



Chapter 2: Digital Image Fundamentals

**Those who wish to succeed must ask
the right preliminary questions.
- Aristotle**



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Elements of Visual Perception

Structure of the Human Eye

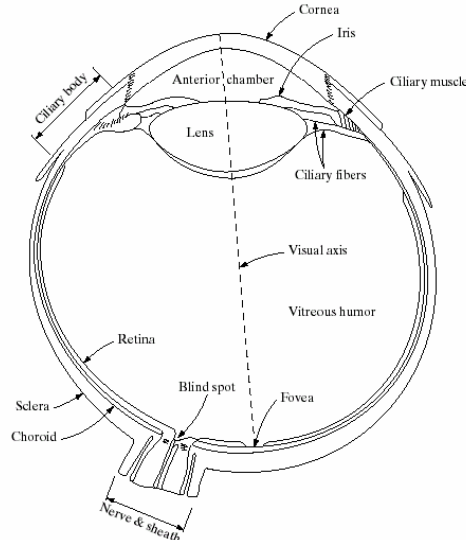


FIGURE 2.1
Simplified diagram of a cross section of the human eye.



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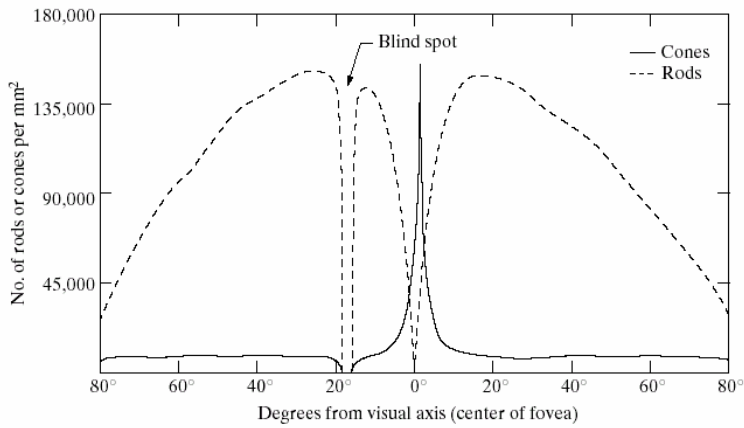


FIGURE 2.2
Distribution of rods and cones in the retina.

Structure of the Human Eye

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FIGURE 2.3

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

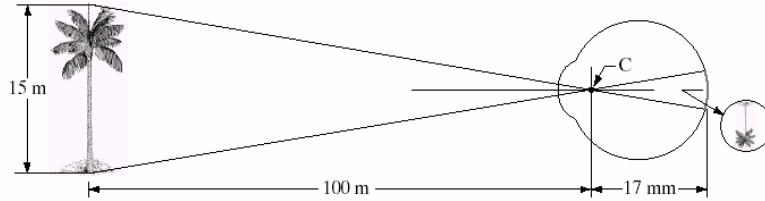


Image Formation in the Eye

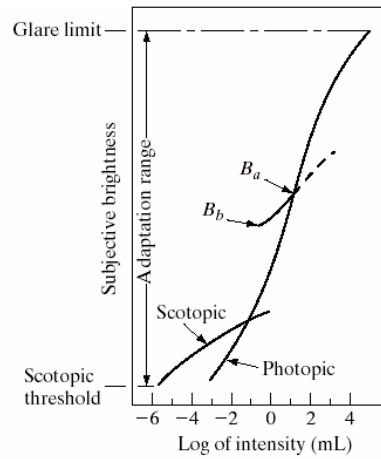
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FIGURE 2.4

