Ψηφιακή Επεξεργασία Εικόνας (ΨΕΕ) – ΜΥΕ037

Εαρινό εξάμηνο 2023-2024

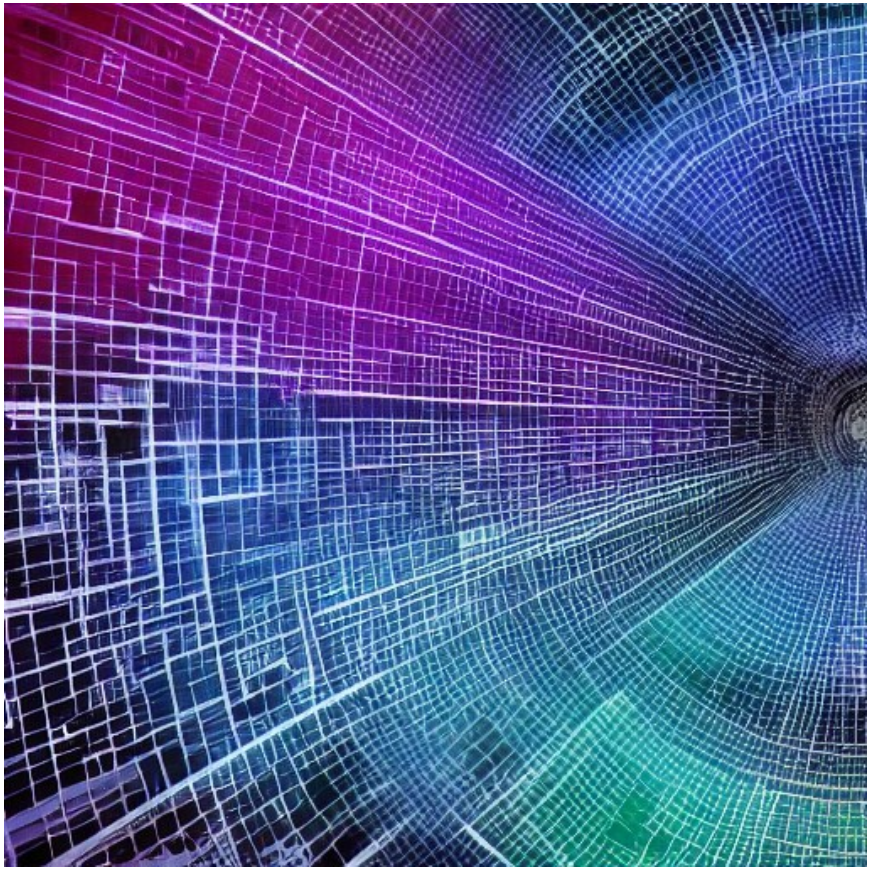
Εισαγωγή στην ΨΕΕ

Άγγελος Γιώτης

a.giotis@uoi.gr

Images taken from:
R. Gonzalez and R. Woods. Digital Image Processing, Prentice Hall, 2008.
Digital Image Processing course by Brian Mac Namee, Dublin Institute of Technology.

Introduction



"One picture is worth more than ten thousand words"

Fred R. Barnard, 1921

Grading

Prerequisites

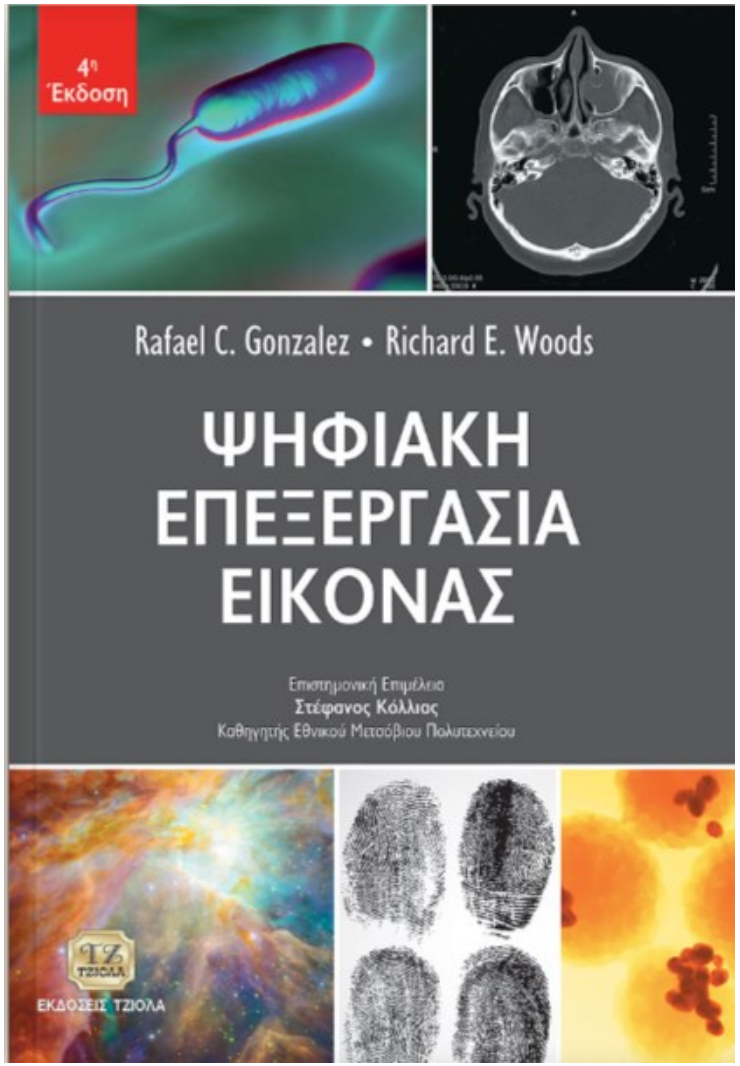
- Linear Algebra
- Signals and systems
- Python Programming skills

Course Grading

- Assignments (30%)
- Final examination (70%)

Bibliography

- R. C. Gonzalez, R. E. Woods, *Ψηφιακή Επεξεργασία Εικόνας*, Εκδόσεις Τζιόλα, 4η Έκδοση, 2018.



Bibliography (cont...)

- Ν. Παραμάρκος, *Ψηφιακή Επεξεργασία και Ανάλυση Εικόνας*, Εκδόσεις ΑΦΟΙ Παπαμάρκου Ο.Ε., 3η Έκδοση, 2013.

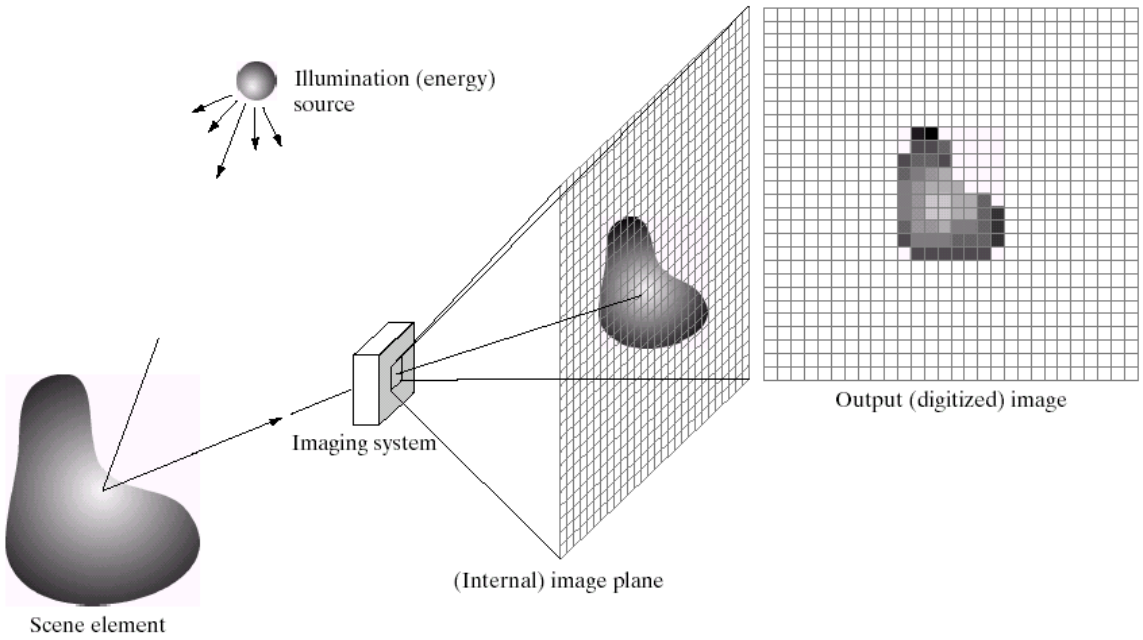
Contents

This lecture will cover:

- What is a digital image?
- What is digital image processing?
- History of digital image processing
- State of the art examples of digital image processing
- Key stages in digital image processing

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

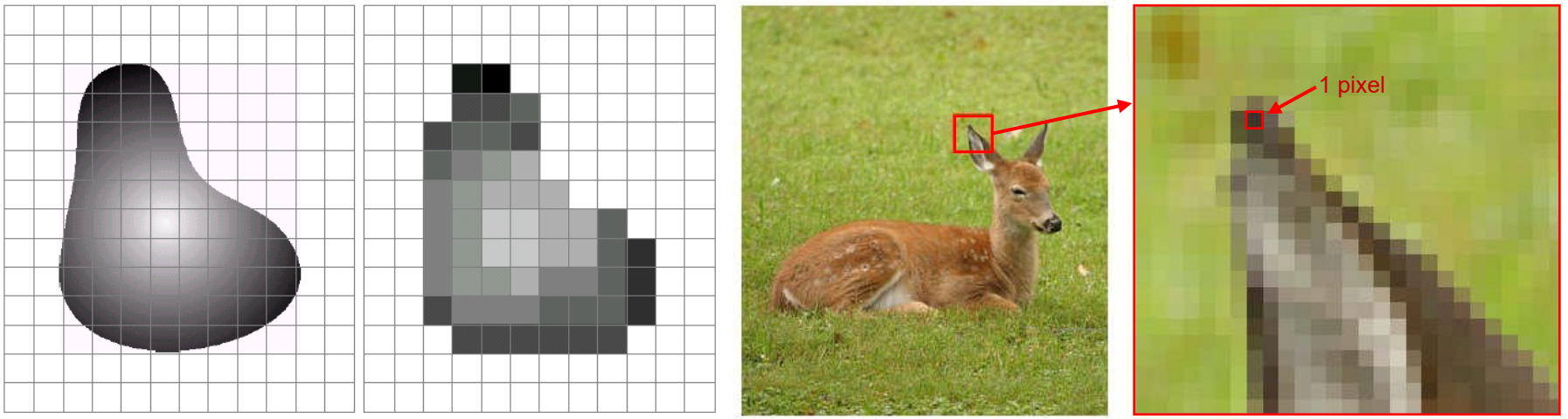


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

What is a Digital Image? (cont…)

Pixel values typically represent gray levels, colours, heights, opacities etc

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

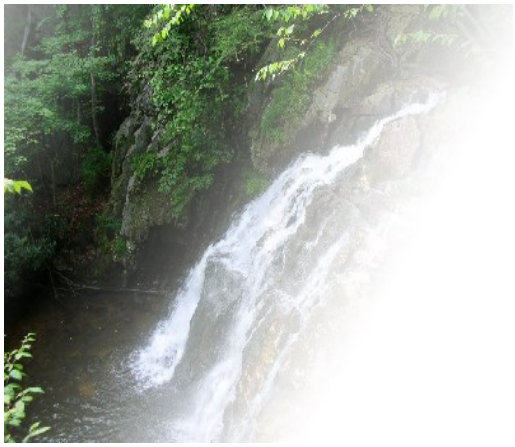


What is a Digital Image? (cont…)

Common image formats include:

- 1 sample per point (B&W or Grayscale)
- 3 samples per point (Red, Green, and Blue)
- 4 samples per point (Red, Green, Blue, and “Alpha”, a.k.a. Opacity)





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

What is Digital Image Processing?

