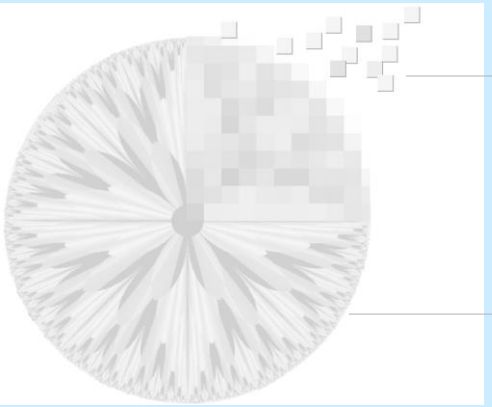

# Digital Image Processing


## Horng, Ming-Huwi

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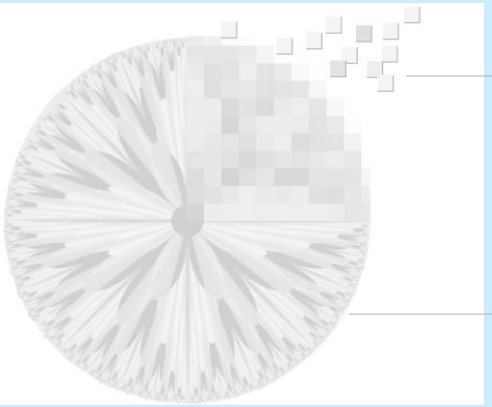
horng@nptu.edu.tw



# Course Contents:

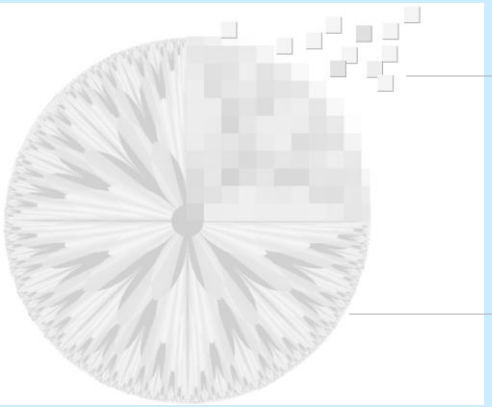
**Digital image processing has become one of the most popular courses in computer science and electrical engineering. The techniques of digital image processing have been rapidly developed and widely adopted in tremendous applications. This course gives a series of introductory lectures on the basic theories and implementations of digital image processing techniques. The major topics cover Digital Image Fundamentals, Image Enhancement, Image Restoration, Color image processing, Segmentation, Morphological processing, Representation & Description, and Classification. Some newly developed Deep Learning techniques for image processing will also be included in the last 4 lectures of the course. The course work includes programming assignments and one examination. It is a fundamental course for digital image processing, recent developments in artificial intelligence based image processing techniques will also be introduced in these lectures.**

## Text book:

- **R.C. Gonzalez, and R.E. Woods, Digital Image Processing, 4rd ed., Prentice Hall.**

## Reference book:

- **PetRC Gonzalez, RE Woods, & SL Eddins, Digital Image Processing Using MATLAB, 2nd ed., Tata McGraw Hill Education, 2011**
- **Maria Petrou and Costas rou, Image Processing: The Fundamentals, 2nd Edition, Wiley & Sons, 2010.**
- **A McAndrew, JH Wang, & CS Tseng, Introduction to Digital Image Processing with Matlab, Thomson course technology, Asia ed. 2010.**
- **Deep learning for image processing applications [electronic resource] / edited by D. Jude Hemanth and Vania Vieira Estrela, IOS Press, 2017.**
- **Pro deep learning with TensorFlow : a mathematical approach to advanced artificial intelligence in Python / by Santanu Pattanayak, Springer eBooks 2017.**
- **Practical computer vision applications using deep learning with CNNs : with detailed examples in Python using TensorFlow and Kivy / by Ahmed Fawzy Gad, Springer ebks, 2018 .**
- **W.K. Pratt, Digital Image Processing, 4th ed, Wiley inter-science, 2007.**



# Grading policy:

**One examination (50%),**

**one midterm assignment (20%),**

**and one Project (30%).**

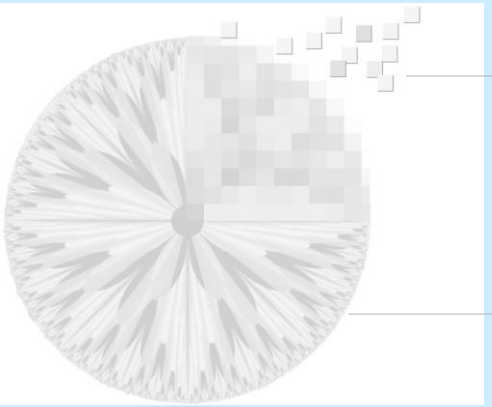
# Prerequisite:

**NONE.**

# Lecture Sequence

Week 1: Introd. to Image Processing
Week 2: Digital Image Fundamentals (Ch2)
Week 3: Image Enhancement in the Spatial Domain (Ch3)
Weeks 4, 5: Image Enhancement in the Freq. Domain (Ch4)
Week 5-6:Image Enhancement in freq. Domain / Image Restoration(Ch4, 5 )
Week 6-7: Image Restoration and Color Image Processing
Week 8:Midterm Program check
Weeks 9-10-11: Image Segmentation

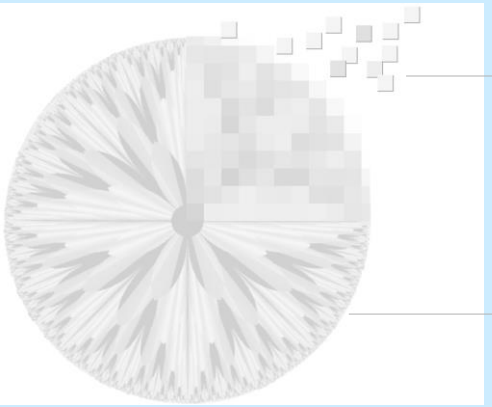
Week 12: Deep learning in Image Analysis (I)
Week 13: Project explanation and Deep learning in Image Analysis (II)
Week 14: Deep learning in Image Analysis (III)
Week 15: Deep learning in Image Analysis (IV)
Week 16: : Deep learning in Image Analysis (V)
Week 17: Final examination
Week 18: Final Project Demo



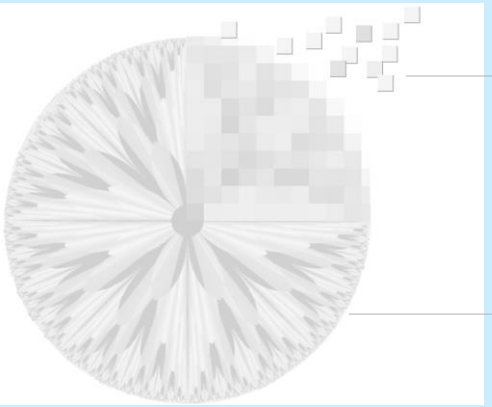
# Digital Image Processing

## 4rd Ed.

R.C. Gonzalez and R.E. Woods



# Chapter 1
# Introduction



# Outline

1.1 What is digital image processing?

1.2 The Origins of Digital Image Processing

1.3 Examples of Fields that use Digital Image Processing

1.4 Fundamental Steps in Digital Image Processing

1.5 Components of an Image Processing System

# 1.1 What is digital image processing?

**Image**: a two-dimensional function *f(x,y)*, where *x* and *y* are spatial coordinates and the amplitude *f* at any pair of coordinates *(x,y)* is called the intensity or gray level.

When *x*, *y*, and *f* are discrete quantities the image is **digital**.

*f* can be a **vector** and represent a color image, e.g. using the RGB model, or in general a multispectral image.

A **video** signal is similarly expressed as a sequence of **frames** *f(x,y,t)*.

- **Digital Image Processing** concerns the transformation of an image to a digital format and its processing by a computer or by dedicated hardware

  - both input and output are digital images

- **Digital Image Analysis** concerns the description and recognition of the image contents.

  - the input is a digital image, the output is a symbolic description

- **Computer Vision** uses digital electronics to emulate human vision, including learning, making inferences, and taking actions

# 1.2 The Origins 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. (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.)

