Digital Image Processing:
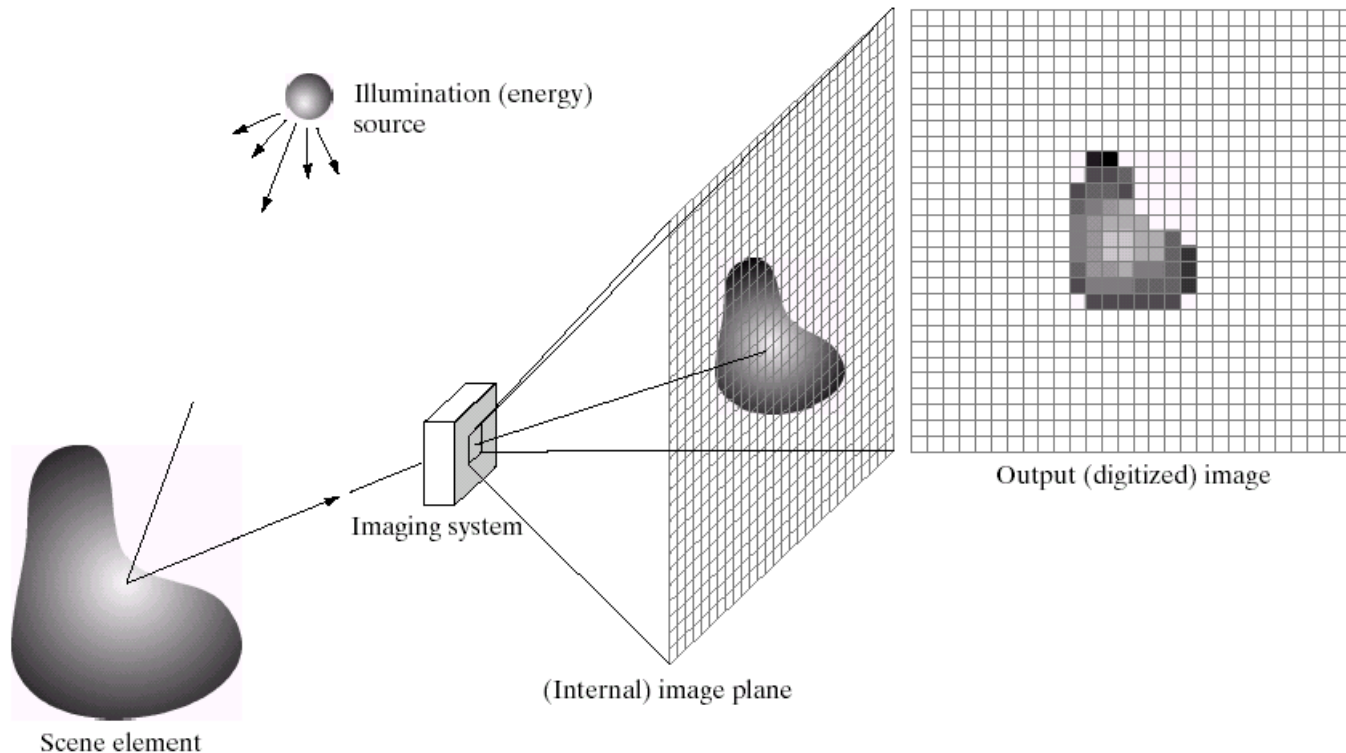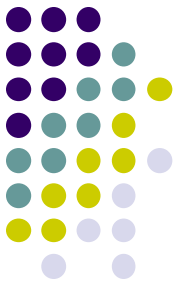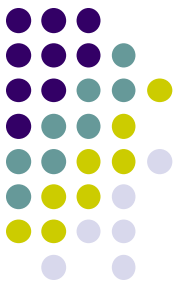
What is a Digital Image?

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

Illumination (energy) source

Imaging system

(Internal) image plane

Scene element

Output (digitized) image

What is a Digital Image? (cont…)

- Pixel values typically represent gray levels, colors, heights, opacities etc

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

1 pixel
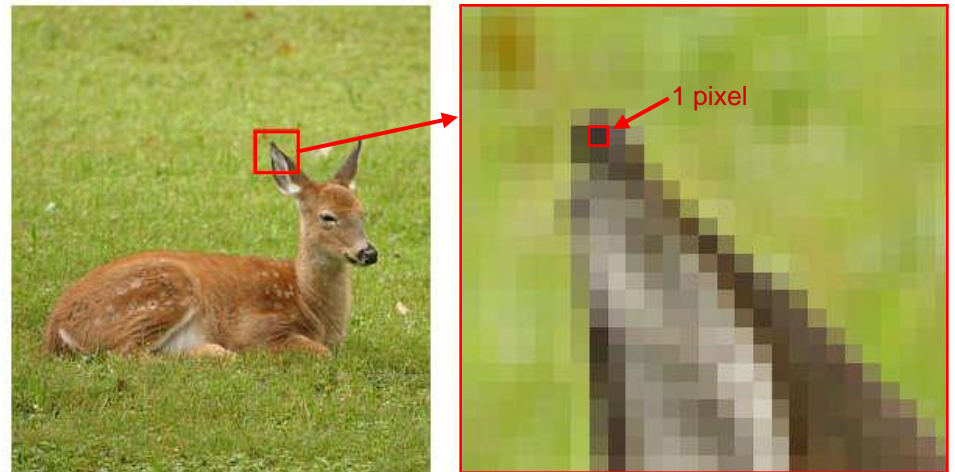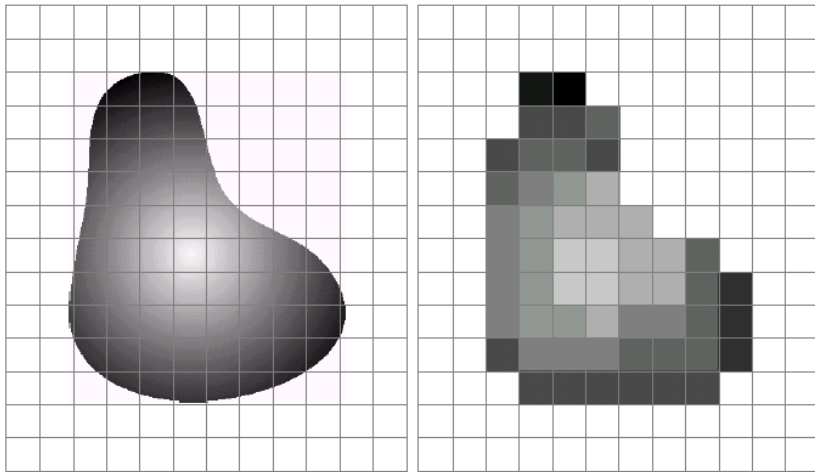
What is a Digital Image? (cont…)

