Introduction

Erkut Erdem

Instructor and Course Schedule

- Dr. Erkut ERDEM
- erkut@cs.hacettepe.edu.tr
- Office: 114
- Tel: 297 7500 / 149

- Lectures: Tuesday, 13:30-16:30
- Office Hour: Friday, 13:00-15:00

Communication

- The course webpage will be updated regularly throughout the semester with lecture notes, programming and reading assignments and important deadlines.
- All other communications will be carried out through Piazza. Please enroll it by following the link https://piazza.com/hacettepe.edu.tr/spring2012/bil717

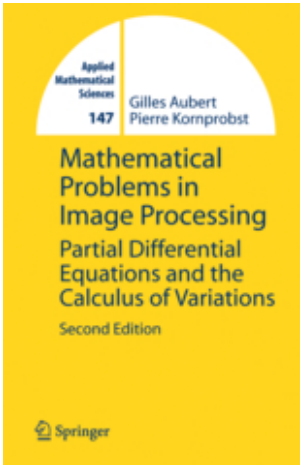
Prerequisites

- Programming skills
  (C/C++, Matlab)
- Good math background
  (Calculus, Linear Algebra, Statistical Methods)
- A prior, introductory-level course in image processing is recommended.

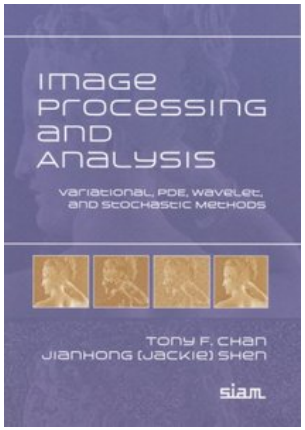
Reading Material

- Lecture notes and handouts
- Papers and journal articles

Reference Books



- Mathematical Problems in Image Processing: Partial Differential Equations and the Calculus of Variations, G. Aubert and P. Kornprobst, 2nd Edition, Springer-Verlag, 2006



- Image Processing And Analysis: Variational, PDE, Wavelet, And Stochastic Methods, T. Chan and J. Shen, Society for Industrial and Applied Mathematics, 2005

Related Conferences

- International Conference on Scale Space and Variational Methods in Computer Vision (SSVM)
- Energy Minimization Methods in Computer Vision and Pattern Recognition (EMMCVPR)
- IEEE Conference on Computer Vision and Pattern Recognition (CVPR)
- Advances in Neural Information Processing Systems (NIPS)
- IEEE International Conference on Computer Vision (ICCV)
- European Conference on Computer Vision (ECCV)
- IEEE International Conference on Pattern Recognition (ICPR)
- IEEE International Conference on Image Processing (ICIP)
- British Machine Vision Conference (BMVC)

Related Journals

- IEEE Transactions on Pattern Analysis and Machine Intelligence (IEEE TPAMI)
- IEEE Transactions on Image Processing (IEEE TIP)
- Journal of Mathematical Imaging and Vision (JMIV)
- International Journal of Computer Vision (IJCV)
- Computer Vision and Image Understanding (CVIU)
- Image and Vision Computing (IMAVIS)
- Pattern Recognition (PR)

Grading Policy

- Class participation, 5%
- Assignments, 30%
- Project, 30%
- Final Exam, 35%

Assignments

- There will be at least four assignments related to the topics covered in the class.
- Each assignment will involve implementing an algorithm, carrying out a set of experiments to evaluate it, and writing up a report on the experimental results.
- There will also be some warm-up and reading assignments.
- All assignments have to be done individually, unless stated otherwise.

Project

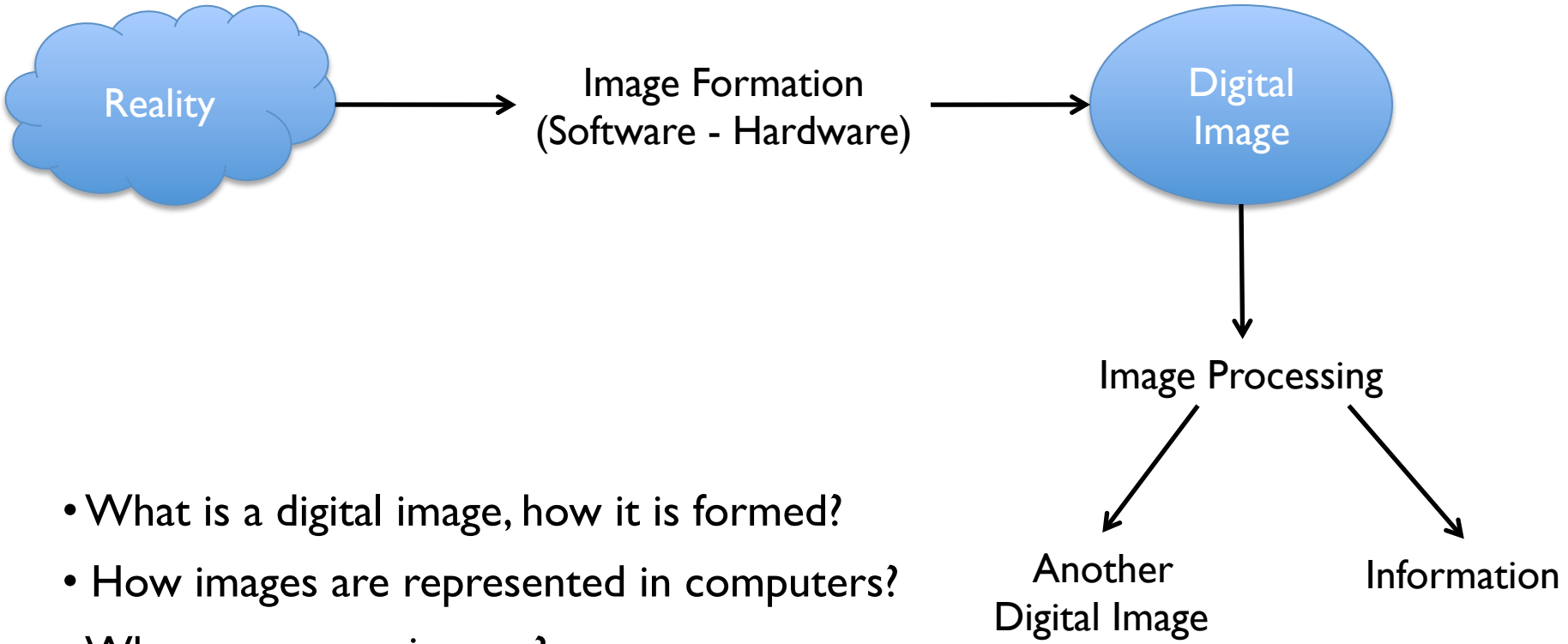
- The students taking the course will be required to do a project in computer vision.
- Students can choose to work individually or in groups of at most 2 people.
- This project may be
  - An original implementation of a new or published study
  - A detailed empirical evaluation of two or more related methods not covered in the class
- ***March 20th****: Brainstorming session on project previews*
- ***April 3rd****: Project Proposals*

