# BSB663
# Image Processing

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Slides are adapted from
Gonzales & Woods,
Emmanuel Agu

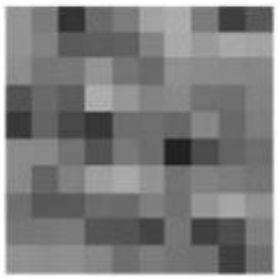
# What is an image?

- 2-dimensional matrix of Intensity (gray or color) values

Set of Intensity values

Image coordinates are integers

$$I(u, v) \in \mathbb{P} \quad \text{and} \quad u, v \in \mathbb{N}.$$



$F(x, y)$

$$\begin{matrix}
148 & 123 & 52 & 107 & 123 & 162 & 172 & 123 & 64 & 89 & \cdots \\
147 & 130 & 92 & 95 & 98 & 130 & 171 & 155 & 169 & 163 & \cdots \\
141 & 118 & 121 & 148 & 117 & 107 & 144 & 137 & 136 & 134 & \cdots \\
82 & 106 & 93 & 172 & 149 & 131 & 138 & 114 & 113 & 129 & \cdots \\
57 & 101 & 72 & 54 & 109 & 111 & 104 & 135 & 106 & 125 & \cdots \\
138 & 135 & 114 & 82 & 121 & 110 & 34 & 76 & 101 & 111 & \cdots \\
138 & 102 & 128 & 159 & 168 & 147 & 116 & 129 & 124 & 117 & \cdots \\
113 & 89 & 89 & 109 & 106 & 126 & 114 & 150 & 164 & 145 & \cdots \\
120 & 121 & 123 & 87 & 85 & 70 & 119 & 64 & 79 & 127 & \cdots \\
145 & 141 & 143 & 134 & 111 & 124 & 117 & 113 & 64 & 112 & \cdots \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots &
\end{matrix}$$

$I(u, v)$

# Examples

a) Natural landscape
b) Synthetically generated scene
c) Poster graphic
d) Computer screenshot
e) Black and white illustration
f) Barcode
g) Fingerprint
h) X-ray
i) Microscope slide
j) Satellite Image
k) Radar image
l) Astronomical object

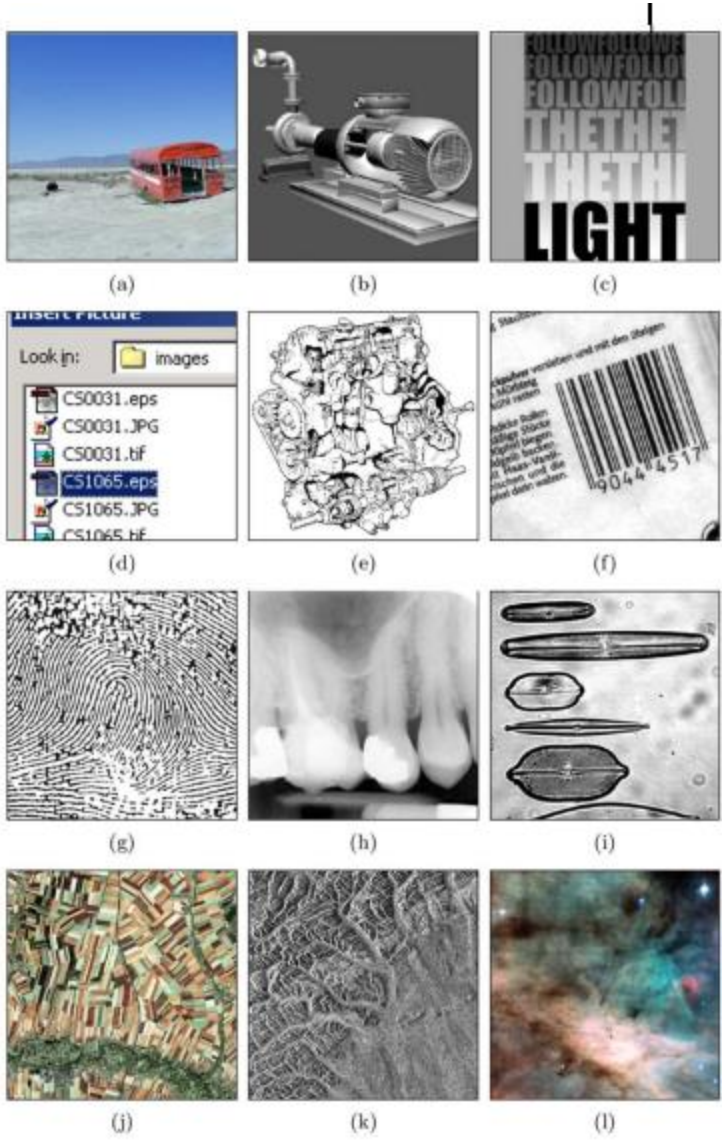


**FIGURE 1.1** A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.[†])

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

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

**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.)

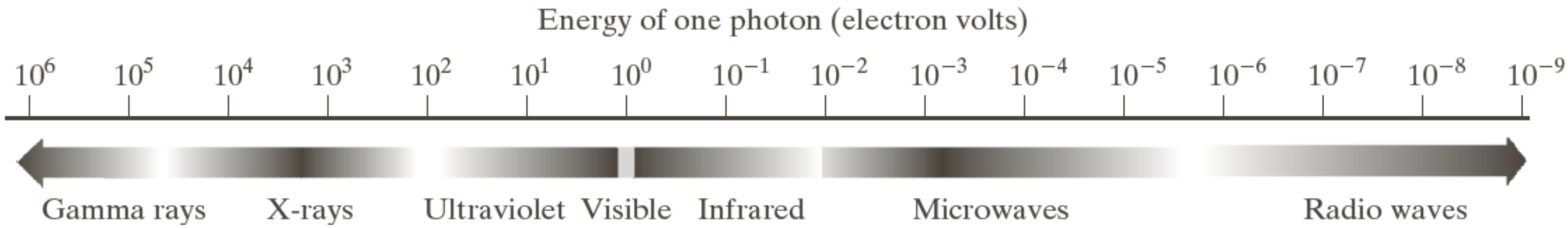
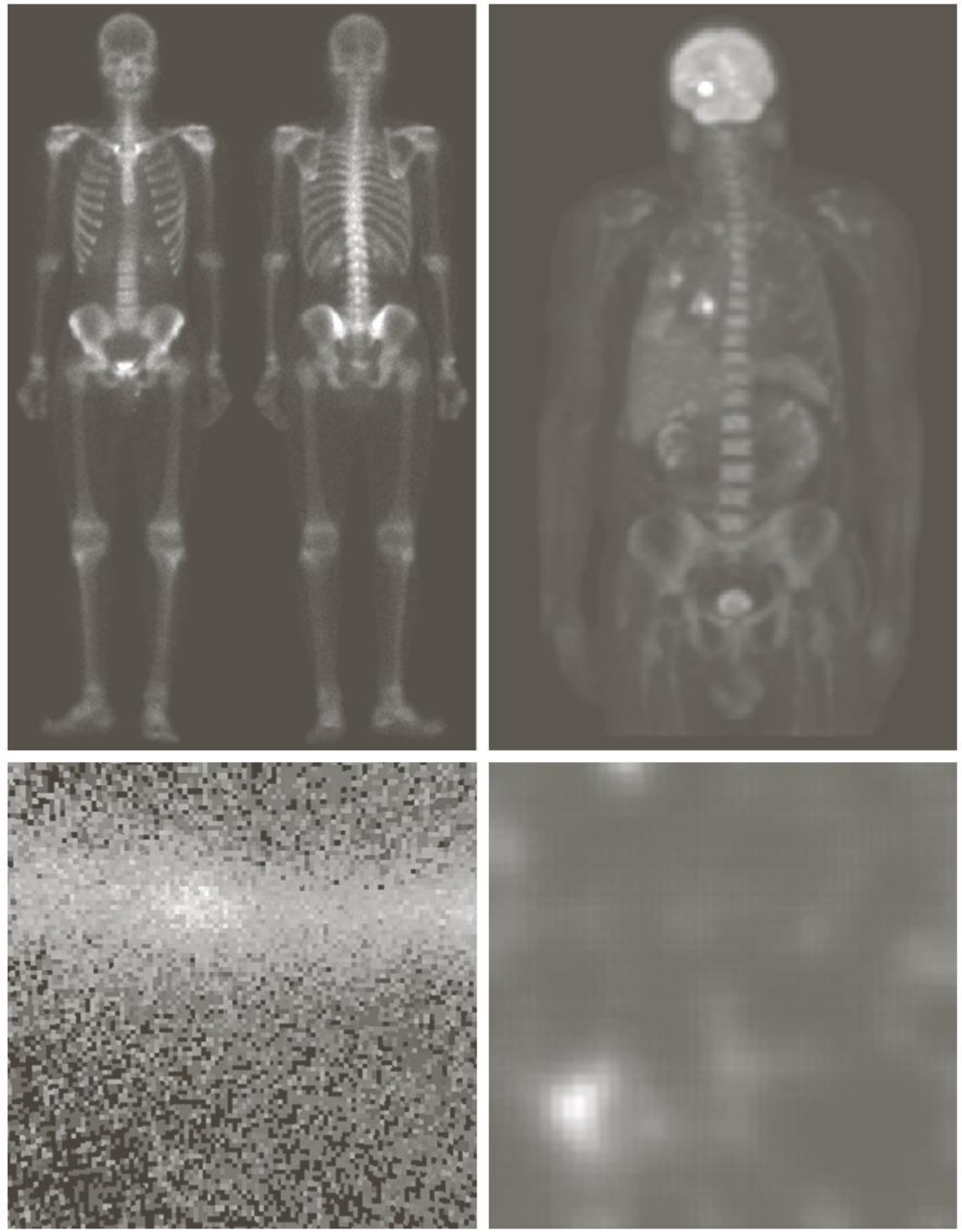
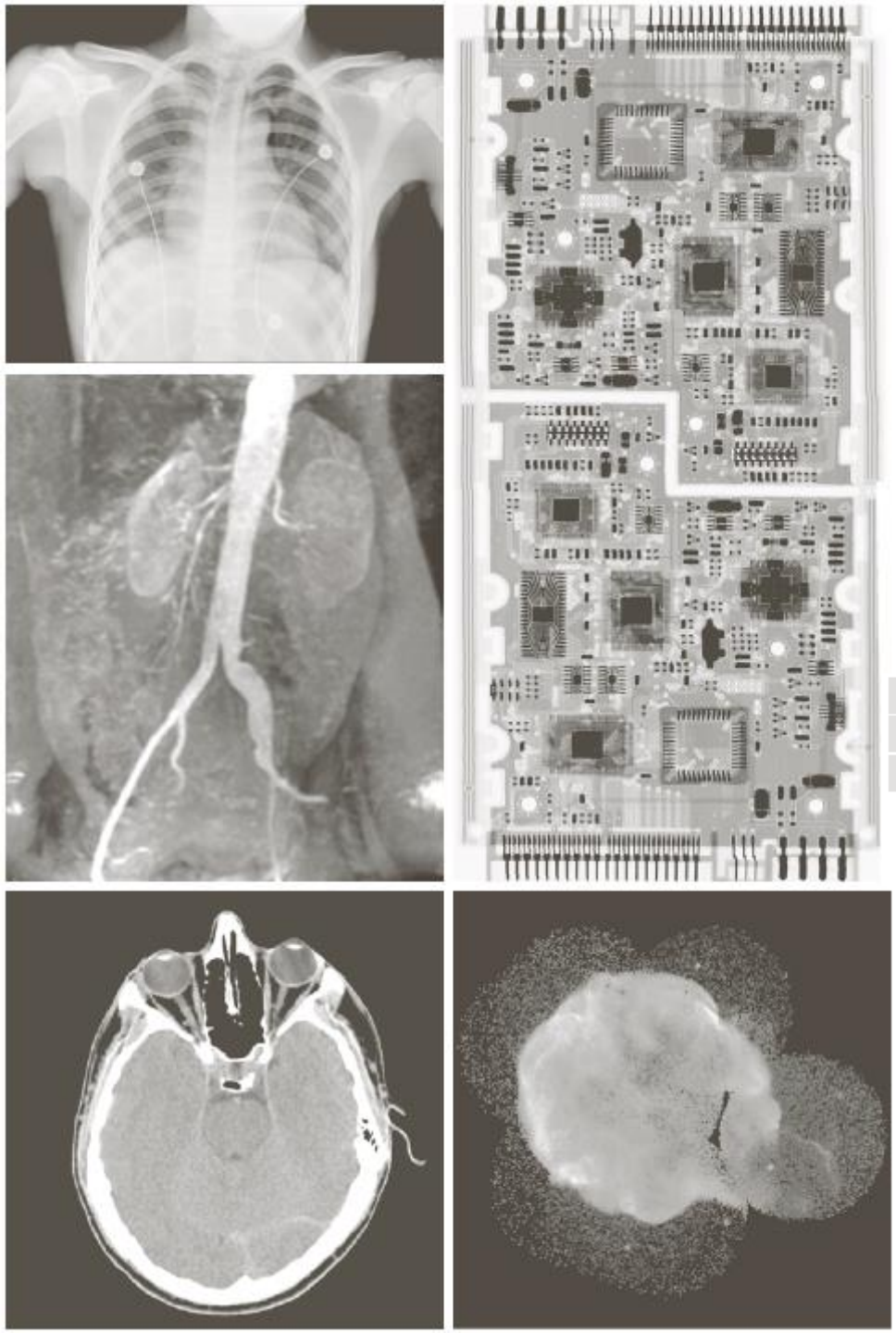