- 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
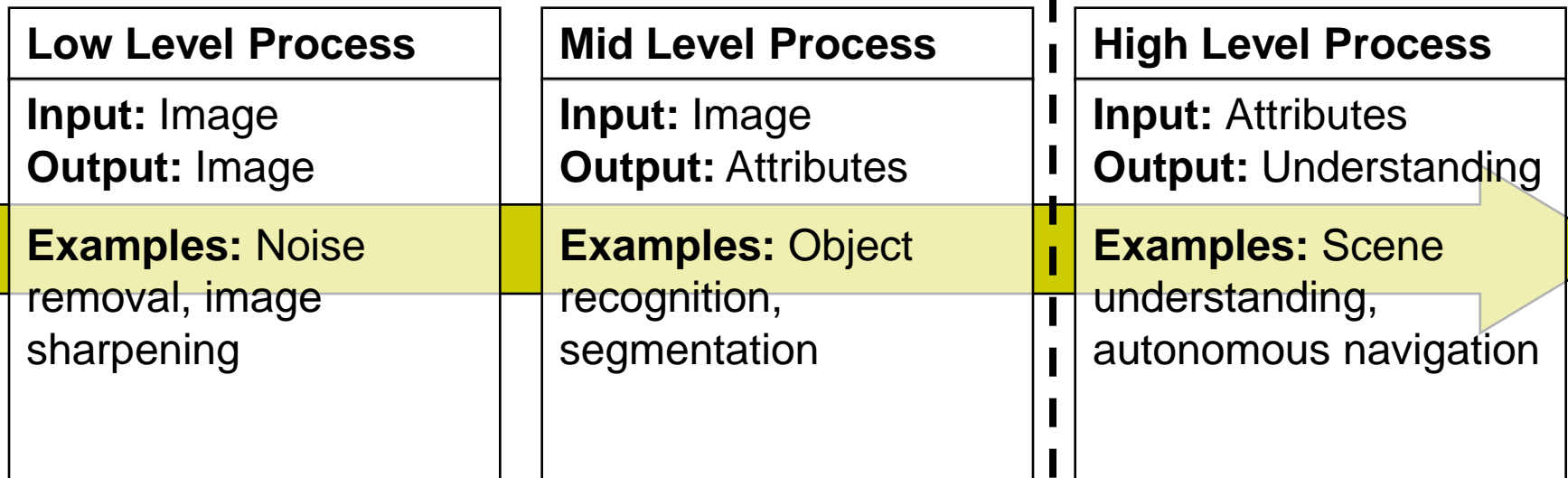
4

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

Low Level Process	Mid Level Process	High Level Process
Input: Image **Output:** Image	**Input:** Image **Output:** Attributes	**Input:** Attributes **Output:** Understanding
Examples: Noise removal, image sharpening	**Examples:** Object recognition, segmentation	**Examples:** Scene understanding, autonomous navigation

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 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
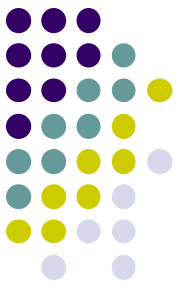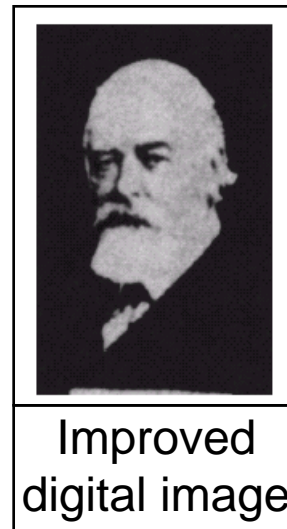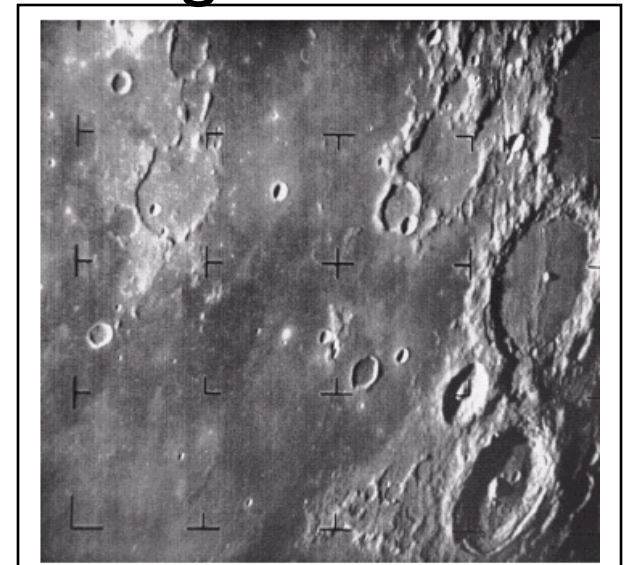
History of DIP (cont…)

- **Mid to late 1920s:** Improvements to the Bartlane system resulted in higher quality images
  - New reproduction processes based on photographic techniques
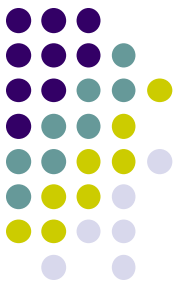 - Increased number of tones in reproduced images

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

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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
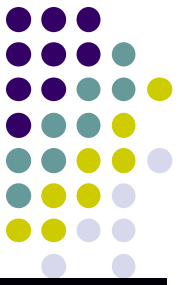 - Law enforcement
  - Human computer interfaces

Examples: Image Enhancement
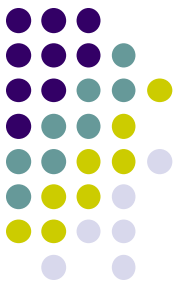
- One of the most common uses of DIP techniques: improve quality, remove noise etc
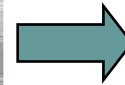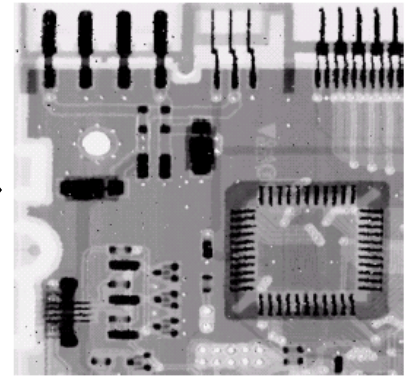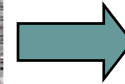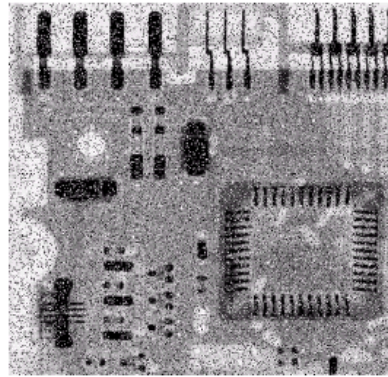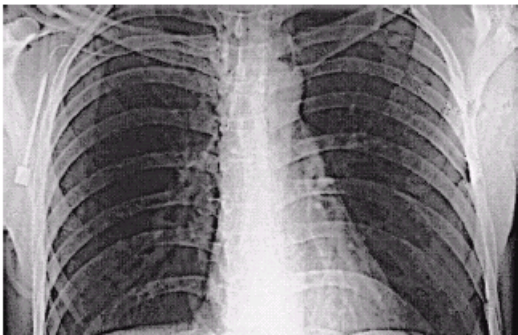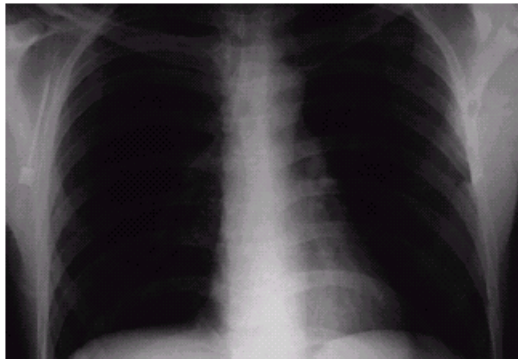
Examples: The Hubble Telescope

