



Digital Image Processing: Introduction

Lecture 01

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Taken and Modified from

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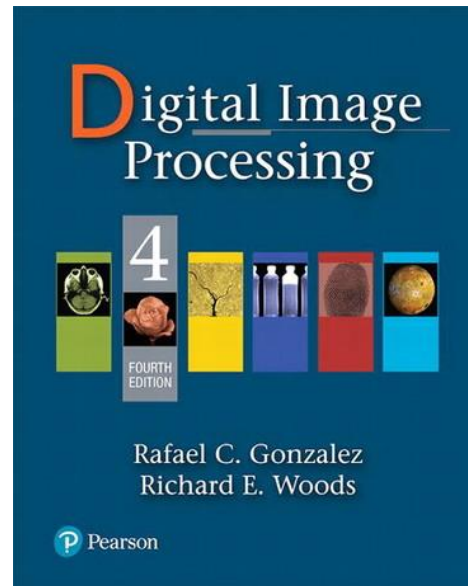
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*“One picture is worth more than ten
thousand words”*



By Confucius

Soon you will realize that it's an understatement...



“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

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.

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

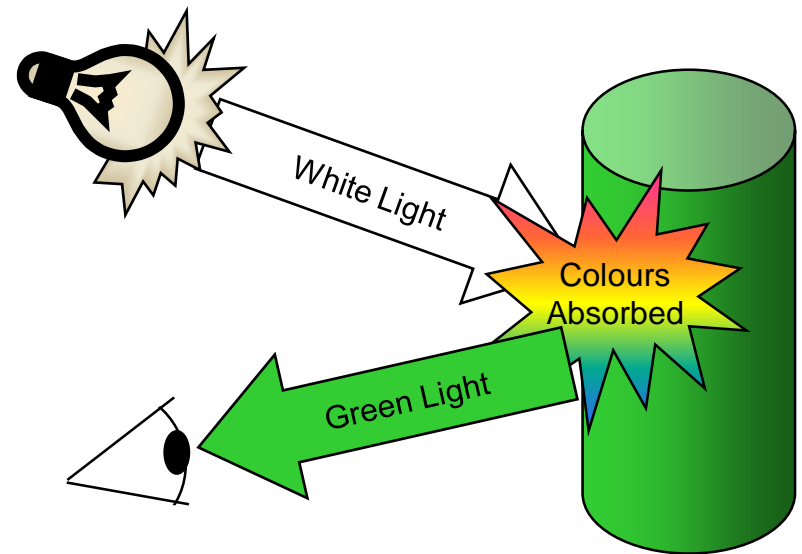


Image Formation Model

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

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

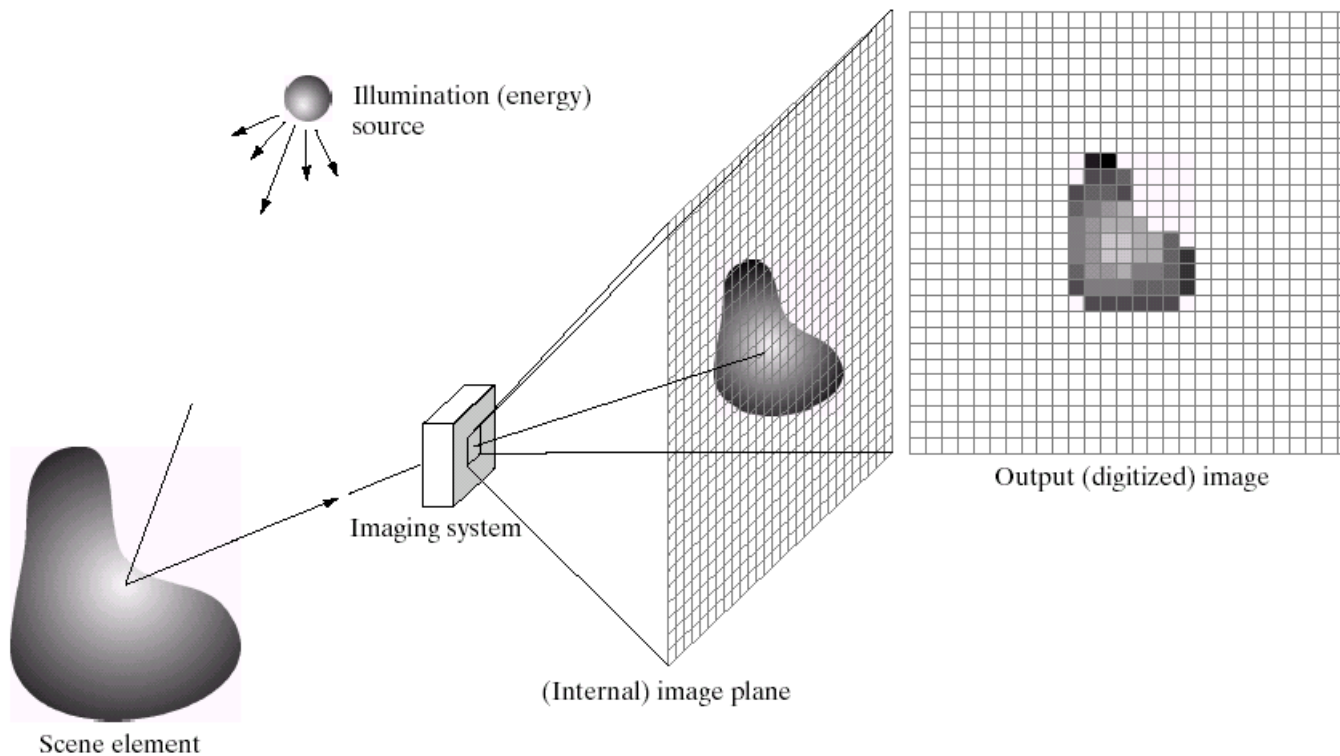
reflectance

$$n(x,y)$$

noise

What is a Digital Image?

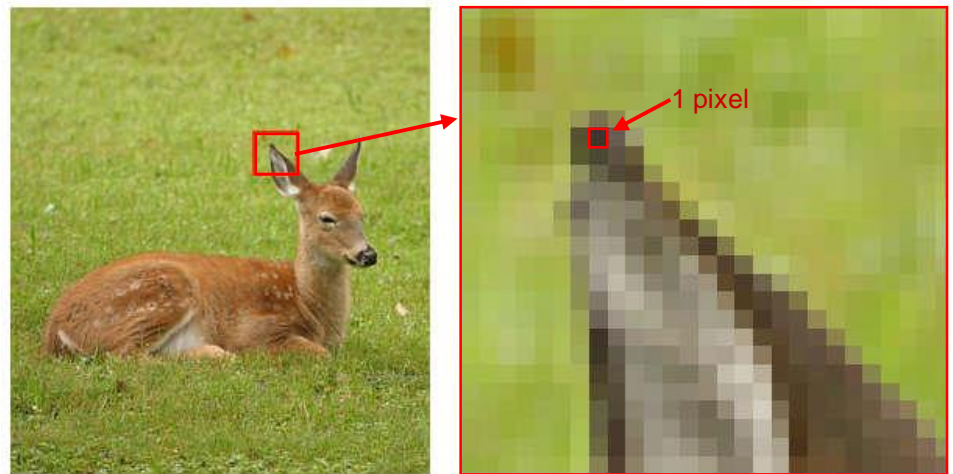
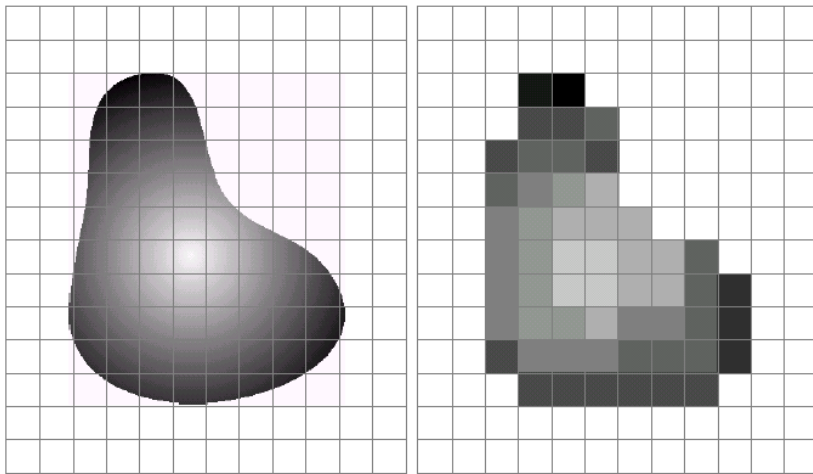
A **digital image** is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels



What is a Digital Image? (cont...)

