Introduction

Lecture-1

Spring 2019

Prof. Megherbi

Introduction

Lecture-1 Outline

- Introduction
- Applications of Digital Image processing and Computer Vision
- What is Digital Image processing and Computer Vision

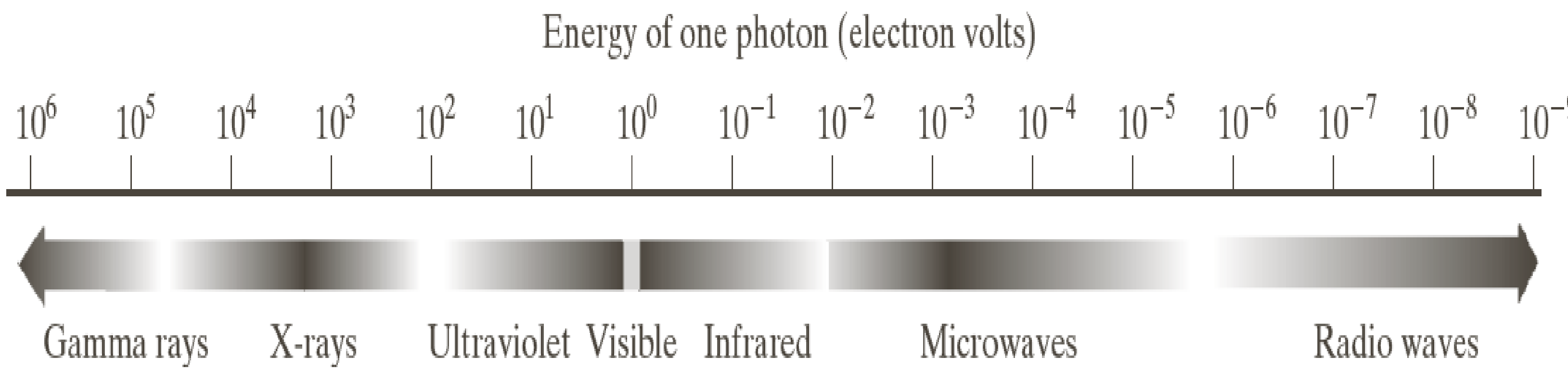
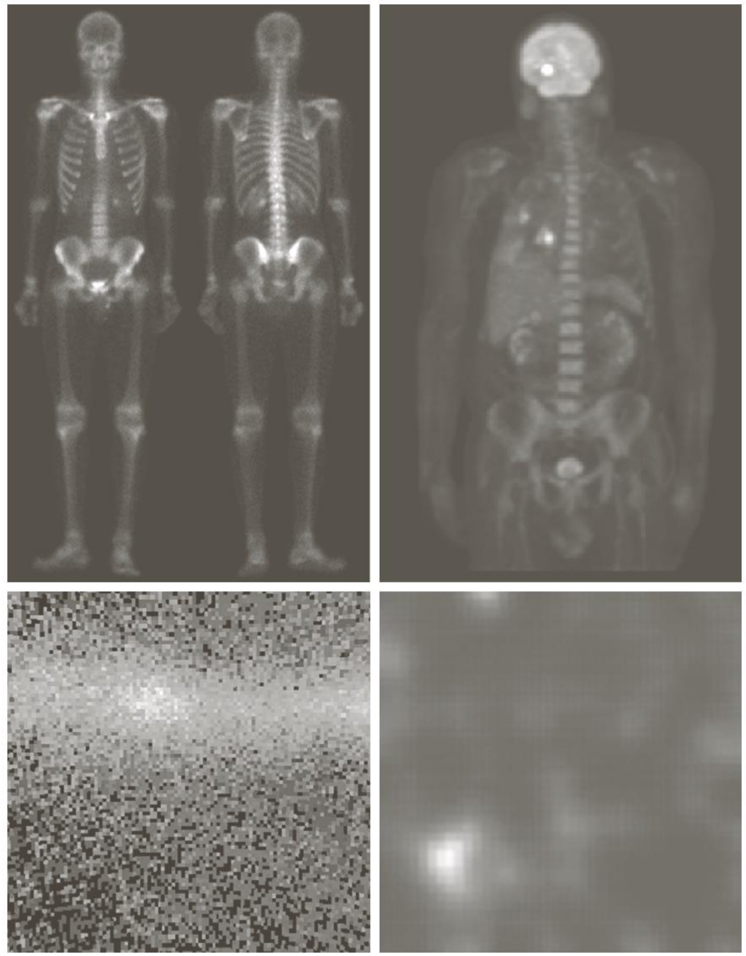


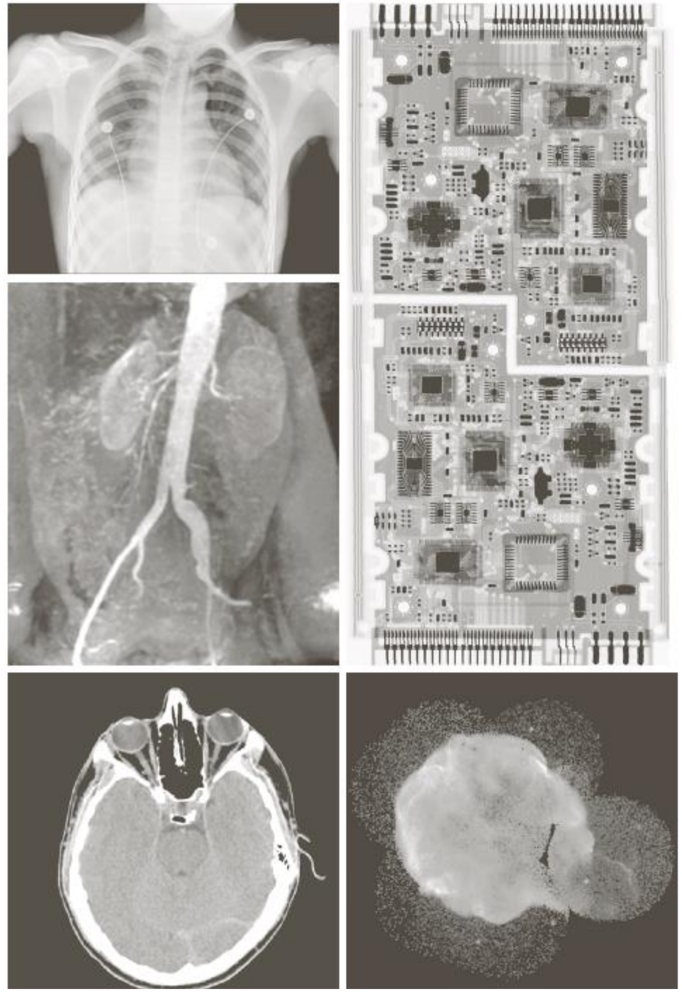
FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

Some Digital Image Processing and Computer Vision Various Application Fields



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.)



