5-Weeks Course on Interactive Visual Network Exploration

Week 5: Exploring Networks with Adjacency Matrix

Feb 9th, 2022

VIS HUB University of Edinburgh
Visual+ Interactive Data
Inria
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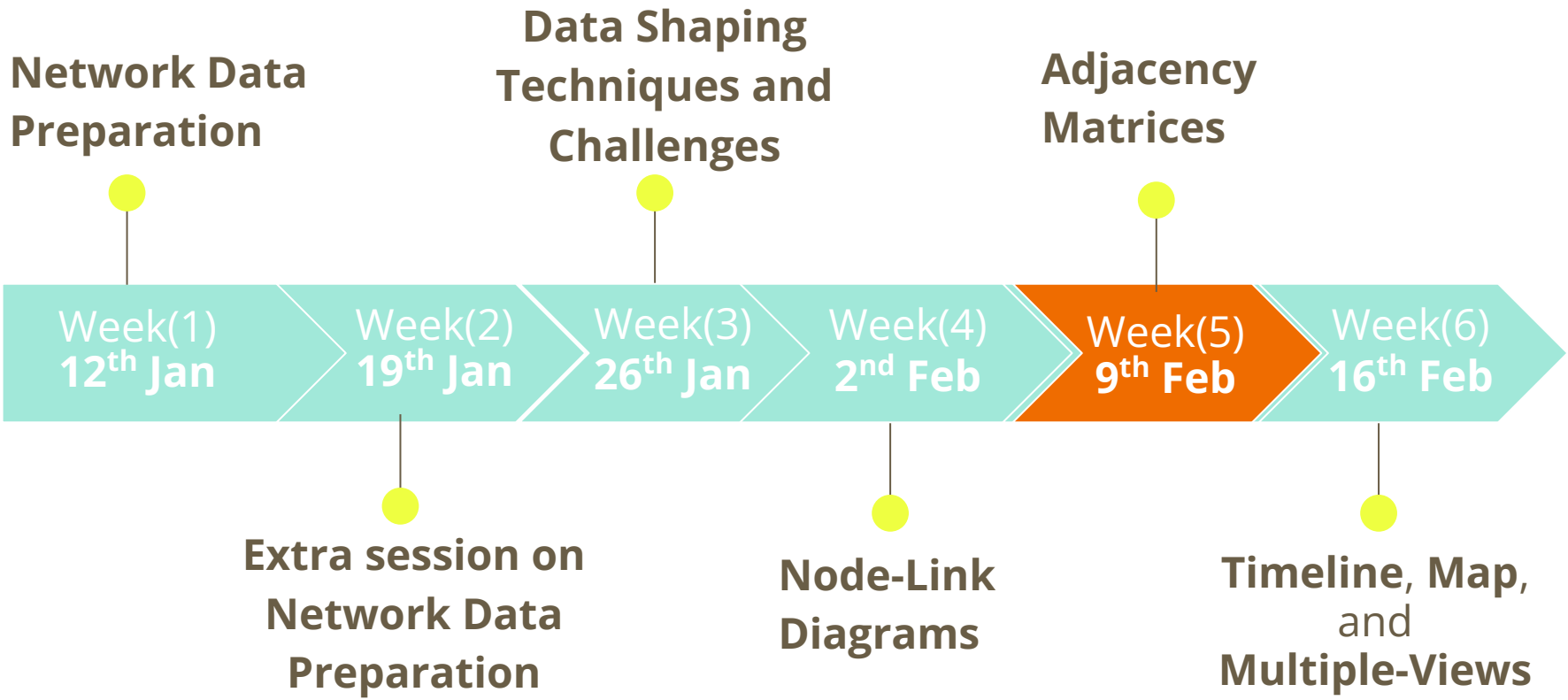
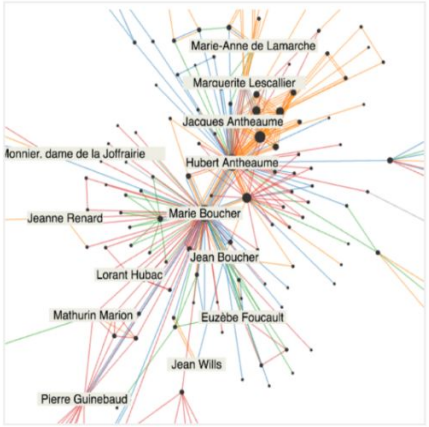
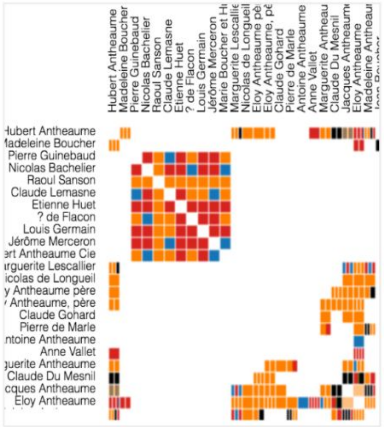

Network Data Preparation
Data Shaping Techniques and Challenges
Adjacency Matrices
Week(1) 12th Jan
Week(2) 19th Jan
Week(3) 26th Jan
Week(4) 2nd Feb
Week(5) 9th Feb
Week(6) 16th Feb
Extra session on Network Data Preparation
Node-Link Diagrams
Timeline, Map, and Multiple-Views

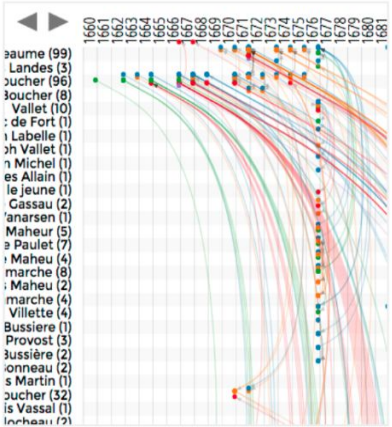
Questions from Last Session

- Questions about data upload?
- Questions about exploring with Node-link diagrams?
  - Special patterns?
  - Data-related problems?

