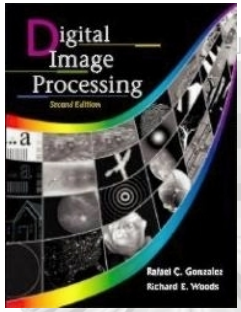
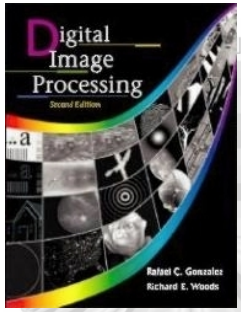


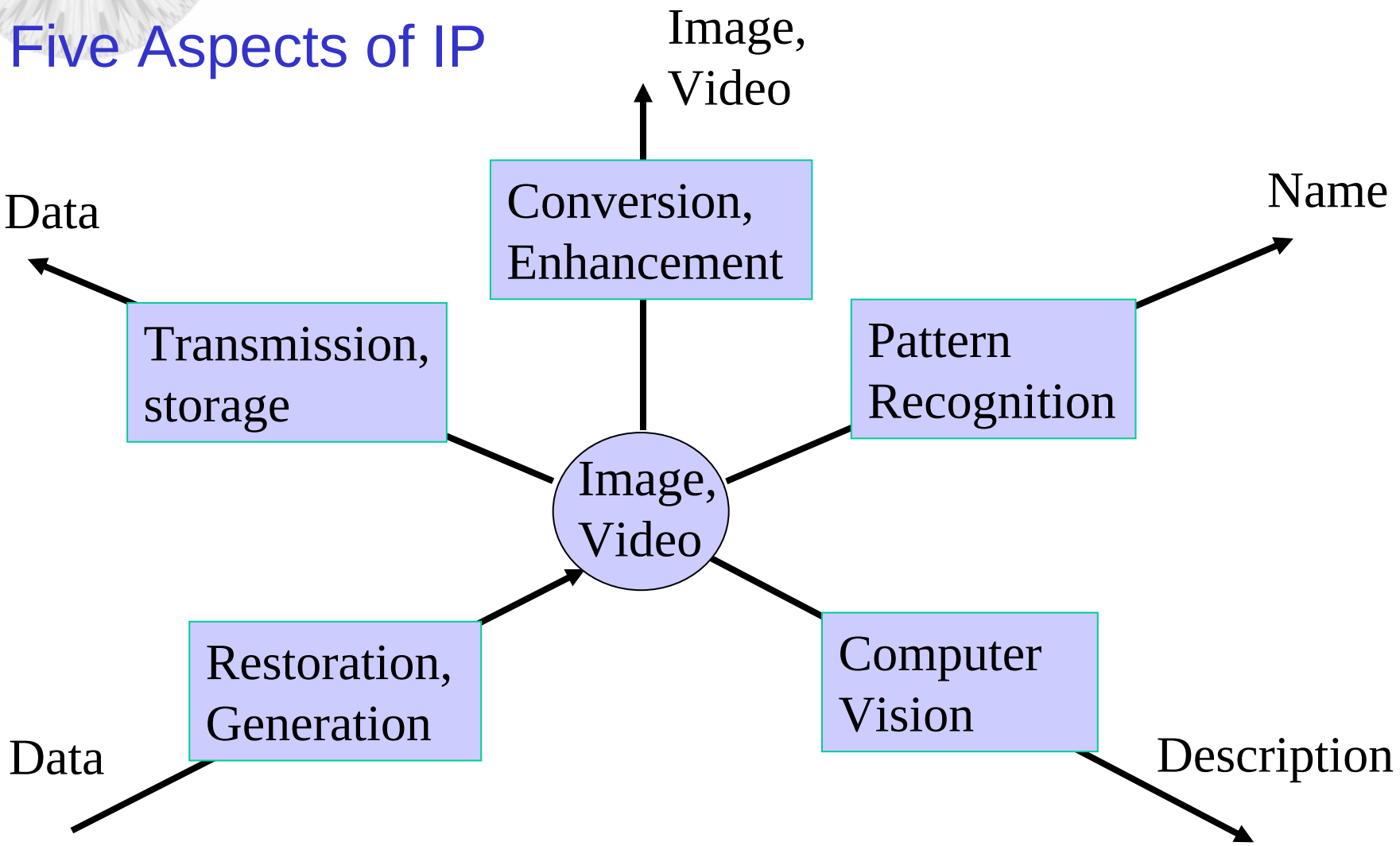
Digital Image/Video Processing

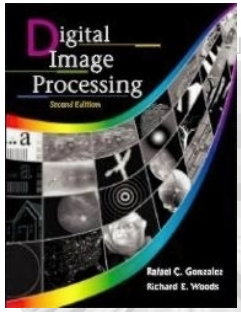
- ***One picture*** *is worth more than* ***ten thousand words****.*
- ***Information*** or ***media*** is the most valuable development tool for human intelligence.
- ***Multimedia*** includes text, ***images, video***, graphic, animation, and audio.



Digital Image/Video Processing

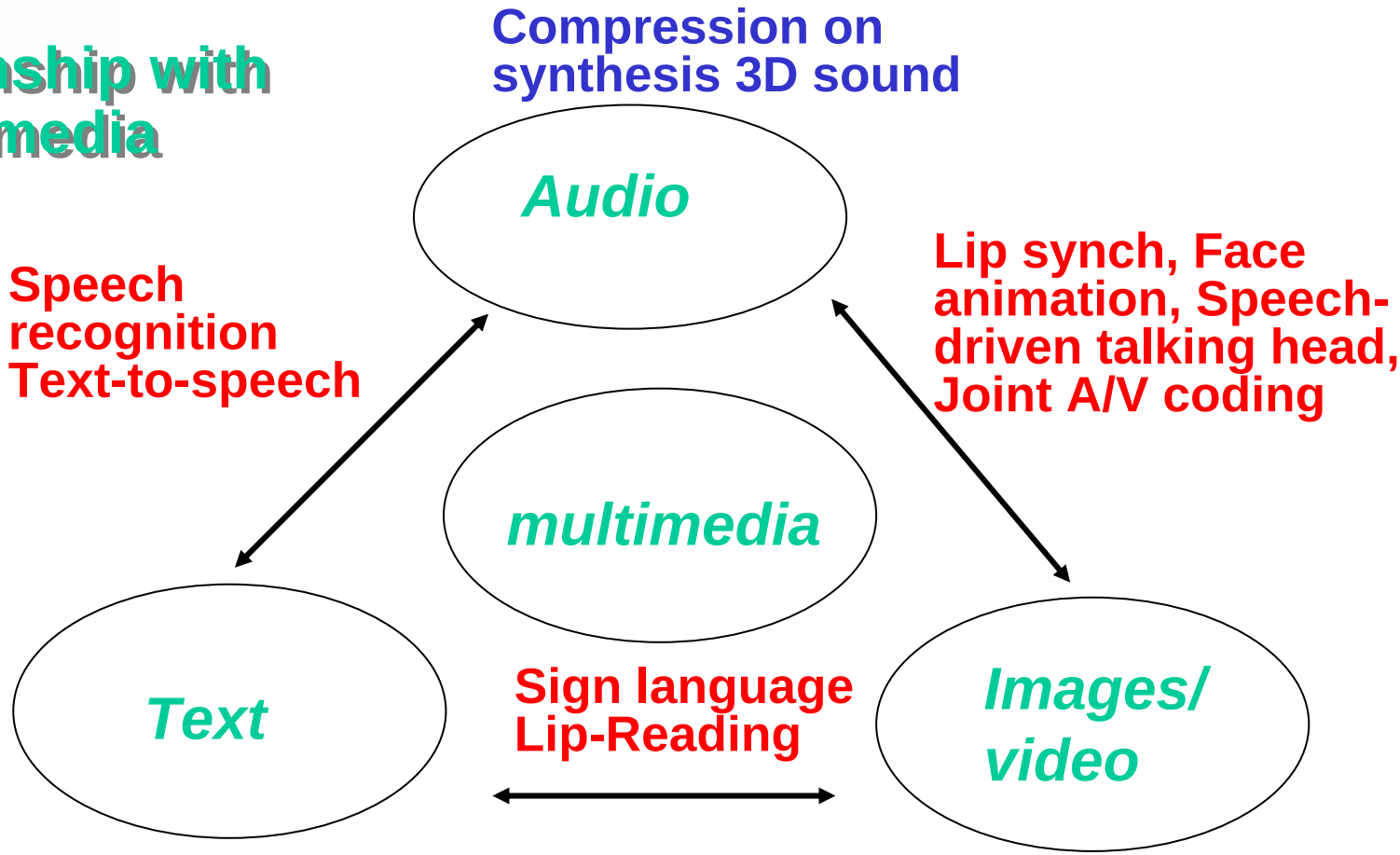
Five Aspects of IP

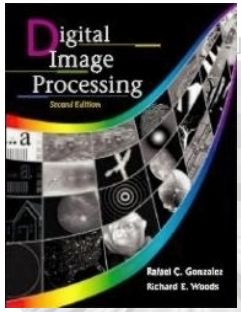




Digital Image/Video Processing

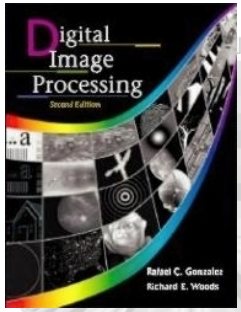
Relationship with multimedia





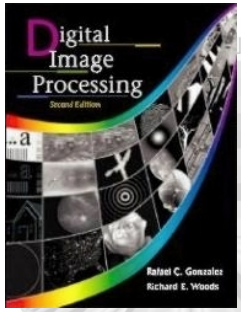
Course Grading

- Projects 40% (3~4 program assignments)
- Midterm 30%
- Final report 30%
- Attendancy 10%



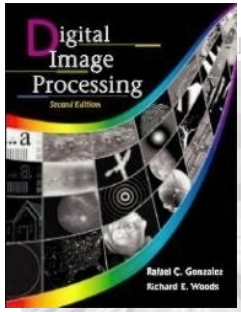
Chapter 1: Introduction

- An ***image*** is defined as a two-dimensional function $f(x, y)$, where x and y are spatial plane coordinates, the amplitude of $f(x, y)$ is the intensity or gray level.
- When x, y, and the amplitude values of f are all finite and discrete quantities, the image is called *a digital image*
- *A digital image is composed of a finite number of elements, each of which has a particular location and value.*
- *These elements are referred as picture elements, image elements, pixels, or pels.*
- A *video* is defined as a three-dimensional function $f(x, y, t)$, where the number a pictures displayed in time domain is called the *frame rate*.