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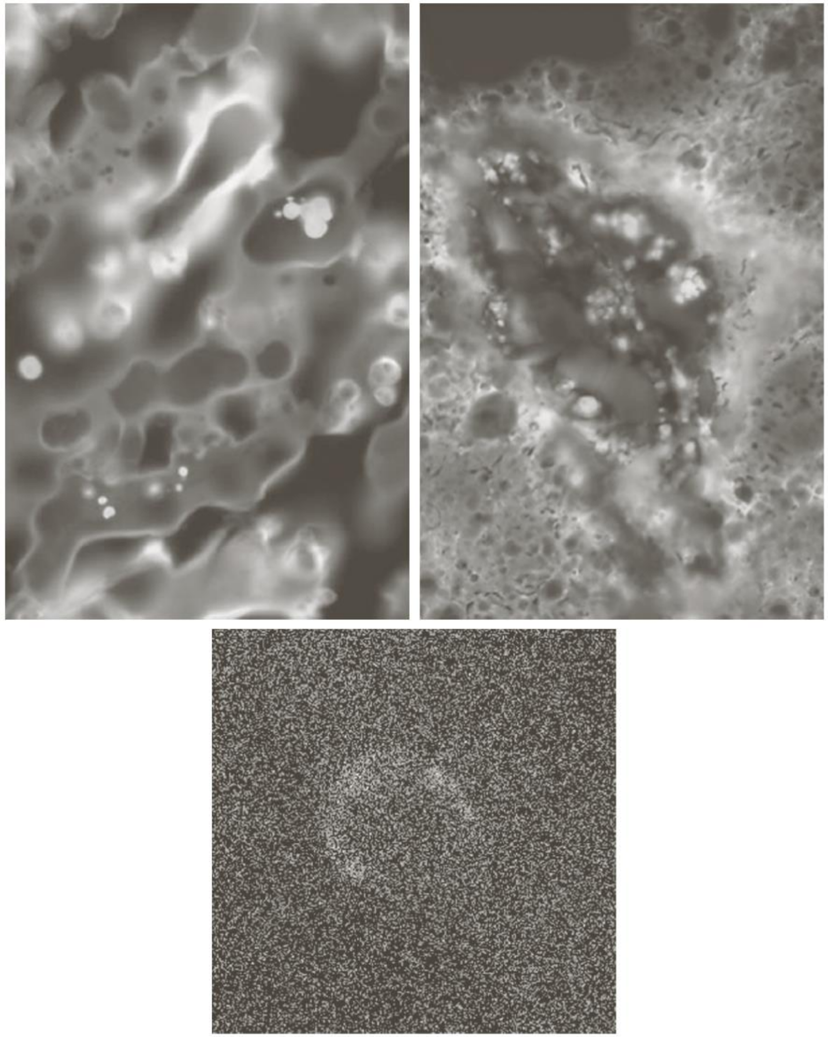
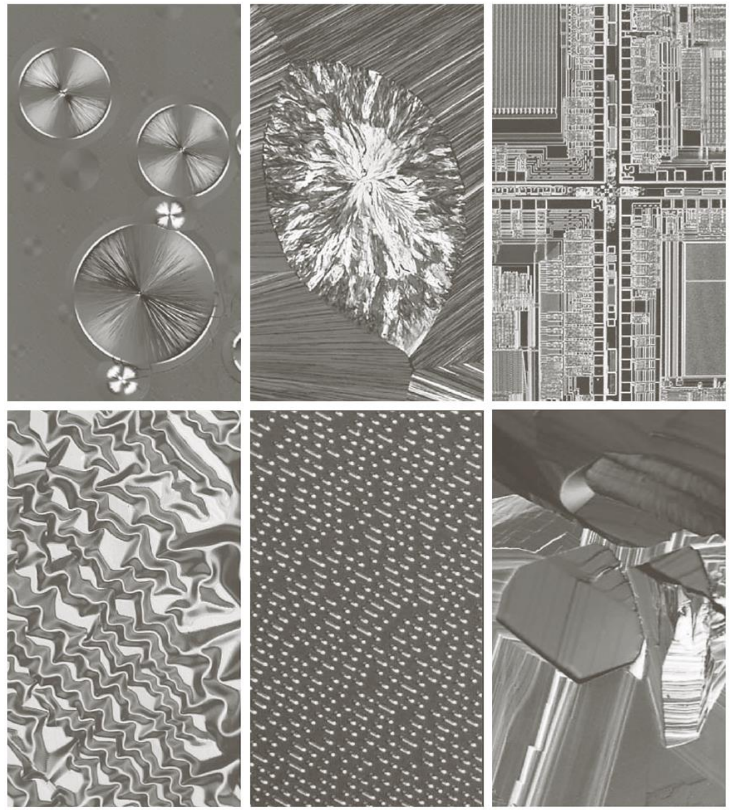
FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of Anatomical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



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.)



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.)

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.

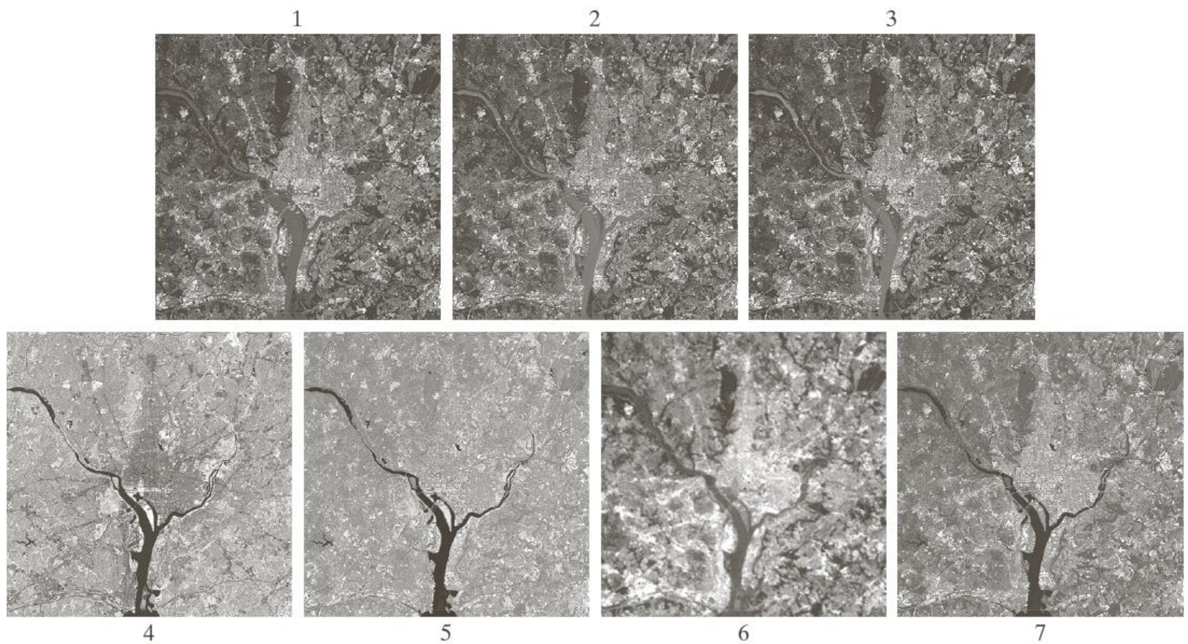


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

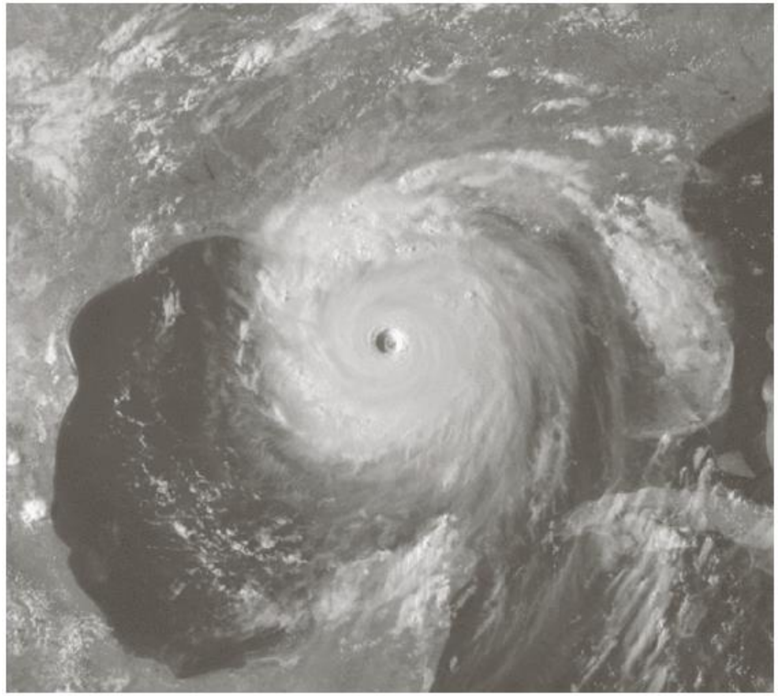
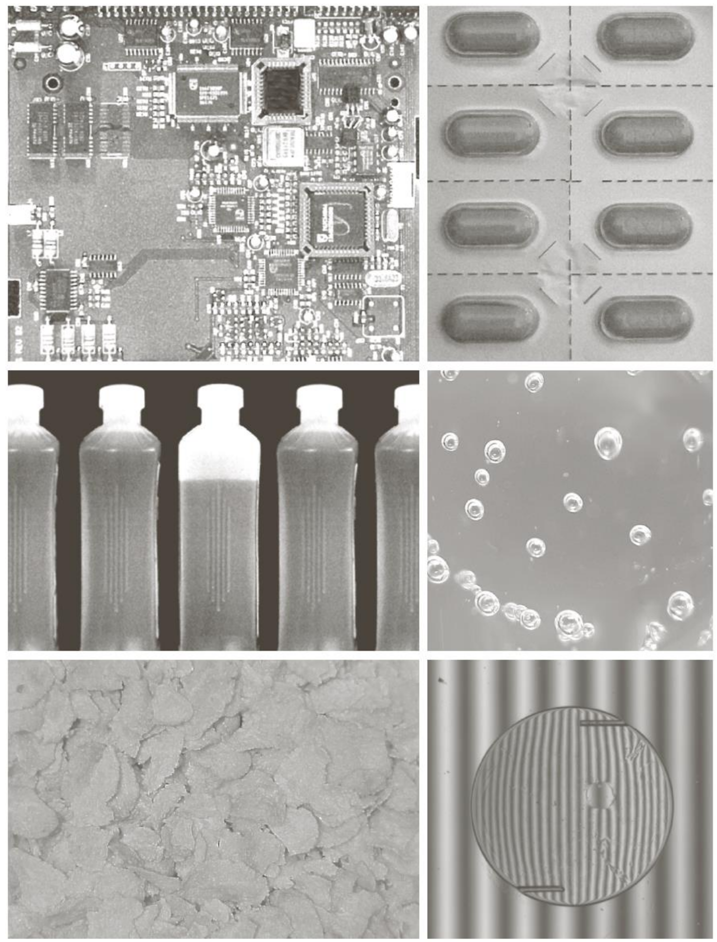


FIGURE 1.11 Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)

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



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.)

