Segmenting Livers

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Overview

• Problem statement
• Approach
• Results
• Demo?
Problem Statement

• Use interaction to help automate organ segmentation in CT data sets

• Segment Liver 2007 Competition
  – 20 tagged training data sets
  – 5 test sets

• Focus just on livers
Approach

• Interactive Video Cutout. SIGGRAPH 2005.
  – Adapt for CT data

• Overview
  – Paint on the CT data to indicate liver regions
  – Use global optimization to propagate the paint to the entire liver
System overview

Preprocessing
- Hierarchical mean shift segmentation
- Local statistics
- Neighbor connectivity

Interaction
- Paint data to indicate liver
- Min-cut/max-flow segmentation
- Repeat

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User Interface

- Paint liver and background on the 3D volume
- Paint on any arbitrary surface, not limited to a data slice or view
Min cut/Max flow

• Energy function

\[ E = \sum_i D(x_i, c_i, \gamma_i) + \lambda_1 \sum_{\text{nghbrs}(i,j)} L(x_i, x_j, c_i, c_j) \]
Painting Data

- Use paint to generate data terms
- Build Gaussian Mixture models (GMM)
  - Liver GMM (foreground)
  - Everything else (Background)
- Infinite weight preserves marked pixels
Painting Data

**White** – high probability Foreground

**Black** – Low probability Foreground

Graph Cut Energy function

- $D_B$ Background
- $D_F$ Foreground
- $L$ Link
- $L_L$ Local slice
- $L_G$ Gradient

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Min cut/Max flow

- Energy function

\[
E = \sum_{i} D(x_i, c_i, \gamma_i) + \lambda_1 \sum_{\text{nghbrs}(i,j)} L(x_i, x_j, c_i, c_j,)
\]
Segmented Liver!

- 10 minutes
- 5 or 6 brush stokes
- ~ 98% accuracy
- If...
  - Pre-processing parameters are well tuned
  - The min-cut optimization doesn’t blow up during construction
Highly variable data

• Resolution, Noise, Signal Levels
  – Preprocessing
    • Sensitive to mean shift parameters
    • Filtering (data noise)
    • Voxel aspect ratio (slice thickness)
    • Cluster size
  – Optimization Energy terms
    • Tuning weights for each data set
    • GMMs are not interchangeable between datasets
    • Difficult to aggregate data

• Morphology, and Field of View
  – Organs are different sizes and shapes
  – Lack of landmarks
Future Work

• Preprocessing
  – Auto tune mean shift parameters

• Aggregate data
  – Auto paint high probability regions

• Post-process
  – Use the interactive result as a starting point
  – Local optimization on tissue surface
Demo
Energy function details
3D Min cut/Max flow

- Energy function

\[ E = \sum_{i} D(x_i, c_i, \gamma_i) + \lambda_1 \sum_{\text{nghbrs}(i,j)} L(x_i, x_j, c_i, c_j, ) \]
Data weight

- User input generates model (GMM)
- Infinite weight preserves marked pixels
- Data weight = abiding to F/B color model

\[
D_{B,G} \left( X_i = B \right) = 1 - \sum_{k=1}^{5} \omega_k e^{-\frac{1}{2} \cdot (c_i - \mu_k)^T \Sigma_k^{-1} (c_i - \mu_k)}
\]
Data weight

**White** – high probability Foreground
**Black** – Low probability Foreground

Graph Cut Energy function
- $D_B$ Background
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- $L_G$ Gradient
Data weight

**White** – high probability
Background

**Black** – Low probability
Background

Graph Cut Energy function

- $D_B$ Background
- $D_F$ Foreground
- $L$ Link
  - $L_L$ Local slice
  - $L_G$ Gradient
Link weight

- Strong gradients segment border
- Link cost encourage cut at edges
Link weight

White – low cut probability
Black – high cut probability
Link weight

- Link span: links between two adjacent pixel spans
Link weight

- Strong edges exists within segment
- Slice and XY Plane resolution differ
- Local slice link cost normalizes gradient for Slices and XY Plane
3D Min cut/Max flow

- Energy function

\[ E = \sum_{i} D(x_i, c_i, \gamma_i) + \lambda_1 \sum_{\text{neighbrs}(i,j)} L(x_i, x_j, c_i, c_j) \]

Graph Cut Energy function

- \( D_B \) Background
- \( D_F \) Foreground
- \( L \) Link
- \( L_L \) Local slice
- \( L_G \) Gradient

\[ \lambda_1 \quad \lambda_3 \]