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

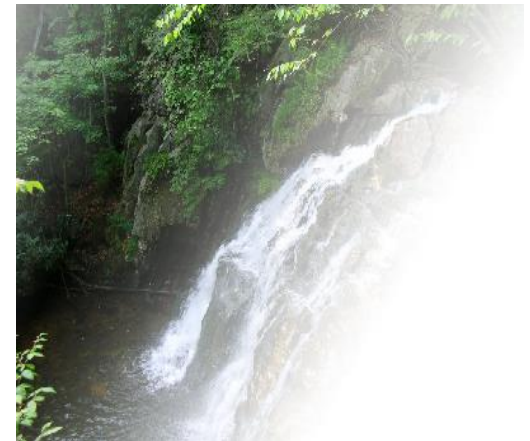
Remember *digitization* implies that a digital image is an approximation of a real scene



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?

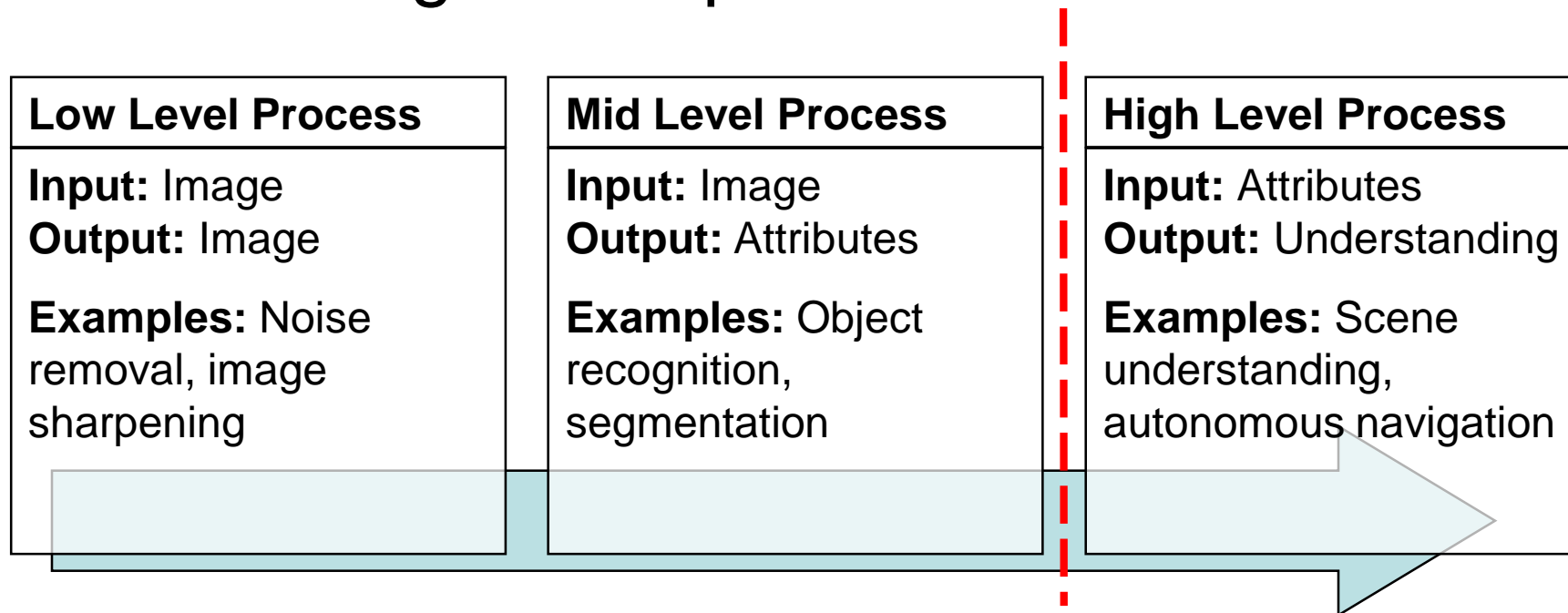
Digital image processing focuses on two major tasks:

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



In this course we will
stop here

History of Digital Image Processing

Early 1920s: One of the first applications of digital imaging was in the newspaper industry

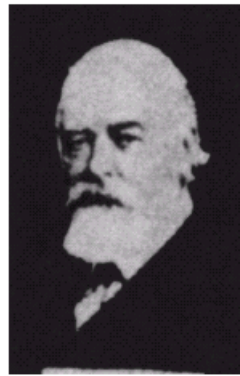
- The **Bartlane cable picture** transmission service
- Images were transferred by submarine cable between London and New York
- Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer



Early digital image

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



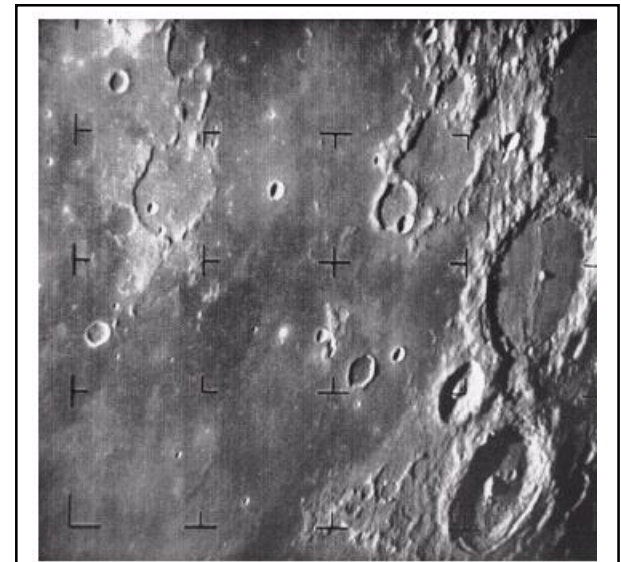
Improved
digital image



Early 15 tone digital
image

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



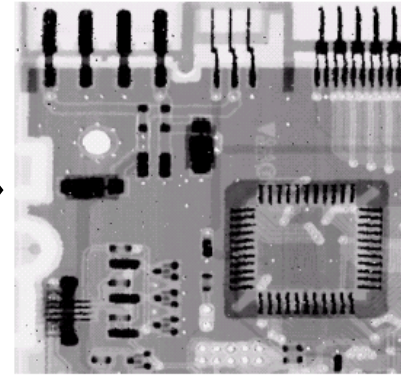
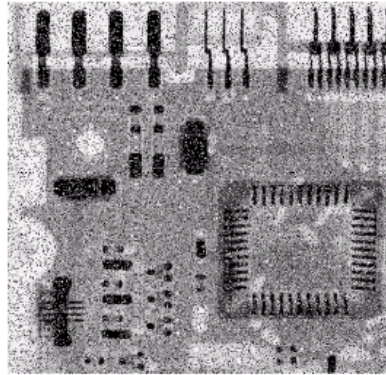
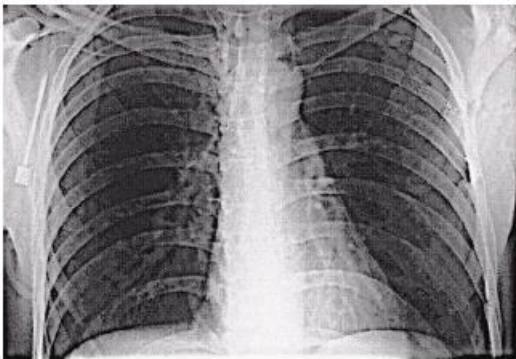
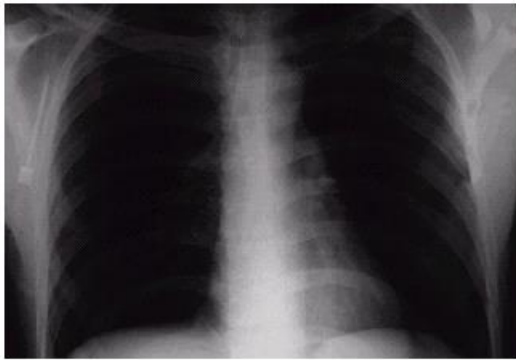
Typical head slice CAT
image

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

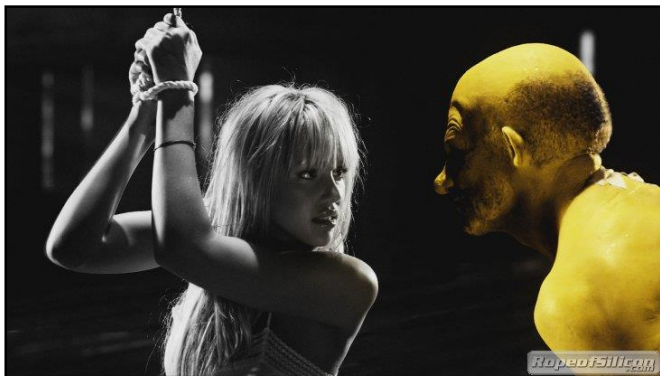
Examples: Image Enhancement

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



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

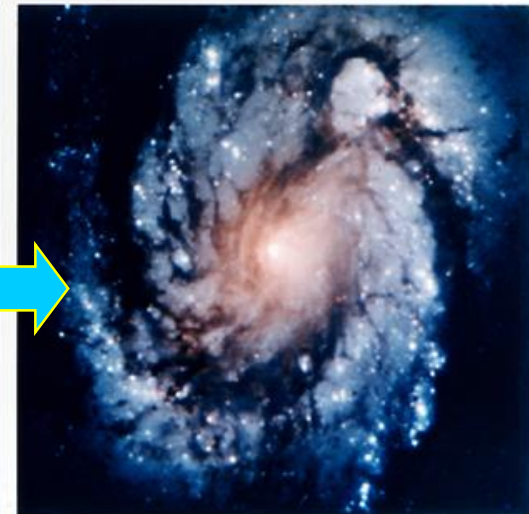
Launched in 1990 the Hubble telescope can take images of very distant objects

