DeCART Summer School 2018

Data Visualization

Day 2 - Morning

17 July 2018

Nils Gehlenborg, PhD - Harvard Medical School

Syllabus

- **Day 1**

  - Morning: Introduction to Data Visualization

  - Afternoon: Design Process, Evaluation, and Interaction

- **Day 2**

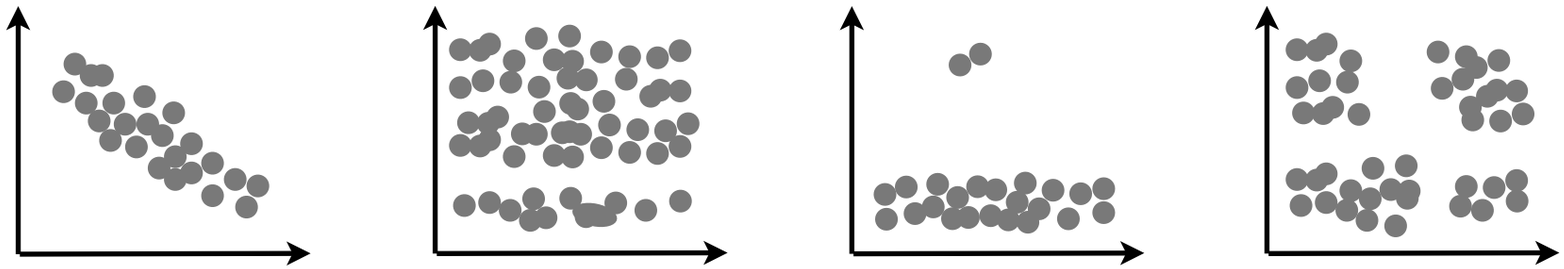
  - **Morning: Visualization of high-dimensional, network, and temporal data**

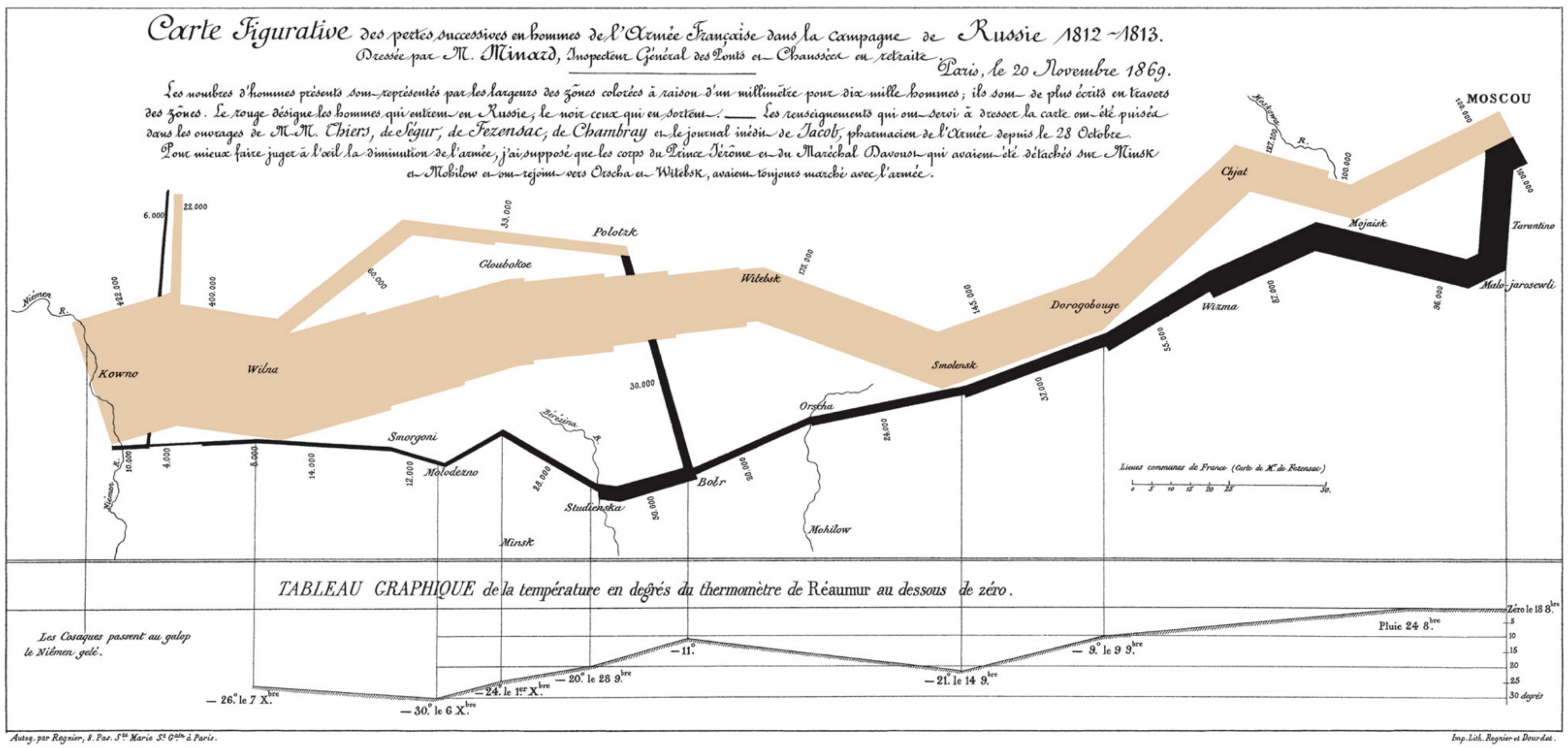
  - Afternoon: Genomic data visualization techniques
    Introduction to Altair and advanced Altair

Syllabus - Day 2 (Morning)

- 9:00 - 9:15 | Review
- 9:15 - 10:00 | High-Dimensional Data
- 10:00 - 10:15 | Break
- 10:15 - 10:45 | Network Data
- 10:45 - 11:30 | Temporal Data

Review of Day 1


trends
gaps
outliers
clusters


Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.
Dressée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite.
Paris, le 20 Novembre 1869.
Les nombres d'hommes présents sont représentés par les largeurs des zônes colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en travers des zônes. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. —— Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M.M. Thiers, de Ségur, de Fezensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre.
Pour mieux faire juger à l'oeil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davoust qui avaient été détachés sur Minsk et Mobilow et ont rejoint vers Orscha et Witebsk, avaient toujours marché avec l'armée.
MOSCOU
Kowno
Wilna
Gloubokoe
Polotzk
Witebsk
Smolensk
Dorogobouge
Wizma
Chjat
Mojaisk
Tarantino
Malo-jarosewli
Smorgoni
Molodezno
Studienska
Minsk
Bobr
Orscha
Mohilow
TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.
Les Cosaques passent au galop le Niémen gelé.
— 26° le 7 X.bre
— 30° le 6 X.bre
— 24° le 1er X.bre
— 20° le 28 9.bre
— 11°
— 21° le 14 9.bre
— 9° le 9 9.bre
Pluie 24 8.bre
Zéro le 18 8.bre
Autog. par Regnier, 8. Pas. Ste Marie St Gain à Paris.
Imp. Lith. Regnier et Dourdet.

Minard 1869

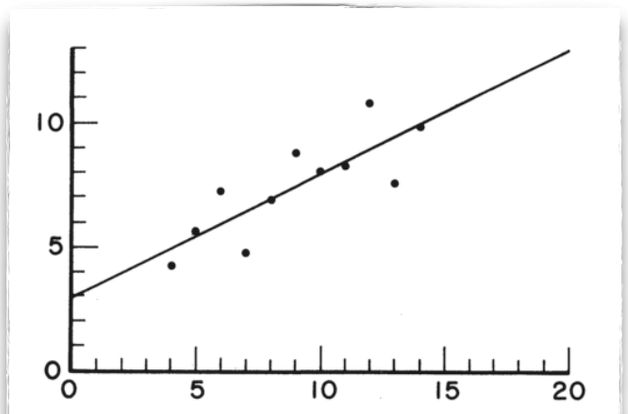


Figure 1

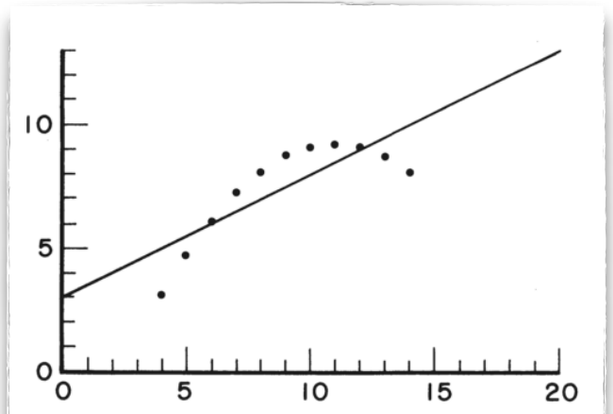


Figure 2

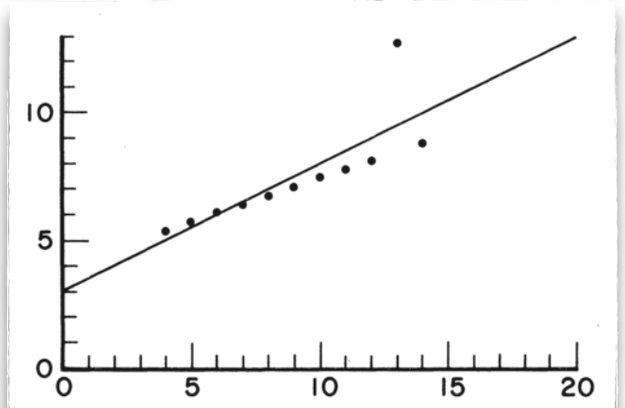


Figure 3

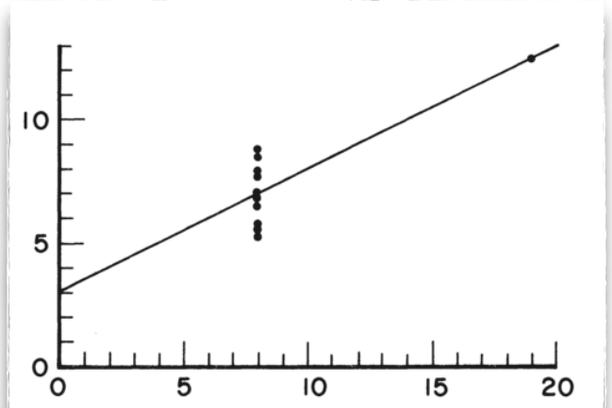


Figure 4

Anscombe 1973, The American Statistician

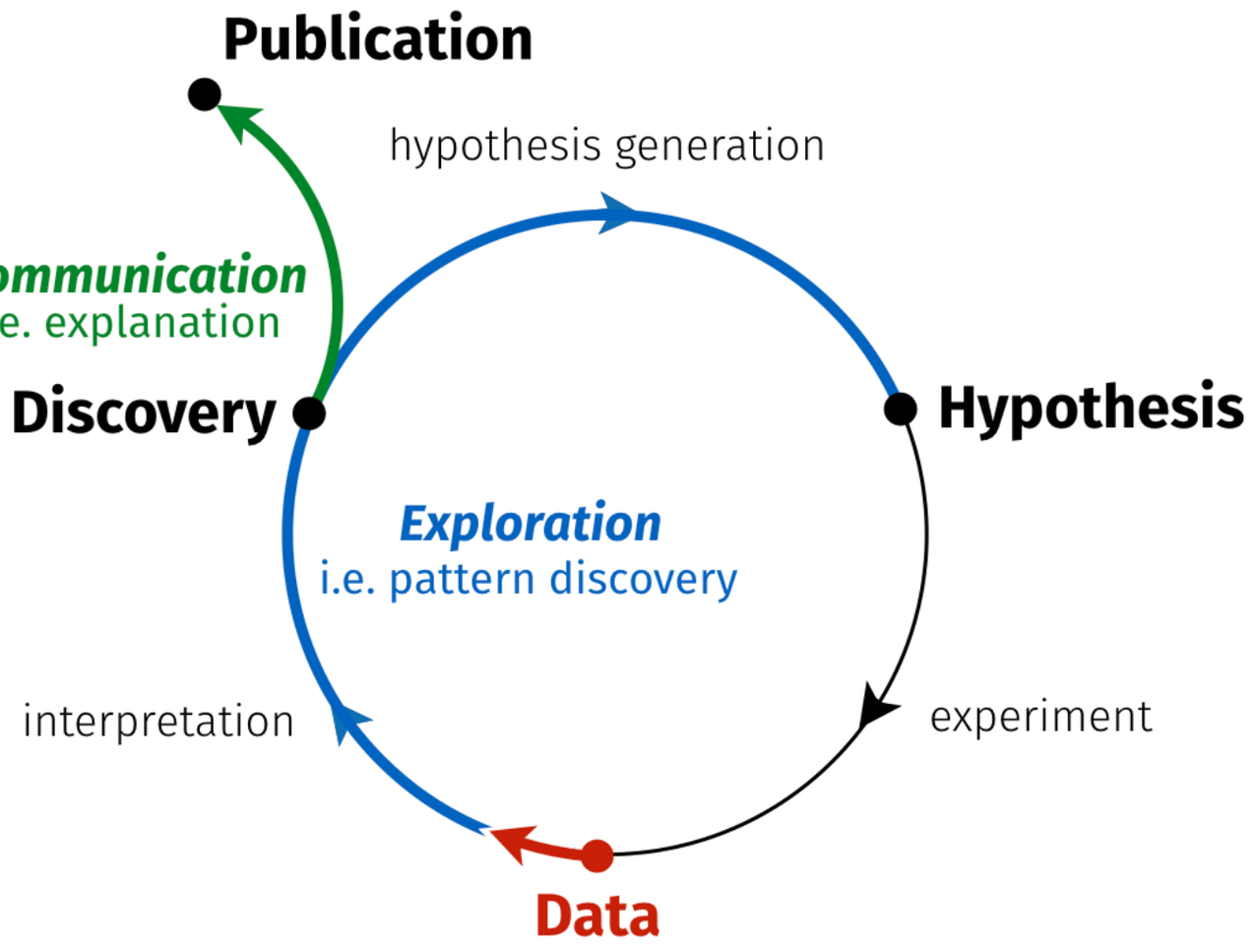
Visualization Use Cases

Exploration

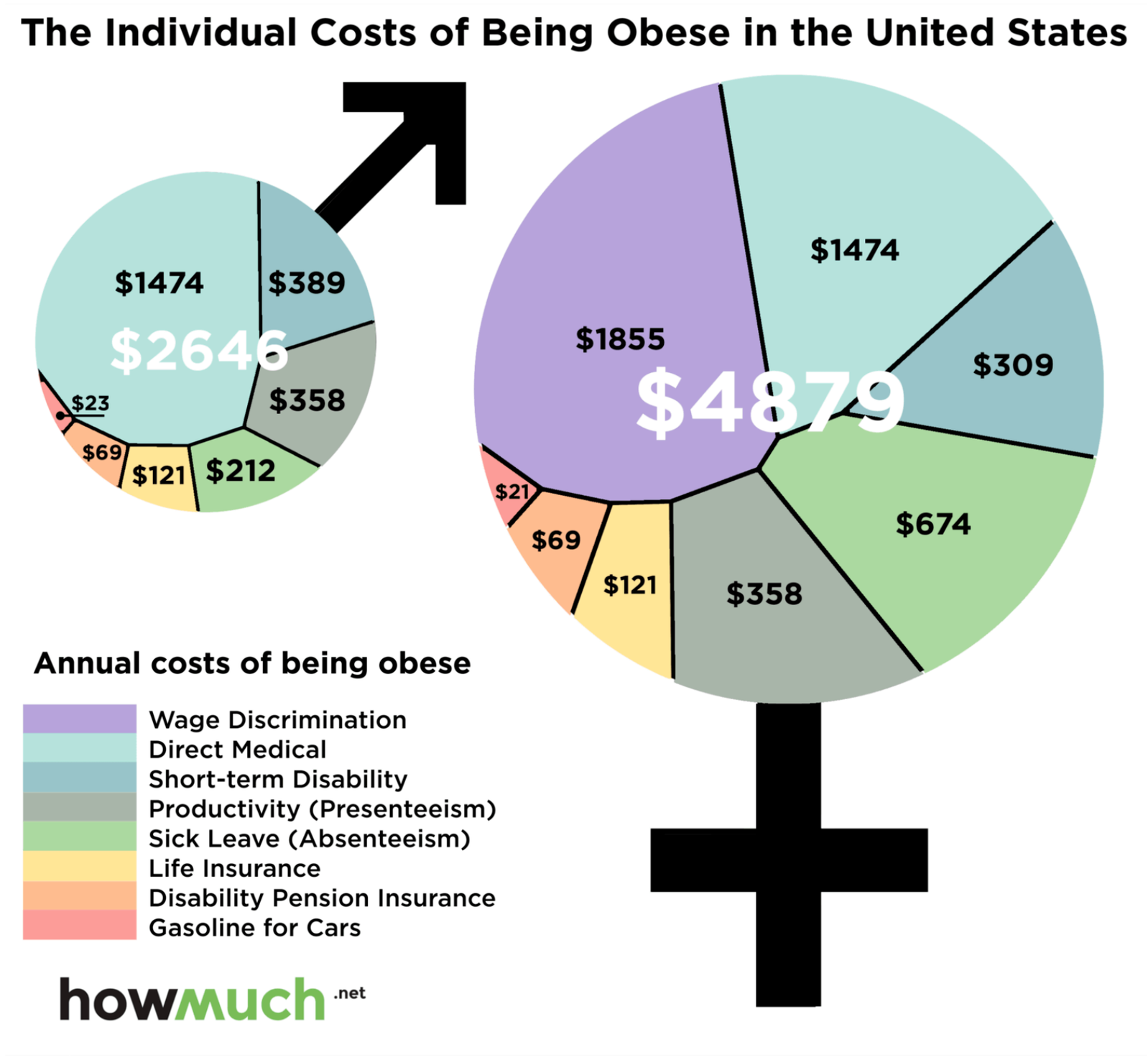
Confirmation

Communication

Visualization Use Cases

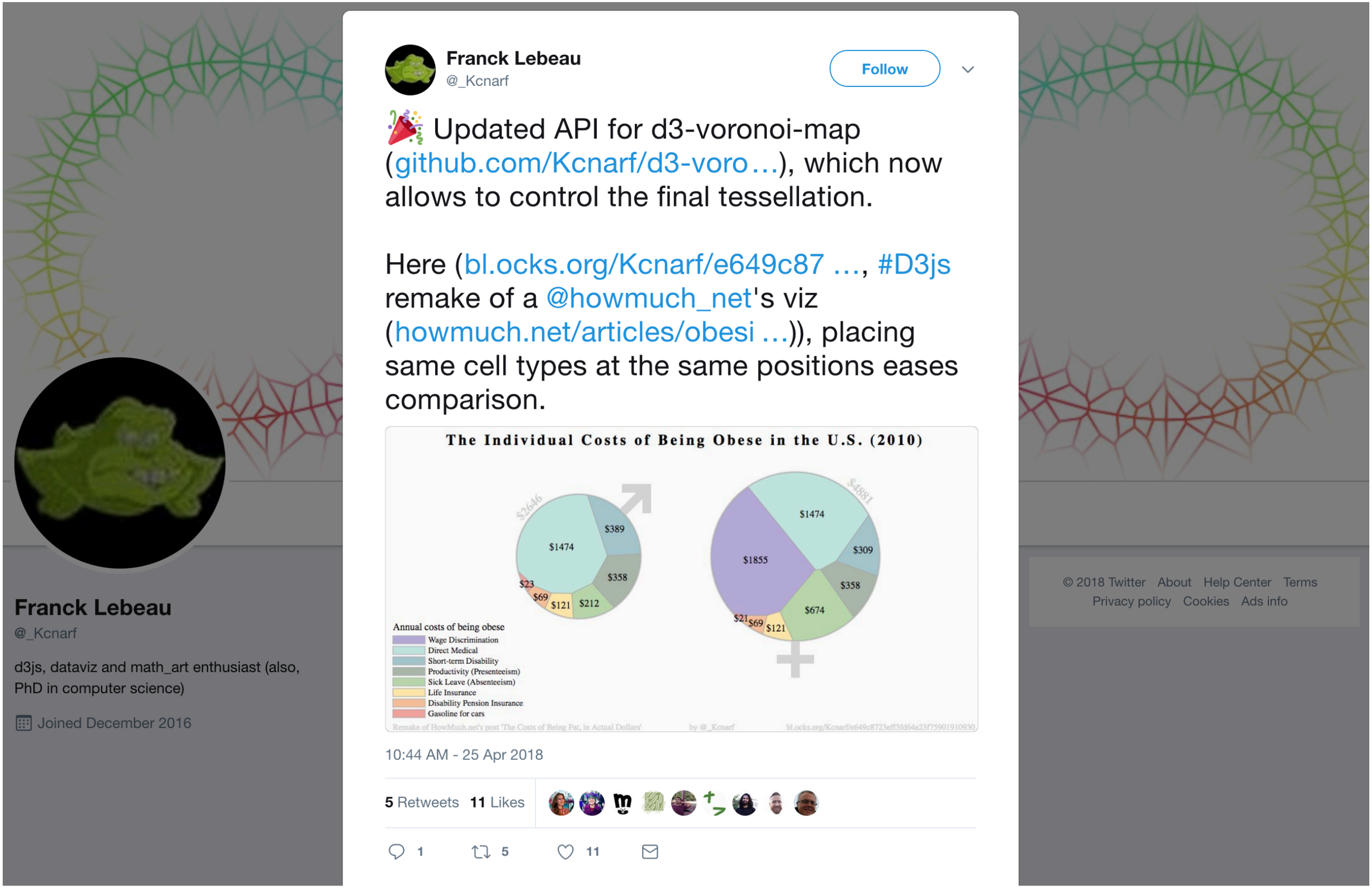


Redesign Exercise



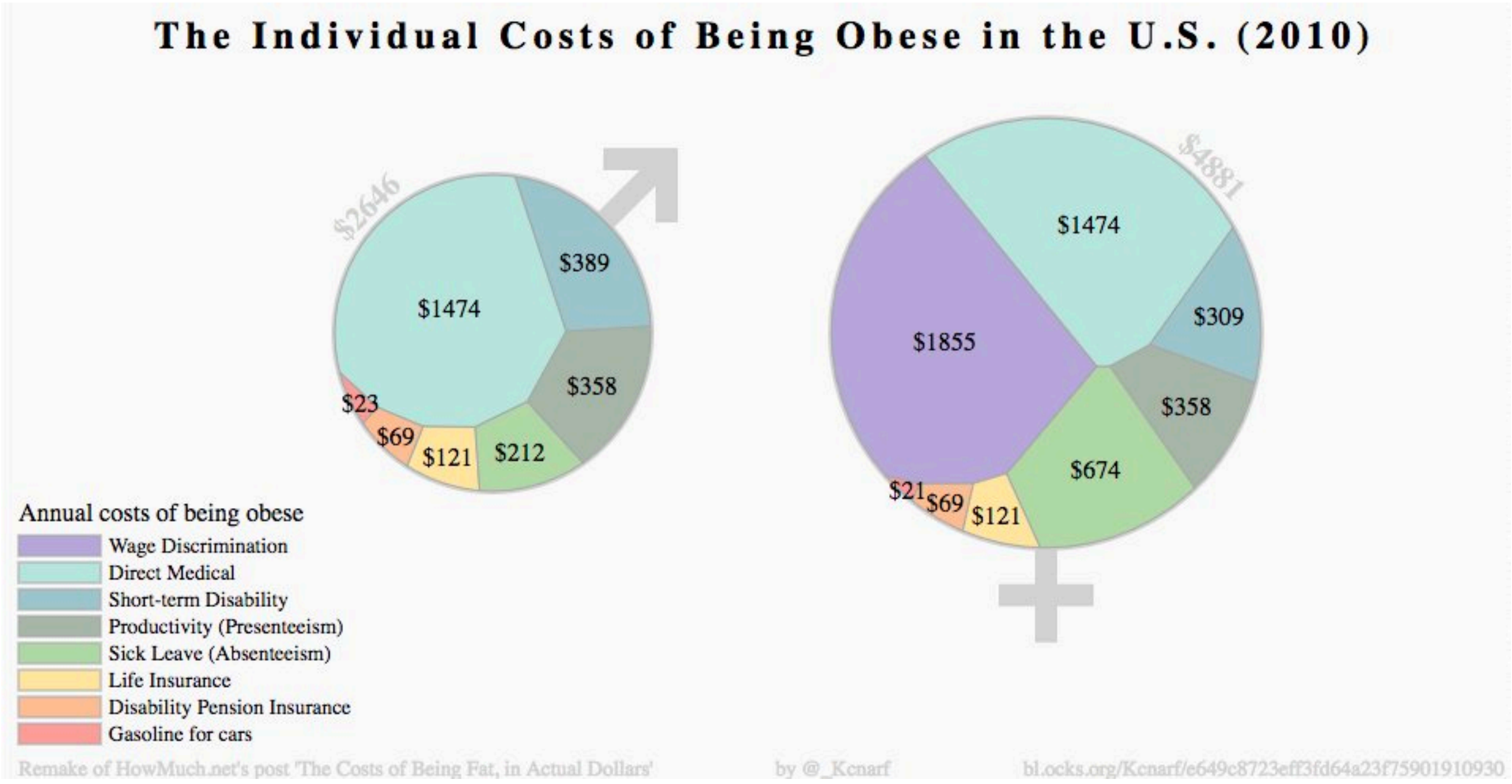
https://howmuch.net/articles/obesity-costs-visualized

Redesign Exercise



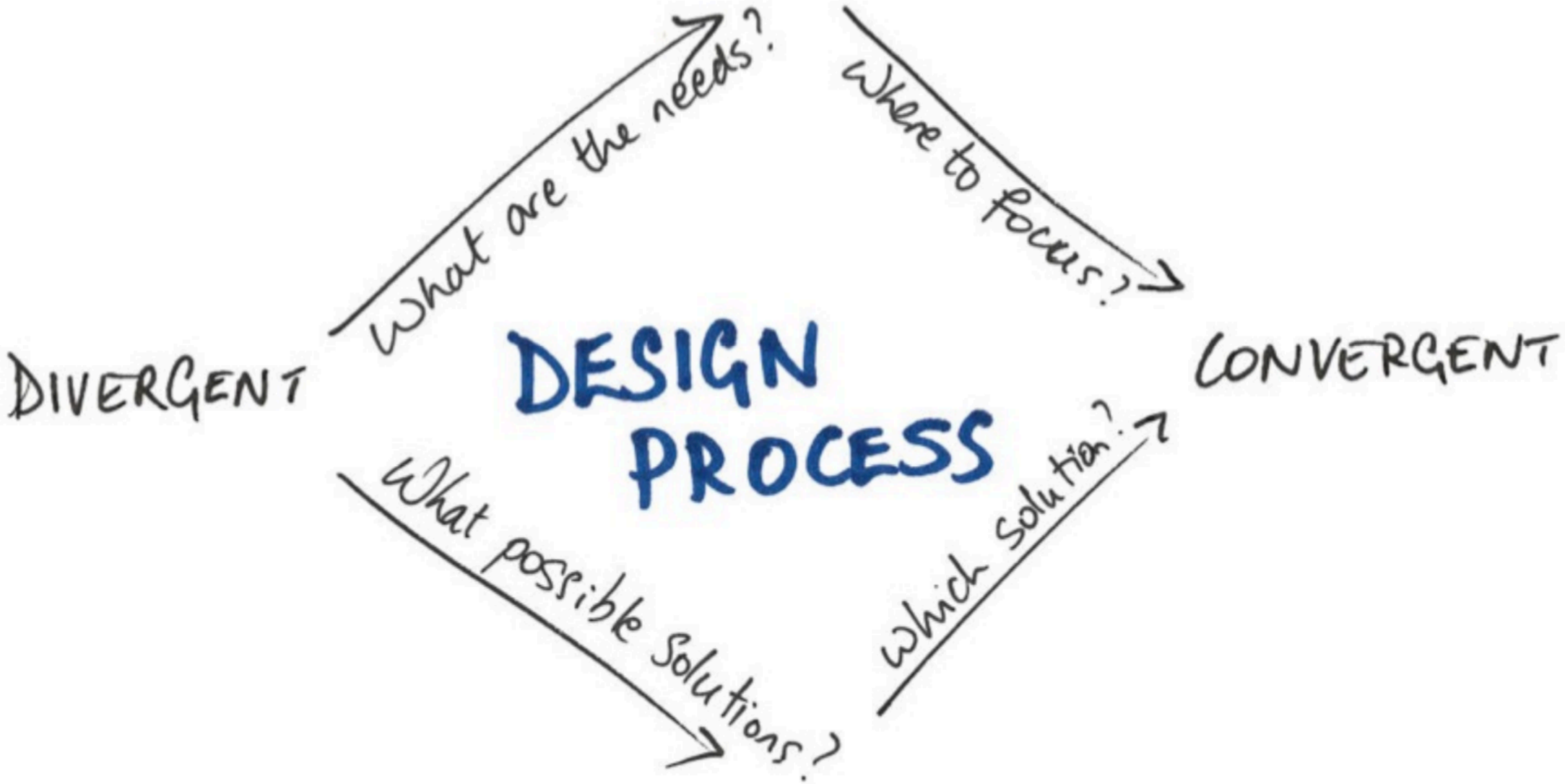
https://twitter.com/_Kcnarf/status/989153096055050240

Redesign Exercise



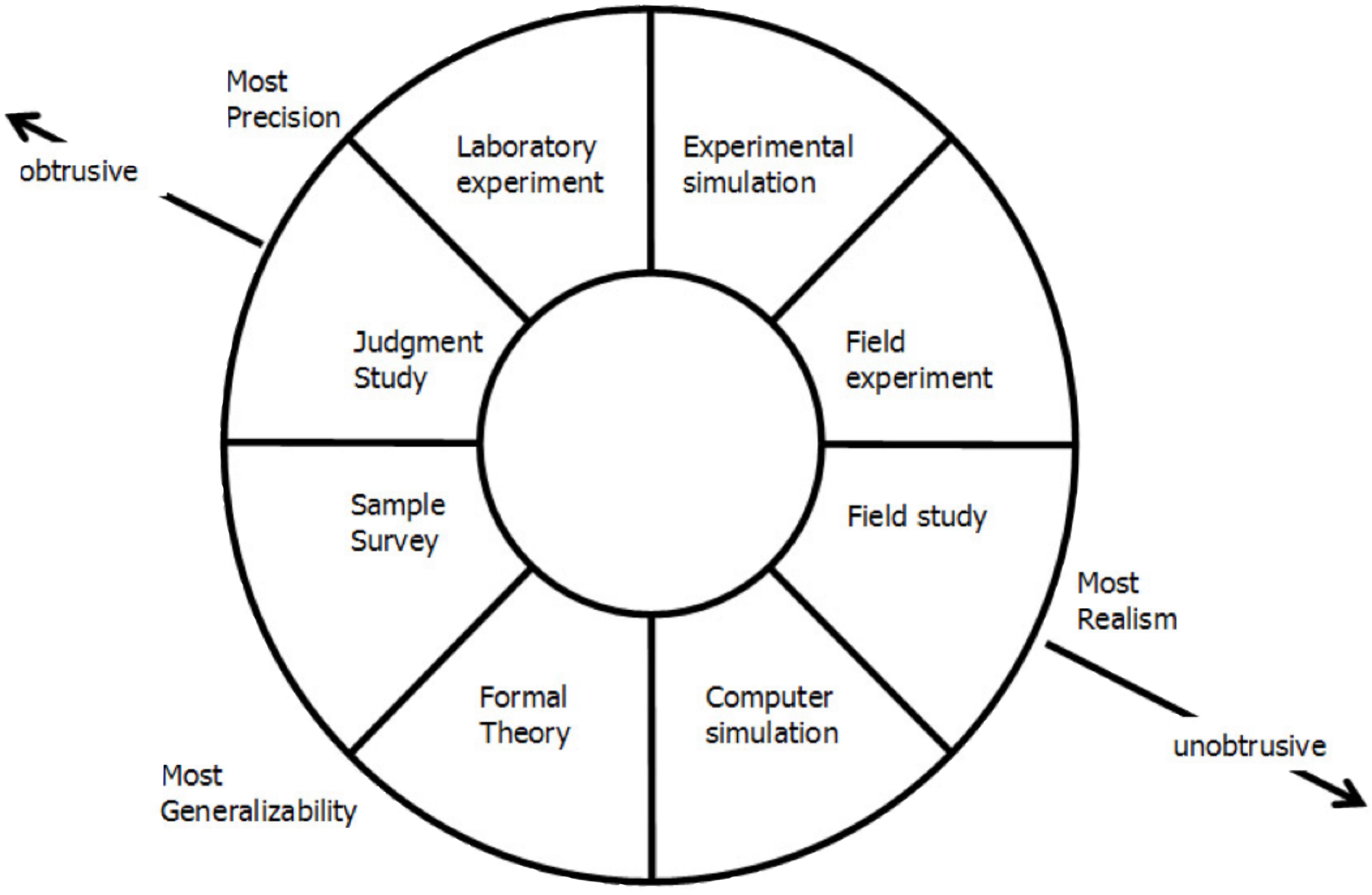
https://twitter.com/_Kcnarf/status/989153096055050240

Design Process



http://fds.design

Validation Techniques



Carpendale 2008, Evaluating Information Visualizations

Why we should ♥ good visualizations

Evaluation of Artery Visualizations for Heart Disease Diagnosis

Michelle A. Borkin, *Student Member, IEEE*, Krzysztof Z. Gajos, Amanda Peters, Dimitrios Mitsouras,
Simone Melchionna, Frank J. Rybicki, Charles L. Feldman, and Hanspeter Pfister, *Senior Member, IEEE*

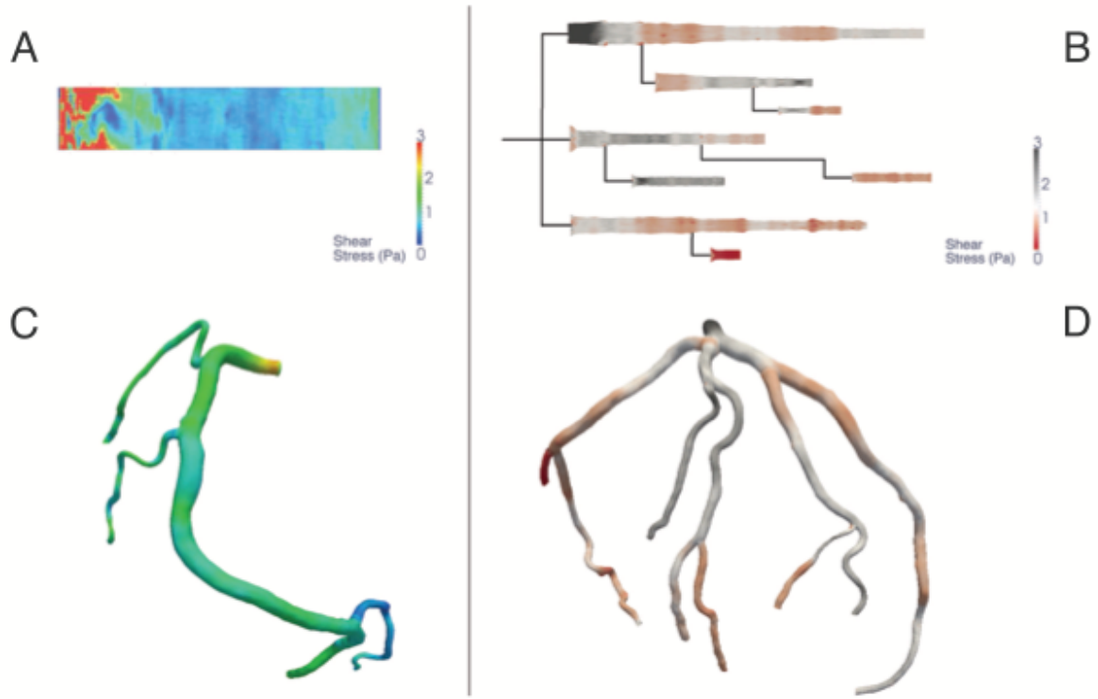


Fig. 1. Left: Traditional 2D projection (A) of a single artery, and 3D representation (C) of a right coronary artery tree with a rainbow color map. Right: 2D tree diagram representation (B) and equivalent 3D representation (D) of a left coronary artery tree with a diverging color map.