**FIGURE 1.5** The electromagnetic spectrum arranged according to energy per photon.



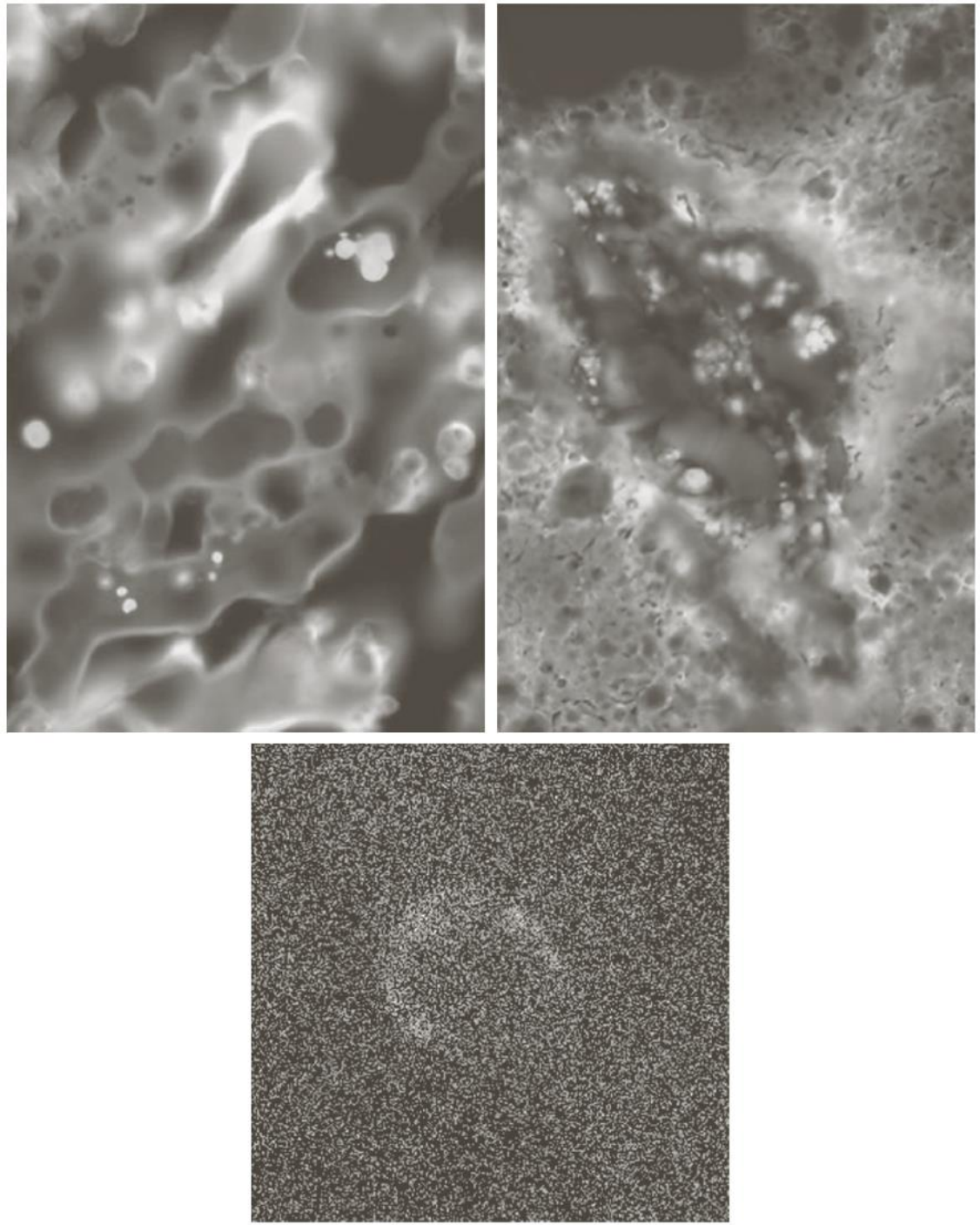
a b
c d

**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.)



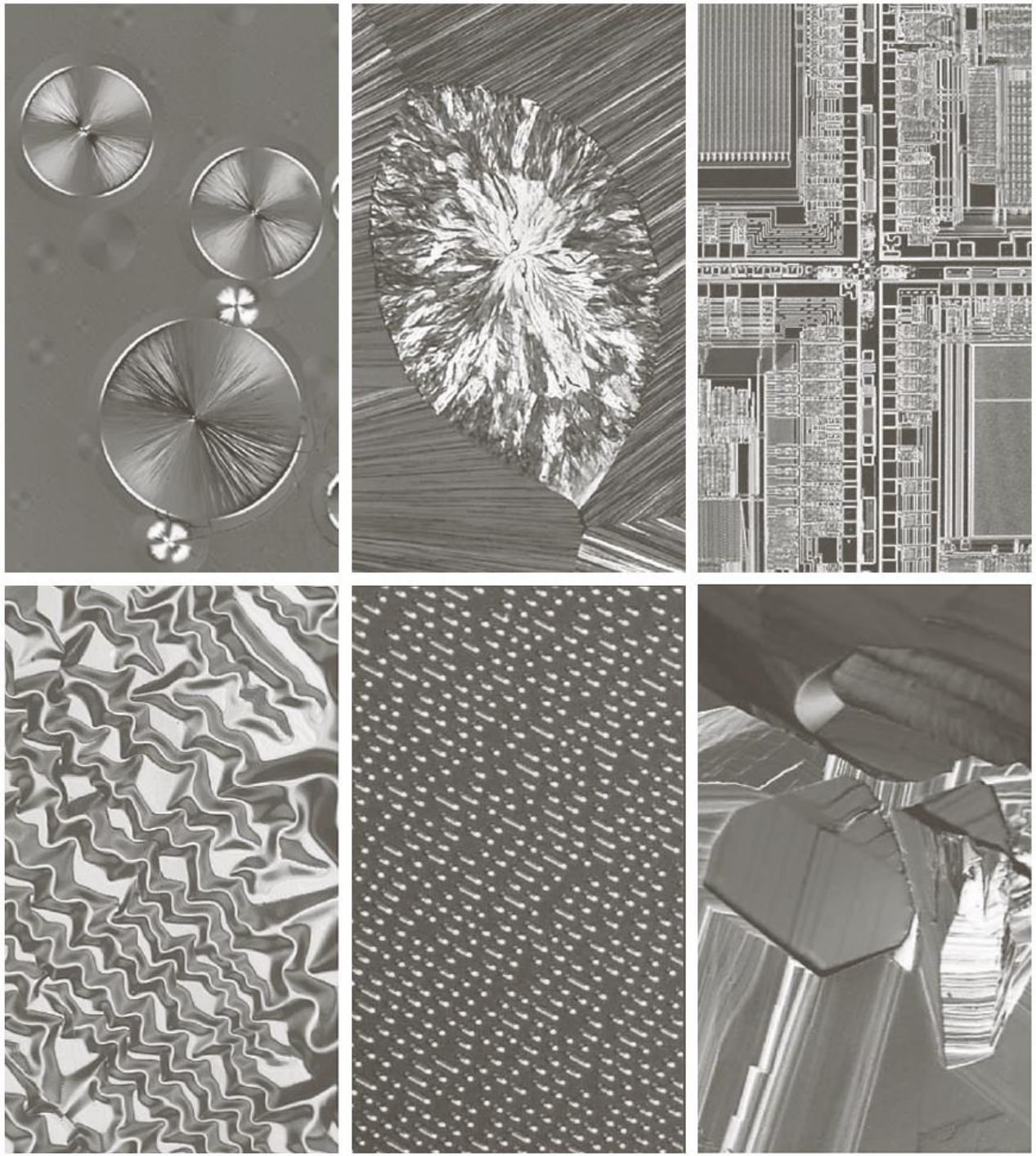
a d
b
c e

**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.)



a b
c

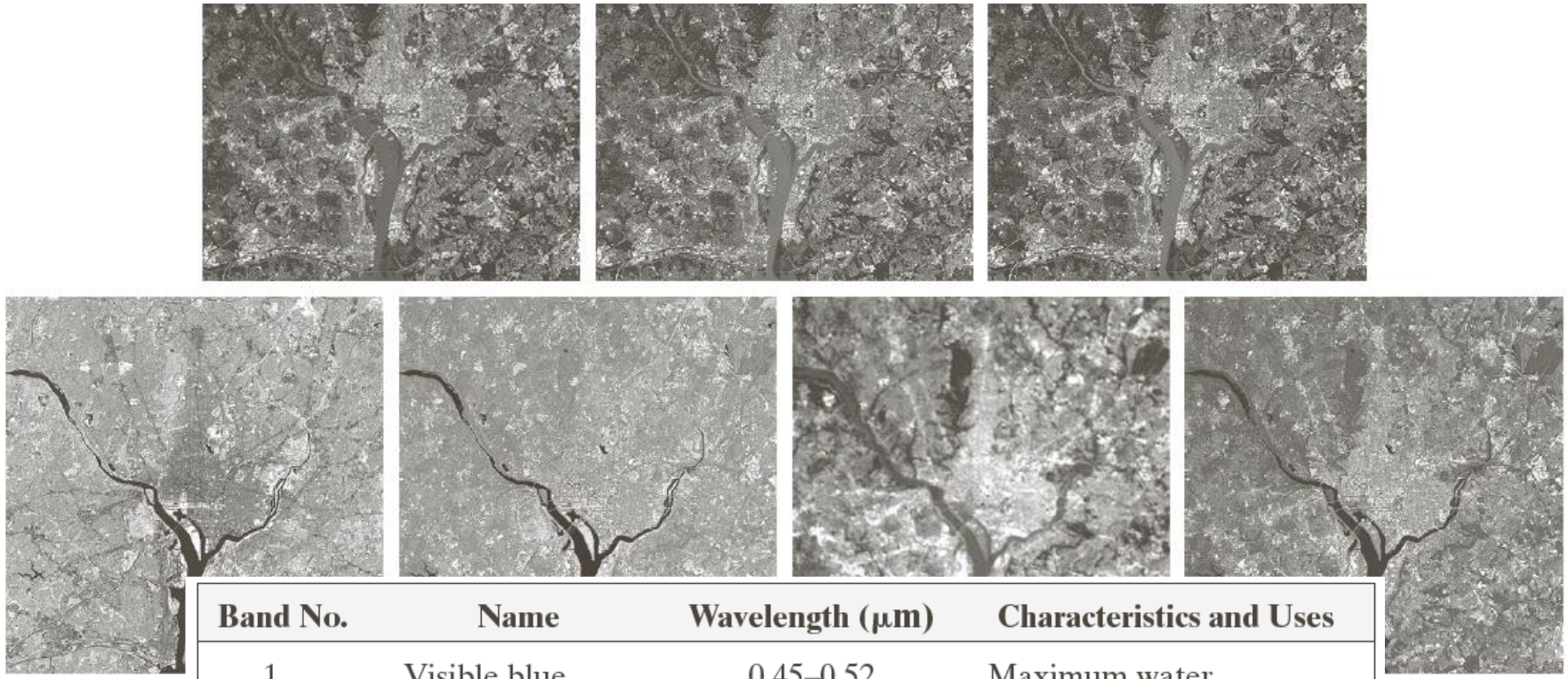
**FIGURE 1.8**
Examples of ultraviolet imaging.
(a) Normal corn.
(b) Smut corn.
(c) Cygnus Loop.
(Images courtesy of (a) and (b) Dr. Michael W. Davidson, Florida State University,
(c) NASA.)



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 |

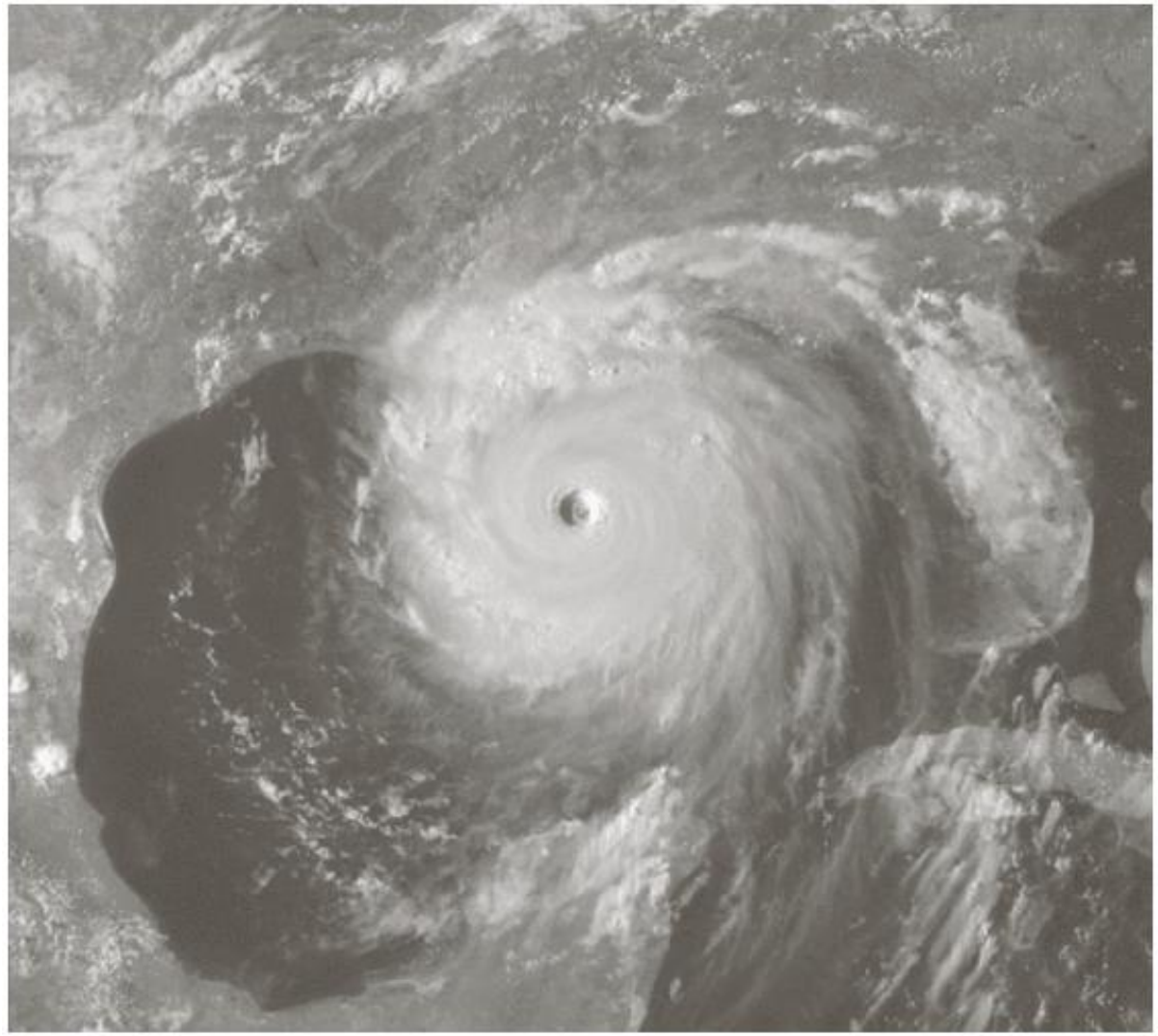
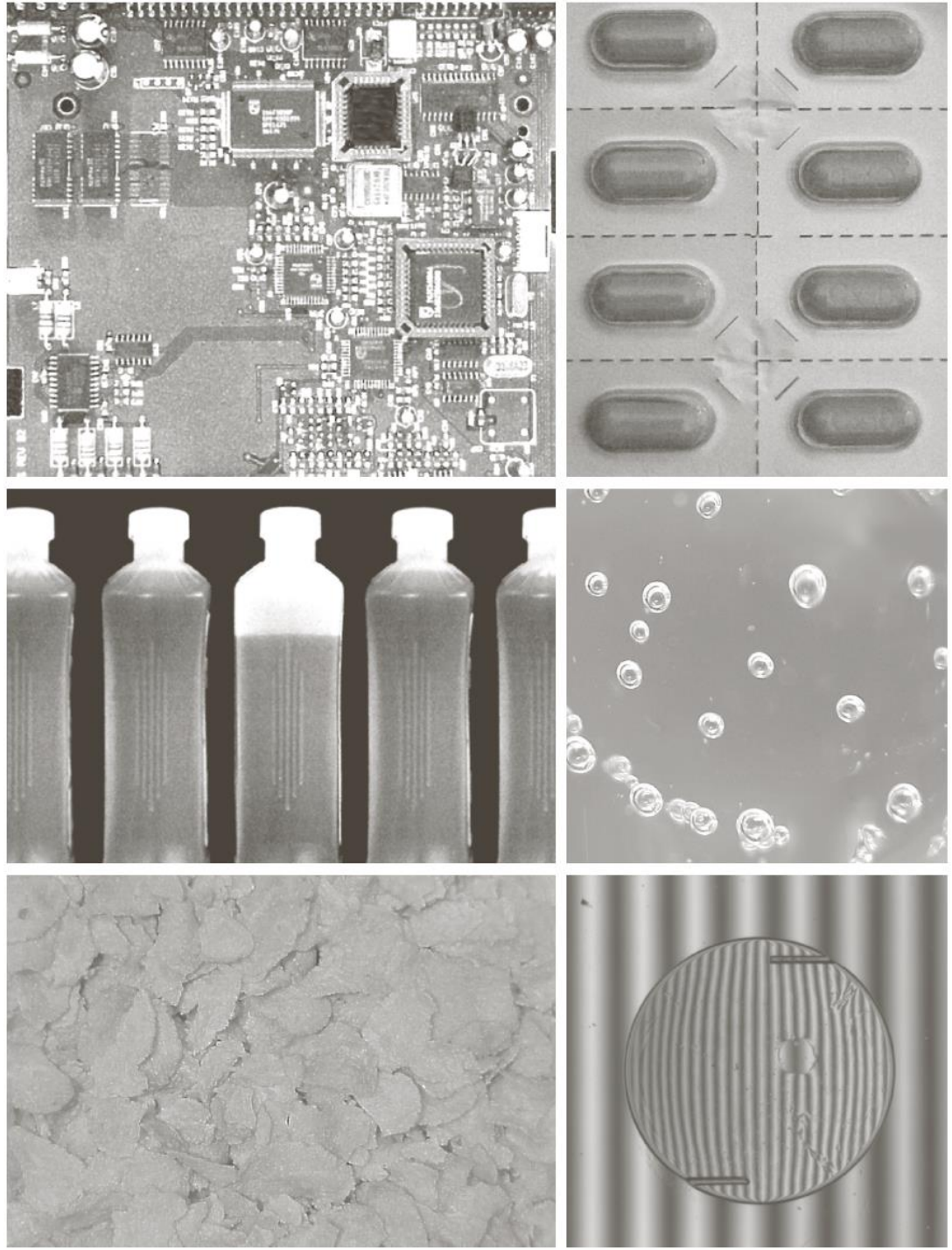


