Segmenting Livers

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CSE 577 2011

Overview

- Problem statement
- Approach
- Results
- Demo?

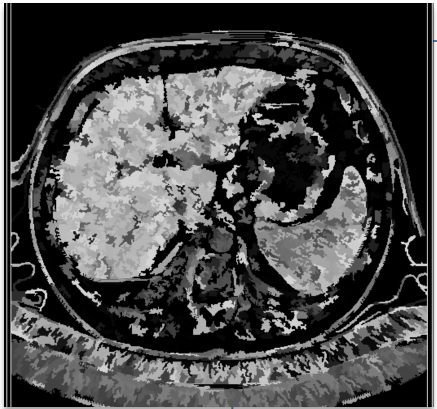
Problem Statement

- 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

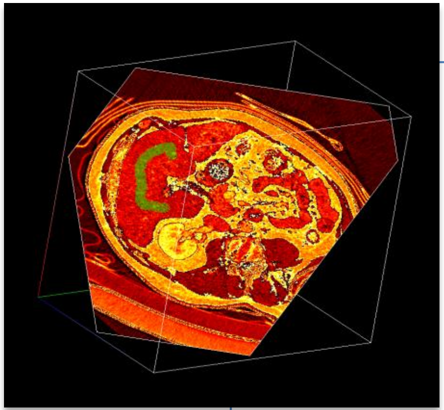
- Interactive Video Cutout. SIGGRAPH 2005.
  - Adapt for CT data
- Overview
  - Paint on the CT data to indicate liver regions
  - Use global optimization to propagate the paint to the entire liver

System overview



Preprocessing

- Hierarchical mean shift segmentation
- Local statistics
- Neighbor connectivity

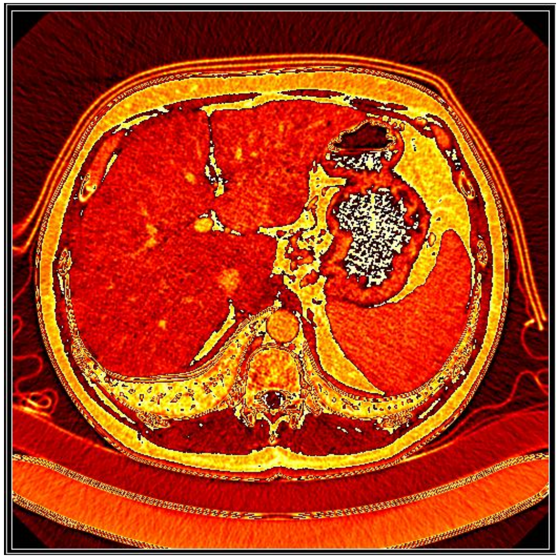
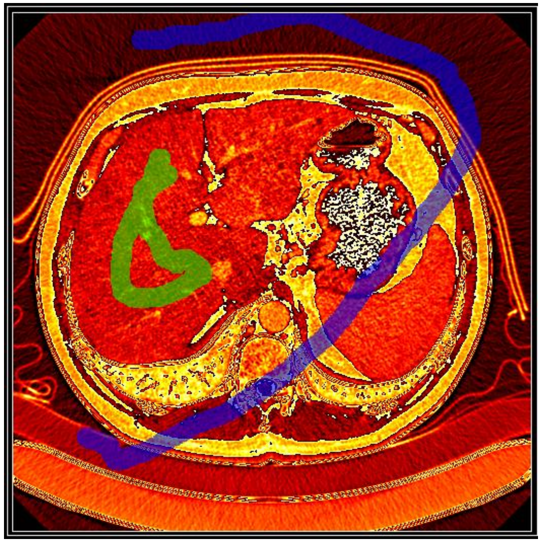
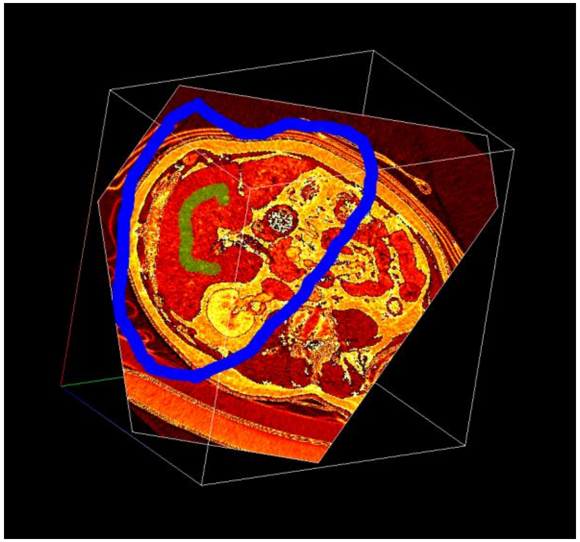