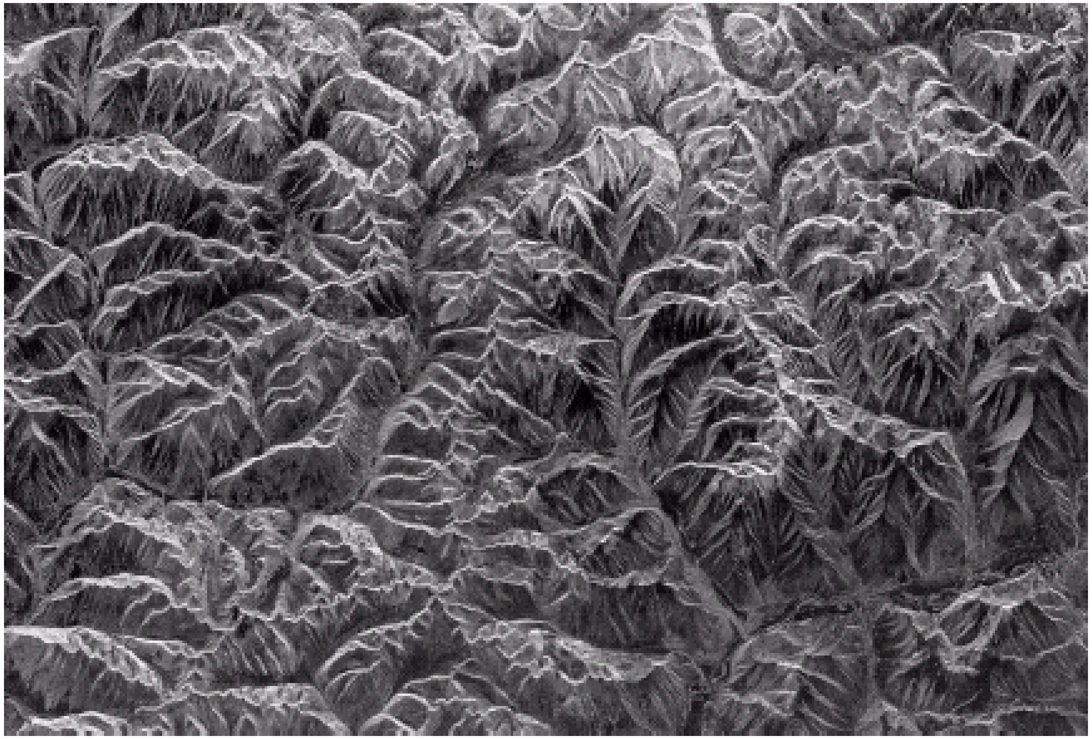
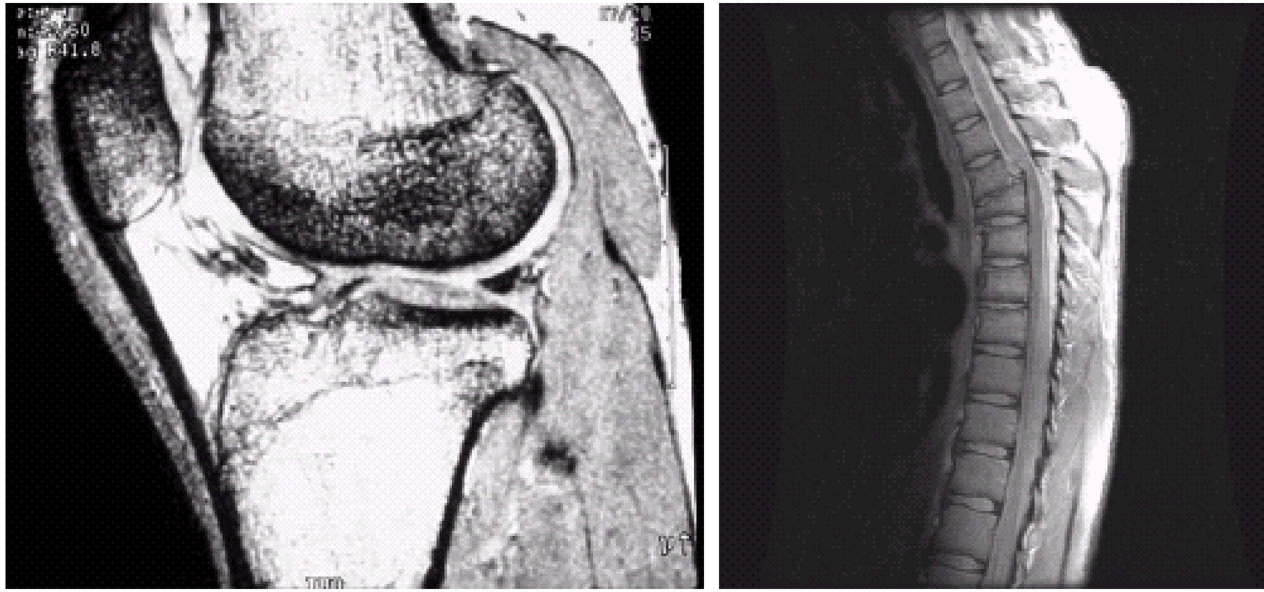


FIGURE 1.16 Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)



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.)

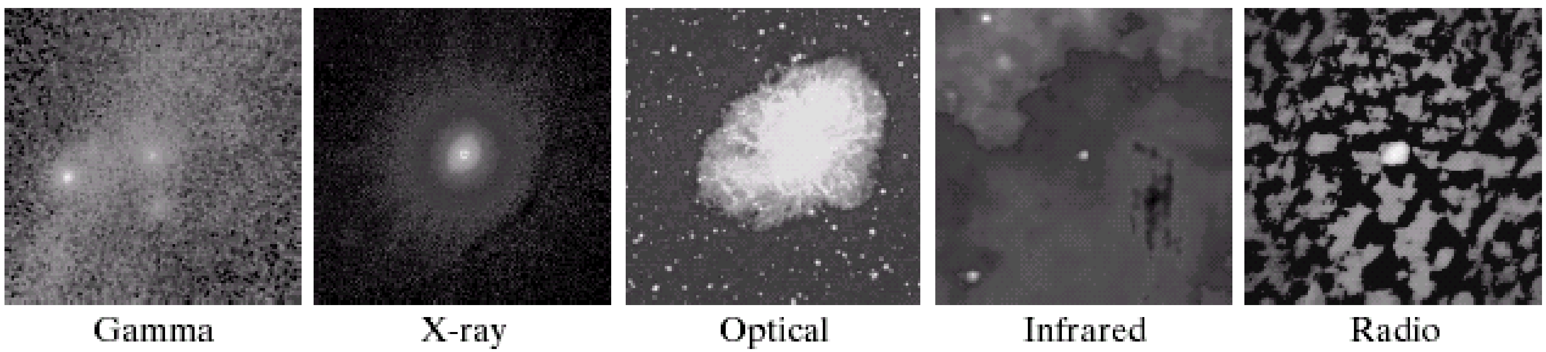
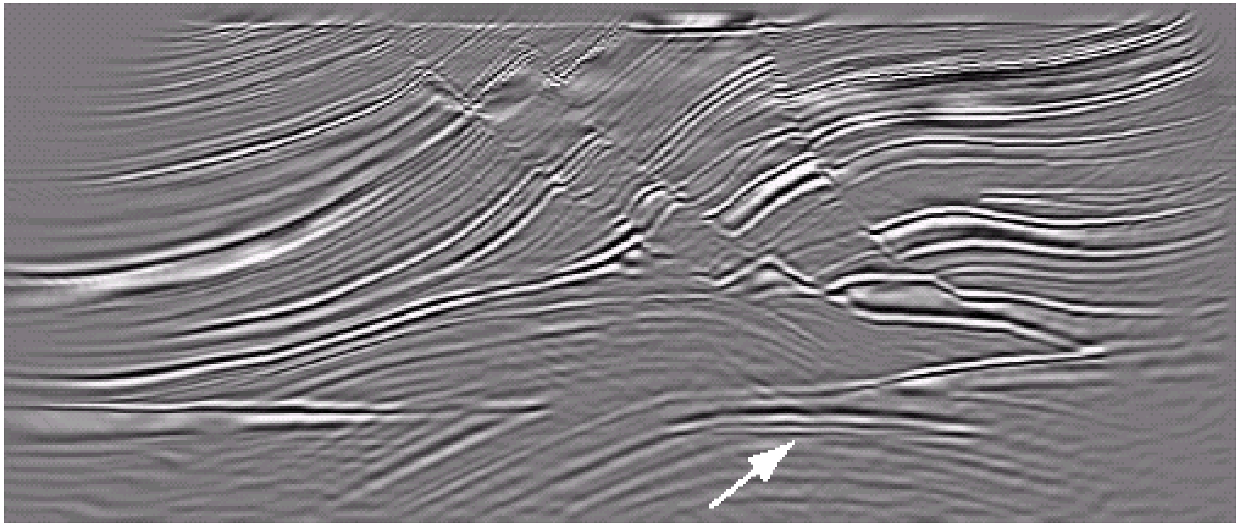


FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

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.)



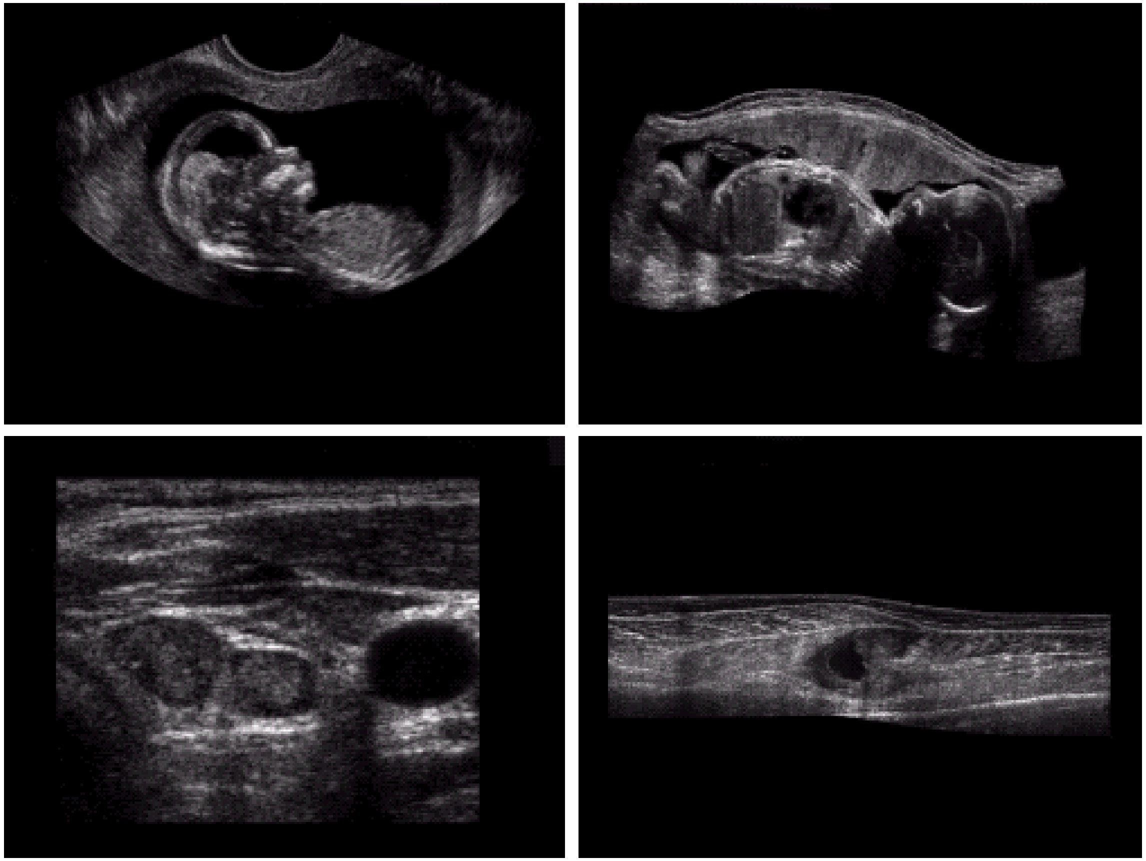


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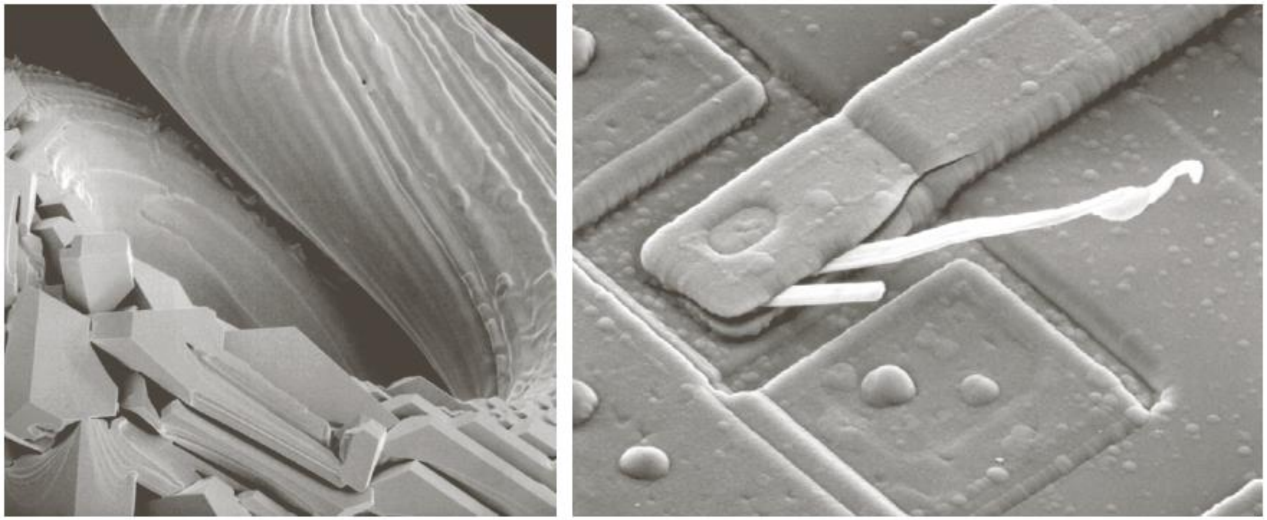
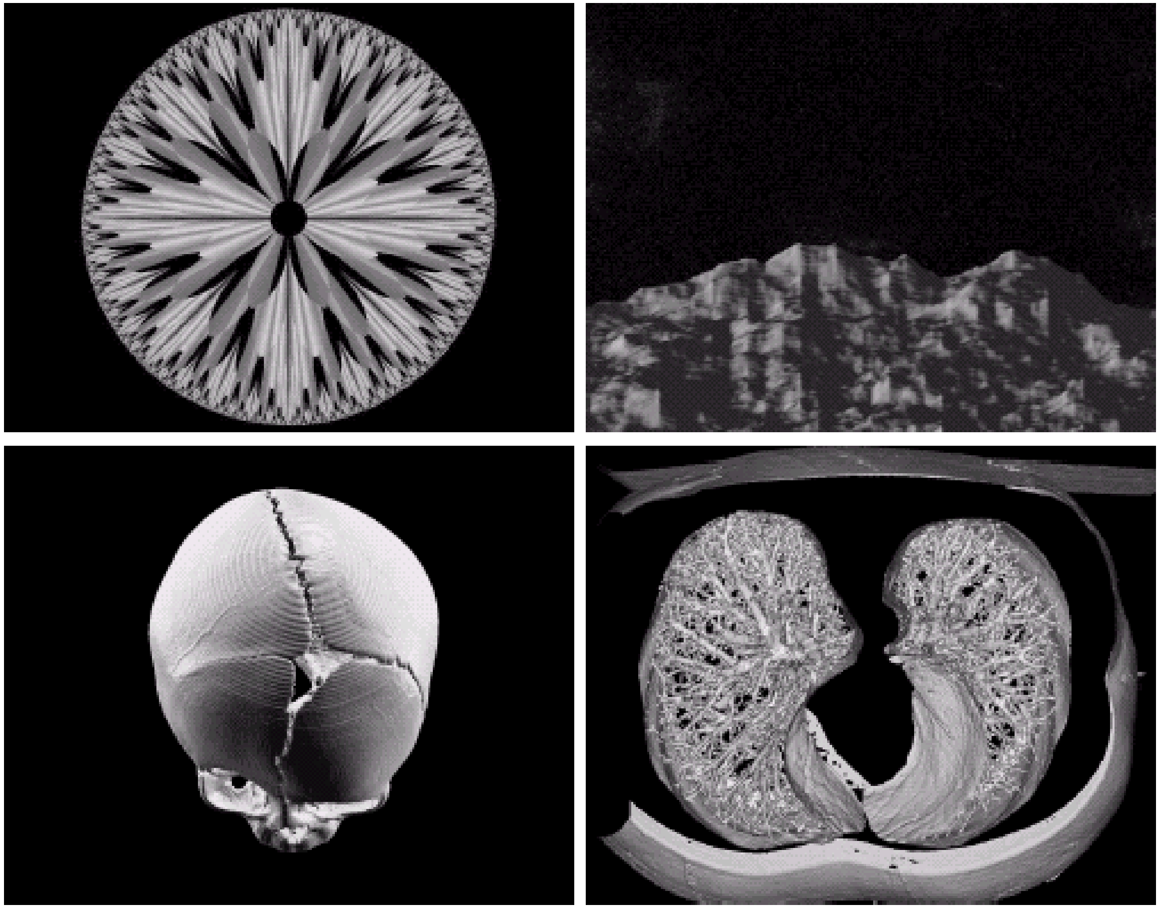
FIGURE 1.20 Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)



