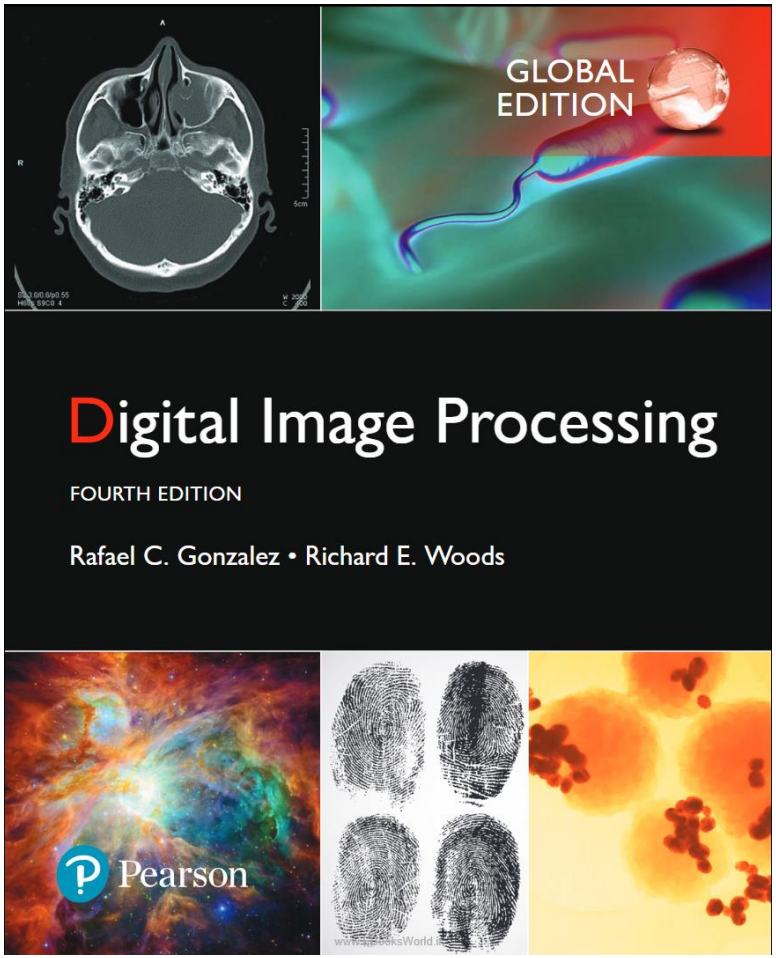
CS370 Computer Imaging

Introduction

Course Info

- **Class time:** Wednesday, Friday 2:00 – 3:40pm
- **Classroom:** Edison
- **Instructor:** Dr. Bhargav Bhatkalkar
- **Instructor email:** bhargav.bhatkalkar@digipen.edu
  Include "[CS370]" in email subject
- **Office Hours:** 4 pm to 5 pm on Tue, Wed, and Fri
- **Other than office hours**, please make an appointment

Textbook


GLOBAL
EDITION
Digital Image Processing
FOURTH EDITION
Rafael C. Gonzalez • Richard E. Woods
Pearson

Pre-requisites

- CS280
- Good implementation skills (C/C++)
- Good background in mathematics
  - Basic math review is provided in the course website
- Enthusiasm to learn!

Grade Distribution

- Quizzes: **20%**
- Programming Assignments: **35%**
- Midterm Exam: **20%**
- Final Exam (Comprehensive): **25%**

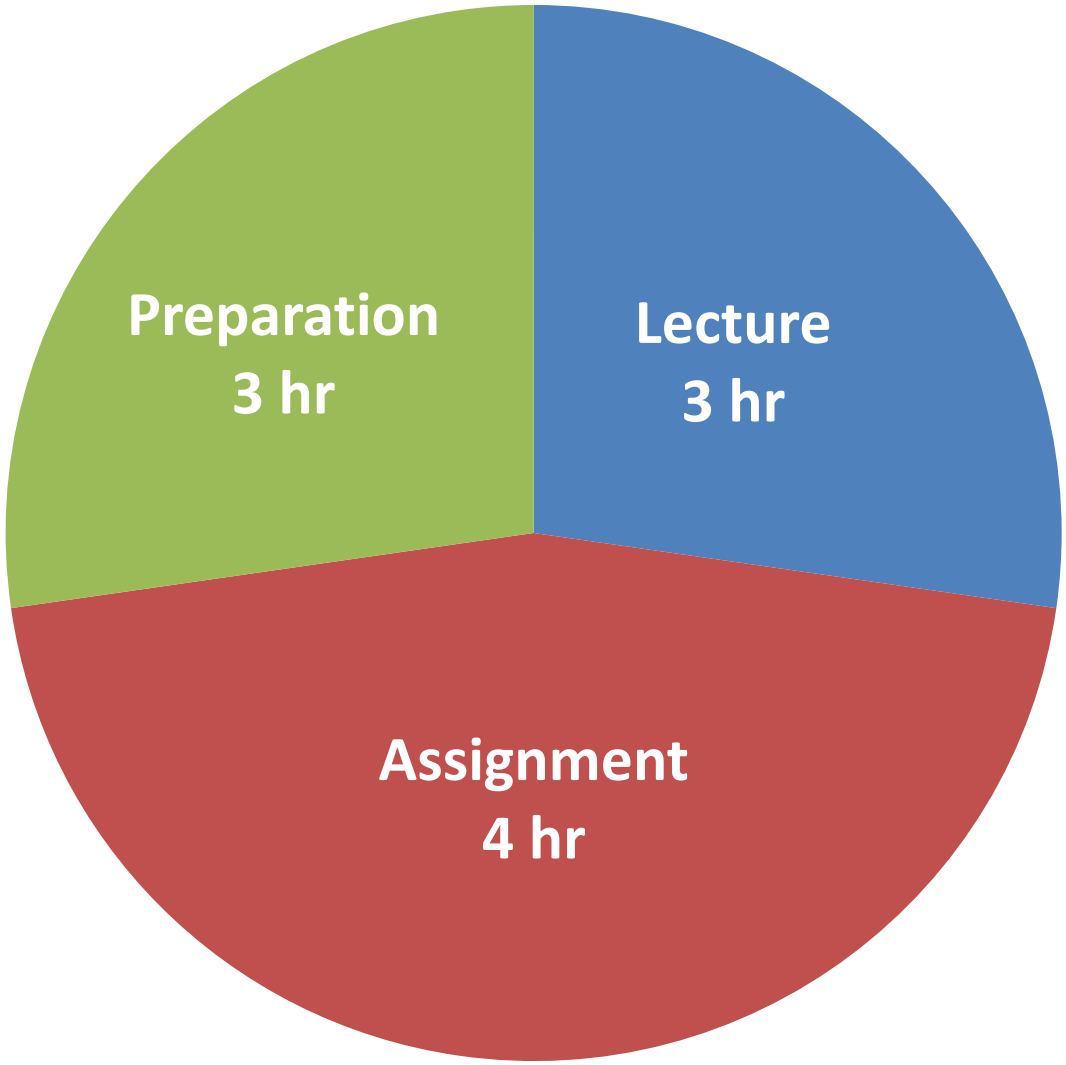
x%	Grade
$x \geq 93$	A
$90 \leq x < 93$	A-
$87 \leq x < 90$	B+
$83 \leq x < 87$	B
$80 \leq x < 83$	B-
$77 \leq x < 80$	C+
$73 \leq x < 77$	C
$70 \leq x < 73$	C-
$60 \leq x < 70$	D
$x < 60$	F

- **A "C-" grade or above is considered as "Pass". You must receive an average score of minimum 60% in the midterm and final exams combined to pass this course, regardless of your quiz/assignment scores.**

Interaction

- Moodle: main interaction platform.
- All study materials will be uploaded to Moodle site after the lectures.
- Assignment submissions will be in Moodle.
- https://distance.sg.digipen.edu

Average Weekly Workload



Class Policies

- Attendance is compulsory, please refer to Syllabus for attendance policy.
- Be on time for class.
- No talking in the class during lecture.
- No sleeping and crunching of food.
- You are encouraged to ask/answer questions during the lectures.
- **Don’t use mobile phones during the lecture hours.**
- No cheating, copying, plagiarizing, or any other form of academic dishonesty – refer to course syllabus document

Programming Assignments

- **Four** assignments, each focusing on implementing specific image processing operations covered in class.
- **Warning: Please follow instructions exactly for assignment submissions, as is described in Syllabus.**
- You will be given sufficient time to submit the assignments. Assignments submitted after the due date are not accepted and will not be graded.
- Any assignment marking will be considered finalized before the deadline of the next assignment.

Programming Assignments

- Use wxWidgets library to write applications.

- First assignment coming up
  - Write a small application in wxWidgets that allows you to load and display images
  - Familiarize yourselves with the APIs

- Why wxWidgets? Popular, cross-platform, good as a first introduction to real-world GUI libraries.

“One picture is worth more than ten thousand words”

Anonymous

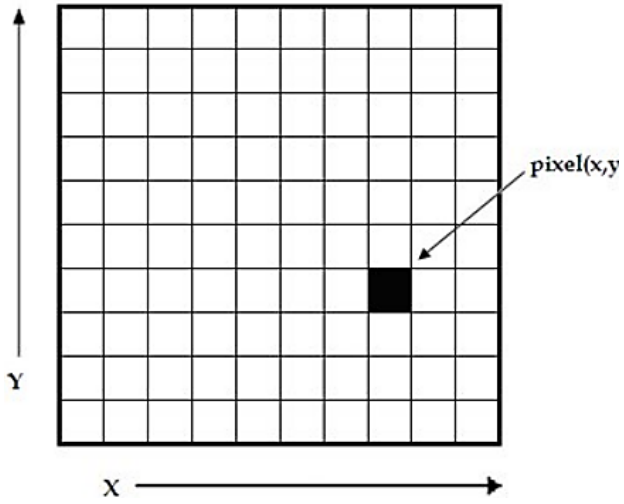
Lecture Objectives

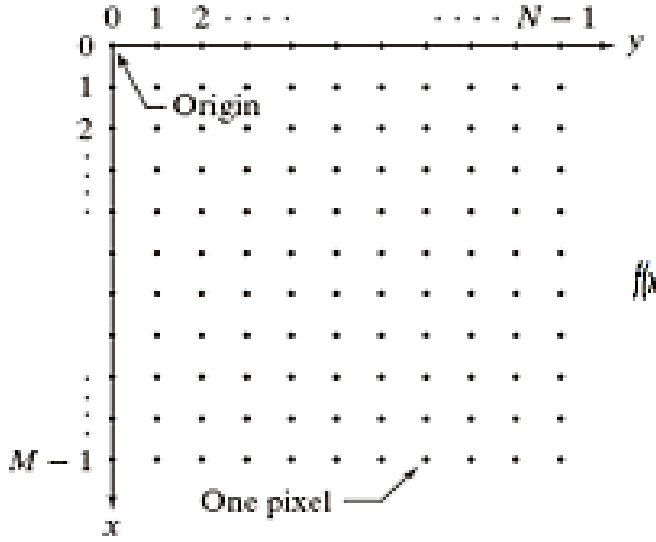
- What is Digital Image?
- What is Digital Image Processing (DIP) ?
- 3-Levels of Processing an Image
- Electromagnetic Spectrum
- DIP Applications
- Key Stages of DIP

What is a Digital Image?

- An **image** may be defined as a two-dimensional function, ***f* (*x*, *y*)**, where ***x*** and ***y*** are *spatial* (plane) coordinates, and the amplitude of ***f*** at any pair of coordinates **(*x*, *y*)** is called the ***intensity(gray level)*** of the image at that point.

- When *x*, *y*, and the intensity values of ***f*** are all **finite**, **discrete quantities**, we call the image a ***digital image***.





$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1) & f(0,2) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & f(1,2) & \dots & f(1,N-1) \\ \vdots & \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & f(M-1,2) & \dots & f(M-1,N-1) \end{bmatrix}$$

What is a Digital Image?

- The field of ***digital image processing*** refers to processing digital images by means of a ***digital computer***.

- A digital image is composed of a **finite number of elements**, each of which has a particular location and value. These elements are called *picture elements*, *image elements*, *pels*, and ***pixels***.

- ***Real world is continuous*** – **an image is simply a digital approximation of the real, continuous world.**

What is a Digital Image?

- The images represented by two-dimensional function of the form ***f* (*x*, *y*)** must be nonnegative and finite:

$$0 \leq f(x, y) < \infty$$

- Function ***f* (*x*, *y*)** is characterized by two components:
  (1) The amount of source ***illumination*** incident on the scene being viewed.
  (2) The amount of illumination ***reflected/transmitted*** by the objects in the scene.

Resulting light energy (intensity or gray level):

$$f(x, y) = i(x, y) * r(x, y)$$

where,

$0 \leq i(x, y) < \infty$ is the incident energy and
$0 \leq r(x, y) \leq 1$ is the reflectance/transmissivity property

What is a Digital Image?

- Preceding bounds are theoretical.

