Digital Image Processing
CS-601, IT-613

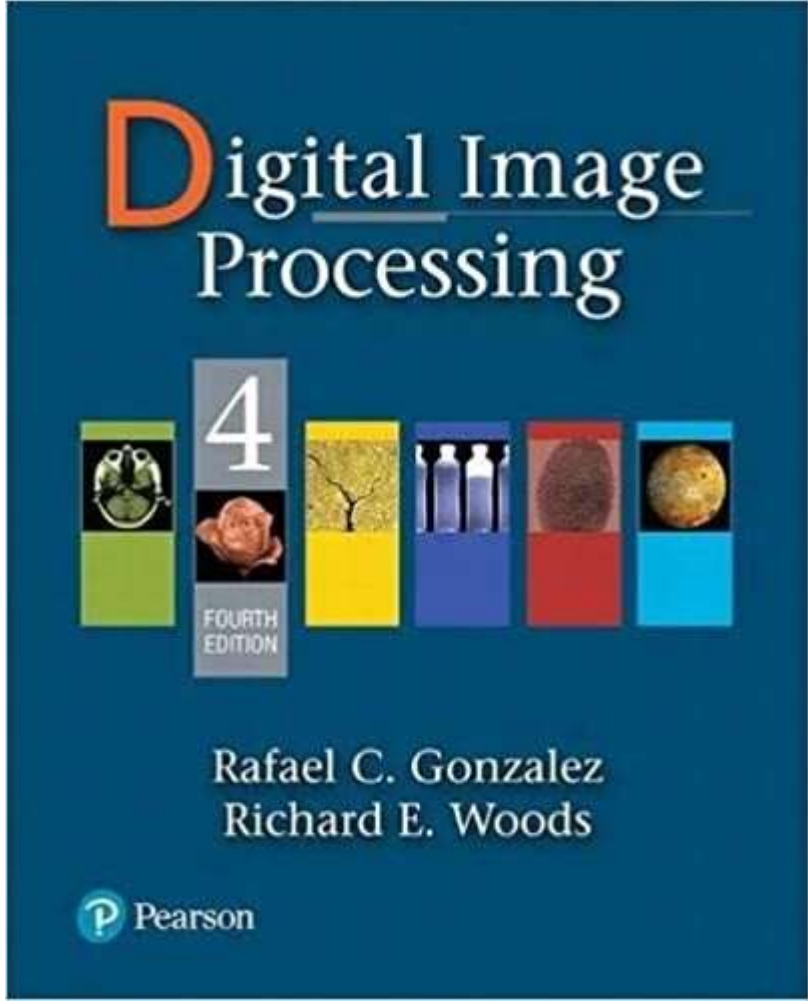
Dr. Arbab Waseem Abbas
ICS/IT, FMCS, The University of Agriculture, Peshawar.

Lecture 1(week1, 2 & 3)

Lecture # 1
Introduction and Fundamentals

Books

- Textbook:
  - *"Digital Image Processing" by Gonzalez & Woods (2nd/3rd/**4th** Edition)*
- Reference:
  - *"Image Processing; Processing and applications" Tinku Acharya & Ajoy K. Ray*
  - *"Machine Vision; Theory, Algorithms & Practicalities" E. R. Davies*
  - *"Digital Image Processing using MATLAB" Gonzalez & Woods*



We will cover many topics in this text book
We will also include special topics on recent progresses on image processing

Others

Department seminars

Guest lectures

Course Outlines/ Major Topics Covered in Class

Digital Image Introduction and Fundamentals

Digital Image Manipulation

Image acquisition and digital image representation

Image enhancement

Image restoration

Two-dimensional digital filters and their application

Color image processing

Image compression and Image segmentation

Morphological image processing

Special topics on recent progresses on digital image processing

Contd.

- The students are expected to develop firm skills in image processing by utilizing software such as MATLAB and SIMULINK in order to generate efficient code for various types of applications.
- MATLAB Onramp should be used
  - MATLAB Onramp is a free two-hour, self-paced, interactive course that allows new users to learn MATLAB. With MATLAB Onramp, users gain confidence, become comfortable with the MATLAB environment, and acquire the basic skills needed to use MATLAB. Link is given below
- https://matlabacademy.mathworks.com/details/matlab-onramp/gettingstarted

This lecture will cover

- Requirements for Semester Project in DIP
- 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

Requirement for Semester Project

Option 1: A complete research project

- Introduction (problem formulation/definition)
- Literature review
- The proposed method and analysis/Methodology
- Experiment/Results and Discussion
- Conclusion
- References

Option 2: A survey research

- A well-defined problem or topic
- A complete list of previous (typical) work on this problem (15+ papers under the topic)
- Clearly and briefly describe the topic
- Analyze each method/group and compare them
- Give the conclusion and list of references

Requirement for Semester Project

Requirements

- Select a topic and write a one-page proposal
- Progress report (discuss with the instructor)
- Research work and report writing
- Oral presentation
  - in class presentation
  - prerecorded video
- Final project report

Requirement for Final Project

Teamwork is acceptable for a research project (Option 1)

- <=2 people
- Get the permission from the instructor first
- Under a single topic, each member must have their own specific tasks
- One combined report with each member clearly stating their own contributions
- One combined presentation

Requirement for Semester Project

Written report

- Report format: the same as a conference paper
  - https://www.scribbr.com/ieee/ieee-paper-format/
- Executable code must be submitted with clear comments except for a survey study

Academic integrity (avoiding plagiarism)

- don’t copy other person’s work
- describe using your own words
- complete citation and acknowledgement whenever you use any other work (either published or online)

Requirement for Semester Project

Evaluation

- written report (be clear, complete, correct, etc.)
- code (be clear, complete, correct, etc.)
- oral presentation
- discussion with the instructor
- quality: publication-level project – extra credits

Requirement for Semester Project

Notes:

- You are encouraged to incorporate your own research expertise in, but the project topic must be related to the content of this course
- Discuss with the instructor on topic selection, progress, writing, and presentation
- Use the library and online resource

Paper Reading and Presentation

- A paper picked by yourself and approved by the instructor
  - Suggested paper source: To be provided
- Thorough understanding of the paper
- Prepare PPT slides
  - Clearly explain the main contributions in the selected paper
  - Critical comments – extra credit
- About 10 mins oral presentation for each student
  - in class presentation
  - prerecorded video

Proposal of Semester Project

Include

- Title and names of the team member
- Topic: a research project or a survey
- Brief introduction on the background
- Timeline and project management for a teamwork

At most one page

Each team only needs one abstract

On the Paper Reading (Both Sections)

includes:

- The paper you are going to present
  - Title, authors, where and when it was published, pages
  - Example: Sing Bing Kang, Ashish Kapoor, Dani Lischinski , “Personalization of Image Enhancement ”, in *Proceedings of IEEE Conference on computer vision and Pattern Recognition (CVPR)*, 2010

I will provide feedback (approve/suggest to change) to your selected paper

Where to Find the Paper

The paper you choose must be published in an official journal or conference!

A journal paper is preferred!

You can find papers from journals

IEEE Transactions on Pattern Analysis and Machine Intelligence
http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?reload=true&punumber=34

IEEE Transactions on Image Processing
http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=83

Other premier conferences or journals, CVPR, ICCV, ECCV, IEEE Trans. Medical Imaging …

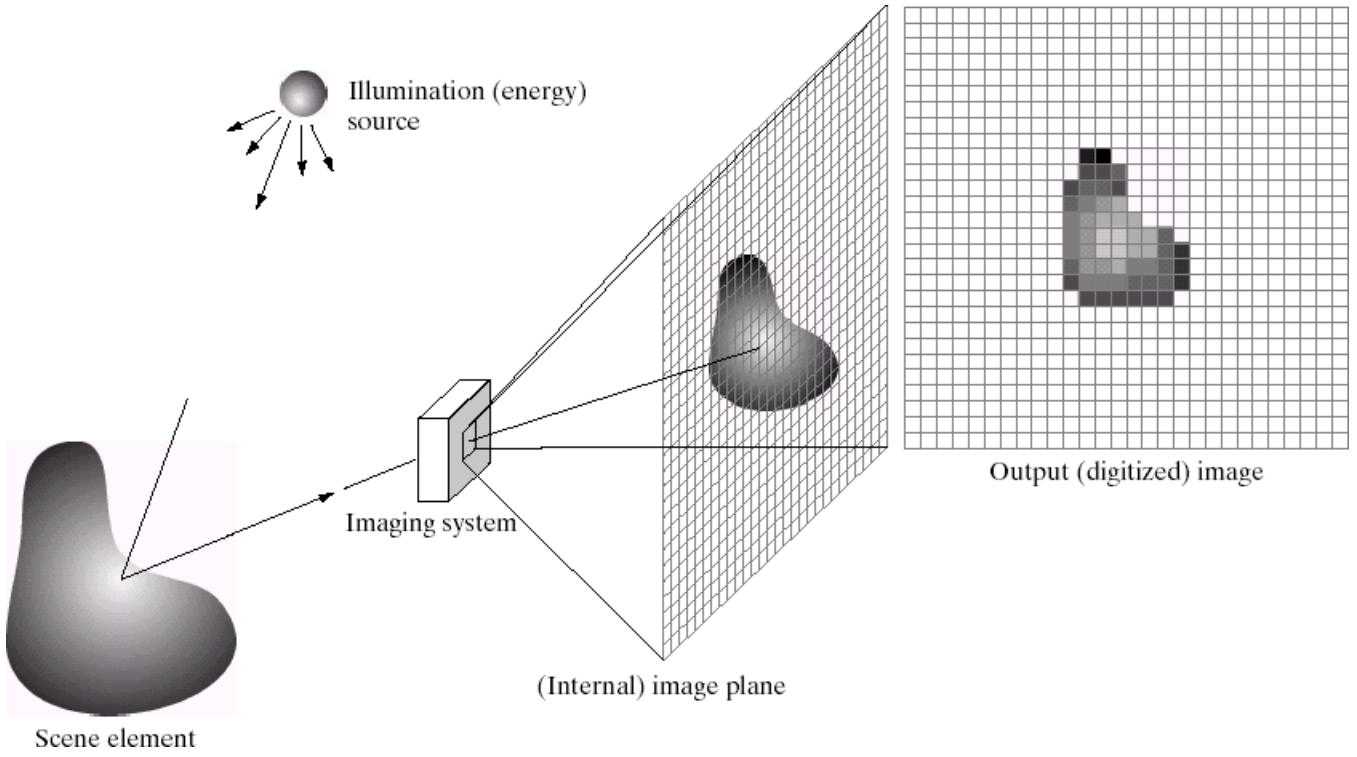
Before we start

How many of you are good in signal processing?

How many of you are familiar with MATLAB?

What is a Digital Image?

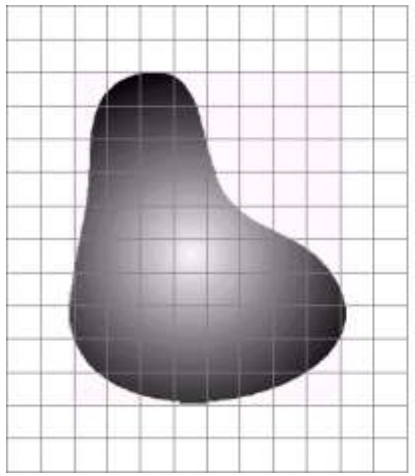
- A **digital image** is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels

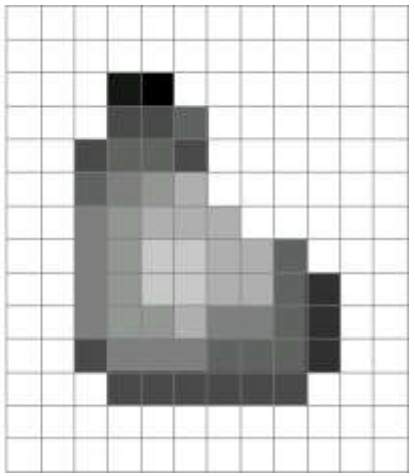


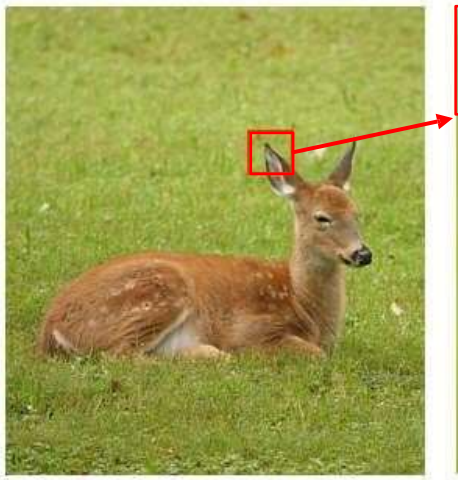
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

