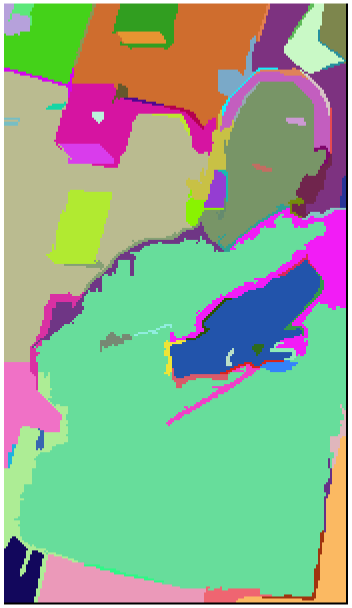
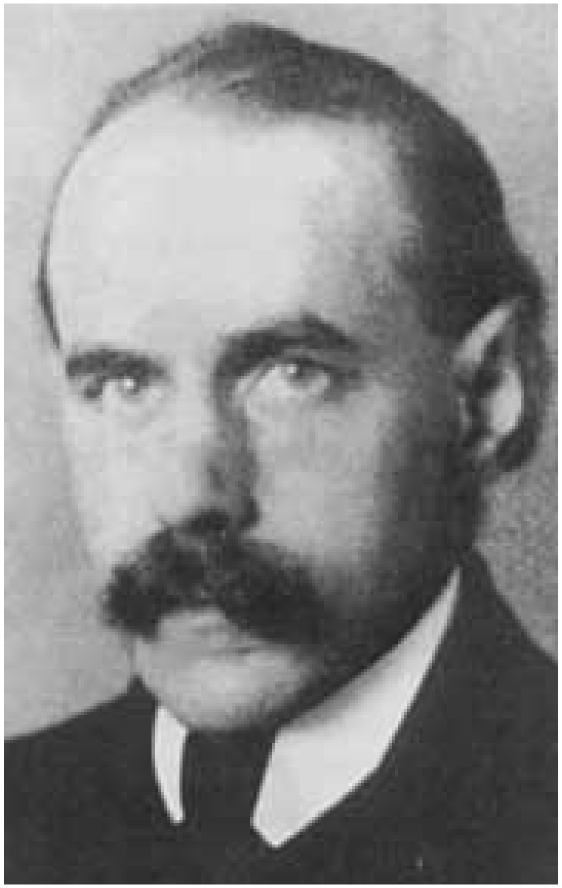
Image segmentation and normalized cuts

Bryan C. Russell



Gestalt school (1938)



Max Wertheimer

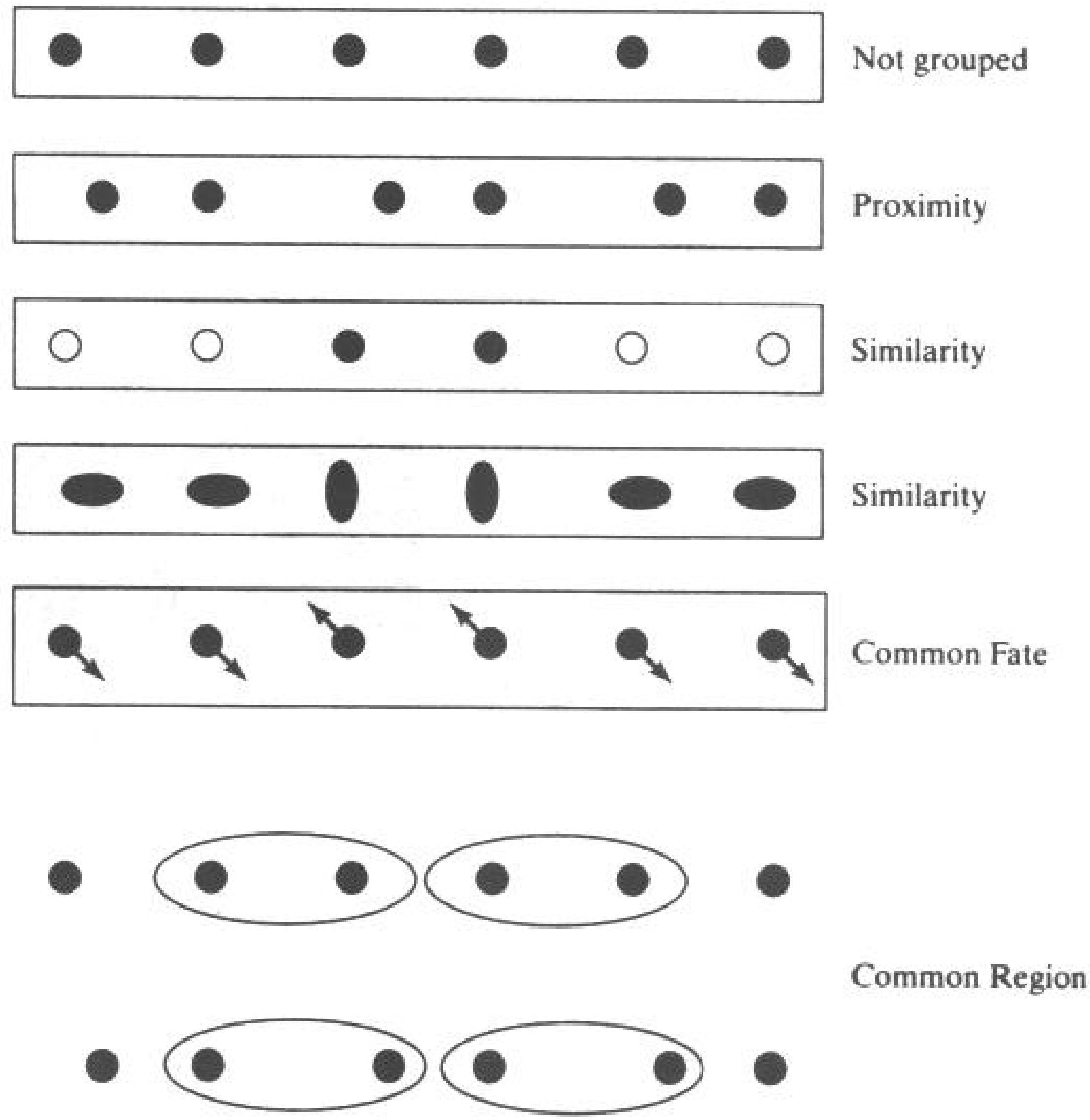
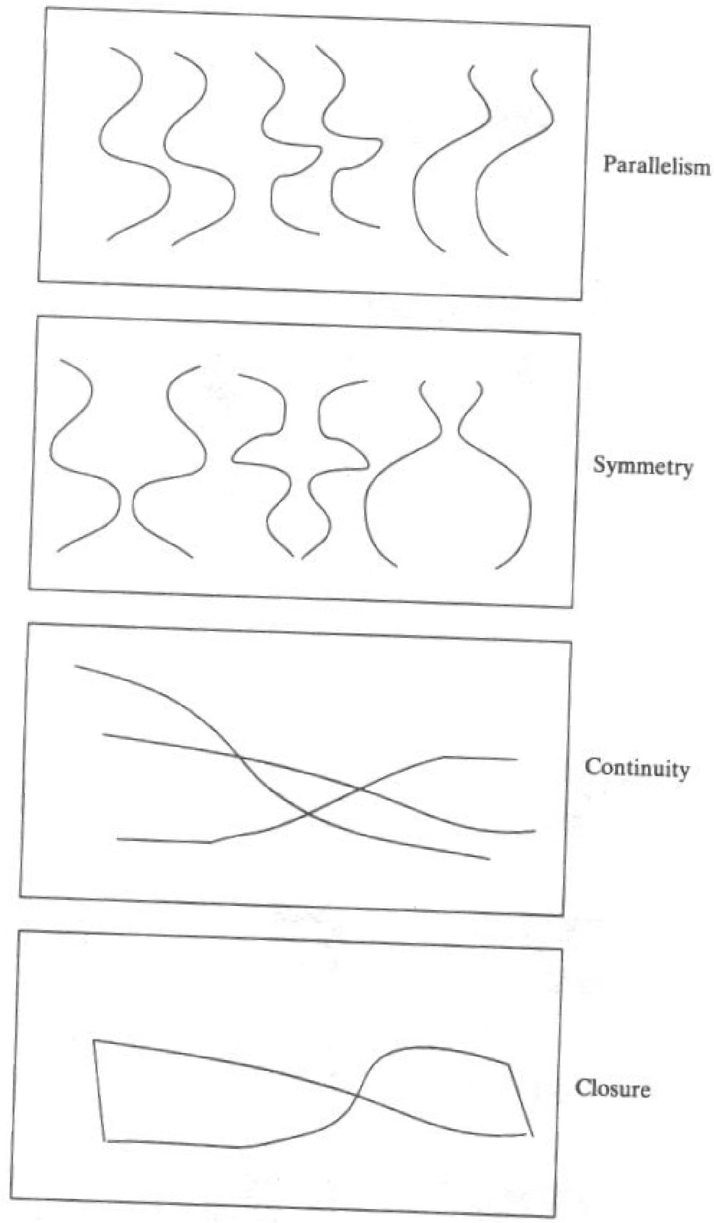


Figure 14.4 Examples of Gestalt factors that lead to grouping (which are described in greater detail in the text).