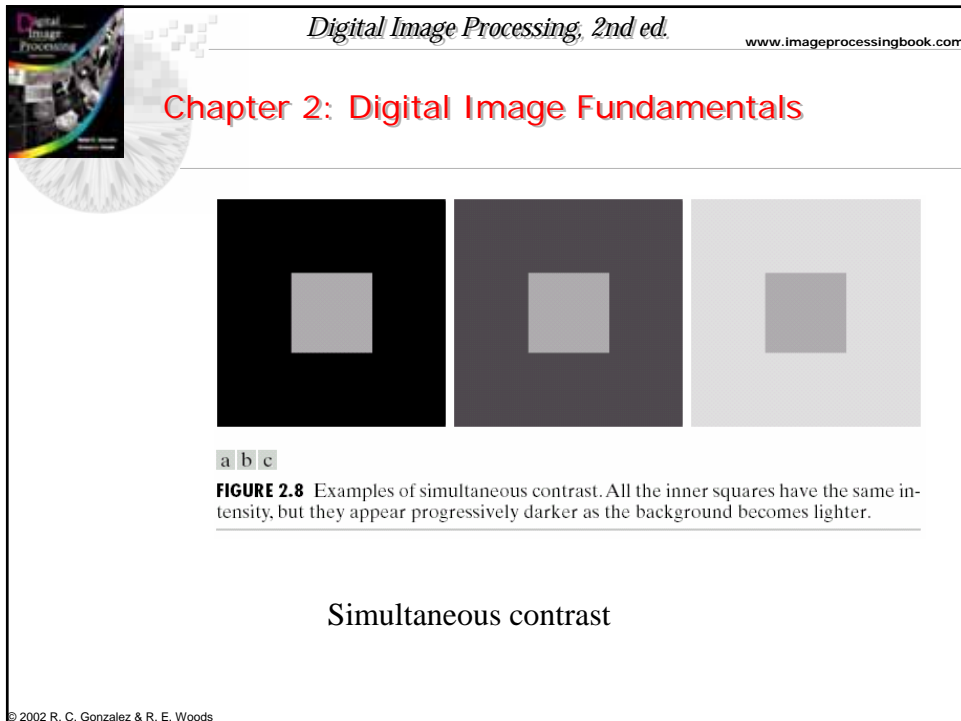
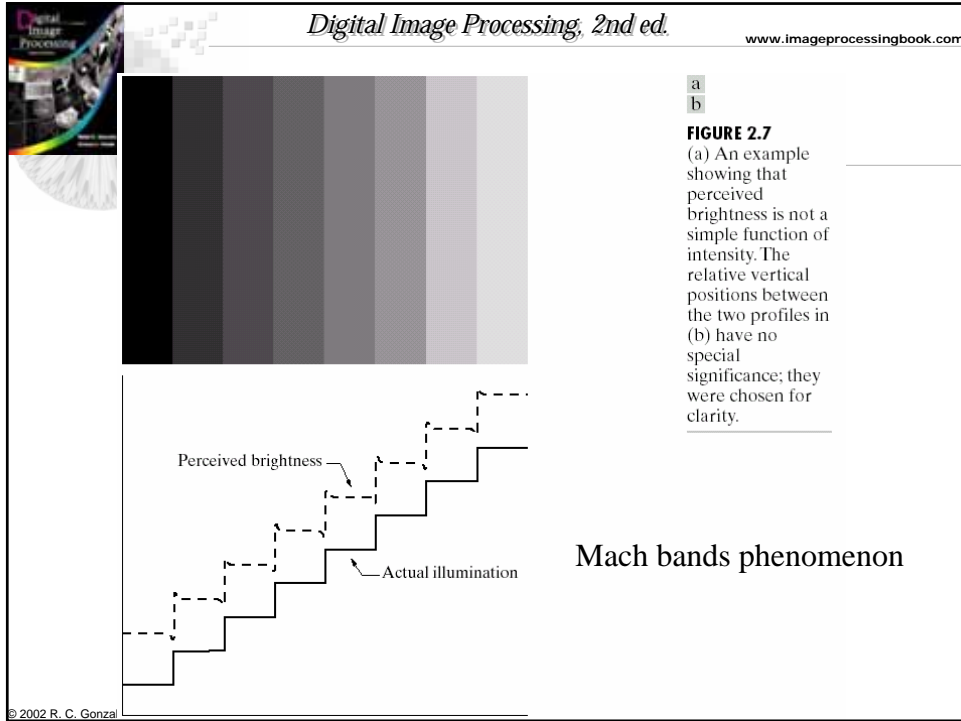
Range of subjective brightness sensations showing a particular adaptation level.

range: 10^{10}
Subjective brightness:
logarithmic



Brightness Adaptation and Discrimination

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FIGURE 2.9 Some well-known optical illusions.

Optical illusions

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Visible Spectrum

$C = f \lambda$
 $E \propto f$

700 nm 400 nm

THE ELECTROMAGNETIC SPECTRUM

Wavelength (in meters) 10^3 10^2 10^1 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12}

longer shorter

Size of a wavelength Soccer Field House Baseball This Period Cell Bacteria Virus Protein Water Molecule

