A Novel Ordering Strategy for 1D Pixel Visualization for Dynamic Networks

Bachelor Project Data Analysis and Visualization

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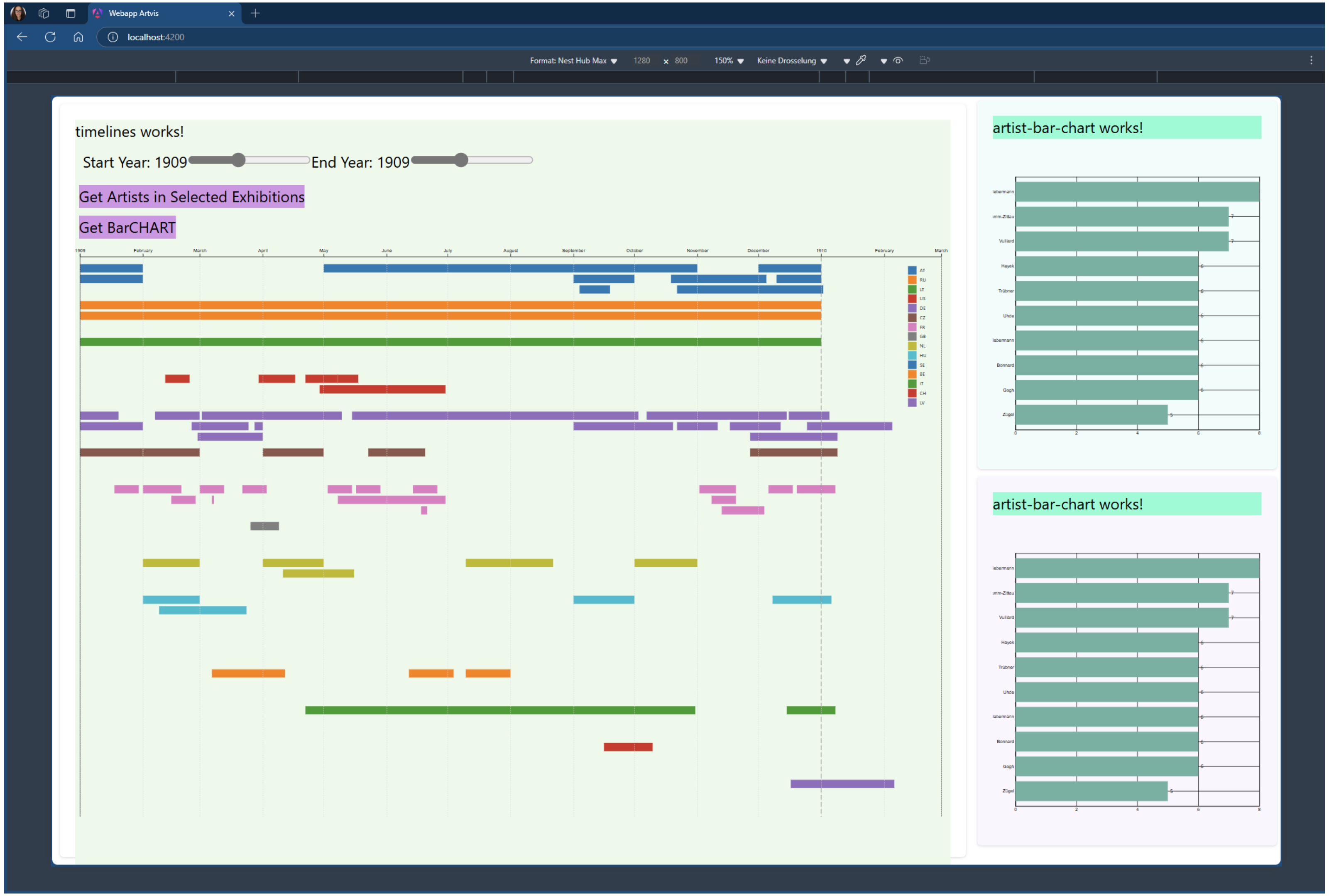
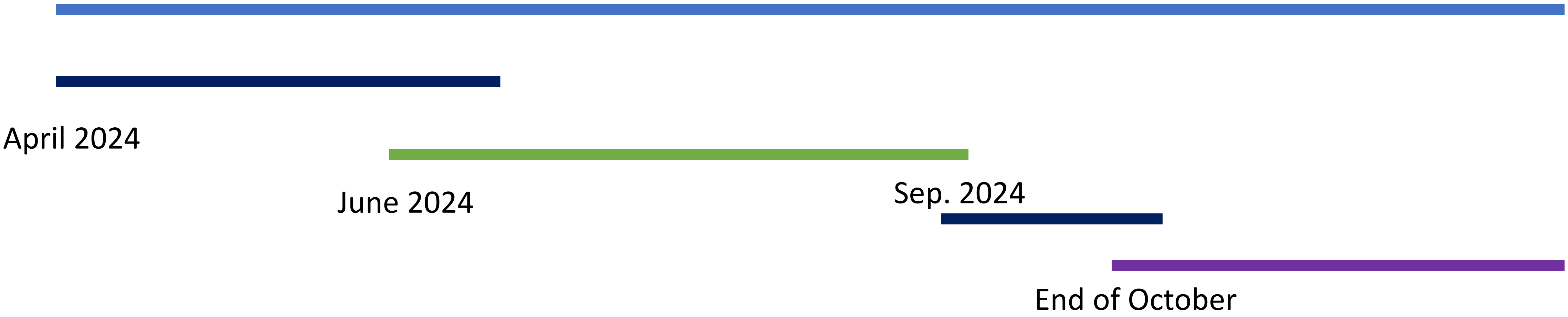
First Dashboard

Introduction



Project Timeline

Introduction

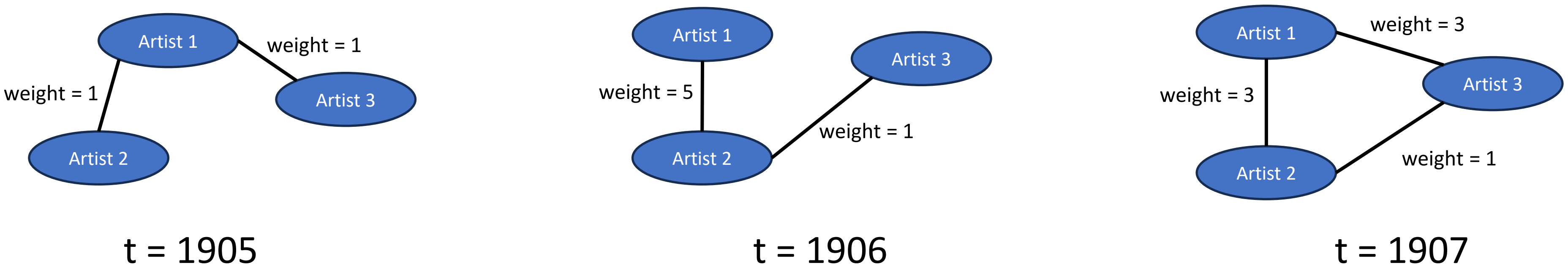


- First Dashboard
- Internship at University of Alberta, Canada
- Decision to switch to Design Study

Dynamic Network in Modern Exhibition Data

Introduction

- Artists
- Exhibitions
- Both combined: dynamic network of co-exhibiting artists

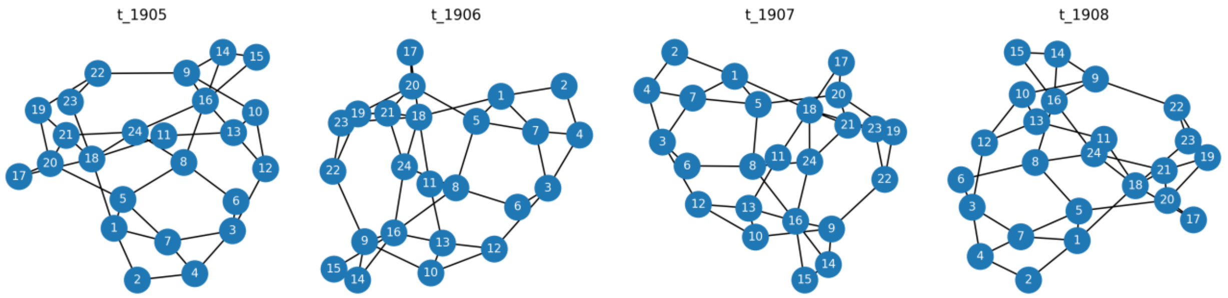


Goal: effectively analyze structural changes in that dynamic network

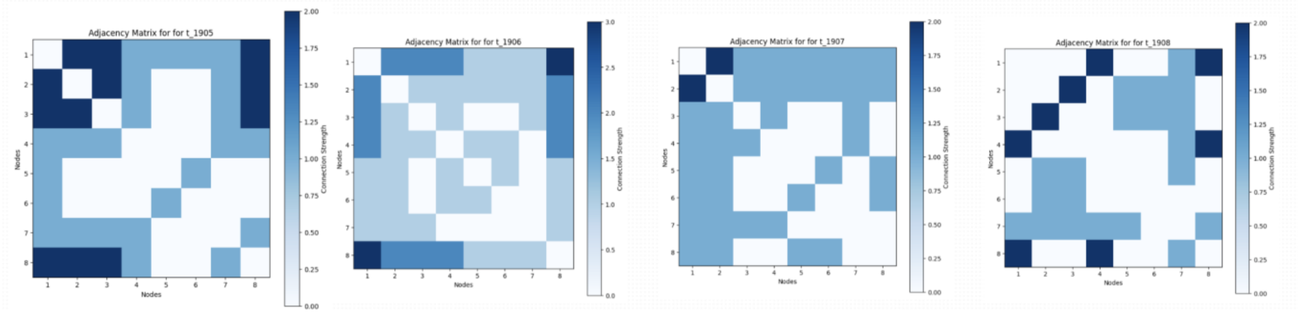
Different Dynamic Network Visualization Techniques

