Challenges in Social Network Visualization: Bigger, Dynamic, Multivariate

Jean-Daniel Fekete
INRIA
http://www.aviz.fr/~fekete

Visualization?

Visualization is any technique for creating images, diagrams, or animations to *communicate a message*

[Wikipedia, Visualization, May 2016]

Information visualization is the study of (interactive) visual representations of abstract data to *reinforce human cognition*

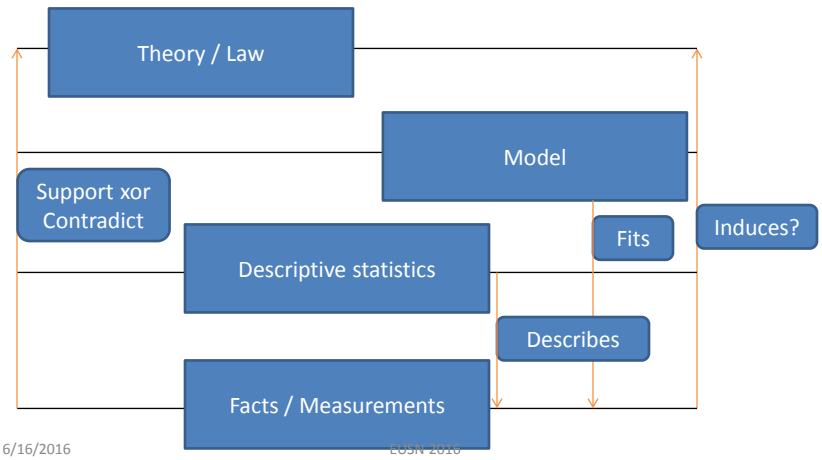
[Card, S. and Mackinlay, J. and Shneiderman B., Readings in Information Visualization, 1999]

Network Visualization

Information visualization applied to network structures:

- The study of interactive visual representations of *networks* to reinforce human cognition

Where does Visualization Stands?



Example

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

Raw Data from Anscombe's Quartet

[Source: Anscombe's quartet, Wikipedia]

Statistical Analysis

For all columns, the main descriptive statistics are identical

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

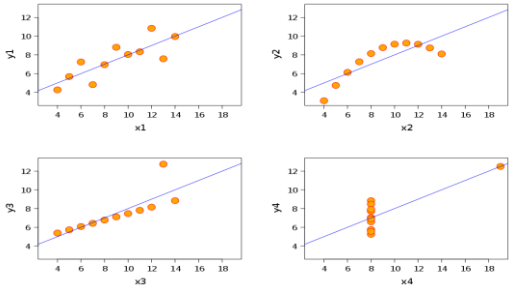
Mean of x	9.0
Variance of x	11.0
Mean of y	7.5
Variance of y	4.12
Correlation between x and y	0.816
Linear regression line	$y = 3 + 0.5x$

[Source: Anscombe's quartet, Wikipedia]

Visual Representation of the Data

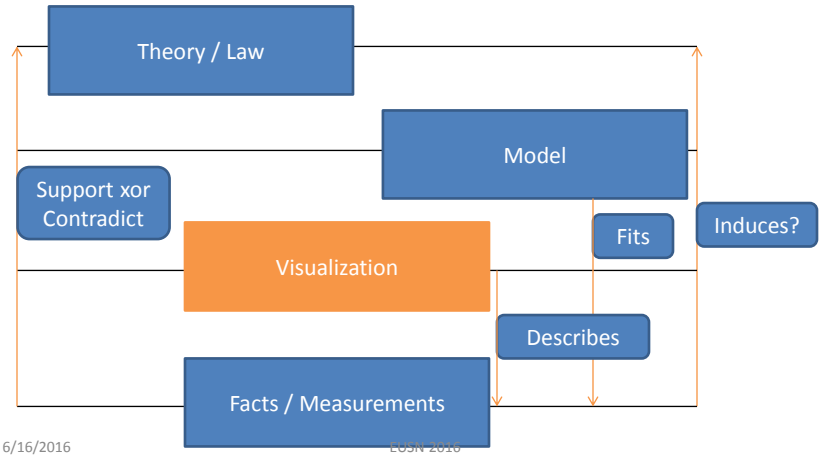
Visual representation reveals a different story

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89



[Source: Anscombe's quartet, Wikipedia]

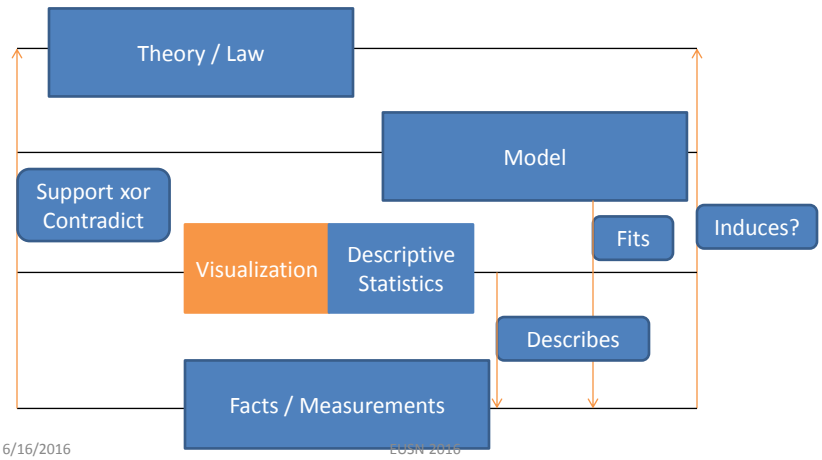
Where does Visualization Stands?