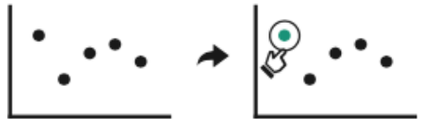
Borkin et al., Evaluation of Artery Visualizations for Heart Disease Diagnosis, 2011

Single View Interactions

Manipulate

Change over Time

Select

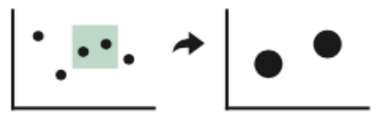


Navigate

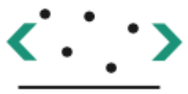
→ Item Reduction

→ *Zoom*

Geometric or *Semantic*



→ *Pan/Translate*

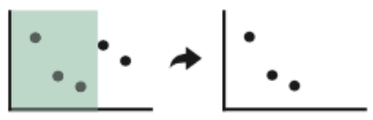


→ *Constrained*

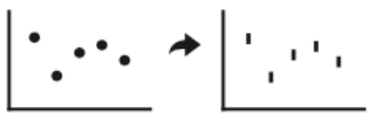
→ Attribute Reduction

→ *Slice*

→ *Cut*



→ *Project*



Munzner, Visualization Analysis and Design, 2014 (Chapter 11)

Multi-View Interactions

Facet

Juxtapose and Coordinate Multiple Side-by-Side Views

→ Share Encoding: Same/Different

→ *Linked Highlighting*

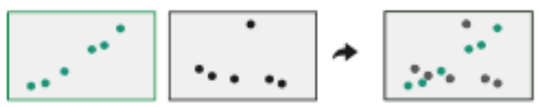
→ Share Data: All/Subset/None

→ Share Navigation

		Data		
		All	Subset	None
Encoding	Same	Redundant	Overview/ Detail	Small Multiples
	Different	Multiform	Multiform, Overview/ Detail	No Linkage

Partition into Side-by-Side Views

Superimpose Layers

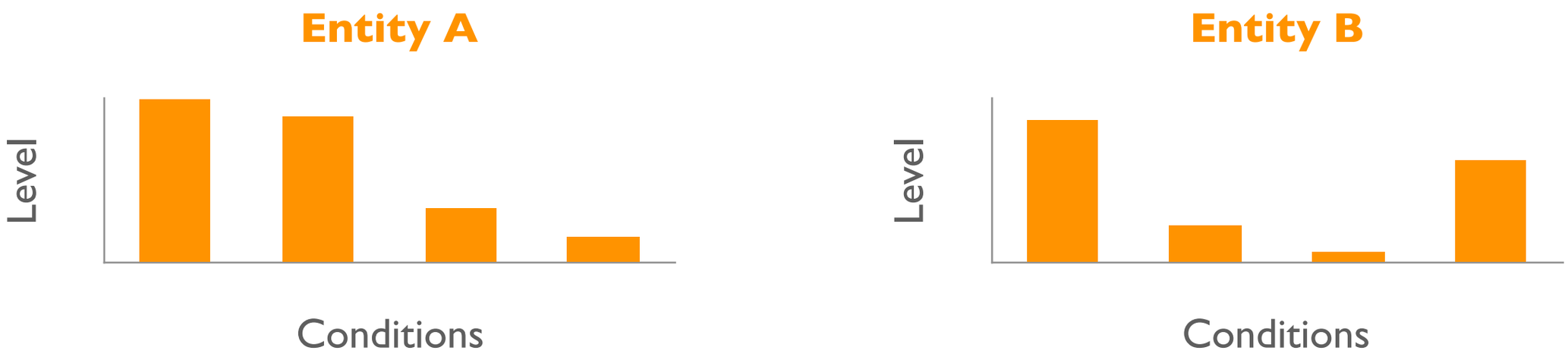


High-Dimensional Multivariate Data

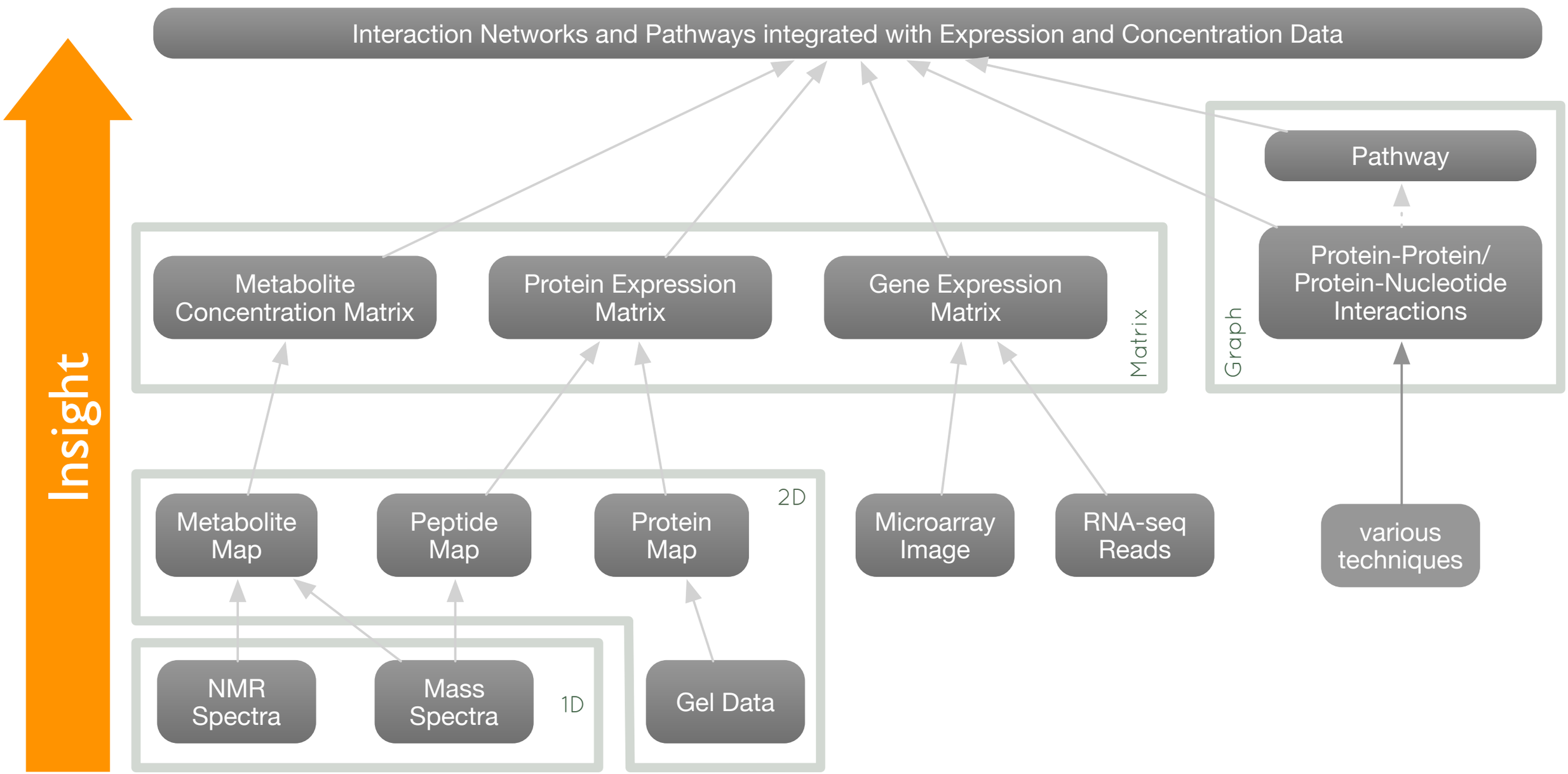
Homogeneous Tables

Multivariate Data

- typical “omics” data: transcriptomics, proteomics, metabolomics
- expression/concentration levels of many biological entities (transcripts, proteins, etc.) across many different conditions/time points
- entity levels measured per sample on a “genome-wide” scale
- often entities are not measured directly



Multivariate Data

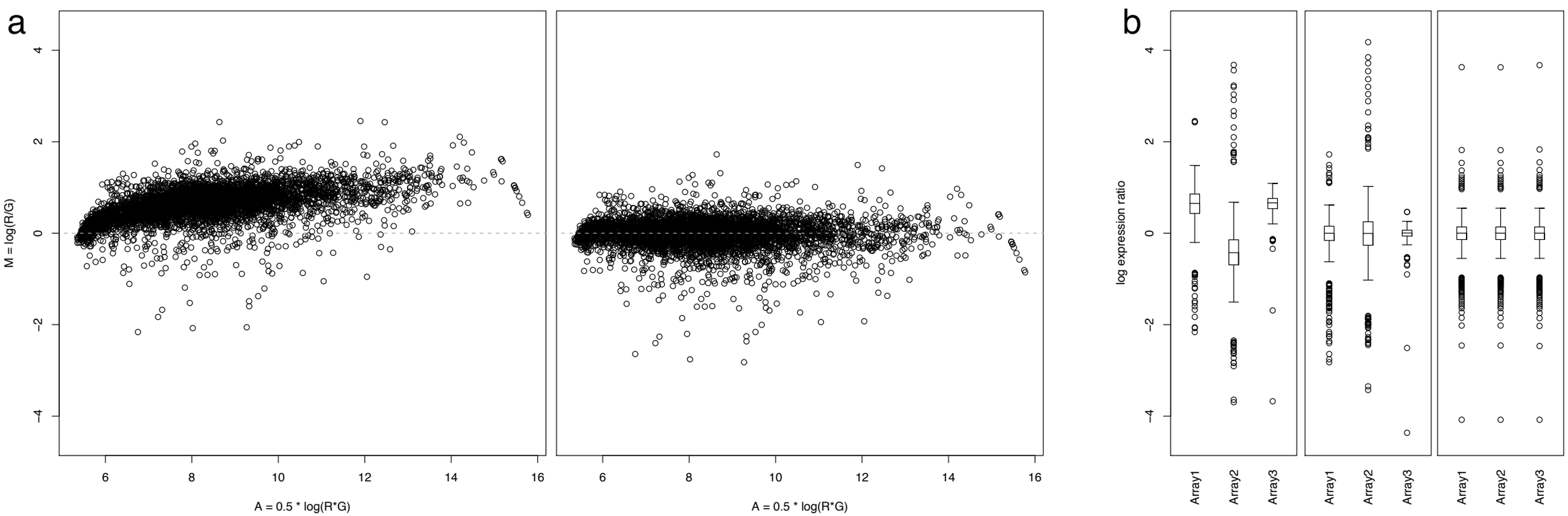


Gehlenborg et al. 2010, Nature Methods

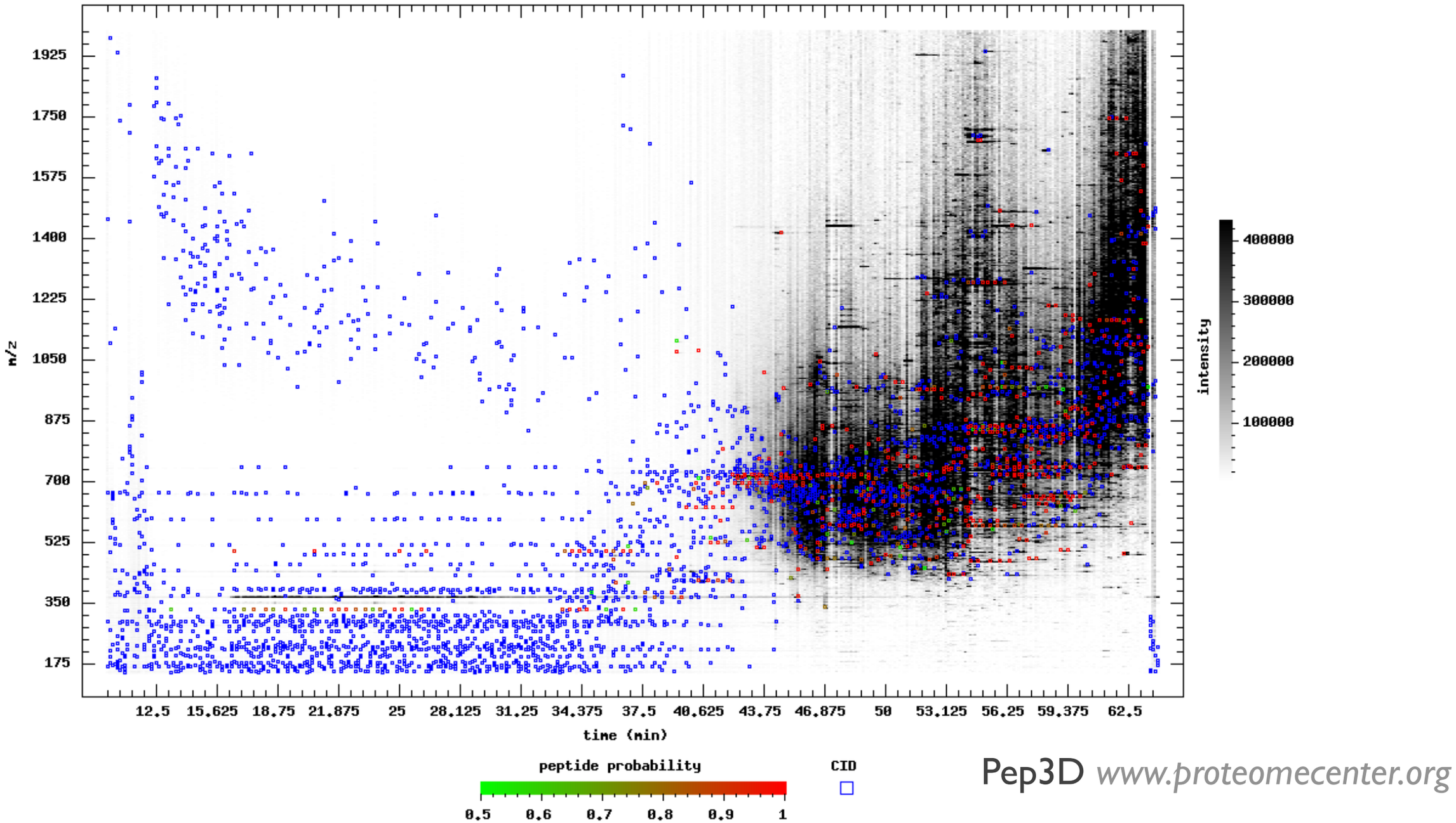
Multivariate Data: Transcriptomics

MA Plot: 1 array

Box Plot: 3 arrays



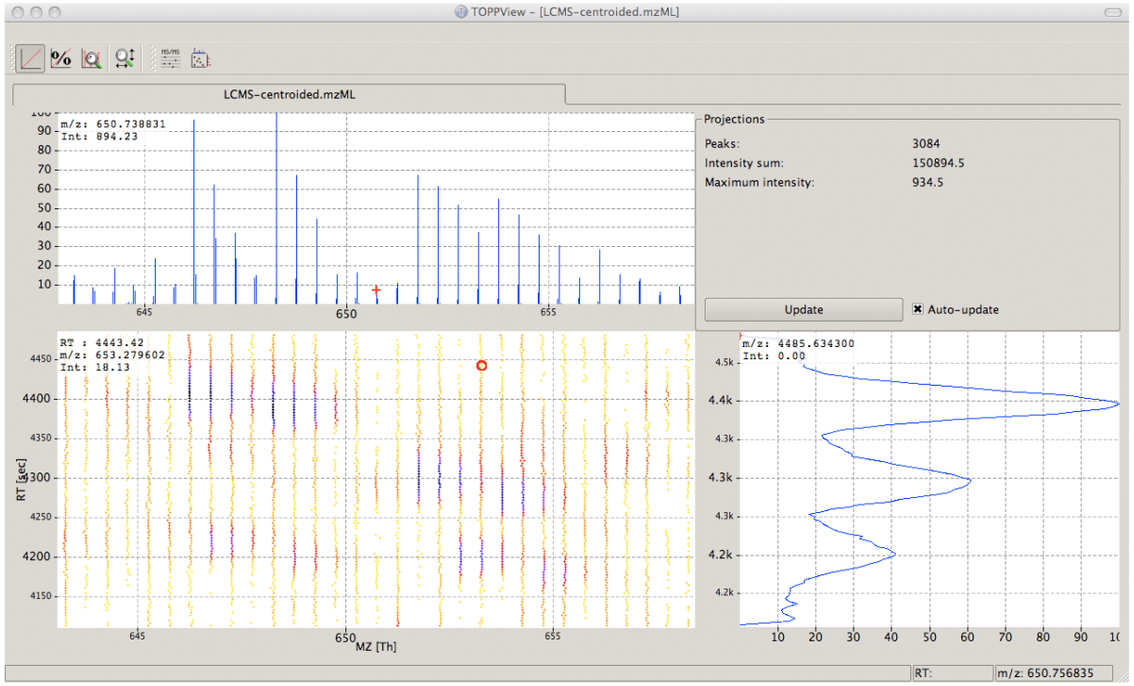
1 = before normalization
2 = after within-array normalization
3 = after between-array normalization



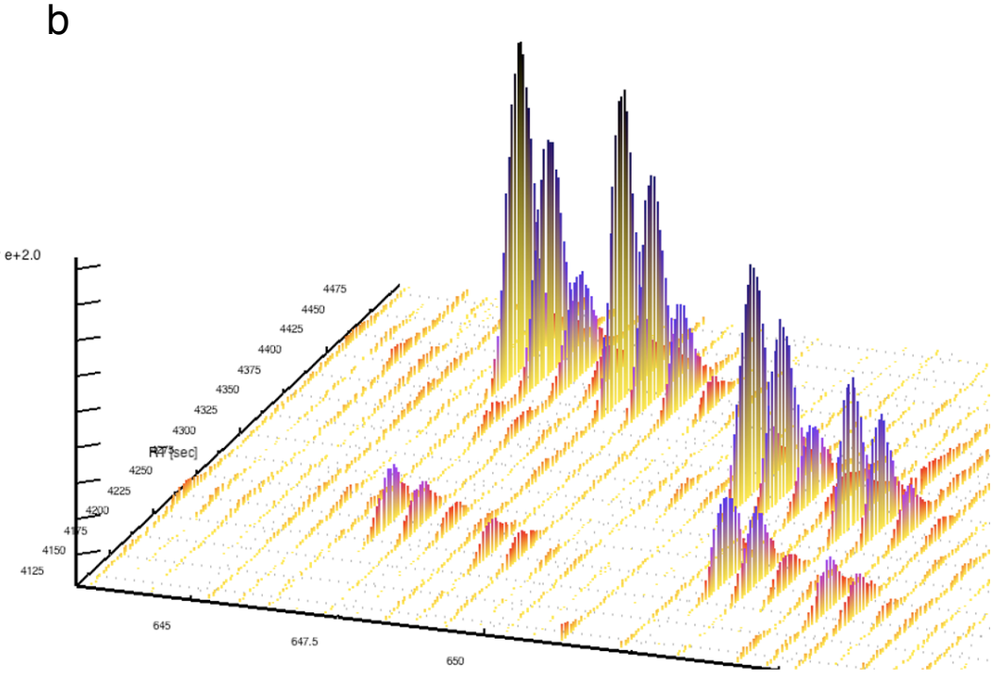
Pep3D *www.proteomecenter.org*

Multivariate Data: Proteomics

a

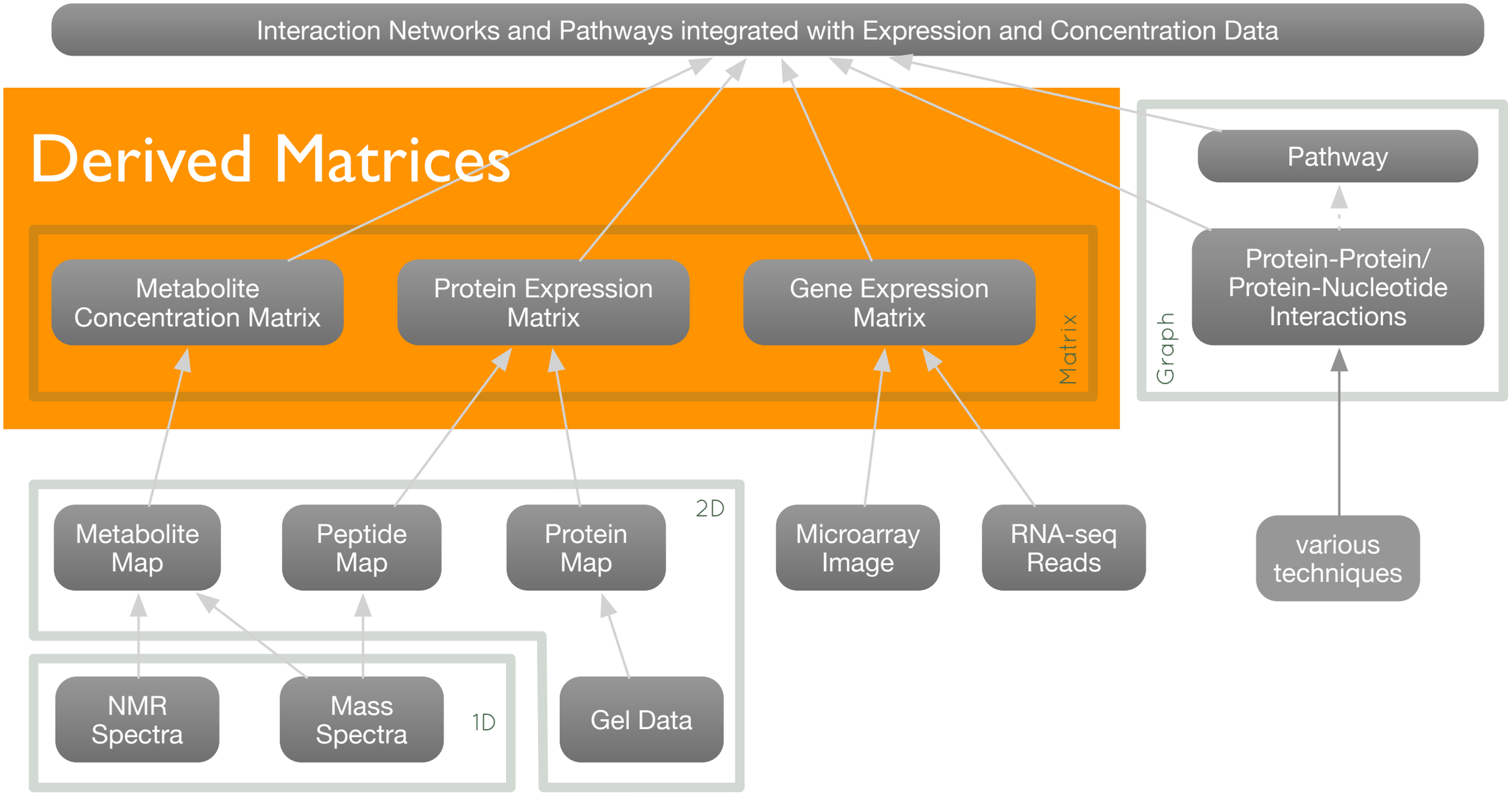


b



TOPPView *www.open-ms.de*

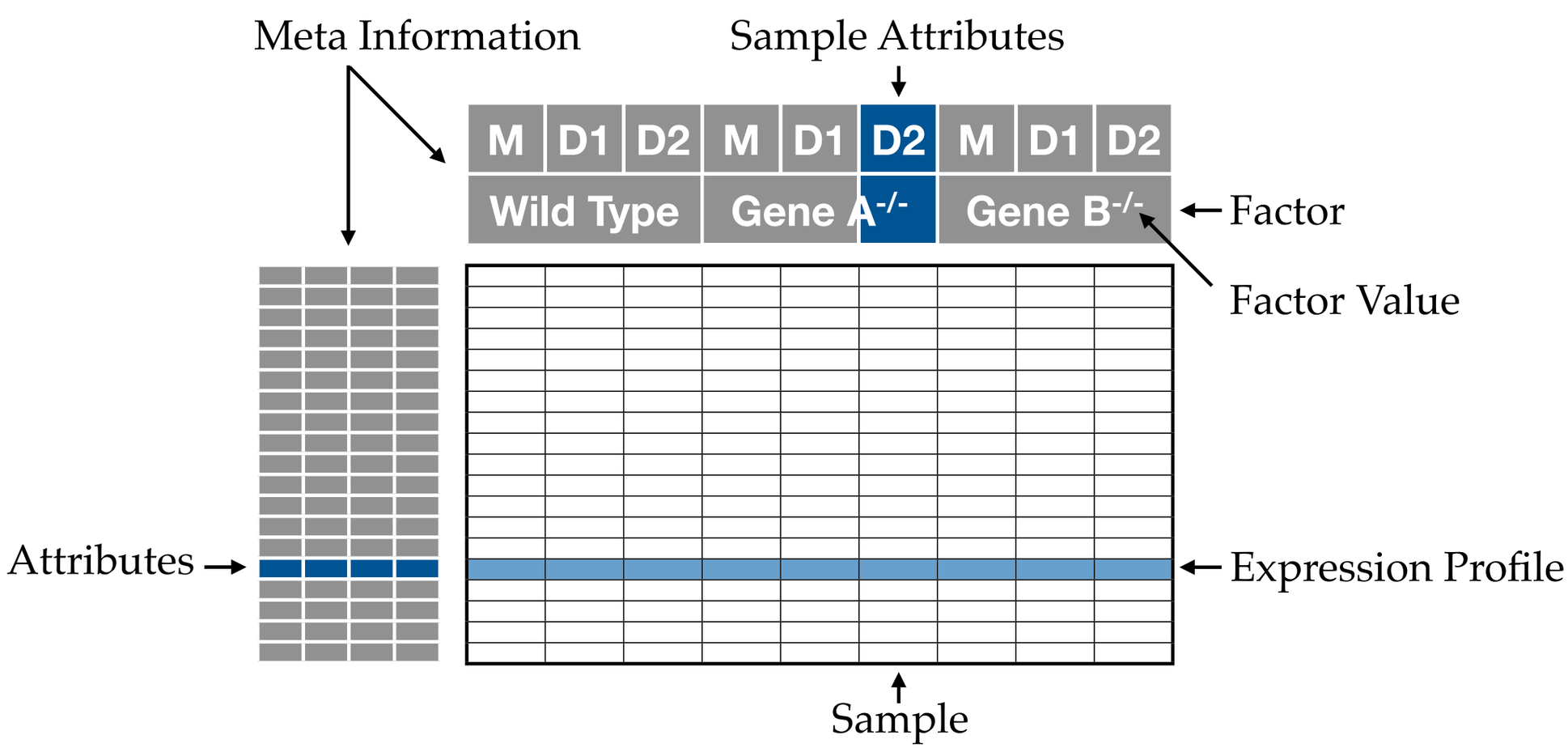
Multivariate Data: Derived Data



Multivariate Data: Derived Matrices

- matrices of multi-dimensional vectors

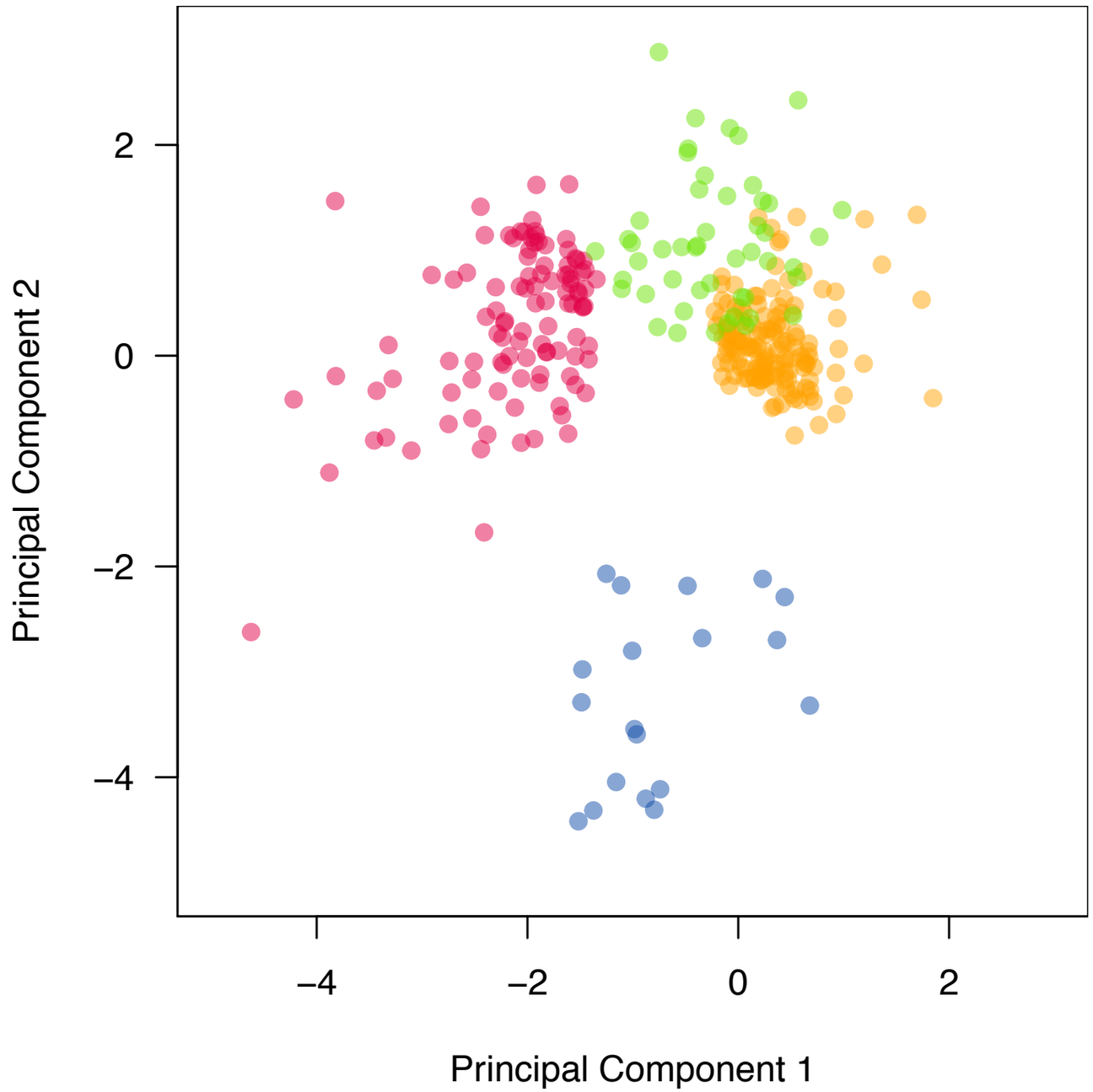
- usually abundance profiles, e.g. transcript or protein levels, metabolite concentrations



Gehlenborg et al. 2010, Nature Methods

Multivariate Data: Derived Matrices

Scatter Plot



Multivariate Data: Derived Matrices

- **Scatter Plots and Dimensionality Reduction**

  - used to visualize high-dimensional profiles as projections in lower-dimensional spaces (usually 2D, sometimes also 3D ...)

  - there is always a loss of information in the process, goal is to minimize the loss of information

- many different algorithms: Principal Components Analysis (PCA), Multi-Dimensional Scaling (MDS), Isomap, etc.

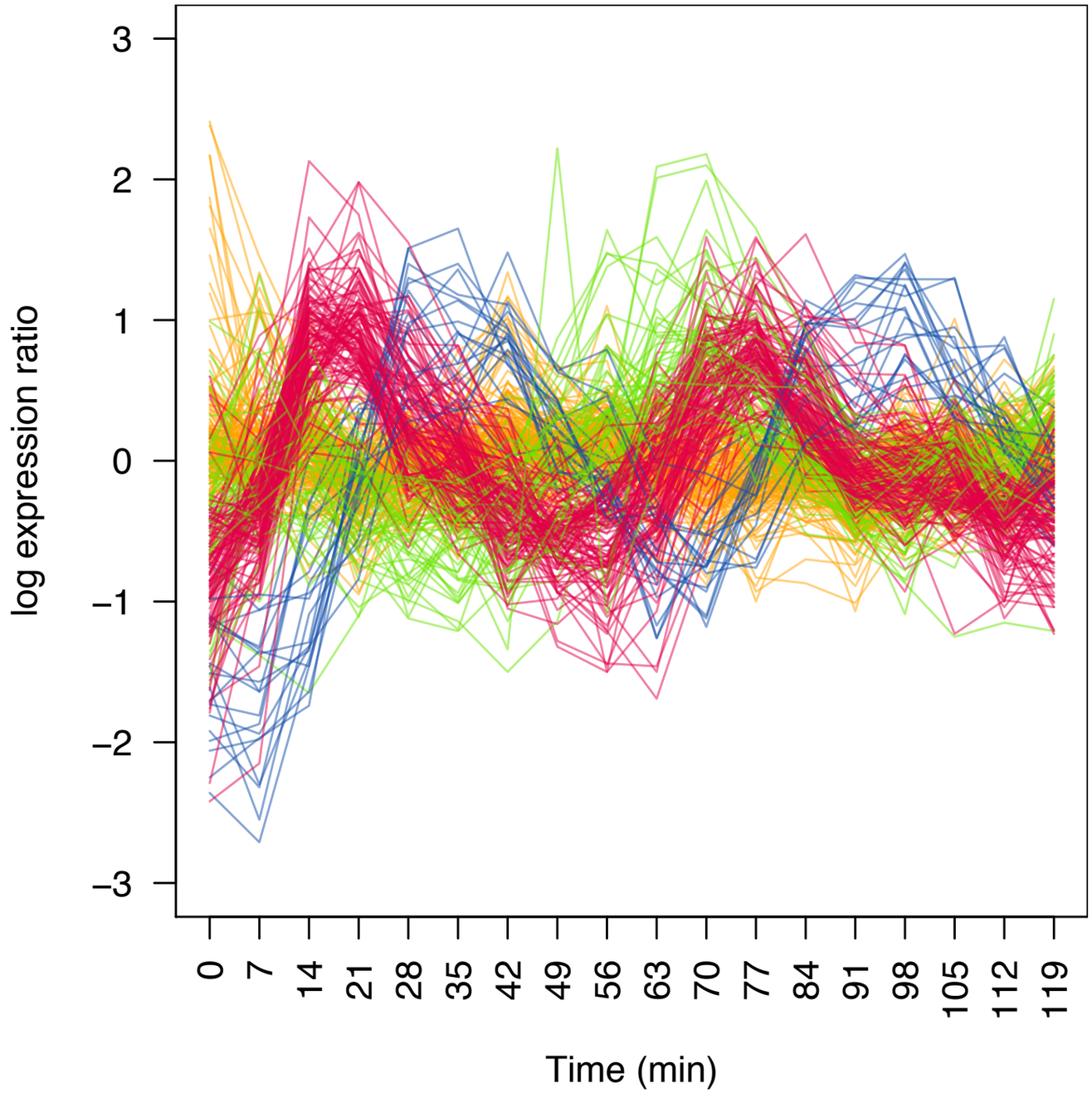
- **Pros** - good choice to get an idea about the overall structure of the whole data set: clusters, outliers, gaps in the data

- **Cons** - because of the dimensionality reduction the original profiles are not accessible in the visualization

Gehlenborg et al. 2010, Nature Methods

Multivariate Data: Derived Matrices

Profile Plot *a.k.a.* Parallel Coordinates



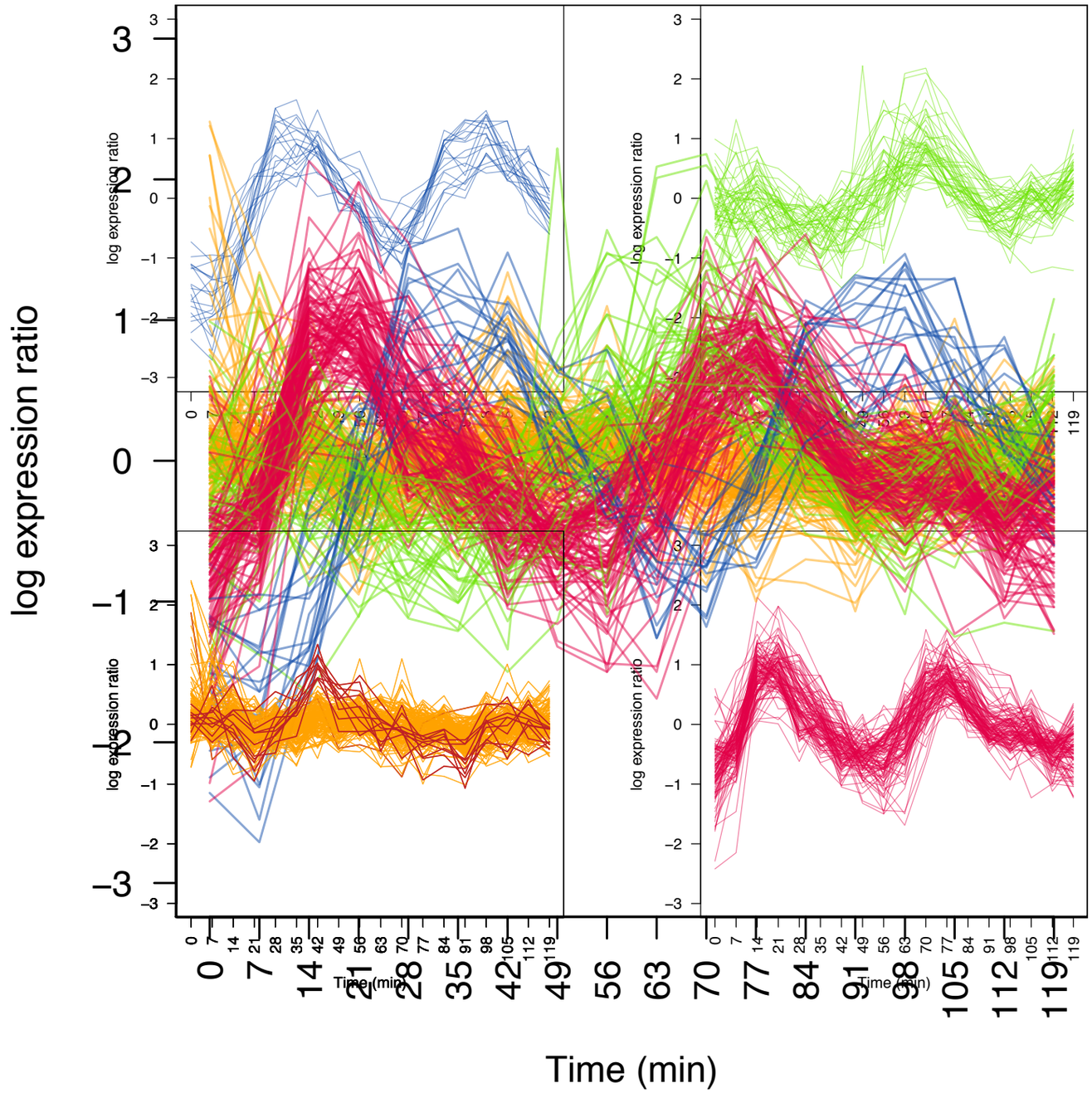
Multivariate Data: Derived Matrices

- **Profile Plot/Parallel Coordinate Plots**
    - **Pros**
        - encoding by position: profiles easy to read
        - color-coding of expression profiles (groups) very efficient
    - **Cons**
        - overplotting
        - grows horizontally with every additional sample