Overview


Marie-Anne de Lamarche
Marguerite Lescallier
Jacques Antheaume
Hubert Antheaume
Marie Boucher
Jeanne Renard
Jean Boucher
Lorant Hubac
Mathurin Marion
Euzèbe Foucault
Jean Wills
Pierre Guinebaud


Hubert Antheaume
Madeleine Boucher
Pierre Guinebaud
Nicolas Bachelier
Raoul Sanson
Claude Lemasne
Etienne Huet
Louis Germain
Jérôme Merceron
Marie Boucher et H
Marguerite Lescallie
Eloy Antheaume, pè
Claude Gohard
Pierre de Marle
Anne Vallet
Marguerite Antheau
Claude Du Mesnil
Madeleine Antheaur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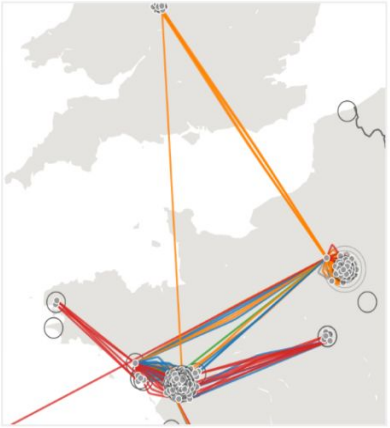
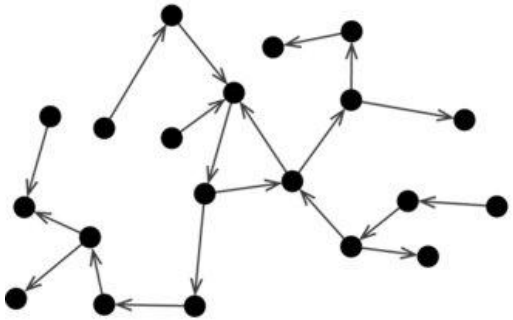


Session Outline

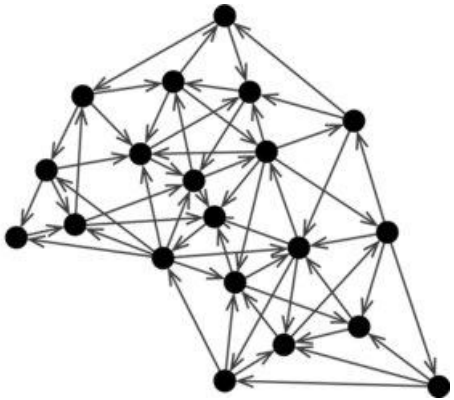
- Sparse vs. Dense Networks
- What is an Adjacency Matrix?
- Visual Encodings
- Visual Patterns
- Demo

Networks Structure

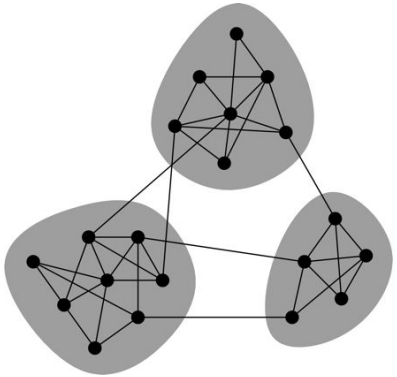
- Networks vary from very sparse (e.g., genealogy trees) to very dense (e.g., migration networks) including a locally dense category.



Sparse Network



Dense Network



Communities (Clusters)

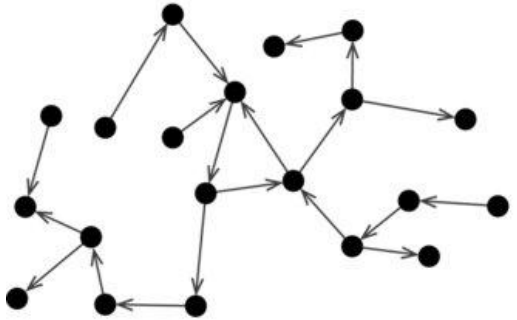
Sparse Networks

Sparse network

- Not-highly dense
- Topology can be clearly seen

Better view using Node-link diagram:

+ Path finding / following
+ Outliers
+ Disconnected components (if sparse)
+ Inbound/outbound relations
- No clear topology in Highly-dense network



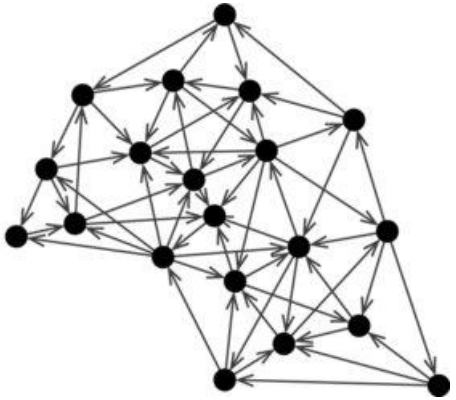
Dense Networks

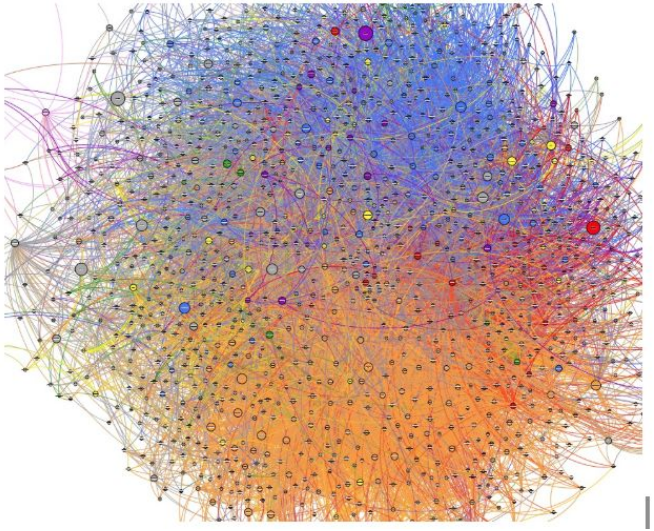
Dense Networks

- Number of edges is close to max number of edges
- Shows 1-to-1 relations

Use **Adjacency Matrix** for more readable view:

