Digital Image Processing: Introduction

By Dr. Hafeez ur Rehman

Taken and Modified from

Brian Mac Namee

Brian.MacNamee@comp.dit.ie

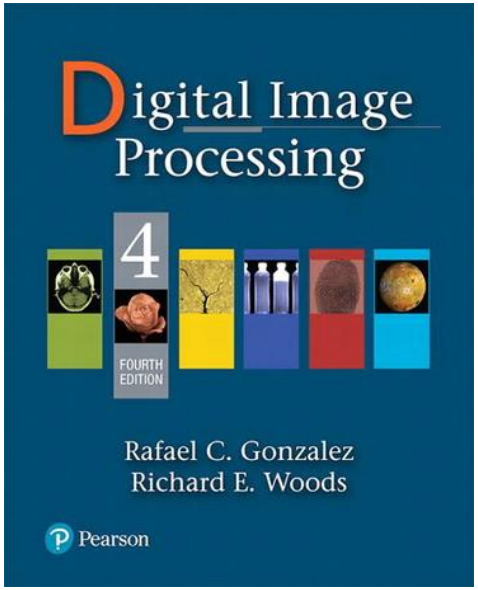
Introduction

“One picture is worth more than ten thousand words”

By Confucius

Soon you will realize that it’s an understatement…

References



"Digital Image Processing", Rafael C. Gonzalez & Richard E. Woods, Addison Wesley, Pearson Education, 4th Edition, 2021.

- Much of the material that follows is taken from this book

Course Outline

Why image processing? The human visual system, electromagnetic system, reflection based imaging, pixels, image representation, sampling, quantization, image formation, point operations, neighborhood based operations, fourier theory, image filtering in spatial and frequency domain, image restoration, image registration, morphological operations, image segmentation, pattern recognition.

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

Image Formation: Reflected Light

The colours that we perceive are determined by the nature of the light reflected from an object

For example, if white light is shone onto a green object most wavelengths are absorbed, while green light is reflected from the object

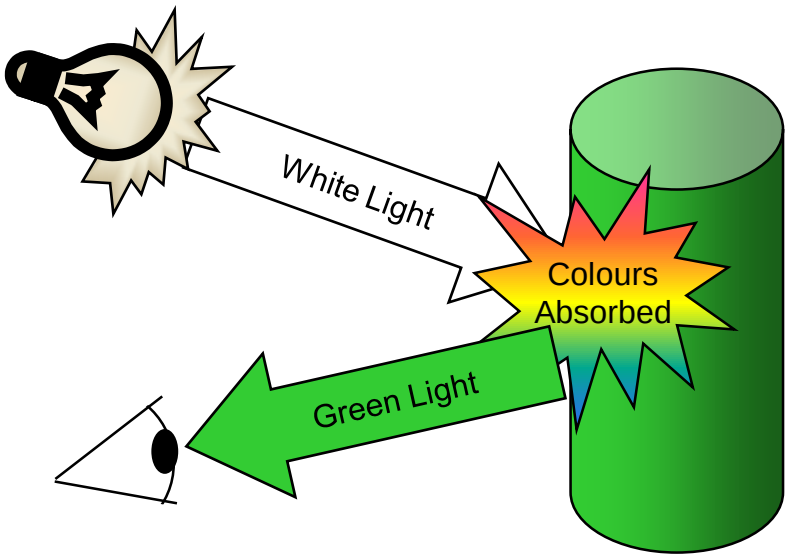


Image Formation Model

Amplitude values:

$$f(x,y) = i(x,y)*r(x,y)+n(x,y)$$

$0<f(x,y)<\infty$ Intensity – proportional to energy radiated by a physical source

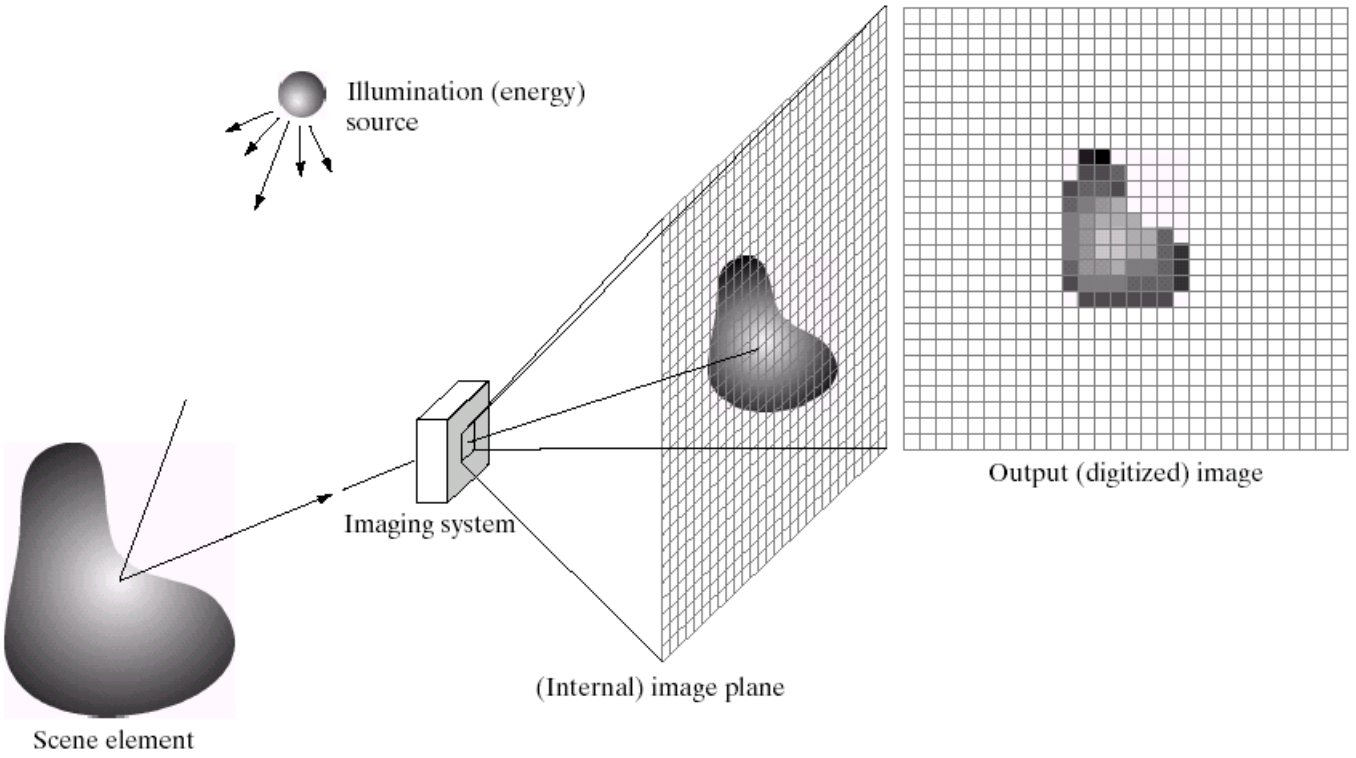
$0<i(x,y)<\infty$ **illumination**

$0<r(x,y)<1$ **reflectance**

$n(x,y)$ **noise**

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

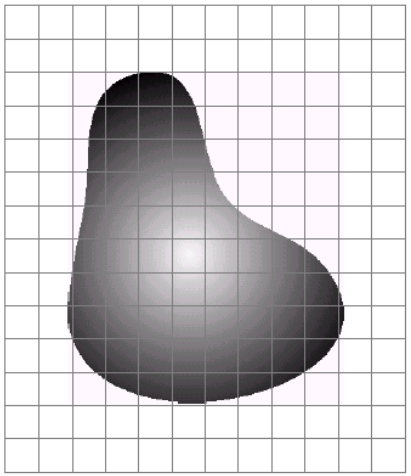


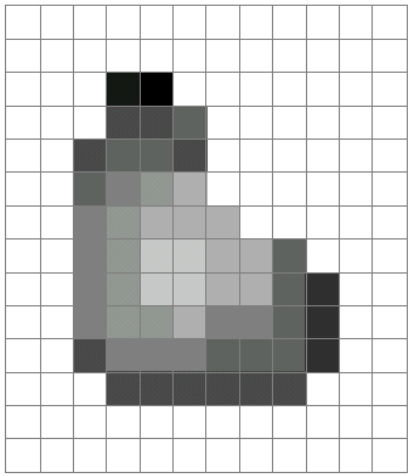
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

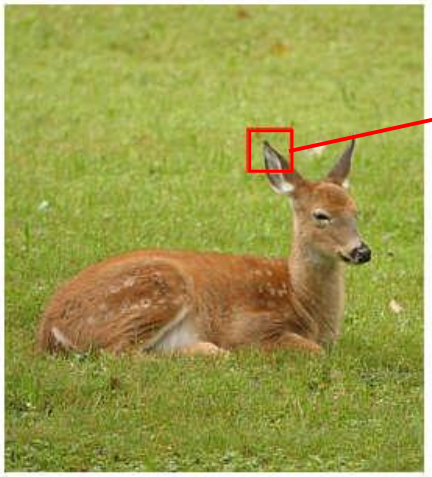
What is a Digital Image? (cont…)

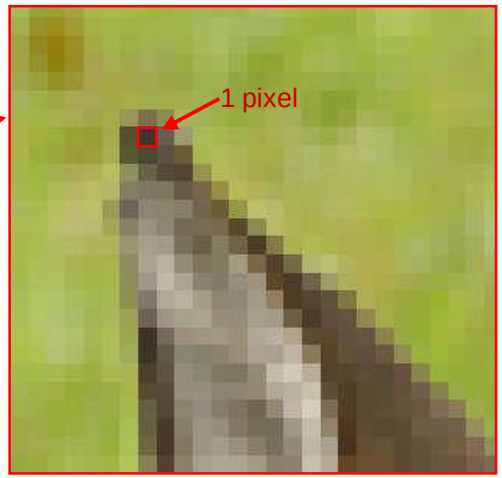
Pixel values typically represent gray levels, colours, heights, opacities etc.