Motivation

- Node-Link Diagrams



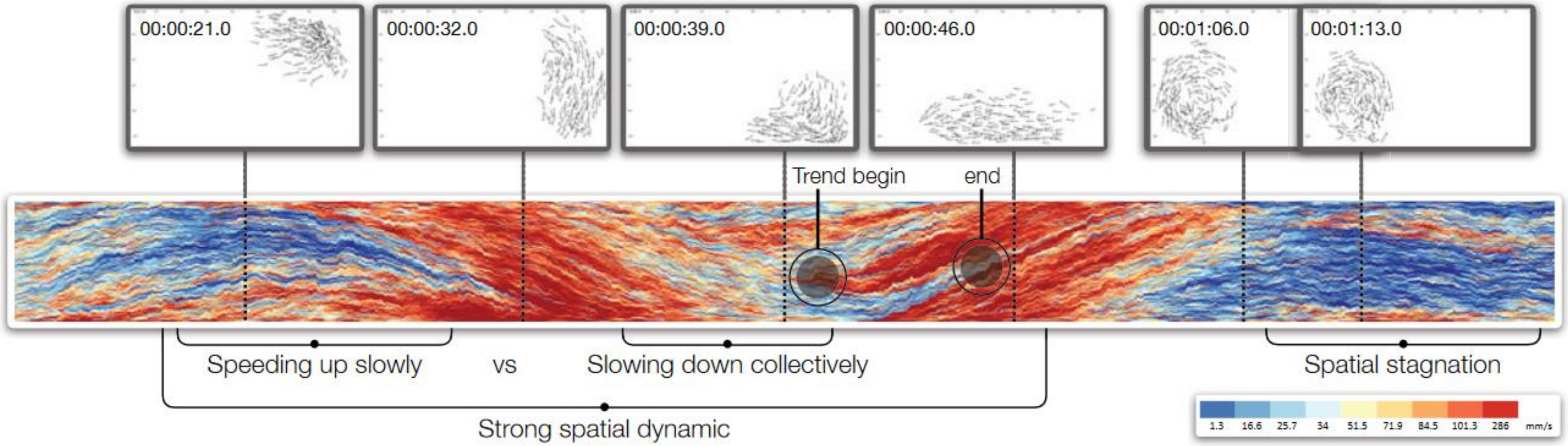
- Adjacency Matrices



Pixel Visualization – Related Work

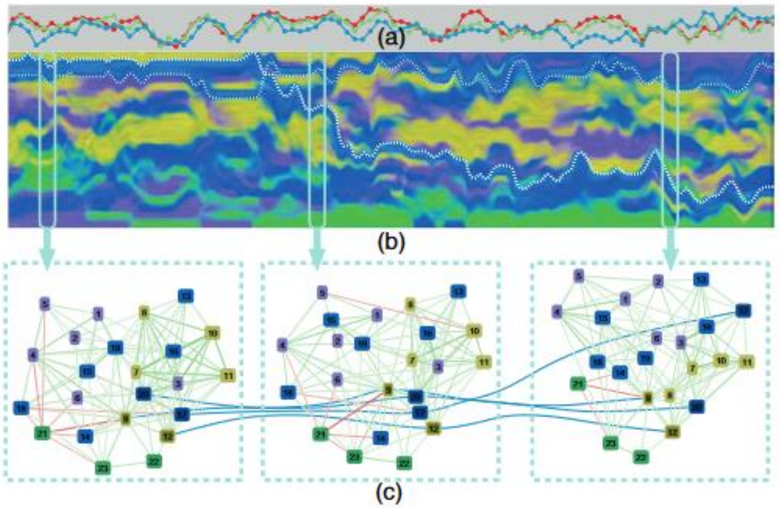
Motivation

- MotionRugs



Buchmüller et al., 2019. MotionRugs: Visualizing Collective Trends in Space and Time.

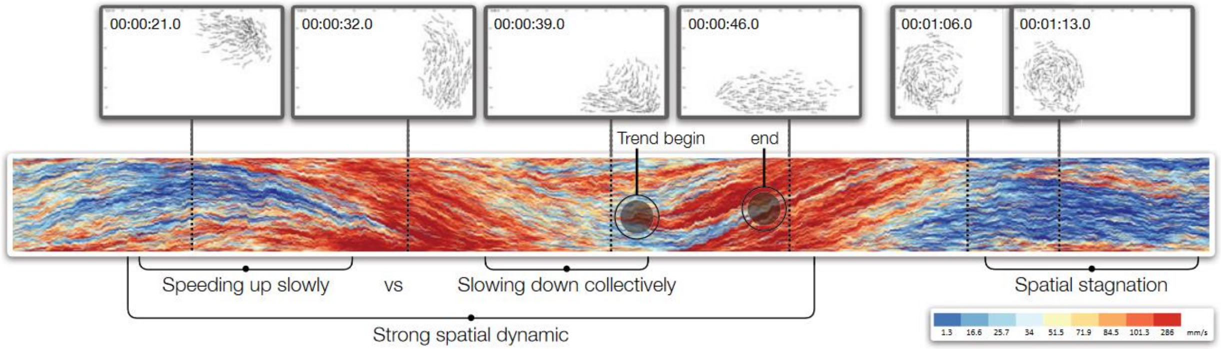
- GraphFlow

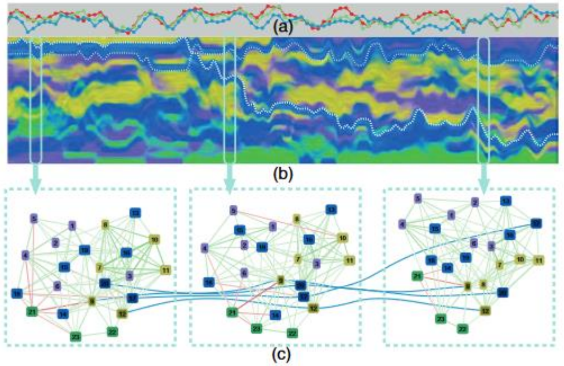


Cui et al., 2014. Let It Flow: A Static Method for Exploring Dynamic Graphs.

NetworkRugs - 1D Pixel Displays for Dynamic Networks

Motivation





Network Rugs

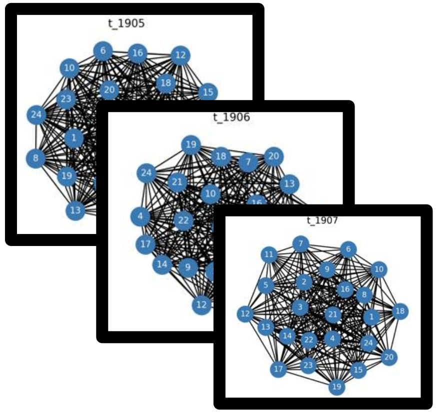
= compact visualization of network changes over time

The NetworkRug Technique

Approach

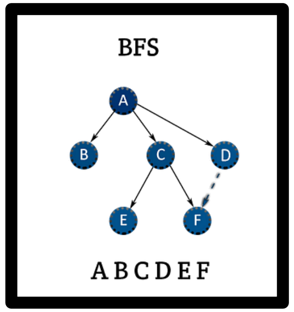
Data

→ 1



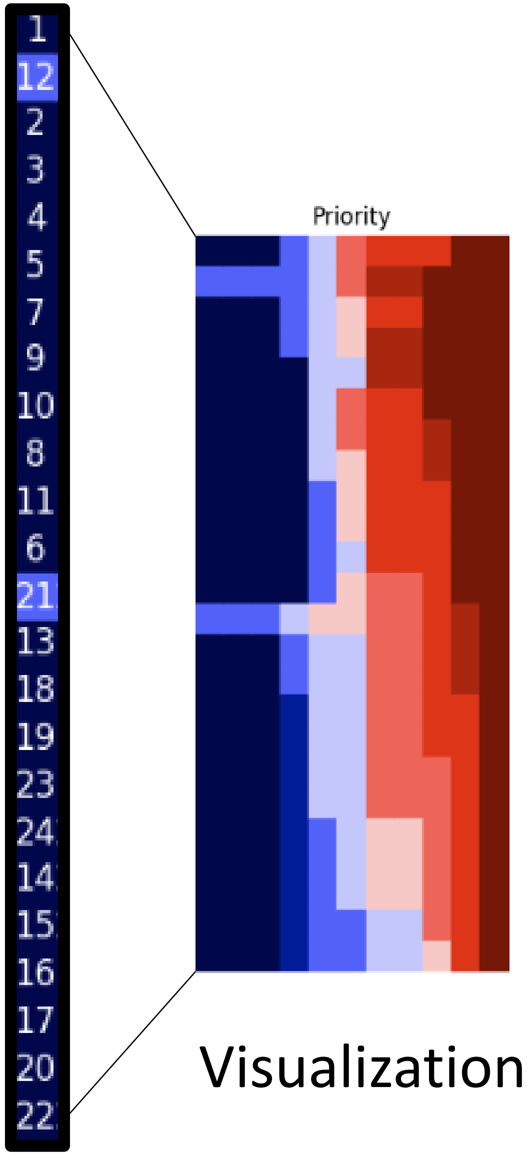
Graph Data

→



1D Ordering

→



Visualization

1 apply graph data structure to each time frame

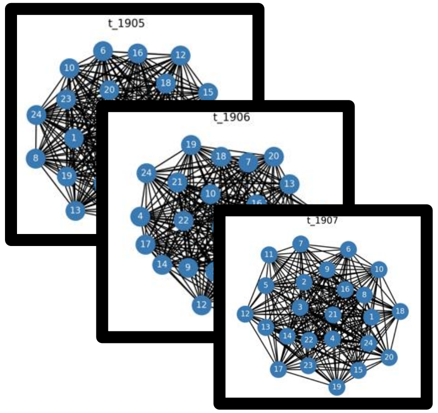
Project Environment and Tools

Data Structure

The NetworkRug Technique

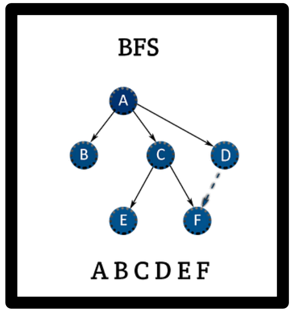
Approach

Data

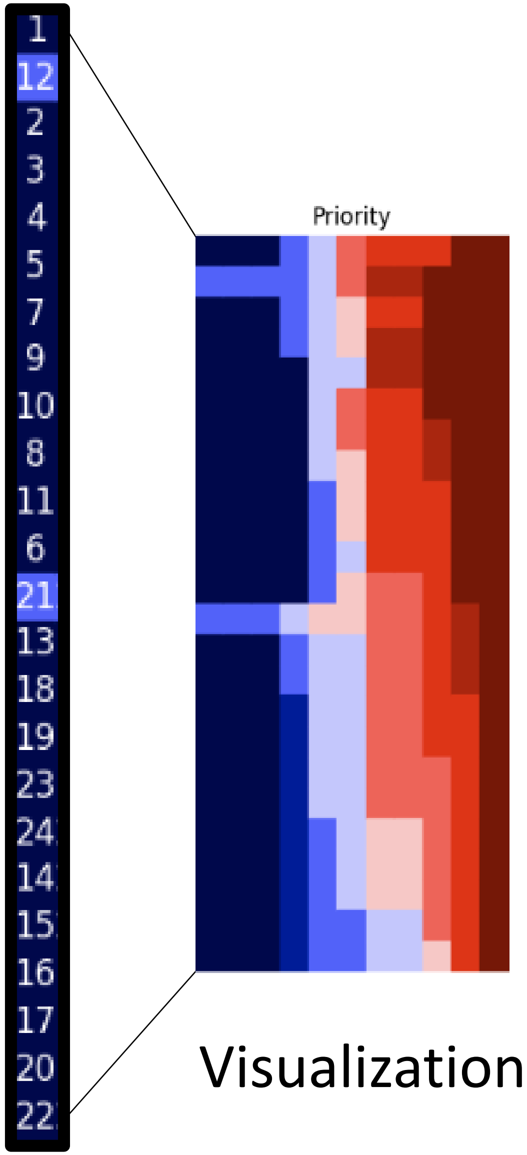


Graph Data

2



1D Ordering



Visualization

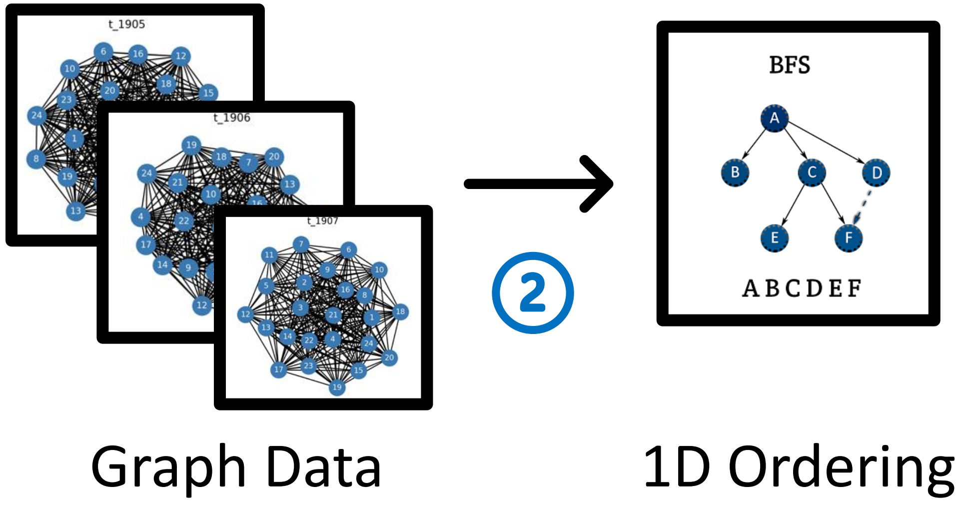
2 apply ordering strategy per time frame

