

# Digital Image Processing using MATLAB

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# Outline

## Introduction to Image Processing

Images

Digital Image Processing

Applications

Fundamental Steps

Sources

## Introduction to MATLAB

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## Introduction to Image Processing

### Images

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## Introduction to MATLAB

## What is an Image?

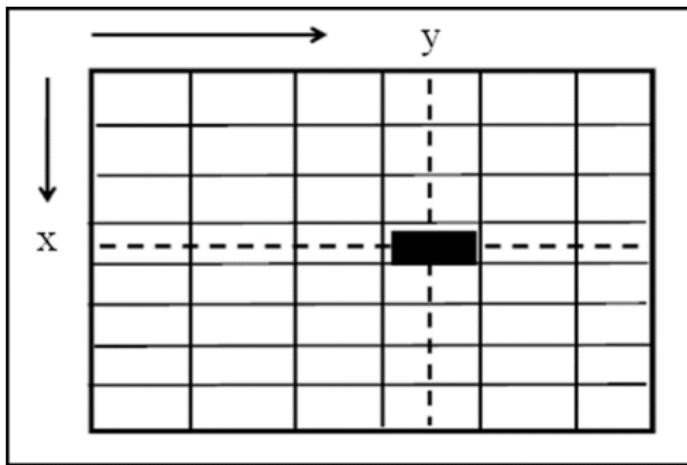
- ▶ An image is a visual representation of some measurable property of person, object, or phenomenon.



# What is a Digital Image?

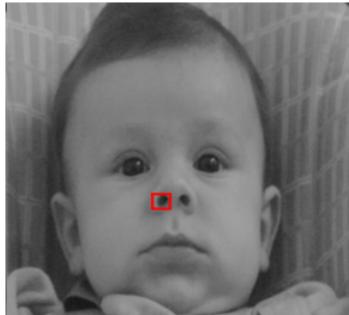
- ▶ In mathematical notation

- ▶ Digital image is defined as a  $2 - D$  function,  $f(x, y)$
- ▶  $x$  and  $y$  denote spatial coordinates
- ▶  $f$  is called intensity or gray level at the point  $(x, y)$



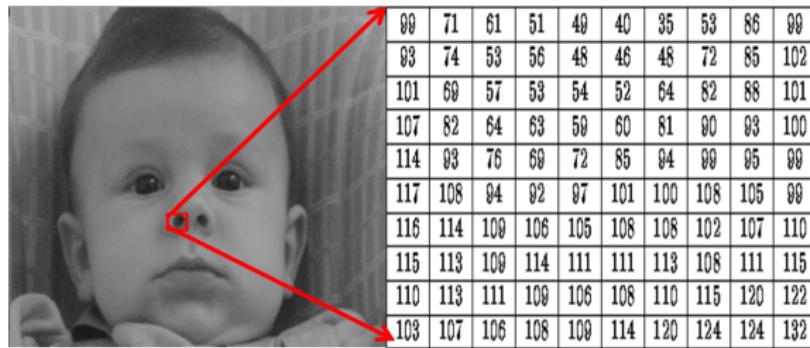
# What is a Digital Image?

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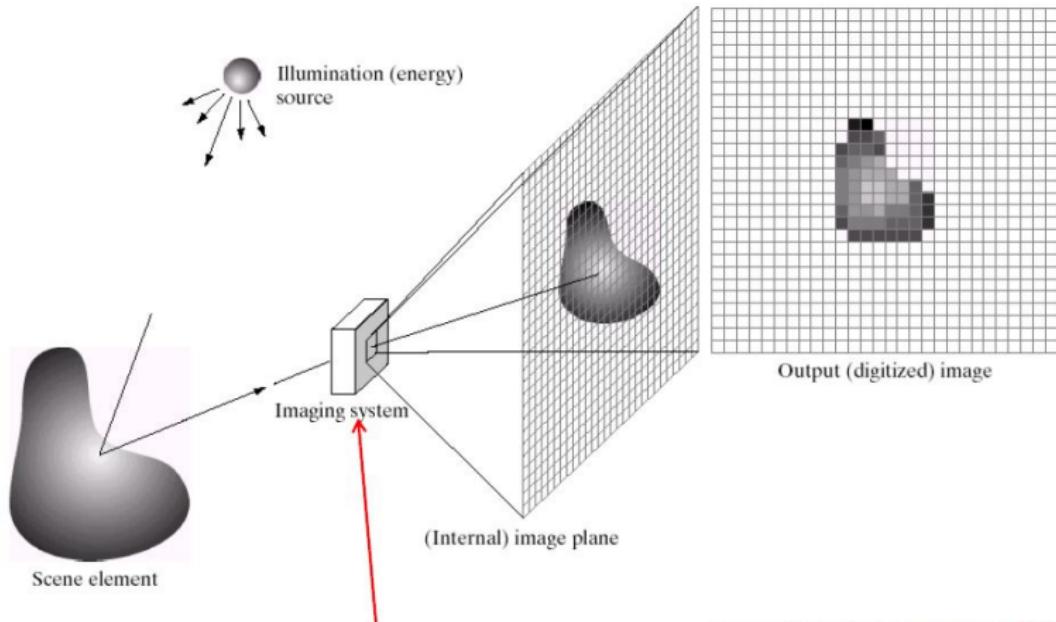


# What is a Digital Image?

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## Imaging System



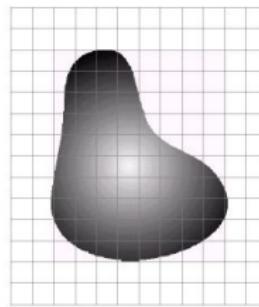
Example: a camera  
Converts light to image

Credits: Gonzales and Woods

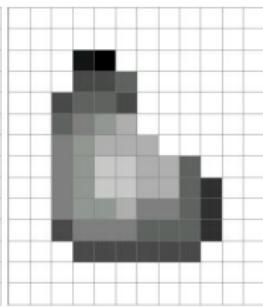


# Digital Image?

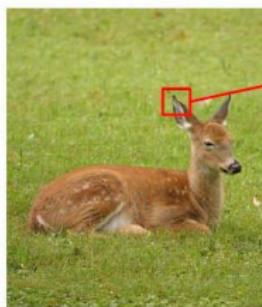
- ▶ Digitization causes a digital image to become an approximation of a real scene



