Overview of Digital Image Processing

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What is digital image processing (DIP)?

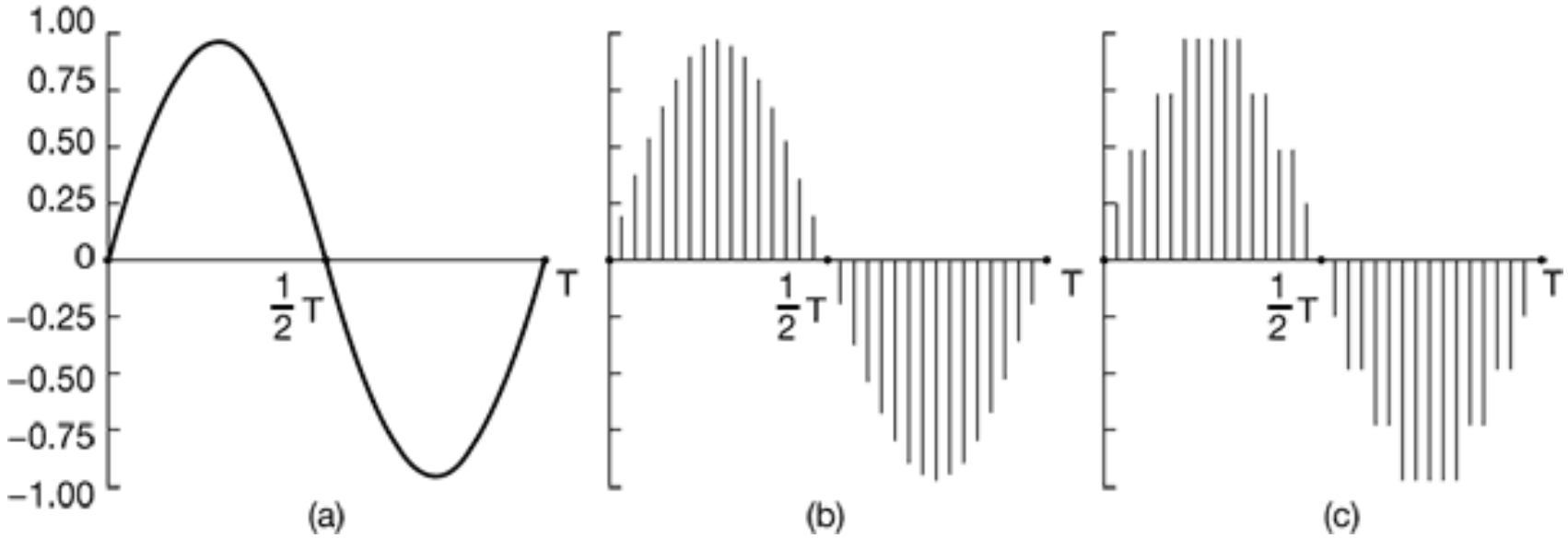
- Lets know the meaning of the string "***Digital Image Processing***".
- The word '***Digital***' is more meaningful when it is associated with other words such as clock, signal, electronics, signature, camera, etc.
- Here signal is our interest.

What is a signal?

- Signal is a function of one or more independent variables, contain information about the behavior or nature of some phenomenon.

- It may be of different types:
  - Continuous time
  - Discrete time
  - Digital

Digital from continuous



(a) Continuous, (b) Discrete time and (c) Digital signal.

Image – A signal?

- No need to mention that image contains significant information.

- So image is a signal and thus “digital image” is valid.

What is an image?

- Generally it can be defined as a pictorial representation of a scene.
- A 2-D function f(x,y).
- x and y are *spatial* (plane) coordinates.
- The amplitude of *f* at any pair of coordinates (*x*, *y*) is called the *intensity* or *gray level* of the image at that point.

What is digital image?

- When *x*, *y*, and the intensity values of *f* are all finite, discrete quantities, we call the image a *digital image.*

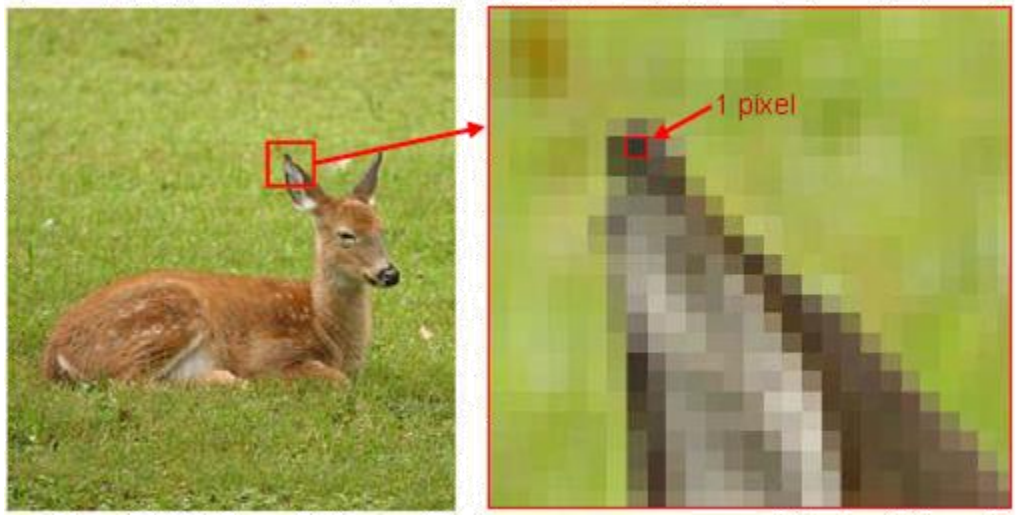
- Two-dimensional image is represented as a finite set of digital values, called picture elements or pixels.

- The field of *digital image processing* refers to processing digital images by means of a digital computer.

More on pixels

- Pixel values typically represent gray levels, colors, heights, opacities etc.

- **Remember** *digitization* implies that a digital image is an *approximation* of a real scene.



Contd..

- Common image formats include:
  - 1 sample per point (B&W or Grayscale)
  - 3 samples per point (Red, Green, and Blue)

Image Processing and related fields

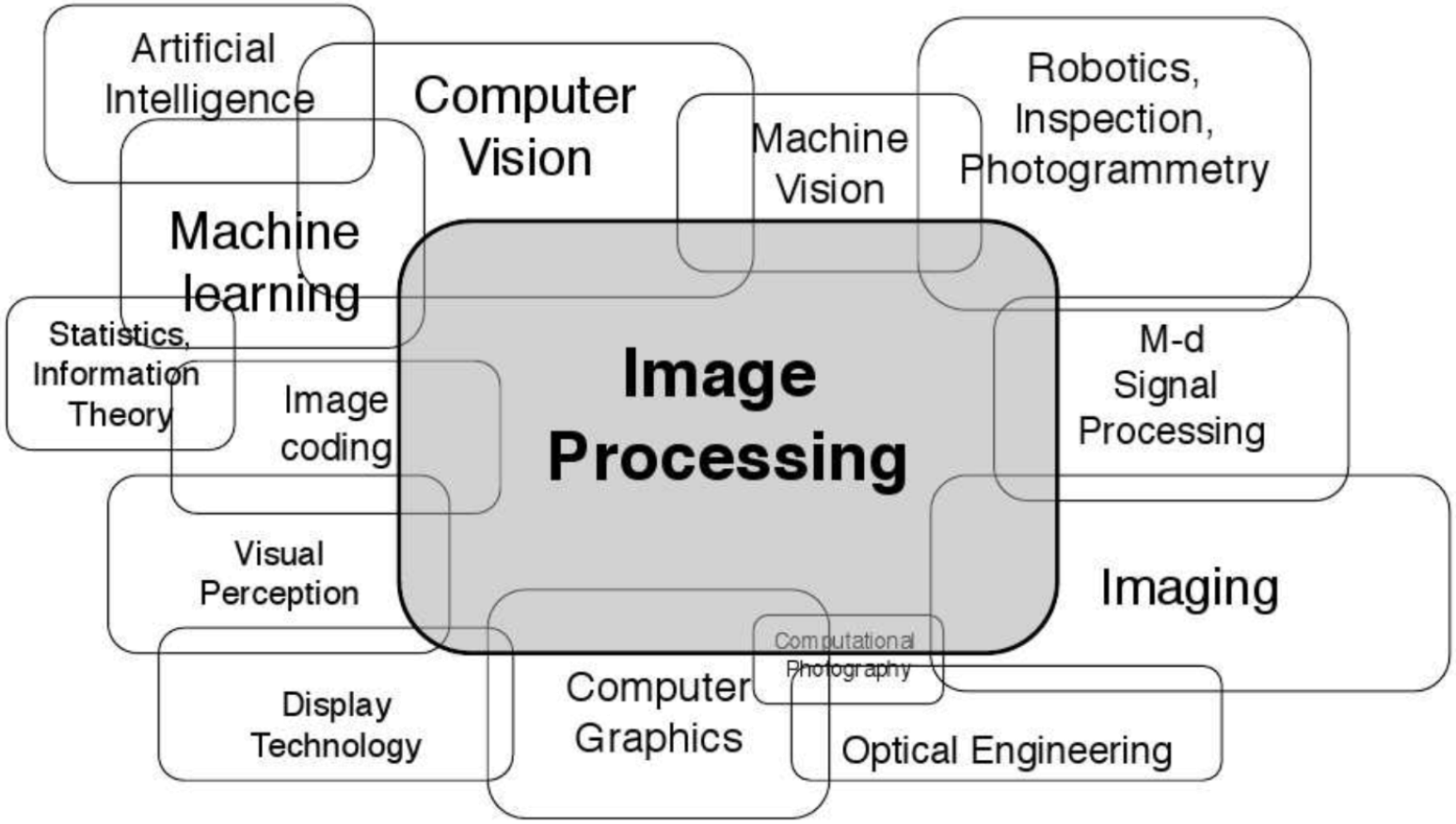
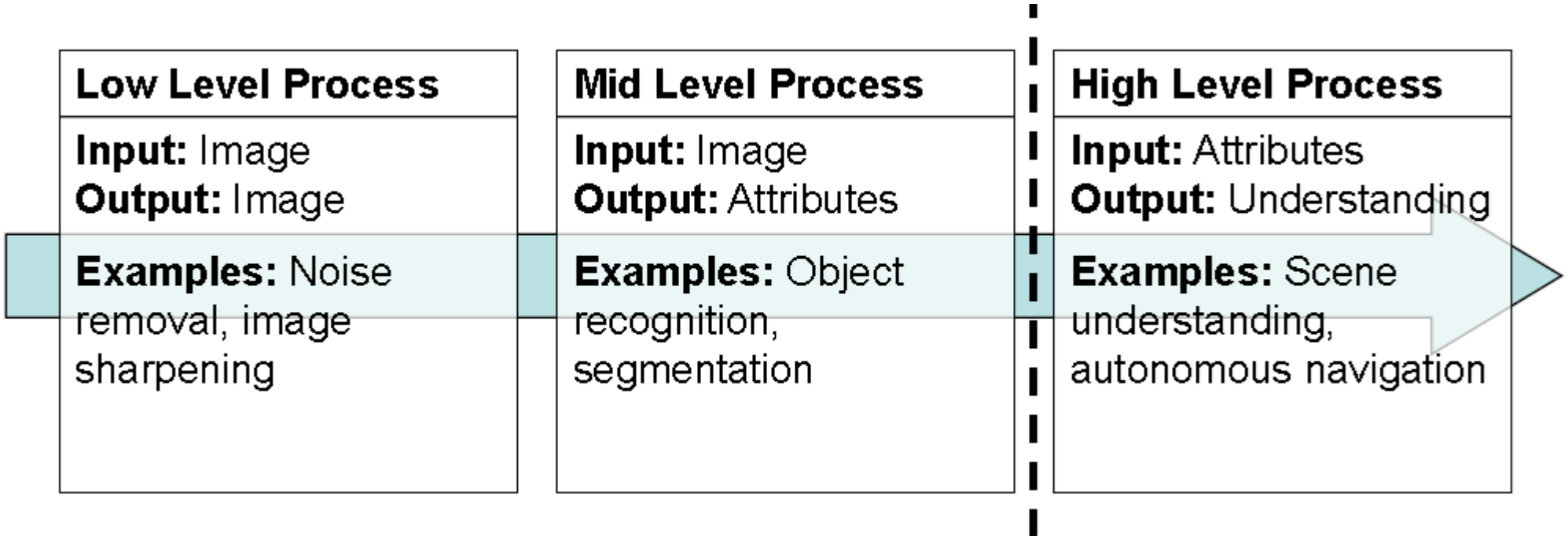


Image Processing to Computer Vision

- The continuum from image processing to computer vision can be broken up into low-, mid- and high-level processes.

