Machine vision

Lecture 4 Part 1

Introduction to image processing.

Stages of image processing

Based on lectures of
Brian Mac Namee
Digital Image Processing.
Revision

Introduction to Image Processing

What is a digital image?

What is digital image processing?

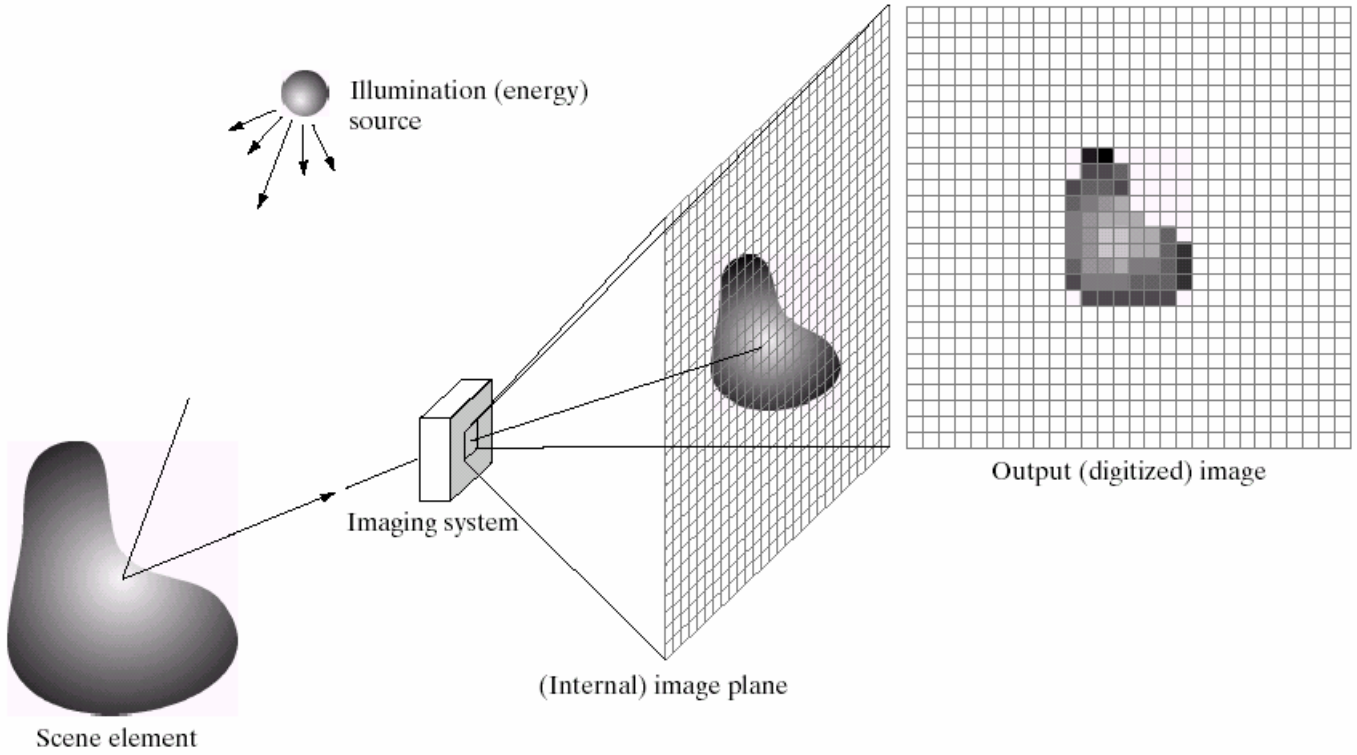
History of digital image processing

Digital image processing application areas

Key stages in digital image processing

What is a Digital Image?

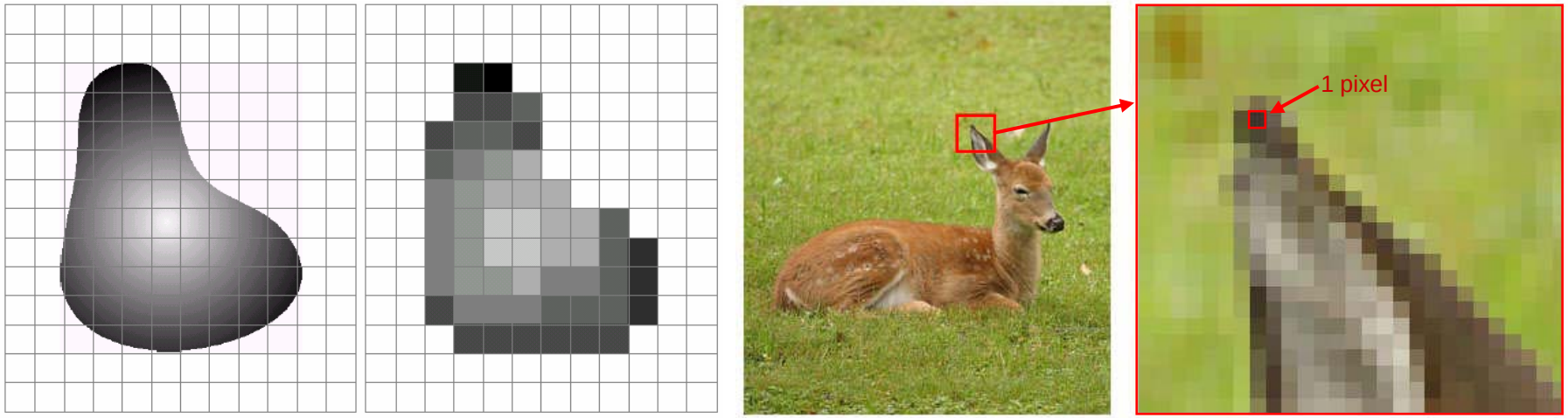
A **digital image** is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels



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?

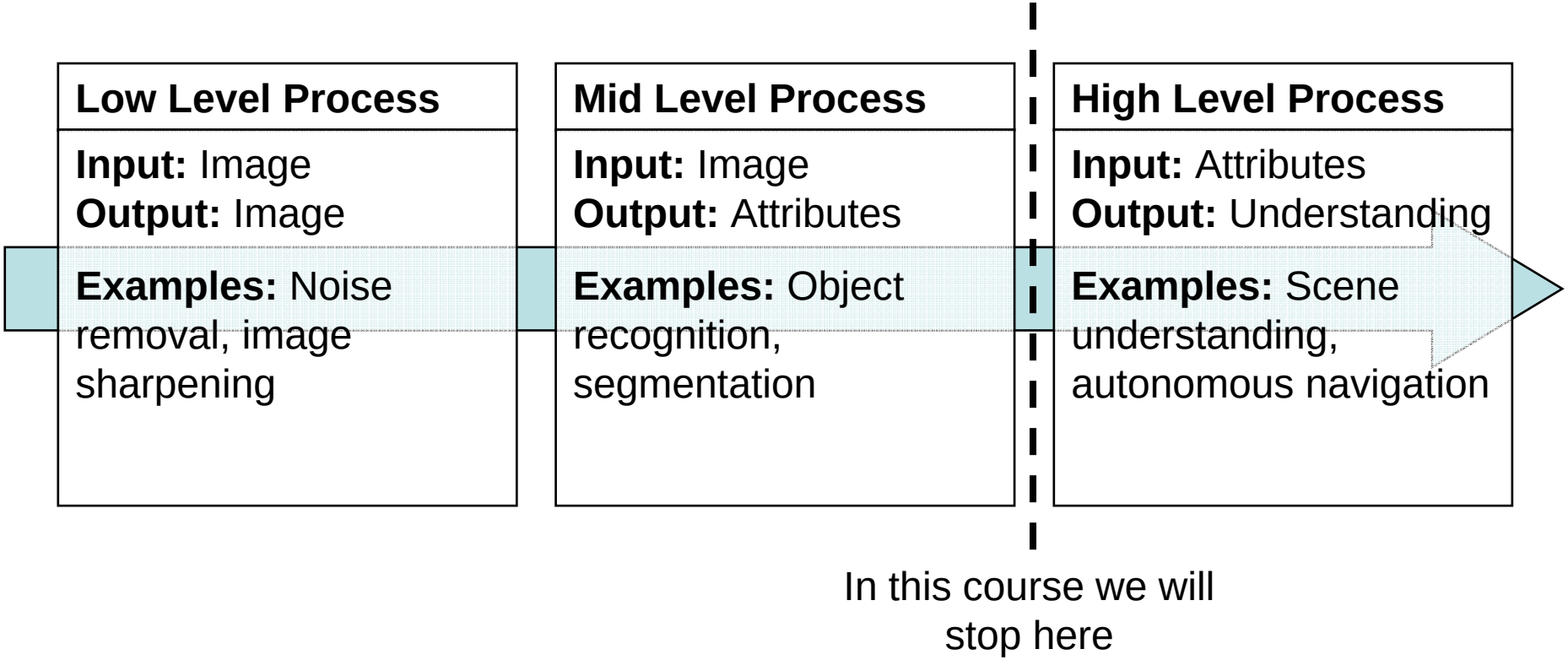
Digital image processing focuses on two major tasks