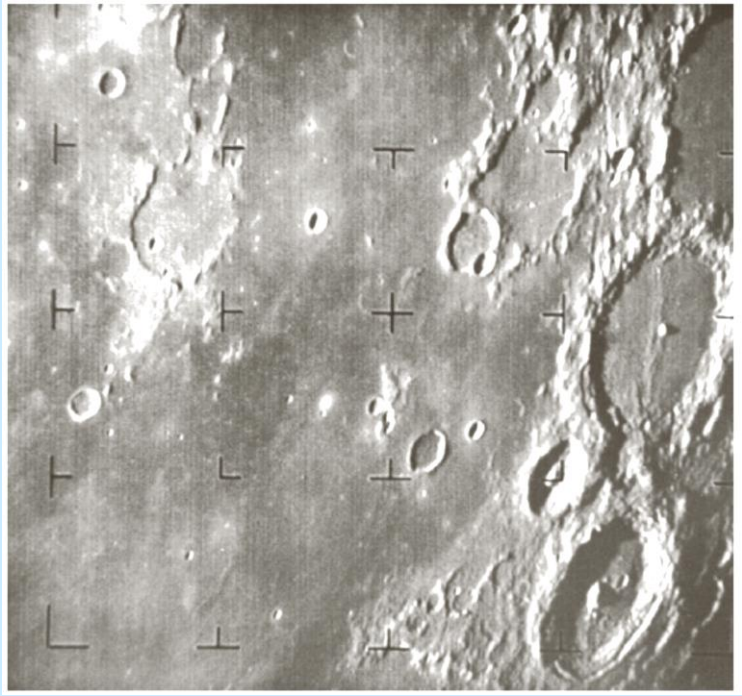


**FIGURE 1.4** The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9 : 09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

# 1.3 Examples of Fields that use Digital Image Processing

-Gamma-Ray Imaging

-X-Ray Imaging

-Imaging in the Ultraviolet Band

-Imaging in the Visible and Infrared Bands

-Imaging in the Microwave Band

-Radio Band

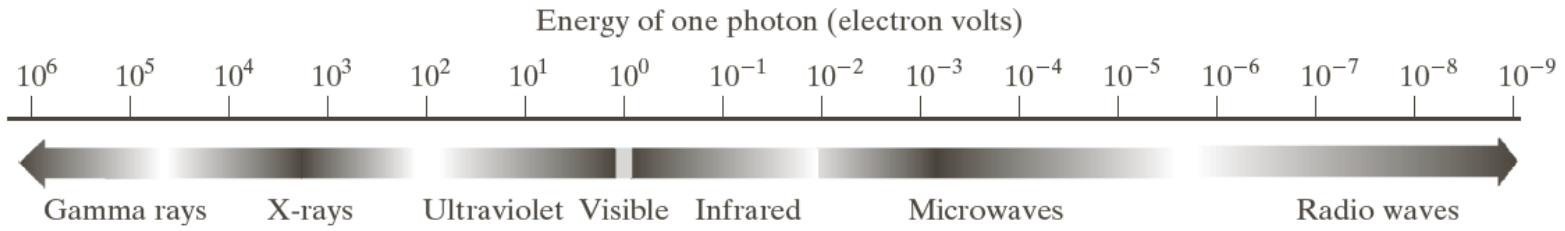
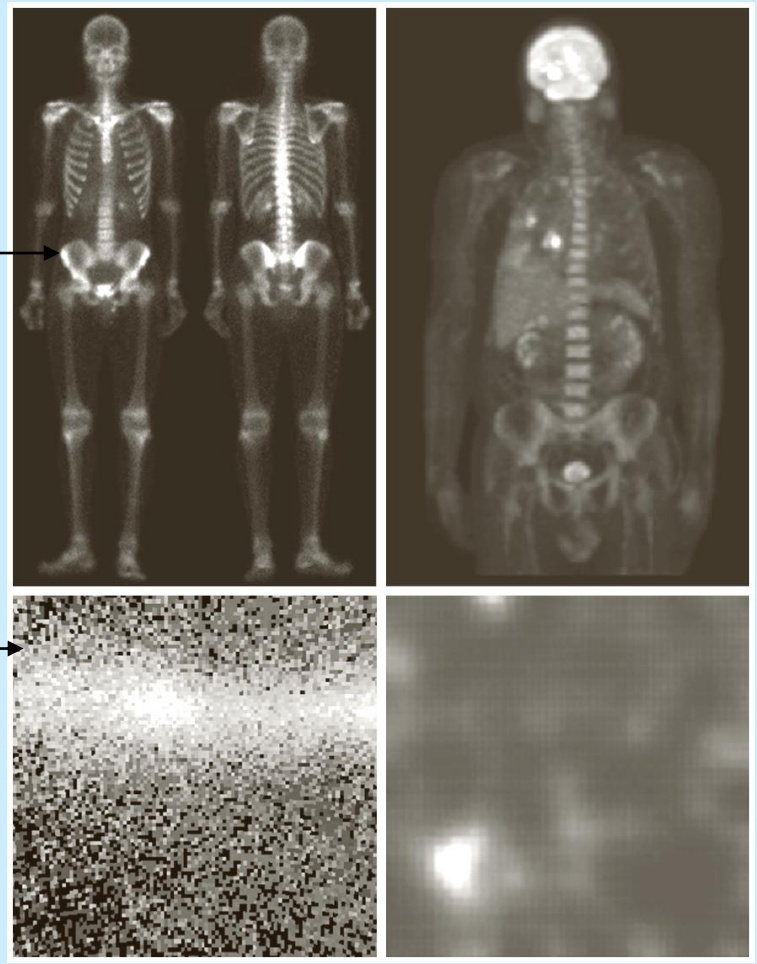



**FIGURE 1.5** The electromagnetic spectrum arranged according to energy per photon.

# 1.3.1 Gamma-Ray Imaging

**a:** A radioactive isotope is injected, which emits positrons as it decays; when a positron meets an electron, both are annihilated and two gamma rays are generated.
**b:** Positron-Emission Tomography
**c:** Natural gamma ray source superheated stationary gas cloud in the constellation of Cygnus.
**d:** An image of gamma radiation from a valve in a nuclear reactor.

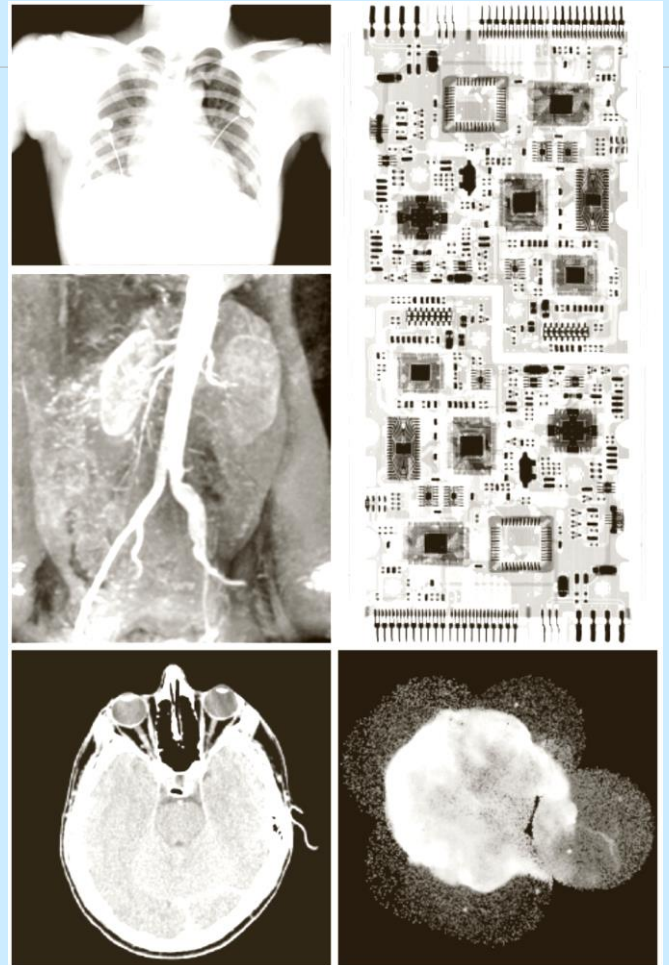


a b
c d

**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

**a:** X-ray imaging.
**b:** Aortic angiogram.
**c:** Head CT
**d:** Circuit boards
**e:** Cygnus Loop



a b c d e

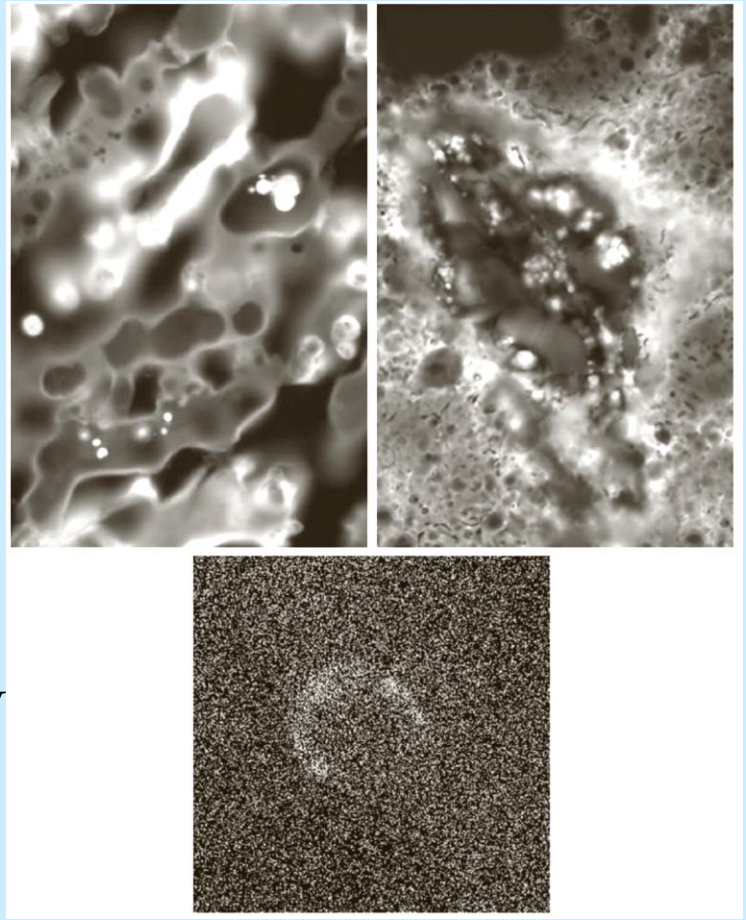
**FIGURE 1.7** Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of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

# 1.3.3 Imaging in the **Ultraviolet** Band

Ultraviolet imaging Microphotography; normal corn and corn infected by parasites.

