

Scientific Images



Mars Expedition

Image from NASA/JPL



Consumer Images and Videos



Movie Postproduction



Pirates of the Caribbean: The Curse of the Black Pearl
Crew member visible

Just as Jack says, "On deck, you scabrous dogs," to the very left edge of the screen over Jack's shoulder is a grip crew member with a tan cowboy hat, white short sleeve tee shirt and sunglasses, just standing there looking

www.movie-mistakes.com





From D. King, “The Commissar vanishes”.





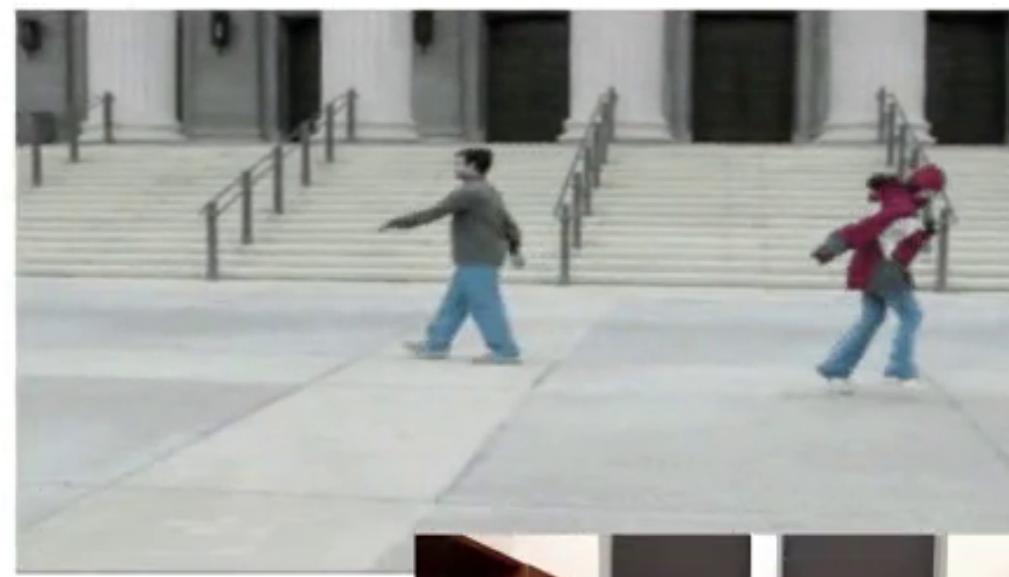
Single frame from a Monty Python movie

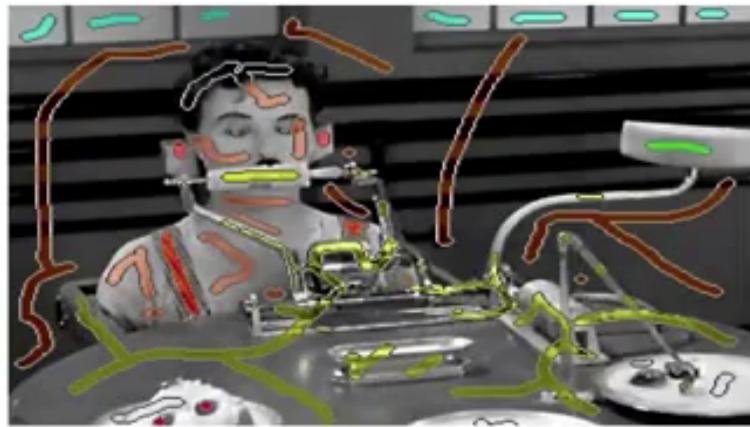




Single frame from a Monty Python movie















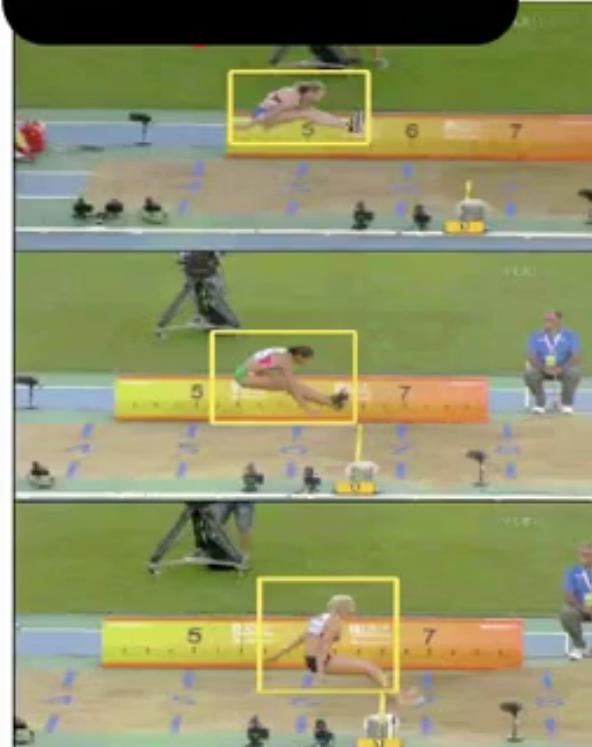
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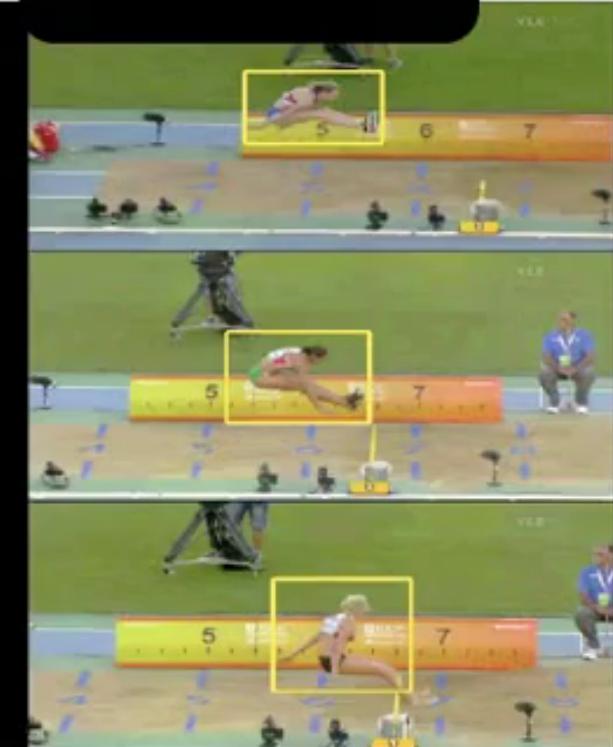


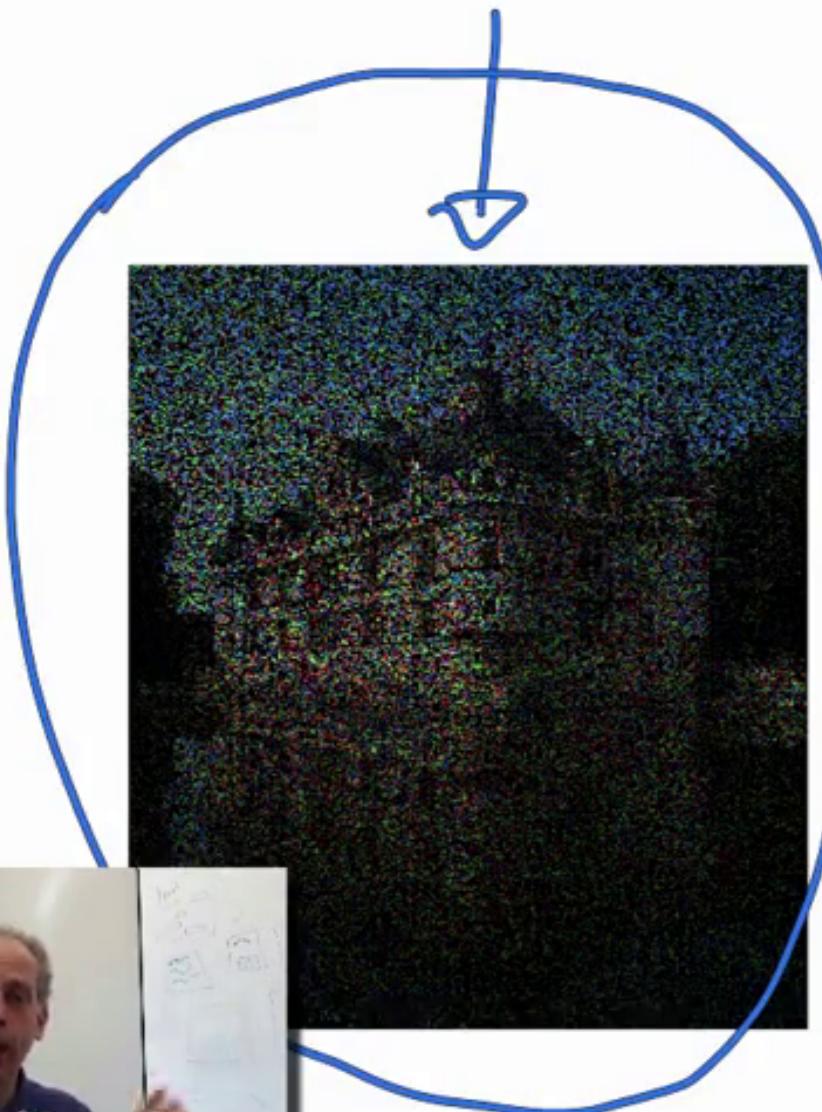


Result



Truth





Motivation



Medical and Biological Images



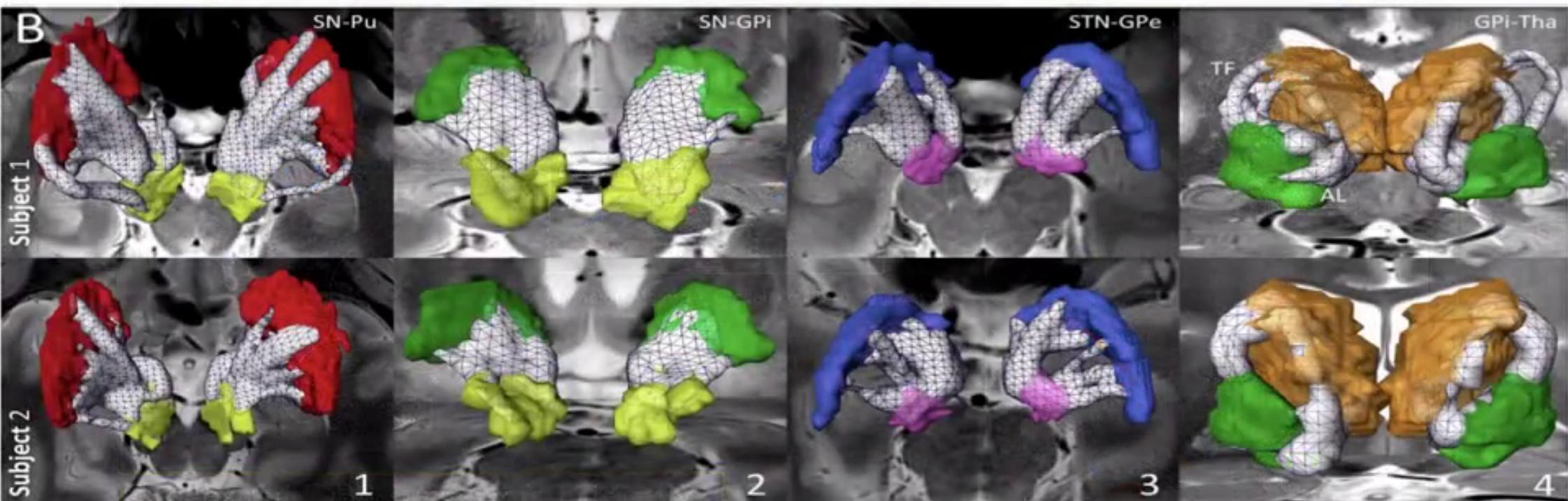
Deep Brain Stimulation (DBS)

The slide contains several diagrams related to DBS:

- A 3D diagram of a human head showing the placement of a DBS electrode (labeled "2") and an implanted stimulator (labeled "1").
- An inset diagram showing a cross-section of the brain tissue. It illustrates the "DBS Electrode" passing through "Fibers of Passage" and "Local Cells", with "Afferent Inputs" also shown.
- Credit to "Cameron McIntyre, Cleveland Clinic Foundation" is displayed below the inset diagram.
- A grayscale MRI scan of a human brain with a red rectangular box highlighting a specific region.
- A detailed anatomical diagram of the basal ganglia and surrounding structures. Labels include: IC (internal capsule), Ca (caudate nucleus), Put (putamen), GPe (globus pallidus, pars externa), VIM (ventral intermediate nucleus of the thalamus), ZI (zona incerta), STN (subthalamic nucleus), and SN (substantia nigra).
- A text box containing the following message:

Successful DBS surgery is critically dependent on precise placement of DBS electrodes into target structures

Specific White Matter Pathways



Nigrostriatal

- Hard to reconstruct
- Consistency
- Some degree of variability between subjects

Nigropallidal

- Involved in PD (loss)



CN



Pu



GPe



GPi

Subthalamopallidal

- Regulate burst activity in BG



SN



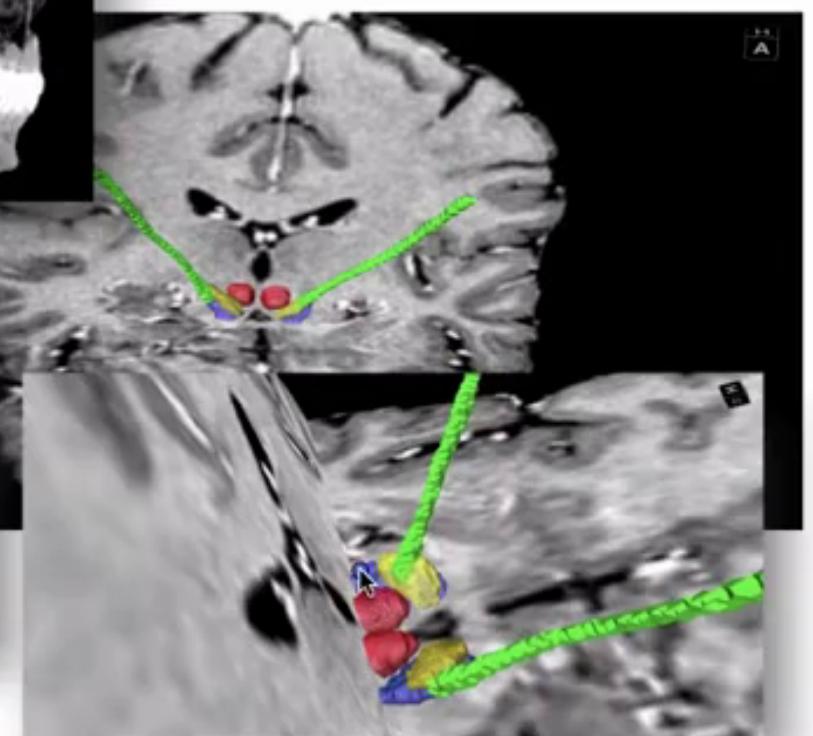
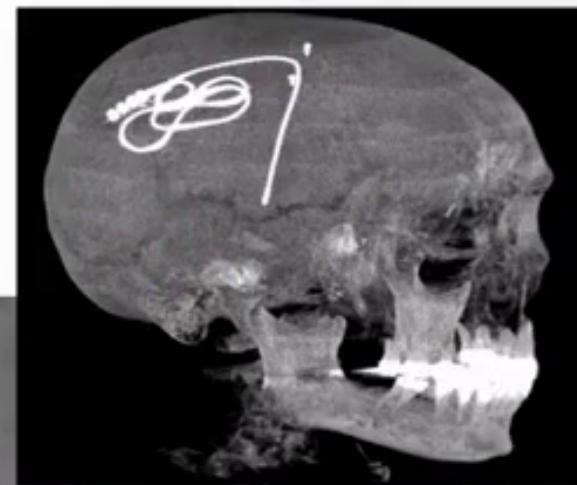
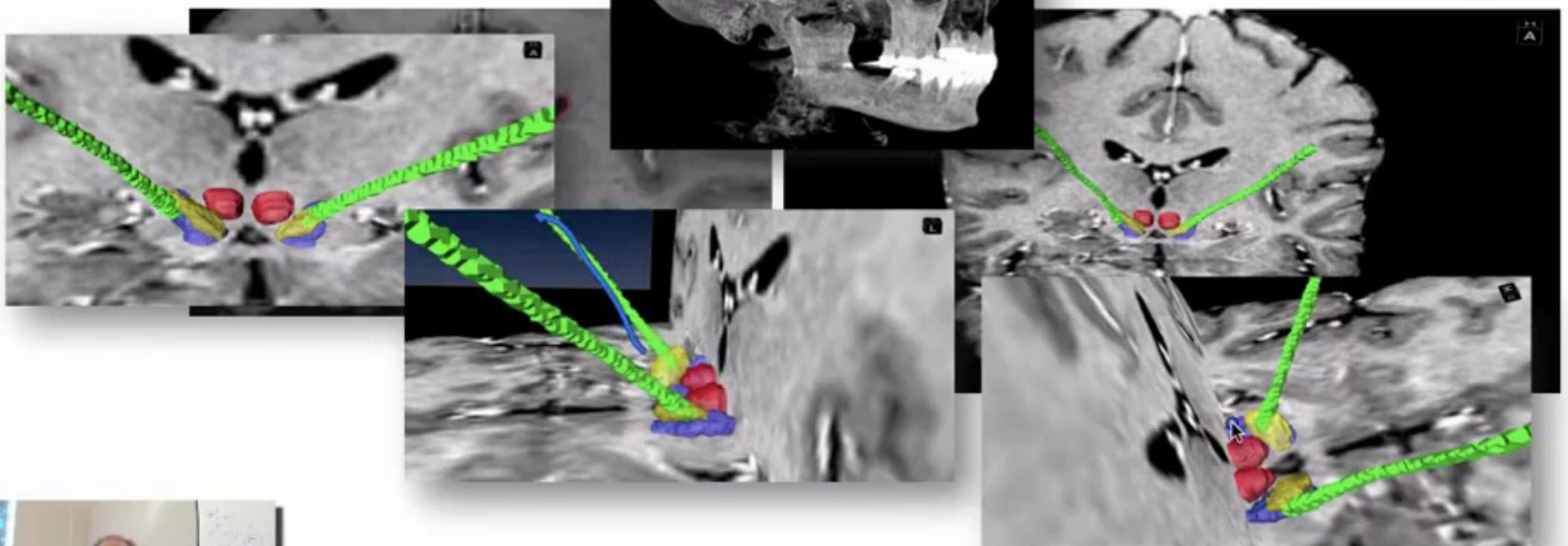
STN



