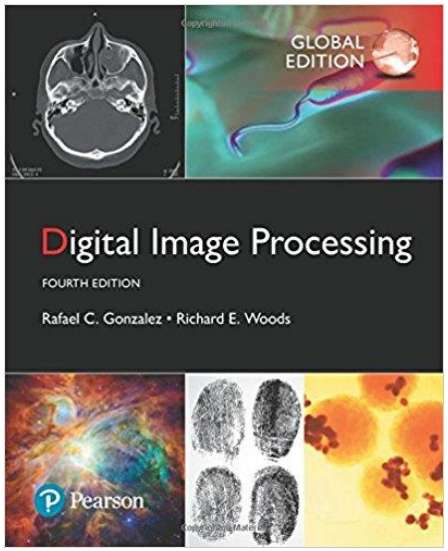


Digital Image Processing

Chapter 1: Introduction

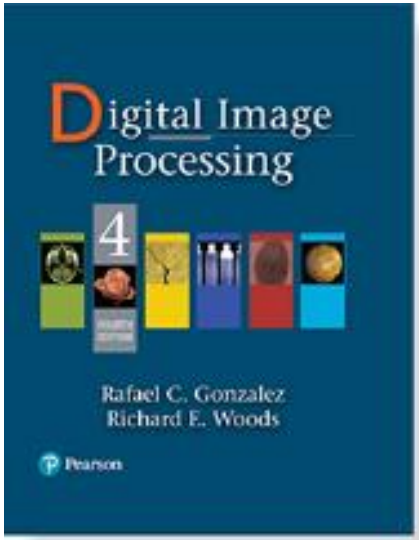
Anas Toma

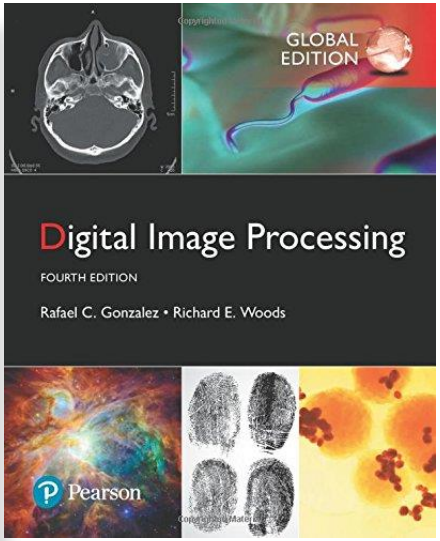
(Slides are based on Rafael C. Gonzalez and Richard E. Woods, Sufyan Samara, and Samer Arandi)

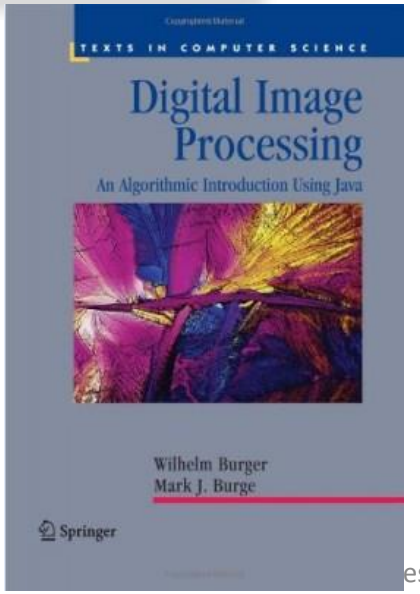
Programming Tools

- ImageJ
- Matlab
- **OpenCV**
- EasyBMP
- Native programming languages (build your own library)
- **CVIPTools**

Textbook







- ***Main textbook:***
  - ***Digital Image Processing,* 4th Edition, by *Rafael* C. *Gonzalez and Richard* E. *Woods.***
- **Another very good book:**
  - **Digital Image Processing; An Algorithmic Introduction using Java, by Wilhelm Burger and Mark James Burge**

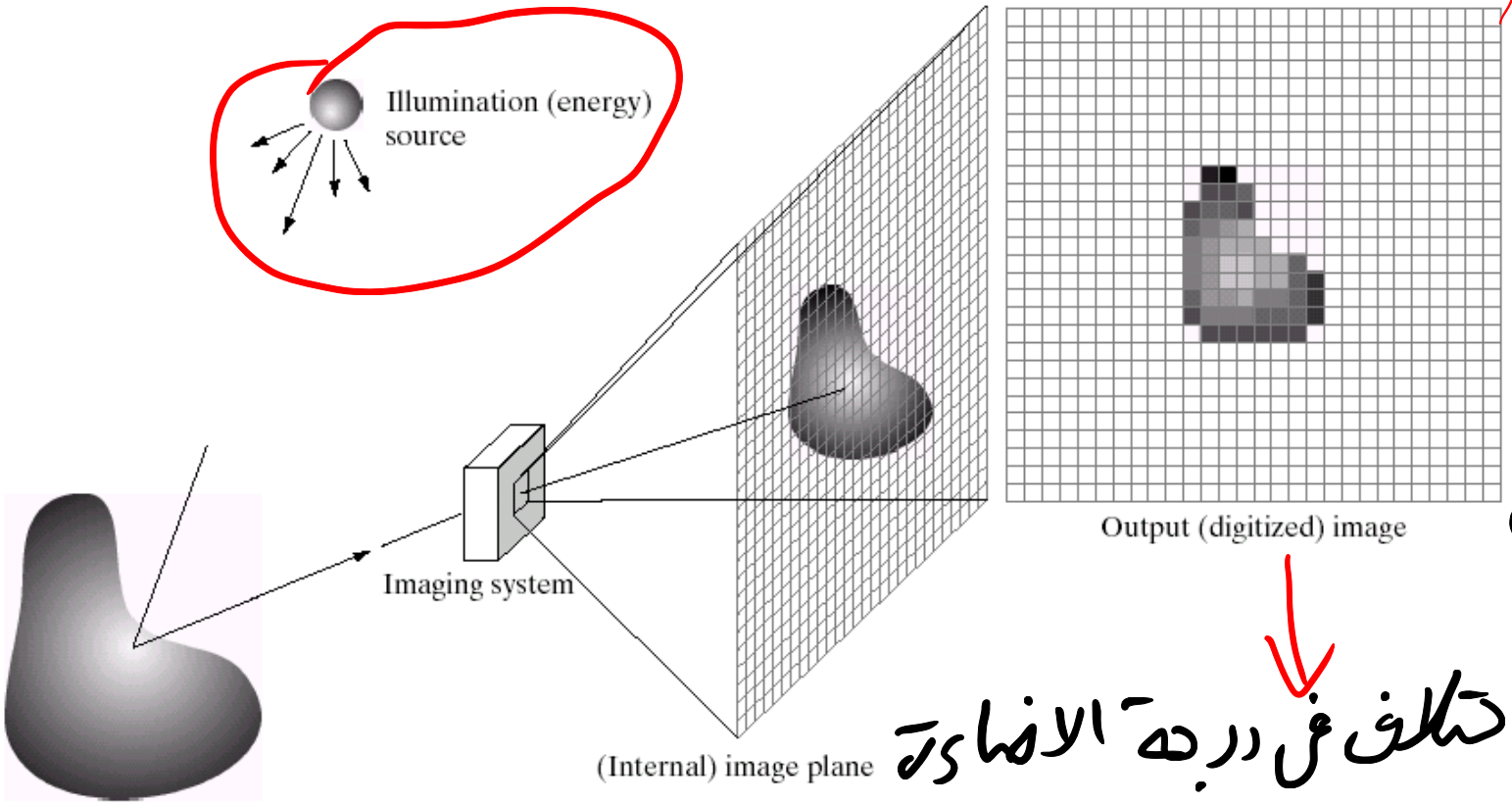
es are from the Digital Image Processing textbook, see slide 7

Grading System

- First Exam 20%
- Second Exam 20%
- Assignments/Project/Presentations 20%
- Final Exam 40%

What is a Digital Image?

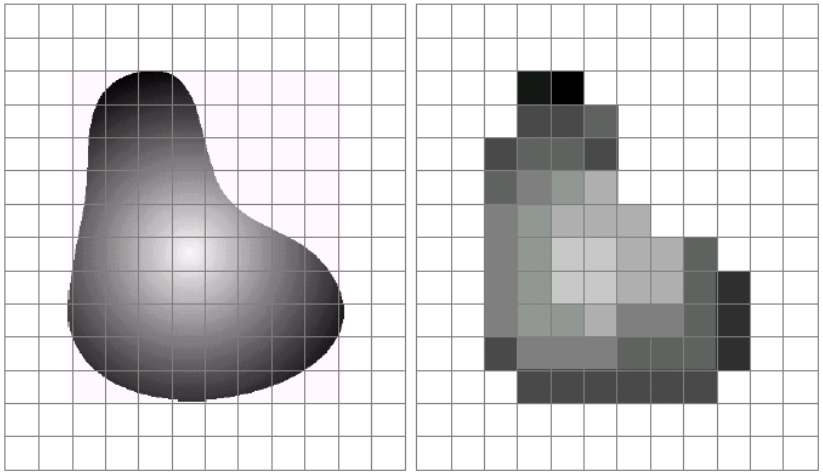
- A **digital image** is a representation of a two-dimensional image as a finite set of digital values, called picture elements or **pixels**

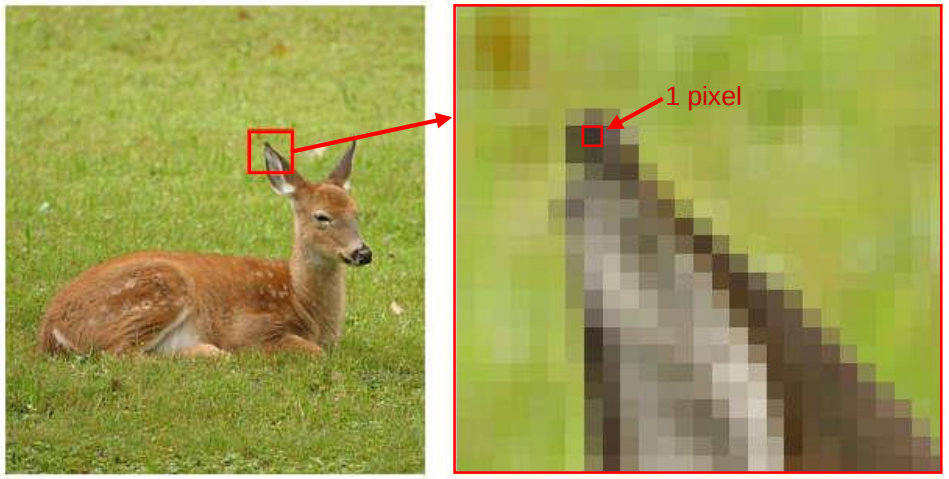


Images are from the Digital Image Processing textbook, see slide 7

What is a Digital Image? – cont.

- Pixel values typically represent gray levels, colors, heights, opacities etc
- Remember *digitization* implies that a digital image is an ***approximation*** of a real scene





Images are from the Digital Image Processing textbook, see slide 7

What is a Digital Image? – cont.

- Common image formats include:
  - 1 – One sample per point (B&W or Grayscale)
  - 2 – Three samples per point (Red, Green, and Blue)
  - 3 – Four samples per point (Red, Green, Blue, and "Alpha", a.k.a. Opacity)

For most of this course we will focus on grey-scale images

Images are from the Digital Image Processing textbook, see slide 7

What is Digital Image Processing (DIP)?

- Digital image processing focuses on **two major tasks**
  - Improvement of pictorial information for **human interpretation**
  - Processing of image data for storage, transmission and representation for autonomous **machine perception**
- Some argument about where image processing ends and fields such as image analysis and computer vision start

Input/Output	Image	Description
Image	Image Processing	Computer Vision
Description	Computer Graphics	AI

Images are from the Digital Image Processing textbook, see slide 7

History of Digital Image Processing

Early 1920s: News-paper industry

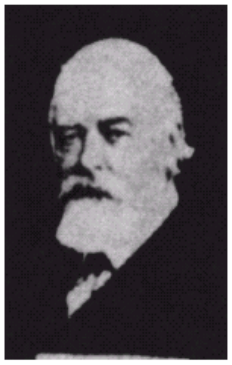
- Images were transferred by submarine cable between London and New York
- Using a telegraph printer

Mid to late 1920s:

- Increased number of tones (gray levels)

Early digital image

الصورة مبكسلة ، الجودة قليلة، مغبشة ، مش ملونة و لو ملونة درجات الألوان قليلة جدًا



Improved digital image Five tone

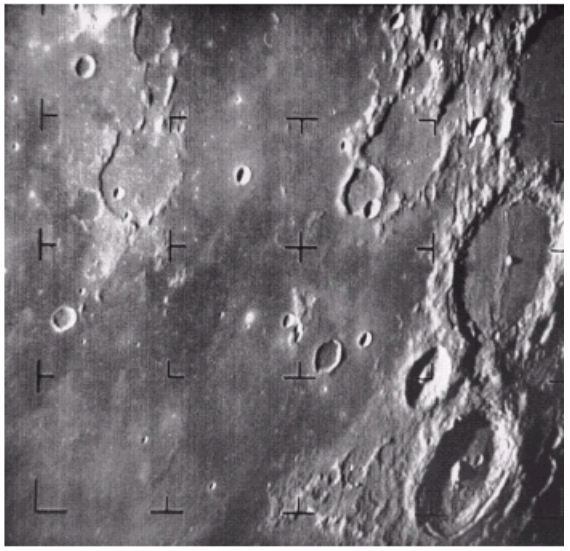
Early 15 tone digital image in 1929

Images are from the Digital Image Processing textbook, see slide 7

History of DIP – cont.

1960s: Space race

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



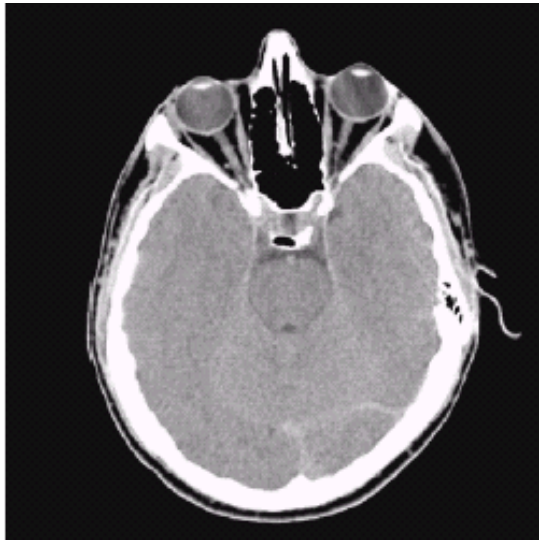
A picture of the moon taken by the Ranger 7 probe, 17 minutes before landing

Images are from the Digital Image Processing textbook, see slide 7

History of DIP – cont.

1970s: Medical applications

- **1979:** Nobel Prize in medicine for the invention of **tomography**, the technology behind Computerised Axial Tomography (CAT) scans



Typical head slice CAT image

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History of DIP – cont.