Overview: Ordering Strategies

Ordering Strategies

- Goals:
    - Prioritize highly connected nodes
    - Ensure locality
    - Minimize redundant processing

- Different approaches:
    - Community detection-based
    - Linear metrics-based
    - Traversal-based

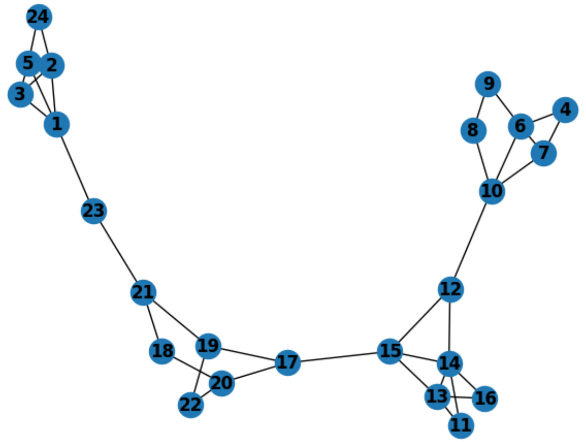


Community Detection-Based Ordering

Ordering Strategies

- community detection algorithm to find node groupings
- Orders nodes by community membership
  - Ensures nodes in same community are grouped together

- Problems:
  - Non-deterministic, detected communities can be different
  - Produces non-overlapping communities
  - Enforces groups too much, not flexible enough to see change



- [1, 2, 3, 5, 24, 17, 18, 19, 20, 21, 22, 23, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16]
- [1, 2, 3, 5, 24, 4, 6, 7, 8, 9, 10, 17, 18, 19, 20, 21, 22, 23, 11, 12, 13, 14, 15, 16]

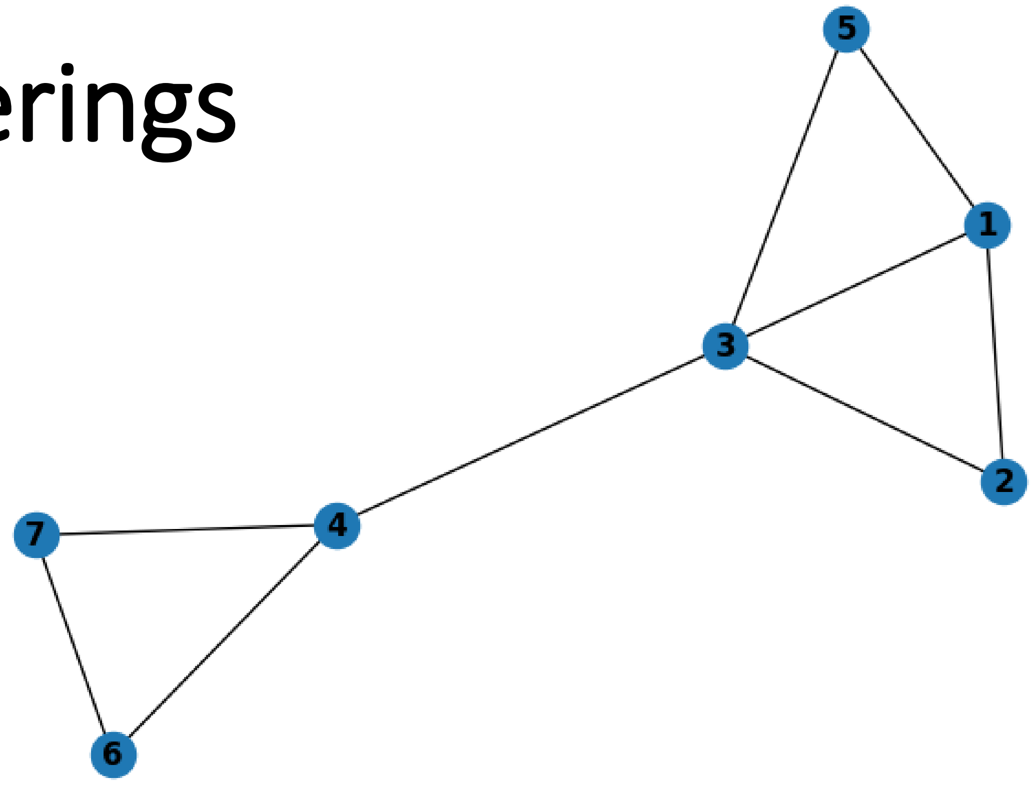
Linear Metrics-Based Orderings

Ordering Strategies

- Makes usage of graph metrics of a node
  - Degree/ Degree centrality
  - Eigenvector centrality
  - Closeness centrality
  - Betweenness centrality

- Orders nodes based on their value
  - Tie-Breaking Criterion: ID

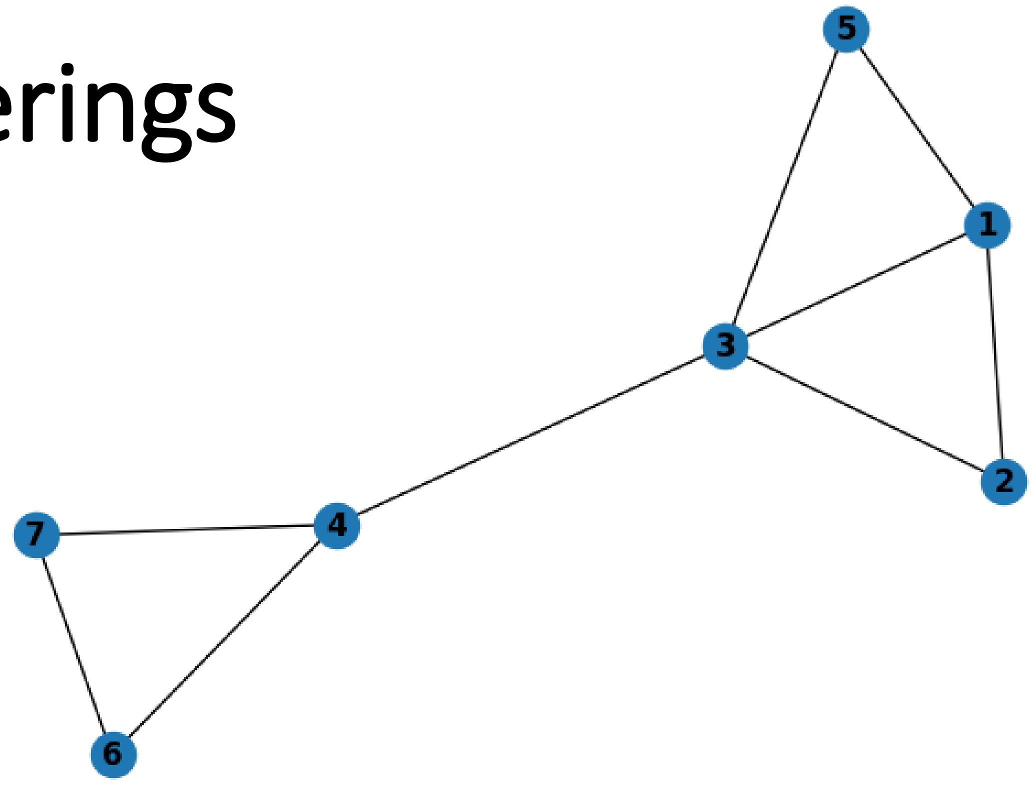
- degree [3, 1, 4, 2, 5, 6, 7]
- closeness [3, 4, 1, 2, 5, 6, 7]
- betweenness [3, 4, 1, 2, 5, 6, 7]
- eigenvector [3, 1, 2, 5, 4, 6, 7]



Node	Betweenness	Degree	Degree Centrality	Eigenvector
1	0.033	3	0.5	0.47
2	0.0	2	0.333	0.371
3	0.633	4	0.667	0.56
5	0.0	2	0.333	0.371
4	0.533	3	0.5	0.34
6	0.0	2	0.333	0.192
7	0.0	2	0.333	0.192

Linear Metrics-Based Orderings

Ordering Strategies



- Makes usage of graph metrics of a node
  - Degree/ Degree centrality
  - Eigenvector centrality
  - Closeness centrality
  - Betweenness centrality

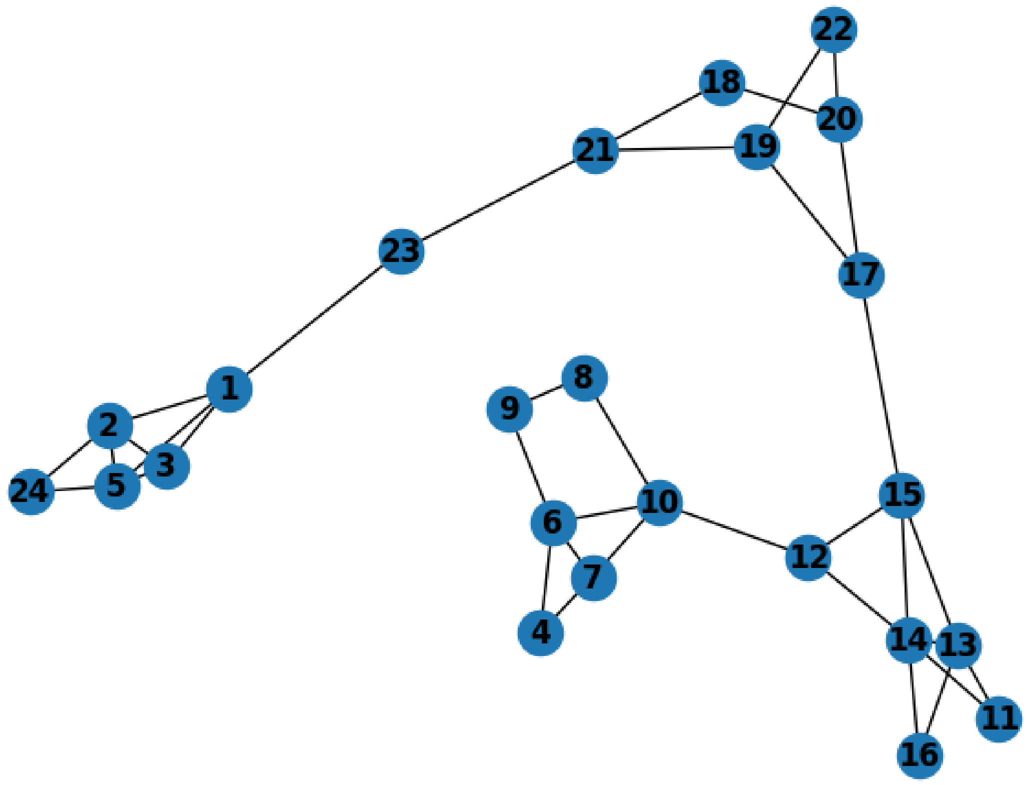
- Orders nodes based on their score
  - Tie-Breaking Criterion: ID