**FIGURE 1.11**
Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)

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



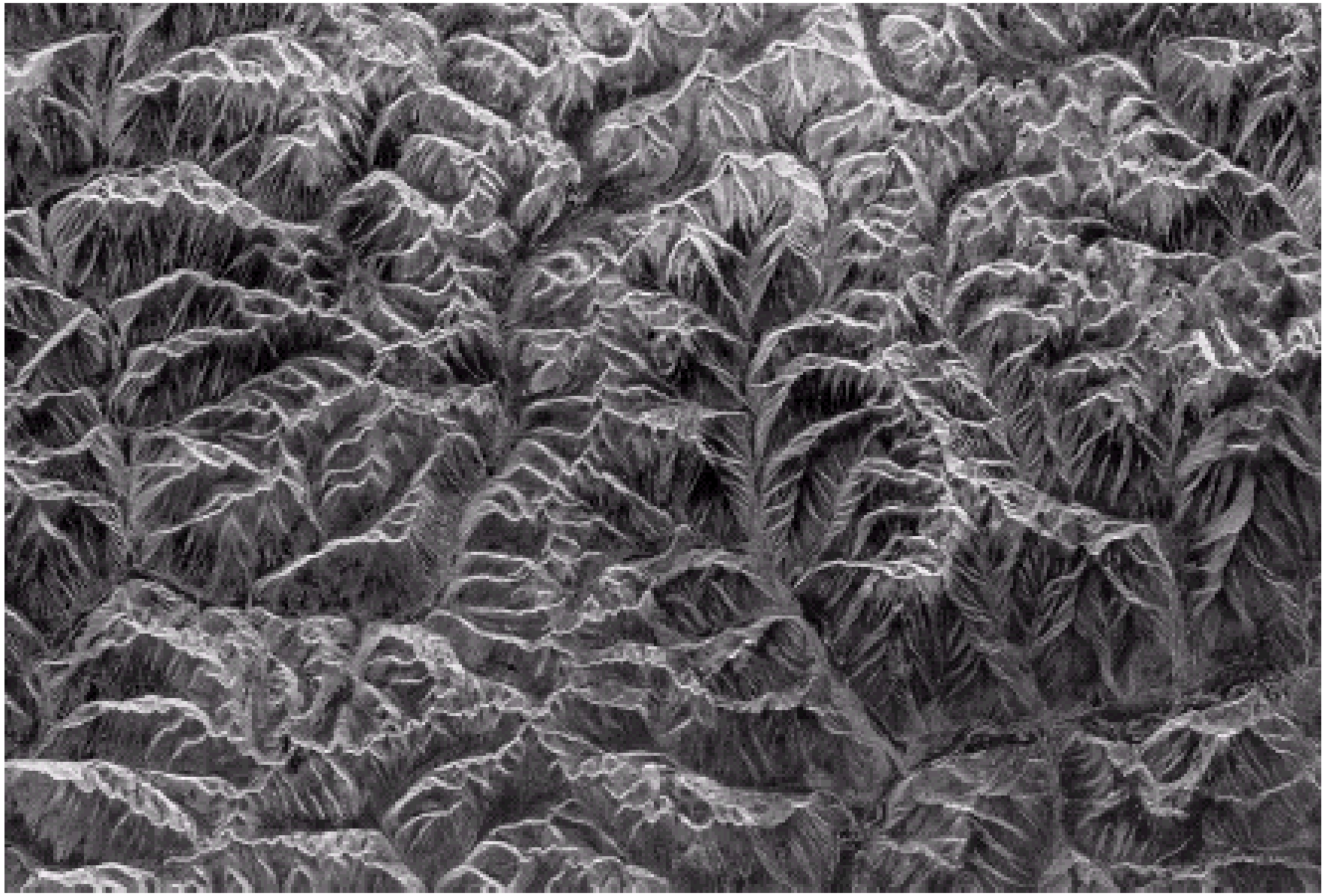
a b
c d
e f

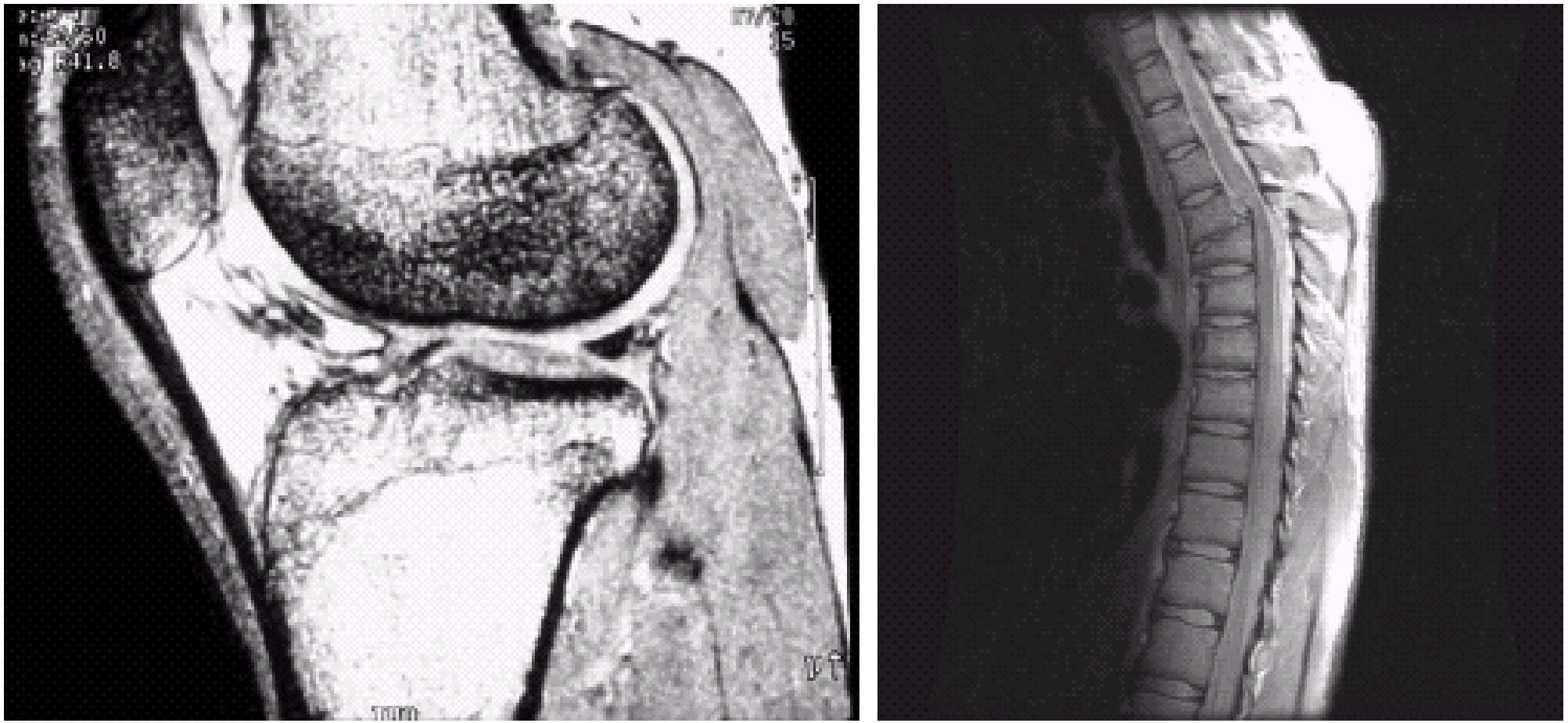
**FIGURE 1.14**
Some examples of manufactured goods often checked using digital image processing.
(a) A circuit board controller.
(b) Packaged pills.
(c) Bottles.
(d) Air bubbles in a clear-plastic product.
(e) Cereal.
(f) Image of intraocular implant.
(Fig. (f) courtesy of Mr. Pete Sites, Perceptics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


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.)

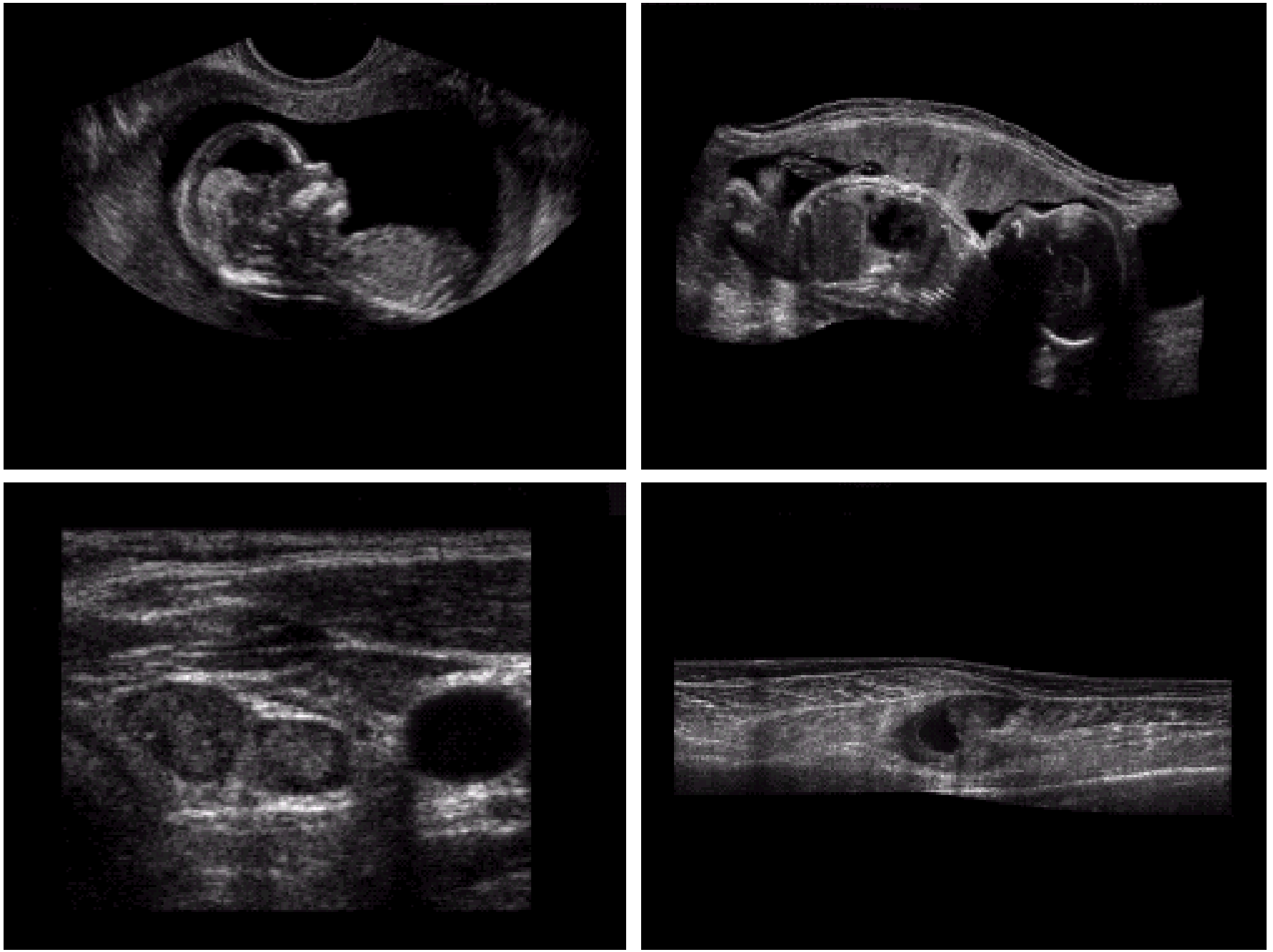
**FIGURE 1.16**
Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)





