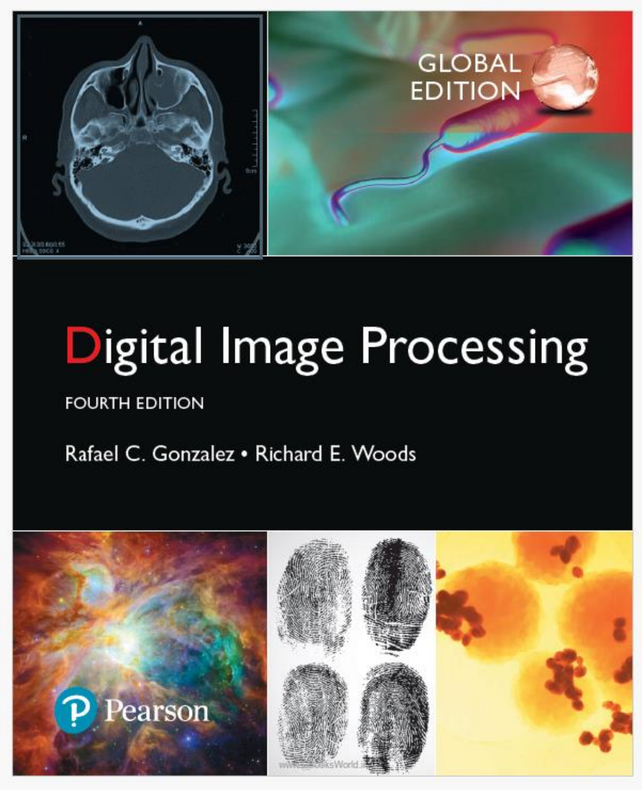
INTRODUCTION TO DIGITAL IMAGE PROCESSING

ICT4201:DIP

Course Objective

- This course introduces digital image processing. It focuses on the theory and algorithms for various operations on images including acquisition and formation, enhancement, segmentation, and representation.
- By the end of this course, students will be able to:
  - Explain how digital images are represented and manipulated in a computer, including reading and writing from storage, and displaying.
  - Write a program which implements fundamental image processing algorithms.
  - Be conversant with the mathematical description of image processing techniques and know how to go from the equations to code.

Text



- **Digital Image Processing , 4th Edition**
- Authors
  - Rafael C. Gonzalez
  - Richard E. Woods
- Pearson

What is Digital Image Processing?

- Digital Image Processing means processing digital image by means of a digital computer. We can also say that it is a use of computer algorithms, in order to get enhanced image either to extract some useful information.
- Digital image processing is the use of algorithms and mathematical models to process and analyze digital images. The goal of digital image processing is to enhance the quality of images, extract meaningful information from images, and automate image-based tasks.
- Digital image processing focuses on two major tasks
  - Improvement of pictorial information for human interpretation
  - Processing of image data for storage, transmission and representation for autonomous machine perception

Origin of Image Processing

- One of the earliest applications of digital images was in the newspaper industry, when pictures were first sent by submarine cable between London and New York.
- The cable picture transmission in 1921 reduced the time required to transport a picture across the Atlantic for more than a week to less than 3 hours.
- Now just imagine , that today we are able to see live video feed , or live CCTV footage from one continent to another with just a delay of seconds. It means that a lot of work has been done in this field too. This field does not only focus on transmission , but also on encoding. Many different formats have been developed for high or low bandwidth to encode photos and then stream it over the internet or e.t.c.

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

Applications of DIP

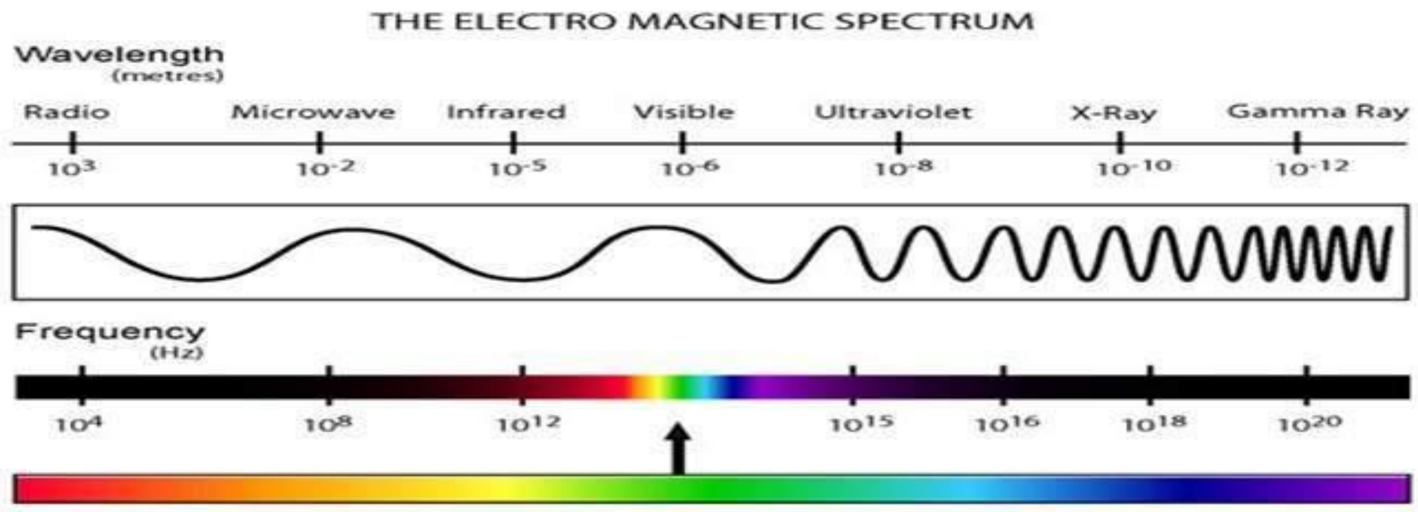
- Some of the major fields in which digital image processing is widely used are mentioned below
  - Image sharpening and restoration
  - Medical field
  - Remote sensing
  - Transmission and encoding
  - Machine/Robot vision
  - Color processing
  - Pattern recognition
  - Video processing
  - Microscopic Imaging
  - Others

Applications on Medical Field

- The common applications of DIP in the field of medical is
  - Gamma ray imaging
  - PET scan
  - X Ray Imaging
  - Medical CT
  - UV imaging

Source of Imaging

- One of the simplest ways to develop a basic understanding of the extent of image processing applications is to categorize images according to their source (e.g., X-ray, visual, infrared, and so on).
- The principal energy source for images in use today is the electromagnetic energy spectrum.
- Other important sources of energy include acoustic, ultrasonic, and electronic (in the form of electron beams used in electron microscopy). Synthetic images, used for modeling and visualization, are generated by computer.

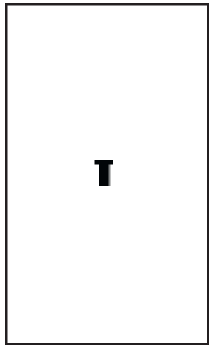


Source of Imaging… (cont.)

- In this electromagnetic spectrum, we are only able to see the visible spectrum. Visible spectrum mainly includes seven different colors that are commonly term as (VIBGOYR). VIBGOYR stands for violet , indigo , blue , green , orange , yellow and Red.
- But that does not nullify the existence of other stuff in the spectrum. Our human eye can only see the visible portion, in which we saw all the objects. But a camera can see the other things that a naked eye is unable to see. For example: x rays , gamma rays , e.t.c. Hence the analysis of all that stuff too is done in digital image processing.
- why do we need to analyze all that other stuff in EM spectrum too?
    - The answer to this question lies in the fact, because that other stuff such as XRay has been widely used in the field of medical. The analysis of Gamma ray is necessary because it is used widely in nuclear medicine and astronomical observation. Same goes with the rest of the things in EM spectrum.

What is a Digital Image?

