Graph-based Segmentation

Computer Vision
CS 543 / ECE 549
University of Illinois

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Images as graphs

- **Fully-connected graph**
  - node for every pixel
  - link between *every* pair of pixels, \( p, q \)
  - similarity \( w_{ij} \) for each link

Source: Seitz
Segmentation by Graph Cuts

• Break Graph into Segments
  – Delete links that cross between segments
  – Easiest to break links that have low cost (low similarity)
    • similar pixels should be in the same segments
    • dissimilar pixels should be in different segments

Source: Seitz
Graph cuts segmentation
Markov Random Fields

\[ \text{Energy}(y; \theta, \text{data}) = \sum_i \psi_1(y_i; \theta, \text{data}) \sum_{i,j \in \text{edges}} \psi_2(y_i, y_j; \theta, \text{data}) \]

Node \( y_i \): pixel label

Edge: constrained pairs

Cost to assign a label to each pixel

Cost to assign a pair of labels to connected pixels
Markov Random Fields

- Example: “label smoothing” grid

\[
\begin{align*}
\text{Unary potential} & \\
0: & -\log P(y_i = 0 ; data) \\
1: & -\log P(y_i = 1 ; data)
\end{align*}
\]

\[
\begin{pmatrix}
0 & 1 \\
0 & 0 & K \\
1 & K & 0
\end{pmatrix}
\]

\[
\text{Pairwise Potential}
\]

\[
\text{Energy}(y; \theta, data) = \sum_i \psi_1(y_i; \theta, data) \sum_{i,j \in \text{edges}} \psi_2(y_i, y_j; \theta, data)
\]
Solving MRFs with graph cuts

\[ \text{Energy}(y; \theta, \text{data}) = \sum_{i} \psi_1(y_i; \theta, \text{data}) \sum_{i,j \in \text{edges}} \psi_2(y_i, y_j; \theta, \text{data}) \]
Solving MRFs with graph cuts

\[ \text{Energy}(y; \theta, \text{data}) = \sum_i \psi_1(y_i; \theta, \text{data}) \sum_{i,j \in \text{edges}} \psi_2(y_i, y_j; \theta, \text{data}) \]
Graph cuts segmentation

1. Define graph
   – usually 4-connected or 8-connected
2. Define unary potentials
   – Color histogram or mixture of Gaussians for background and foreground
     \[ \text{unary\_potential}(x) = -\log \left( \frac{P(c(x); \theta_{\text{foreground}})}{P(c(x); \theta_{\text{background}})} \right) \]
3. Define pairwise potentials
   \[ \text{edge\_potential}(x, y) = k_1 + k_2 \exp \left\{ -\frac{\|c(x) - c(y)\|^2}{2\sigma^2} \right\} \]
4. Apply graph cuts
5. Return to 2, using current labels to compute foreground, background models
Moderately straightforward examples

... GrabCut completes automatically
Difficult Examples

- Camouflage & Low Contrast
- Fine structure
- Harder Case

Initial Rectangle
Initial Result

GrabCut – Interactive Foreground Extraction