DIGITAL IMAGE PROCESSING

Digital Image Fundamentals : Session 1

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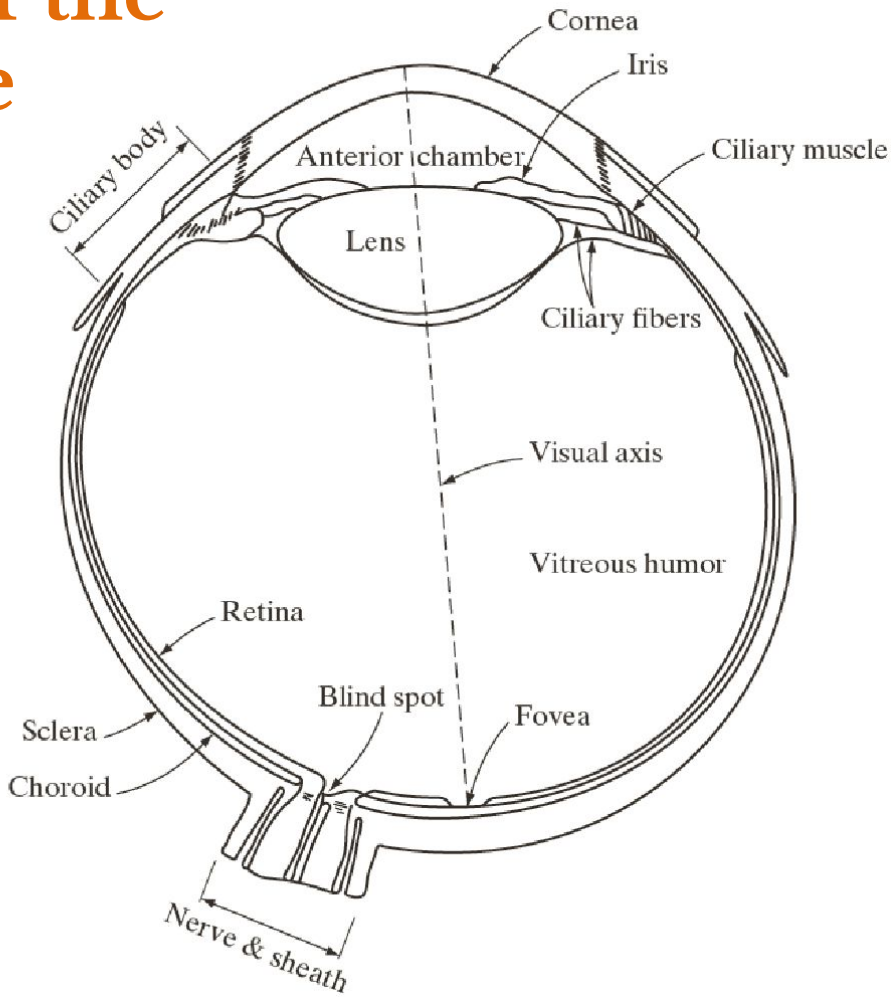
Today's Lecture

- **Elements of Visual Perception**
- **Image Sensing and Acquisition**
- **Image Sampling and Quantization**

Elements of Visual Perception

Structure of the Human Eye



Elements of Visual Perception

Image Formation in the Eye

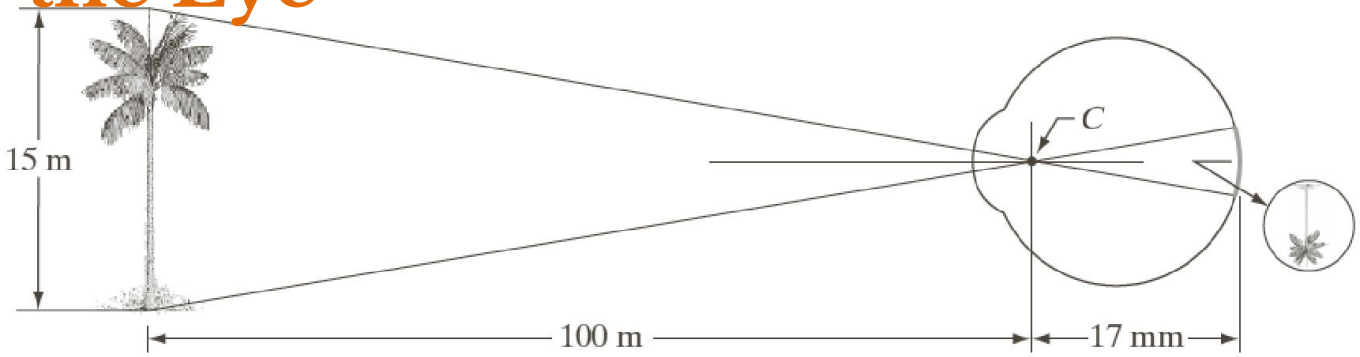


FIGURE 2.3 Graphical representation of the eye looking at a palm tree. Point C is the optical center of the lens.

a. If h is the height in mm of the that object in the retinal image then the figure yields $\frac{15}{100} = \frac{h}{17} \Rightarrow h = 2.55\ mm.$

b. The retinal image is reflected primarily in the area of the fovea.