- 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

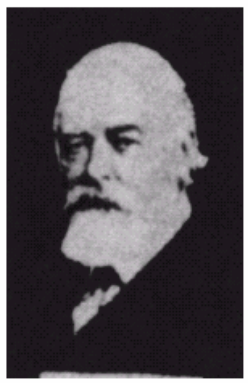
Early digital image

- The Bartlane cable picture transmission service
- Images were transferred by submarine cable between London and New York
- Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer

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



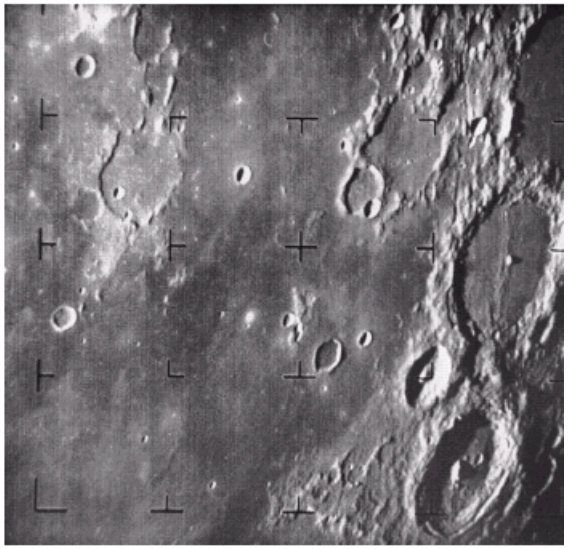
Improved digital image

Early 15 tone digital image

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

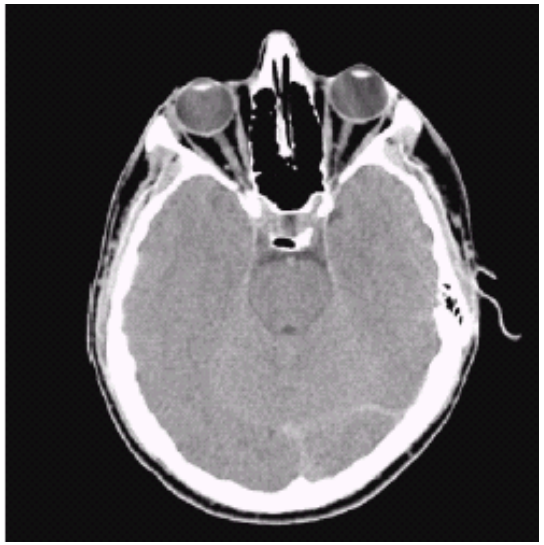


A picture of the moon taken by the Ranger 7 probe minutes before landing

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



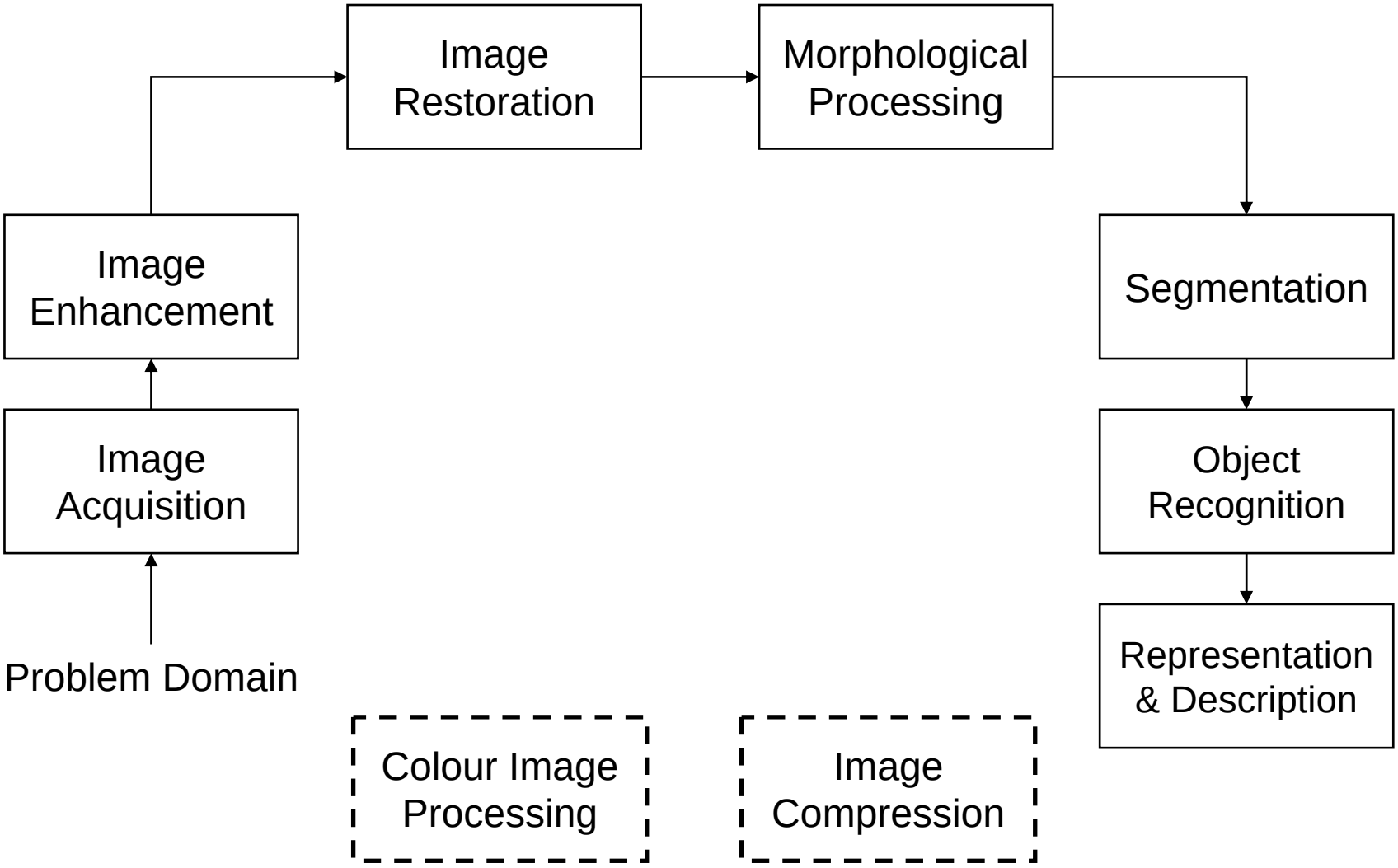
Typical head slice CAT image

History of DIP (cont…)

