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

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Office: 415
Office Hours: (by appointment)

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

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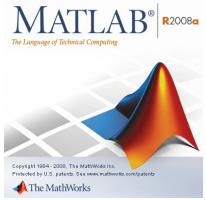
Administration

- 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



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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 !

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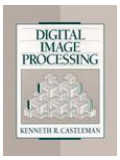
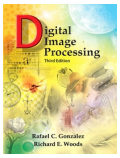
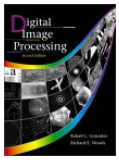
Textbooks



Digital Image Processing
Kenneth R. Castelman
Prentice Hall

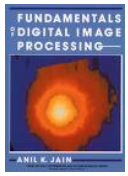
Digital Image Processing
Rafael C. Gonzalez and Richards E. Woods,
Addison Wesley





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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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

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Introduction

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

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Visual Sciences

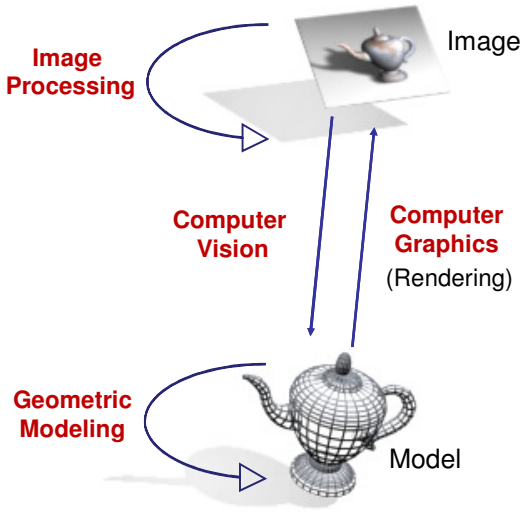

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Image Processing v.s. Computer Vision

Low Level

Image Processing

Acquisition, representation, compression, transmission

image enhancement

edge/feature extraction

Pattern matching

Computer Vision

image "understanding" (Recognition, 3D)

High Level

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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

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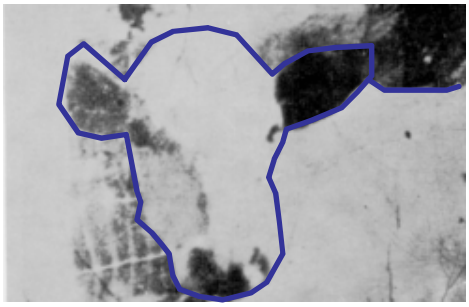

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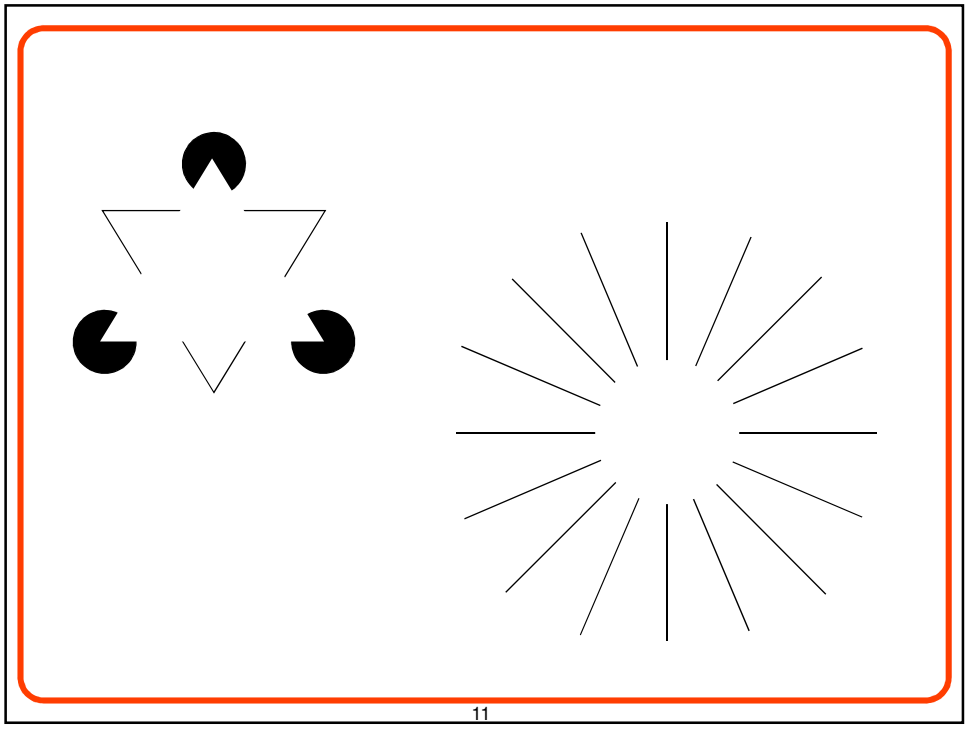