Elements of Visual Perception

Brightness Adaption and Discrimination

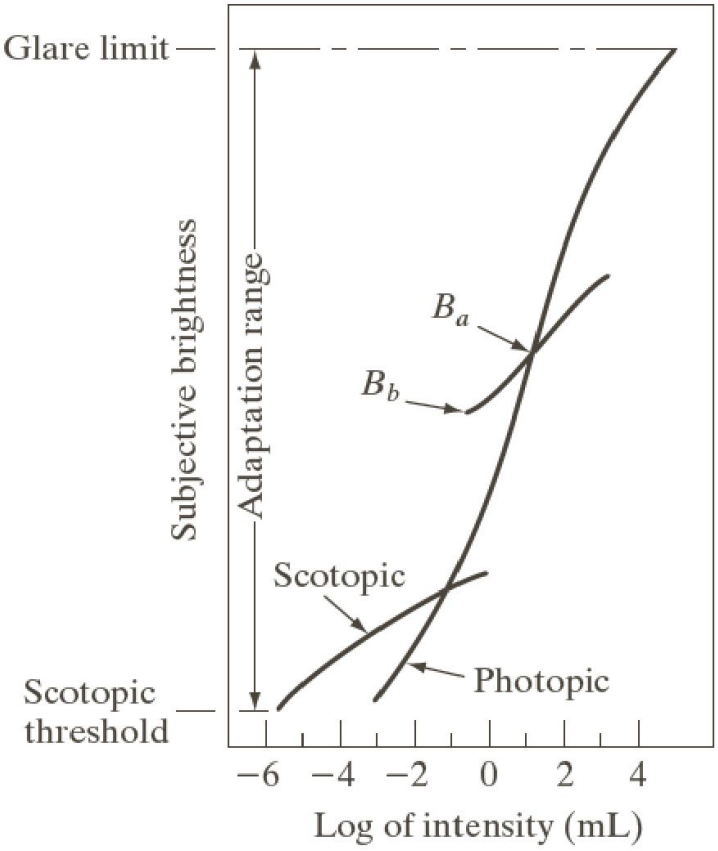


FIGURE 2.4 Range of subjective brightness sensations showing a particular adaptation level.

Elements of Visual Perception

Brightness Adaption and Discrimination

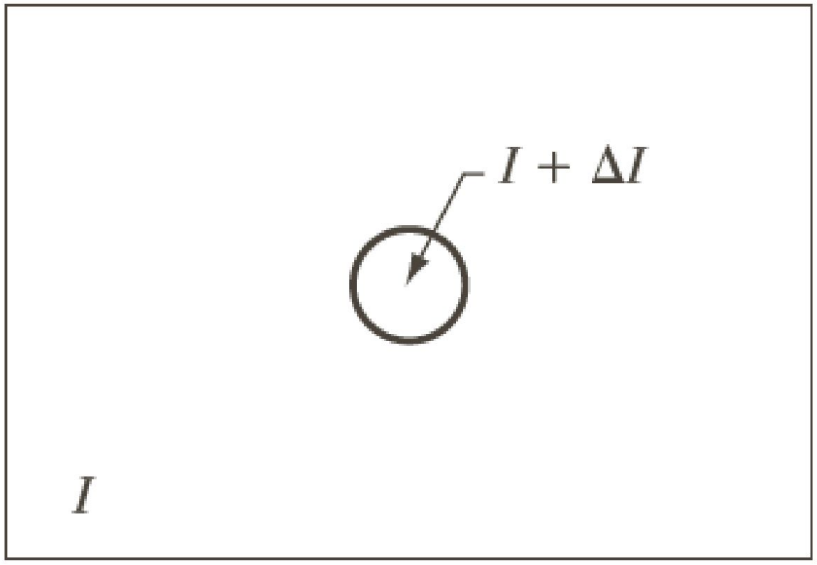


FIGURE 2.5 Basic experimental setup used to characterize brightness discrimination.

Elements of Visual Perception

Brightness Adaption and Discrimination

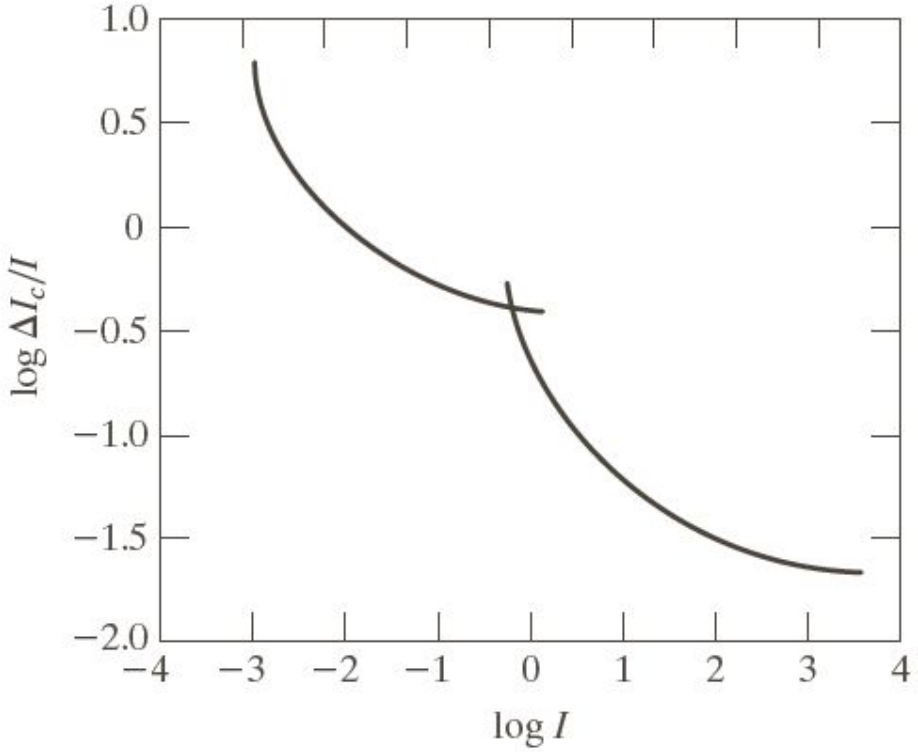
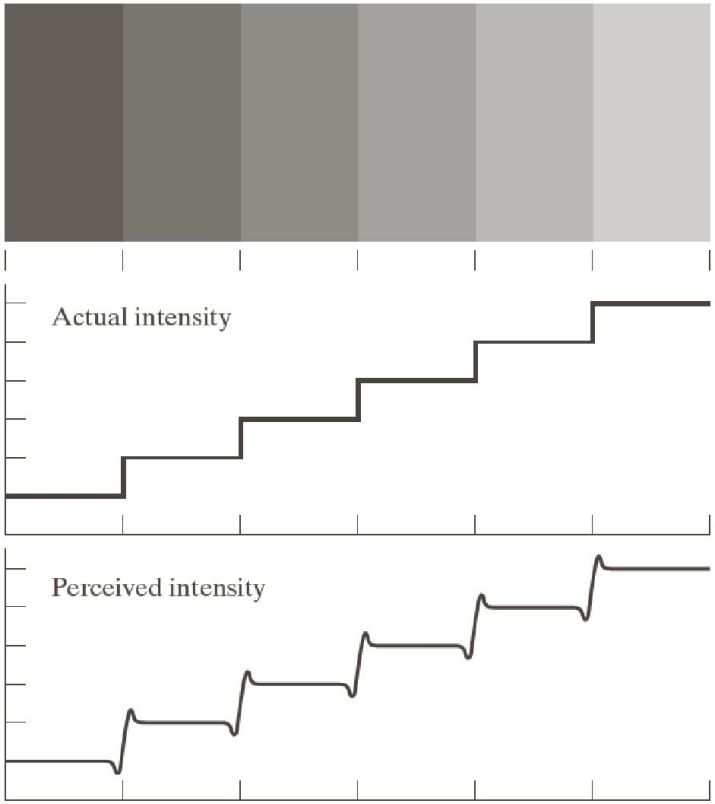