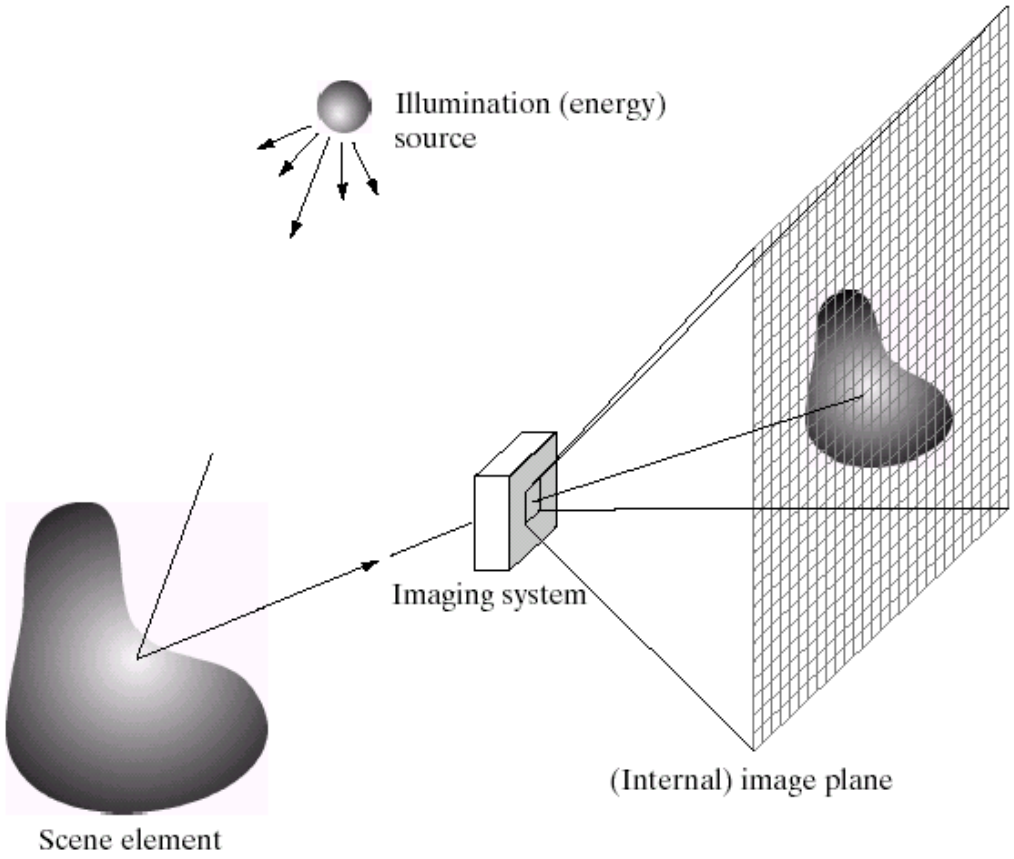
- In practice:

Ambient Conditions	Illumination
Clear day sun light	> 90,000
Cloudy day sun light	< 10,000
Lighted Office	≈ 1,000
Full moon	0.1

lumens/m²

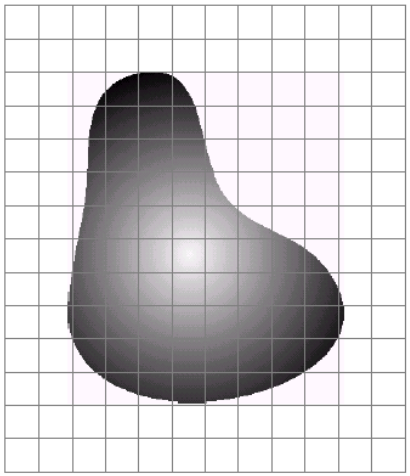
Material	Reflectance
Black velvet	0.01
Stainless Steel	0.65
Flat white wall paint	0.80
Silver plated metal	0.90
Snow	0.93

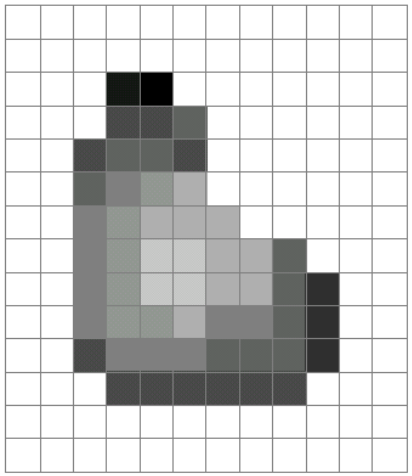
What is a Digital Image?

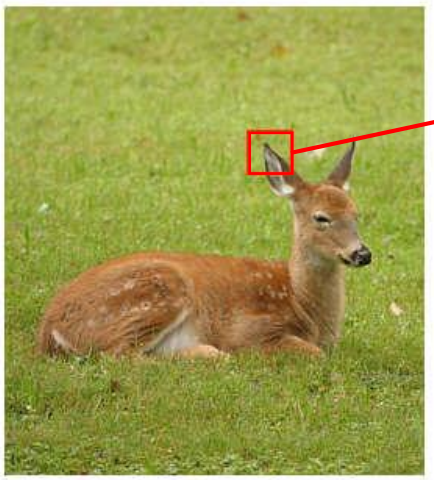


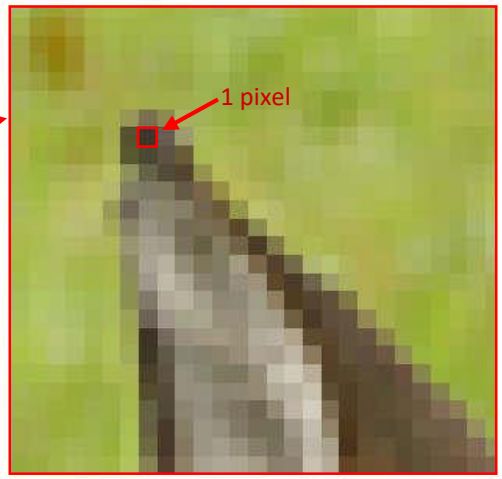
What is a Digital Image?

- Pixel values - gray levels, colors, opacities, etc..
- *Digitization* - digital image is an *approximation* of a real scene.









What is a Digital Image?

Common image formats

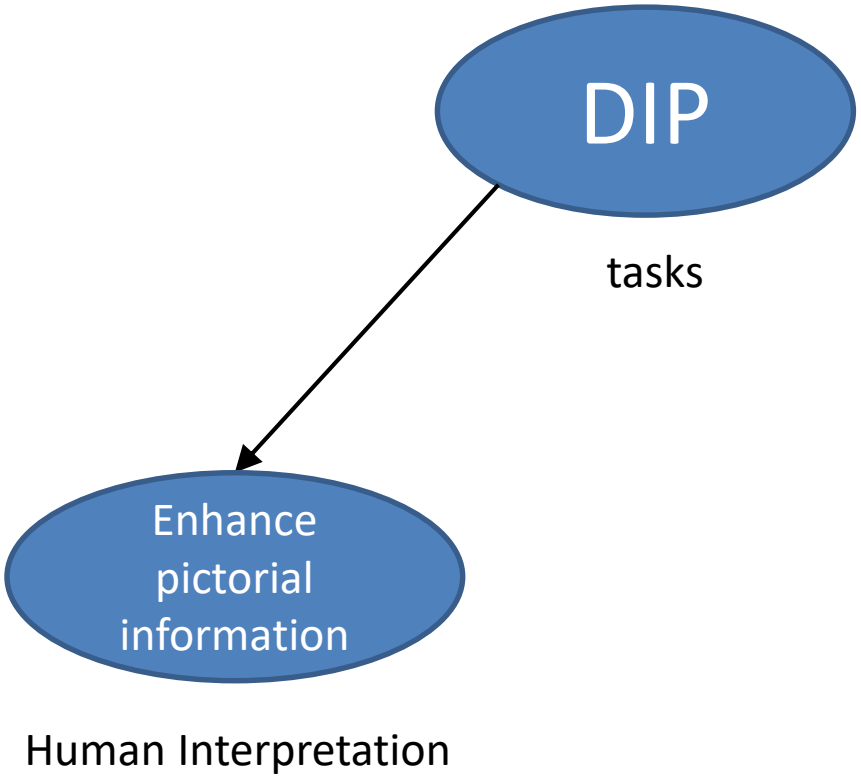
1 sample per point
(B&W or Grayscale)

3 samples per point
(Red, Green, and Blue)

4 samples per point (Red, Green, Blue, and "Alpha", a.k.a. Opacity)

This course will focus on **Grey-scale images**. The techniques learned in this course can be easily extended to color images with minor changes to the algorithms.

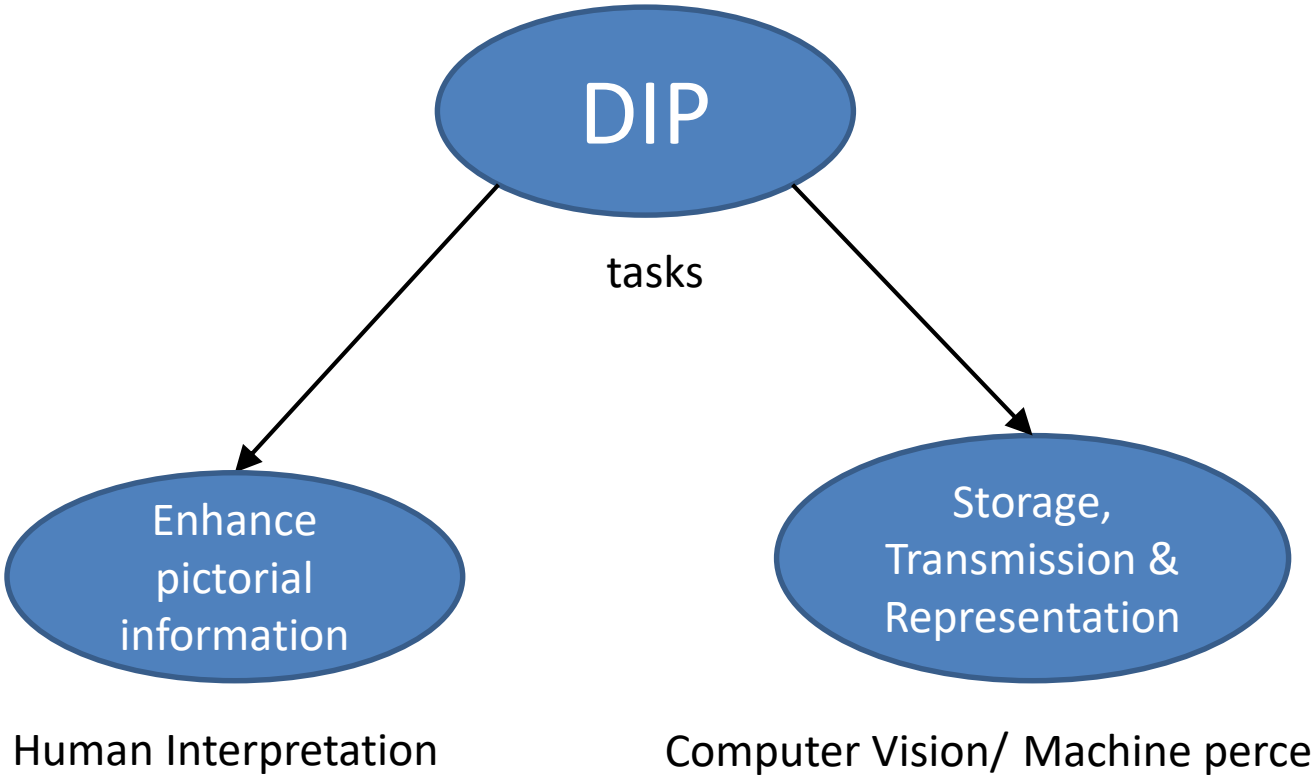
What is Digital Image Processing (DIP)?



What is Digital Image Processing (DIP)?

- Improvement of pictorial information for human interpretation

What is Digital Image Processing (DIP)?



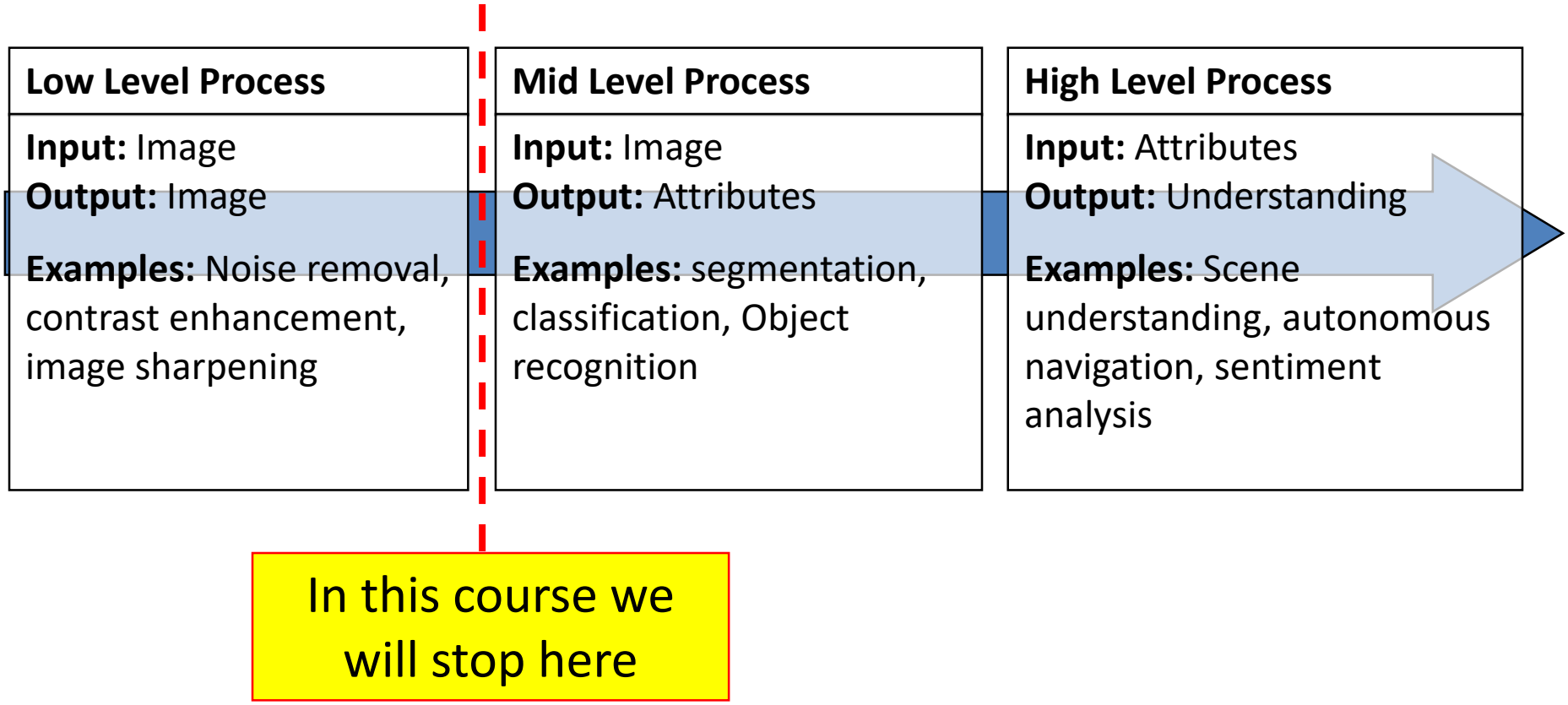
There is some argument about where image processing ends and fields such as image analysis and computer vision start

What is Digital Image Processing (DIP)?

- **Image Analysis**: Extraction of meaningful information from images
  - Face recognition
  - Image segmentation
  - Object recognition

- **Computer Vision**: Let computers emulate human vision
  - Learning
  - Making inferences
  - Performing actions based on observations

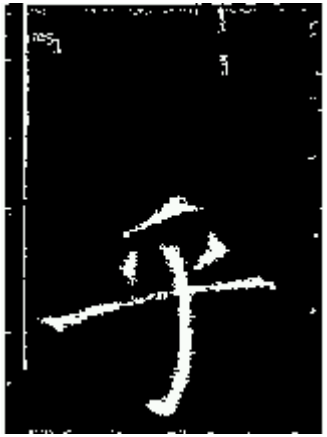
3-Levels of Processing an Image



Low Level Processing

Noise Removal

Image **denoising** is to remove noise from a noisy image, so as to restore the true image.



