A Quality Metric for Visualization of Clusters in Graphs

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Motivation

- Clustering is an important task in graph analysis
- No metric exists that measures how faithfully a graph drawing displays the clustering structure of the graph
- Aim: define, implement and evaluate a quality metric quantifying how faithfully a graph drawing displays a graph’s clustering structure

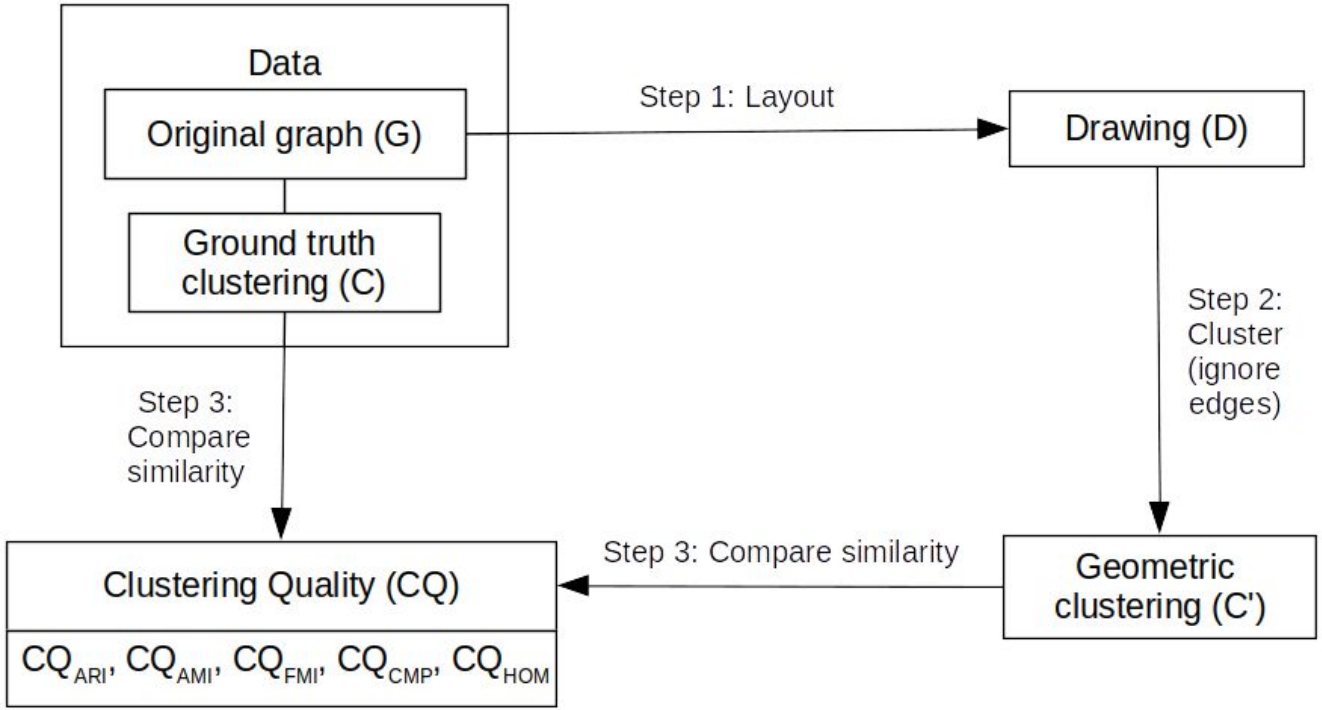
Contribution

1. Design and implement a new clustering quality metric

2. Experiment 1: Validate the clustering quality metric through graph drawing deformation experiments

3. Experiment 2: Compare various graph drawing algorithms using the clustering quality metric

Clustering Quality Metric: Framework



Clustering Quality Metric: Details

- Geometric clustering C': k-means clustering

- Clustering comparison metrics:
  - **Adjusted Rand Index (ARI):** measures clustering similarity based on # of item pairs classified into the same cluster in both clusterings & into different clusters in both clusterings
  - **Adjusted Mutual Information (AMI):** measures how much information of one clustering can be gained from the other
  - **Fowlkes-Mallows Index (FMI):** measures the similarity of C' to C using the number of true positives, false positives, and false negatives
  - **Completeness (CMP):** the extent to which all members of a cluster in C are assigned to the same cluster in C'
  - **Homogeneity (HOM):** the extent to which each cluster in C′ only contains members of the same cluster in C

