Indian Institute of Information Technology, Surat
भारतीय सूचना प्रौद्योगिकी संस्थान ,सूरत
(Institute of National Importance under Act of Parliament)

EC 503:

Image Processing and Computer Vision

By:
Dr. Hemant S. Goklani
IIIT, Surat

UNIT - I

Introduction

"One picture is worth more than ten thousand words"

-Anonymous

Recommended Books

1. Gonzalez R. C. and Woods R. E, "Digital Image Processing", Pearson Prentice Hall, 3n1 Ed., 2008.
2. Linda Shapiro and Stockman George, "Computer Vision", Prentice Hall, 15t Ed., 2001.
3. Forsyth D. and Ponce J., "Computer Vision - A Modern Approach", Prentice-Hall, 1st Ed., 2003.
4. Sonka M. Hlavac V., Boyle R., "Image Processing, Analysis and Machine Vision", Cengage Learning, 2r4 Indian Reprint, 2009.
5. Jain R., Kasturi R. and Schunk B., "Machine Vision", McGraw - Hill, 1st Ed., 1995.
6. Jain A. K., "Fundamentals Of Digital Image Processing", PHI, 1st Ed., 1989.
7. Ballard D. H. and Brown C. N., "Computer Vision", Prentice Hall, 1st Ed., 1982.

UNIT - I

- ***Introduction:***

- Digital Image,

- Image Processing Origins; Imaging In X-Rays, Ultraviolet, Visible Infra red, visible, Microwave And Radio Bands

-

- Fundamentals Of Image Processing

- Components Of Image Processing Systems.

UNIT - I

- ***Digital Image Fundamentals***:

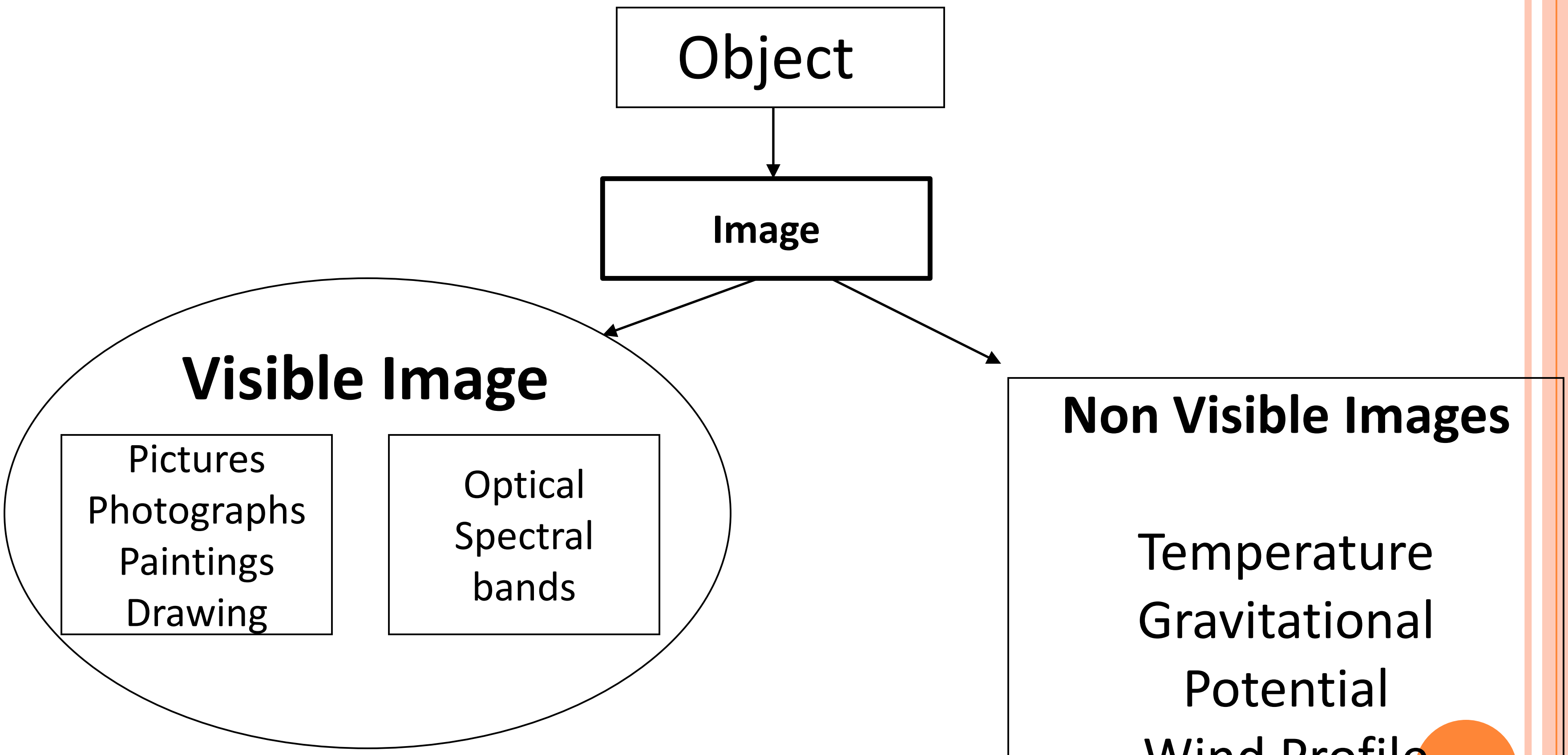
- Visual Perception — Human Eye, Brightness Adaptation And Discrimination, Electromagnetic Spectrum;
- Image Sensing And Acquisition — Single, Strip And Array Sensors,
- Image Formation Models; Image Sampling And Quantization — Basic Concepts, Representation Of Image, Special And Gray Level Resolution, Aliasing, Zooming And Shrinking;
- Relationships Between Pixels — Nearest Neighbor, Adjacency, Connectivity, Regions, And Boundaries; Distance Measures;
- Image Operations On A Pixel Basis; Linear And Nonlinear Operations.

What is IMAGE?

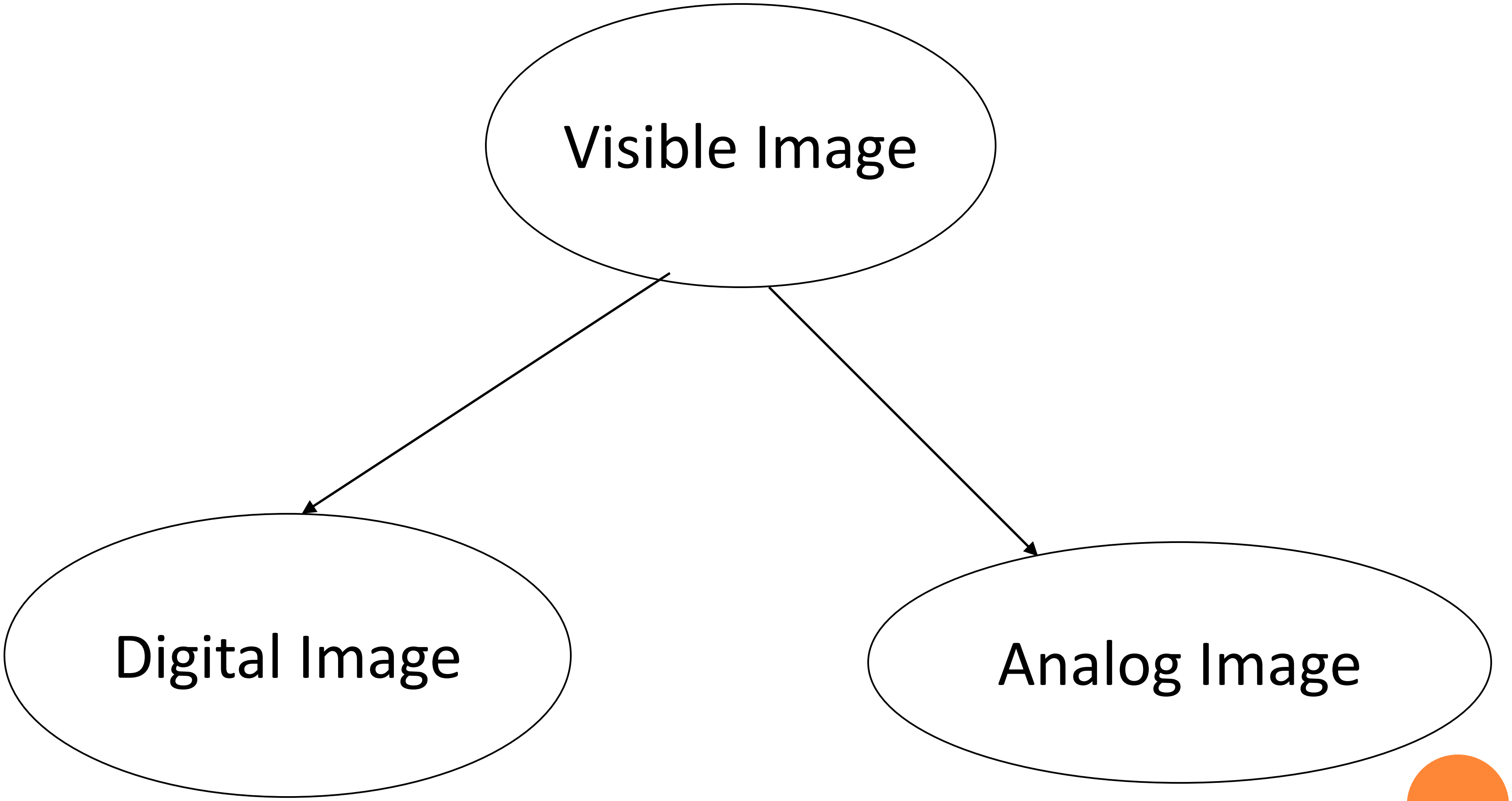
- **“What we see and/or feel is an image” -- (Layman)**

- **“An image is a representation, likeness, or imitation of an object or thing, a vivid or graphic description, something introduced to represent something else” – (Webster dictionary)**

CLASSIFICATION OF IMAGES



Classification of Images



Digital Image

- An image is 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 grey 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 a digital image.
- The field of digital image processing refers to processing digital images by means of a digital computer/processor.
- Digital image is composed of a finite number of elements, which has a particular location and values referred as a picture elements, image elements, pels or pixels

Digital Image representation

Image “After snow storm”

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

The Origins of Digital Image Processing

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. (McFarlane.)

One of the first application areas of digital images was newspapers industries (cable between London and NY)

Important to reduce transfer time

Digital computers: 1940
1st computer able to do digital image manipulations: early 1960

The Origins of Digital Image Processing

- The early Bartlane systems were capable of coding images in five distinct levels of gray. This capability was increased to 15 levels in 1929

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

The Origins of Digital Image Processing

- Fig. shows the first image of the moon taken by *Ranger 7* on July 31, 1964 at 9:09 A.M. Eastern Daylight Time (EDT), about 17 minutes before impacting the lunar surface

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.)

Examples of Fields that Use Digital Image Processing

- Almost each and every area of technical endeavor that is impacted in some way by digital image processing

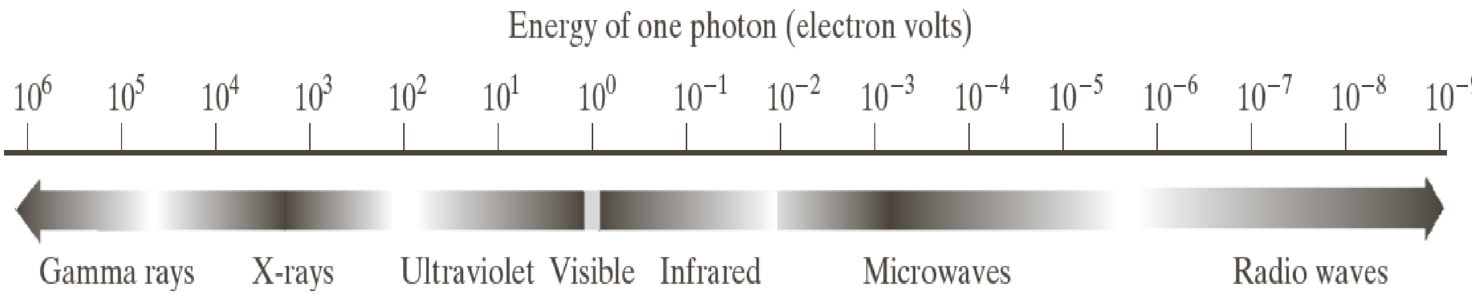


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

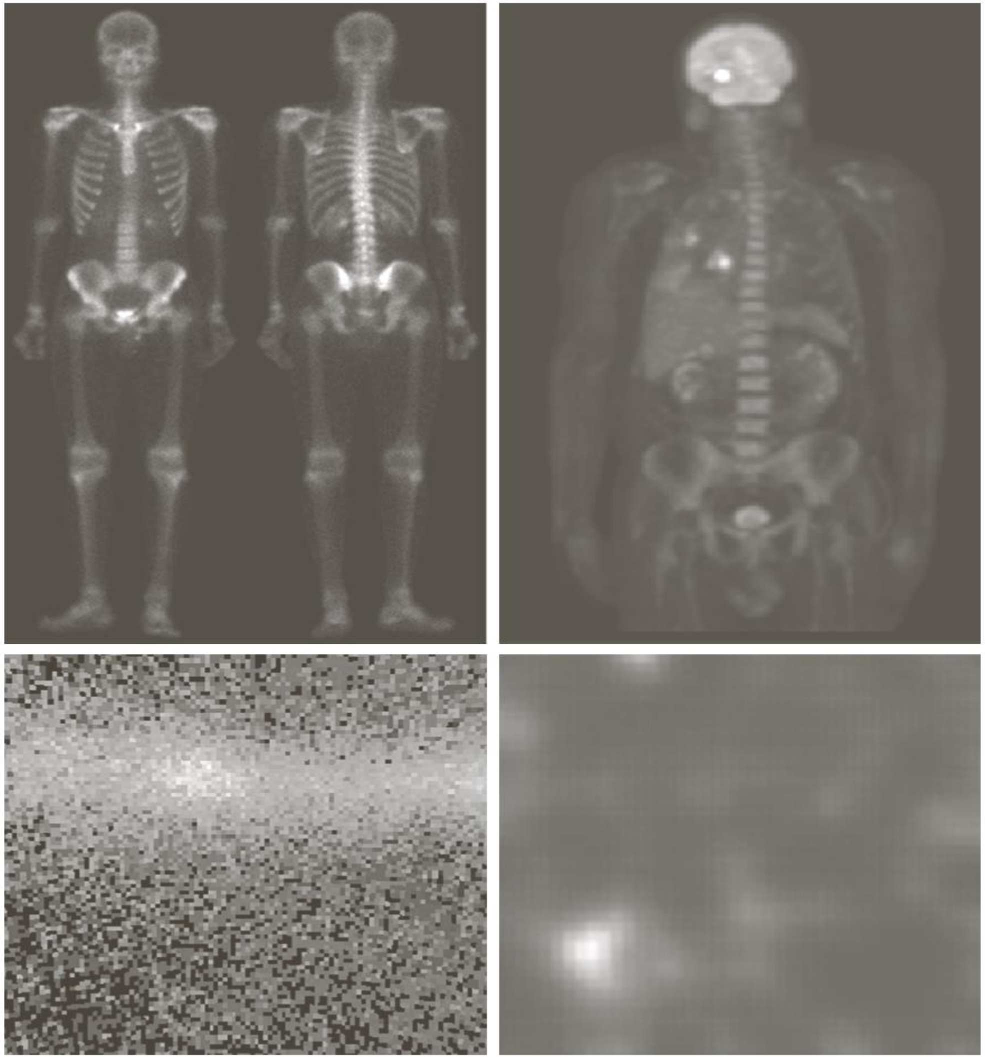
Principal energy source for images today: electromagnetic energy spectrum.