Forsyth and Ponce. *Computer Vision: a modern approach*. Prentice Hall, 2003.



Forsyth and Ponce. *Computer Vision: a modern approach*. Prentice Hall, 2003.

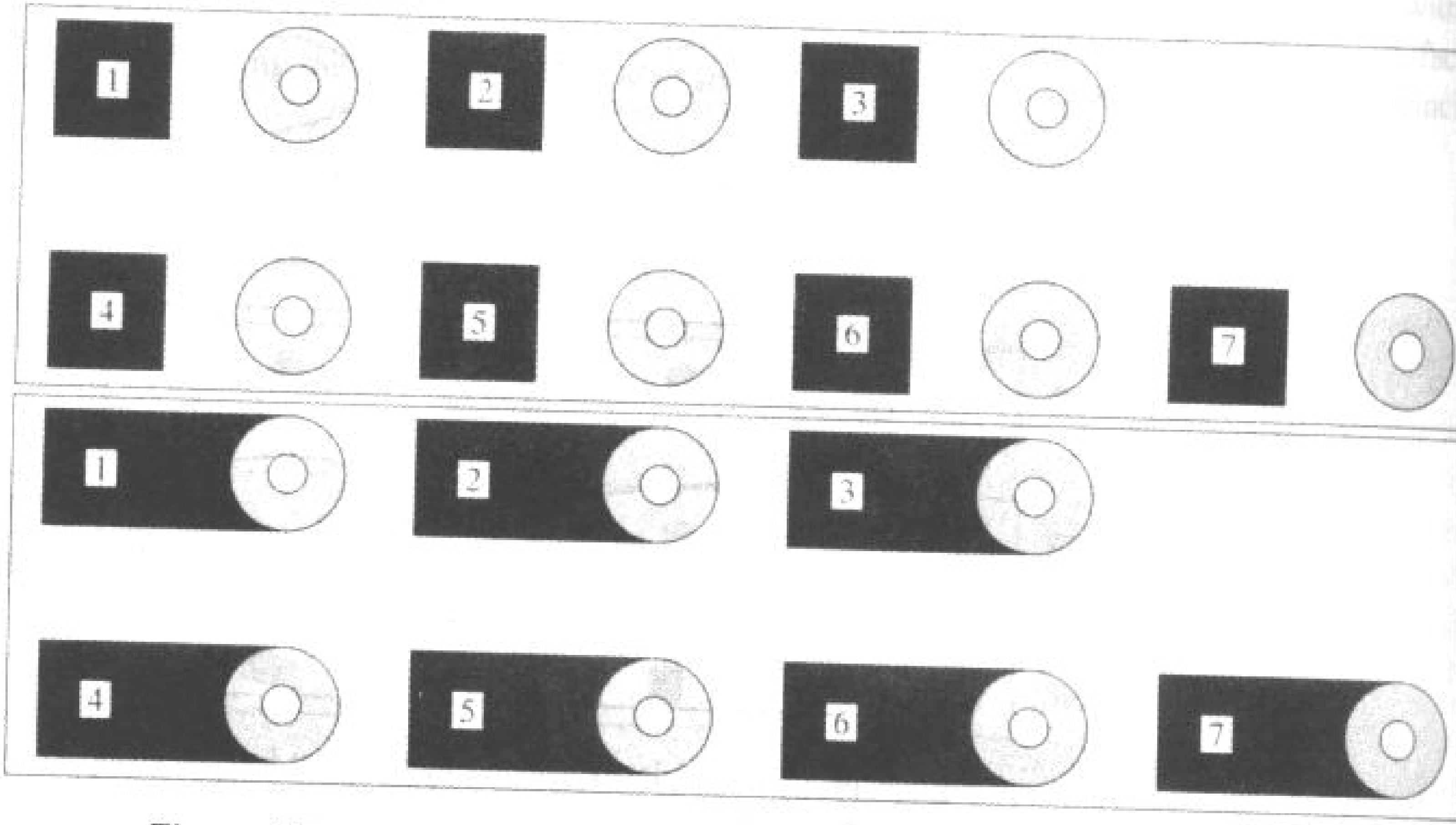


Figure 14.7 An example of grouping phenomena in real life. The buttons on an elevator in the computer science building at U.C. Berkeley used to be laid out as in the **top** figure. It was common to arrive at the wrong floor and discover that this was because you'd pressed the wrong button—the buttons 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.

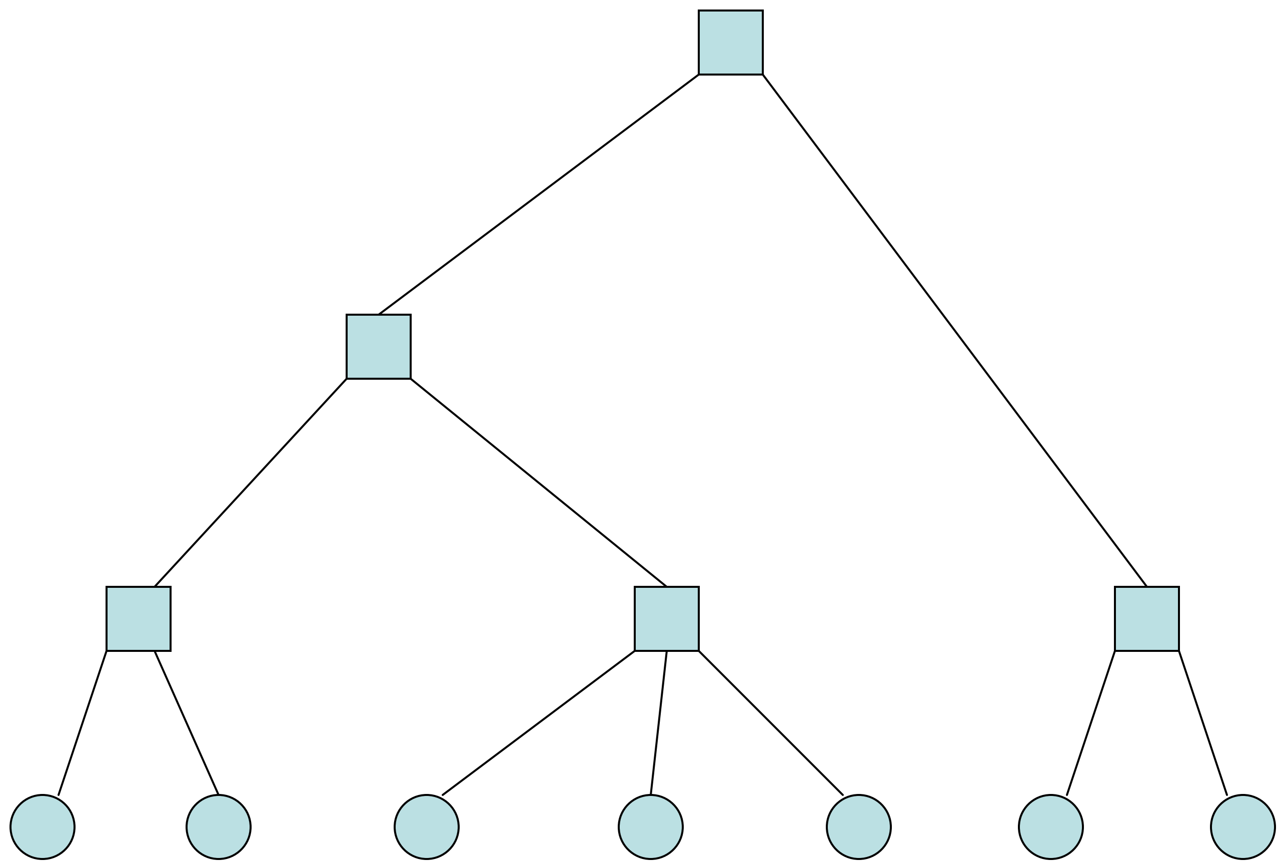
Forsyth and Ponce. *Computer Vision: a modern approach*. Prentice Hall, 2003.


