

Algorithms for Graph Visualization

Introduction

INSTITUT FÜR THEORETISCHE INFORMATIK · FAKULTÄT FÜR INFORMATIK

Tamara Mchedlidze, Marcel Radermacher
19.10.2017



Lectures



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

Exercises



- Marcel Radermacher
- `radermacher@kit.edu`
- Office 306
- Office hours: request by email

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

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Mailing list

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

Website

`i11www.itl.kit.edu/teaching/winter2016/graphvis/`

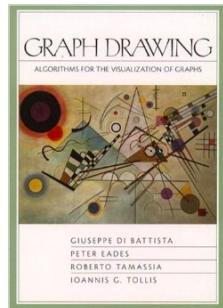
- Latest news
- Lecture slides
- Exercise sheets
- Literature & Additional material
- Lecture notes (skript)

About this Course

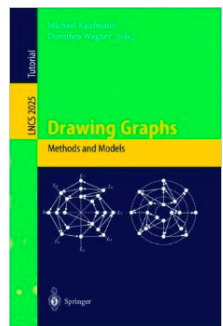
Media:

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

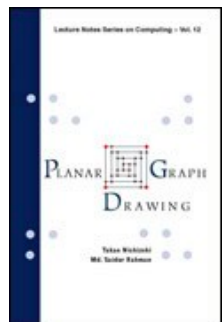
Books (available in the library)



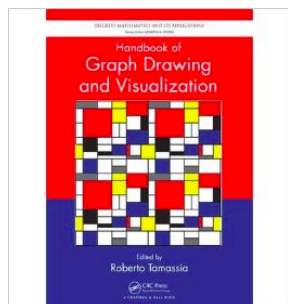
G. di Battista, P. Eades, R. Tamassia, I. Tollis:
Graph Drawing
Prentice Hall, 1998



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

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Master Informatics

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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

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Examination procedure:

- In order to take an exam you need to participate actively in the exercise sessions
(e.g. present your own solutions on the board)
- Submit a visualization for the practical task
- Oral exam(app. 20 Minutes)

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Formal definition of Layout Problem.

About this course: learning objectives.

Applications gallery.

Graph and its Representation

What is a Graph?

Graph and its Representation

What is a Graph?

Tuple $G = (V, E)$

Set of nodes $V = \{v_1, \dots, v_n\}$

Set of edges $E = \{e_1, \dots, e_m\}$,

$e_i = \{v_j, v_k\}$, $1 \leq i \leq m$, $1 \leq j, k \leq n$

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Representations?

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Representations?

Set representation:

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

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Representations?

Set representation

Adjacency list

```
v1 : v2, v8
v2 : v1, v3
v3 : v2, v5, v9, v10
v4 : v5, v6, v9
v5 : v3, v4, v8
v6 : v4, v8, v9
v7 : v8, v9
v8 : v1, v5, v6, v7, v9, v10
v9 : v3, v4, v6, v7, v8, v10
v10 : v3, v8, v9
```

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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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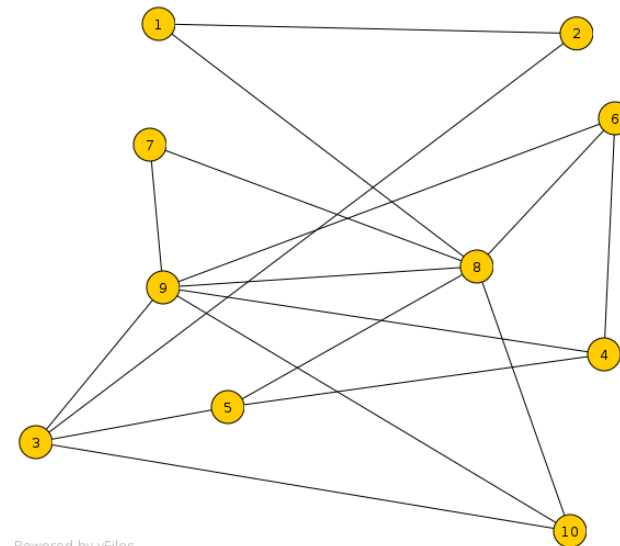
Representations?

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Drawing or Node-link diagram