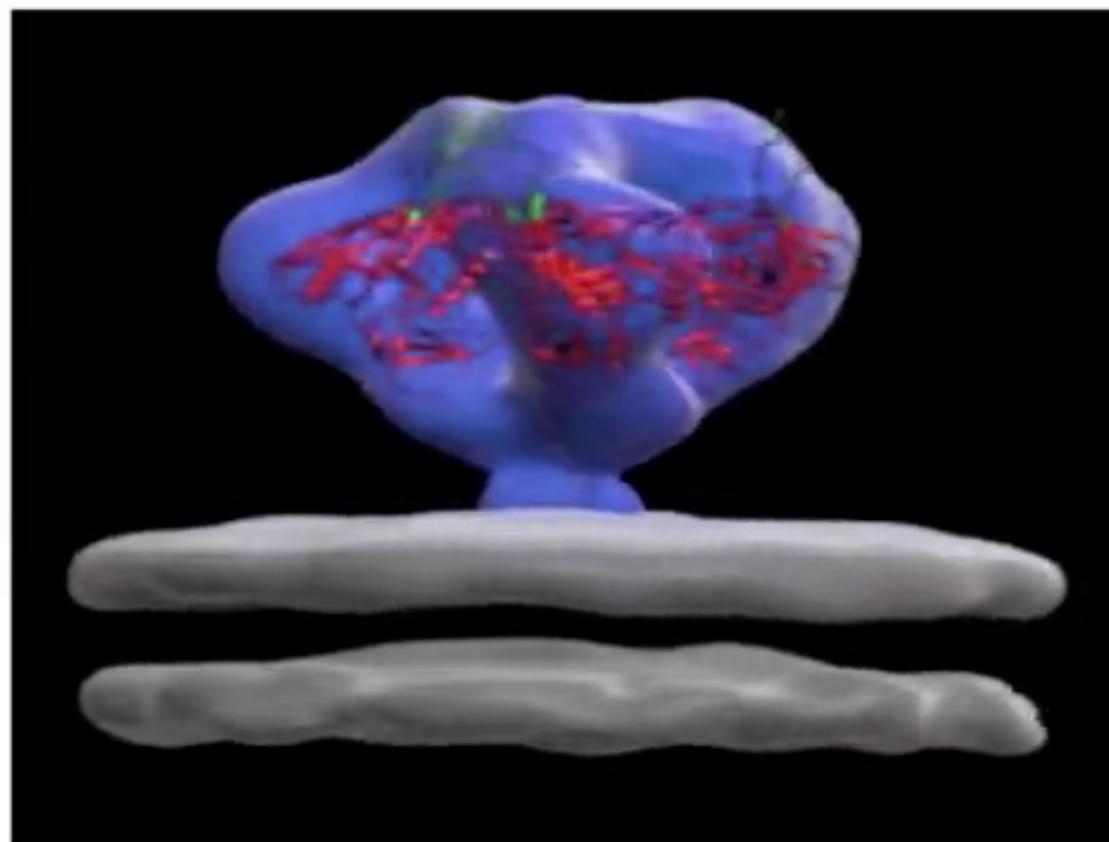
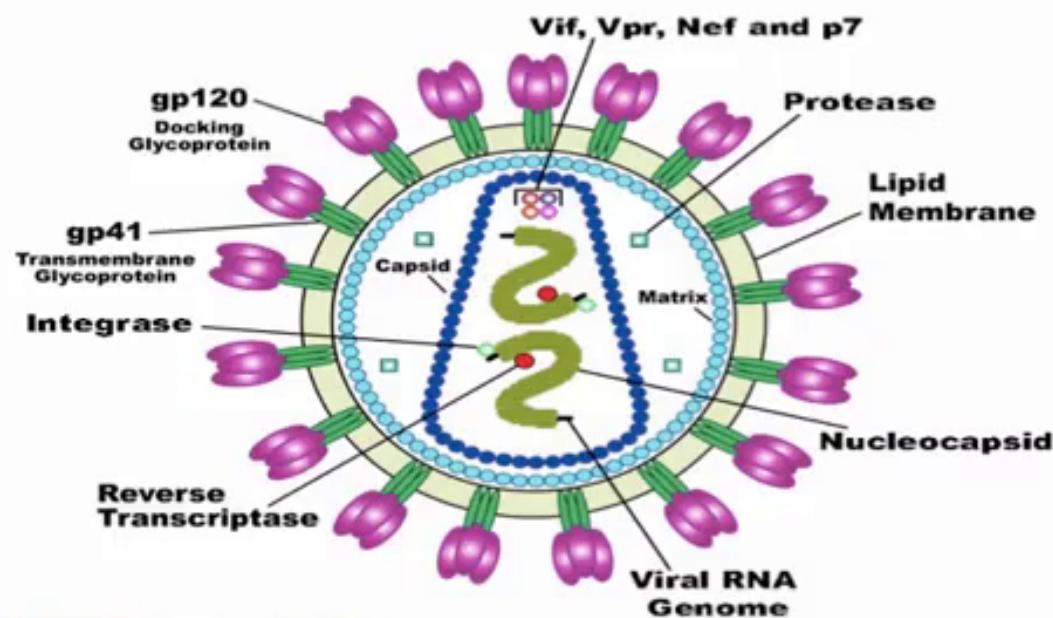
Tha

Pallidothalamic

- Motor control
- Working memory
- To Lpo, Vo, CM/Pf, MD

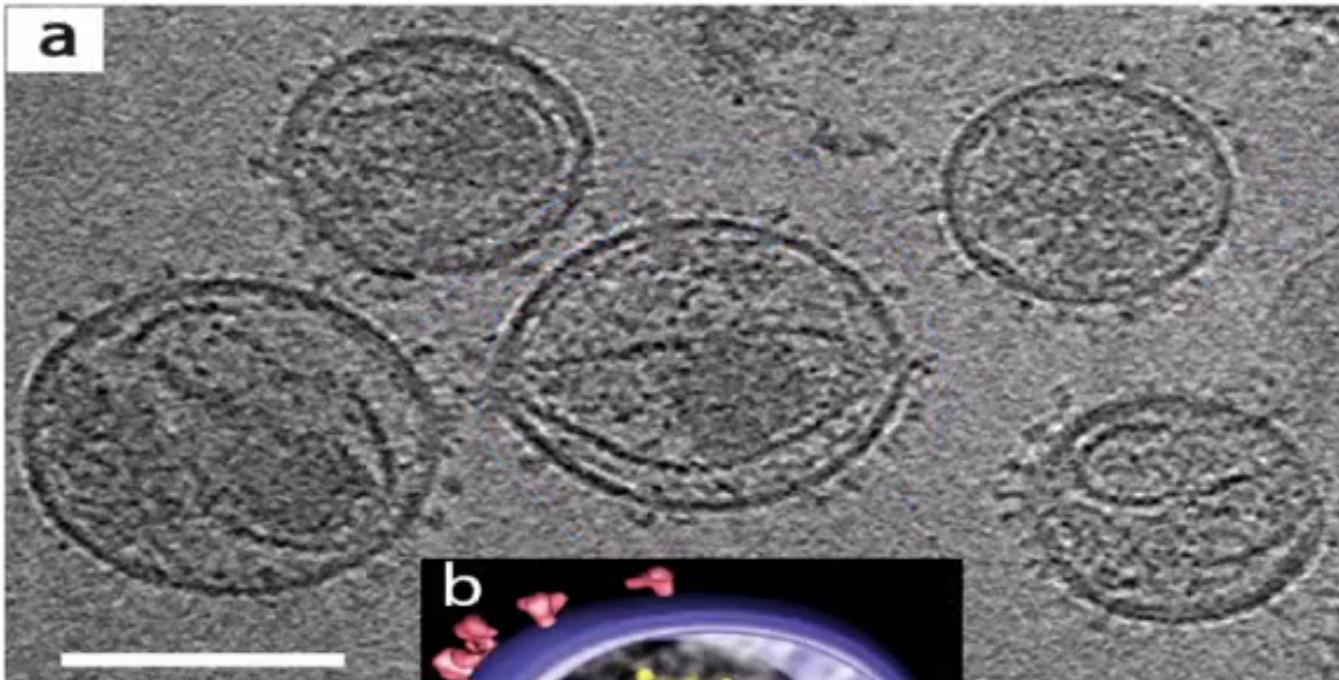


HIV Research

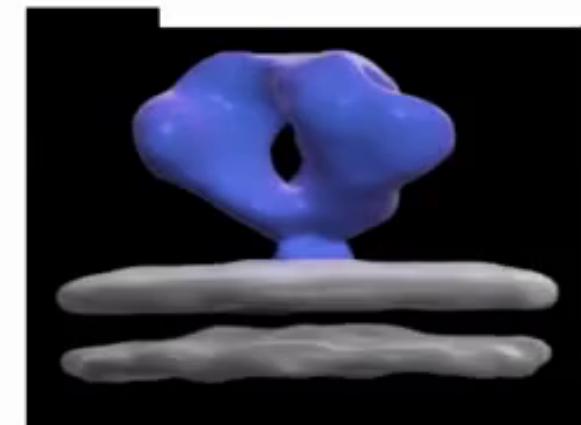
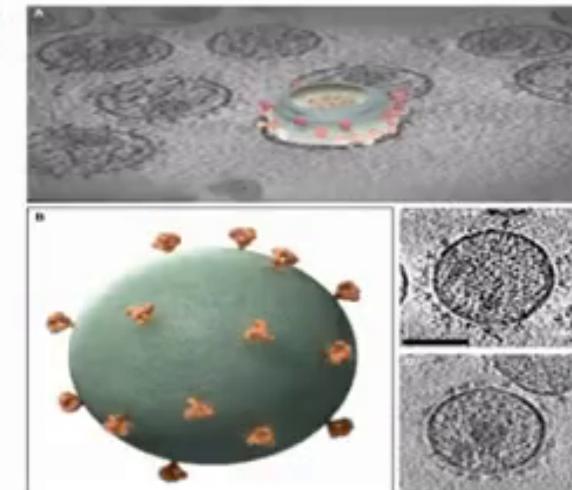
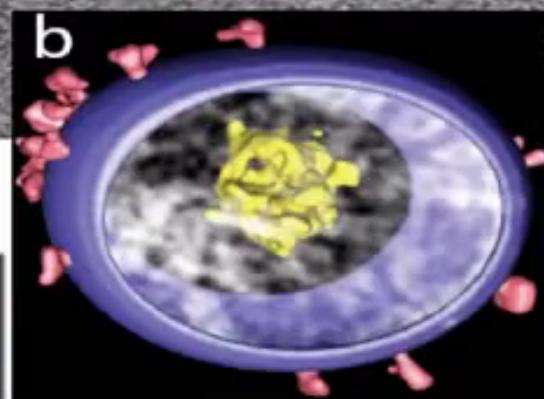


Behind the Scenes

a



b



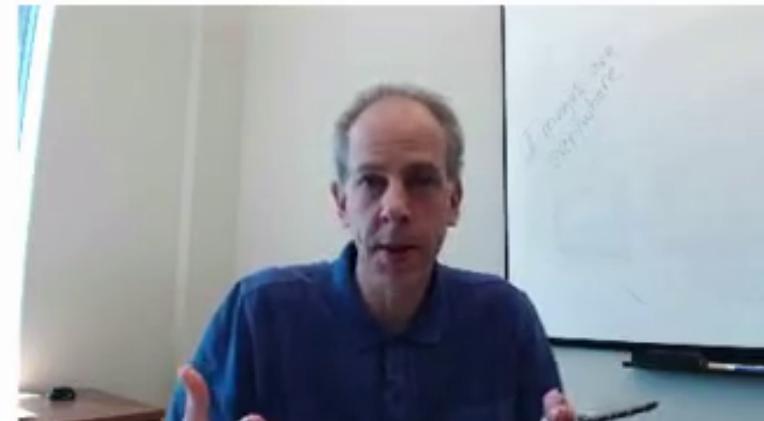
Esophagus Detection for Cardiac Ablation

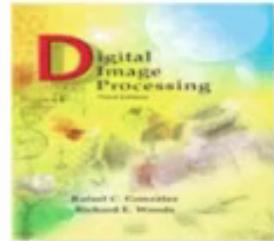


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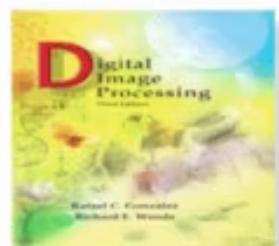
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Chapter 1

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FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9 : 09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)



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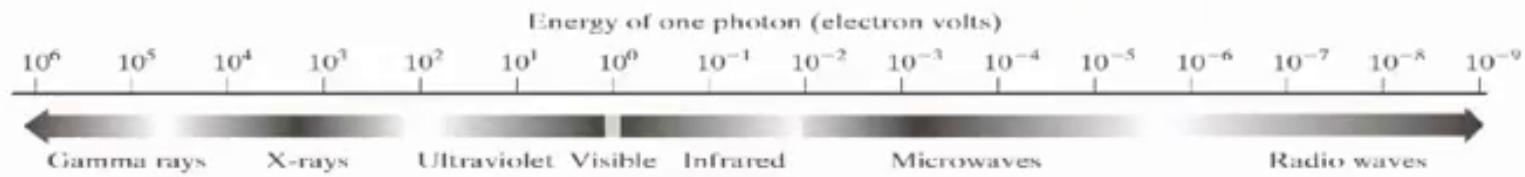
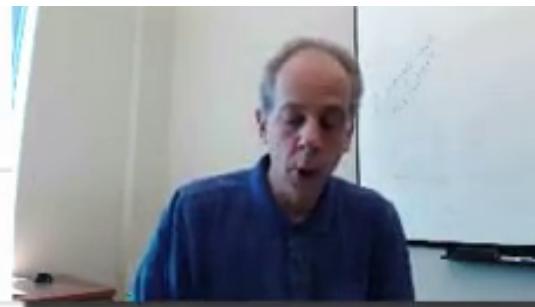
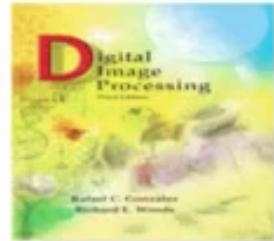


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

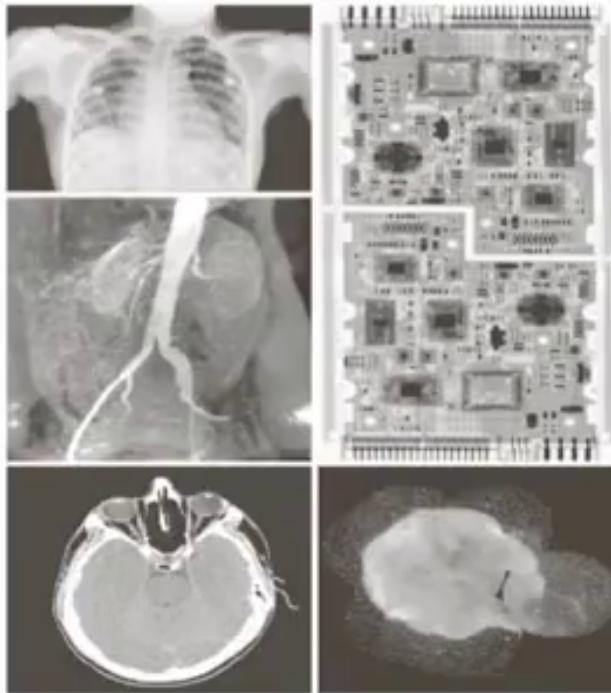
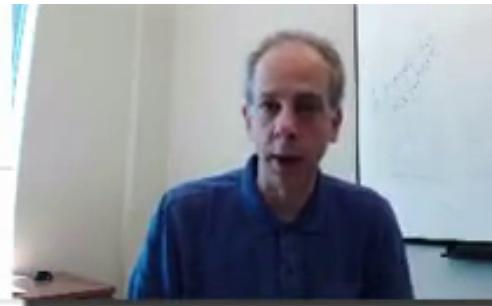


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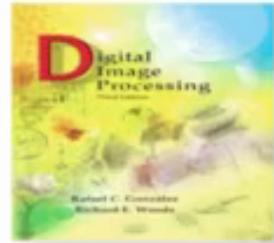
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Chapter 1 Introduction



a
b
c
d
e

FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School; (d) Mr. Joseph E. Pascente, Lixi, Inc.; and (e) NASA.)

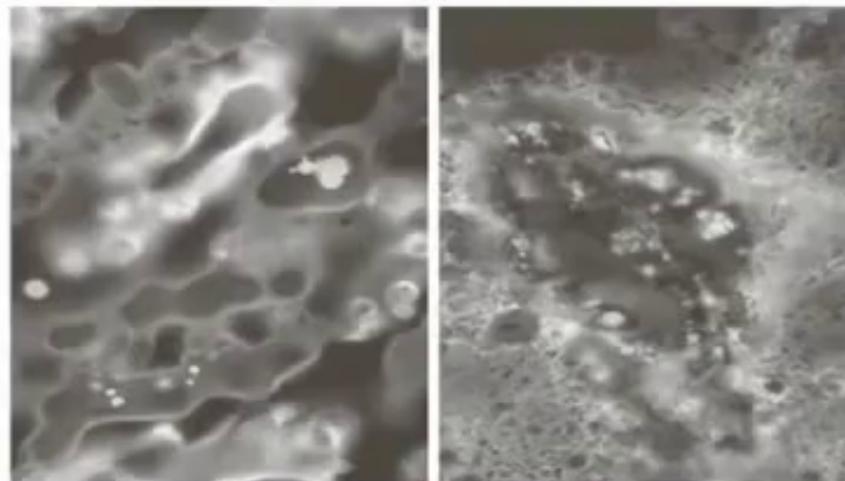
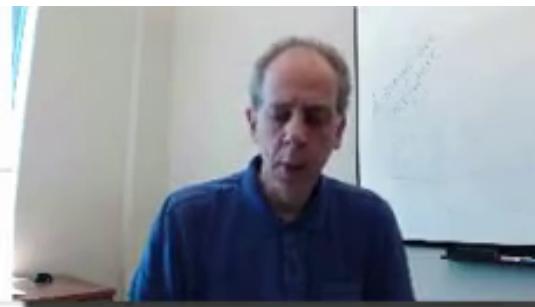


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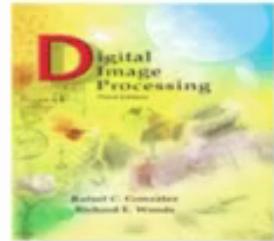
Chapter 1 Introduction



a b
c

FIGURE 1.8
Examples of
ultraviolet
imaging.
(a) Normal corn.
(b) Smut corn.
(c) Cygnus Loop.
(Images courtesy
of (a) and
(b) Dr. Michael
W. Davidson,
Florida State
University,
(c) NASA.)