7273 JB

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
  - Comanicu et al. 2002
- Spectral clustering
  - Shi et al. 2000
- Bayesian, MRF
  - Felzenszwalb 2004, Borenstein et al. 2004

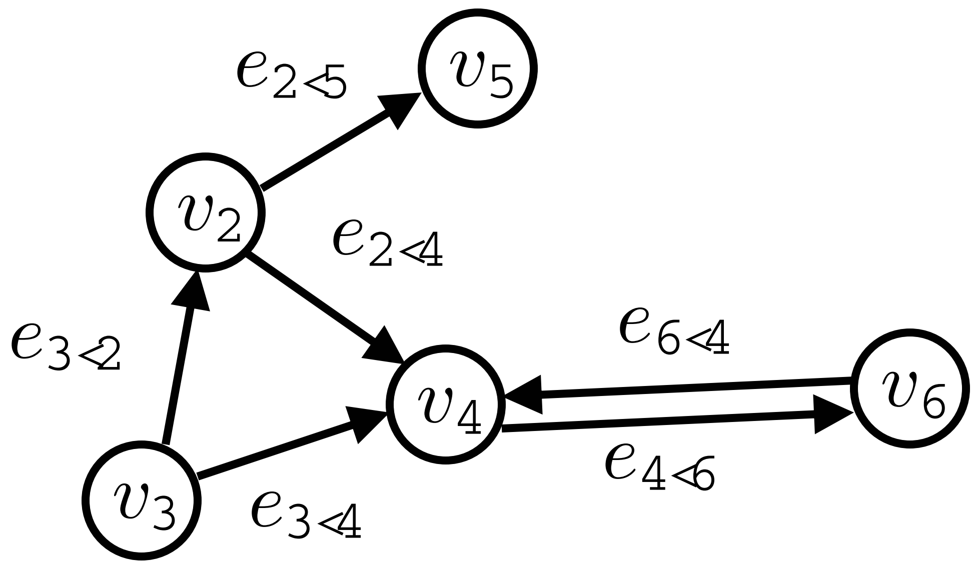
Image segmentation issues

- What is a good segmentation?

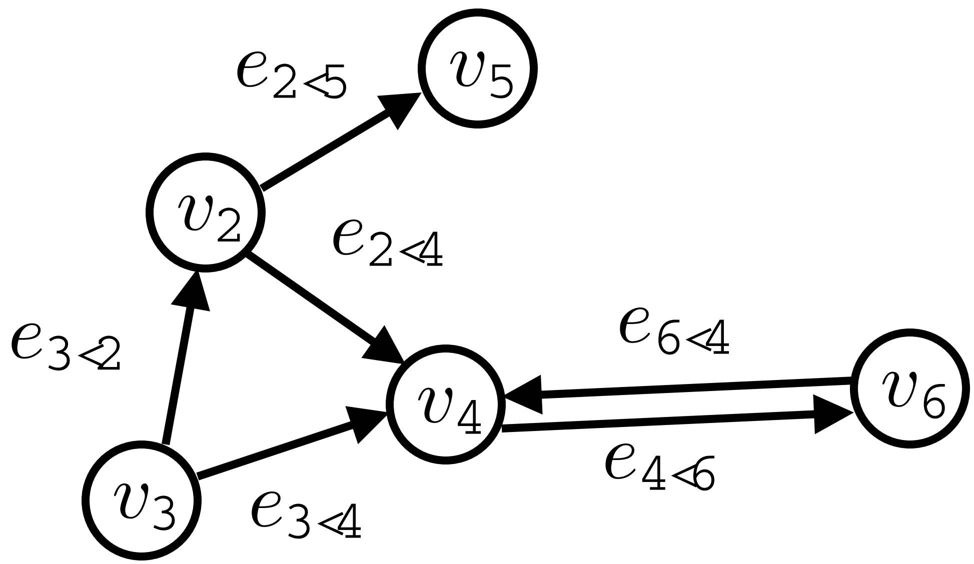
- What are we optimizing? Is the returned image segmentation optimal?

- Let us consider a graph-theoretic approach

$$G = (V, E)$$



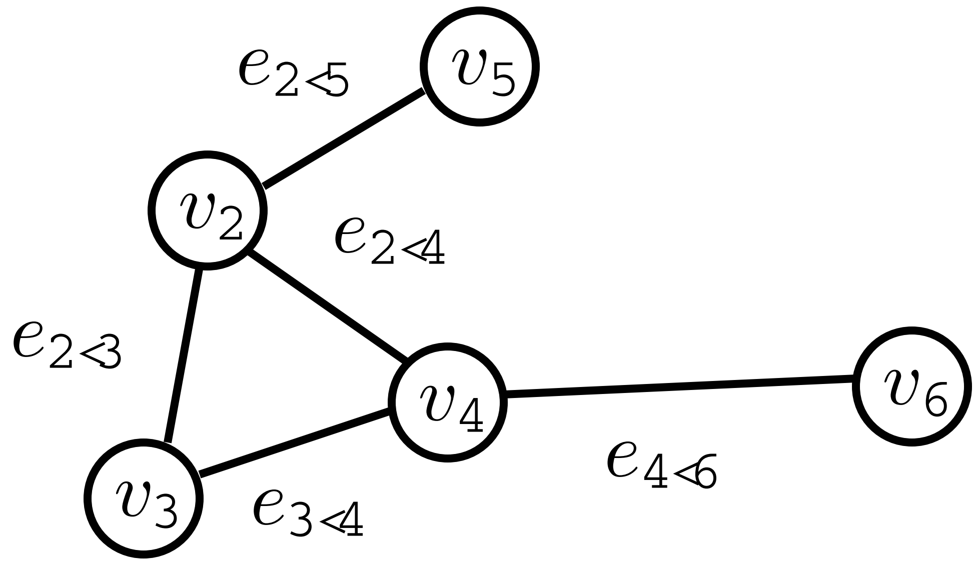
$$G = (V, E)$$



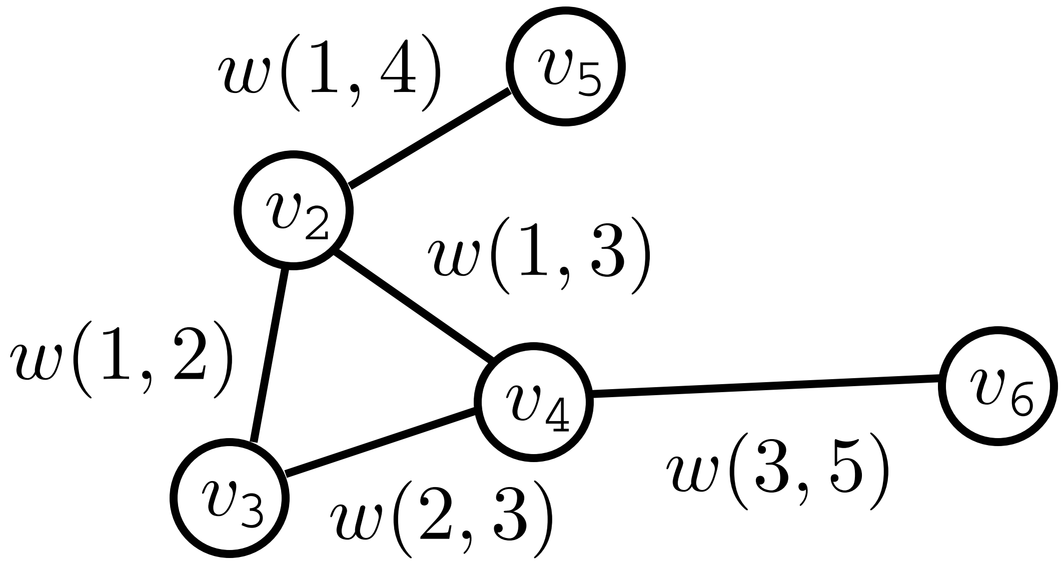
v_j - feature, e.g. pixel intensity, spatial location

