IMAGE PROCESSING: AN INTRODUCTION

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What is Image Processing

- Images
- Image Processing and Computer Vision
- Applications
  - Human Perception
  - Machine Vision Applications
  - Image Compression
  - Biometrics
- Key Stages in Digital Image Processing

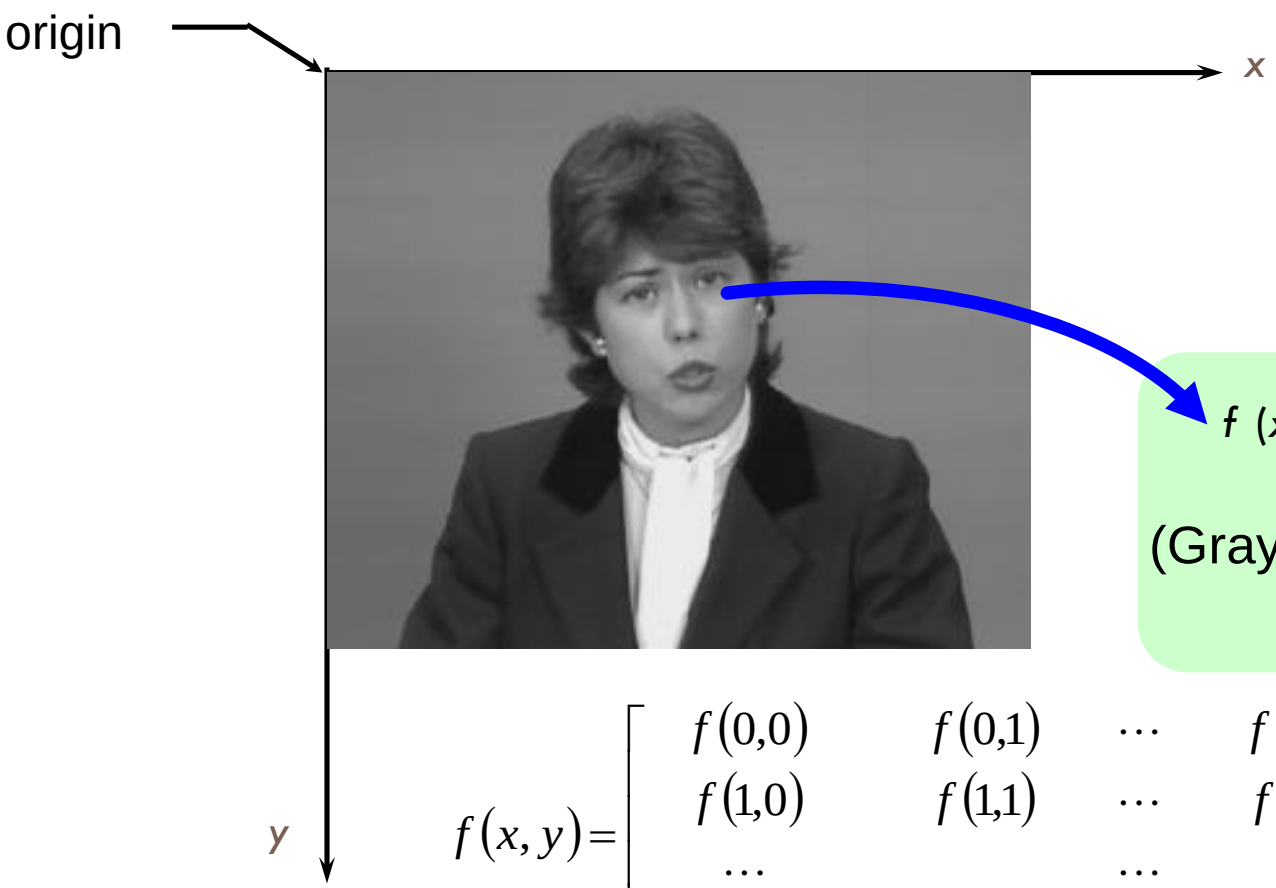
What is an Image

- An Image is a 2D function, $f(x, y)$
  - Where x and y are spatial coordinates
  - Amplitude of f at any pair of coordinates (x, y) is called the intensity or gray level of the image.

- When spatial coordinates and amplitude values are all finite, discrete quantities, the image is called as Digital image.

A Digital Image

Digital image representation



$$f(x,y)=\begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,M-1) \\ f(1,0) & f(1,1) & \cdots & f(1,M-1) \\ \cdots & & \cdots & \cdots \\ f(N-1,0) & f(N-1,1) & \cdots & f(N-1,M-1) \end{bmatrix}$$

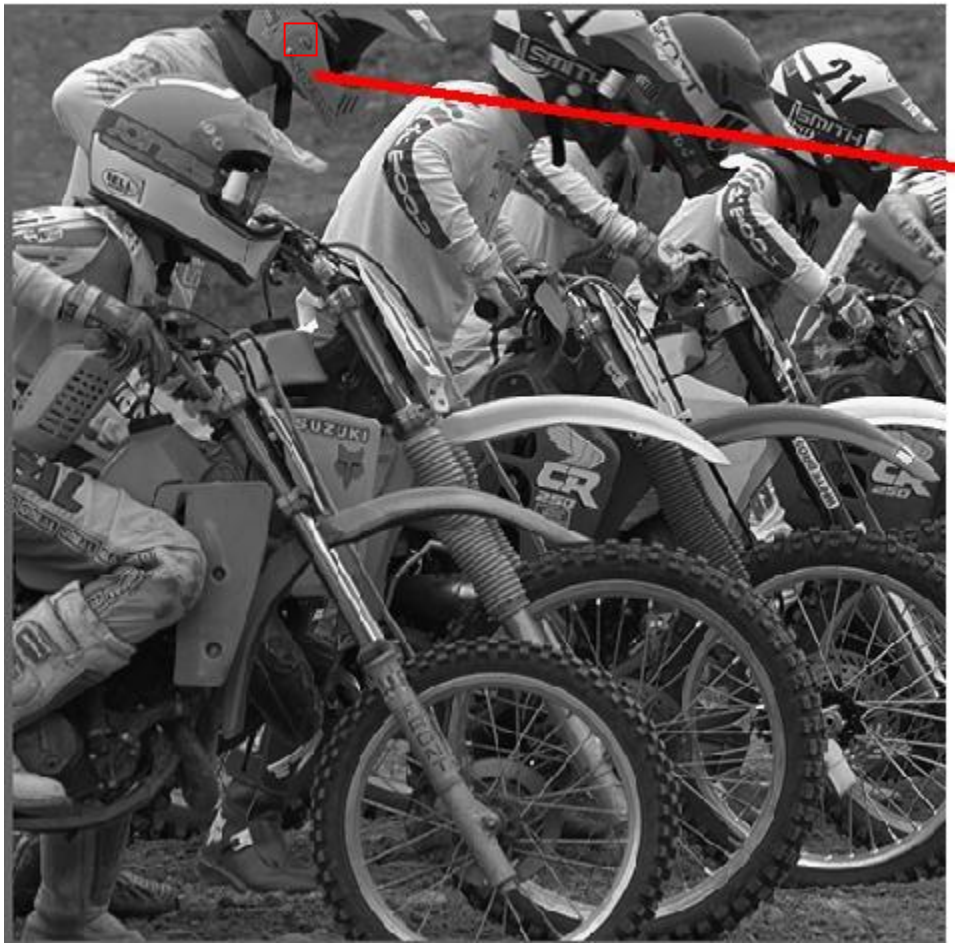
Types of Digital Image

- Black-n-White Image
  - Binary Image (two-tone)
  - Gray level Image (gray-tone)
- Color Image

Another classification

- Still Image
- Movie Image (Video Sequences)

Grayscale Image



Xint				
93	90	90	90	90
90	91	90	91	90
90	88	87	88	88
88	87	89	87	85
87	86	89	87	84
85	84	84	84	84
85	87	84	84	83
86	85	84	83	84

Color Image

RED

132	147	148	106	79	97	112	98	39	35	37
108	118	140	142	97	87	110	95	39	35	34
105	117	130	146	131	83	98	92	36	33	34
106	112	123	134	152	108	91	86	33	34	35
106	106	113	127	151	146	104	68	27	34	34

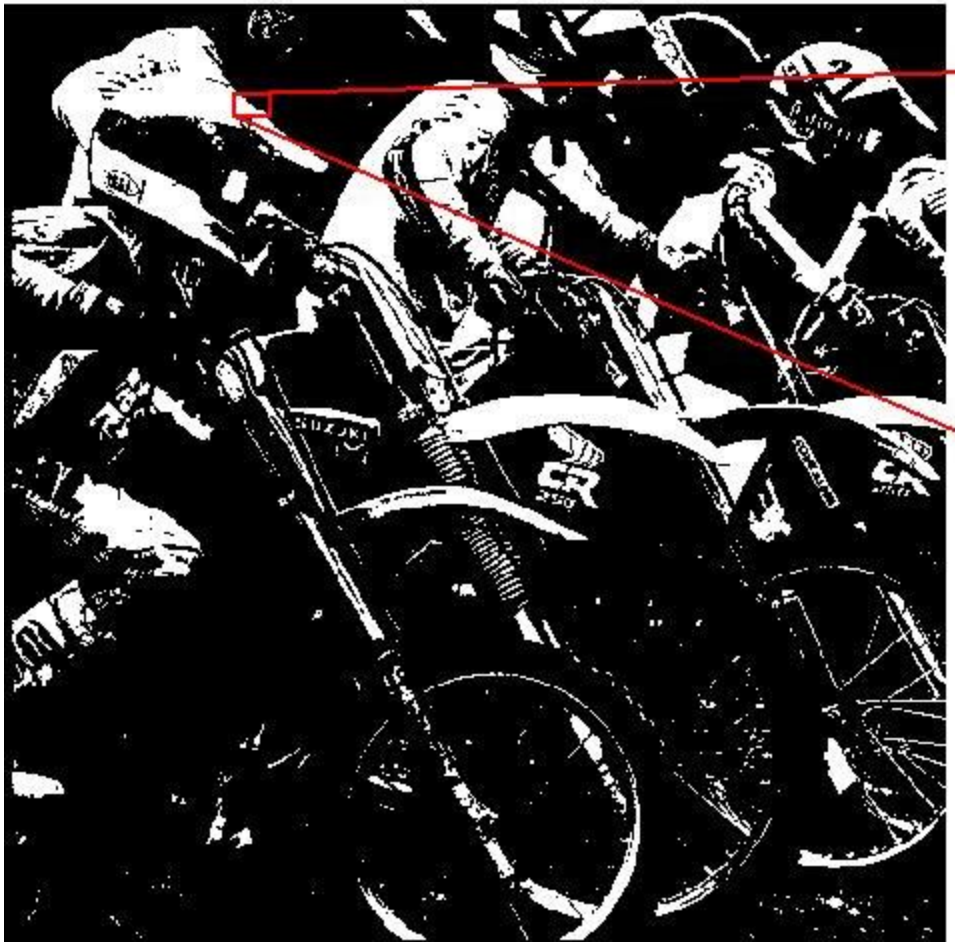
GREEN

103										
101	201	209	194	134	87	85	99	81	24	25	26
96	193	201	211	200	122	80	96	79	24	25	24
91	193	199	205	215	171	93	97	75	23	22	24
94	194	197	205	215	206	139	98	72	20	24	25
107	196	194	198	209	218	195	128	66	20	24	24