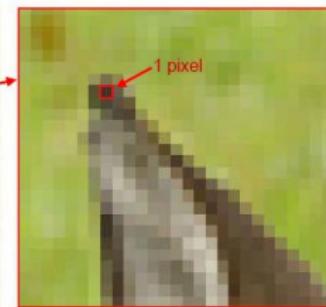
Real image



Digital Image  
(an approximation)



Real image



Digital Image  
(an approximation)

# Digital Image

- ▶ Common image formats include
  - ▶ 1 values per point/pixel (B&W or Grayscale)
  - ▶ 3 values per point/pixel (Red, Green, and Blue)



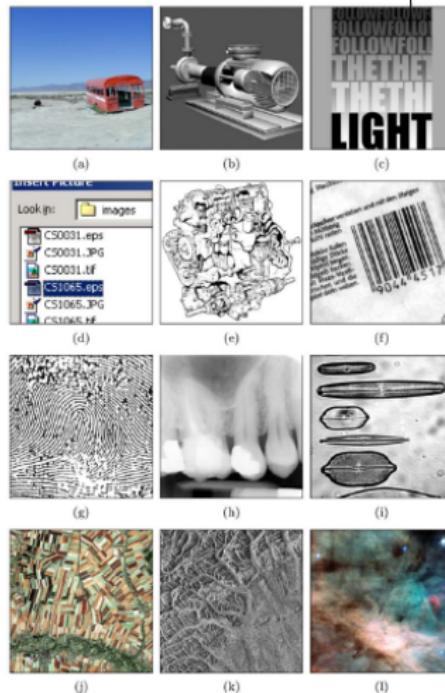
Grayscale



RGB

# Examples of Digital Images

- a) Natural landscape
- b) Synthetically generated scene
- c) Poster graphic
- d) Computer screenshot
- e) Black and white illustration
- f) Barcode
- g) Fingerprint
- h) X-ray
- i) Microscope slide
- j) Satellite Image
- k) Radar image
- l) Astronomical object



# Outline

## Introduction to Image Processing

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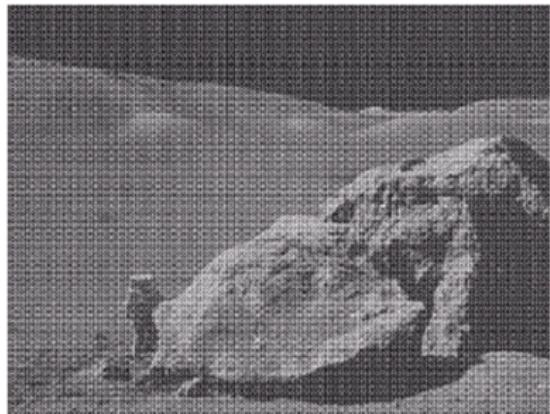
Fundamental Steps

Sources

## Introduction to MATLAB

# What is a Digital Image Processing?

- ▶ Algorithms that alter an input image to create new images
  - ▶ Input is image, output is image



## Examples of Digital Image Processing

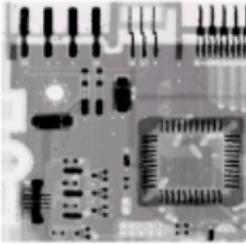
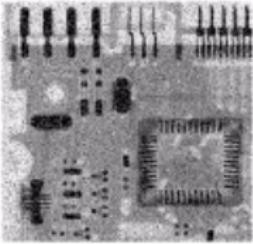
## Noisy Image



Denoised Image



## Examples: Noise Removal



## Examples: Contrast Adjustment



Low Contrast



Original Contrast

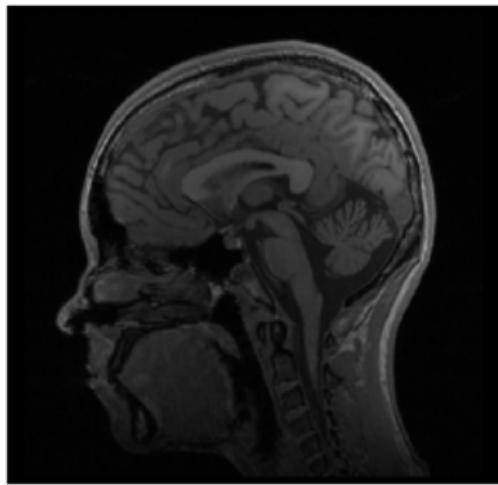


High Contrast

## Examples: Edge Detection



Examples: Region Detection, Segmentation



## Examples: Image Compression



Original, 2.1MB



JPEG Compression, 308KB (15%)

## Examples: Image Inpainting

Damaged Image



Restored Image



Credit: M. Bertalmio, G. Sapiro, V. Caselles, C. Ballester: *Image Inpainting*, SIGGRAPH 2000

Inpainting? Reconstruct corrupted/destroyed parts of an image

## Examples: Artistic (Movie Special) Effects



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## Introduction to MATLAB

## Principal Application Areas

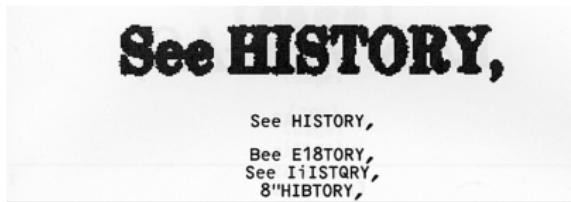
- ▶ Improvement of pictorial information for human interpretation



- ▶ Processing of image data for storage, transmission and representation for machine perception

