



# EIE4512

## Digital Image Processing

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# Basic Information

- Time & Venue
  - Tuesday: 10:30 am – 12:00 pm, TA207
  - Thursday: 10:30 am – 12:00 pm, TA 207
- Staff
  - Instructor: Zhen Li ([lizhen@cuhk.edu.cn](mailto:lizhen@cuhk.edu.cn))
  - Tutors: Qin Wang ([wangqin4377@qq.com](mailto:wangqin4377@qq.com))  
Bin Zeng ([zeng\\_bin8888@163.com](mailto:zeng_bin8888@163.com))
- One tutorial per week:  
Thursday: 8:00pm – 9:00pm, TA 207

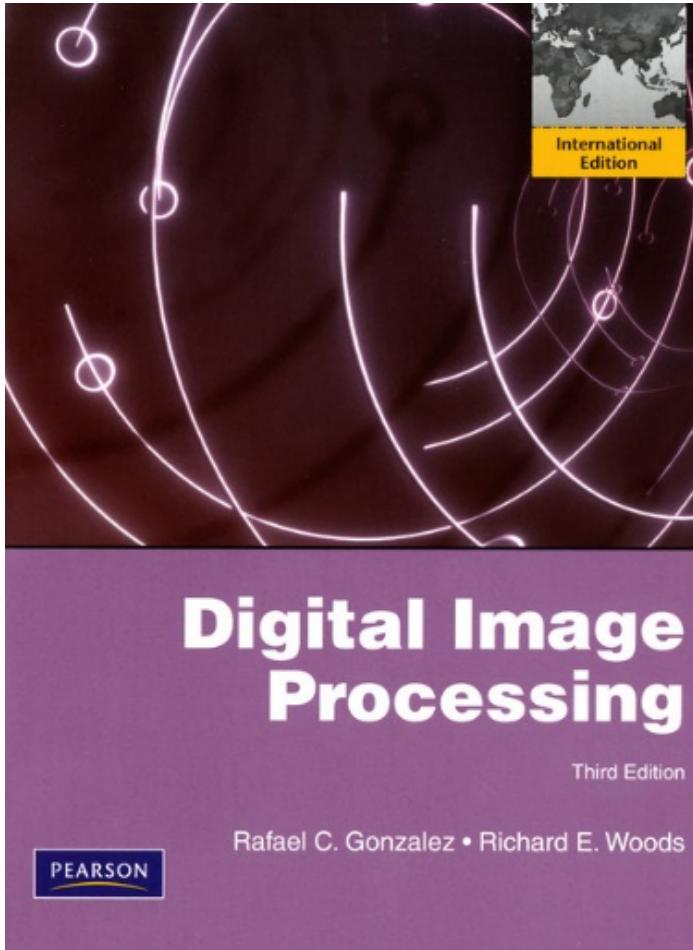
# Slides

- Online address:
  - [https://github.com/icemansina/CUHK SZ\\_DIP](https://github.com/icemansina/CUHK SZ_DIP)
- We use this repository for:
  - Make announcements
  - Release lecture slides
  - Release homework assignments and solutions
  - Discussions: wechat group



该二维码7天内(1月14日前)有效，重新进入将更新

# Reference Textbook



**Digital Image Processing**

By *Rafael C. Gonzalez & Richard E. Woods*

# Grading

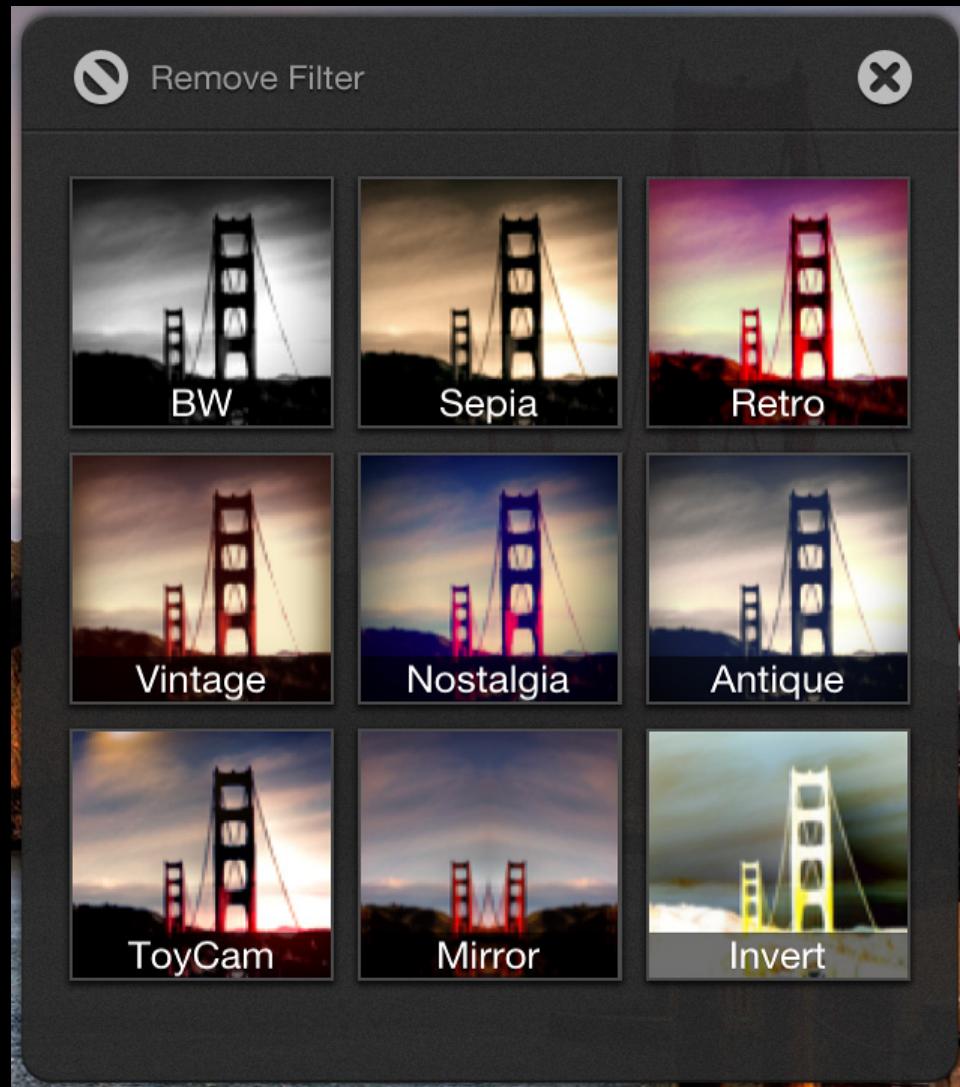
- Three assignments: 10% x 3
- Mid-term exam: 30%
- Final project: 40%
  - Topics
    - Applications of digital image processing
    - Implementation of digital image processing
    - Study digital image processing algorithms
  - You (at most two students as a group) should submit
    - One page proposal which briefly introduces the topic, idea, method, experiments.
    - A term paper of 4 pages (excluding figures) in maximum, double column, font size is equal or no larger than 10.
    - Code and sample data
    - Project presentation (5mins – 10mins)

What is this course about?

# Face Beautification



# Image Filtering



# Image Superresolution



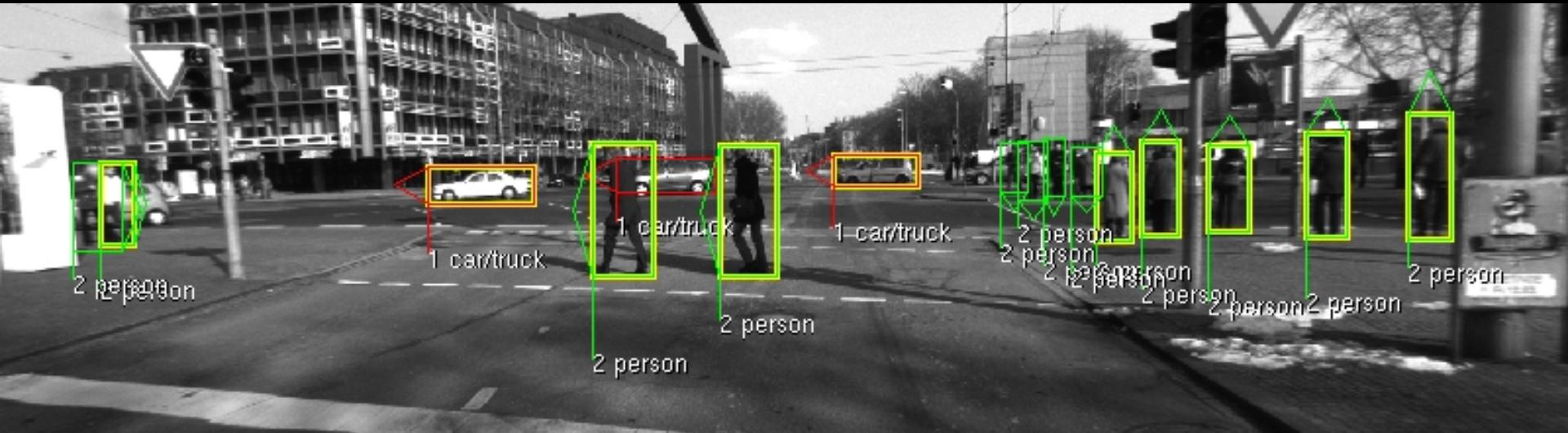
# Face Recognition



# Object Recognition



# Pedestrian Detection



# Scene Parsing

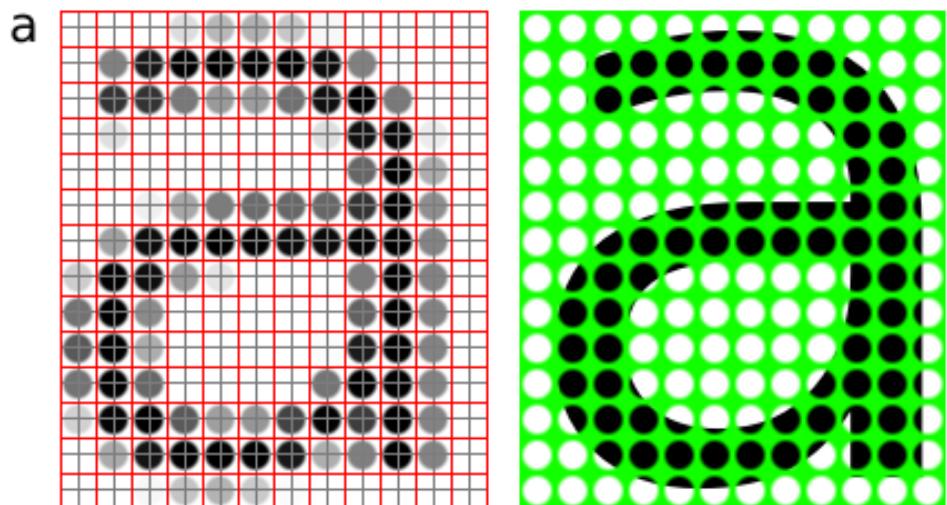


# Topics



# Image Representations

- Image Sensing and Acquisition
- Sampling and Quantization
- Basic Relationships between Pixels



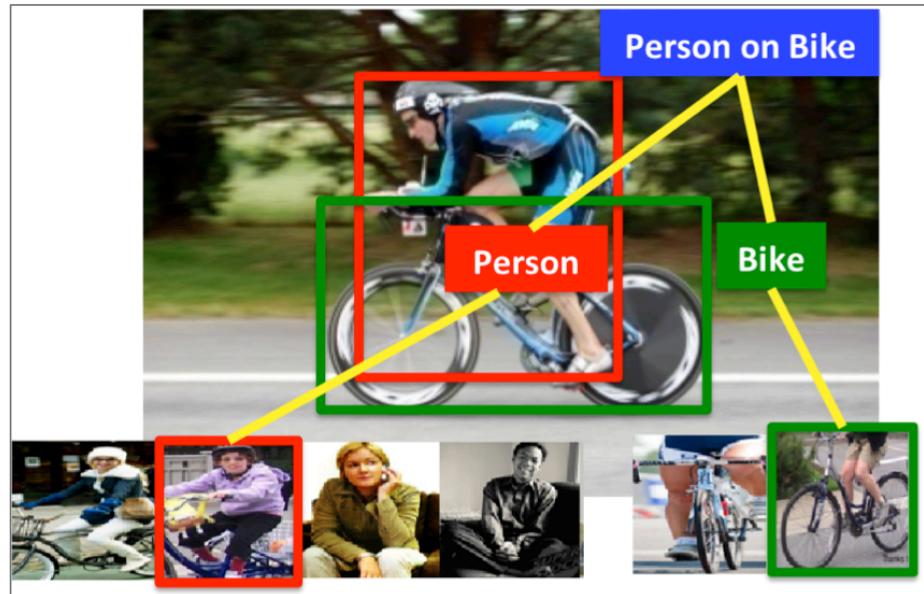
# Image Processing

- Gray-level processing
- Image filtering
- Image restoration
- Morphological processing



# Visual Understanding

- Features
- Image recognition
- Object detection
- Image segmentation





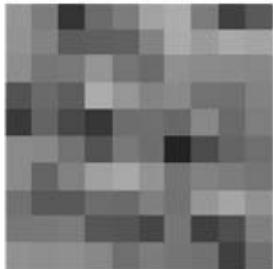
# What is an Image?

