CSCE 763: Digital Image Processing

Spring 2024

Dr. Yan Tong

Department of Computer Science and Engineering
University of South Carolina

Course Information

Instructor: Dr. Yan Tong

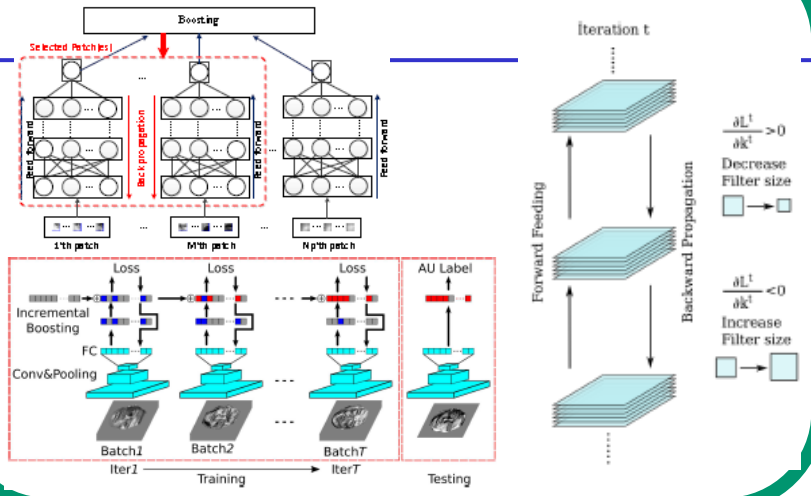
Email: tongy@cse.sc.edu

Office: Storey Innovation Center 2273

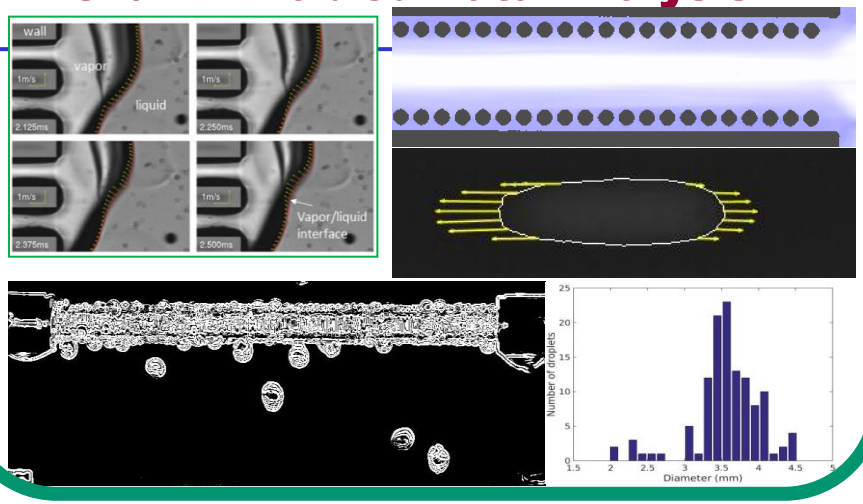
Office Hours: By appointment

Dr. Tong's Main Research Areas

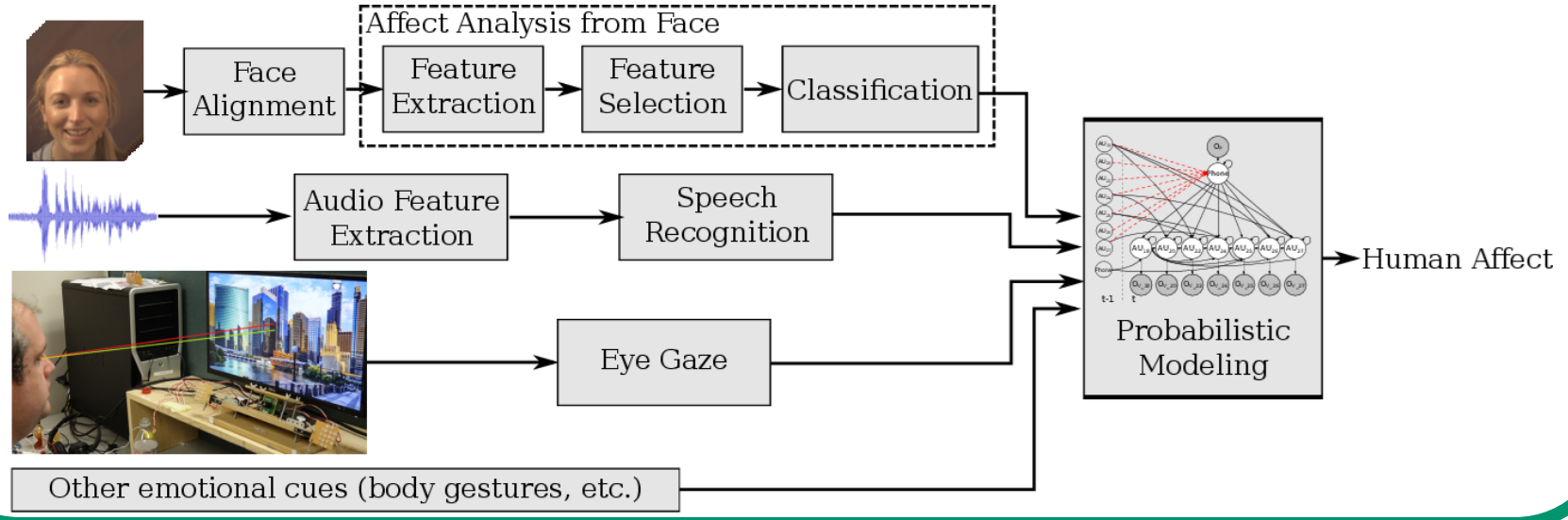
Fundamental Research in CV/ML



CV/ML Enabled Data Analysis



Multimodal Information Fusion



Now, tell me about yourself!

- Name
- Major
- Research interest
- Why do you take this course

Today's Agenda

- Welcome
- Tentative Syllabus
- Topics covered in the course

Class Communication

Class website

http://www.cse.sc.edu/~tongy/csce763/csce763.html

Blackboard Ultra

Tentative Syllabus

- Prerequisites
- Objectives
- Textbook
- Grade

Prerequisites of This Course

This is a computer science course

- It will involve a fair amount of math
  - calculus, linear algebra, geometry
  - probability
  - analog/digital signal processing
  - graph theory etc.

- It will involve the modeling and design of a real system - one final course project
  - Programming skills with matlab, Python, or C++

The Objective of This Course

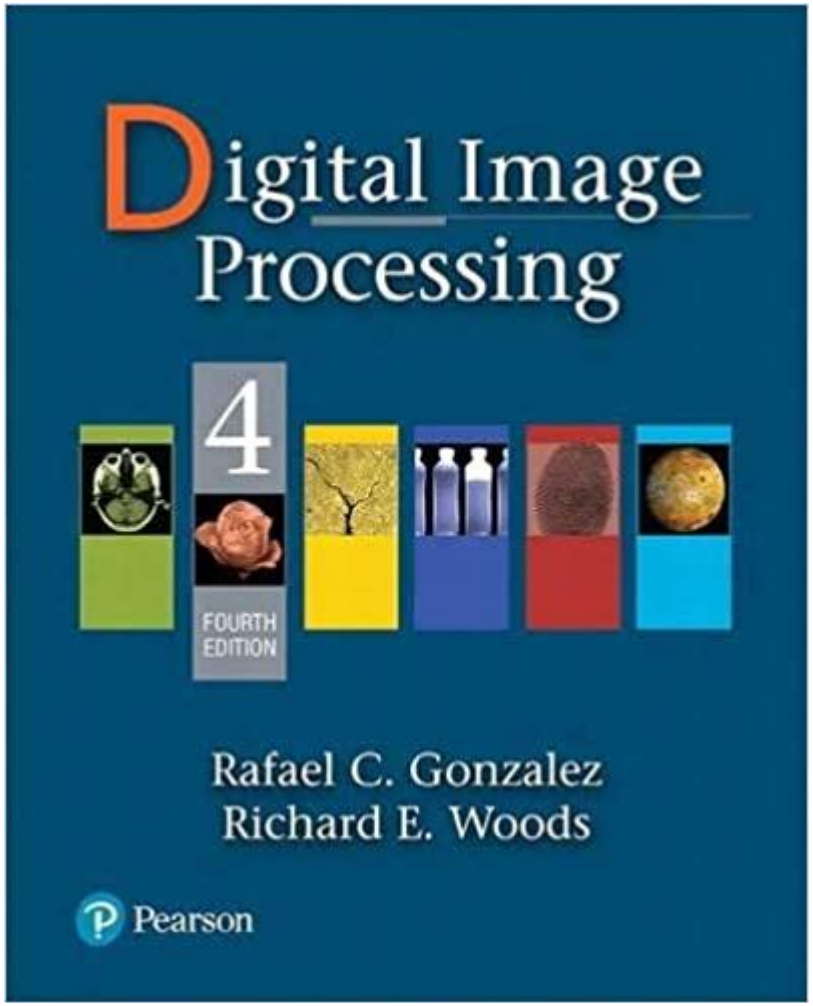
This is a graduate-level topic course

- Research oriented
  - Paper reading & presentation
  - Final project & presentation
  - Review on the state-of-the-art
- Understanding → Innovation
  - your own innovative and original work/opinion/result
- Basic knowledge → Research frontier
  - learn through reading recent papers

Textbook

Required:

Digital Image Processing, **Rafael C. Gonzalez and Richard E. Woods, 4th Edition, Pearson**



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

Requirement for Final Project

Option 1: A complete research project

- Introduction (problem formulation/definition)
- literature review
- the proposed method and analysis
- experiment
- conclusion
- reference

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 Final Project

Requirements

- Select a topic and write a one-page proposal (due Feb 21)
- Progress report (discuss with the instructor)
- Research work and report writing
- Oral presentation
- 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 Final Project

Written report

- Report format: the same as an IEEE conference paper
- 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 Final Project

Evaluation

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

Requirement for Final 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 and discussions
- About 10 mins oral presentation for each student

