CPE409 Image Processing

Part 1
Introduction to Digital Image Processing

Assist. Prof. Dr. Caner ÖZCAN

Fall in love with the process, and the results will come.
~ Eric Thomas

Introduction to the Course

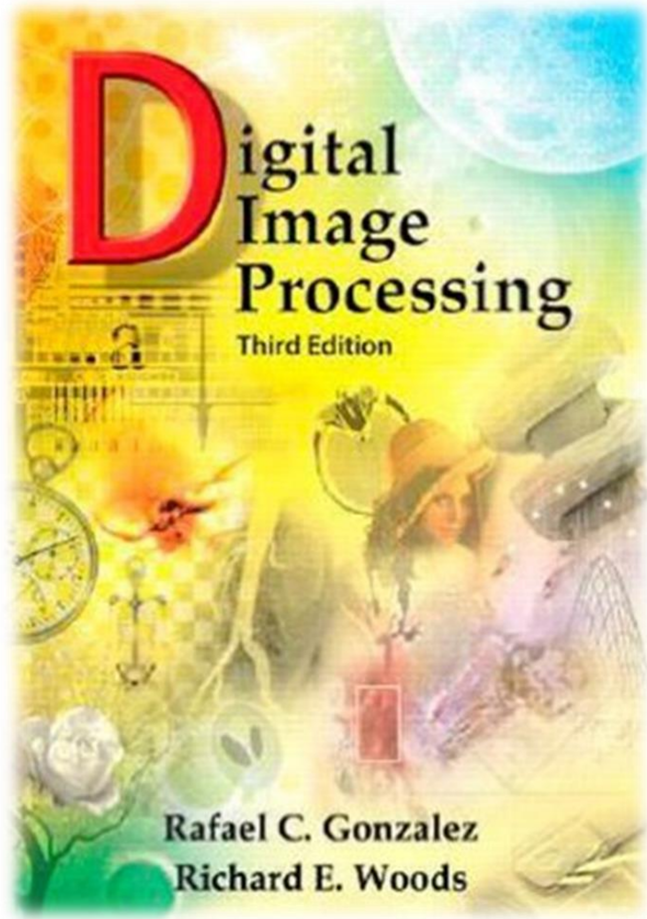
- Course Web Site: www.canerozcan.net

- Office Hours: **Monday 15:30-16:30**
  Tuesday 13:00-14:30

  or appointment by email:
  canerozcan@karabuk.edu.tr

- Textbooks:
  - **Sayısal Görüntü İşleme, Palme Yayıncılık, Üçüncü Baskıdan Çeviri (Orj: Digital Image Processing, R.C. Gonzalez, R.E. Woods)**
  - **"Digital Image Processing Using Matlab", Gonzalez & Richard E. Woods, Steven L. Eddins, Gatesmark Publishing, 2009**

Introduction to the Course



focused again on material that we believe is fundamental and whose scope of application is not limited to the solution of specialized problems. The mathematical complexity of the book remains at a level well within the grasp of college seniors and first-year graduate students who have introductory preparation in mathematical analysis, vectors, matrices, probability, statistics, linear systems, and computer programming. The book Web site provides tutorials to

Course Objectives

- Cover basic theory and algorithms widely used in image processing
- Develop hands-on experience in processing images
- Familiarize with Matlab and OpenCV (Open Source Computer Vision)
- Develop critical thinking about the state of the art

Prerequisites

- Signals and systems
- Linear algebra
  - Matrices, Matrix Operations
  - Determinants, Systems of Linear Equations
- Probability and Statistics
  - Probability density function
  - Probability distribution
  - Mean, variance, co-variance, correlation
  - Gaussian distribution
- Good programming skills

Introduction to the Course

- Grading
  - Midterm Exam: 40%
  - Final Exam: 60%

- Bonus:
  - Presentation
  - Homework
  - Project

Introduction to the Course

- Project
  - Hand Gesture Recognition
  - Iris Recognition
  - Biomedical Image Segmentation and Recognition
  - Content-Based Image Retrieval
  - Fingerprint Recognition
  - Object Tracking in Video Sequences
  - Face and Plate Recognition
  - Watermarking
  - Image Compression
  - Automatic Quality Inspection
  - Traffic Surveillance
  - Security Applications
  - Radar Image Processing Applications
  - Whatever you're interested …

Outline

1. Introduction
   - What Is Digital Image Processing?
   - The Origins of Digital Image Processing
   - Examples of Fields that Use Digital Image Processing
   - Fundamental Steps in Digital Image Processing
   - Components of an Image Processing System

Introduction

▶ What is Digital Image Processing?

Digital Image

— a two-dimensional function $f(x, y)$

x **and** ***y*** **are spatial coordinates**

The amplitude of ***f*** **is called intensity or gray level at the point (x, y)**

Digital Image Processing

— process digital images by means of computer, it covers low-, mid-, and high-level processes

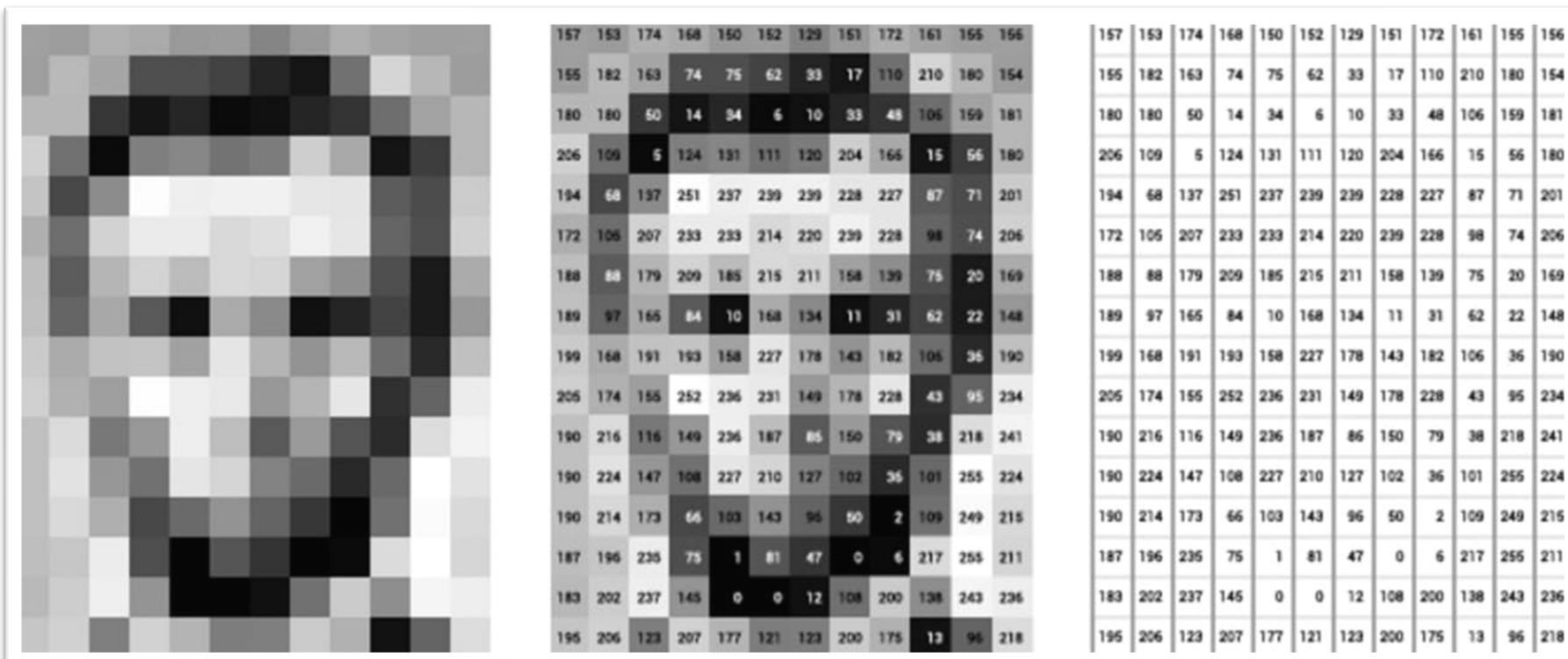
low-level: inputs and outputs are images

mid-level: outputs are attributes extracted from input images

high-level: an ensemble of recognition of individual objects

- **Pixel**
  - components of a digital image

Image processing is actually a set of operations on matrices. Each element of the matrix representing the digital image is called a pixel.



What Is Digital Image Processing?

- Digital image processing focuses on two main tasks
  - Improvement of image information for people's perception and interpretation
  - Processing of image data for storage, transmission and good detection of machines

- There are debates about where the image processing ends and where other areas such as image analysis and computer vision begin.

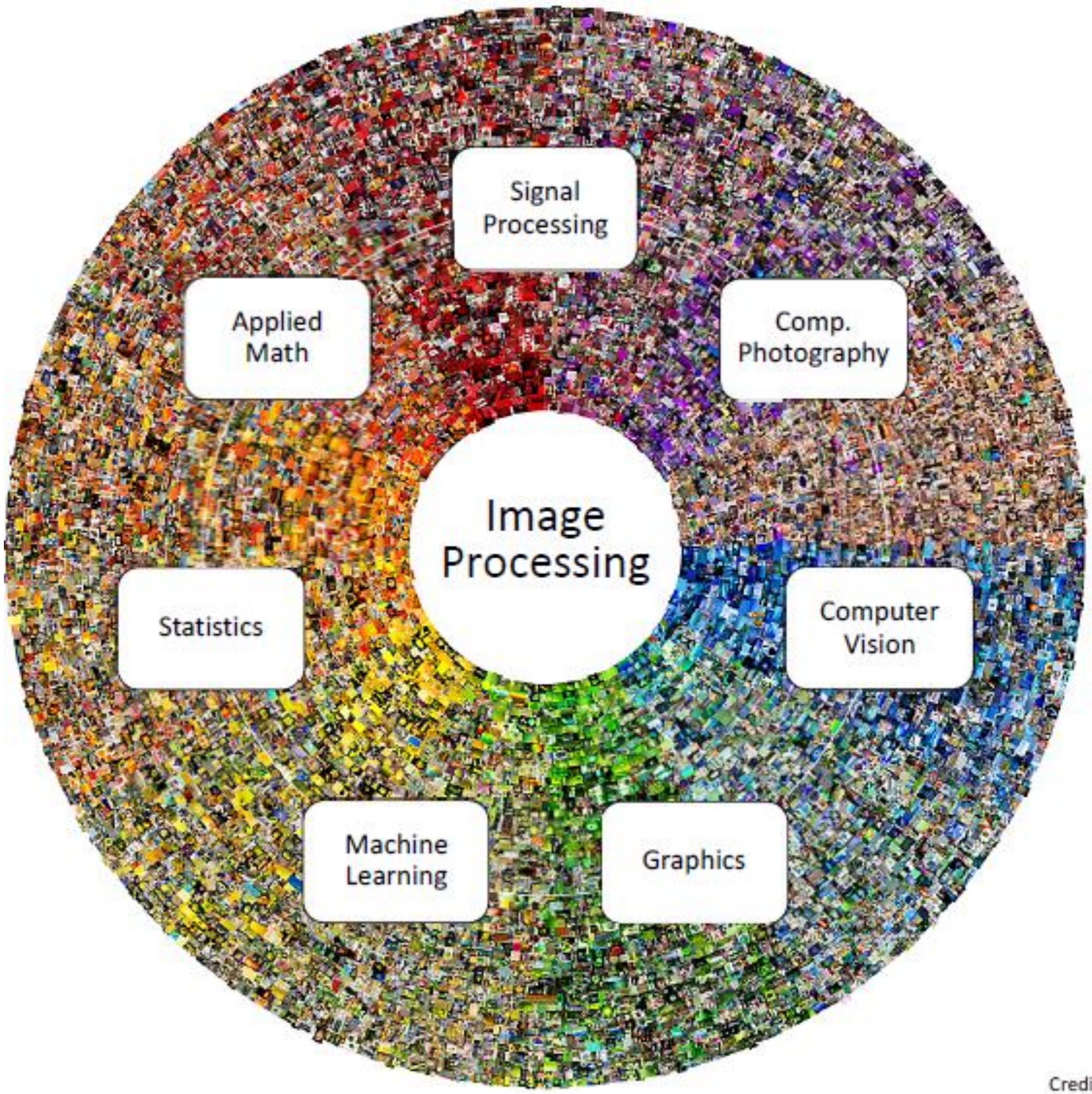
What Is Digital Image Processing?

- We can divide the area from image processing to computer vision to three levels: low, medium and high.

Low Level Processing	Medium Level Processing	High Level Processing
Input: Image **Output:** Image	**Input:** Image **Output:** Features	**Input:** Features **Output:** Recognition
Examples: Denoising, image sharpening, contrast enhancement	**Examples:** Object recognition, segmentation	**Examples:** Screen recognition, automatic navigation

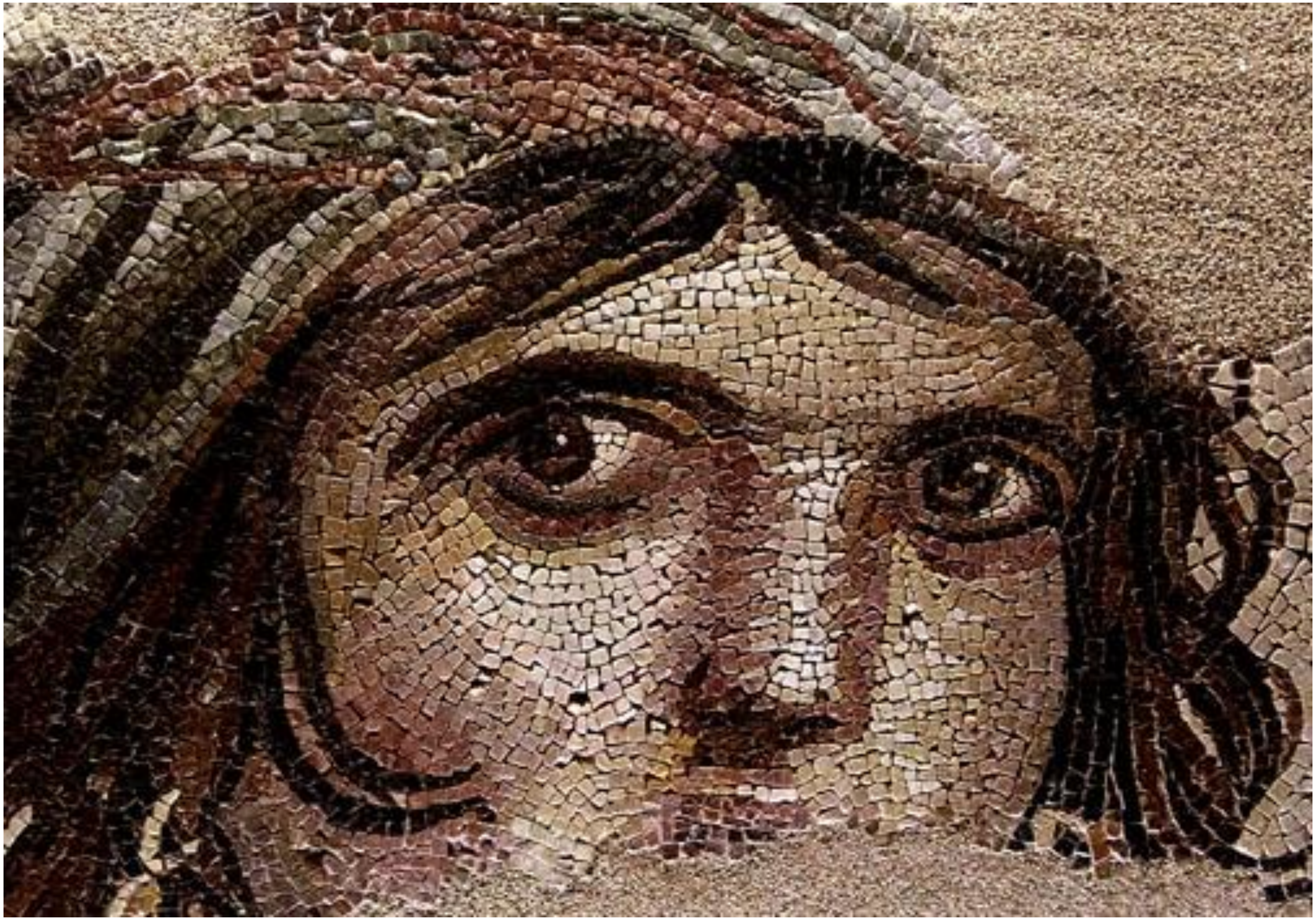
We're gonna stay here.

