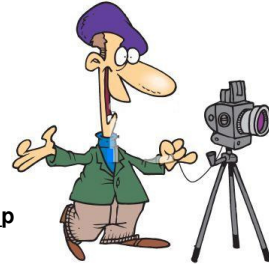# Image Processing

CS 203.2730
Semester A 2012-2013
Lecture: Monday   10:00-12:00 Room: Edu 466
         Wednesday   10:00-12:00 Room: Edu 466

Dr. Hagit Hel-Or
hagit@cs.haifa.ac.il
Office: 415
Office Hours: (by appointment)

Course Internet Site:
http://cs.haifa.ac.il/courses/image_p

1

Administration

- Course Home Page:
  - http://cs.haifa.ac.il/courses/image_p
  - Announcements
  - Lecture slides and handouts
  - Homework, grades
  - Syllabus, References, Matlab guides
- Pre-requisites / prior knowledge
- Lectures / Tirgul
- Exercises:
  - ~5-6 assignments (programming in Matlab).
  - Final exam

MATLAB® R2008a
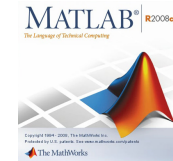
2

Administration (Cont.)

- Matlab software:
  - Available in PC labs
  - Student version
  - Course Webpage: Homework -> homeworkGeneral
  - Matlab Alternatives: Octave, Python.

- Grading policy:
  - Final Grade = Final exam (60%) + Exercises (40%)
  - Exercises will be weighted
  - Exercises are compulsory and will be submitted in pairs

  - You must pass the exam to pass the course !

3

Textbooks

Digital Image Processing
Kenneth R. Castelman
Prentice Hall

Digital Image Processing
Rafael C. Gonzalez and Richards E. Woods,
Addison Wesley

Digital Image Processing
 Rafael Gonzalez and Paul Wintz
Addison Wesley

Fundamentals of Digital Image Processing
 Anil K. Jain
Prentice Hall, 1989.

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1

About the course

Goals of this course:

- **Introductory course**: basic concepts, classical methods, fundamental theorems
- Getting acquainted with basic properties of images
- Getting acquainted with various representations of image data
- Acquire fundamental knowledge in processing and analysis digital images

Pre-requisites:

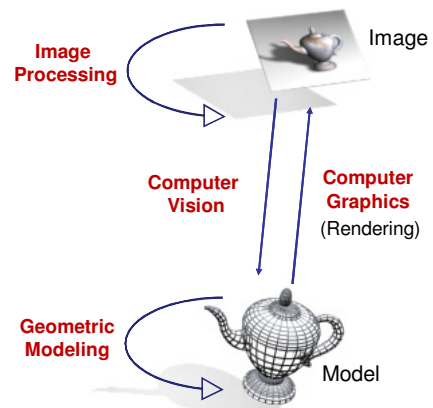- Algebra, Calculus, Discrete Math, Algorithms

5

Introduction

- Introduction to Image Processing
- Image Processing Applications
- Examples
- Course Plan
- Biological Vision: The Human Visual System

6

Visual Sciences

Image Processing

Image

Computer Vision

Computer Graphics (Rendering)

Geometric Modeling

Model

7

Image Processing v.s. Computer Vision

Low Level

Image Processing

Acquisition, representation, compression, transmission

image enhancement

edge/feature extraction

Pattern matching

Computer Vision

image "understanding" (Recognition, 3D)
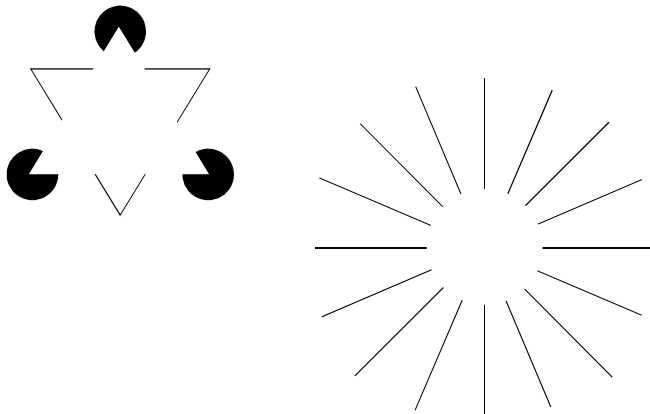
High Level
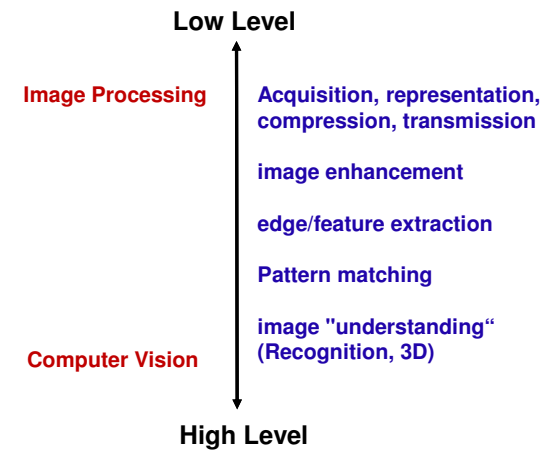
8