Gamma-Ray Imaging

Gamma rays:

Nuclear medicine (injection of radioactive tracer)

Astronomical observations (object generate gamma rays)



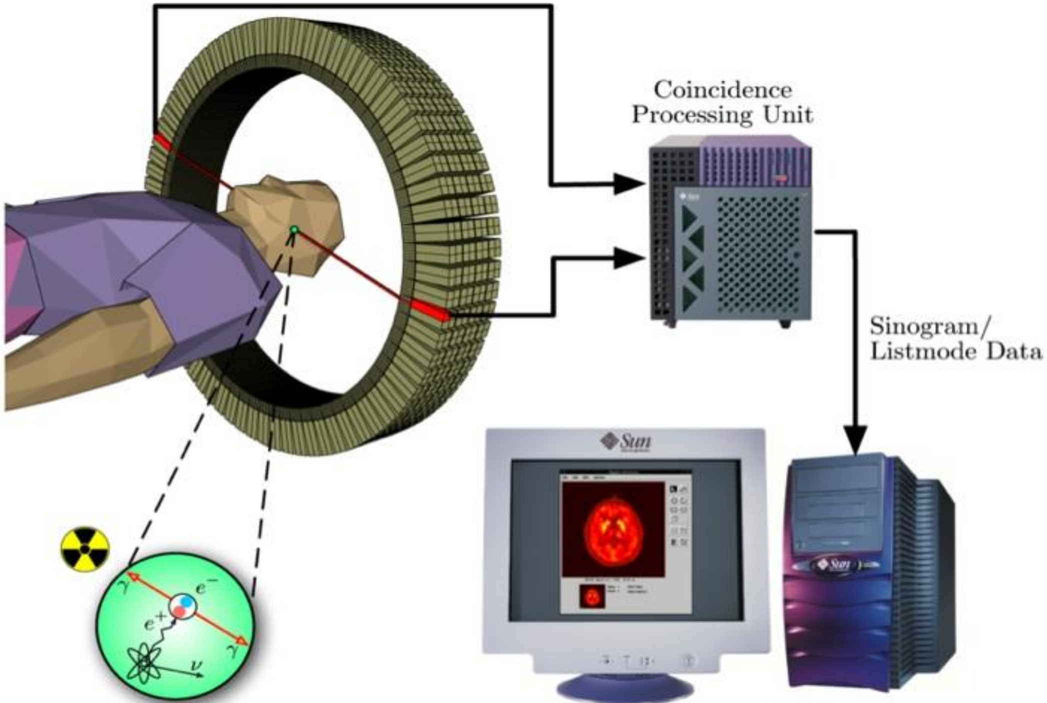
a b
c d

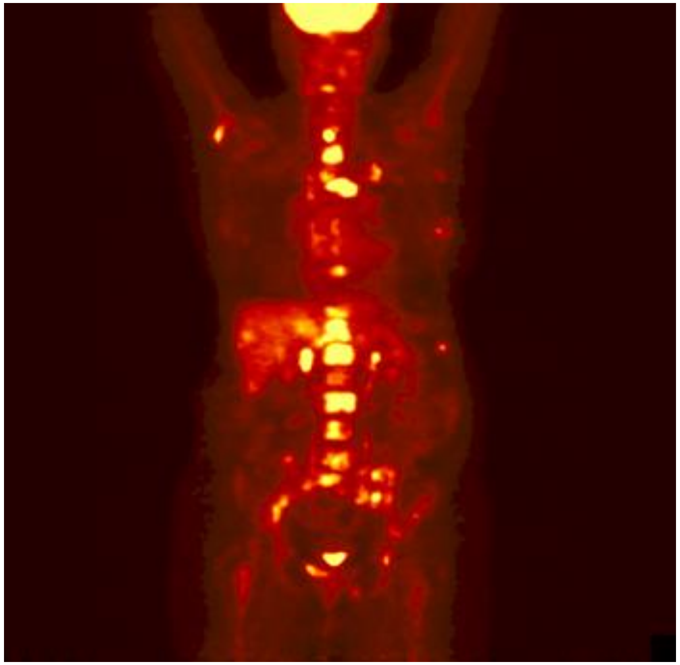
FIGURE 1.6 Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of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

Gamma-Ray Imaging

PET = Positron Emission Tomography

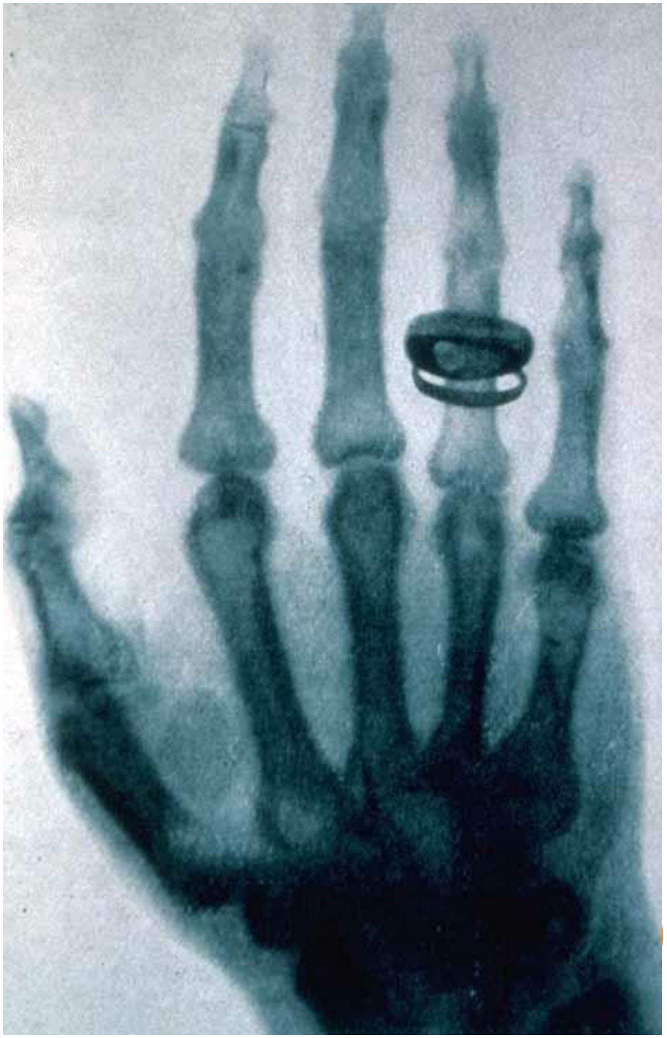
imaging at molecular level





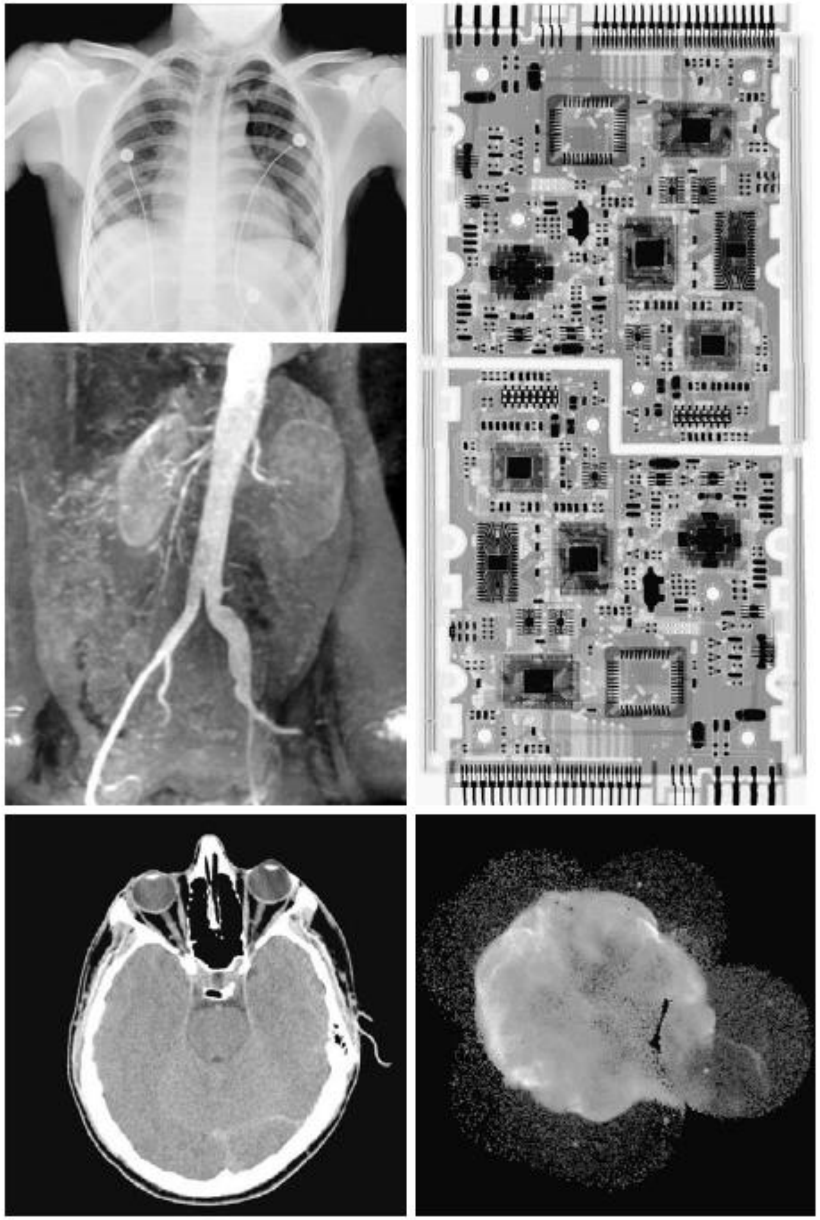
X-Ray Imaging

- X-rays are among the oldest sources of EM radiation used for imaging
- Discovered in 1895 by German physicist William Roentgen (Nobel prize in physics, 1901) - used in medicine/industry/astronomy
- X-ray tube (catode/anode, controlled by voltage), emitting ray, absorption by object, rest captured onto a film, digitized
- C.A.T. (Computerized Axial Tomography) uses X-rays.



An x-ray picture (radiograph) taken by Röntgen of [Albert von Kölliker]'s hand at a public lecture on 23 January 1896

EXAMPLES OF X-RAY IMAGING



a d
b
c e

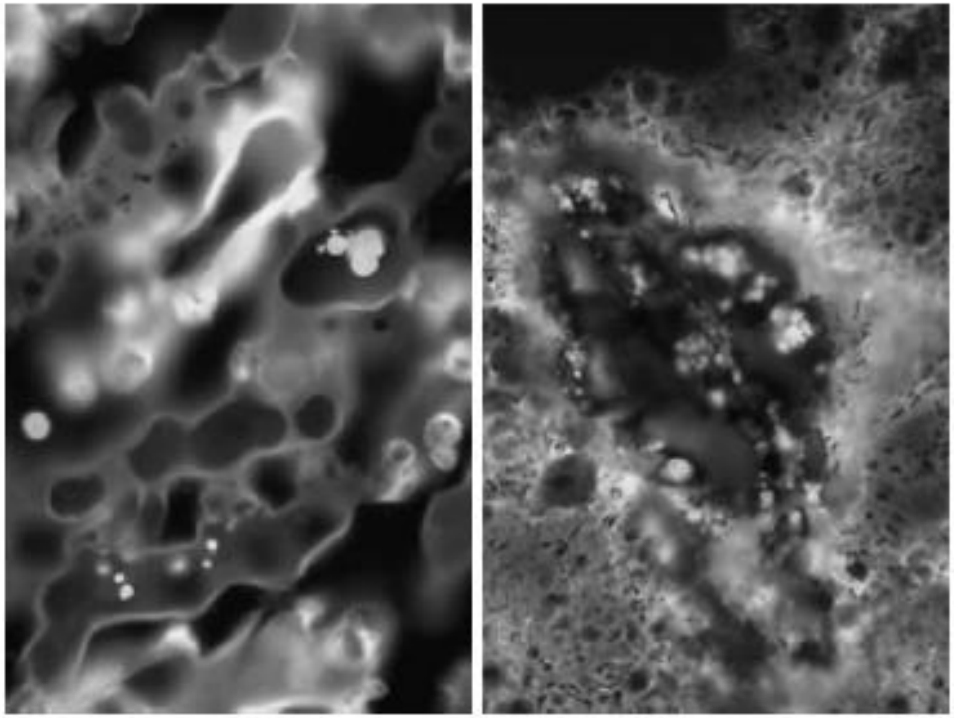
FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of Anatomical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

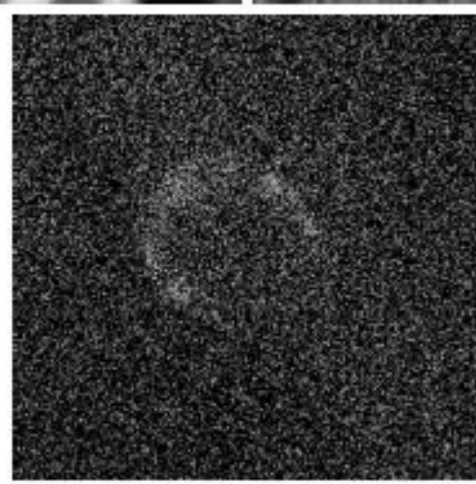
Imaging in the Ultraviolet Band

- Applications of ultraviolet “light” are varied. They include lithography, industrial inspection, microscopy, lasers, biological imaging, and astronomical observations

- Fluorescence microscopy is an excellent method for studying materials that can be made to fluoresce, either in their natural form (primary fluorescence) or when treated with chemicals capable of fluorescing (secondary fluorescence)

Examples of 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.)