- In image processing, the term ‘image’ is used to denote the image data that is sampled, quantized, and readily available in a form suitable for further processing by digital computers.
- An image may be defined as 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.
- When x, y, and the intensity values of f are all finite, discrete quantities, we call the image a *digital image*.



(a)

1	1	1	1	1
0	1	1	1	0
0	1	1	1	0
0	1	1	1	0
0	1	1	1	0

(b)

Fig. 1.3 Digital image representation (a) Small binary digital image (b) Equivalent image contents in matrix form

Pixel

A **digital image** is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels

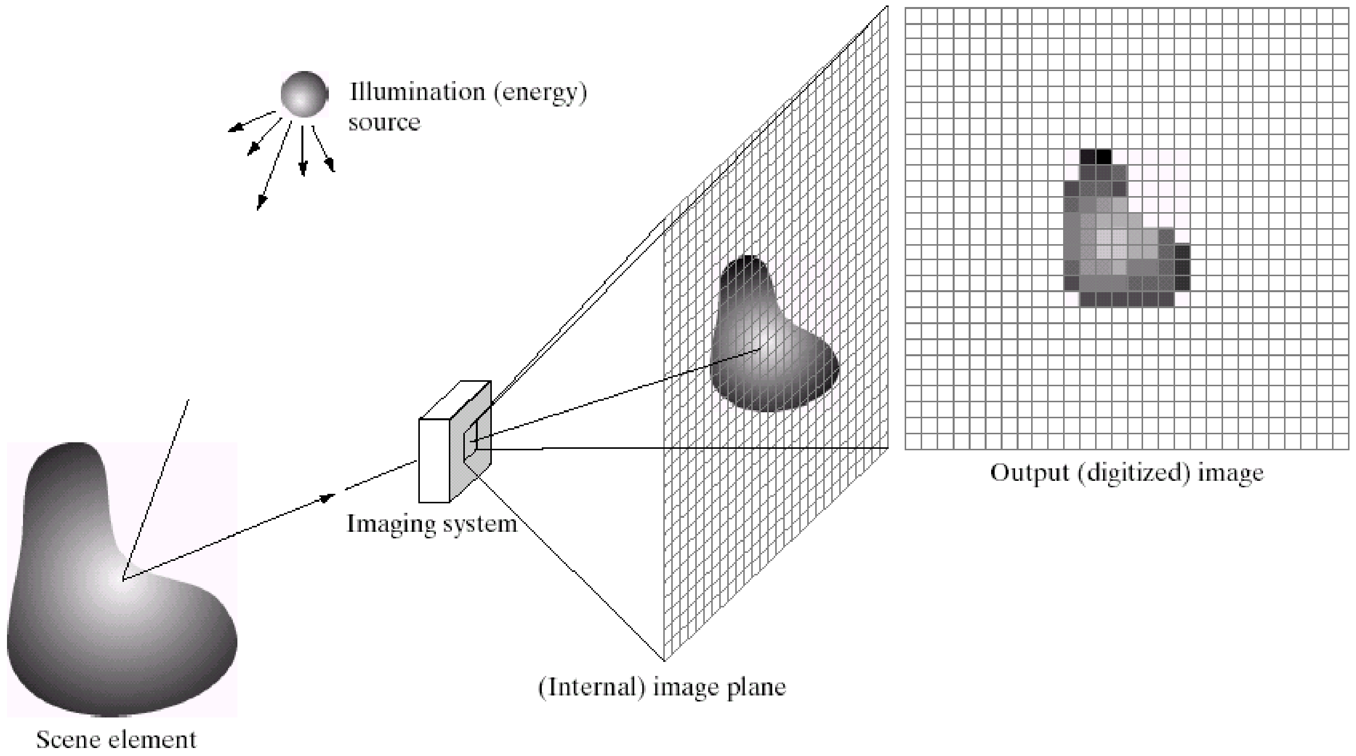


Image as Matrix

- As we know, images are represented in rows and columns we have the following syntax in which images are represented:
  - The right side of this equation is digital image by definition. Every element of this matrix is called image element , picture element , or pixel.

$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1) & f(0,2) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & f(1,2) & \dots & f(1,N-1) \\ \vdots & \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & f(M-1,2) & \dots & f(M-1,N-1) \end{bmatrix}$$

Important Terms

Resolution

Resolution is an important characteristic of an imaging system. It is the ability of the imaging system to produce the smallest discernable details, i.e., the smallest sized object clearly, and differentiate it from the neighboring small objects that are present in the image.

Bit Depth

The number of bits necessary to encode the pixel value is called *bit depth*. Bit depth is a power of two; it can be written as powers of 2.

So the total number of bits necessary to represent the image is

Number of rows *Number of columns * Bit depth

TYPES OF IMAGES

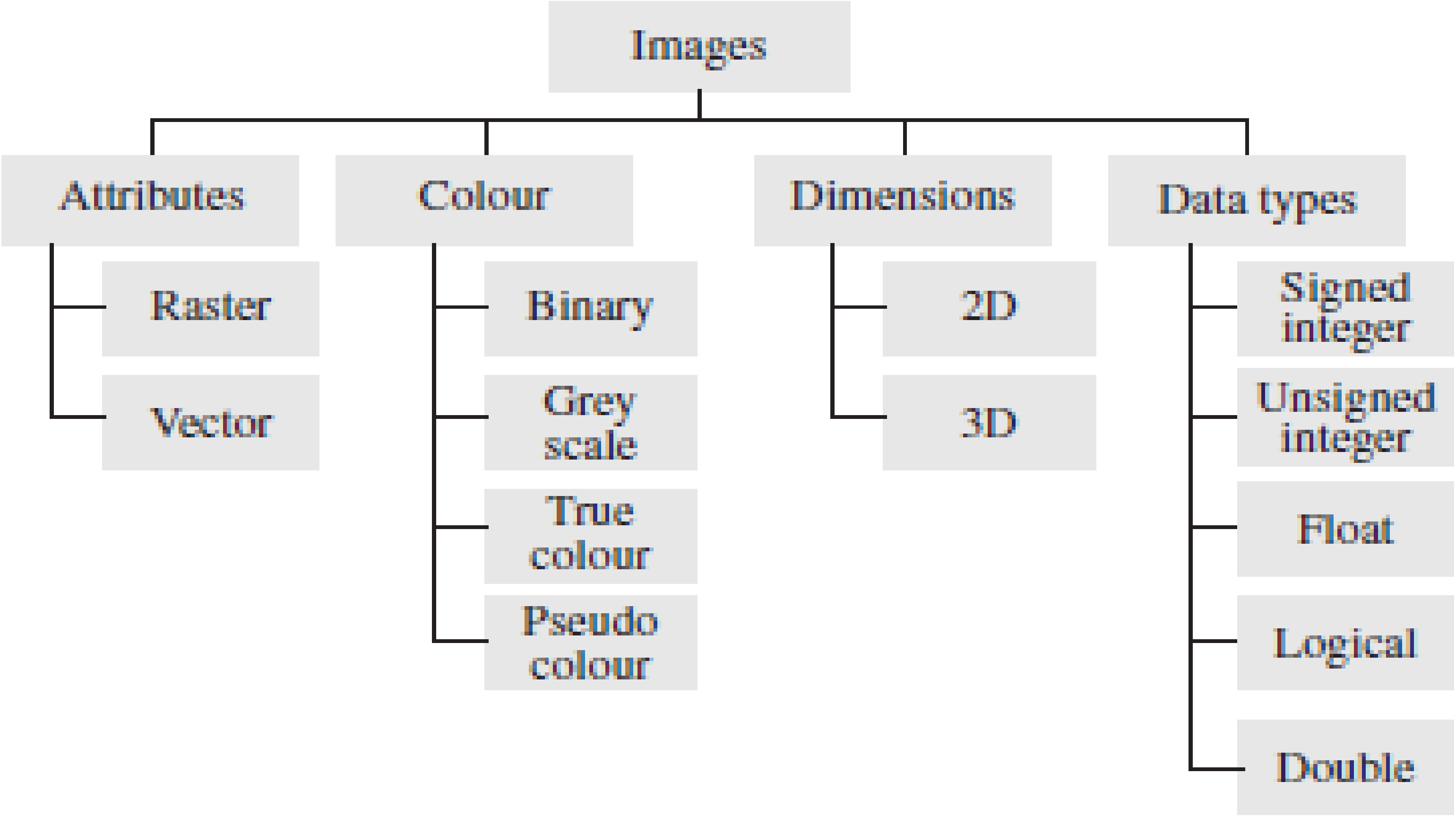


Fig. 1.4 Classification of images

TYPES OF IMAGES….(Cont.)

