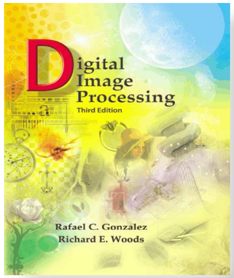


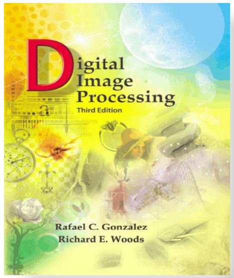
Digital Image Processing

Text Book:

Digital Image Processing, 3rd Ed.

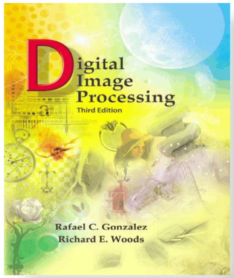
By R. C. Gonzalez, R. E. Woods

"One picture is worth more than ten thousand words"



Grading

- 4 Assignments: 10 Marks
- 4 Quizzes: 15 Marks
- Mid Term Exam: 25 Marks
- Terminal Exam: 50 Marks

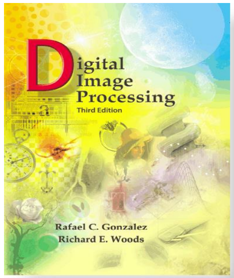


Course Contents

- Introduction (Ch 1)
- Digital Image Fundamentals (Ch 2)
- Image Enhancement in the Spatial Domain (Ch 3)
- Image Enhancement in the Frequency Domain (Ch 4)
- Image Restoration (Ch 5)
- Color Image Processing (Ch 6)
- Image Segmentation (Ch 10)
- Representation and Description (Ch 11)

>> Few Topics

- Morphological Image Processing (Ch 9)

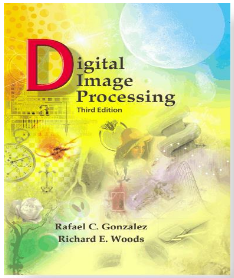


Various Types of signals

One Dimensional

Two Dimensional and

Three/Multi Dimensional Signals

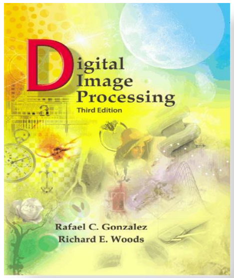


1D Signal Examples

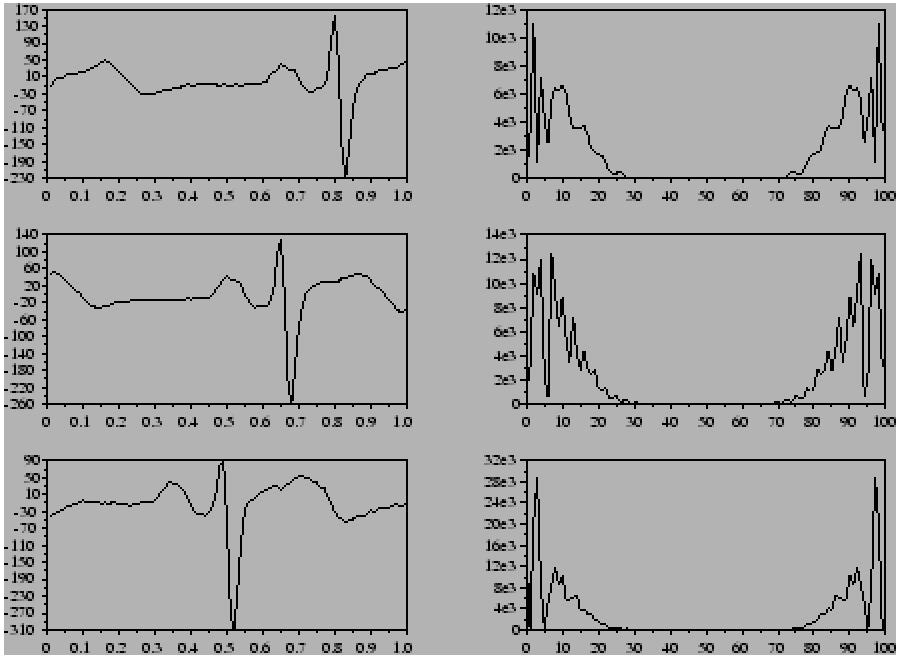
1. Voice signals
2. EEG and ECG signals

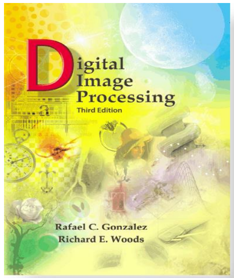
- Electro Encephalo Graphy (EEG) is the measurement of electrical activity produced by the brain as recorded from electrodes placed on the scalp.

- An Electro Cardiogram (ECG or EKG) is a recording of the electrical activity of the heart over time produced by an electrocardiograph via skin electrodes.



Power spectrum of EEG signals





2D Signals

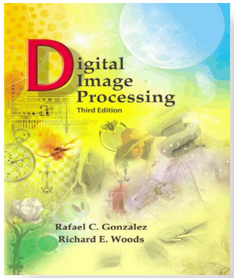

Phil Noble / AP


Mike Hewitt / Allsport


Patrick Gardin / AP


Andy Barron / Reno Gazette-Journal


Sydney Morning Herald



Multidimensional Signals (3D, 4D, …)

Video is 3D signal: f(x,y,t)

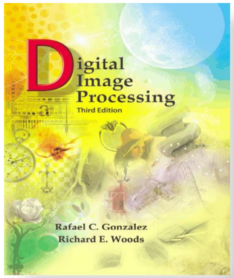
Two spatial axes, one Time axis

3D Film: depth information is incorporated

- Binocular vision of brain is active: two slightly different images are presented/entered into each eye. The brain correlates the images, and estimates the depth.

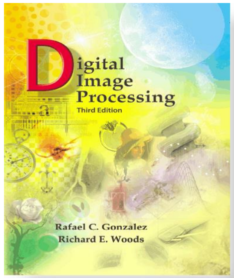
4D Film: physical effects are incorporated like rain, wind, lights, vibration etc

- Requires special infrastructure to produce such effects.



What is an image ?

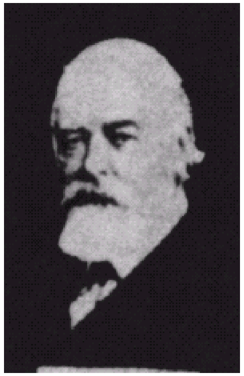
- An image may be defined as a two-dimensional function, *f(x,y)*, where *x* and *y* are spatial (plane) coordinates, and the amplitude of *f* at any pair of coordinates *(x,y)* is called the intensity or gray level of the image at that point.
- When *x, y* and the amplitude values of *f* are all finite, discrete quantities, we call the image as a ***digital image***.
- The field of *digital image processing* refers to processing digital images by means of a digital computer.
- A digital image is composed of a finite number of elements, each of which has particular location and value. These elements are referred to as picture elements, image elements or pixels.

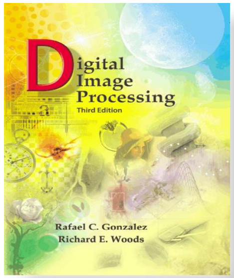


History of DIP

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.)