## Applications of Image Processing

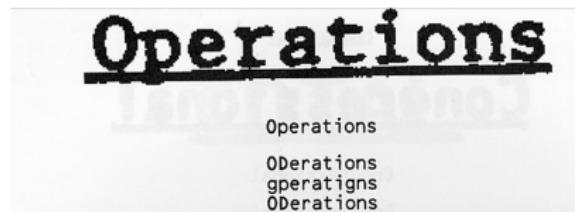
- ▶ Optical character recognition



Heavy Print



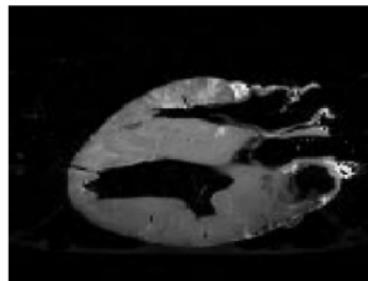
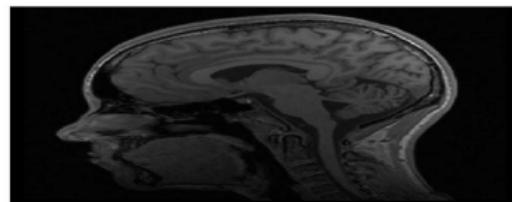
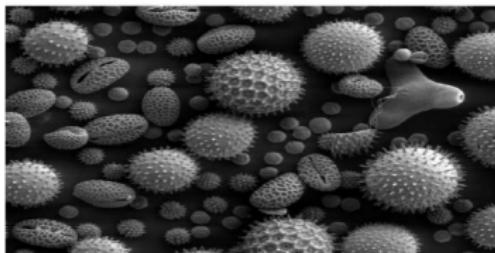
Light Print



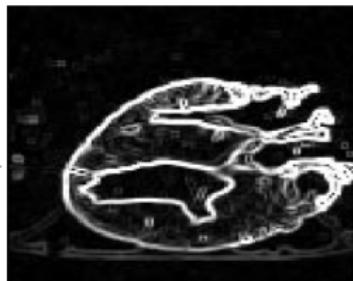
Typing

## Applications of Image Processing

- ▶ Biology and Medicine



Original MRI Image of a Dog Heart



Edge Detection Image

Figure:

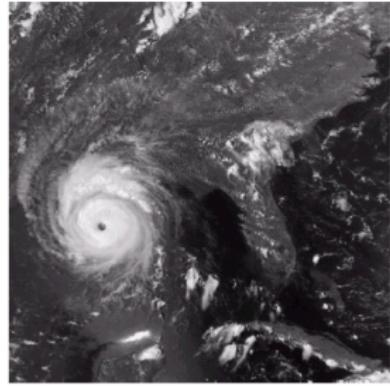
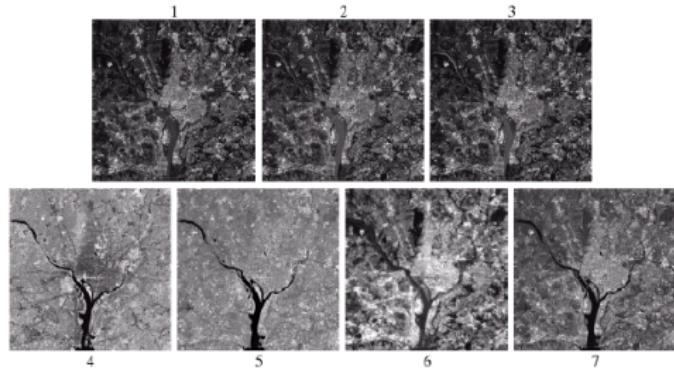
# Applications of Image Processing

- #### ► Satellite Imagery and Personal Photos



# Applications of Image Processing

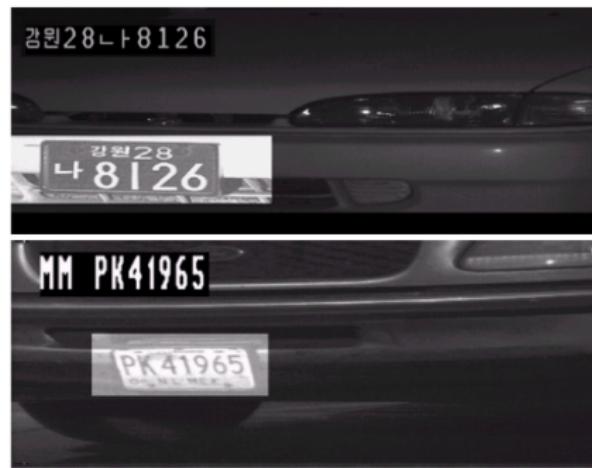
- ▶ Geographic Information Systems (GIS)
  - ▶ Terrain classification
  - ▶ Meteorology (weather)



# Applications of Image Processing

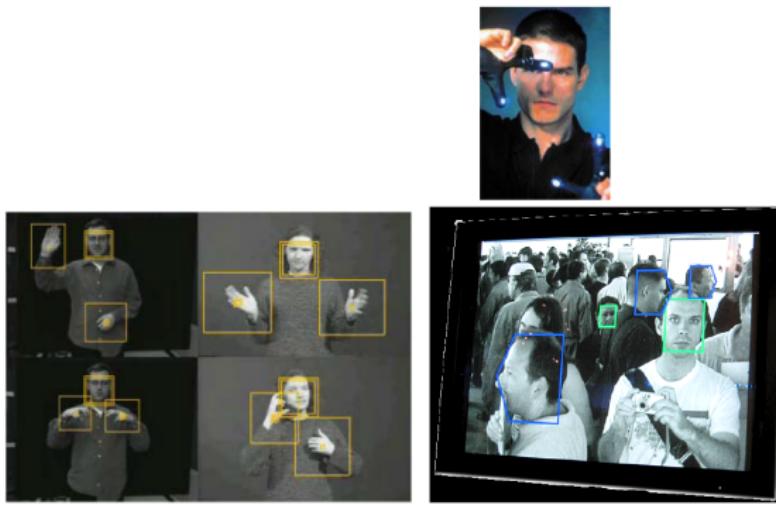
## ▶ Law Enforcement

- ▶ Number plate recognition for speed cameras or automated toll systems
- ▶ Fingerprint recognition