- 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

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Wide Field Planetary Camera 1

Wide Field Planetary Camera 2
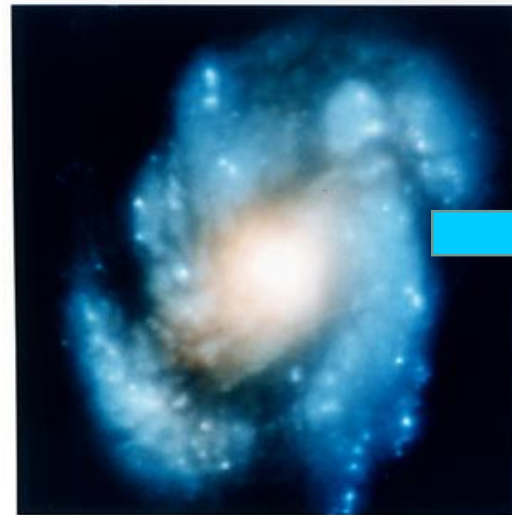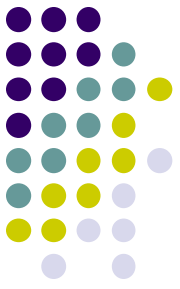
Examples: Artistic Effects
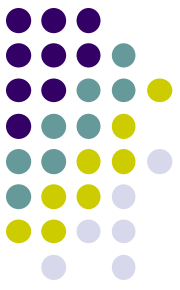
- Artistic effects are used to make images more visually appealing, to add special effects and to make composite images

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
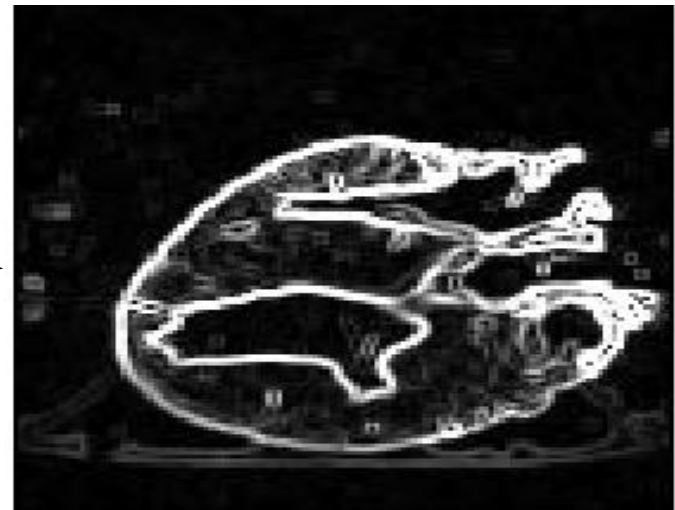
Examples: GIS

- Geographic Information Systems
  - Digital image processing techniques are used extensively to manipulate satellite imagery
  - Terrain classification
  - Meteorology
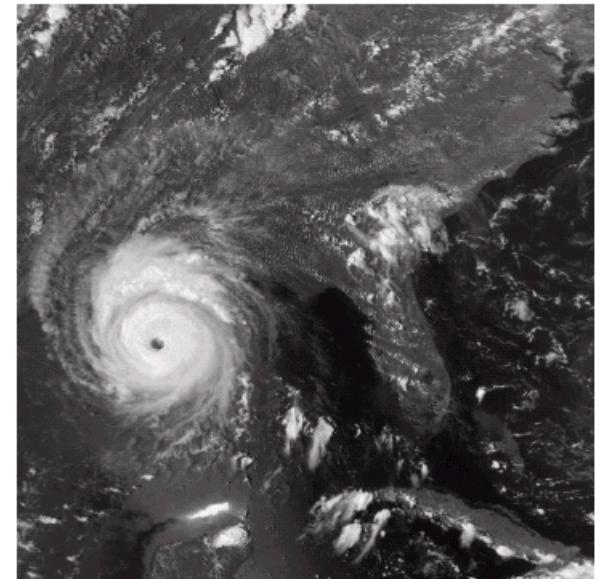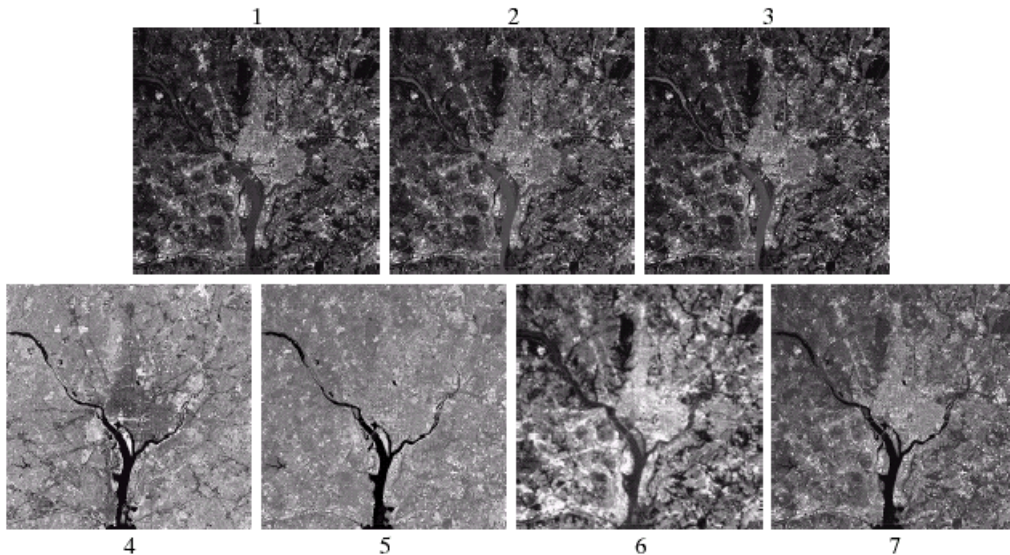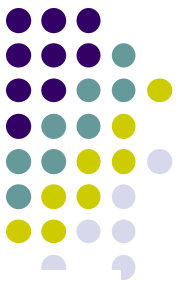
Examples: GIS (cont…)

- *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

13:19
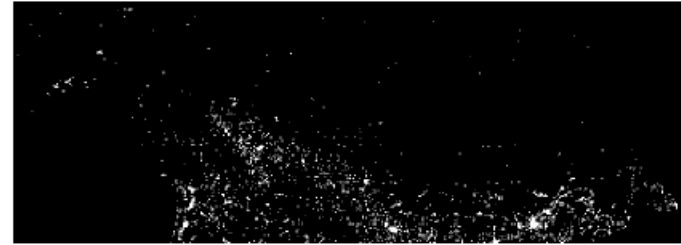
Examples: Industrial Inspection
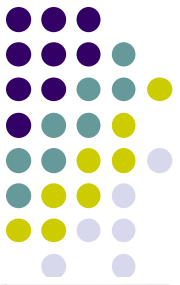
- Human operators are expensive, slow and unreliable

