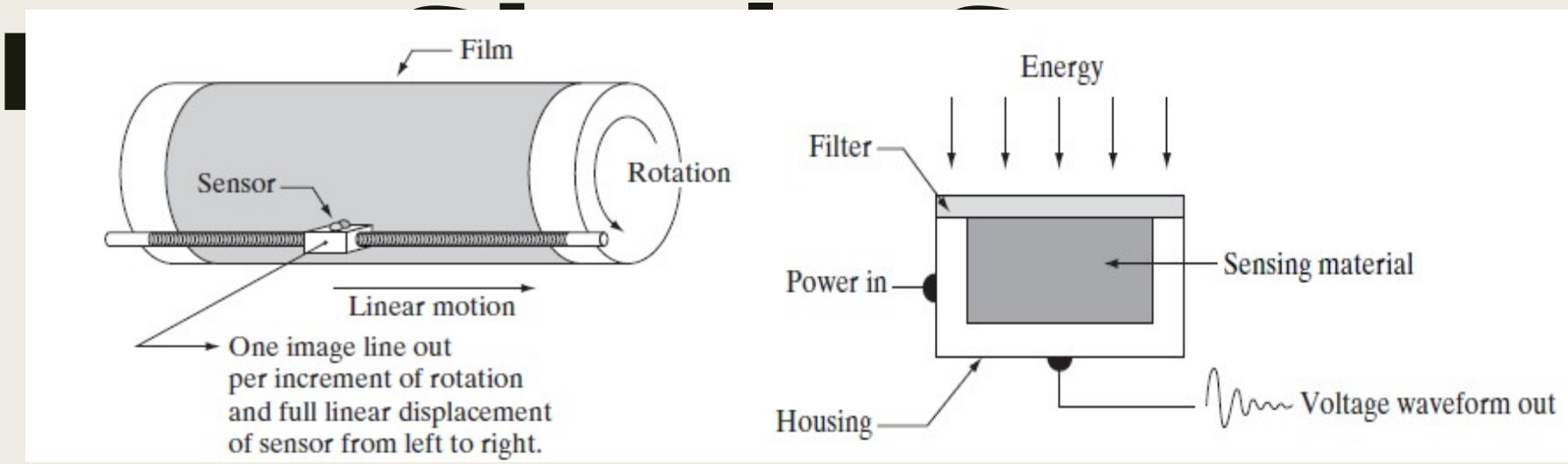
.a Single Sensor

Image Acquisition Using.2

Sensor Strips

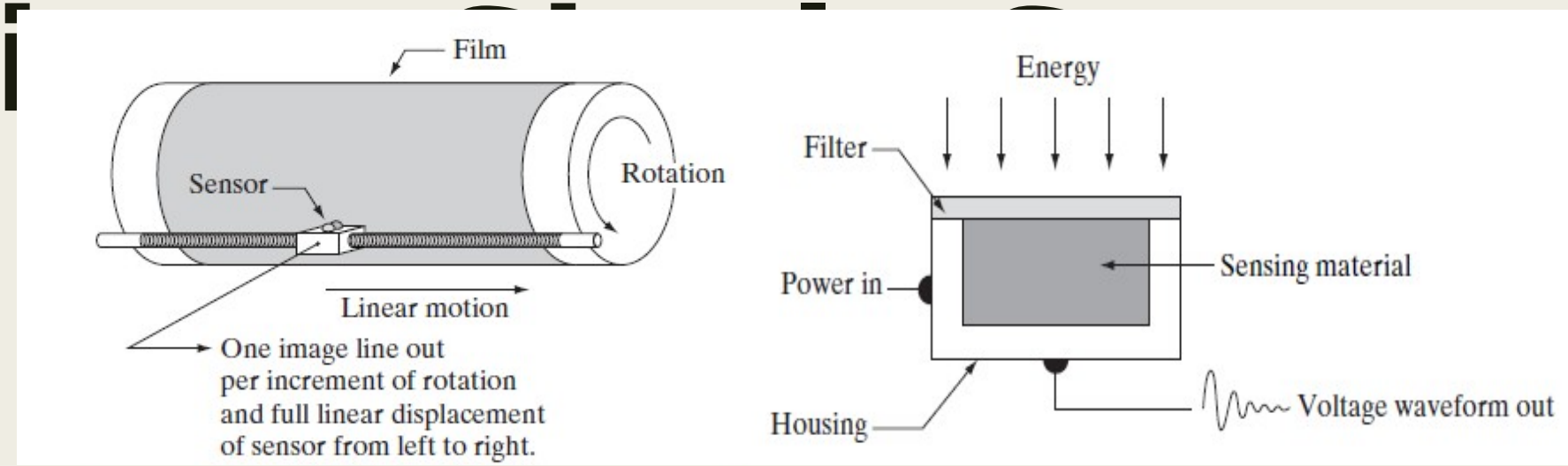
3. Image Acquisition Using

Image Acquisition.1 Usi



In order to generate a 2-D image using a single sensor, there have to be relative displacements in both the x- and y-directions between the sensor and the area to be imaged. An arrangement used in high precision scanning, where a film negative is mounted onto a drum whose mechanical rotation provides displacement in one dimension. The single sensor is mounted on a lead screw that provides motion in the perpendicular

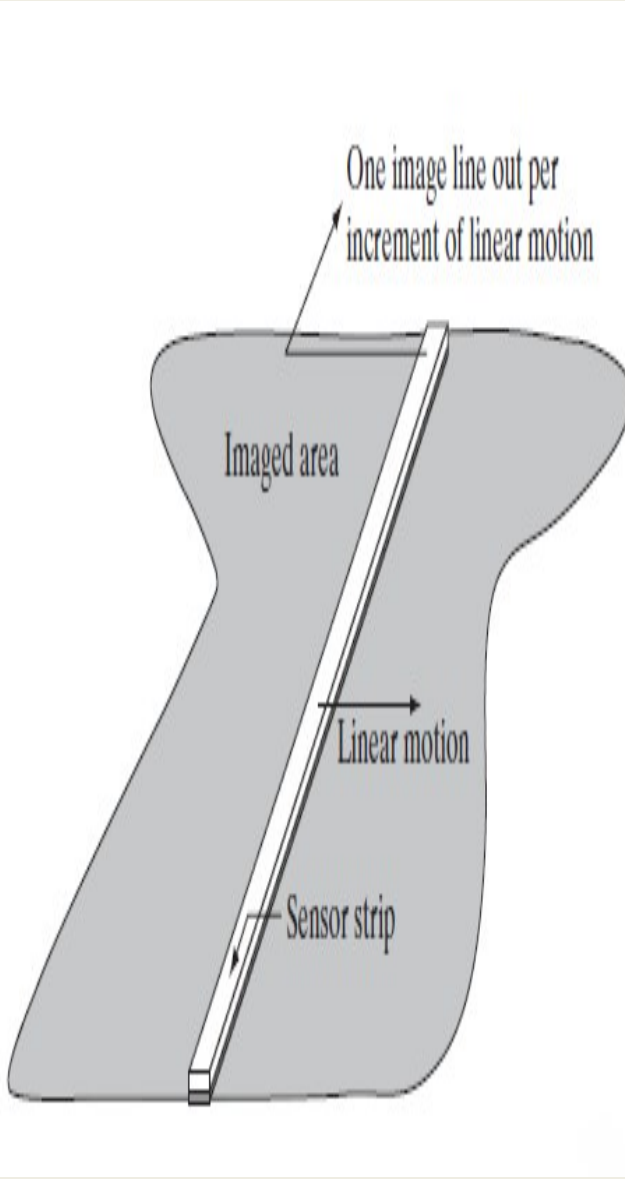
Image Acquisition.1 Usi



من أجل إنشاء صورة ثنائية الأبعاد باستخدام مستشعر واحد، بين yو x يجب أن تكون هناك إزاحات نسبية في كلا الاتجاهين المستشعر والمنطقة المراد تصويرها. وهو ترتيب يستخدم في المسح الضوئي عالي الدقة، حيث يكون الفيلم سلبيًا يتم تركيبه على أسطوانة يوفر دورانها الميكانيكي إزاحة في بُعد واحد. يتم تثبيت المستشعر الفردي على برغي رئيسي يوفر الحركة في الاتجاه العمودي. وبما أنه يمكن التحكم في الحركة الميكانيكية