# Applications of Image Processing

- ▶ Human Computer Interaction (HCI)
  - ▶ Face recognition
  - ▶ Gesture recognition



# Applications of Image Processing

- ▶ Aging Problem



Original Image  
(1962)

## Applications of Image Processing

- ▶ Aging Problem



Original Image  
(1962)



Computer-Aged  
(1997)

## Applications of Image Processing

- ▶ Aging Problem



Original Image  
(1962)

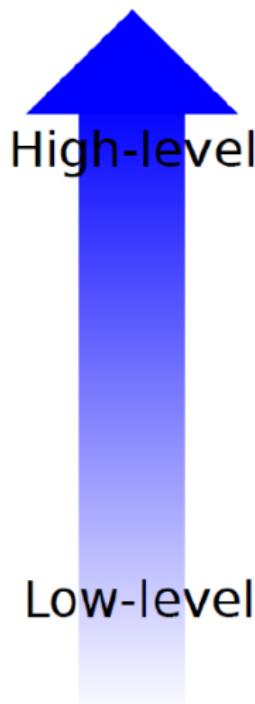


Computer-Aged  
(1997)



Actual Photo  
(1997)

# Levels of Image Processing



## Computer Vision

Object detection, recognition, shape analysis, tracking  
Use of Artificial Intelligence and Machine Learning

## Image Analysis

Segmentation, image registration, matching

## Image Processing

Image enhancement, noise removal, restoration,  
feature detection, compression

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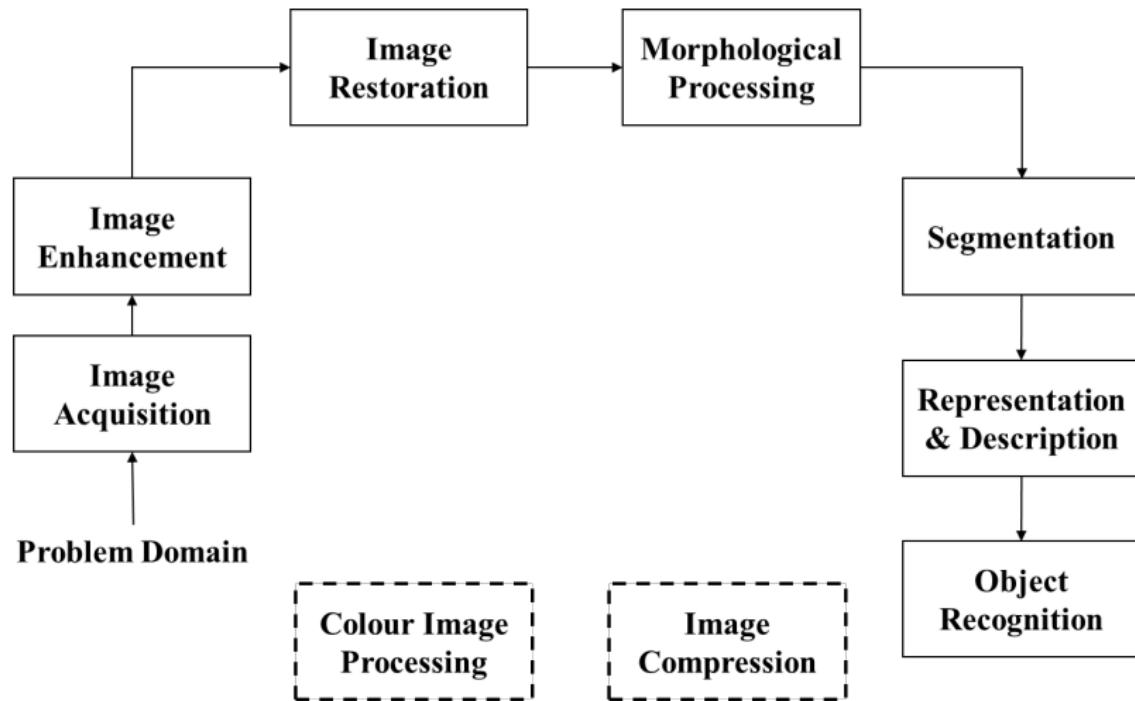
Applications

**Fundamental Steps**

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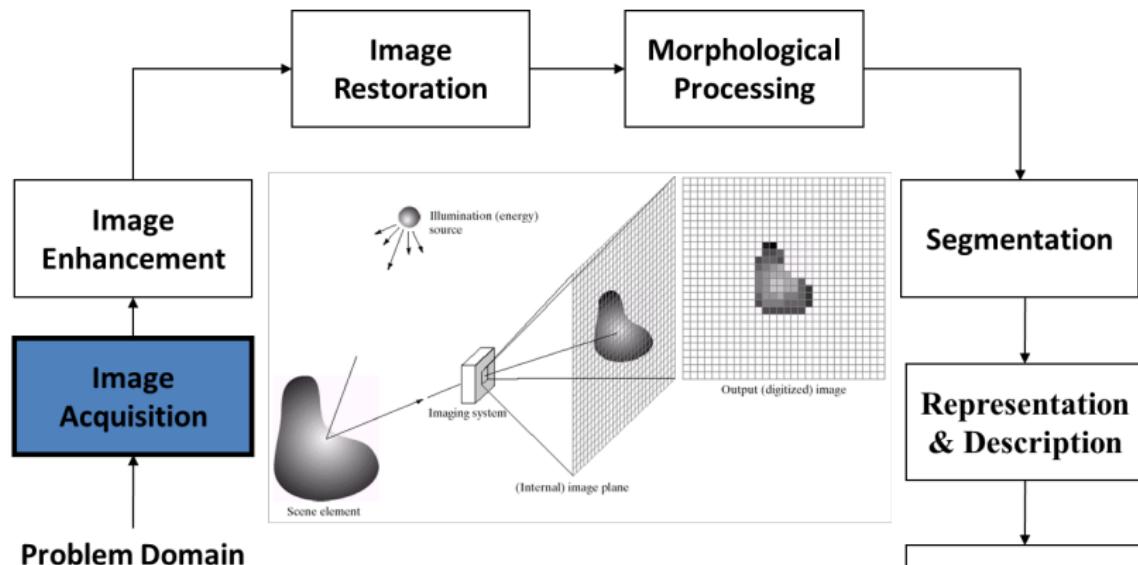
## Introduction to MATLAB