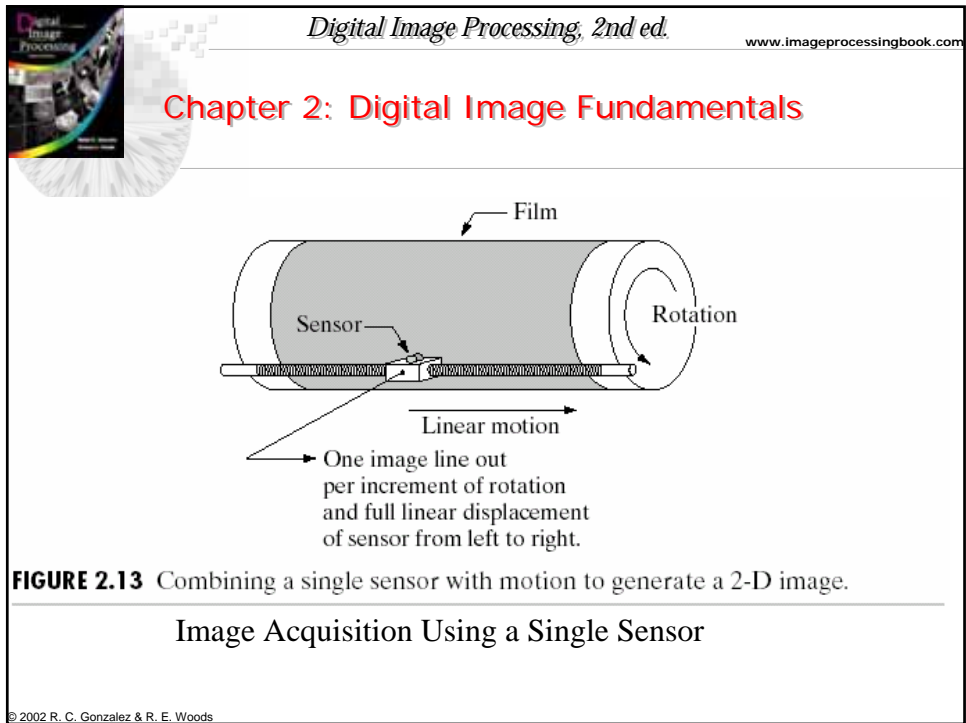
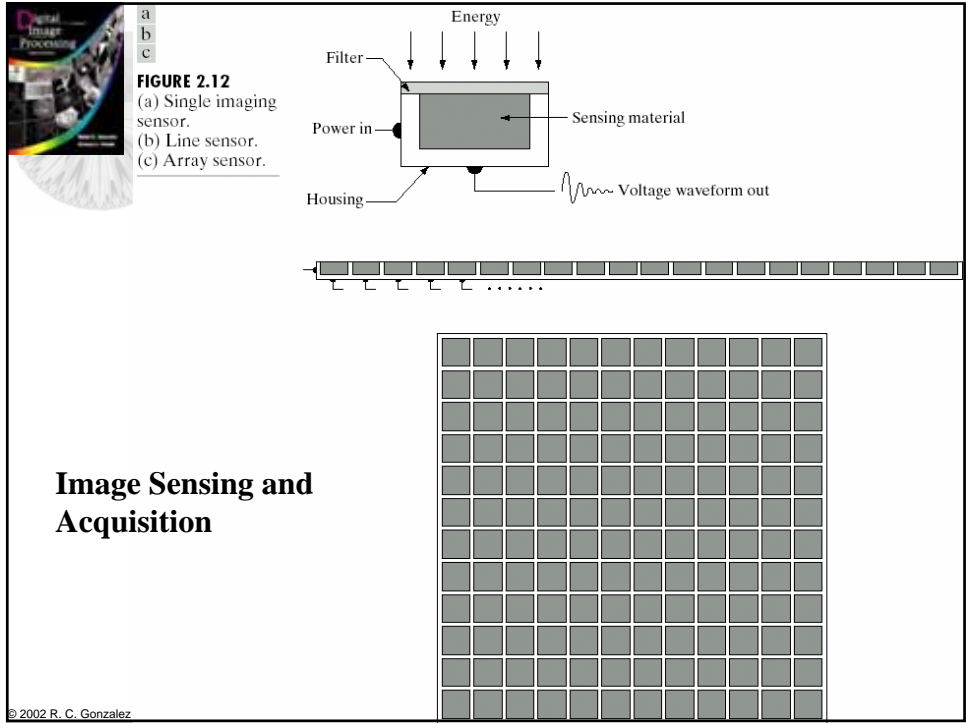
Common name of wave RADIO WAVES INFRARED VISIBLE ULTRAVIOLET "HARD" X RAYS GAMMA RAYS

