Some Applications of Graph Algorithms in Computer Vision

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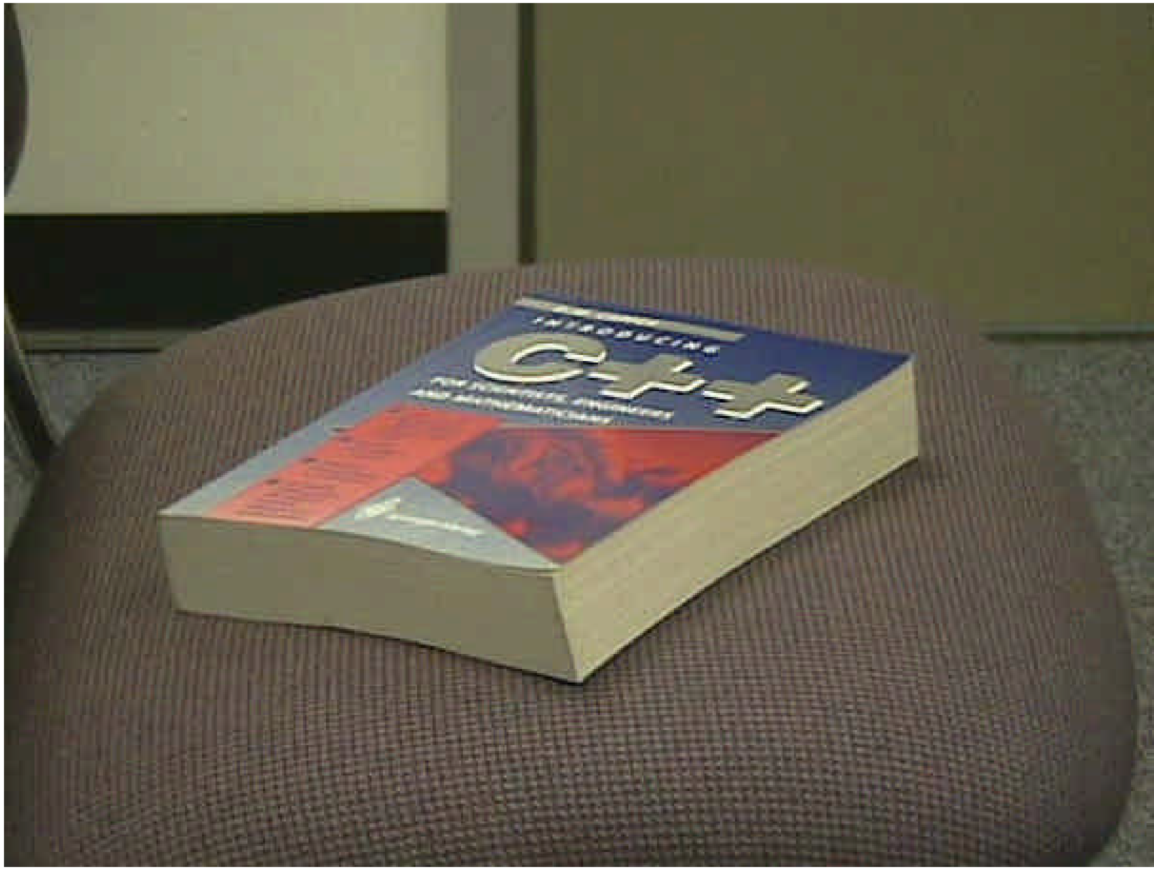
Computer Vision Problems (1)

Some problems that I would like to address now (and solve in the future).