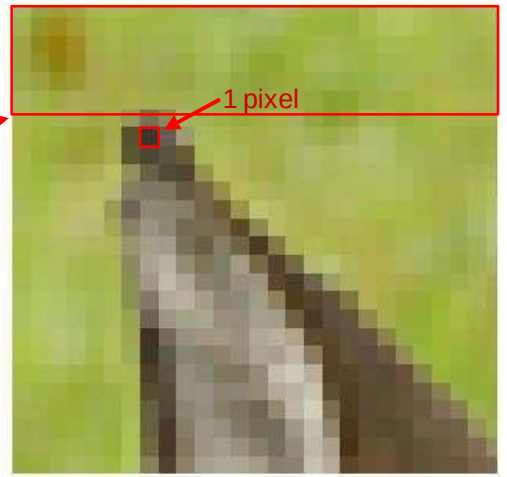
What is a Digital Image? (cont…)

- Pixel values typically represent gray levels, colours, heights, opacities etc
- **Remember** *digitization* implies that a digital image is an *approximation* of a real scene







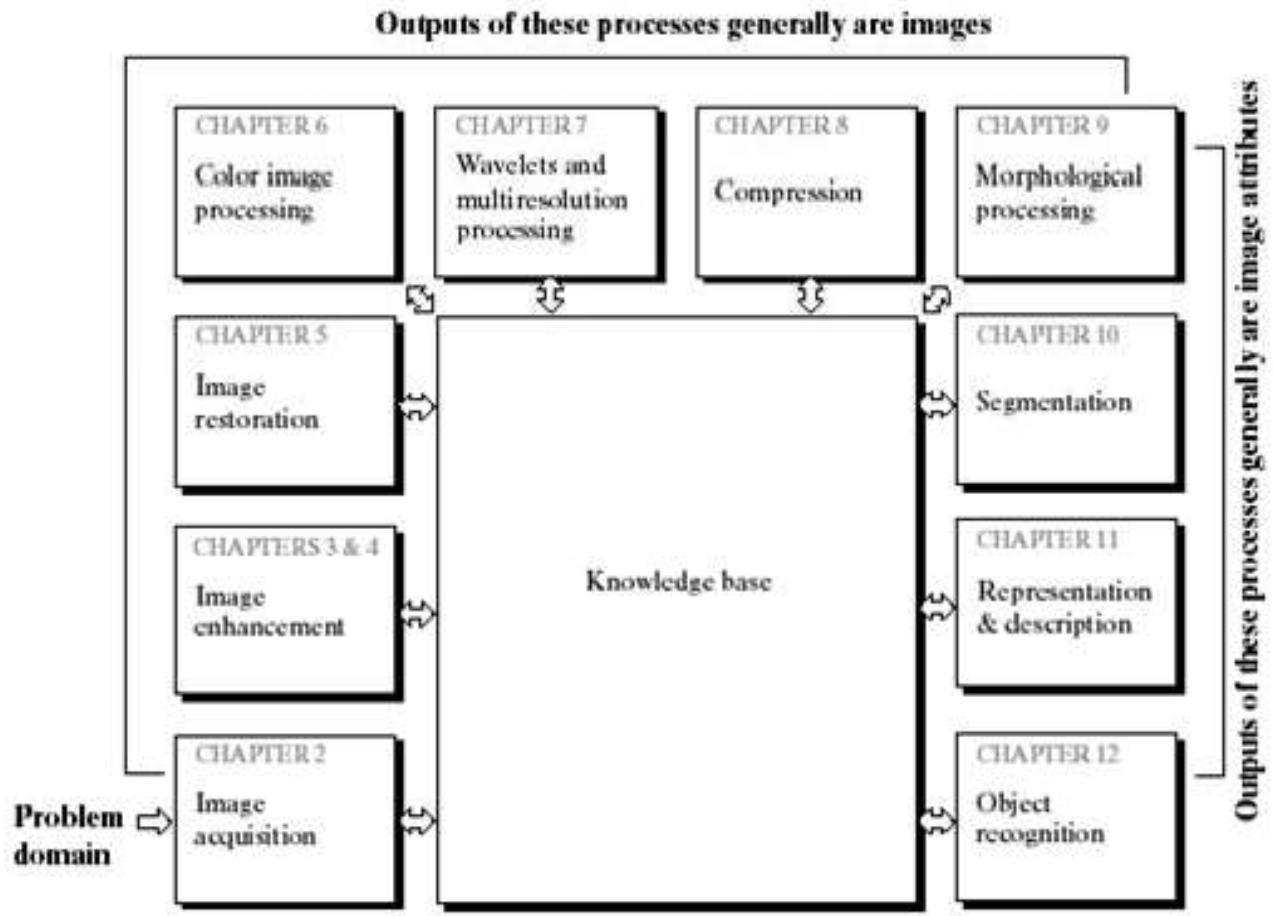


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

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/machine vision start

Fundamental steps in DIP



Important stages in DIP

- Image Acquisition
- Preprocessing
- Segmentation
- Representation and Description
- Recognition and Interpretation
- Knowledge base

Important stages in DIP

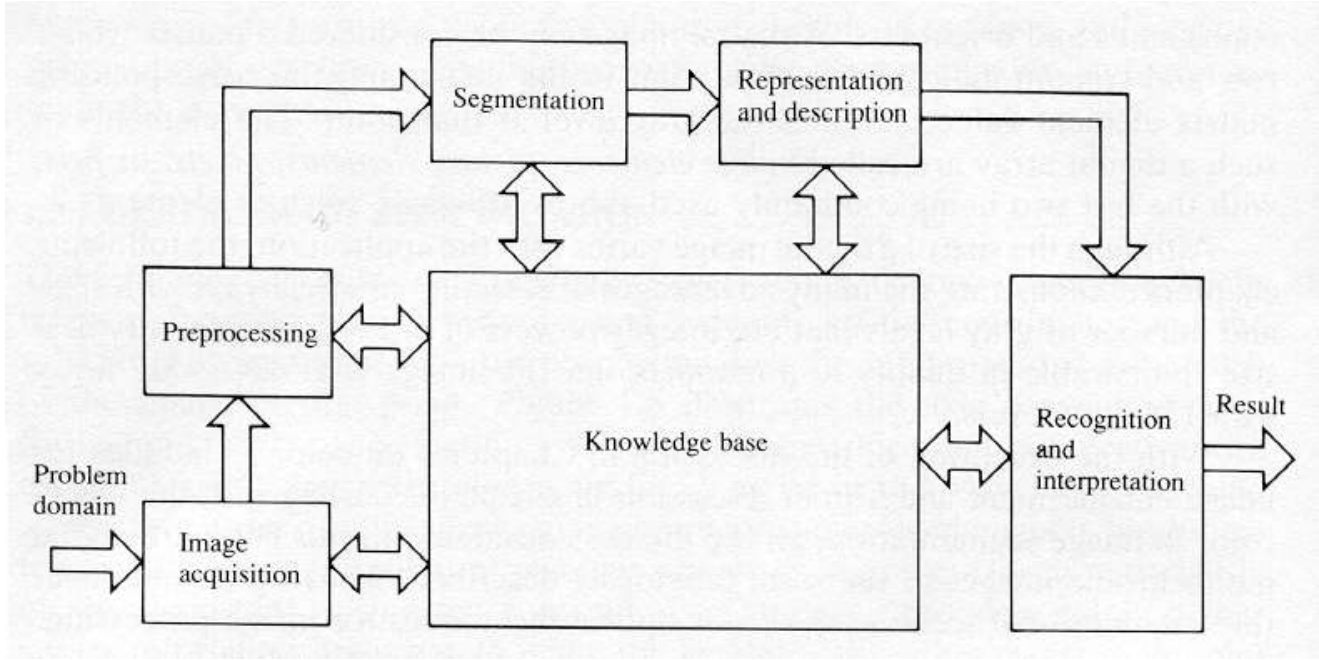


Image Acquisition

- Imaging sensor & capability to digitize the signal collected by the sensor
  - Video camera
  - Digital camera
  - Conventional camera & analog-to-digital converter

Preprocessing

- To improve the image to ensure the success of further processes
- e.g.
  - enhancing contrast
  - removing noise
  - identifying information-rich areas

Segmentation

- To partition the image into its constituent parts (objects)

Representation & Description

- Feature selection (description) deals with extracting:
  - features that result in quantitative information of interest or
  - features that are important for differentiating one class of objects from another

Recognition & Interpretation

- To assign a label to an object based on information provided by the descriptors
- To assign meaning to a group of recognized objects

Knowledge Base

- Knowledge database
  - Guides the operation of each processing module and controls the interaction between modules

Comments

- Image enhancement for human visual interpretation usually stops at preprocessing

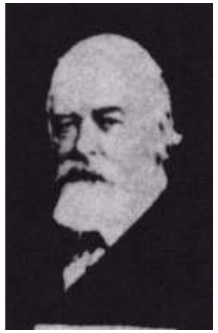
- Recognition and interpretation are associated with image analysis applications where the objective is automation (automated extraction of information from images)

Initial examples of imagery

Before 1920: Image transmission from USA to Europe: more than a week: by ship!

FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.)

FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. Some errors are visible. (McFarlane.)



Early 1920s: *Bartlane cable picture transmission system*: Transmission in three hours!

Why digital?

Improvement

FIGURE 1.3
Unretouched cable picture of Generals Pershing and Foch, transmitted in 1929 from London to New York by 15-tone equipment. (McFarlane.)

The Bartlane systems could only encode pictures into 5 distinct level of gray

Small progress

- Small progress in digital imaging until 1964

  The progress mainly tied with the progress in the development of digital computers (Processing + storage capabilities)
- *Jet Propulsion Lab* (JPL) in Pasadena, CA

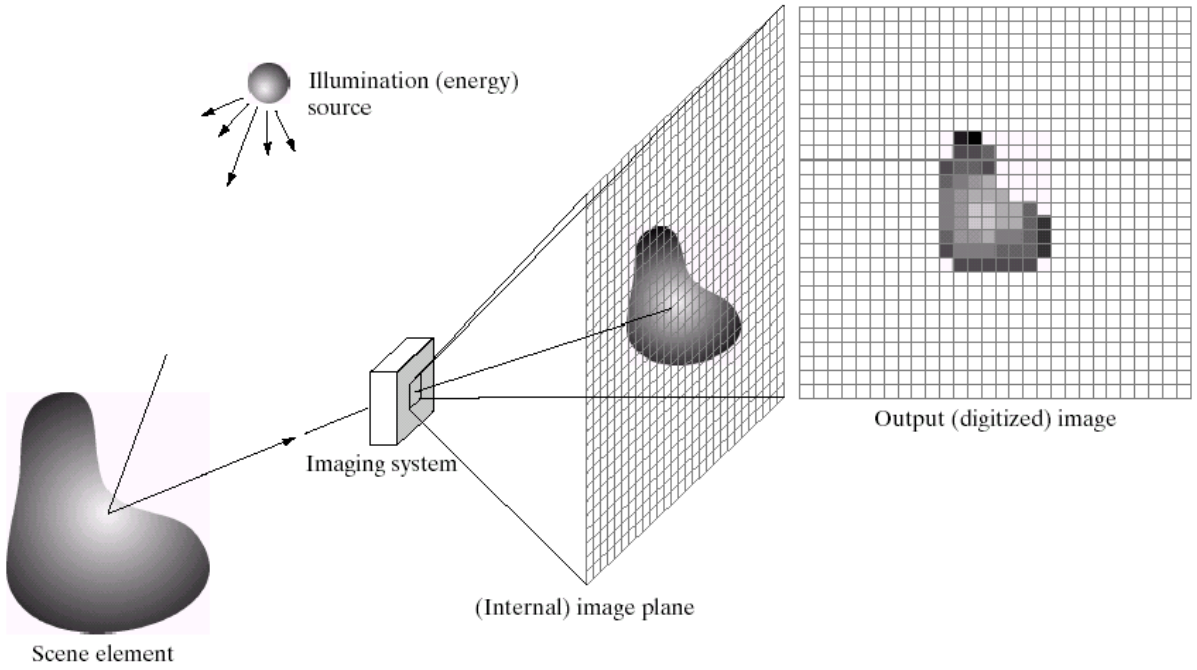
  Transmission and correction of lunar images from Ranger 7
- Not so good quality so the images had to be processed before they could be viewed

First moon picture

FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9:09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