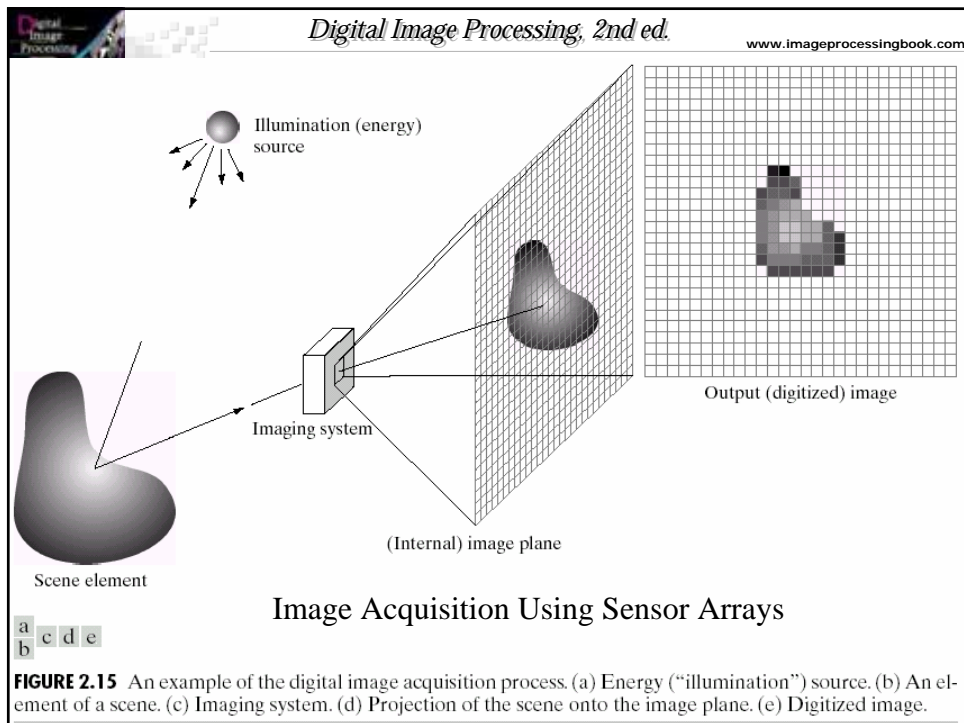
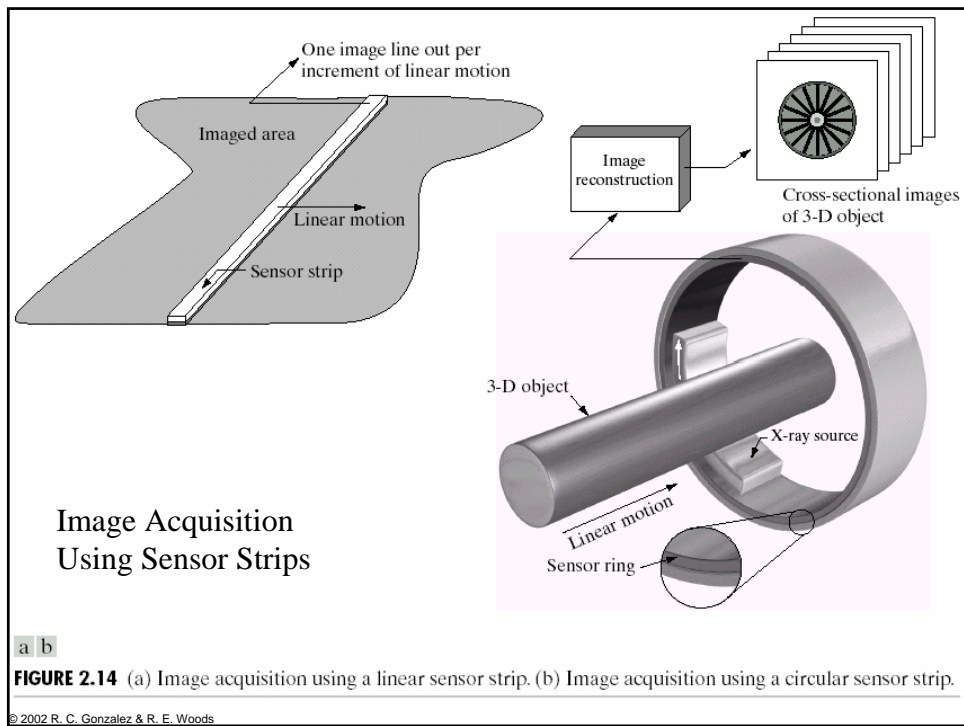
Sources AM Radio RF Cavity FM Radio Microwave Oven Radar People Light Bulb The ALS X-Ray Machines Radioactive Elements

Frequency (waves per second) 10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20}