Interaction

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

User Interface

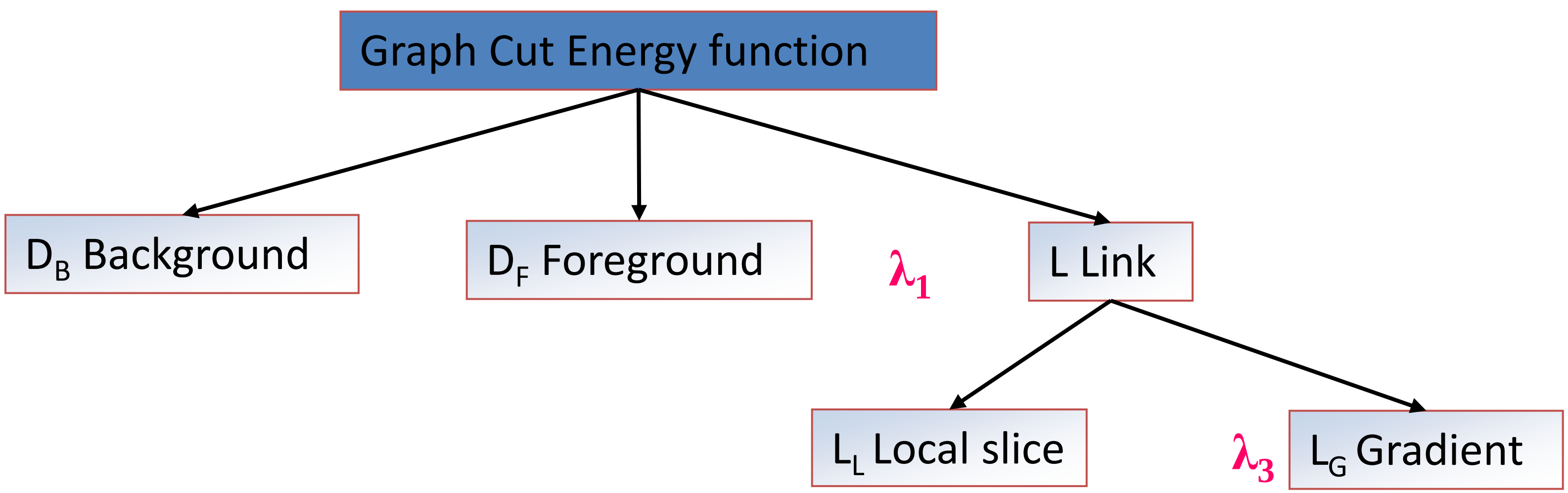
- Paint liver and background on the 3D volume
- Paint on any arbitrary surface, not limited to a data slice or view

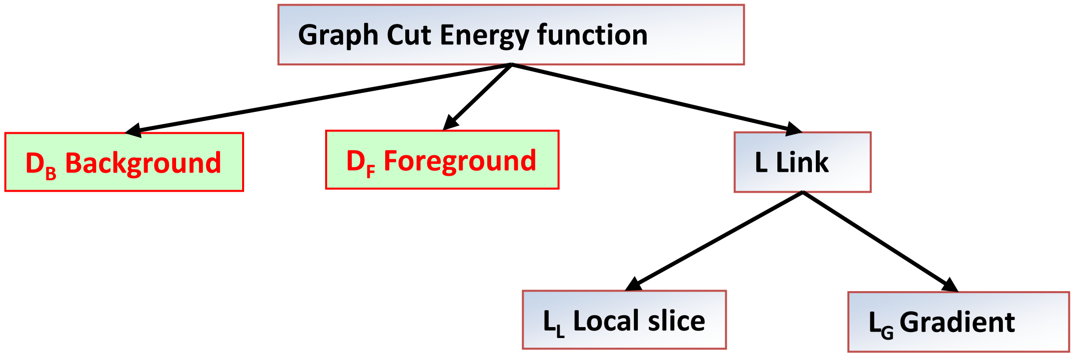
Min cut/Max flow

- Energy function

$$E = \sum_{i} D\left(x_i, c_i, \gamma_i\right) + \lambda_1 \sum_{nghbrs(i,j)} L\left(x_i, x_j, c_i, c_j,\right)$$