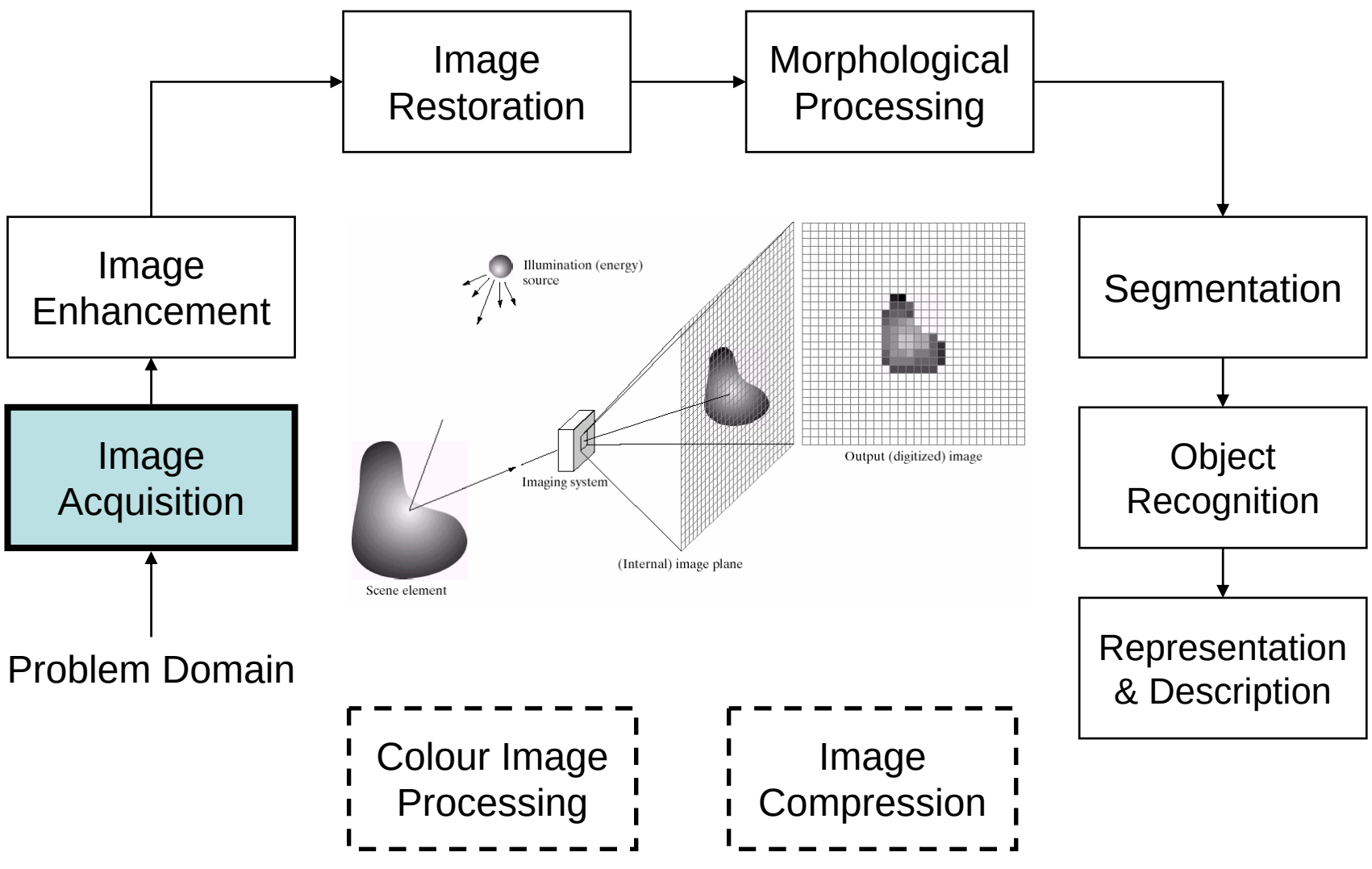
1980s - Today: The use of digital image processing techniques has exploded and they are now used for all kinds of tasks in all kinds of areas