Visible radiation is excited by UV light (fluorescence)

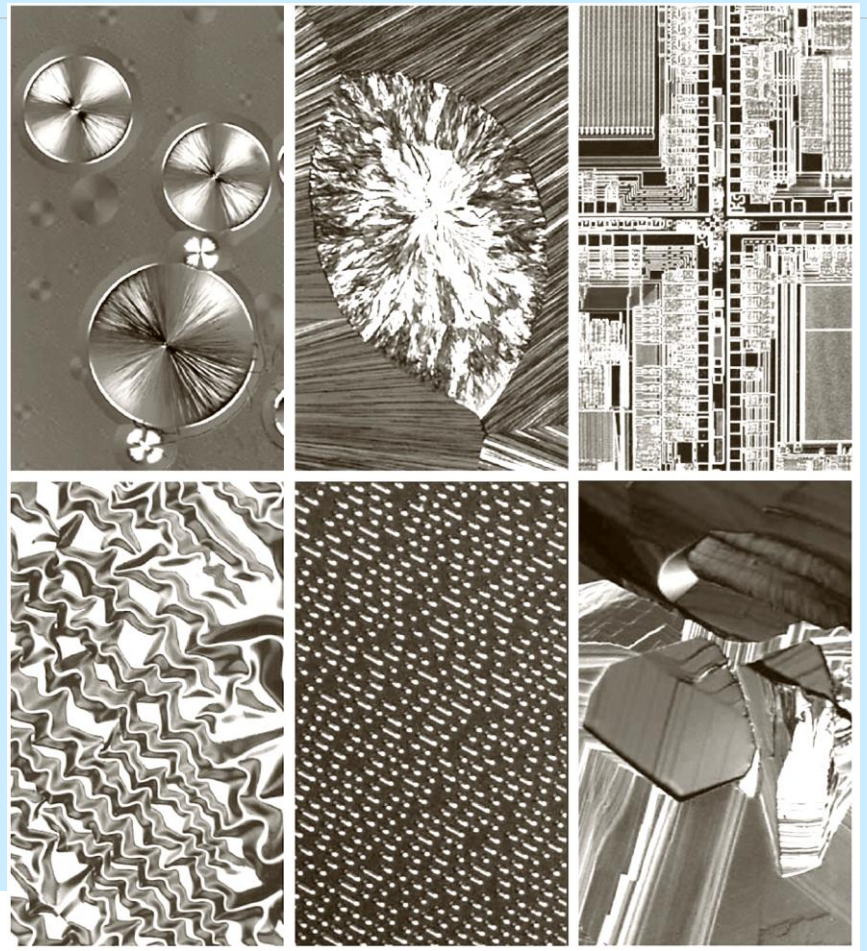
Cygnus Loop in the high-UV band



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.)

# 1.3.4 Imaging in the **Visible** and **Infrared** Bands



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.)

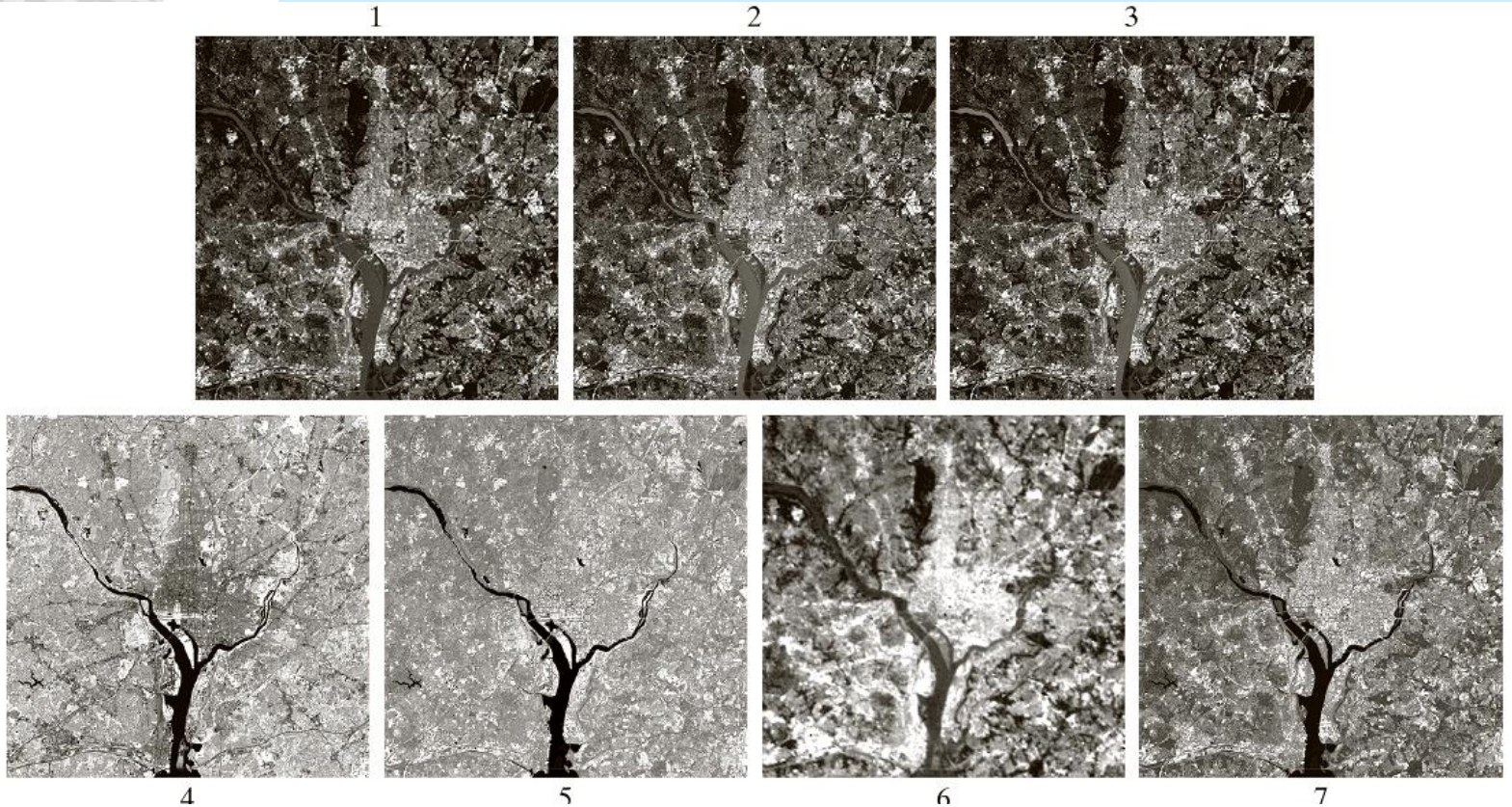



**FIGURE 1.10** LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

| 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 |

**TABLE 1.1** Thematic bands in NASA's LANDSAT satellite.

Bands in **LANDSAT-7** imagery. One more band exists.