Gehlenborg et al. 2010, Nature Methods

Multivariate Data: Derived Matrices

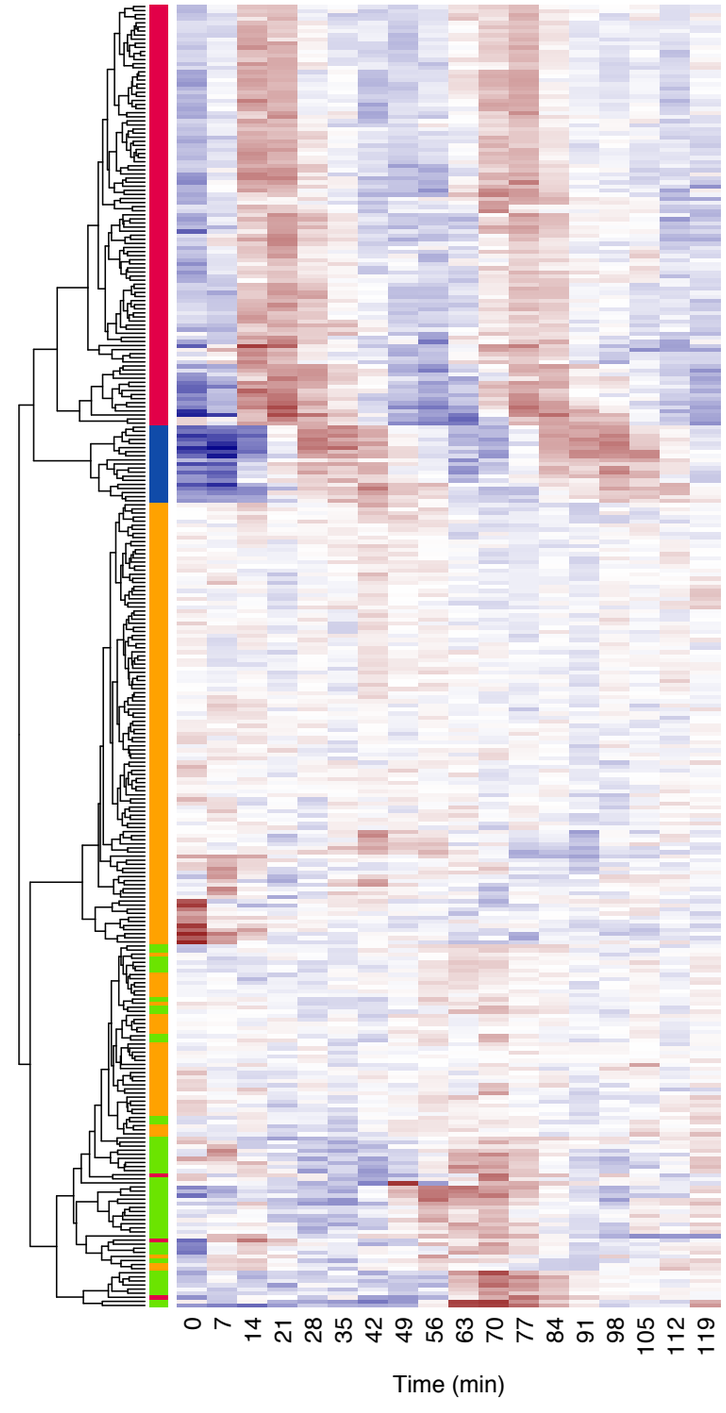
Profile Plot *a.k.a.* Parallel Coordinates



Gehlenborg et al. 2010, Nature Methods

Multivariate Data: Derived Matrices

Heat Map with Dendrogram



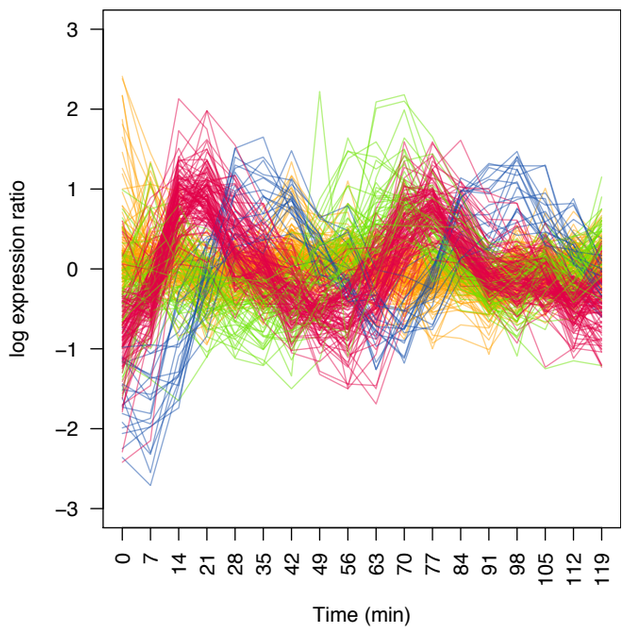
Multivariate Data: Derived Matrices

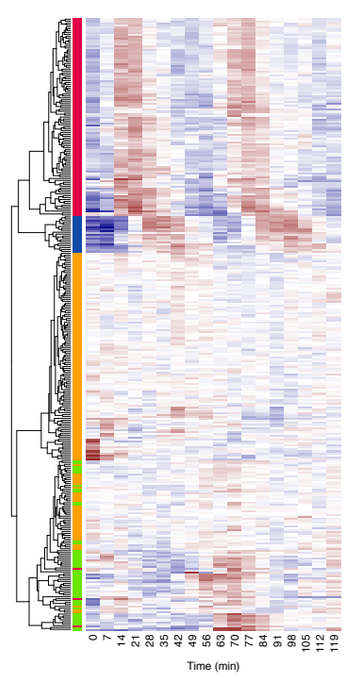
- **Heatmap**
  - **Pros**
    - no overplotting, yet a very dense information display
    - can be combined with dendrogram and additional information can be encoded in further columns or in the height of rows
- **Cons**
  - only qualitative interpretation possible due to color coding
  - grows horizontally with every additional sample and grows vertically with every additional profile

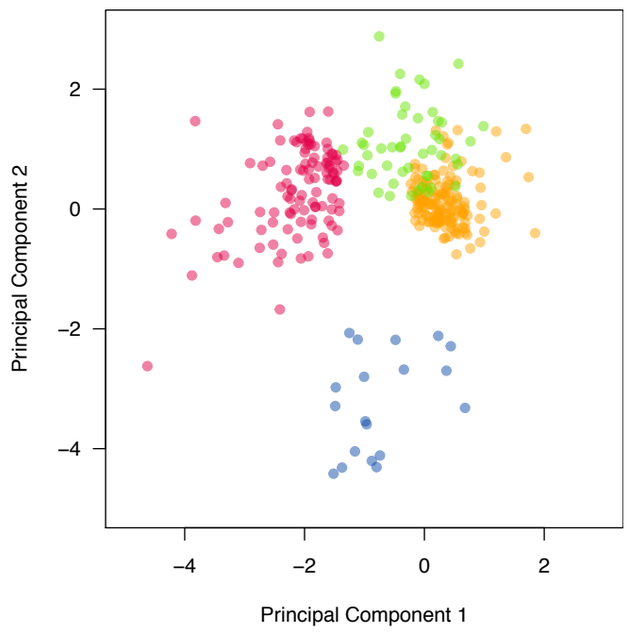
Multivariate Data: Summary

few, high-res

many, low-res

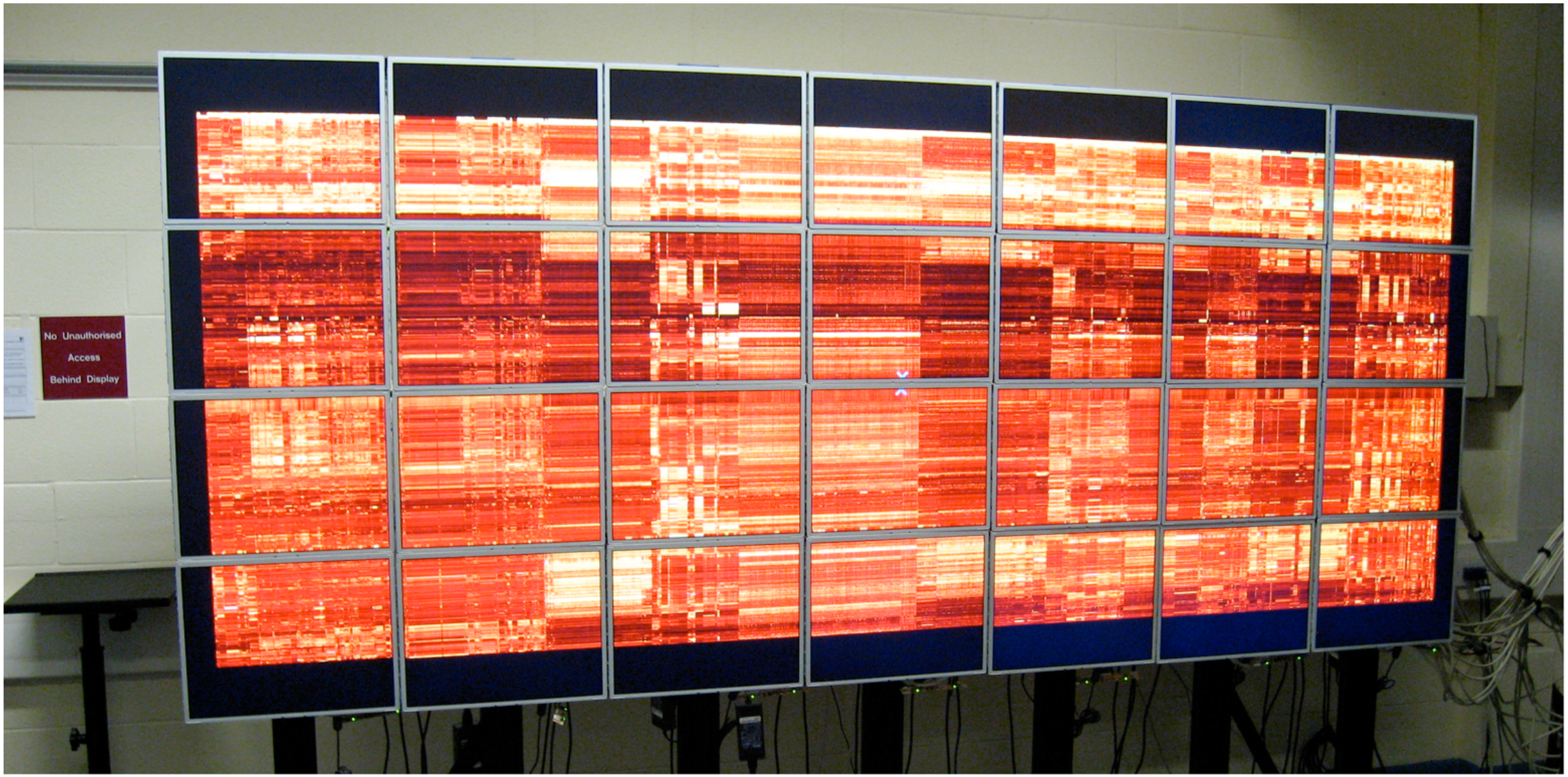






data: Lukk et al., *2010, Nature Biotechnology*

Problem: Very Large Expression Matrices



Power Wall (7x4 screens = 11,200x4,800), University of Leeds

1000 transcripts, 5372 samples

High-Dimensional Multivariate Data

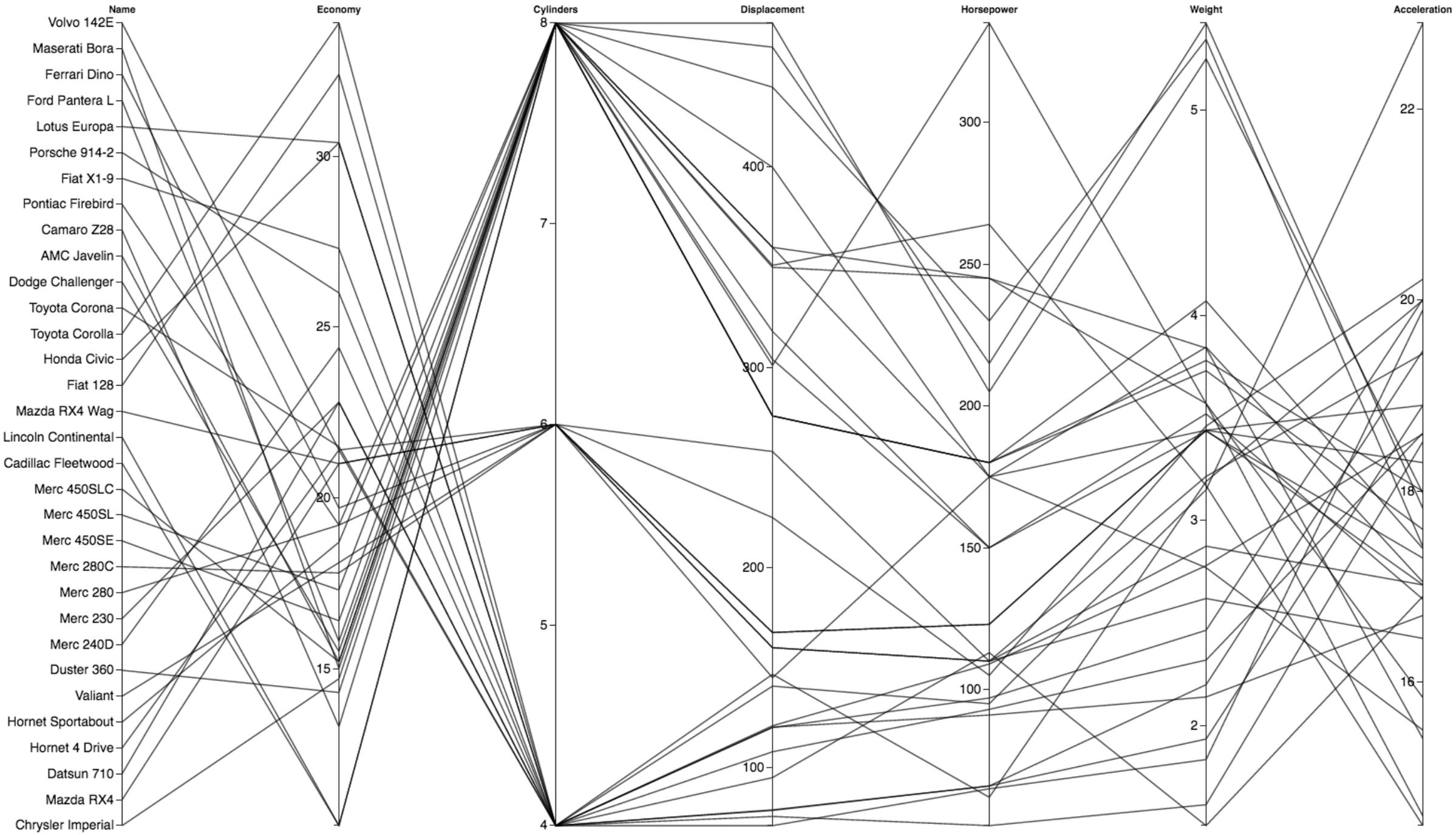
Heterogeneous Tables

parallelcoordinates.de

Nils

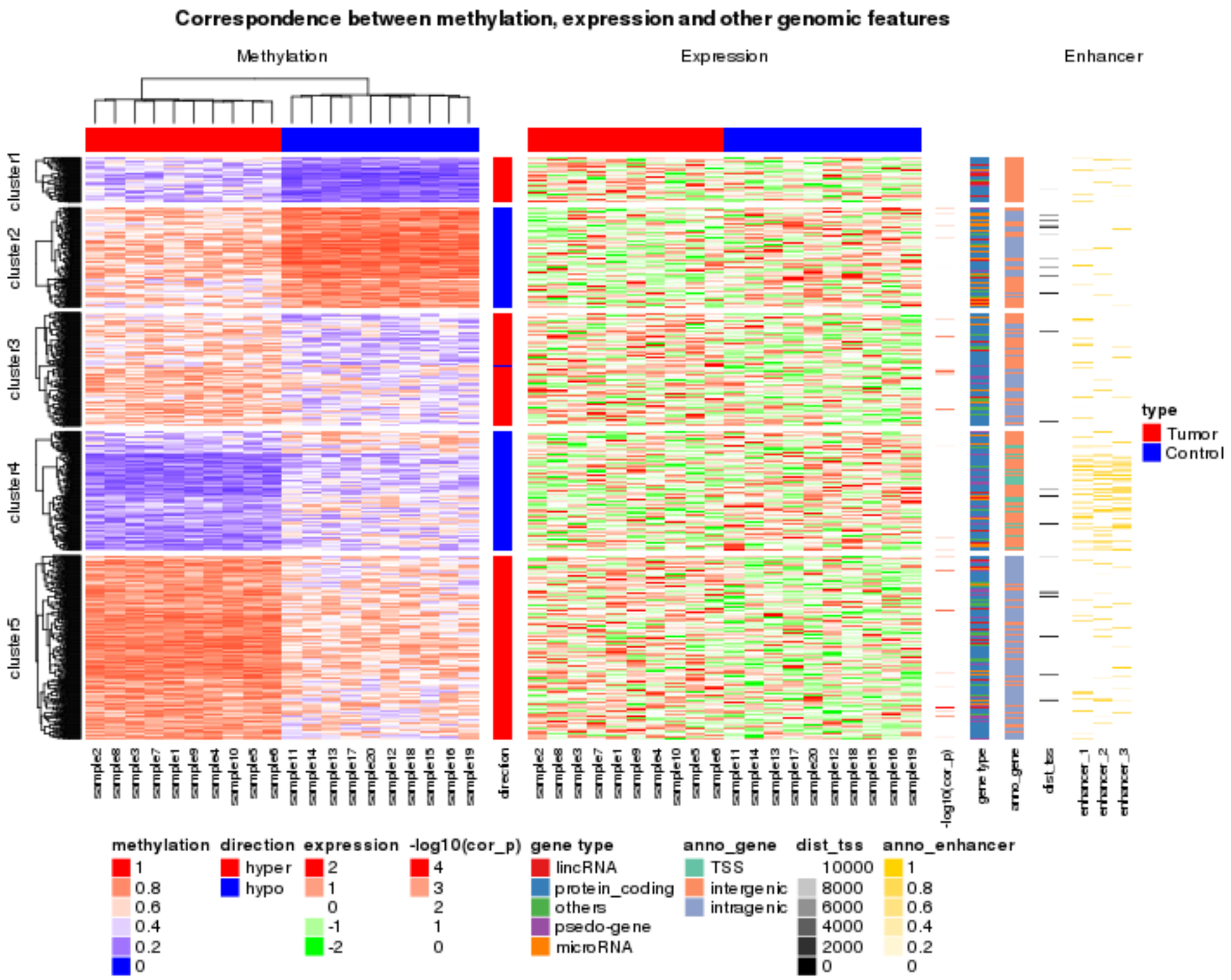
www.parallelcoordinates.de/paco/

parallelcoordinates.de | 1D | 2D | A | Color | ✖ | Density | Bundling | PCA | Clustering | Dimensions

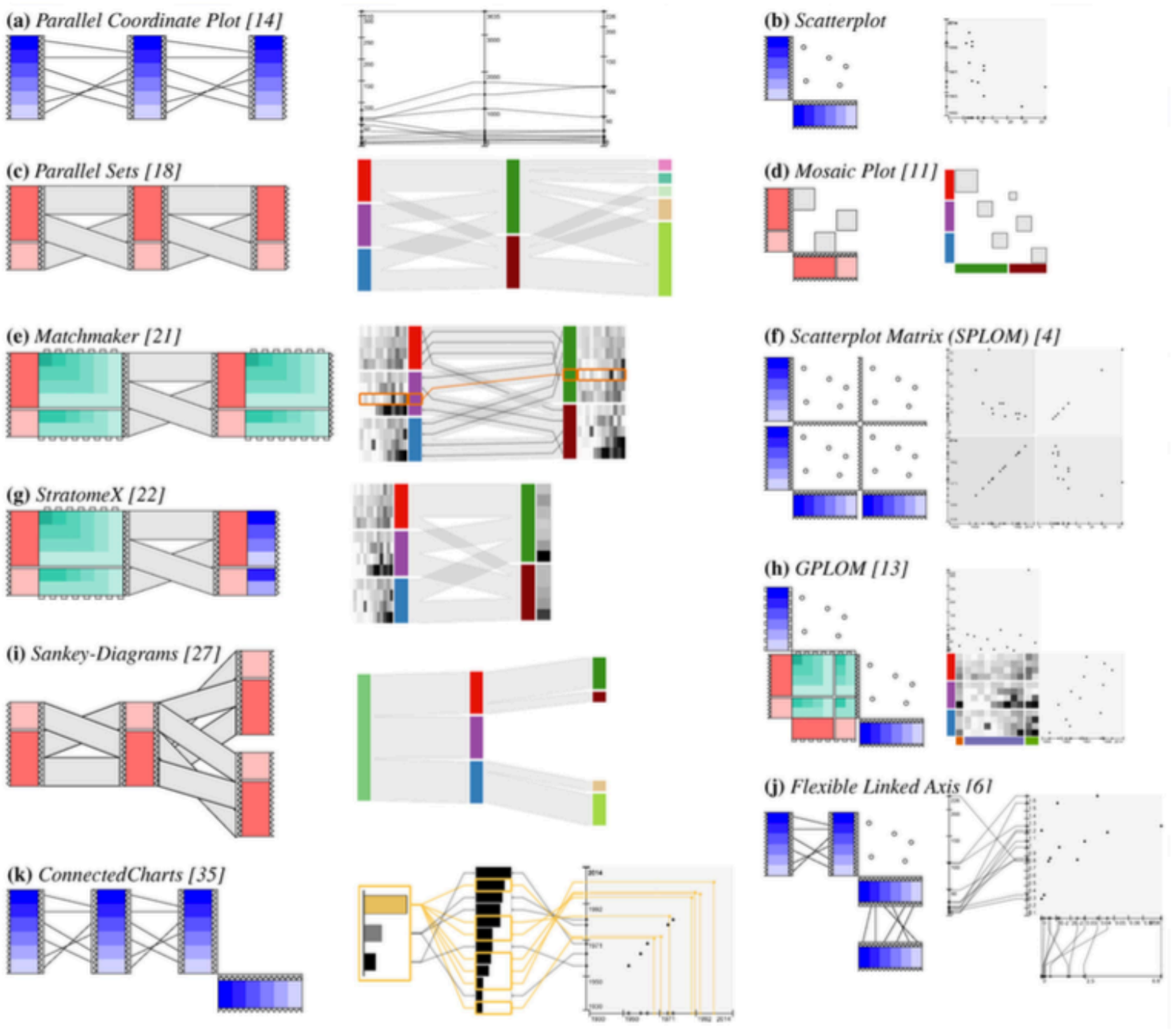


drop a csv-formatted file to load your own data. Note that the first line must describe the data scheme. See this dataset for an example.

http://www.parallelcoordinates.de/paco/


Correspondence between methylation, expression and other genomic features
Methylation
Expression
Enhancer
cluster1
cluster2
cluster3
cluster4
cluster5
sample2
sample8
sample3
sample7
sample1
sample9
sample4
sample10
sample5
sample6
sample11
sample14
sample13
sample17
sample20
sample12
sample18
sample15
sample16
sample19
direction
-log10(cor_p)
gene type
anno_gene
dist_tss
enhancer_1
enhancer_2
enhancer_3
type
Tumor
Control
methylation
1
0.8
0.6
0.4
0.2
0
direction
hyper
hypo
expression
2
1
0
-1
-2
-log10(cor_p)
4
3
2
1
0
gene type
lincRNA
protein_coding
others
psedo-gene
microRNA
anno_gene
TSS
intergenic
intragenic
dist_tss
10000
8000
6000
4000
2000
0
anno_enhancer
1
0.8
0.6
0.4
0.2
0

Domino


(a) Parallel Coordinate Plot [14]
(b) Scatterplot
(c) Parallel Sets [18]
(d) Mosaic Plot [11]
(e) Matchmaker [21]
(f) Scatterplot Matrix (SPLOM) [4]
(g) StratomeX [22]
(h) GPLOM [13]
(i) Sankey-Diagrams [27]
(j) Flexible Linked Axis [61]
(k) ConnectedCharts [35]

Domino

Extracting, Comparing, and Manipulating Subsets across Multiple Tabular Datasets

CALEYDO

JKU JOHANNES KEPLER UNIVERSITY LINZ

HARVARD MEDICAL SCHOOL

HARVARD School of Engineering and Applied Sciences

Samuel Gratzl

Marc Streit

Nils Gehlenborg

Alexander Lex

Hanspeter Pfister

https://sgratzl.github.io/domino_vis2014/#/title

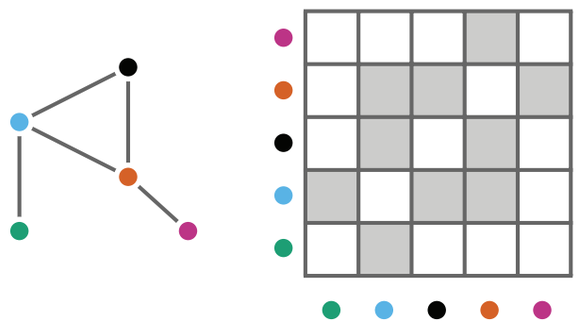
Network Visualization

Refresher

- What is a graph? **This is a data structure not a visual representation!**
  - Set **V** of vertices (= nodes) and set **E** of edges
  - Directed graph vs undirected graph
    - Directed acyclic graph (DAG)
- What is a tree?
  - Binary tree: two children per vertex
  - General tree: any number of children

Storing Graphs and Trees

- Use a matrix for adjacency (edges explicit)
  - edges are matrix cells



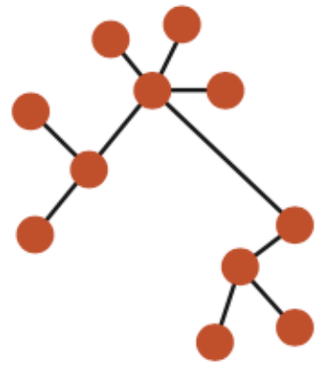
- Use a list with two fields per vertex (edges implicit)
  - incoming edges
  - outgoing edges

Arrange Networks and Trees

Node–Link Diagrams

Connection Marks

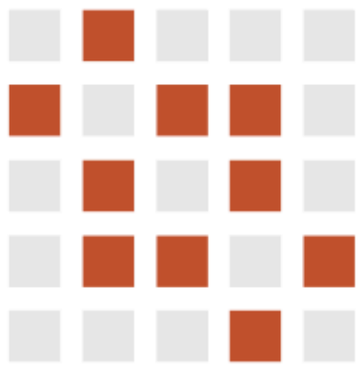
✔ NETWORKS ✔ TREES



Adjacency Matrix

Derived Table

✔ NETWORKS ✔ TREES



Enclosure

Containment Marks

✘ NETWORKS ✔ TREES

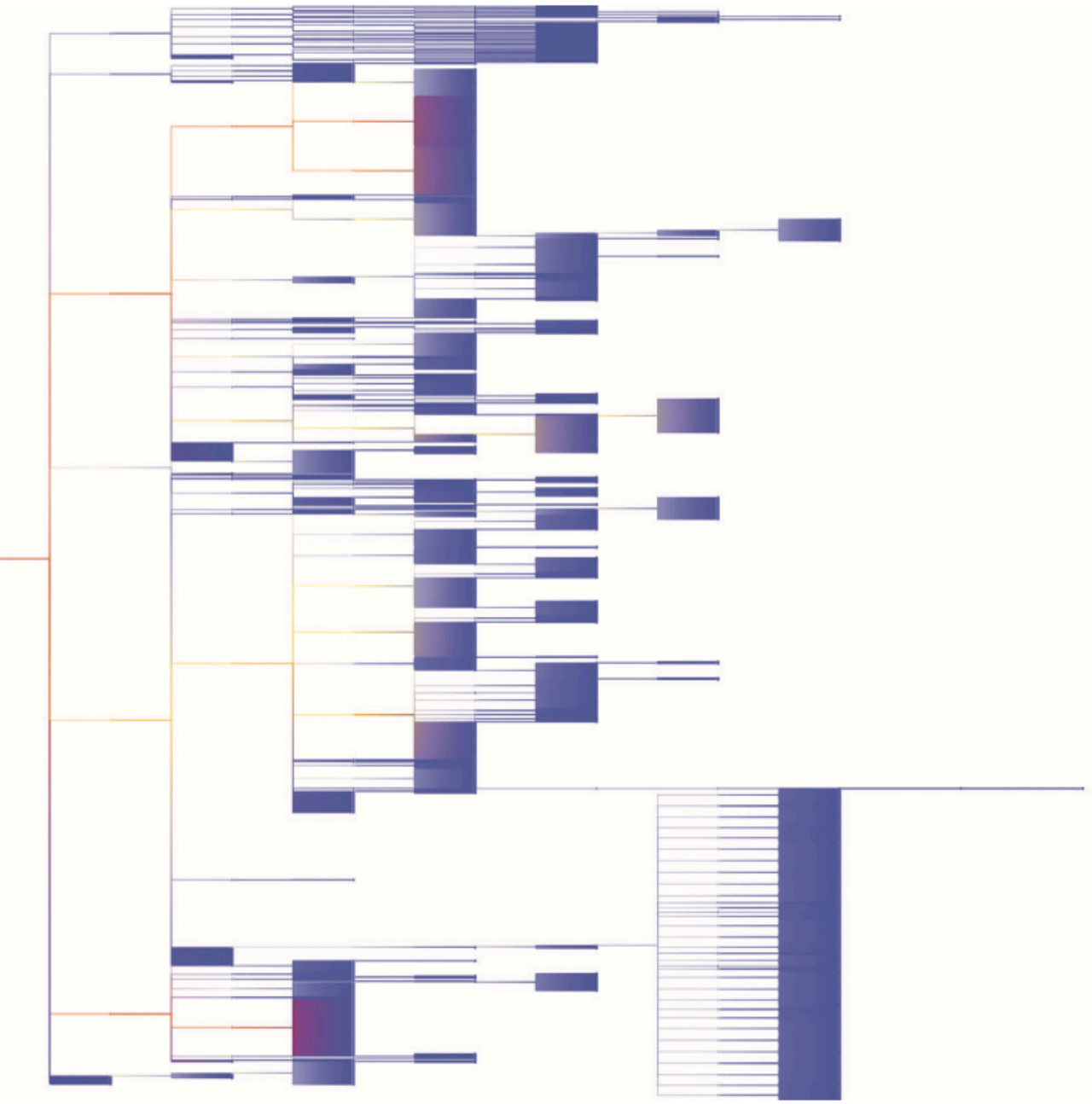
Node-Link Diagram Approaches

Trees

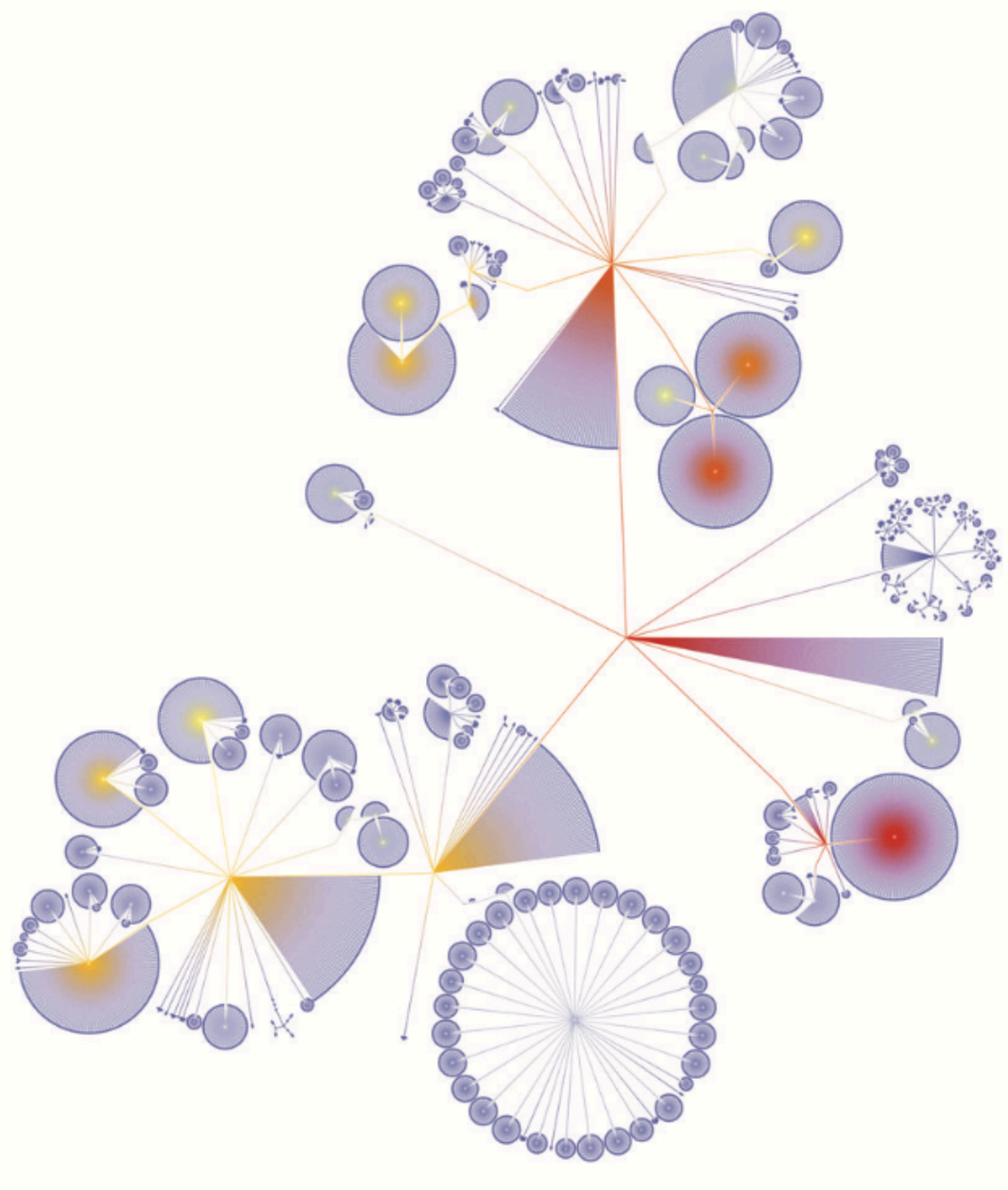
(a) (b)

Figure 9.2. Node–link layouts of small trees. (a) Triangular vertical for tiny tree. From [Buchheim et al. 02, Figure 2d]. (b) Spline radial layout for small tree. From http://mbostock.github.com/d3/ex/tree.html.