BLUE

194											
195	120	133	133	89	57	69	88	74	21	26	27
190	102	110	131	133	81	62	85	71	21	26	24
179	100	111	125	141	118	62	77	71	20	23	24
172	104	110	122	133	143	93	73	67	20	24	26
171	105	106	111	126	148	136	92	54	15	24	24
	100	105	107	115	131	147	139	49	7	24	24
	100	105	109	112	125	142	169	110	14	20	26
	93	102	107	109	121	128	141	164	86	15	22
	89	98	104	113	123	115	111	155	157	57	0
	93	89	98	107	120	110	128	142	161	146	55
	112	103	100	103	118	110	126	142	134	160	165

Binary Image



Xbin										
1	1	1	0	0	0	0	0	0	0	0
1	1	1	1	0	0	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0	0
1	1	1	1	1	1	0	0	0	0	0
1	1	1	1	1	1	1	0	0	0	0
1	1	1	1	1	1	1	1	0	0	0
1	1	1	1	1	1	1	1	0	0	0
1	1	1	1	1	1	1	1	1	0	0
1	1	1	1	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1	1	1

Indexed Image (MATLAB)

Xind				
159	41	159	159	41
159	159	159	159	159
159	159	8	159	159
159	8	159	8	8
159	159	159	159	8
8	8	8	159	8
159	8	8	8	8
8	159	8	8	8

map		
0.0588	0.0157	0.0157
0.3137	0.4824	0.1804
0.1882	0.2471	0.0863
0.4078	0.7490	0.3882
0.1922	0.2314	0.3176
0.2941	0.0510	0.0431
0.4745	0.4824	0.4157
0.1333	0.1333	0.0549
0.4392	0.3137	0.0118
0.3882	0.3412	0.2941

Why do we Process Images

- To facilitate their storage
  - Efficient storage in digital cameras
  - Video streaming on the internet
- To prepare them for display or printing
  - Halftoning
    - It is a reprographic technique that simulates continuous tone imagery through the use of dots, varying either in size, in shape or in spacing.
  - Adjust Image size
- To enhance or restore them
  - Improve visibility of features
  - Repair photographic errors
- To extract information from them
  - Face recognition
  - Aerial surveillance

1-D Signal Processing & Multidimensional Signal Processing

- Both involve such common operations as:
  - Filtering
  - Sampling
  - Transform computation and manipulation
- Most of these operations generalize straightforwardly
- The volume of data is larger

1-D Signal Processing & Image Processing

- Images are two dimensional
  - Mathematics more limiting
  - Mathematics more general
- Images have finite extent
- Notion of Causality goes away
- Recursive systems are rarely used
- Images are not zero mean
- Nonlinear operations are more common
- Fundamental theorem of algebra doesn't hold in MD SP

Image Processing Vs Computer Vision

	input image	Output image
Image processing	Yes	Yes
Computer Vision	Yes	No
Computer graphics	No	Yes

Most real-world applications combine techniques from both categories

Image Processing Tasks

- Image Processing is concerned with lower level tasks
  - Sampling and Quantization
  - Noise removal
  - Restoration
  - Enhancement
  - Geometric manipulation

Computer Vision Tasks

- Computer Vision is concerned with higher level tasks
  - Morphological operations
  - Edge Detection
  - Feature extraction
  - Shape analysis
  - Image Detection and Registration

History of Digital Image Processing

- **Early 1920s:** One of the first applications of digital imaging was in the news-

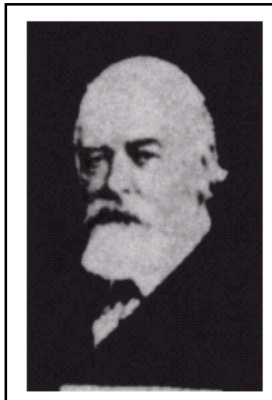
  paper industry

  - 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

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…)

- **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

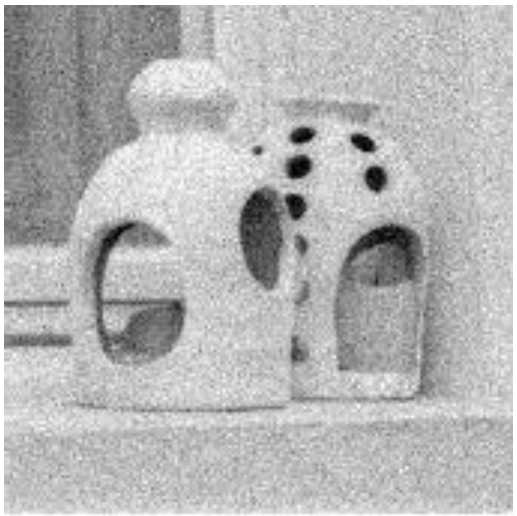
IP Applications: Human Perception

- Noise Filtering
- Contrast Enhancement
- Image Deblurring
- Image Correction
- Image Inpainting
- Image Fusion
- Image Stitching
- Transformations
- Astronomy
- Weather Forecasting
- Medical Imaging
- Artistic Effects
- Document Image Analysis
- Hyperspectral Imaging

Noise Filtering

The procedure of reducing the noise components of an image so as to enhance its information is known as **Noise filtering.**

Original Image



Noised Image

Mean Filtered Image

Contrast Enhancement

- Contrast enhancement increases the total contrast of an image by making light colors lighter and dark colors darker at the same time.

Original Image

Enhanced Image

Image Deblurring: Motion Blur

- Used to restore deblurred images when the camera or object is moved during exposure

Original Image

Blurred Image

Restored Image

Image Deblurring: Out of Focus Blur

- Used to restore deblurred images when the camera was not focused properly!!

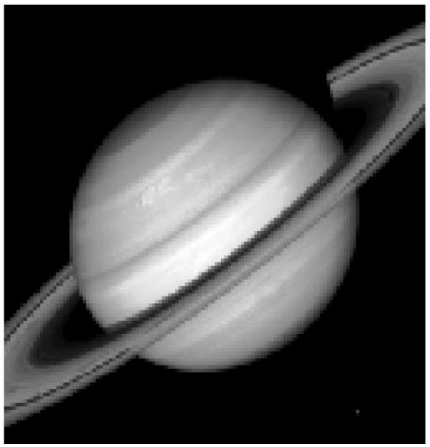
Original Image

Blurred Image

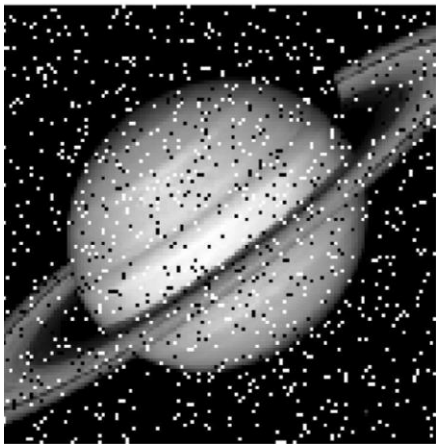
Restored Image

Image Correction

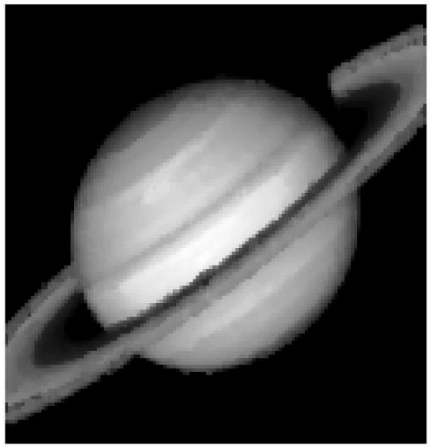
- Needed when image data is erroneous:
  - Bad transmission
  - Bits are missing: *Salt & Pepper Noise*



Original Image



Noisy Image



Corrected Image

Image Inpainting

- Image Inpainting is the process of reconstructing lost or deteriorated parts of images. It also improves brightness, color etc.

Original Image

Processed Image

Image Fusion

- Image fusion is the process of combining relevant information from two or more images into a single image. The resulting image will be more informative than any of the input images.