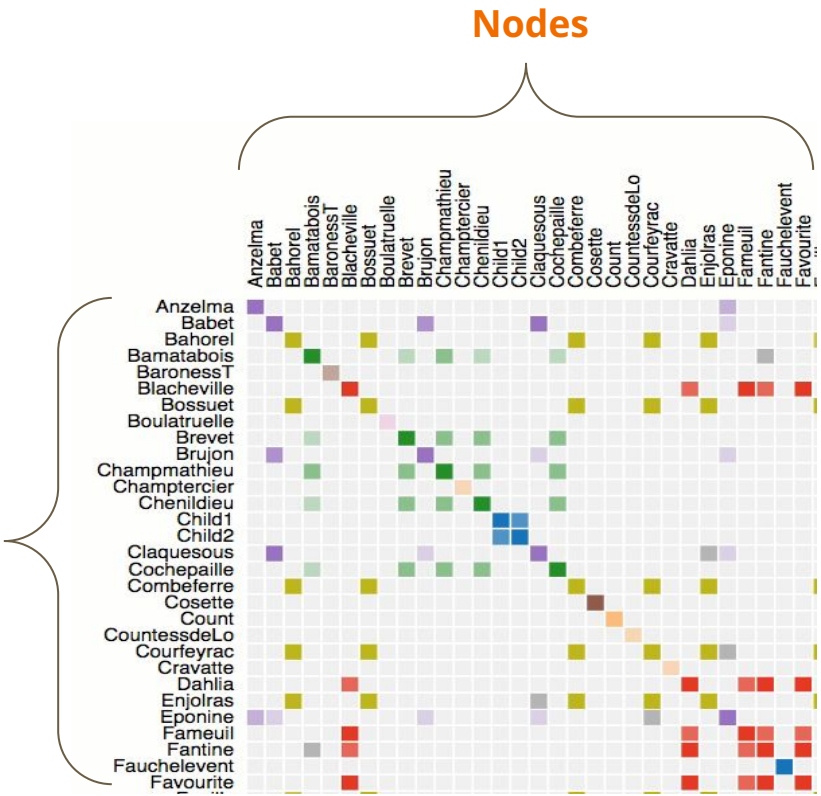
+ Clusters: identity communities
+ Missing links in clusters
+ Highly connected nodes
+ Ordering: Change order of rows and columns
- Does not show the topology





What is an Adjacency Matrix?

- An adjacency matrix is a table with rows and columns, you can represent nodes and edges.
- All rows and columns will contain the nodes names.
- Edges will be represented as the intersection of any row and column, where each cell ij represents an edge from node i to node j.



Co-Authorship Network Example (Author-to- Paper)

Undirected

Author	Paper
John	Paper A
Sara	Paper A
Kyle	Paper A
Jamal	Paper B
Sara	Paper B

	Paper A	Paper B	John	Sara	Kyle	Jamal
Paper A	0	0	**1**	**1**	**1**	0
Paper B	0	0	0	**1**	0	**1**
John	**1**	0	0	0	0	0
Sara	**1**	**1**	0	0	0	0
Kyle	**1**	0	0	0	0	0
Jamal	0	**1**	0	0	0	0

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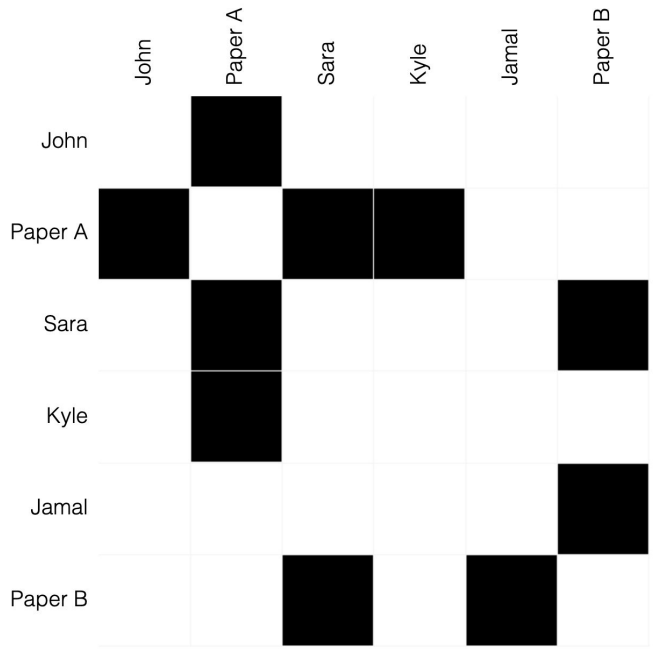

Directed vs Undirected Adjacency Matrix

Co-Authorship Network Example (Author-to- Paper)

Directed

Author	Paper
John	Paper A
Sara	Paper A
Kyle	Paper A
Jamal	Paper B
Sara	Paper B

	Paper A	Paper B	John	Sara	Kyle	Jamal
Paper A	0	0	**0**	**0**	**0**	0
Paper B	0	0	0	**0**	0	**0**
John	**1**	0	0	0	0	0
Sara	**1**	**1**	0	0	0	0
Kyle	**1**	0	0	0	0	0
Jamal	0	**1**	0	0	0	0

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Author	Paper
John	Paper A
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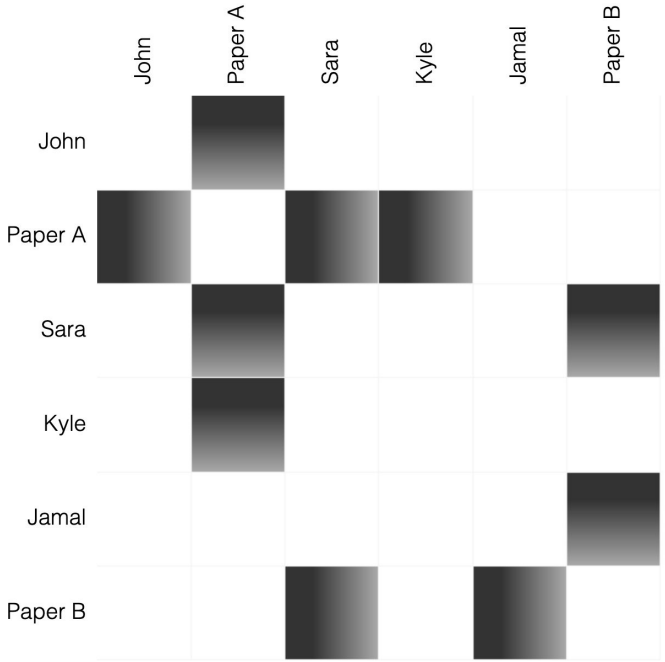


