Segmentation and Grouping

Computer Vision
CS 543 / ECE 549
University of Illinois

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Last week

• Clustering

• EM
Today’s class

• More on EM

• Segmentation and grouping
  – Gestalt cues
  – By boundaries (watershed)
  – By clustering (mean-shift)
Gestalt grouping
Gestalt psychology or gestaltism

German: *Gestalt* - "form" or "whole"

Berlin School, early 20th century

Kurt Koffka, Max Wertheimer, and Wolfgang Köhler

View of brain:
- whole is more than the sum of its parts
- holistic
- parallel
- analog
- self-organizing tendencies

Slide from S. Saverese
Gestaltism

The Muller-Lyer illusion
Explanation
Principles of perceptual organization

- Not grouped
- Proximity
- Similarity
- Similarity
- Common Fate
- Common Region

From Steve Lehar: The Constructive Aspect of Visual Perception
Principles of perceptual organization

- Parallelism
- Symmetry
- Continuity
- Closure
Grouping by invisible completion

From Steve Lehar: The Constructive Aspect of Visual Perception
Grouping involves global interpretation
Grouping involves global interpretation

From Steve Lehar: The Constructive Aspect of Visual Perception
Gestaltists do not believe in coincidence
Emergence
Gestalt cues

- Good intuition and basic principles for grouping
- Difficult to implement in practice
- Sometimes used for occlusion reasoning
Moving on to image segmentation ...

Goal: Break up the image into meaningful or perceptually similar regions
Segmentation for feature support
Segmentation for efficiency

[Felzenszwalb and Huttenlocher 2004]

[Hoiem et al. 2005, Mori 2005]

[Shi and Malik 2001]
Segmentation as a result

Rother et al. 2004
Types of segmentations

Oversegmentation

Undersegmentation

Multiple Segmentations
Major processes for segmentation

- **Bottom-up**: group tokens with similar features
- **Top-down**: group tokens that likely belong to the same object

[Levin and Weiss 2006]
Segmentation using clustering

- Kmeans
- Mean-shift
Feature Space

Source: K. Grauman
K-means clustering using intensity alone and color alone

Image

Clusters on intensity

Clusters on color
K-Means pros and cons

• Pros
  – Simple and fast
  – Easy to implement

• Cons
  – Need to choose K
  – Sensitive to outliers

• Usage
  – Rarely used for pixel segmentation
Mean shift segmentation


• Versatile technique for clustering-based segmentation
Kernel density estimation

Kernel density estimation function

$$\hat{f}_h(x) = \frac{1}{nh} \sum_{i=1}^{n} K \left( \frac{x - x_i}{h} \right)$$

Gaussian kernel

$$K \left( \frac{x - x_i}{h} \right) = \frac{1}{\sqrt{2\pi} h^2} e^{-\frac{(x-x_i)^2}{2h^2}}.$$
Mean shift algorithm

- Try to find *modes* of this non-parametric density
Mean shift

Slide by Y. Ukrainitz & B. Sarel
Mean shift

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Mean shift

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

Region of interest
Center of mass

Mean Shift vector

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

Region of interest
Center of mass

Slide by Y. Ukrainitz & B. Sarel
Real Modality Analysis
Attraction basin

• **Attraction basin**: the region for which all trajectories lead to the same mode

• **Cluster**: all data points in the attraction basin of a mode
Attraction basin
Mean shift clustering

• The mean shift algorithm seeks *modes* of the given set of points

1. Choose kernel and bandwidth
2. For each point:
   a) Center a window on that point
   b) Compute the mean of the data in the search window
   c) Center the search window at the new mean location
   d) Repeat (b,c) until convergence
3. Assign points that lead to nearby modes to the same cluster
Segmentation by Mean Shift

- Find features (color, gradients, texture, etc)
- Set kernel size for features $K_f$ and position $K_s$
- Initialize windows at individual pixel locations
- Perform mean shift for each window until convergence
- Merge windows that are within width of $K_f$ and $K_s$
Mean shift segmentation results

http://www.caip.rutgers.edu/~comanici/MSPAMI/msPamiResults.html
Mean-shift: other issues

• Speedups
  – Uniform kernel (much faster but not as good)
  – Binning or hierarchical methods
  – Approximate nearest neighbor search

• Methods to adapt kernel size depending on data density

• Lots of theoretical support

Mean shift pros and cons

• Pros
  – Good general-practice segmentation
  – Finds variable number of regions
  – Robust to outliers

• Cons
  – Have to choose kernel size in advance
  – Original algorithm doesn’t deal well with high dimensions

• When to use it
  – Oversegmentation
  – Multiple segmentations
  – Other tracking and clustering applications
Watershed algorithm
Watershed segmentation

Image

Gradient

Watershed boundaries
Meyer’s watershed segmentation

1. Choose local minima as region seeds
2. Add neighbors to priority queue, sorted by value
3. Take top priority pixel from queue
   1. If all labeled neighbors have same label, assign to pixel
   2. Add all non-marked neighbors
4. Repeat step 3 until finished

Matlab: seg = watershed(bnd_im)
Simple trick

- Use median filter to reduce number of regions
Watershed usage

• Use as a starting point for hierarchical segmentation
  – Ultrametric contour map (Arbelaez 2006)

• Works with any soft boundaries
  – Pb
  – Canny
  – Etc.
Watershed pros and cons

• Pros
  – Fast (< 1 sec for 512x512 image)
  – Among best methods for hierarchical segmentation

• Cons
  – Only as good as the soft boundaries
  – Not easy to get variety of regions for multiple segmentations
  – No top-down information

• Usage
  – Preferred algorithm for hierarchical segmentation
Things to remember

• Gestalt cues and principles of organization

• Uses of segmentation
  – Efficiency
  – Better features
  – Want the segmented object

• Mean-shift segmentation
  – Good general-purpose segmentation method
  – Generally useful clustering, tracking technique

• Watershed segmentation
  – Good for hierarchical segmentation
  – Use in combination with boundary prediction
Further reading

• Mean-shift paper by Comaniciu and Meer
  http://www.caip.rutgers.edu/~comanici/Papers/MsRobustApproach.pdf

• Adaptive mean shift in higher dimensions

• Contours to regions (watershed): Arbelaez et al. 2009
Next class

- Graph-based segmentation
  - Normalized cuts
  - Graph cuts