Validation of Quantitative Measures for Edge Bundling by Comparing with Human Feeling

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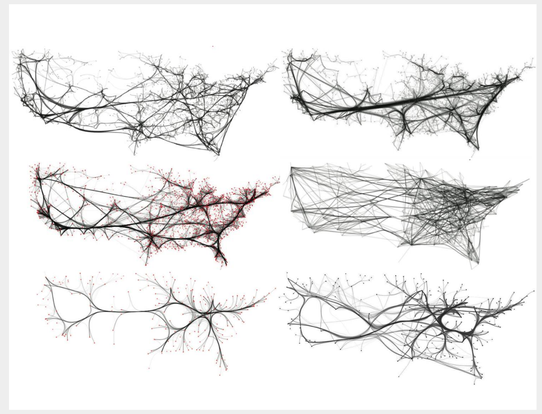
Edge Bundling



Edge Bundling enables observers to recognize the main stream of edges through bundle edges in accordance with certain standards. Actually, there are a lot of edge bundling methods and, to evaluate the Edge bundling quantitatively, the aesthetic-rules-based measures called MELD, NMELD, MOA, and EDD are proposed.

Problem: However, there is no analysis to verify the Measures by comparing with human cognition.

→ That is, it is not clear that these measures can express human feeling and cognition.

Goal : validate and analyze the relationship between human cognition and quantitative measures.

Evaluation Measurement of Edge Bundling (based on Saga(EuroVis 2016))

Mean Edge Length Difference (MELD)

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

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

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

This MELD is extended to **Normalized MELD (NMELD)** to remove the gap and bias of each edge length

Mean Occupation Area(MOA)

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.

Edge Density Distribution (EDD)

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

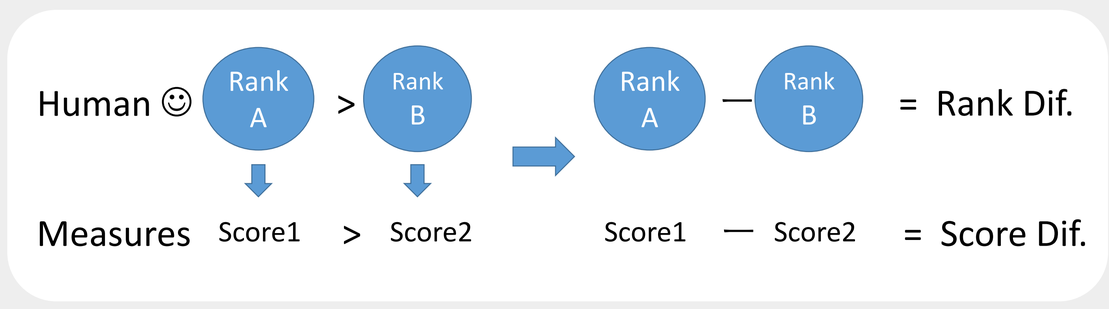
$$EDD = \frac{1}{n}\sum_{a\in A}|p(a) - p|$$

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)

Approach

If the tendency of human's answer like ranking has correlation with their quantified values in any questions,
we can say that the values can express the human cognition.
In this case, **the difference** between ranks has also correlation with **the differences** of measurement scores.

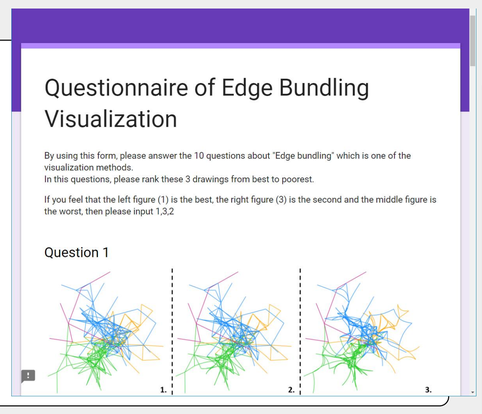
We check the differences between ranks and measurement scores and confirm the correlation and its significant.



Experiments

Questionnaire

- The questionnaire contained **10 questions** about the three graph drawing results.
- Each question shows the three graph including
  1. Original layout
  2. Force-Directed Edge Bundling(FDEB)
  3. Cluster-based Edge Bundling (CBEB))



Result

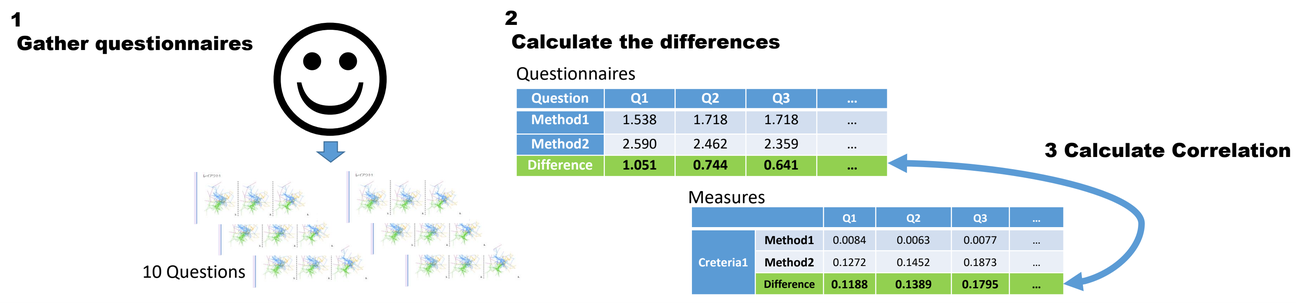
	NMELD	MELD	MOA	EDD
Correlation	**-0.697**	**-0.636**	0.234	**-0.644**
t-value	-2.569	-2.178	0.638	-2.229
p-value	0.033	0.061	0.541	0.056

- The results shows some correlations between the rankings given by the respondents and those given by the three measures (NMELD, MELD, EDD).

  → From the results, we can regard that NMELD, MELD, and EDD have a certain correlation with human cognition so that there is a possibility that these three measures can express human feeling for Edge Bundling.

Analysis Process

1. Ask 39 respondents to answer rank these drawings from best (score of 1) to poorest (score of 3) for 10 questions.
2. The average ranking of each of the four measures (MELD, NMELD, MOA, EDD) and the differences between FDEB and CBEB are calculated for each question.
3. Calculate the correlations between **these differences**



Future work

We conduct a questionnaire survey about graph layouts and examine the correlations between these layouts and human cognition with the more large number of students to acquire reliable results.