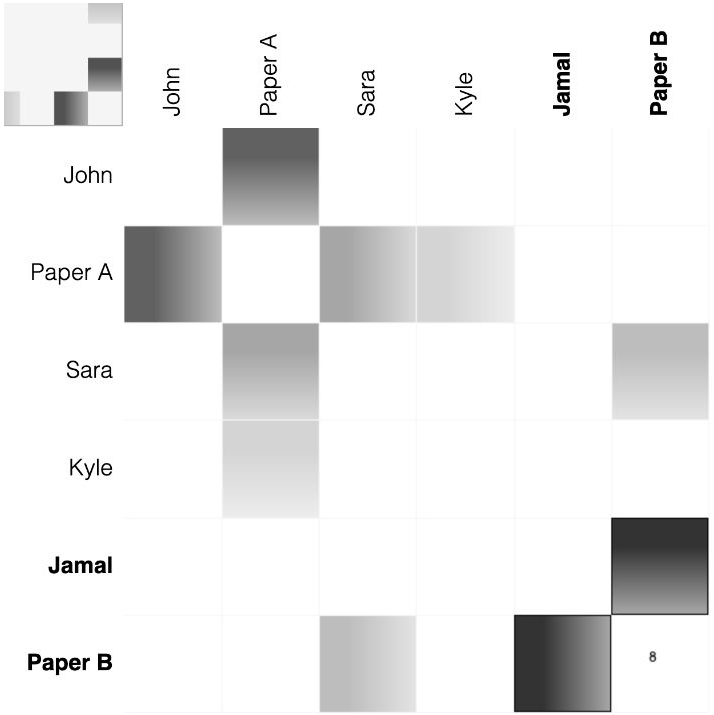
Adjacency Matrices & Weighted Graphs

- You simply replace the 1s with the weight of the edge, and 0s with Null because 0 can be a valid weight.

Co-Authorship Network Example (Author-to- Paper)

Weighted Graphs

Author	Paper	Contr/
John	Paper A	6
Sara	Paper A	3
Kyle	Paper A	1
Jamal	Paper B	8
Sara	Paper B	2



Co-Authorship Network Example (Author-to- Paper)

Weighted Graphs

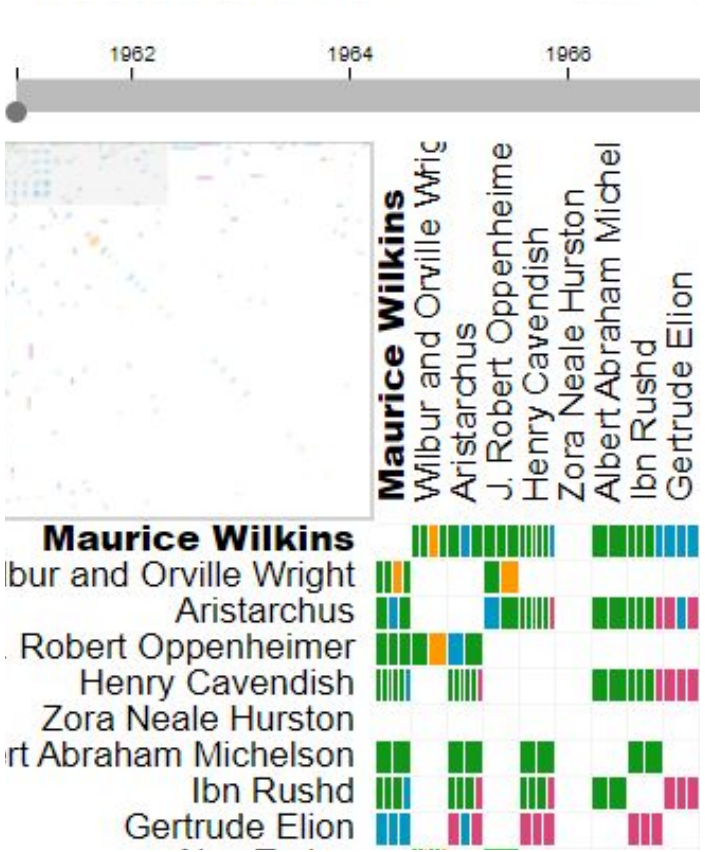
Author	Paper	Weight
John	Paper A	6
Sara	Paper A	3
Kyle	Paper A	1
Jamal	Paper B	8
Sara	Paper B	2

	Paper A	Paper B	John	Sara	Kyle	Jamal
Paper A	Null	Null	**Null**	**Null**	**Null**	Null
Paper B	Null	Null	Null	**Null**	Null	**Null**
John	**6**	Null	Null	Null	Null	Null
Sara	**3**	**2**	Null	Null	Null	Null
Kyle	**1**	Null	Null	Null	Null	Null
Jamal	Null	**8**	Null	Null	Null	Null

Visual Encodings

Visual Encodings

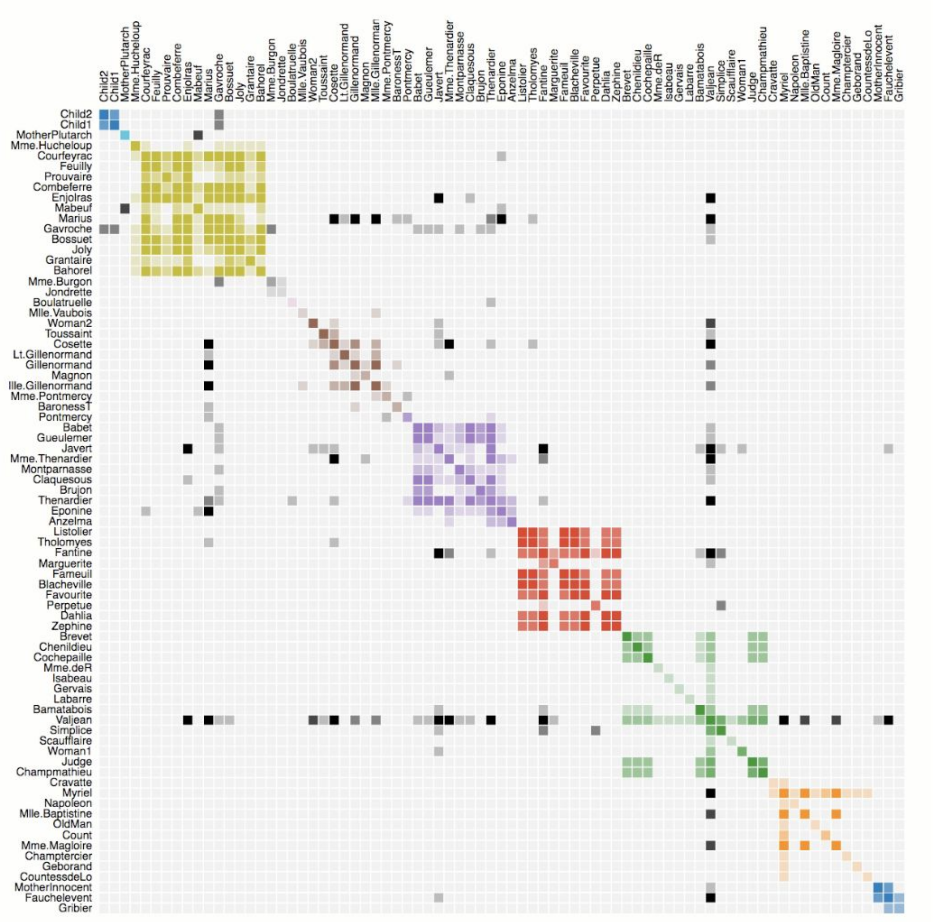
- **Squared cells** = single connections
- **Split cells** = multiple connections between nodes
- **Cell color** = connection type