Trees



(a)

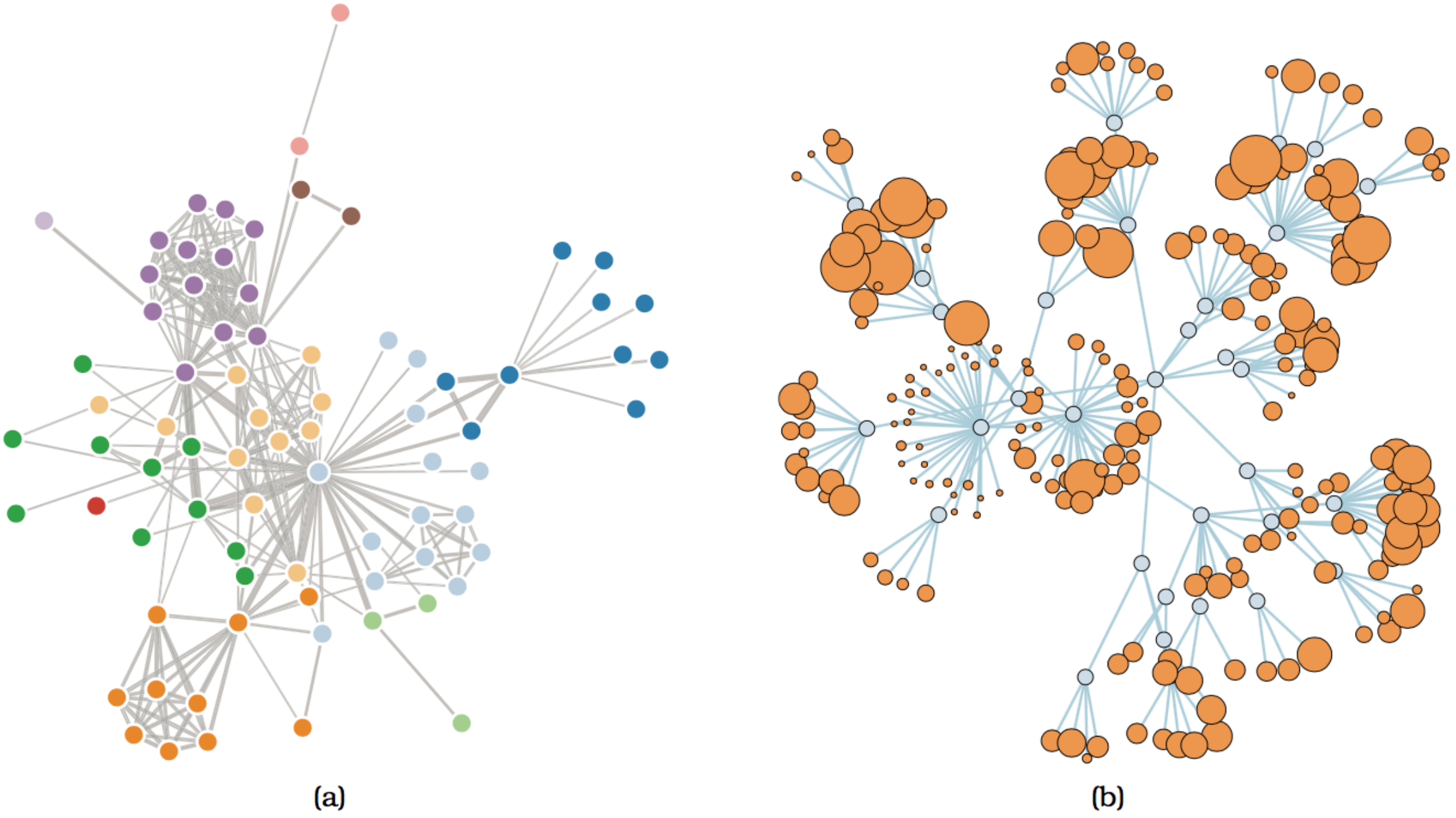


(b)

Figure 9.3. Two layouts of a 5161-node tree. (a) Rectangular horizontal node–link layout. (b) BubbleTree node–link layout.

Munzer, Visualization Analysis and Design, 2014

Graphs

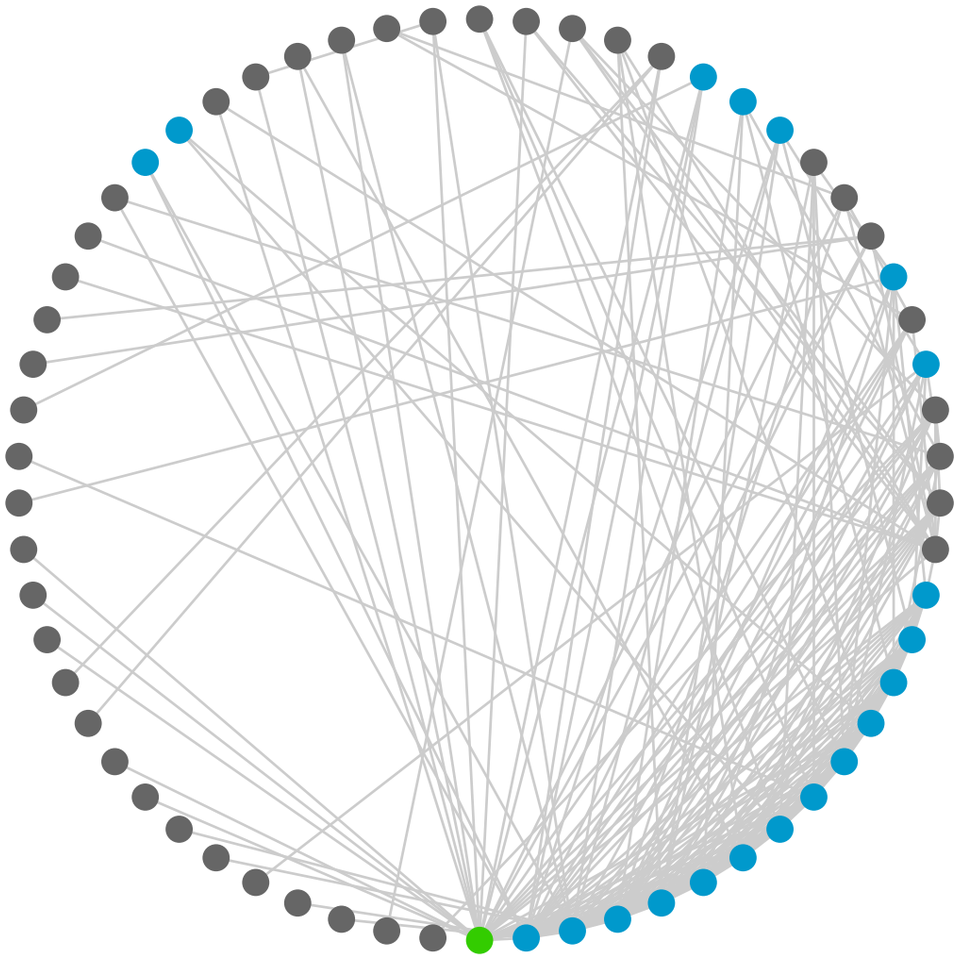


(a) (b)

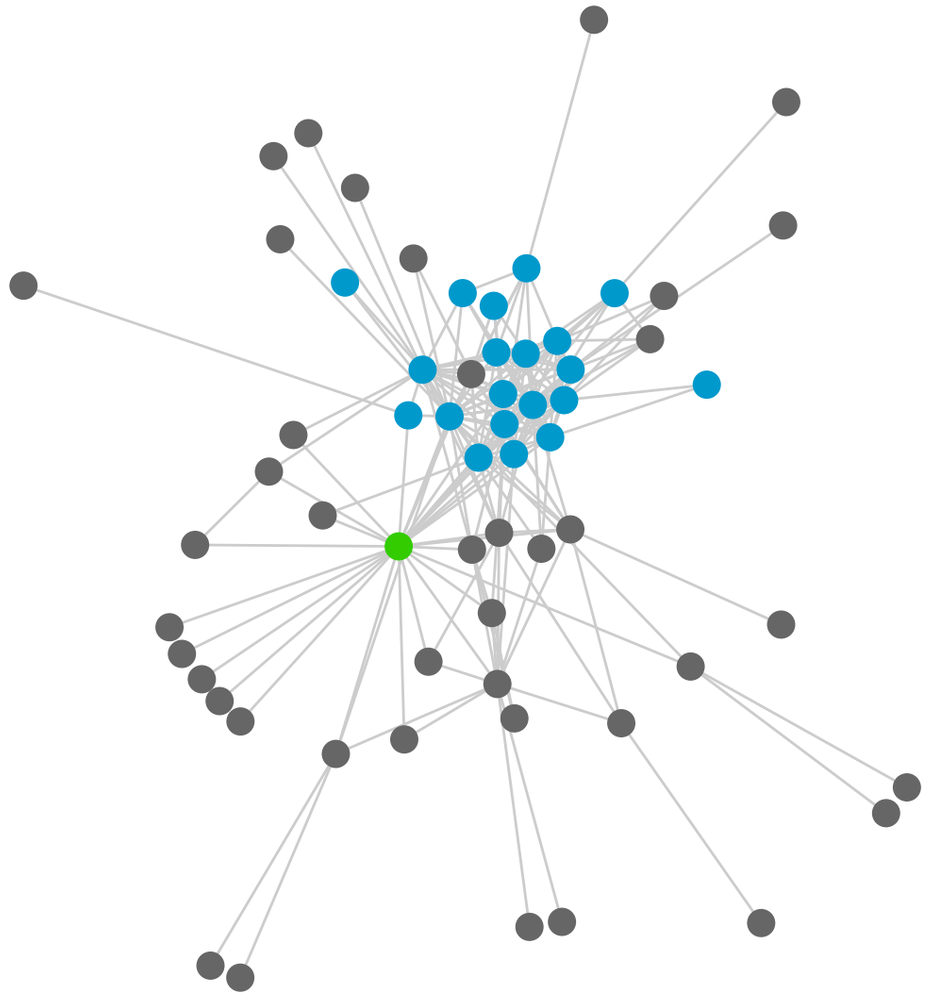
Figure 9.4. Node–link layouts of small networks. (a) Force-directed placement of small network of 75 nodes, with size coding for link attributes. (b) Larger network, with size coding for node attributes. From http://bl.ocks.org/mbostock/4062045 and http://bl.ocks.org/1062288.

Munzer, Visualization Analysis and Design, 2014

Graph Layouts



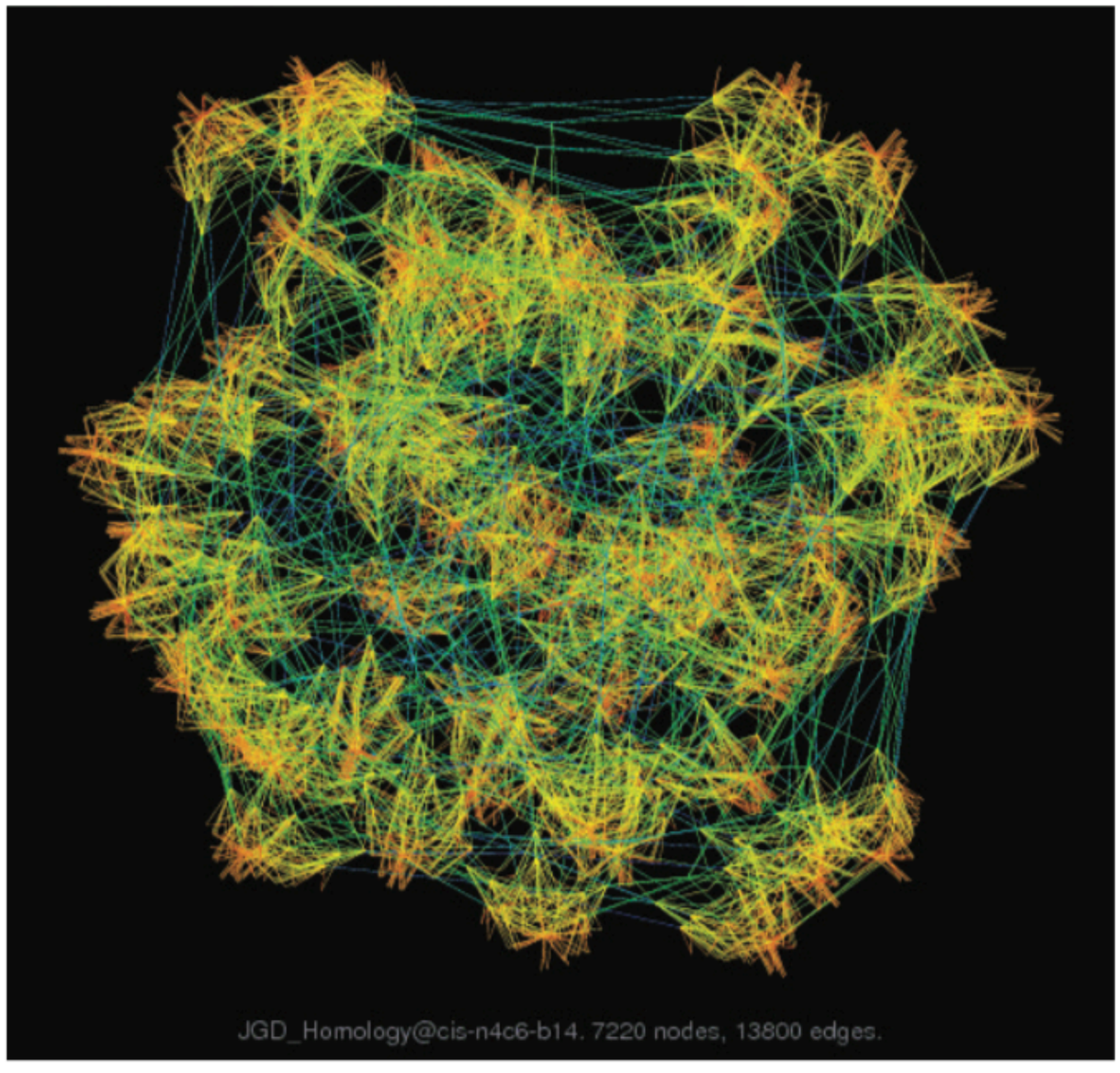
Circular Layout



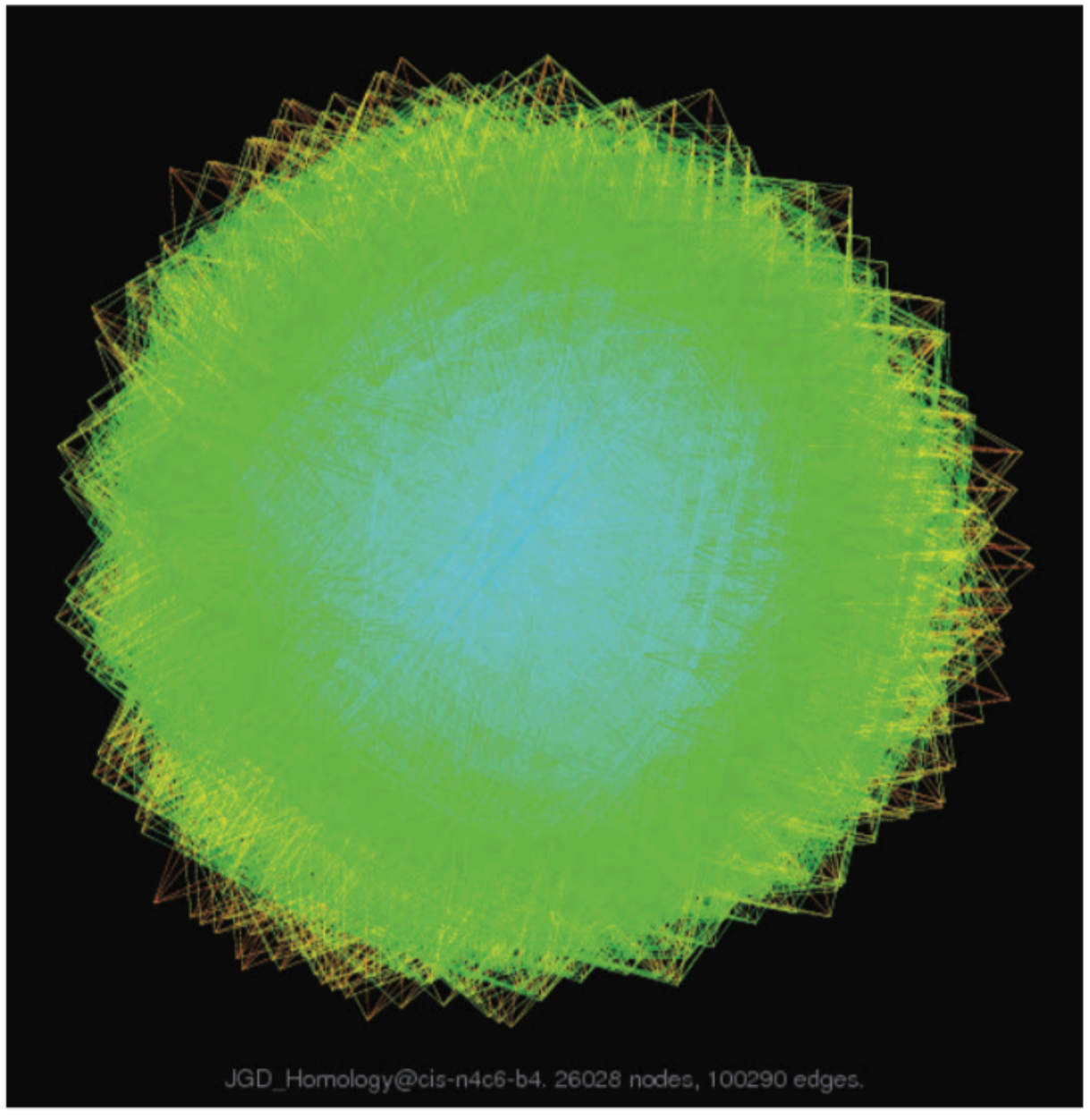
Force-directed Layout

Gehlenborg and Wong, Nature Methods, 2012

Graph Layouts



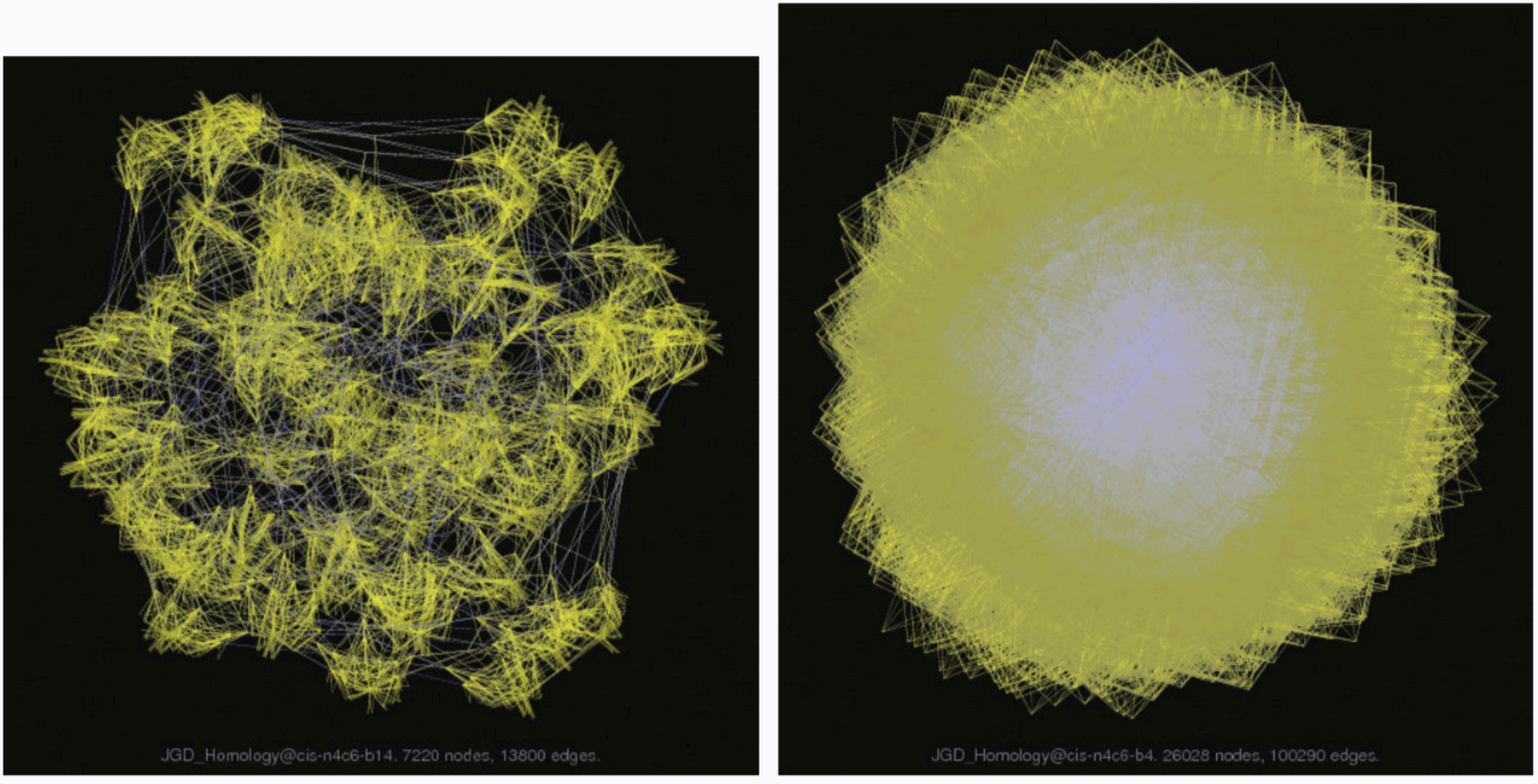
(a)



(b)

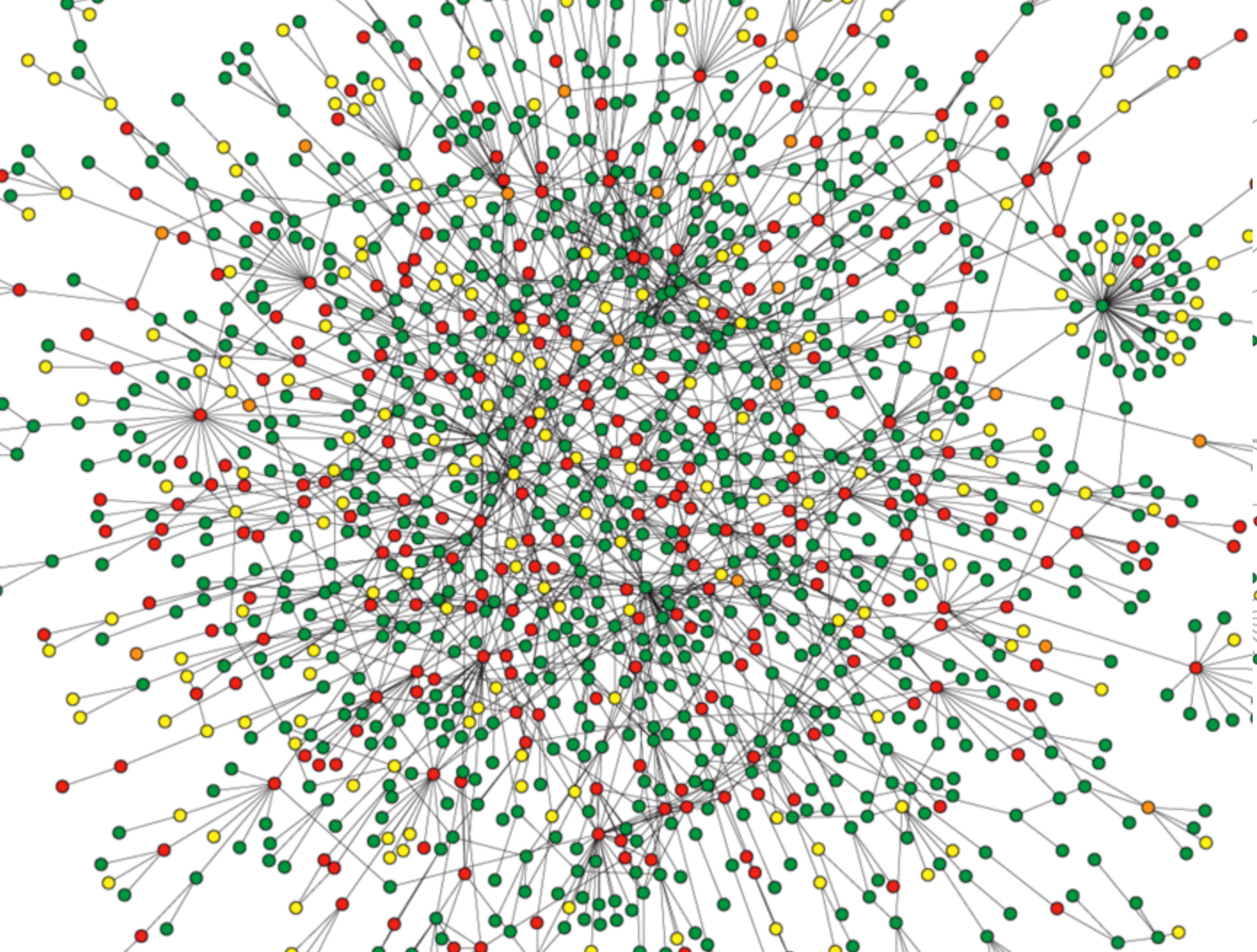
Figure 9.5. Multilevel graph drawing with sfdp [Hu 05]. (a) Cluster structure is visible for a large network of 7220 nodes and 13,800 edges. (b) A huge graph of 26,028 nodes and 100,290 edges is a "hairball" without much visible structure. From [Hu 14].

Reminder: Red-Green Blindness!

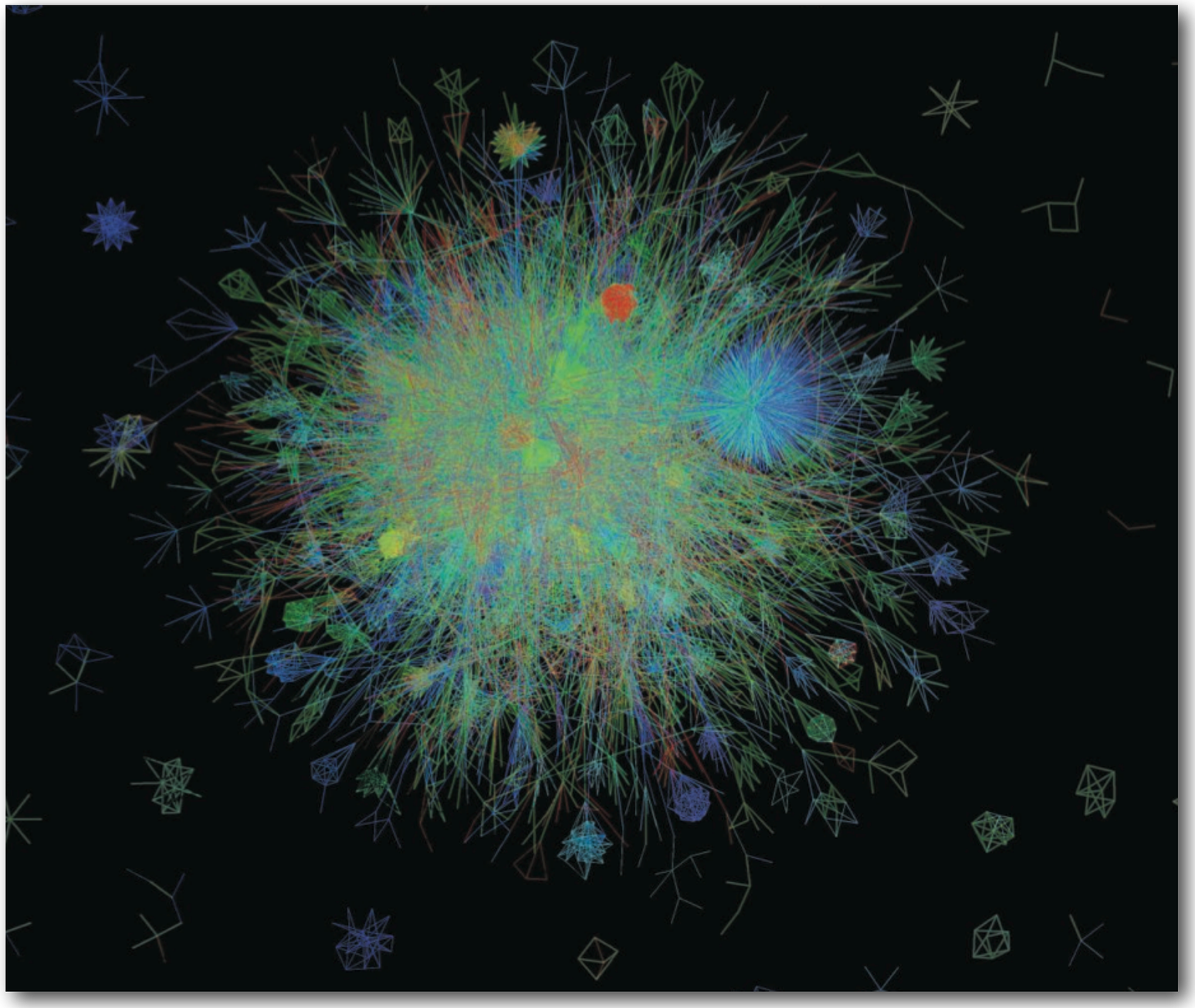


(a) (b)

Figure 9.5. Multilevel graph drawing with sfdp [Hu 05]. (a) Cluster structure is visible for a large network of 7220 nodes and 13,800 edges. (b) A huge graph of 26,028 nodes and 100,290 edges is a "hairball" without much visible structure. From [Hu 14].



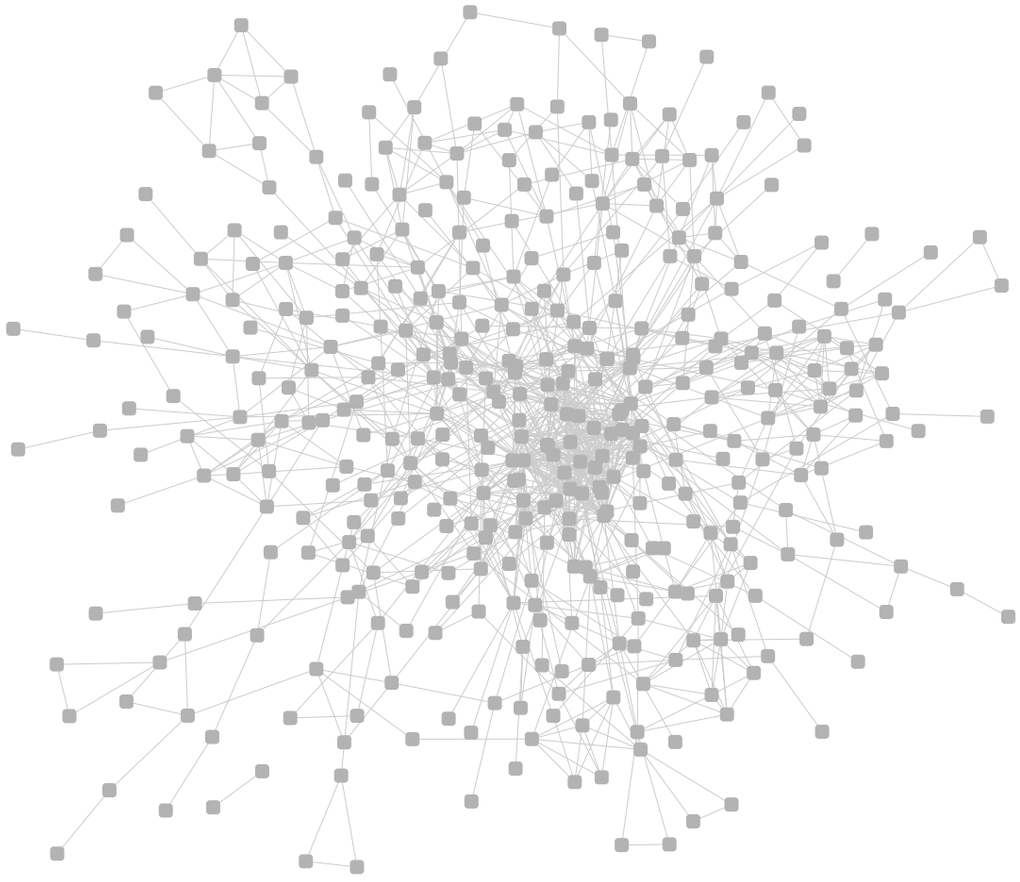
Interactions: Hairballs, Ridiculograms *et al.*