$e_{j<k}$ - indicates two features have nonzero similarity

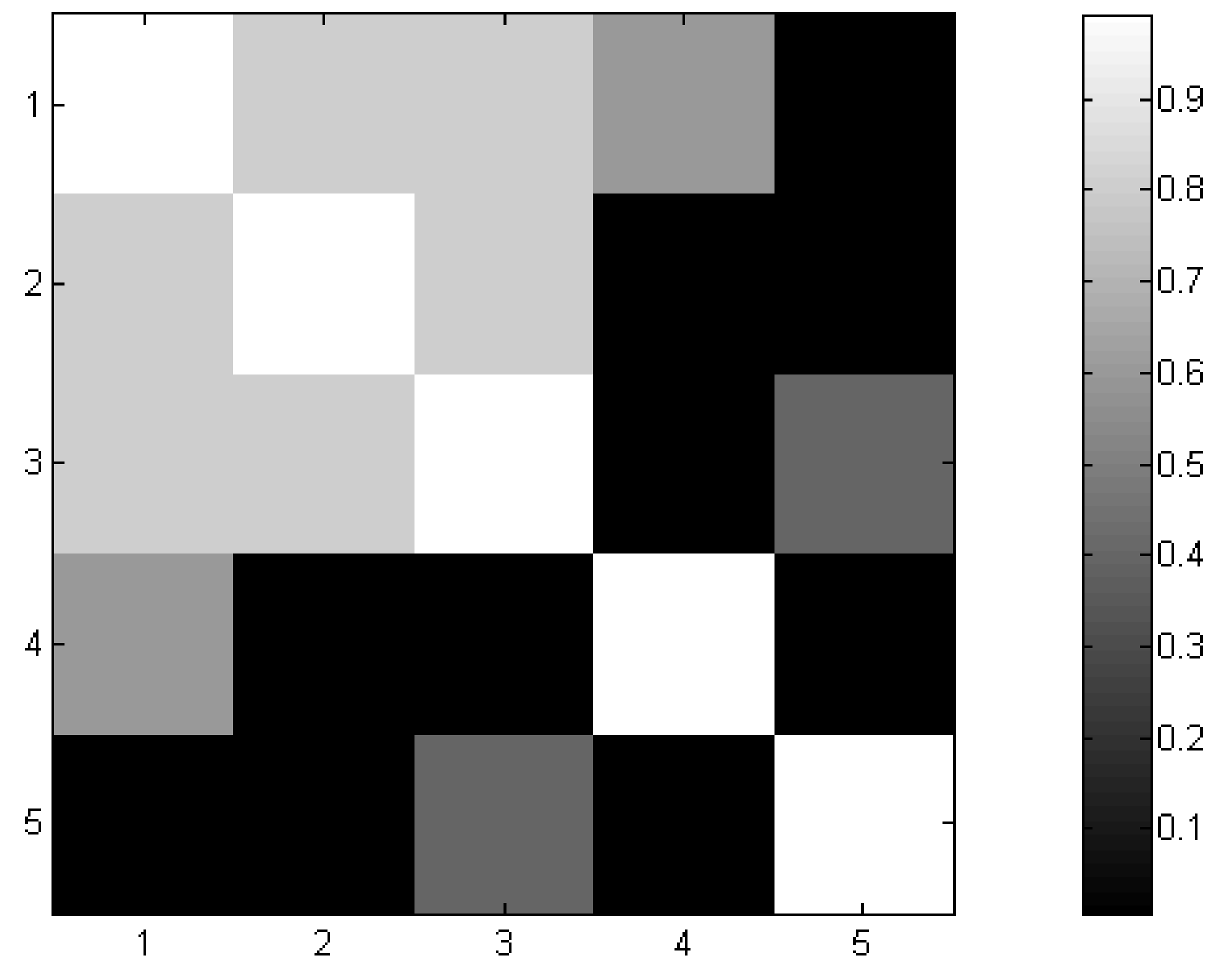
$$G = (V, E) \qquad e_{\mathtt{j} \lessdot \mathtt{k}}, e_{\mathtt{k} \lessdot \mathtt{j}} \in E$$



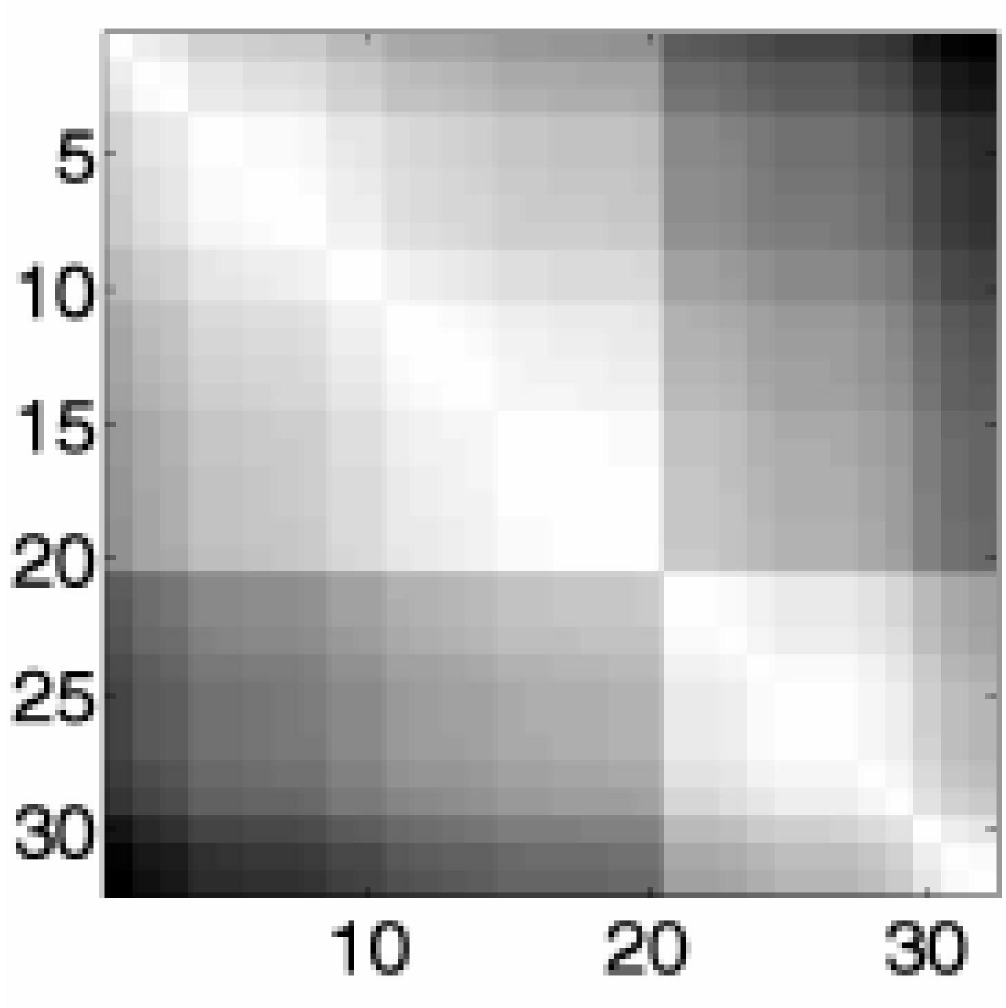
$w(i, j)$ - similarity score of pixels *i* and *j*