Ordering

- **Label Ordering**: Defines the ordering of rows and columns
  - **Alphanumerical**: Order by name
  - **Reverse Alphanumerical**: by name, reversed
  - **Node degree**: according to number of connections, descending
  - **Similarity**: groups nodes with similar connectivity to reveal patterns in the matrix.

Les Misérables Co-occurrence
By Mike Bostock
https://bost.ocks.org/mike/miserables/



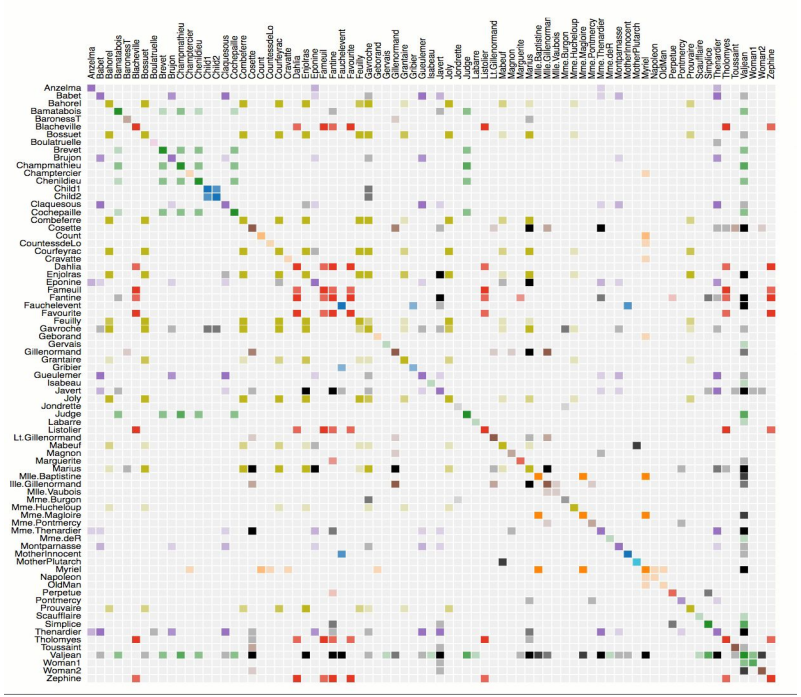
Visual Patterns

- Visual patterns inside the matrix are defined by a reordering algorithm.

- *Patterns* include:
  - Block Pattern
  - Off-diagonal Block Pattern
  - Line/Star Pattern
  - Bands Pattern
  - Noise Anti-Pattern
  - Bandwidth Anti-Pattern

Visual Patterns (Random Pattern)

- Also called *salt-and-pepper*
- The classic pattern for a matrix plot.
- It can be found whenever the row/column ordering is not able to reveal the underlying graph topology or if simply no structure exists.

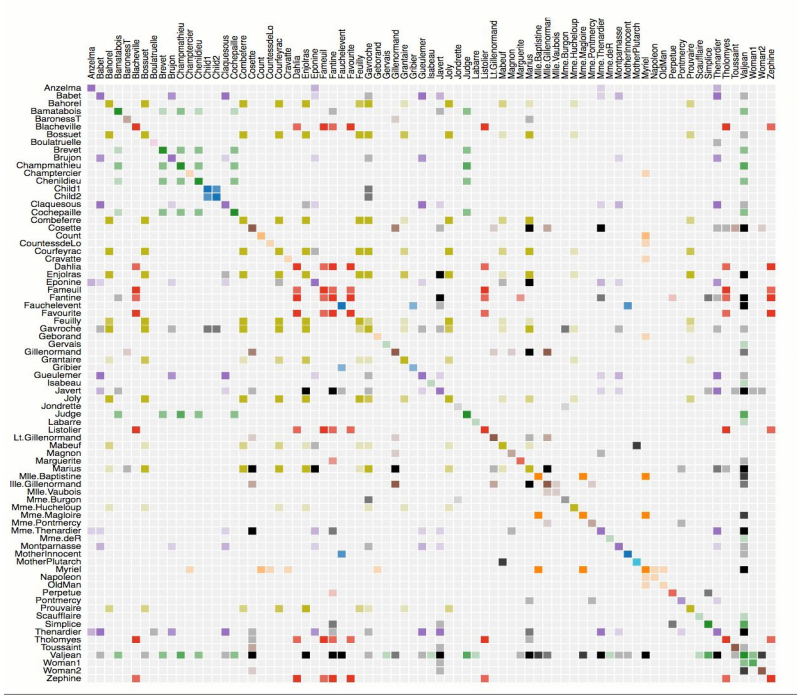


Visual Patterns (Random Pattern)

- Also called *salt-and-pepper*
- The classic anti-pattern for a matrix plot.
- It can be found whenever the row/column ordering is not able to reveal the underlying graph topology or if simply no structure exists.

What can I know about my data with this pattern?

