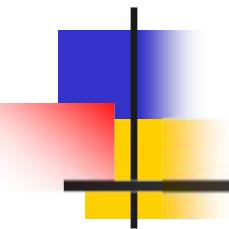


Pattern Recognition and Digital Image Processing (ADIP)

CSE-4875



Dept. of Computer Science & Engineering
International Islamic University Chittagong (IIUC)

Md. Khaliluzzaman

About Myself

- Instructor name : Md. Khaliluzzaman
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- Phone :
017-11-199212(only in emergency)

Requirements

- Prerequisites
 - Data Structures and Algorithms
 - Linear Algebra, Basic probability theory
 - Experience with Matlab or C Programming Language
- Text
 - Digital Image Processing by R. C. Gonzalez and R. E. Woods (2nd or 3rd Ed.)
 - Any other book with a similar title is fine
 - Web is the best and greenest “textbook”
- References
 - will be given in the class

Expected Work

- Lectures
- Assignments
 - Scientific papers (*IEEE Transactions, IJCV, PAMI, Pattern Recognition and so on*) presentations (by students)
 - Programming assignments with class presentations (by students)

Mid-term Syllabus

Chapter	Topics & Contents
1st Chapter	Introduction to DIP
2nd Chapter	Digital Image Fundamentals
3rd Chapter	Image Enhancement & Processing

Introduction

"One picture is worth more than ten thousand words"

Anonymous

Goal

- Understand various basic image processing concepts and algorithms
- Grasp the basics of digital image processing and its connections to other scientific and technological fields such as psychology, morphology, photography and so on

Contents

This lecture will cover:

- What is a digital image?
- What is digital image processing?
- History of digital image processing
- State of the art examples of digital image processing
- Key stages in digital image processing

Goal of Image Processing

Visualization

Enhancement, 3-D display



Quantification

Quantification, measurement

Automation

Minimize human intervention
Flow cytometry

The Birth of Digital Computers

- What do we mean by *Digital Image Processing*
 - **Processing digital images by a digital computer**
- DIP has been dependent on the development of digital computers and other supporting technologies (e.g., data storage, display and transmission)

Definition

Definition:

The term ‘image processing’ means modifying images such that they are either:

--- correction for errors introduced during acquisition or transmission ('restoration').

--- enhanced to overcome the weaknesses of the human visual system ('enhancement').

Finally,

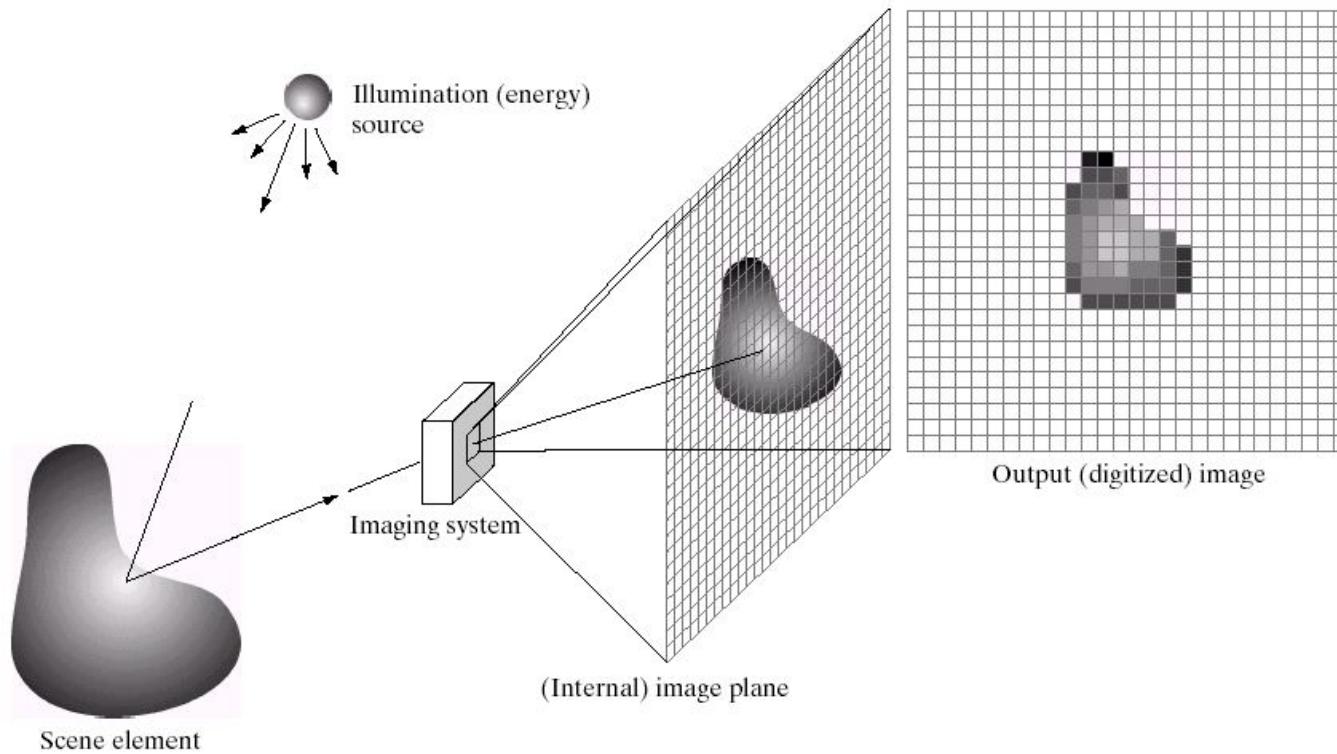
‘a process which takes an image input and generates a modified image output’

Review Question:

What is image and image processing?

What is a Digital Image?

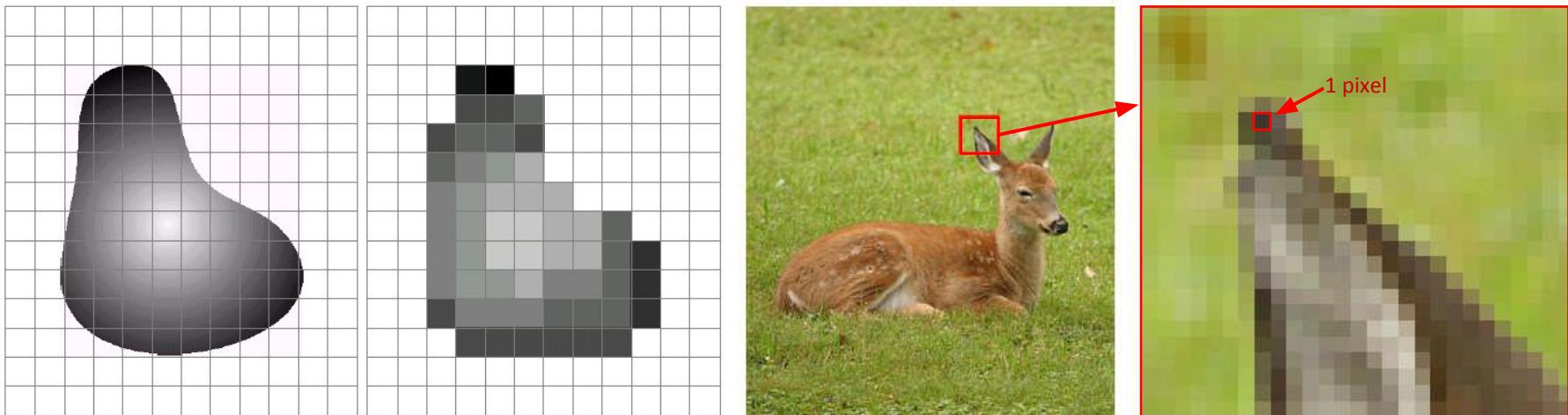
A **digital image** is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels



What is a Digital Image? (cont...)

Pixel values typically represent gray levels, colours, heights, opacities etc

Remember *digitization* implies that a digital image is an *approximation* of a real scene



What is a Digital Image? (cont...)

Common image formats include:

- 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)



grey-scale images

What is Digital Image Processing?

Digital image processing focuses on two major tasks

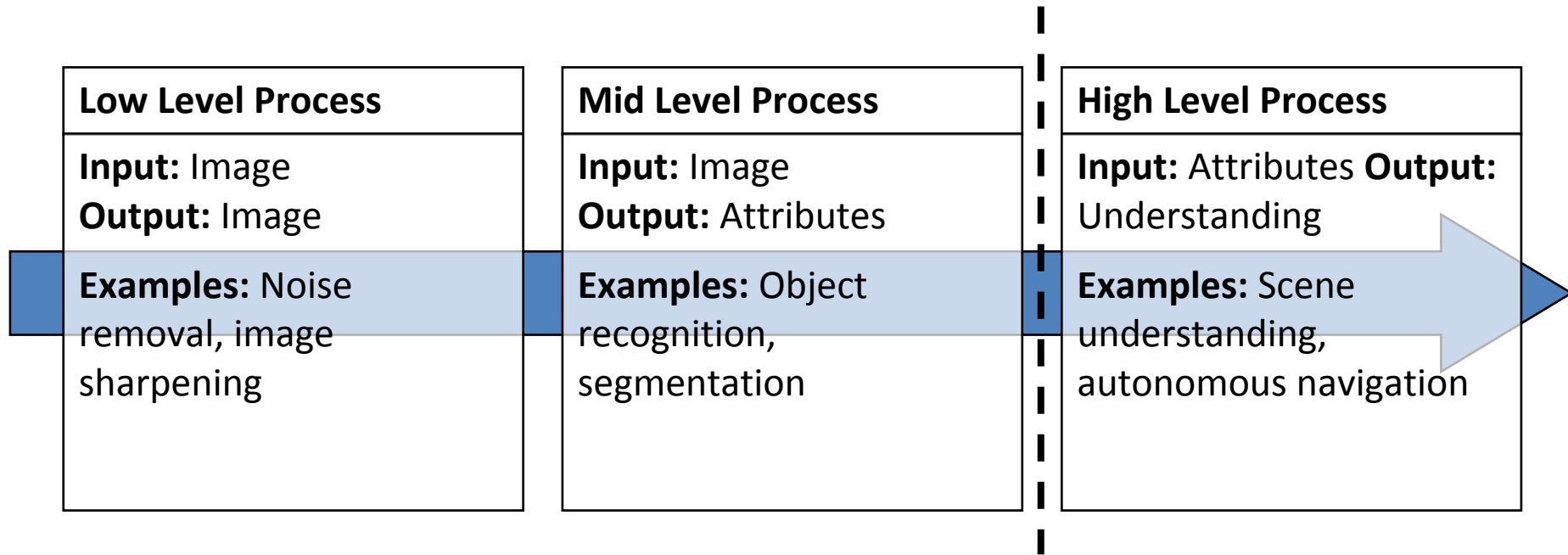
Improvement of pictorial information for human interpretation

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

Some argument about where image processing ends and fields such as image analysis and computer vision start

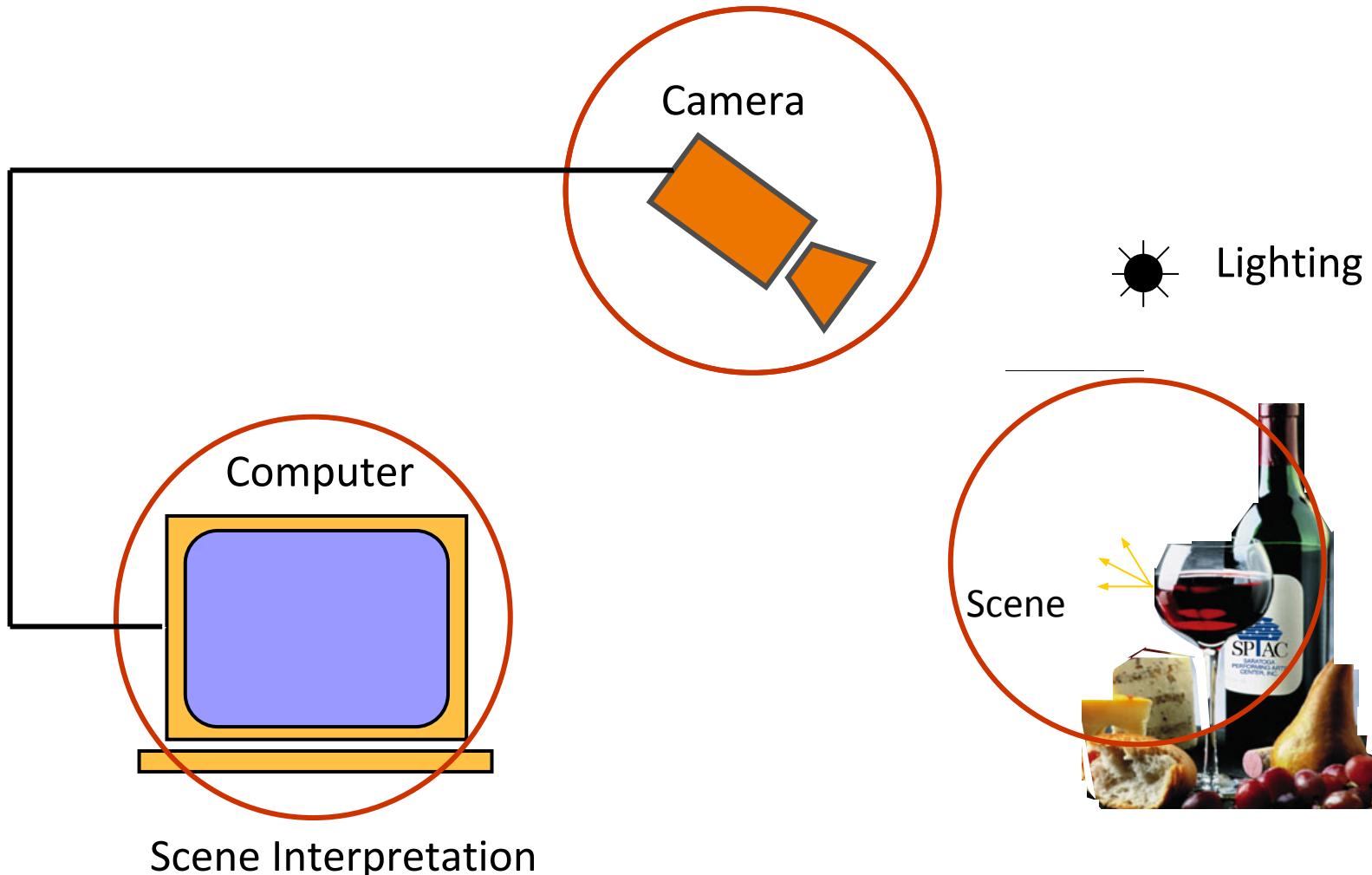
What is DIP? (cont...)

The continuum from image processing to computer vision can be broken up into low-, mid- and high-level processes