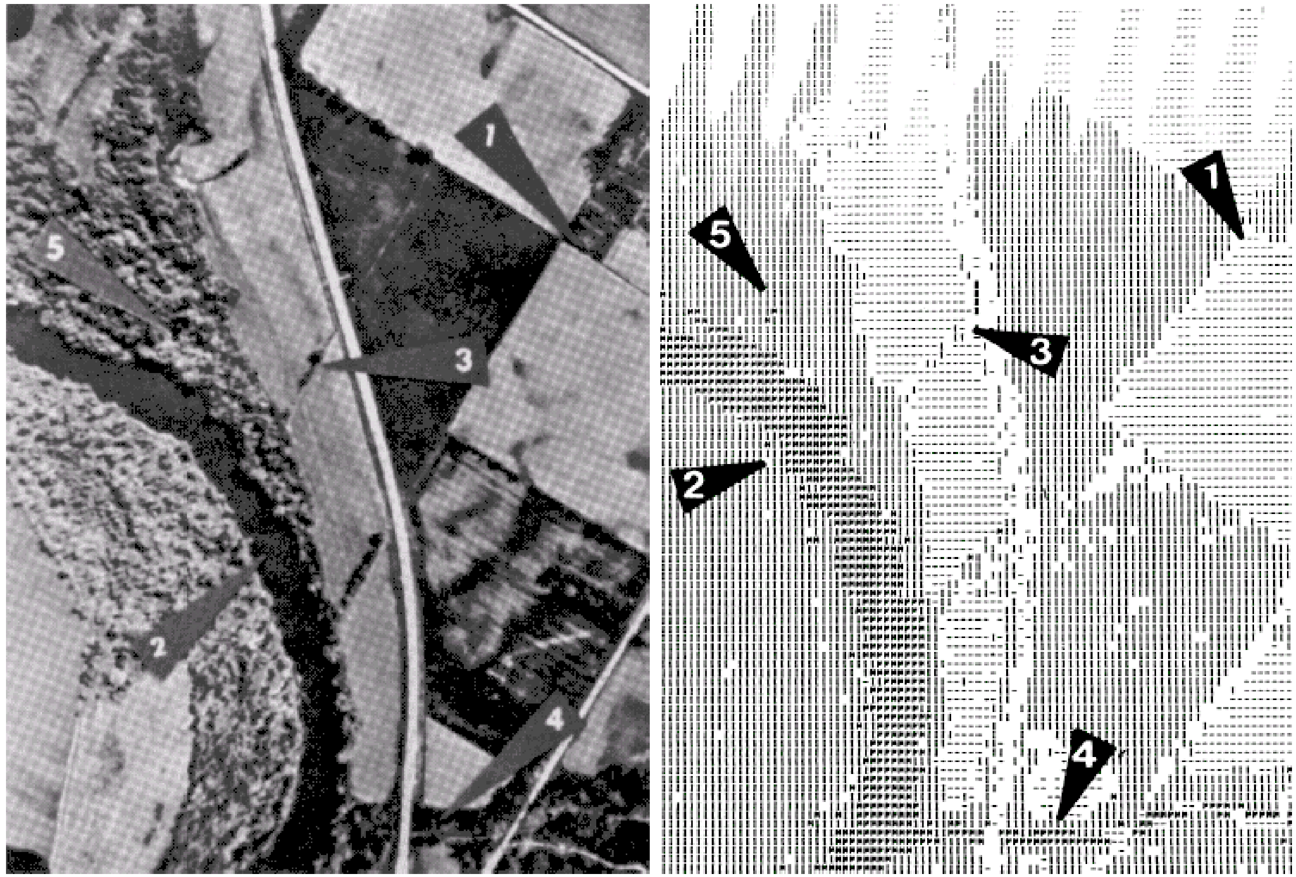
a b

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.)



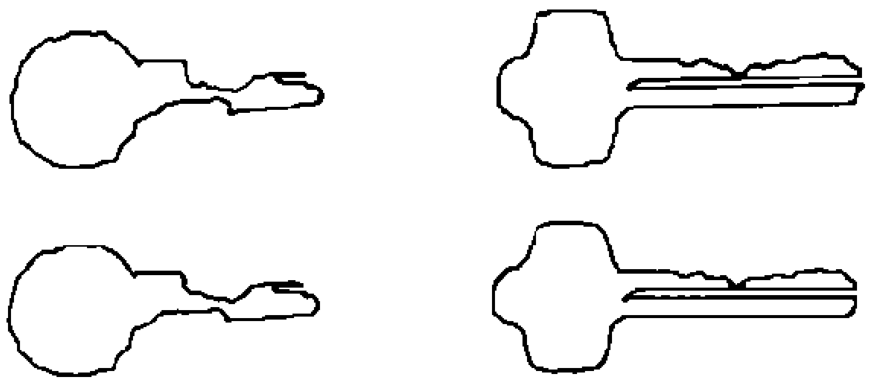
a b
c d

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.)



a b

FIGURE 12.13 (a) Multispectral image. (b) Printout of machine classification results using a Bayes classifier. (Courtesy of the Laboratory for Applications of Remote Sensing, Purdue University.)



R	1.a	1.b	1.c	1.d	1.e	1.f
1.a	∞					
1.b	16.0	∞				
1.c	9.6	26.3	∞			
1.d	5.1	8.1	10.3	∞		
1.e	4.7	7.2	10.3	14.2	∞	
1.f	4.7	7.2	10.3	8.4	23.7	∞

R	2.a	2.b	2.c	2.d	2.e	2.f
2.a	∞					
2.b	33.5	∞				
2.c	4.8	5.8	∞			
2.d	3.6	4.2	19.3	∞		
2.e	2.8	3.3	9.2	18.3	∞	
2.f	2.6	3.0	7.7	13.5	27.0	∞