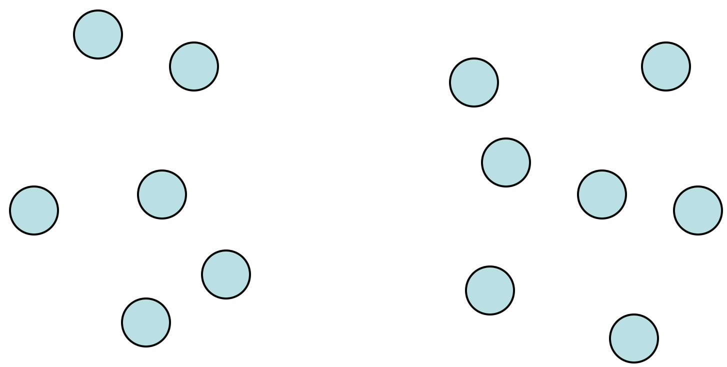
Visualizing similarities



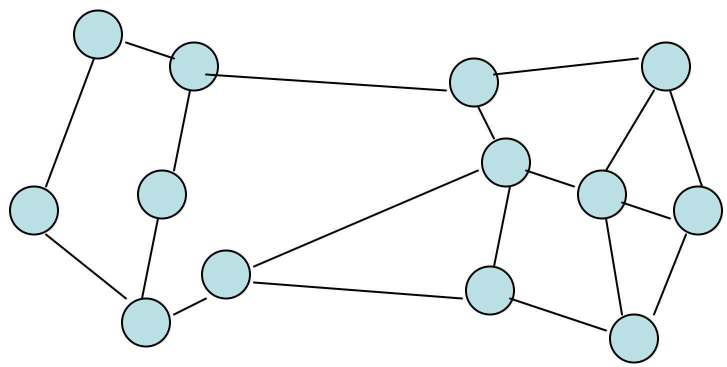
More complex graph



Toy problem: spatial grouping

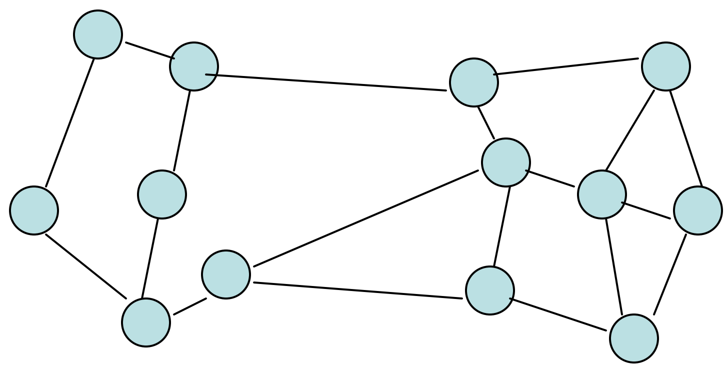


Toy problem: spatial grouping



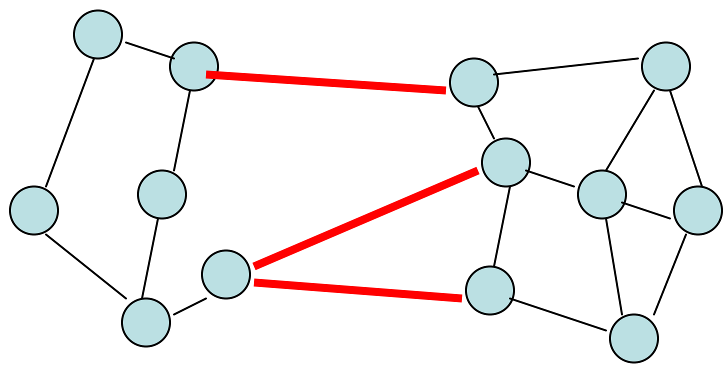
$$w(i,j) \propto \exp(-dist(i,j))$$

Toy problem: spatial grouping



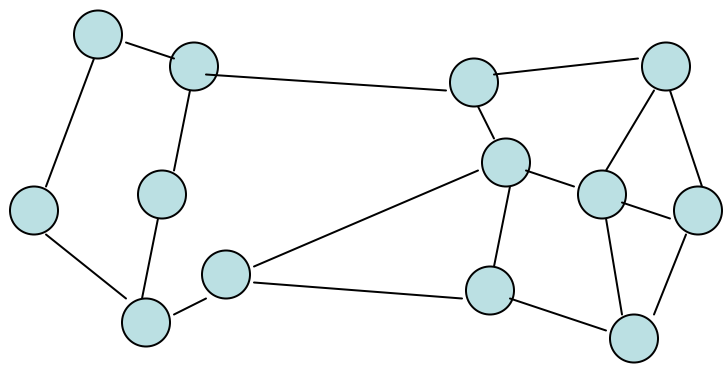
Task: cut the graph to produce a meaningful segmentation

Toy problem: spatial grouping



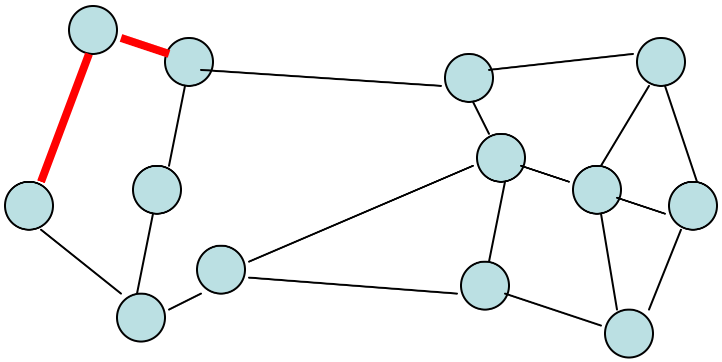
One possible cut…

Toy problem: spatial grouping



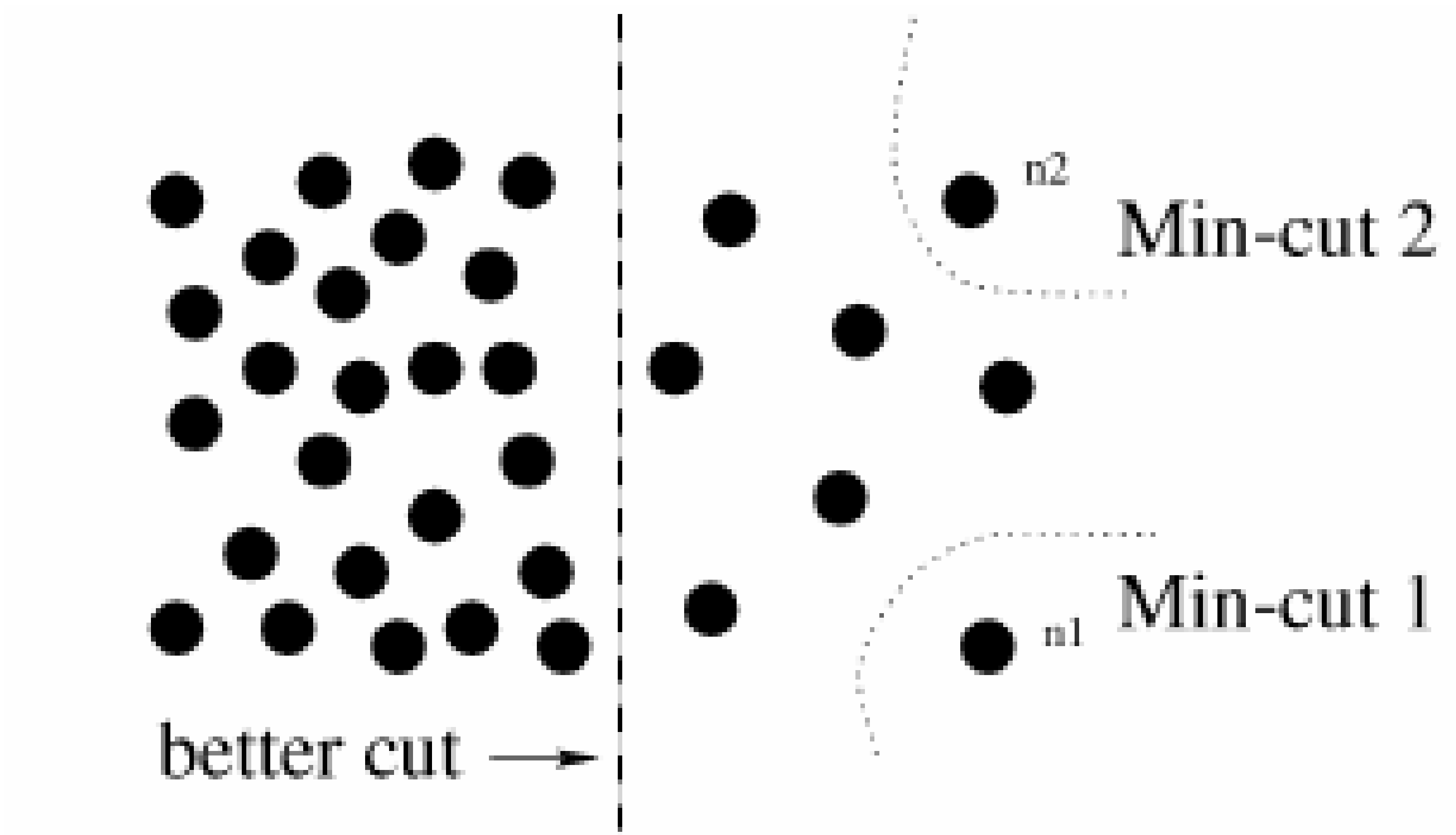
One idea: find set of edges with minimum total weight that partitions the graph - MinCut

