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Digital Image Processing

INTRODUCTION

Definitions

- Image Processing (enhancing an image or extracting information or features from an image)
- Image Analysis (extraction of useful information from images)
- Computer Vision (to program a computer to "understand" a scene or features in an image)

- Low Level Processes: contrast manipulation
- Mid-Level Processes: segmentation, recognition
- High Level Processes: understanding groups of objects

Initial Examples of Imagery

FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.)

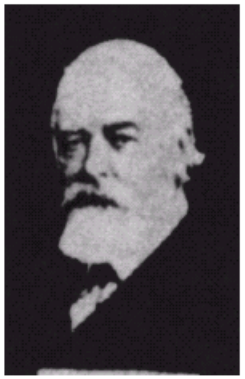


FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. Some errors are visible. (McFarlane.)

FIGURE 1.3
Unretouched cable picture of Generals Pershing and Foch, transmitted in 1929 from London to New York by 15-tone equipment. (McFarlane.)

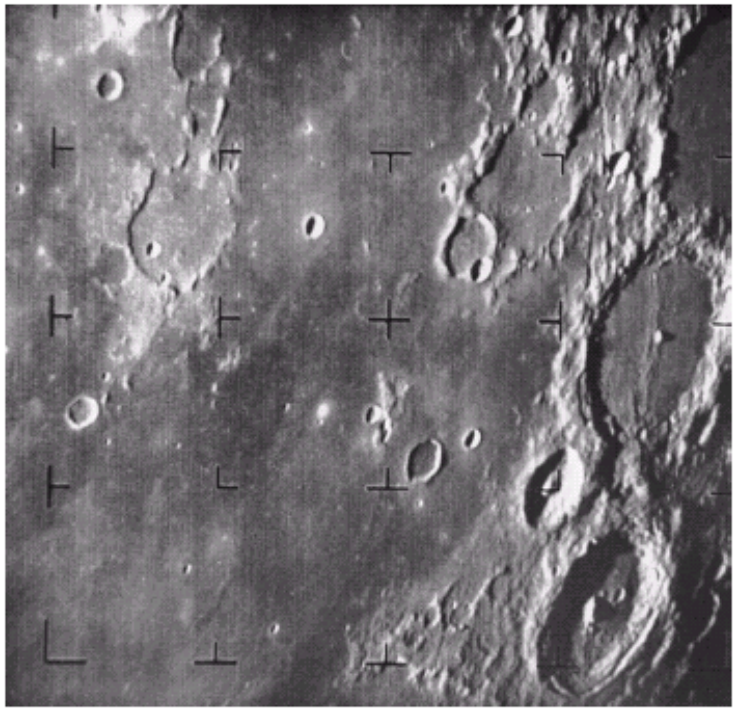


FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9:09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

Image processed by computer to correct various types of image distortion inherent in the on-board television camera .

Energy Sources for Images

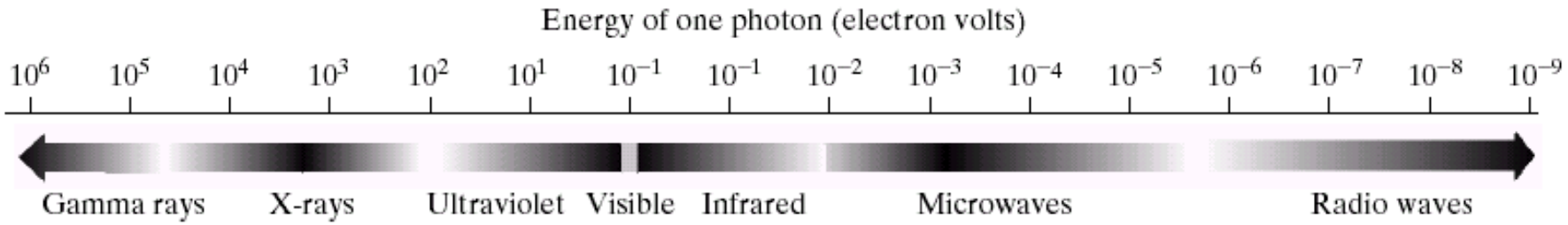


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

major source of energy

electro-magnetic waves

Other sources

- sound wave
- magnetic field
- other ones

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

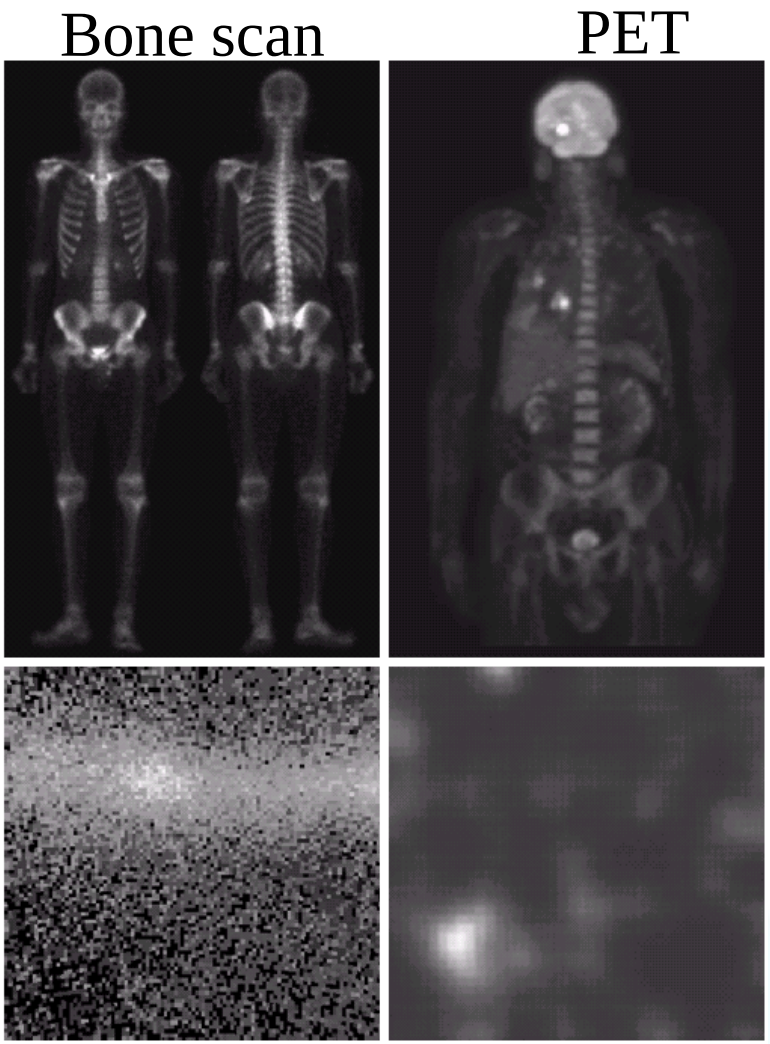
Gamma Ray

External source

- Radioactive isotope decay

Internal Source

- Positron emission
- Star
- Nuclear reaction



(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

X-Ray

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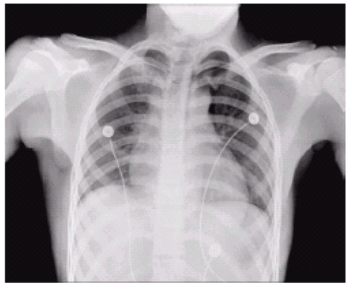
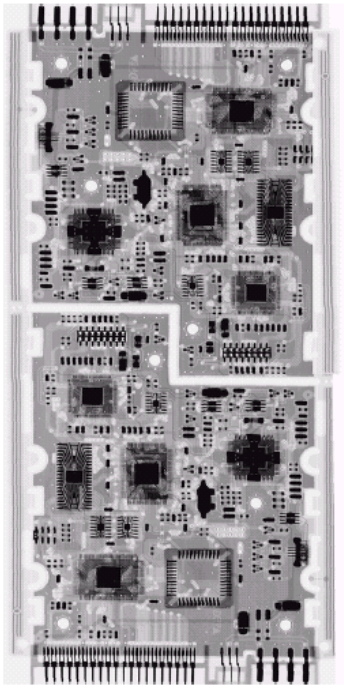
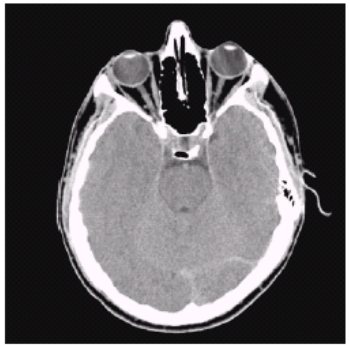
PCB

