



上海交通大學  
SHANGHAI JIAO TONG UNIVERSITY

AU326:  
Fundamentals of  
Digital Image Processing

Instructor: Dr. Xu Zhao

Location: 东中院 402

2020 Fall

# Instructor information

- 赵旭 (Xu Zhao) - Professor @ Department of Automation, SJTU.
- Research direction: Computer Vision, Image Processing, Pattern Recognition, Machine Learning
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# References

- [1] Digital Image Processing (Third Edition). Rafael C. Gonzalez and Richard E. Woods.
- [2] Digital Image Processing. Kenneth R. Castleman.
- [3] Computer Vision: Algorithms and Applications. Richard Szeliski.

# Rule of grading

- Problem set:  $4 * 20\% = 80\%$
- Attendance: 20%
  - Canvas discussions (10%)
  - Classroom attendance (10%)

# Course stuff

- Canvas

# Course outline

- **Unit I: Introduction**

- Lecture 1: Introduction

- **Unit II: From World to Image**

- Lecture 2: Image formation and acquisition

- **Unit III: From Image to Image**

- Lecture 3: Spatial processing
- Lecture 4: Frequency processing
- Lecture 5: Restoration
- Lecture 6: Compression

- **Unit IV: From Image to Attributes**

- Lecture 7: Morphological processing
- Lecture 8: Segmentation
- Lecture 9: Representation
- Lecture 10: Recognition

Course 1:

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# Introduction

# What is digital image processing?

- Image: a two-dimensional function,  $f(x, y)$ , where  $x$  and  $y$  are *spatial* (plane) coordinates, and the amplitude of  $f$  at any pair of coordinates  $(x, y)$  is called the *intensity* or *gray level* of the image at that point.
- Processing digital images by means of a digital computer.



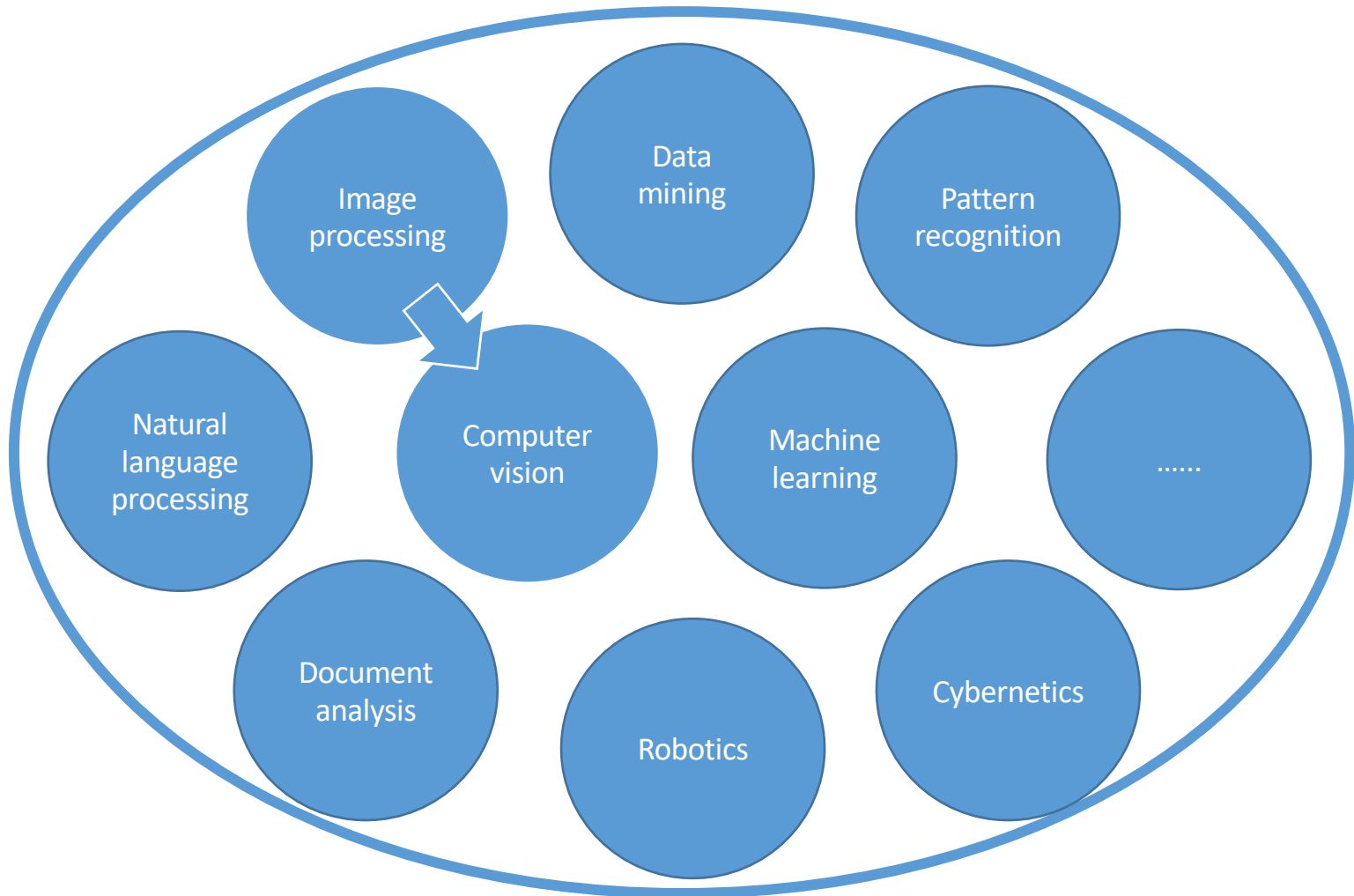
# Motivation

- Improvement of pictorial information for human interpretation.
- Processing of image data for storage, transmission, and representation for autonomous machine perception.
- Images appear everywhere.