History of DIP

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

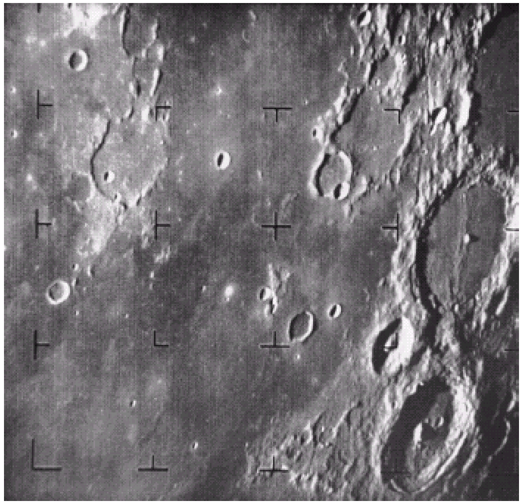
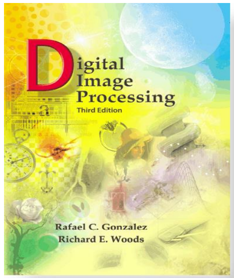
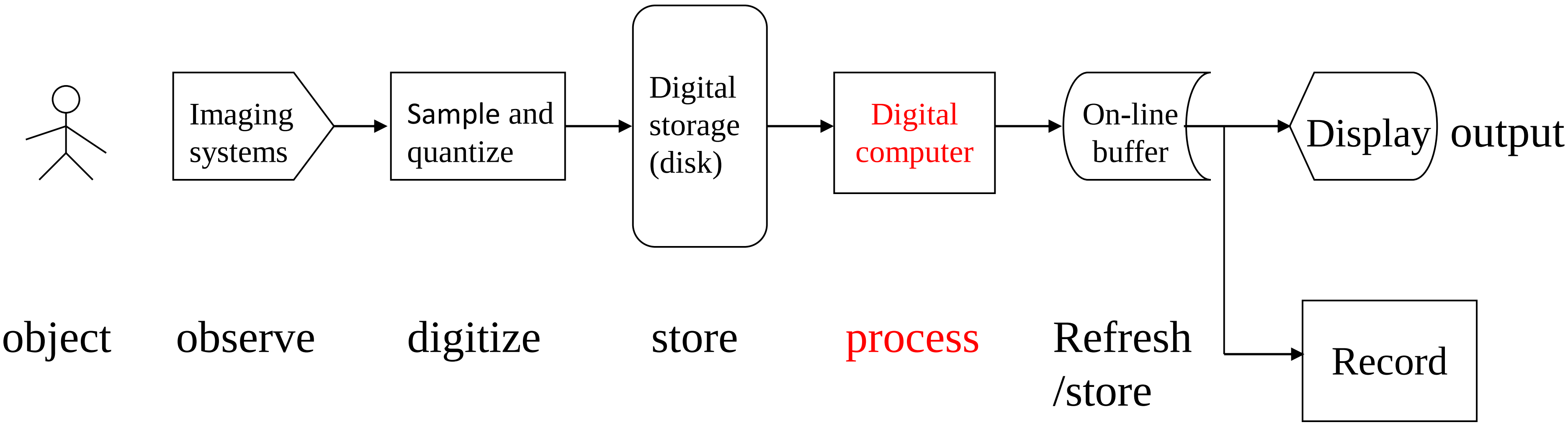
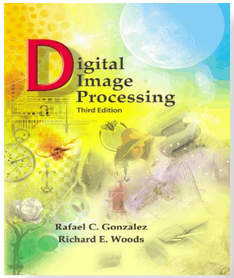


FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9:09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)



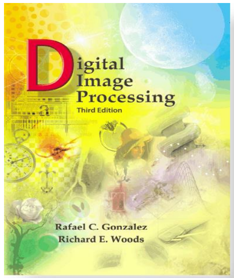
From Analog to Digital





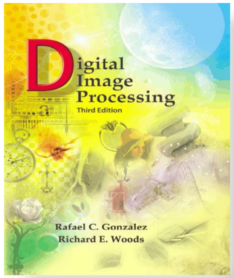
Applications of DIP

- Human being can see only visual band of EM spectrum
- Images can be generated from the entire EM spectrum, ranging from Gamma to Radio waves.
  – Source dependent images:
    - Gamma ray imaging, x-rays, ultrasound, visible (vision) and the infrared bands, microwave, radio band
    - Synthesis images generated by computer
- Thus digital image processing encompasses a wide and varied field of applications.



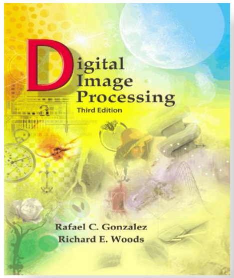
Applications

- **Medical**
  - Enhance the contrast or code the intensity levels into colour for easier representation of X-Rays and other Bio-Medical Images
- **In Geography**
  - Study pollution patterns from aerial and satellite imagery.
- **In Archaeology**
  - Used to process degraded images of unrecoverable objects or experimental results too expensive to duplicate
  - Restoration of blurred pictures that were the only available records of rare artefacts lost or damaged after being photographed.



Applications ...

- **In Physics**
  – Enhance images of experiments in areas such as high-energy plasmas and electron microscopy.
- **Other Application Areas**
  – Law Enforcement
  – Defence
  – Industrial Applications (E.g. Vision based automation)
  – Surveillance
  – Biology



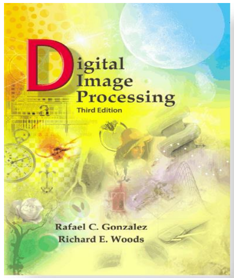
Applications …

Applications of Image processing depends on the type of operation required for a particular image. These operations can be

- Image Enhancement
- Image Restoration
- Image Compression
- Image transforms/Filtering

Problems in machine perception that utilizes image processing techniques

Automatic Character Recognition
Industrial Machine Vision for product assembly and inspection
Military recognizance
Automatic processing of fingerprints
Screening of X-Rays and blood samples
Machine processing of aerial and satellite images for weather prediction and crop assessment.



Electromagnetic Spectrum

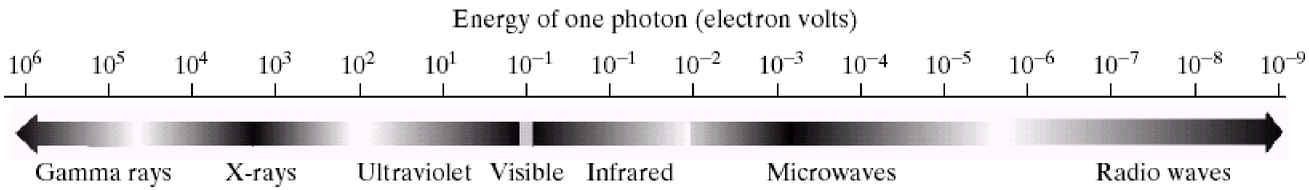
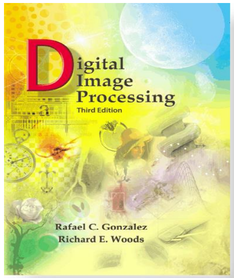


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

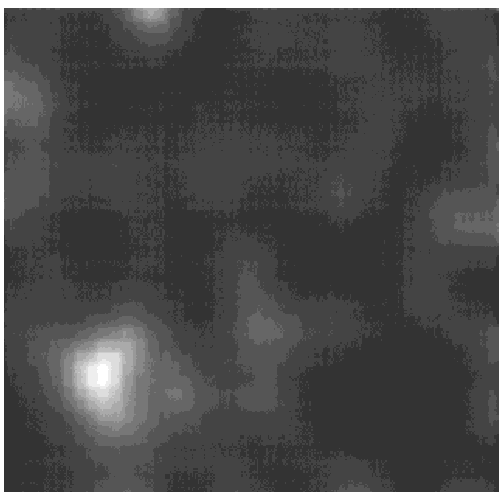
EM spectrum ranges from Gamma rays to Radio Waves