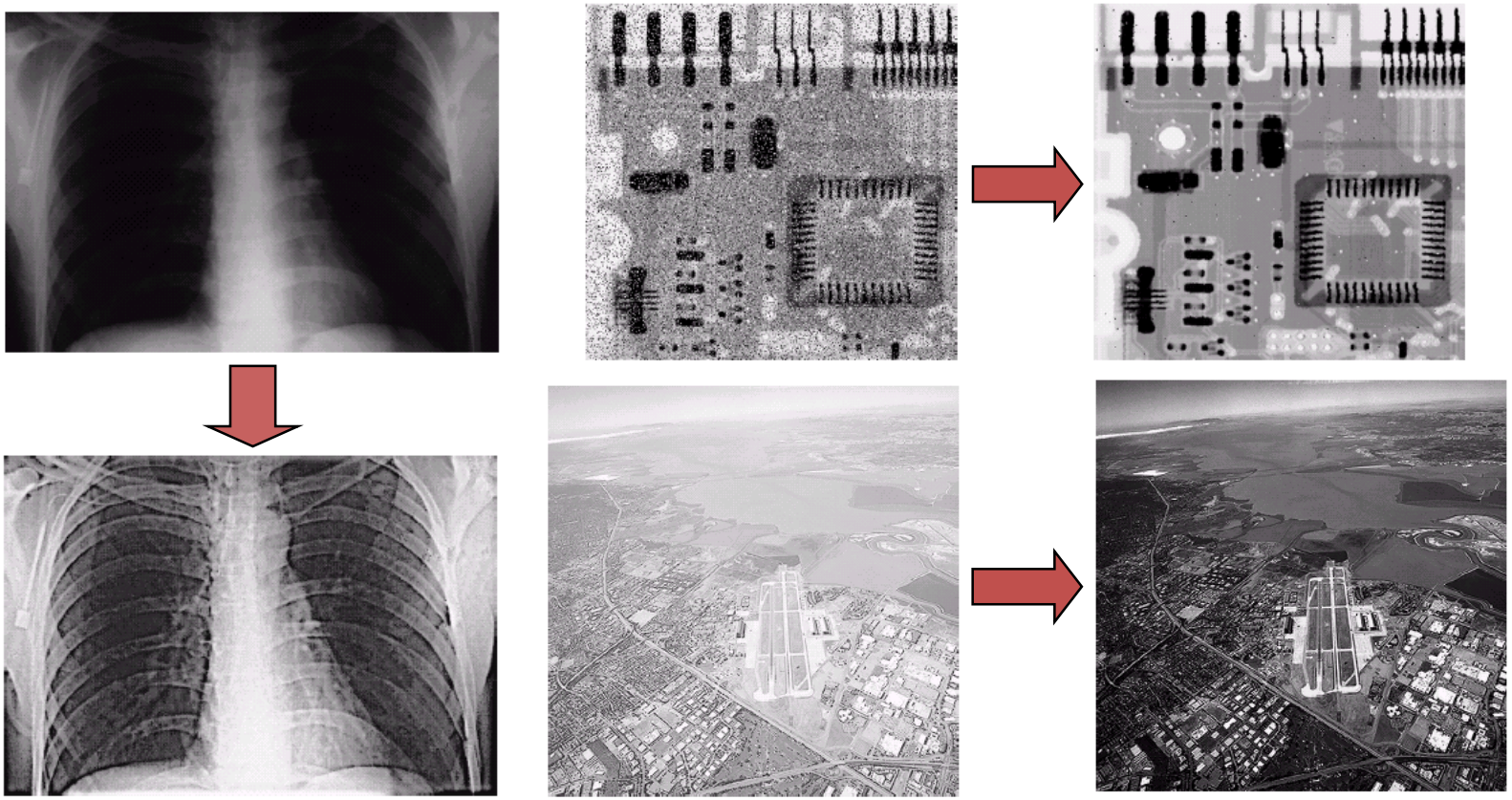
1980s - Today: All kinds of tasks in all kinds of areas

- Image enhancement/restoration
- Artistic effects
- Medical visualisation
- Industrial inspection
- Law enforcement
- Human computer interfaces

Images are from the Digital Image Processing textbook, see slide 7

Examples: Image Enhancement

Improve quality, remove noise etc

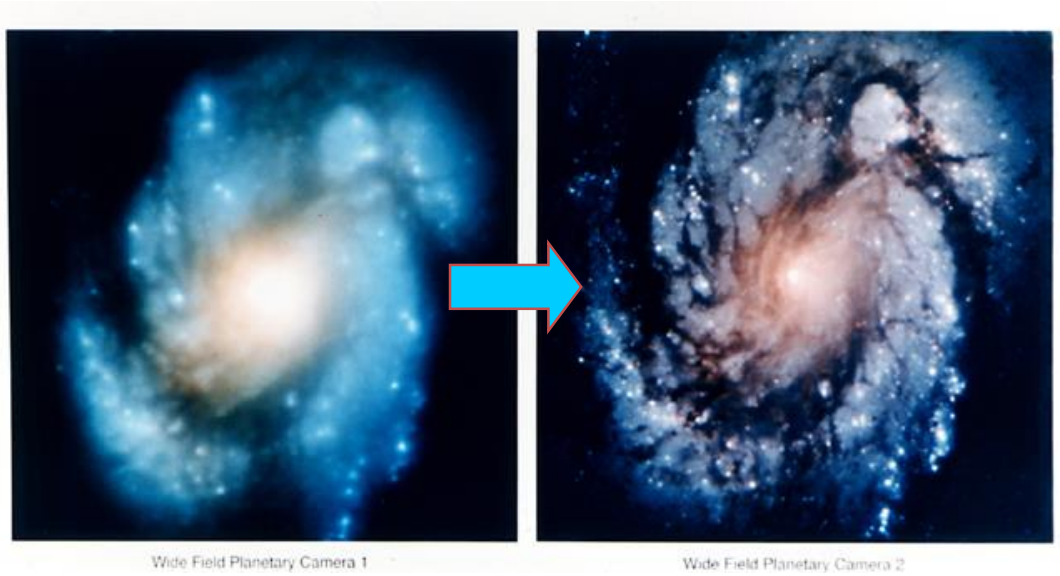


Images are from the Digital Image Processing textbook, see slide 7

Examples: The Hubble Telescope

1990: the Hubble telescope

- taking images of very distant objects
- Incorrect mirror → Blurred images
- Image processing techniques were used to fix this



Images are from the Digital Image Processing textbook, see slide 7

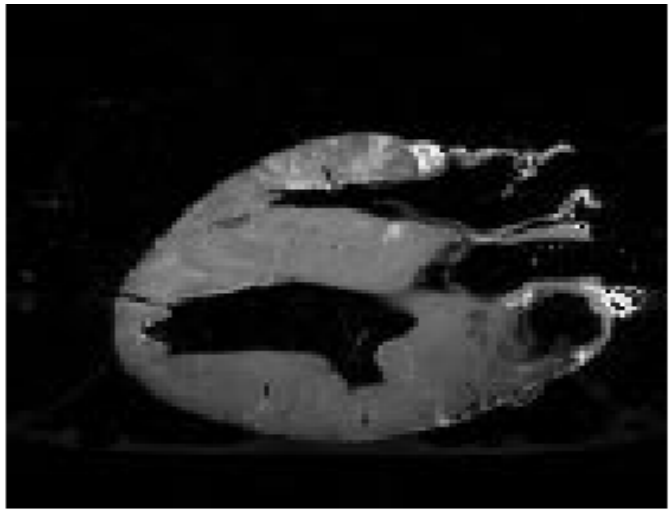
Examples: Artistic Effects

- Artistic effects
- Make images more visually appealing
- Add special effects

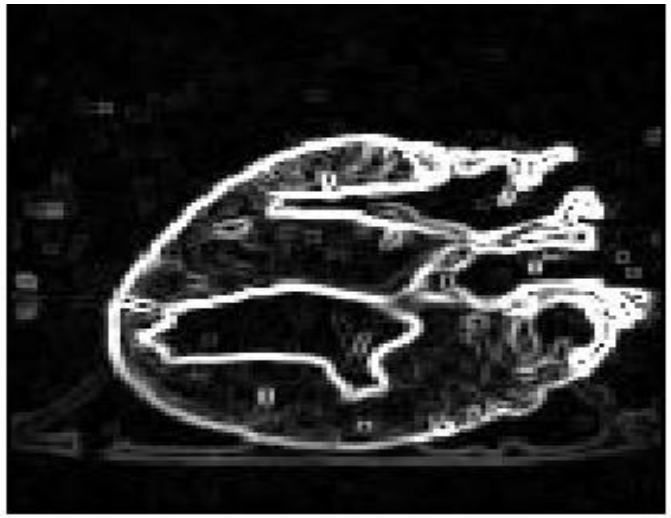
Examples: Medicine

Find boundaries between types of tissue

- Use a suitable filter to highlight edges



Original MRI Image of a Dog Heart



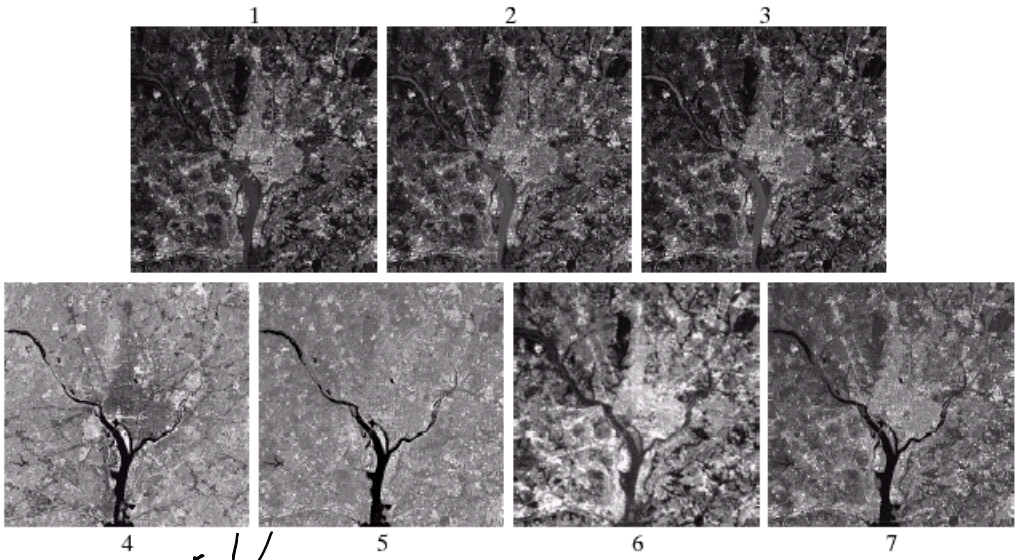
Edge Detection Image

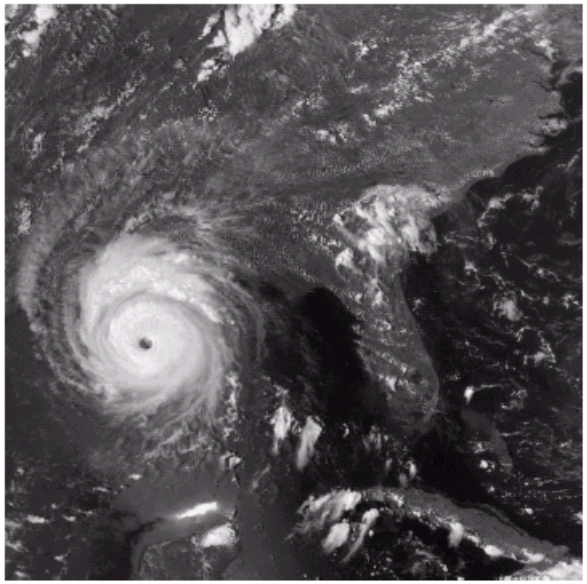
Images are from the Digital Image Processing textbook, see slide 7

Examples: GIS

Geographic Information Systems

- Manipulate satellite imagery
- Terrain classification
- Meteorology

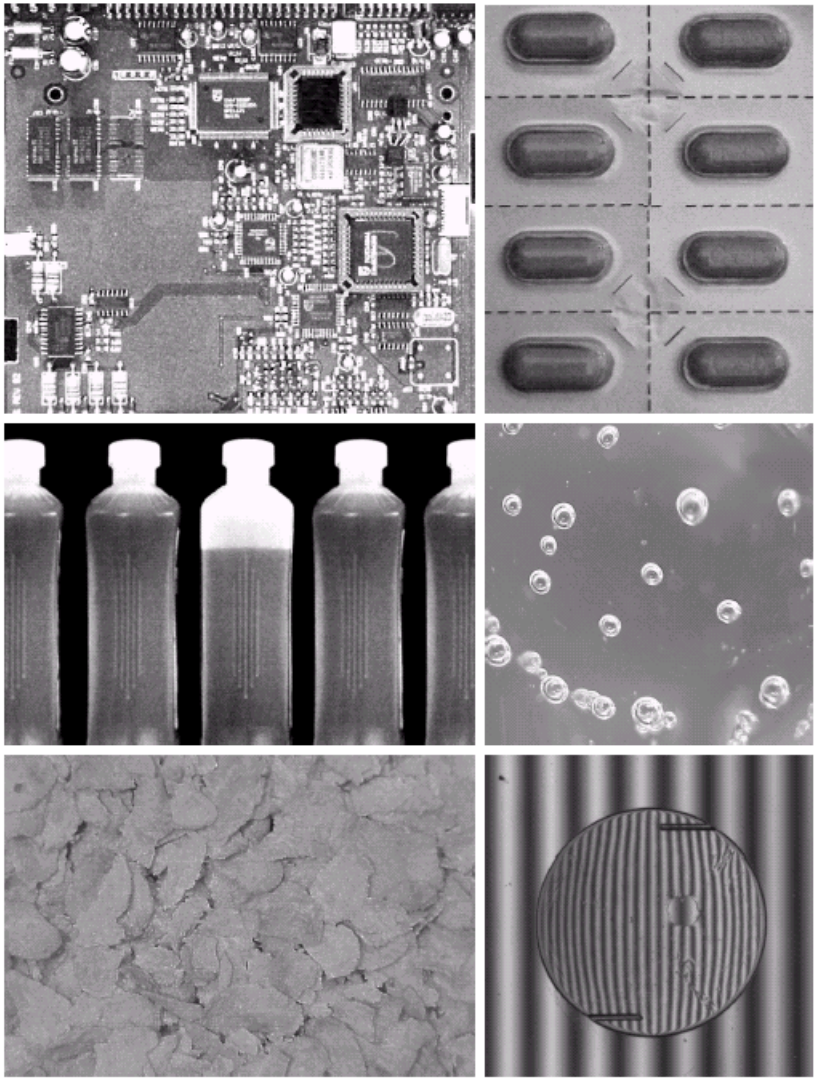




Images are from the Digital Image Processing textbook, see slide 7

Examples: Industrial Inspection

- **Human operators are expensive, slow and unreliable**
- Make machines do the job instead

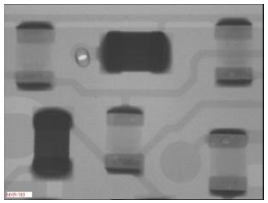


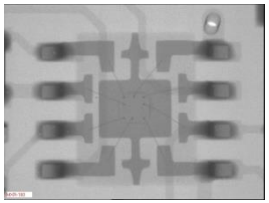
Images are from the Digital Image Processing textbook, see slide 7