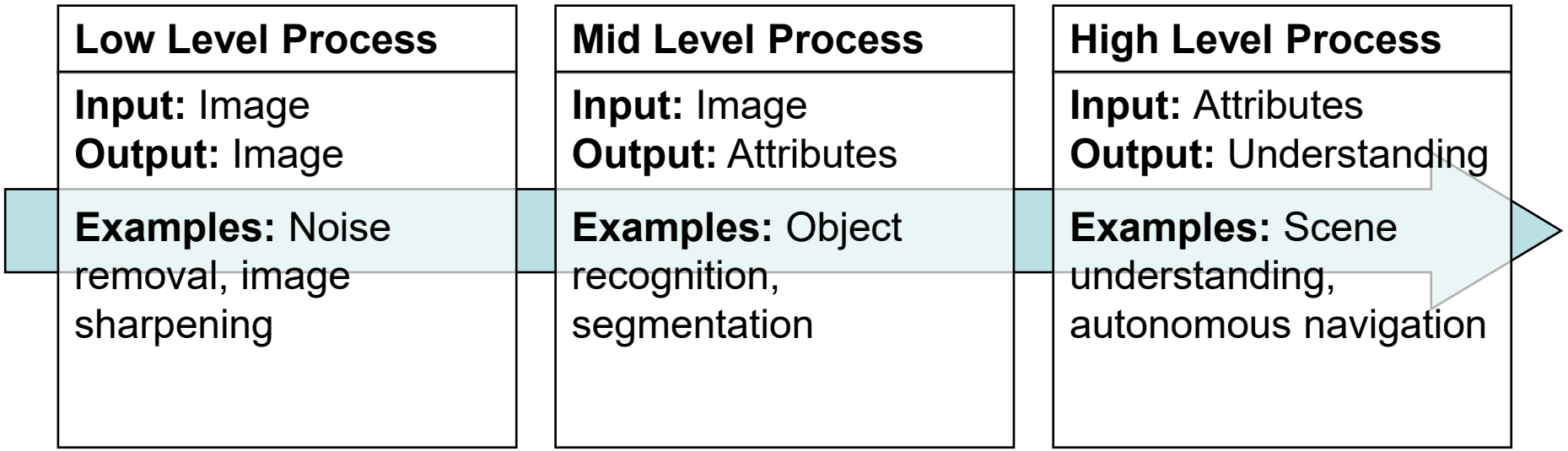
Digital image processing focuses on two major tasks

- 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

What is DIP? (cont…)

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



History of Digital Image Processing

Early 1920s: One of the first applications of digital imaging was in the news-paper industry

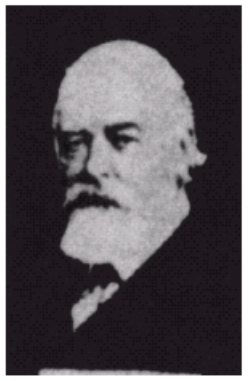
1921

- The Bartlane cable picture transmission service
- An image was transferred by submarine cable between London and New York in 3 hours
- Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer with halftoning

History of DIP (cont…)

Mid to late 1920s: Improvements to the Bartlane system resulted in higher quality images

- New reproduction processes based on photographic techniques
- Increased number of tones in reproduced images



1922

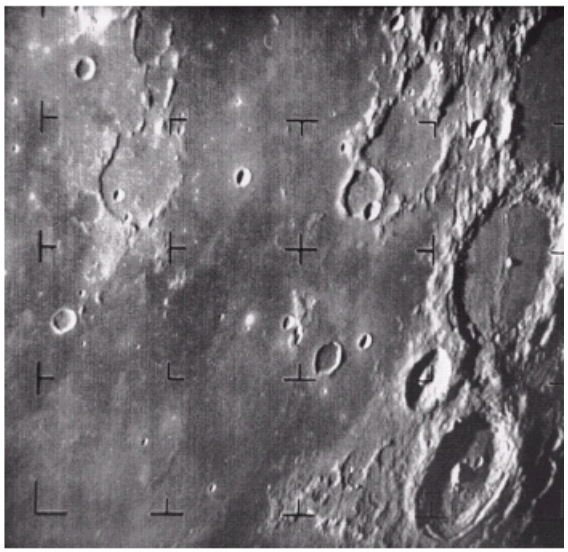
15 tone digital image (1929)

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

History of DIP (cont…)

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



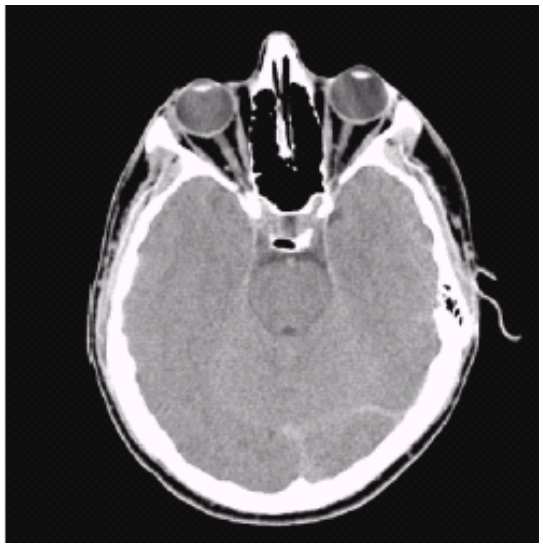
A picture of the moon taken 17 minutes before landing in 1964

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

History of DIP (cont…)

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 Computerised Axial Tomography (CAT) scans



Typical head slice CAT image

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

History of DIP (cont…)

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 visualisation
- Industrial inspection
- Law enforcement
- Human computer interfaces

Imaging modalities

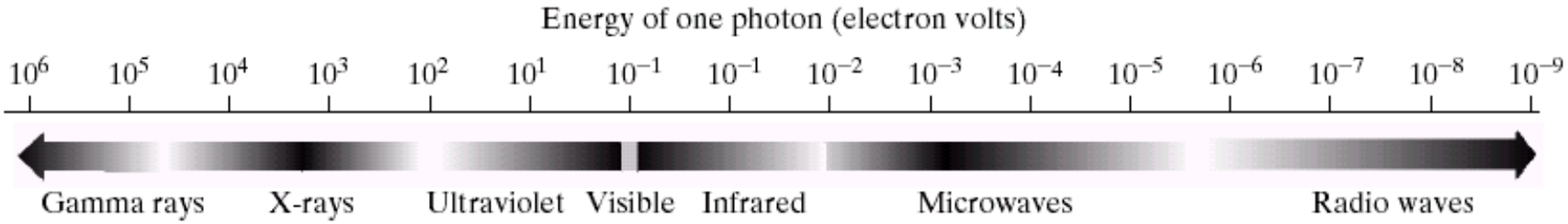
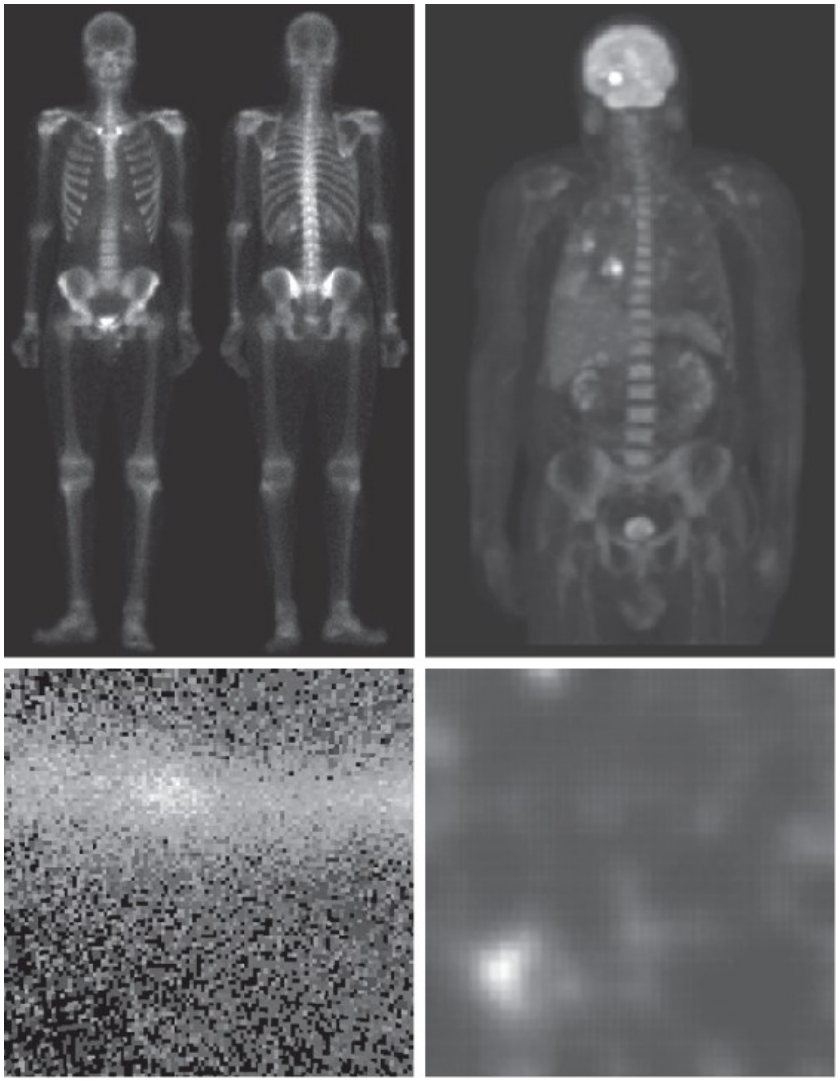


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

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

Gamma-ray imaging

- Bone scan
- Positron Emission Tomography (PET)

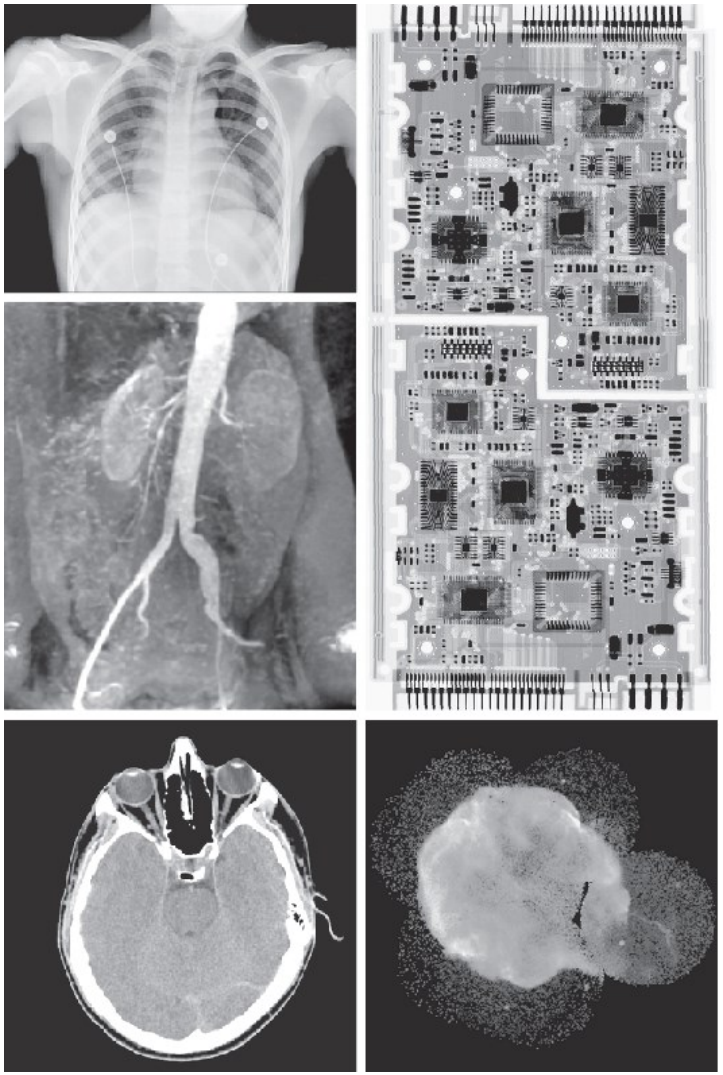


- Cygnus Loop natural radiation of the star (exploded 15k years ago)
- Valve of a nuclear reactor