Introduction



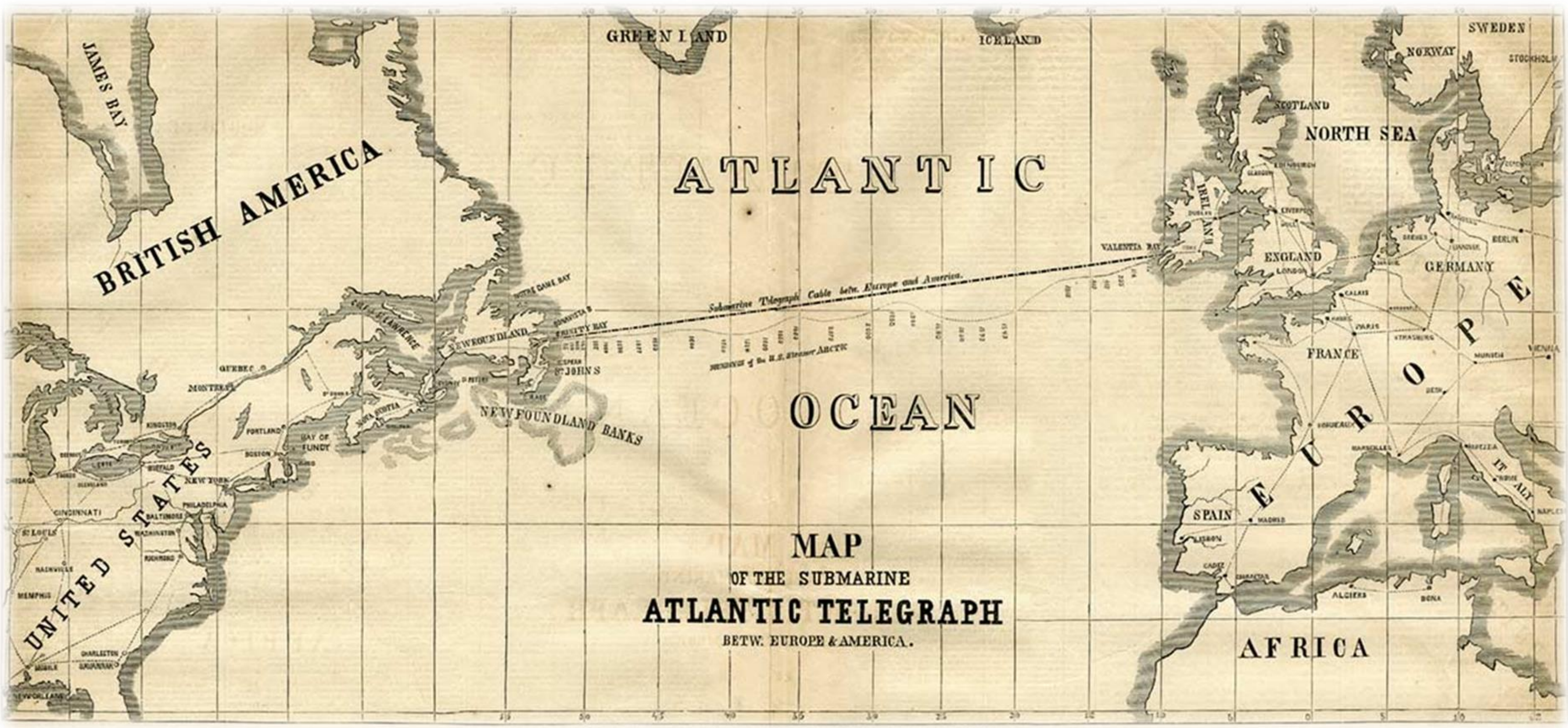
Credit: P. Milanfar

Introduction



When the mosaics are closely examined, it is seen that they are made up of small squares like a digital image.

Start of the Digital Image Processing



submarine cable between London-New York

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.[†])

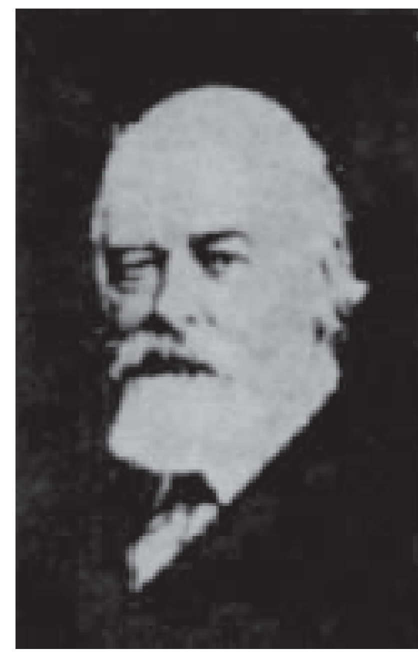


FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. (McFarlane.)

Origins of Digital Image Processing

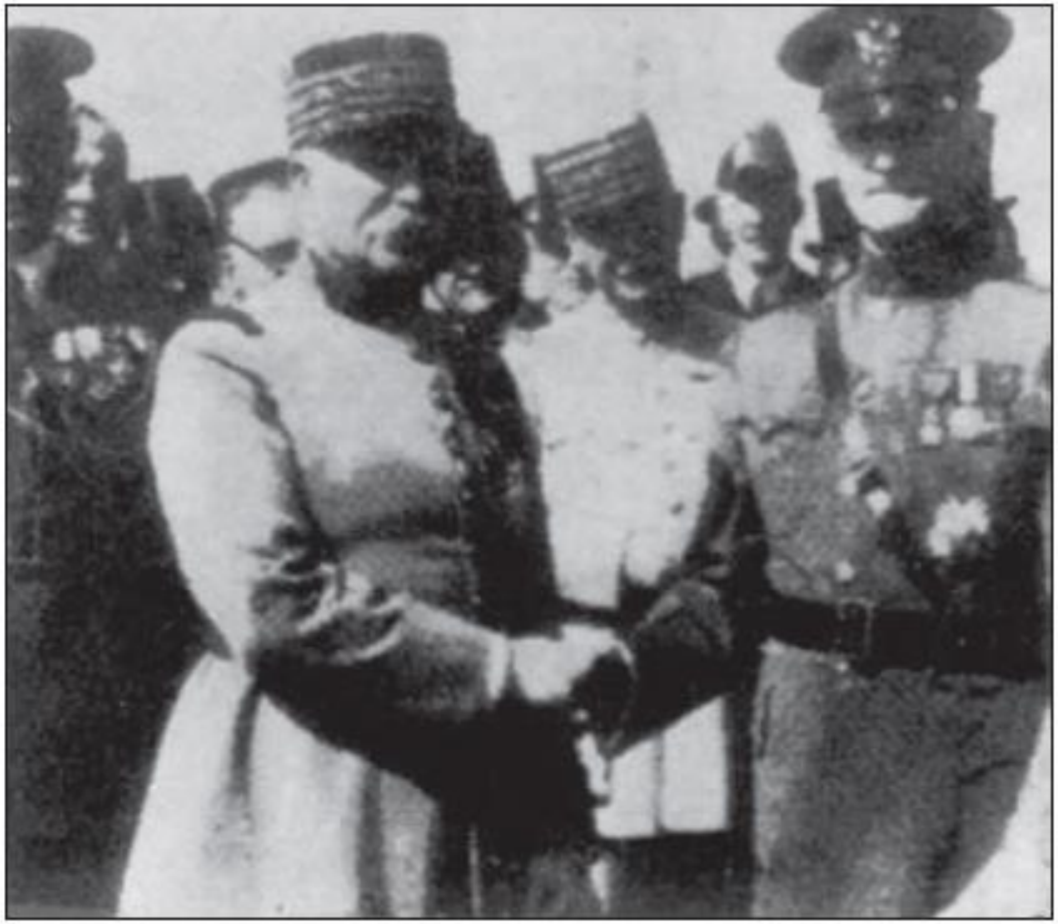


FIGURE 1.3 Unretouched cable picture of Generals Pershing and Foch, transmitted in 1929 from London to New York by 15-tone equipment. (McFarlane.)

Origins of Digital Image Processing

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.)

Sources for Images

- Electromagnetic (EM) energy spectrum
- Acoustic
- Ultrasonic
- Electronic
- Synthetic images produced by computer

Electromagnetic (EM) energy spectrum

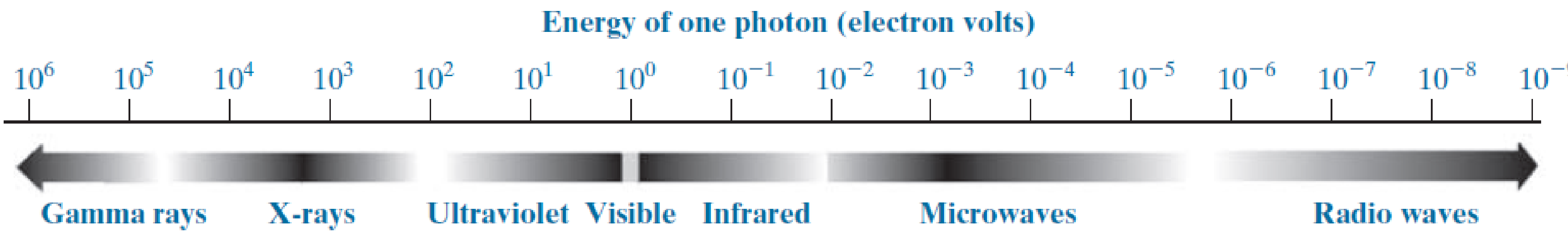
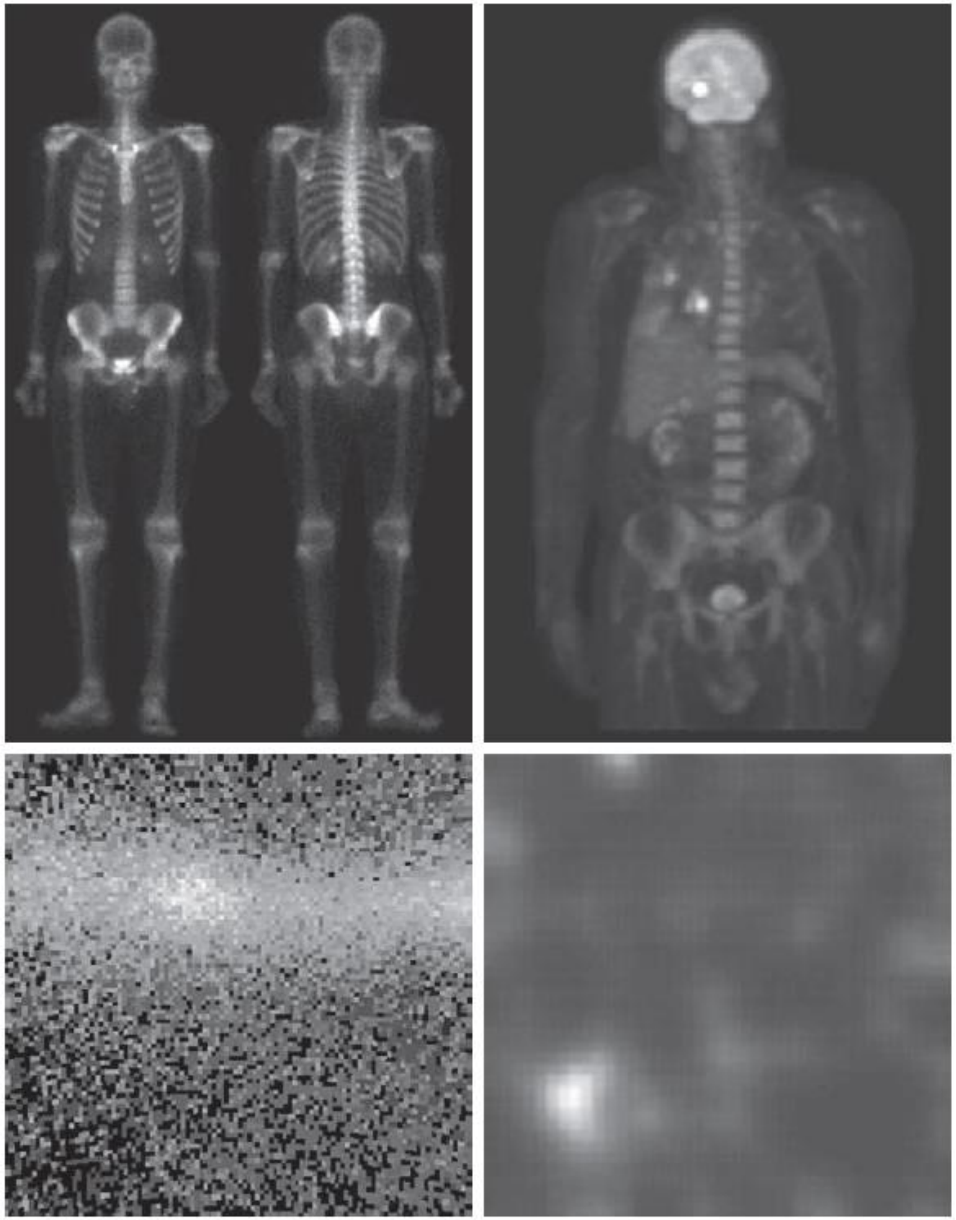


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

Major uses

- **Gamma-ray imaging**: nuclear medicine and astronomical observations
- **X-rays**: medical diagnostics, industry, and astronomy, etc.
- **Ultraviolet**: lithography, industrial inspection, microscopy, lasers, biological imaging, and astronomical observations
- **Visible and infrared bands**: light microscopy, astronomy, remote sensing, industry, and law enforcement
- **Microwave band**: radar
- **Radio band**: medicine (such as MRI) and astronomy

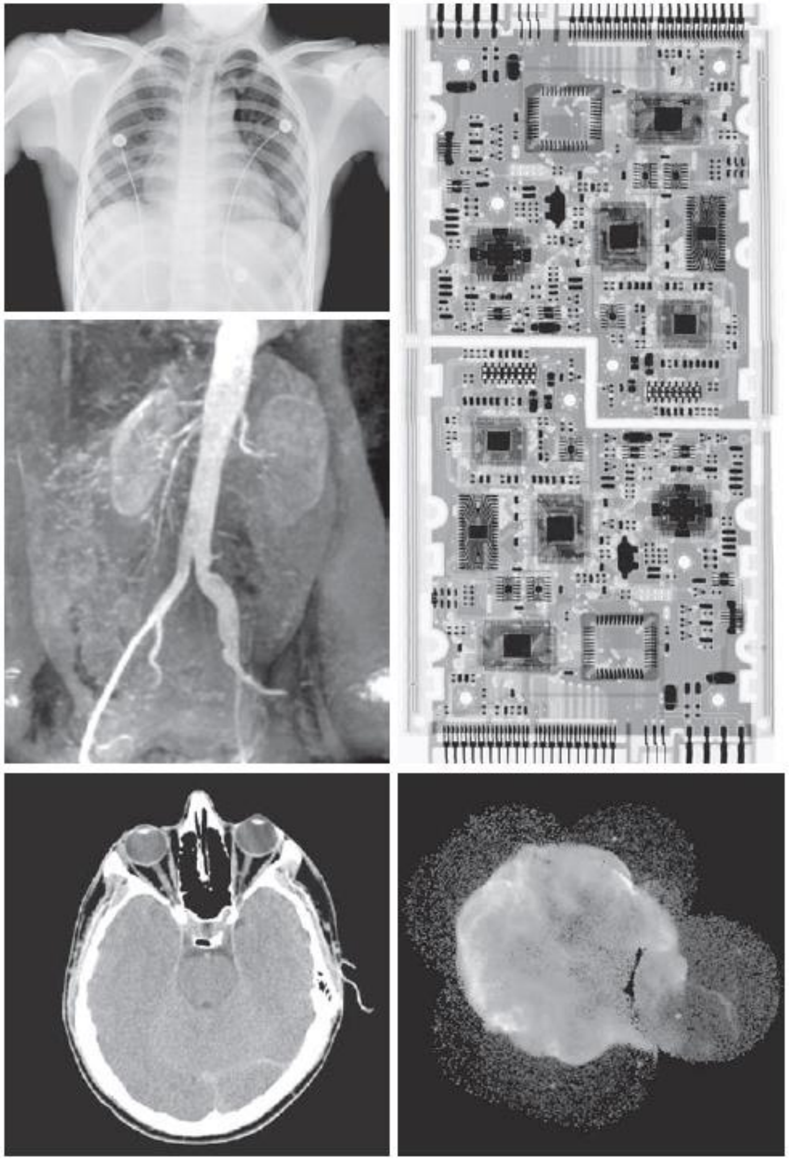
Gama-Ray Imaging



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.)

