Chapter 1 - Motivation

Computação Visual

Get CV_MATERIAL

(Download the material in the following link)

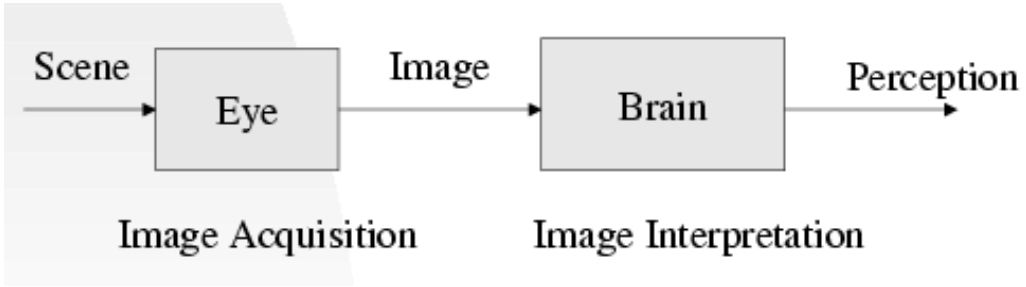
https://github.com/JacintoCNascimento/ist-cv-2526

Topics to be addressed

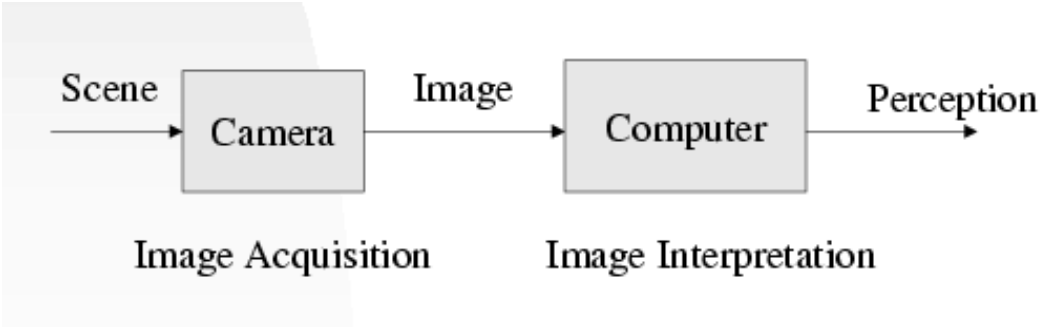
- What is the Image digital processing ?
- Digital images throughout the history;
- Applications (energy source):
  - Electromagnetic;
  - Acoustic;
  - Ultrasound;
  - Electronics (Electron beams /feixes de electrões);
- Components of the DIP (digital image processing);

What is the digital image processing ?

Vision is the most advanced human sensory system!



Naturally, we try to replicate these capacities using machines.



What is the digital image processing ?

An image can be defined by:

$f(x, y)$ where x, y are spatial coordinates and f defines the intensity or the color in that point.

If x, y and f are finite and discrete, the image can be considered as digital.

Thus, one possible definition for DIP :

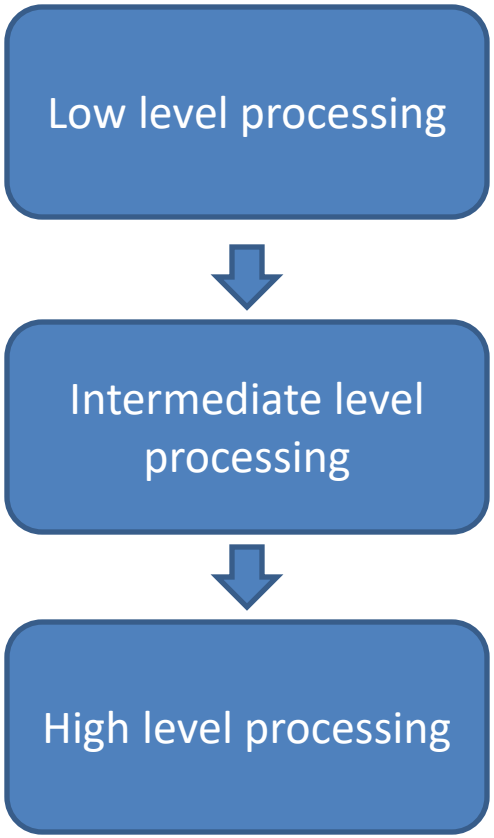
Encompasses processes whose inputs and outputs are images, also it encompasses processes of features extraction

Related research areas

- *Image understanding*
- I*mage Analysis*
- C*omputer Vision*
- C*omputer Graphics*
- Pattern Recognition
- A*rtificial Intelligence*
- Etc…

Frontiers between CV and IP

- Fuzzy! (not well defined)



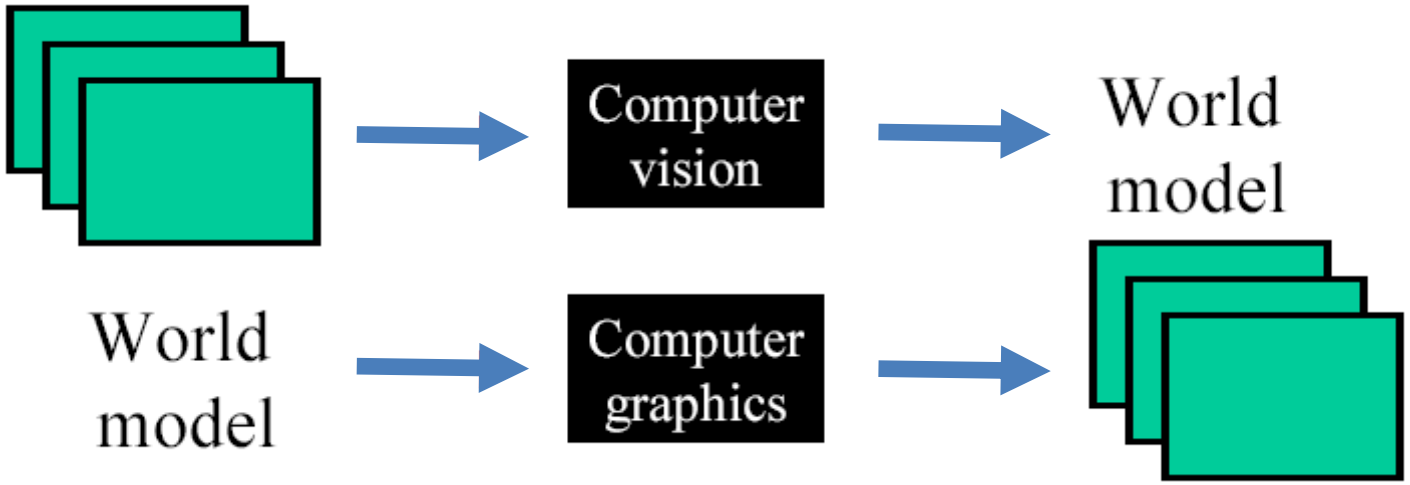
Pre-processing:

Denoising; image enhancement; feature improvement

Segmentation; object region description; classification

Scene interpretation

Computer Vision and Computer Graphics



Digital imaging: some history

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

Harry G. Bartholom
and
Maynard D. McFarlane

Jet Propulsion Laboratory (Pesadena, Califórnia) -> *birth of the PDI*

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.)

Digital images throughout history

- Landmark points in digital age

1940 - John von Neumann Machine (CPU);

1948 - Invention of the transístor (Bell Labs);

1950/60 – Language development such as COBOL e FORTRAN;

1958 – Invention of the integrated circuit (Texas);

1960 – Development of the operating systems;

1970 – Development of the microprocessors (Intel);

1981 – Introduction of the personal computers (IBM – International Business Machines);

1980 – Components miniaturisation (LI, VLSI, ULSI), for storing and visualization.

Digital images throughout history

- Landmark points in digital age

2000- GPU GeForce GTX 1070 – Nvidia

GPU GeForce GTX 1080 – Nvidia

GPU NVIDIA TITAN X Graphics Card

TPU TENSOR Processsor Unit

Applications

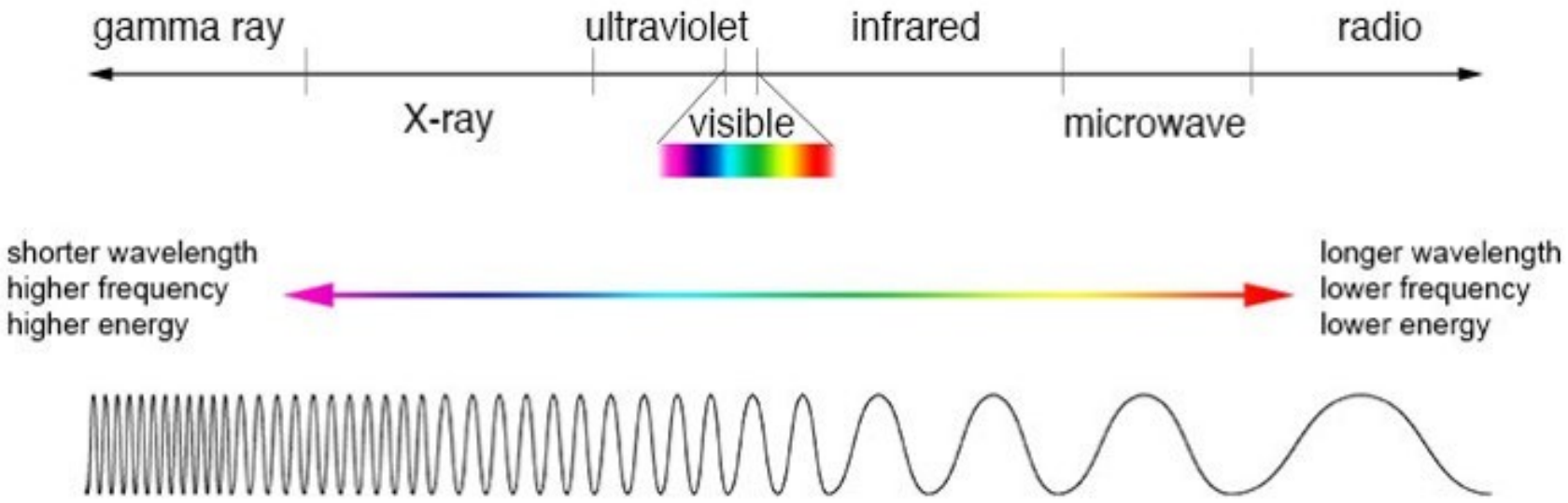
- Is there any area where image digital processing is not used?