- In **Binary images**, the pixels assume a value of 0 or 1. So one bit is sufficient to represent the pixel value. Binary images are also called **bi-level images.**
- **Grey scale images** are different from binary images as they have many shades of grey between black and white. These images are also called monochromatic as there is no color component in the image, like in binary images. *Grey scale* is the term that refers to the range of shades between white and black or vice versa.

TYPES OF IMAGES….(Cont.)

Pseudo color images

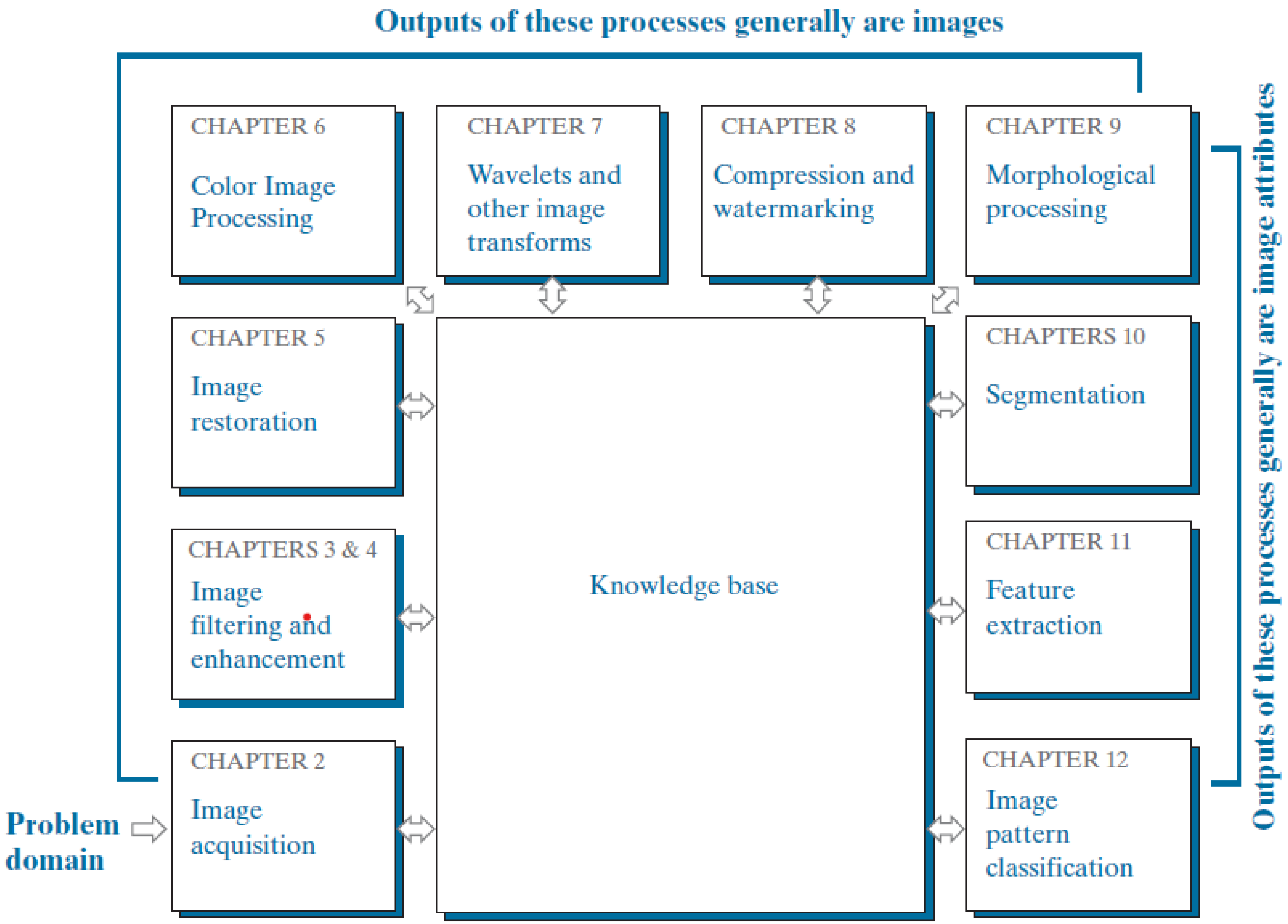
Like true color images, Pseudocolour images are also used widely in image processing. True color images are called three-band images. However, in remote sensing applications, multi-band images or multi-spectral images are generally used. These images, which are captured by satellites, contain many bands.

How a digital image is formed

- Since capturing an image from a camera is a physical process. The sunlight is used as a source of energy. A sensor array is used for the acquisition of the image. So when the sunlight falls upon the object, then the amount of light reflected by that object is sensed by the sensors, and a continuous voltage signal is generated by the amount of sensed data. In order to create a digital image , we need to convert this data into a digital form. This involves sampling and quantization. (They are discussed later on). The result of sampling and quantization results in an two dimensional array or matrix of numbers which are nothing but a digital image.

Fundamental Steps of 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.



Fundamental Steps of DIP… (Cont.)

1. *Image Acquisition* – Image acquisition involves preprocessing such as scaling etc. It could be as simple as being given an image that is already in digital form.
2. *Image Enhancement* – Basically, enhancement techniques bring out detail that is obscured and highlight certain features of interest in an image, such as changing brightness & contrast etc.
3. *Image Restoration* – Image restoration is an area that also deals with improving the appearance of an image. Image restoration is objective, in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image degradation.
4. *Colour Image Processing* – Colour image processing is an area that has been gaining its importance because of the significant increase in the use of digital images over the Internet. This may include colour modelling and processing in a digital domain etc. On the other hand, enhancement is subjective.
5. *Wavelets and Multiresolution Processing* – The foundation for representing images in various degrees of resolution is enabled by wavelets. Images are subdivided into smaller regions for data compression and for pyramidal representation.
6. *Compression* – Compression techniques reduce the storage required to save an image or the bandwidth to transmit it. Particularly for use over the internet, it is very much necessary to compress data.

Fundamental Steps of DIP… (Cont.)