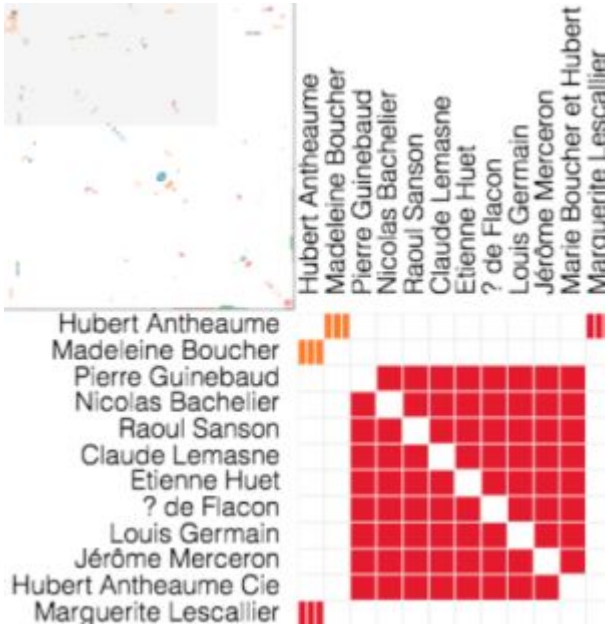
- A matrix can be *noisy* or show *structure on different levels*:
  - *locally*, i.e. for subgraphs (submatrices),
  - and **globally**, i.e. the entire graph (matrix).



Visual Patterns (Block Pattern)

Block along the diagonal of the matrix indicate:

- Groups of densely connected nodes in the network
- Each node indicated in the rows is connected to each node in the column.



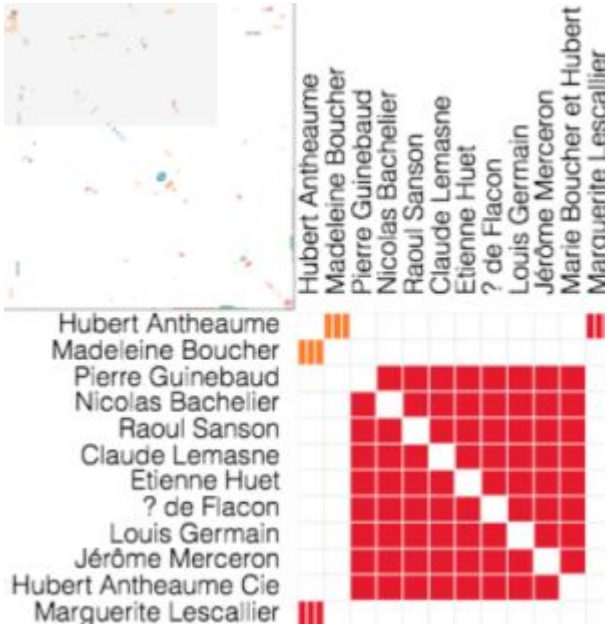
Visual Patterns (Block Pattern)

Block along the diagonal of the matrix indicate:

- Groups of densely connected nodes in the network
- Each node indicated in the rows is connected to each node in the column.

What can I know about my data with this pattern?

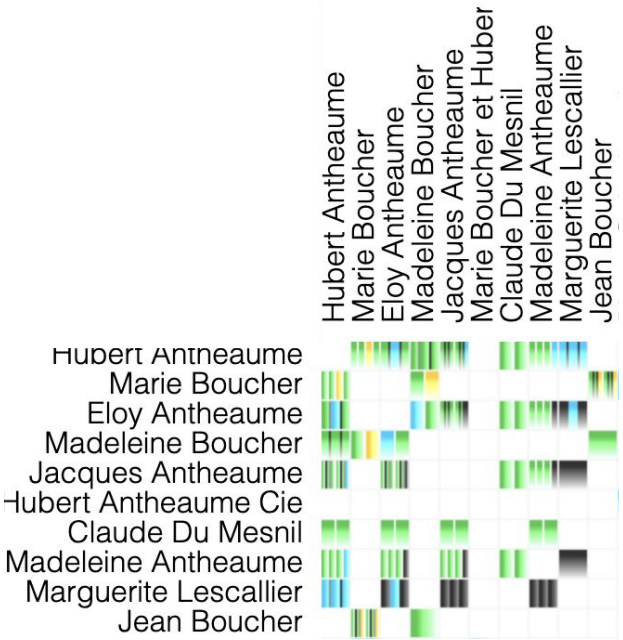
- These blocks would be referred to as *cohesive groups or clusters*.
- Clear block patterns help:
  - C**ounting clusters**,
  - **estimate cluster overlap** and
  - identify larger and smaller clusters.



Visual Patterns (Block Pattern)

Incomplete squares along the diagonal are

- almost squares but are missing some cells,
- i.e. not all nodes in the rows are connected to all nodes in the columns.
- Such incomplete squares are *clusters of densely connected nodes*



Visual Patterns (Block Pattern)

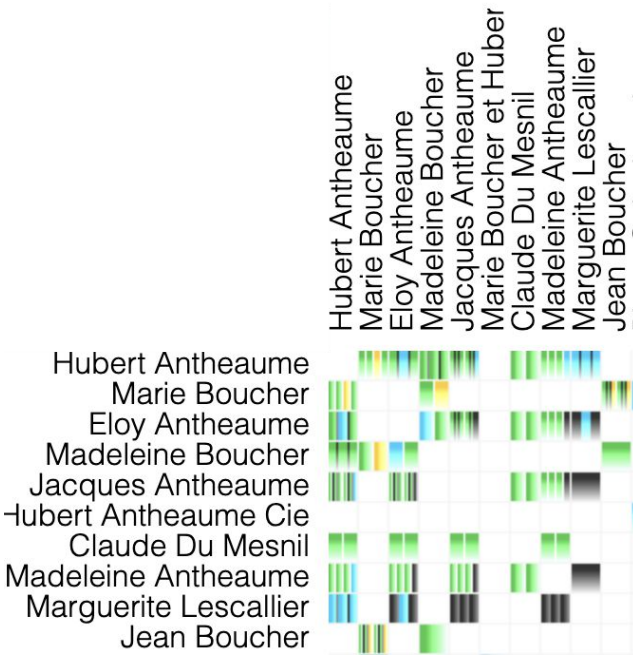
Incomplete squares along the diagonal are

- almost squares but are missing some cells,
- i.e. not all nodes in the rows are connected to all nodes in the columns.
- Such incomplete squares are *clusters of densely connected nodes*

What can I know about my data with this pattern?