Since then many applications…

Typical imaging system

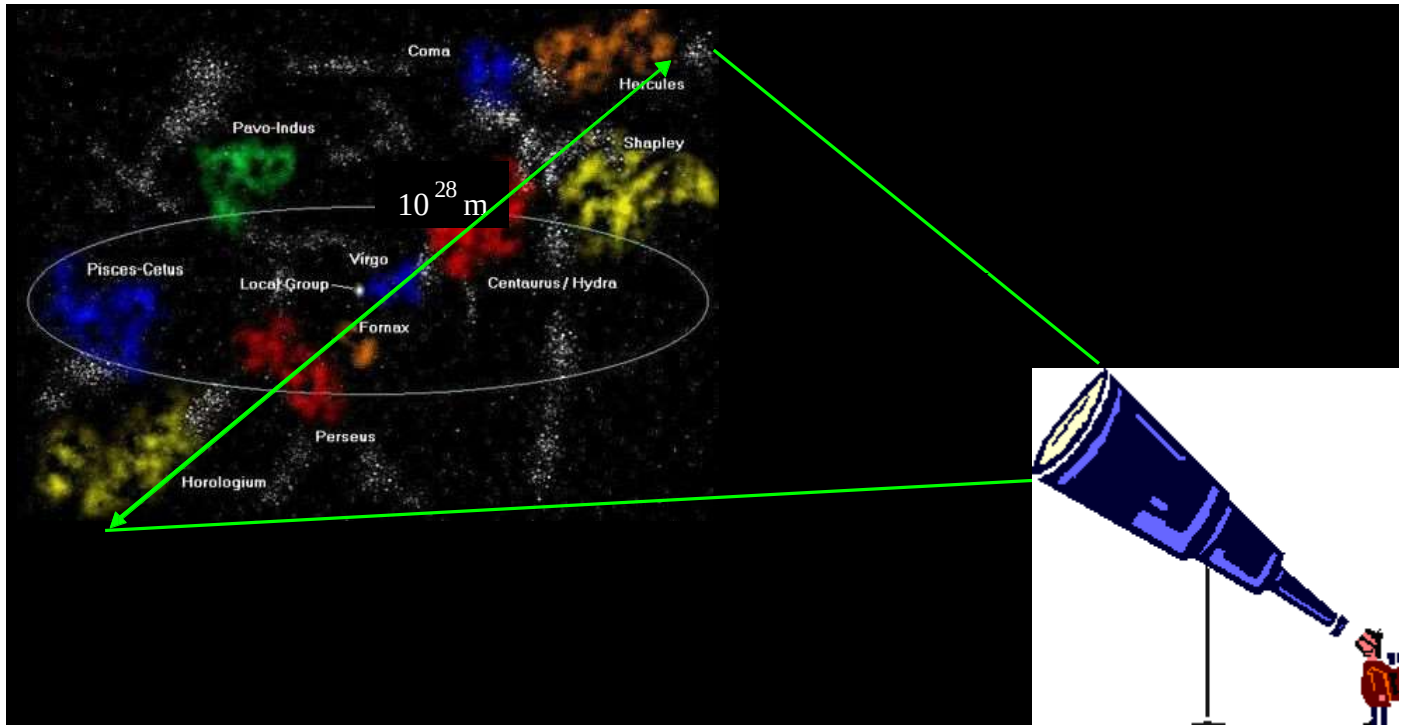


a
b c d e

FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

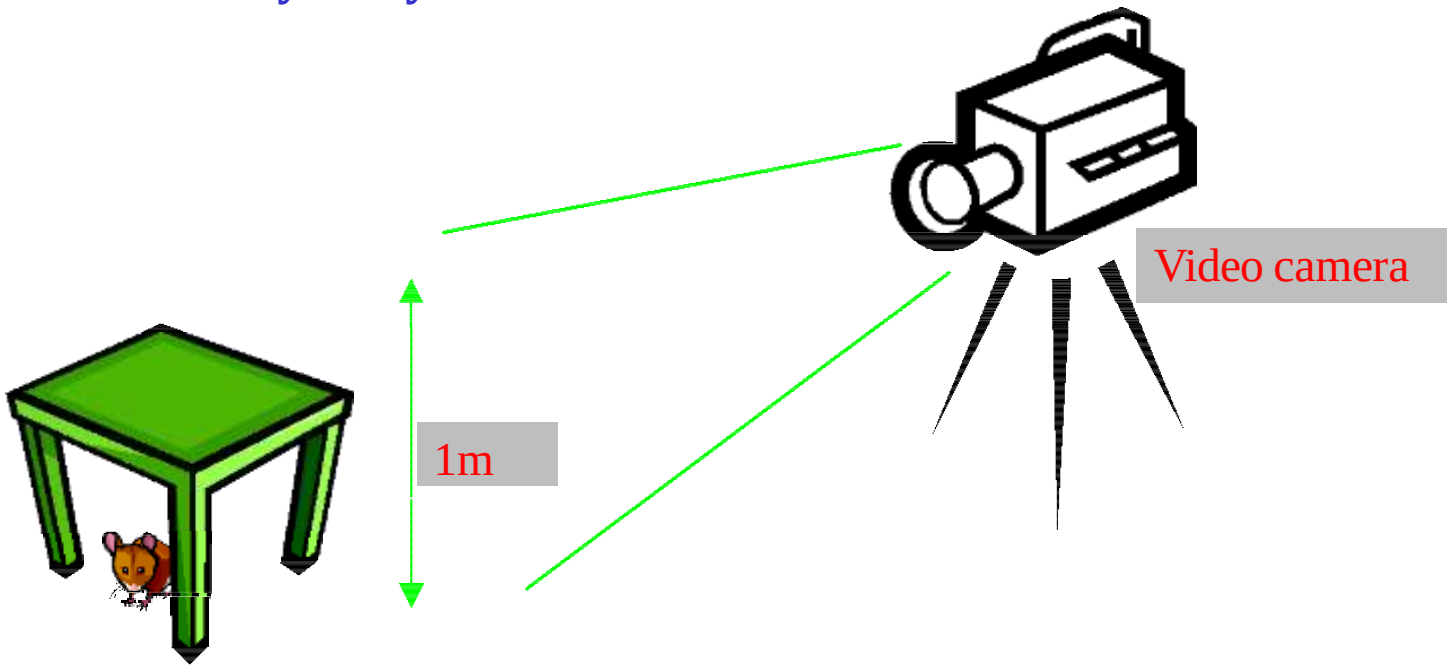
Scales of Imaging

From the gigantic…



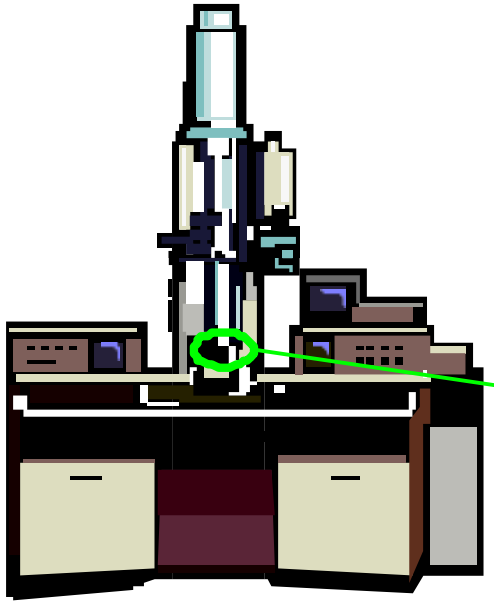
Scales of Imaging

... to the everybody

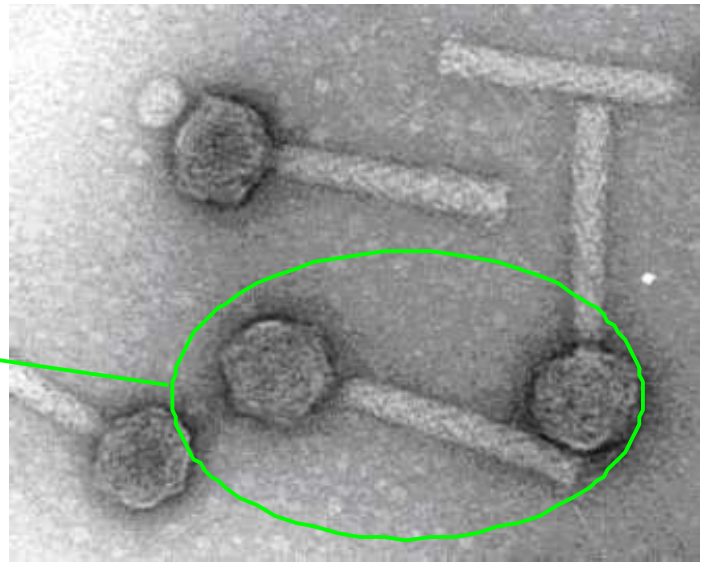


Scales of Imaging

... to the tiny

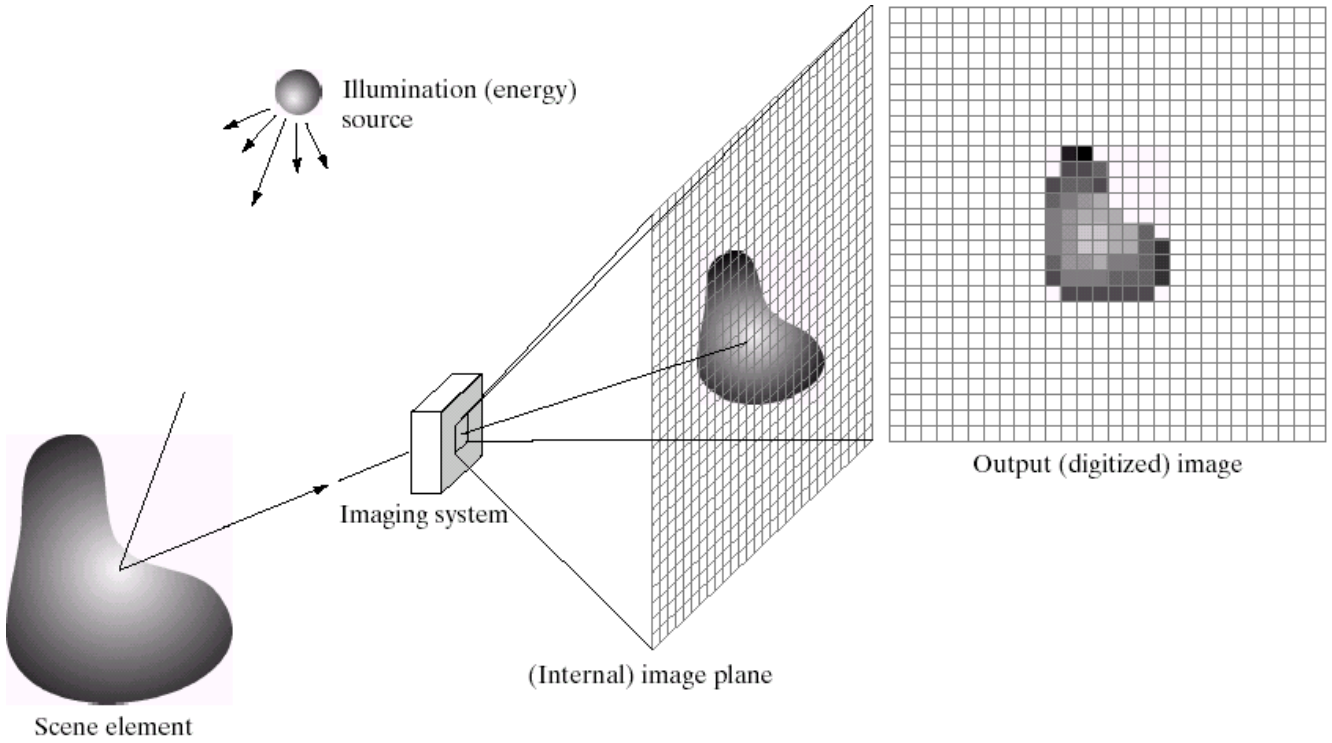


Electron microscope



10^{-6}m

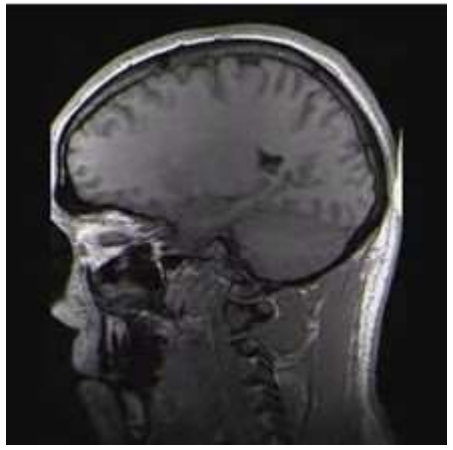
Image Acquisition and Representation



a
b c d e

FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

Examples



1. Brain MRI

2. Cardiac CT

3. Fetus Ultrasound

4. Satellite image

5. IR image

1 and 3. http://en.wikipedia.org
2. http://radiology.rsna.org
4. http://emap-int.com
5. http://www.imaging1.com