- Problems:
  - Breaks up connections between nodes, no locality
  - but possibly good for certain tasks, e.g. to identify most influential artists

Traversal Based-Orderings

Ordering Strategies

- Explores node relationships based on traversal
- Depth First Search (DFS)
  - Start at a node, explore as far as possible
  - backtrack when no further nodes exist

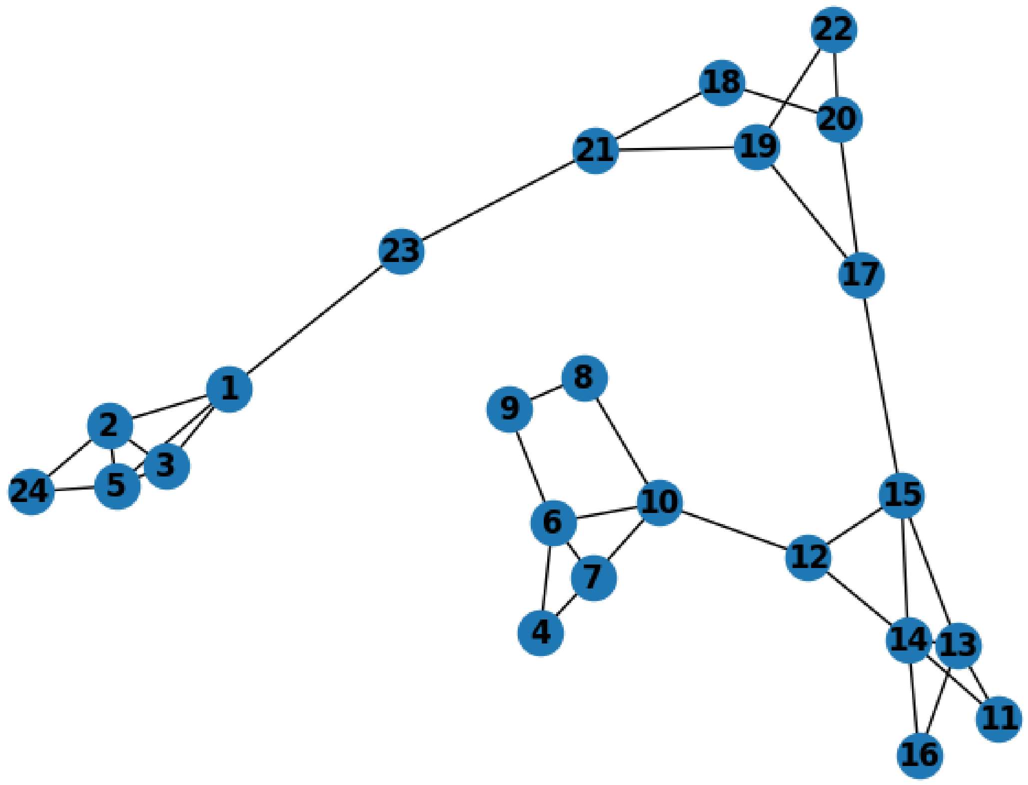


DFS Orderings:
[1, 2, 3, 5, 24, 23, 21, 18, 20, 17, 15, 12, 10, 6, 4, 7, 9, 8, 14, 11, 13, 16, 19, 22]

Traversal Based-Orderings

Ordering Strategies

- Explores node relationships based on traversal
- Depth First Search (DFS)
  - Start at a node, explore as far as possible
  - backtrack when no further nodes exist
- Breath First Search (BFS)
  - Starts at a node, explores nodes layer by layer
    - sorted by weight
    - sorted by common neighbors
    - Combination of weight + common neighbors + priority queue



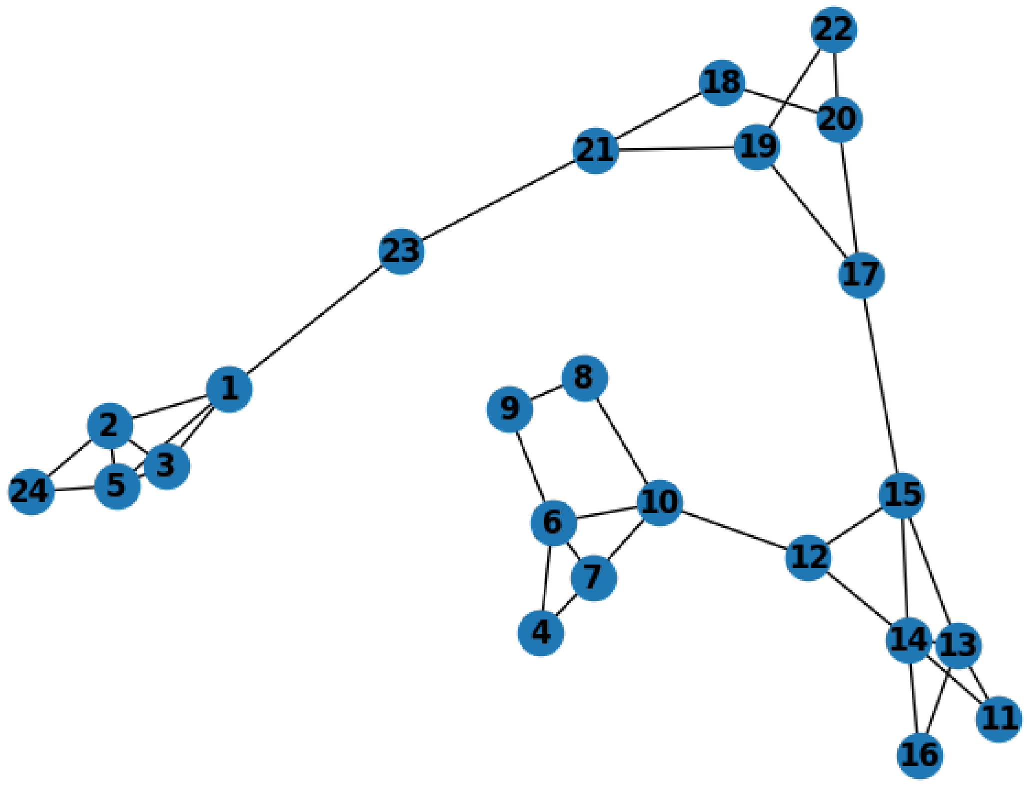
BFS Orderings:
weight: [1, 2, 3, 5, 23, 24, 21, 18, 19, 20, 17, 22, 15, 12, 13, 14, 10, 11, 16, 6, 7, 8, 4, 9]
com_n: [1, 2, 3, 5, 23, 24, 21, 18, 19, 20, 17, 22, 15, 14, 12, 13, 11, 16, 10, 6, 7, 8, 4, 9]
priority:[1, 2, 5, 3, 24, 23, 21, 19, 17, 15, 14, 13, 12, 11, 16, 10, 6, 7, 4, 20, 8, 9, 18, 22]

Traversal Based-Orderings

Ordering Strategies

- Explores node relationships based on traversal

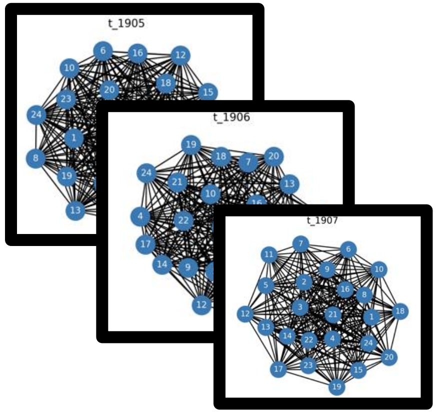
- Problems:
  - need to specify Start node
  - Artifacts



The NetworkRug Technique

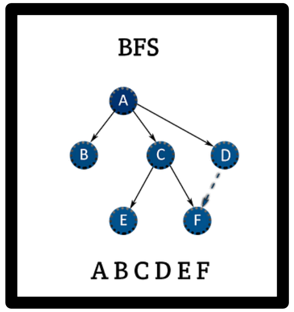
Approach

Data

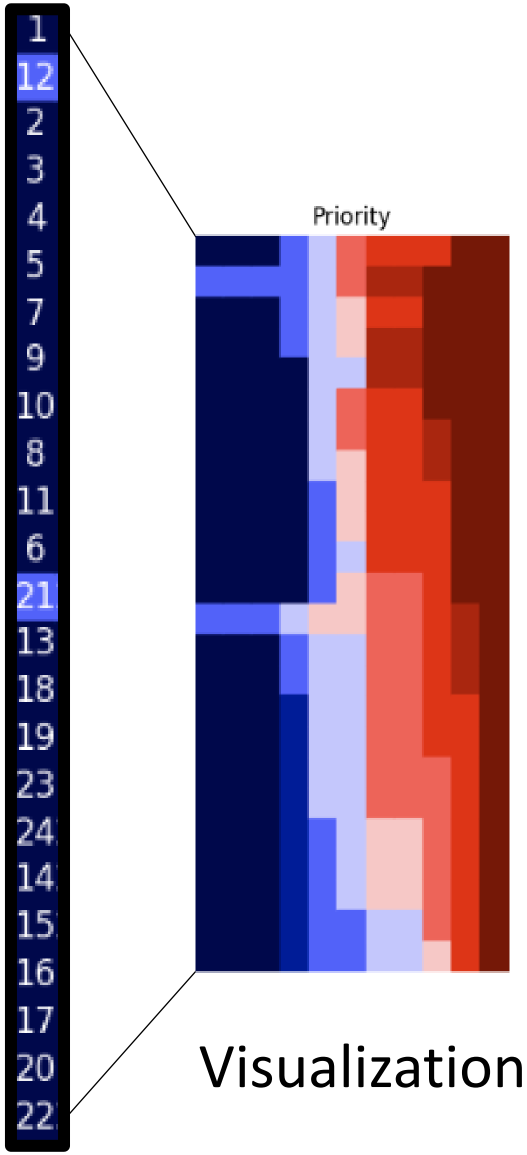


Graph Data

③



1D Ordering



Visualization

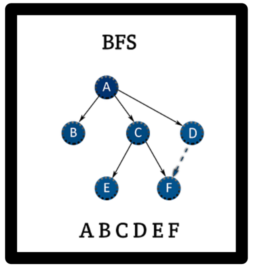
③ sequential alignment of the slices on temporal axis and visualization