FIGURE 2.6
Typical Weber ratio as a function of intensity.

Elements of Visual Perception

Brightness Adaption and Discrimination

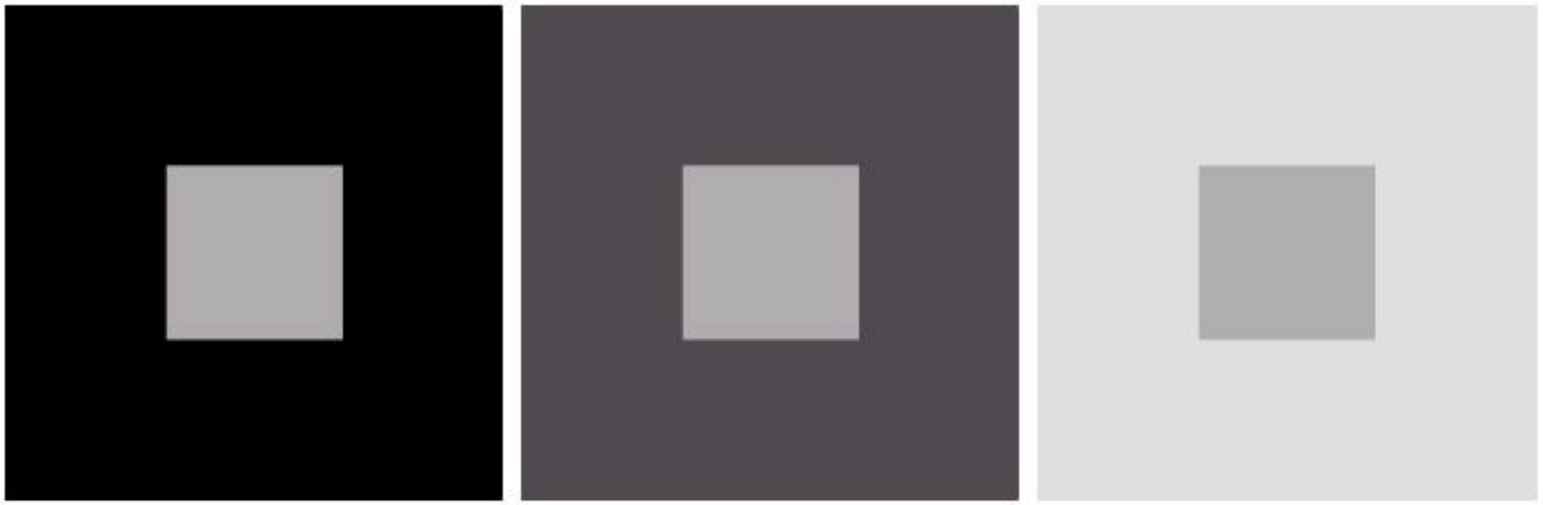


a
b
c

FIGURE 2.7 Illustration of the Mach band effect. Perceived intensity is not a simple function of actual intensity.

Elements of Visual Perception

Brightness Adaption and Discrimination

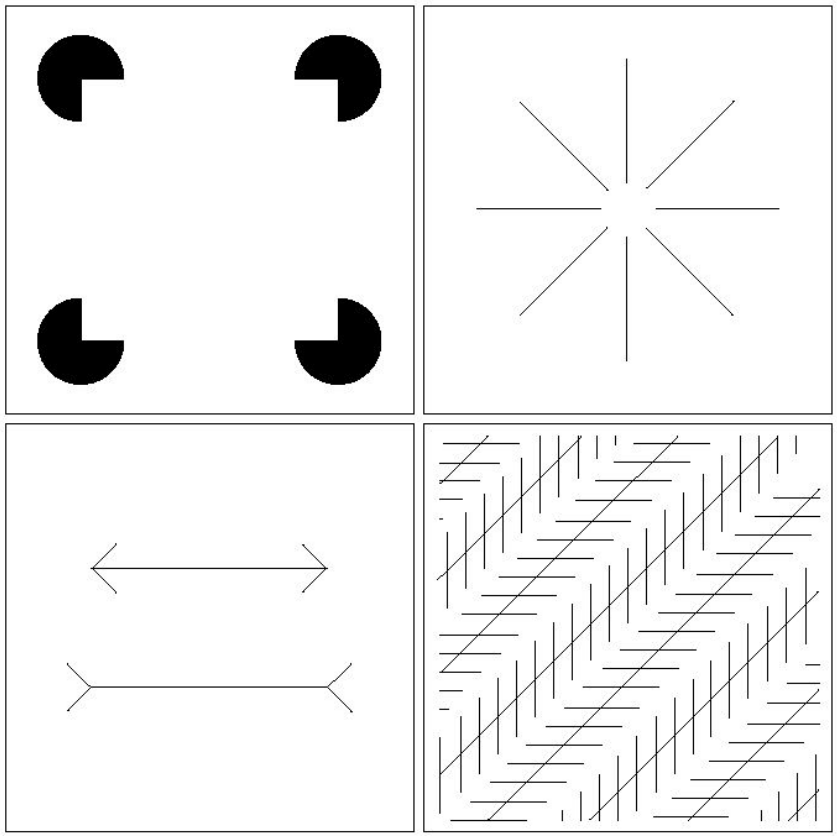


a b c

FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

Elements of Visual Perception

Brightness Adaption and Discrimination



a b
c d

FIGURE 2.9 Some well-known optical illusions.

