Chapter 2

Digital Image Fundamentals

How do we see?

What is an image?

Chapter 2
Digital Image Fundamentals

How do we see?
Elements of Visual Perception

Light receptors on the retina

- *Cones:* 6-7 mill. mainly in fovea
  Highly sensitive to color
  Resolve fine detail
  Photopic vision

- *Rods:*75-150 mill. over retina
  Not involved in color vision
  Sensitive to low illumination
  Coarse view
  Scotopic vision

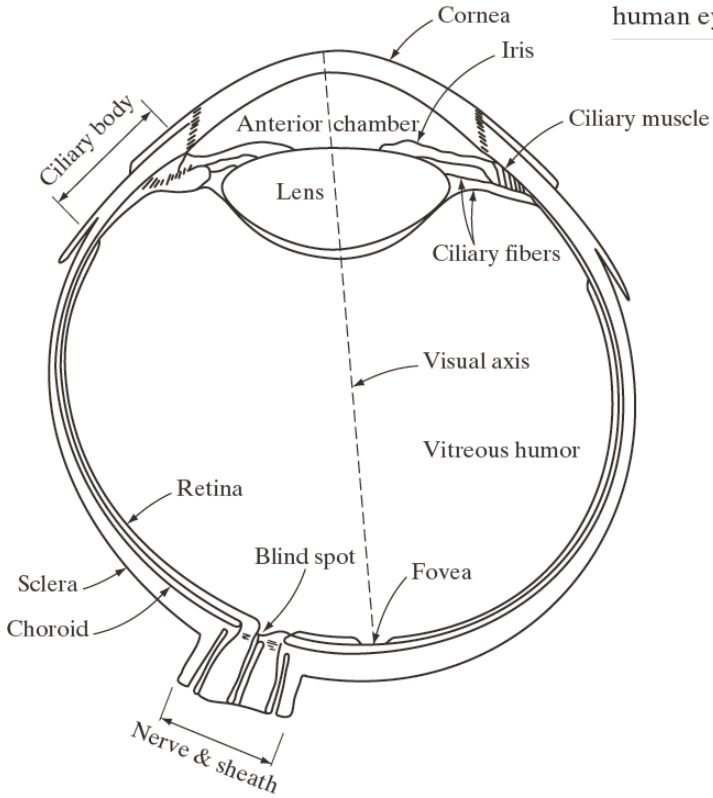


FIGURE 2.1 Simplified diagram of a cross section of the human eye.

Chapter 2

Digital Image Fundamentals

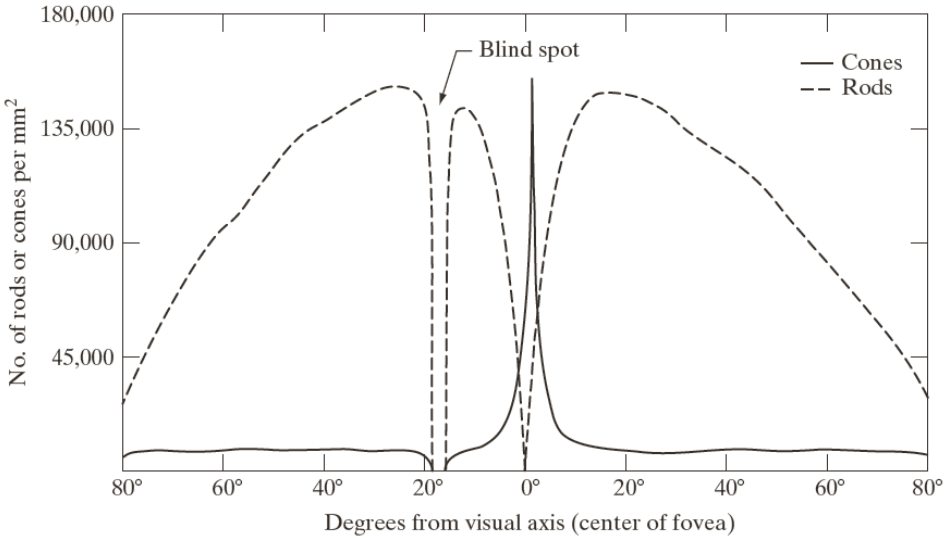


FIGURE 2.2
Distribution of rods and cones in the retina.