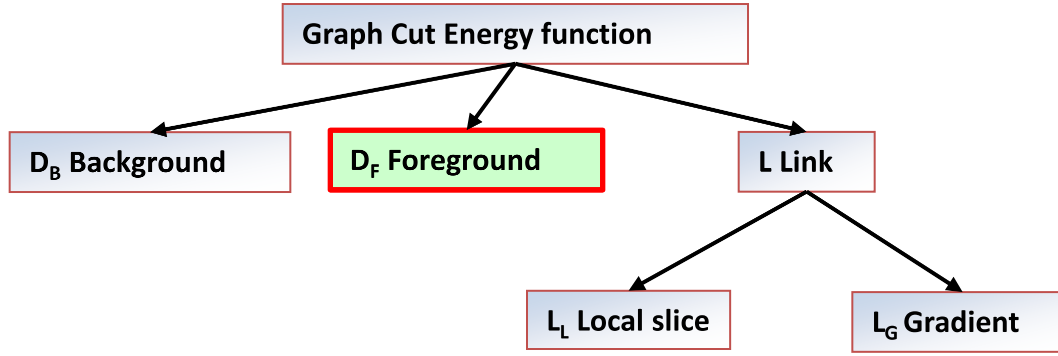


Painting Data

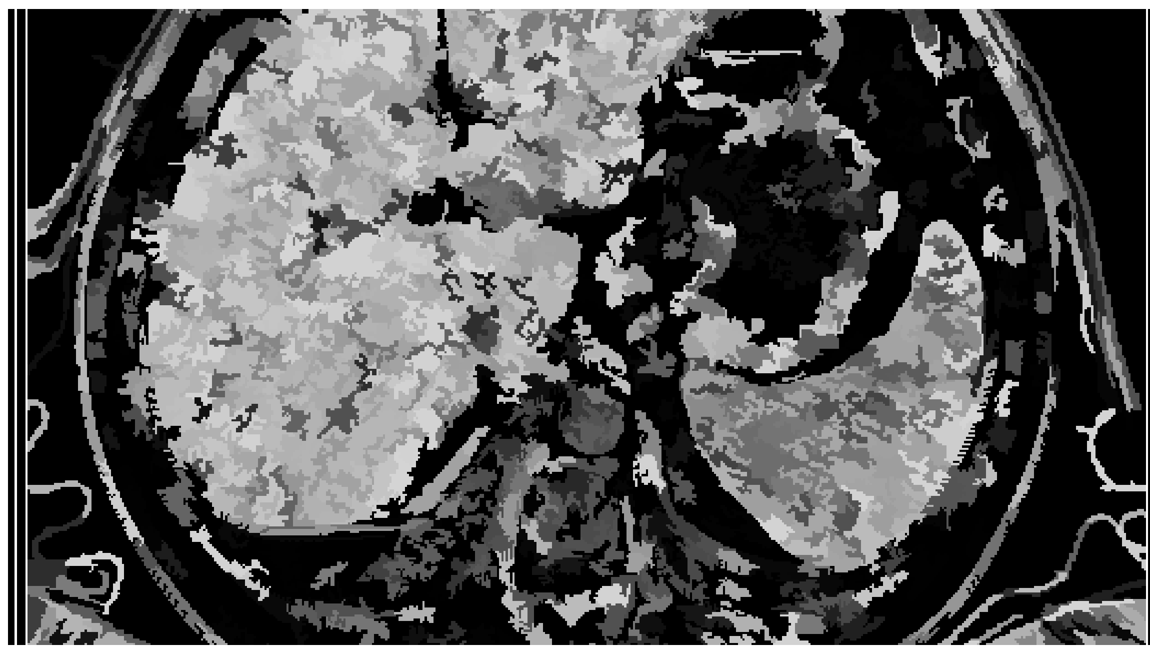


- Use paint to generate data terms
- Build Gaussian Mixture models (GMM)
  - Liver GMM (foreground)
  - Everything else (Background)
- Infinite weight preserves marked pixels