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

X-ray imaging

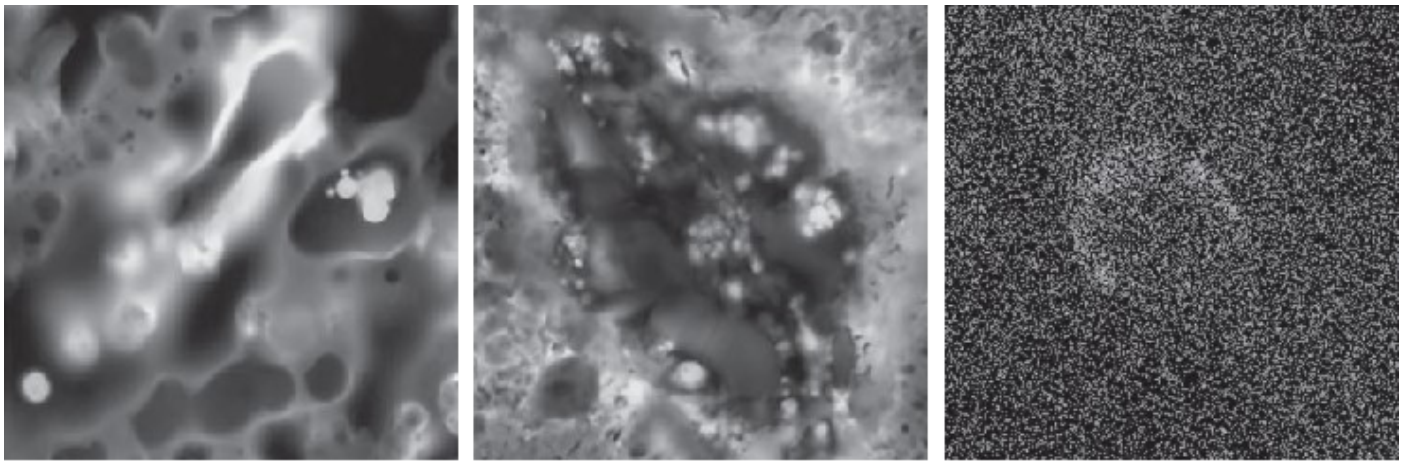
- Chest X-ray
  - Absorption of energy
- Angiography
  - Catheter with contrast medium
- Computed Axial Tomography (CAT)
- Manufacturing errors in electronic circuits
- Cygnus Loop



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

Ultraviolet imaging

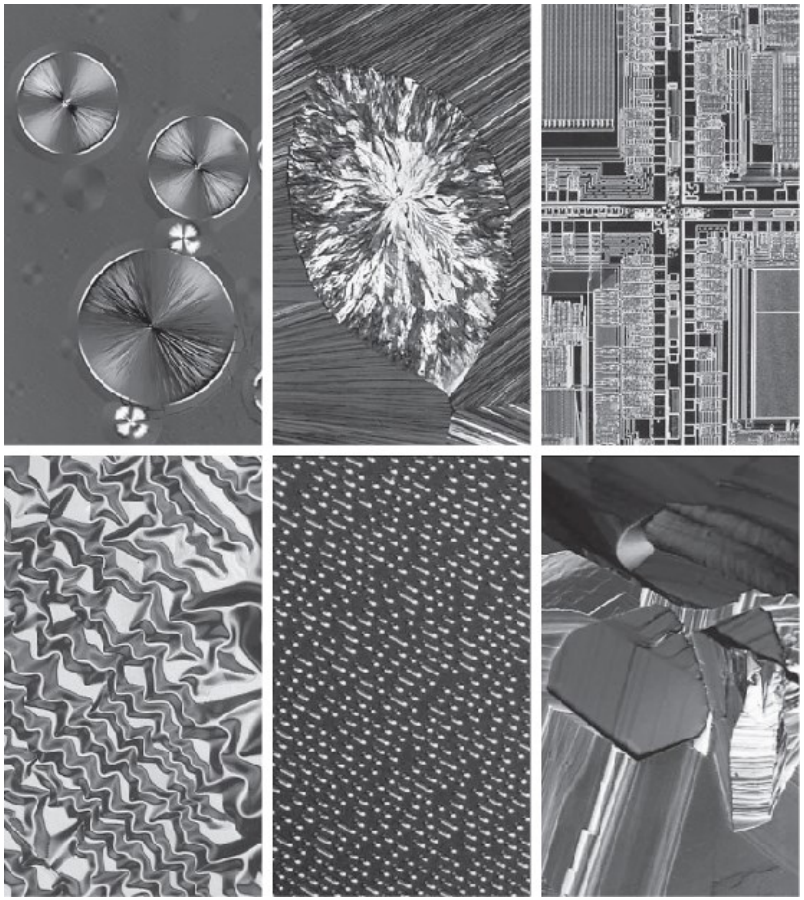
- Fluorescence microscopy
  - Normal corn
  - Corn infected by smut disease
- Cygnus Loop



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

Visible and infrared imaging

- Light microscopy
  - Taxol (anticancer agent) 250x
  - Cholesterol 40x
  - Microprocessor 60x
  - Nickel oxide thin film 600x
  - Surface of audio CD 1750x
  - Organic superconductor 450x

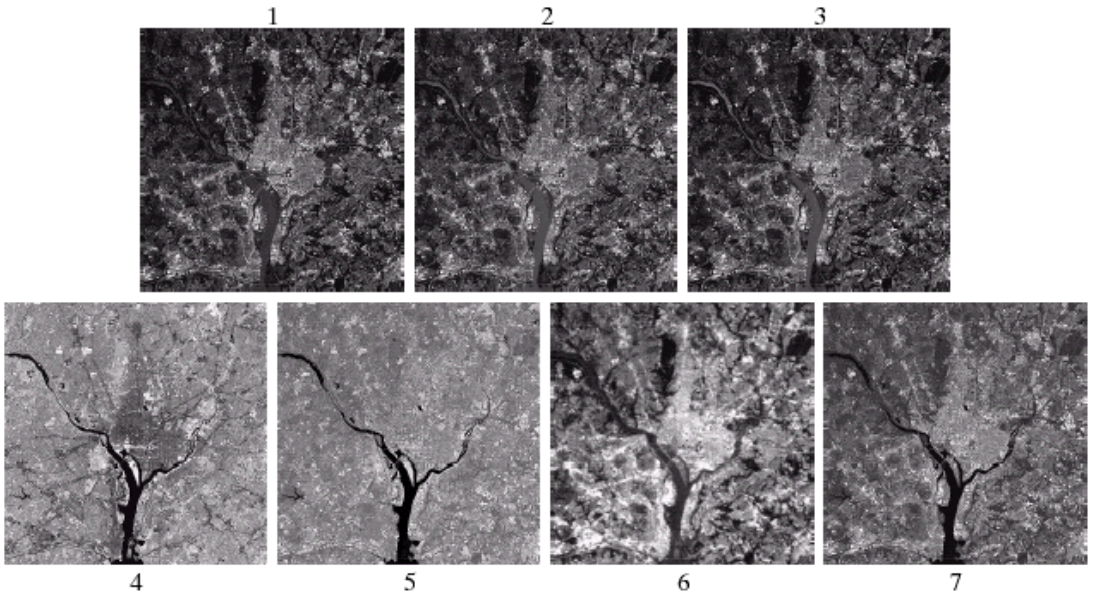


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

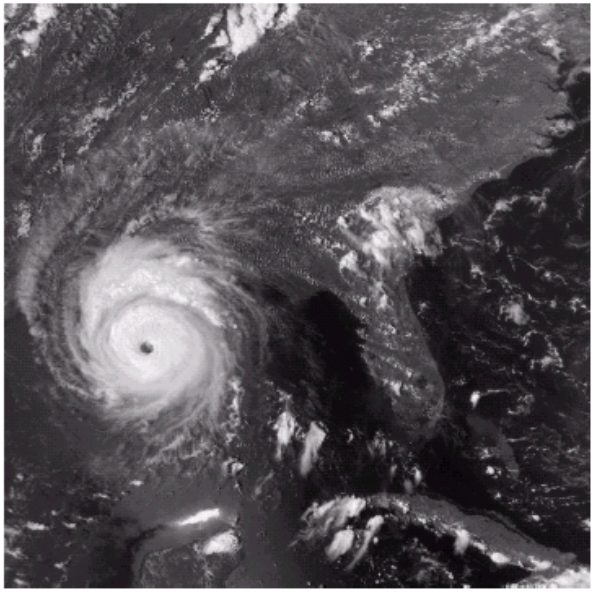
Visible and infrared imaging (cont.)

Remote sensing

- Terrain classification (LANDSAT)
- Meteorology (NOAA)



LANDSAT thematic bands of Washington DC area



Hurricane Katrina, 2005

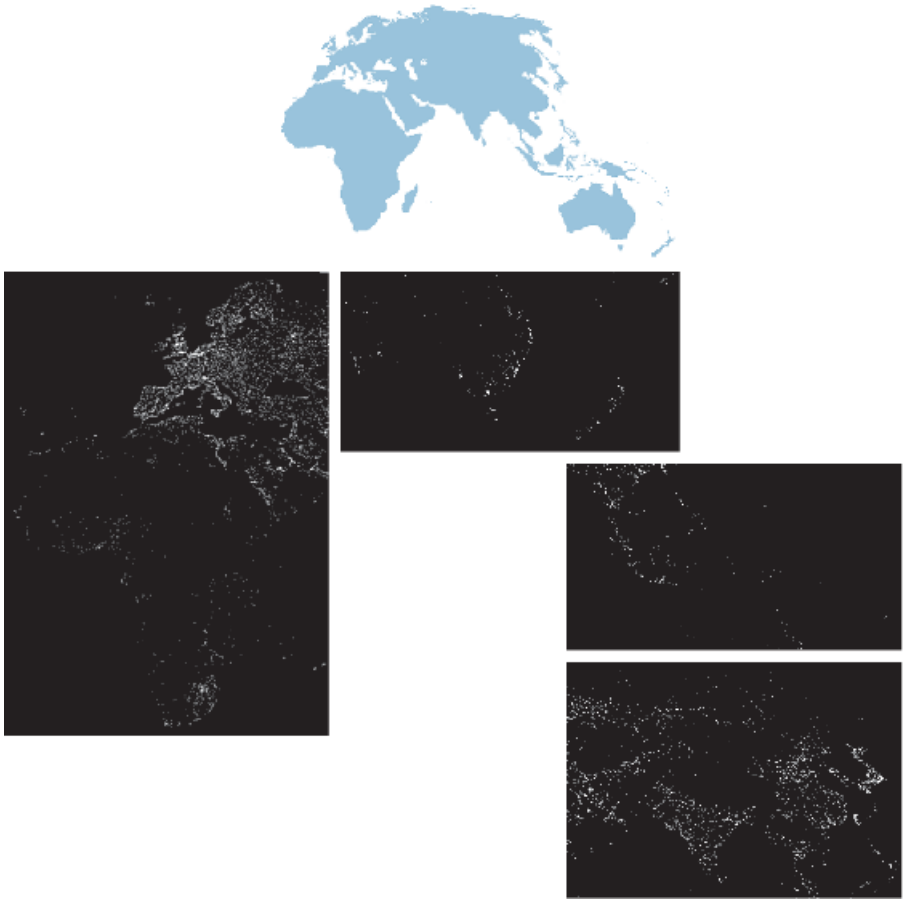
Visible and infrared imaging (cont.)

- Night-time lights of the world
  - Infrared band
  - Useful for estimating the percent of total electrical energy

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

Visible and infrared imaging (cont.)

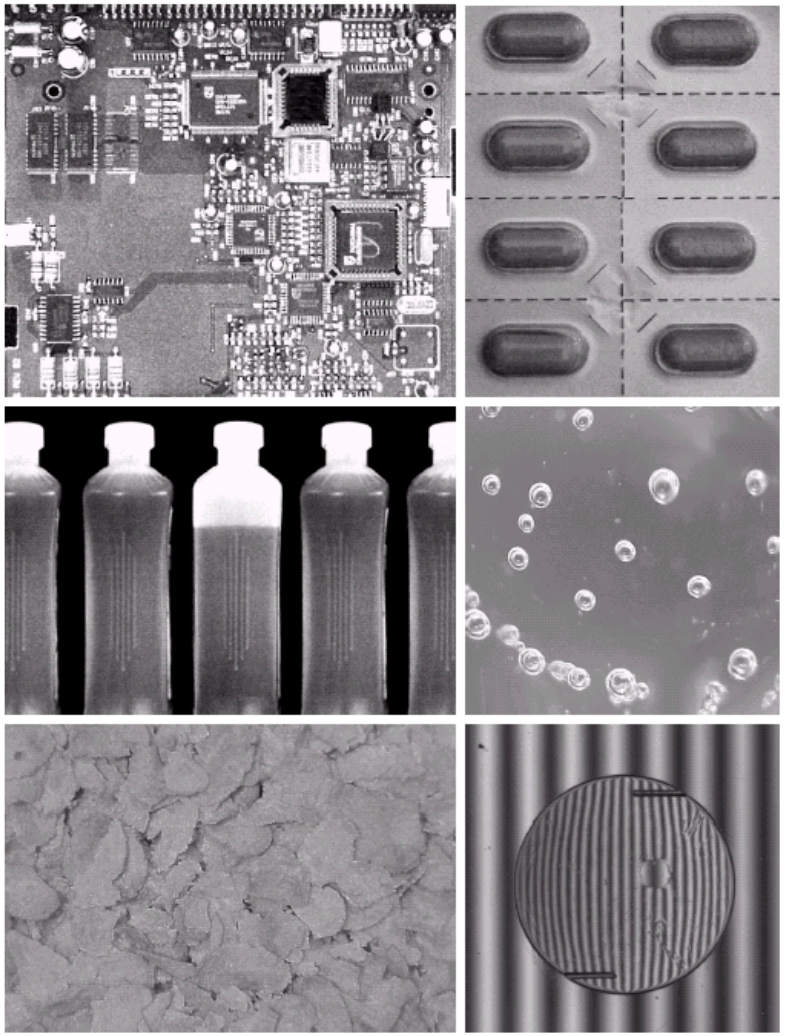
- Night-time lights of the world
  - Infrared band
  - Useful for estimating the percent of total electrical energy



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

Visible and infrared imaging (cont.)