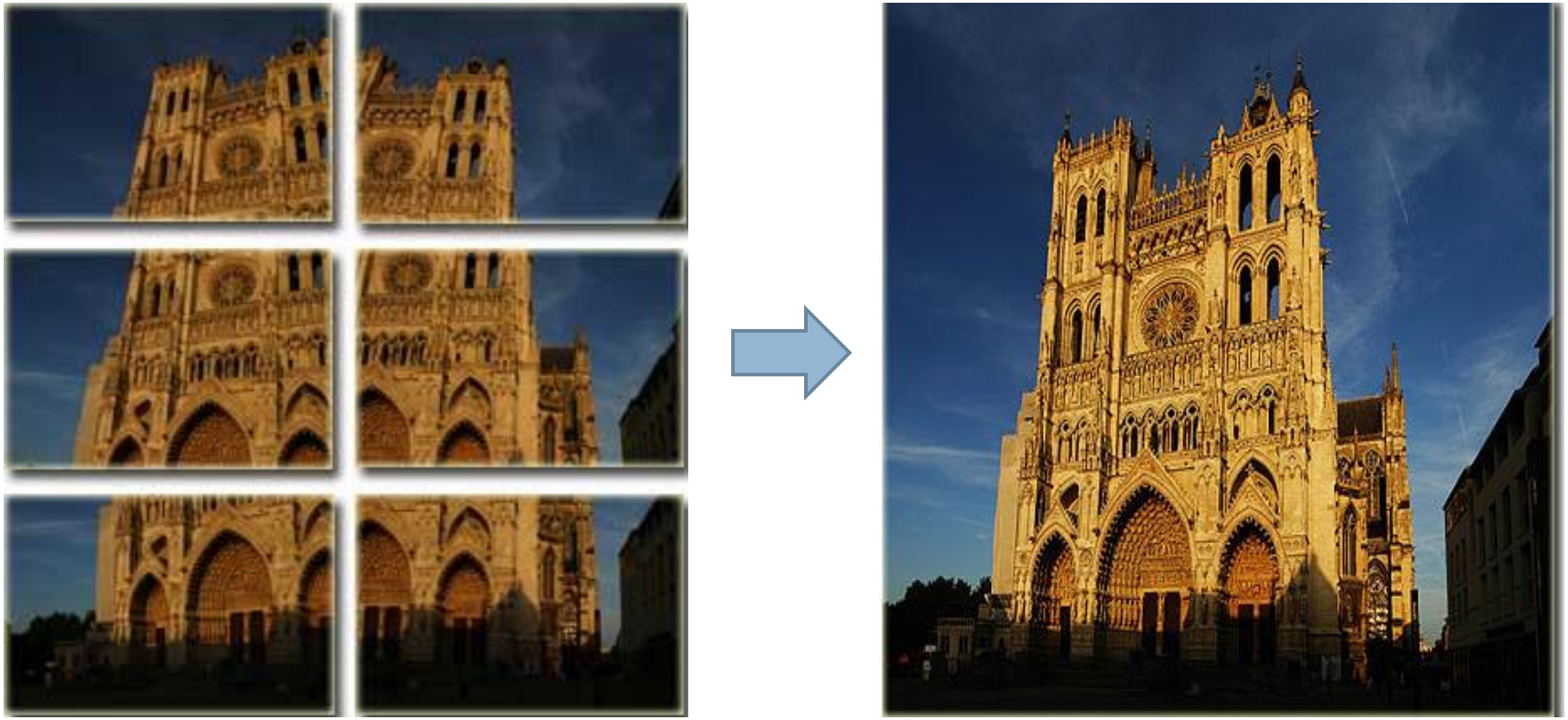
Image1 & Image2 fused to get Image3

Image Stitching

- **Image stitching** is the process of combining multiple photographic images with overlapping fields of view to produce a segmented panorama or high-resolution image.

- Most approaches to Image stitching require nearly exact overlaps between images and identical exposures to produce seamless results.

Image Stitching (Contd)



Geometric Transformations

- Rotate + scale

- Shear

Astronomy

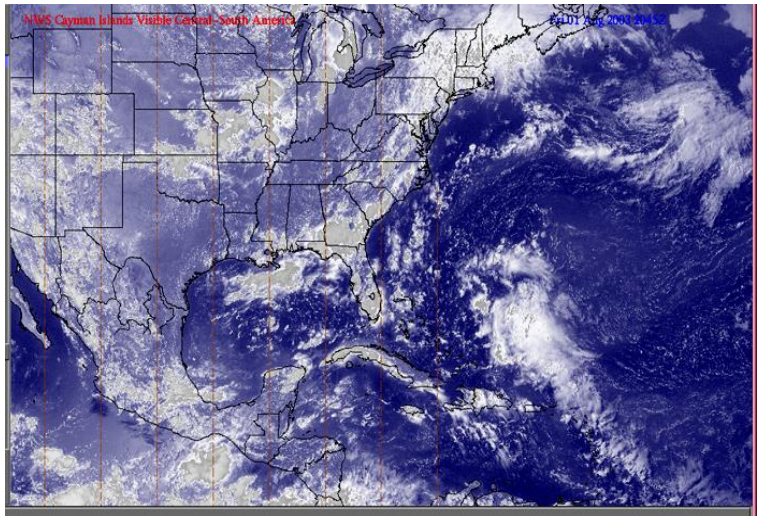
- With a modest telescope or digital camera, we can produce beautiful images of galaxies and nebulas. However, raw images produced through a telescope still require significant enhancement to bring out the secrets hidden within them, which can be easily done using Image Processing.

Raw Image

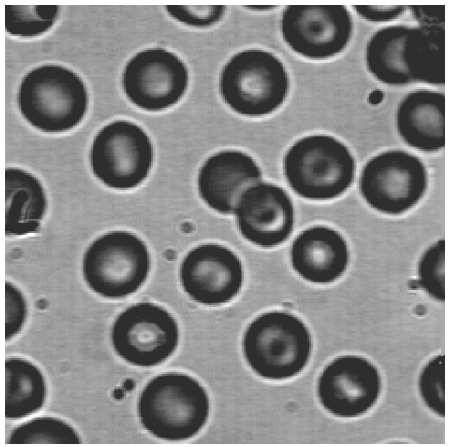
Processed Image

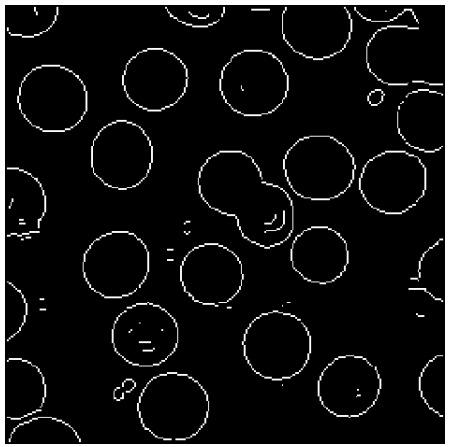
Weather Forecasting

- Image processing combined with the skills and experience of meteorologist, offer solutions to a large range of weather forecasting problems such as defining & modeling weather patterns.



Medical Image Processing

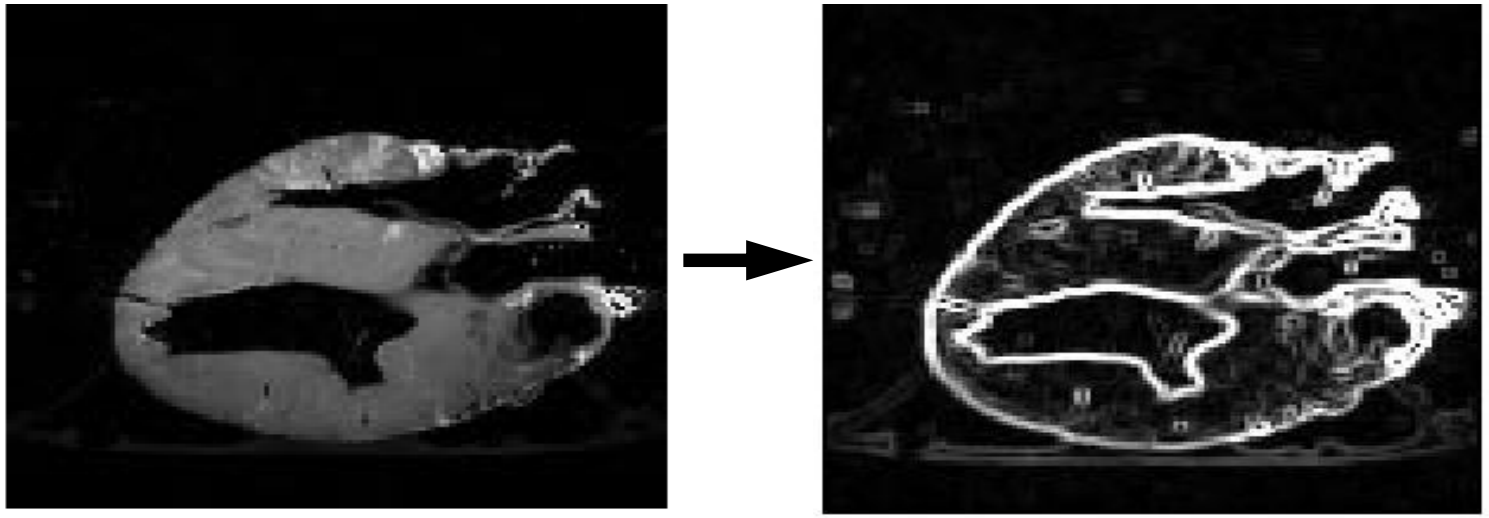




- Image Processing is widely used
- e.g. Analysis of microscopic images

Medical Image Processing (Contd)

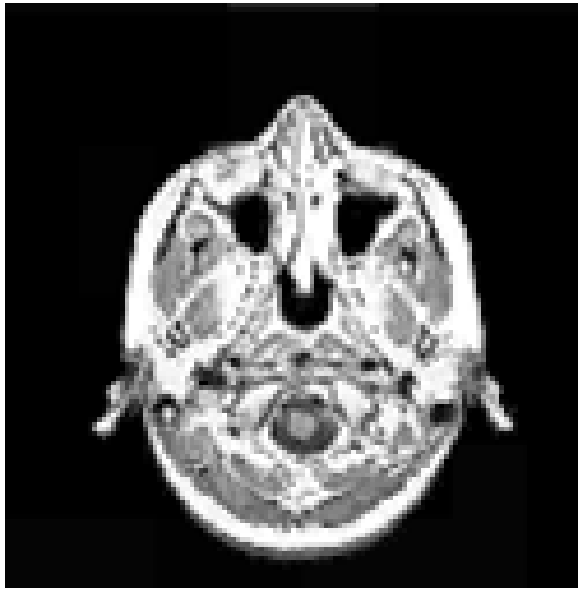
- Take slice from MRI scan of canine heart, and find boundaries between types of tissue
  - Image with gray levels representing tissue density
  - Use a suitable filter to highlight edges



Original MRI Image of a Dog Heart

Edge Detection Image

Medical Image Processing (Contd)