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









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

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?

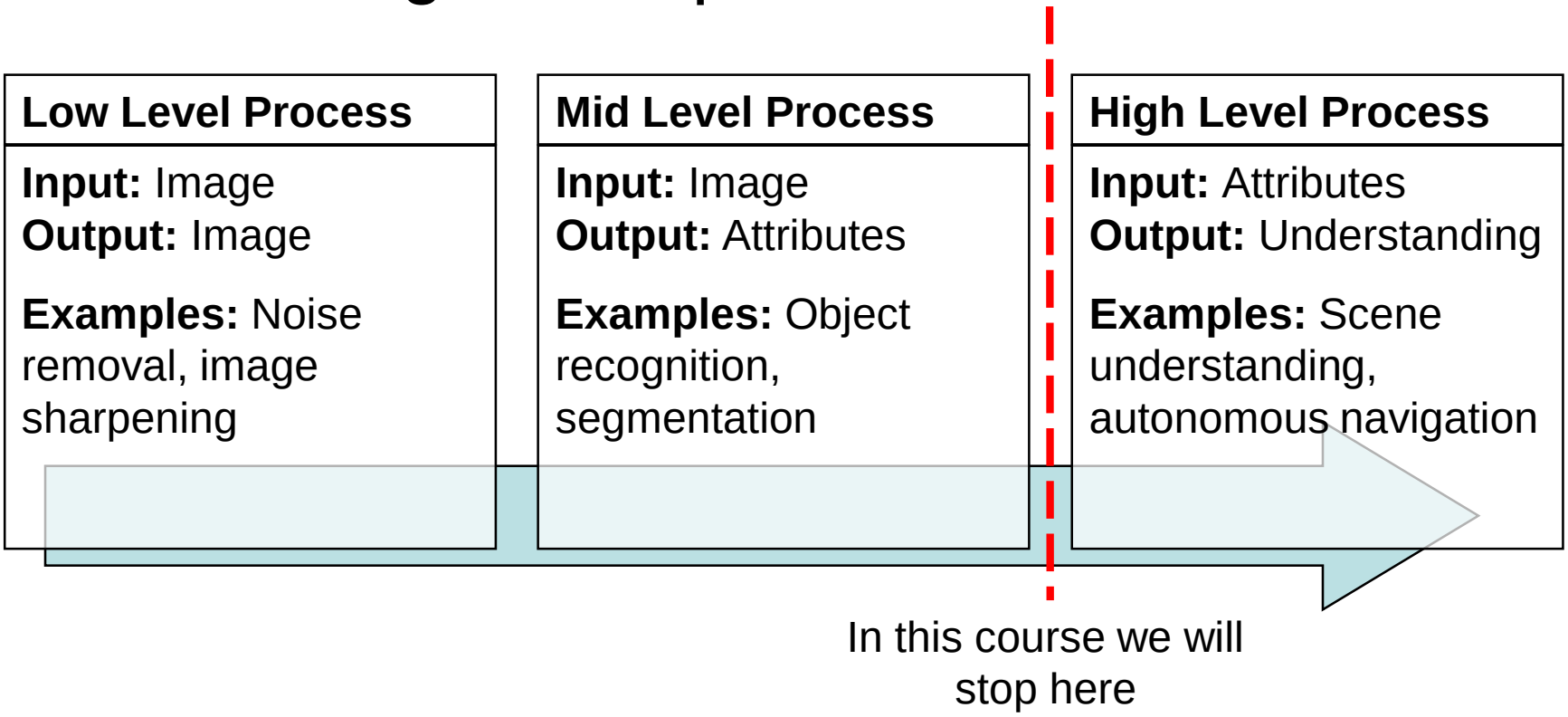
Digital image processing focuses on two major tasks:

1. Improvement of pictorial information for human interpretation
2. 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

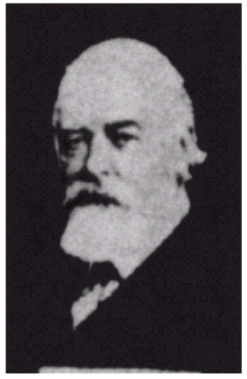
- The **Bartlane cable picture** transmission service
- Images were transferred by submarine cable between London and New York
- Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer

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

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

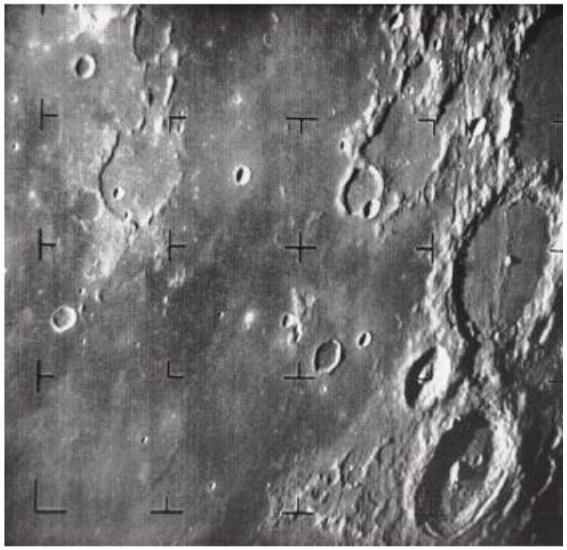
Early 15 tone digital image

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



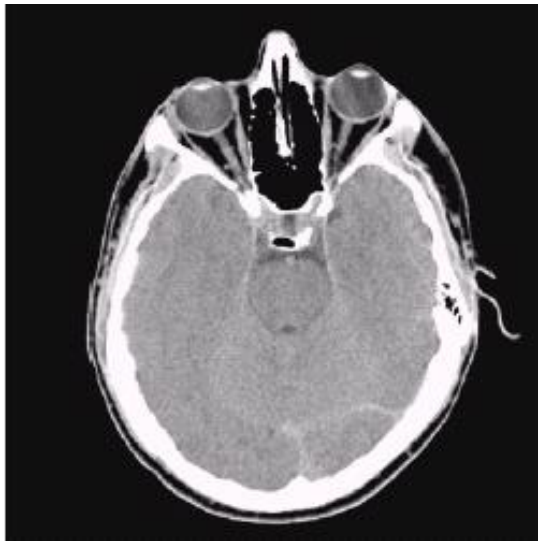
A picture of the moon taken by the Ranger 7 probe minutes before landing

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)

