COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

EE4830 Digital Image Processing
Lecture 13

# Misc. Topics

- image reconstruction from projections
- image/video indexing and retrieval
- review

April 30, 2007

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# Announcements

- PS#7 due Wednesday 10am
  - Solution will be available by the end of this week
- Additional office hours
  - Thursday May 3rd, 5:30 – 7:00pm
  - Monday May 7th, 4:30 – 6:00pm
- Final Exam on May 7th 7:10~10:10pm, Mudd 337
  - 5 problems
  - Open book, notes, calculator
  - Coverage: Lectures 1-13

# Lecture Outline

- Last week: source coding, image/video compression
- Image reconstruction from projections
  - CT, PET and medical imaging
  - Radon transform
  - Projection-slice theorem
- Introduction to image/video indexing
  - The problem
  - Technologies and systems
  - Demos
    - "Video Google", like.com, retrievr, IBM Multimedia Analysis and Retrieval System
- DIP "executive summary"

# Image Reconstruction: Why?

Nobelprize.org

NOBEL PRIZES | ALFRED NOBEL | PRIZE AWARDERS | NOMINATION | PRIZE ANNOUNCEMENTS | AWARD CEREMONIES

By Year | Nobel Prize in Physics | Nobel Prize in Chemistry | **Nobel Prize in Medicine** | Nobel Prize in Literature | Nobel Pe

Medicine

## The Nobel Prize in Physiology or Medicine 1979

"for the development of computer assisted tomography"

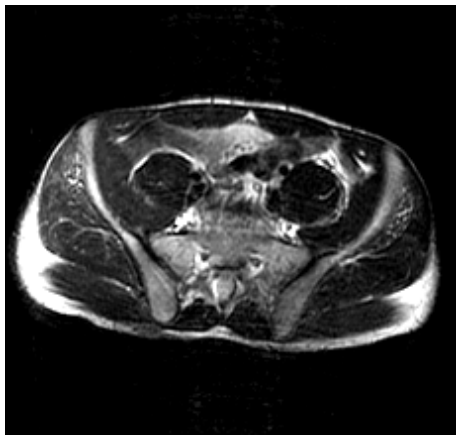
Allan M. Cormack

| Allan M. Cormack | Godfrey N. Hounsfield |
|---|---|
| 1/2 of the prize | 1/2 of the prize |
| USA | United Kingdom |
| Tufts University<br>Medford, MA, USA | Central Research Laboratories, EMI<br>London, United Kingdom |
| b. 1924<br>(in Johannesburg, South Africa)<br>d. 1998 | b. 1919<br>d. 2004 |

Titles, data and places given above refer to the time of the award.

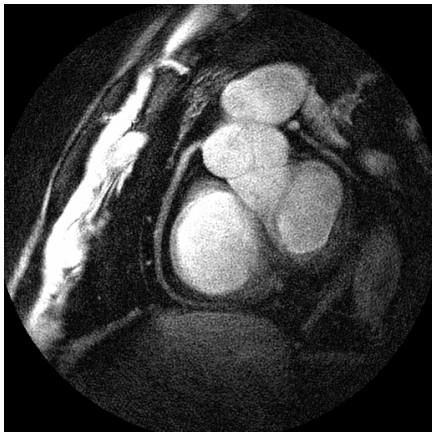
# Magnetic Resonance Imaging

- Non-invasive medical imaging method, like ultrasound and X-ray.
- Clinically used in a wide variety of specialties.



