Imperial College London

Digital Image Processing

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Introduction

“One picture is worth more than ten thousand words”

Anonymous

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Miscellanea

Teacher:

Dr. Tania Stathaki, Reader (Associate Professor) in Signal Processing, Imperial College London

Lectures:

- Thursdays 11:00 – 13:00

Web Site: http://www.commsp.ee.ic.ac.uk/~tania/

Course notes and slides will be available here

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Logistics of the course

Duration

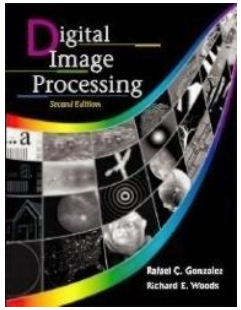
- 20 lectures

Assessment

- 100% exam

Main textbook

- “Digital Image Processing”, Rafael C. Gonzalez & Richard E. Woods, Addison-Wesley, 2002



Content of this lecture

This lecture will cover:

- What is a digital image?
- What is digital image processing?
- History of digital image processing
- Image processing problems
- Material covered in this course
- Applications of image processing

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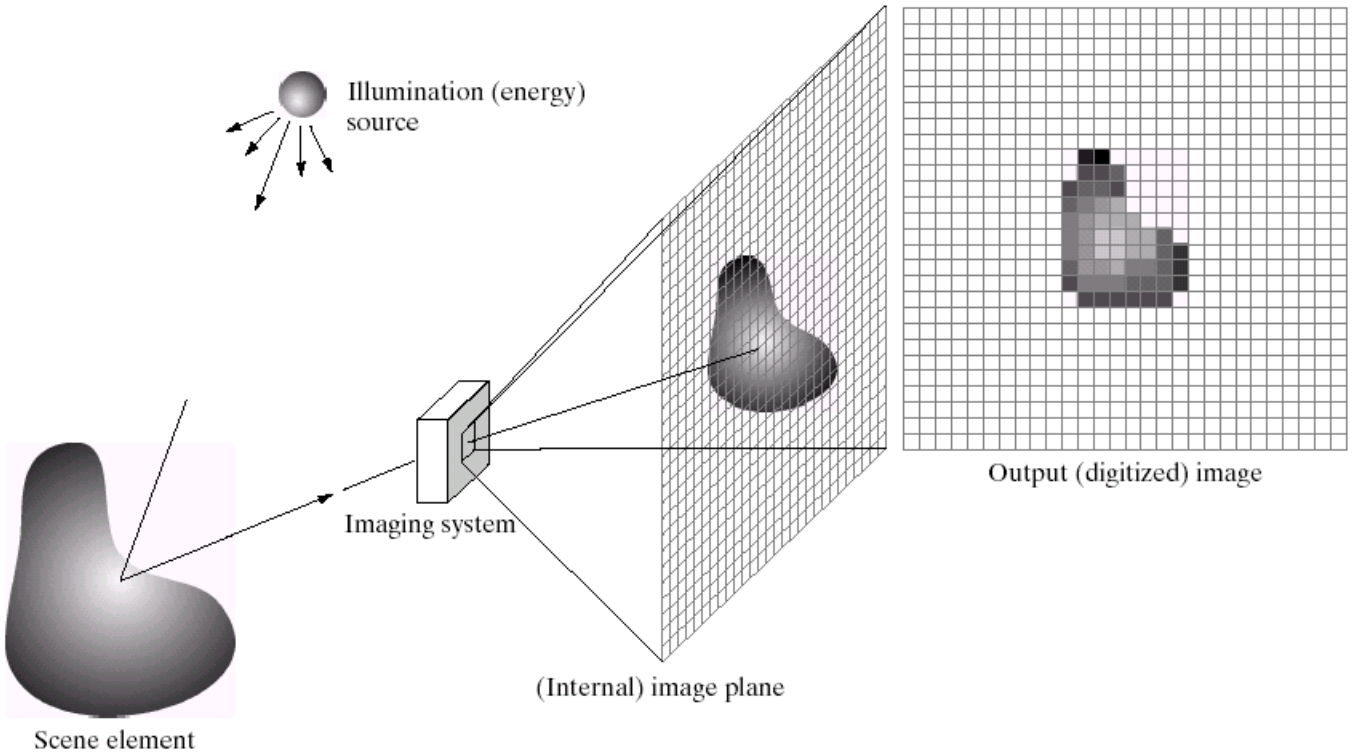
Digital Image

- What is a digital image?
- In what form is a digital image stored?
- Why are we able to use digital images?

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

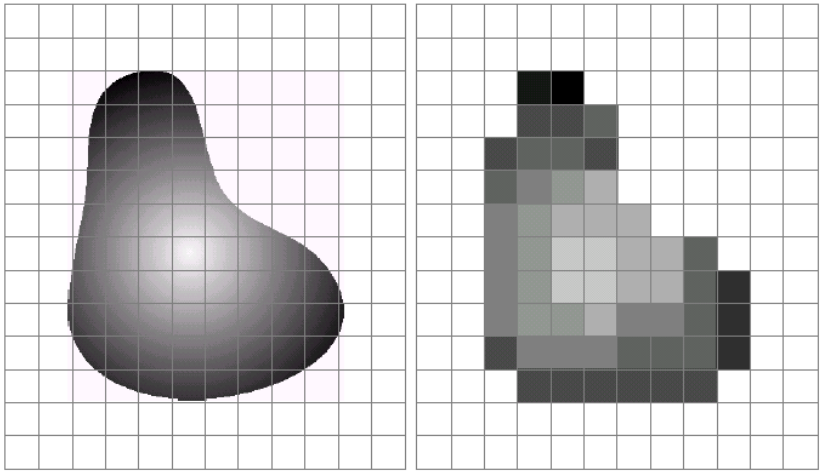


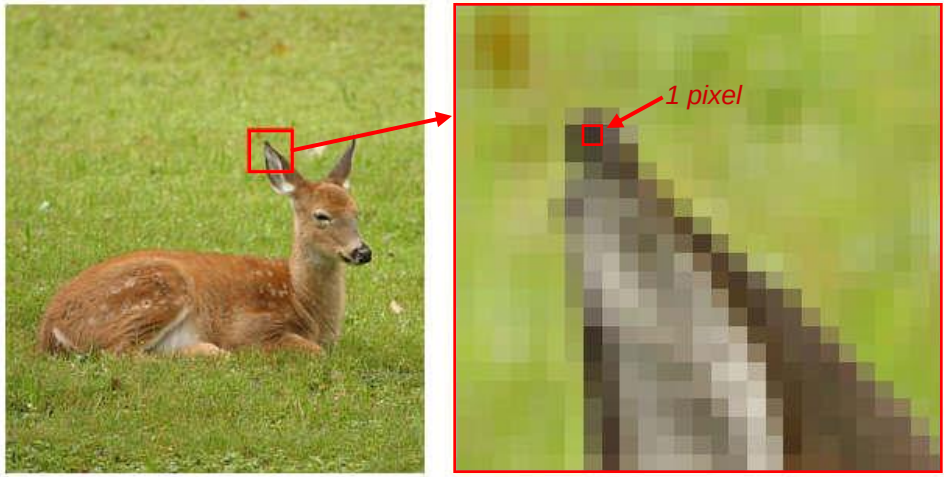
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

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

Pixel values typically represent gray levels, colors, distance from camera, etc.

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





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

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In What Form is a Digital Image Stored?

Common image formats include:

- 1 sample per point (grayscale)
- 3 samples per point (Red, Green, and Blue)
- Video (above information **plus** time)

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

What is Digital Image and Video Processing?

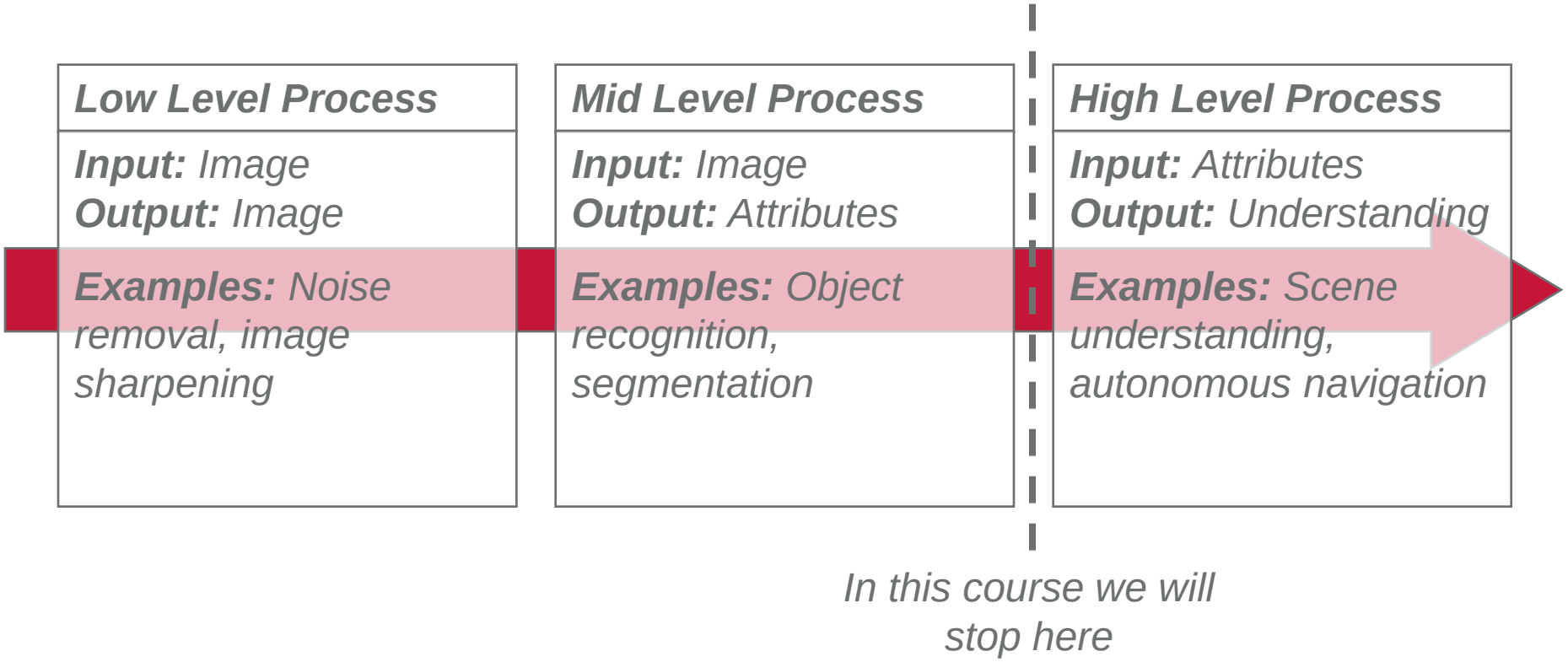
Digital image (and video) processing focuses on two major tasks

- 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



In Terms of Signal Representation

Digital Image and Video Processing is the manipulation of still and moving images, treated as multidimensional signals

- still images $f(x, y)$
- moving images $f(x, y, t)$
- other signals (CT, MRI) $f(x, y, z, t)$

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

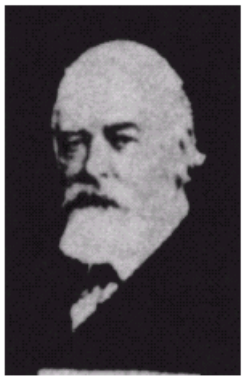
Early digital image

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

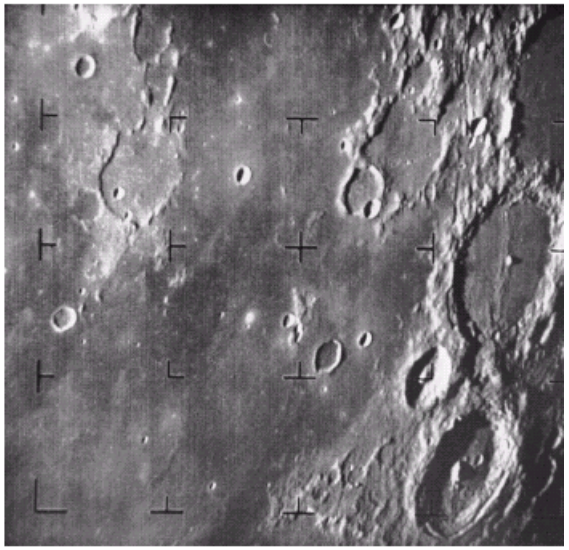
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

History of DIP (cont...)