In this course we will stop here

Components of a DIP/computer vision system



Computer vision vs human vision

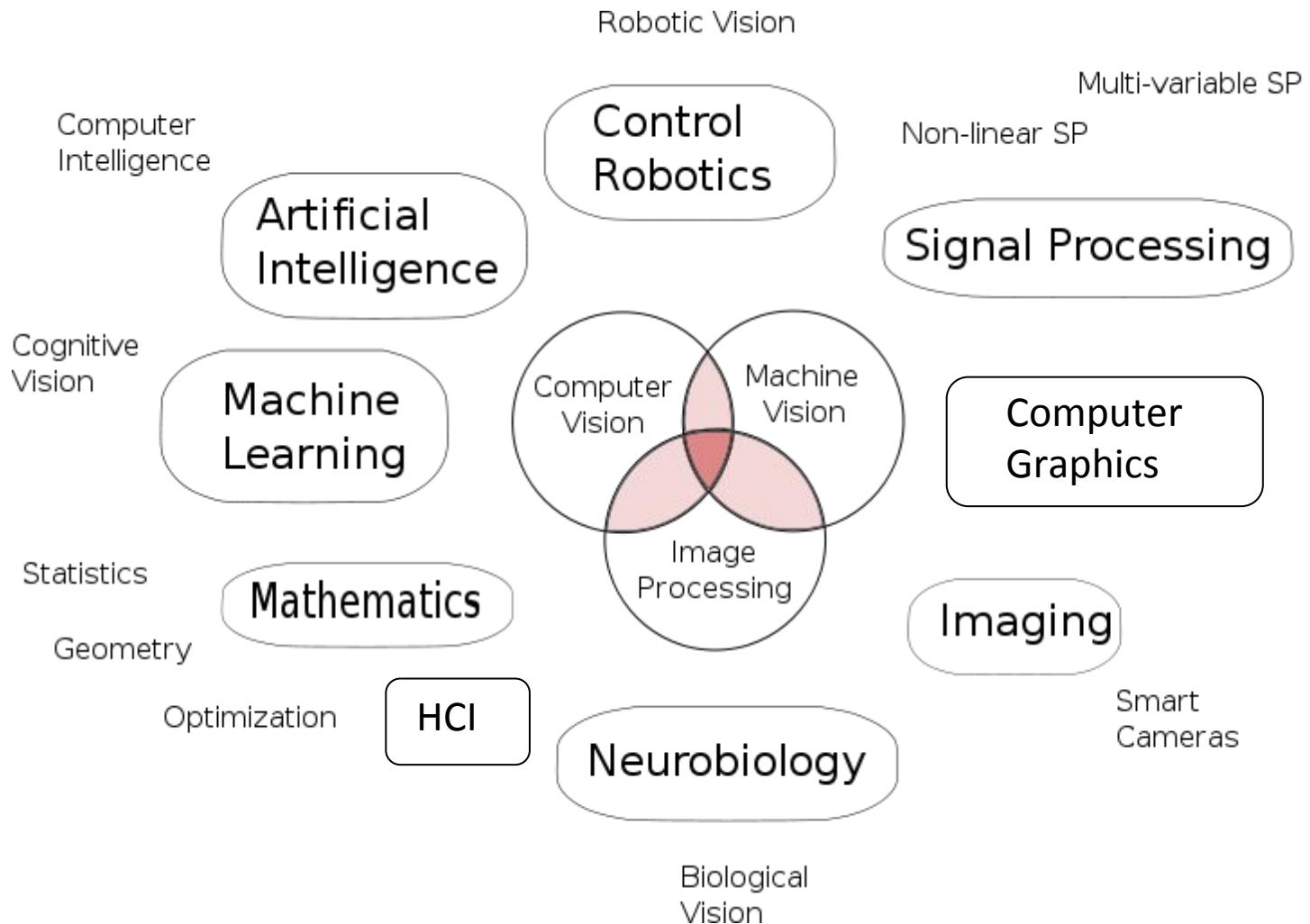


What we see

0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

What a computer sees

DIP/Vision is multidisciplinary

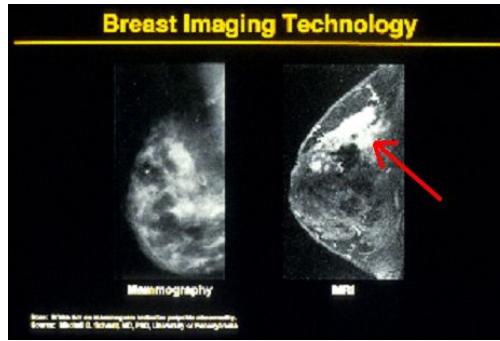


From wiki

Why computer vision/DIP matters



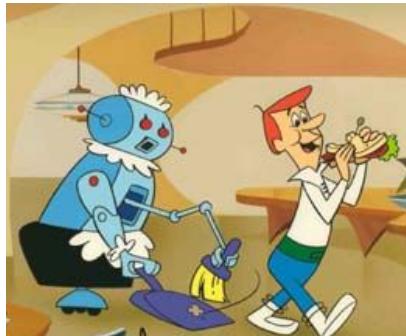
Safety



Health



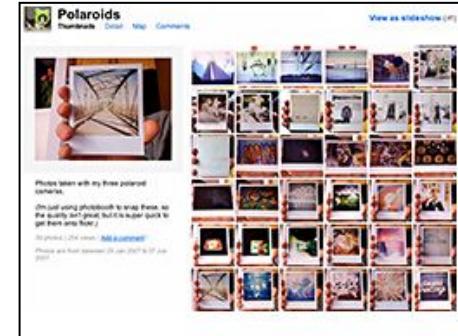
Security



Comfort



Fun



Access

History of Digital Image Processing

Early 1920s: One of the first applications of digital imaging was in the newspaper 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

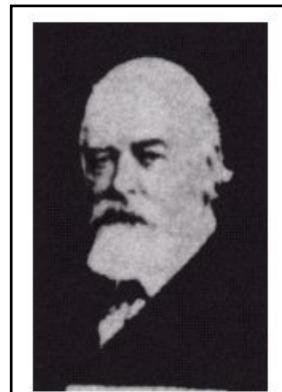


History of DIP (cont...)

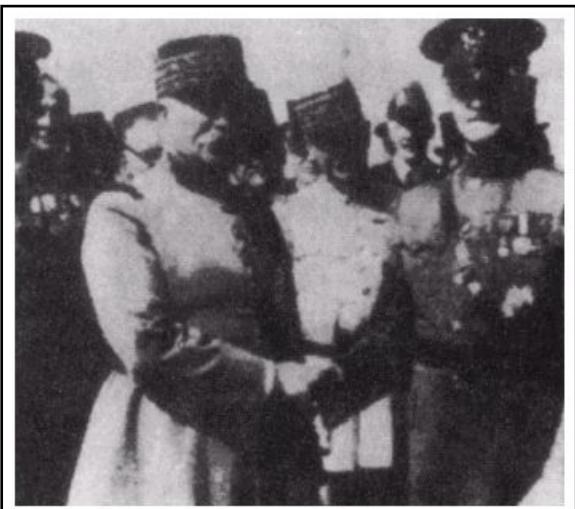
Mid to late 1920s: Improvements to the Bartlane system resulted in higher quality images

New reproduction processes based on photographic techniques

Increased number of tones in reproduced images



Improved digital image

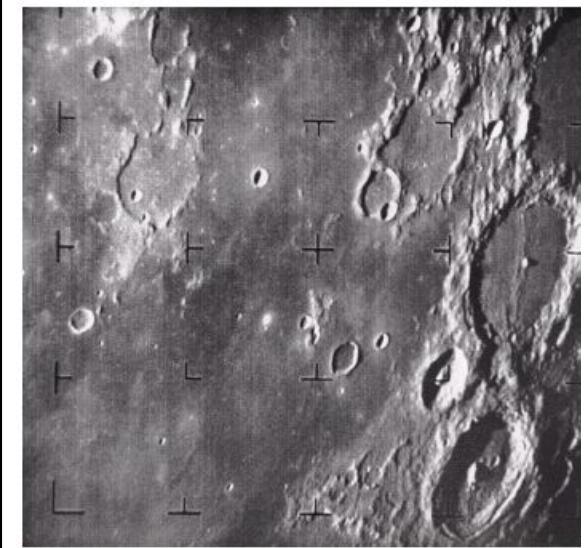


Early 15 tone digital image

History of DIP (cont...)

1960s: Improvements in computing technology and the onset of the space race led to a surge of work in digital image processing

1964: Computers used to improve the quality of images of the moon taken by the *Ranger 7* probe. Such techniques were used in other space missions including the Apollo landings



A picture of the moon taken by the Ranger 7 probe minutes before landing

History of DIP (cont...)

1970s: Digital image processing begins to be used in medical applications

1979: Sir Godfrey N. Hounsfield & Prof. Allan M. Cormack share the Nobel Prize in medicine for the invention of tomography, the technology behind Computerised Axial Tomography (CAT) scans



Typical head slice CAT image

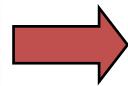
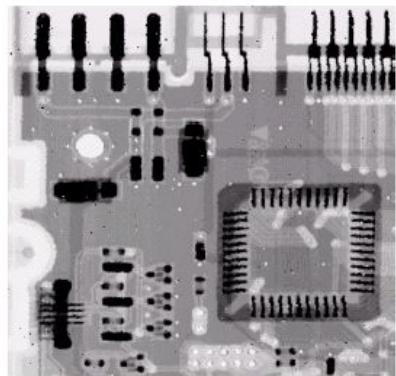
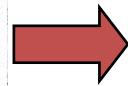
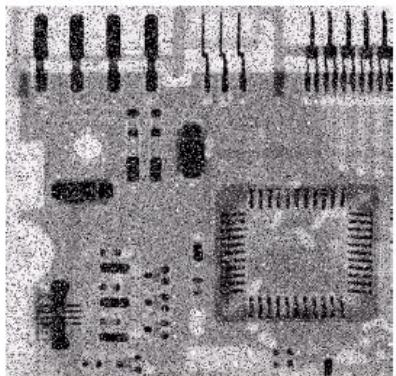
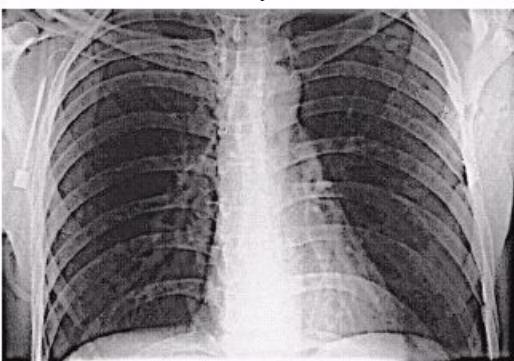
History of DIP (cont...)

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

Examples: Image Enhancement

One of the most common uses of DIP techniques: improve quality, remove noise etc

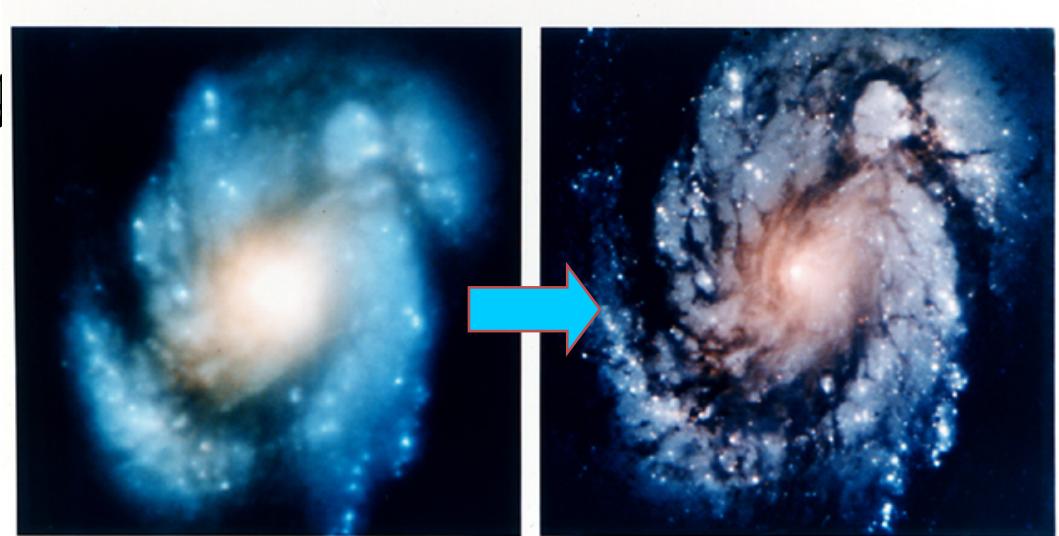


Examples: The Hubble Telescope

Launched in 1990 the Hubble telescope can take images of very distant objects

However, an incorrect mirror made many of Hubble's images useless

Image processing techniques were used to fix this



Wide Field Planetary Camera 1

Wide Field Planetary Camera 2

Examples: Artistic Effects

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

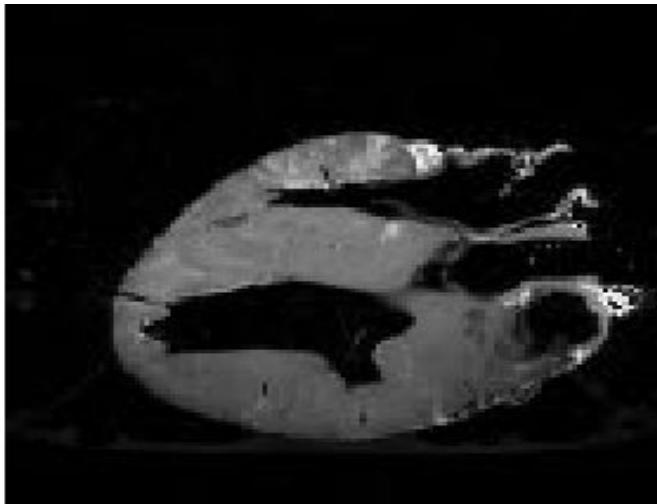


Examples: Medicine

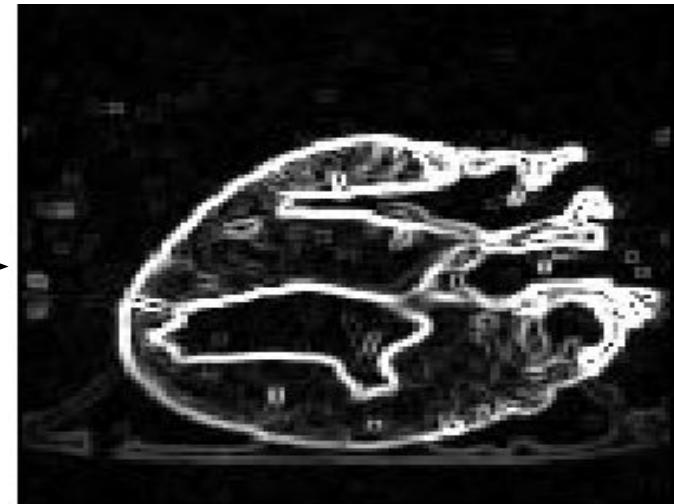
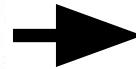
Take slice from MRI scan of canine heart, and find boundaries between types of tissue

Image with gray levels representing tissue density

Use a suitable filter to highlight edges



Original MRI Image of a Dog Heart



Edge Detection Image

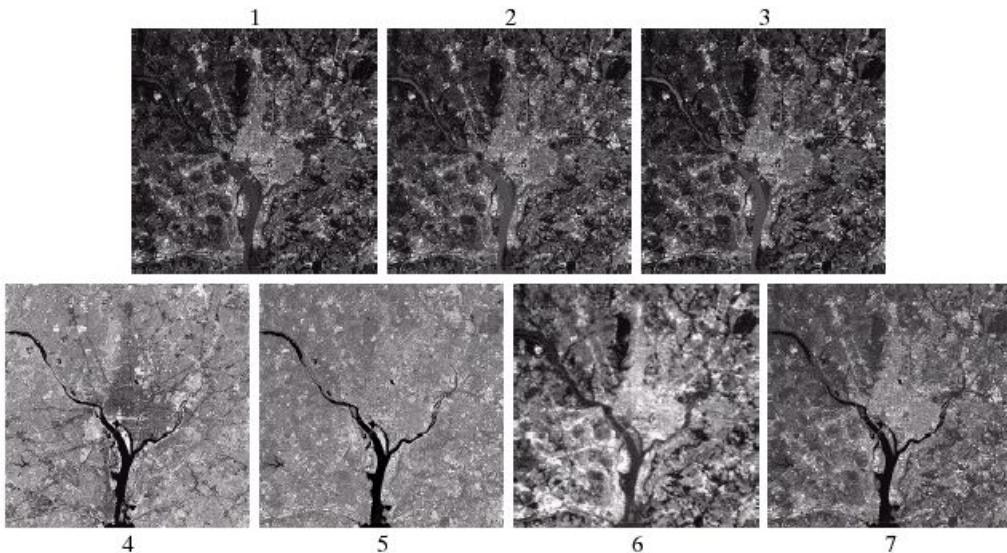
Examples: GIS

Geographic Information Systems

Digital image processing techniques are used extensively to manipulate satellite imagery

Terrain classification

Meteorology

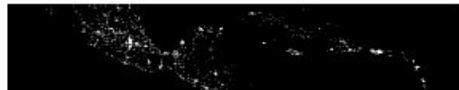
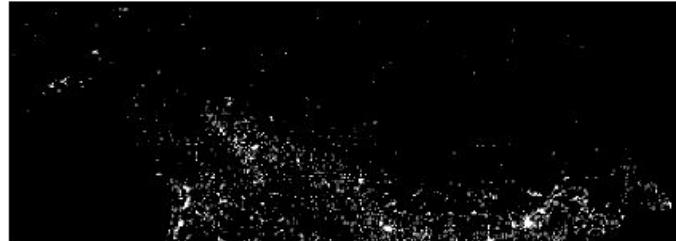


Examples: GIS (cont...)

Night-Time Lights of the World data set

Global inventory of human settlement

Not hard to imagine the kind of analysis
that might be done using this data



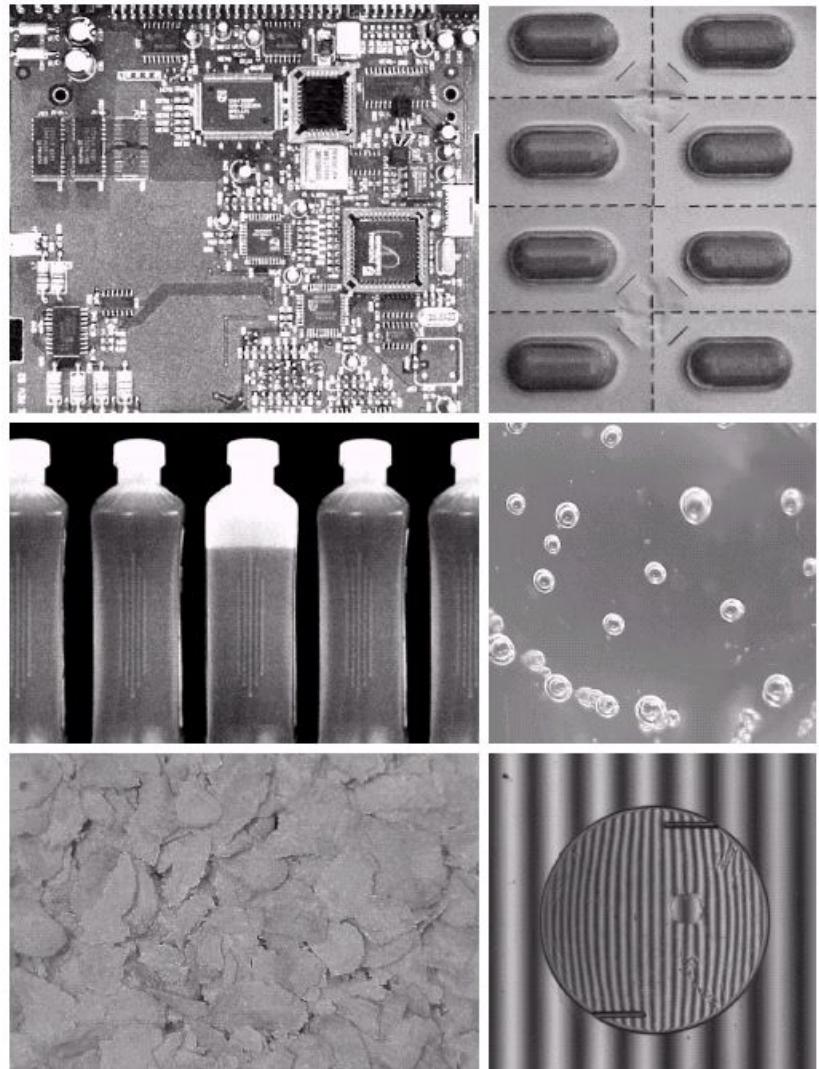
Examples: Industrial Inspection

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?