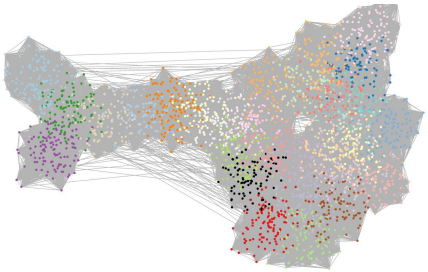
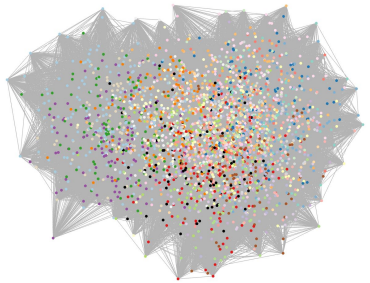
Experiment 1: Validation Experiment

- Validation experiment steps:
  1. Start with a good graph drawing with no cluster overlap
  2. Perturb vertex positions to deform the cluster structures in the drawing

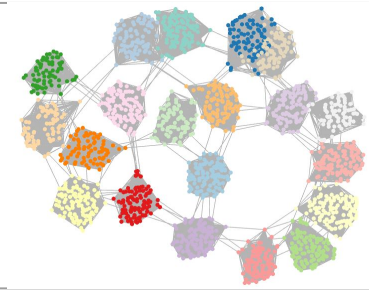
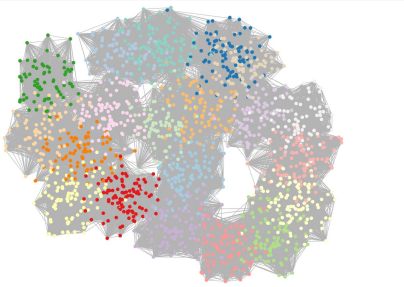
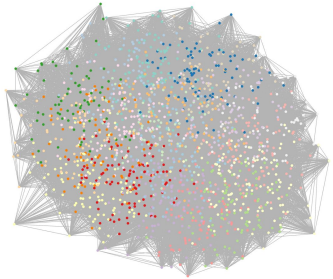
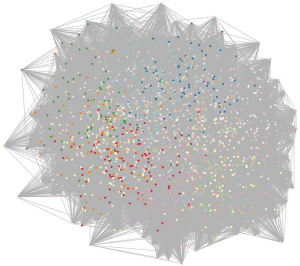
- Validation experiments performed on synthetic graphs with known ground truth clusters

- Hypothesis 1: Clustering quality metric scores will decrease as the drawings are further deformed