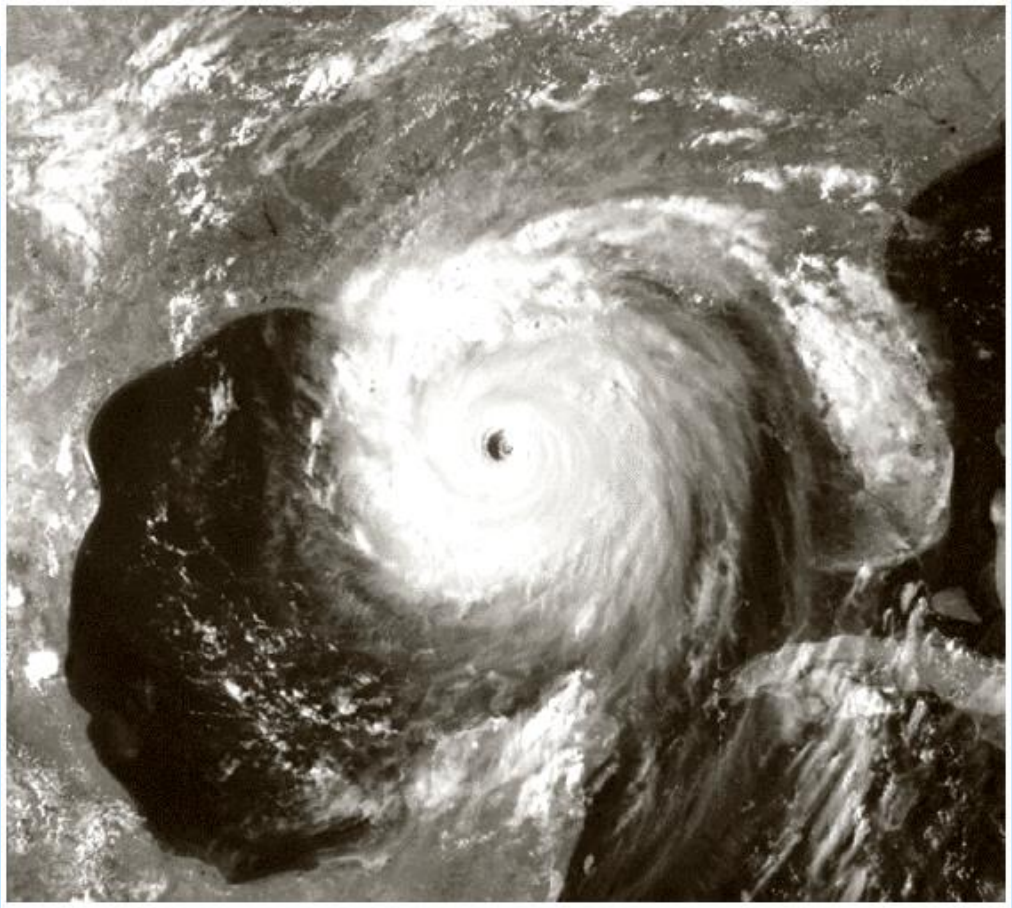


**FIGURE 1.11**
Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)

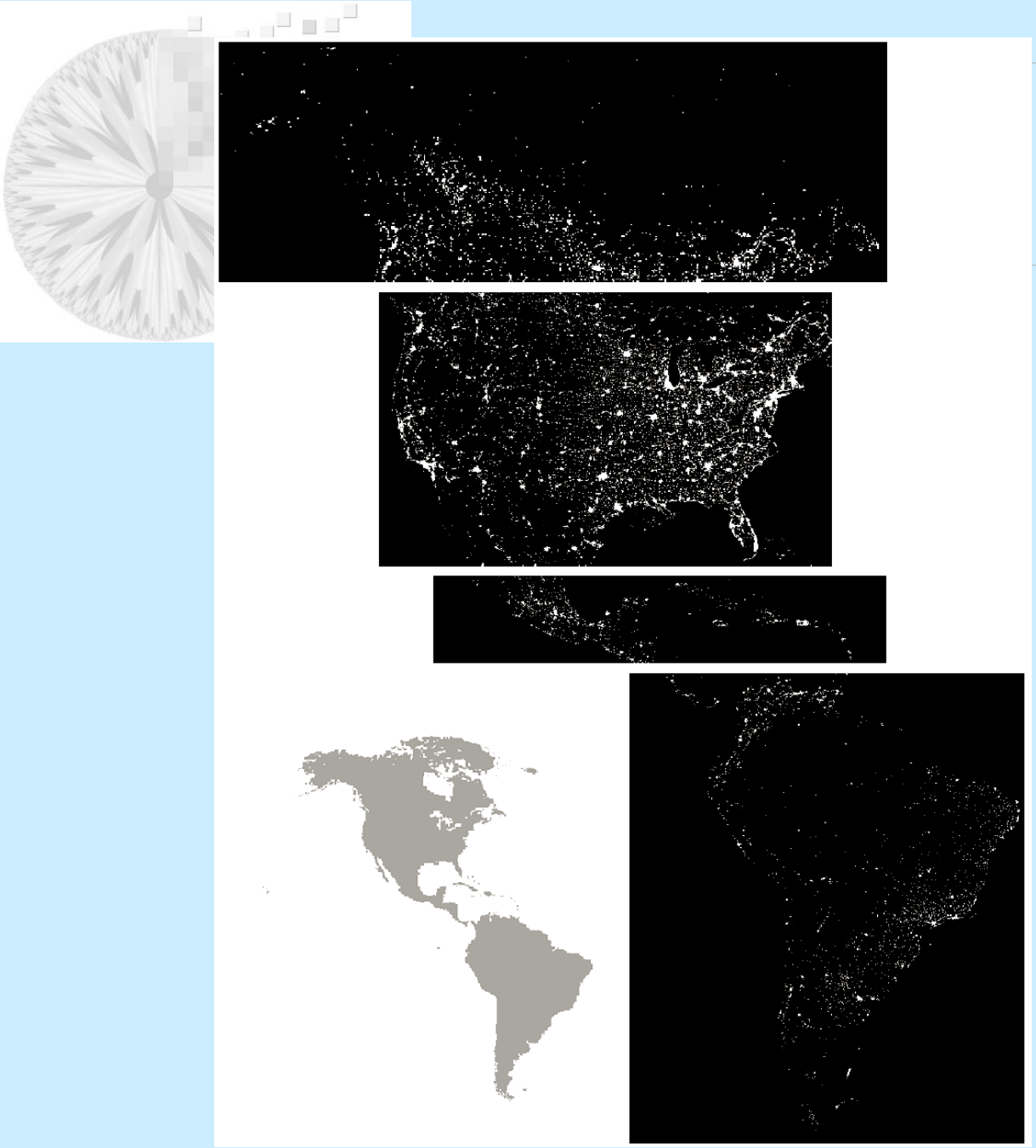


**FIGURE 1.12**
Infrared satellite images of the Americas. The small gray map is provided for reference. (Courtesy of NOAA.)