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

Key Stages in Digital Image Processing

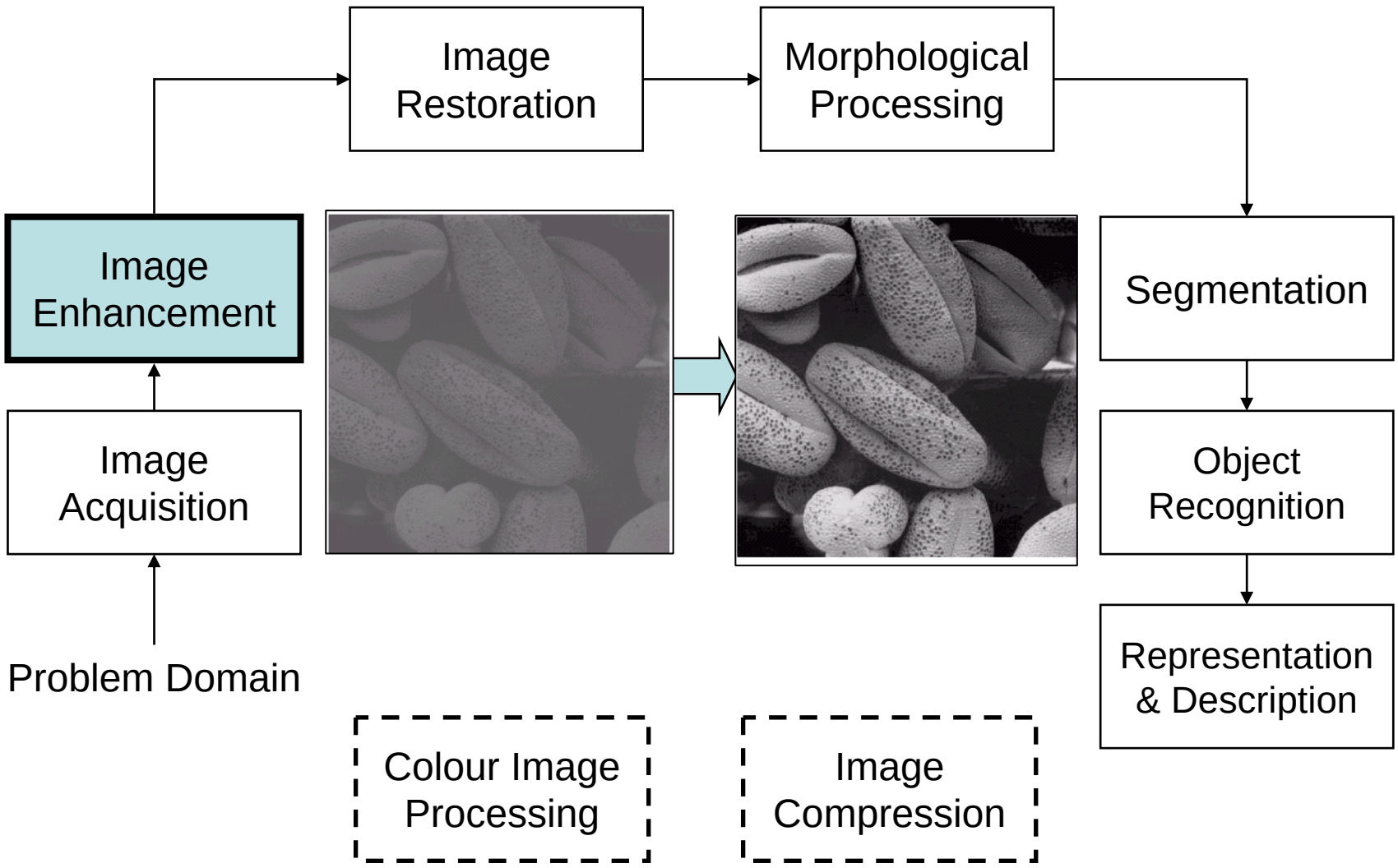


Key Stages in Digital Image Processing: Image Aquisition

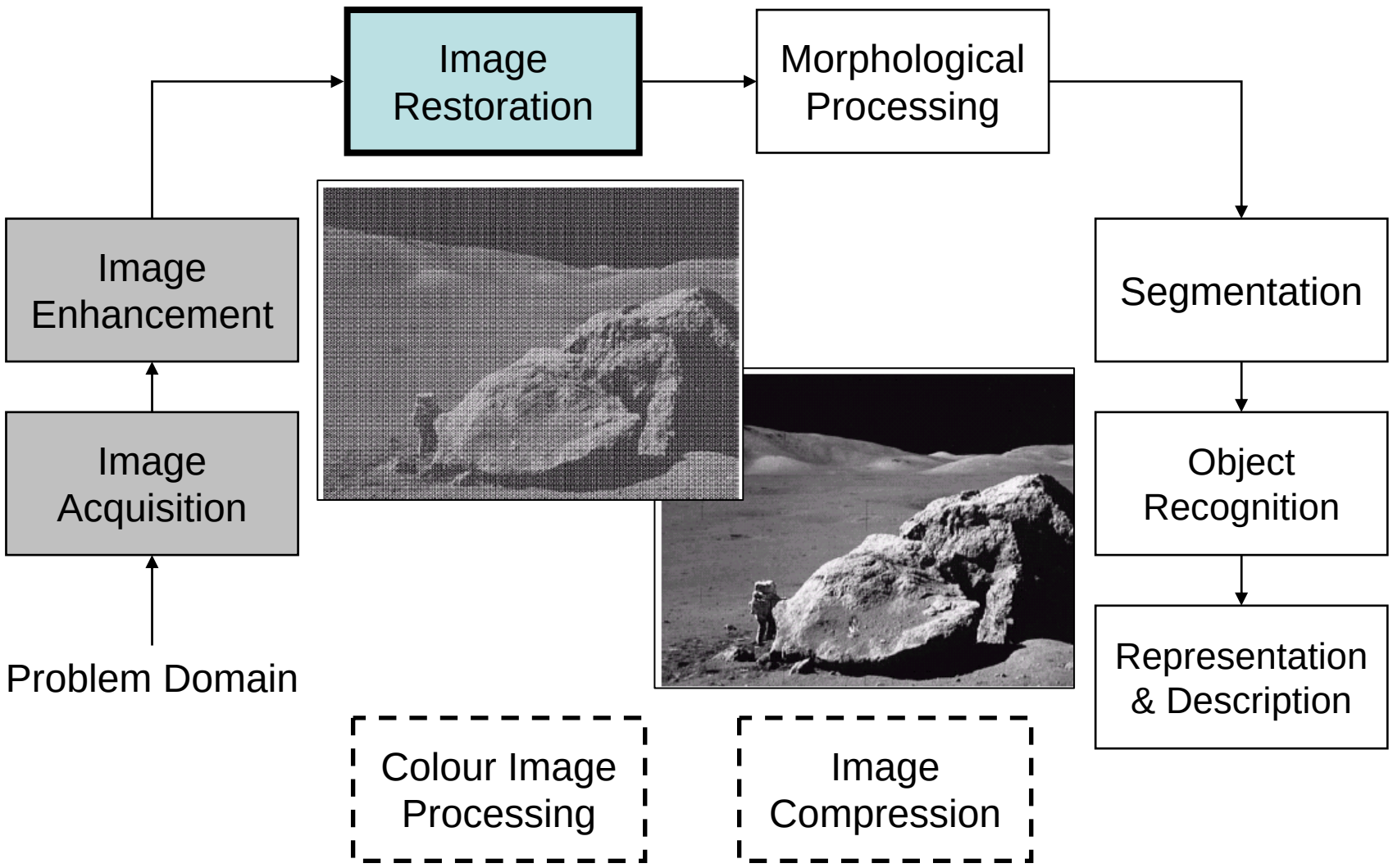


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Key Stages in Digital Image Processing: Image Enhancement