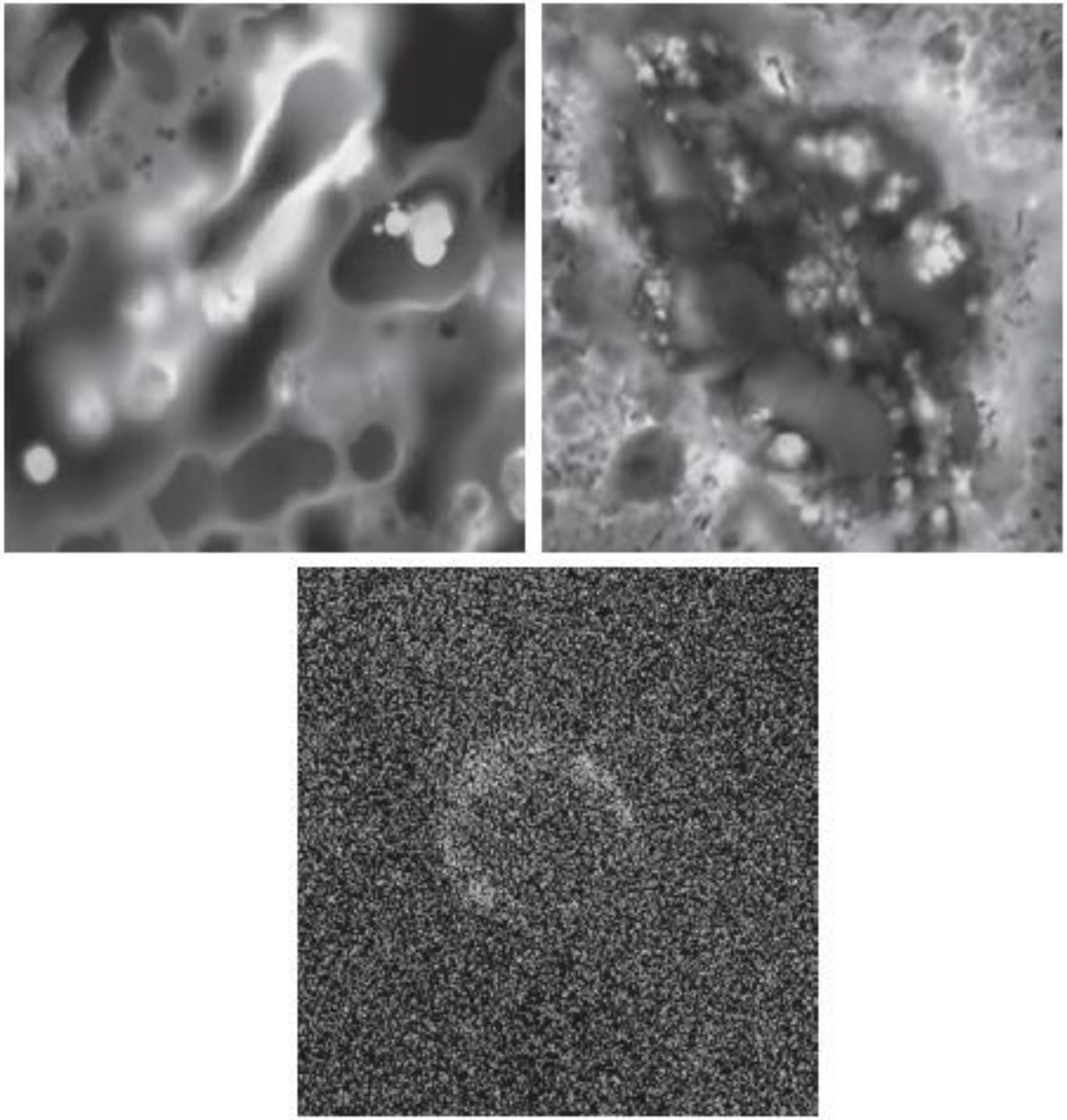
X-Ray Imaging



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.)

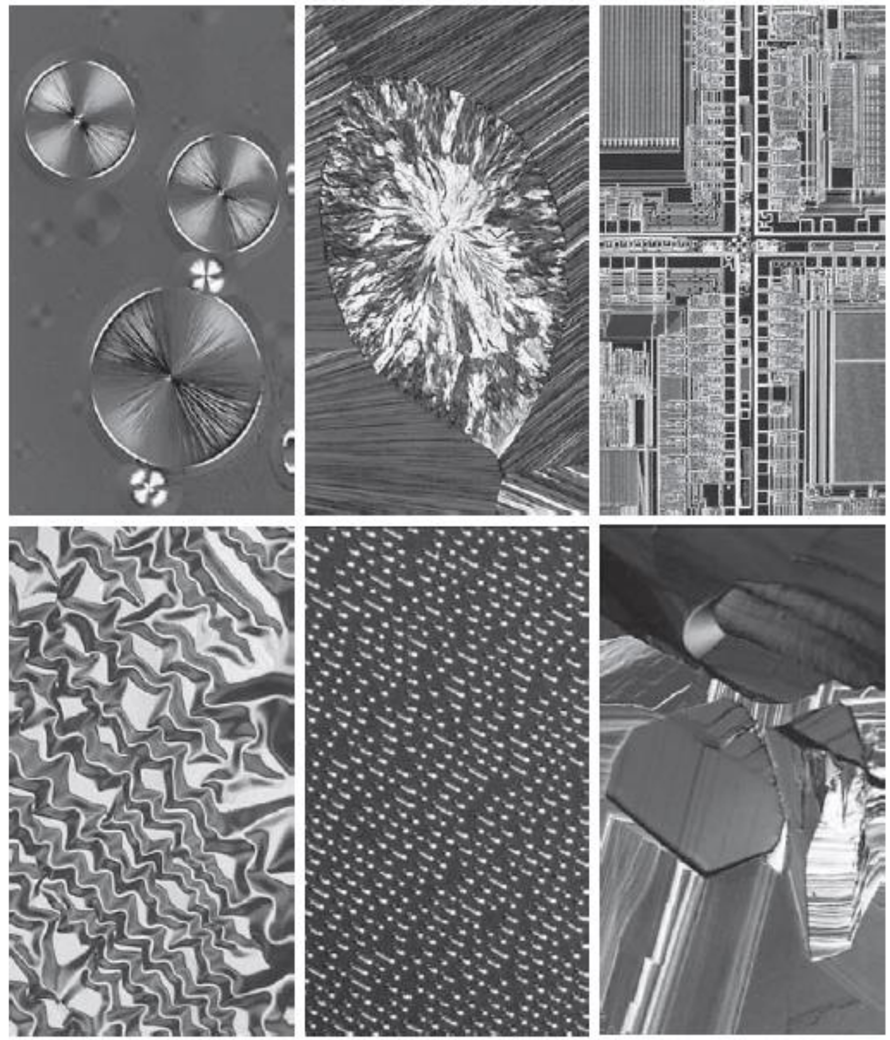
Ultraviolet Imaging



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.)

Visible and Infrared Imaging



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.)

Visible and Infrared Imaging

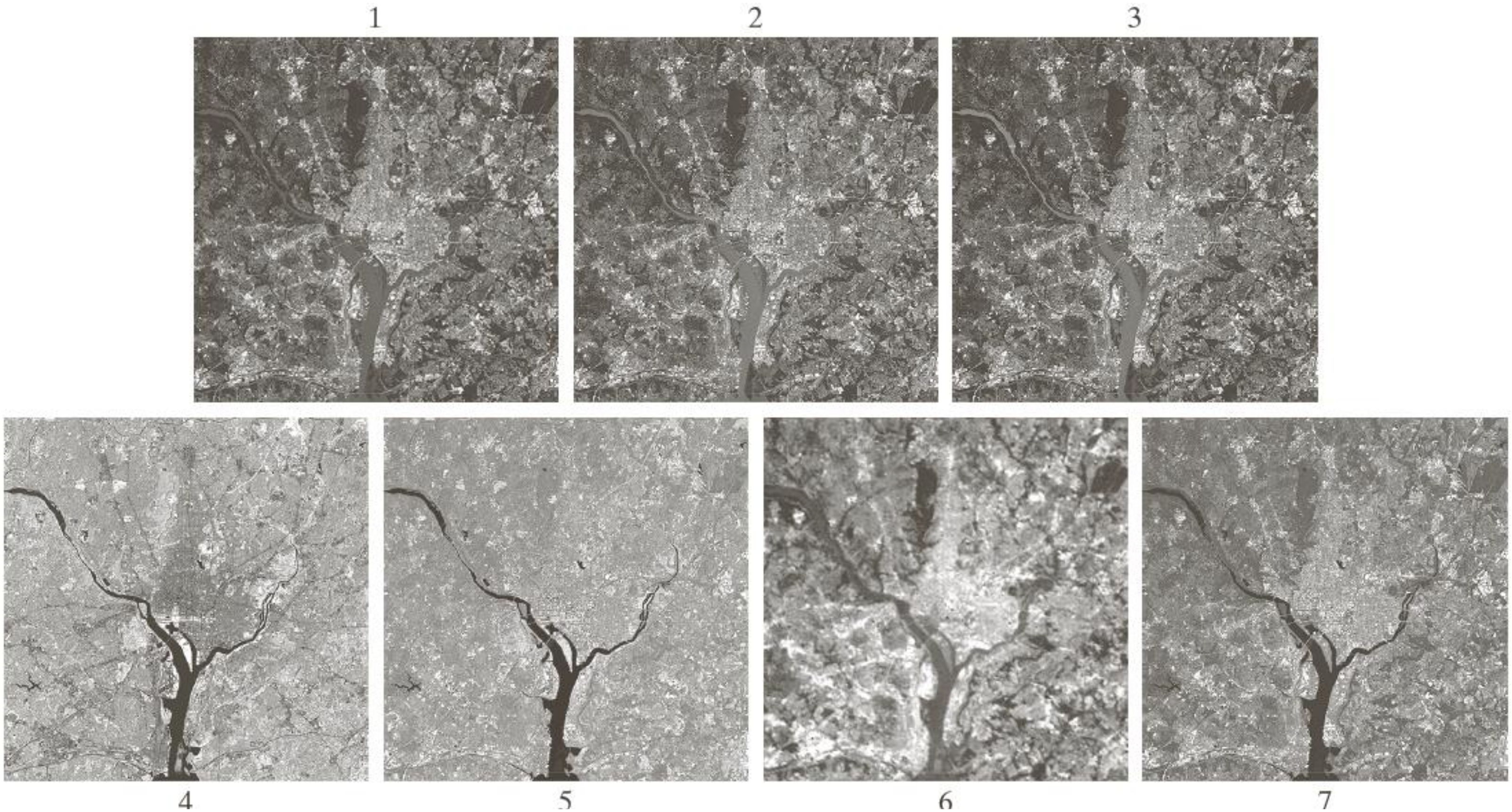


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

Visible and Infrared Imaging

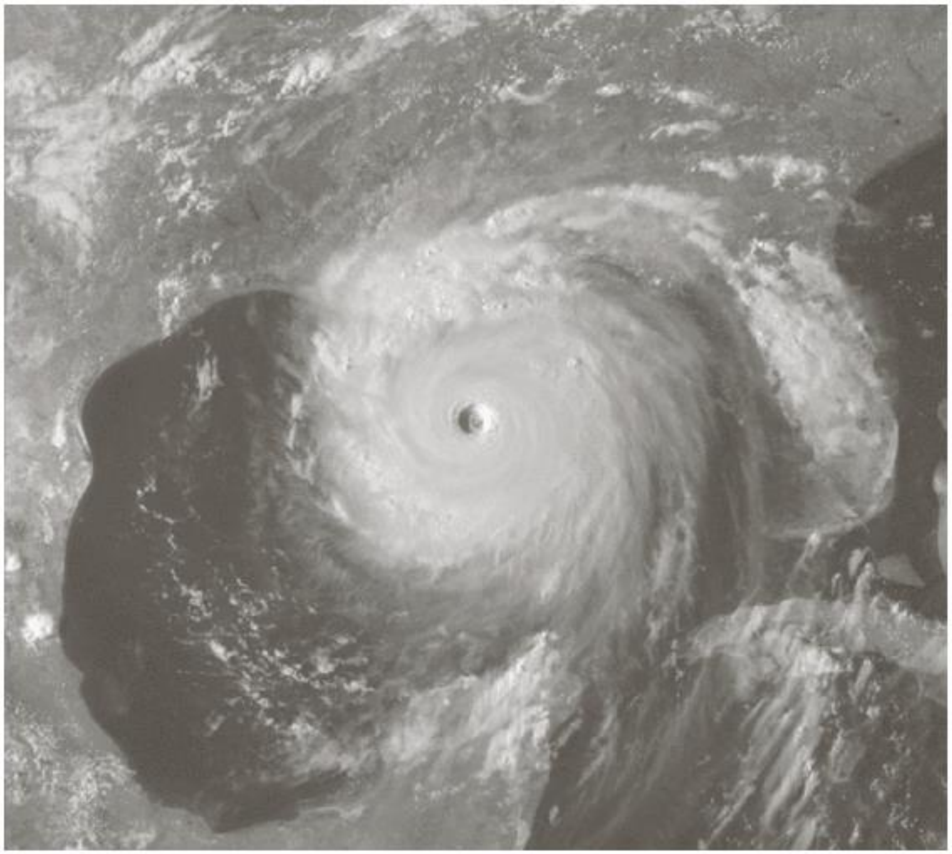


FIGURE 1.11 Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)

Visible and Infrared Imaging

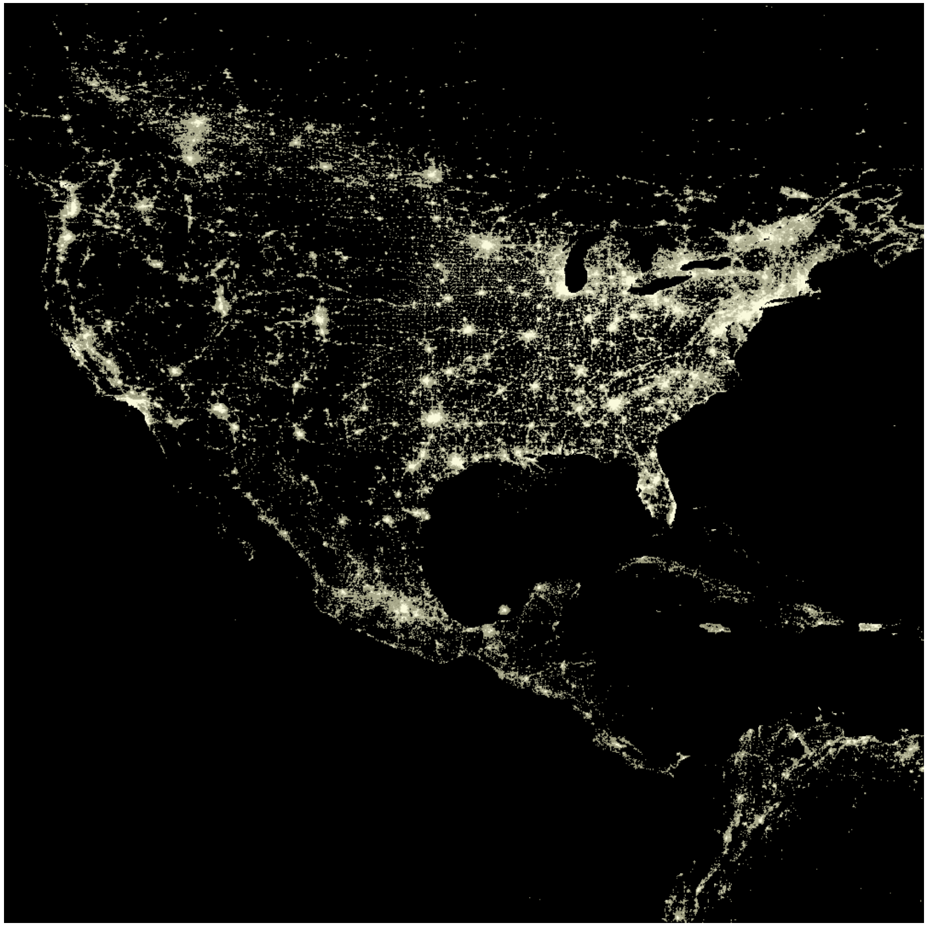


FIGURE 1.12 Infrared satellite images of the Americas. The small gray map is provided for reference. (Courtesy of NOAA.)