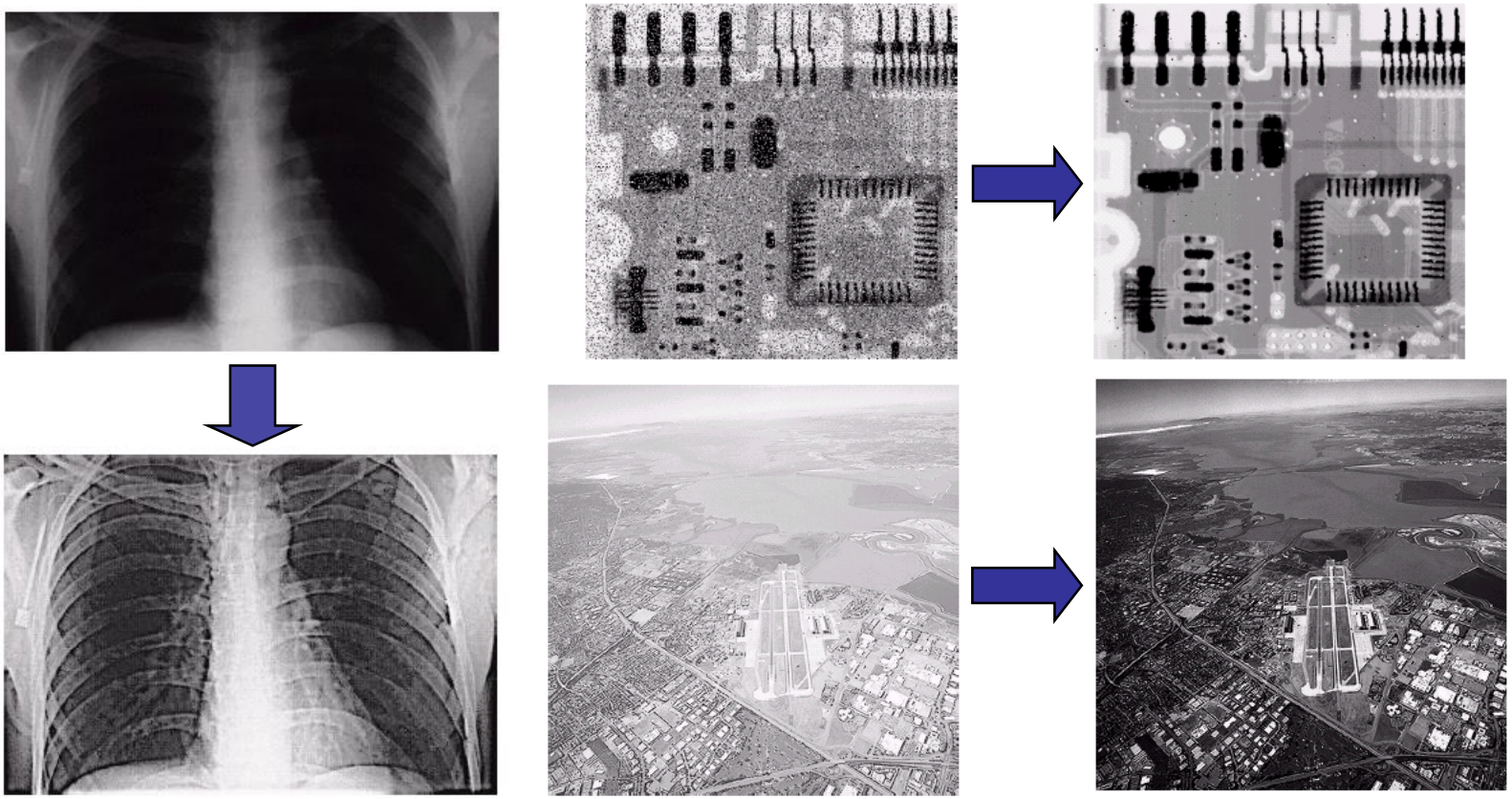
History of DIP (cont…)

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

Examples: 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)

Examples: Artistic Effects

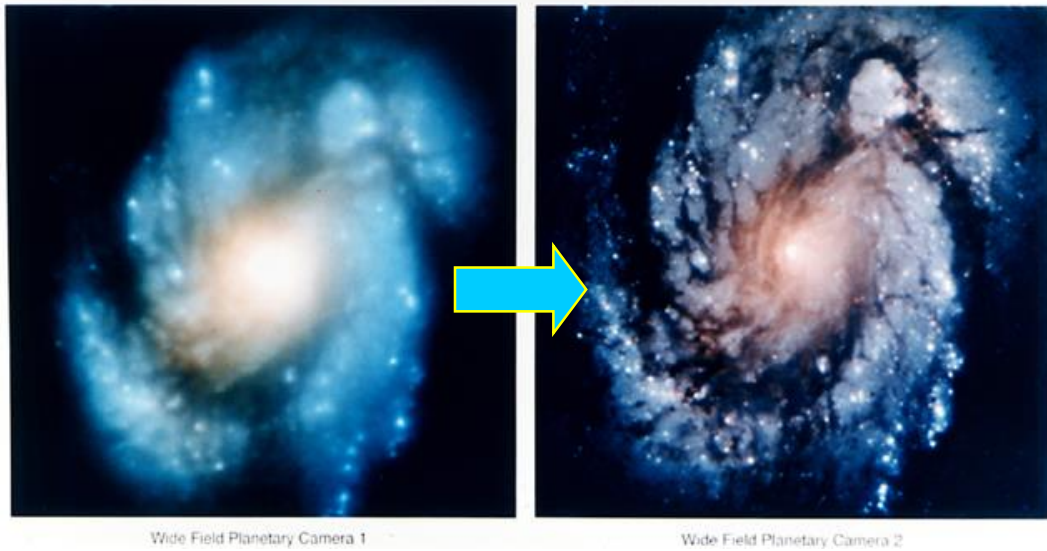
Artistic effects are used to make images more visually appealing, to **add special effects** and to make **composite images**

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

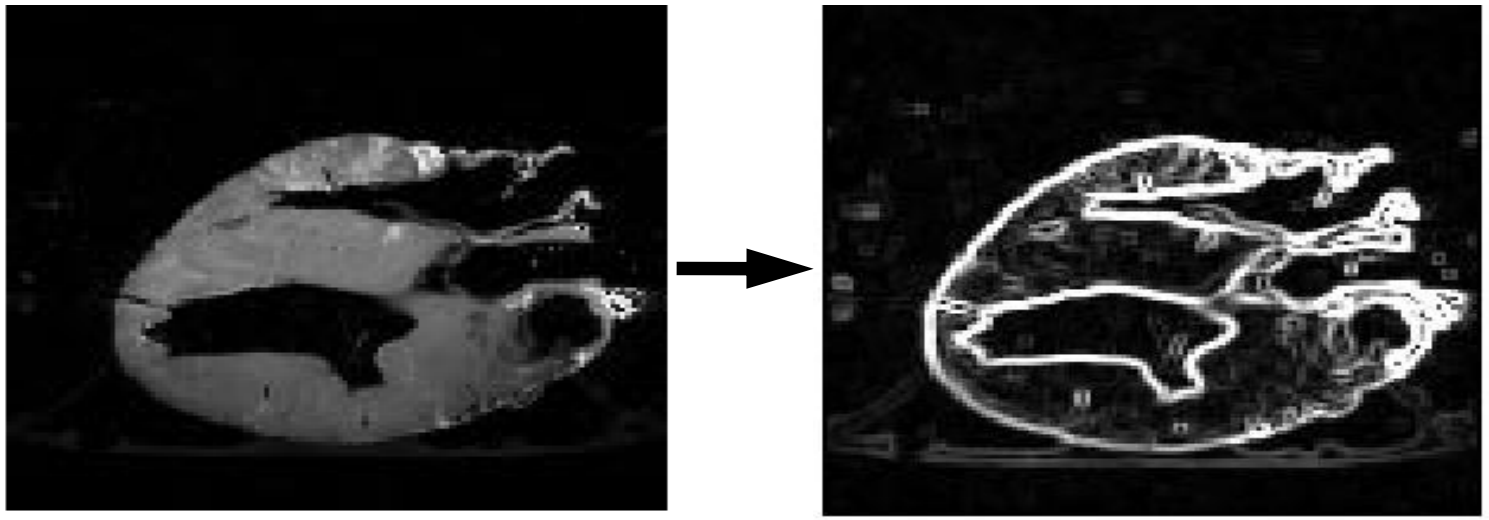
Image processing techniques were used to fix this



Examples: Medicine

Take slice from MRI scan of canine heart, and find boundaries between types of tissue

- Image with gray levels representing tissue density
- Use a suitable filter to highlight edges