Density of cones and rods

- The eye can resolve fine details and colors at the center

Chapter 2

Digital Image Fundamentals

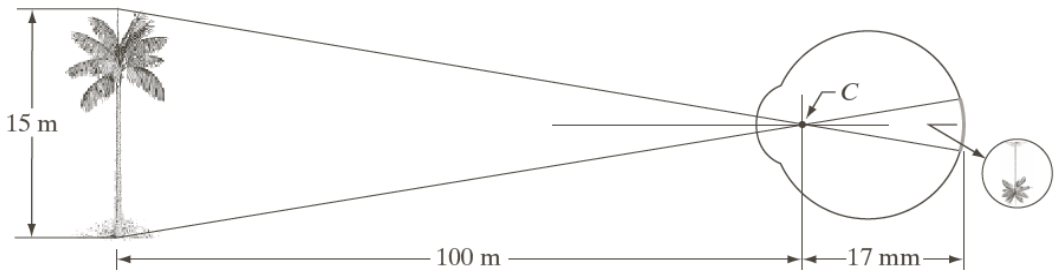


FIGURE 2.3 Graphical representation of the eye looking at a palm tree. Point *C* is the optical center of the lens.

Image formation in the eye

- The distance between the lens and the fovea (imaging region) is fixed

  Example: 15/100 = h/17

  h = 2.5 mm

- The shape of the lens vary to adapt the focus

Chapter 2

Digital Image Fundamentals

Brightness adaptation and discrimination

- The eye can adapt to an enormous intensity range, but not simultaneously
- Subjective (perceived) brightness
- Brightness adaptation level (B_a)
- Shorter adaptation range at specific level

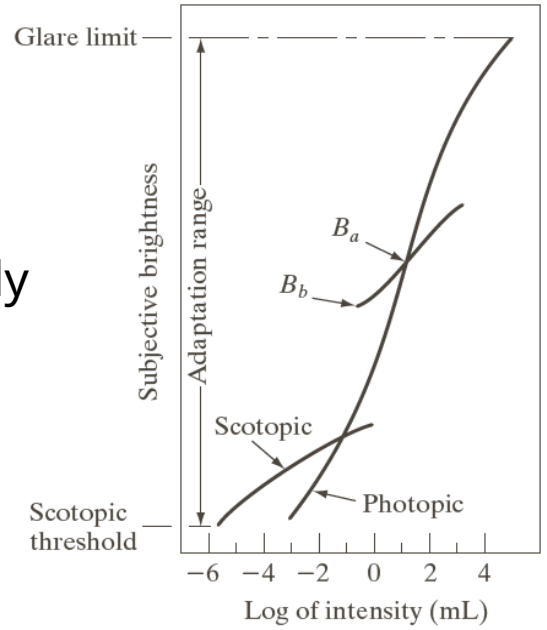


FIGURE 2.4 Range of subjective brightness sensations showing a particular adaptation level.

Chapter 2

Digital Image Fundamentals

- Discrimination of changes in intensity at specific level
- ΔI: Increment of illumination (flash)
- Weber ratio: $\Delta I_c / I$ (50% discernible)

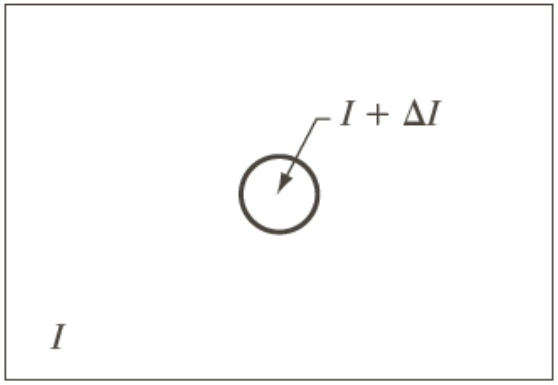


FIGURE 2.5 Basic experimental setup used to characterize brightness discrimination.