Painting Data



White – high probability Foreground
Black – Low probability Foreground



Min cut/Max flow

- Energy function

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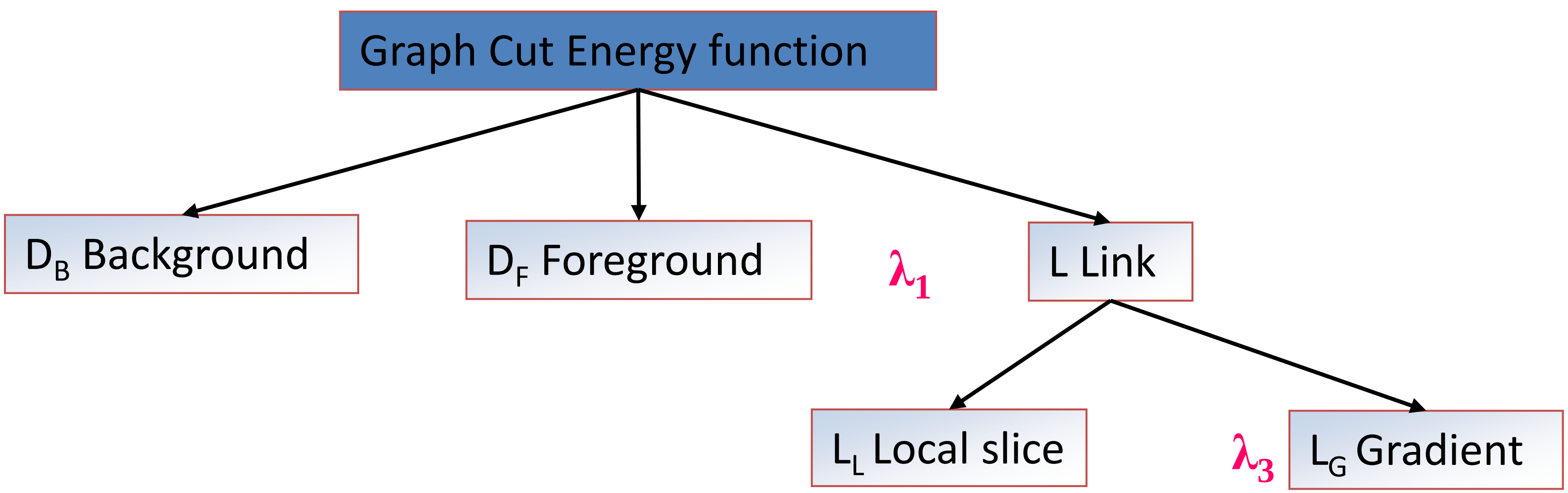
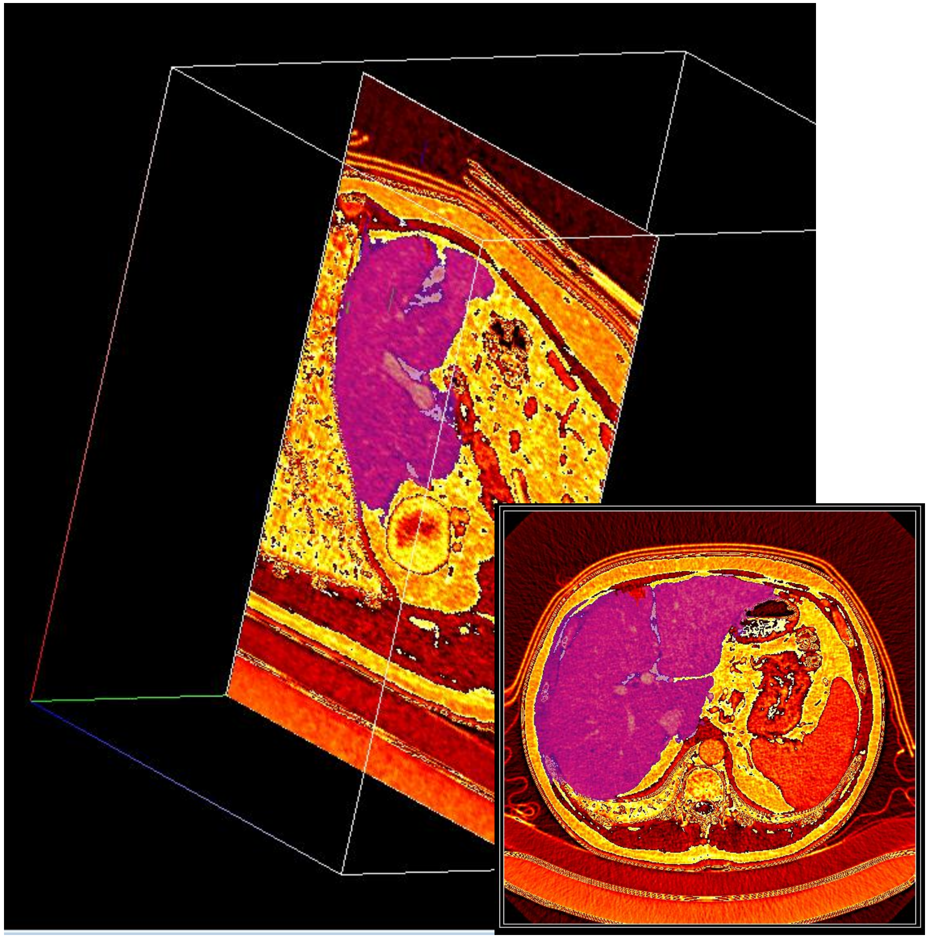


Segmented Liver!