Elements of Visual Perception

Light and the Electromagnetic Spectrum

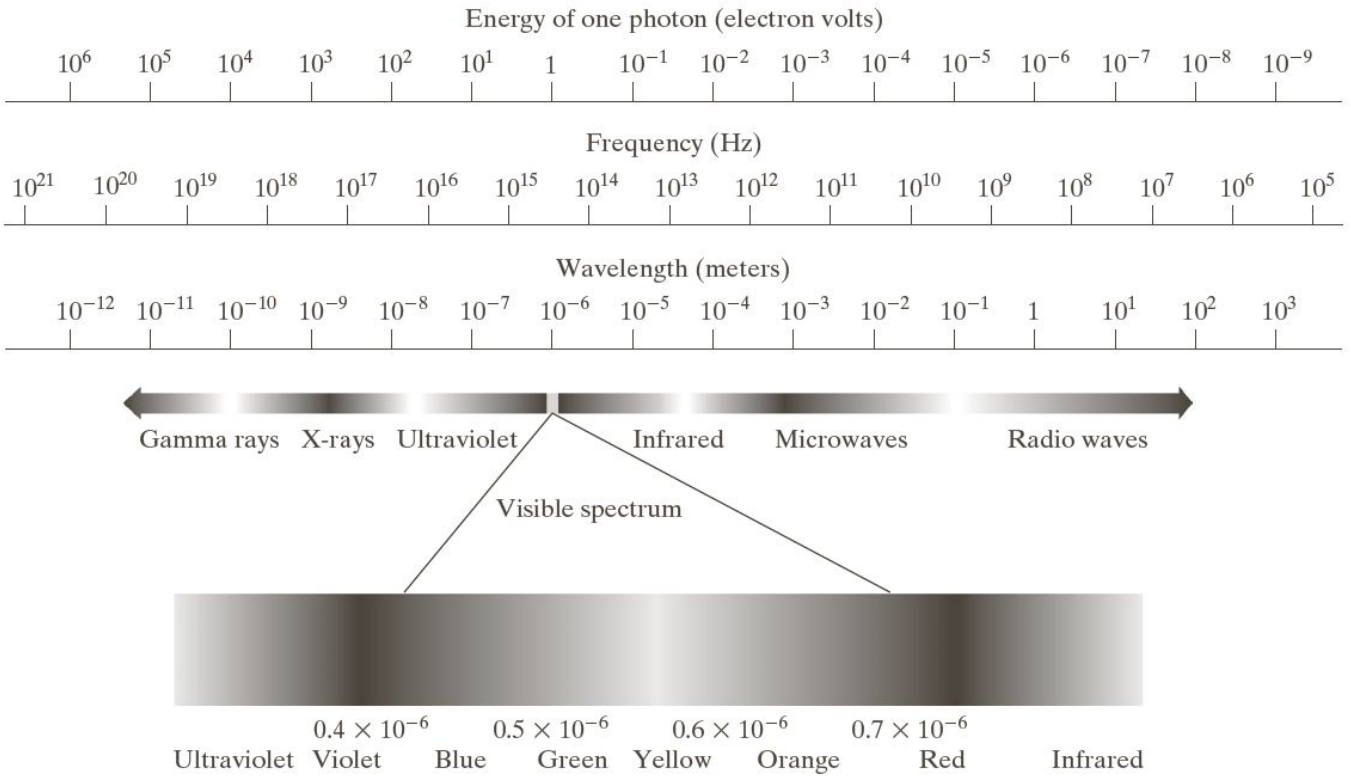
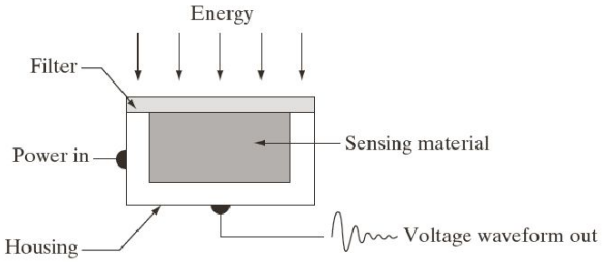
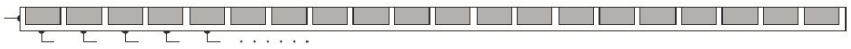


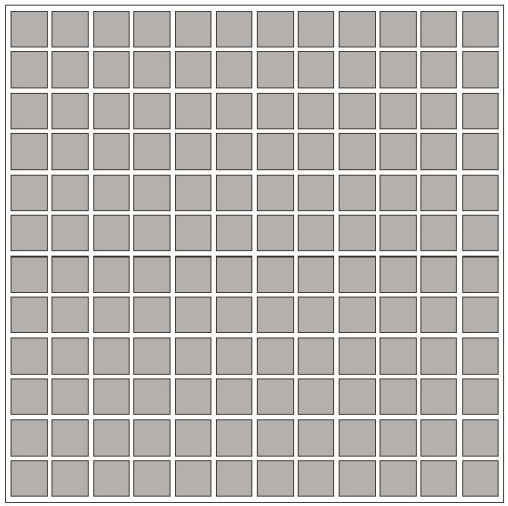
FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