a b

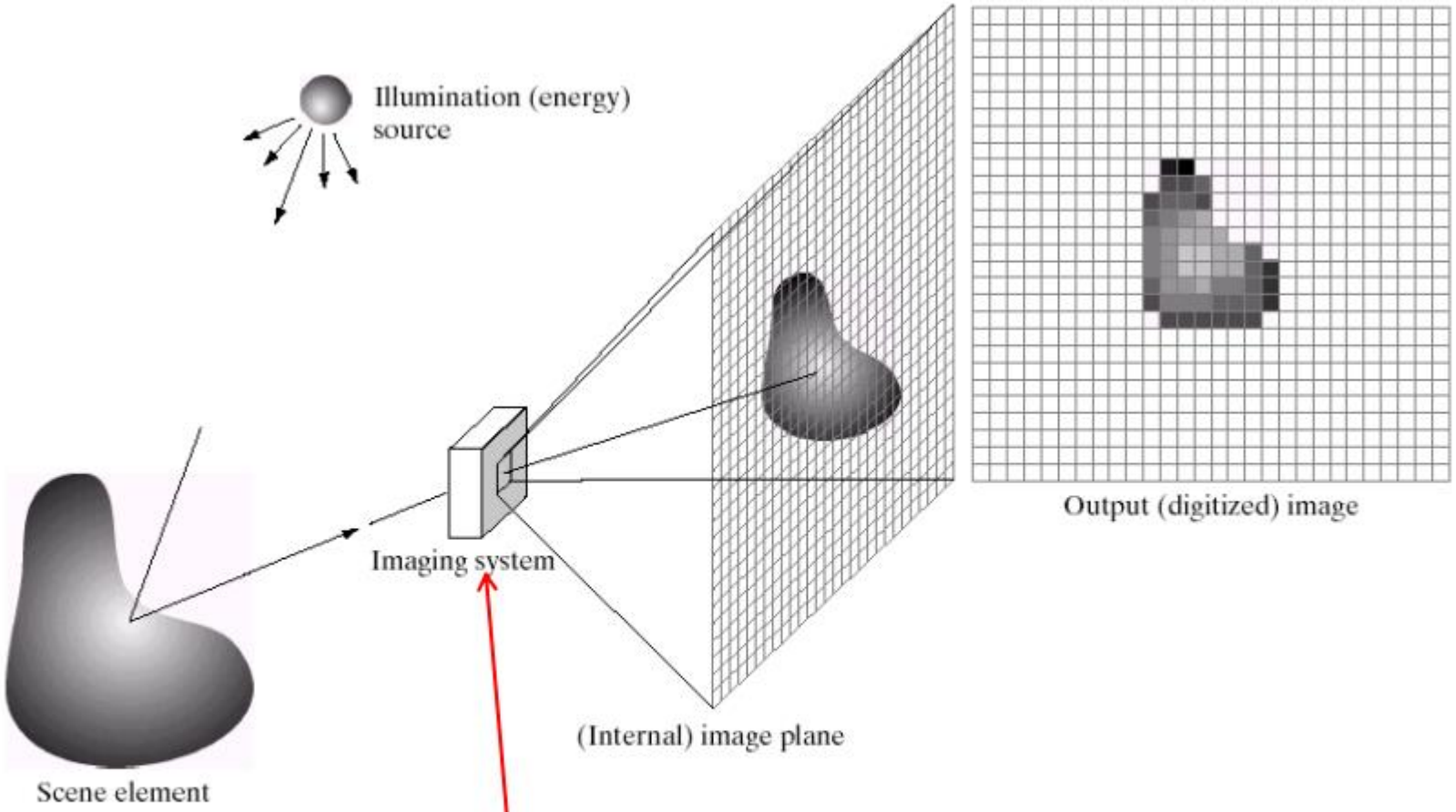
**FIGURE 1.17** MRI images of a human (a) knee, and (b) spine. (Image (a) courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, and (b) Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)



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.)

# Imaging System



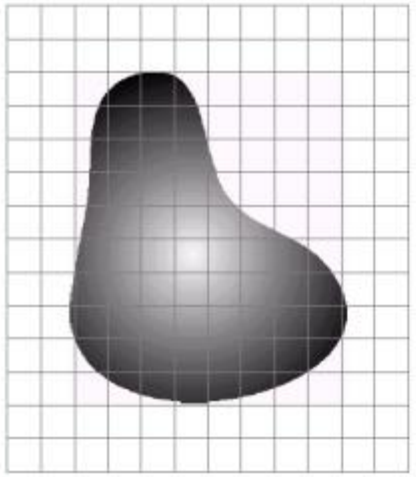

Example: a camera
Converts light to image

Credits: Gonzales and Woods

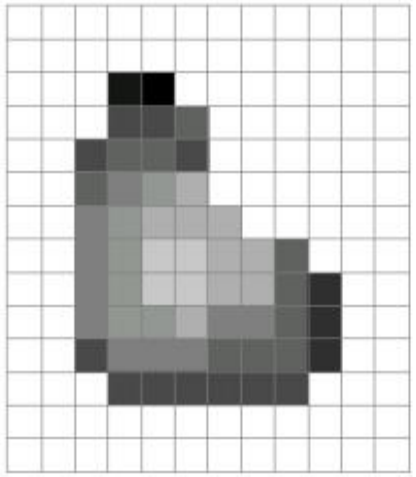
# Digital image

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

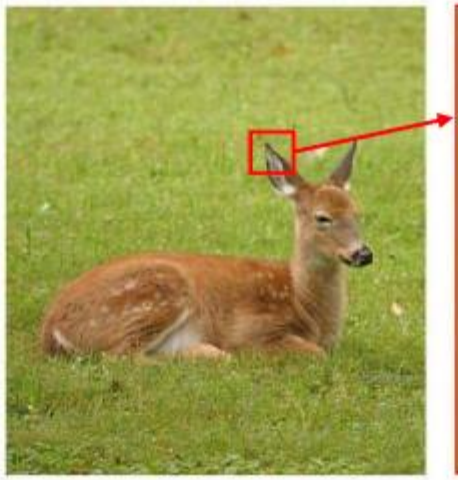
- **Remember:** *digitization* causes a digital image to become an *approximation* of a real scene



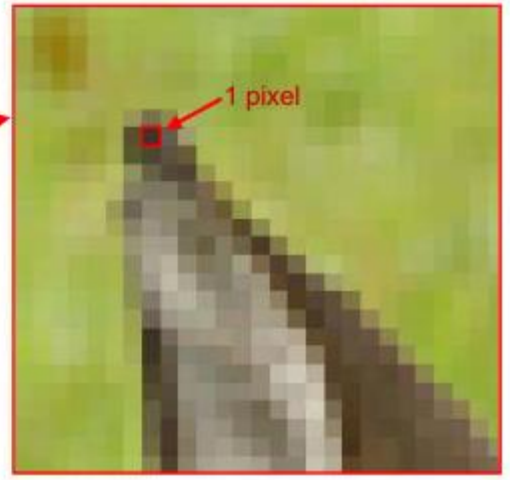
Real image



Digital Image
(an approximation)



Real image




Digital Image
(an approximation)

# Digital image

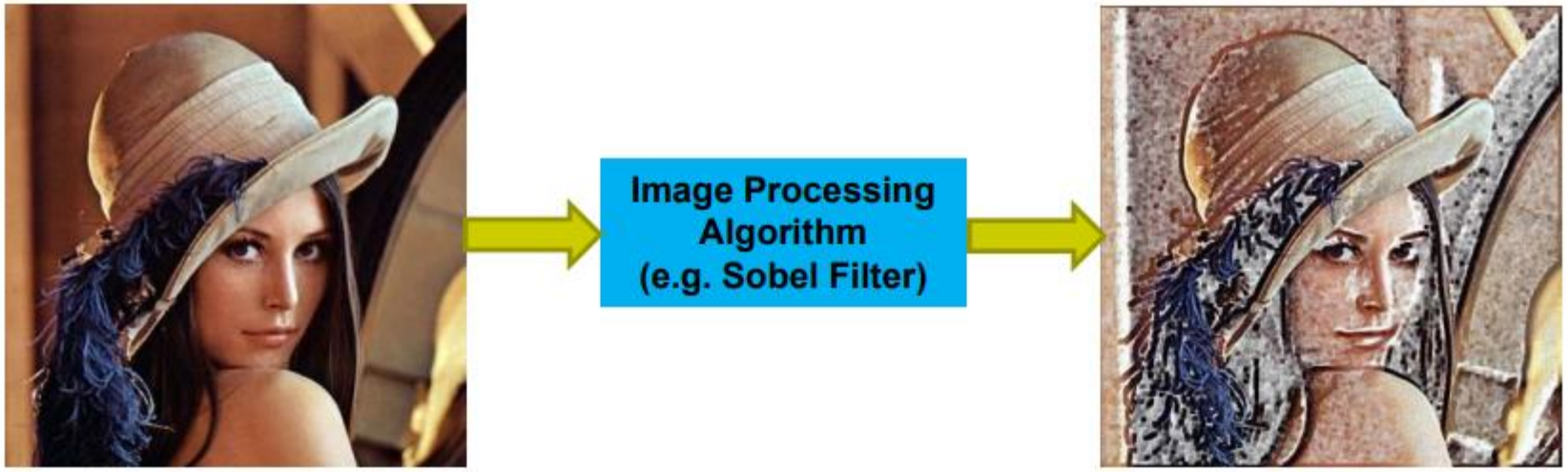
- 1 value per point/pixel (B&W or greyscale)
- 3 values per point/pixel (RGB)

Grayscale

RGB

# What is image processing

- **Algorithms that alter an input image to create new image**
- **Input is image, output is image**

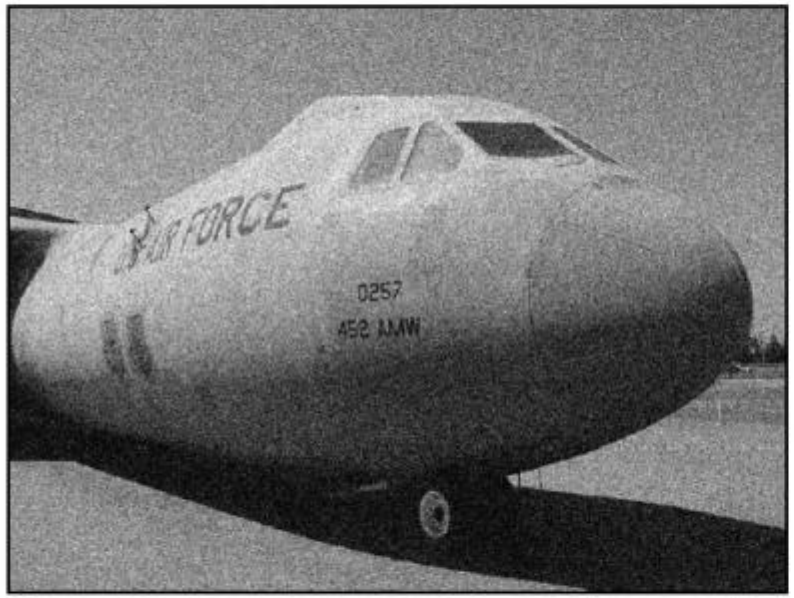



***Original Image*** ***Processed Image***

- **Improves an image for human interpretation in ways including:**
  - Image display and printing
  - Image editting
  - Image enhancement
  - Image compression

# Example operation: Noise removal

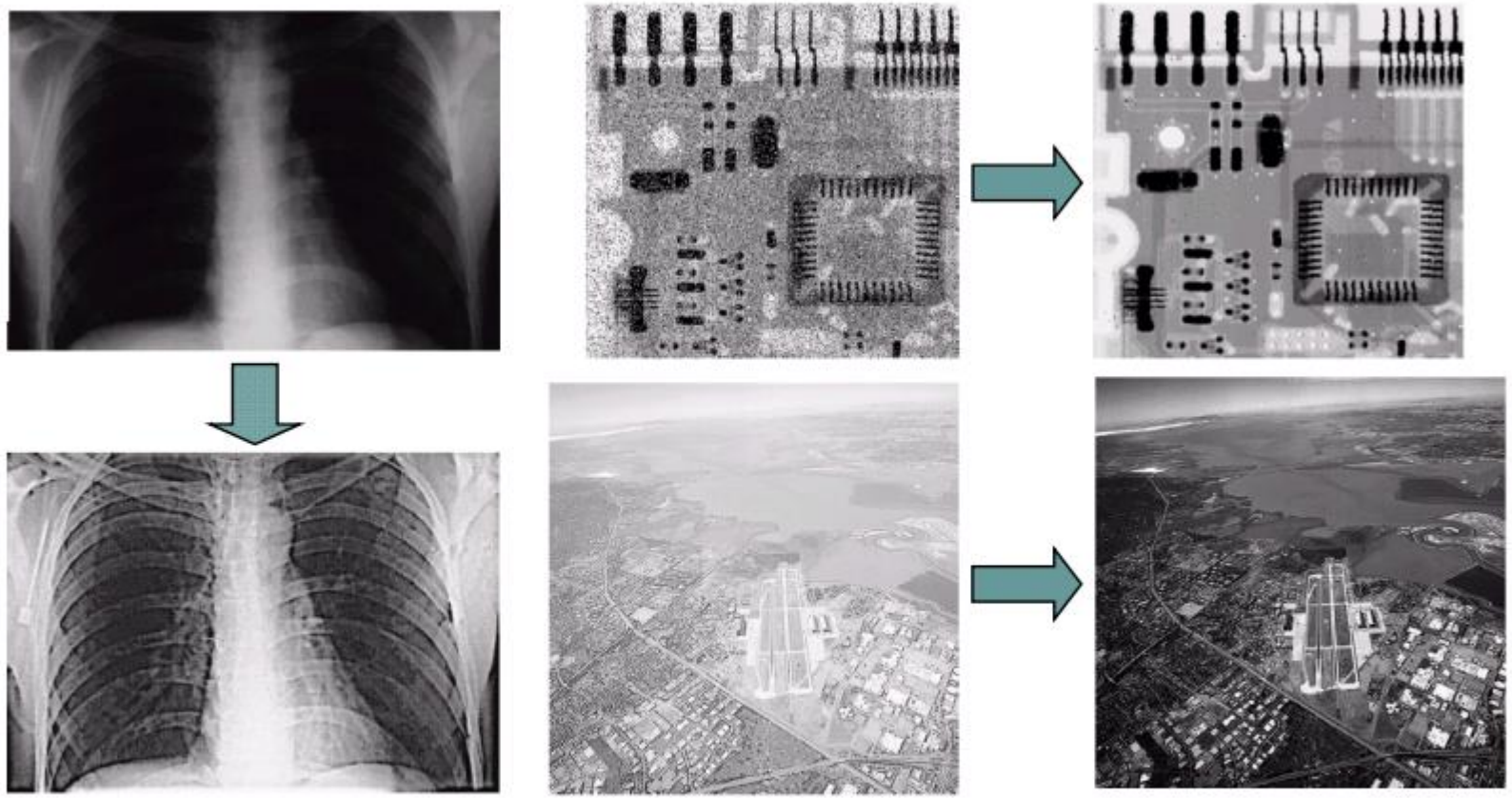
Noisy Image




Denoised Image


Think of noise as white specks on a picture (random or non-random)

