Karlsruhe Institute of Technology

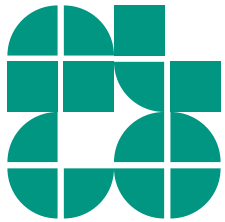
Algorithms for Graph Visualization

Introduction

INSTITUT FÜR THEORETISCHE INFORMATIK · FAKULTÄT FÜR INFORMATIK

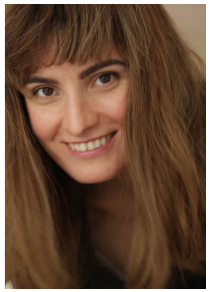
Tamara Mchedlidze, Torsten Ueckerdt, Marcel Radermacher

16.10.2018



Introduction

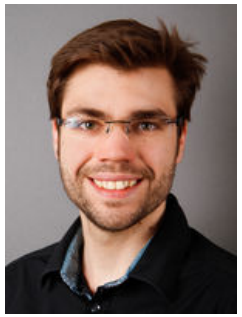
Lectures



- Tamara Mchedlidze
- mched@iti.uka.de
- Office 307
- Office hours: request by email

- Torsten Ueckerdt
- torsten.ueckerdt@kit.edu
- Office 319
- Office hours: request by email

Exercises



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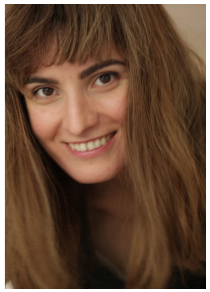
Introduction

Lectures



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Introduction

YOU: Name, Field of your Bachelor studies, why you are interested in this lecture

Mailing list

Overview

Karlsruhe Institute of Technology

About this course

Repetition of the material. We build our Mind Map.

Drawing graphs “by hand”. Complete MindMap.

Formal definition of Layout Problem.

About this course: learning objectives.

Applications gallery.

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About this Course

- **Lecture:** Wednesday 14:00 – 15:30, Room 301
- **Exercise:** Tuesday 14:00 – 15:30, Room 236
- exact plan on the web-page*

Webseite

`i11www.iti.kit.edu/teaching/winter2019/graphvis/`

- Latest news
- Lecture slides
- Exercise sheets
- Literature & Additional material
- Lecture notes (skript)

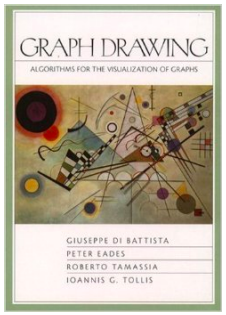
About this Course

Karlsruhe Institute of Technology

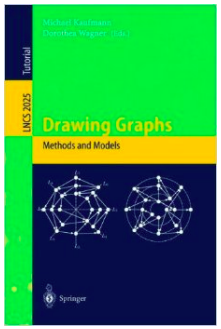
Media:

- **Slides** & Blackboard & Pinboard
- Exercise sheets are provided (at least) a week before the exercise session
- (incomplete) Lecture notes/Books
- Original literature (papers)

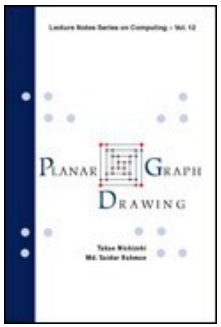
Books (available in the library)



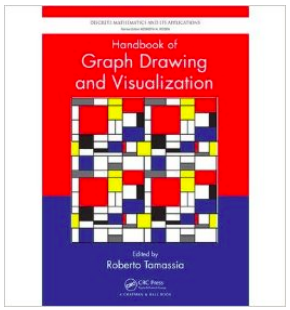
G. di Battista, P. Eades, R. Tamassia, I. Tollis:
Graph Drawing
Prentice Hall, 1998



M. Kaufmann, D. Wagner:
Drawing Graphs: Methods and Models
Springer, 2001



T. Nishizeki, Md. S. Rahman:
Planar Graph Drawing
World Scientific, 2004



R. Tamassia:
Handbook of Graph Drawing and Visualization
CRC Press, 2013 http://cs.brown.edu/~rt/gdhandbook/

About this Course

Master Informatics

- Module: General: M-INFO-102094
  This year: T-INFO-104390

About this Course

Karlsruhe Institute of Technology

Master Informatics

- Module: General: M-INFO-102094
  This year: T-INFO-104390

Suggested time requirements: 5LP = 150h

• Attending Lecture and Exercises:	ca. 35h
• Preparation/post-processing	ca. 35h
• Work on the exercises	ca. 40h
• Preparation for the exam	ca. 40h

About this Course

Karlsruhe Institute of Technology

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Suggested time requirements: 5LP = 150h

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• Preparation/post-processing	ca. 35h
• Work on the exercises	ca. 40h
• Preparation for the exam	ca. 40h

Exercises:

- We expect that you **participate actively** in the exercise sessions (e.g. present your own solutions on the board)

Examination procedure: Oral exam(app. 20 Minutes)

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Graph and its Representation

What is a Graph?

Graph and its Representation

What is a Graph?

Tuple $G = (V, E)$
Set of nodes $V = \{v_1, \ldots, v_n\}$
Set of edges $E = \{e_1, \ldots, e_m\}$,
$e_i = \{v_j, v_k\},\ 1 \leq i \leq m,\ 1 \leq j, k \leq n$

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Representations?

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Representations?

Set representation:

$$
\begin{aligned}
V &= \{v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8, v_9, v_{10}\} \\
E &= \{\{v_1, v_2\}, \{v_1, v_8\}, \{v_2, v_3\}, \{v_3, v_5\}, \{v_3, v_9\}, \\
&\quad \{v_3, v_{10}\}, \{v_4, v_5\}, \{v_4, v_6\}, \{v_4, v_9\}, \{v_5, v_8\}, \\
&\quad \{v_6, v_8\}, \{v_6, v_9\}, \{v_7, v_8\}, \{v_7, v_9\}, \{v_8, v_{10}\}, \\
&\quad \{v_9, v_{10}\}\}
\end{aligned}
$$

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Representations?

Set representation
Adjacency list

$$
\begin{array}{ll}
v_1: & v_2, v_8 \\
v_2: & v_1, v_3 \\
v_3: & v_2, v_5, v_9, v_{10} \\
v_4: & v_5, v_6, v_9 \\
v_5: & v_3, v_4, v_8 \\
v_6: & v_4, v_8, v_9 \\
v_7: & v_8, v_9 \\
v_8: & v_1, v_5, v_6, v_7, v_9, v_{10} \\
v_9: & v_3, v_4, v_6, v_7, v_8, v_{10} \\
v_{10}: & v_3, v_8, v_9
\end{array}
$$

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Representations?

Set representation
Adjacency list
Adjacency matrix

$$\begin{pmatrix}
0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 \\
0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 \\
0 & 0 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\
1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 \\
0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 1 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0
\end{pmatrix}$$

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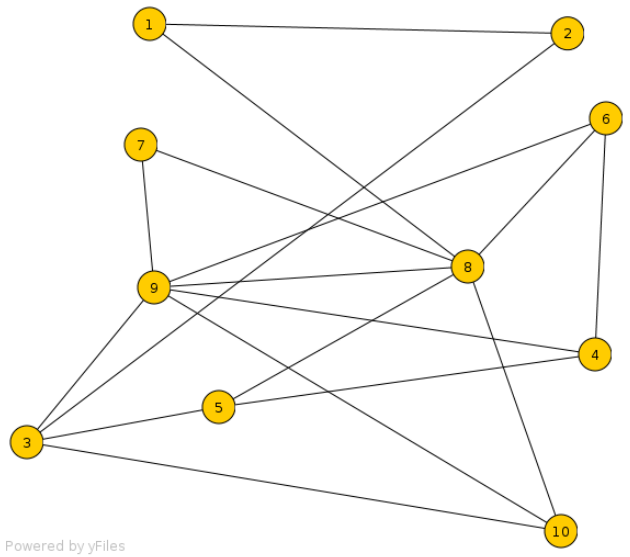
Representations?

Set representation
Adjacency list
Adjacency matrix
Drawing or Node-link diagram



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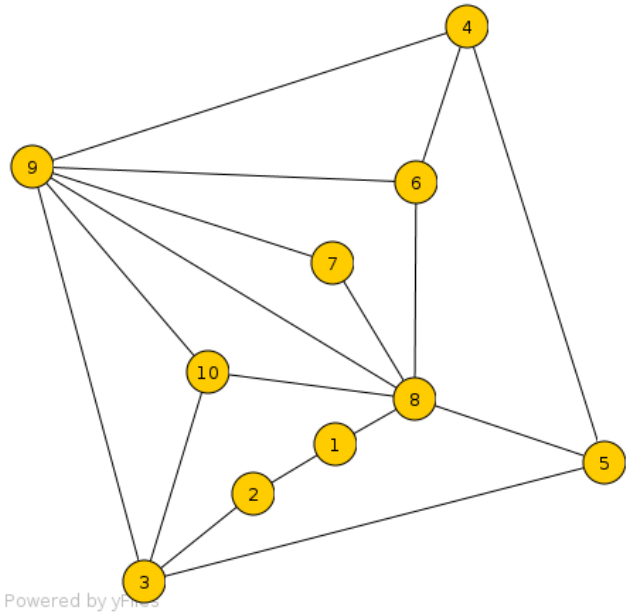
Representations?

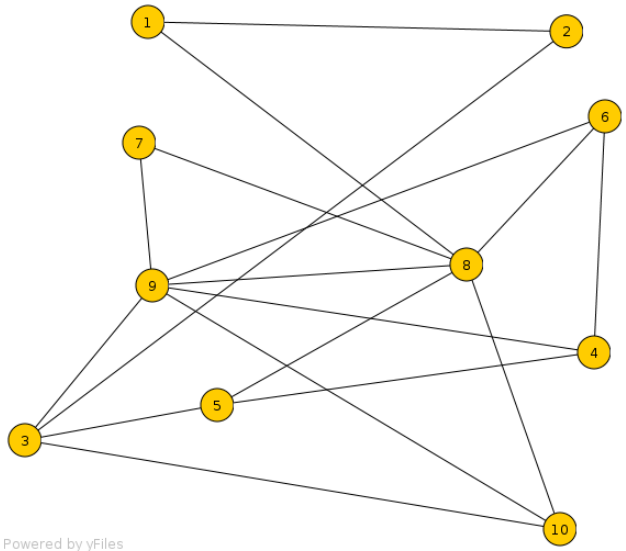
Set representation
Adjacency list
Adjacency matrix
Drawing or Node-link diagram



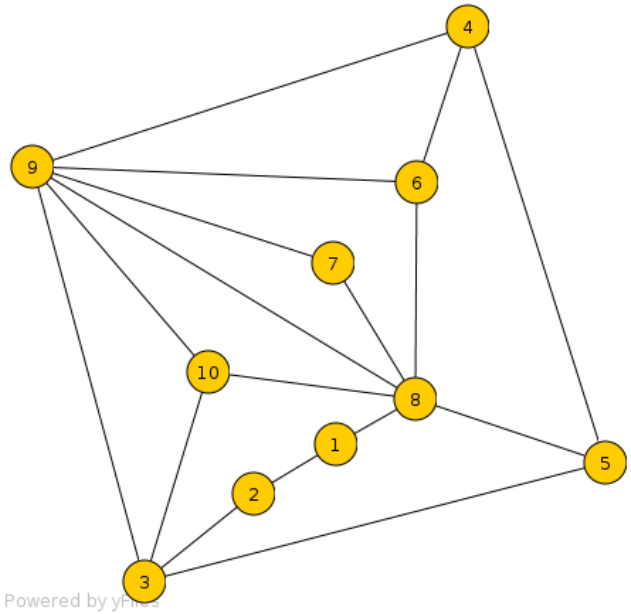
Graph and its Representation

$$V = \{v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8, v_9, v_{10}\}$$
$$E = \{\{v_1, v_2\}, \{v_1, v_8\}, \{v_2, v_3\}, \{v_3, v_5\}, \{v_3, v_9\}, \{v_3, v_{10}\}, \{v_4, v_5\}, \{v_4, v_6\}, \{v_4, v_9\}, \{v_5, v_8\}, \{v_6, v_8\}, \{v_6, v_9\}, \{v_7, v_8\}, \{v_7, v_9\}, \{v_8, v_{10}\}, \{v_9, v_{10}\}\}$$

$$\begin{array}{ll} v_1: & v_2, v_8 \\ v_2: & v_1, v_3 \\ v_3: & v_2, v_5, v_9, v_{10} \\ v_4: & v_5, v_6, v_9 \\ v_5: & v_3, v_4, v_8 \\ v_6: & v_4, v_8, v_9 \\ v_7: & v_8, v_9 \\ v_8: & v_1, v_5, v_6, v_7, v_9, v_{10} \\ v_9: & v_3, v_4, v_6, v_7, v_8, v_{10} \\ v_{10}: & v_3, v_8, v_9 \end{array}$$



$$\begin{pmatrix} 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 \\ 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \end{pmatrix}$$



Graph and its Representation

Think and write down

- **Why do need node-link diagrams?**

2 min

Let's Recall

Discuss with your neighbour or in groups of three and write down

10 min

Graph classes you know (planar etc.)

Algorithmic techniques you know (greedy etc.)

Applications of network visualization you have heard about

We will group your knowledge into a MIND MAP

Let's Recall

Discuss with your neighbour or in groups of three and write down

10 min

Graph classes you know (planar etc.)

Algorithmic techniques you know (greedy etc.)

Applications of network visualization you have heard about

We will group your knowledge into a MIND MAP

Prerequisites: Algorithms 1 & 2, Theoretical Basics of Inf.

Helpful: Algorithms for Planar Graphs

Overview

About this course

Repetition of the material. We build our Mind Map.

Drawing graphs “by hand”. Complete MindMap.

Formal definition of Layout Problem.

About this course: learning objectives.

Applications gallery.

How to draw graphs?

Work with your neighbour or in groups of three

15 min

- graphs in form of adjacency matrix/list
- Use https://www.yworks.com/downloads#yEd or paper
- draw all or some graphs as nice and as readable as possible
- export to PNG or make a picture and send to mched@iti.uka.de

We will show and discuss the results afterwards and complete the MIND MAP

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Karlsruhe Institute of Technology

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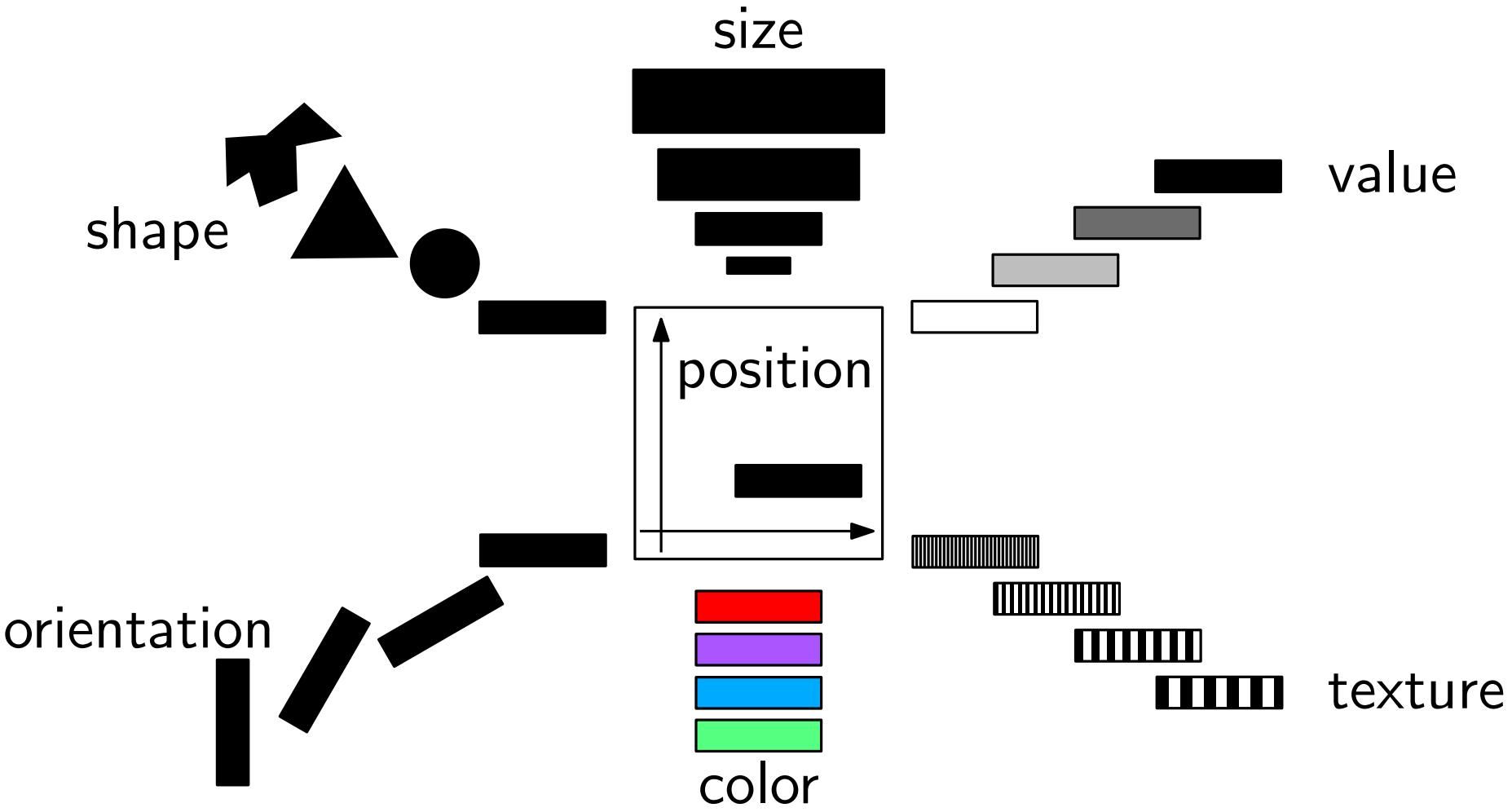
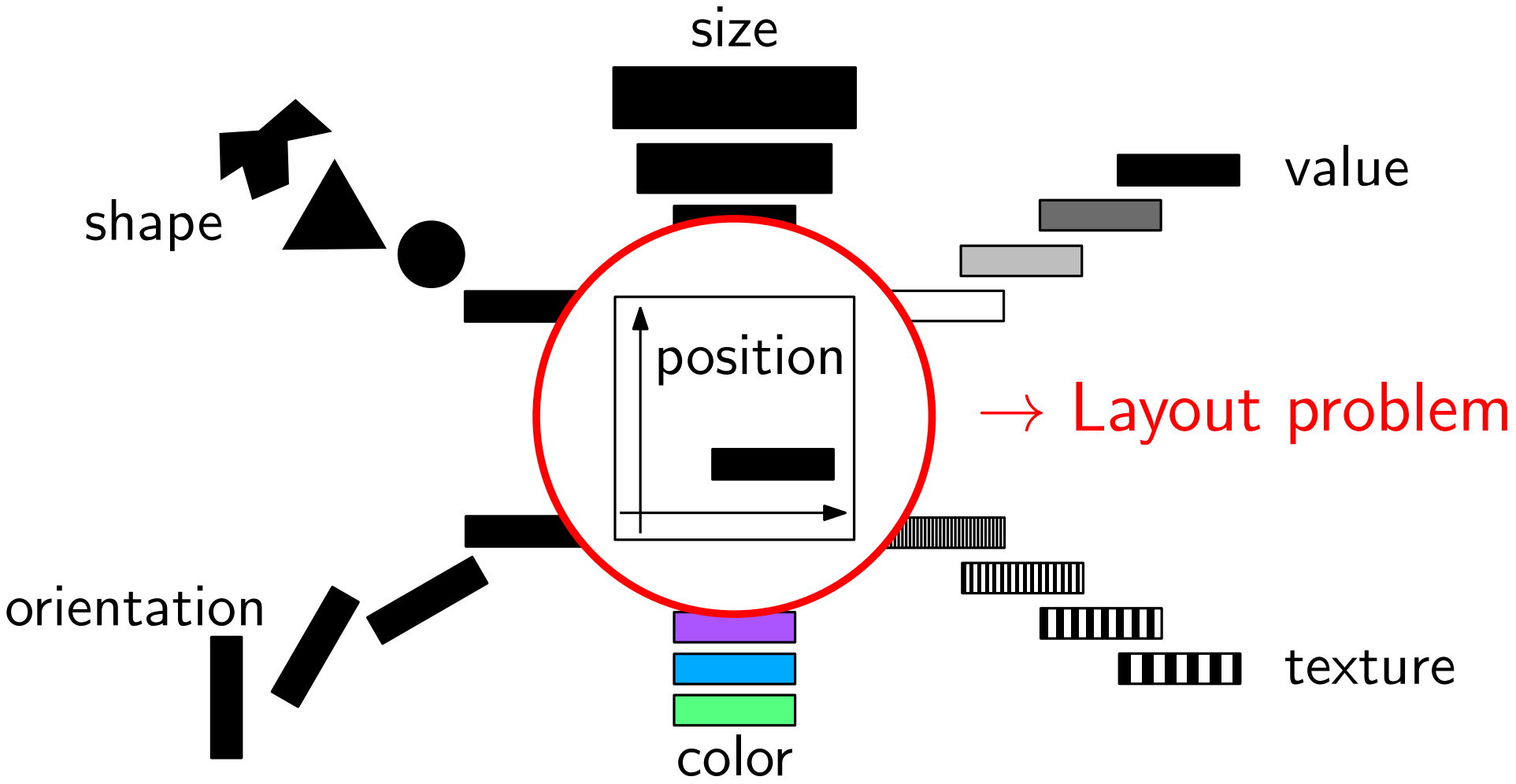
Visual Variables according to Bertin (1967)