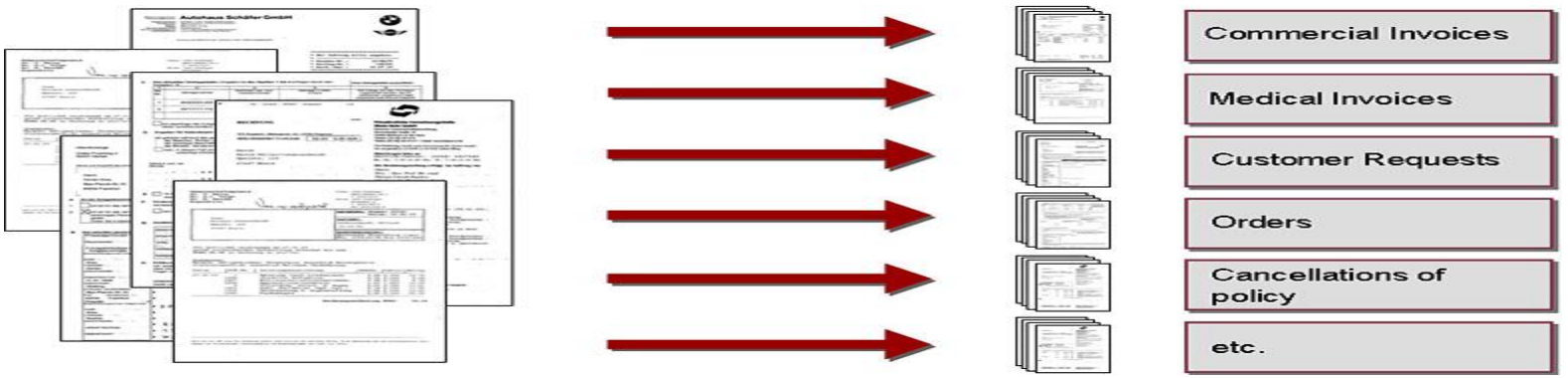
- MR/CT Imaging of a human body
- Use for Brain Surgery

Artistic Effects

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

Document Image Analysis

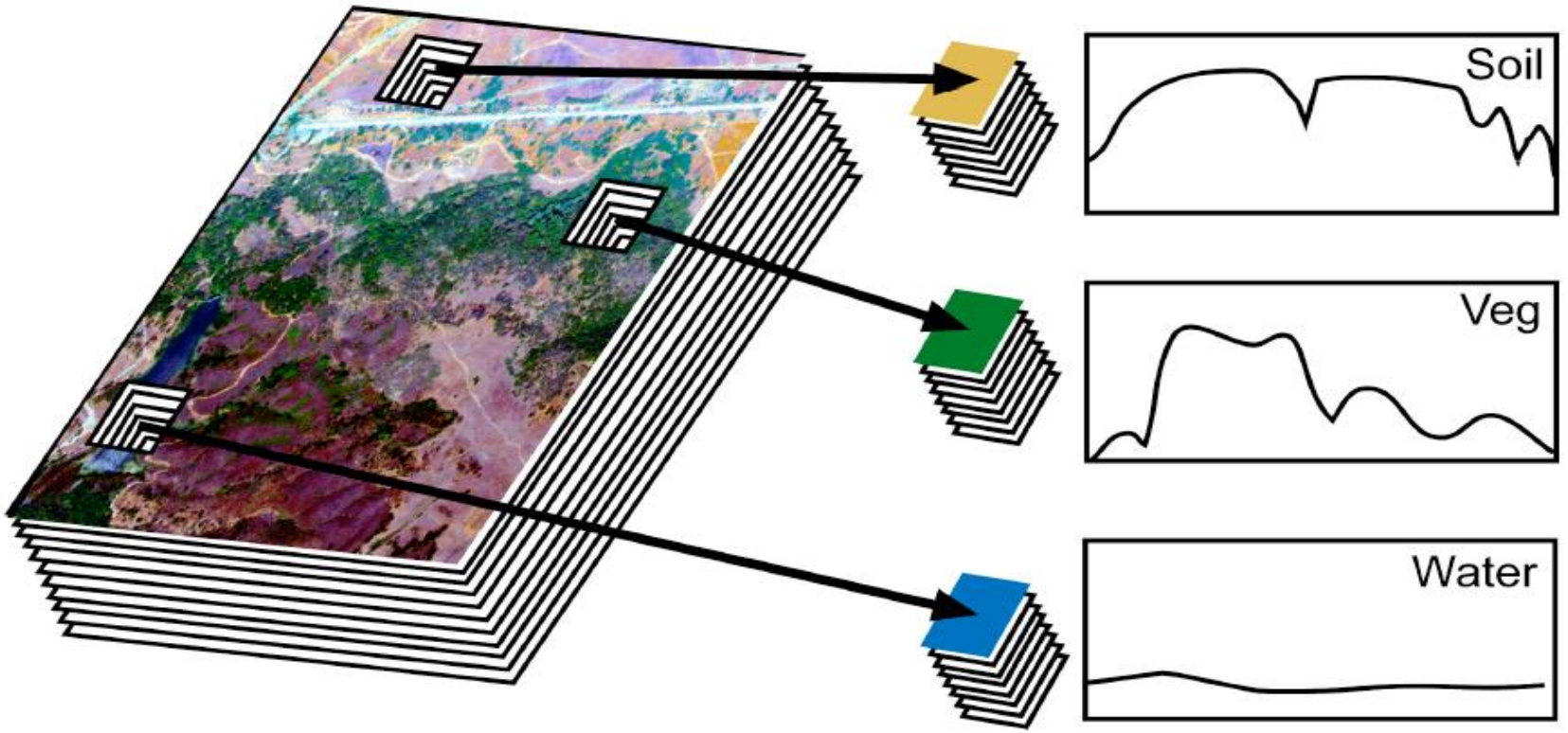
- Document image analysis refers to algorithms that are applied to images of documents to obtain a computer-readable description from pixel data. A well-known document image analysis product is the Optical Character Recognition (OCR) software that recognizes characters in a scanned document.



Hyperspectral Imaging

- Hyperspectral imaging collects and processes information from across the electromagnetic spectrum. It divides the spectrum into many more bands instead of only three.
- Hyperspectral images have been for mineral mapping, to detect soil properties, to identify vegetation species, to detect military vehicles etc.

Hyperspectral Imaging (Contd)



The concept of hyperspectral imagery. Image measurements are made at many narrow contiguous wavelength bands, resulting in a complete spectrum for each pixel.

Machine Vision Applications

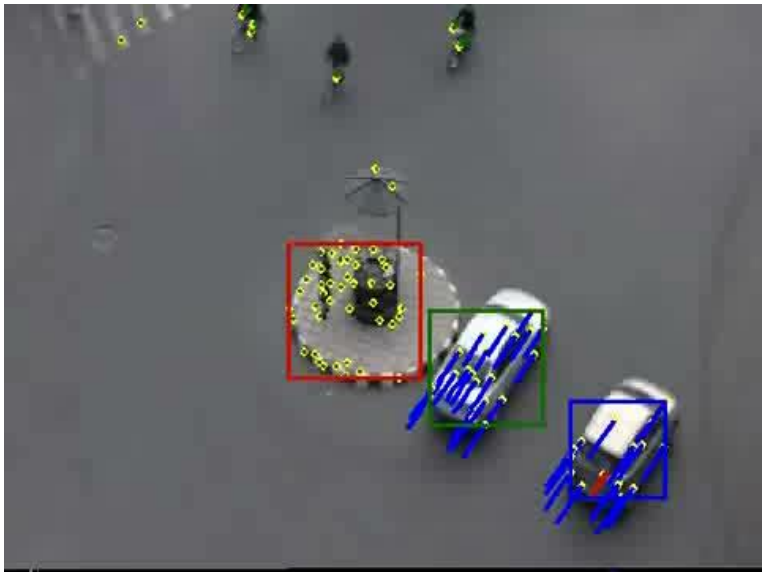
- Object Detection and Tracking
- Video Matching
- Color Based Video Tracking
- Foreground Extraction
- Virtual Tour
- Industrial Inspection
- PCB Inspection
- License Plate Recognition

Object Detection and Tracking

- Object tracking is important because it enables several important applications such as: Security and surveillance - to recognize people, to provide better sense of security using visual information.

Video Matching

- Video matching is the process of locating a moving object (or multiple objects) over time. Its' objective is to depict the path of target objects in consecutive video frames.



Color Based Video Tracking

- Color based video tracking tracks objects based on a specific color and also shows the size of the object in consecutive video frames in terms of number of pixels.

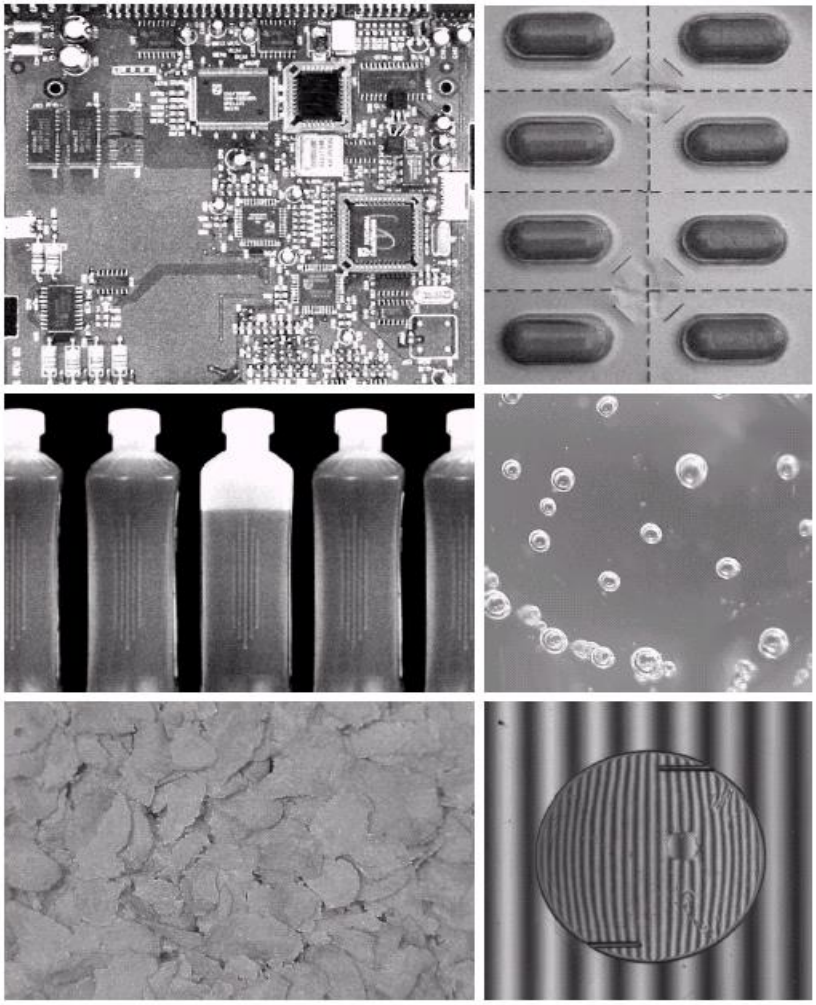
Foreground Extraction

- Foreground Extraction is the process of segmenting the foreground objects from the background.