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

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

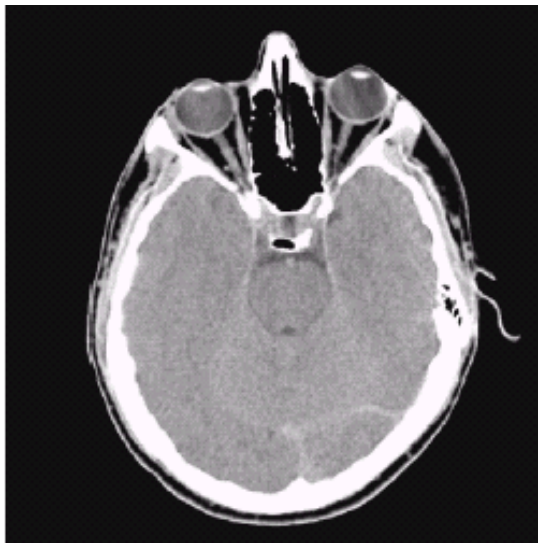


A picture of the moon taken by the Ranger 7 probe minutes before landing

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



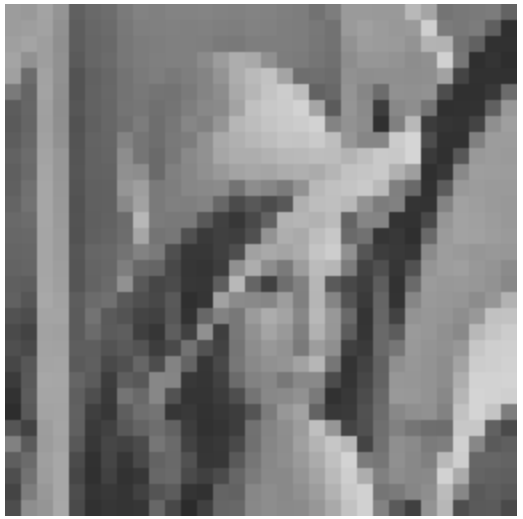
Typical head slice CAT image

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

Digital Image Acquisition: Sampling

256x256

64x64



Digital Image Acquisition: Quantisation

0	255	255	0	0
0	0	255	0	0
0	0	255	0	0
0	0	255	0	0
0	255	255	255	0

Sampling and Quantisation

256x256 256 levels

256x256 32 levels

Sampling and Quantisation cont.

256x256 256 levels

256x256 2 levels

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Key Stages in Digital Image Processing

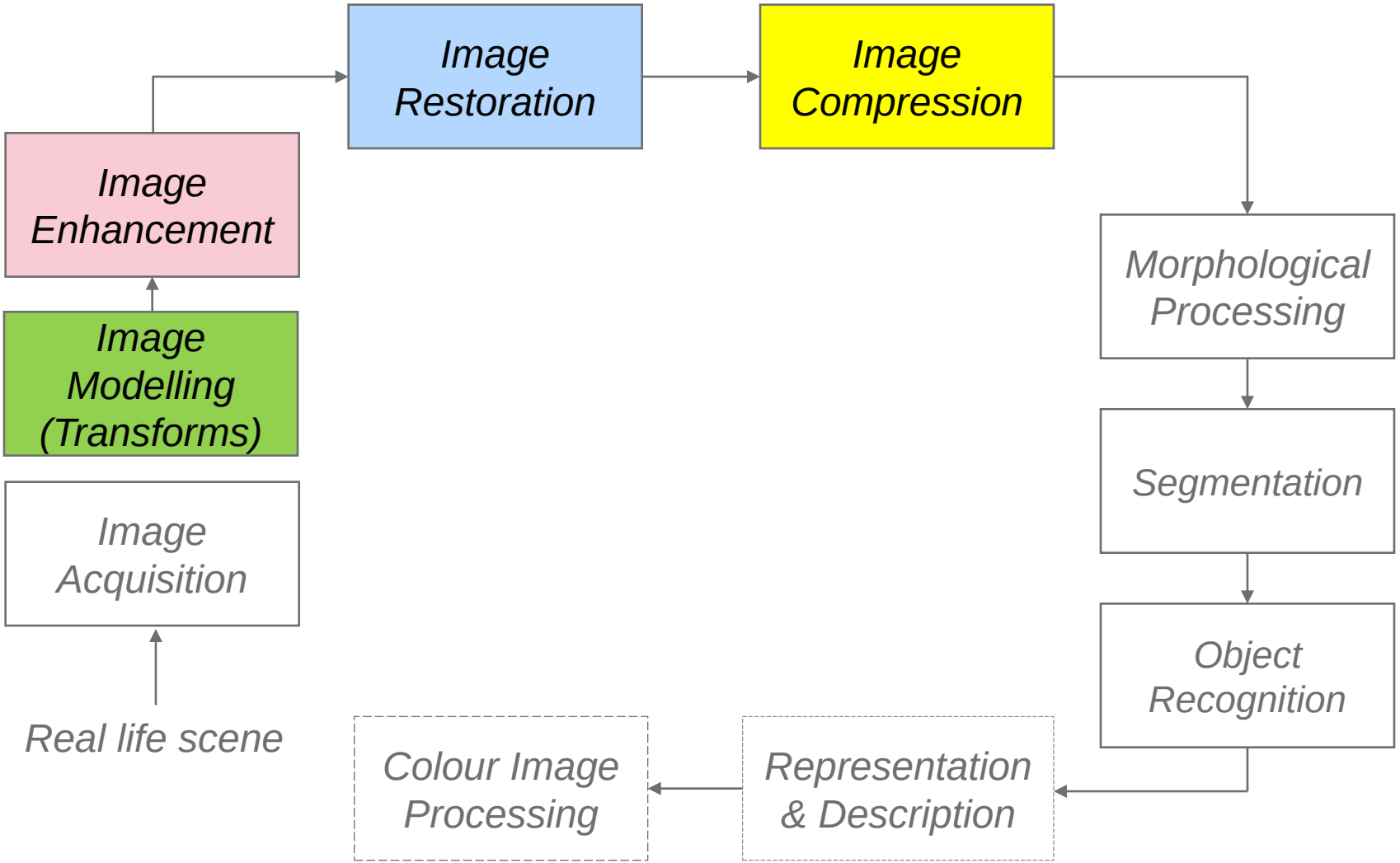

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Image Acquisition

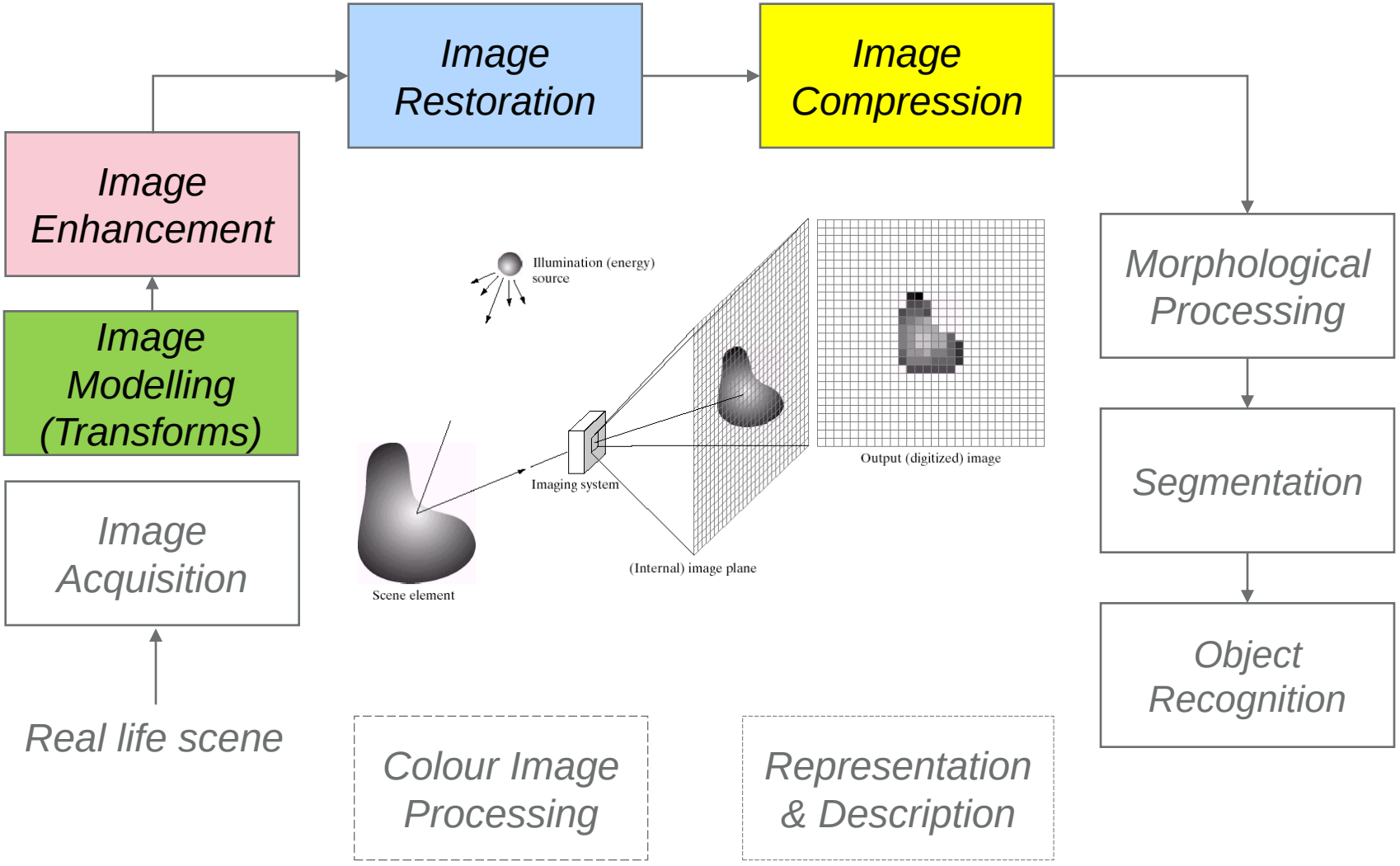

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Image Modelling-Image Transforms (Part 1)