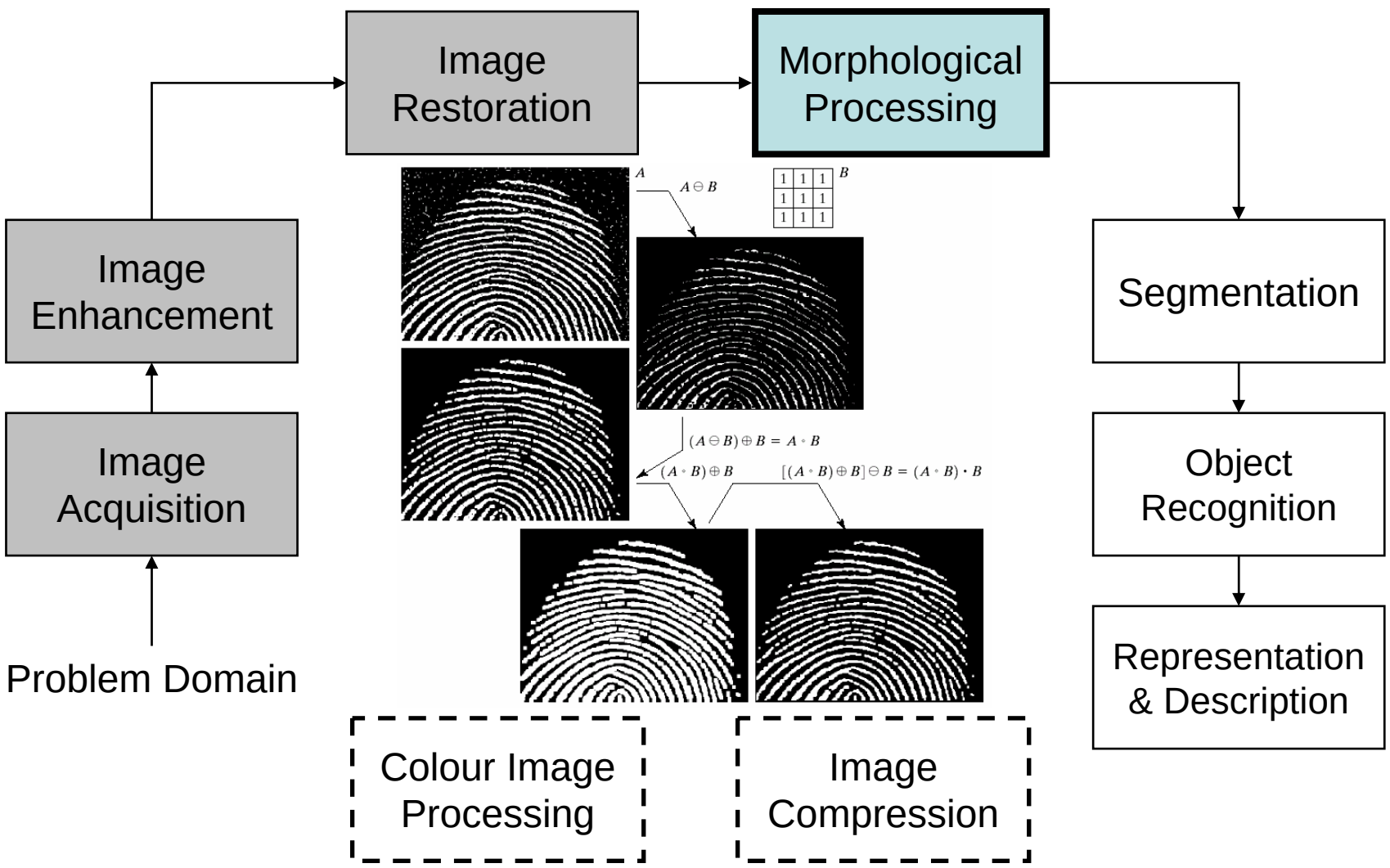


Key Stages in Digital Image Processing: Image Restoration



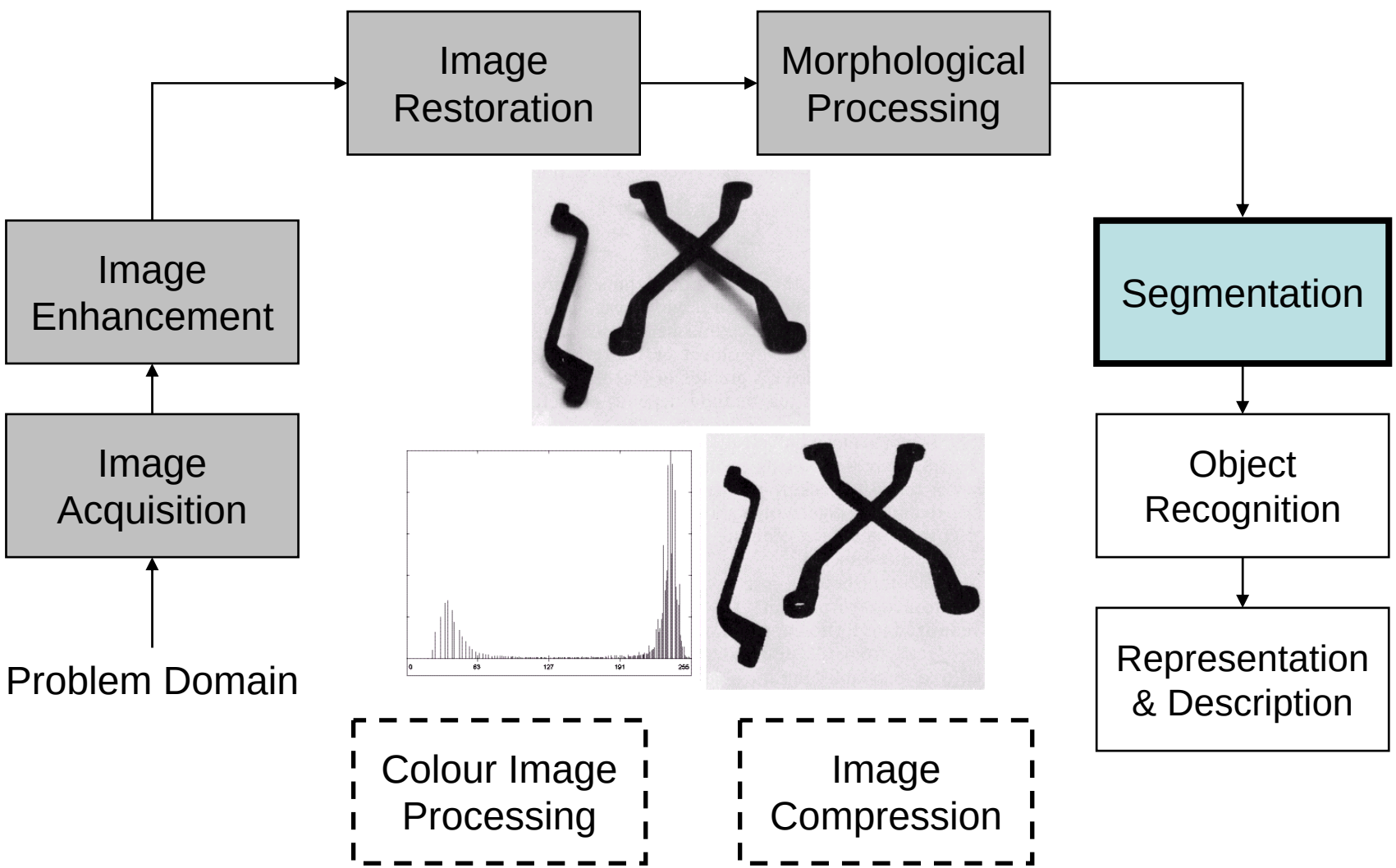
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Key Stages in Digital Image Processing: Morphological Processing