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

Set of Intensity values

Image coordinates  
are integers

$$I(u, v) \in \mathbb{P} \quad \text{and} \quad u, v \in \mathbb{N}.$$



$F(x, y)$



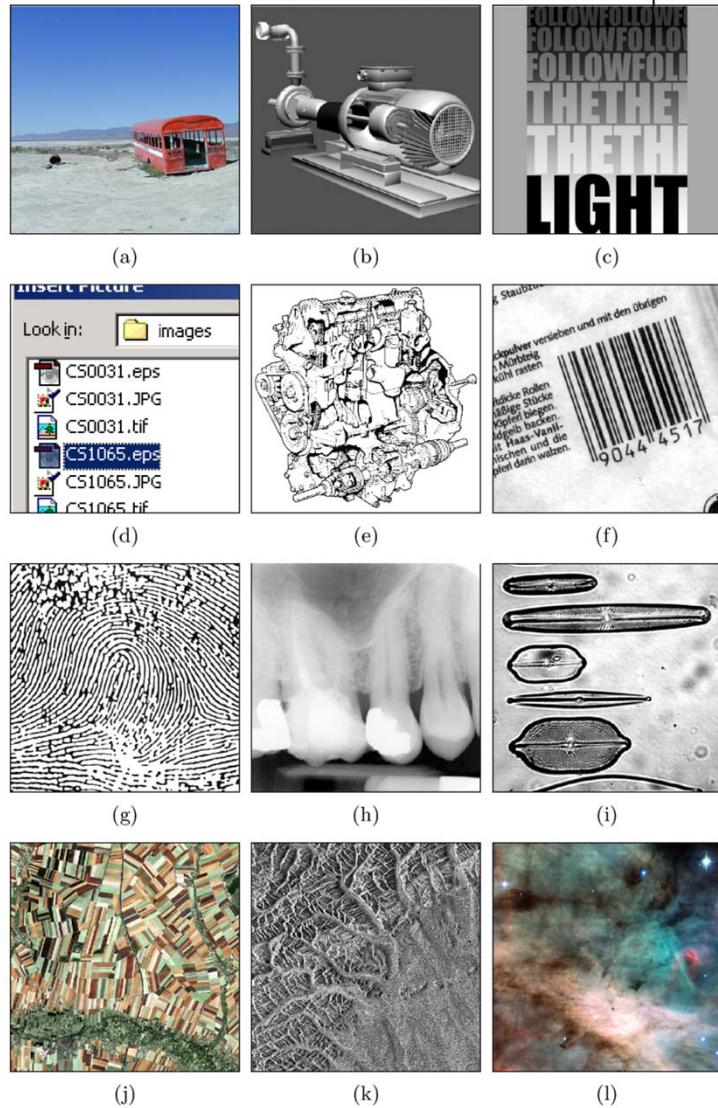
148	123	52	107	123	162	172	123	64	89	...
147	130	92	95	98	130	171	155	169	163	...
141	118	121	148	117	107	144	137	136	134	...
82	106	93	172	149	131	138	114	113	129	...
57	101	72	54	109	111	104	135	106	125	...
138	135	114	82	121	110	34	76	101	111	...
138	102	128	159	168	147	116	129	124	117	...
113	89	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	...
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

$I(u, v)$



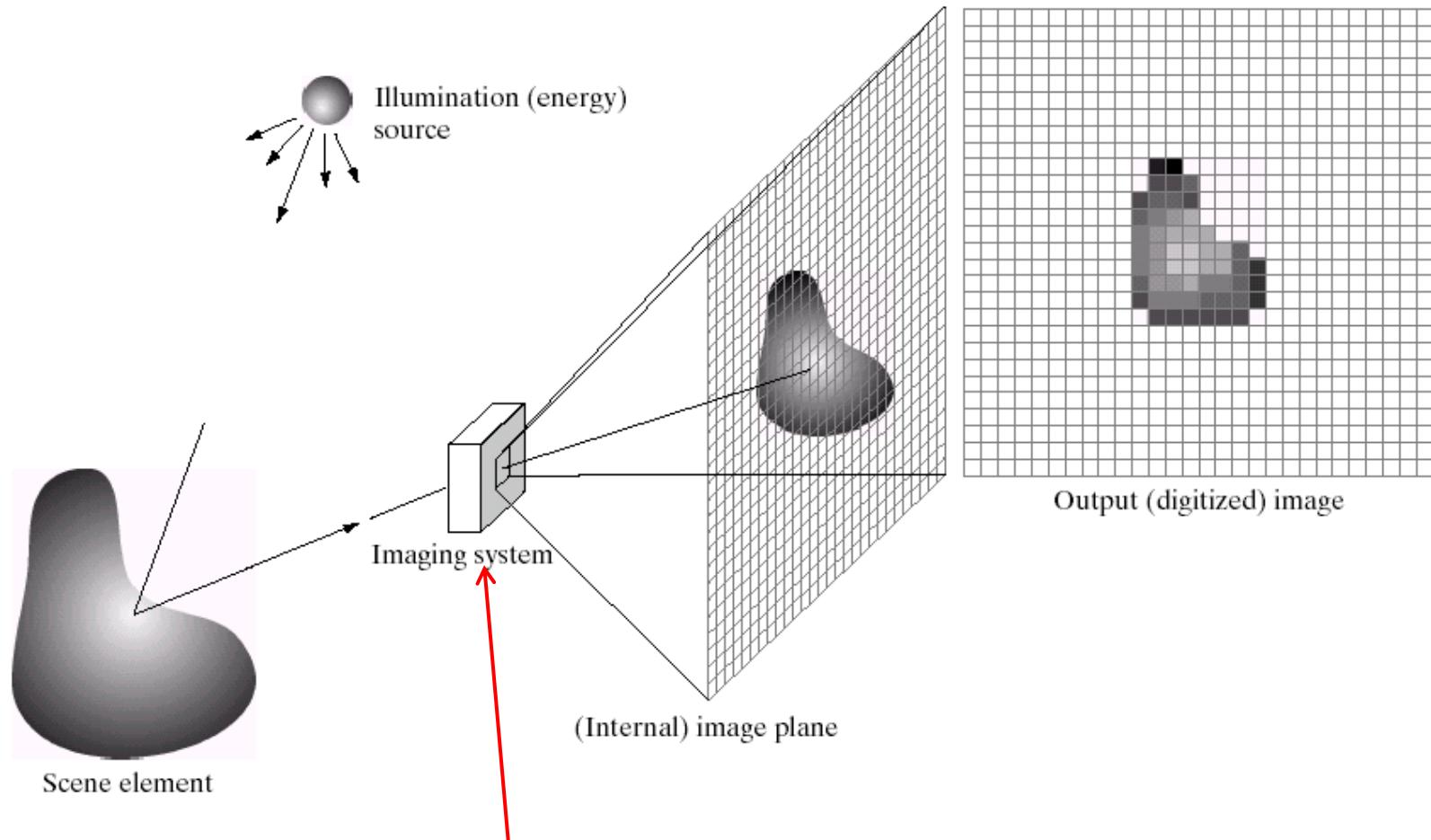
# Example of Digital Images

- 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





# Imaging System



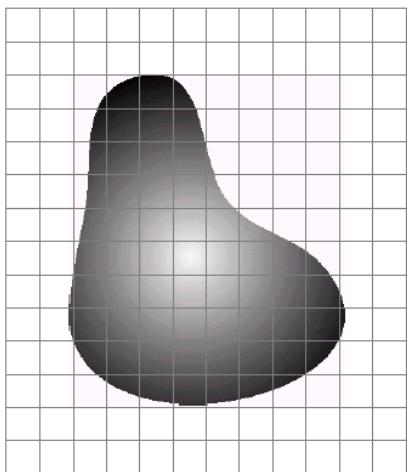
Example: a camera  
Converts light to image

Credits: Gonzales and Woods

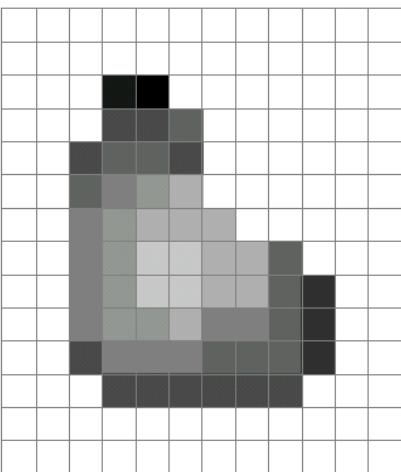


# Digital Image?

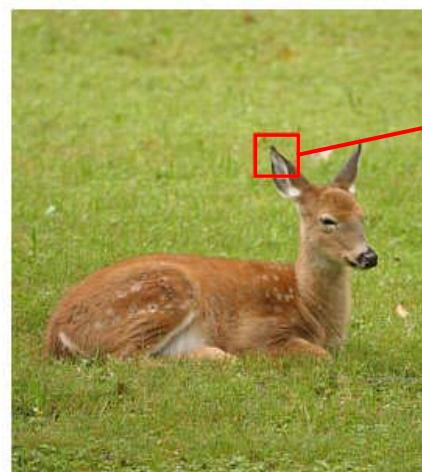
- Remember: *digitization* causes a digital image to become an *approximation* of a real scene



Real image



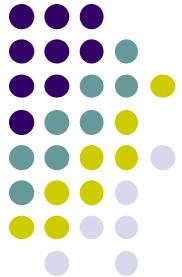
Digital Image  
(an approximation)



Real image



Digital Image  
(an approximation)



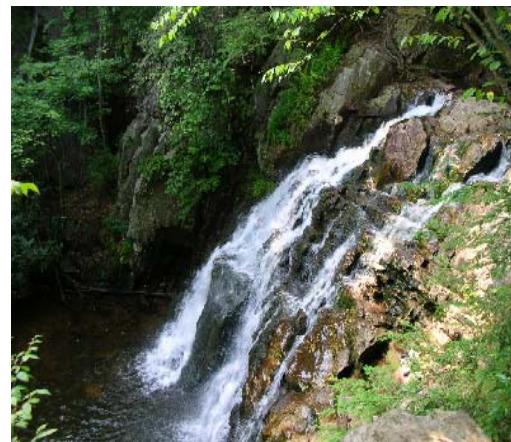
# Digital Image

- Common image formats include:

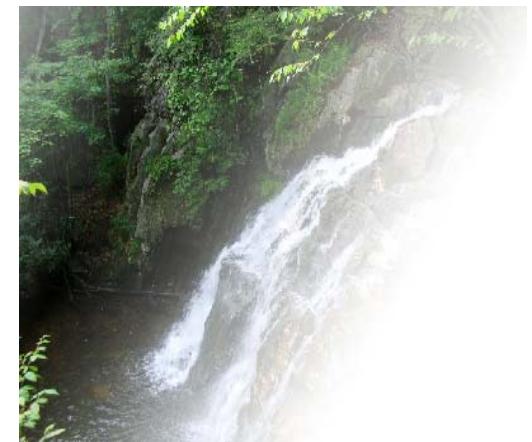
- 1 values per point/pixel (B&W or Grayscale)
- 3 values per point/pixel (Red, Green, and Blue)
- 4 values per point/pixel (Red, Green, Blue, + “Alpha” or Opacity)



Grayscale

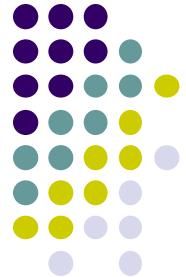


RGB



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



*Original Image*



*Processed Image*

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



# Example Operation: Noise Removal

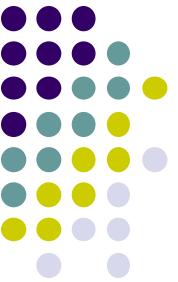
Noisy Image



Denoised Image

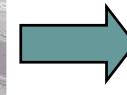
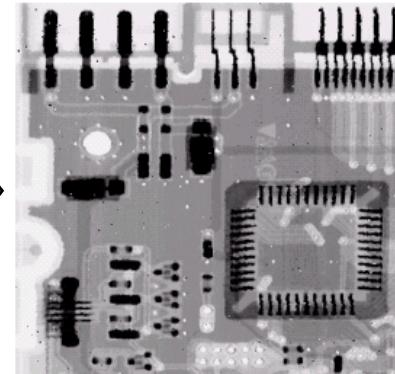
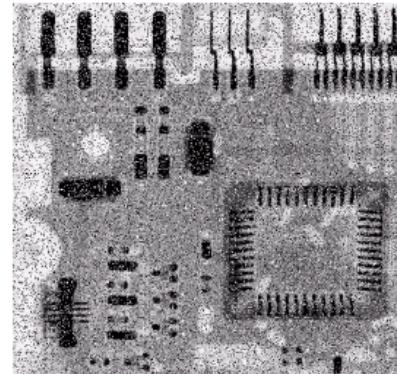
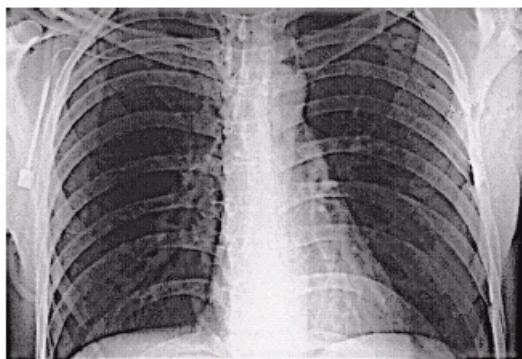
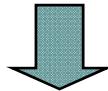
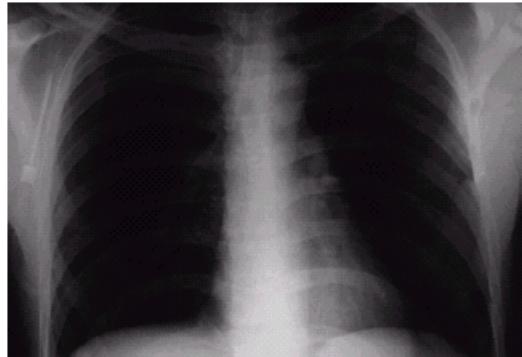


Think of noise as white specks on a picture (random or non-random)



# Examples: Noise Removal

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





# Example: Contrast Adjustment



Low Contrast



Original Contrast



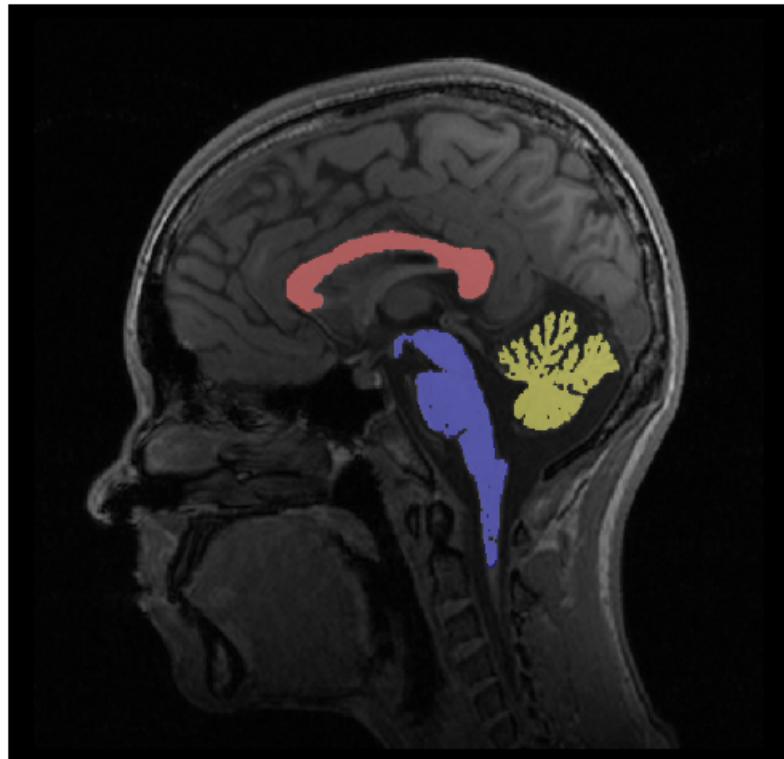
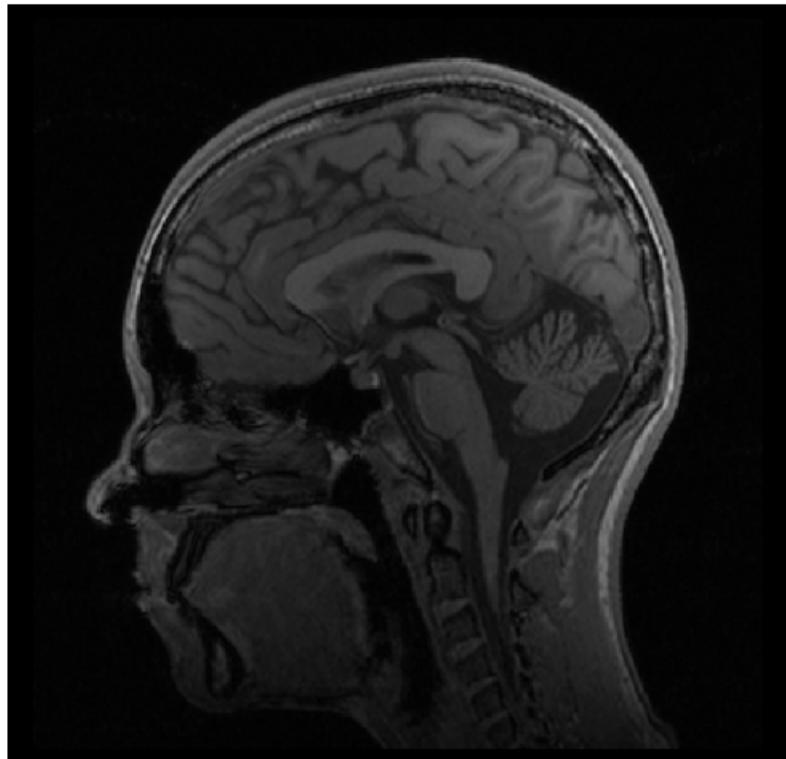
High Contrast



# Example: Edge Detection



# Example: Region Detection, Segmentation





# Example: Image Compression



Original, 2.1MB



JPEG Compression, 308KB (15%)



# Example: Image Inpainting

Damaged Image

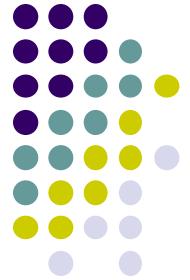


Restored Image



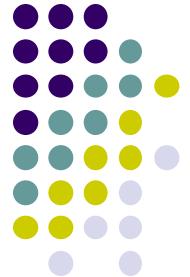
Credit: M. Bertalmio, G. Sapiro, V. Caselles, C. Ballester: *Image Inpainting*, SIGGRAPH 2000

Inpainting? Reconstruct corrupted/destroyed parts of an image



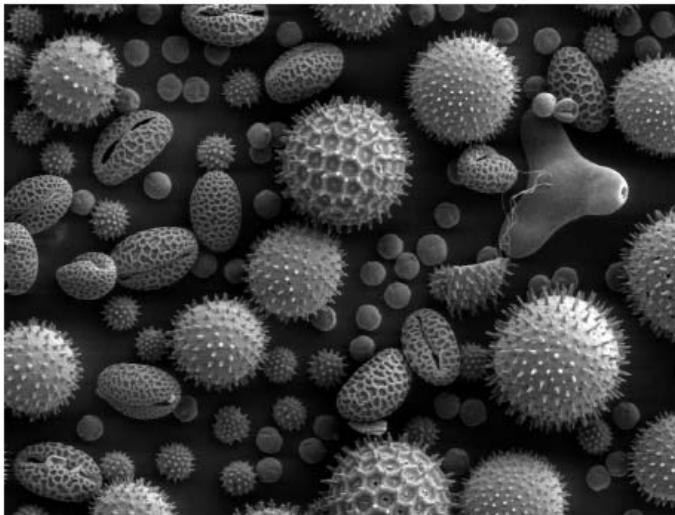
## Examples: Artistic (Movie Special )Effects