Show block patterns with missing cells, meaning:

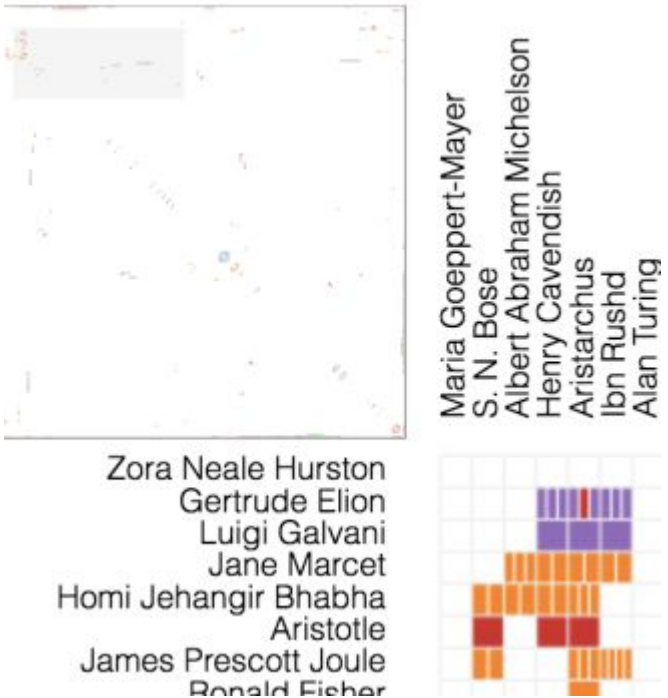
- Clusters have missing connections
- or being connected to other clusters (i.e., off-diagonal dots)



Visual Patterns (Block Pattern)

Complete or incomplete squares **off the diagonal indicate bigraphs**.

- In bigraphs, nodes from one set are only connected to nodes from the other set.
- In the figure from the left (almost all) nodes in the rows are connected to (almost all) nodes in the columns.



Visual Patterns (Off-Diagonal Block Pattern)

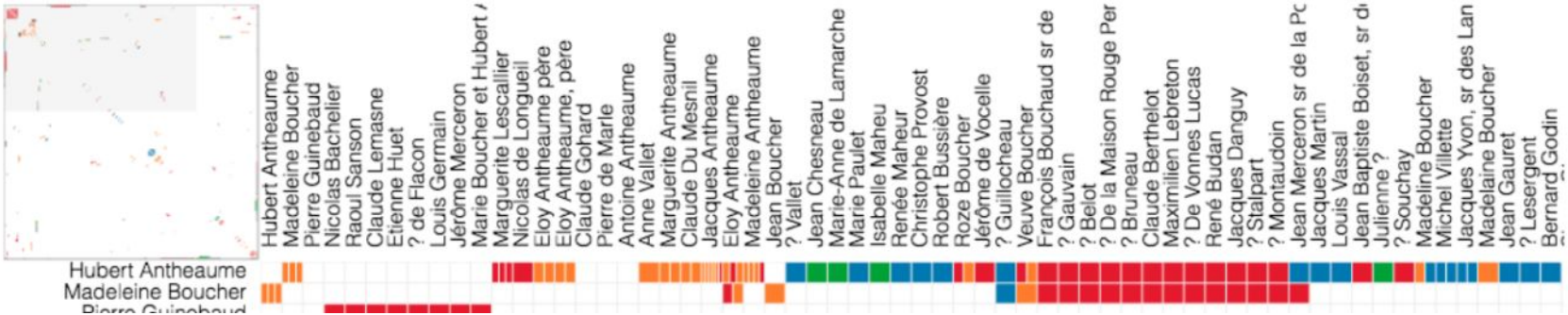
- Off-diagonal coherent areas correspond to either sub-patterns of a block pattern or relations in a bi-graph.

What can I know about my data with this pattern?

- Helps in understanding how groups/entities are connected.

Visual Patterns (Line/Star Pattern)

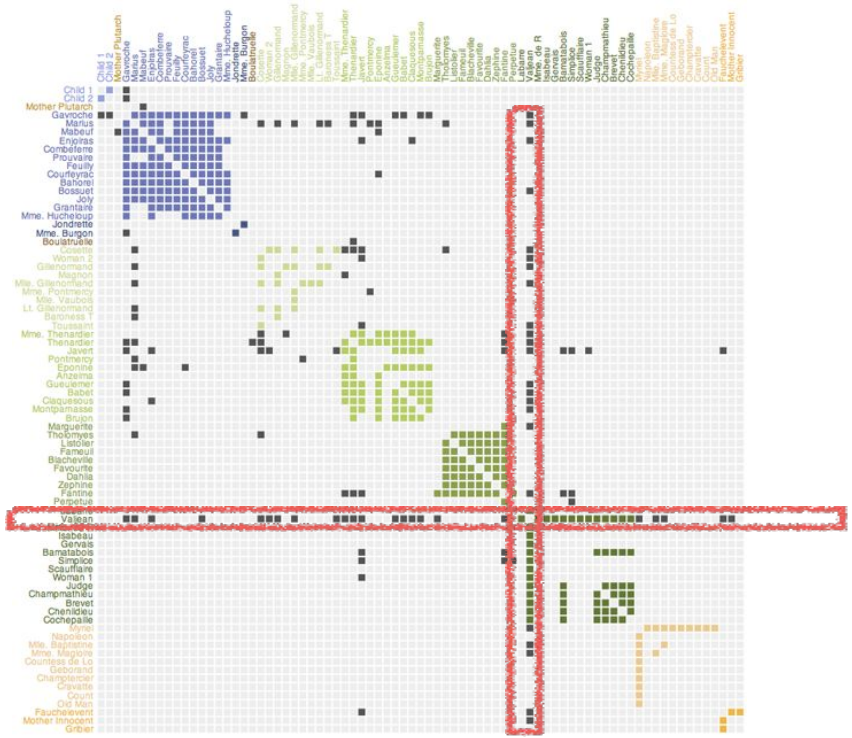
- A row or column with lots of cells indicates a highly connected node (Dense Rows or Columns) .
- In the figure below, the node Hubert Antheaume is connected almost all the nodes in the visible columns. The node can be called a **hub**.



Visual Patterns (Line/Star Pattern)

What can I know about my data with this pattern?