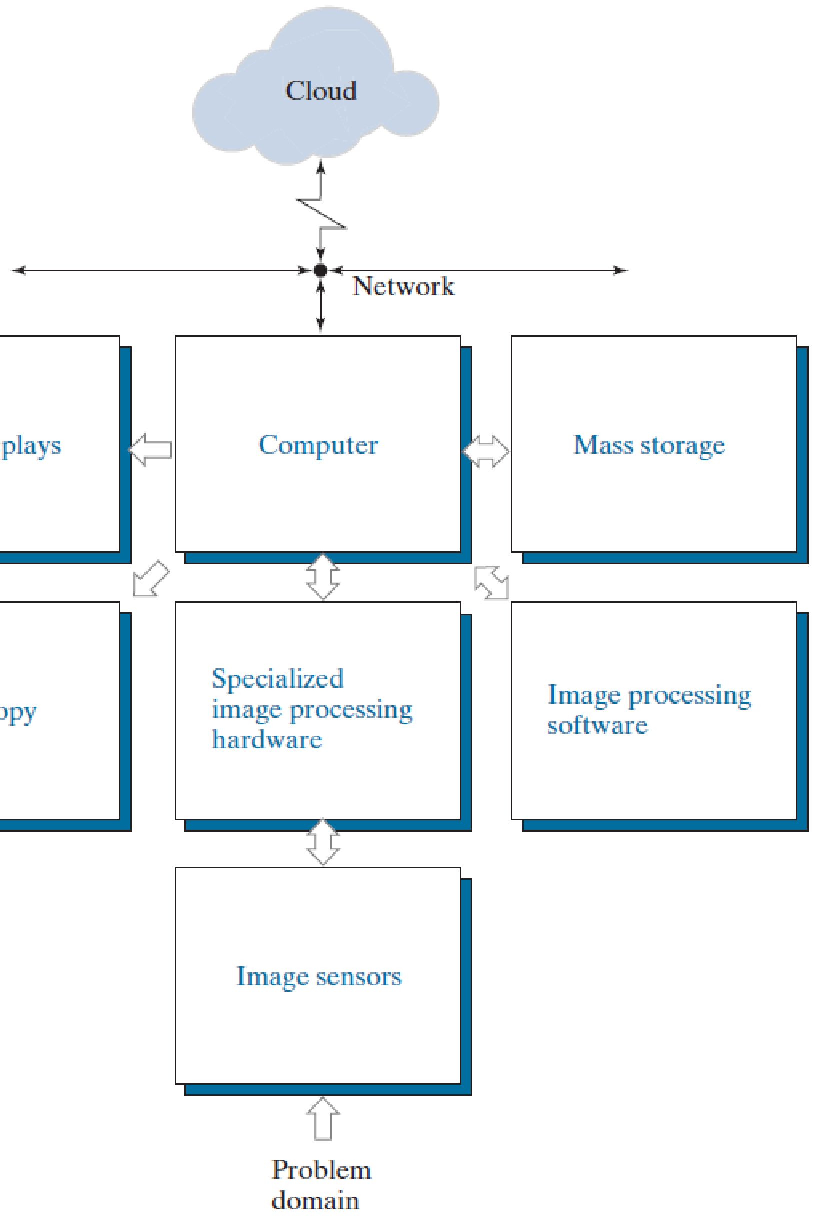
7. *Morphological Processing* – Morphological processing extracts image components that are useful in the representation and description of shape.
8. *Segmentation* – Segmentation procedures partition an image into its constituent parts or objects. In general, autonomous segmentation is one of the most difficult tasks in digital image processing. A rugged segmentation procedure brings the process a long way toward a successful solution of imaging problems that require objects to be identified individually.
9. *Representation and Description* – Representation and description almost always follow the output of a segmentation stage, which usually is raw pixel data that constitutes either the boundary of a region or all the points in the region itself. Description deals with extracting attributes that result in some quantitative information of interest or are basic for differentiating one class of objects from another.
10. *Object recognition* – Recognition is the process that assigns a label, such as, “apple” to an object based on its descriptors.

Main Steps of DIP

- Image processing mainly include the following steps:
  1. Importing the image via image acquisition tools;
  2. Analyzing and manipulating the image;
  3. Output in which result can be altered image or a report which is based on analyzing that image.

Components of DIP

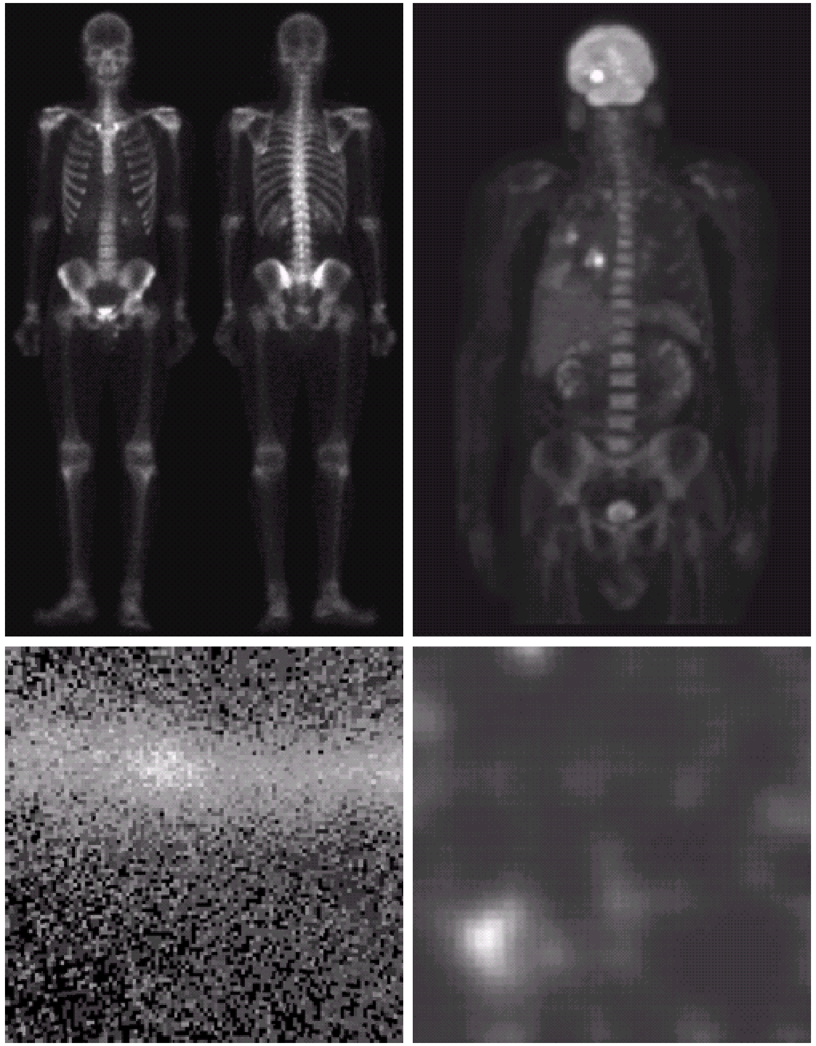
FIGURE 1.24
Components of a general-purpose image processing system.



Example of Gamma-Ray Imaging

a b
c d

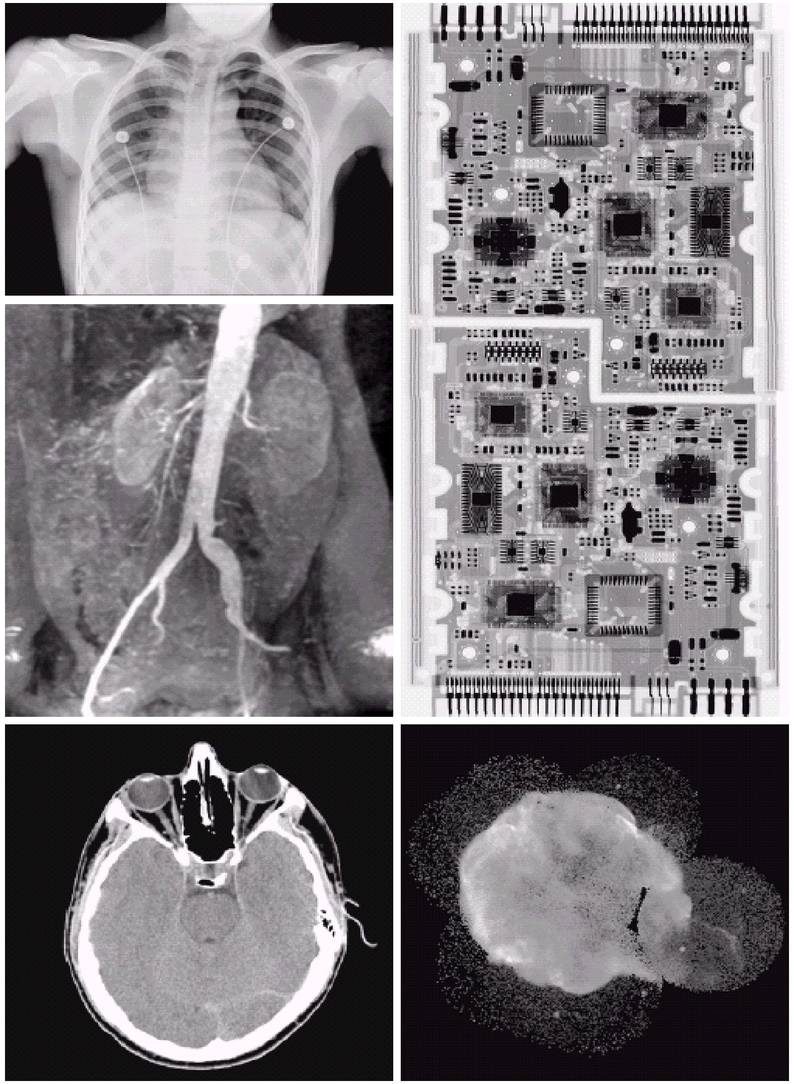
FIGURE 1.6 Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of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