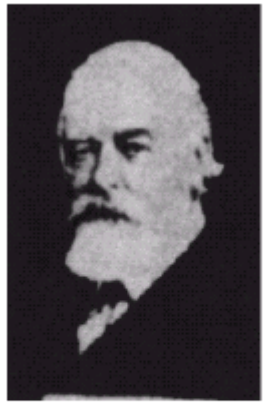


History of DIP

- **Early 1920s:** One of the first applications of digital imaging was in the newspaper industry.
- Images were transferred by submarine cable between London and New York (more than a week)
- Issues: Printing process, intensity level distribution

Early digital image

- Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer
- Photographic reproduction made from tapes



Improved digital image

History contd..

- **Mid to late 1920s:** Improvements to the Bartlane system resulted in higher quality images (less than 3 hours)
- Increased number of tones in reproduced images (5 to 15)
- System that develops a film plate via light beams

that were modulated by the coded picture tape

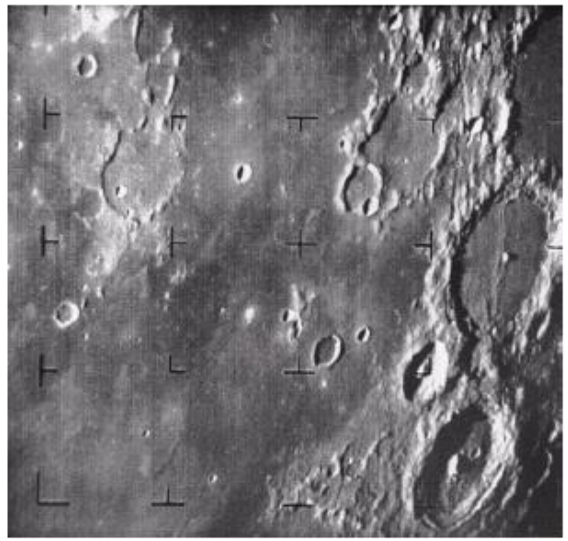
improved the reproduction process.

History contd..

- **1960s:** Improvements in computing technology and the onset of the space race led to a surge of work in digital image processing.

- **1964:** Computers used to improve the quality of images of the moon taken by the *Ranger 7* probe

- Such techniques were used in other space missions including the Apollo landings



A picture of the moon taken by the Ranger 7 probe minutes before landing

History contd..

- **1970s:** Digital image processing begins to be used in medical applications

- **1979:** Sir Godfrey N. Hounsfield &

Prof. Allan M. Cormack share the Nobel Prize in medicine for the invention of tomography, the technology behind Computerized Axial Tomography (CAT) scans

Typical head slice CAT image

History contd..

- **1980s - Today:** The use of digital image processing techniques has exploded and they are now used for all kinds of tasks in all kinds of areas
  - Image enhancement & restoration
  - Artistic effects
  - Medical visualization
  - Industrial inspection
  - Law enforcement
  - Human computer interfaces

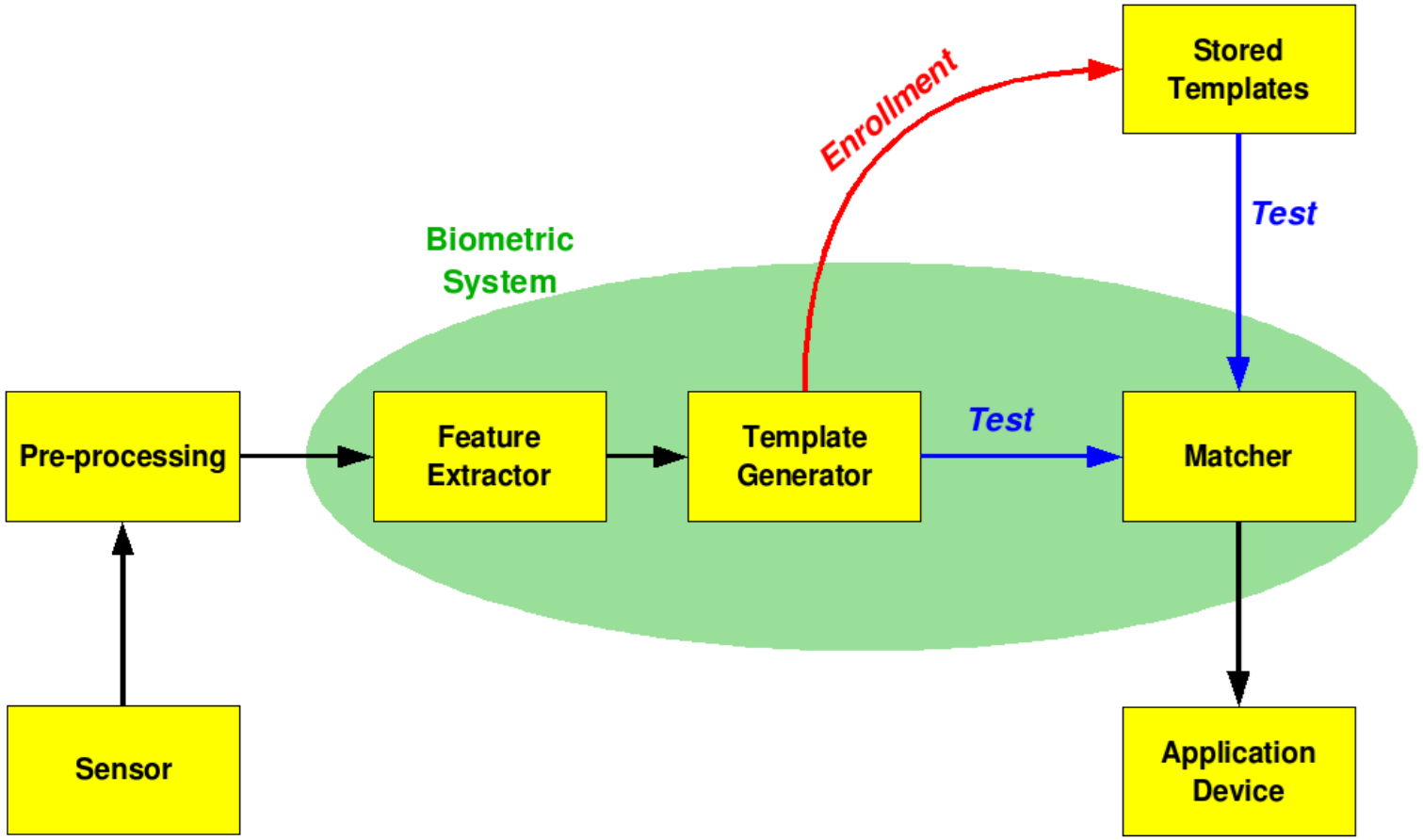
Why do we process image?

- Acquire an image
  - Correct aperture and color balance
  - Reconstruct image from projections: Panoramic view
- Facilitate picture storage and transmission
  - Send an image from space
  - Efficiently store an image in a digital camera
- Enhance and restore images
  - Touch up personal photos
  - Visibility of images in navigation
- Extract information from images
  - Object/Character recognition

Applications

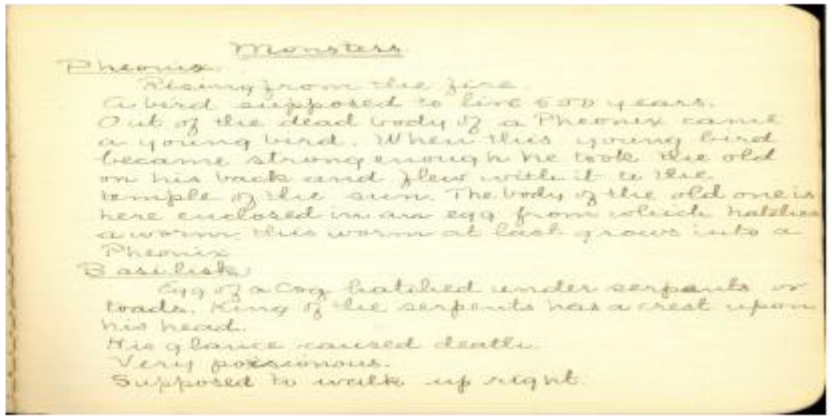
- Biometric:

Generalized biometric system



Applications

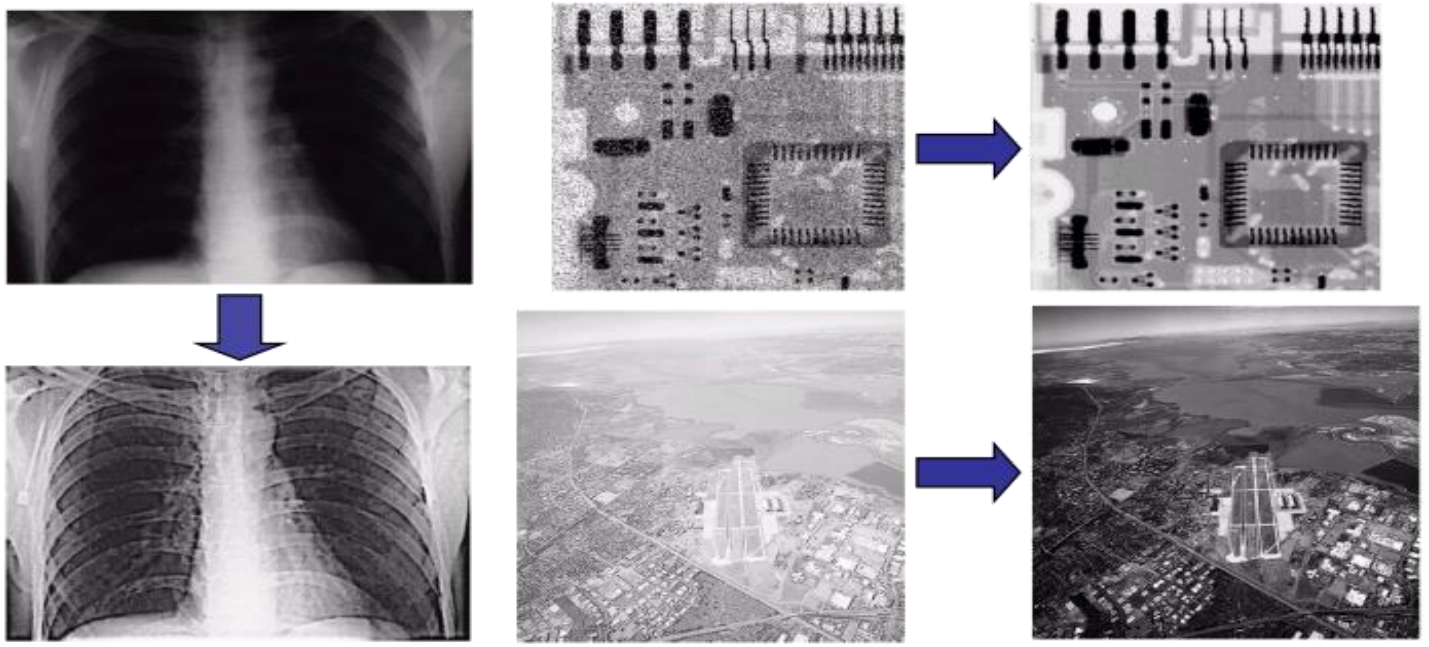
- Text analysis: Archiving the data



- Satellite image
  - Forest management: Forest stock
  - Weather forecasting
  - Road map detection
- Forensic applications and many more.