Image Acquisition

Camera + Scanner → Digital Camera: Get images into computer

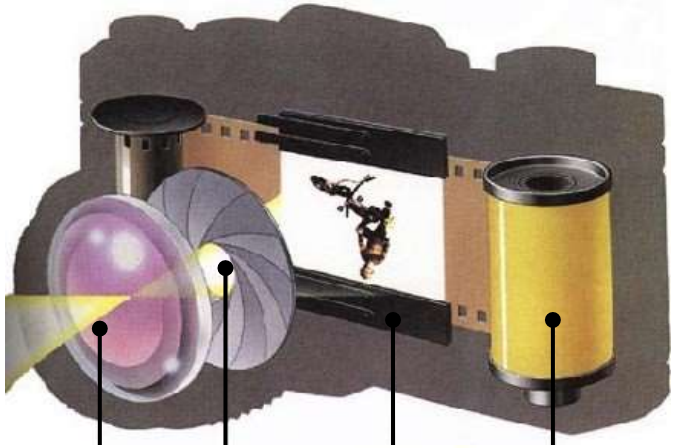
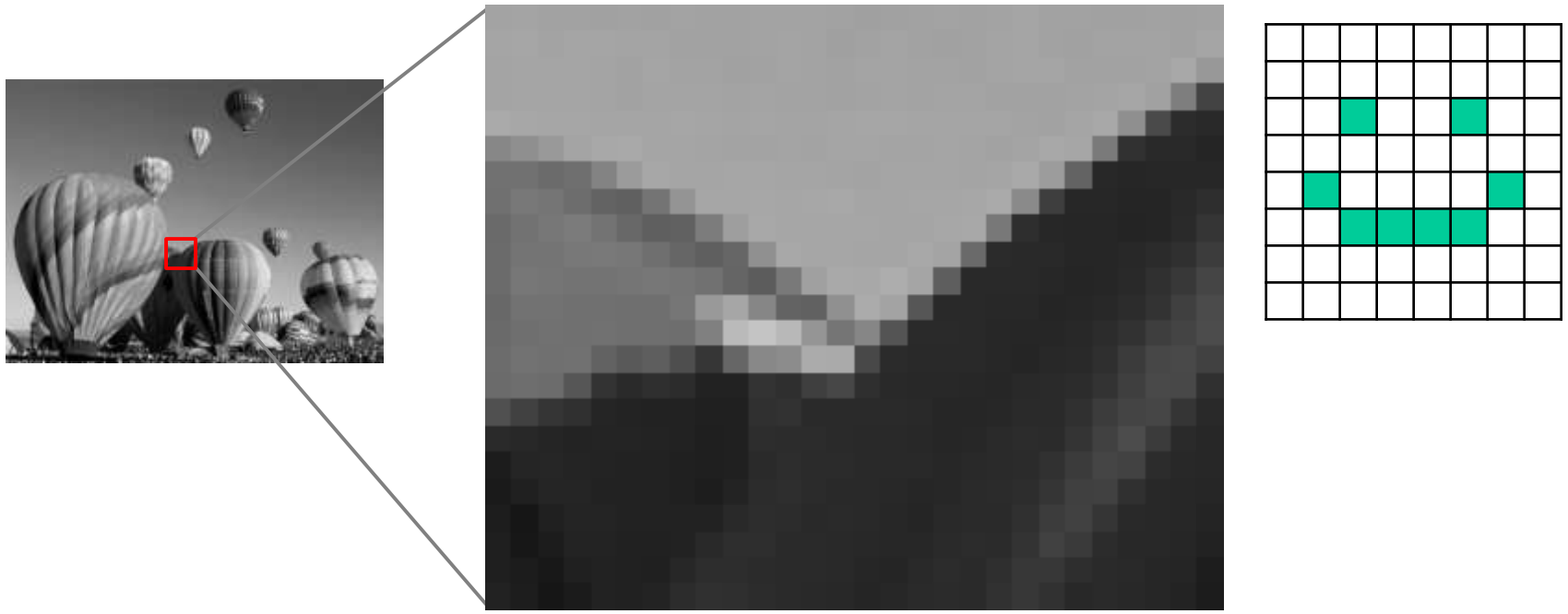


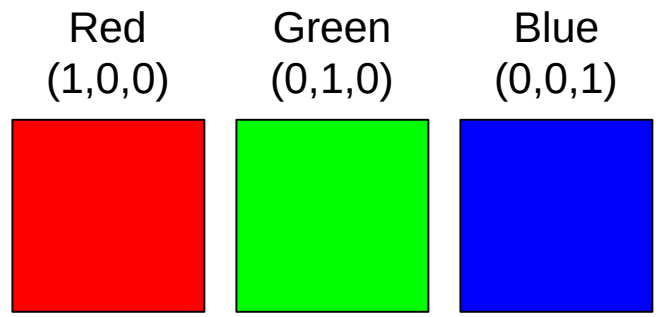
Image Representation

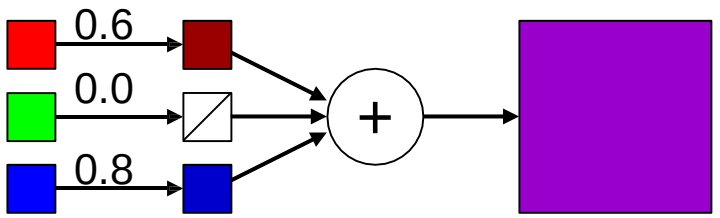
Discrete representation of images

- we'll carve up image into a rectangular grid of pixels $P[x,y]$
- each pixel p will store an intensity value in [0 1]
- 0 → black; 1 → white; in-between → gray
- Image size mxn → (mn) pixels



Color Image


Red
(1,0,0)
Green
(0,1,0)
Blue
(0,0,1)
0
Colors along Red axis
1


0.6
0.0
0.8
+


RGB
channels

Video: Frame by Frame

30 frames/second

Image Enhancement

to bring out detail that is obscured, or simply to highlight certain features of interest in an image

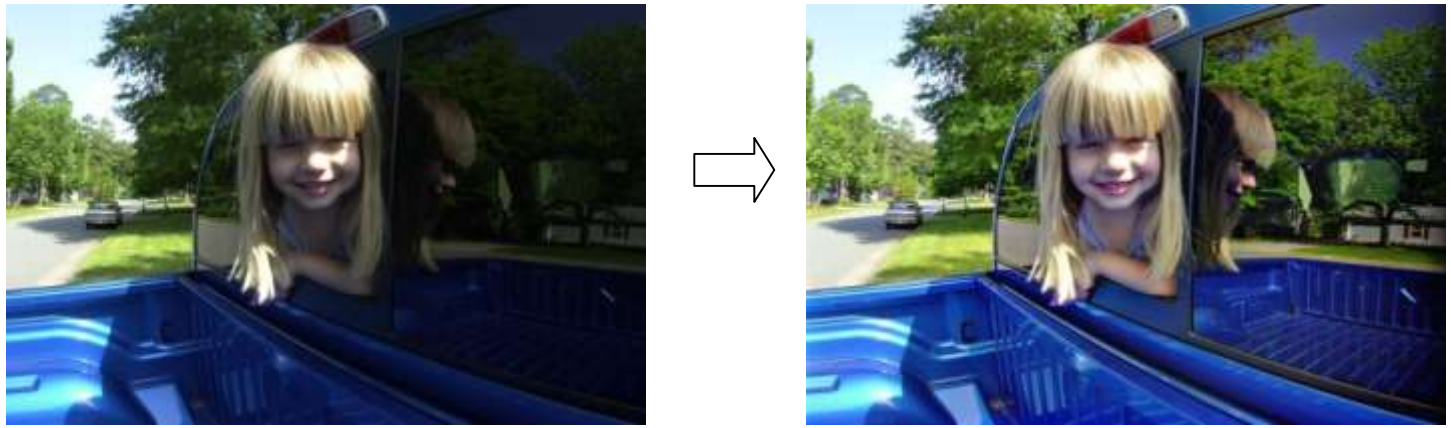


Image Restoration

Image restoration is an area that also deals with improving the appearance **of an image.**
However, unlike enhancement, which is subjective, image restoration is objective, in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image degradation. Enhancement, on the other hand, is based on human subjective preferences regarding what constitutes a "good" enhancement result

