Graph Visualization
An Annotated Bibliography

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Graph visualization has undergone major changes in the last ten years. New techniques, aimed at reducing clutter in large/dense graphs have been developed which greatly simplify the task of spotting patterns and extracting informaion from such graphs.

Fundimental definitions, proofs and algorithms for graphs can be found in [2]. A good collection of data sets is available from [1].

The most common form of graph visualization is as a node-link diagram. A dot or circle is used to represent each vertex and an edge is represeented as a line between verticies. Such depictions are ituitive, but can quickly become cluttered in large or dense graphs. Reciently, edge bundling has been proposed as a solution to reduce the clutter in a graph.

Before edge clutter can be reduced, an underlying geometry must be applied to the graph. For some graphs, node position represents real information (such as cities in a transportation graph) and must be preserved. For others, no node location information is available. McGuffin [7] provides an overview of algorithms to establish graph layouts.

Bundling algorithms are discussed in [3, 5, 6, 4].

Once edge bundling has been accomplished, several techniques exist to improve the overall usability of the resulting graph. These techniques are discussed in [8, 9]

References

[1] V. Batagelj and A. Mrvar. (2006) Pajek datasets. [Online]. Available: http://vlado.fmf.uni-lj.si/pub/networks/data/default.htm

This site has quite a few collections of graph and network data sets for resaerch. They range from small to very large.

[2] T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, *Introduction to Algorithms*, 3rd ed. The MIT Press, 2009.

This is the semnal work for algorithm reference. This book contains fundimental definintions, algorithms and performance proofs for most basic data structures, including graphs.

[3] W. Cui, H. Zhou, H. Qu, P. Wong, and X. Li, “Geometry-based edge clustering for graph visualization,” *Visualization and Computer Graphics, IEEE Transactions on*, vol. 14, no. 6, pp. 1277–1284, 2008.

Referenced by [6], this paper builds on the ideas of [5]. I new bundling technique is introduced which relies on control points. The idea is inspired by road maps, including level of detail information. They claim this is the first algorithm which works on all graphs. The paper details how to create the underlying mesh, then how to bundle edges into sets which follow this mesh. This is a reasonable paper, and implementing the technique might be illustrative.

[4] O. Ersoy, C. Hurter, F. Paulovich, G. Cantareiro, and A. Telea, “Skeleton-based edge bundling for graph visualization,” *Visualization and Computer Graphics, IEEE Transactions on*, vol. 17, no. 12, pp. 2364–2373, 2011.

This is a basic edge bundling algorithm. Basic steps: Cluster Edges, find a surrounding shape, build a skeleton, attract edges towards the skeleton, repeat. Finally they postprocess to make a nicer looking graph. This paper is well presented and the techniques could be duplicated. This was implemented using CUDA and includes a number of nice set of illustrations. There is a large set of articles referenced.

[5] D. Holten, “Hierarchical edge bundles: Visualization of adjacency relations in hierarchical data,” *Visualization and Computer Graphics, IEEE Transactions on*, vol. 12, no. 5, pp. 741–748, 2006.

Presents an early technique for bundling edges. Edges are bundeled like ”electrical wires” over common paths and fan out at the ends. These techniques started with a tree representation of the graph and then forced additional edges to follow the existing tree edges. New paths were interpreted using a number of different spline algorithms. These techniques have been replaced by better algorithms, but the paper is still worthy of a read

[6] D. Holten and J. Van Wijk, “Force-directed edge bundling for graph visualization,” in *Computer Graphics Forum*, vol. 28, no. 3. Wiley Online Library, 2009, pp. 983–990.

A very nice paper which begins with a comprehensive overview of the state of the art. This seems to be early in the reawaking in graph simplification algorithms. This technique begisn with a node-link diagram where each link is represented by a line segment. Edges are subdivided into segments, which are then connected pairwise by ”springs”. A physical simulation is then run to allo the system to stabalize. Further techniques are discussed to determine when edges should be paired. This concludes with a set of future work and a reasonably large set of references.

[7] M. McGuffin, “Simple algorithms for network visualization: A tutorial,” *Tsinghua Science and Technology*, vol. 17, no. 4, pp. 383–398, 2012.

This paper provides an overview of several graph simplification algorithms. It has an outstanding bib, including links to several current overview papers. Topics include Force-Directed Layout of Node-Link Diagrams (how to draw a position-less graph), Arc Diagrams and Barycenter Ordering (representing a graph as a line), Adjacency Matrix Representations (how to reorder an adjacency matrix of a graph to provide information) and Circular Layouts (nodes along the edge of a circle). Finally some basic graph techniques are reviewed and a further reading section gives good pointers. Most of these techniques are foundational and are needed with other techniques. Pseudo code algorithms are given. This is a good starting point.

[8] S. Pupyrev, L. Nachmanson, and M. Kaufmann, “Improving layered graph layouts with edge bundling,” in *Graph Drawing*. Springer, 2011, pp. 329–340.

This paper presents an improvement to the Sugiyama technique for edge bundlling. This technique maintains individual edges within the bundle and attemtps to arrange the edges within each bundle. This technique uses the output from the Sugiyama algorithm. It works on acyclic graphs and appears best when there are a number of disjoint subrgraphs. This work will be interesting to explore later.

[9] A. Telea and O. Ersoy, "Image-based edge bundles: Simplified visualization of large graphs," in *Computer Graphics Forum*, vol. 29, no. 3. Wiley Online Library, 2010, pp. 843–852.

This technique is built upon Edge Bundling. Based upon those edge bundles, edges are clustered acording to a set of features. Next a shape os constructed for the each of the clustered edges and image techniques are applied to the resulting figure. This is an advanced paper that relies on many underlying algorithms, more of a synthesis of techniques. The results are very nice but I am not sure they can be duplicated from the paper alone.