Toy problem: spatial grouping

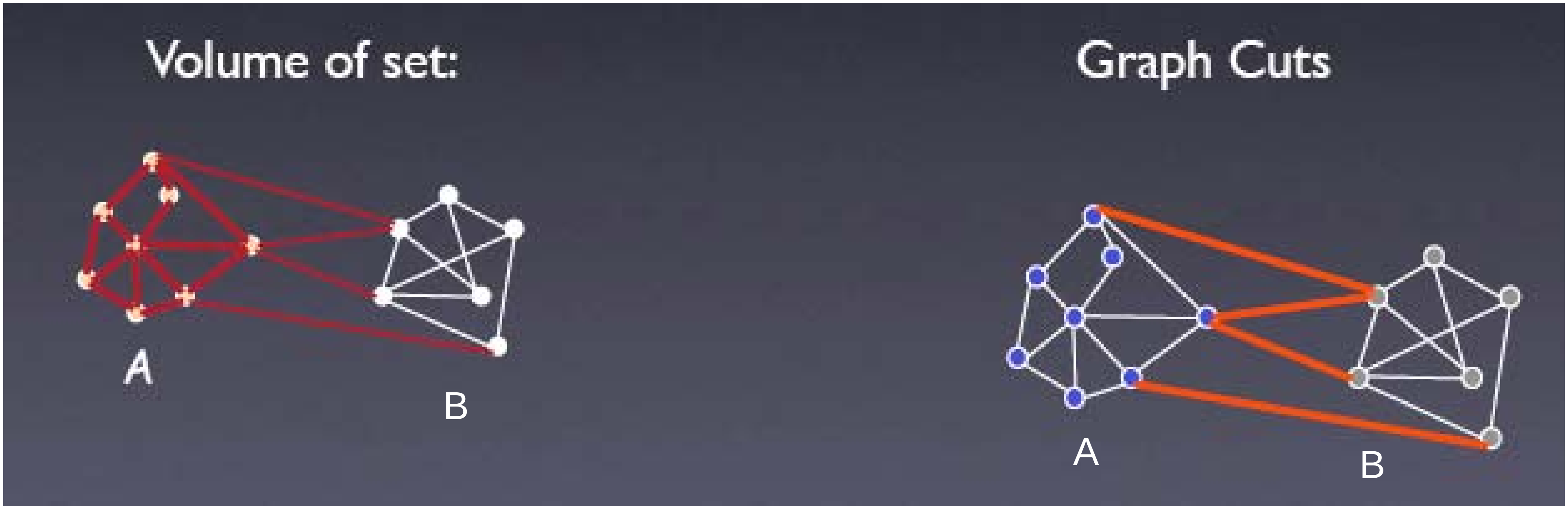


Problem: MinCut prefers isolated points

Problem with MinCut

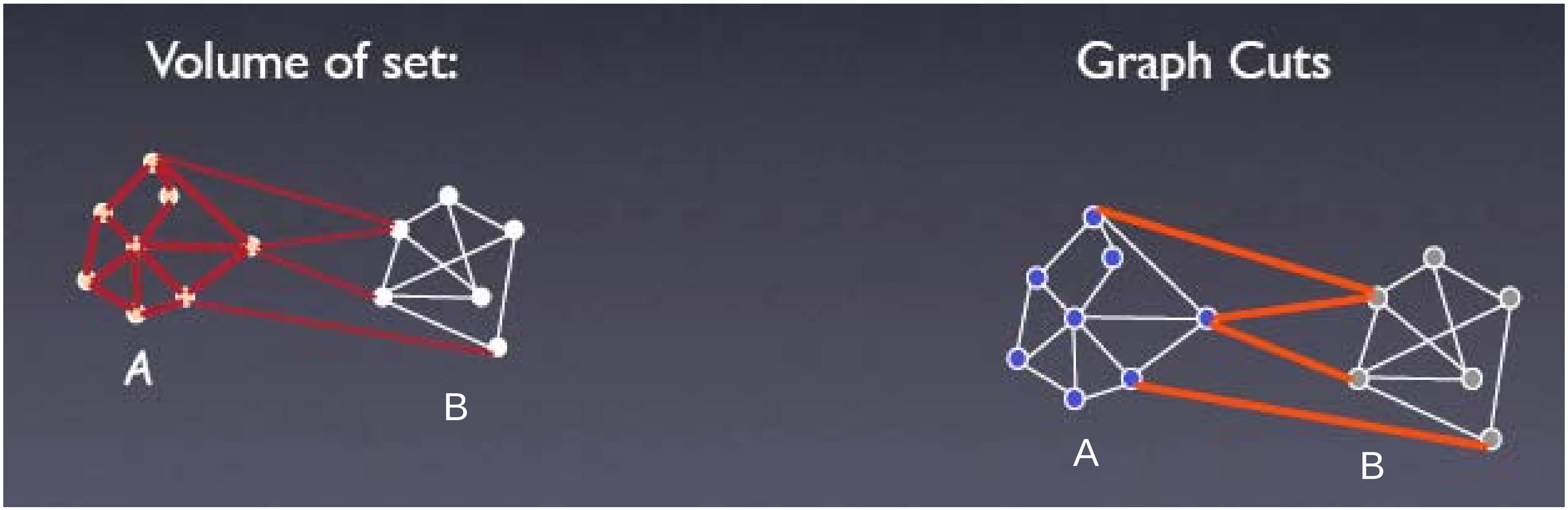


Normalize the cut



Use ratio of cut to the volume of the set

Normalize the cut



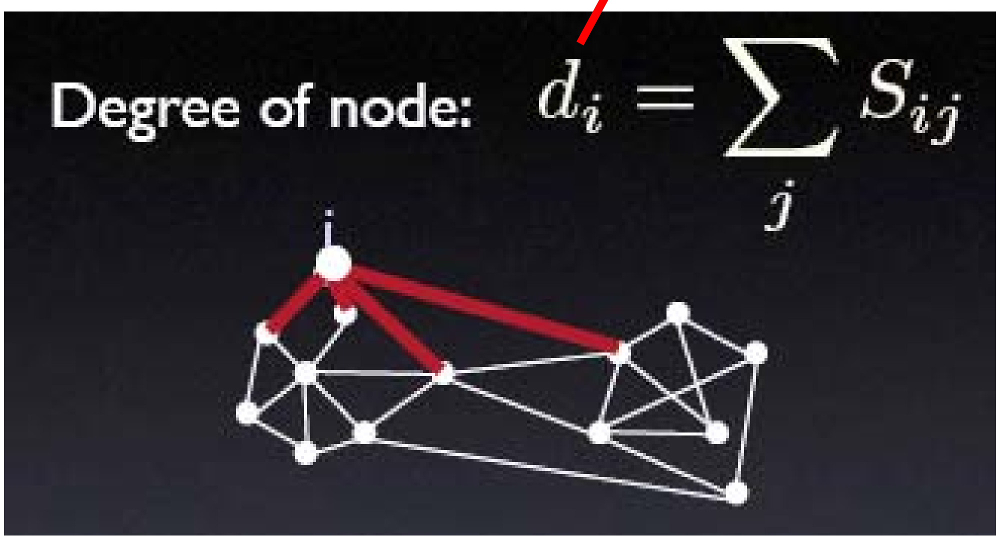
$$Ncut(A,B) = \frac{\mathrm{dvu)B<C\ *}}{\mathrm{wpm)B\ *}} + \frac{\mathrm{dvu)B<C\ *}}{\mathrm{wpm)C\ *}}$$

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

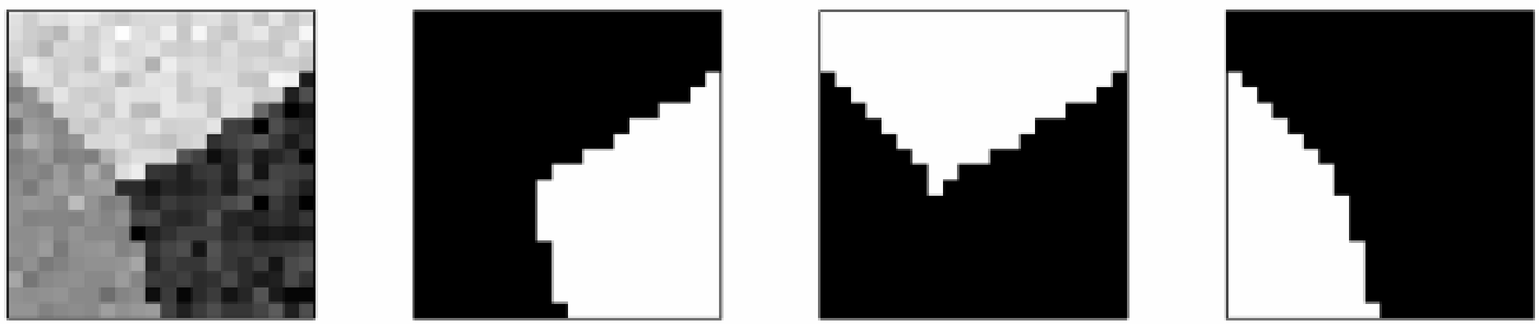
$$D - W$$



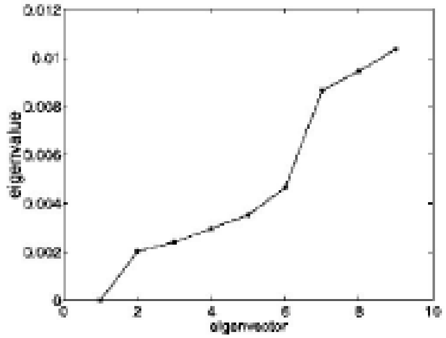
$$W_{j<k} = w(i, j)$$

Find generalized eigenvectors

Toy problem: synthetic image

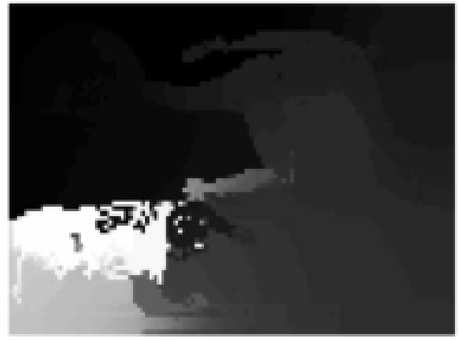


Real image



0.012
0.01
0.008
0.006
0.004
0.002
0
eigenvalue
0
2
4
6
8
10
eigenvector

(a)



(b)

(c)

(d)