Ultraviolet band:

microscopy (fluorescence)

the excited electron jumps to another energy level emitting light as a low-energy photon in the red region

Lasers:

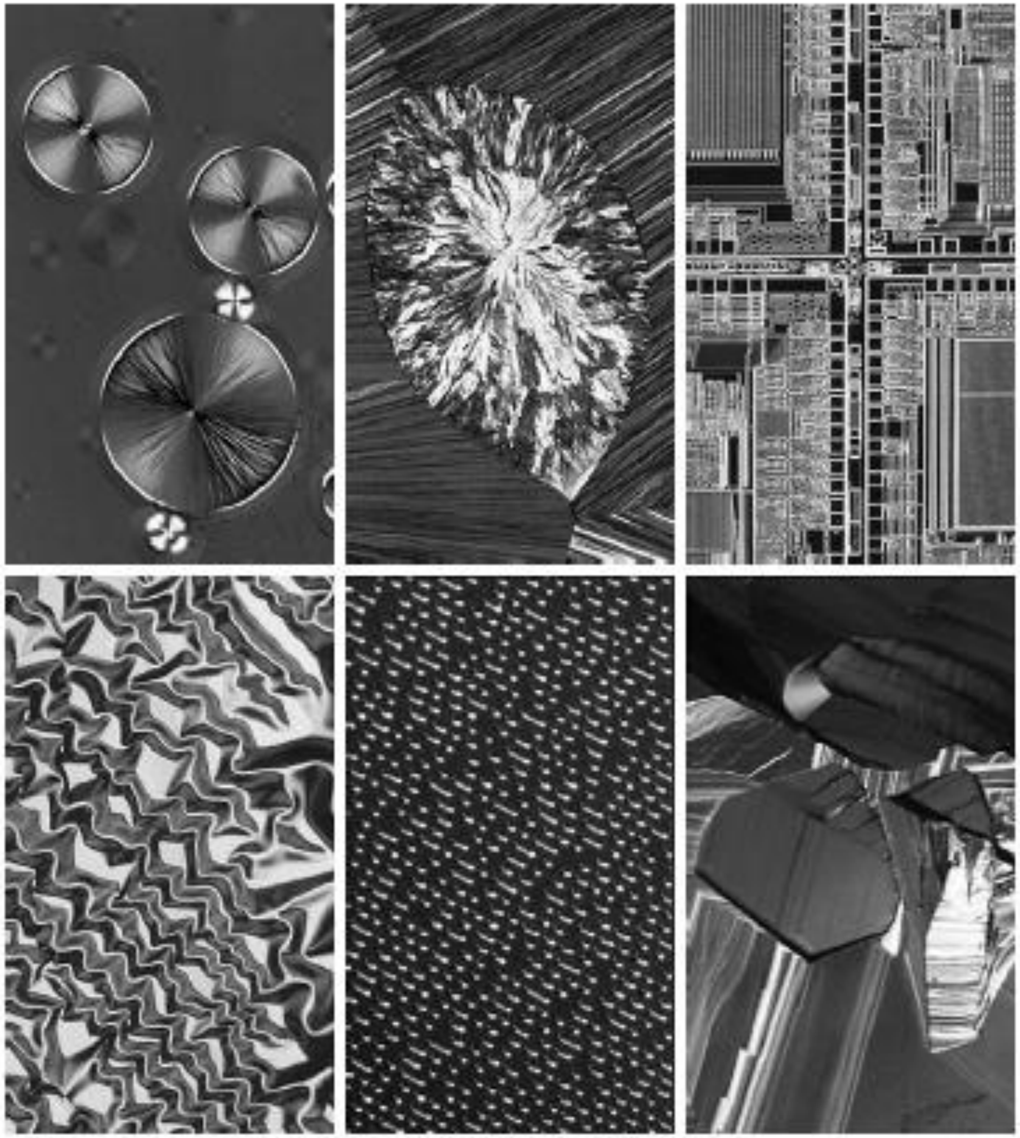
biological imaging
astronomical imaging
industrial inspections

Imaging in the Visible and Infrared Bands

- Considering that the visual band of the electromagnetic spectrum is the most familiar in all our activities, it is not surprising that imaging in this band outweighs by far all the others in terms of breadth of application

- The infrared band often is used in conjunction with visual imaging

EXAMPLES OF 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.)

INFRARED: REMOTE SENSING, WEATHER PREDICTION, SATELLITE SENSING/ NIGHT VISION

- 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

LANDSAT SATELLITE IMAGES OF THE WASHINGTON, D.C. AREA

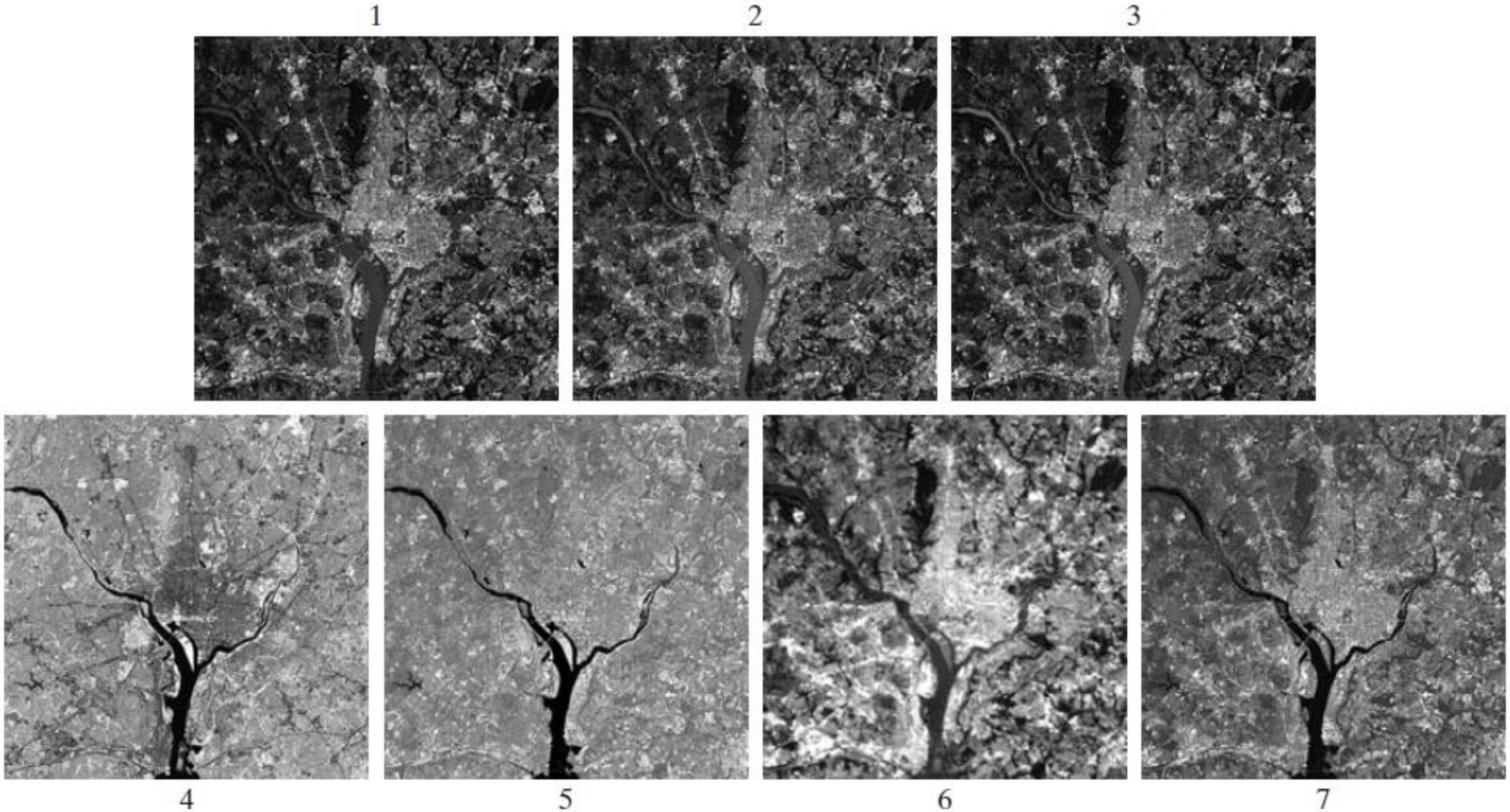


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

WEATHER OBSERVATION AND PREDICTION

- Weather observation and prediction also are major applications of multispectral imaging from satellites

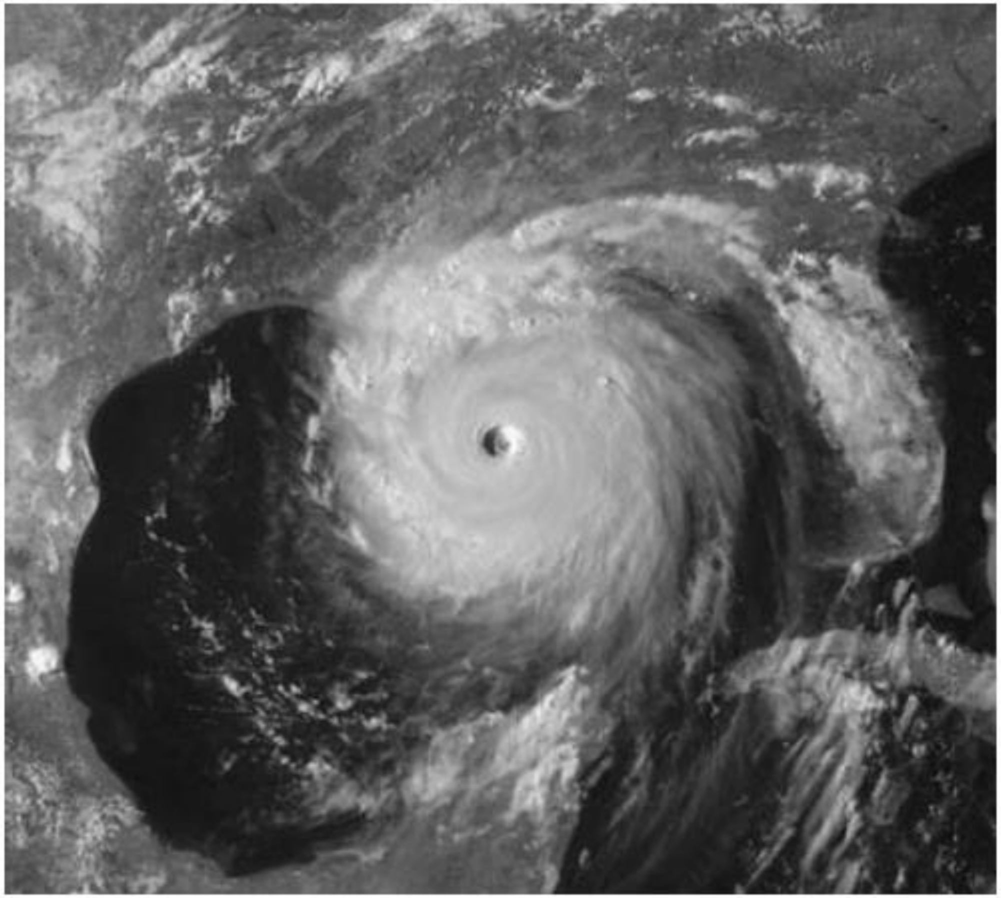
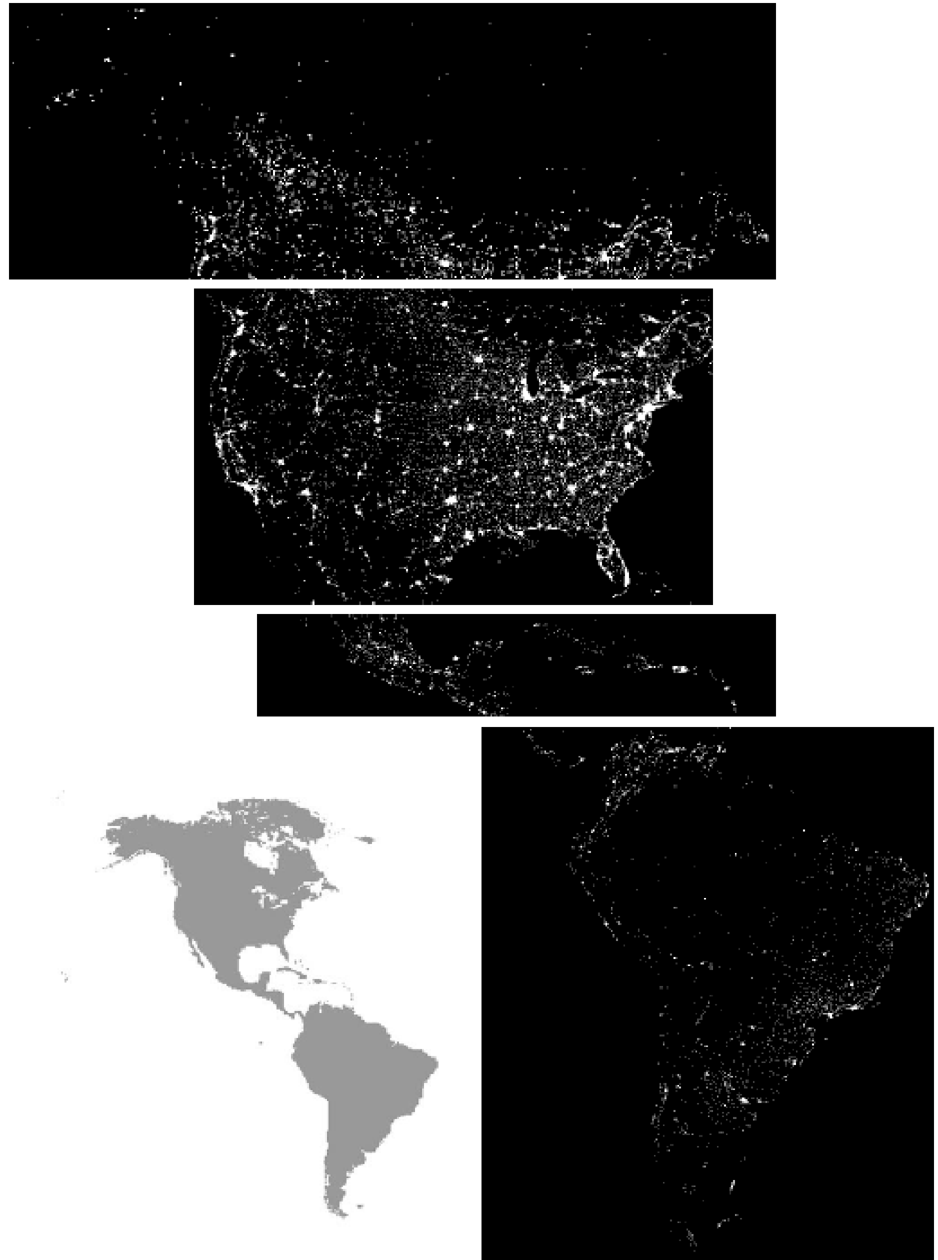