Chapter 2

Digital Image Fundamentals

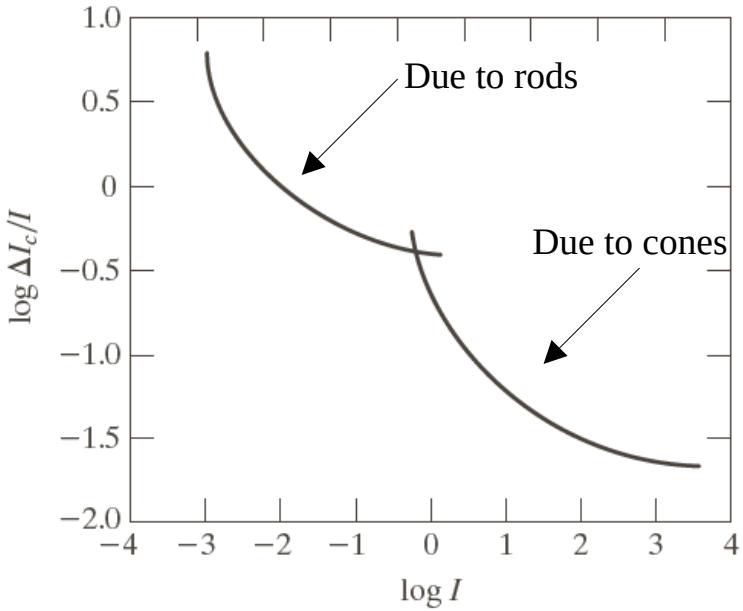


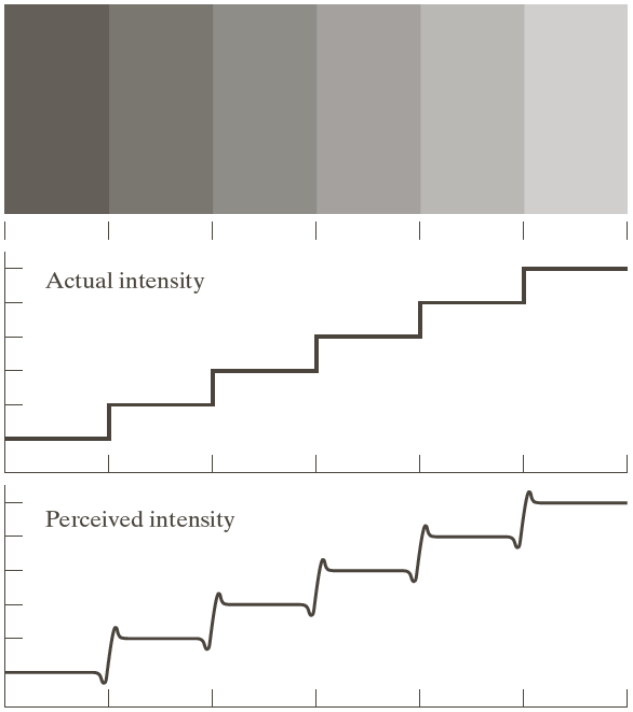
FIGURE 2.6 Typical Weber ratio as a function of intensity.

- Discrimination of itensities better with photopic vision (cones)

Chapter 2

Digital Image Fundamentals

The brain is also processing the image!