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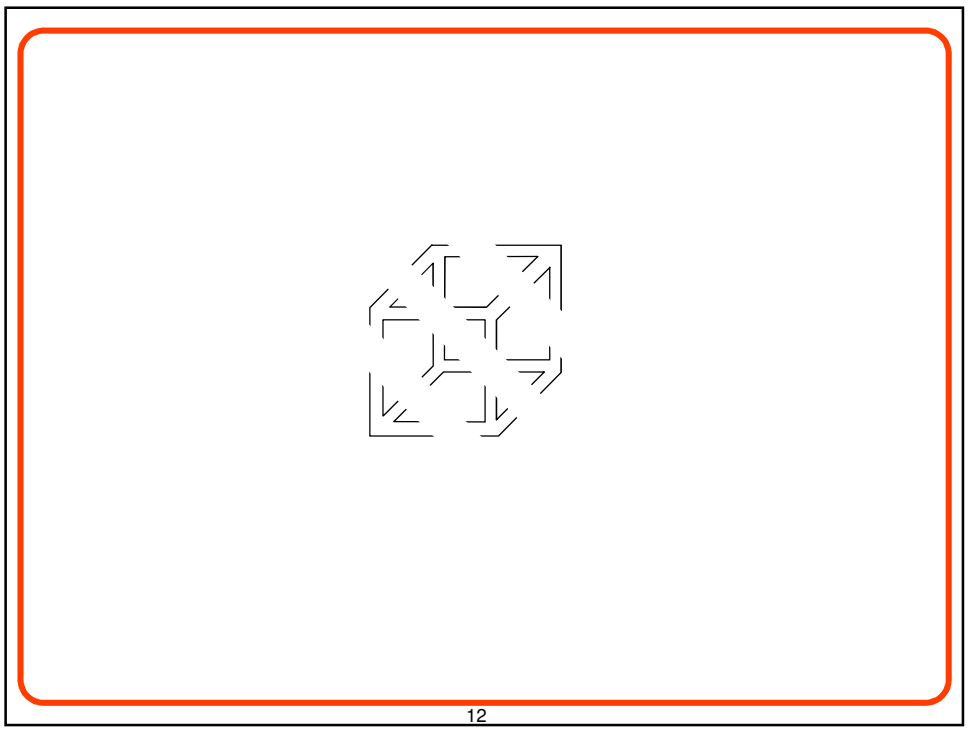

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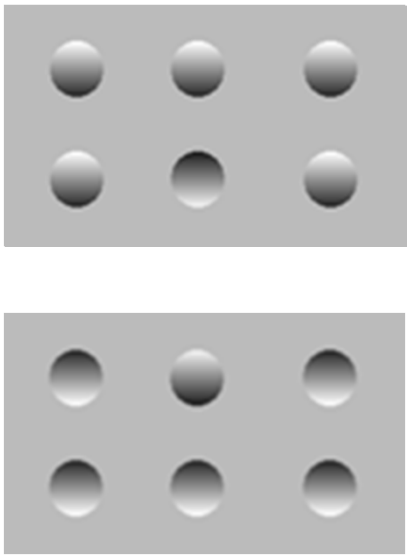

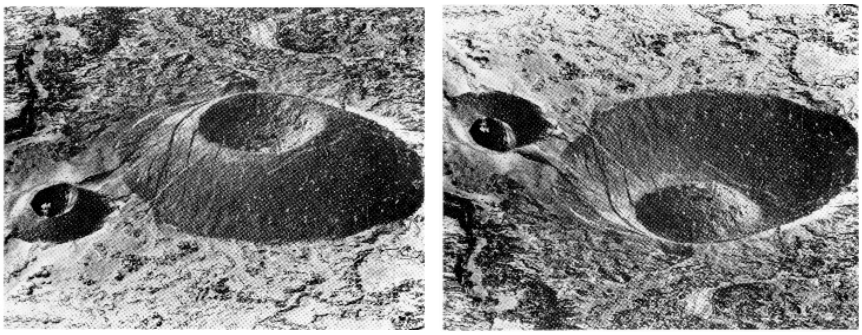

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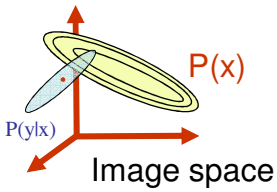
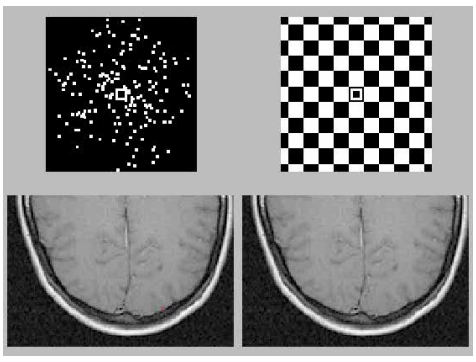
Image Processing and Computer Vision are Interdisciplinary Fields

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





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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

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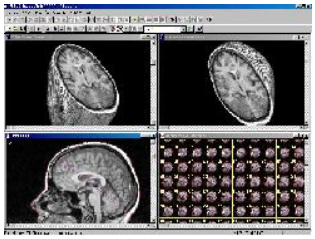
- Film and Video
  - Editing
  - Special effects
- Image Database
  - Content based image retrieval
  - visual search of products
  - Face recognition
- Industrial Automation and Inspection
  - vision-guided robotics
  - Inspection systems
- Medical and Biomedical
  - Surgical assistance
  - Sensor fusion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



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- 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

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- 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

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Image Inpainting 1

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Image Inpainting 2

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

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Image Inpainting 3

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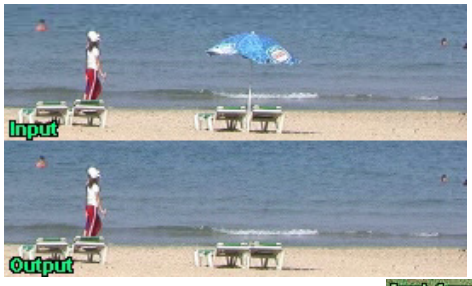
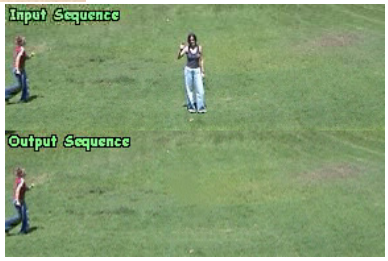
Video Inpainting





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

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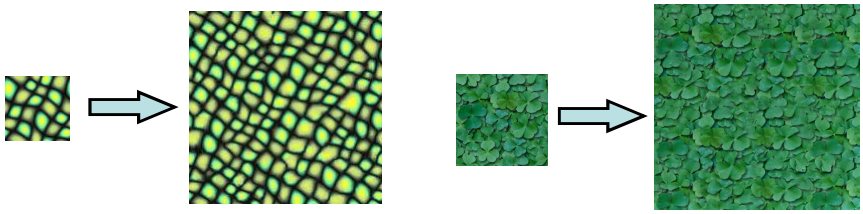
Texture Synthesis