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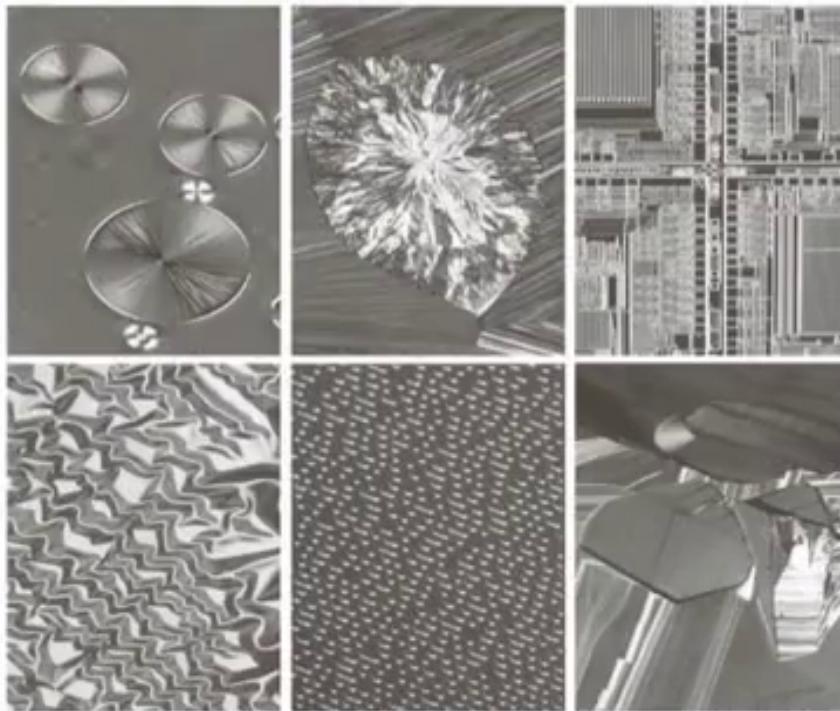
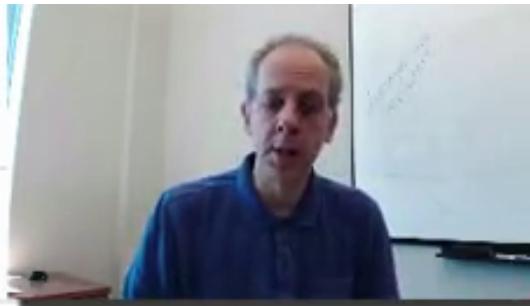
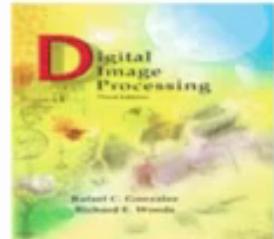


FIGURE 1.9 Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250 \times . (b) Cholesterol—40 \times . (c) Microprocessor—60 \times . (d) Nickel oxide thin film—600 \times . (e) Surface of audio CD—1750 \times . (f) Organic superconductor—450 \times . (Images courtesy of Dr. Michael W. Davidson, Florida State University.)



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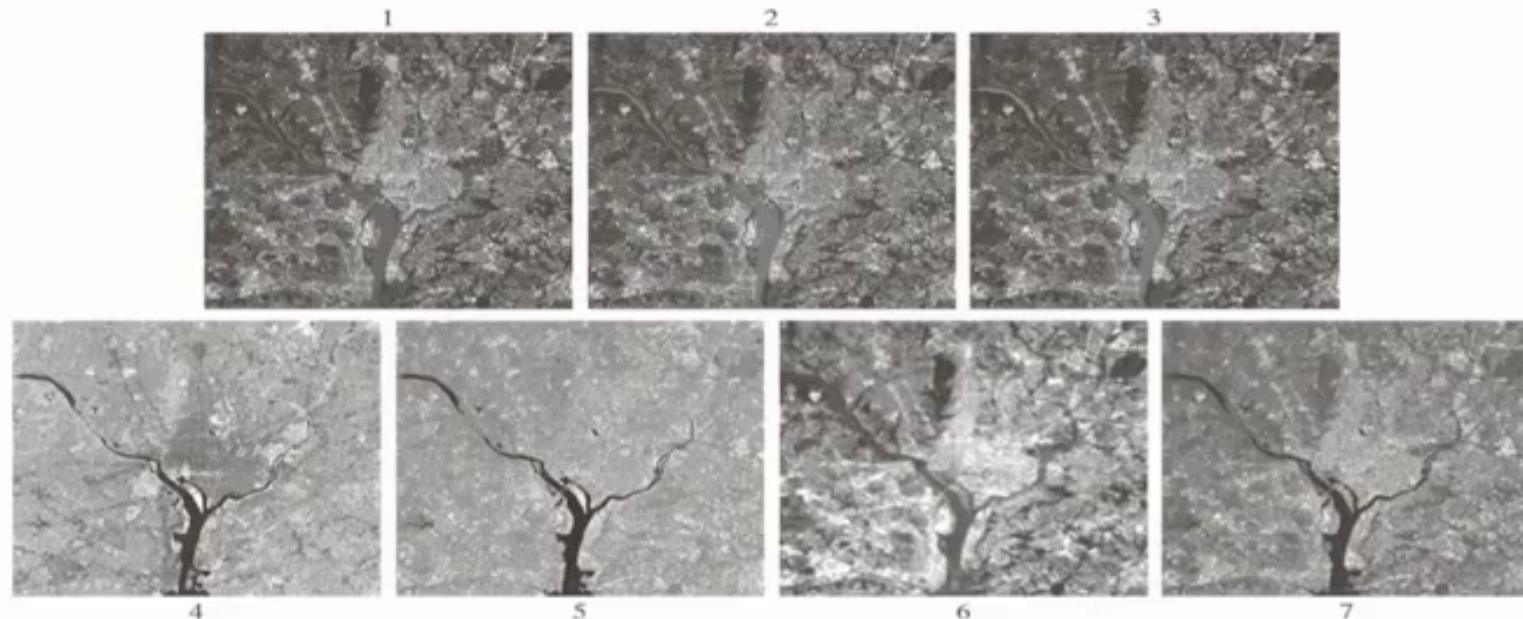
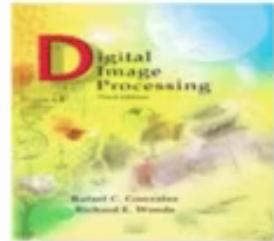


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)



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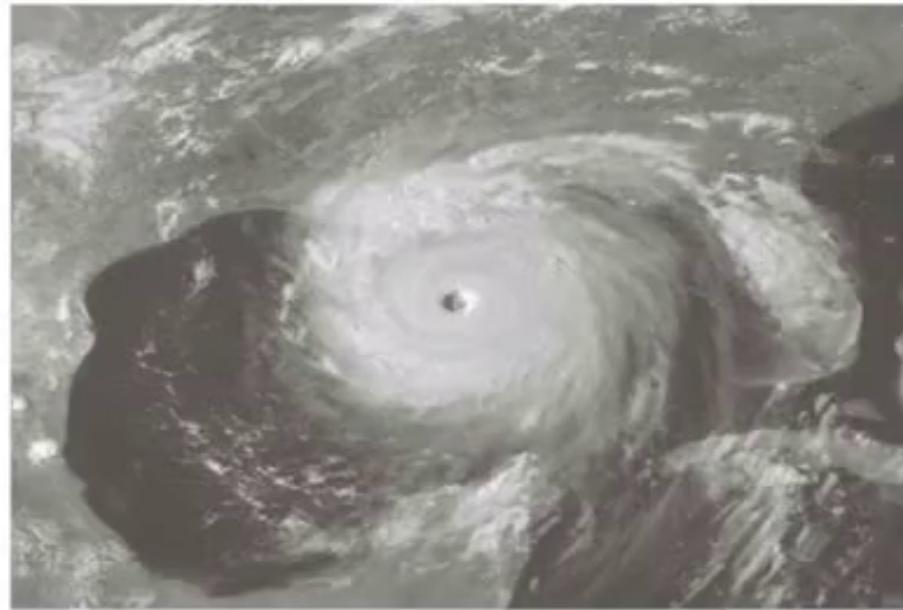
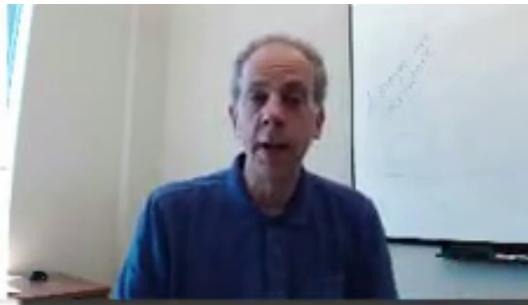
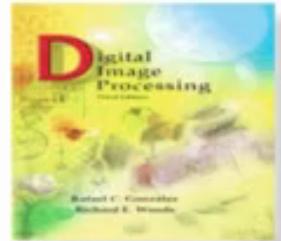


FIGURE 1.11
Satellite image
of Hurricane
Katrina taken on
August 29, 2005.
(Courtesy of
NOAA.)



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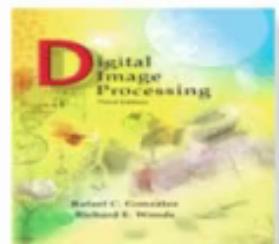
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FIGURE 1.12
Infrared satellite
images of the
Americas. The
small gray map is
provided for
reference.
(Courtesy of
NOAA.)

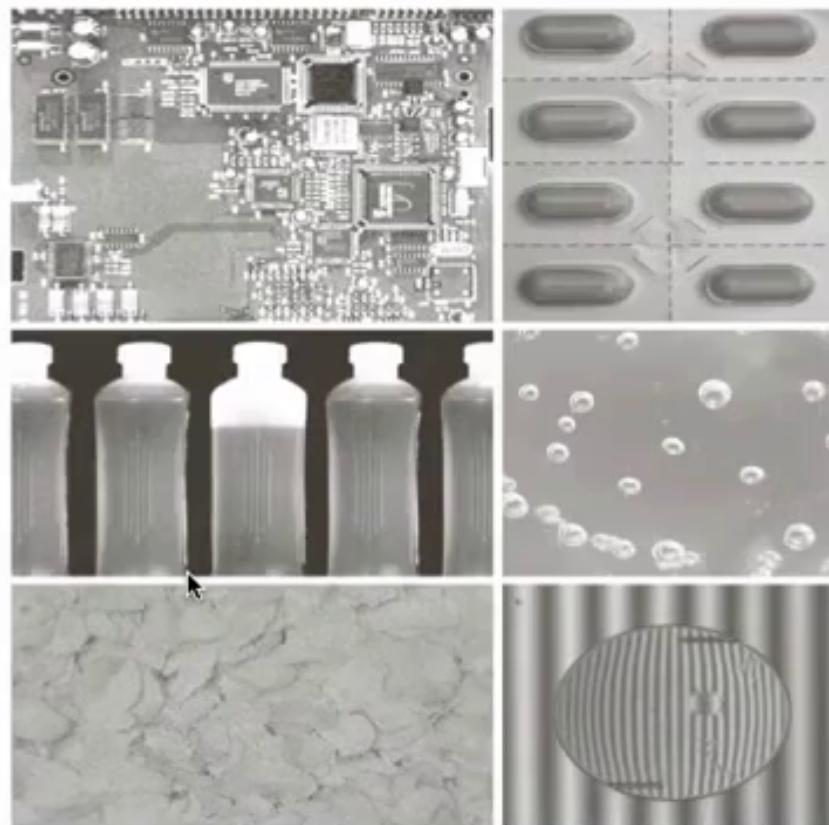
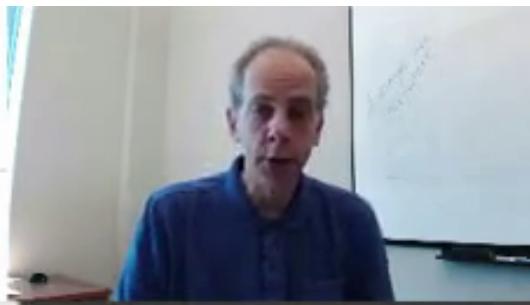


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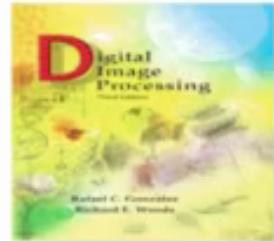
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a b
c d
e f

FIGURE 1.14
Some examples of manufactured goods often checked using digital image processing.
(a) A circuit board controller.
(b) Packaged pills.
(c) Bottles.
(d) Air bubbles in a clear-plastic product.
(e) Cereal.
(f) Image of intraocular implant.
(Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)



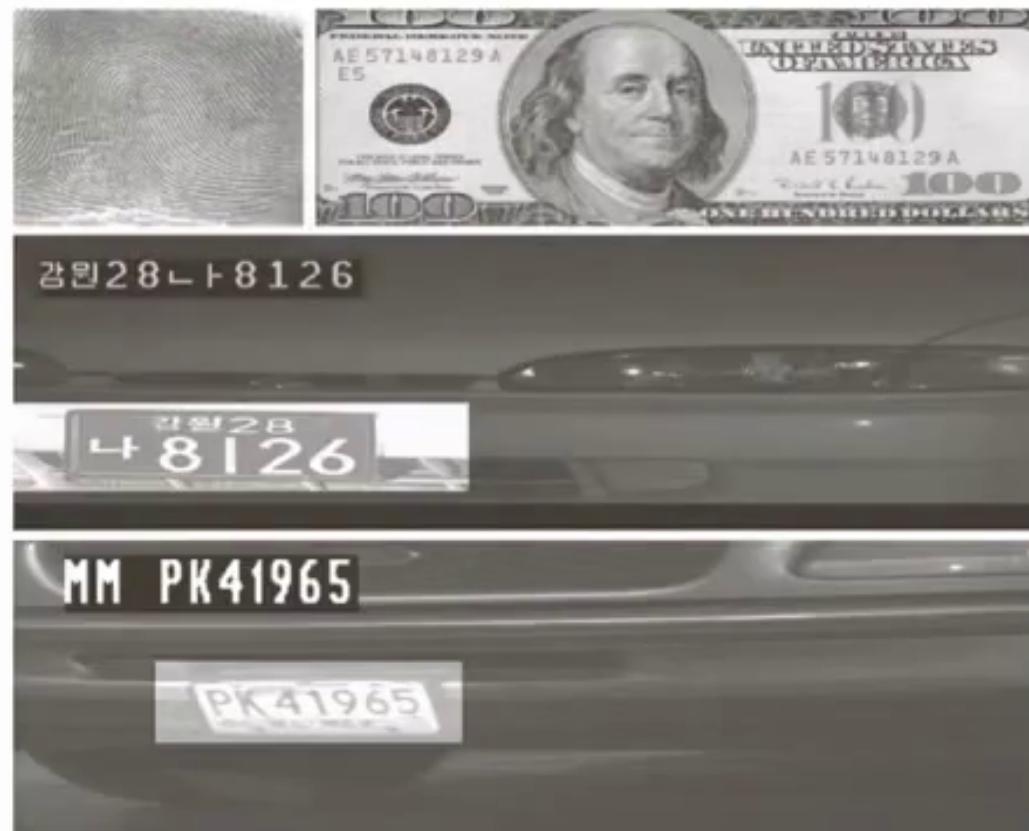
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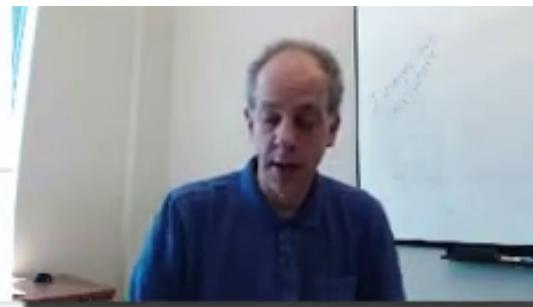
Chapter 1

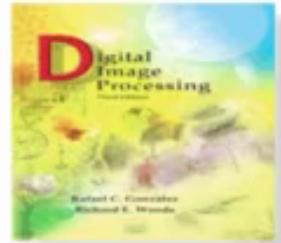
Introduction



a
b
c
d

FIGURE 1.15
Some additional examples of imaging in the visual spectrum.
(a) Thumb print.
(b) Paper currency.
(c) and (d) Automated license plate reading.
(Figure (a) courtesy of the National Institute of Standards and Technology.
Figures (c) and (d) courtesy of Dr. Juan Herrera, Perceptics Corporation.)





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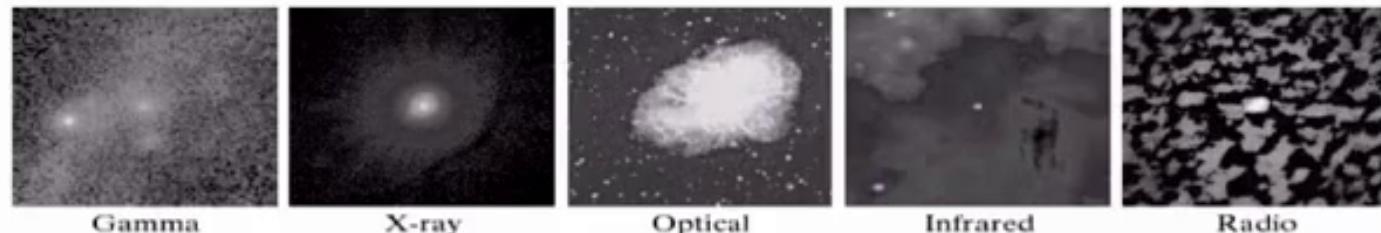
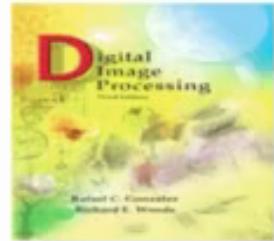


FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum.
(Courtesy of NASA.)