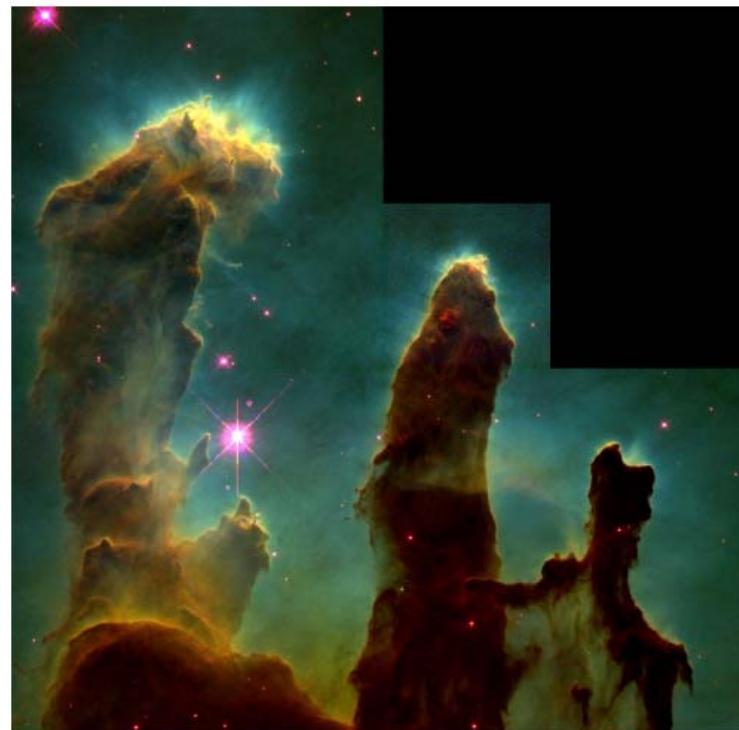
# Applications of Image Processing

Biology

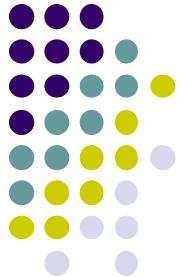


*Credit: Dartmouth Electron Microscopy Facility*

Astronomy

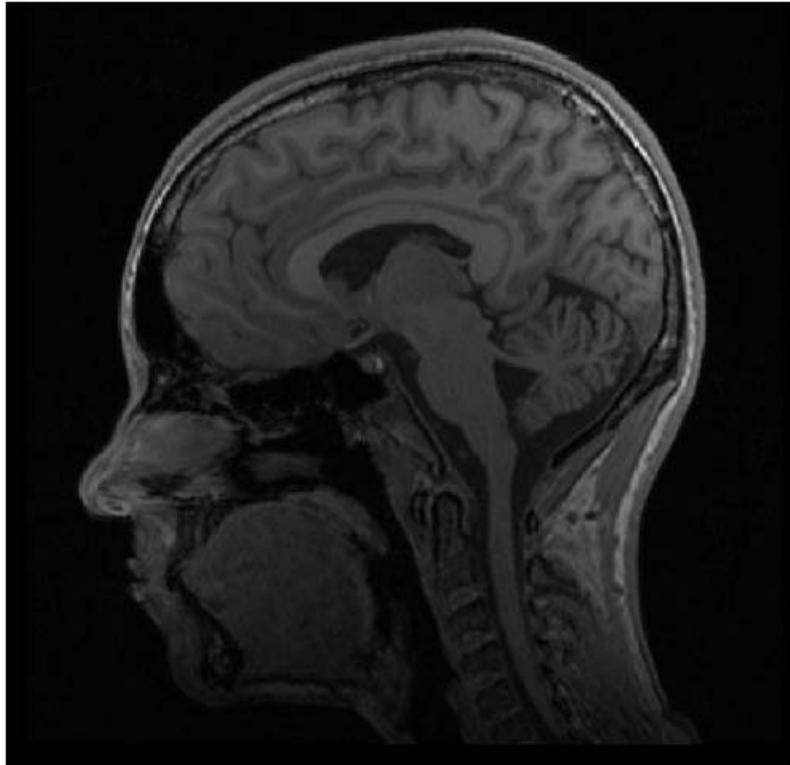


*Credit: NASA, Jeff Hester, and Paul Scowen (Arizona State)  
More info here*



# Applications of Image Processing

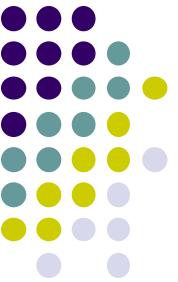
Medicine



*Credit: Dr. Janet Lainhart, UofU Psychiatry*

Security, Biometrics



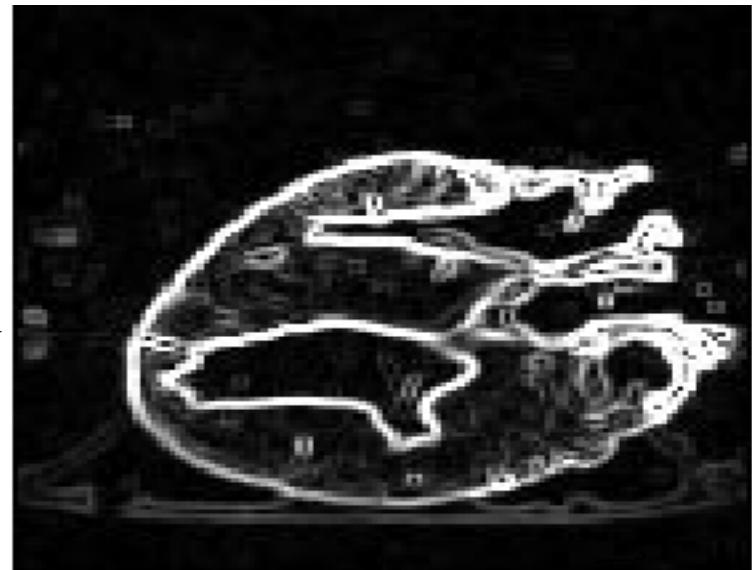


# Applications of Image Processing: Medicine

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



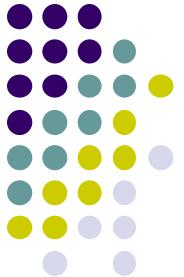
*Credit: NASA*

Personal Photos

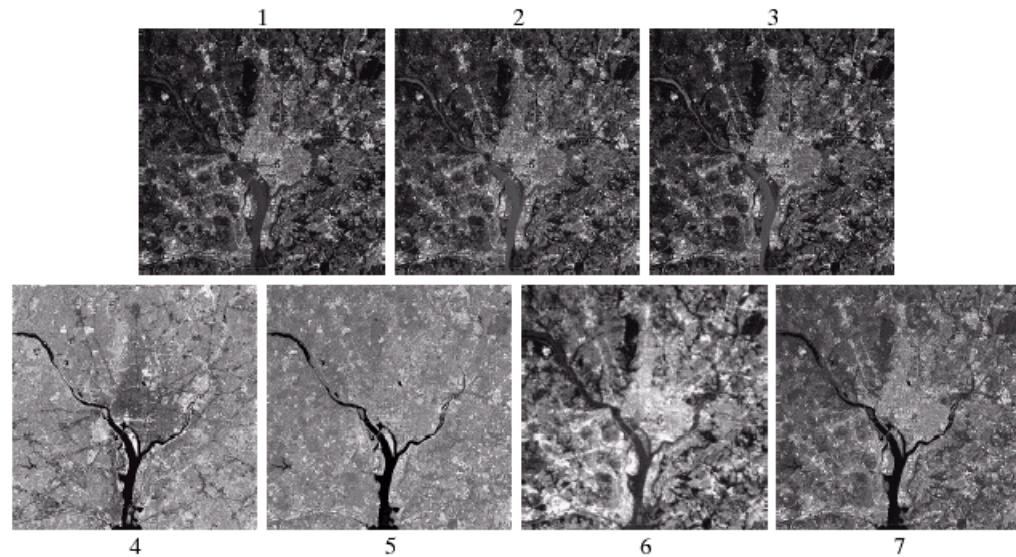


*Credit: Tom Fletcher*

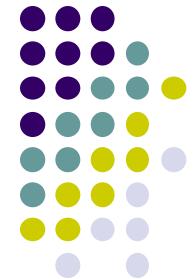
# Applications of Image Processing: Geographic Information Systems (GIS)



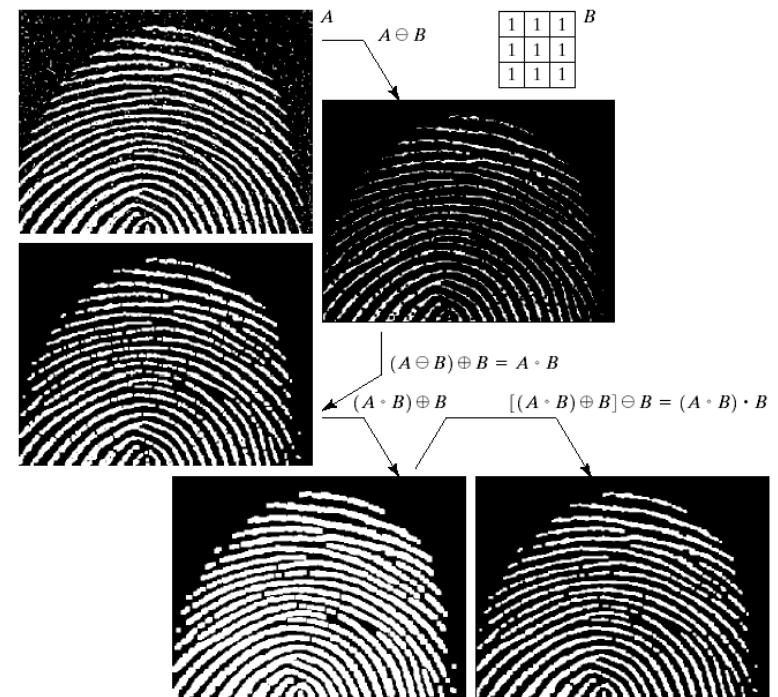
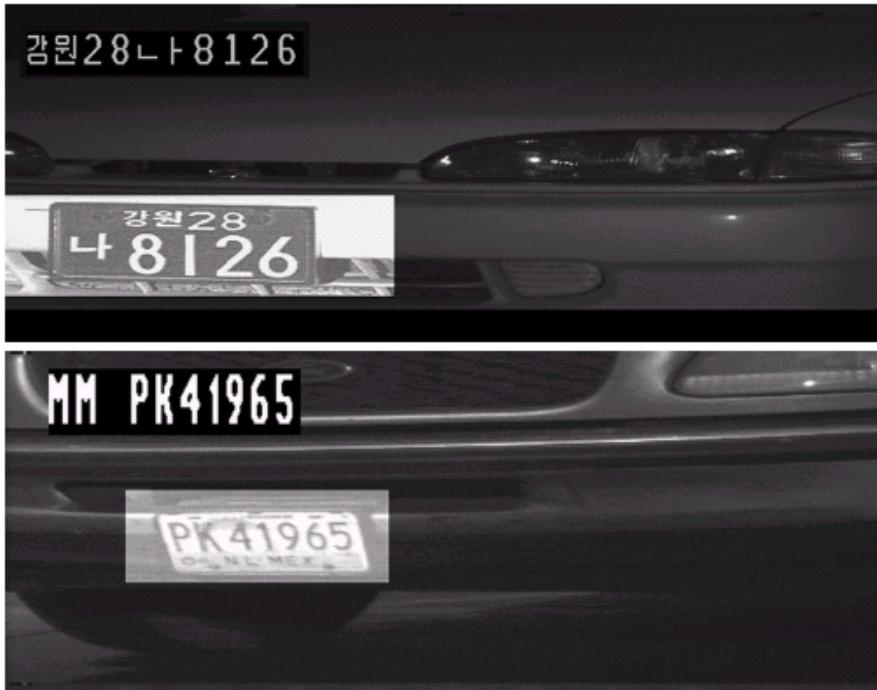
- Terrain classification
- Meteorology (weather)