Virtual Tour

- A Virtual tour is a simulation of an existing location, usually composed of a sequence of video images. They may also include sound effects, music, narration, text. They are used extensively for universities and in the real estate industry

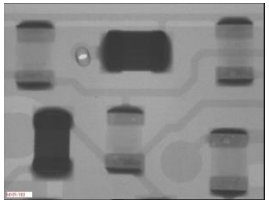
Industrial Inspection

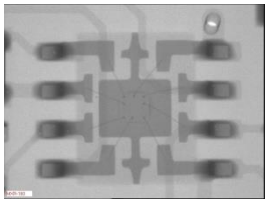


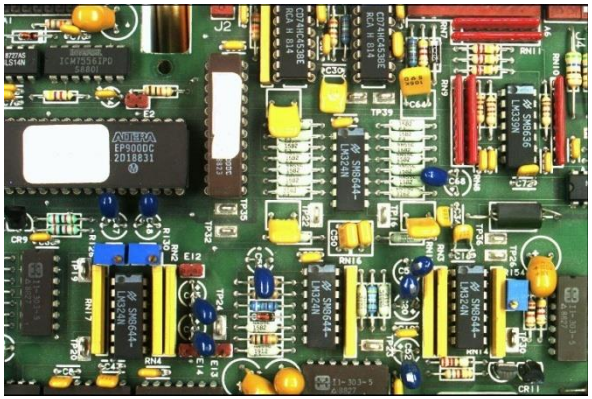
- Human operators are expensive, slow and unreliable
- Make machines do the job instead
- Industrial vision systems are used in all kinds of industries
- Can we trust them?

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







License Plate Recognition

- License Plate Recognition is a mass surveillance method that uses optical character recognition on images to read the license plates on vehicles. LPR have wide range applications in Access control, Parking, Tolling, Border control etc.

In this example, the gate has just been automatically raised for the authorized vehicle, after being recognized by the system.

Image Compression

- Reduced storage
- Reduction in bandwidth
- Removes redundancy
  - Pixel redundancy
  - Coding redundancy
  - Psycho visual redundancy
- Compression ratio a vital fact

Image Compression (Contd)

Uncompressed
Image

Image compressed
With ratio 1:35

Image compressed
With ratio 1:90

Conveyer belt applications

- Checking and sorting
  - For example: checking bottles in the supermarket
- Quality control
  - Does the object have the correct dimensions, color, shape, etc.?
  - Is the object broken?
- Robot control
  - Find precise location of the object to be picked

Biometrics

- Recognizing/verifying the identity of a person by analyzing one or more characteristics of the human body
- Characteristics:
  - Fingerprint, eye (retina, iris), ear, face, heat profile, shape (3D face, hand), motion (gait, writing), …
- Applications:
  - Verifying: Access control (bio-passports)
  - Recognizing: Surveillance: 9/11

Biometric Applications

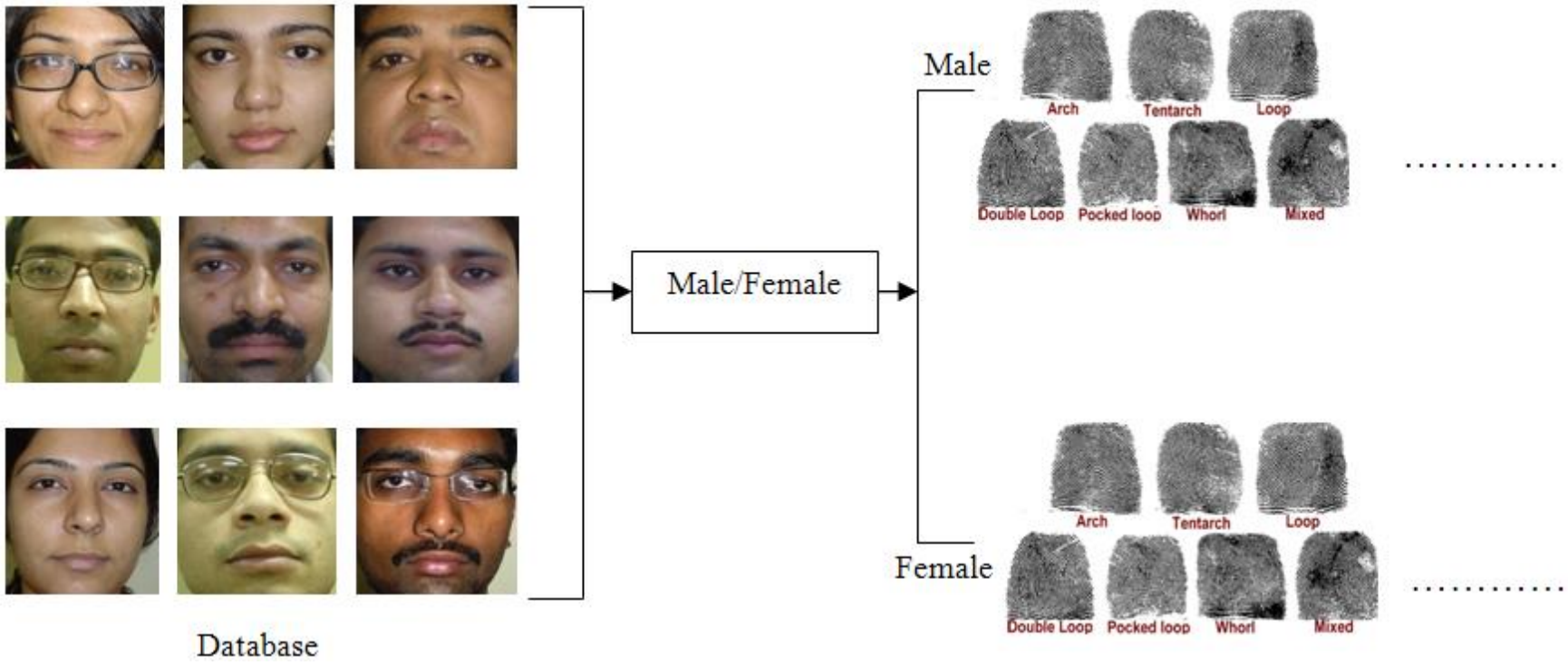
An Iris Recognition System

Biometric Applications

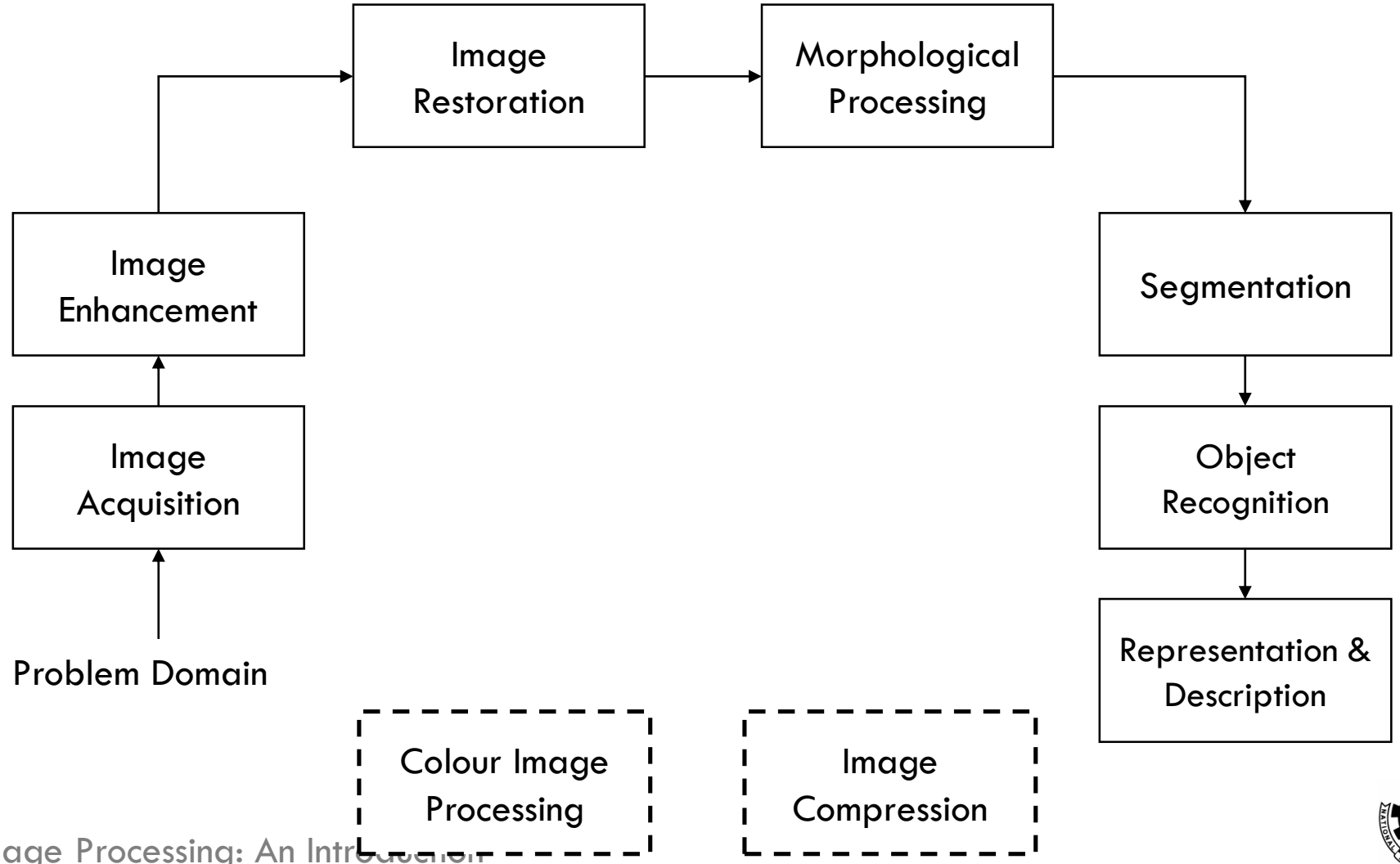
Bio Passport system using Fingerprint Biometric