# A promising direction

- Image carries rich information to **understand** this world. “*One picture is worth more than ten thousand words.*”
- AI is entering into every corner of our daily life and will change this planet deeply in future.
- You can play important role in this tide and to grasp the chances. “**Time and tide wait for no man.**”
- Welcome to the DIP and CV world!

# Artificial intelligence\*

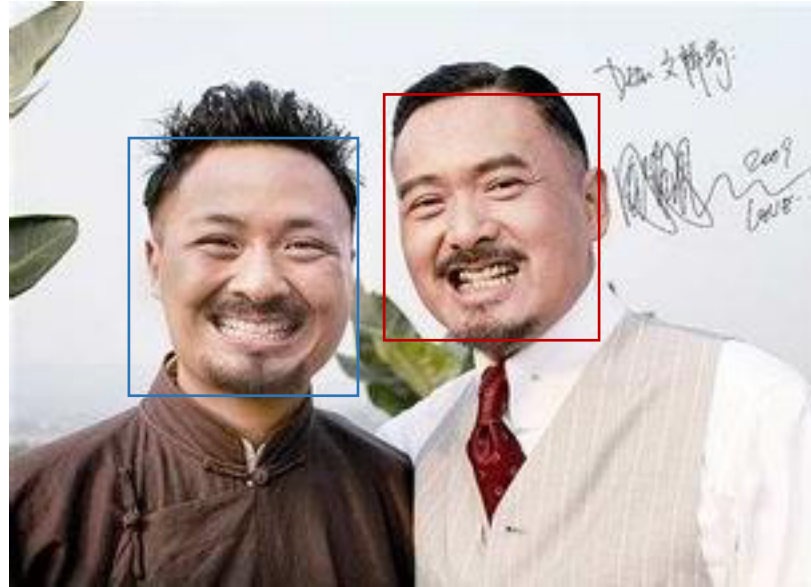


\* intelligence exhibited by machines

# Image processing levels

- Low level processing
  - From image to image: reduce noise, enhancement, sharpening, super-resolution...
- Middle level
  - From image to attributes: segmentation, ROI feature extraction, boundary (contour) extraction...
- High level
  - Object recognition, image analysis, event understanding...

# Example: face recognition



Step 1: image preprocessing

Step 2: face detection

Step 3: face recognition

# Example: License plate recognition



Step 1: image preprocessing

Step 2: license plate detection

Step 3: license recognition

# The origin of DIP

- The first application: newspaper industry (1920s)



**FIGURE 1.1** A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.<sup>†</sup>)



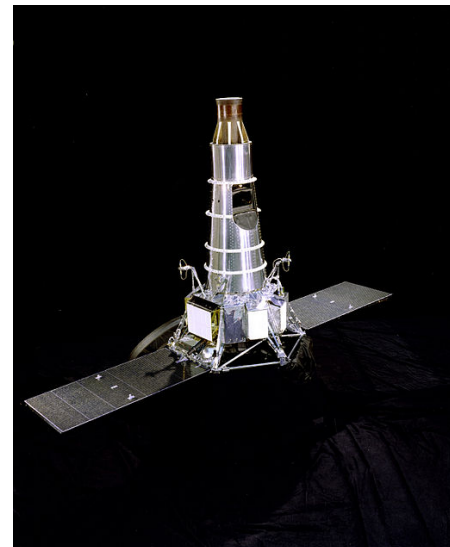
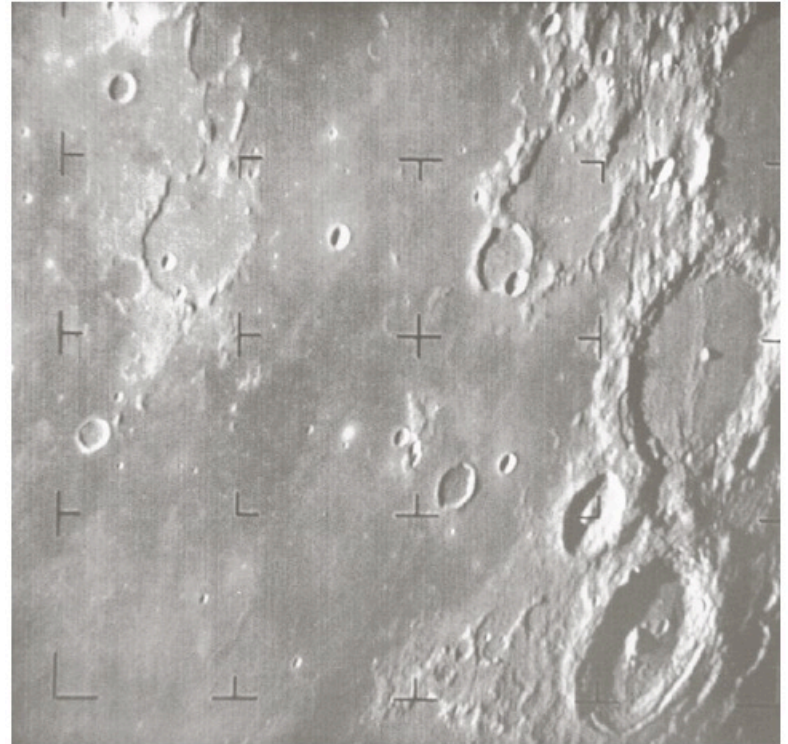
**FIGURE 1.2** A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. (McFarlane.)