# Applications of Image Processing: Law Enforcement



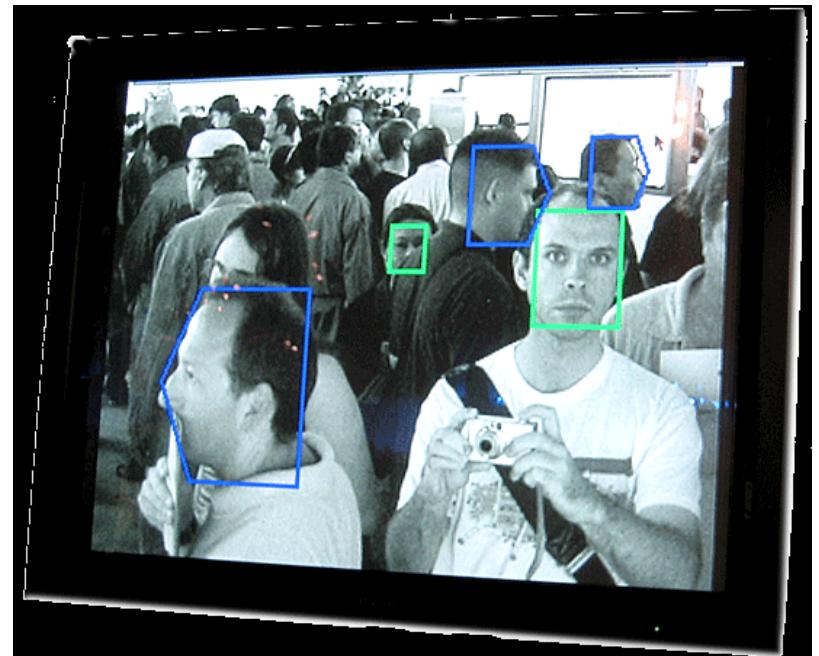
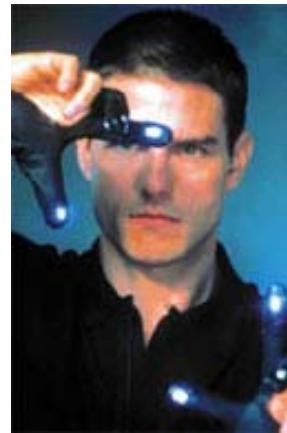
- Number plate recognition for speed cameras or automated toll systems
- Fingerprint recognition





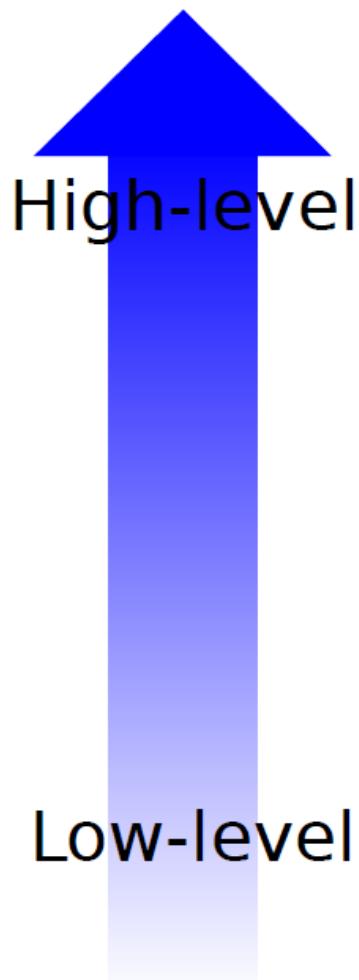
# Applications of Image Processing: HCI

- Face recognition
- Gesture recognition





# Relationship with other Fields



## Computer Vision

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

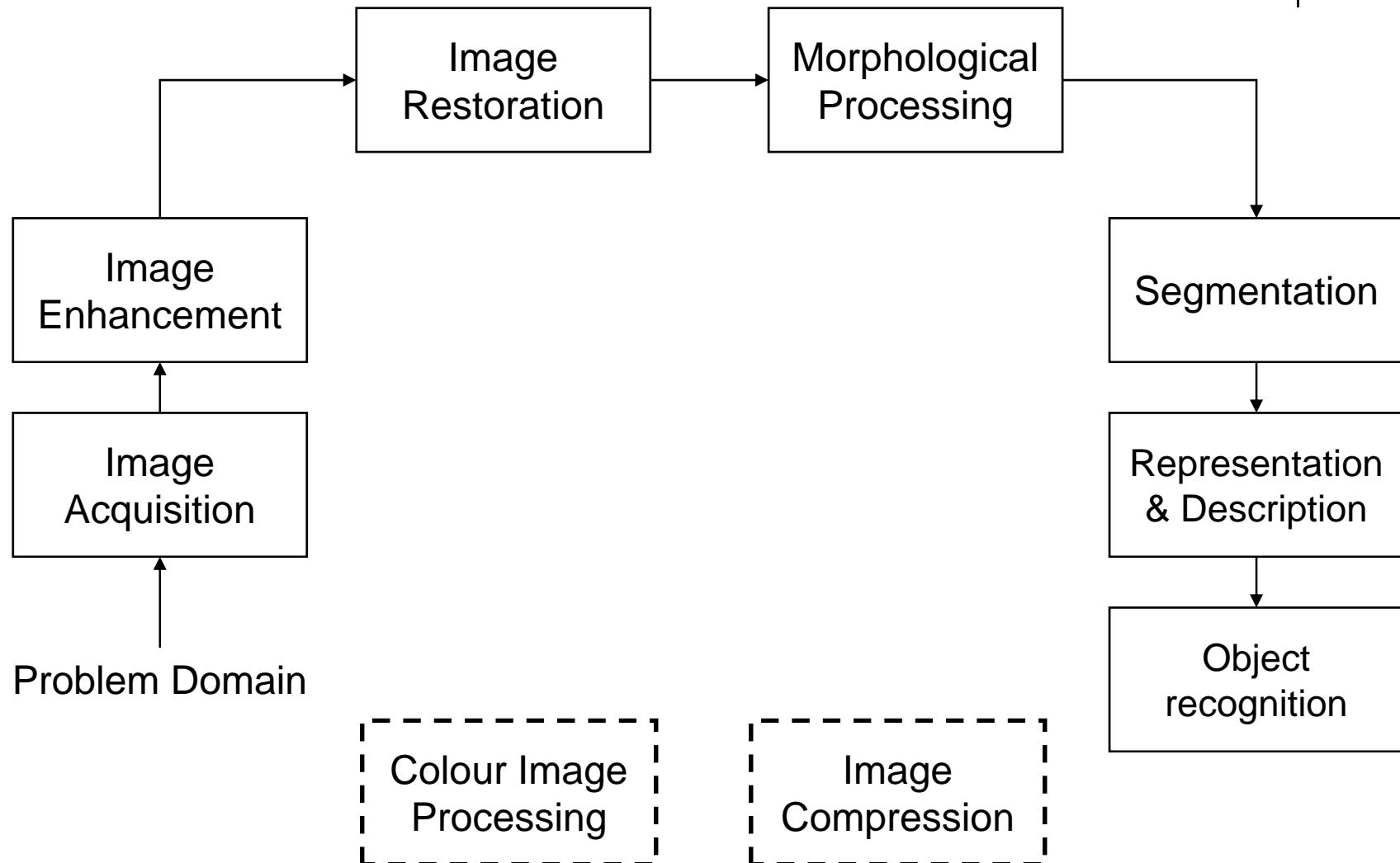
## Image Analysis

Segmentation, image registration, matching

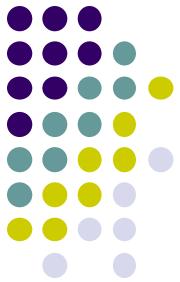
## Image Processing

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

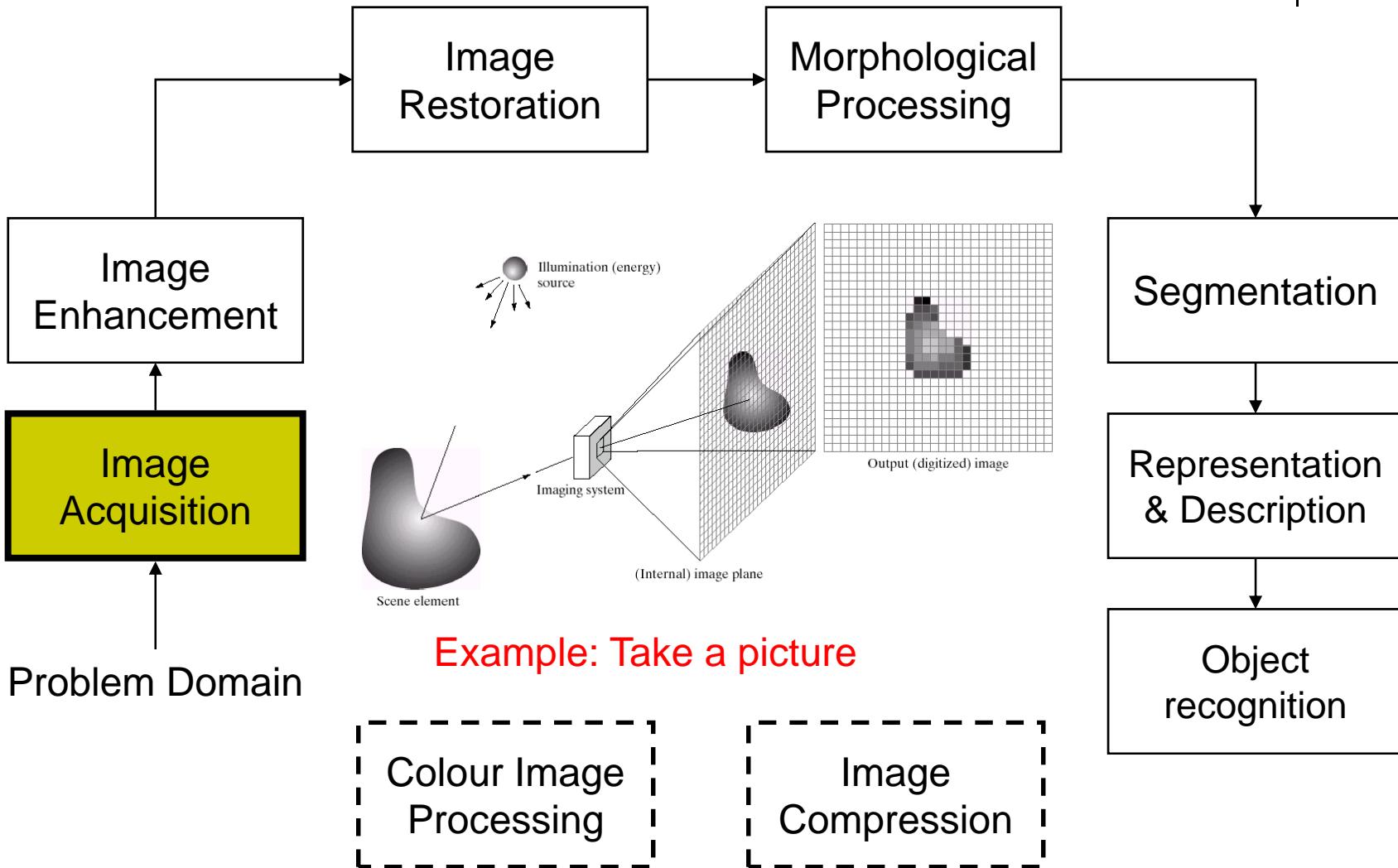
# Key Stages in Digital Image Processing



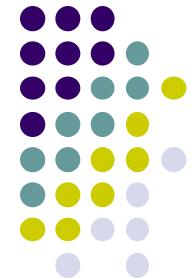
# Key Stages in Digital Image Processing: Image Acquisition