Validation Experiments Examples

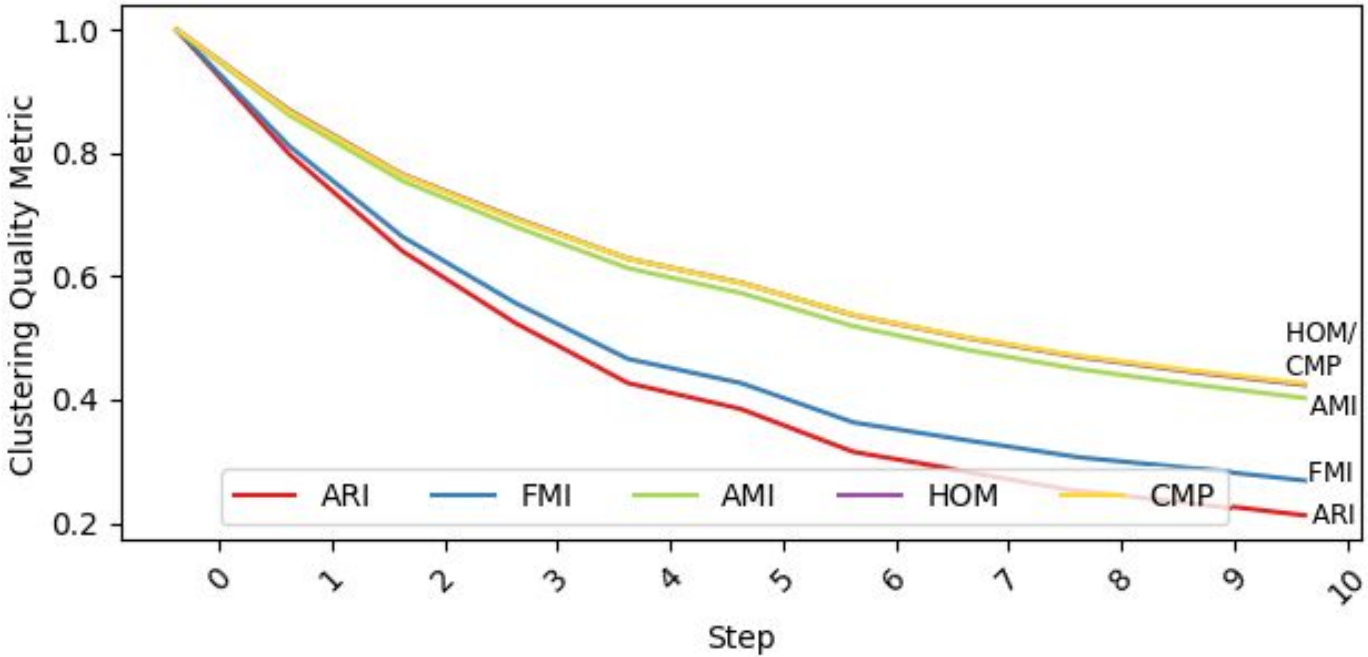
Step 0	Step 3
	
Step 7	**Step 10**
	

Validation Experiments Examples

Step 0	Step 3
	
Step 7	**Step 10**
	

Validation Experiments Results

- Scores decrease as the drawings are distorted, validating Hypothesis 1
- CQ_{ARI} and CQ_{FMI} are more sensitive in capturing changes in quality



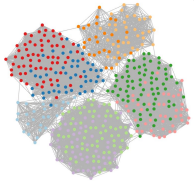
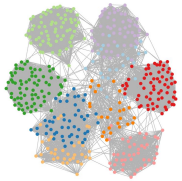
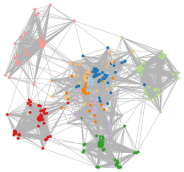
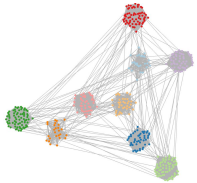
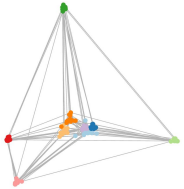
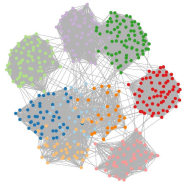
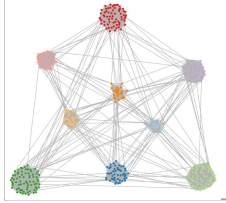
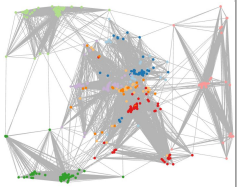
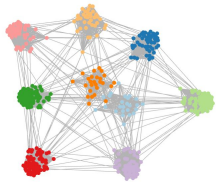
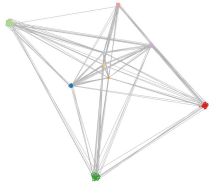
Experiment 2: Layout Comparison

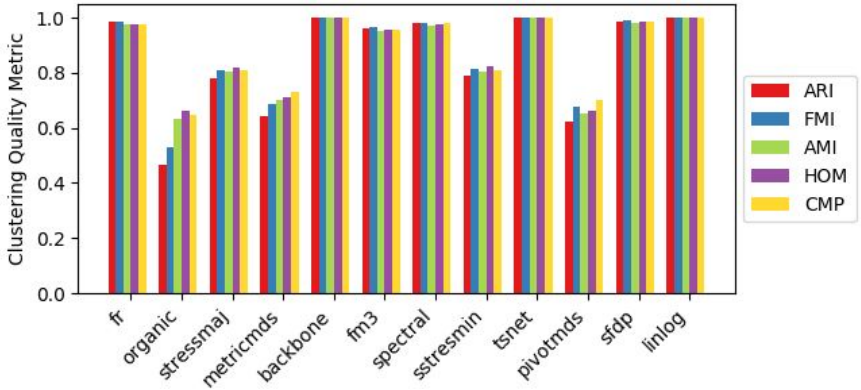
- Layout comparison using clustering quality metrics

- Cluster-focused layouts: ***LinLog, Backbone, tsNET***
- Other layouts:
    - Force-directed layouts (Fruchterman Reingold (FR), Organic)
    - Multilevel force-directed layouts (FM3, sfdp)
    - MDS-based layouts (Metric MDS, Pivot MDS)
    - Stress-based layouts (Stress Majorization, Sparse Stress Minimization)
    - Spectral layout

- Hypothesis 2: the cluster-focused layouts will score higher on clustering quality metrics than other layouts

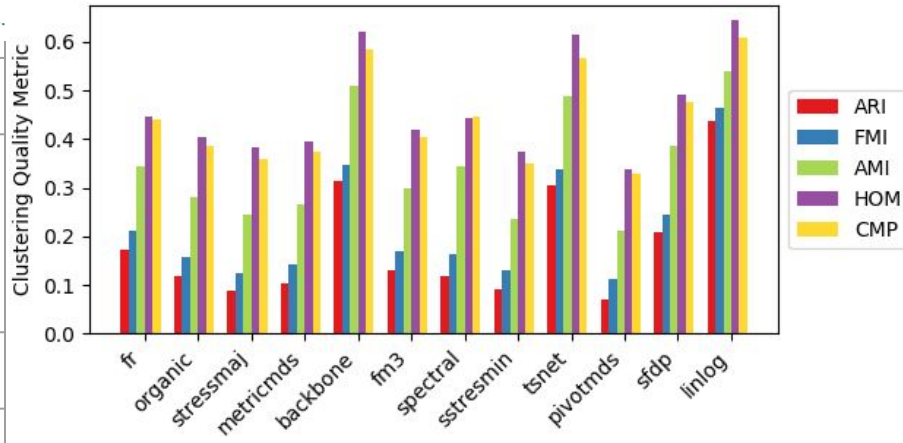
Layout Comparison Example: Synthetic dataset