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

Key Stages in Digital Image Processing: Segmentation



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

Key Stages in Digital Image Processing: Object Recognition

Problem Domain

Image Acquisition

Image Enhancement

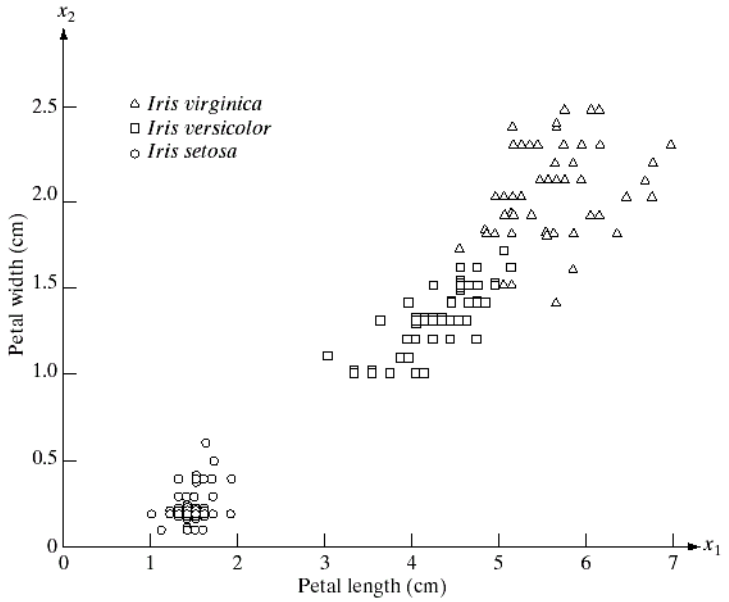
Image Restoration

Morphological Processing

Segmentation

Object Recognition

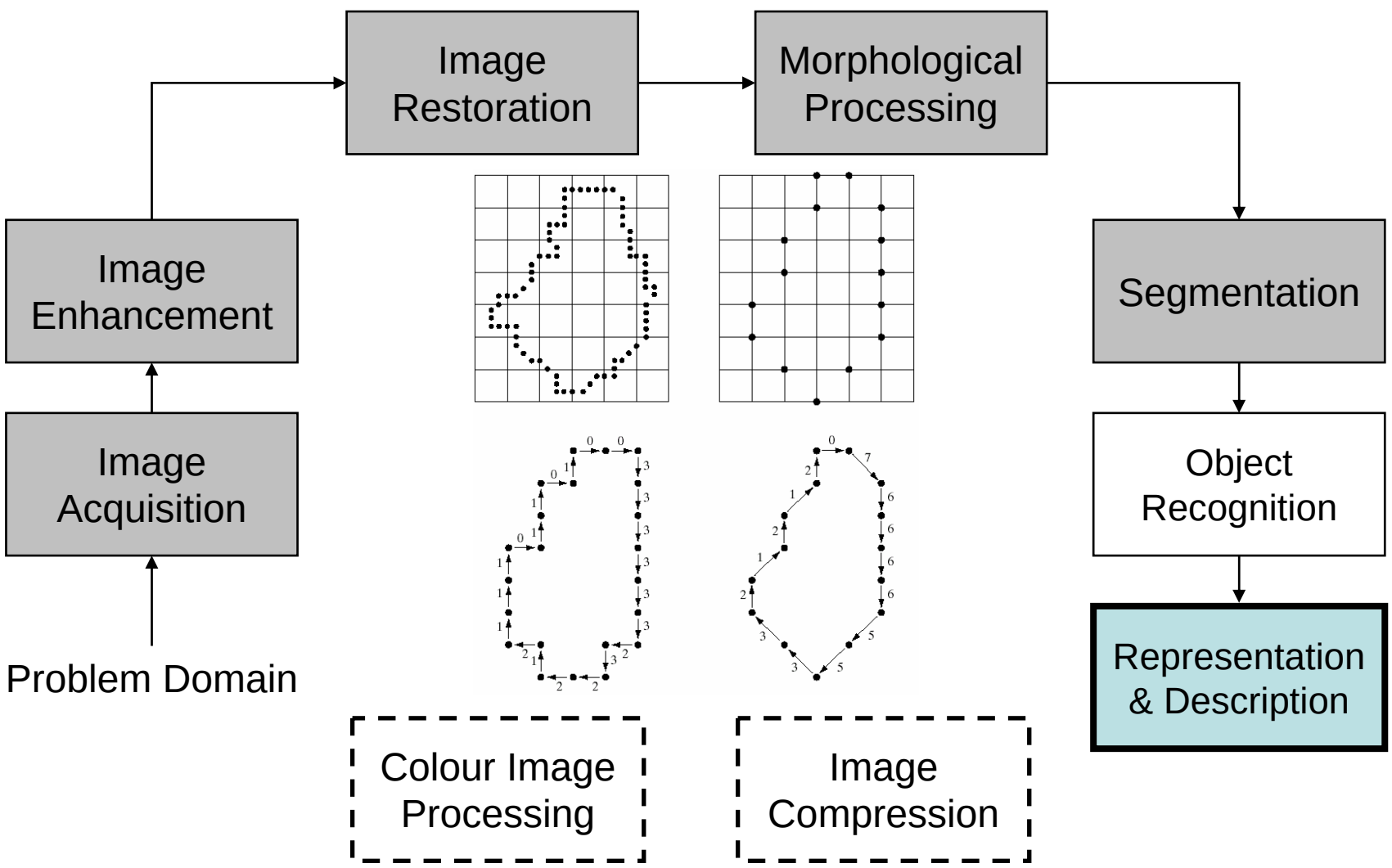
Representation & Description



Colour Image Processing

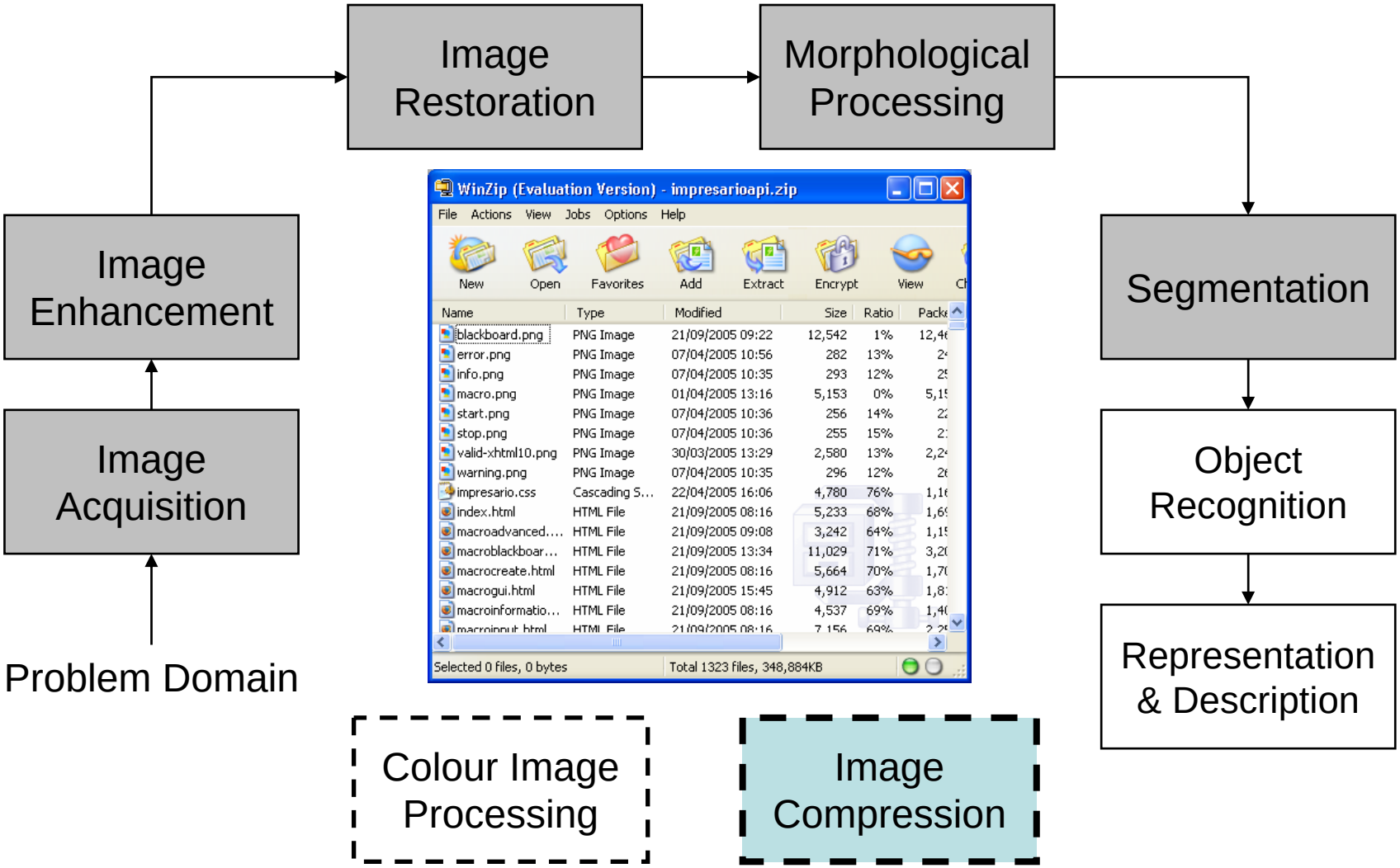