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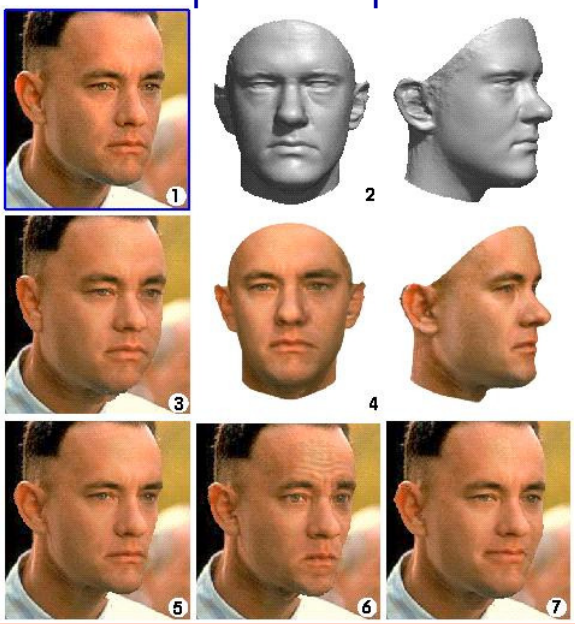
3D Texture Synthesis

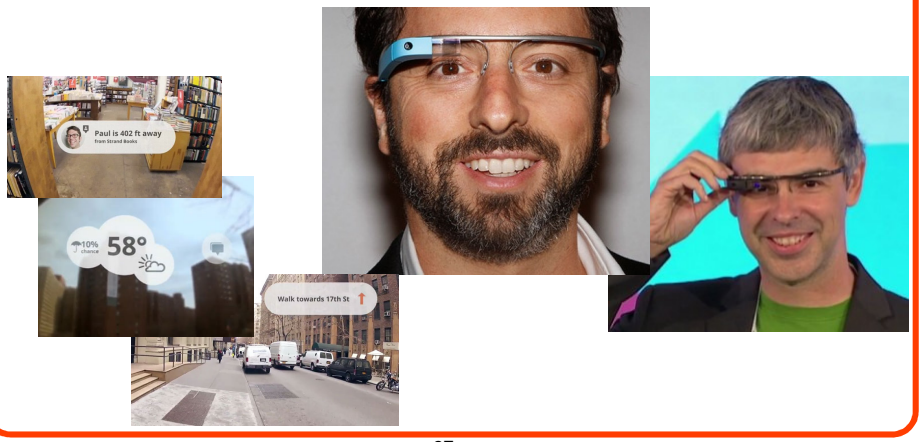
J. Kopf, C.W. Fu, D. Cohen-Or, O. Deussen, D. Lischinski, T.T. Wong, 2007.

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)

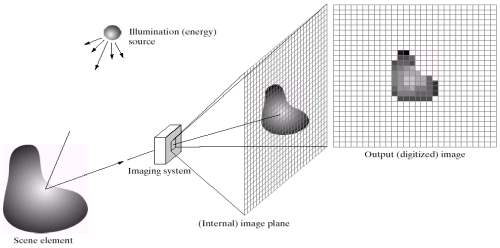

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Image Operations

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

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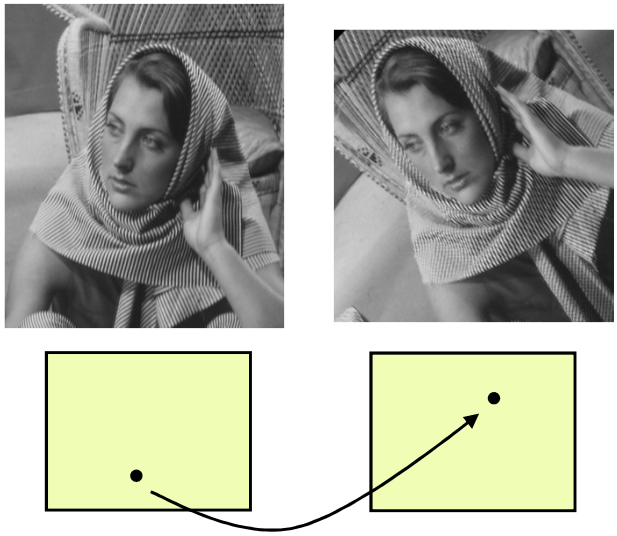
Geometric Operations



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Point Operations

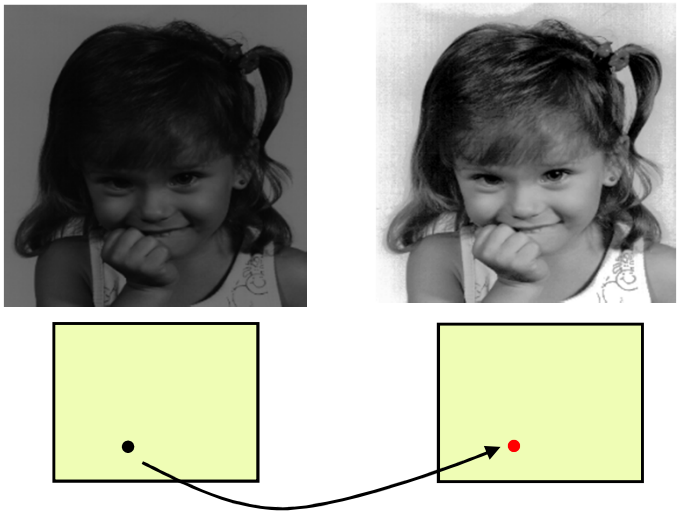

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Image Enhancement

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Image Enhancement

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Geometric and Point Operations