Chapter 1: Introduction

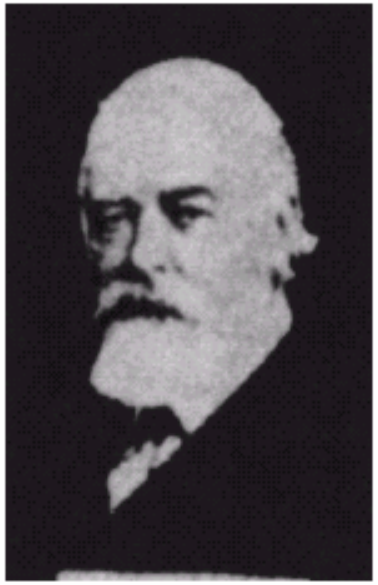
- Images are related to *Human perceptions*
- Human perception → Artificial Intelligence ← Computer Vision
- Image Processing are related to Computer Vision.
- Low-level process : inputs and outputs are images.
- Mid-level process : inputs are images, and outputs are the attributes extracted from the image (e.g., edges, contour, segmented objects).
- High-level process : perform the cognitive function normally associated with the vision.

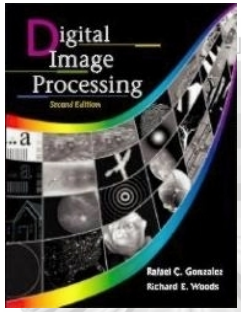


1.2: The original of Digital Image processing

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

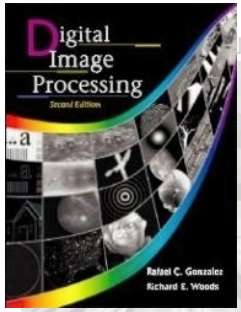
FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. Some errors are visible. (McFarlane.)





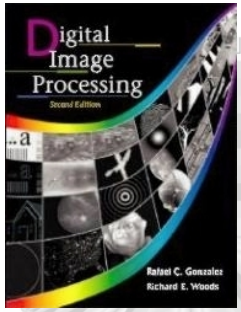
1.2: The original of Digital Image processing

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



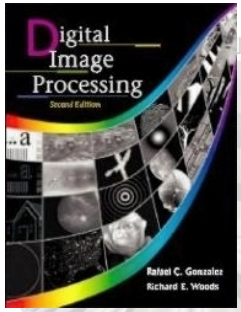
1.2: The original of Digital Image processing

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.)



1.2: The original of Digital Image processing

- Space applications
- Satellite imaging
  - Weather prediction
  - Geographic analysis
- Medical imaging
  - Computerized tomography
- Industry inspection
  - PCB inspections
- Consumer applications
  - Image enhancement and restoration
  - OCR
  - Security system



1.3: Examples of Digital Image processing

- The image processing applications can be categorized based on the source (*e.g.* visual, X-ray, etc.).
- Images based on radiation from ***EM spectrum*** are the most familiar which ranging from ***gamma rays*** to ***radio wave***.

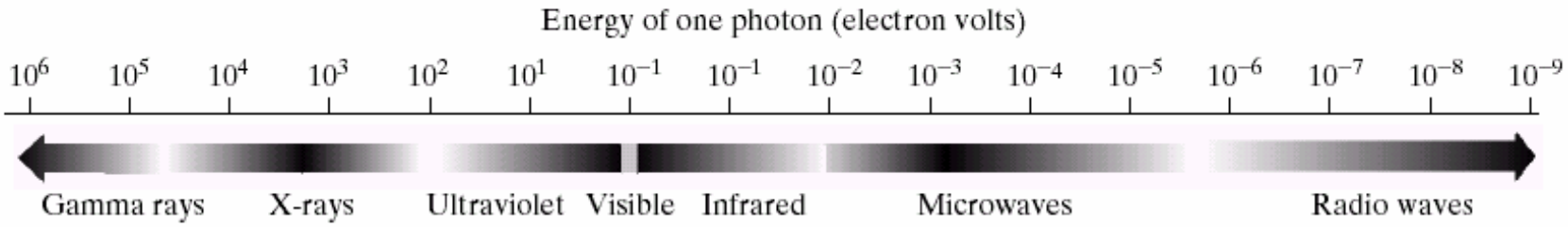
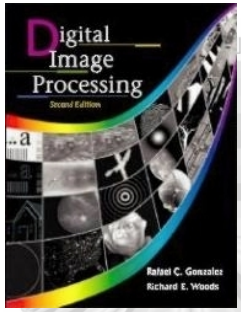
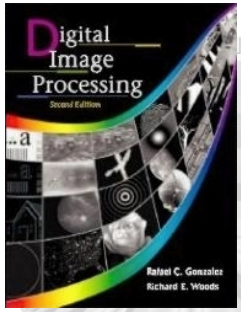


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.



1.3.1: Gamma-Ray Imaging

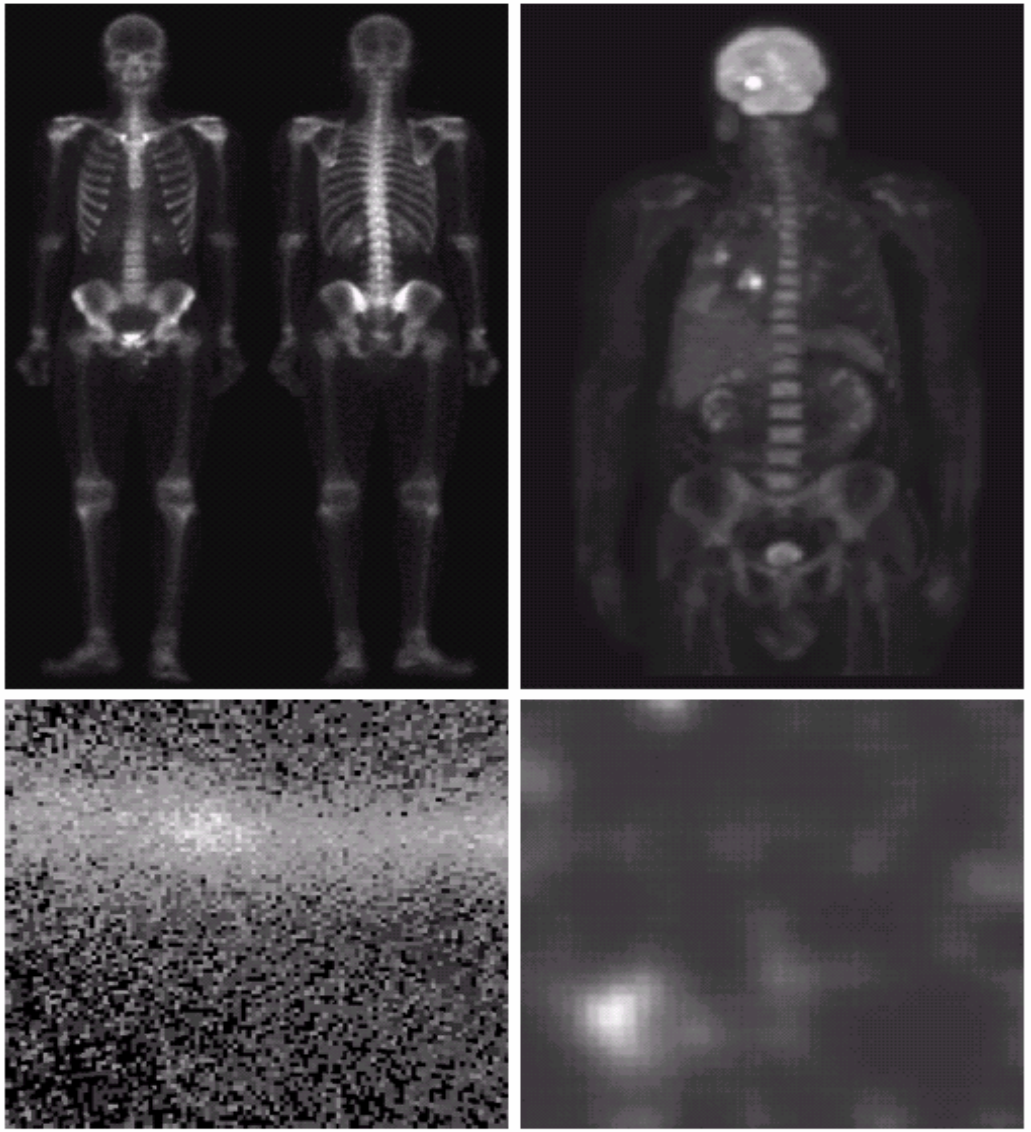
- ***Nuclear imaging***: inject a patient with a radioactive isotope that emits gamma ray as it decays.
- Images are produced from the emission collected by gamma ray detector.
- ***Positron emission tomography*** (PET): The radioactive isotope emits positron as it decays. When a positron meets an electron, both annihilate and two gamma rays are given off.

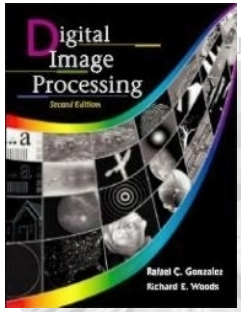


1.3.1: Gamma-Ray Imaging

a b
c d

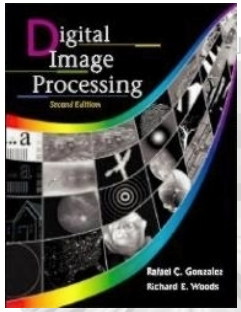
FIGURE 1.6 Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of Michigan.)





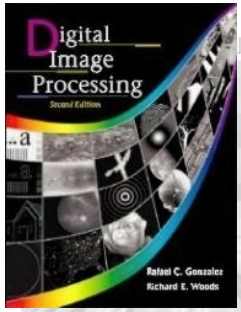
1.3.2: X-Ray Imaging

- X-rays are the oldest EM radiation used for imaging.
- X-ray tube (source) : a vacuum tube
- The intensity of X-rays is modified by absorption as they pass through the patient, and the resulting energy falling on the film develops it.
- Digital radiography
  - Digitizing X-ray film
  - X-ray fall on a device (e.g. Phosphor screen) that convert X-ray to light. The light signal is captured by light-sensitive digitizing system.