Contrast Enhancement

Contrast enhancement processes adjust the relative brightness and darkness of objects in the scene to improve their visibility.

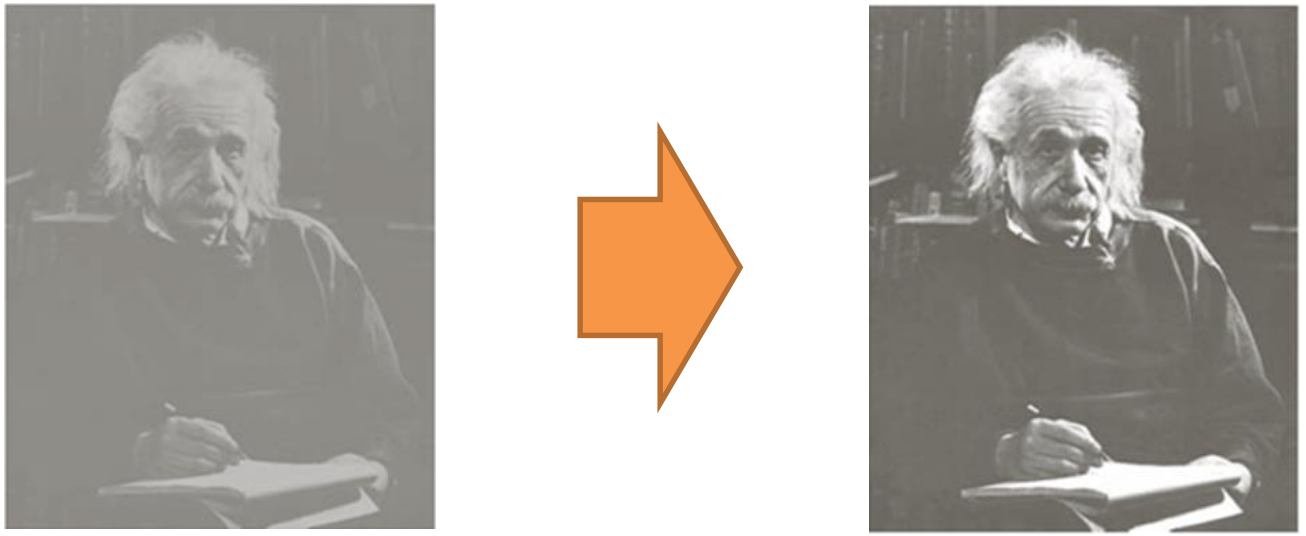
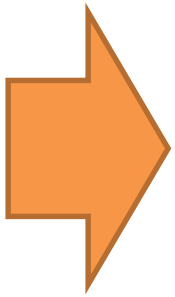
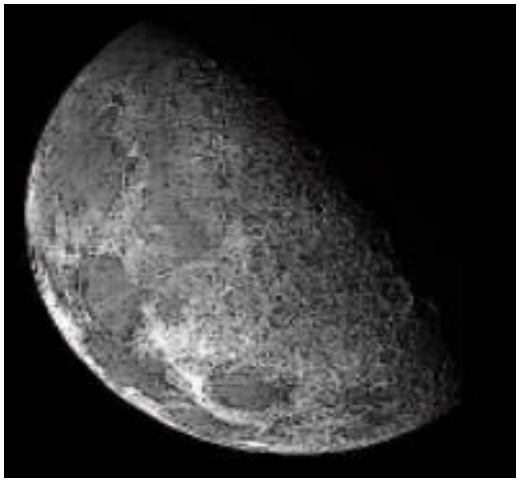
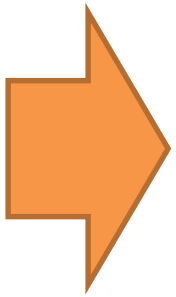


Image Sharpening

Image sharpening highlights the edges and fine details of an image.







Mid Level Processing

Image Segmentation

Image segmentation is a task of partitioning an image into multiple segments.

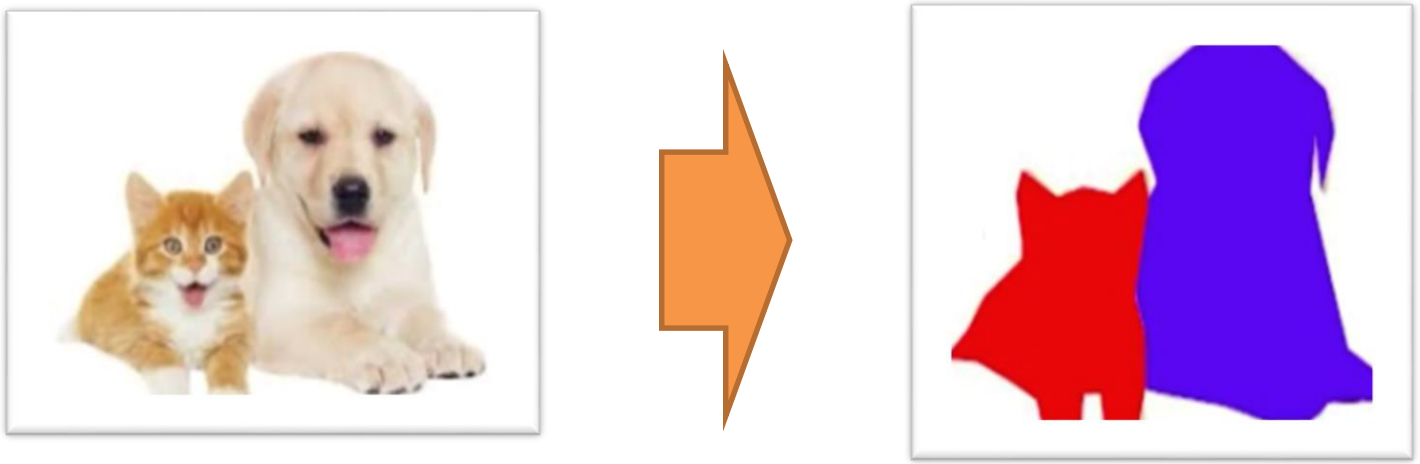
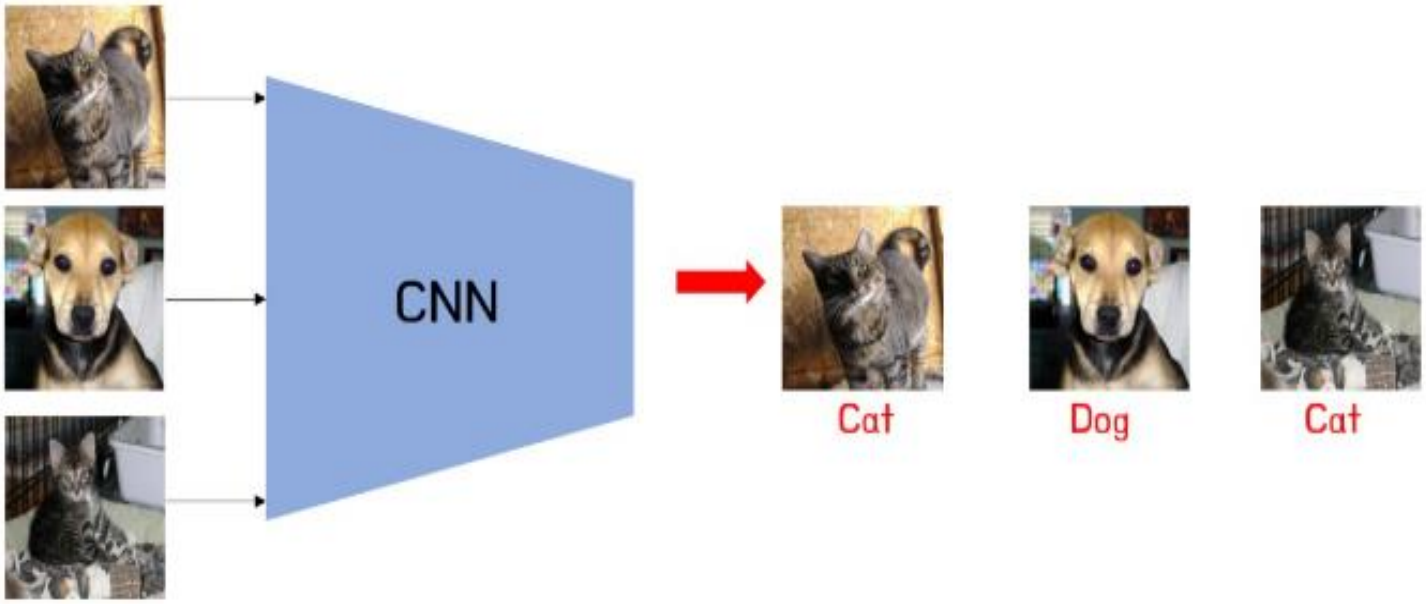


Image classification

Image Classification is the task of associating one (*single-label classification)* or more (*multi-label classification)* **labels** to a given image.

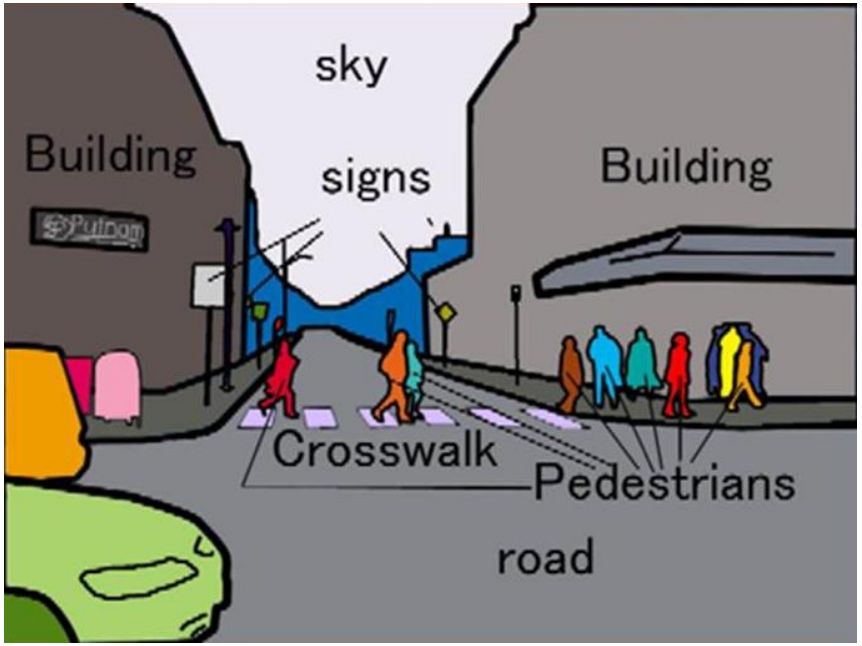


Object Recognition

Object recognition is a technique for identifying objects in images or videos.