# Fundamental Steps in Digital Image Processing



# Fundamental Steps in Digital Image Processing

## ► Image Acquisition



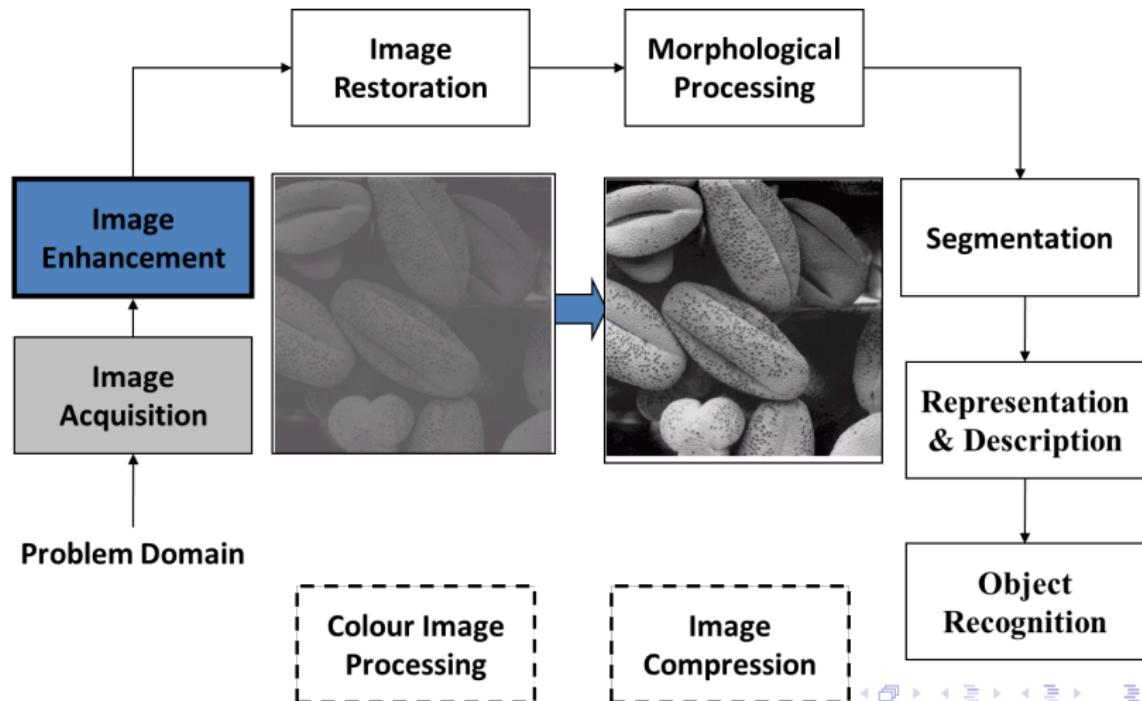
Colour Image Processing

Image Compression

Object Recognition

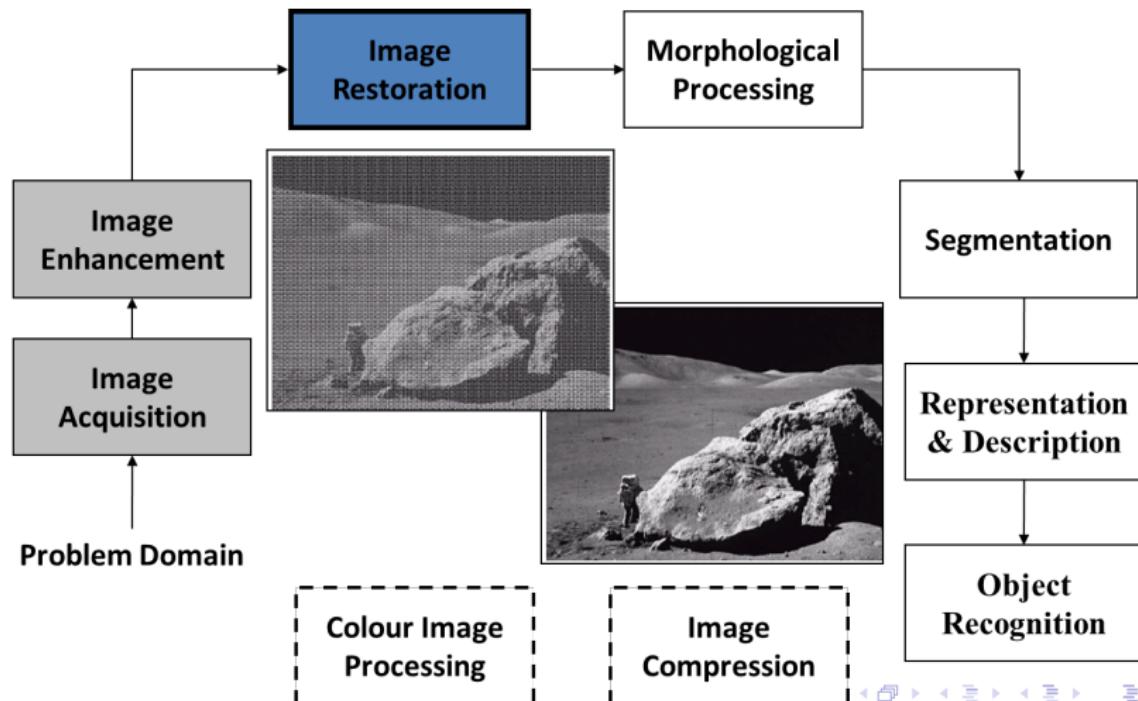
# Fundamental Steps in Digital Image Processing