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

Image processing techniques were used to fix this



Wide Field and Planetary Camera 1

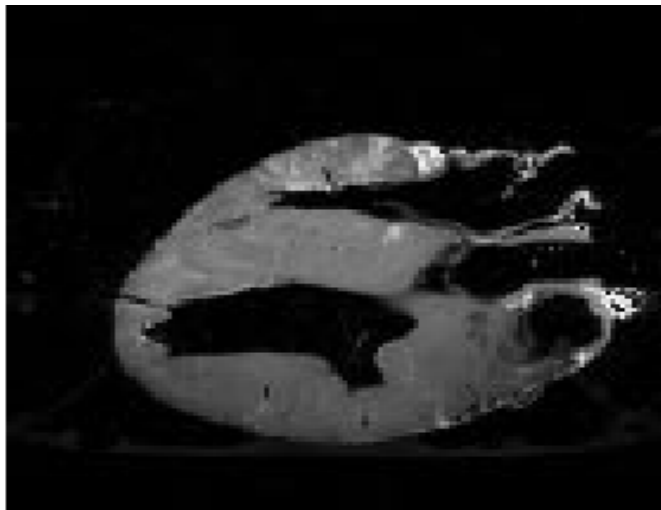


Wide Field and Planetary Camera 2

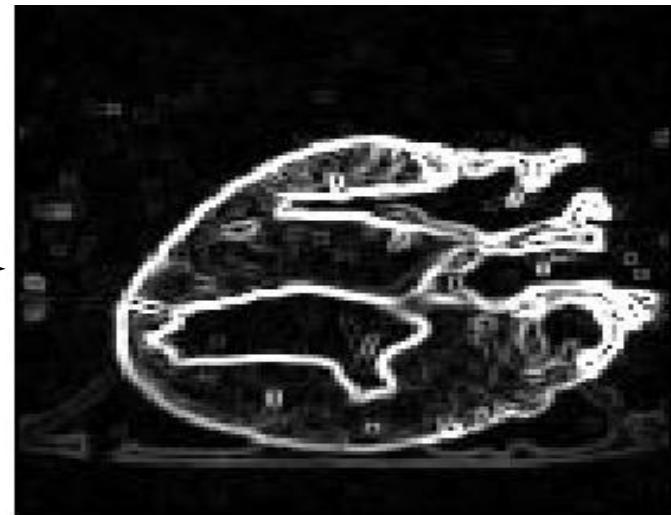
Examples: Medicine

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

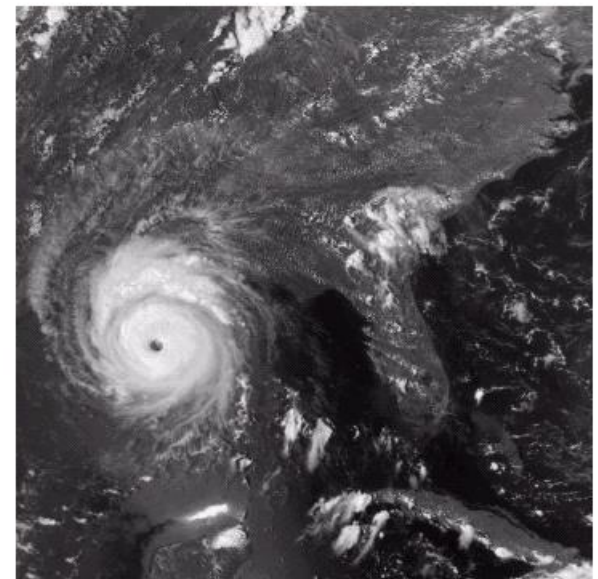
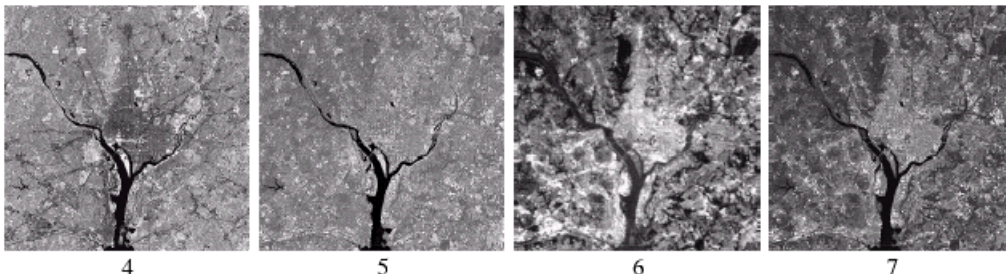
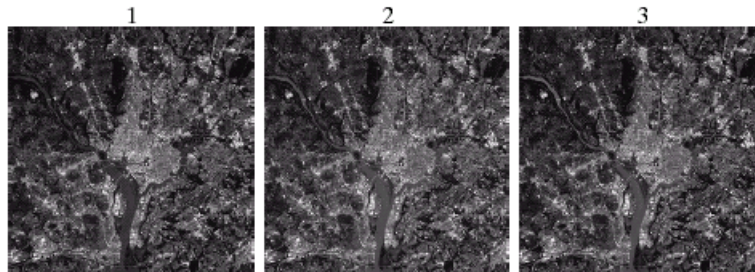


Edge Detection Image

Geographic Information Systems

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

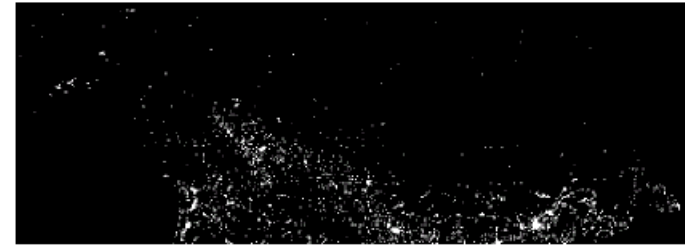
Infrared imaging



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

Examples: Industrial Inspection

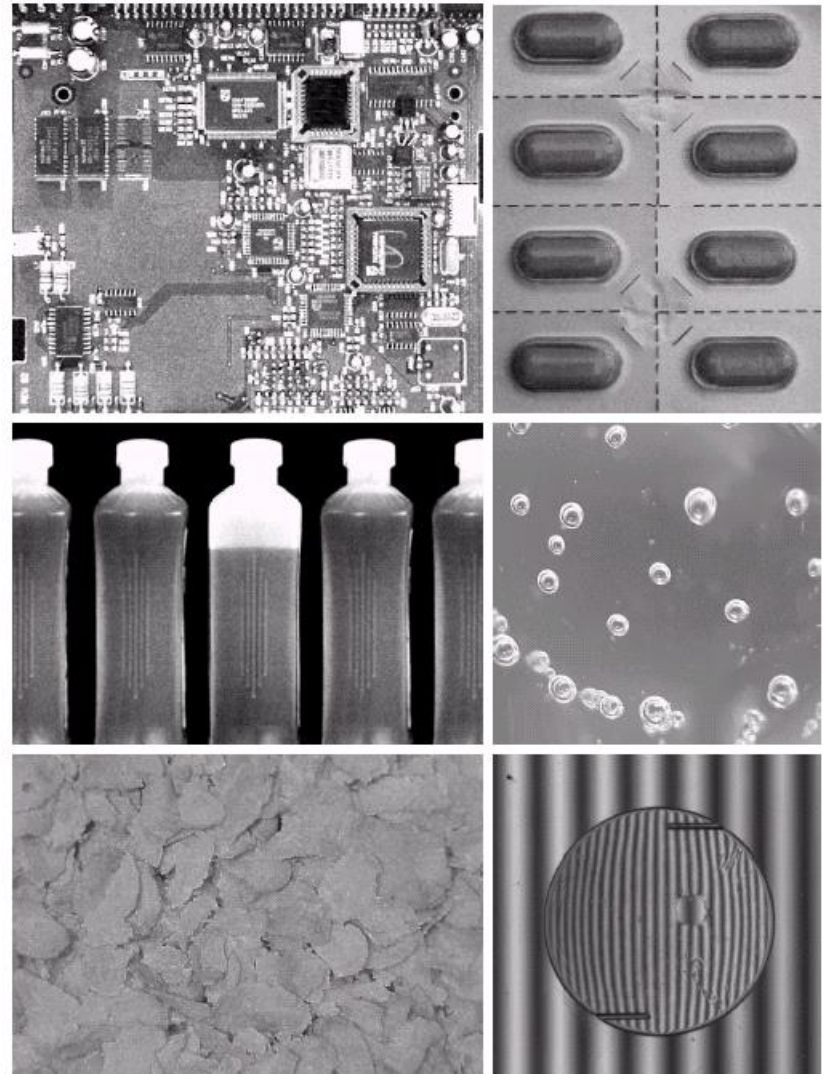
Human operators are expensive, slow and unreliable

Make machines do the job instead

Industrial vision systems are used in all kinds of industries

Can we trust them?