Energy of one photon (electron volts) 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10^1 10^2 10^3 10^4 10^5 10^6

lower higher







Camera Geometry

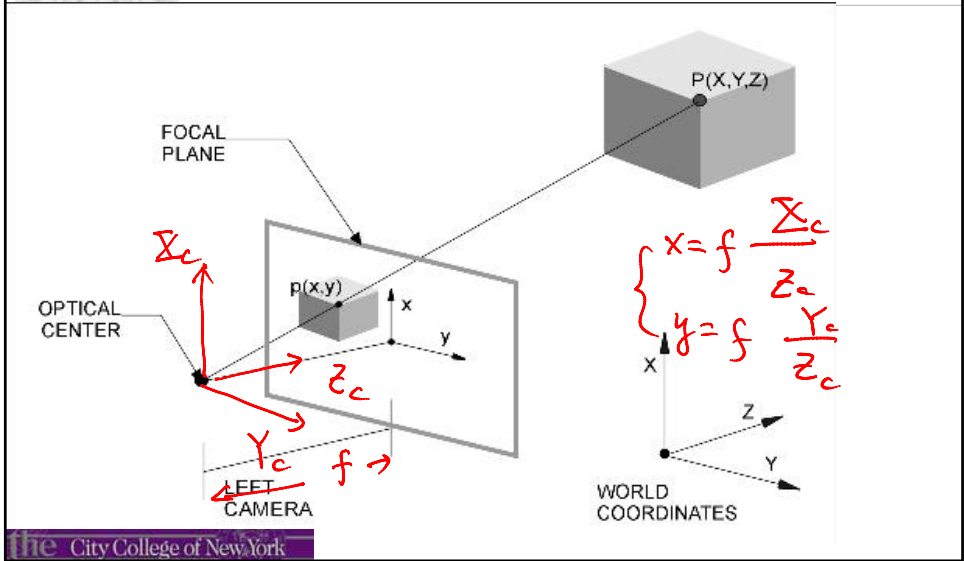
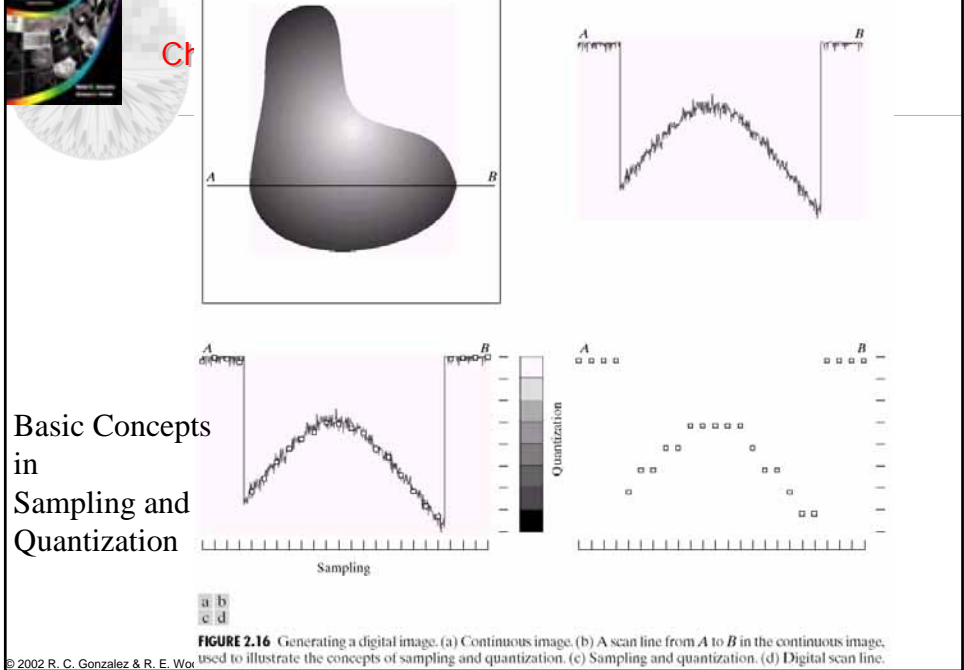
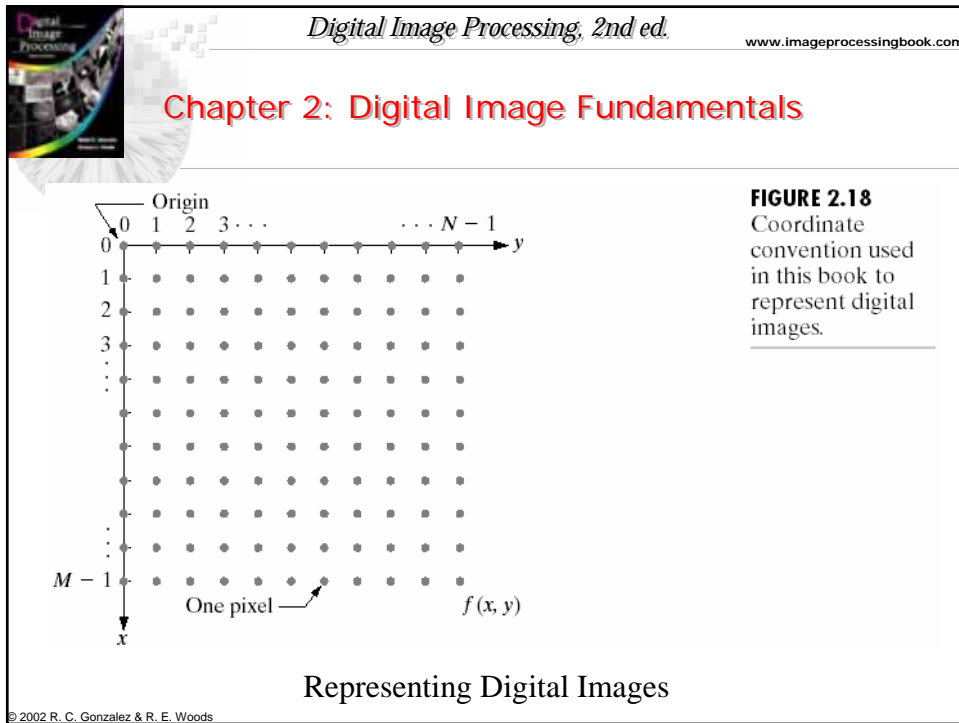
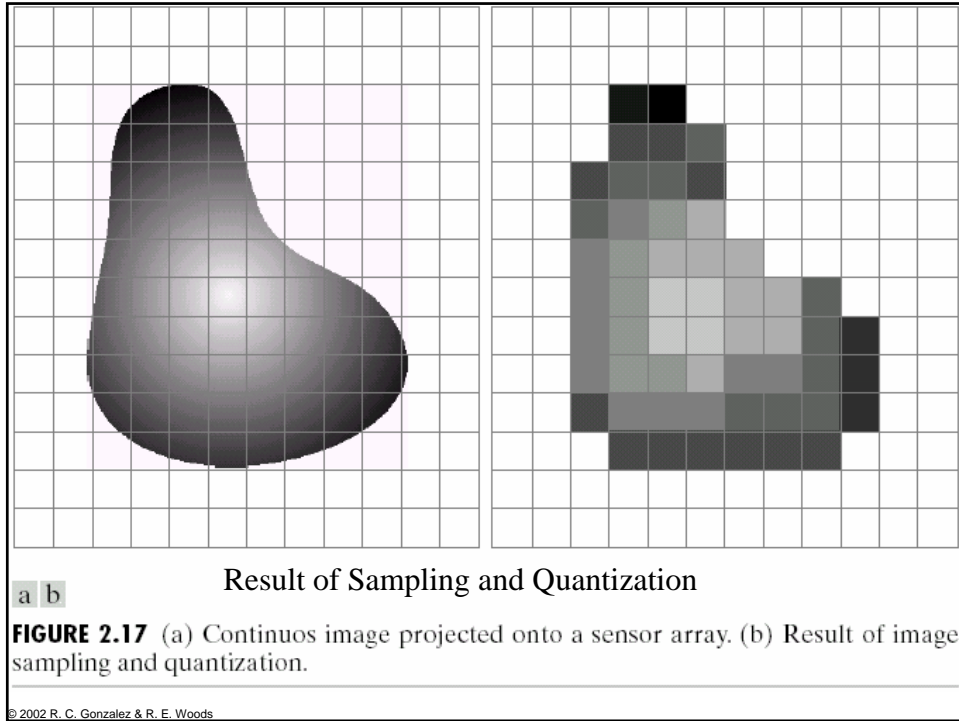


