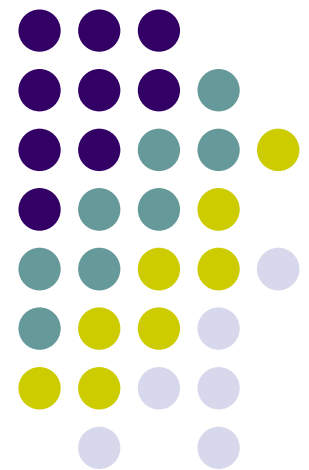


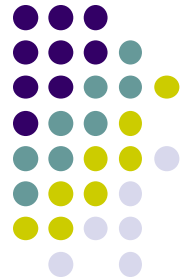
# Introduction to Image Processing

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Prof Emmanuel Agu

*Computer Science Dept.  
Worcester Polytechnic Institute (WPI)*

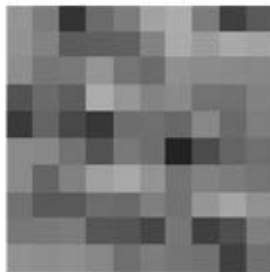




# What is an Image?

- 2-dimensional matrix of Intensity (gray or color) values

Set of Intensity values  $I(u, v) \in \mathbb{P}$  and  $u, v \in \mathbb{N}$ .  
Image coordinates are integers



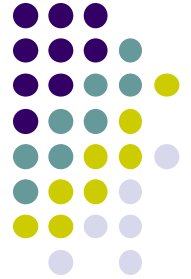
$F(x, y)$



|     |     |     |     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 148 | 123 | 52  | 107 | 123 | 162 | 172 | 123 | 64  | 89  | ... |
| 147 | 130 | 92  | 95  | 98  | 130 | 171 | 155 | 169 | 163 | ... |
| 141 | 118 | 121 | 148 | 117 | 107 | 144 | 137 | 136 | 134 | ... |
| 82  | 106 | 93  | 172 | 149 | 131 | 138 | 114 | 113 | 129 | ... |
| 57  | 101 | 72  | 54  | 109 | 111 | 104 | 135 | 106 | 125 | ... |
| 138 | 135 | 114 | 82  | 121 | 110 | 34  | 76  | 101 | 111 | ... |
| 138 | 102 | 128 | 159 | 168 | 147 | 116 | 129 | 124 | 117 | ... |
| 113 | 89  | 89  | 109 | 106 | 126 | 114 | 150 | 164 | 145 | ... |
| 120 | 121 | 123 | 87  | 85  | 70  | 119 | 64  | 79  | 127 | ... |
| 145 | 141 | 143 | 134 | 111 | 124 | 117 | 113 | 64  | 112 | ... |
| ⋮   | ⋮   | ⋮   | ⋮   | ⋮   | ⋮   | ⋮   | ⋮   | ⋮   | ⋮   | ⋮   |

$I(u, v)$

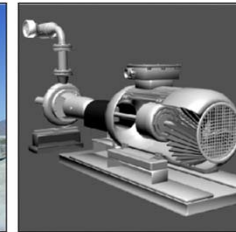
# Example of Digital Images



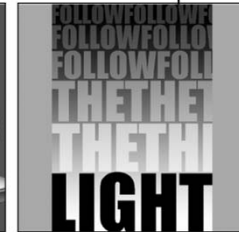
- a) Natural landscape
- b) Synthetically generated scene
- c) Poster graphic
- d) Computer screenshot
- e) Black and white illustration
- f) Barcode
- g) Fingerprint
- h) X-ray
- i) Microscope slide
- j) Satellite Image
- k) Radar image
- l) Astronomical object



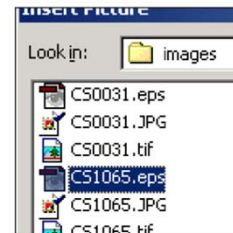
(a)



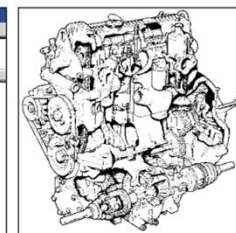
(b)



(c)



(d)



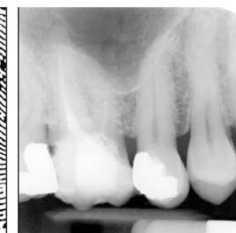
(e)



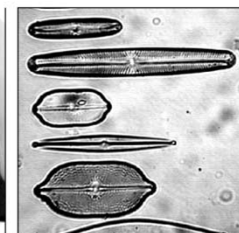
(f)



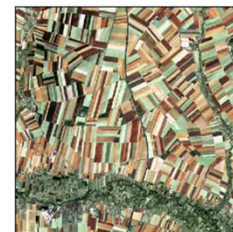
(g)



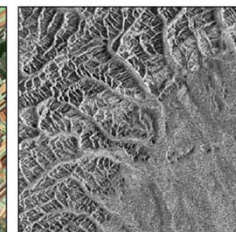
(h)



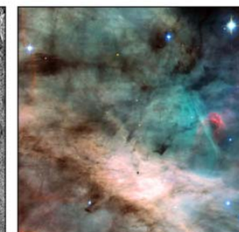
(i)



(j)

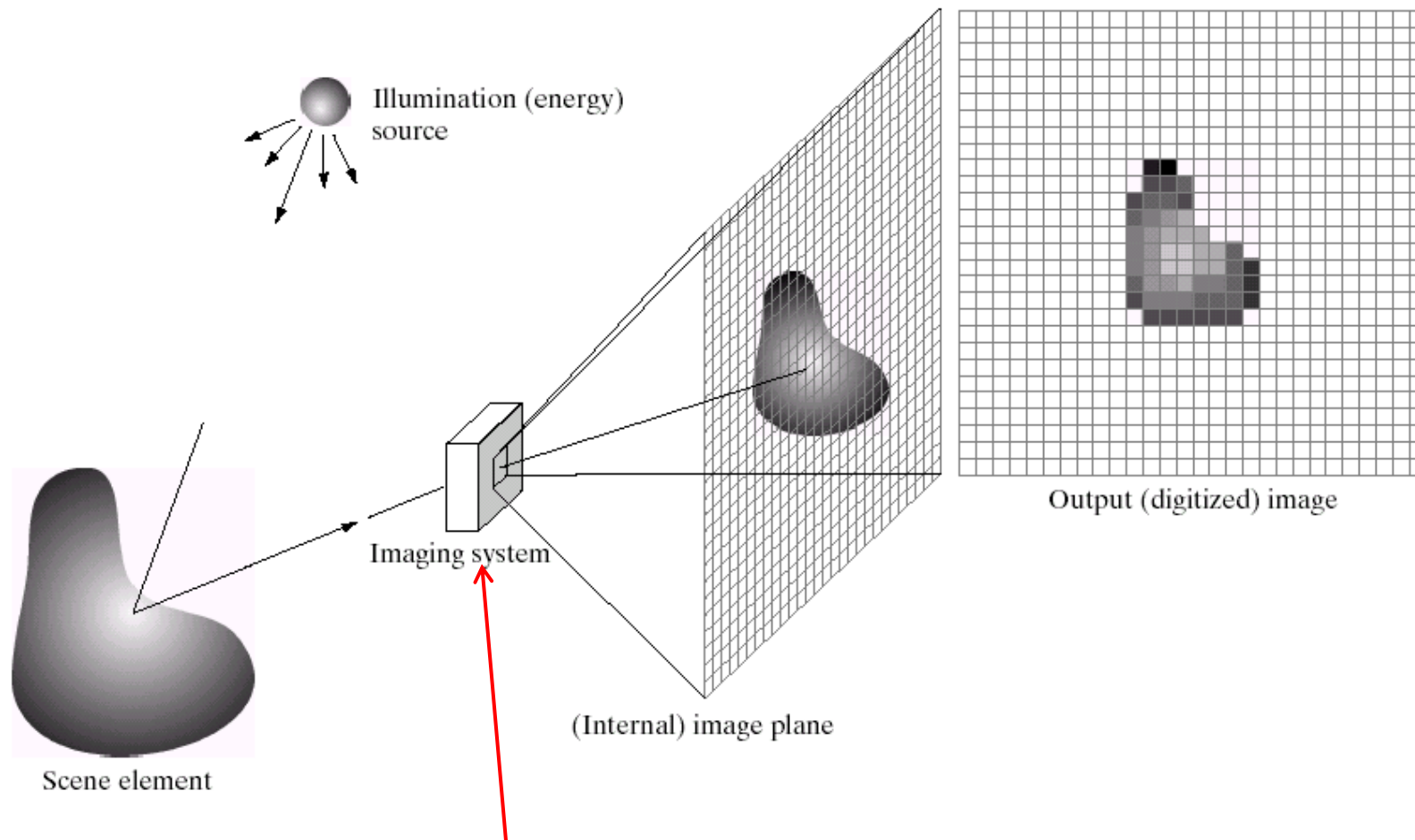
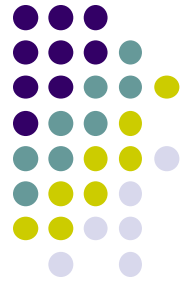


(k)



(l)