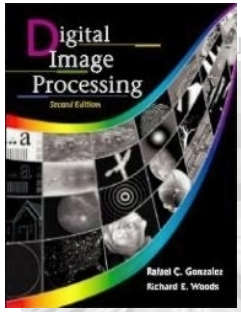
1.3.2: X-Ray Imaging

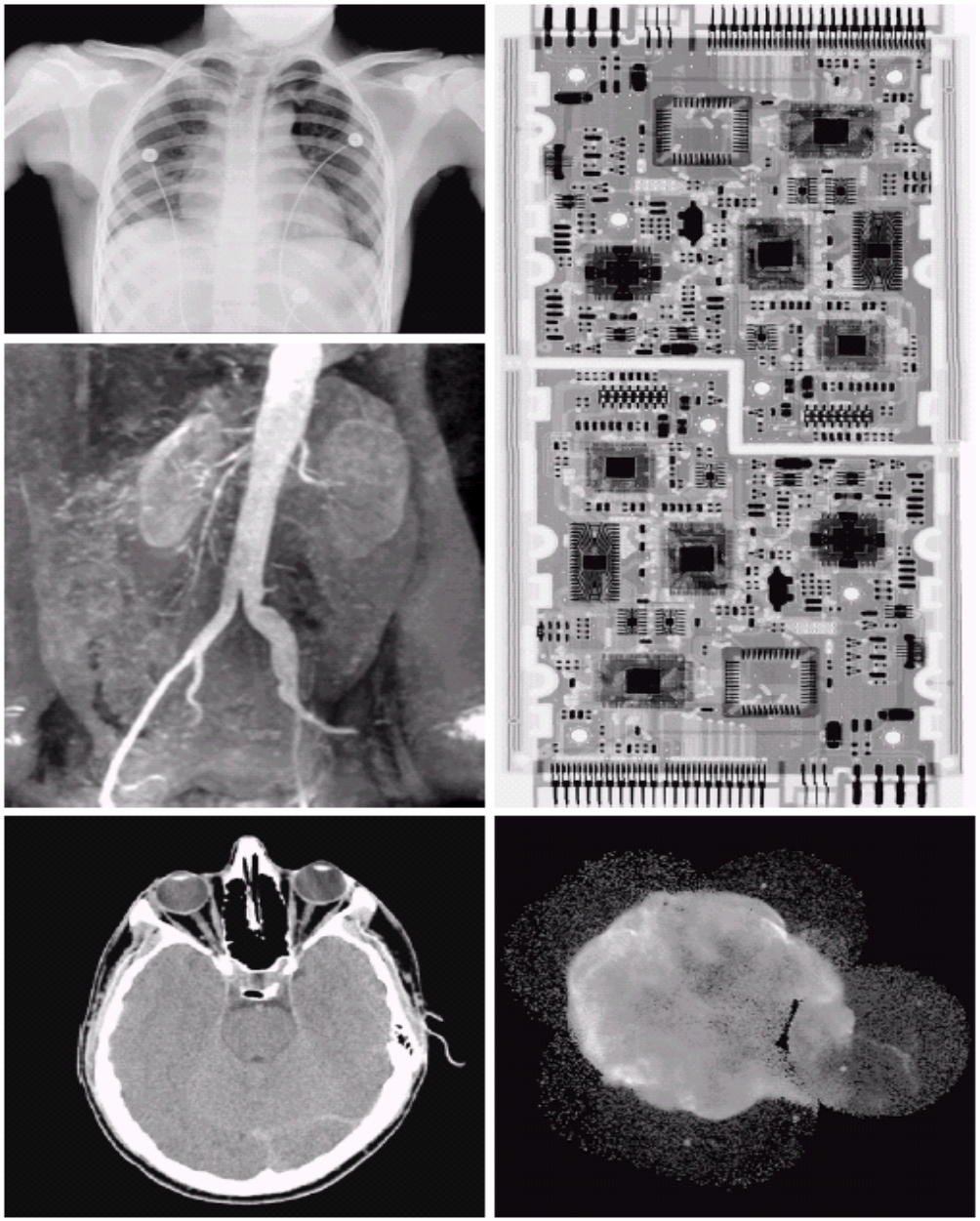
- *Angiography* – contrast enhancement radiography
  - To obtain the images of blood vessel (angiograms)
  - A Catheter (a small flexible hollow tube) is inserted into an artery or vein in the groin. The Catheter is threaded into the blood vessel and guided to the area to be studied.
  - When the Catheter reaches the site under investigation, an X-ray contrast medium is injected through the catheter to enhance the contrast of the blood vessel.



1.3.2: X-Ray Imaging

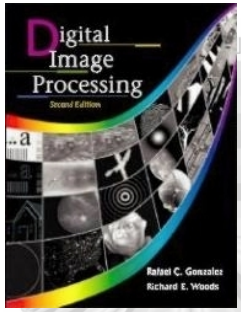
- Computerized Axial Tomography (CAT)
- Each CAT image is a slice taken perpendicularly through the patient
- Numerous slices are generated as the patient is moved in longitudinal direction.
- Industrial inspection using X-ray
- Industrial CAT scans
- X-ray imaging in Astronomy





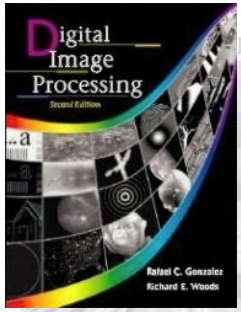
a d
b
c e

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.)



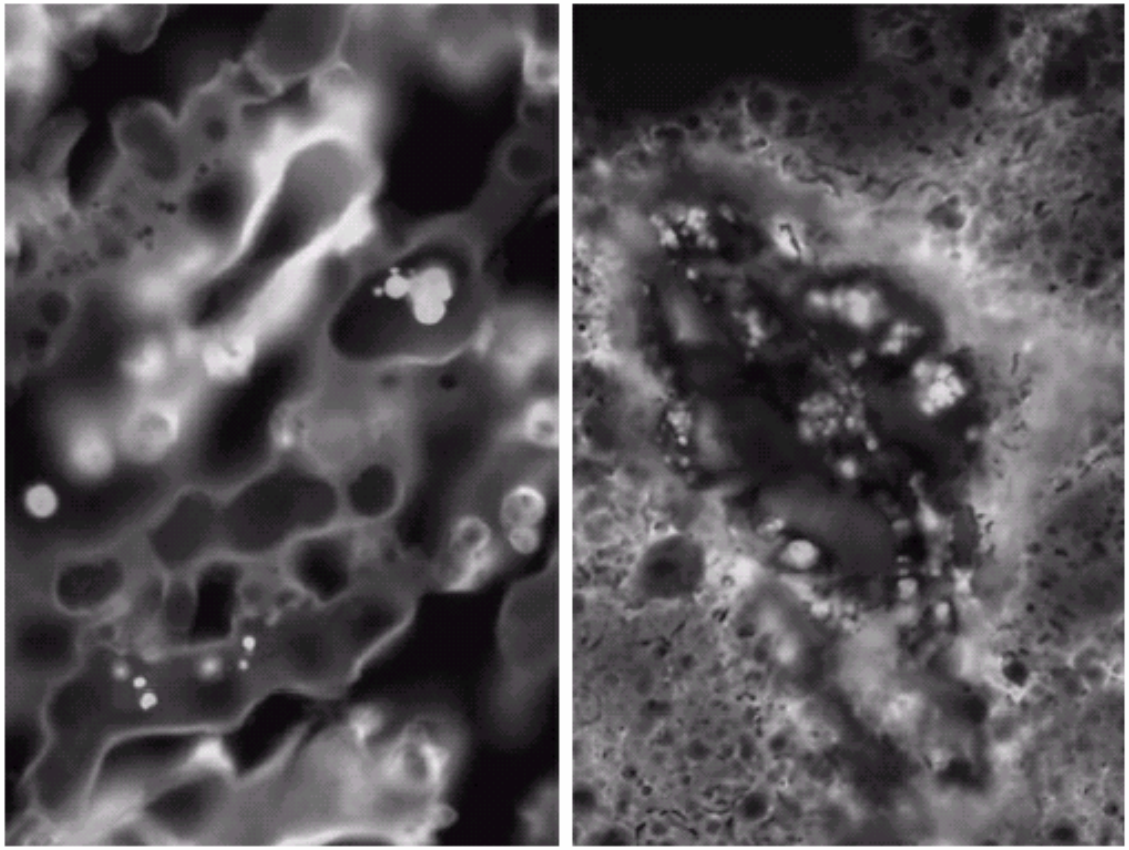
1.3.3: Imaging in the Ultraviolet Band

- Applications of Ultraviolet lights:
  - Lithography
  - Industrial inspection
  - Fluorescence Microscopy (for studying material)
  - Lasers
  - Biological imaging
  - Astronomical observation

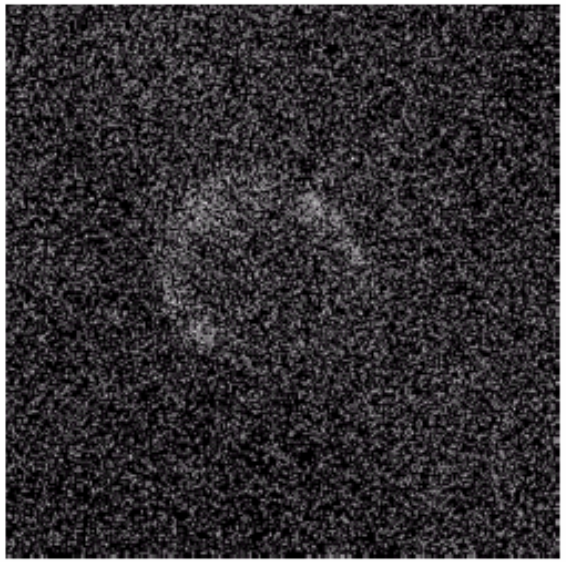


a b
c

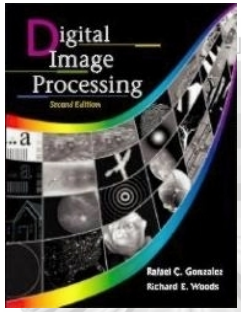
FIGURE 1.8 Examples of ultraviolet imaging. (a) Normal corn. (b) Smut corn. (c) Cygnus Loop. (Images courtesy of (a) and (b) Dr. Michael W. Davidson, Florida State University, (c) NASA.)