The bands are not distinct but rather transition smoothly from one to the other

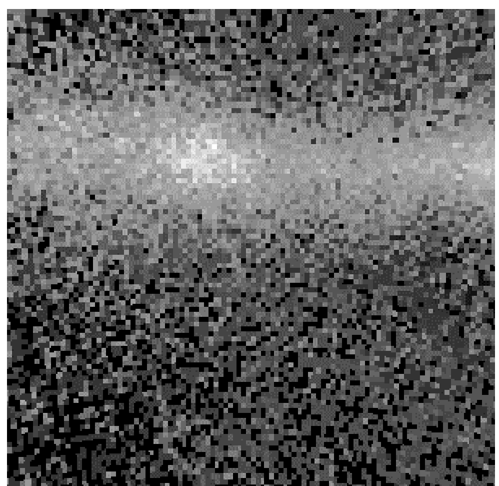


Gamma-ray Imaging

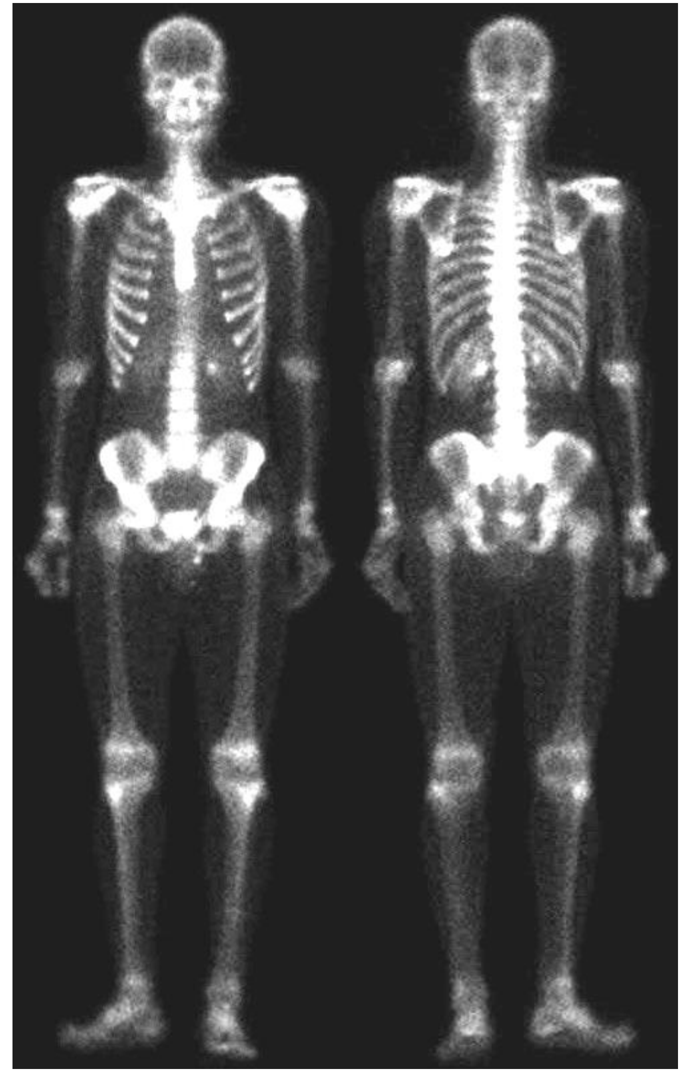
- Imaging based on gamma rays.
- Nuclear medicine: inject the patient with a radioactive isotope that emits gamma rays. Images are produced from the emissions collected by gamma ray detectors.
- Constellation Sygnus: star exploded, superheated gas cloud



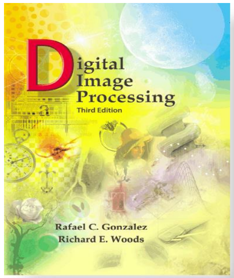
Radiations from Nuclear Reactor Valve



Cygnus Loop

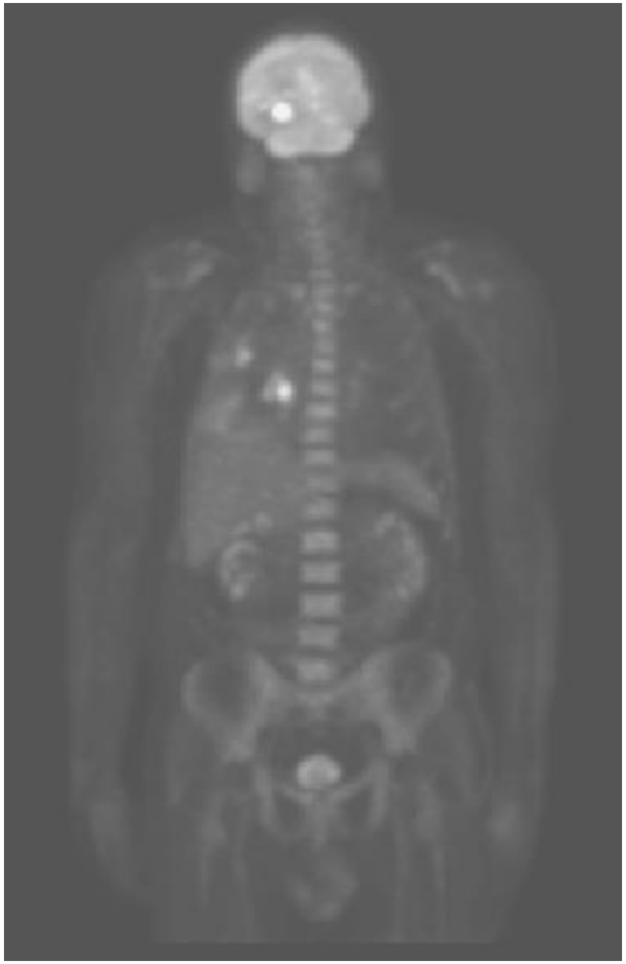


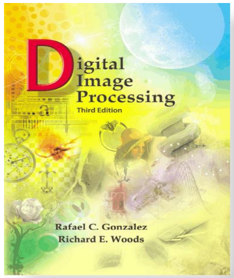
Bone Scan



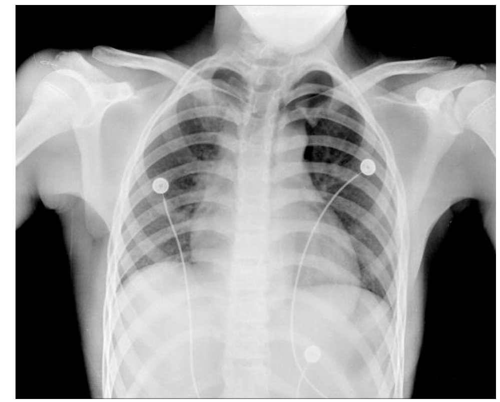
PET (Gamma ray Imaging)

- Positron Emission Tomography (PET): the patient is given a radioactive isotope that emits positron.
- Positron meets electron and two gamma rays are emitted which are detected by gamma ray detector.





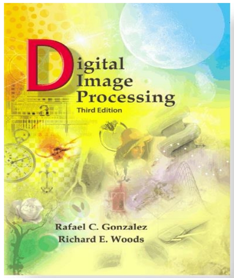
X-ray Imaging



- X-rays are used extensively in medical imaging and in industry.

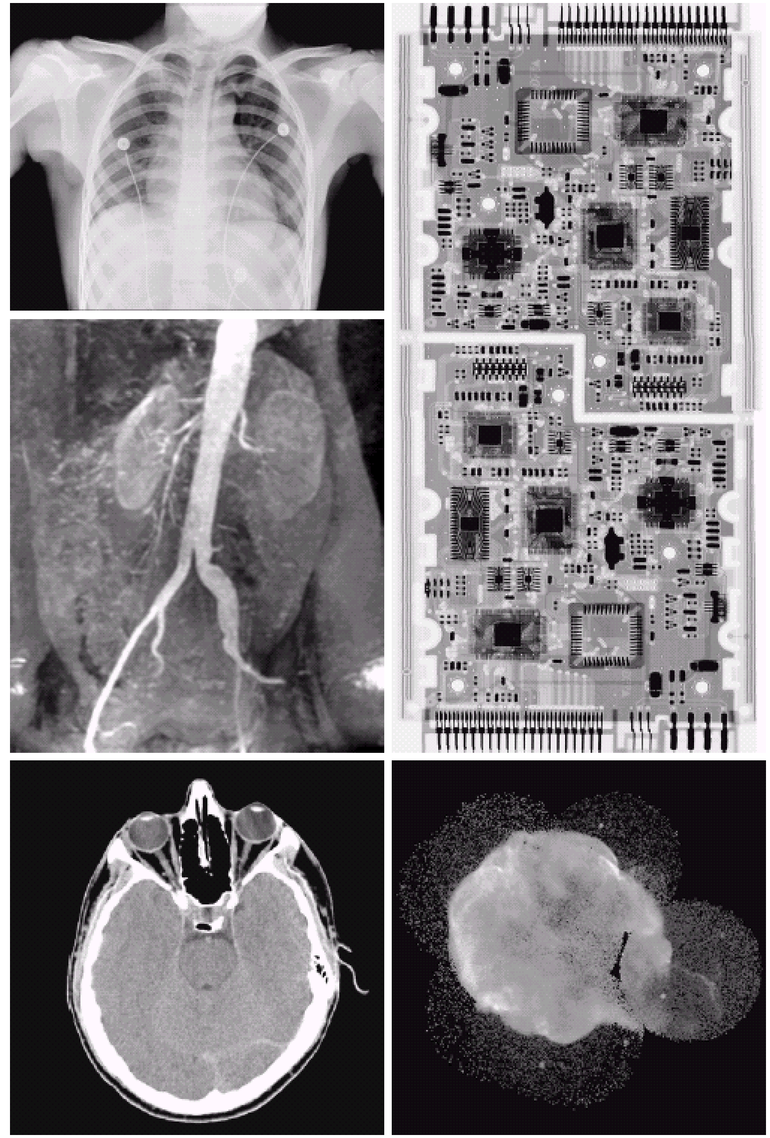
  X-ray tube: a cathode which is heated and releases electrons. Electrons fly at high speed to the positively charged anode.