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

# The origin of DIP

- The modern computer system based image processing (1960s) :
- Transistor (1940s)
- Language (1950s-1960s)
- IC (1950s)
- OS (1960s)
- Microprocessor (1970s)
- PC (1980s)
- VLSI (1980s)



**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.)

Ranger 7

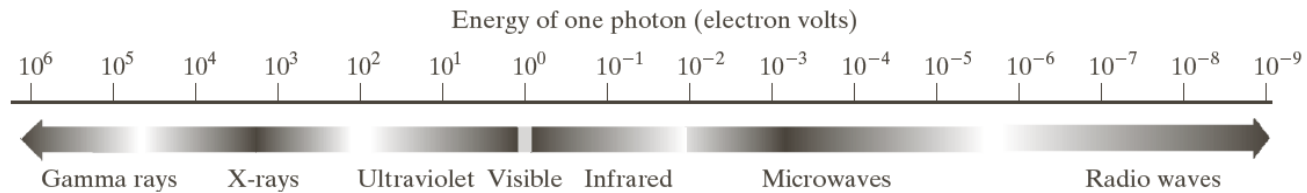


# The origin of DIP

- Medical image processing (1960s-1970s) :  
Computerized Tomography (CT)
- 1960s-now: DIP technique is widely used in the  
medicine, space program, biological field,  
archeology, defense, industry, and so forth.

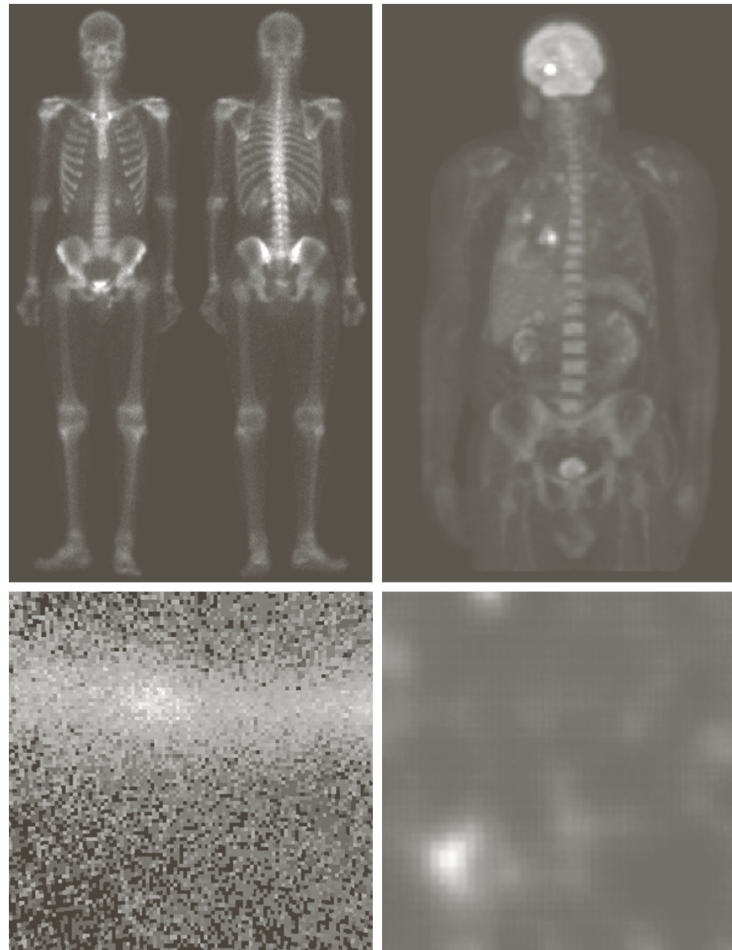
# DIP applications

- Electronic magnetic energy spectrum



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

# 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.

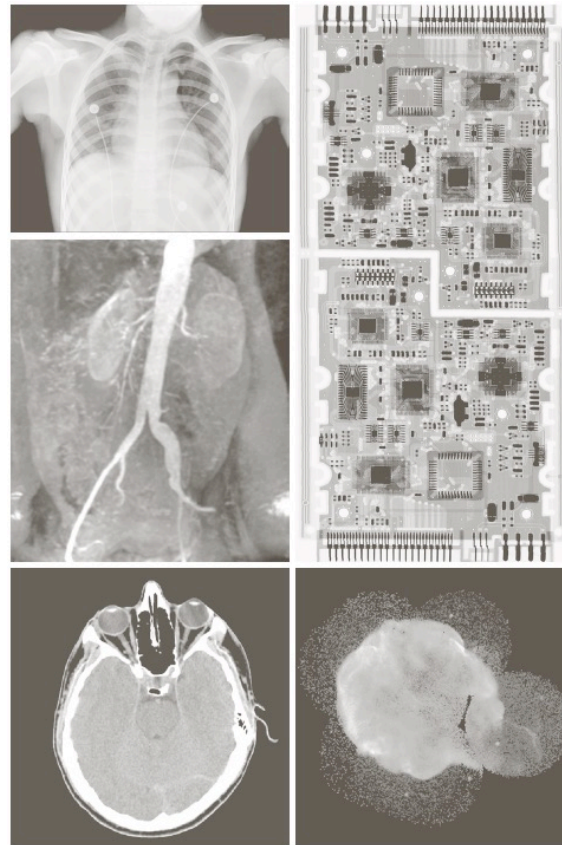
(Images courtesy of (a) G.E.

Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems,

(c) NASA,

(d) Professors Zhong He and David K. Wehe, University of Michigan.)