Examples: Image Enhancement/Restoration

One of the most common uses of DIP techniques: improve quality, remove noise etc

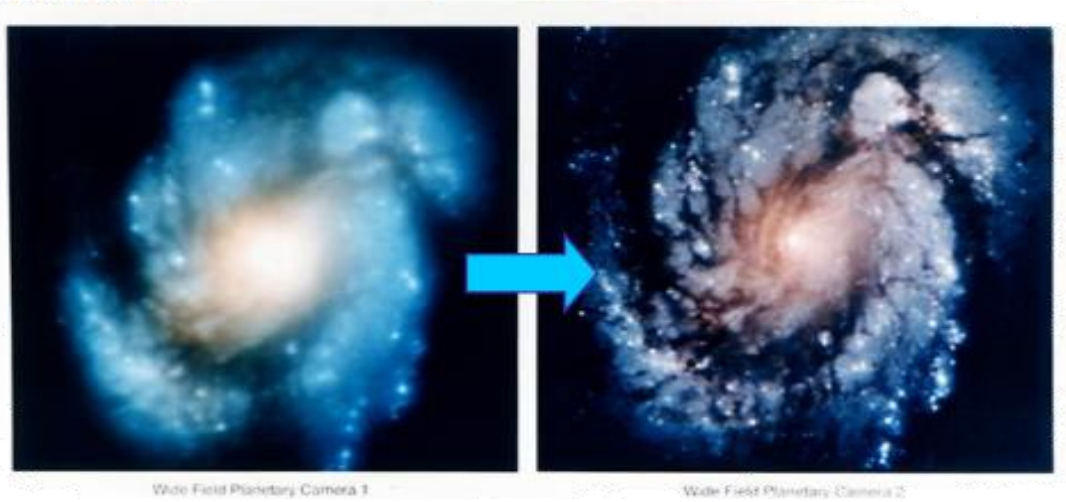


Examples: The Hubble Telescope

Launched in 1990 the Hubble telescope can take images of very distant objects

However, an incorrect mirror made many of Hubble's images useless

Image processing techniques were used to fix this



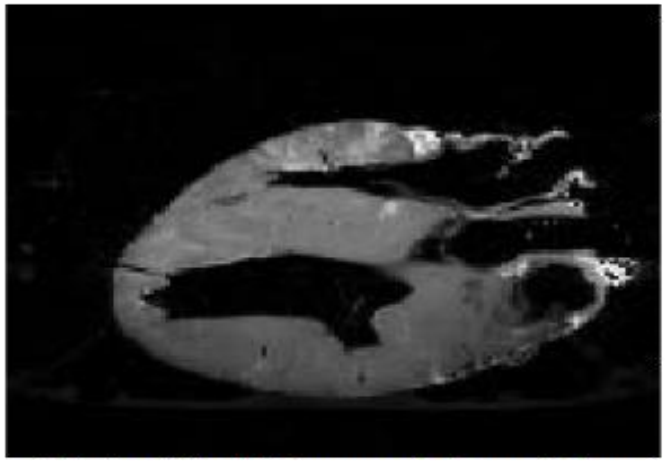
Examples: Artistic Effects

Artistic effects are used to make images more visually appealing, to add special effects and to make composite images

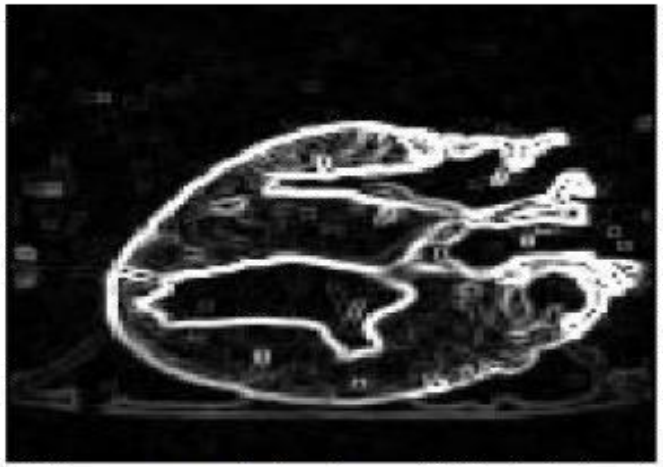
Examples: Medicine

Take slice from MRI scan of canine heart, and find boundaries between types of tissue

- Image with gray levels representing tissue density
- Use a suitable filter to highlight edges



Original MRI Image of a Dog Heart

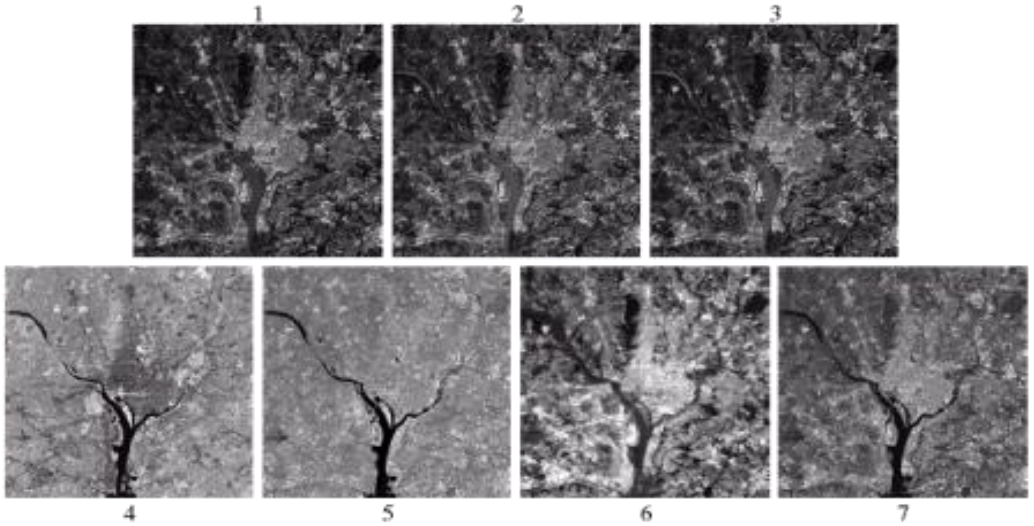


Edge Detection Image

Example: GIS

Geographic Information Systems

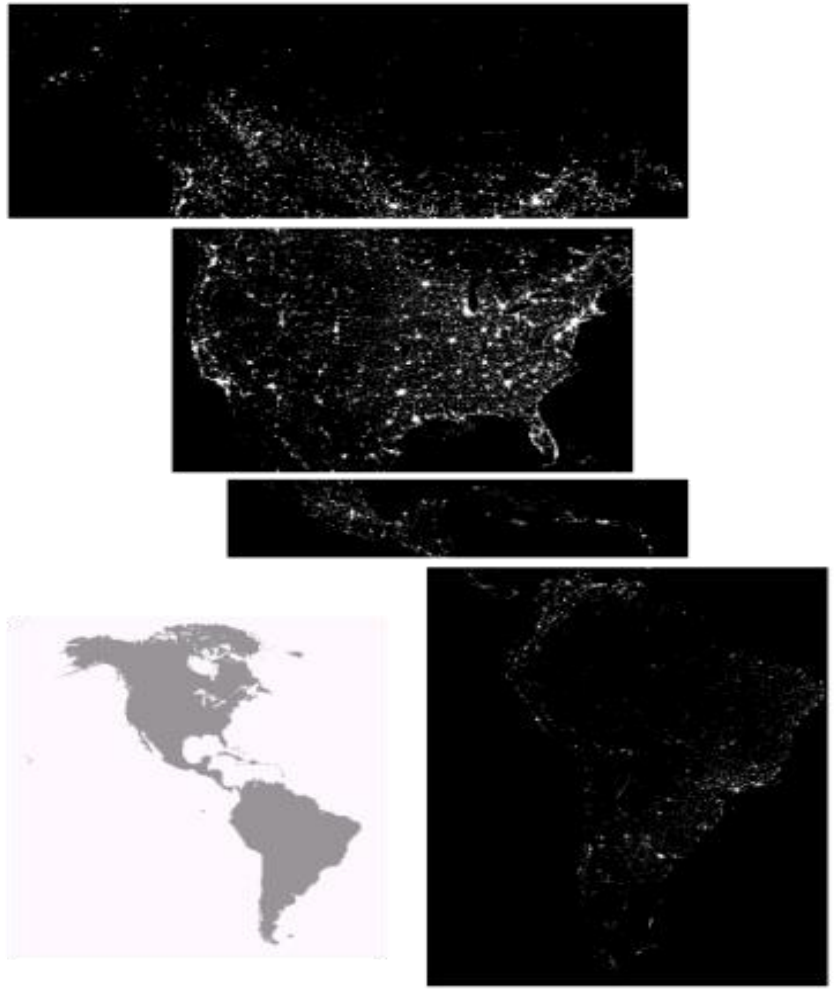
- Digital image processing techniques are used extensively to manipulate satellite imagery
- Terrain classification
- Meteorology



GIS: contd.