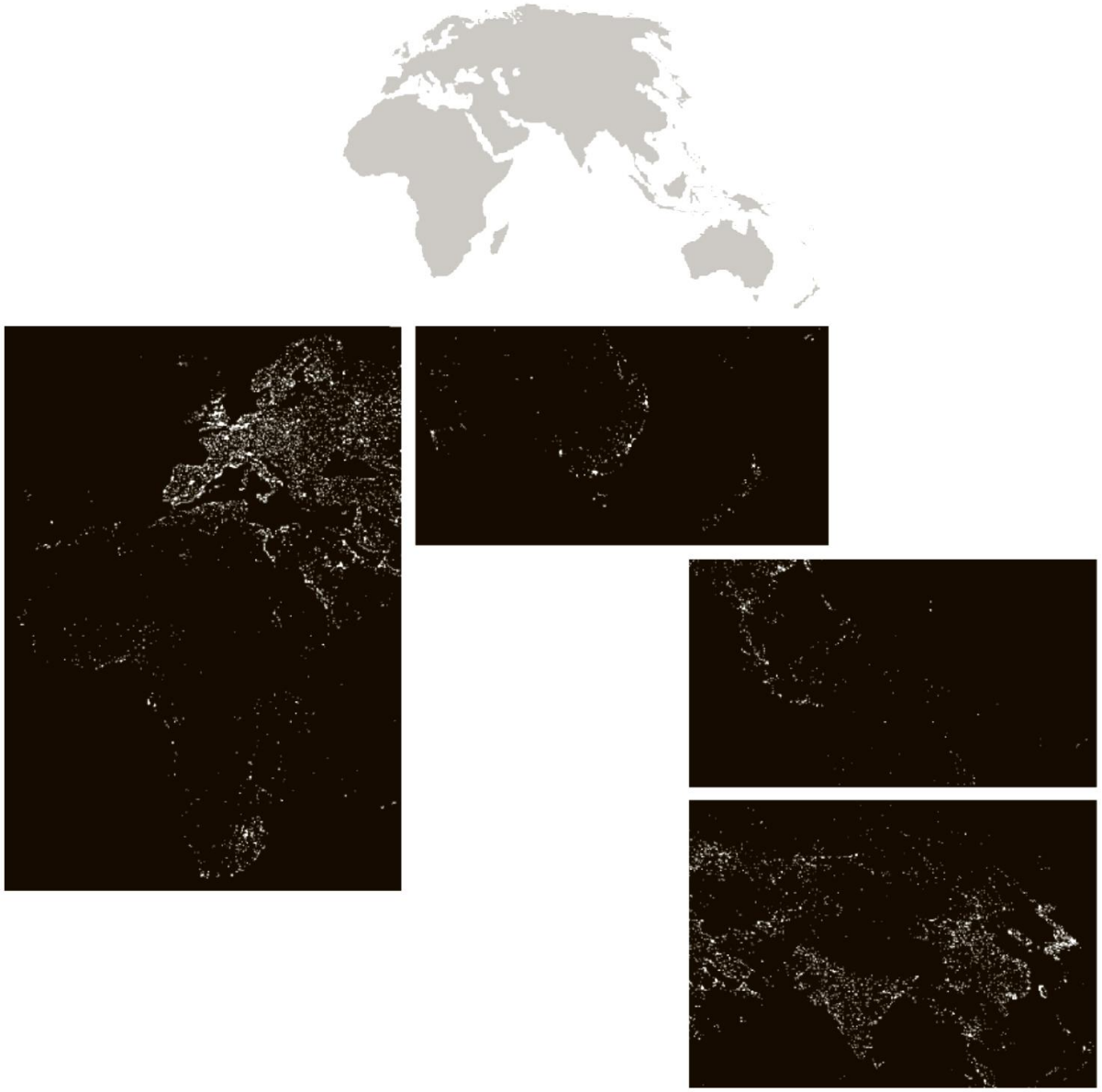
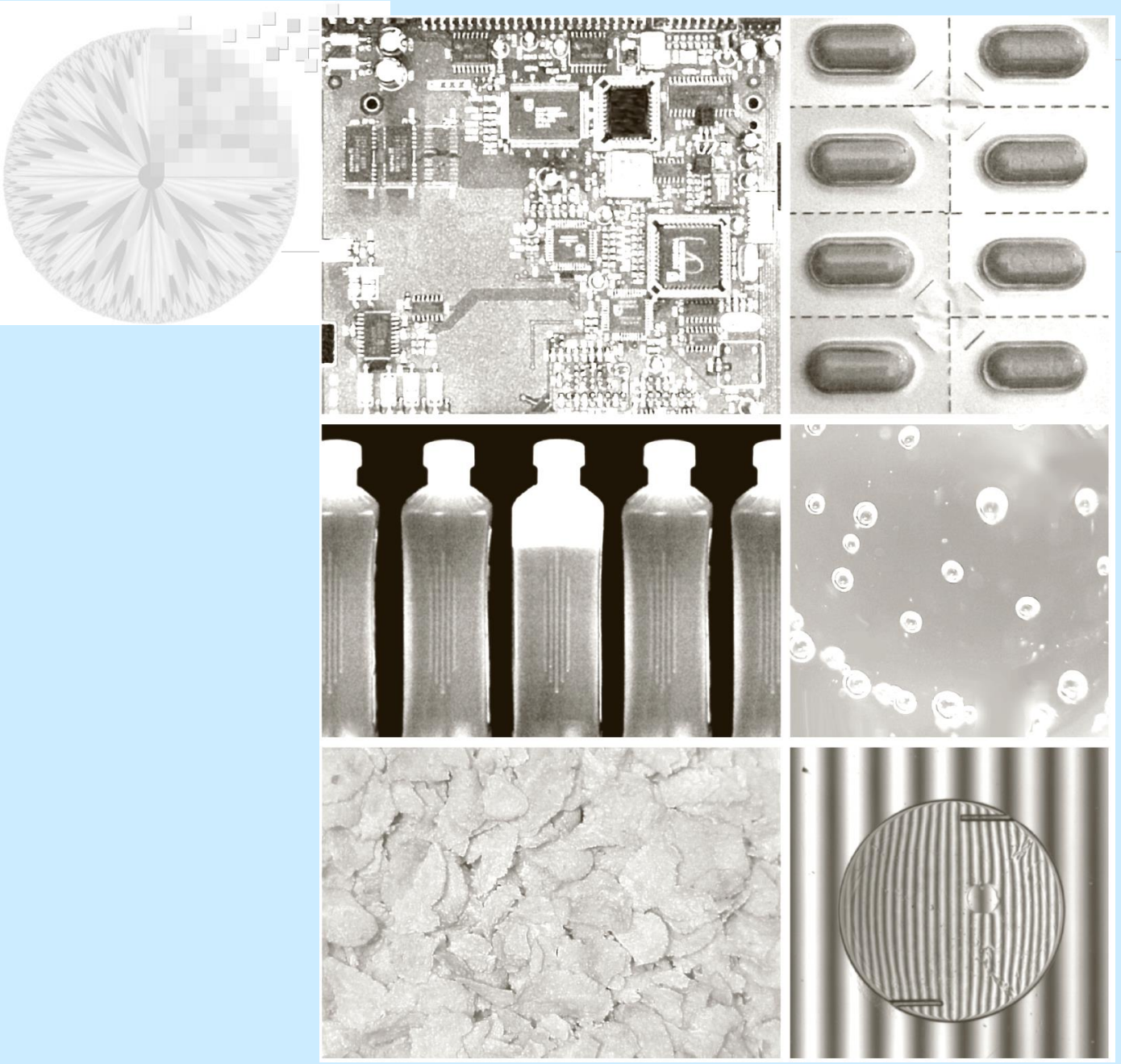


**FIGURE 1.13**
Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)



a b
c d
e f

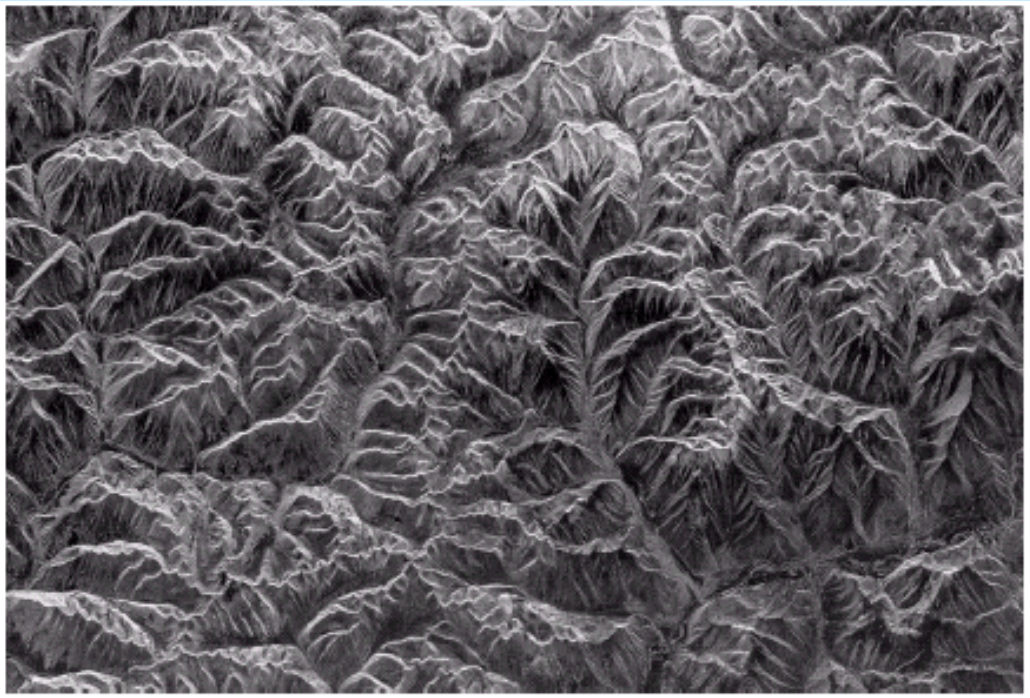
**FIGURE 1.14**
Some examples of manufactured goods often checked using digital image processing.
(a) A circuit board controller.
(b) Packaged pills.
(c) Bottles.
(d) Air bubbles in a clear-plastic product.
(e) Cereal.
(f) Image of intraocular implant.
(Fig. (f) courtesy of Mr. Pete Sites, Perceptics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

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 Band

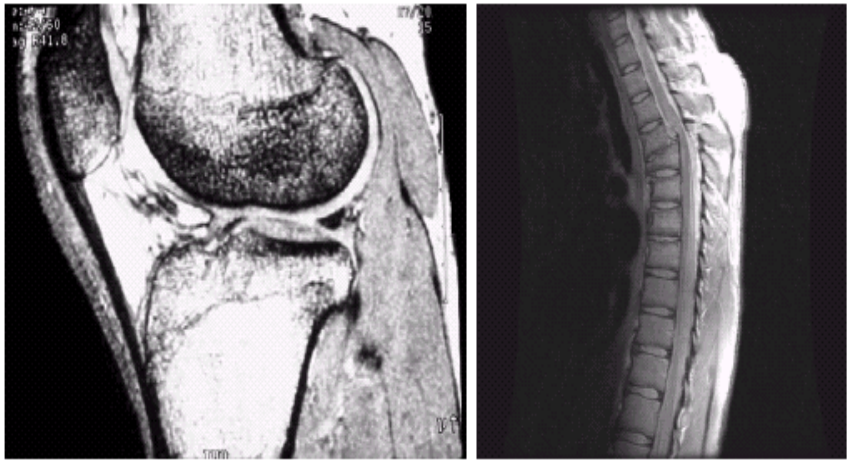
**FIGURE 1.16**
Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)



# 1.3.6 Imaging in the **Radio** Band

**Magnetic Resonance Imaging** (MRI): nuclei with nonzero magnetic moment will align with a strong magnetic field, and resonate with a time varying component of the field.