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Spatial Operations

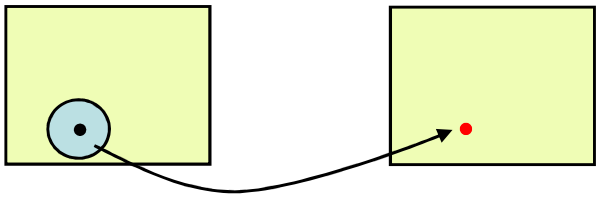

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Image Denoising

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Image Deblurring

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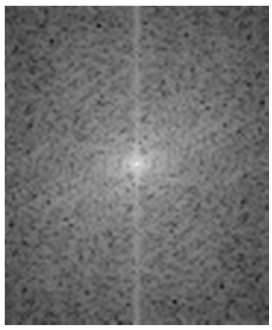
The Fourier Transform



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

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

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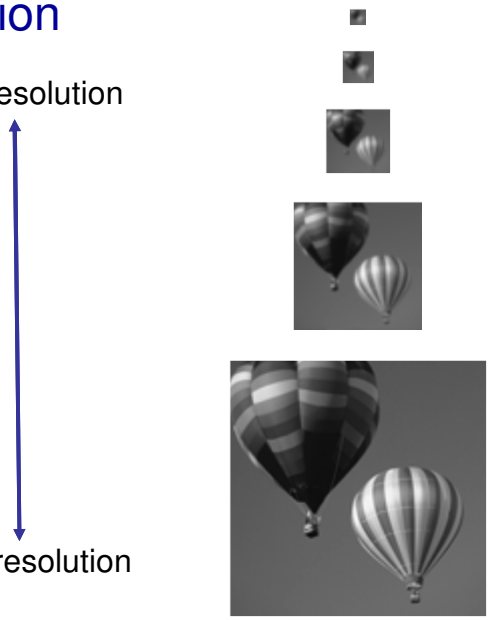
Operations in Frequency Domain

Original
Noisy image

Filtered
image

Multi-Resolution

Low resolution



High resolution

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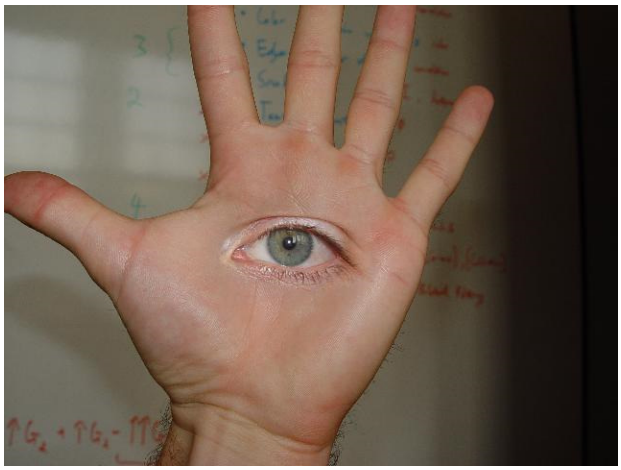
Multi-Resolution Operations



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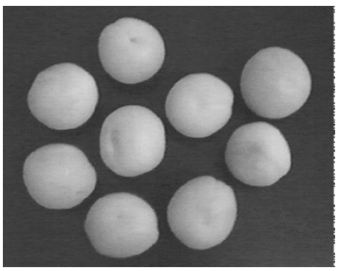
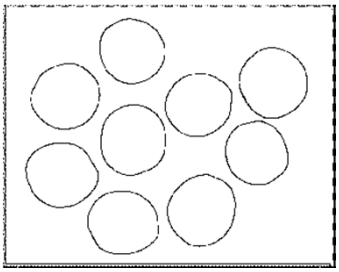
Edge Detection



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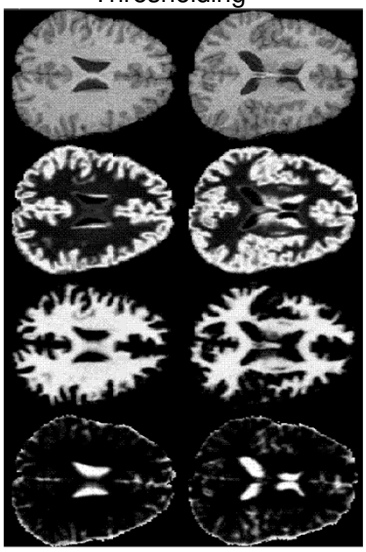
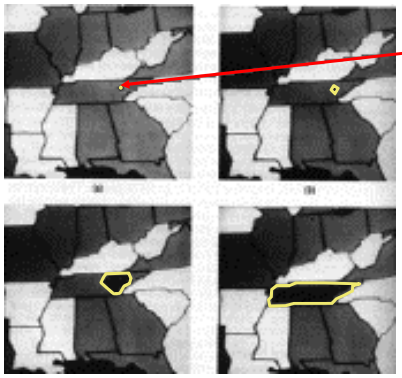
Segmentation

Thresholding



Region Growing



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Graph Cut + Cloning

segment

clone

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

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Pattern Matching

Pattern

Match Results

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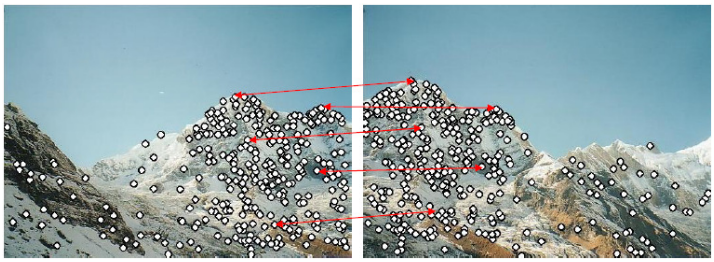
Image Matching



