2.5D Edge Bundling

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Abstract

Drawings in two-and-a-half dimensions are effective for large graphs, especially large clustered graphs. Edge bundling is popular for reducing visual clusters to show high-level structures in large dense networks. Previous bundling work mainly focuses on two and three dimensional drawings of graphs. In this poster, we present a study of edge bundling in 2.5D. We introduce *plane compatibility* to guide the bundling of intra-plane and inter-plane edges in 2.5 dimensional visualizations. Our results show that the new method is effective to highlight the *important skeletal structures* in large clustered graphs.

Keywords: edge bundling, 2.5D, 2.5D bundling, multi-plane, plane compatibility

Index Terms: I.3.3 [Computer Graphics]: Picture/Image Generation—Line and curve generation

1 Introduction

Recent technological advances have led to huge amount of graph data. Visualising large and complex networks is challenging, especially large dense graphs, due to the visual clutters, which hinder human understanding and analytic tasks.

Edge bundling became popular for visualising large dense graphs [9, 11, 5, 12, 16, 18]. Most of the methods are based on *geometry* of graphs, to define *geometry compatibility* between the edges. Edges are bundled together if they are compatible. Amongst them, *Force-Directed Edge Bundling* (FDEB) algorithm [12] models edges as flexible springs that can attract each other. Several studies improved FDEB with new compatibility measures, such as, *semantic compatibility* [15] and *connectivity compatibility* [19] and *tracebility* [8], and *importance compatibility* and *topology compatibility* [17] to improve edge bundled results, and data attribute-driven approach [18]. Most previous work considered drawings on one plane. A few studied edge routing in 3D [3] and in two planes [4].

Representative previous work of 2.5D visualization include, for example, clustered graph layouts 2.5D [7, 14, 13, 10] and 2.5D visualizations for temporal-spatial analysis and visualization of graph thickness [6, 2].

This poster presents our study of edge bundling in general 2.5D visualizations of clustered graphs. To effectively bundle 2.5D drawings, we introduce *plane compatibility* which is based on the plane assignment of nodes and edges. We integrate the new compatibility metric into the FDEB method [12]. Our experimental results show the important topological skeletal structures of the 2.5D visualizations and help visual analysis.

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2 2.5D Bundling (2.5D-EB)

We now present edge bundling to *2.5 dimensional* (2.5D) visualization.

2.1 Plane compatibility

The intuition for our *plane compatibility* is to avoid attractive force between edges that are in different planes or between inter-plane edge with an intra-plane edge. A naive extension of edge bundling to 2.5D would introduce an unexpected bundles such that edges from different planes are bundled together.

2.2 The 2.5D-EB model

The FDEB algorithm [12] inserts control points in each edge, and then uses forces for their position. The forces depend on the geometry compatibility $G(e,e')$. Each control point e_i on edge e has two spring forces exerted by two neighbours e_{i-1} and e_{i+1} and the electrostatic forces F_s. That is, $F_{e_i} = k_e(|\mathsf{p}_{e_{i-1}} - \mathsf{p}_{e_i}| + |\mathsf{p}_{e_i} - \mathsf{p}_{e_{i+1}}|) + F_s$, where k_e is the stiffness of edge e, $\mathsf{p}(x)$ is the location of x, and the electrostatic force $F_s = \sum_{e' \in \mathscr{E}} G(e,e').|\mathsf{p}_{e_i} - \mathsf{p}_{e'_i}|^{-d}$.

We integrate our new edge compatibility - plane compability into FDEB. We adapt FDEB to compute the geometry compatibility $G(e,e')$ to three dimensional vertex positions. The most general form of 2.5D-EB model defines electrostatic force model as:

$$F_s = \sum_{e' \in \mathscr{E}} G(e,e').P(e,e').g(|\mathsf{p}_{e_i} - \mathsf{p}_{e'_i}|), \tag{1}$$

where $P(e,e')$ is the *new* plane compatibility.

Our new model is general and flexible as the weight parameters of $G(e,e')$ and $P(e,e')$ are adjustable and one can define different metrics for geometry compatibility and plane compatibility.