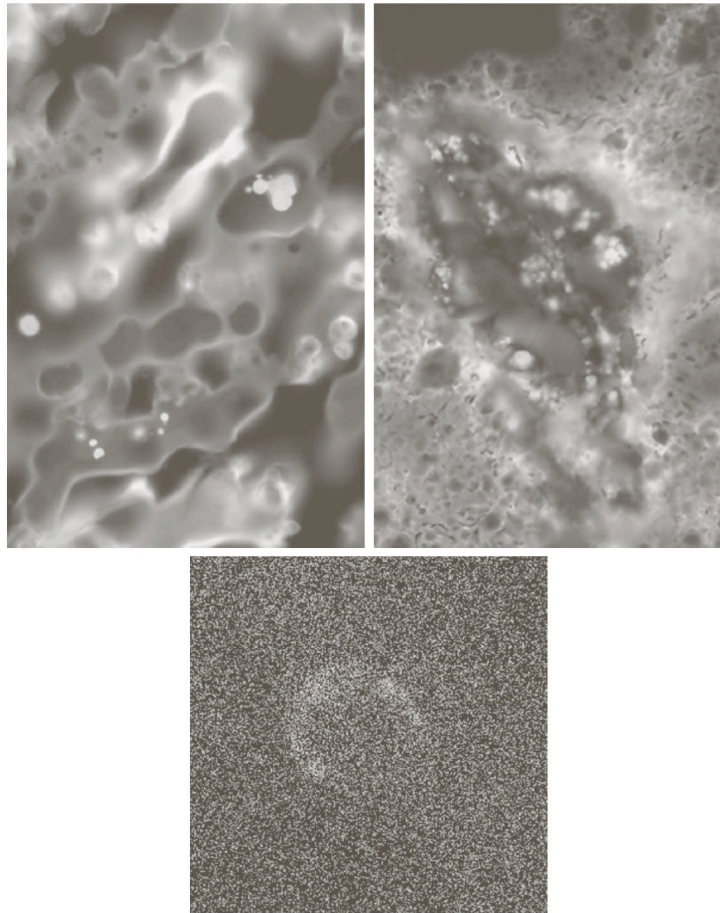
# X-Ray imaging



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.)

# Ultraviolet band imaging



a b  
c

## FIGURE 1.8

Examples of  
ultraviolet  
imaging.

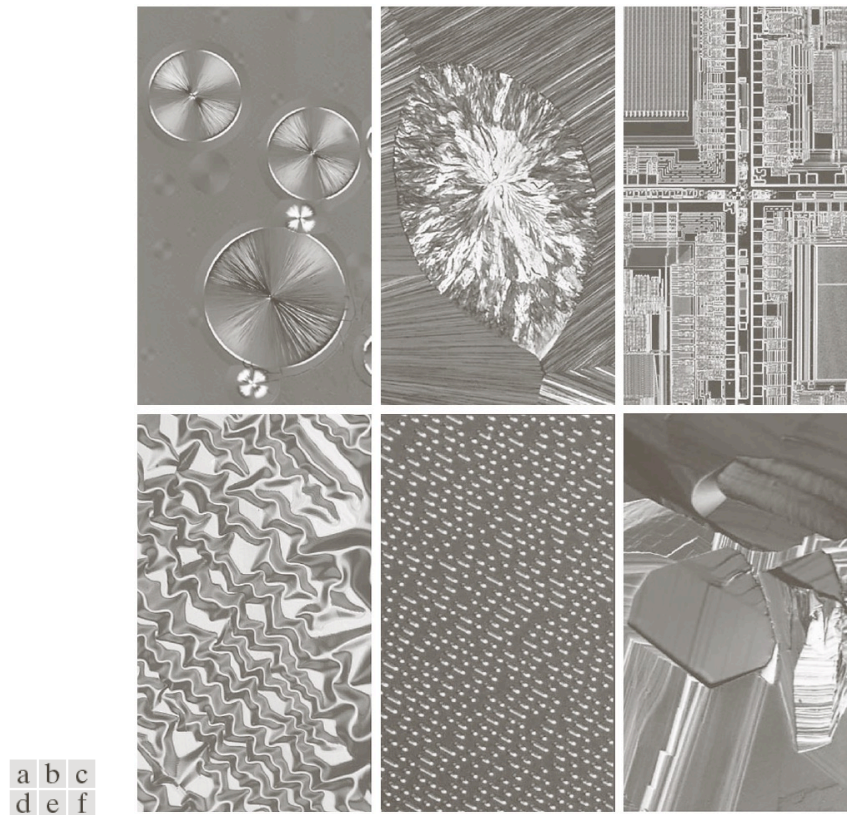
(a) Normal corn.

(b) Smut corn.

(c) Cygnus Loop.