Visual Variables according to Bertin (1967)



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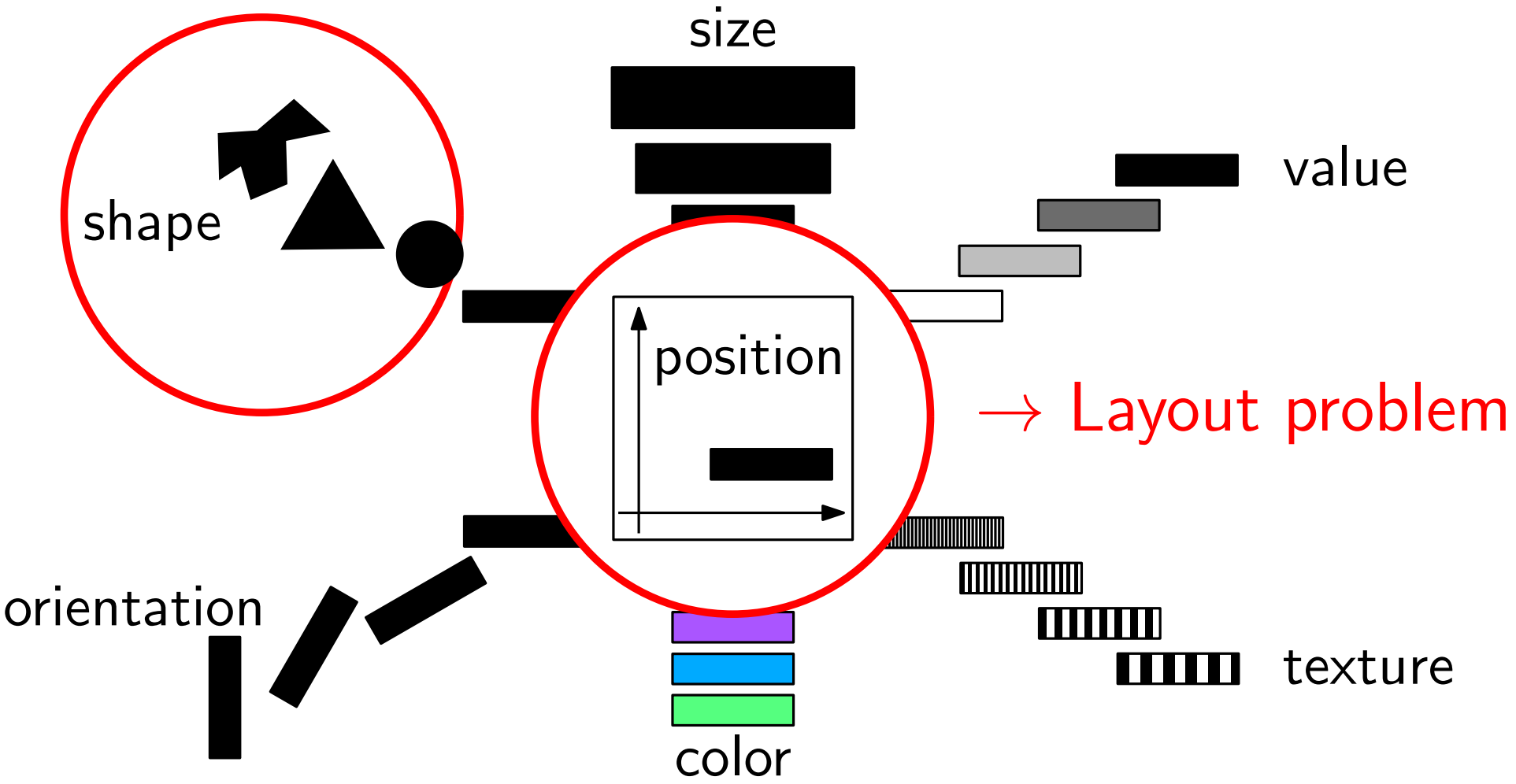

Layout Problem

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Graph visualization problem

given : Graph $G = (V, E)$

find: good drawing Γ of G

- $\Gamma : V \to \mathbb{R}^2$, nodes $v \mapsto$ point $\Gamma(v)$
- $\Gamma : E \to$ curves in $\mathbb{R}^2$, edge $\{u, v\} \mapsto$ simple open curve $c_{uv} : [0, 1] \to \mathbb{R}^2$ where $c_{uv}(0) = \Gamma(u)$ and $c_{uv}(1) = \Gamma(v)$

Layout Problem

Graph visualization problem

given : Graph $G = (V, E)$

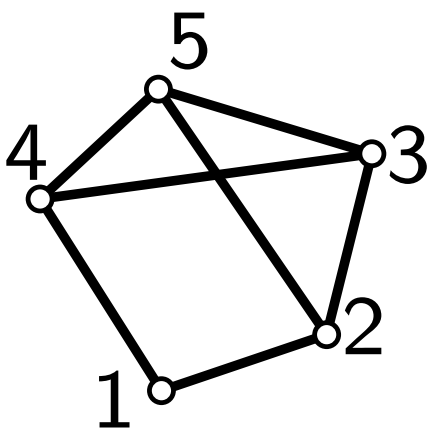
find: **good** drawing Γ of G

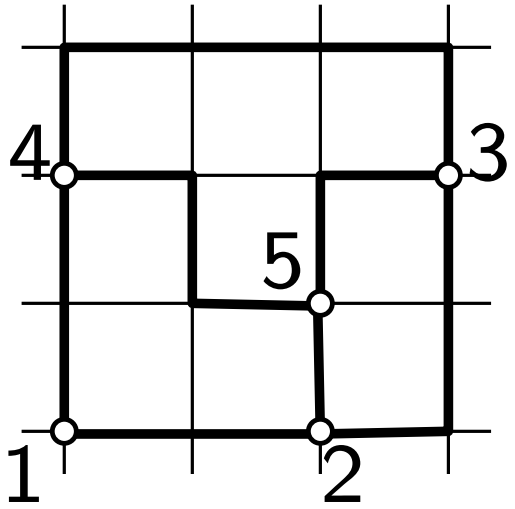
- $\Gamma : V \to \mathbb{R}^2$, nodes $v \mapsto$ point $\Gamma(v)$
- $\Gamma : E \to$ curves in $\mathbb{R}^2$, edge $\{u, v\} \mapsto$ simple open curve $c_{uv} : [0, 1] \to \mathbb{R}^2$ where $c_{uv}(0) = \Gamma(u)$ and $c_{uv}(1) = \Gamma(v)$

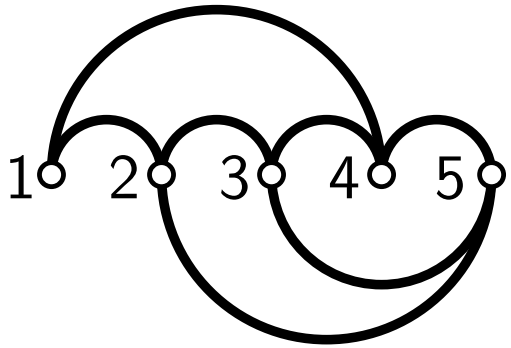
Layout Problem

1) **Drawing conventions**, required properties, for example

- straight-line edges
- orthogonal edges (with bends 90 degrees)
- Drawing on a grid
- crossing-free
- ...







Layout Problem

1) **Drawing conventions**, required properties

2) **Aesthetics** (to be optimized), for example:

- Number of crossing
- Number of bends
- Uniform edge length
- Area/length
- Angular resolution
- Symmetry
- ...

Layout Problem

1) **Drawing conventions**, required properties

2) **Aesthetics** (to be optimized)

3) **Partial/local constraints**, for example:

- Positions of several vertices
- Relative positions of vertices
- Group of nodes drawn close to each other

Layout Problem – Second Attempt

Karlsruhe Institute of Technology

Graph visualization problem

given: Graph $G = (V, E)$

find: a drawing Γ of G, that

- complies with drawing conventions
- optimizes aesthetics
- satisfies local/partial constraints

Layout Problem – Second Attempt

Karlsruhe Institute of Technology

Graph visualization problem

given: Graph $G = (V, E)$

find: a drawing Γ of G, that

- complies with drawing conventions
- optimizes aesthetics
- satisfies local/partial constraints

$\rightarrow$ often lead to NP-hard optimization problems!

$\rightarrow$ often several competing criteria

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Learning Objectives

At the end of the semester you are able to:

Learning Objectives

Karlsruhe Institute of Technology

At the end of the semester you are able to:

- List various network visualization styles
- Formally state a network visualization problem
- Describe several algorithms for network visualization in a intuitive way
- Describe formally several network visualization algorithms
- Identify the techniques behind the algorithms (greedy, iterative, dynamic programming, etc.)
- Analyze the time complexity of algorithms
- Proof correctness of the algorithms
- Solve new network visualization problems by selecting and adapting known approaches

Learning Objectives

Karlsruhe Institute of Technology

At the end of the semester you are able to:

Recall Level

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Karlsruhe Institute of Technology

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Analyze, Apply, Generalize Level

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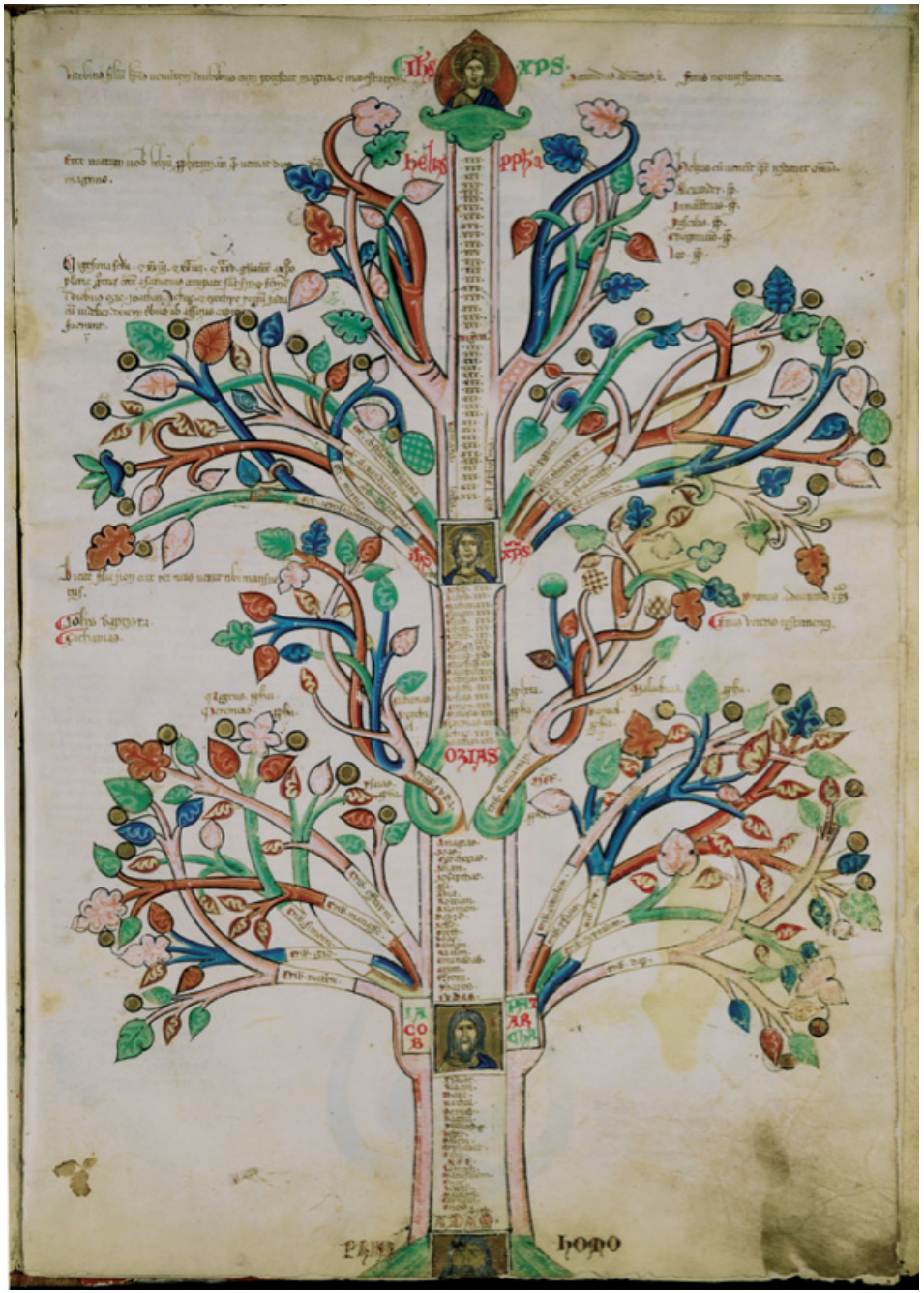
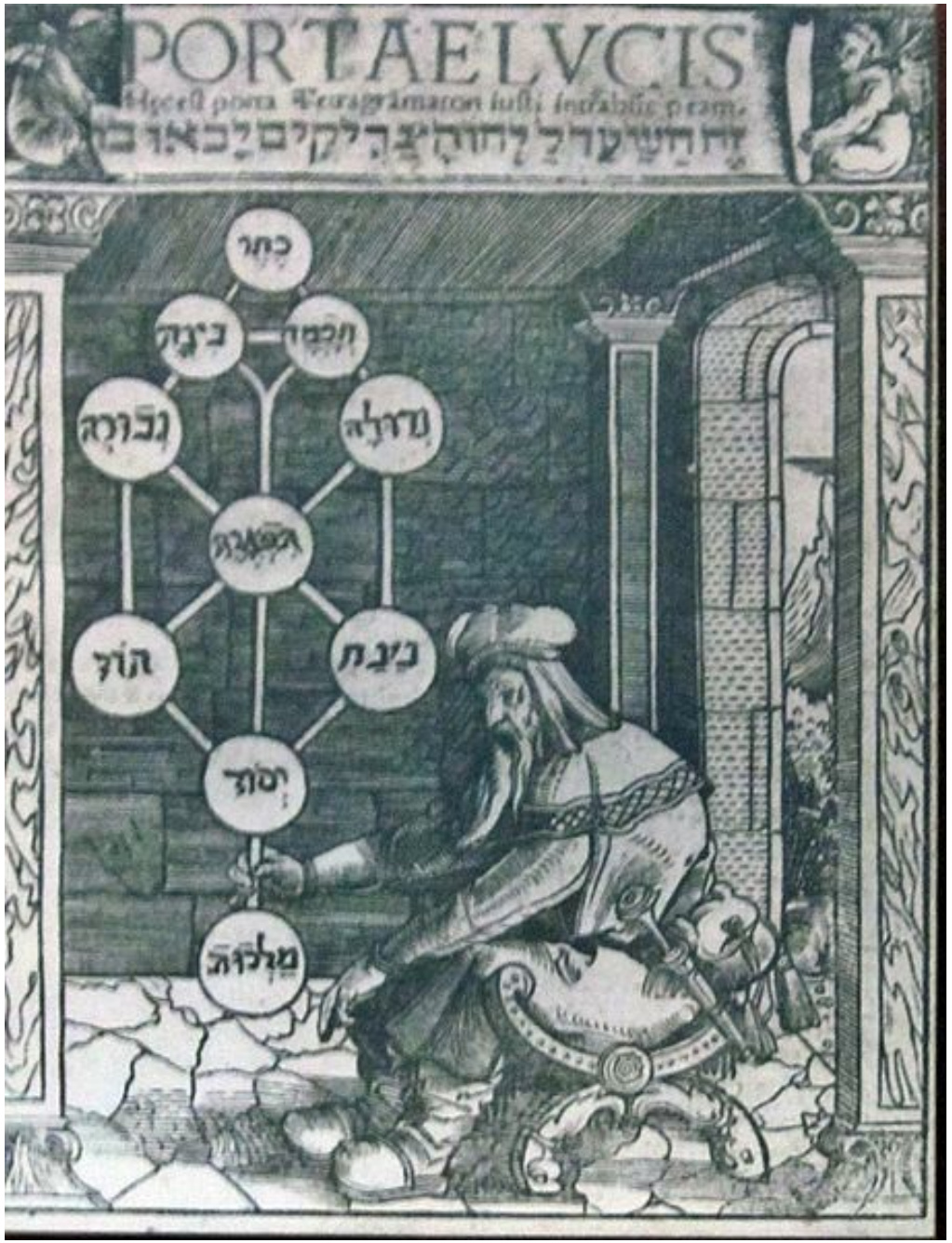
Biblical characters and events (1202)