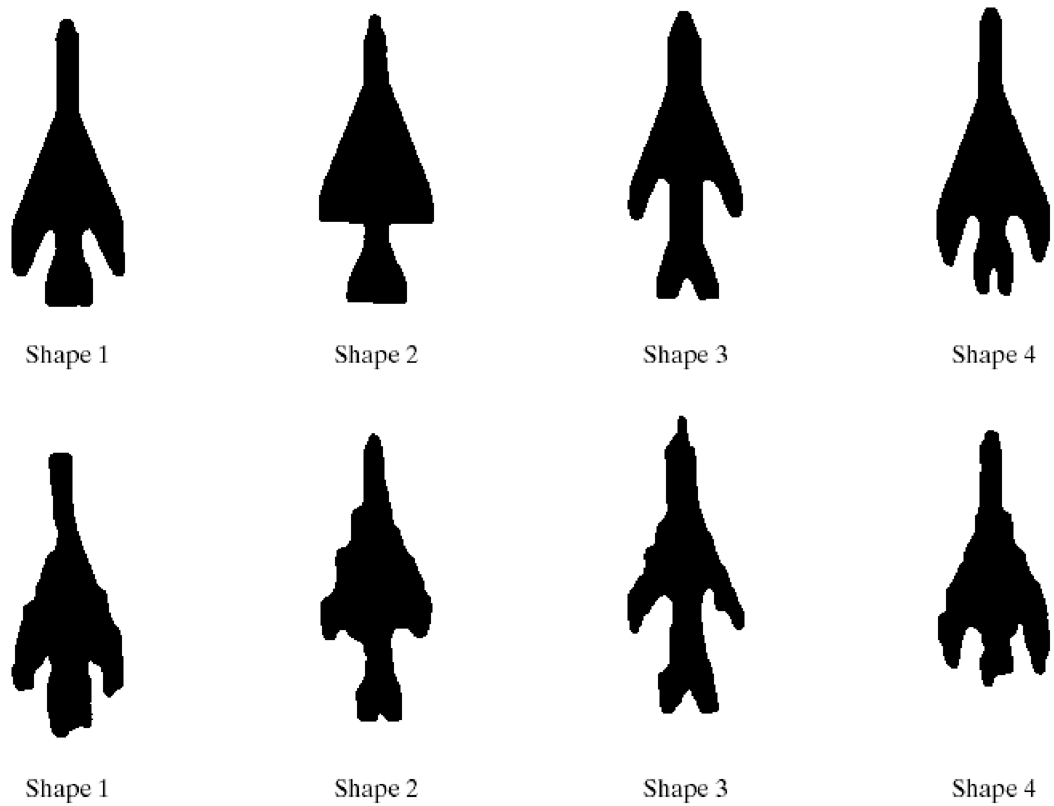
R	1.a	1.b	1.c	1.d	1.e	1.f
2.a	1.24	1.50	1.32	1.47	1.55	1.48
2.b	1.18	1.43	1.32	1.47	1.55	1.48
2.c	1.02	1.18	1.19	1.32	1.39	1.48
2.d	1.02	1.18	1.19	1.32	1.29	1.40
2.e	0.93	1.07	1.08	1.19	1.24	1.25
2.f	0.89	1.02	1.02	1.24	1.22	1.18

a	b
c	d
e	f
g	

FIGURE 12.25 (a) and (b) Sample boundaries of two different object classes; (c) and (d) their corresponding polygonal approximations; (e)–(g) tabulations of ***R***. (Sze and Yang.)

a
b

FIGURE 12.18 (a) Reference shapes and (b) typical noisy shapes used in training the neural network of Fig. 12.19. (Courtesy of Dr. Lalit Gupta, ECE Department, Southern Illinois University.)



a b
c d

FIGURE 5.25 Illustration of the atmospheric turbulence model. (a) Negligible turbulence. (b) Severe turbulence, $k = 0.0025$. (c) Mild turbulence, $k = 0.001$. (d) Low turbulence, $k = 0.00025$. (Original image courtesy of NASA.)

What Is Digital Image Processing and Computer Vision?

COMPUTER VISION

(also called image understanding or machine vision)

"is the construction of explicit, meaningful descriptions of physical objects from images" (D. Ballard)

"creating a model of the real world from images, recovering useful information about a scene from its 2D projections" (R. Jain)

"analyzing images and producing descriptions of what is imaged" (B. Horn)

"automatic deduction of the structure and properties of a possibly dynamic 3D world from either a single or multiple 2D images of the world" (V. Nalwa)

COMPUTER VISION

- we know a lot about the structure and function of the human eye, but we know very little of what happens in the brain ----> computer vision is faced with a very difficult problem: it must reinvent the most basic and yet inaccessible talents of specialized biological visual systems

- it is a new and fast-growing field; first experiments we done in the **late 1950s**

- there is no "universal" vision system available; there are computer vision systems that perform a particular task in a defined application, for example:

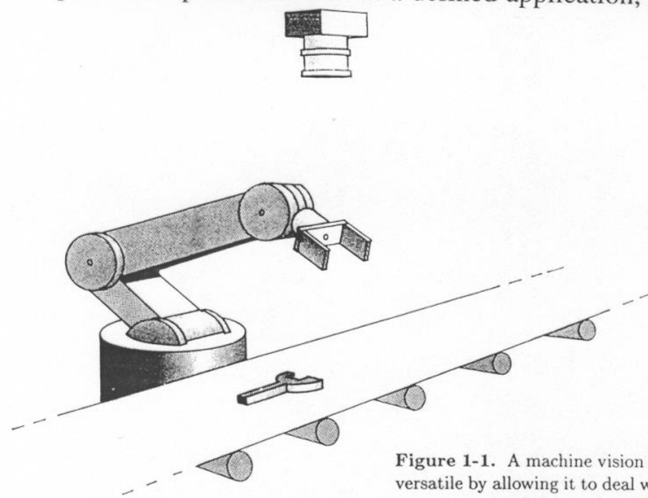


Figure 1-1. A machine vision system can make a robot manipulator much more versatile by allowing it to deal with variations in part position and orientation. In some cases simple binary image-processing systems are adequate for this purpose.

Examples of some applications:

automatic robot assembly
automatic navigation of automobiles, airplanes, tanks and robots
detection and recognition of various types of targets (example ships)
automatic interpretation of documents
character recognition
checking of fingerprints
human blood cell analysis
analysis of the remote sensing data
automated visual inspection
interpretation of chromosome images
human-computer communication (e.g. through gesturing)
aids for visually impaired (e.g. mechanical guide dogs)
automatic analysis of medical images
detection of tumors from CT and NMR images
...

RELATION TO OTHER FIELDS

Computer vision is closely related with:

- image processing
  input image -> output image
  examples: image enhancement, image compression, correcting images, smoothing, etc.

Computer vision algorithms take images as inputs and produce other types of outputs, such as representations for the object contours in an image; emphasis is on recovering information **automatically**, with minimal interaction with a human.
Image processing algorithms are useful in early stages of machine vision system.

- computer graphics
  lines, circles, free-form surfaces -> images

Computer vision is the **analysis** of images, while the computer graphics is the **synthesis** of images.
Computer vision is using curve and surface representations and some other techniques from computer graphics. **Visualization and virtual reality** are using techniques from computer vision and computer graphics.

- pattern recognition
  feature vector -> class number

Computer vision is using techniques from pattern recognition for recognizing objects.

- artificial intelligence
  designing intelligent systems and studying computational aspects of intelligence

Computer vision is often considered a subfield of artificial intelligence.

Machine vision generates a symbolic description from one or more images.

Vision = Geometry + Measurement + Interpretation

VISION

"Every image is the image of a thing merely for him who knows how to read it, and who is enabled by the aid of the image to form an idea of the thing"

Helmholtz
Handbook of Physiological Optics

- vision is our most powerful sense; but our knowledge of the human visual system is very limited; we know it is complex
- human visual system is able to interpret complex scenes easily - we see trees in a landscape, books on a desk, widgets in a factory, etc.
- sometimes humans may "see" what is not (i.e. hallucinate), and they may not "see" what is (i.e., overlook) - examples: Fraser's spiral and paintings by Escher
- illusions of the human visual system - they are also important; they reflect hidden assumptions that the brain is making in processing visual data

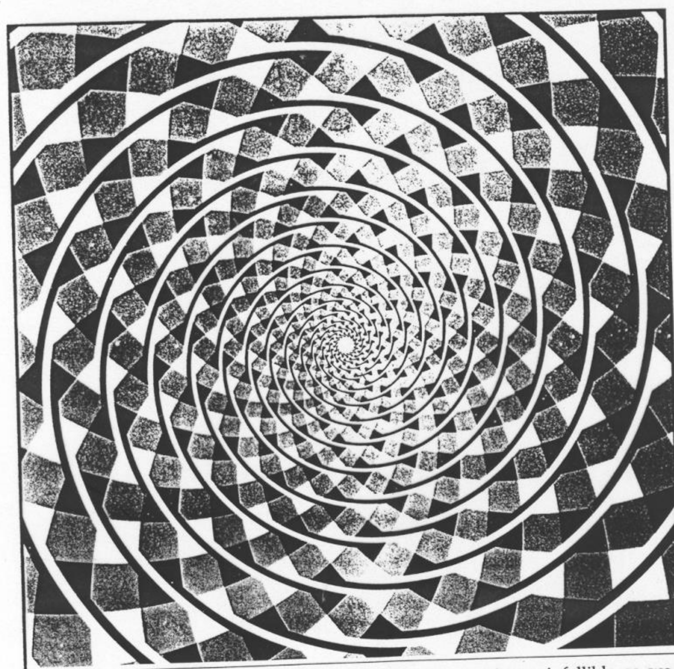


Figure 1.1 Fraser's spiral. Human vision is not quite as infallible as we tend to believe. A case in point is the illusory spiral evoked here by a collection of concentric circles, each circle comprising segments angled toward the center. To convince yourself that there is indeed no spiral, try tracing a spiral with your finger. (After [Fraser 1908].)