Abdomen

Spine

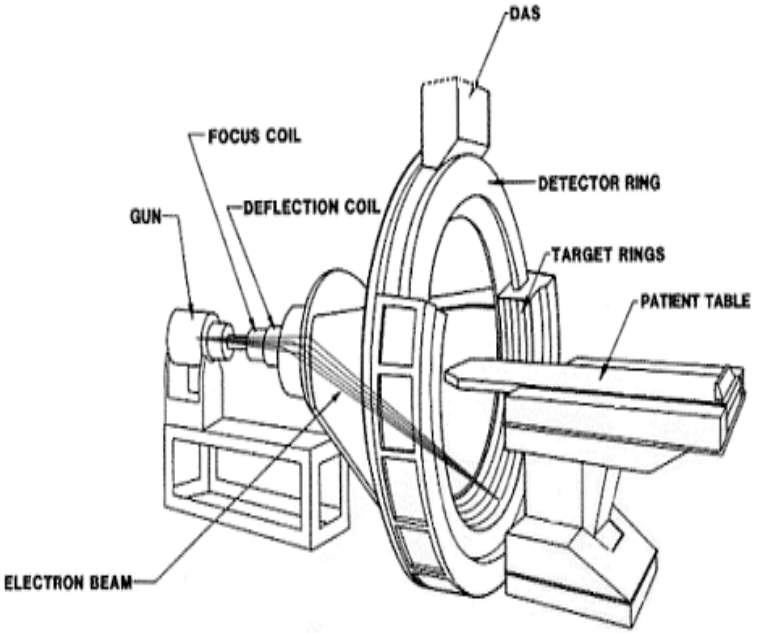


Heart / Coronary

material courtesy of Brian Hargreaves, Stanford Univ.

# What is Computed Tomography?

- Computed Tomography (CT) is a computer aided imaging technique performed by illuminating the object of interest with radiation and measuring the attenuation.
- Commonly, X-ray emitters and detectors are used to collect the attenuation data. That data is then processed to reconstruct 2D or 3D images of the regions of interests in a non-invasive manner, using a machine like the one on the right.
- CT is widely used in the medical field in the diagnosis of cancers, disease, and to recover muscular-skeletal information in the human body. It can also be useful in determining dosimetry for radiation treatments.
- CT is also used in imaging non-biological systems: engine performance diagnostics,materials research and Geology




**CT Scanner [1]**

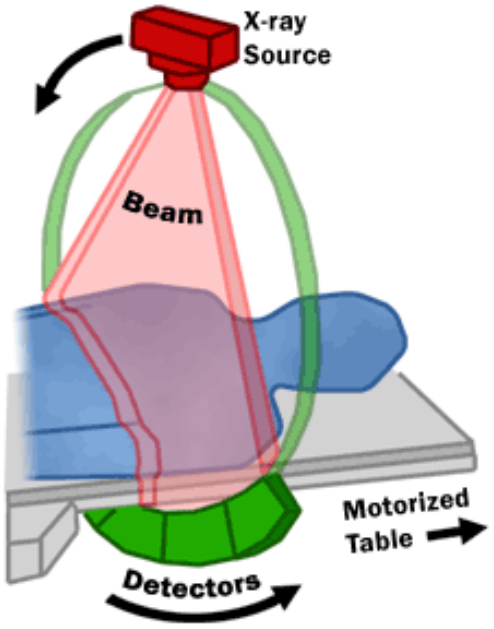
Slide 5-7 courtesy of Omar Negrete, U. New Mexico

# Tomography Scanners



CT Machines are basically a motorized table with an array of cathode ray X-ray tubes positioned around the patient's body in a radial fashion. With the aid of computers, image data can be acquired and processed to reconstruct images of the underlying information.

[2]




[2]

**Check out some very impressive examples of CT at GE's website below**

http://www.gemedicalsystems.com/rad/ct/products/cvct/cases.html

# More Scanners

- As mentioned earlier scanners are also used in other applications

Large Cargo Scanner :

[3]

- CT Scanner made out of LEGOS! Great teaching device.

http://innovexpo.itee.uq.edu.au/2003/exhibits/s804697/


[4]

# CT $\approx$ The Process of Collapsing Image Data and Then Reconstructing It

Switch to EE631 slides …

- A dual problem:
  - Fourier Volume Rendering
  - [Totsuka and Levoy '93] [Malzbender'93]

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# Demos of image retrieval systems

# But Google Does not Understand Web Pages!



Visual Geometry Group

video google demo

**Josef Sivic, Frederik Schaffalitzky and Andrew Zisserman**
**(with thanks to James Philbin and Karen McGaul)**
http://www.robots.ox.ac.uk/~vgg

This is a demonstration of the Video Google retrieval system. The goal is to retrieve objects or scenes in a movie with the ease, speed and accuracy with which Google retrieves web pages containing particular words. The query is specified by outlining an object of interest in a frame of the video and the system returns ranked list of shots from the entire movie containing the object. Objects are retrieved despite viewpoint or scale variations and some amount of lighting changes. Note that the current version is not optimized for retrieving faces, people and deformable or motion blurred objects. These pages have been tested with Internet Explorer 7 and Firefox 1.5.

Please read the instructions on how to use Video Google.

To find out more read the how it works page.