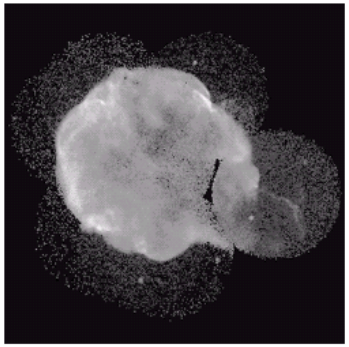
Chest X-Ray





Angiogram





Head CT

Cygnus loop

Source : X-Ray tube

Star

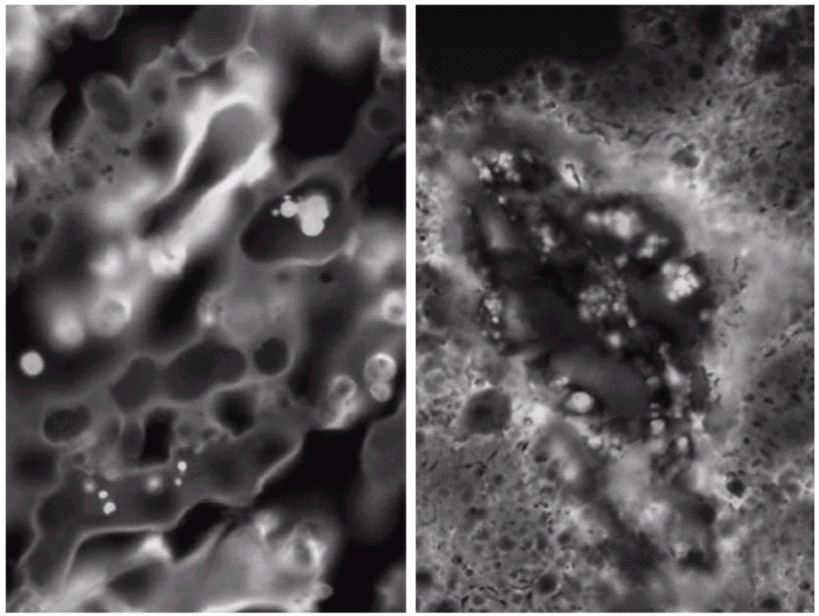
Nuclear reaction

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

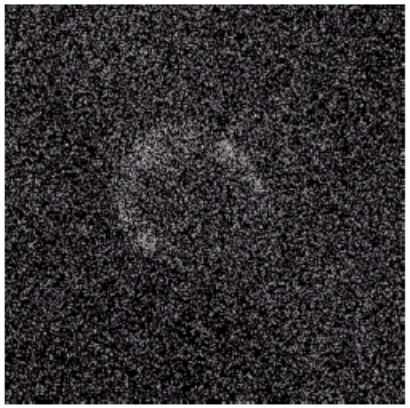
Ultraviolet

Normal corn

Smut corm



Fluorescence phenomenon



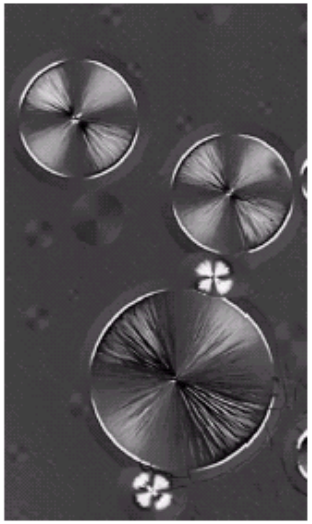
Cygnus Loop

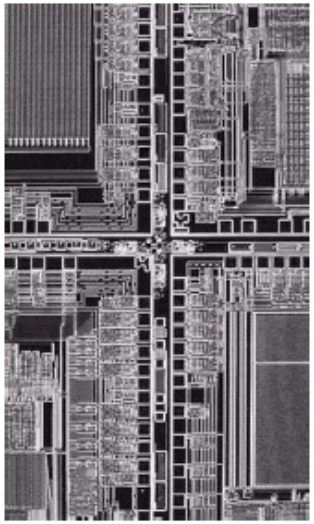
(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Visible Light and Infrared

Cholesterol

Taxol





Microprocessor

Nickel oxide
Thin film

Organic
superconductor

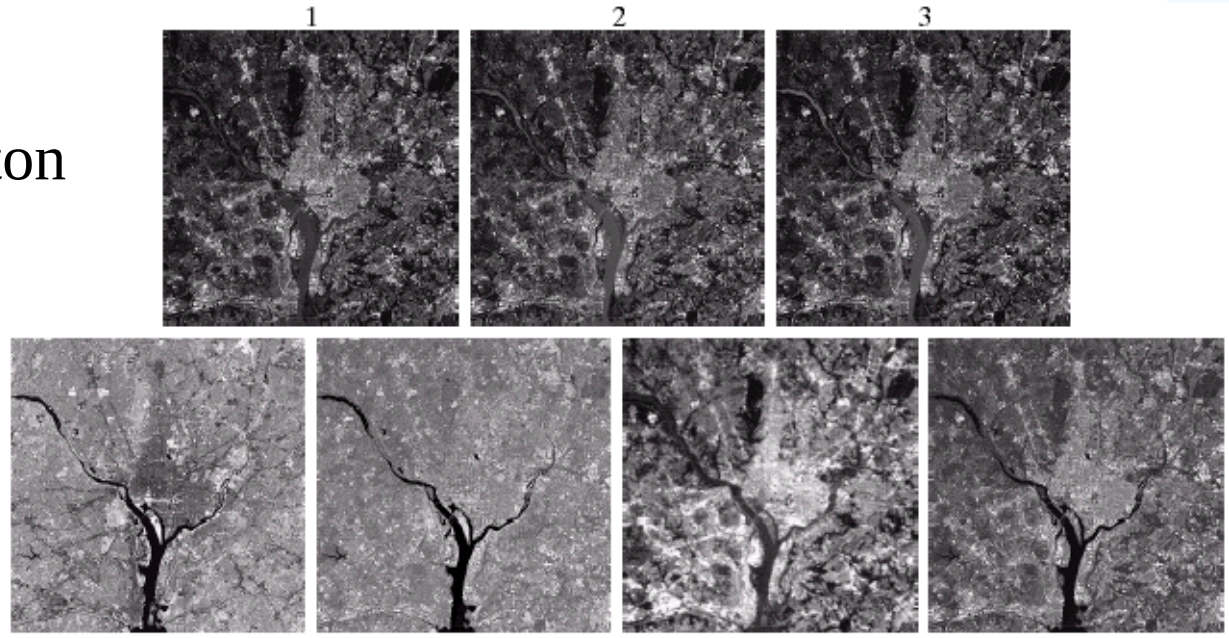
?