FIGURE 1.11 Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)

EXAMPLES OF INFRARED SATELLITE IMAGES

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



Examples of infrared satellite images

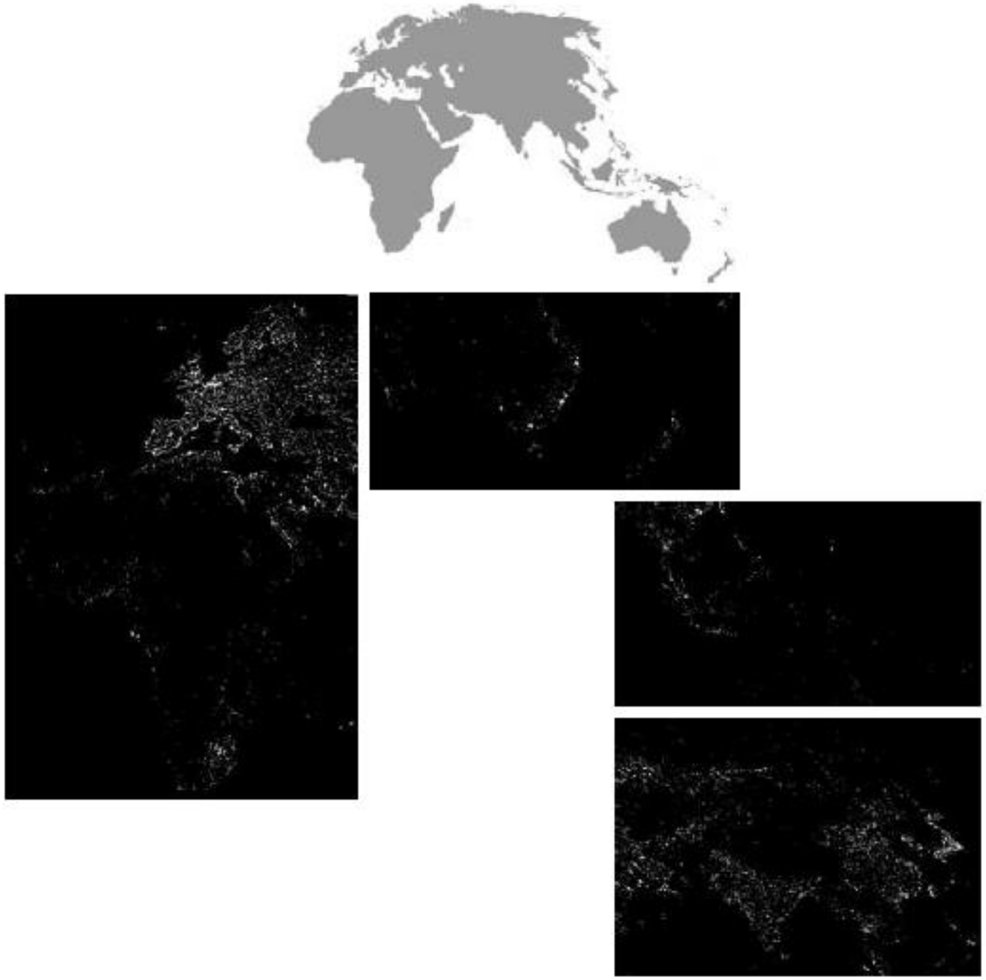
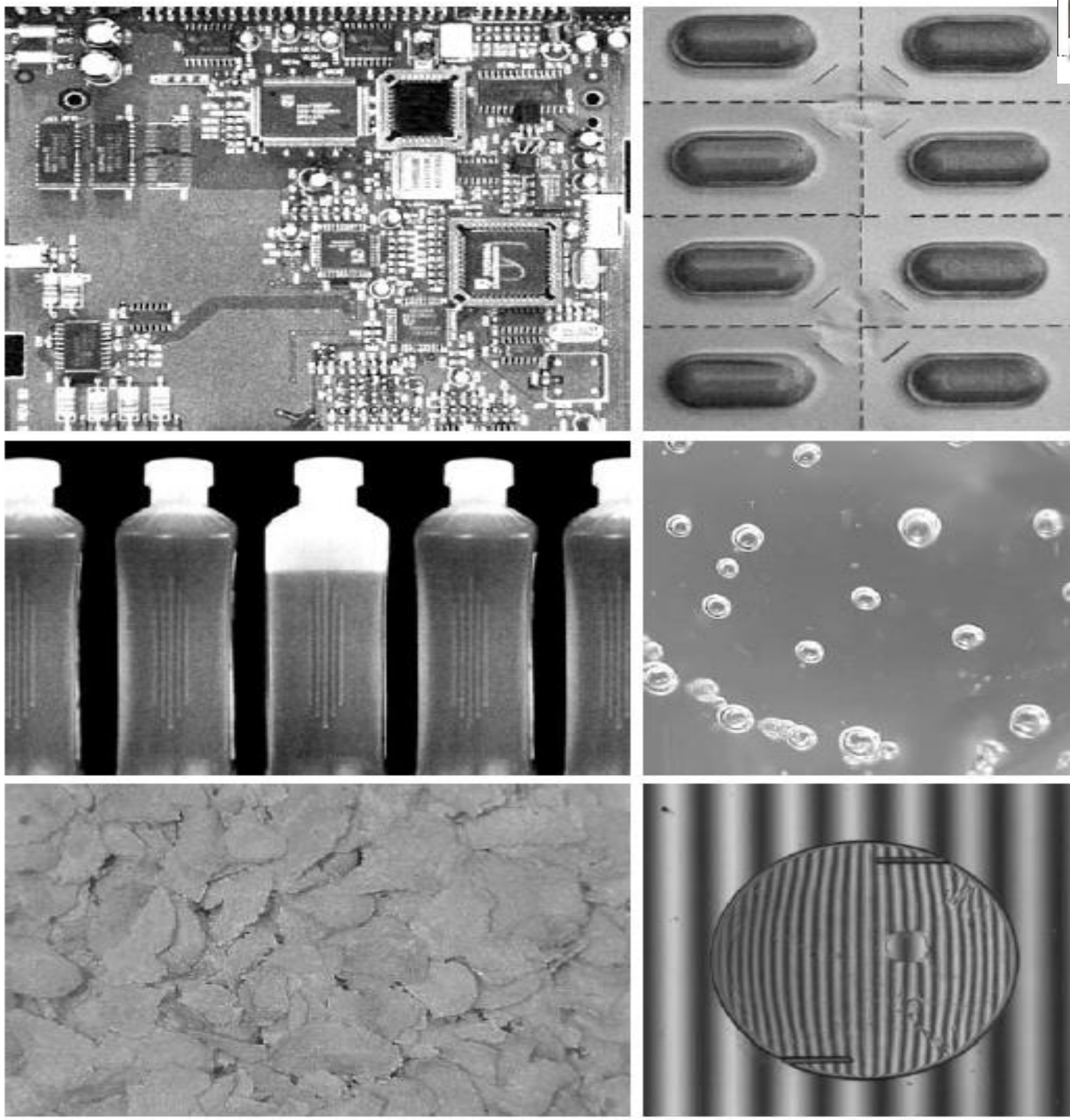


FIGURE 1.13 Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)

AUTOMATED INSPECTION TASKS

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.)



EXAMPLES OF IMAGING IN THE VISUAL SPECTRUM

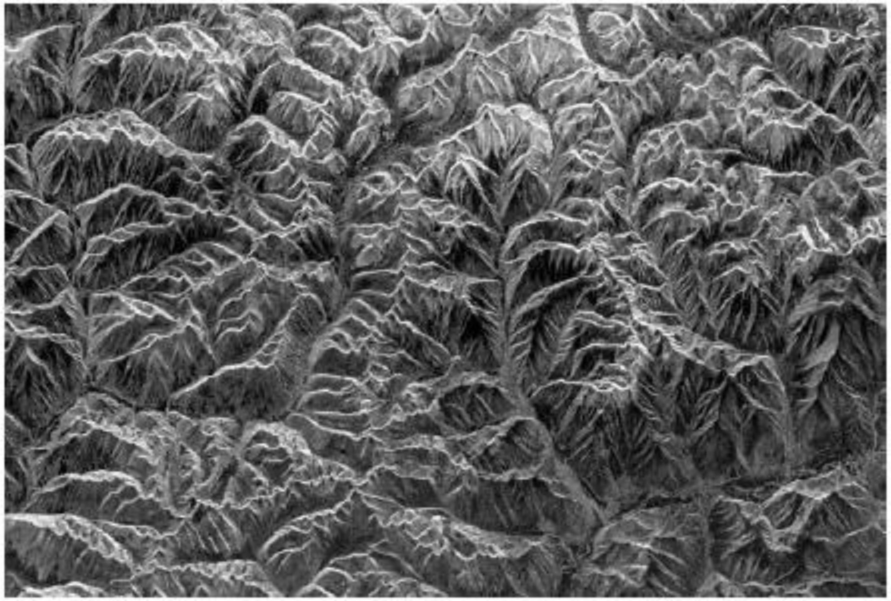
a b
c
d

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

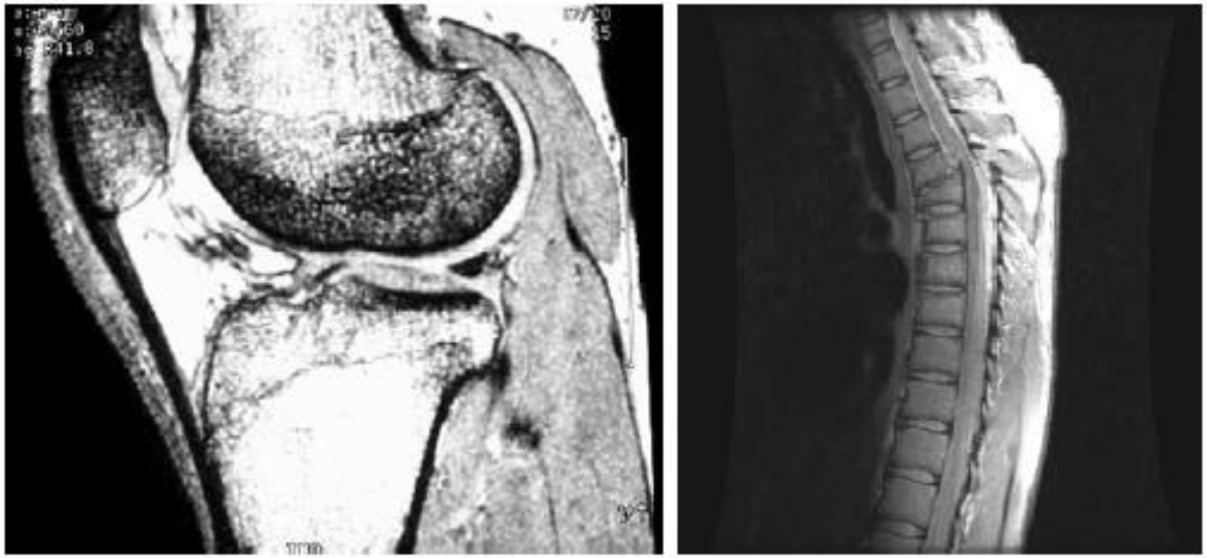
- The dominant application of imaging in the microwave band is radar
- The unique feature of imaging radar is its ability to collect data over virtually any region at any time, regardless of weather or ambient lighting conditions

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



Imaging in the Radio Band

- The major applications of imaging in the radio band are in medicine and astronomy
- In medicine, radio waves are used in Magnetic Resonance Imaging (MRI)



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) courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

