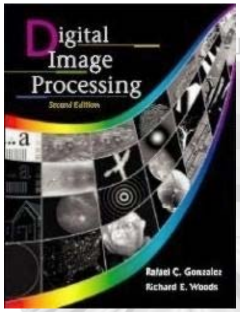


Prepared by

Waleed A. Yousef, Ph.D.,

Following DIP and DIPUM and using the arts available on
`www.ImageProcessingPlace.com`

Chapter 1: Introduction

Objectives:

1- Define the field and its scope.

2- Some history about the field.

3- Principal approaches to the field

4- …

1.1 What is Digital image processing?

Image is nothing but a function in two dimensions plotted as a 2D display with expressing the value of the function as intensity of a gray level; we can display it as a 3D figure.

The value is called intensity.

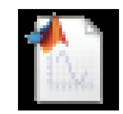
We can do the opposite; i.e., view any 2D function as an image instead of viewing it in a 3D display, by representing the value of the function as a gray level.

Digital image processing refers to processing a digital image, where X and Y have finite elements (picture elements) or (pixels).

Images are not limit to the visible range or any other range of the EM spectrum.

107 108 107 106 99 ……
108 109 106 108 107
107 106 110 110 106
106 107 108 108 108
…..

$$Z = f\,(\mathrm{X},\, \mathrm{Y}).$$



3dview.fig

```
I = imread('pout.tif');
figure; imshow(I);
[y x]=size(I);
figure;
mesh(1:x, 1:y, double…
       (I(end:-1:1, :)))
```

What is processing?

Low-level processing: the input is image and the output is image. (primitive operations, e.g., scaling, coloring…etc).

Mid-level processing: the input is image and the output is features, objects, regions, …etc. for recognition and classification, …

High-level processing: the input is recognized objects, regions,… and the output is understanding, making sense,…etc. This is the field of computer vision, image analysis,…

Our study in the course involves the first two levels.

1.2 The Origins of Digital Image Processing.

Some of the earliest produced digital images; however, no DIP was involved since there was no digital computer at that time.

We can see how the quality is poor because of the generation and reproduction mechanisms.

The start of the **digital** computers was in 1940s with Von Neumann. (read some nice history in the book).

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

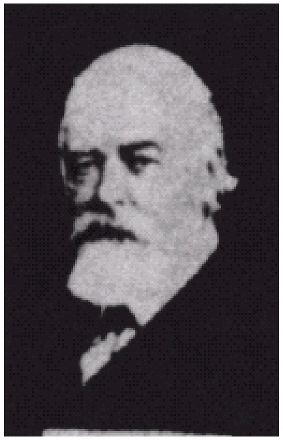


FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. Some errors are visible. (McFarlane.)

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

First image of the moon to be processed by Digital Computer.

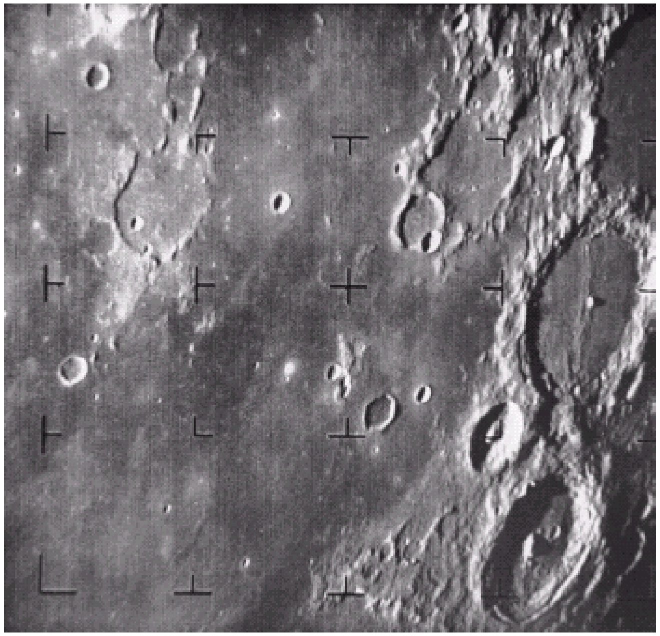


FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9:09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

In parallel, medical imaging started in 1960s. Many medical imaging techniques started to develop, e.g., Computer Tomography (CT), X-rays.

Later, digital images took place in many other applications, e.g.,
Geography: Studying pollution patterns by enhancing degraded images.
Archeology: restoring blurred images,
Physics and Cosmology: studying galaxies…
…
Processing in the above examples are intended for human perception. Other processing techniques involves extracting mathematical feature (e.g., Fourier and wavelet transforms) for machine perception and recognition (e.g., CAD, ATR, …). Let's take some examples from different fields:

1.3 Examples of Fields that Use Digital Image Processing

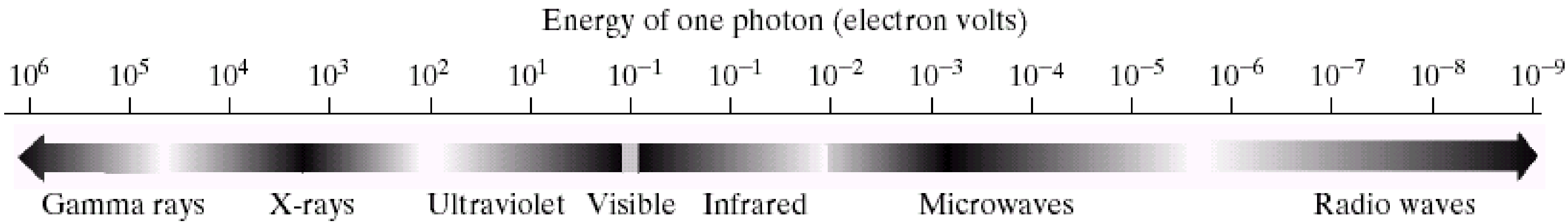


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

EM waves are propagating and have the dual nature, waves and particles.

We will demonstrate some images from each band.

We have to notice that in each application we use the band that it is suitable and capable of displaying the properties of the object (we will comment on each application while displaying the images)

We could have other taxonomies of images than the band, e.g., by transmitting mechanism, by receiving, by technology,…etc (See Barrette and Myers).

We can detect the portion of the wave penetrated the object or that reflected from the object. This depends on both the imaging system and the object. (Barrette and Myers)

1.3.1 Gamma-Ray Imaging.

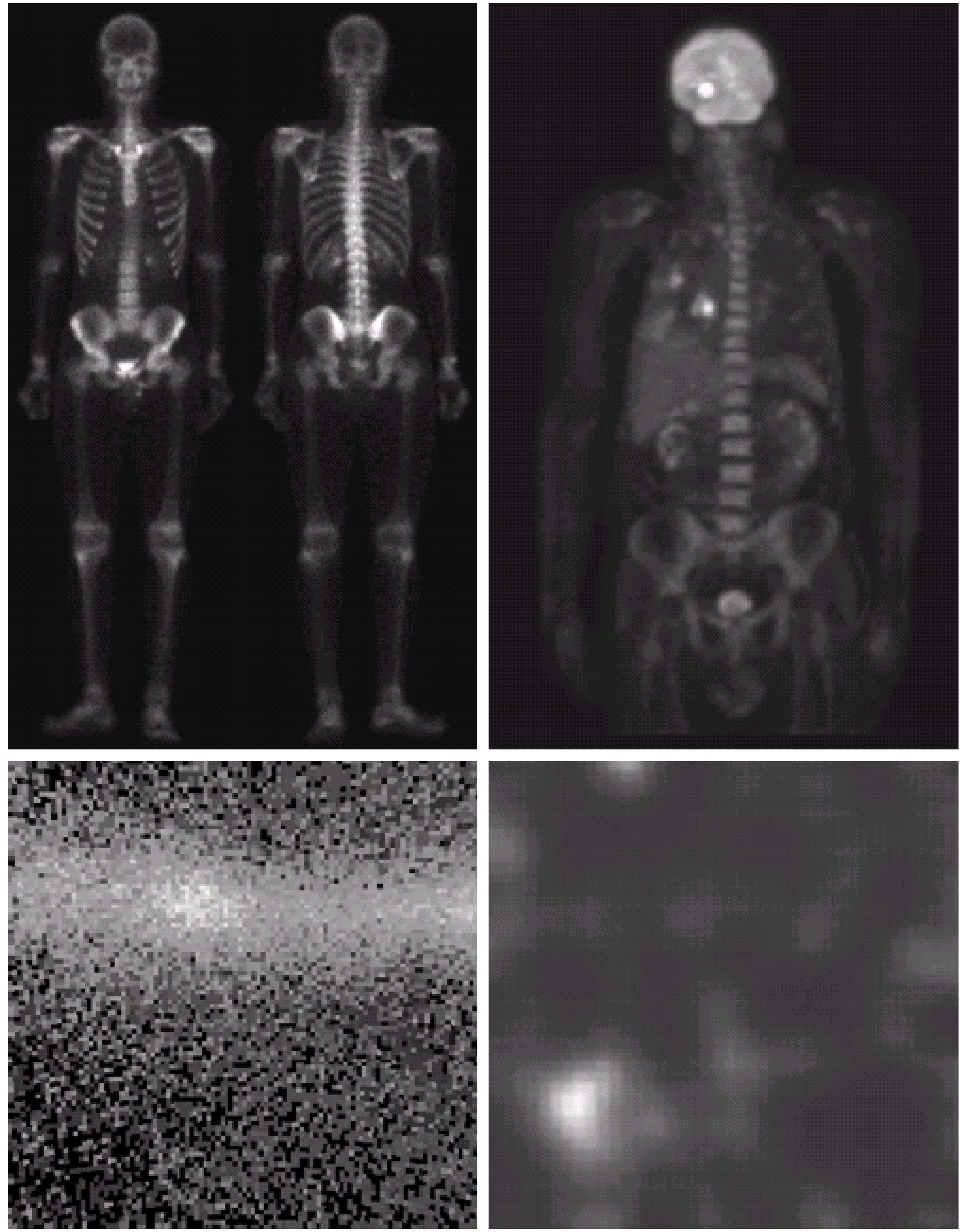
Major use in:

Nuclear medicine: injection of radio-active material (rather than external source of radiation) that decays after transmission and received by detector (Fig a, b). See the tumors in brain and lung of Fig. b.

Astronomy: Fig. c is a self radiating star that exploded 15,000 ago.

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

Mainly used in medical imaging, but also used in astronomy.

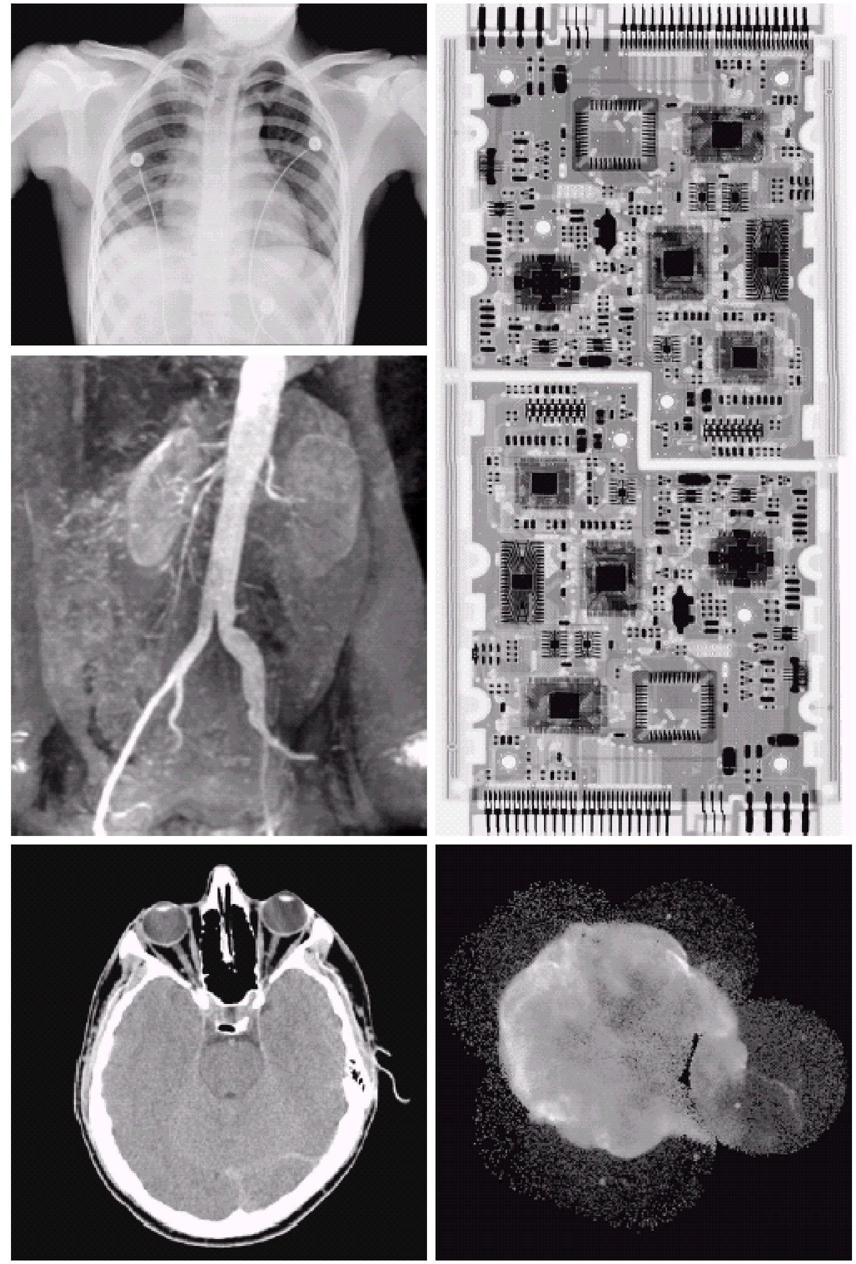
Emission is produced by heating a cathode and the patient is placed between it and the detector (which is a film). This is called analog X-ray.

The object modifies the X-Ray and, hence modulation is detected on the film.

Digital X-ray is produced by either digitizing the analog or directly by having the X-ray fall on digital device (e.g., digital mammography). See Fig. a., b.

Other X-Ray uses is CT scans, in which the object is sliced and each slice is imaged, Fig. c.