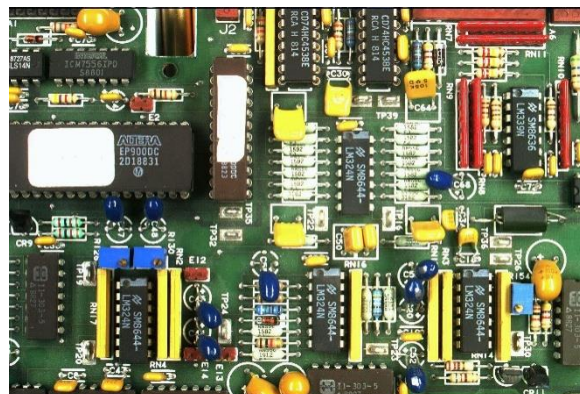
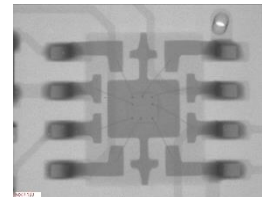
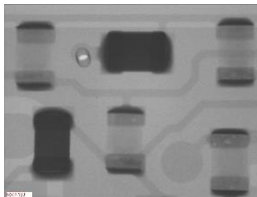
X-Ray imaging



Examples: PCB Inspection

Printed Circuit Board (PCB) inspection

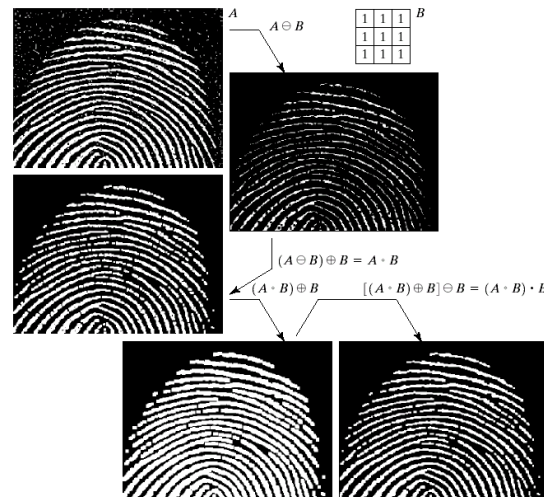
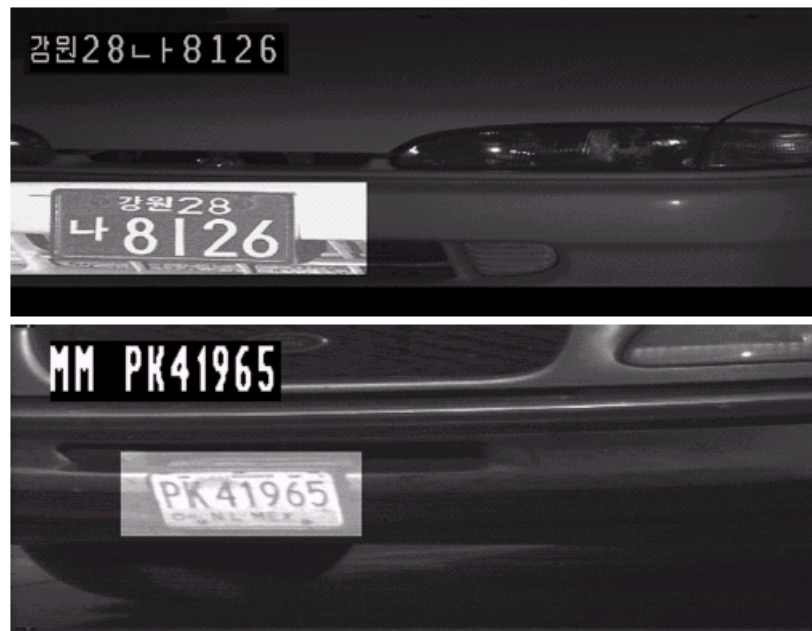
- Machine inspection is used to determine that all components are present and that all solder joints are acceptable
- Both conventional imaging and x-ray imaging



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

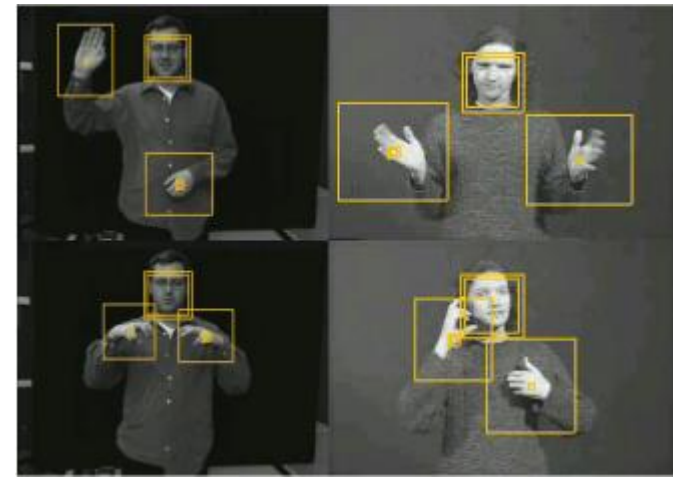


Try to make human computer interfaces more natural

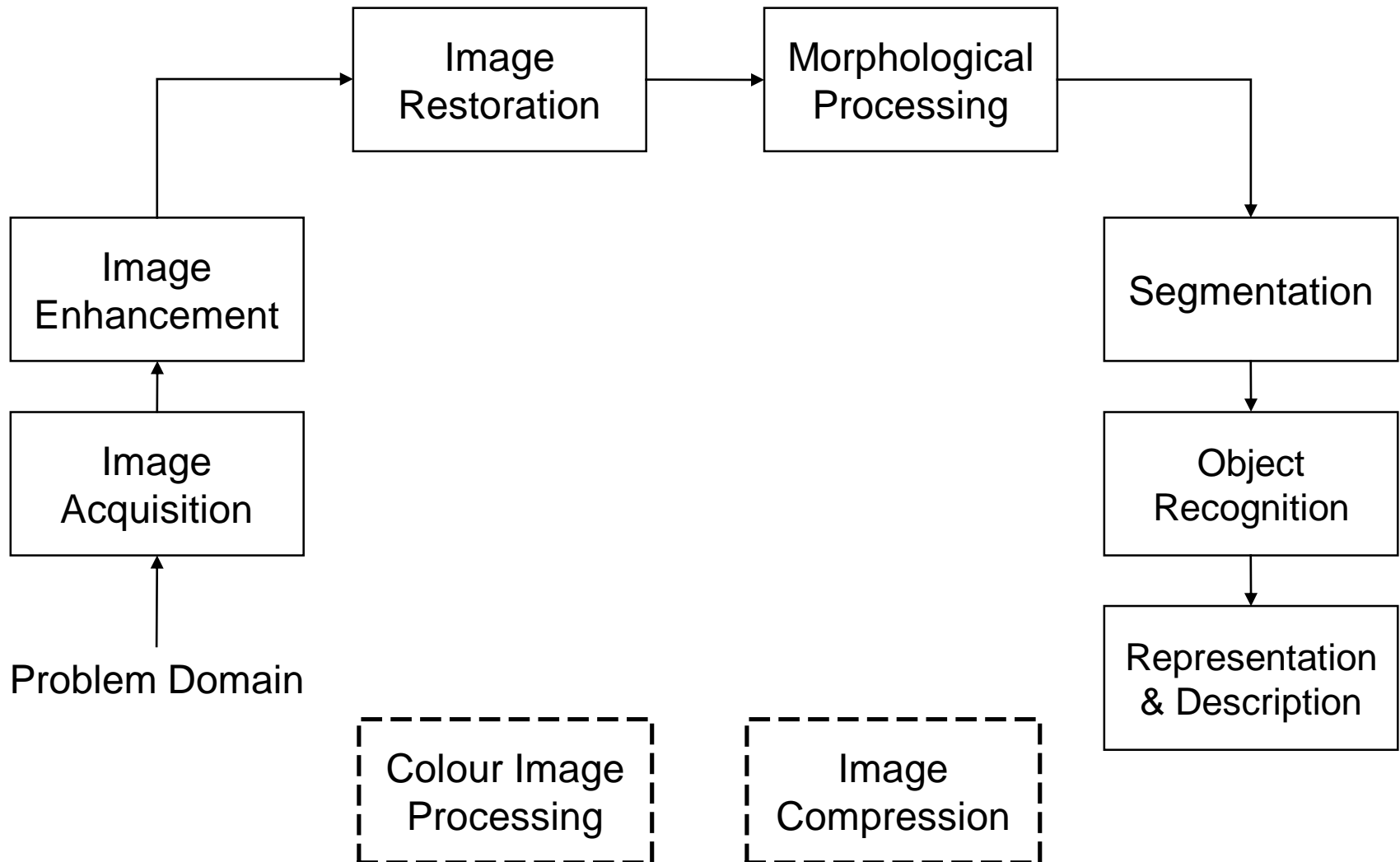
- Face recognition
- Gesture recognition

One application is the smart stay?