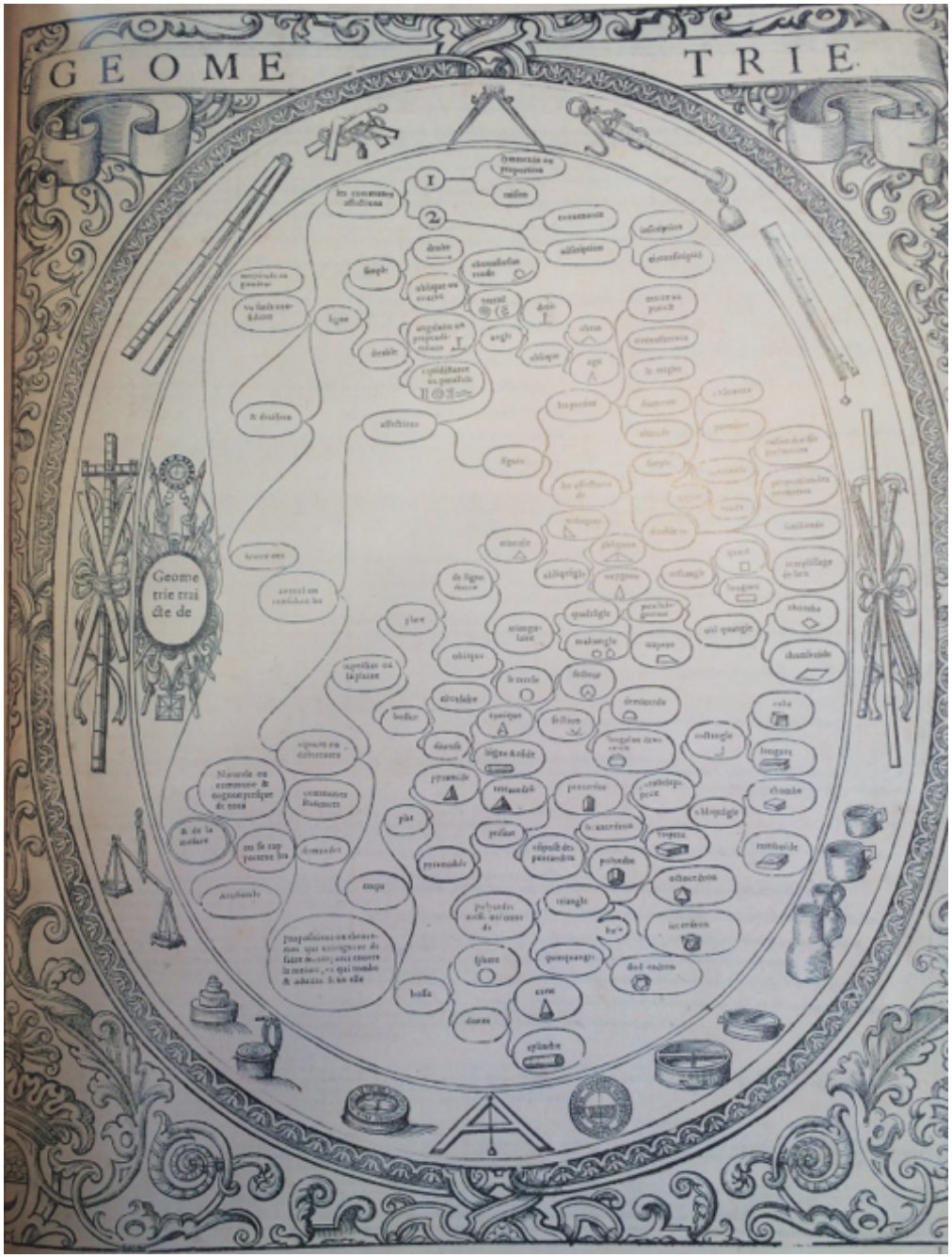
Source: Joachim de Fiore

"Tree of Life" (1516)



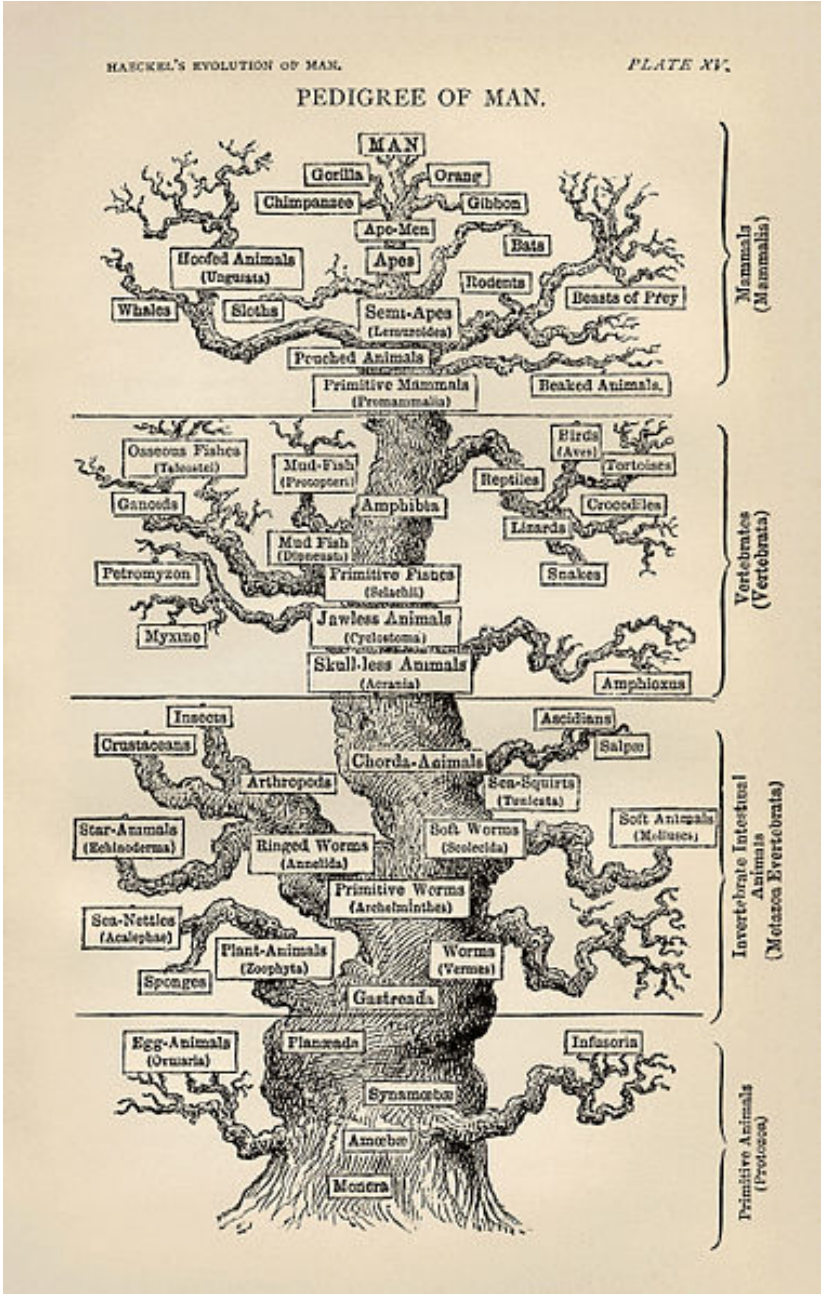
Source: Paul Riccius, Portae Lucis

Geometrical Concepts (1587)



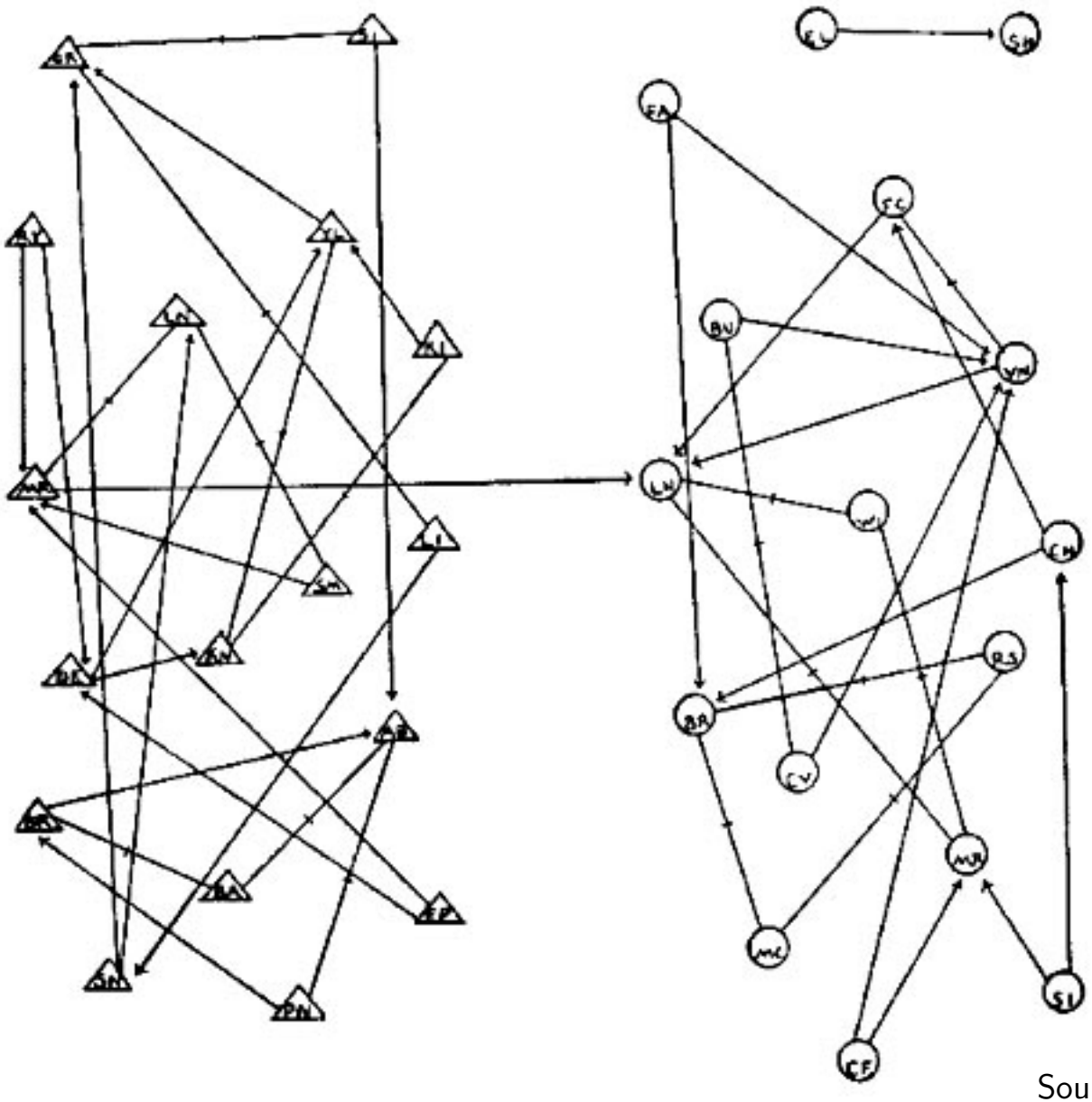
Source: Christophe de Savigny

Genealogical Tree (1879)



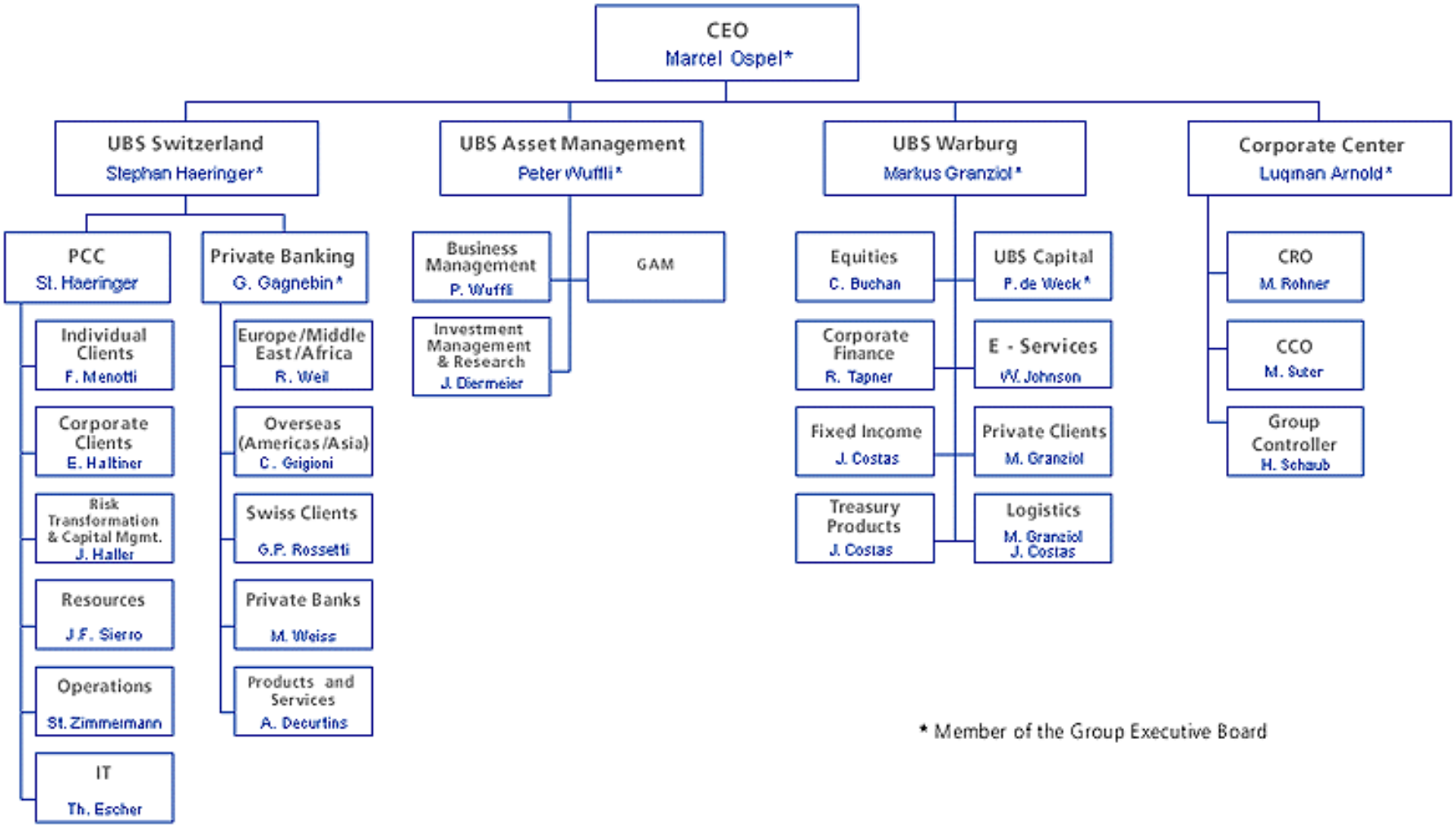
Source: Ernst Haeckel

Sociogramm (1933)



Source: Moreno, 1933

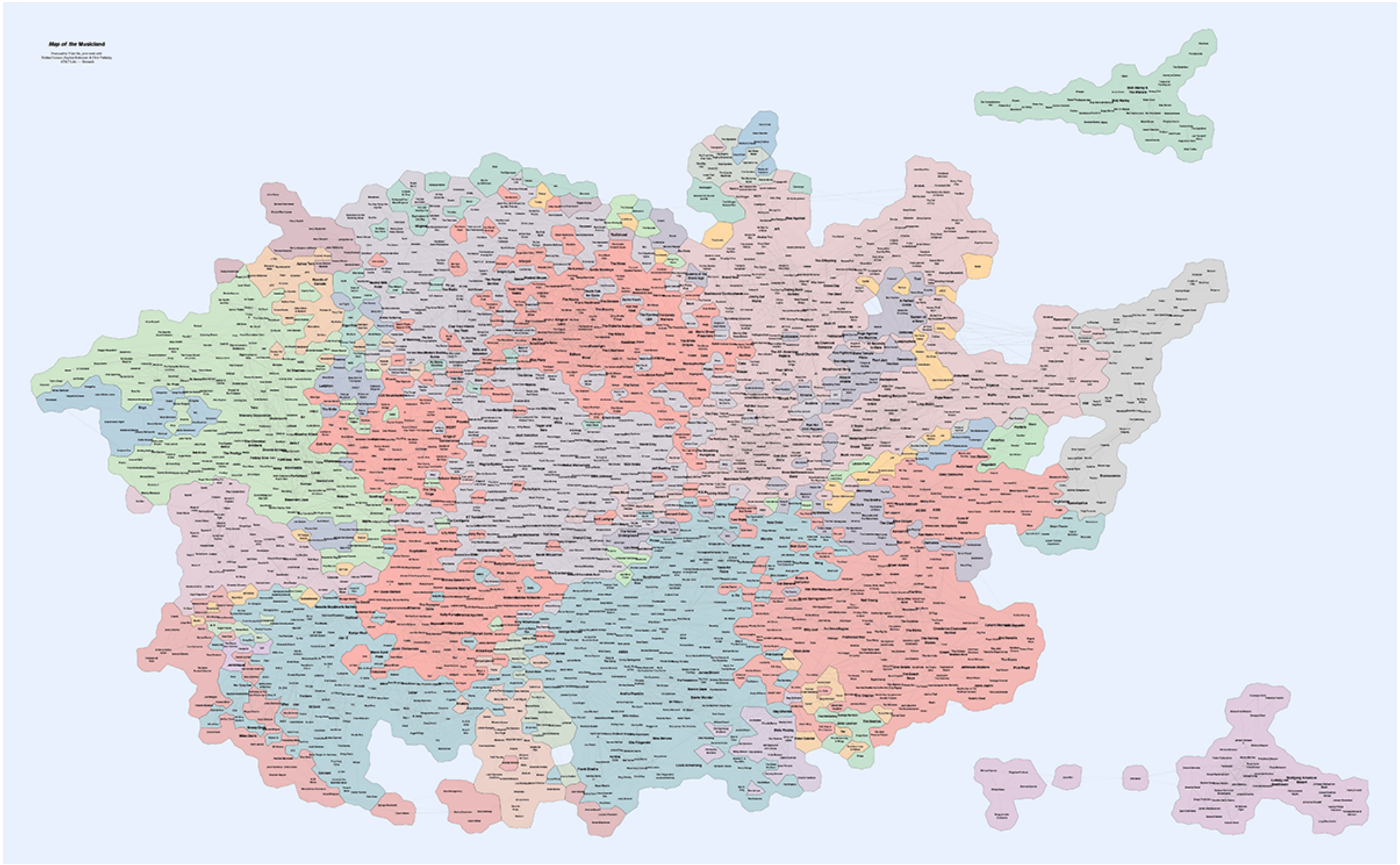
Social Network – Organization within UBS