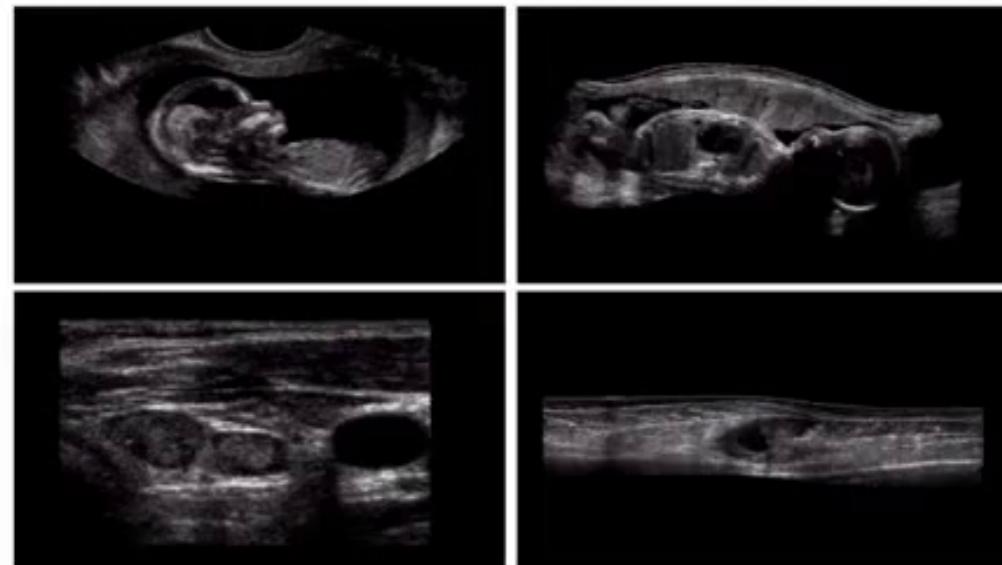


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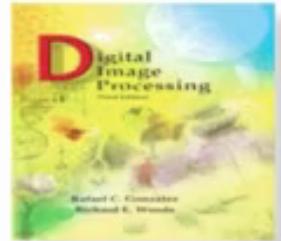
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Chapter 1 Introduction



a b
c d

FIGURE 1.20
Examples of ultrasound imaging. (a) Baby.
(2) Another view of baby.
(c) Thyroids.
(d) Muscle layers showing lesion.
(Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

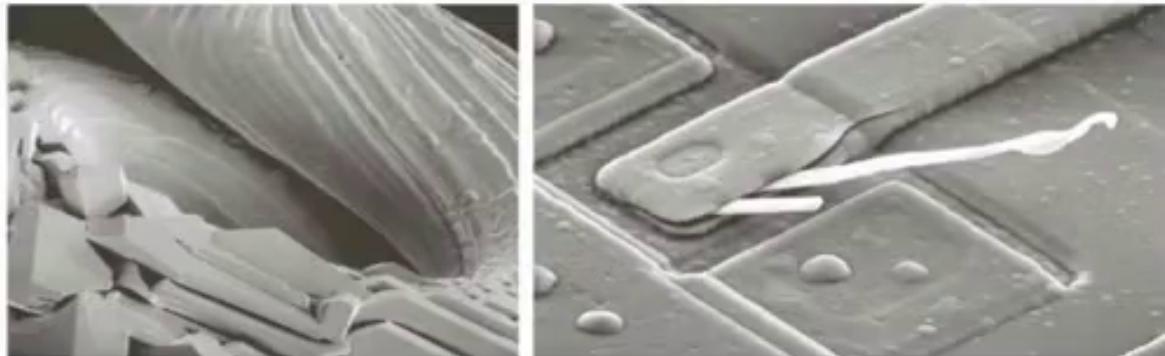
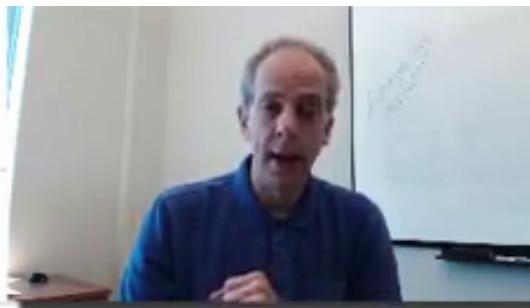


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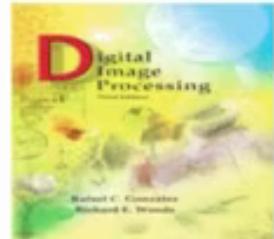
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Chapter 1 Introduction



a b

FIGURE 1.21 (a) 250 \times SEM image of a tungsten filament following thermal failure (note the shattered pieces on the lower left). (b) 2500 \times SEM image of damaged integrated circuit. The white fibers are oxides resulting from thermal destruction. (Figure (a) courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene; (b) courtesy of Dr. J. M. Hudak, McMaster University, Hamilton, Ontario, Canada.)

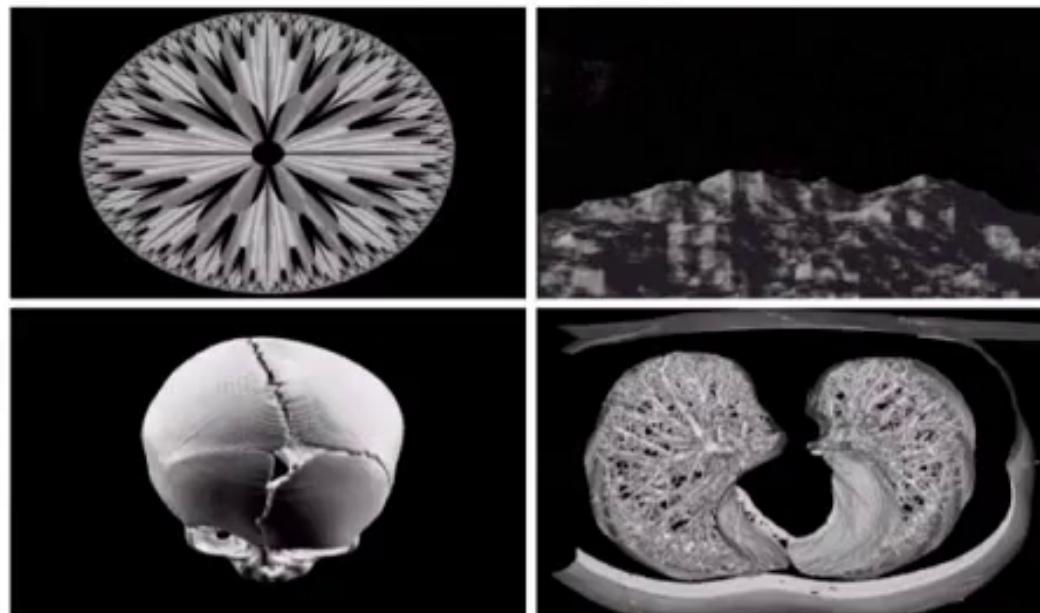


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a b
c d

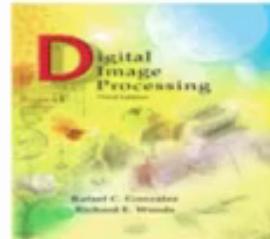
FIGURE 1.22
(a) and (b) Fractal images. (c) and (d) Images generated from 3-D computer models of the objects shown. (Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College, (c) and (d) courtesy of NASA.)



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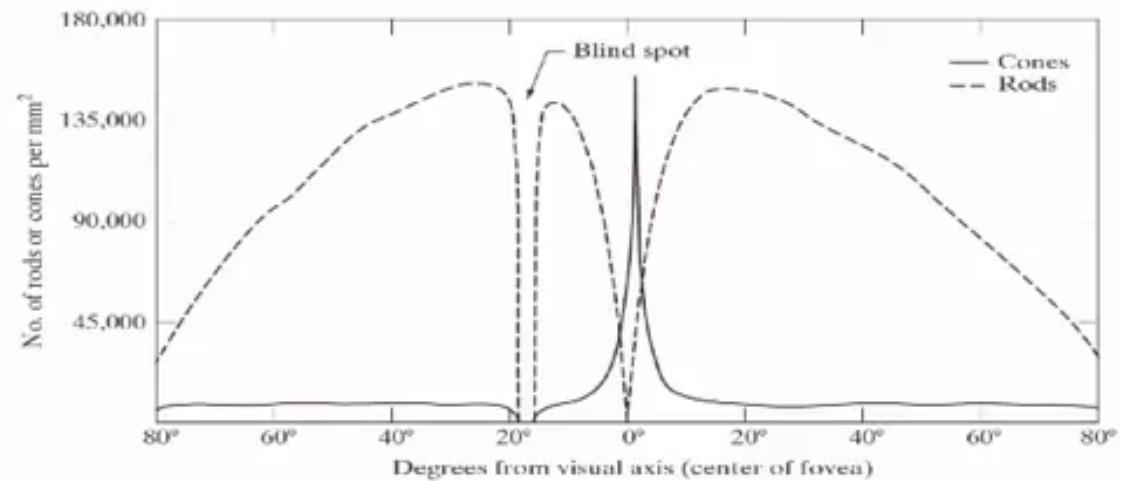
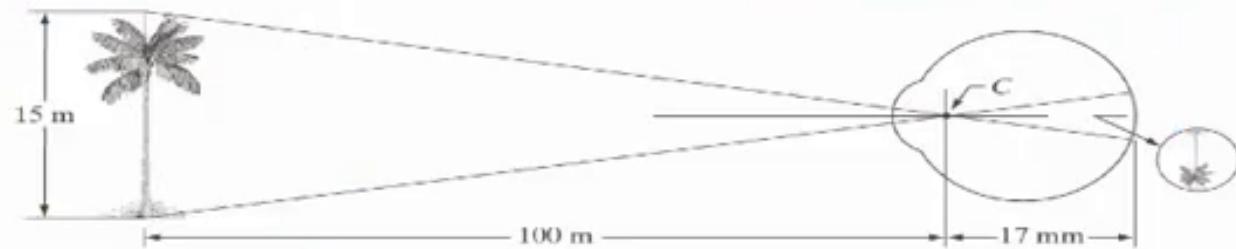
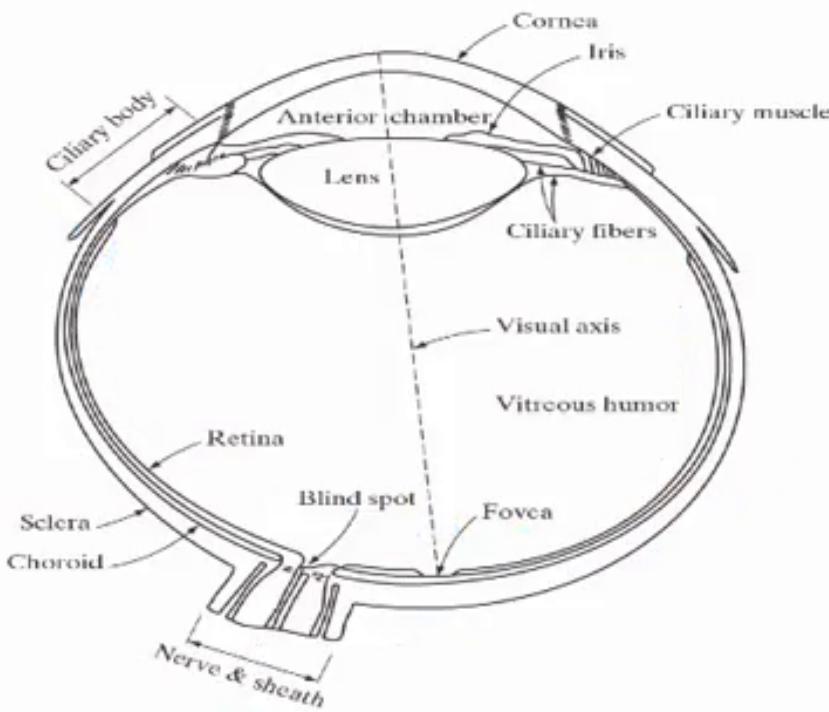
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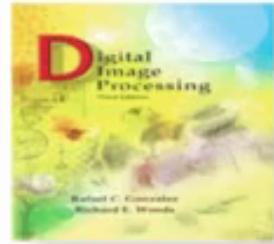
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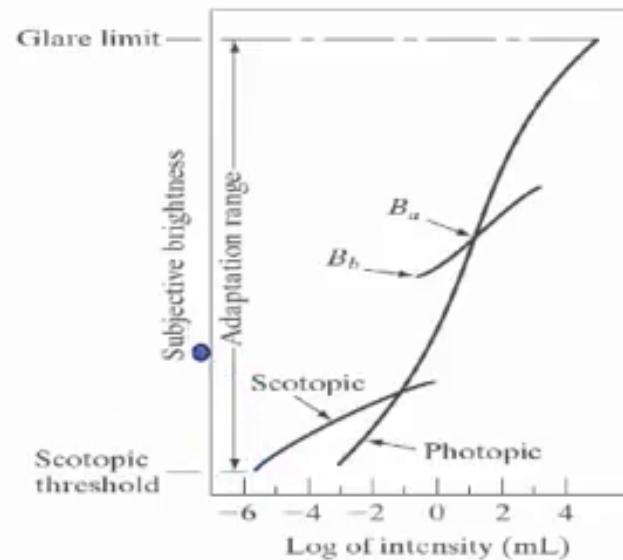
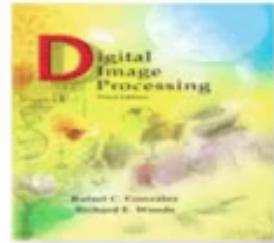


FIGURE 2.4
Range of subjective brightness sensations showing a particular adaptation level.



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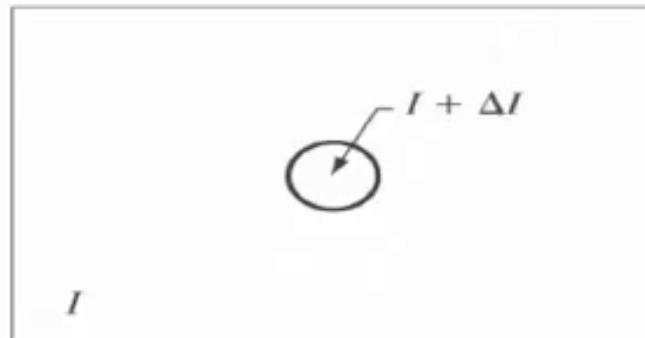
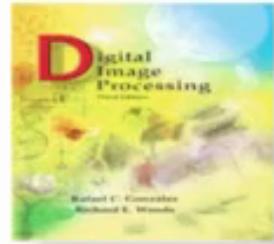


FIGURE 2.5 Basic experimental setup used to characterize brightness discrimination.



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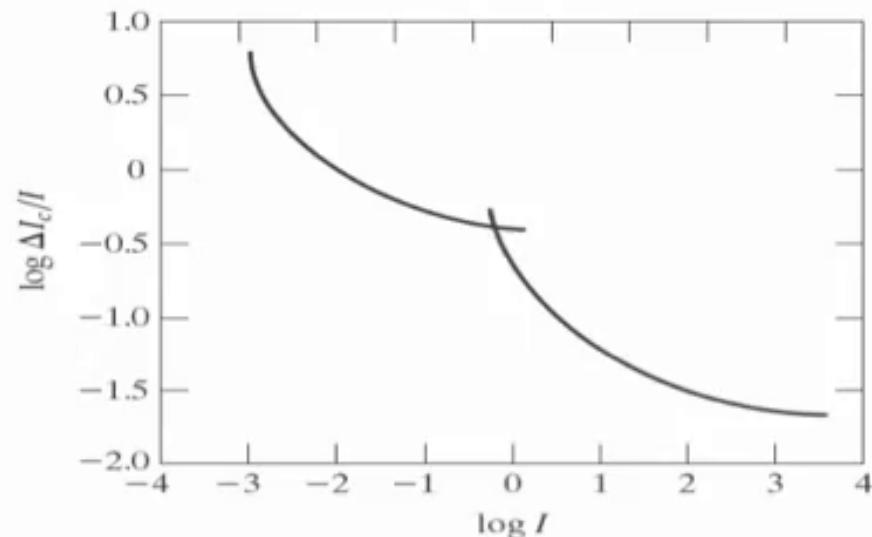
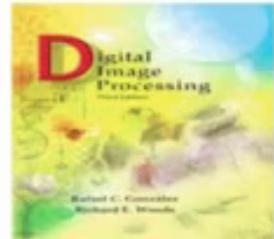


FIGURE 2.6
Typical Weber
ratio as a function
of intensity.

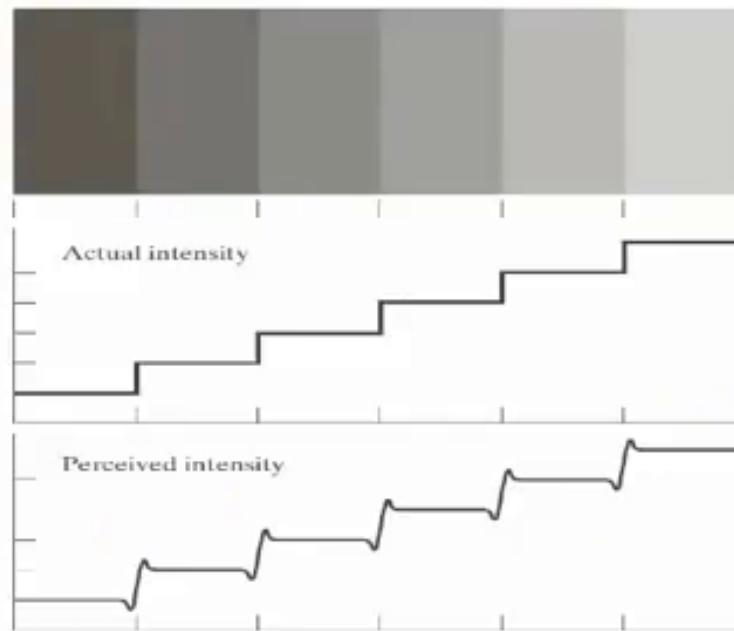


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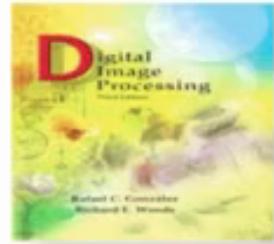
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Chapter 2 Digital Image Fundamentals



a
b
c

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

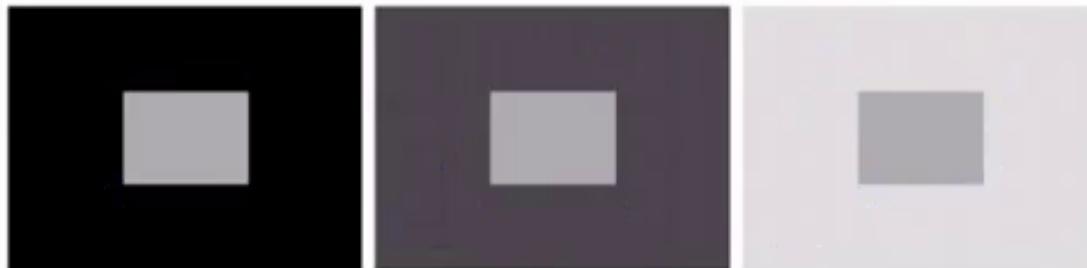


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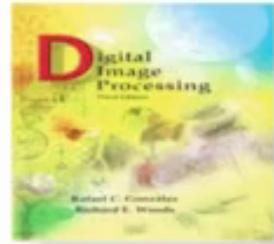
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a b c

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.