- Figure 1.6 (a) shows an image if a complete bone scan obtained by using gamma-ray imaging.
- Figure 1.6 (b) shows a tumor in the brain and one in the lung.
- Figure 1.6 (c) shows the Cygnus Loop imaged in the gamma-ray band.
- Figure 1.6 (d) shows an image of gamma radiation from a valve in a nuclear reactor.

X-Ray Images

- Figure 1.7 (a) : Chest X-ray.
- Figure 1.7 (b) : Aortic angiogram.
- Figure 1.7 (c) : Head.
- Figure 1.7 (d) : Circuit boards.
- Figure 1.7 (e) : Cygnus Loop imaged in the X-ray band.



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.)

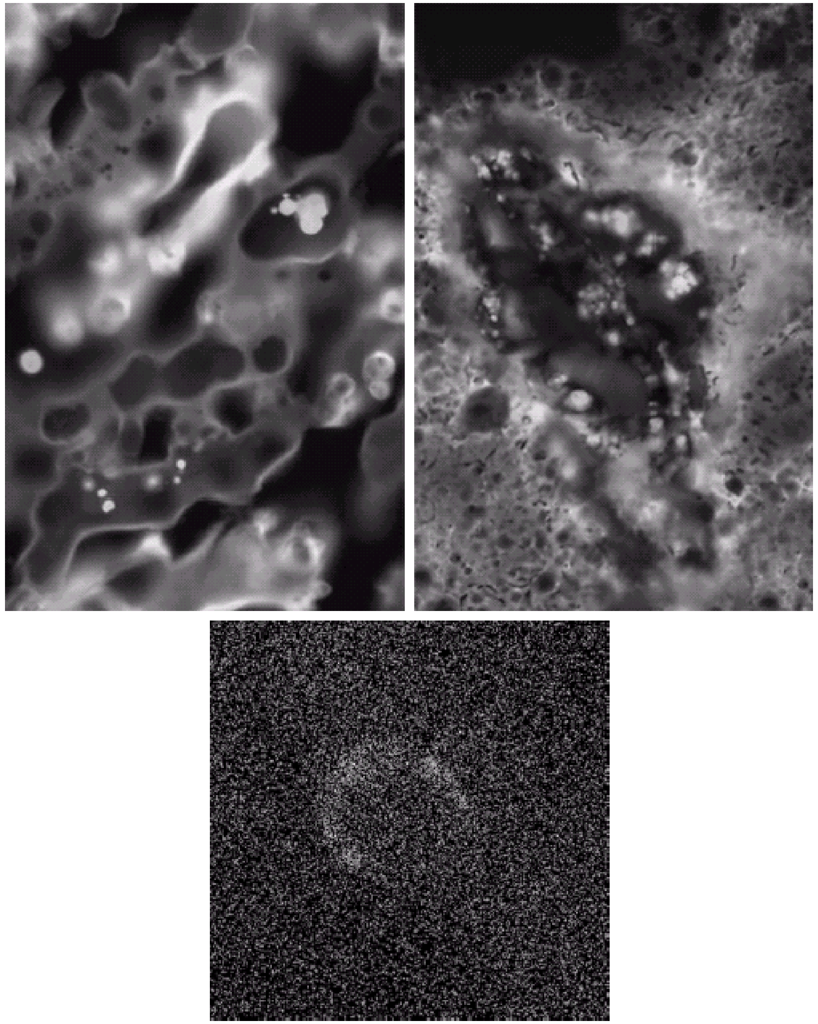
Ultra Violet imaging

- In the field of remote sensing , the area of the earth is scanned by a satellite or from a very high ground and then it is analyzed to obtain information about it. One particular application of digital image processing in the field of remote sensing is to detect infrastructure damages caused by an earthquake.
- As it takes longer time to grasp damage, even if serious damages are focused on. Since the area effected by the earthquake is sometimes so wide , that it not possible to examine it with human eye in order to estimate damages. Even if it is , then it is very hectic and time consuming procedure. So a solution to this is found in digital image processing. An image of the effected area is captured from the above ground and then it is analyzed to detect the various types of damage done by the earthquake.
- The key steps include in the analysis are
  - The extraction of edges
  - Analysis and enhancement of various types of edges

UV 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.)



- Figure 1.8 (a) : normal corn
- Figure 1.8 (b) : smut corn
- Figure 1.8 (c) : Cygnus Loop imaged in the ultraviolet band.

Imaging in the Visible and Infrared Bands

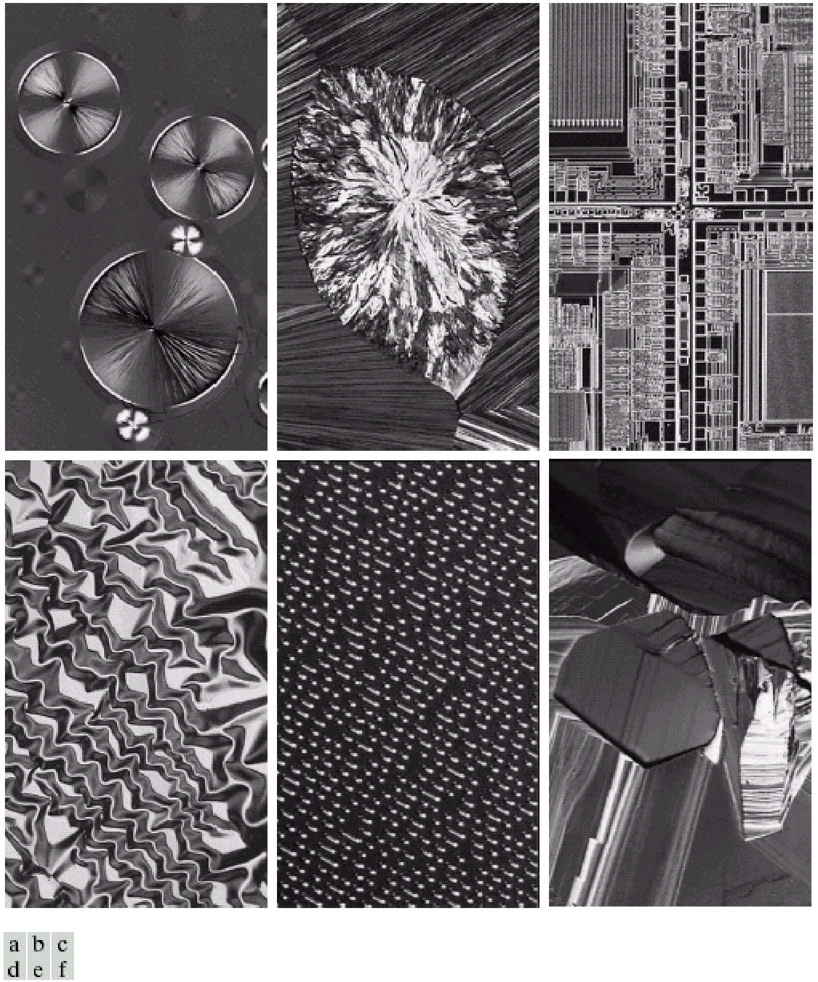


FIGURE 1.9 Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250×. (b) Cholesterol—40×. (c) Microprocessor—60×. (d) Nickel oxide thin film—600×. (e) Surface of audio CD—1750×. (f) Organic superconductor—450×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)