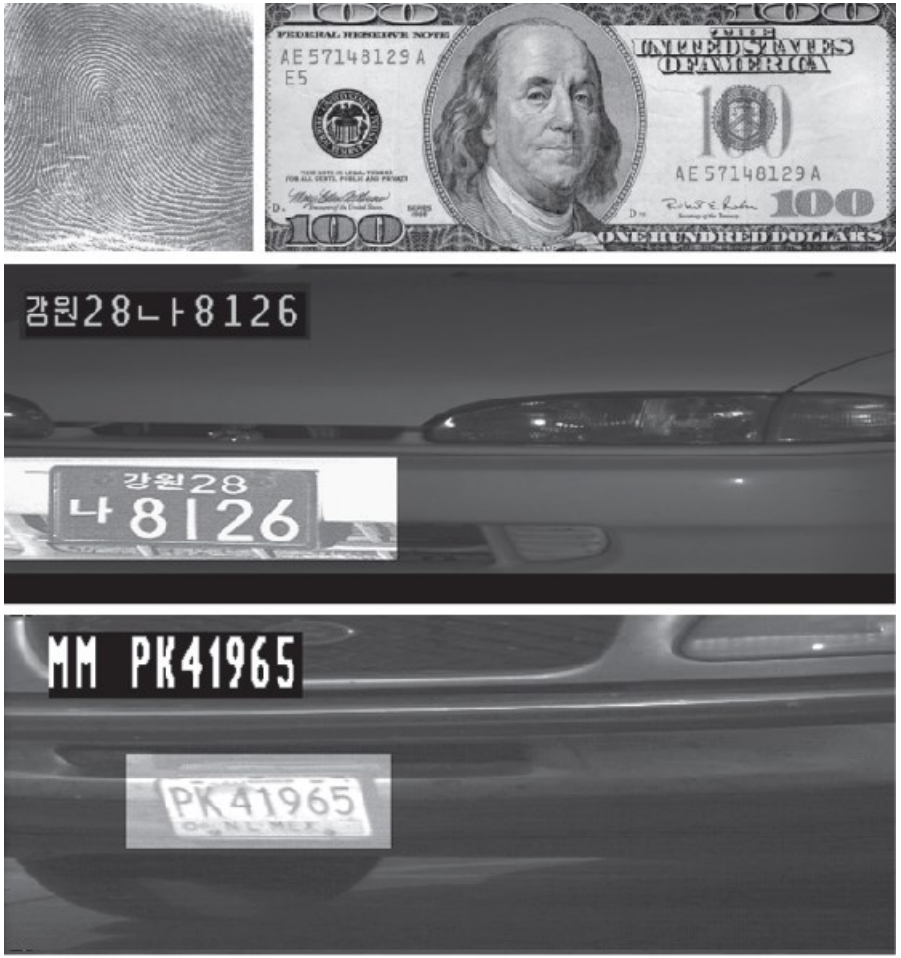
- Industrial inspection
  - Circuit board controller
  - Pill container
  - Bottle filling
  - Air pockets in plastic parts
  - Burned flakes
  - Intraocular implant
    - Structured light for detecting lens deformations (damages at 1 and 5 o'clock)



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

Visible and infrared imaging (cont.)

- Law enforcement
  - Fingerprint for database search
  - Automated counting
  - Bill identification
  - Licence plate detection and reading

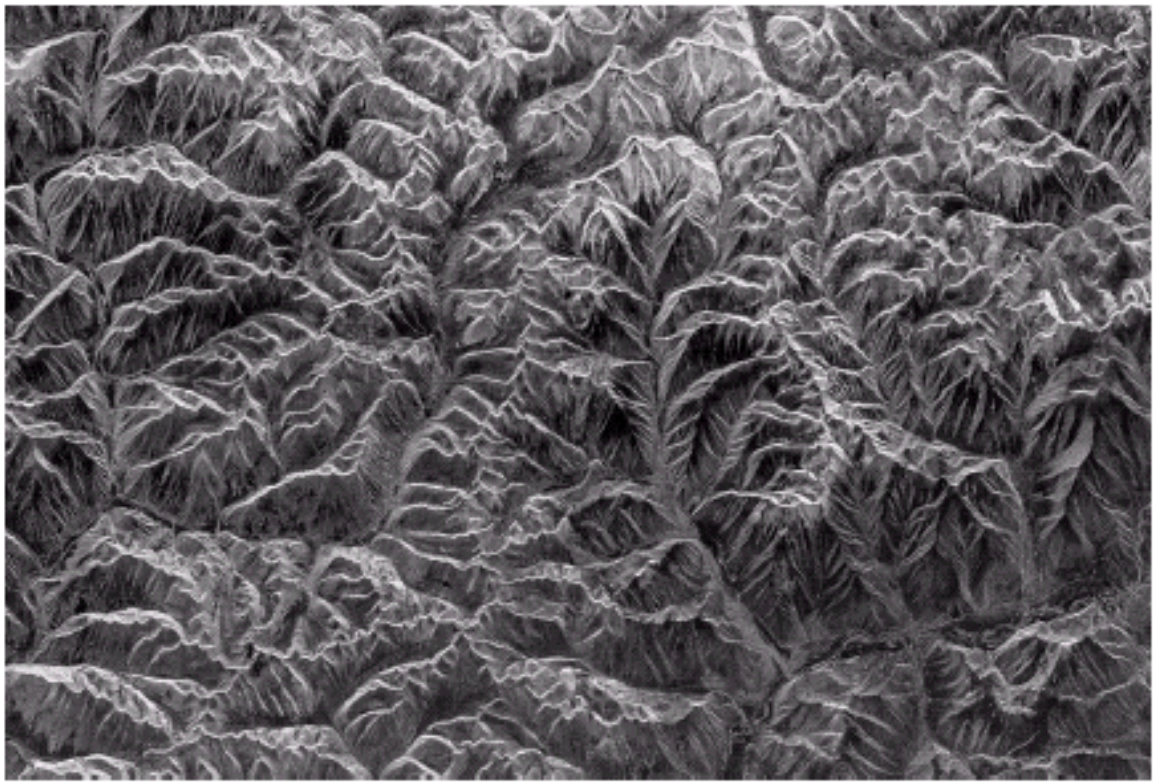


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Imaging in the microwave

- Radar is the dominant application
  - It emits pulses and receives them back at its antenna

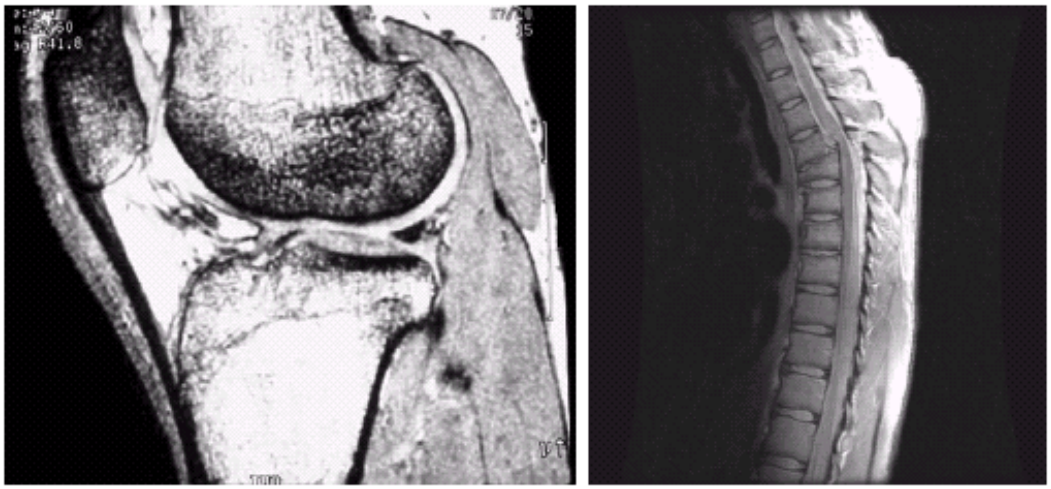
FIGURE 1.16
Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)



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

Imaging in the radio band

- Magnetic Resonance Imaging (MRI)
  - Patient placed in a magnet and radio wave pulses are emitted through the body
  - Resonance takes place with tissues (e.g. water molecules)



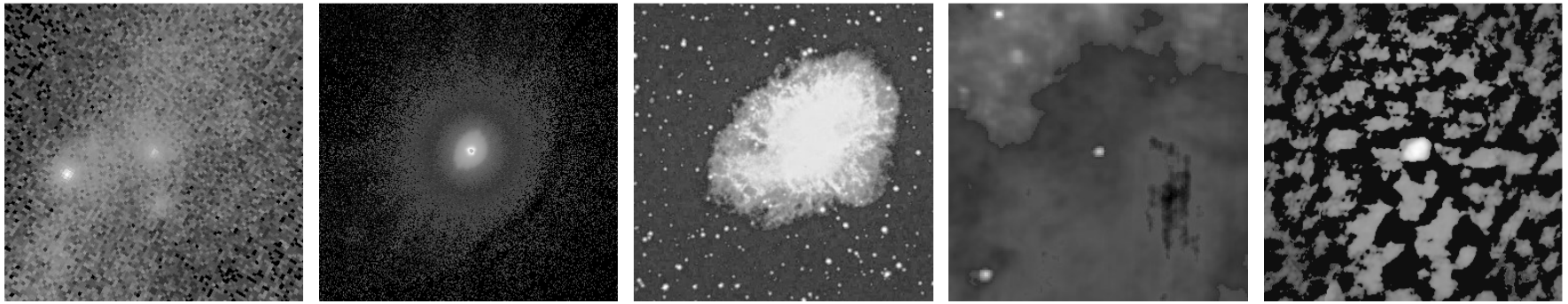
a b

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.)