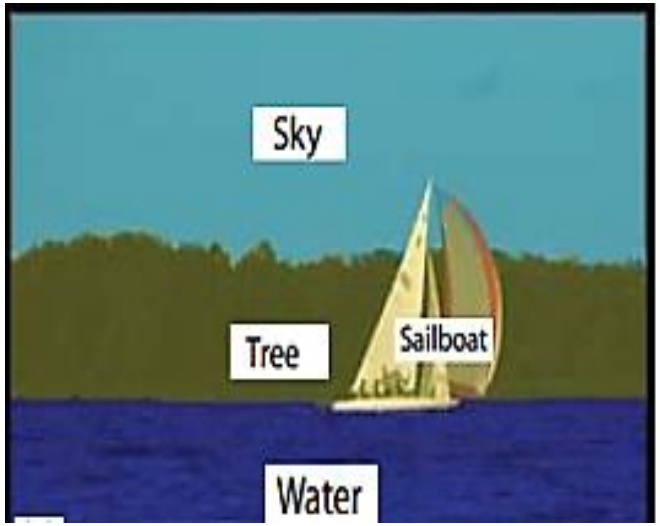
High Level Processing

Scene Understanding

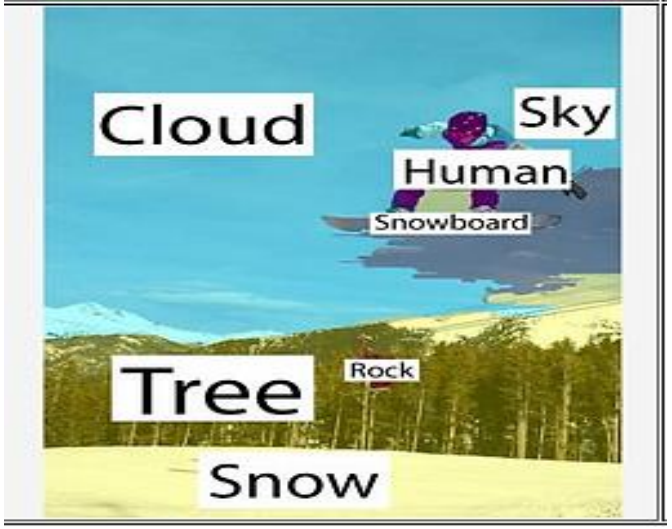


Scene Understanding

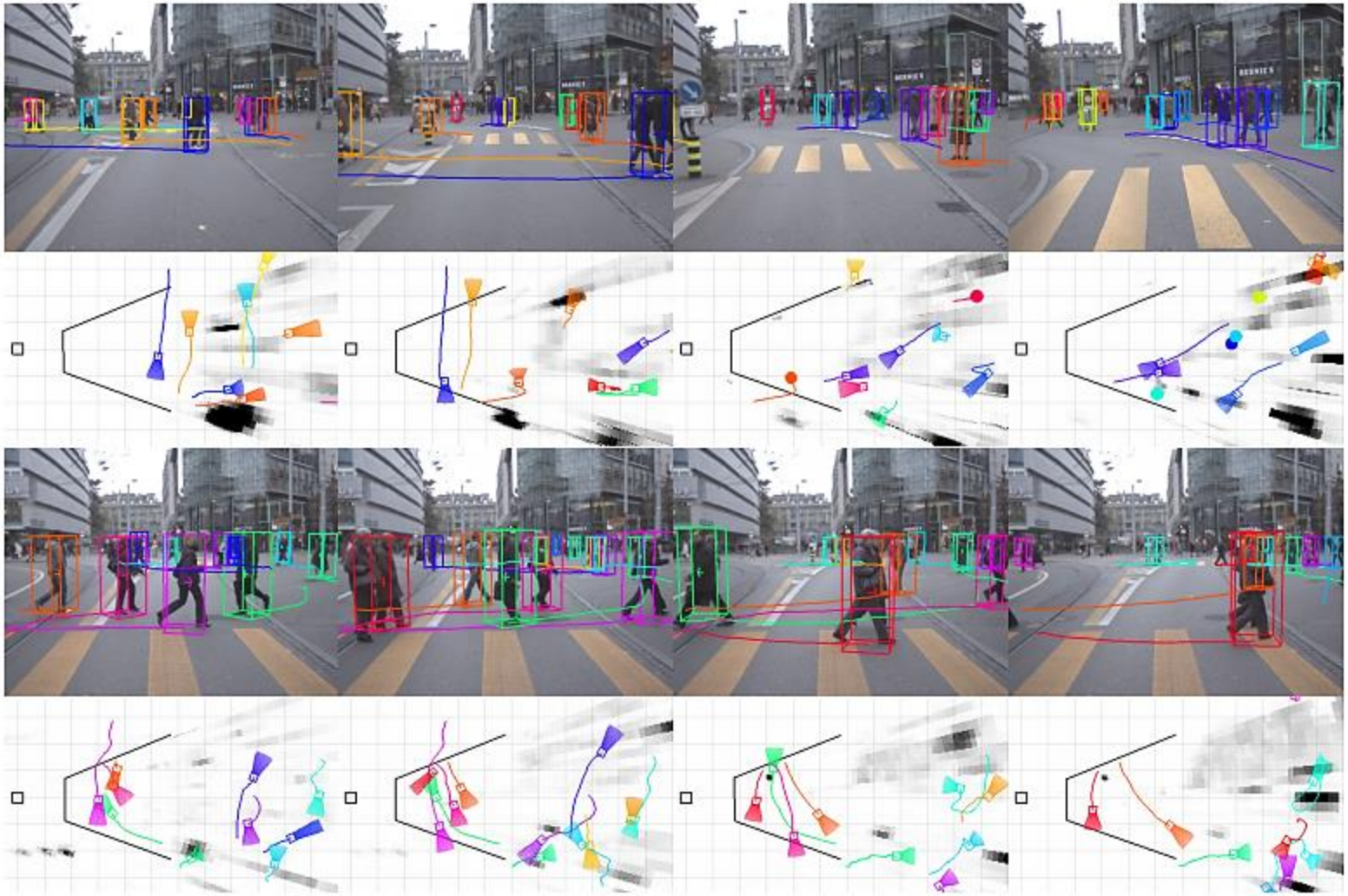
Original words:
sailboat,
boat,
Delavan Lake,
Delavan,
Wisconsin,
dusk,
water



Annotation:
sailboat,
water,
sky,
tree,
wind
seaside



Autonomous Navigation



Sentiment Analysis

Why We Study DIP?

DIP techniques are used in many applications:

- Image enhancement/restoration
- Medical visualisation
- Industrial inspection
- Law enforcement
- Human computer interface

Electromagnetic Spectrum

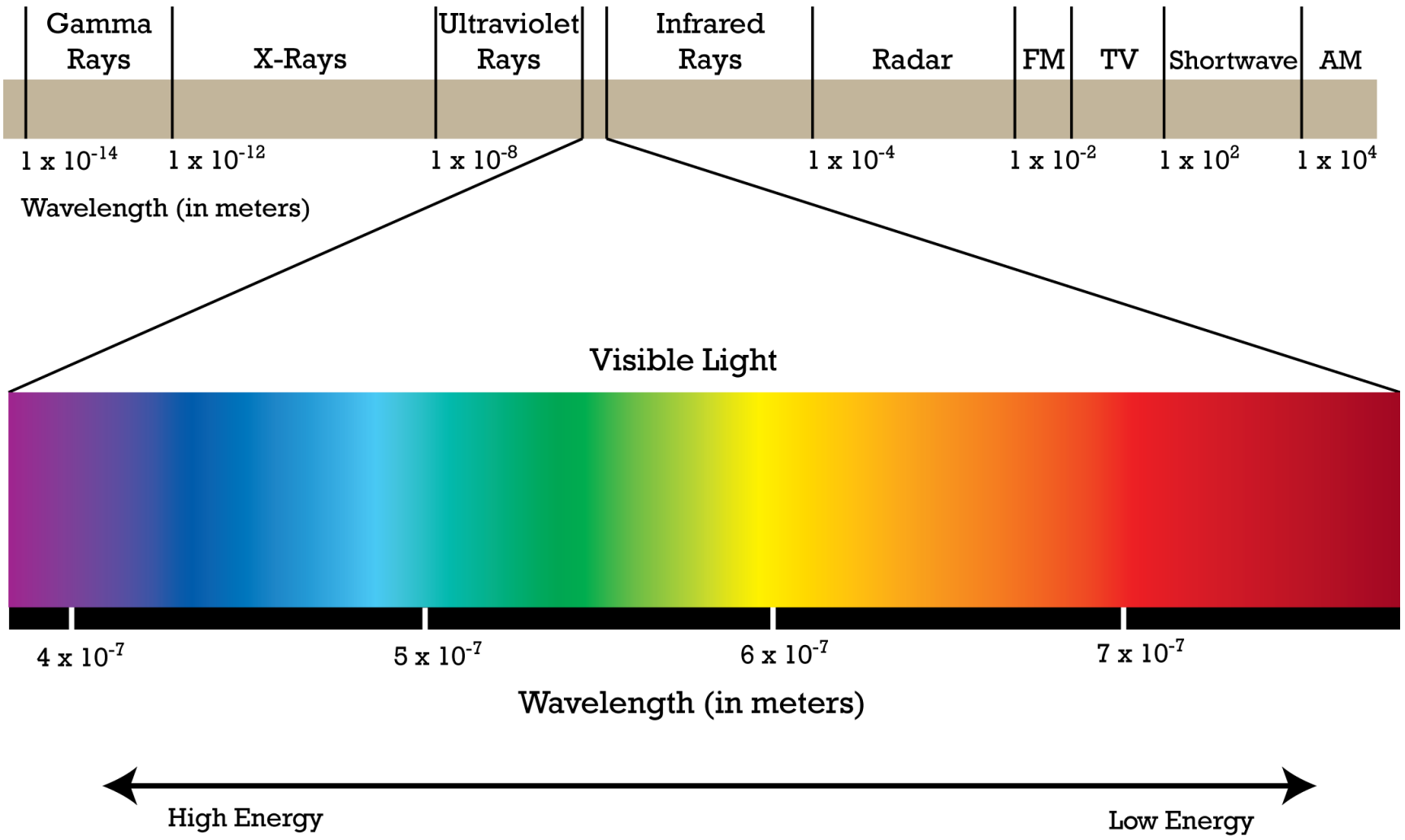
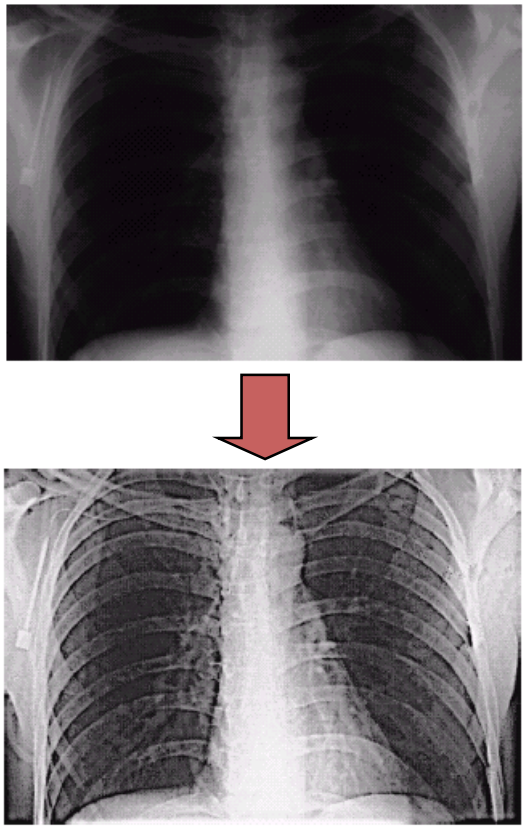
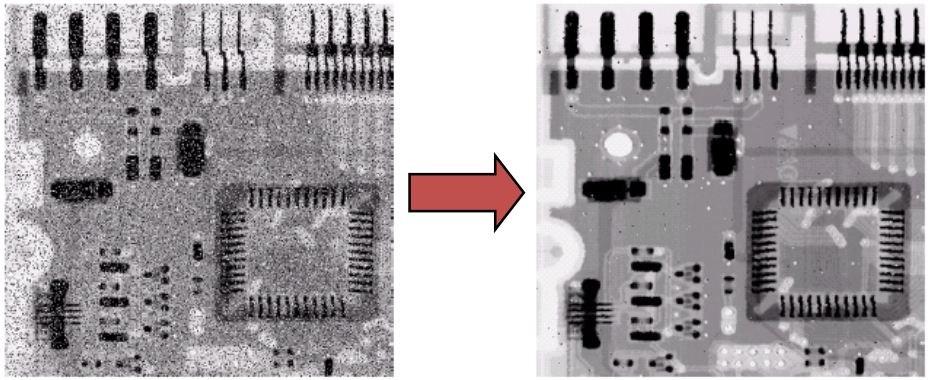