**Pick a movie to search in:**


Charade (1963)
Featuring Audrey Hepburn and Cary Grant
(clicking the image or title will take you to the movie browser)

**Director:** Stanley Donen

Find more information about the movie on its IMDb page.
Wikipedia discusses the copyright issue.

**Example frames to start the search:**
Click on the picture to get the corresponding frame. Then outline the suggested (or any other) query region and click on 'Search'. You should then receive a page of shots - one shot per line.


Frame 106725


Frame 29300


Frame 18300

http://www.robots.ox.ac.uk/~vgg/research/vgoogle/index.html

# Making the Best of Two Worlds: Image Understanding and Information Retrieval




Welcome to the IBM Research MARVEL Multimedia Analysis and Retrieval System (2007).

Please click image to begin.

IBM MARVEL Multimedia Analysis and Retrieval System

Contact: John R. Smith, IBM T. J. Watson Research Center

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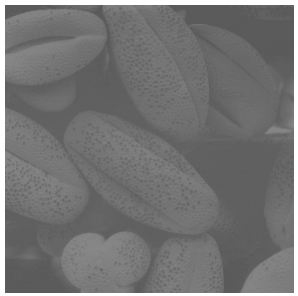
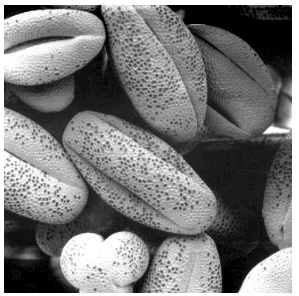
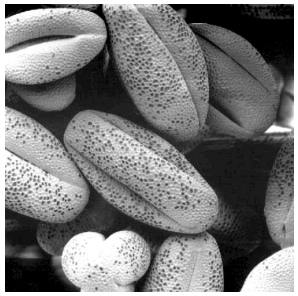
# Digital Image Processing





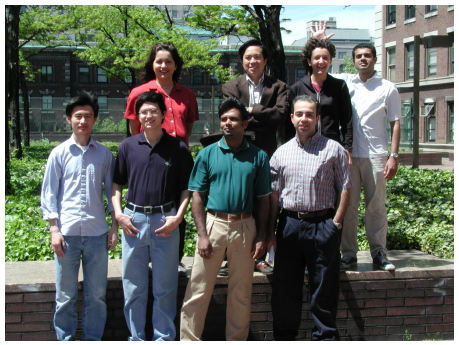
Low level



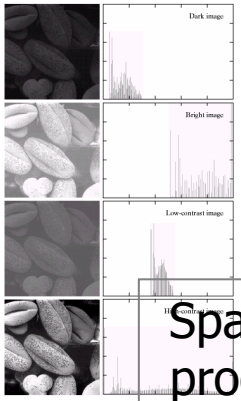


Mid level

$$\bar{x} = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_P \end{bmatrix}$$



High level




Spatial Domain processing and enhancement

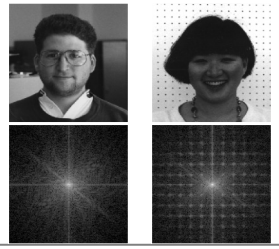


Image Transform and Filtering

Morphological Processing

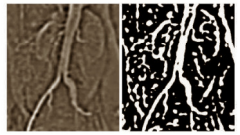


Image Segmentation

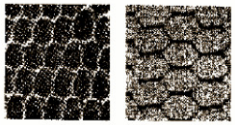
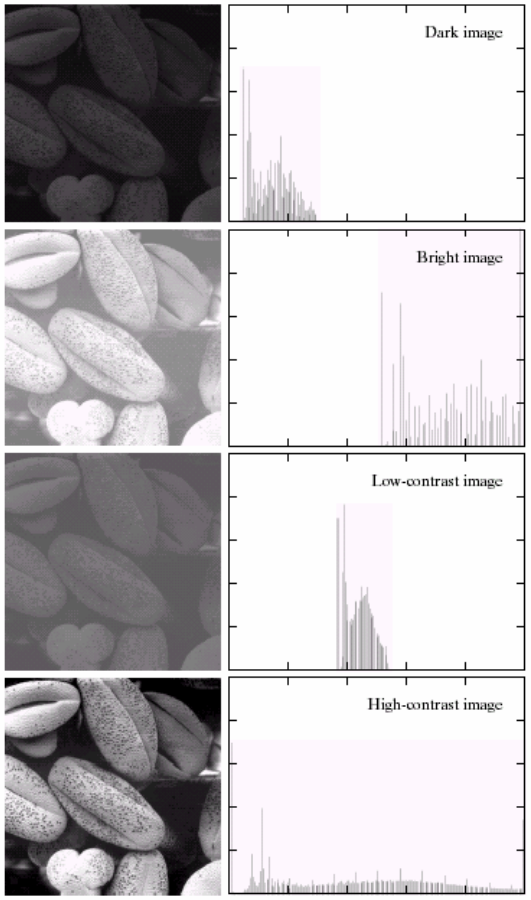