Tentative Outline

- (1 week) Introduction, course policy
- (1 week) Review of basic concepts
- (4 weeks) Image de-noising
- (4 weeks) Boundary/region detection
- (2 weeks) Selected topics
- (2 weeks) Project presentations

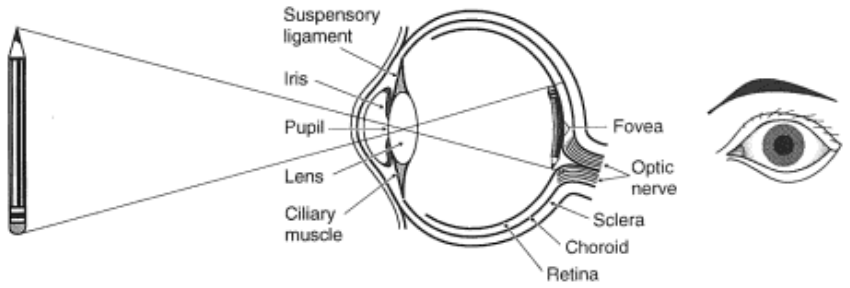
Image Processing

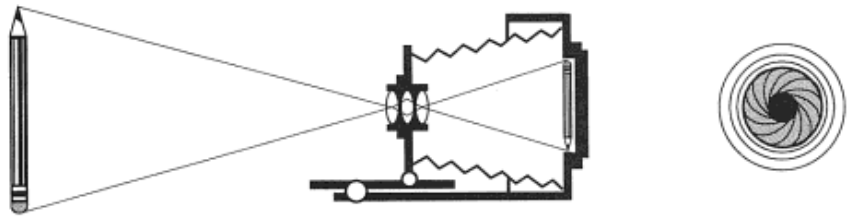
Fundamentals of Image Processing



- What is a digital image, how it is formed?
- How images are represented in computers?
- Why we process images?
- How we process images?

Image Formation





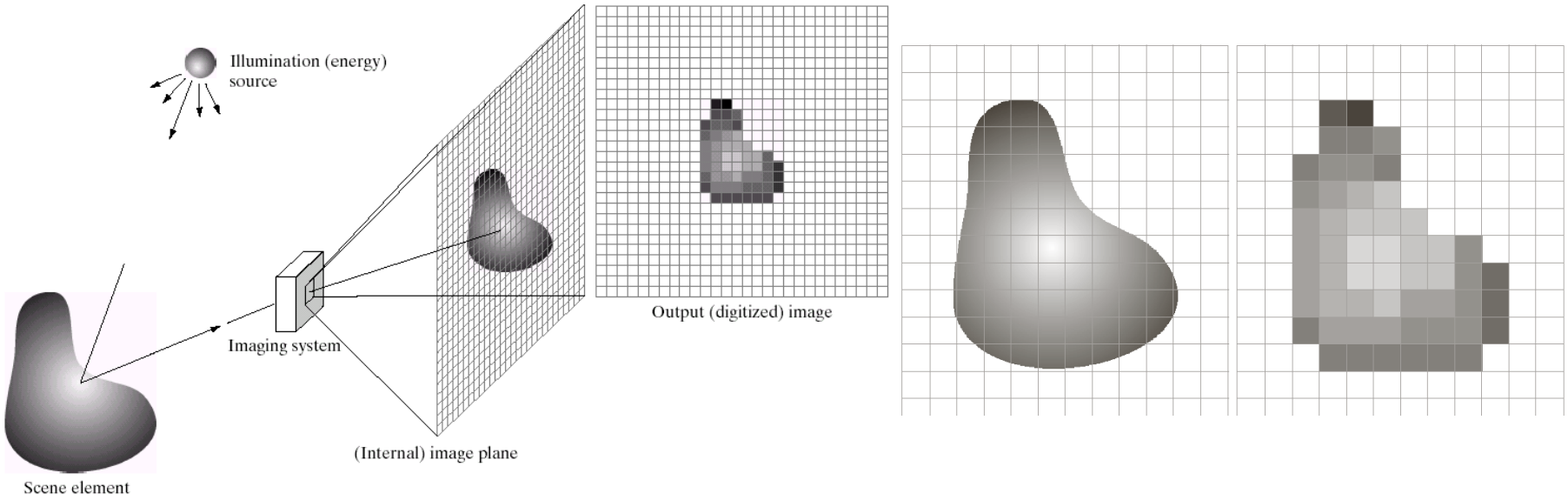
Three Dimensional World ⟶ Two Dimensional Image Space

- What is measured in an image location?
  - brightness
  - color

<< viewpoint
illumination conditions
local geometry
local material properties

Figures: Francis Crick, The Astonishing Hypothesis, 1995

Image Formation



- Discretization
  - in image space - sampling
  - In image brightness - quantization

Figures: Gonzalez and Woods, Digital Image Processing, 3rd Edition, 2008

Image Representation

- **Digital image:** 2D discrete function f
- **Pixel**: Smallest element of an image f(x,y)

