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


• 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 $\rightarrow$ Two Dimensional Image Space

• What is measured in an image location?
  – brightness
  – color

$\ll$

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

Image Representation

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

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

![Image Representation Diagram](image)

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 $\rightarrow$ 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

\[ f(x) = u(x) + n(x) \]

\[ \downarrow \quad \downarrow \quad \downarrow \]

observed image \quad desired image \quad irrelevant data

• Image denoising, image sharpening, image smoothing, image deblurring, etc.

• Edge detection
Edge Detection

- Uniformity of intensity or color
- Texture uniformity

Canny edge detector
Image Filtering

- **Difficulty**: 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
  – the most widely used method
  \[ \frac{\partial u}{\partial t} = \nabla \cdot (\nabla u) = \nabla^2 u \]

• 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, $w(p,q_1)$ and $w(p,q_2)$, while much different neighborhoods give a small weight $w(p,q_3)$.

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, JMIIV, 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

Normalized Cuts

- A graph-theoretic formulation

Prior-Shape Guided Segmentation

• Incorporate prior shape information into the segmentation process

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

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