Image Descriptors

Applications:
Object recognition, Image/Video Compression
Indexing and Retrieval, Reconstruction

# Spatial Domain Image Processing

- Spatial domain tools
  - Point operations vs. Kernel Operations
  - Image Histogram
- Image Enhancement
  - Using Point Operators
    - Contrast Stretching
    - Gamma Correction
  - Using Image Histogram
    - Histogram Equalization
    - Histogram Matching
  - Using Kernel Operators
    - Low-pass filtering (averaging)
    - High-pass filtering (sharpening)



# Color Perception and Color Images

- Visual Perception – Basics
- Color Representation
- Color Models
- Color Image Processing
  - Point & Kernel operations
- Multi-spectral Images

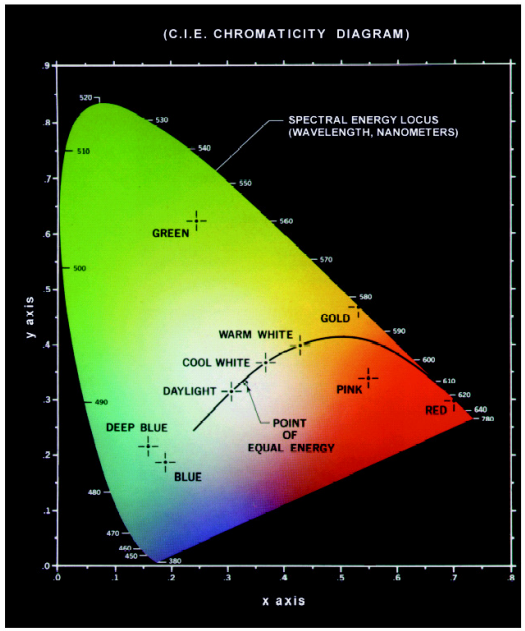
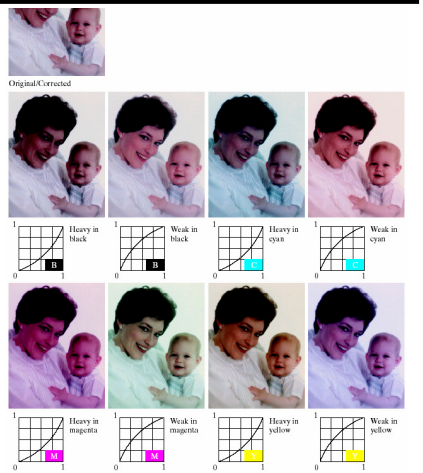