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

Imaging in the radio band

- Astronomy

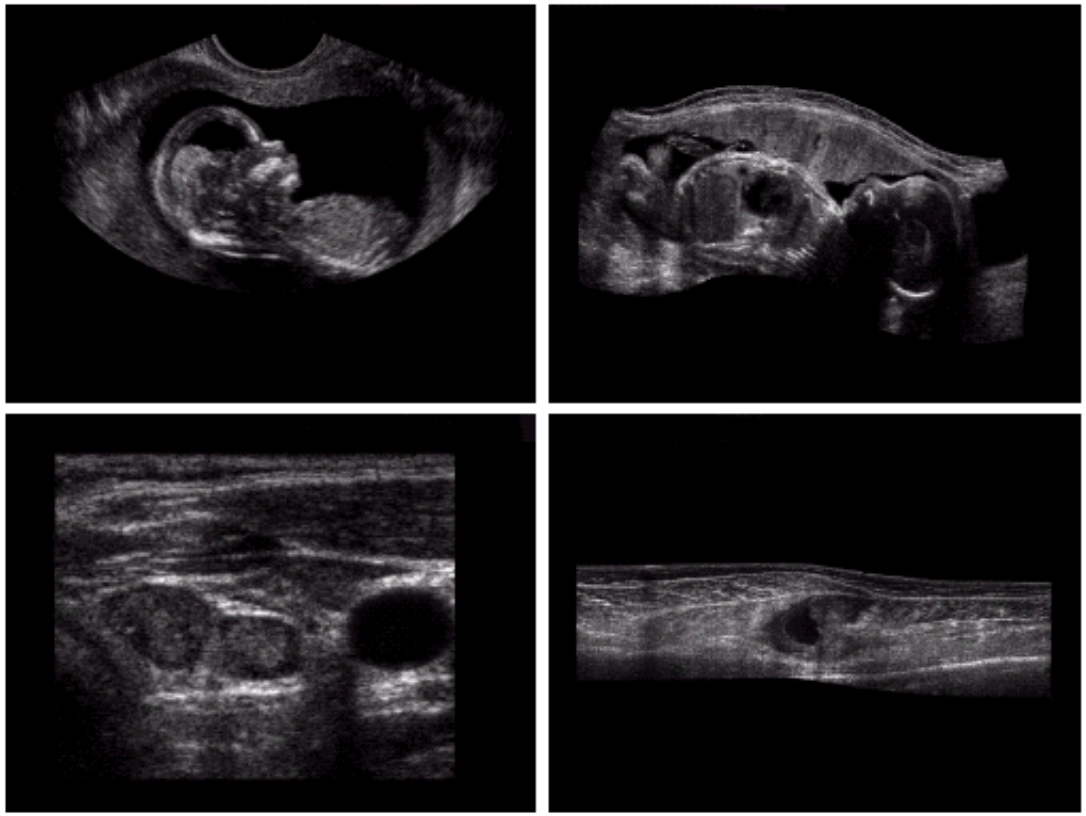


Gamma X-ray Optical Infrared Radio

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

Other imaging modalities

- Ultrasound imaging



a b
c d

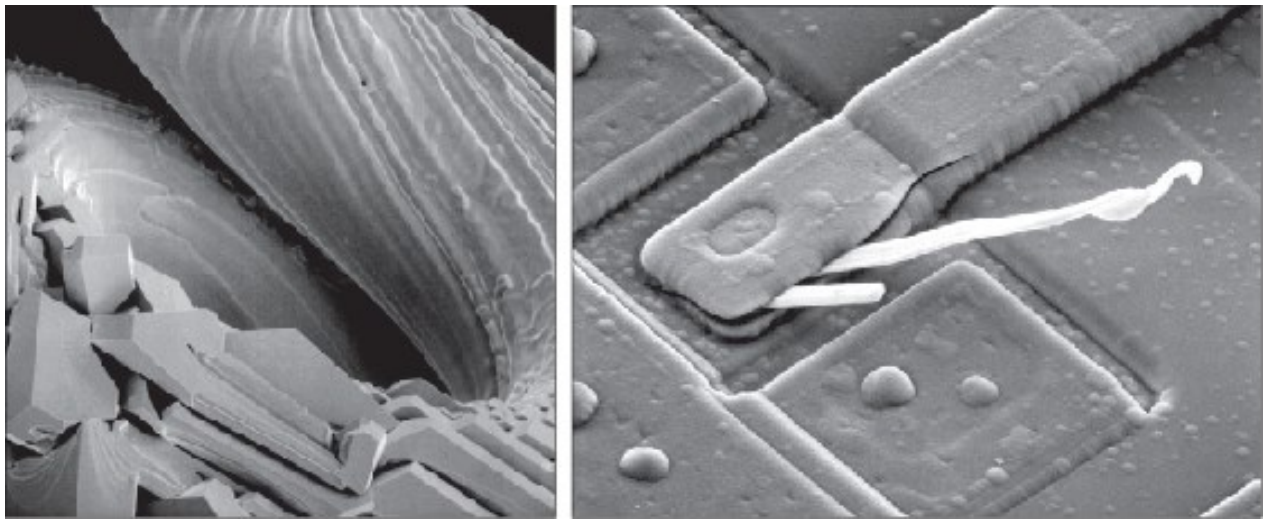
FIGURE 1.20 Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

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

Other imaging modalities (cont.)

- Electron Microscopy (EM)
  - Works like a slide projector emitting a beam of electrons instead of light
  - The transmitted beam is projected on a phosphor screen
  - The interaction of the beam with the slide produces light which is recorded
    - Scanning Electron Microscopy (SEM)
    - Transmission Electron Microscopy (TEM)
- Very high magnification (10000x)

Other imaging modalities (cont.)



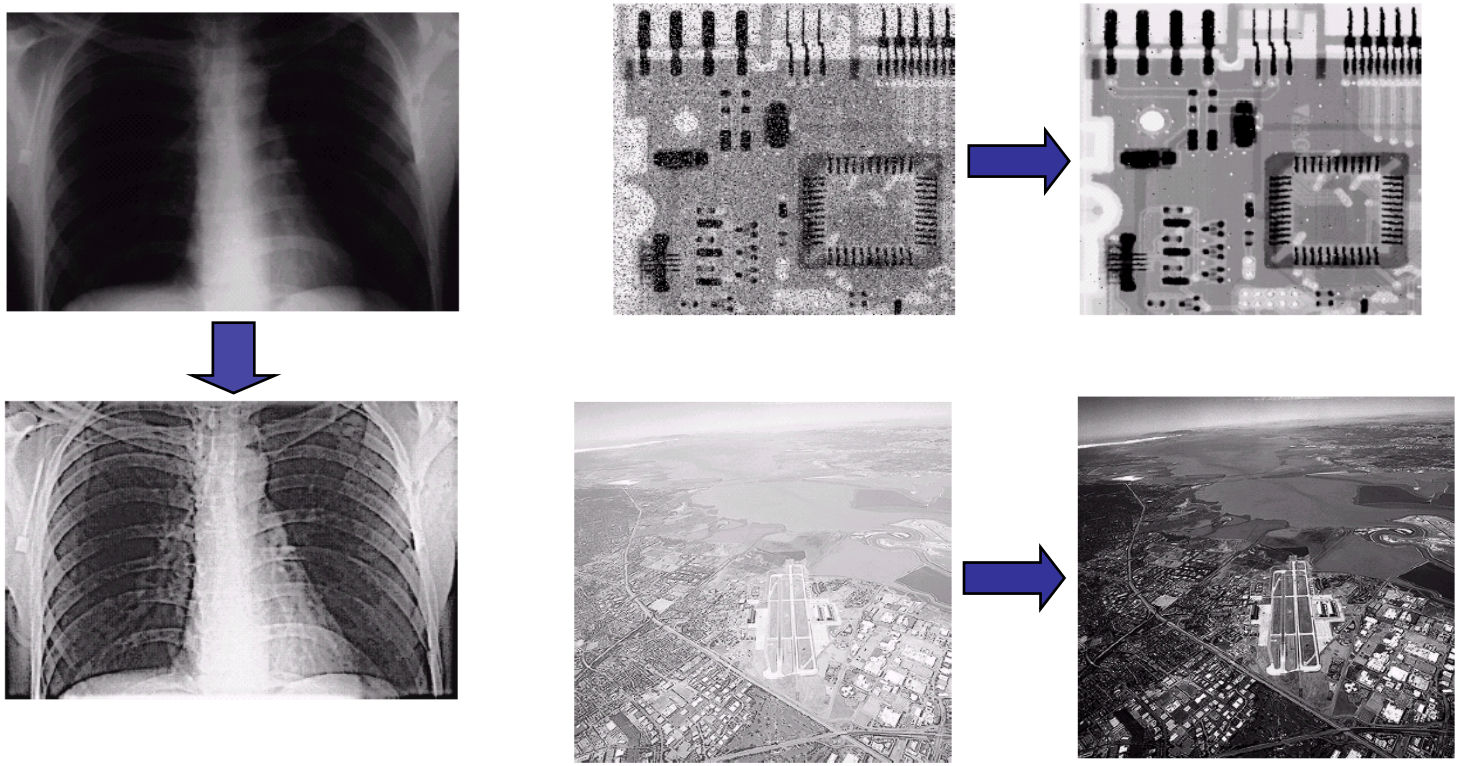
a b

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 a 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.)

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

Applications: Image Enhancement

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



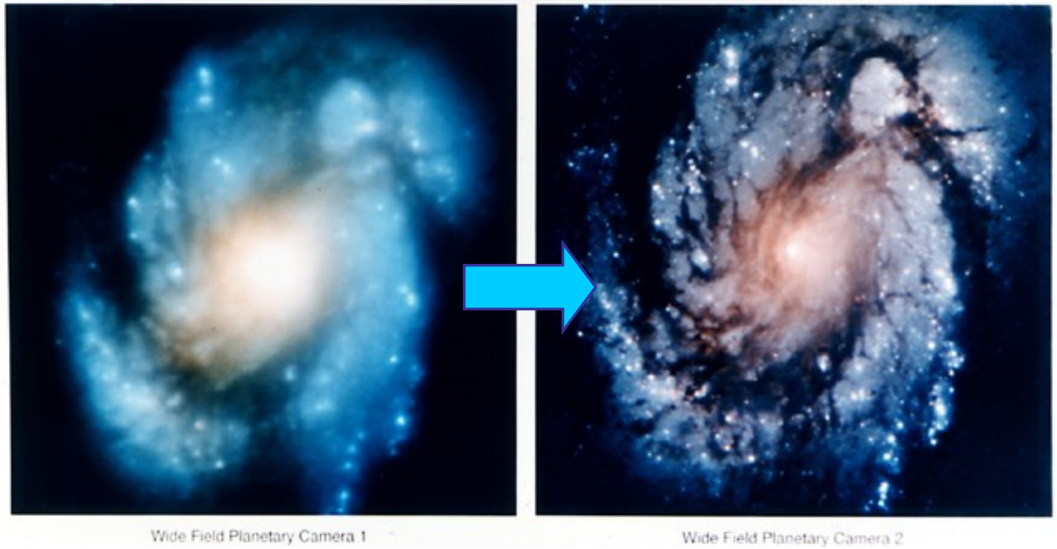
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Applications: 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



Applications: Newspaper Article Tracking

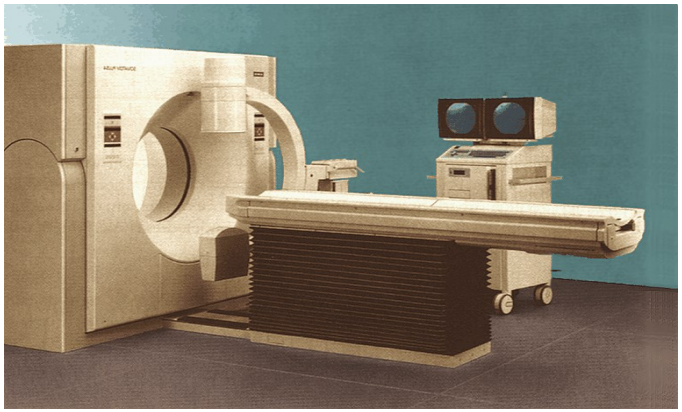
- Same colored image regions belong to the same semantic category (title)
- Same colored background indicates regions belonging to the same article

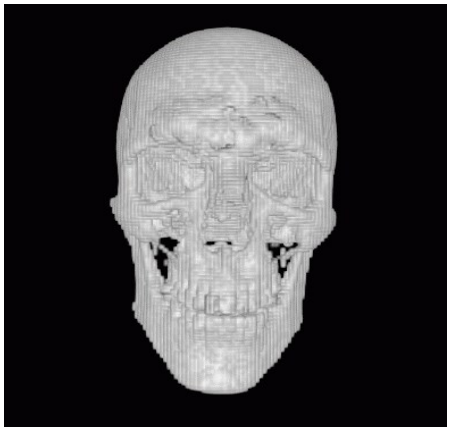
Applications: Artistic Effects

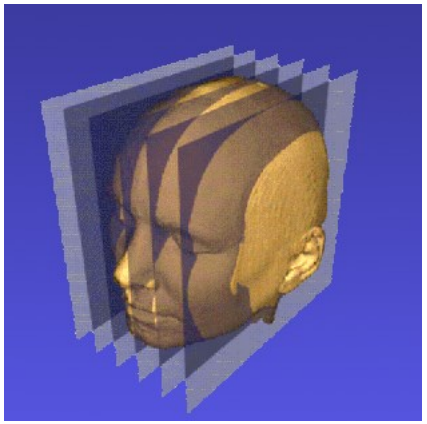
Artistic effects are used to make images more visually appealing, to add special effects and to make composite images

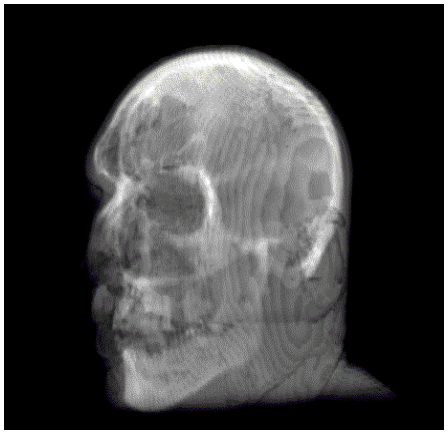
Applications: Medicine

3D tomography and rendering with transparencies







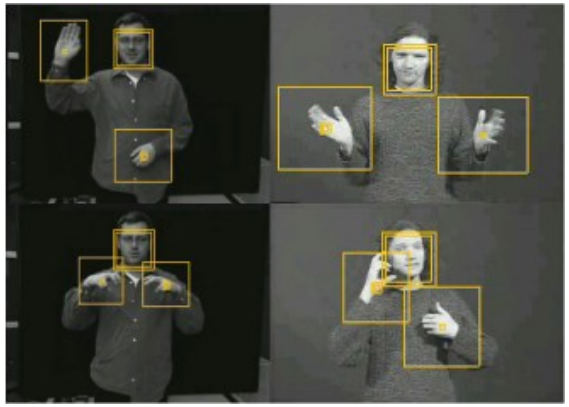


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

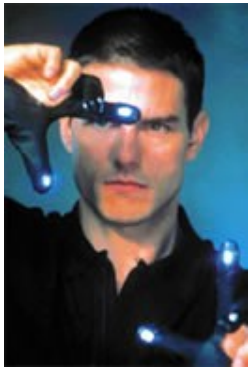
Applications: HCI

Try to make human computer interfaces more natural

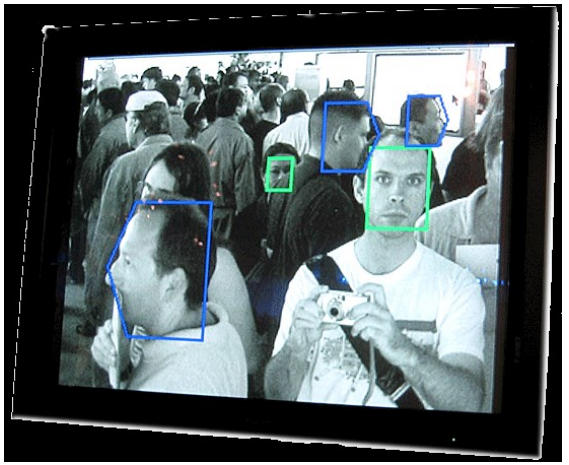
- Face recognition
- Gesture recognition