One way to describe its application is to resort to the signal energy font:

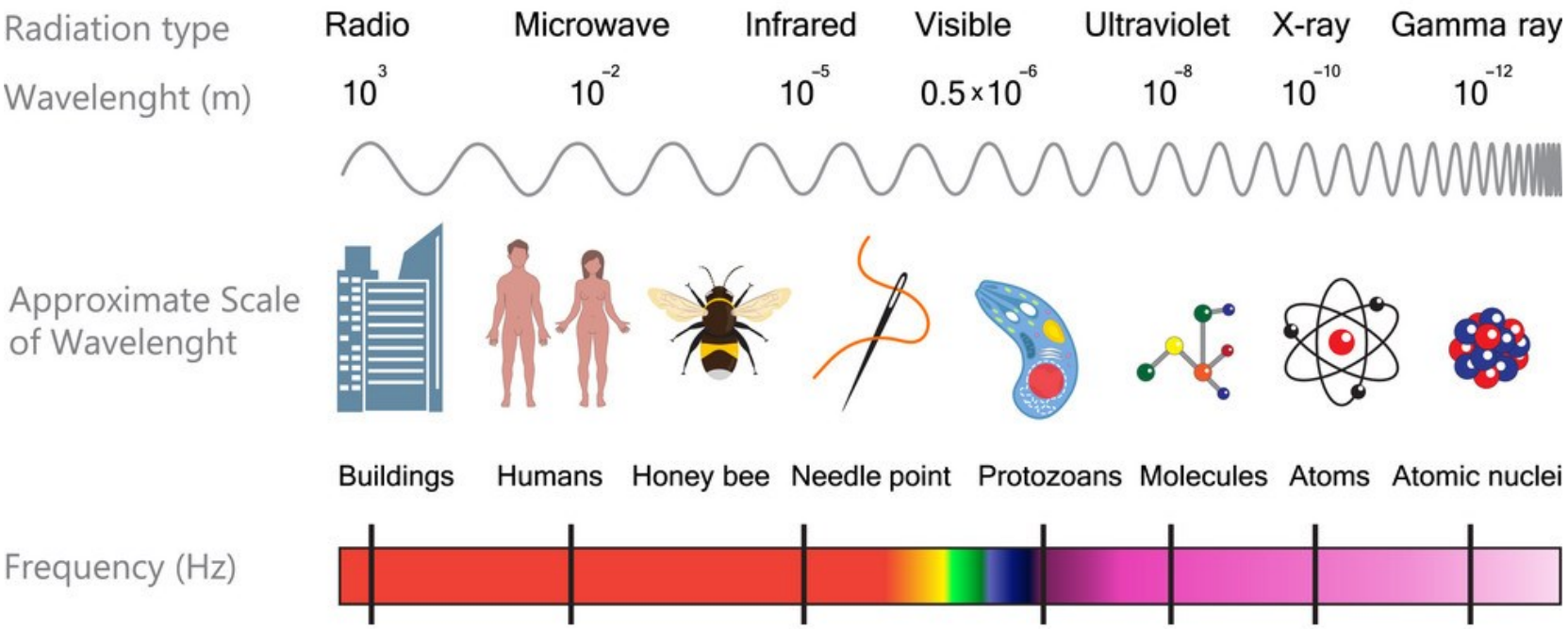
  - Electromagnetic;
  - Acoustic;
  - Ultra-sound;
  - Electronic;

Electromagnetic Spectrum

(the main source of energy for images in use)

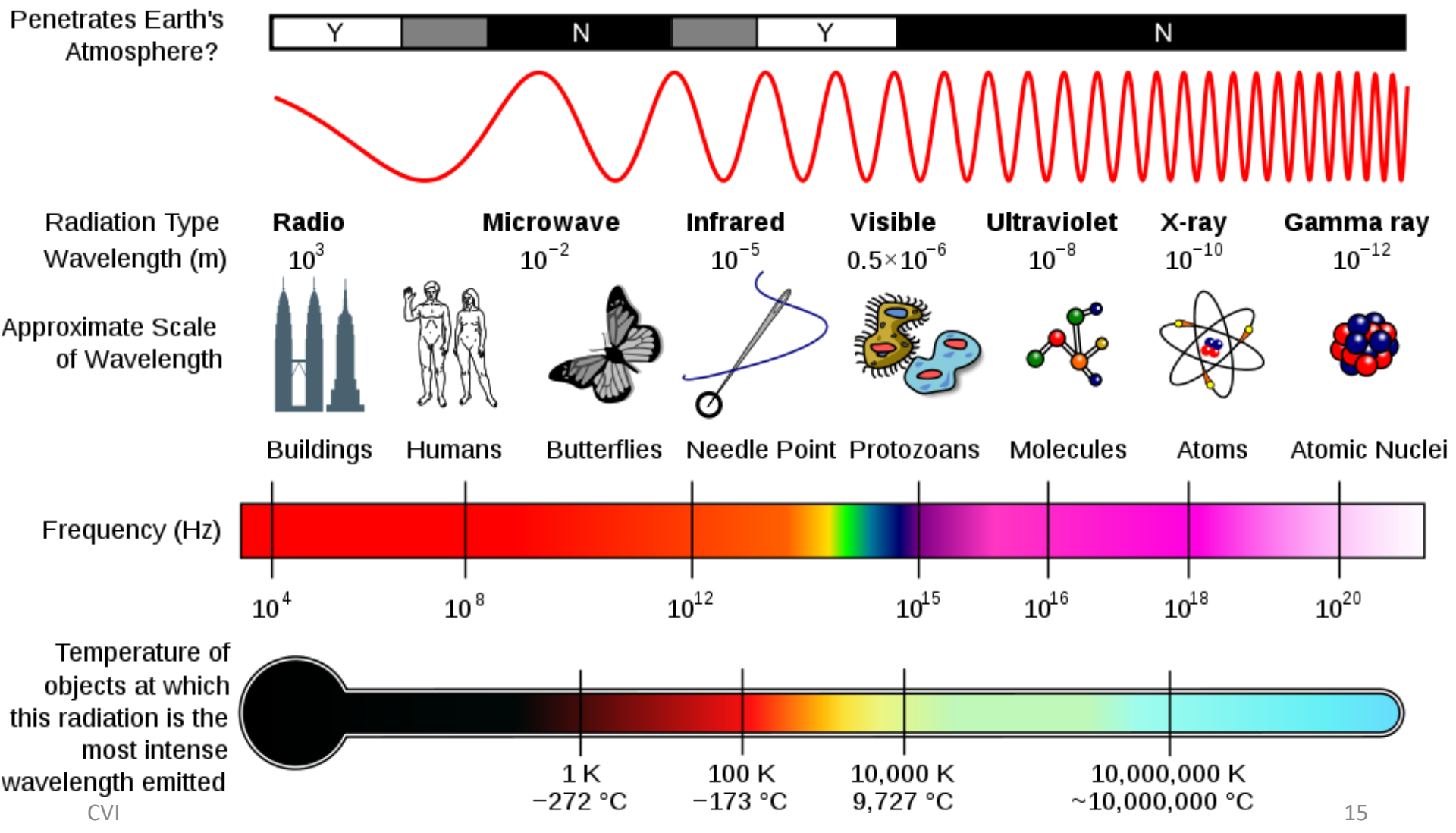


Electromagnetic Spectrum



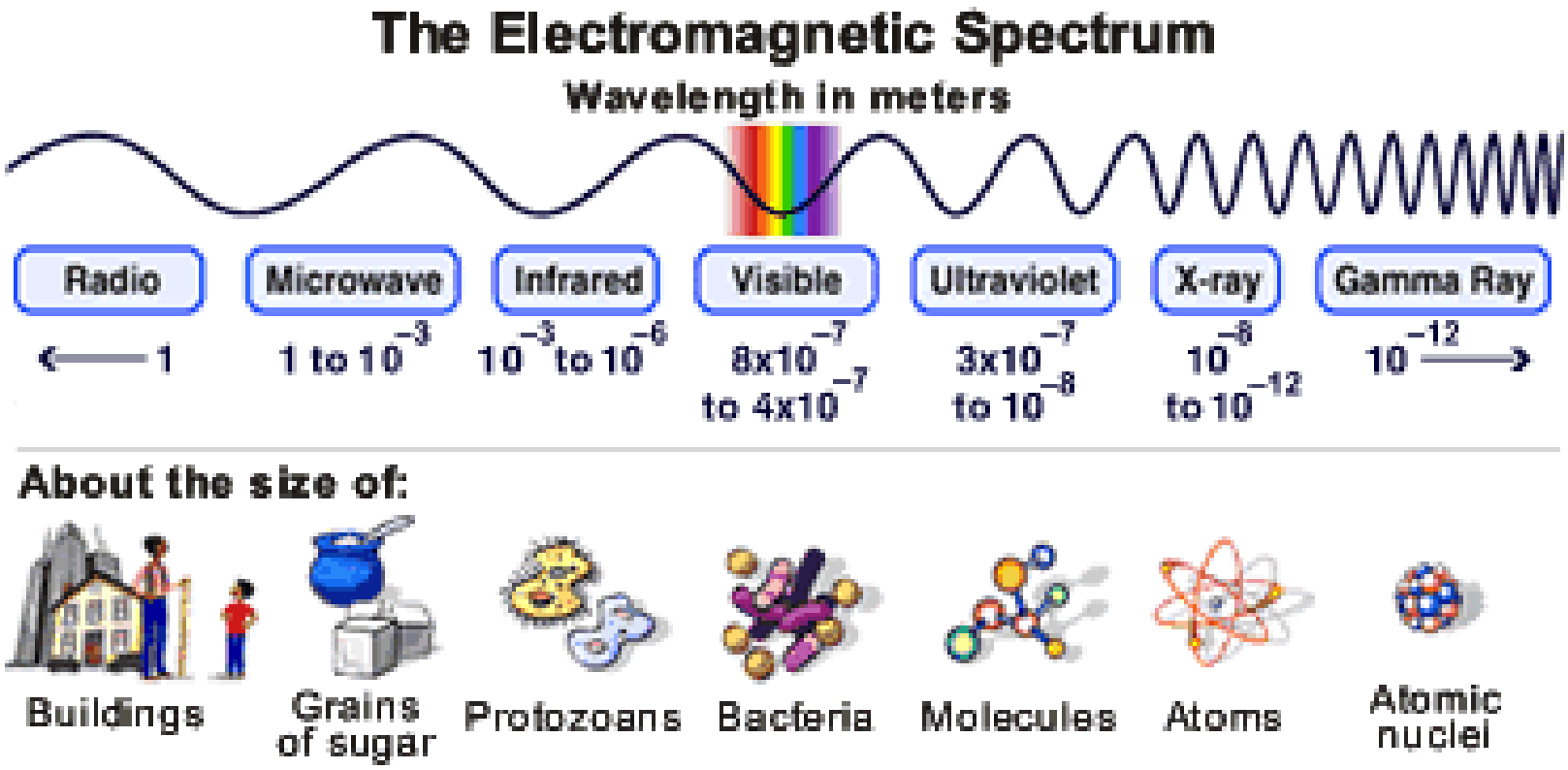
Electromagnetic Spectrum

(the main source of energy for images in use)