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Visible Light and Infrared

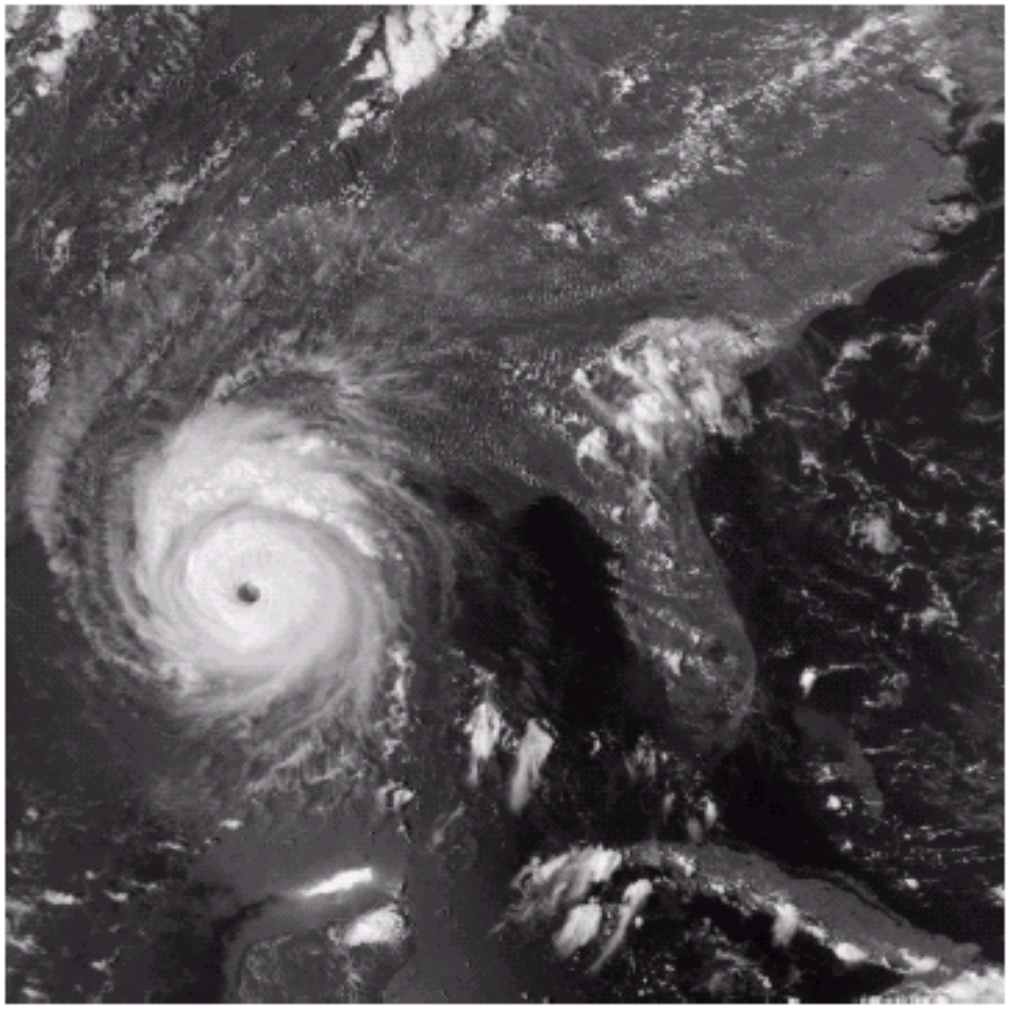
Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

Washington D.C.



(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Multispectral Imaging



Hurricane Andrew

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Nighttime light of the world

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

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Nighttime light of the world (cont.)

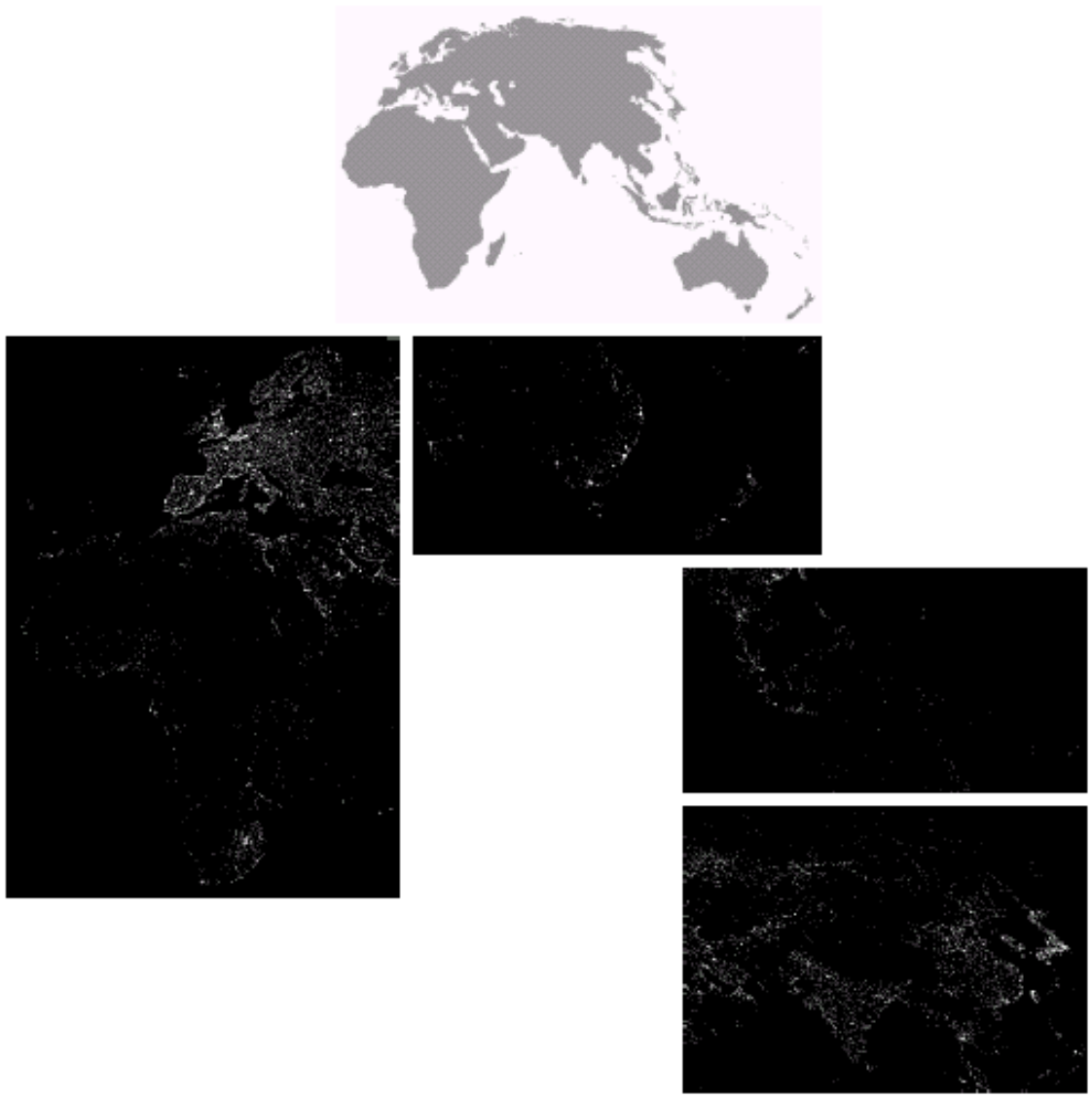
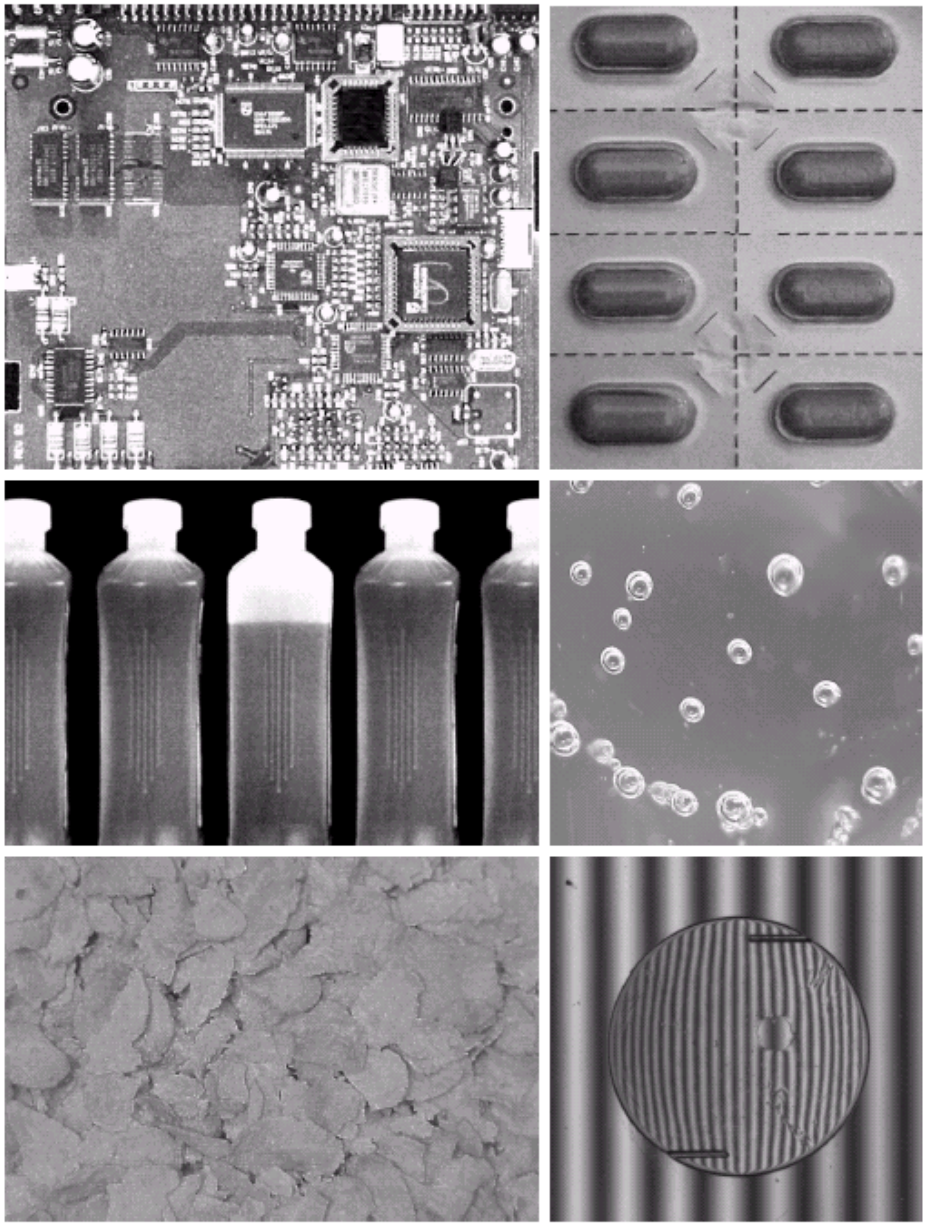