- Make machines do the job instead

- Industrial vision systems
are used in all kinds of industries

13:19
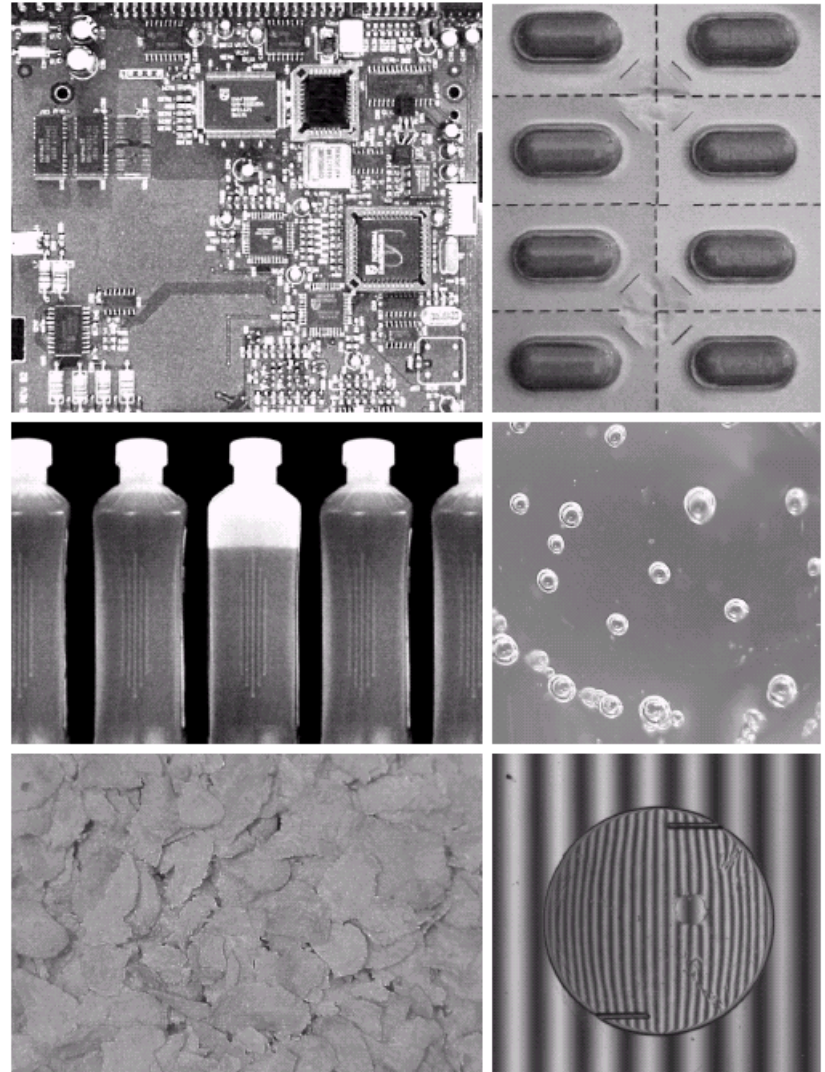
Examples: PCB Inspection

- 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 are used
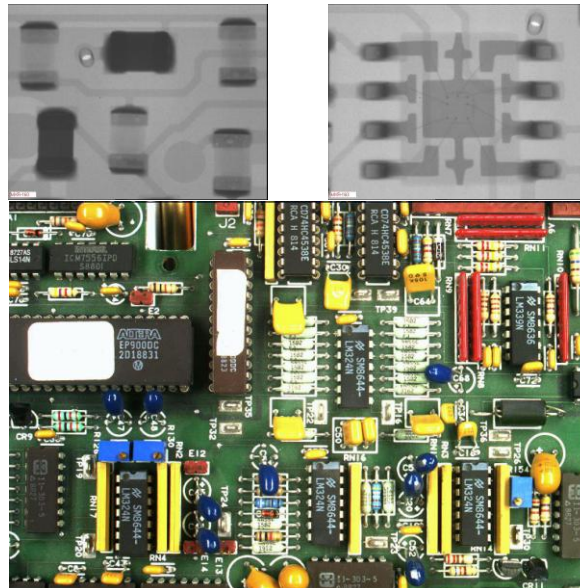
Examples: Law Enforcement

- Image processing techniques are used extensively by law enforcers
  - Number plate recognition for speed cameras/automated toll systems
  - Fingerprint recognition
  - Enhancement of CCTV images

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$A \ominus B$ B

$(A \ominus B) \oplus B = A \circ B$

$(A \circ B) \oplus B$ $[(A \circ B) \oplus B] \ominus B = (A \circ B) \bullet B$

13:19
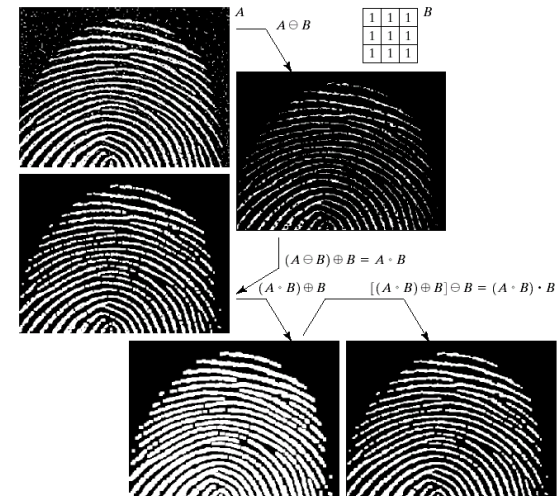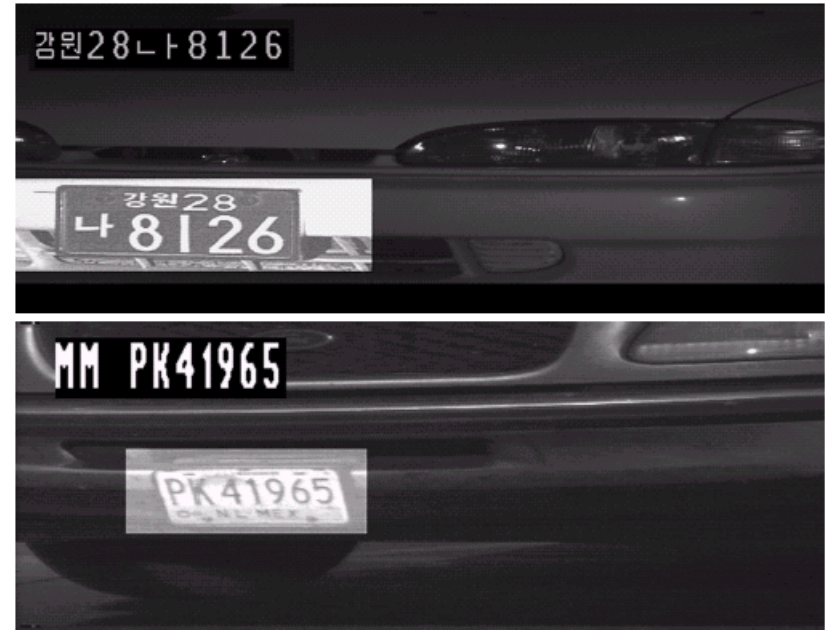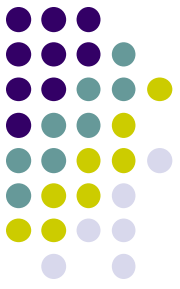
Examples: HCI

