Quantitative Evaluation for Edge Bundling Based on Structural Aesthetics

Ryosuke Saga saga@cs.osakafu-u.ac.jp
Graduate School of Engineering, Osaka Prefecture University

OSAKA PREFECTURE UNIVERSITY

Abstract

This study proposes a method to evaluate the efficiency of edge bundling. Edge bundling is important to improve visual clutter of edge visualization. However, the evaluation of edge bundling is based only on qualitative evaluations, and the evaluation cost is expensive. Therefore, this paper proposes three measurement strategies to evaluate edge bundling, namely, the edge lengths before and after edge bundling, occupation area, and edge density.

Evaluation in Edge Bundling

Edge Bundling enables observers to recognize the main stream of edges through bundle edges in accordance with certain standards.

The main evaluation points in edge bundling
- **Time**
  e.g. calculation time and complexity
- **Presentation**
  e.g. expression, representation, visual encoding
- **Comprehension**
  e.g. readability

Comprehension and Presentation need to be qualitatively evaluated by a questionnaire and interview.

Problem

1. It takes a lot of time and cost to evaluate them.
2. Comparing among edge bundling algorithms is difficult.

Goal

Propose the quantitative evaluation for Edge Bundling

Aesthetics Rules

It is said that **structural aesthetics** are related to comprehension and presentation [WGK10].

Typical aesthetics rules:
- **To minimize the number of bends in edges,**
- **To minimize the total area of a drawing,** etc.

For Edge Bundling, we proposed the
E1. To minimize changes in the length before and after bundling.
E2. To minimize the drawing areas after edge bundling
E3. To maximum the density of edges after bundling

[WGK10] WARD M et al..: Interactive Data Visualization : Foundations, Techniques, and Applications. A.K.Peters,Ltd., Natick, MA, USA, 2010. 1

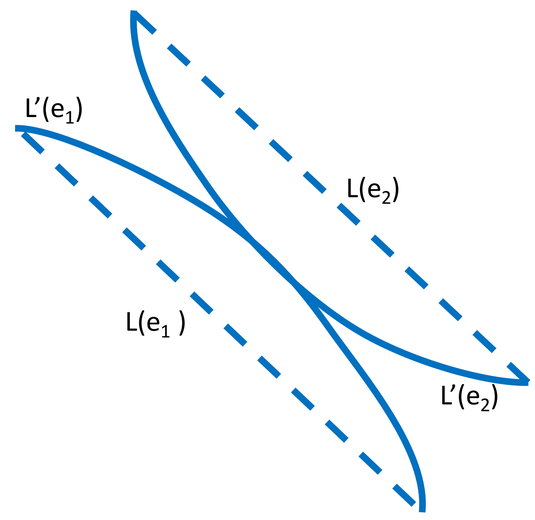
Evaluation Measurement of Edge Bundling

Mean Edge Length Difference

Concept:
Less change in edge lengths is assumed to indicate better edge bundling results.

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

L'(e): the edge length of after edge bundling
L(e) : the edge length of before edge bundling



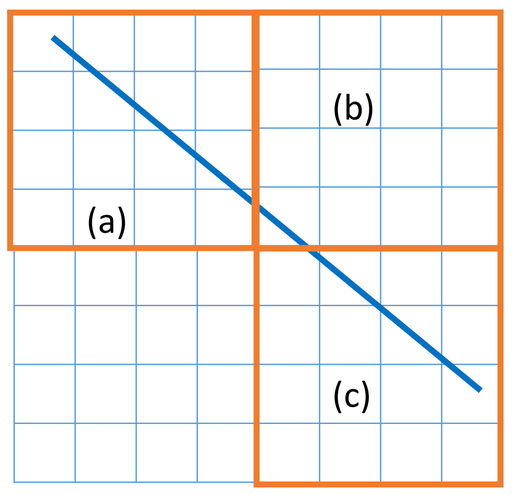
MELD

Mean Occupation Area

Concept:
A better bundling can compress the area occupied by the edges because the area of edges before edge bundling is larger than that after bundling.

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

N: the number of total areas,
O(e): the set of occupied areas by edge *e*,
| | : the number of elements contained by a set.



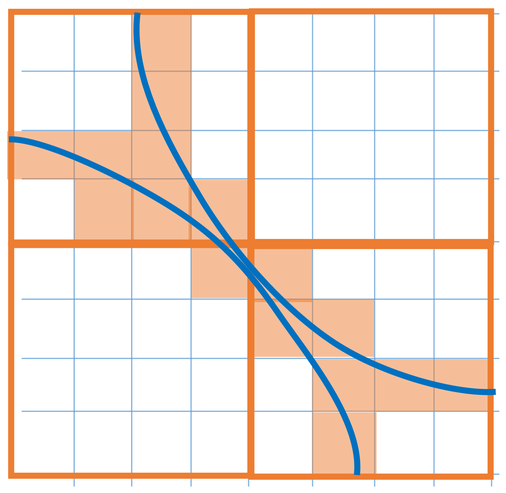
MOA

Edge Density Distribution

Concept:
A better edge bundling method can gather edges within a unit area, and the density per unit area is high.

$$EDD = \frac{1}{n}\sum_{a\in A} |p(a) - p|$$

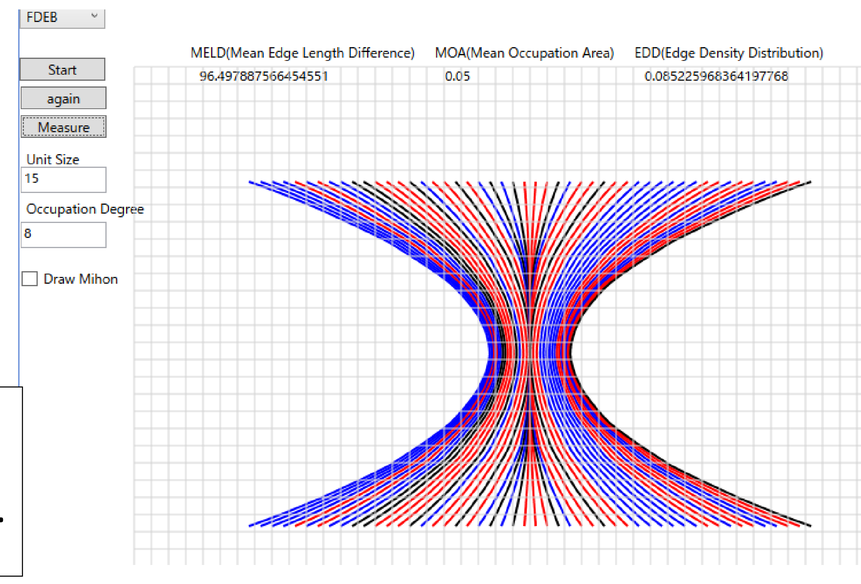
A: a set of unit areas
p(a): the rate of the number of pixels , in which the edges pass in Area *a*
p: a mean of p(a)



EDD

Case Study

The right figure shows an example of measurements for edge bundling of 50 edges.
In this study, a force-directed model is adopted to perform edge bundling.
The unit size is 15, and the occupation degree is 8.



Contribution

The contributions of this research are that this evaluation method is first trial in the world, and that conducting studies on edge bundling is not necessary to evaluate qualitative measurement.

Acknowledgement: This work was supported by JSPS KAKENHI Grant Numbers 25420448 and 16K01250.