FIGURE 1.13 Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Automated Visual Inspection

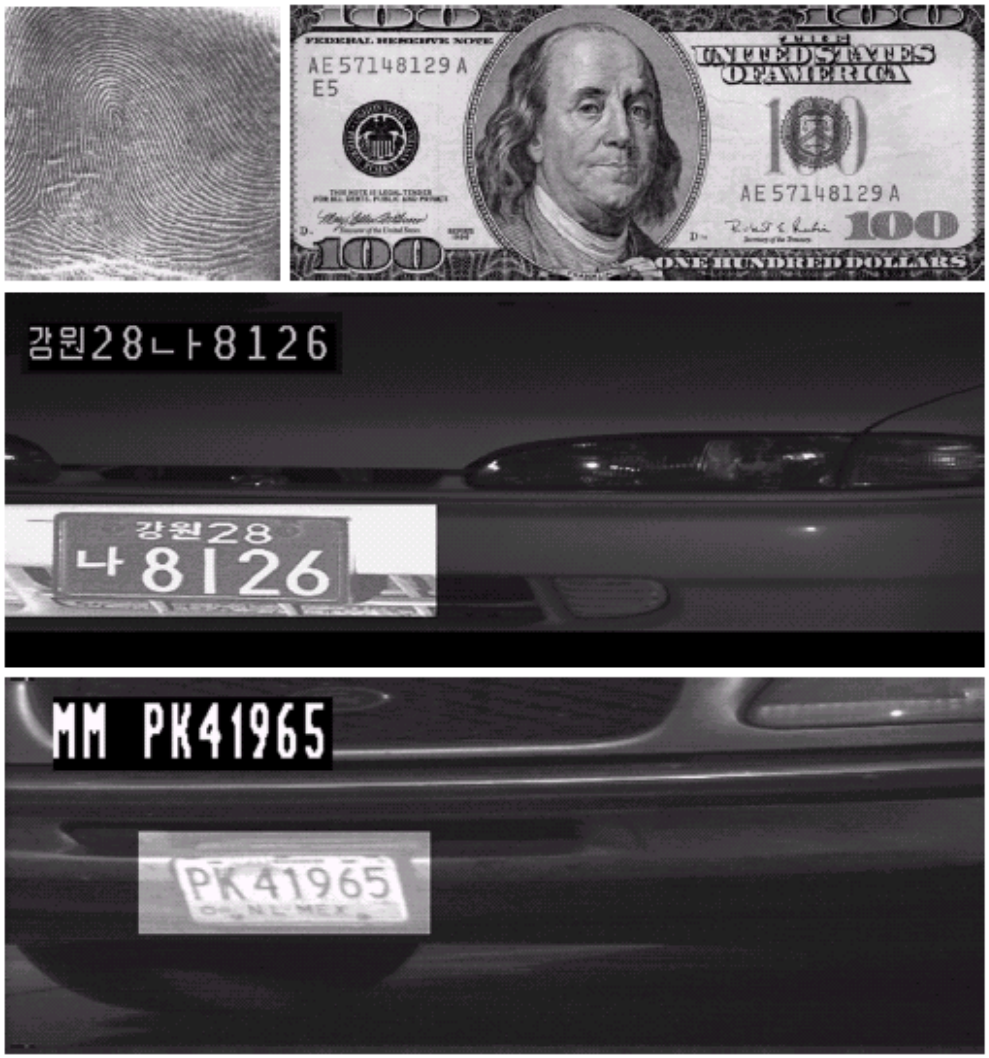


a b
c d
e f

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) Bubbles in clear-plastic product. (e) Cereal. (f) Image of intraocular implant. (Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Automated Visual Inspection (cont.)



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.)