Image Acquisition Using.2 Sensor Strips

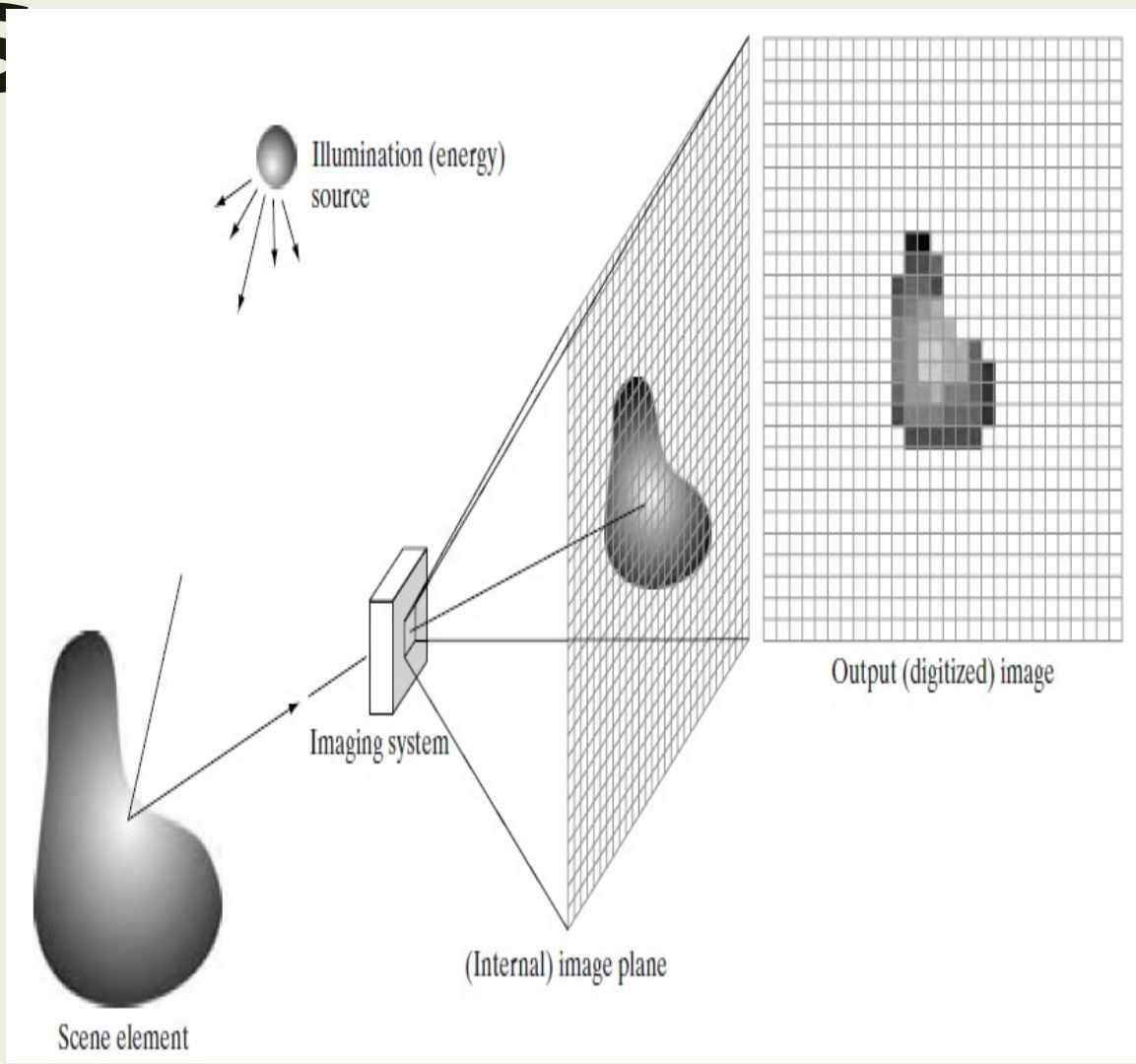
- عملية الحصول على الصور باستخدام شرائح الاستشعار تشير إلى عملية التقاط الصور باستخدام مجموعة خطية من أجهزة الاستشعار المرتبة في شريط أو خط واحد. يتم استخدام هذا النهج بشكل شائع في أنظمة التصوير المختلفة، بما في ذلك الماسحات الضوئية المسطحة وتطبيقات التصوير الجوي والتصوير الطبي والصناعي.
- في حالة الماسحات الضوئية المسطحة، يتم استخدام شريط استشعار واحد لمسح الوثيقة أو الصورة. يتكون الشريط الاستشعار من مجموعة خطية من أجهزة الاستشعار الحساسة للضوء. يتم وضع الوثيقة أو الصورة على سطح الماسح الضوئي، ويتحرك الشريط الاستشعار عبر الوثيقة، مع التقاط الصورة سطراً بسطر.



- وفي حالة التطبيقات الجوية، يتم استخدام أشرطة استشعار خطية للاستجابة لمختلف نطاقات الطيف الكهرومغناطيسي،

Image Acquisition Using Sensor Arrays

يتم التركيز على هذا النوع من الجهاز في الكاميرات الرقمية. المستشعر النموذجي لهذه الكاميرات هو مصفوفة CCD، والتي يمكن تصنيعها بنطاق واسع من خصائص الاستشعار ويمكن تعبئتها في مصفوفات متينة مكونة من 4000 * 4000 عنصر أو أكثر. تُستخدم مستشعرات CCD على نطاق واسع في الكاميرات الرقمية وأدوات استشعار الضوء الأخرى. تتناسب استجابة كل مستشعر مع تكامل الطاقة الضوئية المسقطة على سطح المستشعر، وهي خاصية تستخدم في التطبيقات



A Simple Image Formation Model

- An image is a two-dimensional function of the form f(x, y). f(x, y) must be nonzero and finite

$$0 < f(x,y) < \text{infinit}$$

- f(x, y) may be characterized by two components: (1) the amount of source illumination incident on the scene being viewed, and (2) the amount of illumination reflected by the objects in the scene. Appropriately, these are called the *illumination* and *reflectance.*

$$f(x, y)=i(x, y)r(x, y)$$

A Simple Image Formation Model

$$0 < i(x,y) < \text{infinite}$$

$$0 < r(x,y) < 1$$

- *gray level* (l) : $f(x_0,y_0)=l$

$$L_{min} < l < L_{max}$$

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

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

- Gray scale : [Lmin,Lmax] and shifted to [0,L-1]