- 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

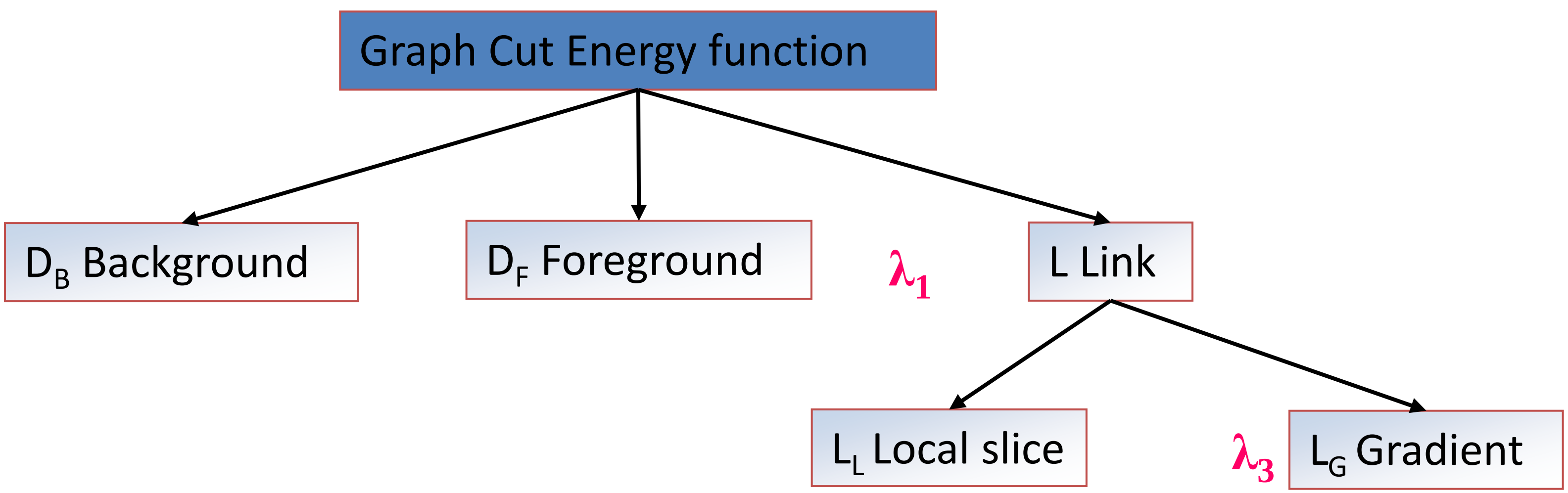
Demo

Energy function details

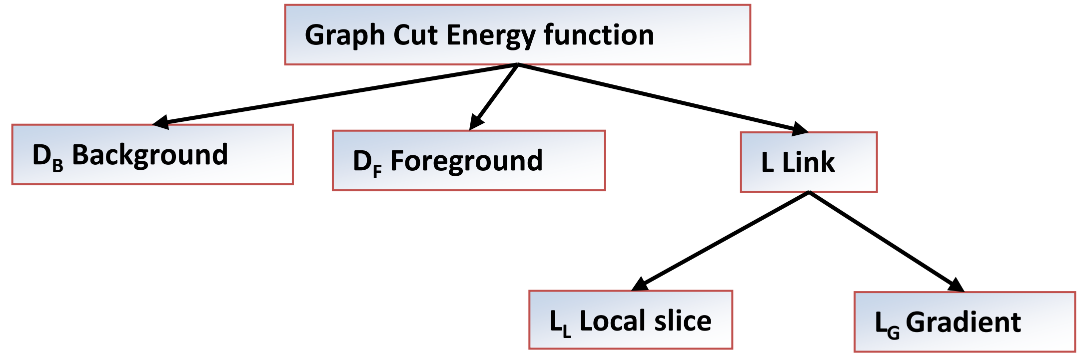
3D Min cut/Max flow

- Energy function

$$E = \sum_i D\left(x_i, c_i, \gamma_i\right) + \lambda_1 \sum_{nghbrs(i,j)} L\left(x_i, x_j, c_i, c_j,\right)$$