Fluorescence Microscopy

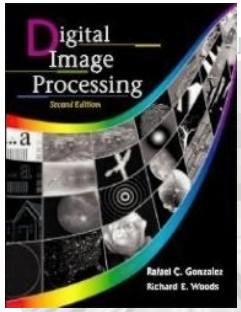


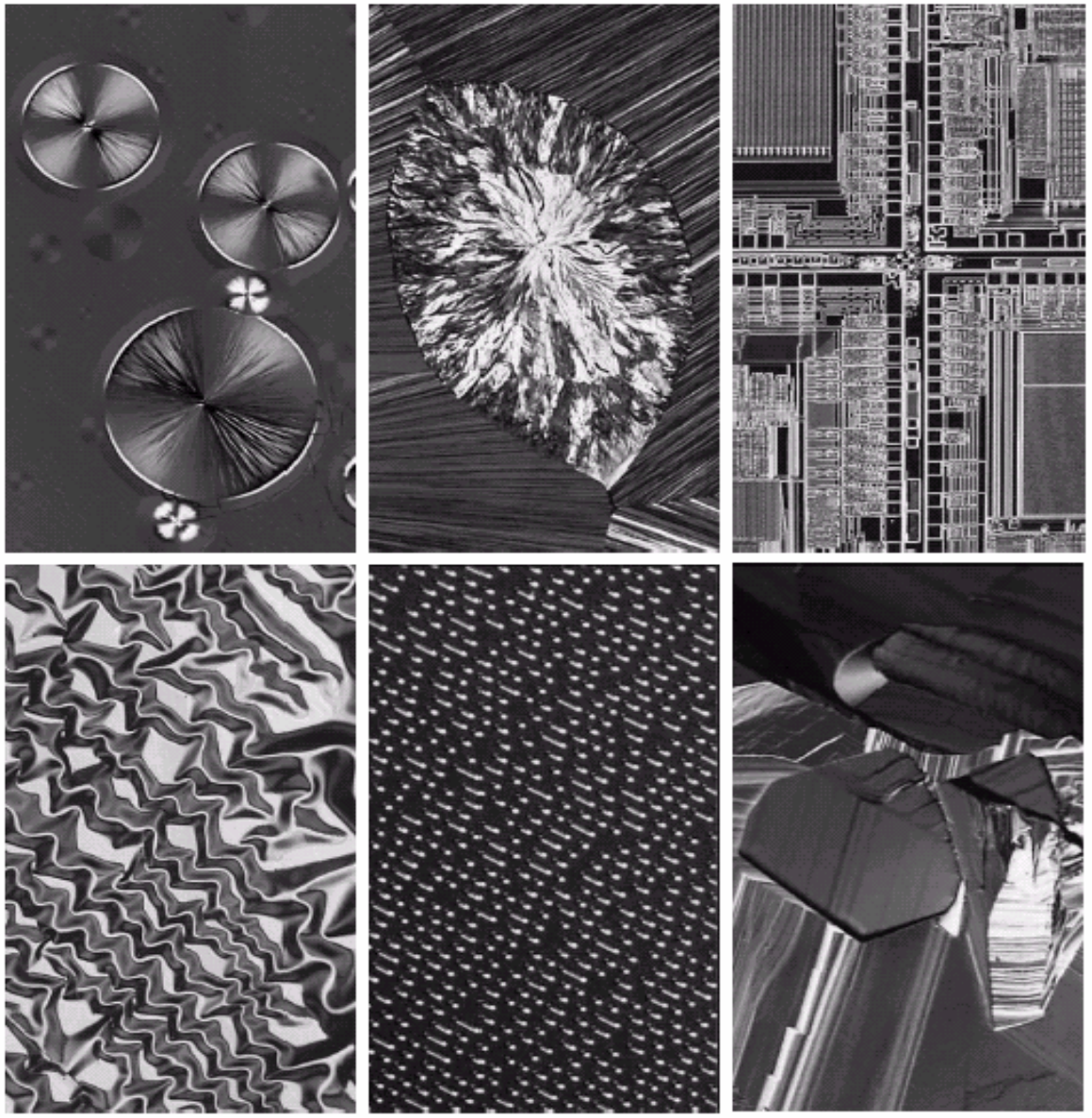
Astronomical observation



1.3.4: Imaging in the visible and infrared Bands

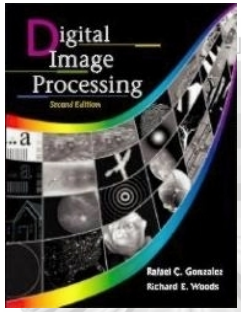
- Visual band is the most familiar in our activity
  - inspection
- Infrared band for satellite image
- Astronomy
- Light microscope
  - Pharmaceuticals
  - Micro-inspection
- Satellite image for remote sensing
  - Thermal bands for LANDSAT
  - Multi-spectral image





a b c
d e f

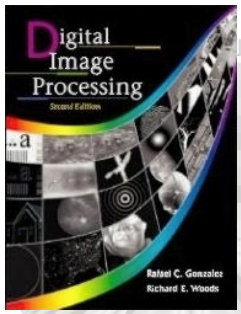
FIGURE 1.9 Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250×. (b) Cholesterol—40×. (c) Microprocessor—60×. (d) Nickel oxide thin film—600×. (e) Surface of audio CD—1750×. (f) Organic superconductor—450×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)



1.3.4: Imaging in the visible and infrared Bands

TABLE 1.1
Thematic bands in NASA's LANDSAT satellite.

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



1.3.4: Imaging in the visible and infrared Bands

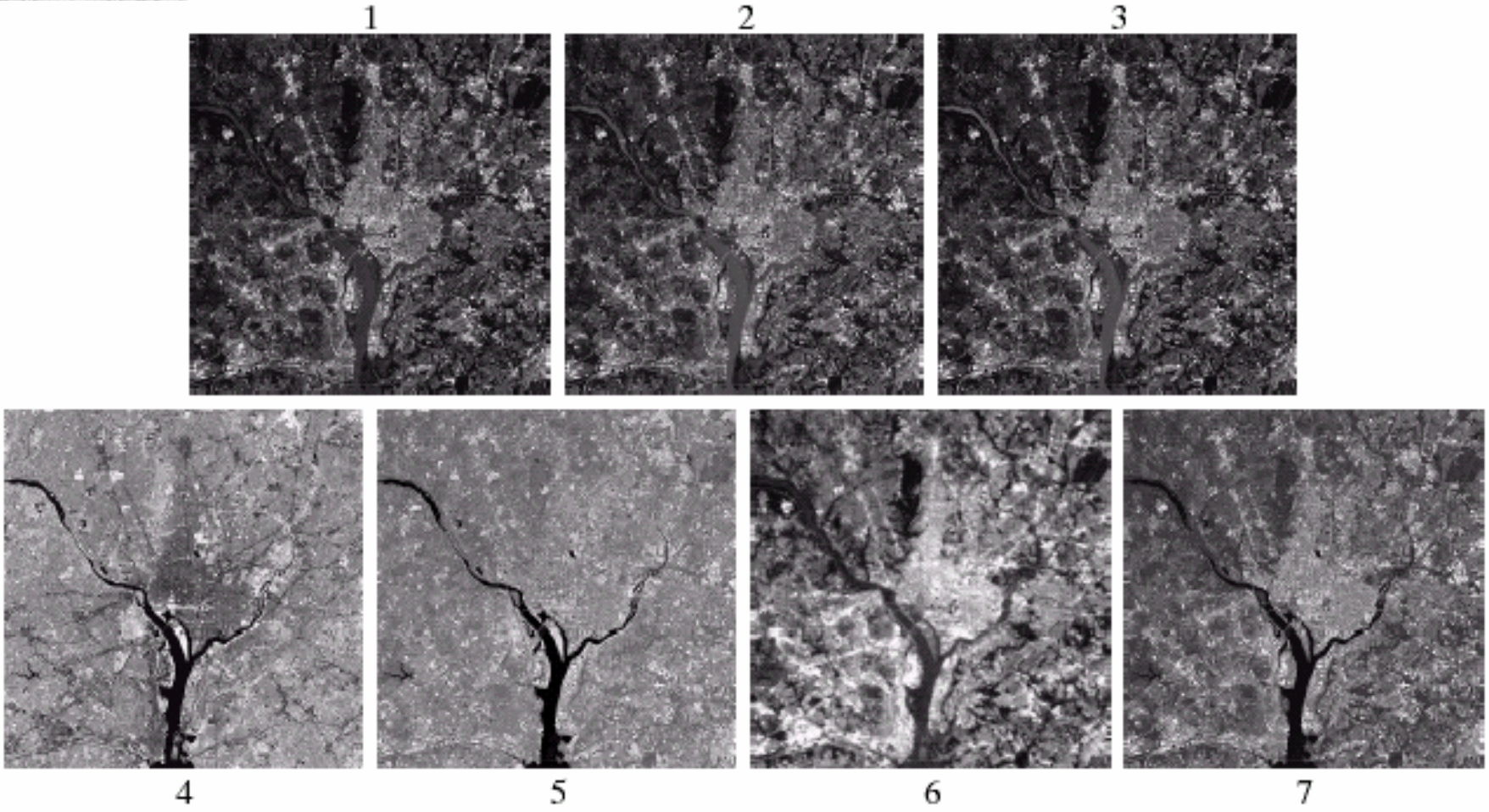
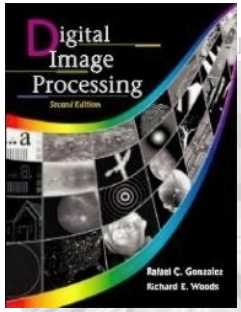


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)



1.3.4: Imaging in the visible and infrared Bands

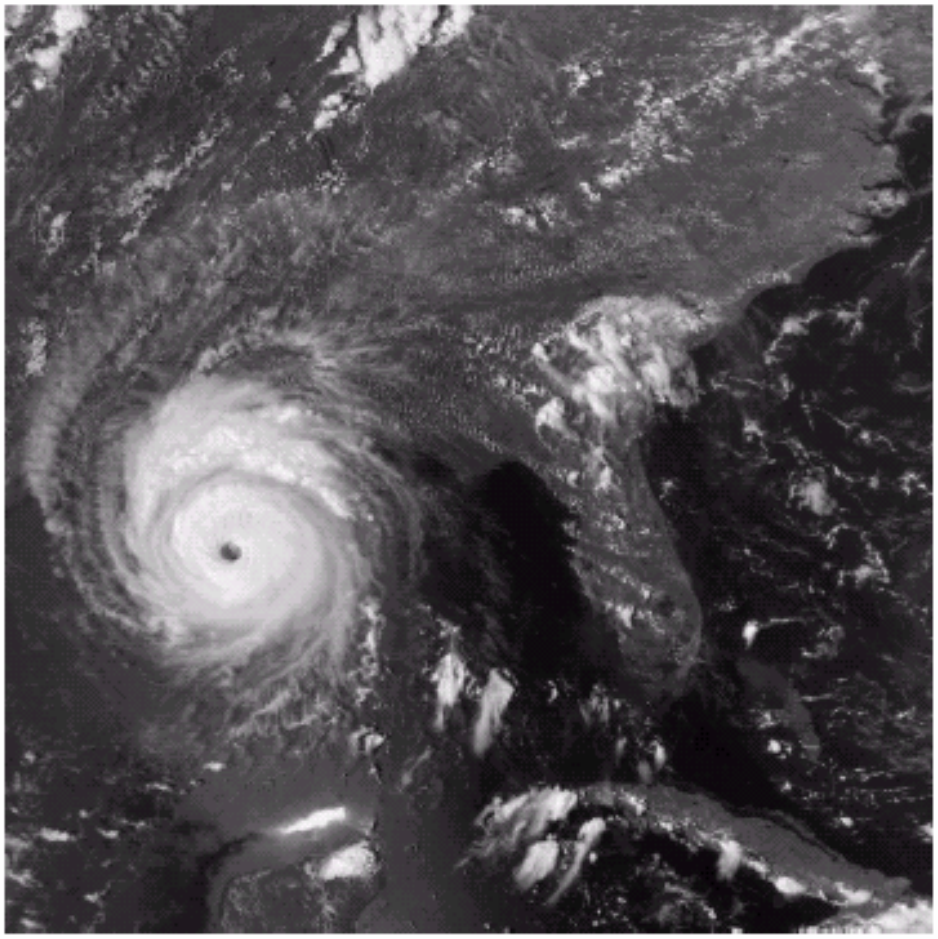


FIGURE 1.11 Multispectral image of Hurricane Andrew taken by NOAA GEOS (Geostationary Environmental Operational Satellite) sensors. (Courtesy of NOAA.)

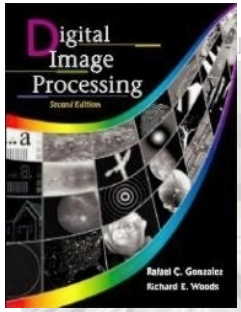
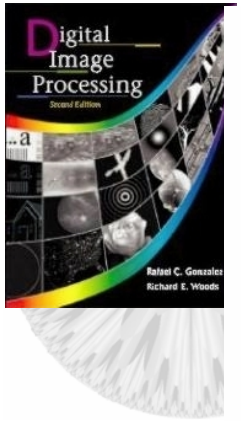


FIGURE 1.12 Infrared satellite images of the Americas. The small gray map is provided for reference. (Courtesy of NOAA.)