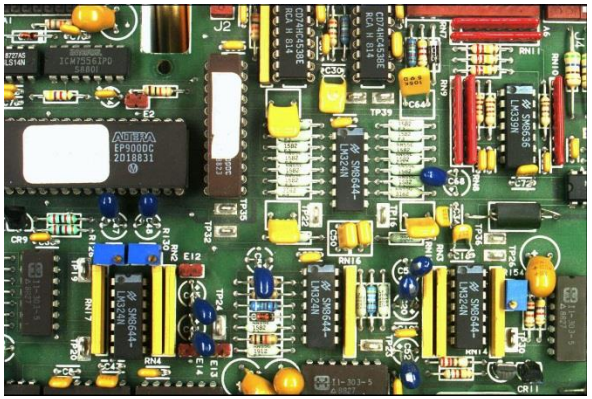
Examples: PCB Inspection

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 are used



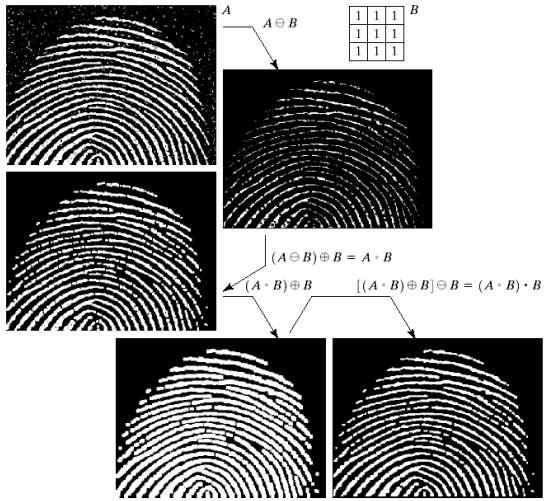




Examples: Law Enforcement

Image processing techniques are used extensively by law enforcers

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

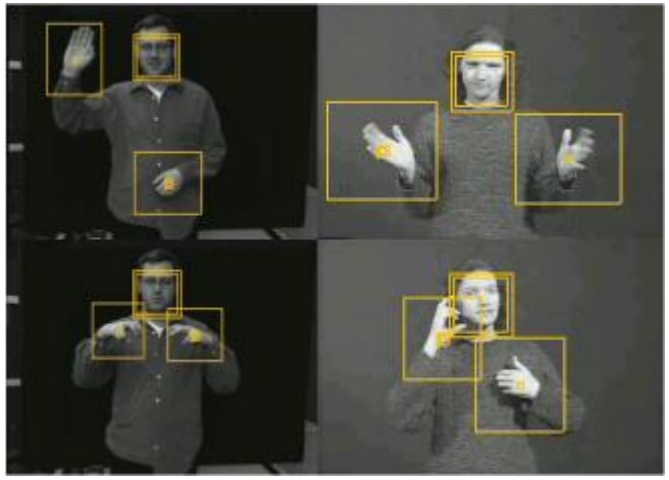


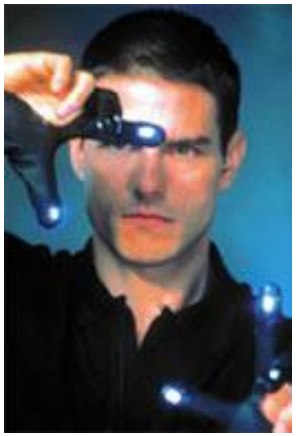
Examples: HCI

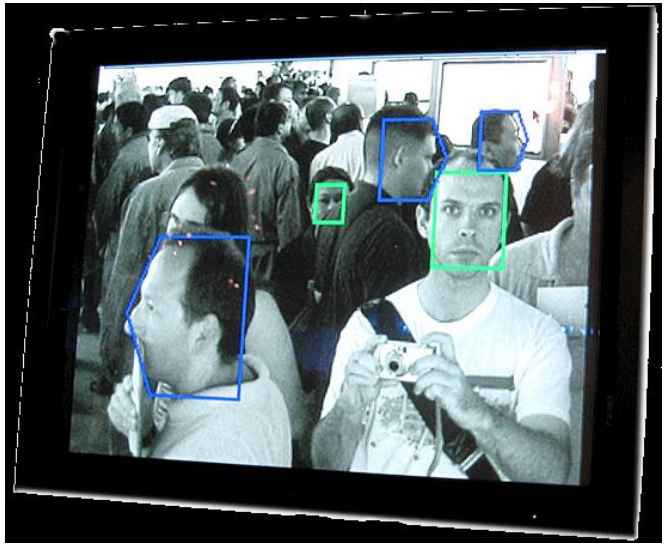
Try to make **H**uman **C**omputer **I**nterfaces (HCI) more natural

- Face recognition
- Gesture recognition

These tasks can be extremely difficult







Images are from the Digital Image Processing textbook, see slide 7

Image Sources

Image processing applications can be categorize according to their source

- Radiation from the Electromagnetic (EM) spectrum
- Acoustic
- Ultrasonic
- Electronic (in the form of electron beams used in electron microscopy)
- Computer (synthetic images used for modeling and visualization)

Electromagnatic spectrum

- Images based on radiation from the EM are the **most familiar**, especially images in the X-ray and visual bands.
- EM waves = a stream of massless (proton) particles, each traveling in a wavelike pattern and moving at the speed of light.

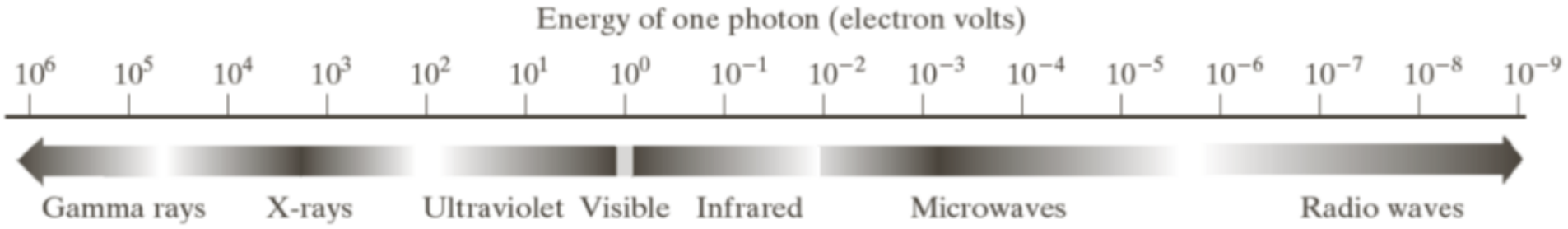
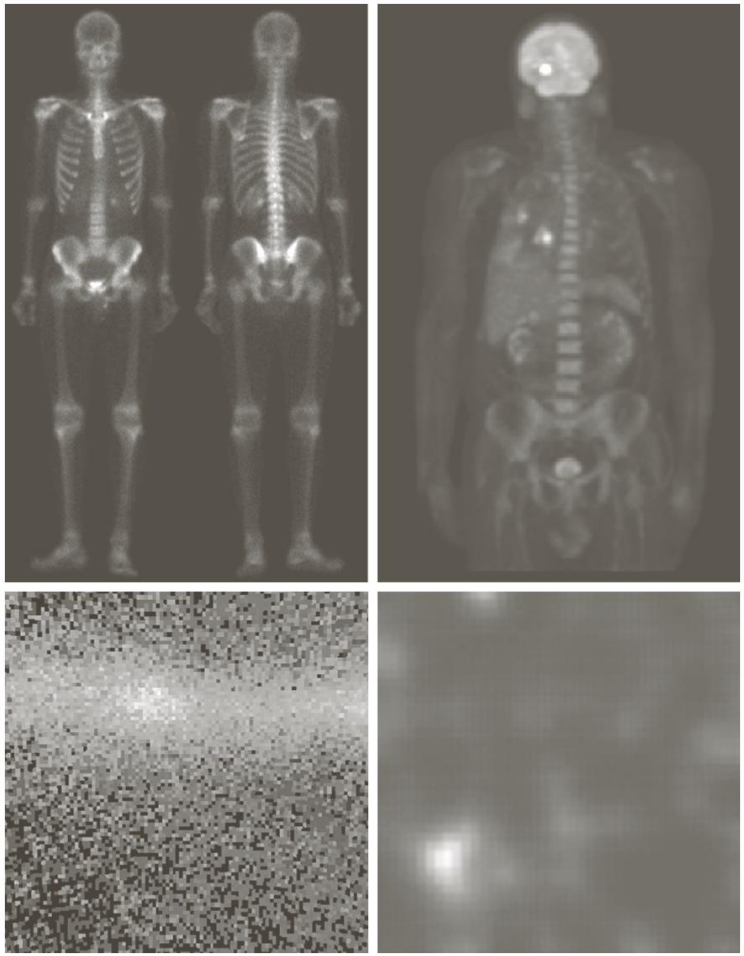


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

Gamma-Ray Imaging

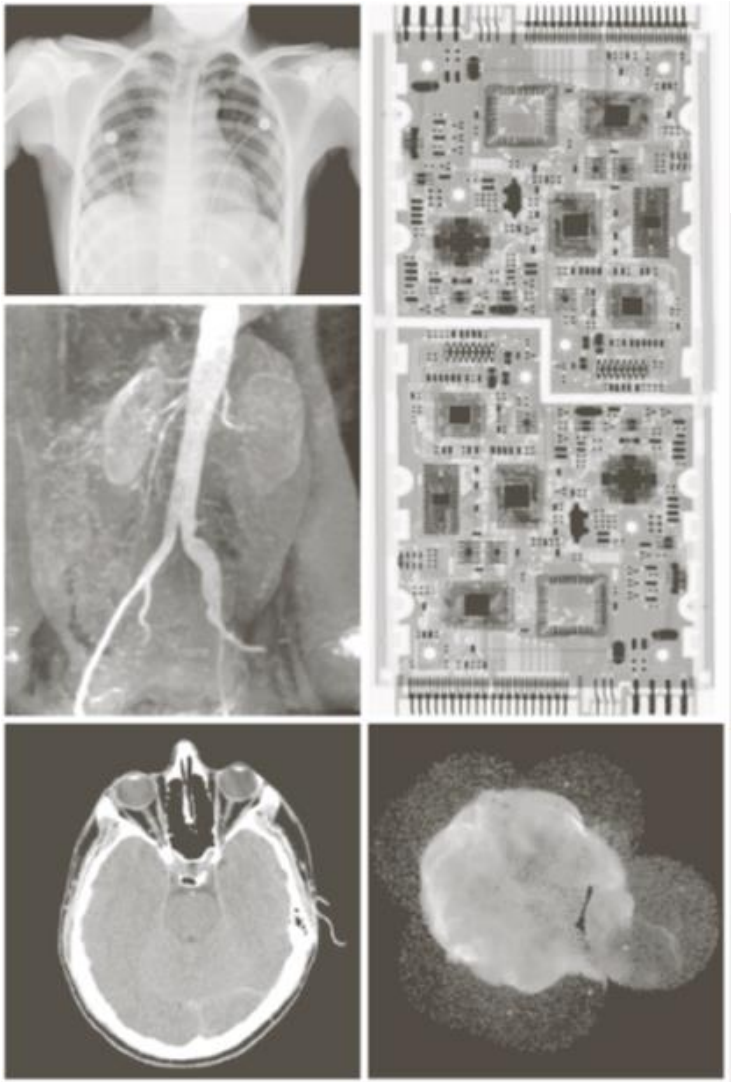


a b
c d

Nuclear Image
(a) Bone scan
(b) PET (Positron emission tomography) image
Astronomical Observations.
(c) Cygnus Loop (A star in the constellation of Cygnus exploded about 15,000 years ago)
Nuclear Reaction
(d) Gamma radiation from a reactor valve

Images are from the Digital Image Processing textbook, see slide 7

X-ray Imaging



Medical diagnostics

(a) chest X-ray (familiar)

(b) aortic angiogram

(c) head Computerized Axial Tomography (CAT)

Industrial imaging

(d) Circuit board

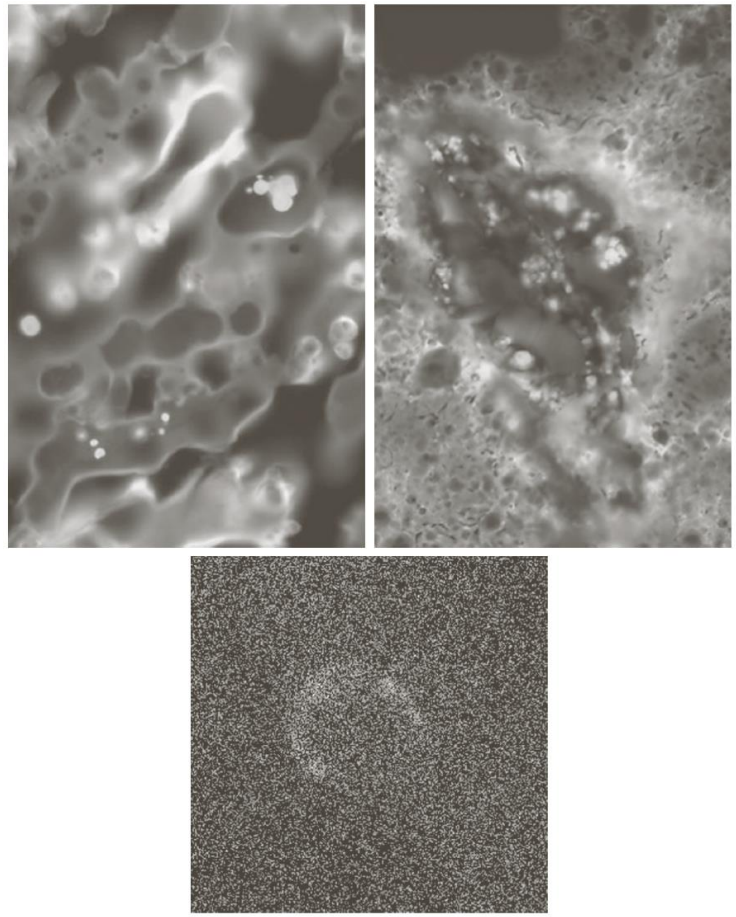
Astronomy

(e) Cygnus Loop (A star in the constellation of Cygnus exploded about 15,000 years ago, sensed using X-ray)

Images are from the Digital Image Processing textbook, see slide 7

Imaging in Ultraviolet Band

- Industrial inspection (money)
- Microscopy (fluorescence)
  - (a) Normal corn
  - (b) Smut corn
- Lasers
- Biological imaging
- (c) Astronomical observations