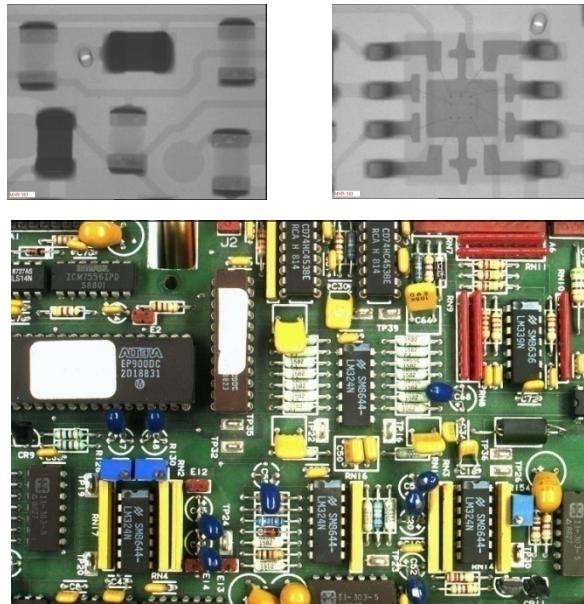


Examples: PCB Inspection

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



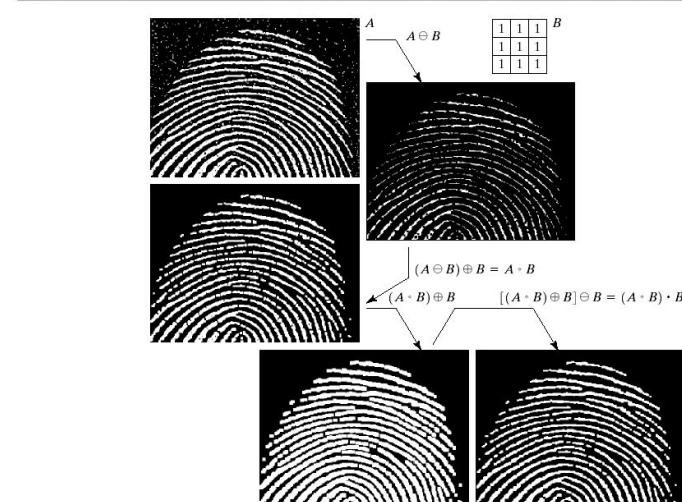
Examples: Law Enforcement

Image processing techniques
are used extensively by law
enforcers

Number plate recognition for speed
cameras/automated toll systems

Fingerprint recognition

Enhancement of CCTV images



Examples: HCI

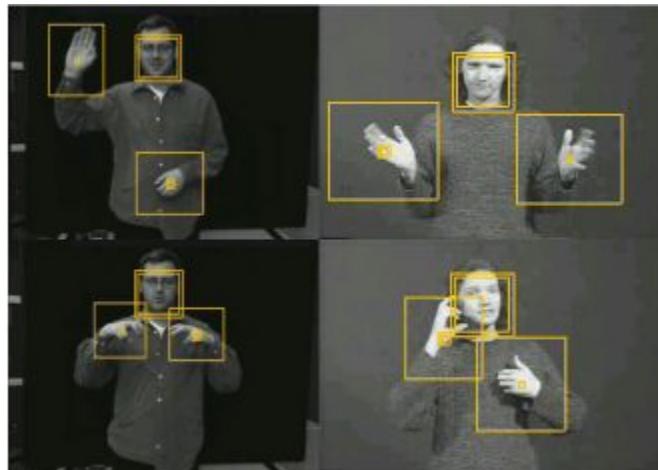
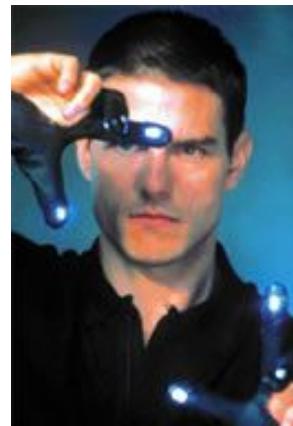
Try to make human computer interfaces more natural

Face recognition

Gesture recognition

Does anyone remember the user interface from “Minority Report”?

These tasks can be extremely difficult



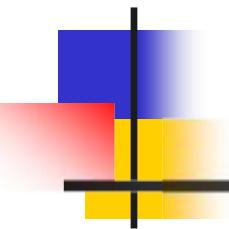


Image Processing and Analysis

**One picture is worth more than
ten thousand words**

The first photograph in the world



Joseph Nicéphore Niépce, *View from the Window at Le Gras*, 1826.

Images Application Area

- **Satellite Imagery**

- Meteorological, agricultural, environmental, military

- **Aerial Imagery:** Crop inspection, cartography

- **Printing and hand writing:** postal code reading

- **Bar codes:** also on documents, biochemical samples

- **Radiology:** X-ray, CT, MRI, Ultrasound, etc.

- **Karyotyping:** chromosome paring

- **Cytology and histology:** microscopic cell imaging

- **Digital Camera**

Applications areas

Application areas:

1. Industrial machine vision applications.

- Automated visual inspection.
- Process control.
- Parts identification.
- Robotic guidance and control.

2. Space exploration.

3. Astronomy.

4. Diagnostic medical imaging.

- Medical image processing
- Medical image reconstruction

Application areas

5. Scientific analysis
6. Military guidance and reconnaissance/investigation
7. Remote sensing
 - Meteorology
 - Natural resource location
 - Environmental monitoring
 - Cartography
8. Information technology system (DIP- document image processing)
 - Image data compression
 - Analysis of document content
9. Telecommunications
 - Facsimile
 - Videotext
 - Video conferencing and video phones

Application areas

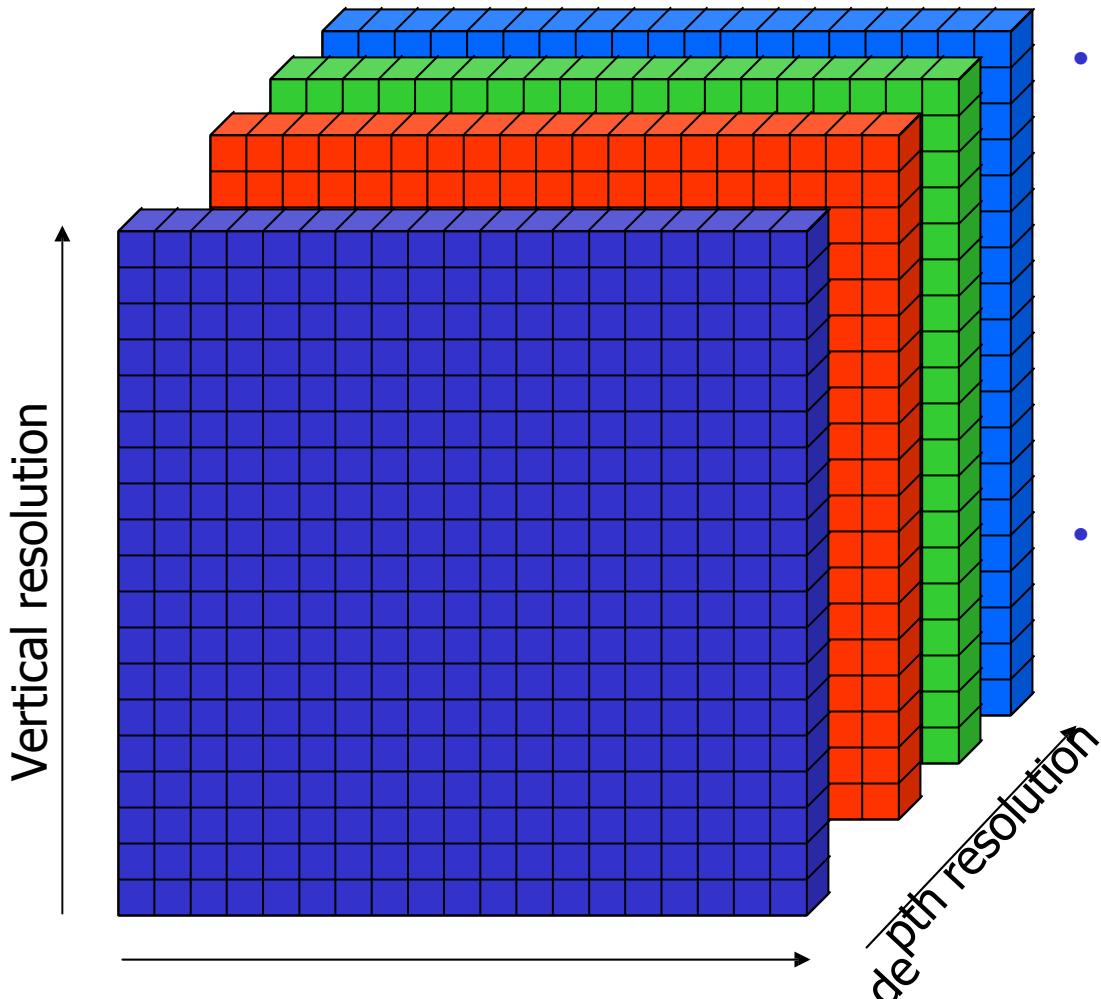
10. Security, surveillance and law enforcement

- Verification of identity
- Monitoring and surveillance
- Forensic investigations

11. Entertainment and consumer electronics

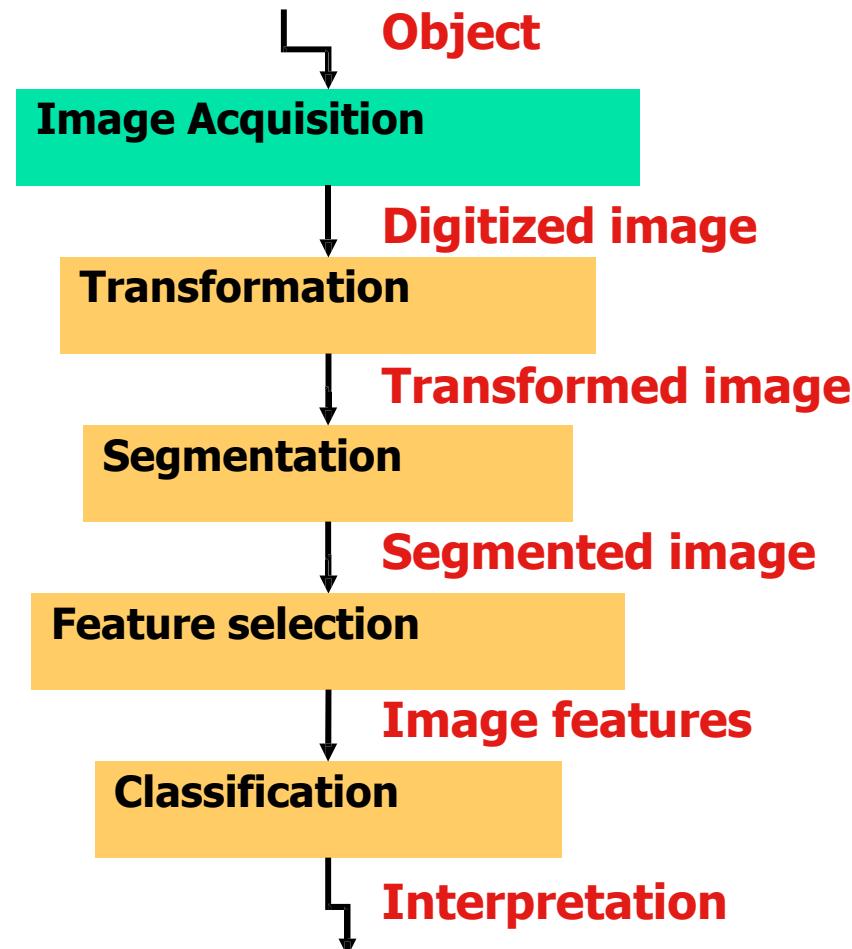
12. Printing and the graphics arts

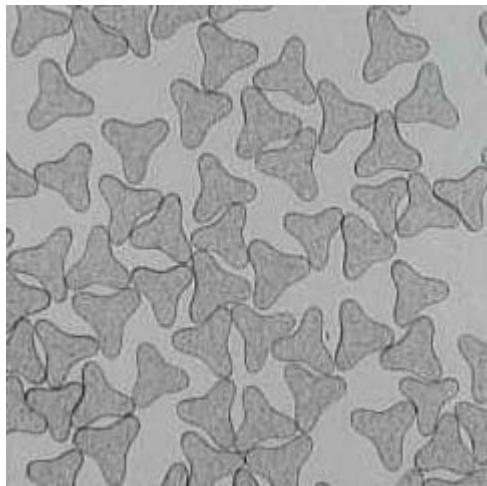
Image Format



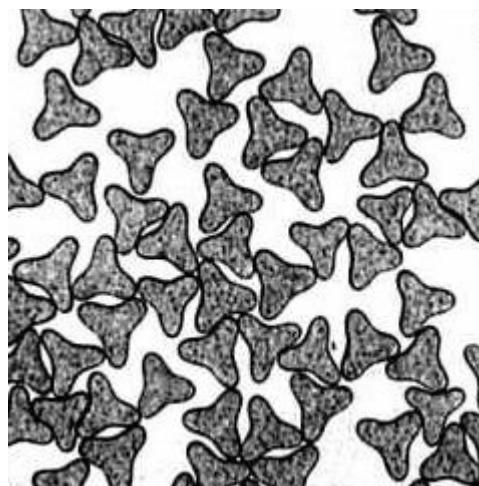
- **Spatial resolution**
 - horizontal/vertical
 - **256×256, 512×512**
 - **1024×768, 1280 ×1024**
 - **2048×2048**
 - **1800×1200**
- **Depth resolution**
 - B/W: **8bits, 12bits**
 - Color: **24bits(true color)** **16bits(high color)**
 - 8 bits (256colors)**