Similar uses is for X-Ray exist in industry, e.g., testing circuits. Fig. d

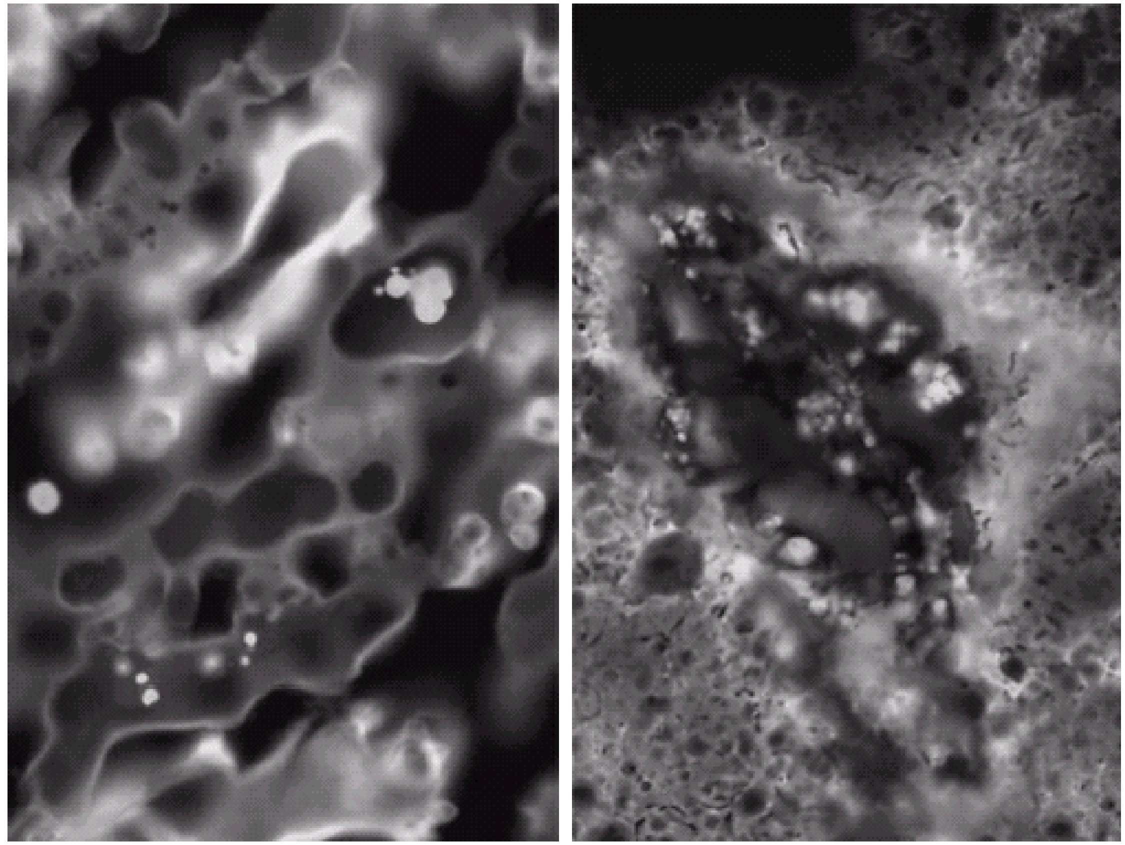


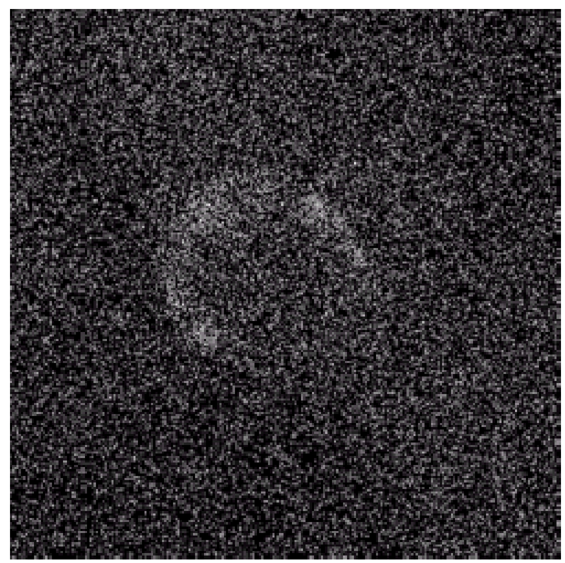
a d
b
c e

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.)

1.3.3 Imaging in the Ultraviolet Band

Appear in many applications, e.g., microscopy, lasers, biological imaging, and astronomical observations.





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.)

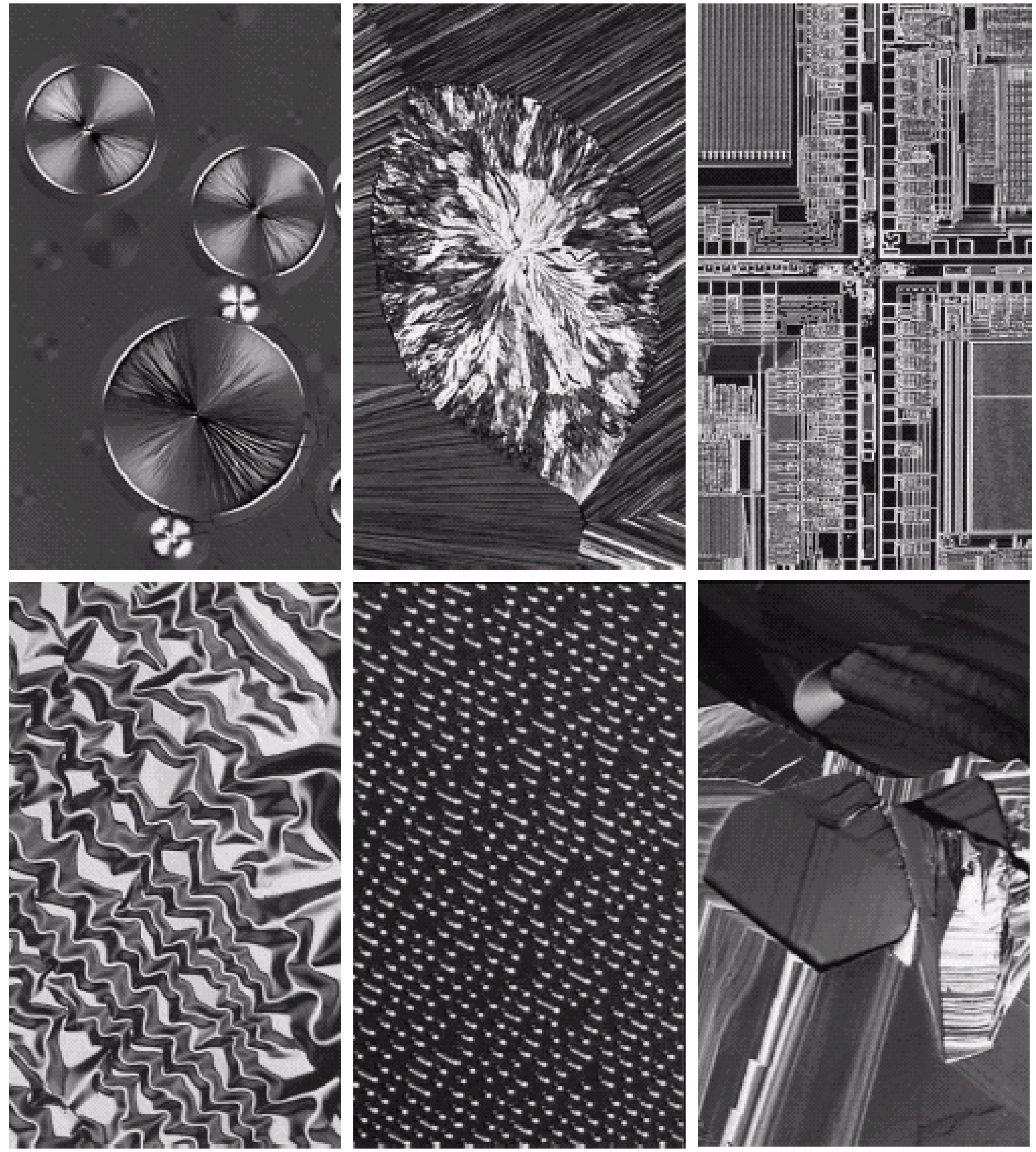
Fluorescence microscopy: when a photon of Ultraviolet light (not visible) collides with electron of fluorescent material it is elevated to higher energy level, and when relaxes it emits light in the visible region.

The material to be examined is either self fluorescing or, we treat it with another fluorescing material. See Fig. a., b.

1.3.4 Imaging in the Visible and Infrared Bands

Imaging in visible band is ubiquitous; frequently it is accompanied by infrared imaging.

The images in the Fig. are from light microscopes, but from different fields.



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.)

TABLE 1.1 Thematic bands in NASA's LANDSAT satellite.

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

Remote Sensing: is another area of application for visible band; one object is imaged using different bands, all in the visible range (called thematic bands) in NASA's LANDSAT satellite.

In Fig 1.10, notice the difference between the infrared bands (4-7) and the first three; e.g., the river is so obvious in band 4 and 5.

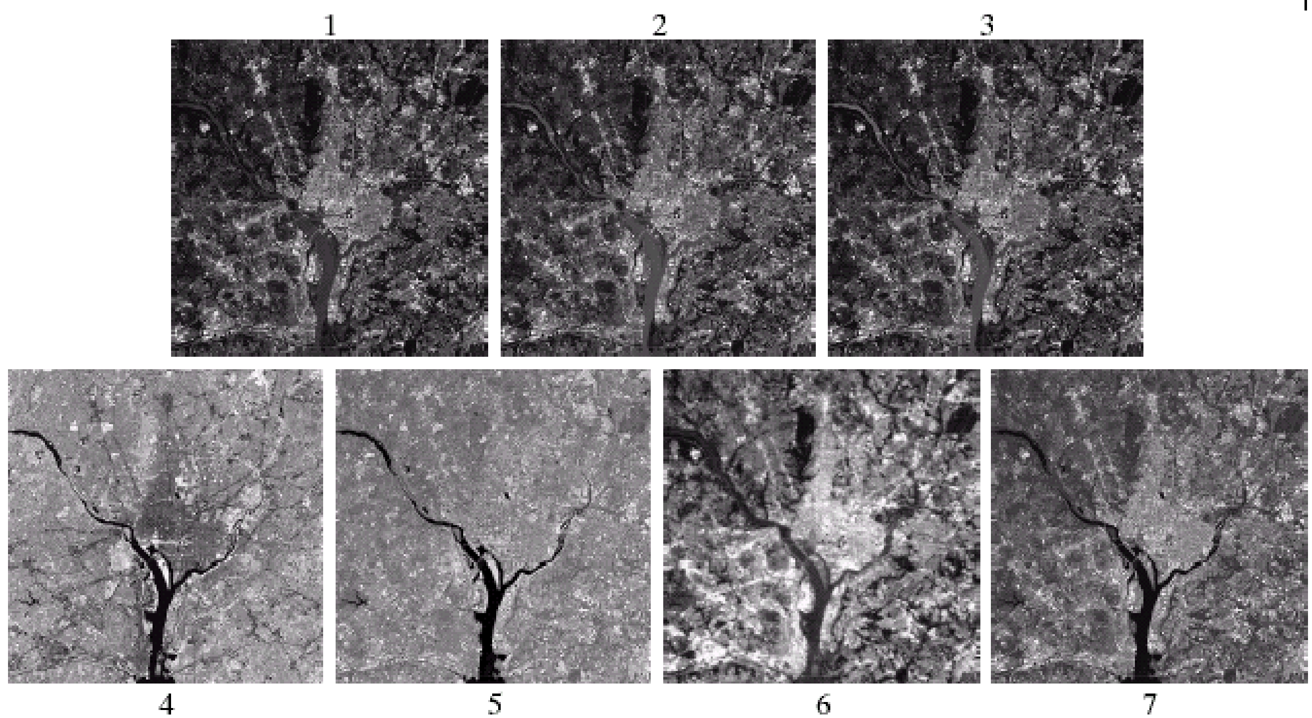


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

Whether observation and Prediction: another application for multispectral imaging from satellites.