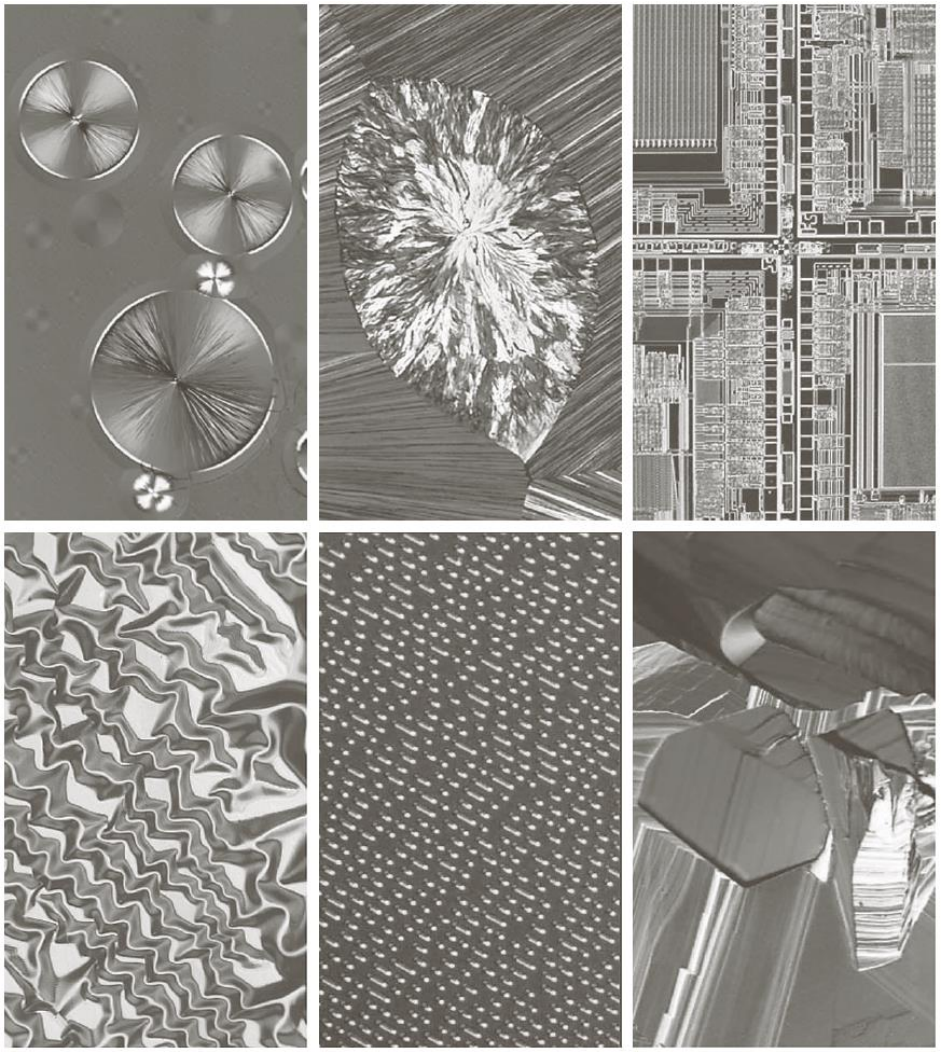


Images are from the Digital Image Processing textbook, see slide 7

Imaging in Visible and Infrared Bands

- Astronomy
- Light microscopy
  - Pharmaceuticals
    - (a). taxol (anticancer agent)
    - (b). cholesterol
  - Microinspection to materials characterization
    - (c). Microprocessor
    - (d). Nickel oxide thin film
    - (e). Surface of audio CD
    - (f). Organic superconductor

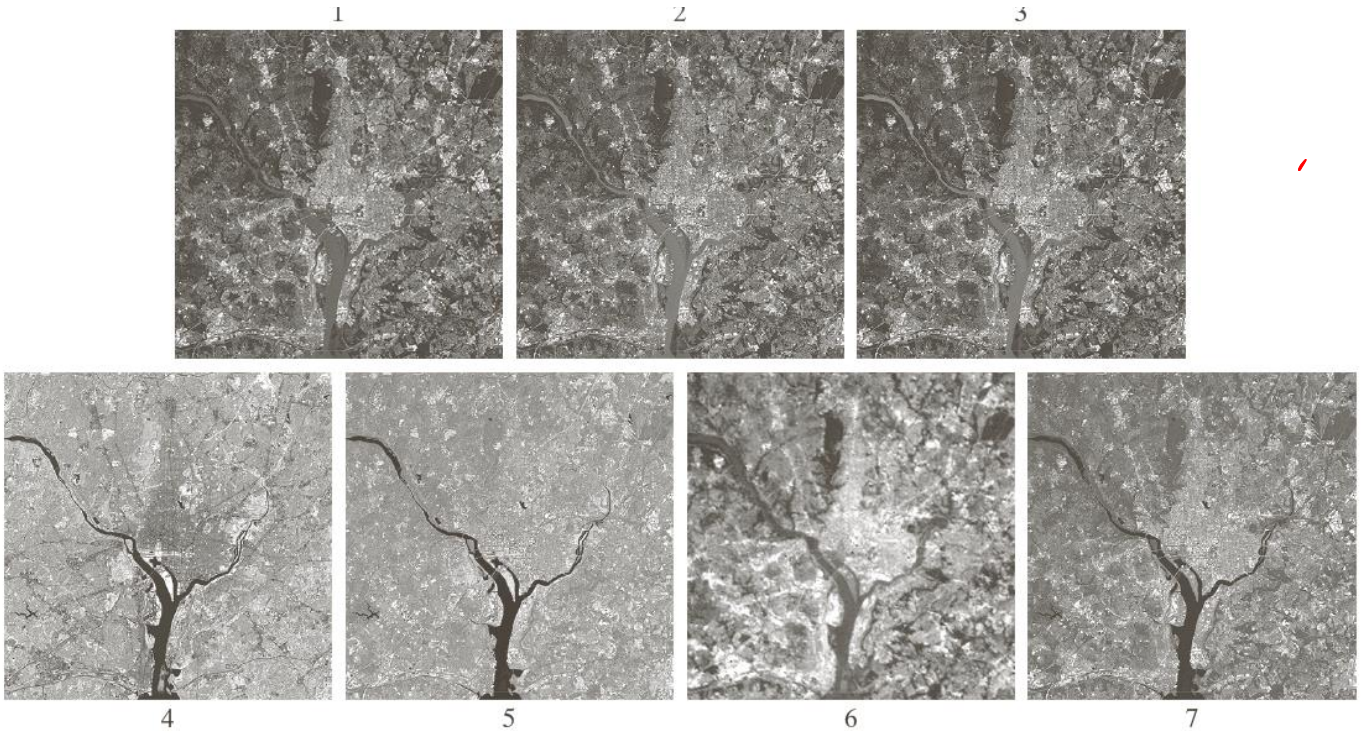
a b c
d e f



Images are from the Digital Image Processing textbook, see slide 7

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

Thematic bands in NASA's LANDSAT satellite



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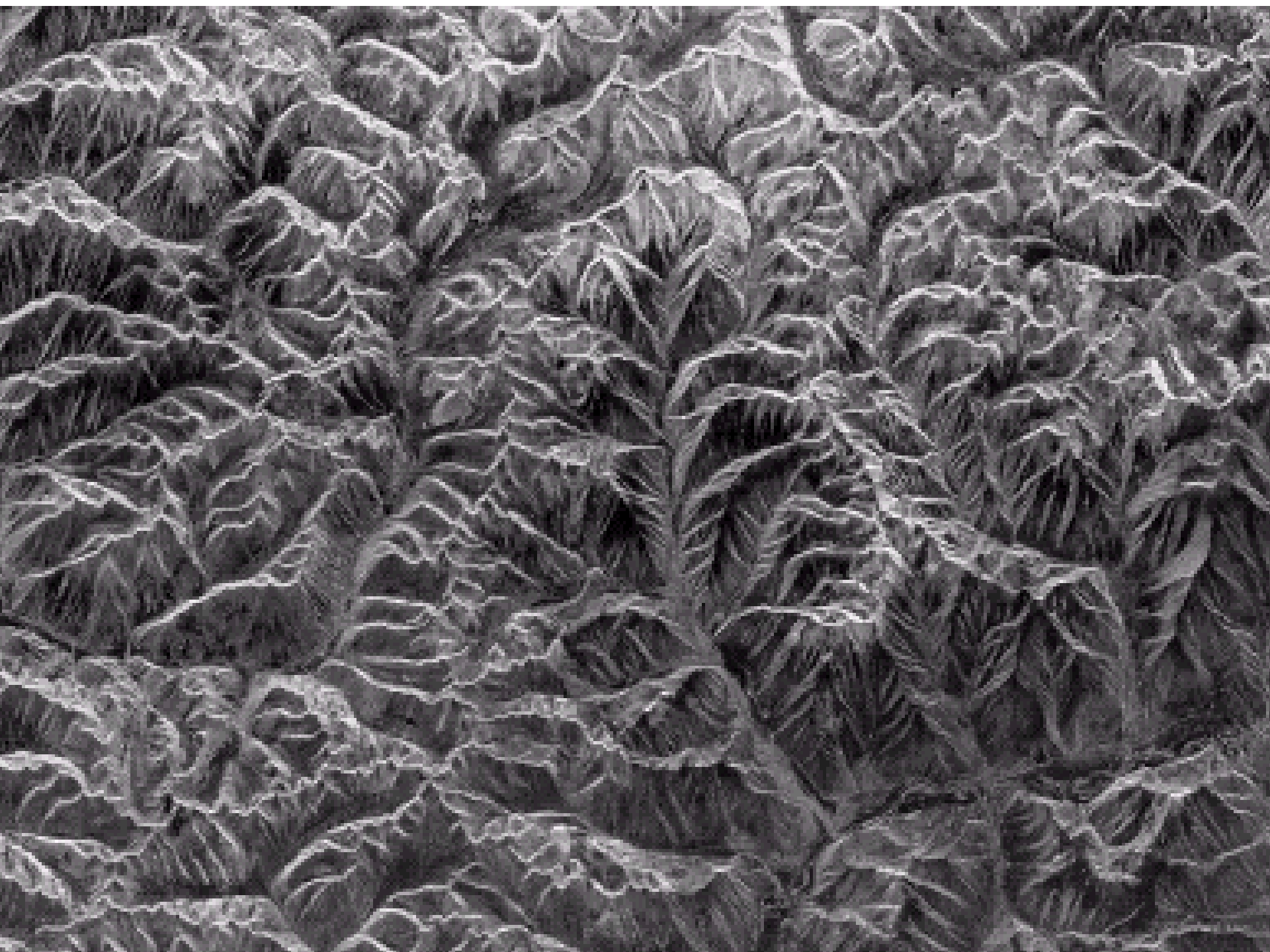
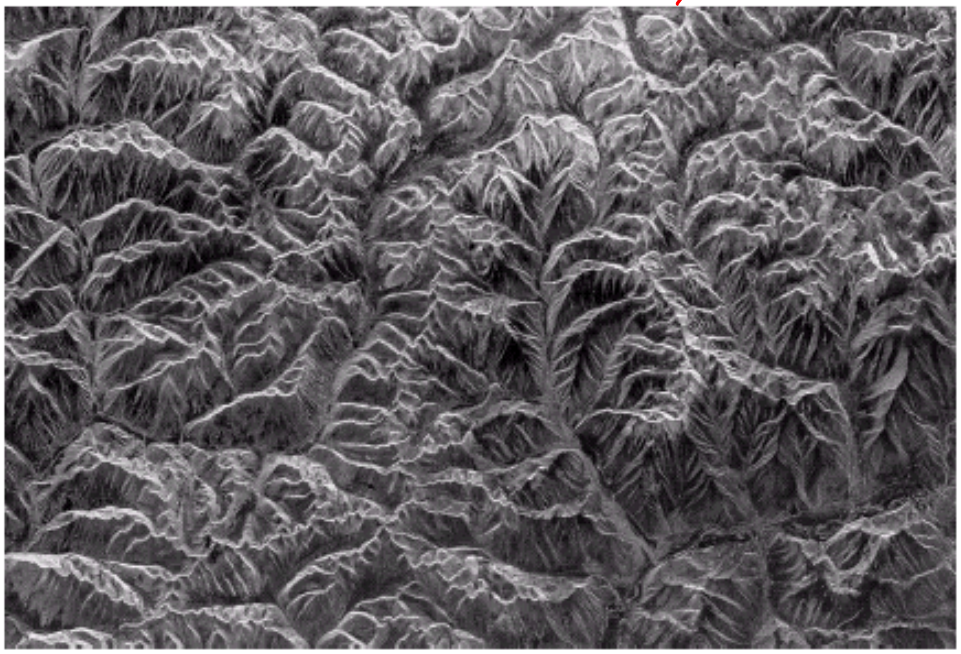


Imaging in Microwave Band



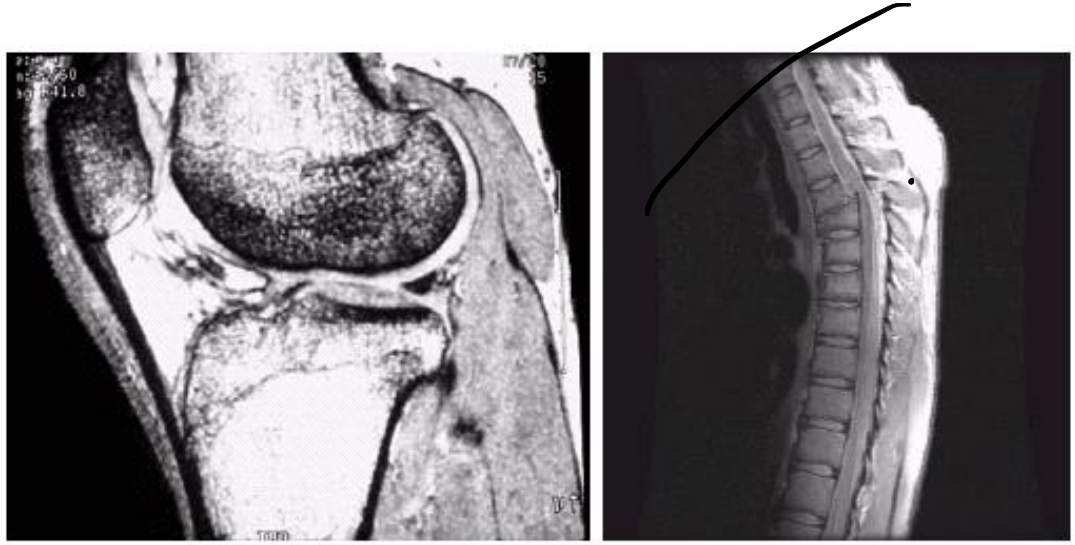
- Imaging radar : the only way to explore inaccessible regions of the Earth's surface
- Radar image of mountains in southeast Tibet
- Note the **clarity** and **detail** of the image, **unencumbered by** clouds or other **atmospheric conditions** that normally interfere with images in the **visual band**.