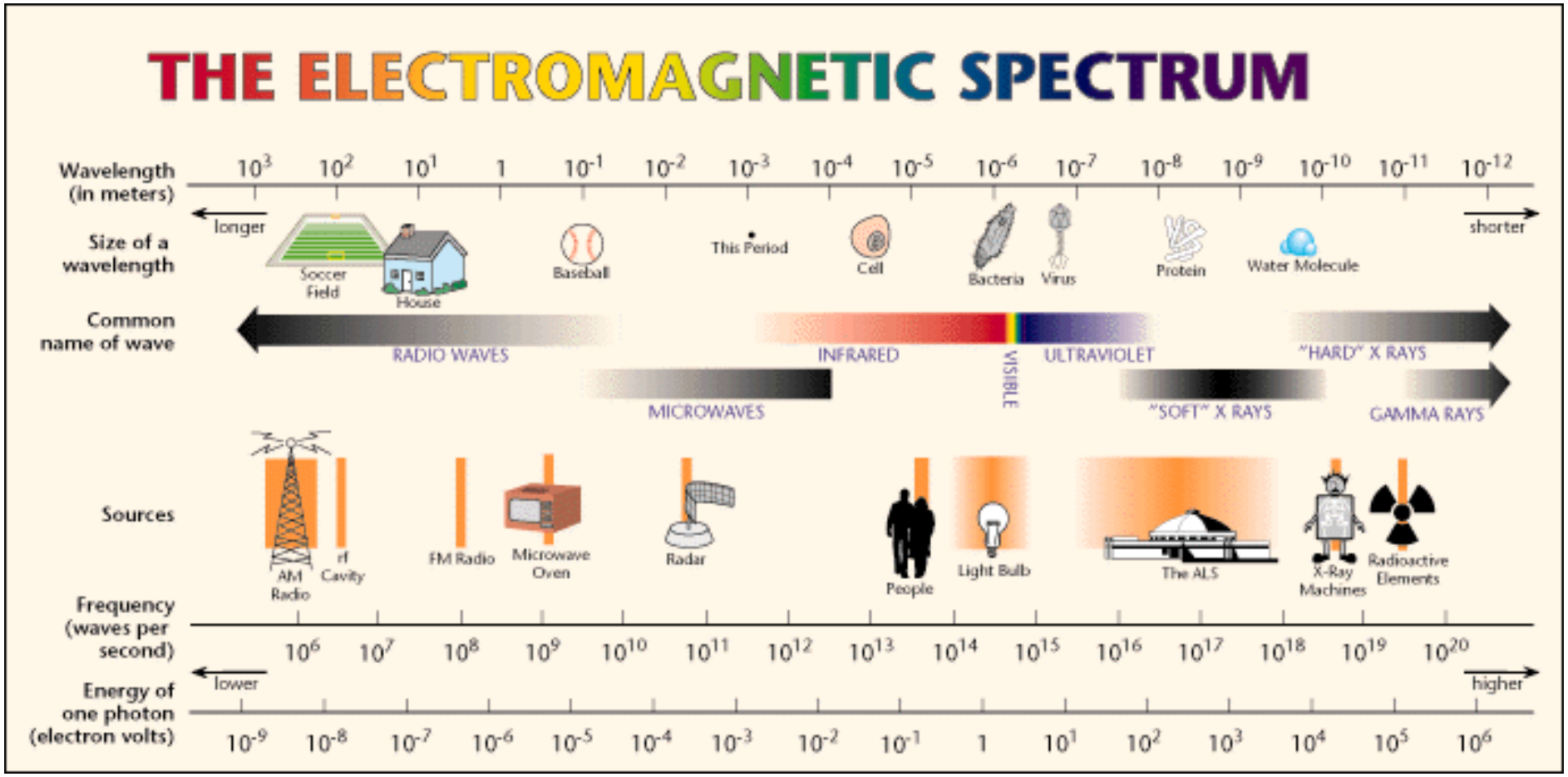
Electromagnetic Spectrum

(the main source of energy for images in use)

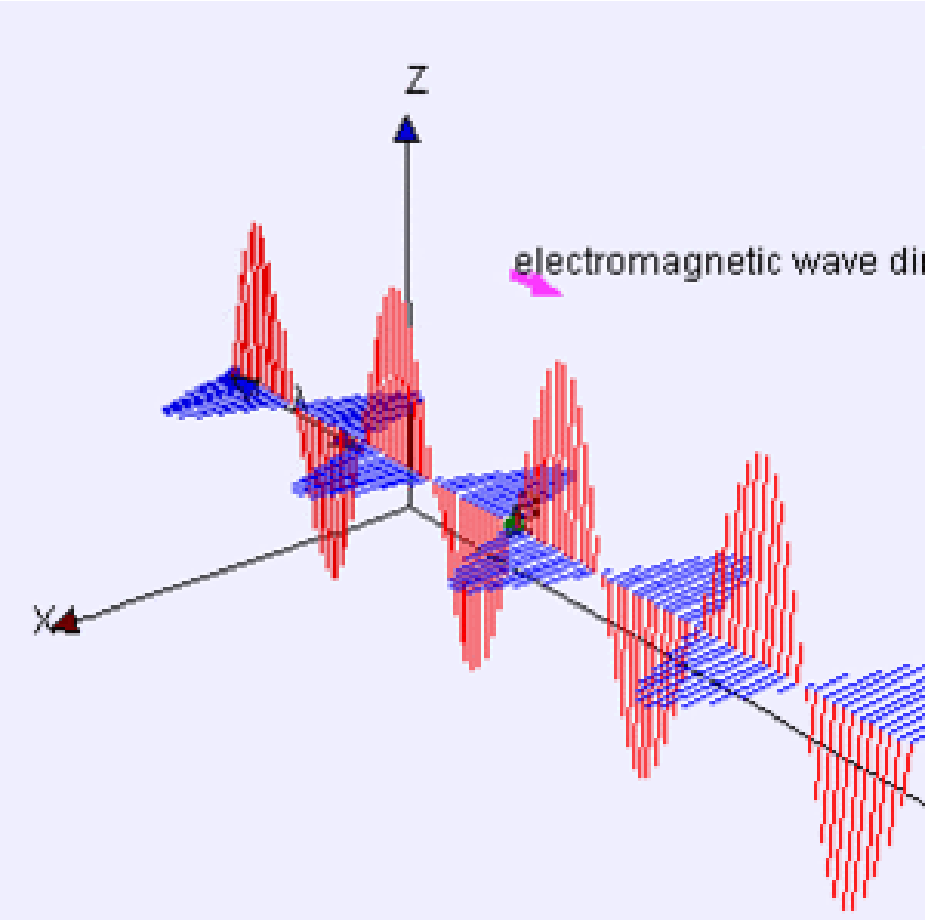


Electromagnetic Spectrum

(the main source of energy for images in use)

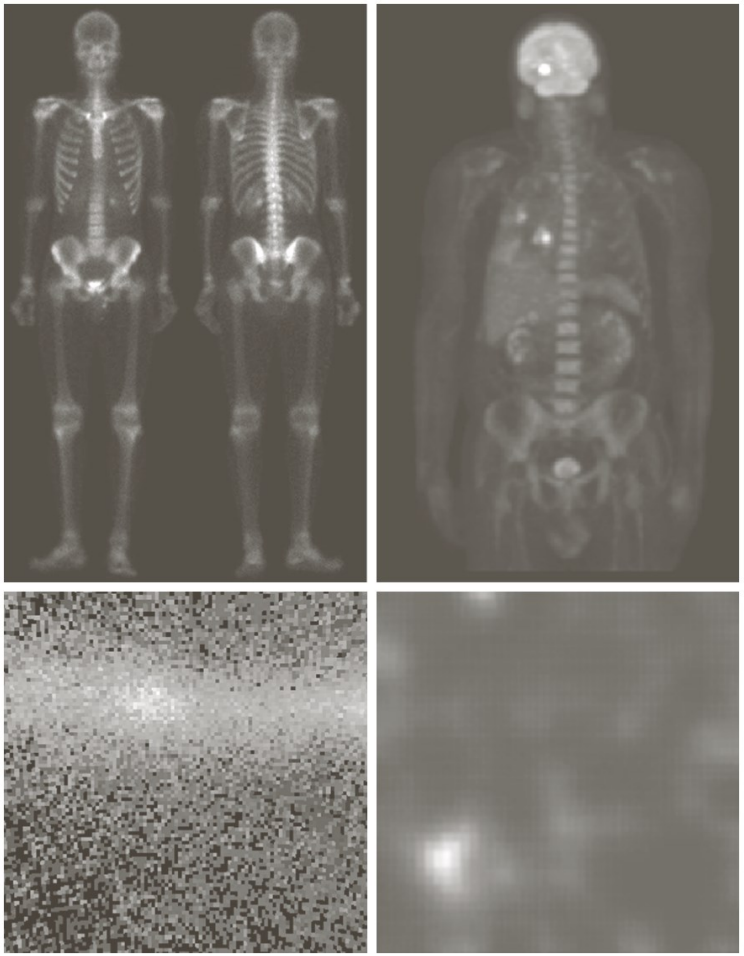


Behaviour of the Electromagnetic Waves



Imaging in Gamma ray

Applications in Nuclear medicine



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 star in the constellation of Cygnus that exploded generating gas clouds