Night-Time Lights of the World data set

- Global inventory of human settlement
- Not hard to imagine the kind of analysis that might be done using this data



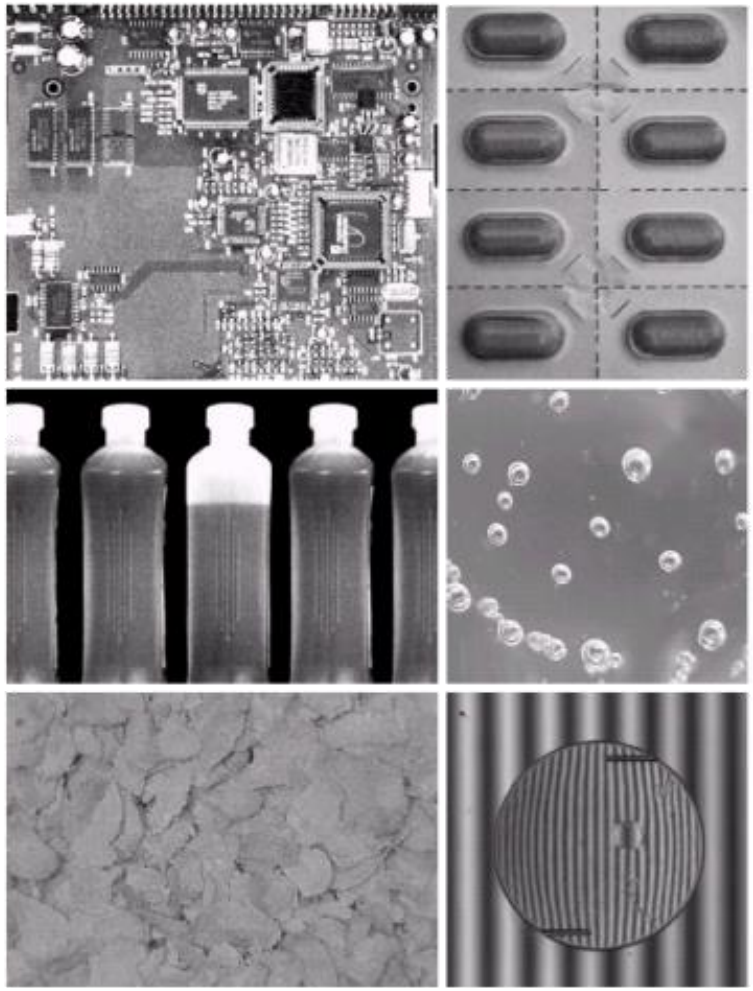
Industrial Inspection

Human operators are expensive, slow and unreliable

Make machines do the job instead

Industrial vision systems are used in all kinds of industries

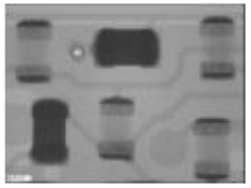
Can we trust them?

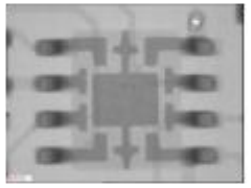


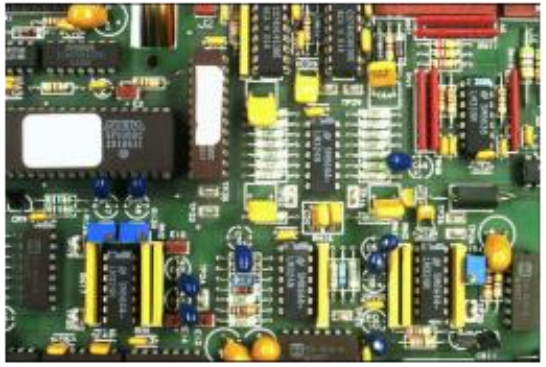
Examples: PCB Inspection

Printed Circuit Board (PCB) inspection

- Machine inspection is used to determine that all components are present and that all solder joints are acceptable
- Both conventional imaging and x-ray imaging



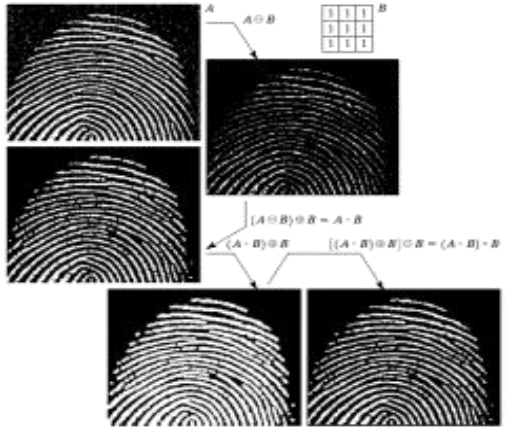




Examples: Law Enforcement

Image processing techniques are used extensively by law enforcers

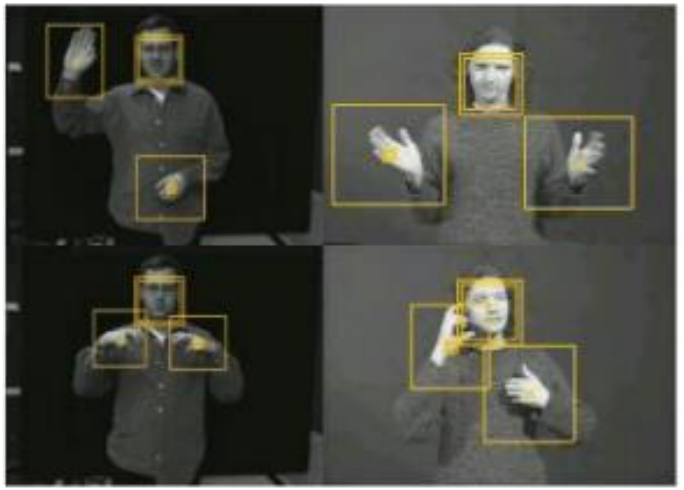
- Number plate recognition for speed cameras/automated toll systems
- Fingerprint recognition
- Enhancement of CCTV images



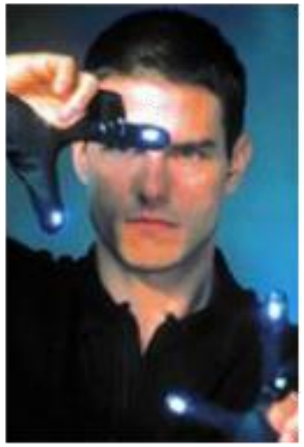
Examples: HCI

Try to make human computer interfaces more natural

- Face recognition
- Gesture recognition



Does anyone remember the user interface from “Minority Report”?