Original MRI Image of a Dog Heart

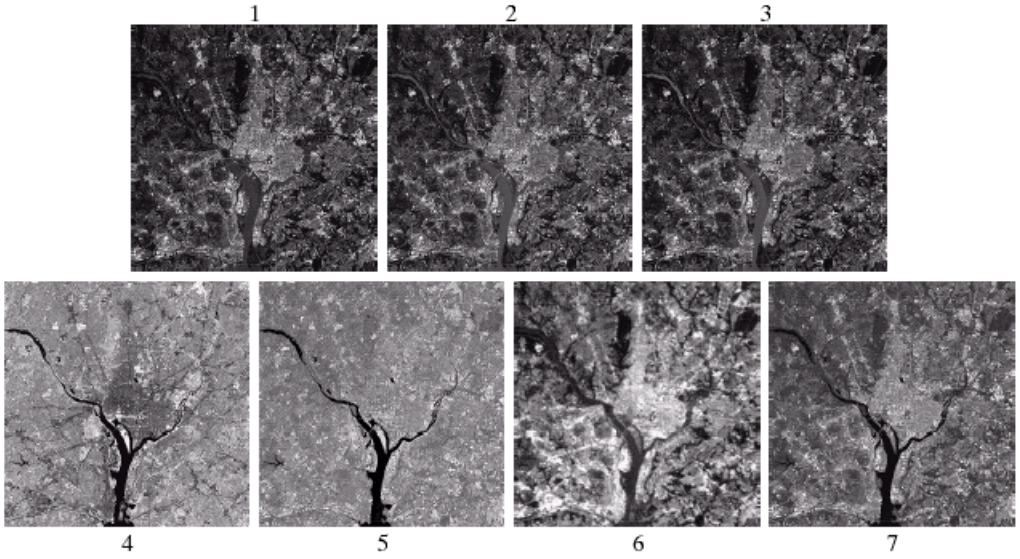
Edge Detection Image

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

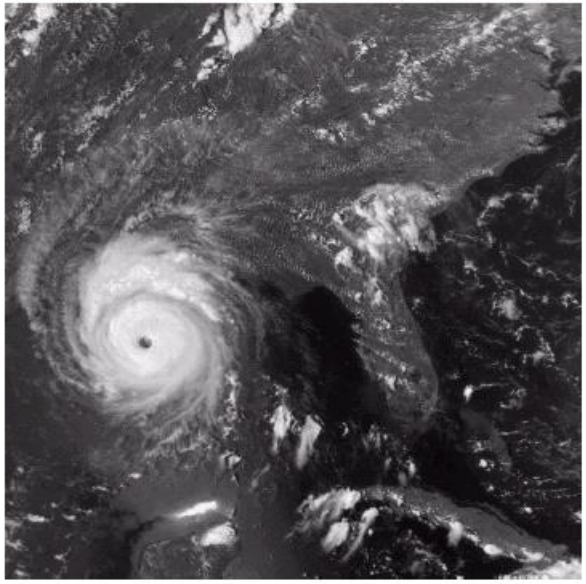
Examples: GIS

Geographic Information Systems

- Digital image processing techniques are used extensively to manipulate satellite imagery
- Terrain classification
- Meteorology



Infrared imaging

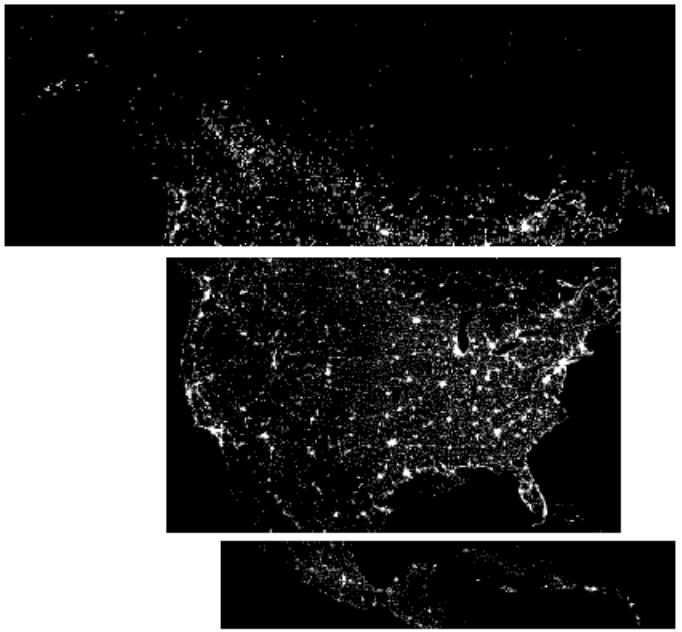


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Examples: GIS (cont…)

Night-Time Lights of the World data set

- Global inventory of human settlement
- Not hard to imagine the kind of analysis that might be done using this data



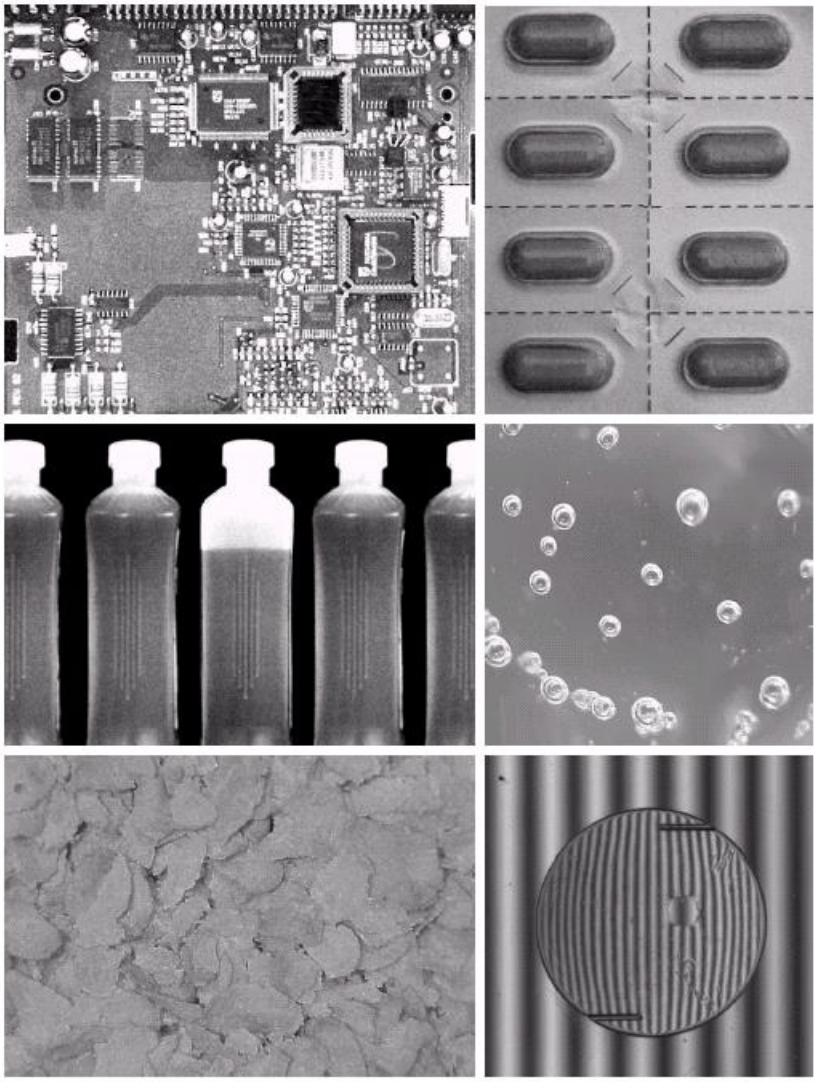
Visible + Infrared imaging

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

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?

X-Ray imaging

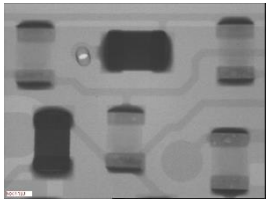


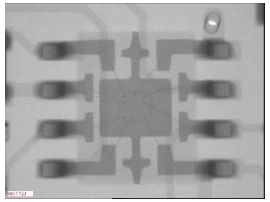
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

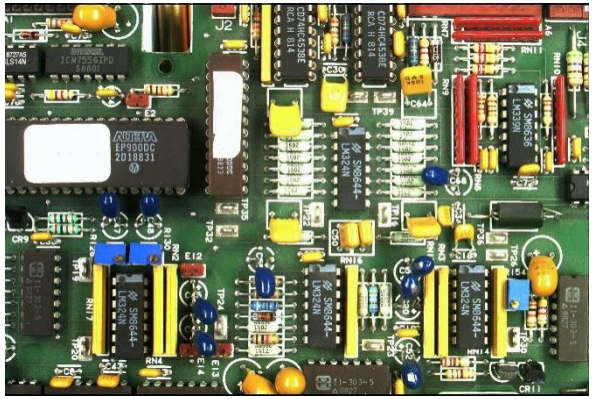
Examples: PCB Inspection

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



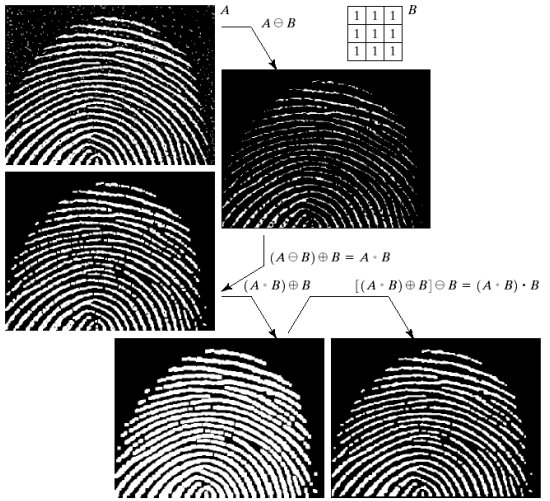




Examples: Law Enforcement

Image processing techniques are used extensively by law enforcers

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

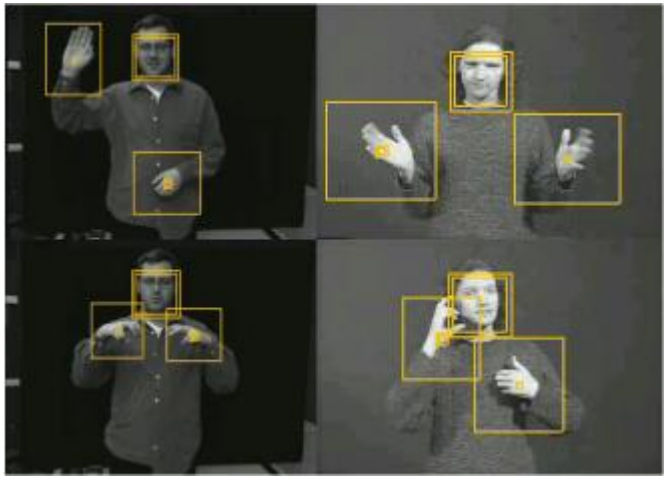


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Examples: HCI

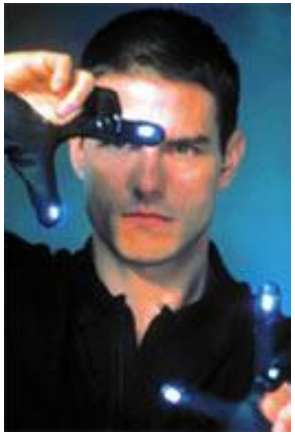
Try to make human computer interfaces more natural