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

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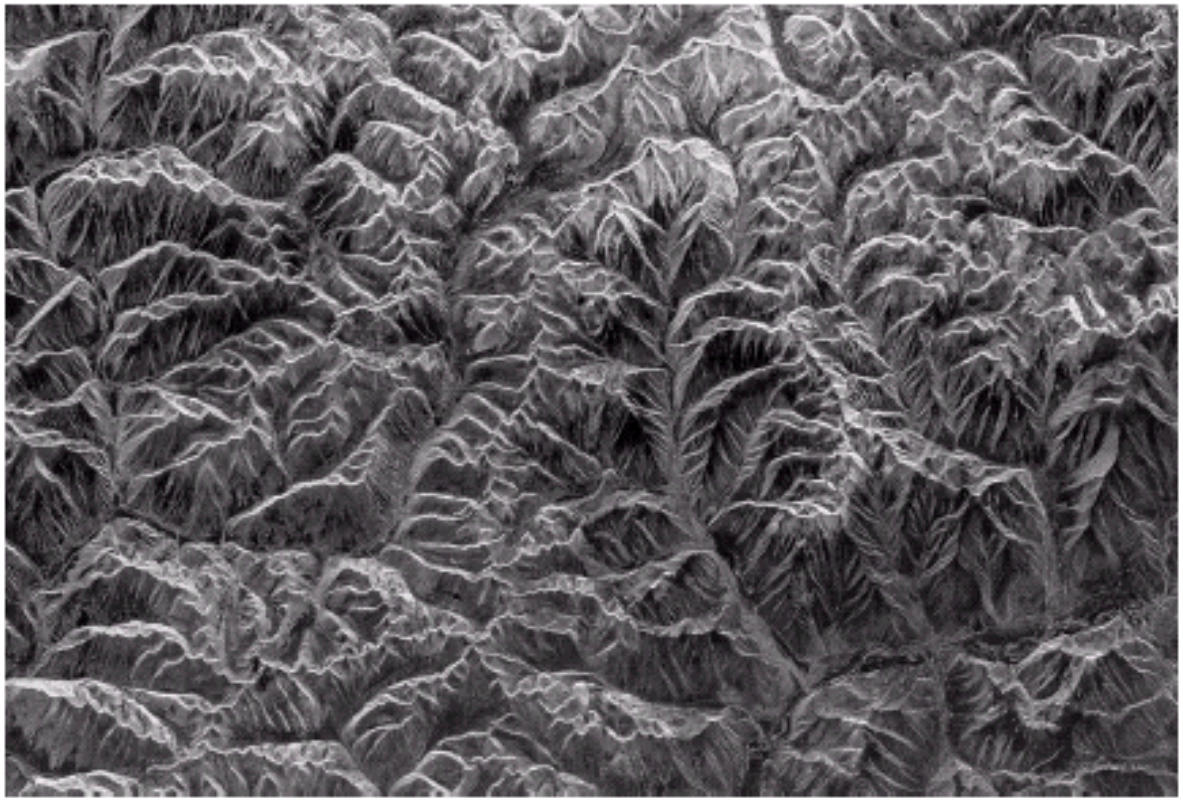
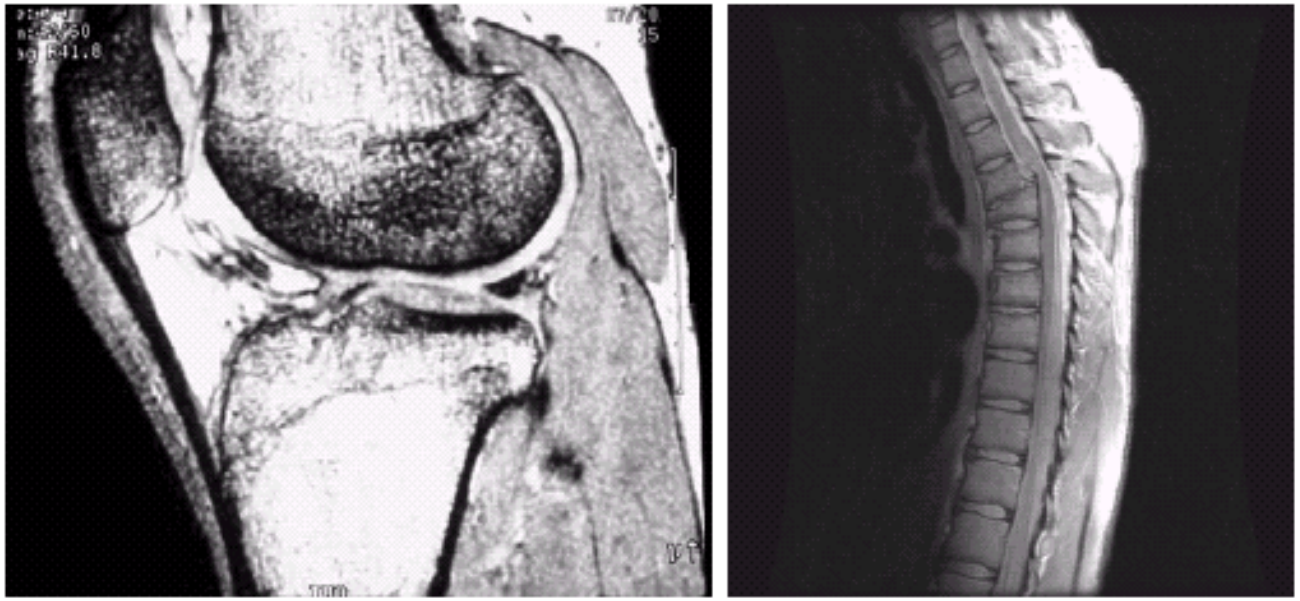
FIGURE 1.16
Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)



Spaceborne Radar image

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Magnetic



a b

FIGURE 1.17 MRI images of a human (a) knee, and (b) spine. (Image (a) courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, and (b) Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Multispectral images

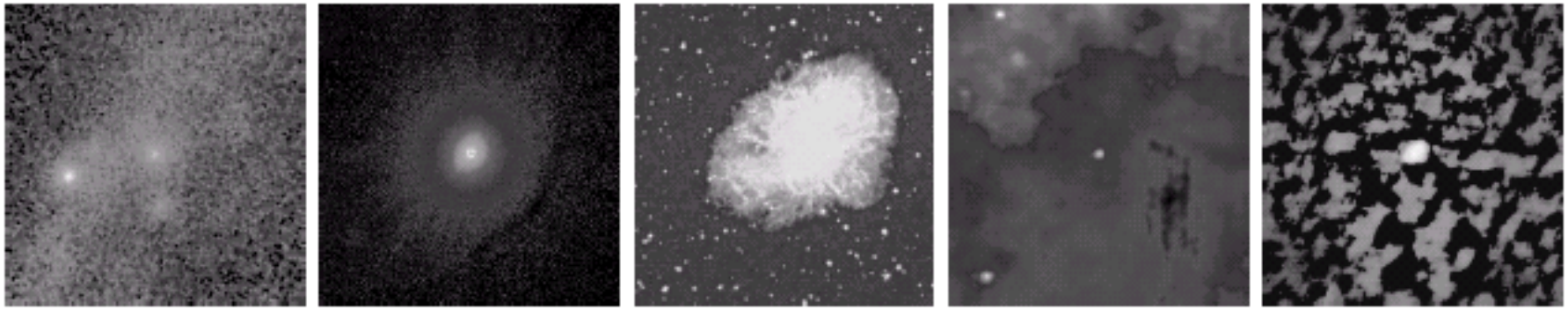


FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Seismic imaging

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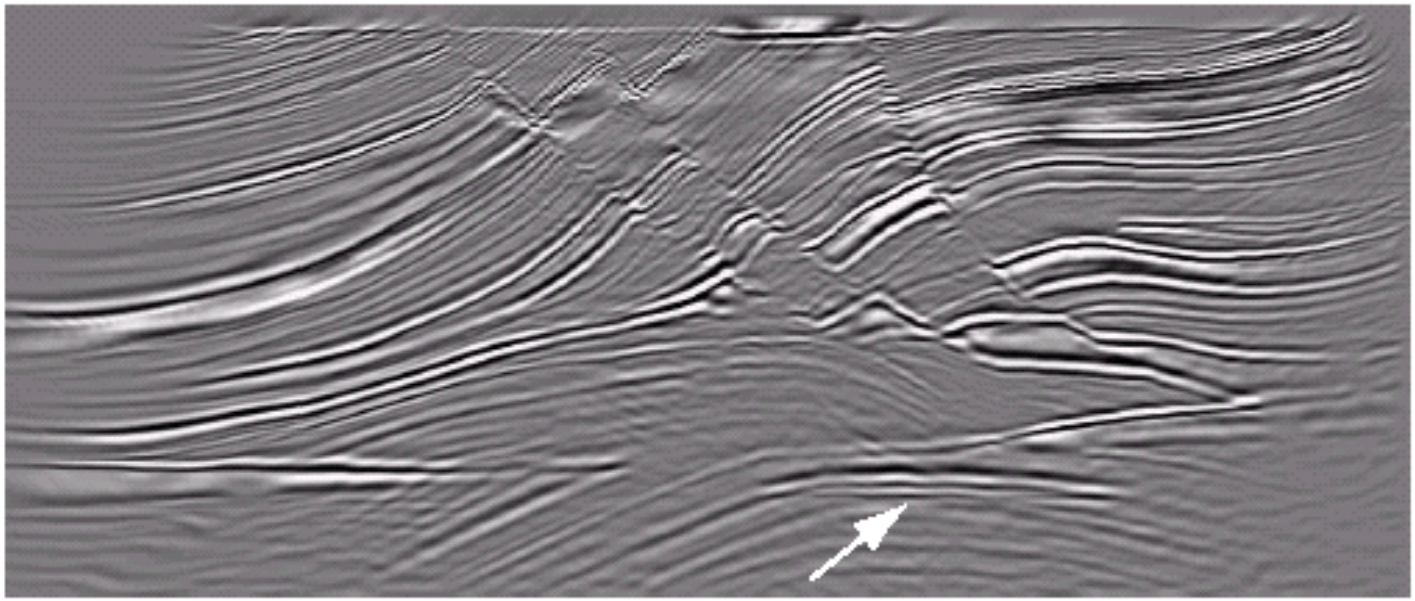