Image of gamma radiation from a valve in a nuclear reactor

Imaging in X ray

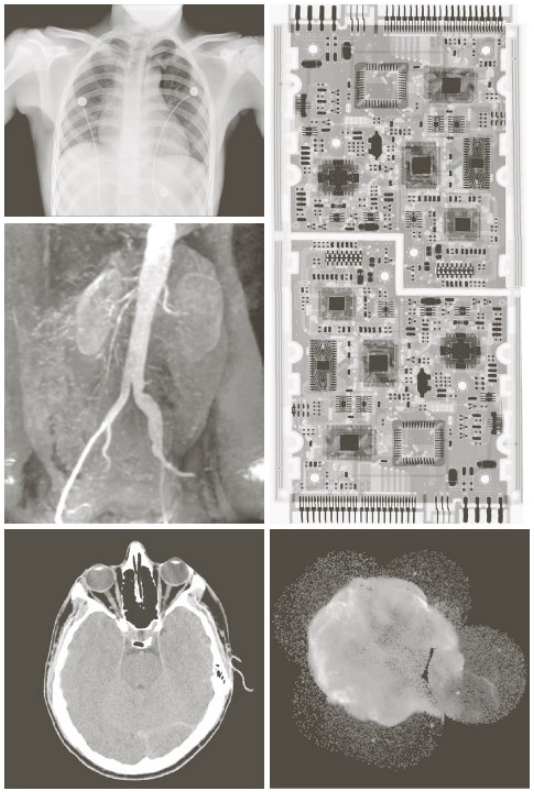
(are among the oldest sources of EM, best know use in medical diagnosis, e.g. Tomography)

(TAC industrial)

(angiography)

(TAC)

(TAC astronomic)

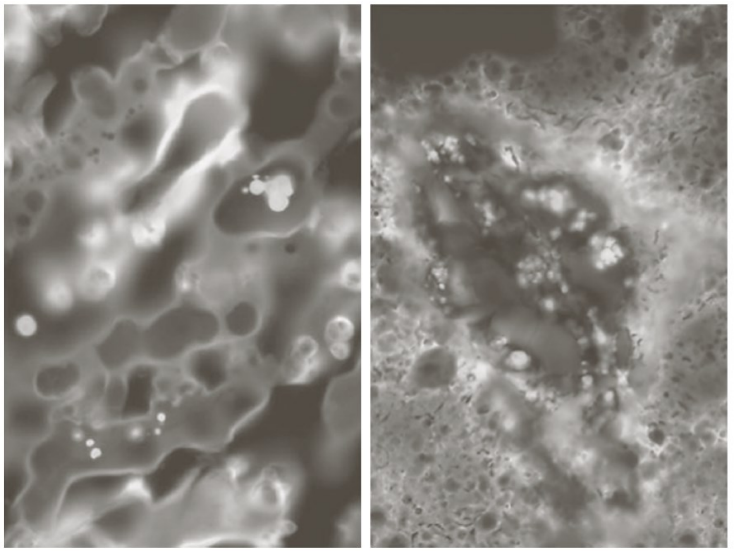


a d
b
c e

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.)

Imaging in the UV band

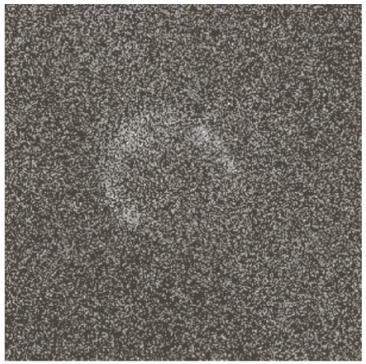
(fluorescent microscopy)



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.)

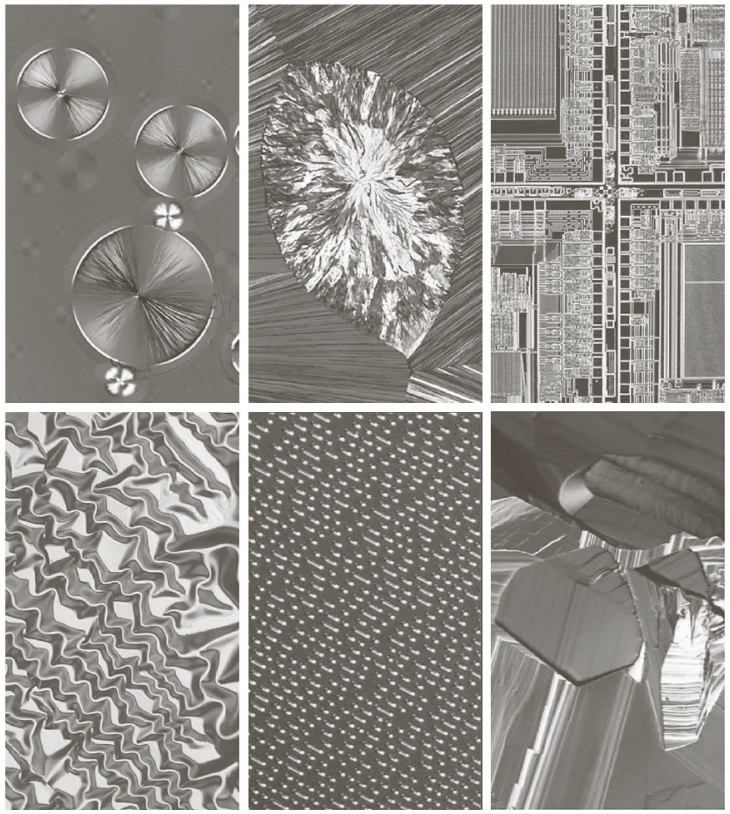
(astronomy)



(Cygnus Loop in high-region of the ultravioleta band)

Imaging in the visible and infrared Band (1)

(Images obtained with a light microscope)



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.)

These examples range from Pharmaceutical and Micro-inspection to material characterization

Imaging in the visible band (2)

Satellite image with a hurricane

Weather observation and prediction

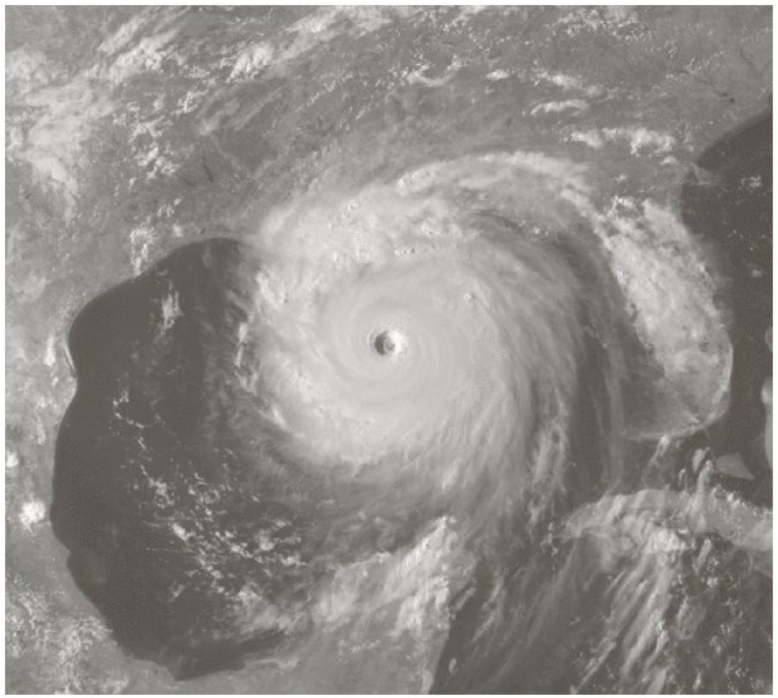
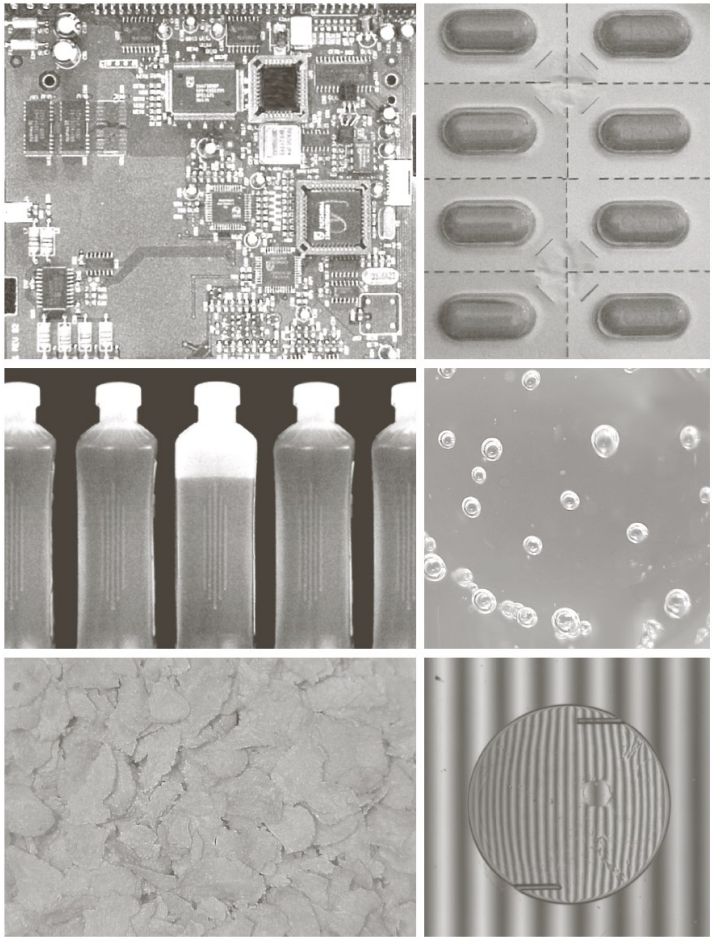


