Image segmentation and normalized cuts

Bryan C. Russell
Gestalt school (1938)

Max Wertheimer

Figure 14.4 Examples of Gestalt factors that lead to grouping (which are described in greater detail in the text).
Figure 14.7  An example of grouping phenomena in real life. The buttons on an elevator in the computer science building at U.C. Berkeley used to be laid out as in the top figure. It was common to arrive at the wrong floor and discover that this was because you’d pressed the wrong button—the buttons are difficult to group unambiguously with the correct label, and it is easy to get the wrong grouping at a quick glance. A public-spirited individual filled in the gap between the numbers and the buttons, as in the bottom figure, and the confusion stopped because the proximity cue had been disambiguated.
Image segmentation

• Can group based on brightness, color, texture, spatial location, shape, size, orientation, motion, etc.

• How do we realize this notion of grouping computationally?

• Here’s one way…
Agglomerative/merge clustering
Popular segmentation methods

• Mean shift
  – Comaniciu et al. 2002

• Spectral clustering
  – Shi et al. 2000

• Bayesian, MRF
  – Felzenszwalb 2004, Borenstein et al. 2004
Image segmentation issues

• What is a good segmentation?

• What are we optimizing? Is the returned image segmentation optimal?

• Let us consider a graph-theoretic approach
$G = (V, E)$
\[ G = (V, E) \]

- \( v_j \) - feature, e.g. pixel intensity, spatial location
- \( e_{j<k} \) - indicates two features have nonzero similarity
\[ G = (V, E) \quad e_{j<k}, e_{k<j} \in E \]
\[ w(i, j) \] - similarity score of pixels \( i \) and \( j \)
Visualizing similarities
More complex graph
Toy problem: spatial grouping
Toy problem: spatial grouping

\[ w(i, j) \propto \exp(-\text{dist}(i, j)) \]
Toy problem: spatial grouping

Task: cut the graph to produce a meaningful segmentation
Toy problem: spatial grouping

One possible cut…
Toy problem: spatial grouping

One idea: find set of edges with minimum total weight that partitions the graph - MinCut
Toy problem: spatial grouping

Problem: MinCut prefers isolated points
Problem with MinCut
Normalize the cut

Use ratio of cut to the volume of the set
Normalize the cut

\[ Ncut(A, B) = \frac{\text{vol}(A \cup B)}{\text{vol}(B^*)} + \frac{\text{vol}(B \cup C)}{\text{vol}(C^*)} \]
Normalized Cuts caveats

• Finding the exact solution is NP-hard

• Need to relax the problem to be continuous-valued and use iterative methods
Laplacian matrix

\[ D - W \]

Find generalized eigenvectors
Toy problem: synthetic image
Real image
Automatic Photo Popup

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Robust Spatial Support

RGB Pixels  Superpixels

[Felzenszwalb and Huttenlocher 2004]

- Safe oversegmentation of image
- Better but not still not enough spatial support
Cutting and Folding

- Construct 3D model
- Texture map
Noise Estimation from a Single Image

Ce Liu     William T. Freeman     Richard Szeliski     Sing Bing Kang
Segmentation-based Approach

Over-segmentation
Test on Low and High Noise

low noise $\sigma_s = 0.030$, $\sigma_c = 0.015$

high noise $\sigma_s = 0.090$, $\sigma_c = 0.045$
Segment scores for a given topic

Car topic

White indicates low KL divergence

Russell et al. CVPR 2006.
Results II. – LabelMe dataset

1,554 images
Learn 20 topics
4 topics shown

Each topic shown by top 25 segments

Russell et al. CVPR 2006.
Thank you

• Ncuts software:
  – http://www.cis.upenn.edu/~jshi/software/

• Pedro Felzenszwalb software:
  – http://people.cs.uchicago.edu/~pff/segment/