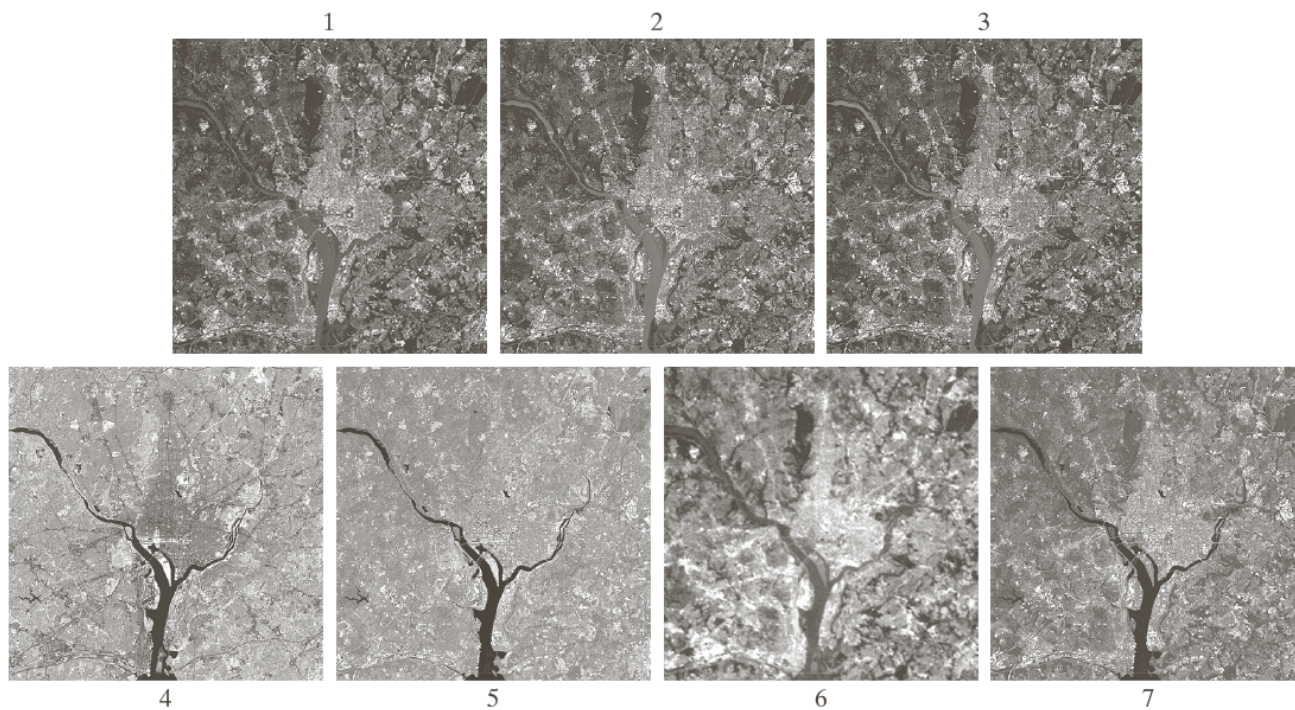
(Images courtesy  
of (a) and  
(b) Dr. Michael  
W. Davidson,  
Florida State  
University,  
(c) NASA.)

# Visible and infrared band



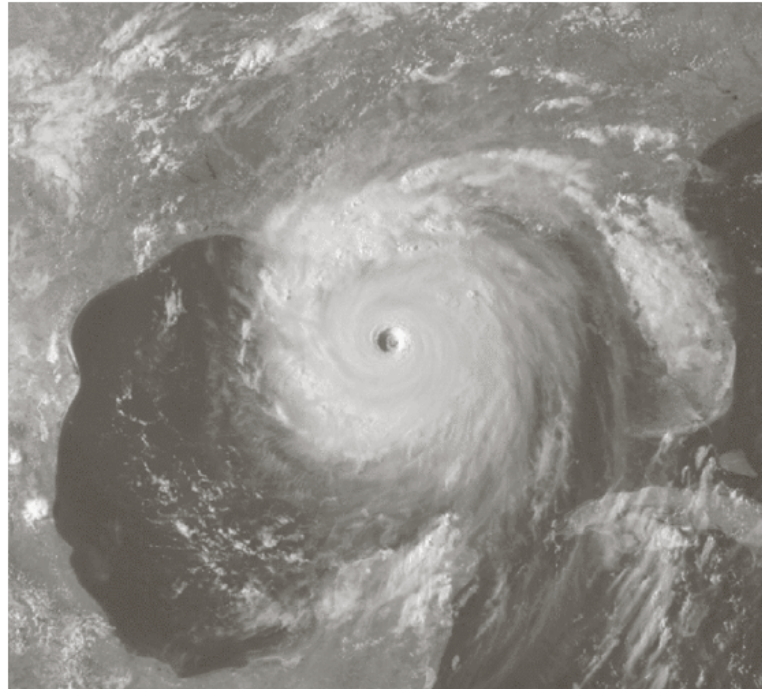
**FIGURE 1.9** Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250 $\times$ . (b) Cholesterol—40 $\times$ . (c) Microprocessor—60 $\times$ . (d) Nickel oxide thin film—600 $\times$ . (e) Surface of audio CD—1750 $\times$ . (f) Organic superconductor—450 $\times$ . (Images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





**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.)

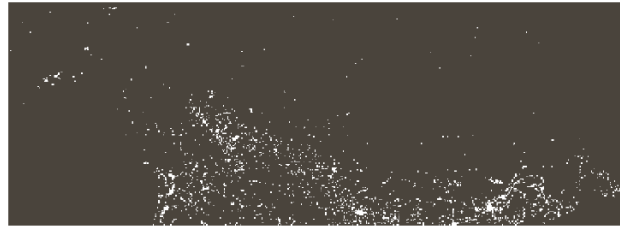
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**FIGURE 1.11**  
Satellite image  
of Hurricane  
Katrina taken on  
August 29, 2005.  
(Courtesy of  
NOAA.)