Image Sampling and Quantization

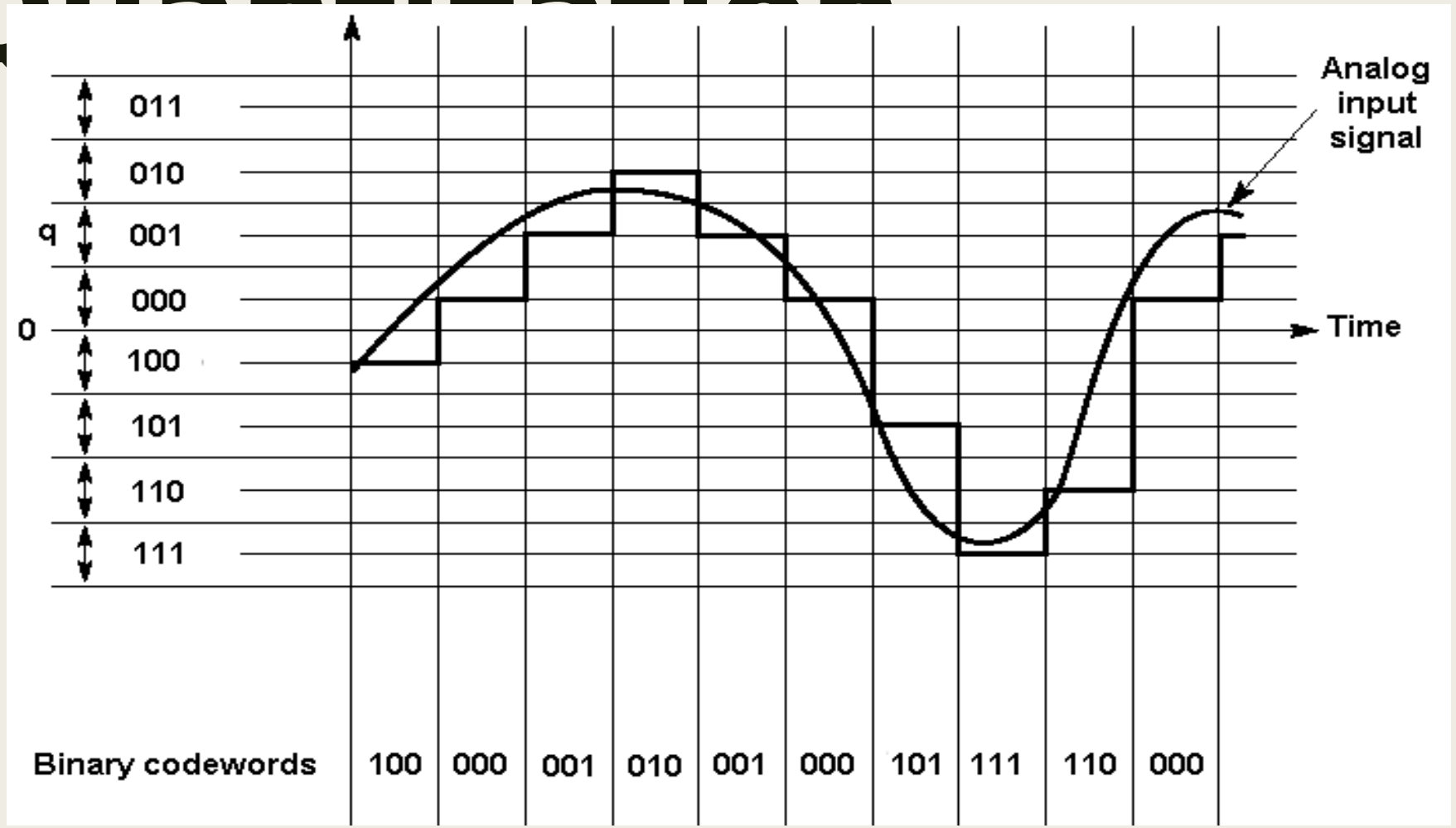


Image Sampling and

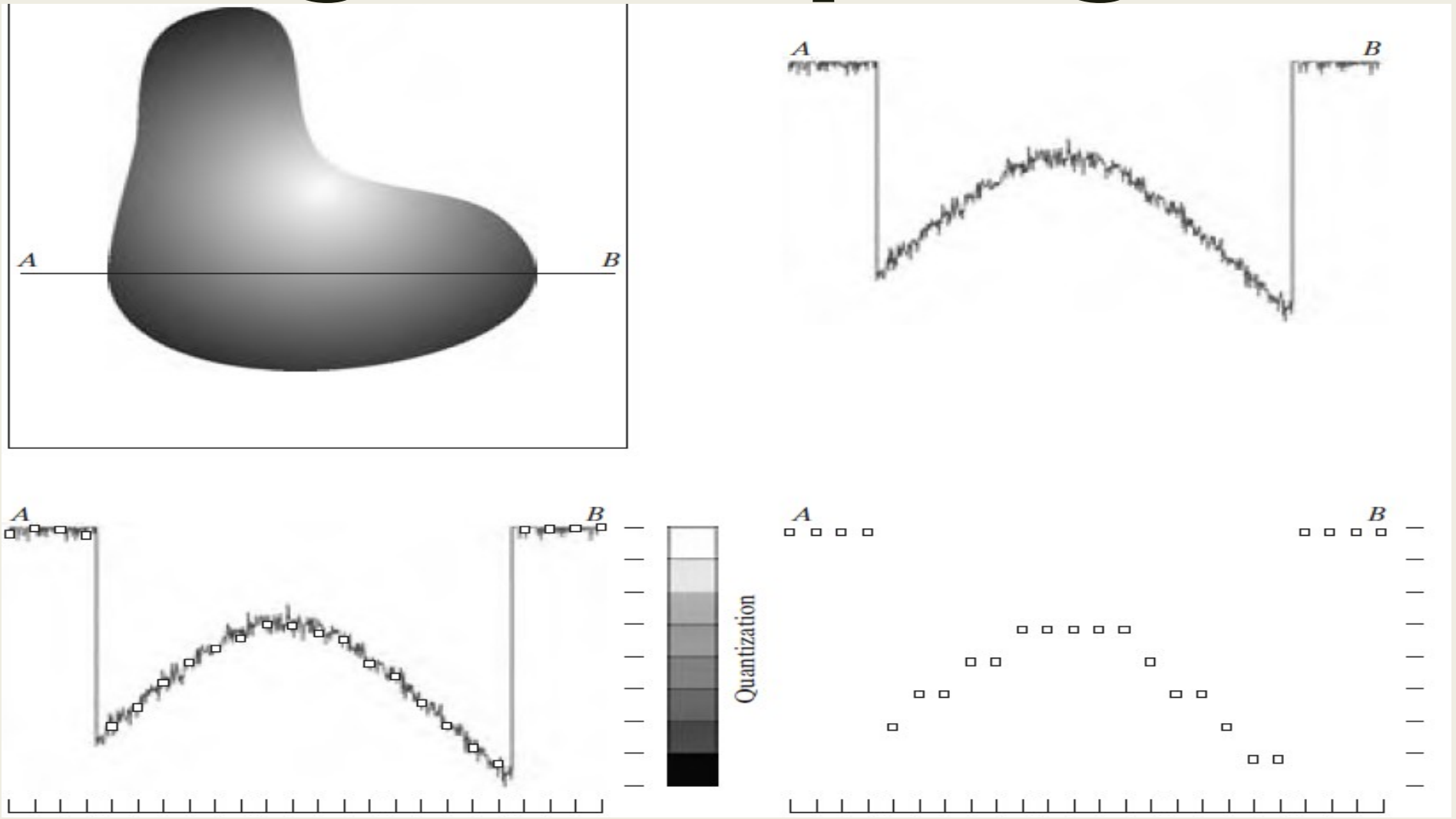
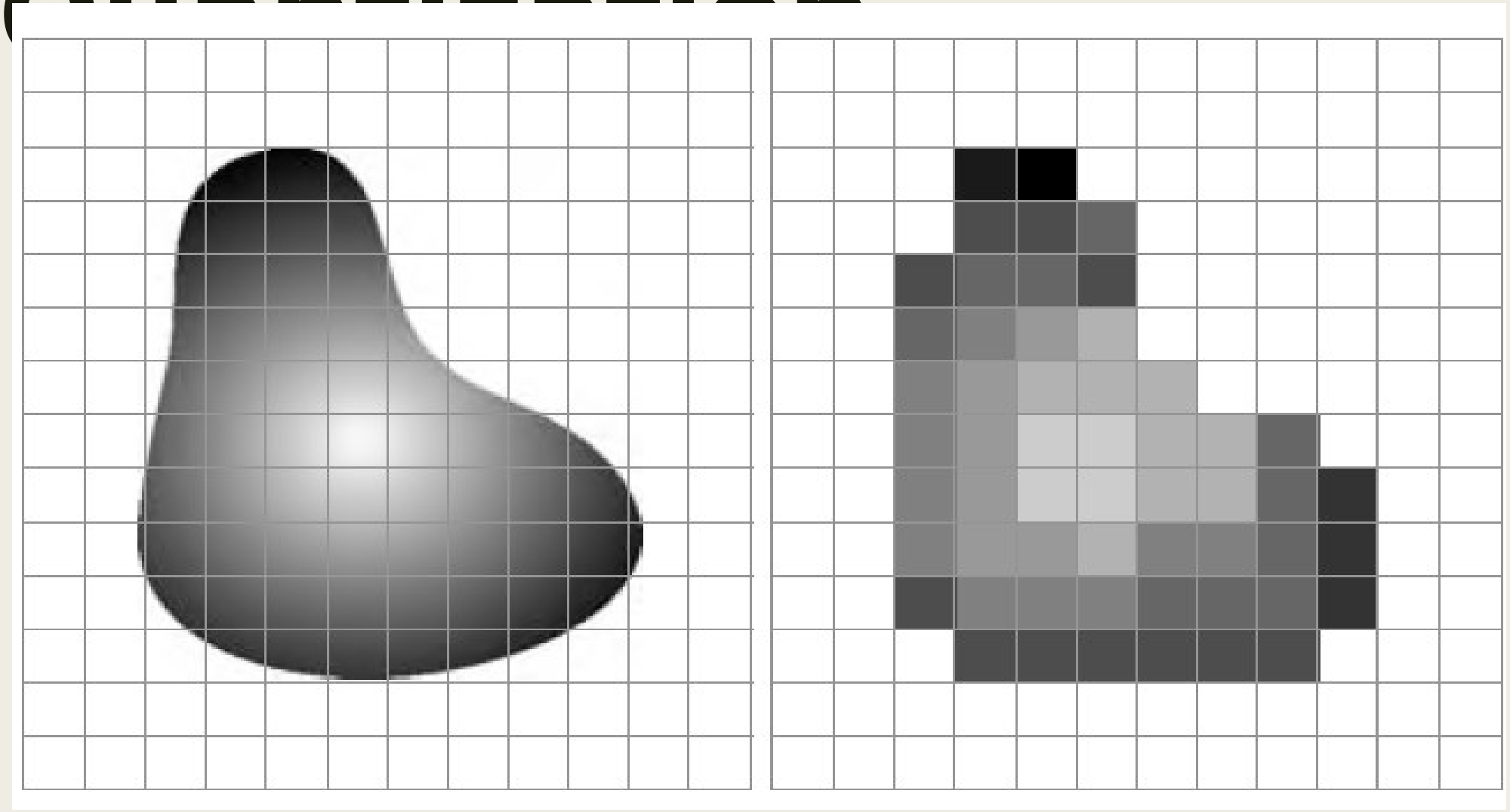
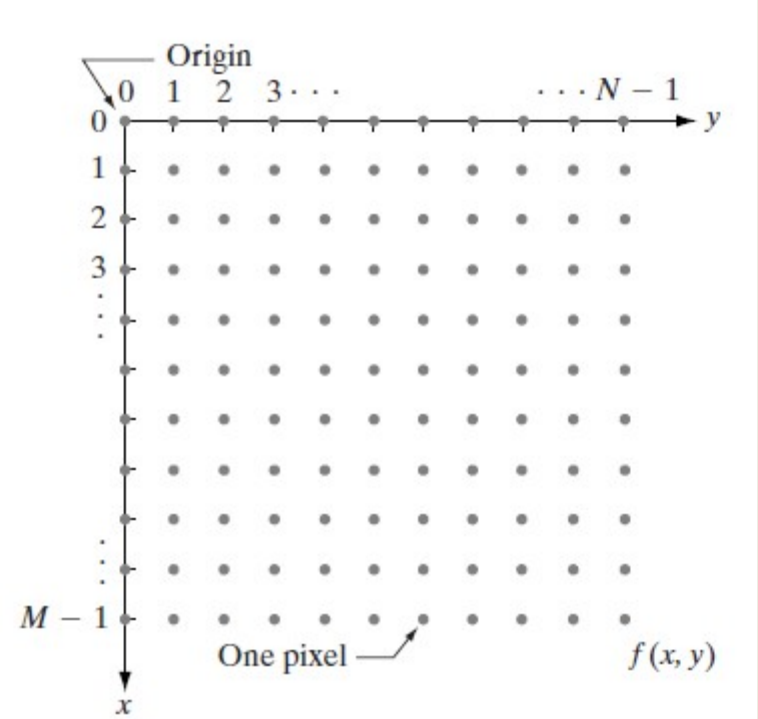