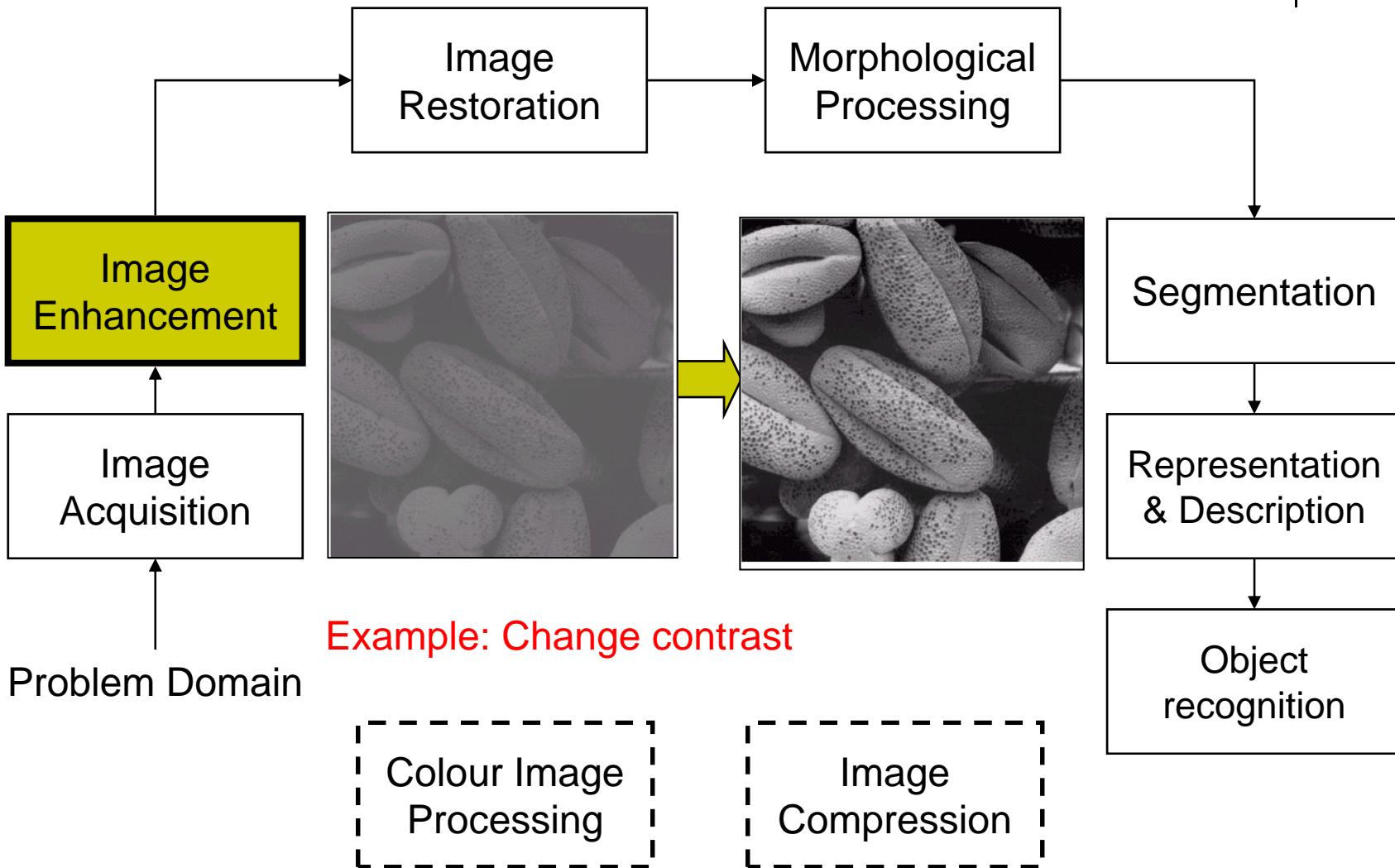
Images taken from Gonzalez & Woods, Digital Image Processing (2002)



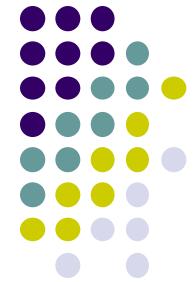
# Key Stages in Digital Image Processing: Image Enhancement



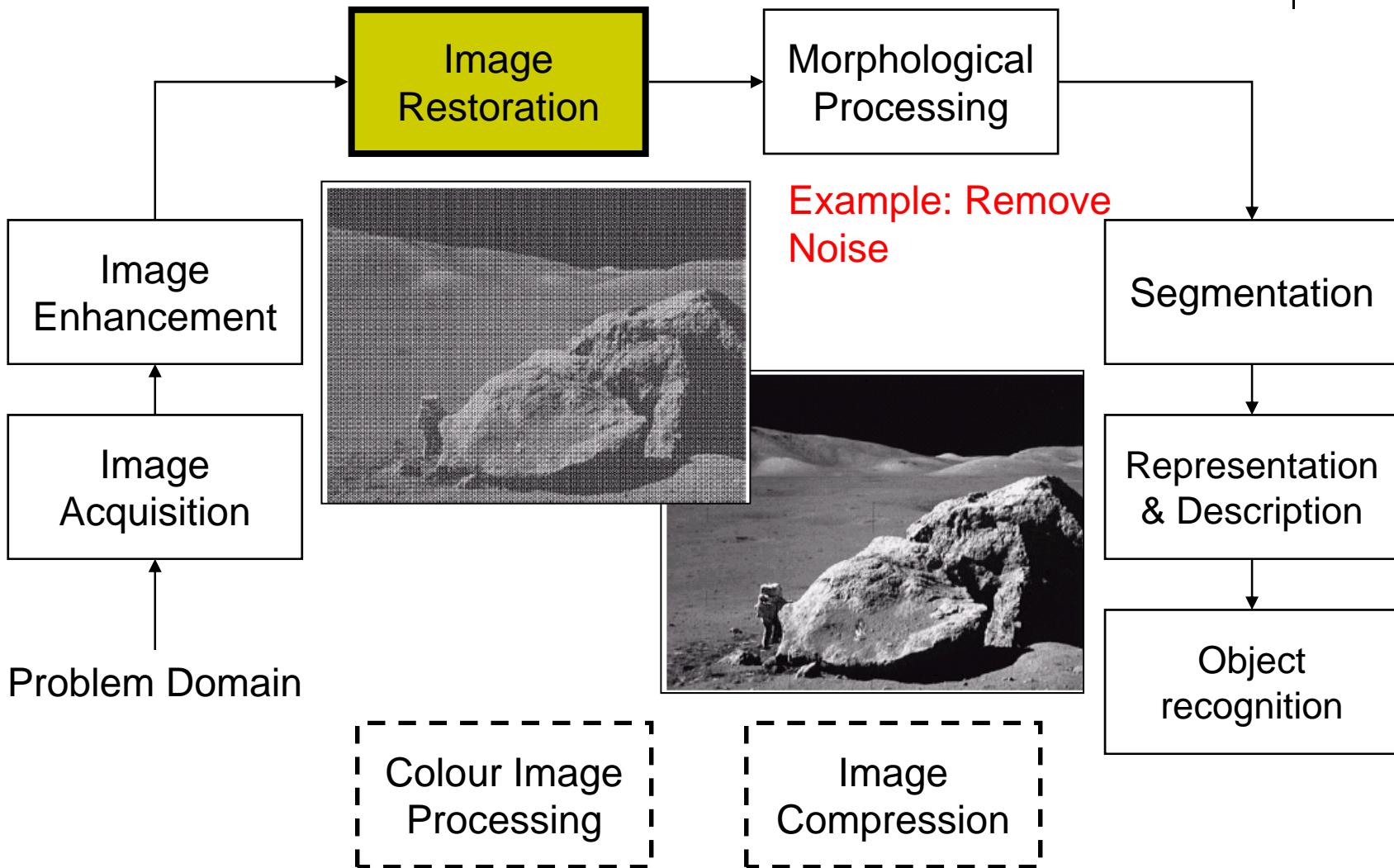
Images taken from Gonzalez & Woods, Digital Image Processing (2002)



# Key Stages in Digital Image Processing: Image Restoration



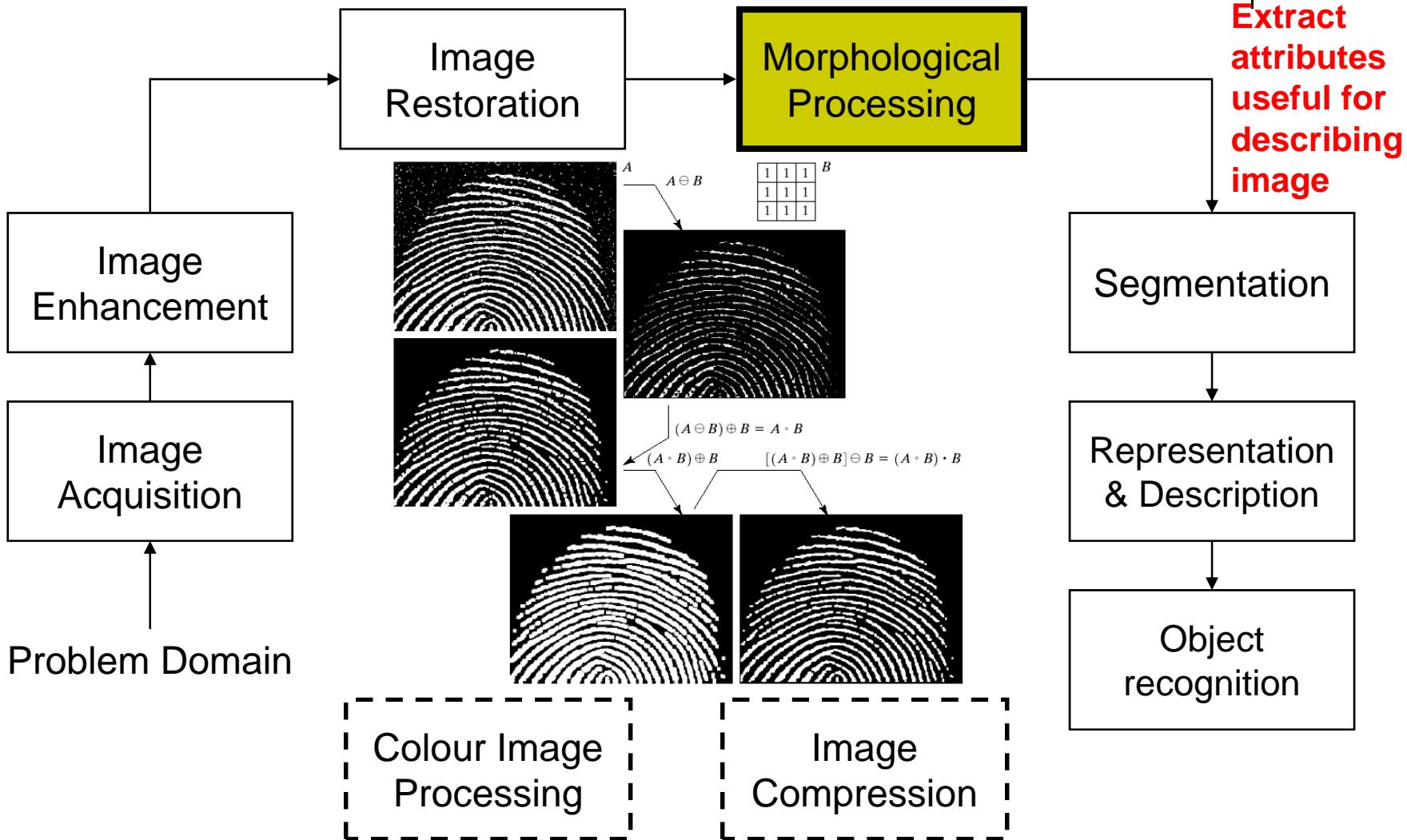
Images taken from Gonzalez & Woods, Digital Image Processing (2002)