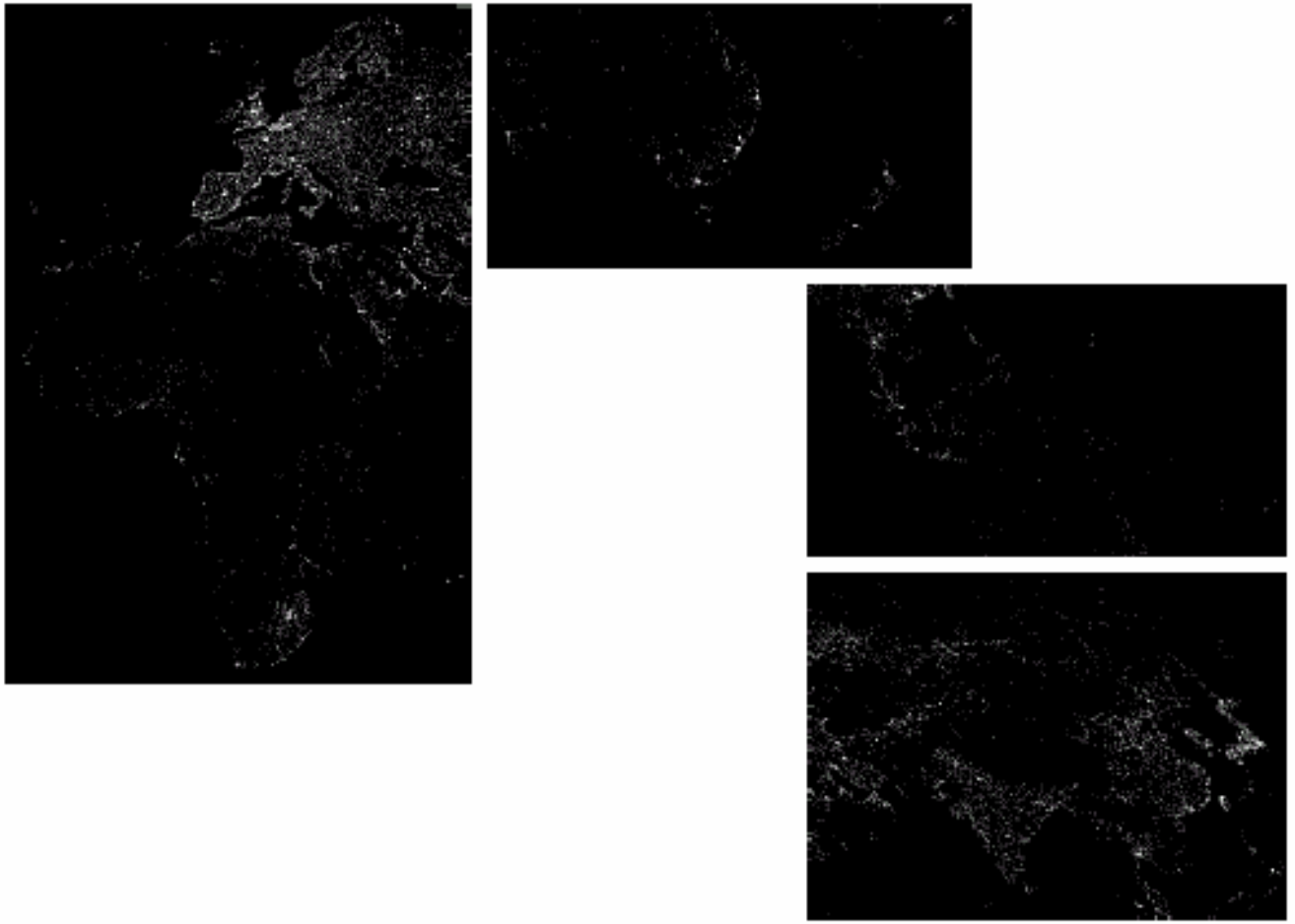
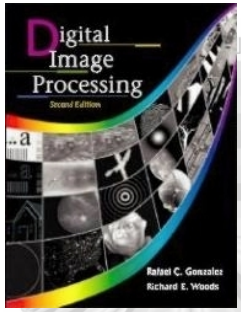
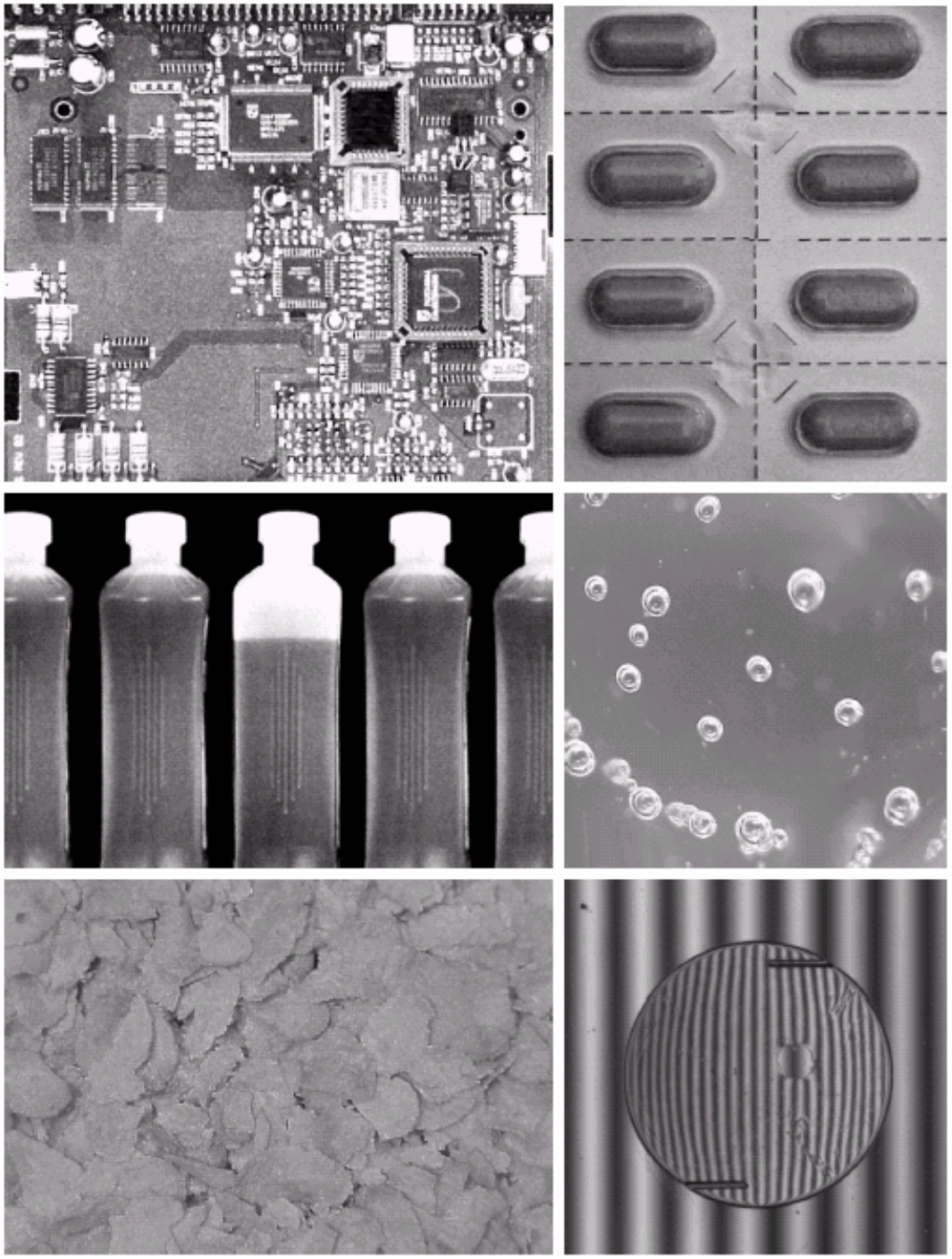


FIGURE 1.13 Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)

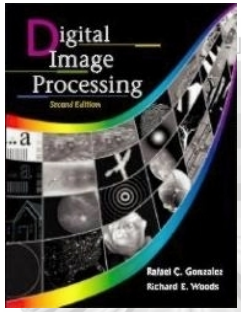


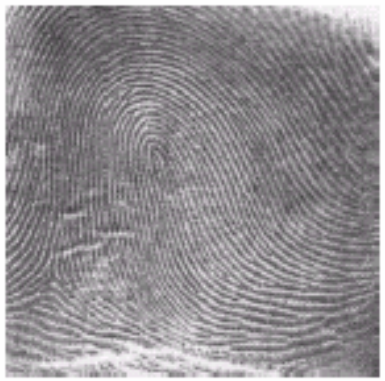
a b
c d
e f

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.)



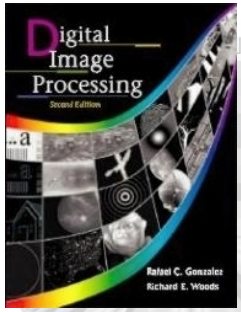
Automatic visual inspection





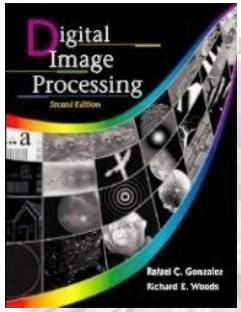
a b
c
d

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.)