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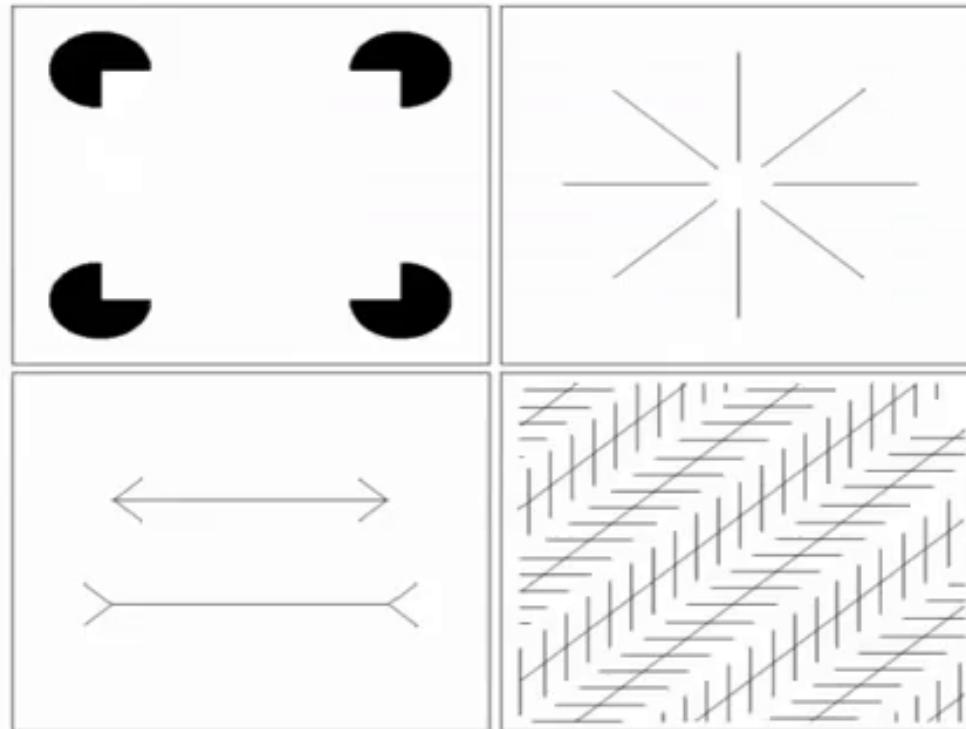
www.ImageProcessingPlace.com

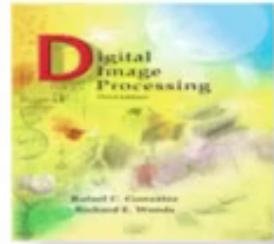
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a
b
c
d

FIGURE 2.9 Some well-known optical illusions.





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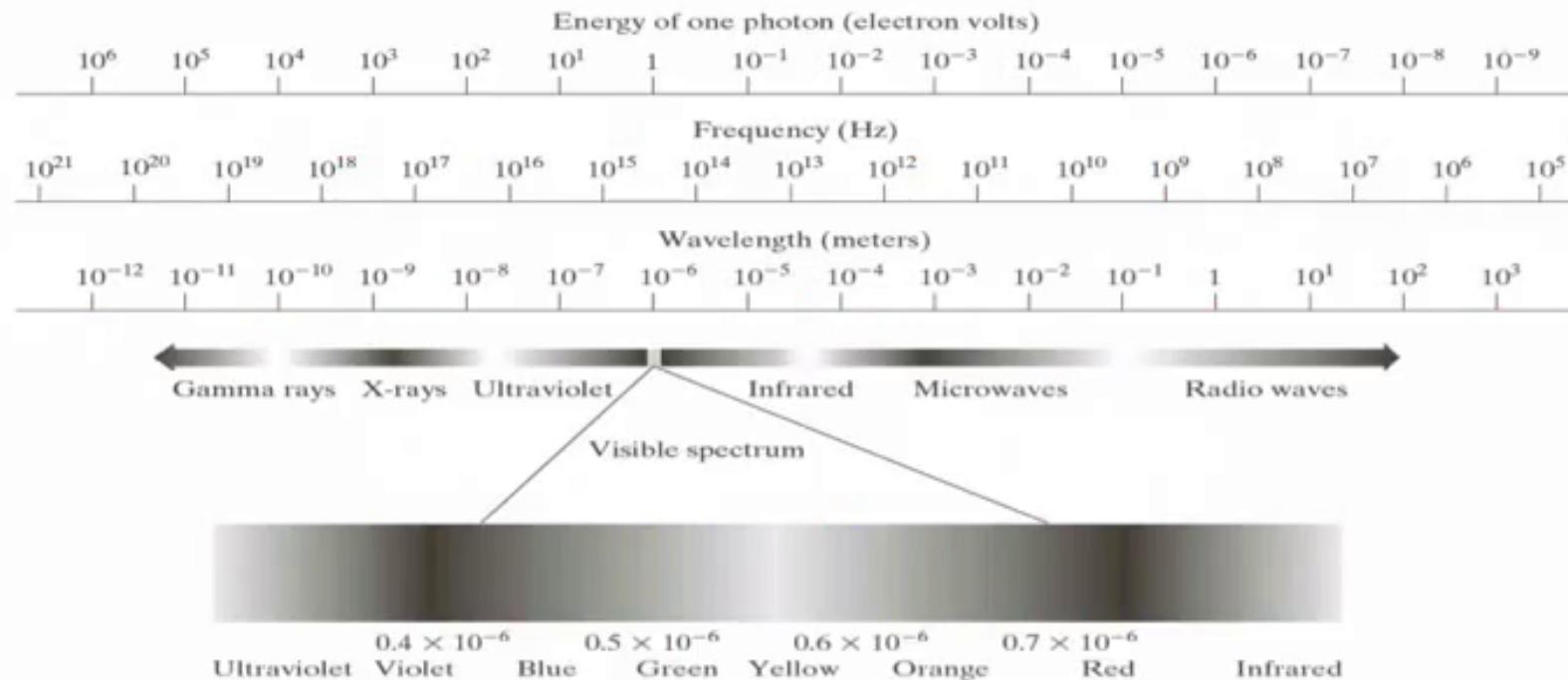
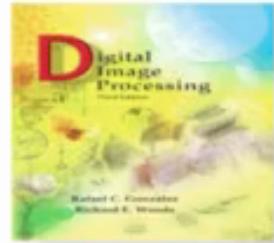


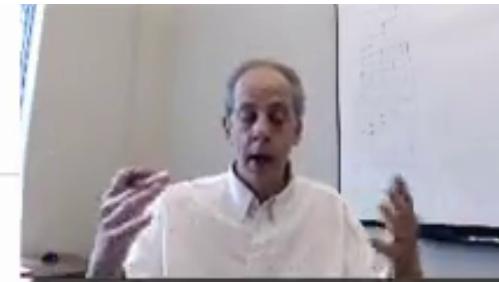
FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.



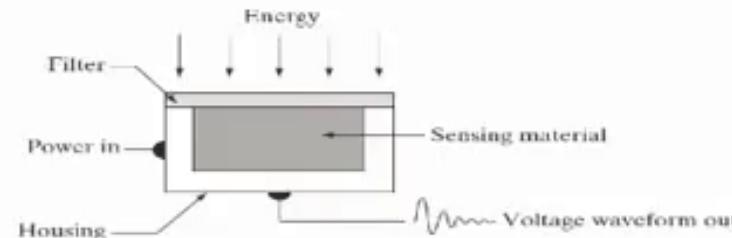
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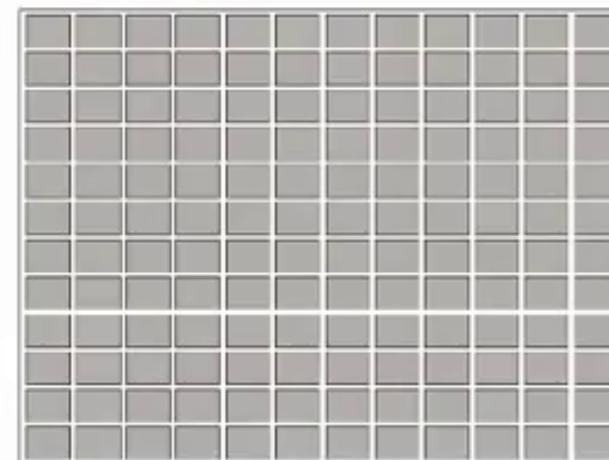


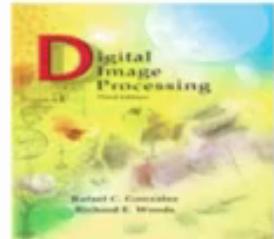
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a
b
c

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





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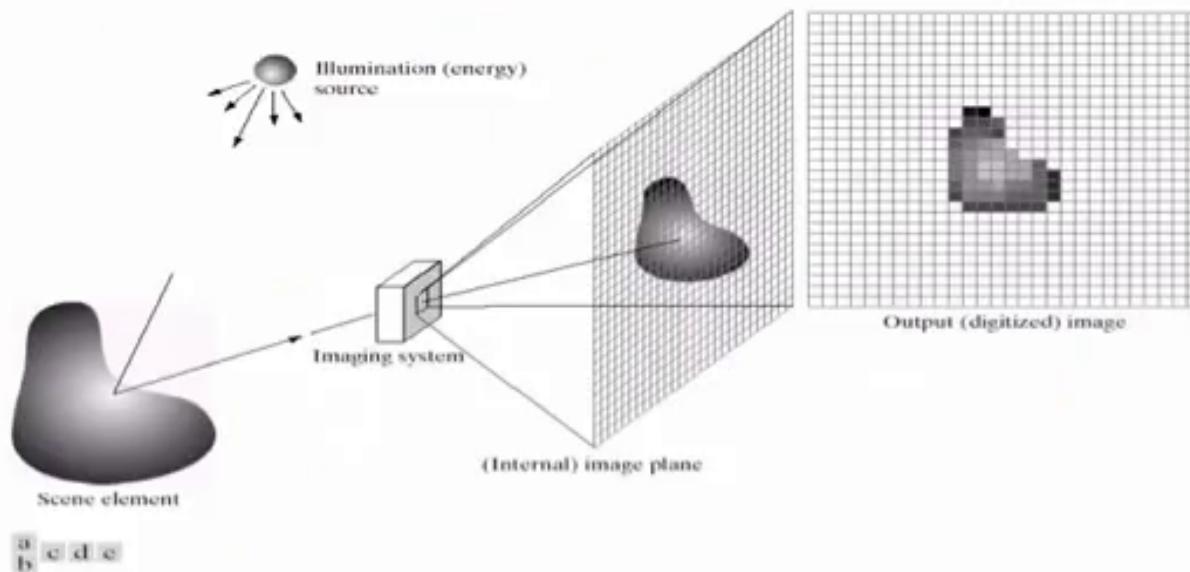
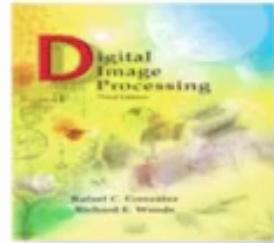


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.



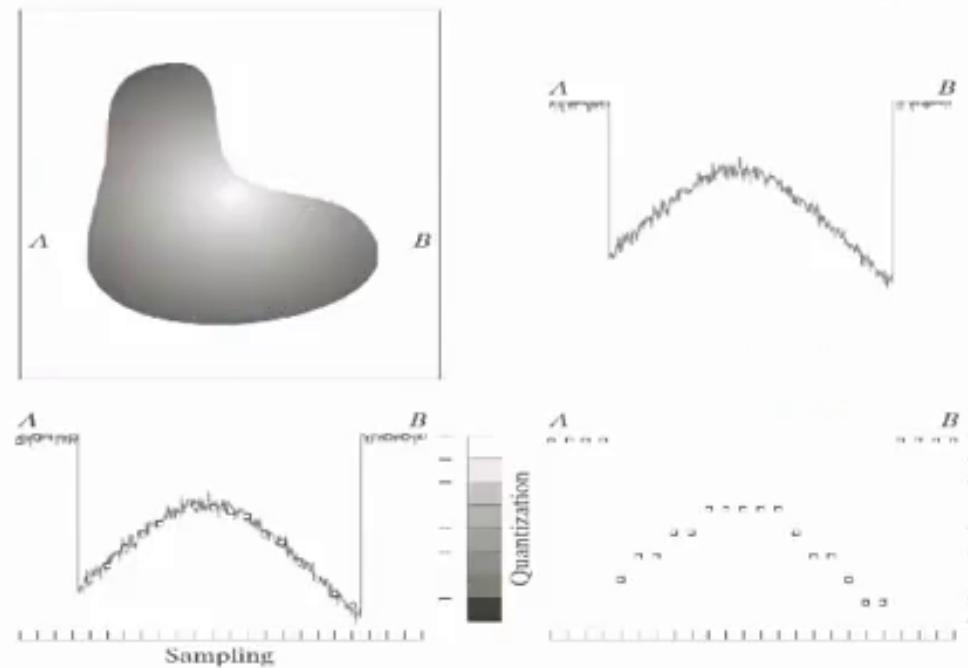
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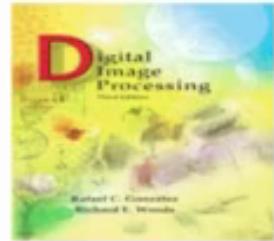


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a b
c d

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.



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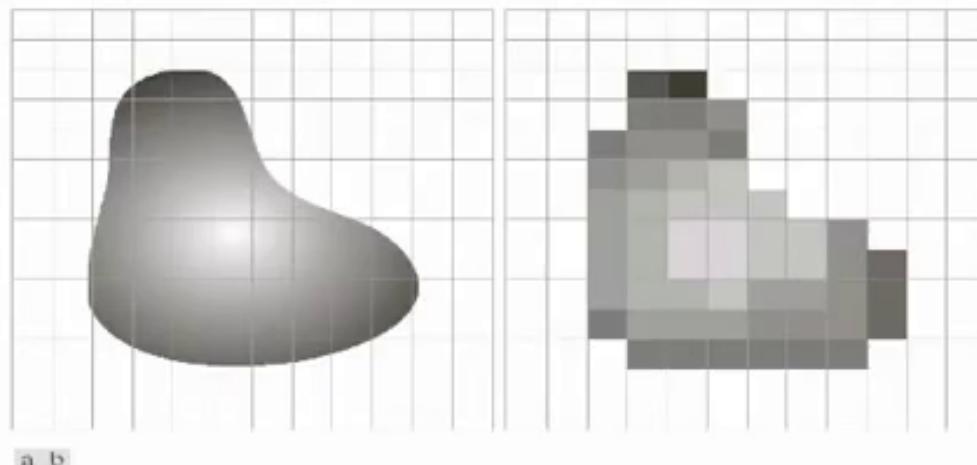
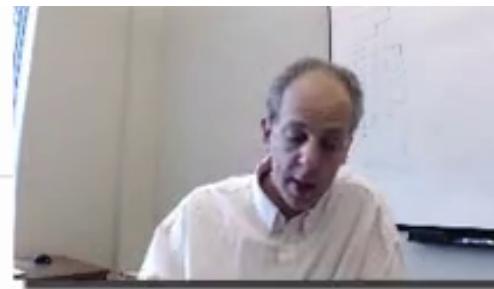
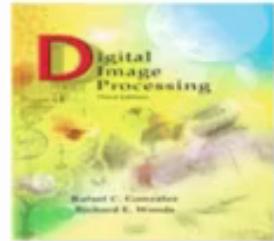


FIGURE 2.17 (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.



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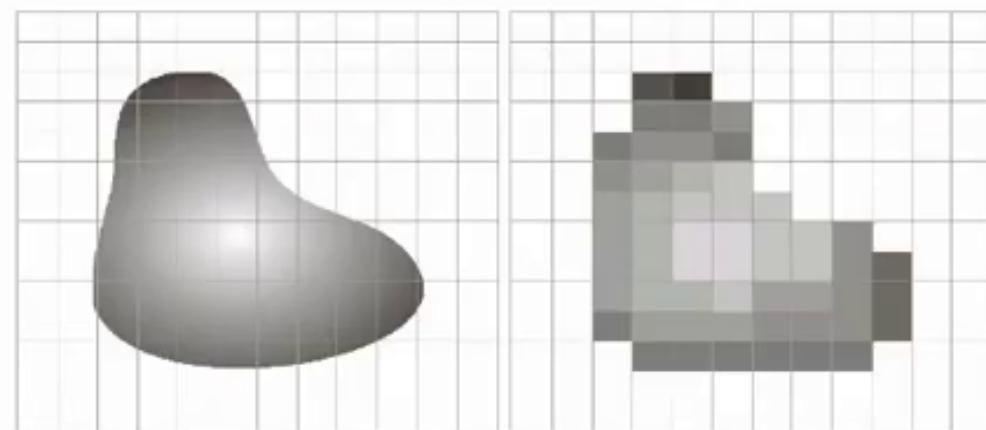
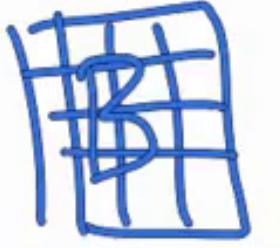
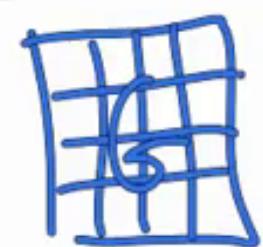
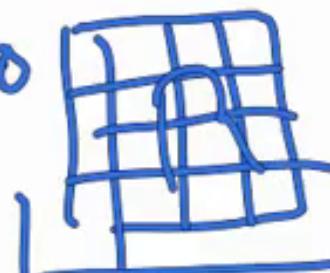
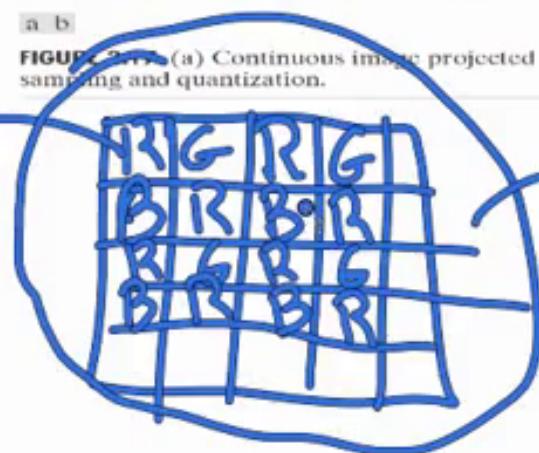
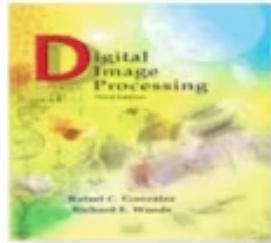


FIGURE 1.1 (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.