# Key Stages in Digital Image Processing: Morphological Processing



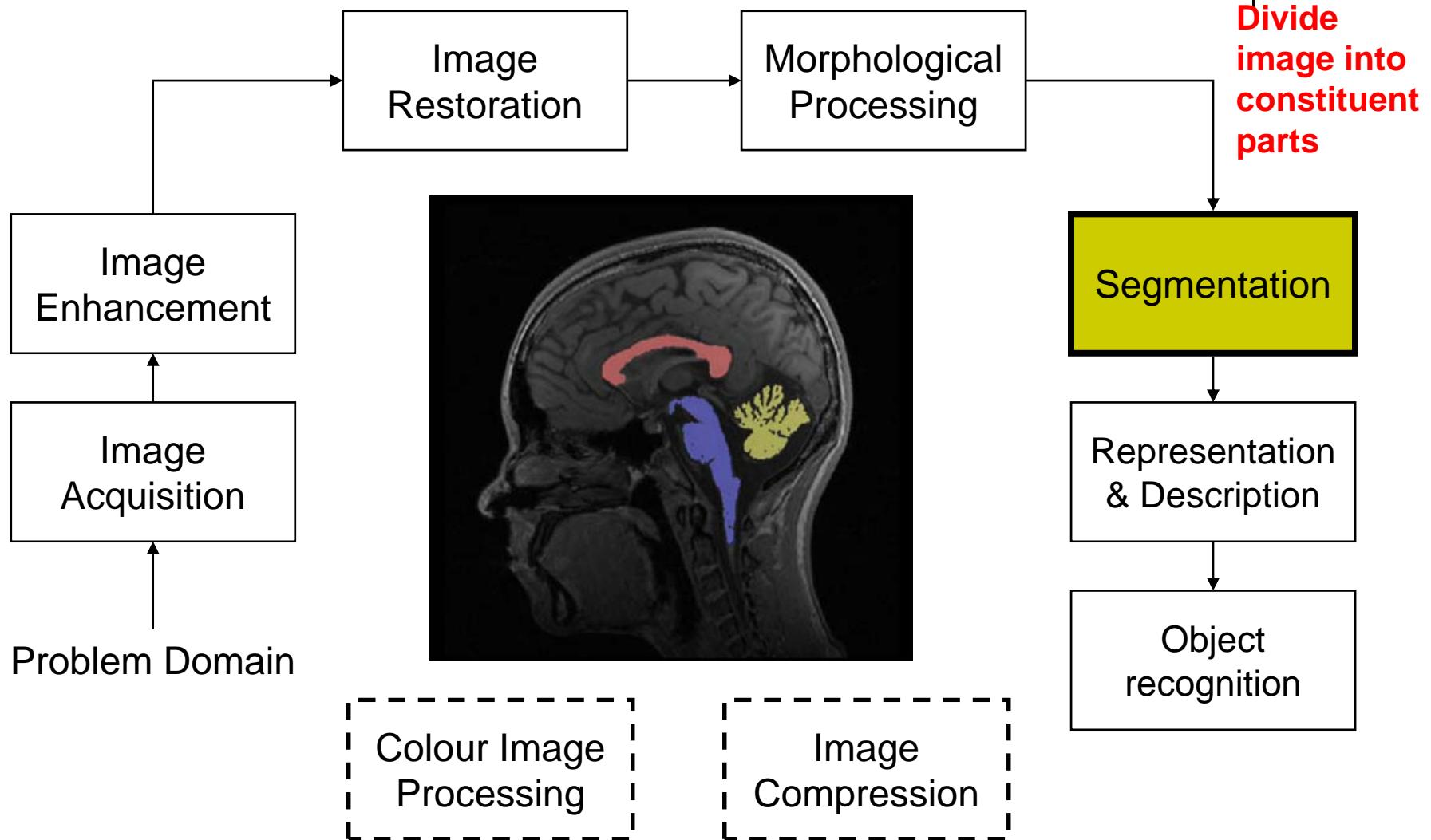
Extract  
attributes  
useful for  
describing  
image



# Key Stages in Digital Image Processing: Segmentation



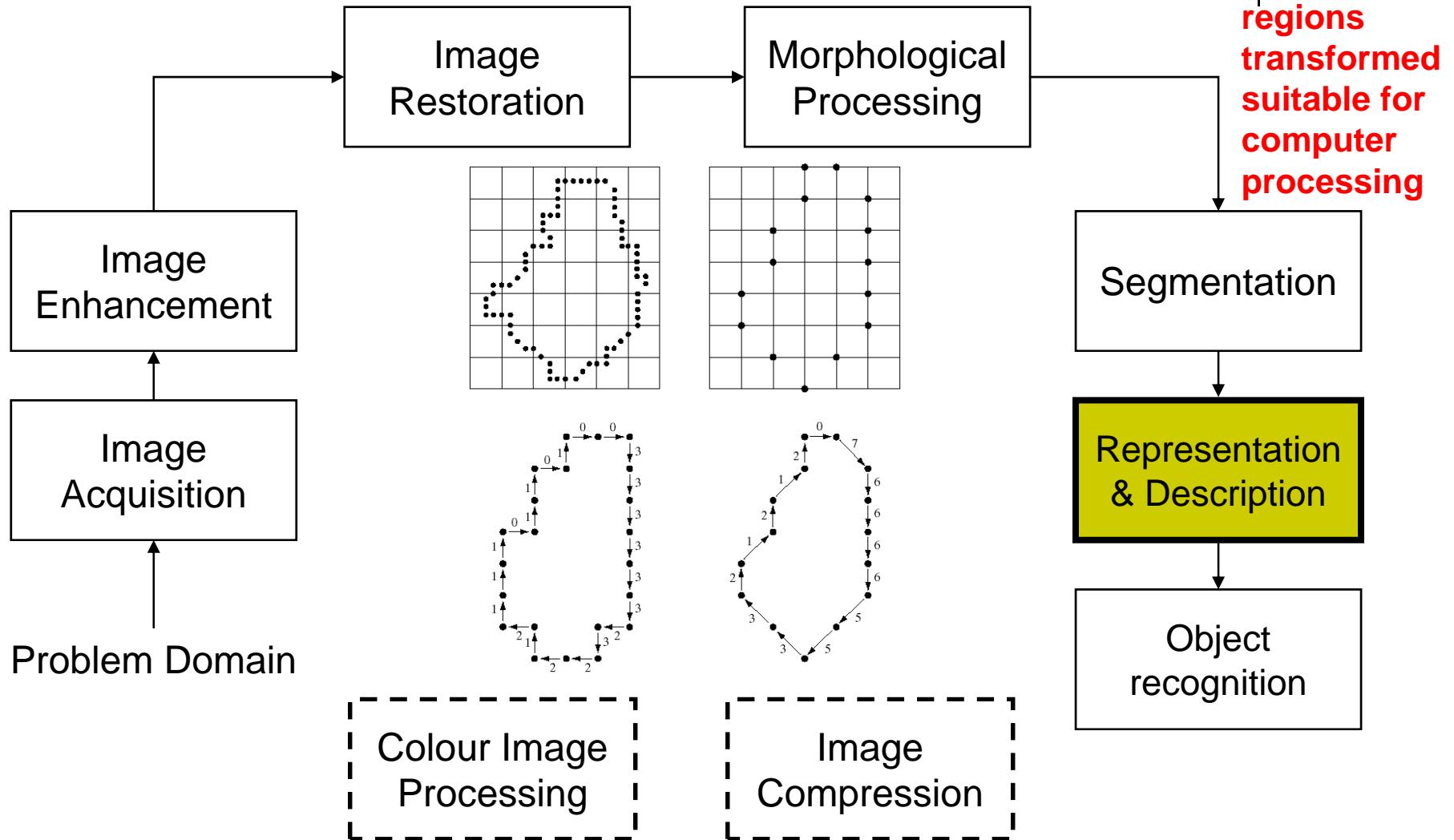
Divide  
image into  
constituent  
parts



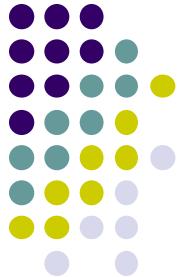
# Key Stages in Digital Image Processing: Object Recognition



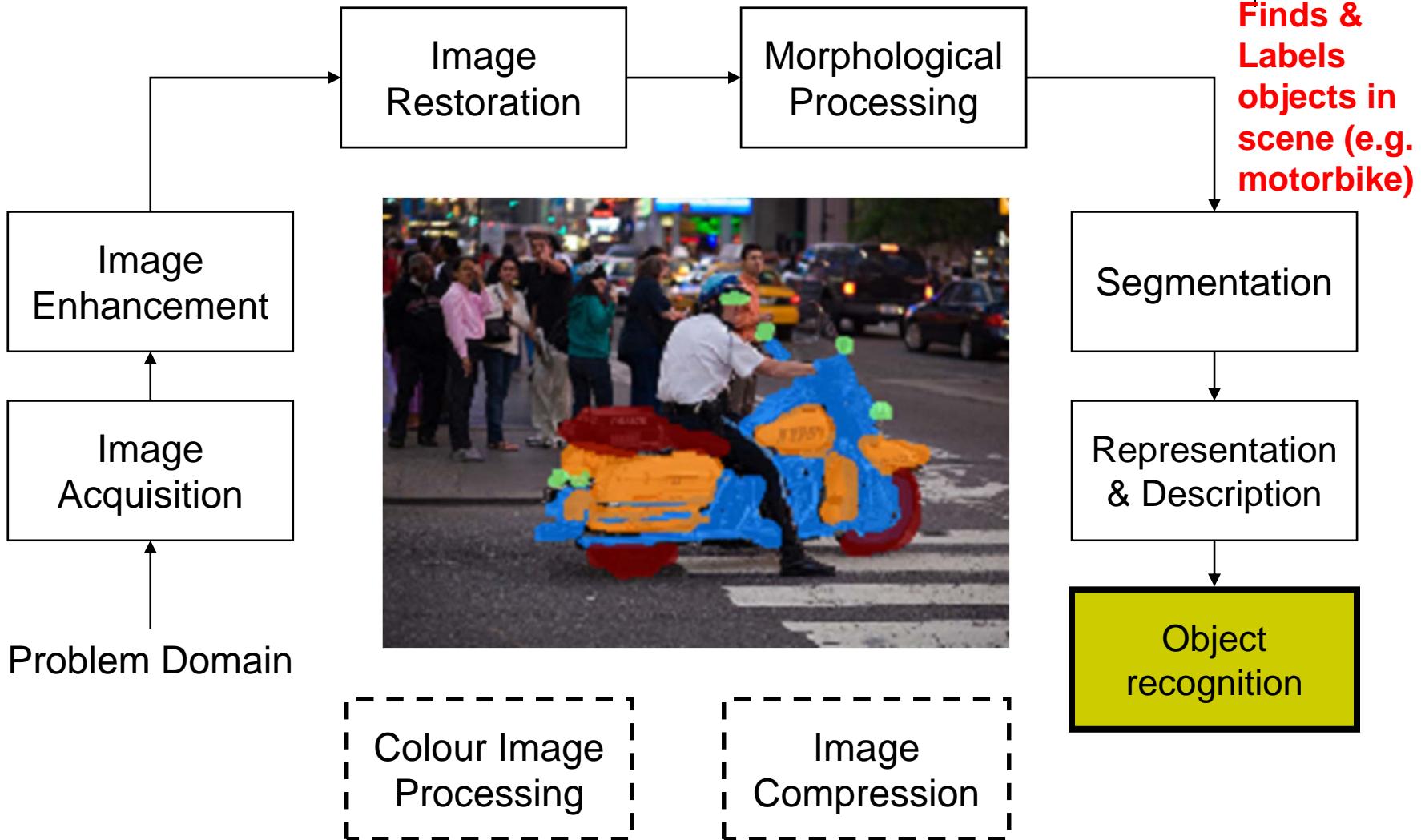
Image regions transformed suitable for computer processing