CPAN Developer-Graph

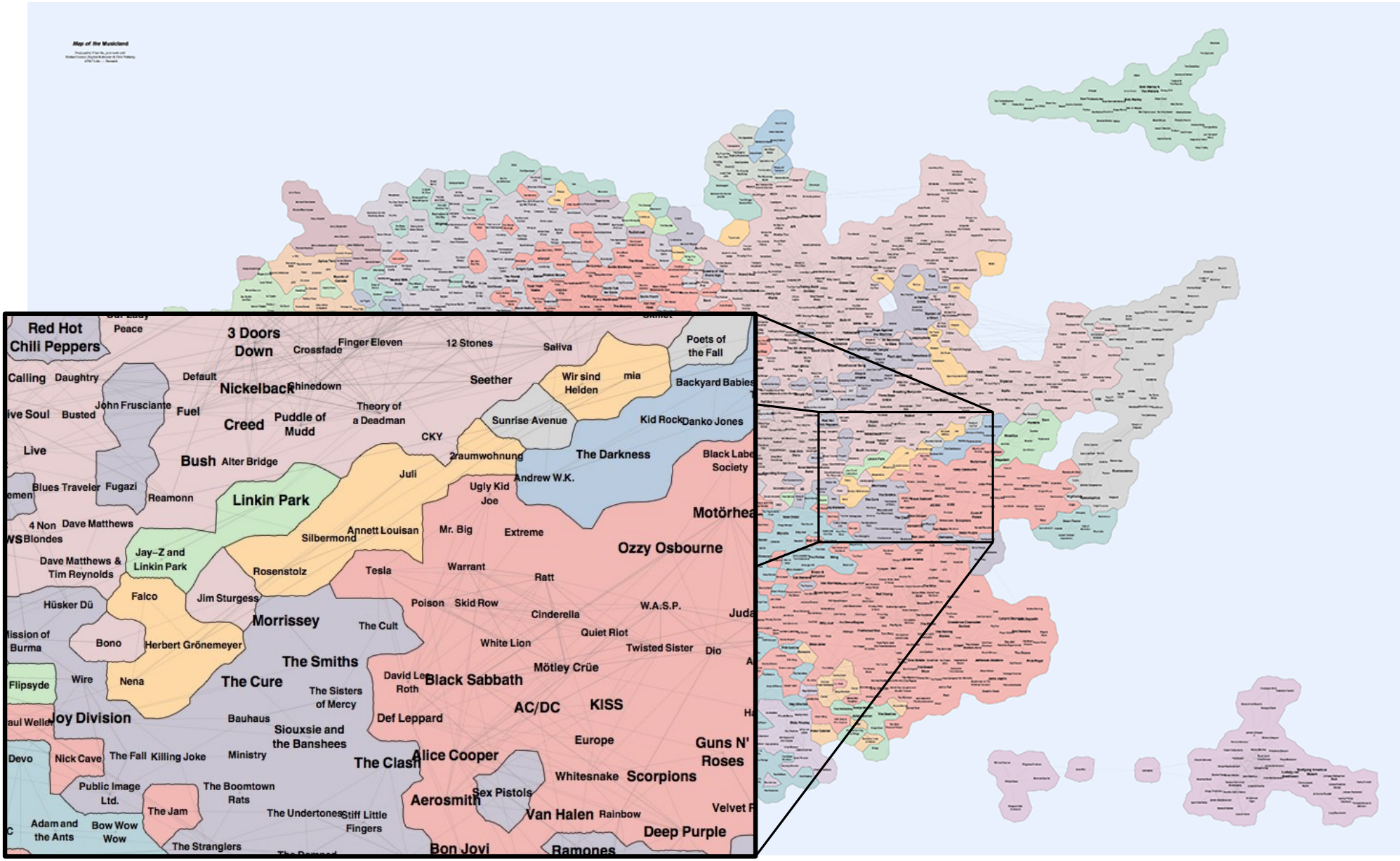
Source: cpan-explorer.org

last.fm Graph of musics as political map



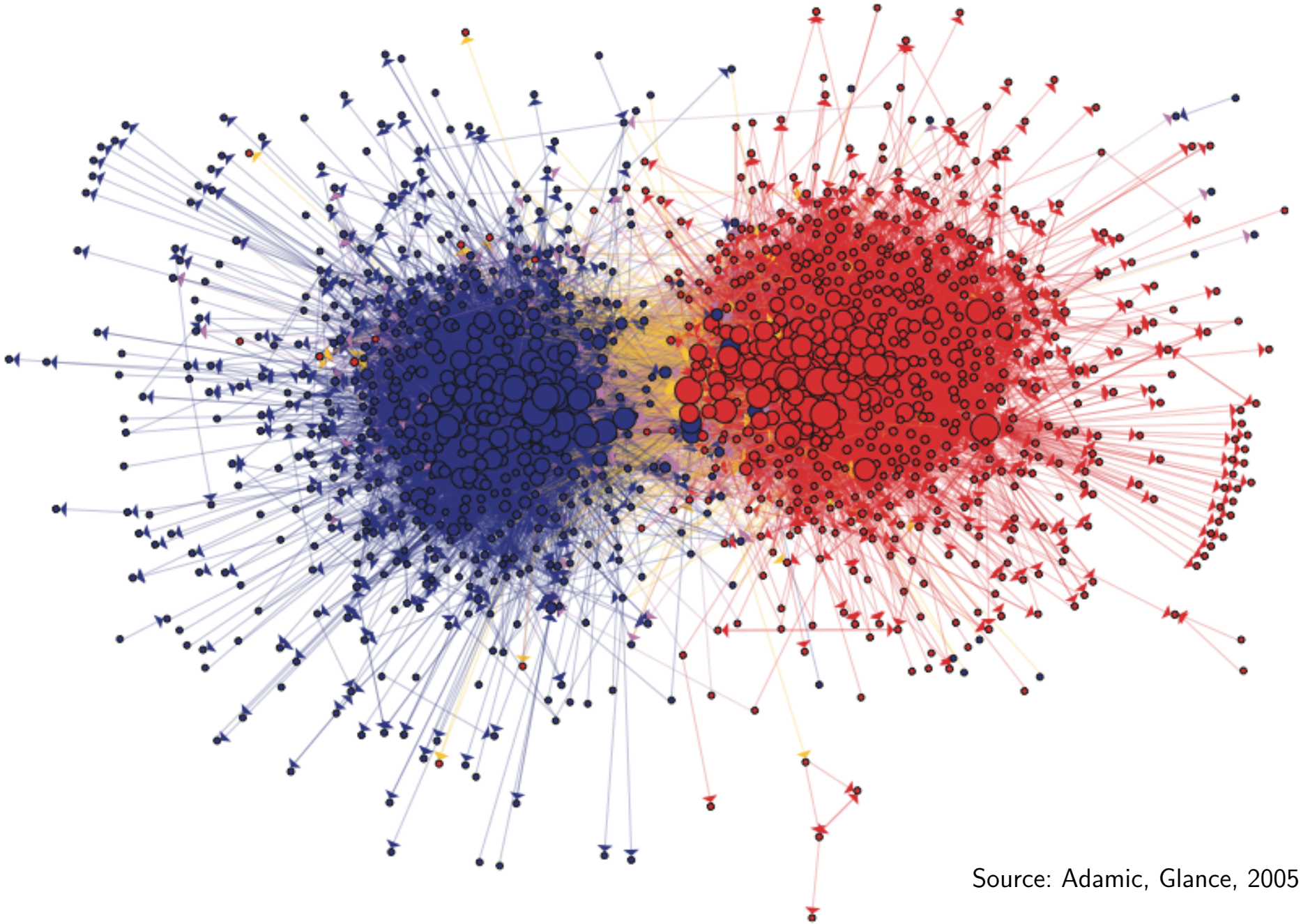
(Gansner, Hu, Kobourov: GMap, 2009)

last.fm Graph of musics as political map



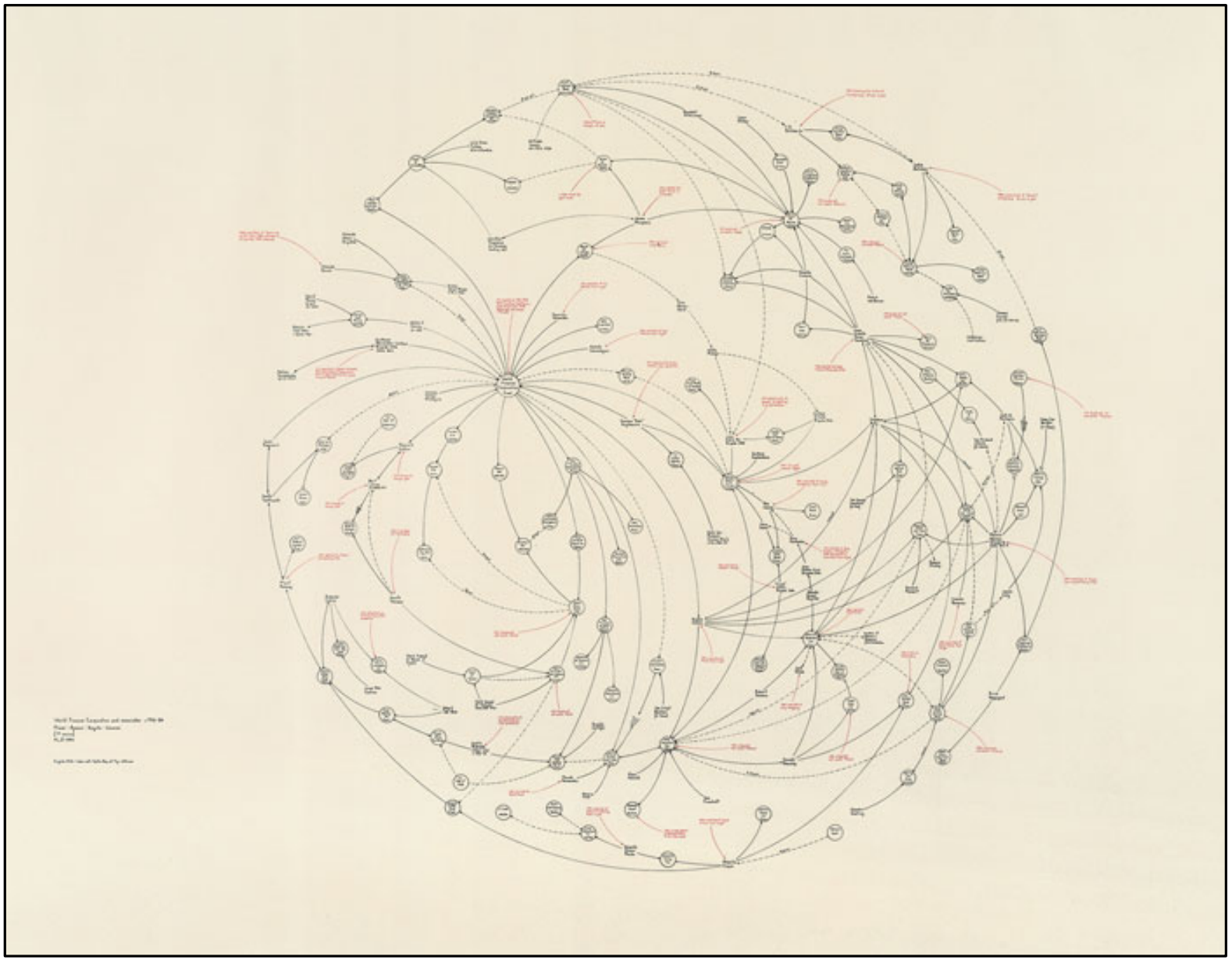
(Gansner, Hu, Kobourov: GMap, 2009)