FIGURE 1.11 Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)

Imaging in the visible band (3)

Automatic visual inspection



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 (4)

(which we are more accustomed to seeing)

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 infrared band (1)

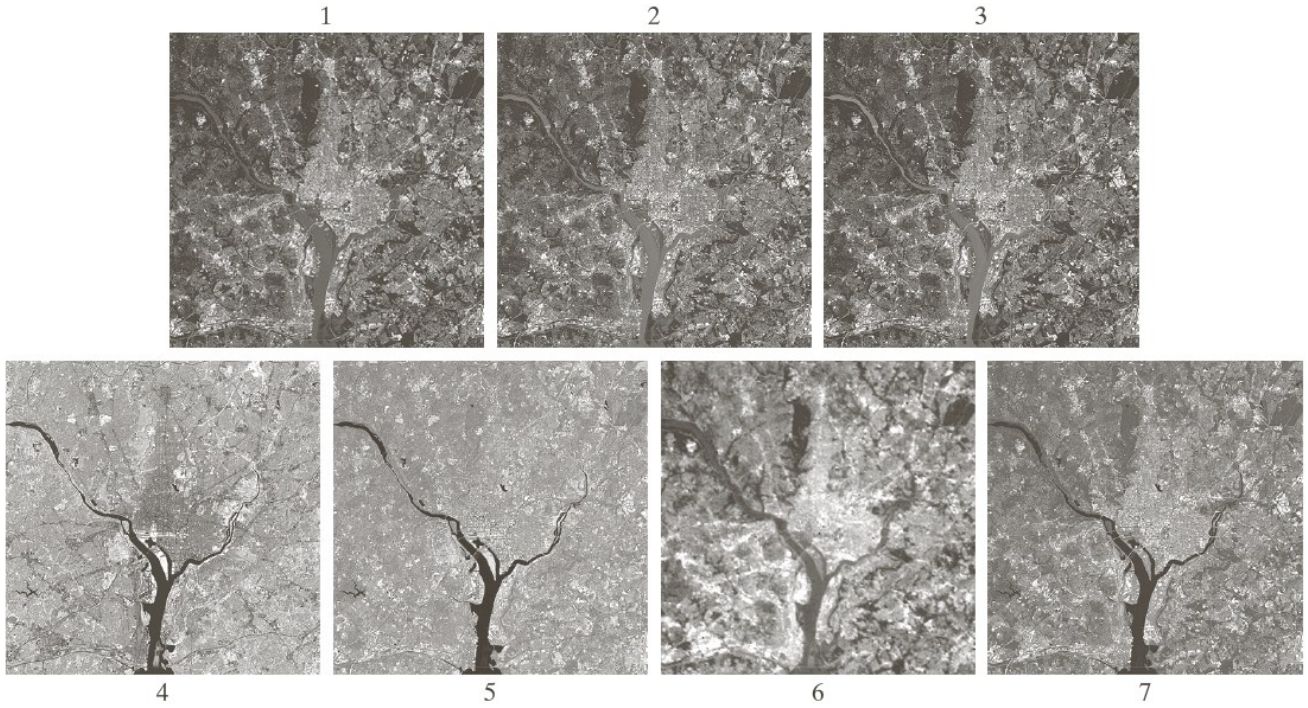


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

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.

Imaging in infrared band (2)

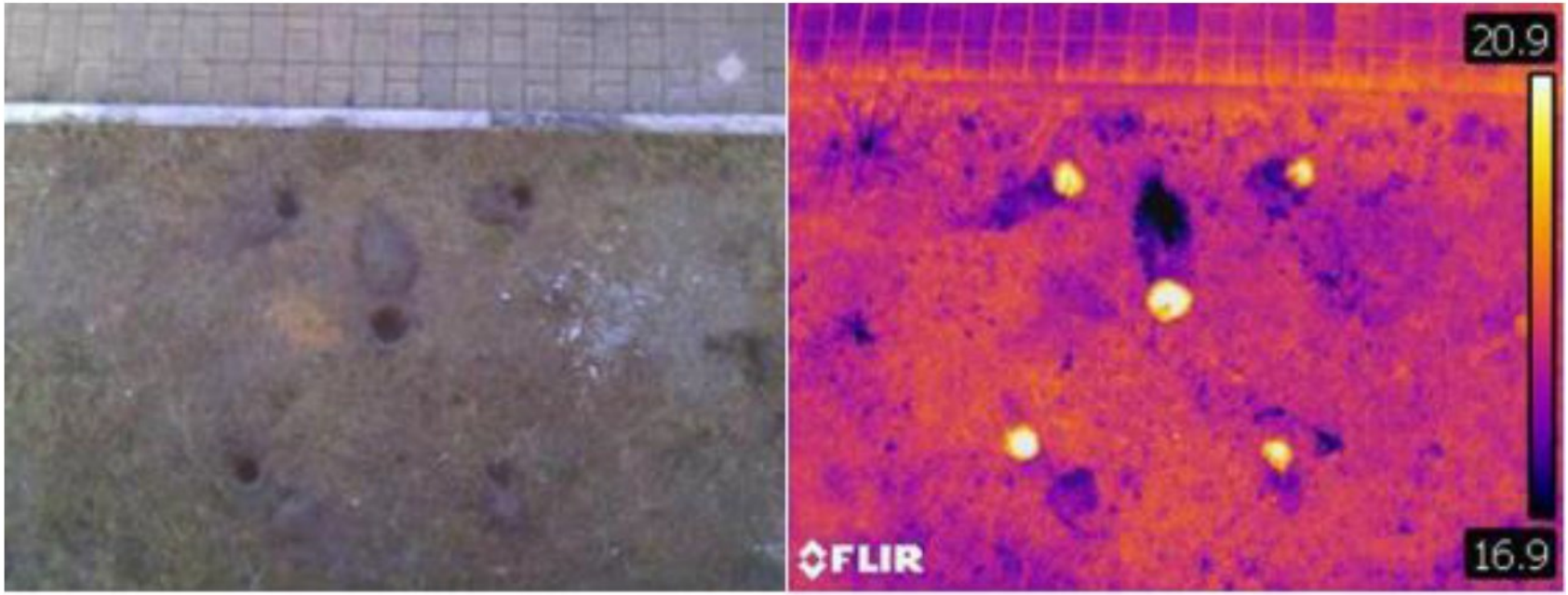
FIGURE 1.13
Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)

Unique capability to observe faint sources of visible near infrared emissions presente on Earth.

Including cities, towns, villages, gas flares and fires

Imaging in infrared band

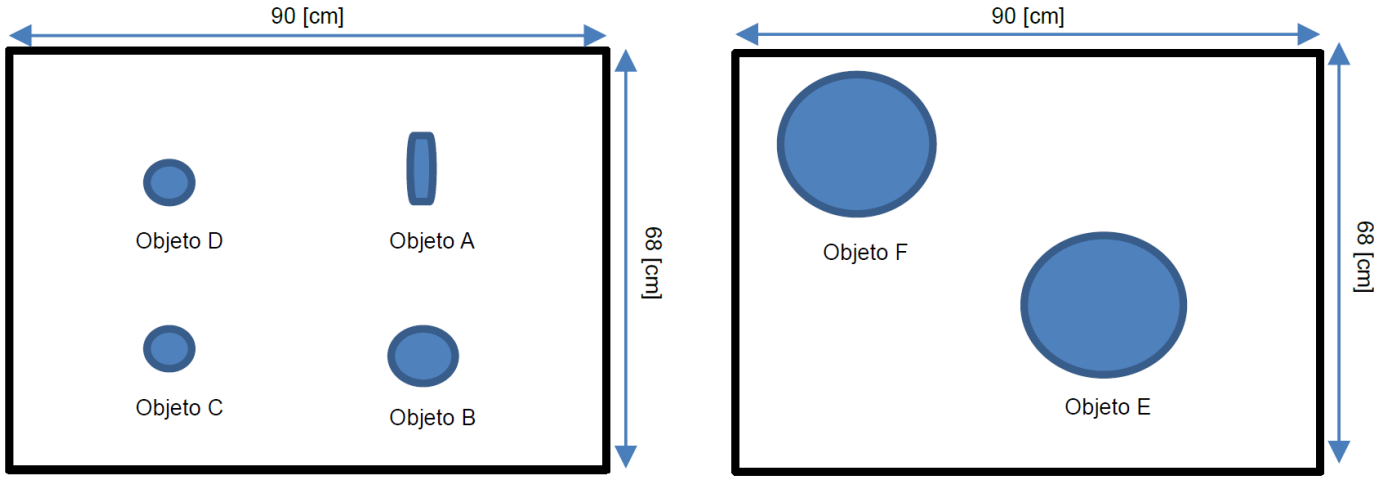
Mine detection

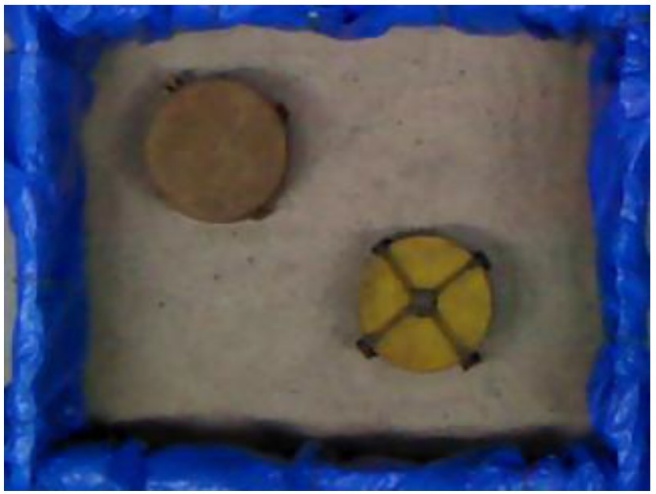


RGB image containing five mines under the ground (left), and the corresponding infra-red image (right)