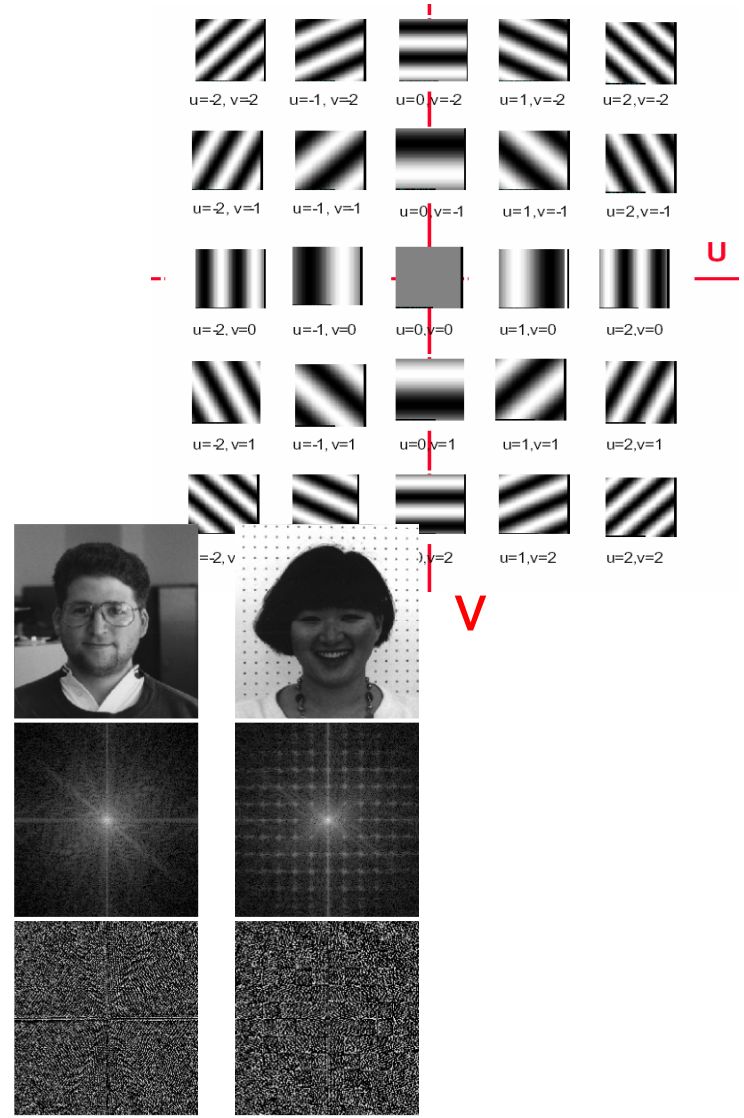

**FIGURE 6.5** Chromaticity diagram. (Courtesy of the General Electric Co., Lamp Business Division.)



# Image Transform



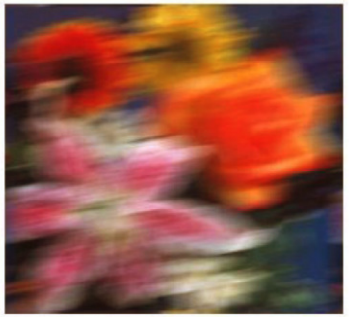
- Why transform
- 2D Fourier Transform
  - Definition, Properties, Implementation
- Transform in other flavors
  - Unitary transforms
  - DCT, KLT
  - Properties of KLT
- Applications: fast filtering, denoising, enhancement …



# Image Restoration

- What is image restoration
  - Scope, history and applications
  - A model for (linear) image degradation
- Restoration from noise
  - Different types of noise
  - Examples of restoration operations
- Restoration from linear degradation
  - Inverse and pseudo-inverse filtering
  - Wiener filters
  - Blind de-convolution
- Geometric distortion and its corrections

Original image



Blurred image

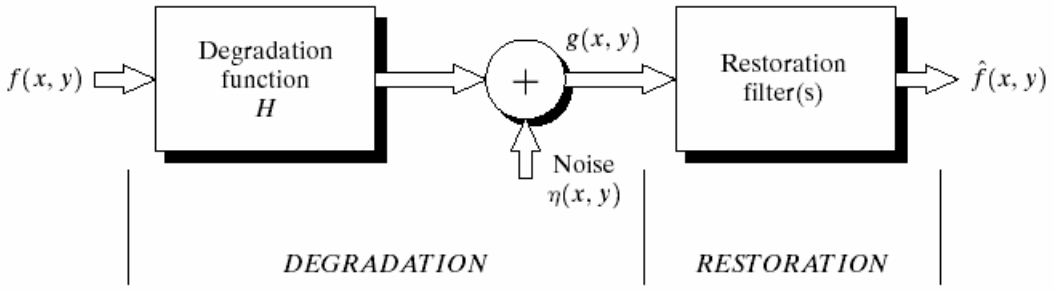
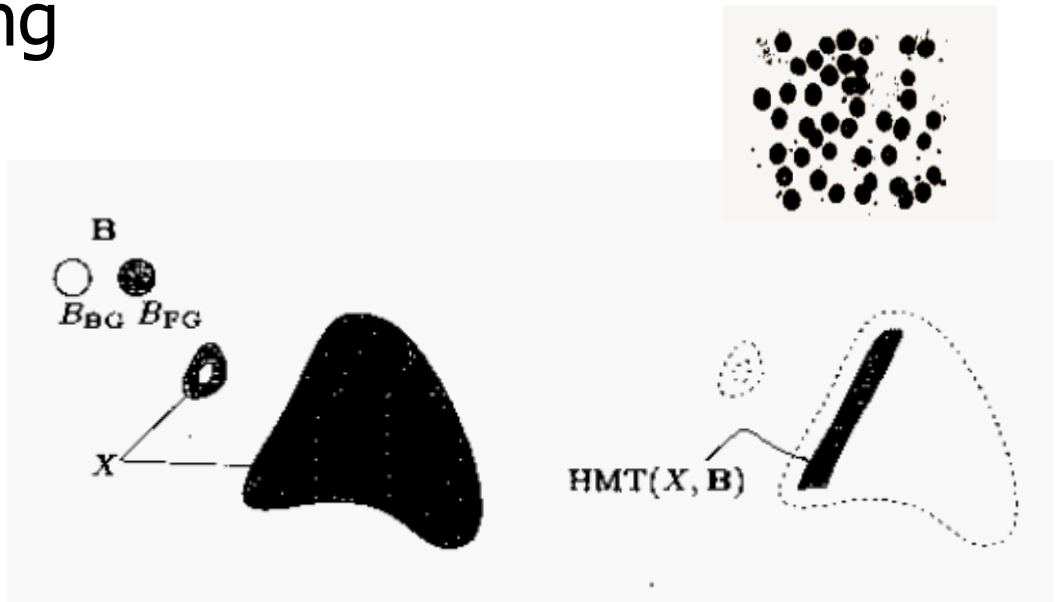