In the Fig., the eye of the hurricane is obvious. The image is taken in both the visible and the infrared bands.

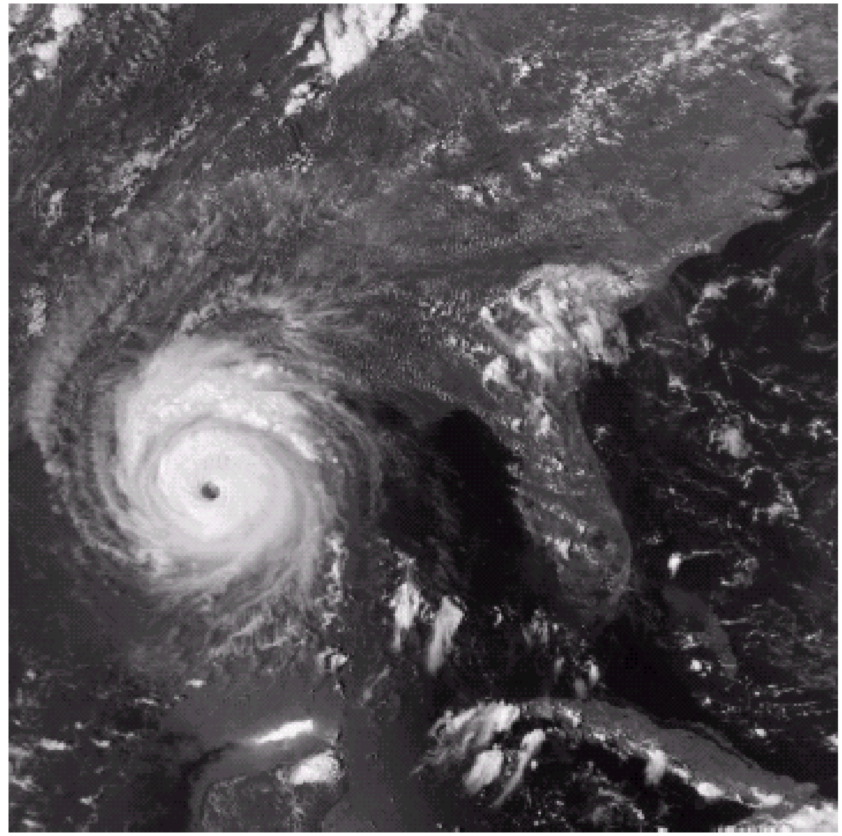


FIGURE 1.11 Multispectral image of Hurricane Andrew taken by NOAA GEOS (Geostationary Environmental Operational Satellite) sensors. (Courtesy of NOAA.)

Fig 1.12 and 1.13 are images part of “*Nighttime Lights of the World*” dataset

This infrared imaging system has unique capability to observe faint sources of visible-near infrared emissions (this includes cities, towns, …).

It is very easy to calculate electrical energy usage by various regions in the world using this image.

Also, the difference is obvious between, e.g., US and Africa.

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

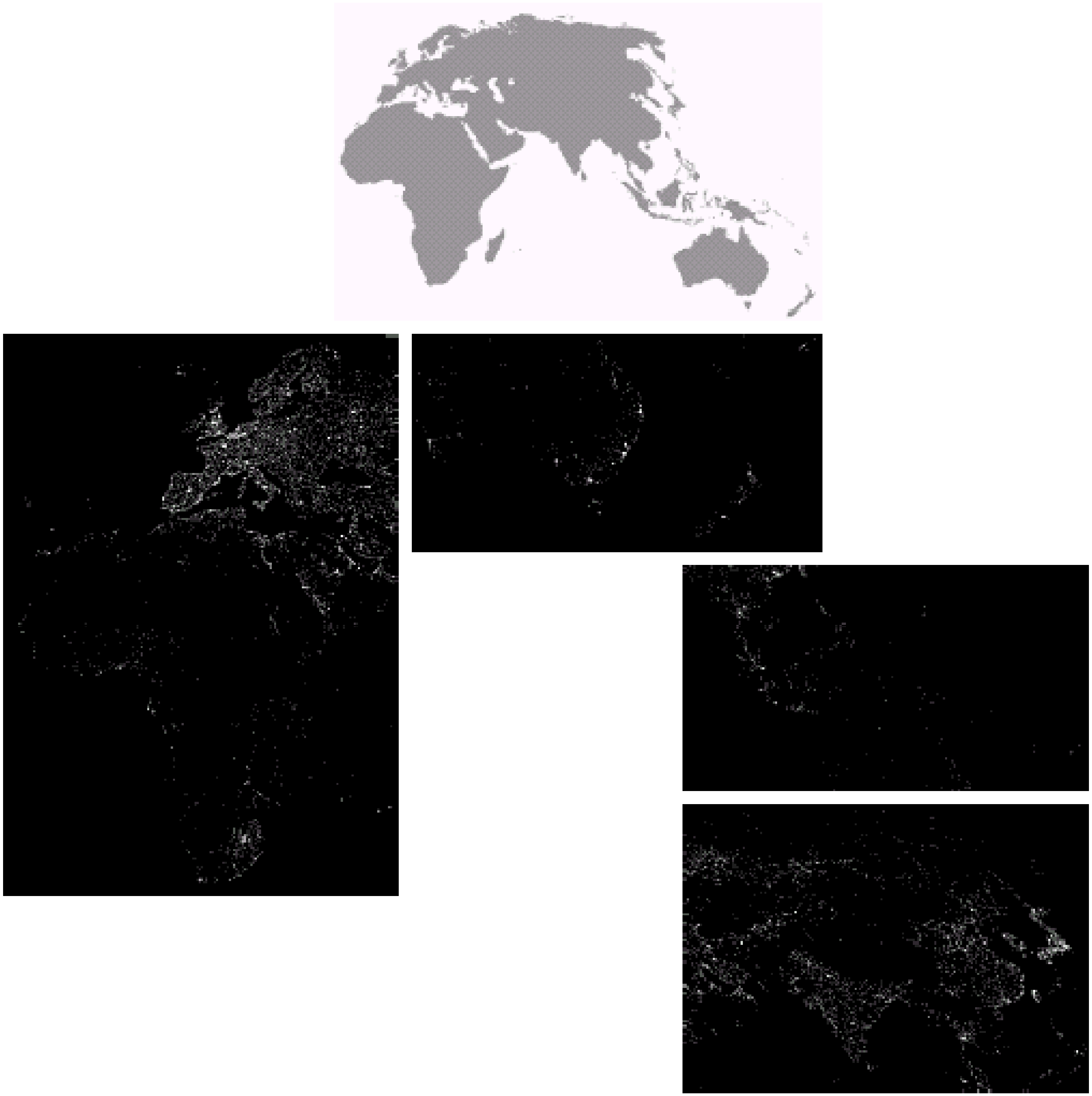


FIGURE 1.13 Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)

Automated visual inspection of manufactured goods:

Fig. a. the black square is a missing part.