Image Enhancement and Restoration





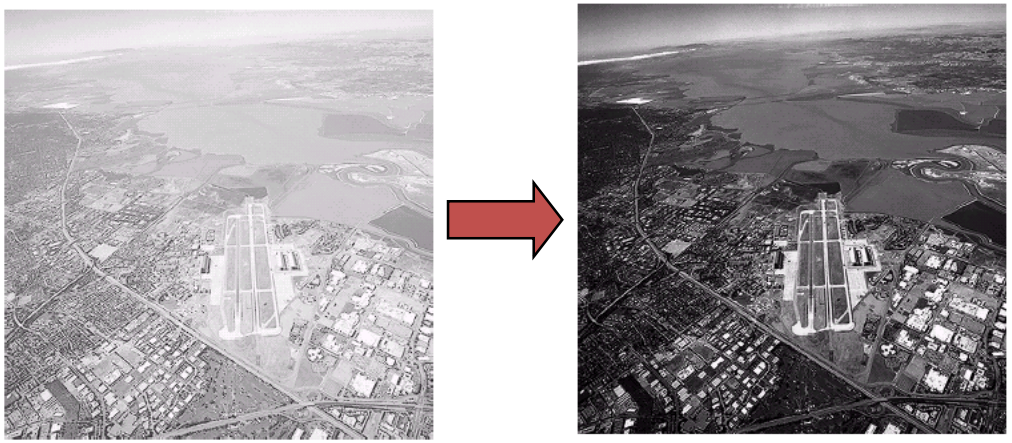


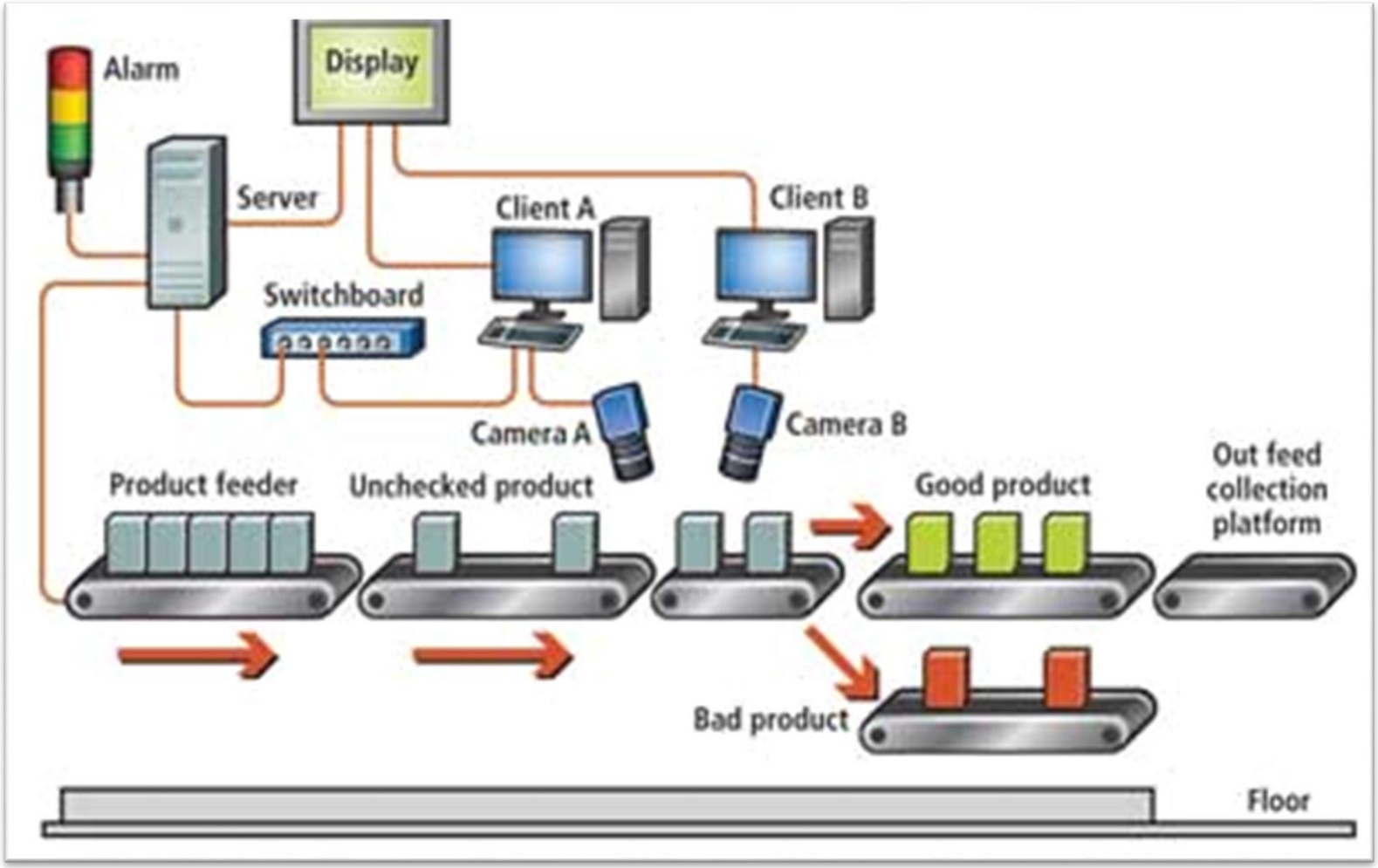
Image Enhancement and Restoration

Hubble Telescope

Galaxy M100 Galaxy

Image Enhancement and Restoration

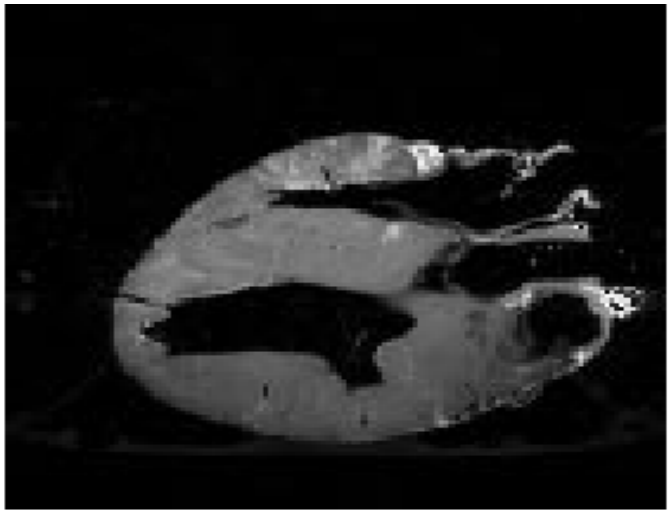
Industrial Inspection



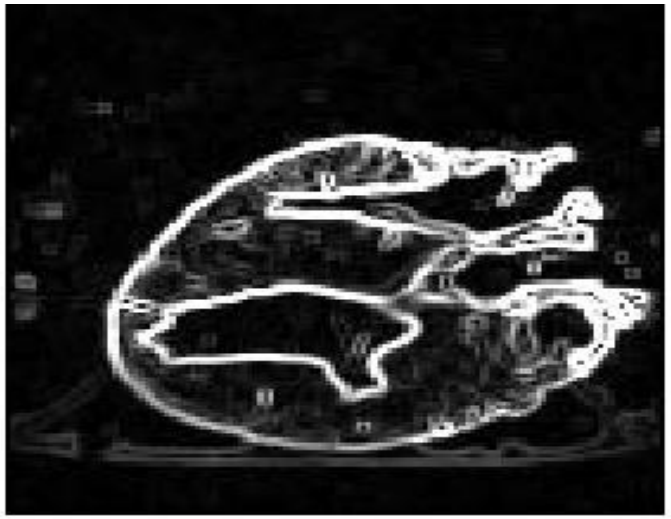
Medical Imaging

MRI scan image slice of Dog's heart:

- Image with gray levels representing tissue density
- Use a suitable filter to highlight edges