Imaging in infrared band

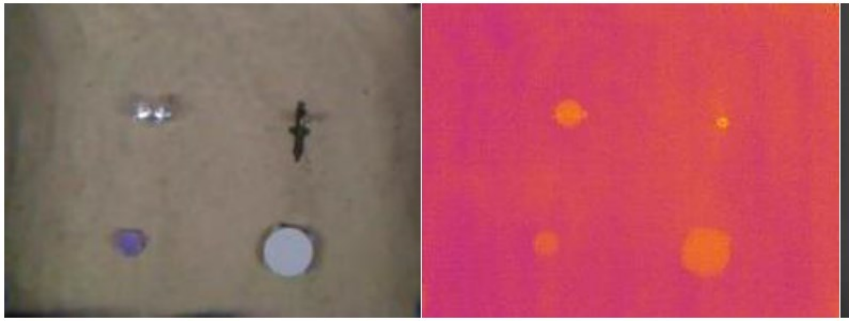
Mine detection – mine-laying diagram



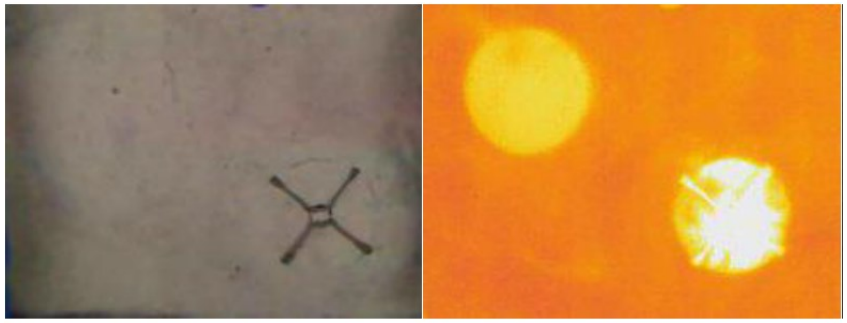


Imaging in infrared band

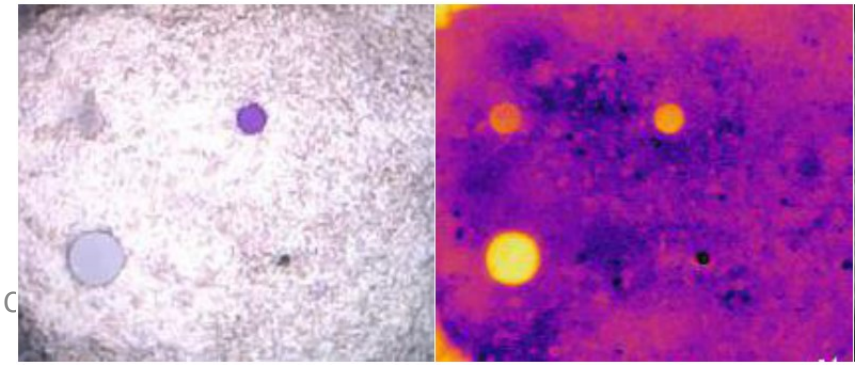
Mine detection – burying the mines



The mines are placed at the surface



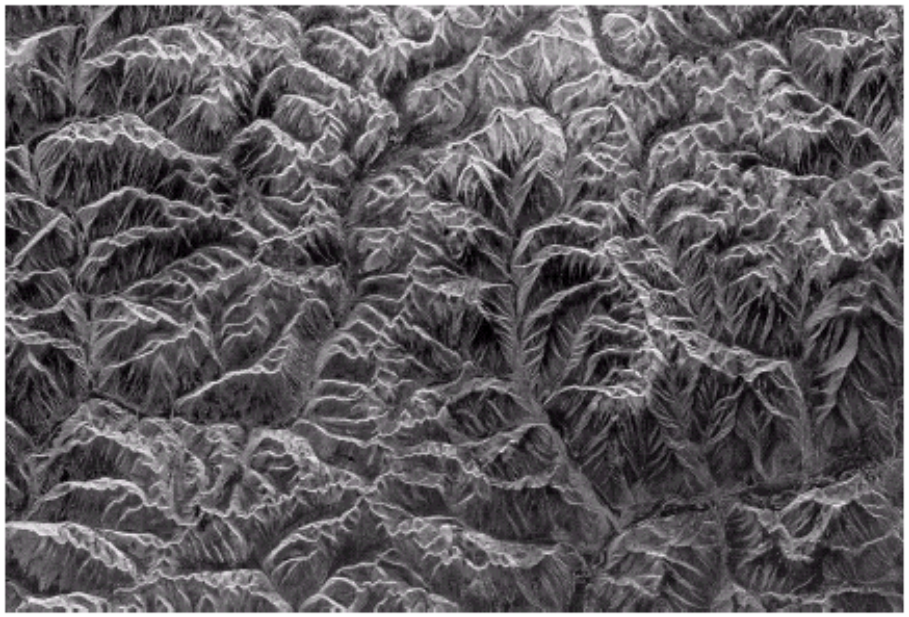
The mines are buried at 1-10 mm deeper



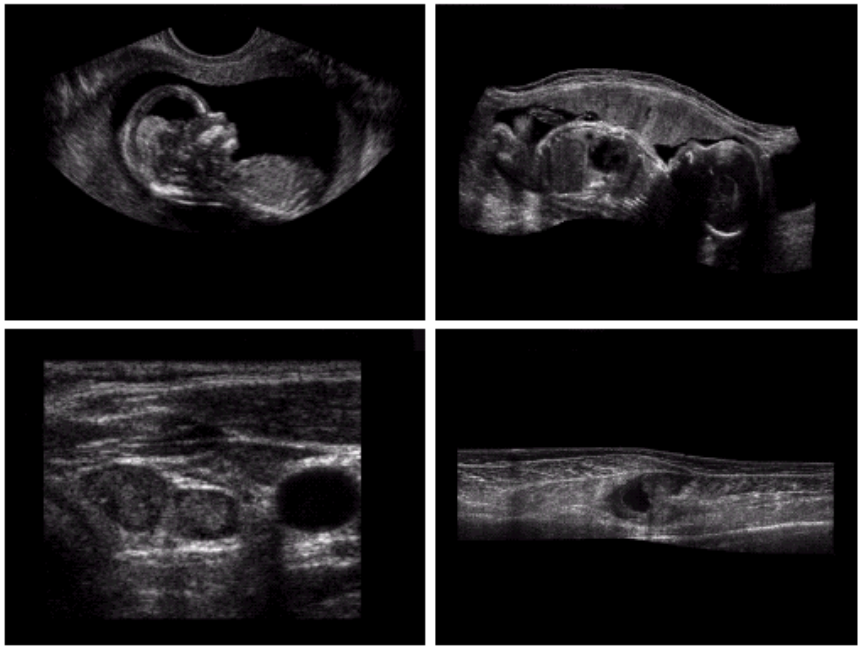
The mines are buried at 1-10 mm deeper

Imaging in the microwave band

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



Imaging in Ultrasound



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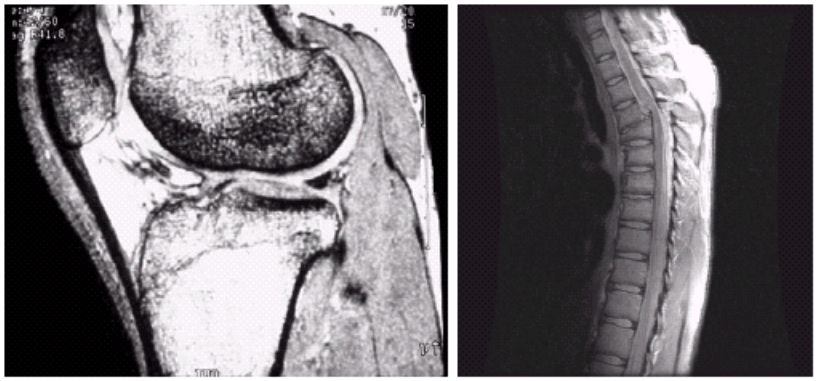
FIGURE 1.20
Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

Imaging in the radio band (I)



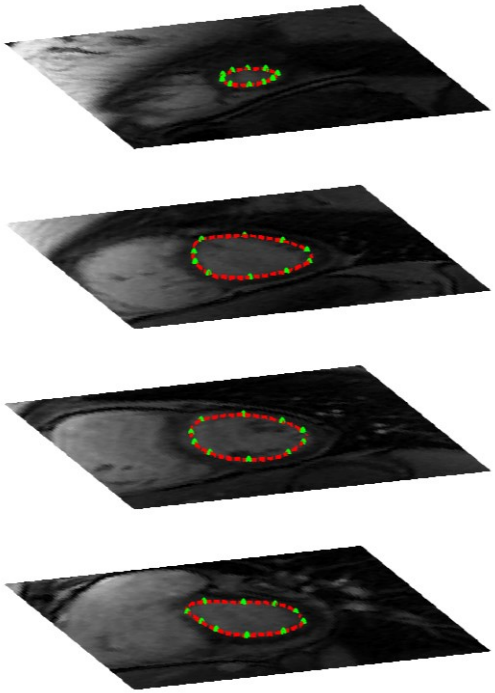
a b

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.)