Visible and Infrared Imaging

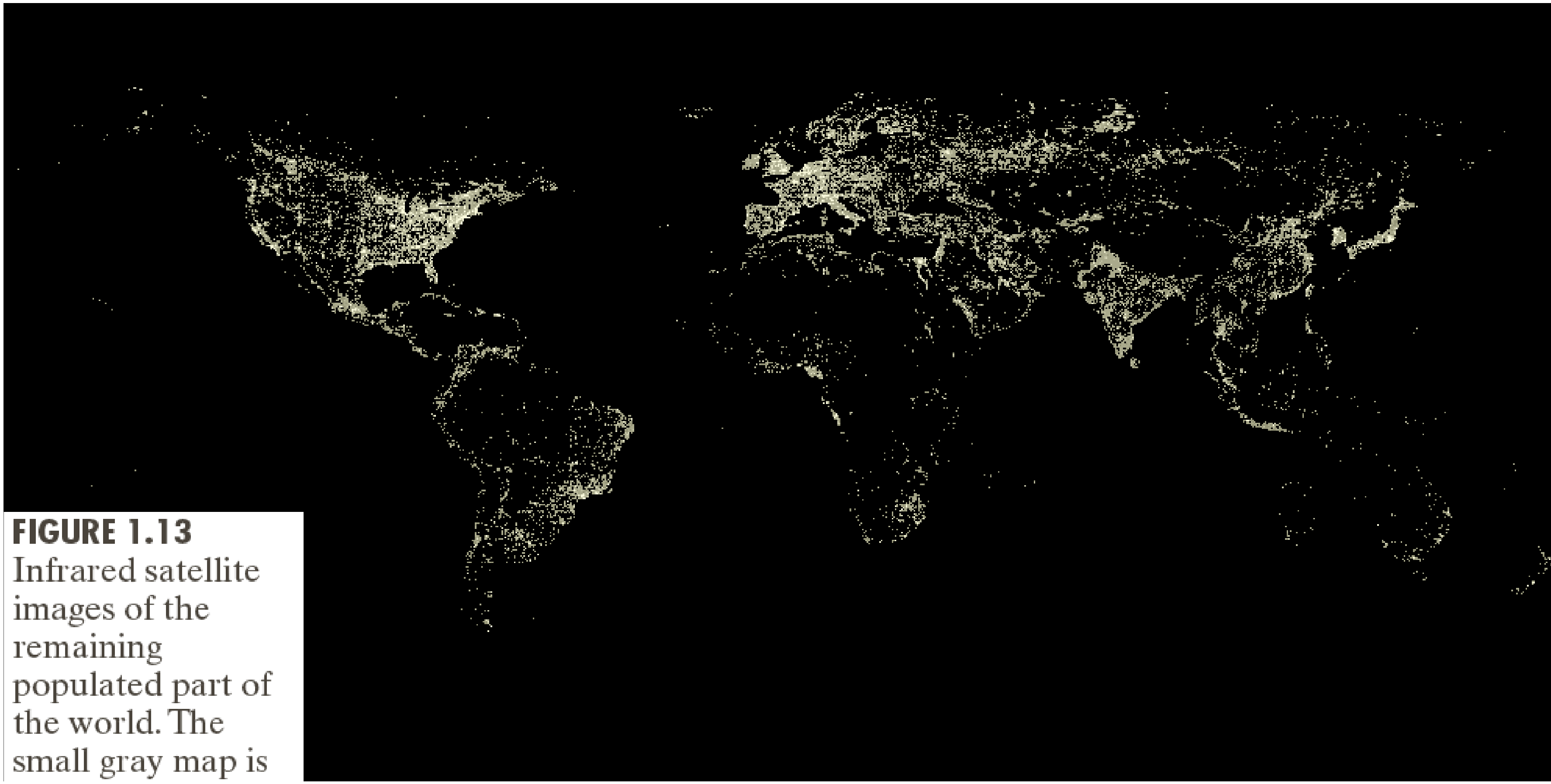


FIGURE 1.13 Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)

Visible and Infrared Imaging

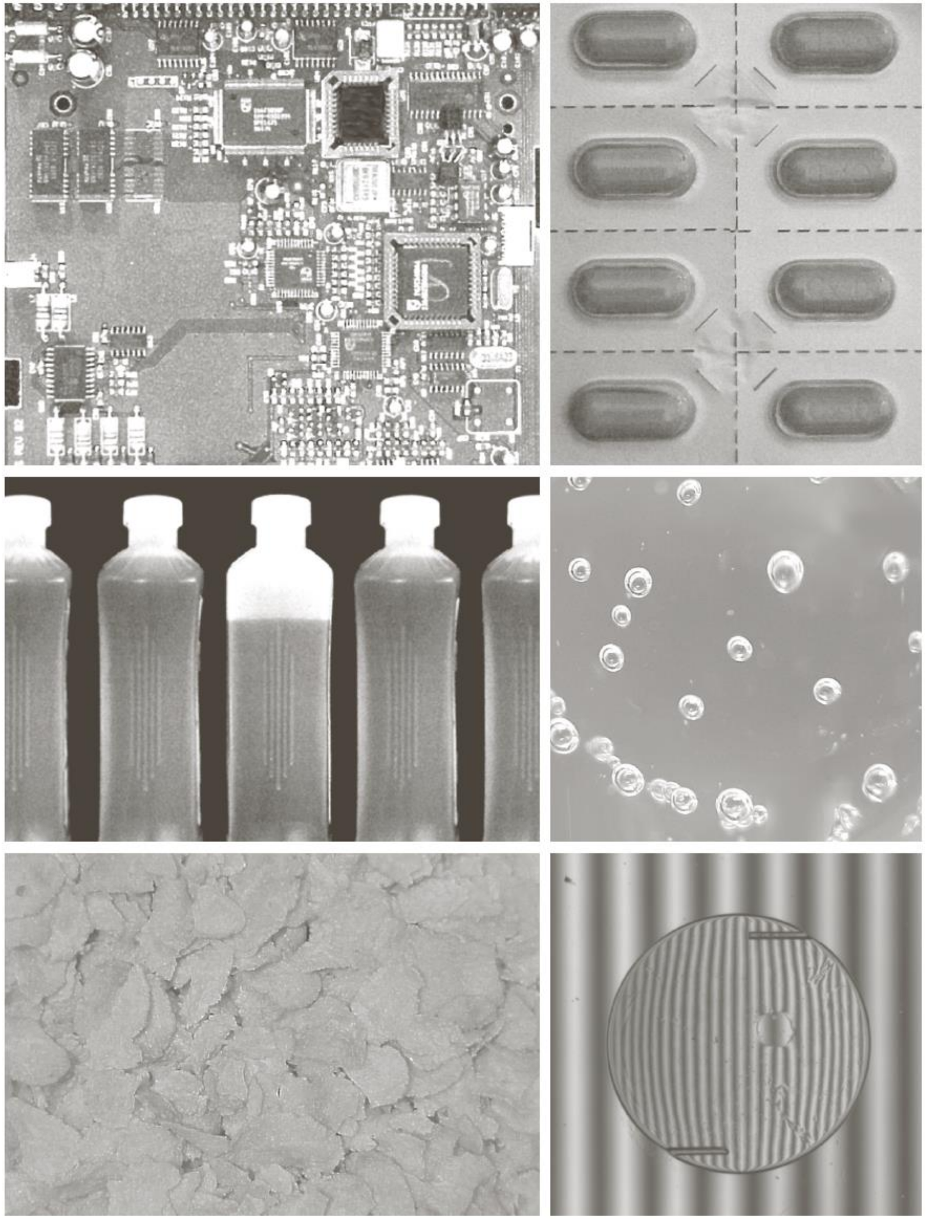


FIGURE 1.14 Some examples of manufactured goods often checked using digital image processing. (a) A circuit board controller. (b) Packaged pills. (c) Bottles. (d) Air bubbles in a clear-plastic product. (e) Cereal. (f) Image of intraocular implant. (Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)

Visible and Infrared Imaging

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.)

Results of automated reading of the plate content by the system

The area in which the imaging system detected the plate

Microwave Band Imaging

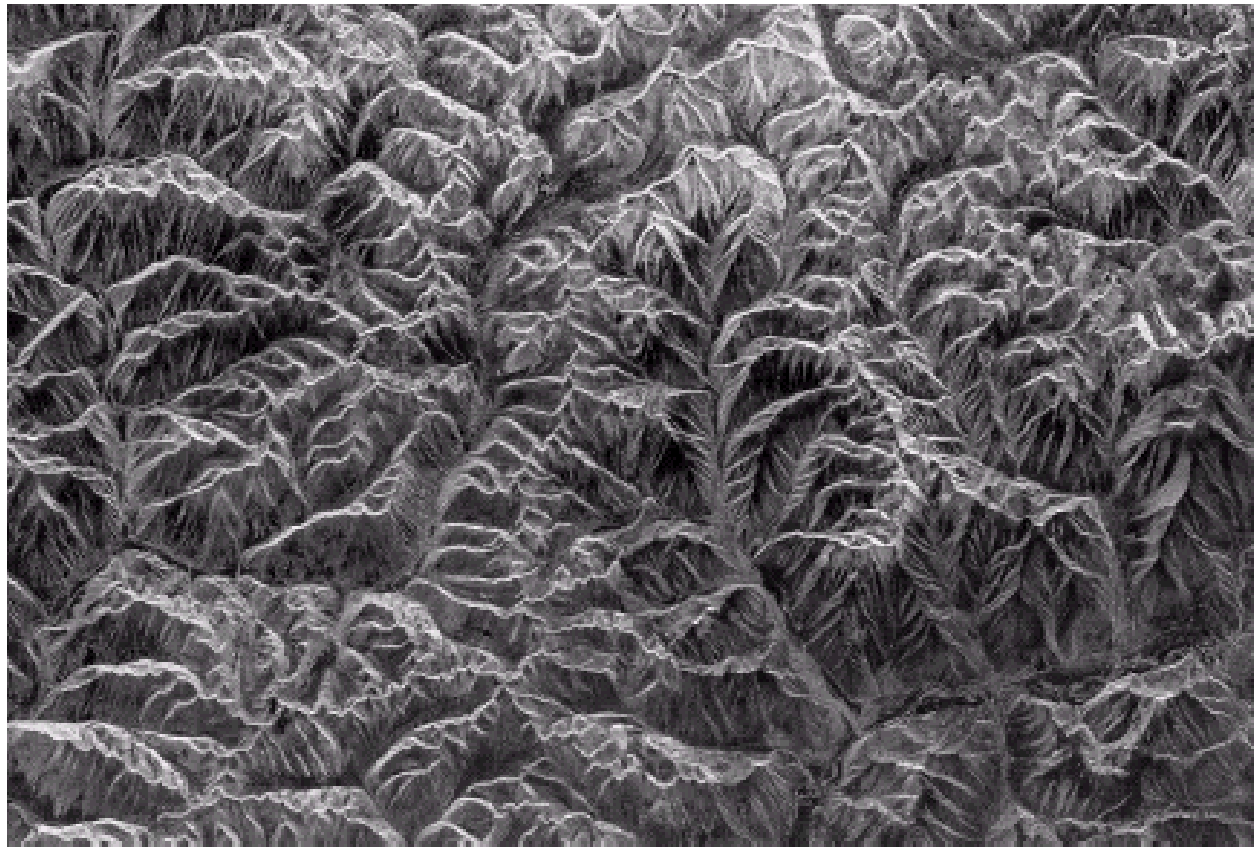
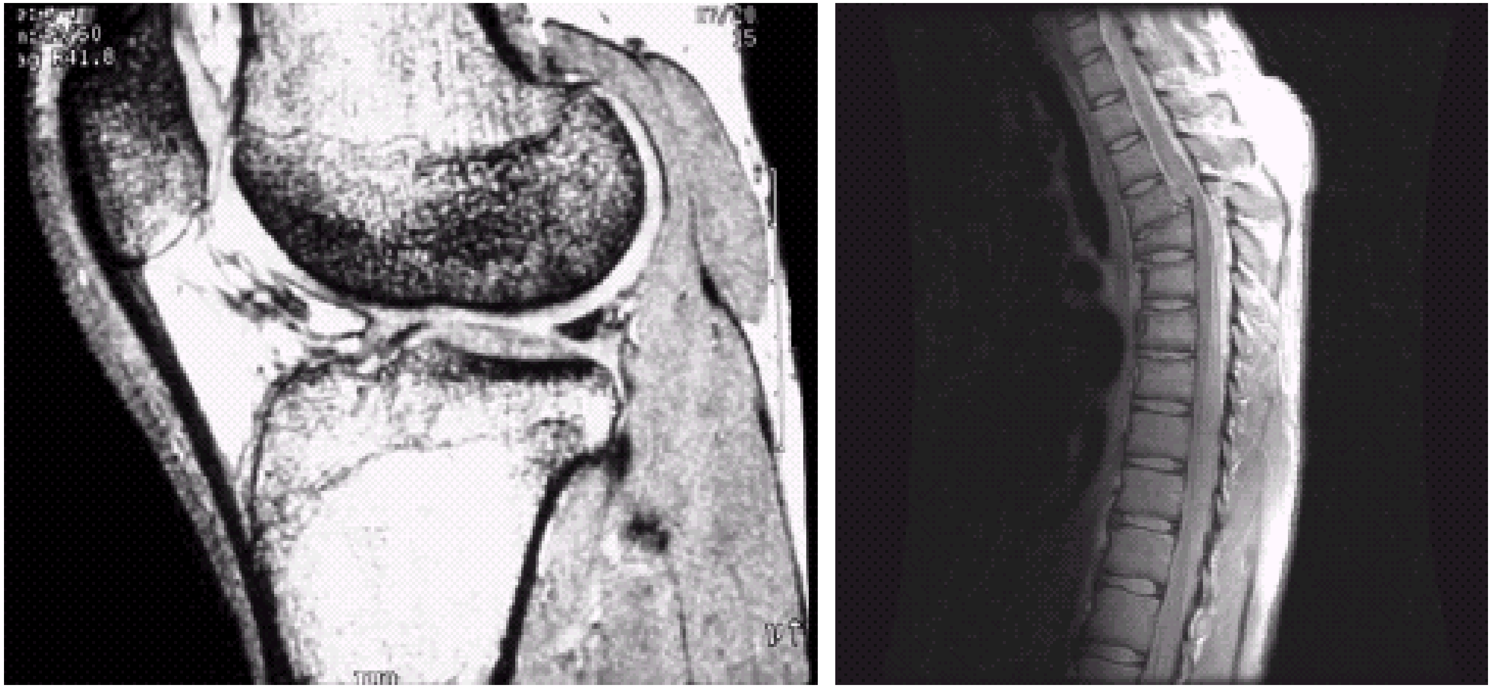


FIGURE 1.16 Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)

Radio Band Imaging



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.)