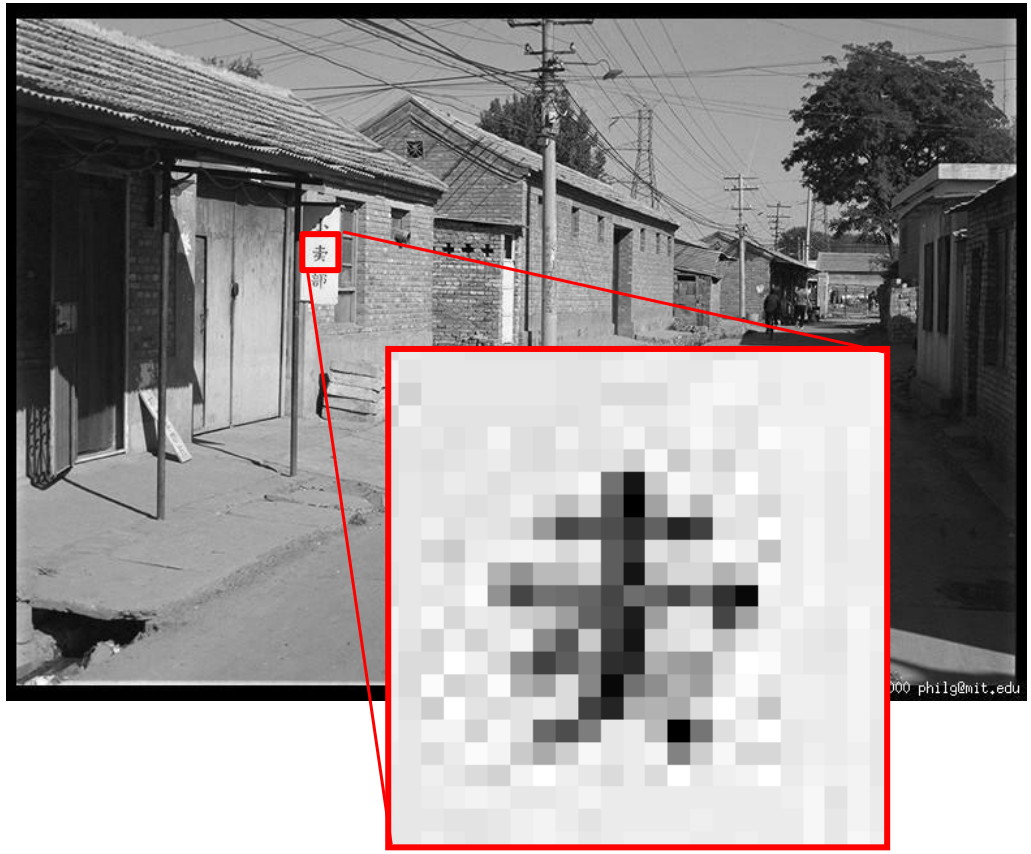


Figure: M. J. Black

Image Representation

- **Digital image:** 2D discrete function f
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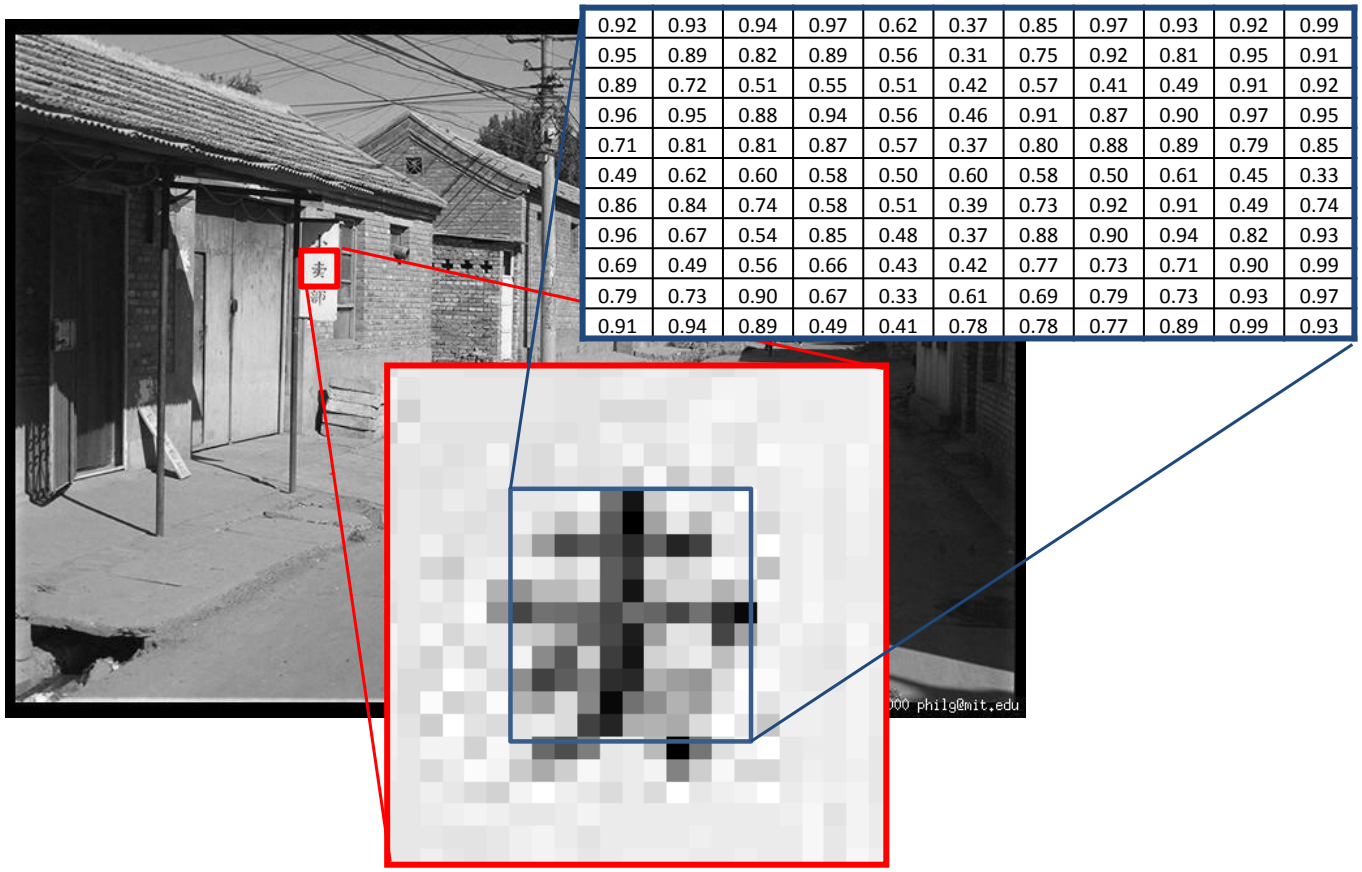
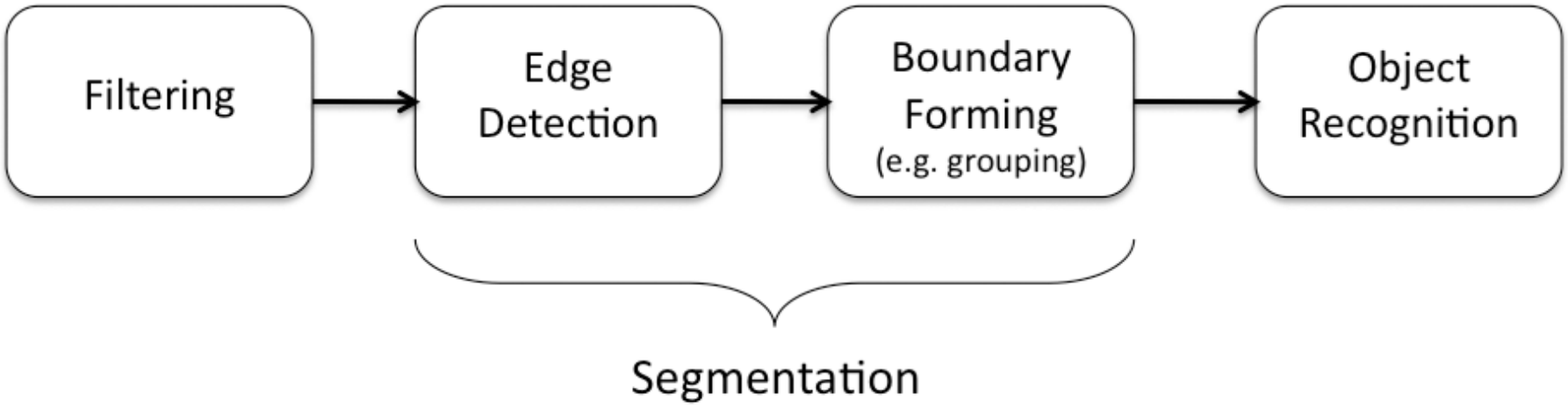