Why Computer Vision is Hard?

- Inverse problems

- Apriori-knowledge is required

- Complexity extensive
  - Top-Down v.s. Bottom-Up paradigm
  - Parallelism

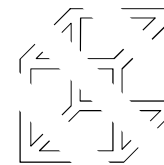- Non-local operations
  - Propagation of Information
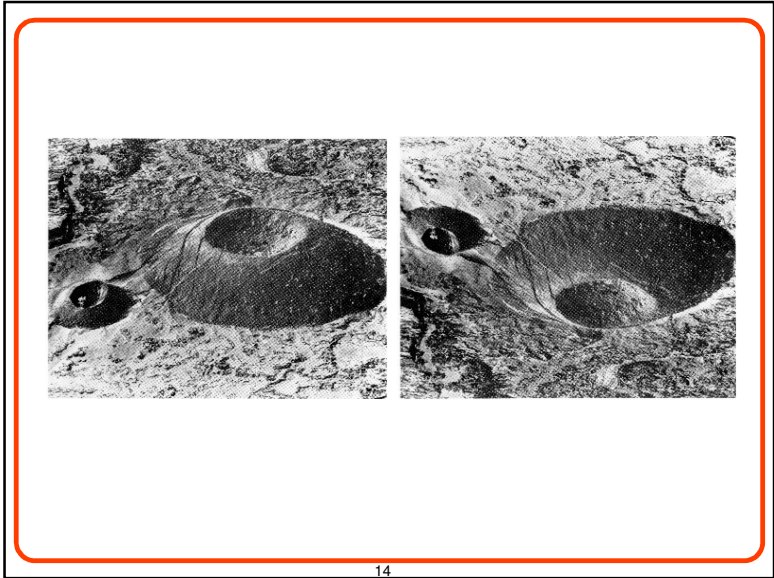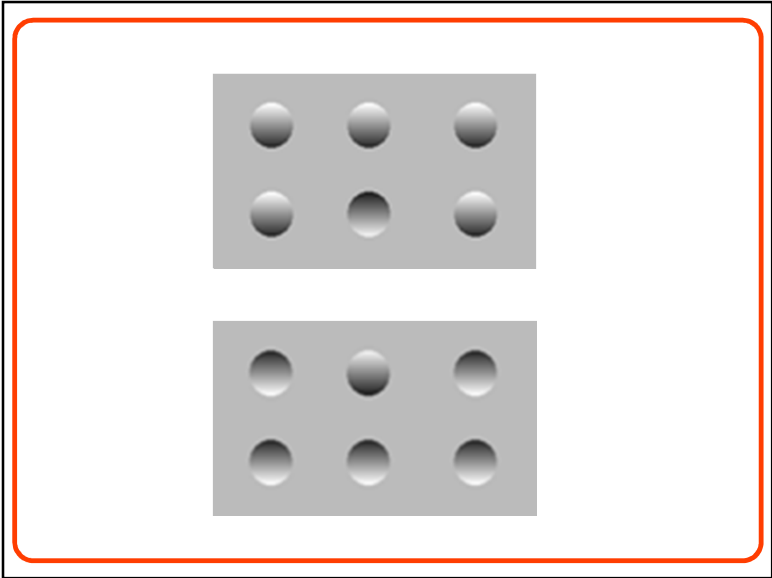
9

10

11

12

3
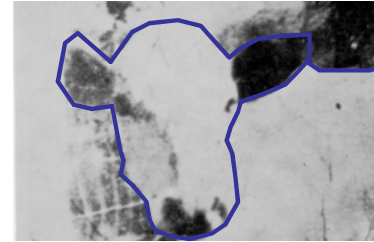
Image Processing and Computer Vision are Interdisciplinary Fields

P(x)

P(y|x)