**FIGURE 5.1** A model of the image degradation/ restoration process.

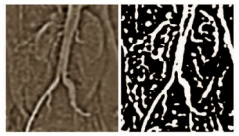
# Morphological Image Processing

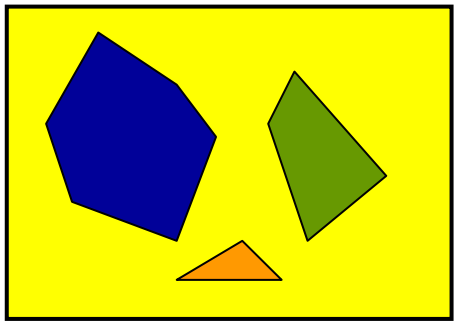
- What is Mathematical Morphology?
- Background Notions
- Introduction to Set Operations on Images
- Erosion and Dilation
- Opening and Closing
- Hit-or-Miss
- Skeletonization

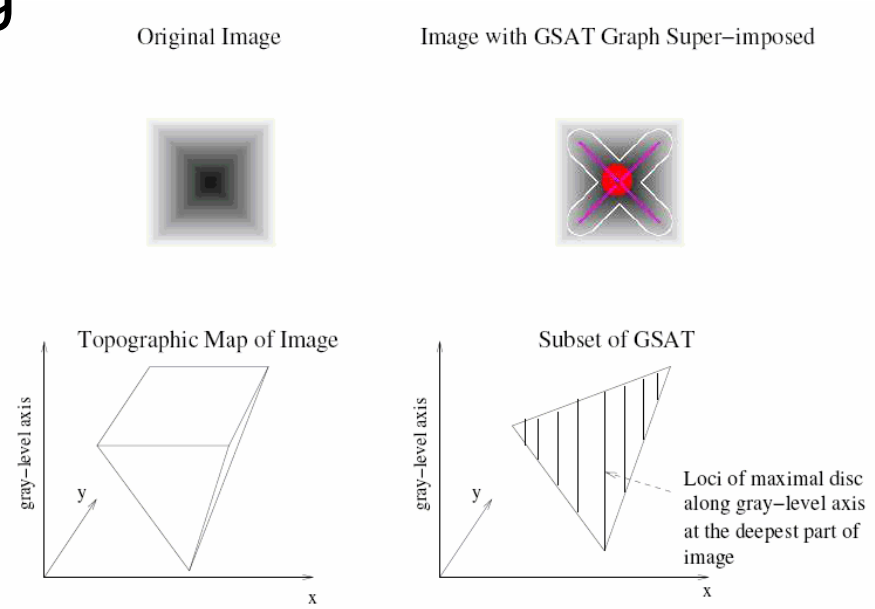


# Image Segmentation

- GSAT
- Watershed Algorithm
- Image Segmentation
- Edge detection and linking
- Thresholding
- Region-based Approach
- Motion Segmentation