Image Sampling and Quantization

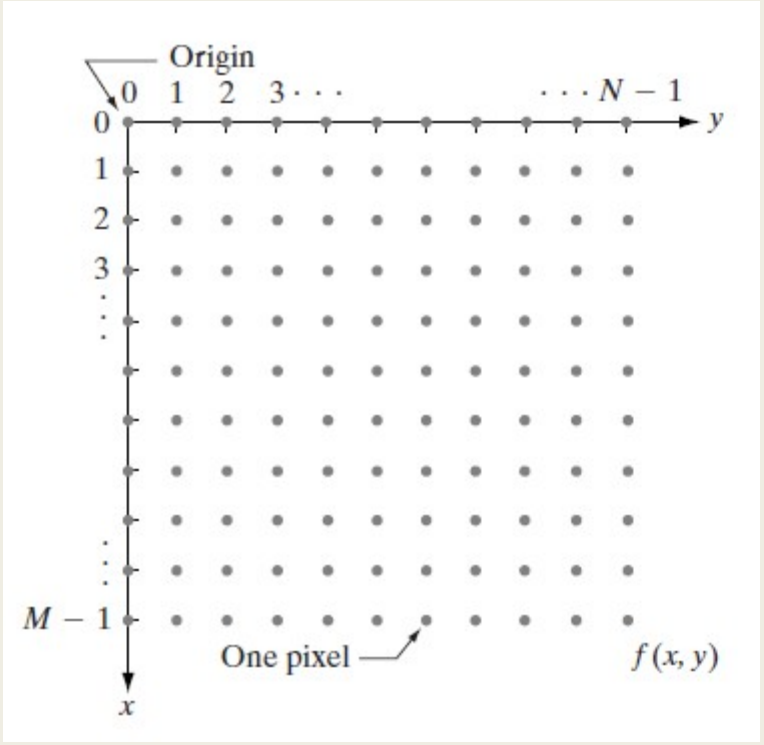


Representing Digital Images



An image f(x, y) is sampled so that the resulting digital image has M rows and N columns.
The values of the coordinates (x, y) now become *discrete* quantities.
Thus, the values of the coordinates at the origin are (x, y)=(0, 0).
The next coordinate values

Representing Digital Images



This digitization process requires decisions about values for M, N, and for the number, L, of discrete gray levels allowed for each pixel (*M ,N and L are positive integers*).