Image Processing Steps





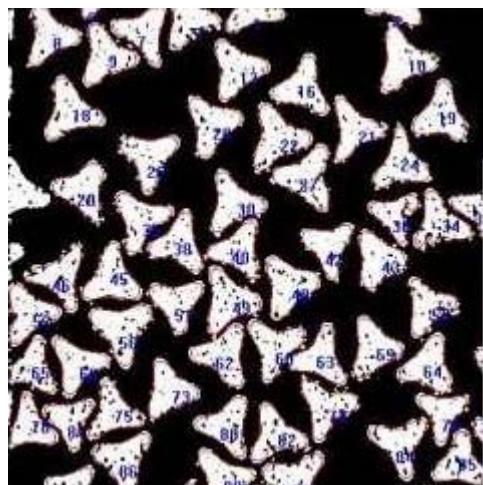
Cross-sections of fibers



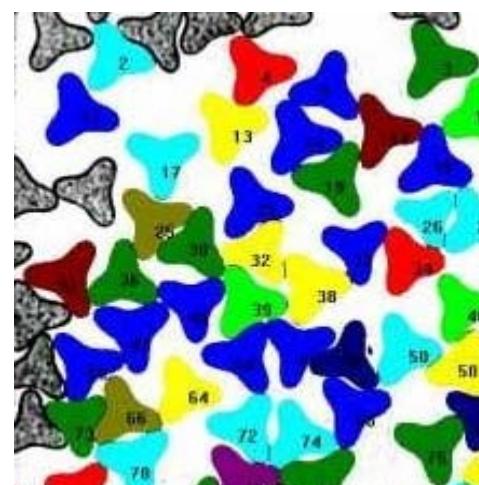
High-pass filtering



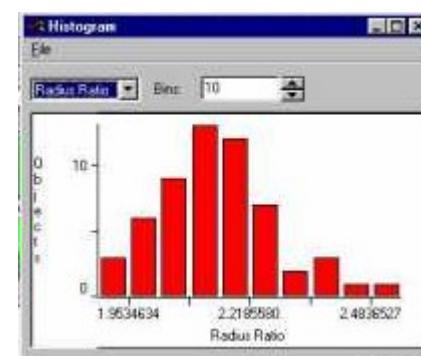
Segmentation



Area measurement

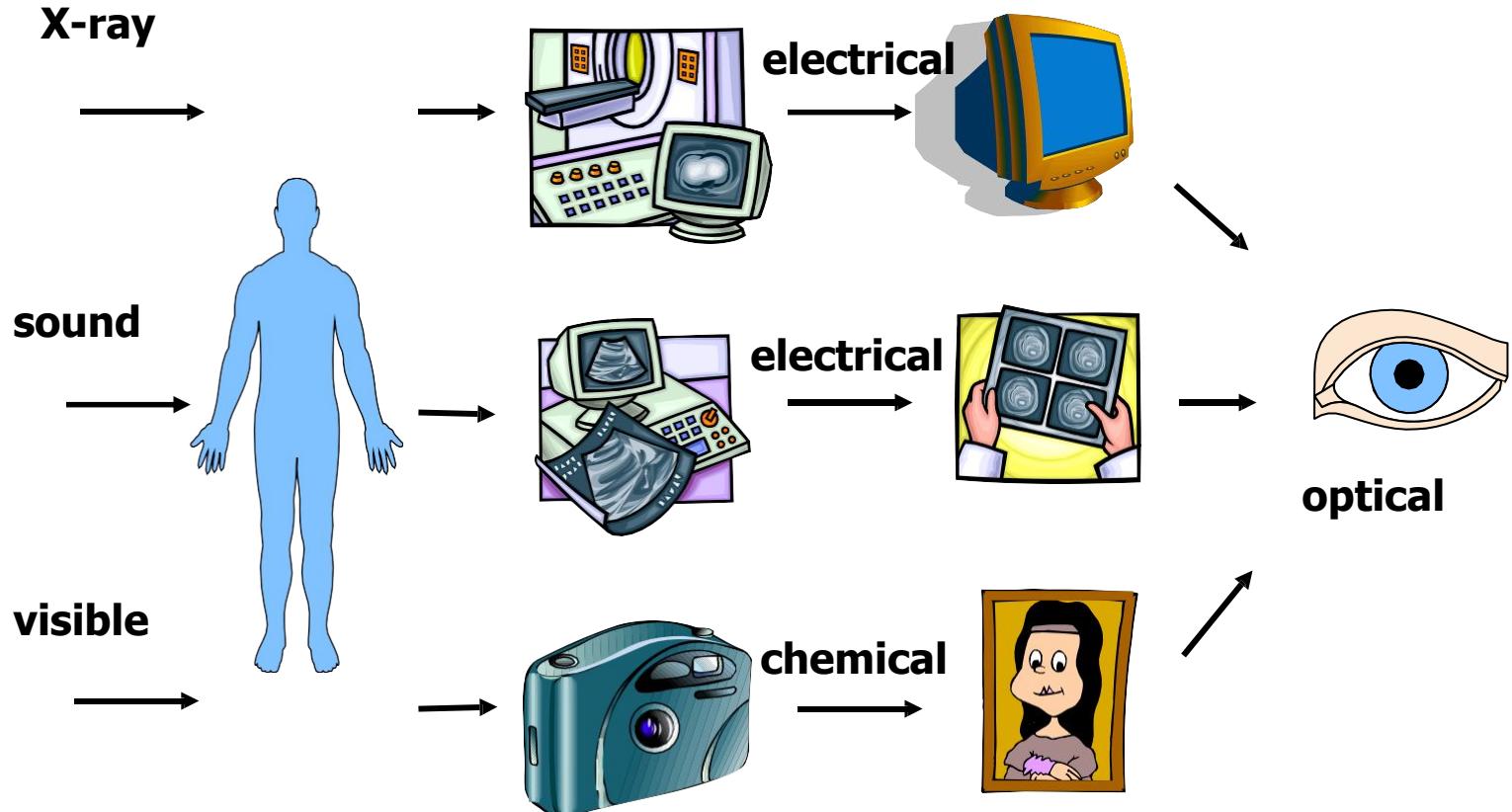


Classification

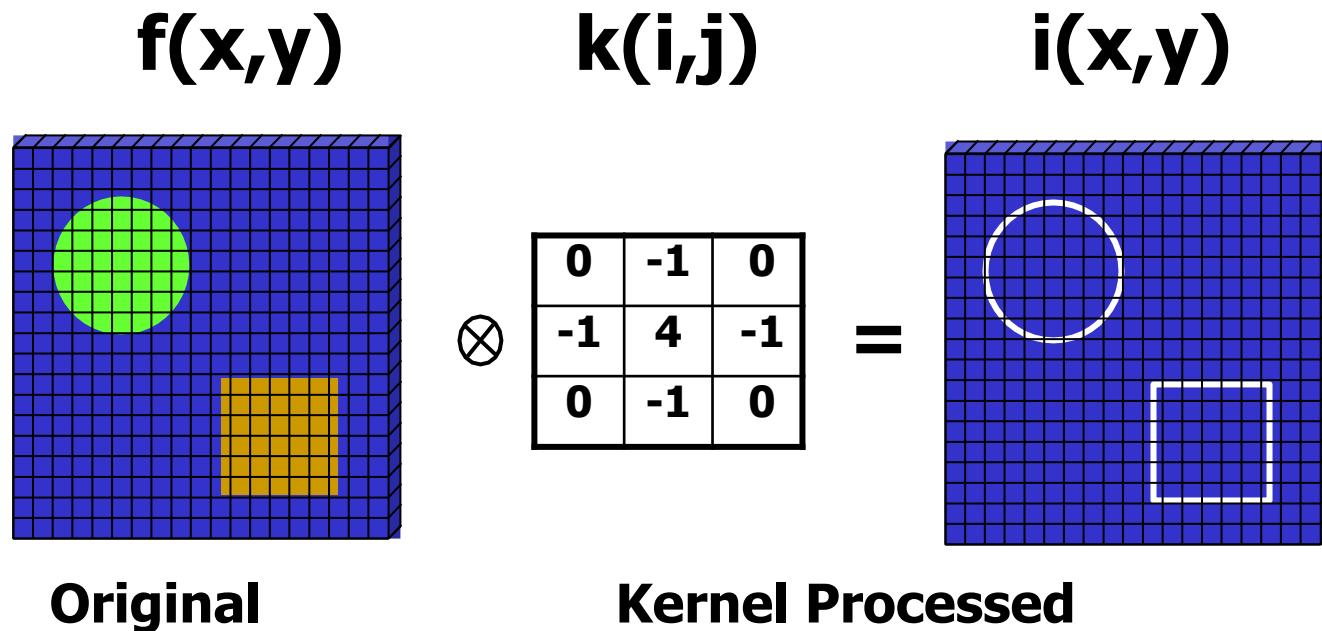


Quantification

1. Image Acquisition



2. Local Transformation



$$i(x,y) = \sum \sum k(i,j) f(x+i, y+j)$$

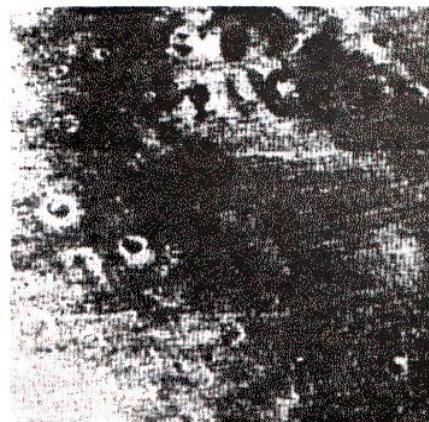
3. Image Restoration



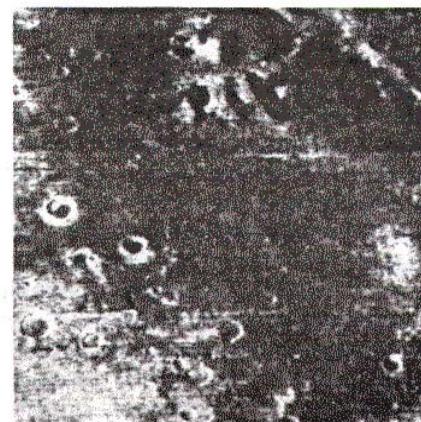
(a)



(b)



(c)



(d)

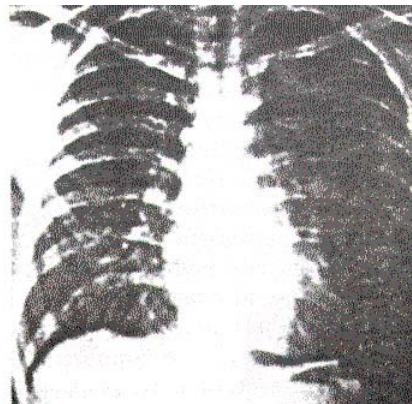
- **Correction for the degradation**
- **Based on a model**
- **Improve quality**
 - for visual inspection
 - for further processing

denoising

Image Restoration



(e)



(f)



(g)



(h)

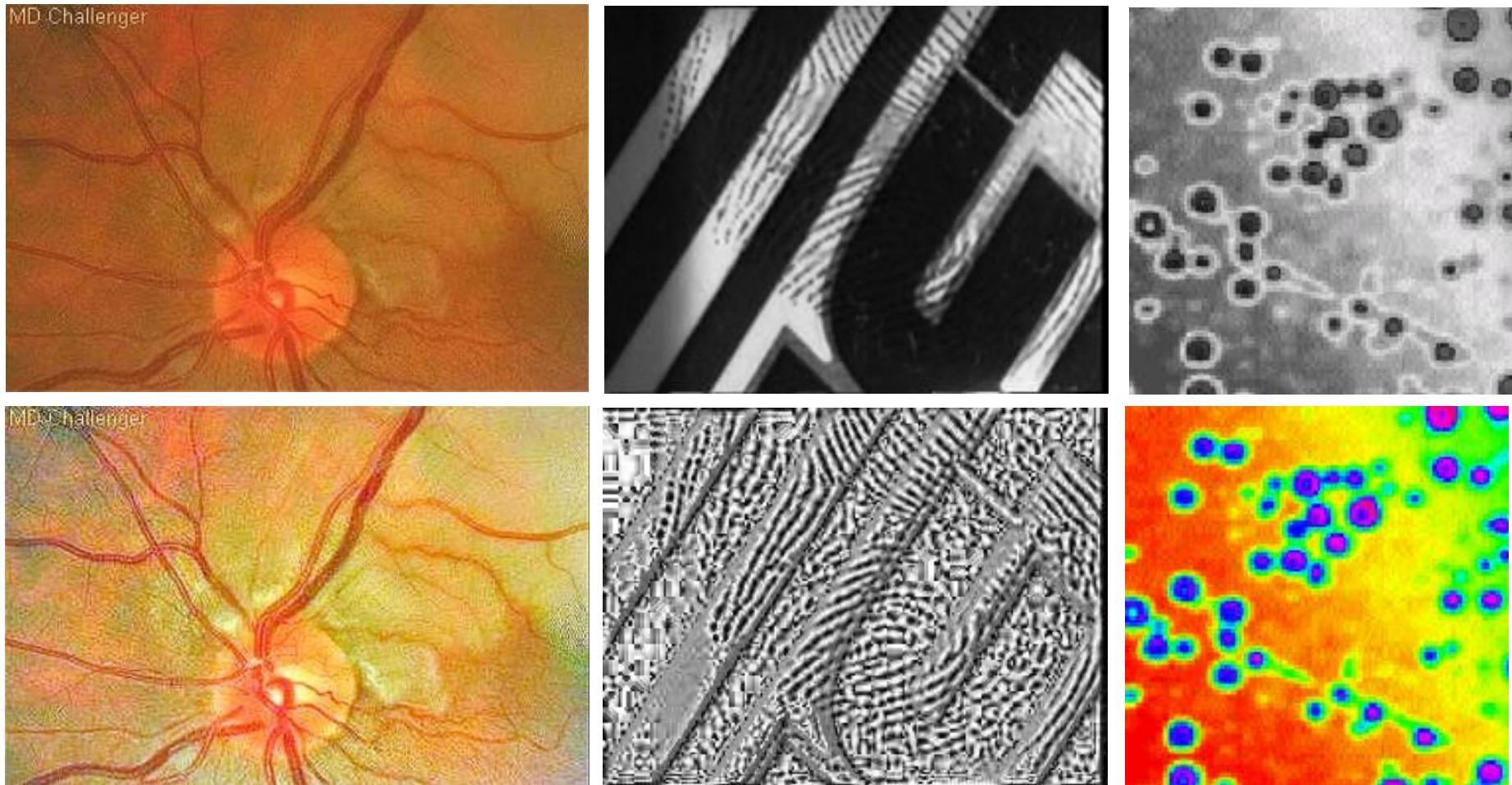
- **Objective enhancement**

Motion artifact rejection

4. Image Enhancement

- Improve quality **in some way**
- **with different objectives:**
 - for visual inspection
 - : contrast enhancement(windowing)
 - for further image processing
- **Subjective image enhancement**
- **global/local**

Image Enhancement



Color contrast enhancement

Equalization filter

Pseudo coloring

Image Enhancement



Original image



Image enhancement



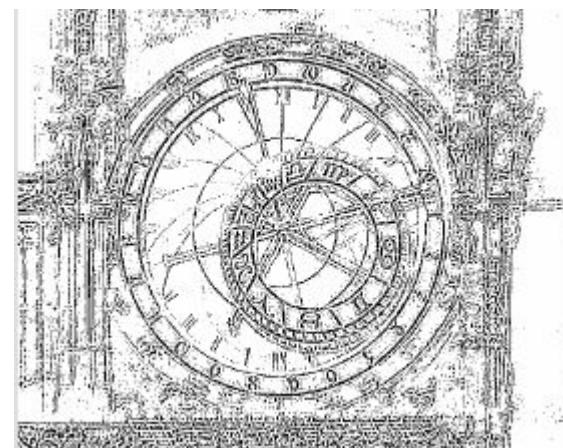
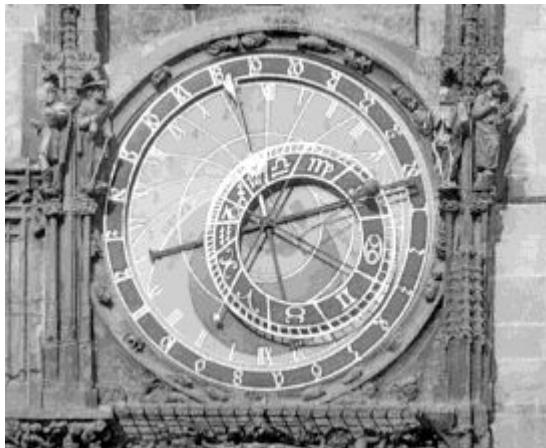
Image sharpening



Enlargement

5. Edge/Contour detection

- **Detection of line-like structure**
- **Preprocessing to segmentation**
- **Gradient operator**
 - Horizontal, vertical, Laplacian



6. Image segmentation

- **Decompose image into its components**
- **Histogram segmentation**
 - thresholding
- **Region growing**
 - seed points
 - check similarity of neighboring points
 - enlarge region
- **Gradient method**
 - following the edge detection



Image segmentation

-1	0	1
-2	0	2
-1	0	1

-1	-2	-1
0	0	0
1	2	1

Sobel operator



Original Image

X-gradient

Y-gradient

Total Gradient

Bilevel Thresholding

7. Measurements in Images: Representation and Description

- **Geometric features:** length, area, shape
- **Intensity features:** grey levels, mean
- **Color features:** multispectral information
- **Texture:** fine structure in image

8. Image Compression

- **Save in storage space**
 - and transmission time
 - by removing redundancy
- **Loss-less Compression**
 - decompression without error
 - 2~3: 1
- **Lossy Compression**
 - without noticeable differences
 - 5:1, 10:1, 20:1

9. Image registration

- **Alignment for comparison**

- Intra-modal registration: X-ray
- Inter-modal registration: PET-MRI, CT-PET

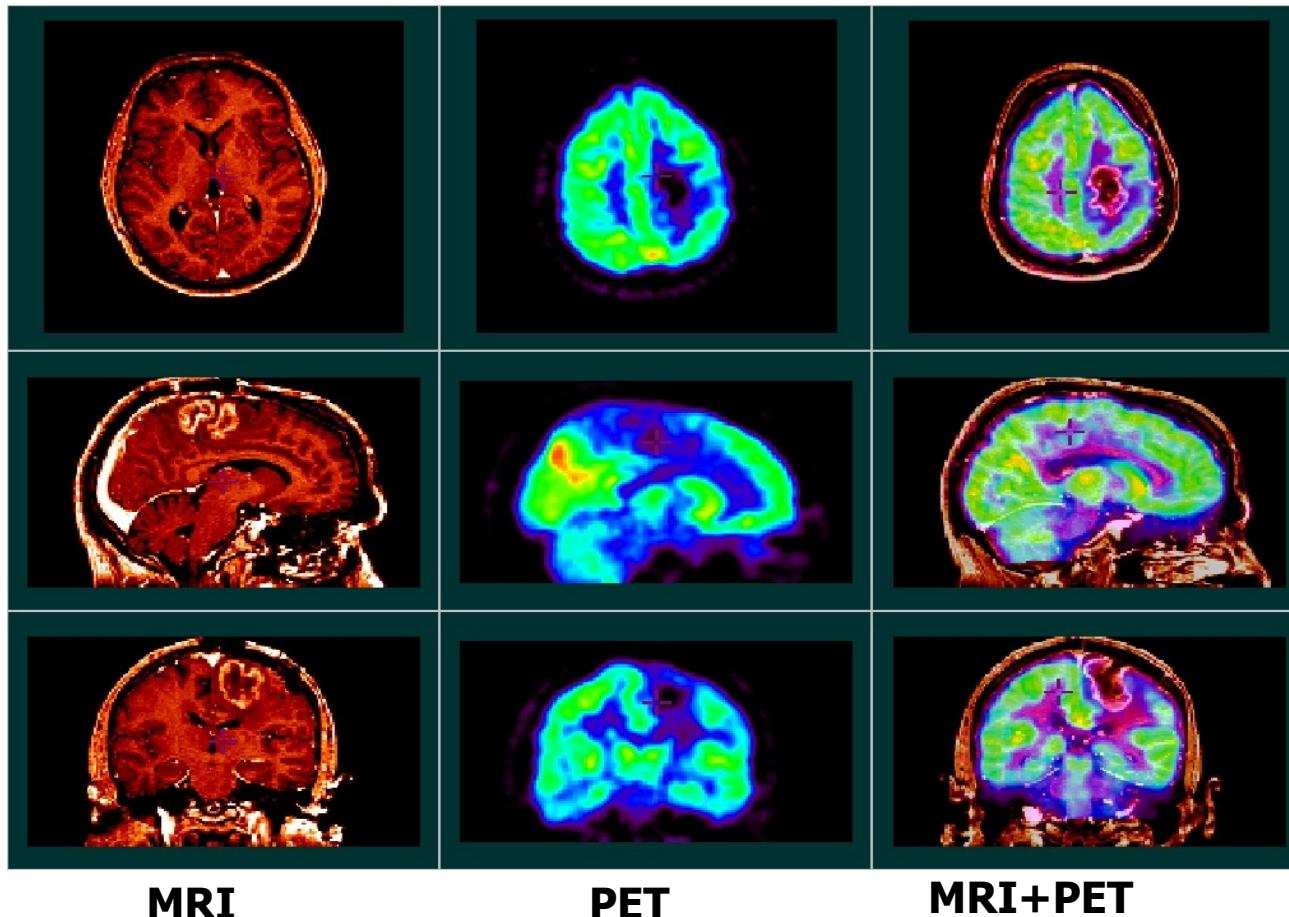
- **By image manipulation**

- translation, rotation, scaling, stretching, warping

- **Methods**

- using special mark points(fiducial marks)
- correlation technique: noise sensitive