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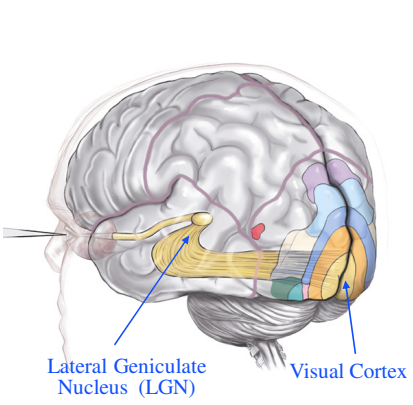
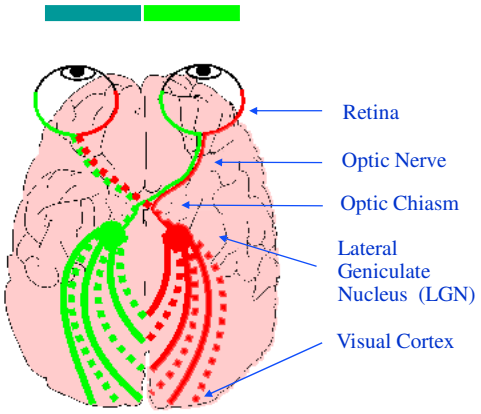
The Human Visual System





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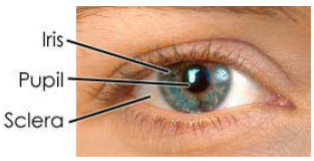
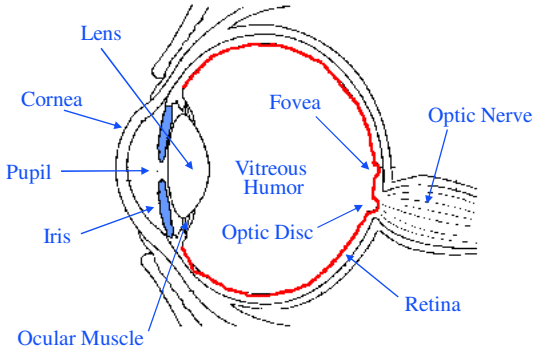
The Human Eye





- Cornea - קרנית
- Pupil - אישון
- Iris - קשתית
- Retina - רשתית

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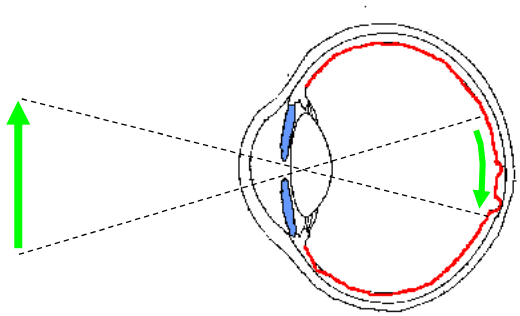
The Human Eye

Image Acquisition



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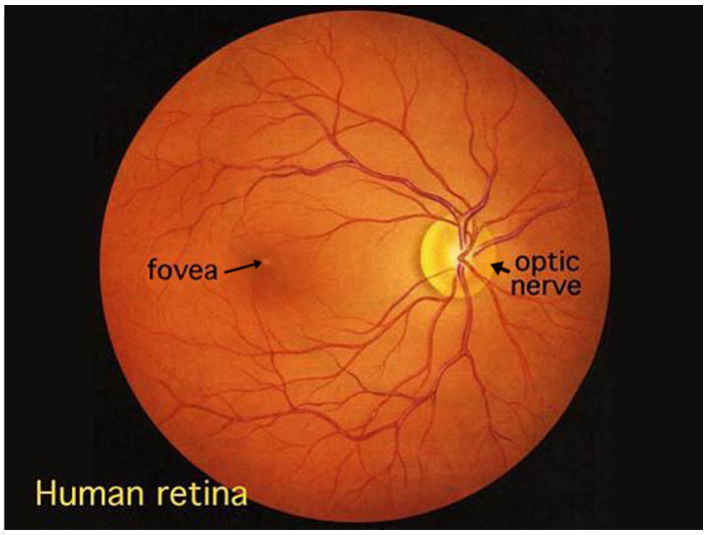

Fig. 1. Human retina as seen through an opthalmoscope.

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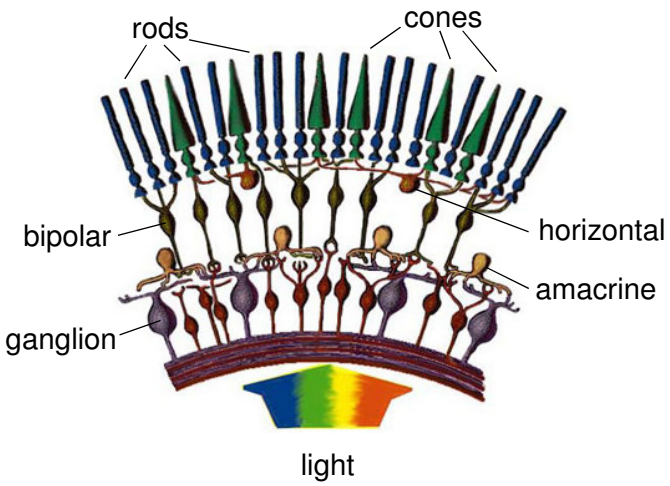
The Human Retina



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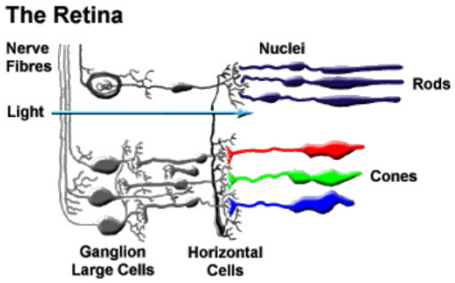
- Retina contains 2 types of photo-receptors
  - Cones:
    - Day vision, can perceive color tone
  - Rods:
    - Night vision, perceive brightness only