- This pattern helps you to analyze the reason on the general connectivity aspects within the network.
- The length of a line thereby indicates the number of connections (node degree)

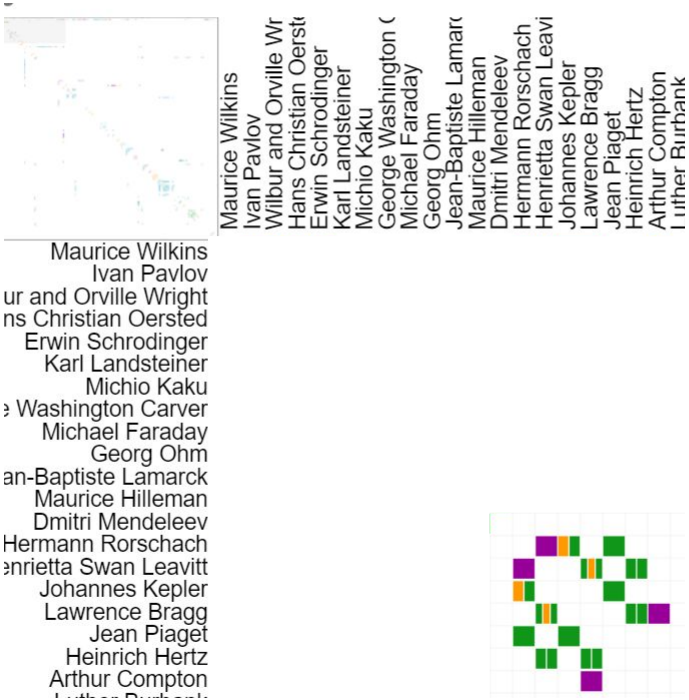


Visual Patterns (Band Pattern)

- Off-diagonal continuous lines refer to paths and cycles in a network.
- They represent a set of vertices with a few connections to other vertices

What can I know about my data with this pattern?

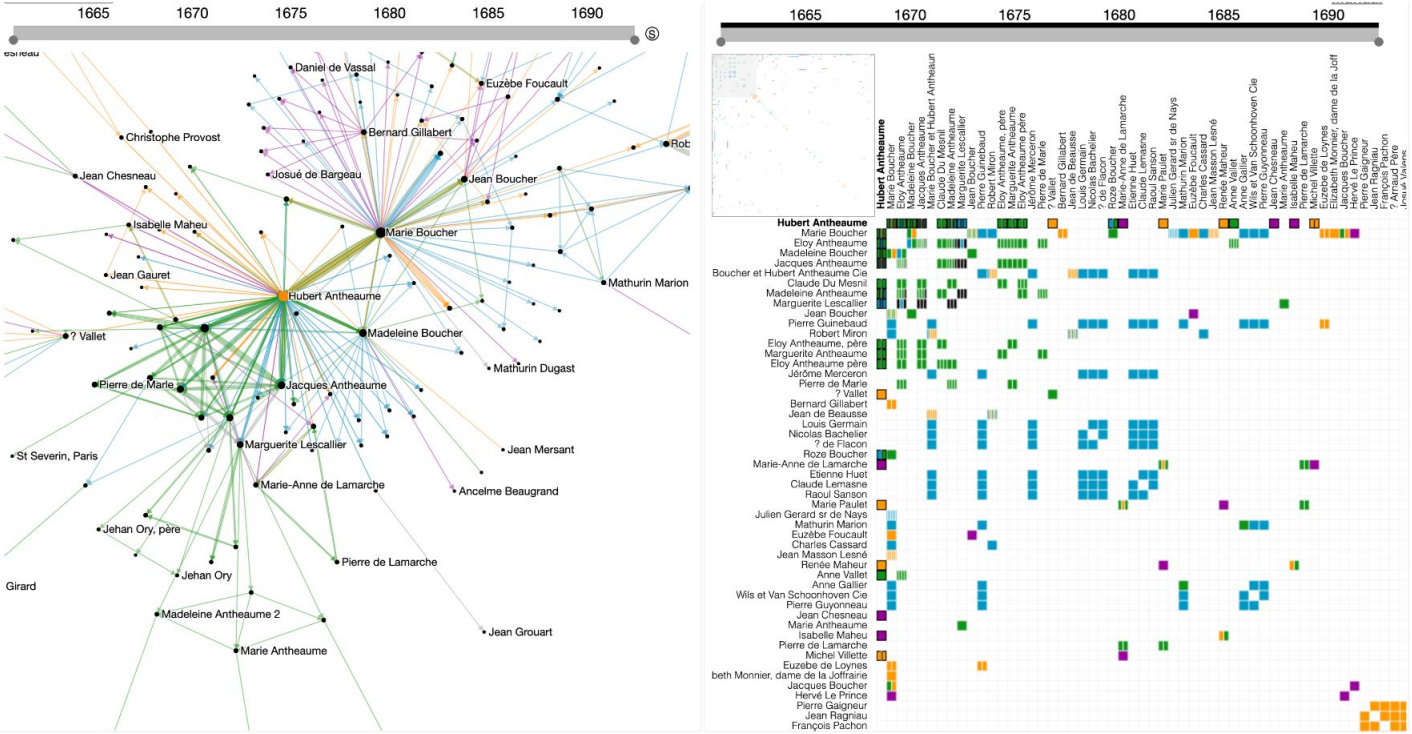
- Bands would refer connection paths and transition chains, where the width of the band visually depicts how many distinct paths could be taken through the network.



Notes

- Real world graphs exhibit a mixture of overlapping patterns appearing at different scales.
- The visual patterns describe are not always clearly distinguishable and may appear merged together.
- Reordering algorithms take into consideration different aspects of the topology, inducing different patterns.

Multiple-Coordinates View in The Vistorian



Demo

- **Zoom**
- **Pan**
- Show **connection weight**
- Changing **labelling order**

General Questions?

- **Homework:**
  Run an exploration session with your insights/findings from your exploration with the Node-link diagram and compare them to those you may find through the adjacency matrix.

- **Feedback**:
  Please share your feedback : https://forms.office.com/r/aXeFRsxHeb

References

- https://vistorian.github.io/visualizations.html
- Matrix Cheat Sheets
- Matrix Reordering Methods for Table and Network Visualization (inria.fr)
- Task taxonomy for graph visualization