FIGURE 1.19
Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Ultrasound imaging

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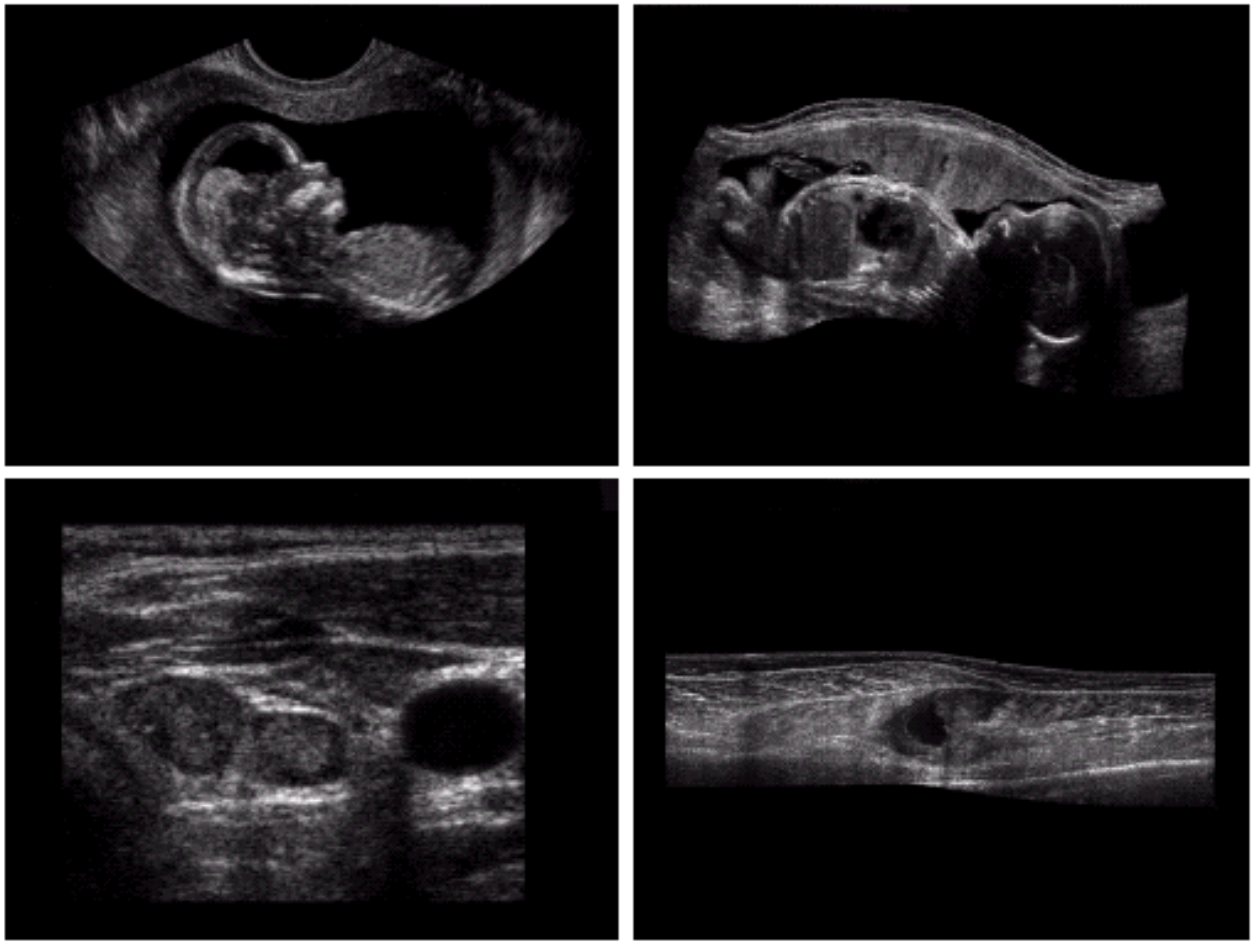
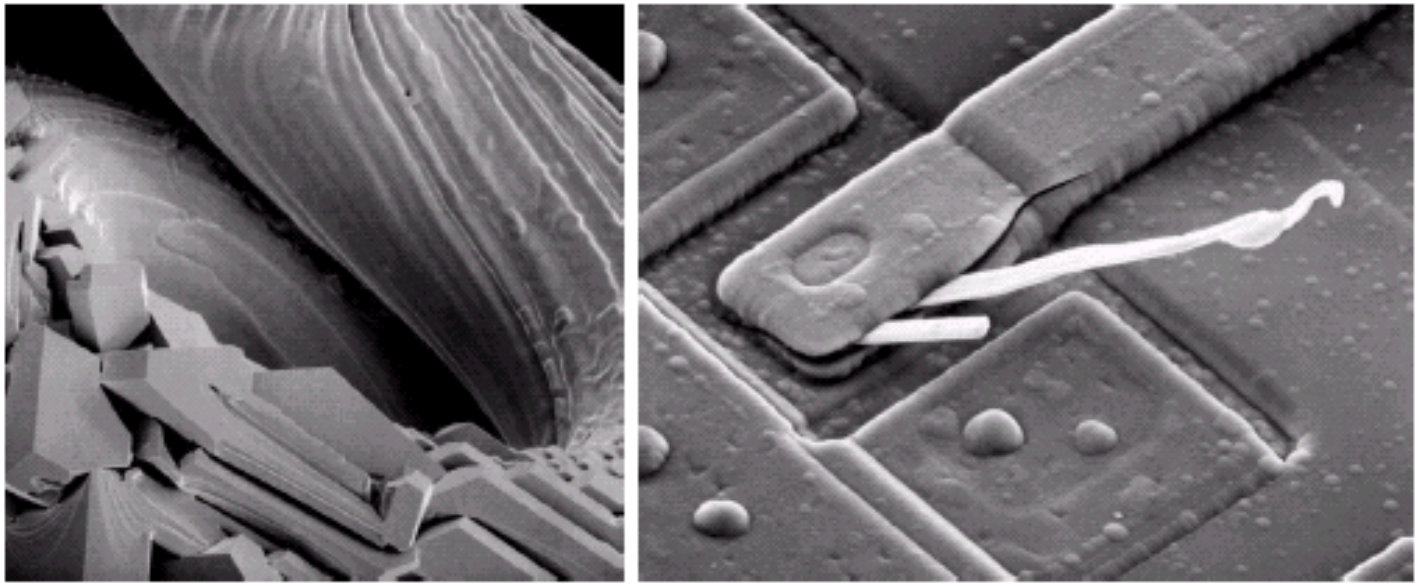


a b
c d

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.)