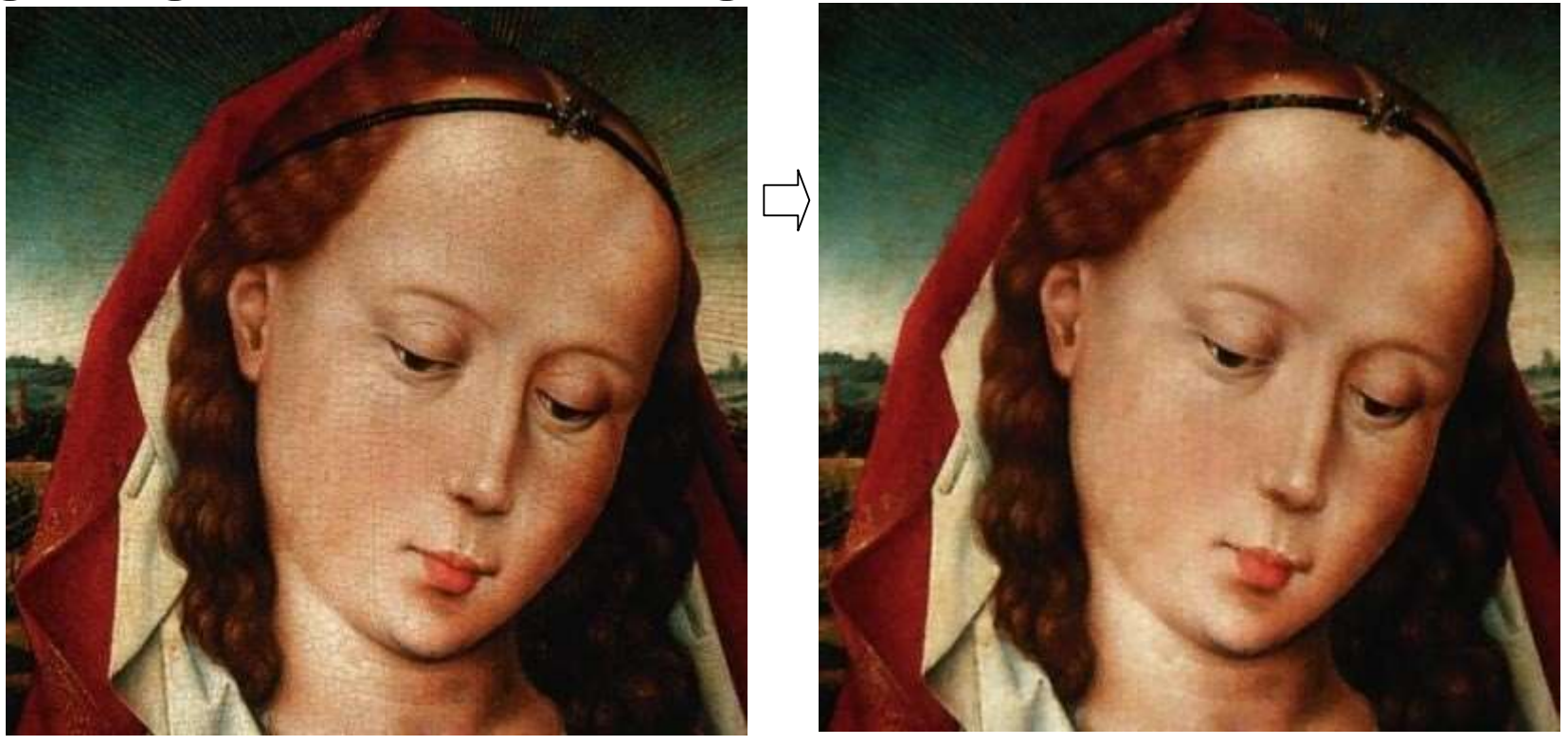


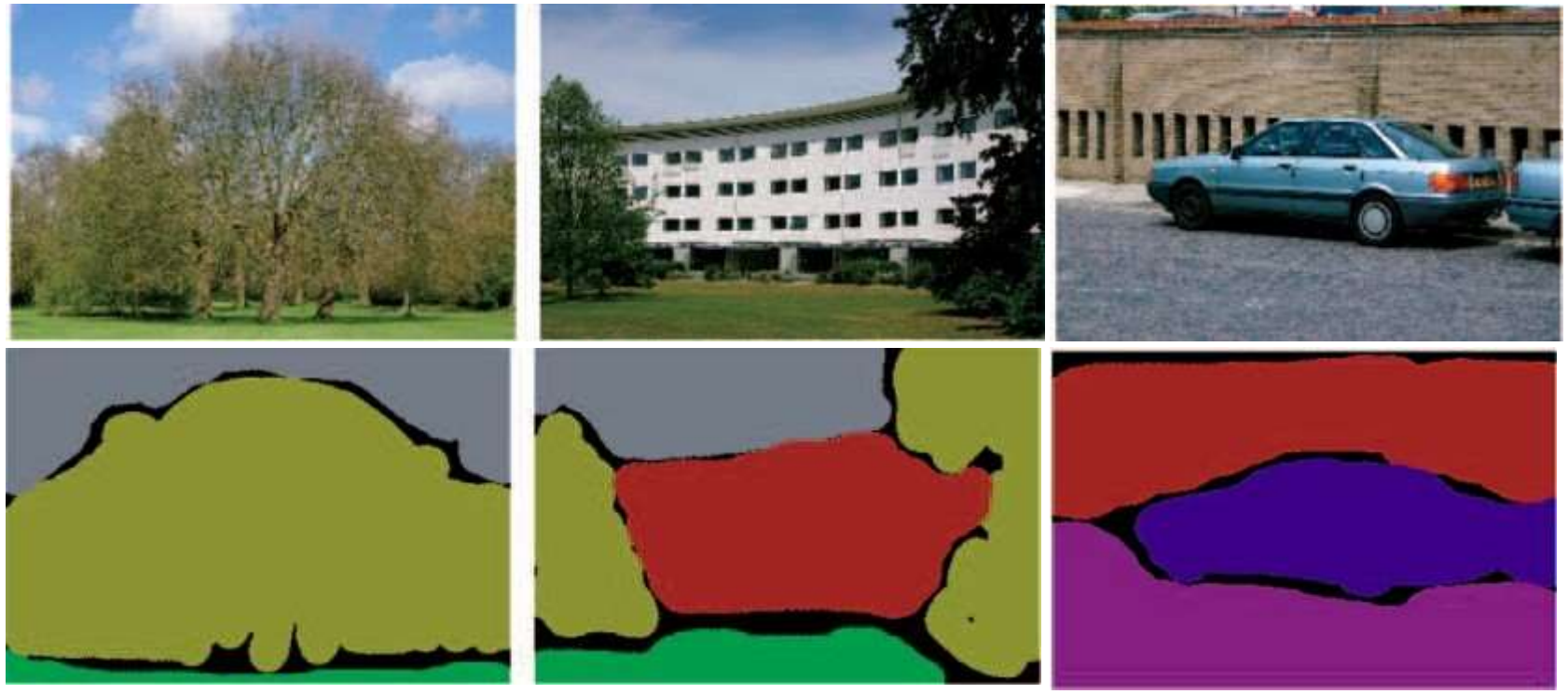
Image Compression

deals with techniques for reducing the storage required to save an image, or the bandwidth required to transmit it.

→ **Video compression**

Image Segmentation

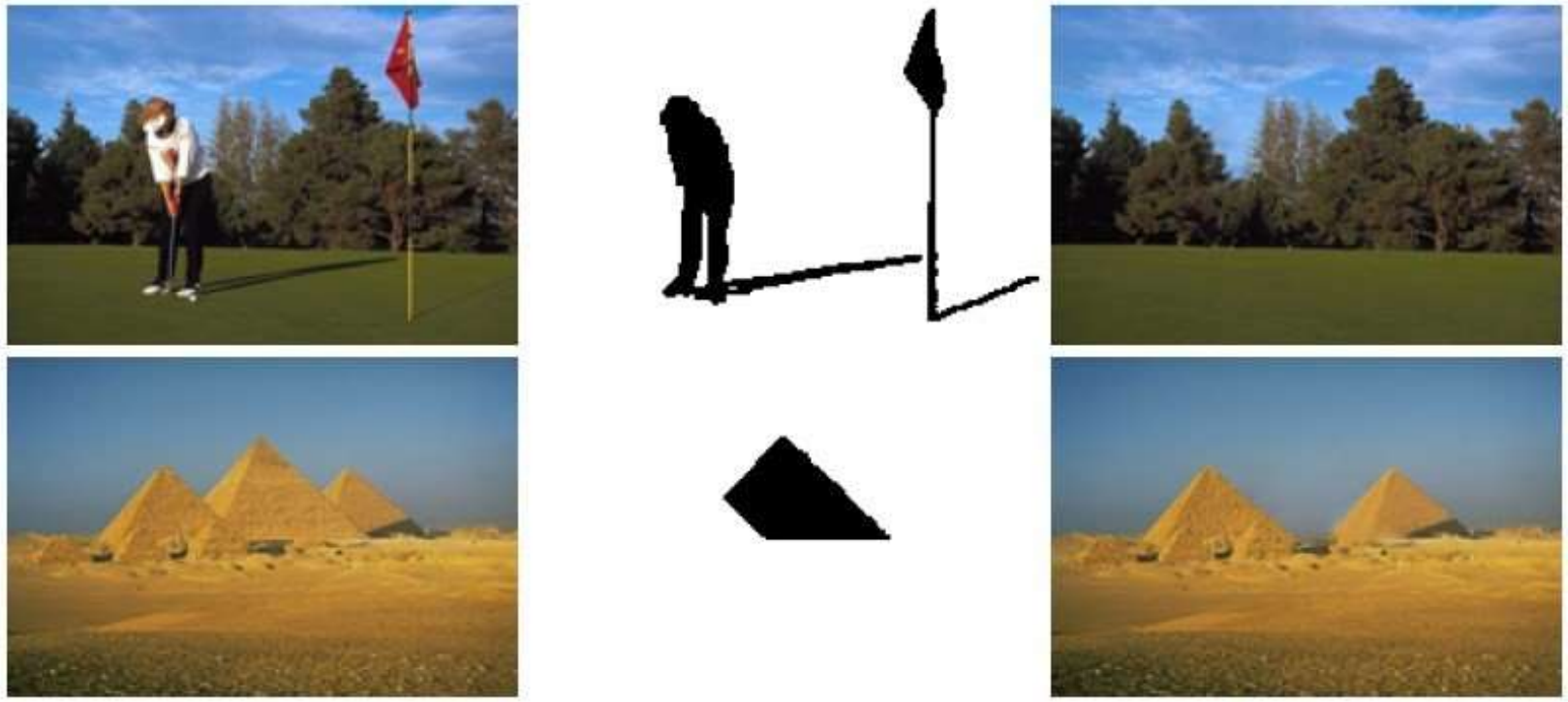
- To partition the image into its constituent parts (objects)



Microsoft multiclass segmentation data set

Image Completion

Interactively select objects. Remove them and automatically fill with similar background (from the same image)

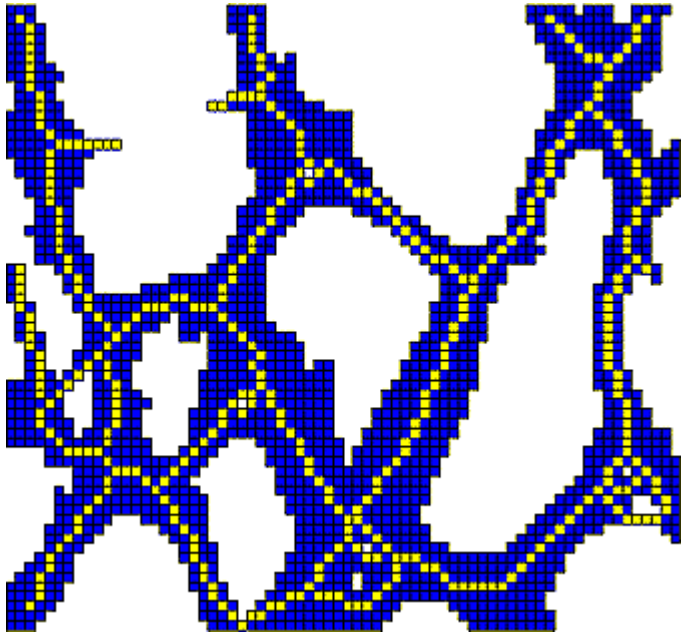


I. Drori, D. Cohen-Or, H. Yeshurun, SIGGRPAH'03

More Examples

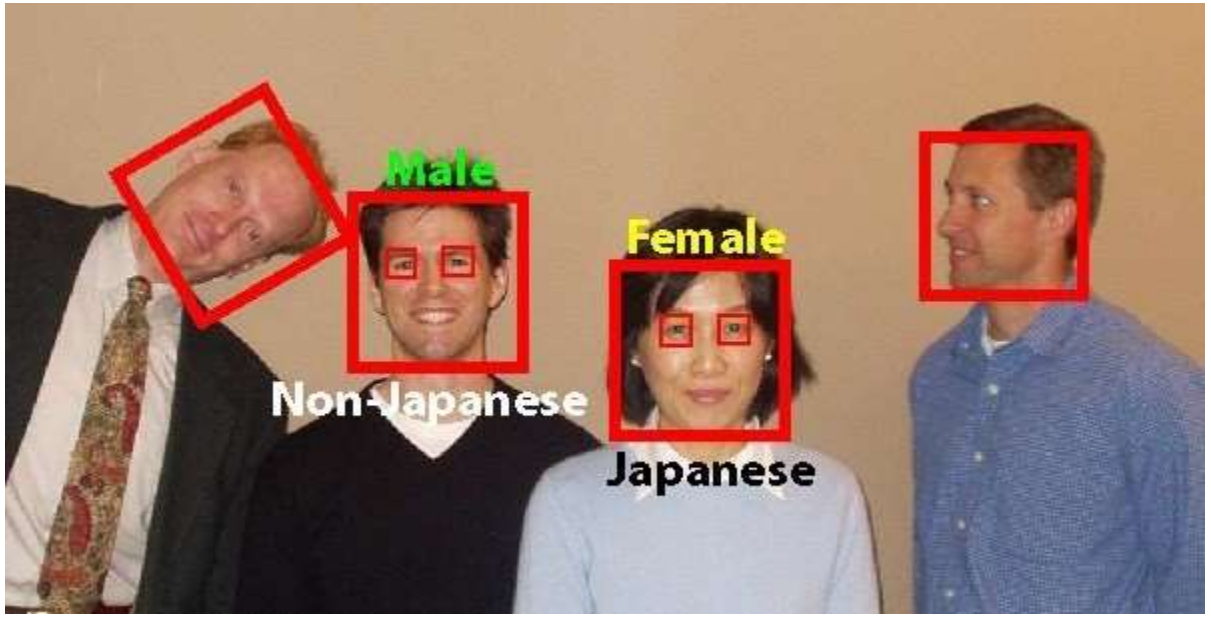
Morphological Image Processing

a group of non-linear operations that correlate to the shape or morphology of features in an image