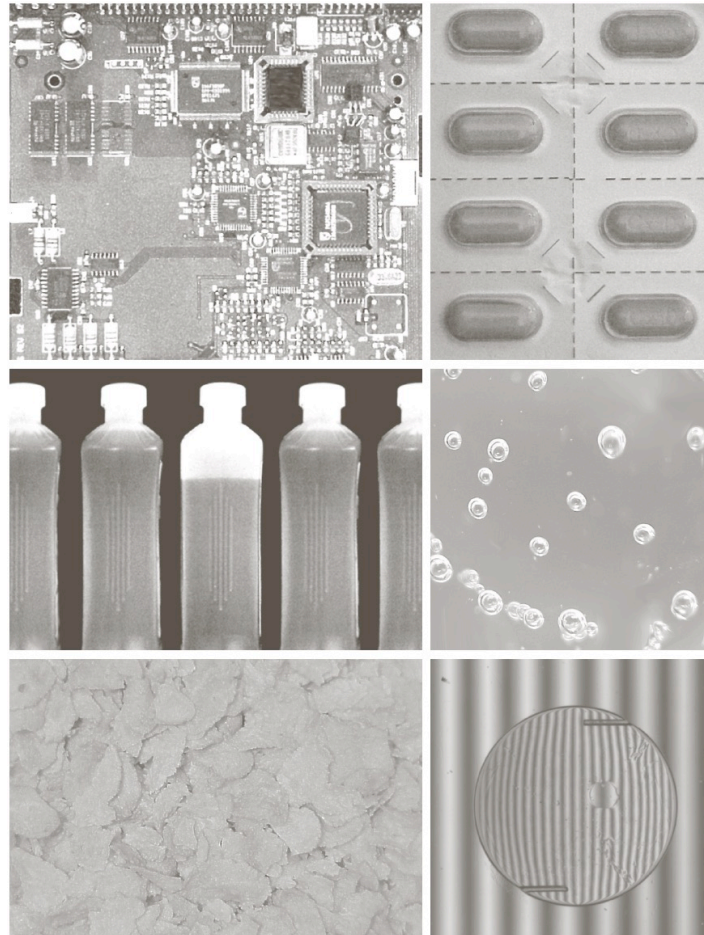
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**FIGURE 1.12**  
Infrared satellite  
images of the  
Americas. The  
small gray map is  
provided for  
reference.  
(Courtesy of  
NOAA.)

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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.)



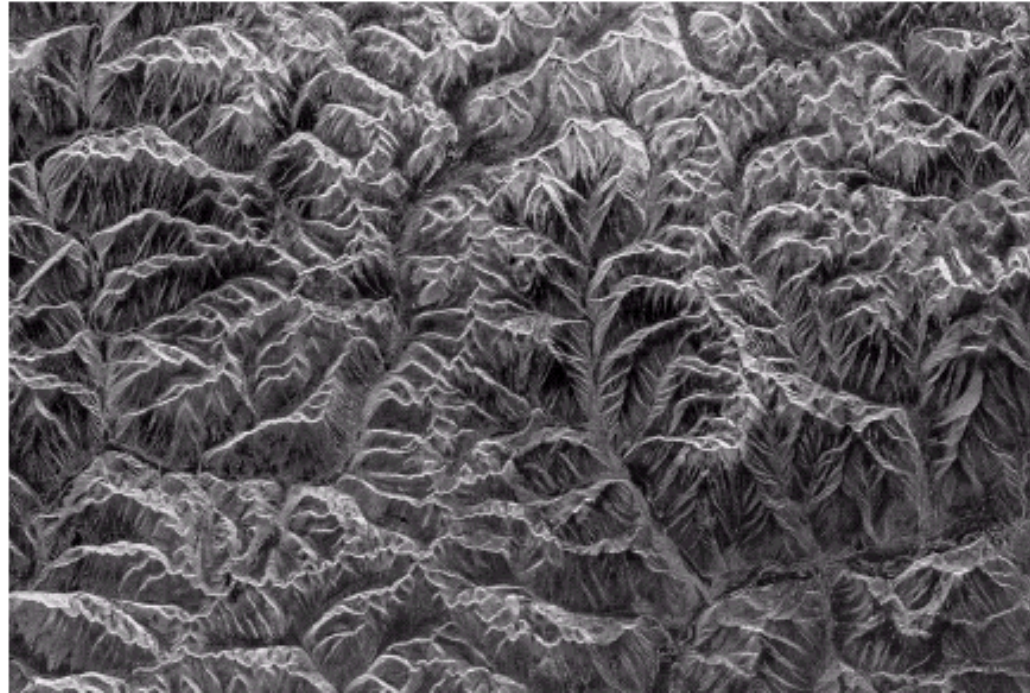
a b  
c  
d

**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.)

# Microwave band imaging

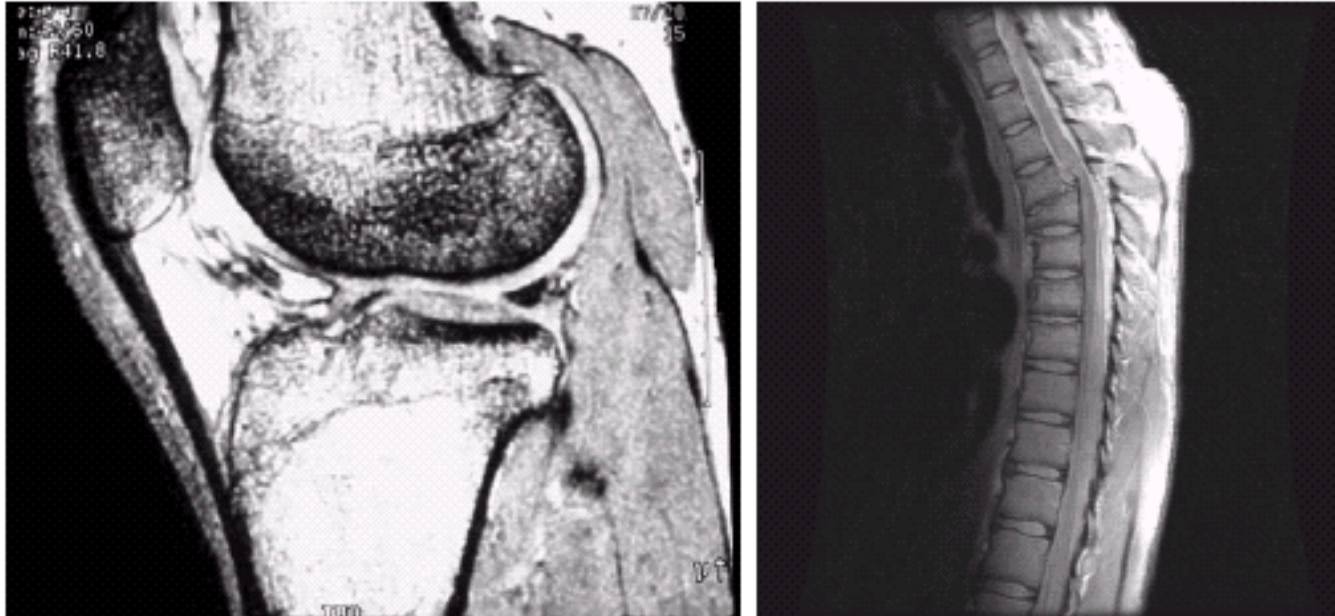
**FIGURE 1.16**  
Spaceborne radar  
image of  
mountains in  
southeast Tibet.  
(Courtesy of  
NASA.)