Layout Decisions

Visualization

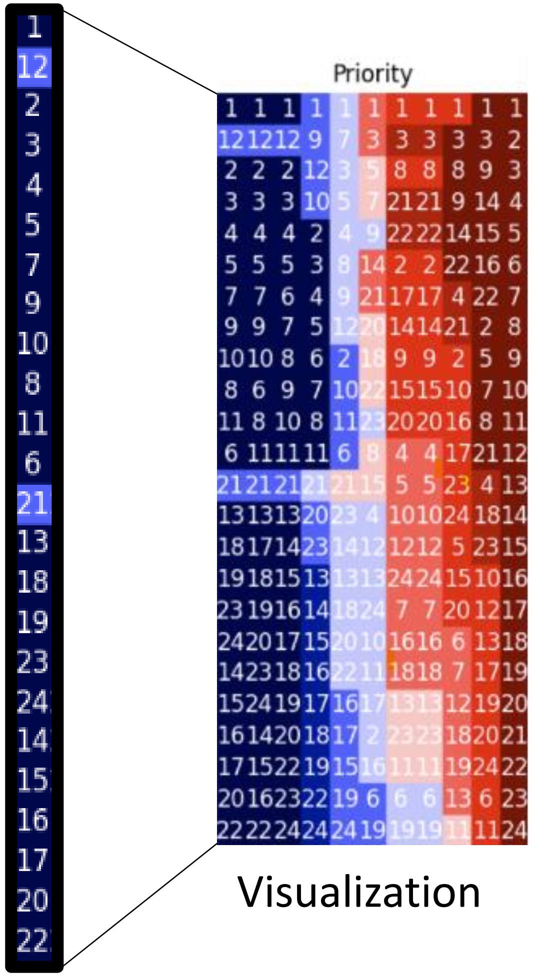
- How do we map the ordering to the visualization?

[1, 12, 2, 3, 4, 5, 7, 9 ,10, 8, 11, 6 ,21, 13, 18, 19, 23, 24, 14, 15, 16, 17, 20, 22]



1D Ordering

③

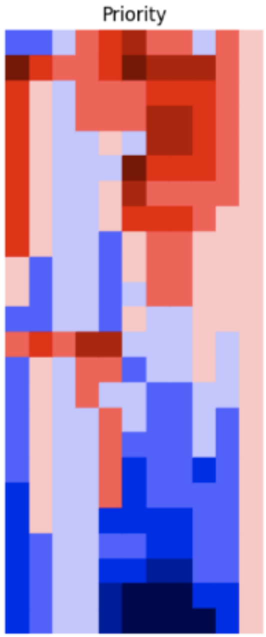


Visualization

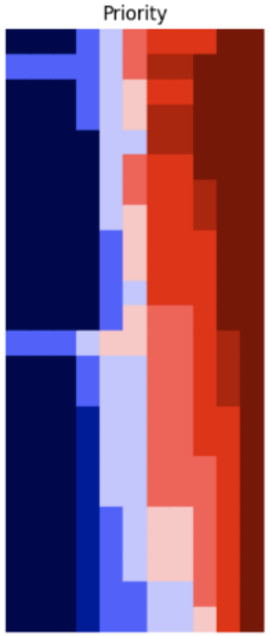
Color Encoding

Visualization

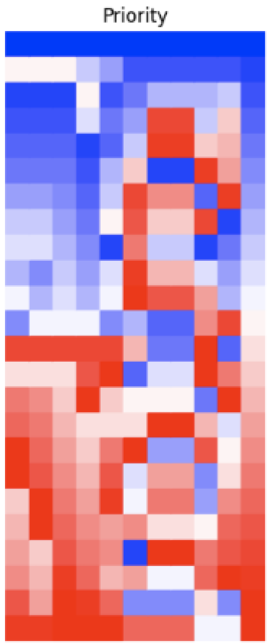
- each pixel represents one artist in one time frame
- coloring by different features, using different colormaps improves ability to identify and distinguish patterns