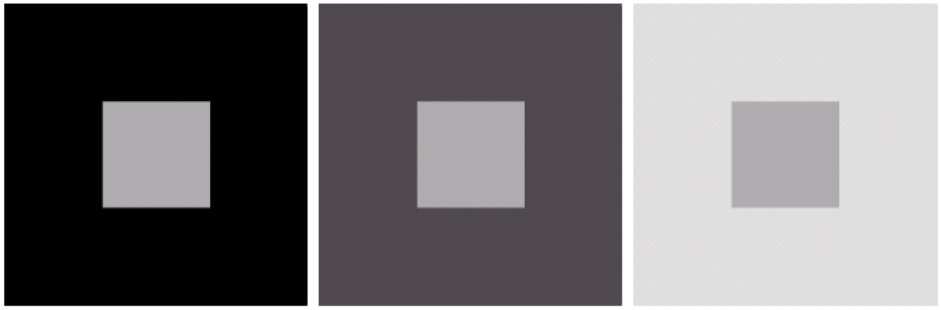
a
b
c

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

Example1: Undershoot/overshoot effect near boundary regions

Chapter 2

Digital Image Fundamentals



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.

- Example 2: Different contrast between regions may lead to different subjective brightness

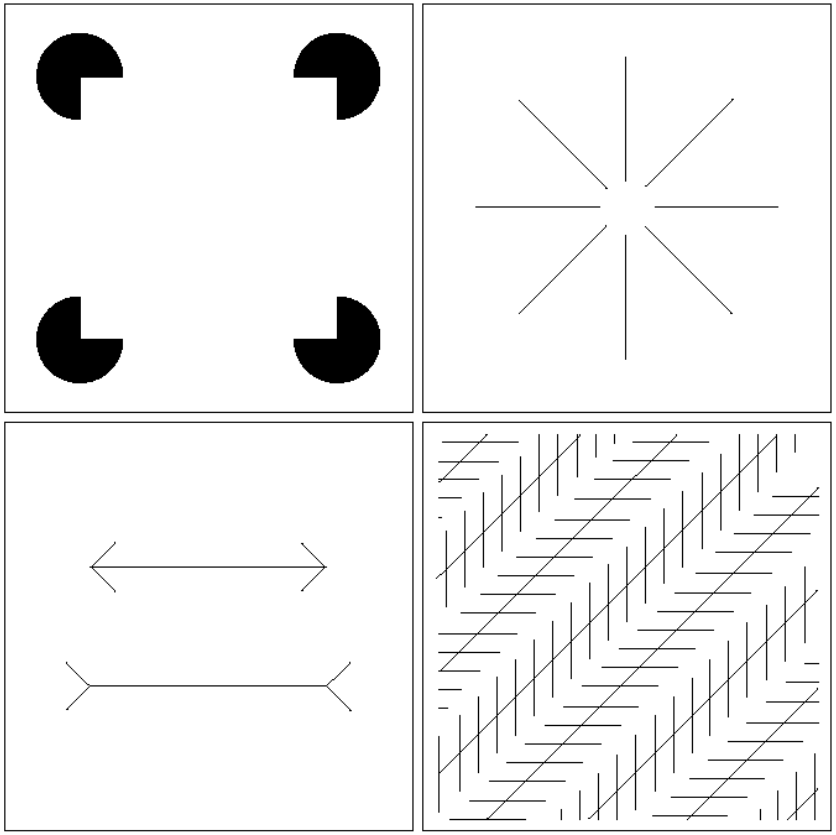
Chapter 2

Digital Image Fundamentals

- Example 3: Related phenomena of optical illusions

a b
c d

FIGURE 2.9 Some well-known optical illusions.



Chapter 2

Digital Image Fundamentals

What is an image?