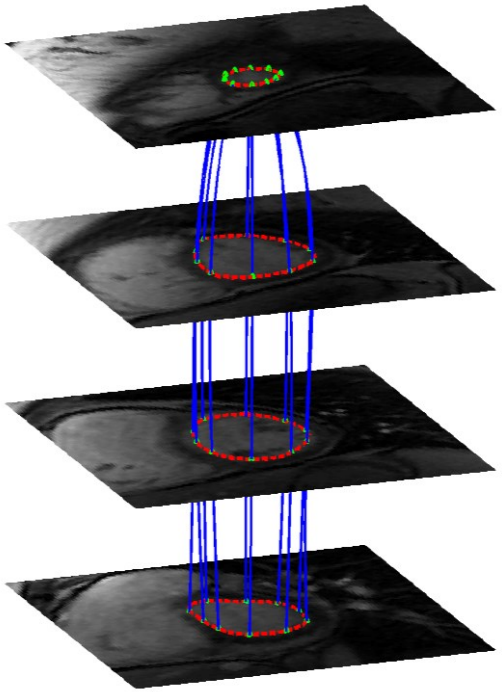
Human knee and spine (e.g. chondromalacia in the kneee)

Imaging in the radio band (II)

Available Annotations

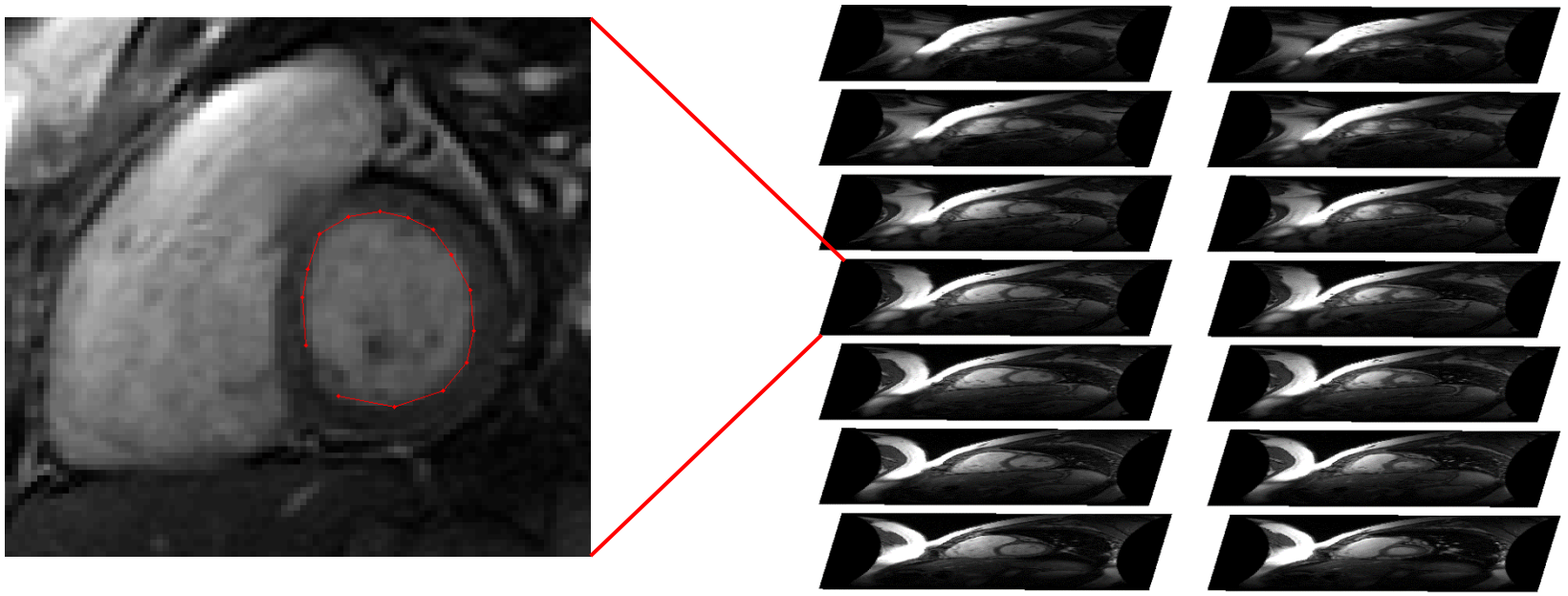


Interpolation Model



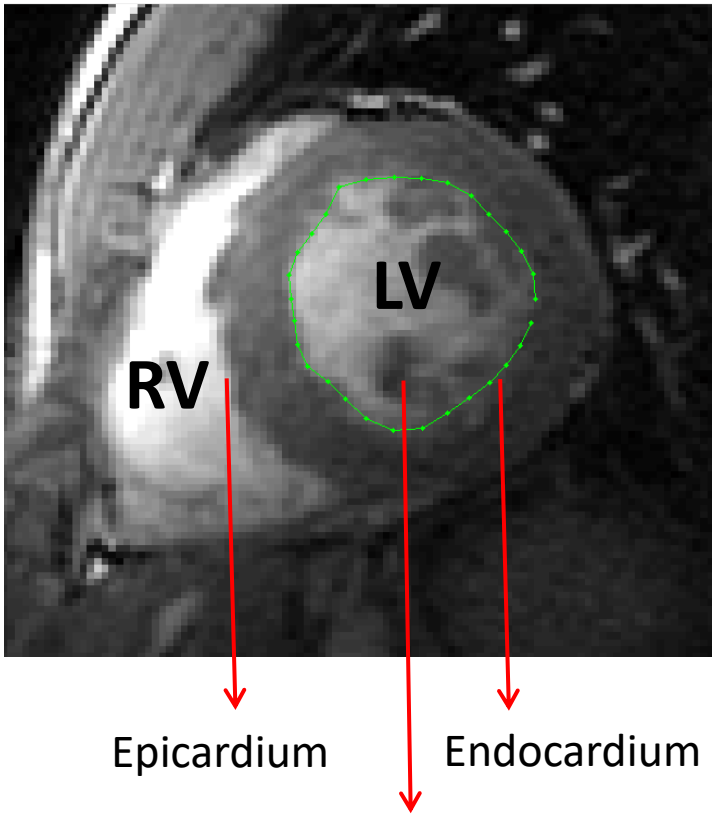
Imaging in the radio band (III)

Application to the segmentation of the endocardium of the left ventricle (in 3D)

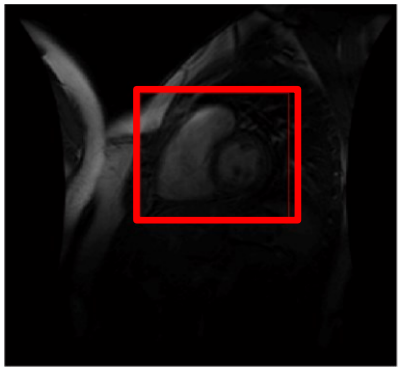


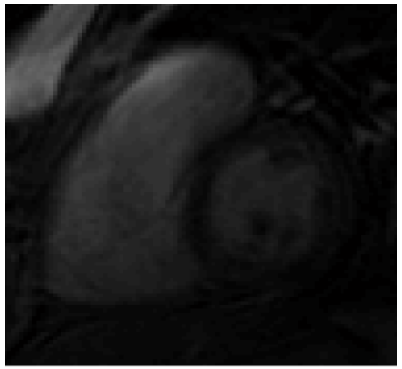
Imaging in the radio band (IV)

Goal – Segmenting the endocardium of hte LV

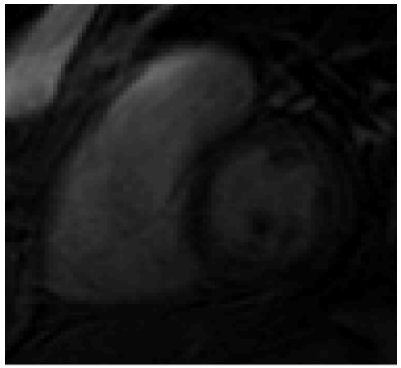


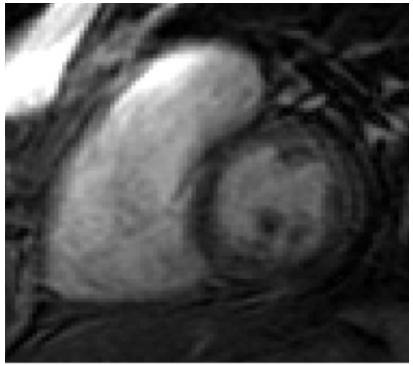
1) ROI (region of interest)



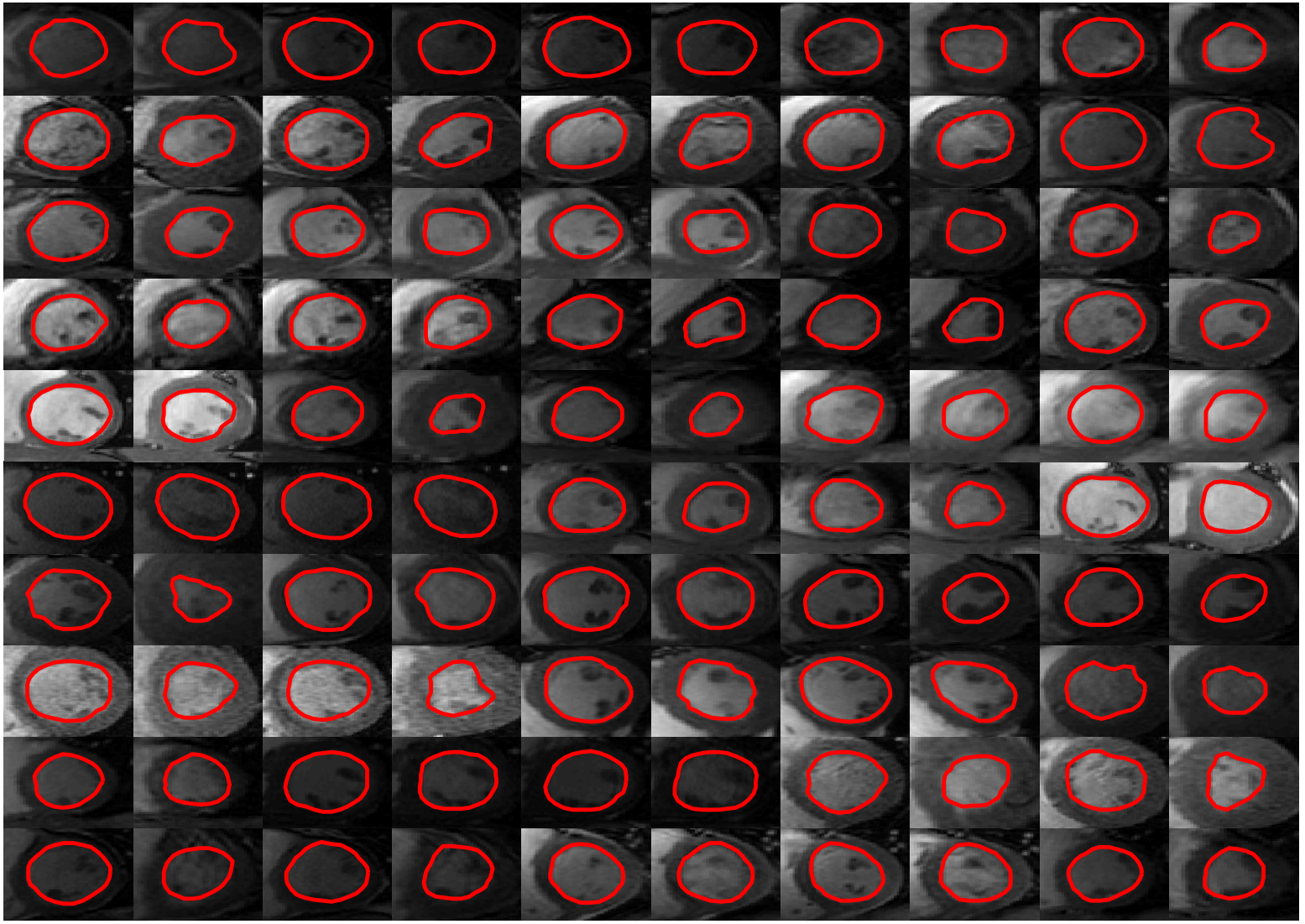


2) Adjustment of the intensity





Imaging in the radio band (V)