These tasks can be extremely difficult

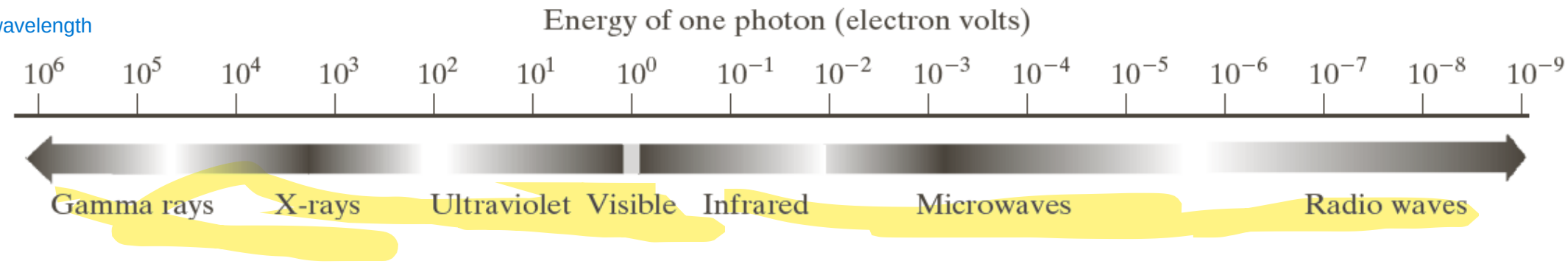
The EM Spectrum

low frequncy

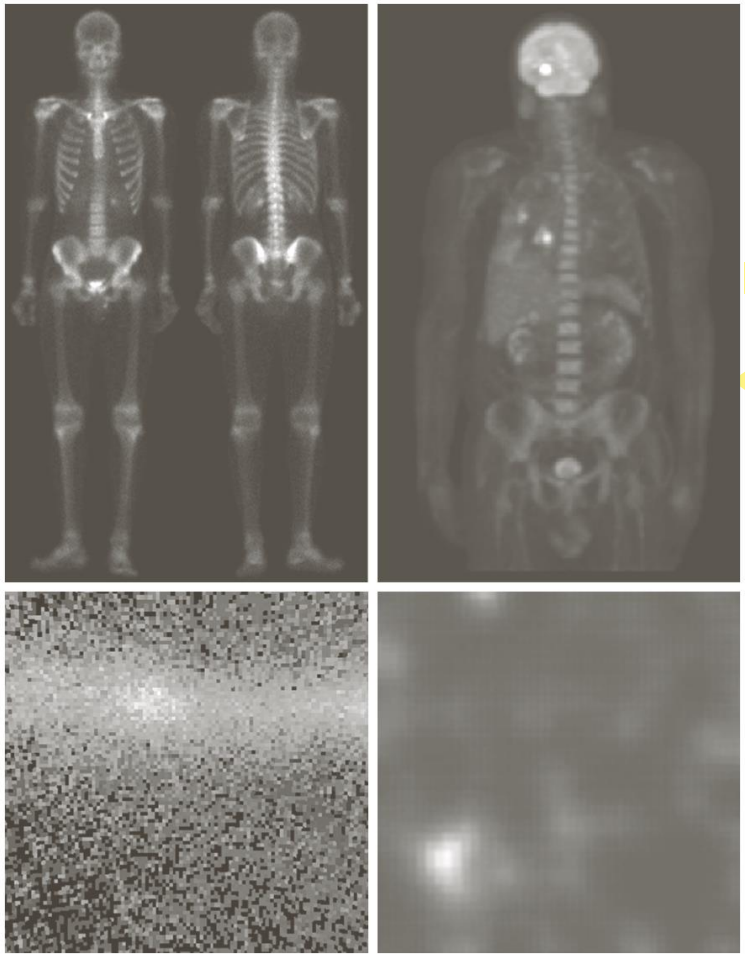
high wavelength

high frequency

low wavelength

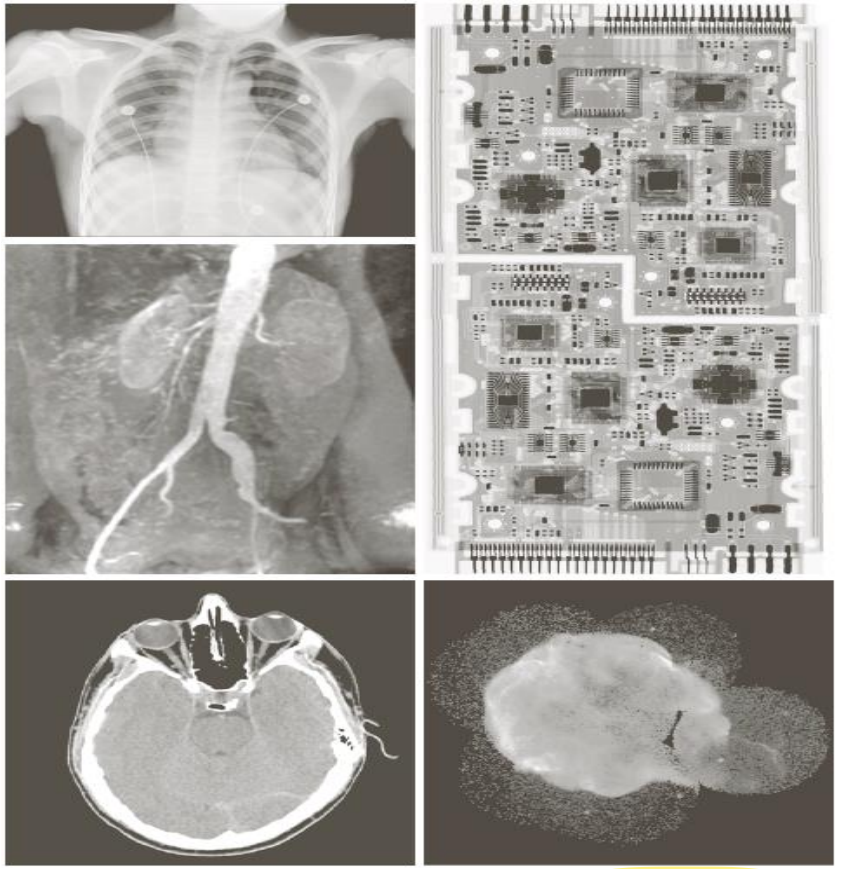


Gamma ray and X-ray Imaging



a b
c d

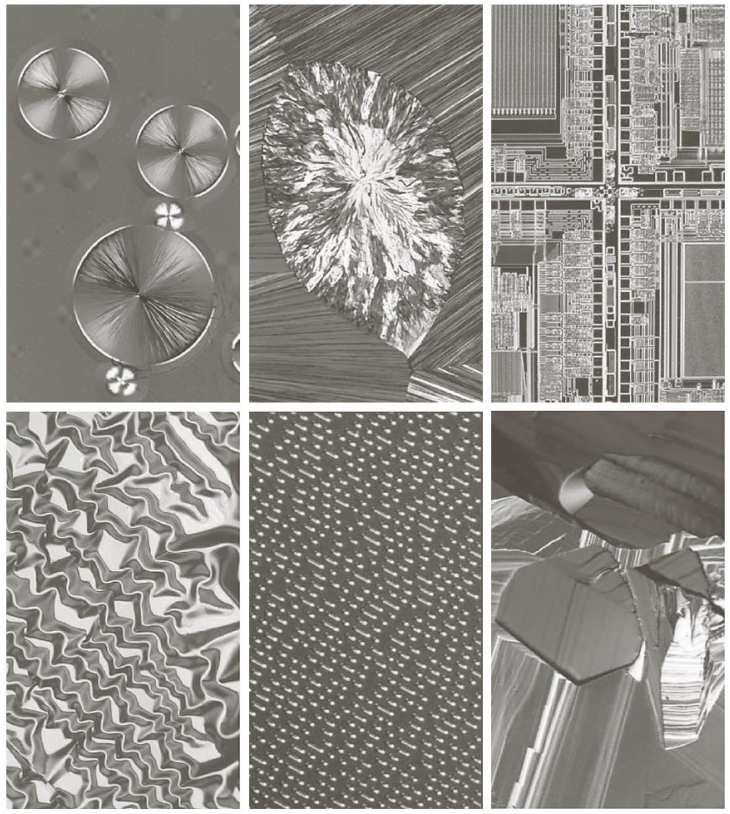
FIGURE 1.6 Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of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



a d
b e
c

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.)

Visible & Infrared



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.)

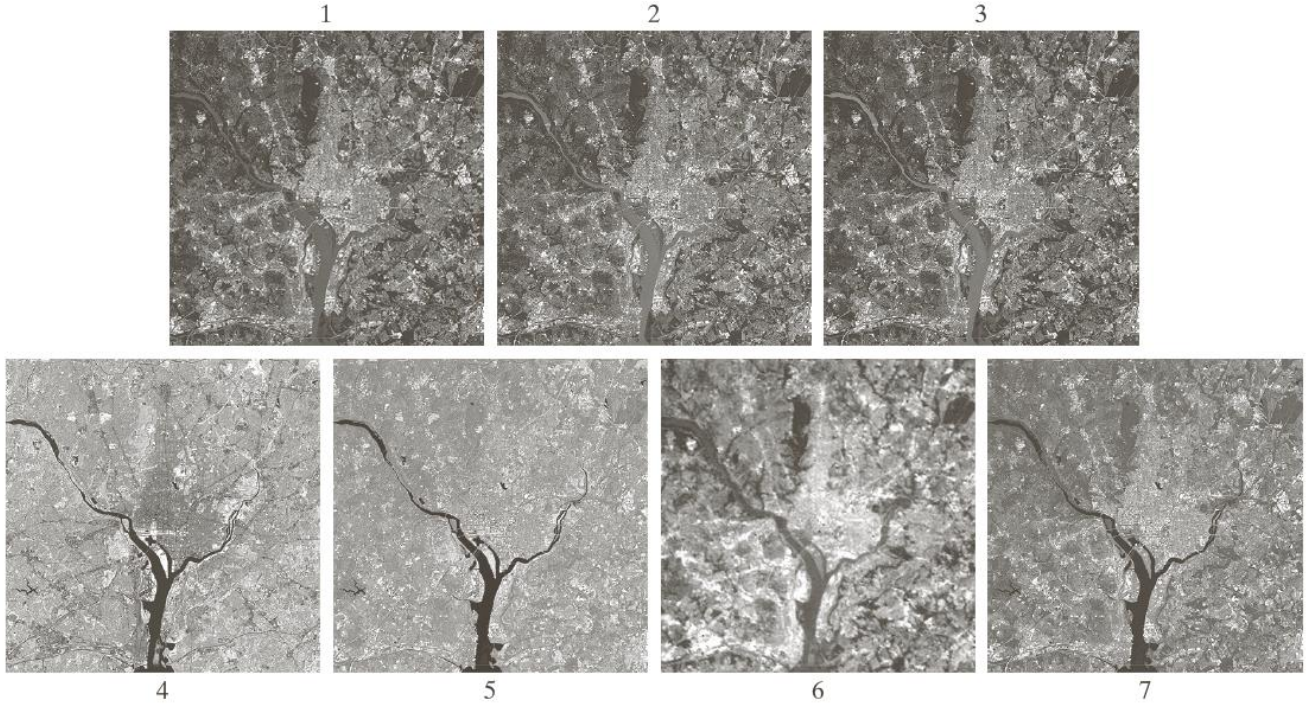


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

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.

Micro and Radio Waves

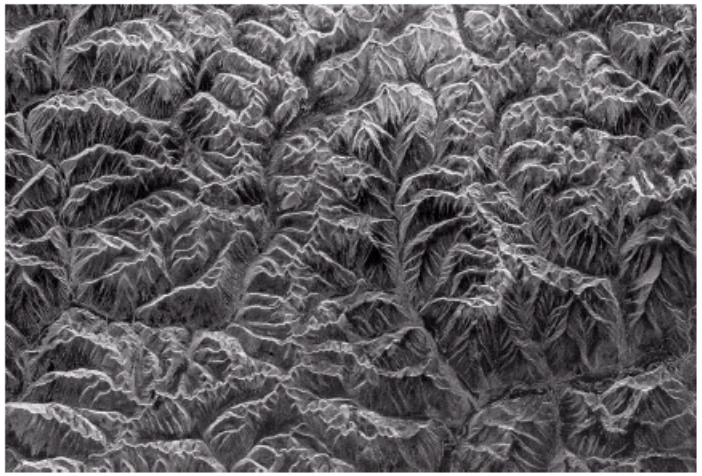
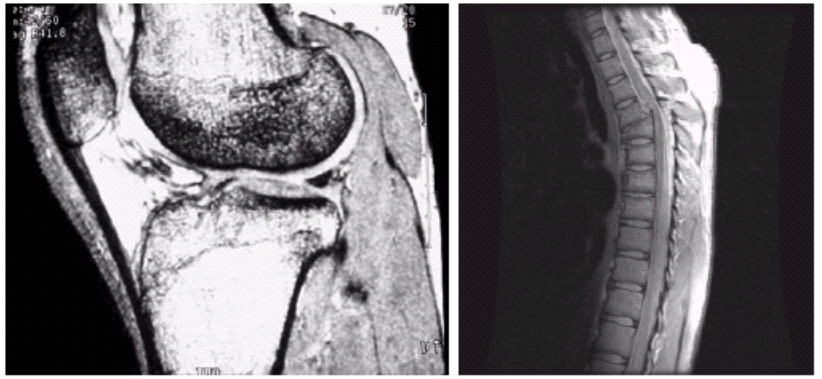


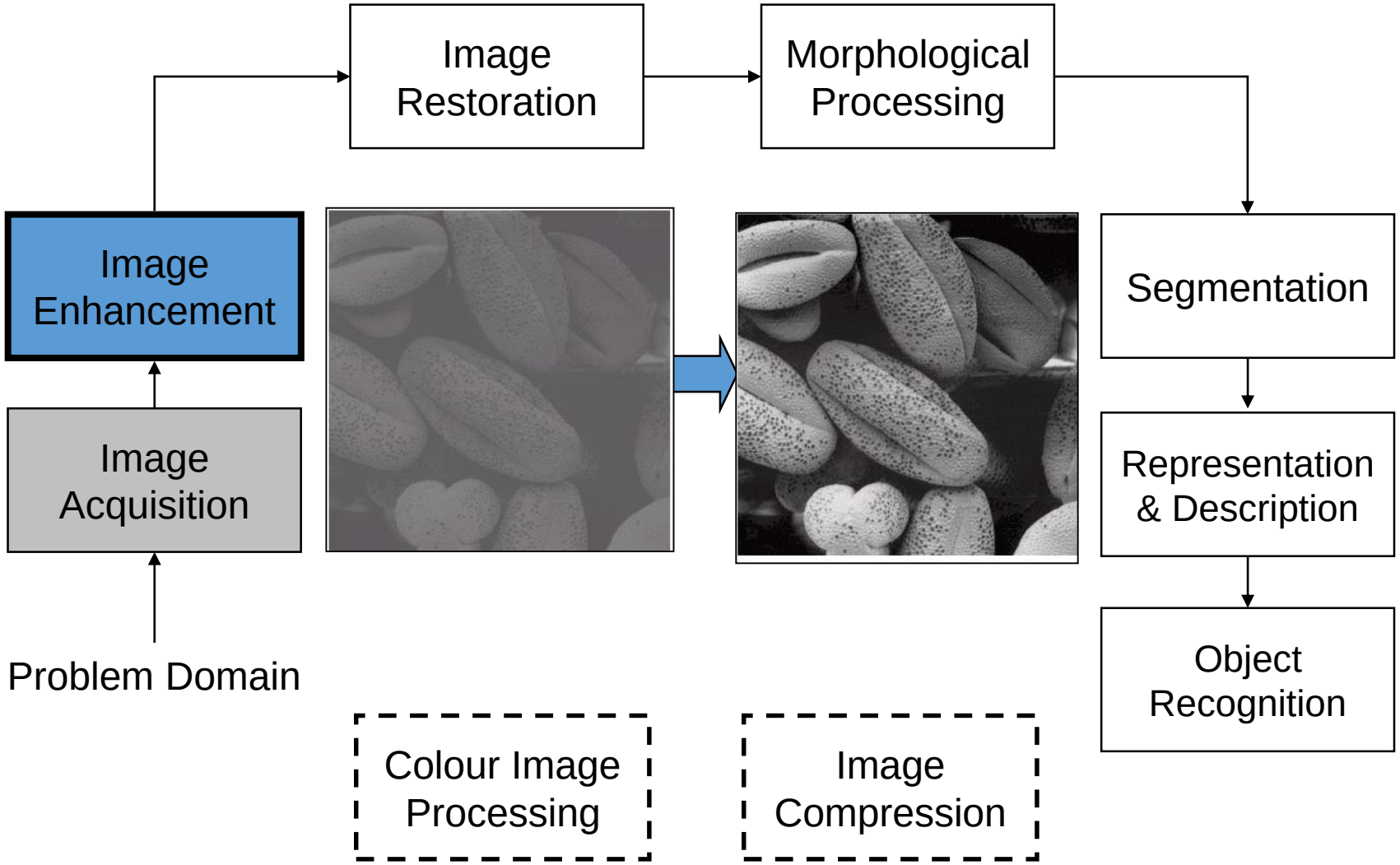
FIGURE 1.16
Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)



