Segmentation and Clustering
Outline

• **Image Segmentation with Clustering**
  – K-means
  – Mean-shift

• **Graph-based Segmentation**
  – Normalized-cut
  – Felzenszwalb et al.
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Image Segmentation

- **Partitioning**
  - Divide into regions/sequences with coherent internal properties

- **Grouping**
  - Identify sets of coherent tokens in image

Segmentation as Clustering

- Feature space (ex: RGB values)

Source: K. Grauman
Segmentation as Clustering

- Cluster together tokens with high similarity (small distance in feature space)

Questions:
1. How many clusters?
2. Which data belongs to which group?
Segmentation as Clustering

- Cluster together tokens with high similarity (small distance in feature space)
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K-means

- Assign each of the N points, $x_j$, to clusters by nearest $\mu_i$
- Re-compute mean $\mu_i$ of each cluster from its member points
- If no mean has changed more than some $\varepsilon$, stop

K-means

- Solving the optimization problem

\[
\arg\min_{s} \sum_{i=1}^{k} \sum_{x_j \in S_i} \|x_j - \mu_i\|^2
\]

- Every iteration is a step of gradient descent

\[
\frac{\partial e}{\partial \mu_i} = 0 \quad \Rightarrow \quad \mu_i^{t+1} = \frac{1}{|S_i^{(t)}|} \sum_{x_j \in S_i^{(t)}} x_j
\]

Source:
http://www.heikohoffmann.de/htmlthesis/node28.html
K-means

- **Pros**
  - Simple and fast
  - Converges to a local minimum of the error function
  - K-means in matlab

- **Cons**
  - Need to pick K
  - Sensitive to initialization
  - Only finds “spherical” clusters
  - Sensitive to outliers
K-means

• Demo
  – Image segmentation with K-means
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Mean-shift
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Slide by Y. Ukrainitz & B. Sarel
Mean-shift

Region of interest
Center of mass

Mean Shift vector

Slide by Y. Ukrainitz & B. Sarel
Mean-shift

Slide by Y. Ukrainitz & B. Sarel
Mean-shift

- **Attraction basin:** the region for which all trajectories lead to the same mode
- **Cluster:** all data points in the attraction basin of a mode
Segmentation by Mean-shift

- Find features (color, gradients, texture, etc)
- Initialize windows at individual pixel locations
- Perform mean shift for each window until convergence
- Merge windows that end up near the same “peak” or mode
Segmentation by Mean-shift

• **Pros**
  – Does not assume spherical clusters
  – Just a single parameter (window size)
  – Finds variable number of modes
  – Robust to outliers

• **Cons**
  – Output depends on window size
  – Computationally expensive
  – Does not scale well with dimension of feature space
Mean-shift

- Demo
  - Image segmentation with mean-shift
  - Mean-shift tracking (camshift in OpenCV)
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Graph-based Segmentation

- Images as graphs
  - Node for every pixel
  - Edge between every pair of pixels
  - Each edge is weighted by the affinity or similarity of the two nodes

Source: S. Seitz
Graph-based Segmentation

- CUT: Set of edges whose removal makes a graph disconnected
- Cost of a cut: sum of weights of cut edges
- Example: Cost of the blue cut?

Source: S. Seitz
Minimum Cut

- We can do segmentation by finding the *minimum cut* in a graph
  - Efficient algorithms exist for doing this
- Drawback: minimum cut tends to cut off very small, isolated components

*Slide from Khurram Hassan-Shafique CAP5415 Computer Vision 2003*
Normalized Cut

- IDEA: normalizing the cut by component size
- The normalized cut cost is:

\[
\frac{\text{cut}(A, B)}{\text{assoc}(A, V)} + \frac{\text{cut}(A, B)}{\text{assoc}(B, V)}
\]

\[
\text{assoc}(A, V) = \text{sum of weights of all edges in } V \text{ that touch } A
\]
Normalized Cut

- Demo
  - Image segmentation with normalized cut
    http://timotheecour.com/software/ncut/ncut.html
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Other State-of-the-art Algorithm

- Efficient Graph-Based Image Segmentation.
  Pedro F. Felzenszwalb and Daniel P. Huttenlocher
  IJCV, 2004

- Demo