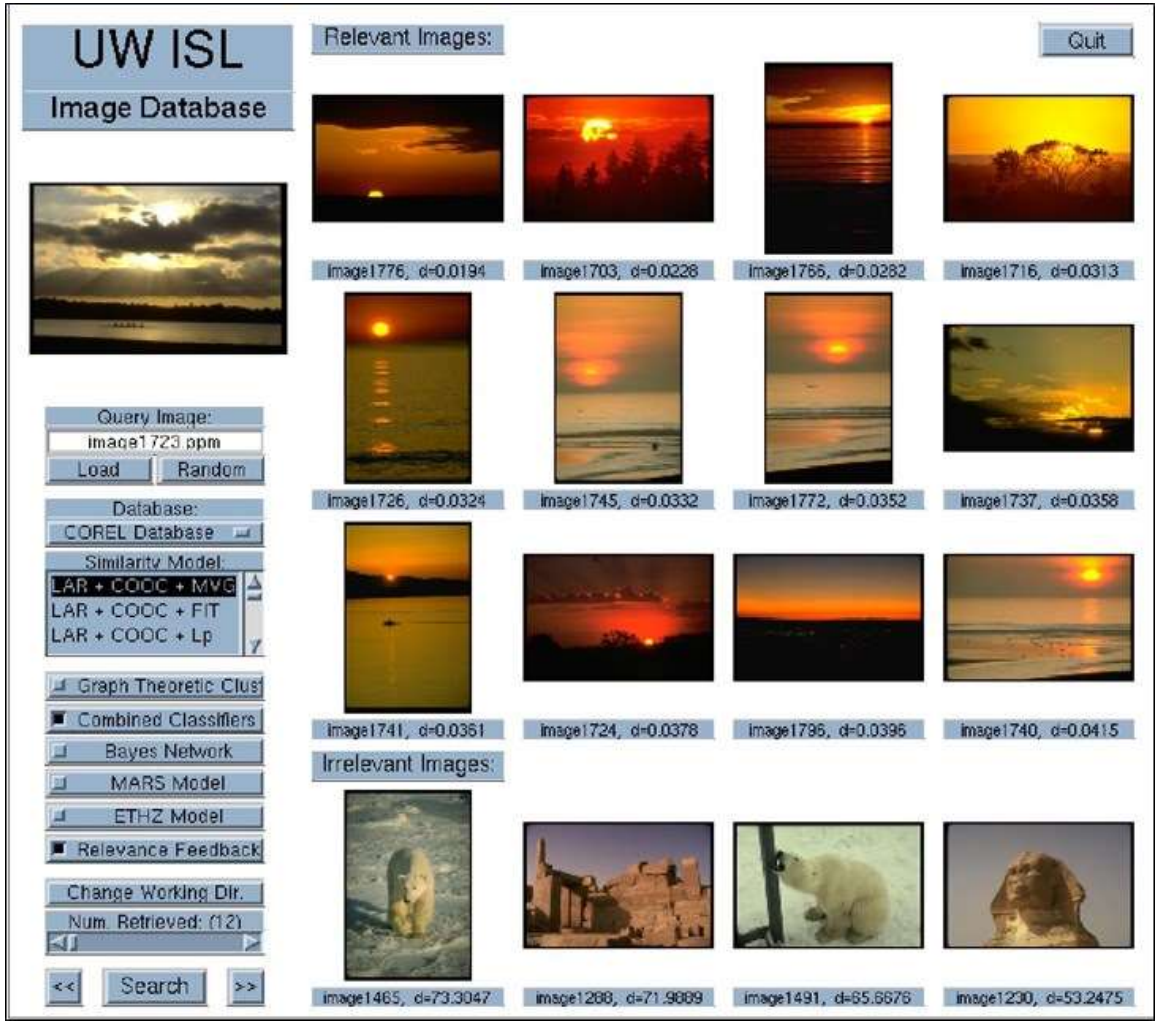


Object Detection / Recognition

- *Recognition is the process that assigns a label (e.g., "vehicle") to an object* based on its descriptors

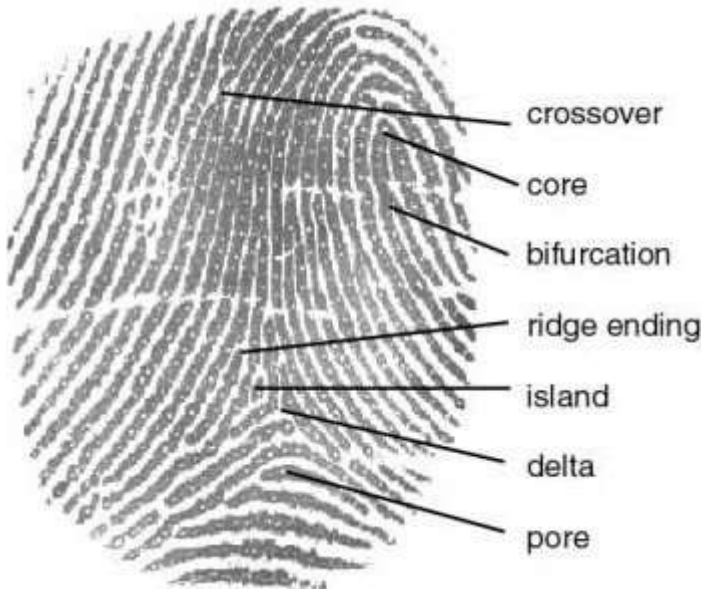


Content-Based Image Retrieval

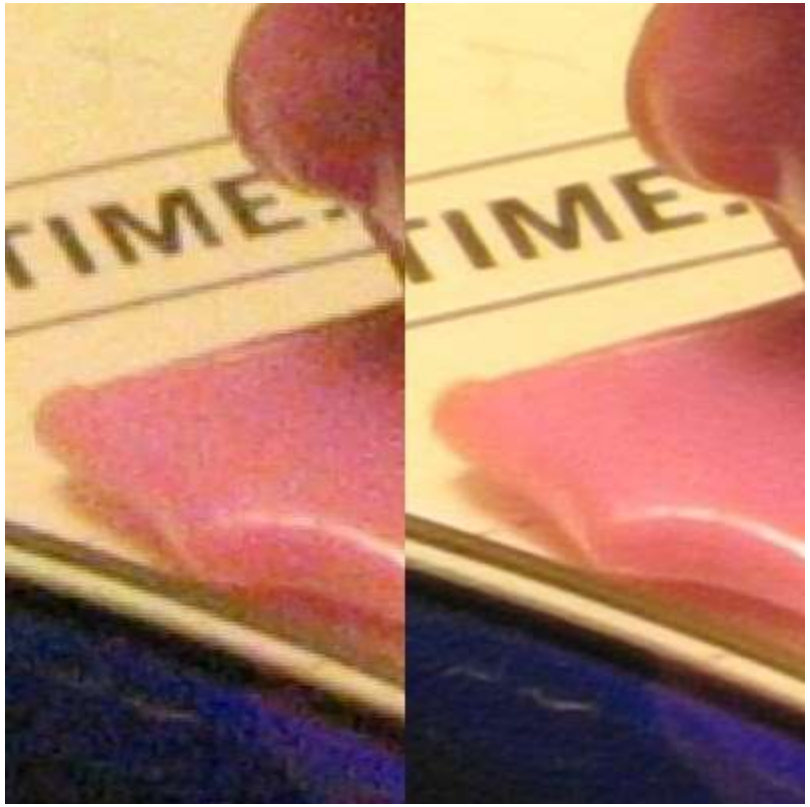


Biometrics


iris scan v1.1b


crossover
core
bifurcation
ridge ending
island
delta
pore

Super-Resolution



Applications of Digital Image Processing

Digital camera

Photoshop

Human computer interaction

Medical imaging for diagnosis and treatment

Surveillance

Automatic driving

…

Fast-growing market!

Electromagnetic spectrum

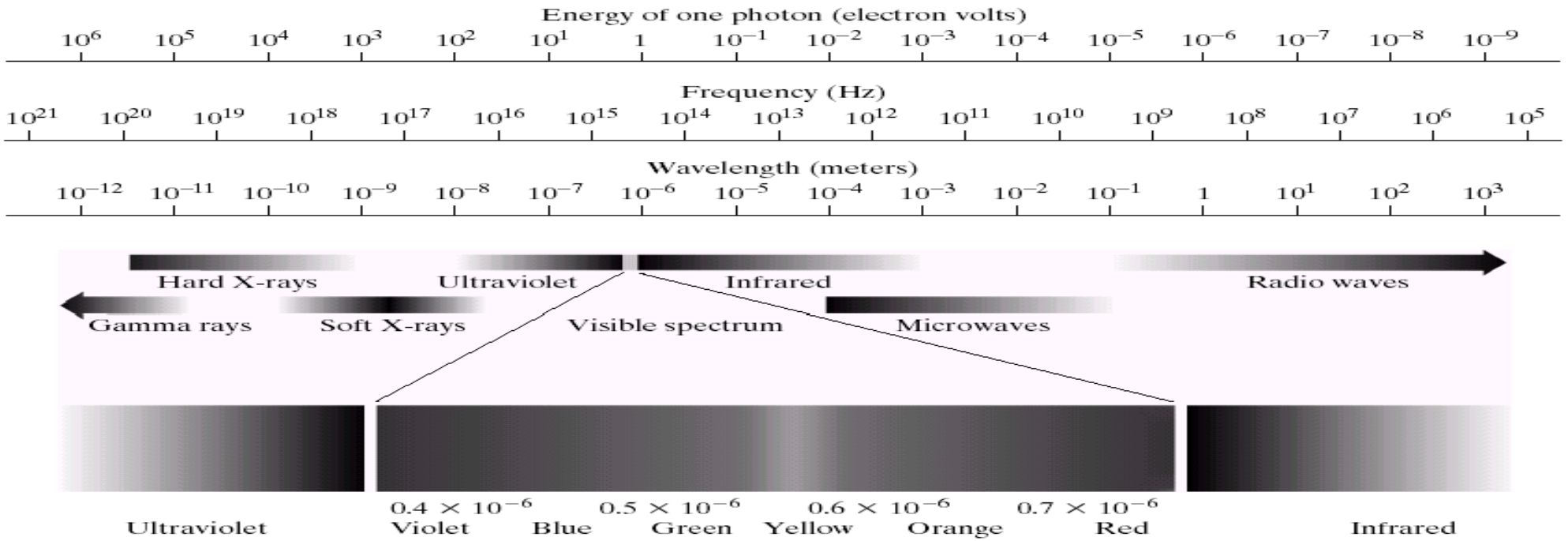


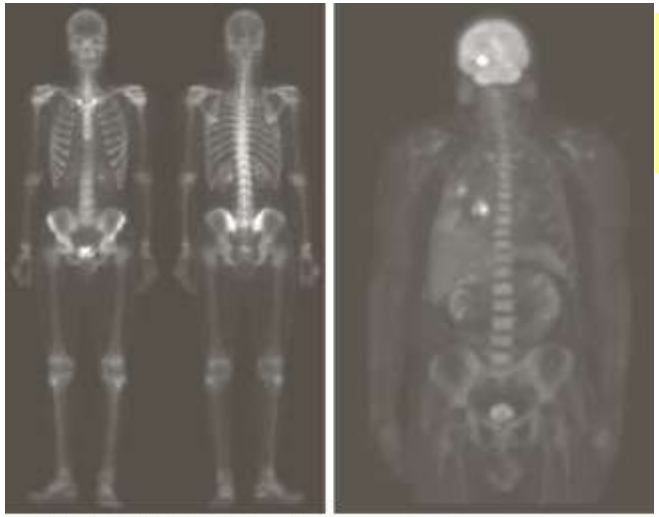
FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

The whole electromagnetic spectrum is used for "imaging"

Relationship between wavelength and objects to see?

Examples: Gamma ray imaging

Bone scan



Positron emission tomography…

Cygnus loop: An exploded star in the constellation of Cygnus

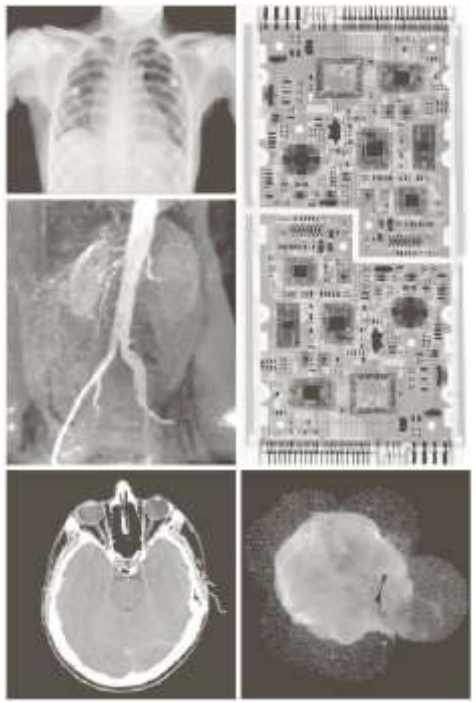
Gamma radiation from a reactor

Examples: X-ray imaging

Chest X-ray

Angiogram

Head CAT slice



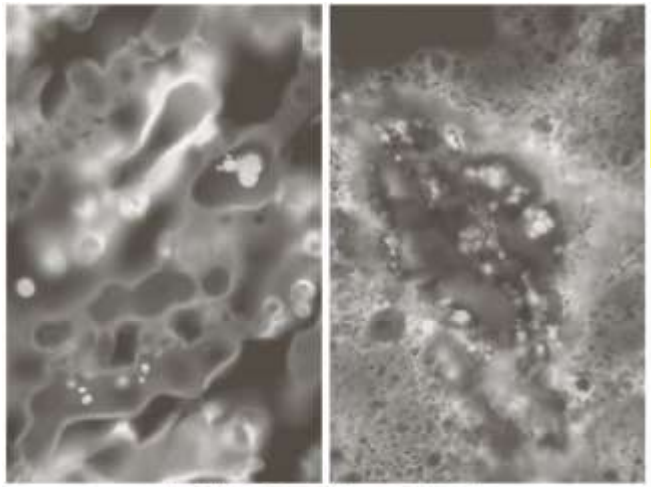
Cygnus loop imaged in the X-ray band

a d
b
c e

FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School; (d) Mr. Joseph E. Pascente, Lixi, Inc.; and (e) NASA.)