Major Topics Covered in Class

Image acquisition and digital image representation

Image enhancement

Image restoration

Color image processing

Image compression

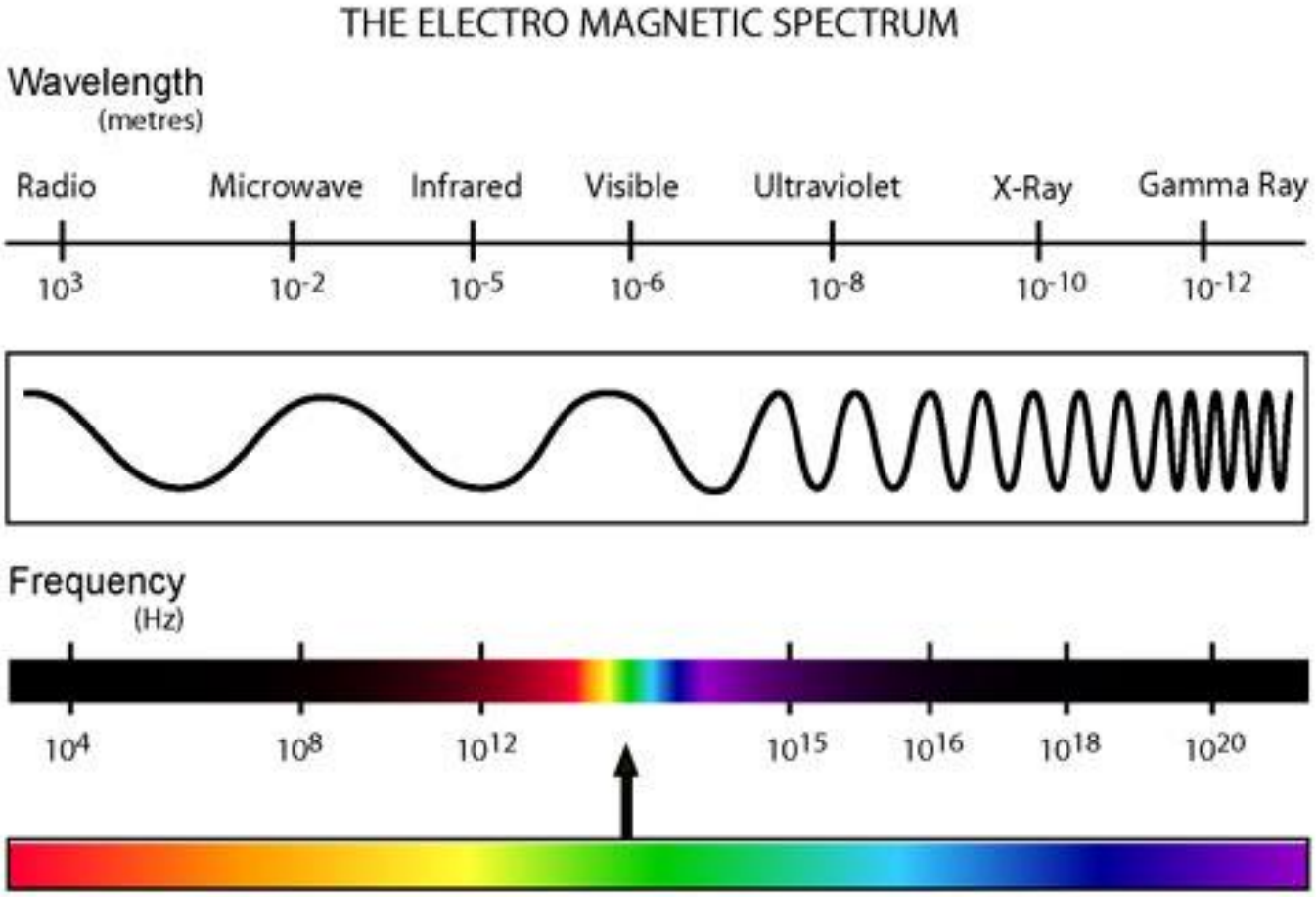
Image segmentation

Morphological image processing

Special topics on recent progresses on digital image processing

Human Perception VS Machine Vision

- **Limited vs entire EM spectrum**



http://www.kollewin.com/blog/electromagnetic-spectrum/

Image Processing → Image Analysis

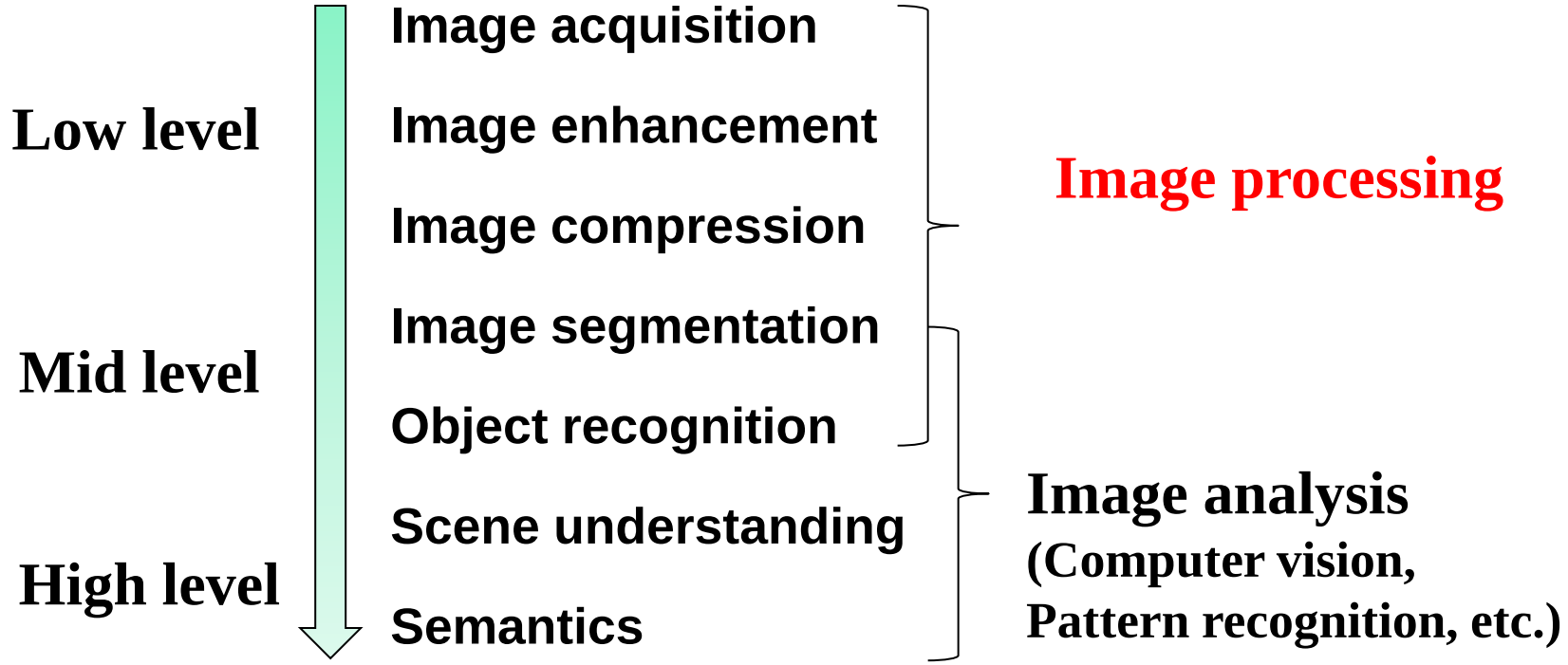
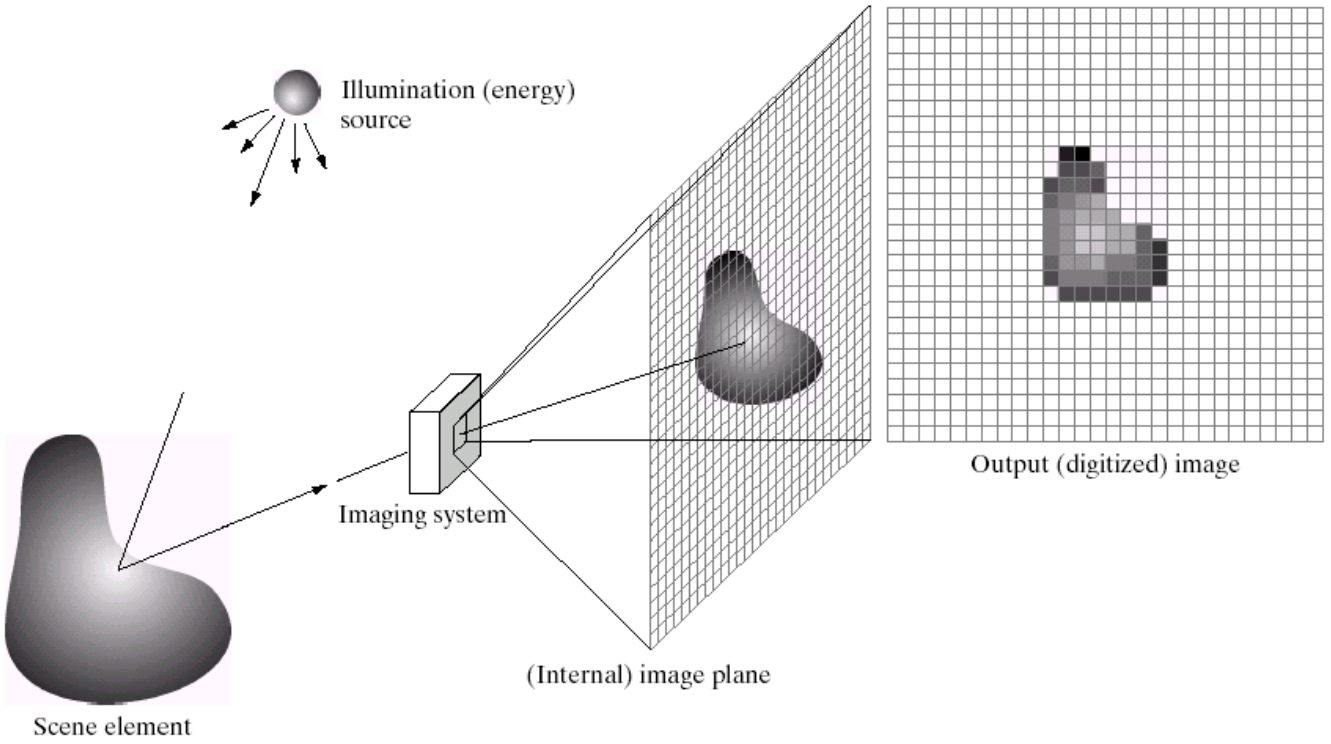