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Electron Microscope Images

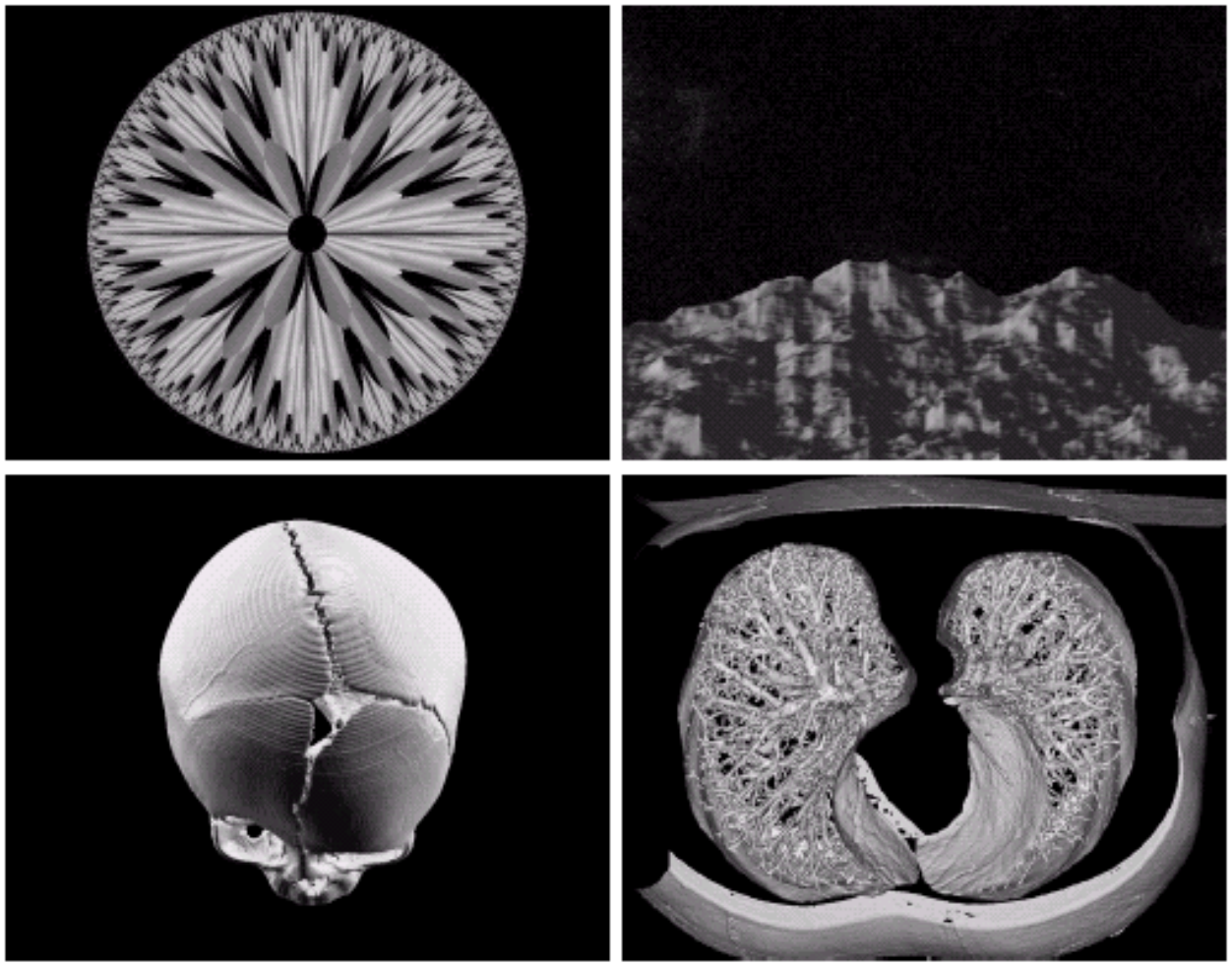


a b

FIGURE 1.21 (a) 250× SEM image of a tungsten filament following thermal failure. (b) 2500× 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.)

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Synthesis Images

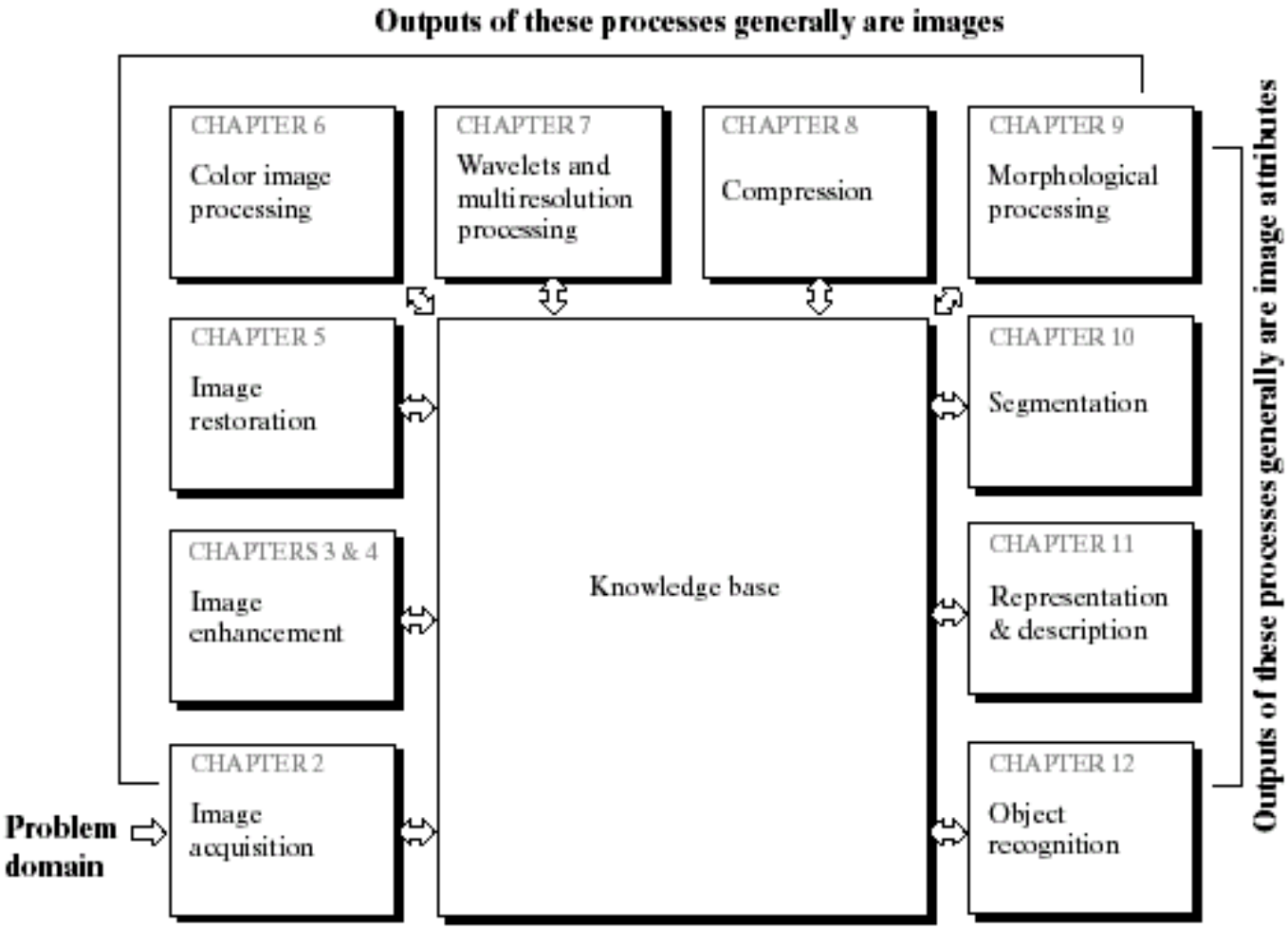


a b
c d

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.)

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

FIGURE 1.23
Fundamental steps in digital image processing.