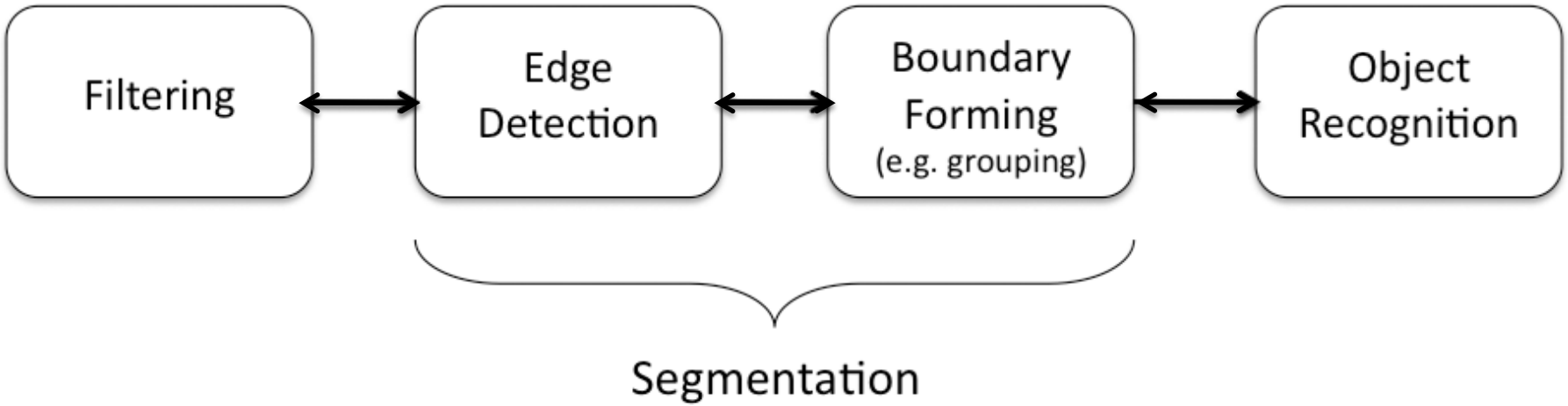
Figure: M. J. Black

Visual Modules and the Information Flow



- Visual perception as a data-driven, bottom-up process (traditional view since D. Marr)
- Unidirectional information flow
- Simple low-level cues >> Complex abstract perceptual units

Visual Modules and the Information Flow



- Vision modules can be categorized into three groups according to their functionality:
  - Low-level vision: filtering out irrelevant image data
  - Mid-level vision: grouping pixels or boundary fragments together
  - High-level vision: complex cognitive processes

Sample Image Processing Applications

- Image Filtering
- Image Segmentation
- Image Registration
- Image Inpainting
- Seam Carving
- Image Analysis
- Image Compression
- …

Image Filtering

- Filtering out the irrelevant information

$$f(x) = u(x) + n(x)$$

observed image | desired image | irrelevant data

- Image denoising, image sharpening, image smoothing, image deblurring, etc.
- Edge detection

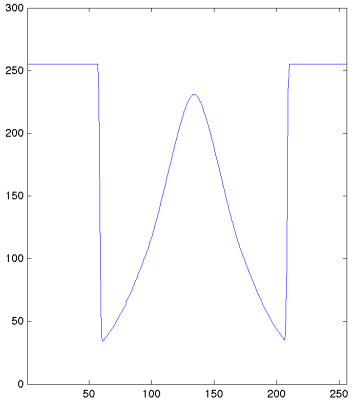
Edge Detection

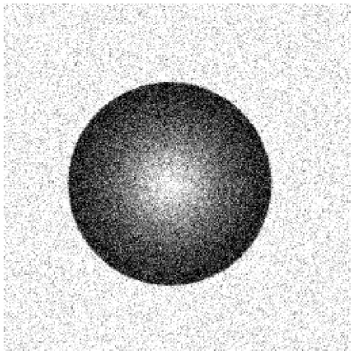
Canny edge detector

- Uniformity of intensity or color
- Texture uniformity

Image Filtering

- **<u>Difficulty:</u>** Some of the irrelevant image information have characteristics similar to those of important image features





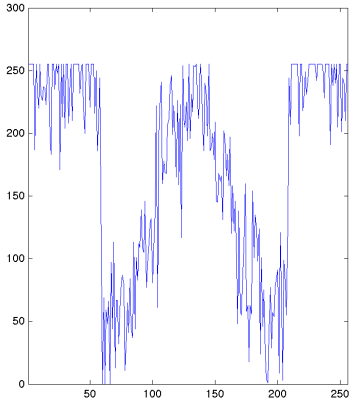


Image Smoothing - A Little Bit of History

- Gaussian Filtering / linear diffusion

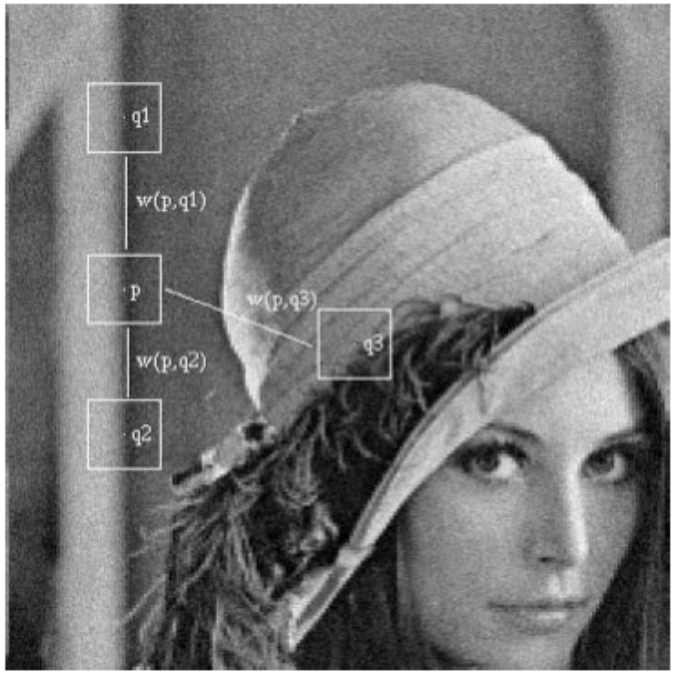
$$\frac{\partial u}{\partial t} = \nabla \cdot (\nabla u) = \nabla^2 u$$