## ► Image Enhancement



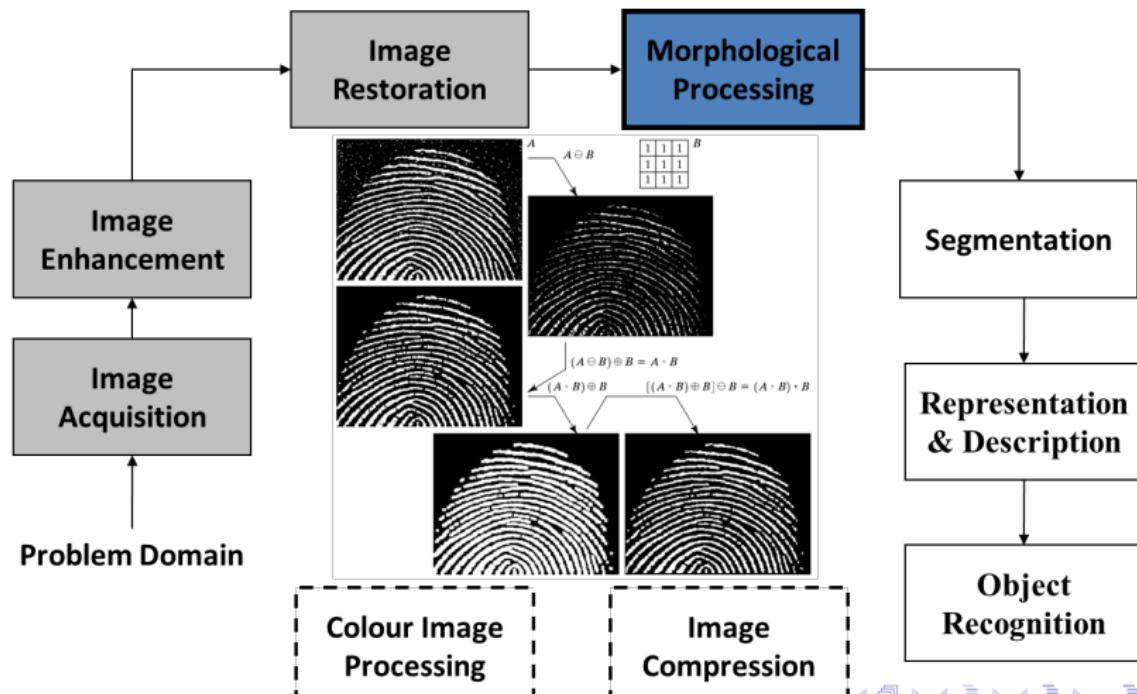
# Fundamental Steps in Digital Image Processing

## ► Image Restoration



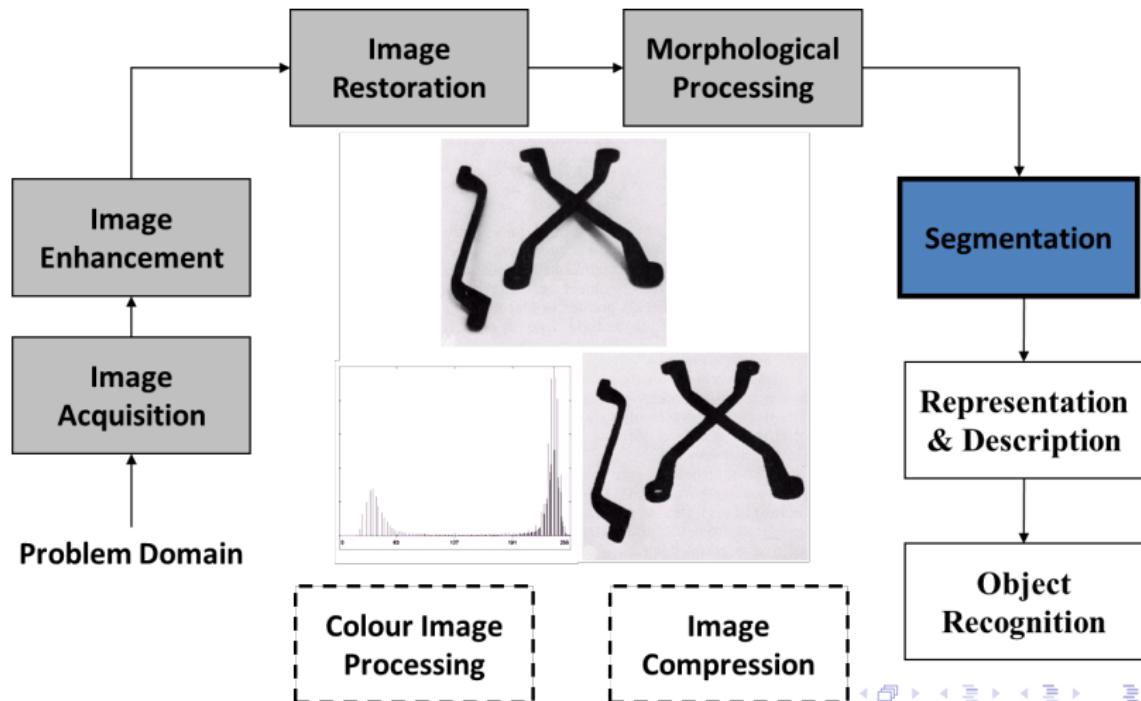
# Fundamental Steps in Digital Image Processing