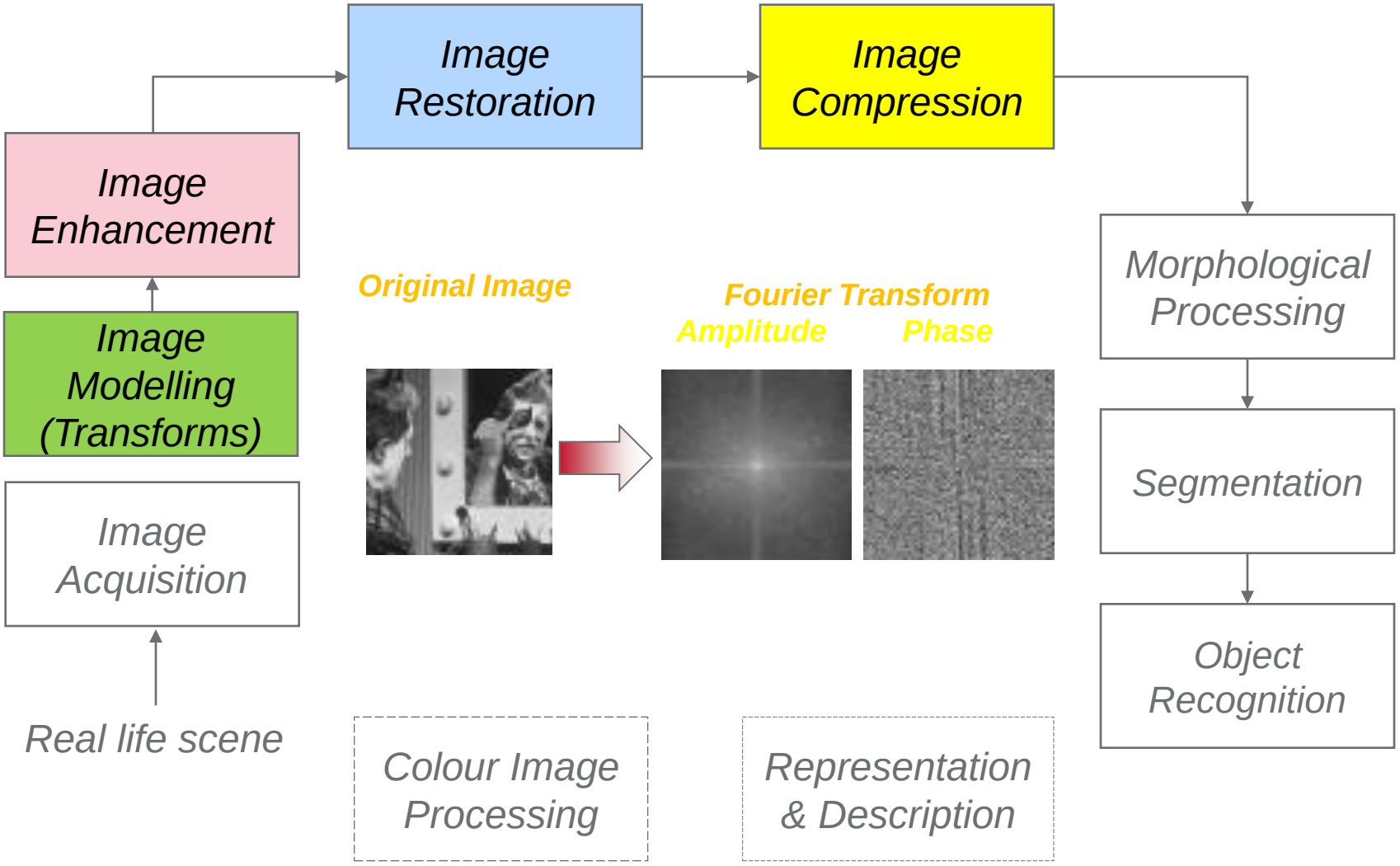

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Image Enhancement (Part 2)

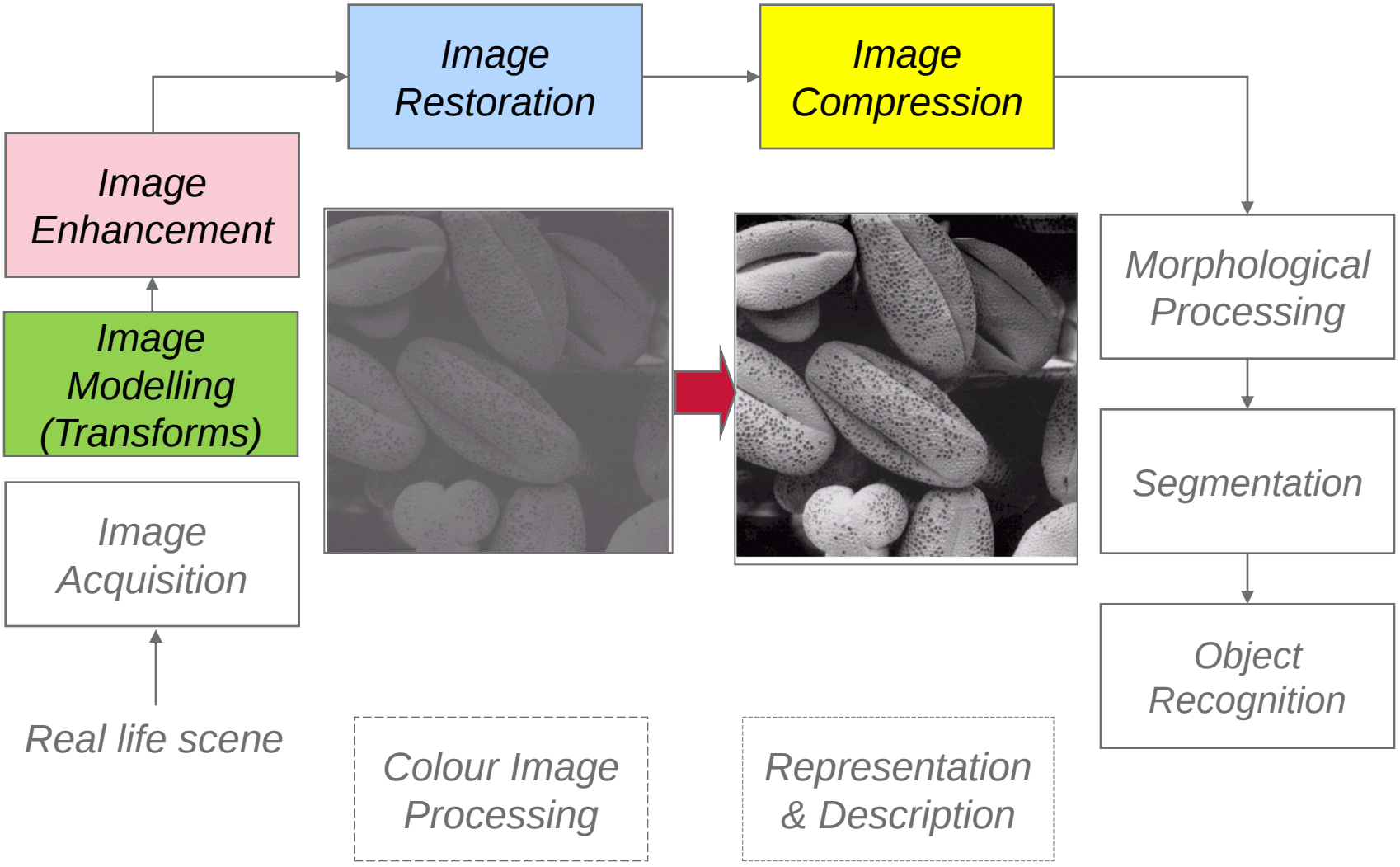

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Image Restoration (Part 3)