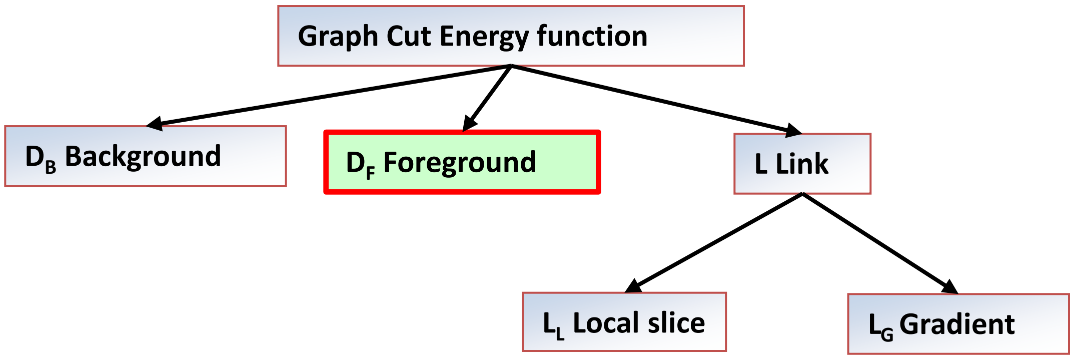
Data weight



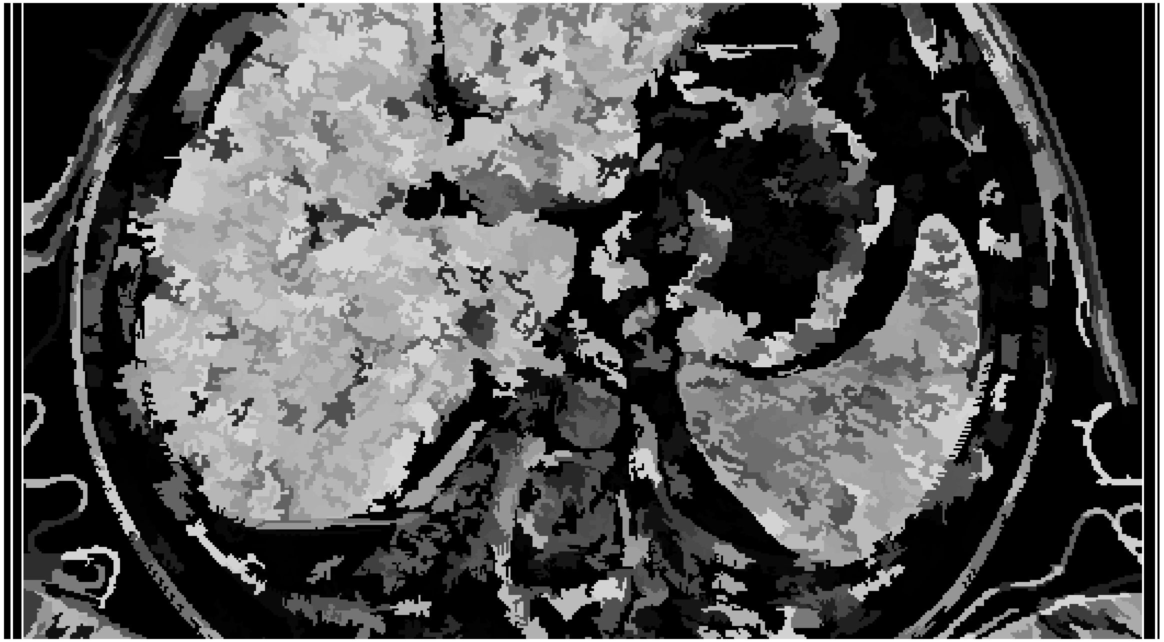
- User input generates model (GMM)
- Infinite weight preserves marked pixels
- Data weight = abiding to F/B color model