  - the most widely used method



- mid 80's – unified formulations
  - methods that combine smoothing and edge detection
  - Geman & Geman'84, Blake & Zisserman'87, Mumford & Shah'89, Perona & Malik'90

Non-local Means Denoising



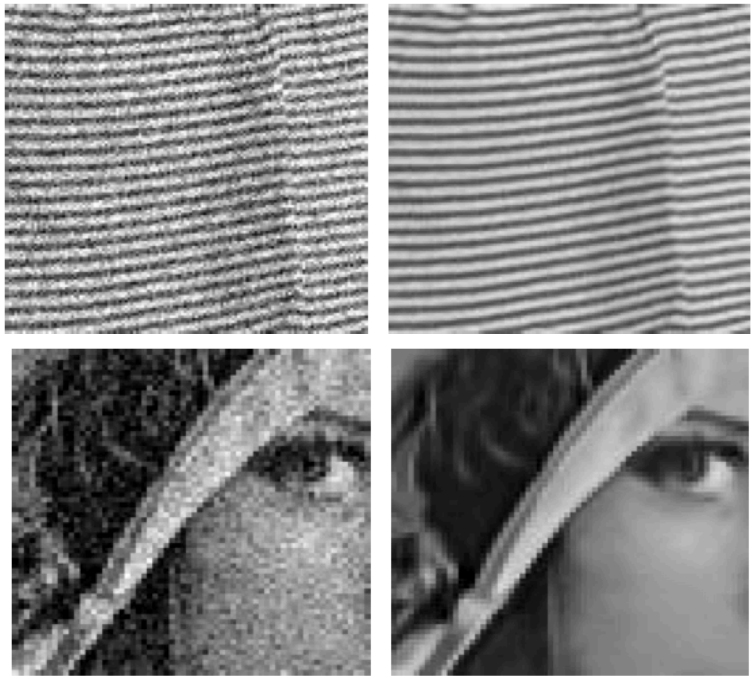
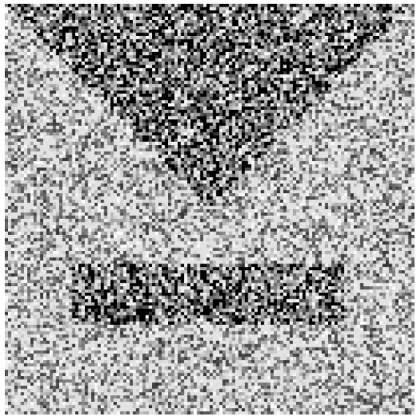
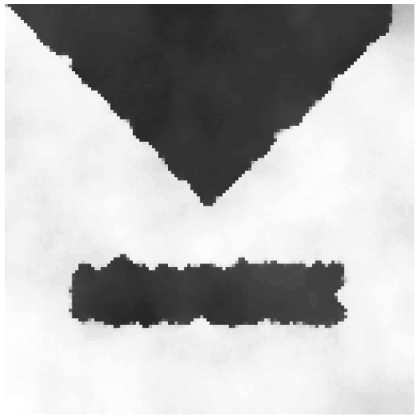


Figure 1. Scheme of NL-means strategy. Similar pixel neighborhoods give a large weight, w(p,q1) and w(p,q2), while much different neighborhoods give a small weight w(p,q3).

A. Buades, B. Coll, J. M. Morel, A non-local algorithm for image denoising, CVPR, 2005

Context-Guided Filtering

- Use local image context to steer filtering

E. Erdem and S. Tari, Mumford-Shah Regularizer with Contextual Feedback, JMIV, 2009

Image Segmentation

- Partition an image into meaningful regions that are likely to correspond to objects exist in the image

Figures: A. Erdem

Image Segmentation

- **Difficulty:** Images may have missing or corrupting features due to partial occlusion, noise and weak edges.