# Imaging System



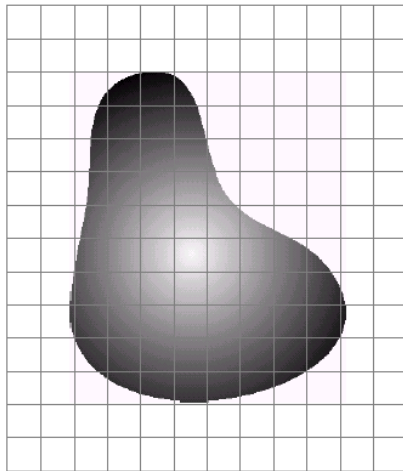
Example: a camera  
Converts light to image

Credits: Gonzales and Woods

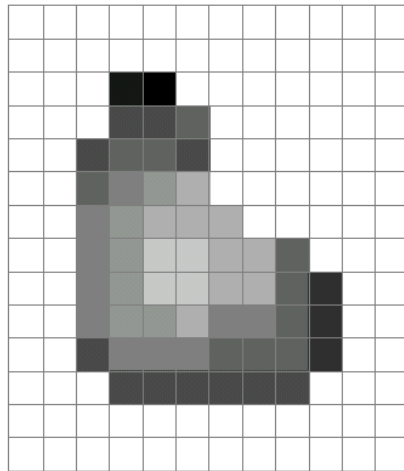


# Digital Image?

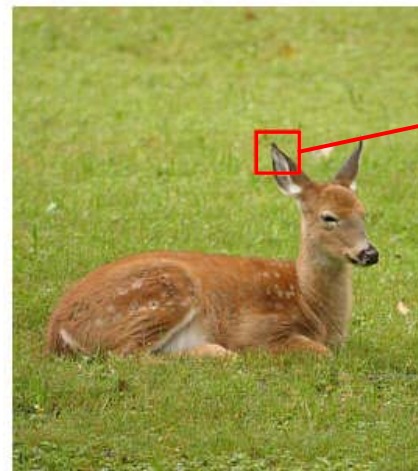
- **Remember:** *digitization* causes a digital image to become an *approximation* of a real scene



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)
  - 4 values per point/pixel (Red, Green, Blue, + “Alpha” or Opacity)



Grayscale



RGB



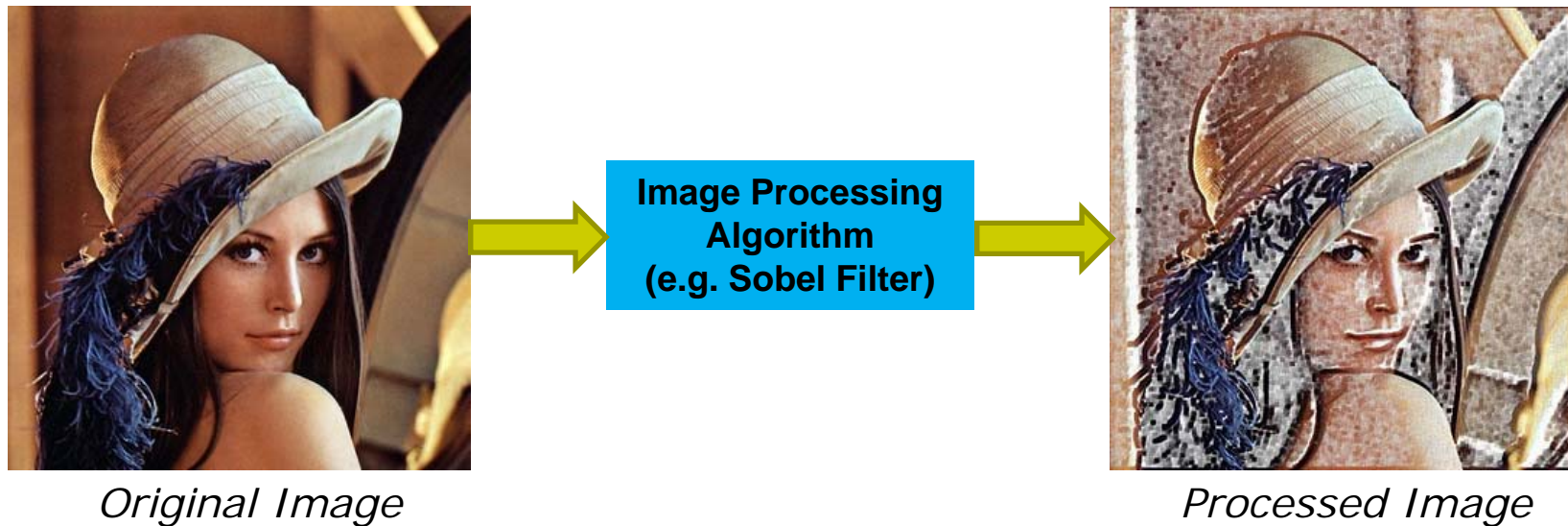
RGBA

- We will start with gray-scale images, extend to color later

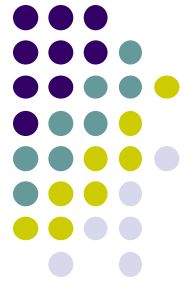
# What is image Processing?



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

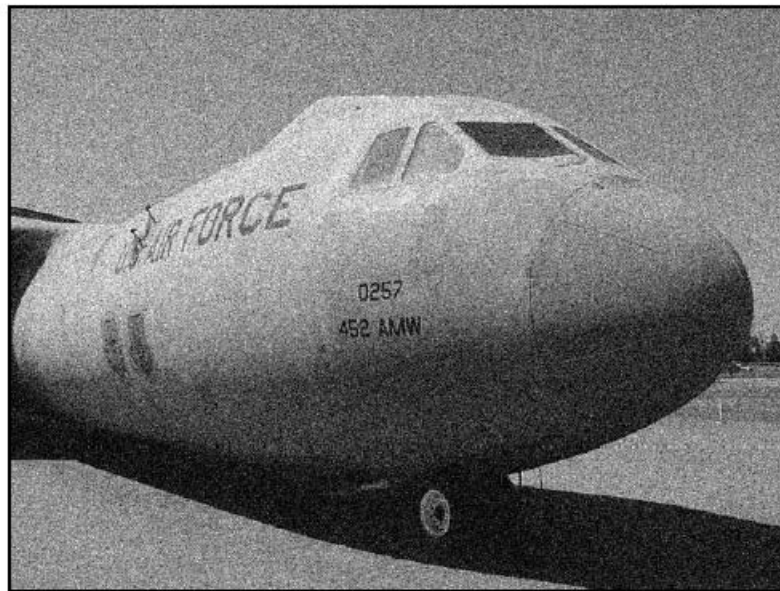


- **Improves an image for human interpretation in ways including:**
  - Image display and printing
  - Image editing
  - Image enhancement
  - Image compression



# Example Operation: Noise Removal

Noisy Image



Denoised Image

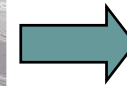
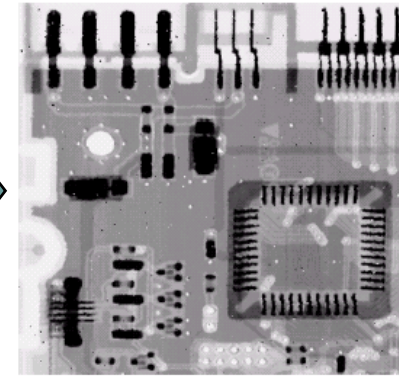
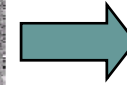
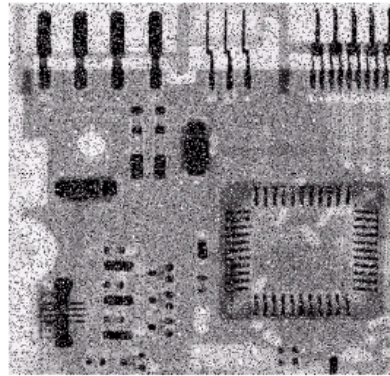
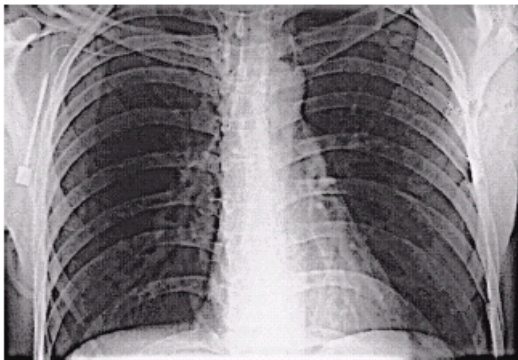
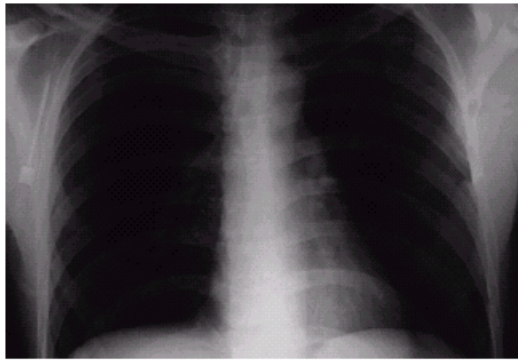


Think of noise as white specks on a picture (random or non-random)