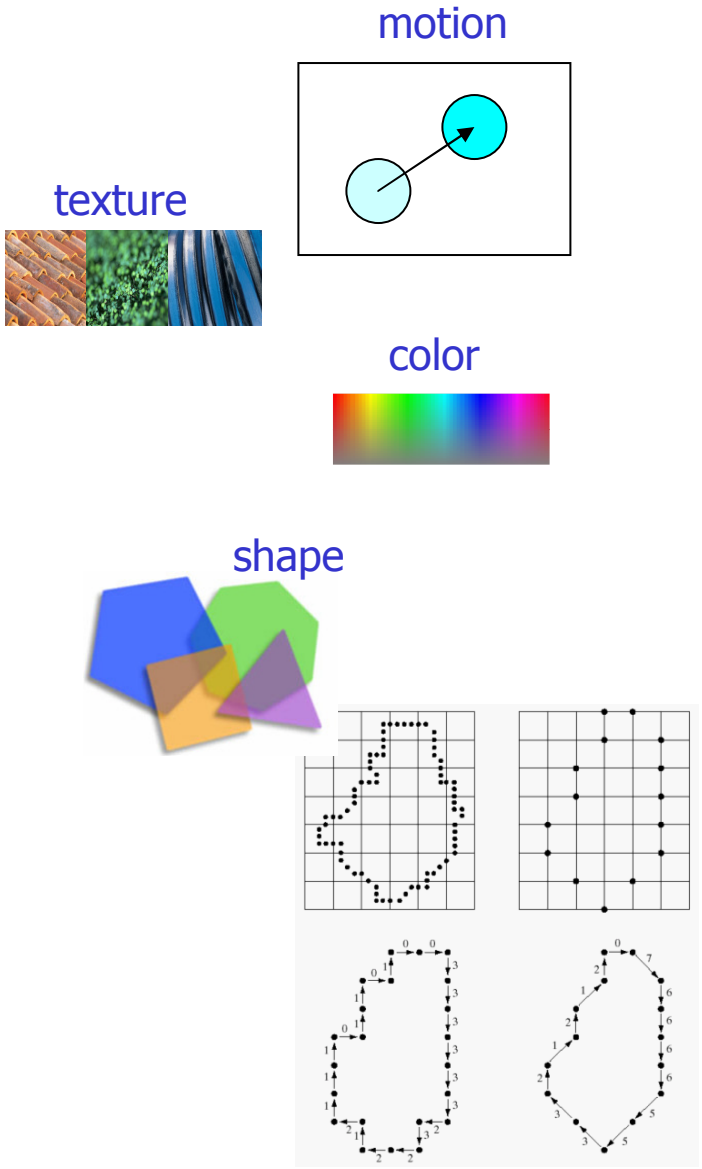
# Image Descriptors



- Color Description
- Texture
- Boundary Description
- Motion

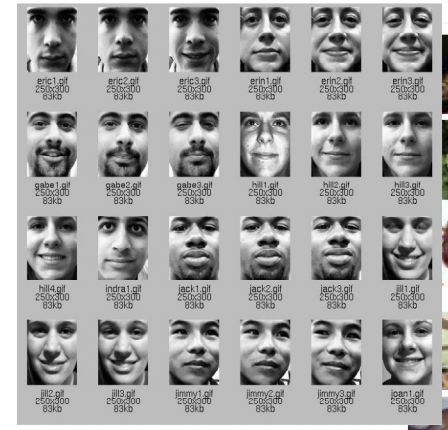
- Moments and other statistical aggregations