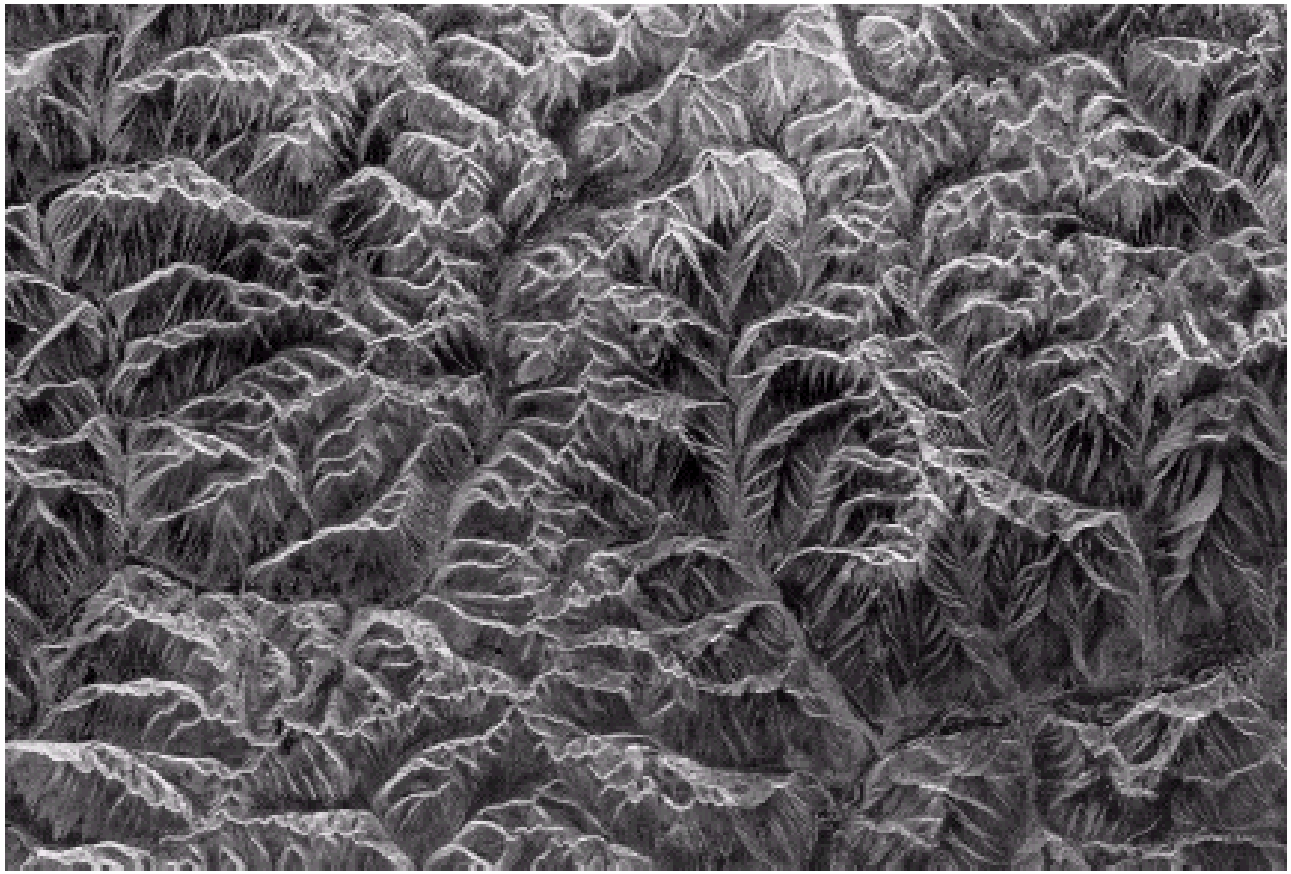
1.3.5: Imaging in the microwave Bands

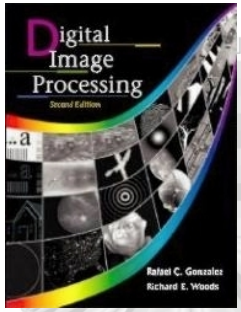
- ***Radar image***
  - Collect data over virtually any region at any time regardless of weather and ambient lightning conditions.
  - Like a flash camera using its own illumination.
  - Using antenna and digital image processing techniques to record its image



1.3.5 Imaging in the microwave Bands

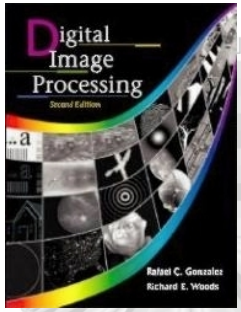
FIGURE 1.16
Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)



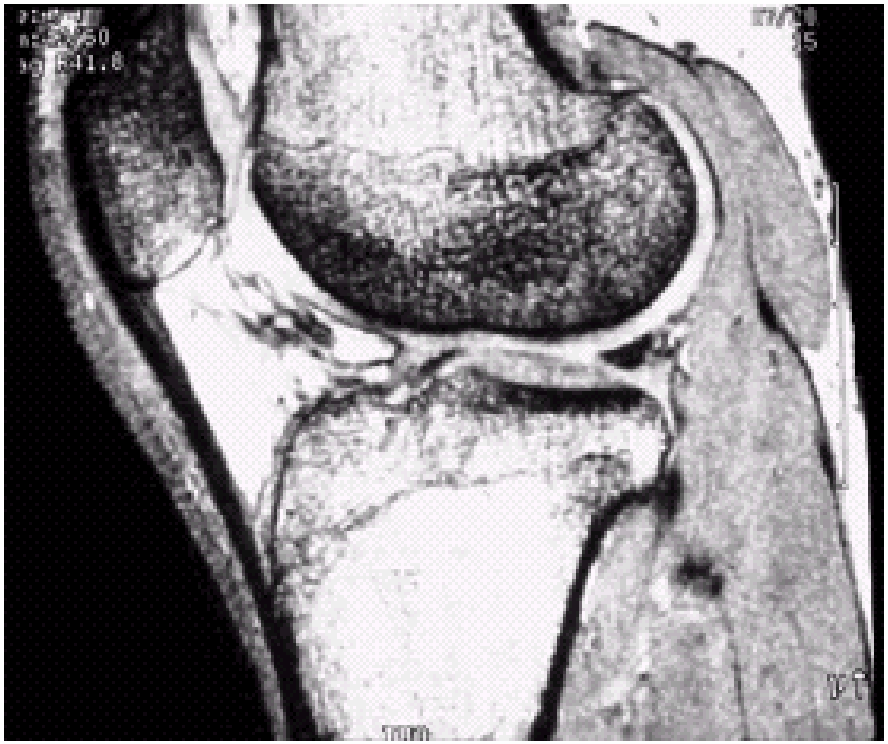


1.3.6: Imaging in the radio bands

- ***Medicine***
  - Magnetic resonance imaging (MRI)
  - Patient is placed in a magnet
  - Passing a radio wave through his body
  - Each pulse causes a responding pulse of radio wave emitted from the patient tissue
  - The location and strength of the signal is detected and then calculated by the computer to generate the image.
- ***Astonomy***

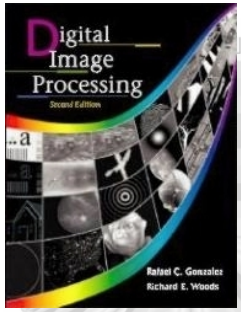


1.3.6: Imaging in the radio bands

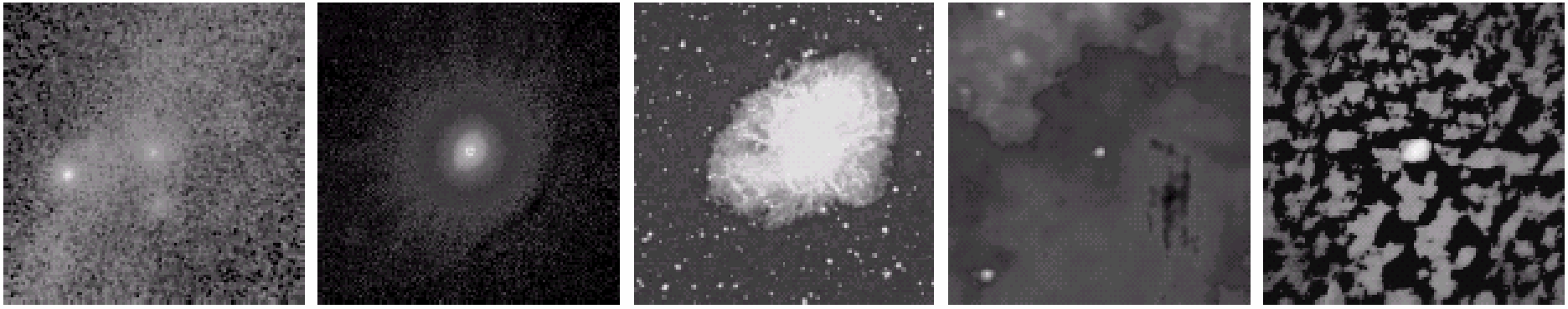


a b

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.)

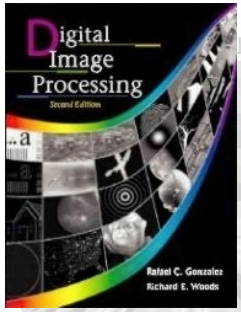


1.3.6: Imaging in the radio bands



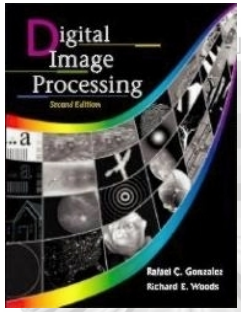
Gamma X-ray Optical Infrared Radio

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



1.3.7: Examples in which other image modalities are used

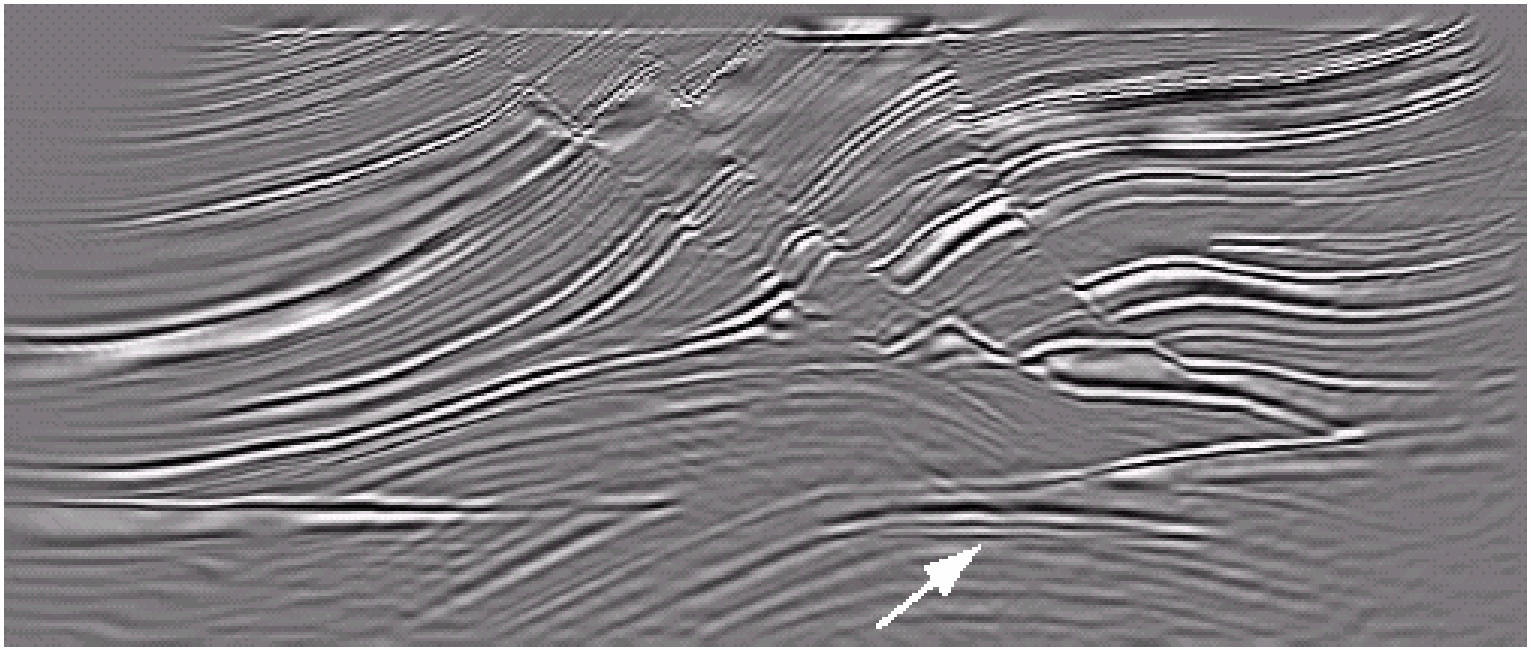
- Acoustic imaging
  - Geological exploration
  - Industry
  - medicine
- Electron microscopy
  - Transmission electron microscopy (TEM)
    - For thin sample
  - Scanning electron microscopy (SEM)
    - For "bulky" sample
- Synthetic image
  - Fractal image
  - 3-D rendering of the computerized tomography



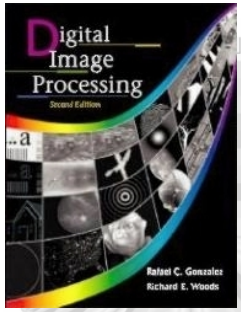
1.3.7: Examples in which other image modalities are used

Seismic interpretation looks for these “bright spots” to find oil and gas.