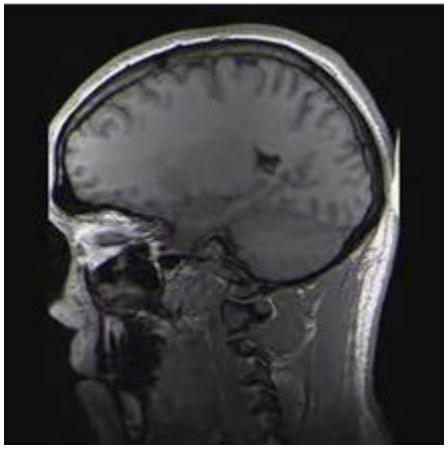
Image Acquisition and Representation



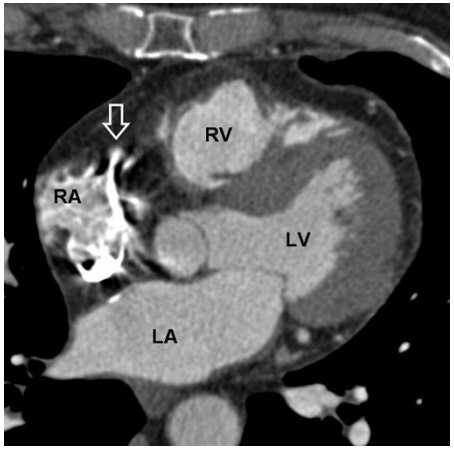
a
b c d e

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

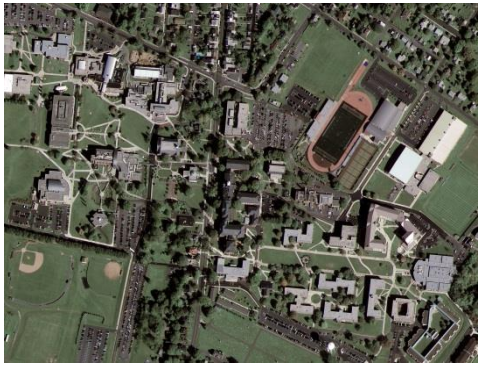


1. Brain MRI



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

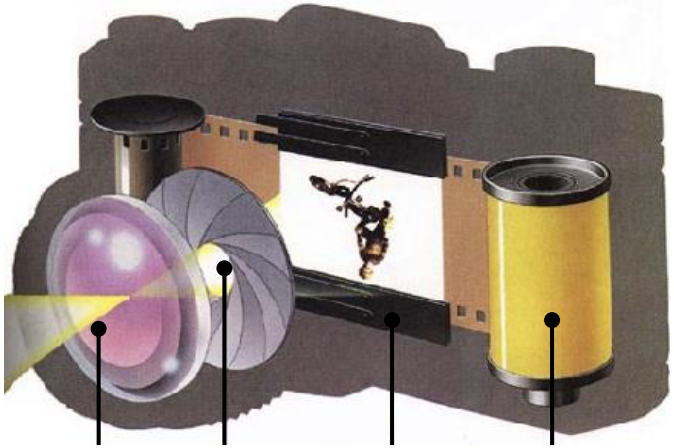
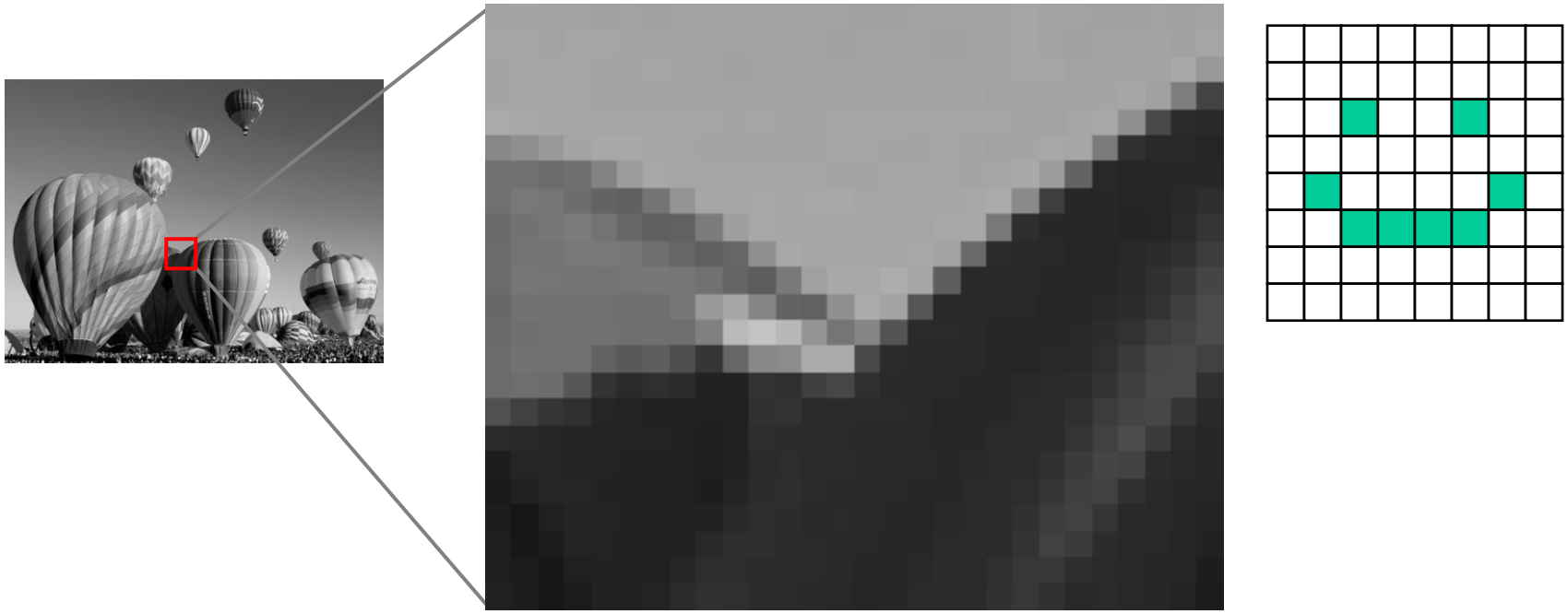


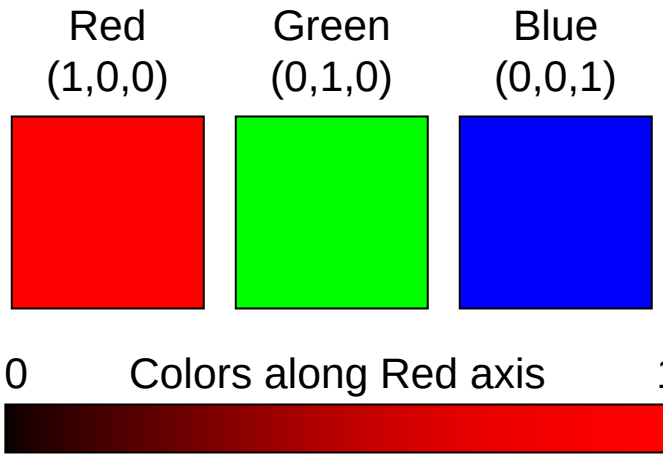
Image Representation

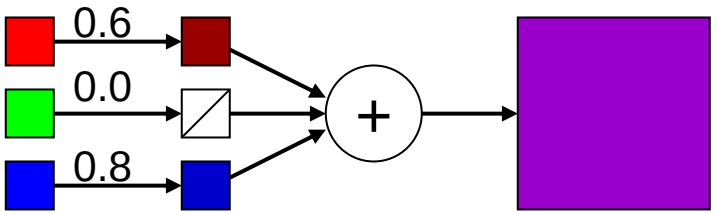
Discrete representation of images

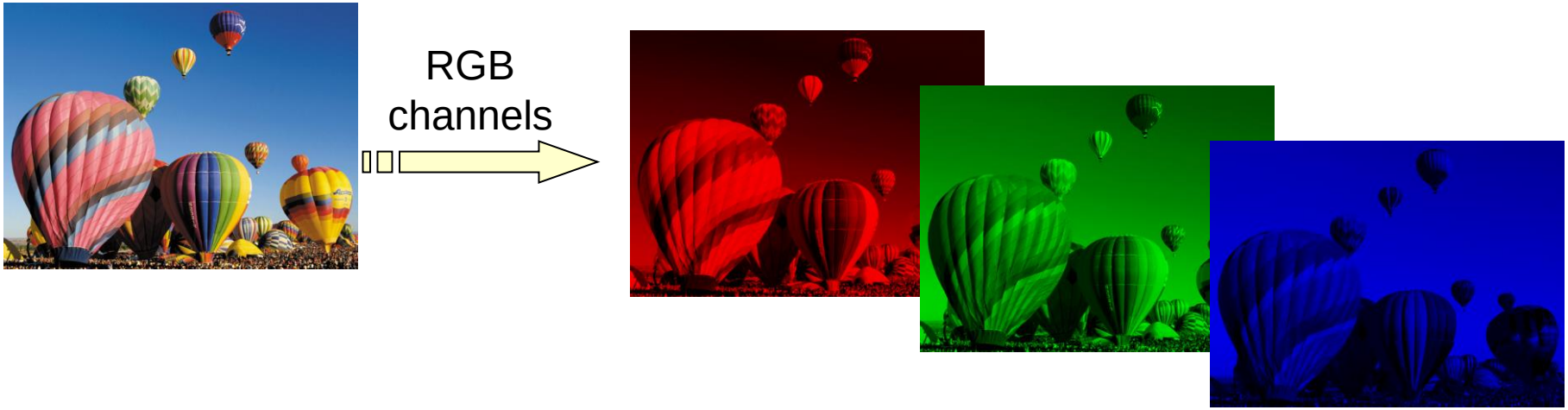
- we'll carve up image into a rectangular grid of pixels $P[x,y]$
- each pixel p will store an intensity value in [0 1]
- 0 → black; 1 → white; in-between → gray
- Image size mxn → (mn) pixels