Biometric Applications

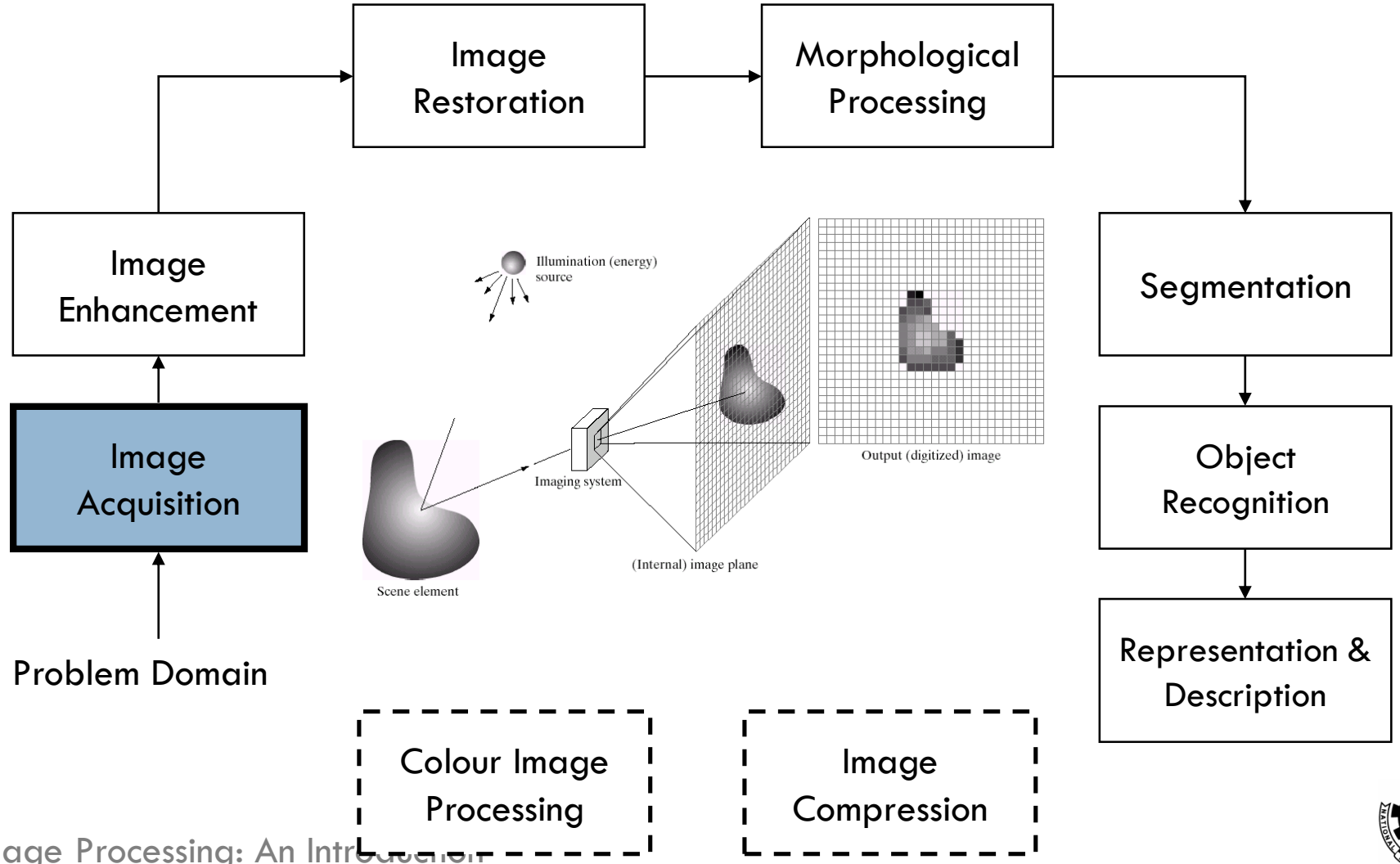
Classification of Multi model Biometric databases



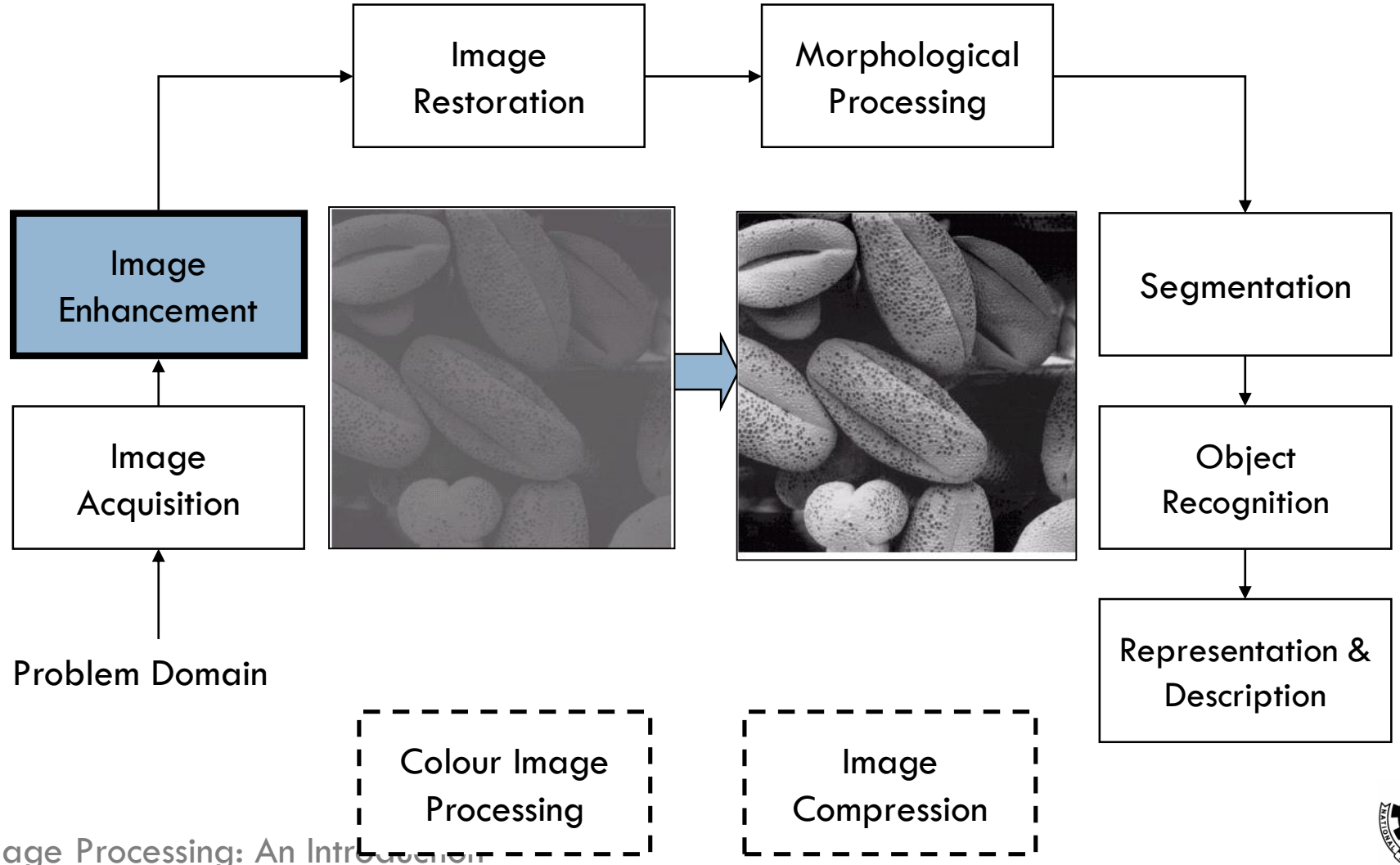
Key Stages in Digital Image Processing



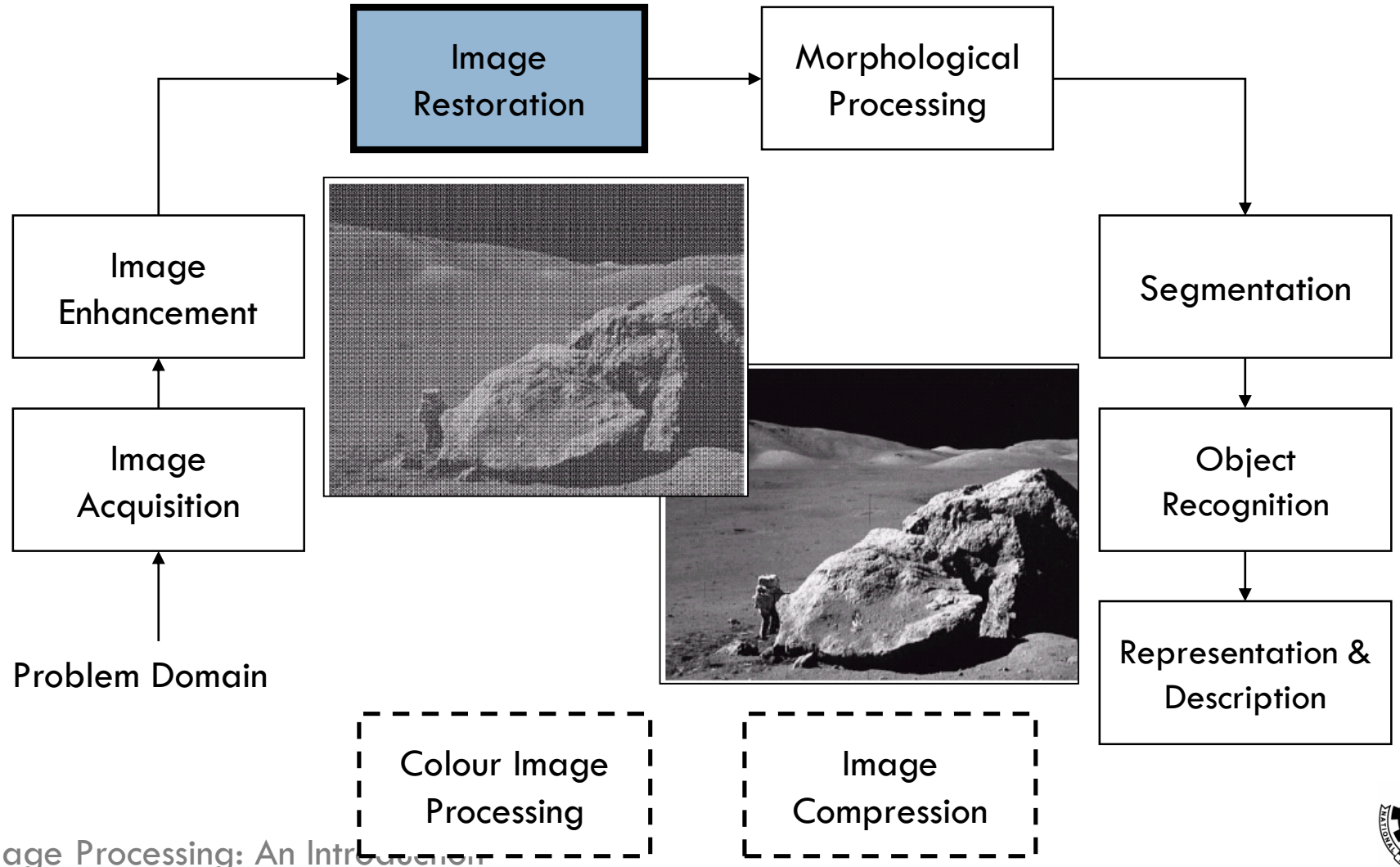
Key Stages in Digital Image Processing: Image Aquisition