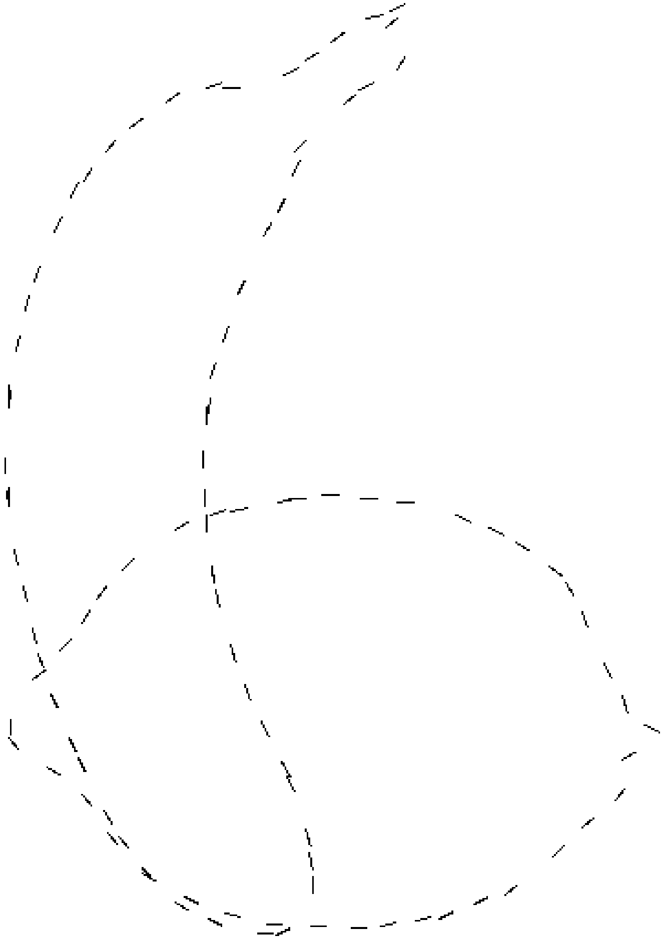
- Segmentation: given an image, partition it into a number of regions, so that each region corresponds to an object.



Computer Vision Problems (2)

Some problems that I would like to address now (and solve in the future).

- Perceptual Grouping: given a set of edge fragments, group some of those fragments to obtain contours of some meaningful objects.



Computer Vision Problems (3)

Some problems that will be addressed in a subsequent talk by Dr. Sven Dickinson:

- Object Matching: given two objects, find a correspondence at the level of their parts.
- Object Abstraction: given a set of objects, compute an abstract representation of the collection that retains perceptually significant features.

Problems that can be Addressed with Graph Algorithms

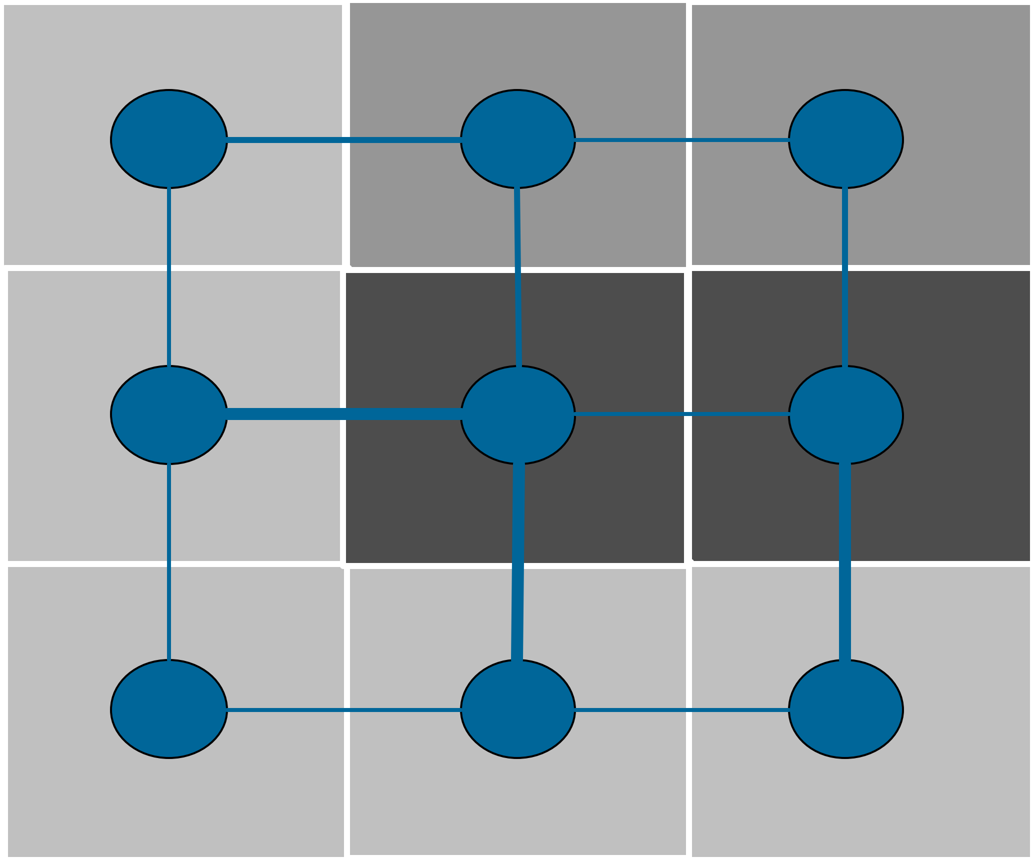
- Segmentation
- Perceptual Grouping
- Object Matching
- Object Abstraction