Examples: Ultraviolet imaging

Normal corn



Smut corn

Cygnus loop imaged in the ultraviolet band

Multispectral imaging

Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

TABLE 1.1 Thematic bands in NASA's LANDSAT satellite.

Multispectral imaging

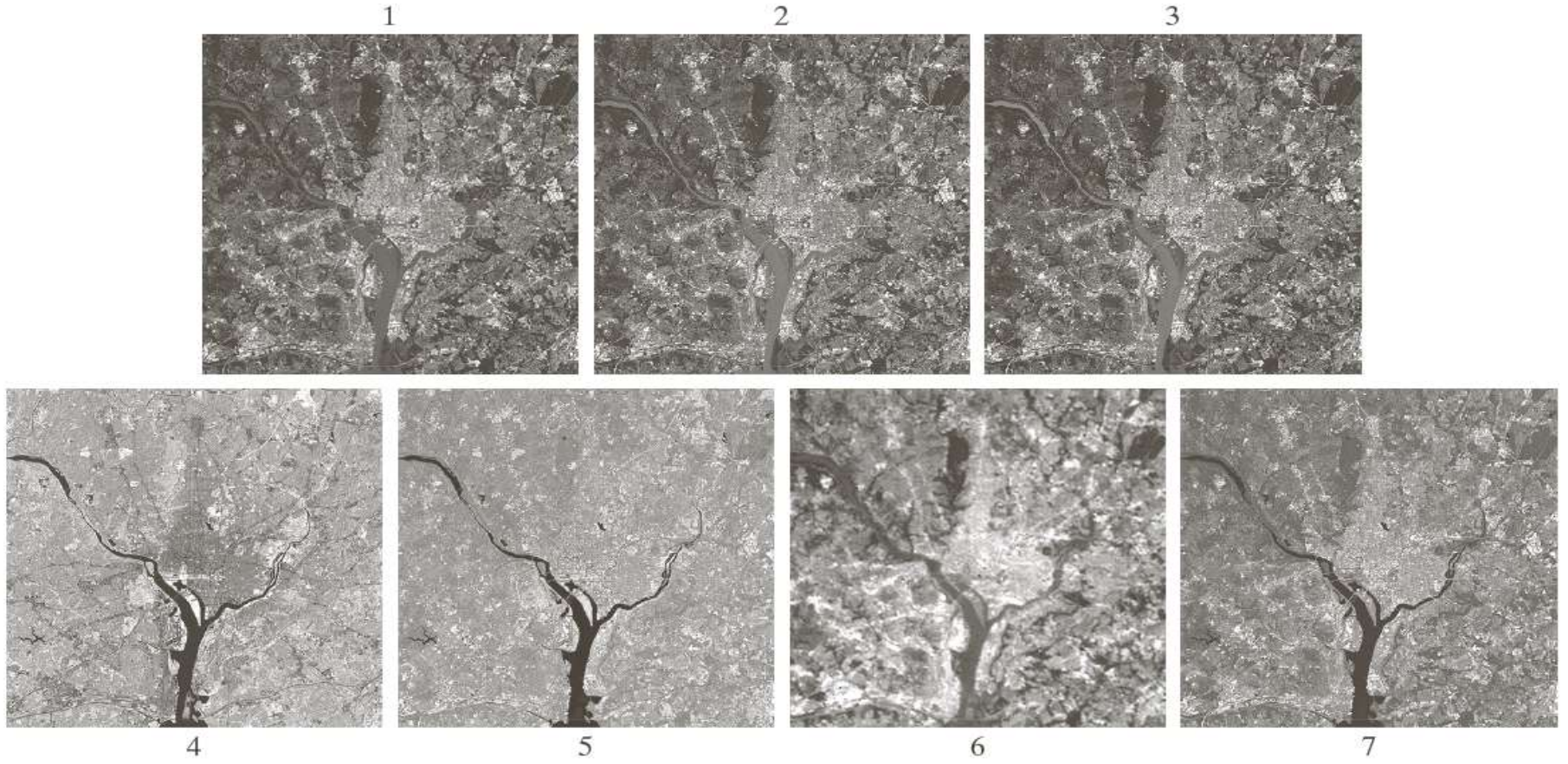


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

Multispectral imaging

FIGURE 1.11
Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)

Infrared imaging

FIGURE 1.12
Infrared satellite images of the Americas. The small gray map is provided for reference. (Courtesy of NOAA.)

Infrared imaging

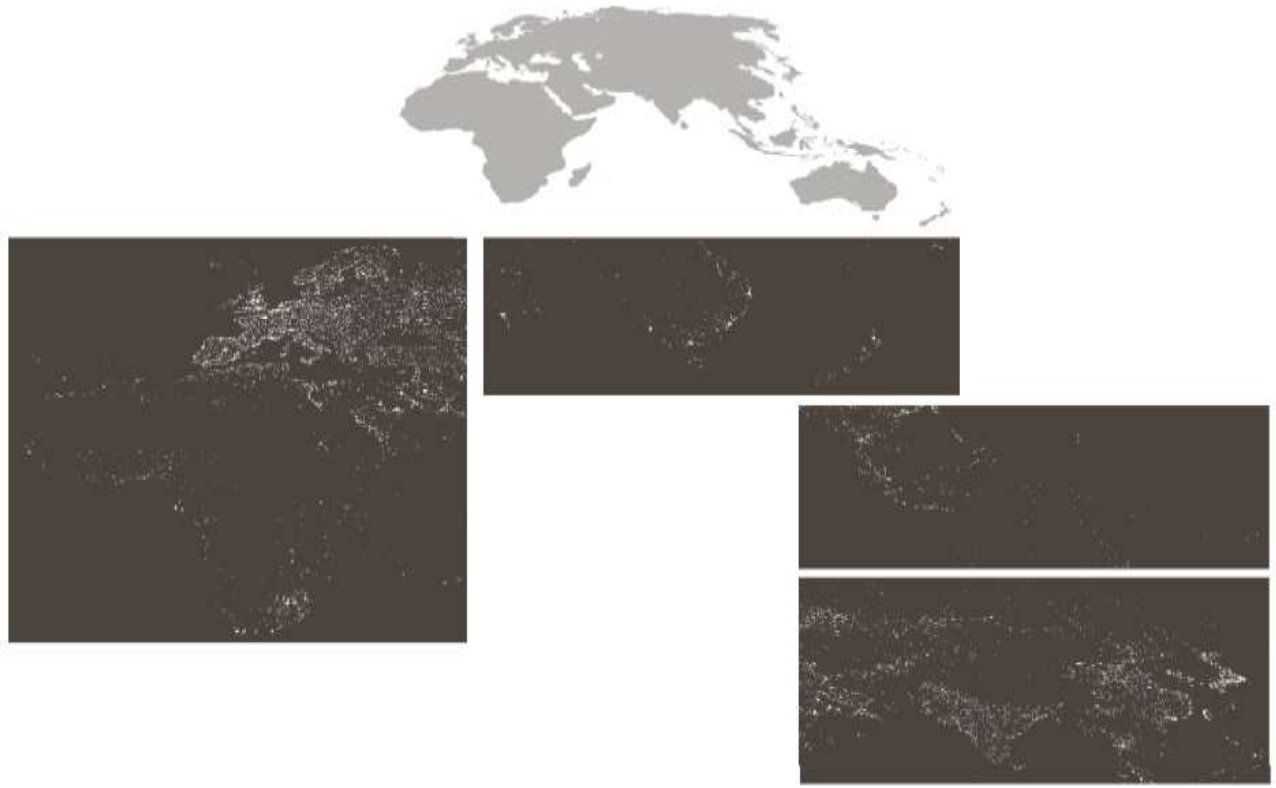
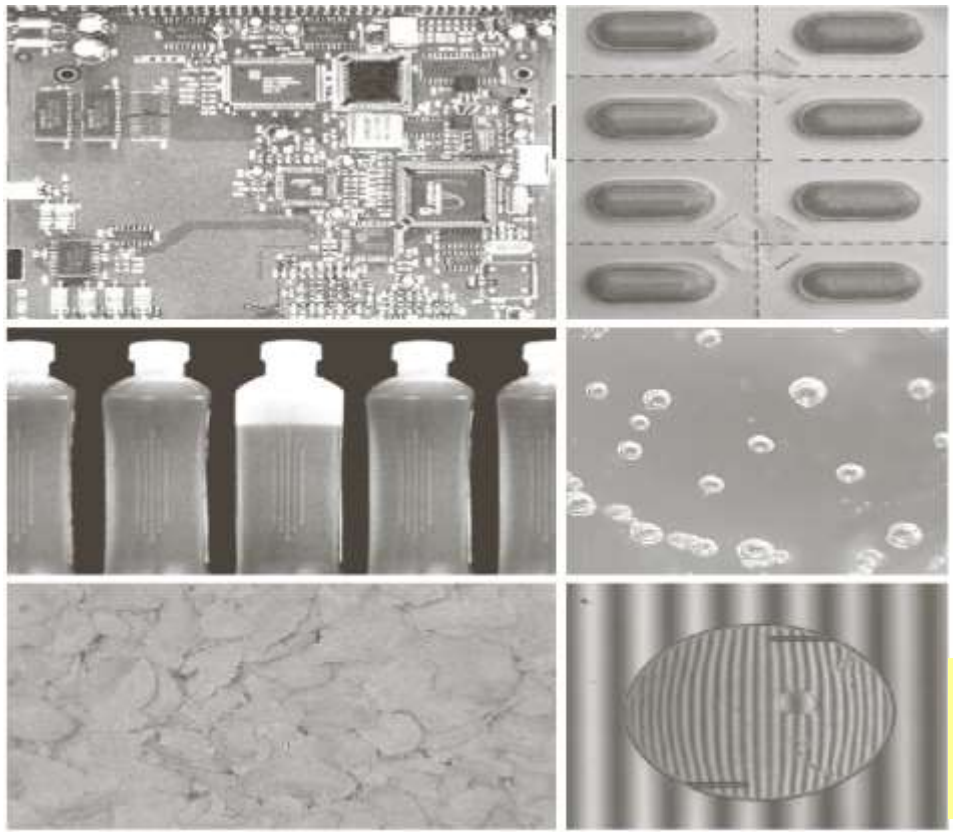


FIGURE 1.13
Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)

Visible spectrum



a b
c d
e f

FIGURE 1.14 Some examples of manufactured goods often checked using digital image processing. (a) A circuit board controller. (b) Packaged pills. (c) Bottles. (d) Air bubbles in a clear-plastic product. (e) Cereal. (f) Image of intraocular implant. (Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)