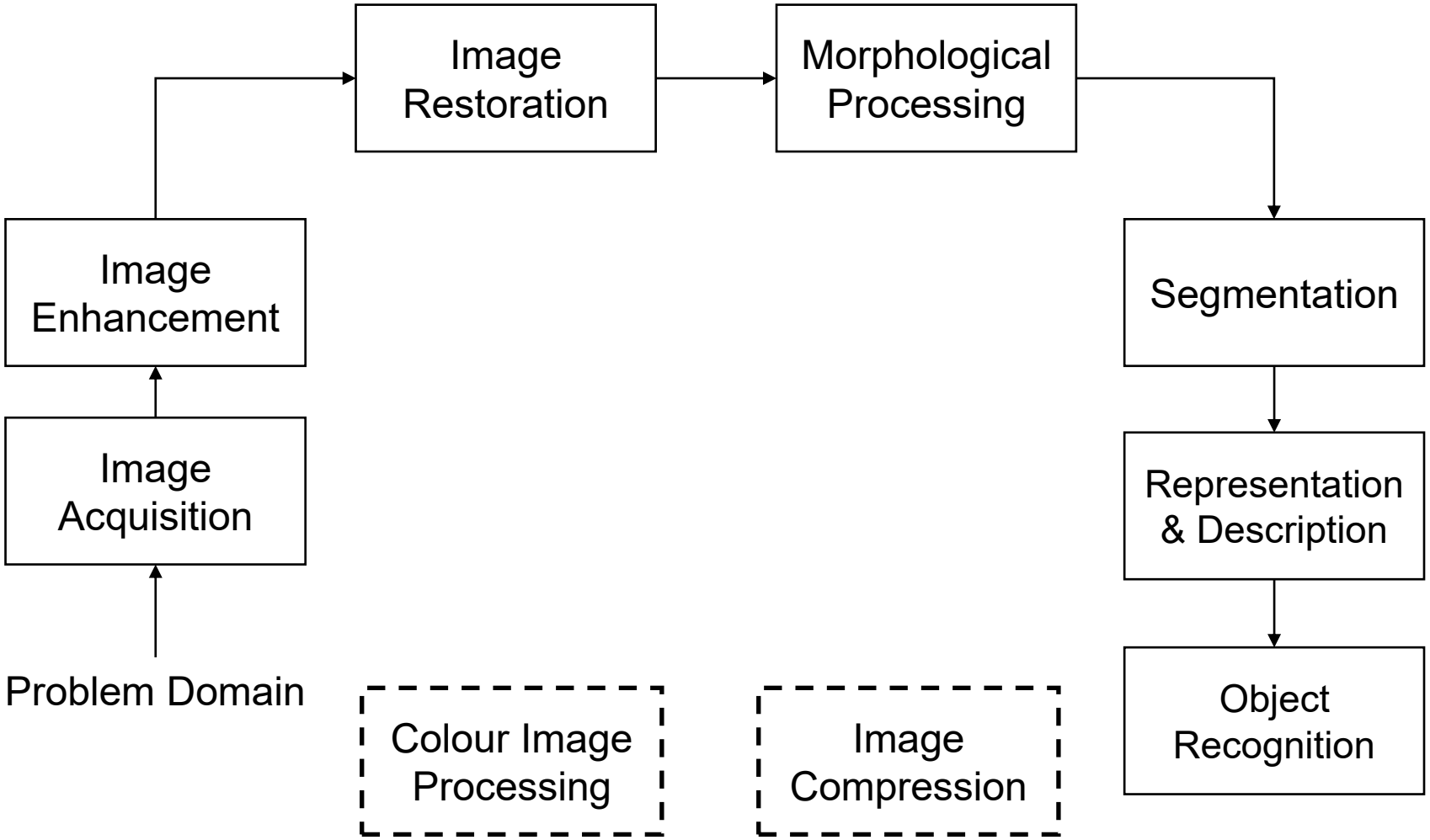
Does anyone remember the user interface from “Minority Report” (2002)?



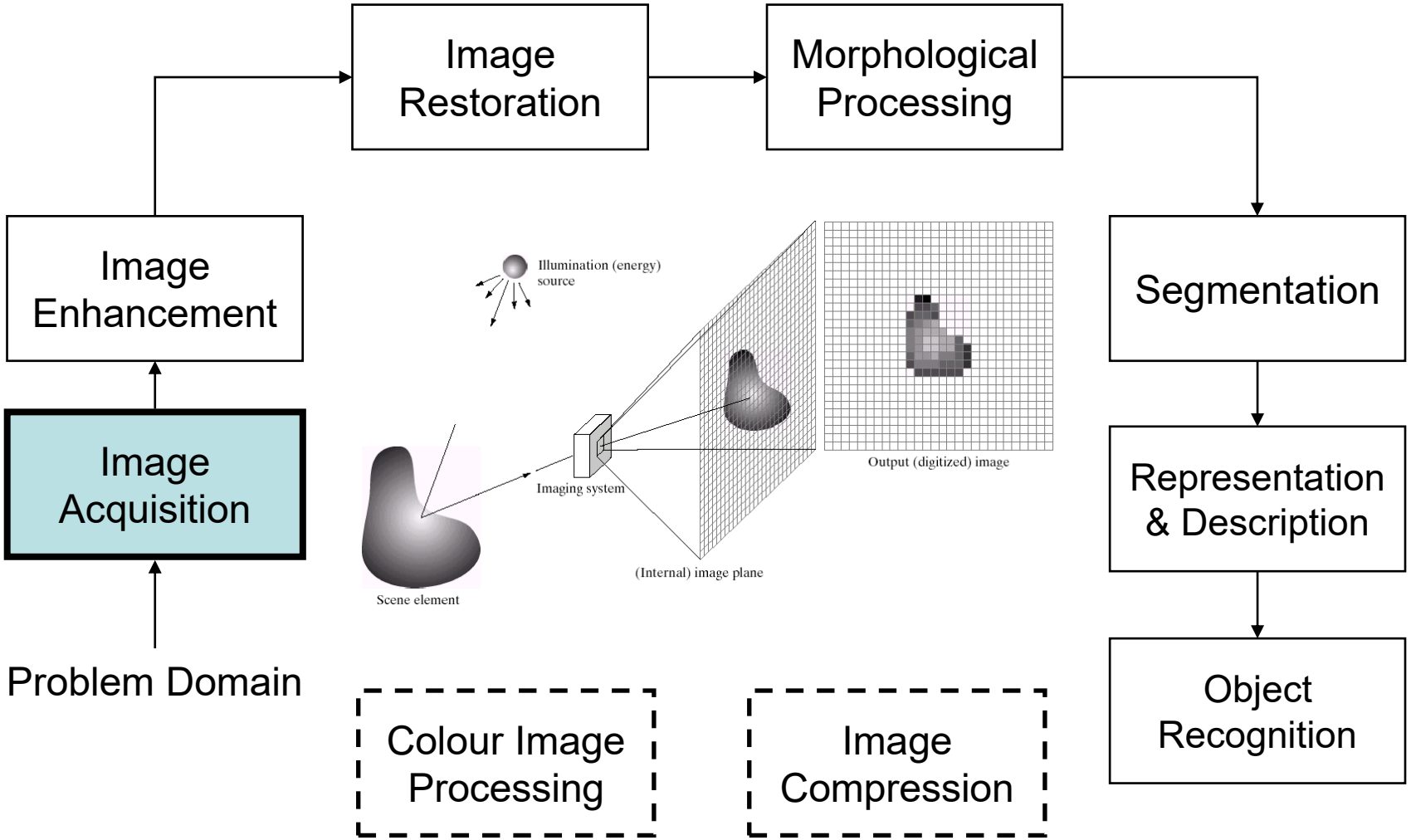
These tasks were really difficult at that time