- And many, many more …

- All graphs that I will consider in the remainder of the talk will be connected (will consist of one piece).

Representing Images as Graphs Based on Pixels

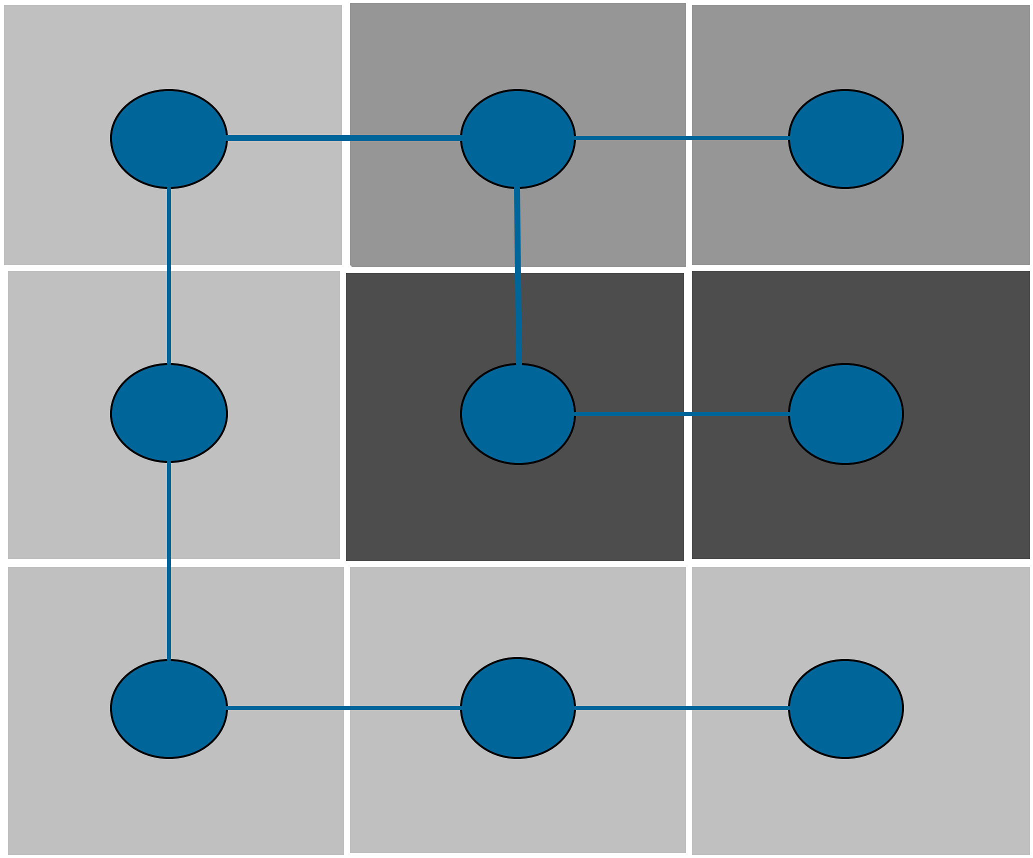
- Idea: treat each pixel as a graph node. Connect nearby pixels by edges. Edge weights are proportional to the difference in pixel intensities.