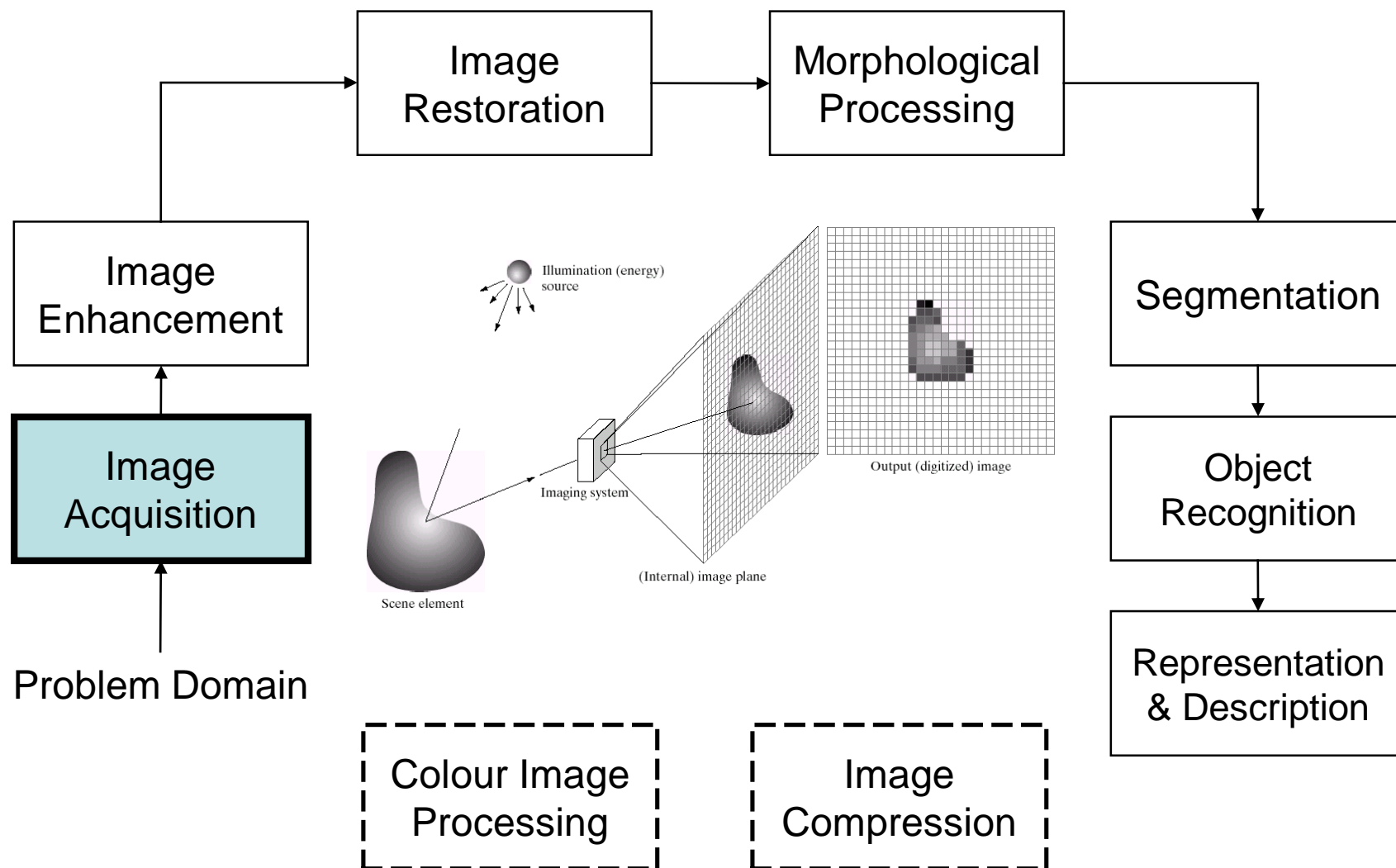
These tasks can be extremely difficult



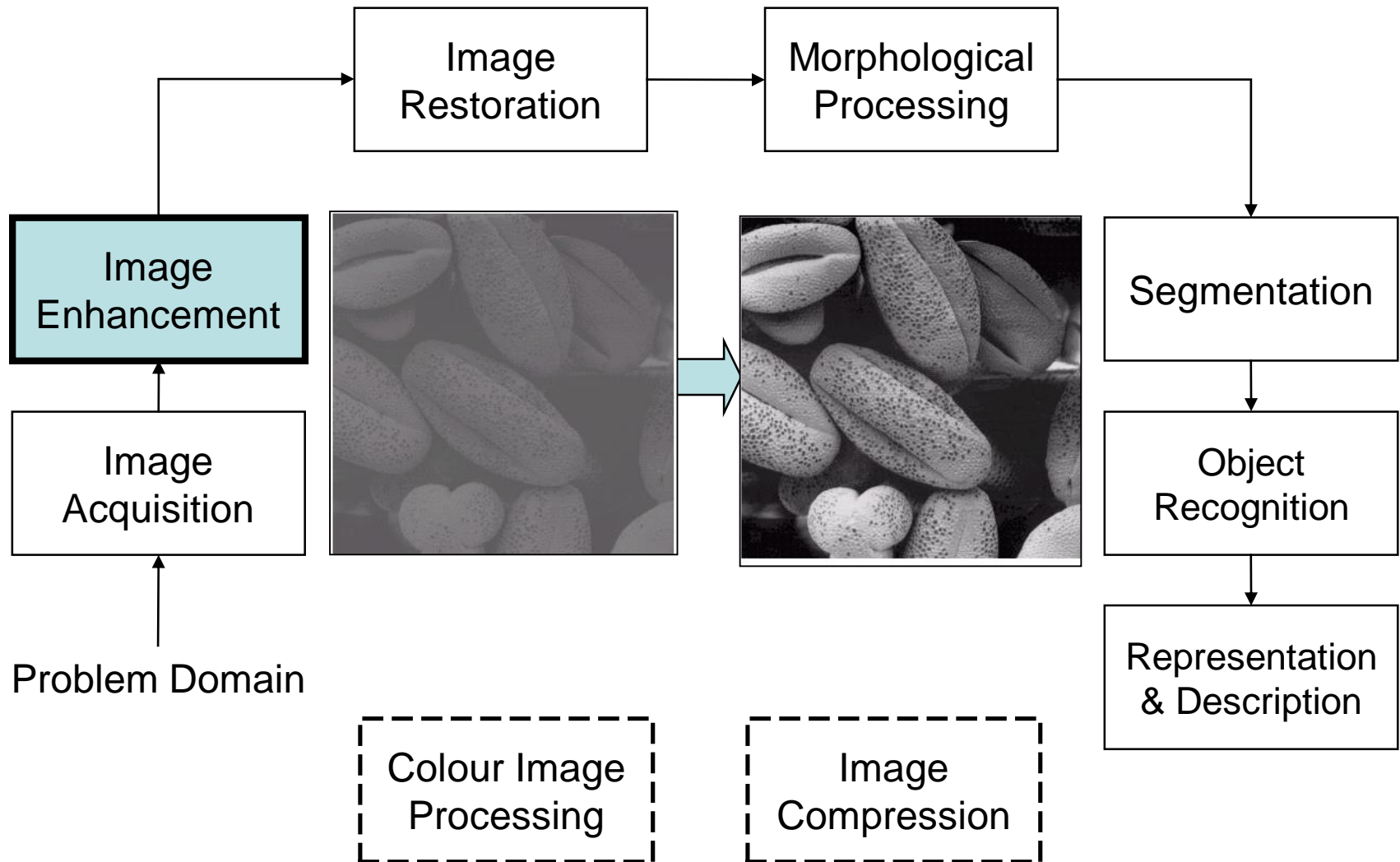
Key Stages in Digital Image Processing