- Figure 1.9 (a) : Taxol
- Figure 1.9 (b) : Cholesterol
- Figure 1.9 (c) : Microprocessor
- Figure 1.9 (d) : Nickel oxide thin film
- Figure 1.9 (e) : Surface of audio CD
- Figure 1.9 (f) : Organic superconductor

Imaging in the Visible and Infrared Bands

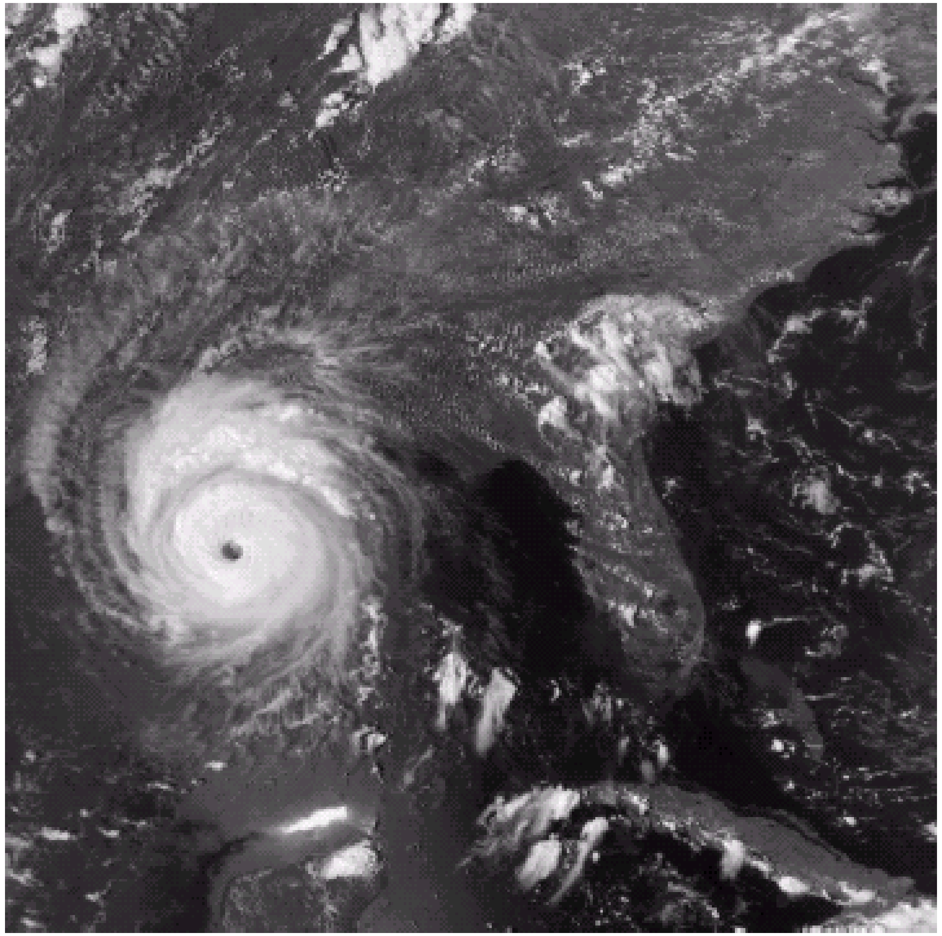
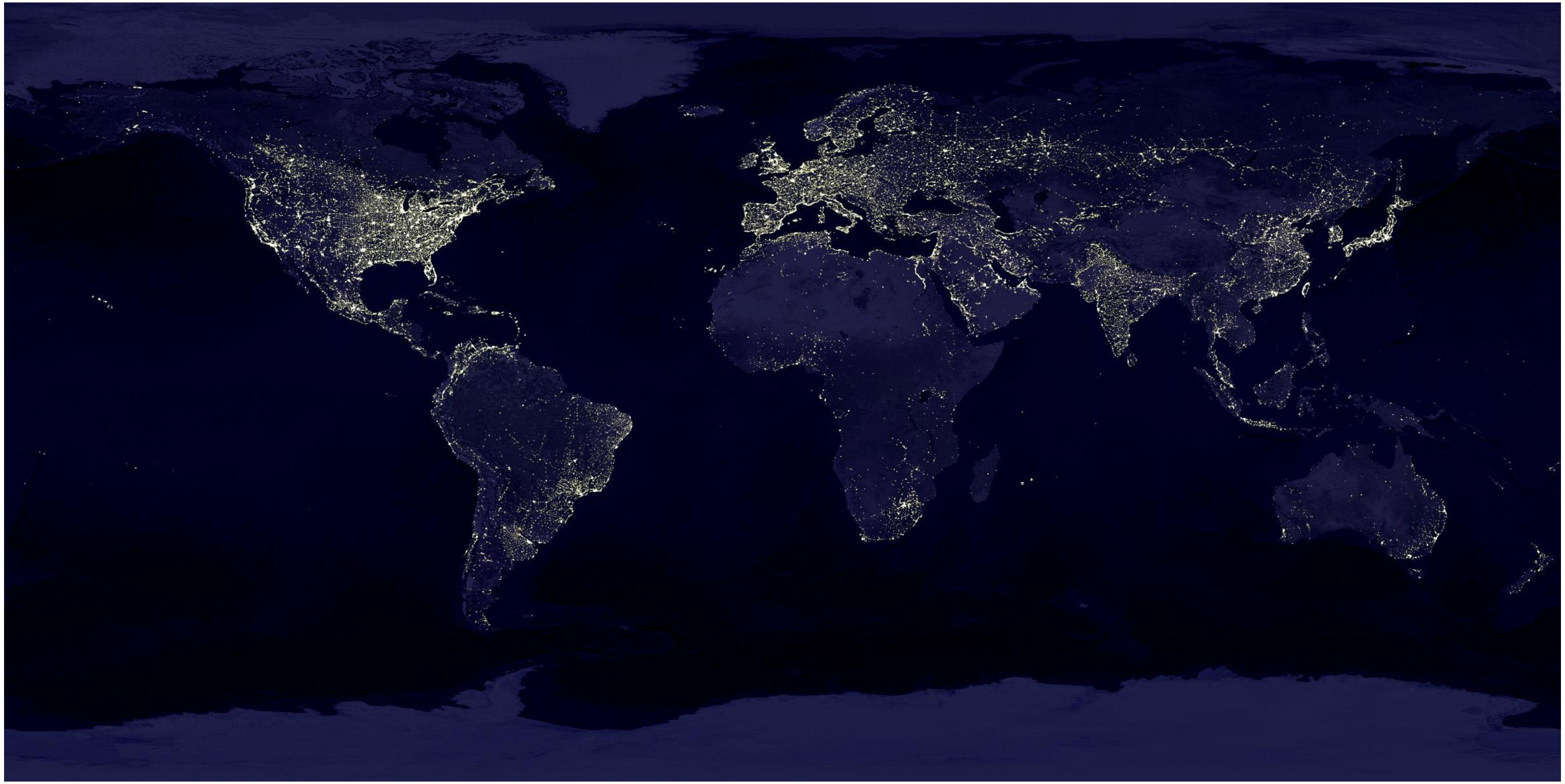


FIGURE 1.11 Multispectral image of Hurricane Andrew taken by NOAA GEOS (Geostationary Environmental Operational Satellite) sensors. (Courtesy of NOAA.)