Network Visualization Revisited

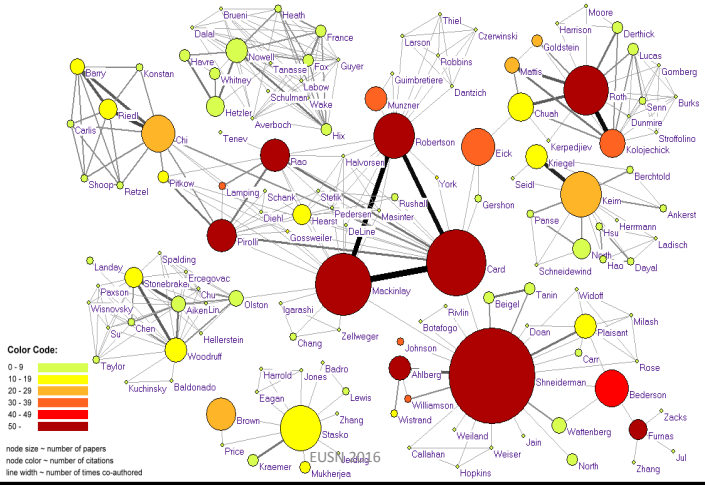
- Most (99%) network visualization tools use the node-link visual representation
- Other representations exist, more or less general
- Why use one or another?
  - Efficiency (to be defined)
  - Familiarity

Where does Visualization Stands?

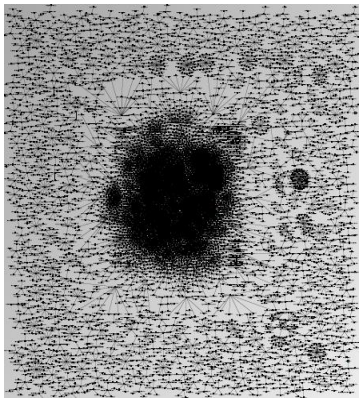


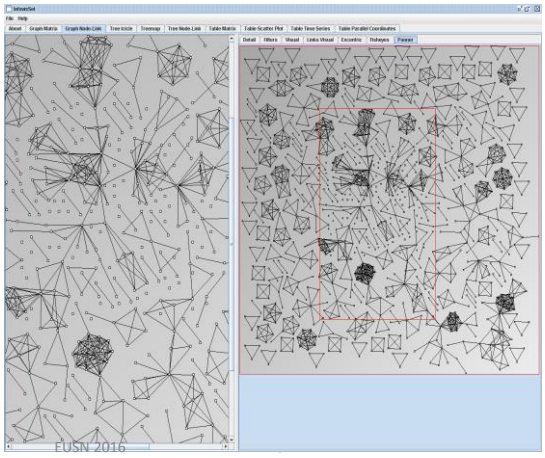
InfoVis Co-authoring

(K. Börner et al. 04)

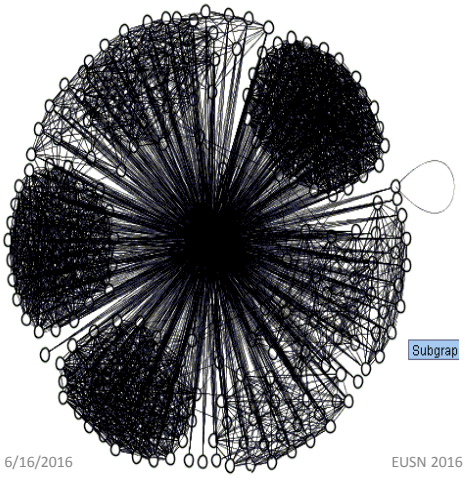


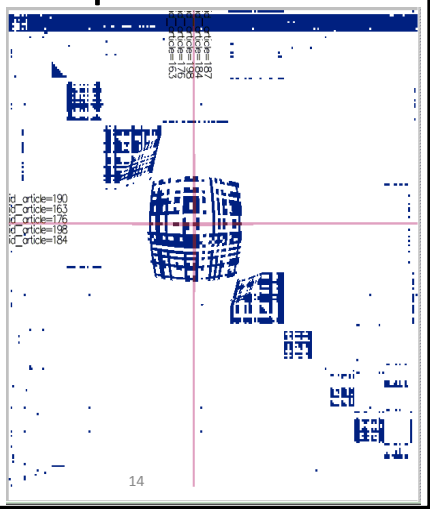
Generally, after loading…



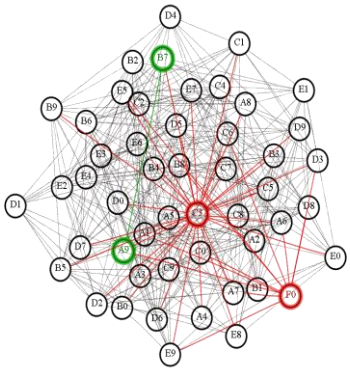


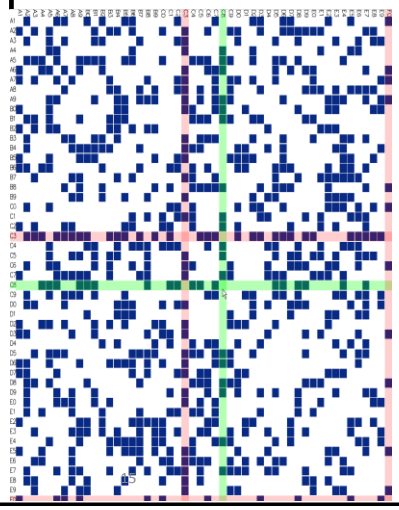
Web Site Example





Readability Experiment





Controlled Experiment: Node Link Diagrams vs. Adjacency Matrices

The Tasks:

- Tasks related to the overview
  - Number of vertices
  - Number of arcs
- Tasks related to graph elements
  - Finding an element (a vertex, a link)
  - Finding the most connected vertex (a central actor, a pivot, a hub)
  - Finding a common neighbor
  - Finding a path
- Random graphs (3 sizes et 3 densities)
- 2 representations: Node-Link + Matrix

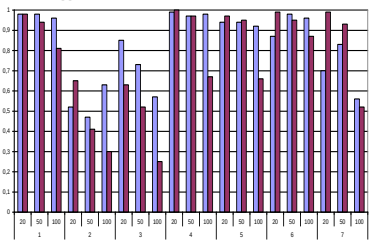
Results:

- Node-link diagrams are preferable for small sparse graphs (20 vertices)

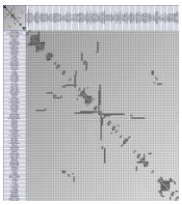
Matrices are more readable *wrt* dense graphs and medium/large graphs (> 20 vertices) *wrt* the selected tasks, except path finding

References:

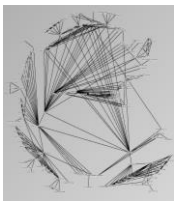
Mohammad Ghoniem, Jean-Daniel Fekete and Philippe Castagliola *Readability of Graphs Using Node-Link and Matrix-Based Representations: Controlled Experiment and Statistical Analysis*, Information Visualization Journal, 4(2), Palgrave Macmillan, Summer 2005, pp. 114-135.