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# Radio band imaging

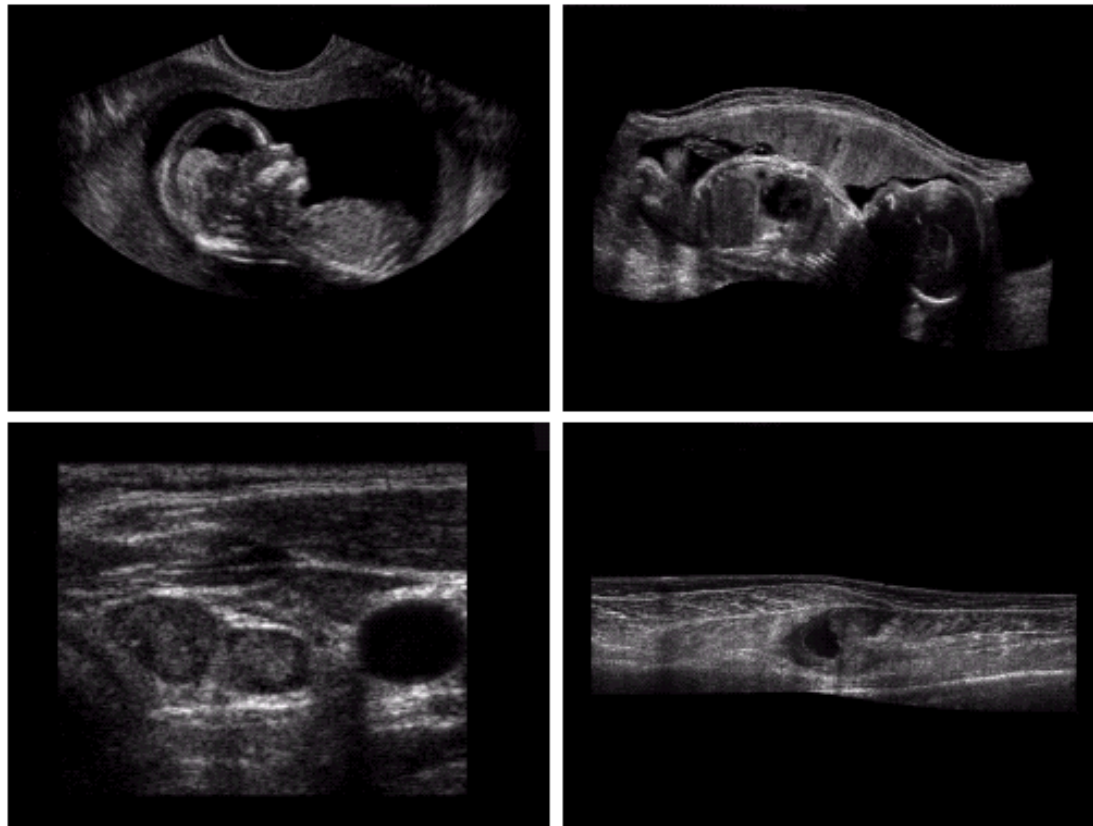


a b

**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.)

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# Other imaging modalities

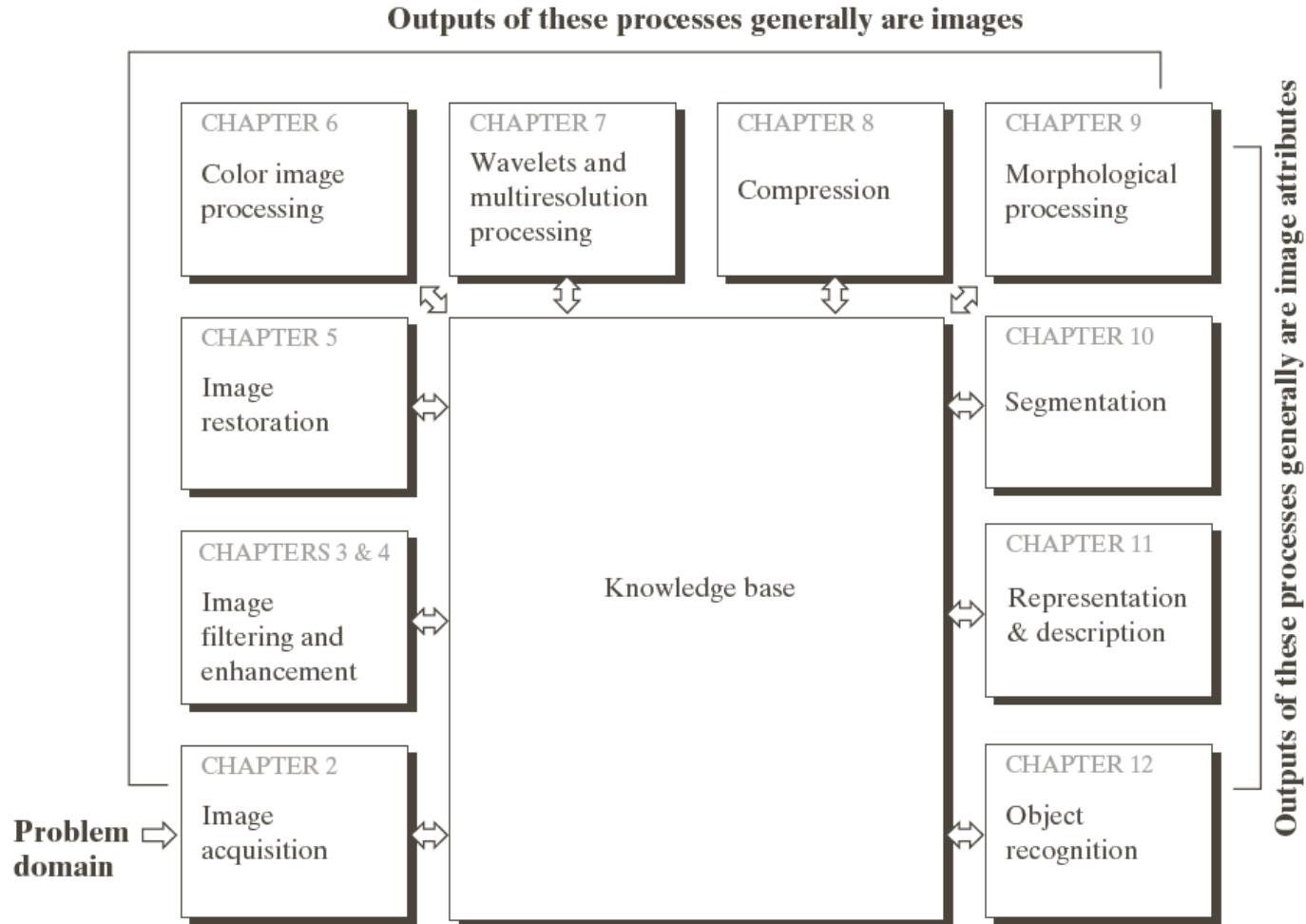


a	b
c	d

**FIGURE 1.20**

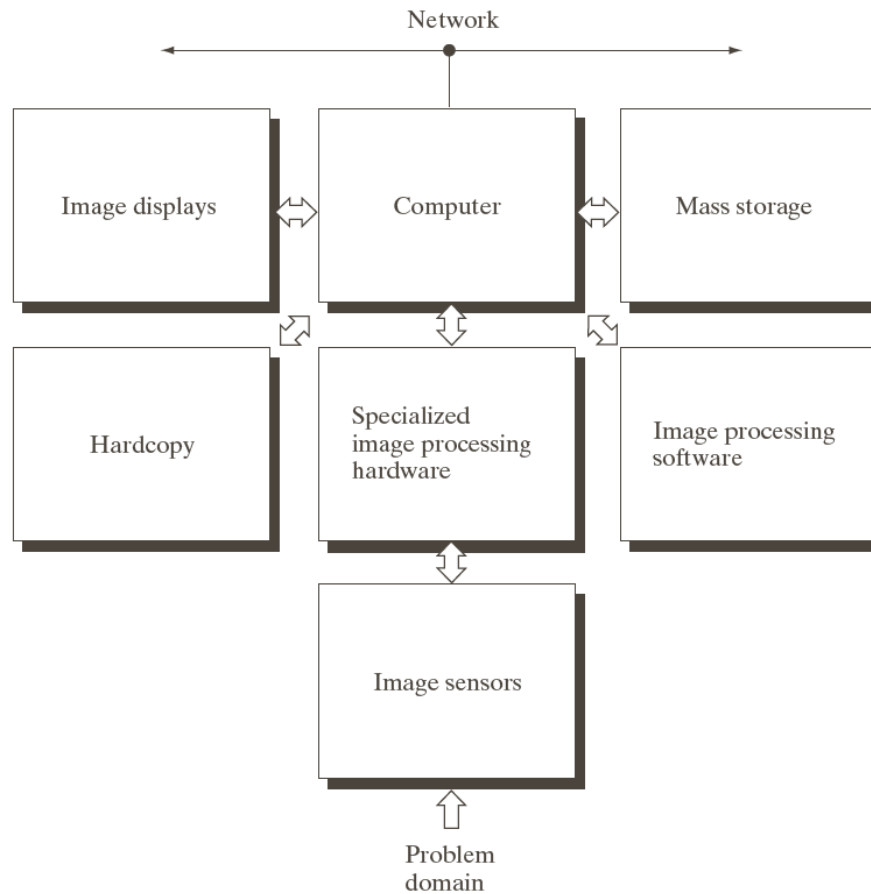
Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

# Fundamental steps in DIP



**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.

# Components of DIP system



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



# Conference and journal

- ICIP - International Conference on Image Processing
- CVPR – IEEE Conference on Computer Vision and Pattern Recognition
- ICCV - IEEE International Conference on Computer Vision
- ECCV - Europe Conference on Computer Vision
- ACCV - Asia Conference on Computer Vision
- ACM MM – ACM Multimedia Conference
- ICME - IEEE International Conference on Multimedia and Expo

# Conference and journal

- IEEE TIP – IEEE Transactions on Image Processing
- IEEE TPAMI – IEEE Transactions on Pattern Analysis and Machine Intelligence
- IJCV – International Journal on Computer Vision