Examples in which Other Imaging Modalities Are Used

- Other sources of energy beside electromagnetic waves are

- **Acoustic waves**: seismic, marine/atmospheric, sonar/radar, ultrasound

- **Electron microscopy**

- **Synthetic (computer generated) images**

EXAMPLES

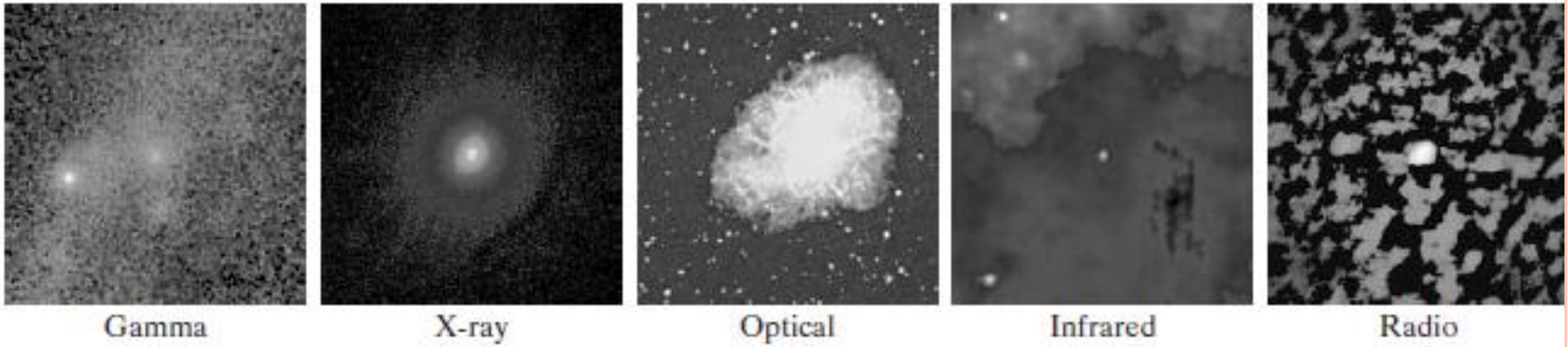
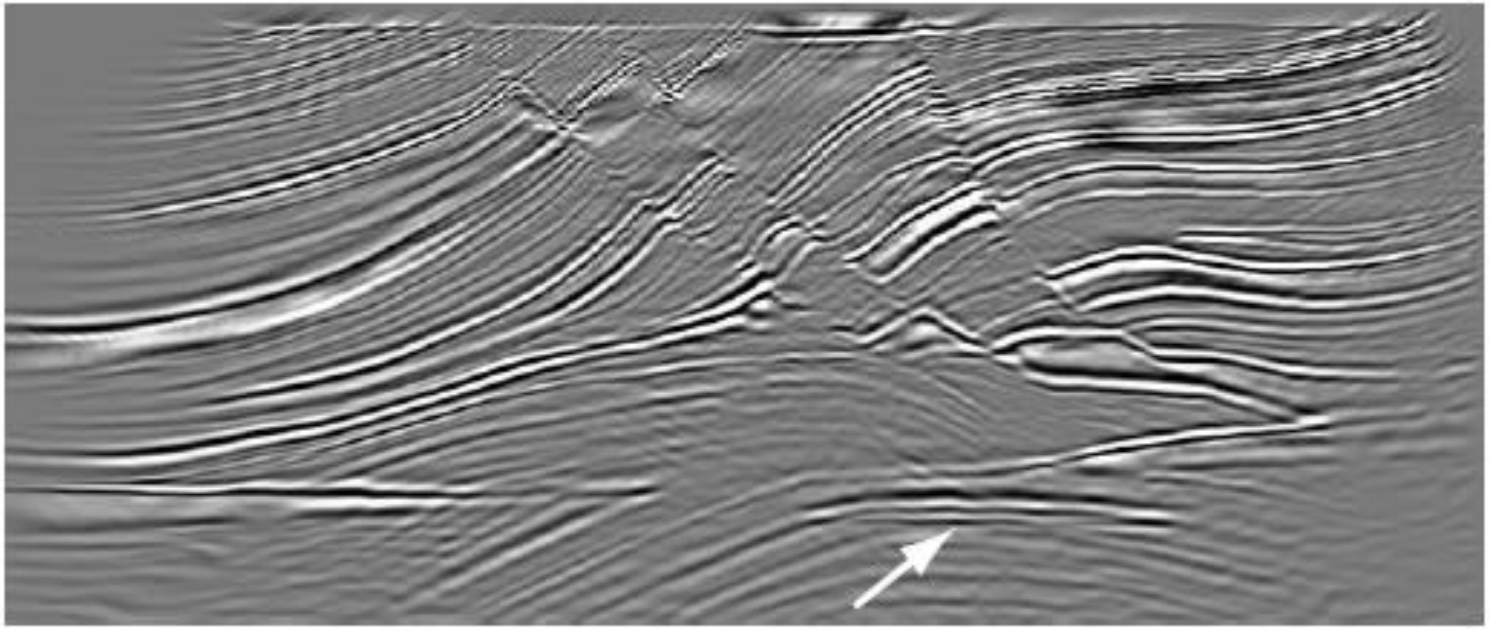


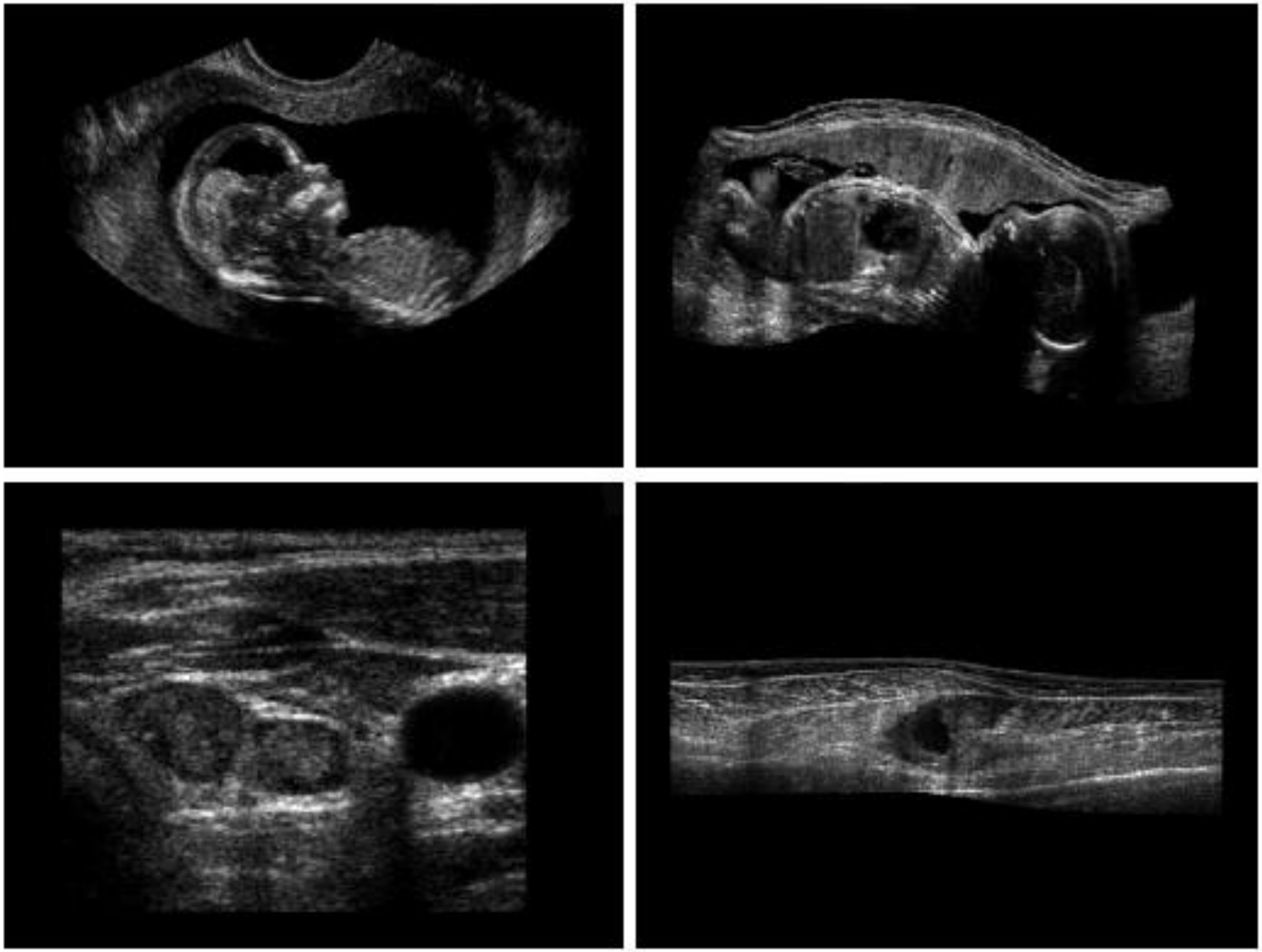
FIGURE 1.18 Images of the Crab Pulsar (in the center of each image) covering the electromagnetic spectrum. (Courtesy of NASA.)

Examples

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.)



Examples

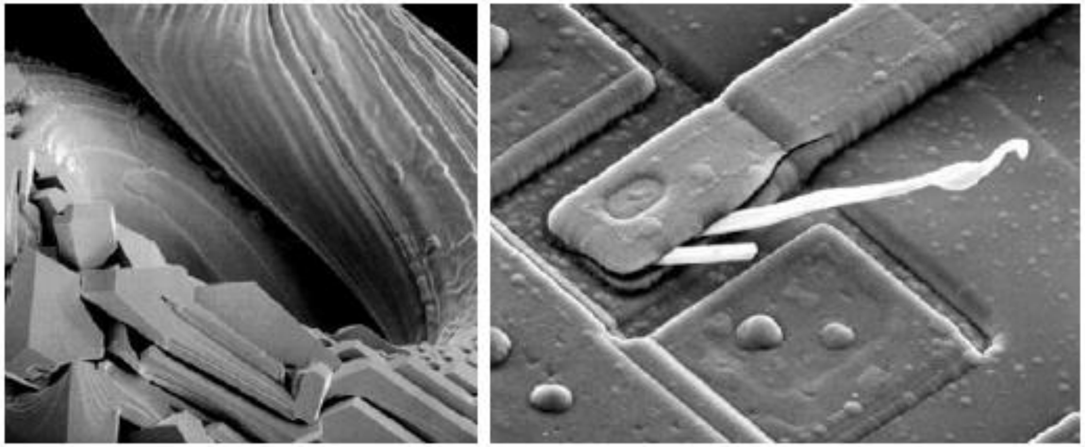


a b
c d

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

Examples

- A *transmission electron microscope* (TEM) works much like a slide projector
- A *scanning electron microscope* (SEM), on the other hand, actually scans the electron beam and records the interaction of beam and sample at each location



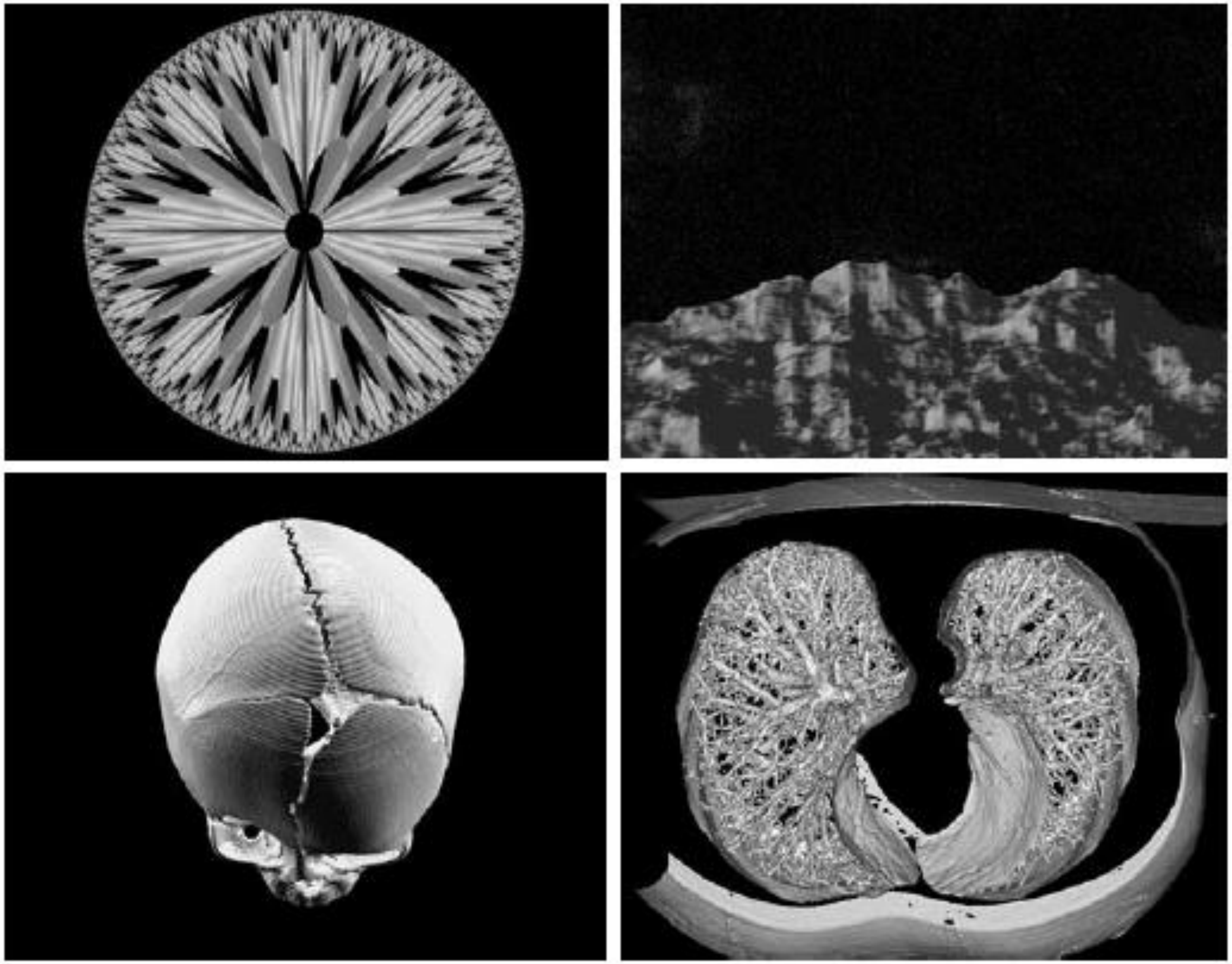
a b

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.)

Examples

- *Fractals* are striking examples of computer-generated images (Lu [1997])
- **Basically, a fractal is nothing more than an iterative reproduction of a basic pattern according to some mathematical rules**
- For instance, *tiling* is one of the simplest ways to generate a fractal image
- A square can be subdivided into four square sub-regions, each of which can be further subdivided into four smaller square regions, and so on
- Depending on the complexity of the rules for filling each sub-square, some beautiful tile images can be generated using this method. Of course, the geometry can be arbitrary

EXAMPLES OF FRACTAL IMAGES



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.)