Percentage of correct answers for the 7 tasks, 3 densities and 2 representations. NL in purple, Matrix in blue



Matrix vs. Node-Link



+

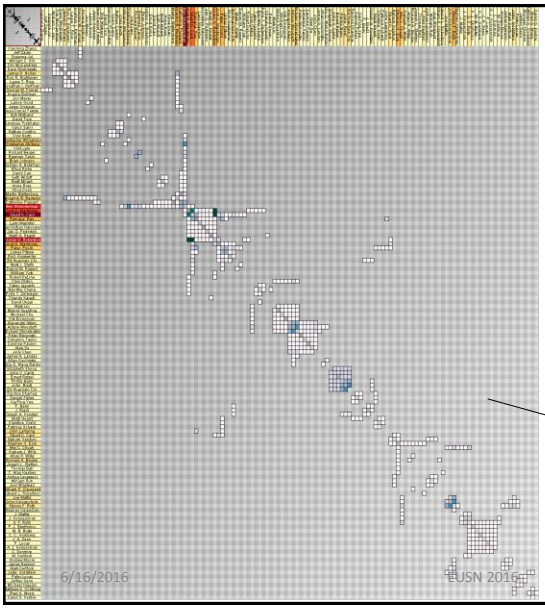
- Usable without reordering
- No node overlapping
- No edge crossing
  - ➔ Readable for dense graphs
- Fast navigation
- Fast manipulation
  - ➔ Usable interactively
- More readable for some tasks

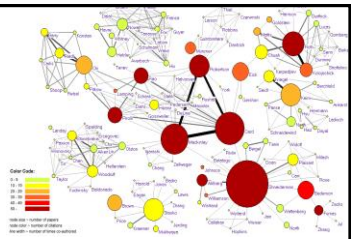
−

- Less familiar
- Use more space
- Weak for path following tasks

- Familiar
- Compact
- More readable for path following
- More effective for small graphs
- More effective for sparse graphs

- Useless without layout
- Node overlapping
- Edge crossing
  - ➔ Not readable for dense graphs
- Manipulation requires layout computation

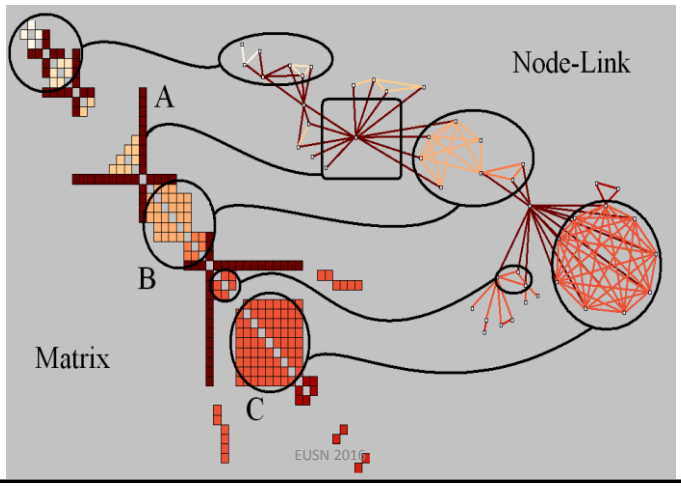




Communicate

Explore

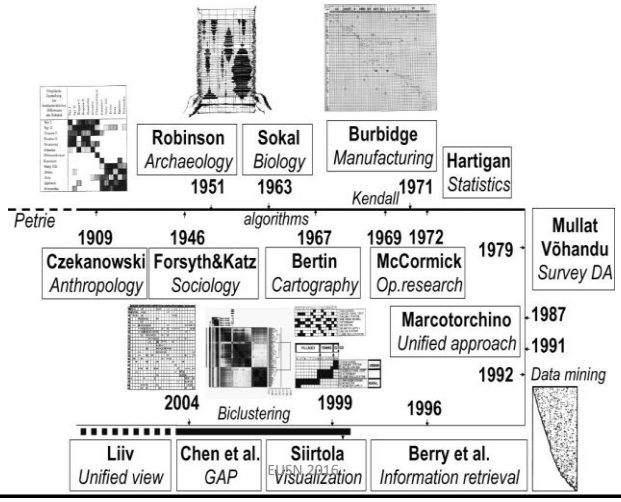
Visual Patterns with Ordered Matrices



The Ordering Problem

- Seriation instead of clustering
  - Finding a linear order for rows and columns
  - Postpone the decision of separating into clusters
  - Avoid creating clusters when they don't make sense
- Naïve approach:
  - Define an objective function (e.g. favor diagonal placement and dense blocks)
  - Try all permutations and keep the best wrt the function
- Problem: for a n×m table, there are n!×m! permutations
- Problem 2: there is no consensual objective function

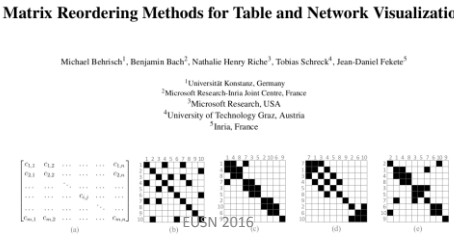
Liiv: visual abstract of the history of seriation from different disciplines



Seriation and Matrix Ordering

Innar Liiv, Seriation and Matrix Reordering Methods: An Historical Overview, Statistical analysis and data mining, 2010 – Wiley