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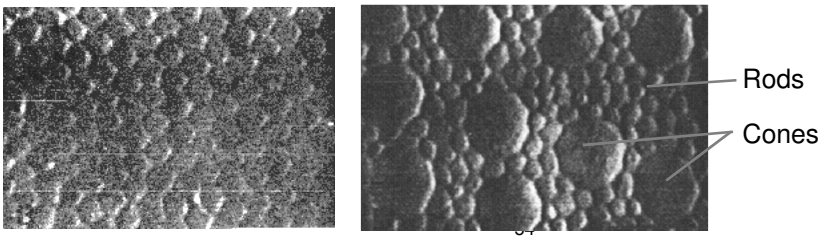
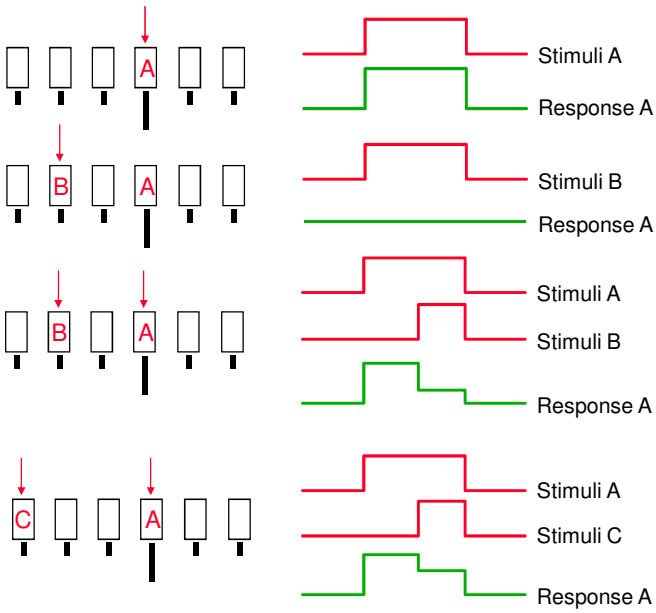
Cone Mosaic



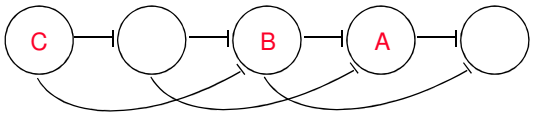
Cone Mosaic at Fovea Cone Mosaic in periphery

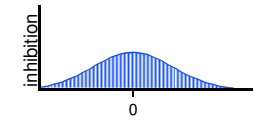
10 µm

Response is Spatial Dependent

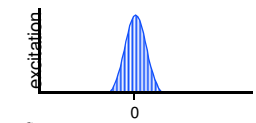


Inhibitory Model

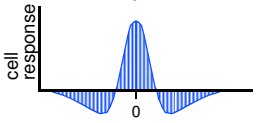




Inhibition on A as a function of distance from A



Excitation on A as a function of distance from A



Response of A (Excitation minus Inhibition)

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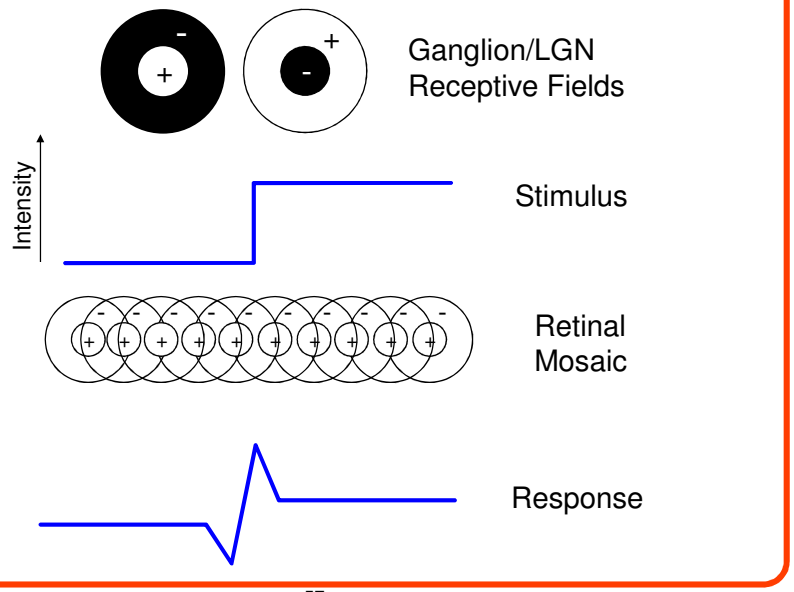
Mach Bands



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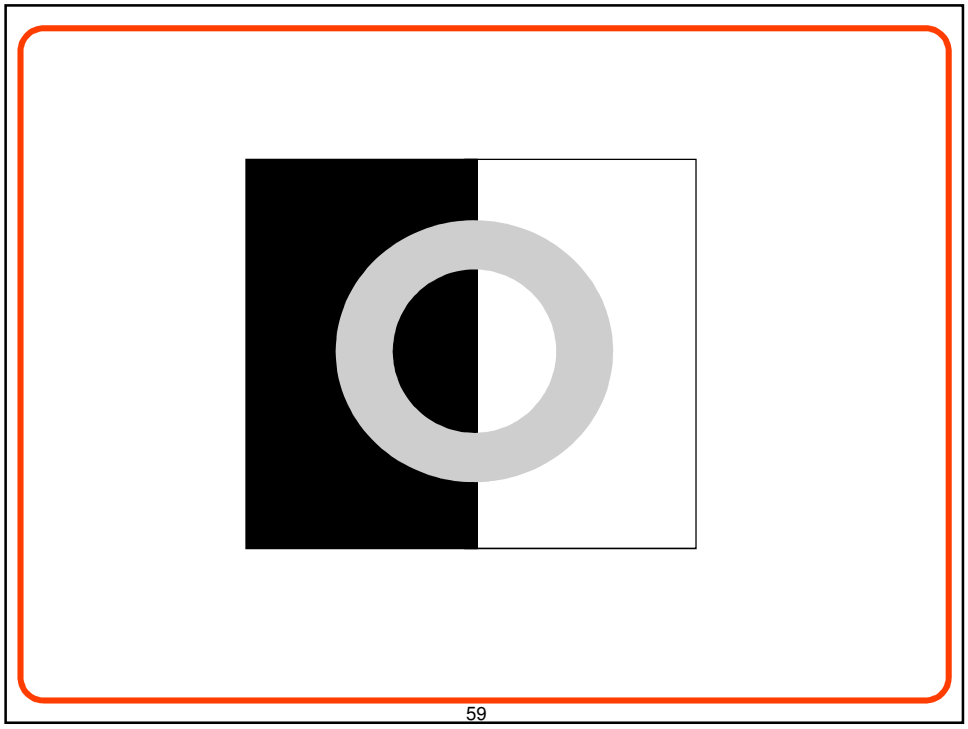