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.)

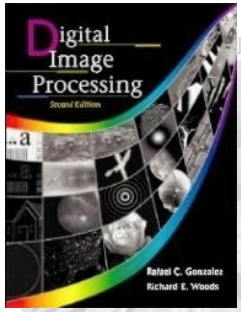


The target is brighter than the surrounding layer

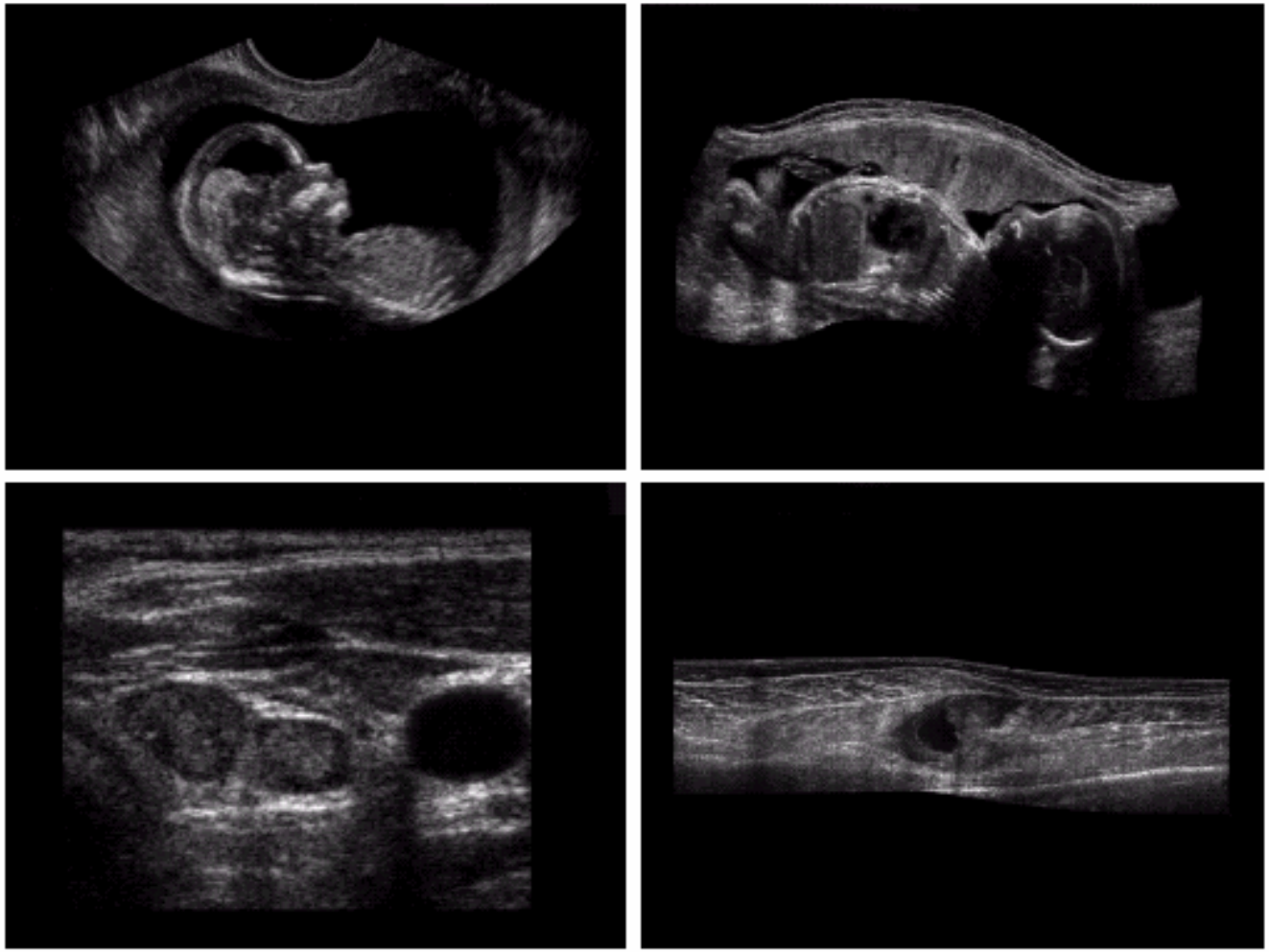


1.3.7: Examples in which other image modalities are used

- ***Ultrasound image*** is generated as follows:
  - Ultrasound system (computer, source, receiver, display) transmits high freq. sound (1~5MHz) pulse into the body
  - Sound hits the boundary between tissues (between fluid and soft tissue, soft tissue and bone)
  - The reflected wave is picked up by the probe.
  - Machine calculates the distance from the probe to the tissue or organ boundaries using the speed of sound in tissue (1540m/sec) and time of the each echo return.
  - Display the distance and intensities of the echoes on the screen, forming a 2-D image

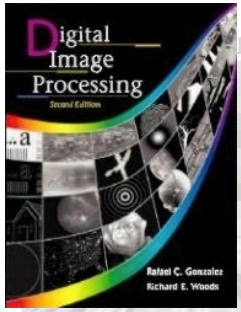


1.3.7: Examples in which other image modalities are used

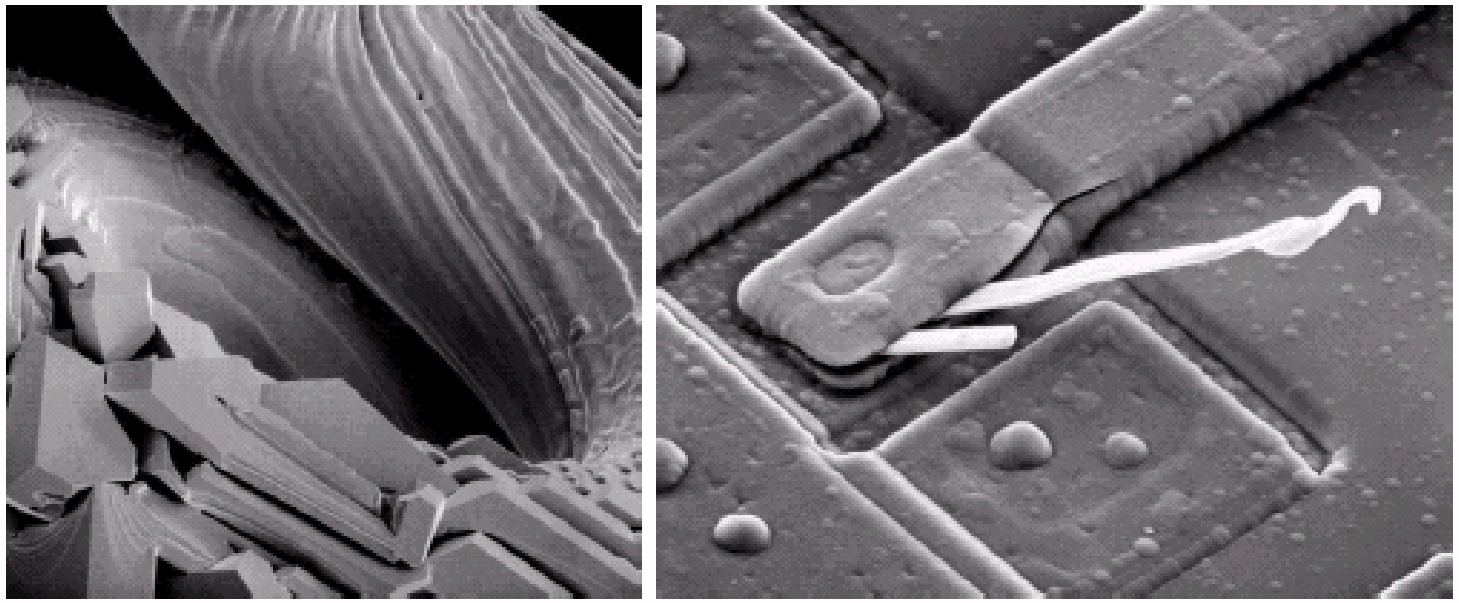


a b
c d

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.)