Images are from the Digital Image Processing textbook, see slide 7

Imaging in Radio Band

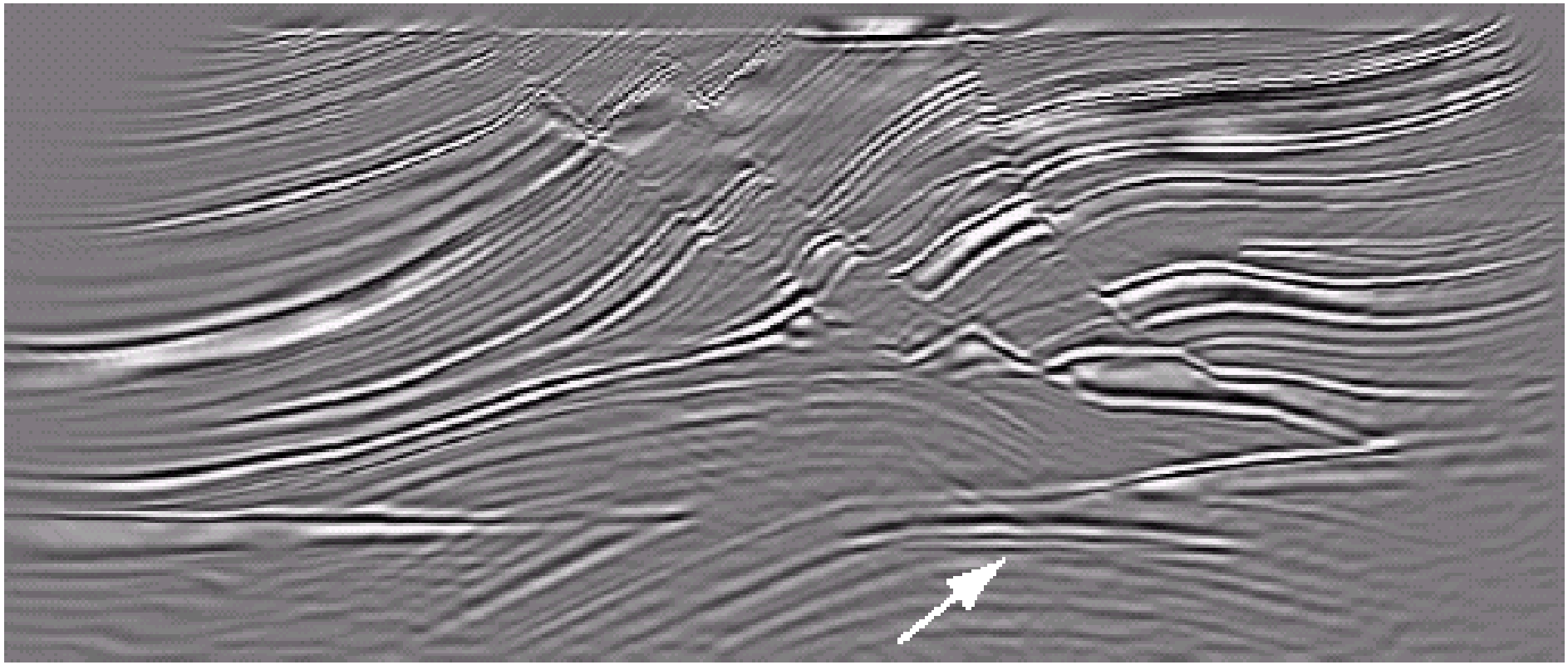
Imaging in Radio Band

- Medicine
  - Magnetic resonance image (MRI) : 2D picture of a section of the patient
    - (a) knee
    - (b) spine
- Astronomy



a b

Acoustic Imaging



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Acoustic Imaging

- Geological applications : use sound in the low end of the sound spectrum (hundred of Hz)
  - Mineral and oil exploration

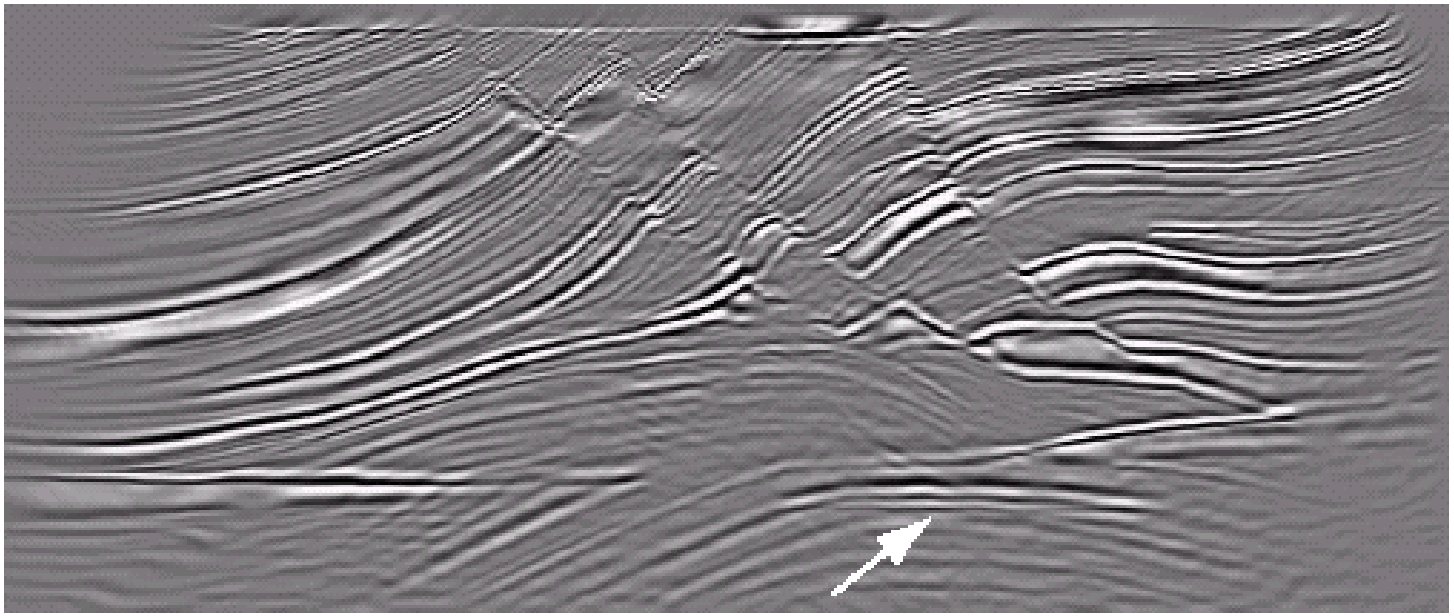
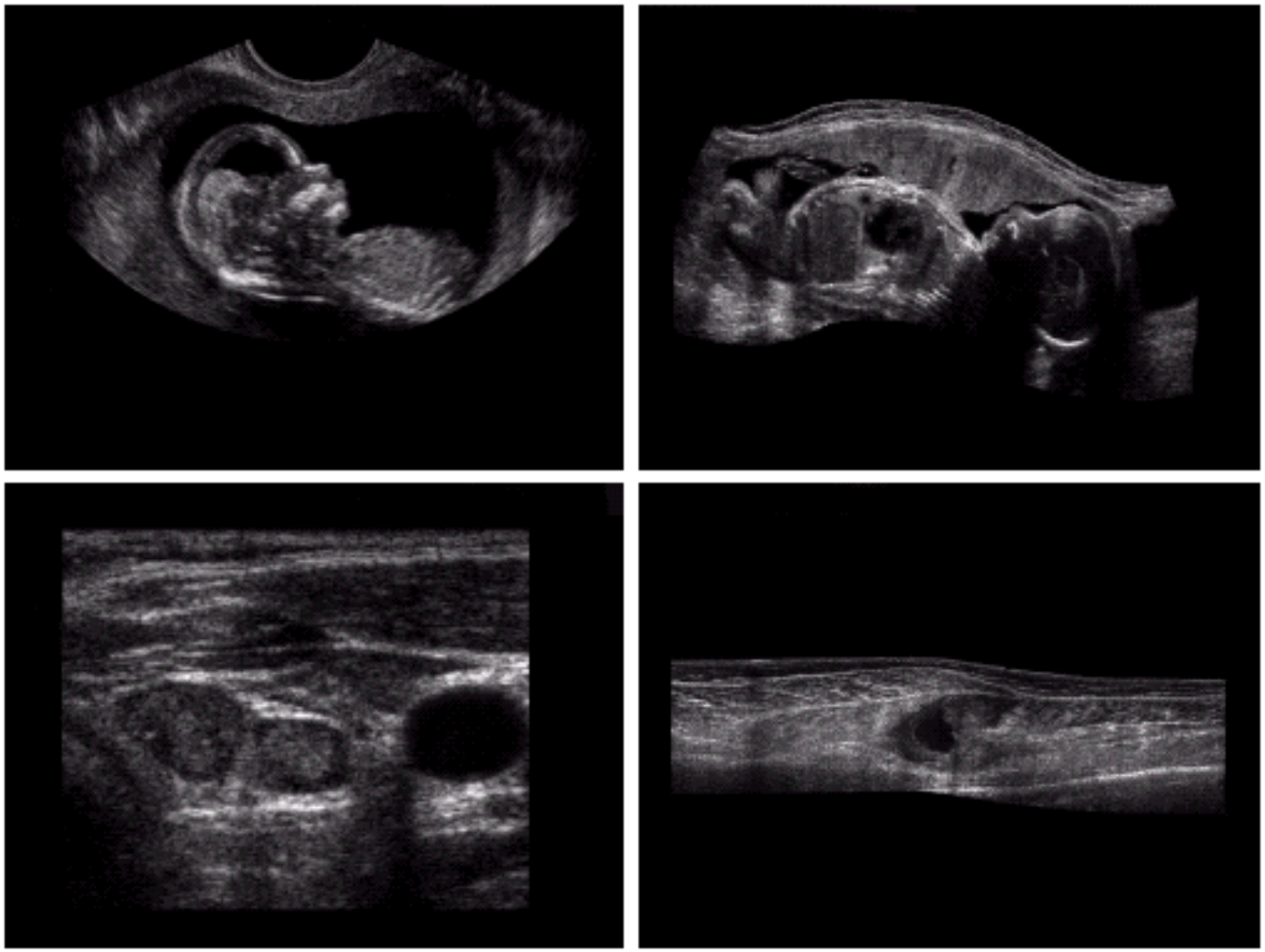


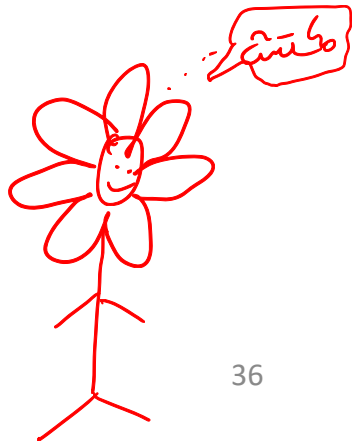
FIGURE 1.19
Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)

Ultrasound Imaging



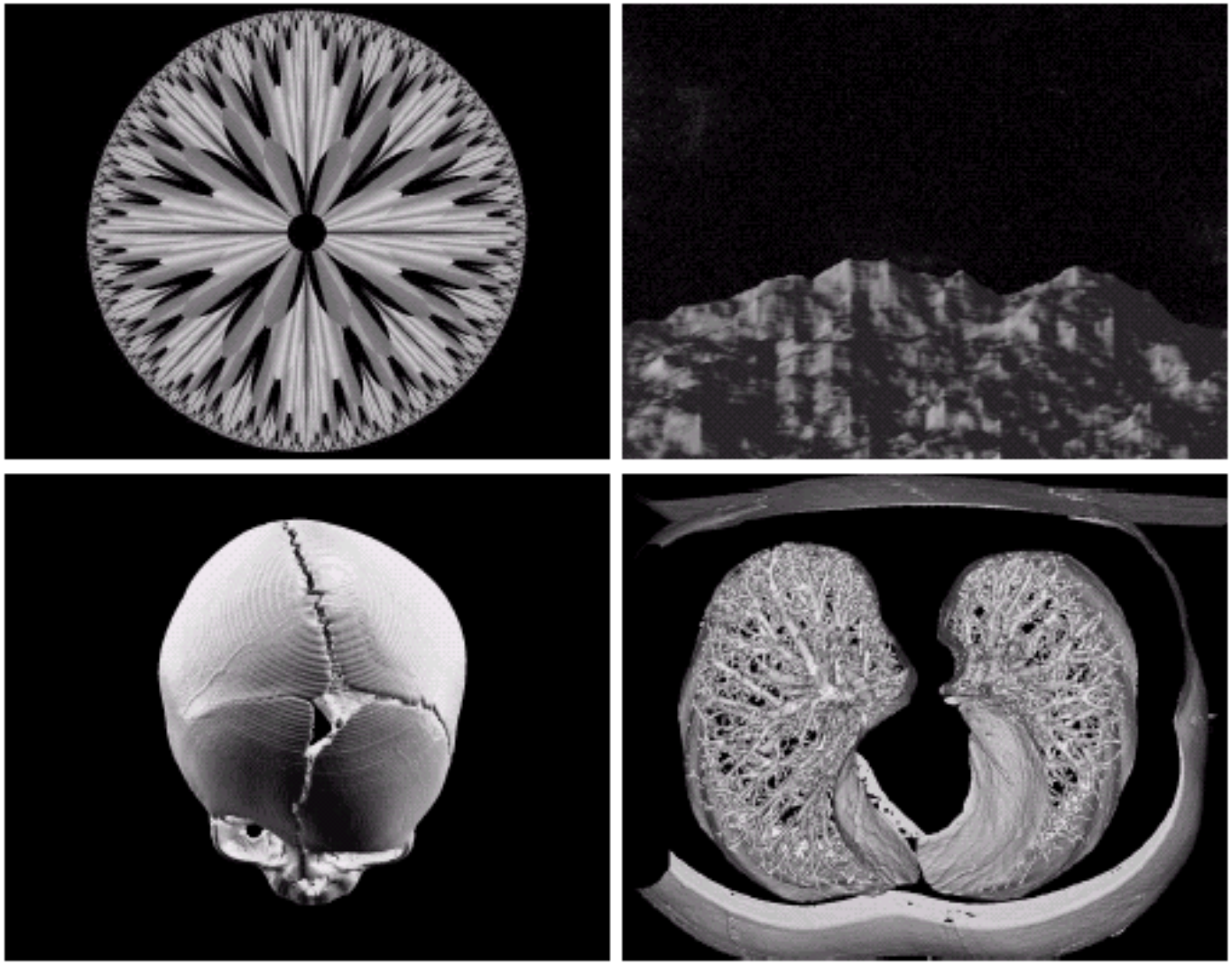
a b
c d

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.)