Comparative Sample Image

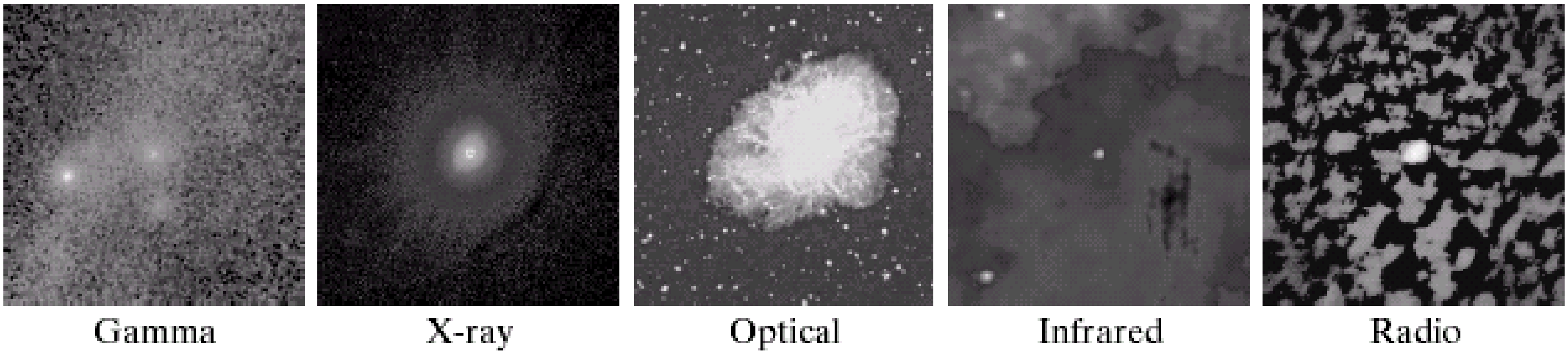
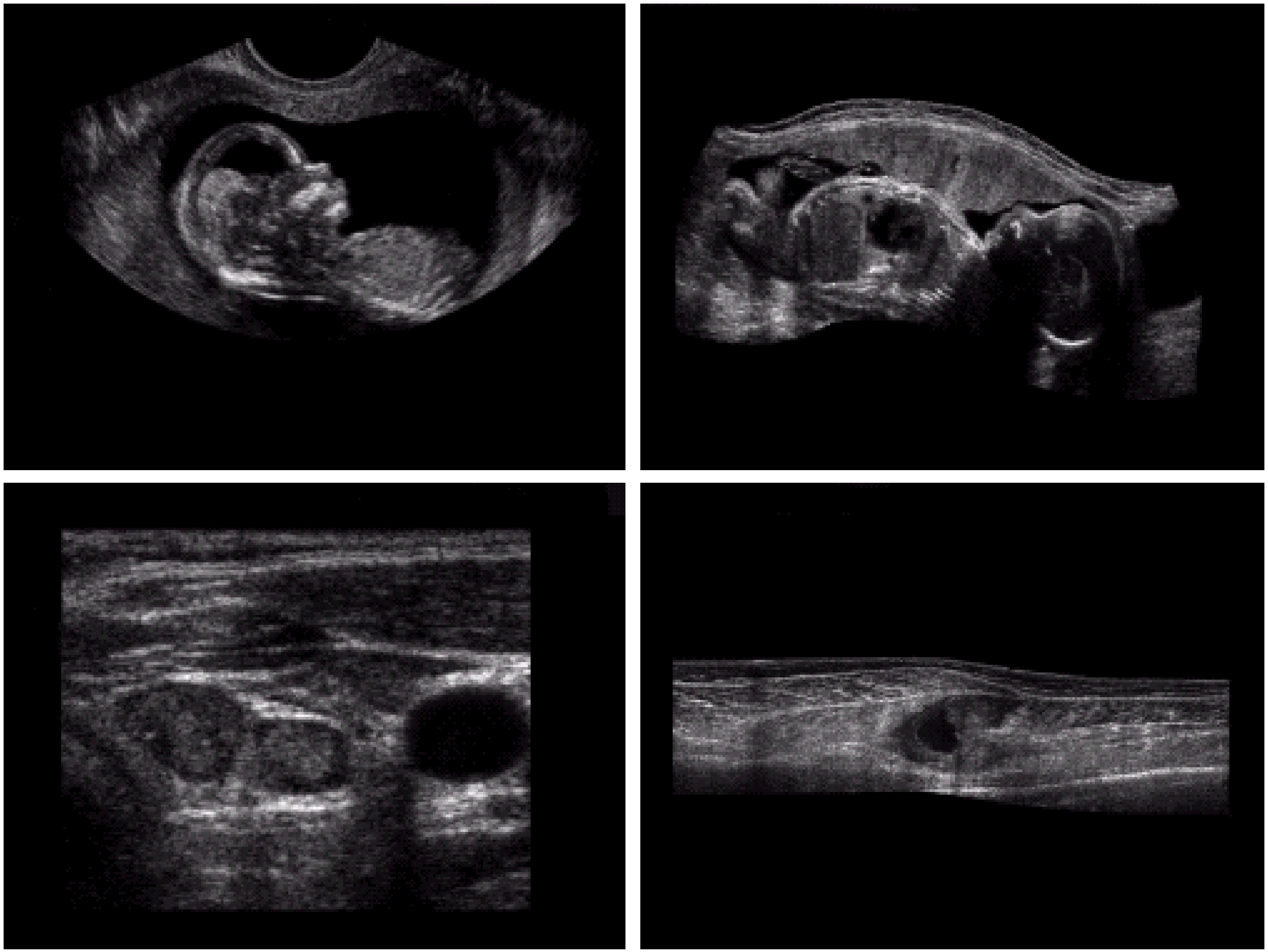


FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

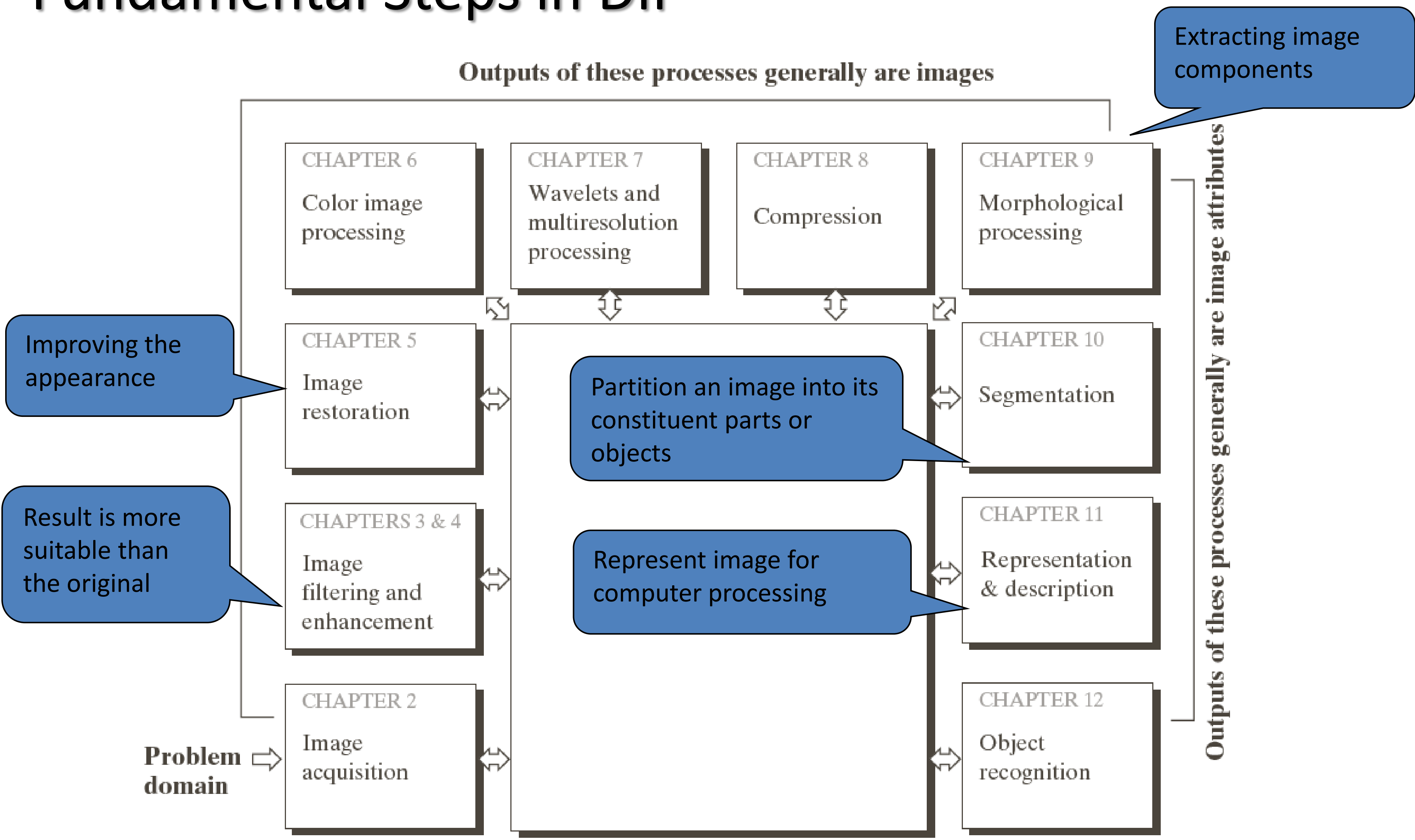
Ultrasound Imaging



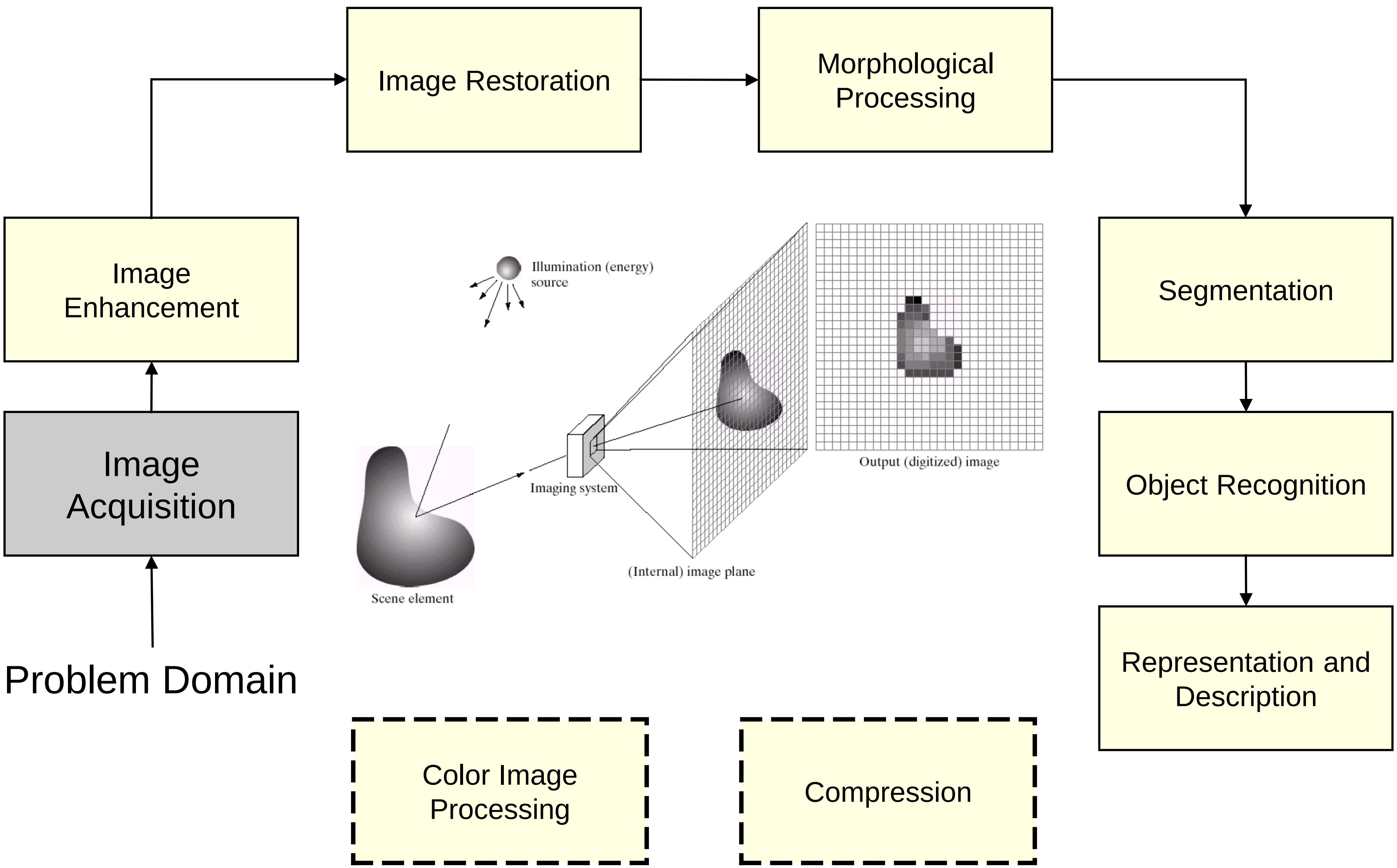
a	b
c	d

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.)