- Face recognition
- Gesture recognition

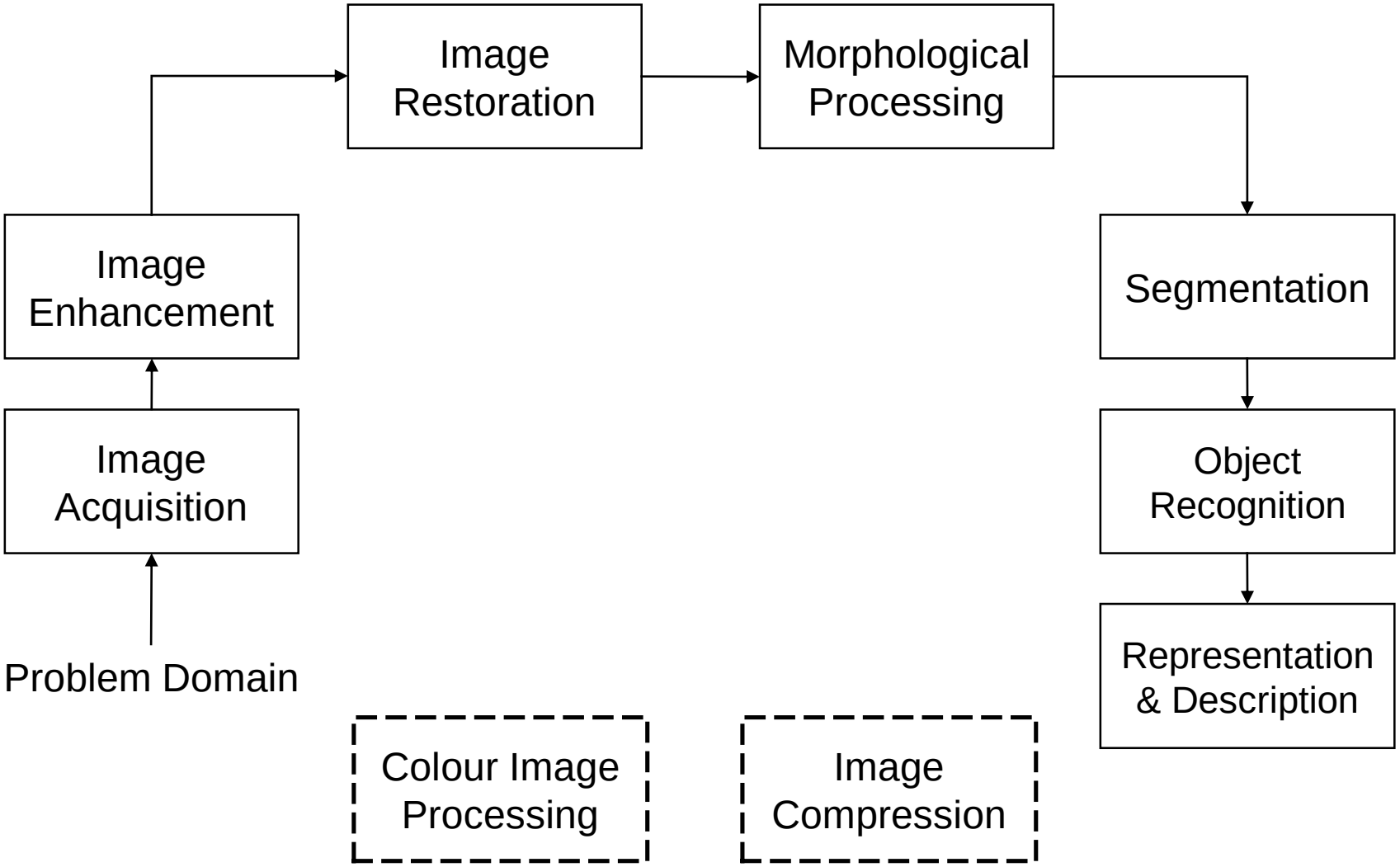


One application is the smart stay?