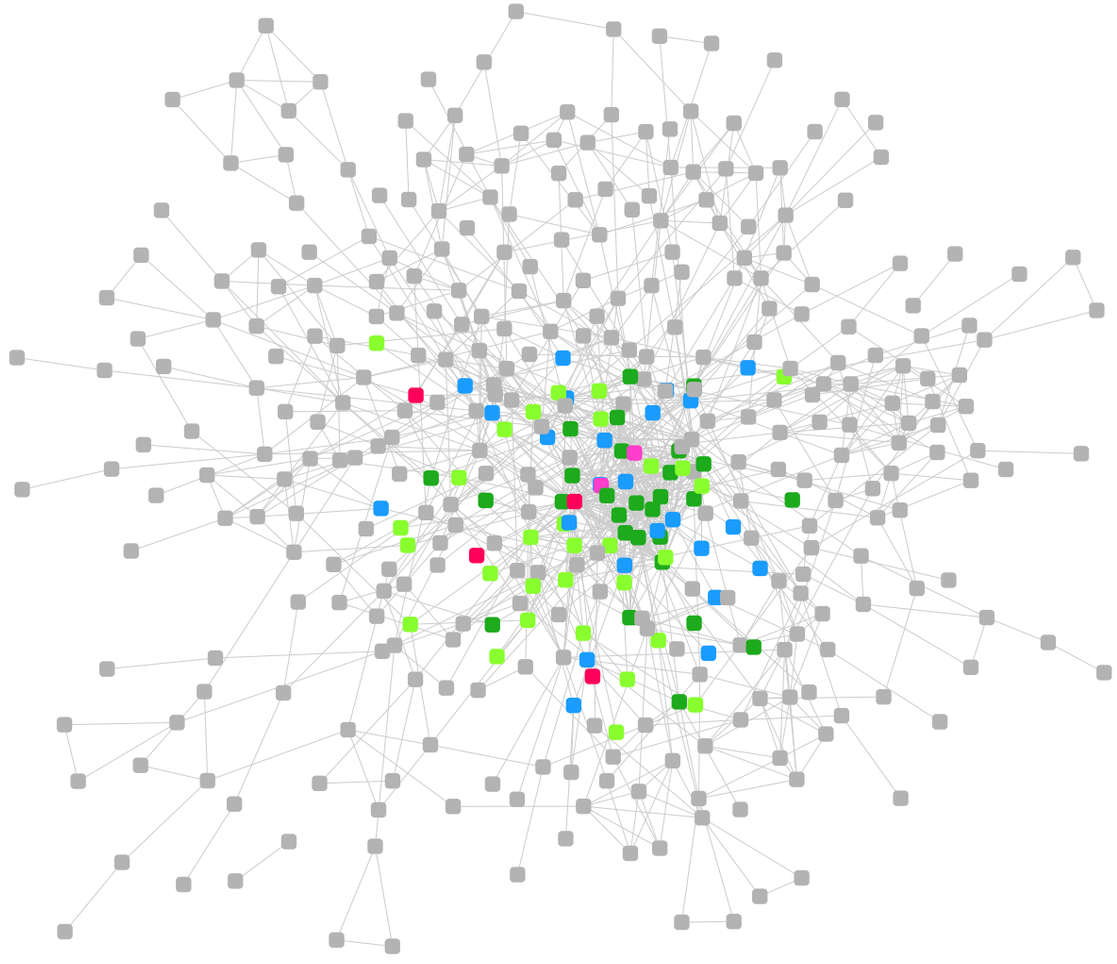
Gehlenborg et al. 2010, Nature Methods

Interactions: Manual Layout

Step 1

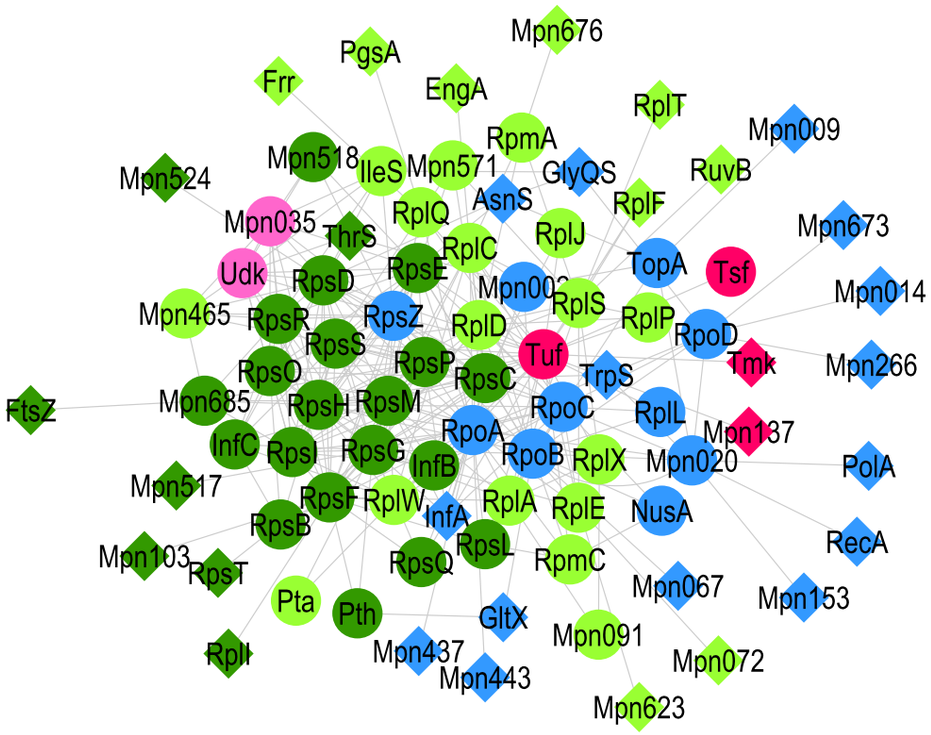


Step 2



Interactions: Manual Layout

Step 3



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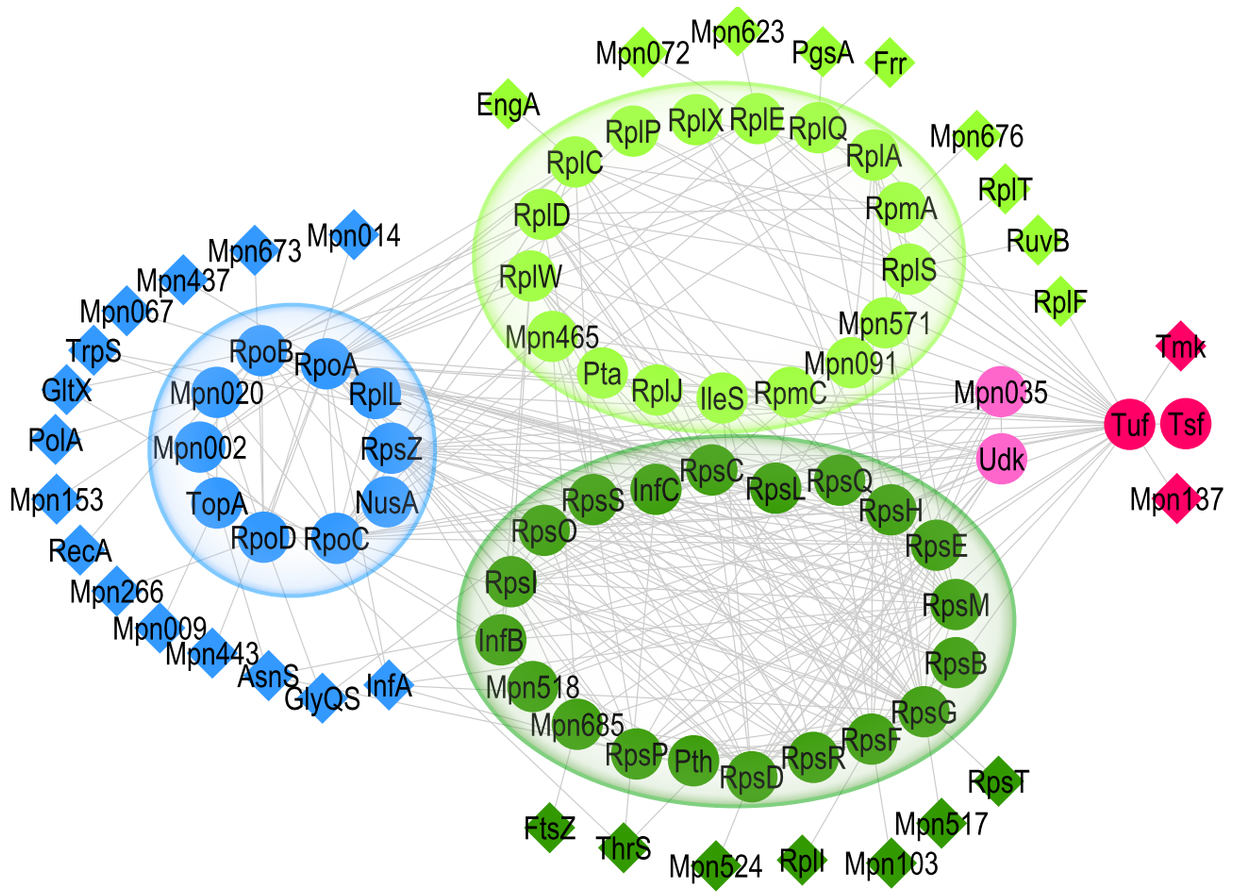
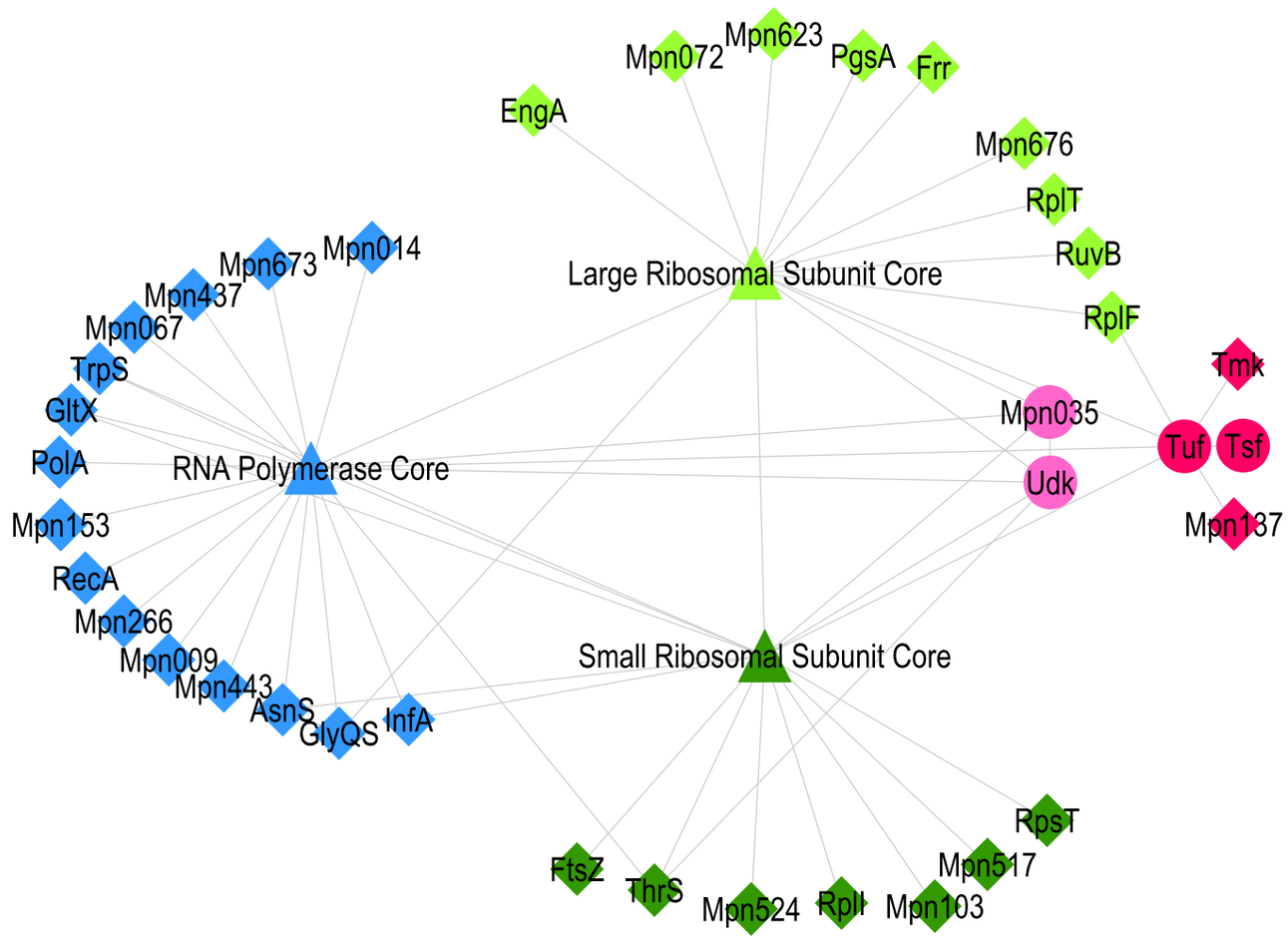
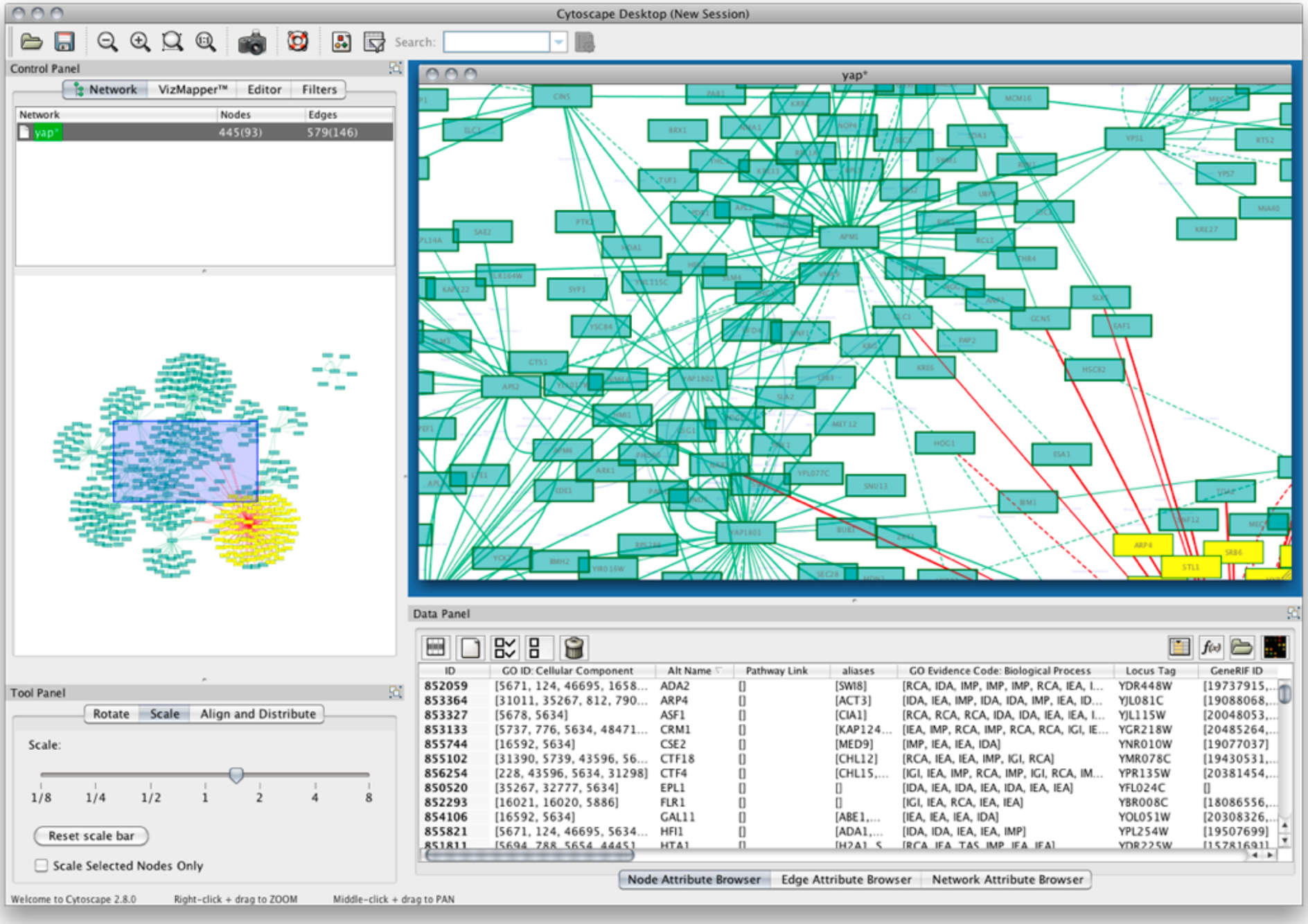


Interactions: Manual Layout

Step 5



Cytoscape


Cytoscape Desktop (New Session)
Search:
Control Panel
Network
VizMapper™
Editor
Filters
Network
Nodes
Edges
yap*
445(93)
579(146)
yap*
Tool Panel
Rotate
Scale
Align and Distribute
Scale:
1/8
1/4
1/2
1
2
4
8
Reset scale bar
Scale Selected Nodes Only
Data Panel
ID
GO ID: Cellular Component
Alt Name
Pathway Link
aliases
GO Evidence Code: Biological Process
Locus Tag
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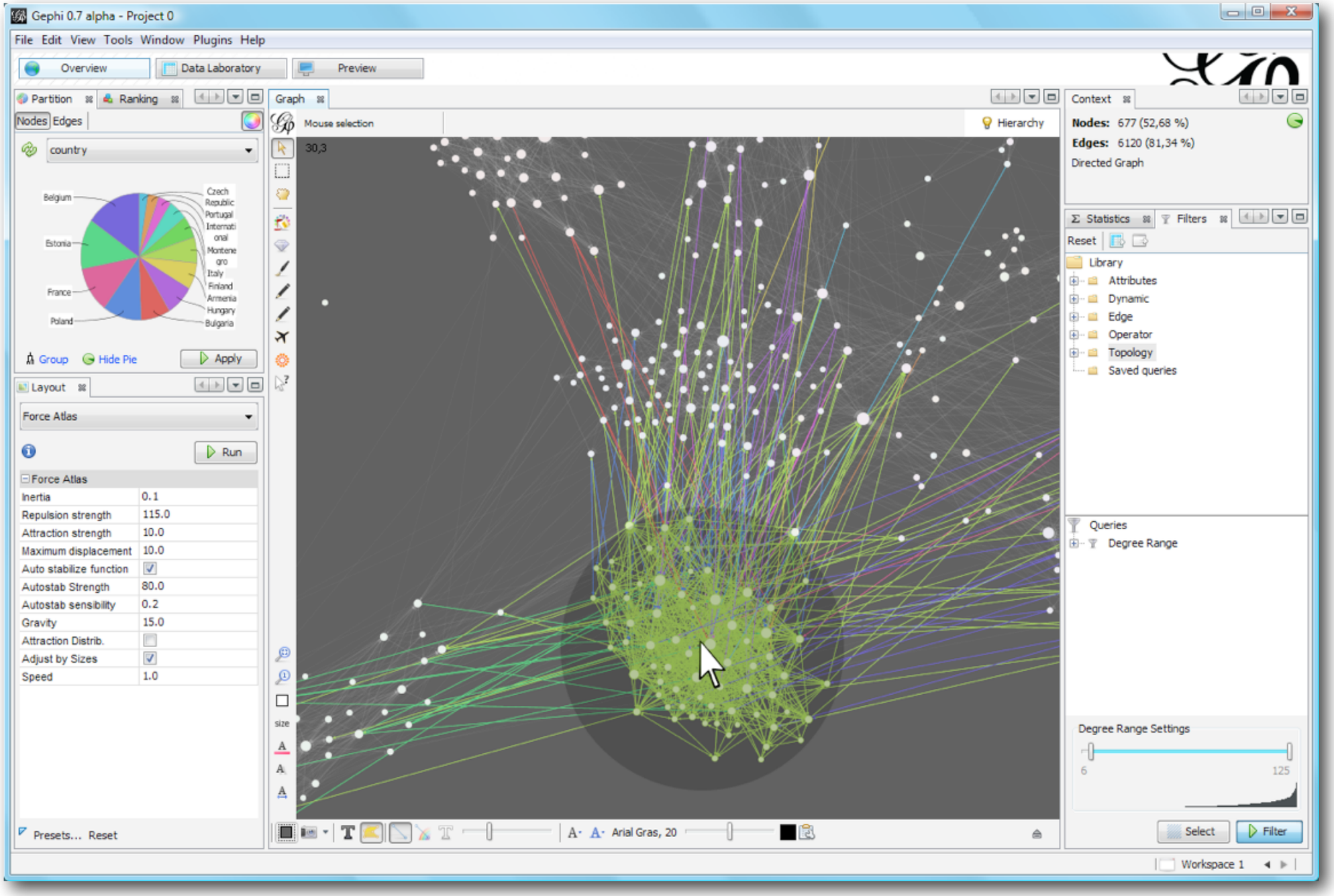
Node Attribute Browser
Edge Attribute Browser
Network Attribute Browser
Welcome to Cytoscape 2.8.0
Right-click + drag to ZOOM
Middle-click + drag to PAN

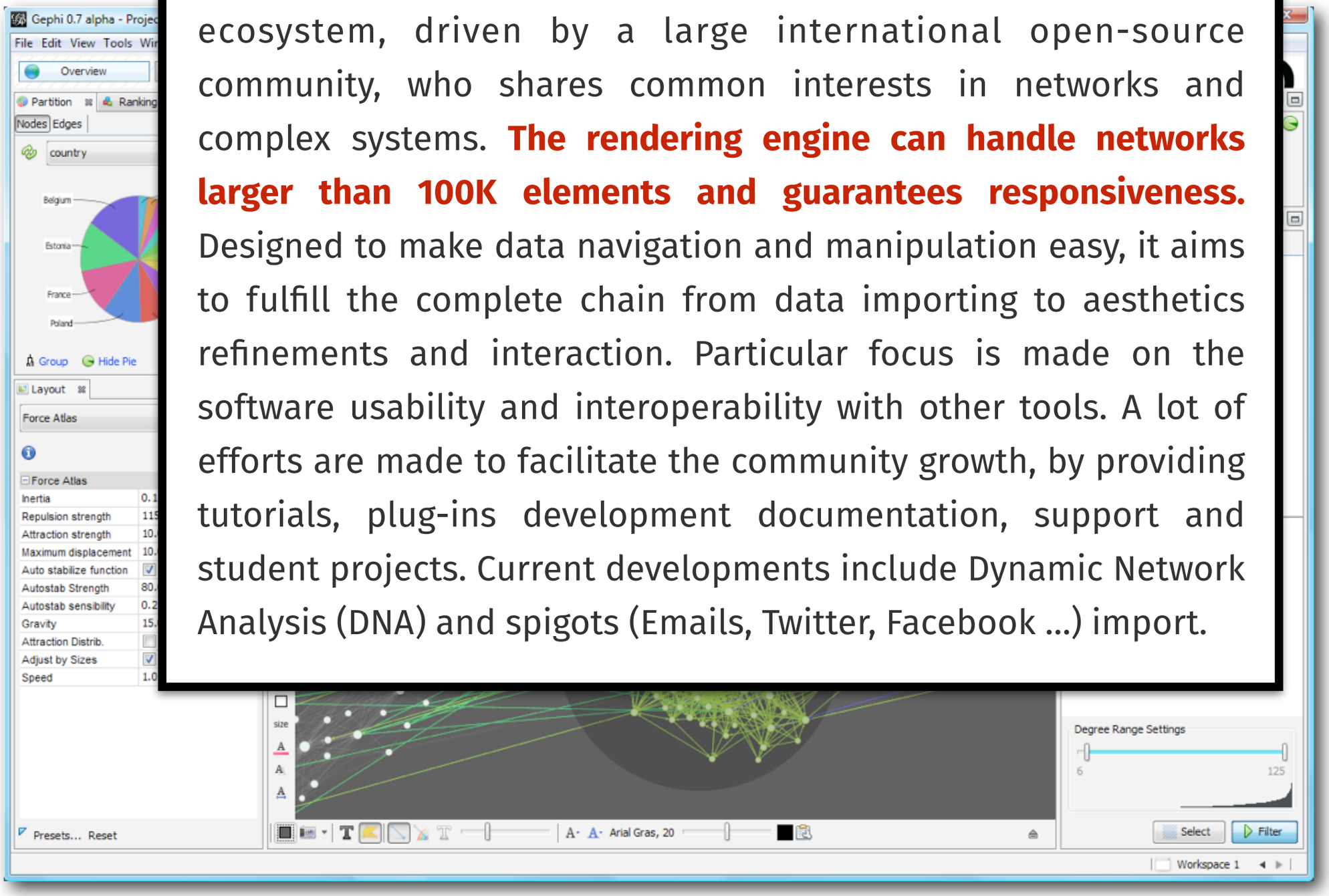
http://www.gephi.org

Gephi



Gephi

Abstract: Gephi is a new open-source network visualization platform. It aims to create a sustainable software and technical ecosystem, driven by a large international open-source community, who shares common interests in networks and complex systems. **The rendering engine can handle networks larger than 100K elements and guarantees responsiveness.** Designed to make data navigation and manipulation easy, it aims to fulfill the complete chain from data importing to aesthetics refinements and interaction. Particular focus is made on the software usability and interoperability with other tools. A lot of efforts are made to facilitate the community growth, by providing tutorials, plug-ins development documentation, support and student projects. Current developments include Dynamic Network Analysis (DNA) and spigots (Emails, Twitter, Facebook ...) import.



Westenberg et al. *2008, Comp Graph Forum*
Westenberg et al. *2010, Bioinformatics*

Interactions: Gene Regulatory Networks

SpotXplore

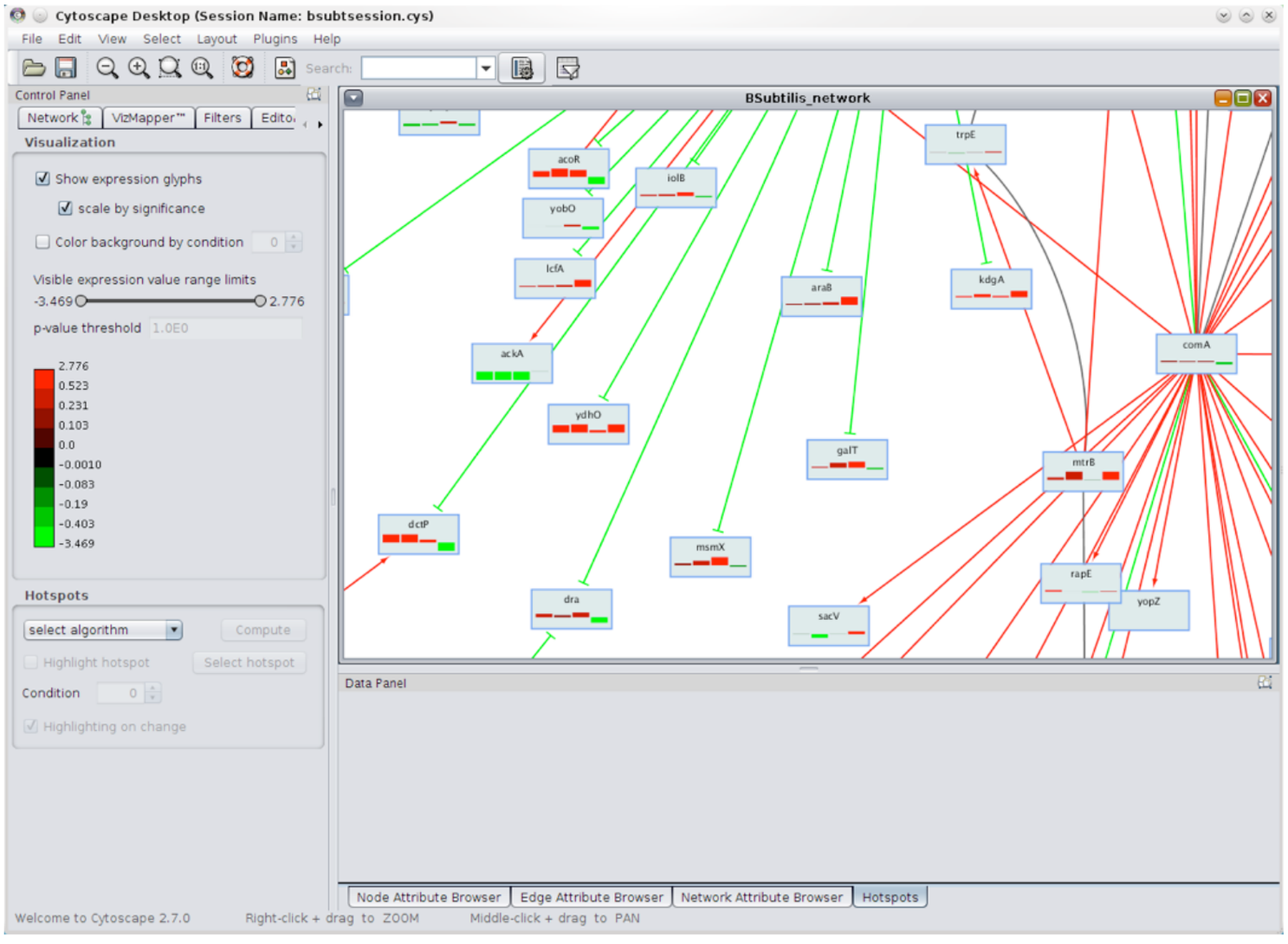
- maps expression profiles onto regulatory network

- statistics can be visualized

- interaction

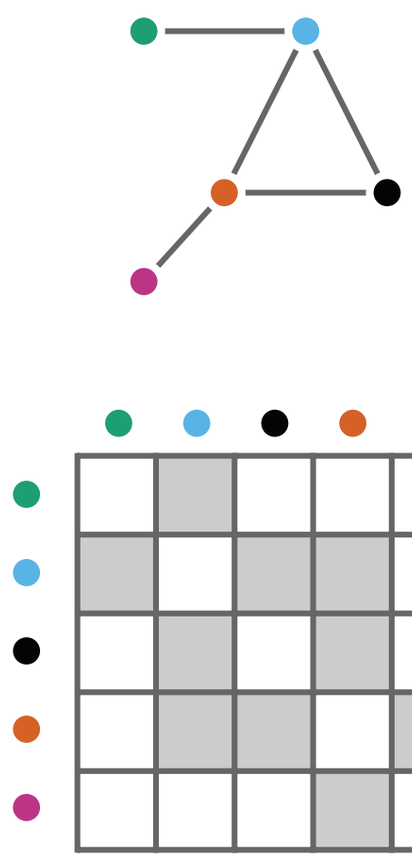
- highlight subnetworks

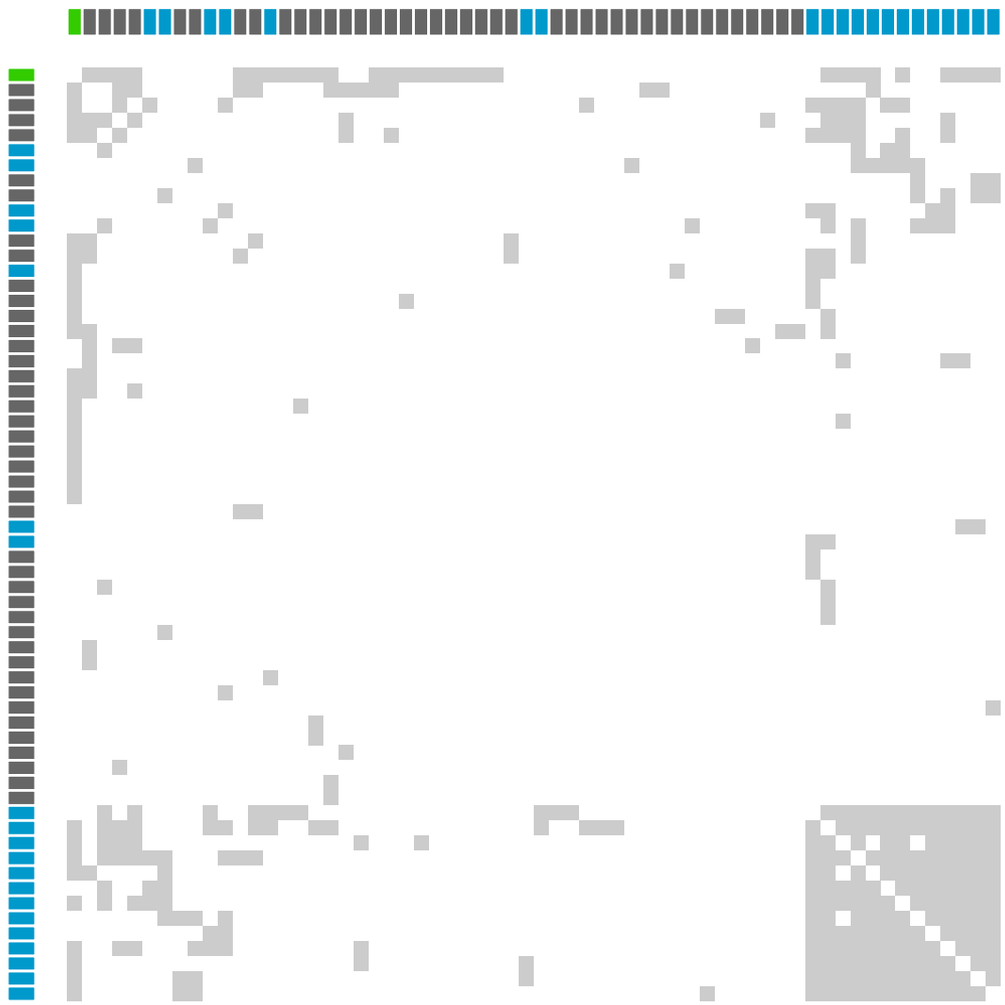
- Cytoscape plugin



Adjacency Matrix Approaches

Adjacency Matrix





Gehlenborg and Wong, Nature Methods, 2012

Adjacency Matrix

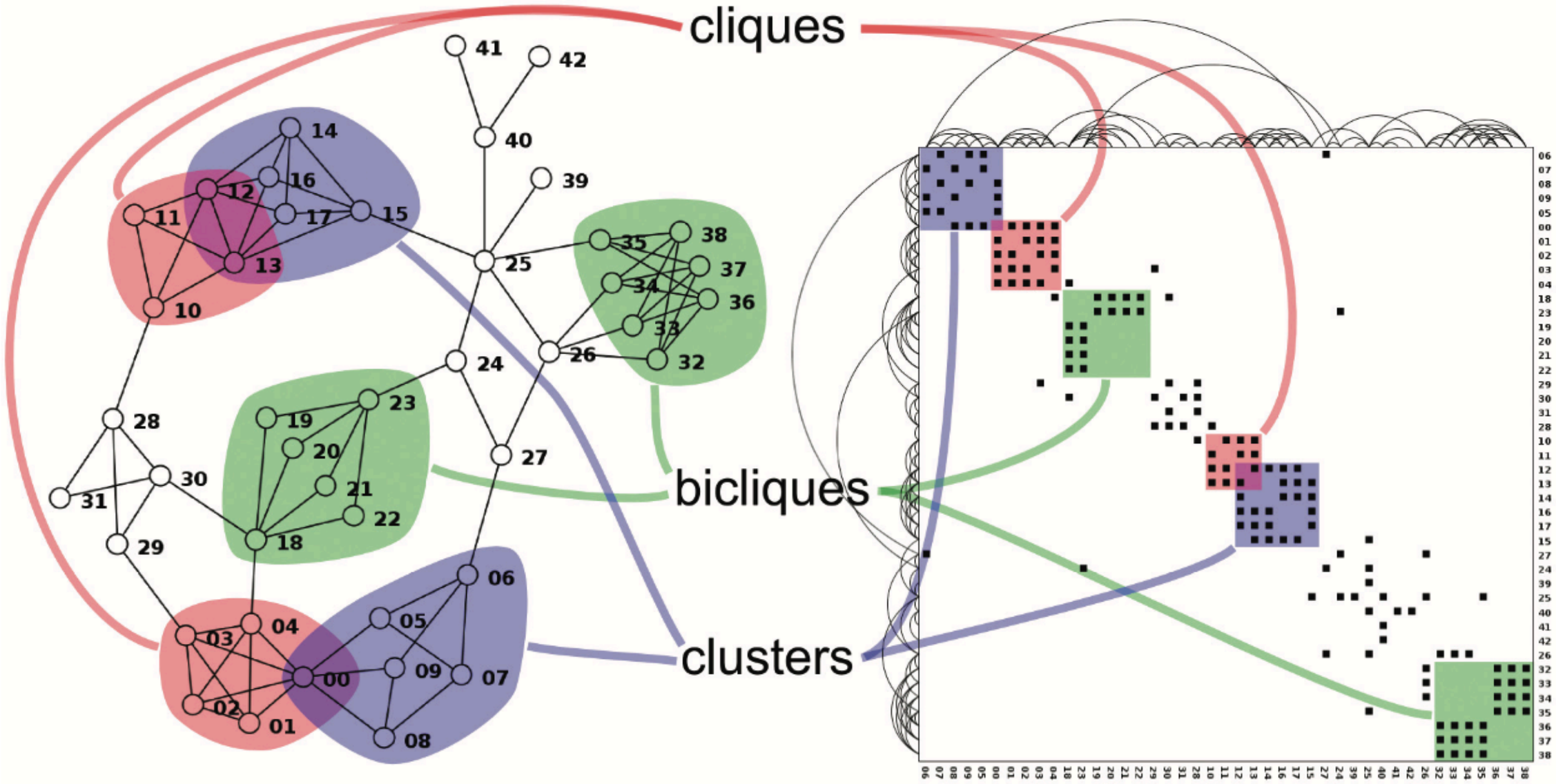
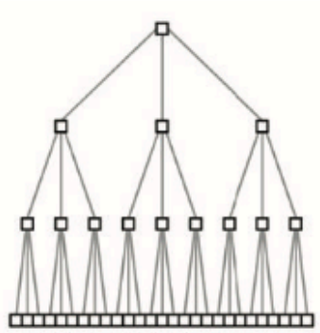
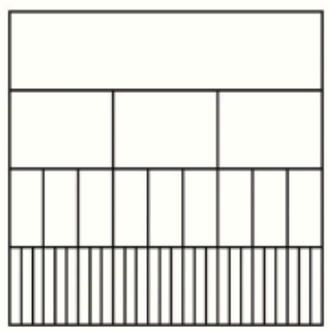


Figure 9.7. Characteristic patterns in matrix views and node–link views: both can show cliques and clusters clearly. From [McGuffin 12, Figure 6].

Nested Representations



(a)



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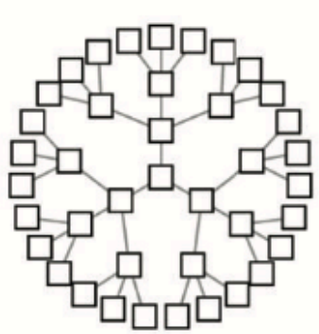

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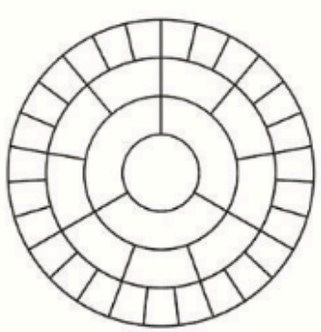
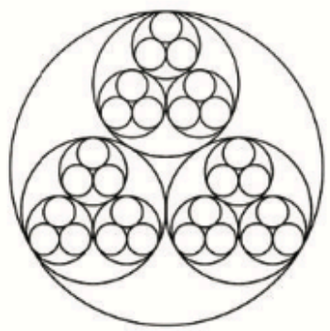


(d)



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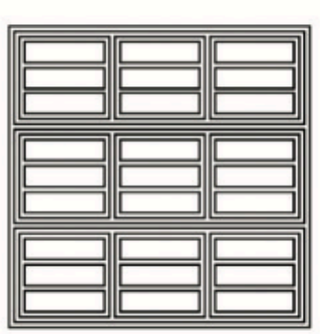

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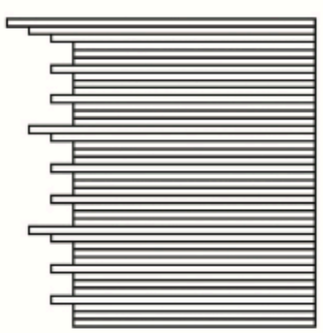


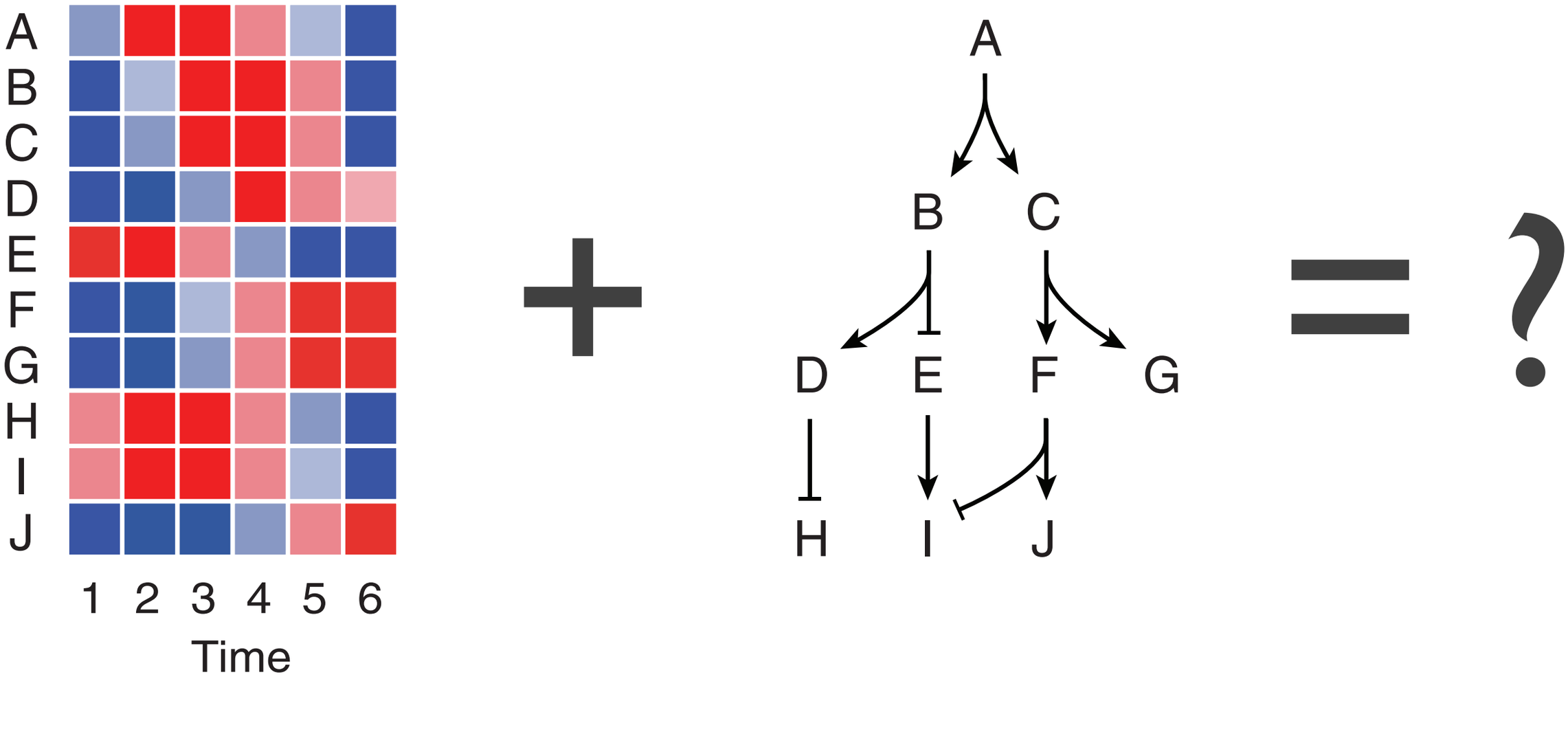
(g)

Munzer, Visualization Analysis and Design, 2014

https://finviz.com/map.ashx?t=sec&st=w4

Graphs and Multivariate Data

Interactions: And Multivariate Data?