Images are from the Digital Image Processing textbook, see slide 7

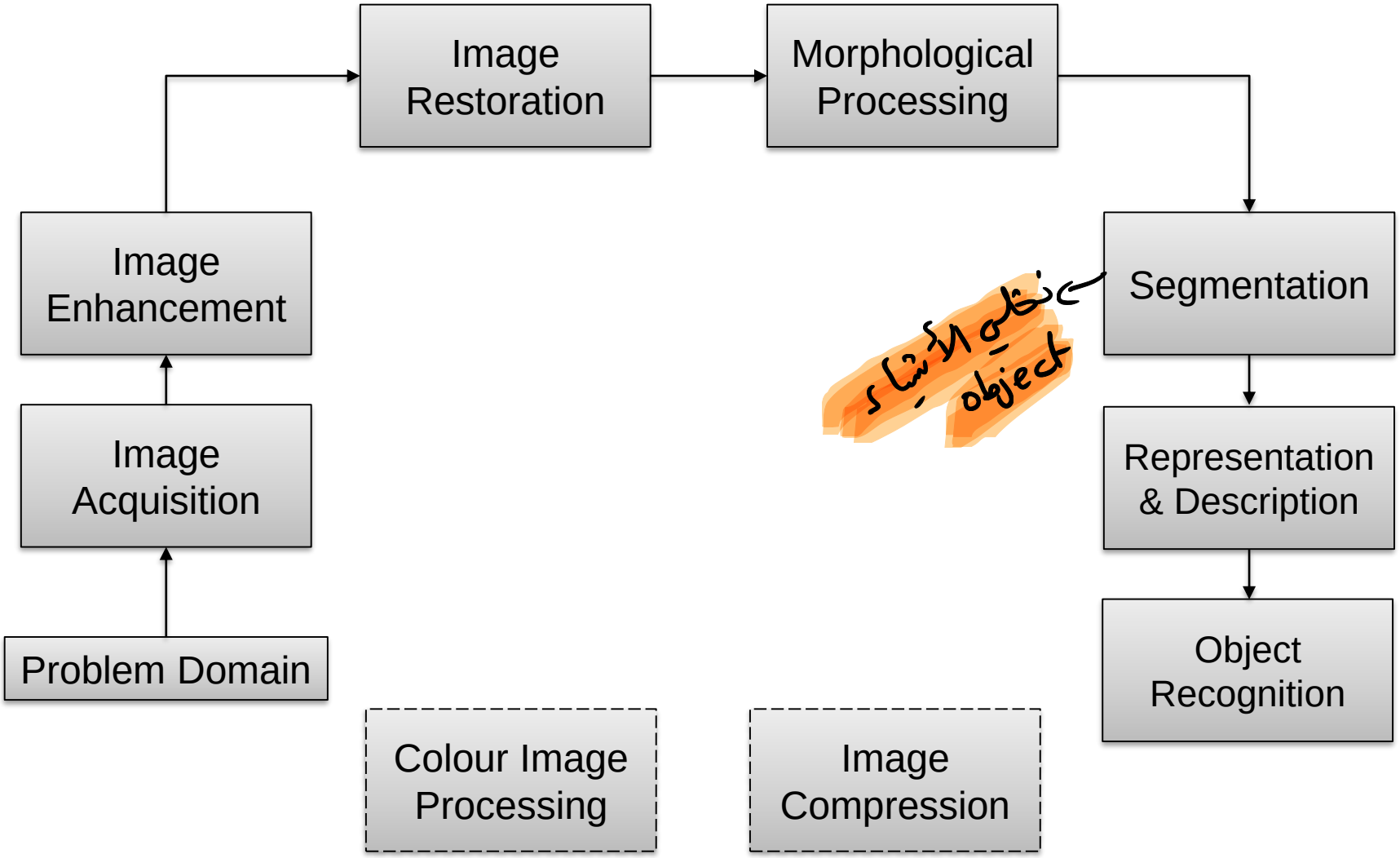
Generated images by computer



a b
c d

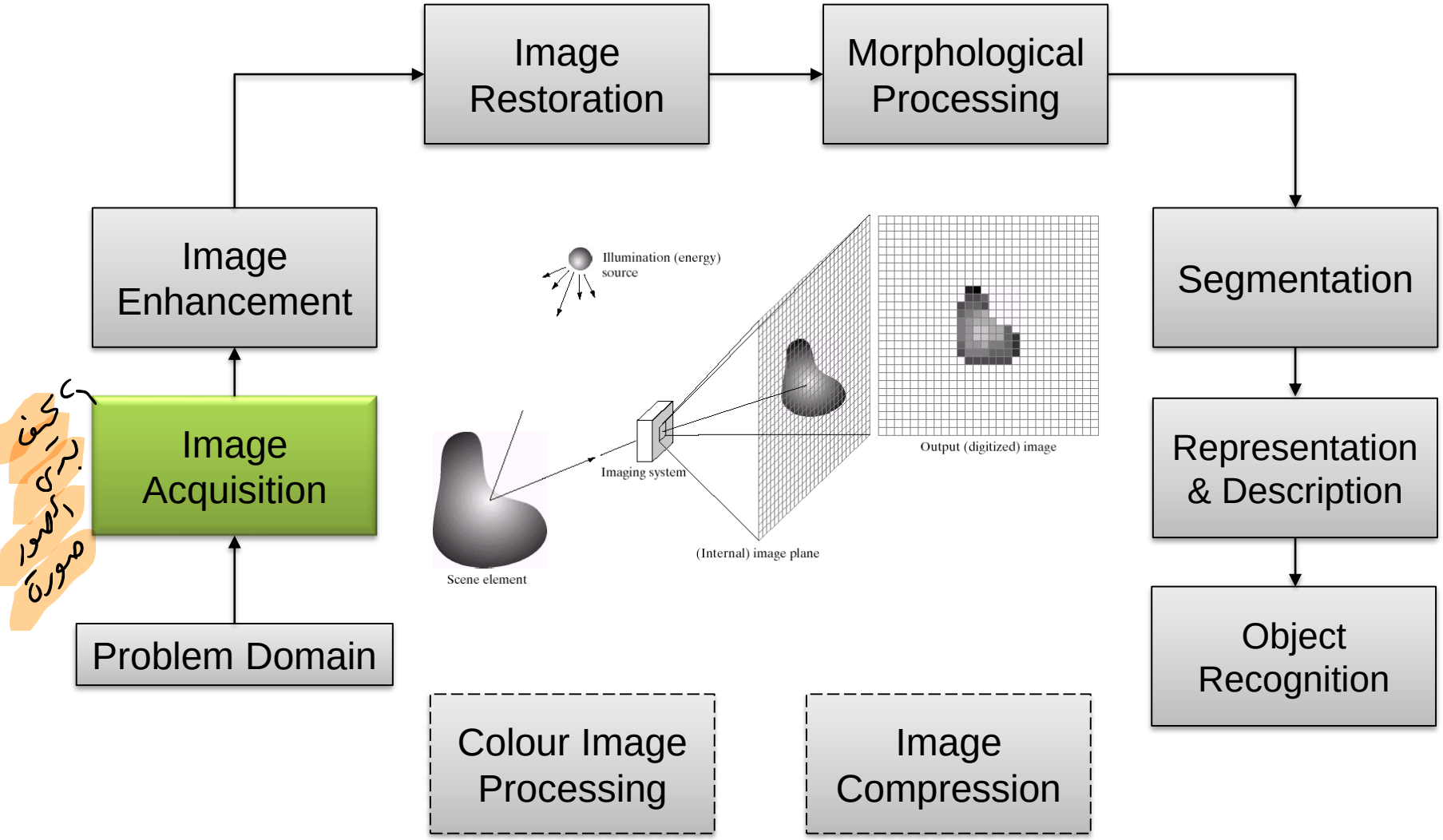
FIGURE 1.22
(a) and (b) Fractal images. (c) and (d) Images generated from 3-D computer models of the objects shown. (Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College, (c) and (d) courtesy of NASA.)

Key Stages in Digital Image Processing



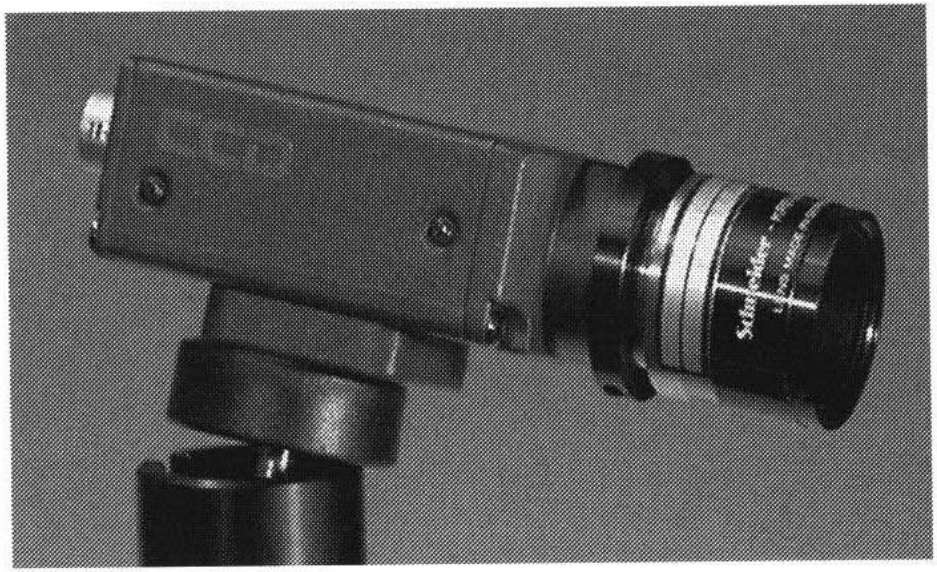
Images are from the Digital Image Processing textbook, see slide 7

Key Stages in Digital Image Processing: Image Aquisition



Camera

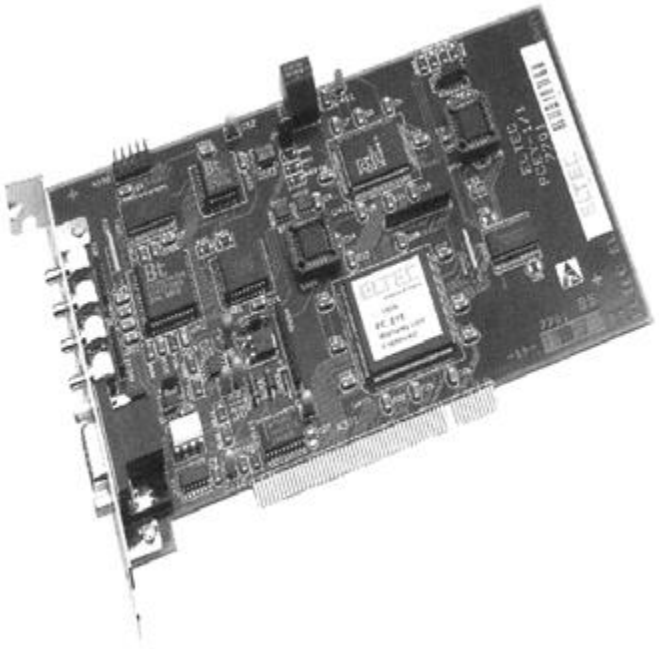
- Camera consists of 2 parts
  - A **lens** that collects the **appropriate type of radiation** emitted from the object of interest and that forms an image of the real object
  - a semiconductor device, so called **charged coupled device** or **CCD**, which converts the image into an electrical signal



Images are from the Digital Image Processing textbook, see slide 7

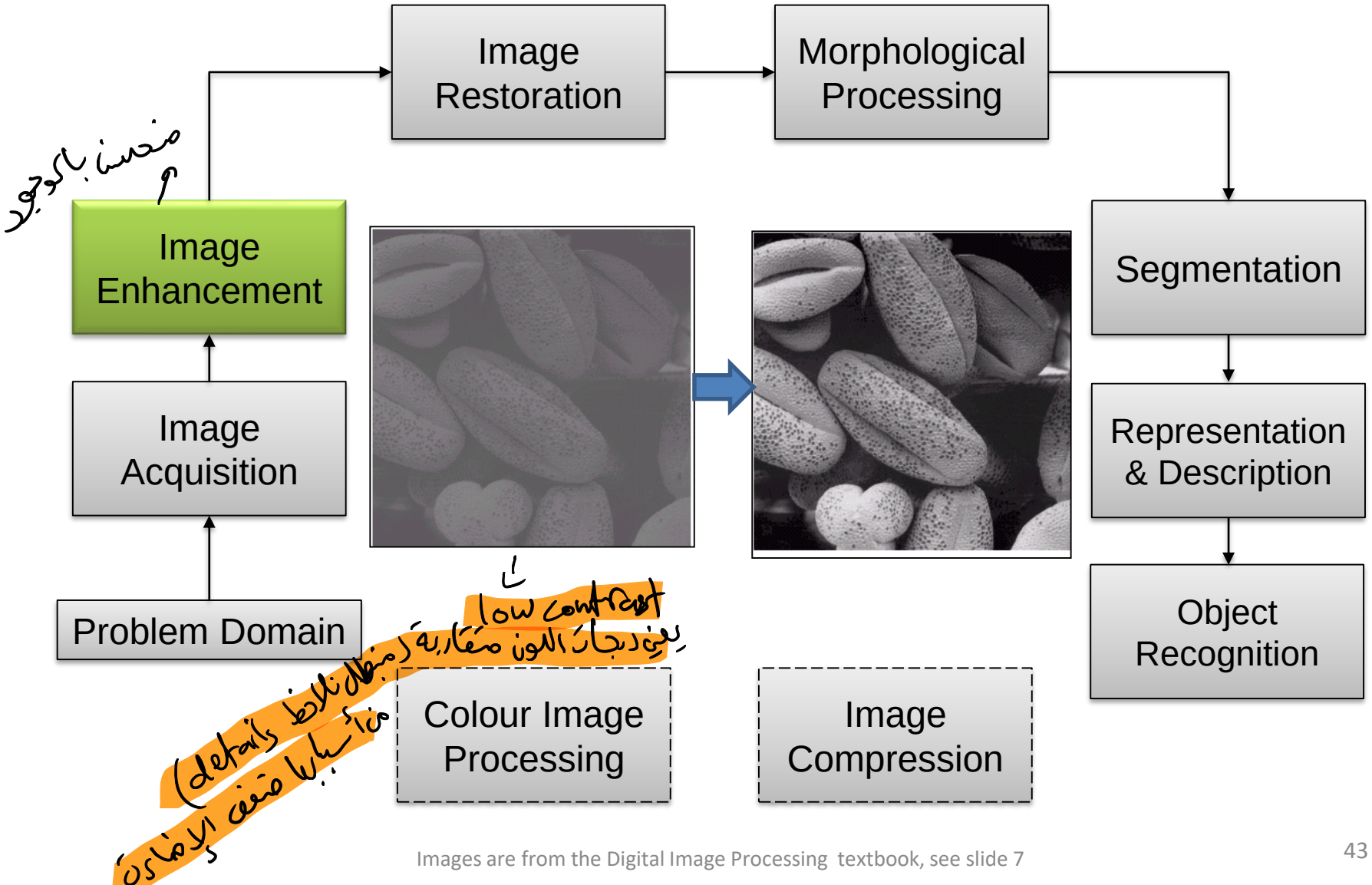
Frame Grabber

- Frame grabber only needs circuits to **digitize the electrical signal** from the imaging sensor to store the **image** in the memory (RAM) of the computer