Minimum Spanning Trees (1)

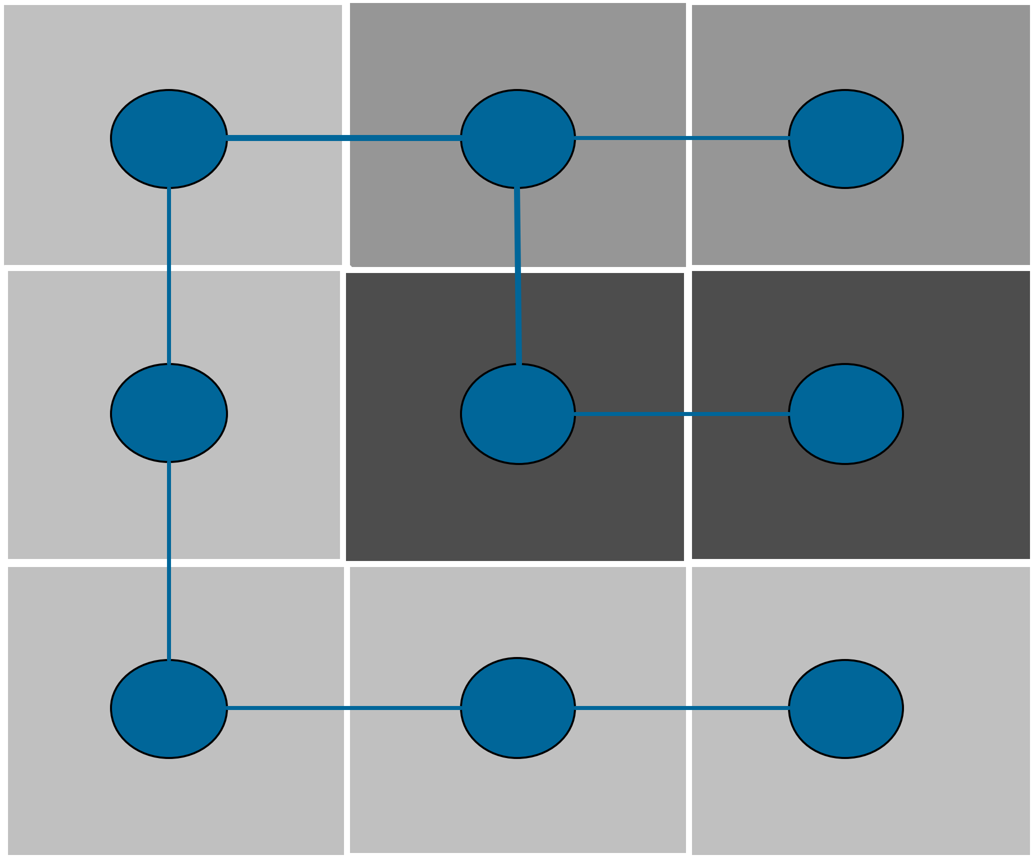
- The minimum spanning tree (MST) of an edge-weighted graph is a tree (no cycles) that spans all nodes of the graph and of minimum total weight among all such trees.

- MST's are used in segmentation and clustering.



Minimum Spanning Trees (2)

- An MST can be constructed by “deleting” all edges from the graph, and adding them one-by-one, starting from the minimum-weight edge, checking that the new edge does not result in a cycle.