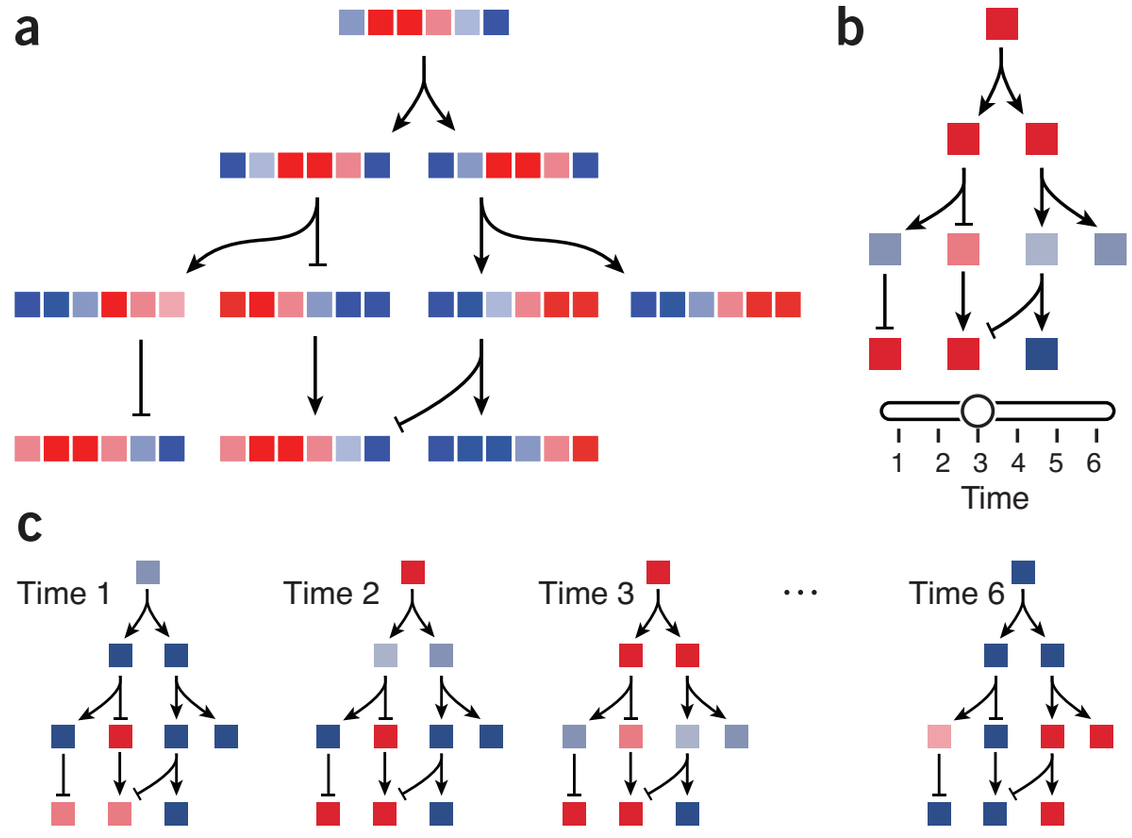
Gehlenborg and Wong, Nature Methods, 2012

Interactions: And Multivariate Data!?

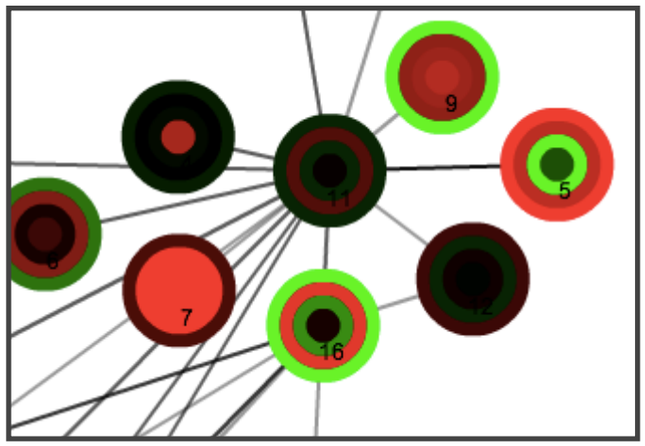
(a) **Complex glyphs** = multiple values per node?

(b) **Animation** = one value per node, one network shown at a time?

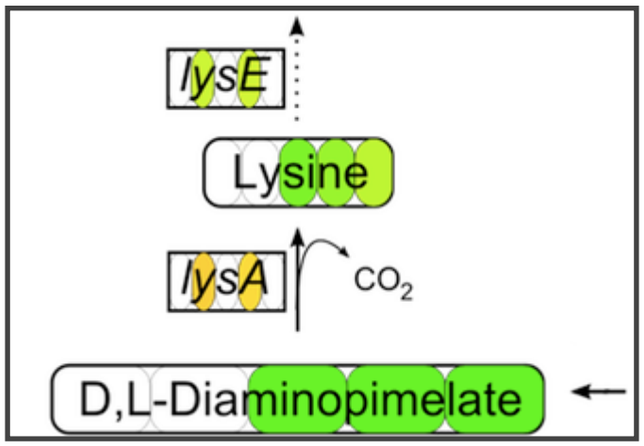
(c) **Small multiples** = one value per node, all networks shown simultaneously?



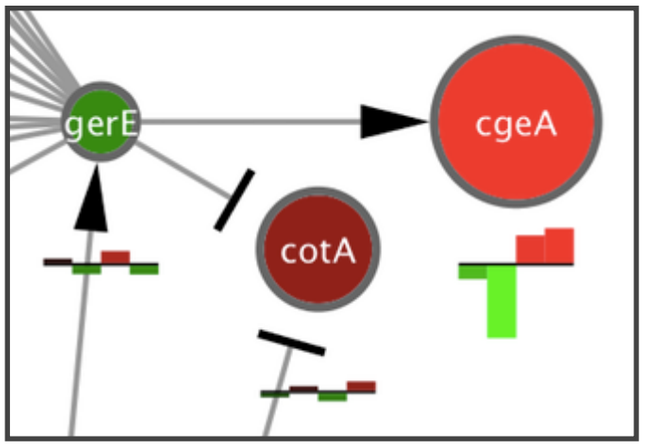
Interactions: And Multivariate Data!



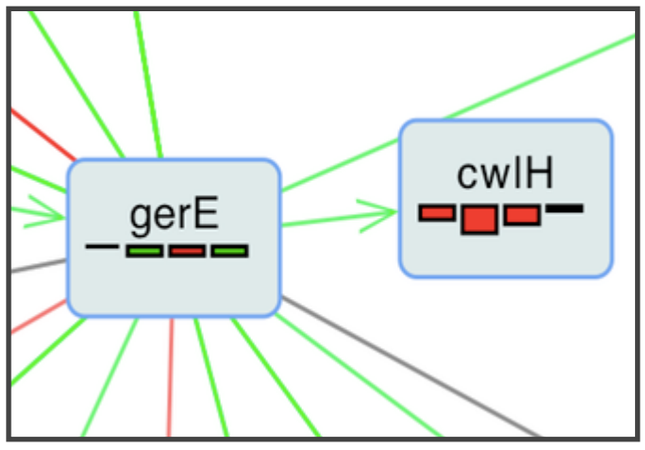
Lichen



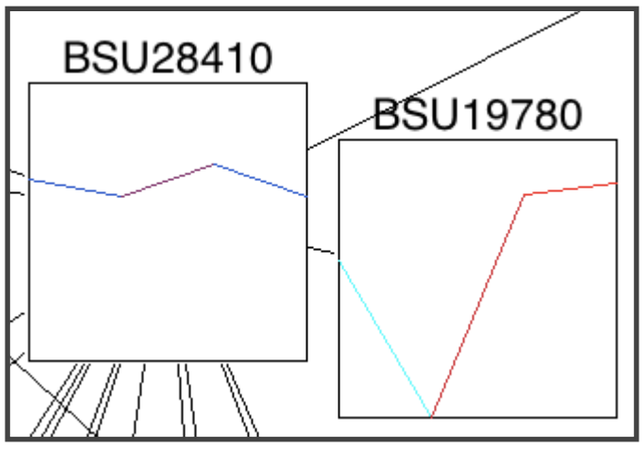
Prometra



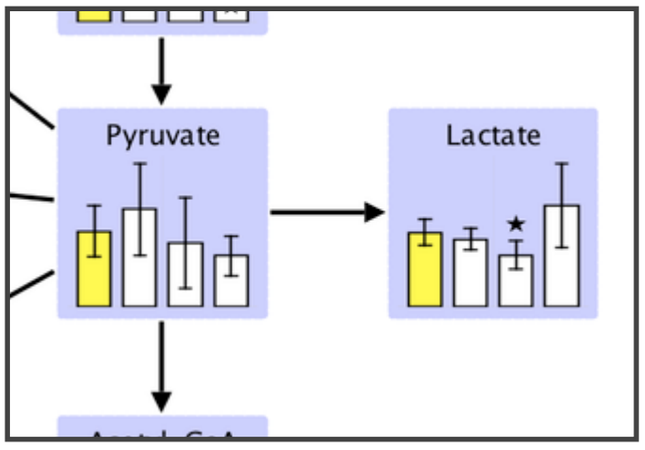
VistaClara (Cytoscape)



GENeVis

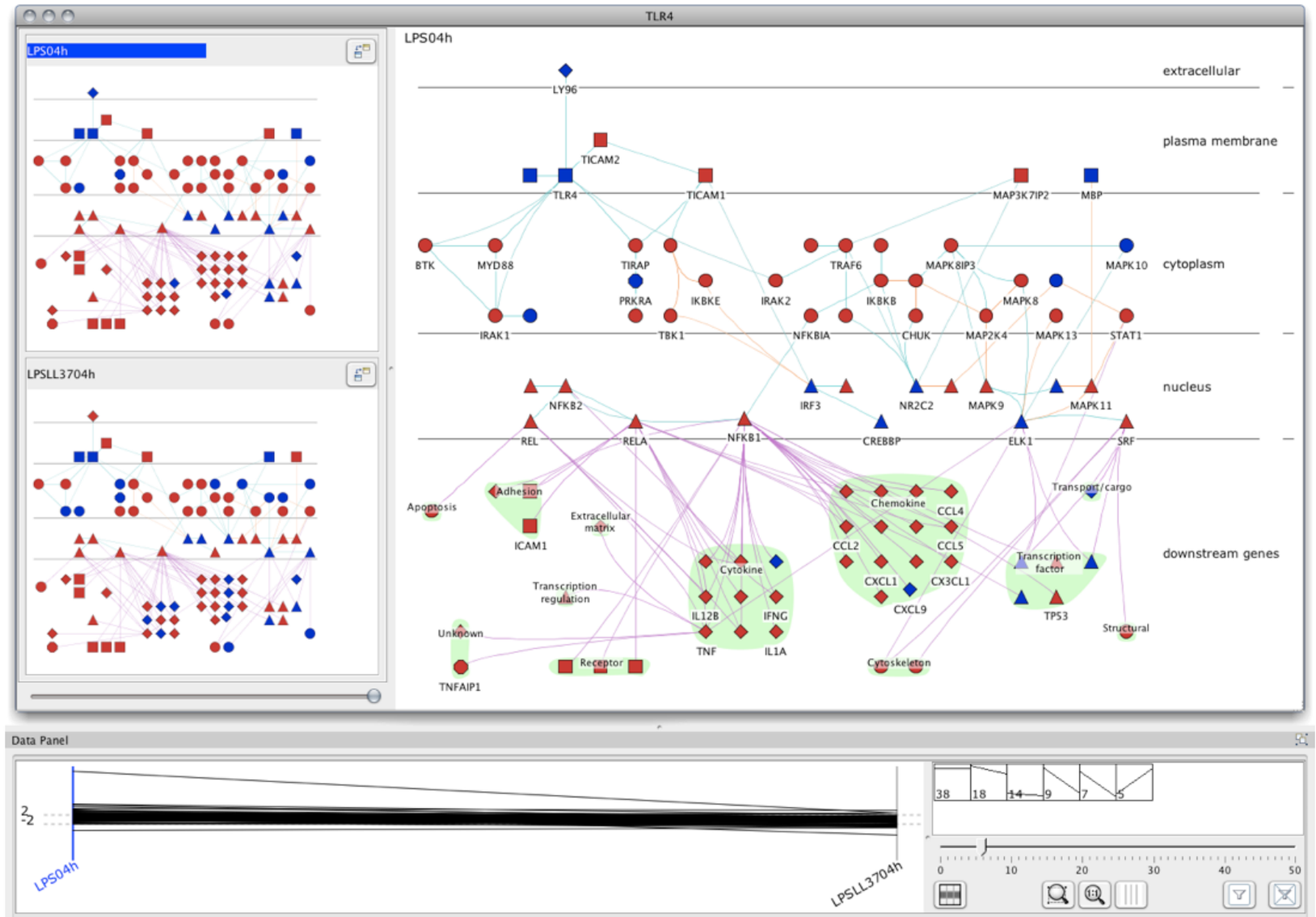


VisANT



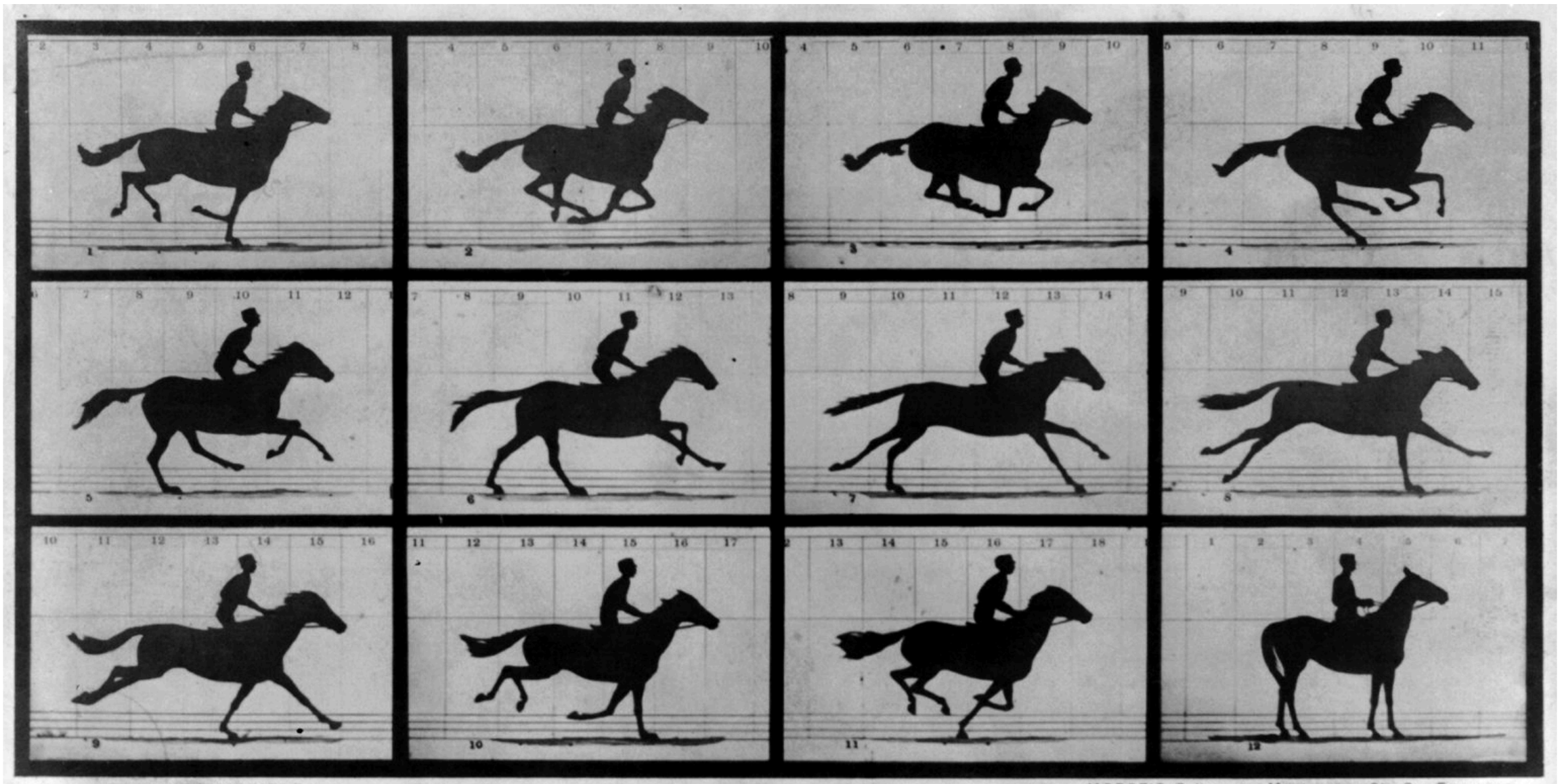
VANTED

Interactions: And Multivariate Data!



Cerebral (Cytoscape plugin)

Small Multiples



Copyright, 1878, by MUYBRIDGE.

MORSE'S Gallery, 417 Montgomery St., San Francisco.

THE HORSE IN MOTION.

Illustrated by

MUYBRIDGE.

AUTOMATIC ELECTRO-PHOTOGRAPH.

"SALLIE GARDNER," owned by LELAND STANFORD; running at a 1.40 gait over the Palo Alto track, 19th June, 1878.

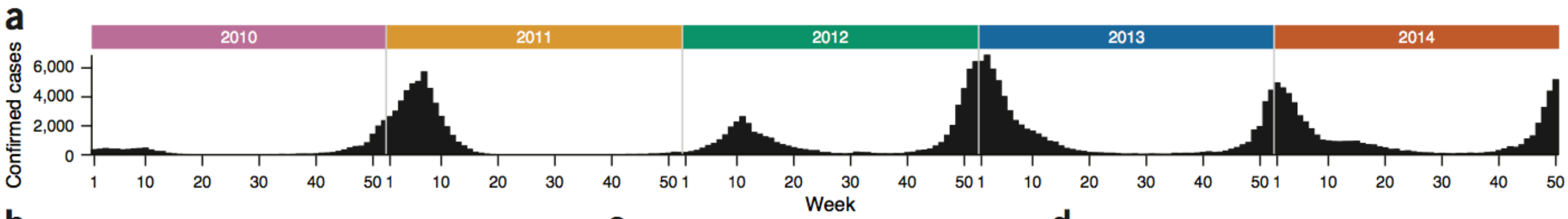
The negatives of these photographs were made at intervals of twenty-seven inches of distance, and about the twenty-fifth part of a second of time; they illustrate consecutive positions assumed in each twenty-seven inches of progress during a single stride of the mare. The vertical lines were twenty-seven inches apart; the horizontal lines represent elevations of four inches each. The exposure of each negative was less than the two-thousandth part of a second.

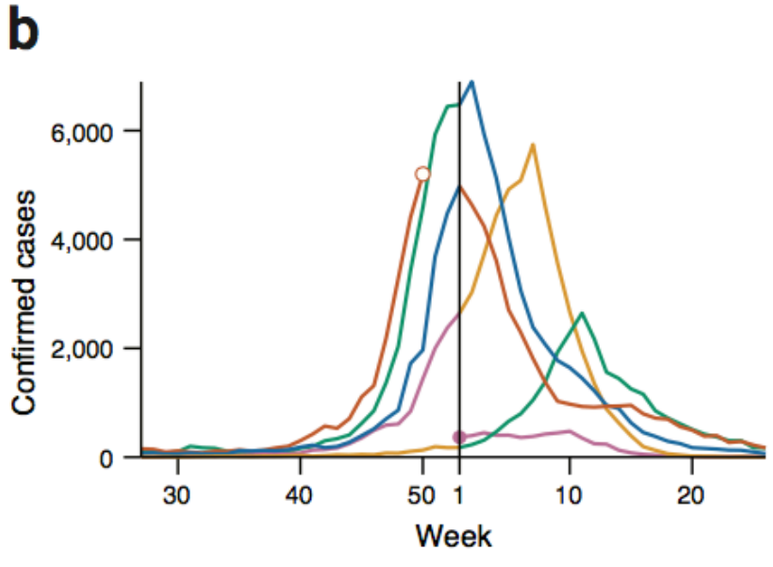
Small Multiples

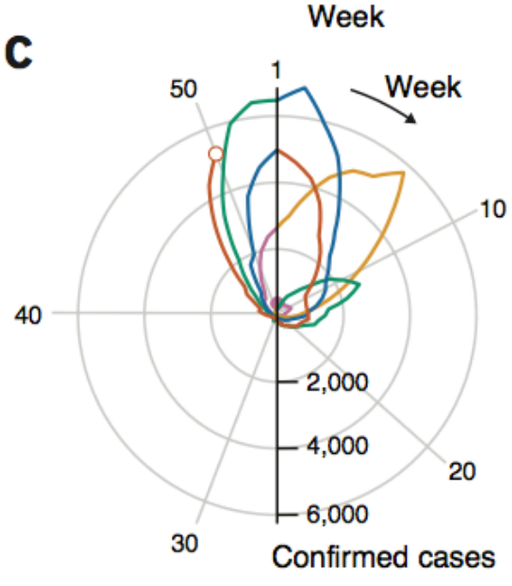
http://www.nytimes.com/interactive/2012/07/20/us/drought-footprint.html

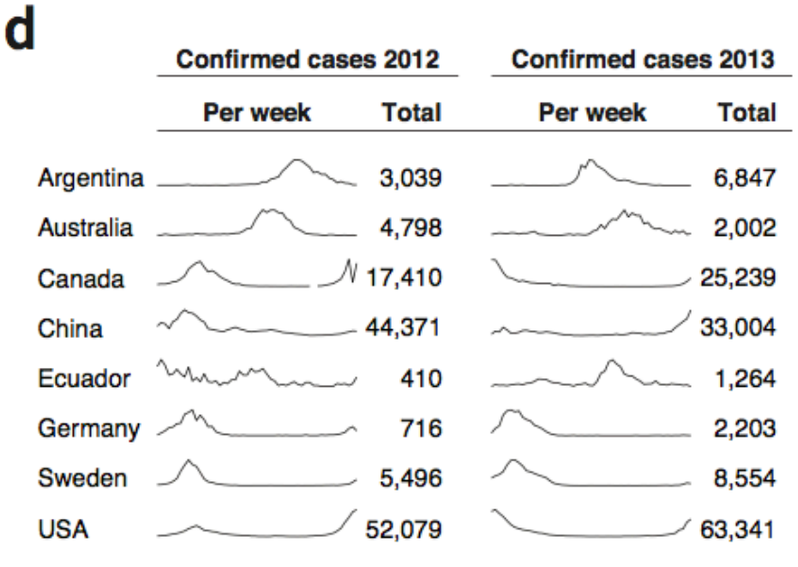
Temporal Data

Temporal Data



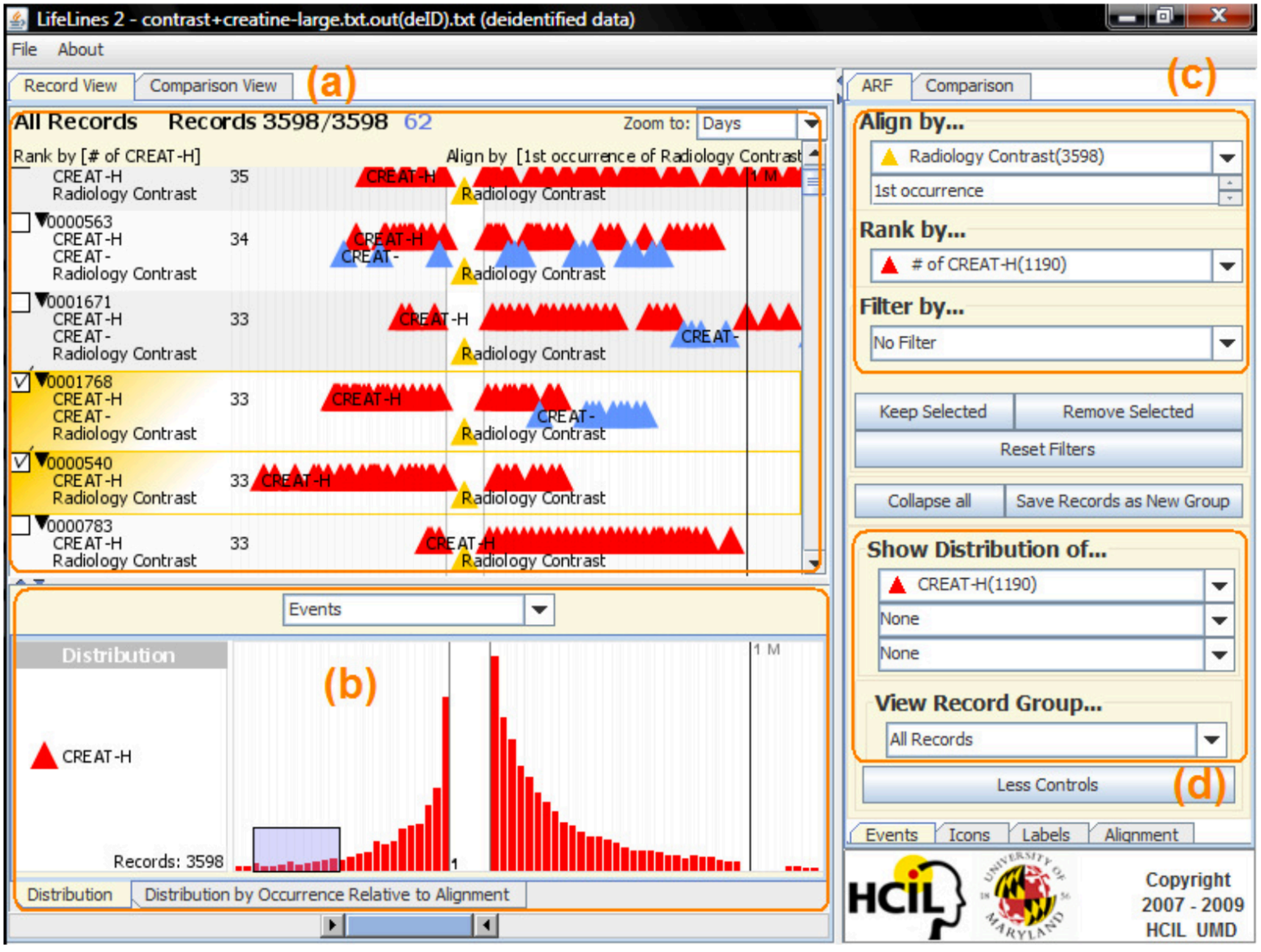






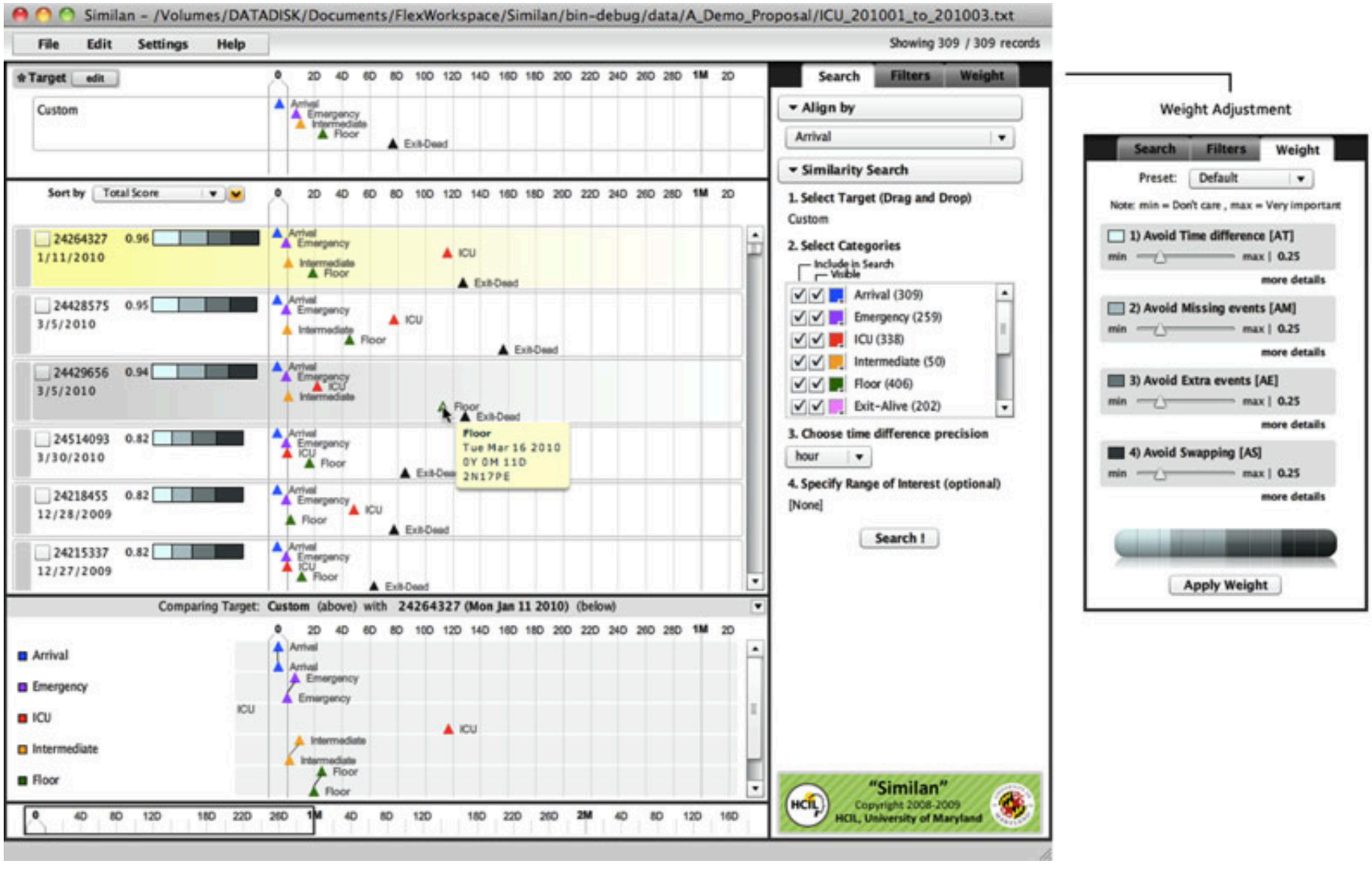
Streit & Gehlenborg, Nature Methods, 2015

LifeLines 2



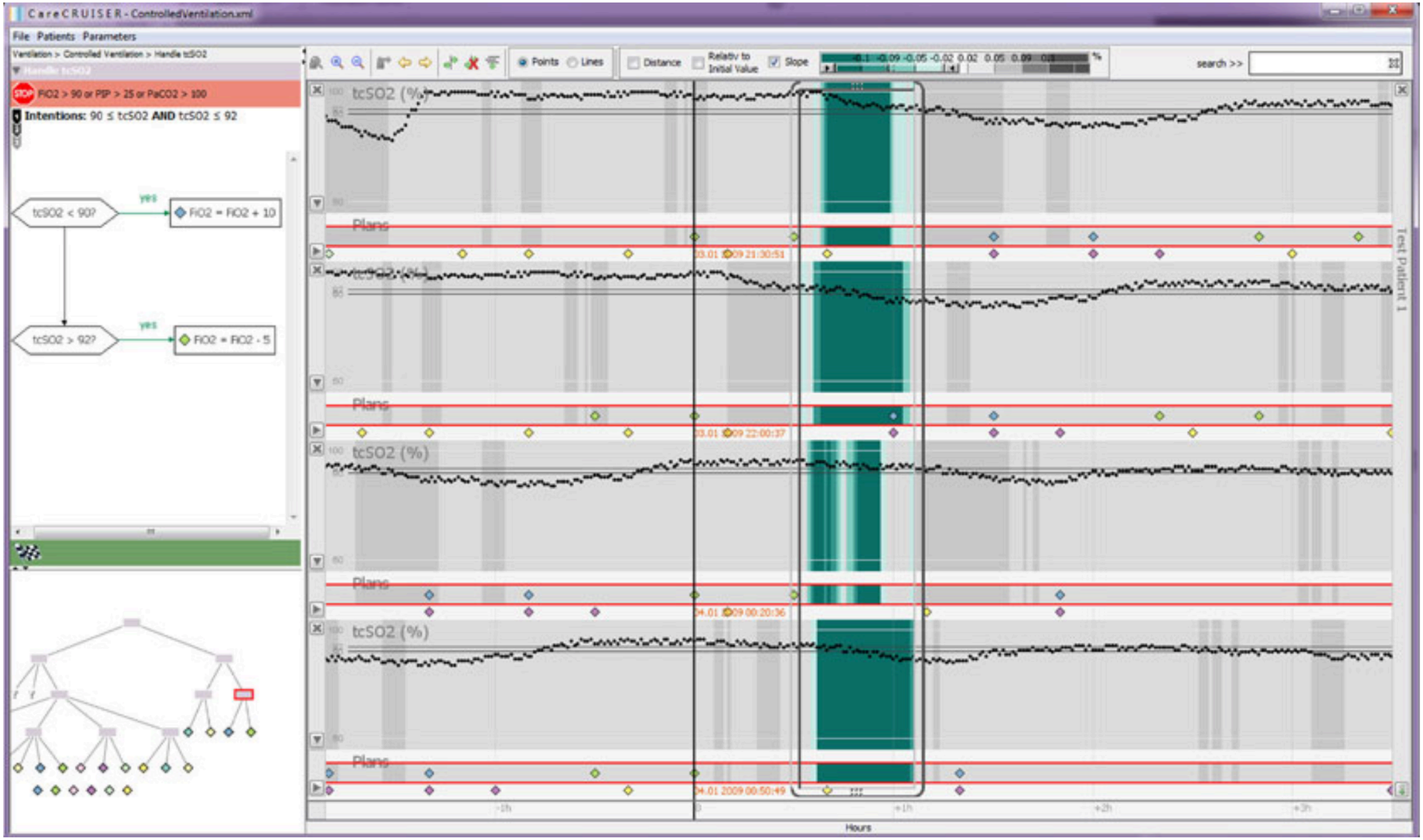
Wang et al., Temporal Summaries: Supporting Temporal Categorical Searching, Aggregation and Comparison, 2009

Similan



Wongsuphasawat and Shneiderman (2009)

CareCruiser



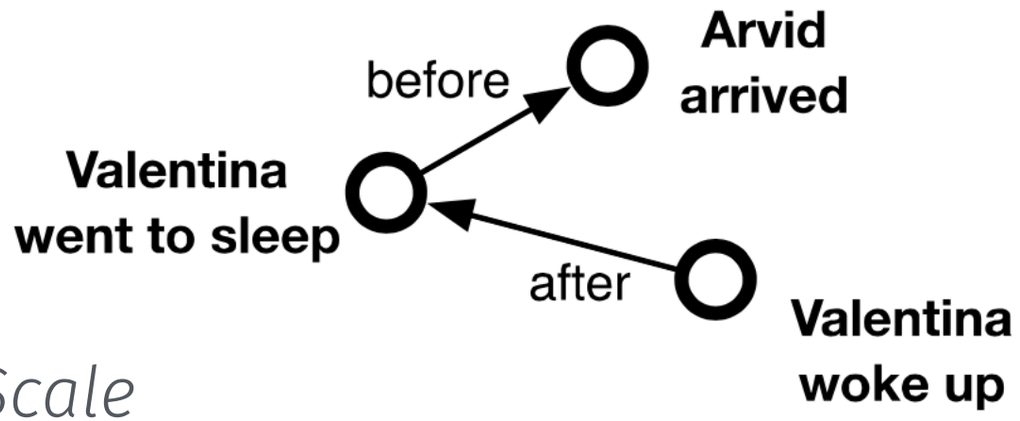
Gschwandtner et al. (2011)

Temporal Data: Properties

- Scale
- Scope
- Arrangement
- Viewpoint

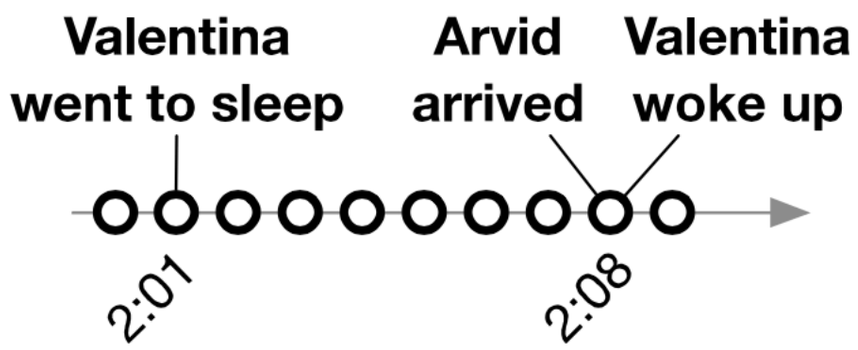
Scales

Fig. 3.1 Ordinal scale. Only relative order relations are present. At this level it is not possible to discern whether Valentina woke up before or after Arvid arrived.