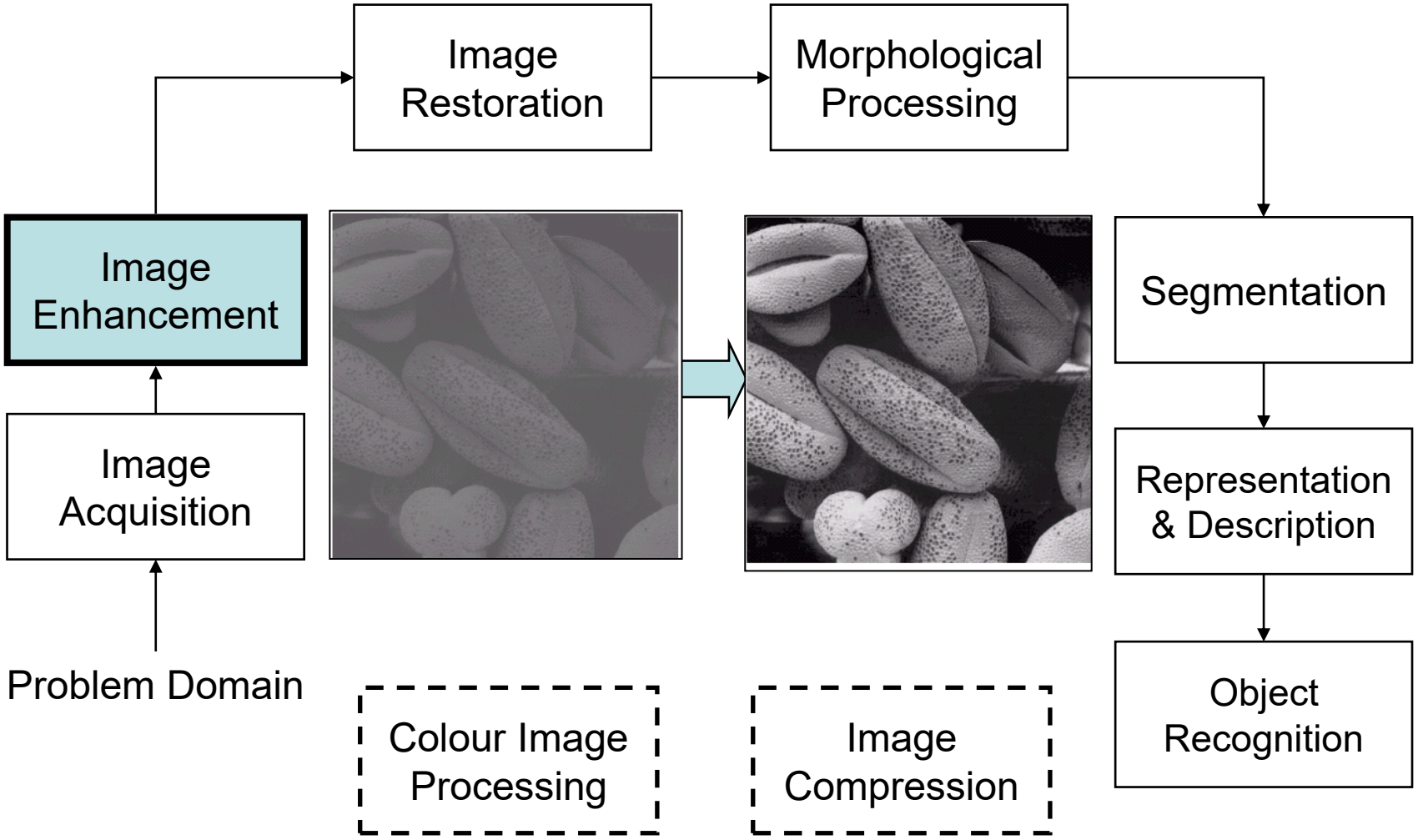
Key Stages in Digital Image Processing



Key Stages in Digital Image Processing: Image Aquisition

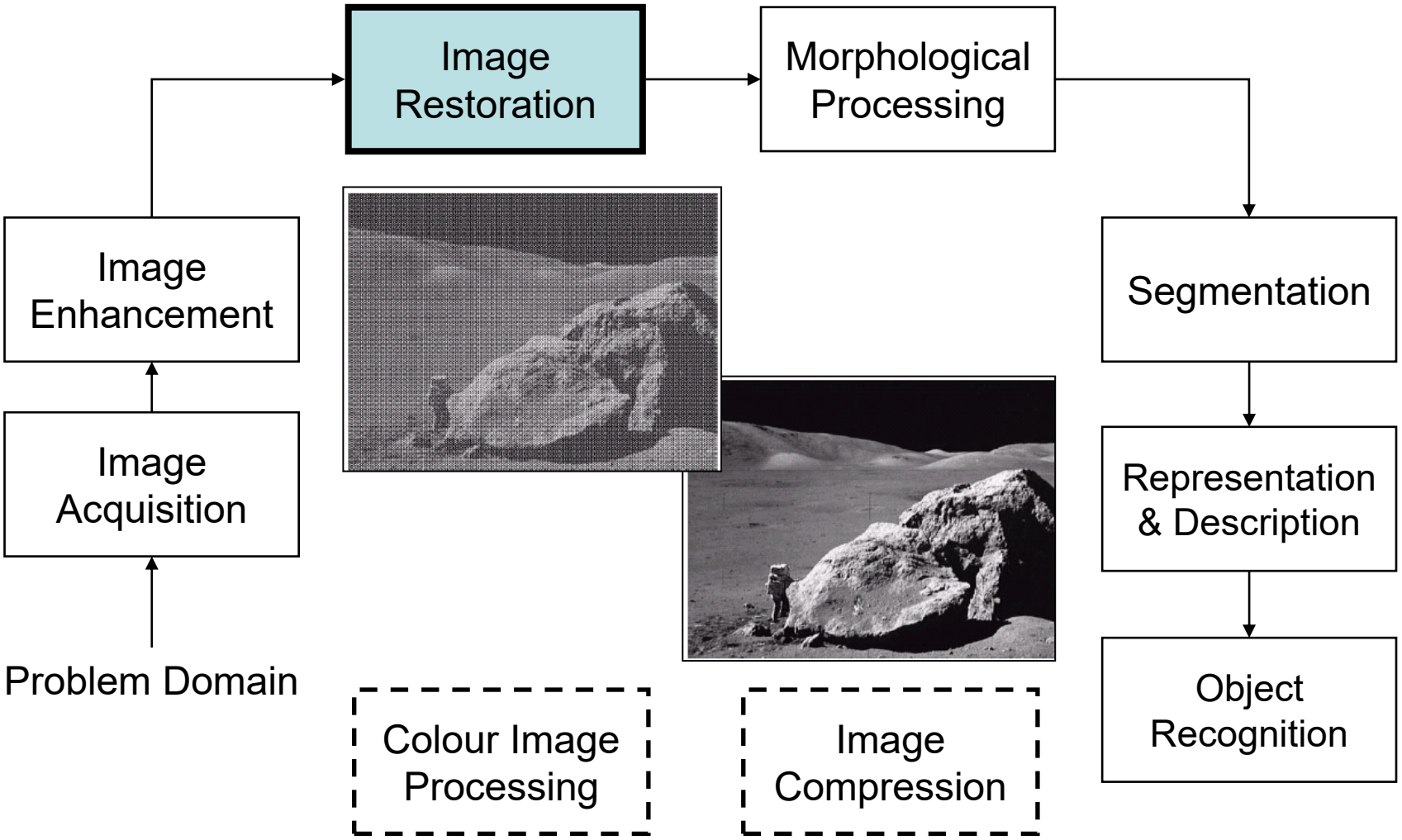


Key Stages in Digital Image Processing: Image Enhancement

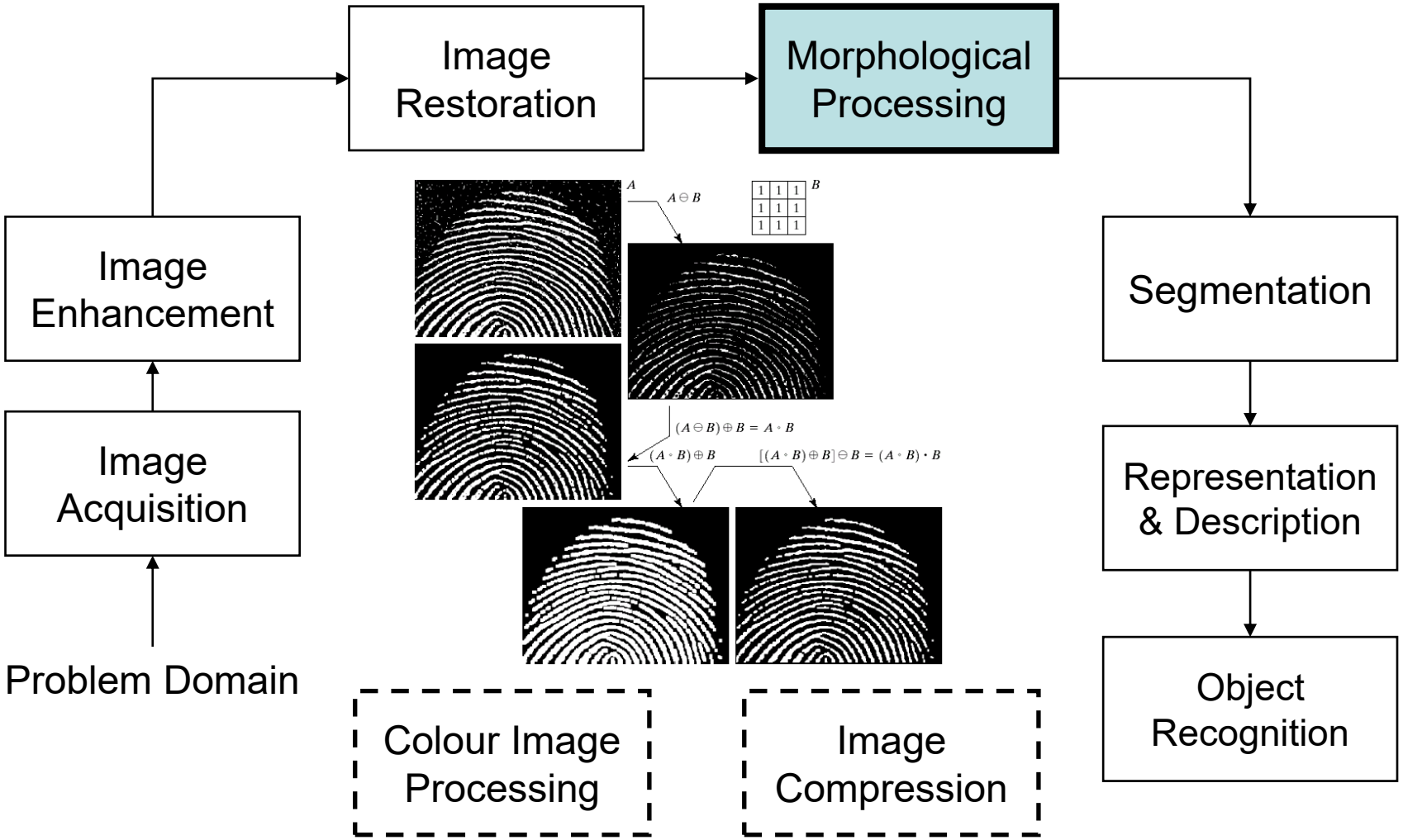


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Key Stages in Digital Image Processing: Image Restoration