- Try to make human computer interfaces more natural

  - Face recognition

  - Gesture recognition

- These tasks can be extremely difficult

Key Stages in Digital Image Processing

Image Restoration

Morphological Processing

Image Enhancement

Image Acquisition

Problem Domain

Segmentation

Object Recognition

Representation & Description

Colour Image Processing

Image Compression
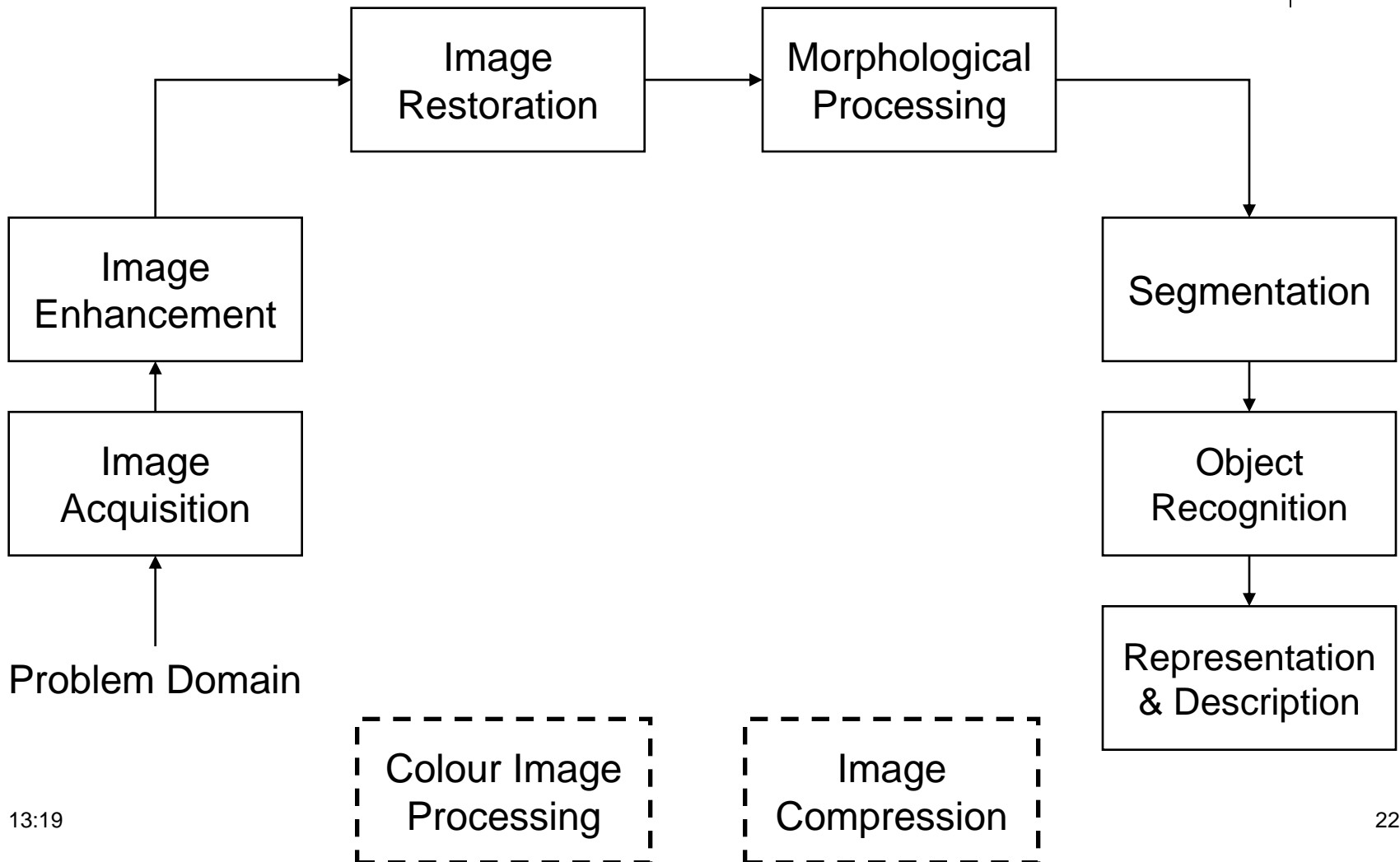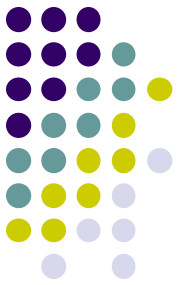
Key Stages in Digital Image Processing: Image Acquisition

Image Restoration

Morphological Processing

Image Enhancement

Image Acquisition

Segmentation

Object Recognition

Representation & Description

Problem Domain

Colour Image Processing

Image Compression

Illumination (energy) source

Imaging system

Scene element

(Internal) image plane

Output (digitized) image

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Key Stages in Digital Image Processing: Image Restoration

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Key Stages in Digital Image Processing: Morphological Processing

Image Restoration

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Representation & Description

Colour Image Processing

Image Compression

$A \ominus B$

$(A \ominus B) \oplus B = A \circ B$

$(A \circ B) \oplus B$

$[(A \circ B) \oplus B] \ominus B = (A \circ B) \cdot B$

Key Stages in Digital Image Processing: Segmentation

Image Restoration

Morphological Processing

Image Enhancement

Image Acquisition

Problem Domain

Segmentation

Object Recognition

Representation & Description

Colour Image Processing
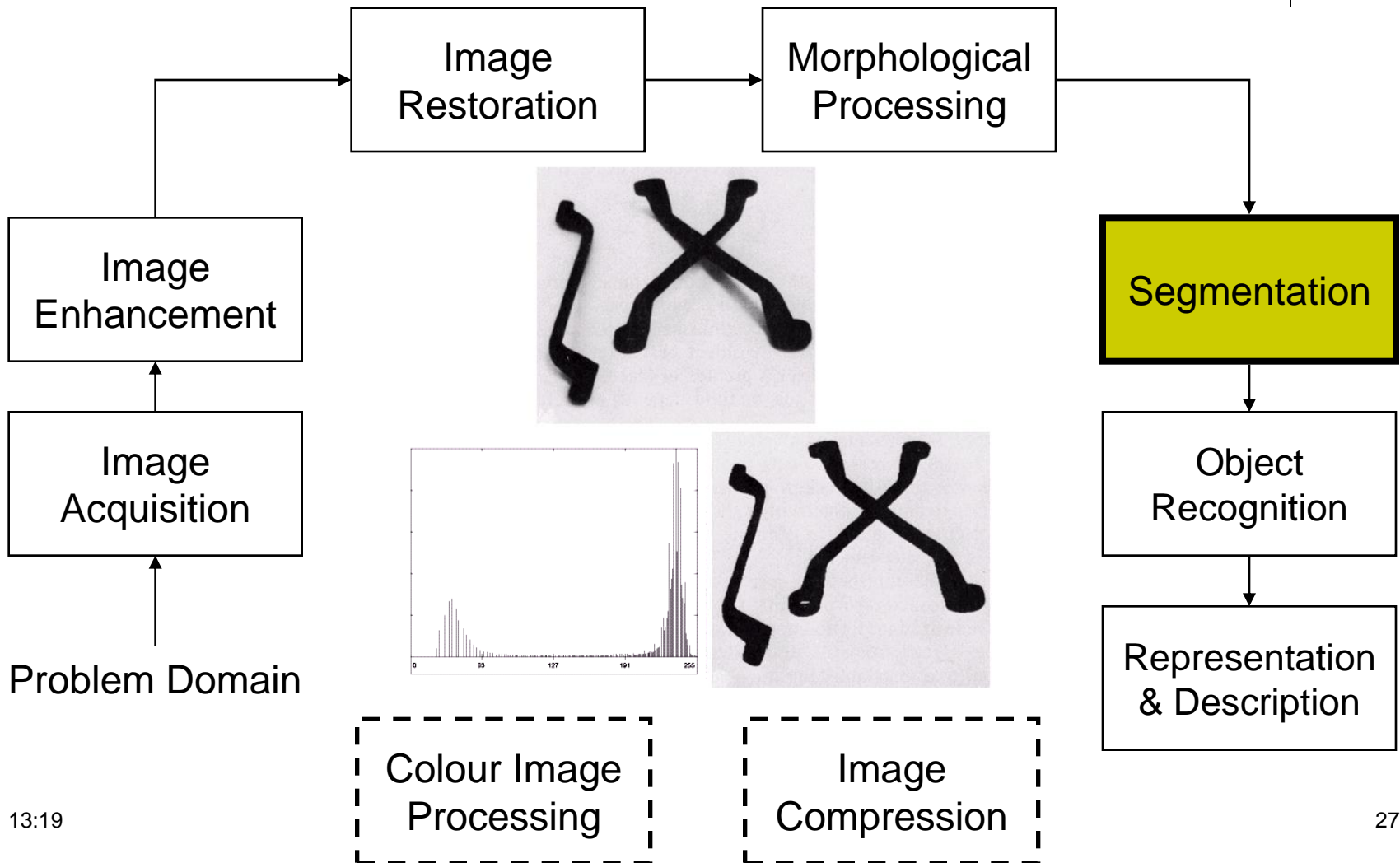
Image Compression