Fundamental steps in digital image processing

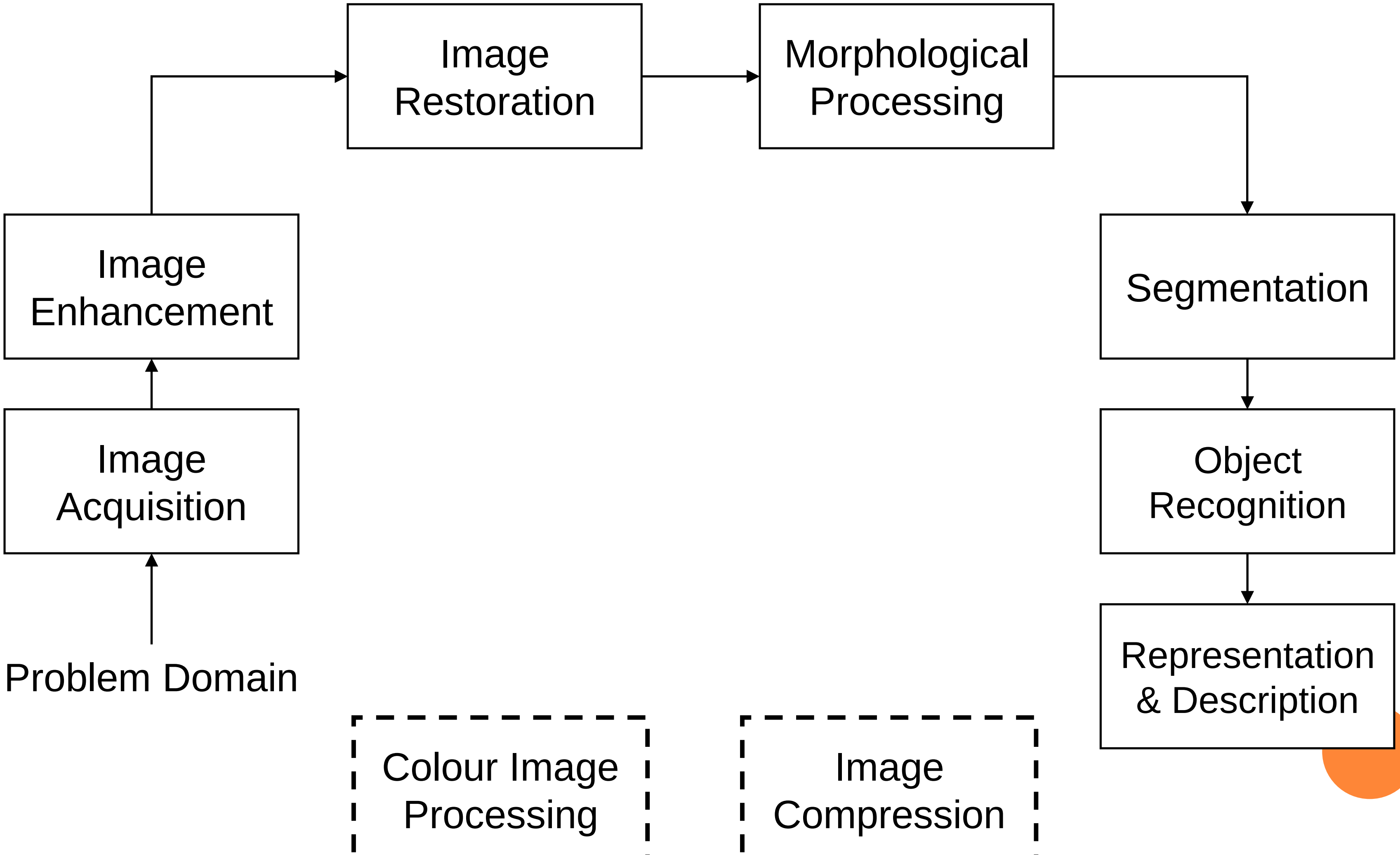


Image Acquisition

- *Image acquisition* is the first process

- Acquisition could be as simple as being given an image that is already in digital form

- Generally, the image acquisition stage involves preprocessing, such as scaling

FUNDAMENTAL STEPS IN DIGITAL IMAGE PROCESSING: IMAGE ACQUISITION

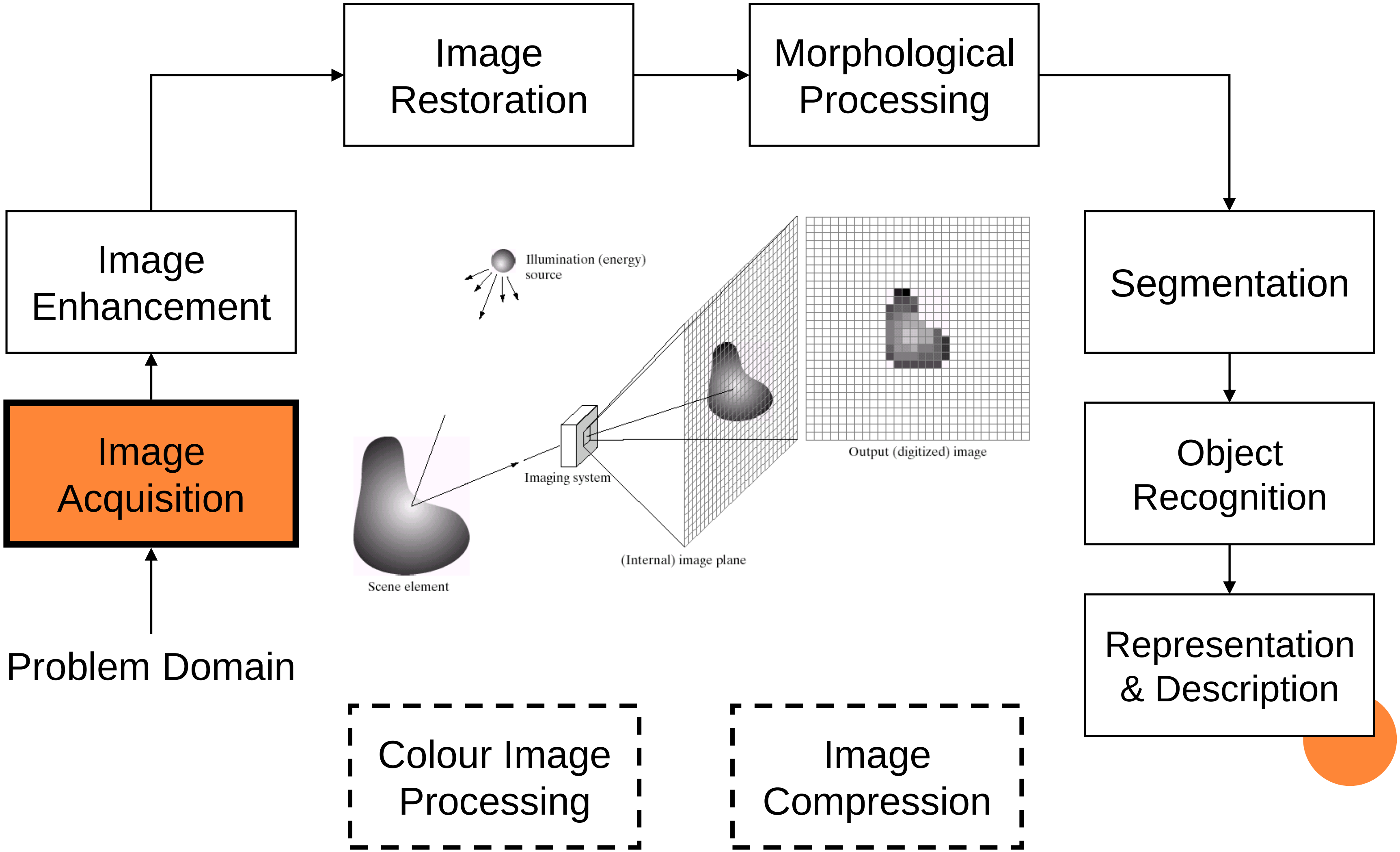


Image Enhancement

- *Image enhancement* is the process of manipulating an image so that the result is more suitable than the original for a specific application

- The word specific is important here, because it establishes at the outset that enhancement techniques are **problem oriented**

- Ex. A method that is quite useful for enhancing X-ray images may not be the best approach for enhancing satellite images taken in the infrared band of the electromagnetic spectrum

Fundamental steps in digital image processing: Image Enhancement

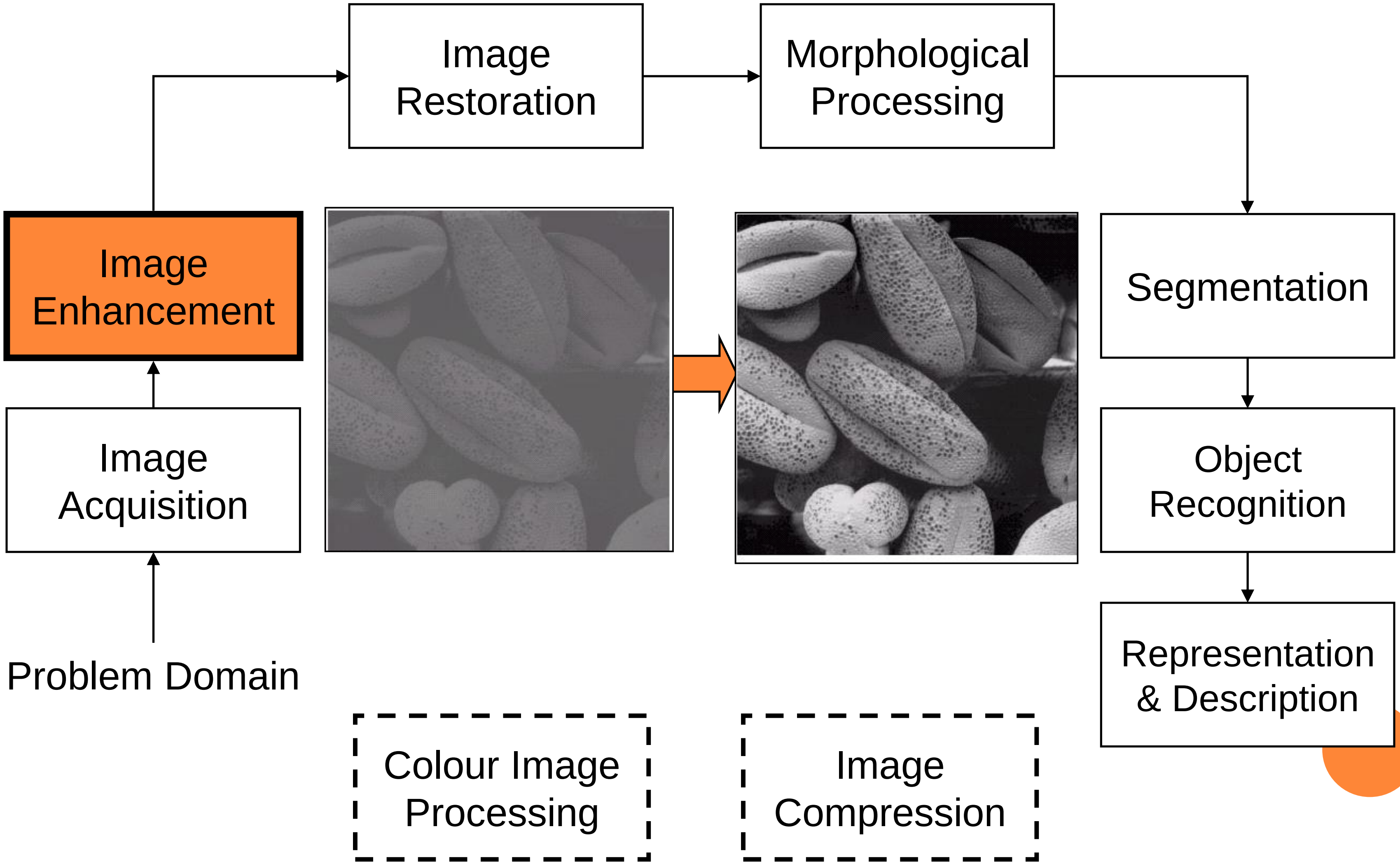
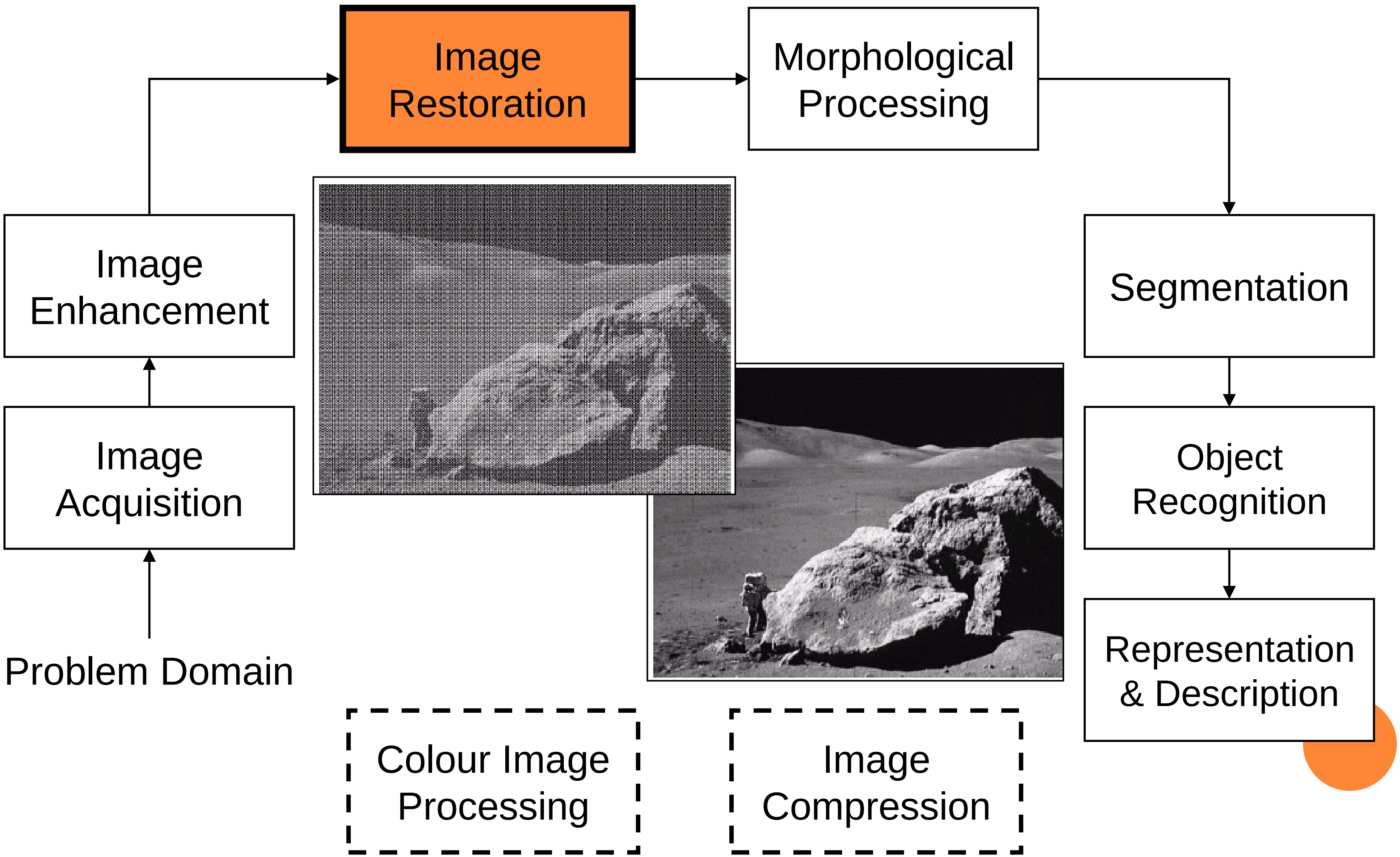