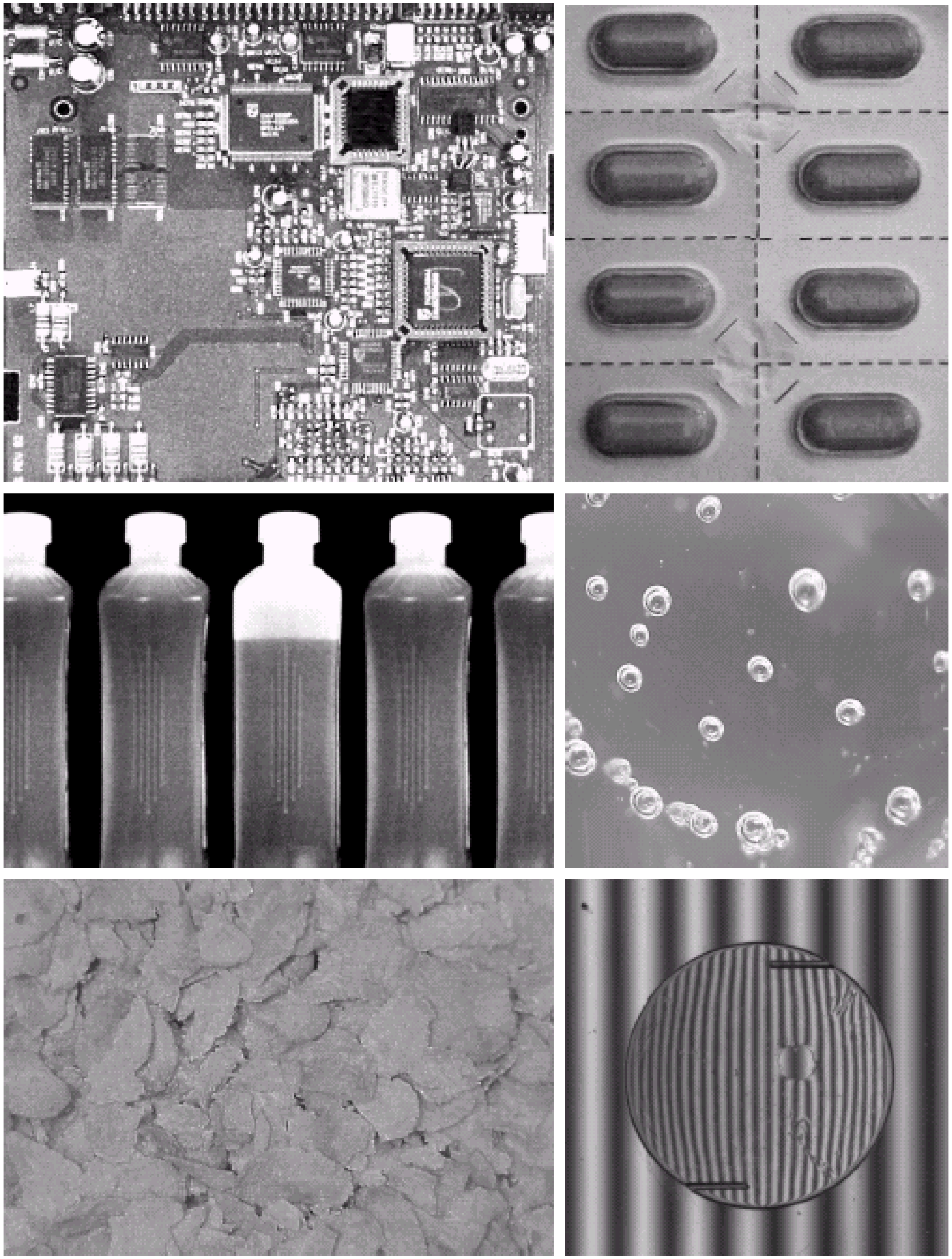
Fig. b. no missing pills

Fig. c. There is a bottle that is not filled up.

Fig. d. unacceptable plastic product because of bubbles.

Fig. e. Some burned flakes exist, which degrades the quality.

Fig. f. detection of imperfections in lens.



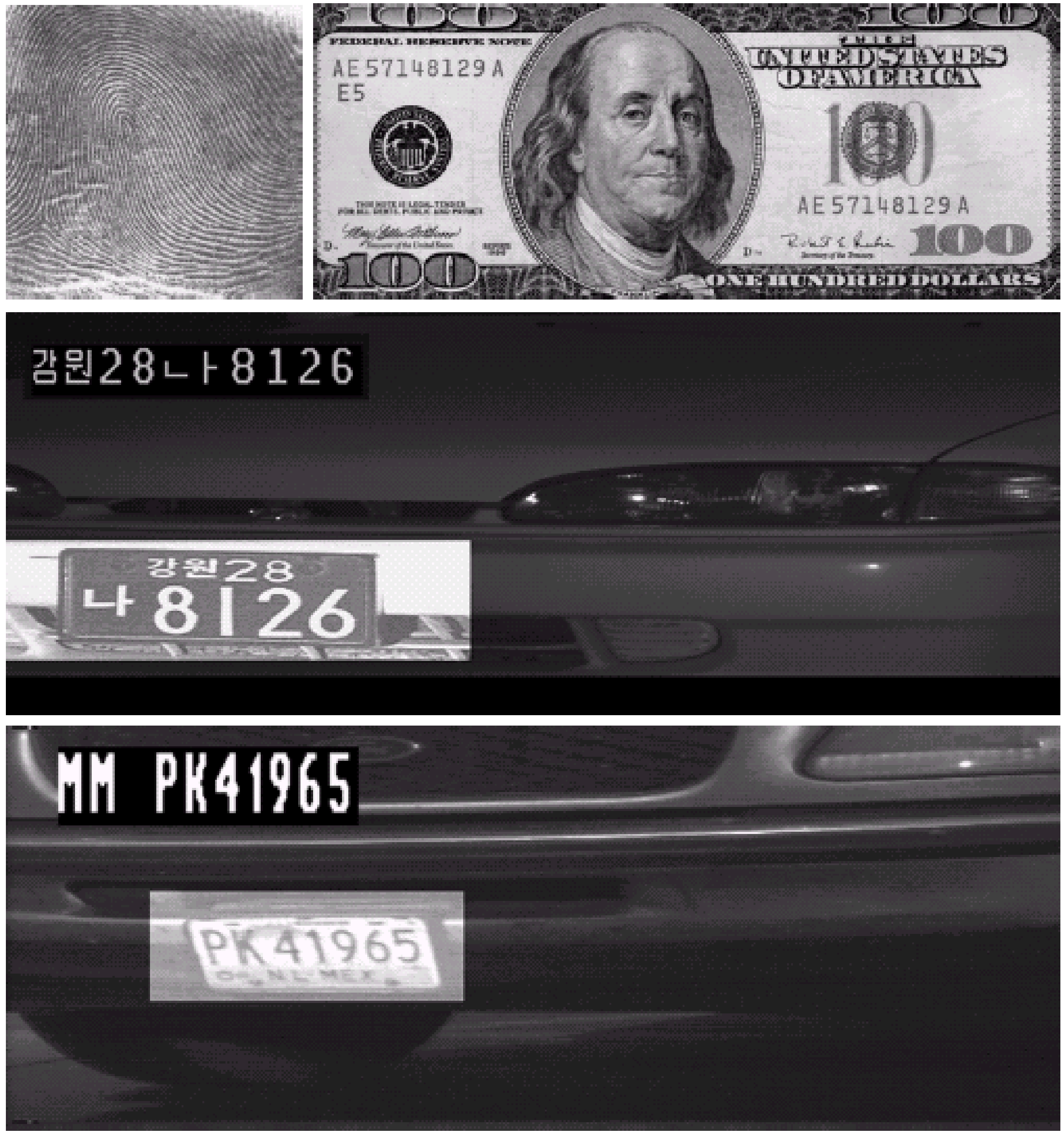
a b
c d
e f

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.)

Fig. a. Finger print identification.

Fig. b. Automatic counting of bills, reading of serial numbers, …etc.

Fig. c. and d. automatic plate reading. The white rectangles are the areas detected by the system, and the black rectangles are the recognized numbers by OCR system.

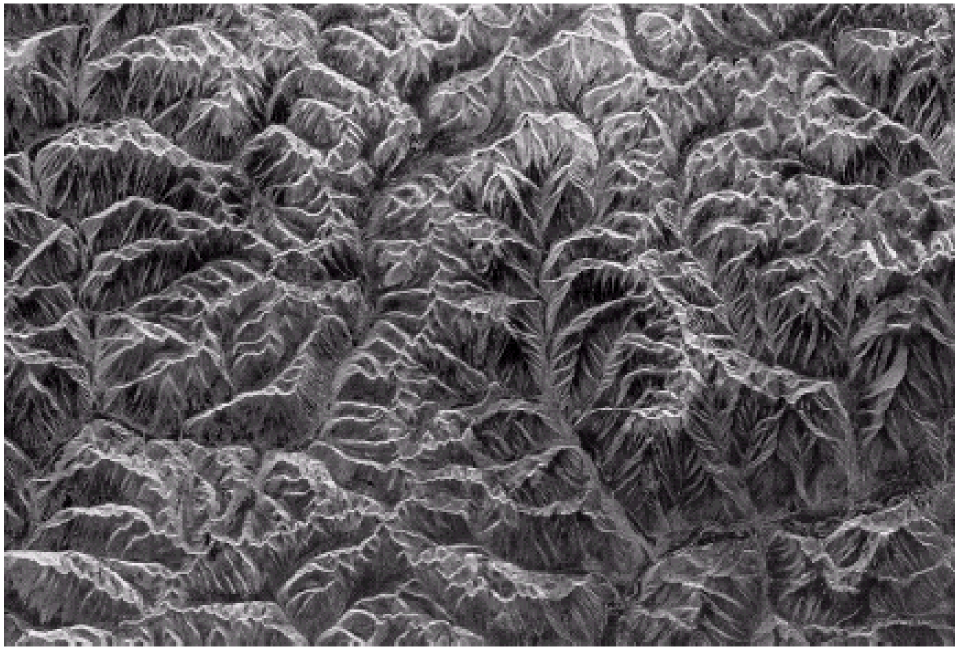


a b
c
d

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.)