RGB



Red R
Green G
Blue B
RGB



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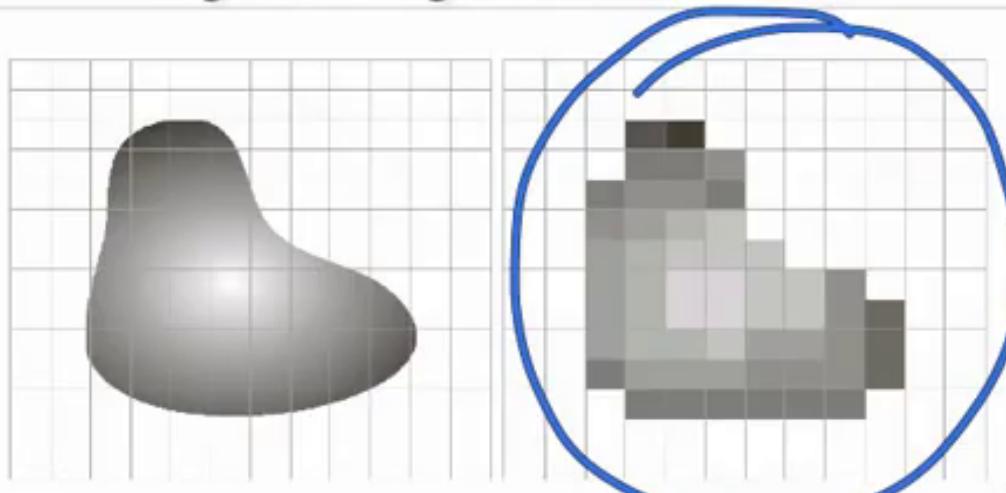


FIGURE 2.17 (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.

RGB

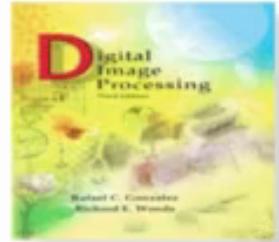
$30 \times (\text{RGB})$

$$\underline{30 \times 3 = 90}$$

90

512×512

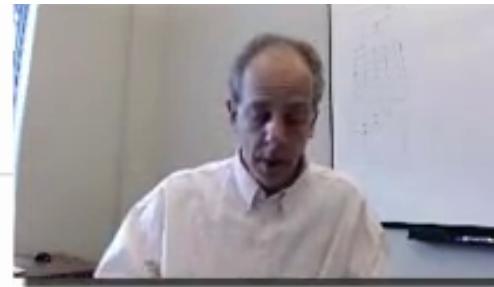
8 bits



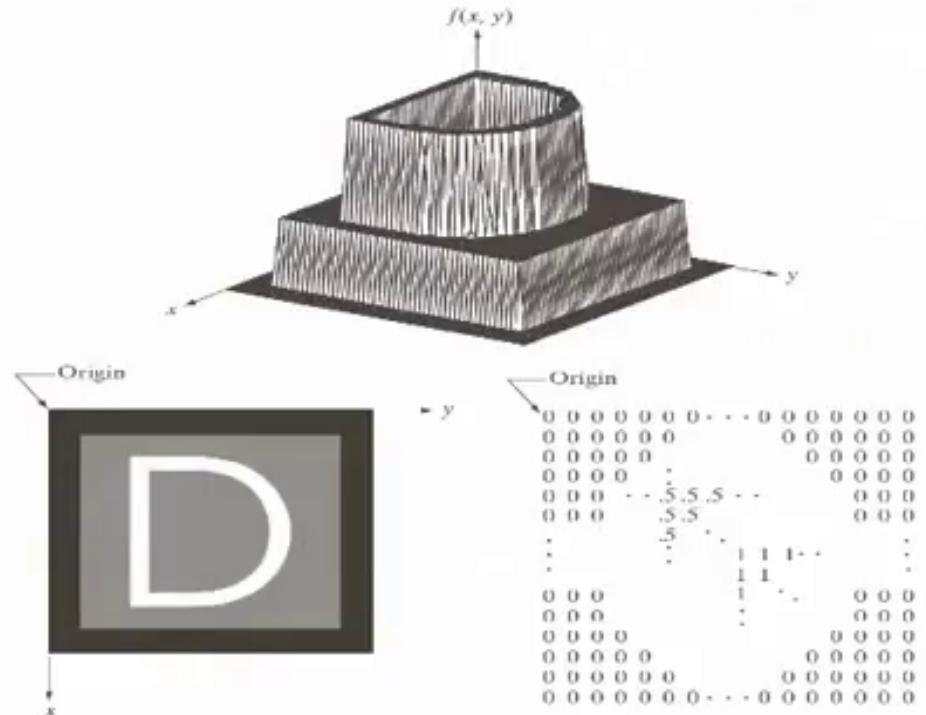
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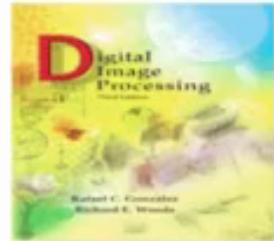


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a
b c

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).



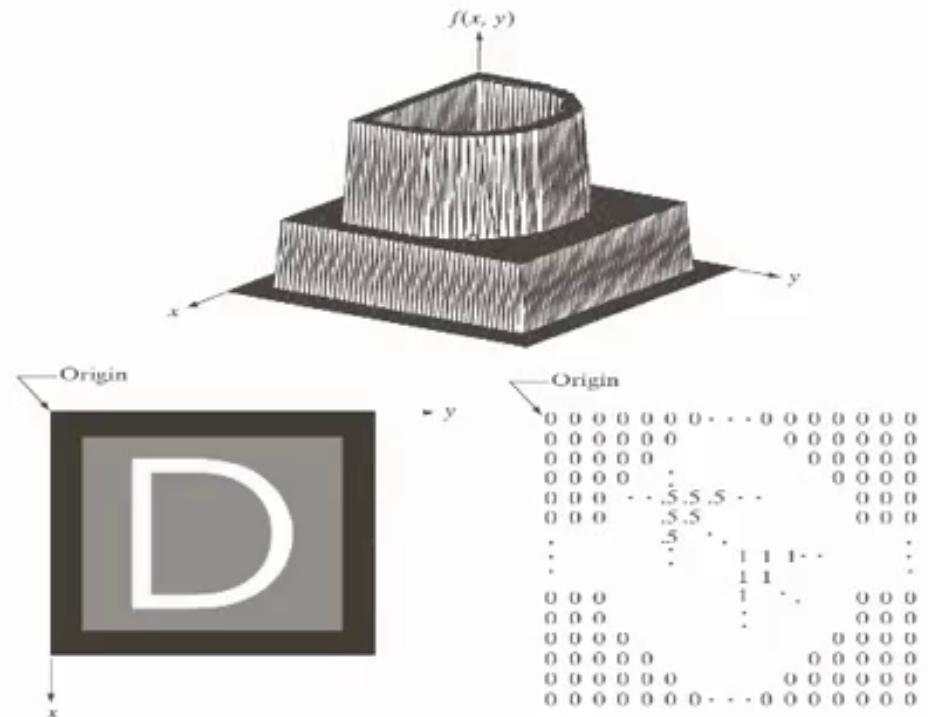
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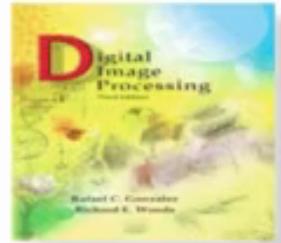
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a
b c

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).

8 bits
0 = black
255 = white



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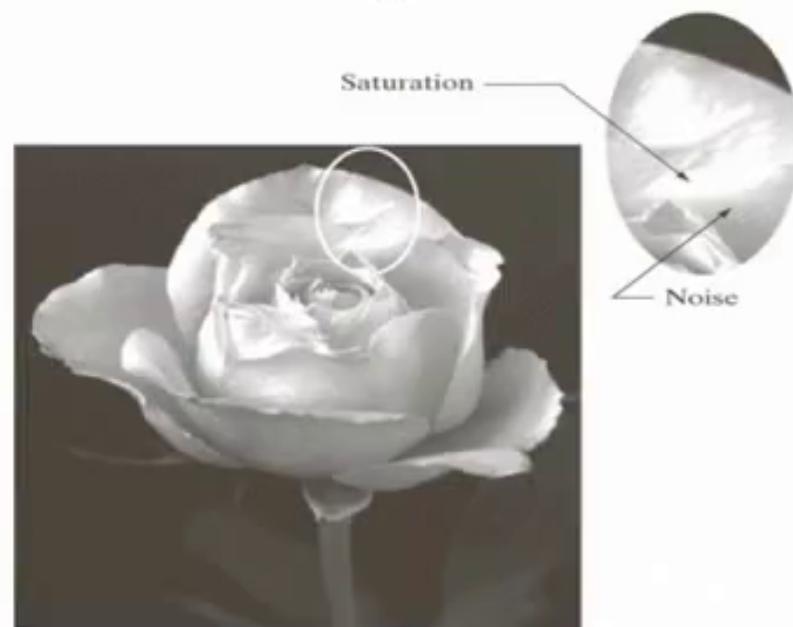
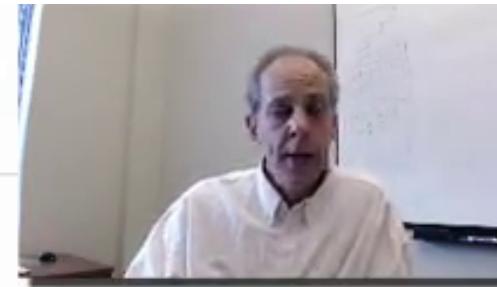
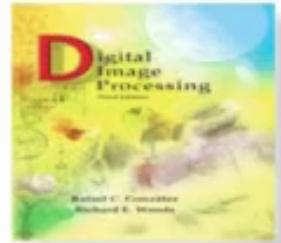


FIGURE 2.19 An image exhibiting saturation and noise. Saturation is the highest value beyond which all intensity levels are clipped (note how the entire saturated area has a high, *constant* intensity level). Noise in this case appears as a grainy texture pattern. Noise, especially in the darker regions of an image (e.g., the stem of the rose) masks the lowest detectable true intensity level.



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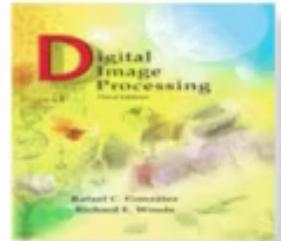
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FIGURE 2.20 Typical effects of reducing spatial resolution. Images shown at: (a) 1250 dpi, (b) 300 dpi, (c) 150 dpi, and (d) 72 dpi. The thin black borders were added for clarity. They are not part of the data.

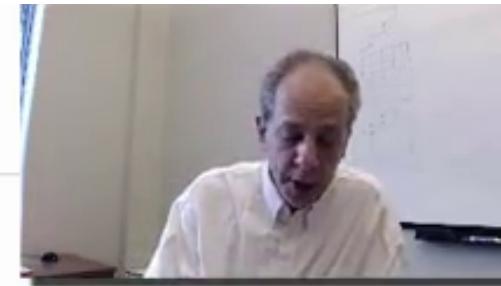


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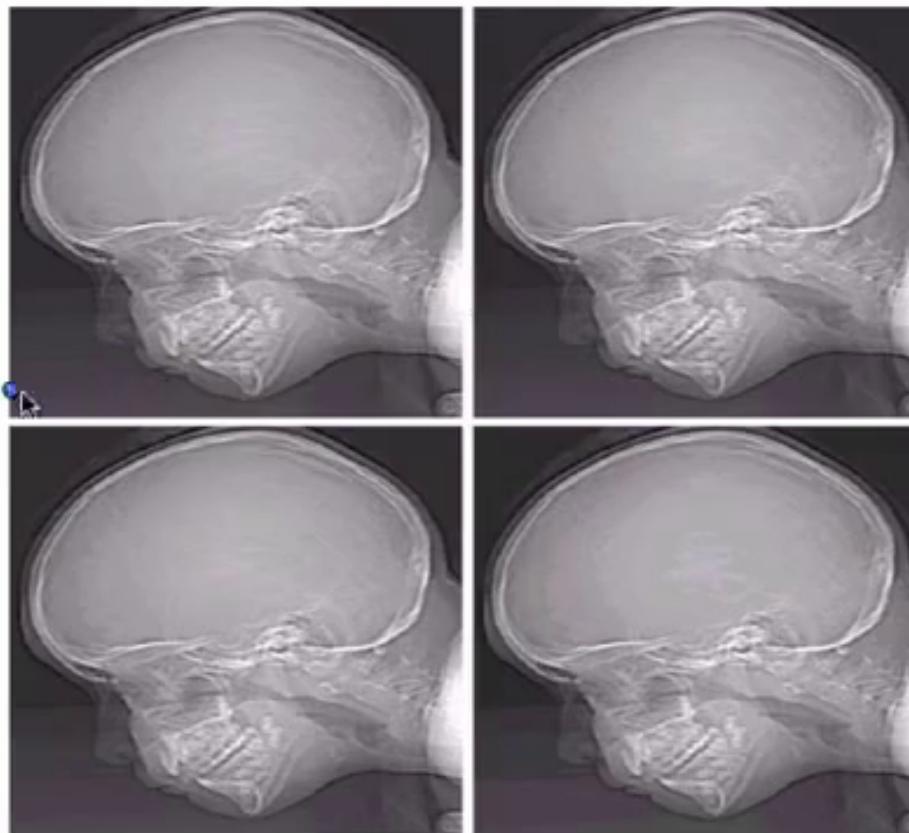
www.ImageProcessingPlace.com

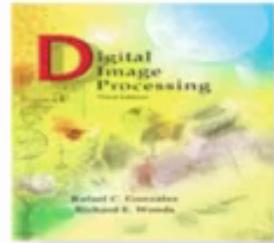
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a b
c d

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.



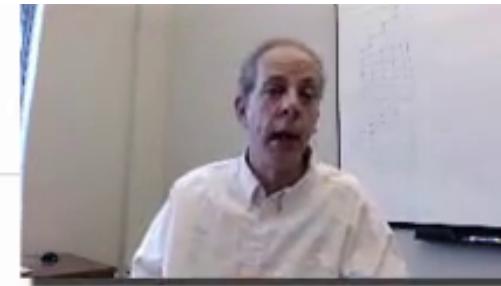


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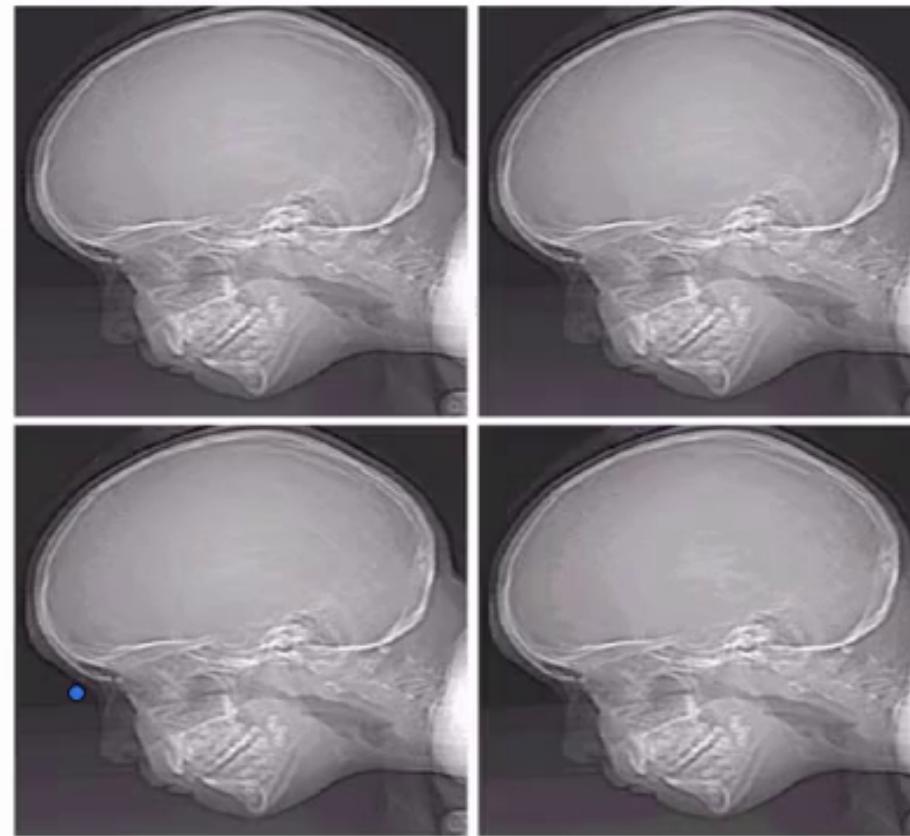
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$$\left\lfloor \frac{9}{2} \right\rfloor \times 2 = 8$$



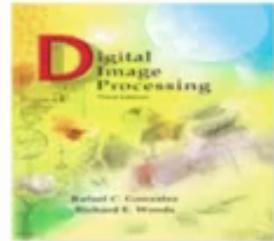
a
b
c
d

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.

452×374

256
128

$$\left\lfloor \frac{\text{value}}{2} \right\rfloor \times 2 = 8$$
$$\left\lfloor \frac{8}{2} \right\rfloor \times 2 = 8$$



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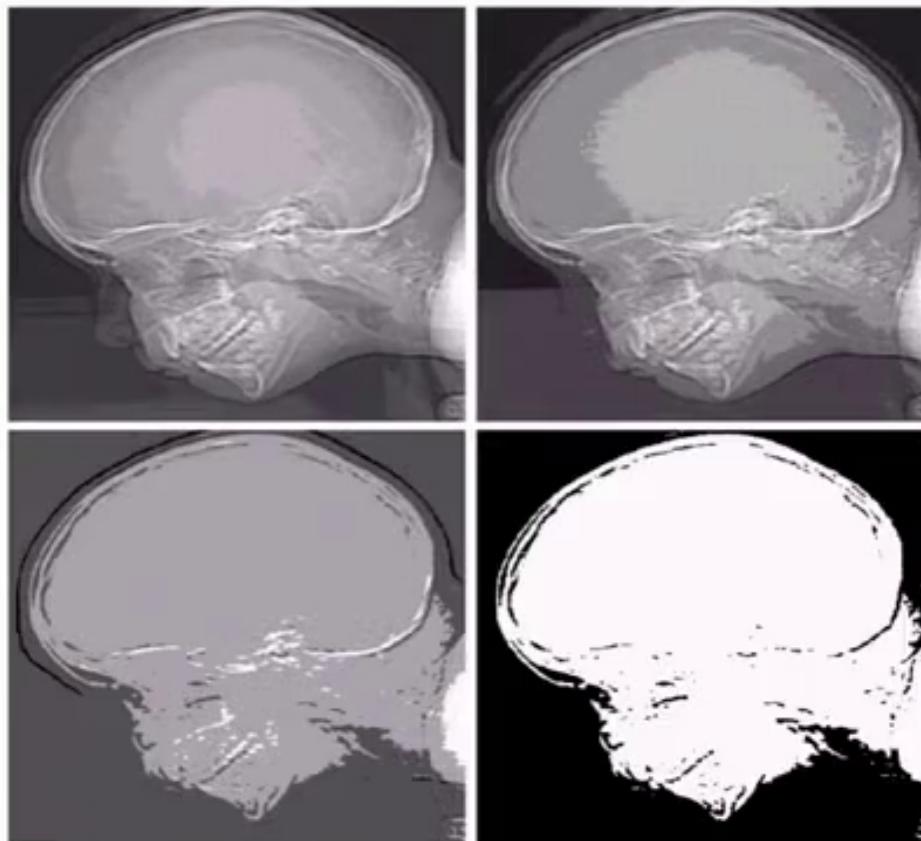
www.ImageProcessingPlace.com

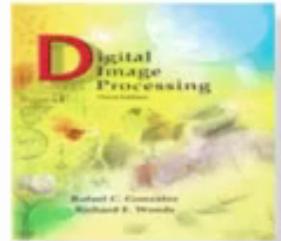
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e f
g h

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.)