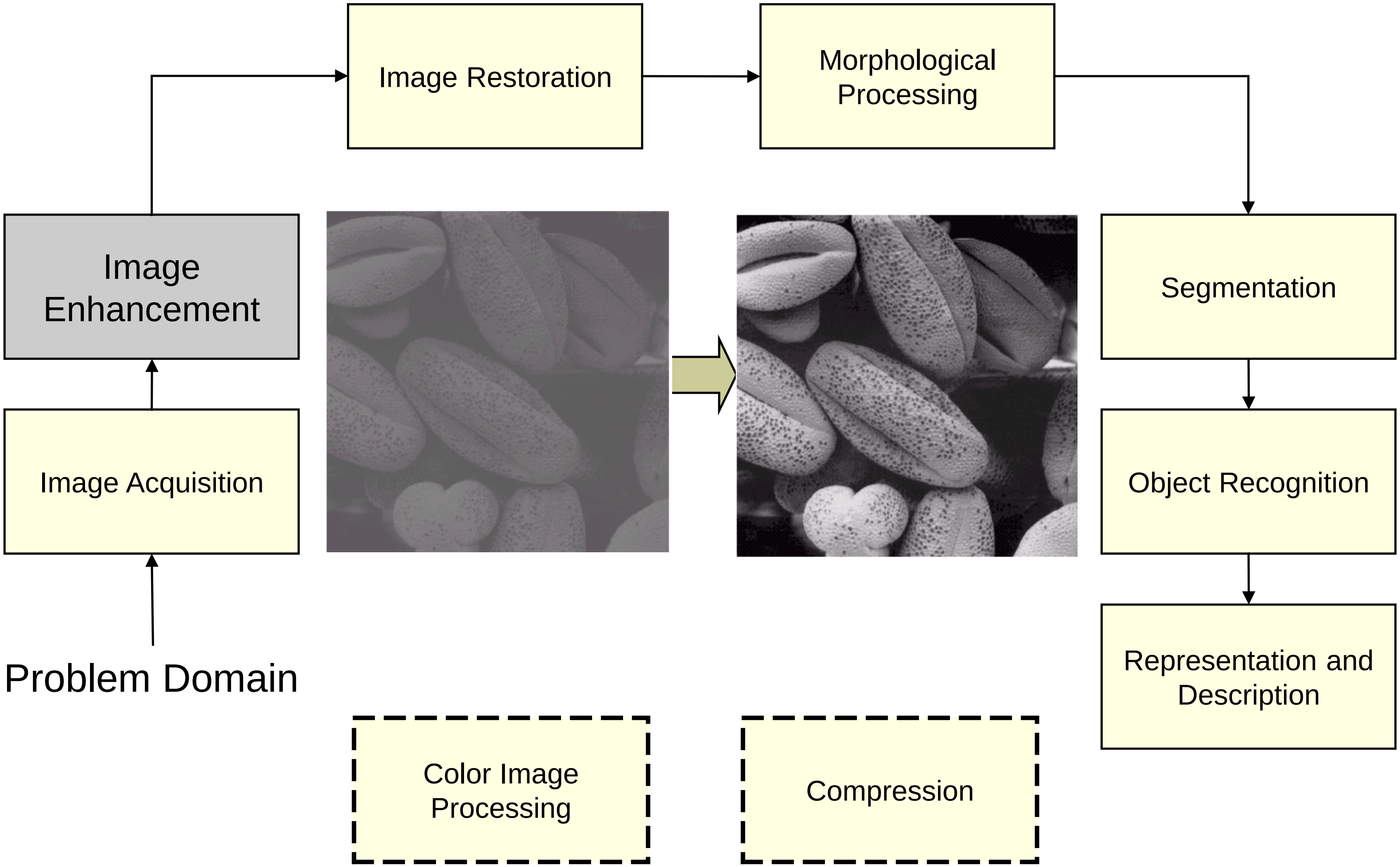
Fundamental Steps in DIP



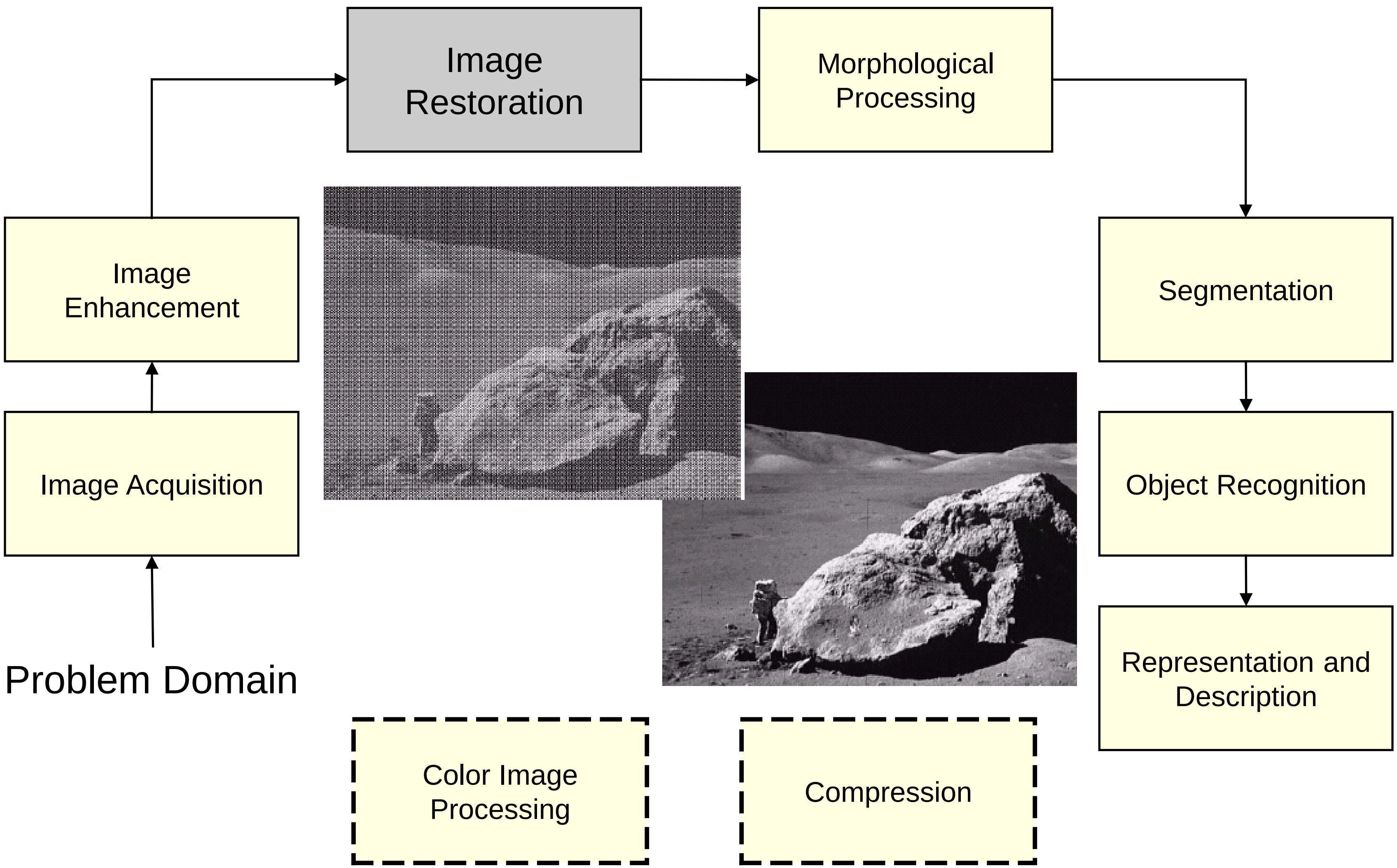
Fundamental Steps in DIP: Image Acquisition



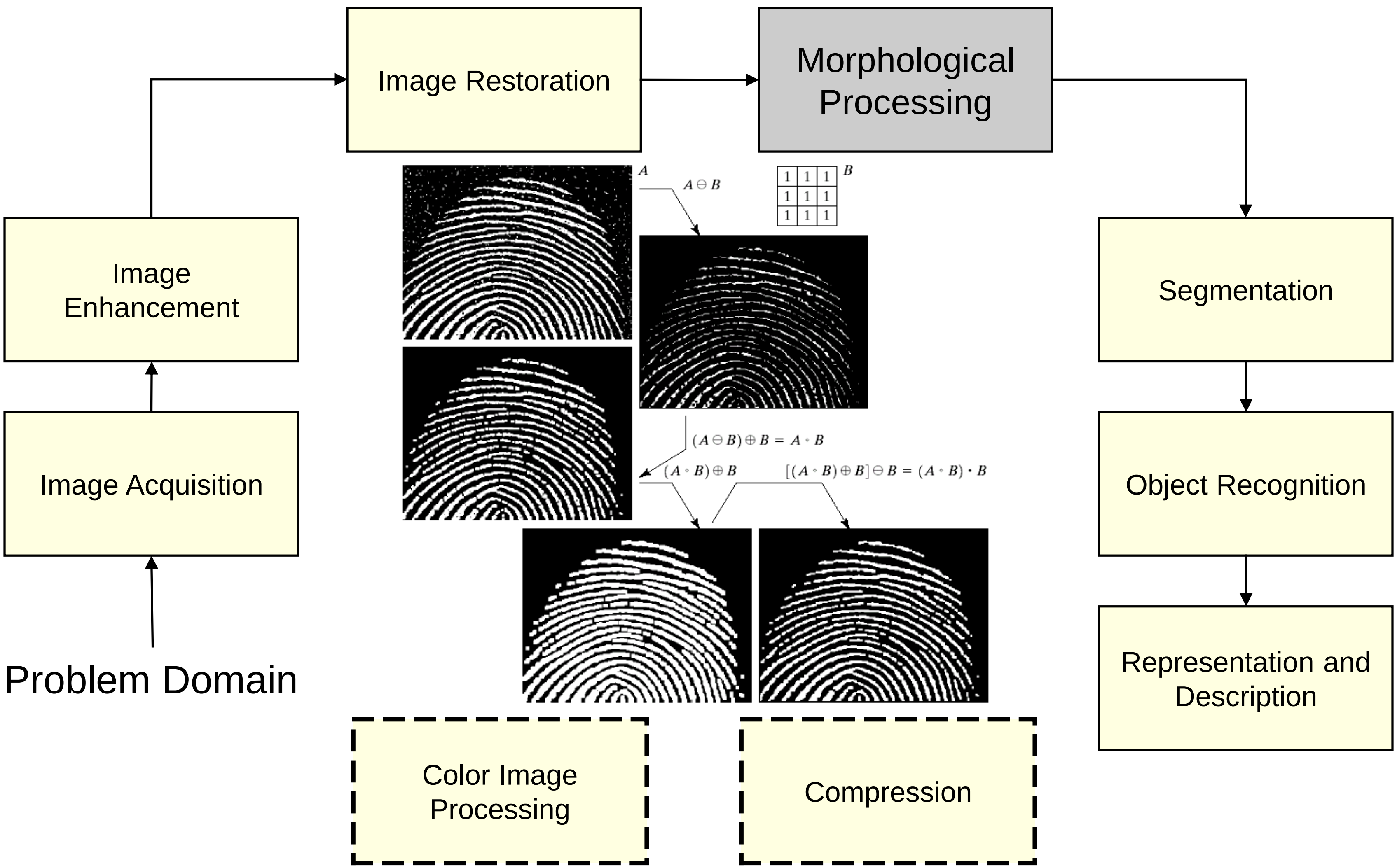
Fundamental Steps in DIP: Image Enhancement



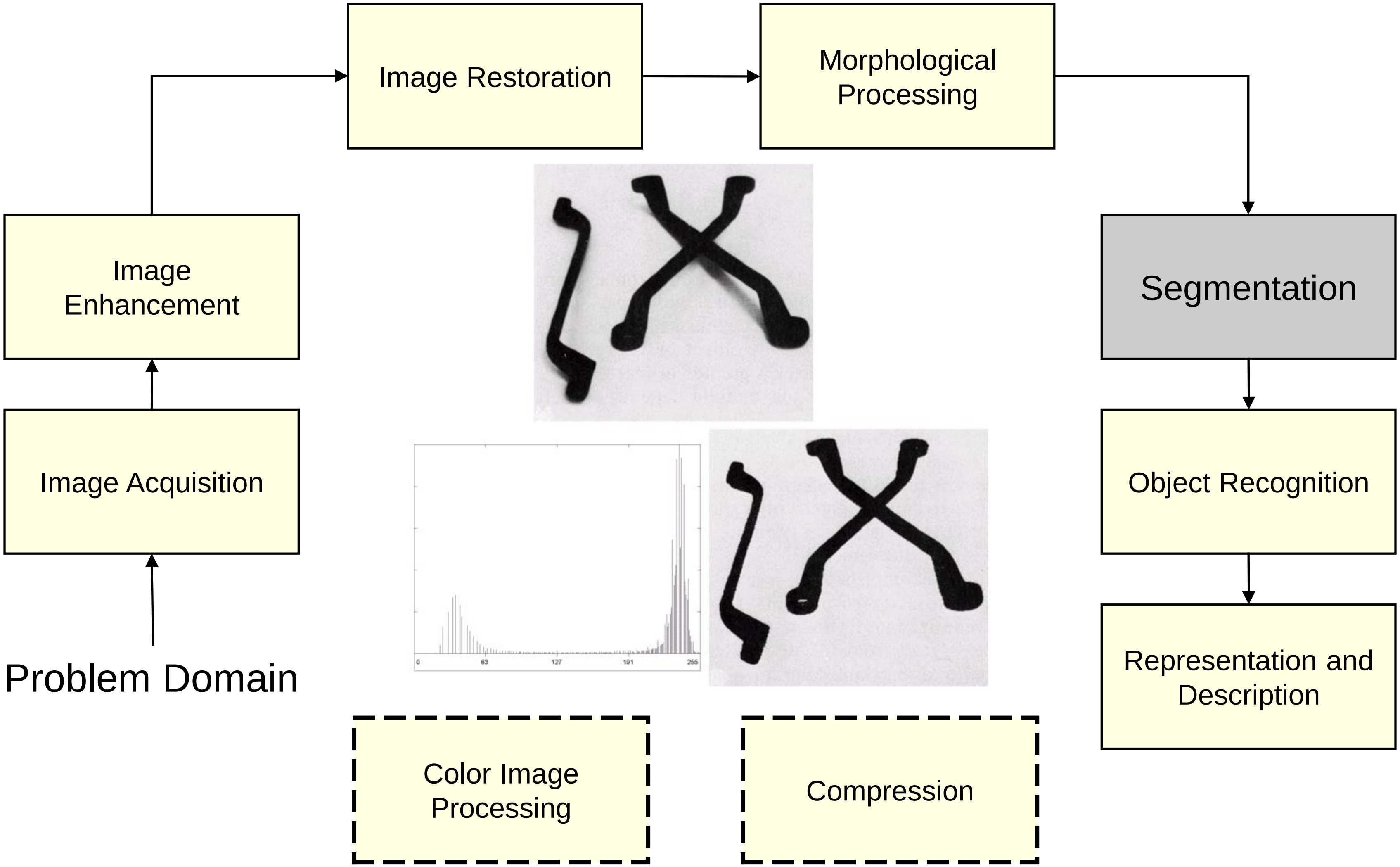
Fundamental Steps in DIP: Image Restoration