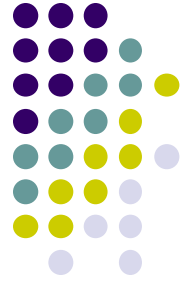




# Examples: Noise Removal



# Example: Contrast Adjustment



Low Contrast



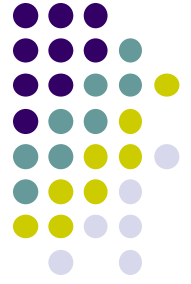
Original Contrast



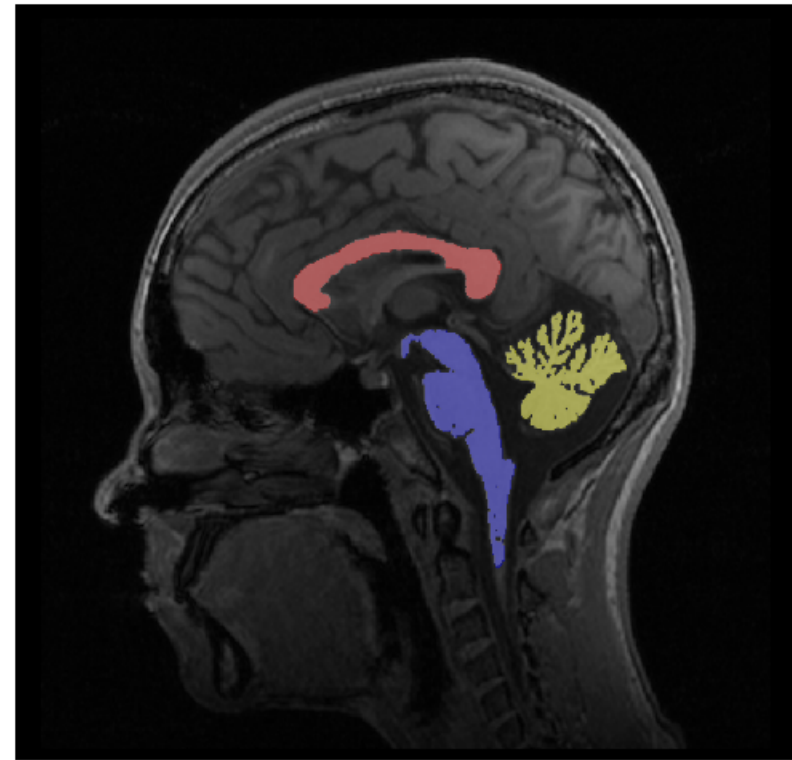
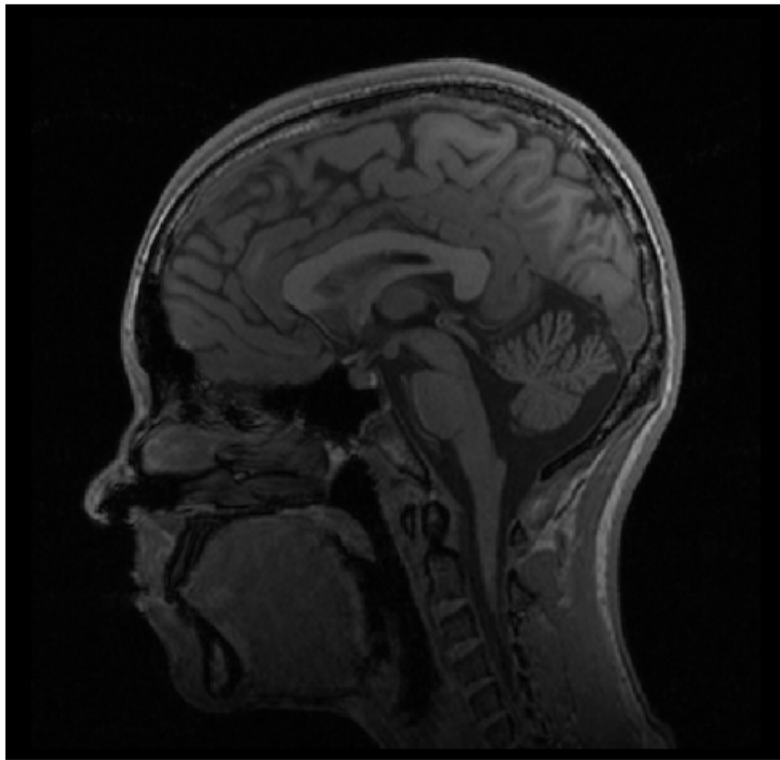
High Contrast



# Example: Edge Detection



# Example: Region Detection, Segmentation



# Example: Image Compression



Original, 2.1MB



JPEG Compression, 308KB (15%)





# Example: Image Inpainting

Damaged Image

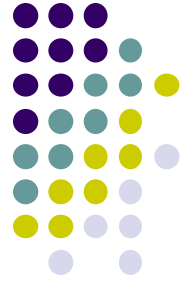


Restored Image



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

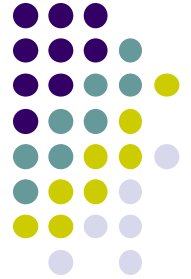
**Inpainting? Reconstruct corrupted/destroyed parts of an image**



## Examples: Artistic (Movie Special )Effects

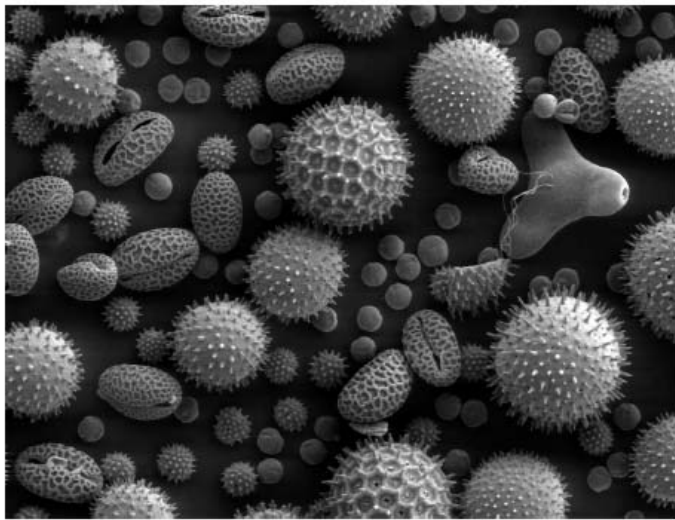


# Applications of Image Processing

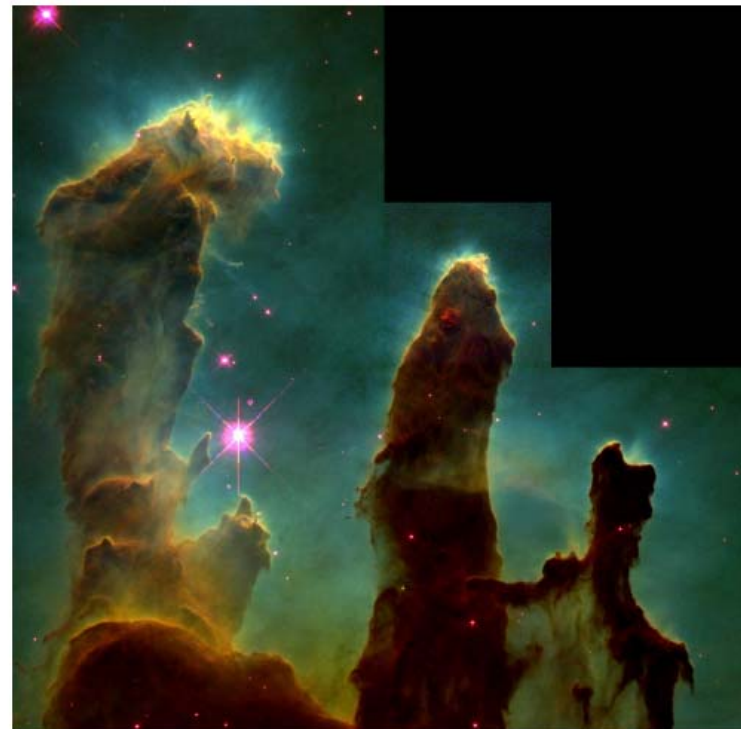


## Astronomy

## Biology



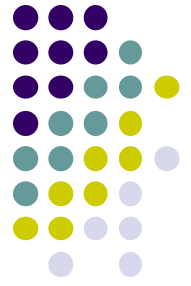
*Credit: Dartmouth Electron Microscopy Facility*