These tasks can be extremely difficult



Key Stages in Digital Image Processing



Key Stages in Digital Image Processing: Image Aquisition

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

Problem Domain

Image Acquisition

Image Enhancement

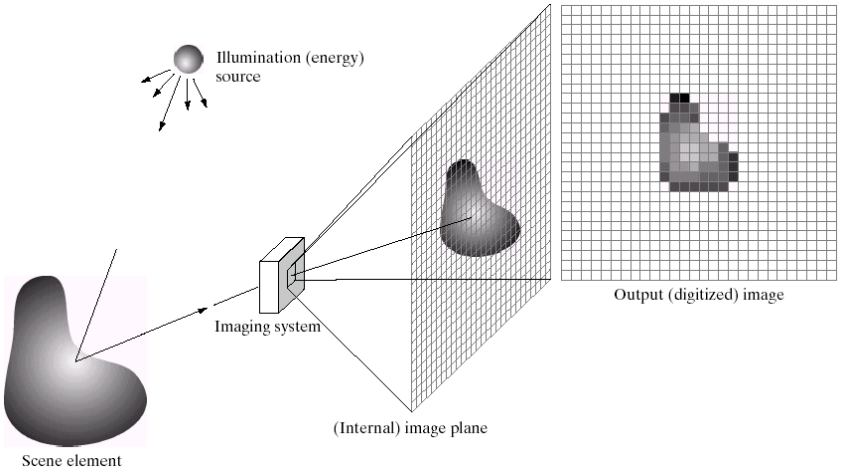
Image Restoration

Morphological Processing

Segmentation

Object Recognition

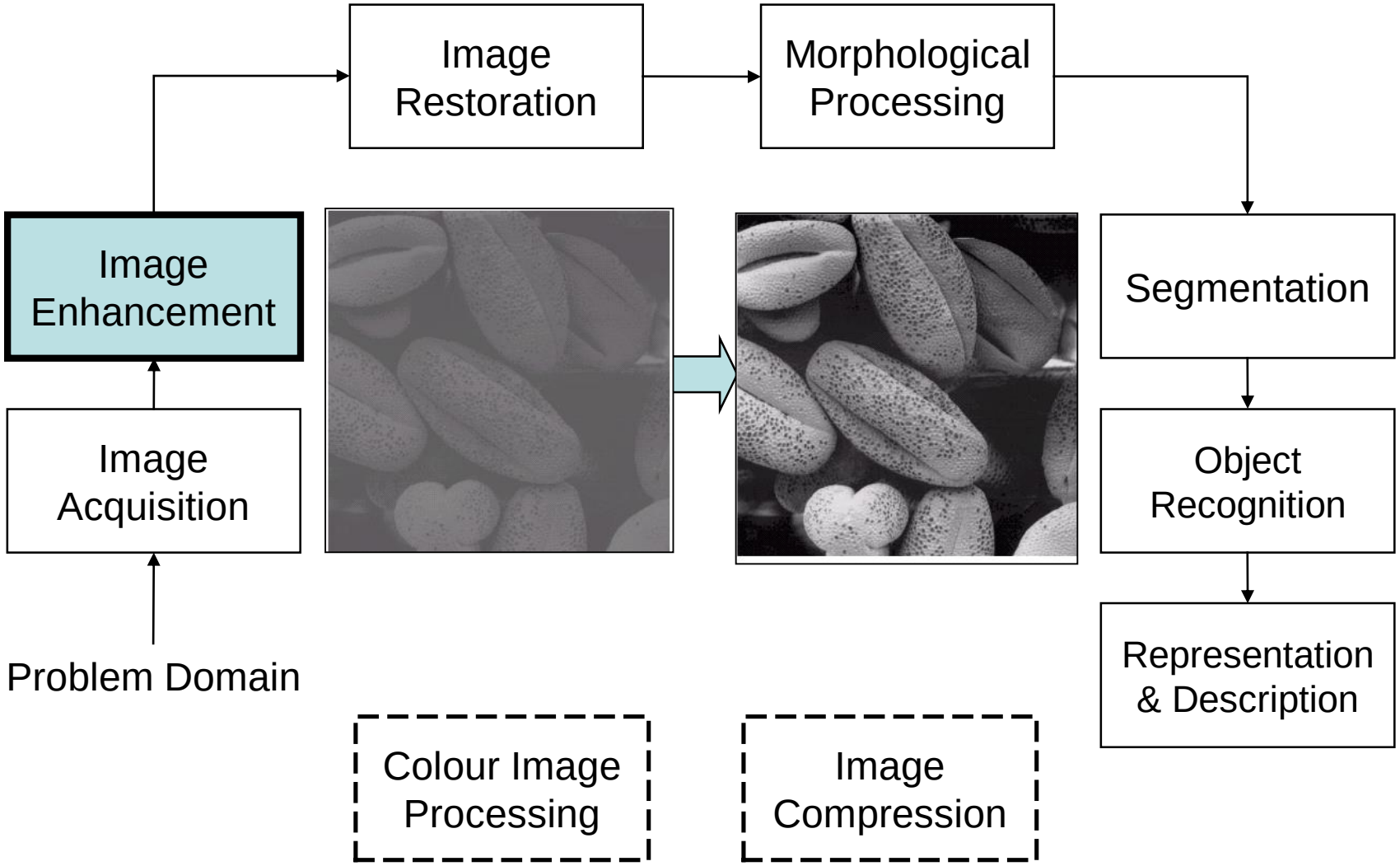
Representation & Description



Colour Image Processing

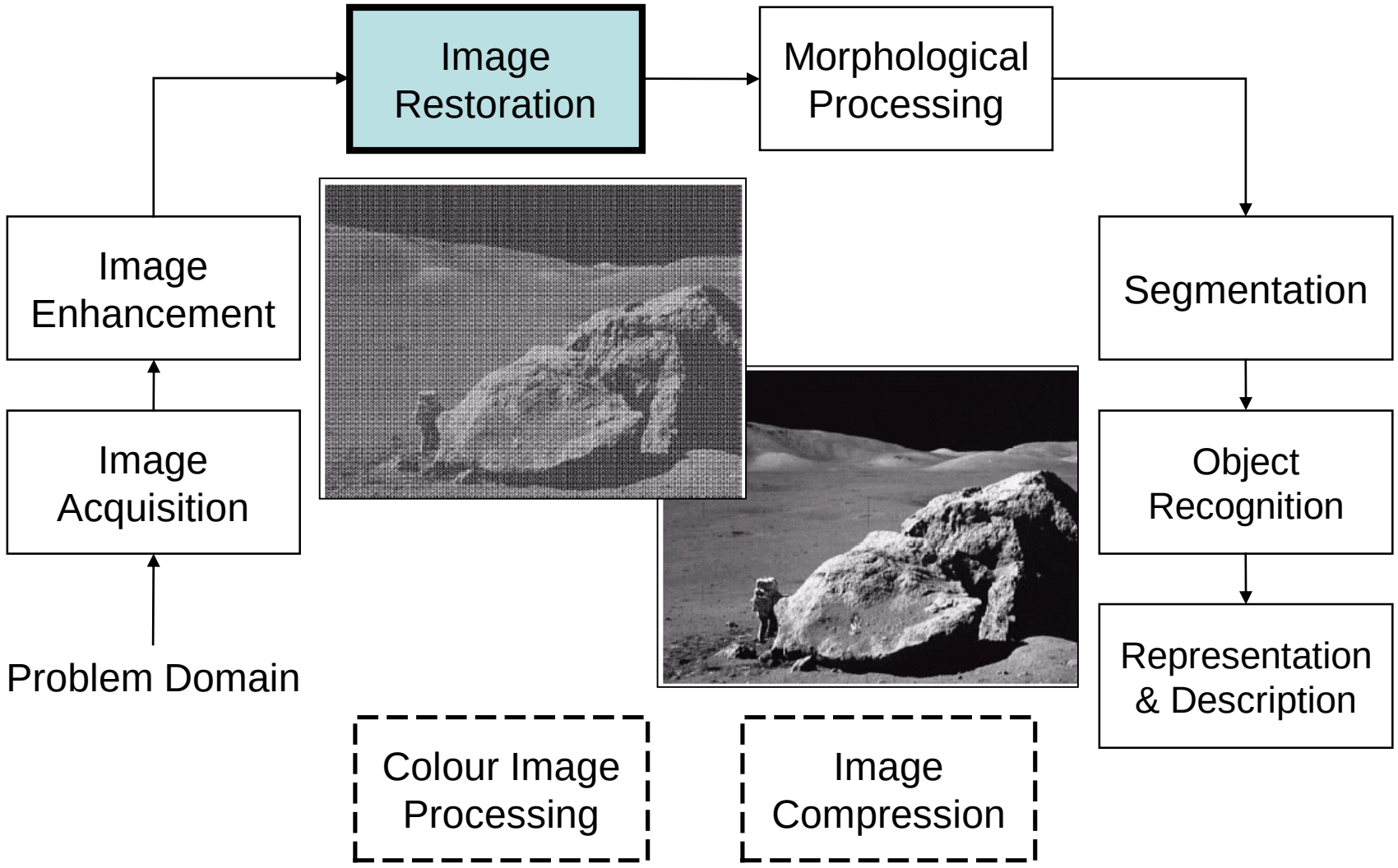
Image Compression

Key Stages in Digital Image Processing: Image Enhancement



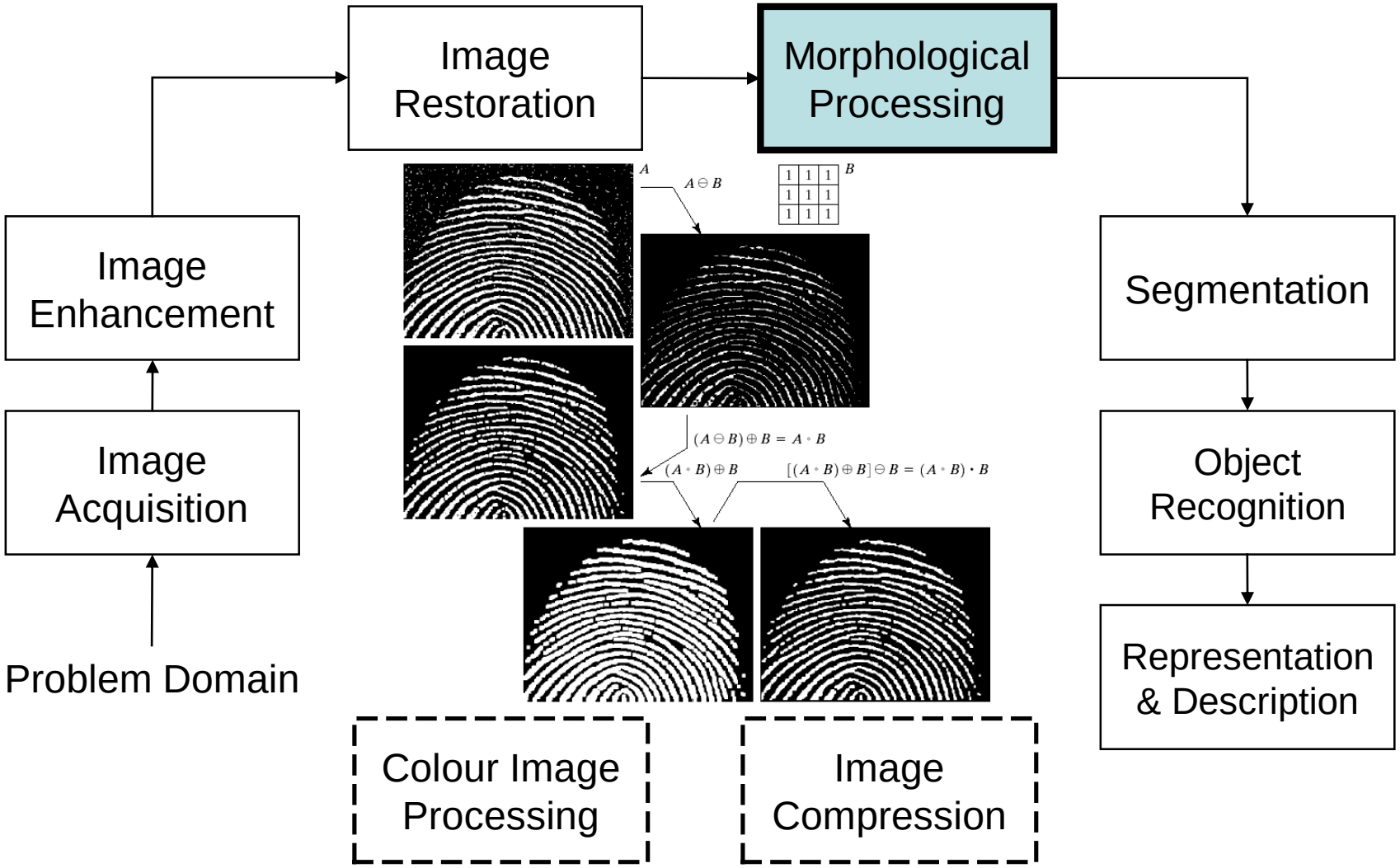
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Key Stages in Digital Image Processing: Image Restoration