After the time-varying component is removed, the exponential decay time of the re-alignment is measured and used to develop image contrast between different tissues.



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.)

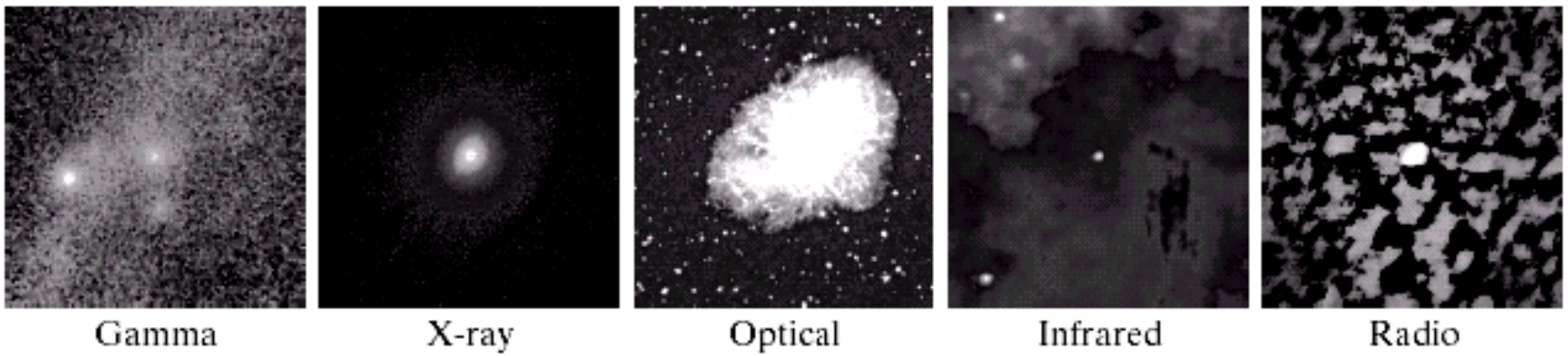



**FIGURE 1.18** Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

- Each image gives a totally different view of the Pulsar

# 1.3.7 Examples in which Other Imaging Modalities Are Used

-**Ultrasound** Imaging

-Scanning Electron Microscope (**SEM**) Imaging

-3D Computer **Models**

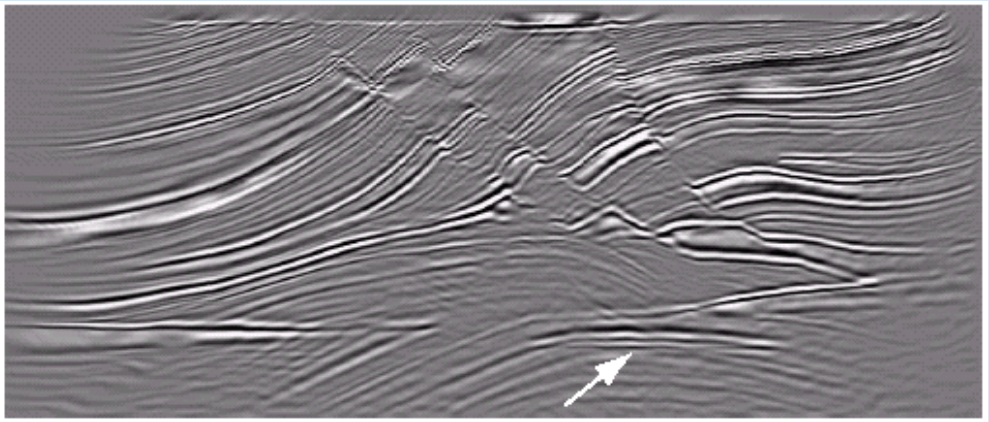
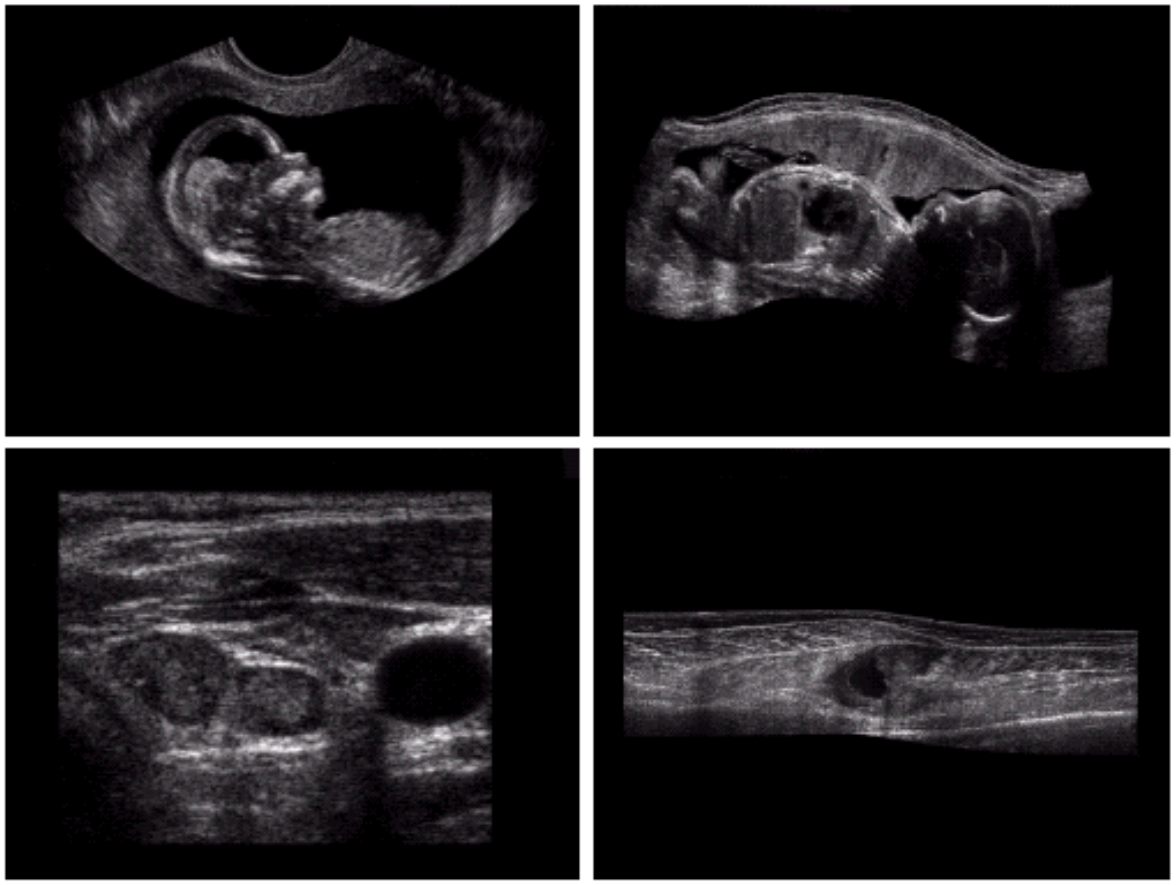