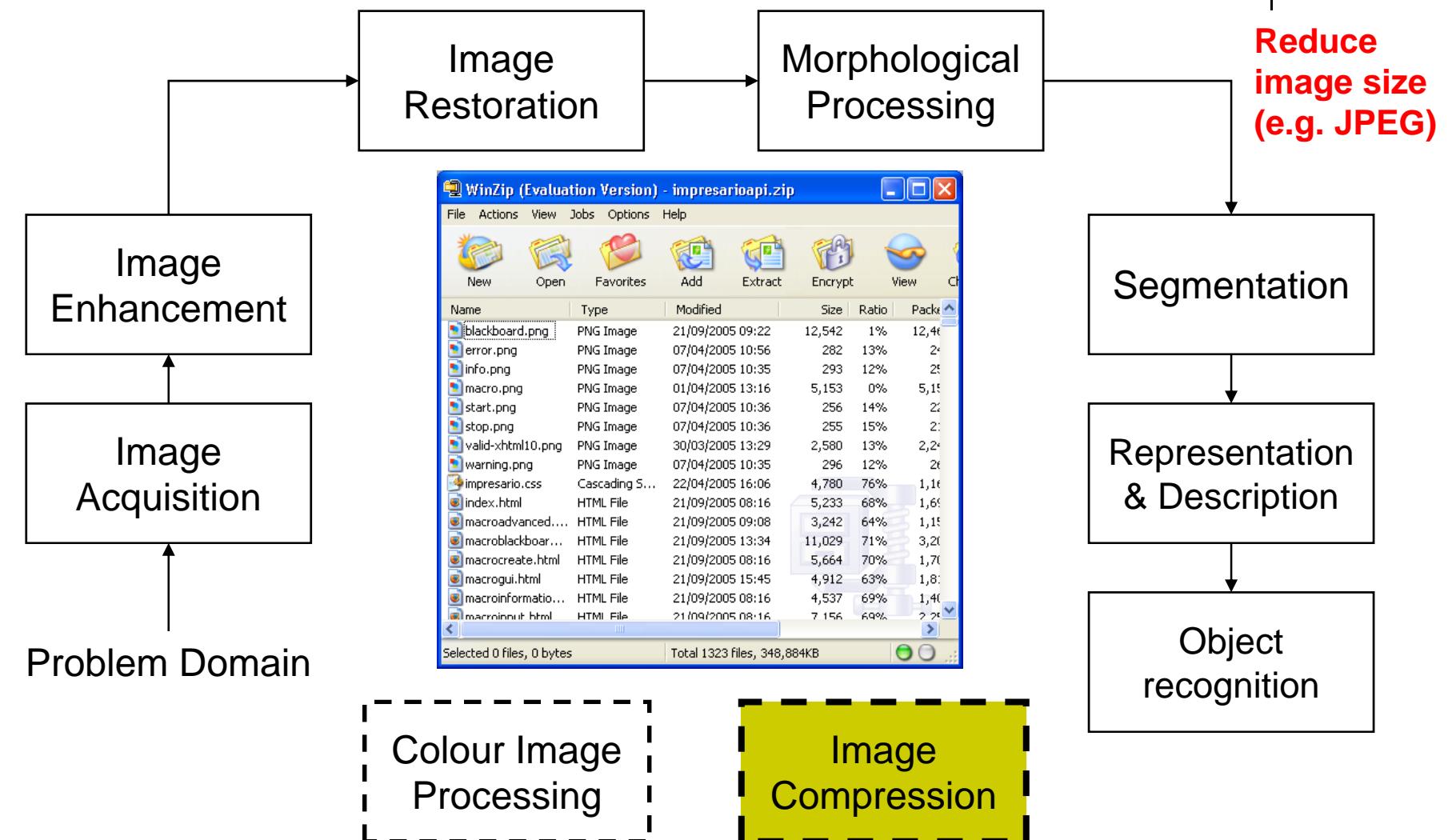
# Key Stages in Digital Image Processing: Representation & Description



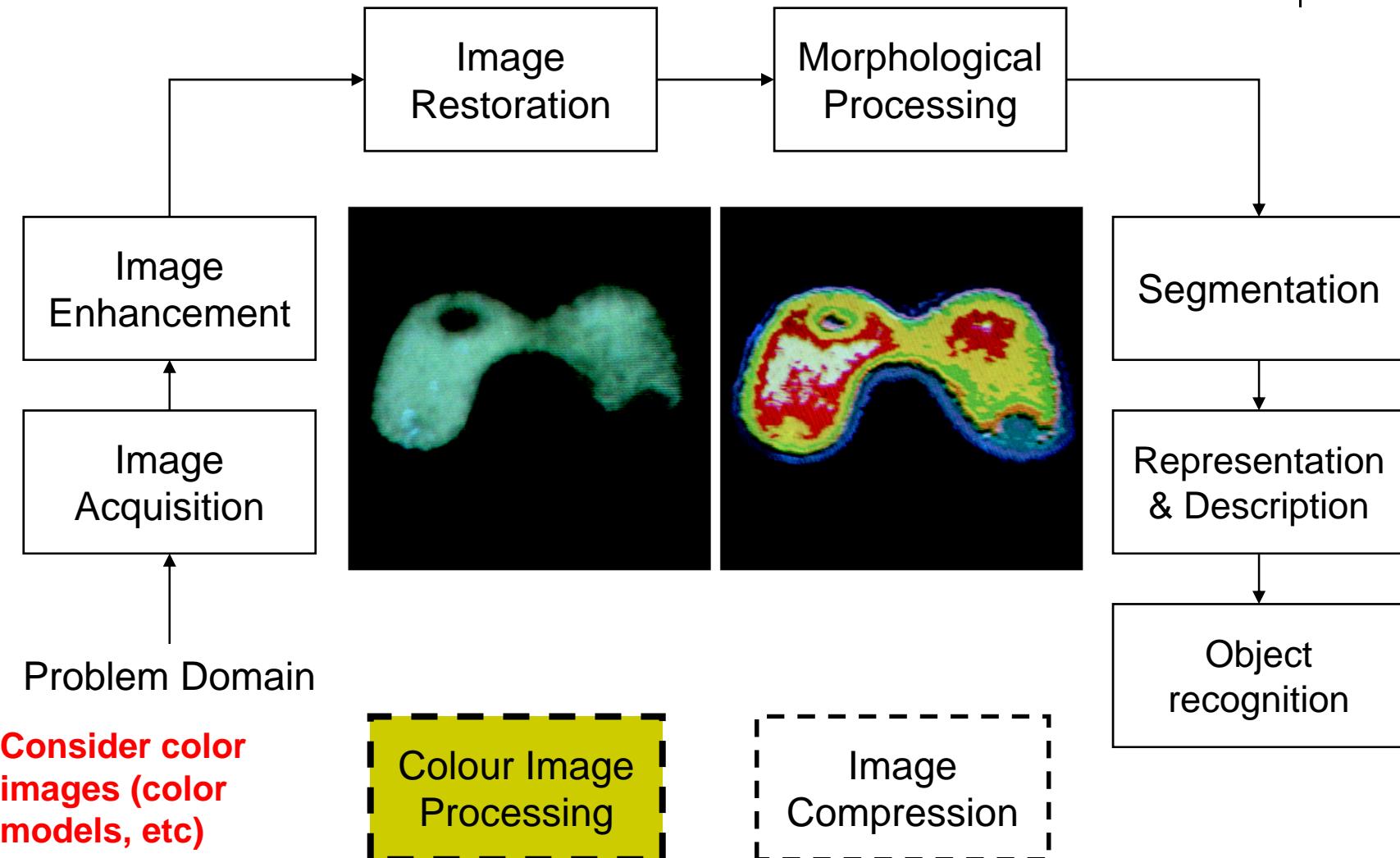
Images taken from Gonzalez & Woods, Digital Image Processing (2002)



# Key Stages in Digital Image Processing: Image Compression



# Key Stages in Digital Image Processing: Colour Image Processing





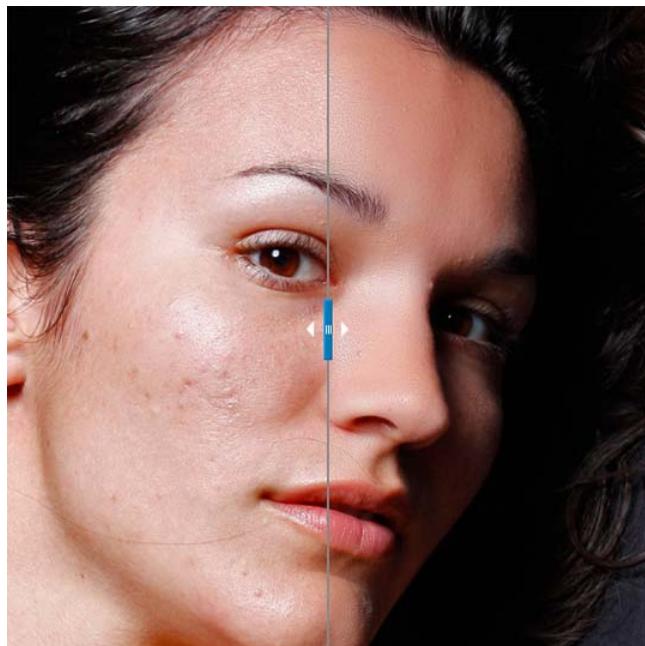
# Mathematics for Image Processing

- Calculus
- Linear algebra
- Probability and statistics
- Differential Equations (PDEs and ODEs)
- Differential Geometry
- Harmonic Analysis (Fourier, wavelet, etc)



# About This Course

- Image Processing has many aspects
  - **Computer Scientists/Engineers** develop tools (e.g. photoshop)
    - **Requires** knowledge of maths, algorithms, programming
  - **Artists** use image processing tools to modify pictures
    - **DOES NOT** require knowledge of maths, algorithms, programming



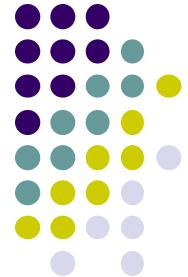
*Example: Portraiture photoshop plugin*



*Example: Knoll Light Factory photoshop plugin*

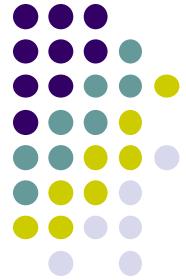


*Example: ToonIt photoshop plugin*



## About This Course

- Most hobbyists follow artist path. Not much math!
- **This Course: Image Processing for computer scientists and Engineers!!!**
- Teaches concepts, uses Matlab/Python as concrete example
- Matlab Image Processing Toolbox
  - Includes lots of already working algorithms,
  - Can be extended by programming new image processing techniques
- Course is **NOT**
  - just about programming Matlab image processing toolbox
  - a comprehensive course in matlab image processing toolbox and python image processing library (PIL, scipy, opencv-python and so on)
  - about using packages like Photoshop



## About This Course

- Class is concerned with:
  - How to implement image processing algorithms
  - Underlying mathematics
  - Underlying algorithms
- This course is a lot of work. **Especially heavy coding!!!**  
Requires:
  - Lots of programming (maybe in MATLAB/Python)
  - Lots of math, linear systems, fourier analysis



# Administrivia: Syllabus Summary

- 3 Assignments (30%), one Mid-Exam (30%), 1 final Projects (40%)
- Projects:
  - Develop image processing algorithm on any platform using MATLAB/Python
  - May discuss projects but turn in individual projects
- Class website: <http://web.cs.wpi.edu/~emmanuel/courses/cs545/S14/>
- Text:
  - *Digital Image Processing: An Algorithmic Introduction using Java* by Wilhelm Burger and Mark J. Burge, Springer Verlag, 2008
- Cheating: Immediate ‘F’ in the course
- My advice:
  - Come to class
  - Read the text
  - Understand concepts before coding



## References

- Wilhelm Burger and Mark J. Burge, Digital Image Processing, Springer, 2008
- University of Utah, CS 4640: Image Processing Basics, Spring 2012
- Gonzales and Woods, Digital Image Processing (3<sup>rd</sup> edition), Prentice Hall
- Digital Image Processing slides by Brian Mac Namee

Thank You