Chapter 2

Digital Image Fundamentals

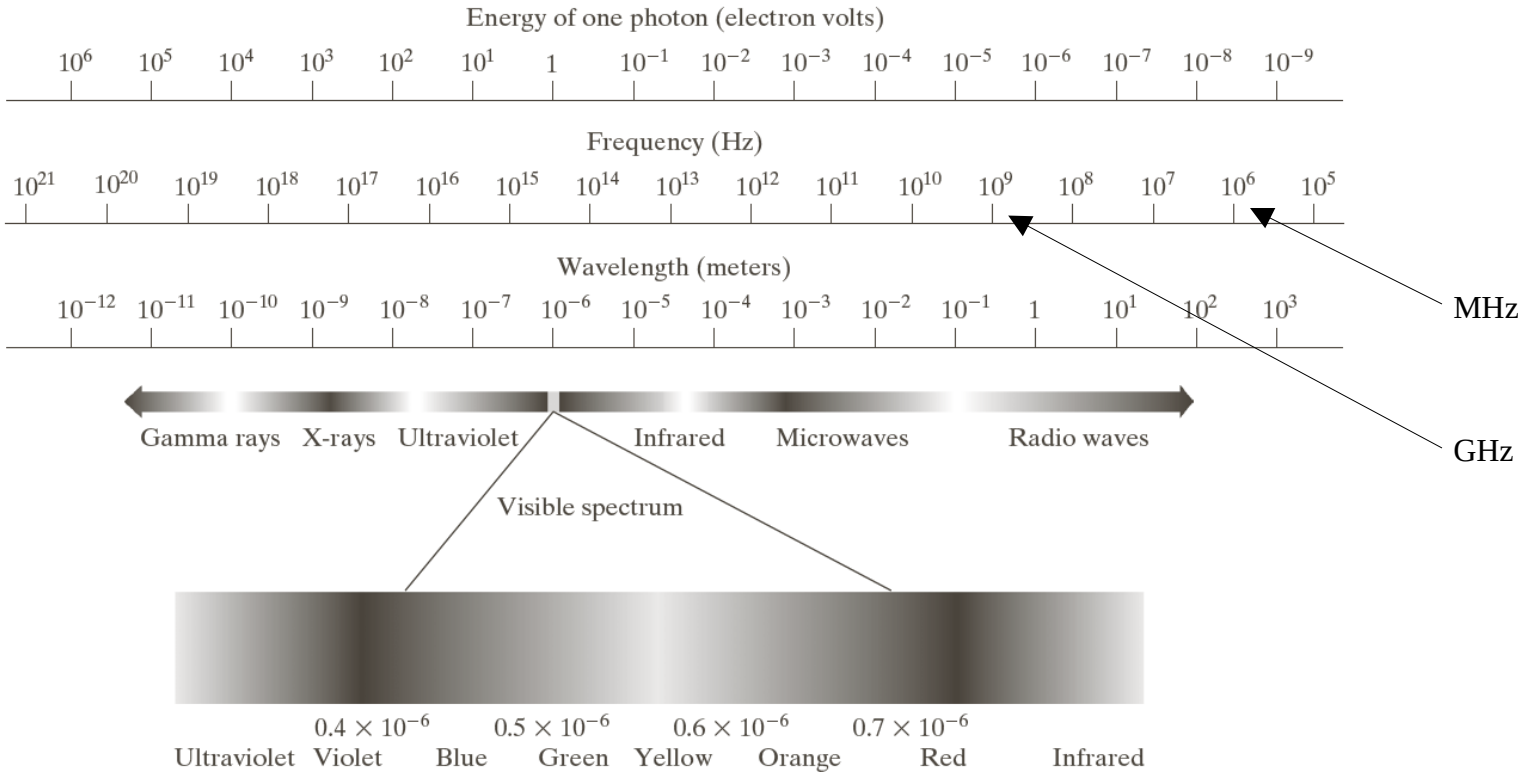


FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

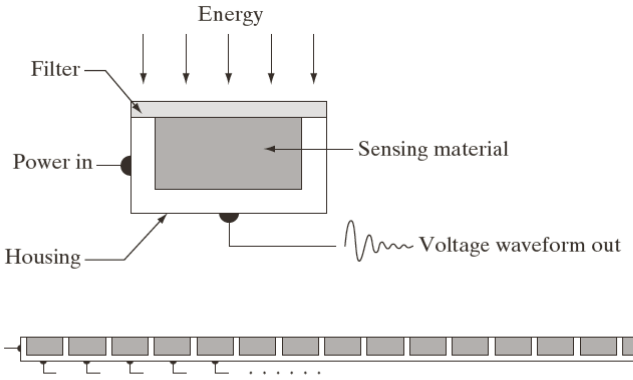
Intensity: number of photons, **color:** frequency of the photons