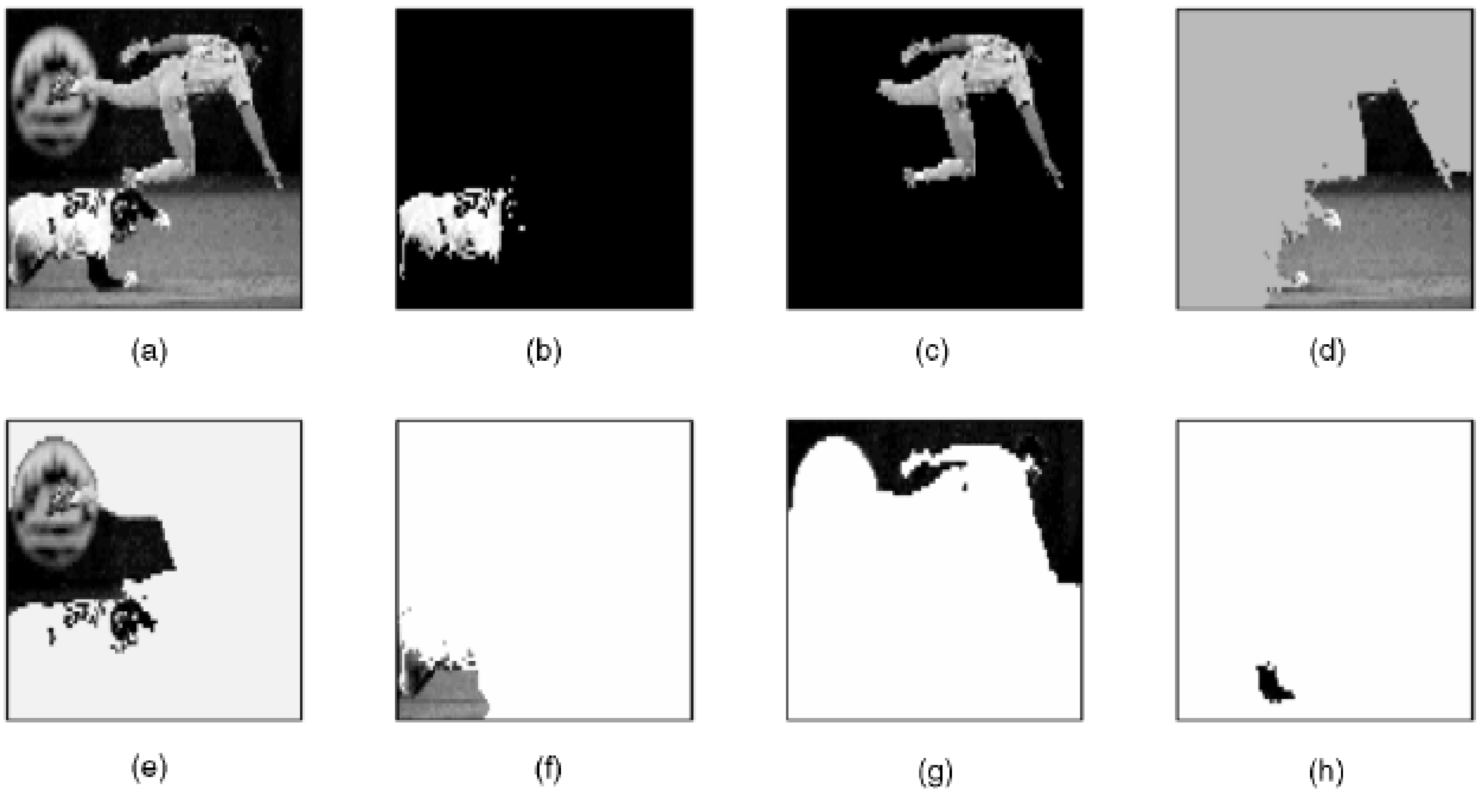
(e)

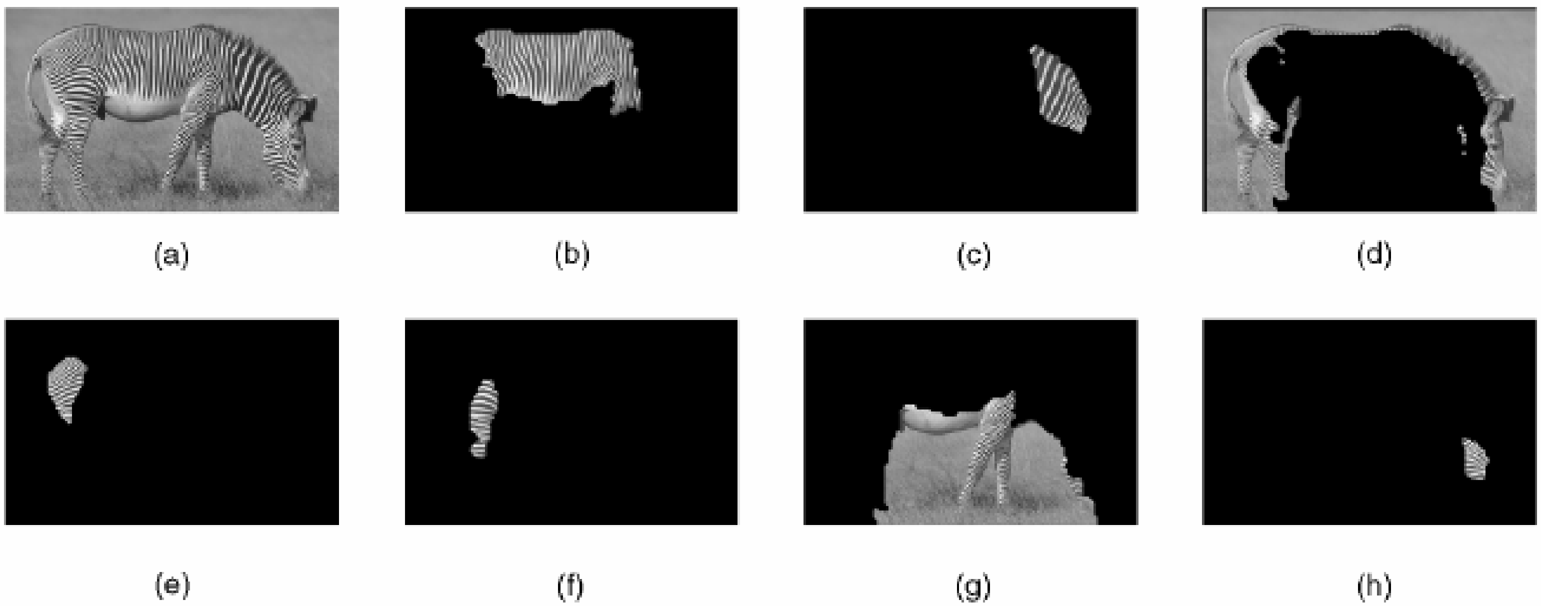
(f)

(g)

(h)

(i)


(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)


(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)

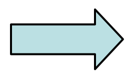
Automatic Photo Popup

Derek Hoiem
Alexei A. Efros
Martial Hebert

Carnegie Mellon University

Robust Spatial Support

RGB Pixels

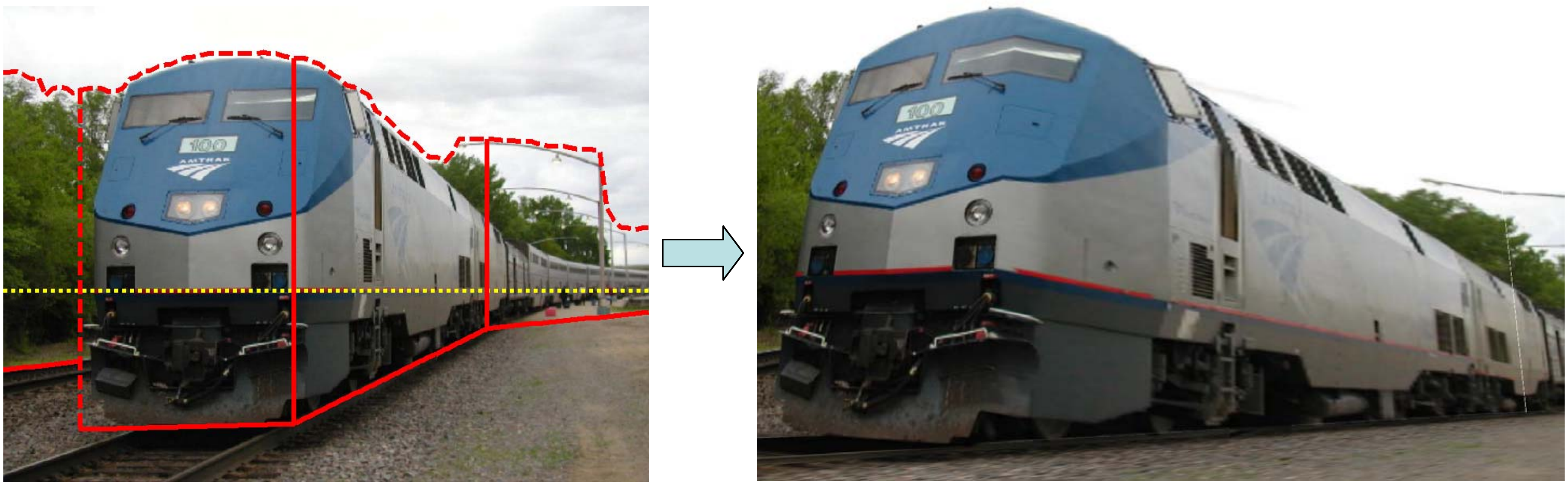


Superpixels

[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

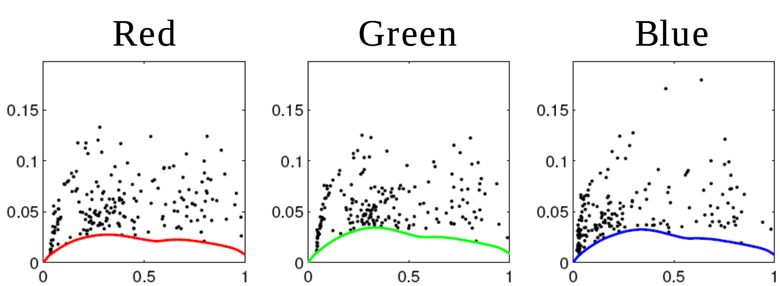
CSAIL
Massachusetts Institute of Technology
Microsoft Research