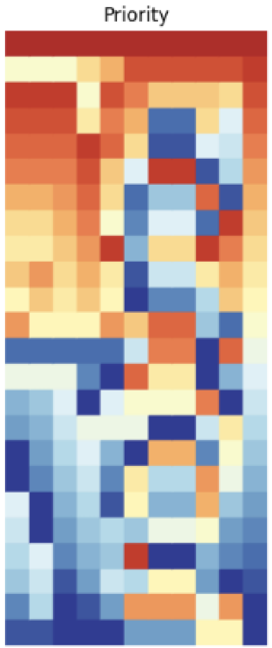
Closeness



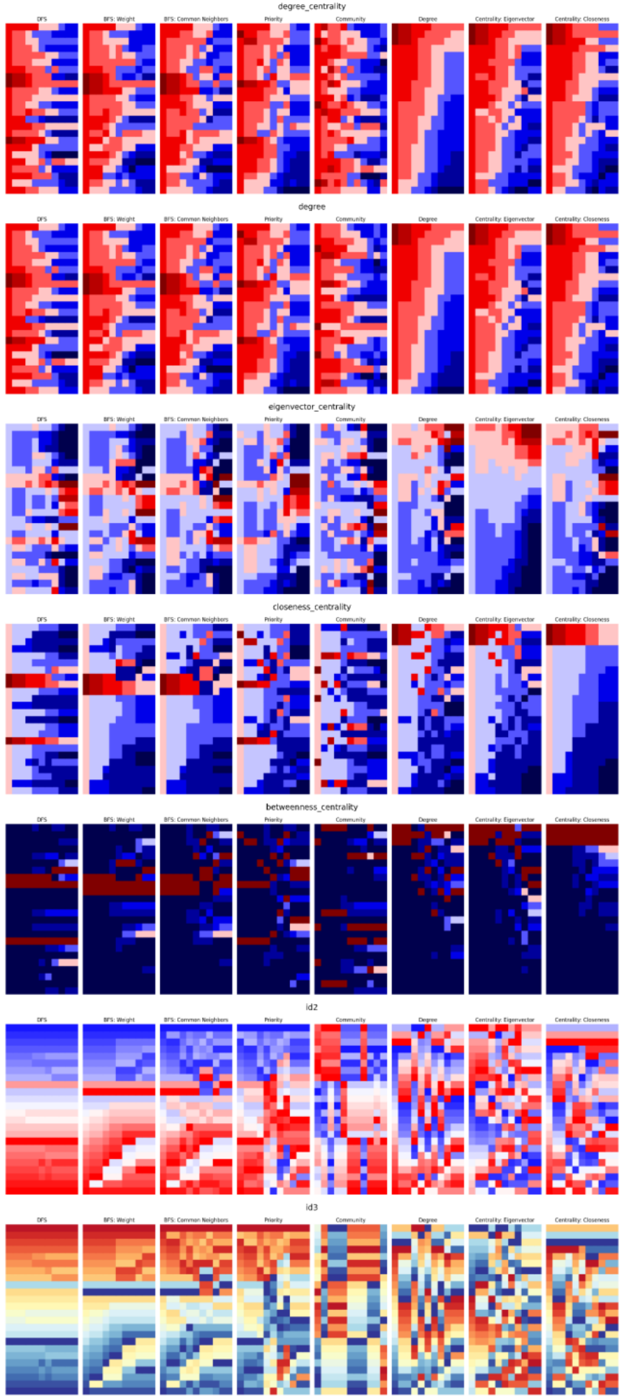
eigenvector



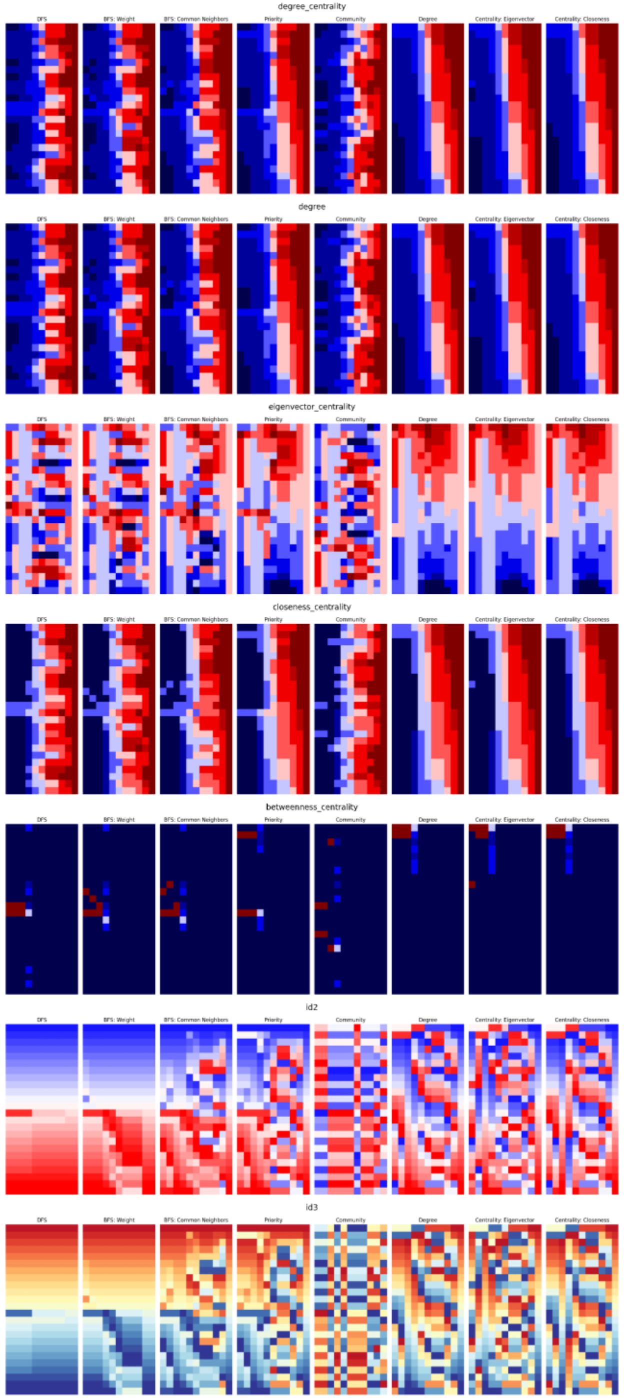
id red-blue



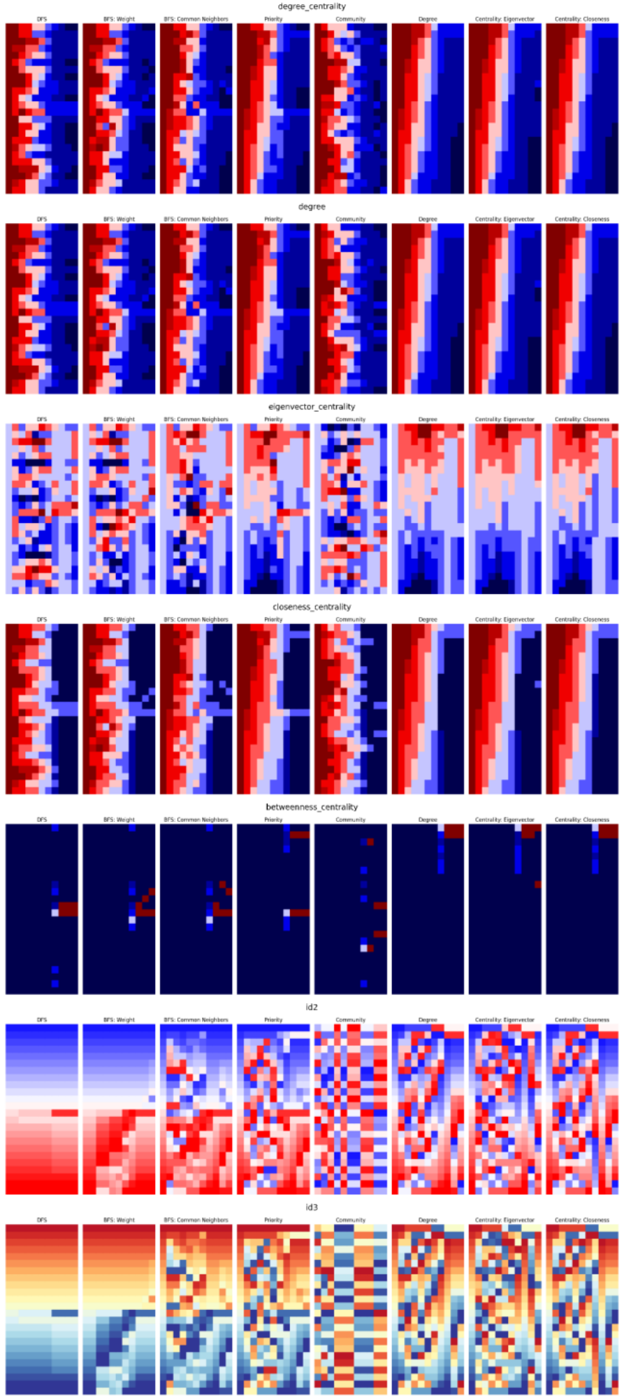
id red-yellow-blue



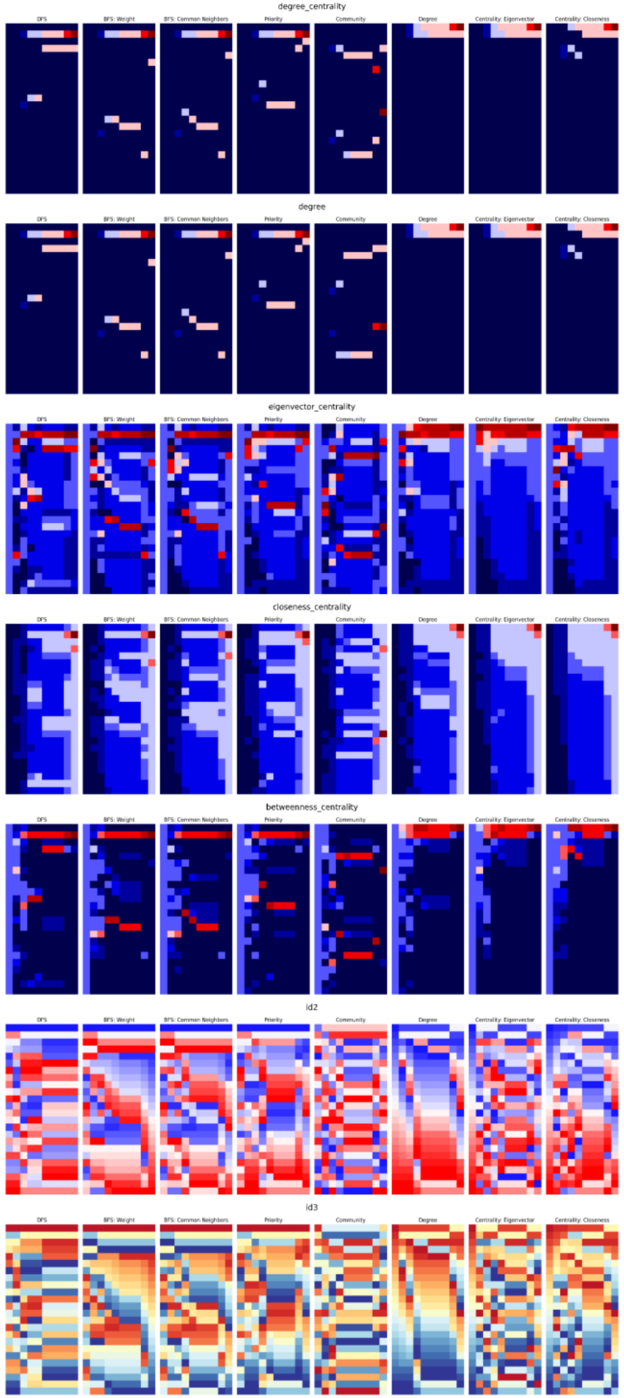
Comparison for Three Groups unlabeled



Comparison for Merge unlabeled



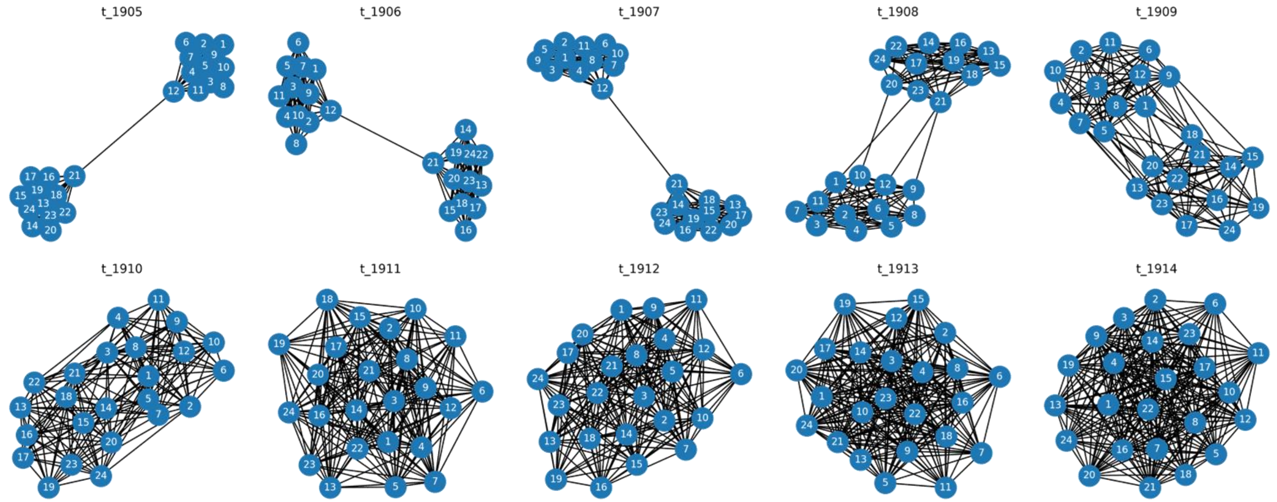
Comparison for Split unlabeled

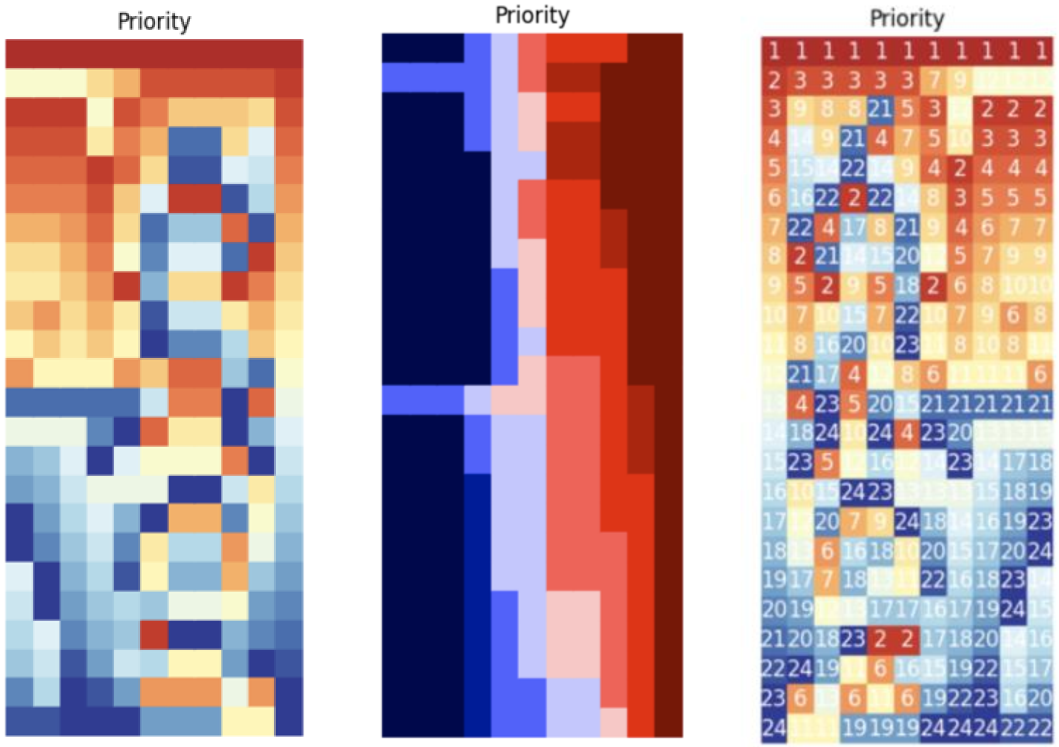


Comparison for Trend unlabeled

Results: Merge and Split

Evaluation





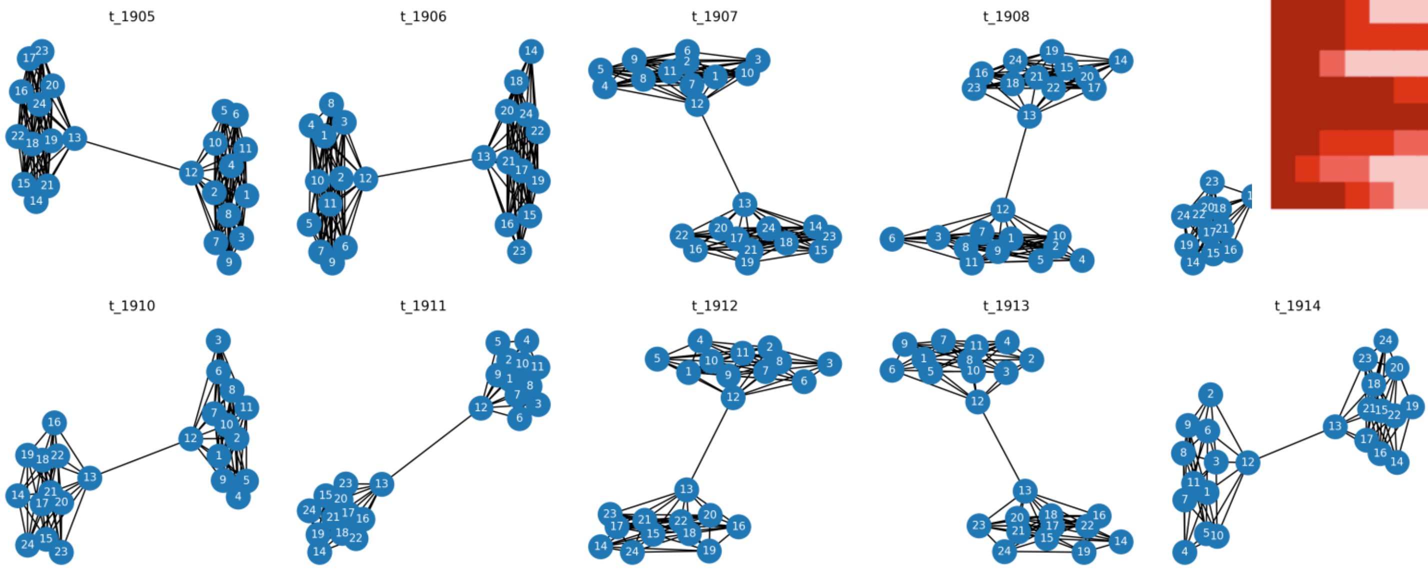
ID coloring

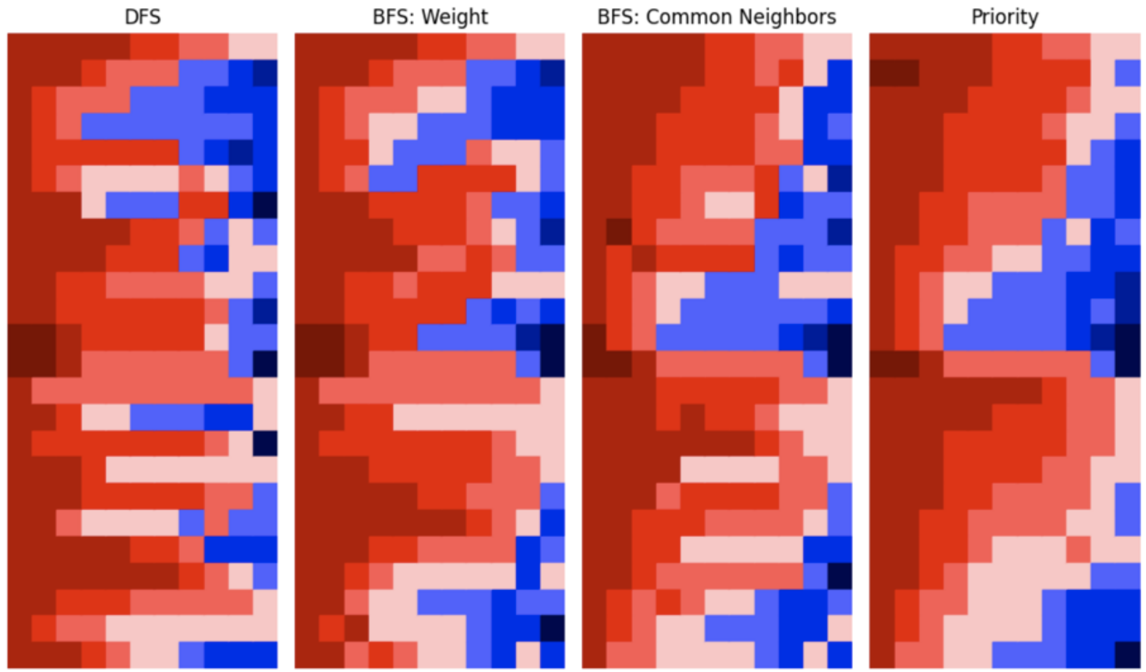
closeness coloring

split

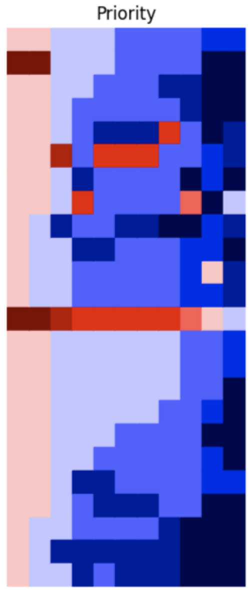
Result: Two Groups

Evaluation





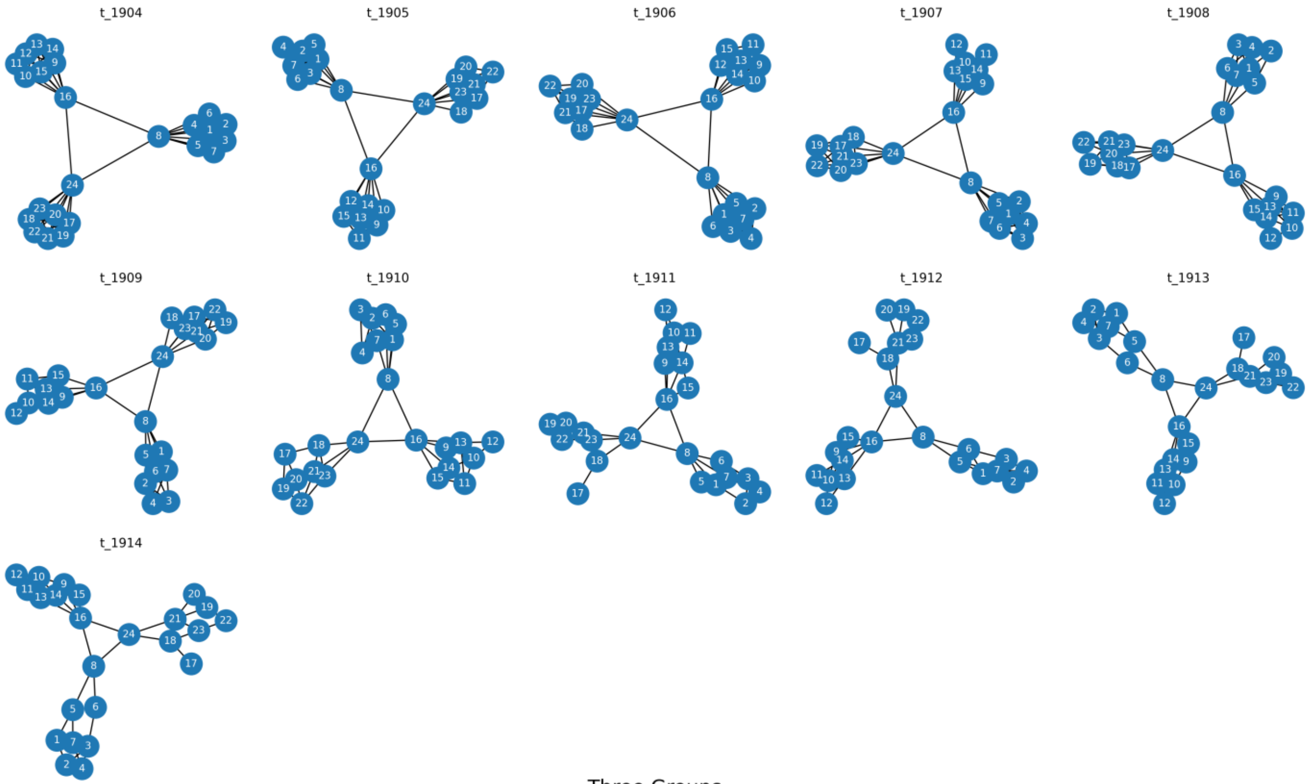
degree coloring



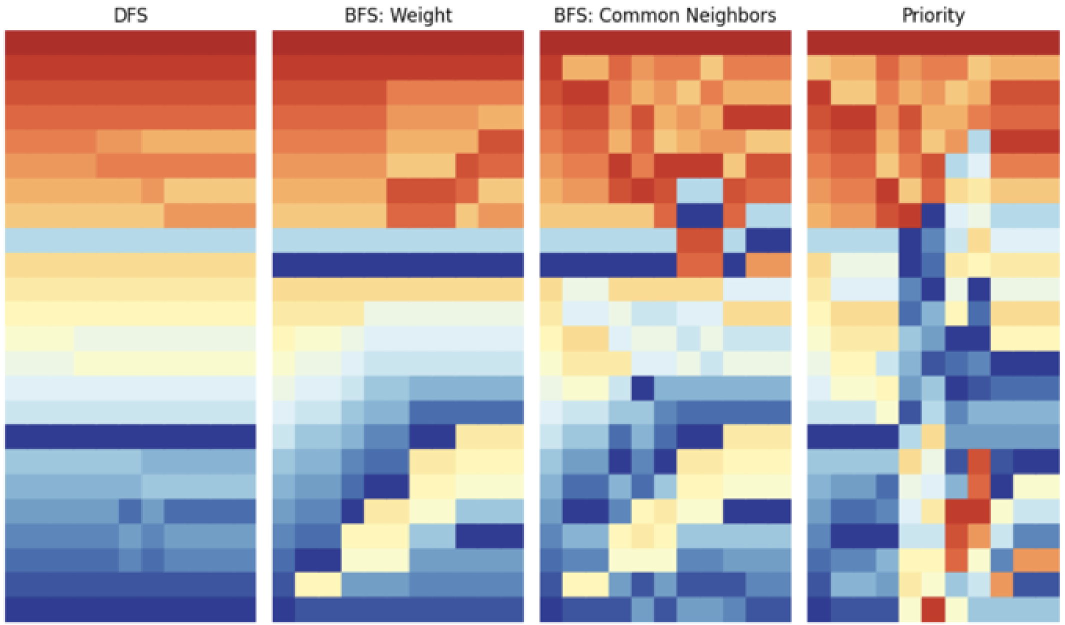
closeness coloring

Results: Three Groups

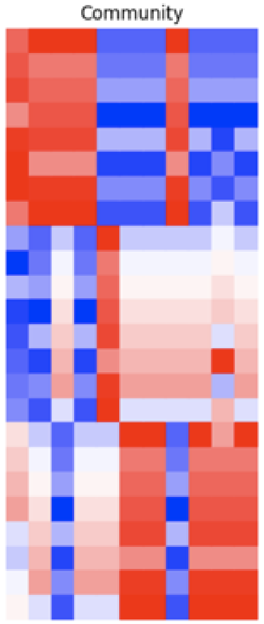
Evaluation



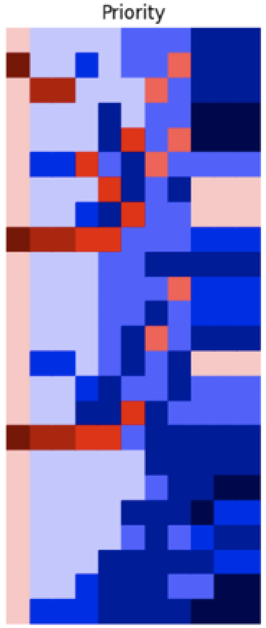
Three Groups