Due to processing, storage, and sampling hardware considerations, the number of gray levels typically is an integer power of 2:

$L = 2^k$

Representing Digital Images

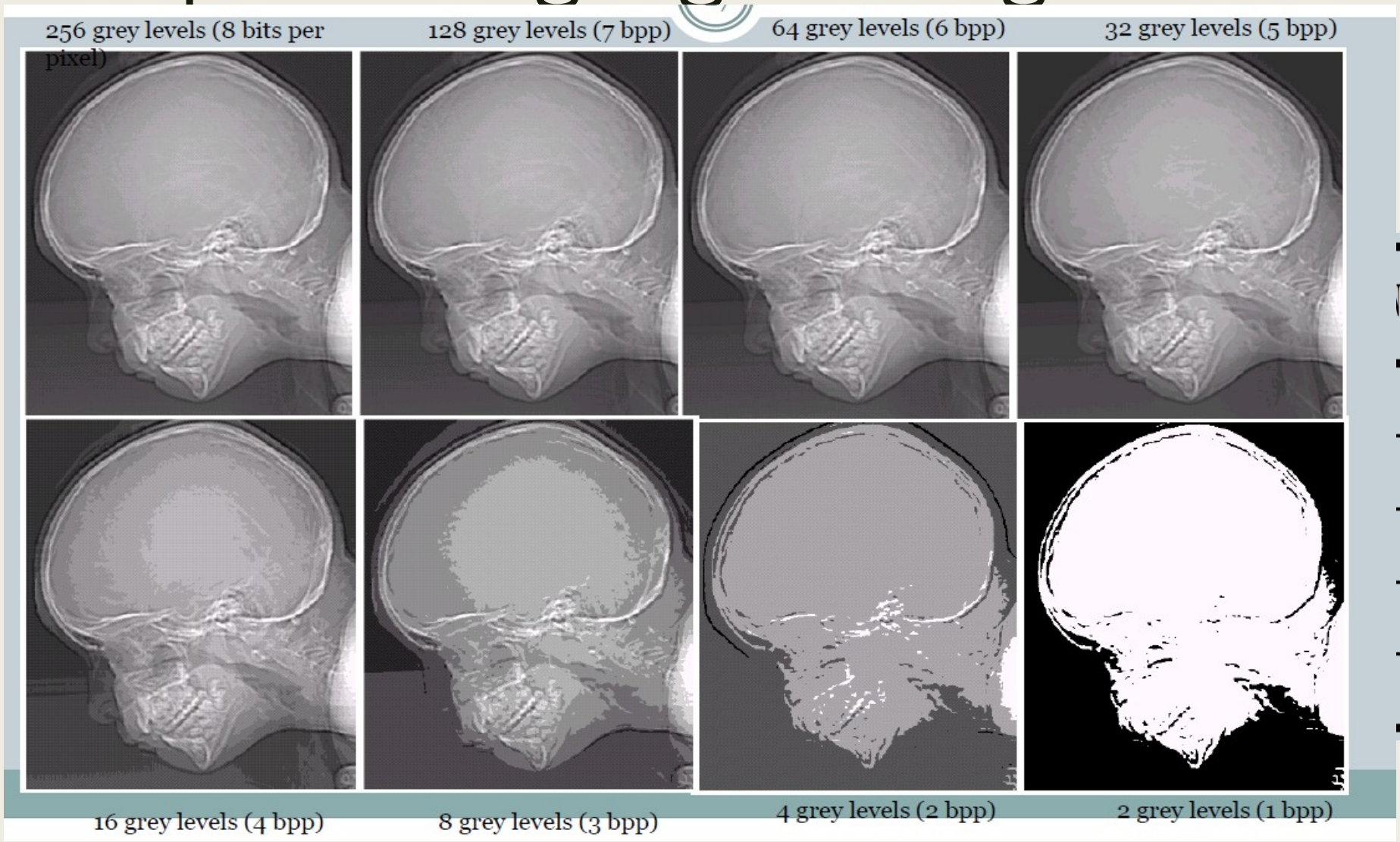
The number, b, of bits required to store an image is : $b = M \times N \times K$

When M=N : $b = N^2 K$

We have 4-bits, 8-bits , ..., images.

N/k	1 ($L = 2$)	2 ($L = 4$)	3 ($L = 8$)	4 ($L = 16$)	5 ($L = 32$)	6 ($L = 64$)	7 ($L = 128$)	8 ($L = 256$)
32	1,024	2,048	3,072	4,096	5,120	6,144	7,168	8,192
64	4,096	8,192	12,288	16,384	20,480	24,576	28,672	32,768
128	16,384	32,768	49,152	65,536	81,920	98,304	114,688	131,072
256	65,536	131,072	196,608	262,144	327,680	393,216	458,752	524,288
512	262,144	524,288	786,432	1,048,576	1,310,720	1,572,864	1,835,008	2,097,152
1024	1,048,576	2,097,152	3,145,728	4,194,304	5,242,880	6,291,456	7,340,032	8,388,608
2048	4,194,304	8,388,608	12,582,912	16,777,216	20,971,520	25,165,824	29,369,128	33,554,432
4096	16,777,216	33,554,432	50,331,648	67,108,864	83,886,080	100,663,296	117,440,512	134,217,728
8192	67,108,864	134,217,728	201,326,592	268,435,456	335,544,320	402,653,184	469,762,048	536,870,912

Representing Digital Images

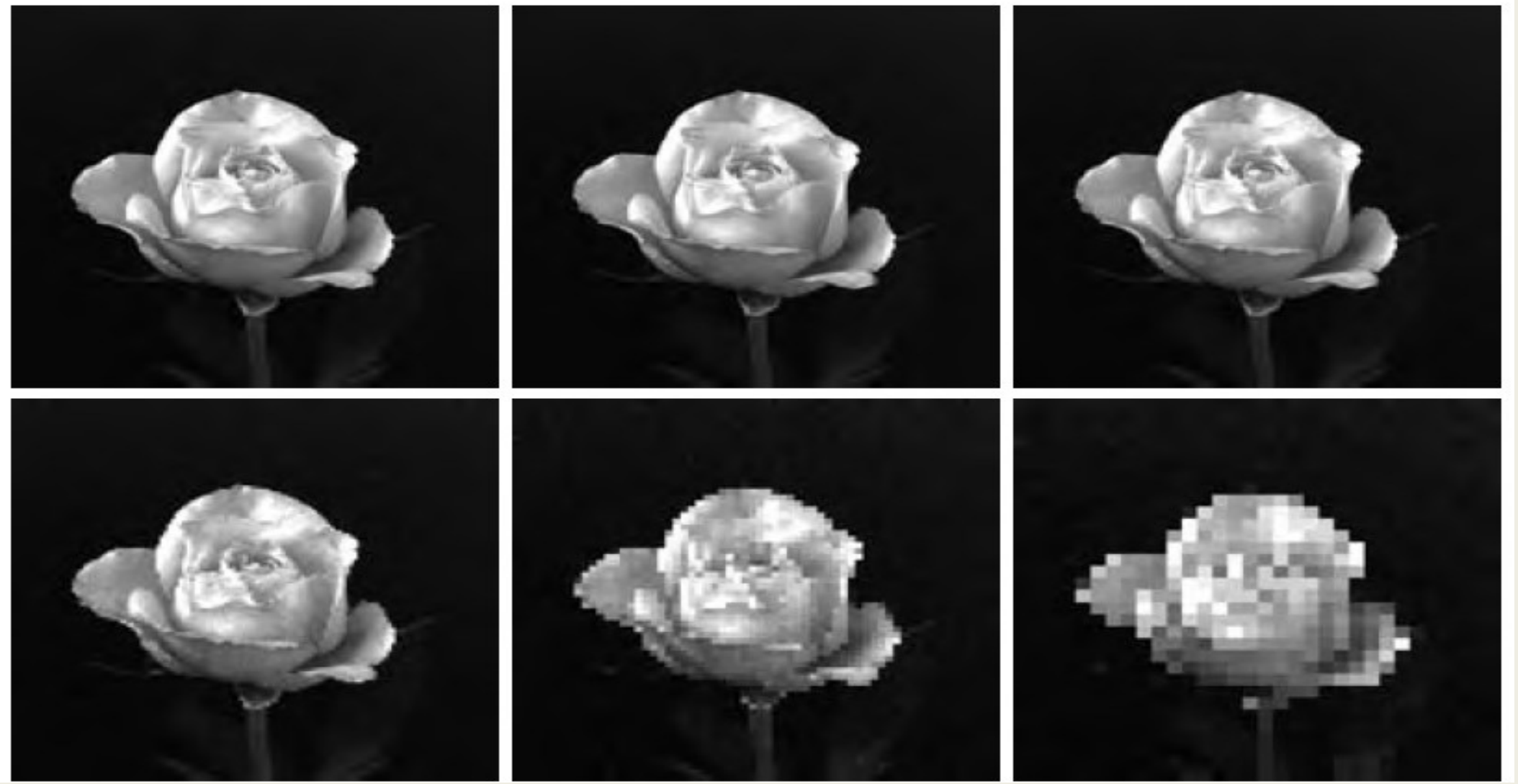


Number of Bits	Number of Intensity Levels	Examples
1	2	0, 1
2	4	00, 01, 10, 11
4	16	0000, 0101, 1111
8	256	00110011, 01010101
16	65,536	1010101010101010

Spatial and Gray-Level Resolution

- Sampling is the principal factor determining the *spatial resolution* of an image.
- Spatial resolution is the smallest discernible detail in an image.
- Or, it is simply the smallest number of discernible line pairs per unit distance; for example, 100 line pairs per millimeter.
- *Gray-level resolution* refers to the smallest discernible change in gray level.