Image Restoration

- *Image restoration* is an area that also deals with improving the appearance of an image
- However, unlike enhancement, which is subjective, image restoration is objective, in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image degradation
- Enhancement, on the other hand, is based on human subjective preferences regarding what constitutes a "good" enhancement result

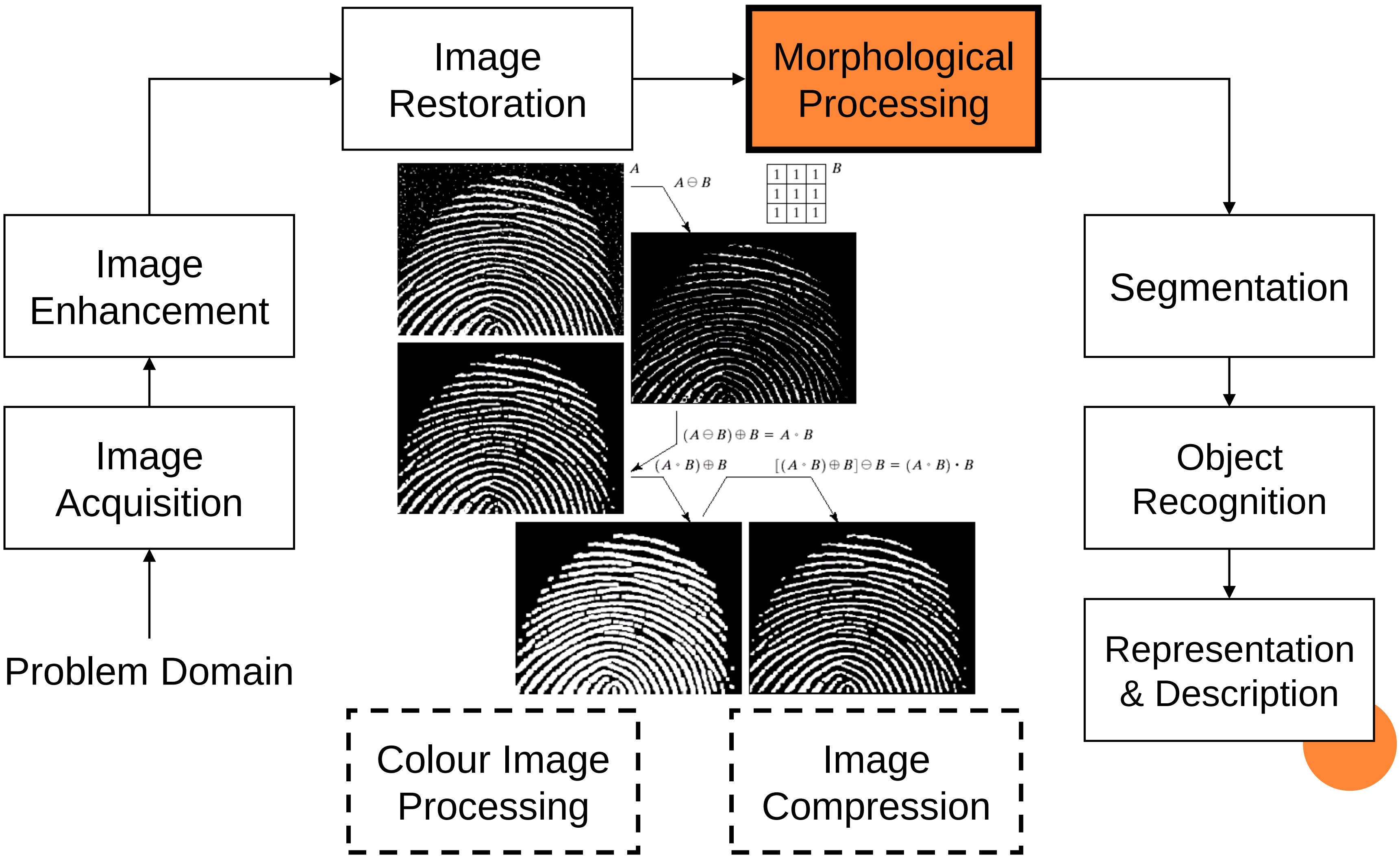
Fundamental steps in digital image processing: Image Restoration



Morphological Processing

- *Morphological processing* deals with tools for extracting image components that are useful in the representation and description of shape

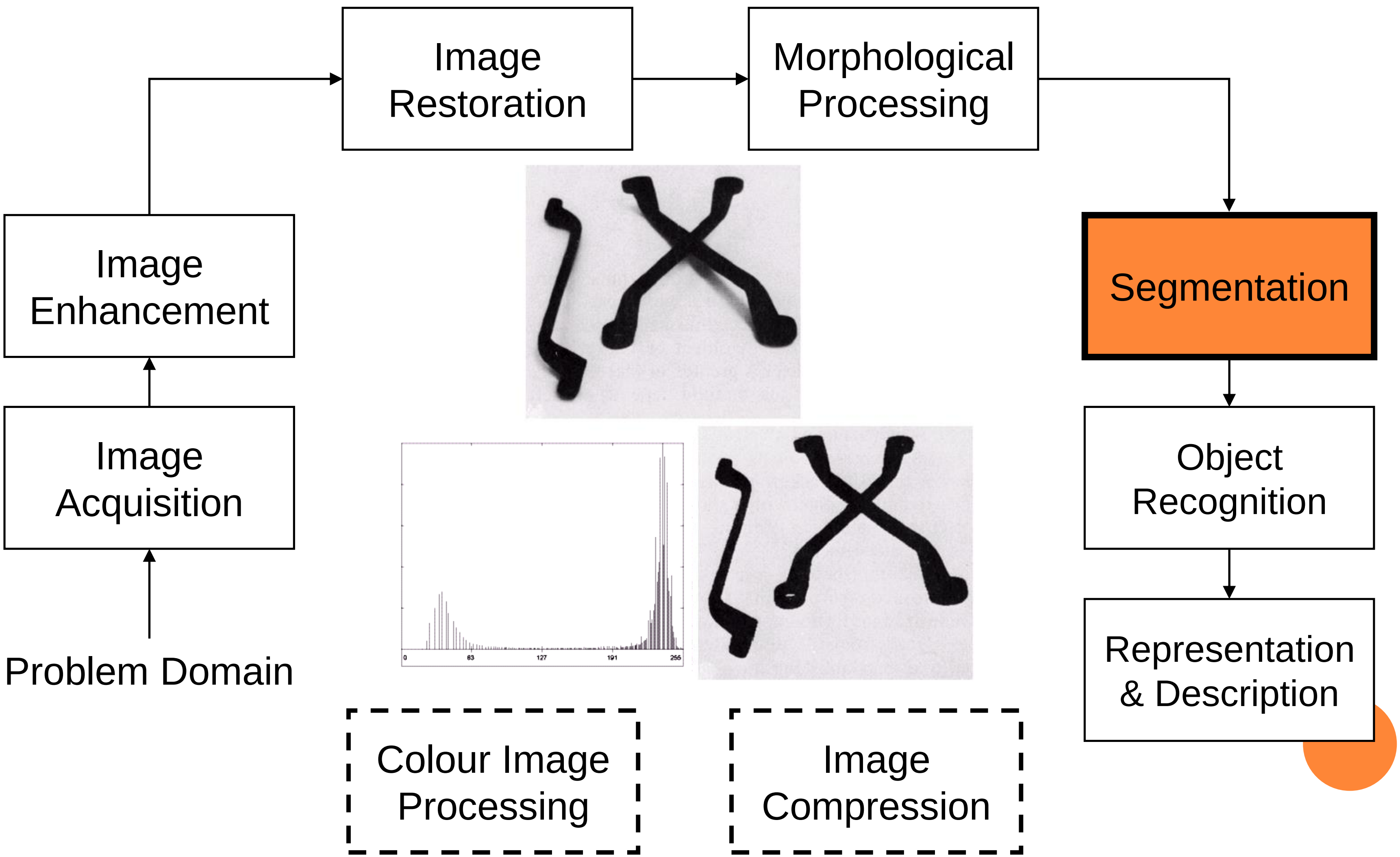
Fundamental steps in digital image processing: Morphological Processing



Segmentation

- *Segmentation* procedures partition an image into its constituent parts or objects

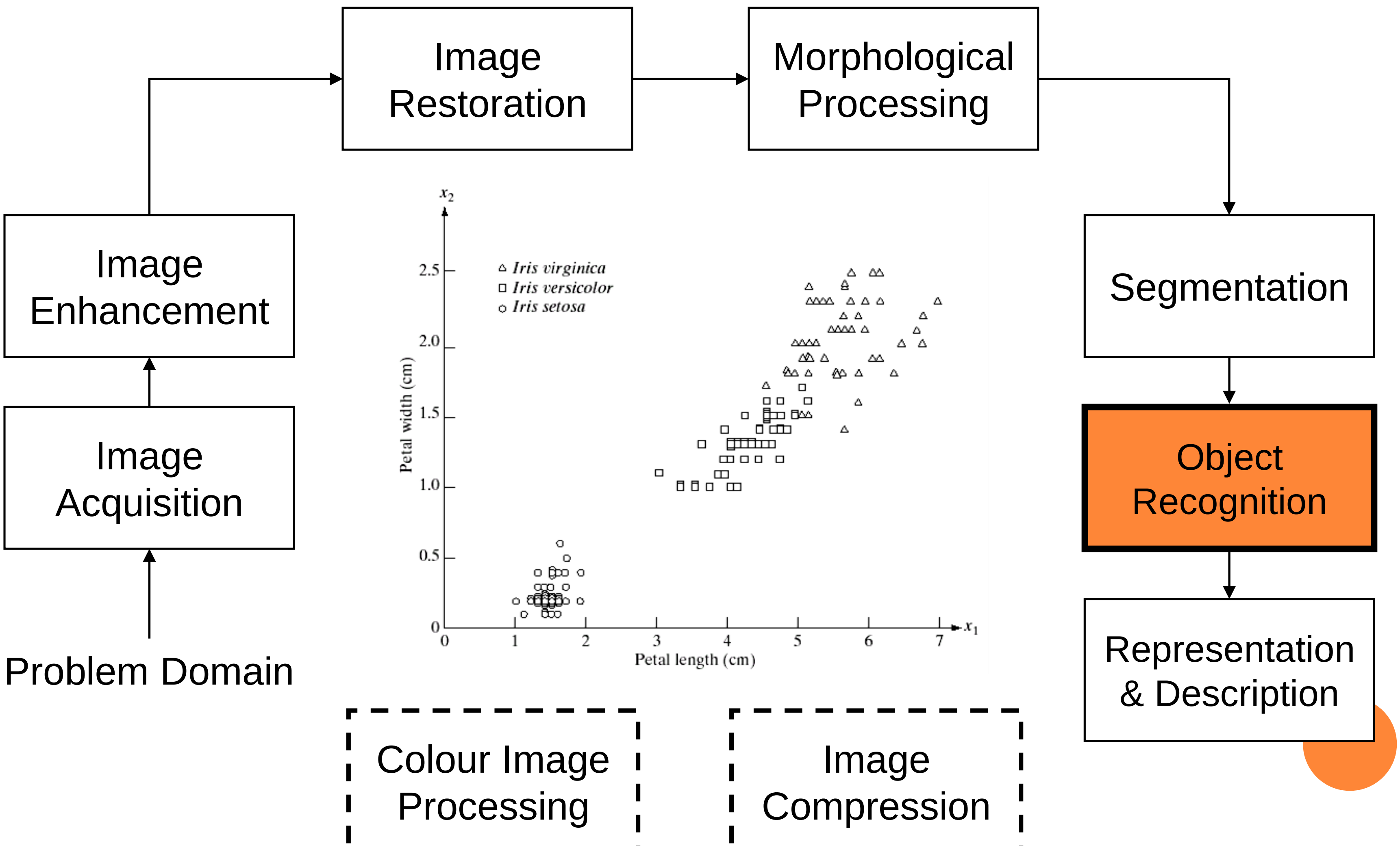
Fundamental steps in digital image processing: Segmentation



Object Recognition

- *Recognition* is the process that assigns a label (e.g., “vehicle”) to an object based on its descriptors

Fundamental steps in digital image processing: Object Recognition



Representation & Description

- *Representation and description* almost always follow the output of a segmentation stage, which usually is raw pixel data, constituting either the boundary of a region (i.e., the set of pixels separating one image region from another) or all the points in the region itself