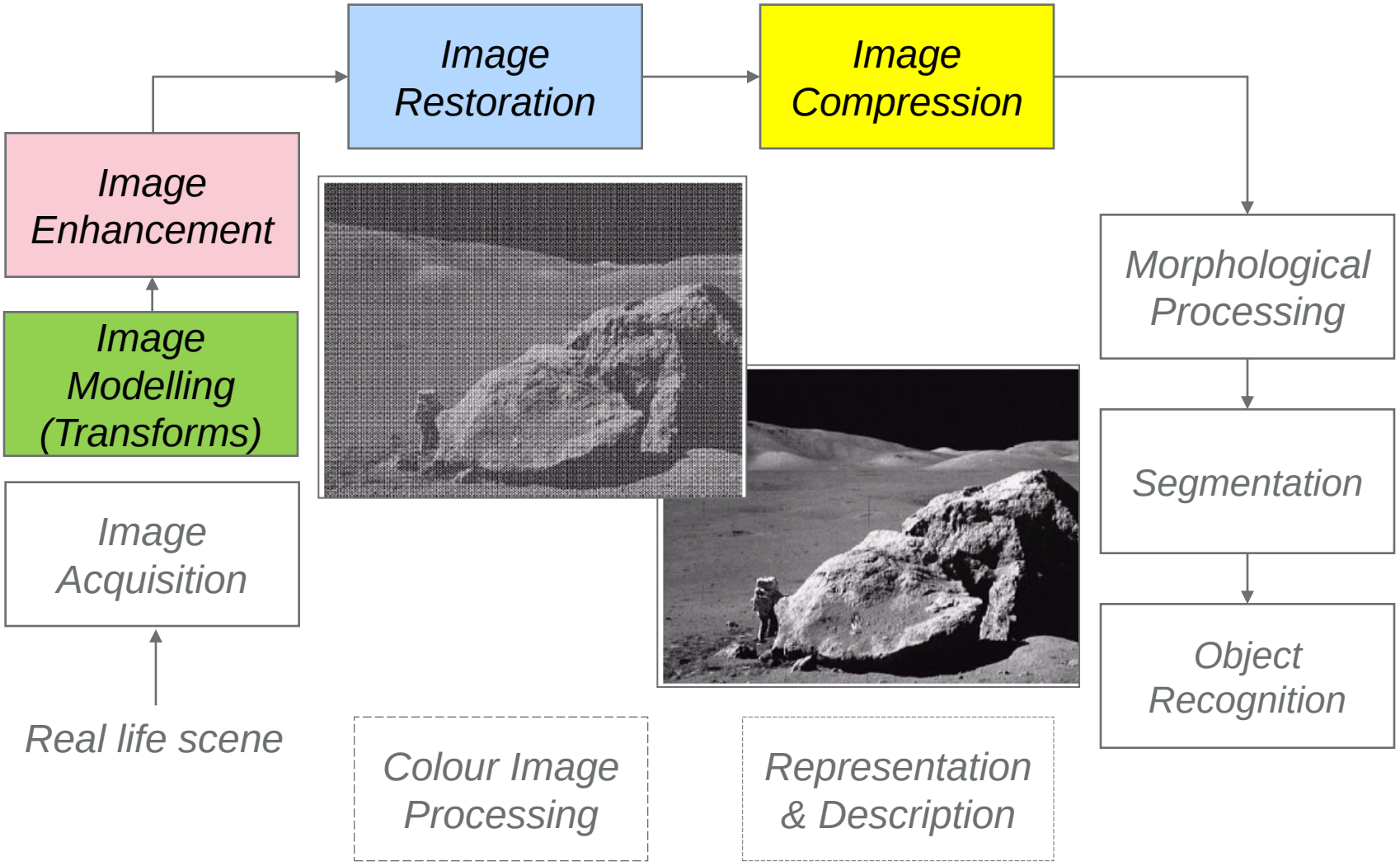

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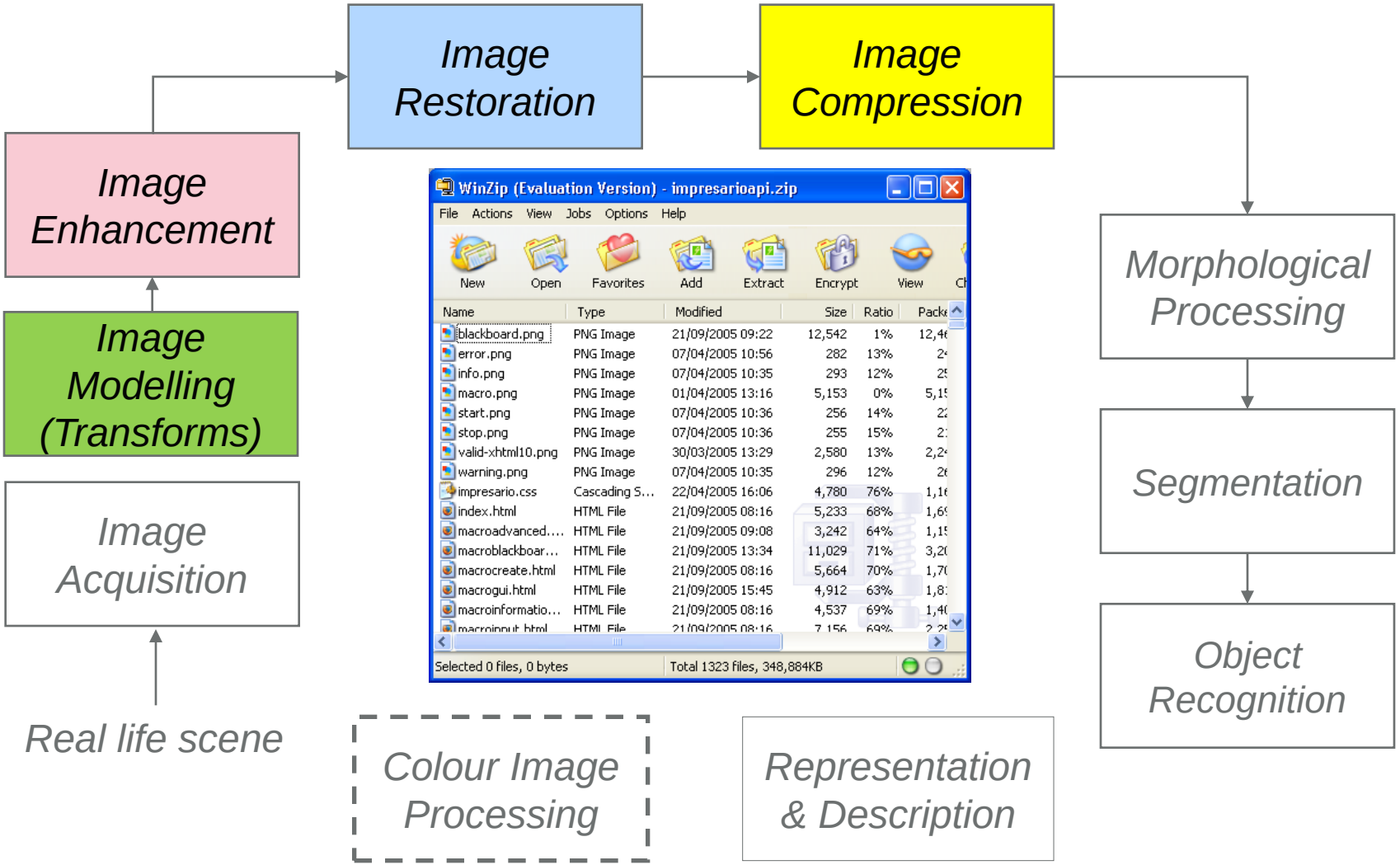
Image Compression (Part 4)



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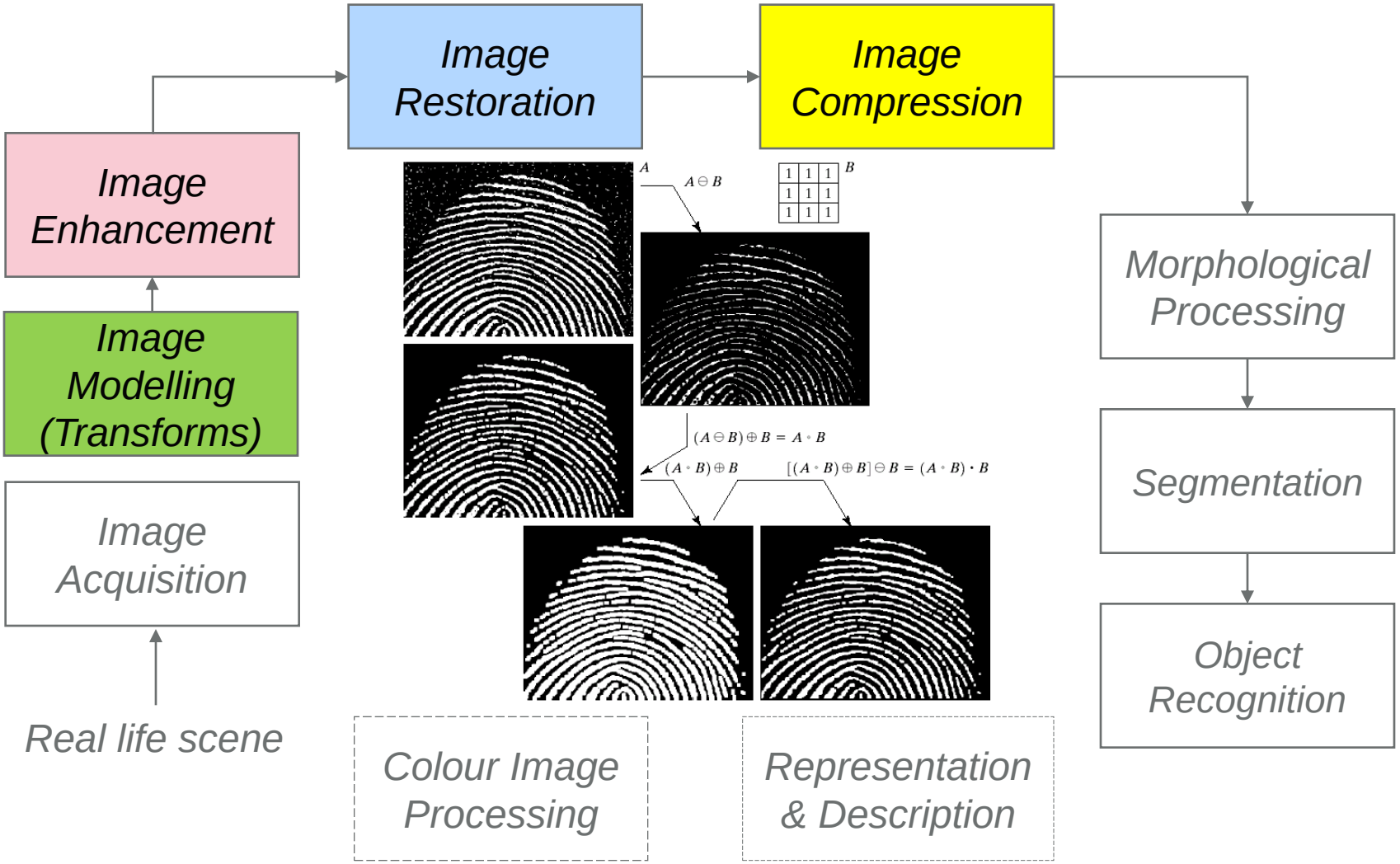
Morphological Processing



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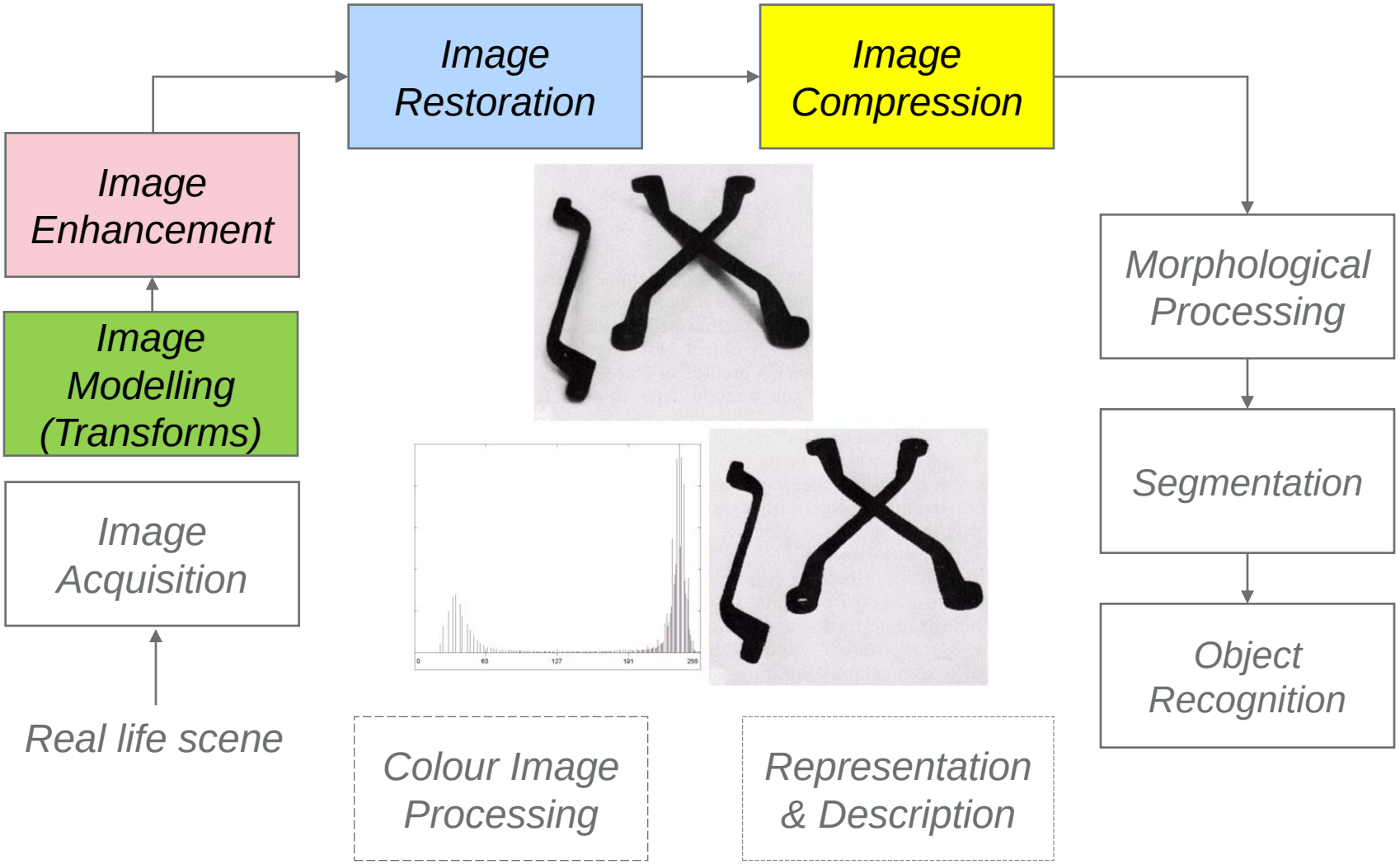
Segmentation