Spatial and Gray-Level



Zooming and Shrinking Images

Zooming and Shrinking Images

- *Zooming requires two steps: the creation of new pixel locations, and the assignment of gray levels to those new locations.*
- *Simple method is Pixel replication. It is used when we want to increase the size of an image an integer number of times (Exp 2,3,..).*
- *Pixel interpolation such as nearest neighbor interpolation. It is used when we want to increase the size of an image real number of times (Exp 1.3,2.3,..).*
- *bilinear interpolation is another kind of Pixel interpolation and the best.*

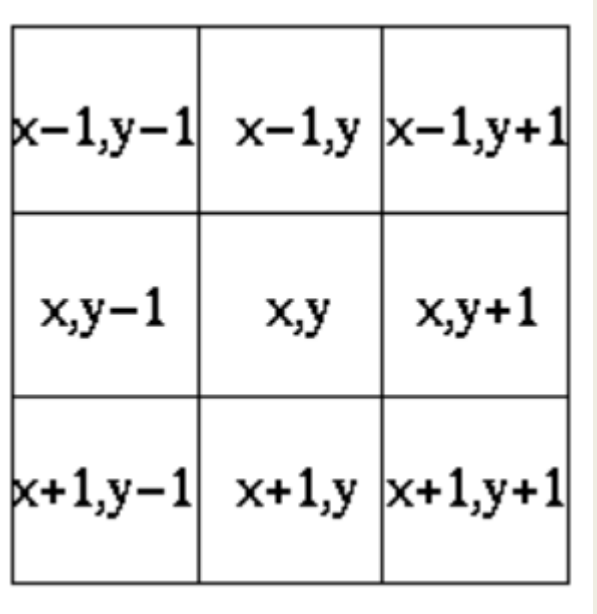
Some Relationships Between Pixels

Neighbors of a Pixel :

- (4-neighbors) of a pixel p at coordinates (x, y) have coordinates : (x+1, y), (x-1, y), (x, y+1), (x, y-1).
- (4-*diagonal* neighbors) : have coordinates

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

- 4-diagonal neighbors together with



Some Relationships Between Pixels

- **Neighboring Connectivity:**

  two pixels are connected if they are neighbors and if their gray levels satisfy a specified criterion of similarity.تــفيـــمعيار

- **(a)** 4-*adjacency*. Two pixels p and q with values from V are 4-adjacent if q is in the set $N_4(p)$.
- **(b)** 8-*adjacency*. Two pixels p and q with values from V are 8-adjacent if q is in the set $N_8(p)$.

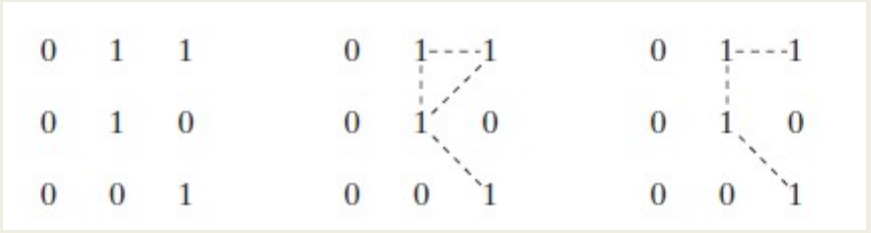
(c) *m-adjacency* (mixed adjacency). Two pixels p and q with values from V are m-adjacent if

(i) q is in $N_4(p)$, *or*

(ii) q is in $N_D(p)$ *and* the set $N_4(p) \cap N_4(q)$ has no pixels whose values are from V.

Some Relationships Between Pixels

- Adjacency:



- Path : A (*digital*) *path* (or *curve*) from pixel p with coordinates (x, y) to pixel q with coordinates (s, t) is a sequence of distinct pixels with coordinates:

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

According to one of the adjacency types.

Some Relationships Between Pixels

- **Connectivity in a region** :

  Let *S* represent a subset of pixels in an image. Two pixels p and q are said to be *connected* in *S* if there exists a path between them consisting entirely of pixels.

- **Connected Set**:

  For any pixel p in *S*, the *set* of pixels that are connected to it in *S* is called a *connected component*. If it only has one connected component, then set *S* is called a *connected set*

Some Relationships Between Pixels

- **Region**:

  Let R be a subset of pixels in an image. We call R a *region* of the image if R is a connected set.

- **Boundary** (also called *border* or *contour*):

  A boundary of a region R is the set of pixels in the region that have one or more neighbors that are not in R.

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

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

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

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

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

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

Image Operations on a Pixel Basis

- Division, addition, subtraction, ...
- arithmetic and logic operations are similarly defined between corresponding pixels in the images involved.

Image Operations on a Pixel Basis

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$

The *array product* of these two images is

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} = \begin{bmatrix} a_{11}b_{11} & a_{12}b_{12} \\ a_{21}b_{21} & a_{22}b_{22} \end{bmatrix}$$

On the other hand, the *matrix product* is given by

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} = \begin{bmatrix} a_{11}b_{11} + a_{12}b_{21} & a_{11}b_{12} + a_{12}b_{22} \\ a_{21}b_{11} + a_{22}b_{21} & a_{21}b_{12} + a_{22}b_{22} \end{bmatrix}$$

Image Operations on a Pixel Basis

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$

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On the other hand, the *matrix product* is given by

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} = \begin{bmatrix} a_{11}b_{11} + a_{12}b_{21} & a_{11}b_{12} + a_{12}b_{22} \\ a_{21}b_{11} + a_{22}b_{21} & a_{21}b_{12} + a_{22}b_{22} \end{bmatrix}$$

Image Operations on a Pixel Basis

Four arithmetic operation are denoted as:

🗣

Images in arithmetic operations must be of the same size.