Key Stages in Digital Image Processing: Object Recognition

Image Restoration

Morphological Processing

Image Enhancement

Image Acquisition

Problem Domain

Segmentation

Object Recognition

Representation & Description

Colour Image Processing

Image Compression

Key Stages in Digital Image Processing: Representation & Description
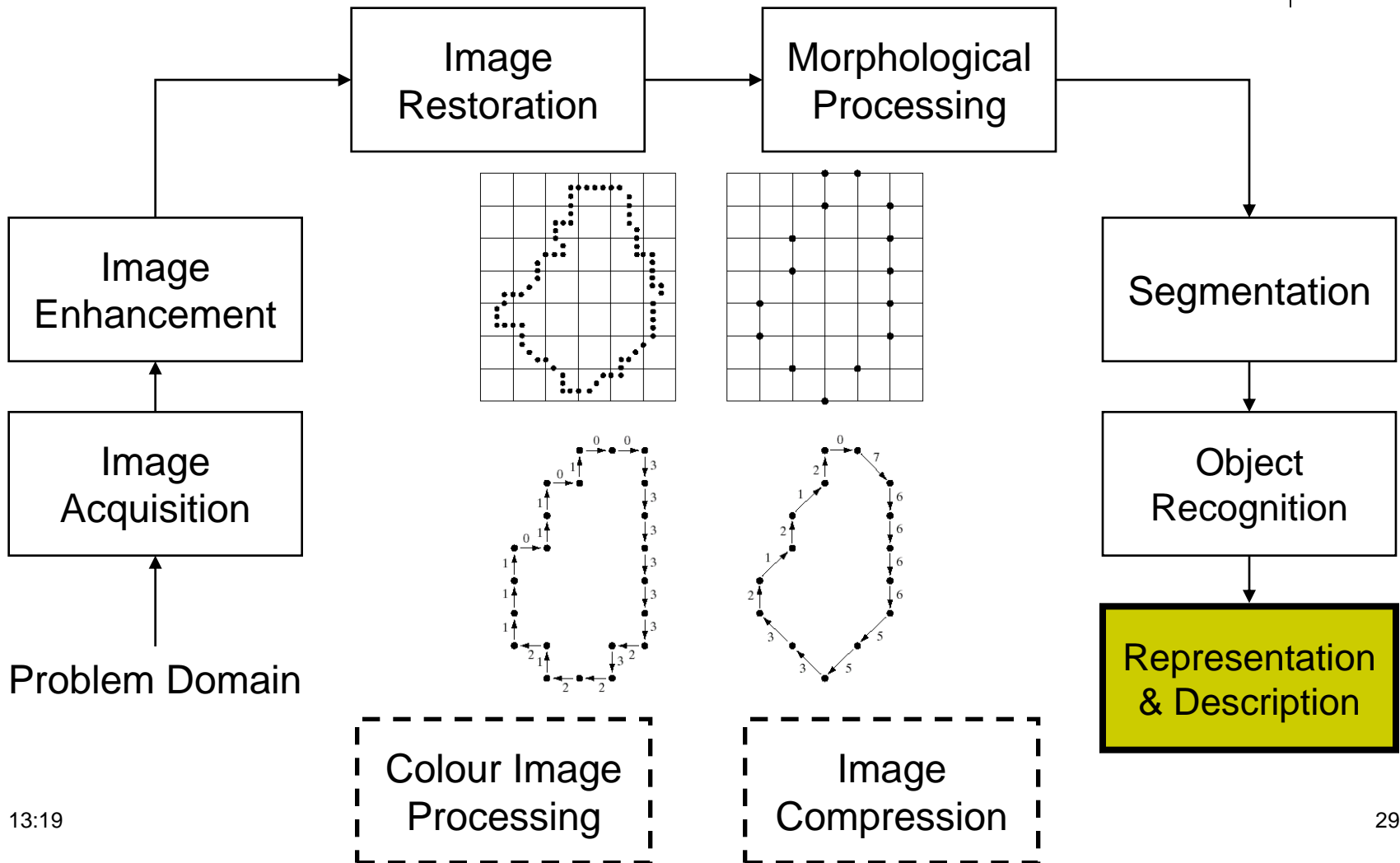
Image Restoration