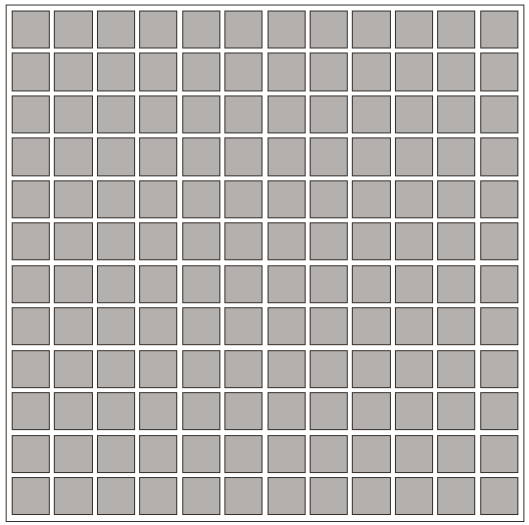
Chapter 2

Digital Image Fundamentals

Image Sensing and Aquisition

- (Light) sensor
- Output proportional to light
- Arranged in lines
- Or in arrays (like in digital cameras)





a
b
c

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

Chapter 2

Digital Image Fundamentals

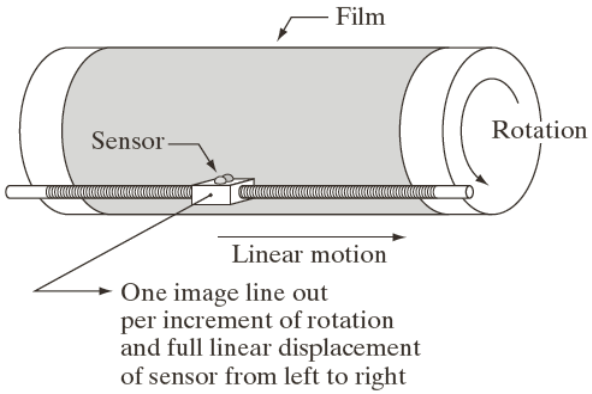
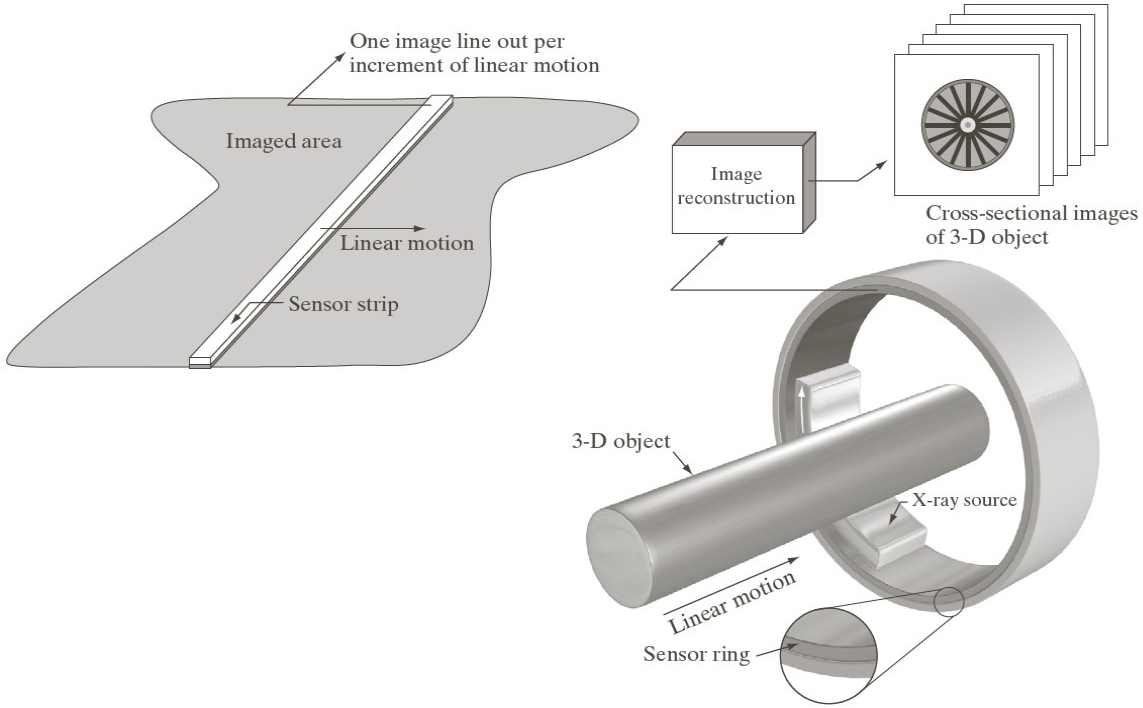