Image Sampling and Quantization





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TABLE 2.1
Number of storage bits for various values of N and k .

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

$N \times N$ pixels \times k bits

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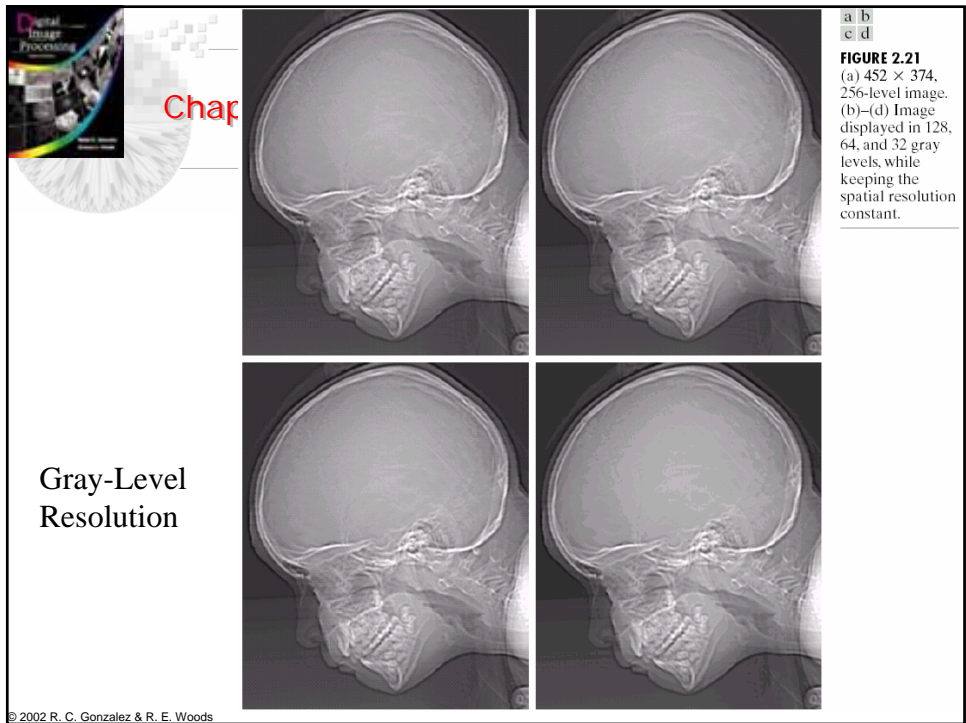
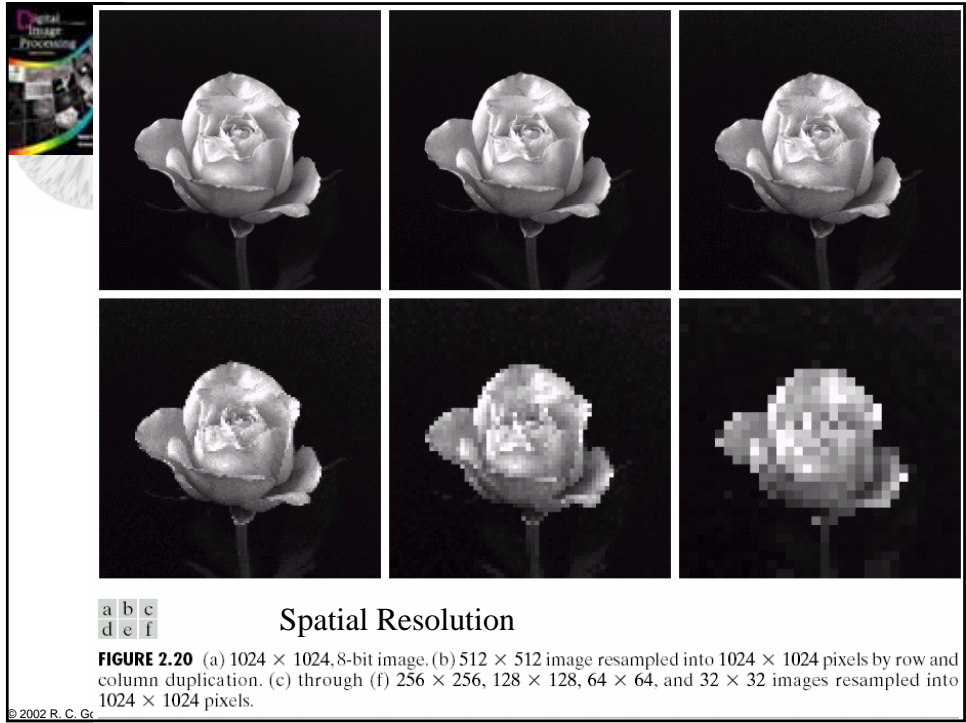
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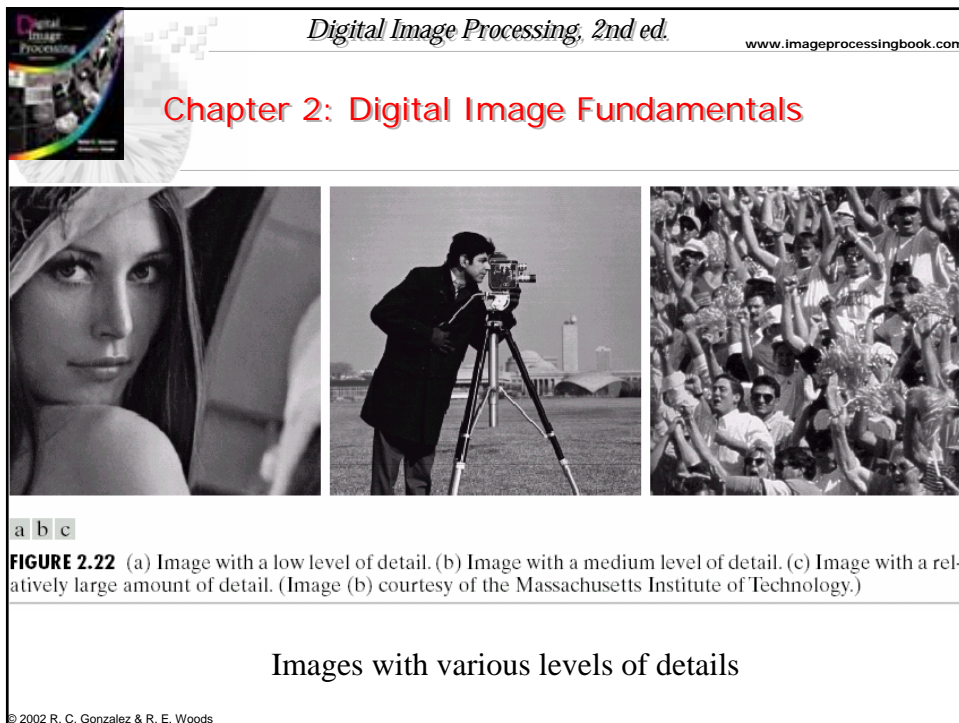
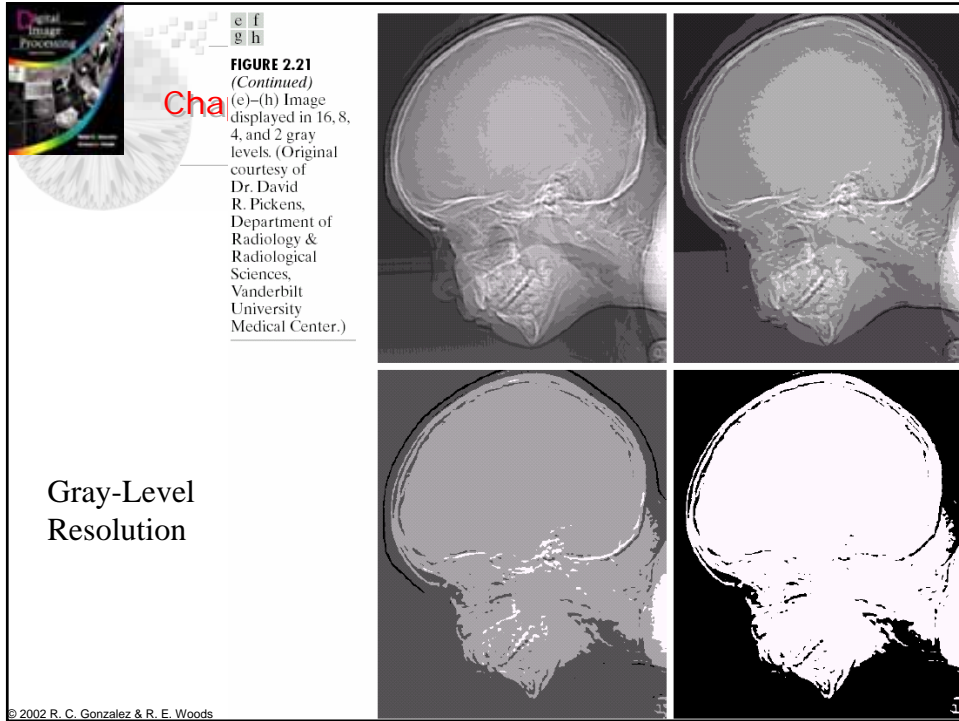
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Spatial Resolution

