Quantitative Evaluation for Edge Bundling by Difference of Edge Lengths and Area Occupation

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Abstract. There are a lot of information visualization techniques to utilize and analyze big data. Network visualization as node-link diagrams is one of techniques, which can visualize the relationship of multidimensional data, but when the data become very large, the visualization becomes obscure because of visual clutter. In order to solve this problem, a lot of edge bundling techniques have been proposed. However, although graphs may have some attributions, previous techniques don't reflect these attributions. In this paper, we propose a new method of edge bundling for attributed co-occurrence graph. Electrostatic force works between each pair of edges, but if edges are different attribution, repulsion works between the pairs. By bundling edges by same attribution, the graph shows relationships of data more clearly.

Keywords: Edge bundling · Network visualization · Evaluation

1 Introduction

Network visualization is one of the visualization methods that can express the data and the relationships between data. Network visualization is based on graphical representation in mathematics. Hence, a network consists of vertices and edges, which also exhibit attributes. The vertex set is V, the edge set is E, and a network G is presented as $G = \mathrm{G}(V,E)$.

Several methods can be used to visualize networks [1]. Recently, edge bundling has drawn attention as a new approach to improve visual clutter. This method enables observers to recognize the main stream of edges through bundle edges in accordance with certain standards. For example, several methods based on the hierarchical structure of nodes [2], parallel coordinates [3], mechanical models [4], spring force-based approach [5] have been proposed. However, visualization results are qualitatively evaluated using questionnaires and other similar materials. Although researchers evaluate the calculation times for visualization, the efficiency or effect of edge bundling is not evaluated quantitatively.

Therefore, this study proposes a new evaluation strategy for edge bundling by using three measurements on the basis of edge lengths before and after edge bundling, area occupation, and edge density. Overall, this research will help develop an evaluation

method to conduct studies on edge bundling without qualitative measurement. Therefore, this study proposes a new evaluation strategy for edge bundling by using two measurements on the basis of edge lengths before and after edge bundling, area occupation. The first measurement, Mean Edge Length Difference (MELD) (Fig. 1), is based on the length in edge bundling, less change in edge lengths is assumed to indicate better edge bundling result. The second measurement, Mean Occupation Area (MOA), is based on occupation area in screen. Generally, the area of edges before edge bundling is larger than that after bundling. Given this phenomenon, a better bundling can compress the area occupied by the edges (Fig. 2).

2   Measurement of Edge Bundling

2.1   Edge Length

The first measurement is based on the length. In edge bundling, less change in edge lengths is assumed to indicate better edge bundling result. In fact, edge bundling changes the lengths of the edges and tries to bundles them. However, over-bundling often loses the meaning of the original network. Therefore, the above assumption can be considered reasonable. From this assumption, an evaluation measure called Mean Edge Length Difference (MELD) is proposed, as shown in Eq. (1) and Fig. 1. Spring force F_s working at p_i is the following:

$$MELD = \frac{1}{n}\sum_{e \in E} |L'(e) - L(e)| \tag{1}$$

where n is the number of edges, $L'(e)$ is the length of edge e after edge bundling, and $L(e)$ is the original length of e.
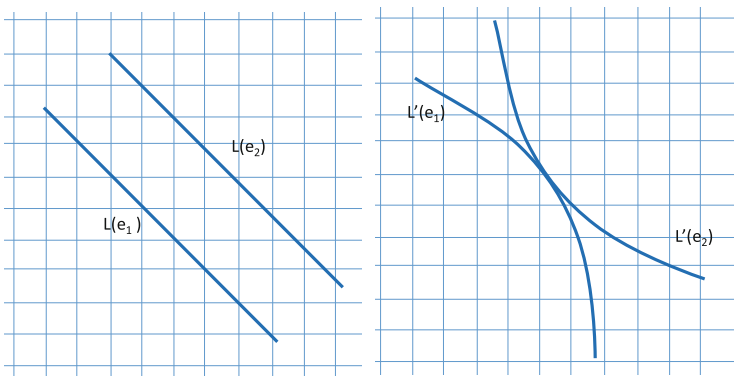

Fig. 1. Concept of Edge Length Difference (MELD) Left: before edge bundling, Right: after edge bundling.
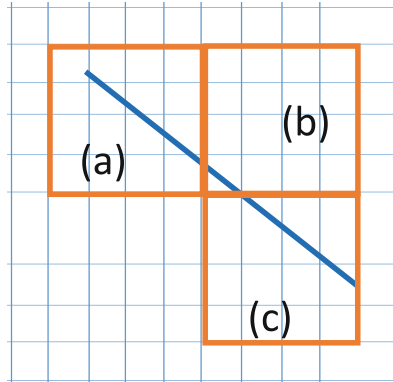
Fig. 2. Occupied area by edge (Unit Size: 4)

2.2 Divided Edge Bundling

Generally, the area of edges before edge bundling is larger than that after bundling. Given this phenomenon, a better bundling can compress the area occupied by the edges.

To calculate the area occupied by the edges, two parameters are used: the size of unit area and the occupation degree. The size of unit area or unit size defines the areas by separating canvas, and the value is given as pixel size. The occupation degree is an integer number used to determine whether an edge occupies the given area.

For example, as shown in Fig. 2, the unit size is 4, and the occupation degree is set to 2. The edges pass through three areas (a), (b), and (c). Areas (a) and (c) are identified as occupied but area (b) is as not occupied because only one pixel is passed by an edge.

By using the above parameters, a measurement called Mean Occupation Area (MOA) is proposed, as shown in Eq. (2).

$$MOA = \frac{1}{N} \left| \bigcup_{e \in E} O(e) \right| \qquad (2)$$

where N is the number of total areas, O(e) is the set of occupied areas by edge e, and | | shows the number of elements contained by a set.

3 Conclusion

This research proposes two measurements to quantitatively evaluate edge bundling. The measurements are developed using the features of edge bundling and can use it to optimize the parameters to do edge bundling. For future works, the measurements will be extended for multi-type edge bundling [6].

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