Image space

- Mathematical Models (CS, EE, Math)
- Eye Research (Biology)
- Brain Research:
  - Psychophysics (Psychologists)
  - Electro-physiology (Biologists)
  - Functional MRI (Biologists)

Industry and Applications

- Automobile driver assistance
  - Lane departure warning
  - Adaptive cruise control
  - Obstacle warning
- Digital Photography
  - Image Enhancement
  - Compression
  - Color manipulation
  - Image editing
  - Digital cameras
- Sports analysis
  - sports refereeing and commentary
  - 3D visualization and tracking sports actions

MobilEye system

- Film and Video
  - Editing
  - Special effects
- Image Database
  - Content based image retrieval
  - visual search of products
  - Face recognition
- Industrial Automation and Inspection
  - vision-guided robotics
  - Inspection systems
- Medical and Biomedical
  - Surgical assistance
  - Sensor fusion
  - Vision based diagnosis
- Astronomy
  - Astronomical Image Enhancement
  - Chemical/Spectral Analysis

- Arial Photography
  - Image Enhancement
  - Missile Guidance
  - Geological Mapping
- Robotics
  - Autonomous Vehicles
- Security and Safety
  - Biometry verification (face, iris)
  - Surveillance (fences, swimming pools)
- Military
  - Tracking and localizing
  - Detection
  - Missile guidance
- Traffic and Road Monitoring
  - Traffic monitoring
  - Adaptive traffic lights

Cruise Missiles

- Google Driverless Car
  - Google Street View
  - Video cameras inside car.
  - LIDAR (Light Detector and Ranging) sensors on top of the vehicle
  - Radar sensors on the front of the vehicle
  - Position sensor on rear wheels

Image Inpainting 1

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Image Inpainting 2

DAMAGED

M. Bertalmio, A. Bertozzi, and G. Sapiro, CVPR 2001.

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Image Inpainting 3

23

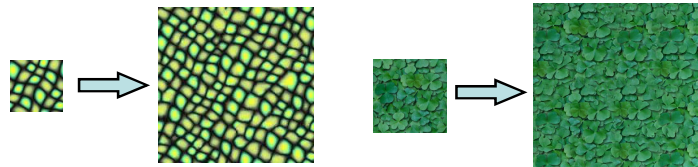## Video Inpainting

Input

Output

Input Sequence

Output Sequence

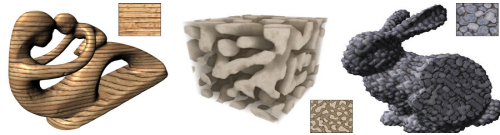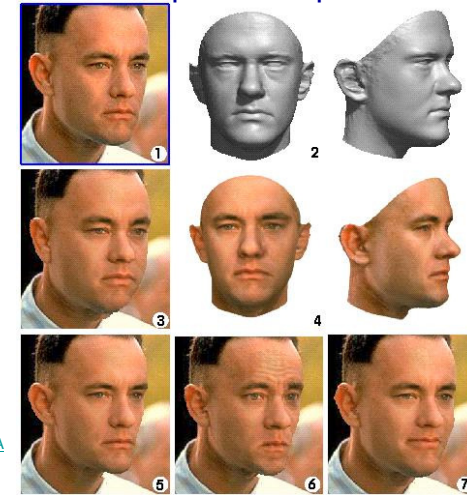Y. Wexler, E. Shechtman and M. Irani 2004

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6

Texture Synthesis

25

3D Texture Synthesis

J. Kopf, C.W. Fu, D. Cohen-Or, O. Deussen, D. Lischinski, T.T. Wong, 2007.

Computer Vision + Computer Graphics

Kurihara, T. & Arai, K. (1991)
http://www.youtube.com/watch?v=pSRA8GpWIrA

- Google Glass
  - Wearable computing
  - Transparent Display
  - Memory, processor, camera, speaker microphone, bluetooth, Wi-Fi antennas, accelerometer, gyroscope, compass and a battery. All inside the earpiece.