Imaging in several bands

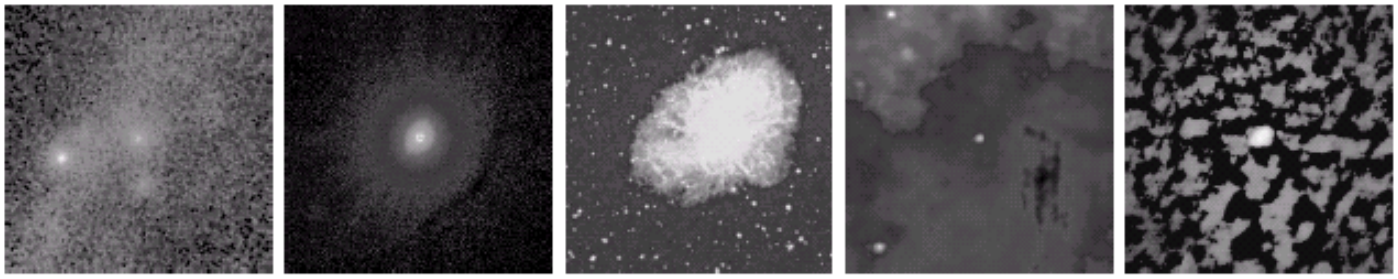
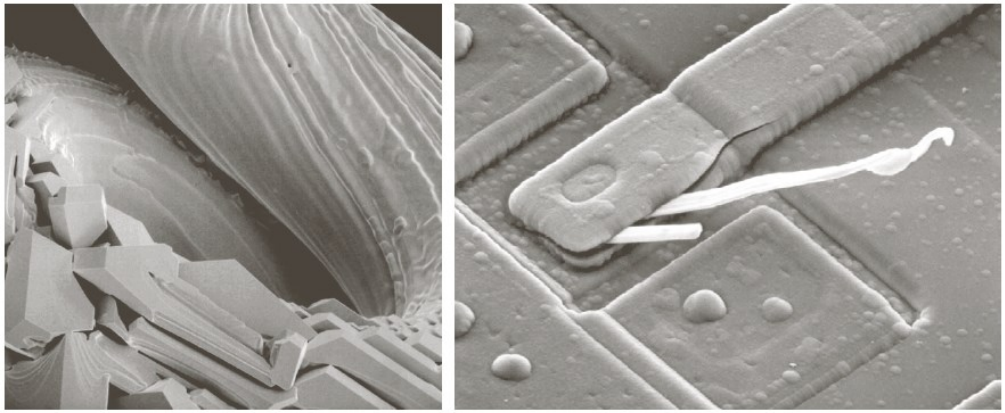


FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

Images of the Crap Pulsar, that is a star. Notice that, there is a sifnificant difference of the same region, if we change the image modality.

Image Scanning electron microscope (SEM)

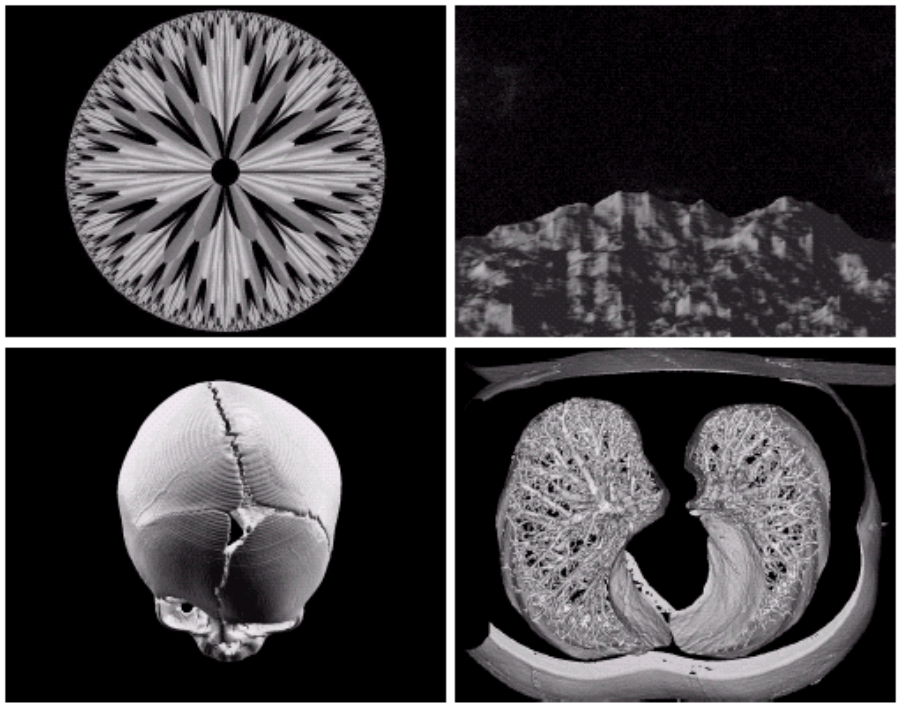


a b

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.)

Synthetic images

(Images that are not obtained from the physical properties of the objects)



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.)

Components of an Image Processing System

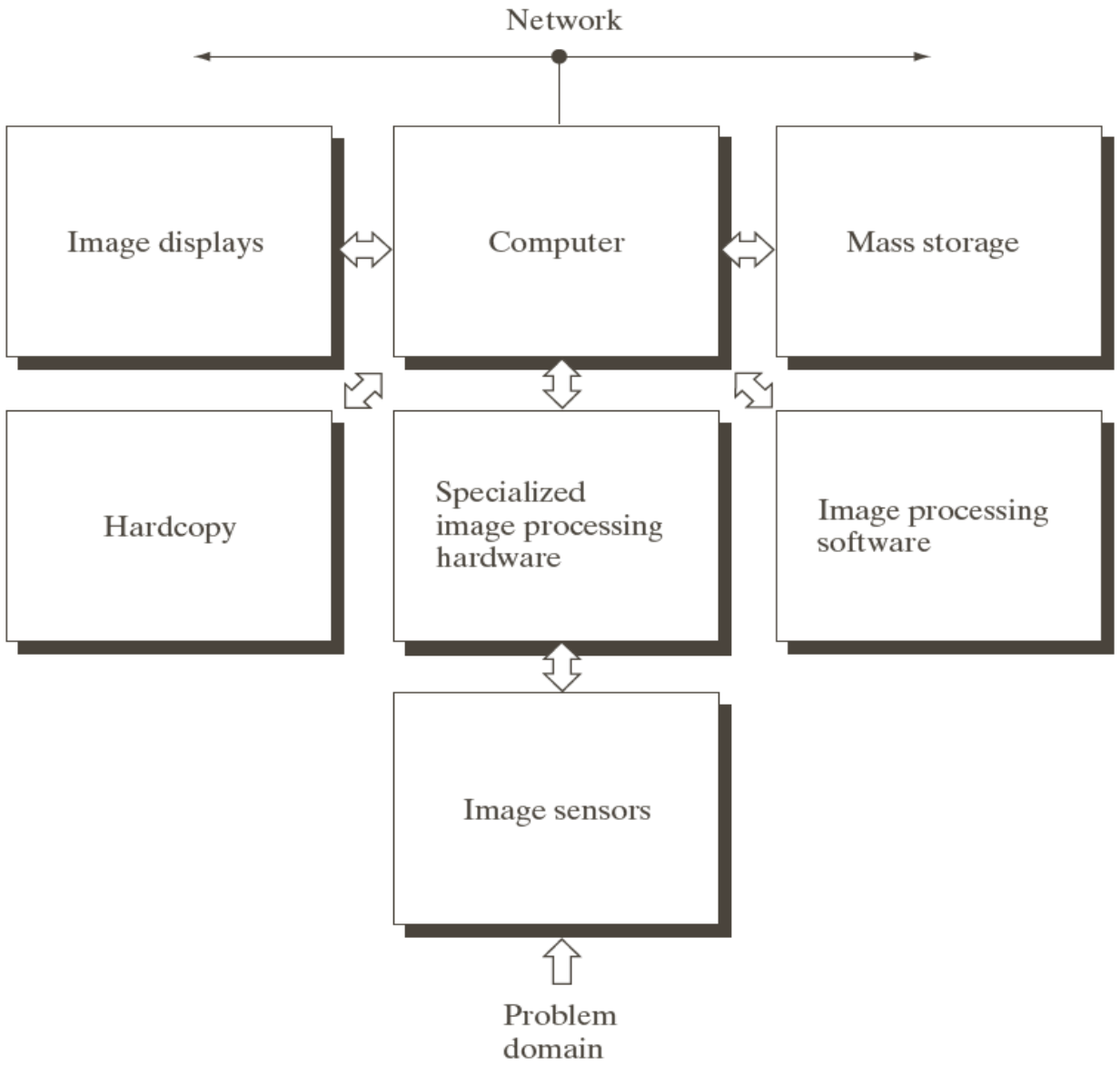


FIGURE 1.24
Components of a general-purpose image processing system.

Readings

- Chapter 1 de R. Gonzalez, R. Woods, “Digital Image Processing”, 3rd edition, 2008.