$$s(x, y) = f(x, y) + g(x, y)$$

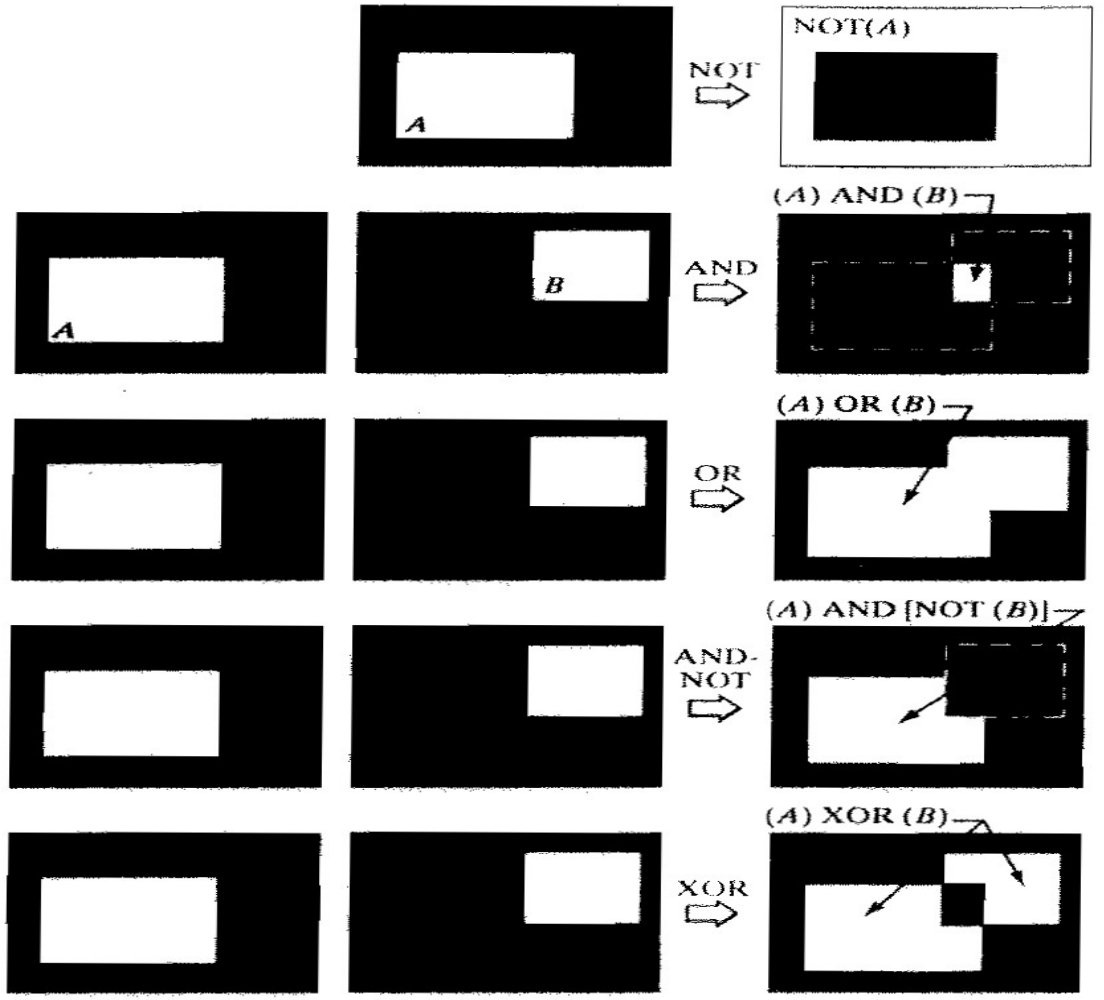
$$d(x, y) = f(x, y) - g(x, y)$$

$$p(x, y) = f(x, y) \times g(x, y)$$

$$v(x, y) = f(x, y) \div g(x, y)$$

Logical operations

FIGURE 2.33
Illustration of logical operations involving foreground (white) pixels. Black represents binary 0s and white binary 1s. The dashed lines are shown for reference only. They are not part of the result.



Averaging noisy images for noise reduction

Let $g(x, y)$ denote a corrupted image formed by the addition of noise, $\eta(x, y)$, to a noiseless image $f(x, y)$; that is,

$$g(x, y) = f(x, y) + \eta(x, y) \qquad (2.6\text{-}4)$$

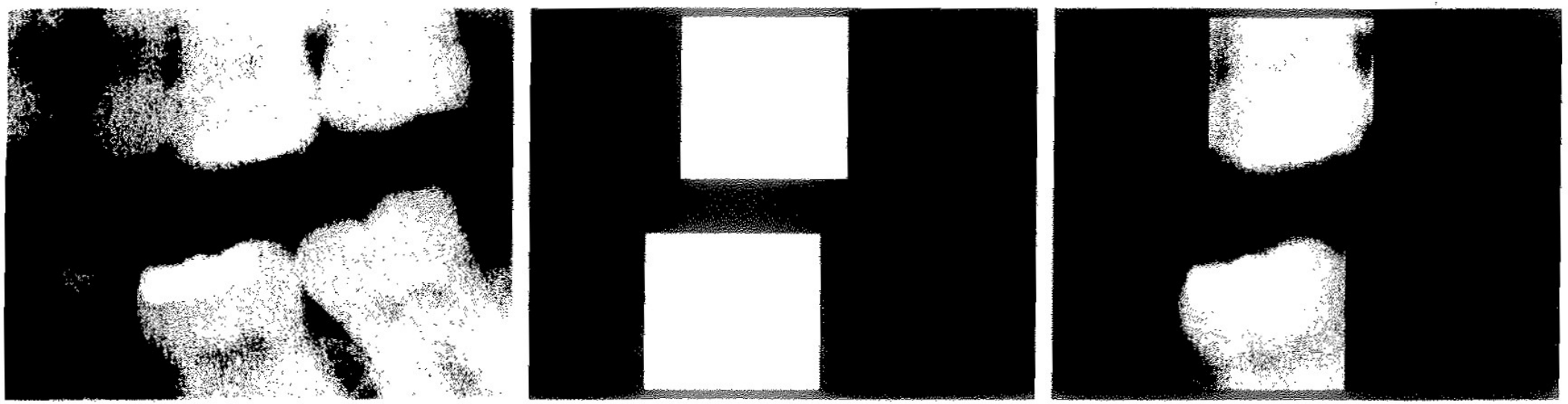
if an image $\bar{g}(x, y)$ is formed by averaging K different noisy images,

$$\bar{g}(x, y) = \frac{1}{K} \sum_{i=1}^{K} g_i(x, y) \qquad (2.6\text{-}5)$$

then it follows that

$$E\{\bar{g}(x, y)\} = f(x, y)$$

Averaging noisy images for noise reduction



a b c

FIGURE 2.30 (a) Digital dental X-ray image. (b) ROI mask for isolating teeth with fillings (white corresponds to 1 and black corresponds to 0). (c) Product of (a) and (b).

Note:

- In arthmetic operations such as difference between two 8-bit images can range from a min. Of -255 and a max. Of 255 ,and the values of sum two images can range from 0 to 510.
- So we need to set all negative values to 0 and set to 255 all values exceed this limit.

Spatial operations

- Spatial operations are performed directly on the pixels of a given image.
- ↯ Point : the output value at a specific coordinate is dependent only on the input value at that same coordinate.
- ↯ Local : the output value at a specific coordinate is dependent on the input values in the neighborhood of that same coordinate
- ↯ Global : the output value at a specific