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

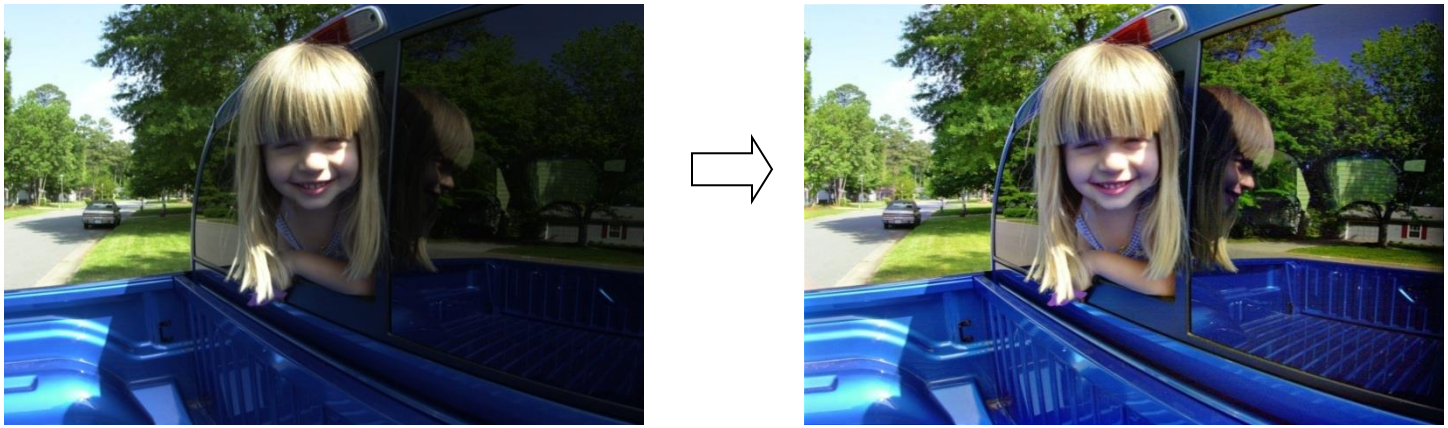


Image Restoration

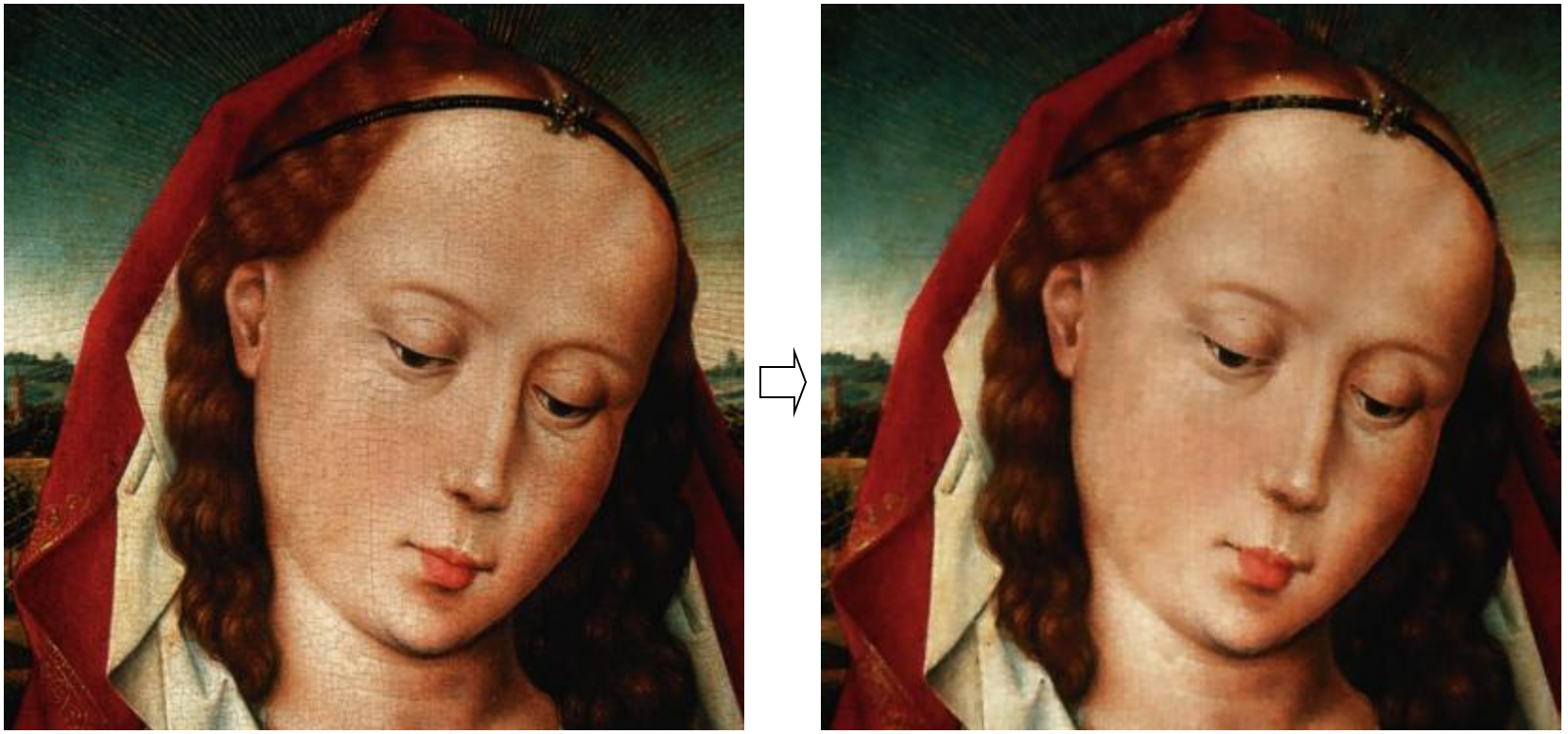
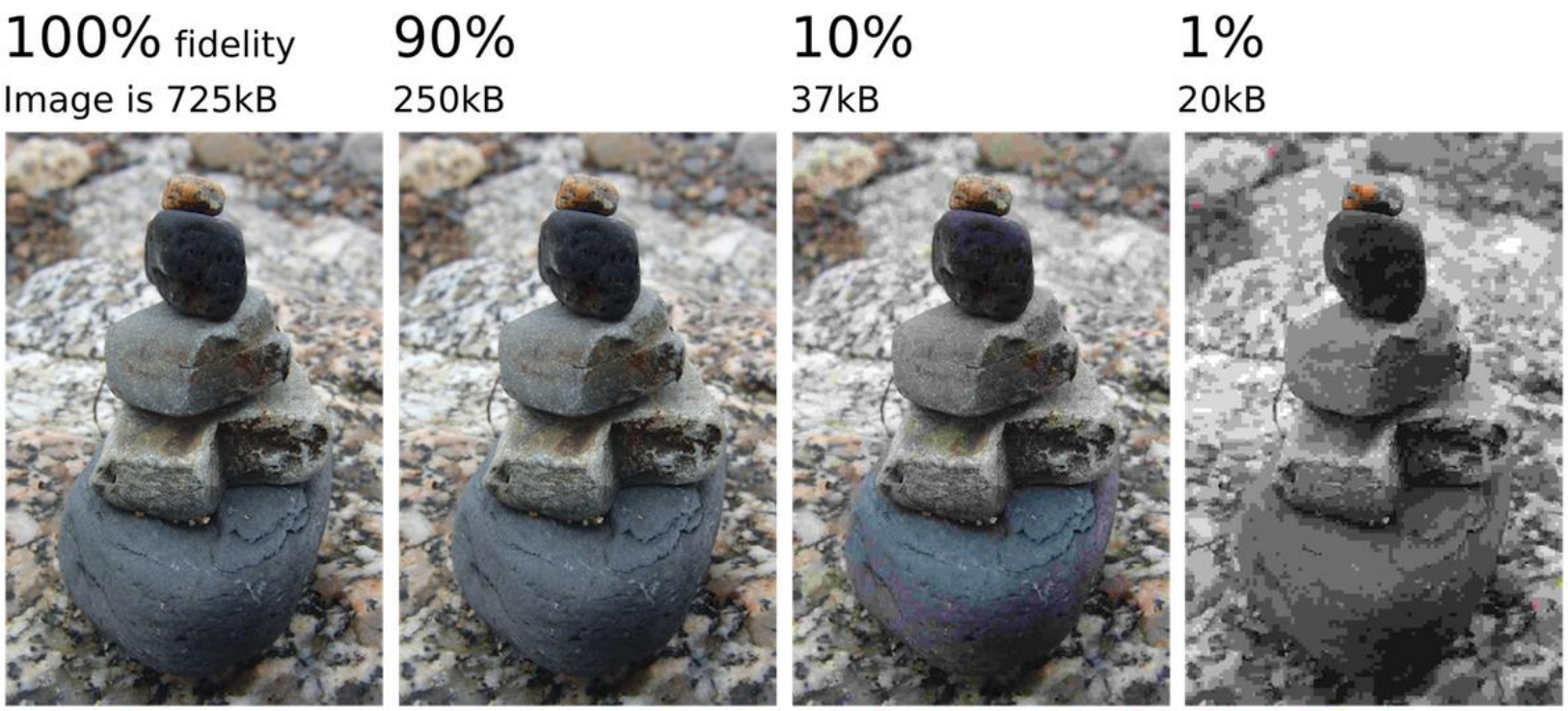