Dominant application is radar. Some radar waves penetrate clouds and vegetation which makes it capable of collecting data over any region any time.

A flash camera produces microwave pulses, then reflects from the surface of the object to be detected and a snapshot image is taken.

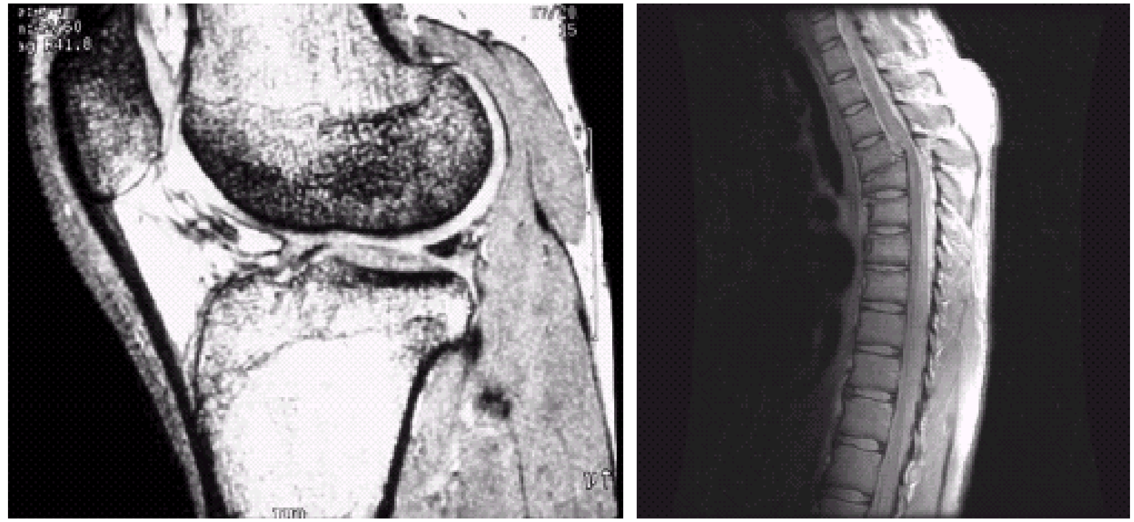
This image shows very clearly the mountains although at these heights there is a lot of clouds and other atmospheric conditions that interfere with visible light.

1.3.6 Imaging in the Radio Band

This is the other extreme end of the spectrum (as opposed to Gamma Rays).

Major application is in medical applications, e.g., Magnetic Resonance Imaging (MRI), and astronomy.

The patient is placed in a strong magnet and radio pulses are passed through his body. Each pulse results in another pulse emitted by the patient tissues. The strength and location is detected by a computer and an image is produced.



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.)

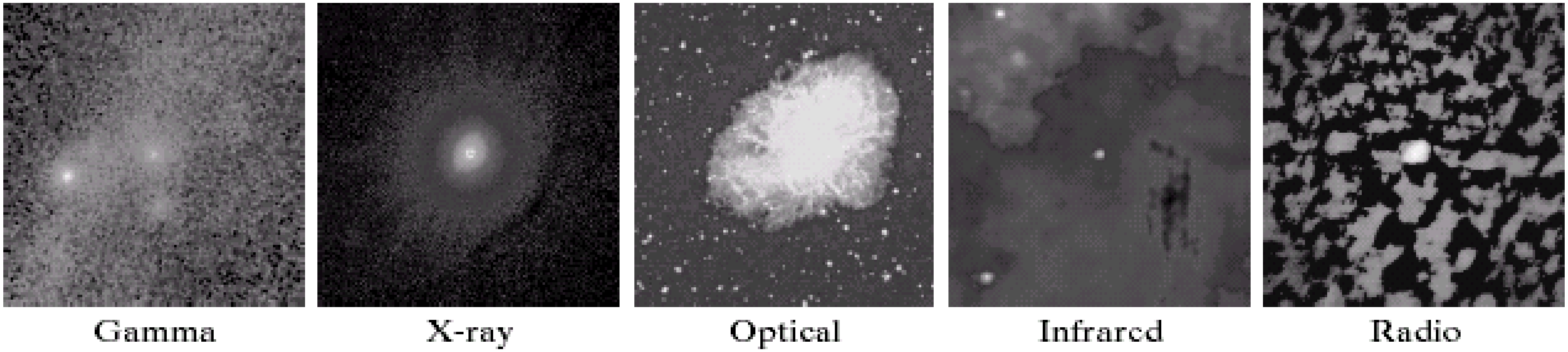


FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

Many images in many bands for exactly the same object; totally different images!!

Which one of these is the object? The question is wrong, because all of these (and other images in other bands) are the interaction among three things:

1- the wave hitting the object.
2- the quality of the object and how it reacts with the wave.
3- the receiver quality, whether it is the human eye or a special purpose camera.

No one knows the essence of anything; we cannot prove anything in science. We just observe indicators and understand in terms of these indicators. (More on this in Ch. 2).
We really do not know and cannot know but very little.
Even, we can use other modalities for the same object than the EM-based modality:

1.3.7 Examples in which Other imaging Modalities Are used

A. Acoustic Imaging.

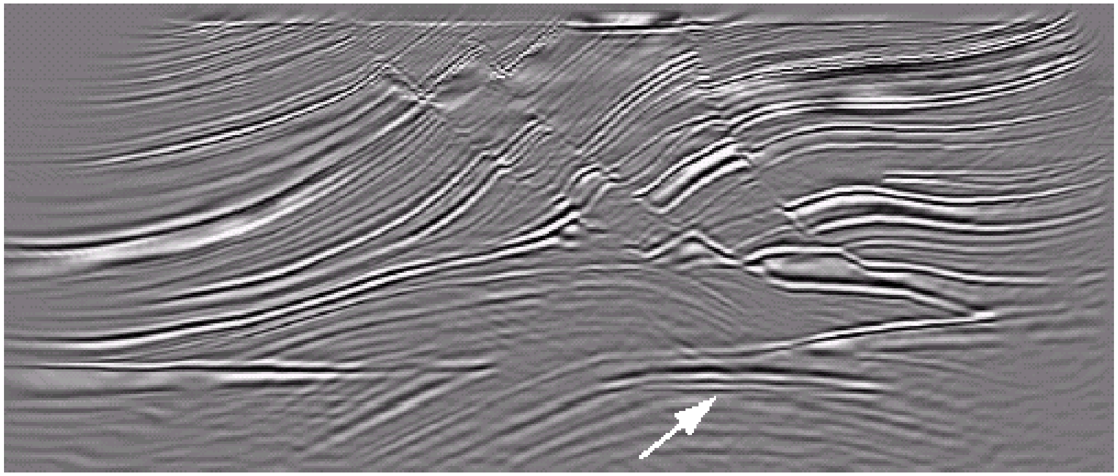


FIGURE 1.19 Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)

Finds applications in Geology, e.g., mineral and oil exploration
In low end of the sound spectrum (hundreds of HZ)

Image acquisition over land is performed by putting a large flat steel sheet and vibrate it. The speed and frequency of returning depends on the earth below the surface.