  When the electrons strike a nucleus, energy is released in the form of X-ray radiation. The intensity of the X-ray is modified by absorption as it passes through the patient.
- **Angiography**: To obtain the images of blood vessels(Angiograms), used in the area of Contrast-Enhancement Radiography.
- Catheter (a small, flexible, hollow tube) is inserted into artery/vein. When reached into area to be observed, a high contrast medium is inserted to enhance contrast to examine any irregularity/blockage.



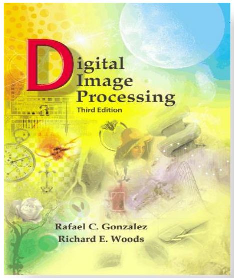
X-ray, Angiogram, CAT

(Computerized Axial Tomography)

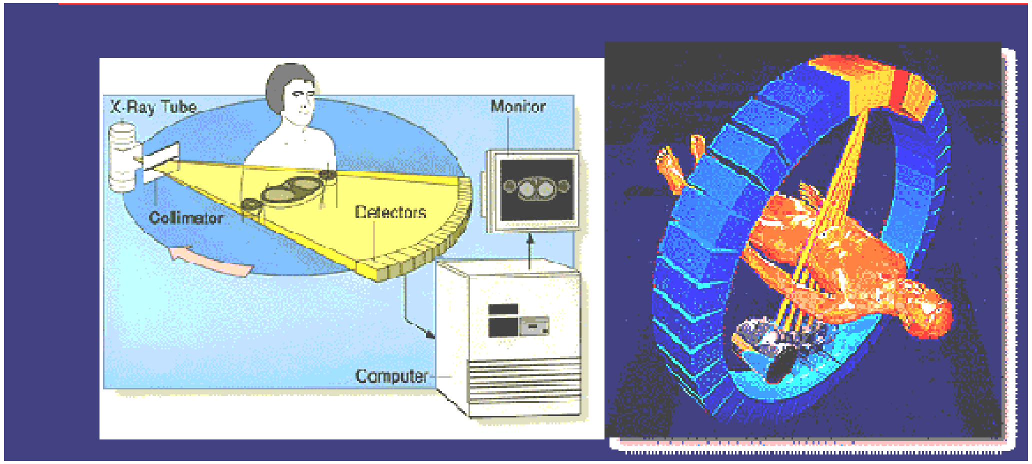


a	d
b	
c	e

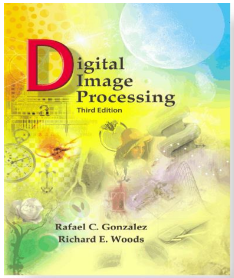
FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center, (b) Dr. Thomas R. Gest, Division of Anatomical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



Computerized Tomography

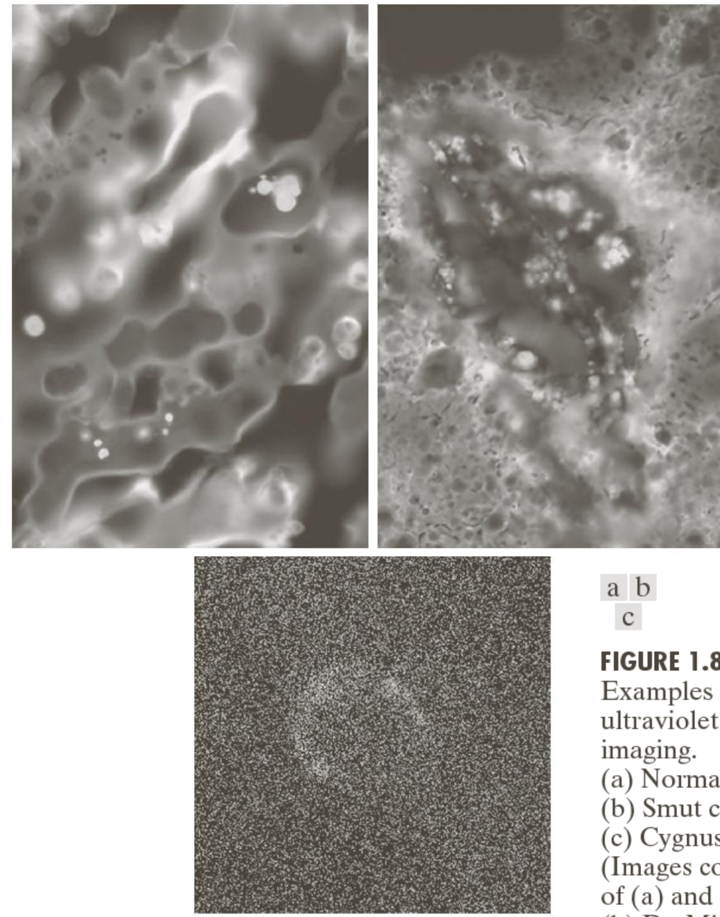


Computed tomography (CT) is a medical imaging method employing tomography, where digital processing is used to generate a three-dimensional image of the internals of an object from a large series of 2-dimensional X-ray images taken around a single axis of rotation.



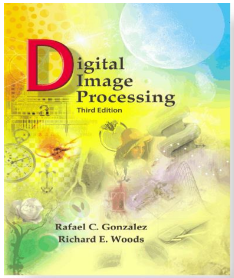
Imaging in the Ultraviolet (UV) Band

- Ultraviolet light is used in fluorescence microscopy.
- **Fluorescence**: a phenomena discovered in the middle of 19th century in which some material (called fluorescent) emits visible light when ultraviolet light is directed at it.
- Ultraviolet light is invisible, when directed on fluorescent material (photon on electron, energy level transition) visible light is emitted which is observed. High contrast in image w.r.t flors to non-flors region means efficient equipment.

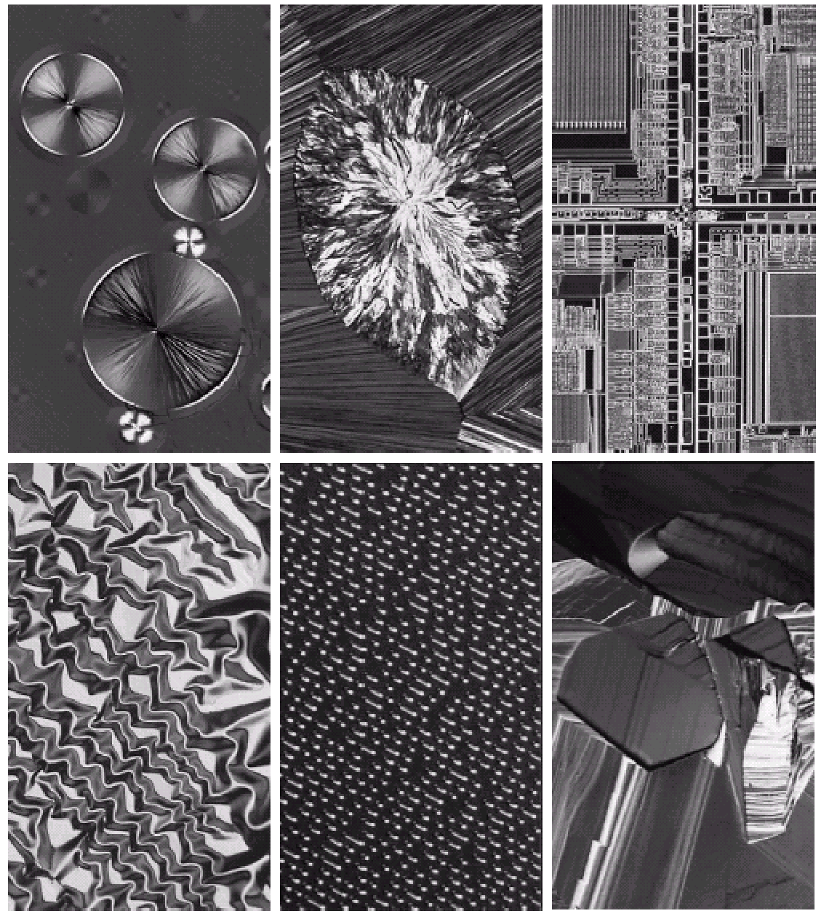


a b
c

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.)

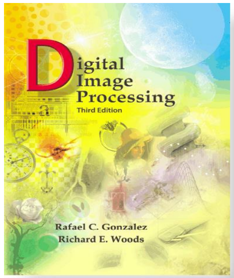


Imaging in the Visible/Infrared Band



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.)



Imaging in the Visible/Infrared Band

- Remote sensing: to obtain images of the earth from space for purposes of monitoring environmental conditions
- Usually a scene is imaged in several bands

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.