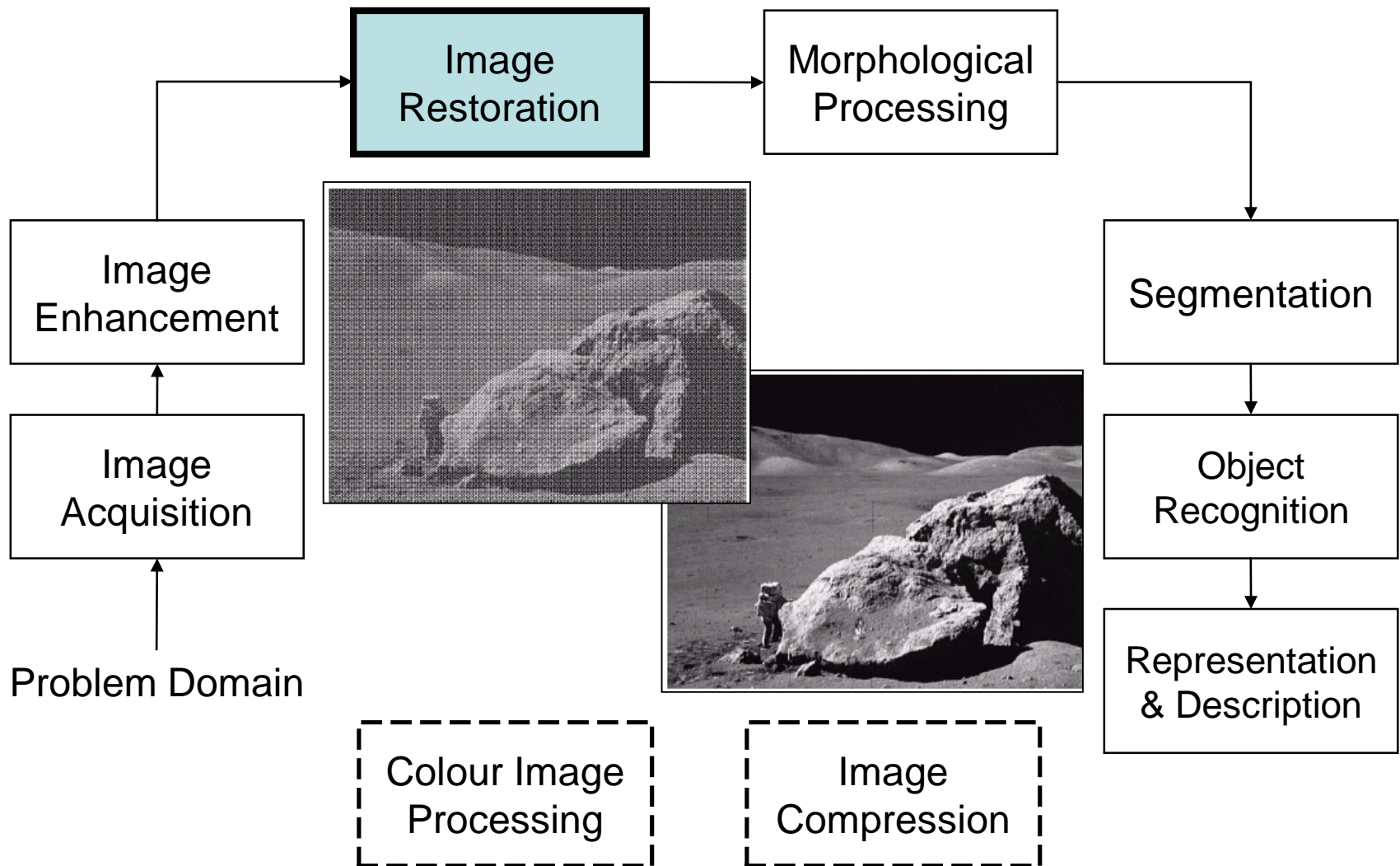
Key Stages in Digital Image Processing: Image Aquisition



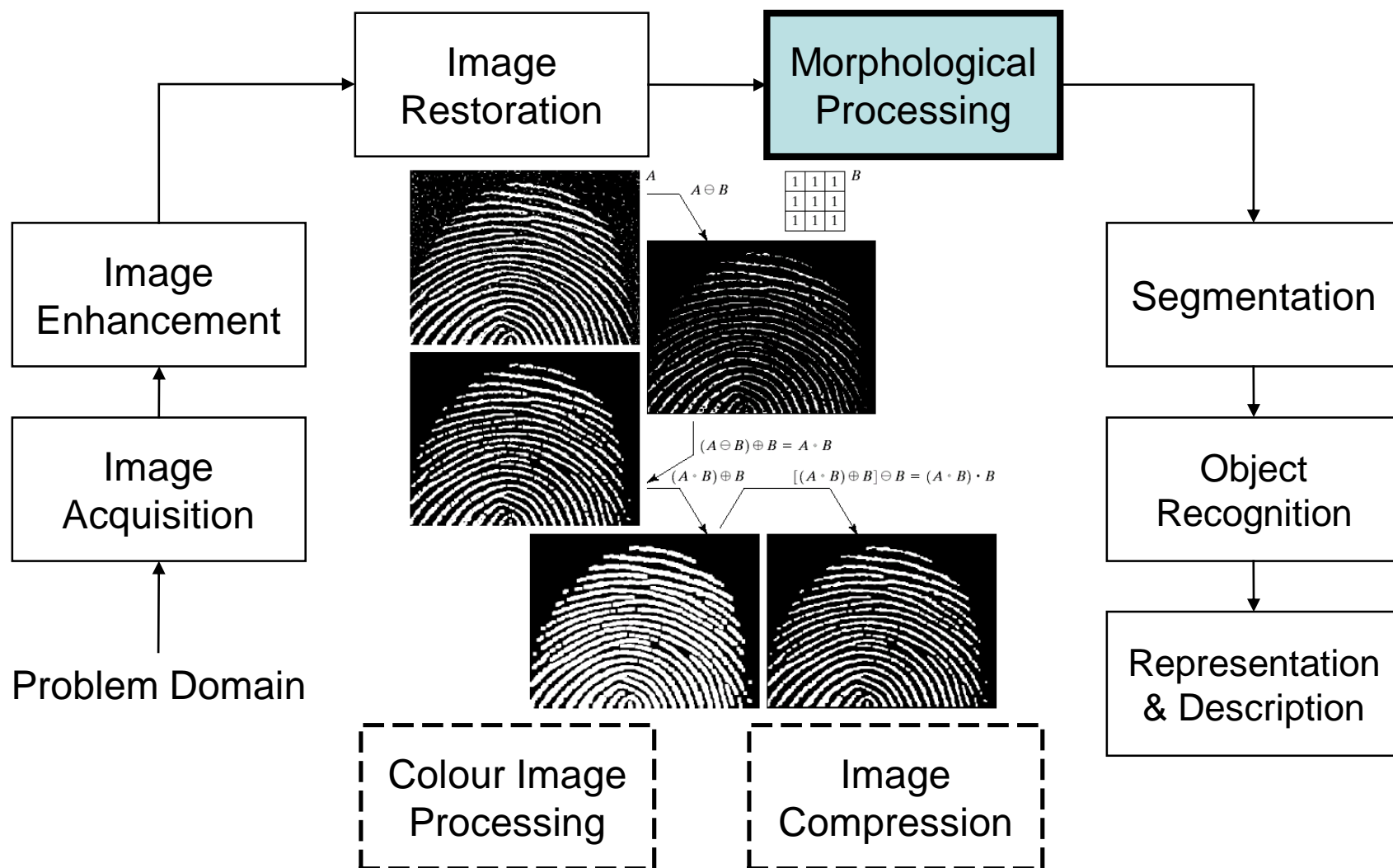
Key Stages in Digital Image Processing: Image Enhancement