Michael Behrisch, Benjamin Bach, Nathalie Henry Riche, Tobias Schreck, Jean-Daniel Fekete. Matrix Reordering Methods for Table and Network Visualization. Computer Graphics Forum, Wiley, 2016, 35, pp.24. <hal-01326759>


Matrix Reordering Methods for Table and Network Visualization

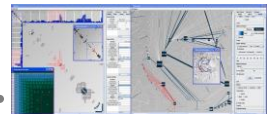
Michael Behrisch[1], Benjamin Bach[2], Nathalie Henry Riche[3], Tobias Schreck[4], Jean-Daniel Fekete[5]

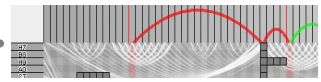
[1]Universität Konstanz, Germany
[2]Microsoft Research-Inria Joint Centre, France
[3]Microsoft Research, USA
[4]University of Technology Graz, Austria
[5]Inria, France

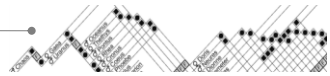
Advances in Social Network Visualization: Improving Matrices

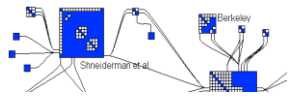
Several representations:

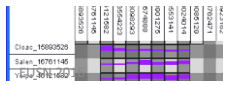
1. **Combined**
   - MatrixExplorer (Henry&Fekete InfoVis'06)
2. **Augmented**
   - MatLink (Henry&Fekete Interact'07, Best Paper)
   - GeneaQuilts (Bezerianos et al. InfoVis'10)
3. **Hybrid**
   - NodeTrix (Henry et al. InfoVis'07)
   - CoCoNutTrix (Isenberg et al. CG&A'09)
4. **Multiscale**
   - ZAME (Elmqvist et al. PacificVis'08)

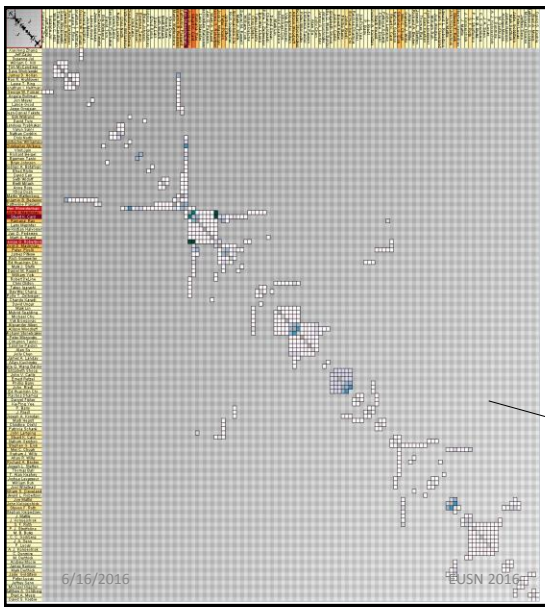


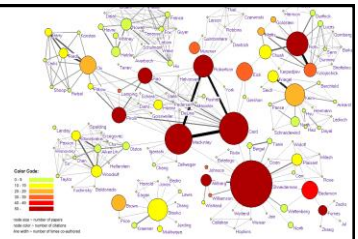










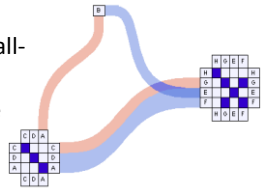


Compact

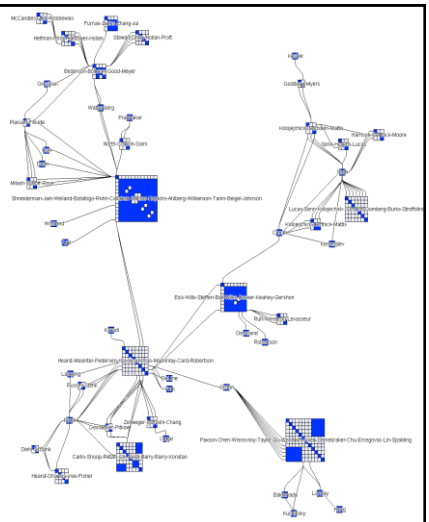
Not compact for sparse nets

NodeTrix [Henry et al.07]

Hybrid representation



- Designed for small-world networks
  - Globally sparse
  - Locally dense
- Visualizing dense sub-graphs as matrices
- Interact to create, edit and remove the matrices



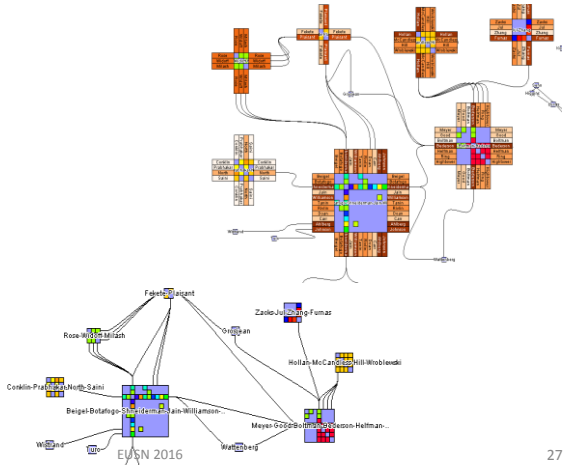
Video

NodeTrix: the NetVis Nirvana?

- ✓ Can you see every node?
- ✓ Can you count each node's degree?
- ✓ Can follow every link from its source to its destination?
- ✓ Can you identify clusters and outliers?

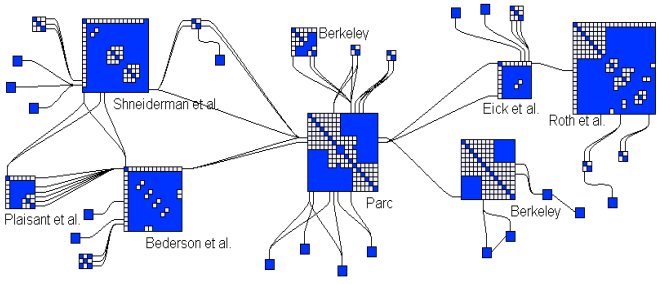
- Node Labels
- Link Labels (excentric labels?!)
- … even cluster labels
- Node Attributes
- Link Attributes
- … even clusters attributes
- Directed Graph (links width?!)