2.3 Plane compatibility metric

To define plane compatibility in 2.5D, we use a multi-plane graph model [7]. A *clustered graph* C=($G(V_G,E_G)$, $H(V_H,E_H)$) is defined from a graph G with an additional cluster hierarchy H. An edge that connects two nodes in the same plane is called an *intra-plane edge*, while an edge connecting two nodes from different planes is called an *inter-plane edge*.

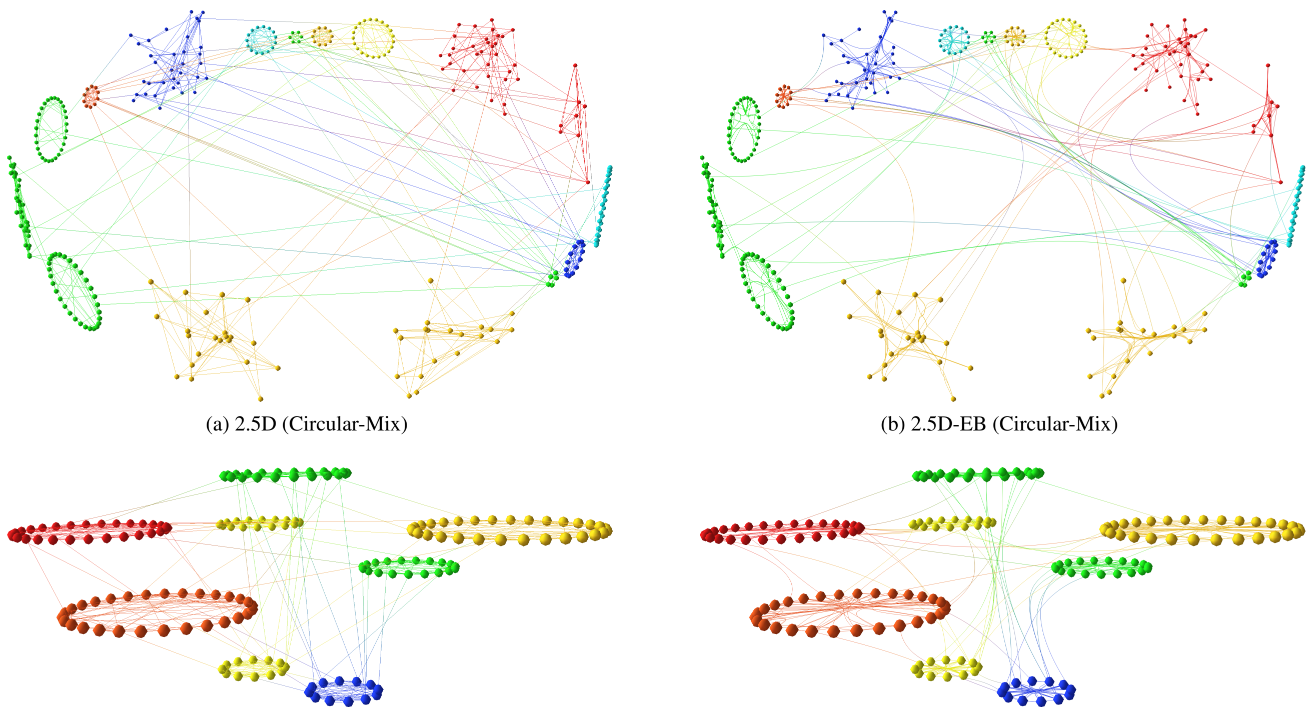
We then define *plane compatibility* for 2.5D bundling: (1) Two edges are plane-compatible only if residing in the same plane; (2) All inter-plane edges are plane-compatible; (3) Intra-plane edge and inter-plane edge are not plane-compatible.

A single plane in our multi-plane model may consist of a normal graph or a clustered graph. Thus, the 2.5D model subsumes the existing 2D edge bundling.

3 Experiments

We have implemented our new 2.5D edge bundling using GEOMI [1].

Figure 1a shows a 2.5D visualization of a random clustered graph. The drawing uses Circular layout to position the clusters. Each cluster is then drawn on a plane using either circular and force-directed layout. Figure 1b shows a bundled result using our



(a) 2.5D (Circular-Mix)

(b) 2.5D-EB (Circular-Mix)

(c) 2.5D (Force-Circular)

(d) 2.5D-EB (Force-Circular)

Figure 1: Clustered graphs in multi-plane drawings and 2.5D edge bundling

2.5D-EB. Compared to the original drawing, the 2.5D-EB visualization reduces the visual clutter and shows clearer the structure of the clustered graph.