FIGURE 2.13 Combining a single sensor with motion to generate a 2-D image.

- Line sensors need mechanical motion to produce images

Chapter 2
Digital Image Fundamentals

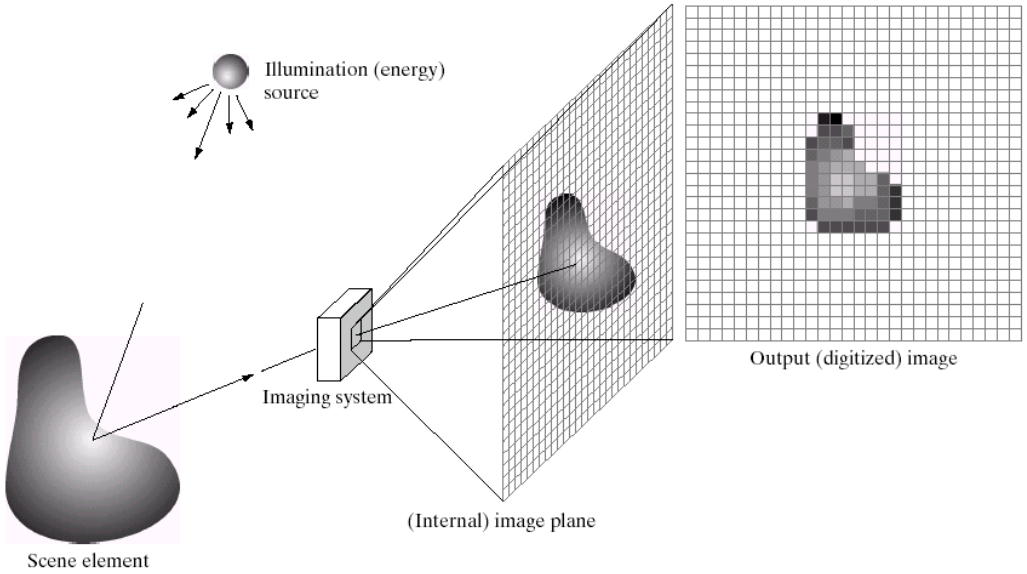


a b

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

Chapter 2

Digital Image Fundamentals



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.

Principle of digital images

- Focus energy (light) onto sensing array
- Sensors integrate light
- Analog signal produced
- Digitizing process!

Pixels!