Image Segmentation

- Boundary-based segmentation
- Region-based segmentation
- Unified formulations

Snakes

- Curve Evolution - parametric curve formulation

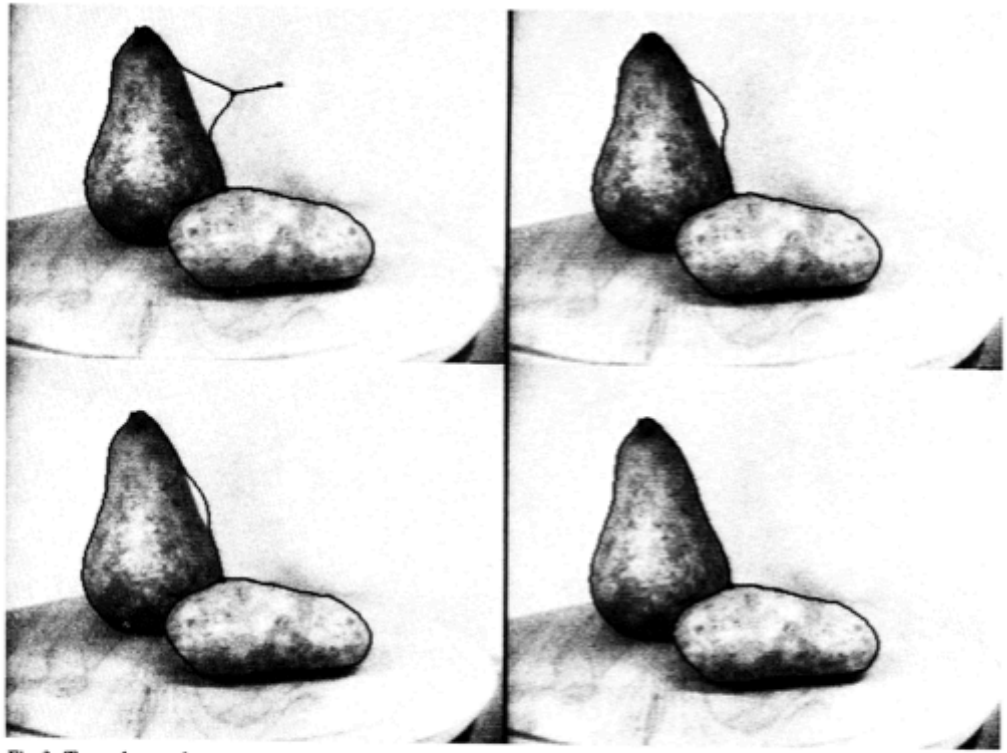
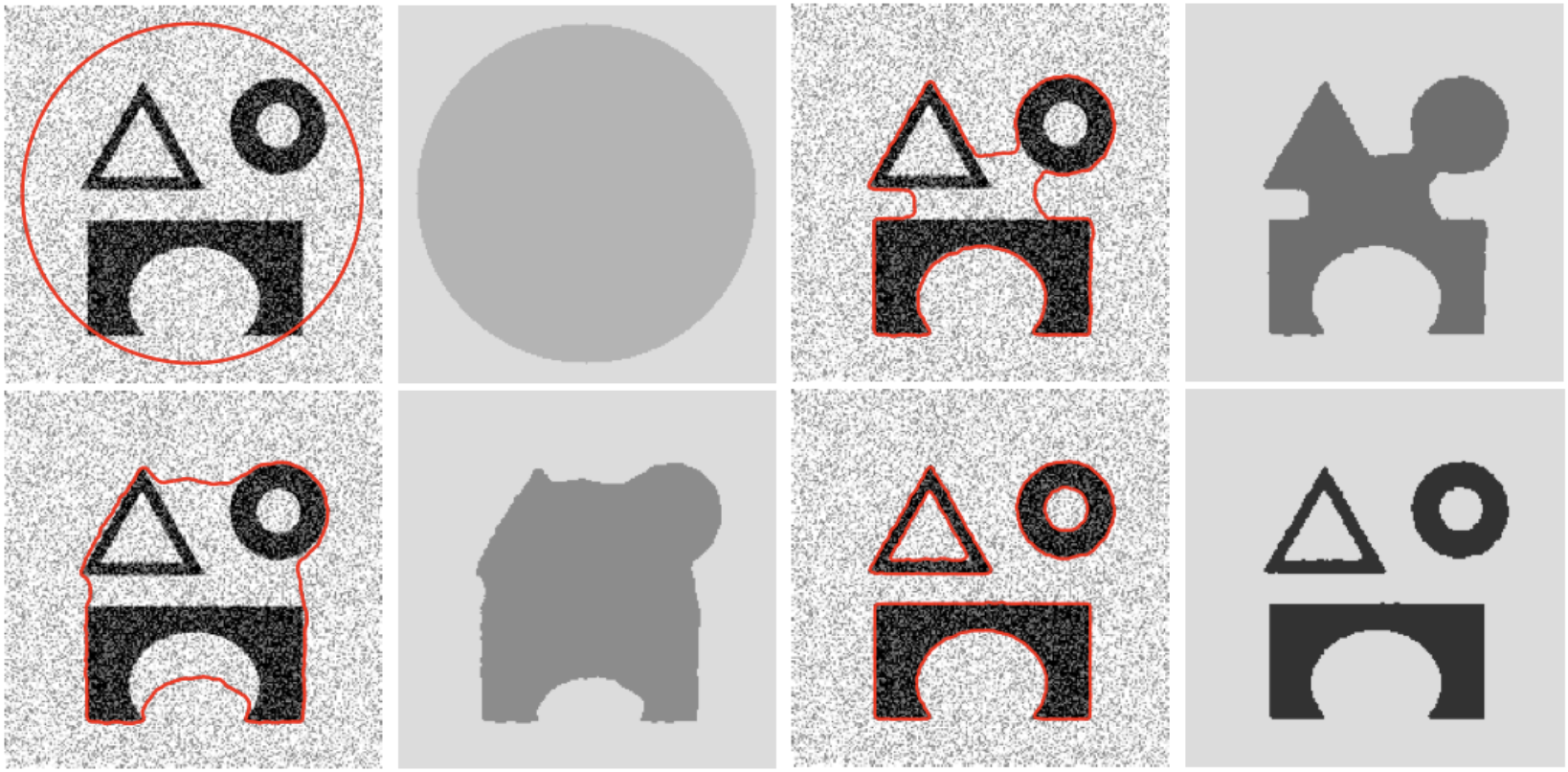


Fig. 3. Two edge snakes on a pear and potato. Upper-left: The user has pulled one of the snakes away from the edge of the pear. Others: After the user lets go, the snake snaps back to the edge of the pear.

M. Kass, A. Witkin, and D. Terzopoulos, Snakes: Active Contour Models, IJCV, 1988

Active Contours Without Edges

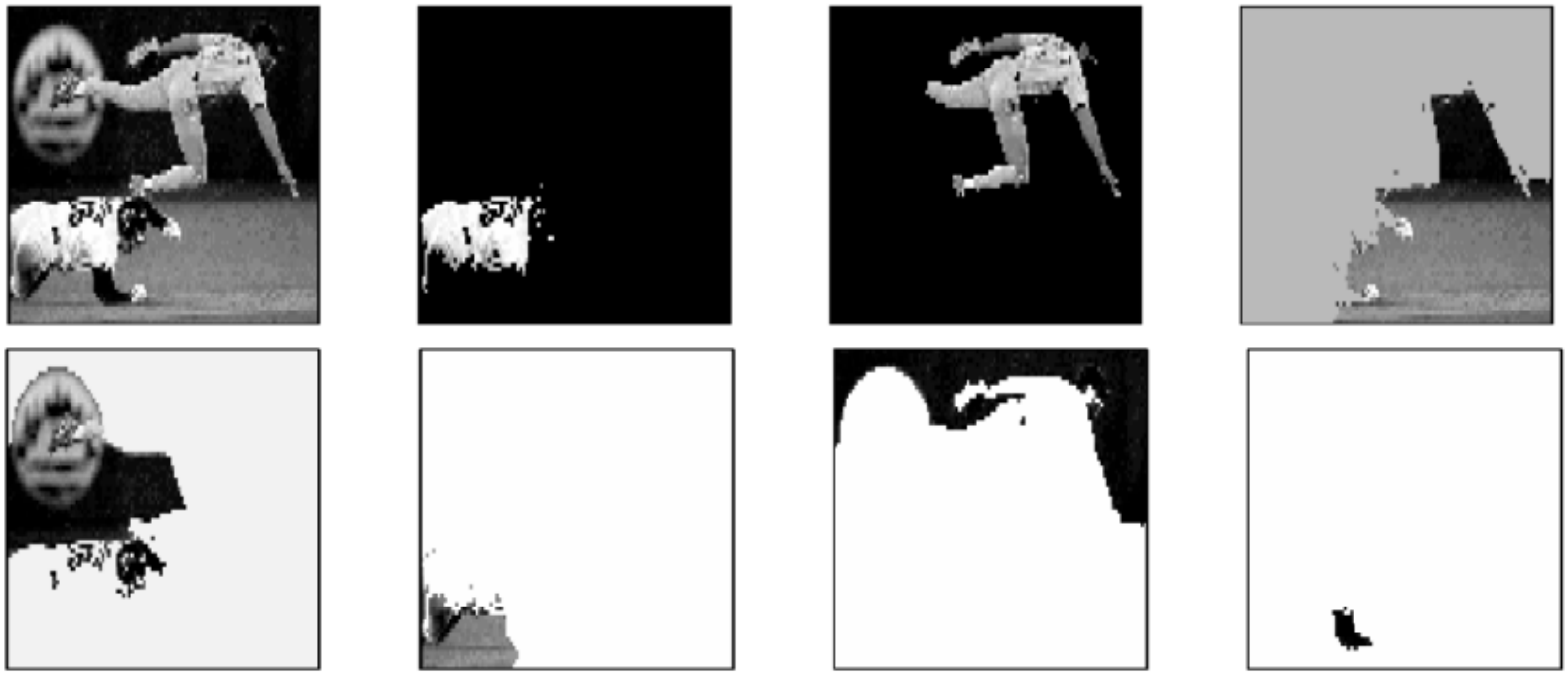
- Curve Evolution – a level-set based curve formulation