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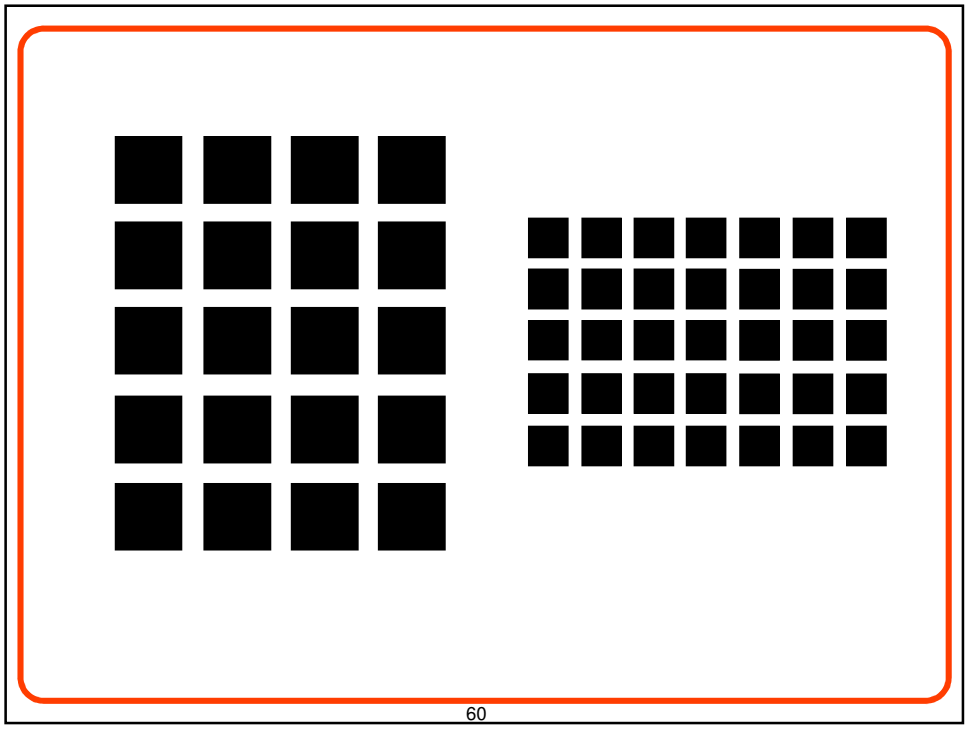

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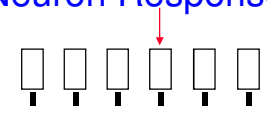
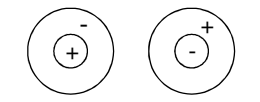
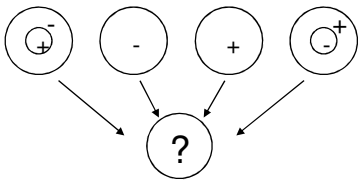
Neuron Responses in the Visual Pathway







Photoreceptors

Ganglion Cells

LGN Cells

Visual Cortex Cells

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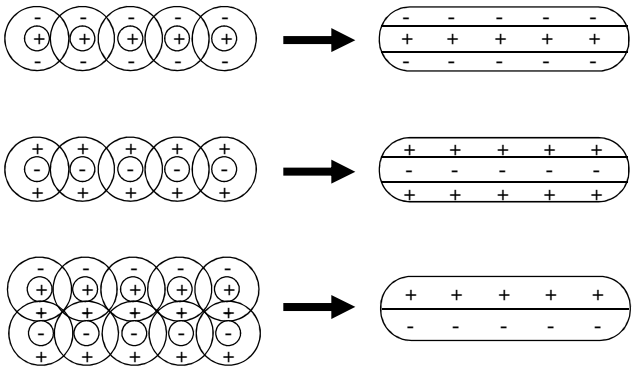
Visual Cortex Cells

Simple Cells



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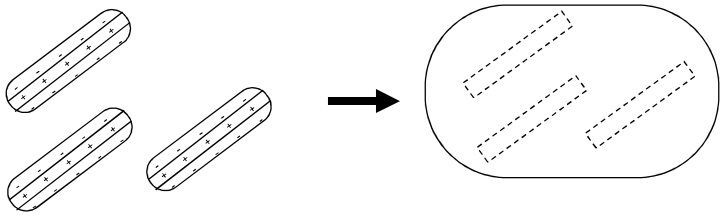
Visual Cortex Cells