Fundamental steps in digital image processing: Representation & Description

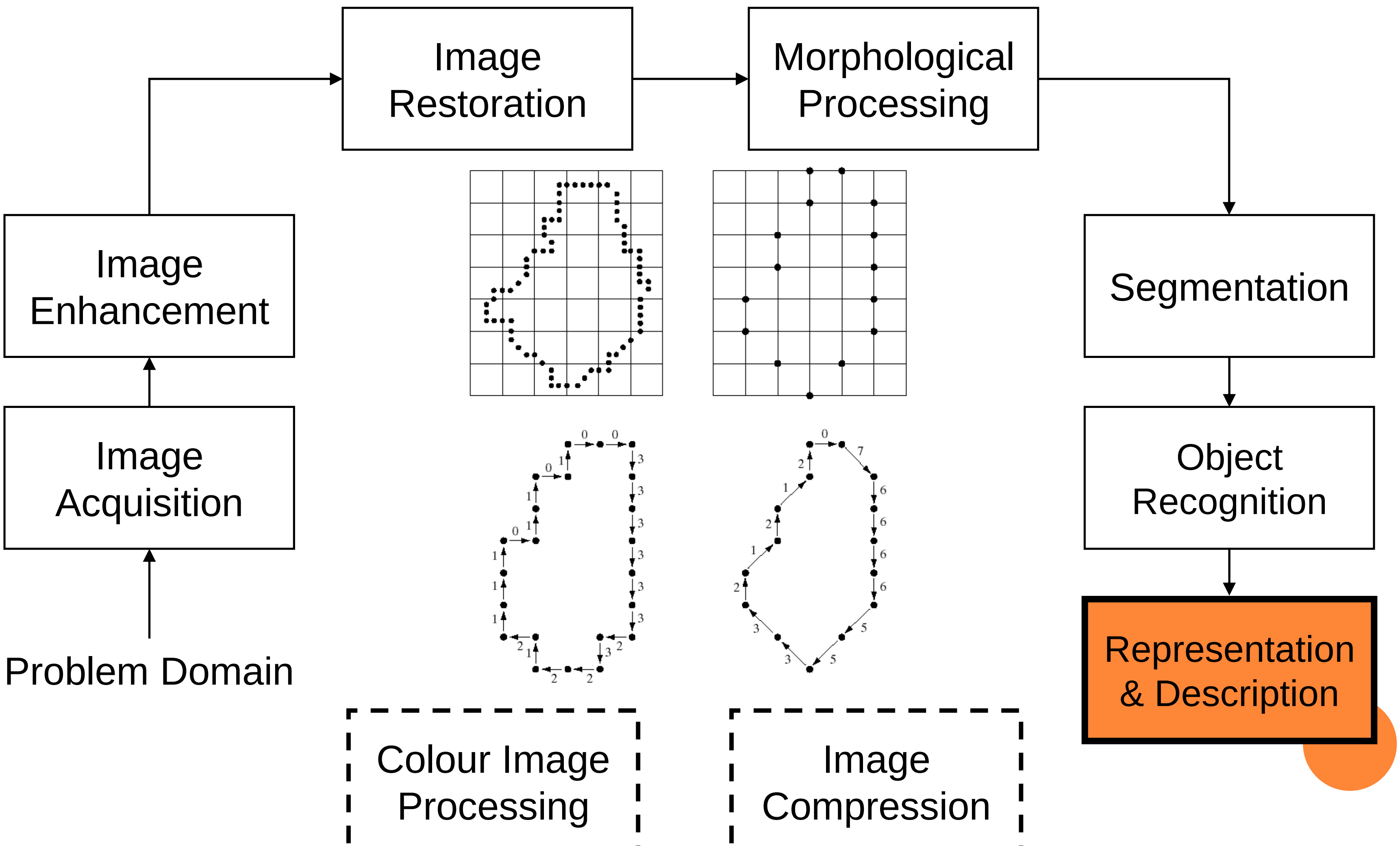
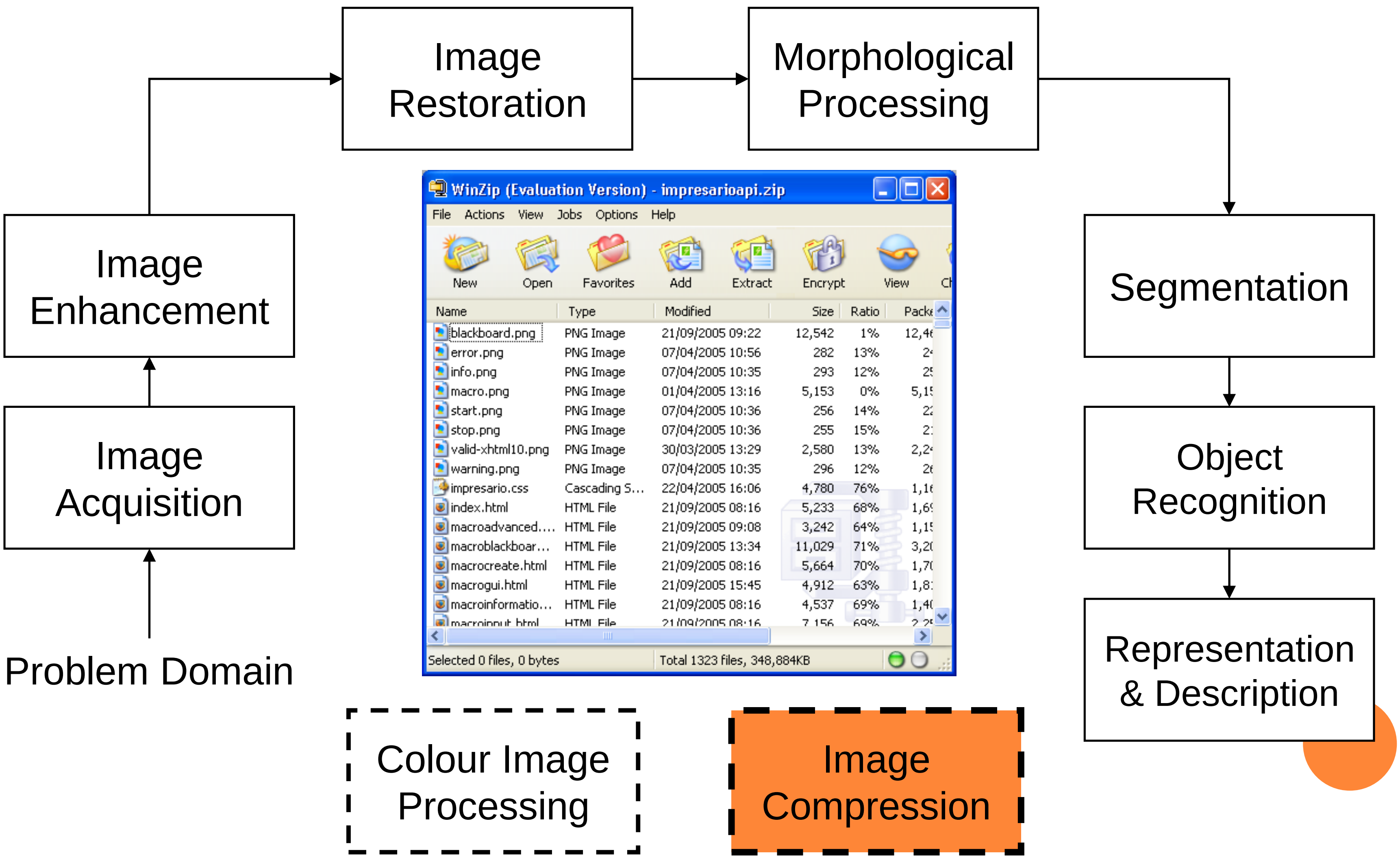


Image Compression

- *Compression*, as the name implies, deals with techniques for reducing the storage required to save an image, or the bandwidth required to transmit it
- Image compression is familiar (perhaps inadvertently) to most users of computers in the form of image file extensions, such as the jpg file extension used in the JPEG (Joint Photographic Experts Group) image compression standard

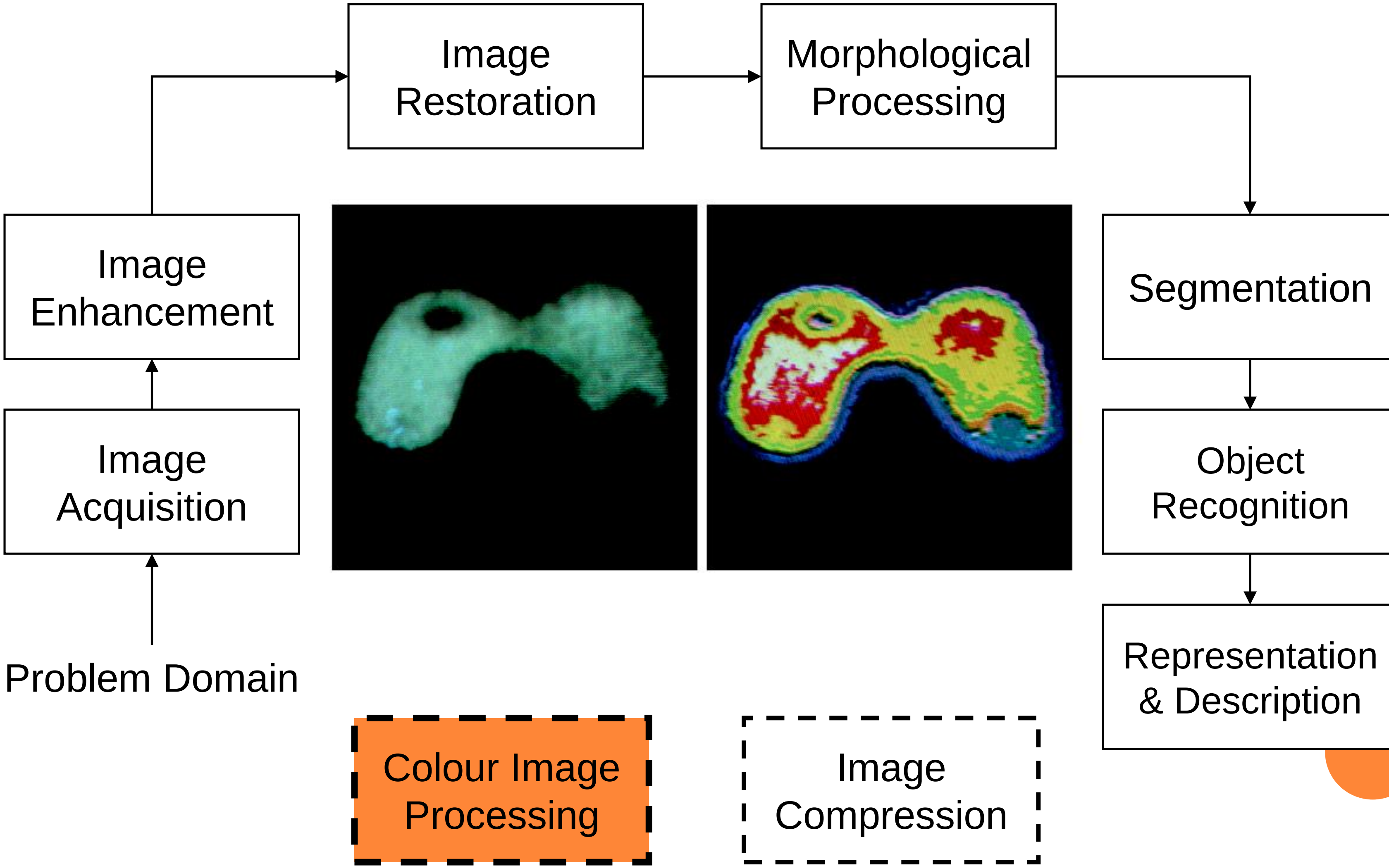
Fundamental steps in digital image processing: Image Compression



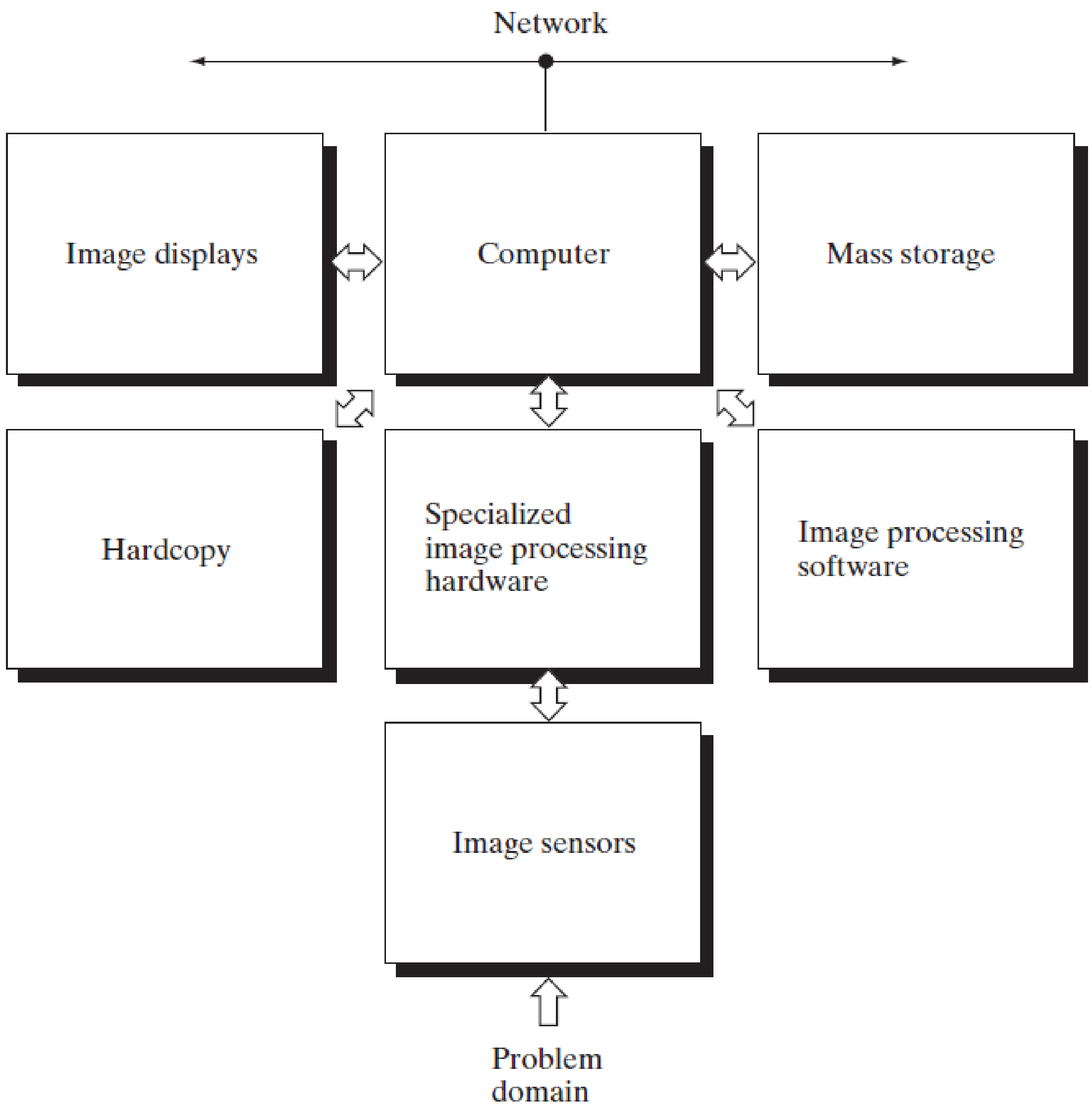
Colour Image Processing

- *Color image processing* is an area that has been gaining in importance because of the significant increase in the use of digital images over the Internet
- Color is used also as the basis for extracting features of interest in an image

Fundamental steps in digital image processing: Colour Image Processing



Components of an Image Processing System



Thank you