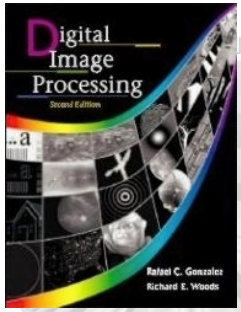


1.3.7: Examples in which other image modalities are used

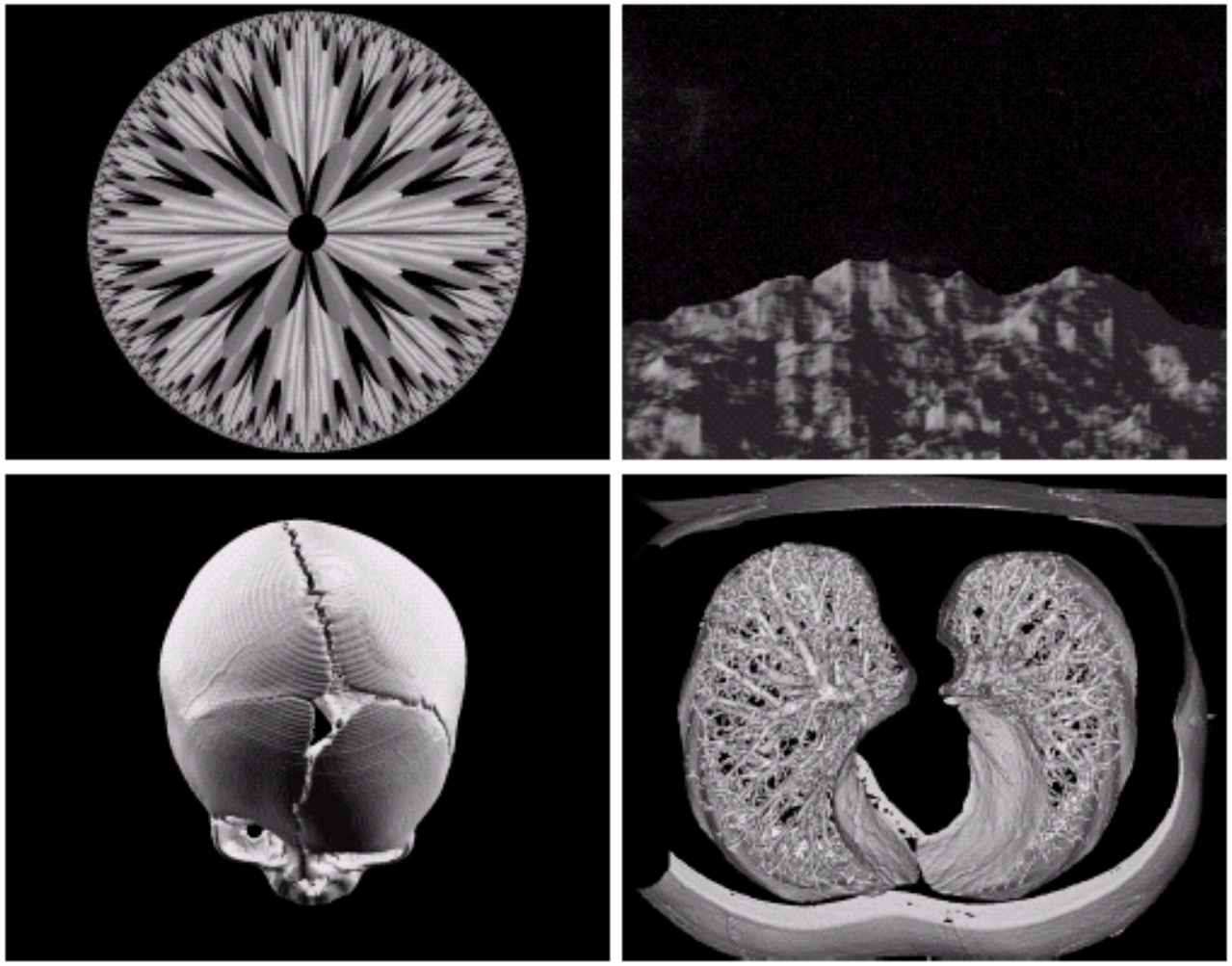


a b

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.)

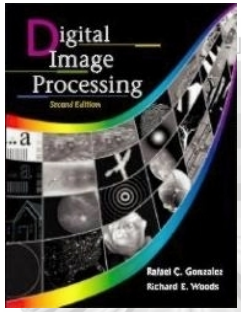


1.3.7: Examples in which other image modalities are used



a b
c d

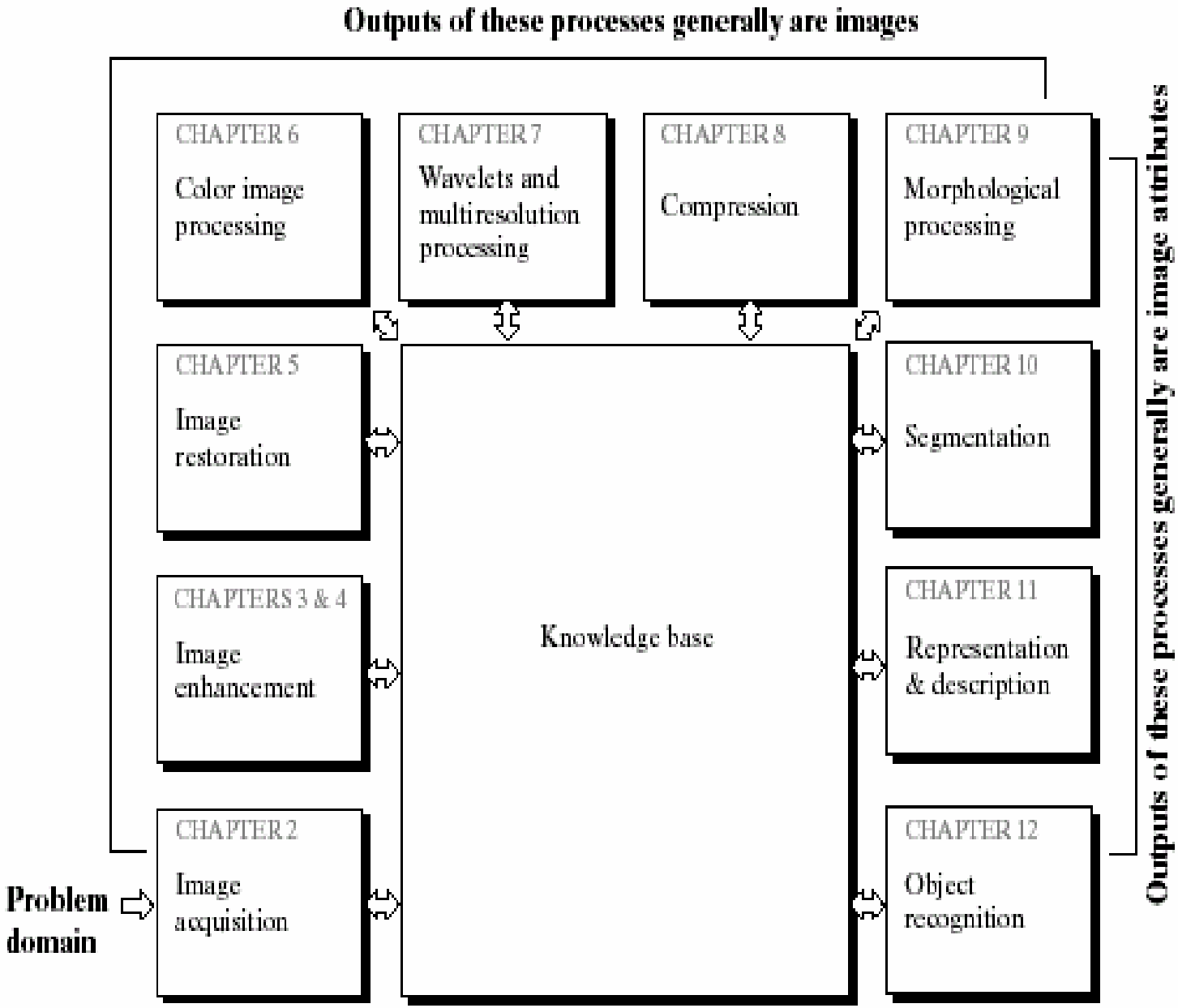
FIGURE 1.22
(a) and (b) Fractal images. (c) and (d) Images generated from 3-D computer models of the objects shown. (Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College, (c) and (d) courtesy of NASA.)

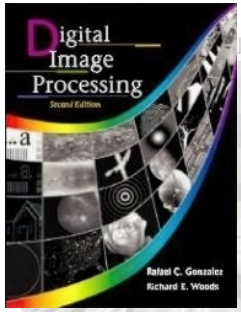


1.4: Fundamental Steps in Digital Image Processing

- Image Acquisition
- Image Enhancement
- Image Restoration
- Color Image Processing
- Wavelet
- Compression
- Morphological Processing
- Segmentation
- Representation and description
- Recognition

FIGURE 1.23
Fundamental steps in digital image processing.





1.5: Components of an image processing system

- Sensing
- Specialized Image processing hardware
- Computer
- Software
- Mass storage
- Display
- Hardcopy
- Network

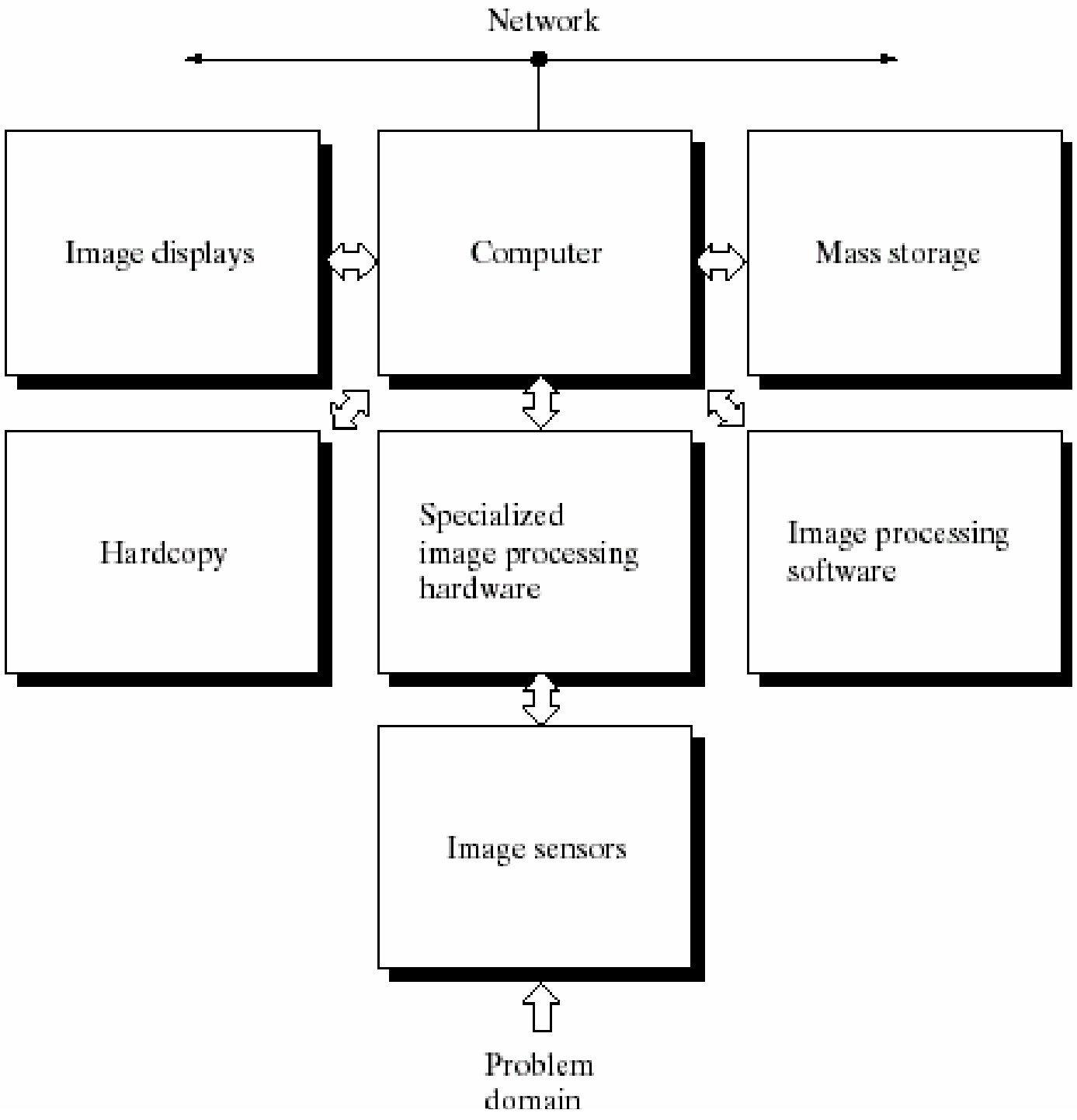


FIGURE 1.24
Components of a general-purpose image processing system.