Figure 1d shows another result of 2.5D-EB on a random clustered graph. The 2.5D drawing uses Force-directed layout to compute the cluster position and then circular layout is used for individual clusters.

Our bundled results reduce visual clusters and help common analyses such as identifying important actors and connections in a cluster and across the clusters.

4 Future Work

Our study of 2.5D bundling is presented. The 2.5D bundled results enable visual analysis of large dense clustered networks to help identify underlying structures in 2.5D visualization. We will study the new bundling method for real-world network data.

References

[1] A. Ahmed, T. Dwyer, M. Forster, X. Fu, J. Ho, S. Hong, D. Koschtzki, C. Murray, N. Nikolov, R. Taib, A. Tarassov, and K. Xu. Geomi: Geometry for maximum insight. In *Graph Drawing*, pages 468–479. Springer, 2005.

[2] U. Brandes, T. Dwyer, and F. Schreiber. Visualizing related metabolic pathways in two and a half dimensions. In *Graph Drawing*, pages 111–122. Springer, 2004.

[3] P. Caserta, O. Zendra, and D. Bodénès. 3d hierarchical edge bundles to visualize relations in a software city metaphor. In *Visualizing Software for Understanding and Analysis (VISSOFT), 2011 6th IEEE International Workshop on*, pages 1–8. IEEE, 2011.

[4] C. Collins and S. Carpendale. Vislink: Revealing relationships amongst visualizations. *Visualization and Computer Graphics, IEEE Transactions on*, 13(6):1192–1199, 2007.

[5] W. Cui, H. Zhou, H. Qu, P. Wong, and X. Li. Geometry-based edge clustering for graph visualization. *TVCG*, pages 1277–1284, 2008.

[6] T. Dwyer. *Two-and-a-half-dimensional Visualisation of Relational Networks*. PhD thesis, School of Information Technologies, Faculty of Science, University of Sydney, 2004.

[7] P. Eades and Q. Feng. Multilevel visualization of clustered graphs. In *Graph drawing*, pages 101–112. Springer, 1997.

[8] B. F., P. M., B. P., B. M., and D. S. Edge bundling without reducing the source to target traceability. In *InfoVis*, pages 298–305. IEEE, 2011.

[9] E. Gansner and Y. Koren. Improved circular layouts. In *Graph Drawing*, pages 386–398. Springer, 2006.

[10] J. Ho and S. Hong. Drawing clustered graphs in three dimensions. In *Graph Drawing*, pages 492–502. Springer, 2006.

[11] D. Holten. Hierarchical edge bundles: Visualization of adjacency relations in hierarchical data. *TVCG*, pages 741–748, 2006.

[12] D. Holten and J. J. van Wijk. Force-directed edge bundling for graph visualization. *Computer Graphics Forum*, 28(3):983–990, June 2009.

[13] S. Hong. Multiplane: A new framework for drawing graphs in three dimensions. In *Graph Drawing*, pages 514–515, 2005.

[14] S. Hong and N. S. Nikolov. Hierarchical layouts of directed graphs in three dimensions. In *Graph Drawing*, pages 251–261, 2005.

[15] W. Kienreich and C. Seifert. An application of edge bundling techniques to the visualization of media analysis results. In *InfoVis*, pages 375–380. IEEE, 2010.

[16] A. Lambert, R. Bourqui, and D. Auber. Winding Roads: Routing edges into bundles. In *Computer Graphics Forum*, volume 29, pages 853–862. Wiley Online Library, 2010.

[17] Q. Nguyen, S. Hong, and P. Eades. TGI-EB: A new framework for edge bundling integrating topology, geometry and importance. In *Graph Drawing*, pages 123–135. Springer, 2011.

[18] V. Peysakhovich, C. Hurter, and A. Telea. Attribute-driven edge bundling for general graphs with applications in trail analysis. In *PacificVis*, pages 39–46, 2015.

[19] D. Selassie, B. Heller, and J. Heer. Divided edge bundling for directional network data. *TVCG*, 17(12):2354–2363, 2011.