**FIGURE 1.19** Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)

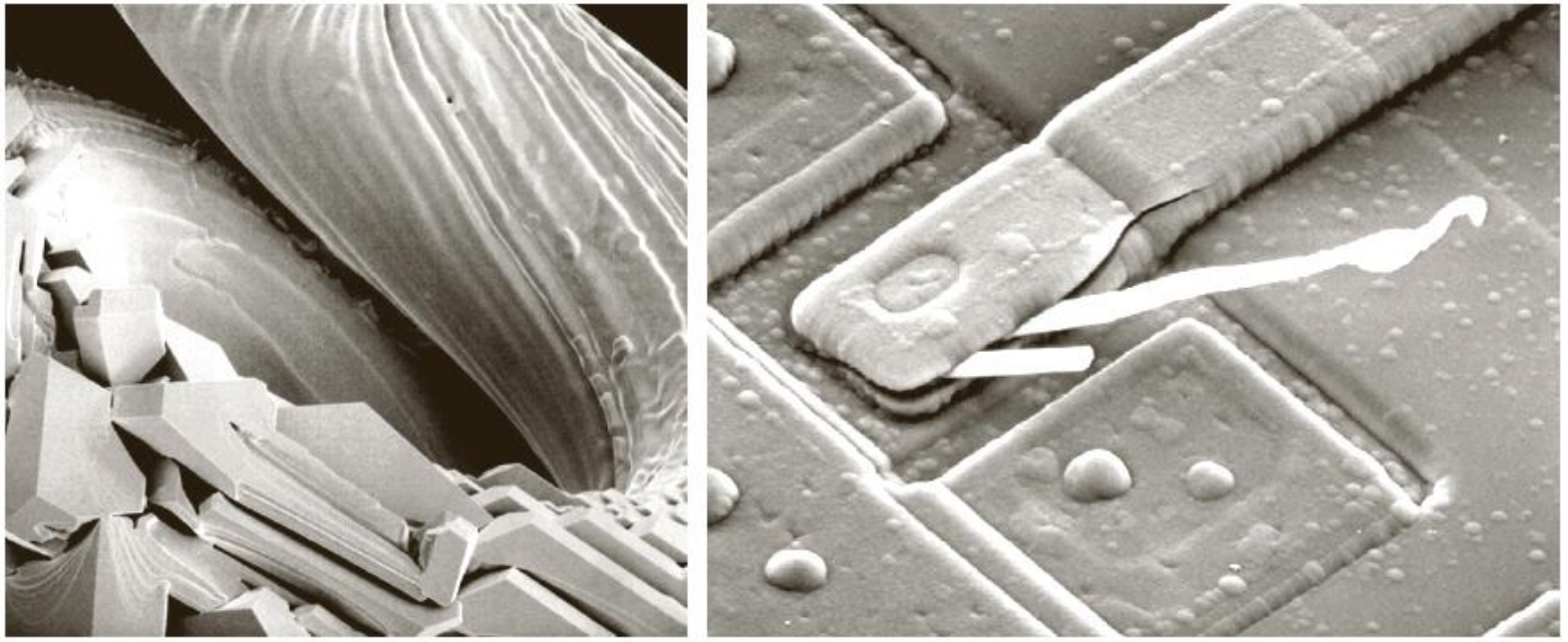
# Ultrasound Imaging



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.)

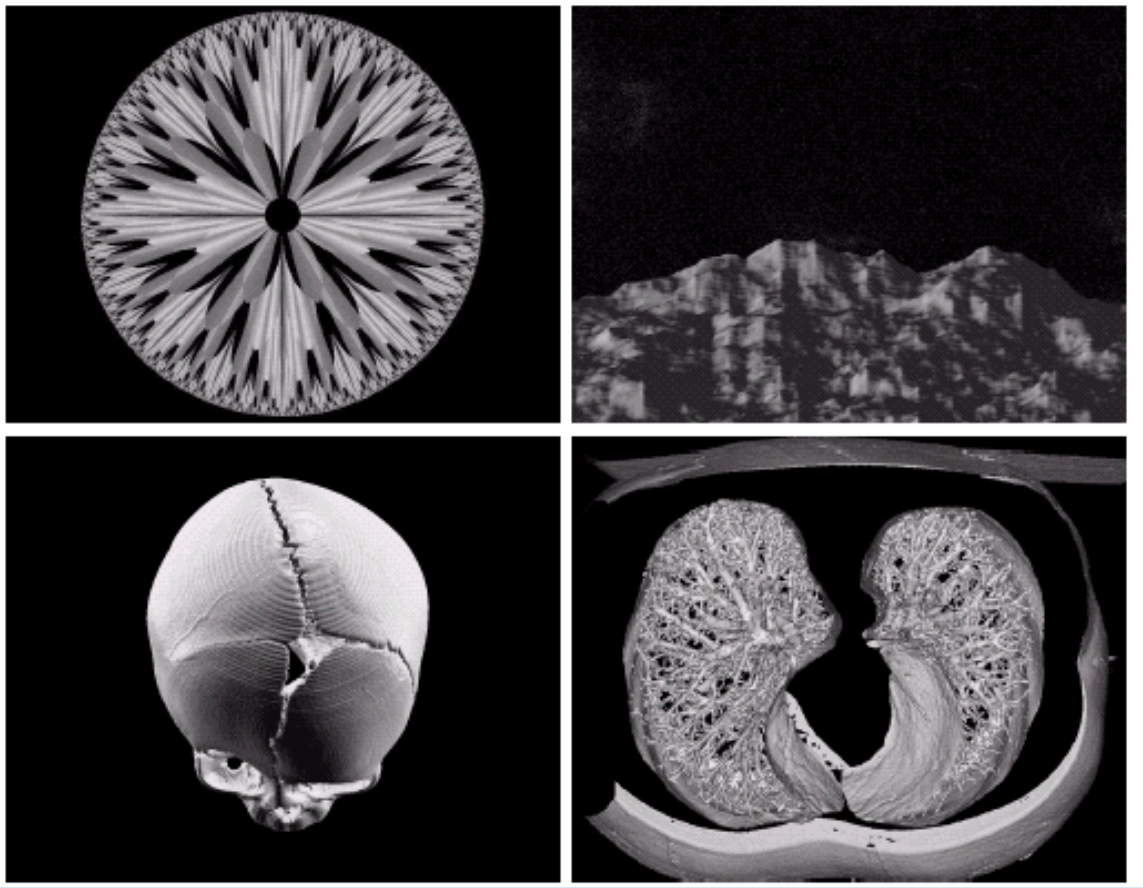
# Scanning Electron Microscope (SEM) Imaging



a b

**FIGURE 1.21** (a) 250× SEM image of a tungsten filament following thermal failure (note the shattered pieces on the lower left). (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.)

# 3D Computer Models



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

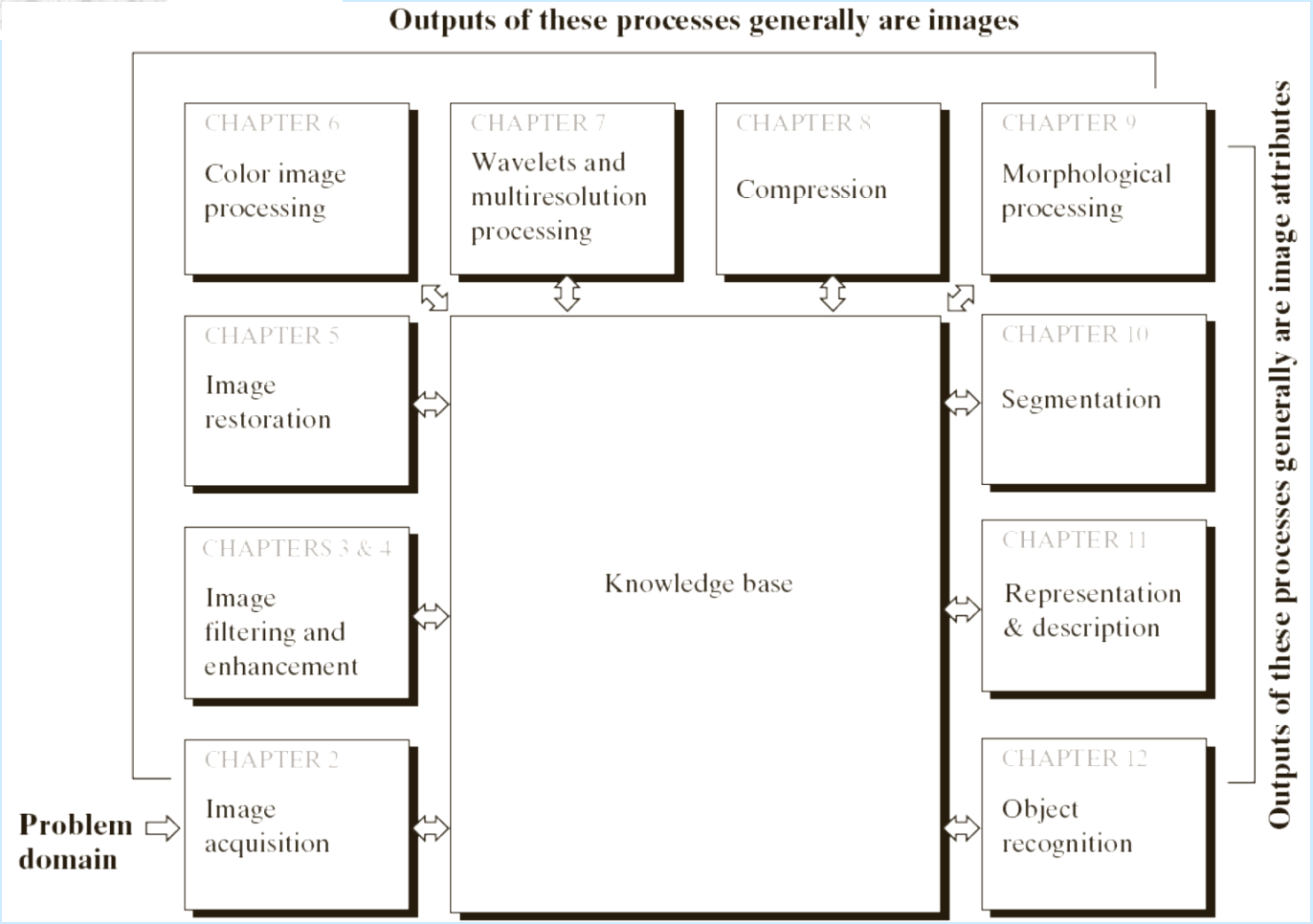



**FIGURE 1.23** Fundamental steps in digital image processing. The chapter(s) indicated in the boxes is where the material described in the box is discussed.