Image registration



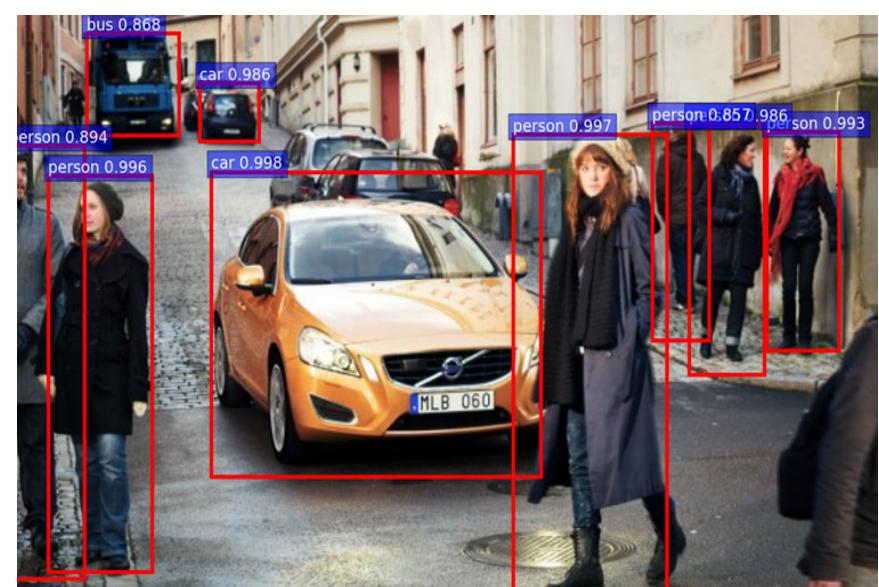
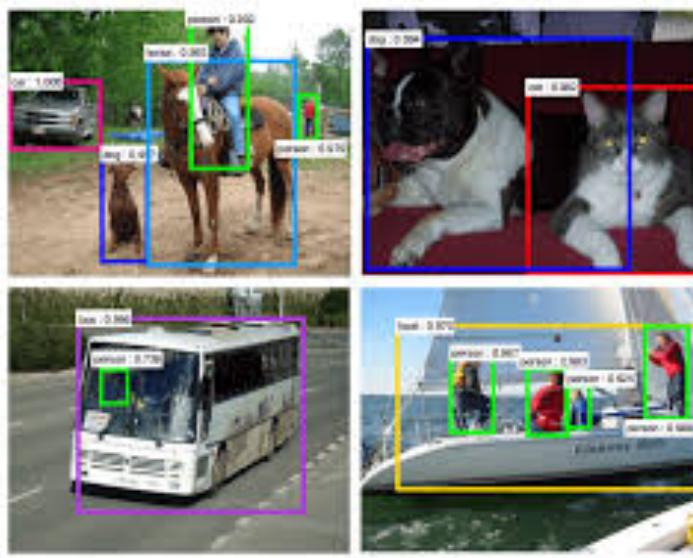
10. Image Database

- Not just a collection of images
- Indexing, retrieving image
 - by pictorial contents
- Distance measure
 - $d(X,Y)=\text{distance}(\text{image } X, \text{ image } Y)$
 - color histogram, texture, object recognized
 - whatever measurable

Object Recognition

- **Recognize the object/pattern**

- Human
- Face
- Finger print
- Printed/Handwritten Character
- vehicles



Components of digital Image Processing:

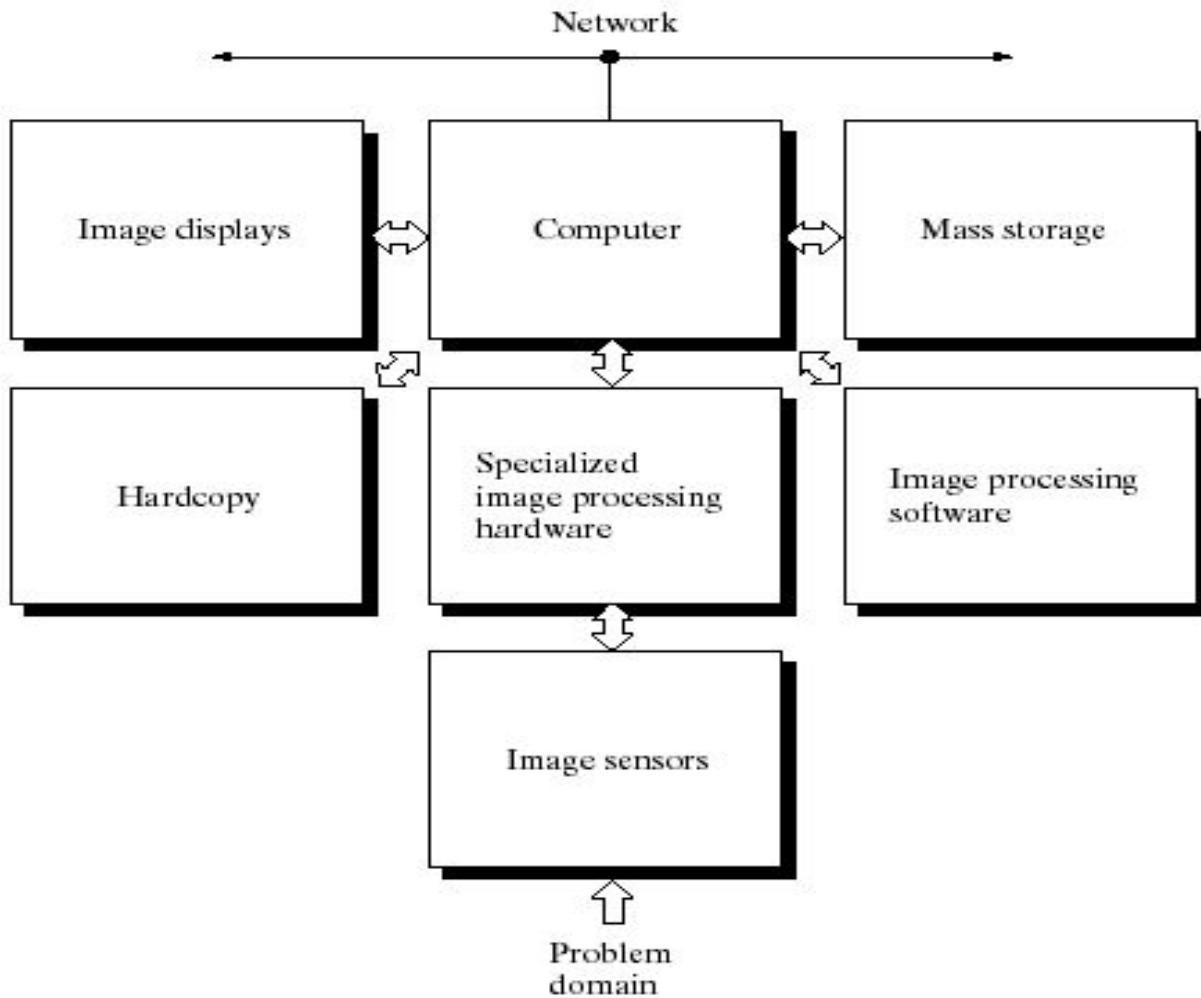
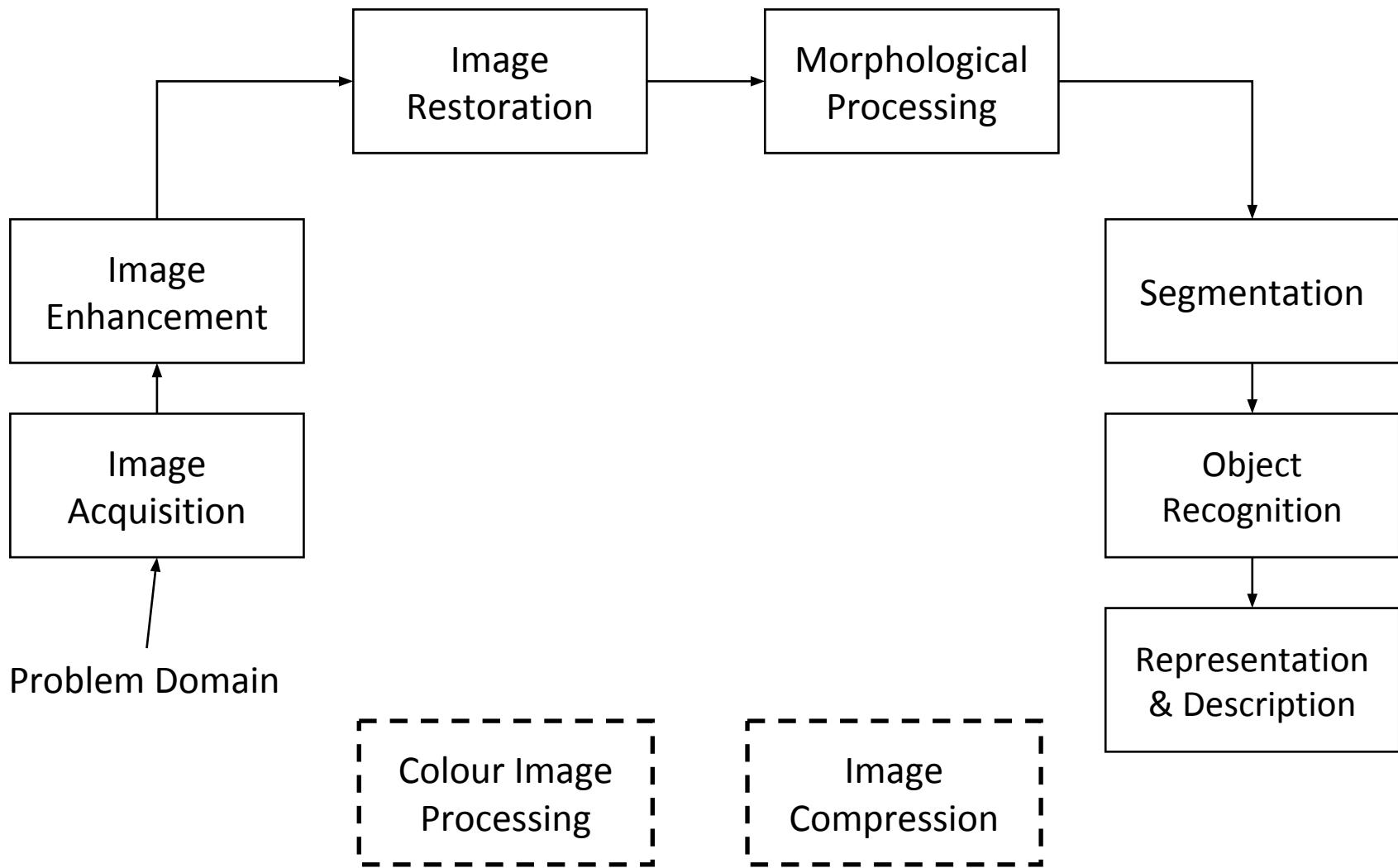


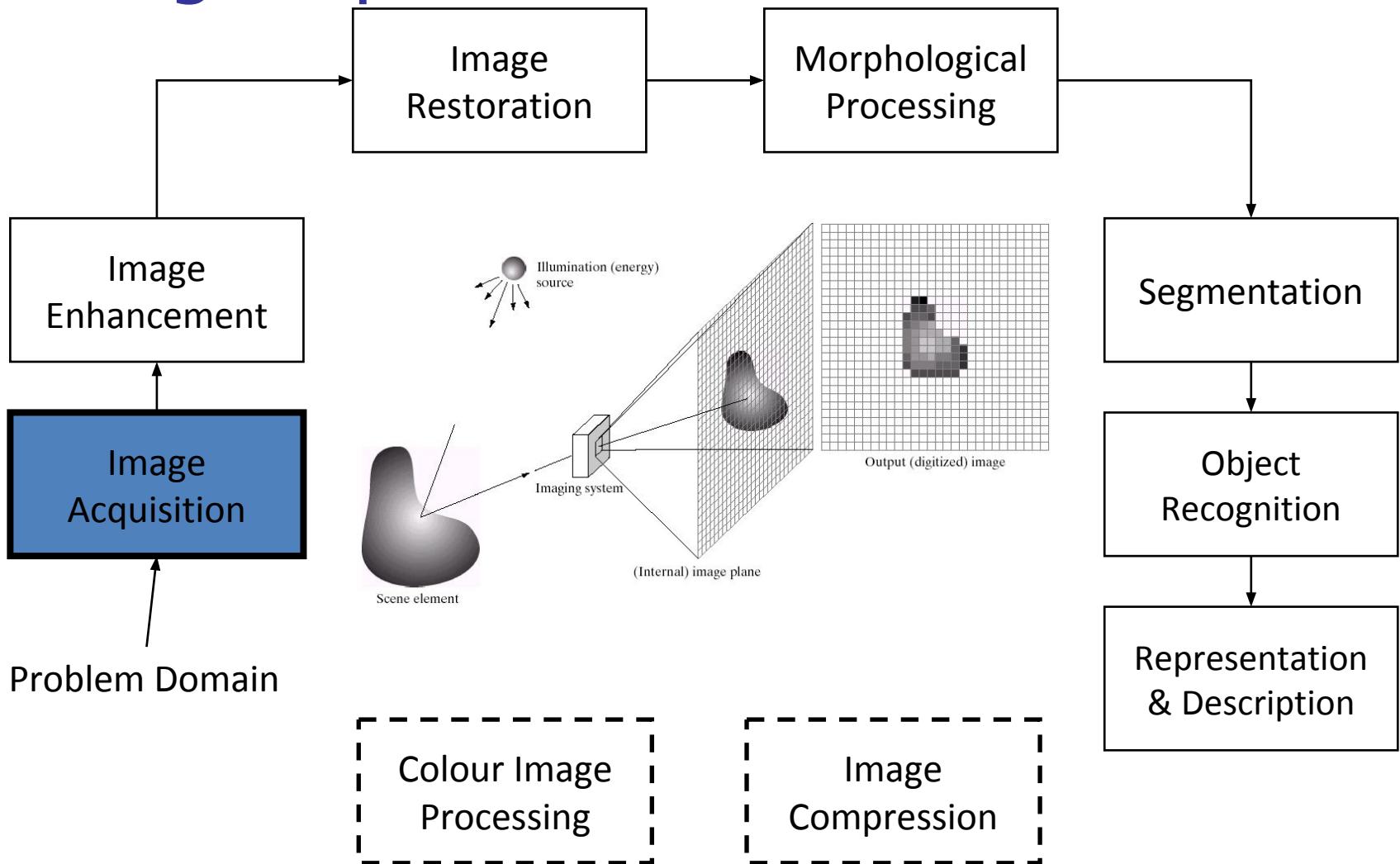
FIGURE 1.24
Components of a general-purpose image processing system.