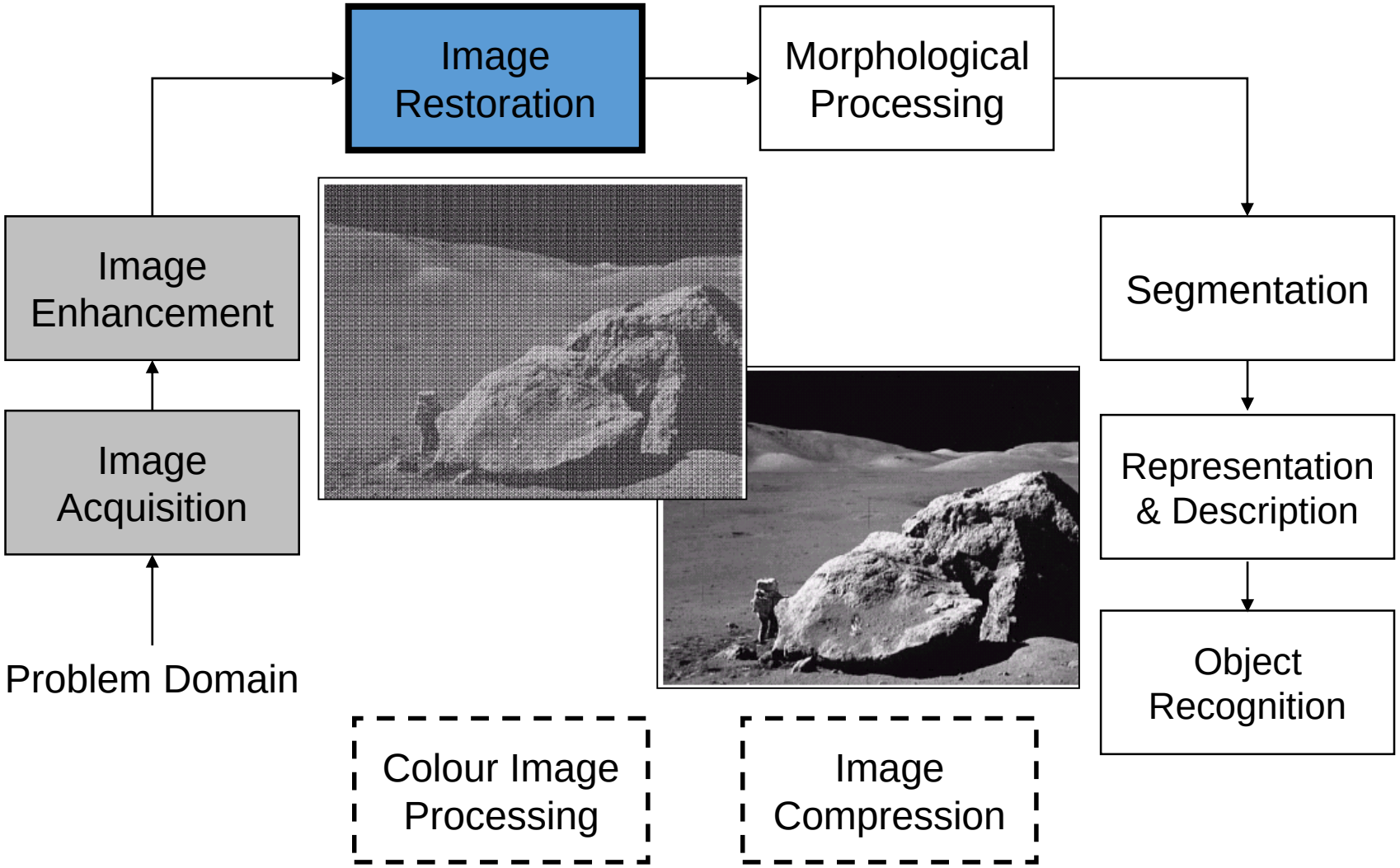
a b

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.)

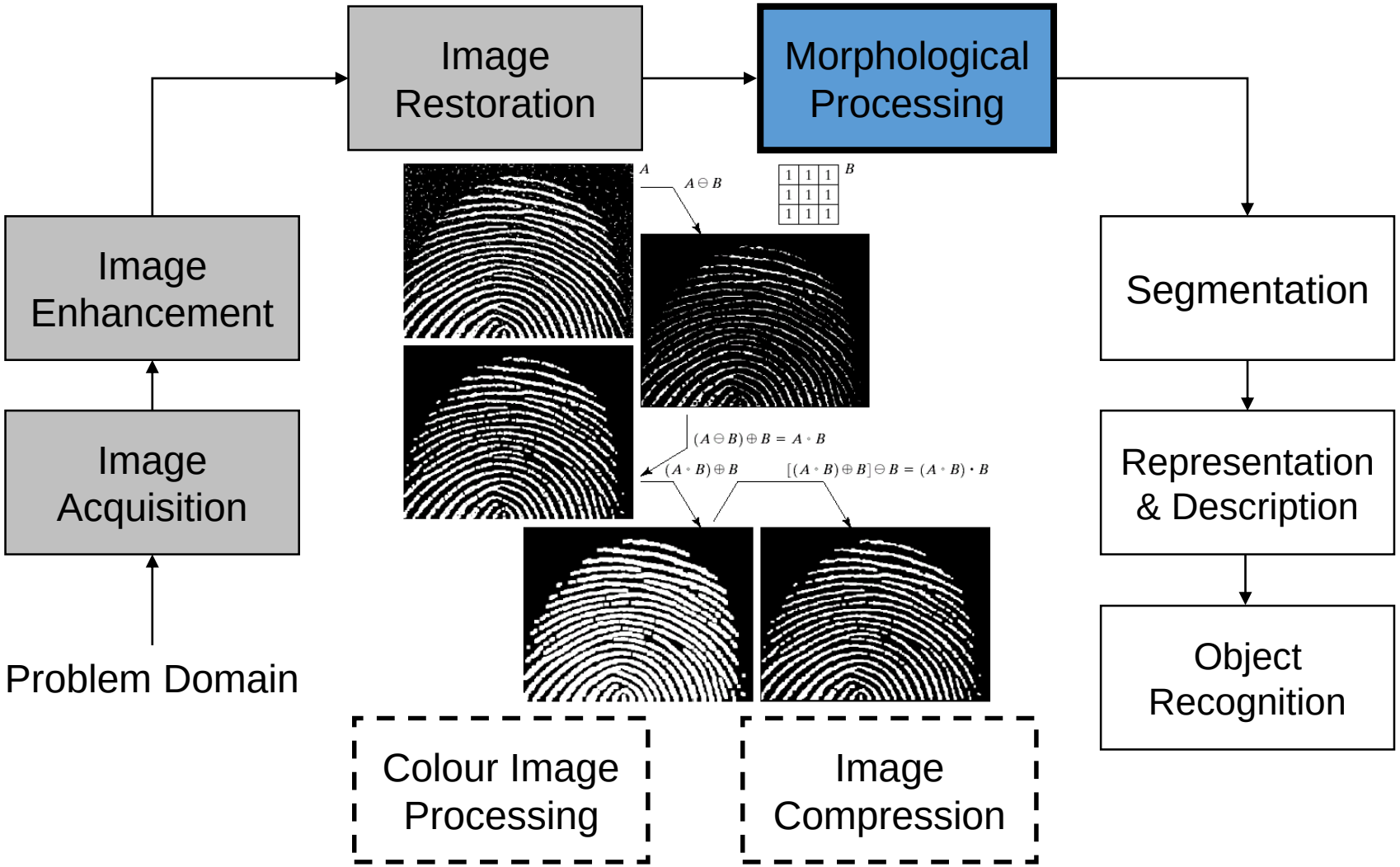
Key Stages in Digital Image Processing: Image Enhancement



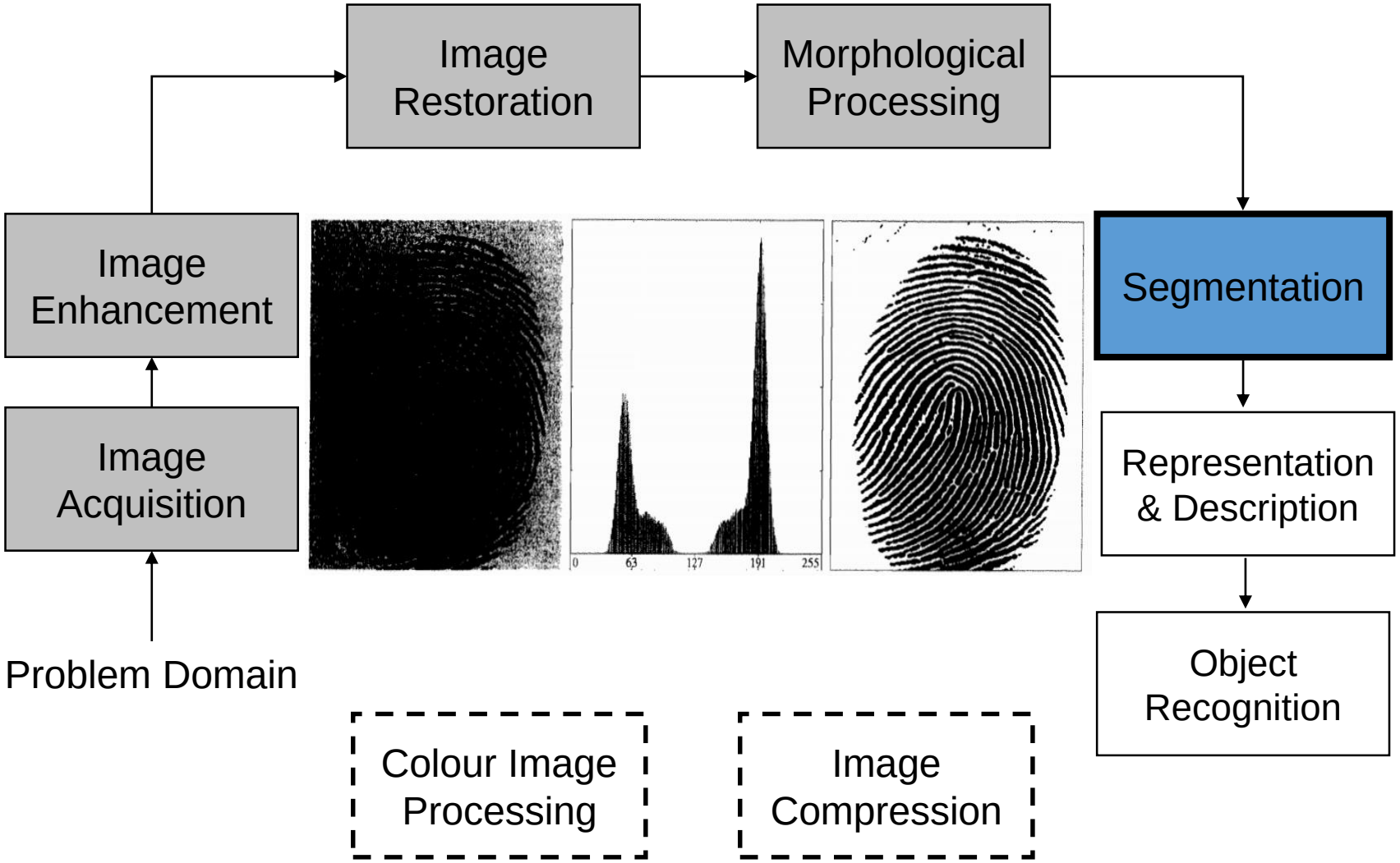
Key Stages in Digital Image Processing: Image Restoration