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Object Recognition

Image Restoration

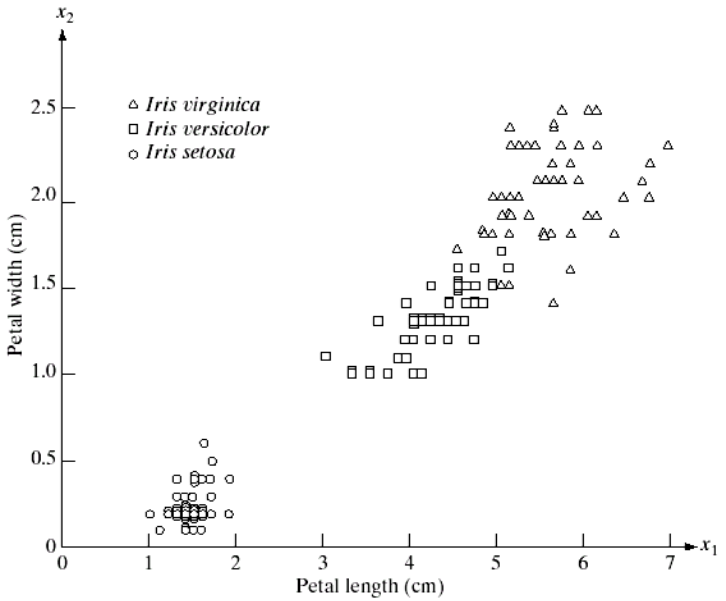
Image Compression

Image Enhancement

Image Modelling (Transforms)

Image Acquisition

Real life scene



Morphological Processing

Segmentation

Object Recognition

Colour Image Processing

Representation & Description

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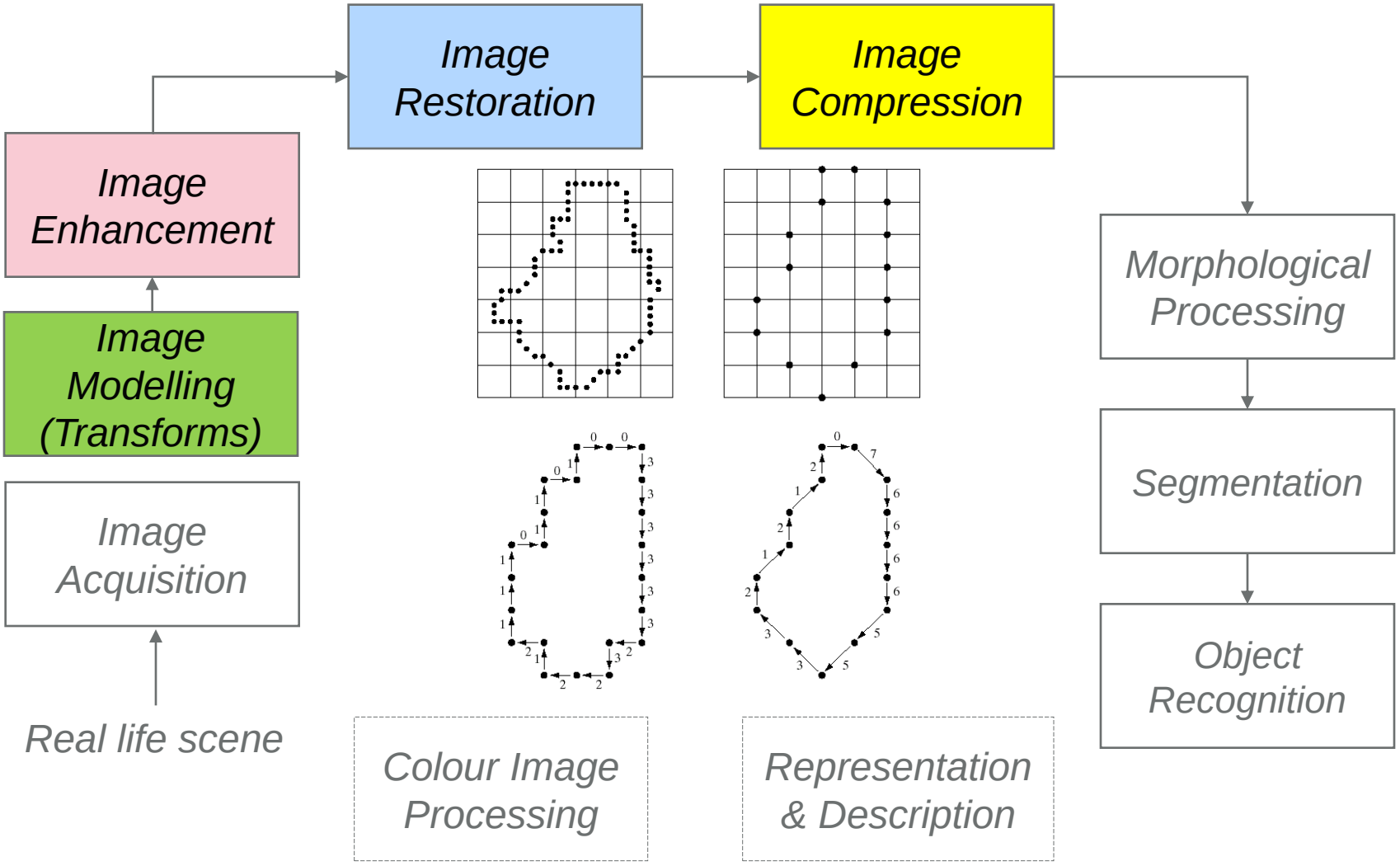
Representation and Description



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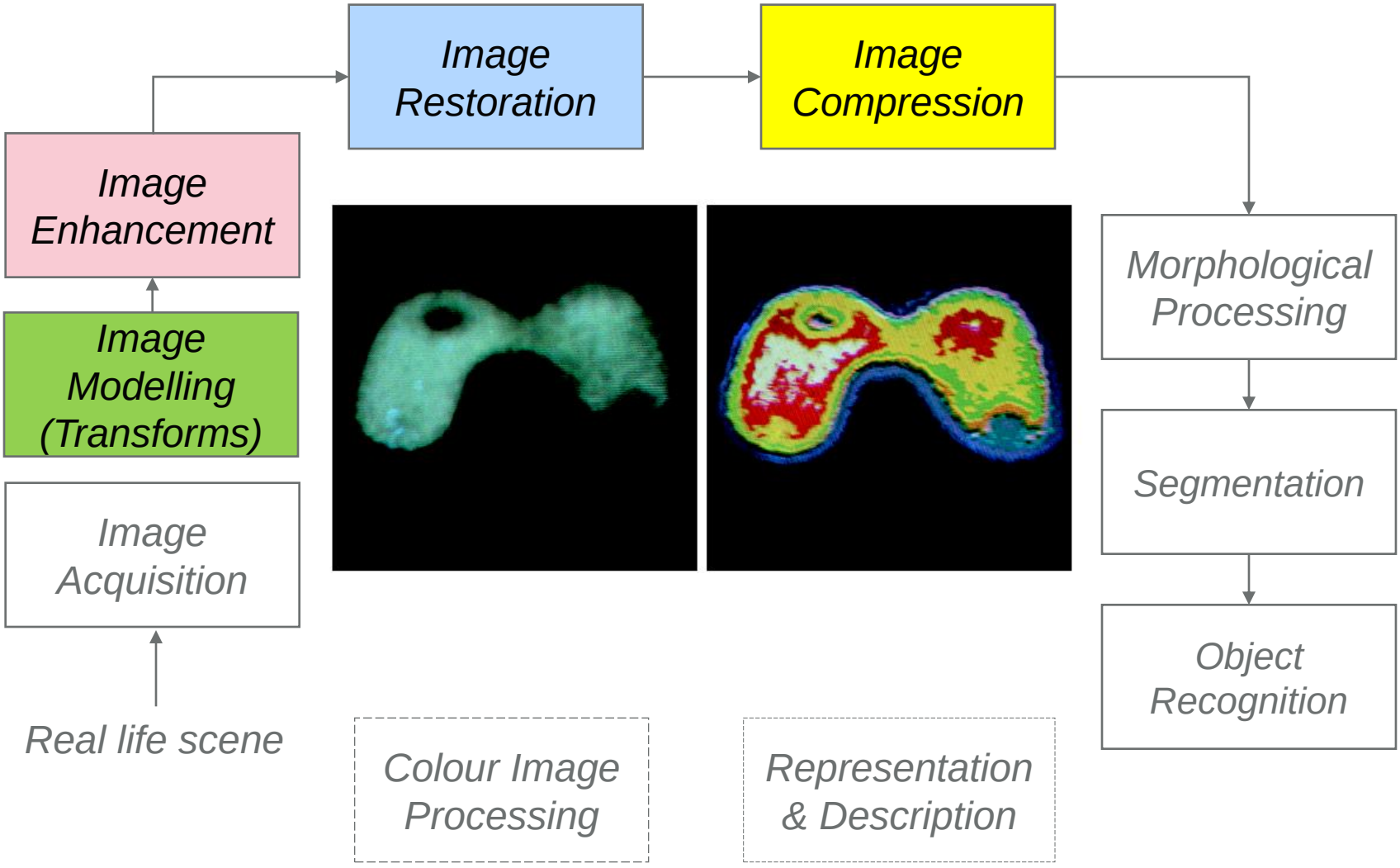
Colour Image Processing



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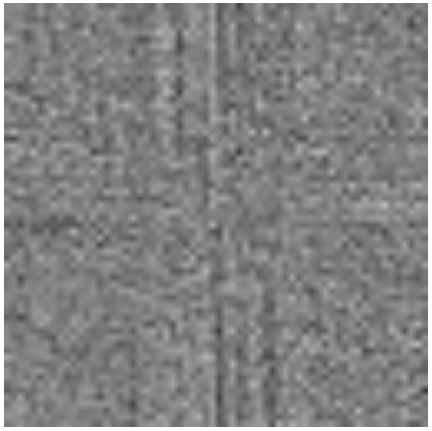
Part 1: Image Transforms