Important Stages in Image Processing

- Image Acquisition
- Preprocessing
- Segmentation
- Representation and Description
- Recognition and Interpretation
- Knowledge base

Important Stages in Image Processing

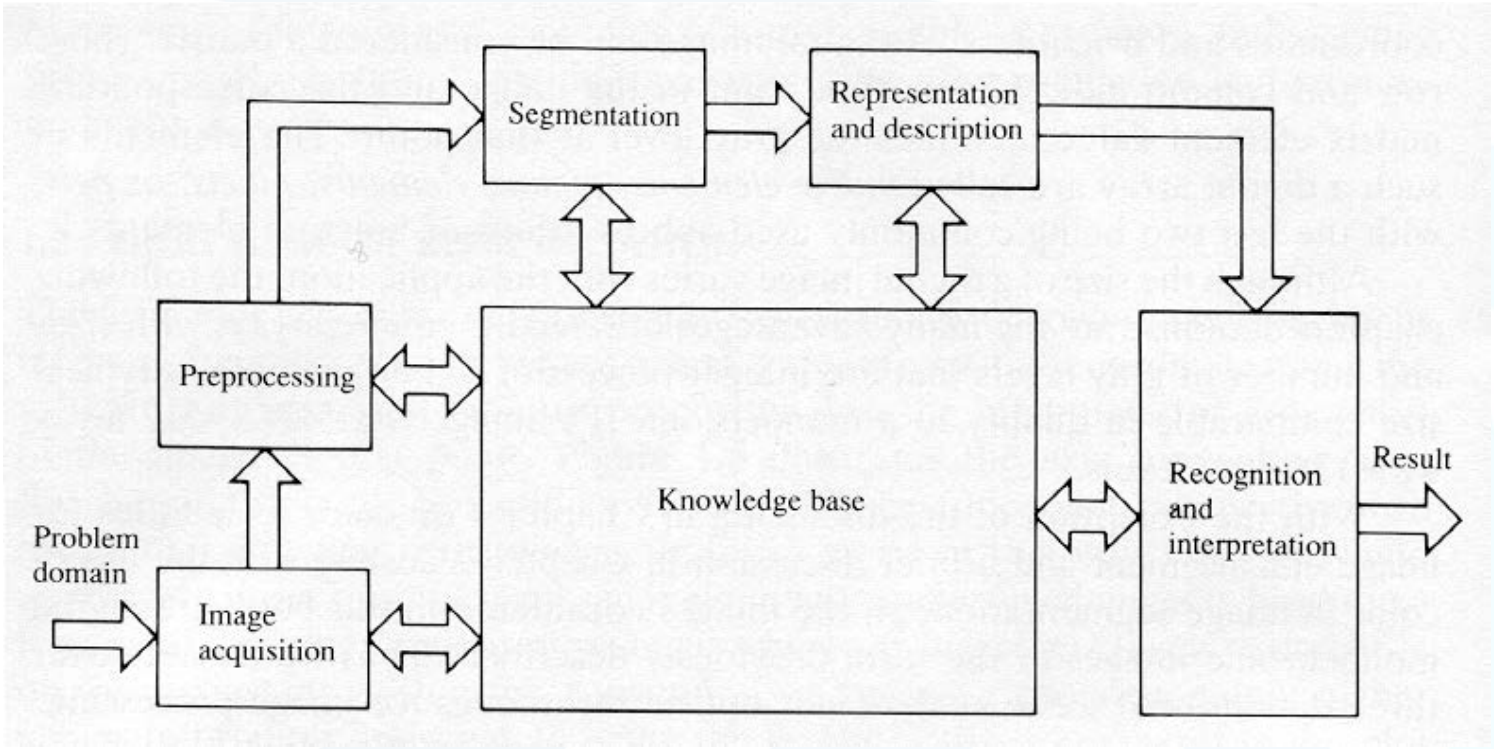


Image Acquisition

- Imaging sensor & capability to digitize the signal collected by the sensor
  - Video camera
  - Digital camera
  - Conventional camera & analog-to-digital converter

Preprocessing

- To improve the image to ensure the success of further processes
- e.g. enhancing contrast
  removing noise
  identifying information-rich areas

Segmentation

- To partition the image into its constituent parts (objects)
  - Autonomous segmentation (very difficult)
    - Can facilitate or disturb subsequent processes
  - Output (representation):
    - Raw pixel data, depicting either boundaries or whole regions (corners vs. texture for example)
    - Need conversion to a form suitable for computer processing
  - (Description)

Representation & Description

- Feature selection (description) deals with extracting:
  - features that result in quantitative information of interest or
  - features that are important for differentiating one class of objects from another

Recognition & Interpretation

- To assign a label to an object based on information provided by the descriptors
- To assign meaning to a group of recognized objects

Knowledge Base

- Knowledge database
  - Guides the operation of each processing module and controls the interaction between modules

Comments

- Image enhancement for human visual interpretation usually stops at preprocessing

- Recognition and interpretation are associated with image analysis applications where the objective is automation (automated extraction of information from images)

Components

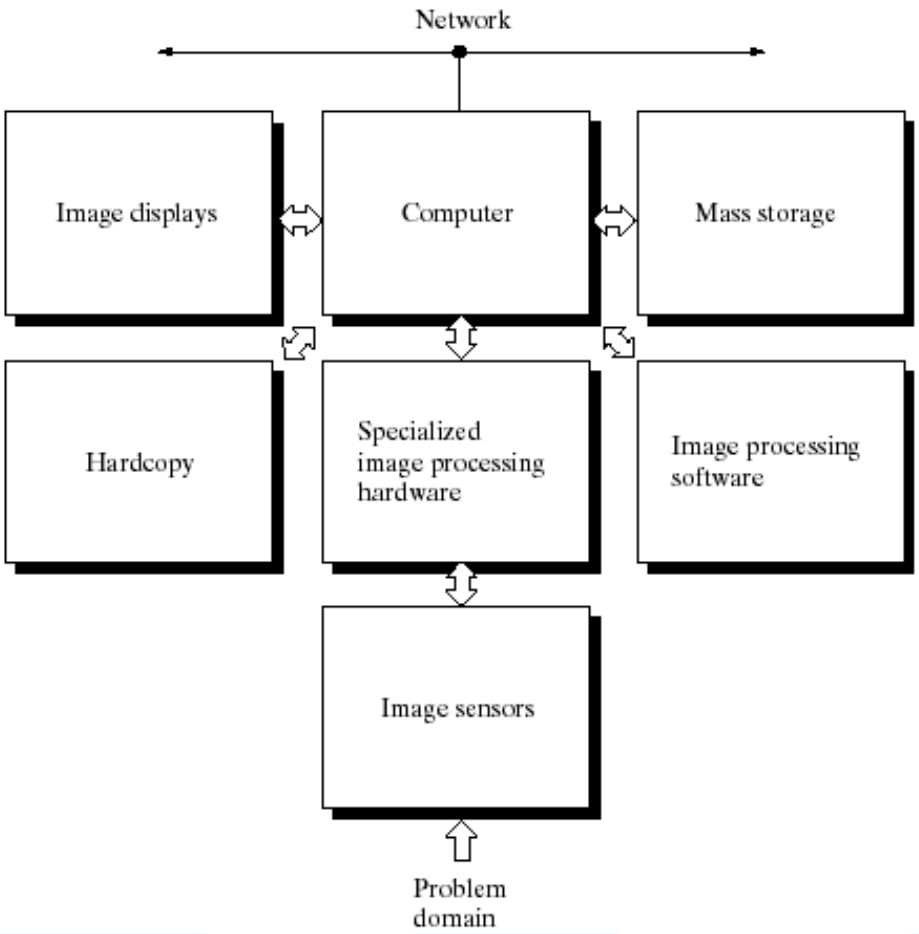


FIGURE 1.24
Components of a general-purpose image processing system.