Image Compression



→ **Video compression**

Image Processing → Image Analysis

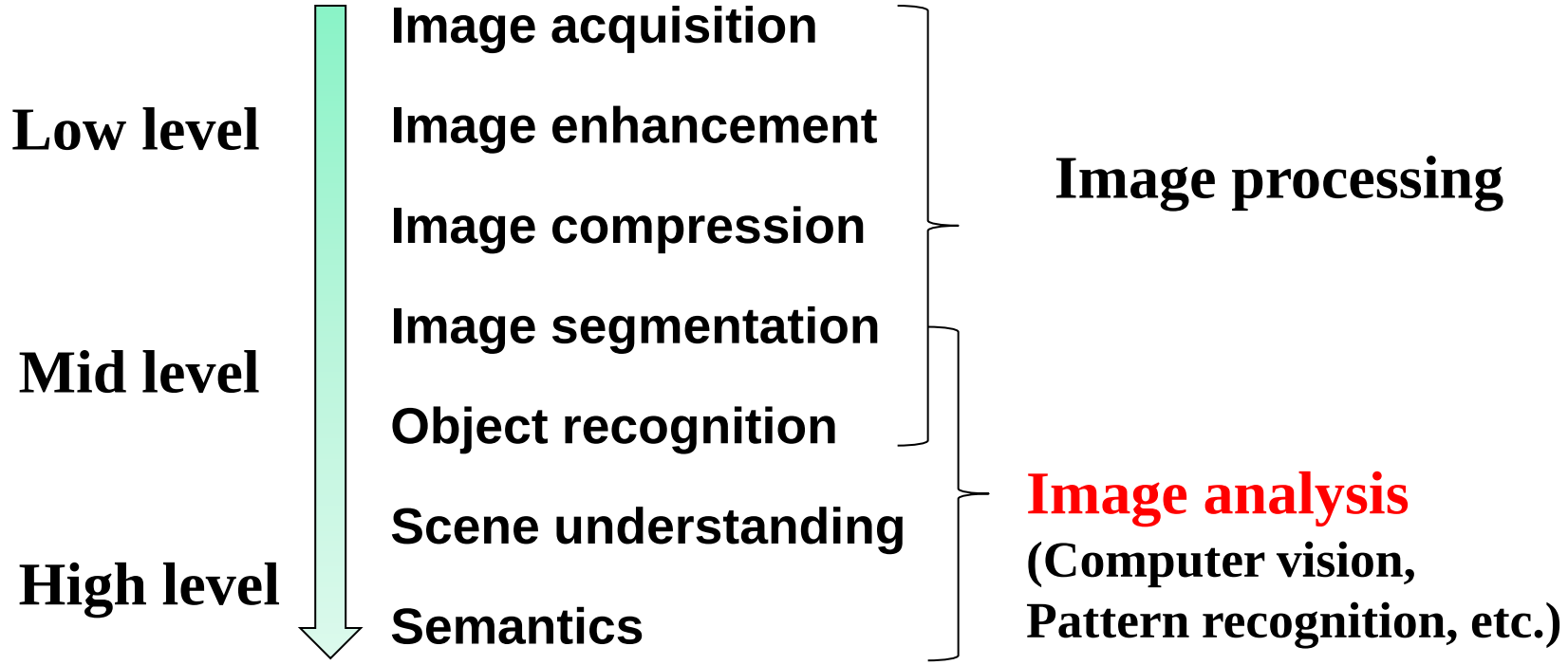
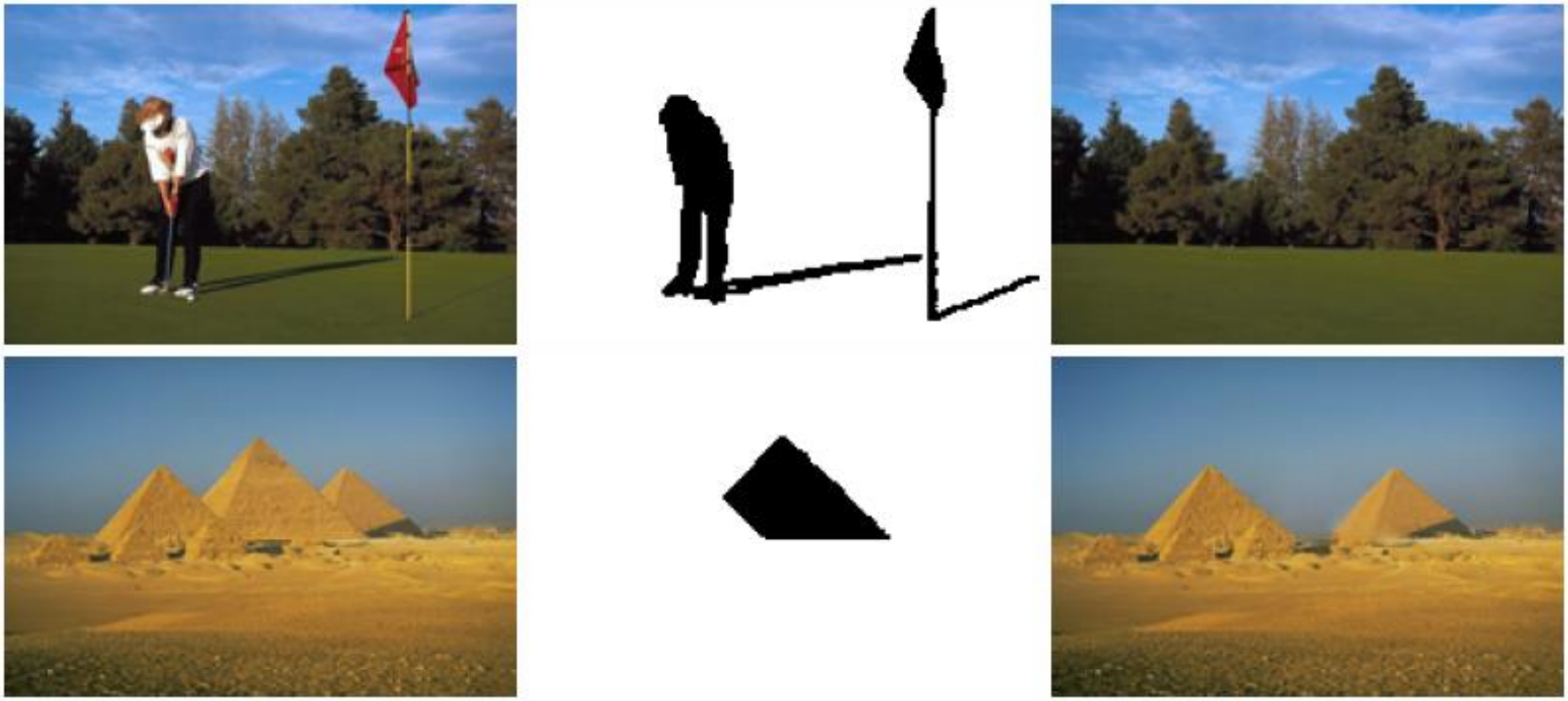


Image Segmentation

Microsoft multiclass segmentation data set

Image Completion

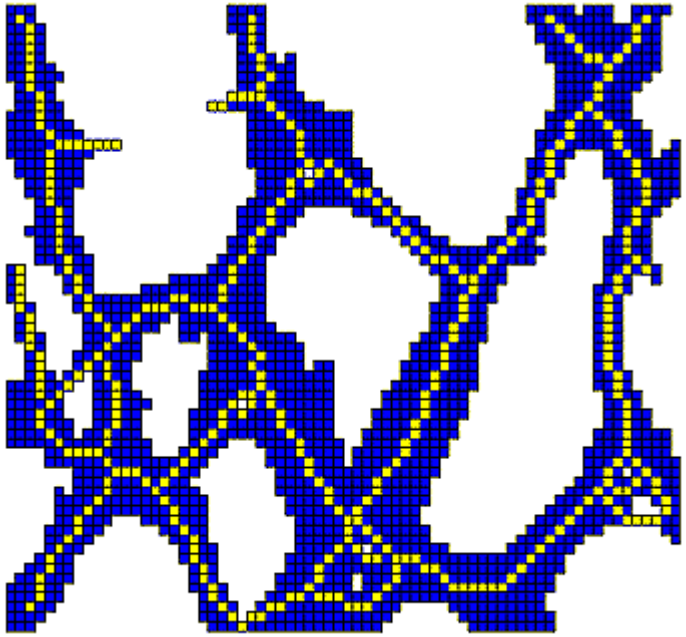
Interactively select objects. Remove them and automatically fill with similar background (from the same image)



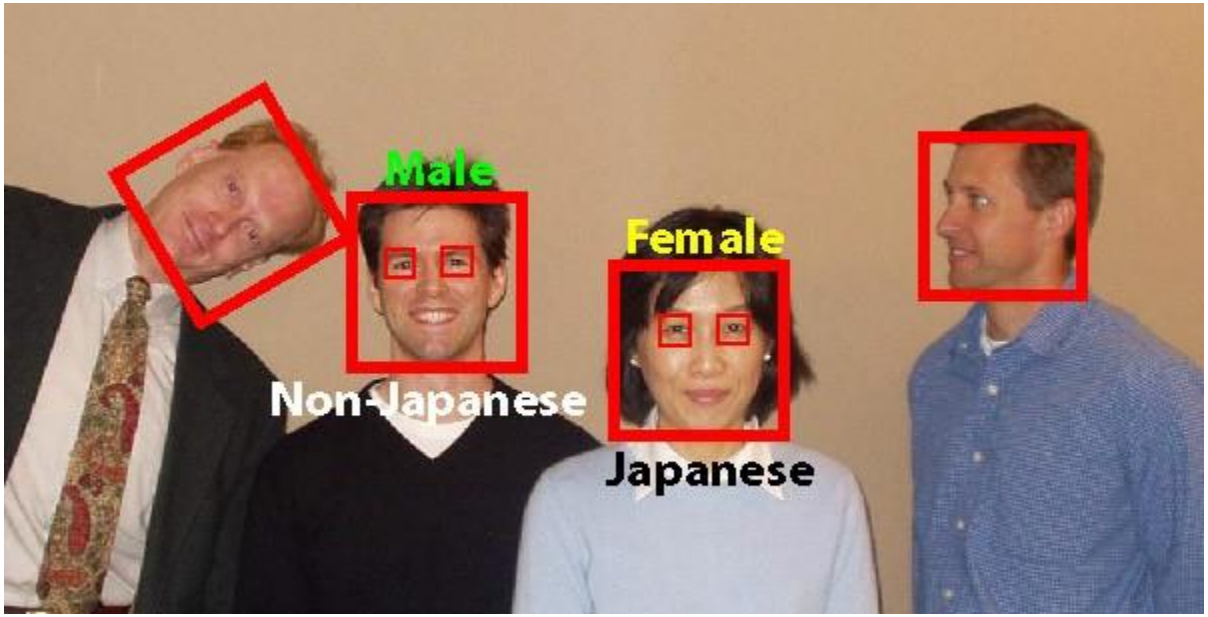
I. Drori, D. Cohen-Or, H. Yeshurun, SIGGRPAH'03