Marine image acquisition is performed by using air guns behind the ship

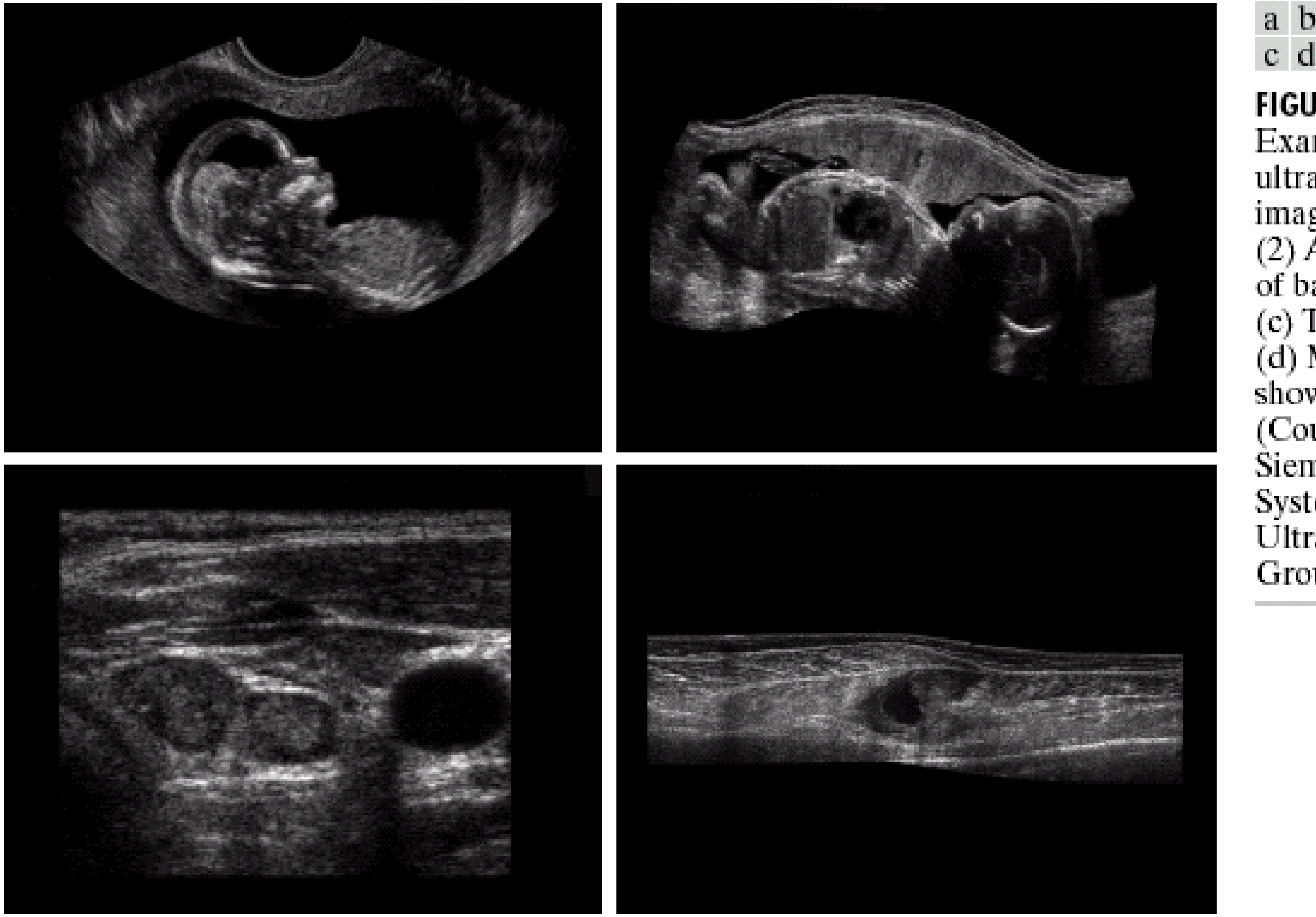


FIGURE 1.20 Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

Acoustic images in medical applications (specially for imaging unborn babies) use ultrasound (millions of HZ)

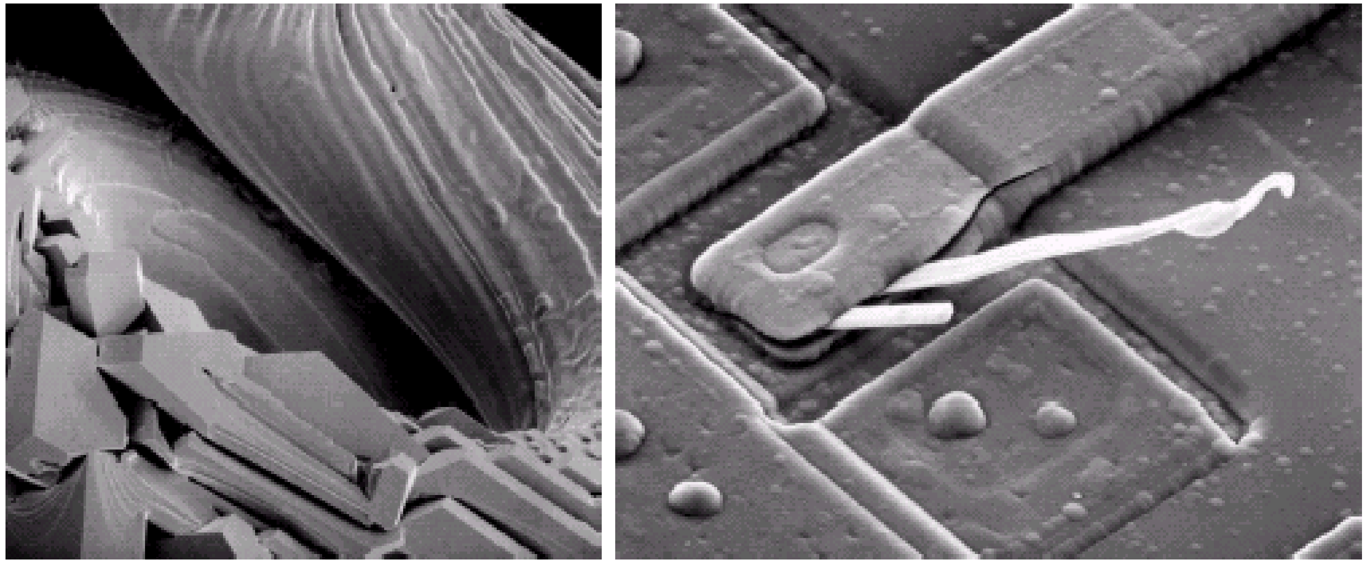
The idea is the same but with using a probe.

(of course other kinds of EM imaging is dangerous here.

B. Electron Microscopy

Electron microscopes work as optical ones except that they transmit electrons that penetrate the specimen, which absorbs and/or reflects according to its characteristics. Usually, used for inspecting components

Kinds of Electron microscopes are Transmission Electron Microscopes (TEM) and Scanning Electron Microscopes (SEM); read the book.



a b

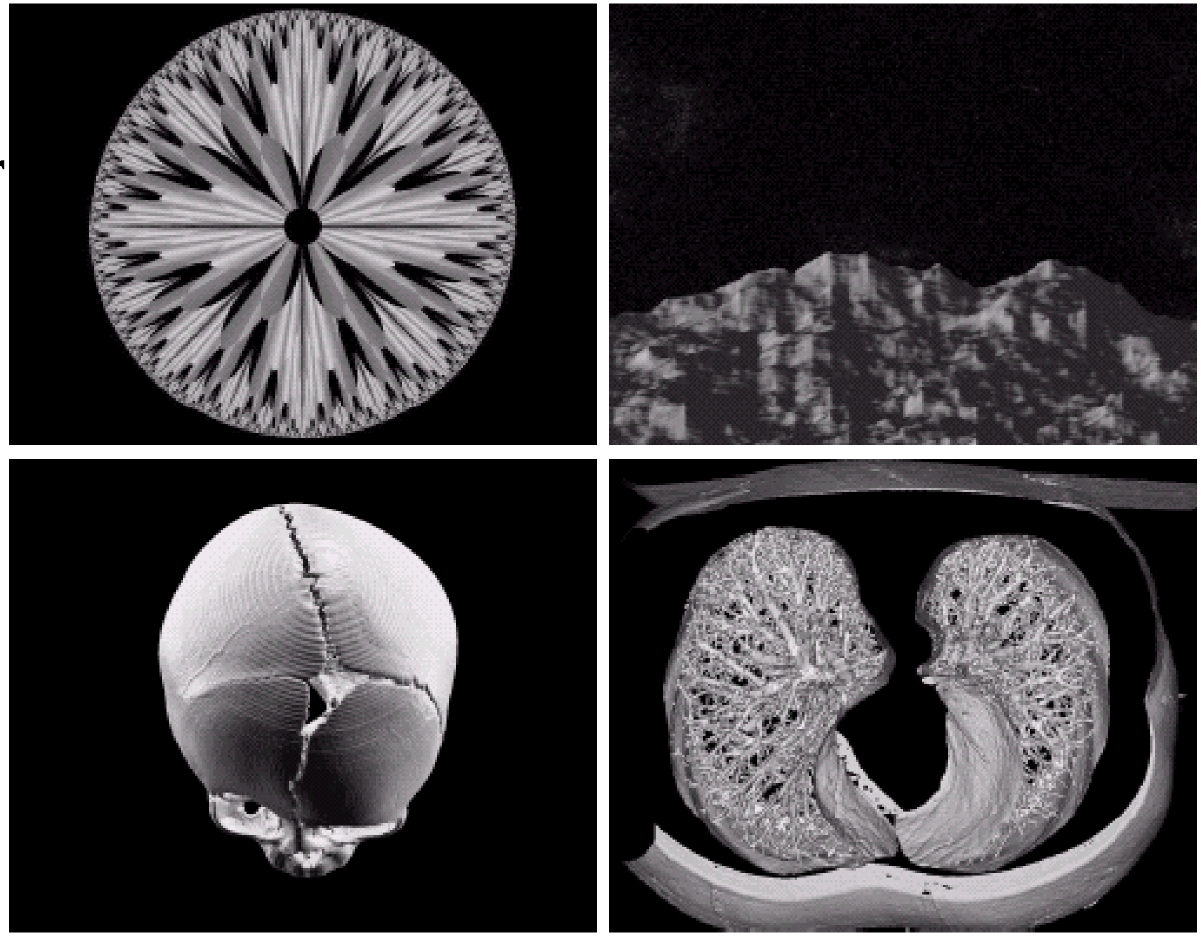
FIGURE 1.21 (a) 250× SEM image of a tungsten filament following thermal failure. (b) 2500× SEM image of damaged integrated circuit. The white fibers are oxides resulting from thermal destruction. (Figure (a) courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene; (b) courtesy of Dr. J. M. Hudak, McMaster University, Hamilton, Ontario, Canada.)