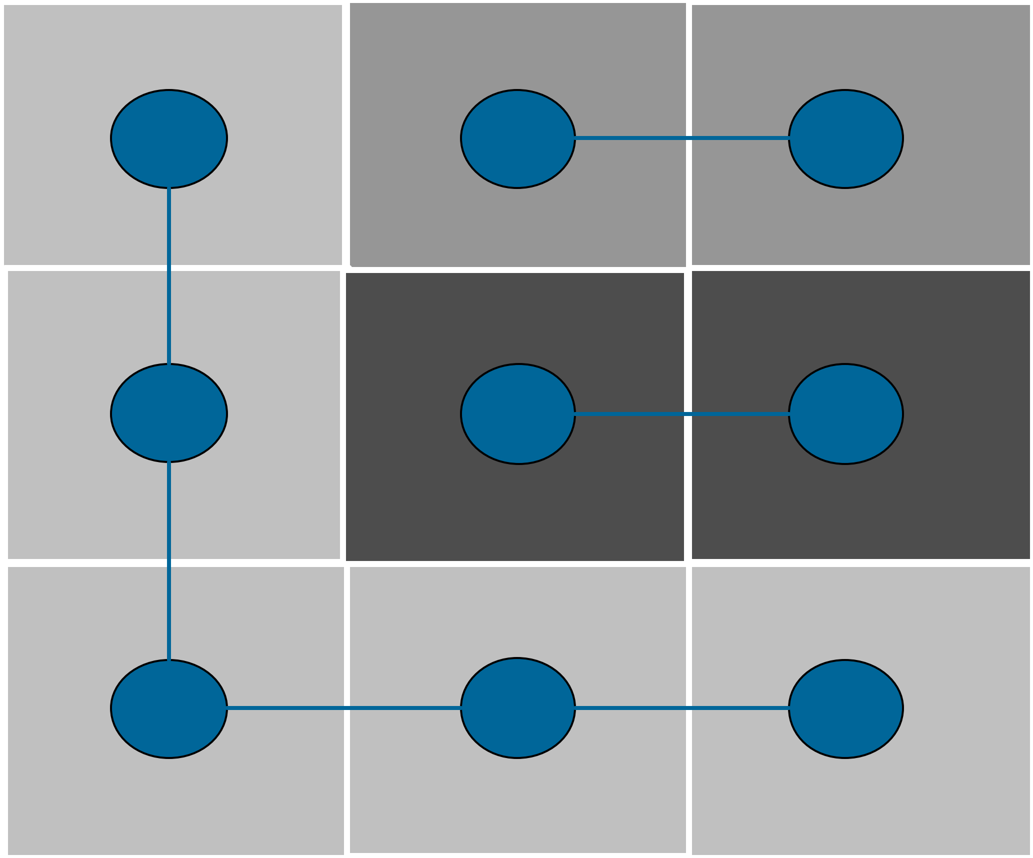
Outline of an MST-based Image Segmentation Algorithm

- Authors: Pedro F. Felzenszwalb, Daniel P. Huttenlocher
- Objective: obtain regions (connected components) that hopefully correspond to objects in the image.
  - Form the weighted graph: nodes are pixels, edges are between adjacent pixels, edge weights are differences between pixel intensities.
  - Start with a graph with the same nodes but no edges (as many components as there are nodes).
  - Add one edge at a time, of a minimum weight, that connects two different disconnected components.
- Go on until the difference between adjacent components becomes too large (the value is determined by a parameter).

Thus, the main difference between this algorithm and the MST algorithm is that here we don't go all the way to the end (one component), but instead stop short, when some image-based properties of the components become too different.

An illustration of the MST-Based Segmentation Algorithm

- The main difference between the segmentation algorithm and the MST algorithm is that here we stop short of constructing the full minimum spanning tree, obtaining "uniform" regions.



Results From the Paper

- The algorithm can also produce regions of non-uniform color due to some tricks used.
- In general, the objective is to balance the internal intensity variation within a region and external intensity variation between adjacent regions.
- Paper can be found at: http://citeseer.ist.psu.edu/felzenszwalb98efficiently.html

- What do you think of the results?