More Examples

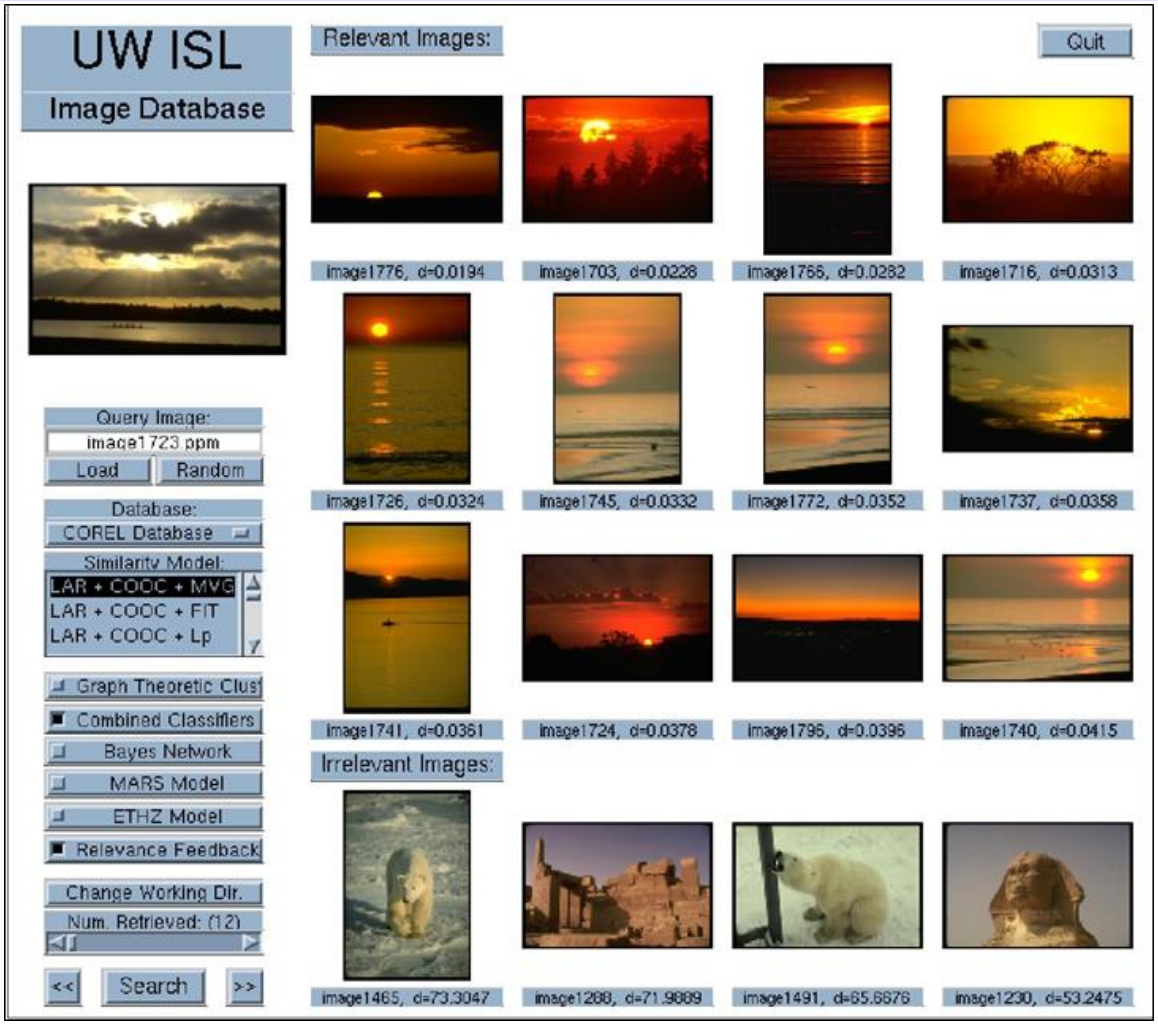
Morphological Image Processing



Object Detection / Recognition

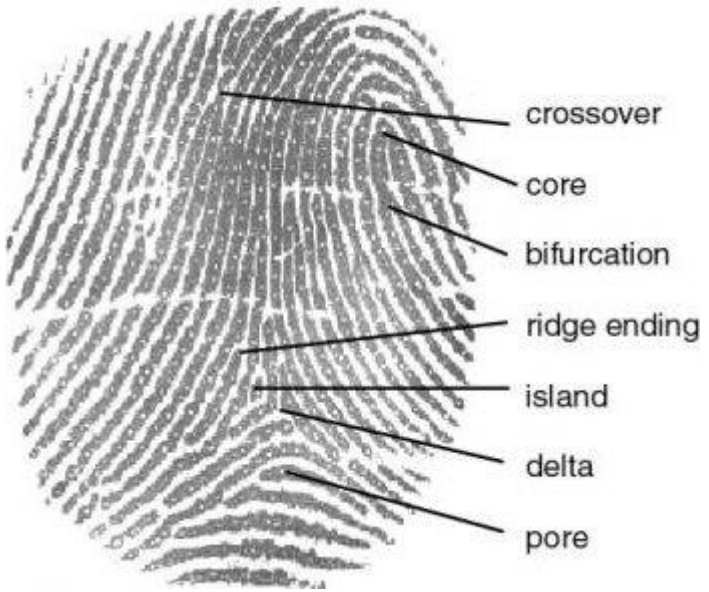


Content-Based Image Retrieval

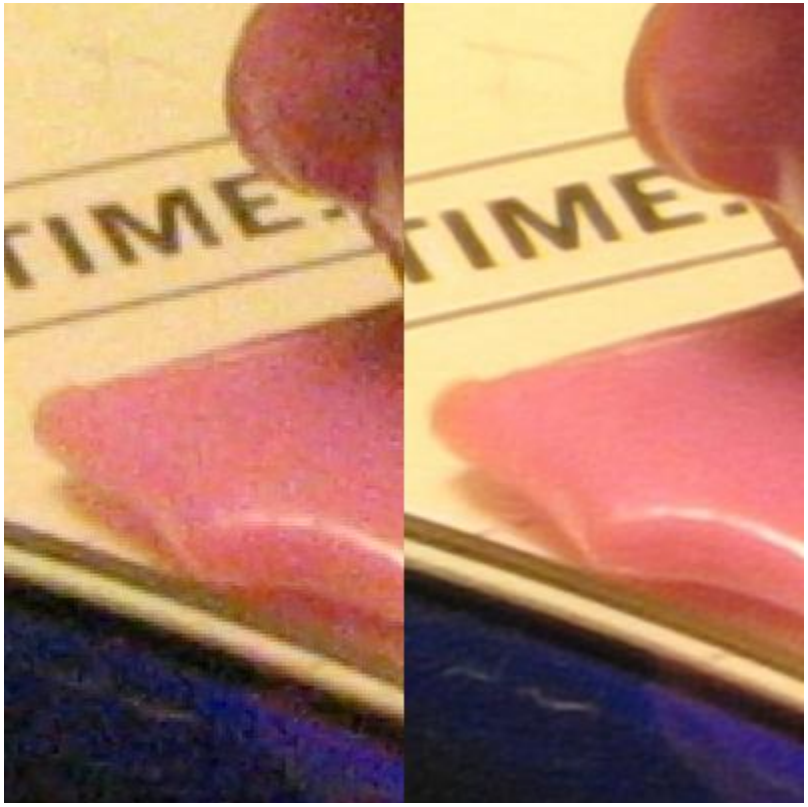


Biometrics


SCANNING
iris scan v1.1b
CONNECTING


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!

Basic Concepts in Digital Image Processing

Now,

Introducing some basic concepts in digital image processing

- **Human vision system**
- **Basics of image acquisition**

Reading: Chapter 2.

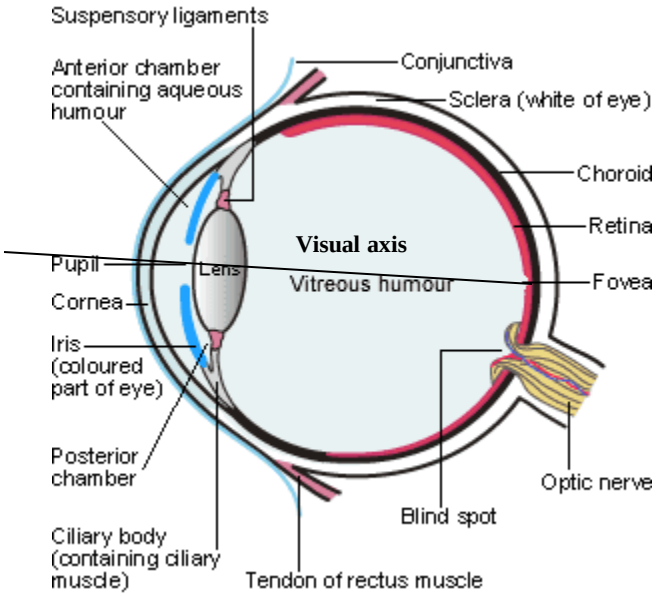
Elements of Human Visual Perception

Human visual perception plays a key role in selecting a technique

Lens and Cornea: focusing on the objects

Two receptors in the retina:

- Cones and rods
- Cones located in fovea and are highly sensitive to color
- Rods give a general overall picture of view, are insensitive to color and are sensitive to low level of illumination



http://www.mydr.com.au/eye-health/eye-anatomy

Distribution of Rods and Cones in the Retina

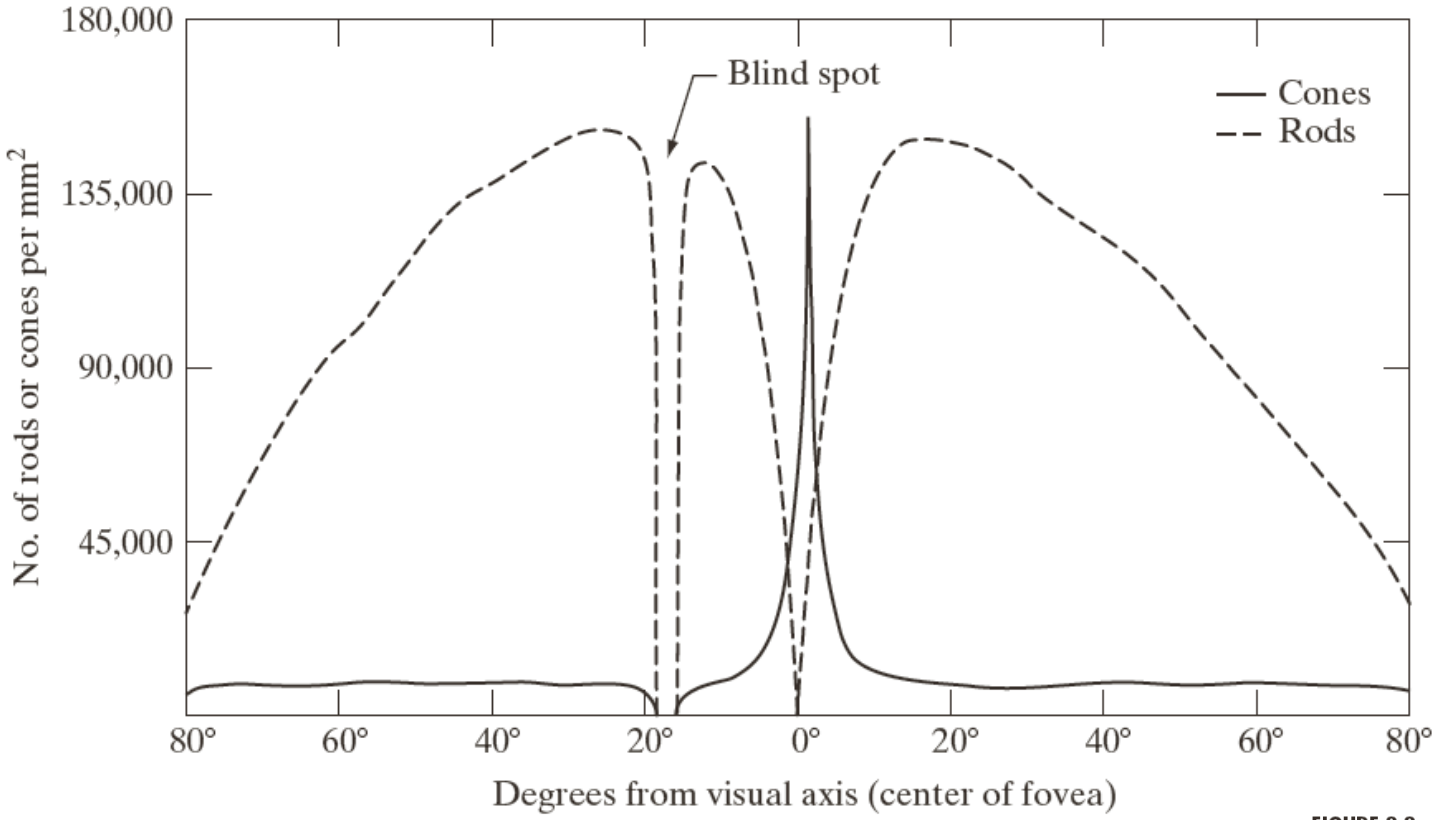


FIGURE 2.2
Distribution of rods and cones in the retina.