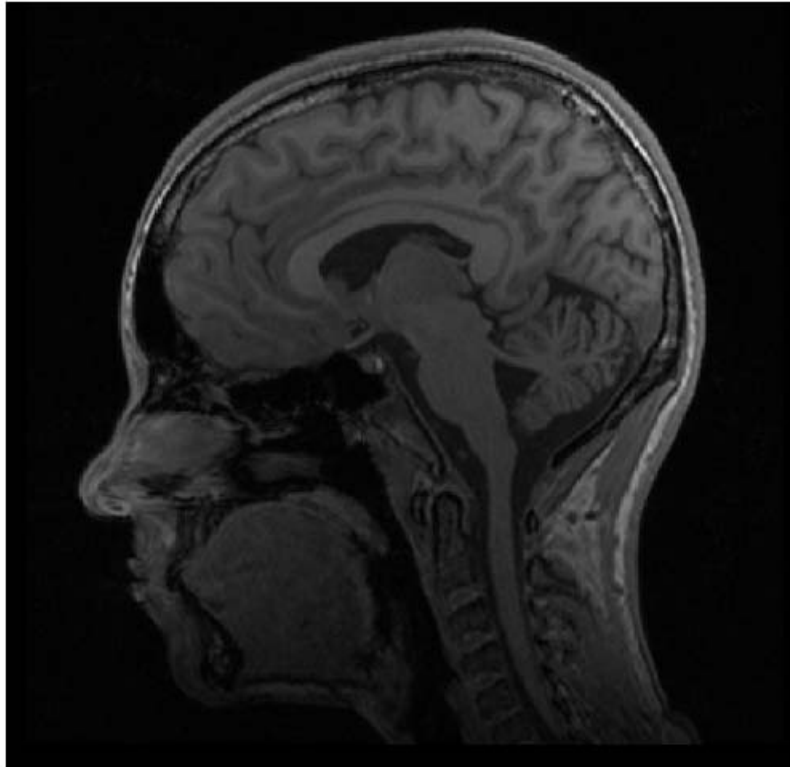
*Credit: NASA, Jeff Hester, and Paul Scowen (Arizona State)*

[More info here](#)

# Applications of Image Processing



Medicine



*Credit: Dr. Janet Lainhart, UofU Psychiatry*

Security, Biometrics

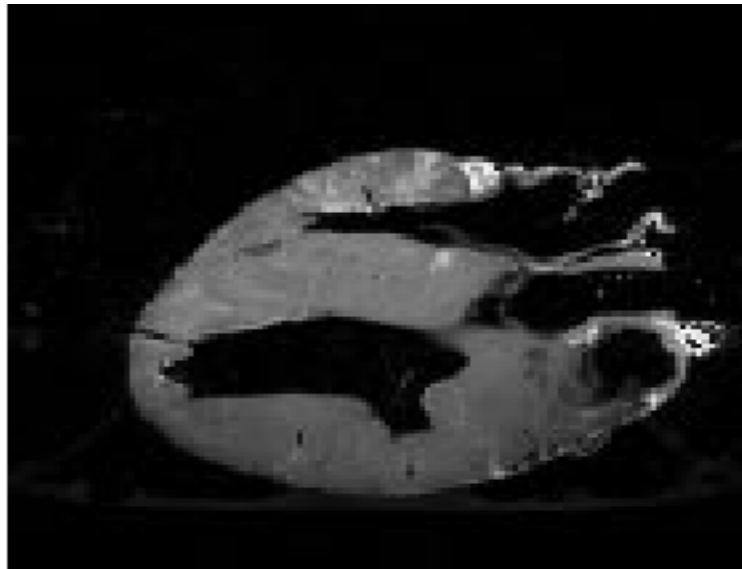




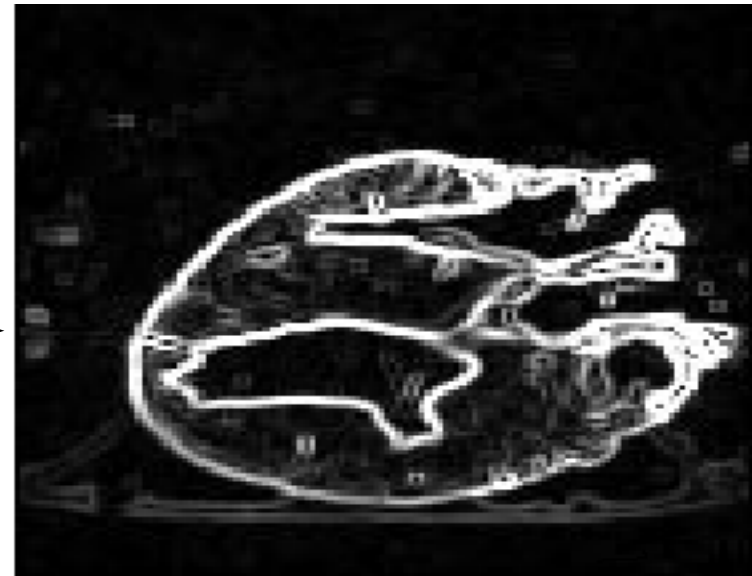


# Applications of Image Processing: Medicine

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



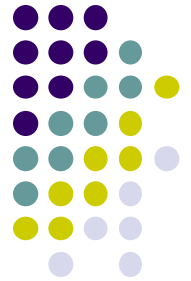
Original MRI Image of a Dog Heart



Edge Detection Image



# Applications of Image Processing



## Satellite Imagery



*Credit: NASA*

## Personal Photos

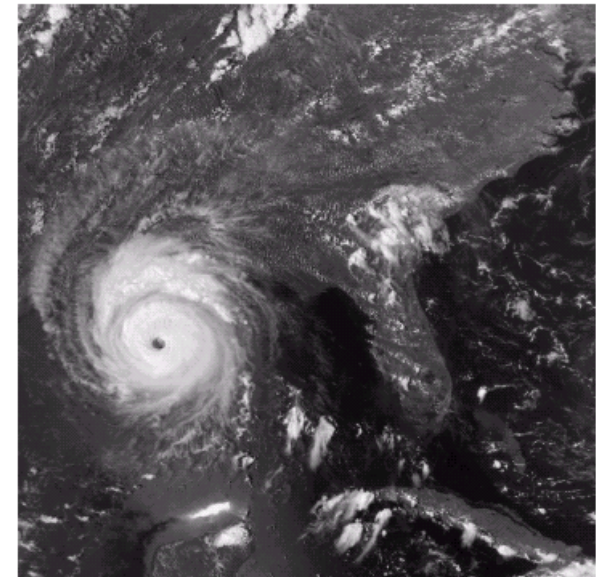
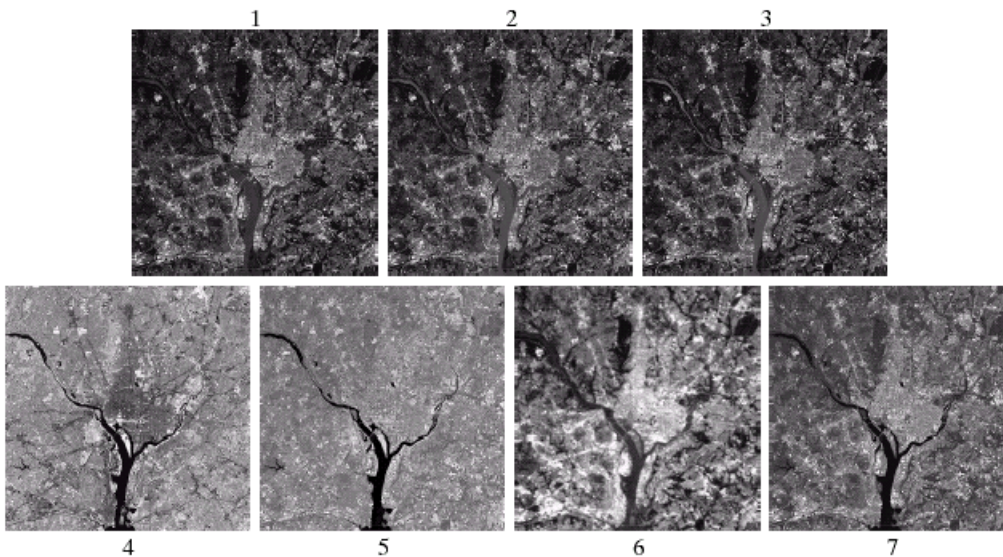


*Credit: Tom Fletcher*

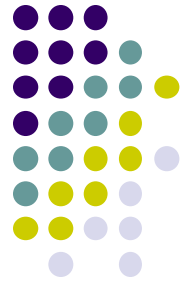
# Applications of Image Processing: Geographic Information Systems (GIS)



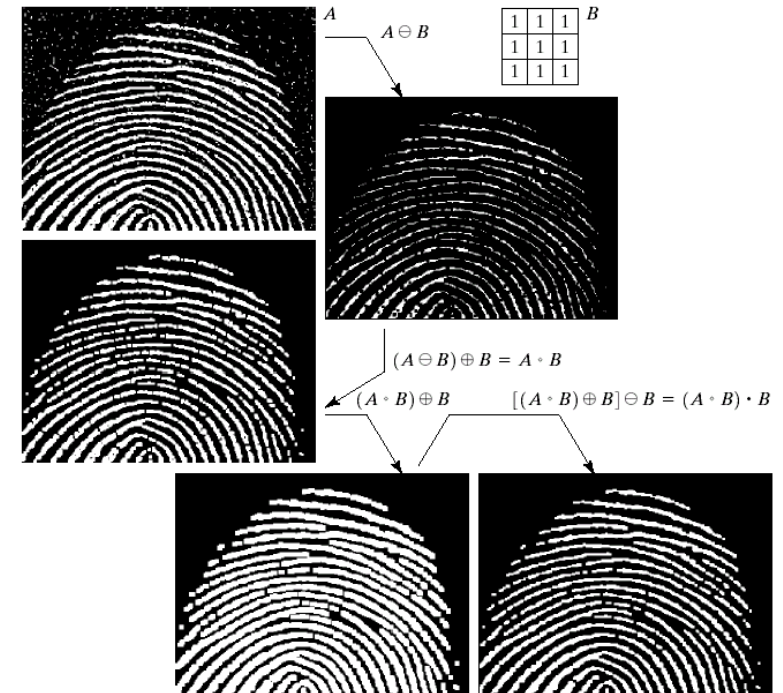
- Terrain classification
- Meteorology (weather)