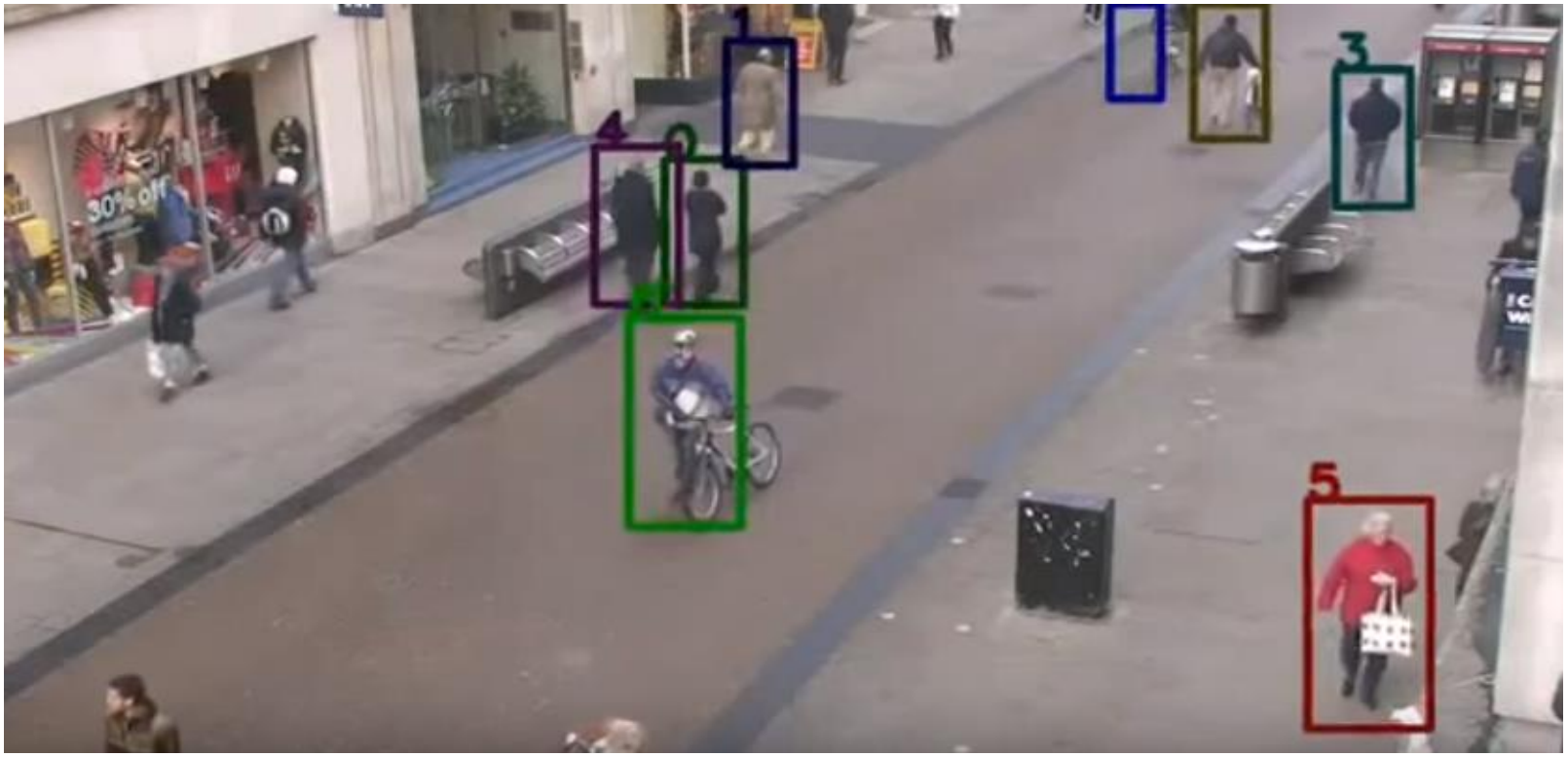
Original MRI Image of a Dog Heart



Edge Detected Image

Law Enforcement

Law Enforcement



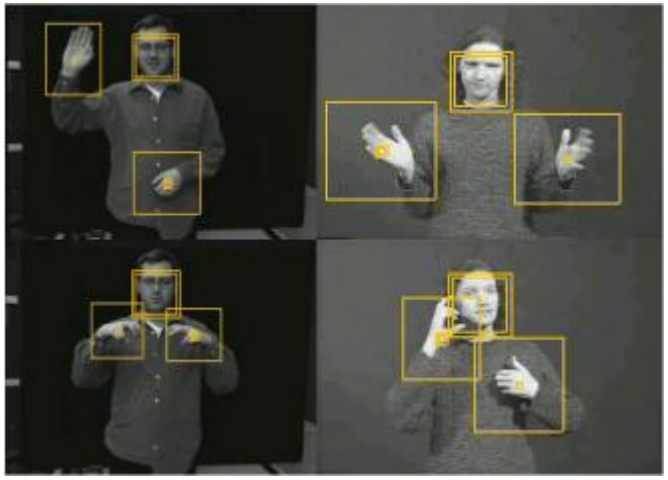
HCI – Human Computer Interface

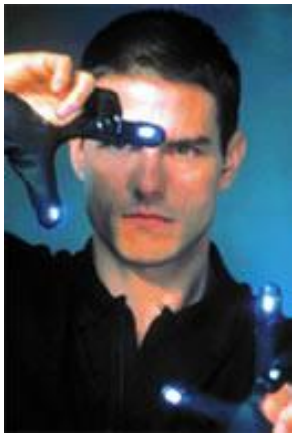
Digital Signage

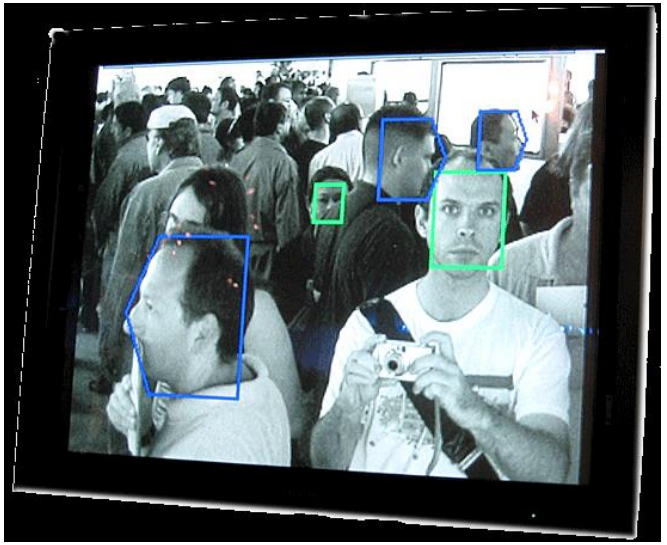
inform

promote

engage

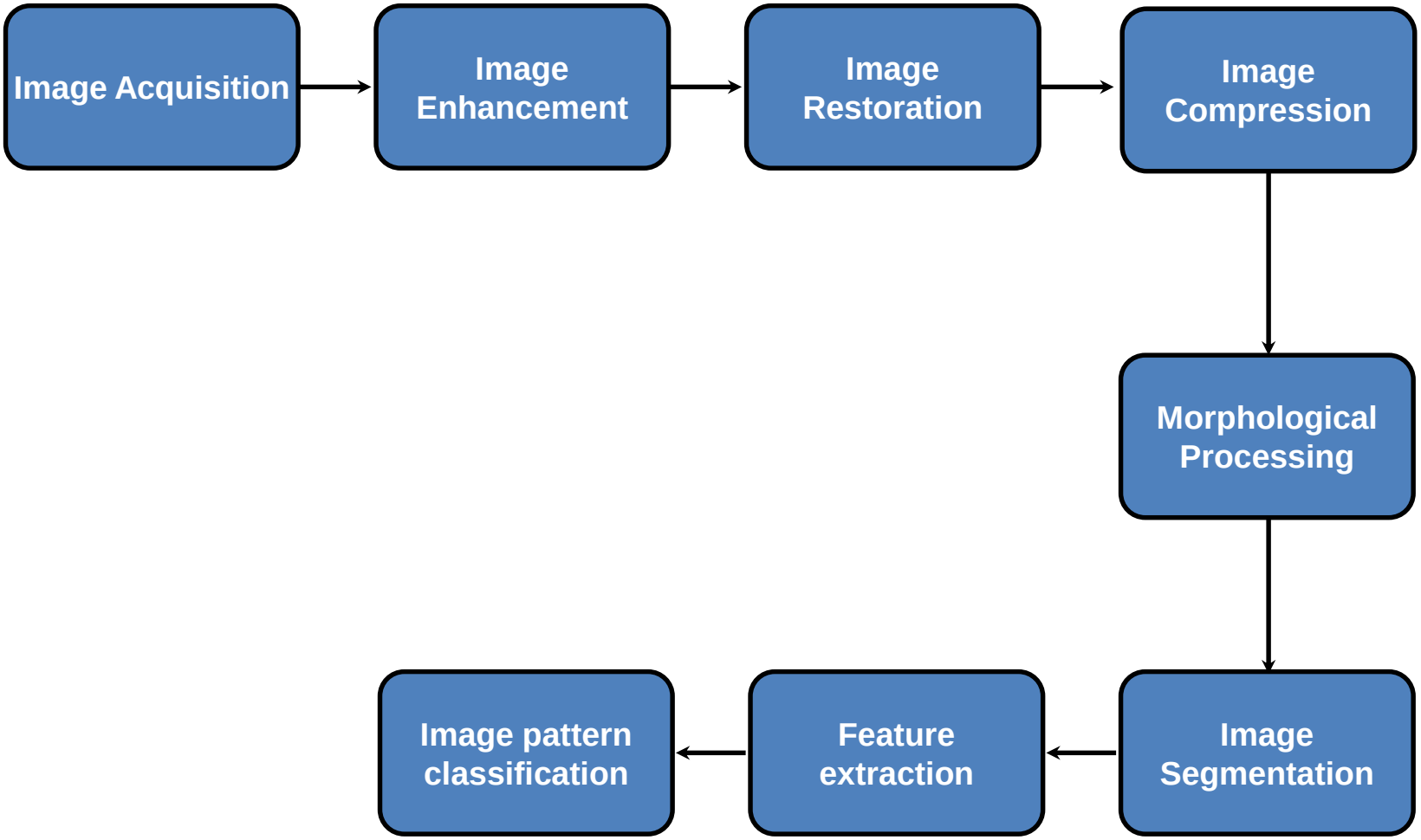




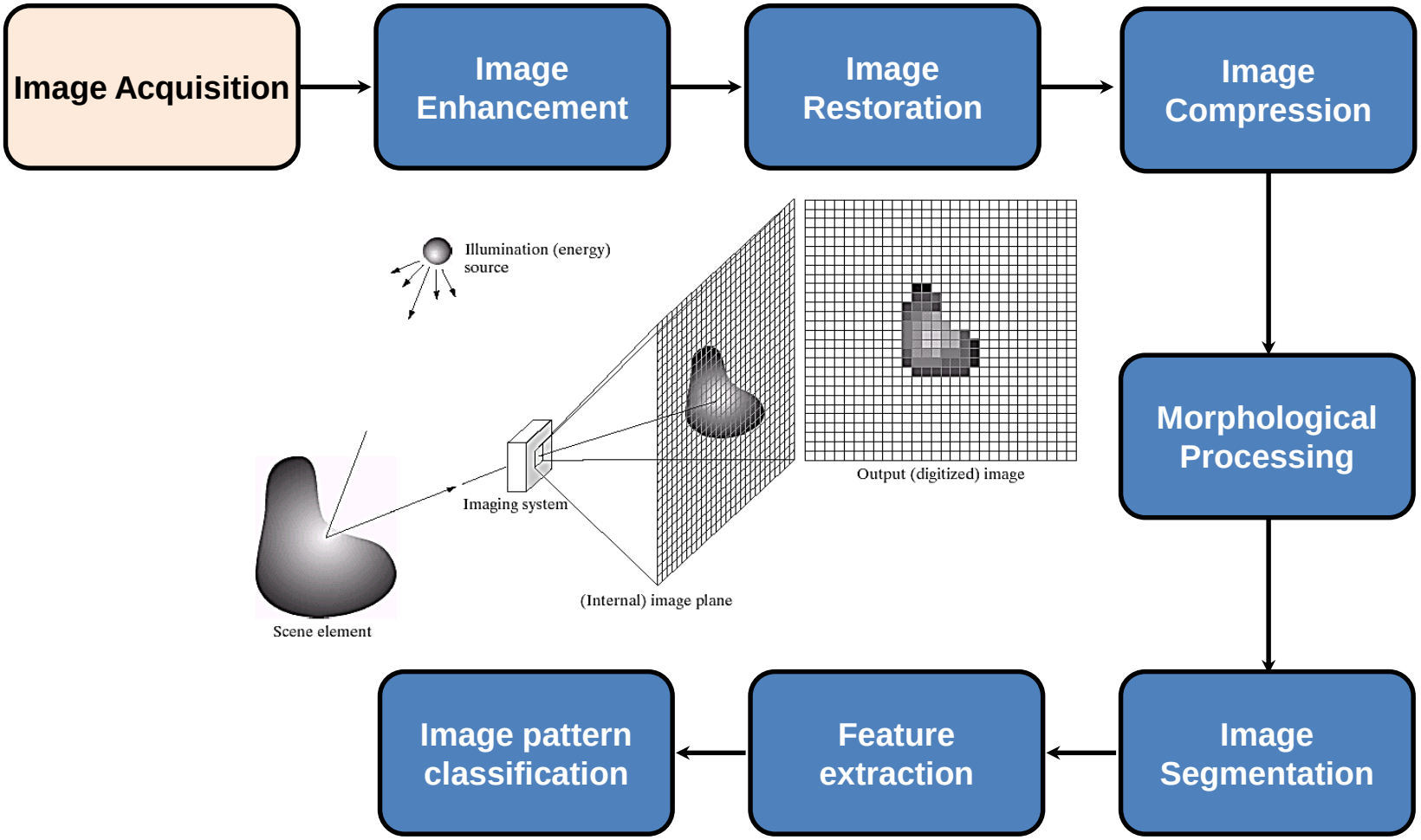


Key Stages of DIP

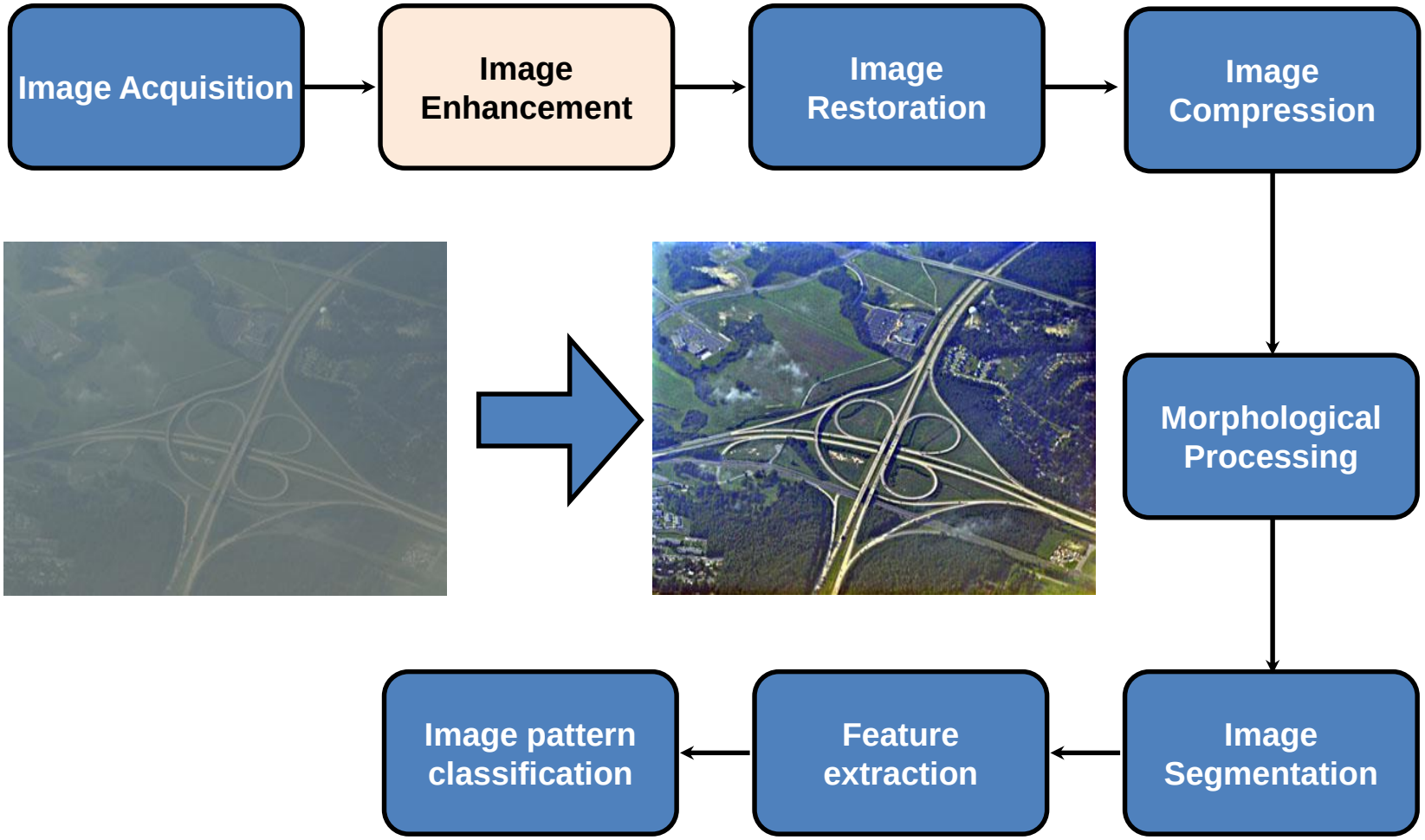
Key Stages in DIP



Key Stages in DIP



Key Stages in DIP



Key Stages in DIP

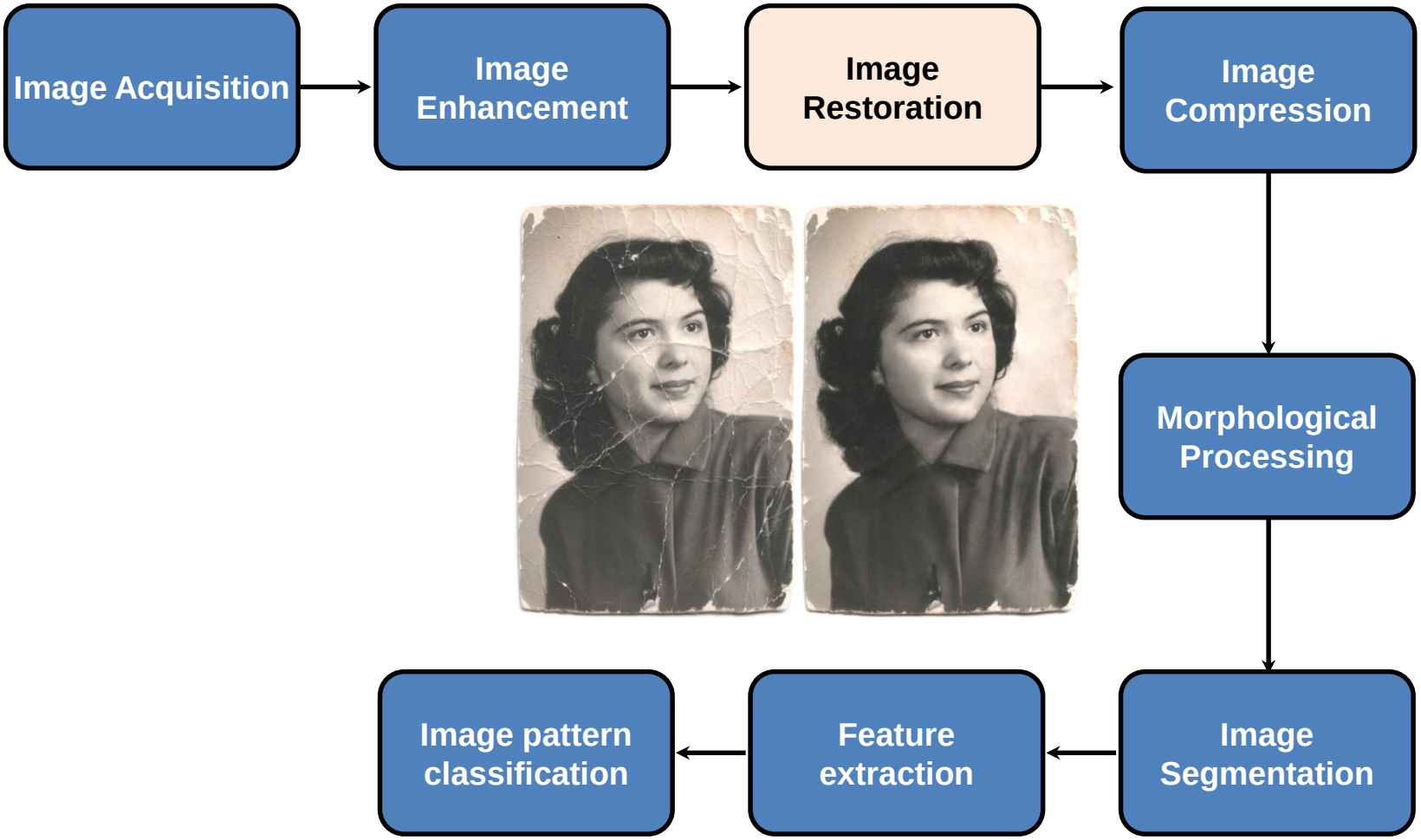


Image enhancement Vs. Image restoration

	Image Enhancement	**Image Restoration**
1.	As the name suggests, in Image Enhancement, the original image is processed so that the resultant image is more suitable than the original for specific applications.	The aim of image restoration is to bring the image towards what it would have been if it had been recorded without degradation.

Image enhancement Vs. Image restoration

	Image Enhancement	**Image Restoration**
1.	As the name suggests, in Image Enhancement, the original image is processed so that the resultant image is more suitable than the original for specific applications.	The aim of image restoration is to bring the image towards what it would have been if it had been recorded without degradation.
2.	Image enhancement makes a picture look better, without regard to how it really truly should look.	Image restoration tries to fix the image to get back to the real, true image.

Image enhancement Vs. Image restoration

	Image Enhancement	**Image Restoration**
1.	As the name suggests, in Image Enhancement, the original image is processed so that the resultant image is more suitable than the original for specific applications.	The aim of image restoration is to bring the image towards what it would have been if it had been recorded without degradation.
2.	Image enhancement makes a picture look better, without regard to how it really truly should look.	Image restoration tries to fix the image to get back to the real, true image.
3.	Image enhancement means improving the image to show some hidden details.	Image restoration means improving the image to match the original image.

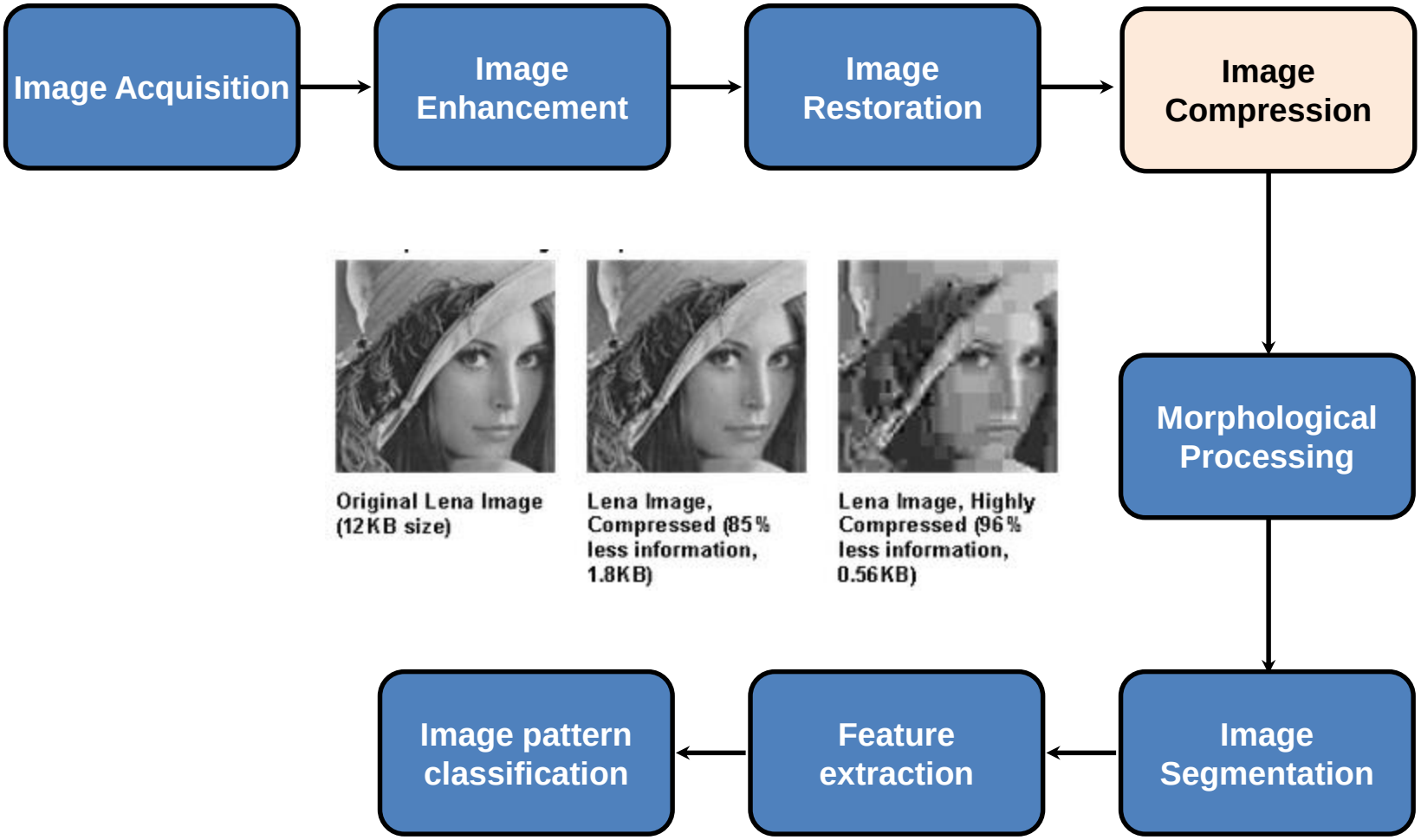
Image enhancement Vs. Image restoration

	Image Enhancement	**Image Restoration**
1.	As the name suggests, in Image Enhancement, the original image is processed so that the resultant image is more suitable than the original for specific applications.	The aim of image restoration is to bring the image towards what it would have been if it had been recorded without degradation.
2.	Image enhancement makes a picture look better, without regard to how it really truly should look.	Image restoration tries to fix the image to get back to the real, true image.
3.	Image enhancement means improving the image to show some hidden details.	Image restoration means improving the image to match the original image.
4.	Image enhancement is a purely subjective processing technique.	Image restoration is an objective process.