Image Sensing and Acquisition

Image Acquisition using Sensor Strips and Sensor Arrays





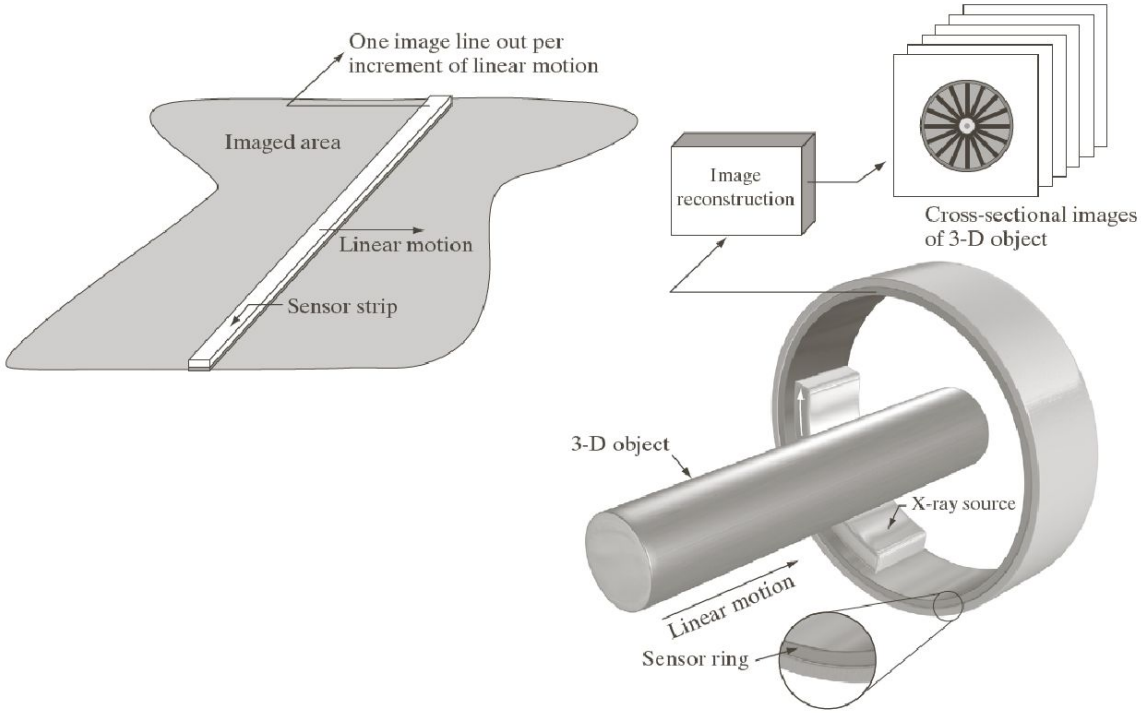


a
b
c

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

Image Sensing and Acquisition

Image Acquisition using Linear Sensor Strip and Circular Senso

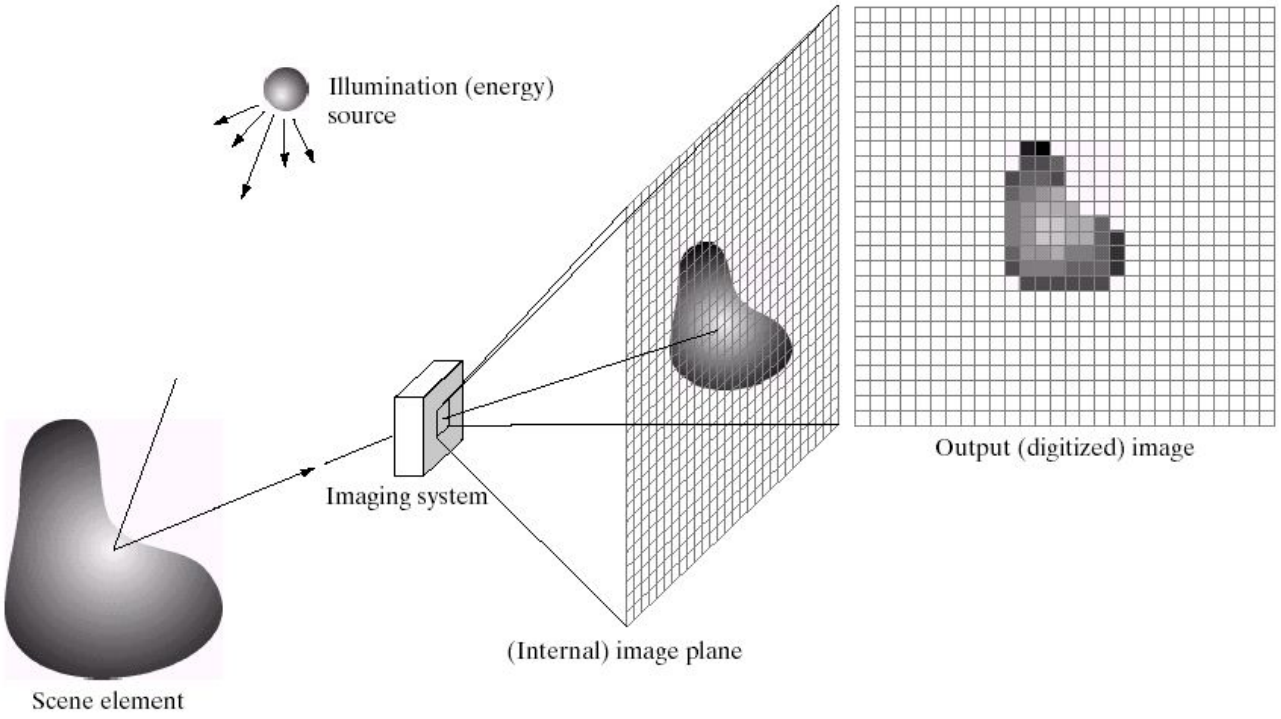


a b

FIGURE 2.14 (a) Image acquisition using a linear sensor strip. (b) Image acquisition using a circular sensor strip.