ID coloring



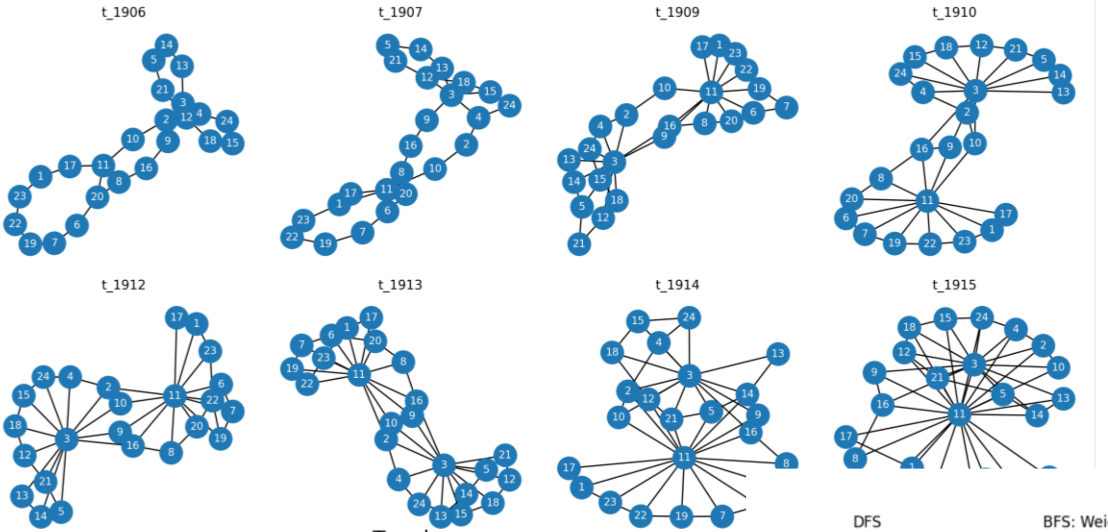
ID coloring



closeness coloring

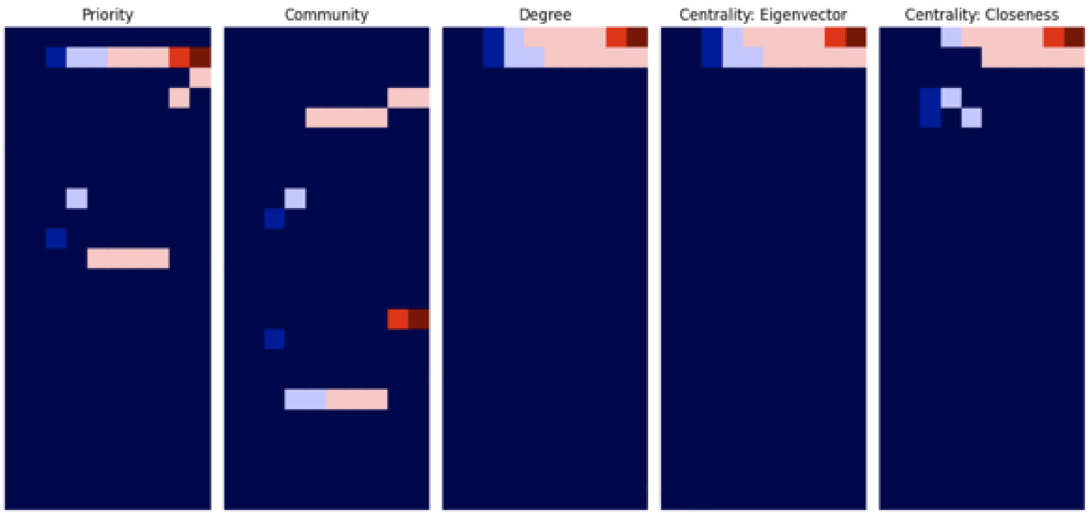
Results: Trend

Evaluation

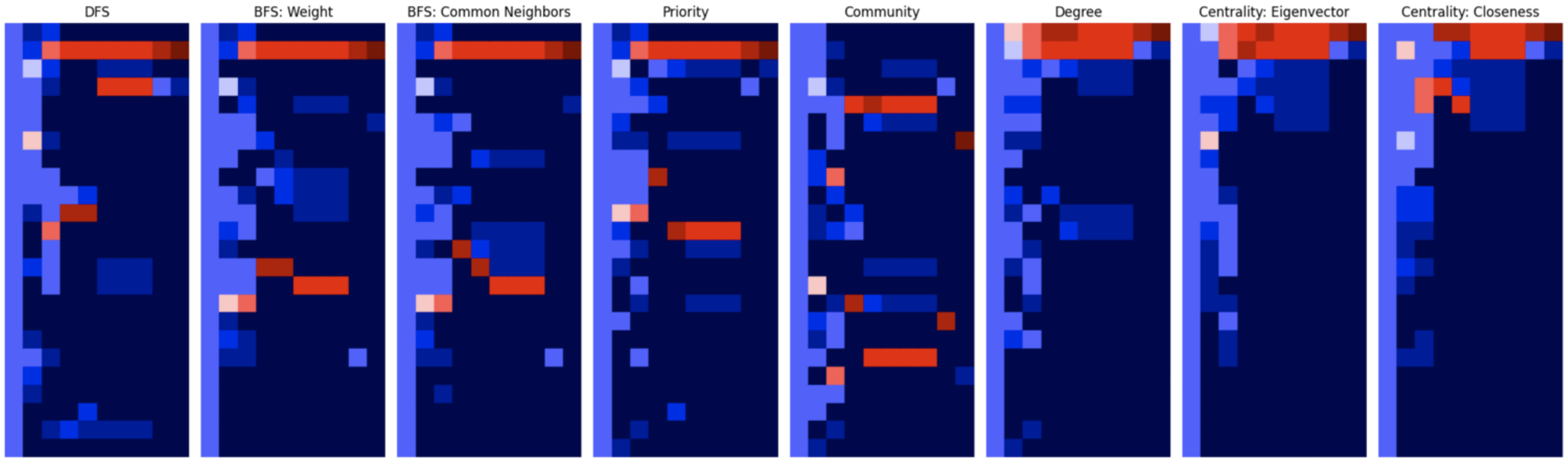


Trend

degree coloring



betweenness_centrality coloring



Limitations

Conclusion

- Visual outcome highly sensitive to ordering strategy
- ID has no semantic meaning
- Validation only on artificial dataset
- High degree/ same exhibition not necessarily meaningful

Outlook to Bachelor Thesis

Conclusion

- Needs to be tested on much bigger datasets
- Edge Weights
- Delay Effect
- Network Embedding/Projection as Ordering Strategy

Conclusion

Conclusion

- This is a novel approach
- We introduce one way to solve it – still experimental
- Choice of ordering strategy is key
- Closeness coloring + priority ordering most promising

References

[1] Juri Buchmüller, Dominik Jackle, Eren Cakmak, Ulrik Brandes, and Daniel A. Keim. MotionRugs: Visualizing Collective Trends in Space and Time. IEEE Transactions on Visualization and Computer Graphics, 25(1):76–86, January 2019.

