Comp 775: Summary

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Course Overview

• Medical imaging modalities
• Image processing methods on which segmentations and registrations are based
• Simple segmentation methods, only usable interactively or in “easy images”
• Deformable model segmentation
• Registration
• Statistical shape analysis
  – Classification
  – Hypothesis testing
Medical Imaging Modalities

• 2D
  – Projections
    • Radiograph
    • Scintigram
  – Slices: Ultrasound
  – Light images, e.g., from endoscopy

• 3D
  – CT
  – PET and SPECT
  – MRI
  – Ultrasound

Image: Siemens
Basic image processing methods

Basis for segmentation and registration methods

- First derivatives (of Gaussian): edginess
- Second derivatives (of Gaussian): barness (large magnitude) and edginess ridges (zeroes)
- Mathematical morphology for fixup of segmentations
- Hough transform
Simple segmentation methods

Usable interactively or in “easy” images

- Thresholds
- Watersheds
- Live-wire
- Voxel classification
Deformable model segmentation and registration

• Optimize objective function
  – E.g., (conjugate) gradient descent optimization
    • Definition of gradient over functions $h(x)$ or $z(u)$

• Shape spaces to optimize over
  – Segmentation: Over discrete, limited dimension models $z$ or continuous models $z(u)$
  – Registration: Over deformations $h(x)$

• Objective function = geometric atypicality (regularizer) + geometry-to-image mismatch
Geometry-to-Image Mismatch

For deformable model segmentation **and** registration

- **Appearance models** $A$
  - For intensities
  - For landmarks

- **Mismatch** = Distance function between $A$ and $A_{\text{ref}}$
Appearance Models

For deformable model segmentation and registration

• For intensities
  – Intensities in voxels in region
  – Derivatives in voxels in region
  – Histograms in regions
  – (Quantile functions)

• For landmarks
  – Landmarks positions
Distance Functions between Appearance

For deformable model segmentation and registration

- Euclidean distances
- Normalized correlation over regions
- (Earthmover’s distance for histograms)
- Mahalanobis distances
- Mutual information for intensities in different modalities (for registration)
For deformable model segmentation and registration

- Integral of local atypicality
  - Region of integration
    - Over boundaries or near-boundary regions
    - Over object interiors and near-boundary regions
    - Over whole image
  - Local integrand
    - $|\text{first derivatives}|$
    - $|\text{second derivatives}|$, e.g., curvature or derivatives of intensity
    - physical energy
For deformable model segmentation and registration

- Mahalanobis distance
- Euclidean distance of orthogonal function coefficients between desired entity
- None, but use it to constrain the shape space
Shape Spaces

For deformable model segmentation and registration

• PCA
  – Yields eigenmodes
  – Select eigenmodes according to eigenvalues
  – Possibly select ranges on eigenmodes
• Eigenmodes of physical models (registration)
Deformable Model Segmentation Methods

• Active contours

  – With objective function as integral over boundary of local atypicality + local mismatch
    • Also allows graph cuts approach
    • Possibly w/ objective function including global regional integration

Different flavors: Standard active contour, Chan-Vese, Mumford Shah

Different implementations: Particles, level-sets, indicator function, graph
Deformable Model Segmentation Methods

- Active shape models
- (Active appearance models)
- Posterior optimization
- Segmentation by registration
- (Zhou / Zhang machine learning approaches)
Object representations for deformable models

• Point distribution models

• Coefficients of orthogonal functions
  – Pre-determined functions, e.g., spherical harmonics
  – PCA eigenmodes
  – Basis functions with locality, e.g., orthogonal wavelets

• Medial models
Registration Methods

• For landmarks only
  – Thin-plate splines

• For intensities or intensities and landmarks
  – Free-form deformation
  – Elastic deformation (incl. optic flow)
  – Fluid flow deformation

Images: Ashburner
Statistical Shape Analysis

• Classification
• Hypothesis testing
Classification Methods

• Posterior optimization
• Distance to data
• Determine separation direction and threshold
  – DWD
  – SVM

Image: L. van Vliet
Hypothesis Testing

- Reject null hypothesis if observed interclass differences are appropriately unlikely to happen by chance under null hypothesis
  - Parameterized tests
  - Permutation tests
Thanks for attending

Some other related courses:
- Computer Vision
- Medial Models (*offered in Spring*)
- Visual Solid Shape
- Optimal Estimation in Image Analysis
- ...