Key Stages in Digital Image Processing



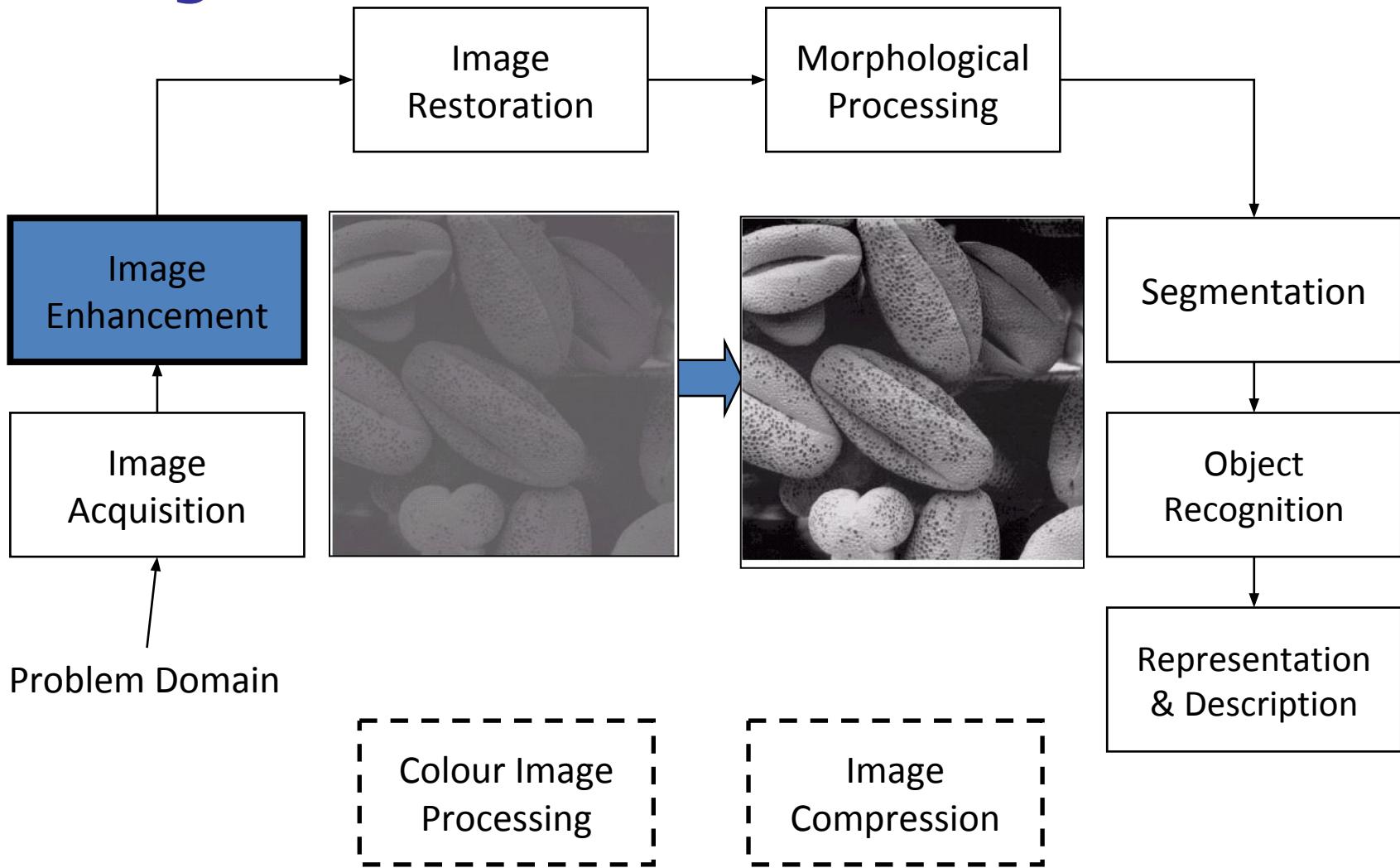
Key Stages in Digital Image Processing:

Image Acquisition



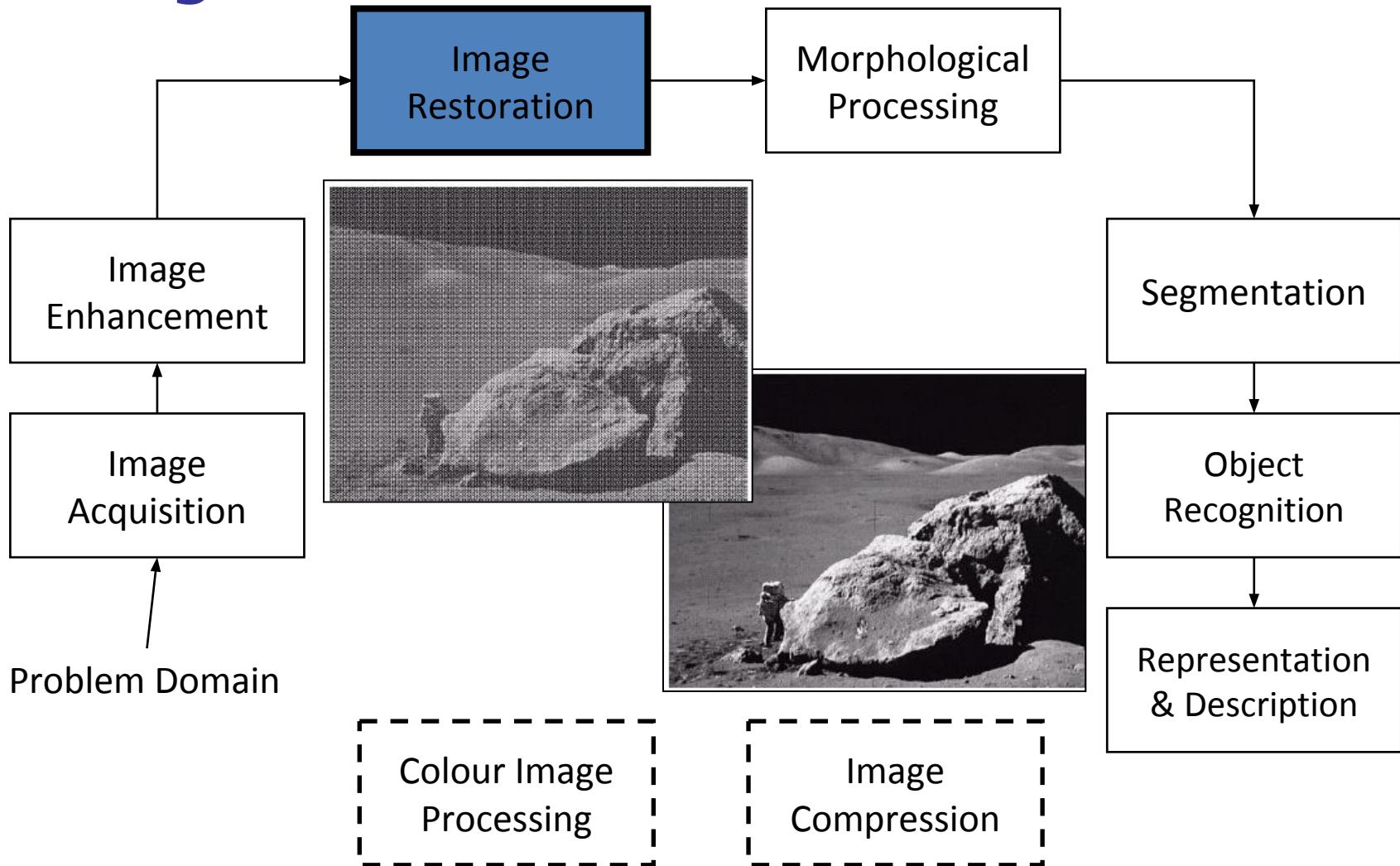
Key Stages in Digital Image Processing:

Image Enhancement



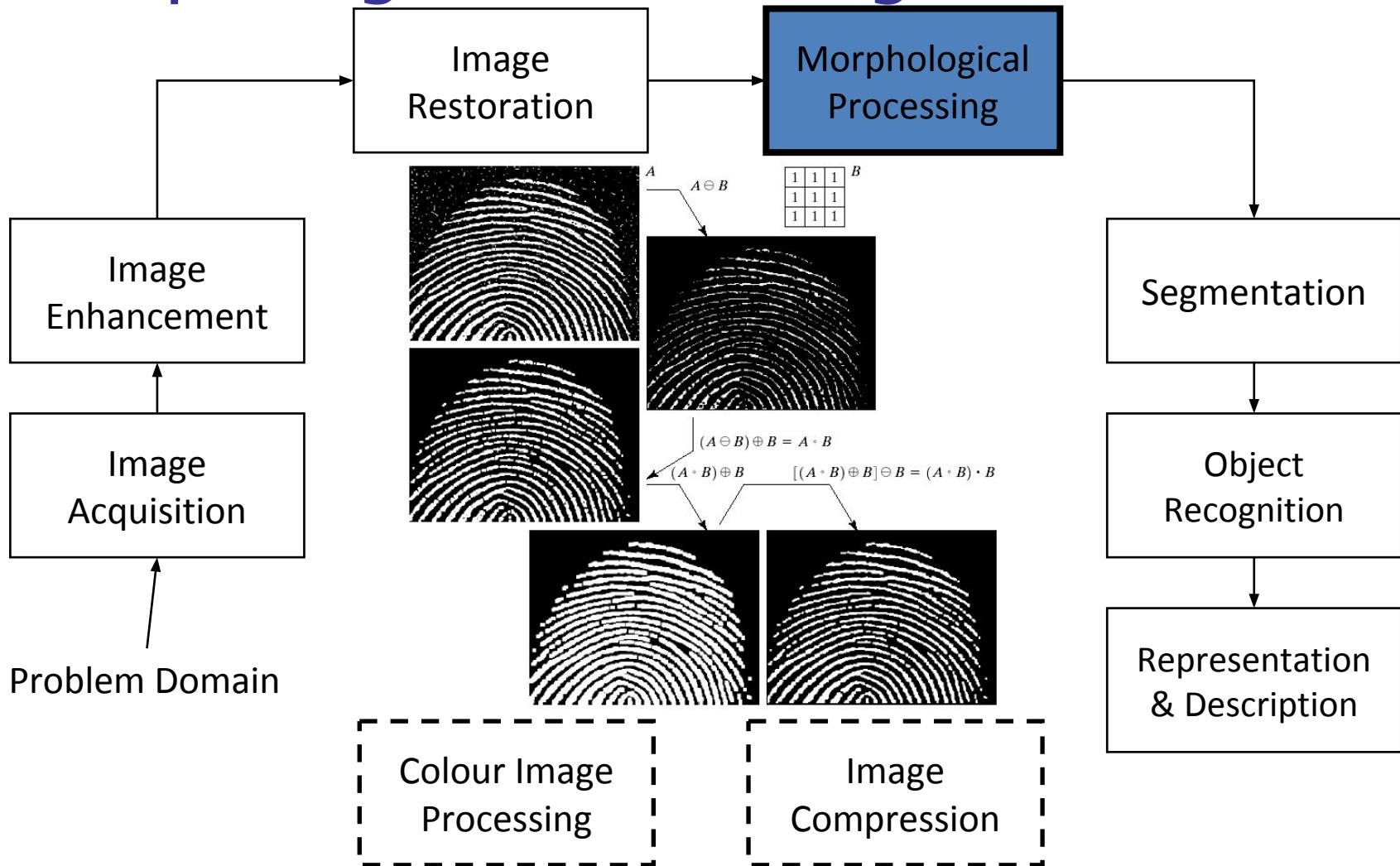
Key Stages in Digital Image Processing:

Image Restoration



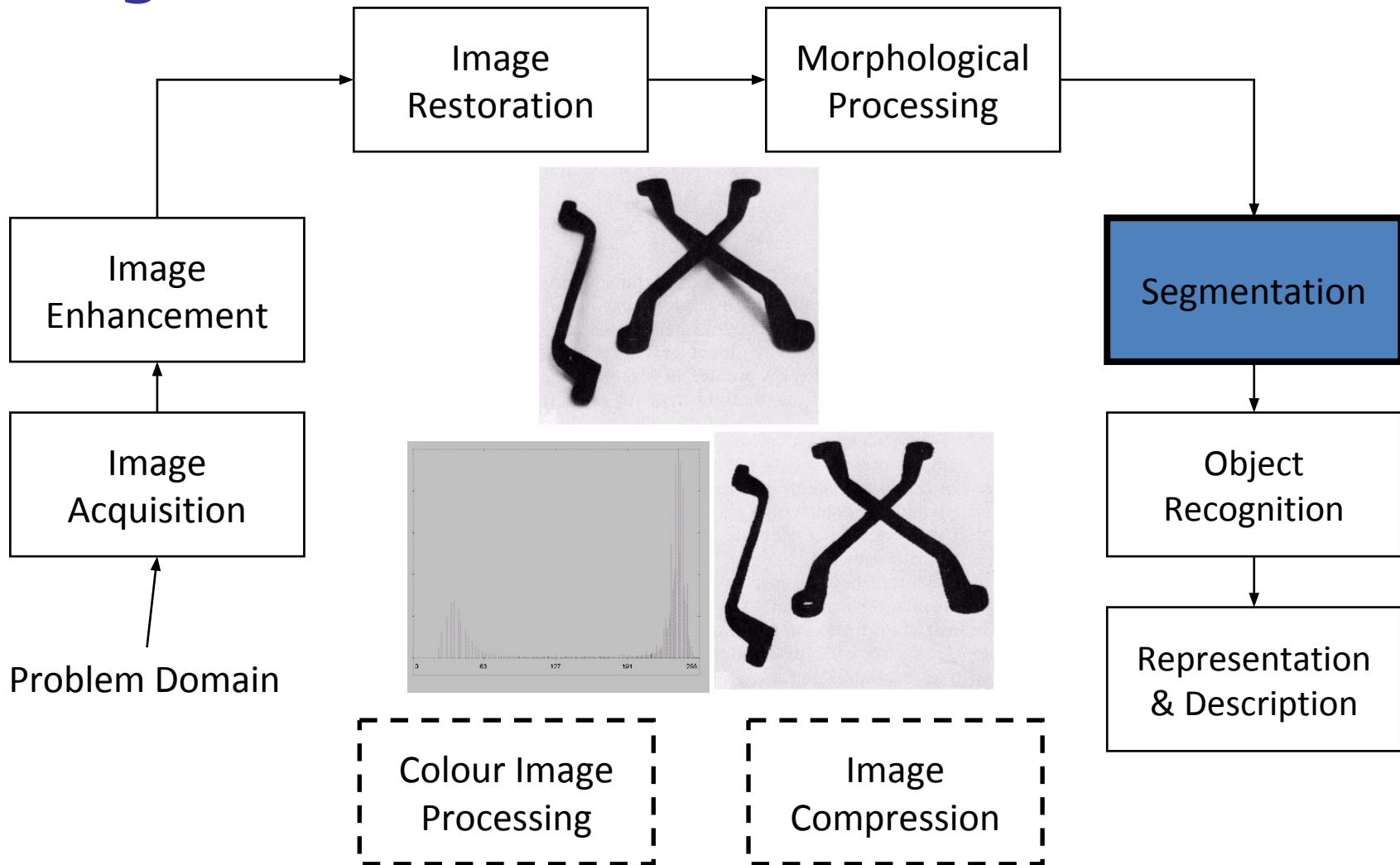
Key Stages in Digital Image Processing:

Morphological Processing

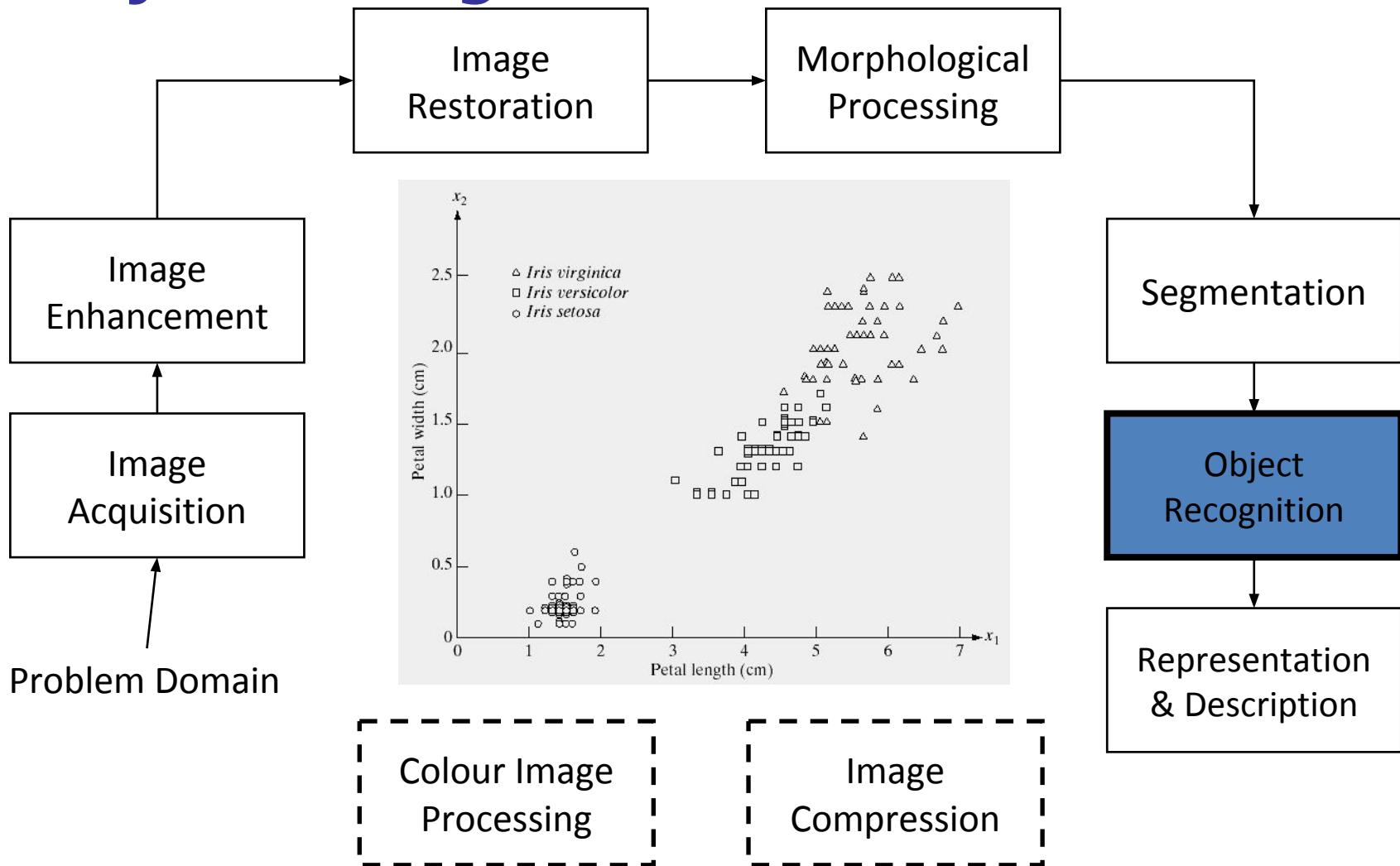


Key Stages in Digital Image Processing:

Segmentation

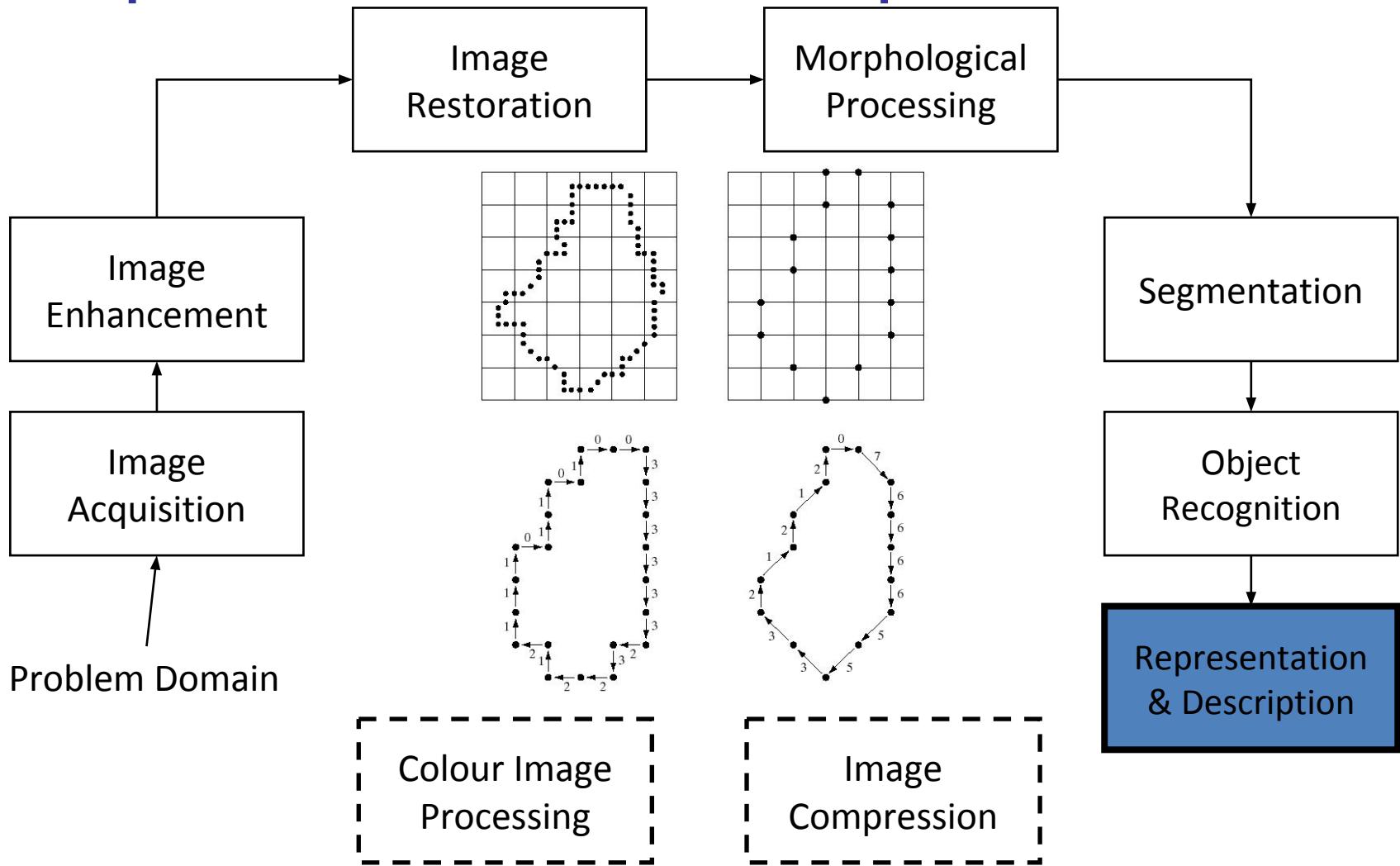


Key Stages in Digital Image Processing: Object Recognition



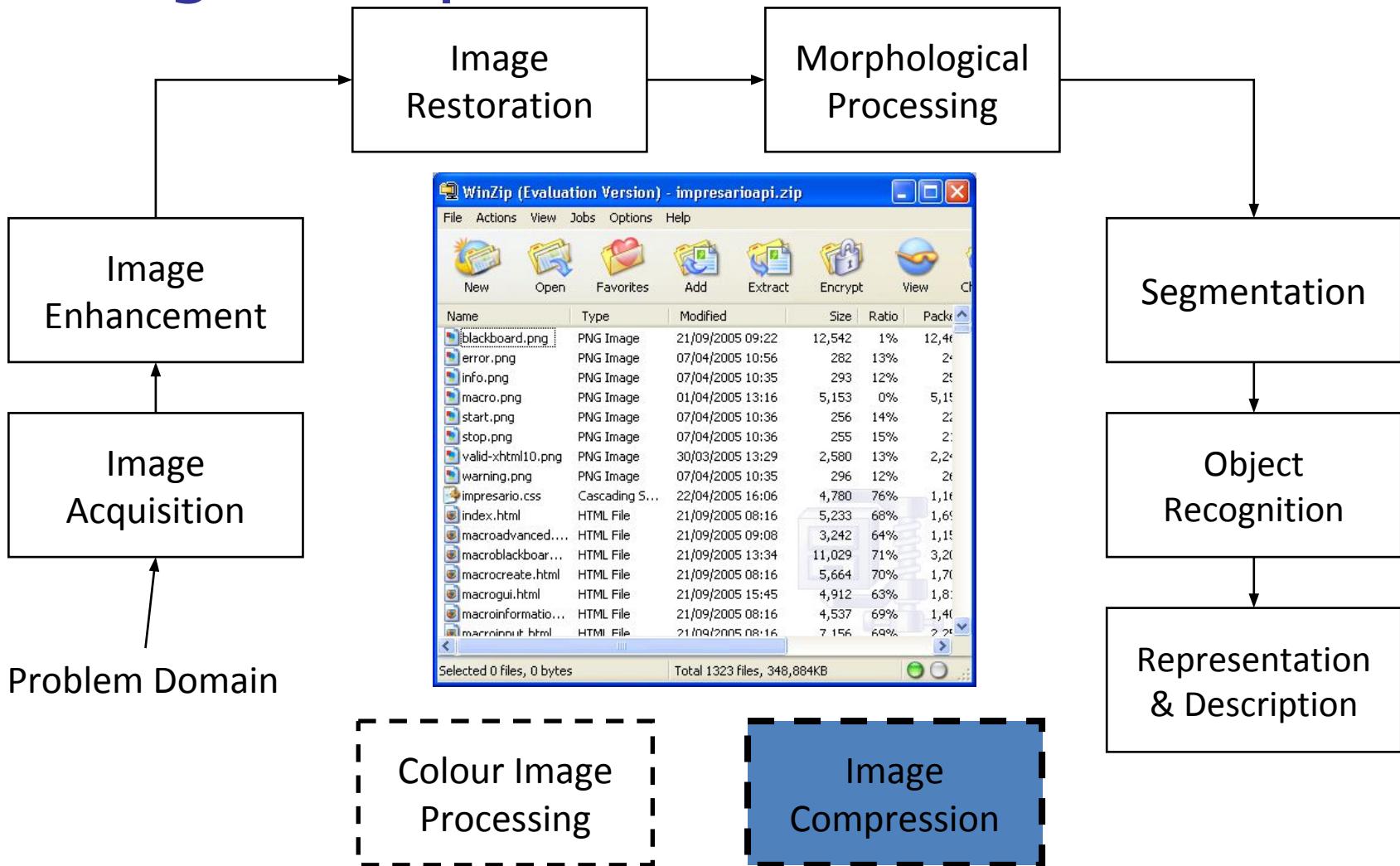
Key Stages in Digital Image Processing:

Representation & Description



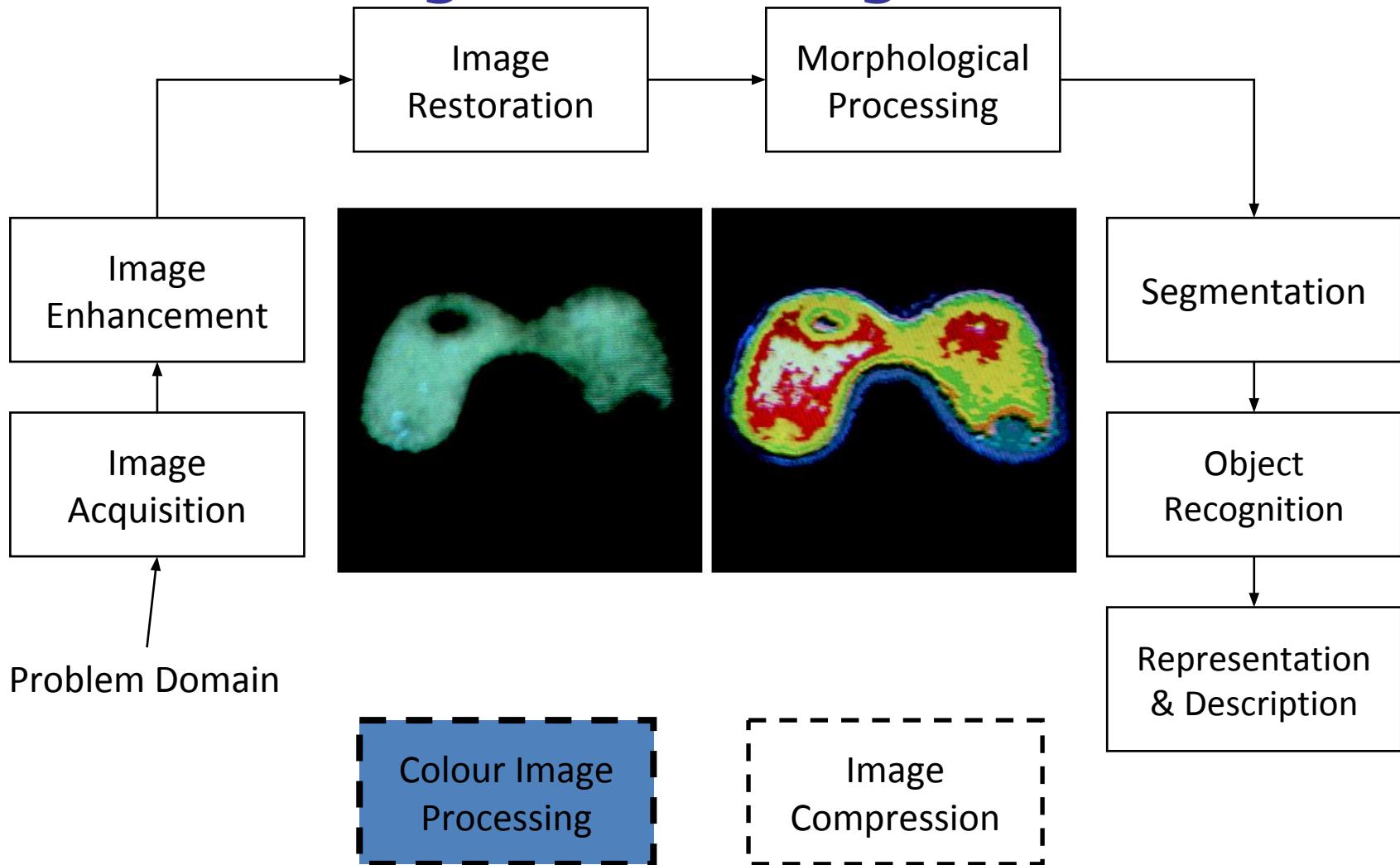
Key Stages in Digital Image Processing:

Image Compression



Key Stages in Digital Image Processing:

Colour Image Processing



Special Topics

- Resolution
- Pixel
- Aspect Ratio
- Simple Maths about resolution and aspect ratio

Monitor size/Resolution of monitor:

Problem:

Find the resolution of a 15" monitor working with

-800 x 600

-1024 x 768

-1280 x 1024

Summary

We have looked at:

What is a digital image?

What is digital image processing?

History of digital image processing

State of the art examples of digital image processing

Key stages in digital image processing

Next time we will start to see how it all works...

Video Parameters:

three standard video schemes that are currently in worldwide use - NTSC, PAL, and SECAM.

<i>Standard</i>	NTSC	PAL	SECAM
<i>Property</i>			
images / second	29.97	25	25
ms / image	33.37	40.0	40.0
lines / image	525	625	625
(horiz./vert.) = aspect ratio	4:3	4:3	4:3
interlace	2:1	2:1	2:1
us / line	63.56	64.00	64.00

Types of Images

Monochrome Image: Monochrome means one color. Typically one color is presented in different values and intensities — or different shades of the single color.

In computing, monochrome has two meanings:

it may mean:

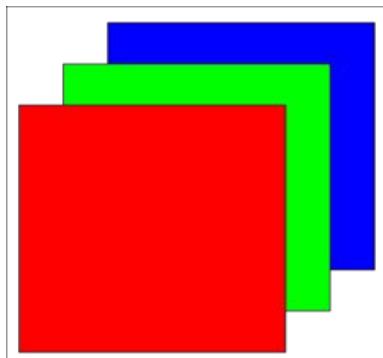
- having only one color which is either on or off (0 and 1) (also known as a binary image),
- allowing shades of that color (Gray Scale Image).



Types of Images

Color Image: A color image is a digital image that includes color information for each pixel.

- A color image is usually stored in memory as a raster map, a two-dimensional array of small integer triplets; or as three separate values (or channels/ color space) per pixel.
- The RGB color space is commonly used in computer displays, but other spaces such as YCbCr, HSV, and are often used in other contexts.



Types of Images

- Resolution of a good eye at 15"= 600 dpi
- Photography negative (35mm) = 4000 dpi

Problem:

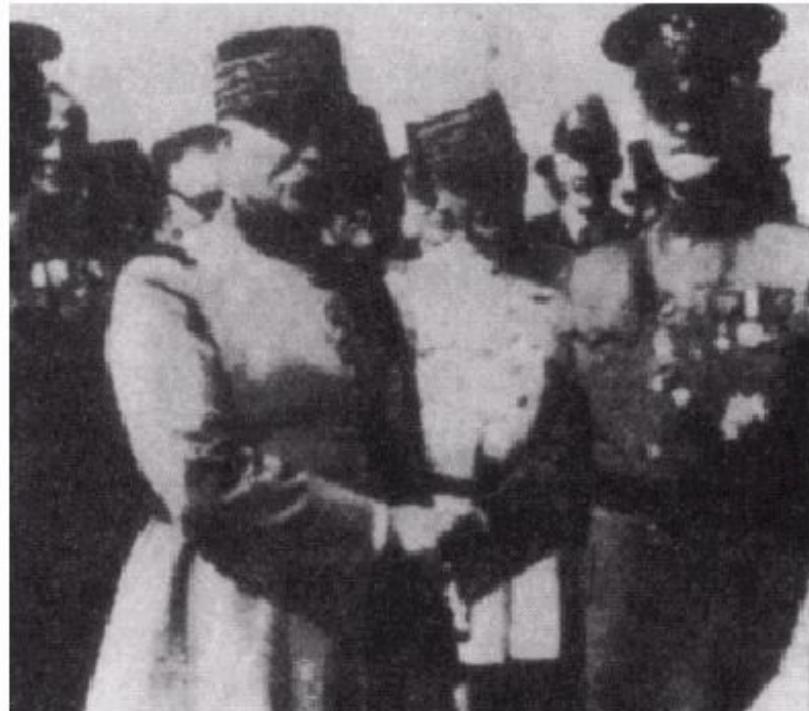
- Calculate the resolution of a 14"x9" photo.
- Find the resolution of a 15" monitor working with
 - 800 x 600
 - 1024 x 768
 - 1280 x 1024

A Historical Overview of DIP



Newspaper industry used Bartlane cable picture transmission system to send pictures by submarine cable between London and New York in 1920s