Infrared Bands Image



a b
c d
e f

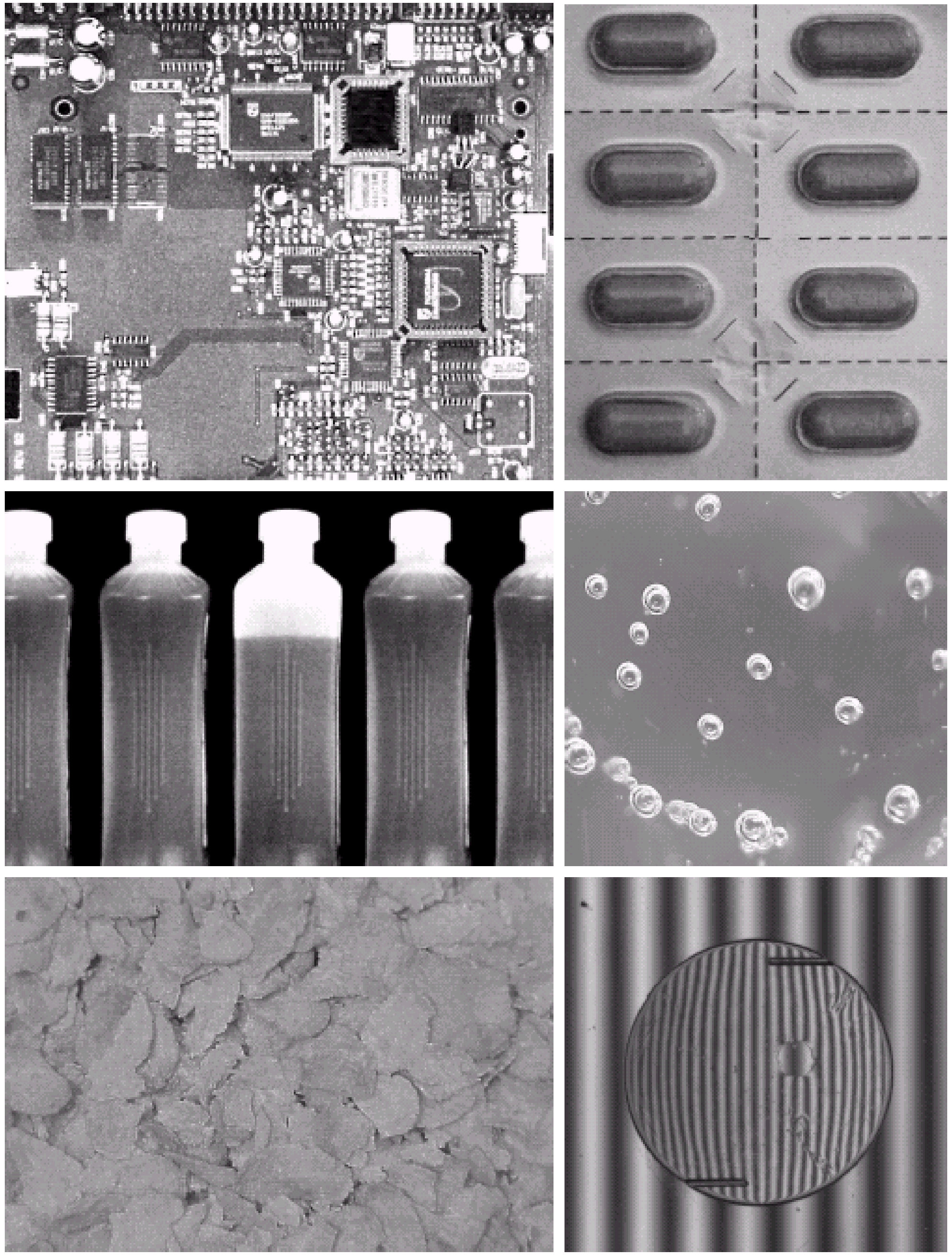
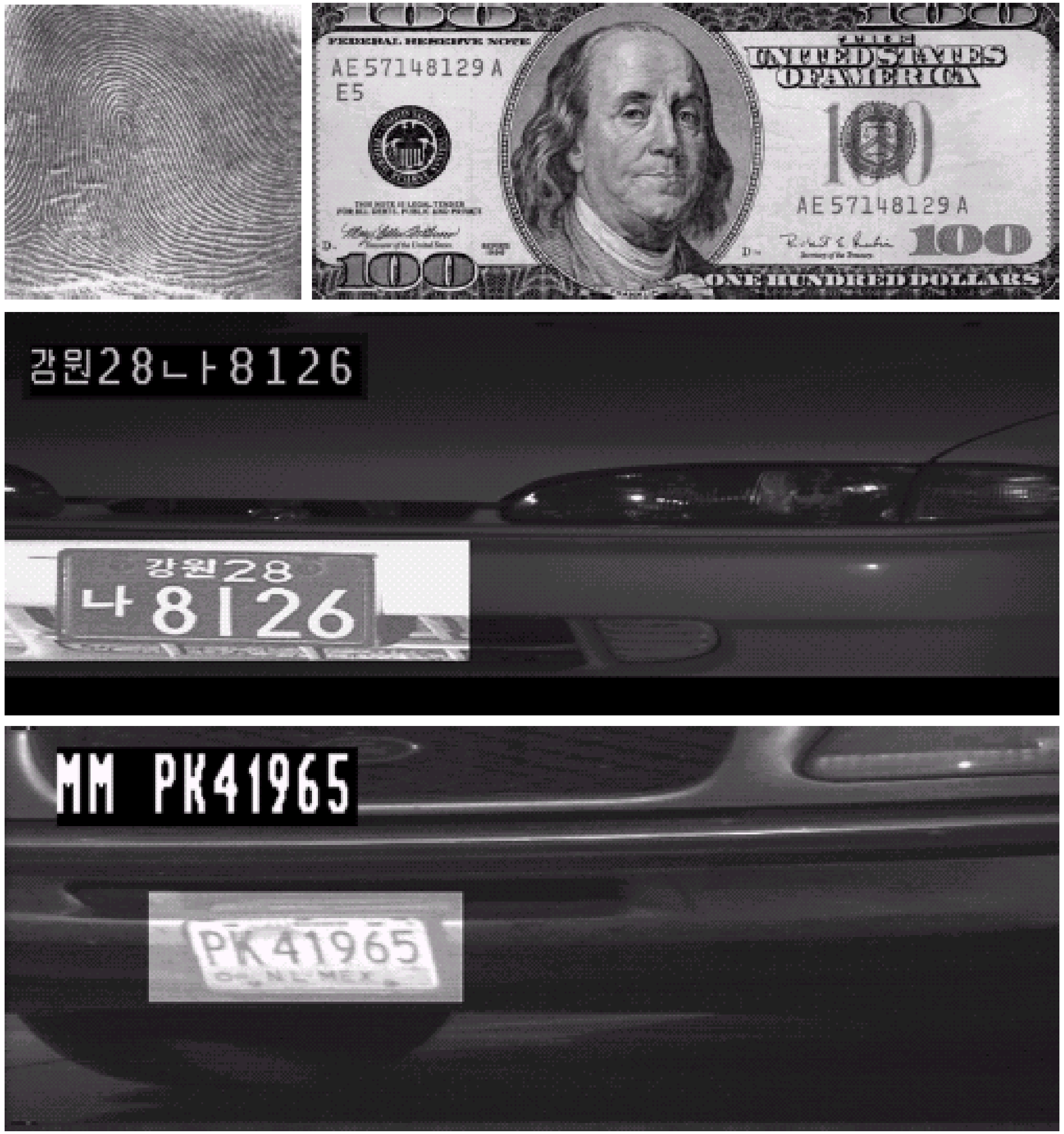


FIGURE 1.14 Some examples of manufactured goods often checked using digital image processing. (a) A circuit board controller. (b) Packaged pills. (c) Bottles. (d) Bubbles in clear-plastic product. (e) Cereal. (f) Image of intraocular implant. (Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)



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.)