## ► Morphological Processing



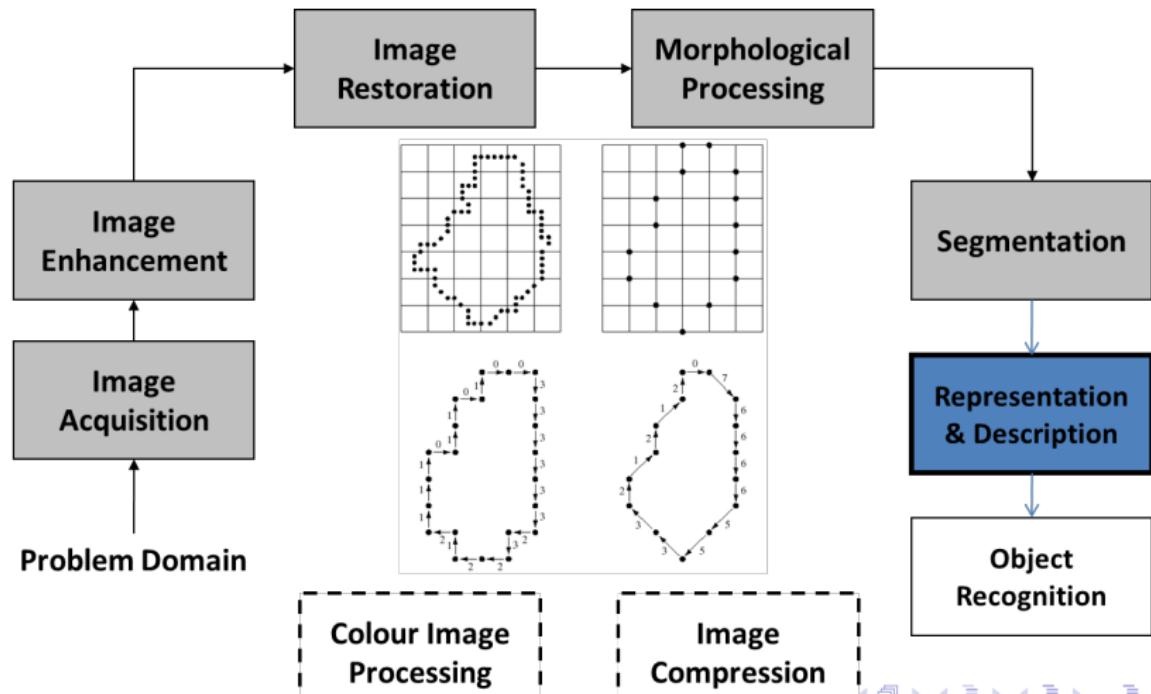
# Fundamental Steps in Digital Image Processing

- ▶ Segmentation



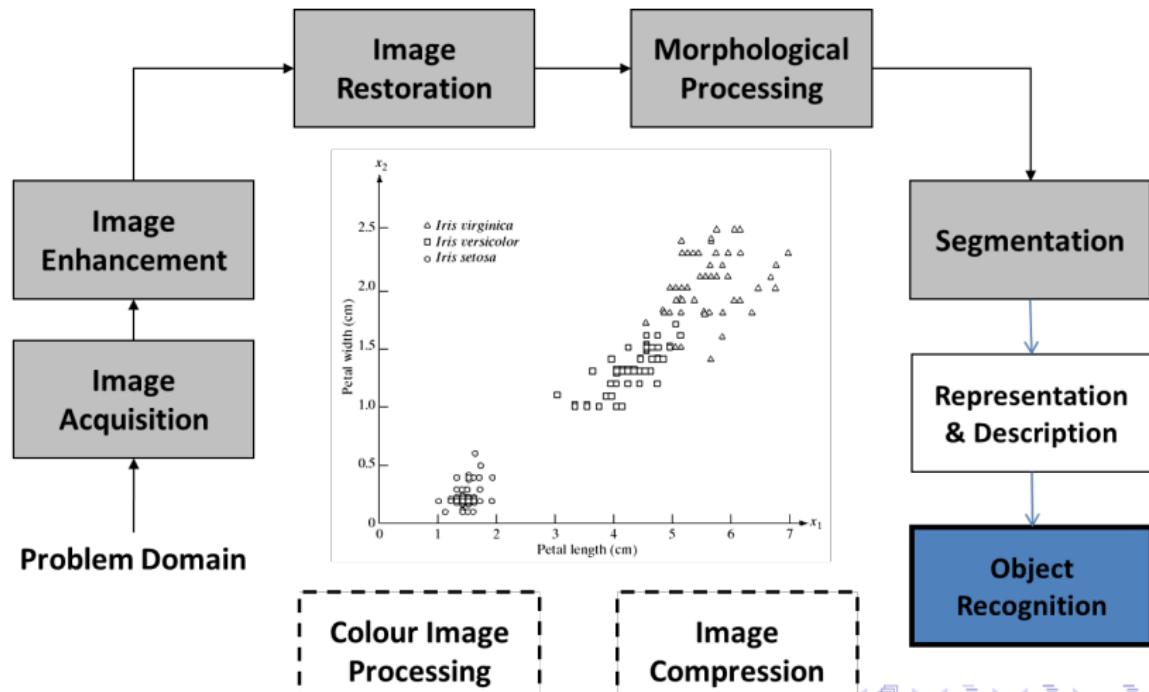
# Fundamental Steps in Digital Image Processing

- ▶ Representation & Description



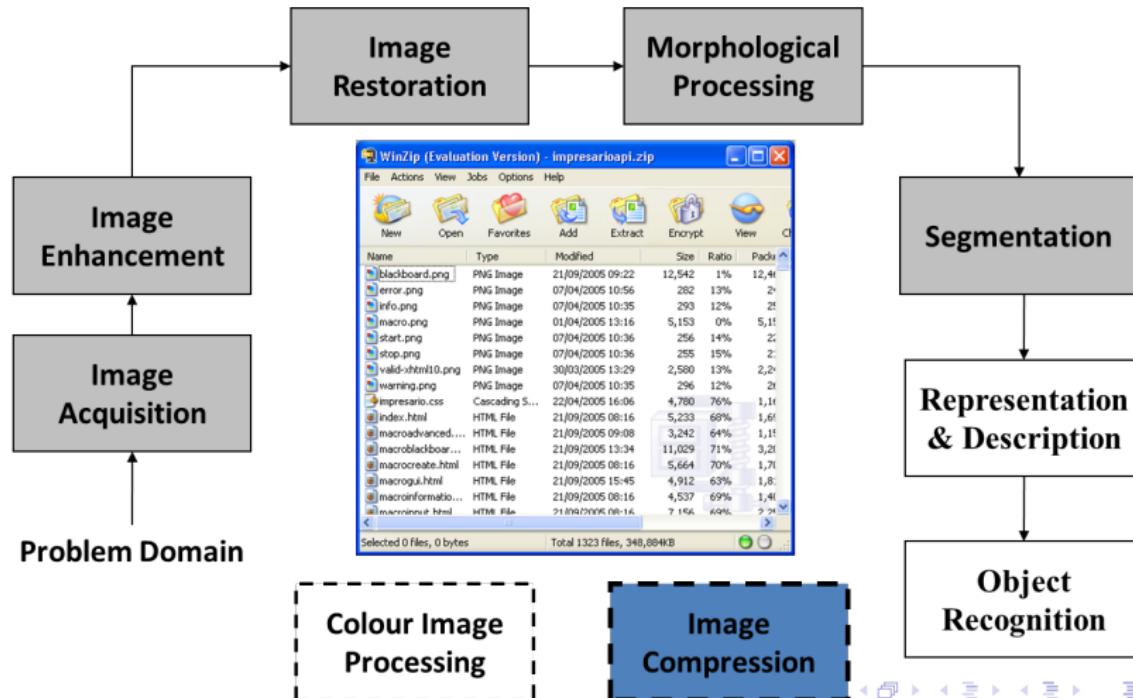
# Fundamental Steps in Digital Image Processing