# Example : Noise removal



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

# Example : Contrast adjustment

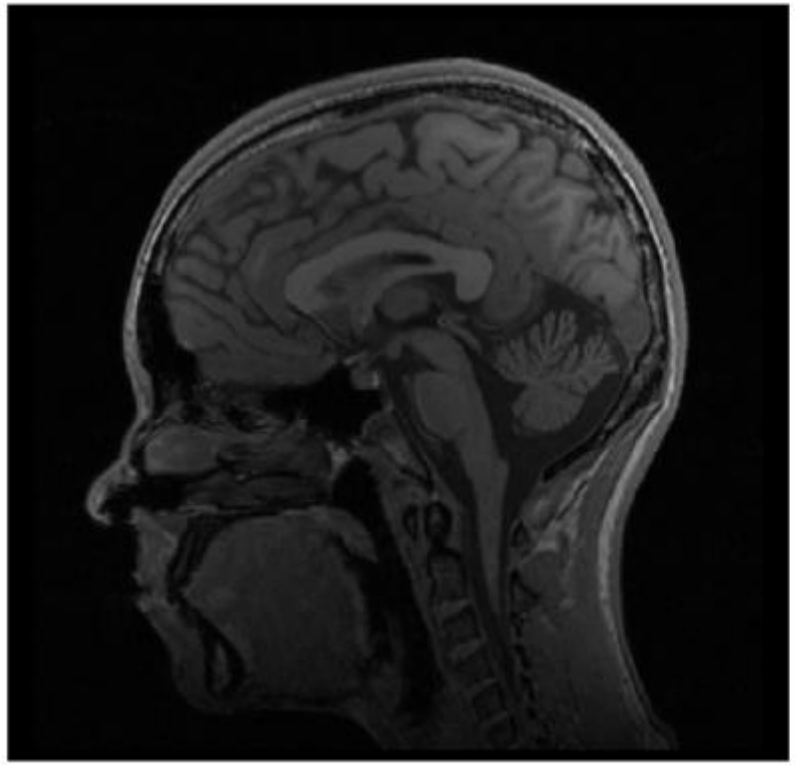
Low Contrast

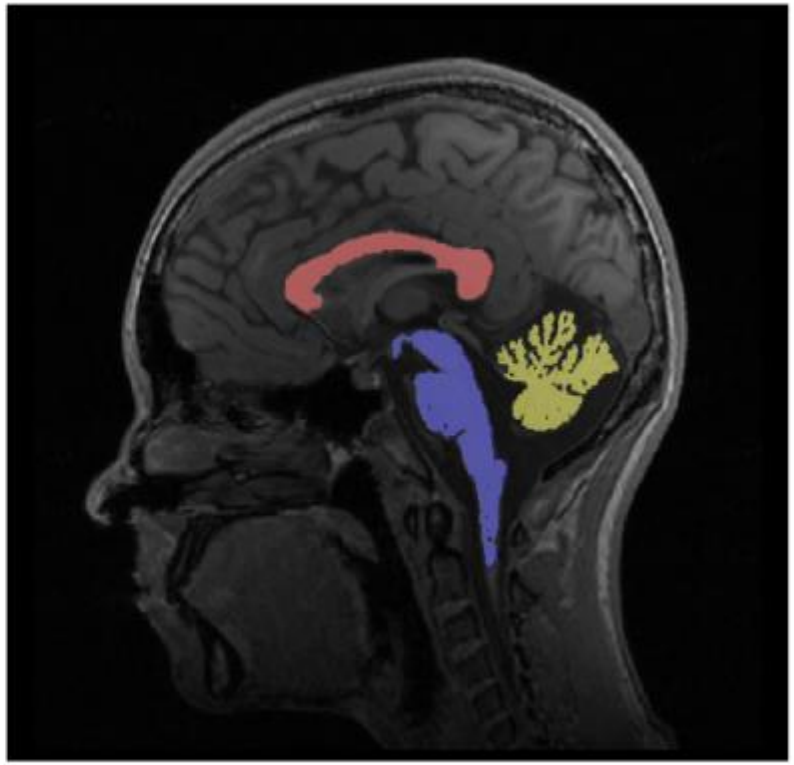
Original Contrast

High Contrast

# Example: Edge detection

# Example: region detection, segmentation





# Example: Image Compression

Original, 2.1MB

JPEG Compression, 308KB (15%)

# Example : Image inpainting

Damaged Image

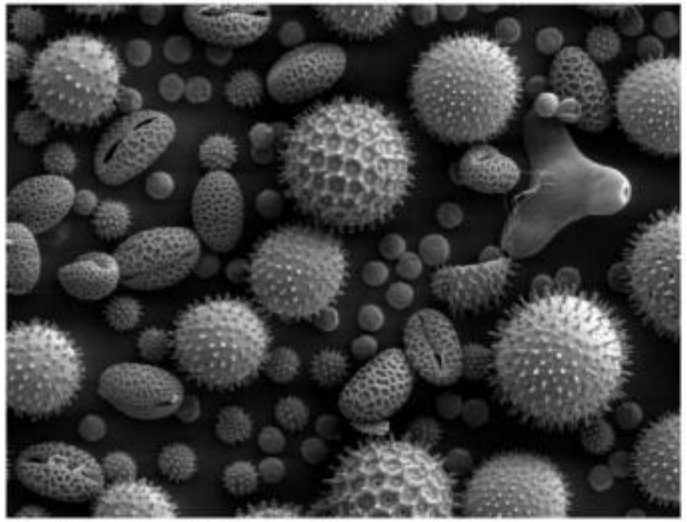
Restored Image

*Credit: M. Bertalmio, G. Sapiro, V. Caselles, C. Ballester: Image Inpainting, SIGGRAPH 2000*

Inpainting? Reconstruct corrupted/destroyed parts of an image

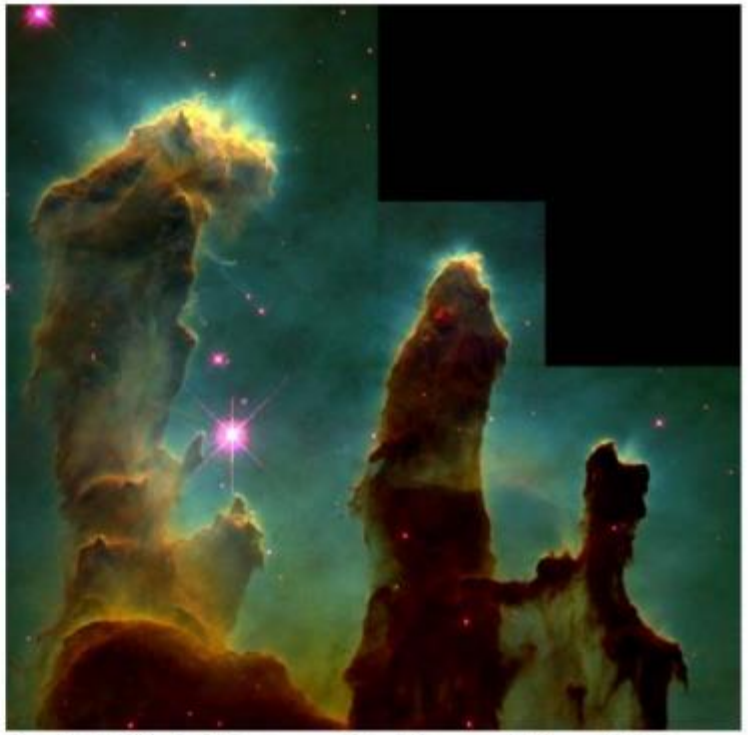
# Applications

## Biology



*Credit: Dartmouth Electron Microscopy Facility*

## Astronomy



*Credit: NASA, Jeff Hester, and Paul Scowen (Arizona State)*
More info here

# Applications

Satellite Imagery

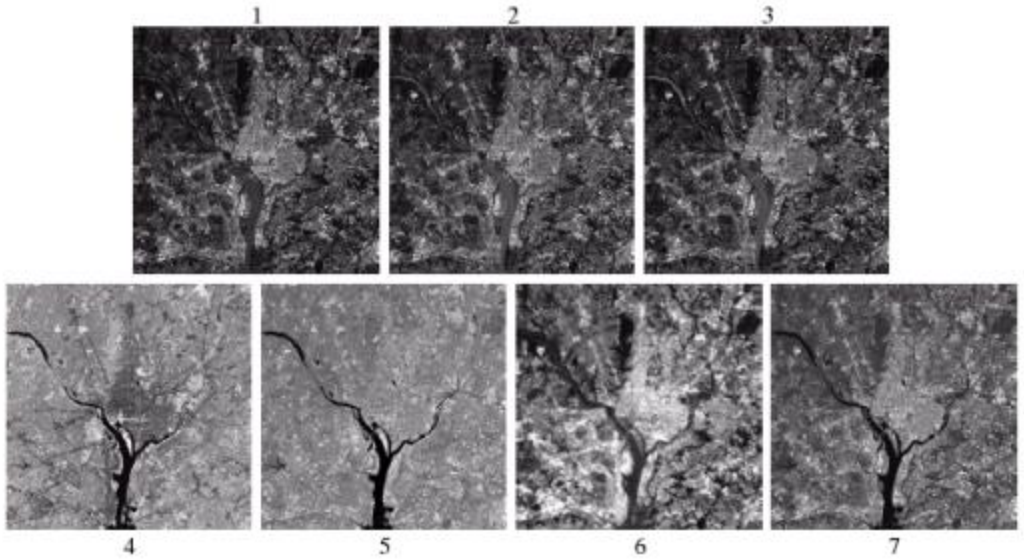
*Credit: NASA*

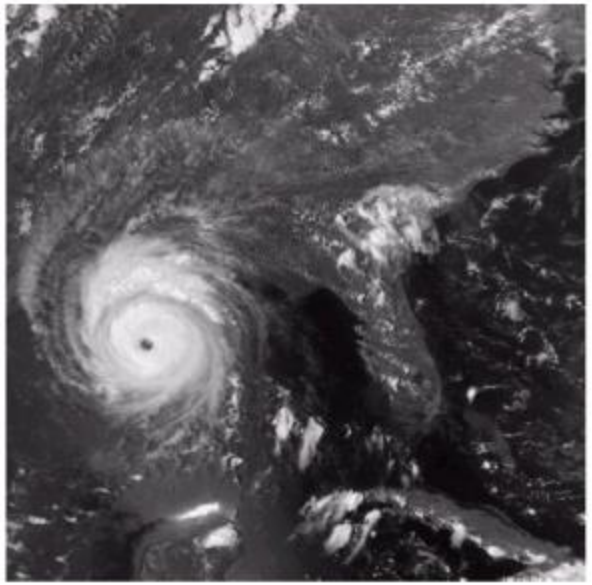
Personal Photos

*Credit: Tom Fletcher*

# Applications (Geographic Information Systems)

- Terrain classification
- Meteorology (weather)



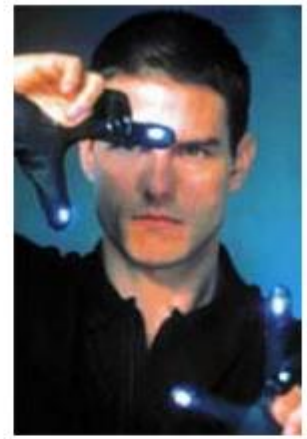
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

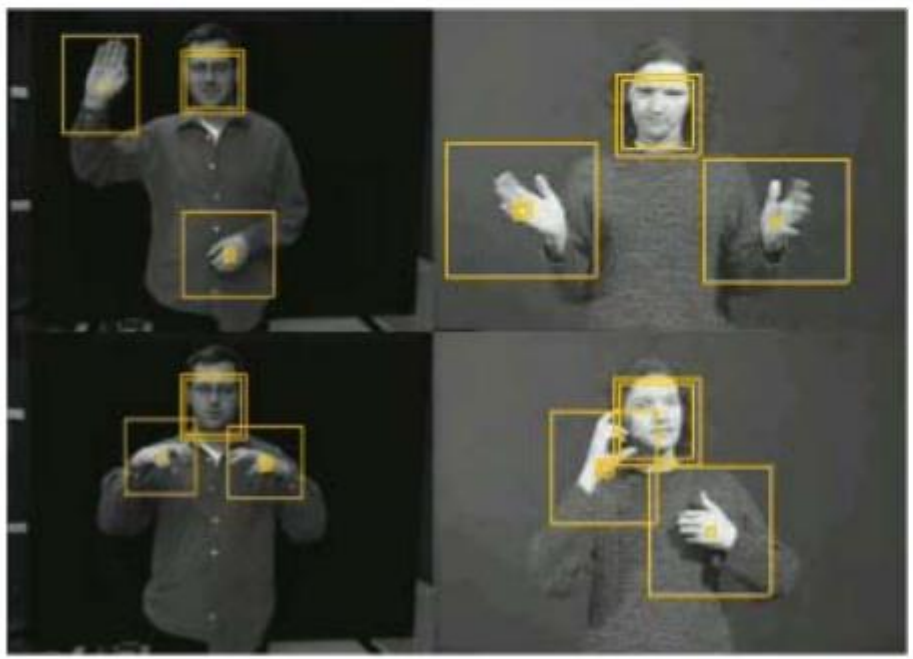
# Applications: Law enforcement

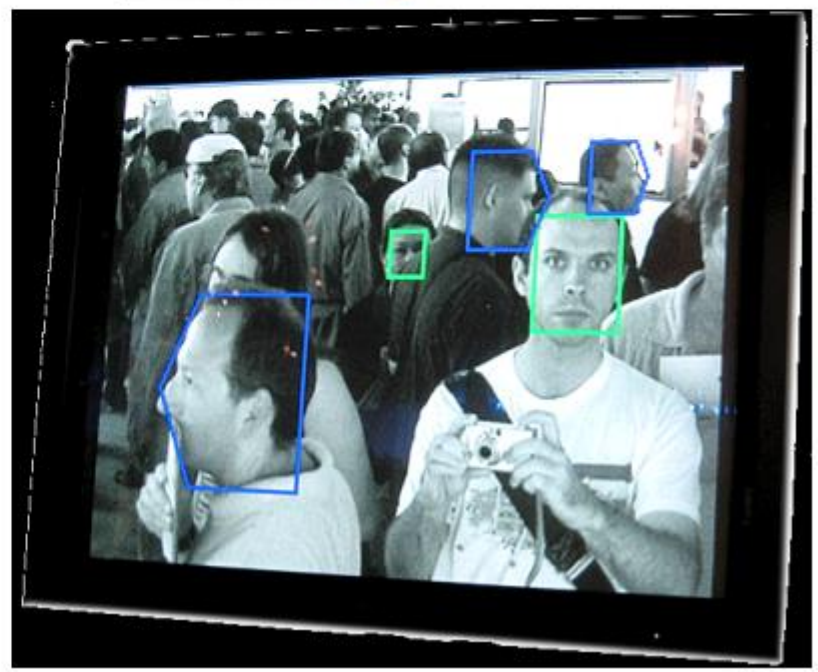
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