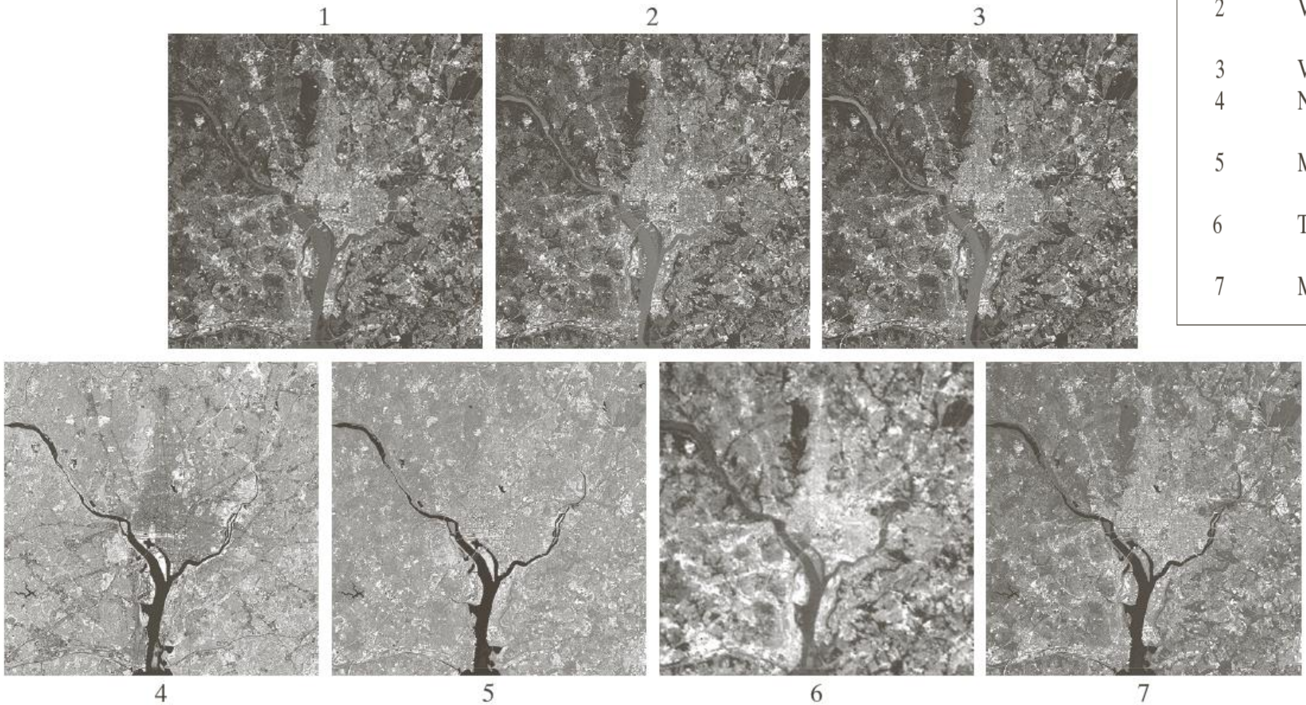
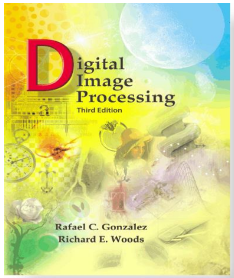


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)



Visible/Infrared Imaging

- Image taken by NOAA (National Oceanographic and Atmospheric Administration) Satellite using sensors in visible and infrared bands

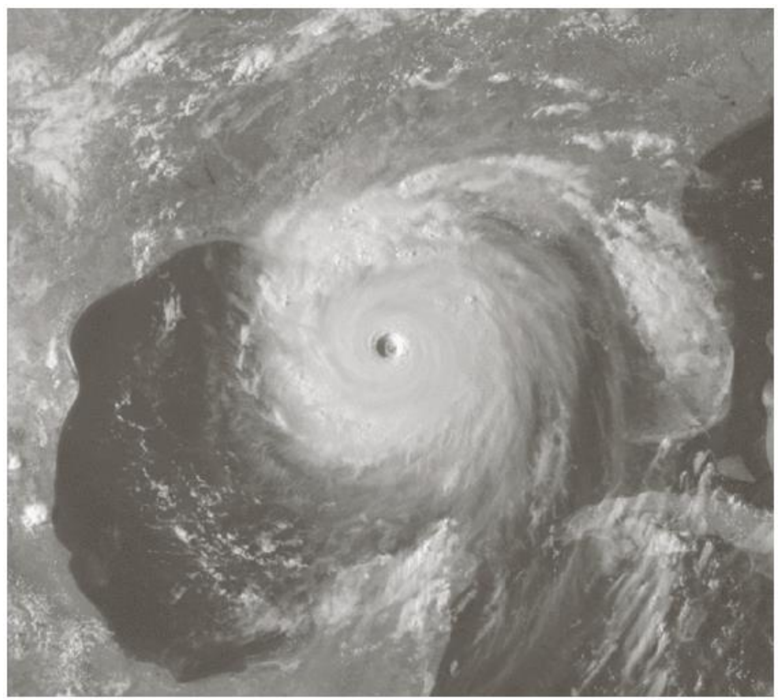
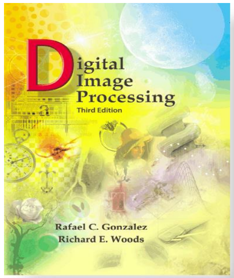


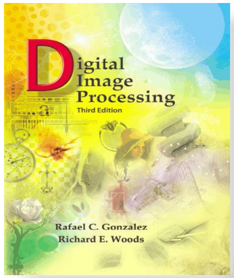
FIGURE 1.11 Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)



Infrared Imaging

- *Nighttime Lights of World* Data set
- Images captured by infrared imaging system mounted on NOAA DMSP (Defense Military Satellite Program) satellite, provides a global inventory of human settlements.
- 10.0-13.4 Micro meter: observe faint sources of visible near infrared emissions present on earth surface.

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



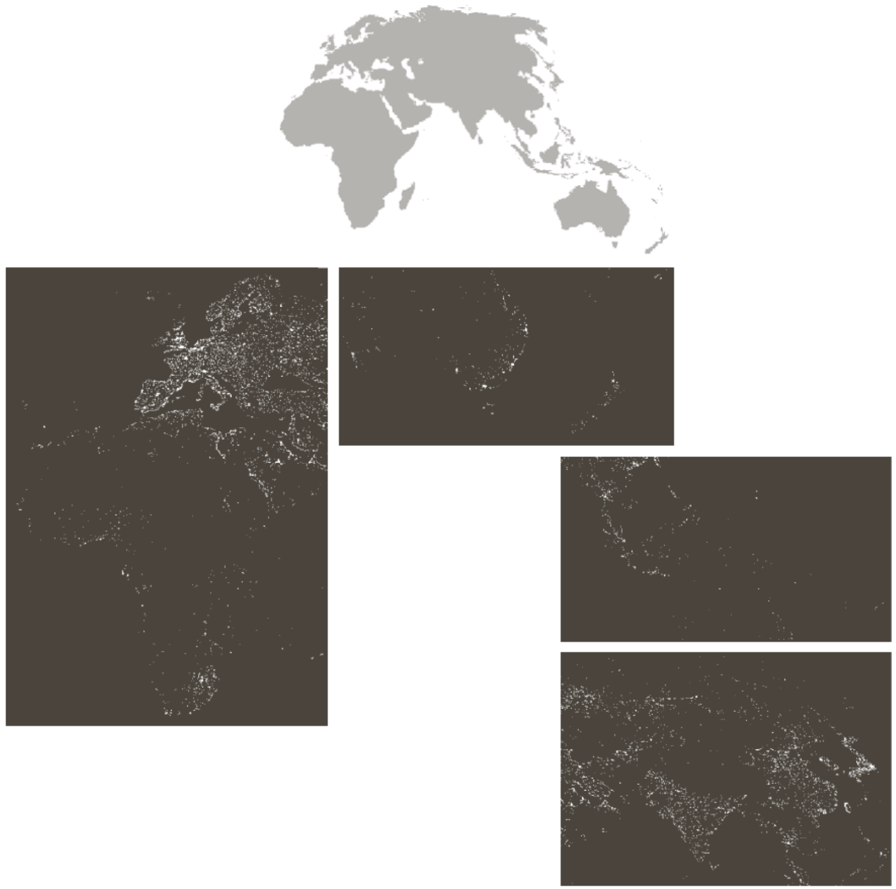
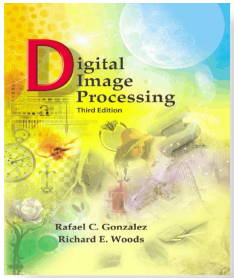
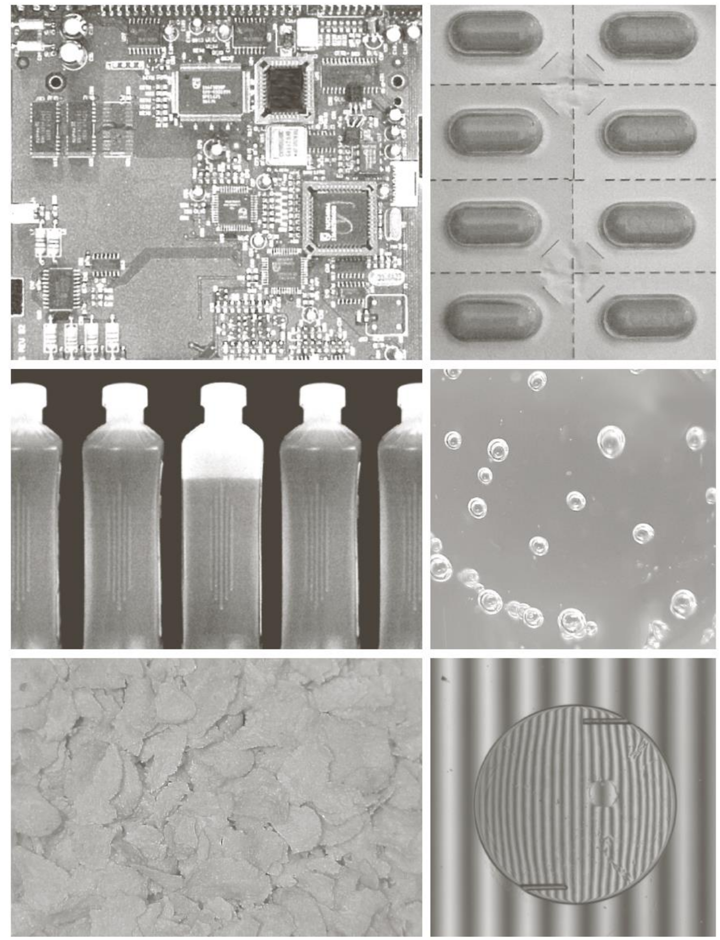