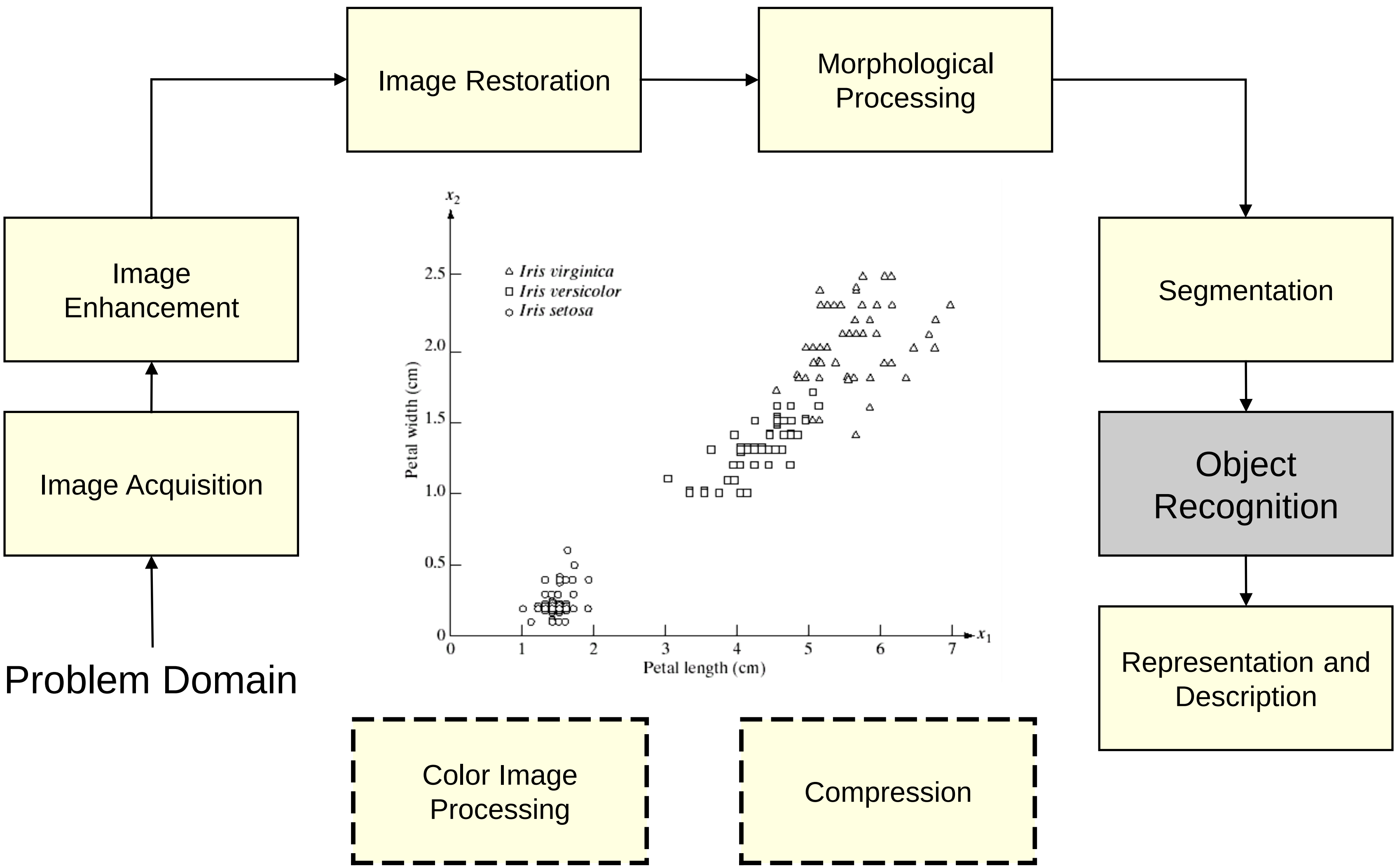
Fundamental Steps in DIP: Morphological Processing



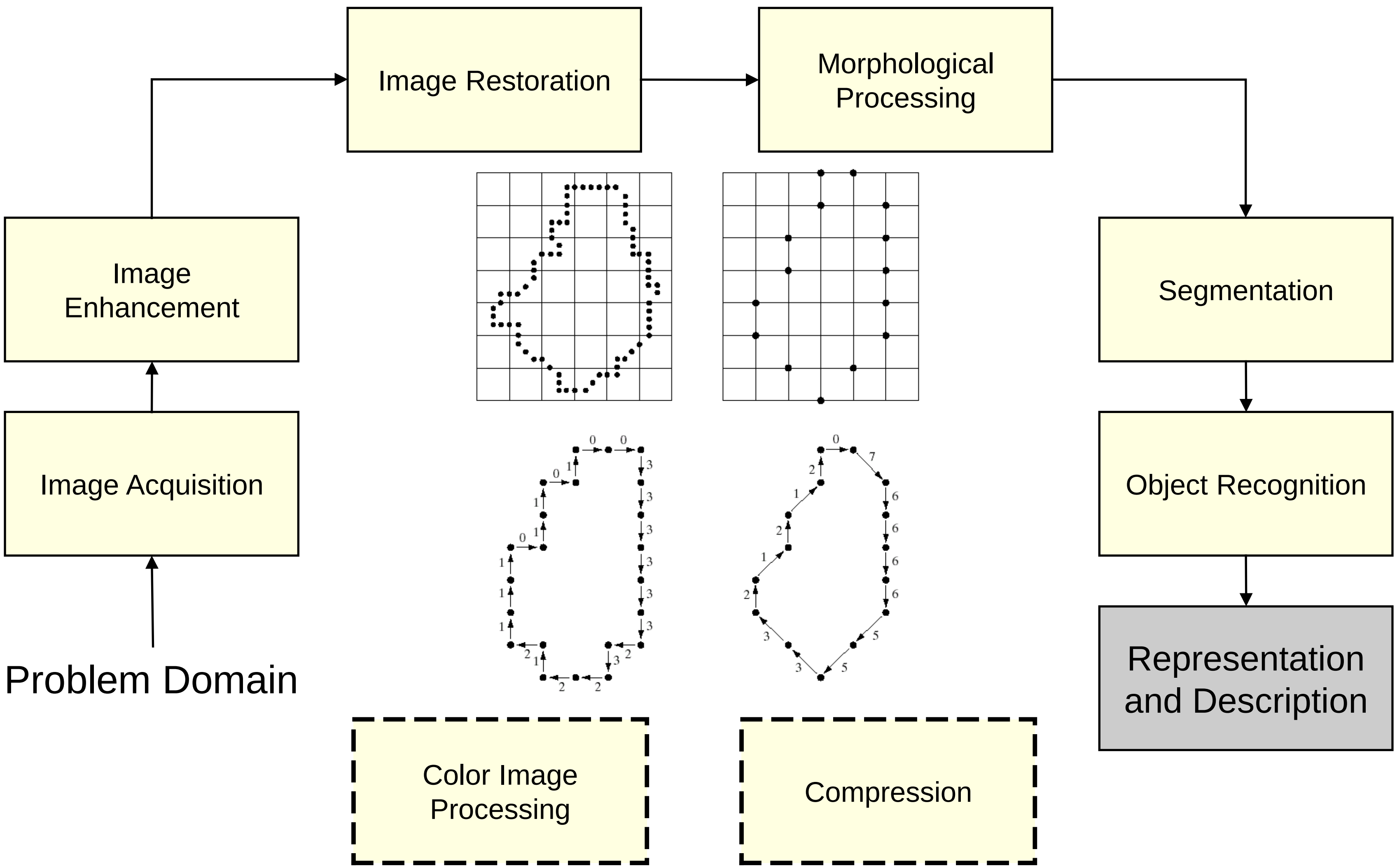
Fundamental Steps in DIP: Segmentation



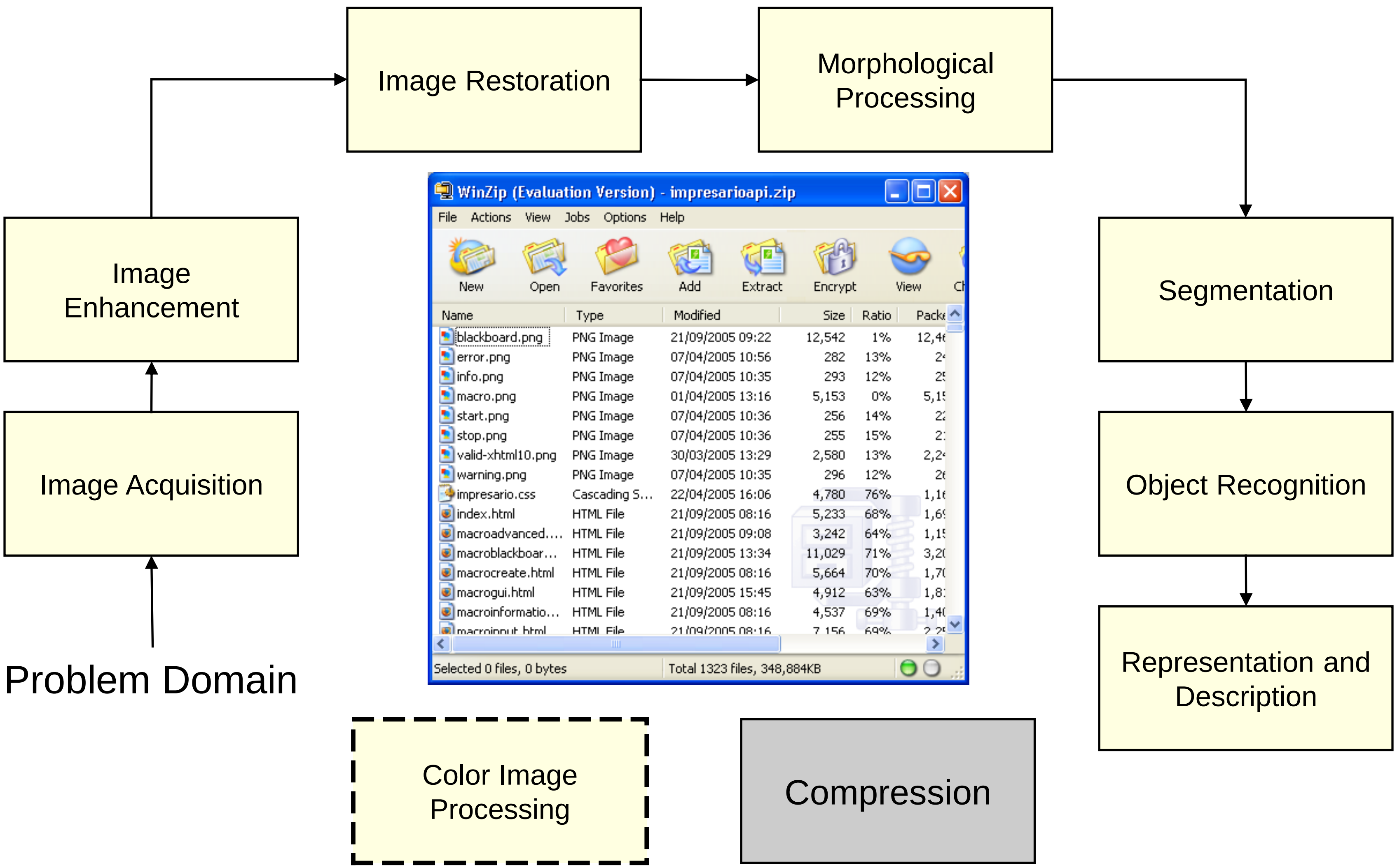
Fundamental Steps in DIP: Object Recognition



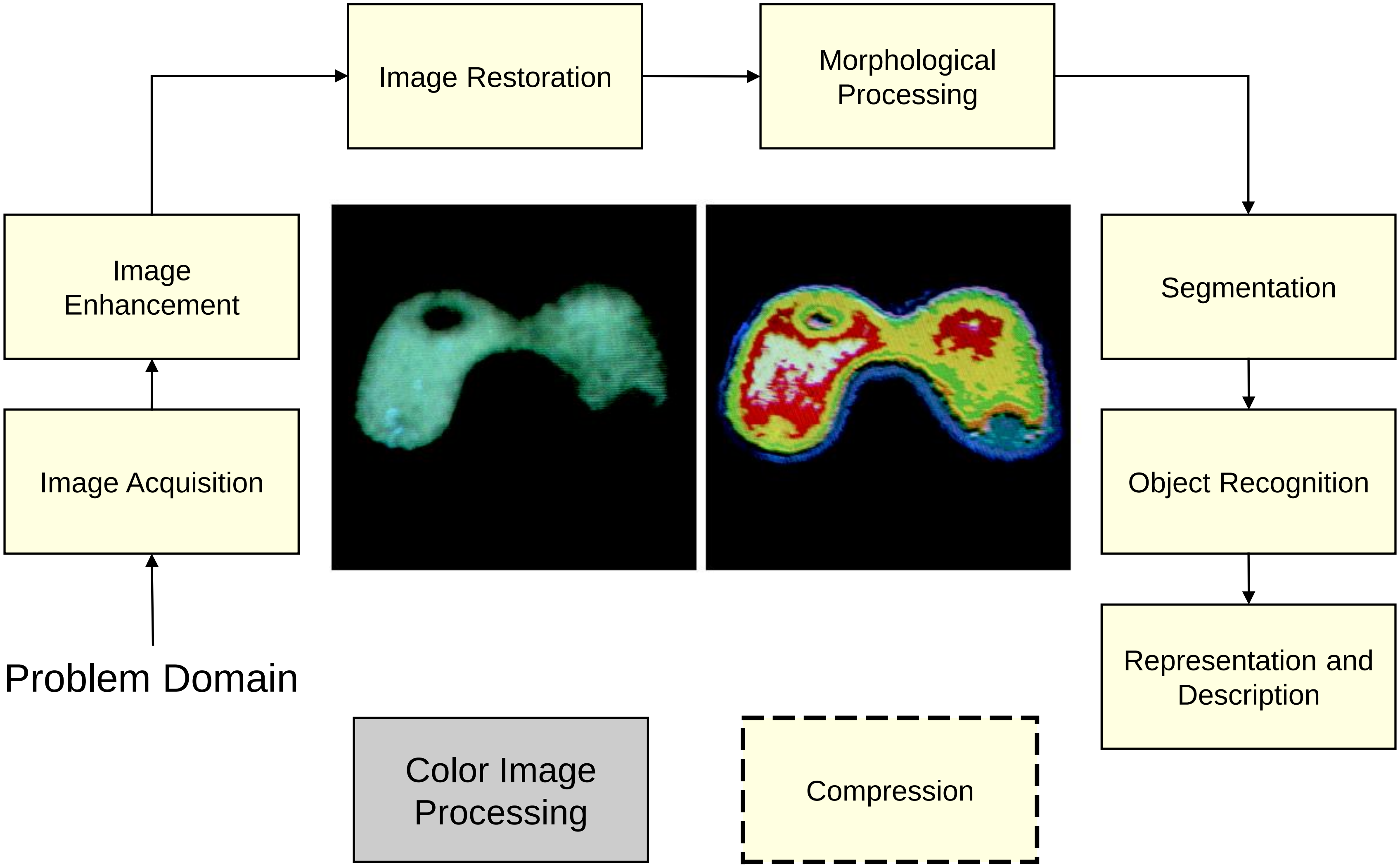
Fundamental Steps in DIP: Representation & Description