T. Chan and L. Vese. Active Contours Without Edges, IEEE Trans. Image Processing, 2001

Normalized Cuts

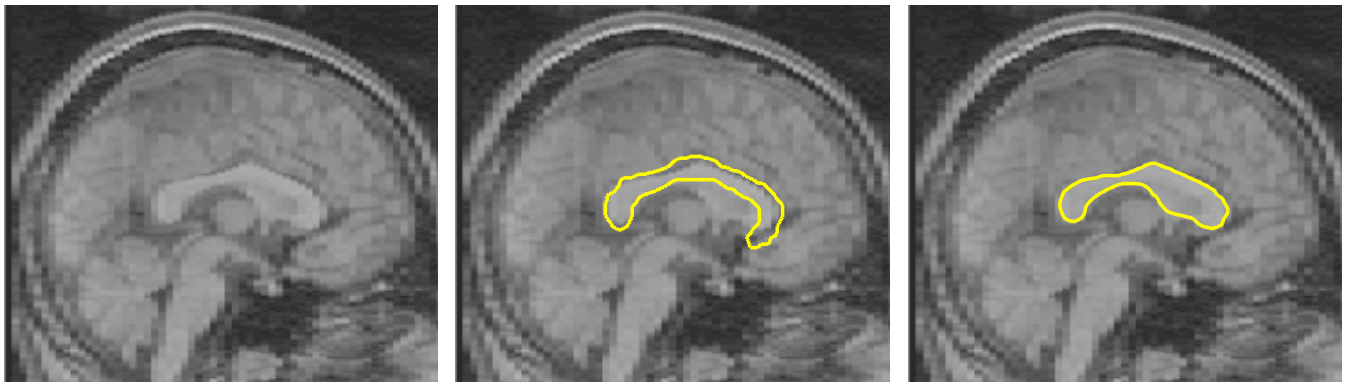
- A graph-theoretic formulation

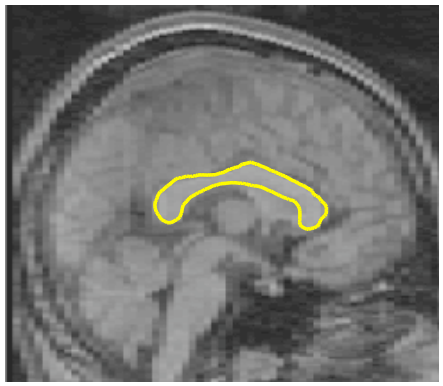


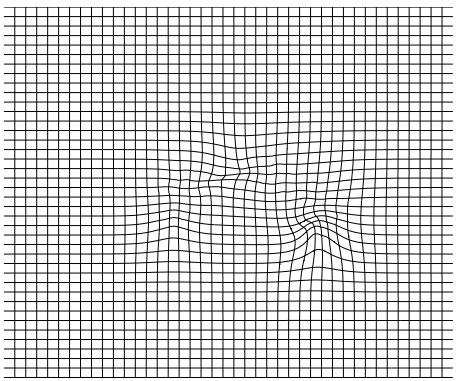
J. Shi and J. Malik, Normalized Cuts and Image Segmentation, IEEE Trans. Pattern Anal. Mach. Intel.

Prior-Shape Guided Segmentation

- Incorporate prior shape information into the segmentation process







Our result Deformation map

E. Erdem, S. Tari, and L. Vese, Segmentation Using The Edge Strength Function as a Shape Prior within a Local Deformation Model, ICIP 2009

Registration

- Estimate a transformation function between
  - two images
  - two point sets
  - two shapes
  - …

Registration

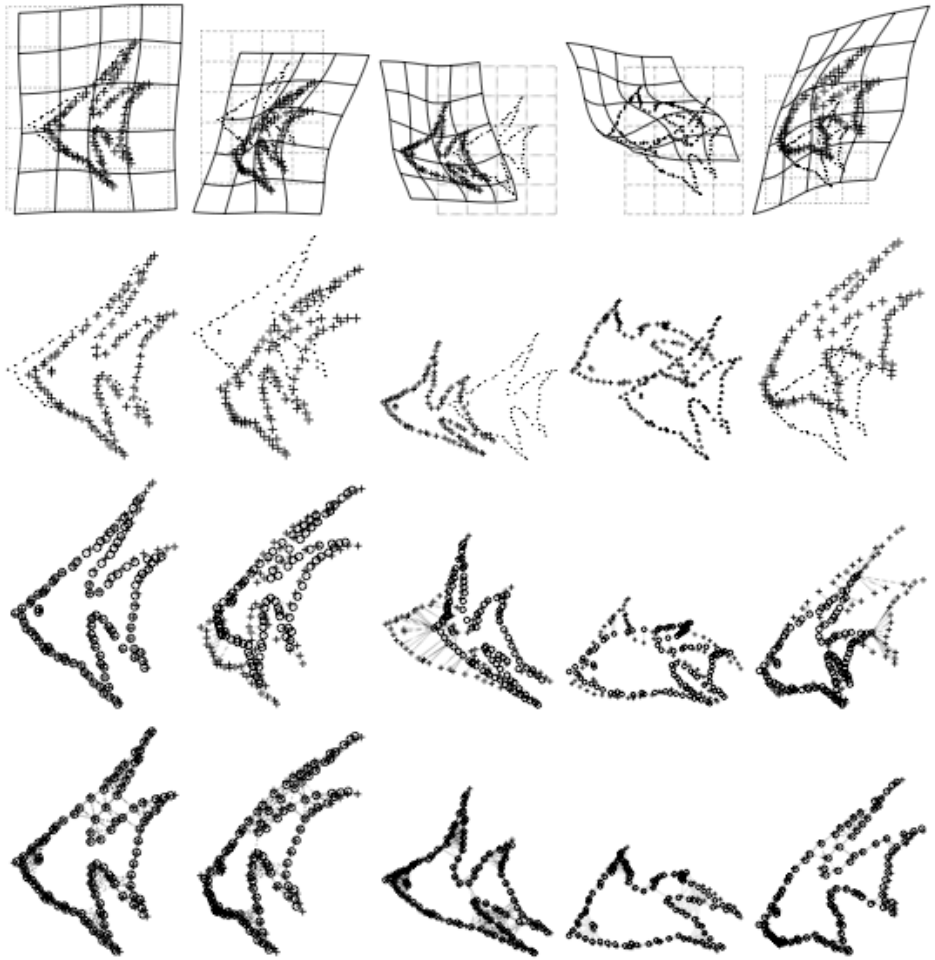


Fig. 5. Experiments on deformation. Each column represent one example. From left to right, increasing degree of deformation. *Top row*: warped template. *Second row*: template and target (same as the warped template). *Third row*: ICP results. *Bottom row*: RPM results.