Chapter 2

Digital Image Fundamentals

Analog signal of form

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

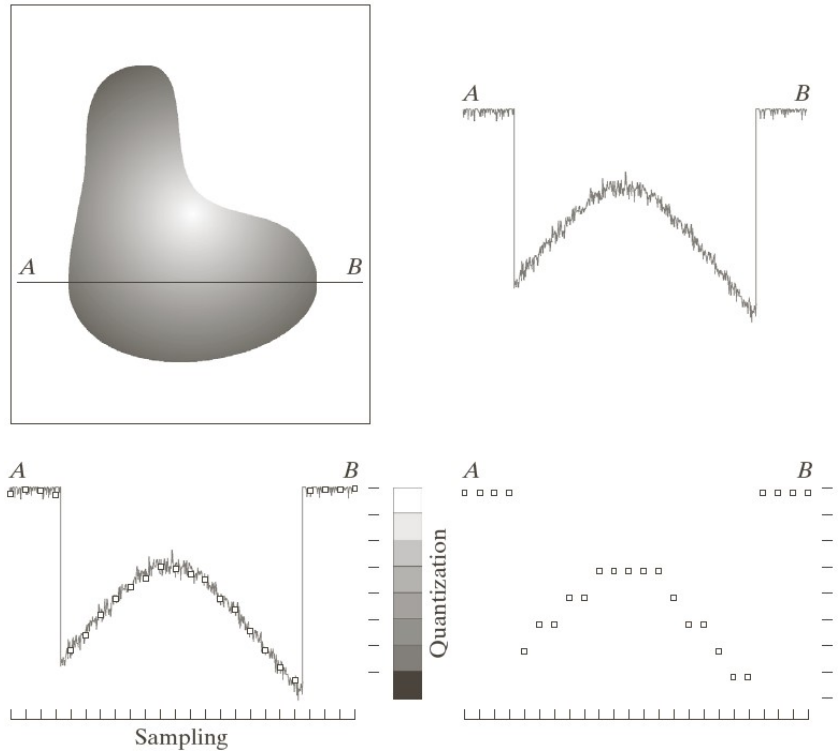
- x, y are spatial coordinates
- f is amplitude
- i: illumination <0,infinity> (light source)
- r: reflectance <0,1> (object property)

E.g: Black velvet: 0.01. Snow: 0.93.

Chapter 2

Digital Image Fundamentals

- Sampling: Digitize the *coordinate* values
- Quantization: Digitize the *amplitude* values



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.

Chapter 2

Digital Image Fundamentals

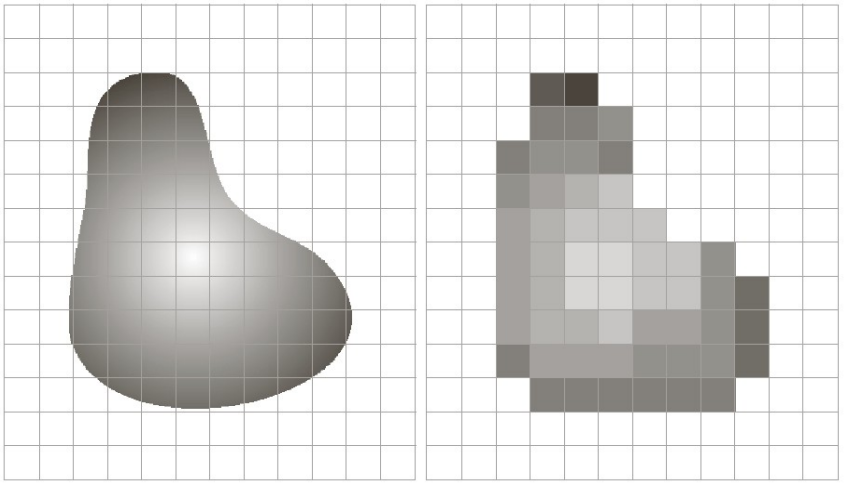
Quality of digital image:

- Number of samples
- Number of quantization levels:

$$L = 2^k$$

- Integers in [0,L-1]
- k-bit image

$$L = 256,\ k = 8$$



a b

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