Image Compression

Key Stages in Digital Image Processing: Representation & Description

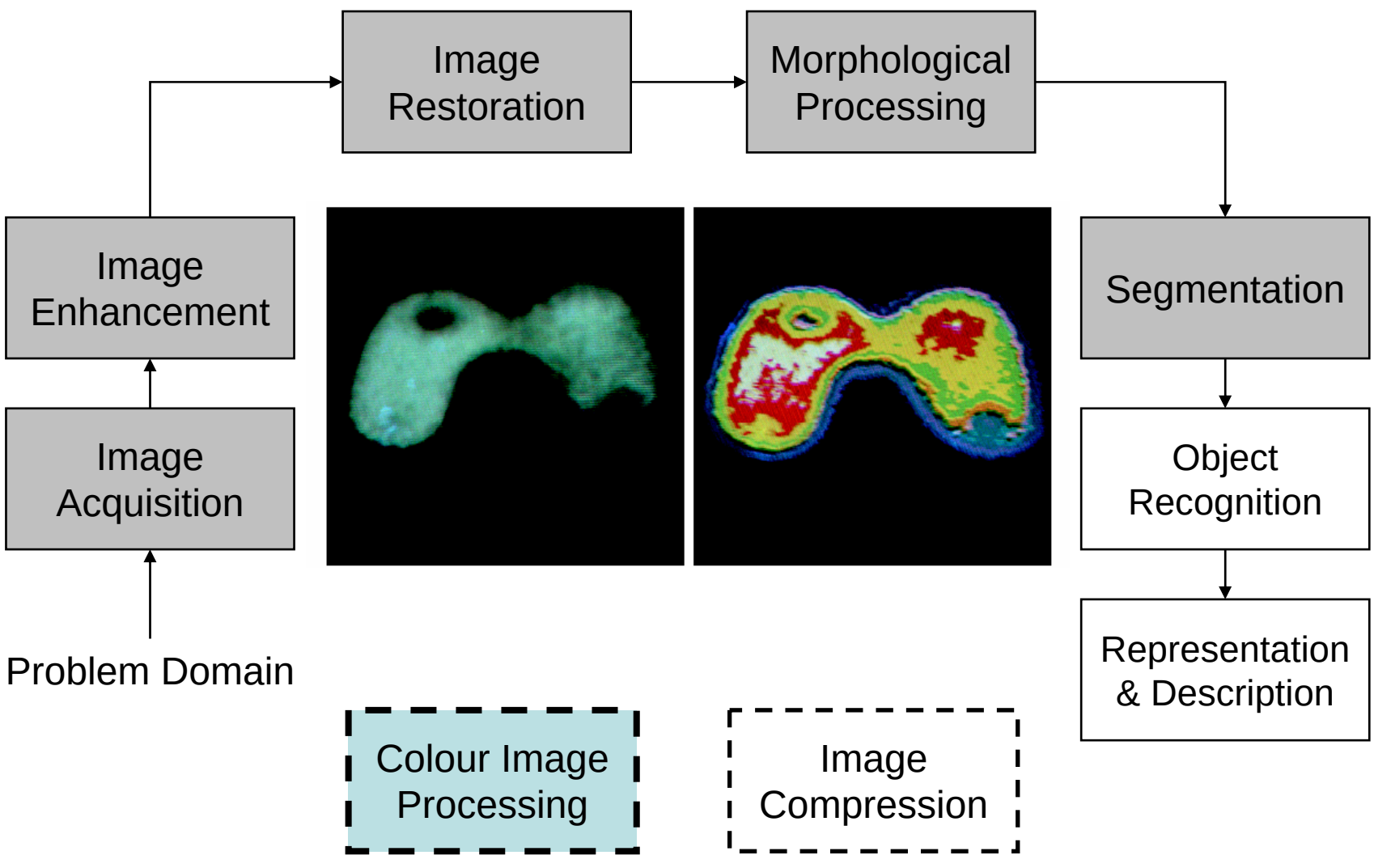


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Key Stages in Digital Image Processing: Image Compression



Key Stages in Digital Image Processing: Colour Image Processing



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

Image Enhancement

Enhancement in the spatial and frequency domains

Point processing

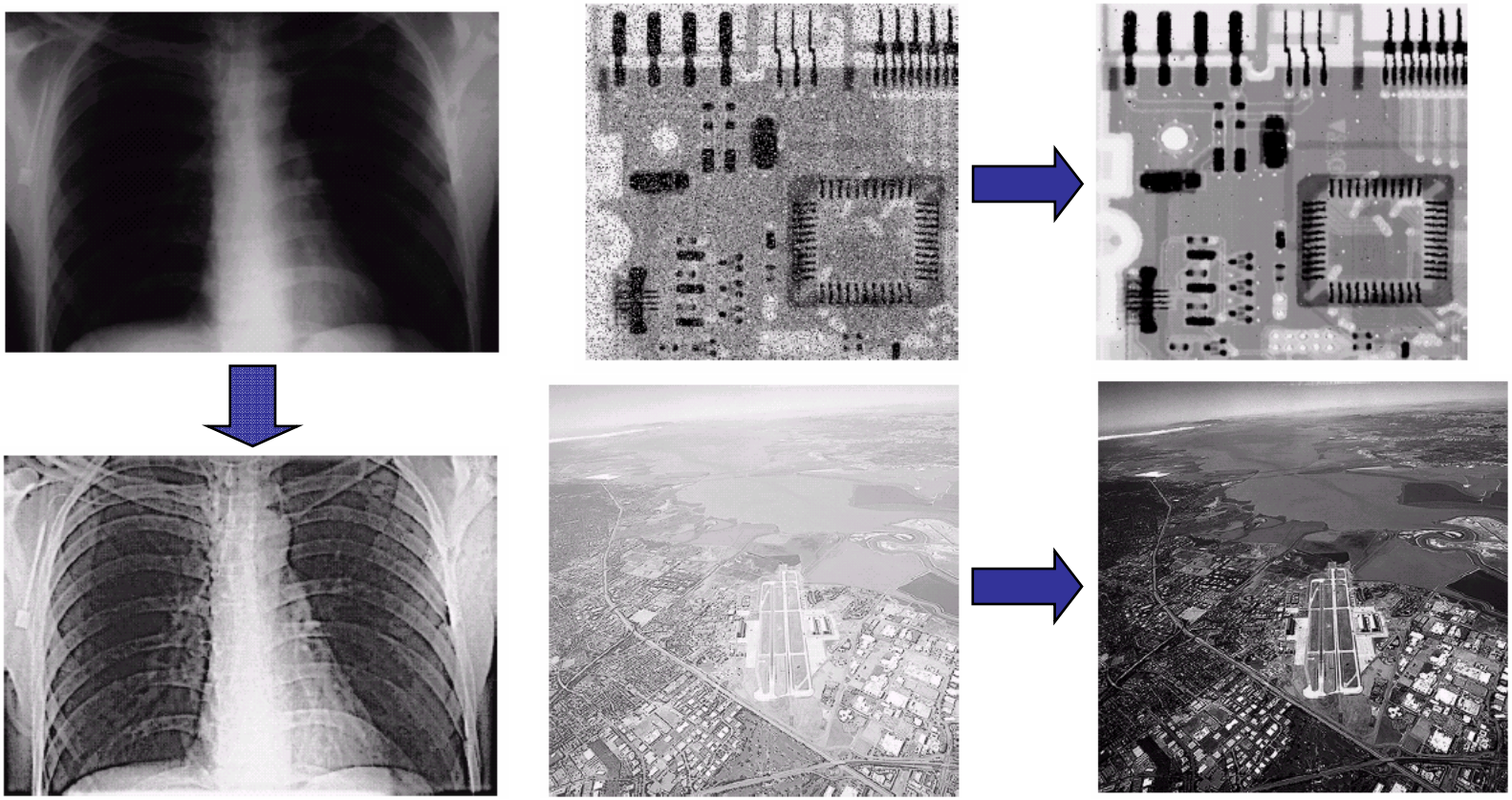
- Log transformation
- Power law transformation