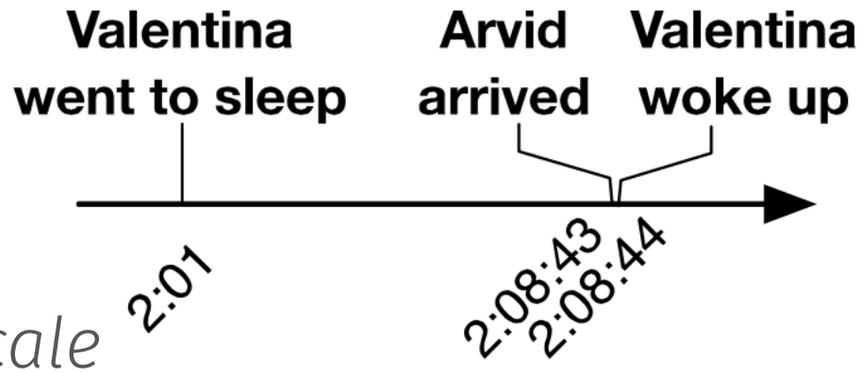
Ordinal Scale

Fig. 3.2 Discrete scale. Smallest possible unit is minutes. Although Arvid arrived and Valentina woke up within the same minute, it is not possible to model the exact order of events.



Discrete Scale

Fig. 3.3 Continuous scale. Between any two points in time, another point in time exists. Here, it is possible to model that Arvid arrived shortly before Valentina woke up.



Continuous Scale

from: Aigner et al., Visualization of Time-oriented Data (2011)

Scope: Point vs Interval

Fig. 3.7 Time value "August 1, 2008" in a point-based domain. No information is given in between two time points.

Point

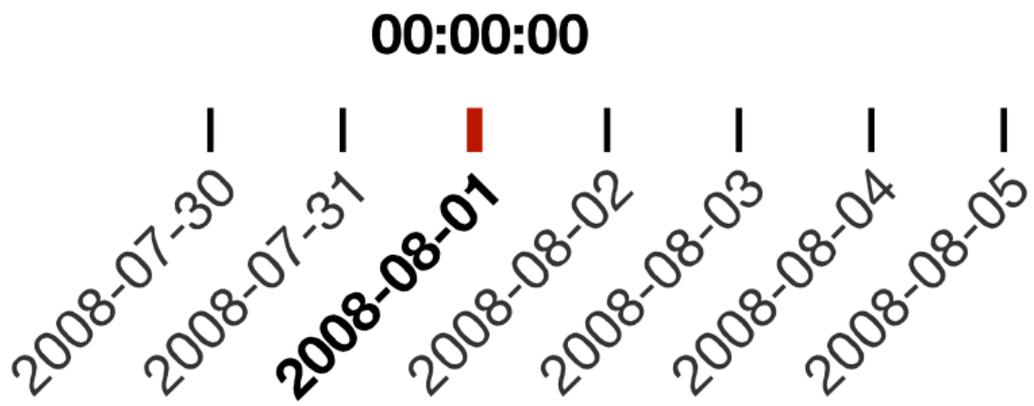
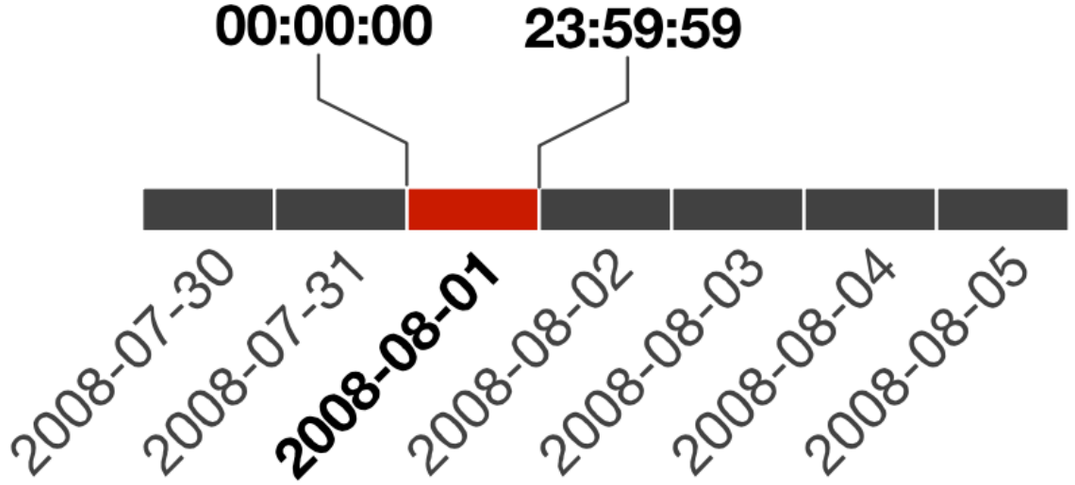


Fig. 3.8 Time value "August 1, 2008" in an interval-based domain. Each element covers a subsection of the time domain greater than zero.

Interval



from: Aigner et al., Visualization of Time-oriented Data (2011)

Arrangement: Linear vs Cyclic

Fig. 3.10 Linear time. Time proceeds linearly from past to future.

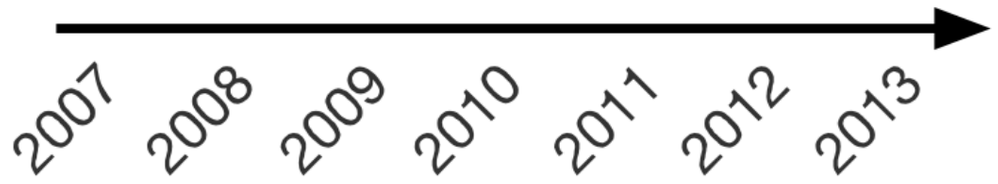
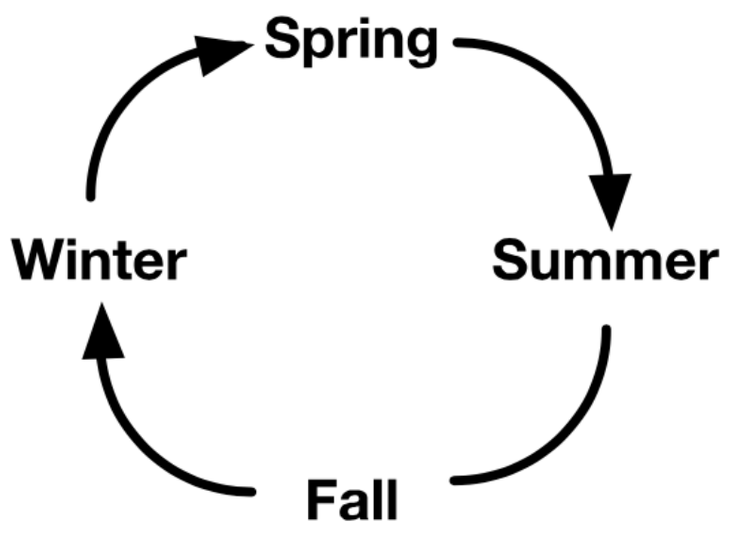


Fig. 3.11 Cyclic time. Set of recurring time values such as the seasons of the year.



from: Aigner et al., Visualization of Time-oriented Data (2011)

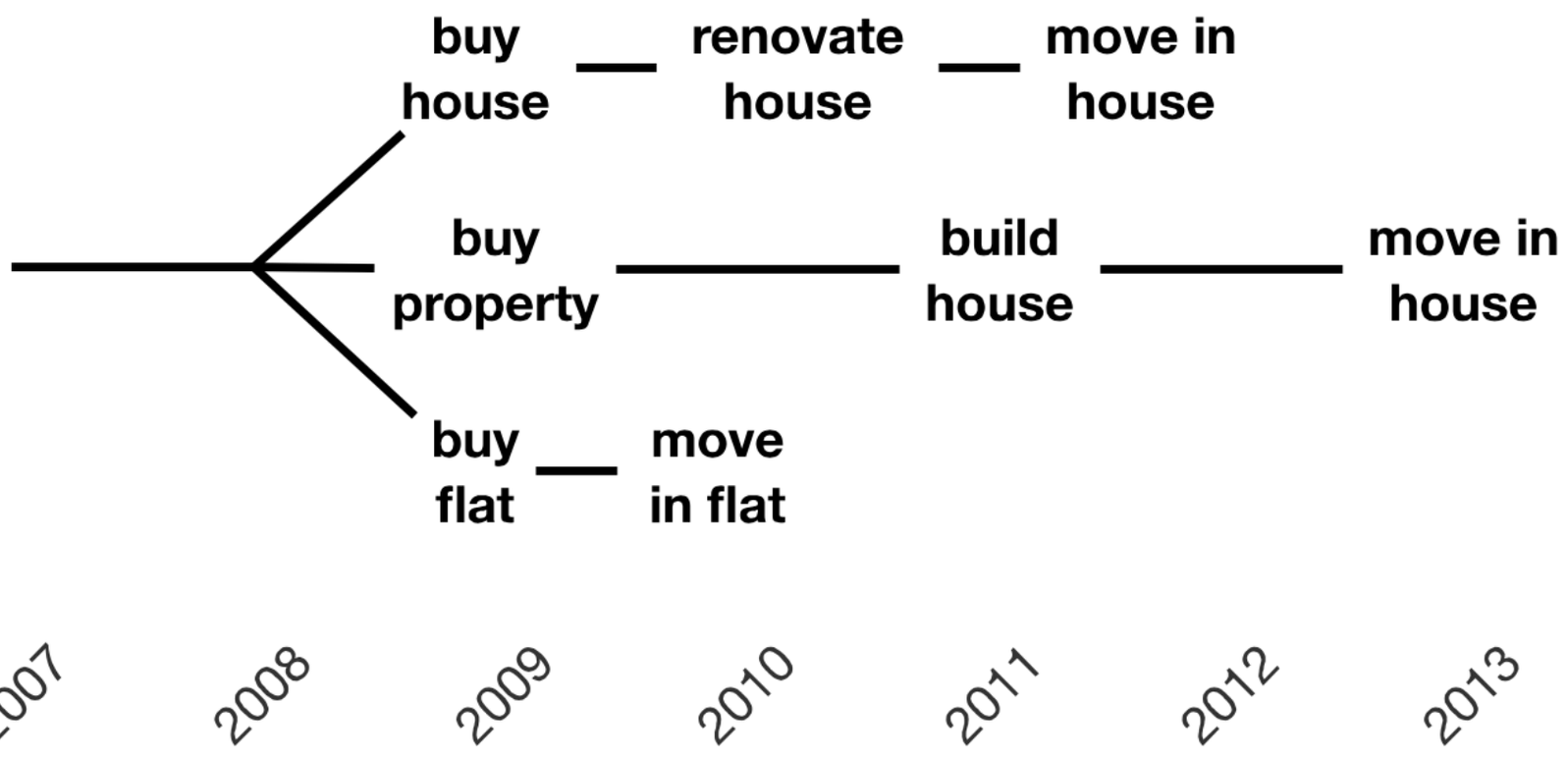
Viewpoint: Ordered

totally ordered: only one event can happen at a time

partially ordered: events can overlap

from: Aigner et al., Visualization of Time-oriented Data (2011)

Viewpoint: Branching



from: Aigner et al., Visualization of Time-oriented Data (2011)

Viewpoint: Multiple Perspectives

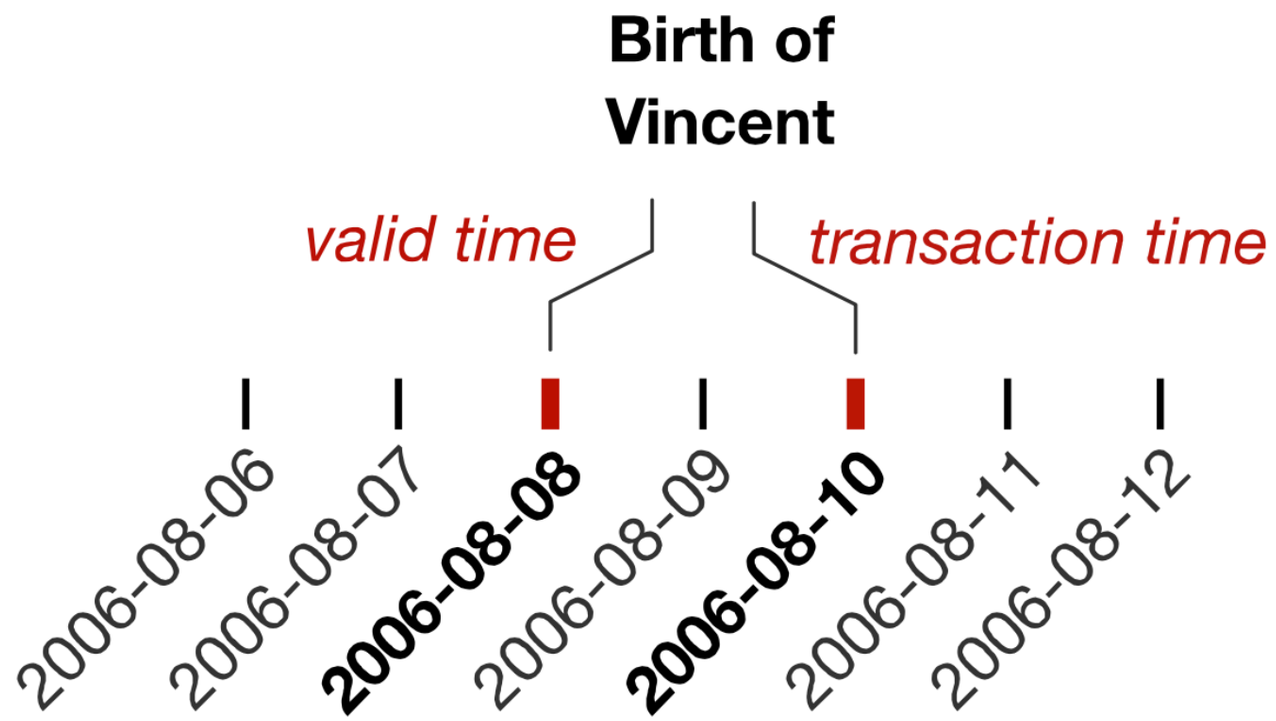
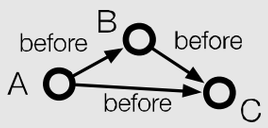
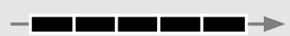
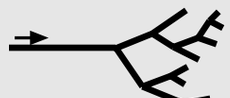


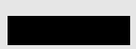
Fig. 3.13 Multiple perspectives. Vincent was born on August 8, 2006 (valid time) and this fact was stored in the register of residents two days later on August 10, 2006 (transaction time).

from: Aigner et al., Visualization of Time-oriented Data (2011)

Temporal Data: Properties

scale	 ordinal	 discrete	 continuous
scope	 point-based	 interval-based	
arrangement	 linear	 cyclic	
viewpoint	 ordered	 branching	 multiple perspectives

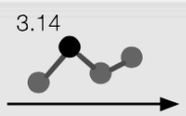
Abstractions

granularity & calendars	 none	 single	 multiple
time primitives	 instant	 interval	 span
determinacy	 determinate	 indeterminate	

from: Aigner et al., Visualization of Time-oriented Data (2011)

Temporal Data: Design Space

What?	time	scale, scope, arrangement, viewpoint granularity & calendars, time primitives, determinacy *see Chapter 3*	
	data	scale, frame of reference, kind of data, number of variables *see Chapter 3*	
	time & data	internal time, external time *see Chapter 3*	

Why?	1st level	 individual values	 sets
	2nd level	 lookup	 comparison
	3rd level	 identification	 localization

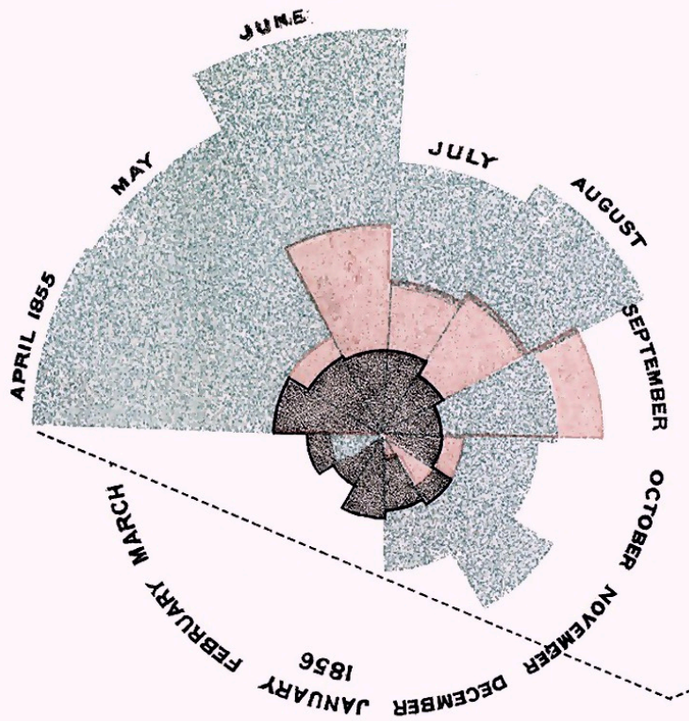
How?	mapping	 static	 dynamic
	dimensionality	 2D	 3D

from: Aigner et al., Visualization of Time-oriented Data (2011)

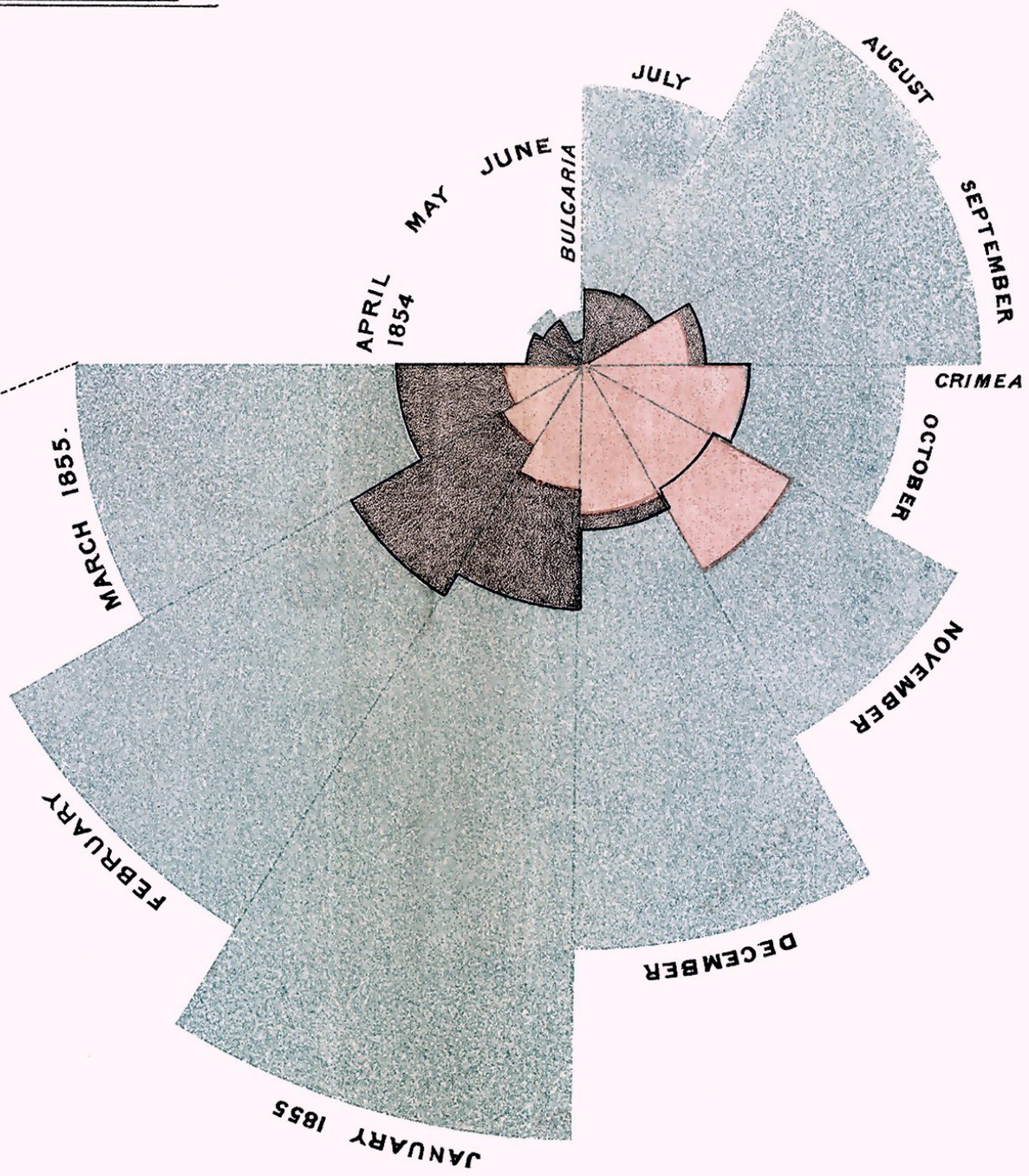
Nightingale: Rose Charts (1858)

DIAGRAM of the CAUSES of MORTALITY IN THE ARMY IN THE EAST.

2.
APRIL 1855 to MARCH 1856.



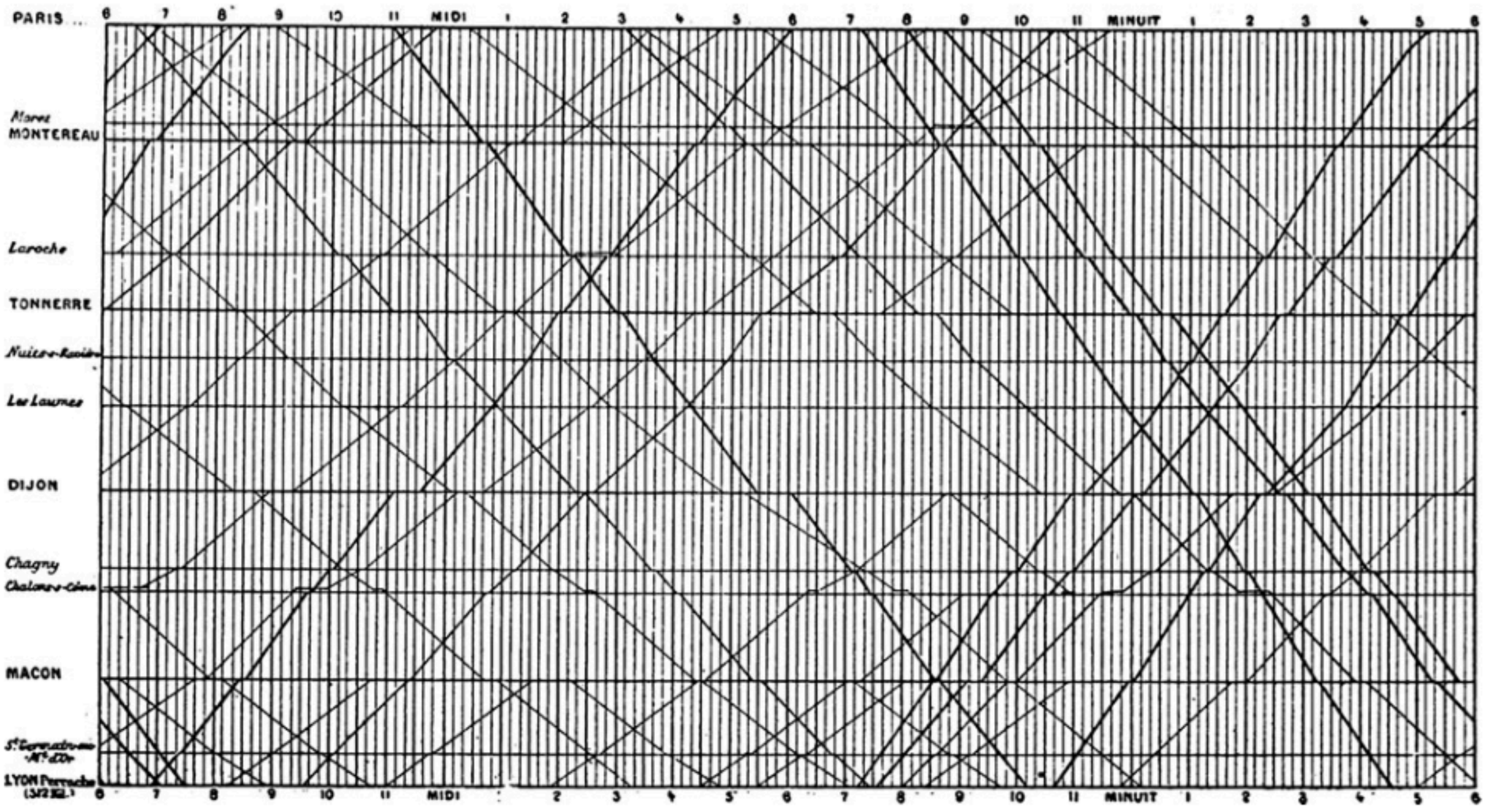
1.
APRIL 1854 to MARCH 1855.



The Areas of the blue, red, & black wedges are each measured from the centre as the common vertex.
The blue wedges measured from the centre of the circle represent area for area the deaths from Preventible or Mitigable Zymotic diseases; the red wedges measured from the centre the deaths from wounds; & the black wedges measured from the centre the deaths from all other causes.
The black line across the red triangle in Nov.r 1854 marks the boundary of the deaths from all other causes during the month.
In October 1854, & April 1855, the black area coincides with the red; in January & February 1856, the blue coincides with the black.
The entire areas may be compared by following the blue, the red & the black lines enclosing them.

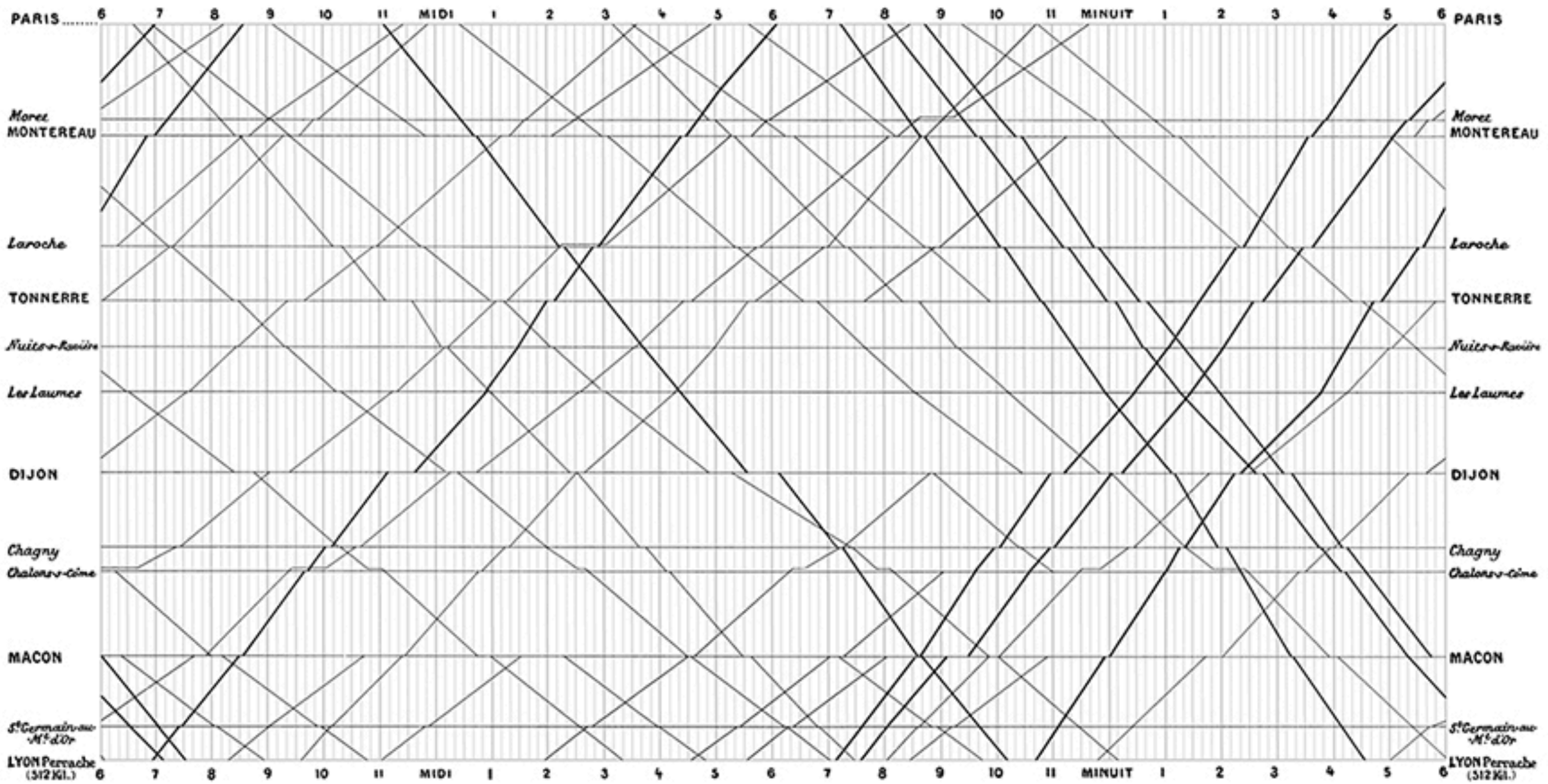
https://upload.wikimedia.org/wikipedia/commons/1/17/Nightingale-mortality.jpg

Marey: Train Schedule (1875)



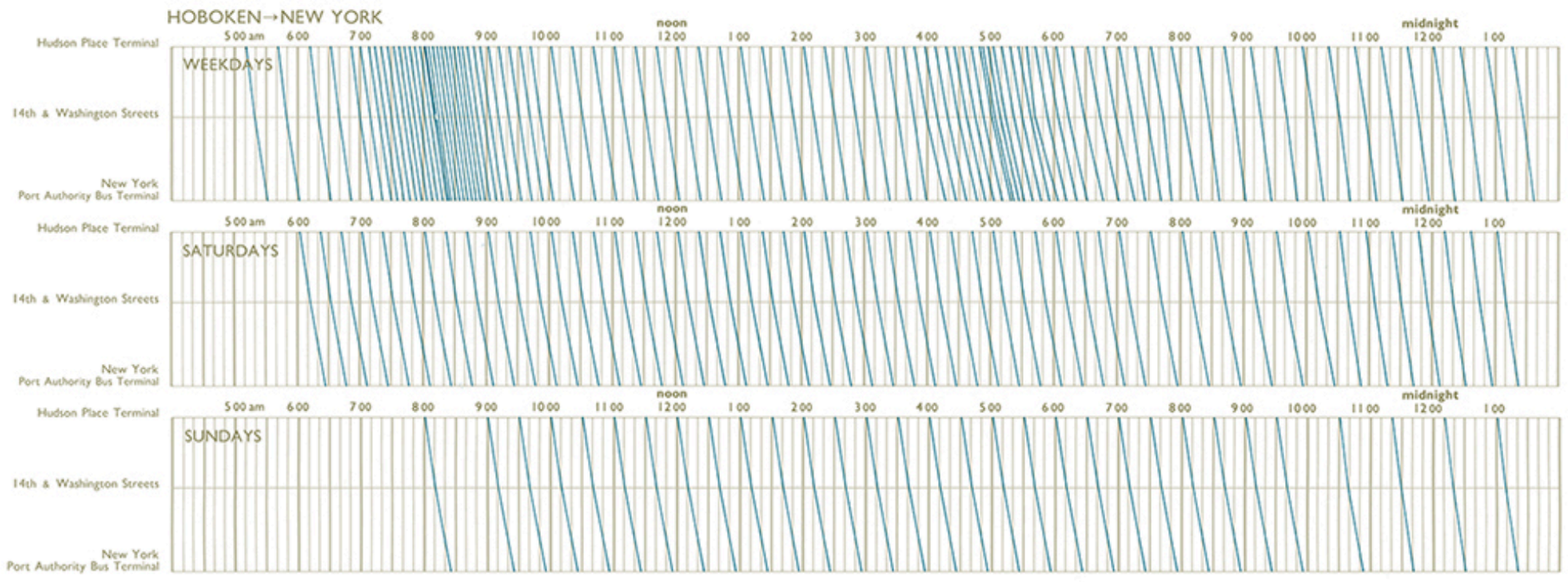
from: Aigner et al., Visualization of Time-oriented Data (2011)

Marey: Train Schedule (1875) - Redesigned by Tufte (1983)



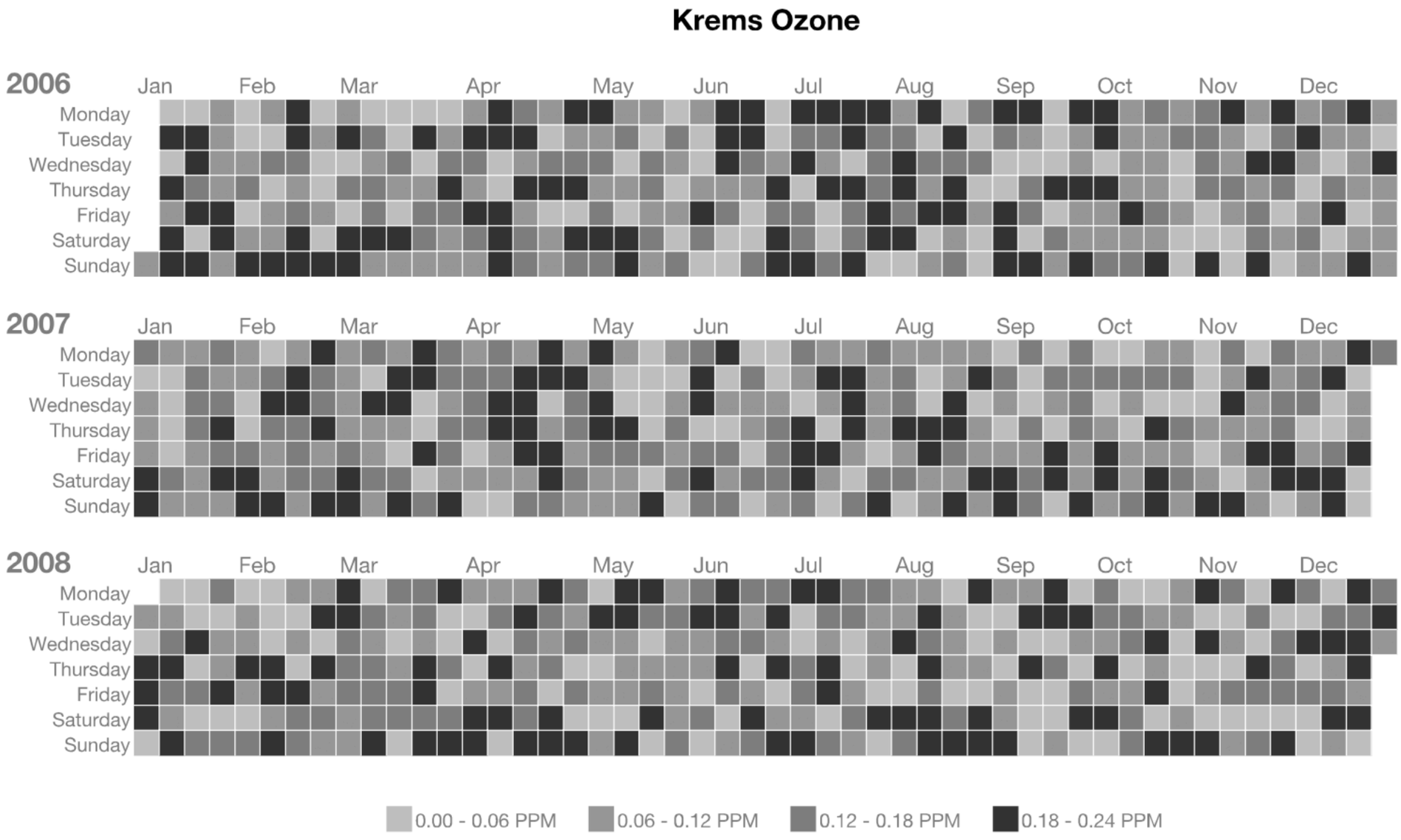
from: Tufte, Visual Display of Quantitative Information (1983)

Tufte: Bus Schedule (1990)



from: Tufte, Envisioning Information (1990)

Tile Maps

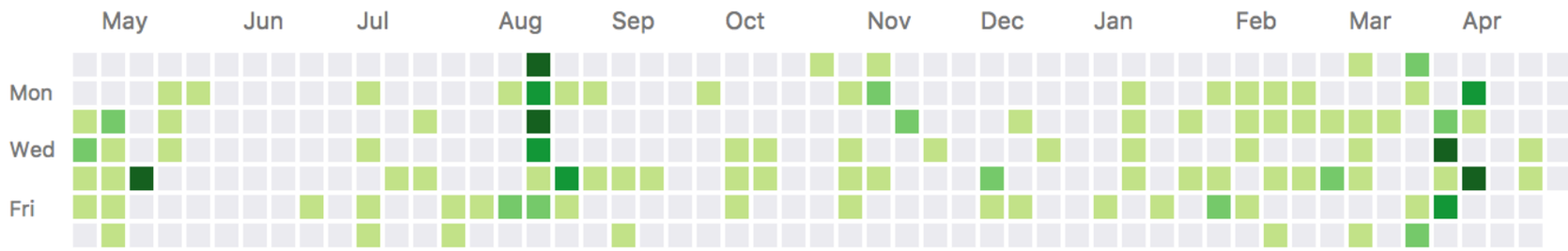


from: Aigner et al., Visualization of Time-oriented Data (2011)

Tile Maps

492 contributions in the last year

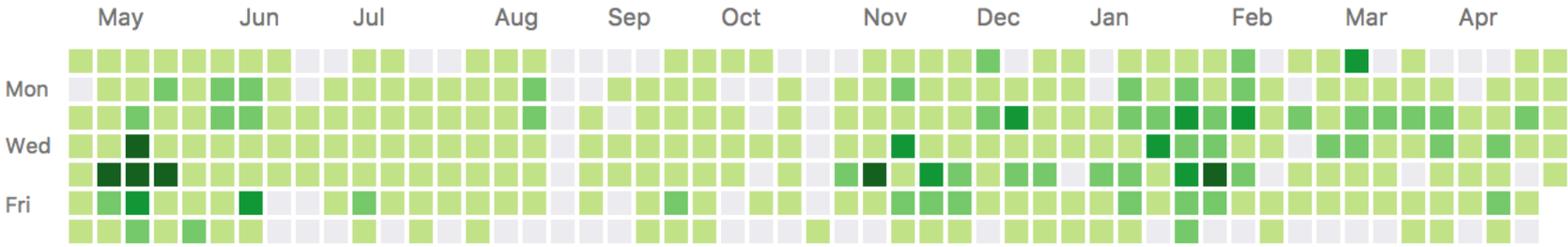
Contribution settings



Learn how we count contributions.