# Applications of Image Processing: Law Enforcement



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



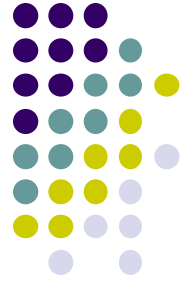


# Applications of Image Processing: HCI



- Face recognition
- Gesture recognition





# Relationship with other Fields

High-level

## Computer Vision

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

## Image Analysis

Segmentation, image registration, matching

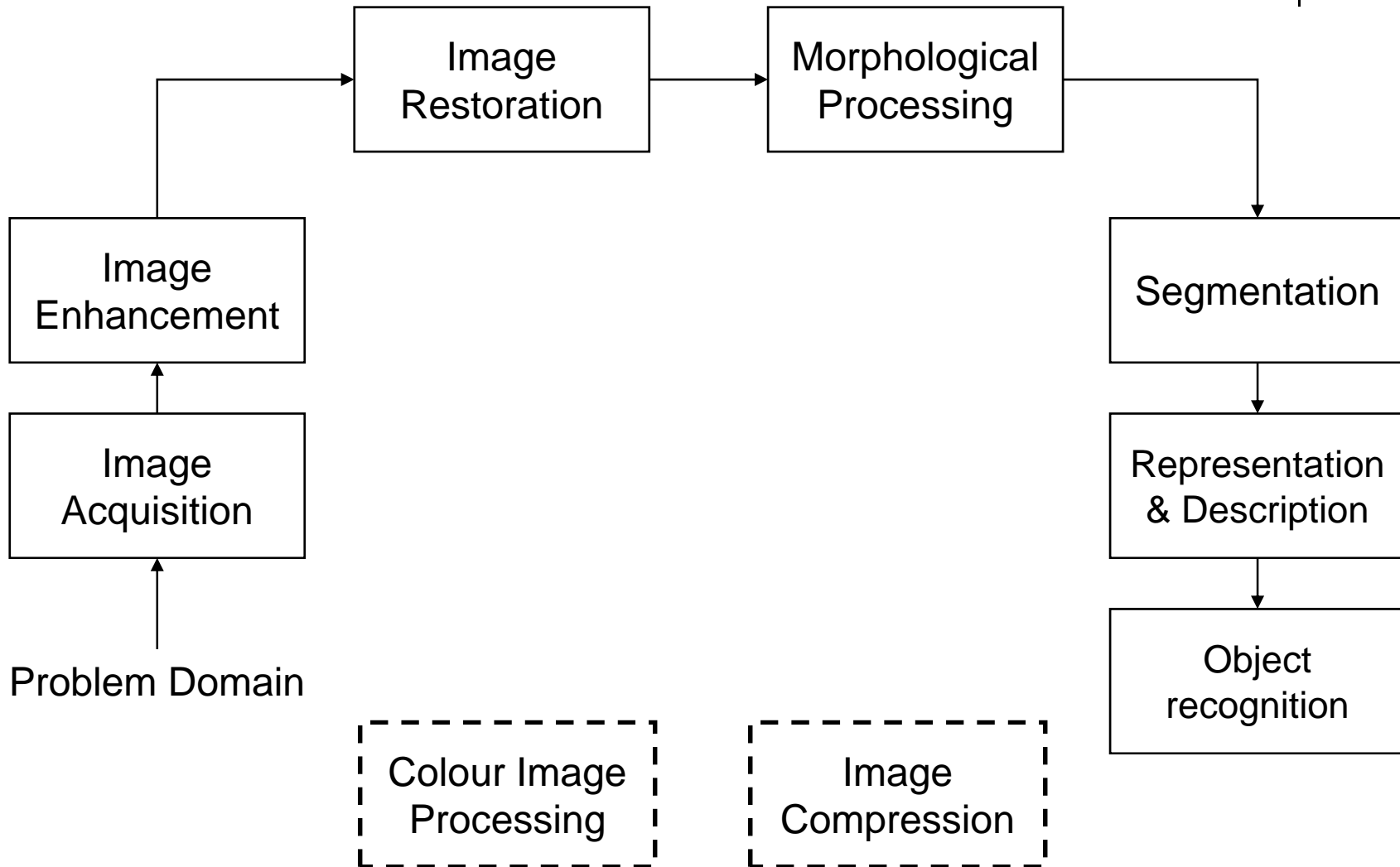
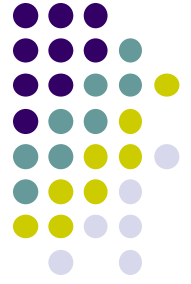
Low-level

## Image Processing

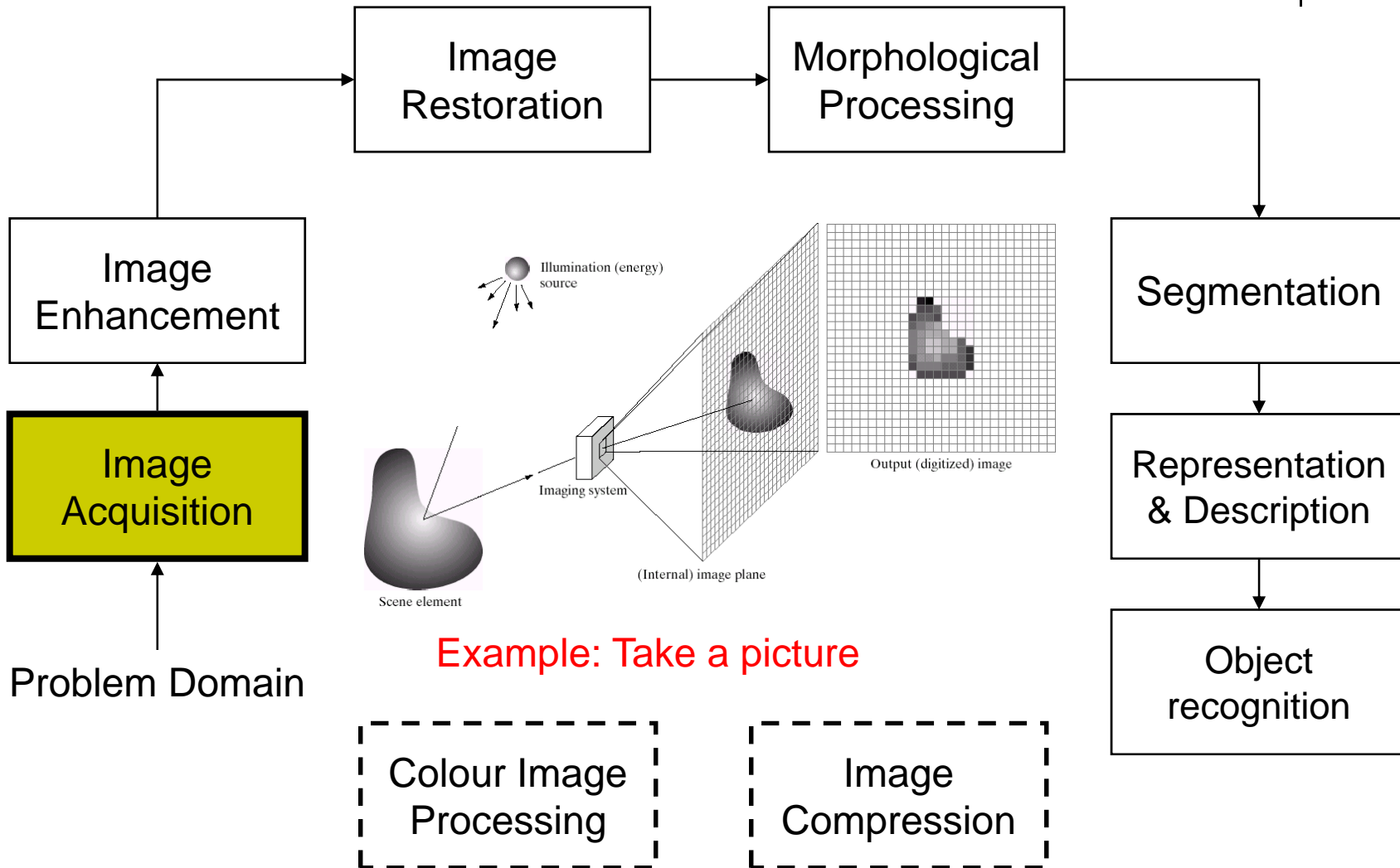
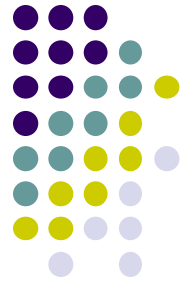
Image enhancement, noise removal, restoration,  
feature detection, compression