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Syllabus

- Image Acquisition
- Point Operations
- Geometric Operations
- Spatial Operation
- Feature Extraction
- Frequency Domain and the FFT
- Image Operations in Freq. Domain
- Multi-Resolution
- Restoration

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Image Acquisition

- Image Characteristics
- Image Sampling (spatial)
- Image Quantization (gray level)
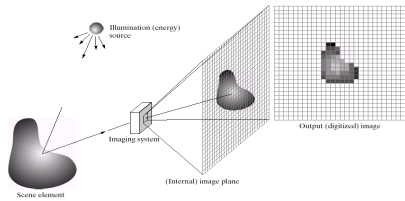
Image Operations

- Point Operations
- Geometric Operations
- Spatial Operations
- Global Operations (Freq. domain)
- Multi-Resolution Operations

Geometric Operations

Point Operations

8
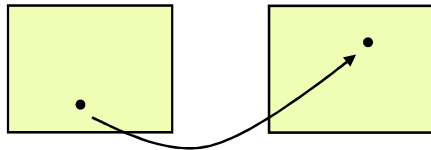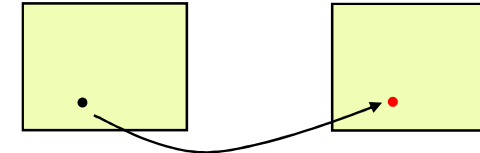
Image Enhancement

Image Enhancement

Geometric and Point Operations

Spatial Operations

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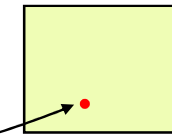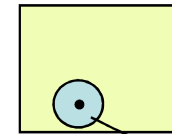
Image Denoising

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Image Deblurring

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The Fourier Transform

$$F(u,v) = \int \int_{-\infty}^{\infty} f(x,y)e^{-j2\pi(ux+vy)}dx\,dy$$

$$f(x,y) = \int \int_{-\infty}^{\infty} F(u,v)e^{j2\pi(ux+vy)}du\,dv$$

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Operations in Frequency Domain

Original
Noisy image
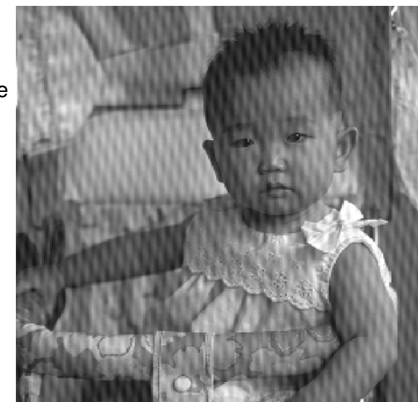
Filtered
image

Multi-Resolution

Low resolution

High resolution
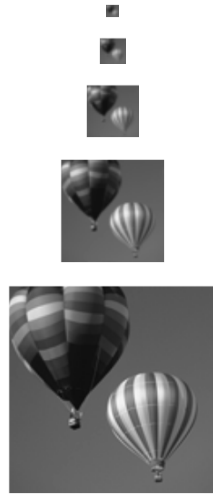
Multi-Resolution Operations
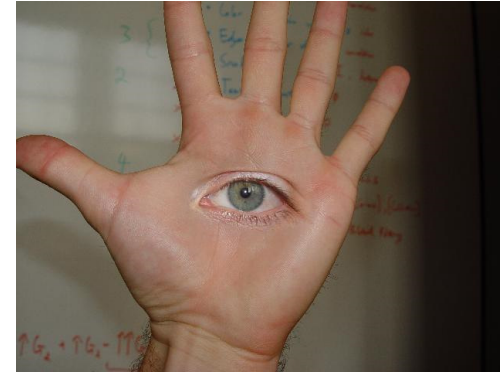
Edge Detection
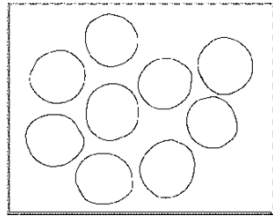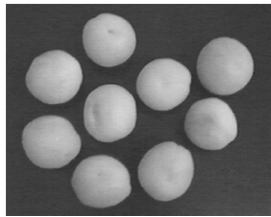
Segmentation