C. Fractals

Here, their **neither** object **nor** wave; it is synthesized by computers!!!

This is generated according to mathematical model (Fig. a., b.)

It can generate beautiful shapes and patterns.



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.)

D. Model-based images

Also, their **neither** object **nor** wave; it is synthesized by computers!!! However, the model here is a model for some object, e.g., skulls, organs,..etc. (Fig. c., d.)

More advanced application is virtual reality.

1.4 Fundamental Steps in Digital Image Processing

Each module of these is either low- or mid-level processing.

The knowledge about the problem is necessary for many of these modules.

Bilateral arrows indicate interaction between modules is done using the knowledge base.

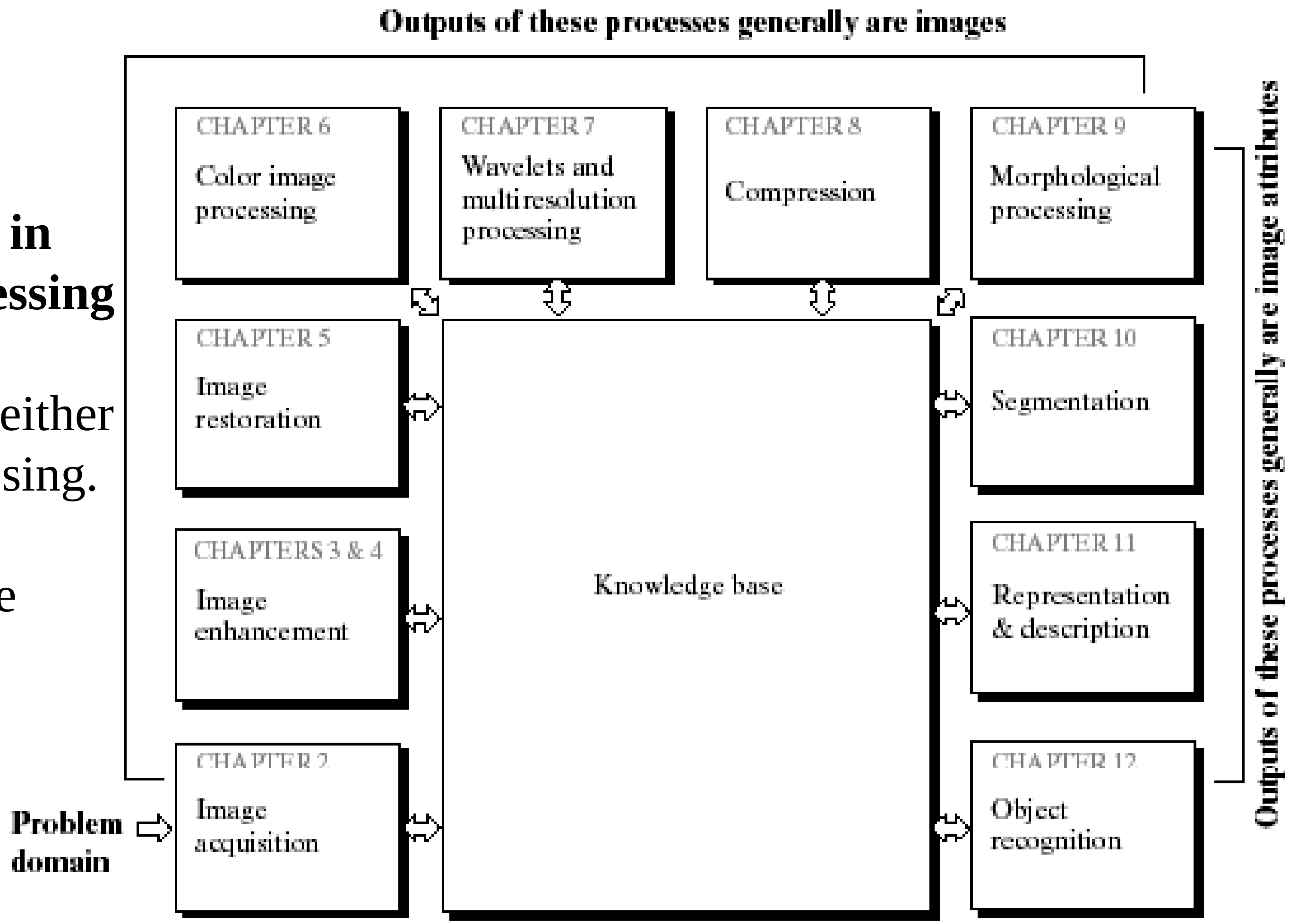


FIGURE 1.23 Fundamental steps in digital image processing.

1.5 Components of an Image Processing System

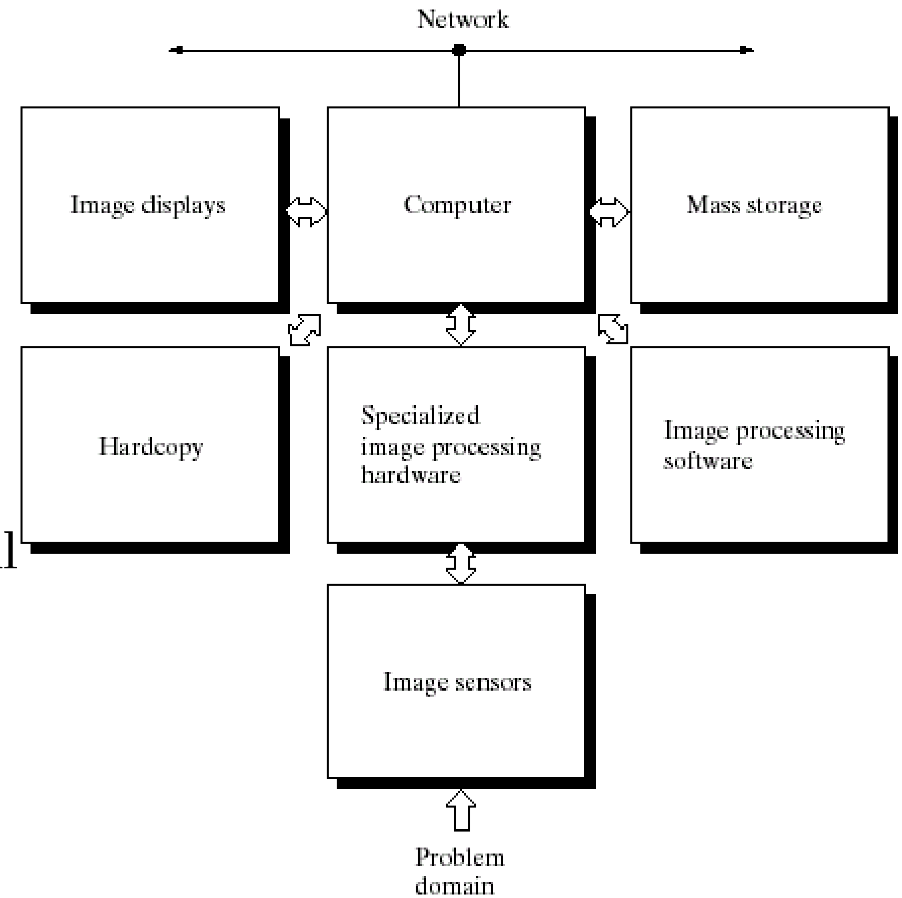


FIGURE 1.24 Components of a general-purpose image processing system.

For some applications, these blocks need a great deal of design, e.g.,:

Image displays: FDA requires some specs for viewing medical imaging.

Mass storage: is a big problem in satellite images that are transmitted at high rate.

Image processing software: can be a standalone project for processing some images.

…