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

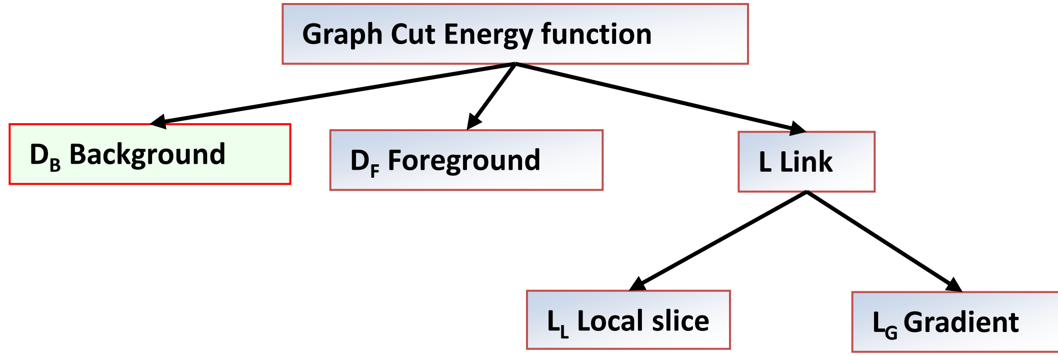
Data weight



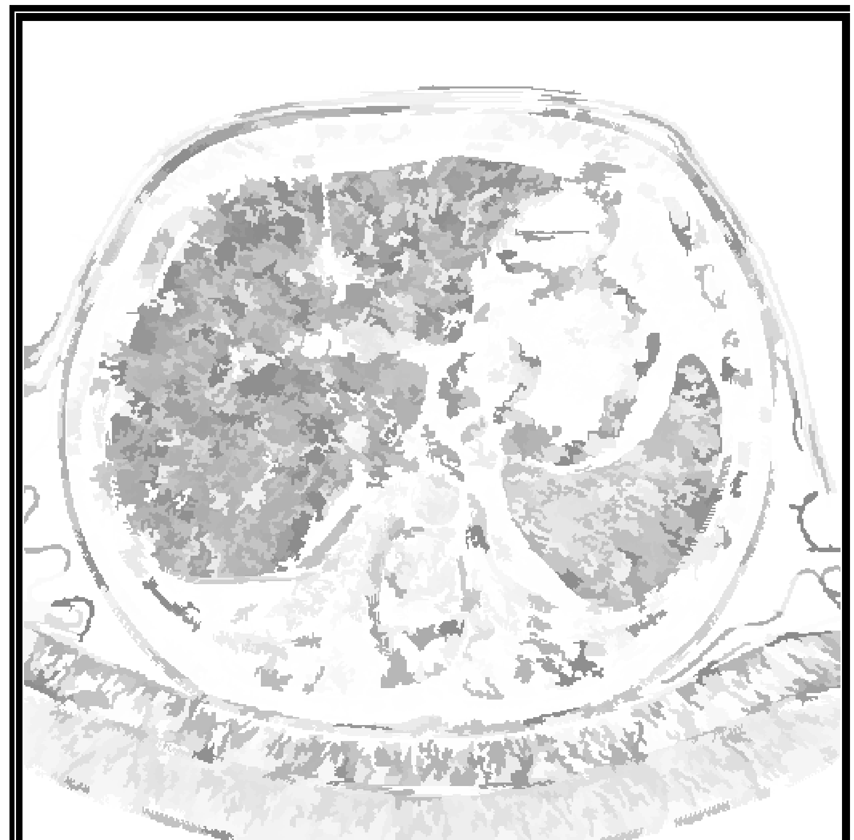
White – high probability Foreground
Black – Low probability Foreground