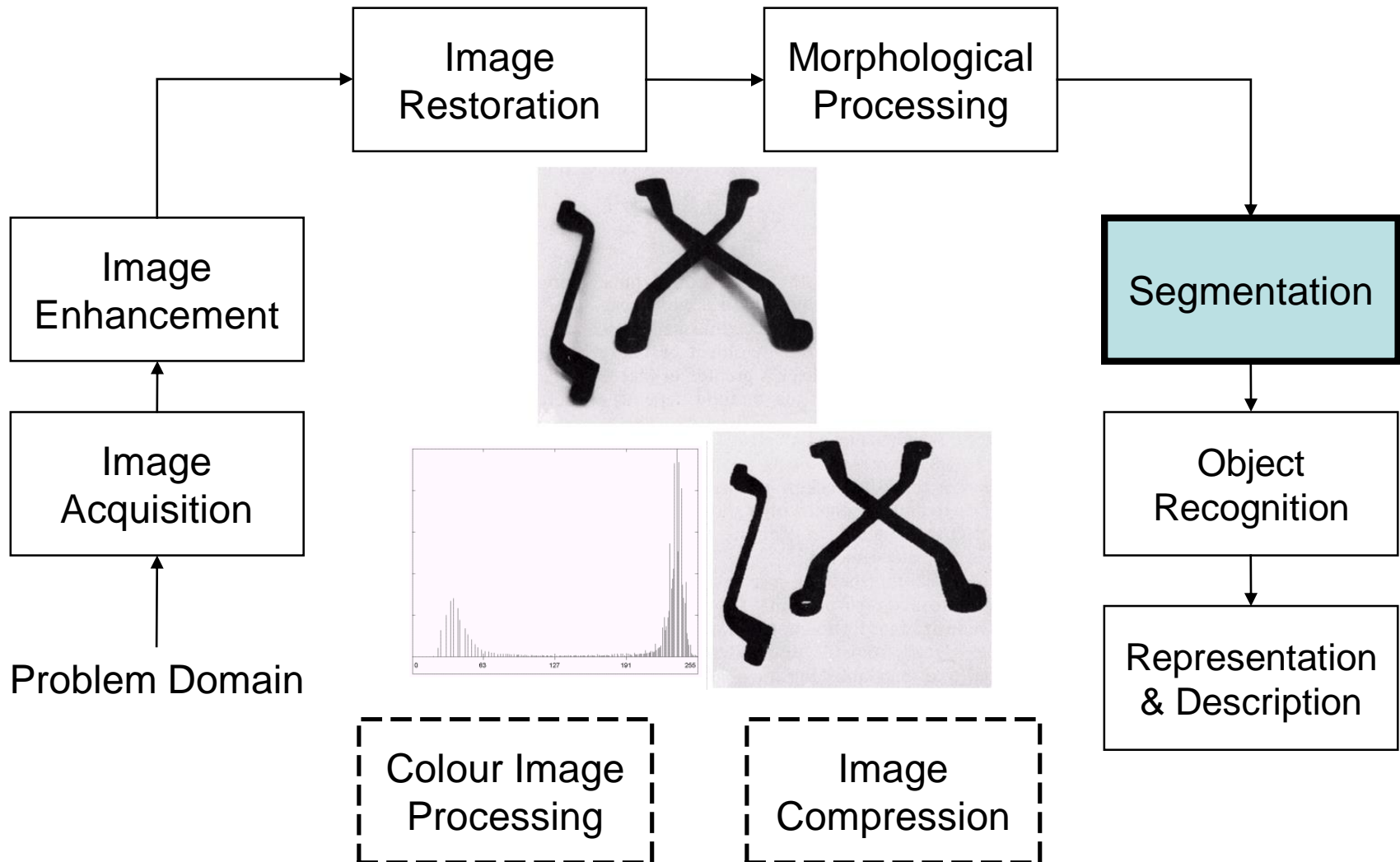
Key Stages in Digital Image Processing: Image Restoration



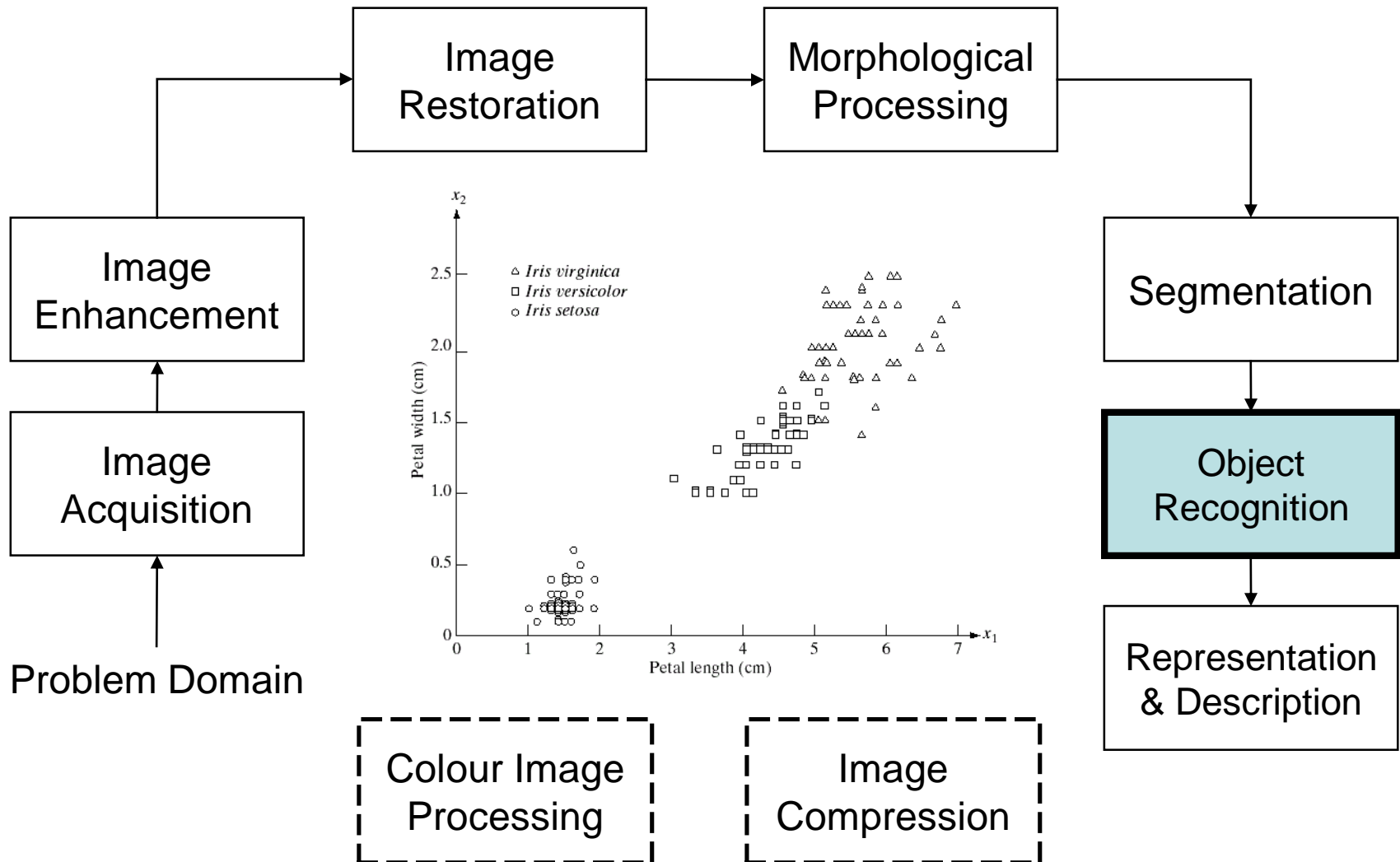
Key Stages in Digital Image Processing: Morphological Processing



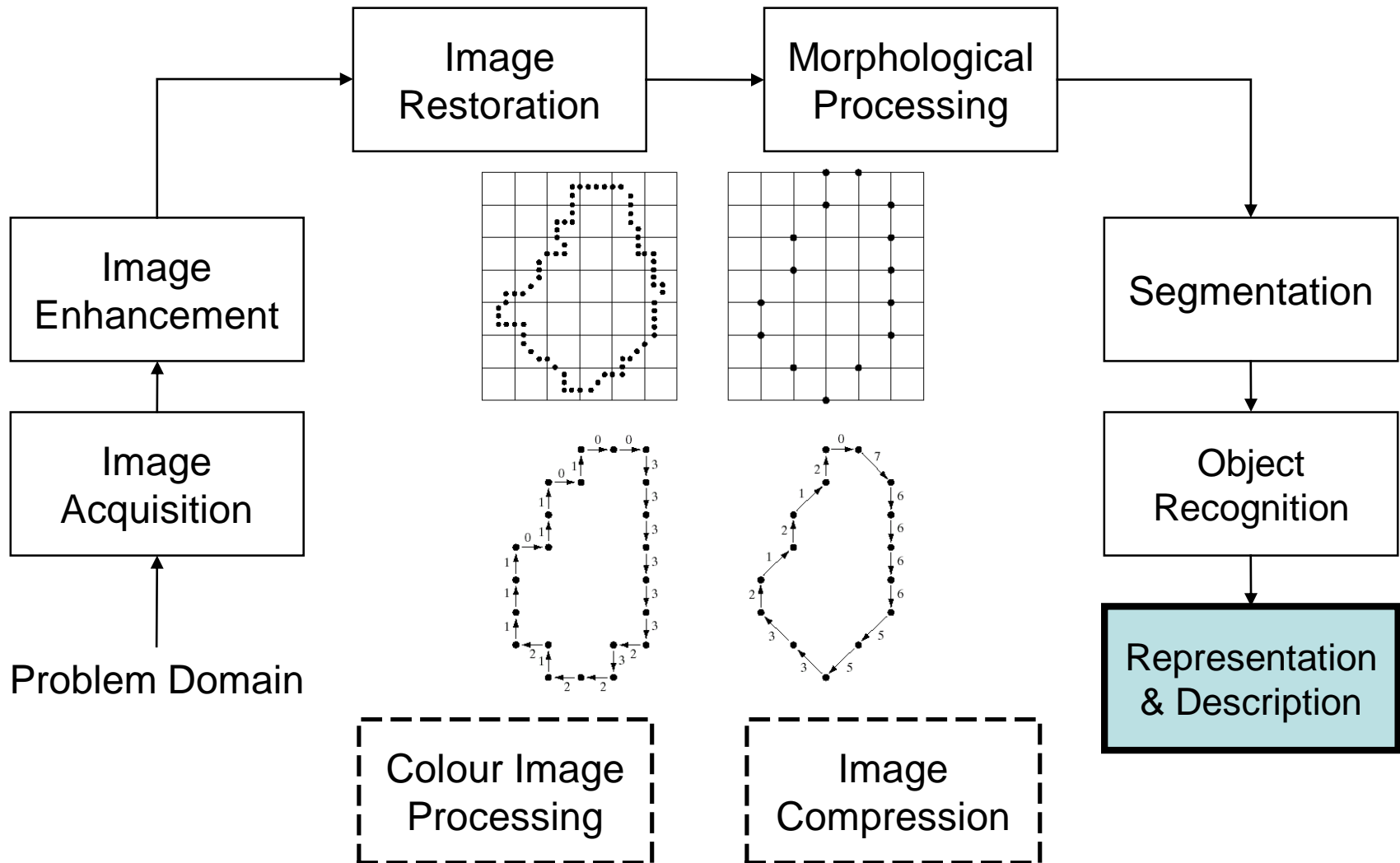
Key Stages in Digital Image Processing: Segmentation