Thresholding

Region Growing

Seed

11

Graph Cut + Cloning

segment

clone

C. Rother, V. Kolmogorov,
A. Blake, M.Brown, 2009
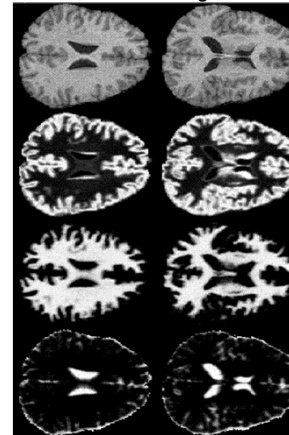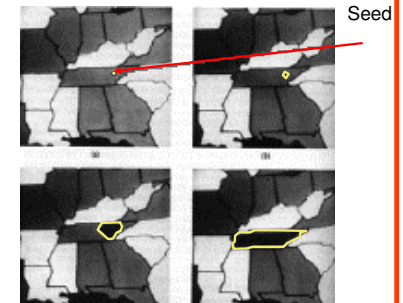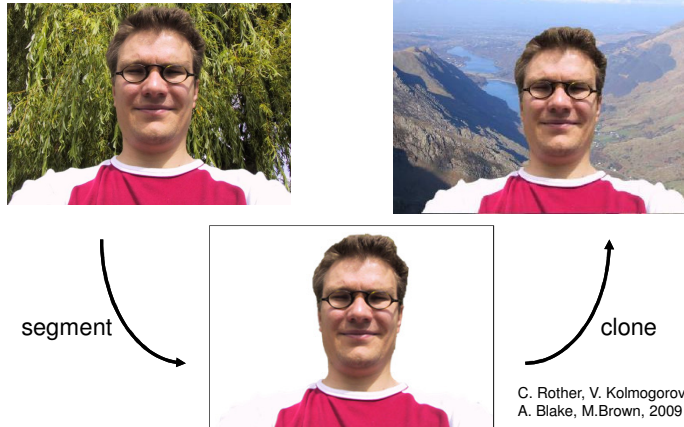
45

Pattern Matching

Pattern

Match Results

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Image Matching

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The Human Visual System

Retina

Optic Nerve

Optic Chiasm

Lateral
Geniculate
Nucleus (LGN)

Visual Cortex

Lateral Geniculate
Nucleus (LGN)

Visual Cortex

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The Human Eye

Iris
Pupil
Sclera

Lens
Cornea
Pupil
Iris
Ocular Muscle
Fovea
Vitreous Humor
Optic Disc
Optic Nerve
Retina
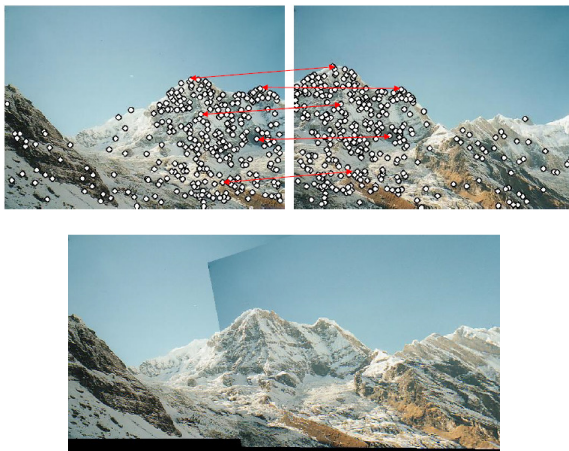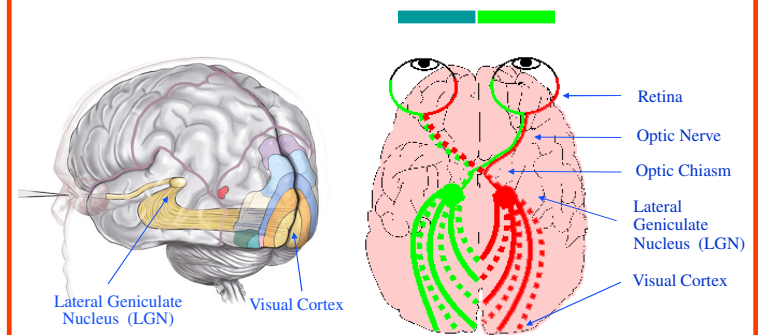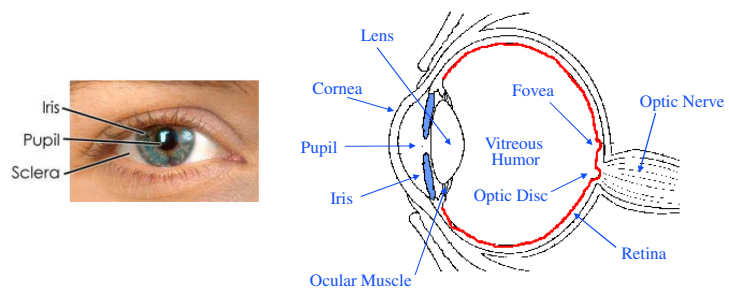
➢Cornea - קרנית
➢Pupil - אישון
➢Iris - קשתית
➢Retina - רשתית