FR	Organic	Stress Maj.	Metric MDS
			
Backbone	**FM3**	**Spectral**	**S. Stress Min.**
			
tsNET	**Pivot MDS**	**sfdp**	**LinLog**
			



Layout Comparison Examples: real world dataset

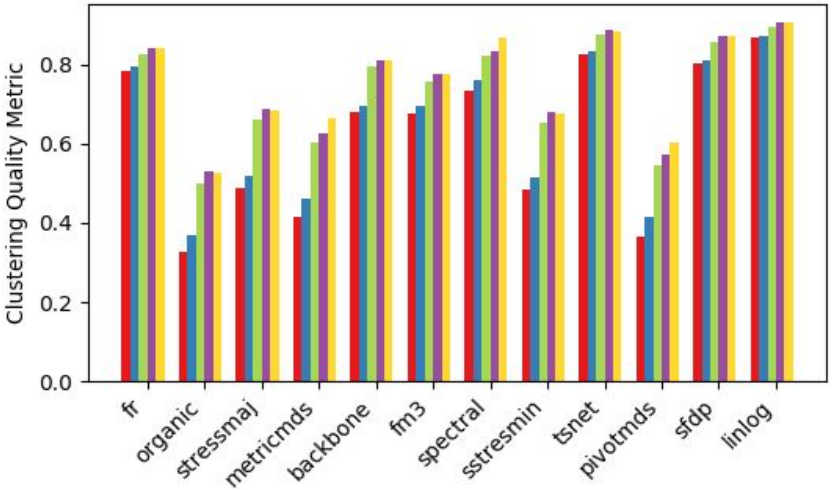
FR	Organic	Stress Maj.	Metric MDS
Backbone	FM3	Spectral	S. Stress Min.
tsNET	Pivot MDS	sfdp	LinLog



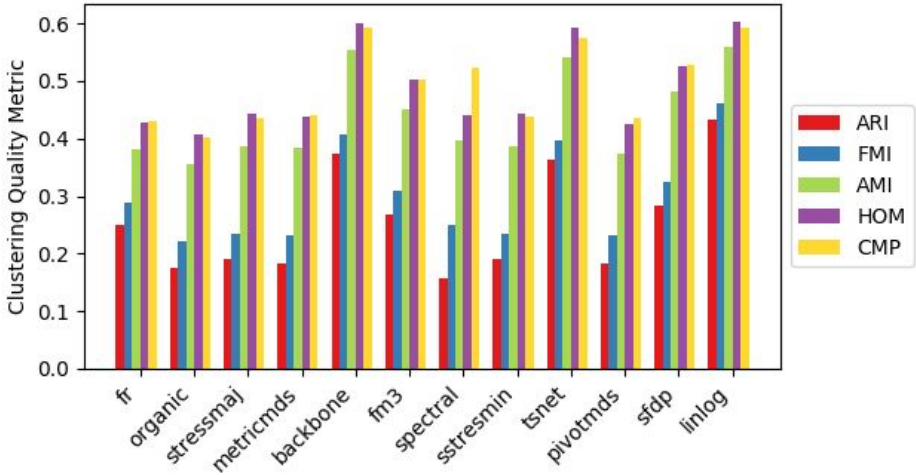
Data taken from: Leskovec, J., Krevl, A.: SNAP Datasets: Stanford large network dataset collection. http://snap.stanford.edu/data (Jun 2014)

Layout Comparison Results

- ***LinLog*** and ***tsNET*** attain the top two scores averaged over all datasets, supporting Hypothesis 2
- ***Backbone*** is in the top three for real world datasets
- ***sfdp*** scores highest among non-cluster focused layouts
- ***Organic*** and ***MDS*** layouts fall on the low end of CQ scores



Average over all comparison datasets



Average over real world datasets

Summary

- Designed, implemented, and validated a clustering quality metric for graph drawings
- Evaluated various graph layout algorithms using the metrics and validated the claims of some cluster-focused layout

Future work

- Combination with readability metrics (e.g. to address node overlap issues)
- Use other geometric clustering methods
- Extension to data clustering metrics