Original Image

Fourier Transform

Amplitude

Phase



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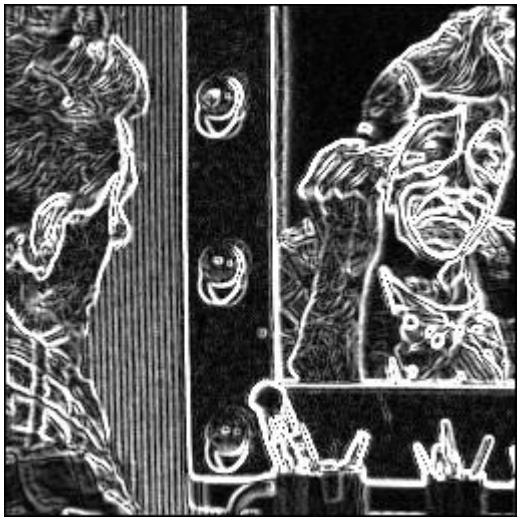
Part 2: Image Enhancement

Original Image

High Pass Filtering



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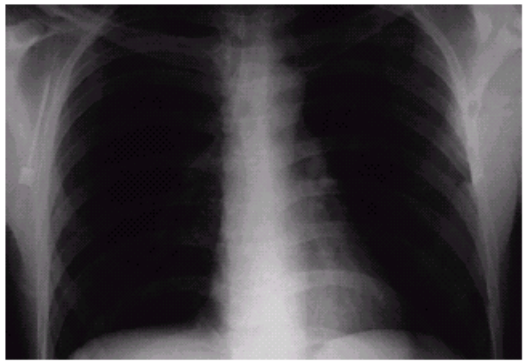
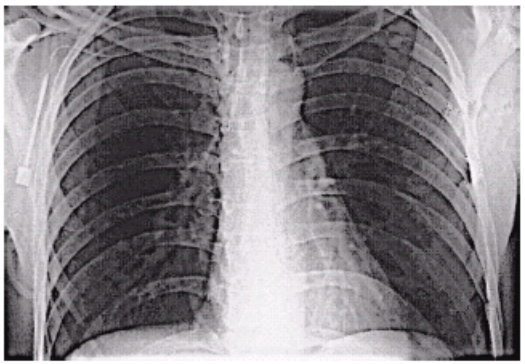
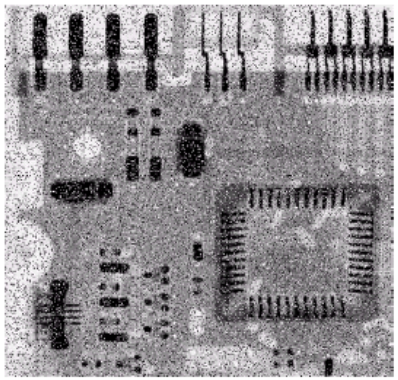
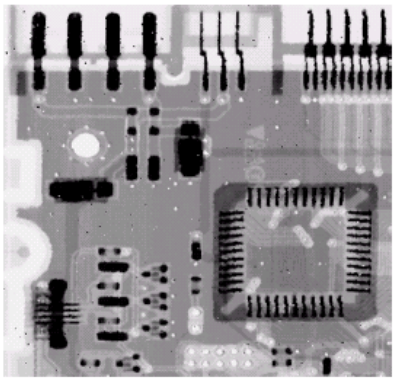
Examples: Image Enhancement

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









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

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Part 3: Image Restoration

Distorted Image

Restored Image

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Distortion due to camera misfocus

Original image

Distorted image

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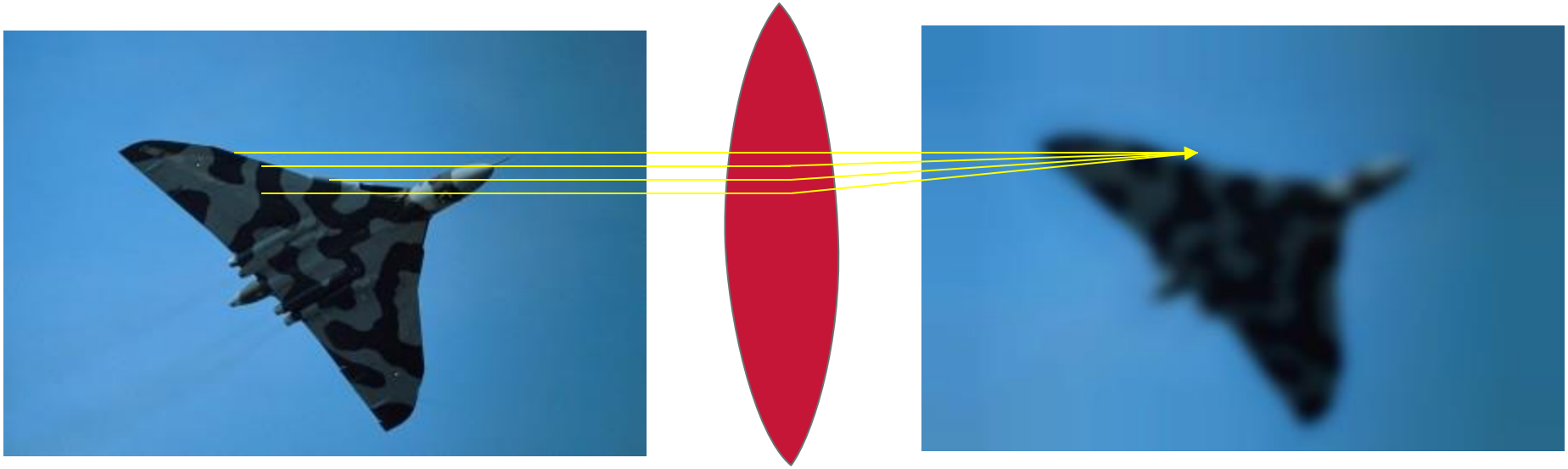
Distortion due to camera misfocus



Camera lens

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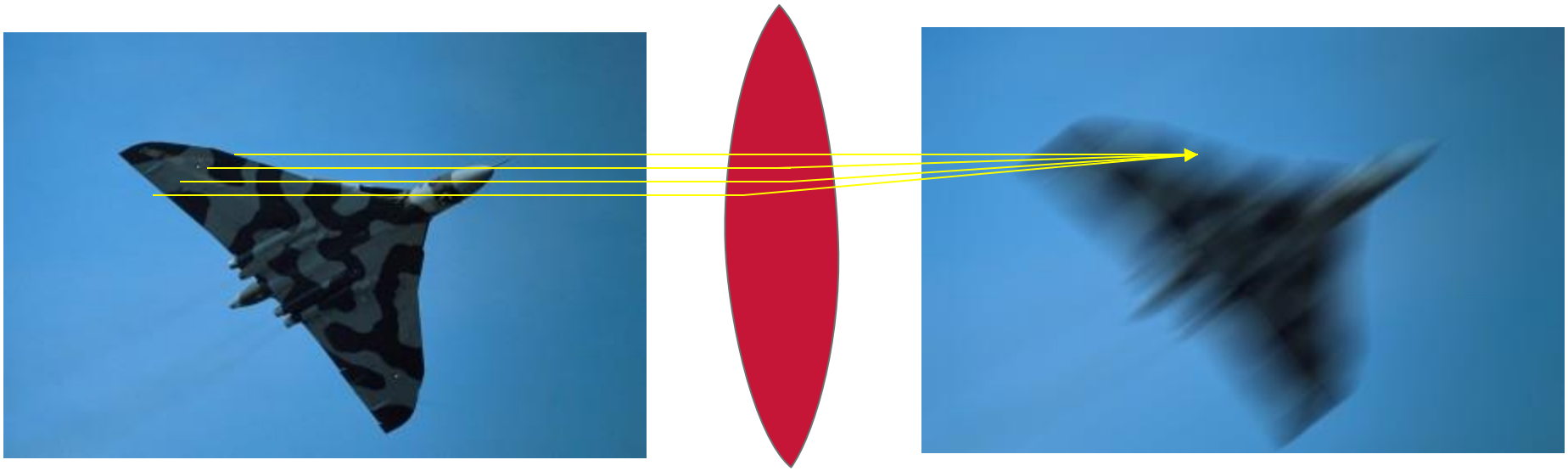
Distortion due to motion



Camera lens

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Distortion due to random noise

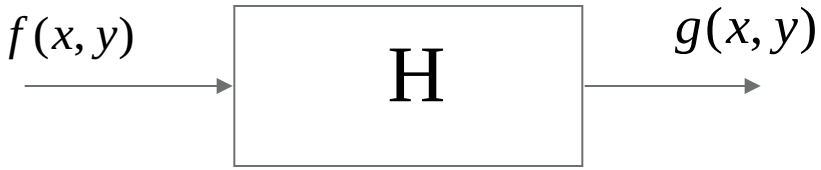
Original image

Distorted image

Part IV: Image Compression

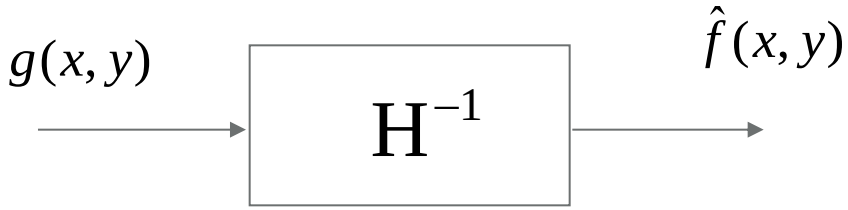
Signal-Processing Based:

Encoder



Compressed Representation

Decoder



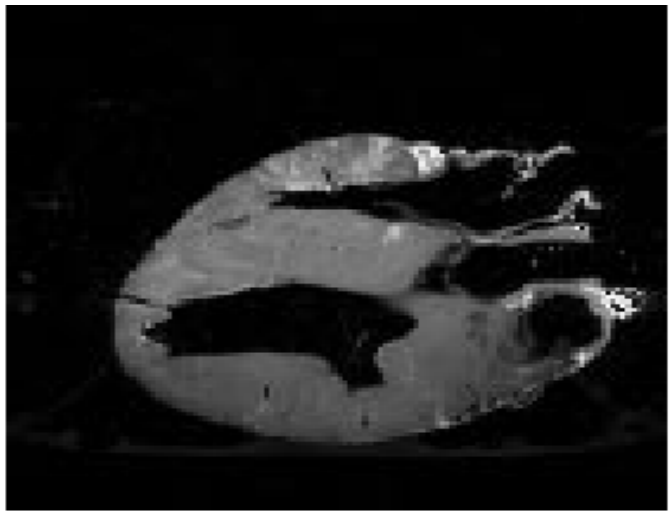
Applications

- Medical images
- Satellite images
- Astronomy
- Industrial inspection
- Artistic effects
- Geographical Information Systems
- Law
- Human computer interfaces