Blogosphere 2004 Elections USA



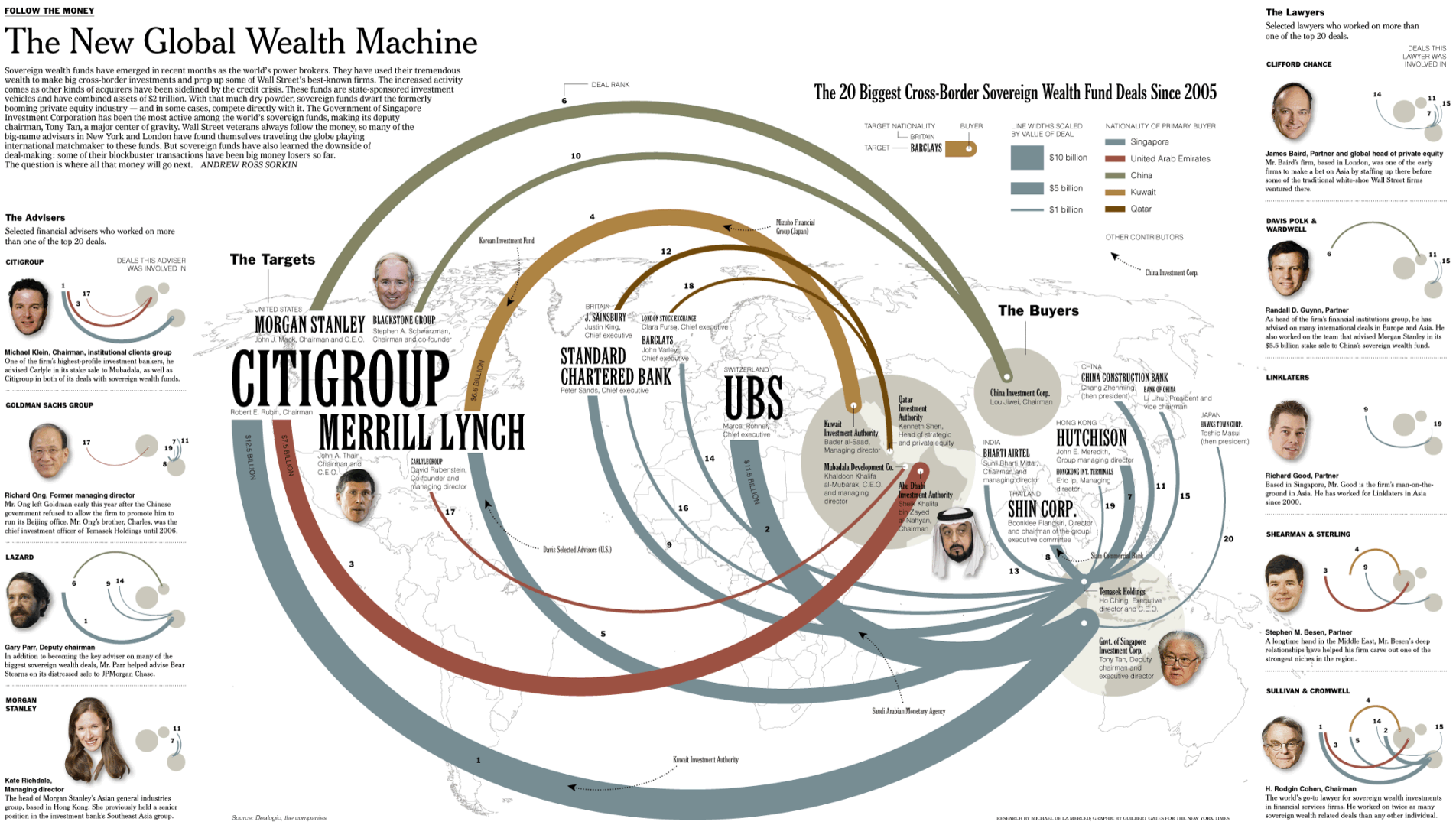
Source: Adamic, Glance, 2005

Social Network – World Finance System

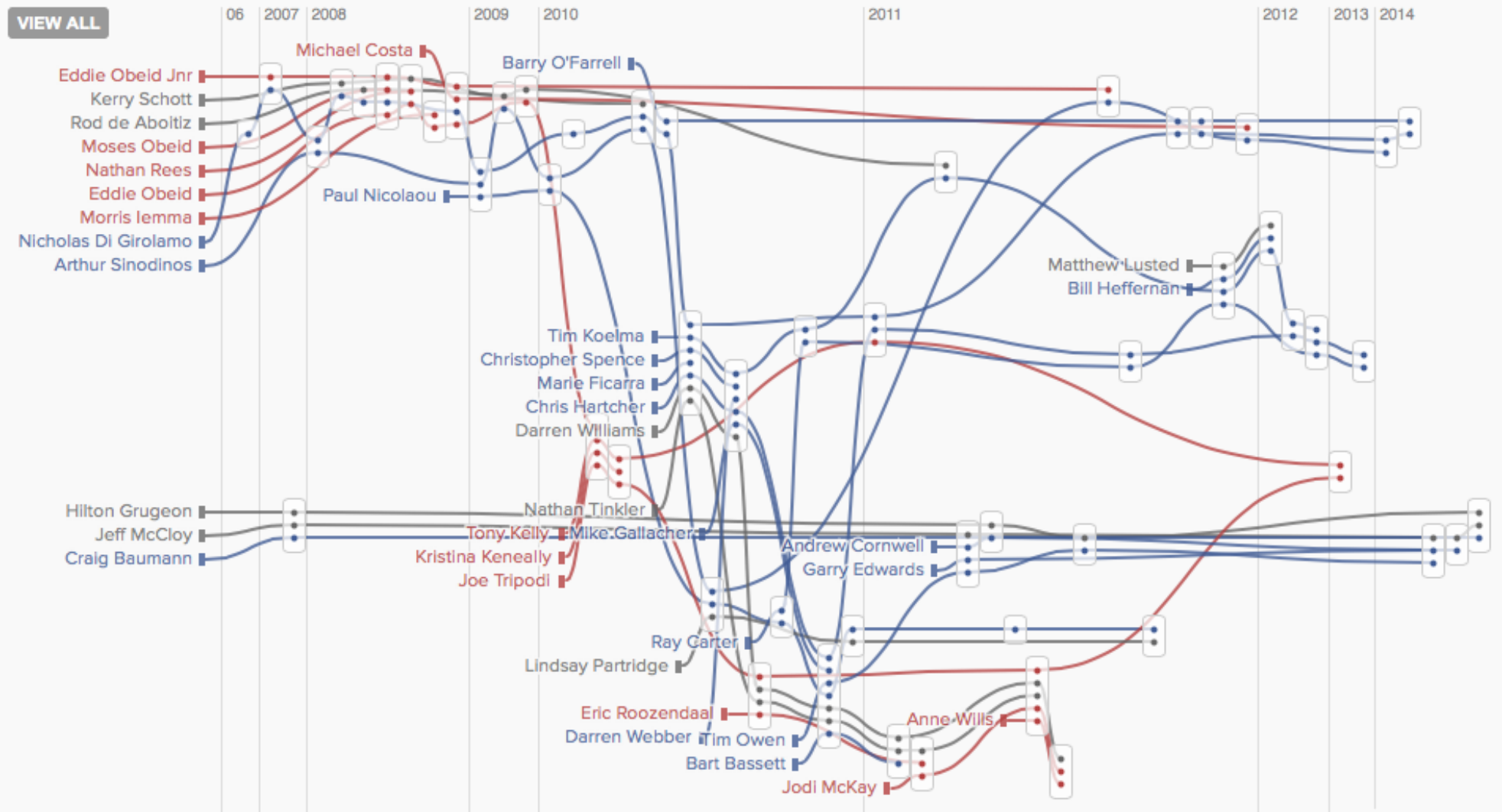


World Finance Corporation
© Mark Lombardi

Social Networks – State Funds

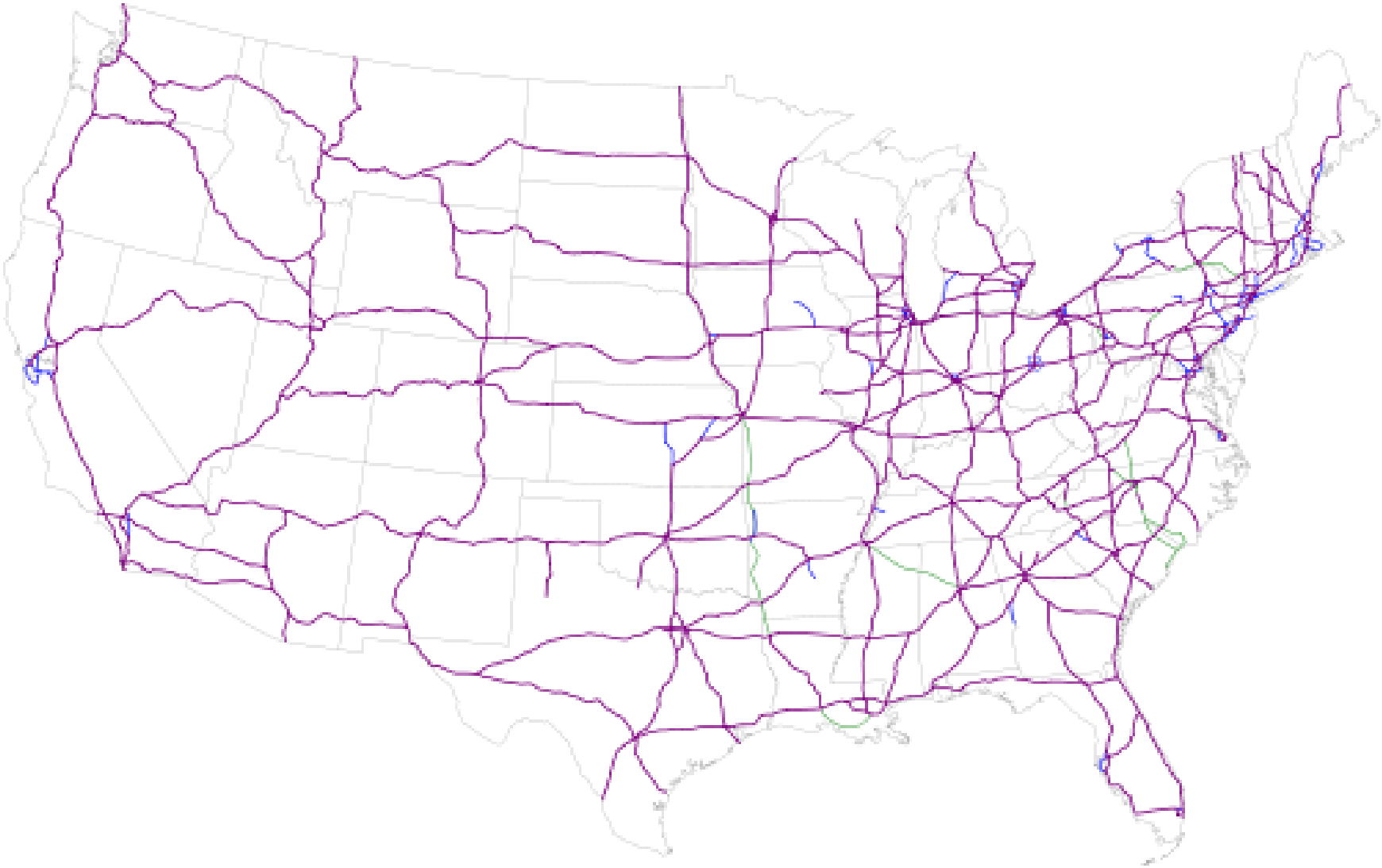


Temporal Graph Layout: Storylines

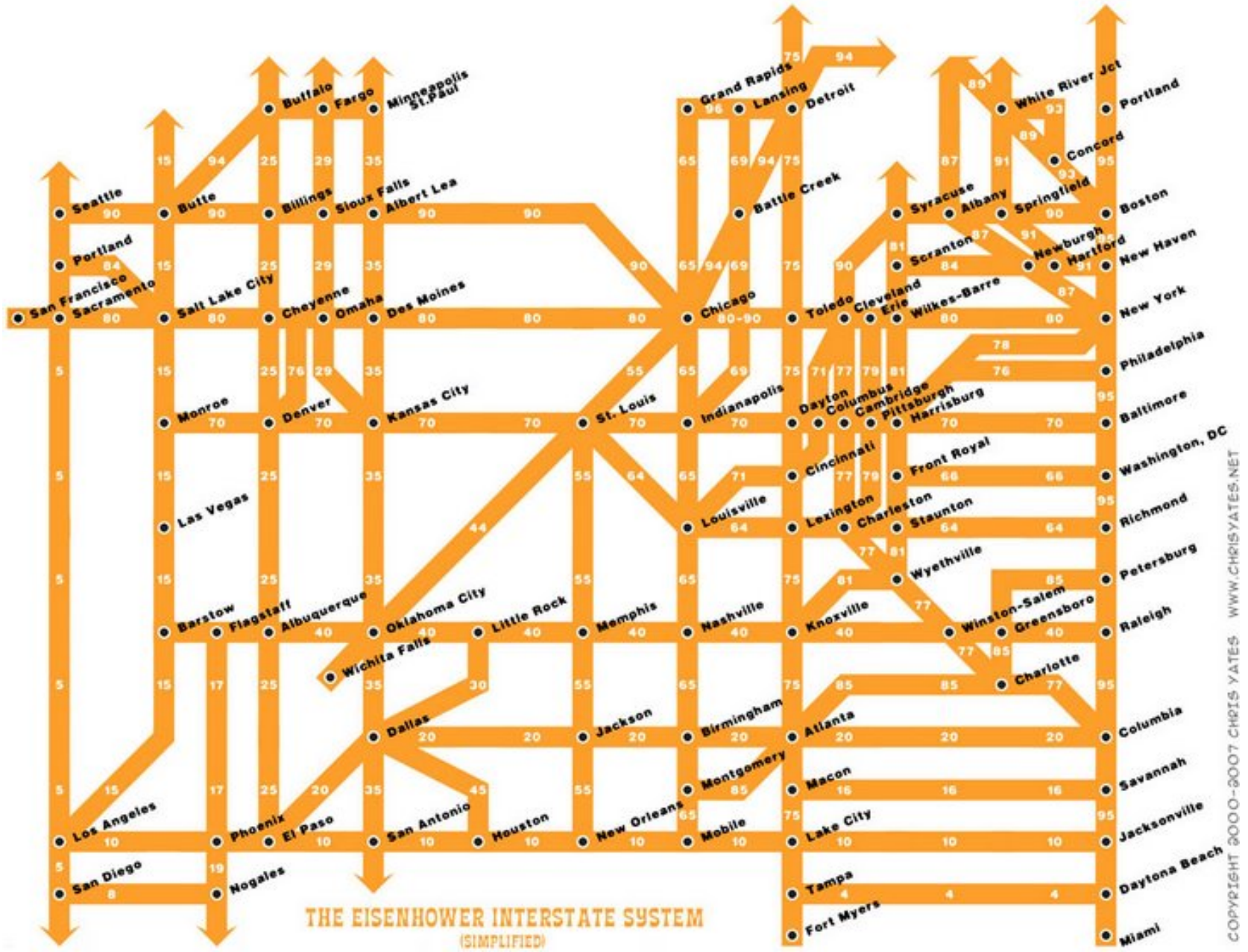


Source: ABC news, Australia

Traffic network – Highways USA



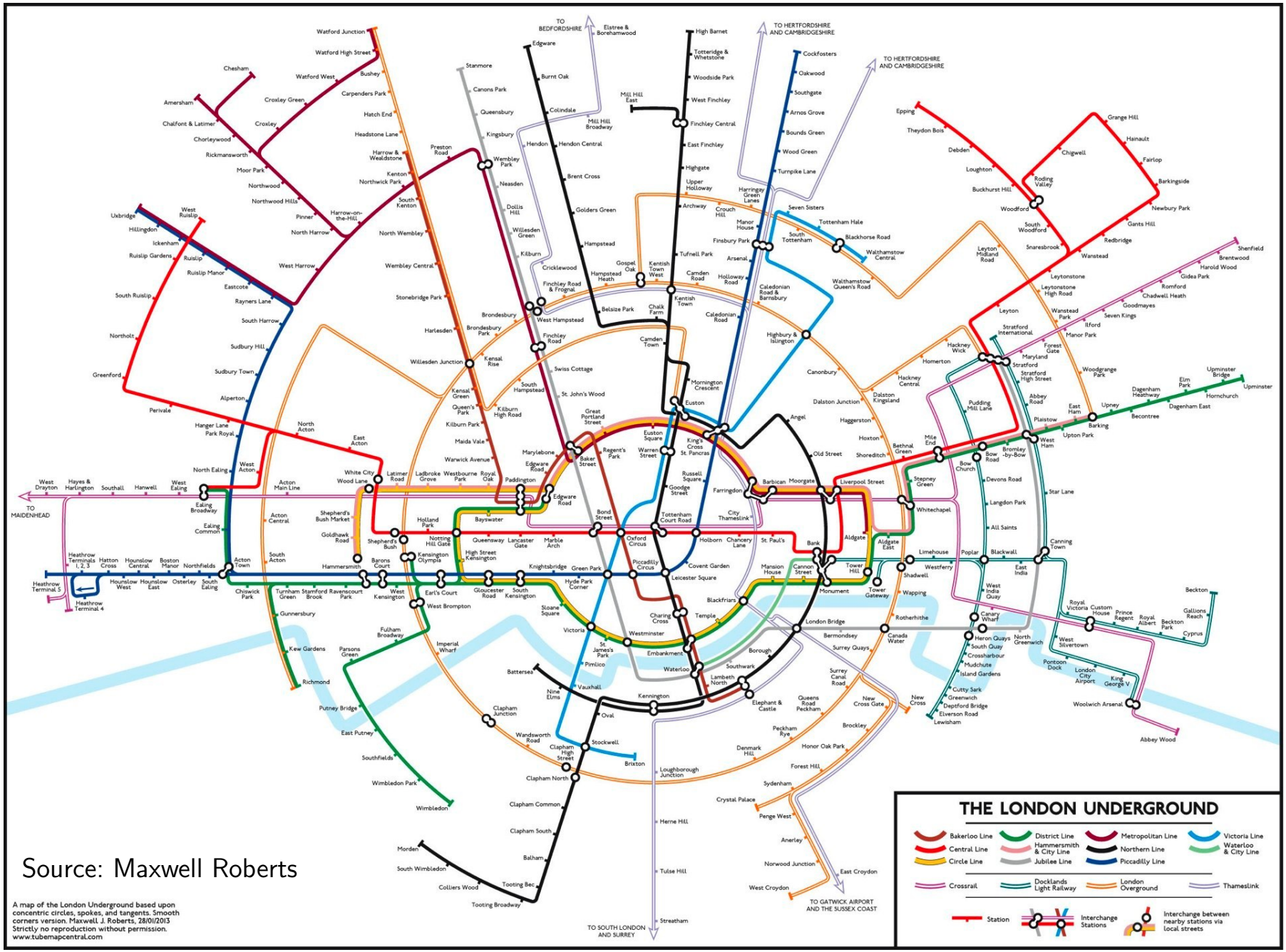
Traffic network – Highways USA



London Tube Map (1933)