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The Human Eye

Image Acquisition

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fovea
optic nerve
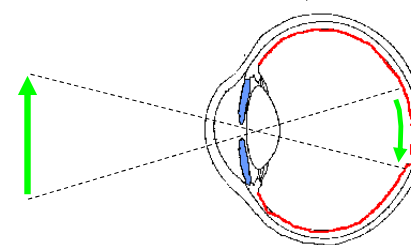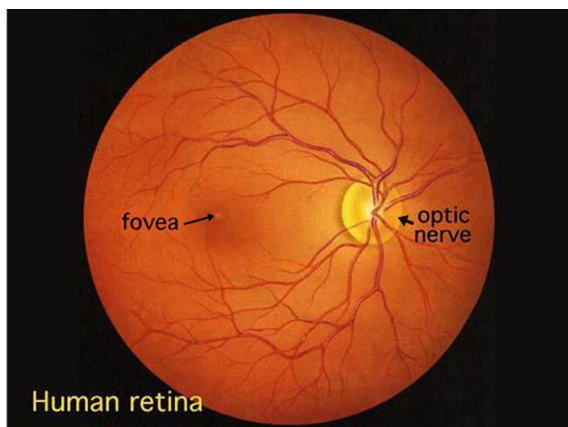
Human retina

Fig. 1. Human retina as seen through an opthalmoscope.

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The Human Retina

rods
cones
bipolar
horizontal
amacrine
ganglion
light

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Slide 1
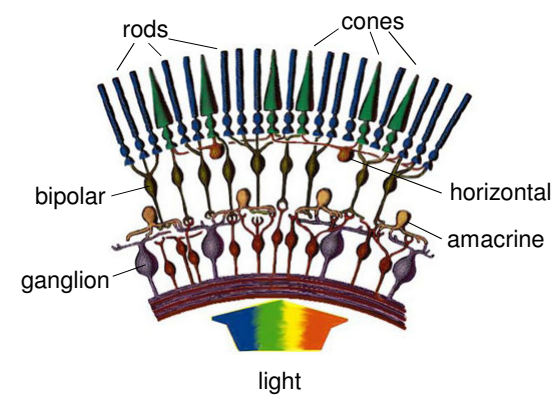
- Retina contains 2 types of photo-receptors
  - Cones:
    - Day vision, can perceive color tone
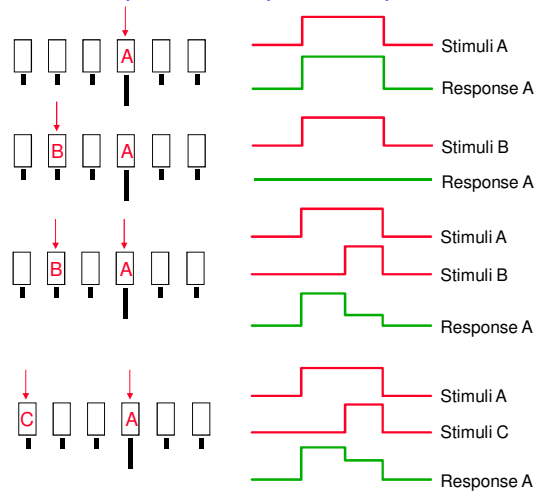 - Rods:
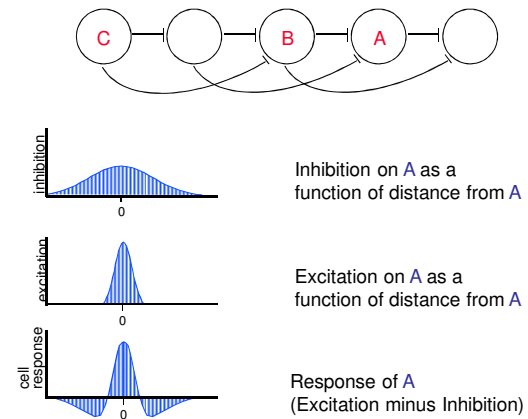   - Night vision, perceive brightness only