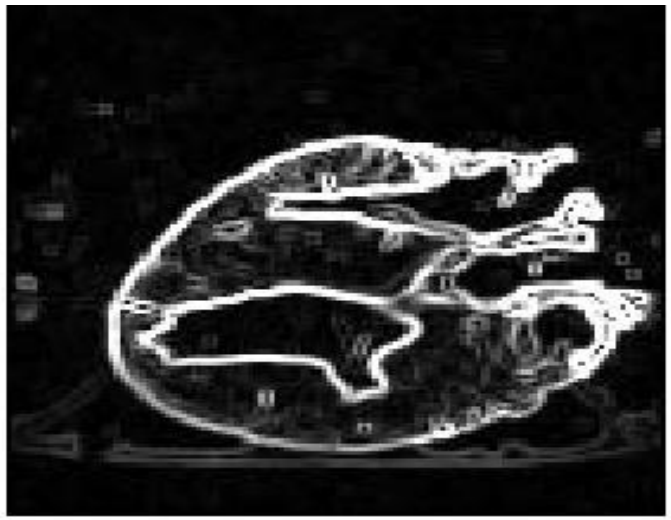
Medicine

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)

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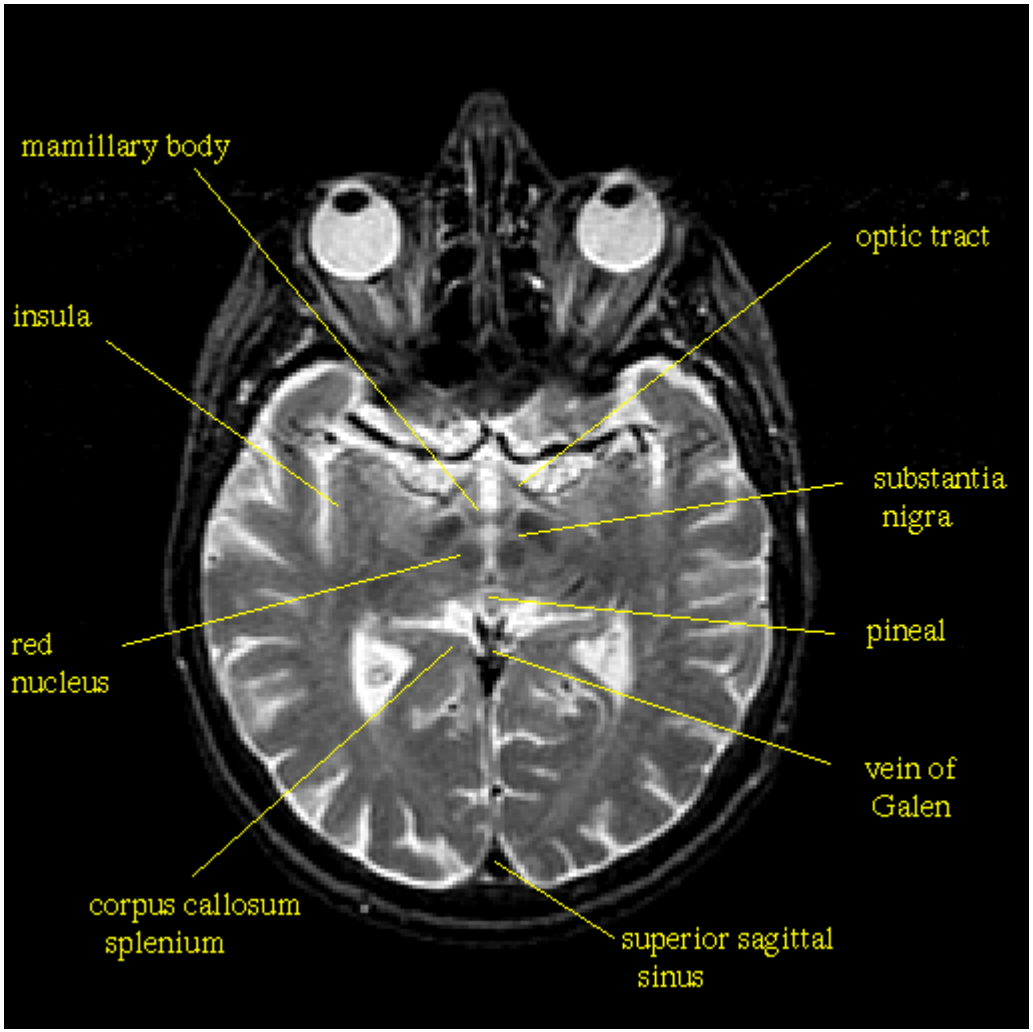
Medical Images

MRI of normal brain



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Medical Images

X-ray of knee

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Medical Images

Fetal ultrasound

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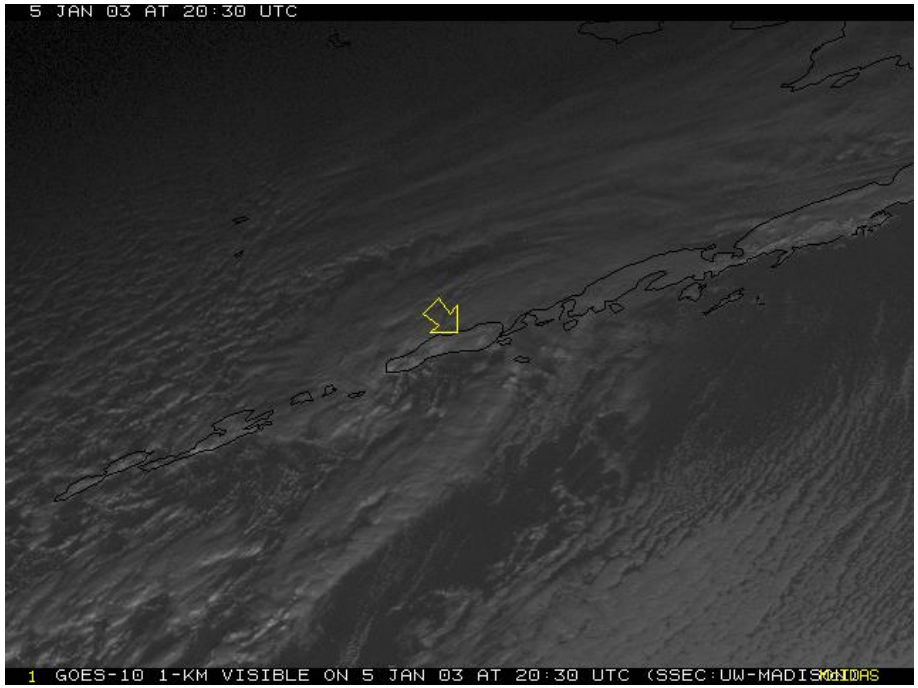
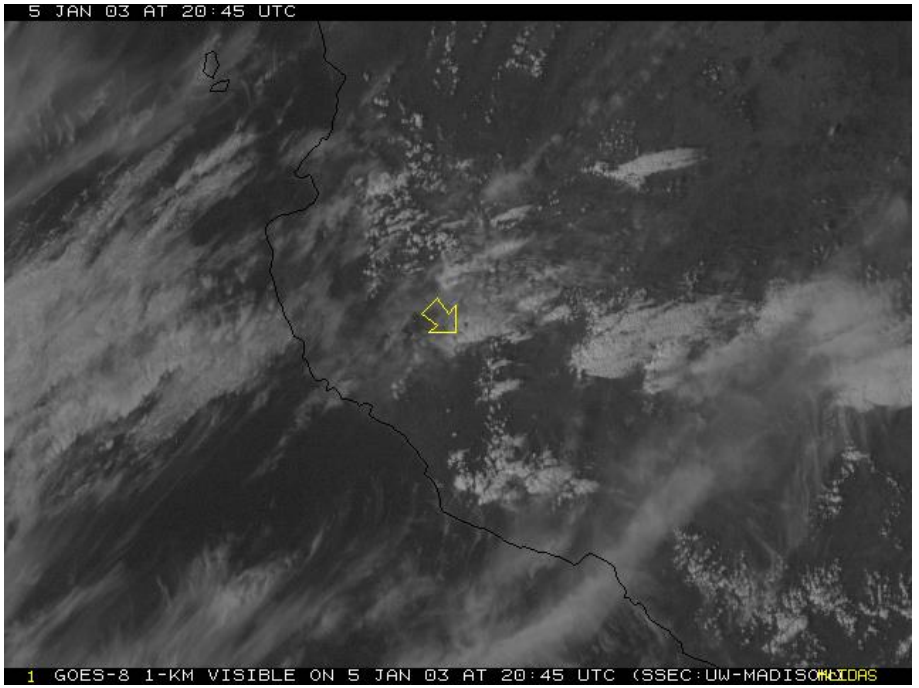
Satellite imagery

Volcanos in Russia and Alaska





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Astronomical images

Spiral Galaxy NGC 1232 - VLT UT 1 + FORS1

ESO PR Photo 37d/98 (23 September 1998)

©European Southern Observatory

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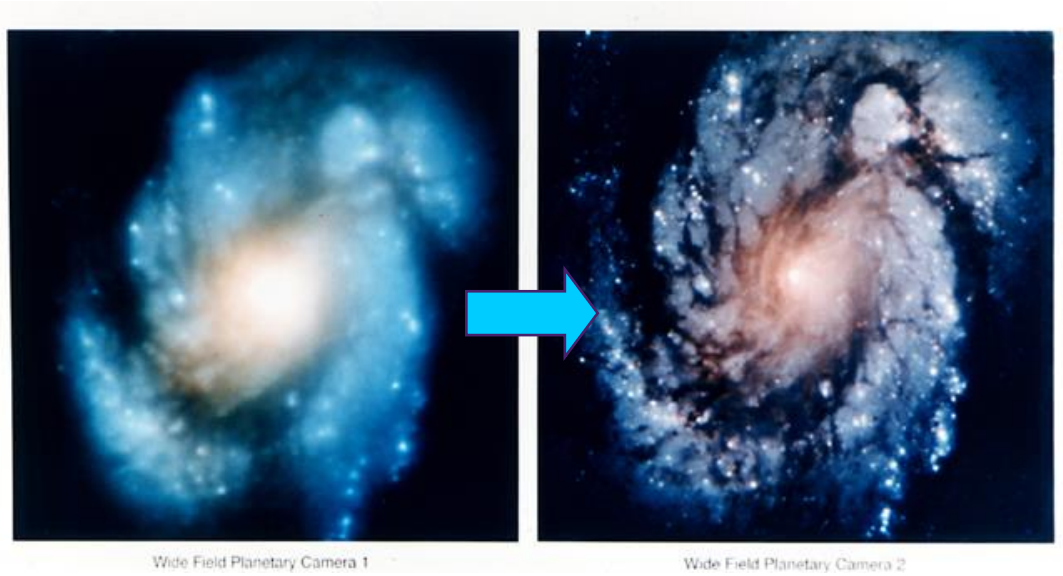
Examples: The Hubble Telescope