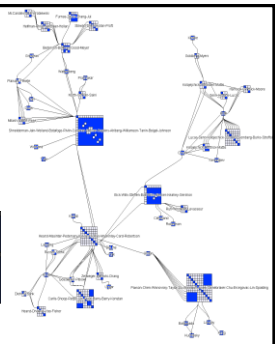
… But… beware the graphics overload!



Visual Patterns

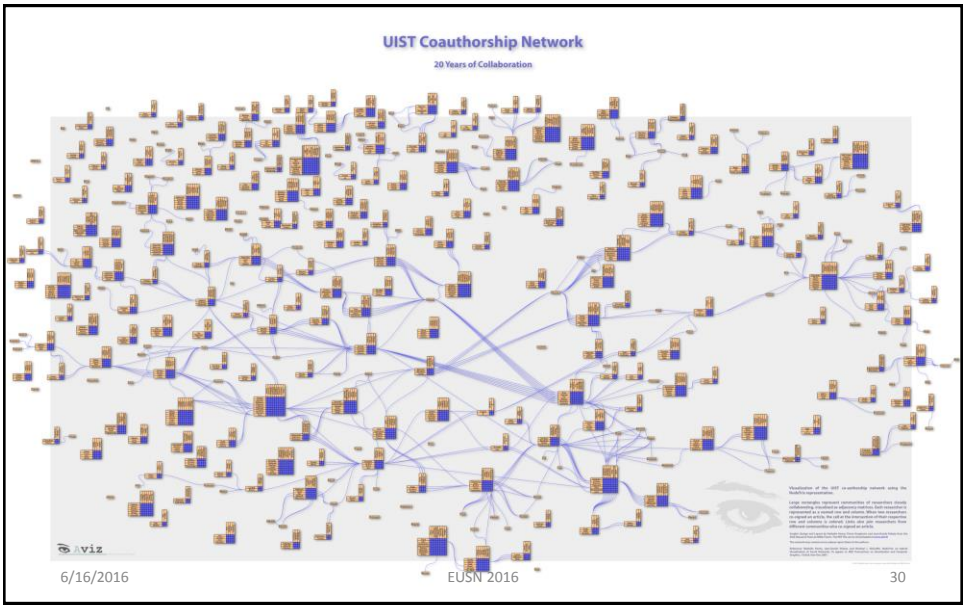
https://github.com/IRT-SystemX/nodetrix





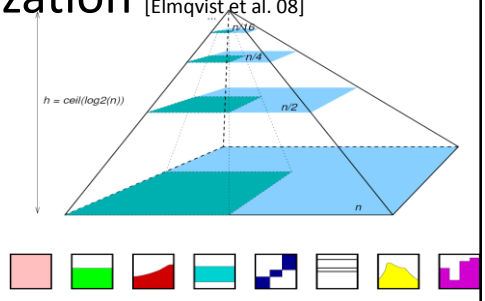
Infovis Coauthorship (133 actors)

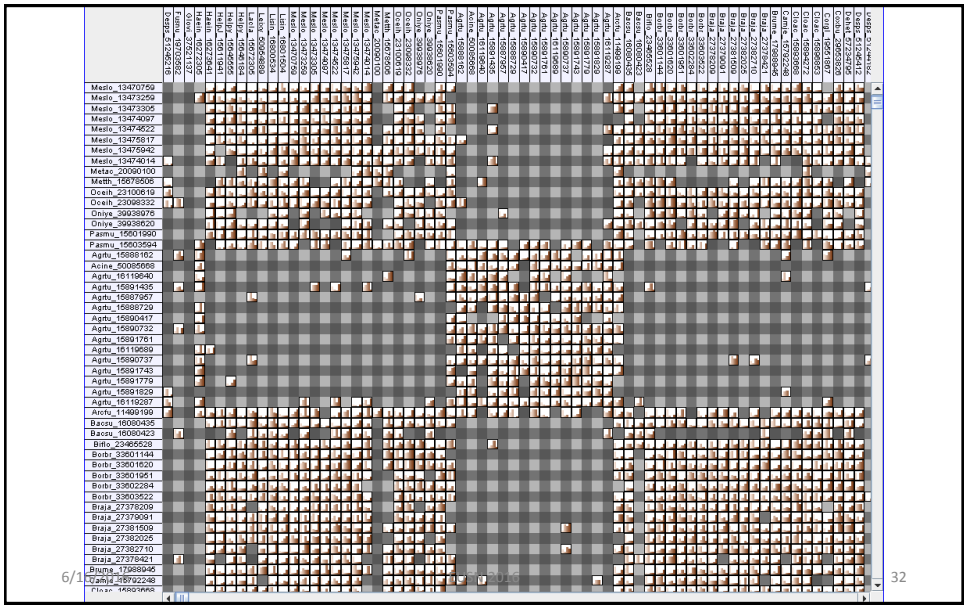
Bigger



ZAME: Interactive Large-Scale Graph Visualization [Elmqvist et al. 08]

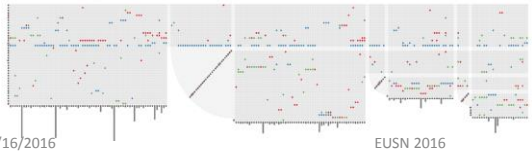
Visualize very large networks:
- Larger than 10^7 vertices and edges
- Reorder
- Create a pyramid
- Aggregate attributes
- Visualize using enhanced glyphs





Other Related Research

- Van Ham et al. 2004-2005 have shown techniques to navigate in large matrices
- Brandes&Nick 2011 have visualized temporal networks (friendship evolution)
- Dinkla et al. 2012 have introduced Compressed Adjacency Matrices