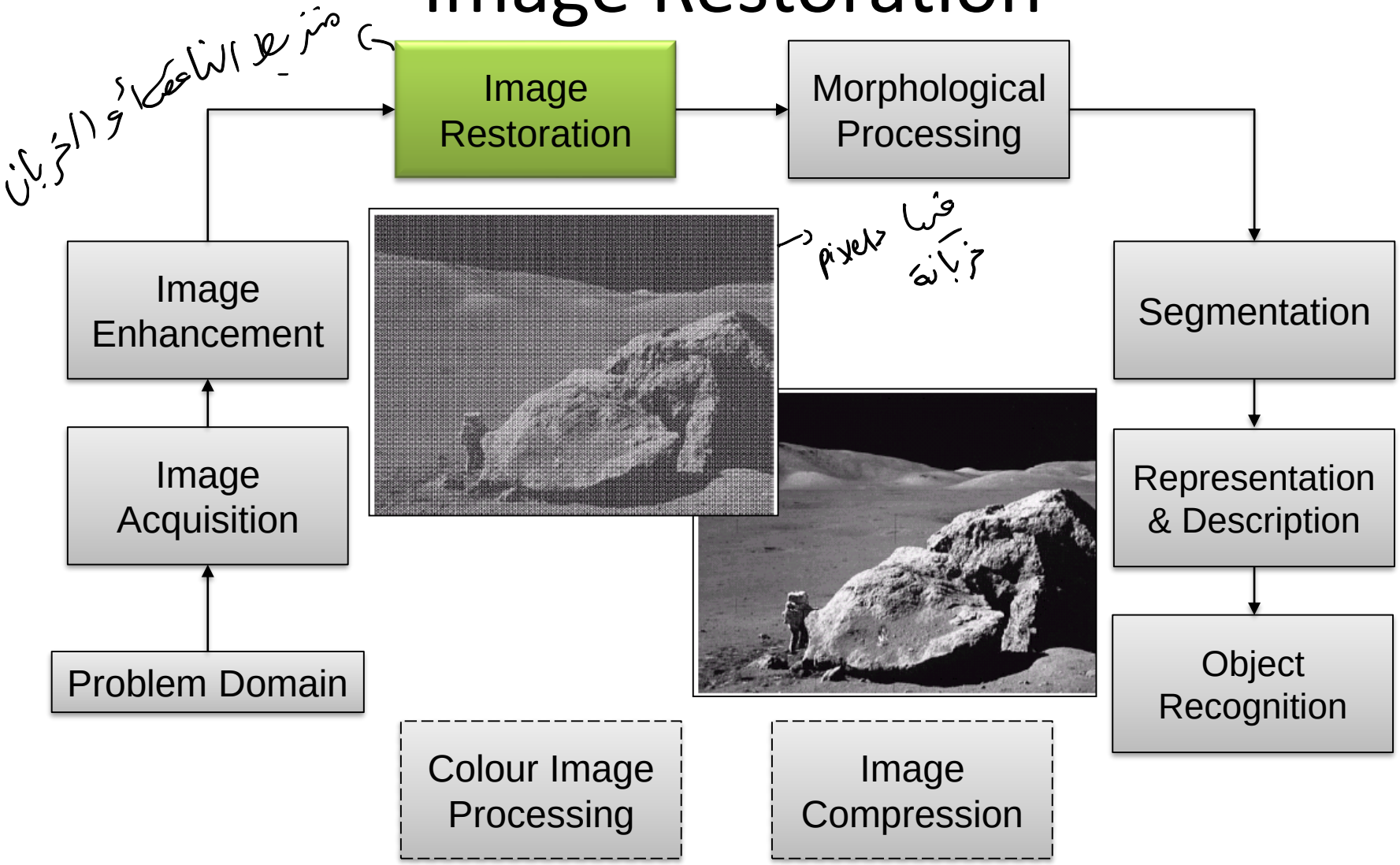
Images are from the Digital Image Processing textbook, see slide 7

Key Stages in Digital Image Processing: Image Enhancement



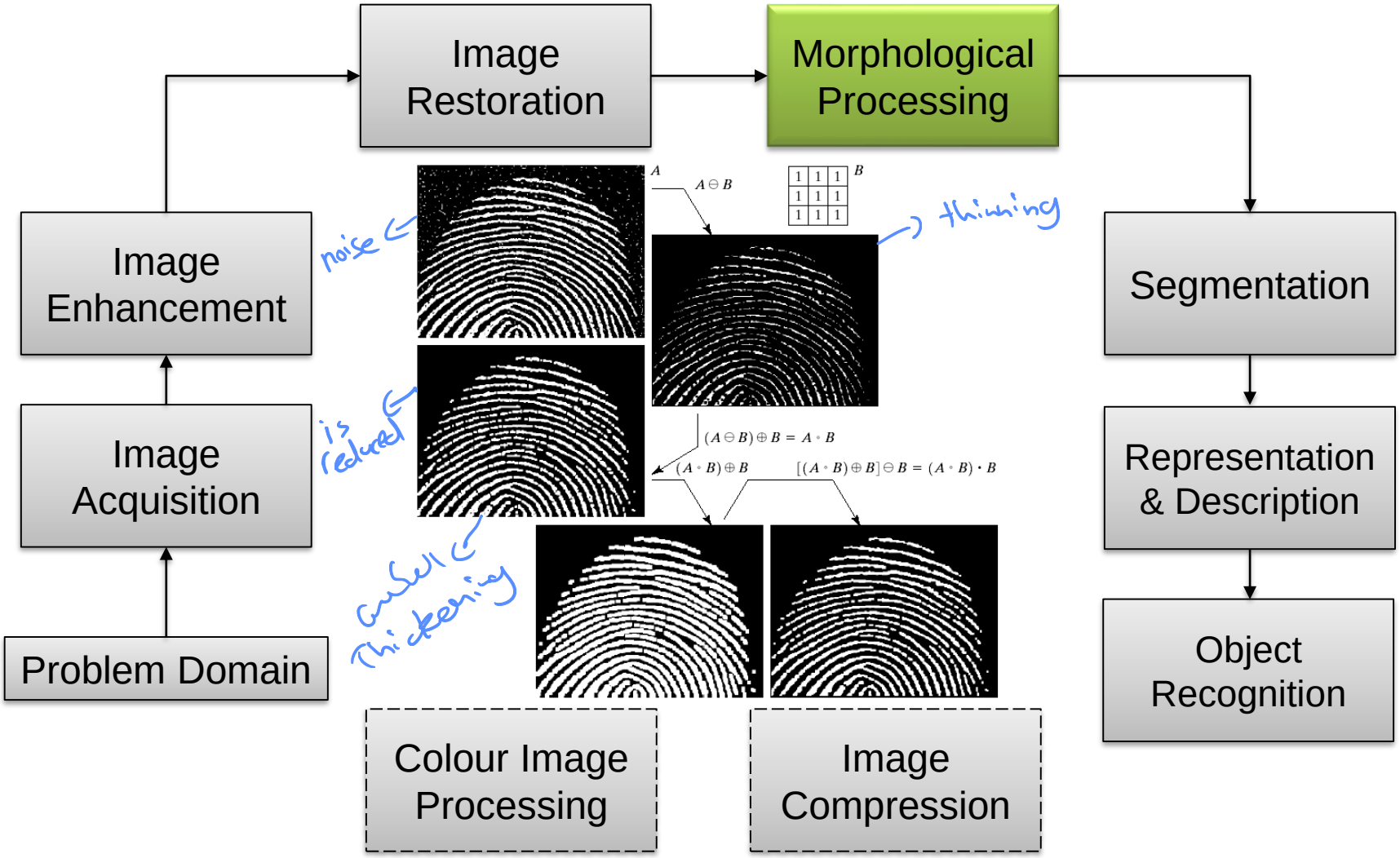
Images are from the Digital Image Processing textbook, see slide 7

Key Stages in Digital Image Processing: Image Restoration



Images are from the Digital Image Processing textbook, see slide 7

Key Stages in Digital Image Processing: Morphological Processing



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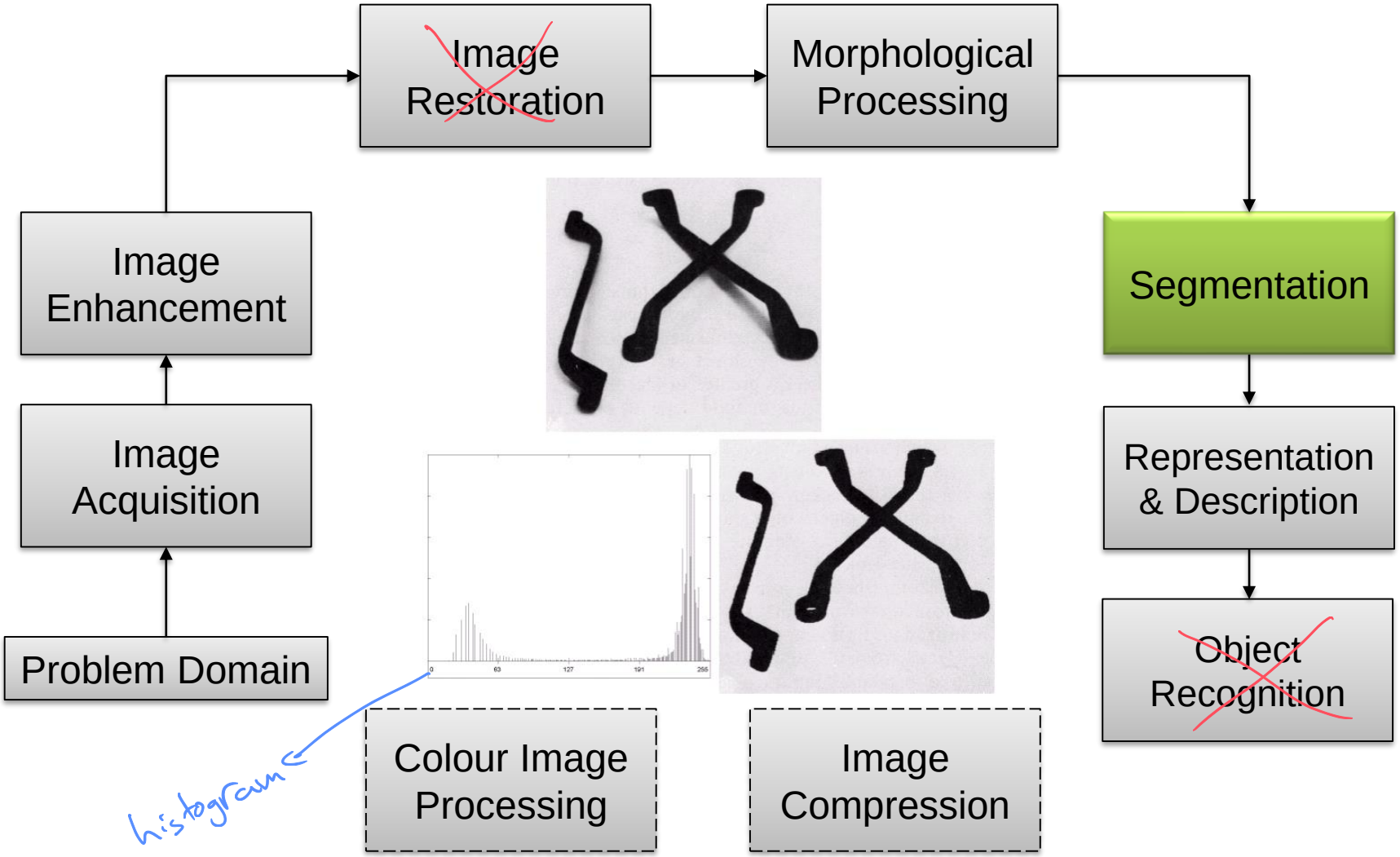
Key Stages in Digital Image Processing: Segmentation



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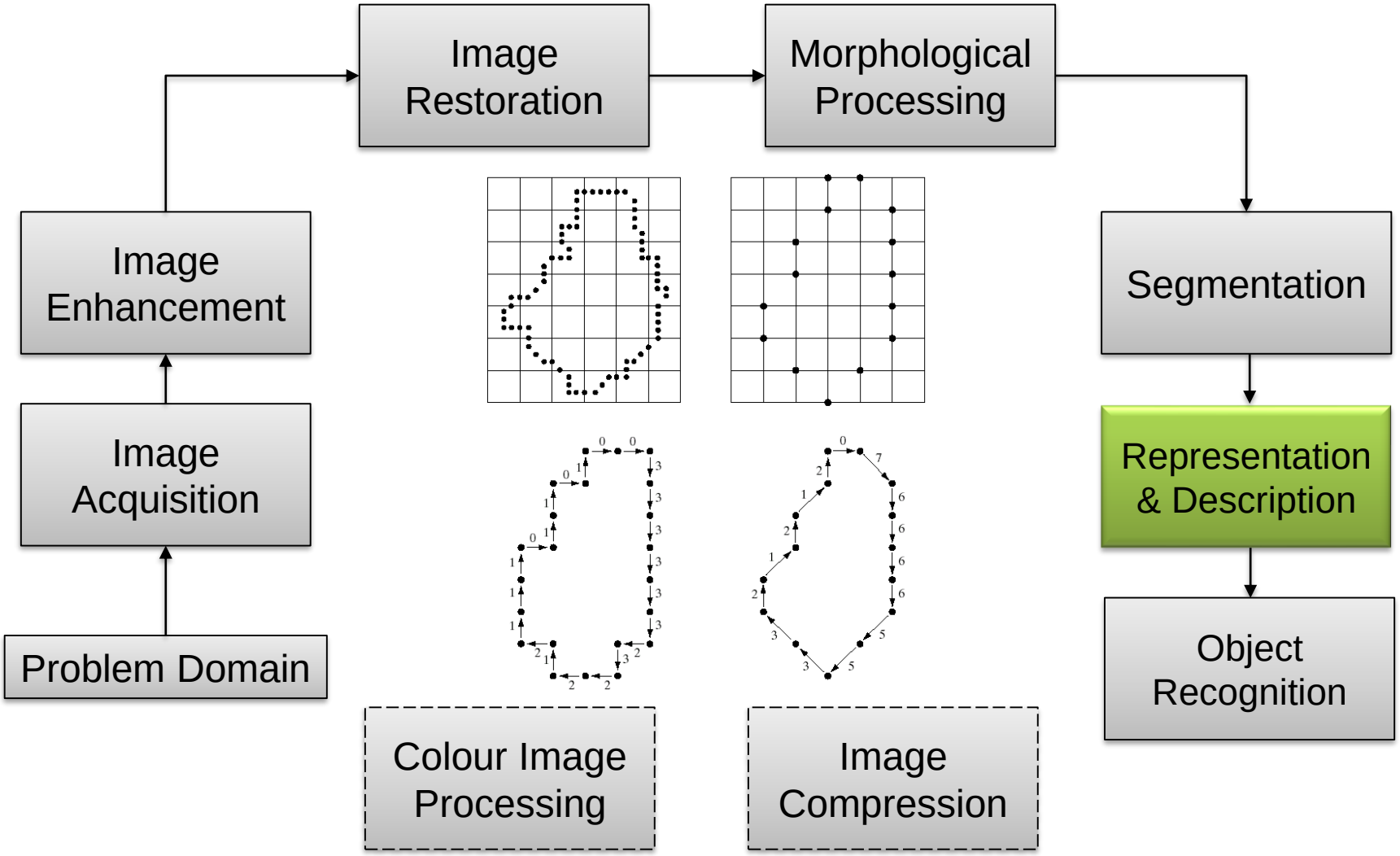
Key Stages in Digital Image Processing: Representation & Description