Image Sensing and Acquisition

Image Acquisition Proc



a b c d e

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

Image Sensing and Acquisition

A Simple Image Formation Model

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

$f(x,y)$: intensity at the point (x,y)

$i(x,y)$: illumination at the point (x,y)

(the amount of source illumination incident on the scene)

$r(x,y)$: reflectance at the point (x,y)

(the amount of illumination reflected by the object)

where $0 < i(x,y) < \infty$ and $0 < r(x,y) < 1$

Image Sensing and Acquisition

Some Typical Ranges of Illumination

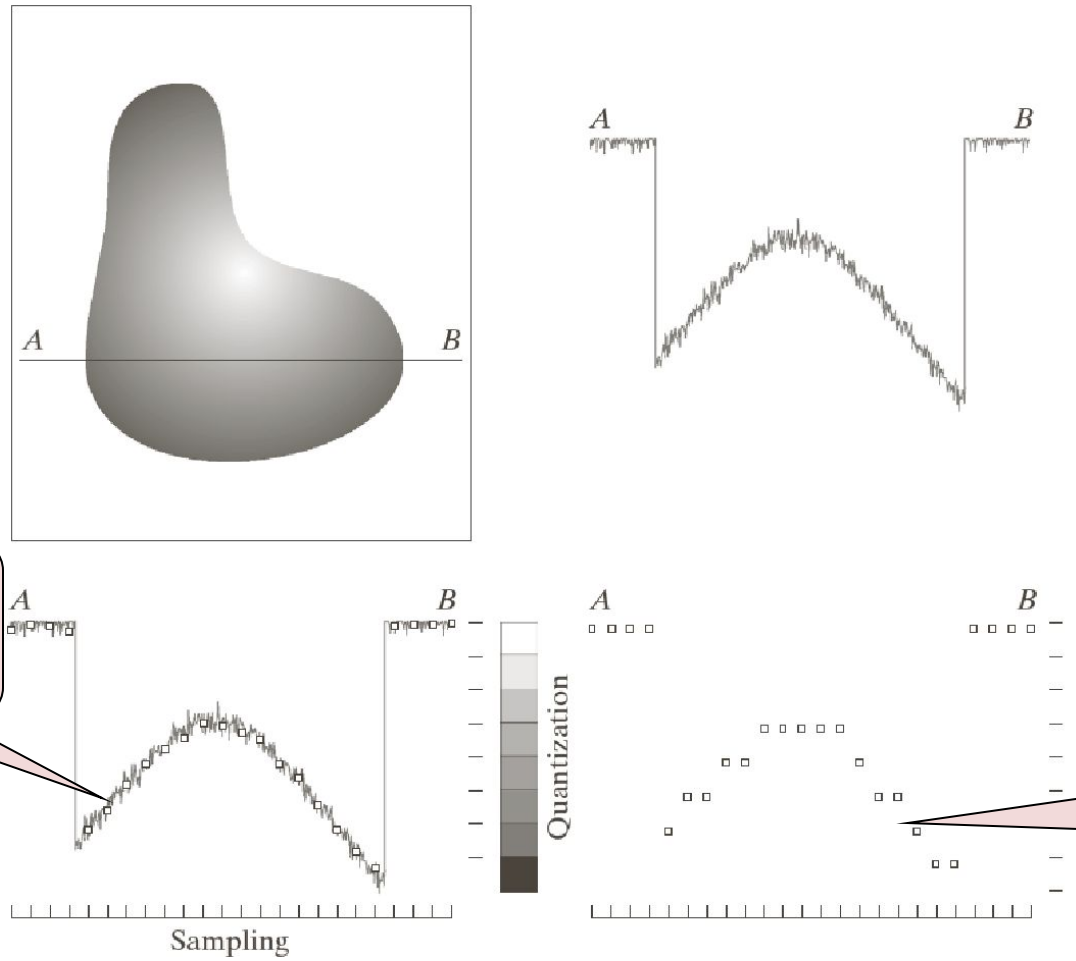
- **Lumen -** a unit of light flow or luminous flux
- **Lumen per square meter (lm/m^2) -** the metric unit of measure for illuminance of a surface
- On a clear day, the sun may produce in excess of 90,000 lm/m^2 of illumination on the surface of the Earth
- On a cloudy day, the sun may produce less than 10,000 lm/m^2 of illumination on the surface of the Earth
- On a clear evening, the moon yields about 0.1 lm/m^2 of illumination