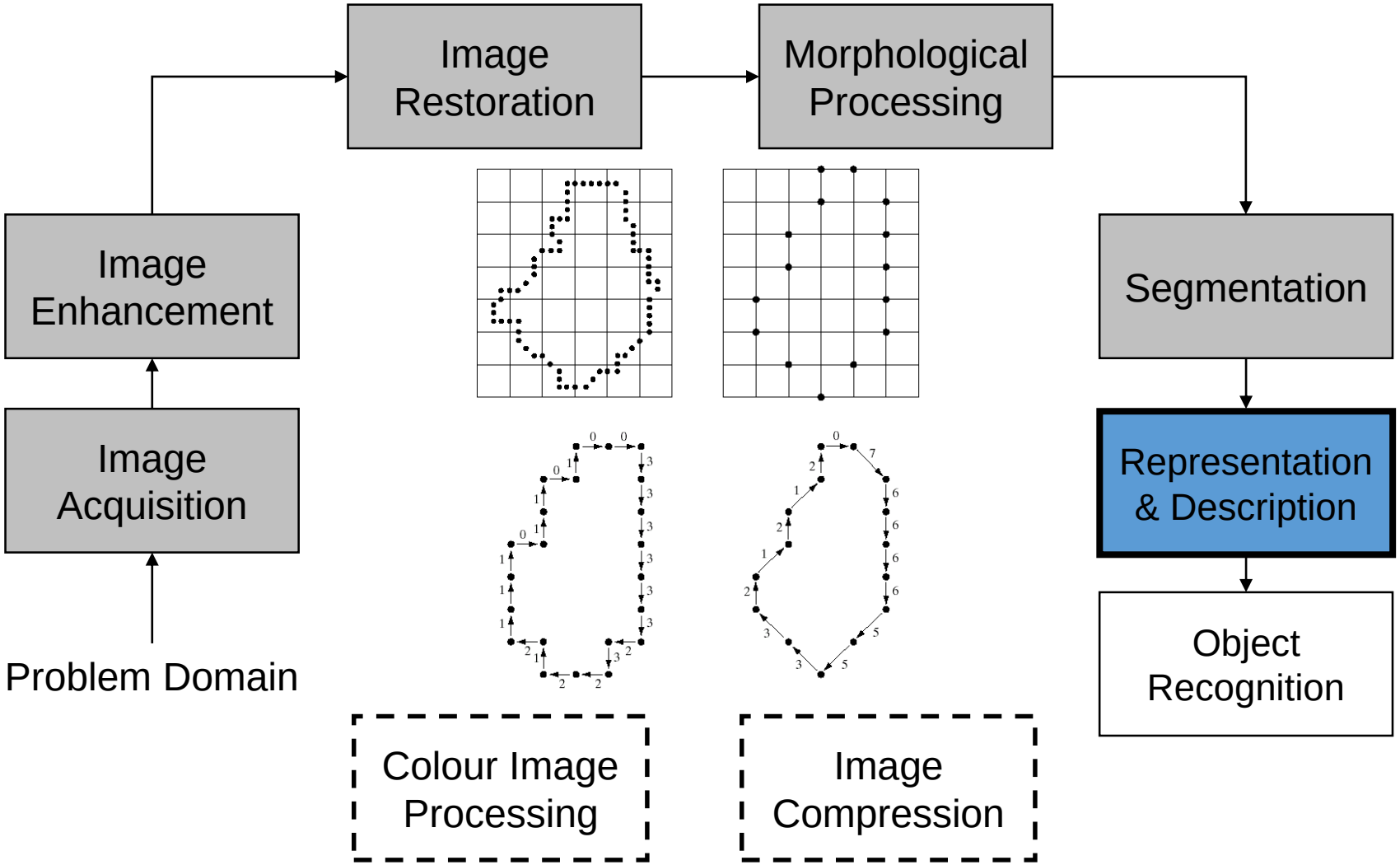
Key Stages in Digital Image Processing: Morphological Processing



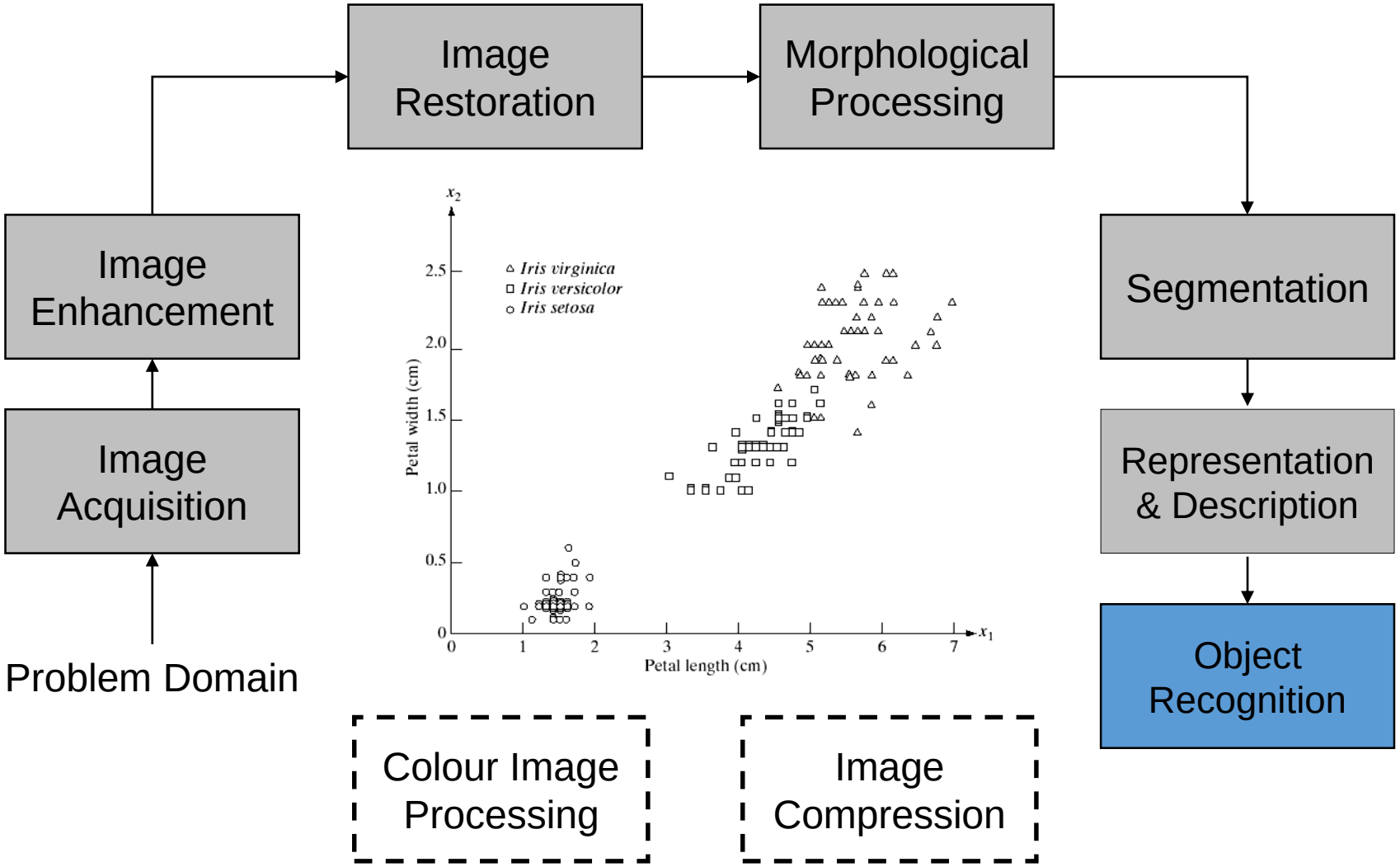
Key Stages in Digital Image Processing: Segmentation



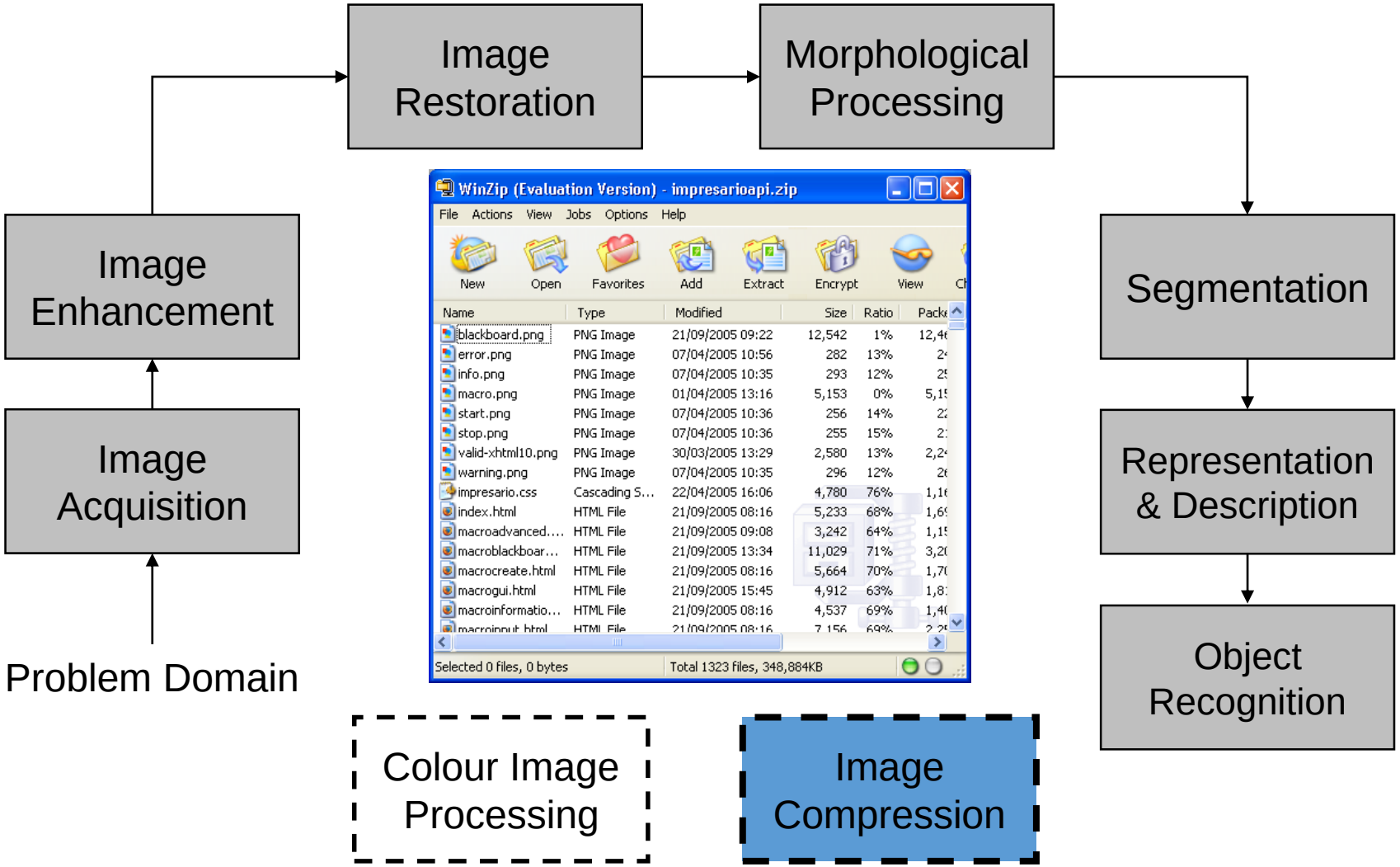
Key Stages in Digital Image Processing: Representation & Description