Spatial operations

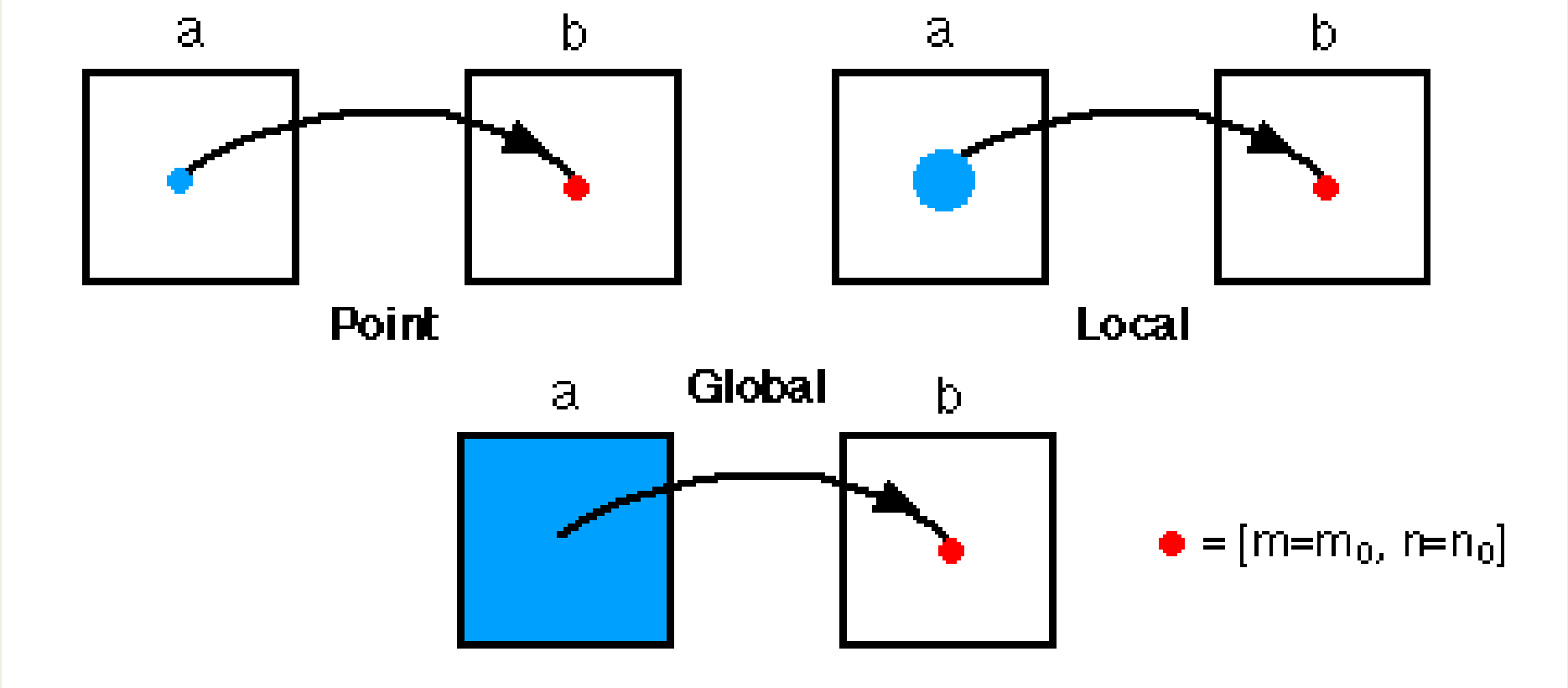


Image Enhancement

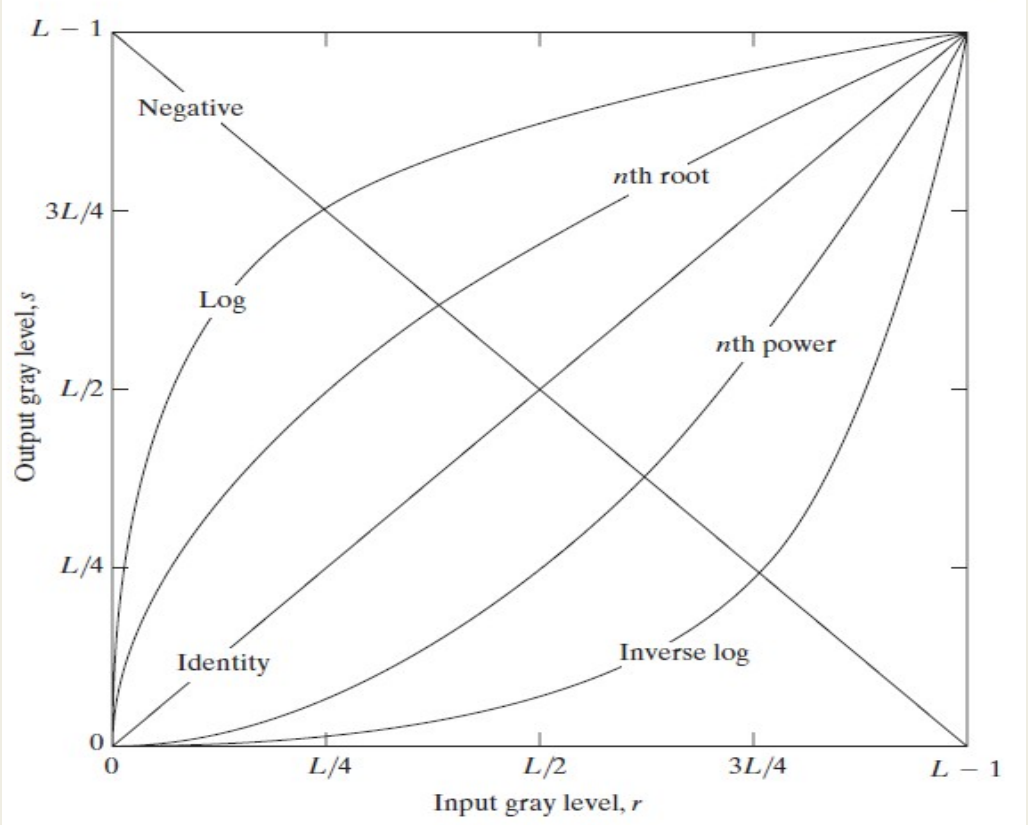
Image Enhancementin the Spatial Domain

- The term *spatial domain* refers to the aggregate of pixels composing an image.
- Spatial domain methods are procedures that operate d $g(x, y) = T[f(x, y)]$ ese pixels. denoted by

- where f(x, y) is the input image, g(x, y) is the processed image, and *T* is an operator on *f*, defined over some

Some Basic Gray Level Transformations

- **Image Negatives :** The negative of an image with gray levels in the range [0,L-1]is obtained by: $s = L - r - 1$



Some Basic Gray Level Transformations

- **Log transformations :** maps a narrow range of low gray-level values in the input image into a wider range of output levels.

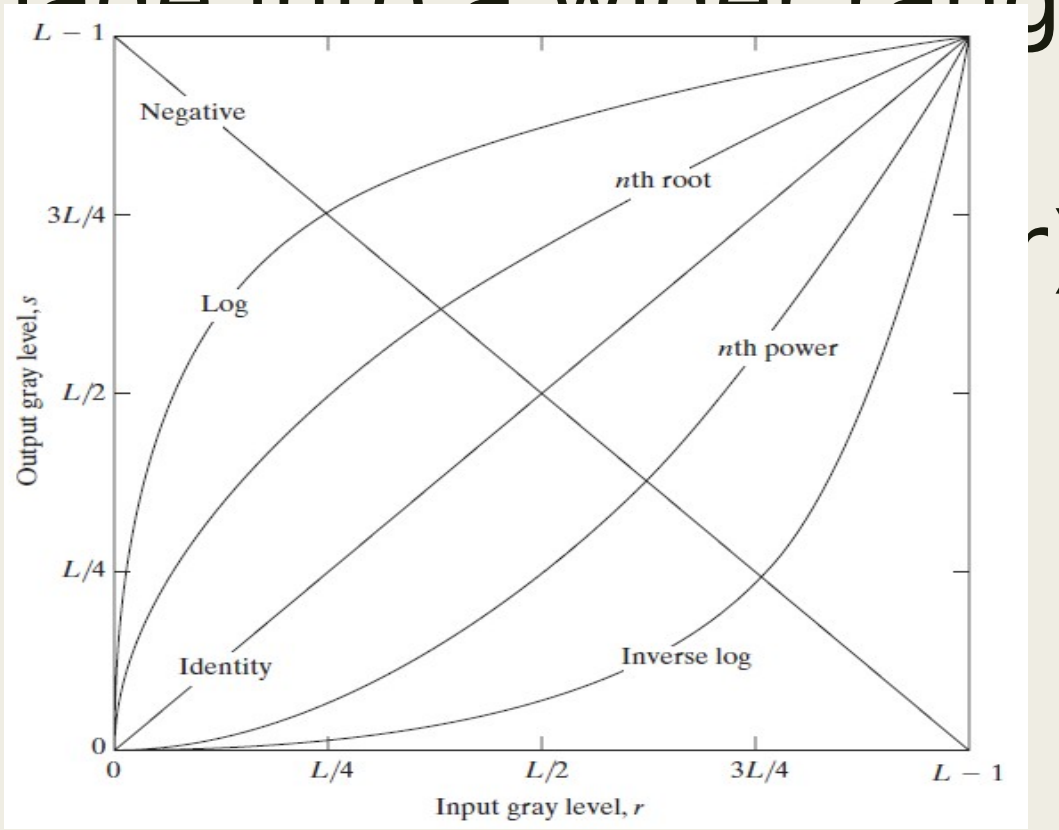


Image Enhancement