FIGURE 1.13 Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)



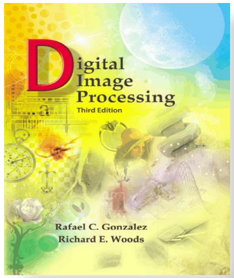
Imaging in the Visible Band (Industrial Applications)

- Automated visual inspection of manufactured goods



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.)

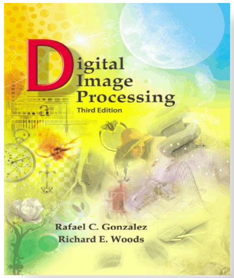


Imaging in the Visible Band

- Biometrics
- Automated license plate reading (OCR)
- Security

a b
c
d

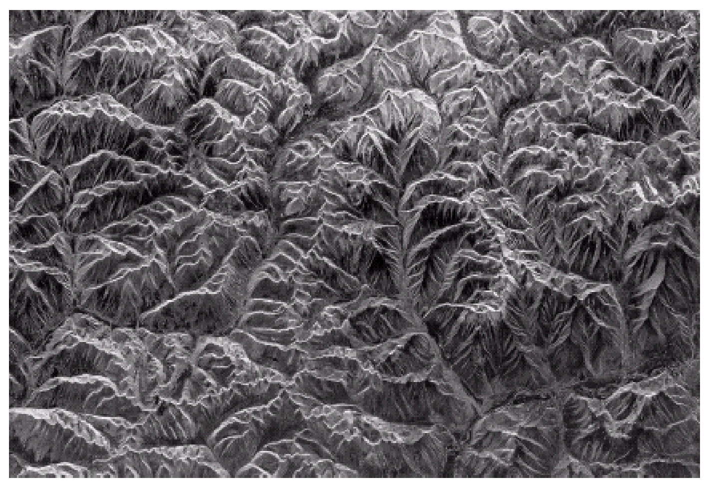
FIGURE 1.15 Some additional examples of imaging in the visual spectrum. (a) Thumb print. (b) Paper currency. (c) and (d) Automated license plate reading. (Figure (a) courtesy of the National Institute of Standards and Technology. Figures (c) and (d) courtesy of Dr. Juan Herrera, Perceptics Corporation.)

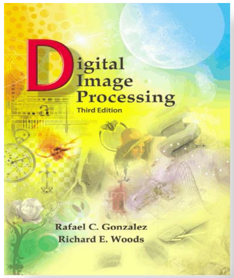


Imaging in the Microwave Band

- The dominant application of imaging in the microwave band is radar, where radar works like a flash camera (transmit microwave pulses and receive energy).
- Unique feature: able to collect data over virtually any region at any time regardless of weather or lighting condition.

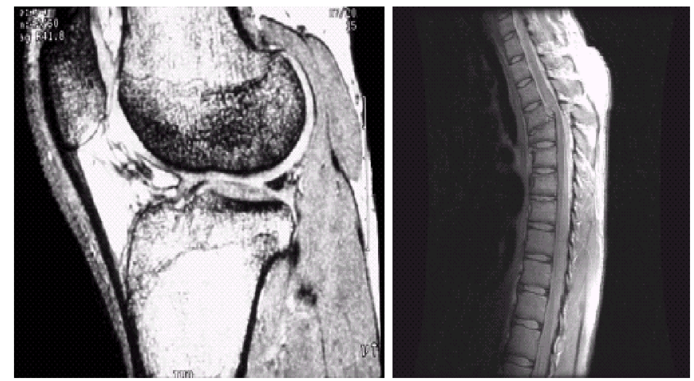
FIGURE 1.16 Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)





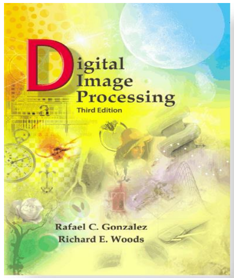
Imaging in the Radio Band: MRI

- Magnetic Resonance Imaging (MRI): The radio waves pass through a patient' body in short pulses, which is kept in a high magnetic field.
- Each pulse causes a responding pulse emitted by the patient's tissue.
- The signal origin and strength are determined by a computer, which produces a two dimensional image of a section of the patient.

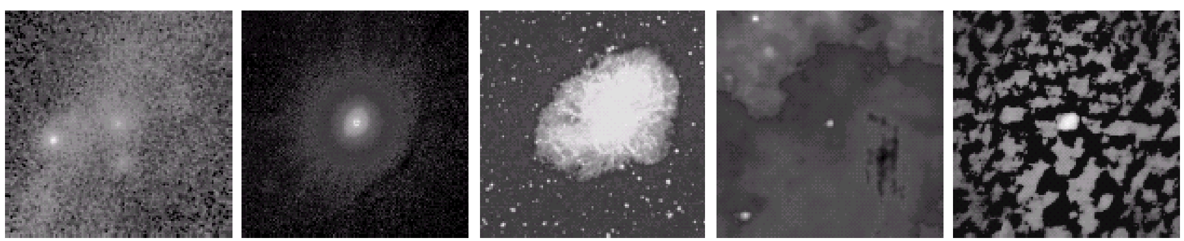


a b

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.)

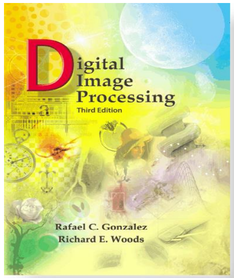


- Crab pulsar (a neutron star), emits energy in the entire EM spectrum.



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.)