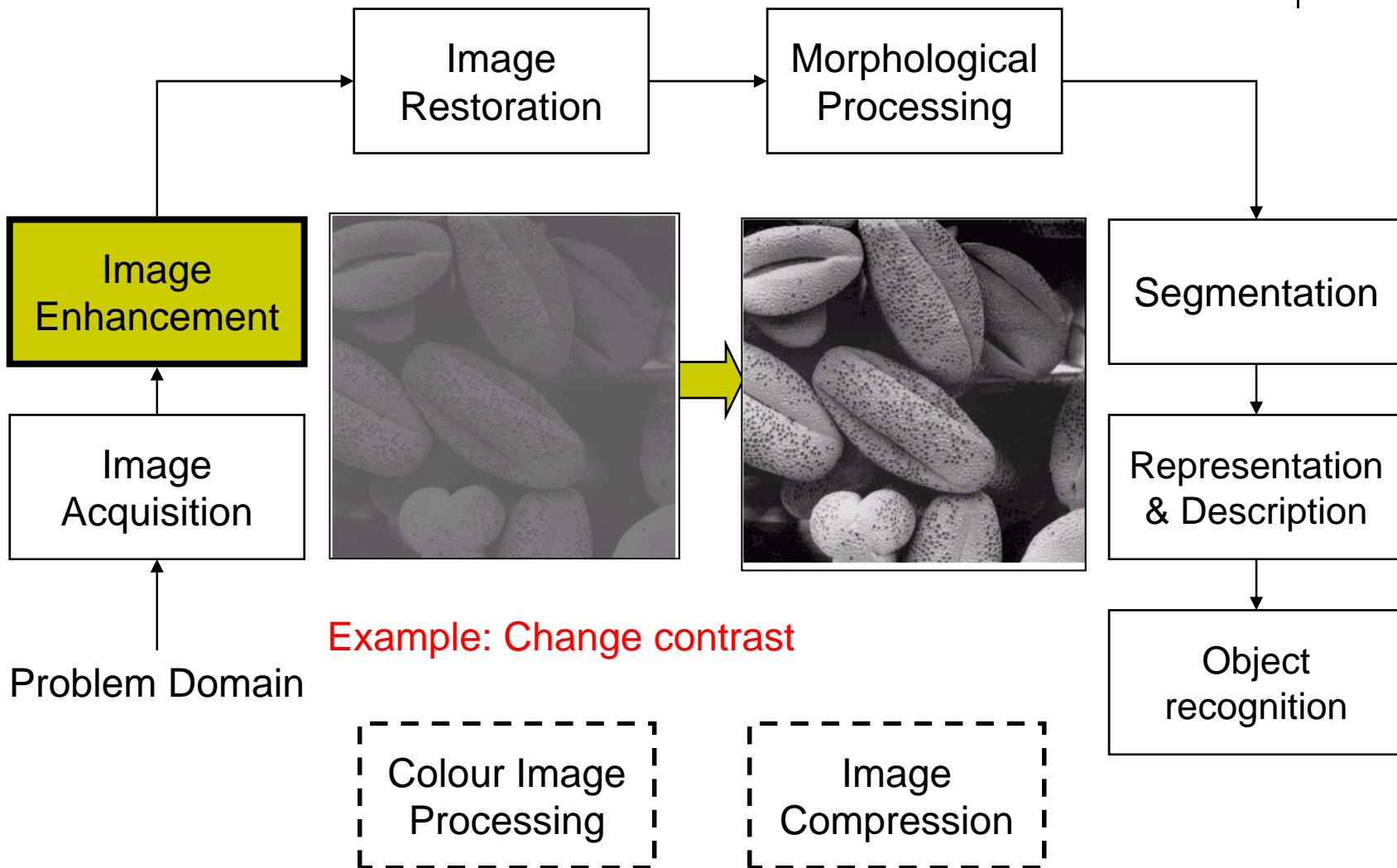
# Key Stages in Digital Image Processing



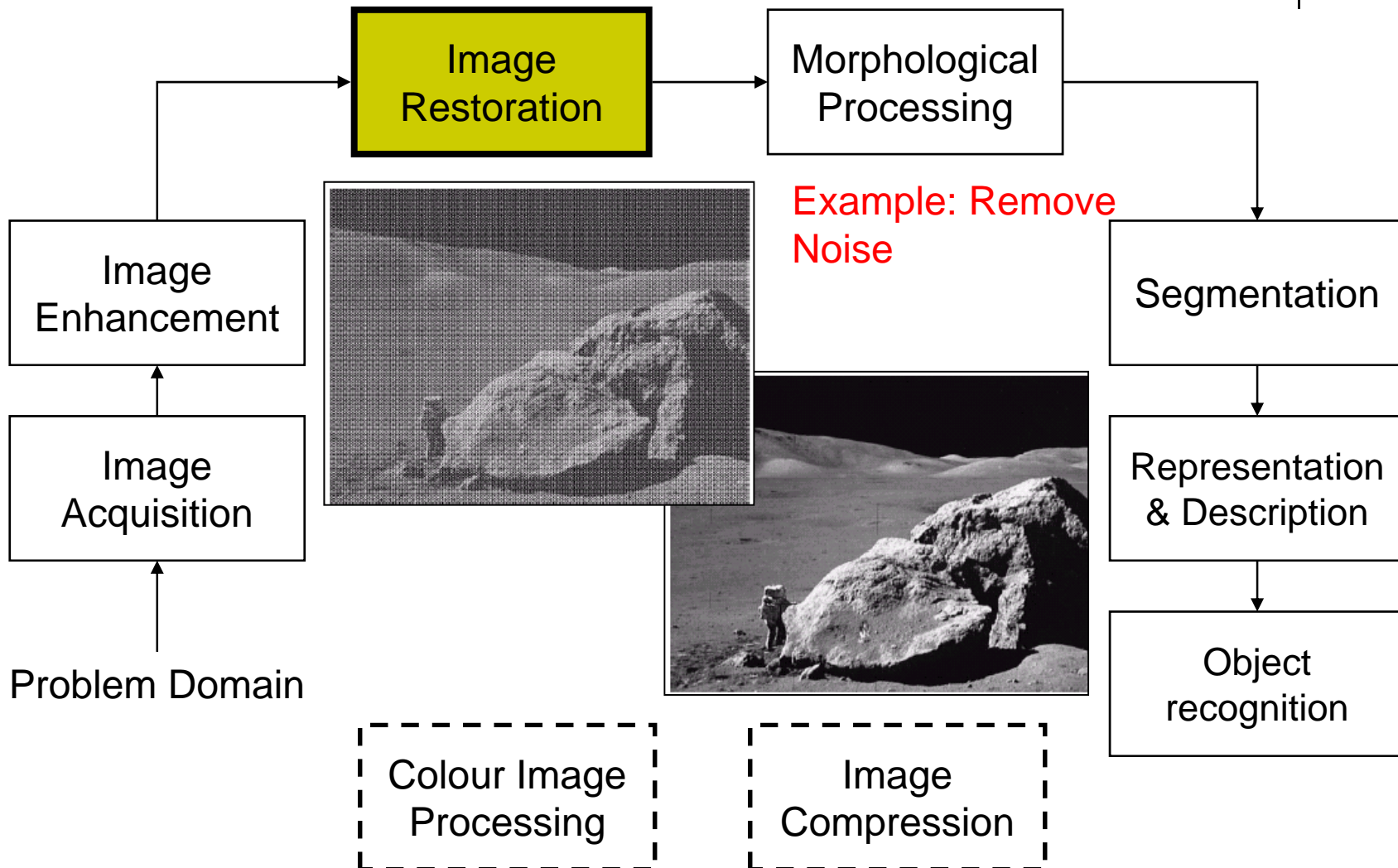
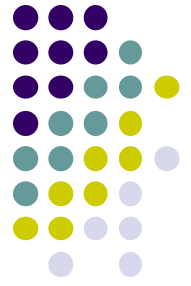
# Key Stages in Digital Image Processing: Image Aquisition