Morphological Processing

Image Enhancement

Image Acquisition

Problem Domain

Segmentation

Object Recognition
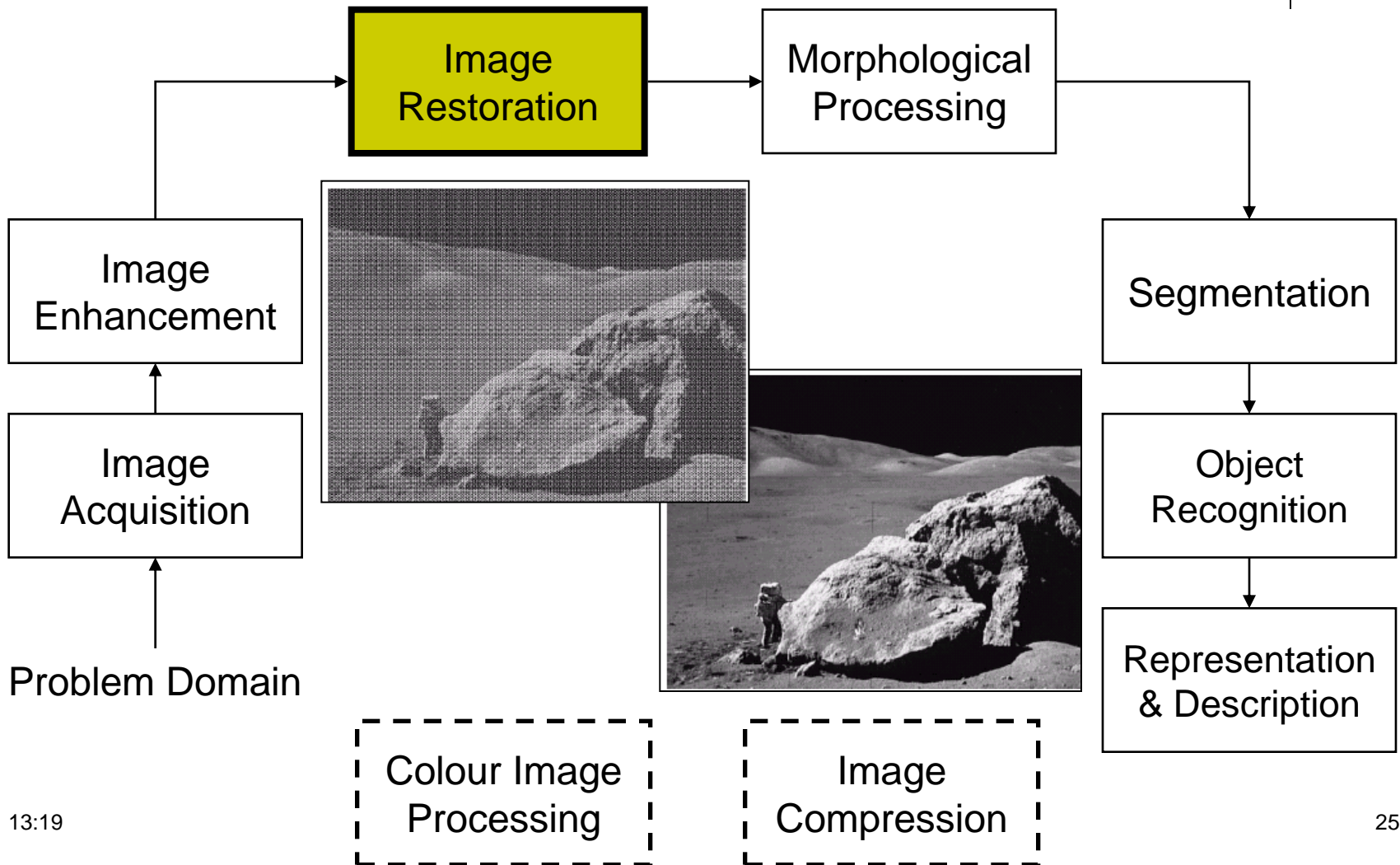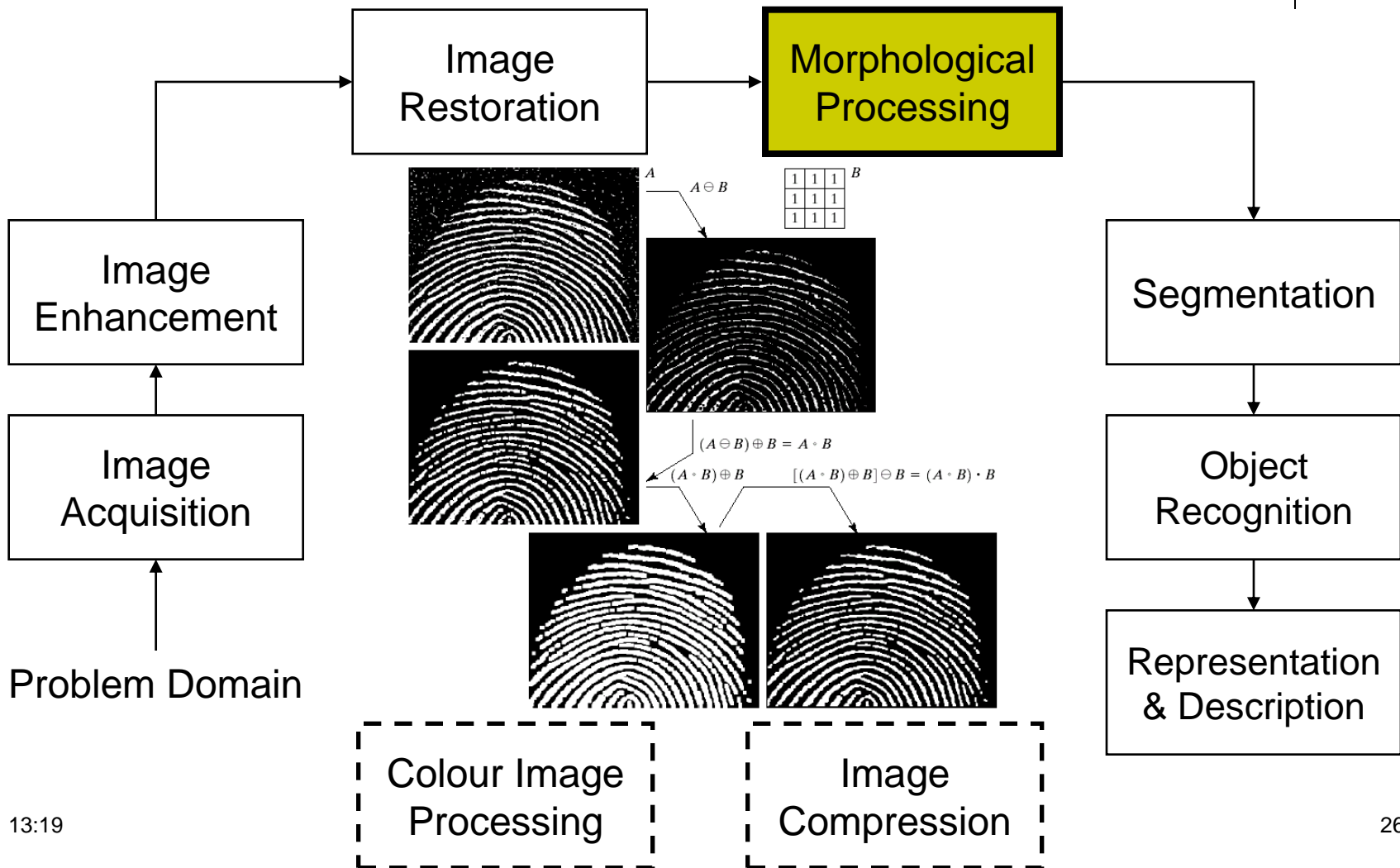
Representation & Description