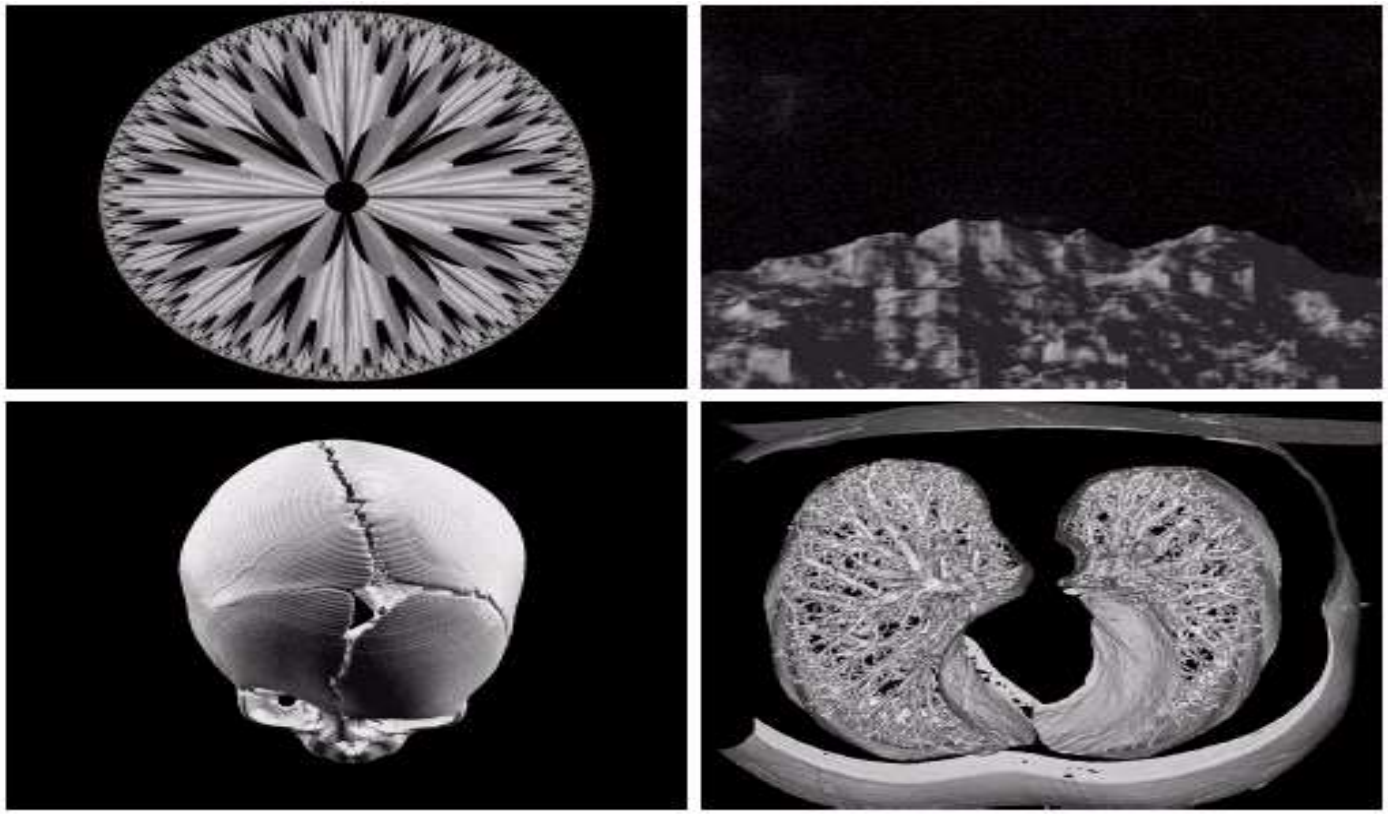
Replacement lens for the human eye

Visible spectrum

a b
c
d

FIGURE 1.15 Some additional examples of imaging in the visual spectrum. (a) Thumb print. (b) Paper currency. (c) and (d) Automated license plate reading. (Figure (a) courtesy of the National Institute of Standards and Technology. Figures (c) and (d) courtesy of Dr. Juan Herrera, Perceptics Corporation.)

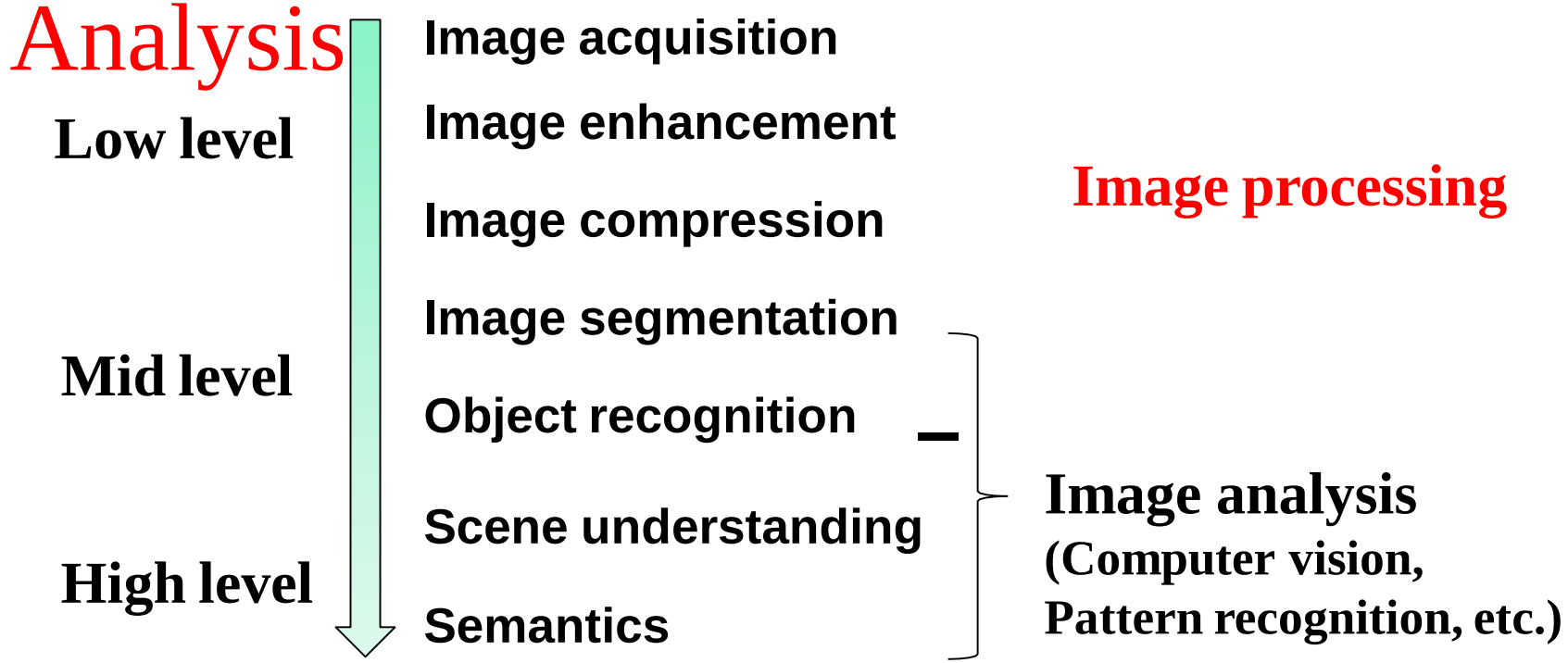
Synthetic images



a b
c d

FIGURE 1.22
(a) and (b) Fractal images. (c) and (d) Images generated from 3-D computer models of the objects shown. (Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College, (c) and (d) courtesy of NASA.)

Image Processing → Image Analysis



- Low level processes: contrast manipulation
- Mid-level processes: segmentation, recognition
- High level processes: understanding groups of objects

Image Processing & Machine Vision

- From Image Processing to Machine Vision:
  - low, mid and high-level processes

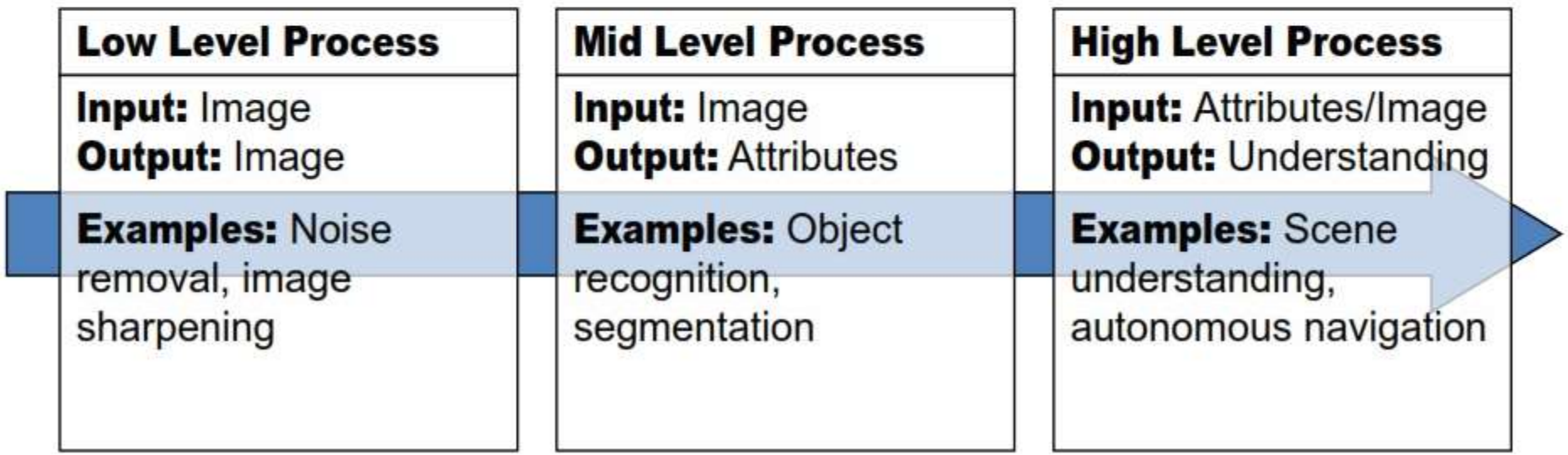


Image Processing & Machine Vision

- From Image Processing to Machine Vision:
  - low, mid and high-level processes

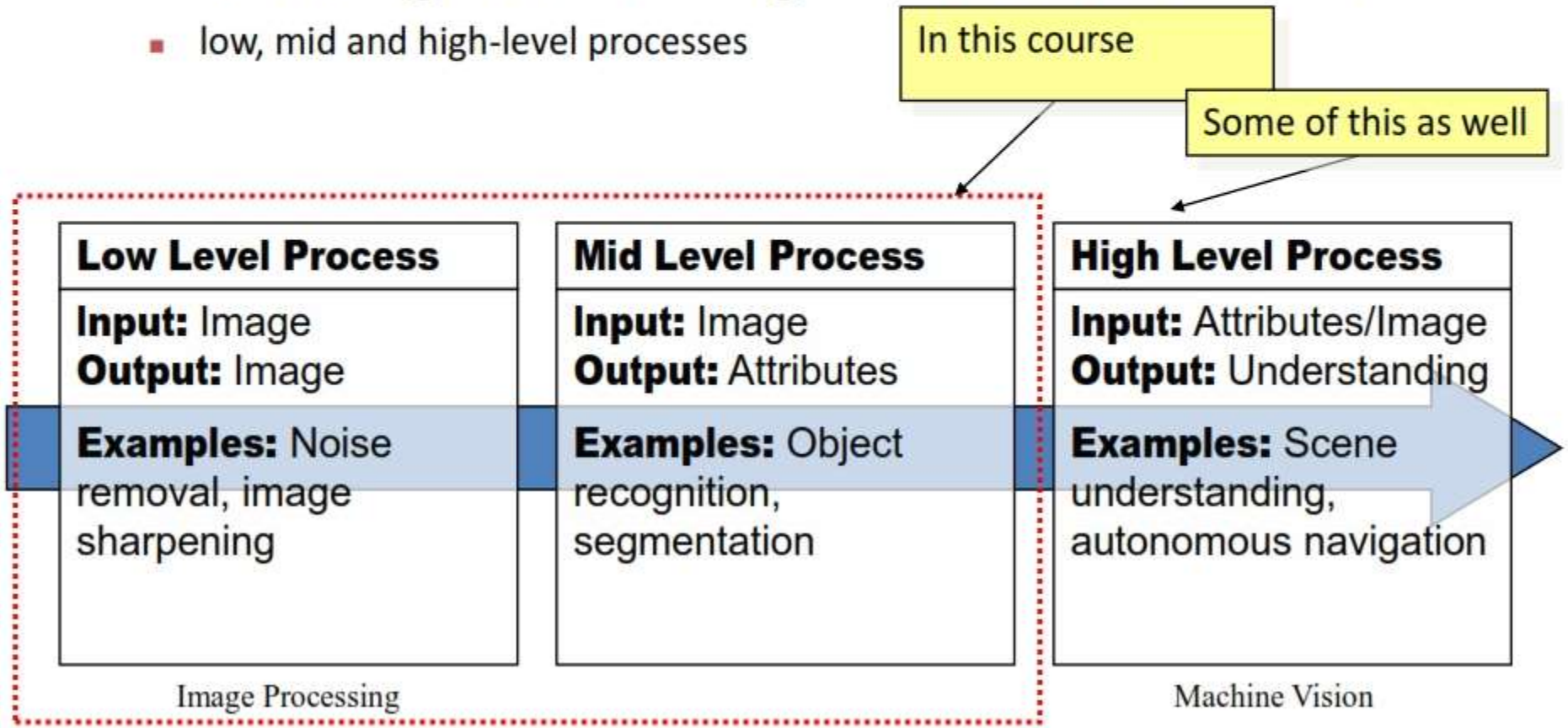


Image Processing to Computer Vision

- Low-level: input, output are images
  - *Primitive operations such as image preprocessing to reduce noise, contrast enhancement, and image sharpening*
- Mid-level: inputs may be images, outputs are attributes extracted from those images
  - *Segmentation*
  - *Description of objects*
  - *Classification of individual objects*
- High-level:
  - *Image analysis*
  - *Recognition*

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
  - Matlab review
- Next time we will start to see how it all works…