Image Sensing and Acquisition

Some Typical Ranges of Reflectance

- 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

Image Sampling and Quantization



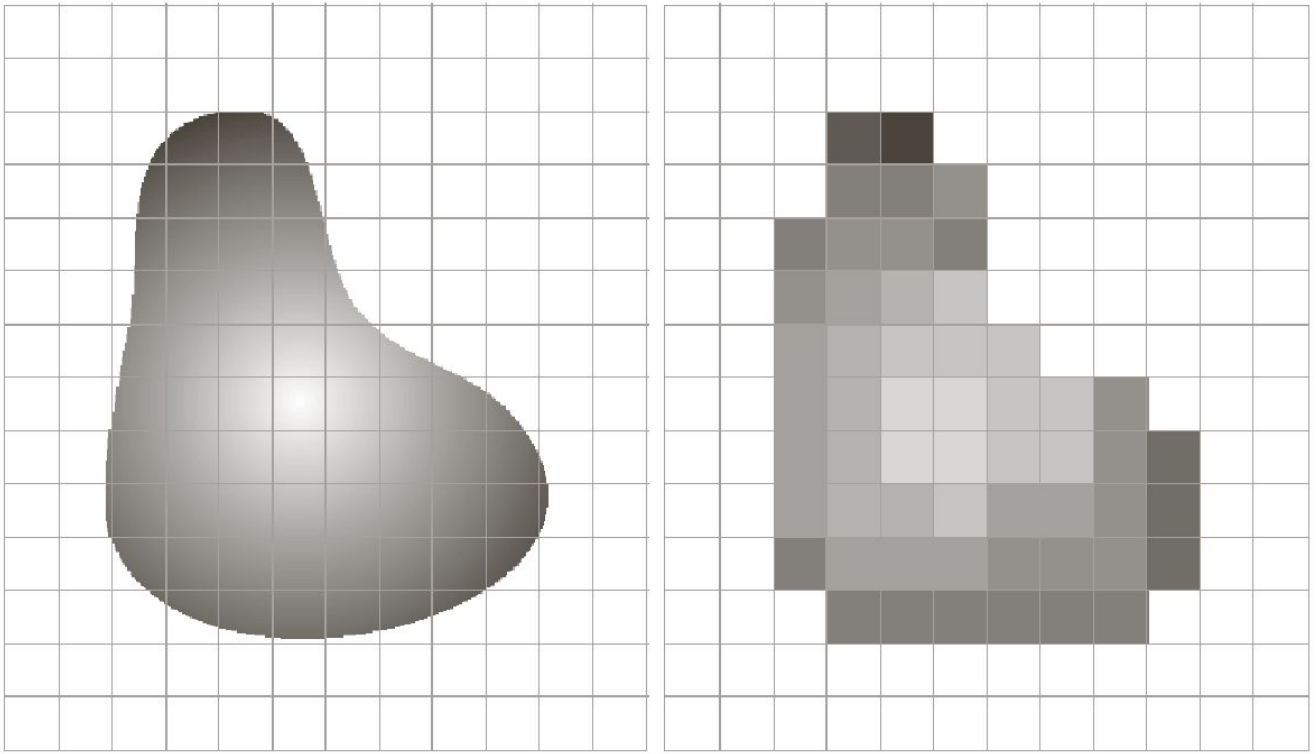
a b
c d

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

Digitizing the coordinate values

Digitizing the amplitude values

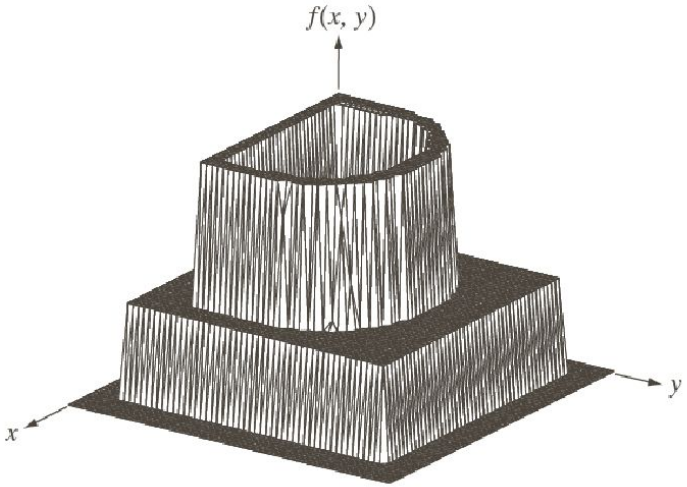
Image Sampling and Quantization

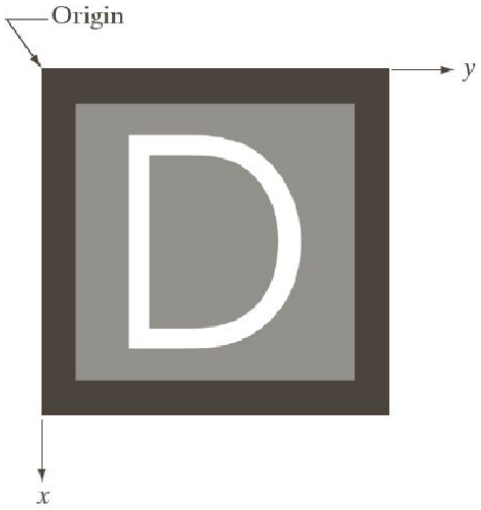


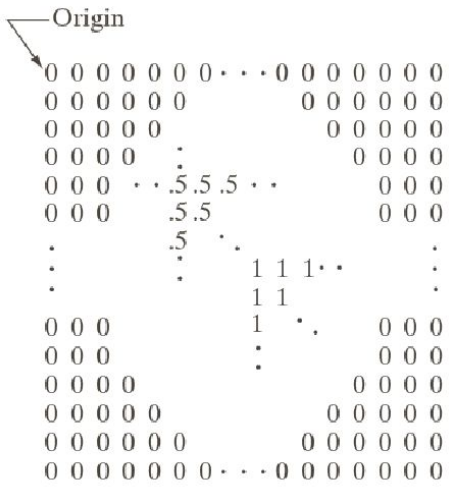
a b

FIGURE 2.17 (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.

Representing Digital Images







a
b c

FIGURE 2.18
(a) Image plotted as a surface.
(b) Image displayed as a visual intensity array.
(c) Image shown as a 2-D numerical array (0, .5, and 1 represent black, gray, and white, respectively).

Representing Digital Images

The representation of a $M \times N$ numerical array as

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

Representing Digital Images

- Discrete intensity interval $[\mathbf{0}, \boldsymbol{L} - \mathbf{1}]$, $\boldsymbol{L} = \mathbf{2}^{\boldsymbol{k}}$
- The number $\boldsymbol{b}$ bits required to store a $\boldsymbol{M} \times \boldsymbol{N}$ digitized Image

$$\boldsymbol{b} = \boldsymbol{M} \times \boldsymbol{N} \times \boldsymbol{k}$$

Spatial and Intensity Resolution

- **Spatial Resolution**
  - a measure of smallest discernible detail in an image
  - stated with ***dots (pixels) per unit distance, dots per inch (dpi)***