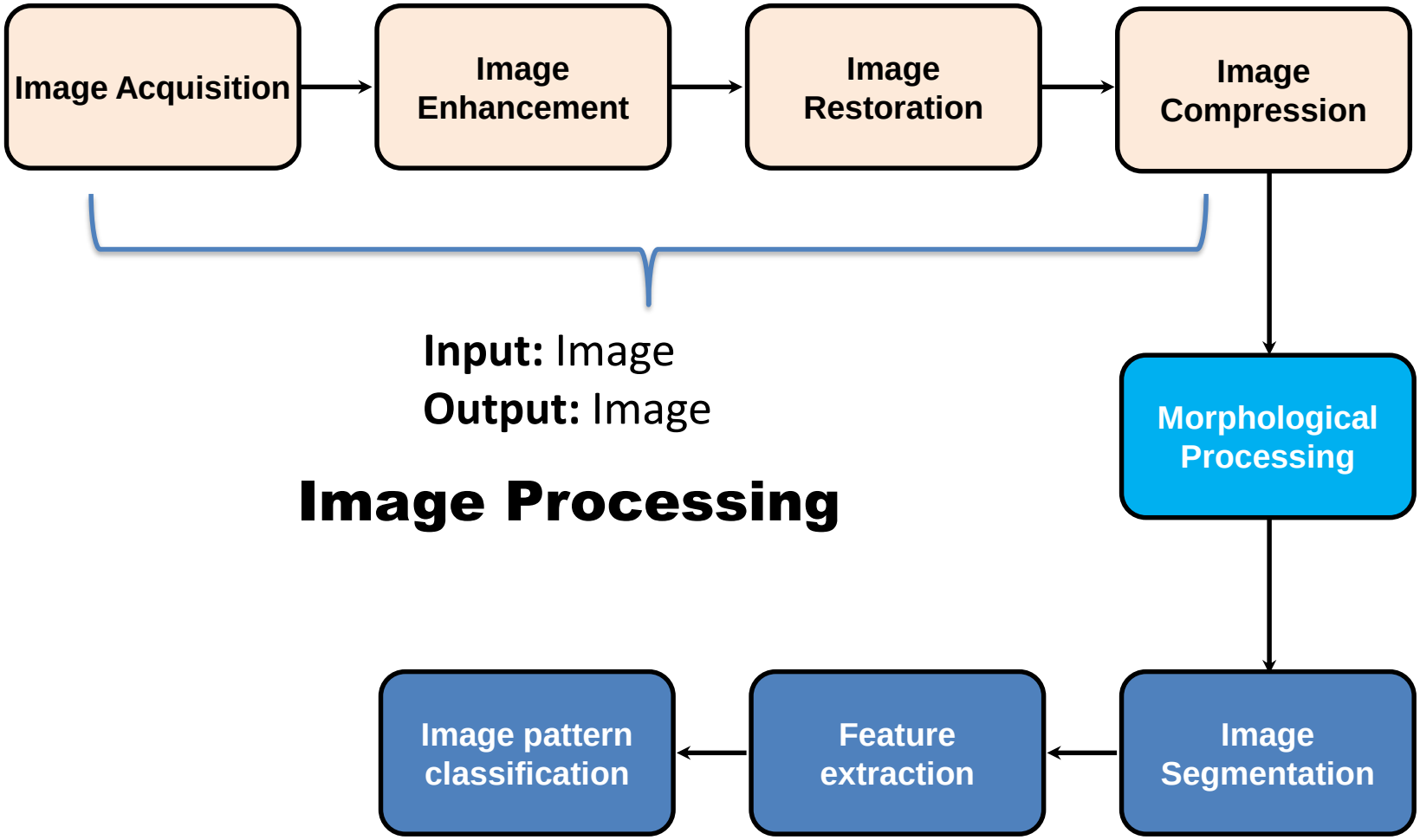
Image enhancement Vs. Image restoration

	Image Enhancement	**Image Restoration**
1.	As the name suggests, in Image Enhancement, the original image is processed so that the resultant image is more suitable than the original for specific applications.	The aim of image restoration is to bring the image towards what it would have been if it had been recorded without degradation.
2.	Image enhancement makes a picture look better, without regard to how it really truly should look.	Image restoration tries to fix the image to get back to the real, true image.
3.	Image enhancement means improving the image to show some hidden details.	Image restoration means improving the image to match the original image.
4.	Image enhancement is a purely subjective processing technique.	Image restoration is an objective process.
5.	Image enhancement is a cosmetic procedure i.e. it does not add any extra information to the original image. It merely improves the subjective quality of the images by work in with the existing data.	Restoration tries to reconstruct by using a priori knowledge of the degradation phenomena. Restoration hence deals with getting an optimal estimate of the desired result