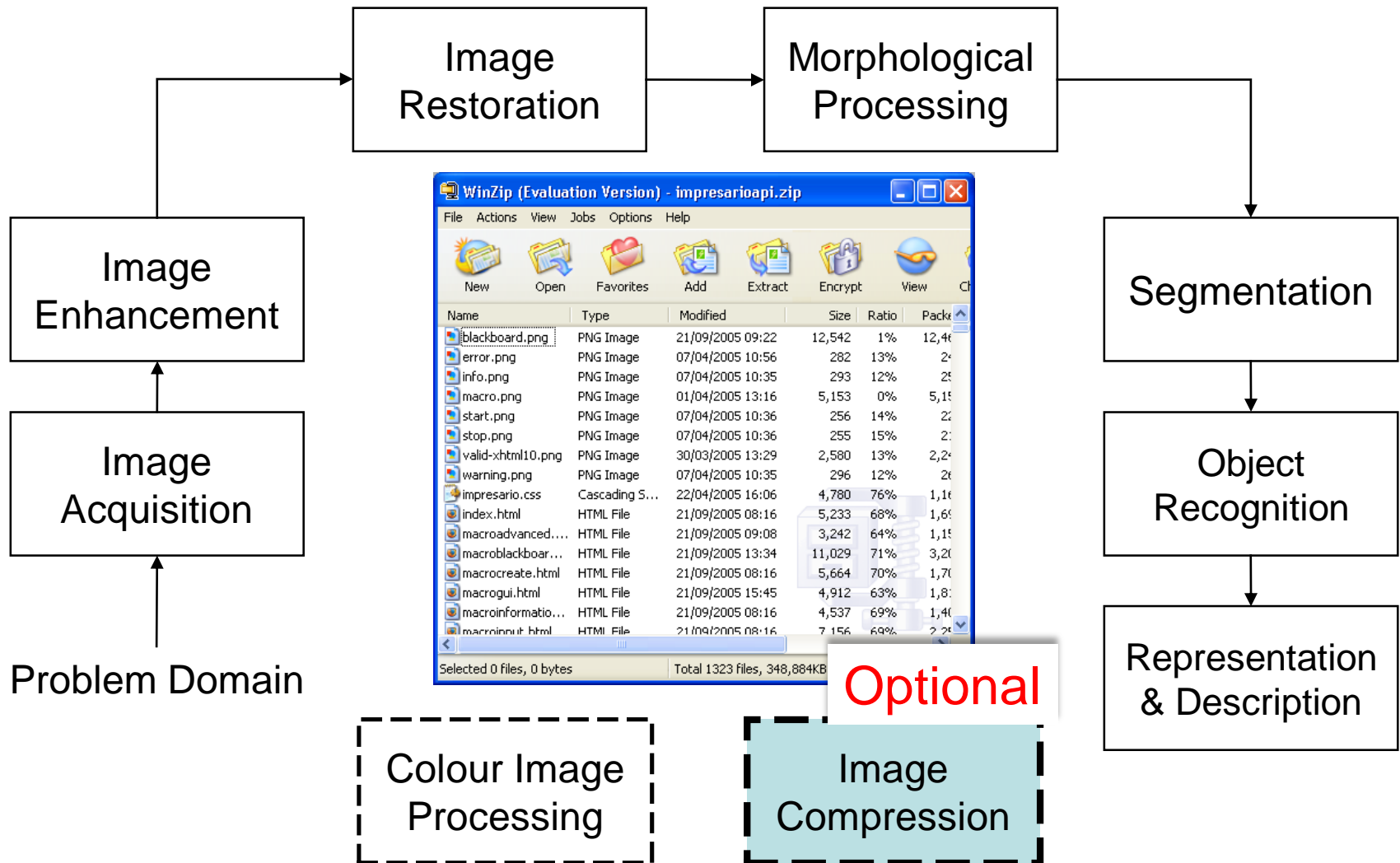
Key Stages in Digital Image Processing: Object Recognition



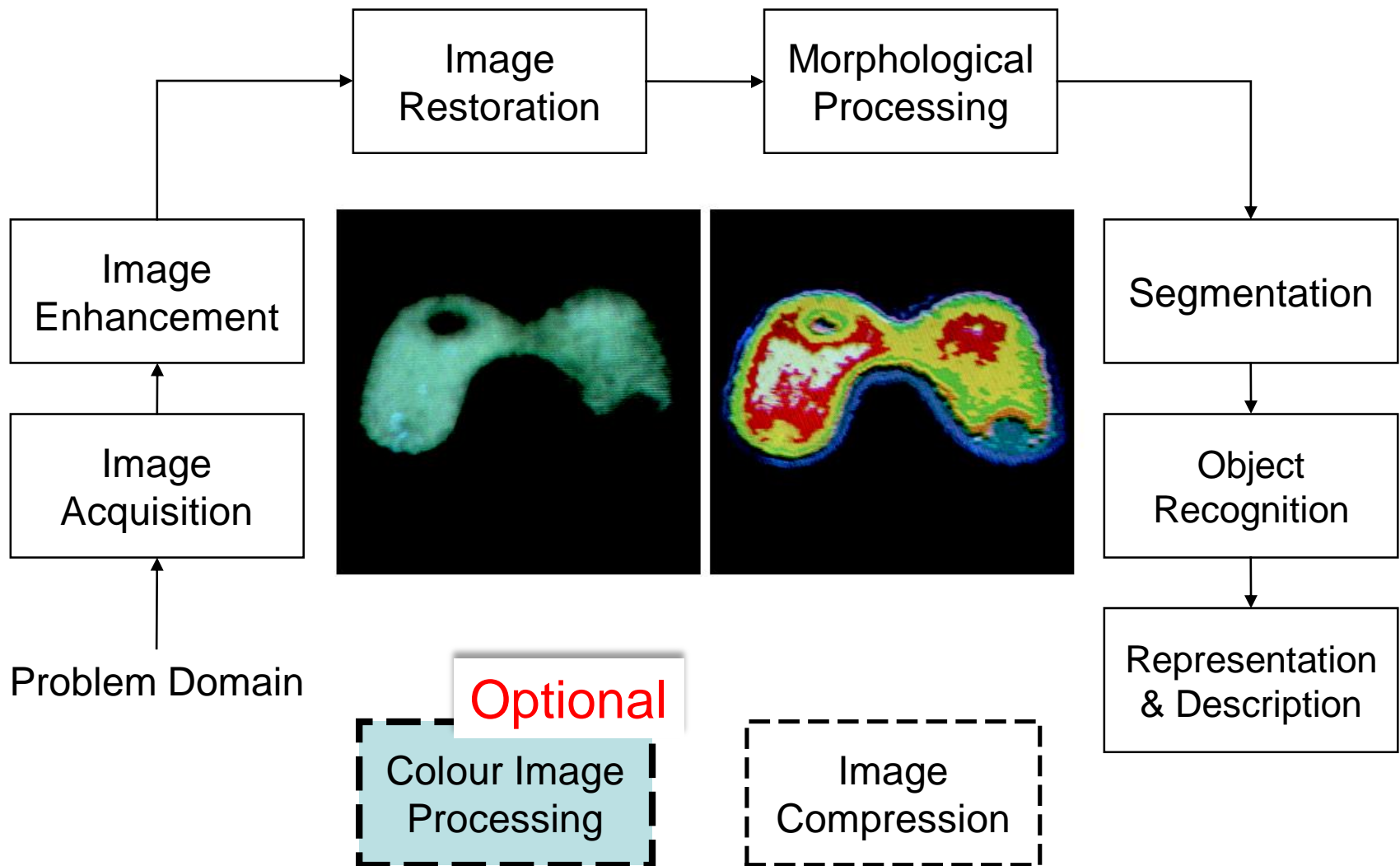
Key Stages in Digital Image Processing: Representation & Description



Key Stages in Digital Image Processing: Image Compression



Key Stages in Digital Image Processing: Colour Image Processing



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...