[2] Juri F. Buchmüller, Udo Schlegel, Eren Cakmak, Daniel A. Keim, and Evanthia Dimara. SpatialRugs: A compact visualization of space and time for analyzing collective movement data. Computers & Graphics, 101, December 2021.

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[5] Marie Stolk. GroupRugs: Visualizing Group Motion.

[6] Jules Wulms, Juri Buchmuller, Wouter Meulemans, Kevin Verbeek, and Bettina Speckmann. Stable Visual Summaries for Trajectory Collections. In 2021 IEEE 14th Pacific Visualization Symposium (PacificVis), pages 61–70, Tianjin, China, April 2021. IEEE.

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Faculty of Science

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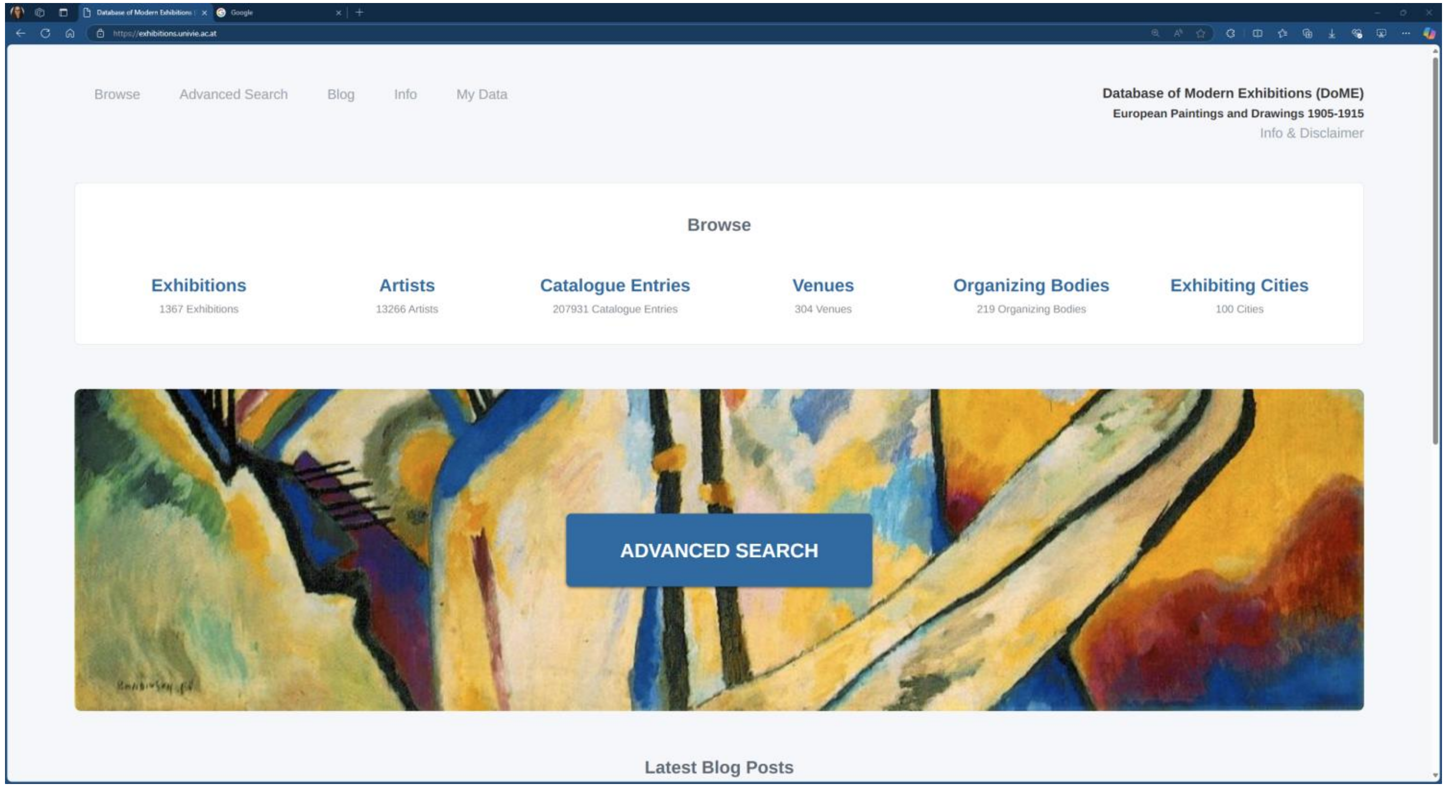
Project Idea

Introduction

- Database of Modern Exhibitions (DoME) – University of Vienna https://exhibitions.univie.ac.at/



Design Phase

Introduction