# 1.5 Components of an Image Processing System

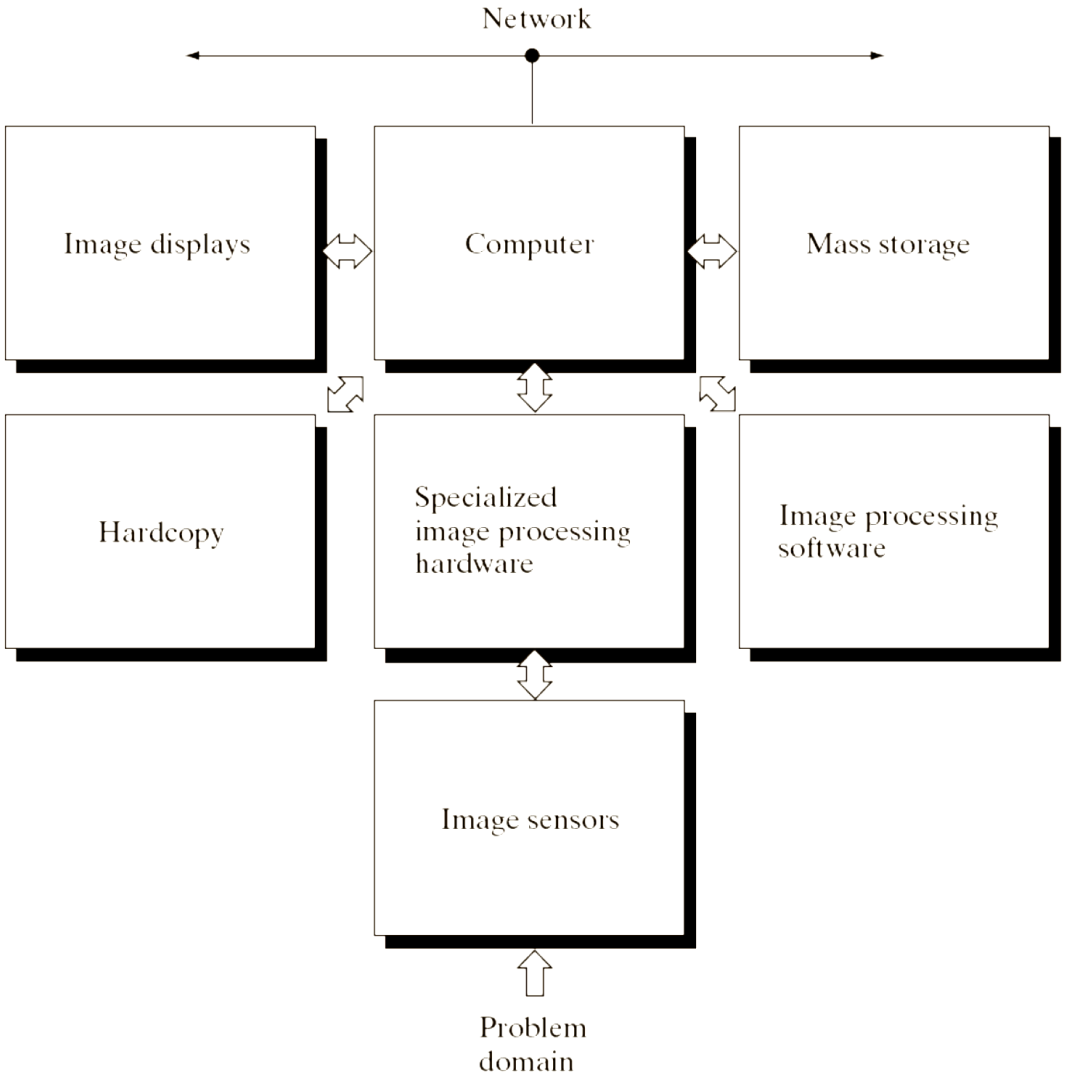
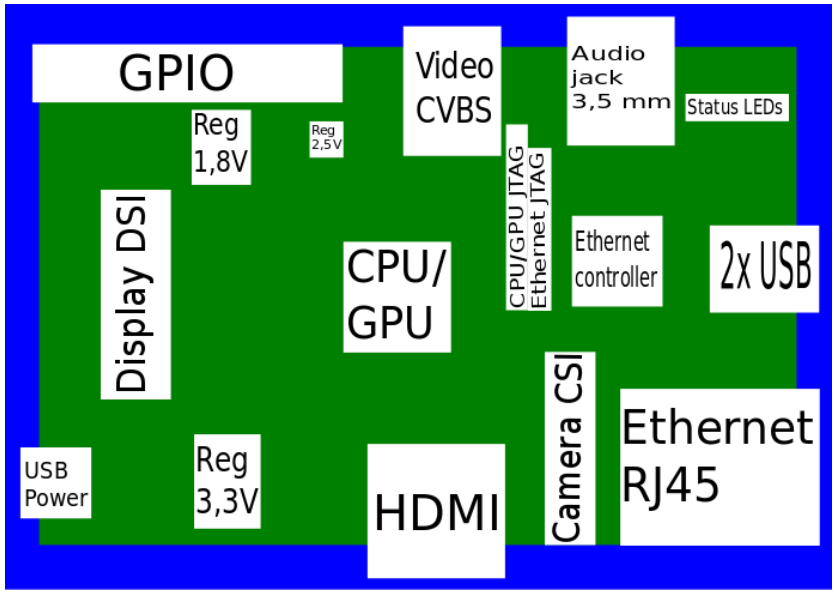
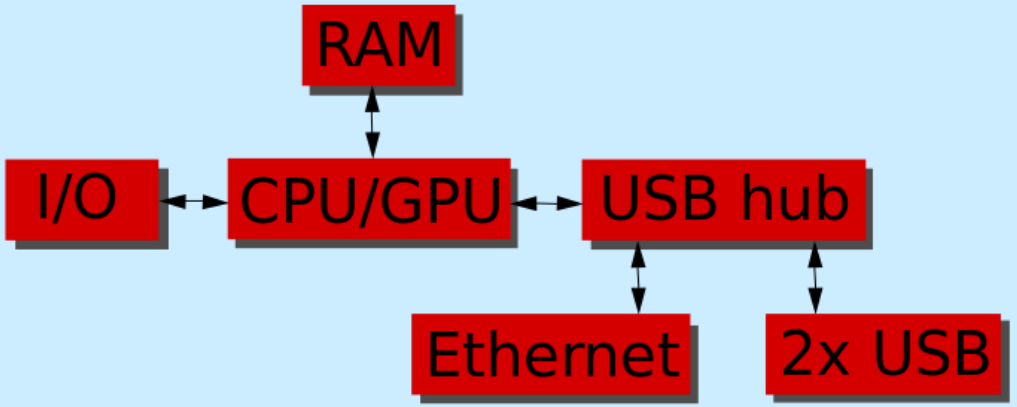



**FIGURE 1.24** Components of a general-purpose image processing system.

# Raspberry Pi（樹莓派)




| 計畫 | A型 | B型 | B+型 |
|---|---|---|---|
| 上市價格 | $25 | $35[38] | |
| SoC | Broadcom BCM2835（CPU，GPU DSP和SDRAM, USB）[1] | | |
| CPU | ARM1176JZF-S核心（ARM11系列）700MHz | | |
| GPU | Broadcom VideoCore IV[39], OpenGL ES 2.0, 1080p 30 h.264/MPEG-4 AVC高畫質解碼器 | | |
| 記憶體 | 256 MByte（與GPU共享，可以理解為整合顯示卡的視訊記憶體與記憶體共享） | 512 MByte（於2012年10月15日） | |
| USB 2.0介面個數[40] | 1 | 2（支援USB hub擴充功能）[41] | 4 |
| 影像輸出 | Composite RCA（PAL & NTSC）,HDMI（rev 1.3 & 1.4）[42],raw LCD Panels via DSI[43][44] 14 HDMI resolutions from 640 x 350 to 1920x1200 plus various PAL and NTSC standards. | | |
| 音源輸出 | 3.5mm插孔，HDMI | | |
| 板載儲存 | SD / MMC / SDIO卡插槽 | | |
| 網路介面 | 沒有（需通過USB） | 10/100 乙太網介面（RJ45介面） | |
| 外設 | 8 x GPIO、UART、I²C、帶兩個選擇的SPI匯流排，+3.3 V, +5 V, ground（負極） | | |
| | 300 mA（1.5 W）[45] | 700 mA（3.5 W） | 600 mA（3.0 W） |
| 電源輸入 | 5V / 透過MicroUSB或GPIO頭 | | |
| 總體尺寸 | 85.60 x 53.98 mm（3.370 x 2.125 in） | | |
| 重量 | 45 g（1.6 oz）[46] | | |
| 操作系統 | GNU/Linux(Debian, Fedora, Arch Linux ARM) [47], RISC OS, FreeBSD, Plan 9 | | |

** Data from WiKipedia

# Raspberry Pi（樹莓派)