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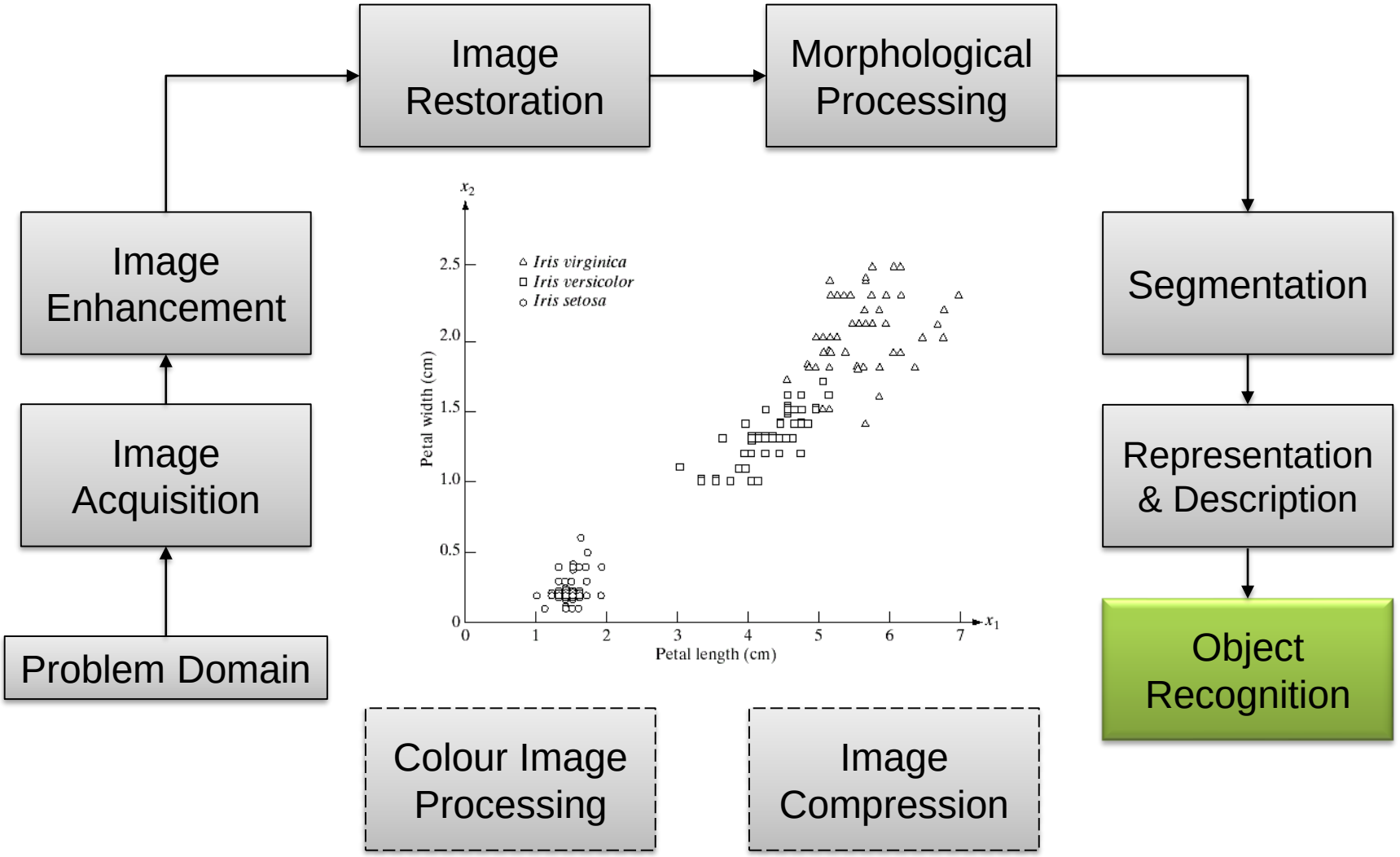
Key Stages in Digital Image Processing: Object Recognition



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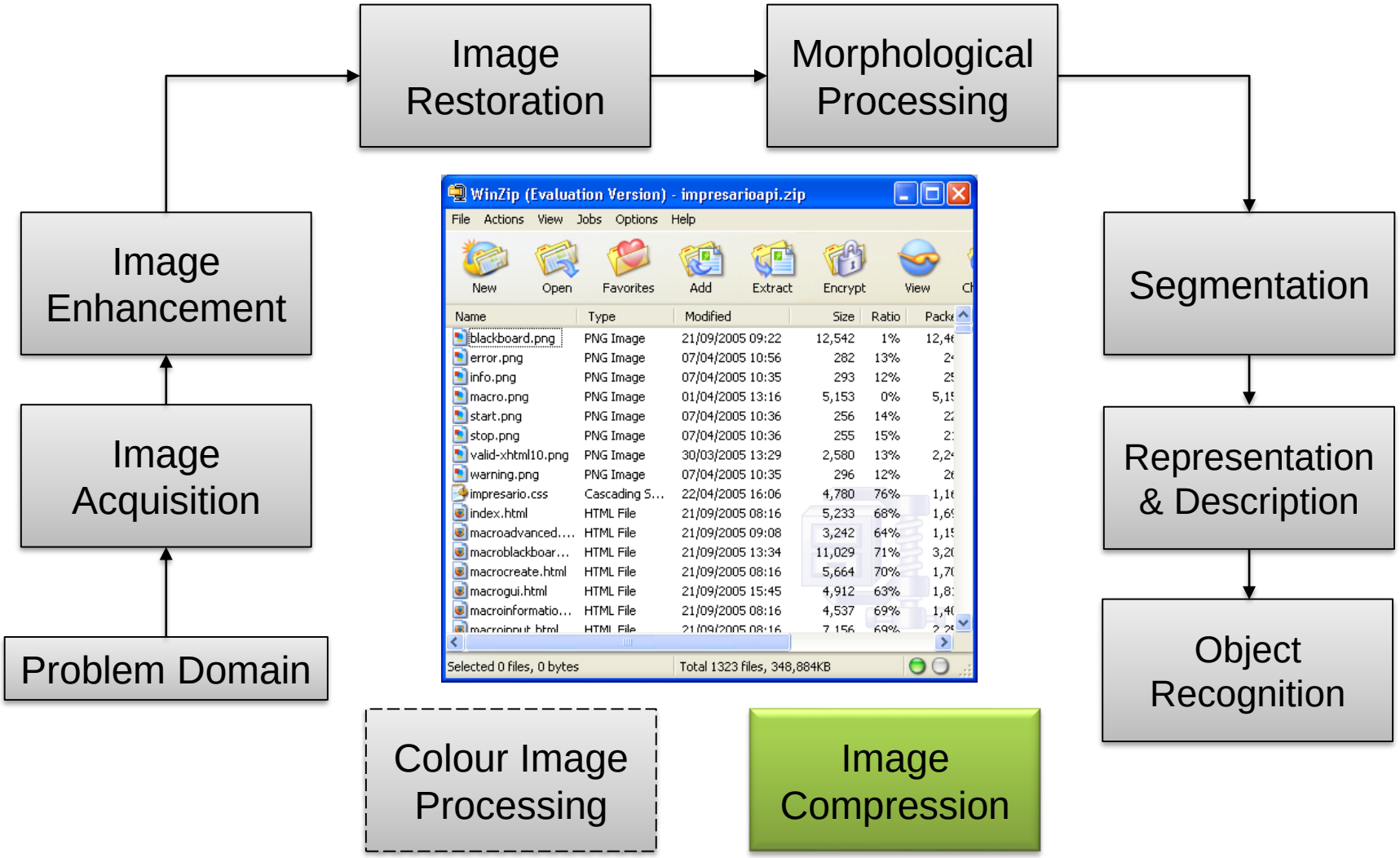
Key Stages in Digital Image Processing: Image Compression



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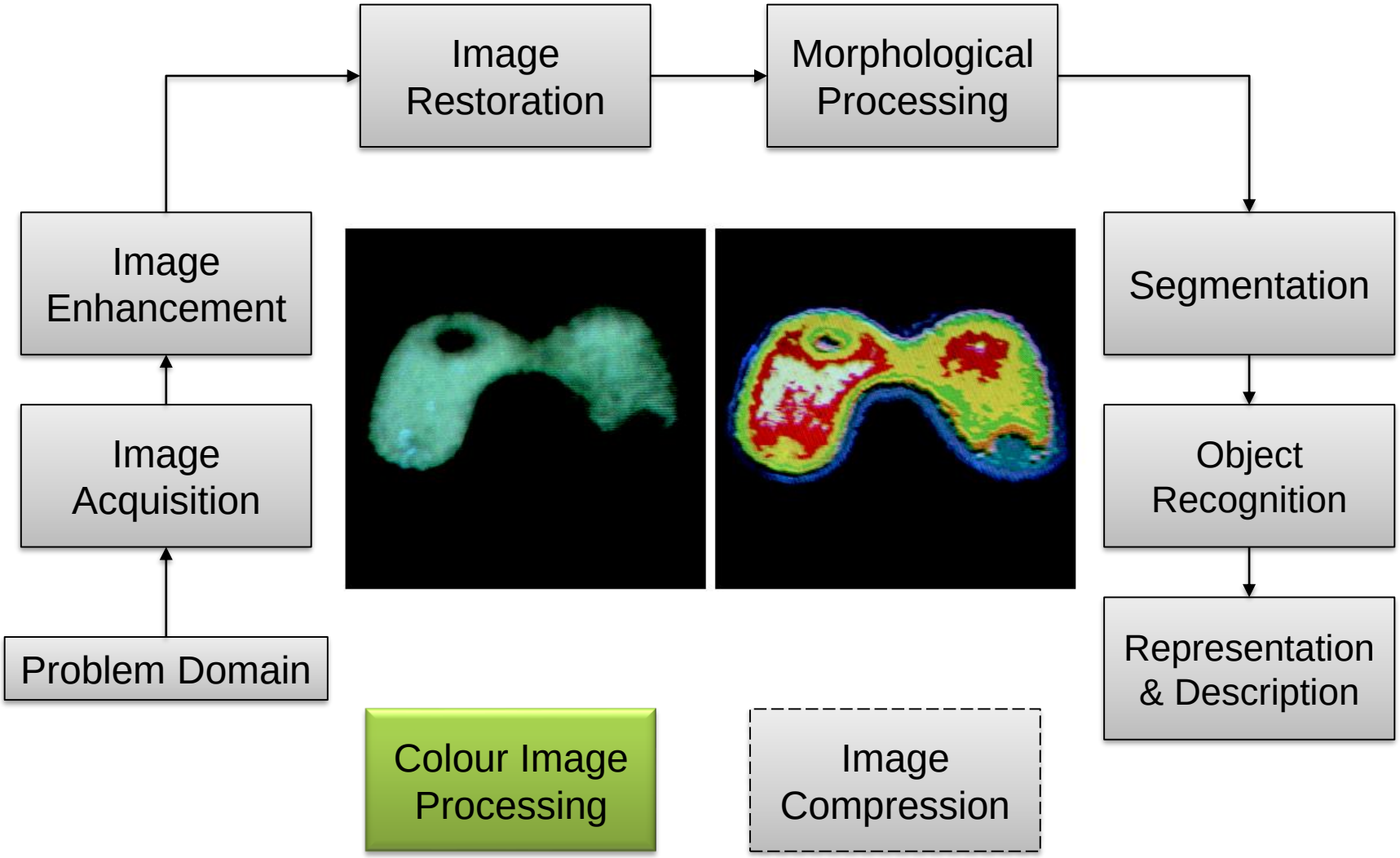
Key Stages in Digital Image Processing: Colour Image Processing



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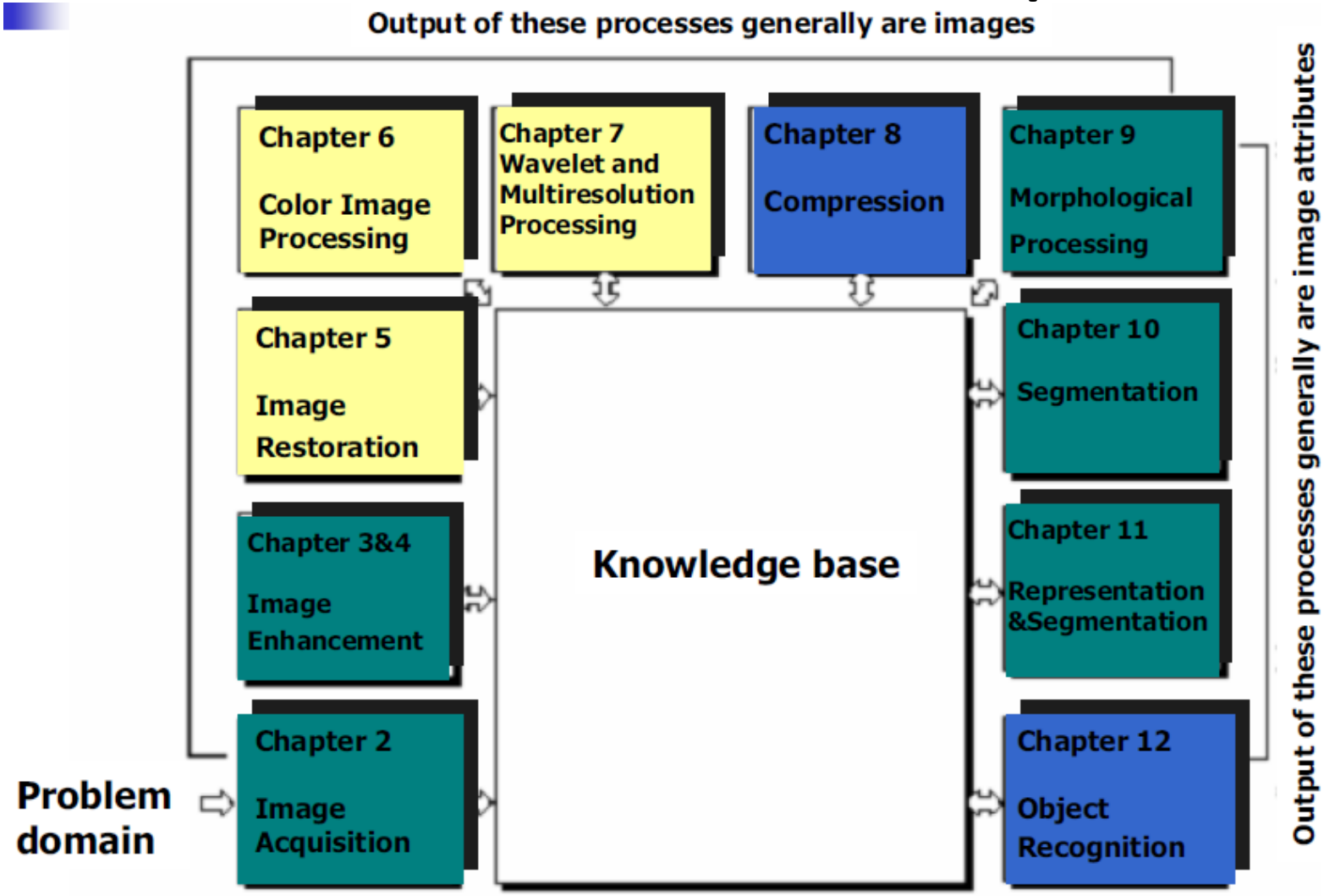
Fundamental Steps



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