Less More

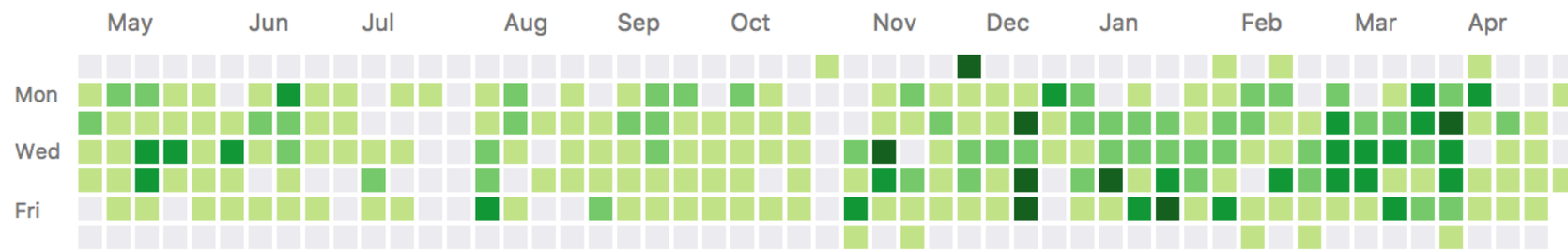
3,259 contributions in the last year



Learn how we count contributions.

Less More

1,884 contributions in the last year



Learn how we count contributions.

Less More

Calendar-based Views

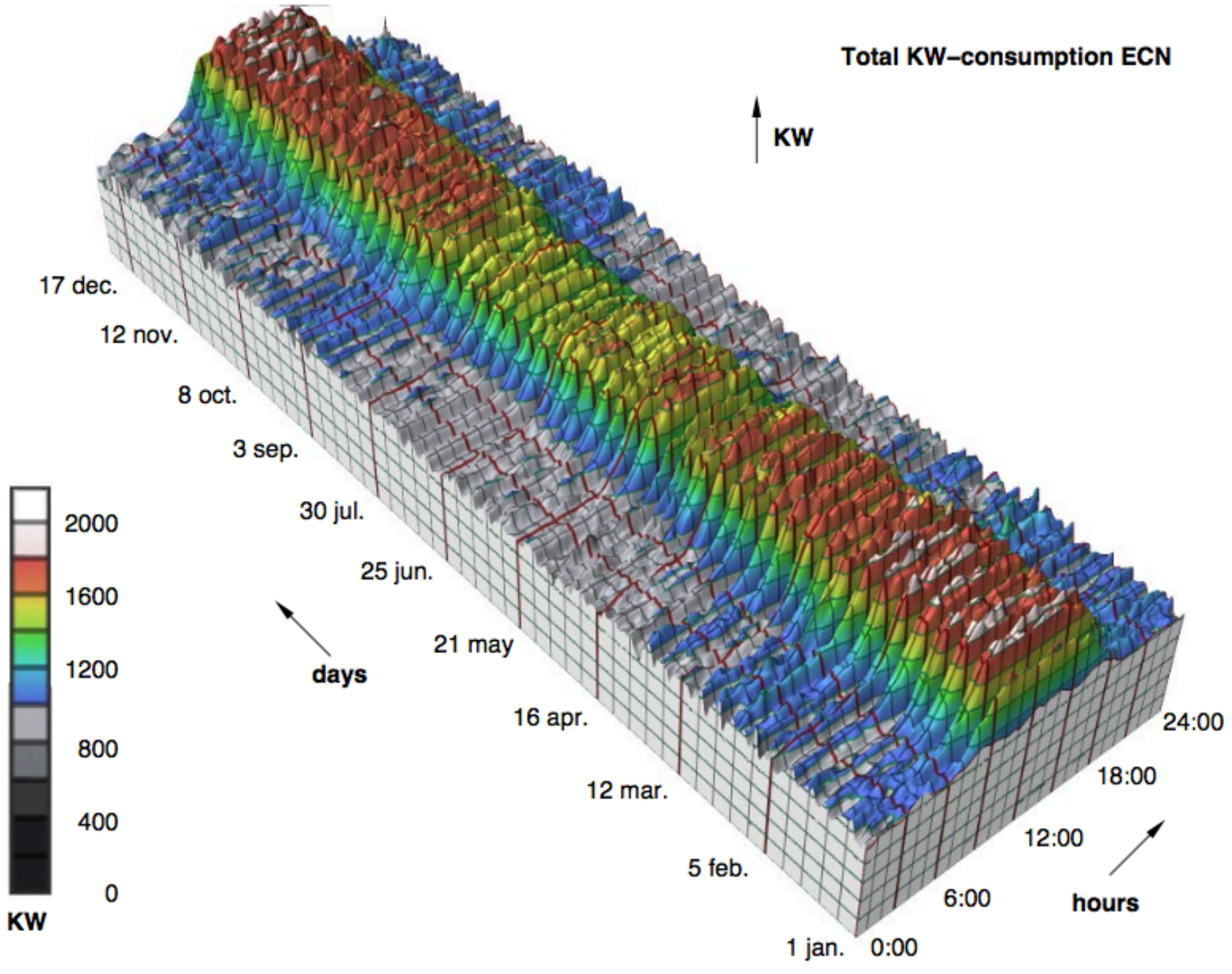


Figure 1. Power demand by ECN, displayed as a function of hours and days

Van Wijk and Selow, Cluster and Calendar based Visualization of Time Series Data, 1999

Calendar-based Views

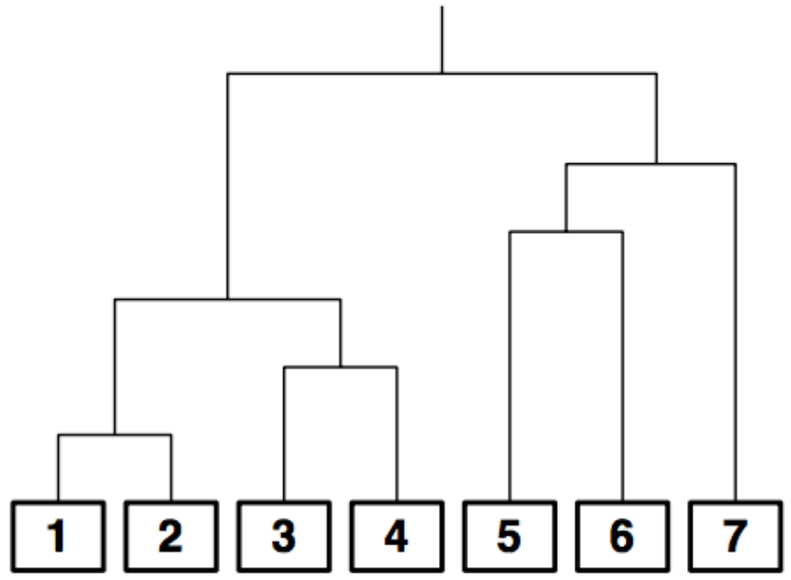


Figure 2. Dendrogram

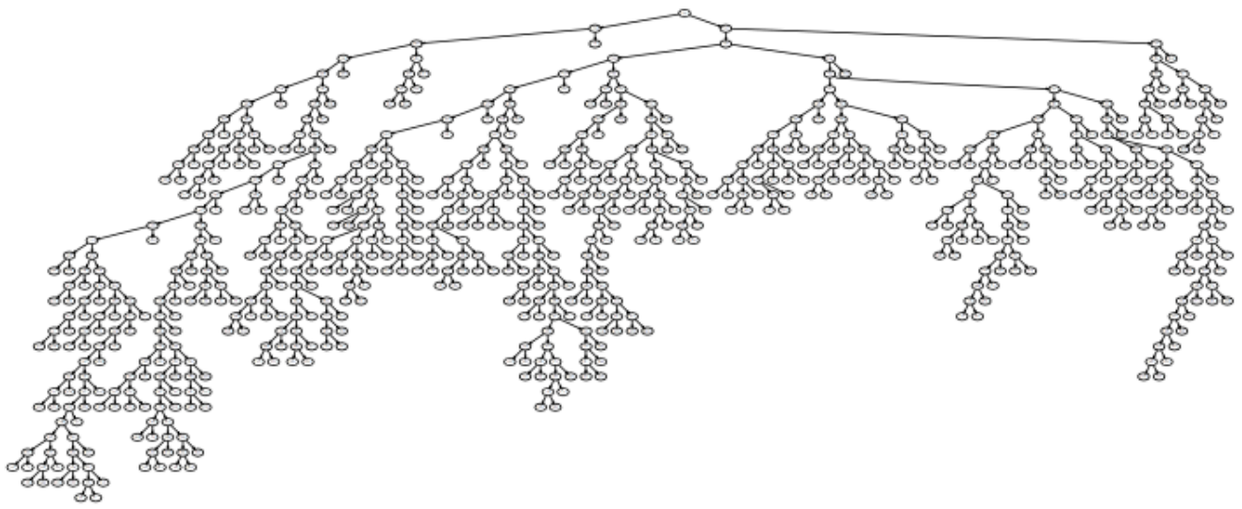


Figure 3. Full clustering tree

Van Wijk and Selow, Cluster and Calendar based Visualization of Time Series Data, 1999

Calendar-based Views

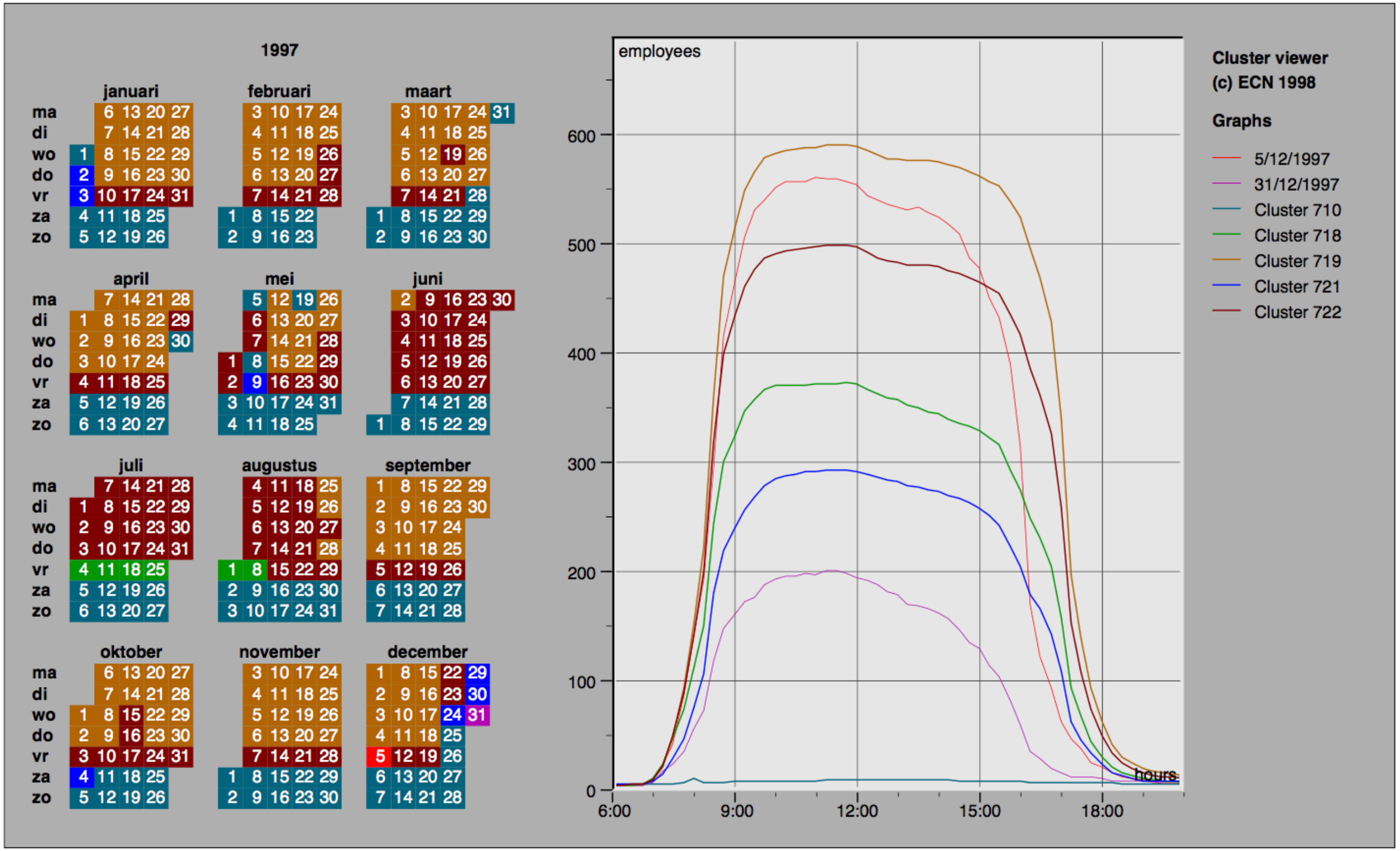
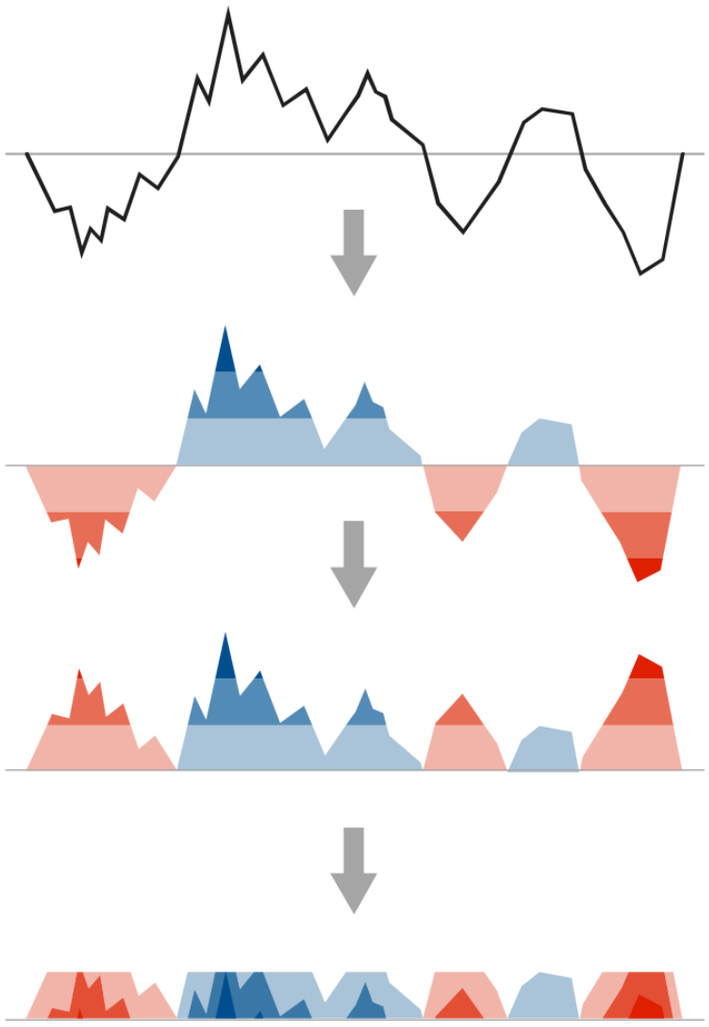
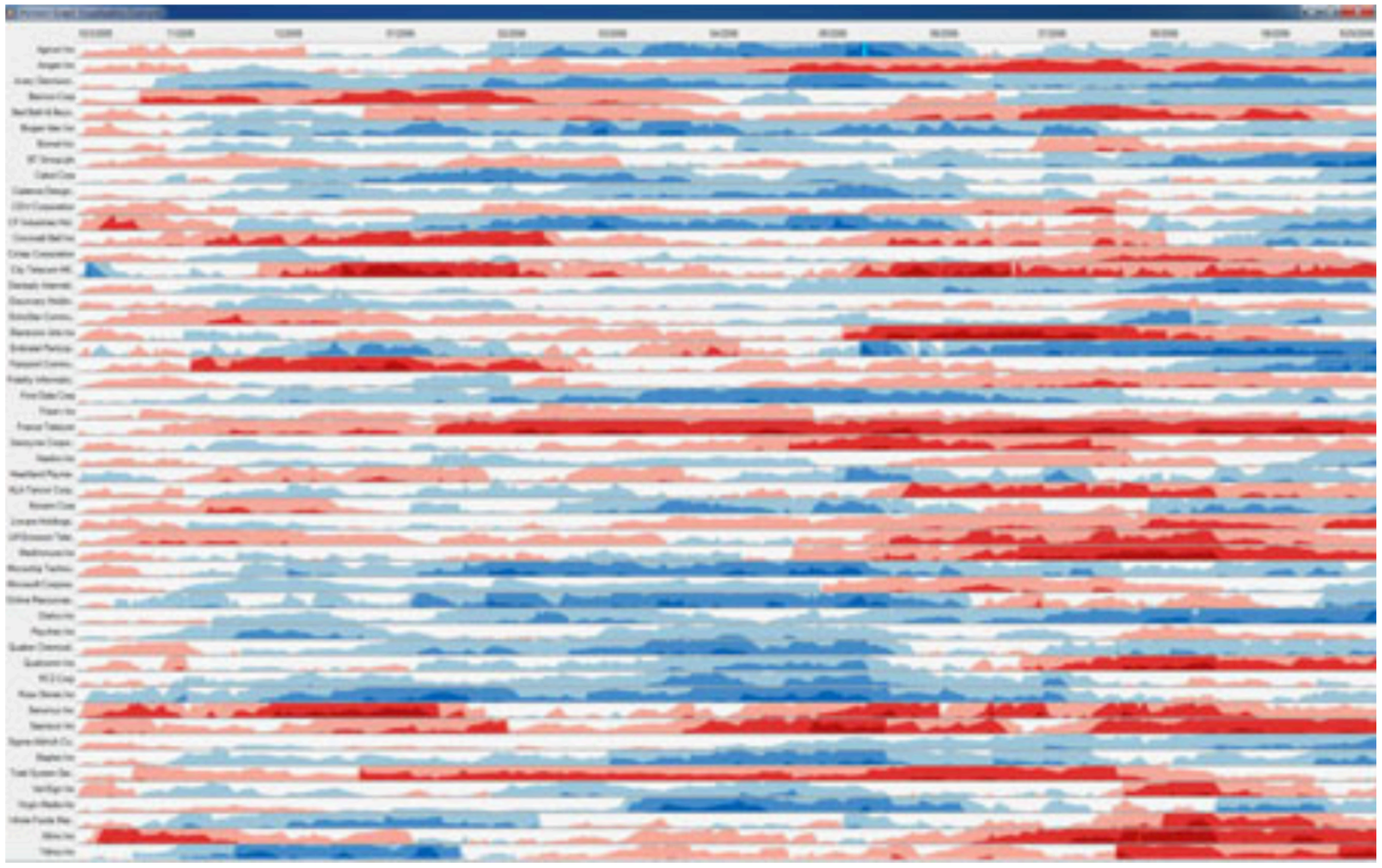


Figure 4. Calendar view of the number of employees

Van Wijk and Selow, Cluster and Calendar based Visualization of Time Series Data, 1999

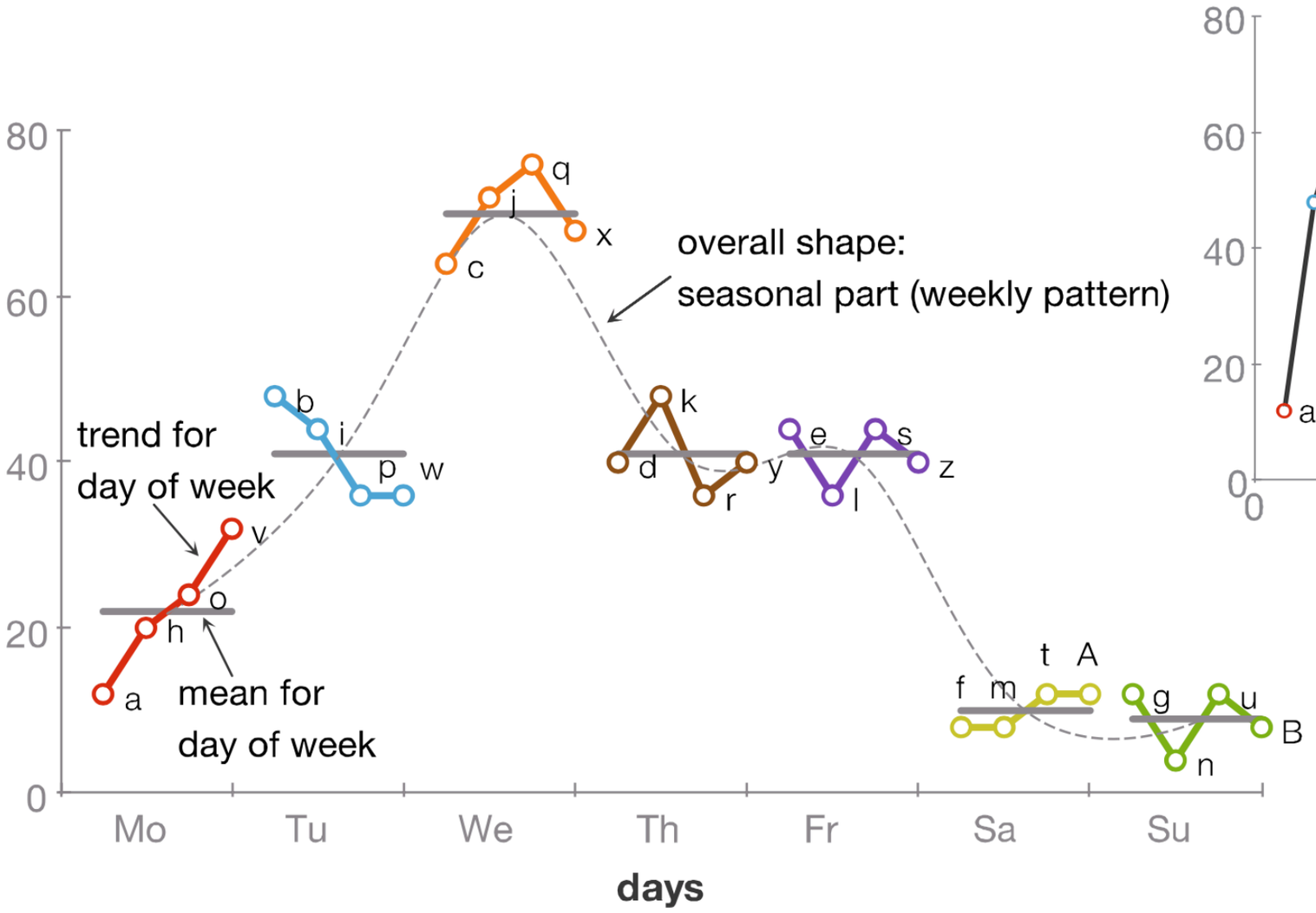
Horizon Charts

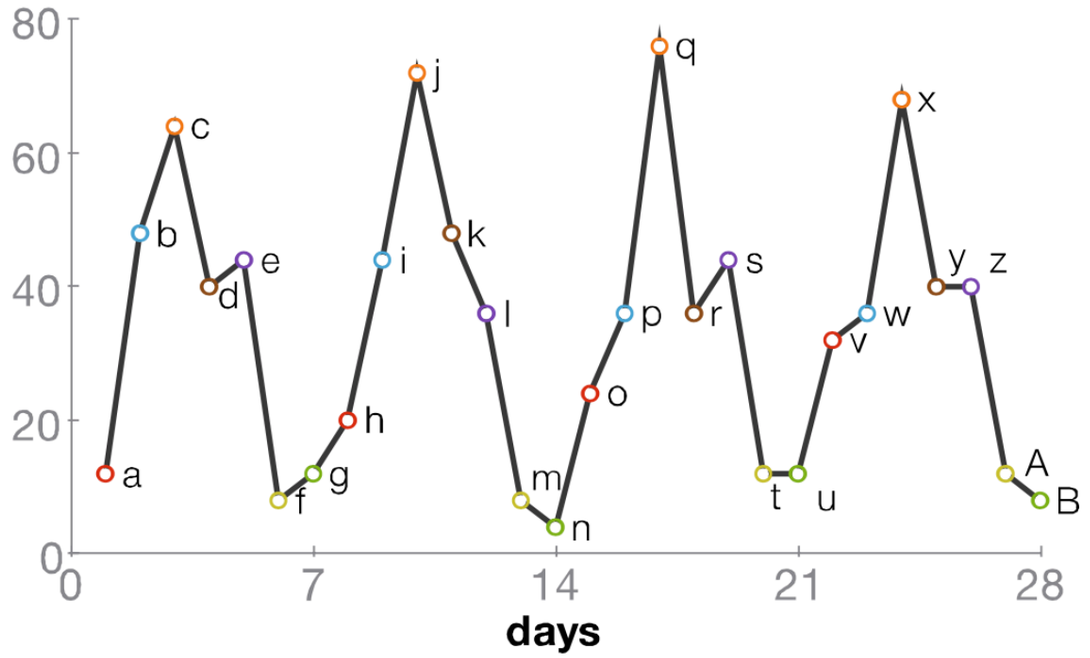




from: Aigner et al., Visualization of Time-oriented Data (2011)

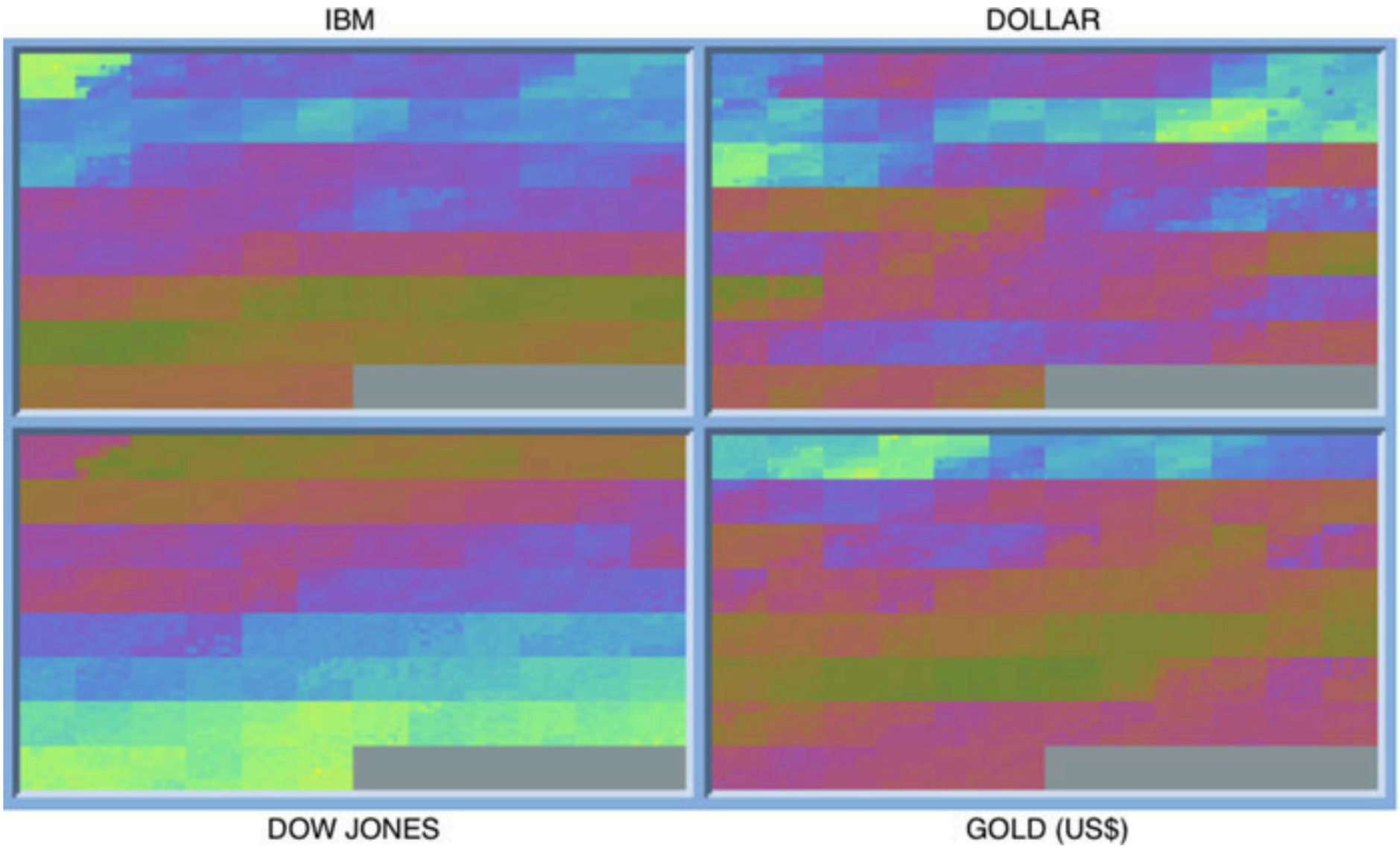
Cycle Plot

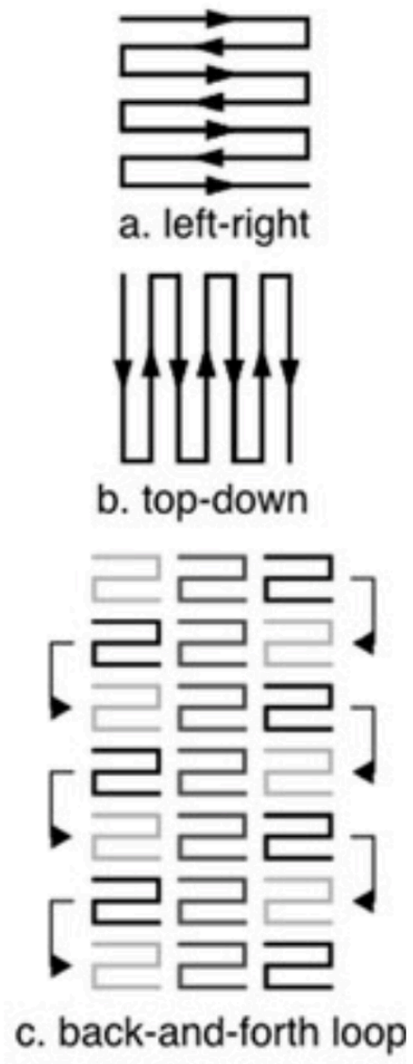




from: Aigner et al., Visualization of Time-oriented Data (2011)

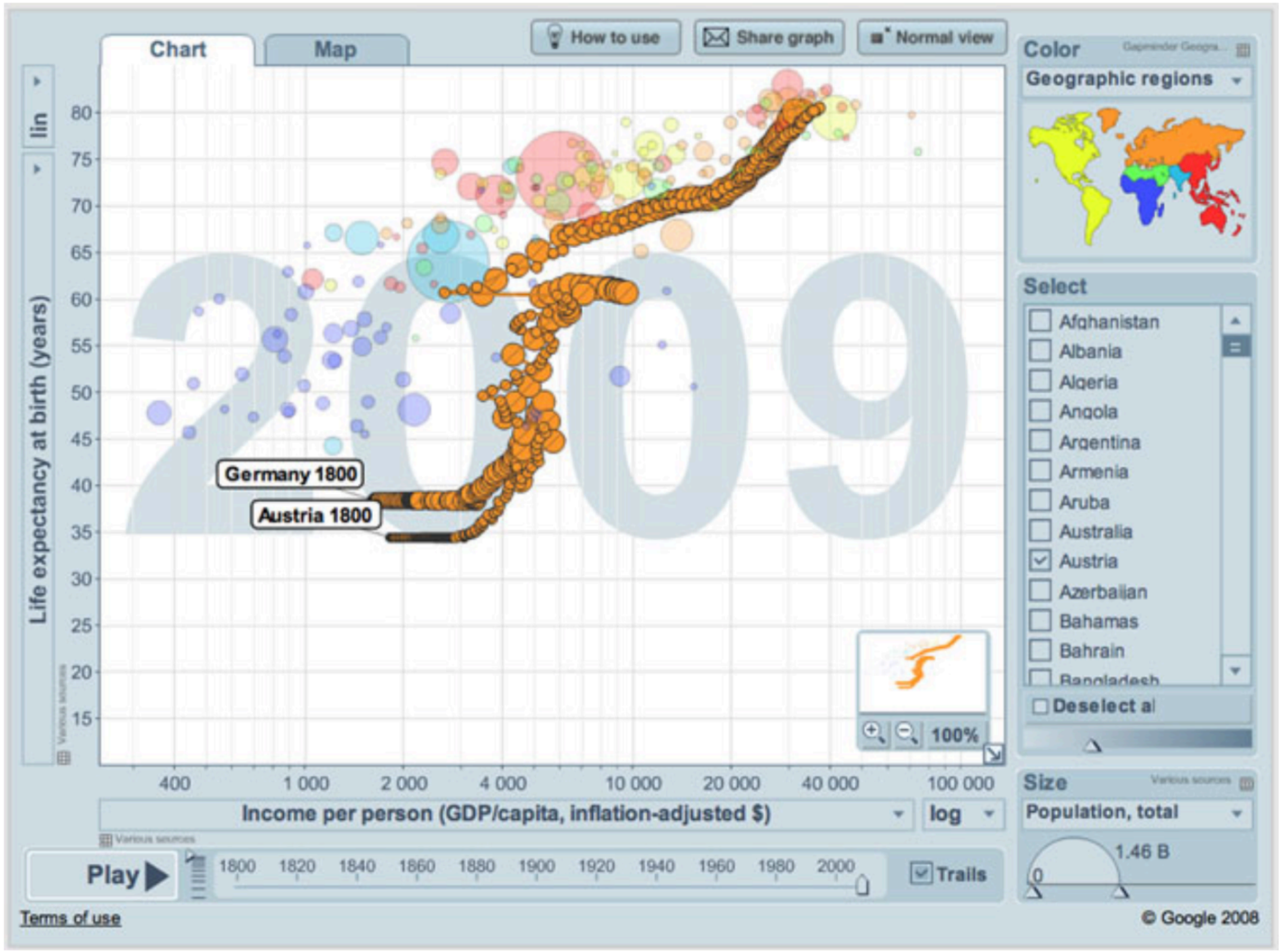
Pixel Maps





from: Aigner et al., Visualization of Time-oriented Data (2011)

Trendalyzer/Gap Minder



from: Aigner et al., Visualization of Time-oriented Data (2011)