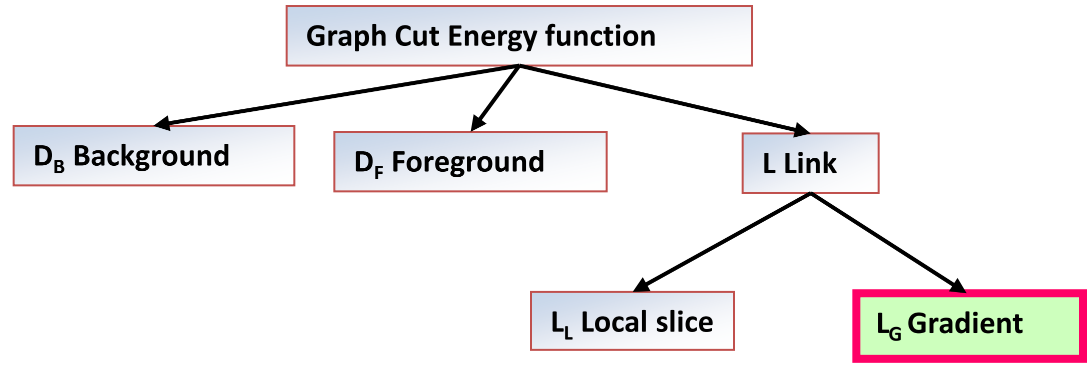
Data weight



White – high probability Background
Black – Low probability Background

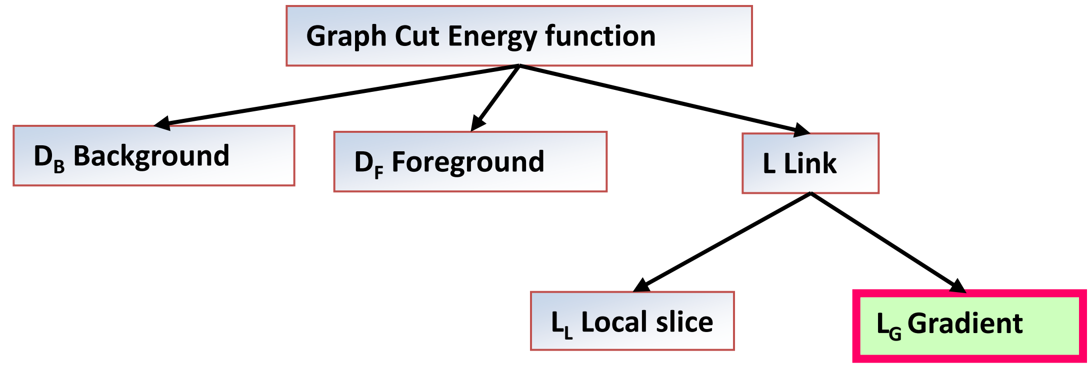


Link weight



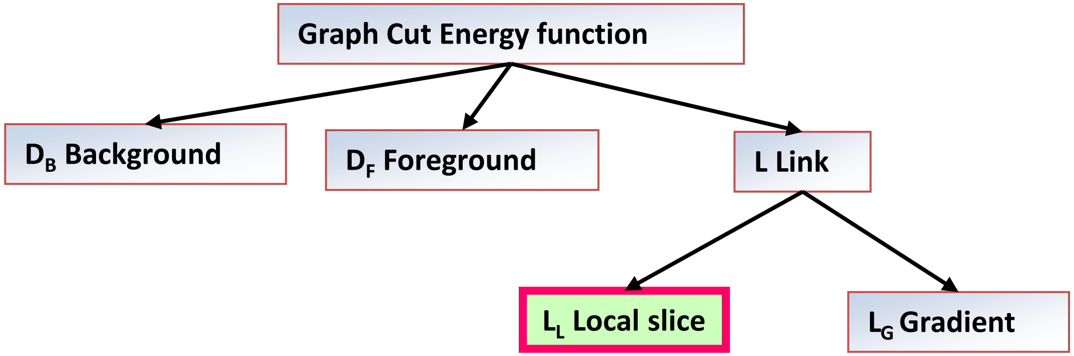
- Strong gradients $\Rightarrow$ segment border
- Link cost encourage cut at edges

Link weight

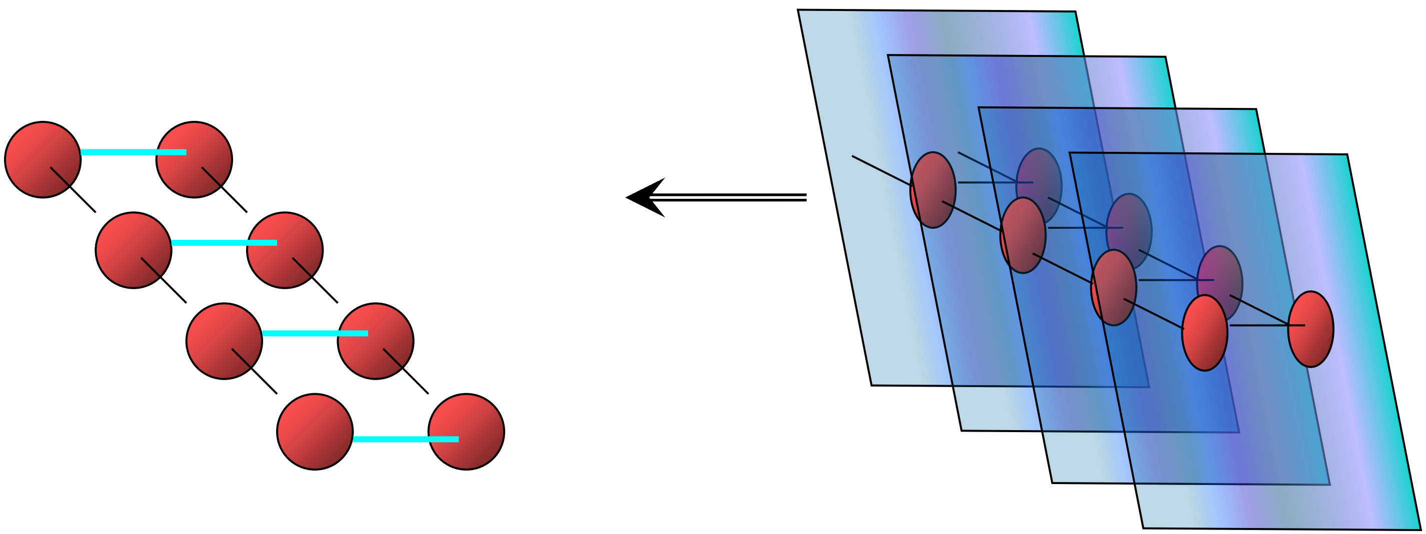


White – low cut probability
Black – high cut probability

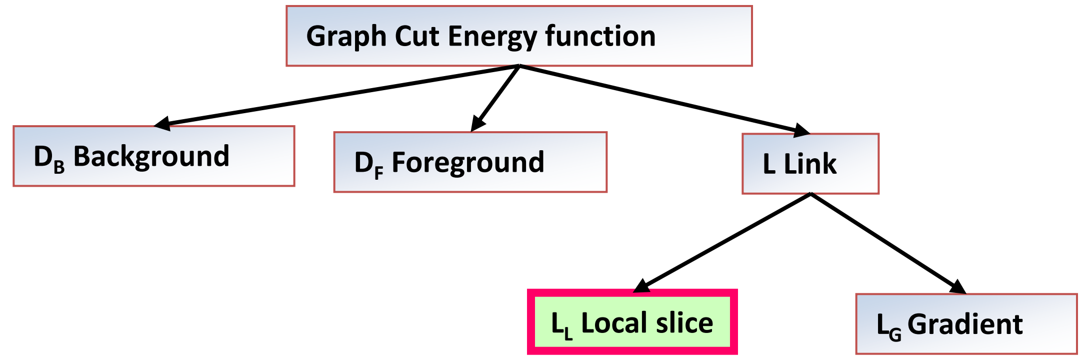
Link weight



- 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

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