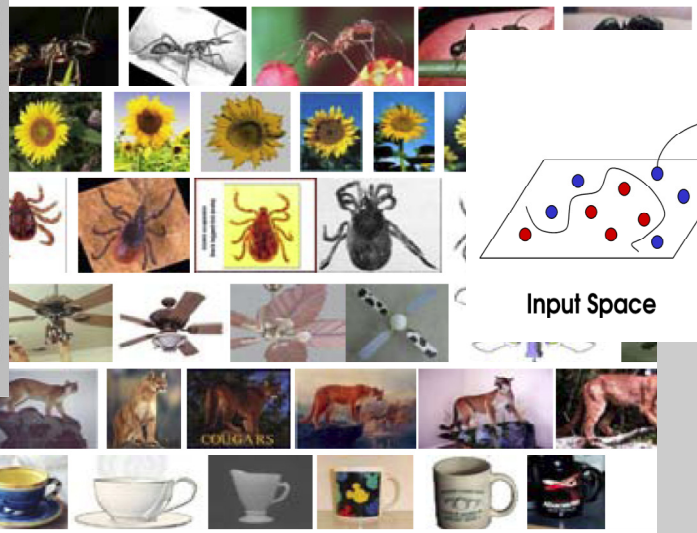
- MPEG-7 Descriptors

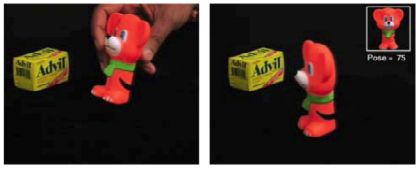


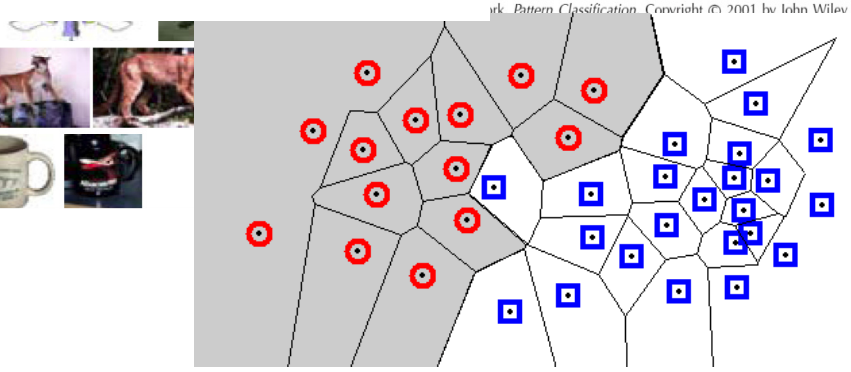
# Object Recognition

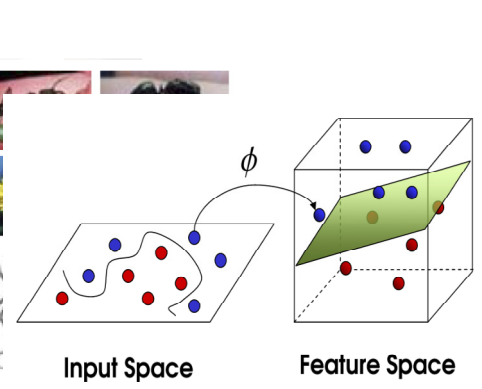
- What and why
- Object recognition as pattern classification
- General object recognition systems

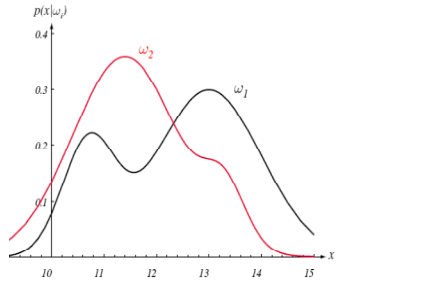








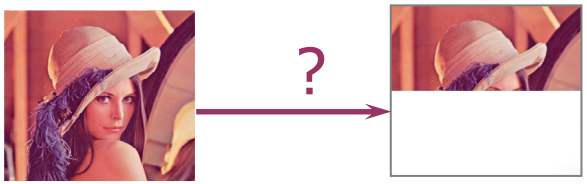



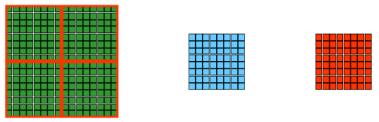

pothetical class-conditional probability density functions show the ty of measuring a particular feature value $x$ given the pattern is in represents the lightness of a fish, the two curves might describe the ness of populations of two types of fish. Density functions are normal- area under each curve is 1.0. From: Richard O. Duda, Peter E. Hart, rk. Pattern Classification. Copyright © 2001 by John Wiley & Sons

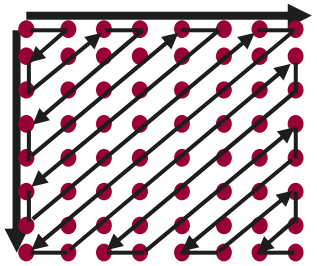
# Image Compression



- What and why
- Source coding
  - Basic idea… L(C) → H(X)
    - What are good codes
  - Entropy coding for i.i.d. symbols
    - Huffman, Arithmetic, …
  - Coding symbol sequences/matrixes
    - LZW, run-length, DPCM, transform coding …
- Source coding systems
  - Compression standards
    - JPEG / MPEG / …
- Recent developments



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