Results on My Images

Minimum Mean Cycles

- A minimum mean cycle in a weighted graph is a cycle of the minimum average (mean) weight.
- With appropriately defined edge weights, minimum mean cycle is likely to correspond to a closed contour (silhouette) of an object.
- On the other hand, a cycle of minimum total weight is likely to correspond to a small spot that does not correspond to an object.
- Besides, a minimum mean cycle is much easier to find algorithmically.

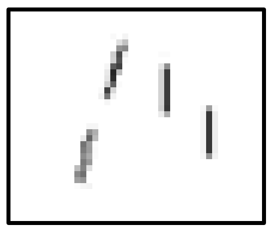
Segmenting Images with Minimum Mean Cycles

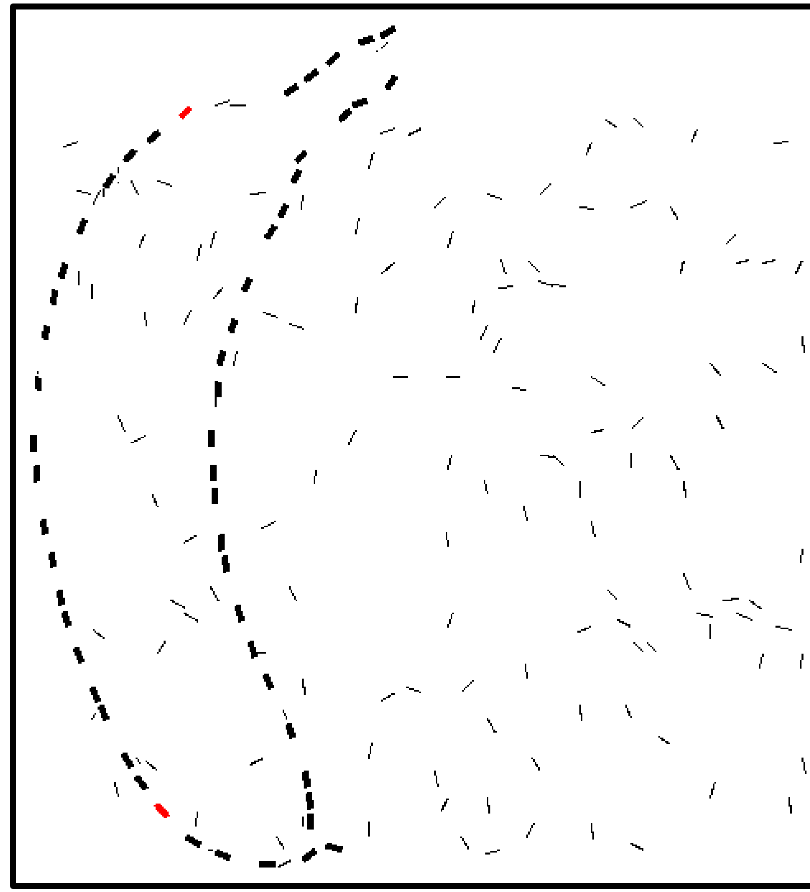
- Authors: Ian H. Jermyn, Hiroshi Ishikawa
- Paper can be found at: http://citeseer.ist.psu.edu/jermyn99globally.html

- Note that the graph defined by the authors is somewhat different from the pixel-based graph I introduced earlier. Details are in the paper.

Perceptual Grouping with Minimum Mean Cycles

- Some results obtained for graphs based on image edge fragments (an image edge fragment is a node; the degree of perceptual "coherence" determines the weight of the graph edge).





Conclusions

- The language of graphs can be used to formulate a variety of problems that arise in Computer Vision.
- Graph algorithms are abundant and give good results on many Computer Vision problems.
- Because segmentation and grouping often depend on higher-level knowledge, graph algorithms are just a starting point in the quest to find better Computer Vision algorithms.

- Any questions? Comments?