Brightness Adaptation: Subjective Brightness

Scotopic:

- **Vision under low illumination**
- **rod cells are dominant**

Photopic:

- **Vision under good illumination**
- **cone cells are dominant**

The total range of distinct intensity levels the eye can discriminate *simultaneously* is rather small

Brightness adaptation level

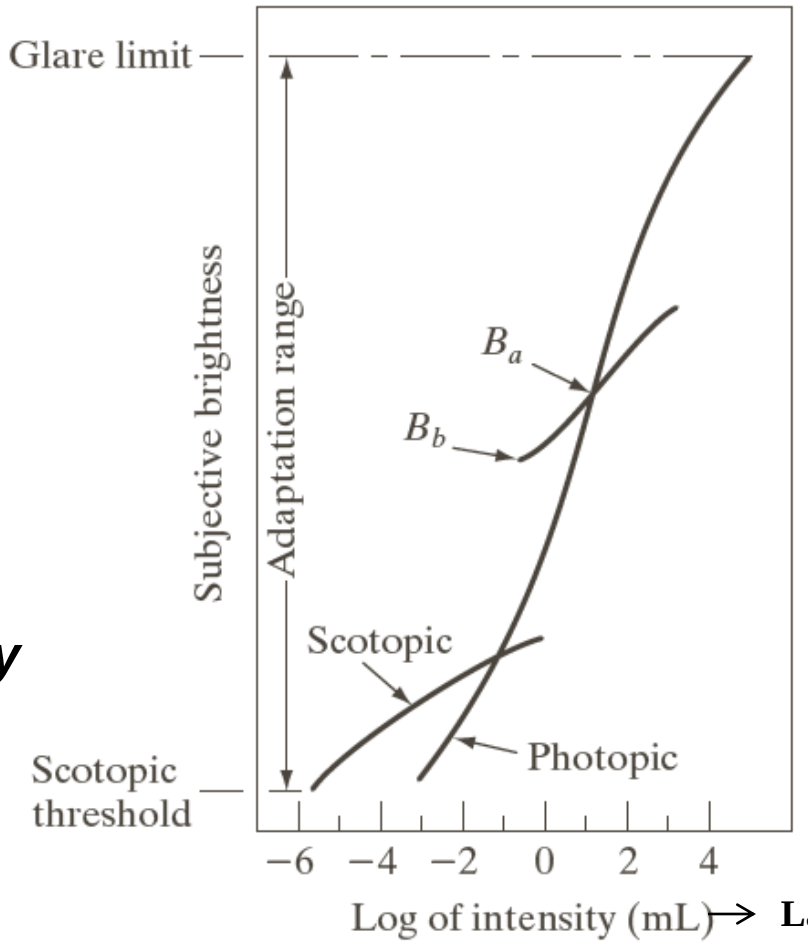


FIGURE 2.4 Range of subjective brightness sensations showing a particular adaptation level.

Brightness Discrimination

Weber Ratio/Fraction

$$\frac{\Delta I_c}{I}$$

$I + \Delta I_c$:

Short-duration flash

Small ratio: good brightness discrimination

Large ratio: poor brightness discrimination

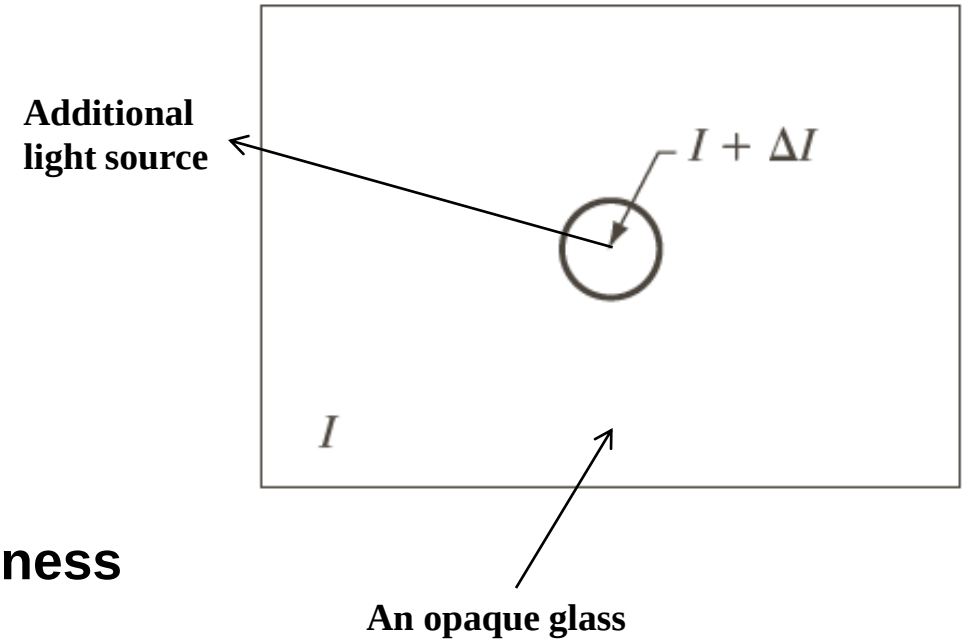


FIGURE 2.5 Basic experimental setup used to characterize brightness discrimination.

Brightness Discrimination at Different Intensity Levels

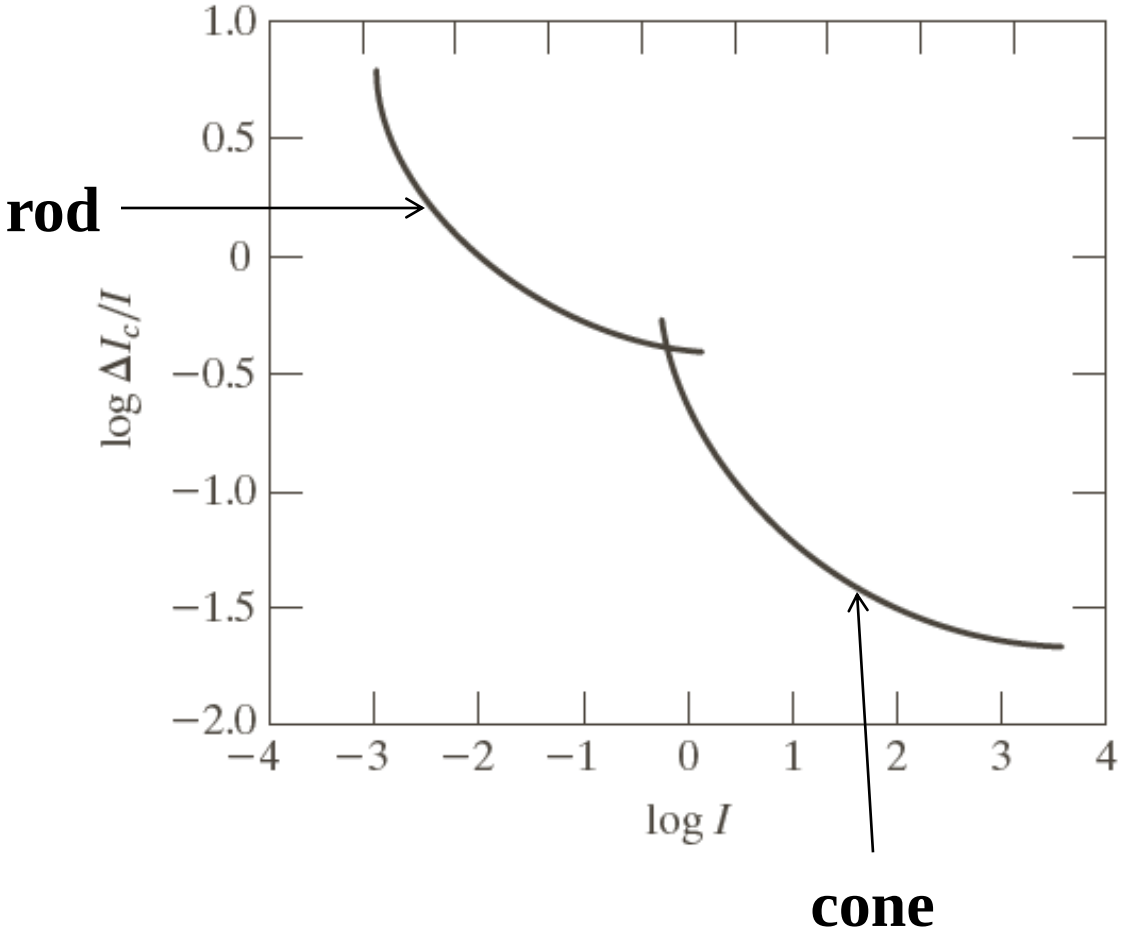
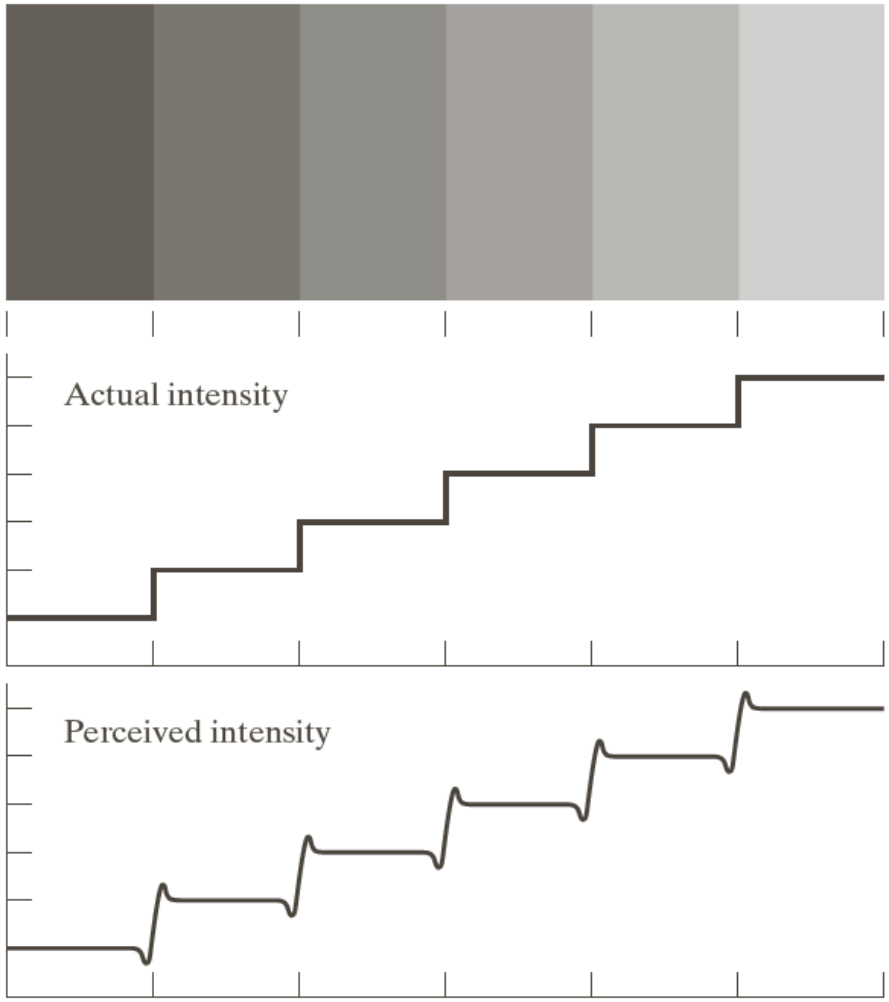


FIGURE 2.6
Typical Weber ratio as a function of intensity.