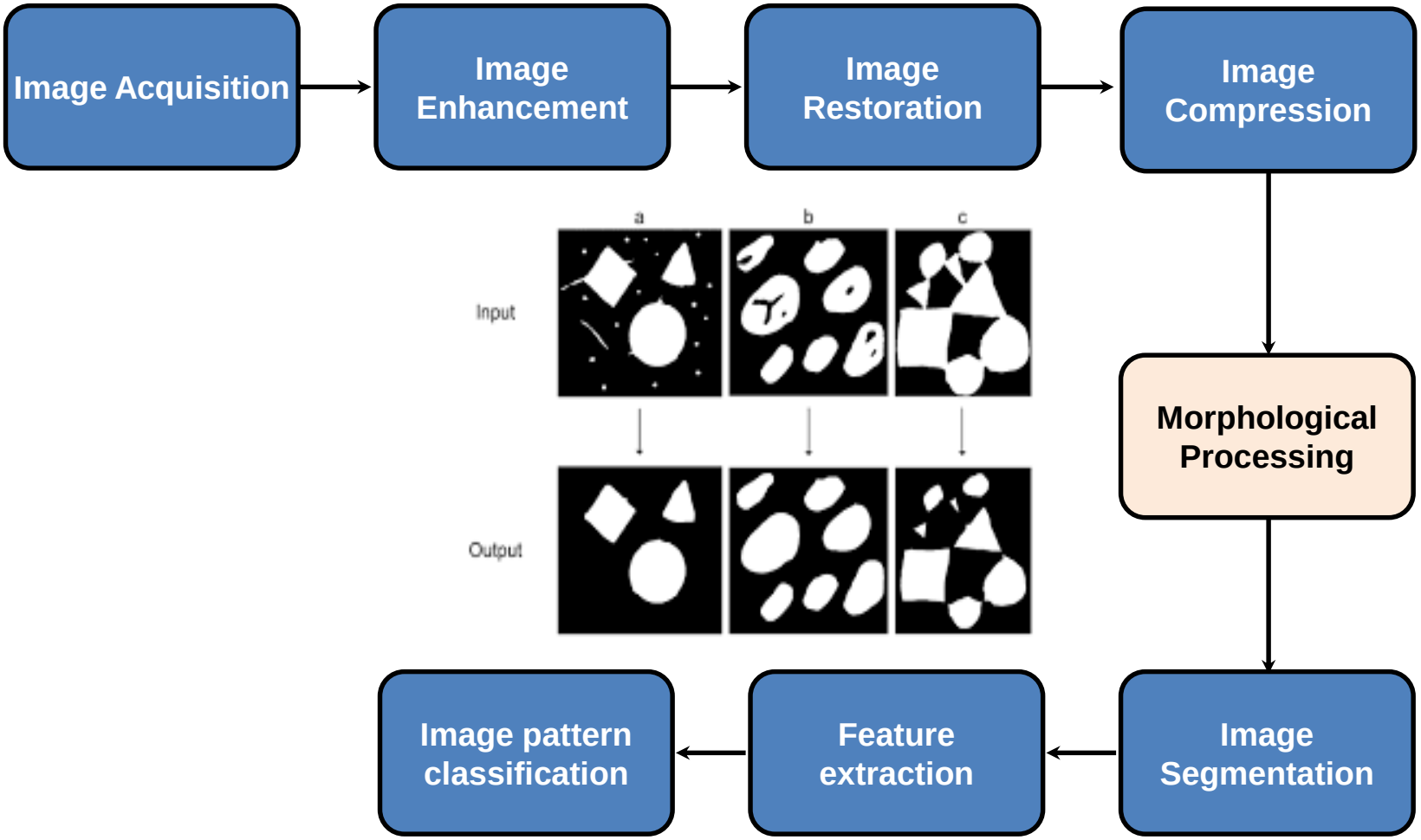
Key Stages in DIP



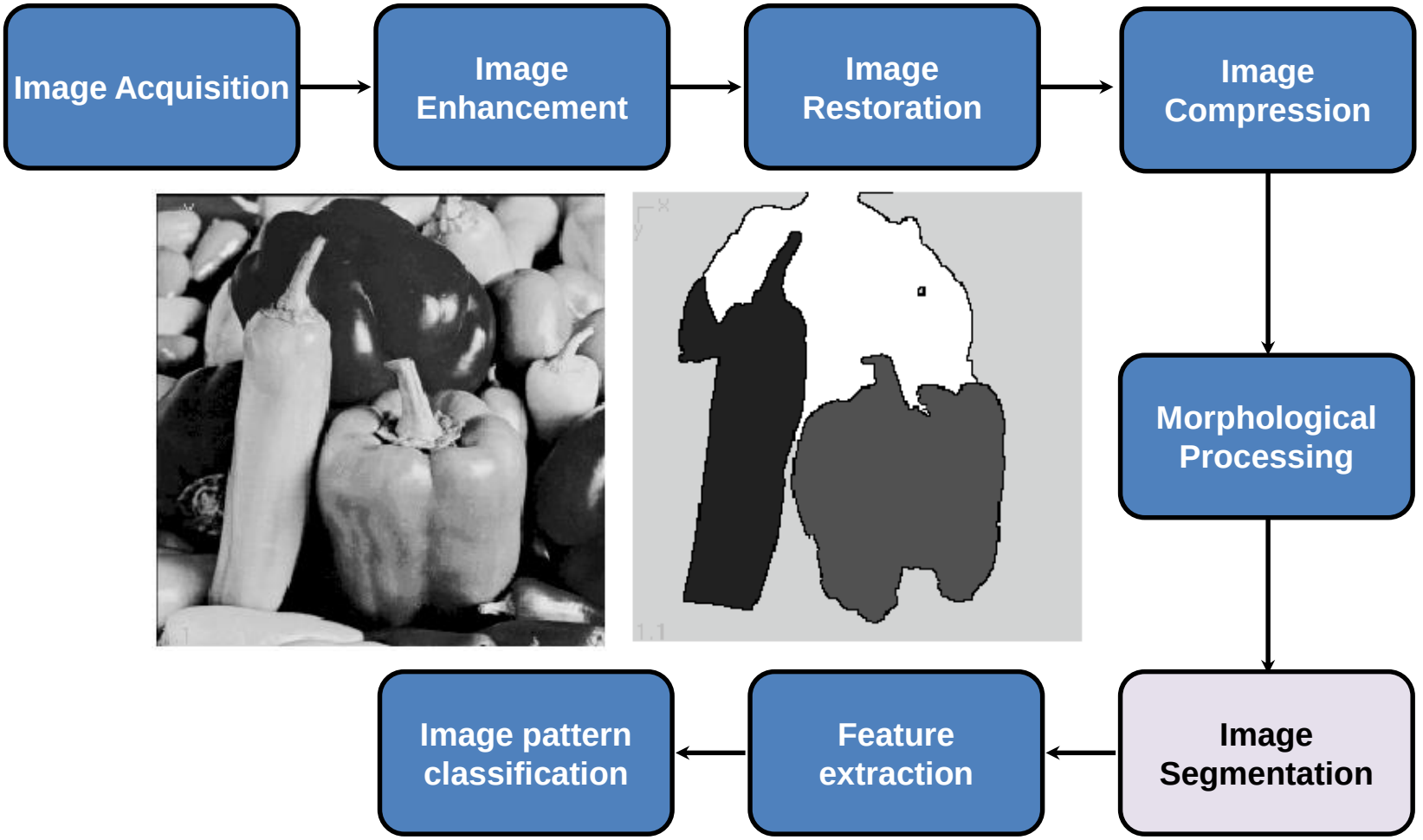
Key Stages in DIP



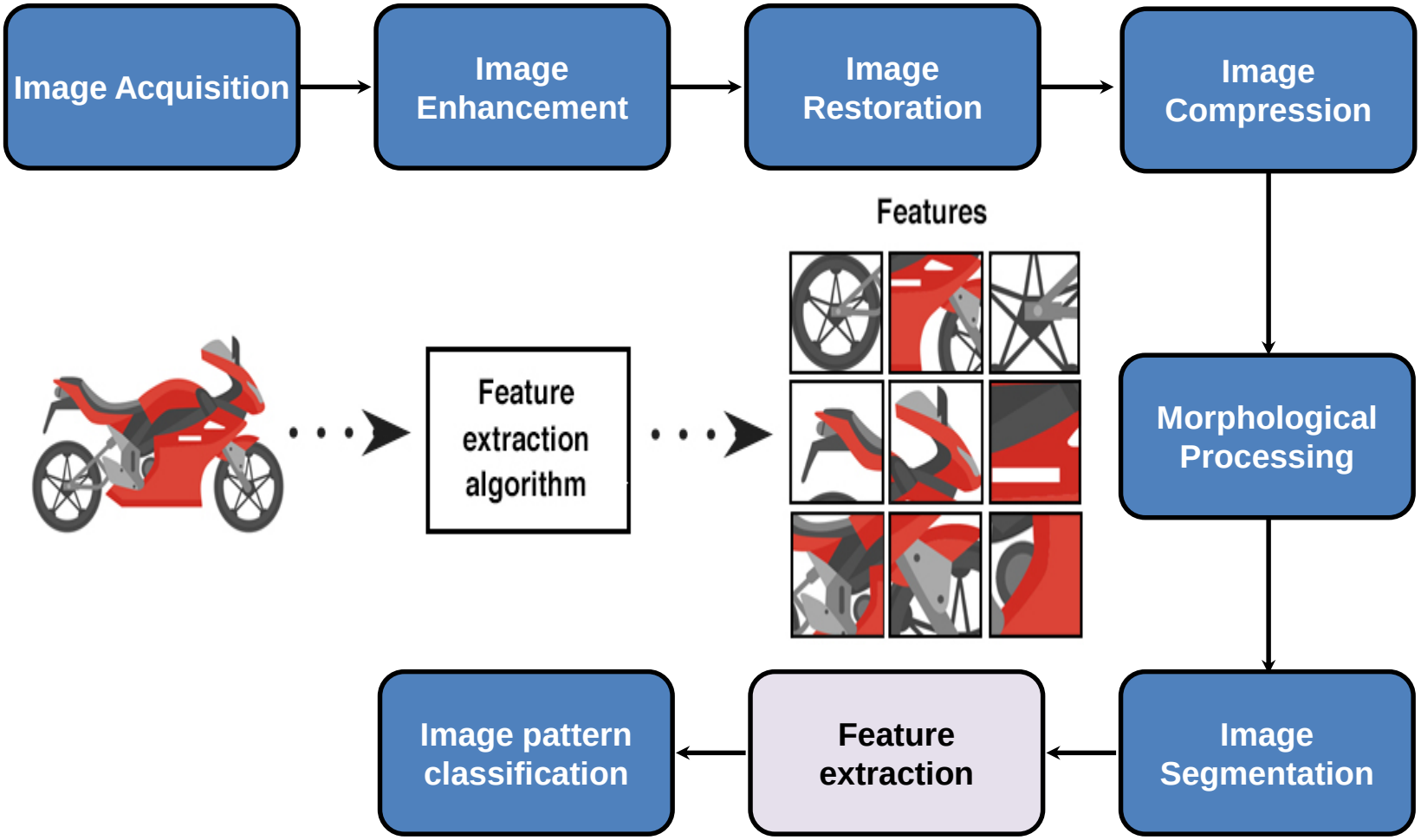
Key Stages in DIP



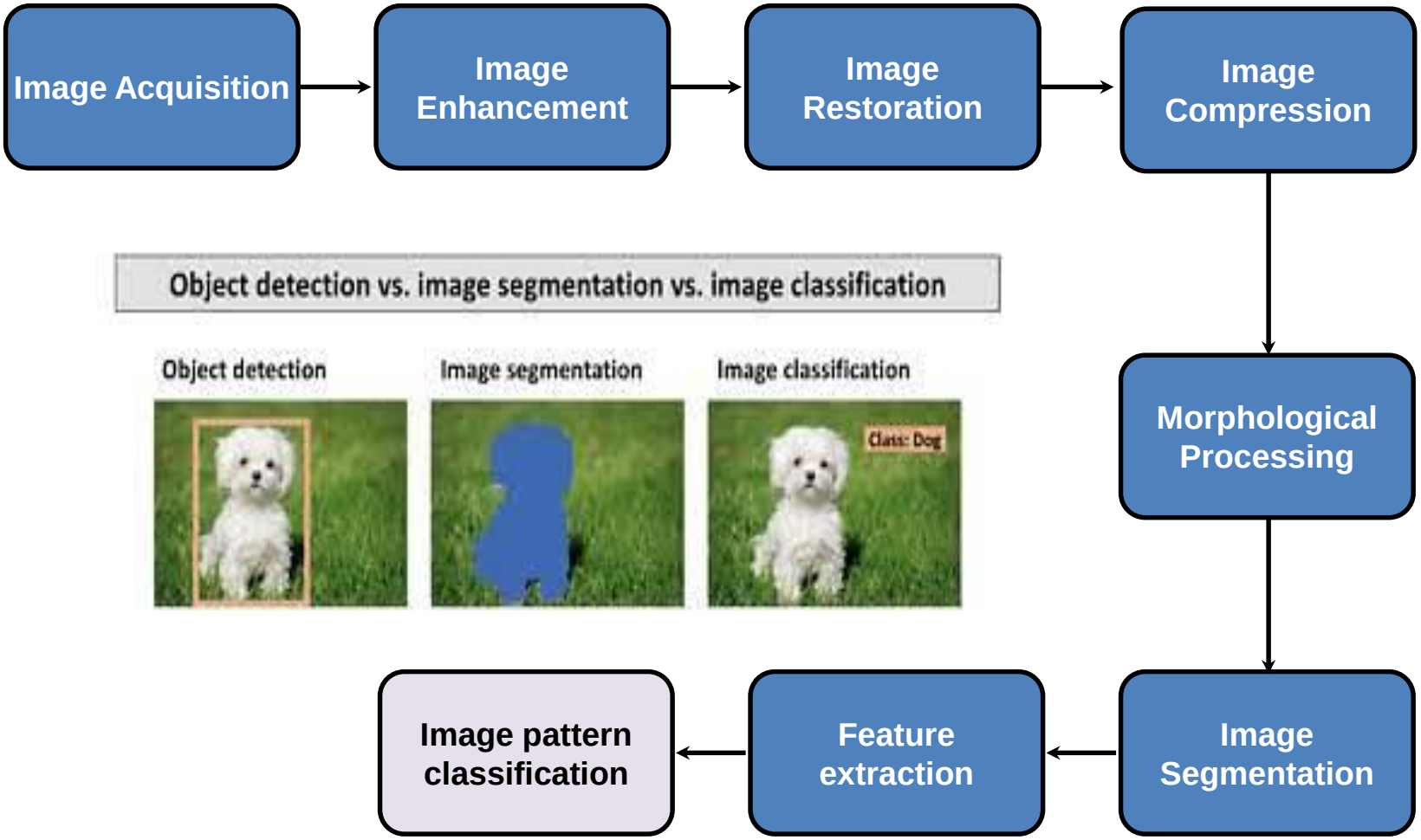
Key Stages in DIP



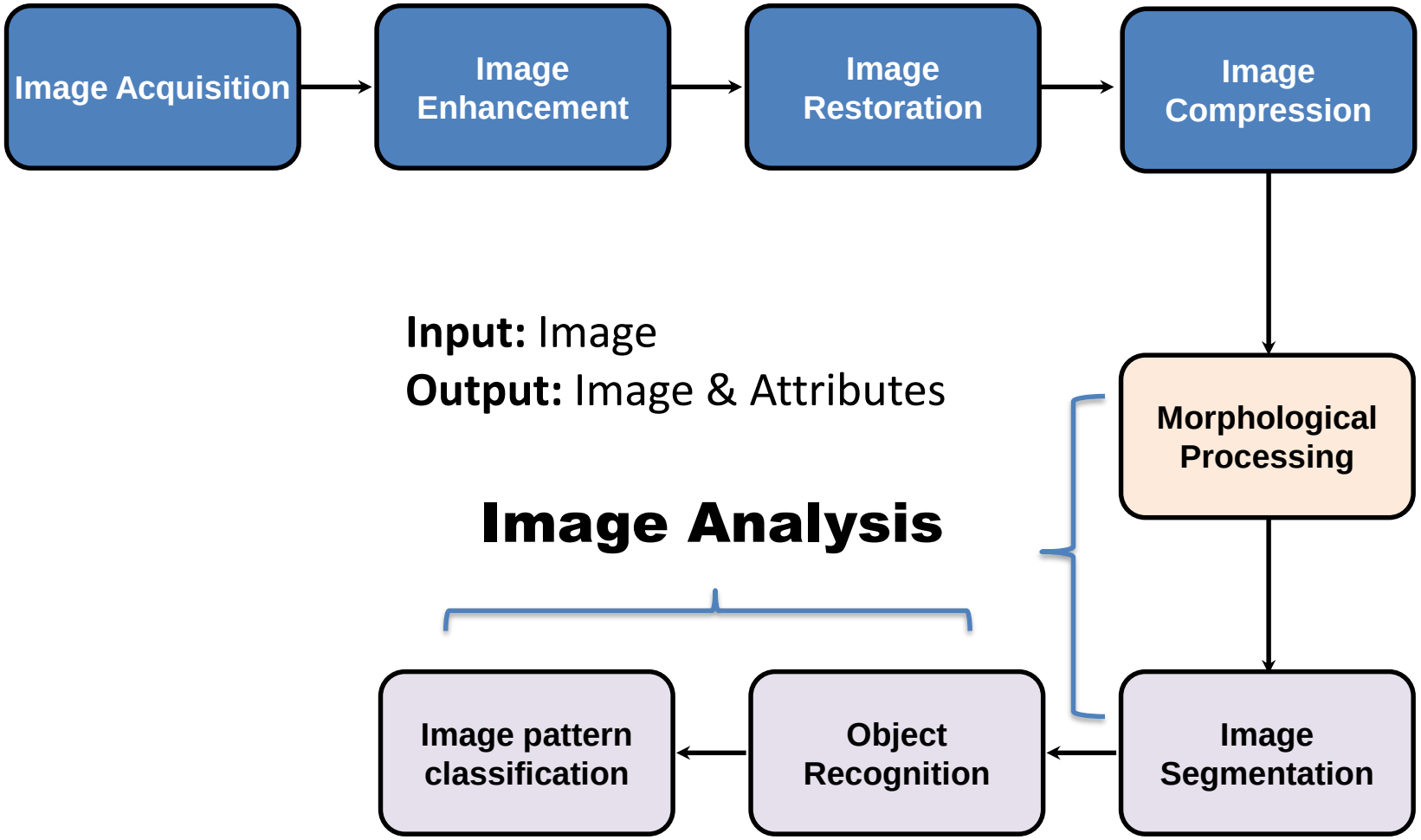
Key Stages in DIP



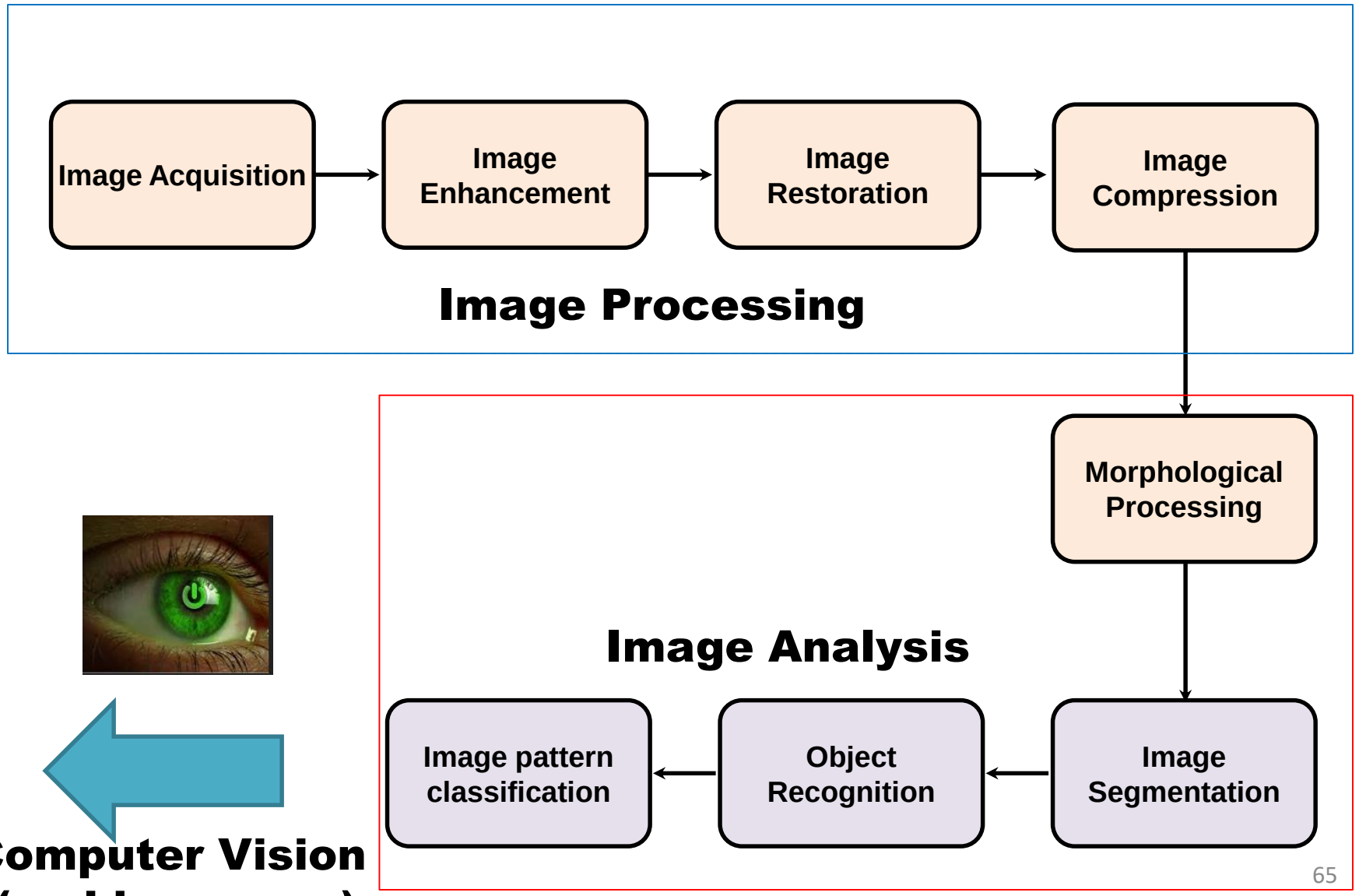
Key Stages in DIP



Key Stages in DIP



Key Stages in DIP



Tentative Schedule

Wk	Topic
1	Introduction to CS370 Fundamentals of Computer Imaging
2	Image Representation and Operations
3	Intensity Transforms Histogram - 1
4	Histogram - 2
5	Spatial Filtering Sharpening Filter
6	Filtering In Frequency Domain – 1
7	Filtering In Frequency Domain - 2 **MIDTERM**
8	Discrete Fourier Transform
9	Convolution, Procedure of Filtering in Frequency Domain
10	Image Smoothing/Sharpening in Frequency Domain
11	Color Image Processing – 1
12	Color Image Processing - 2 Image Restoration
13	Image Compression
14	Review
15	**FINAL**

Next Lecture

- Goal of Image Processing
- Human Visual System
- Image Acquisition
- Digital Image Representation
- Image Sampling And Quantisation
- Image Resolution