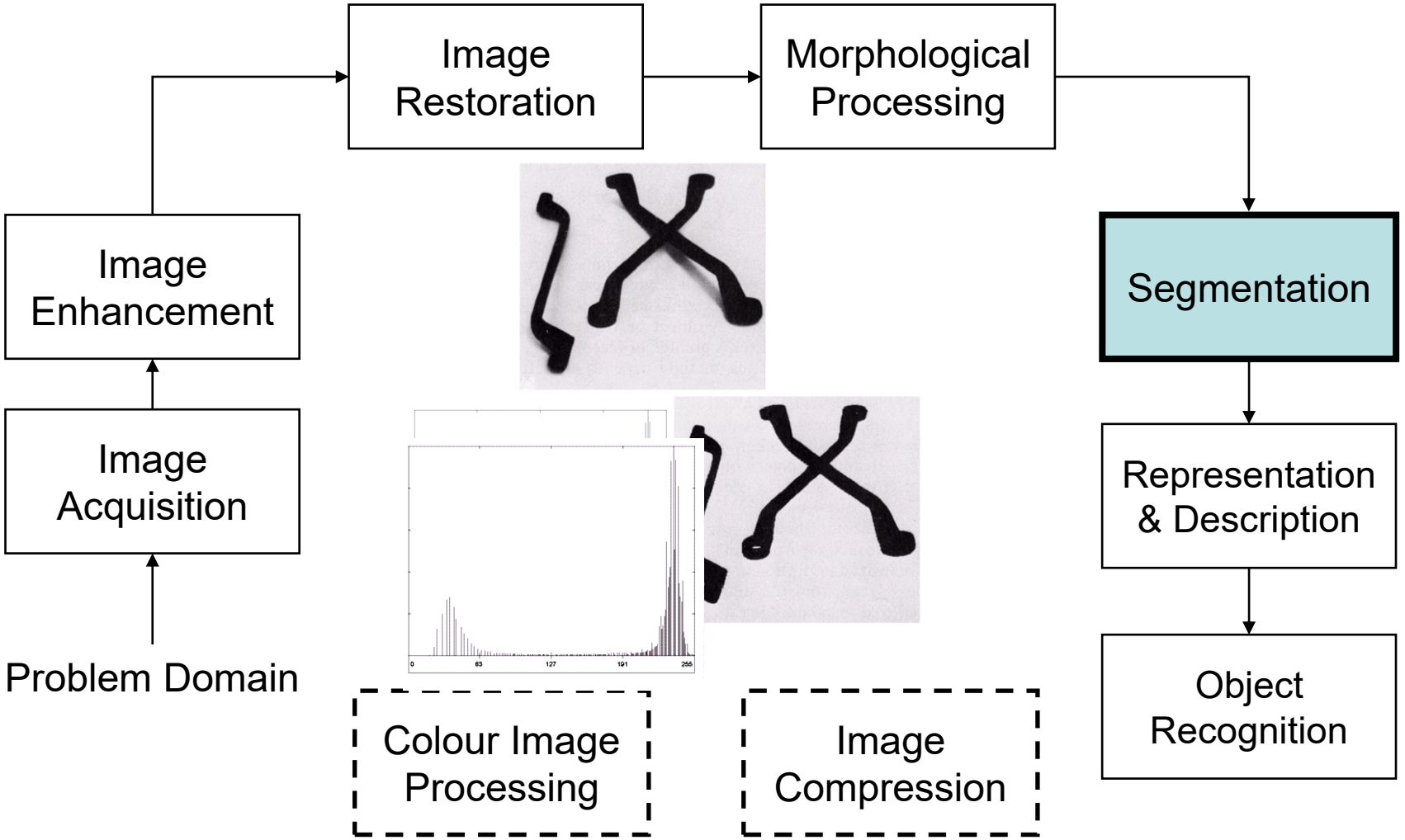


Key Stages in Digital Image Processing: Morphological Processing

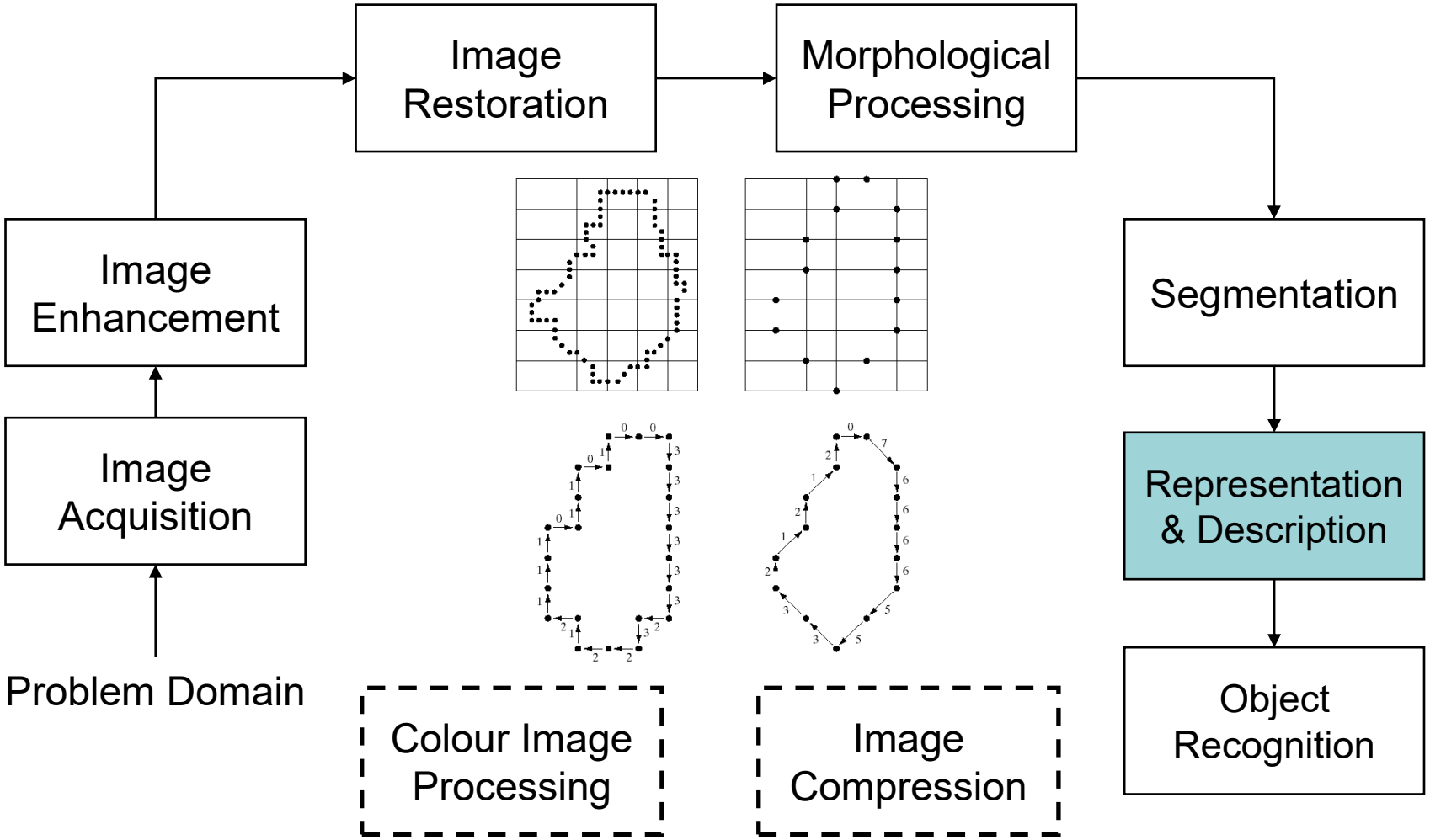


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Key Stages in Digital Image Processing: Segmentation



Key Stages in Digital Image Processing: Representation & Description



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

Key Stages in Digital Image Processing: Object Recognition

Problem Domain

Image Acquisition

Image Enhancement

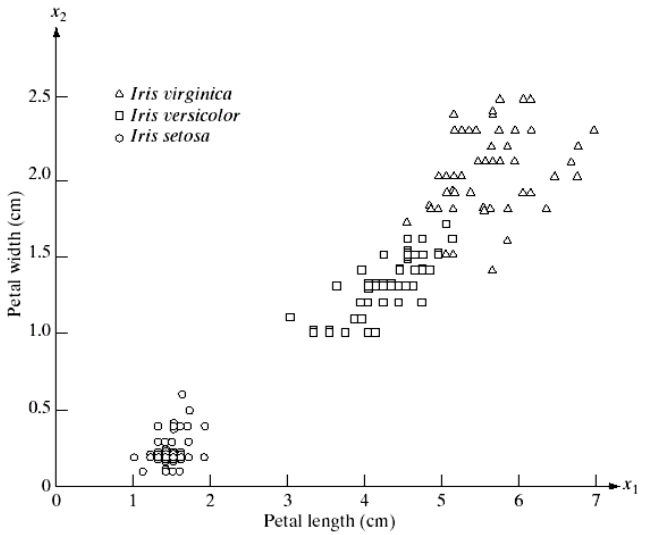
Image Restoration

Morphological Processing

Segmentation

Representation & Description

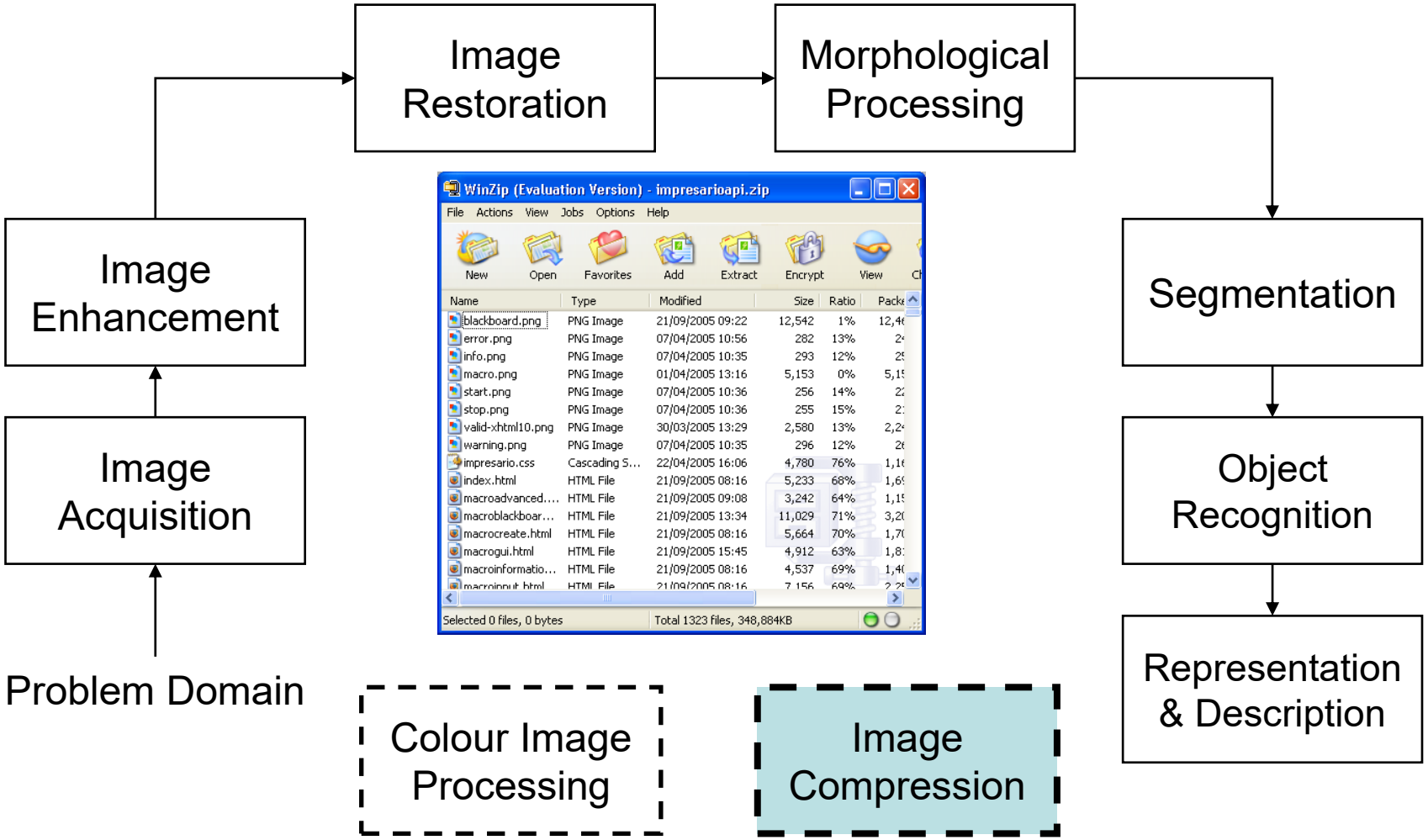
Object Recognition



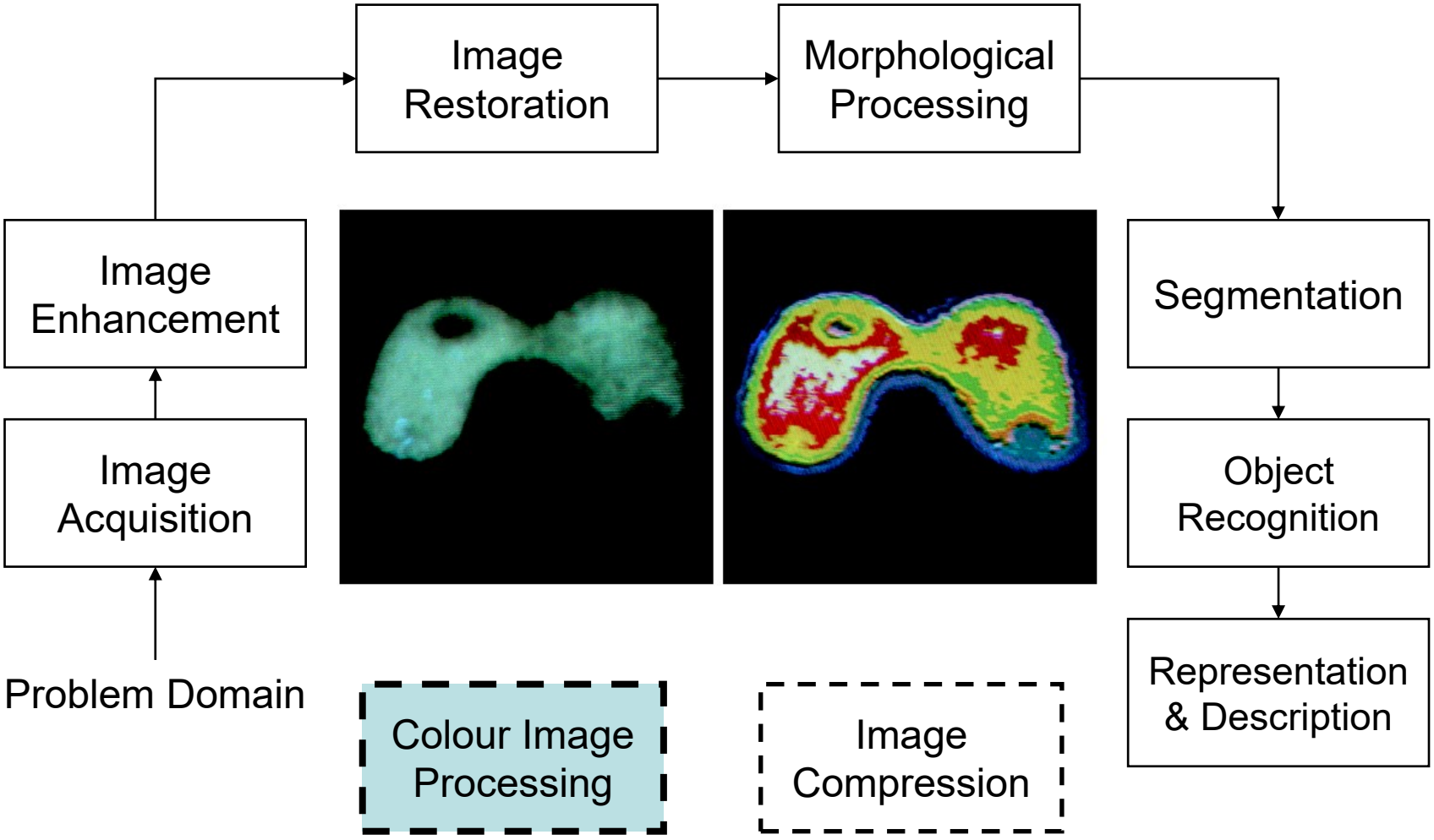
Colour Image Processing

Image Compression

Key Stages in Digital Image Processing: Image Compression



Key Stages in Digital Image Processing: Colour Image Processing



Summary

We have looked at:

- What is a digital image?
- What is digital image processing?
- History of digital image processing
- State of the art examples of digital image processing
- Key stages in digital image processing

Important: Acquire some experience with Python.

Until next Wednesday

Readings

- Book: Ψηφιακή επεξεργασία Εικόνας, Gonzalez - Woods
  - ***Chapter 1***

Practice

- Fundamentals in image processing (basic steps): https://github.com/zengsn/image-processing-python/blob/master/lecture1216.ipynb

- Python NumPy Tutorial (with Jupyter and Colab)
- https://cs231n.github.io/python-numpy-tutorial/