Complex Cells



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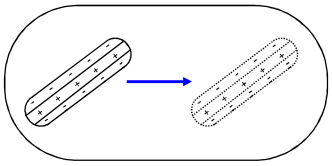
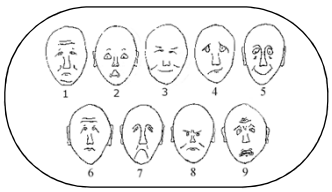
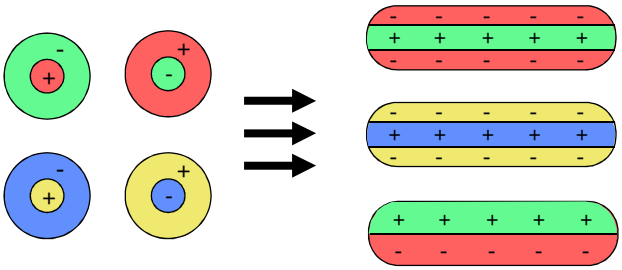
Motion Detection Cells (area MT)



Grandmother Cells (area IT)



Color Cells (area V4)



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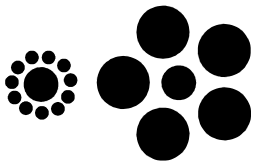
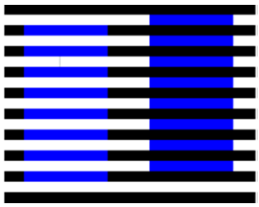
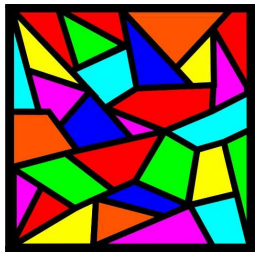
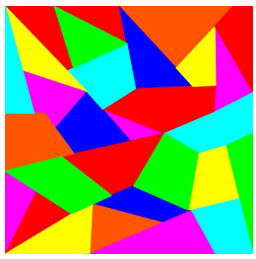
Contrast Illusions

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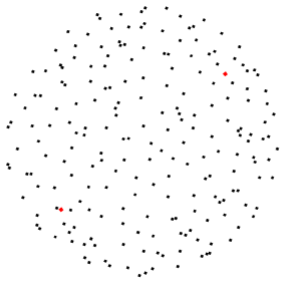

http://www.brl.ntt.co.jp/IllusionForum/basics/visual/english/MO.Kerr2.html

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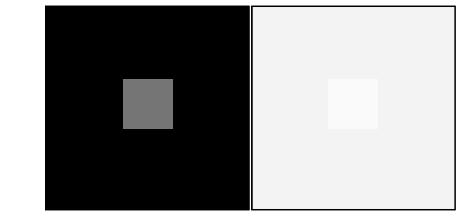
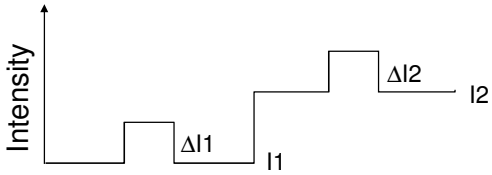
Intensity vs Brightness





$I1 < I2,\ \Delta I1 = \Delta I2$

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Intensity vs Brightness

Equal intensity steps:

Equal brightness steps:

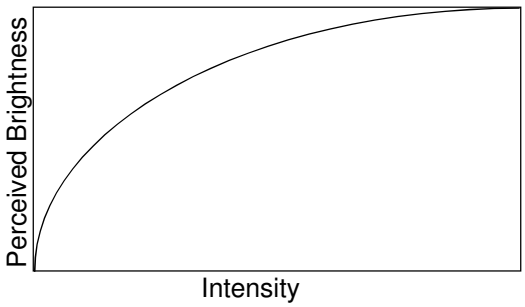
Weber's Law

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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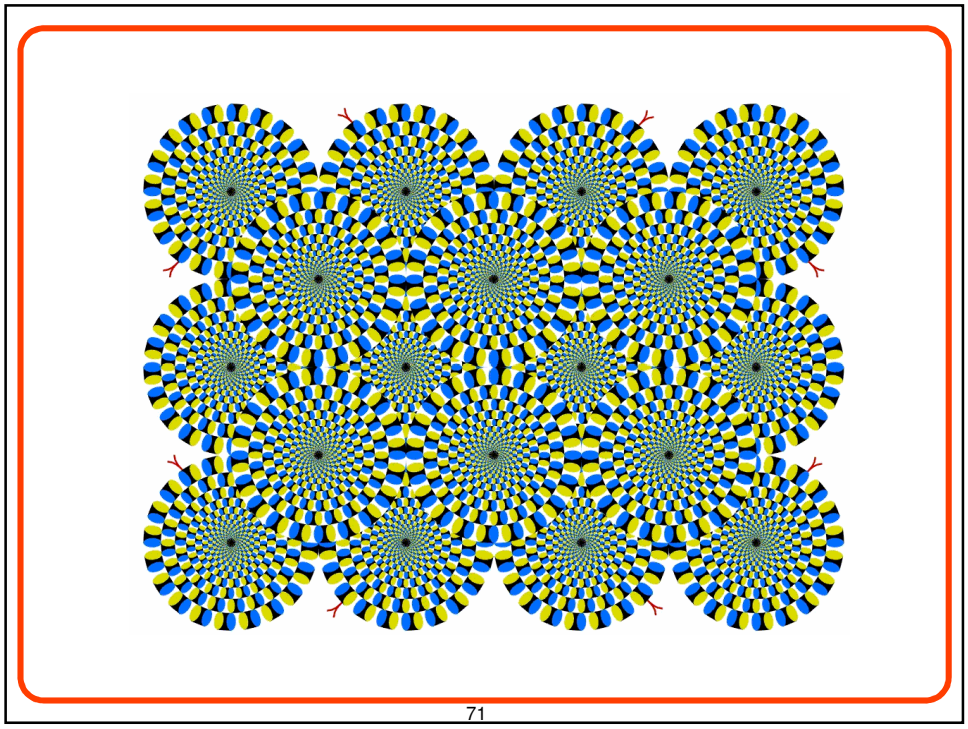

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