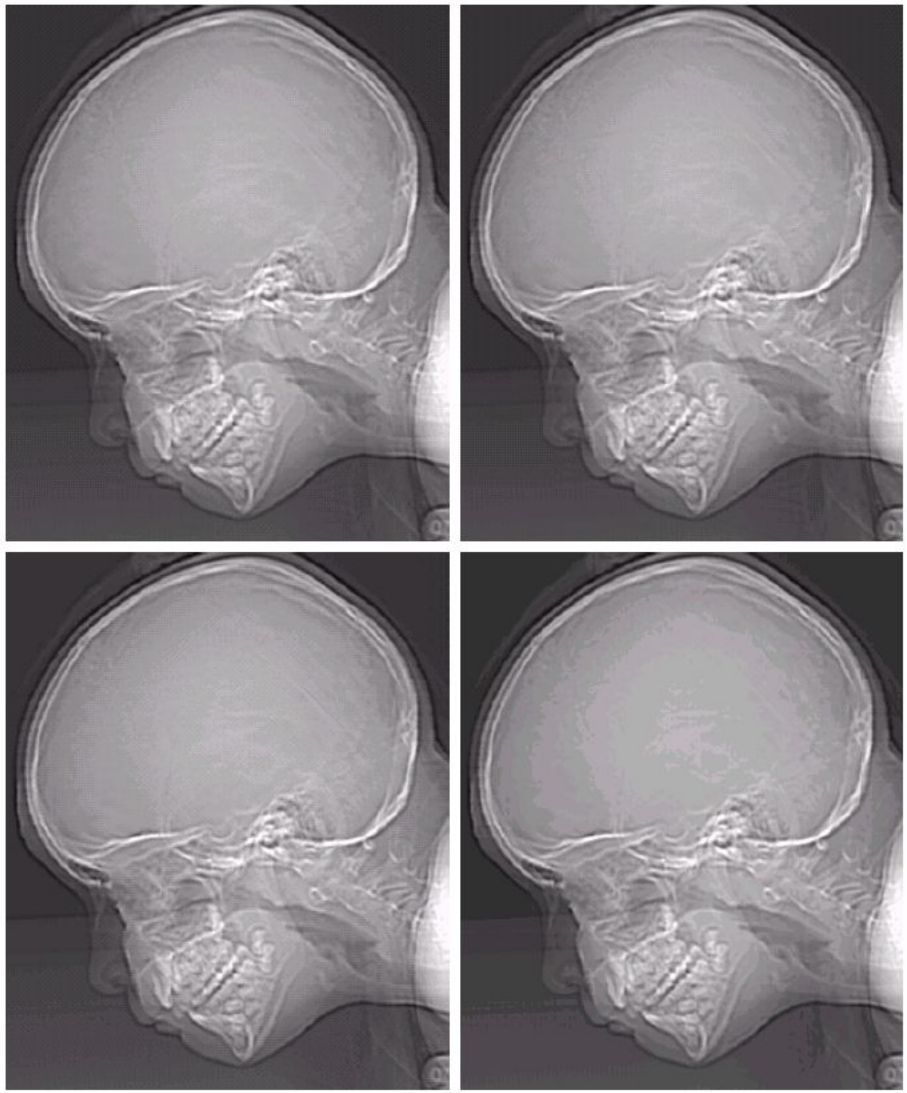
- **Intensity Resolution**
  - the smallest discernible change in intensity level
  - stated with ***8 bits, 16 bits, 24 bits,*** etc.

Spatial and Intensity Resolution

a b
c d

FIGURE 2.20 Typical effects of reducing spatial resolution. Images shown at: (a) 1250 dpi, (b) 300 dpi, (c) 150 dpi, and (d) 72 dpi. The thin black borders were added for clarity. They are not part of the data.

Spatial and Intensity Resolution



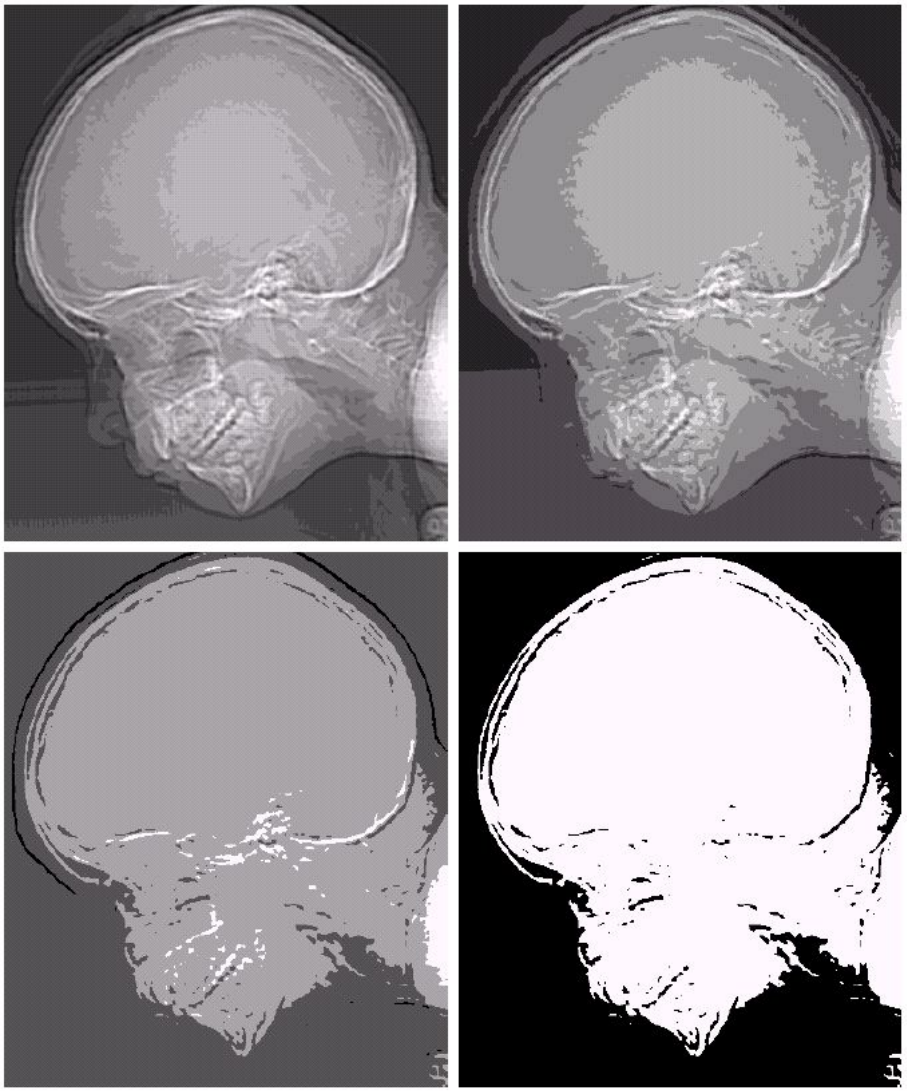
a b
c d

FIGURE 2.21
(a) 452 × 374, 256-level image. (b)–(d) Image displayed in 128, 64, and 32 gray levels, while keeping the spatial resolution constant.

Spatial and Intensity Resolution

e f
g h

FIGURE 2.21
(Continued)
(e)–(h) Image displayed in 16, 8, 4, and 2 gray levels. (Original courtesy of Dr. David R. Pickens, Department of Radiology & Radiological Sciences, Vanderbilt University Medical Center.)



Next Class

- **Digital Image Fundamentals**
  - Image sampling and quantization – image interpolation
  - Relationship between pixels
  - The conditions for linear operations

Thank you:
Question?