- Number plate recognition for speed cameras or automated toll systems
- Fingerprint recognition

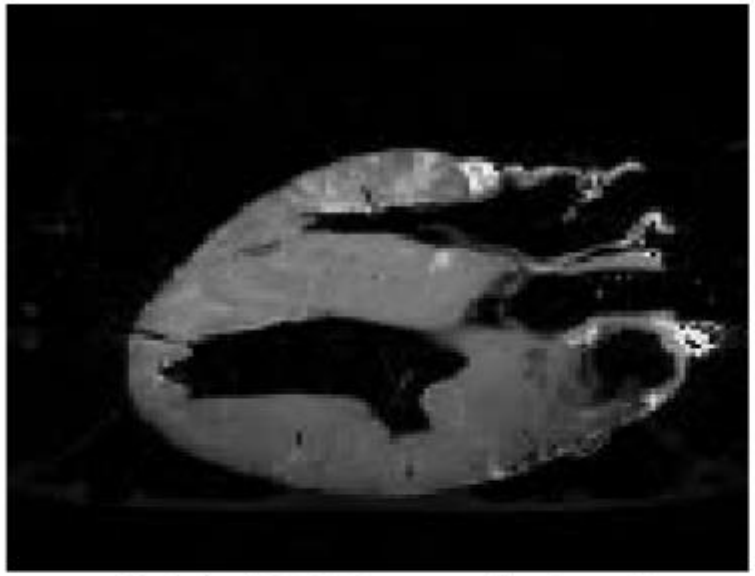

- Face recognition
- Gesture recognition



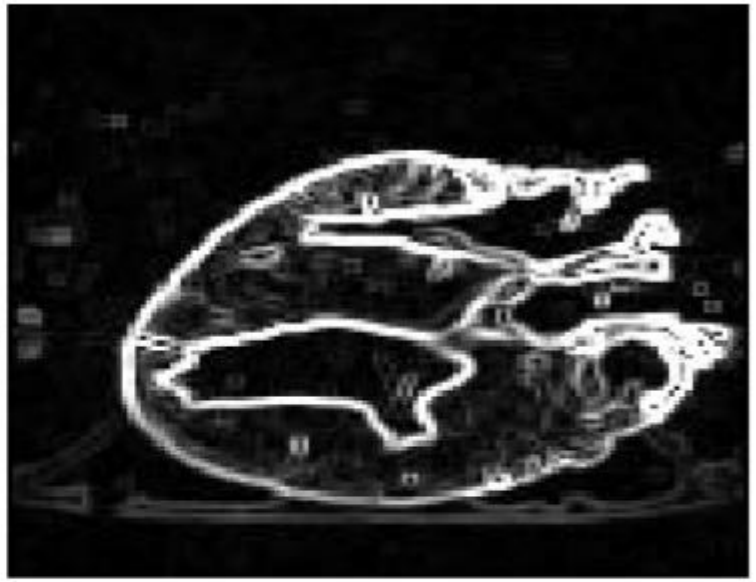




# Applications: Medicine



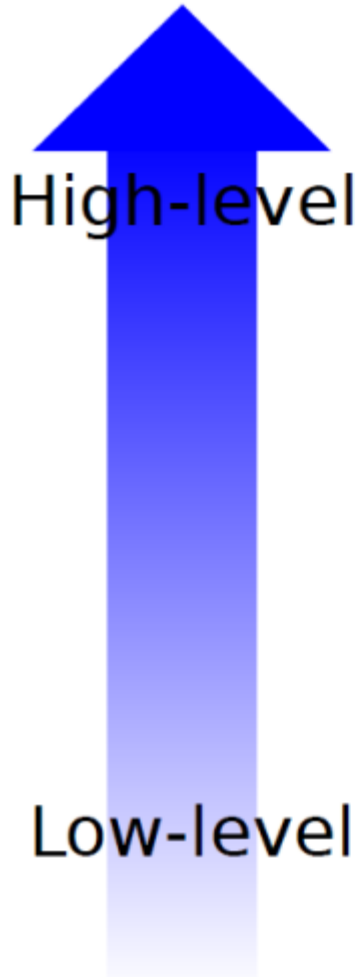
Original MRI Image of a Dog Heart



Edge Detection Image

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

# Relationships to other fields




## Computer Vision

Object detection, recognition, shape analysis, tracking
Use of Artificial Intelligence and Machine Learning