Imaging in the Microwave Band

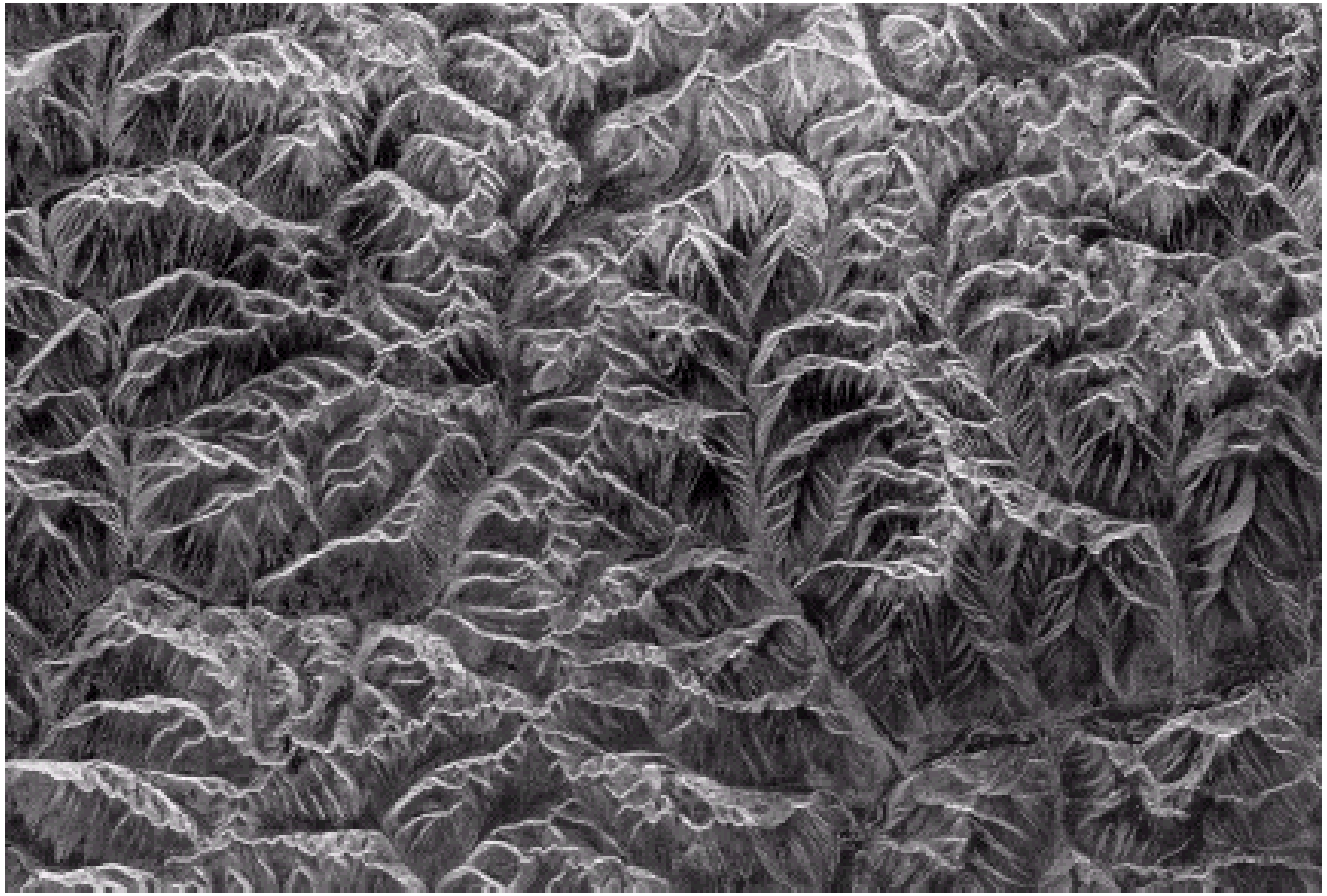
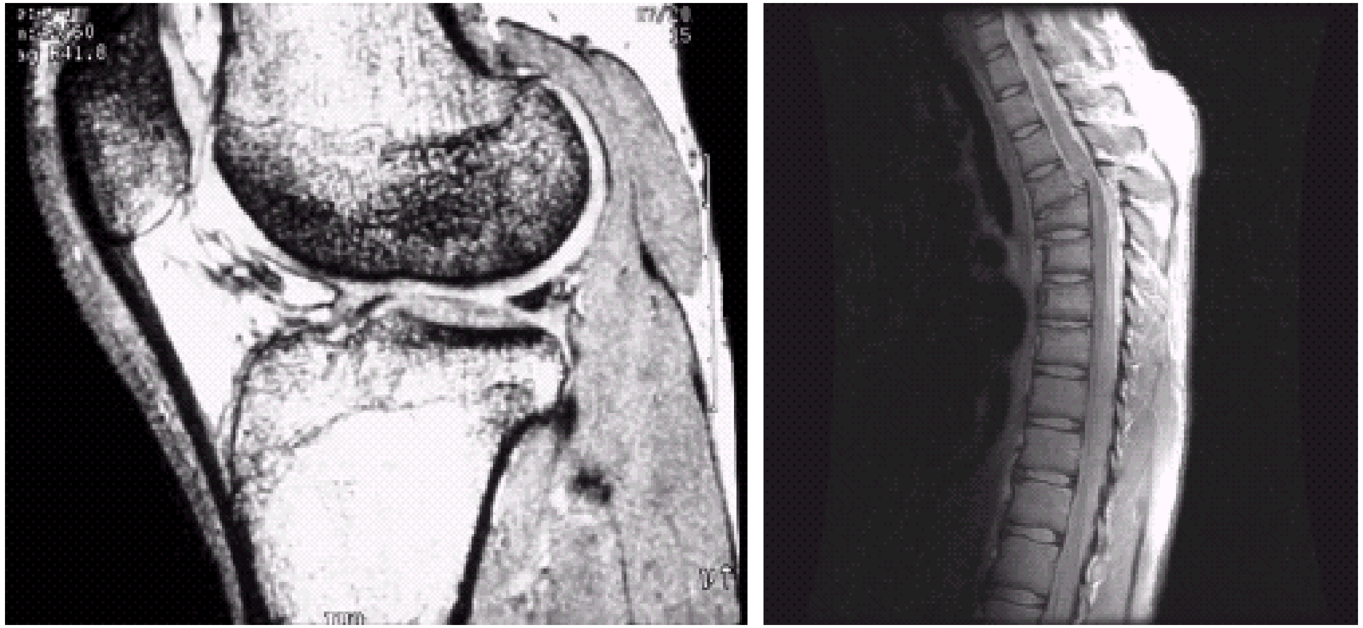


FIGURE 1.16 Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)

Imaging in the Radio Band
MRI: magnetic resonance 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.)

Machine/Robot vision

- Apart form the many challenges that a robot face today , one of the biggest challenge still is to increase the vision of the robot. Make robot able to see things , identify them , identify the hurdles e.t.c. Much work has been contributed by this field and a complete other field of computer vision has been introduced to work on it.
  - **Hurdle detection** is one of the common task that has been done through image processing, by identifying different type of objects in the image and then calculating the distance between robot and hurdles.
  - **Line follower robot**
    - Most of the robots today work by following the line and thus are called line follower robots. This help a robot to move on its path and perform some tasks. This has also been achieved through image processing.

Hurdle detection

Line follower robot

Color processing

- Color processing includes processing of colored images and different color spaces that are used. For example RGB color model , YCbCr, HSV. It also involves studying transmission , storage , and encoding of these color images.

Pattern recognition

- Pattern recognition involves study from image processing and from various other fields that includes machine learning (a branch of artificial intelligence). In pattern recognition , image processing is used for identifying the objects in an images and then machine learning is used to train the system for the change in pattern. Pattern recognition is used in computer aided diagnosis , recognition of handwriting , recognition of images e.t.c

Video processing

- A video is nothing but just the very fast movement of pictures. The quality of the video depends on the number of frames/pictures per minute and the quality of each frame being used. Video processing involves noise reduction , detail enhancement , motion detection , frame rate conversion , aspect ratio conversion , color space conversion e.t.c.

References

- Chapter 1, Digital Image Processing, 4e
- Internet

Thank You