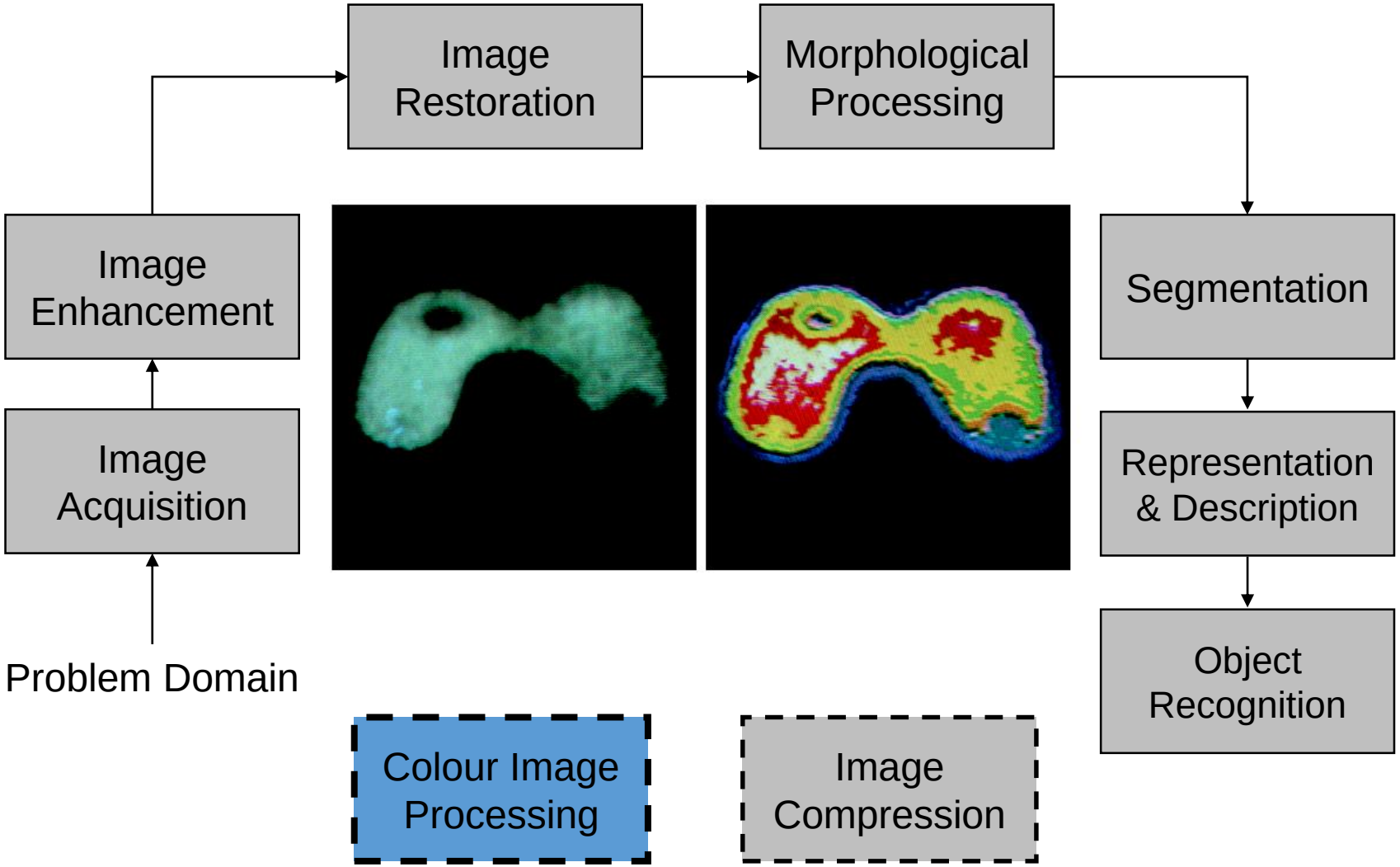
Key Stages in Digital Image Processing: Object Recognition



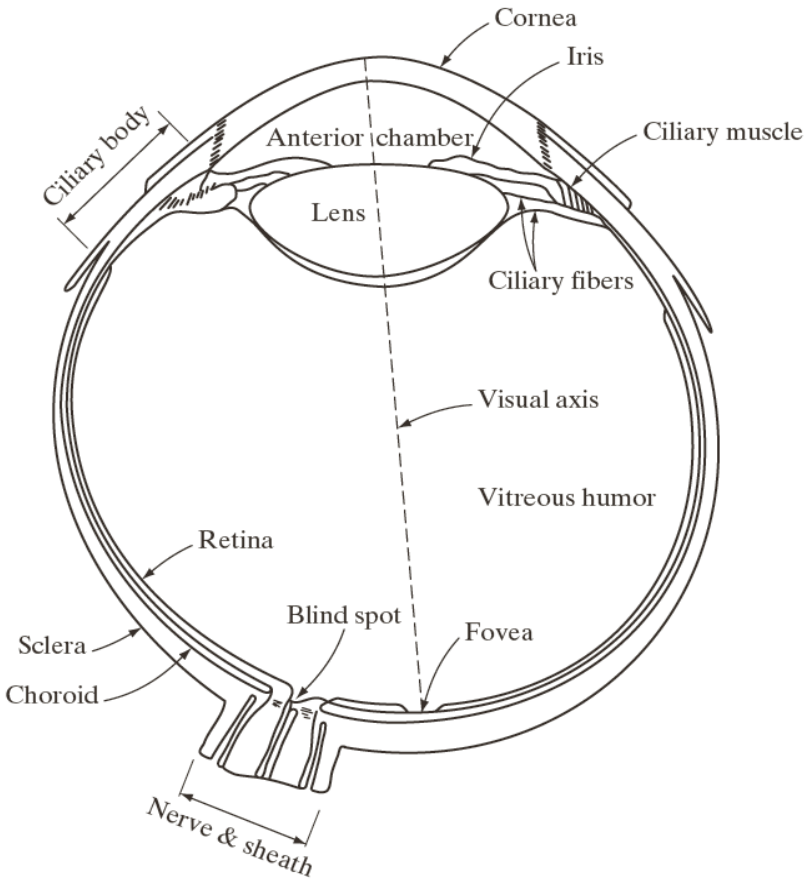
Key Stages in Digital Image Processing: Image Compression

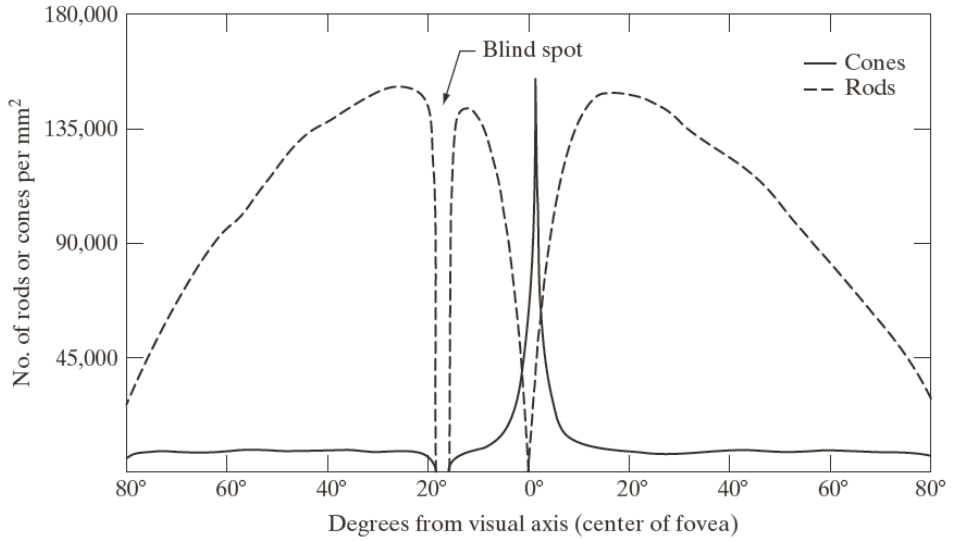


Key Stages in Digital Image Processing: Colour Image Processing



Vision by Human Eye





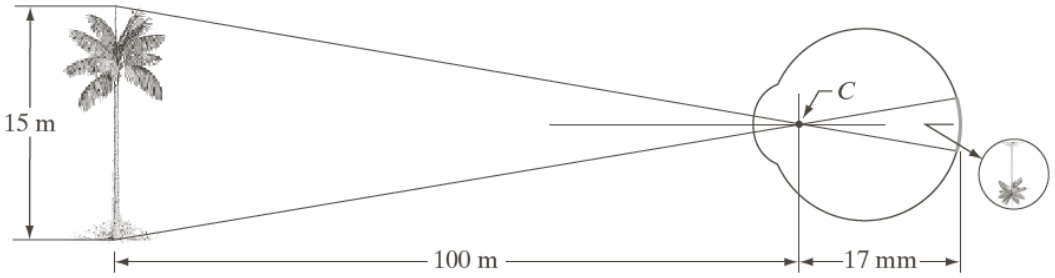
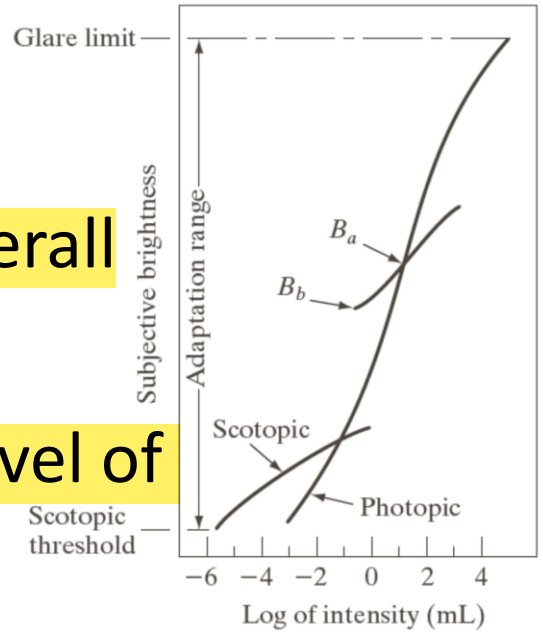


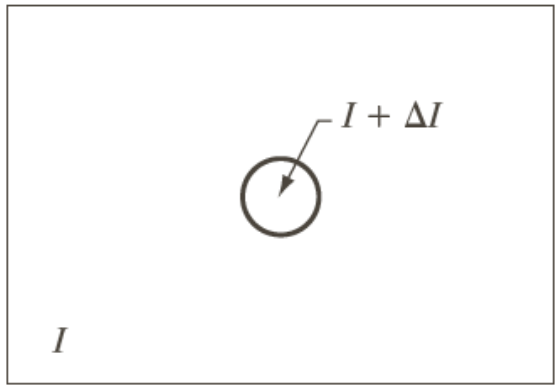
FIGURE 2.3 Graphical representation of the eye looking at a palm tree. Point *C* is the optical center of the lens.

Brightness Adaptation and Discrimination

- The range of light intensity levels to which the HVS can adapt is enormous.
- HVS cannot operate over such range simultaneously.
- It accomplishes such large variation by changes in its overall sensitivity (brightness adaptation)
- For any given set of conditions, the current sensitivity level of the visual system is called adaptation level (B_a).



Weber Ratio



- The quantity $\frac{\Delta I_c}{I}$, where ΔI_c is the increment of the illumination discriminable 50% of the time with background illumination I is called the Weber ratio.
- A small Weber ratio indicates good brightness discrimination.