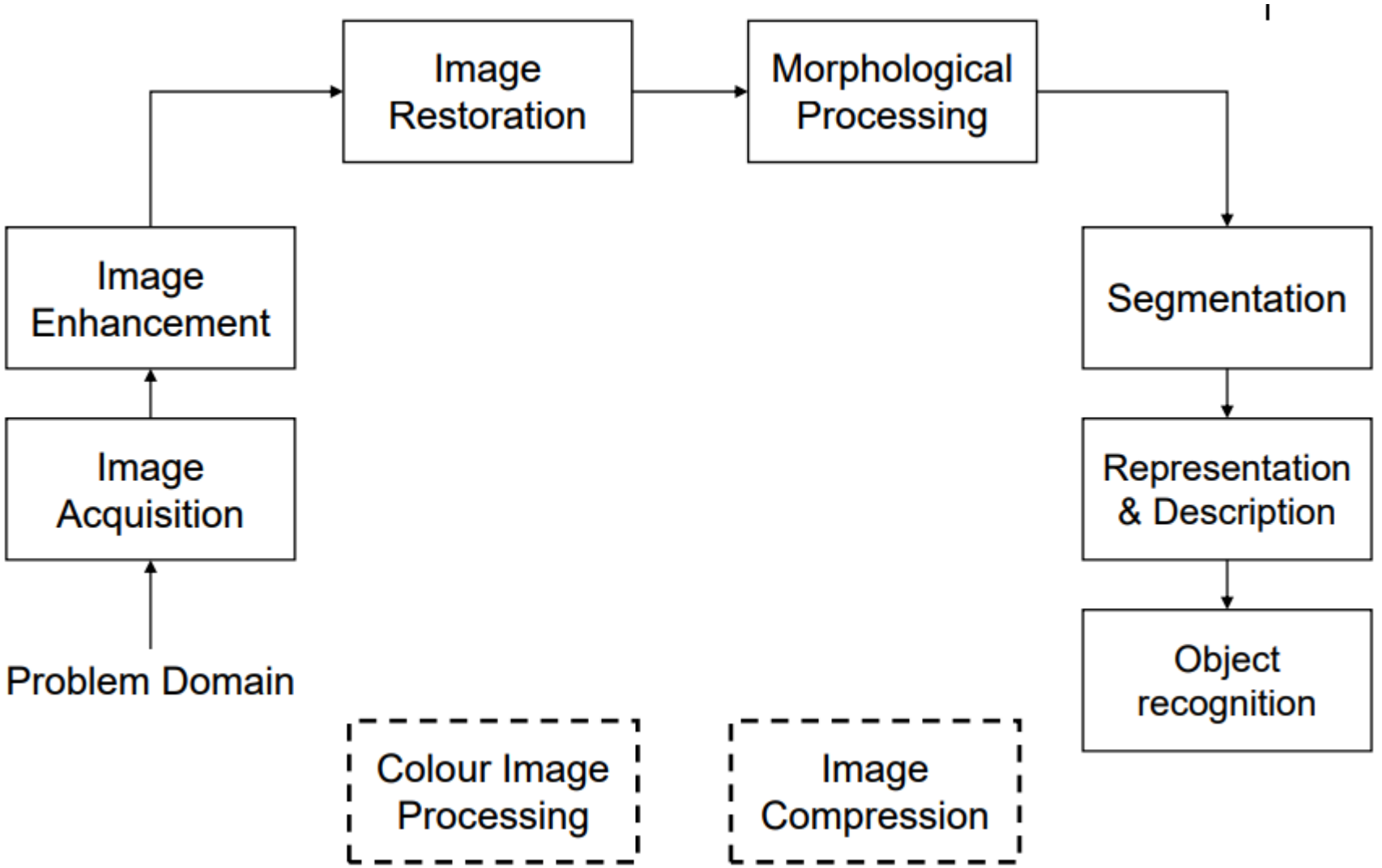
## Image Analysis

Segmentation, image registration, matching

## Image Processing

Image enhancement, noise removal, restoration,
feature detection, compression

# Key stages in Digital Image Processing



# Image Acquisition

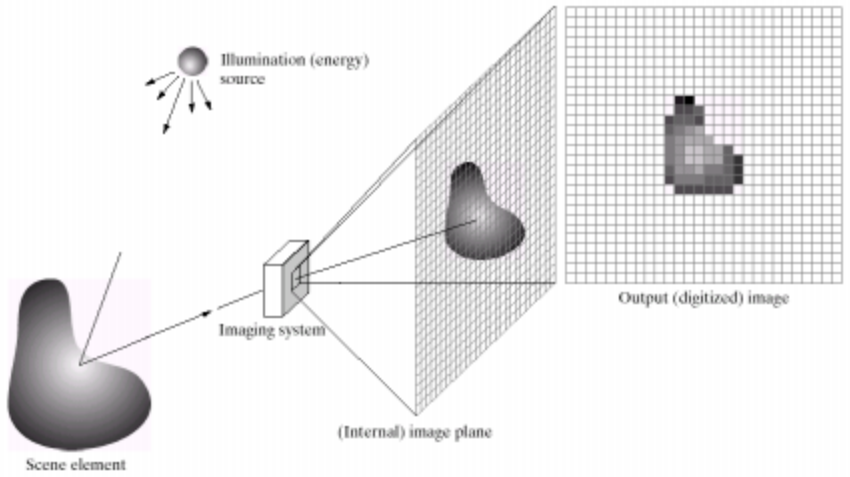

Image Restoration

Morphological Processing

Image Enhancement

Segmentation

Image Acquisition




Representation & Description

Problem Domain

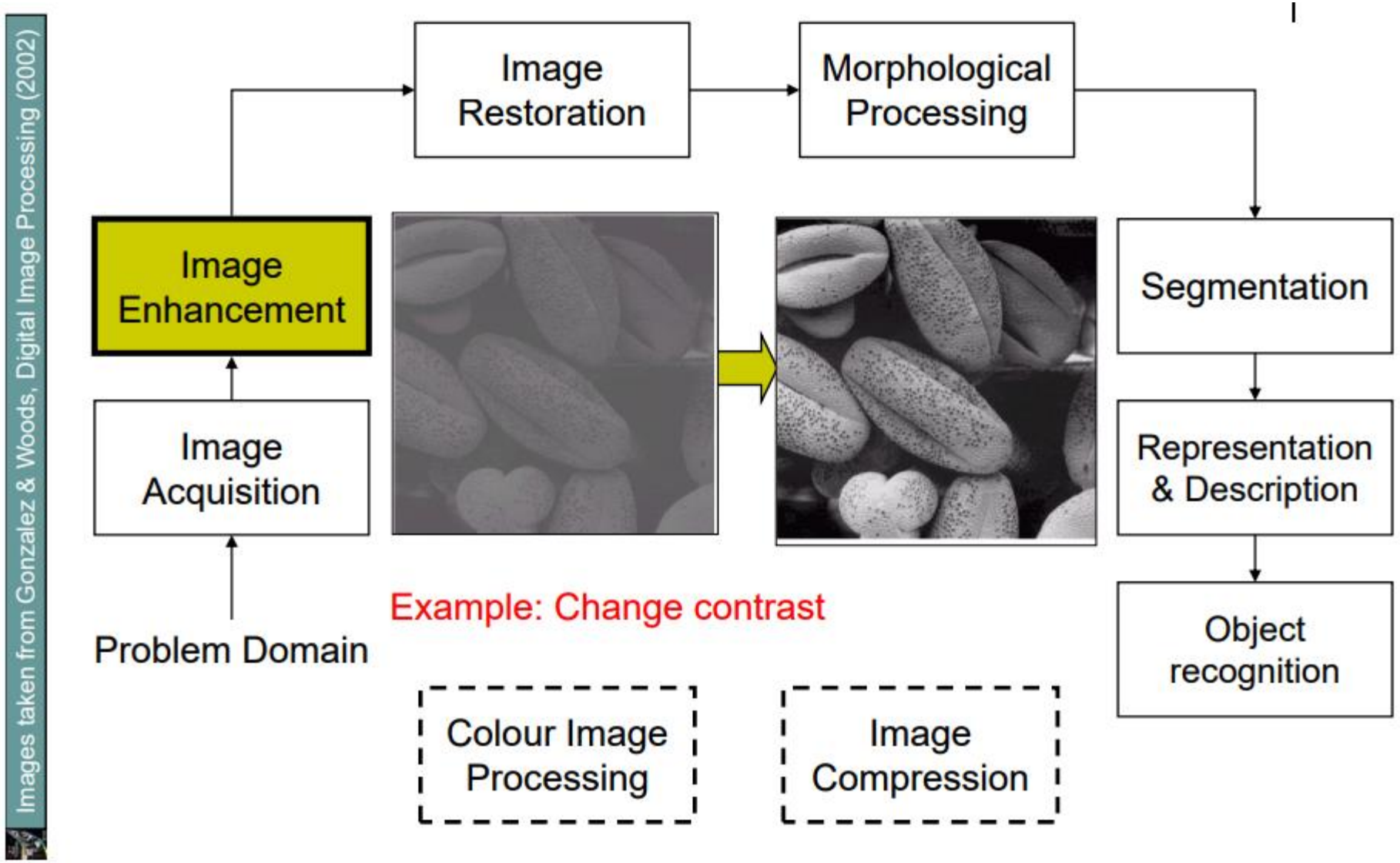
Example: Take a picture

Object recognition

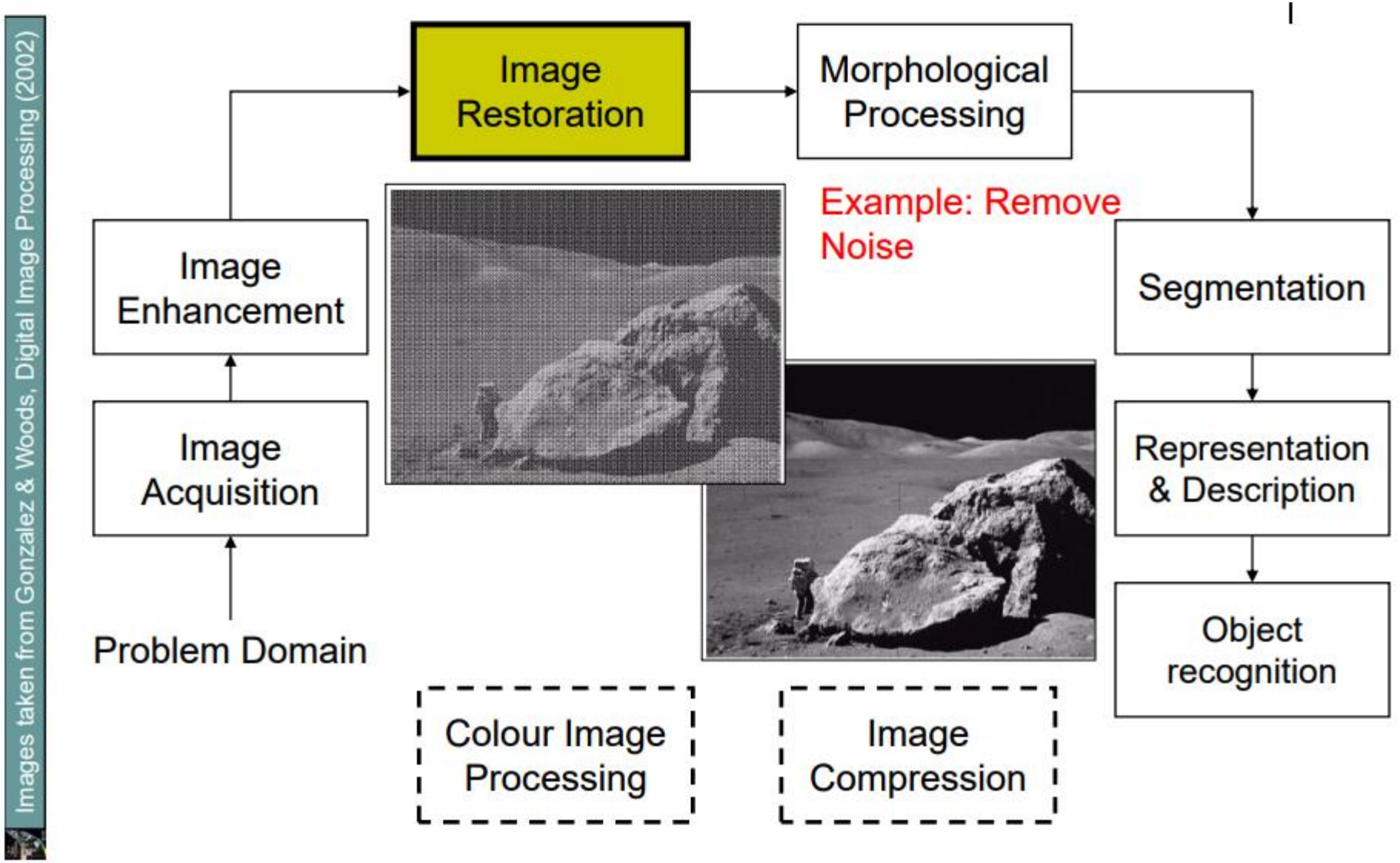
Colour Image Processing

Image Compression

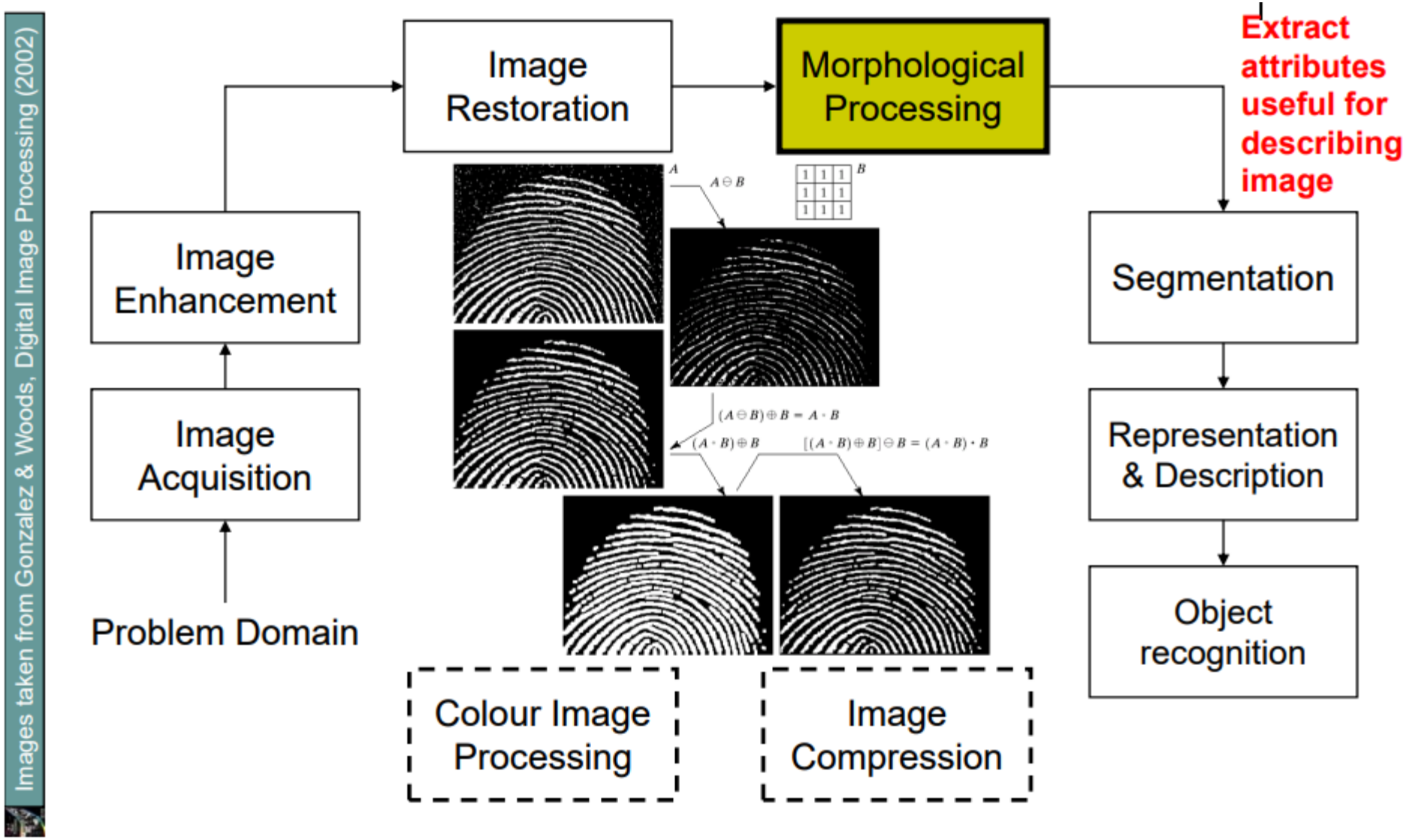