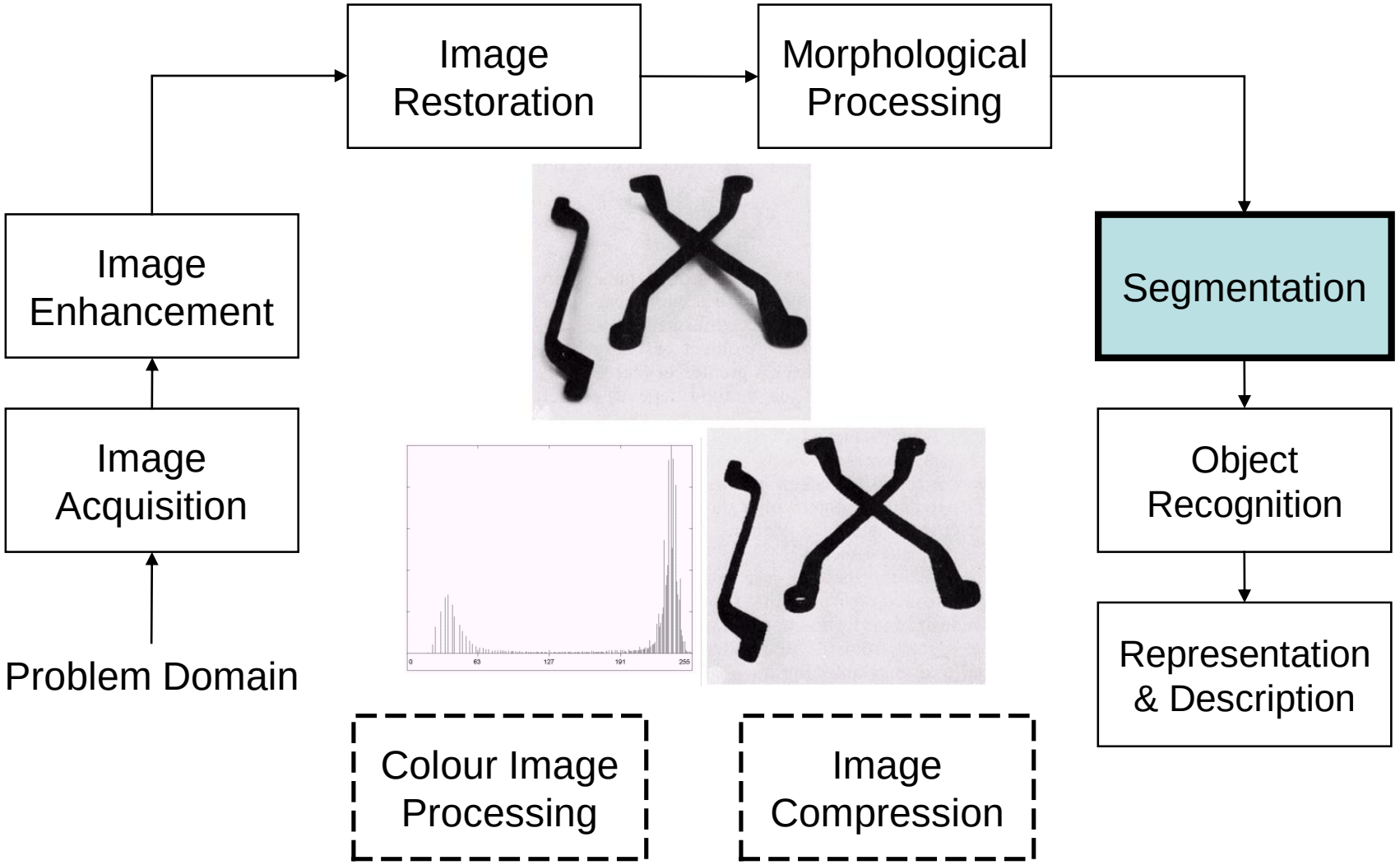
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