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



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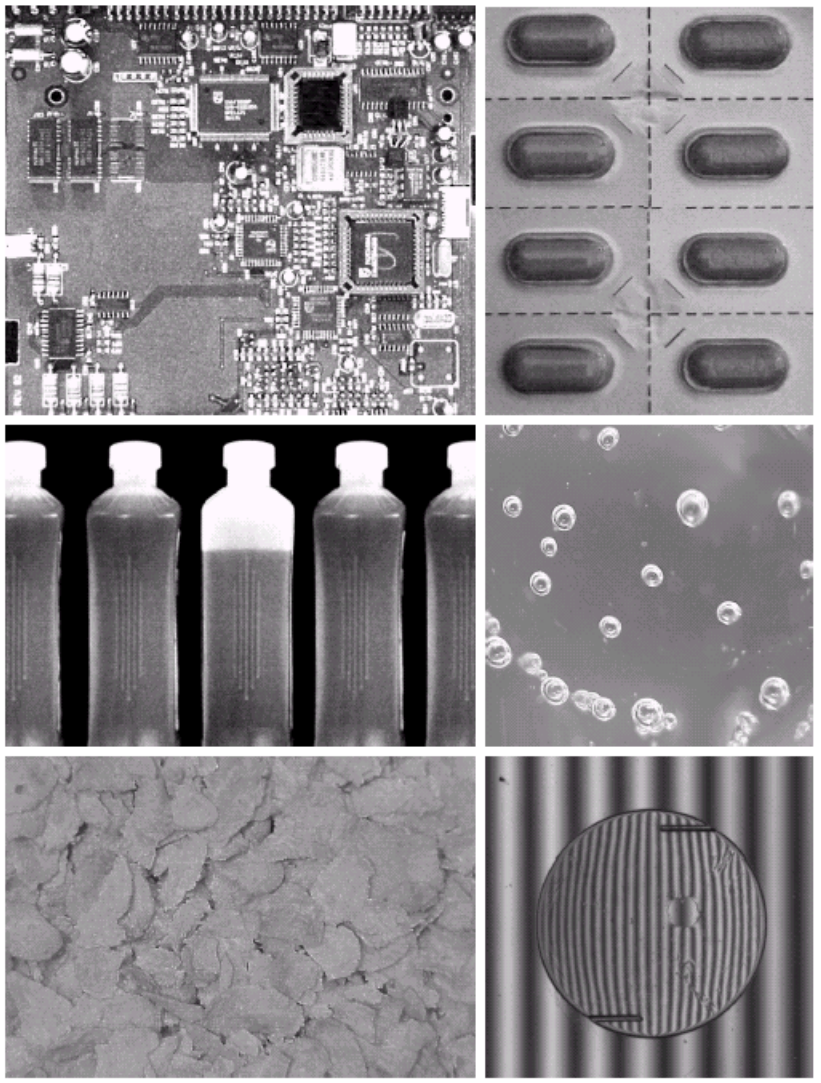
Industrial Inspection

- Human operators are expensive, slow and unreliable
- Make machines do the job instead
- Industrial vision systems are used in all kinds of industries



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

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Artistic Effects

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

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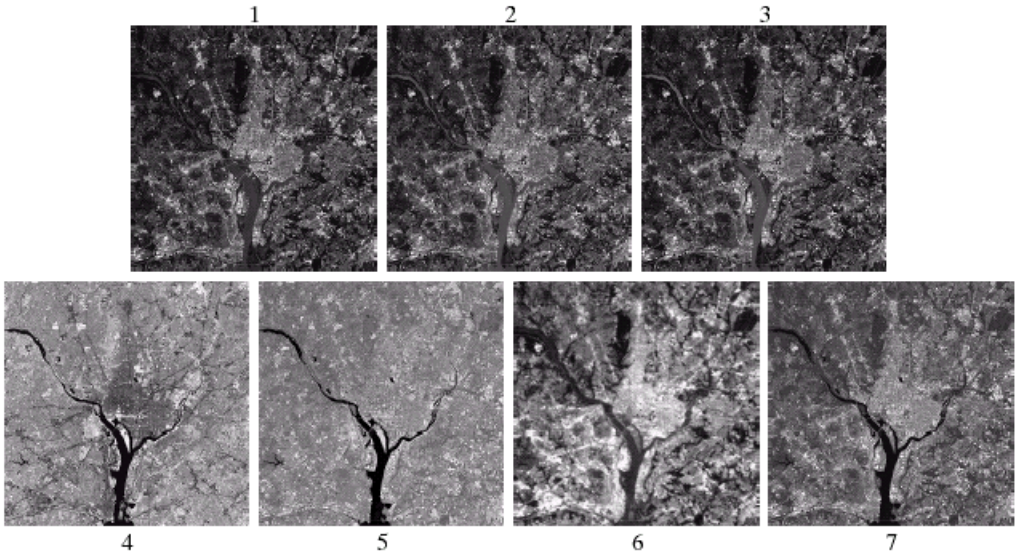
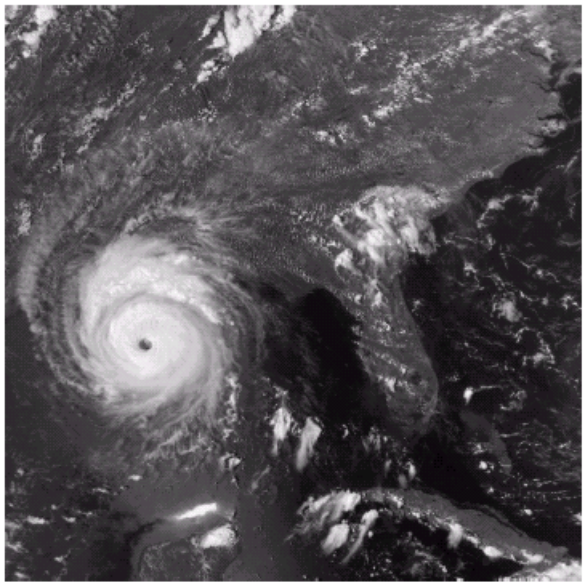
Geographical Information Systems

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

Geographic Information Systems

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

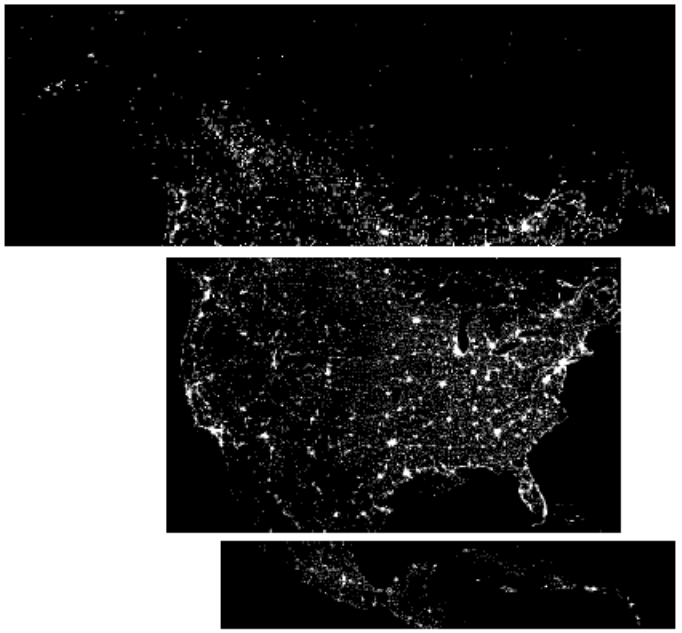




Examples: GIS (cont...)

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

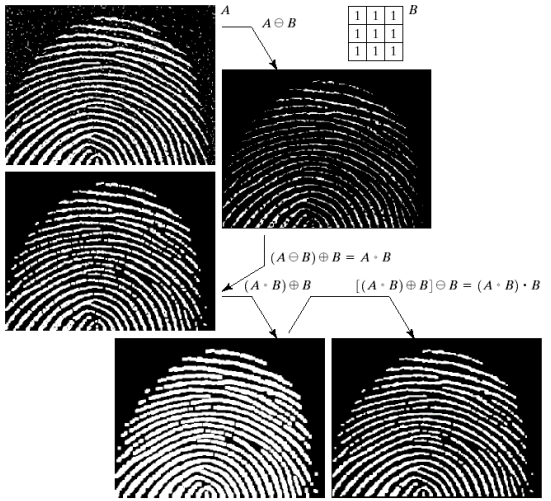


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Law

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)

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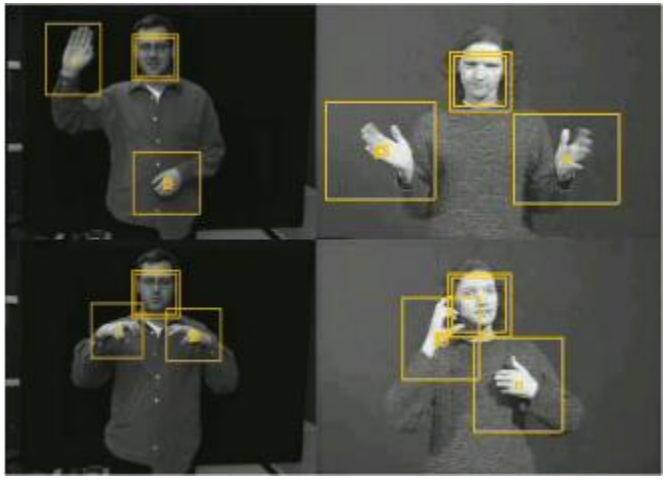
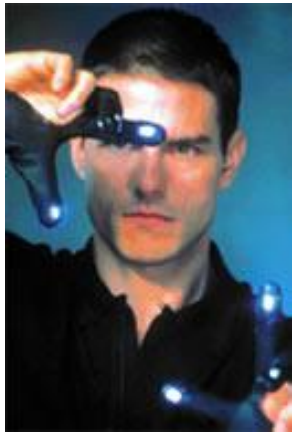
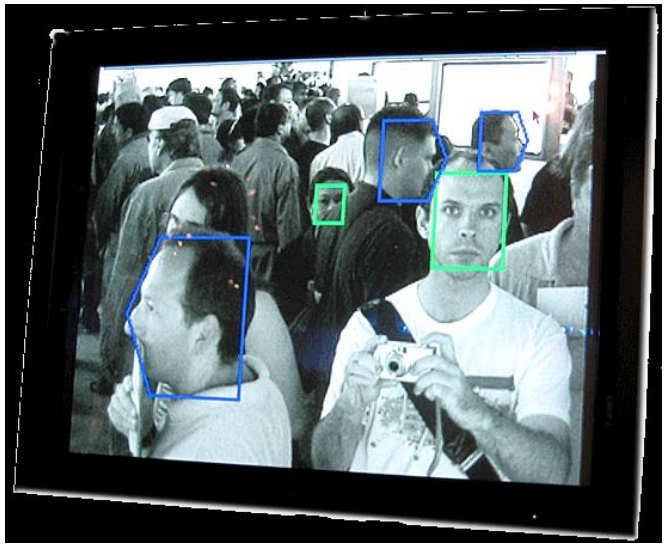
HCI

- Try to make human computer interfaces more natural
  - Face recognition
  - Gesture recognition
- Does anyone remember the user interface from “Minority Report”?
- These tasks can be extremely difficult