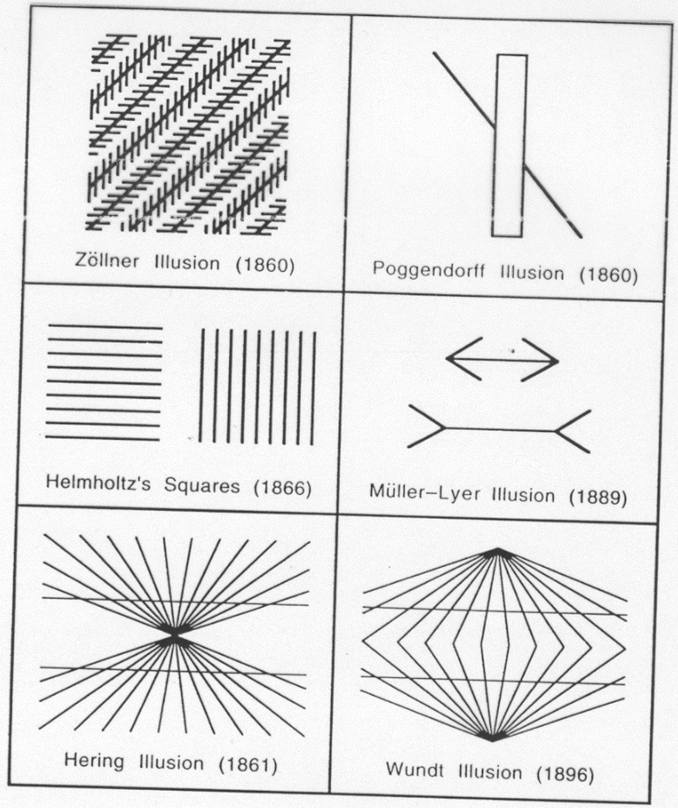


Figure 1.3 Six classical optical illusions. In each of the drawings, geometric truths appear untrue. The illusory effect is so strong that you might wish to have a ruler handy to verify the various assertions. In the Zöllner illusion, the diagonals are parallel, but appear otherwise. In the Poggendorff illusion, the two diagonal straight-line segments seem offset even though they are collinear. Helmholtz's two squares appear rectangular. In the Müller–Lyer illusion, the horizontal line with the reversed arrowheads appears longer than the line with the normal arrowheads, even though both lines have the same length. Finally, in both the Hering and Wundt illusions, the two horizontal and parallel straight lines appear bowed. (See [Boring 1942] for the origins of these optical illusions.)

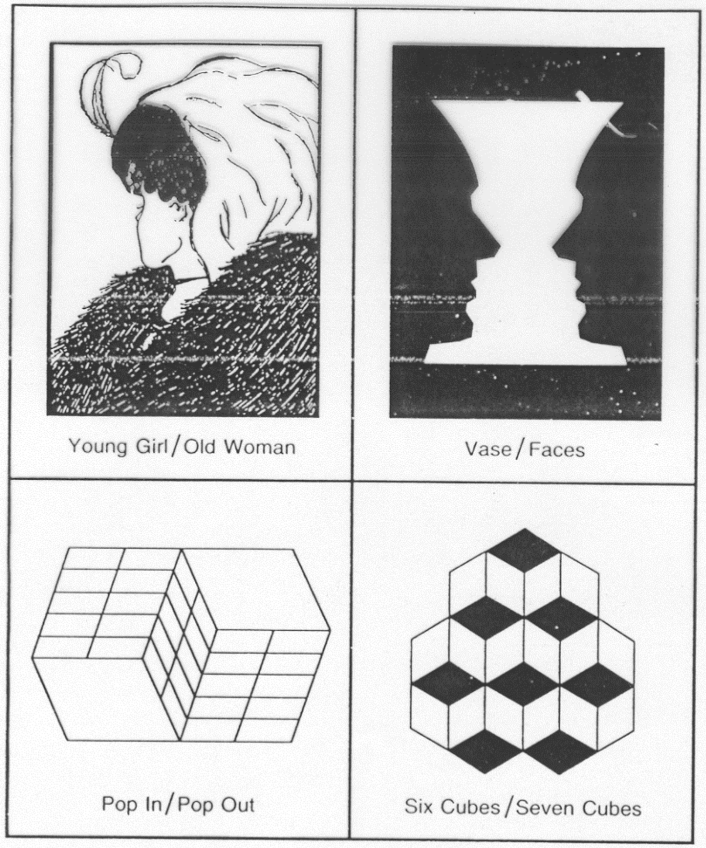


Figure 1.5 Four well-known visual ambiguities. In each of the drawings, two interpretations compete for attention. In the young-girl/old-woman illustration, the young girl's chin is the old woman's nose. The interpretation of the vase/faces illustration depends on whether the black region is seen as the background or as the foreground. Finally, the pop-in/pop-out and six-cubes/seven-cubes ambiguities depend on the spontaneous reversal of the perceived concavities and convexities. (See [Boring 1930] for the origin of the young-girl/old-woman ambiguity, which is based on a cartoon by Hill in 1915; see [Boring 1942] for the origin of the vase/faces ambiguity, which is based on an ambiguous figure by Rubin in 1915; the pop-in/pop-out and six-cubes/seven-cubes ambiguities are based on the Schröder staircase (illustrated in Figure 4.2), which was proposed in 1858 and whose origin is described in [Boring 1942].)

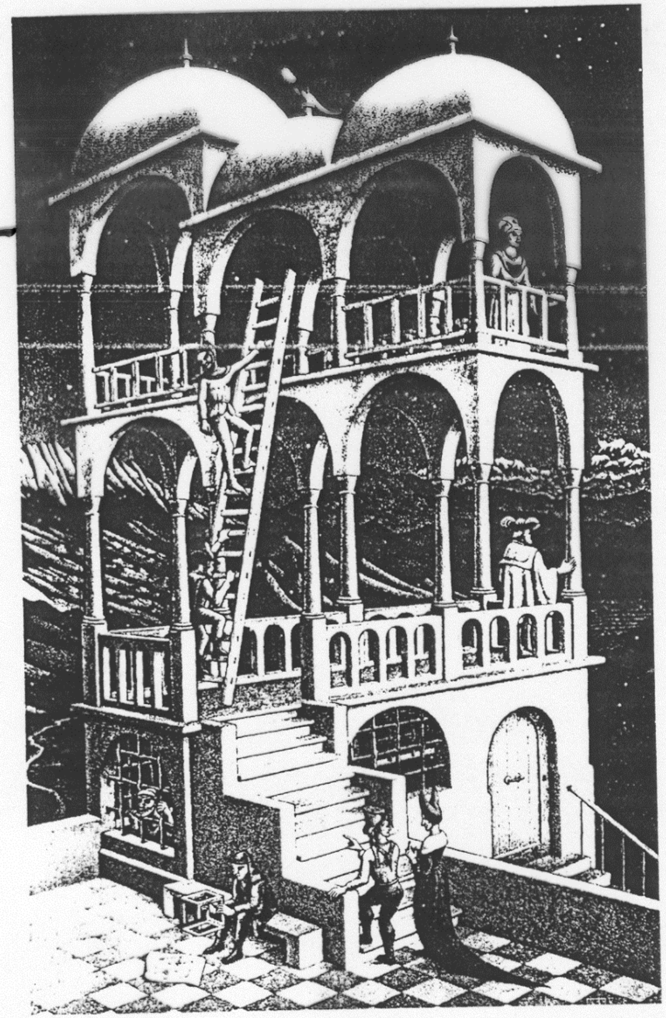


Figure 1.6 *Belvedere*, by Maurits C. Escher, 1958. This well-known lithograph exhibits several geometrical inconsistencies that are not readily apparent. The middle-level pillars cross from the front to the rear, and vice versa; the ladder's base is inside the building, but its top is outside; the topmost level is at right angles to the middle level; the cube being examined by the person on the bench is geometrically impossible. (Copyright © 1990 by M. C. Escher Heirs / Cordon Art – Baarn – Holland.)