Dynamic

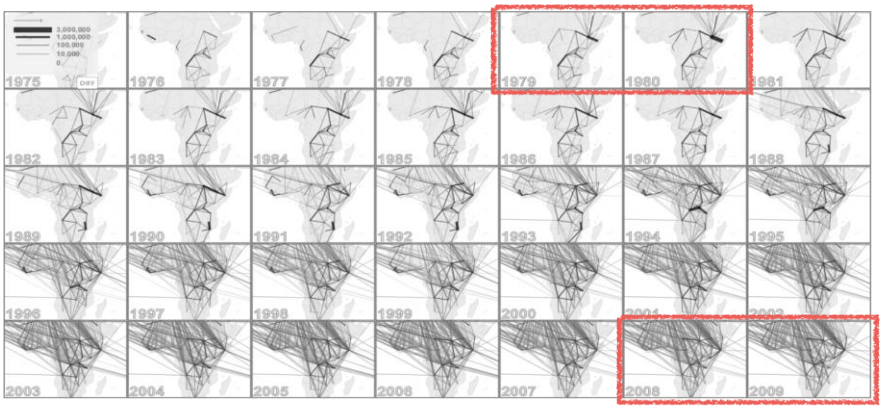
PhD defense

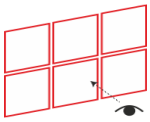
Connections, Changes, and Cubes: Unfolding Dynamic Networks for Visual Exploration

- Benjamin Bach
- 9 May 2014

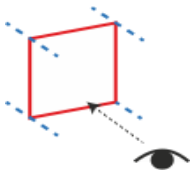
Advisors:
Jean-Daniel Fekete
Emmanuel Pietriga

Jury:
Chantal Reynaud
Jarke J. van Wijk
Tim Dwyer
Silvia Miksch
Guy Melançon

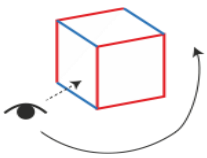


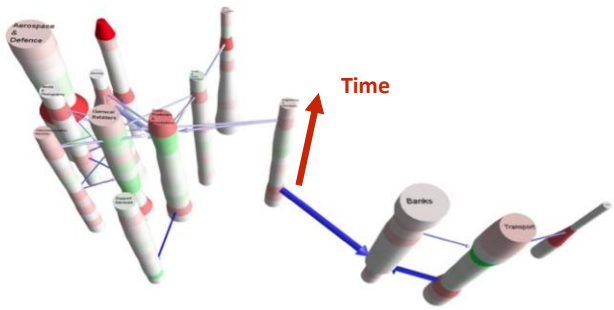


Boyandin et al., 2012



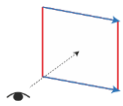
Maray Friedrich and Eades, 2001
TempoVis Ahn et al, 2011

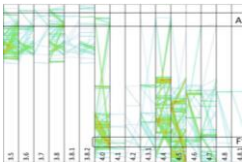




2.5D visualization Dwyer, 2004
Visual Unrolling Brandes & Corman, 2003
Gaertler & Wagner, 2005

Timelines





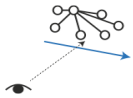
Parallel Edge Splatting Burch et al, 2011

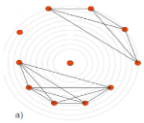
Massive Parallel Sequence Views Willems et al, 2012