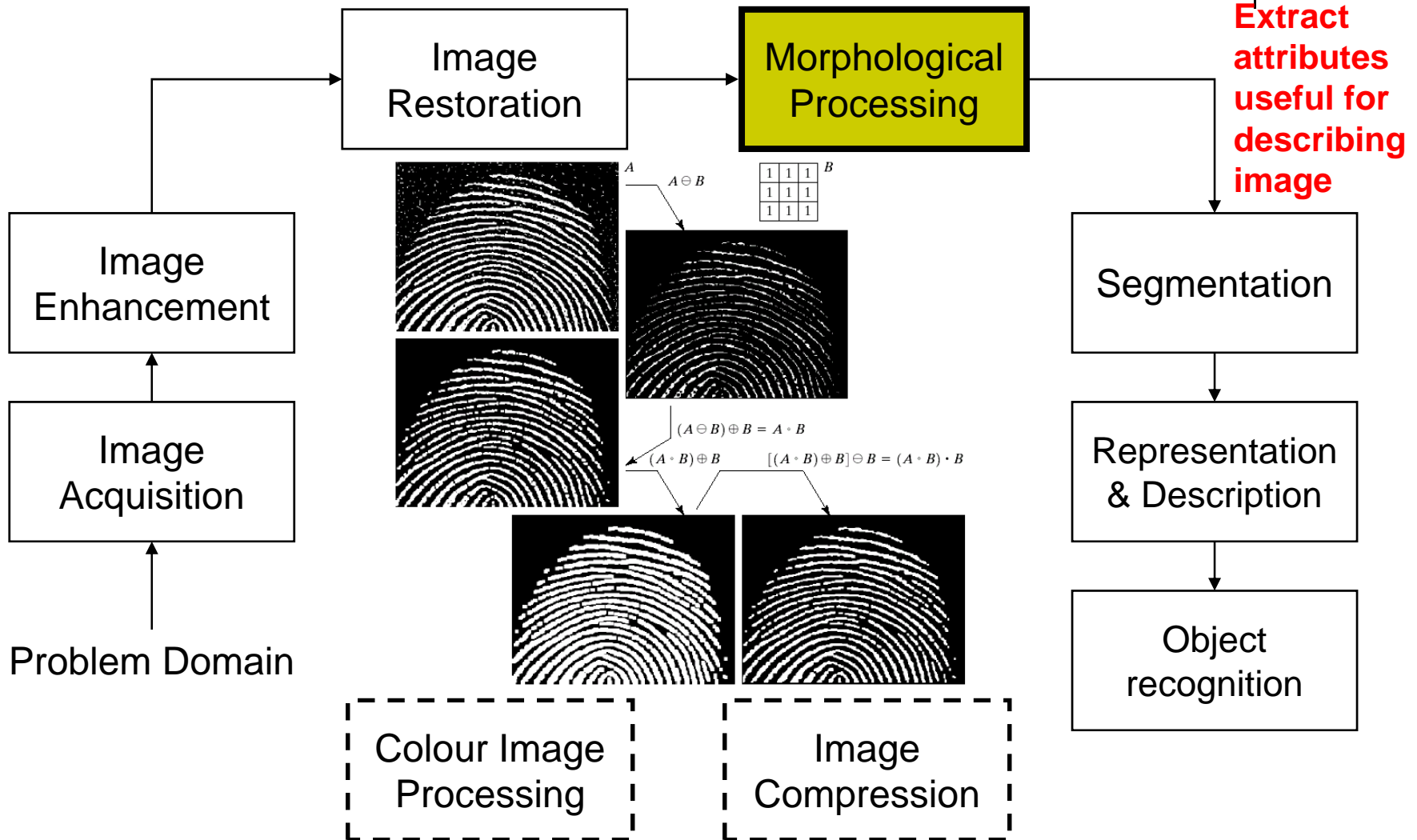
# Key Stages in Digital Image Processing: Image Enhancement



# Key Stages in Digital Image Processing: Image Restoration



# Key Stages in Digital Image Processing: Morphological Processing

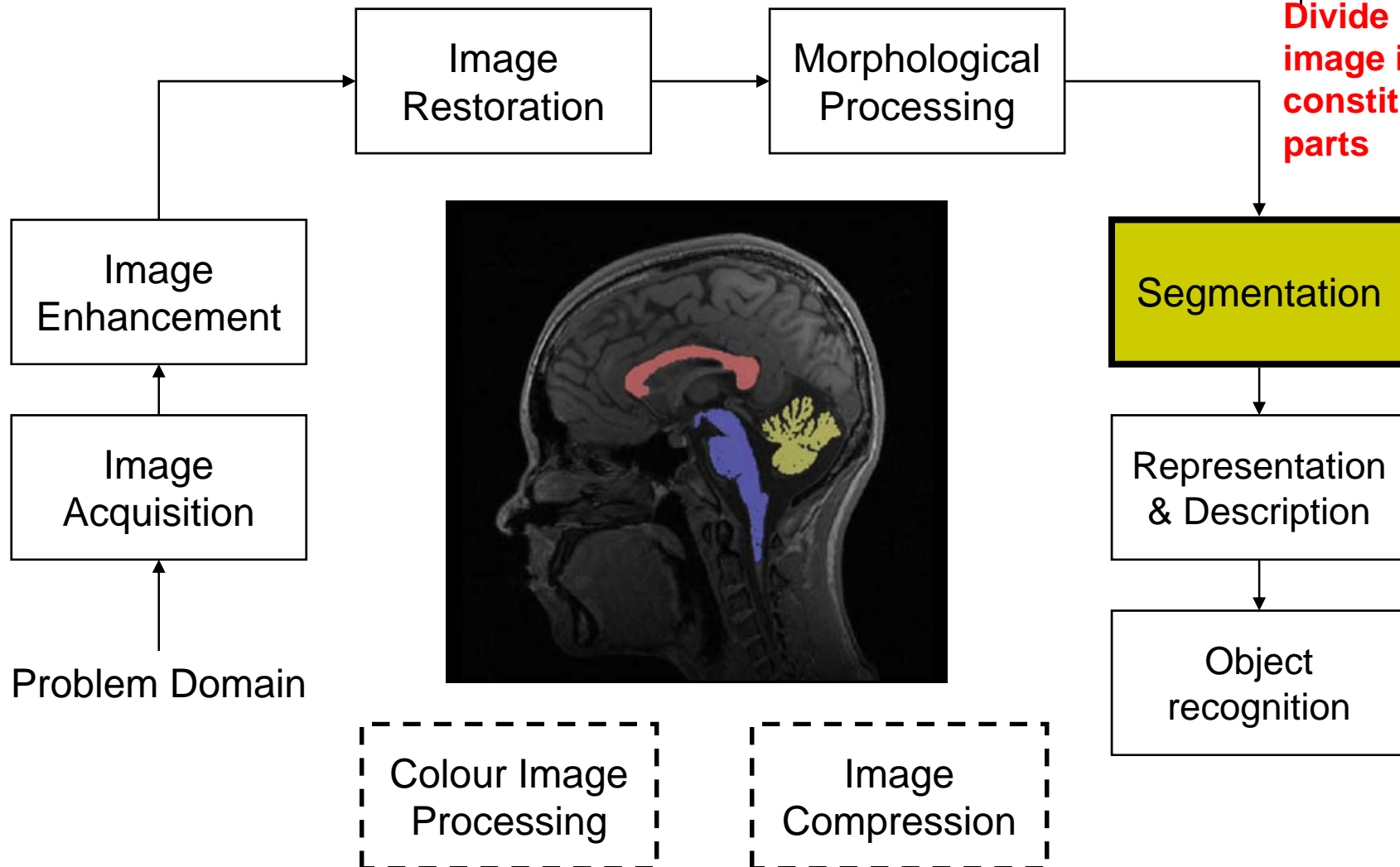




# Key Stages in Digital Image Processing: Segmentation



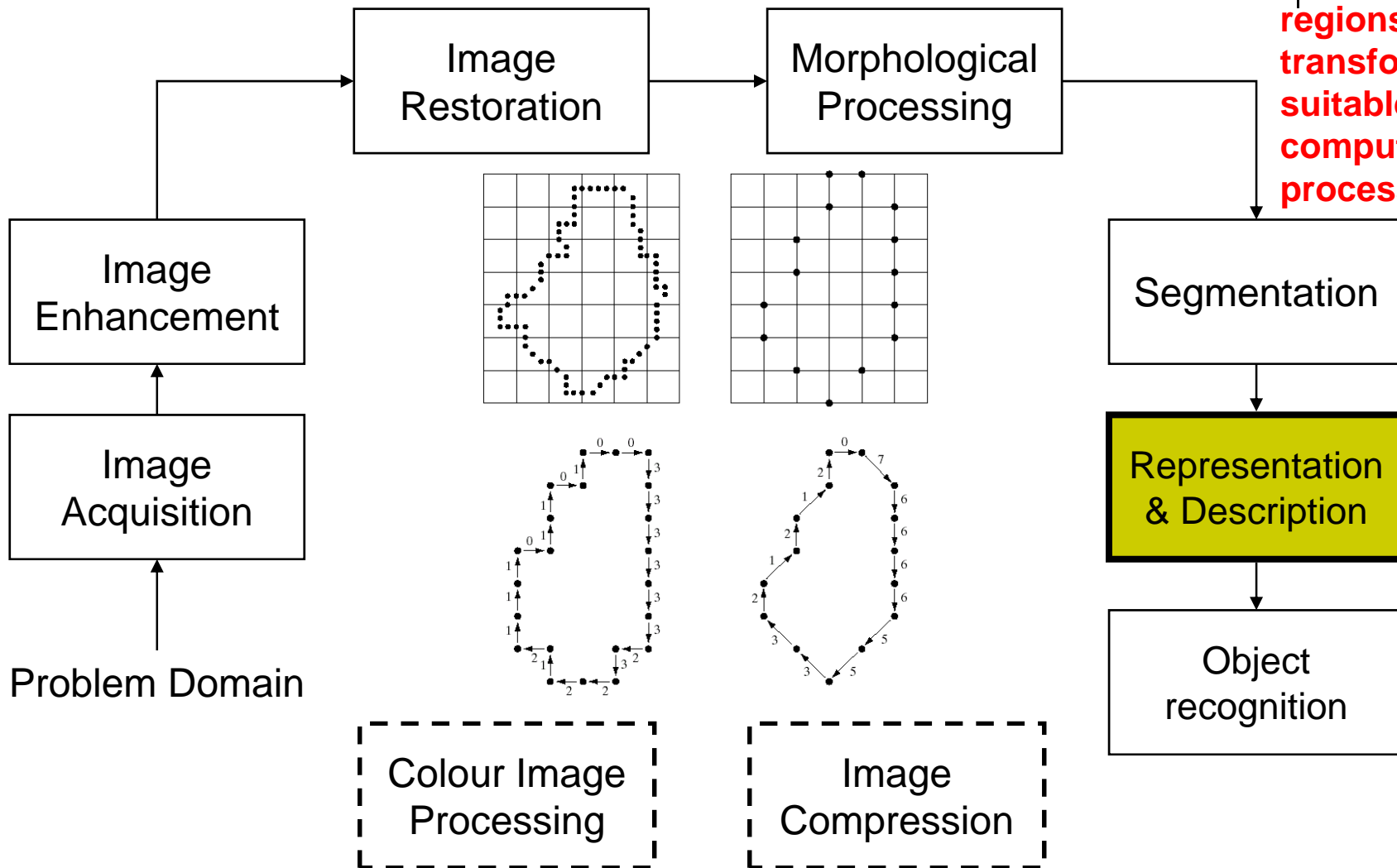
Divide  
image into  
constituent  
parts