Histograms

- What is an image histogram?
- Histogram equalisation

Examples: Image Enhancement

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

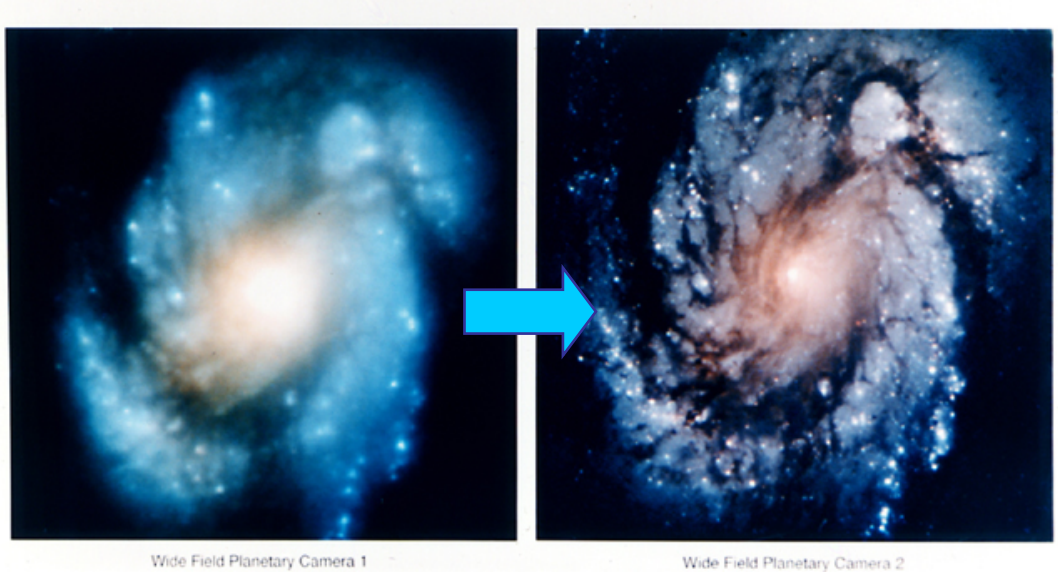


Examples: The Hubble Telescope

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

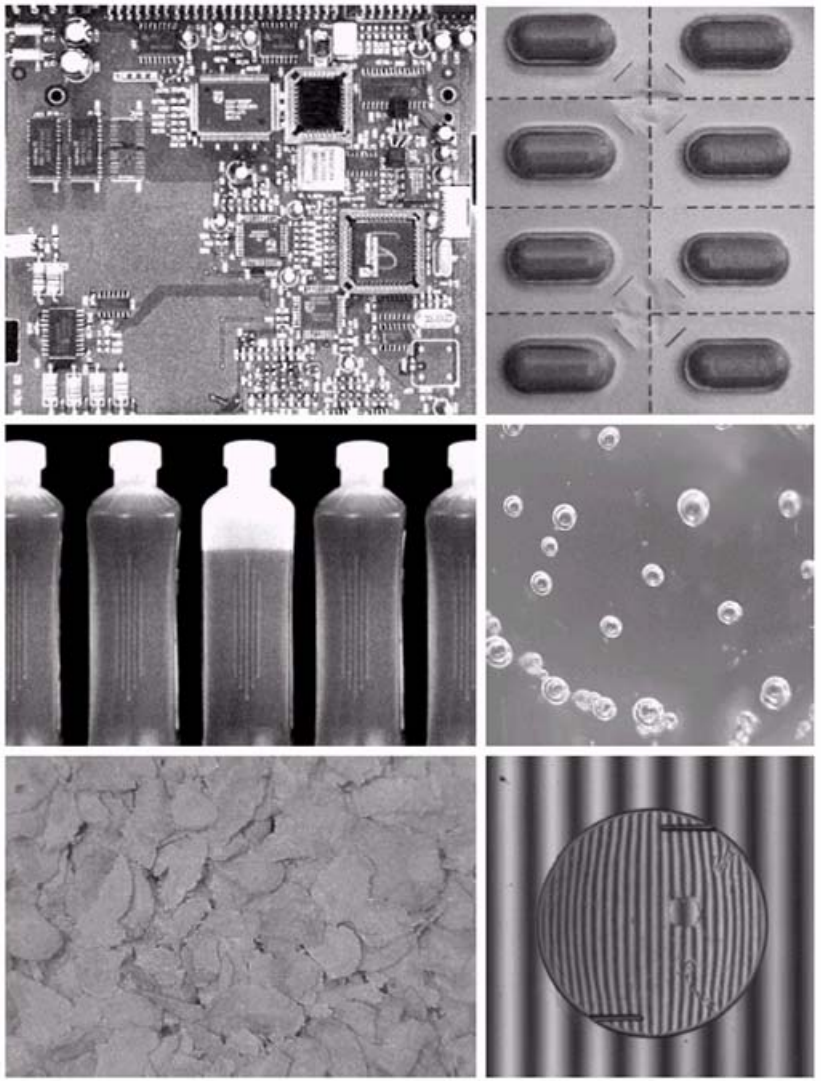
However, an incorrect mirror made many of Hubble's images useless

Image processing techniques were used to fix this



Examples: 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?



Spatial Filtering

- Spatial filtering process
  - Can you explain how it works?
- Smoothing filters
- Problems at image edges during filtering
  - Padding and different padding techniques
- Difference between correlation and convolution

Spatial Filtering (cont…)

Spatial differentiation

– 1st derivative $$\frac{\partial f}{\partial x} = f(x+1) - f(x)$$

– 2nd derivative $$\frac{\partial^2 f}{\partial^2 x} = f(x+1) + f(x-1) - 2f(x)$$

Differentiation based filters

0	1	0
1	-4	1
0	1	0

Laplacian

-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

Sobel

You don’t need to know the maths used to derive these filters

How to do sharpening using these filters

Frequency Domain Filtering

- The Fourier transform
  - Be able to explain the big idea behind it
  - You do not need to know the maths for it
  - Importance of the inverse Fourier transform
- How filtering in the frequency domain works
- Low pass filters
  - What are they for?
  - Ideal low pass filter
  - Butterworth low pass filter
  - Gaussian low pass filter

You don't need to know the equations for these, but you must be able to draw them and explain what they do

Frequency Domain Filtering (cont…)

- High pass filters
  - What are they for?
  - Ideal high pass filter
  - Butterworth high pass filter
  - Gaussian high pass filter

You don't need to know the equations for these, but you must be able to draw them and explain what they do

- The Fast Fourier Transform and its importance

Image Restoration: Noise Removal

Image enhancement vs. image restoration

What is meant by noise removal?

What is meant by a noise model?

$$g(x, y) = f(x, y) + \eta(x, y)$$

– Common noise models

- Gaussian
- Rayleigh
- Erlang
- Exponential
- Uniform
- Impulse (salt & pepper)

Filtering to remove noise

– Simple mean filter

– Other mean filters

Image Restoration: Noise Removal (cont…)

- Order statistics filters
  - Median filter
  - Max and min filter
  - Midpoint filter
  - Alpha trimmed mean filter
- Removing noise in the frequency domain
  - Particularly good for removing periodic noise
  - Band reject filters
    - Ideal band reject filter
    - Butterworth band reject filter
    - Gaussian band reject filter

Image Segmentation: Thresholding

The segmentation problem

Importance of good thresholding

Problems that can arise with thresholding

The basic global thresholding algorithm

Single value thresholding vs. multiple value thresholding

Basic adaptive thresholding

Morphological Image Processing

Basic morphological concepts and operations

- Hitting, fitting and missing
- Erosion and dilation
- Opening and closing

Morphological algorithms

- Boundary extraction
- Region filling

Summary

There are two main jobs in image processing

- Enhancement of images for human viewing
- Preparation of images for machine processing

Both of these are hard areas to work in!

The subject of machine vision is huge, growing and really interesting