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

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

Problem Domain

Image Acquisition

Image Enhancement

Image Restoration

Morphological Processing

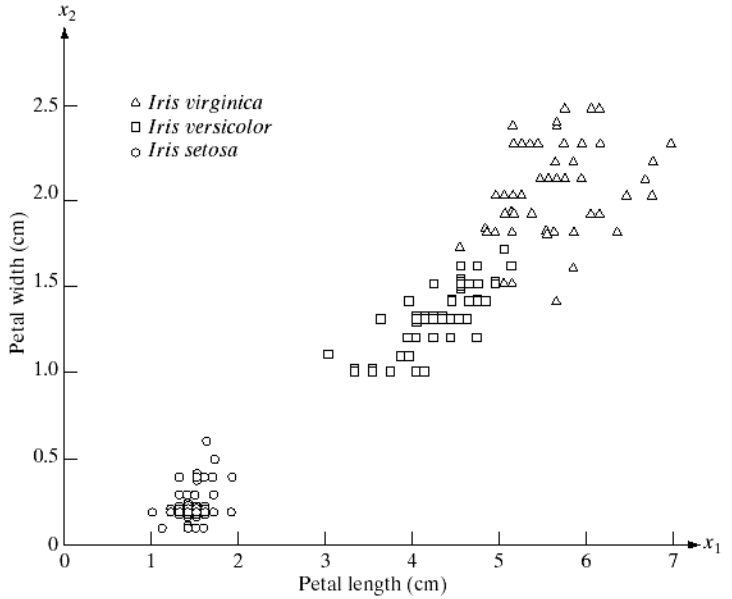
Segmentation

Object Recognition

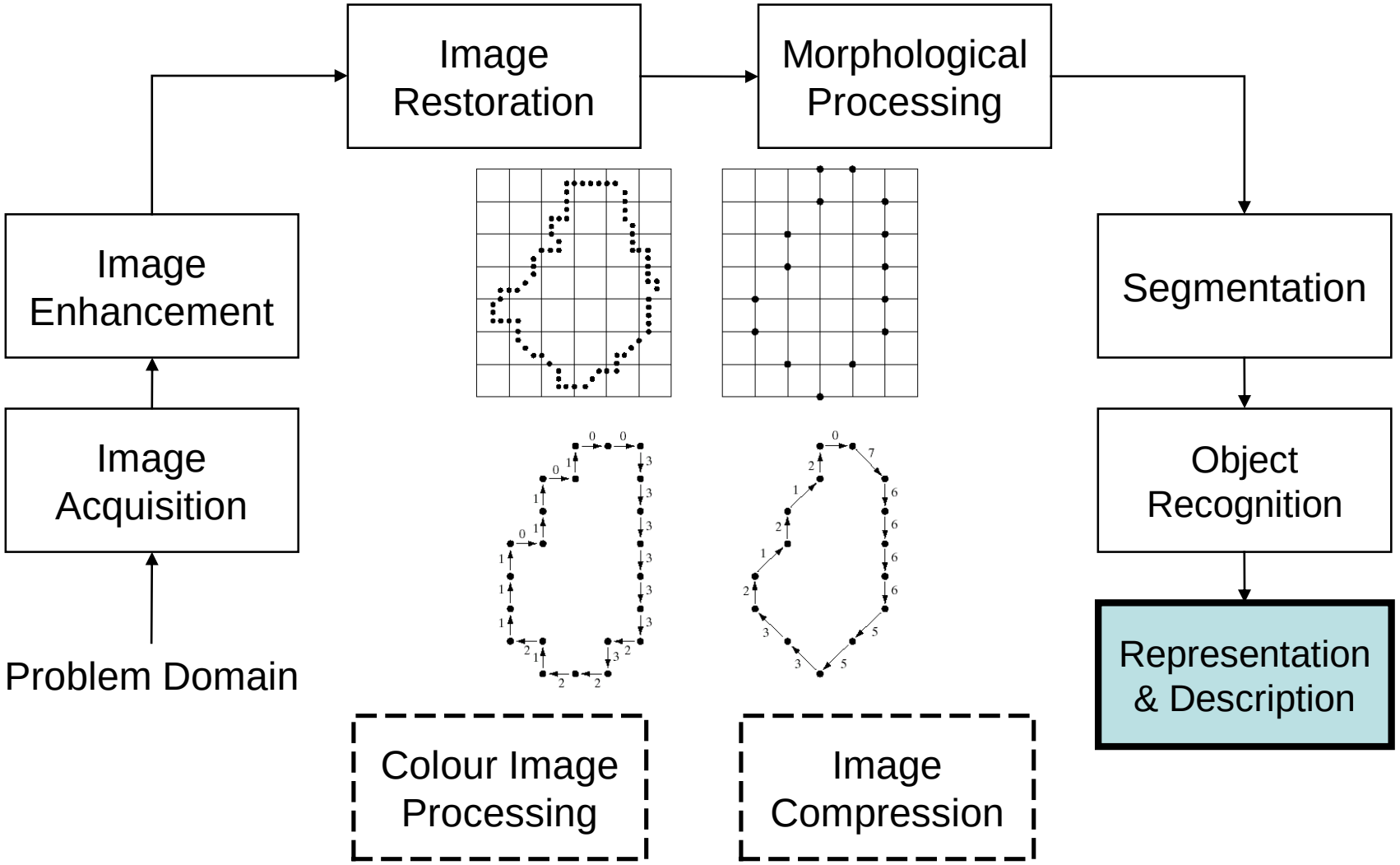
Representation & Description

Colour Image Processing

Image Compression

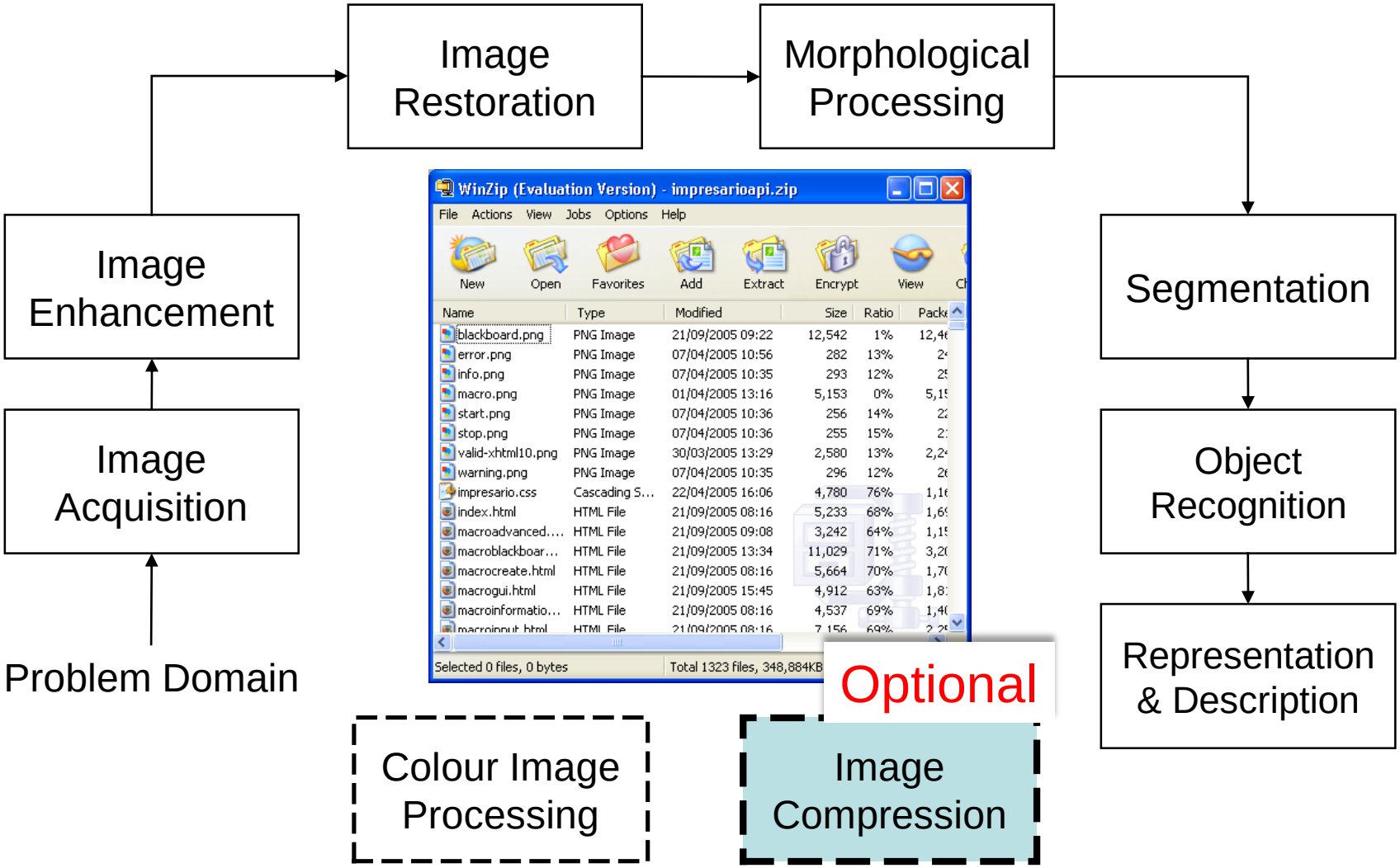


Key Stages in Digital Image Processing: Representation & Description

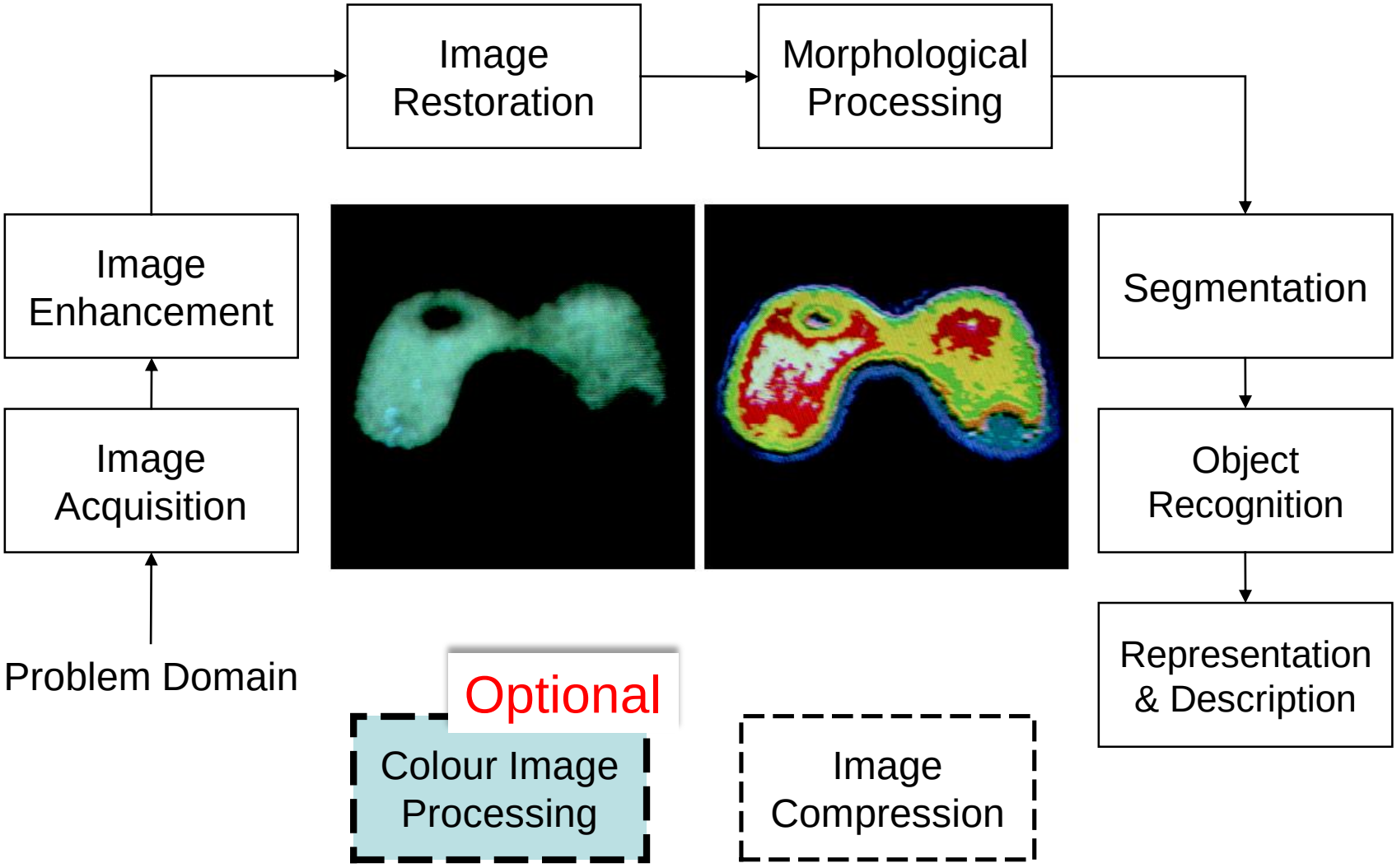


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Key Stages in Digital Image Processing: Image Compression



Key Stages in Digital Image Processing: Colour Image Processing



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

Next time we will start to see how it all works…