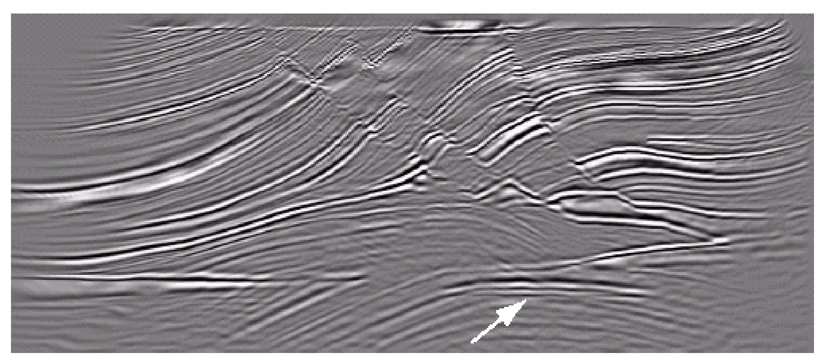


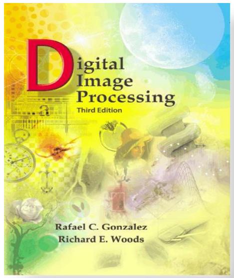
Acoustic (Ultrasound) Imaging

- Ultrasound imaging used mainly in obstetrics.
- Basic procedure in ultrasound imaging:

1. Ultrasound system transmits high-frequency (1 to 5 MHz) sound pulses into the body.
2. The sound waves travel into the body and hit a boundary between tissues (e.g., soft tissue and bone). Some of the sound waves are reflected back to the probe, while some travel on further until they reach another boundary.

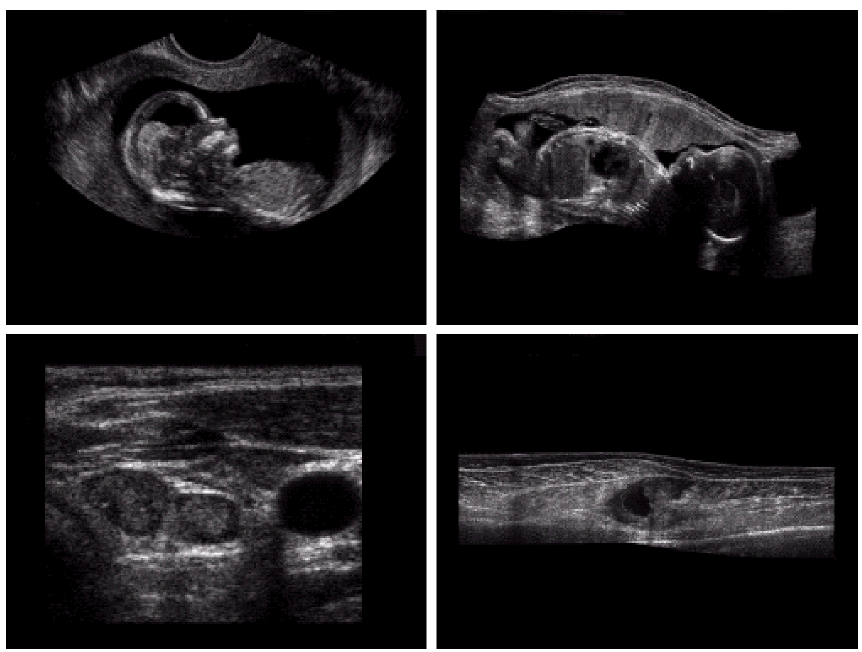
FIGURE 1.19 Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)





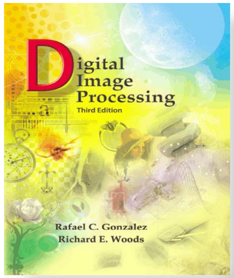
Acoustic (Ultrasound) Imaging

3. The reflected waves are picked by the probe and relayed to a computer.
4. The computer calculates the distance from the probe to the tissue using the speed of sound in tissue(1540 m/s).
5. The system displays the distance and intensities of the echoes on the screen, forming a two-dimensional image.

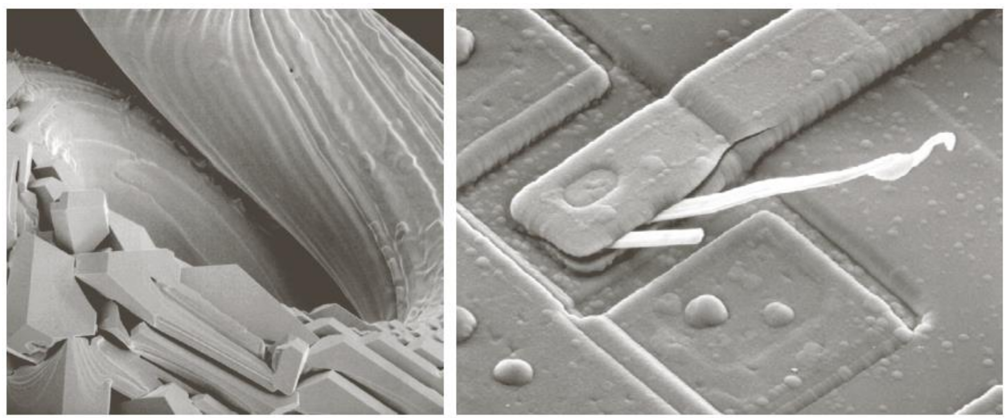


a b
c d

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.)

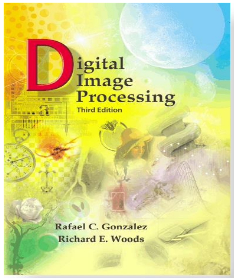


- TEM (Transmission Electron Microscope)
- SEM (Scanning Electron Microscope)
- Beam of electron pass though the slide, the beam transmitted through the slide is projected on phosphor screen. Electrons interact with phosphor screen and produce light.
- Light Microscope: magnification 1000x
- Electron Microscope: magnification up to 10,000x and more



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.)