The Retina

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Slide 2
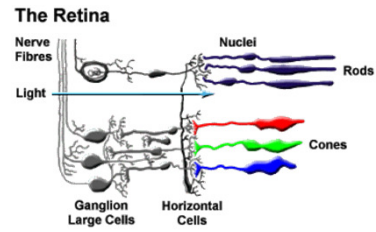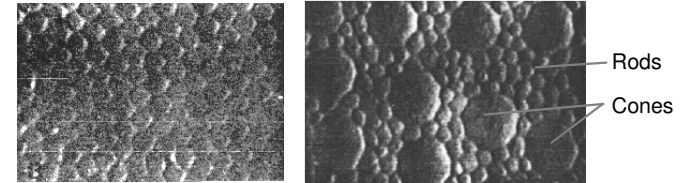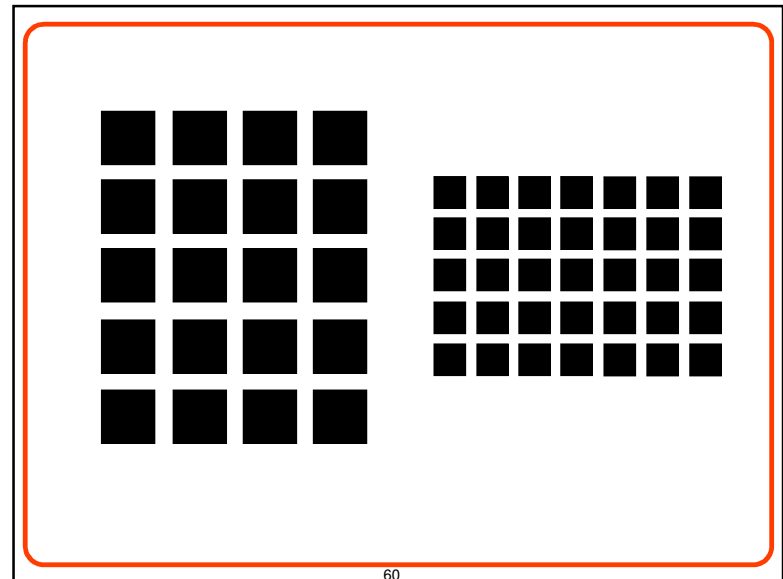
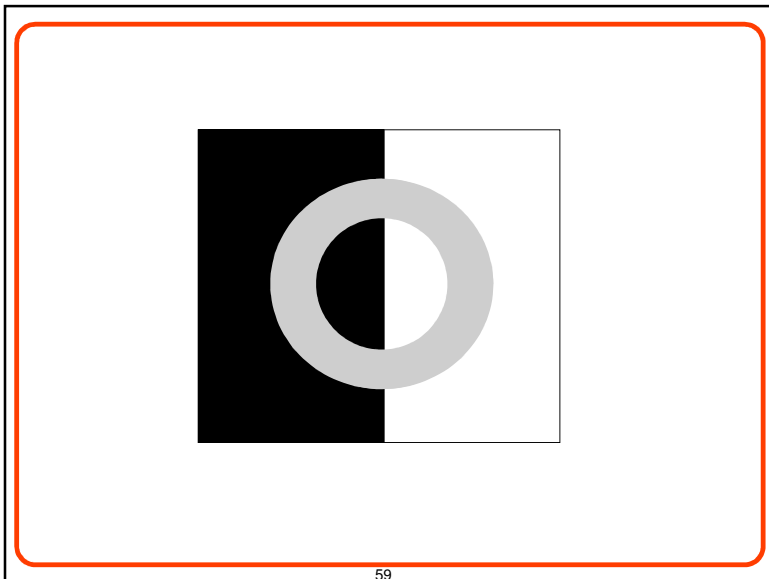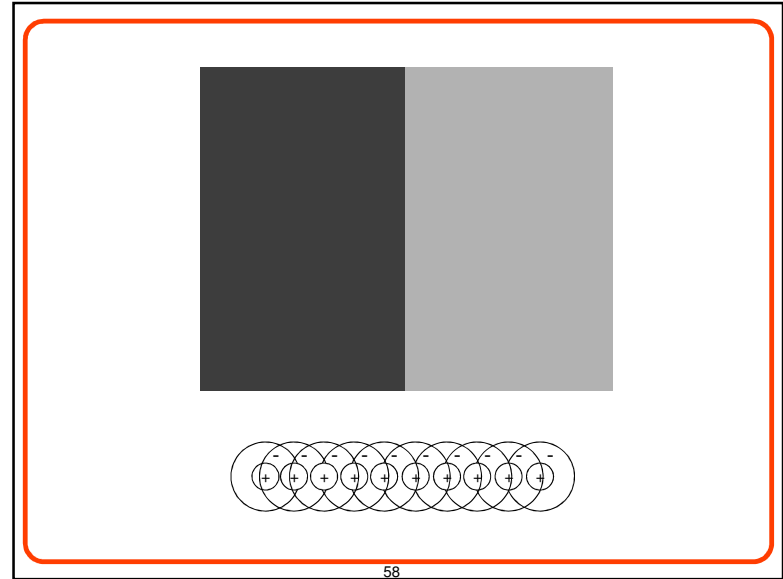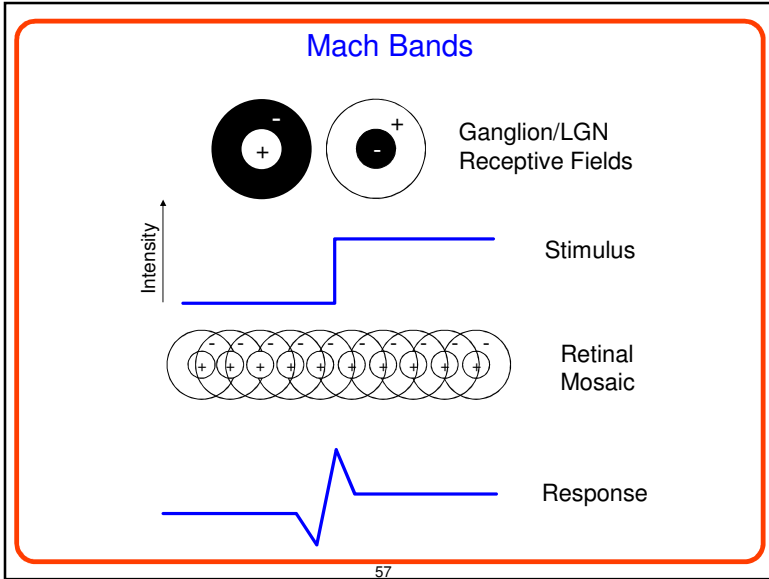### Cone Mosaic