# Image Enhancement



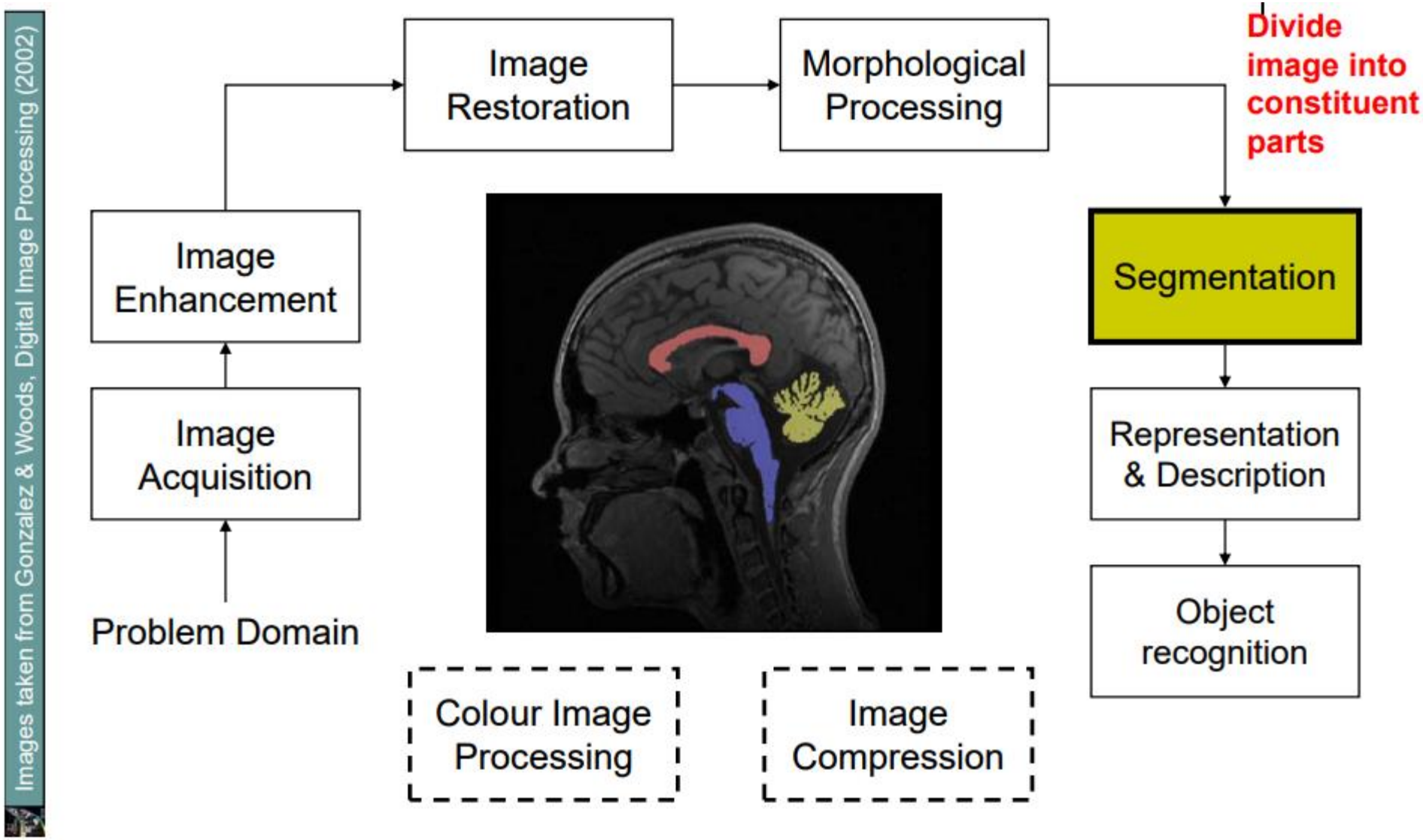
# Image Restoration



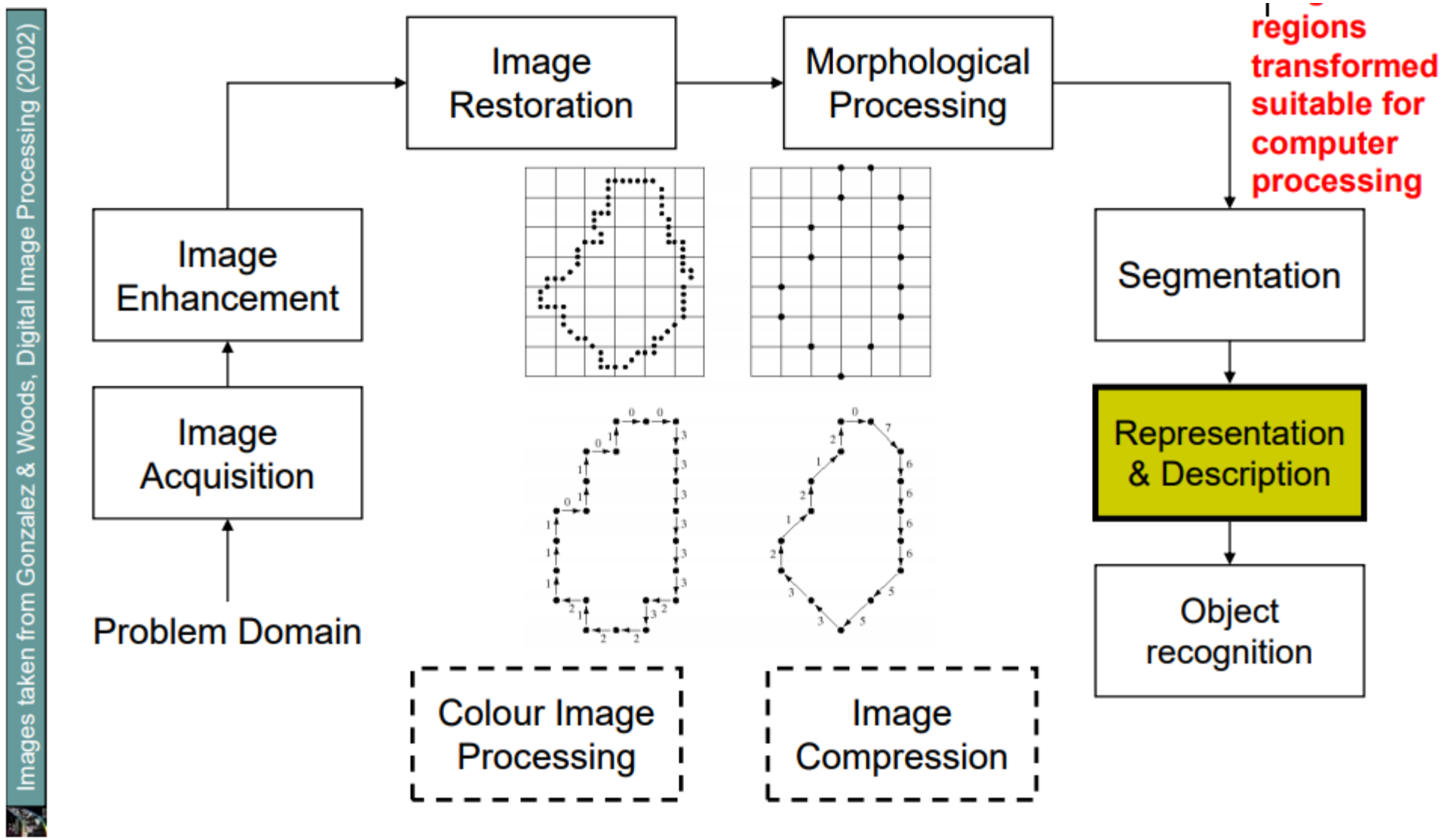
# Morphological Processing



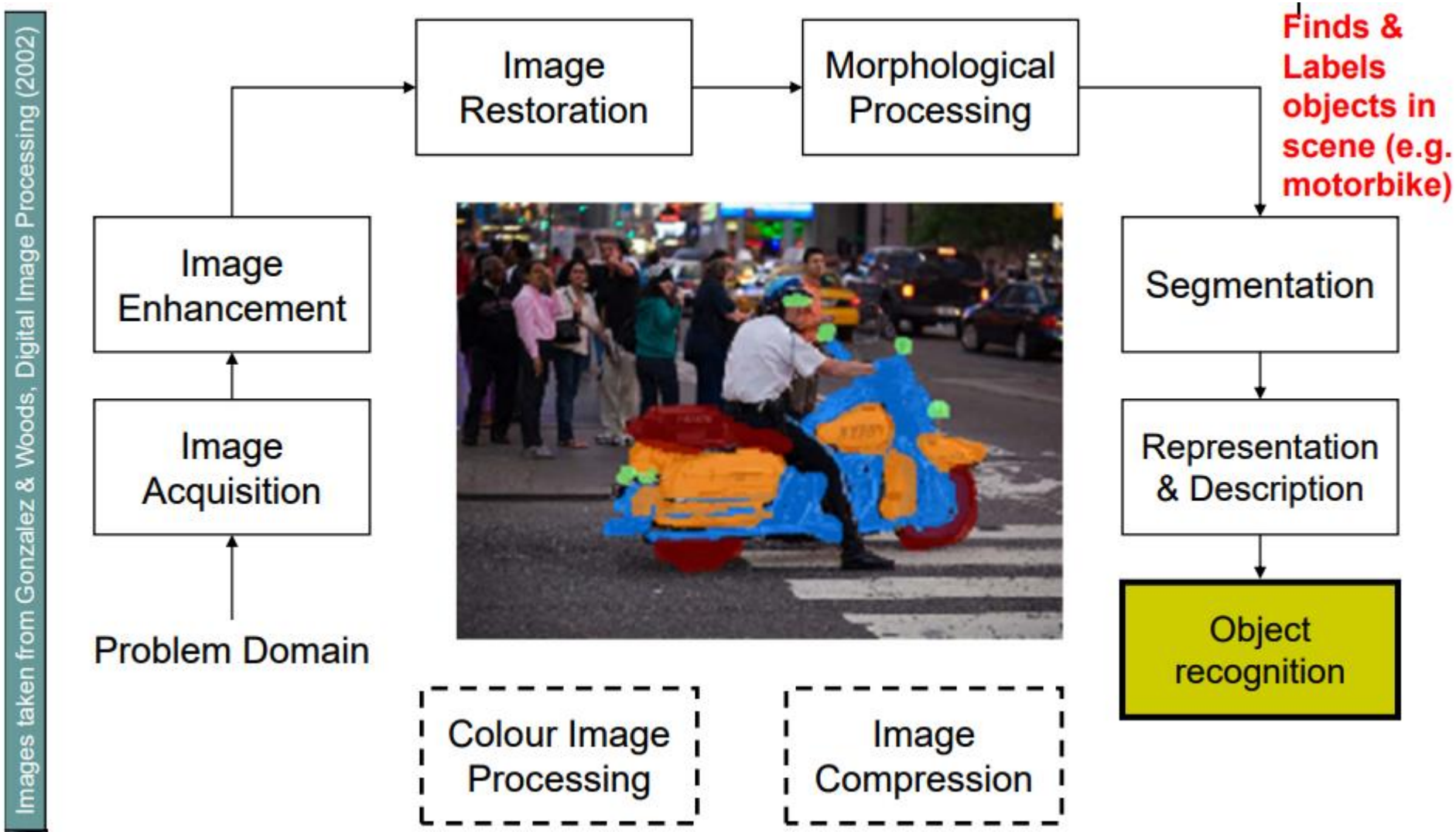
# Segmentation



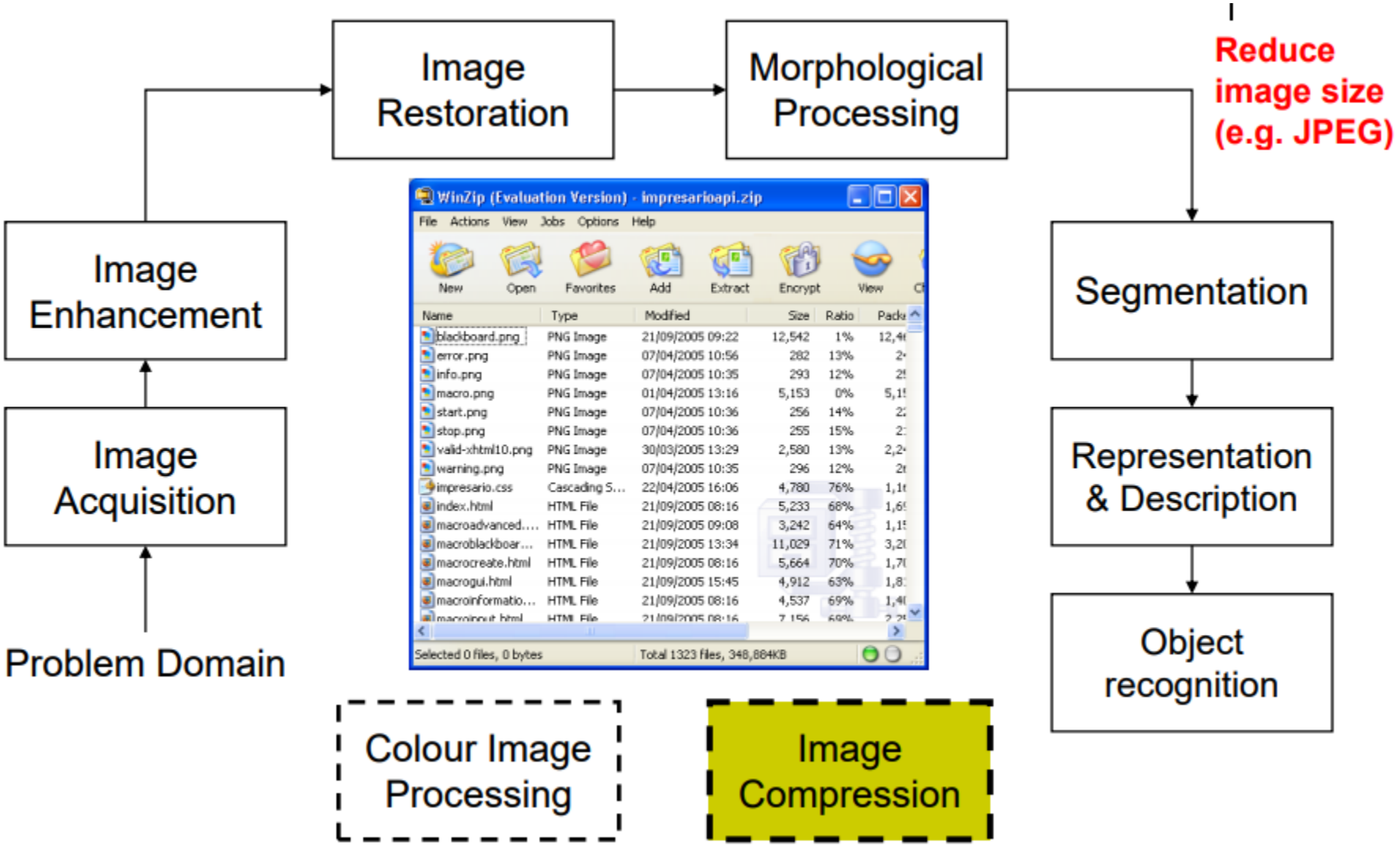
# Description



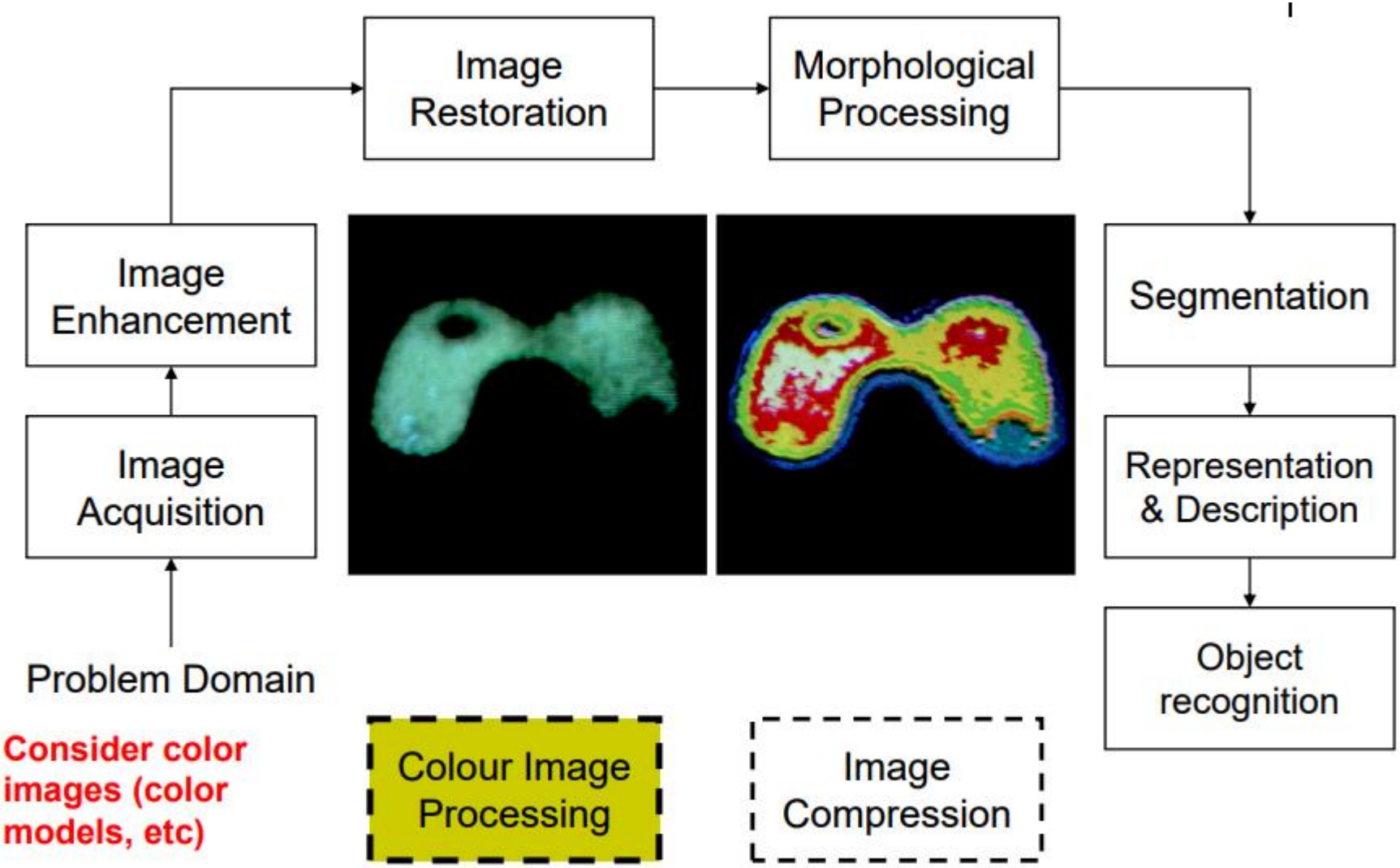
# Recognition

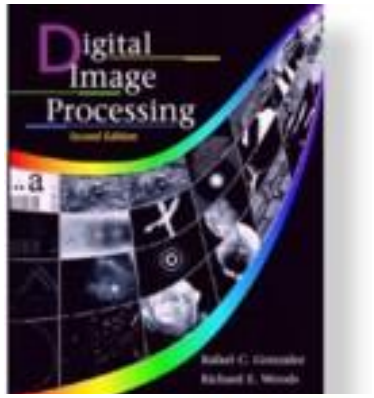


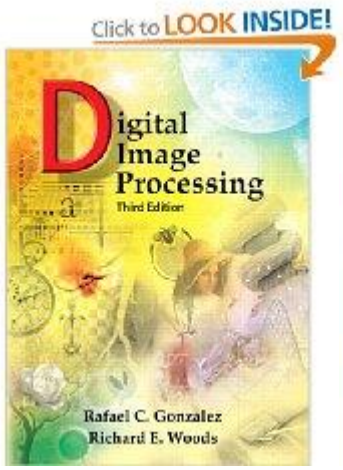
# Image Compression



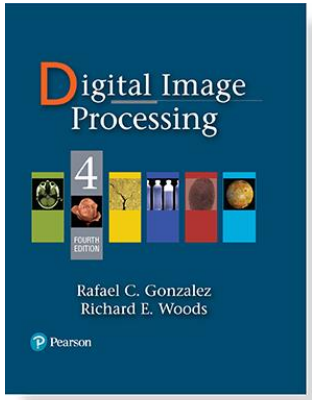
# Colour image processing










Course textbook:

Digital Image Processing

R.C.Gonzalez & R.E.Woods

Prentice-Hall

# Grading

- 40% Exam
- 60% Homeworks and Project

- Attendance and participation are required