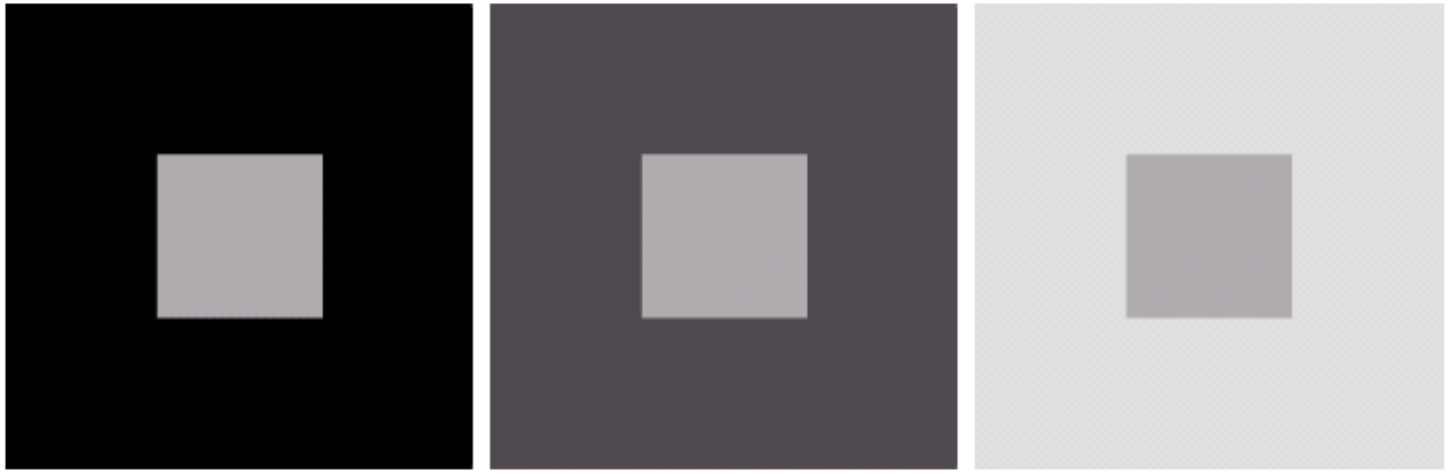
Perceived Intensity is Not a Simple Function of the Actual Intensity (1)



a
b
c

FIGURE 2.7 Illustration of the Mach band effect. Perceived intensity is not a simple function of actual intensity.

Perceived Intensity is Not a Simple Function of the Actual Intensity – Simultaneous Contrast



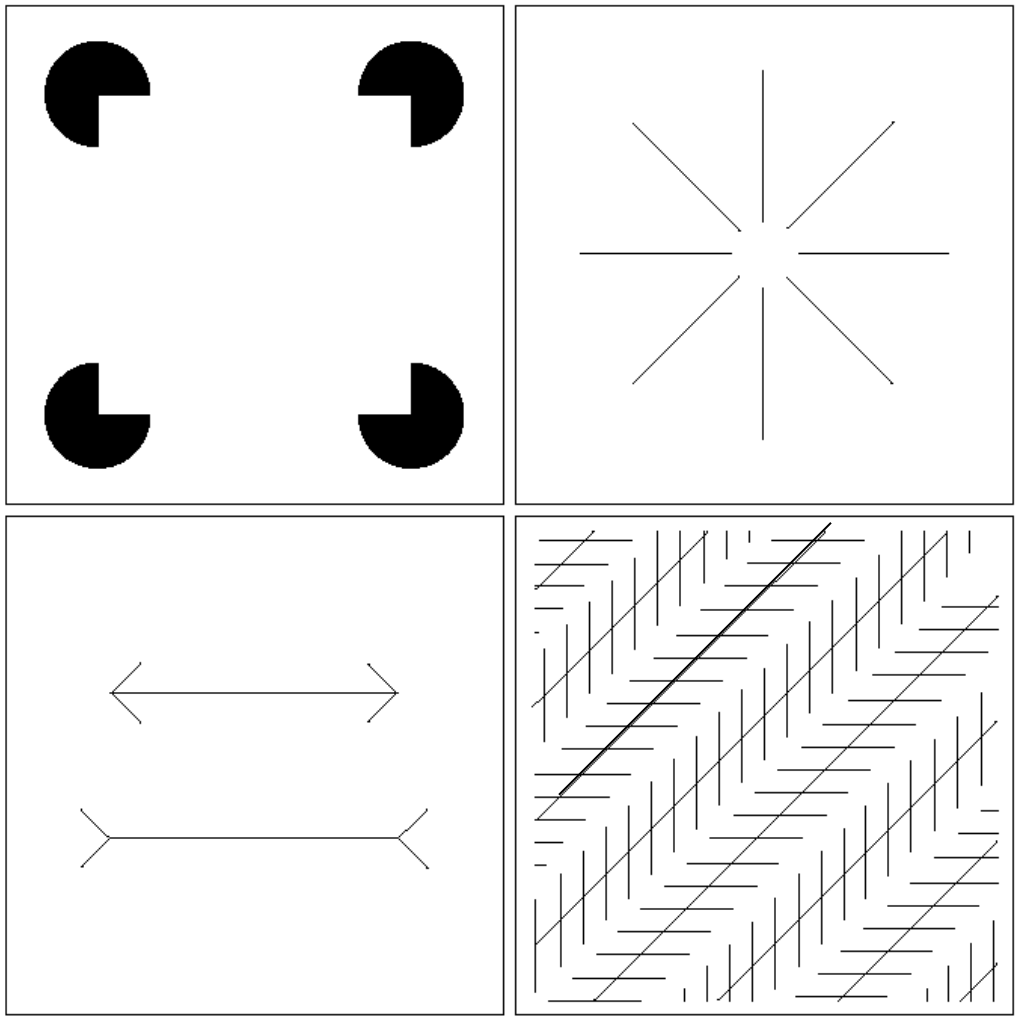
a b c

FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

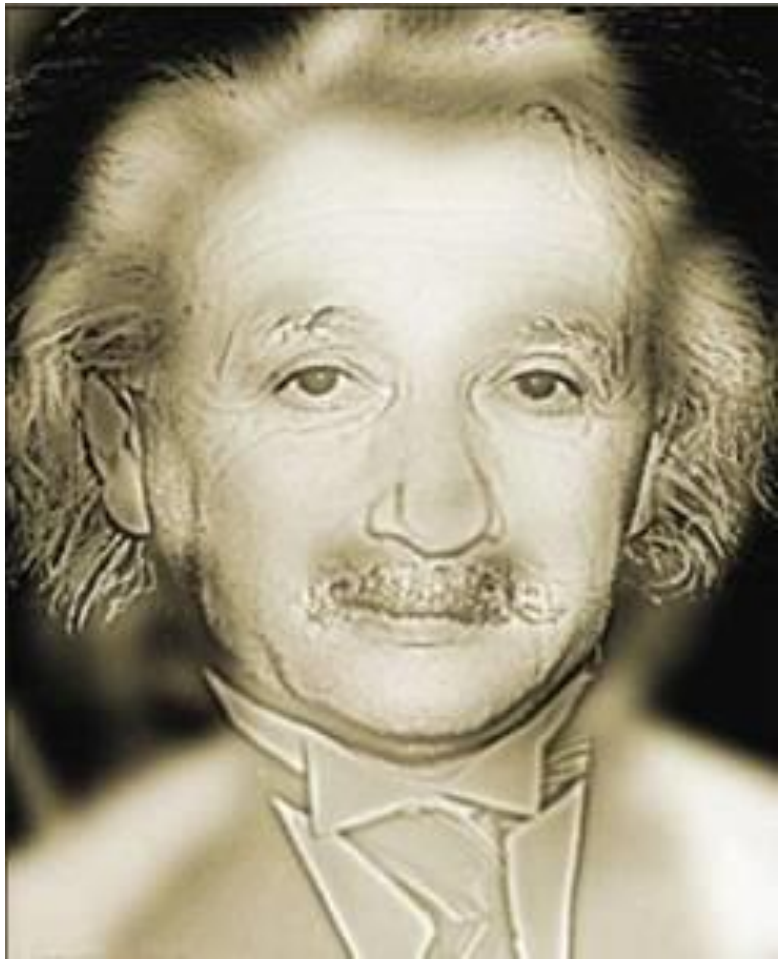
Optical Illusions: Complexity of Human Vision

a b
c d

FIGURE 2.9 Some well-known optical illusions.



More Optical Illusions



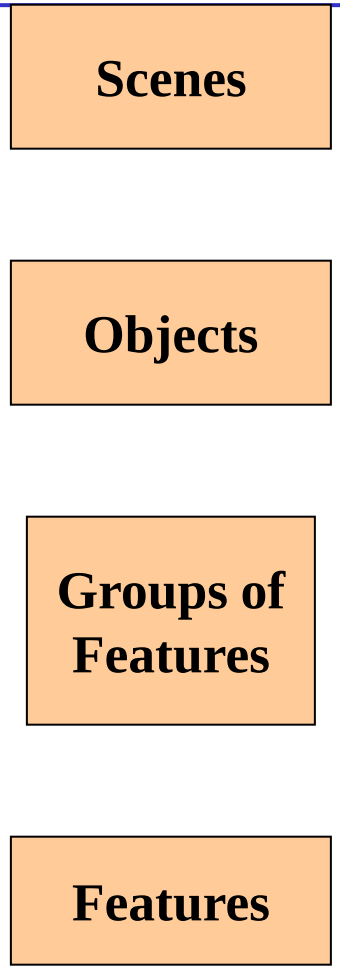
http://www.123opticalillusions.com/

http://brainden.com/optical-illusions.htm

Object Perception

How do we perceive separate features, objects, scenes, etc. in the environment?

- **Perception of a scene involves multiple levels of perceptual analysis.**



What Do We Do With All Of This Visual Information??

"Bottom up processing"

- Data-driven
- Sensation reaches brain, and then brain makes sense of it

"Top down processing"

- Cognitive functions informs our sensation
- E.g., walking to refrigerator in middle of night