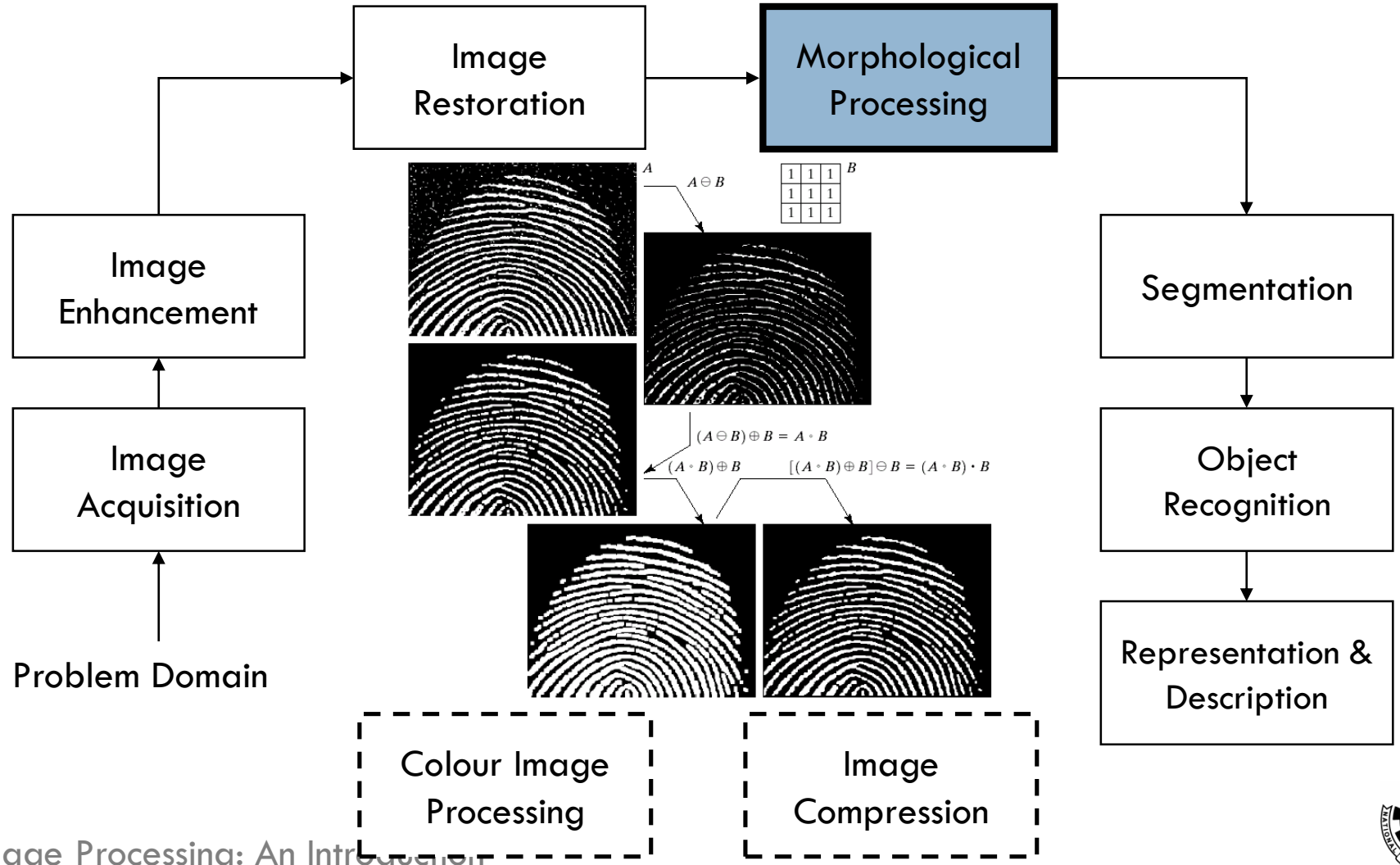
Key Stages in Digital Image Processing: Image Enhancement



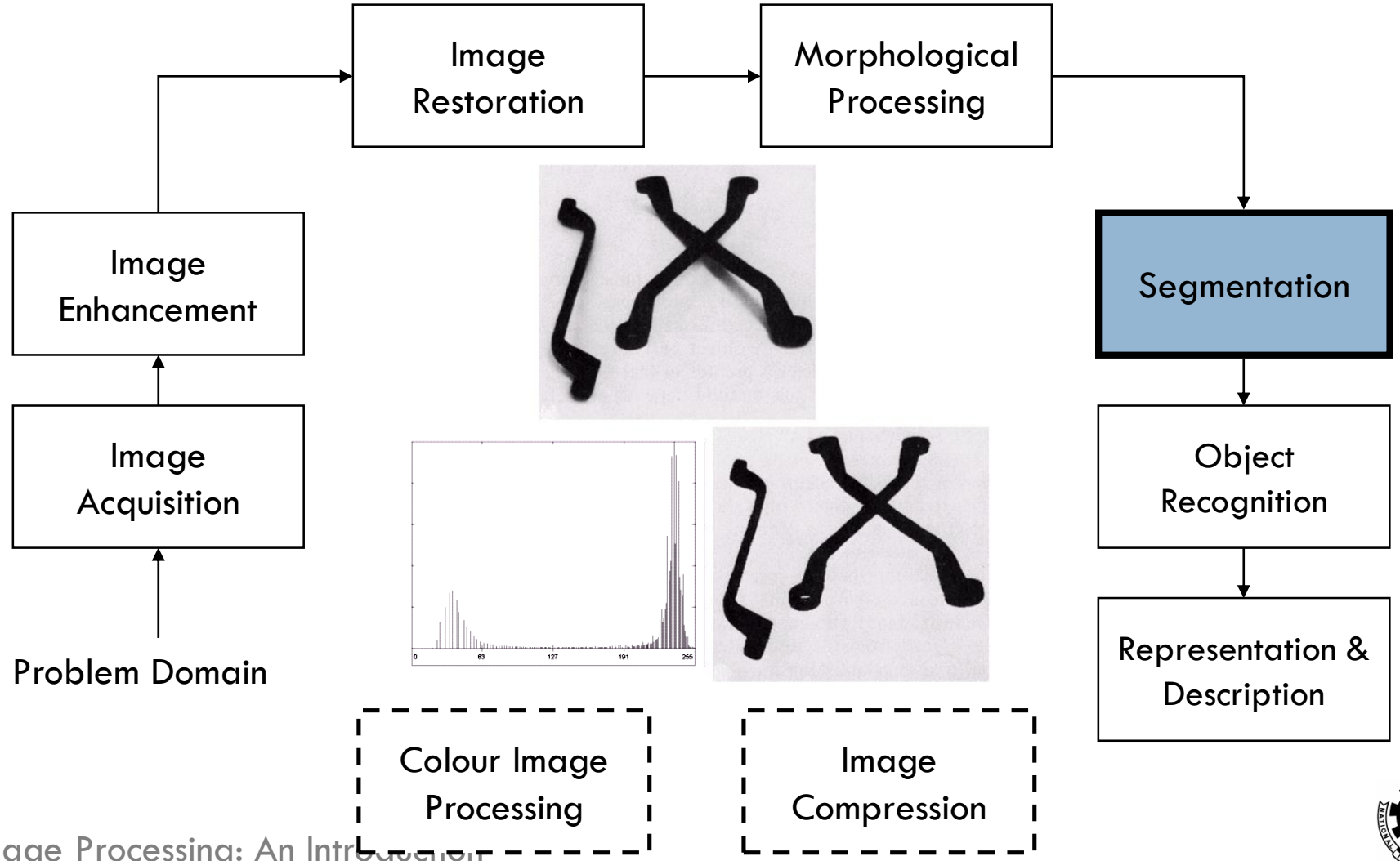
Key Stages in Digital Image Processing: Image Restoration