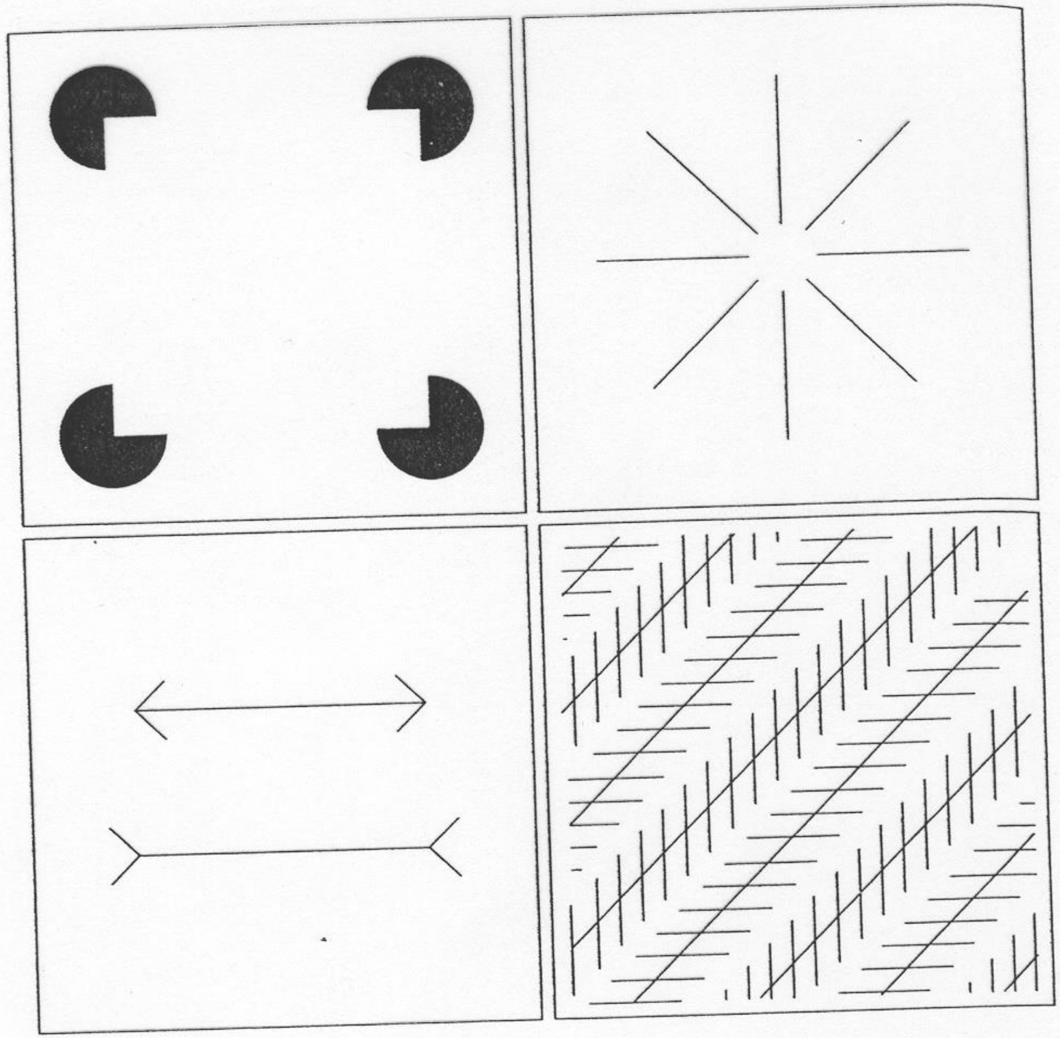


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FIGURE 2.9 Some well-known optical illusions.

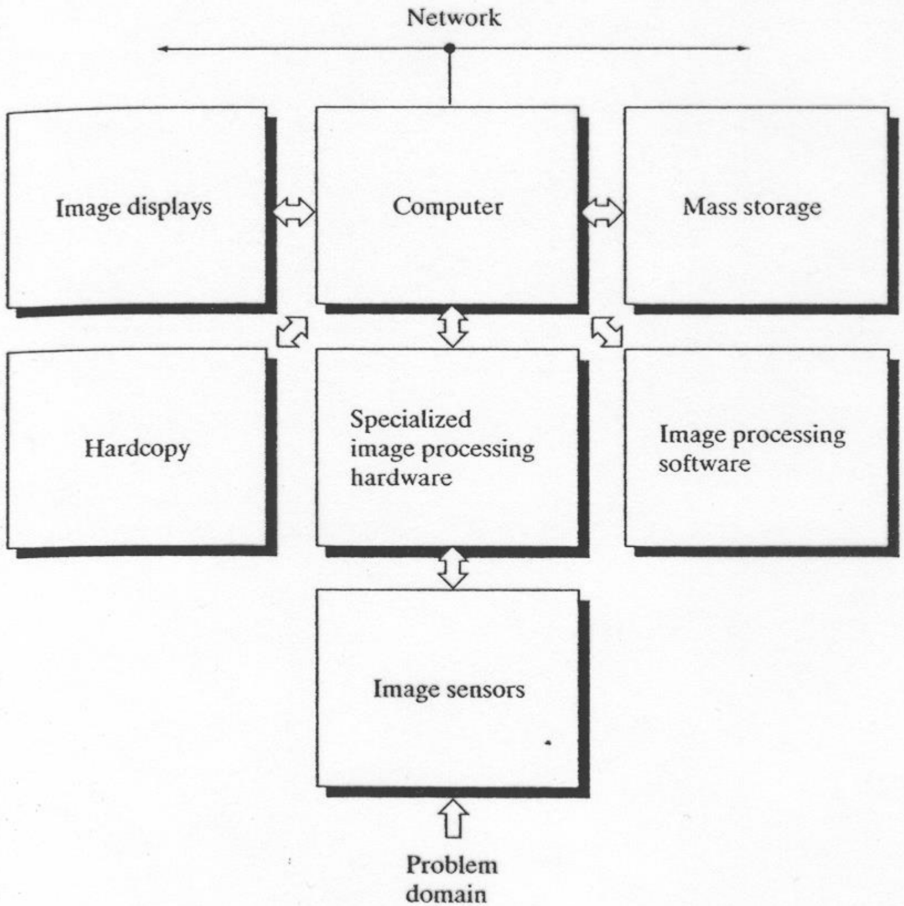
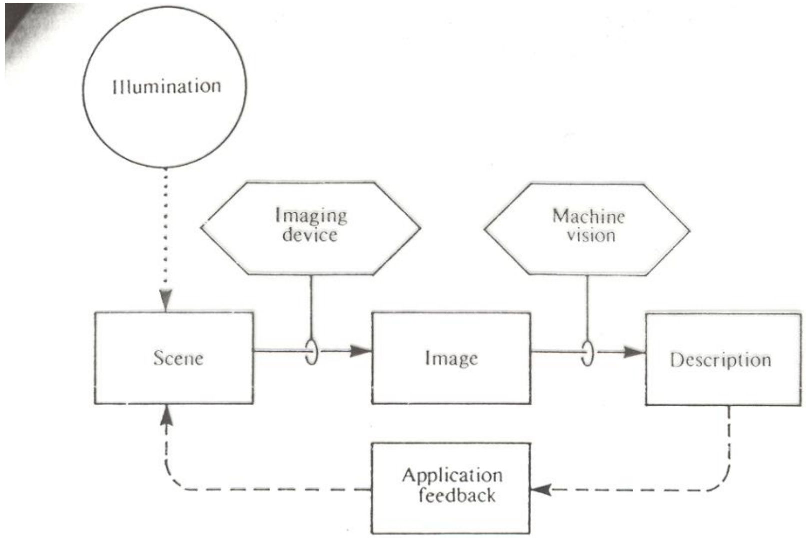


FIGURE 1.24 Components of a general-purpose image processing system.



igure 1-2. The purpose of a machine vision system is to produce a symbolic escription of what is being imaged. This description may then be used to direct ie interaction of a robotic system with its environment. In some sense, the ision system's task can be viewed as an inversion of the imaging process.

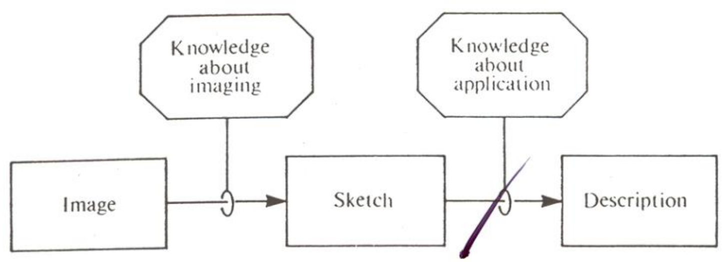


Figure 1-10. In many cases, the development of a symbolic description of a cene from one or more images can be broken down conveniently into two stages. The first stage is largely governed by our understanding of the image-formation rocess; the second depends more on the needs of the intended application.

FIGURE 1.23 Fundamental steps in digital image processing.