Cone Mosaic at Fovea   Cone Mosaic in periphery

— Rods
— Cones

10 µm

Slide 3

Response is Spatial Dependent

Stimuli A
Response A

Stimuli B
Response A

Stimuli A
Stimuli B
Response A

Stimuli A
Stimuli C
Response A

Slide 4

Inhibitory Model

Inhibition on A as a function of distance from A

Excitation on A as a function of distance from A

Response of A (Excitation minus Inhibition)

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Mach Bands

Ganglion/LGN
Receptive Fields

Intensity

Stimulus

Retinal
Mosaic

Response

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59

60

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Neuron Responses in the Visual Pathway

cell response

0

Photoreceptors

Ganglion Cells

LGN Cells

Visual Cortex Cells

?

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Visual Cortex Cells

Simple Cells

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Visual Cortex Cells

Complex Cells

63

Motion Detection Cells (area MT)

Grandmother Cells (area IT)

Color Cells (area V4)

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Contrast Illusions

Intensity vs Brightness

Intensity

ΔI2
I2
ΔI1
I1

I1 < I2, ΔI1 = ΔI2

Intensity vs Brightness

Equal intensity steps:

Equal brightness steps:

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Weber's Law

In general, ΔI needed for just noticeable difference (JND) over background I was found to satisfy:

(I is intensity, ΔI is change in intensity)

$$\frac{\Delta I}{I} = \text{constant}$$
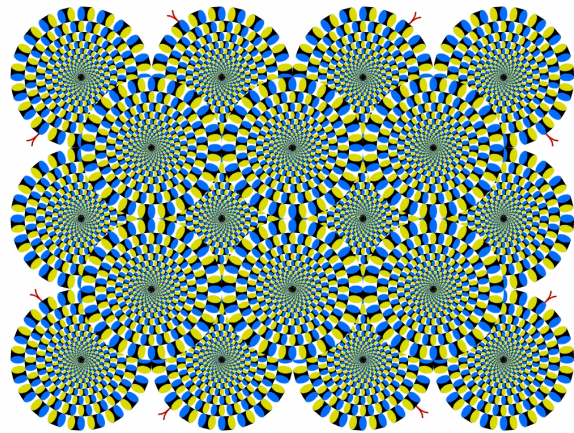
Weber's Law: Perceived Brightness = log (I)
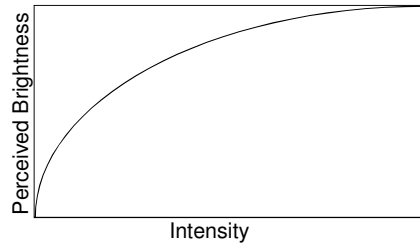
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Summary

- Image Processing and Computer Vision in the context of Visual Sciences.
- Image Processing v.s. Computer Vision.
- The Human Visual System:
  - The structure of the human eye.
  - Inhibition model.
  - Bach bands.
  - Composition of complex cells.
  - Intensity v.s. Brightness.

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