GraphDice Bezerianos et al, 2010

Reda et al, 2012

Ego Network Representations

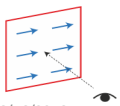


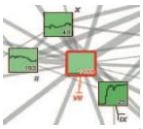


1.5D Visualization Shi et al., 2011

Dynamic Ego Networks Farrugia et al., 2011

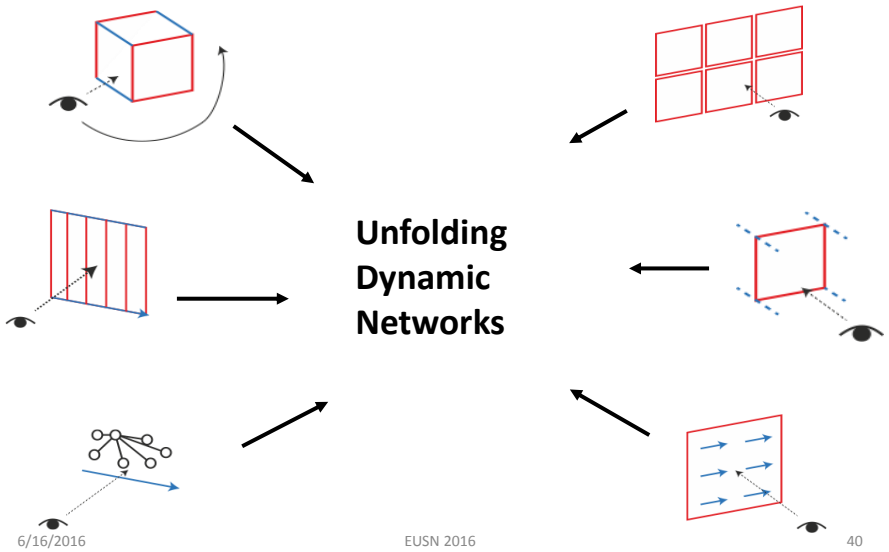
Temporal Aggregation

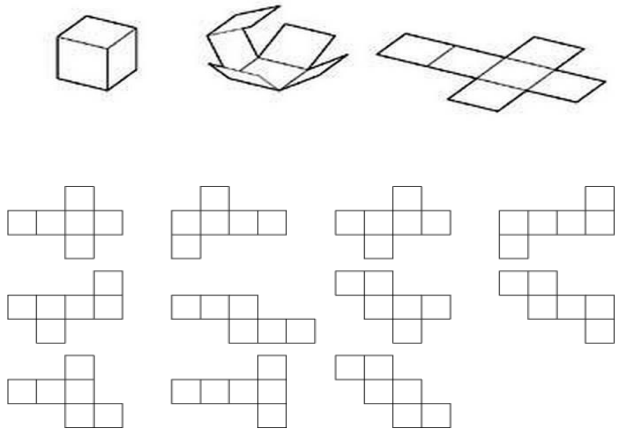




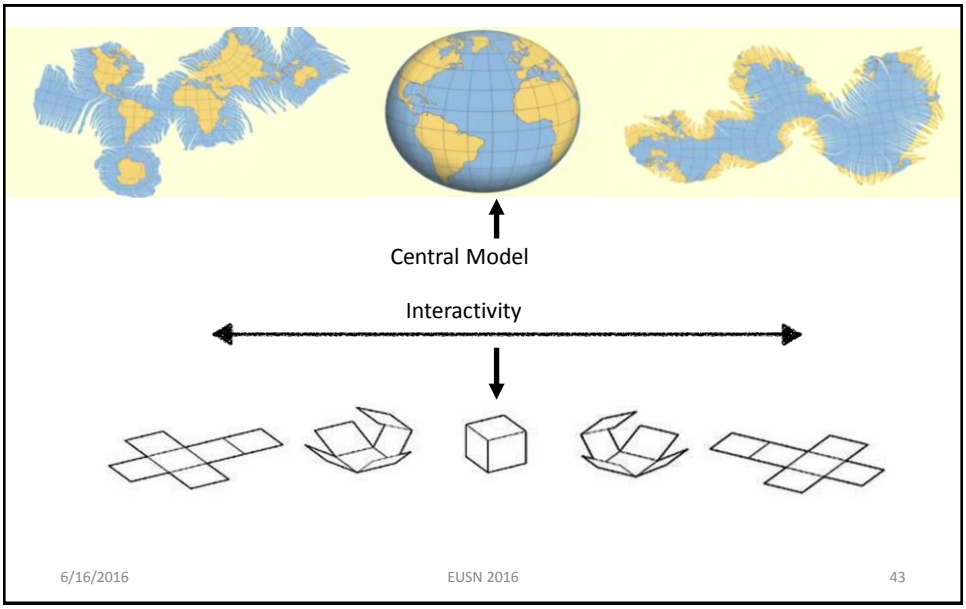
Collberg et al. 2003

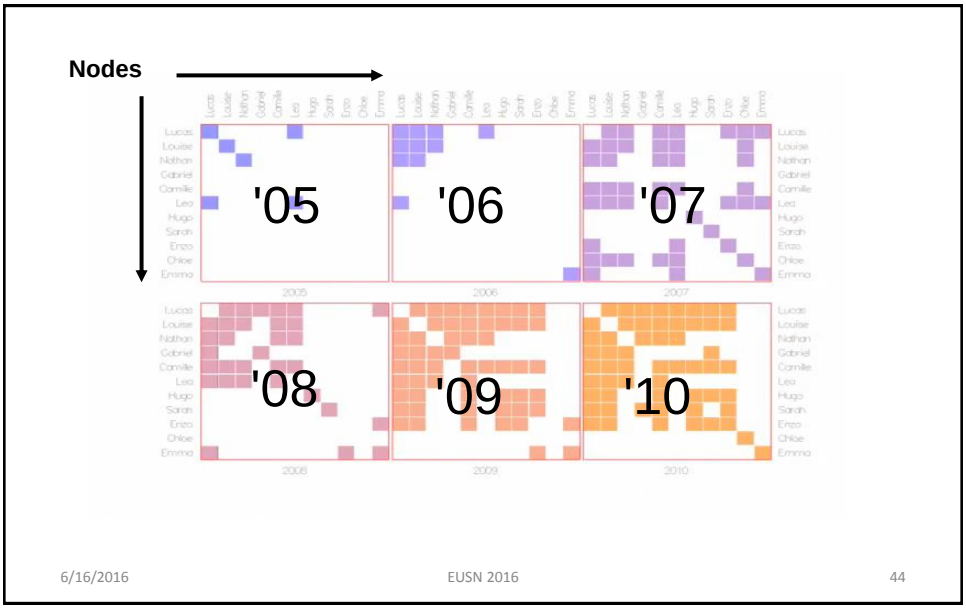
Gestalt Lines Brandes & Nick, 2011



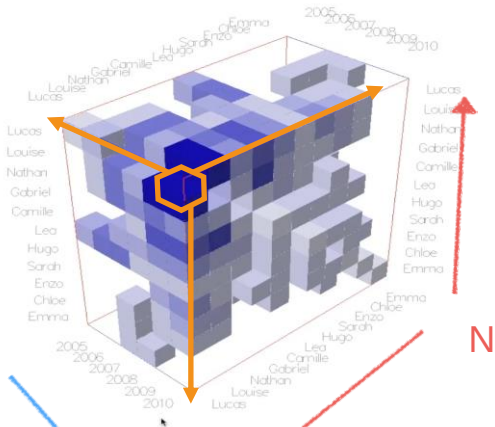


[van Wijk 2008]


Central Model
Interactivity

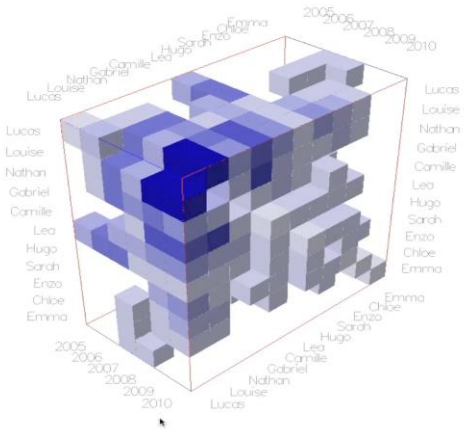

Nodes
'05
'06
'07
'08
'09
'10

Connection



Time

Nodes



Ceci n'est pas une visualisation 3D

Cubix: http://aviz.fr/cubix

Visualizing Dynamic Networks
with Matrix Cubes

submitted to
CHI2014

Cubix

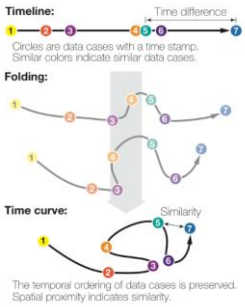
- Works for relatively small networks up to 1000 time steps
- Usable with a bit of training (10-20mn)
- Try it on your data: http://aviz.fr/cubix

- But what about bigger networks?