Fundamental Steps in DIP: Compression



Fundamental Steps in DIP: Color Image Processing



Components of an Image Processing System

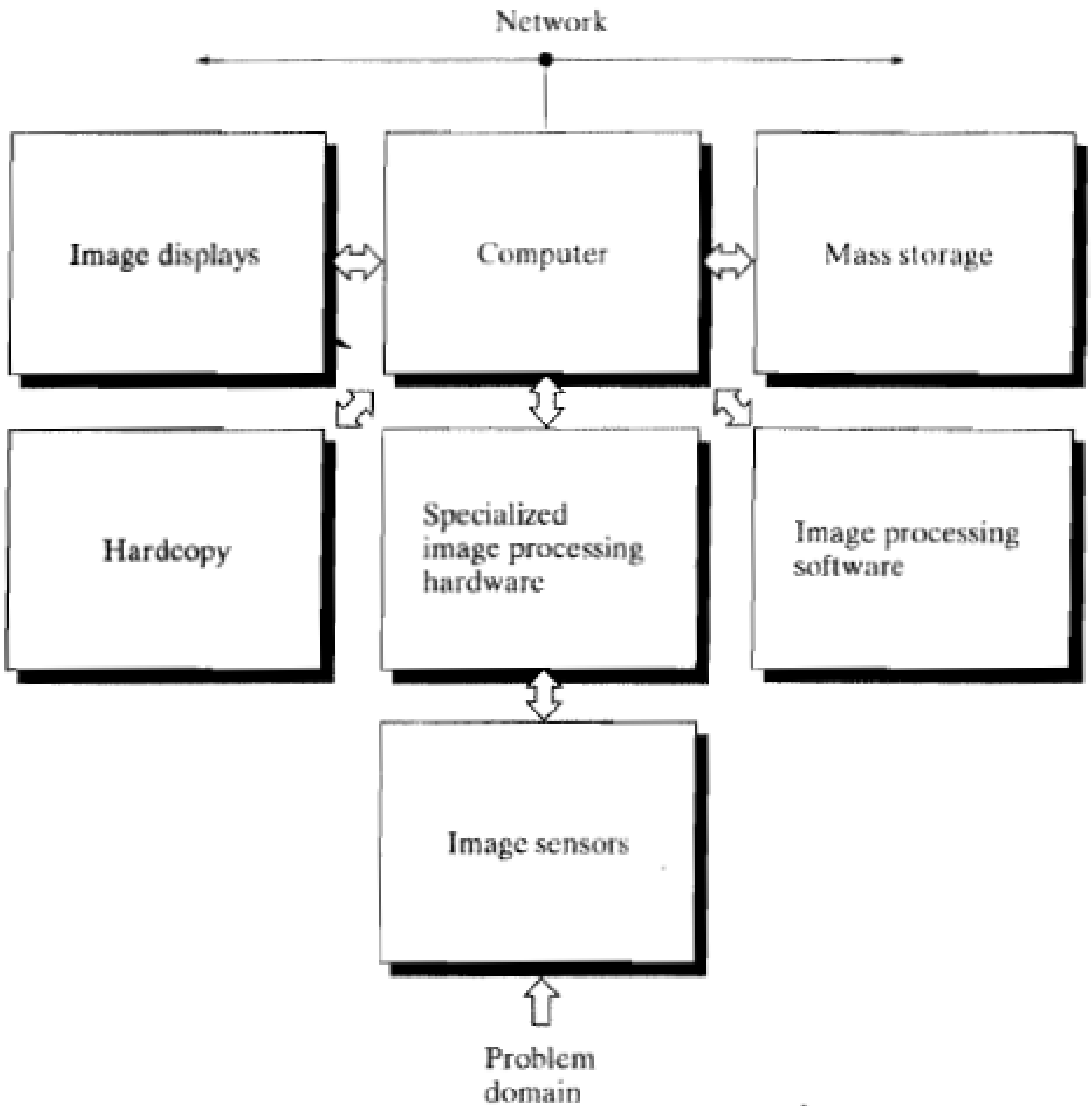
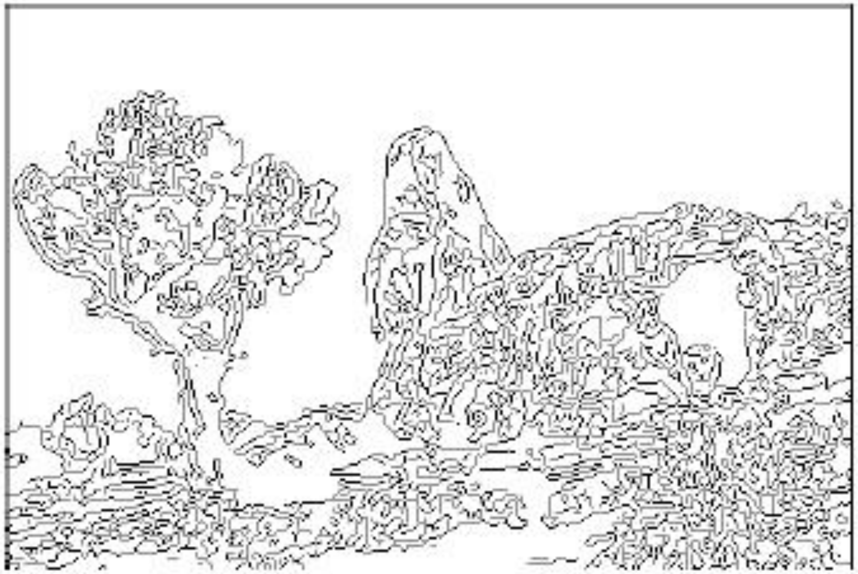


FIGURE 1.24 Components of a general-purpose image processing system.

Sample Problems

- Edge Detection
- Image Denoising
- Image Smoothing
- Image Segmentation
- Image Registration
- Image Inpainting
- …

Edge Detection

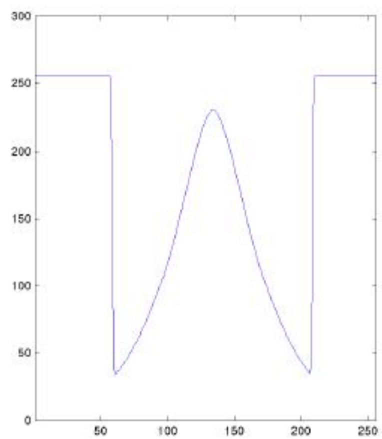


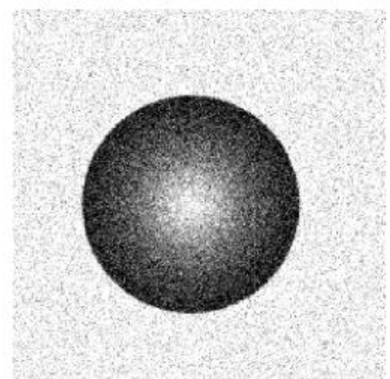
Canny edge detector

- Edges: sudden changes in the intensity
  - Uniformity of intensity or color
- Edges to object boundaries

Image Filtering

- Difficulty: Some of the irrelevant image information have characteristics similar to those of important image features.





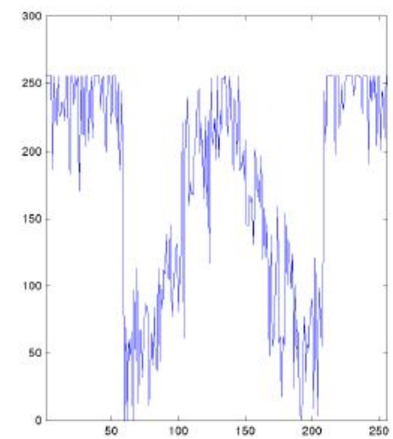
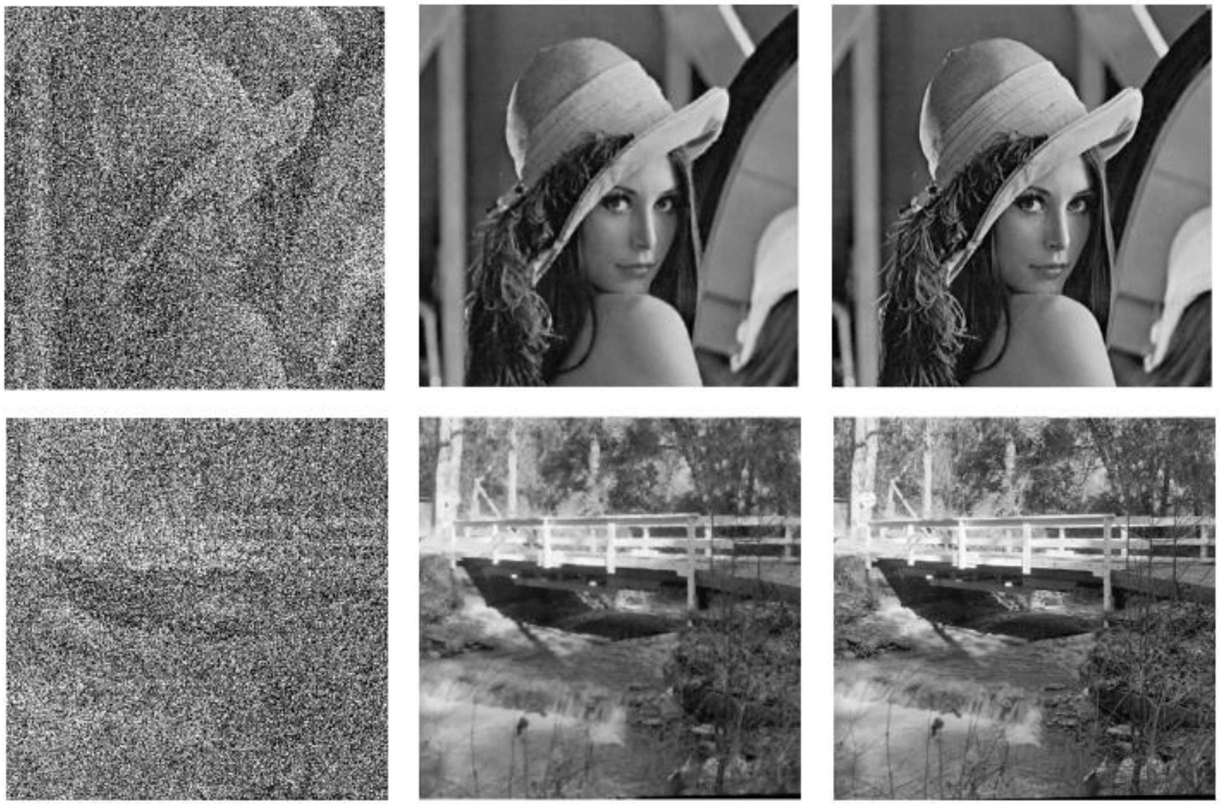


Image Denoising

- Images are corrupted with 70% salt-and-pepper noise.



Noisy input | Recovered image | Original image

What do these examples demonstrate?

R. H. Chan, C.-W. Ho, and M. Nikolova, Salt-and-Pepper Noise Removal by Median-Type Noise Detectors and Detail-Preserving Regularization. IEEE TIP 2005

Image Smoothing

L. Xu, C. Lu, Y. Xu, J. Jia, Image Smoothing via L0 Gradient Minimization, SIGGRAPH ASIA 2011

Image Segmentation

- Partition an image into meaningful regions that are likely to correspond to objects exist in the image.

Figures: A. Erdem

Registration

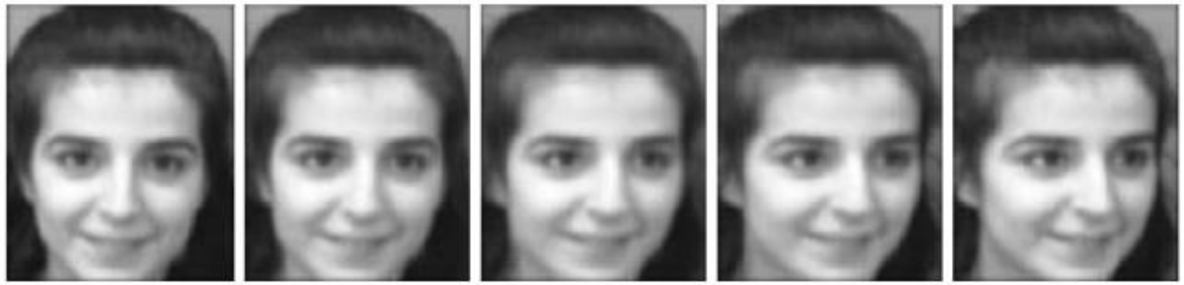
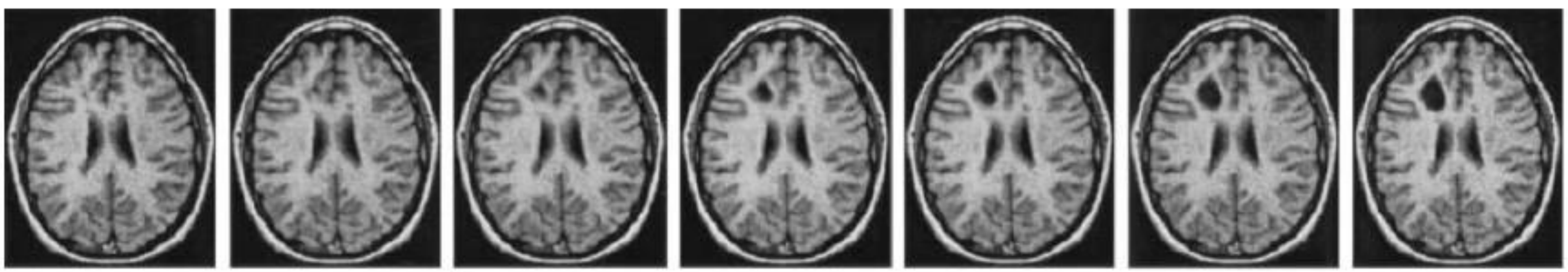
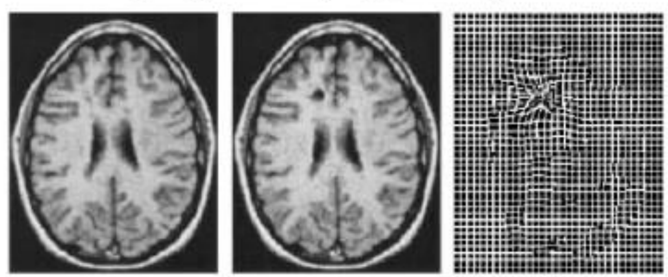


Fig. 2. An example of a geodesic between images (original images taken from the Olivetti face database). The three intermediate images are generated by the optimization algorithm.



A tumor progressively appearing on a brain



Tumor: Reference image, registered target and deformation

(top) Alain Trouve and Laurent Younes, Metamorphoses Through Lie Group Action, Found. Comput. Math., 2005
(bottom) M. I. Miller and L. Younes, Group Actions, Homeomorphisms, and Matching: A General Framework, IJCV, 2001

Image Inpainting

- Reconstructing lost or deteriorated parts of images

M. Bertalmio, G. Sapiro, V. Caselles and C. Ballester, Image Inpainting, SIGGRAPH, 2000

Image Processing Toolboxes and Softwares

- Python

- OpenCV

- etc.

Image Processing Toolboxes and Software

- Numpy, one of the Python libraries, was developed to work on matrices. Images are matrix!
- It provides a comprehensive set of reference standard algorithms, functions, and applications for image processing, analysis, visualization, and algorithm development.
- You can perform image analysis, image segmentation, image enhancement, noise reduction, geometric transformations and image registration.
- It supports multi-core processors, GPUs and C-code generation through many tool functions.

OpenCV

- OpenCV means Intel® Open Source Computer Vision Library.
- It is a collection of C functions and a few C++ classes that implement some popular Image Processing and Computer Vision algorithms.
- It has C++, C, Python and Java interfaces and supports Windows, Linux, Mac OS, iOS and Android.
- FREE for commercial and non-commercial uses.
- Written in optimized C/C++, the library can take advantage of multi-core processing.
- Available on Sourceforge
  - http://opencv.org/
  - http://sourceforge.net/projects/opencvlibrary/

What Can Be Done With OpenCV?

- Read and save images, videos or webcam images
- Detecting faces and facial features
- Detect specific shapes in images
- Detecting texts on images (plate, money, etc.)
- Handwriting analysis
- Object detection – DarkNet YOLO
- Object counting
- Automatic game play
- Capture emotions on faces
- Vehicle tracking
- Color tracking
- Motion tracking
- Captcha solving

Image Processing Toolboxes

- In C/C++
  - IPL ... : http://www.cs.nott.ac.uk/~jzg/nottsvision/old/index.html
  - OpenCV: http://sourceforge.net/projects/opencvlibrary
  - ImageMagick: http://www.imagemagick.org/
  - Insight Toolkit ITK (medical image) : http://www.itk.org/
  - mathtools.net: http://www.mathtools.net/C_C__/Image_Processing/
- In Java
  - Java Media APIs: JAI, JMF, Java image I/O ...: http://java.sun.com/javase/technologies/desktop/media/
  - http://www.mathtools.net/Java/Image_Processing/index.htmlPython
- Python Imaging Library (PIL)
  - http://www.pythonware.com/products/pil/
  - numpy, scipy
- SciKit

References

- Sayısal Görüntü İşleme, Palme Publishing, Third Press Trans. (*Orj: R.C. Gonzalez and R.E. Woods: "Digital Image Processing", Prentice Hall, 3rd edition, 2008*).
- "Digital Image Processing Using Matlab", Gonzalez & Richard E. Woods, Steven L. Eddins, Gatesmark Publishing, 2009
- Lecture Notes, CS589-04 Digital Image Processing, Frank (Qingzhong) Liu, http://www.cs.nmt.edu/~ip
- Lecture Notes, BIL717-Image Processing, Erkut Erdem
- Lecture Notes, EBM537-Image Processing, F.Karabiber
- https://docs.opencv.org/
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