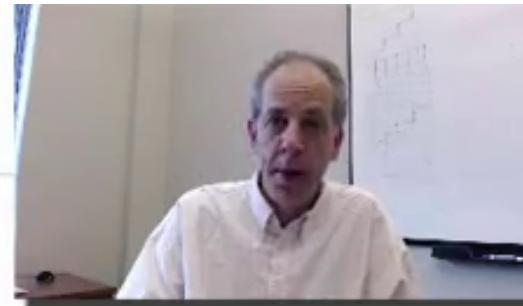




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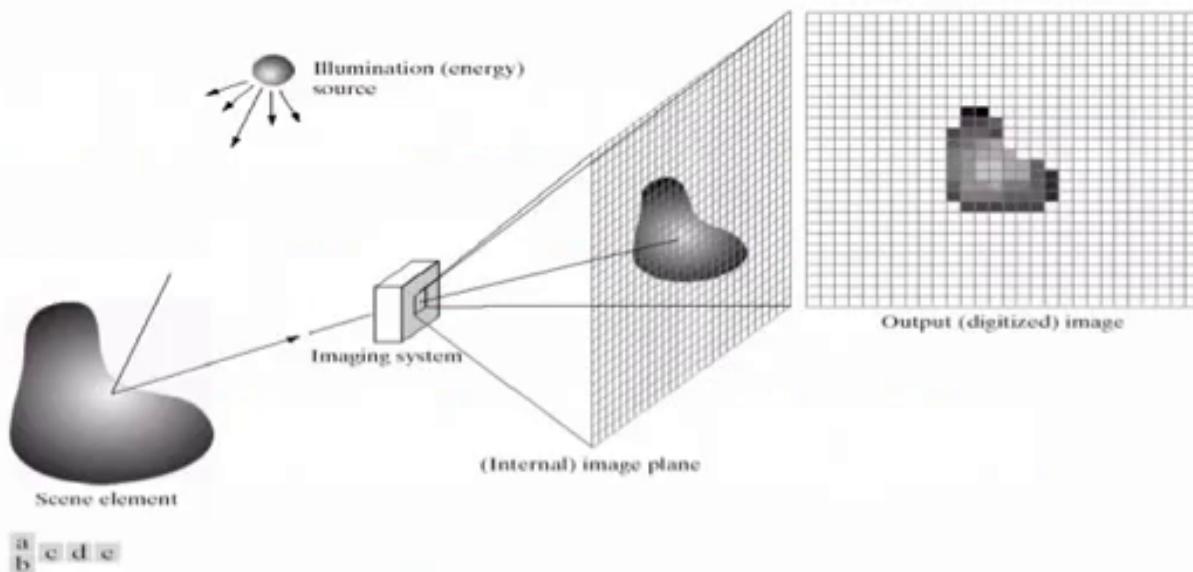
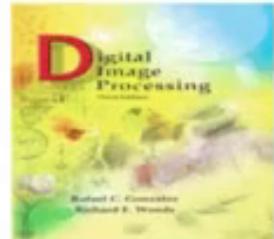


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.



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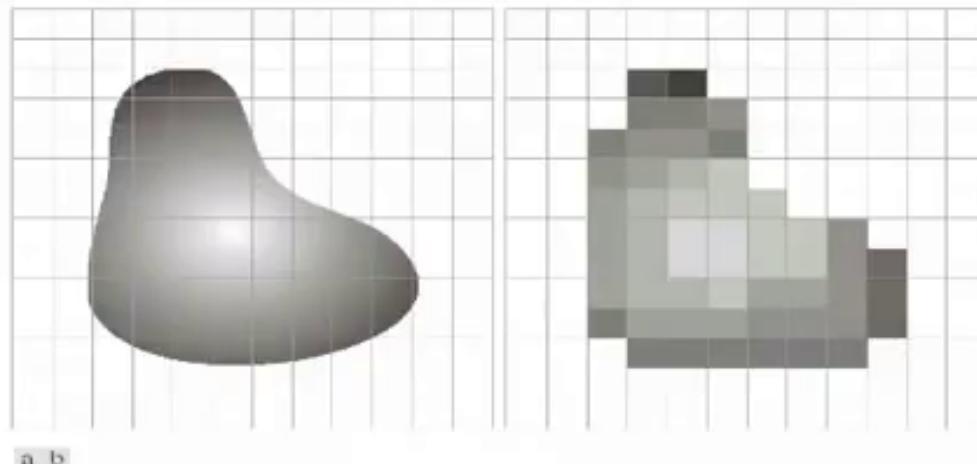
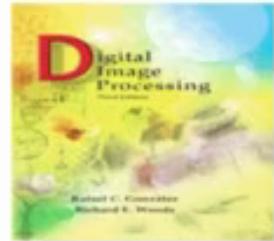


FIGURE 2.17 (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.



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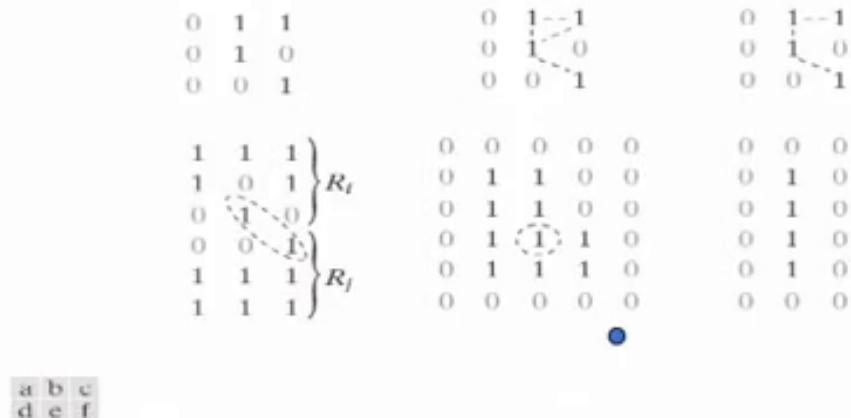
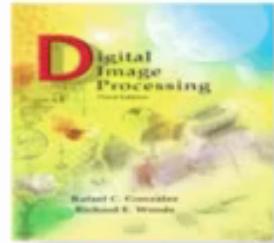


FIGURE 2.25 (a) An arrangement of pixels. (b) Pixels that are 8-adjacent (adjacency is shown by dashed lines; note the ambiguity). (c) m -adjacency. (d) Two regions that are adjacent if 8-adjacency is used. (e) The circled point is part of the boundary of the 1-valued pixels only if 8-adjacency between the region and background is used. (f) The inner boundary of the 1-valued region does not form a closed path, but its outer boundary does.



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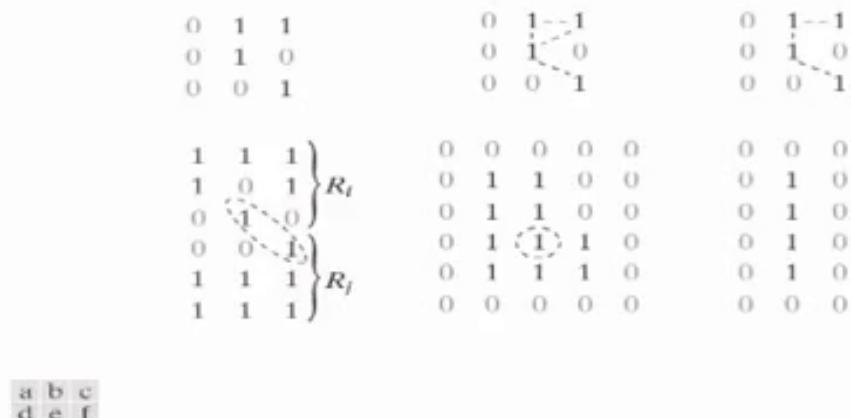
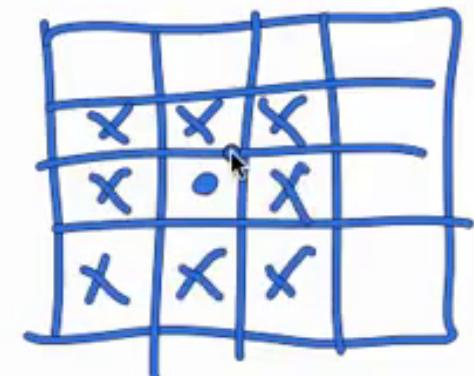
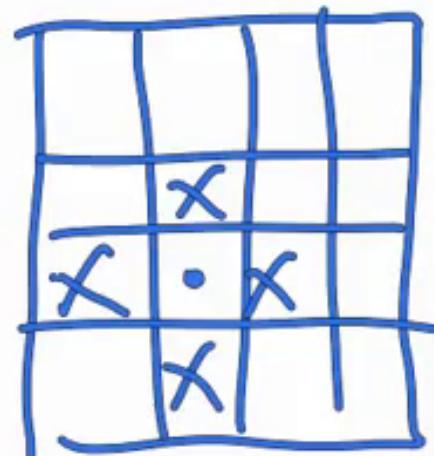
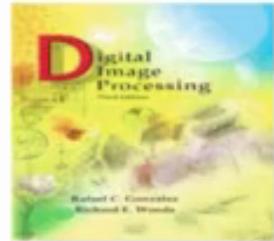


FIGURE 2.25 (a) An arrangement of pixels. (b) Pixels that are 8-adjacent (adjacency is shown by dashed lines; note the ambiguity). (c) m -adjacency. (d) Two regions that are adjacent if 8-adjacency is used. (e) The circled point is part of the boundary of the 1-valued pixels only if 8-adjacency between the region and background is used. (f) The inner boundary of the 1-valued region does not form a closed path, but its outer boundary does.



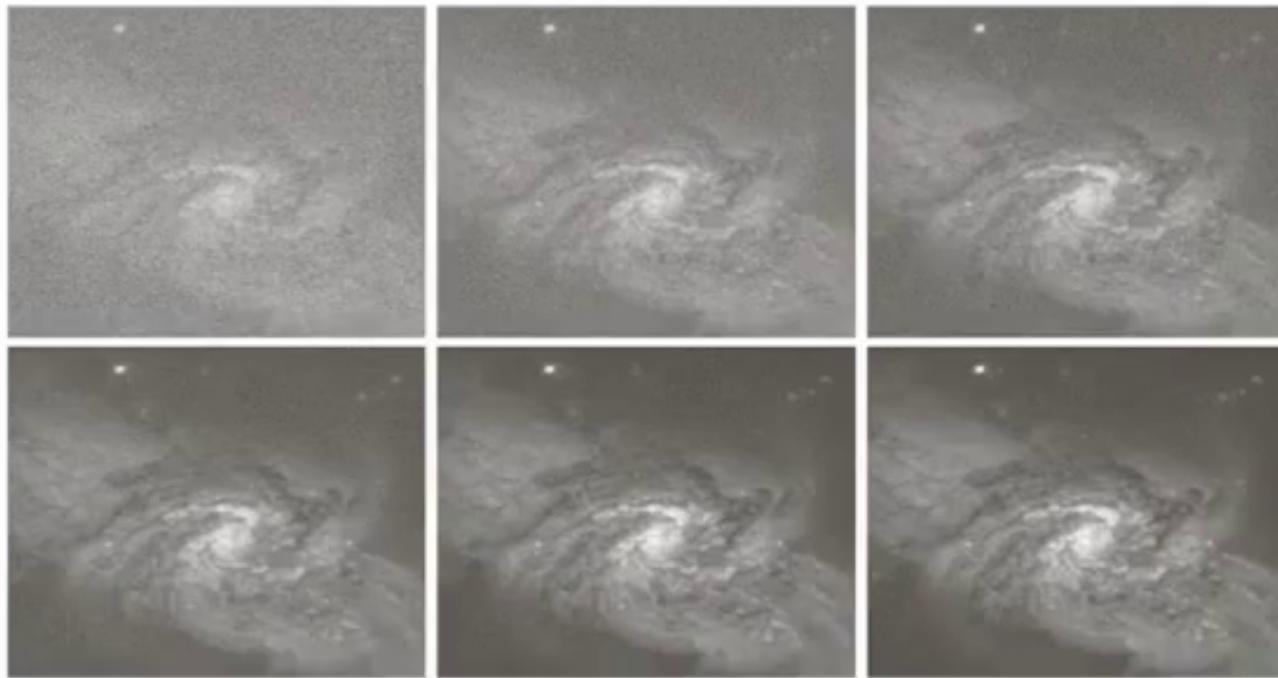
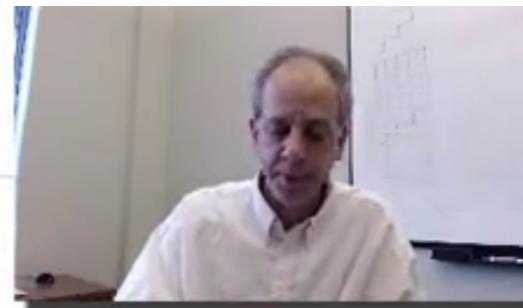


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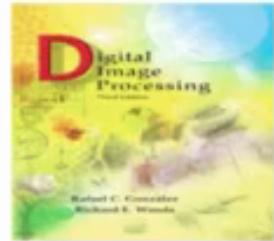
www.ImageProcessingPlace.com

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a b c
d e f

FIGURE 2.26 (a) Image of Galaxy Pair NGC 3314 corrupted by additive Gaussian noise. (b)–(f) Results of averaging 5, 10, 20, 50, and 100 noisy images, respectively. (Original image courtesy of NASA.)

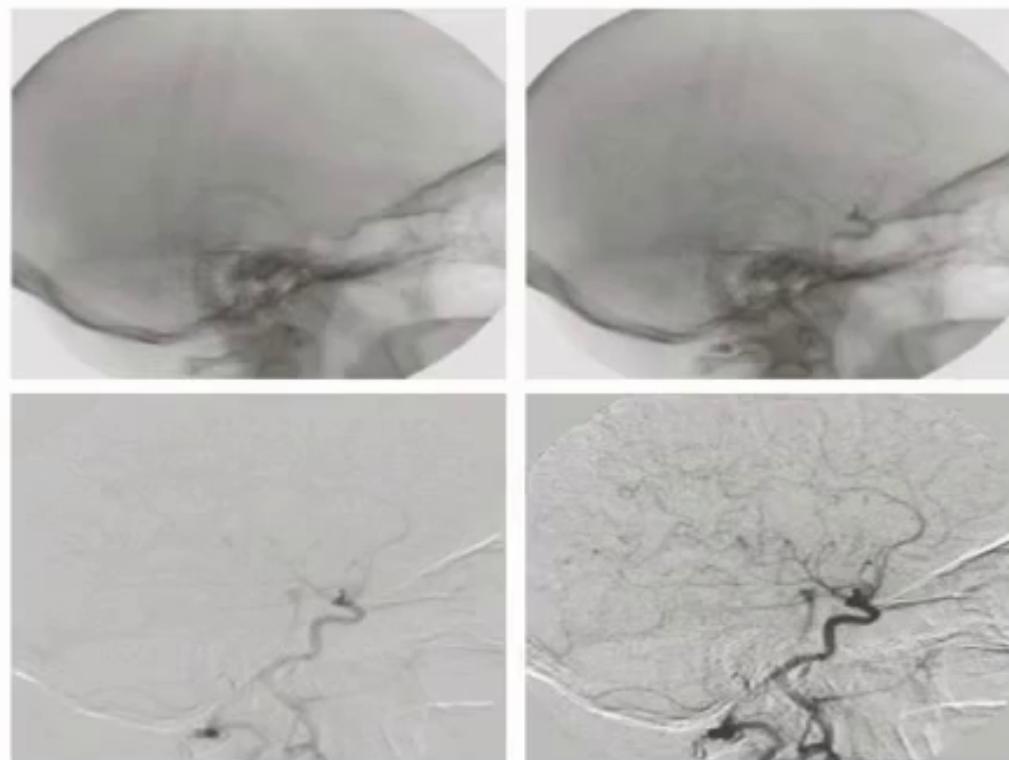
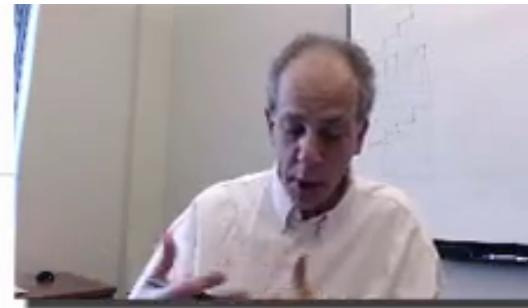


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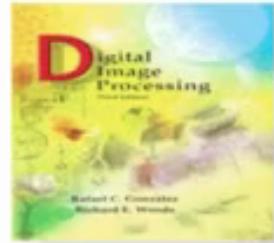
www.ImageProcessingPlace.com

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a b
c d

FIGURE 2.28
Digital subtraction angiography.
(a) Mask image.
(b) A live image.
(c) Difference between (a) and (b).
(d) Enhanced difference image.
(Figures (a) and (b) courtesy of The Image Sciences Institute, University Medical Center, Utrecht, The Netherlands.)