Time Curves

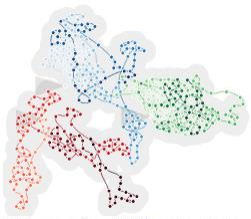
Benjamin Bach, Conglei Shi, Nicolas Heulot, Pierre Dragicevic

- Compute distances between multiples networks
- Use MDS to create a 2D map
- Connect them by time

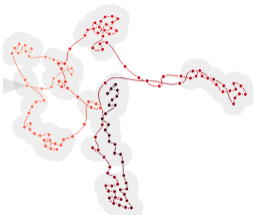


http://www.aviz.fr/~bbach/timecurves/

Time Curves on Networks



fMRI scans from 3 different subjects.

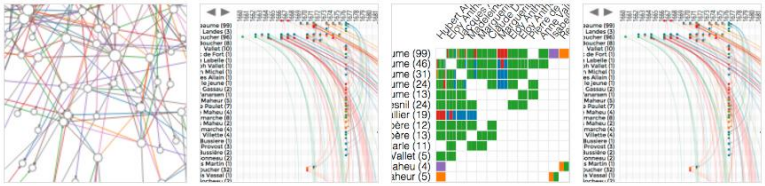


Parkinsons control RC4201 1 graphdat 20 (150)

Parkinsons control RC4205 1 graphdat 20 (150)

THE VISTORIAN

Interactive Online Visualizations for Dynamic Networks.



Benjamin Bach, Microsoft-Research, Inria
Nathalie Henry Riche, Microsoft Research
Nicole Dufournaud, EHESS
Jean-Daniel Fekete, Inria

https://vistorian.azurewebsites.net/vistorian/

Transferring Network Visualization

As researchers, we do not make products, but we tried many strategies:

- Publishing in high-ranked journals and conferences
- Writing open-source prototype applications
- Writing open-source libraries
- Writing open-source web sites

Prototype Applications

- Cubix: http://www.aviz.fr/cubix
- GeneaQuilts: http://www.aviz.fr/geneaquilts
  - Integrated with **PUCK** (Program for the Use and Computation of Kinship data) http://www.kintip.net/puck-topmenu-37

Open Source Libraries

- Reordering of Networks and Tables:
  - https://github.com/jdfekete/reorder.js
- NodeTrix library:
  - https://github.com/IRT-SystemX/nodetrix

Open Source Web Sites

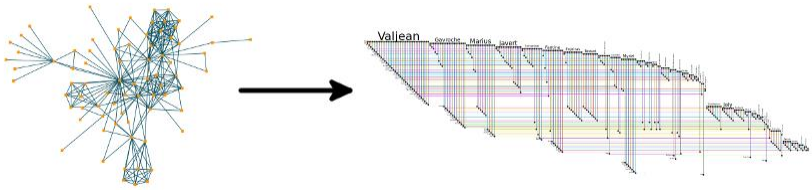
- Multipiles: http://www.aviz.fr/~bbach/multipiles/
- Time Curves: http://www.aviz.fr/~bbach/timecurves/
- Vistorian: http://vistorian.azurewebsites.net/

Research is not Engineering

- We continue our research to provide better visualization techniques for exploring and visually analyzing networks
- Practitioners should try them and, if satisfied, find funding for engineering work
- Researchers cannot and should not do it!
  - But are very willing to help
  - Don't do it without involving the researchers

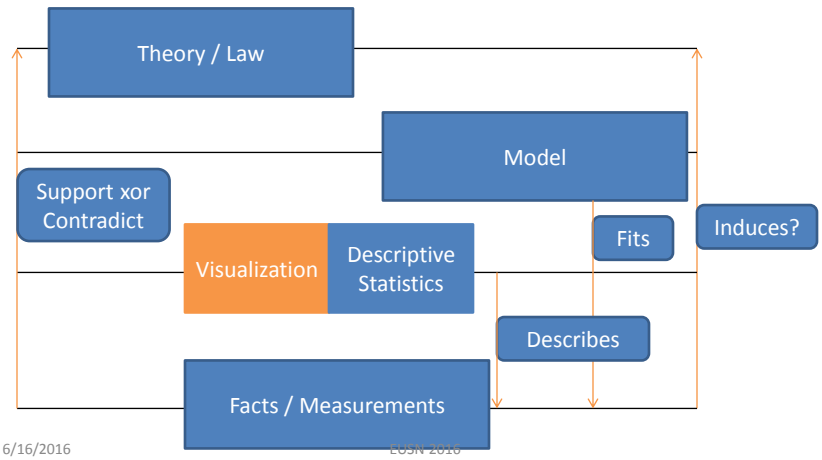
Research Continues

- More things are coming, like BioFabric from William JR Longabaugh: http://www.biofabric.org/

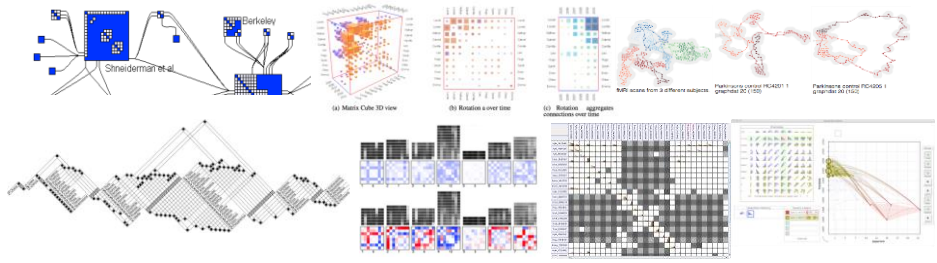


- Stay tuned, and come talk to the Visualization community!

Where does Visualization Stands?



Thanks! Questions?



http://www.aviz.fr/Research/Projects

Reference

- Tamara Munzner. Visualization Analysis and Design. A K Peters Visualization Series, CRC Press, 2014