Colour Image Processing
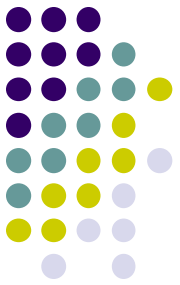
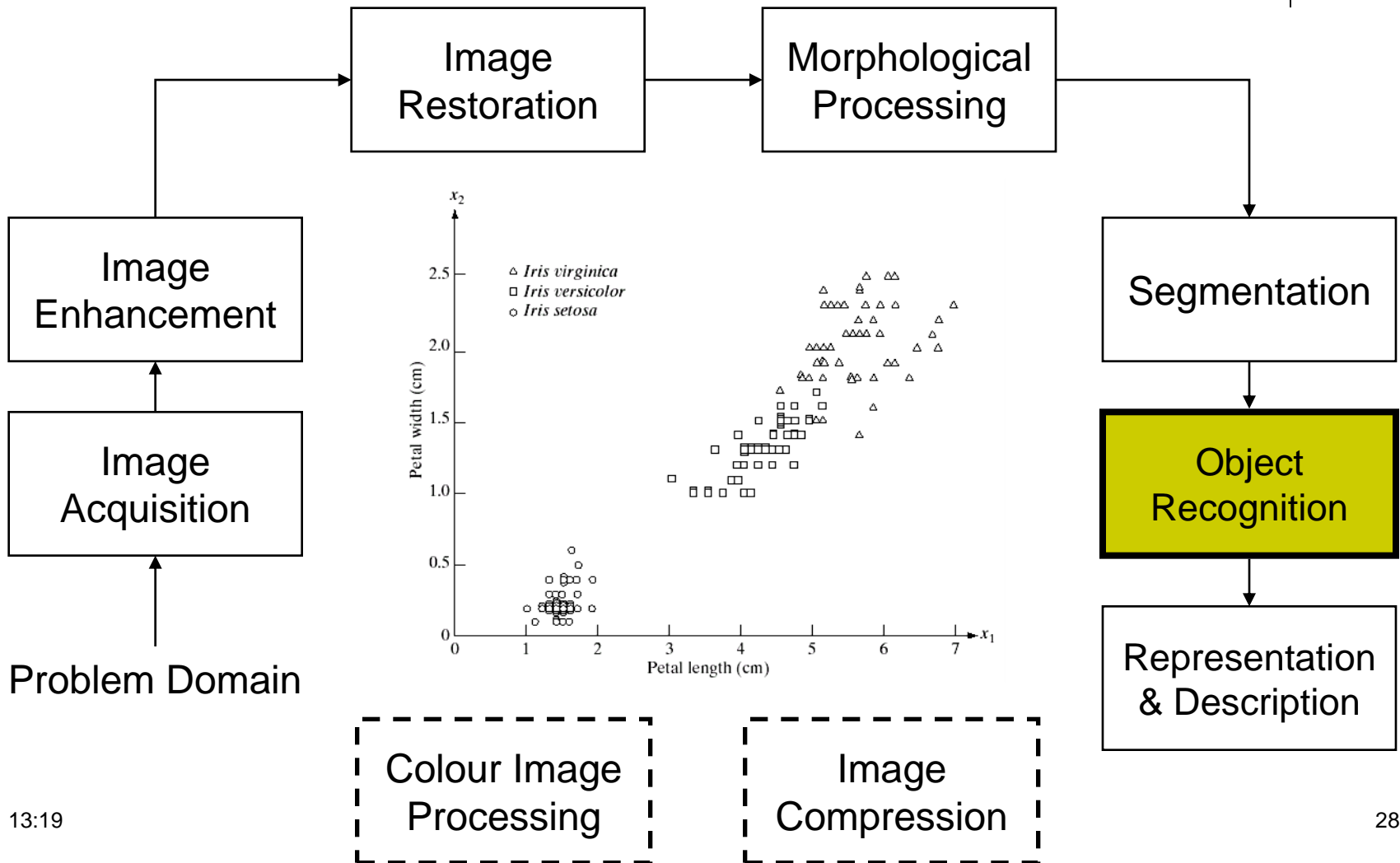Image Compression

Key Stages in Digital Image Processing: Image Compression

```
Image
Restoration
```

```
Morphological
Processing
```

```
Image
Enhancement
```

```
Image
Acquisition
```

Problem Domain

```
Segmentation
```

```
Object
Recognition
```

```
Representation
& Description
```

```
Colour Image
Processing
```

```
Image
Compression
```

13:19
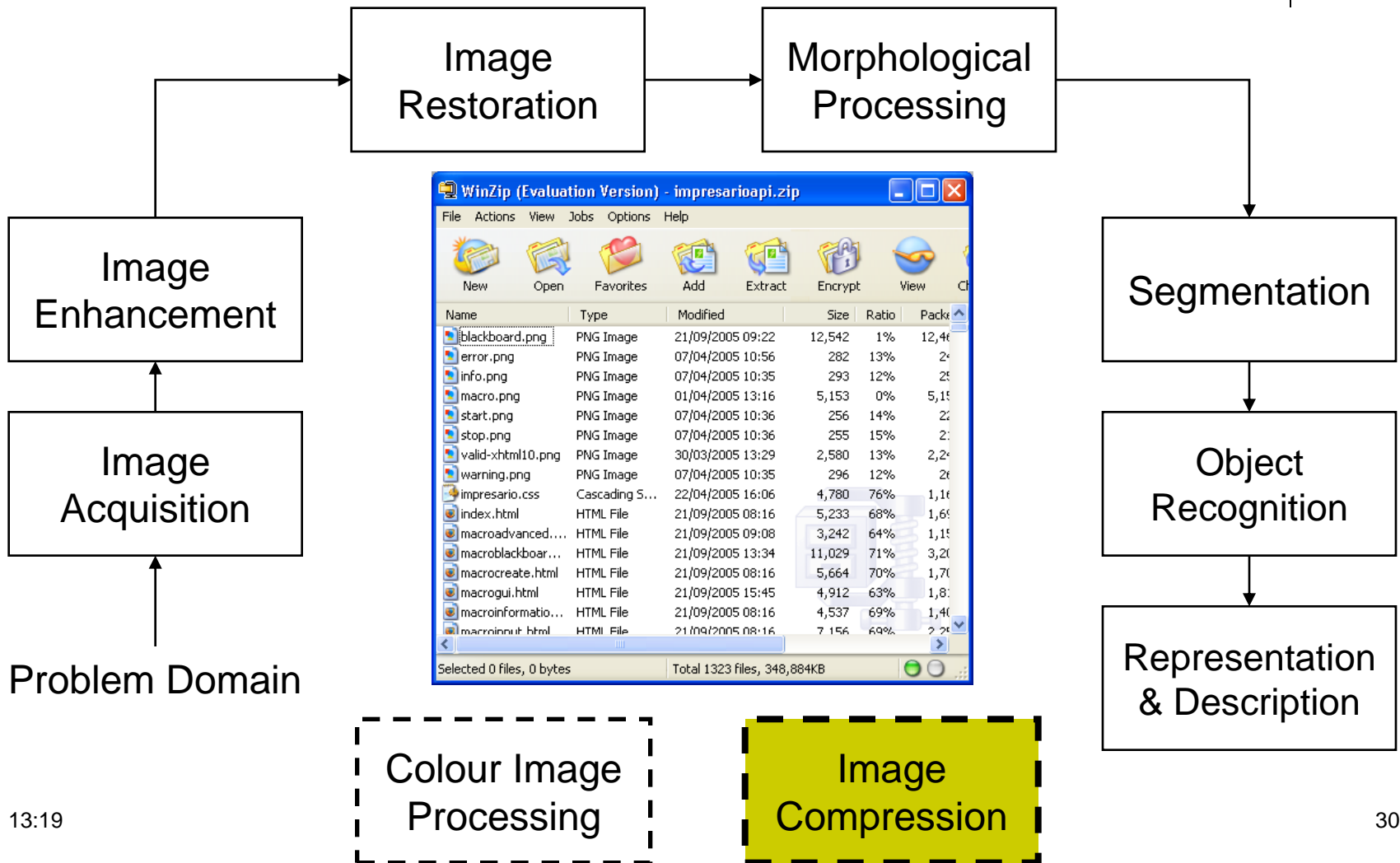
Key Stages in Digital Image Processing: Colour Image Processing

	Image Restoration	Morphological Processing	
Image Enhancement			Segmentation
Image Acquisition			Object Recognition
Problem Domain			Representation & Description
	Colour Image Processing	Image Compression	