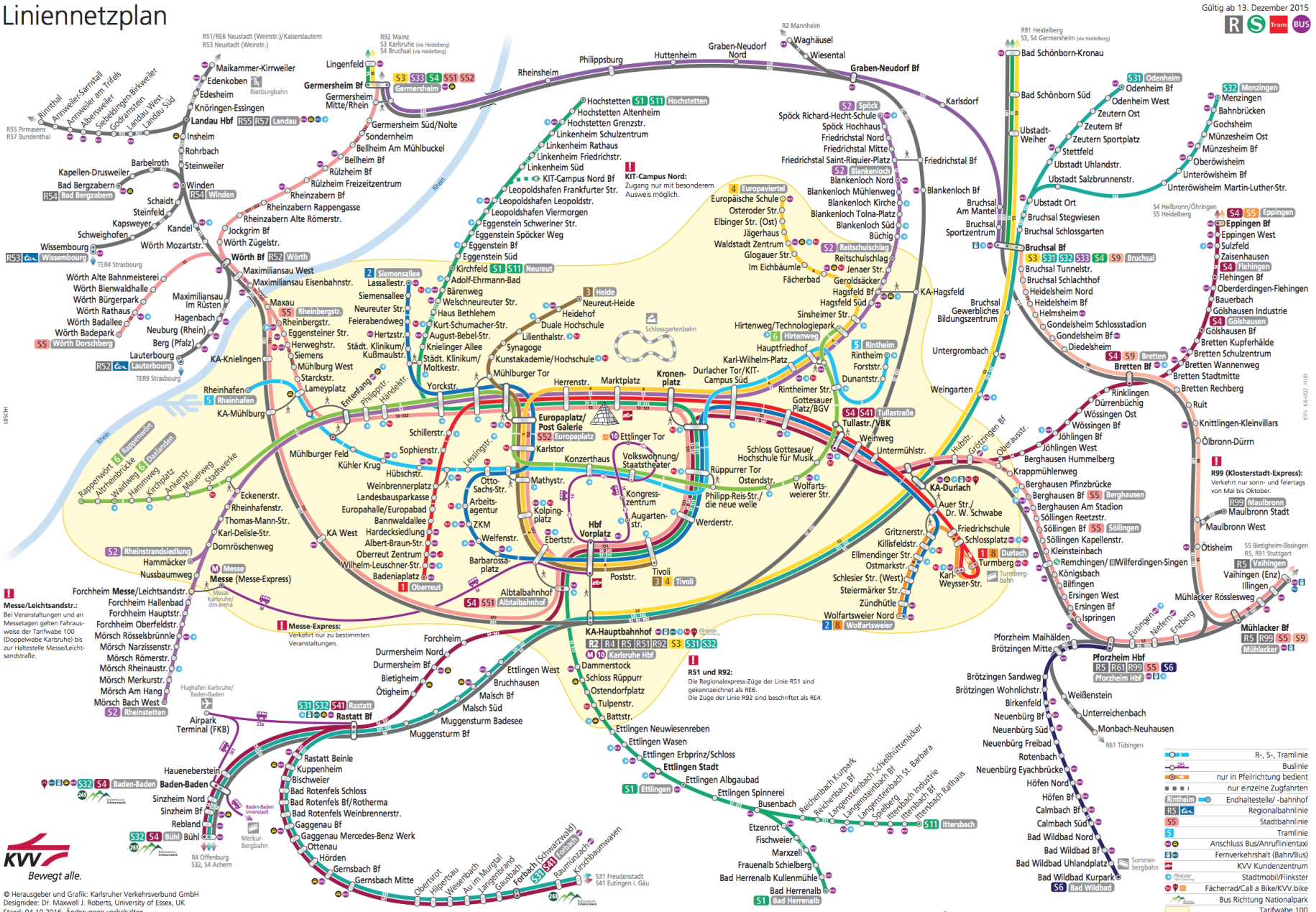
Source: Henry Beck

Co-centric Tube Map

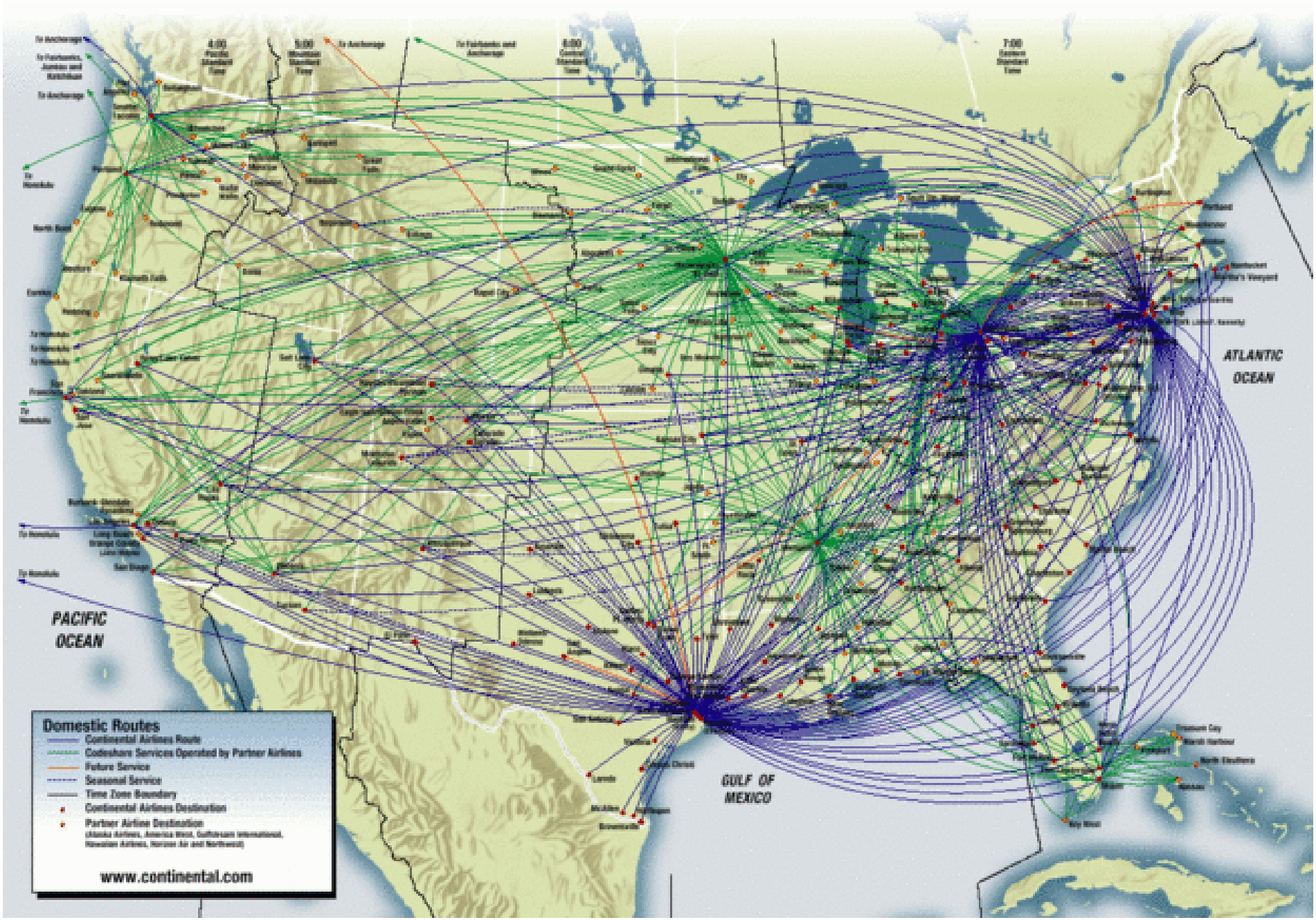


Source: Maxwell Roberts

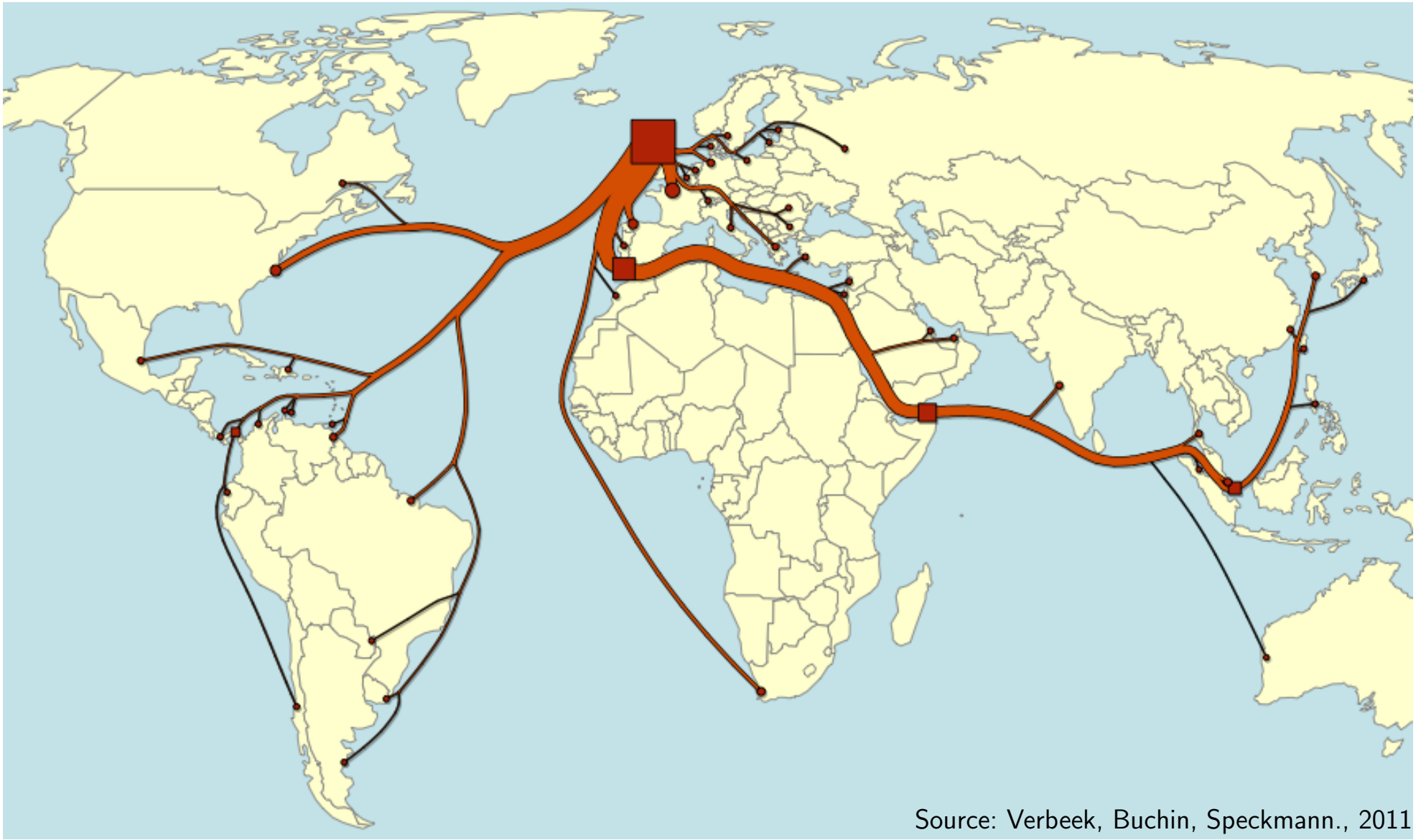
Curvilinear S/U-bahn map



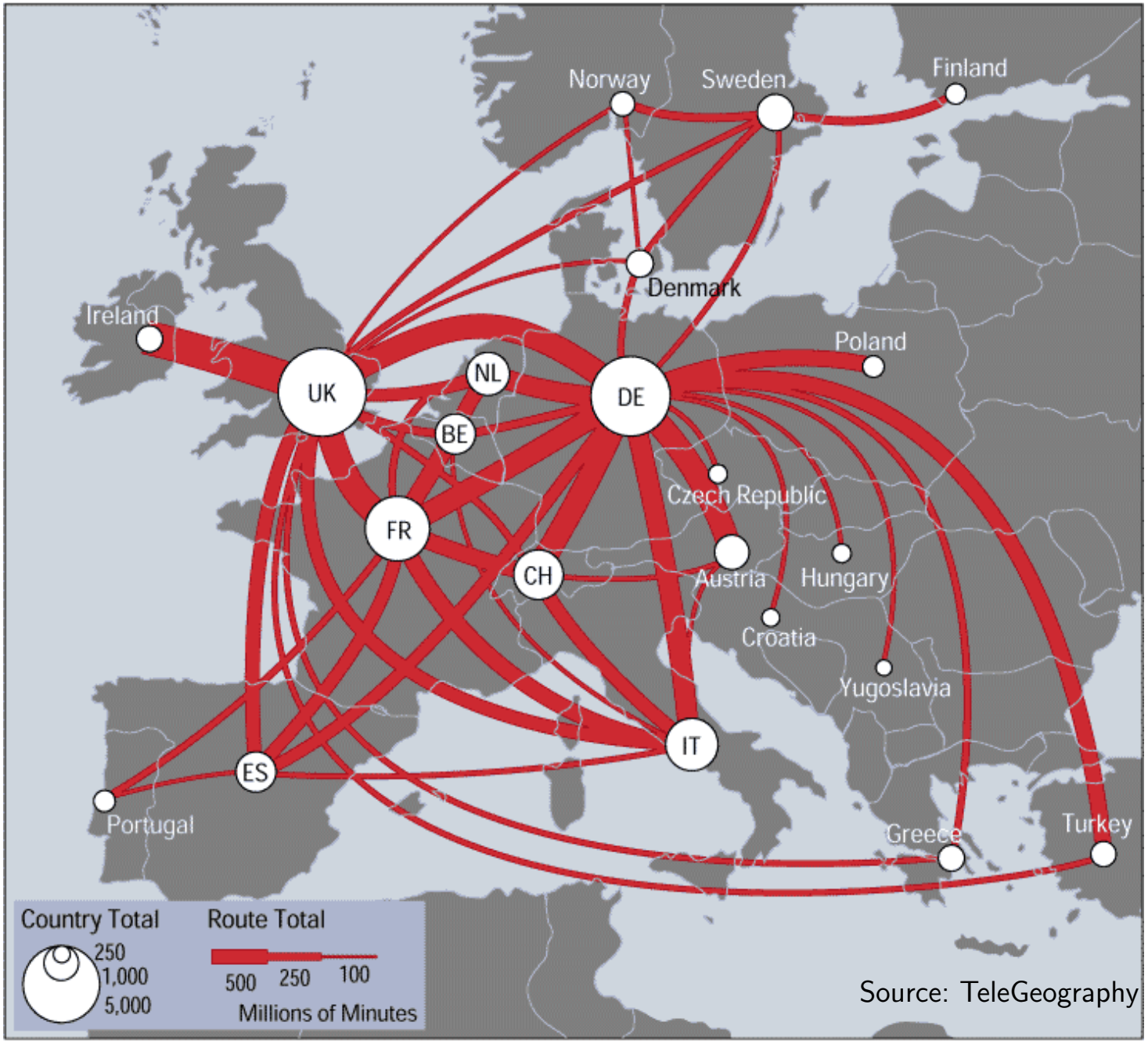
Flight Connections



Flow-Map: Whiskey Export



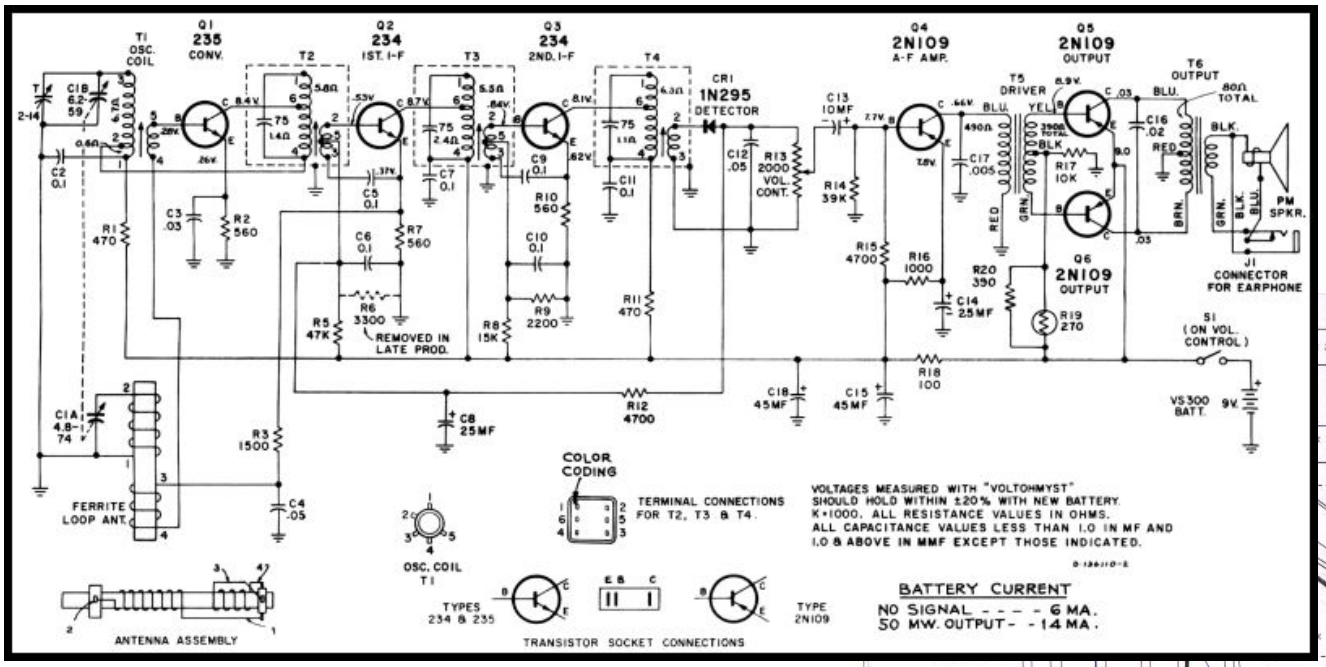
Telephony Map

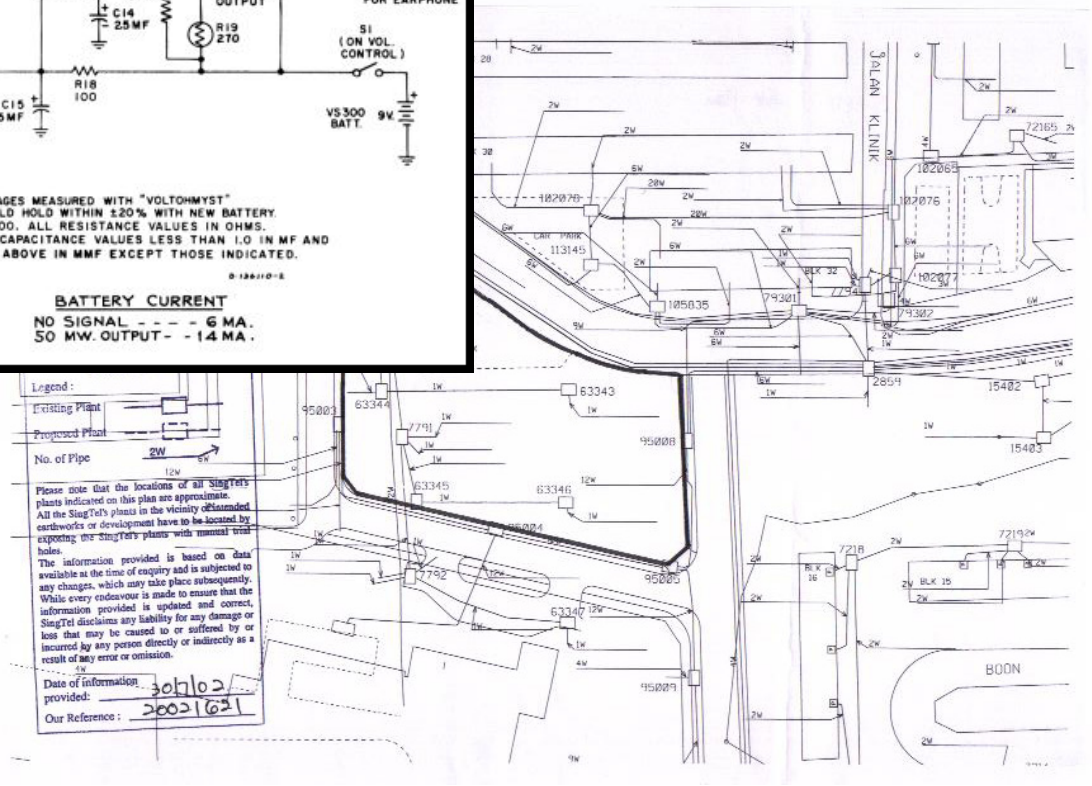


Monitoring of Energy Network

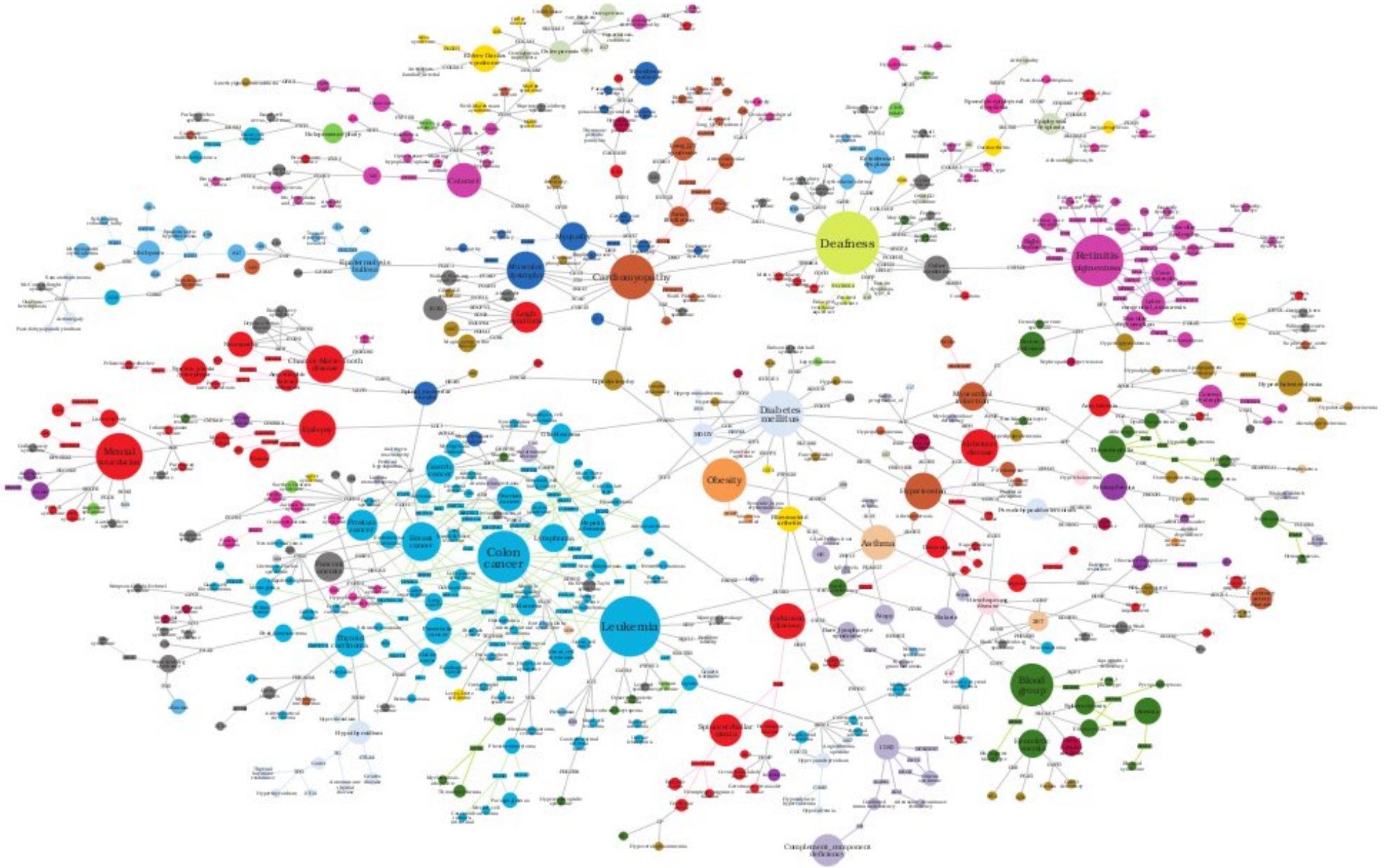
Source: Eir Grid, Irland

Wiring plan/ Cable plan

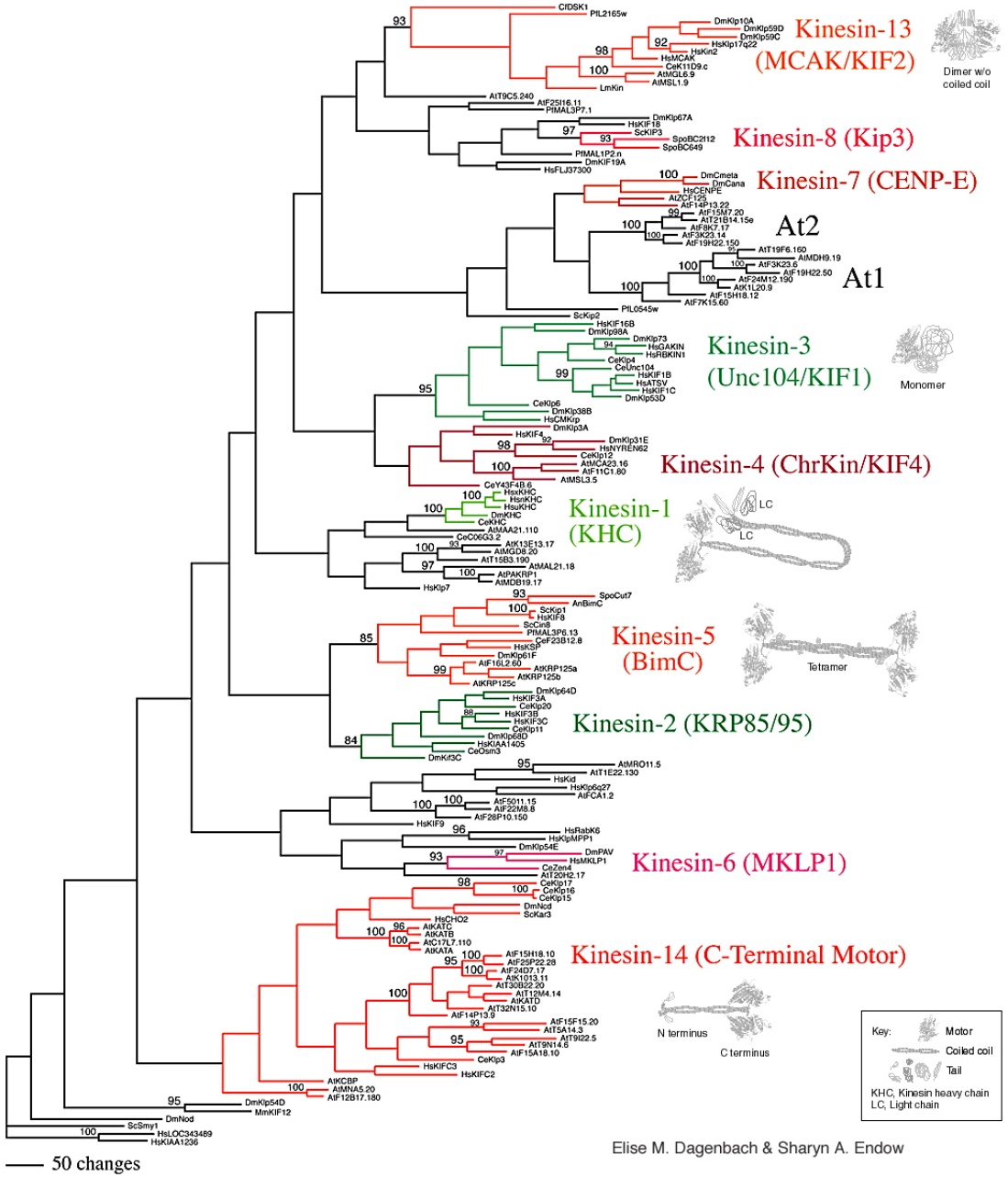




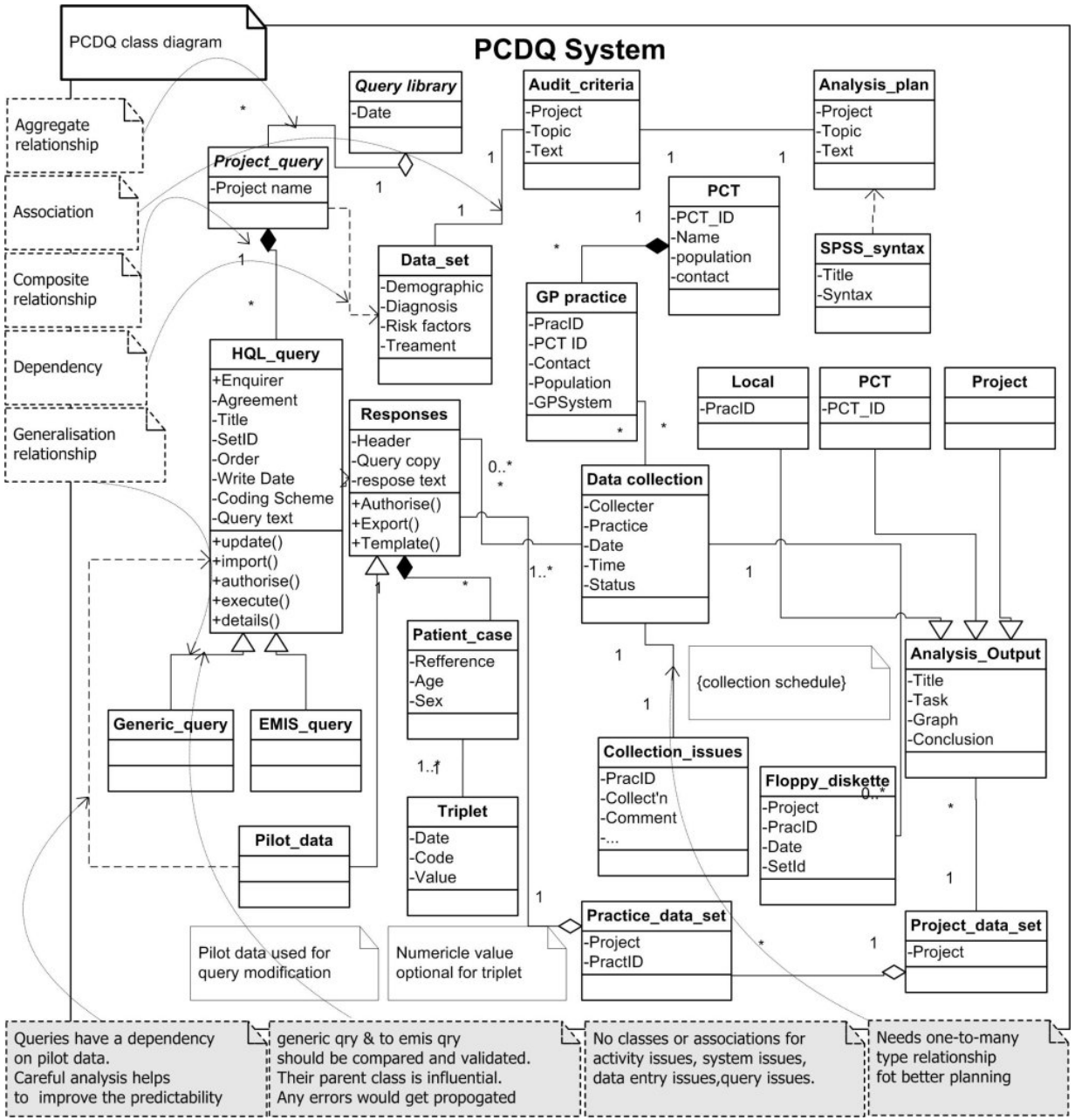
Medicine – Deseases



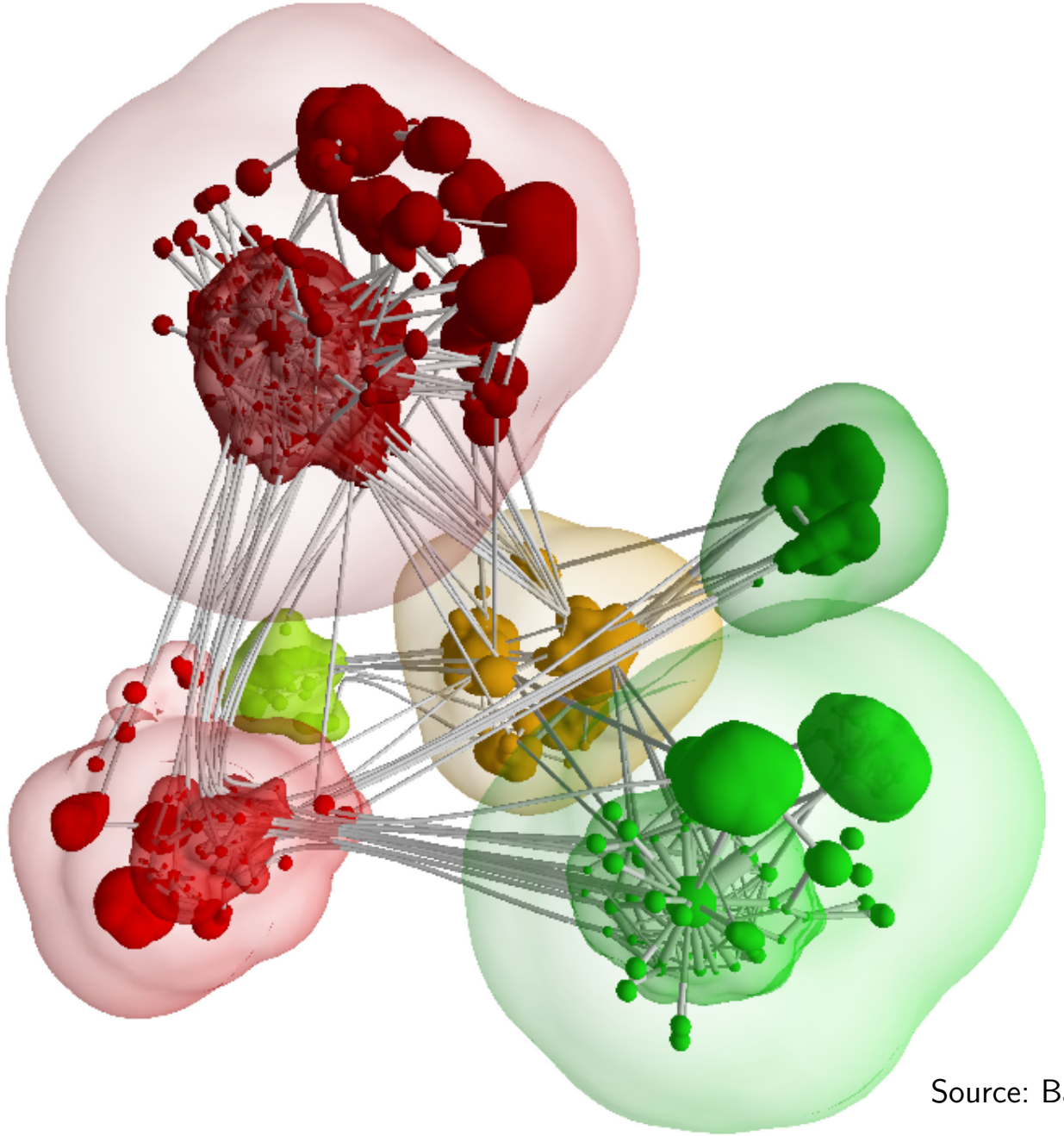
Medicine – phylogenetic Tree