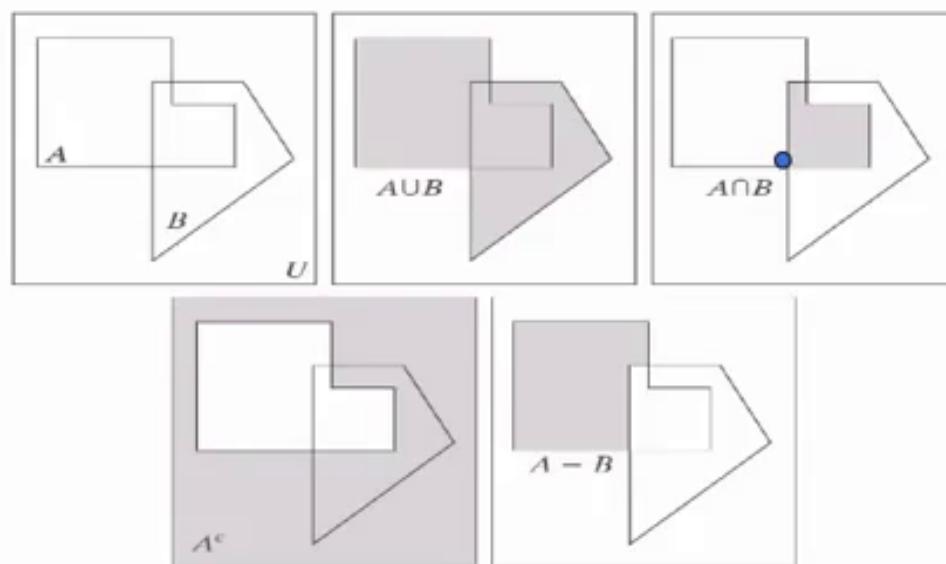
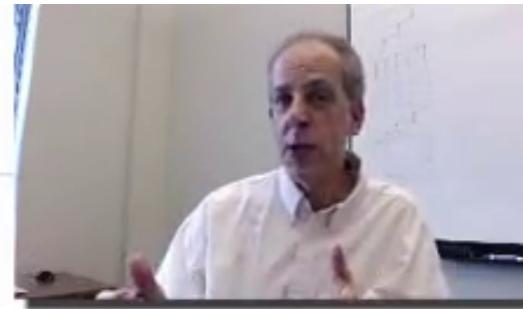


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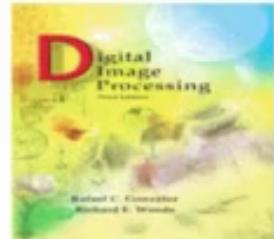
www.ImageProcessingPlace.com

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a b c
d e

FIGURE 2.31
(a) Two sets of coordinates, A and B , in 2-D space. (b) The union of A and B . (c) The intersection of A and B . (d) The complement of A . (e) The difference between A and B . In (b)–(e) the shaded areas represent the member of the set operation indicated.

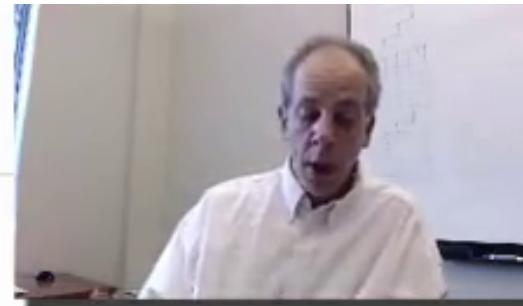


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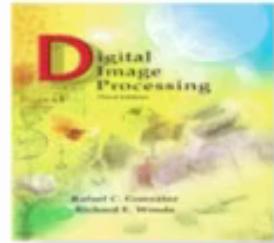
www.ImageProcessingPlace.com

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a b c

FIGURE 2.32 Set operations involving gray-scale images.
(a) Original image. (b) Image negative obtained using set complementation.
(c) The union of (a) and a constant image.
(Original image courtesy of G.E. Medical Systems.)

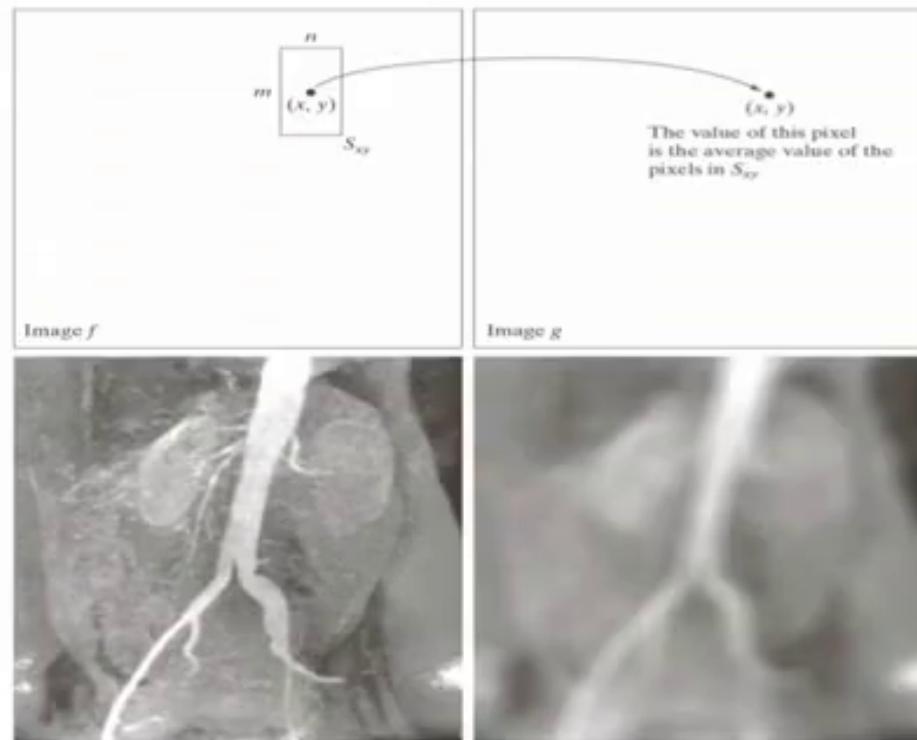


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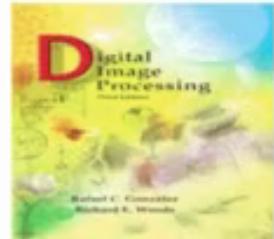
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a b
c d

FIGURE 2.35
Local averaging using neighborhood processing. The procedure is illustrated in (a) and (b) for a rectangular neighborhood. (c) The aortic angiogram discussed in Section 1.3.2. (d) The result of using Eq. (2.6-21) with $m = n = 41$. The images are of size 790×686 pixels.

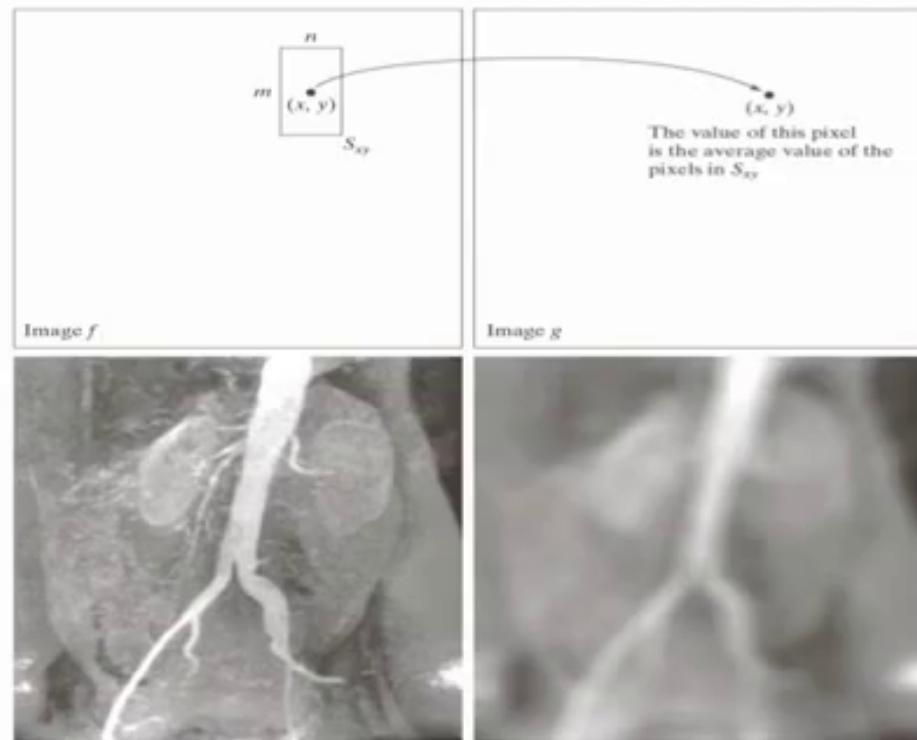


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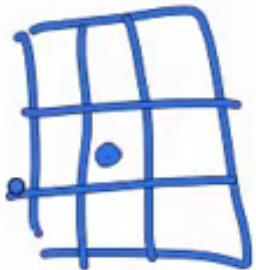
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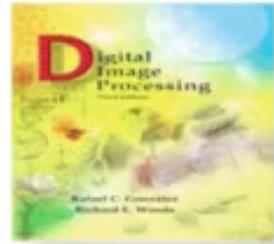
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a b
c d

FIGURE 2.35
Local averaging using neighborhood processing. The procedure is illustrated in (a) and (b) for a rectangular neighborhood. (c) The aortic angiogram discussed in Section 1.3.2. (d) The result of using Eq. (2.6-21) with $m = n = 41$. The images are of size 790×686 pixels.





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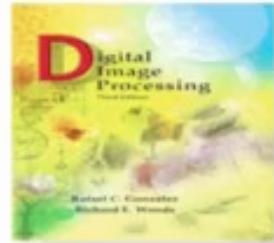


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TABLE 2.2

Affine transformations based on Eq. (2.6.-23).

Transformation Name	Affine Matrix, T	Coordinate Equations	Example
Identity	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v$ $y = w$	
Scaling	$\begin{bmatrix} c_x & 0 & 0 \\ 0 & c_y & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = c_x v$ $y = c_y w$	
Rotation	$\begin{bmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v \cos \theta + w \sin \theta$ $y = v \cos \theta + w \sin \theta$	
Translation	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ t_x & t_y & 1 \end{bmatrix}$	$x = v + t_x$ $y = w + t_y$	
Shear (vertical)	$\begin{bmatrix} 1 & 0 & 0 \\ s_v & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v + s_v w$ $y = w$	
Shear (horizontal)	$\begin{bmatrix} 1 & s_h & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v$ $y = s_h v + w$	

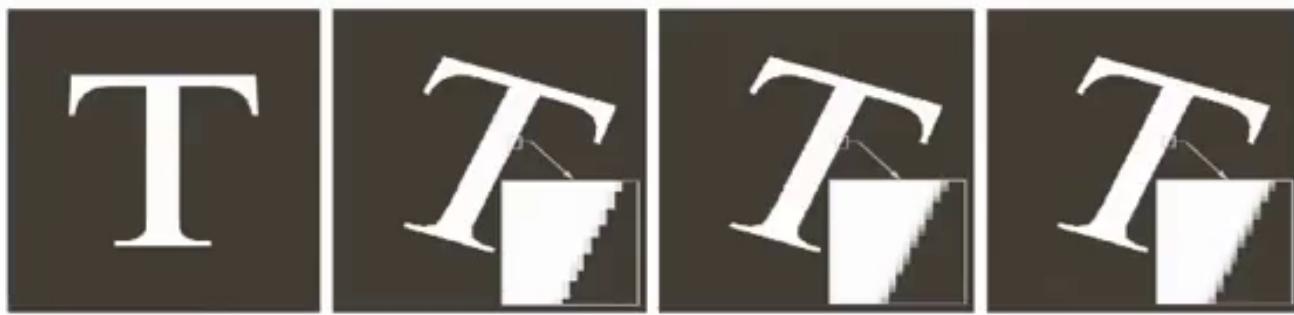


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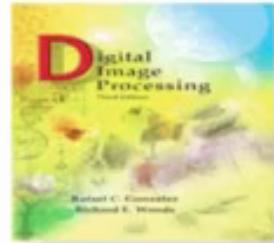
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a b c d

FIGURE 2.36 (a) A 300 dpi image of the letter T. (b) Image rotated 21° clockwise using nearest neighbor interpolation to assign intensity values to the spatially transformed pixels. (c) Image rotated 21° using bilinear interpolation. (d) Image rotated 21° using bicubic interpolation. The enlarged sections show edge detail for the three interpolation approaches.

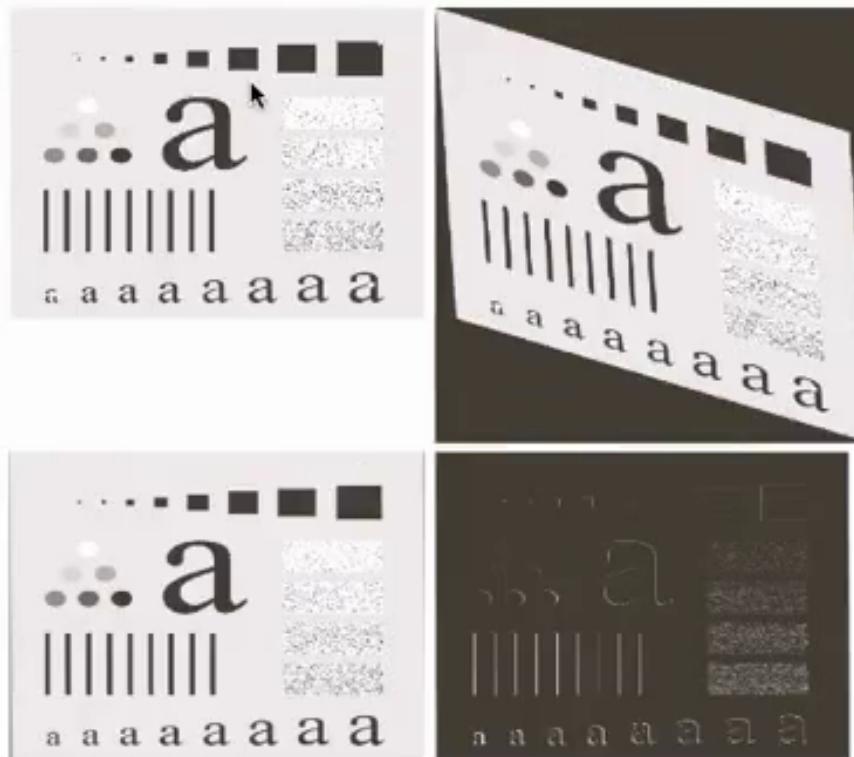


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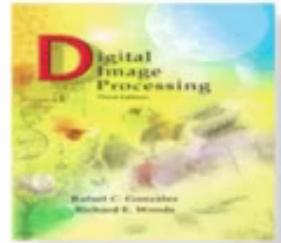
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a b
c d

FIGURE 2.37
Image registration.
(a) Reference image.
(b) Input (geometrically distorted image). Corresponding tie points are shown as small white squares near the corners.
(c) Registered image (note the errors in the borders).
(d) Difference between (a) and (c), showing more registration errors.



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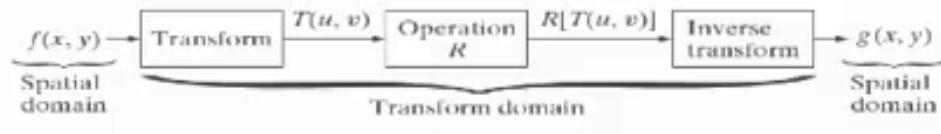
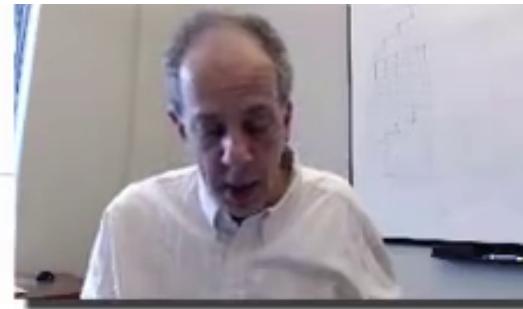
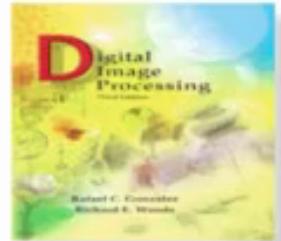


FIGURE 2.39
General approach
for operating in
the linear
transform
domain.

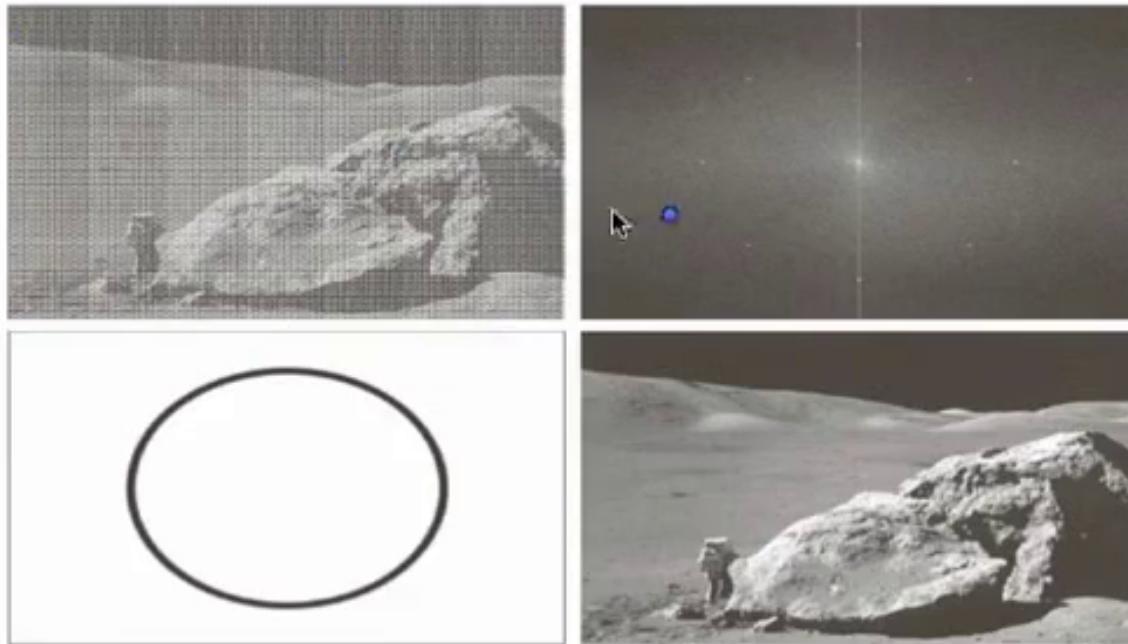


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a
b
c
d

FIGURE 2.40
(a) Image corrupted by sinusoidal interference. (b) Magnitude of the Fourier transform showing the bursts of energy responsible for the interference. (c) Mask used to eliminate the energy bursts. (d) Result of computing the inverse of the modified Fourier transform. (Original image courtesy of NASA.)