## ► Object Recognition



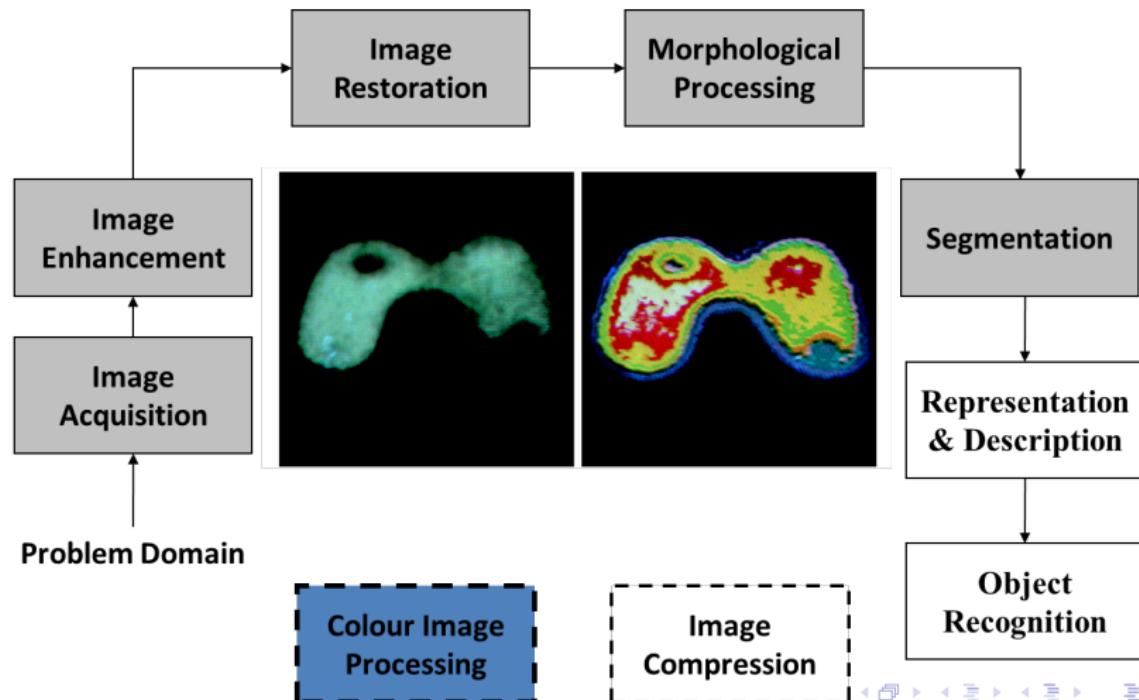
# Fundamental Steps in Digital Image Processing

- ▶ Image Compression



# Fundamental Steps in Digital Image Processing

## ► Colour Image Processing



## Image File Formats

- ▶ Hundreds of image file formats.
  - ▶ Tagged Image File Format (TIFF)
  - ▶ Graphics Interchange Format (GIF)
  - ▶ Portable Network Graphics (PNG)
  - ▶ JPEG, BMP, Portable Bitmap Format (PBM), etc.
- ▶ Image pixel values can be
  - ▶ **Grayscale:** 0 – 255 range
  - ▶ **Binary:** 0 or 1
  - ▶ **Color:** RGB colors in 0 – 255 range (or other color model)
  - ▶ **Application specific** (e.g. floating point values in astronomy)

# How many Bits Per Image Element?

## Grayscale (Intensity Images):

Chan.	Bits/Pix.	Range	Use
1	1	0...1	Binary image: document, illustration, fax
1	8	0...255	Universal: photo, scan, print
1	12	0...4095	High quality: photo, scan, print
1	14	0...16383	Professional: photo, scan, print
1	16	0...65535	Highest quality: medicine, astronomy

## Color Images:

Chan.	Bits/Pix.	Range	Use
3	24	$[0\dots255]^3$	RGB, universal: photo, scan, print
3	36	$[0\dots4095]^3$	RGB, high quality: photo, scan, print
3	42	$[0\dots16383]^3$	RGB, professional: photo, scan, print
4	32	$[0\dots255]^4$	CMYK, digital prepress

## Special Images:

Chan.	Bits/Pix.	Range	Use
1	16	$-32768\dots32767$	Whole numbers pos./neg., increased range
1	32	$\pm3.4 \cdot 10^{38}$	Floating point: medicine, astronomy
1	64	$\pm1.8 \cdot 10^{308}$	Floating point: internal processing

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**Sources**

## Introduction to MATLAB

## References

- ▶ Gonzalez, R.C. and R.E. Woods, "Digital Image Processing"
- ▶ Anil K Jain, "Fundamentals of Digital Image Processing"
- ▶ Rafael C gonzalez, "Digital Image Processing Using MATLAB"
- ▶ William K Pratt, "Digital Image Processing: PIKS Scientific Inside"

## MATLAB

Let's Learn MATLAB for  
Image Processing



# Thank You