Software-Network – UML Diagram



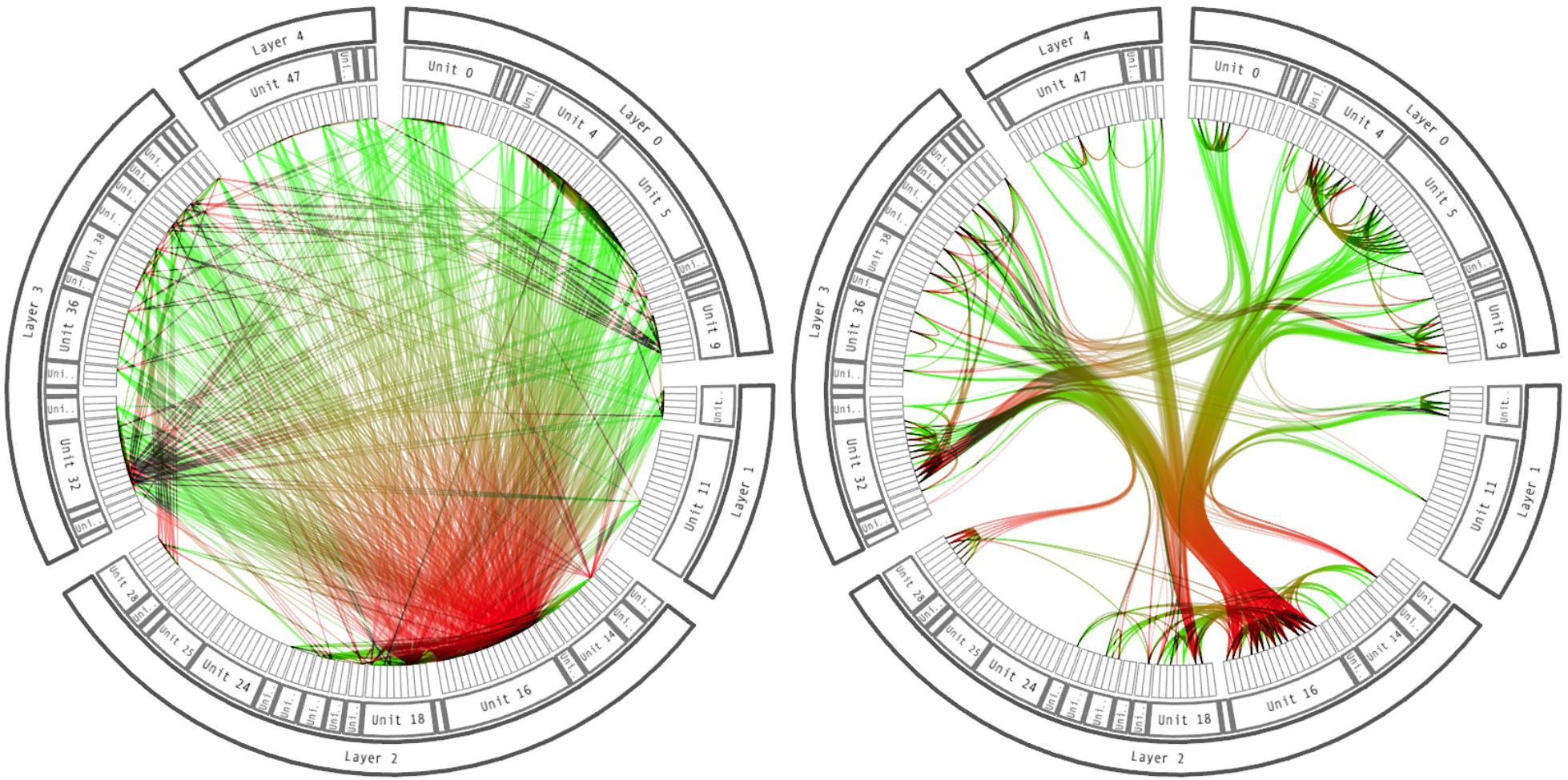
Clustered Software-Graph in 3D



Source: Balzer, Deussen, 2007

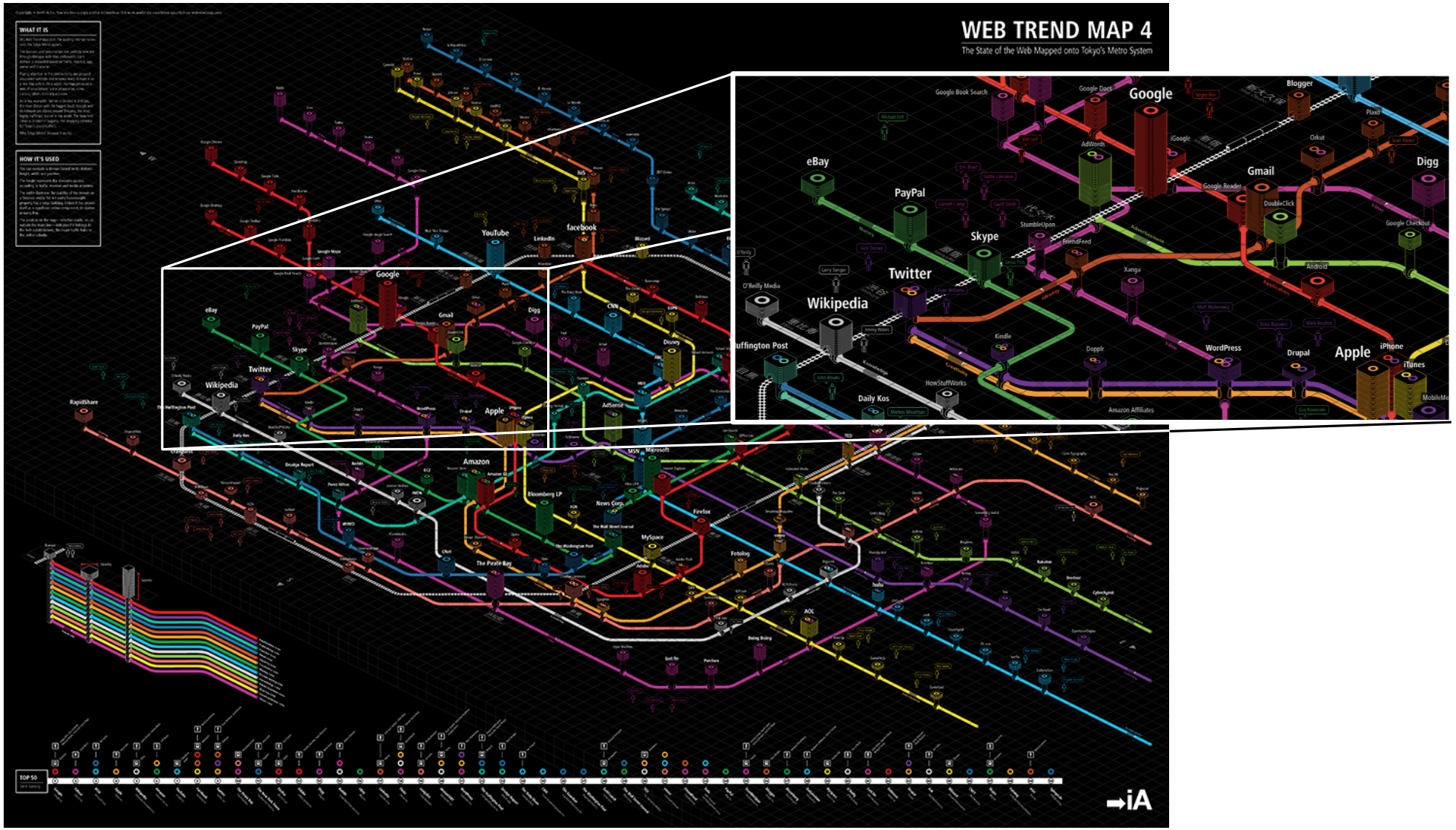
Software Call-Graph with edge-bundling

Karlsruhe Institute of Technology



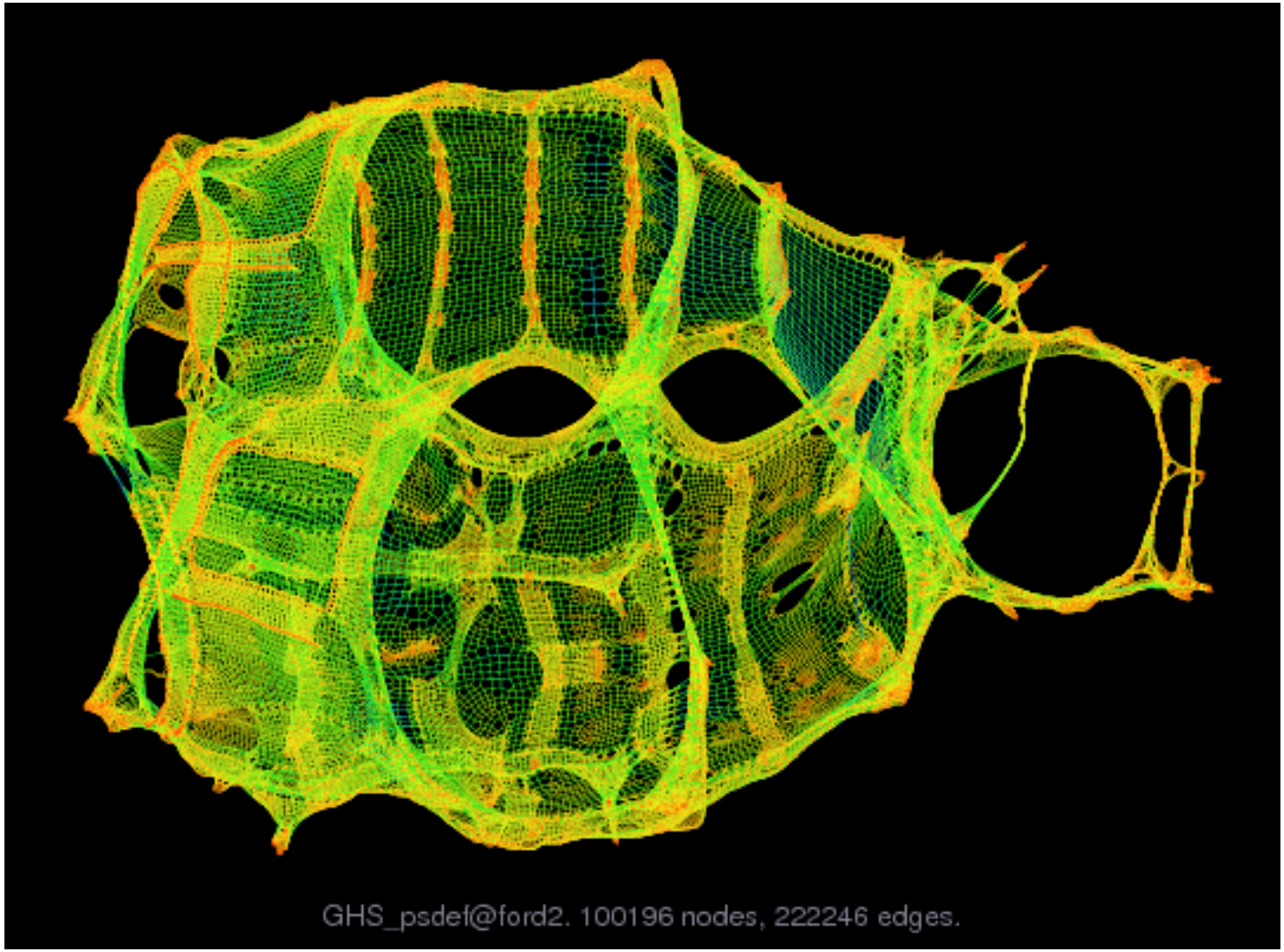
Source: Danny Holten, 2011

Web Trend Map



Source: information Architects, 2009

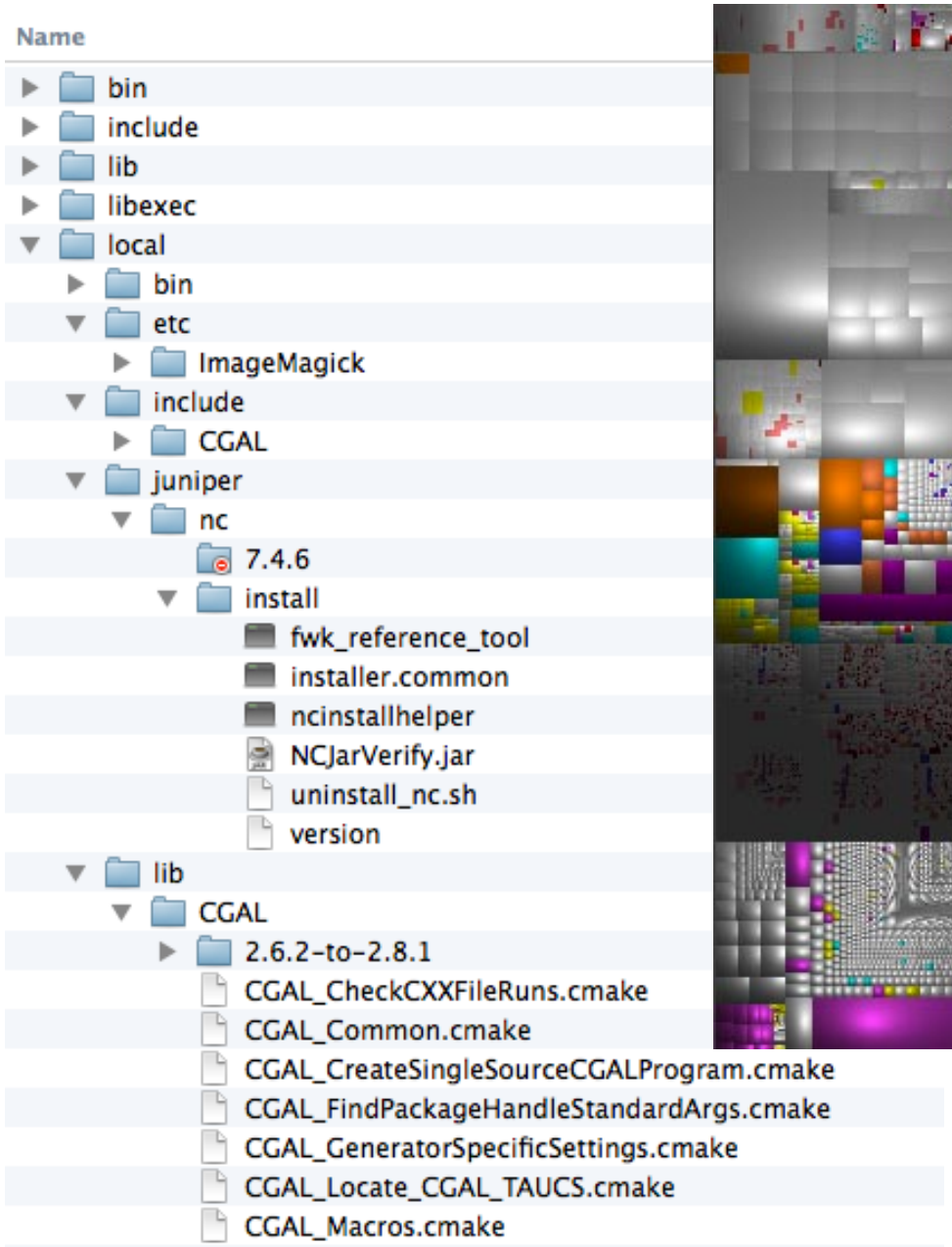
Large Graphs – Object Mesh

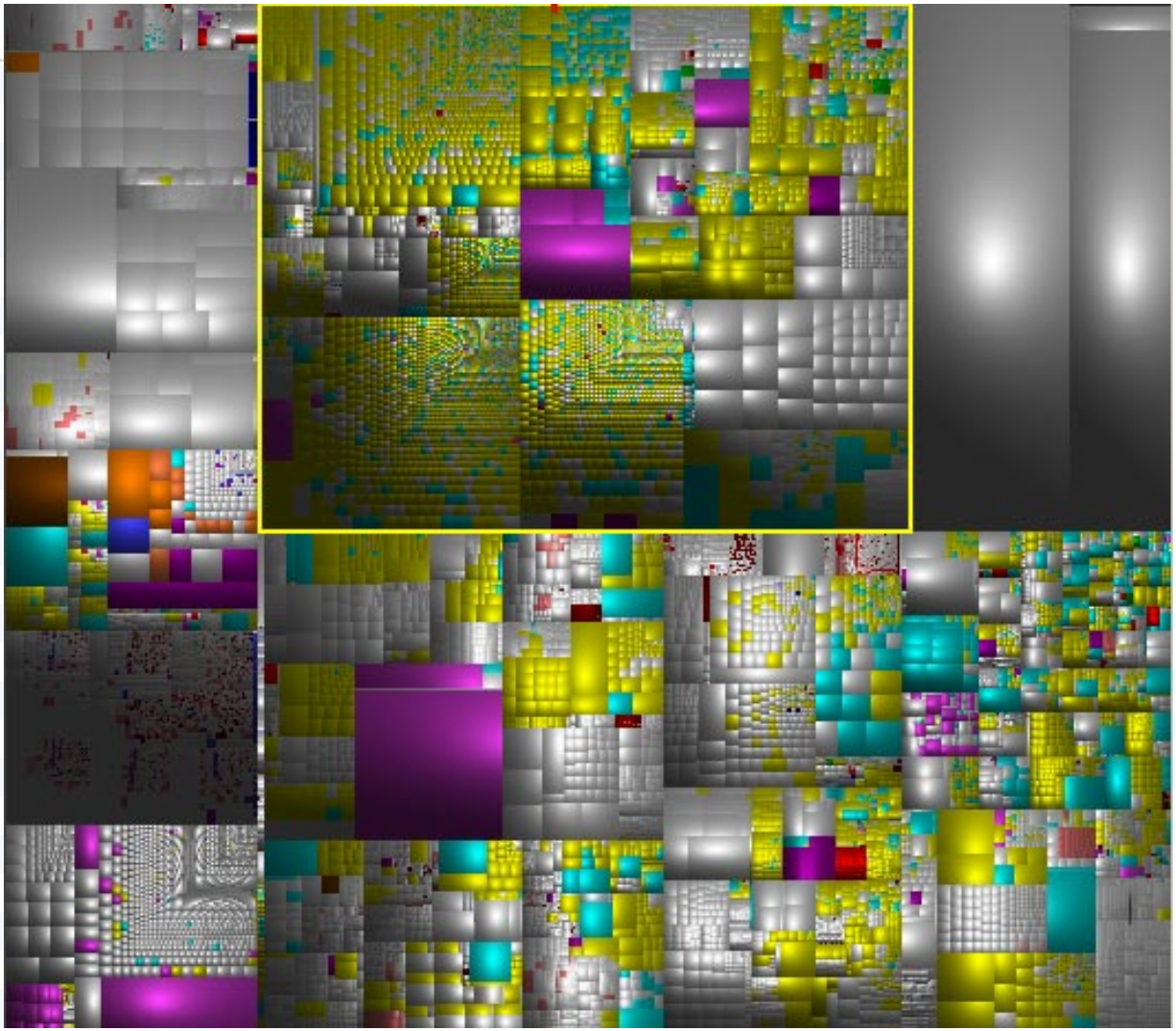


Source: Yifan Hu

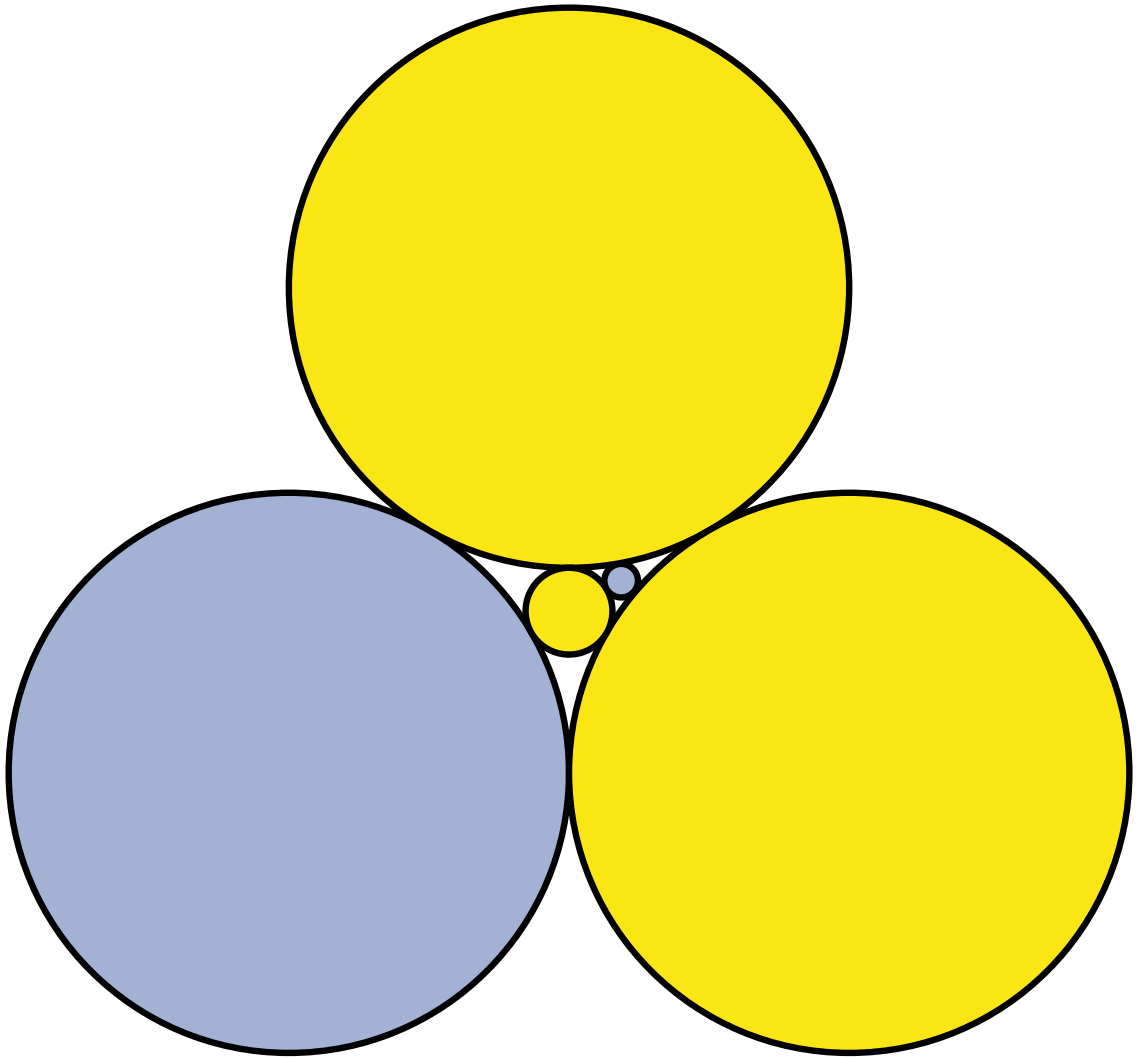
Alternative Visualizations: Explorer vs Treemap

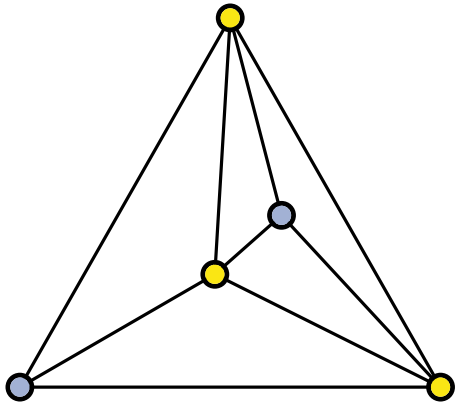
Karlsruhe Institute of Technology



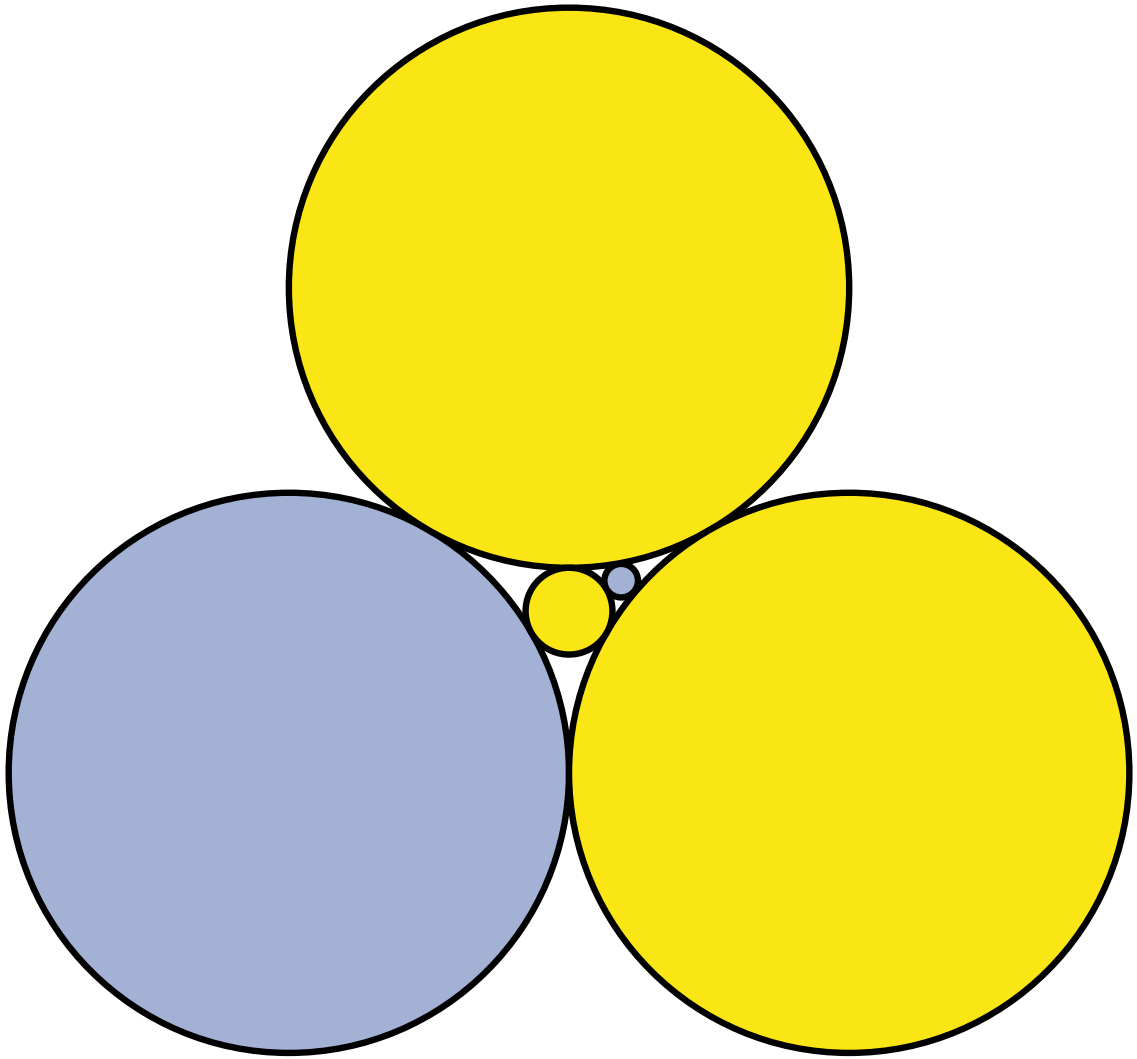