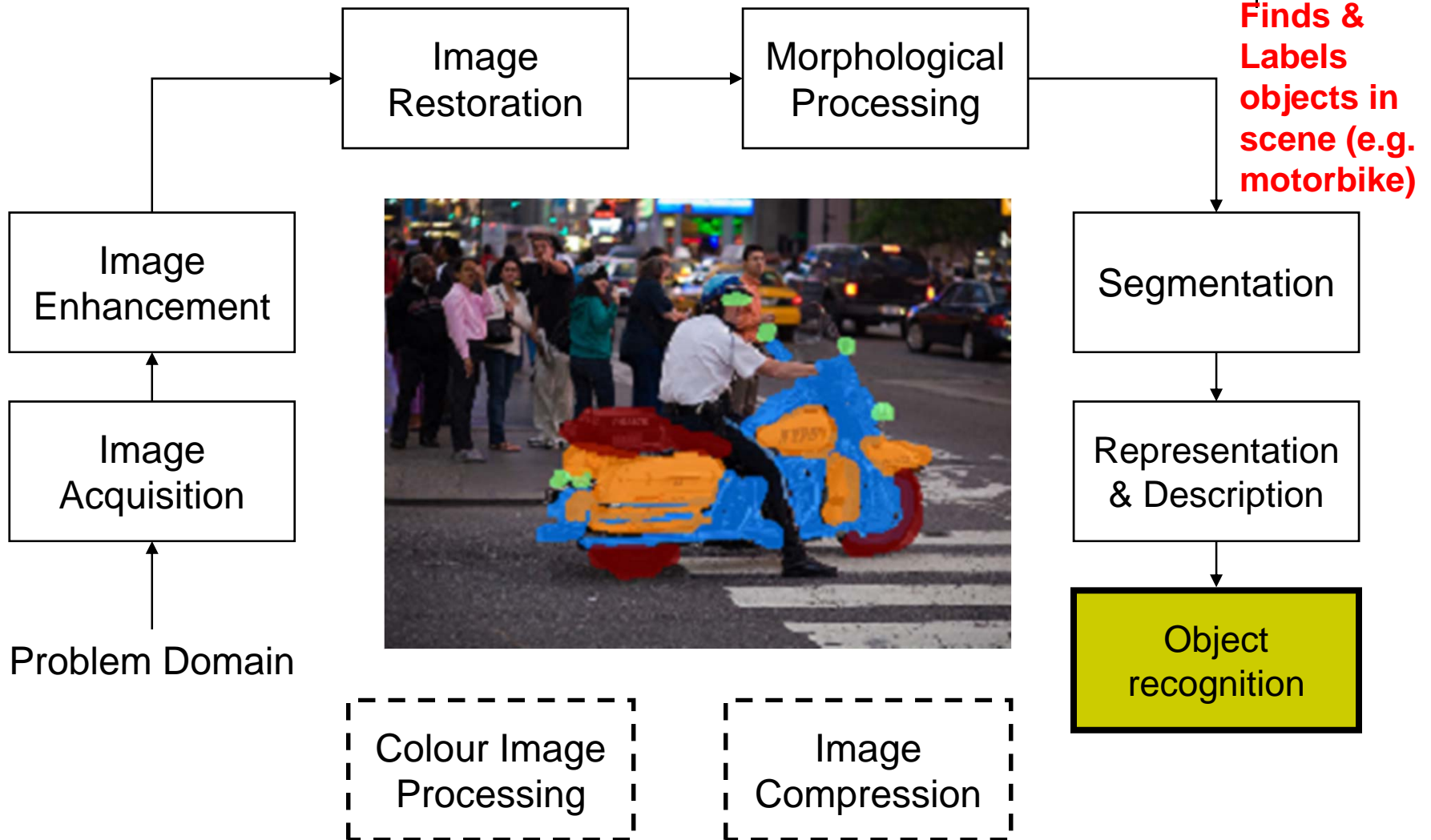
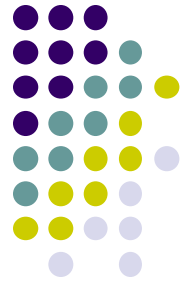
# Key Stages in Digital Image Processing: Object Recognition

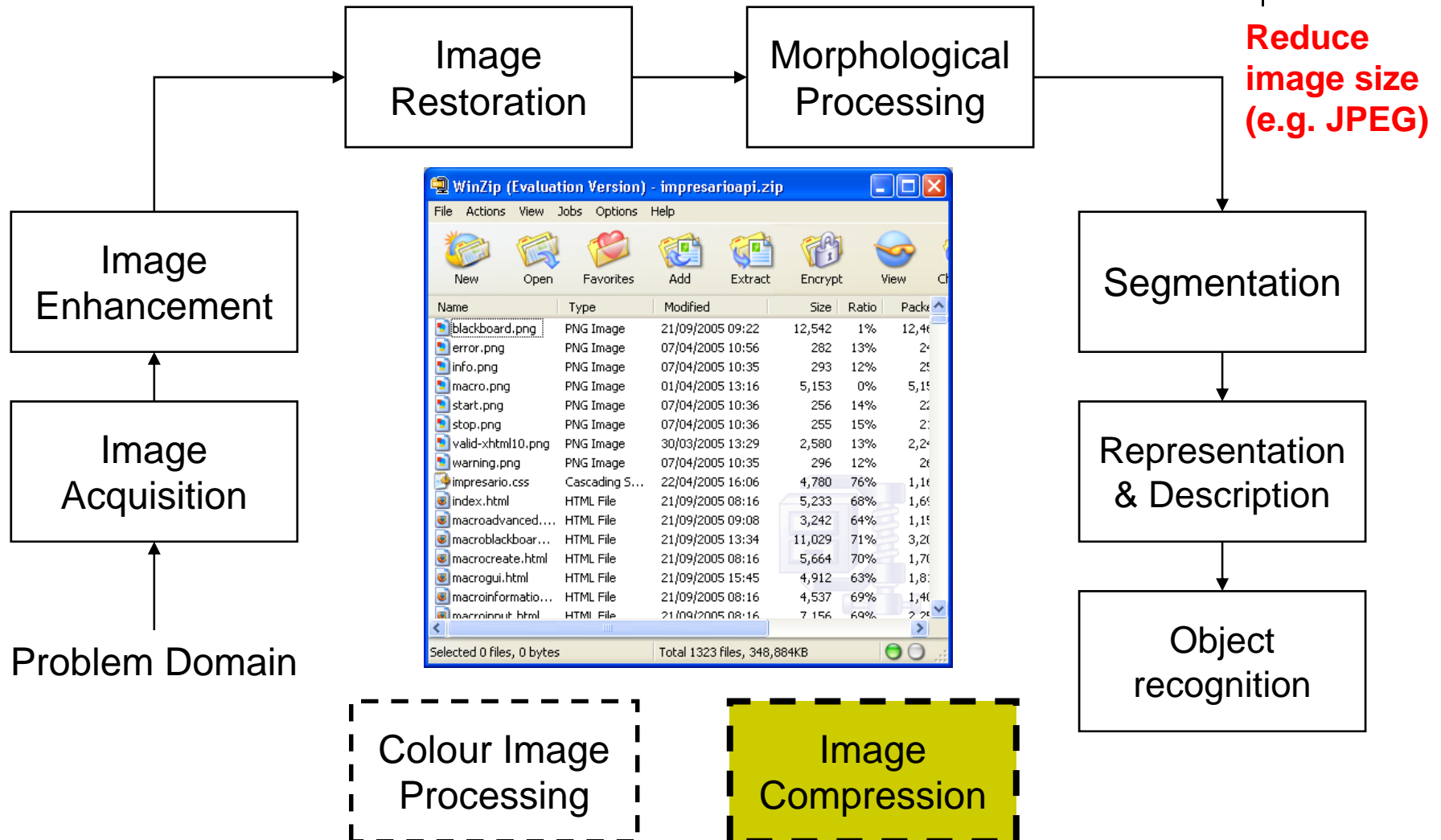


Image  
regions  
transformed  
suitable for  
computer  
processing



# Key Stages in Digital Image Processing: Representation & Description







# Key Stages in Digital Image Processing: Colour Image Processing