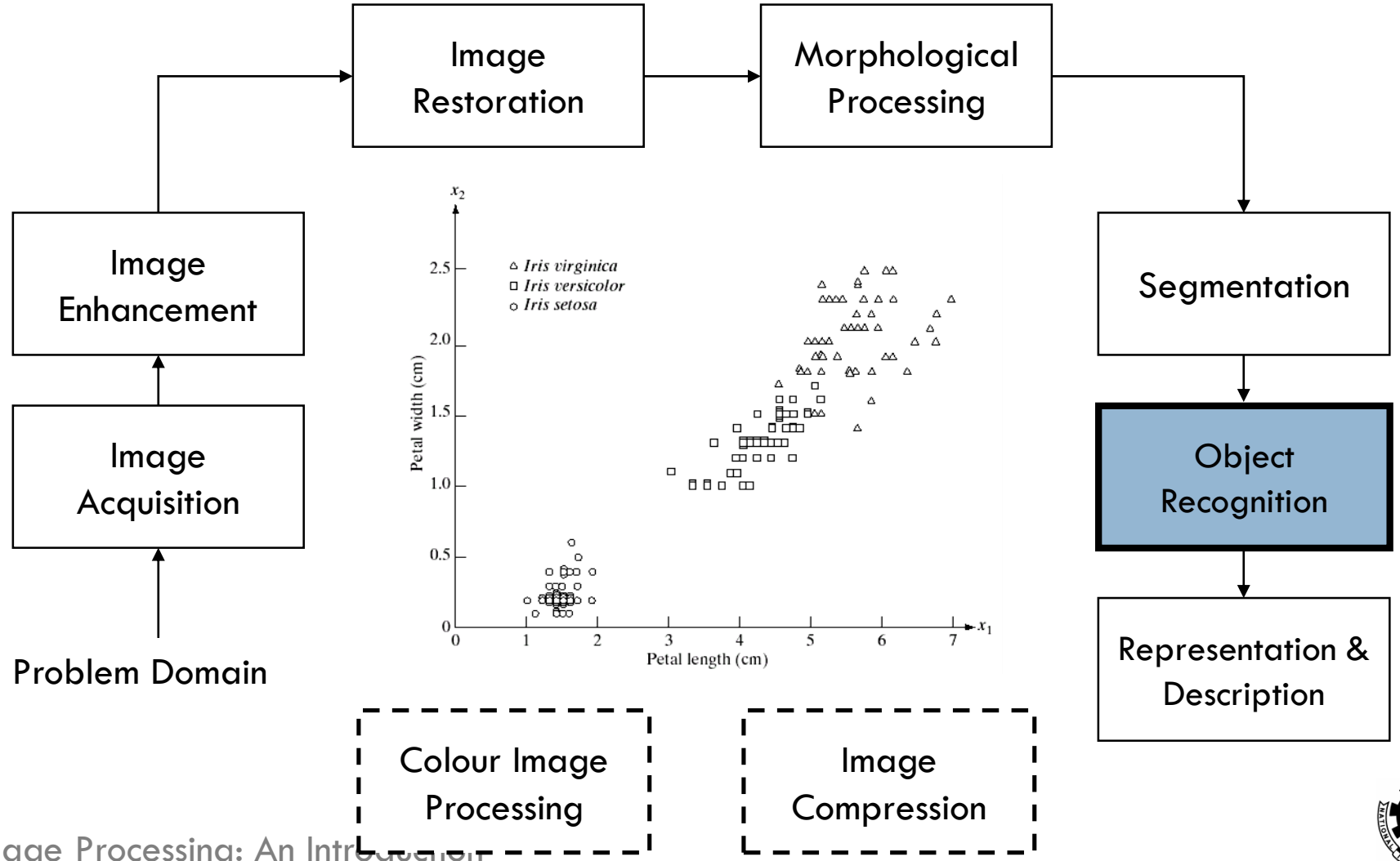
Key Stages in Digital Image Processing: Morphological Processing



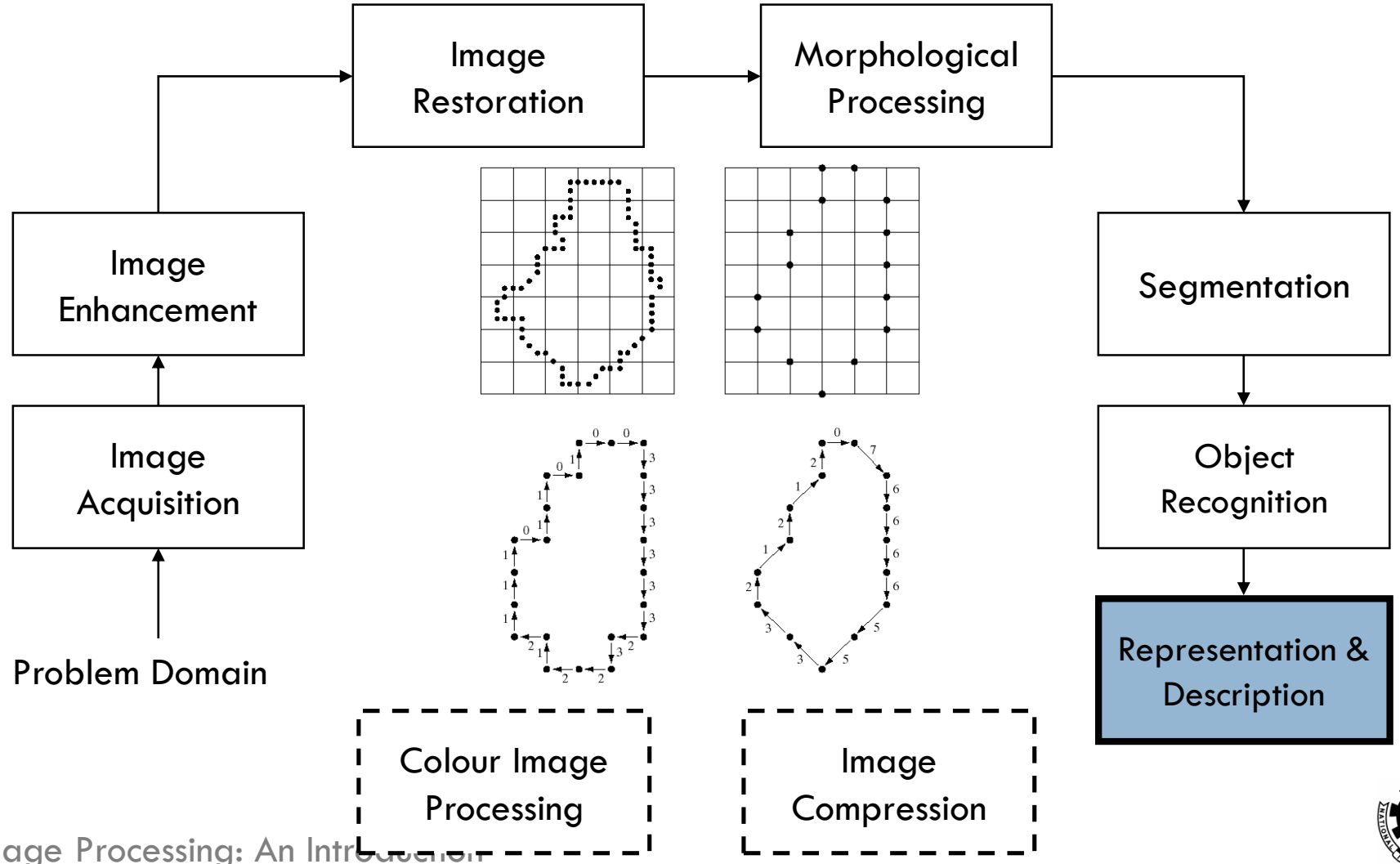
Key Stages in Digital Image Processing: Segmentation



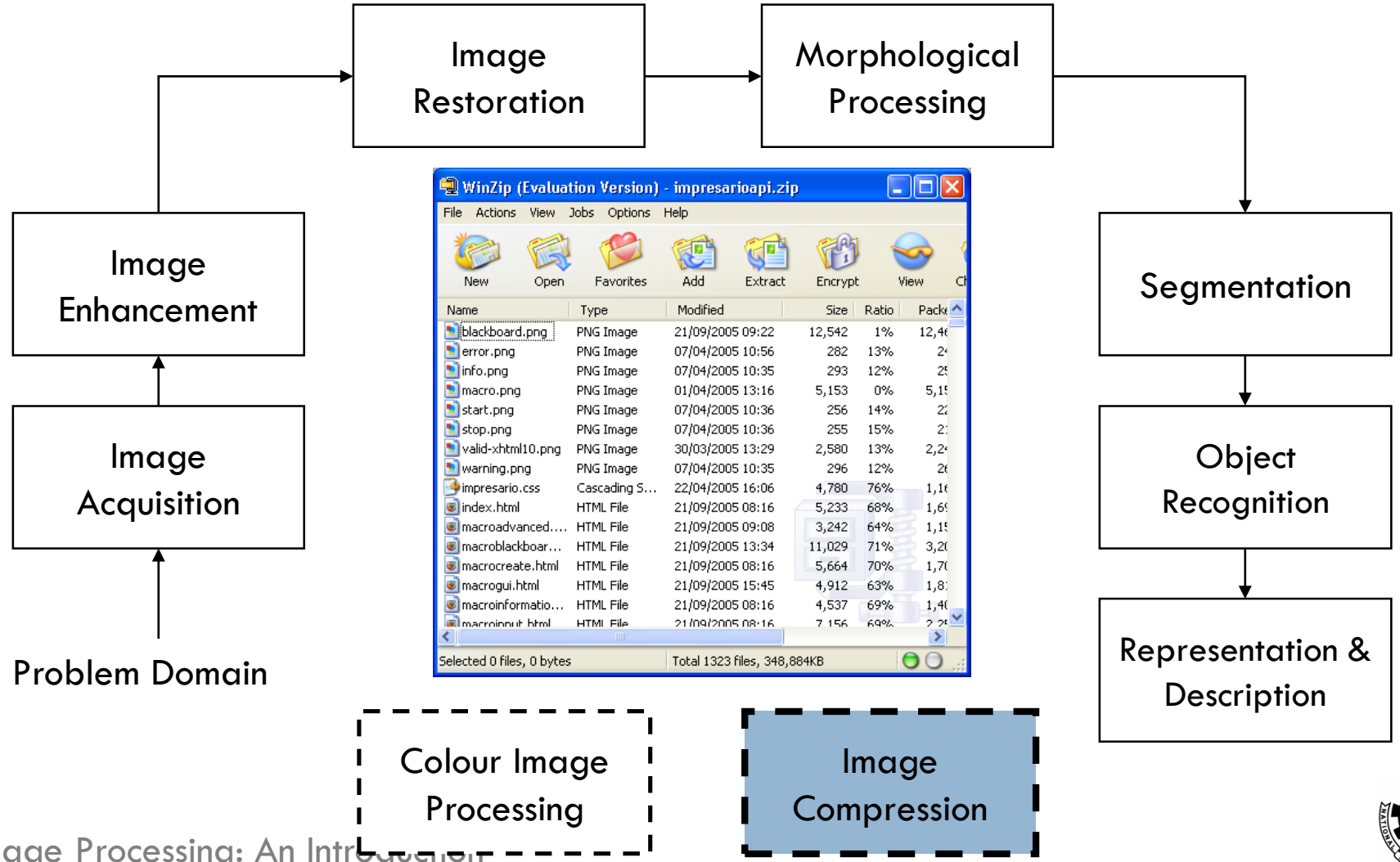
Key Stages in Digital Image Processing: Object Recognition



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