Segmentation-based Approach

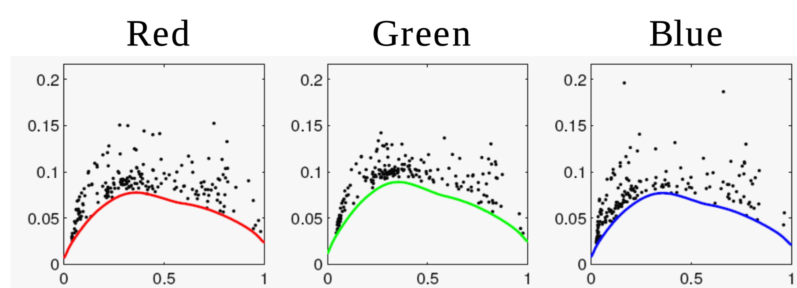
Over-
segmentation

Test on Low and High Noise

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

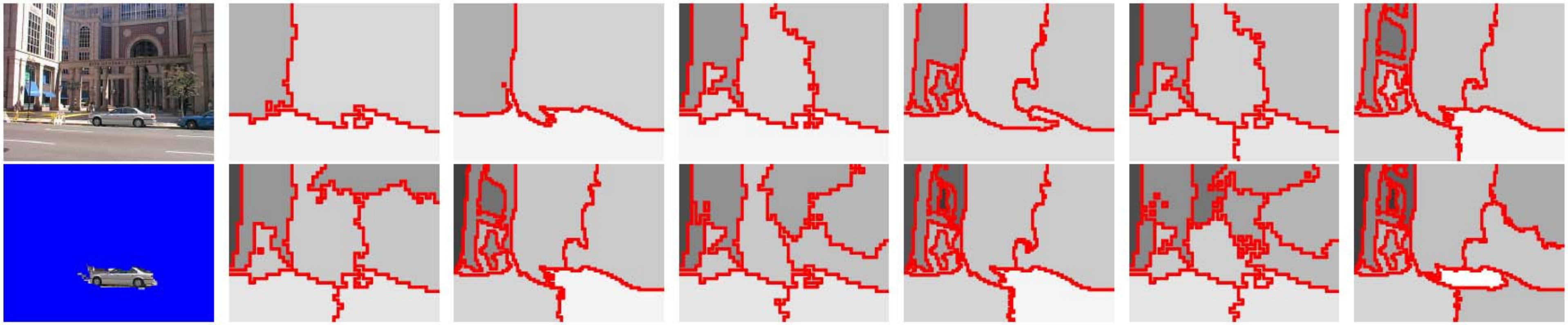


high noise $\sigma_s = 0.090,\ \sigma_c = 0.045$

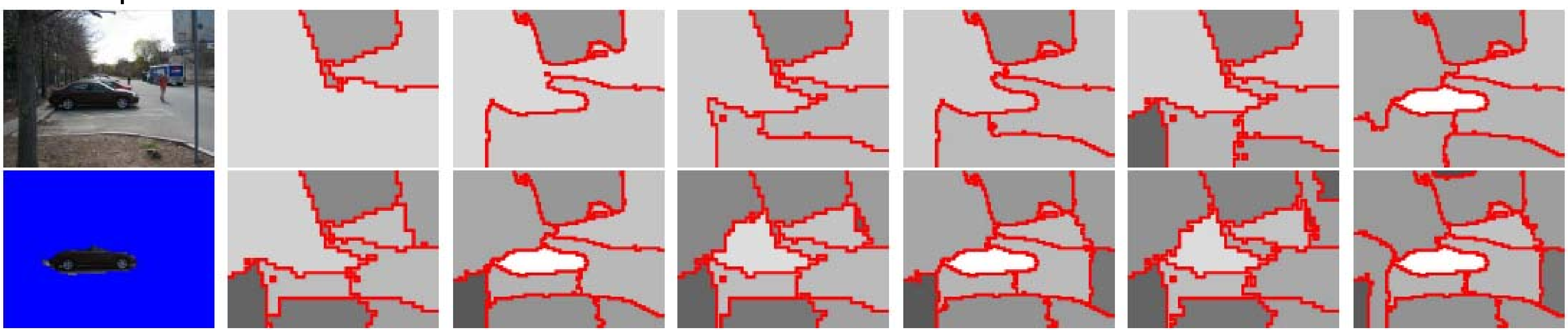


Segment scores for a given topic

Car topic



Car topic



White indicates low KL divergence

Russell et al. CVPR 2006.

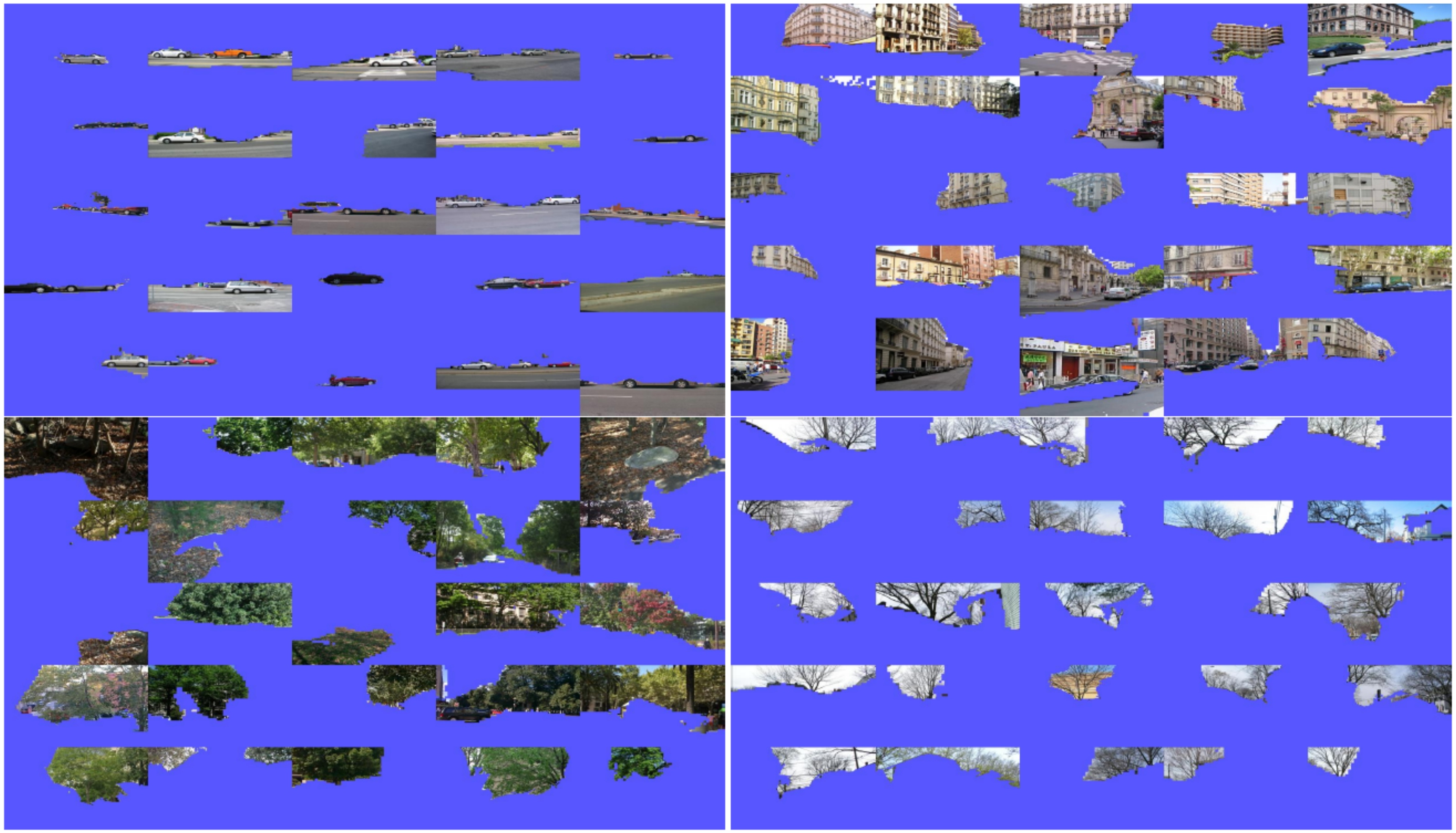
Results II. – LabelMe dataset

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/