H. Chui and A. Rangarajan, A new point matching algorithm for non-rigid registration, CVIU, 2003

Image Registration

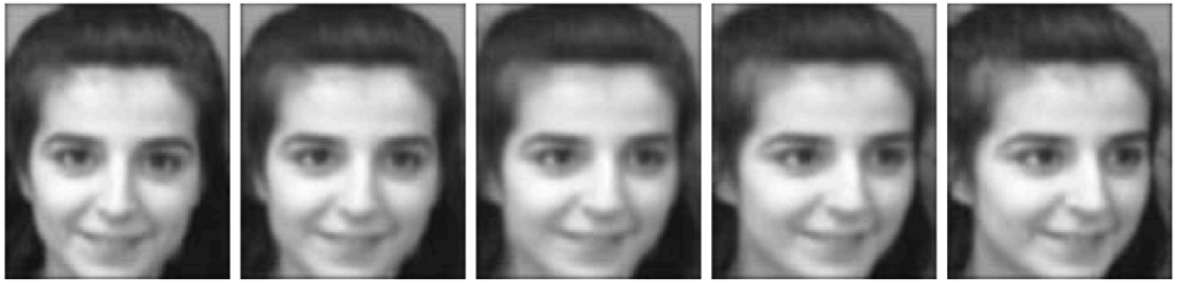
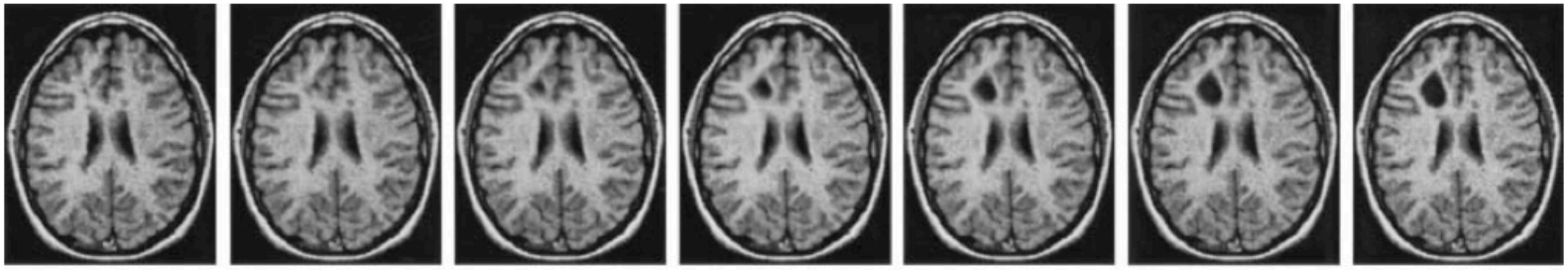
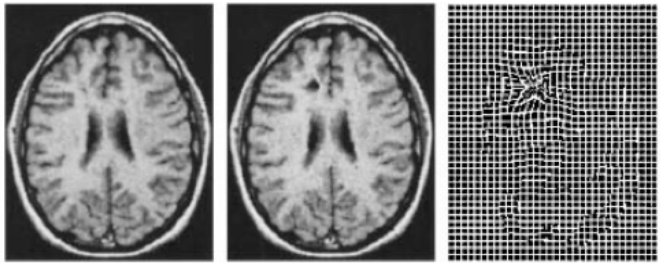


Fig. 2. An example of a geodesic between images (original images taken from the Olivetti face database). The three intermediate images are generated by the optimization algorithm.



A tumor progressively appearing on a brain



Tumor: Reference image, registered target and deformation

(top) Alain Trouve and Laurent Younes, Metamorphoses Through Lie Group Action, Found. Comput. Math., 2005
(bottom) M. I. Miller and L. Younes, Group Actions, Homeomorphisms, and Matching: A General Framework, IJCV, 2001

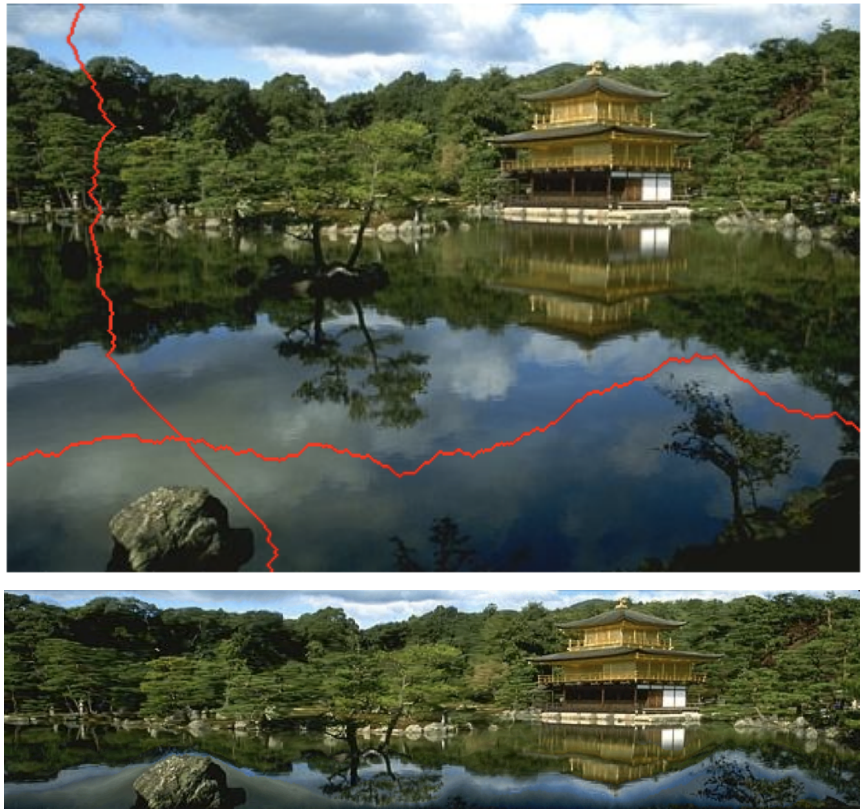
Image Inpainting

- Reconstructing lost or deteriorated parts of images

M. Bertalmio, G. Sapiro, V. Caselles and C. Ballester, Image Inpainting, SIGGRAPH, 2000

Seam Carving

- Content-aware image resizing



S. Avidan and A. Shamir, Seam Carving for Content-Aware Image Resizing, SIGGRAPH, 2007

Image Analysis

- Extracting information from images

- Image/Scene Classification
- Object Detection/Recognition
- Shape Analysis