Early Improvement



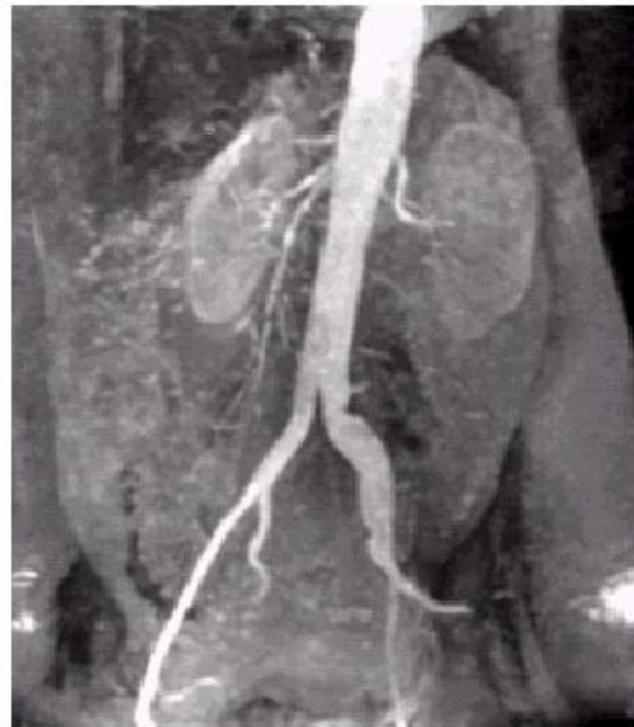
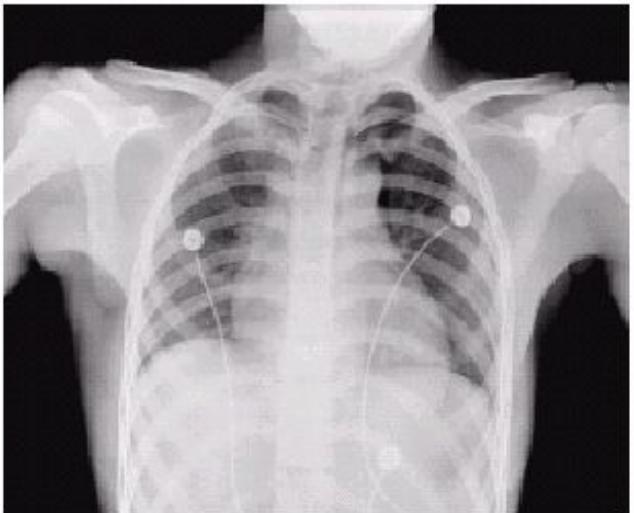
The number of distinct gray levels coded by Bartlane system was improved from 5 to 15 by the end of 1920s

Soar Into Outer Space



The first picture of moon by US spacecraft *Ranger 7* on July 31, 1964 at 9:09AM EDT

The Birth of Computer Tomography



Sir Godfrey N. Hounsfield and Prof. Allan M. Cormack shared 1979 Nobel Prize in Medicine for the invention of CT

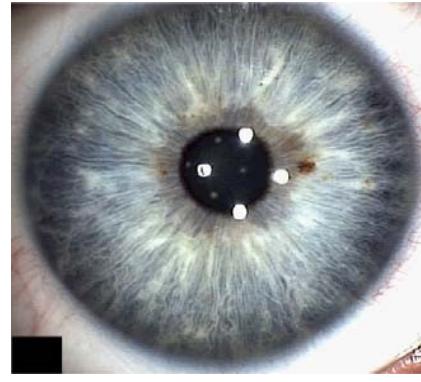
The Boom of Digital Images in the Last 20 Years

- Acquisition
 - Digital cameras, scanners
 - MRI and Ultrasound imaging
 - Infrared and microwave imaging
- Transmission
 - Internet, satellite and wireless communication
- Storage
 - CD/DVD, Blu-ray
 - Flash memory, Phase-change memory
- Display
 - Printers, LCD monitor, digital TV
 - Portable DVD player, PDAs, cell-phone

Visible (I): Motion Pictures



Visible (II): Biometrics and Forensics

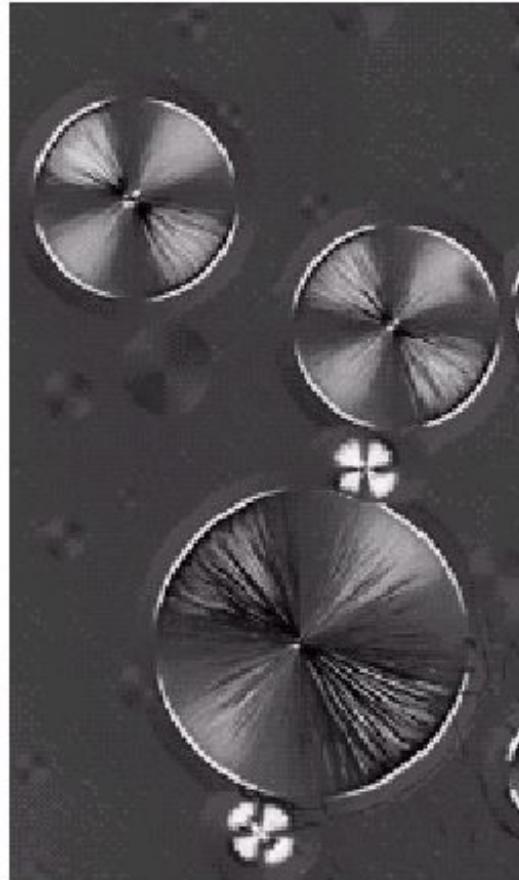


You=ID

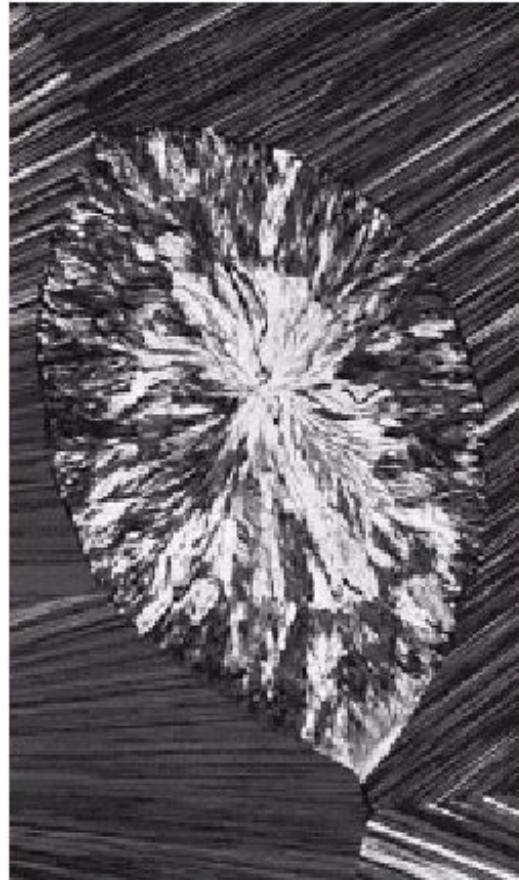


Real or PS?

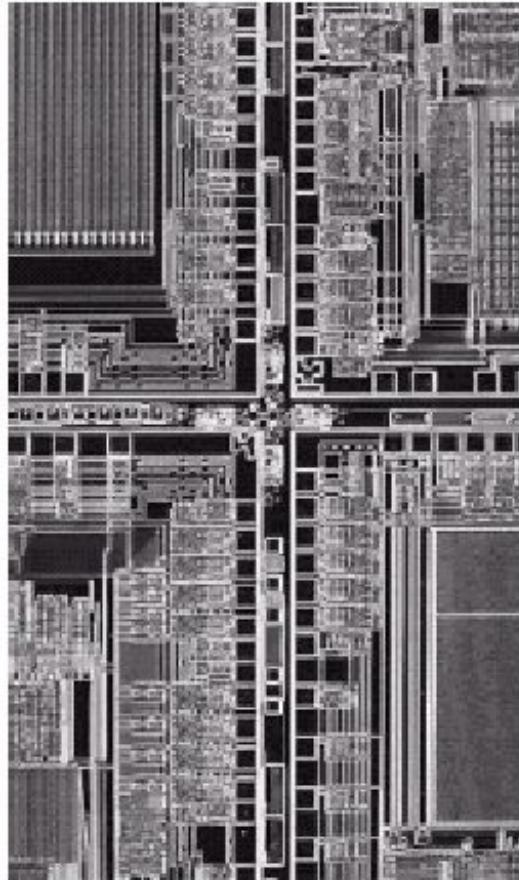
Visible (III): Light Microscopy



Taxol (250 \times)



Cholesterol (40 \times)



Microprocessor (60 \times)

Visible (IV): Remote Sensing



Earth at night (Only Asia/Europe shown)

Beyond Visible (V): Thermal Images

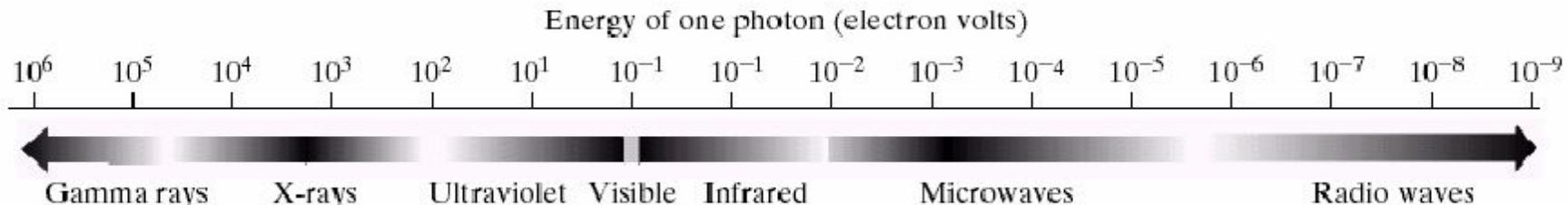
Operate in infrared frequency



Human body disperses heat (red pixels)

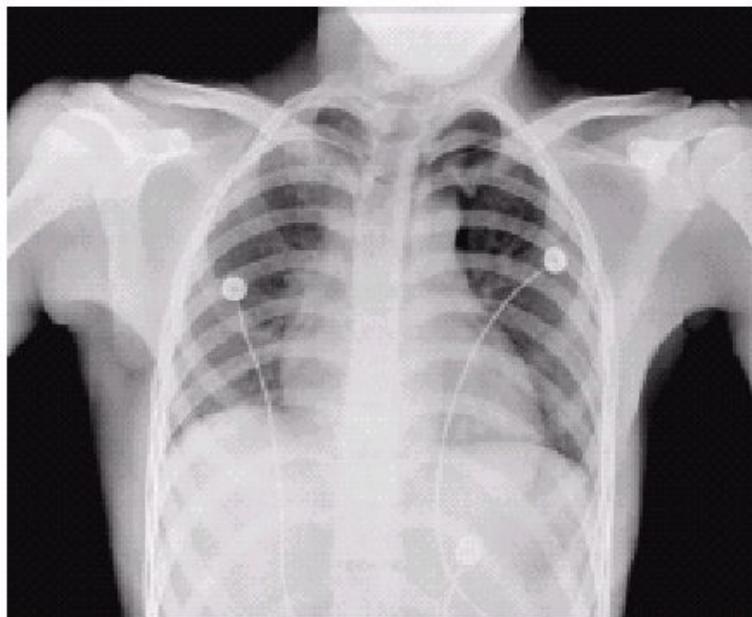


Autoliv's night vision system on the BMW 7 series

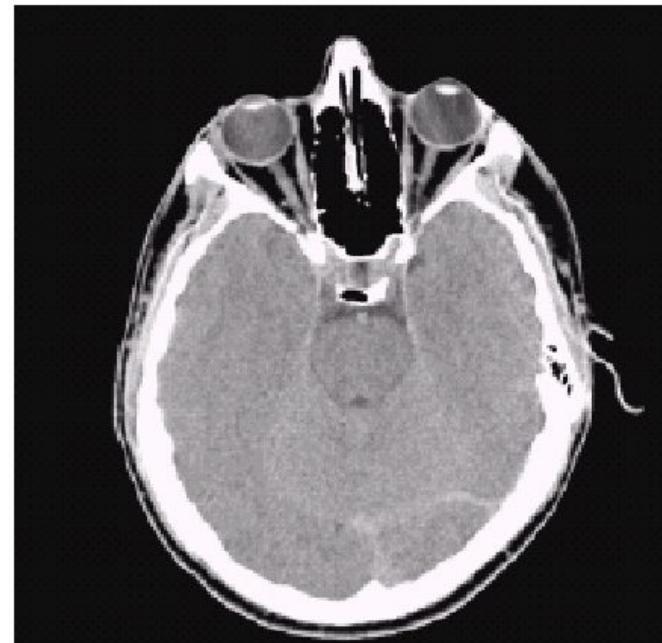


Beyond Visible (VI): Medical Diagnostics

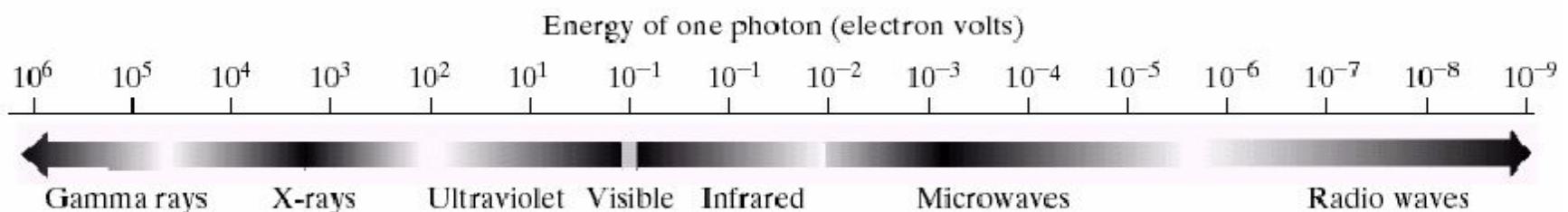
Operate in X-ray frequency



chest



head



Summary: Importance of Visual Information

- Various imaging modalities help us to see invisible objects due to
 - Opaqueness (e.g., see through human body)
 - Far distance (e.g., remote sensing)
 - Small size (e.g., light microscopy)
- Other signals (e.g., seismic) can also be translated into images to facilitate the analysis
- Images are important to convey information and support reasoning

Related Areas

Image Processing : process an image to enhance certain aspects.

Computer Graphics : Pictorial synthesis of real/imaginary objects
from *models*.

Pattern Recognition : classification of numerical and symbolic

data Artificial Intelligence : designing intelligent systems

Neural networks : Computational methods using neuron model

Psychophysics : studies in human vision

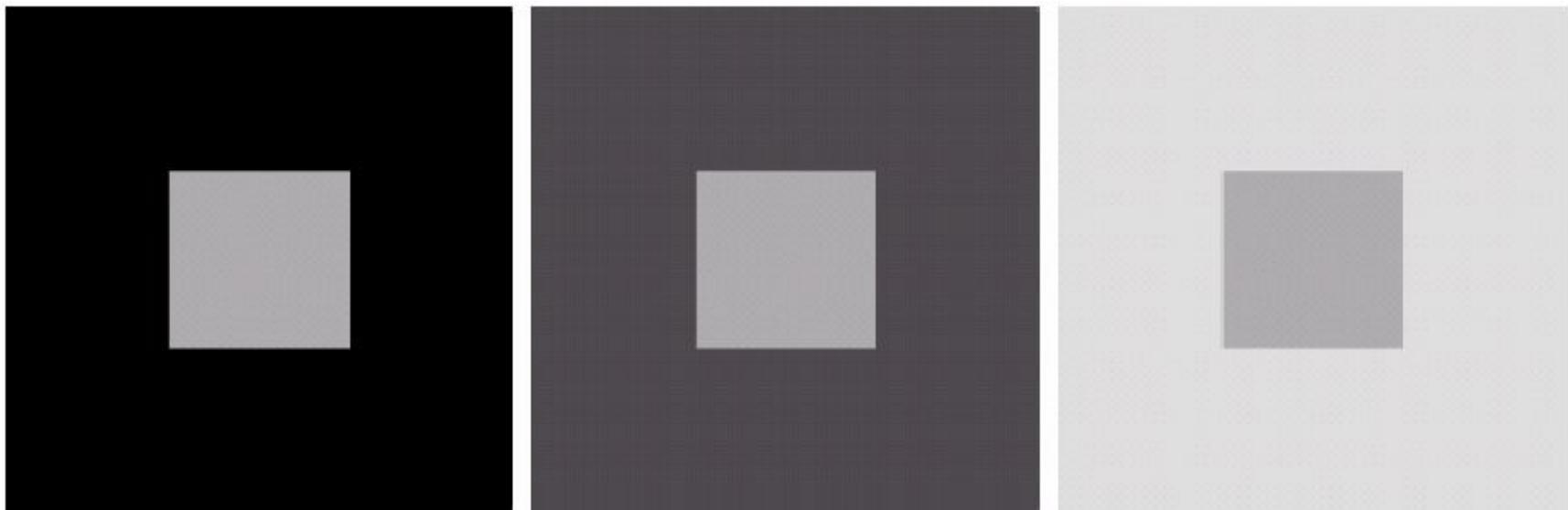
Examples

- Security : Human Face Recognition
- Medical : Cancerous cells
- Military : Automated target recognition
- Space exploration : autonomous vehicles
- Remote sensing : feature extraction
- Industrial : Inspection
- Office automation : OCR

Levels in DIP

- Low level : **Image to image**
 - filtering, noise removal, etc.
- Intermediate level : **image to sub-symbolic**
 - segmentation, line finding
- High level: **sub-symbolic to symbolic**
 - matching, scene labeling

Human Vision System



Simultaneous contrast



Advanced Digital Image Processing