Computer Generated Images

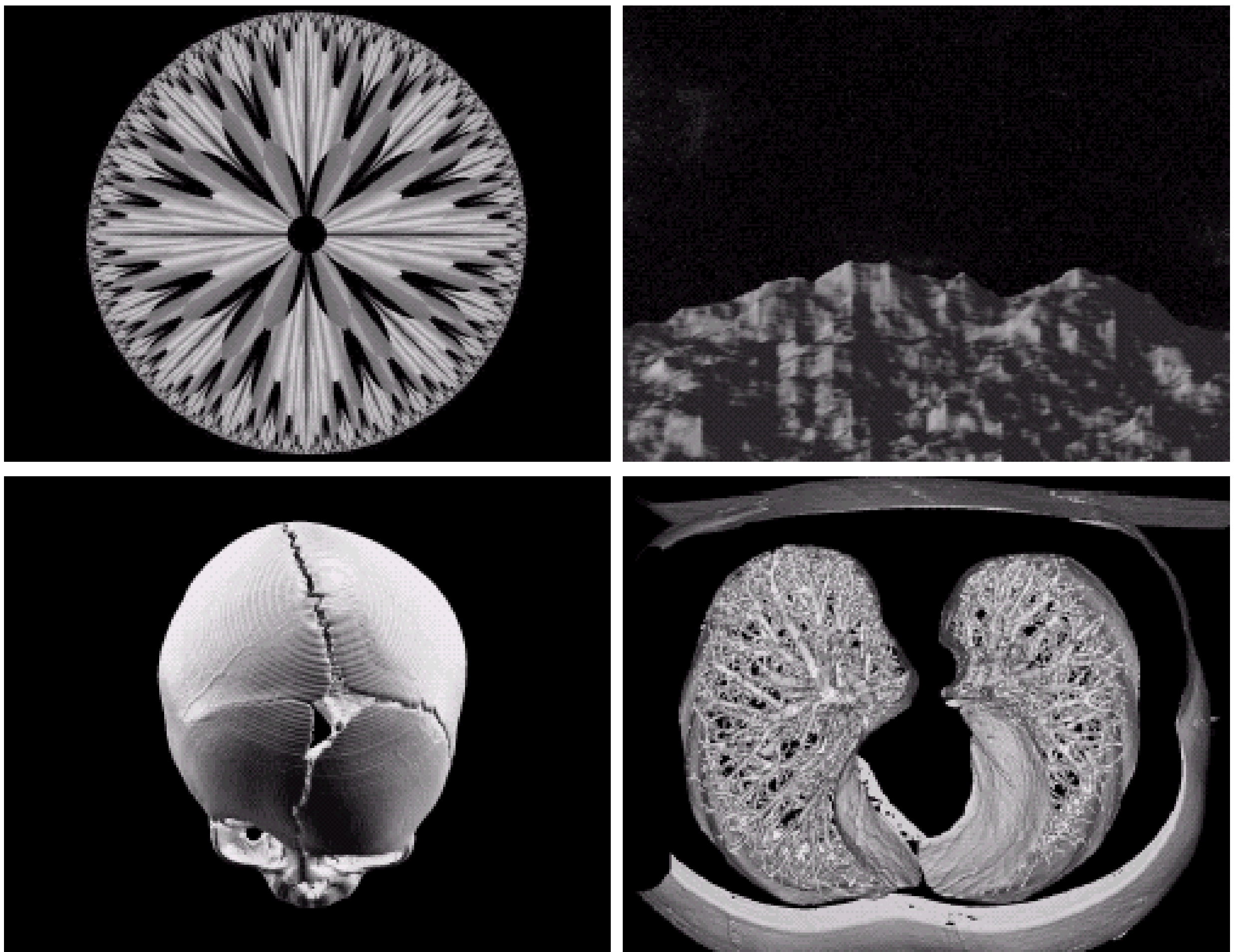


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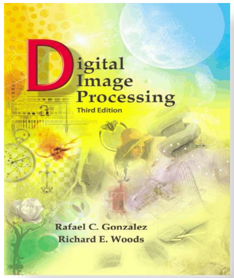
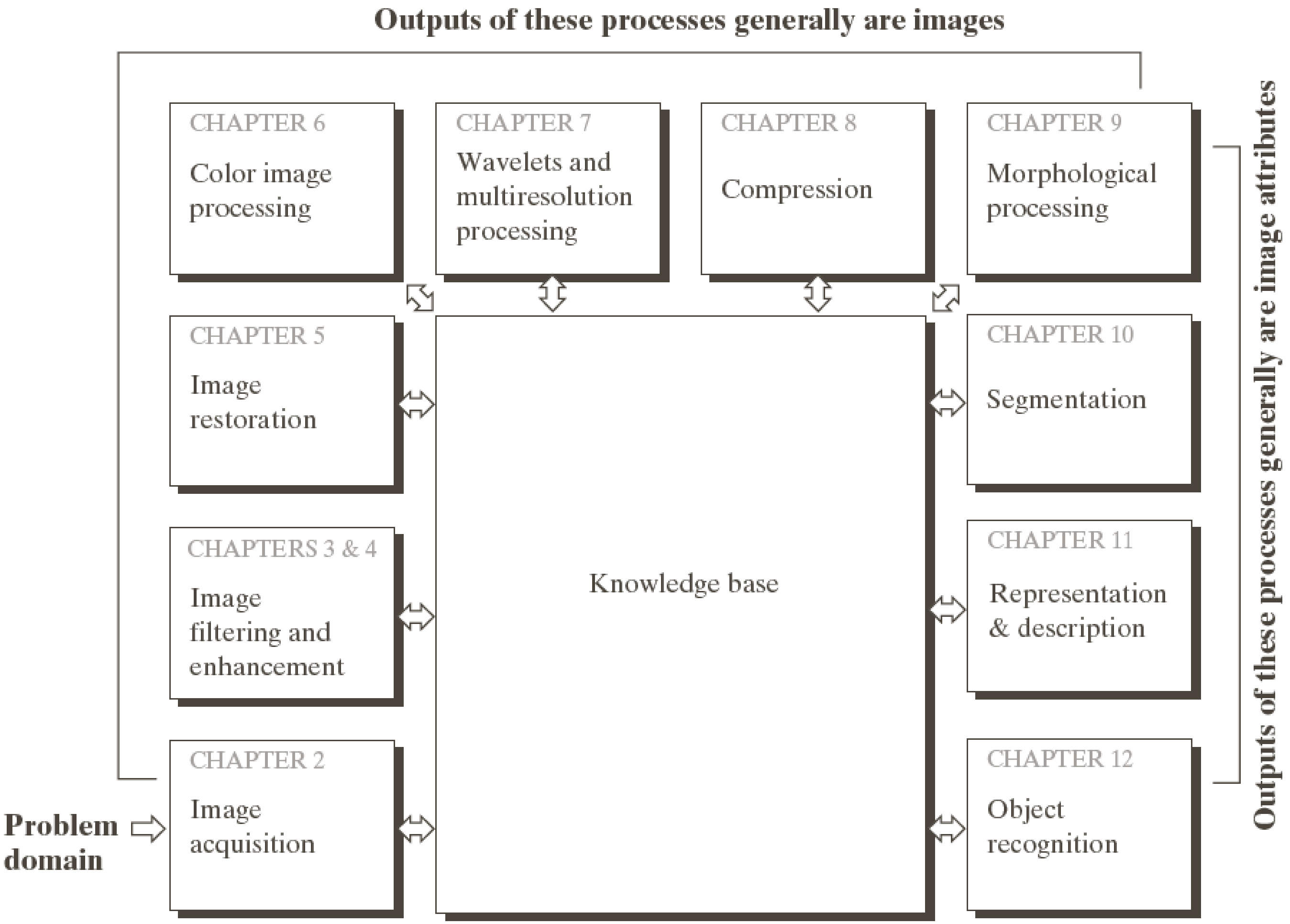
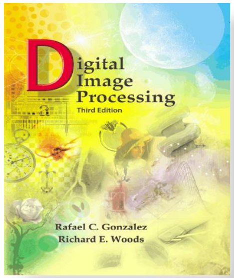
FIGURE 1.22
(a) and (b) Fractal images. (c) and (d) Images generated from 3-D computer models of the objects shown. (Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College, (c) and (d) courtesy of NASA.)


Digital
Image
Processing
Third Edition
Rafael C. Gonzalez
Richard E. Woods


Outputs of these processes generally are images
CHAPTER 6
Color image processing
CHAPTER 7
Wavelets and multiresolution processing
CHAPTER 8
Compression
CHAPTER 9
Morphological processing
CHAPTER 5
Image restoration
CHAPTER 10
Segmentation
CHAPTERS 3 & 4
Image filtering and enhancement
Knowledge base
CHAPTER 11
Representation & description
CHAPTER 2
Image acquisition
CHAPTER 12
Object recognition
Problem domain
Outputs of these processes generally are image attributes



Components of an Image Processing System

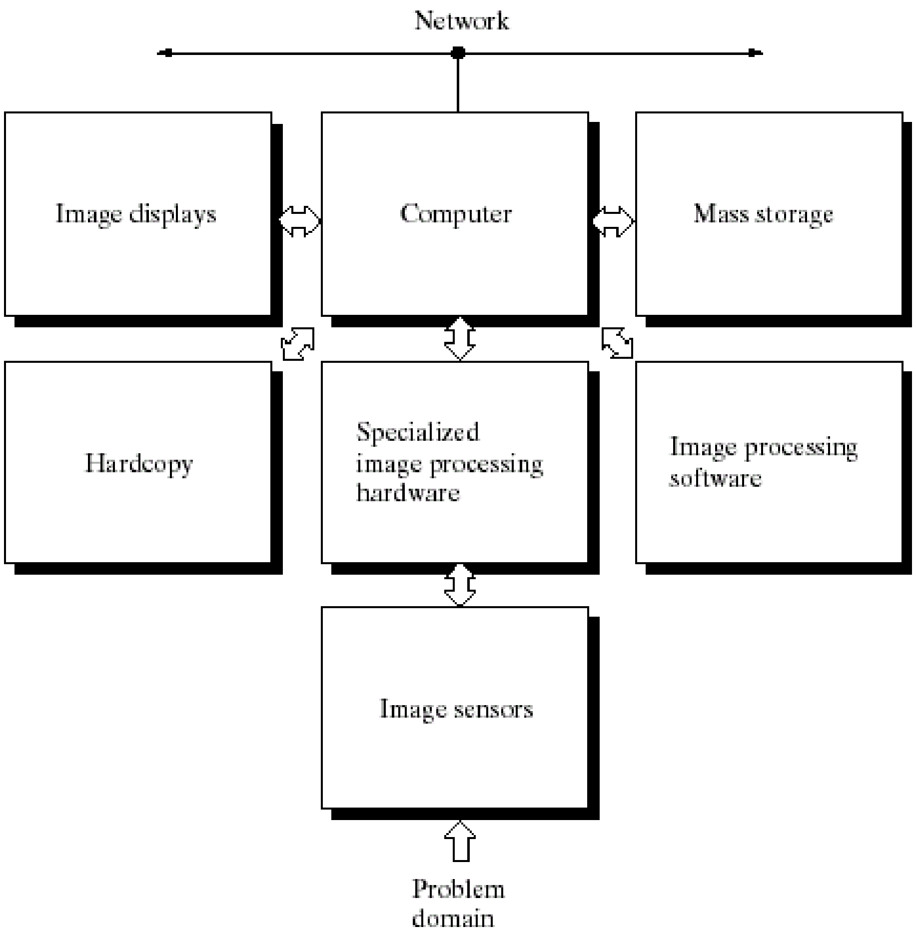


FIGURE 1.24 Components of a general-purpose image processing system.