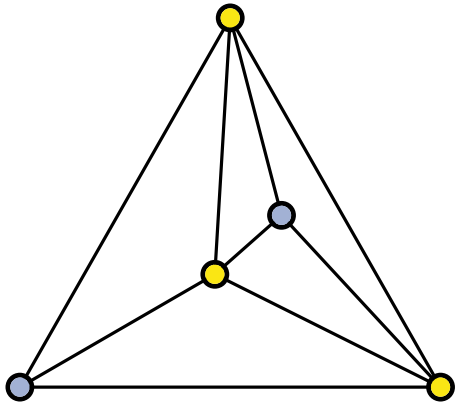
Alternative Visualizations: Contact map





Alternative Visualizations: Contact map





For more: `http://www.visualcomplexity.com/`

Tools

Libraries for graph visualization

- JUNG `jung.sourceforge.net` (Java)
- OGDF `www.ogdf.net` (C++)

Visualization tools

- visone `visone.info`
- graphviz `www.graphviz.org`
- yEd `www.yworks.com`
- Gephi `www.gephi.org`

Next Meeting

Lectures 16.10, 23.10 14:00
Exercise on 22.10 14:00

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Lectures 16.10, 23.10 14:00
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Topic Tree Layouts

Home task In which applications we need to construct a tree layout?