FIGURE 2.19 A 1024×1024 , 8-bit image subsampled down to size 32×32 pixels. The number of allowable gray levels was kept at 256.

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Zooming and Shrinking Digital Images

FIGURE 2.25 Top row: images zoomed from 128×128 , 64×64 , and 32×32 pixels to 1024×1024 pixels, using nearest neighbor gray-level interpolation. Bottom row: same sequence, but using bilinear interpolation.

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Some Basic Relationships Between Pixels

0	1	1
0	1	0
0	0	1

0	1	1
0	1	0
0	0	1

0	1	1
0	1	0
0	0	1

FIGURE 2.26 (a) Arrangement of pixels; (b) pixels that are 8-adjacent (shown dashed) to the center pixel; (c) *m*-adjacency.

Neighbors of a Pixel

Adjacency, Connectivity, Regions, and Boundaries

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Two points in an image are 'connected' if a path can be found for which the value of the image function is the same all along the path.

P₁ connected to P₂

P₃ connected to P₄

P₁ not connected to P₃ or P₄

P₂ not connected to P₃ or P₄

P₃ not connected to P₁ or P₂

P₄ not connected to P₁ or P₂

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Alternate distance metrics for digital images

Euclidean Distance

$$= \sqrt{(i-n)^2 + (j-m)^2}$$

City Block Distance

$$= |i-n| + |j-m|$$

Chessboard Distance

$$= \max[|i-n|, |j-m|]$$

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