Graph and its Representation

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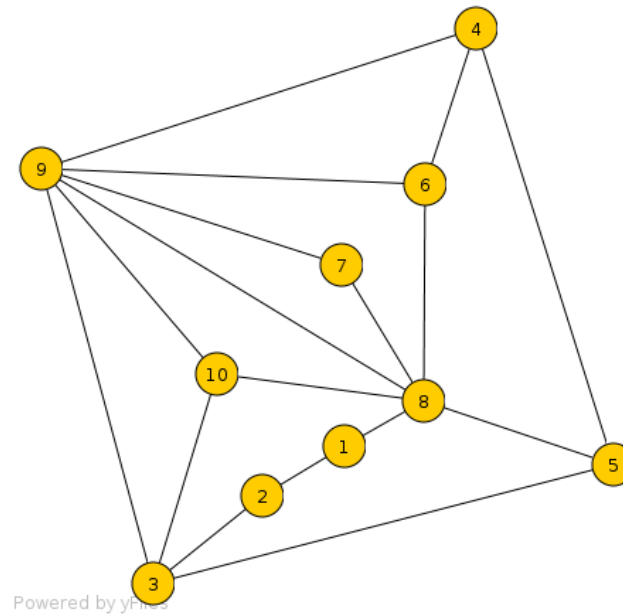
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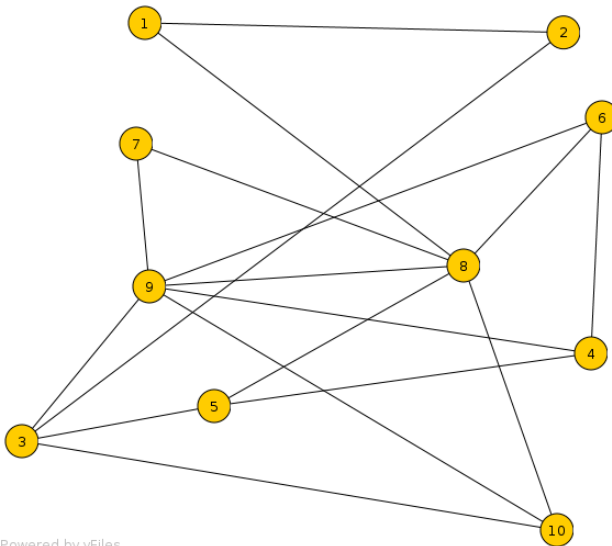


Graph and its Representation

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

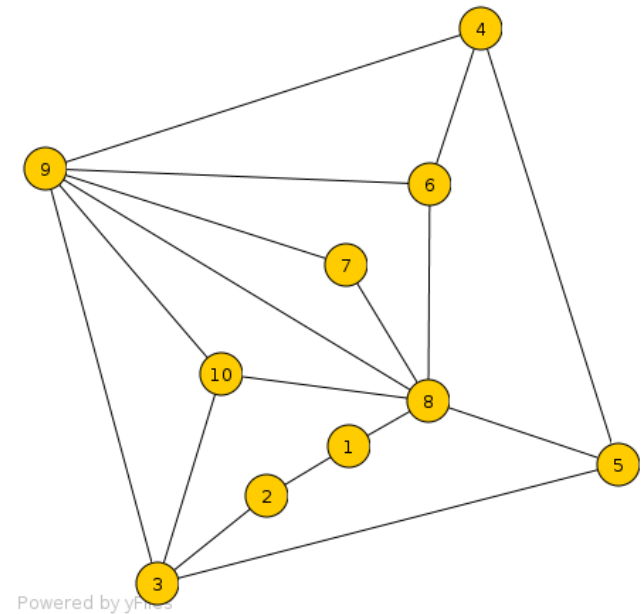
$$E = \{\{v_1, v_2\}, \{v_1, v_8\}, \{v_2, v_3\}, \{v_3, v_5\}, \{v_3, v_9\}, \{v_3, v_{10}\}, \{v_4, v_5\}, \{v_4, v_6\}, \{v_4, v_9\}, \{v_5, v_8\}, \{v_6, v_8\}, \{v_6, v_9\}, \{v_7, v_8\}, \{v_7, v_9\}, \{v_8, v_{10}\}, \{v_9, v_{10}\}\}$$

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



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



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Graph and its Representation



Think and write down

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

2 min

Why to visualize graphs?

- A picture says more than words: human perception of images is better than of text
- To ease revealing information
- Finding patterns in data
- To communicate the data

Let's Recall



Discuss with your neighbour or in groups of three and then 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

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

Helpful: Algorithms for Planar Graphs

Overview

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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
- <https://www.yworks.com/downloads#yEd>
- draw all or some graphs as nice and as readable as possible

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

Puzzle games

SOCIAL NETWORK ANALYSIS

chip design

Tube Maps

UML-Diagrams

Syntax highlighting

Neural Networks

dynamic programming

Heuristic

Randomized

Backtracking

k-regular

co-planar

Brute-Force

APPROXIMATION

Trees

Complete Graphs

Divide and conquer (recursion)

Simulated Annealing

TRIANGULATIONS

Directed

Algorithms for Graph Visualization

Evolutionary Algorithms

Bipartite

Symmetry

Crossing Angle

Number of slopes

Crossings

Angle Resolution

Large Faces

Fixed or Prescribed Outer face

Grouping of Clusters

Partial / Local Restrictions
Can be soft / hard constraints

Drawing Aesthetics / Constraints

Drawing Conventions / Hard Constraints

Straight line edges

Upward Edges

Curvilinear Edges

Orthogonal Polyline as Edges

Planar Drawing

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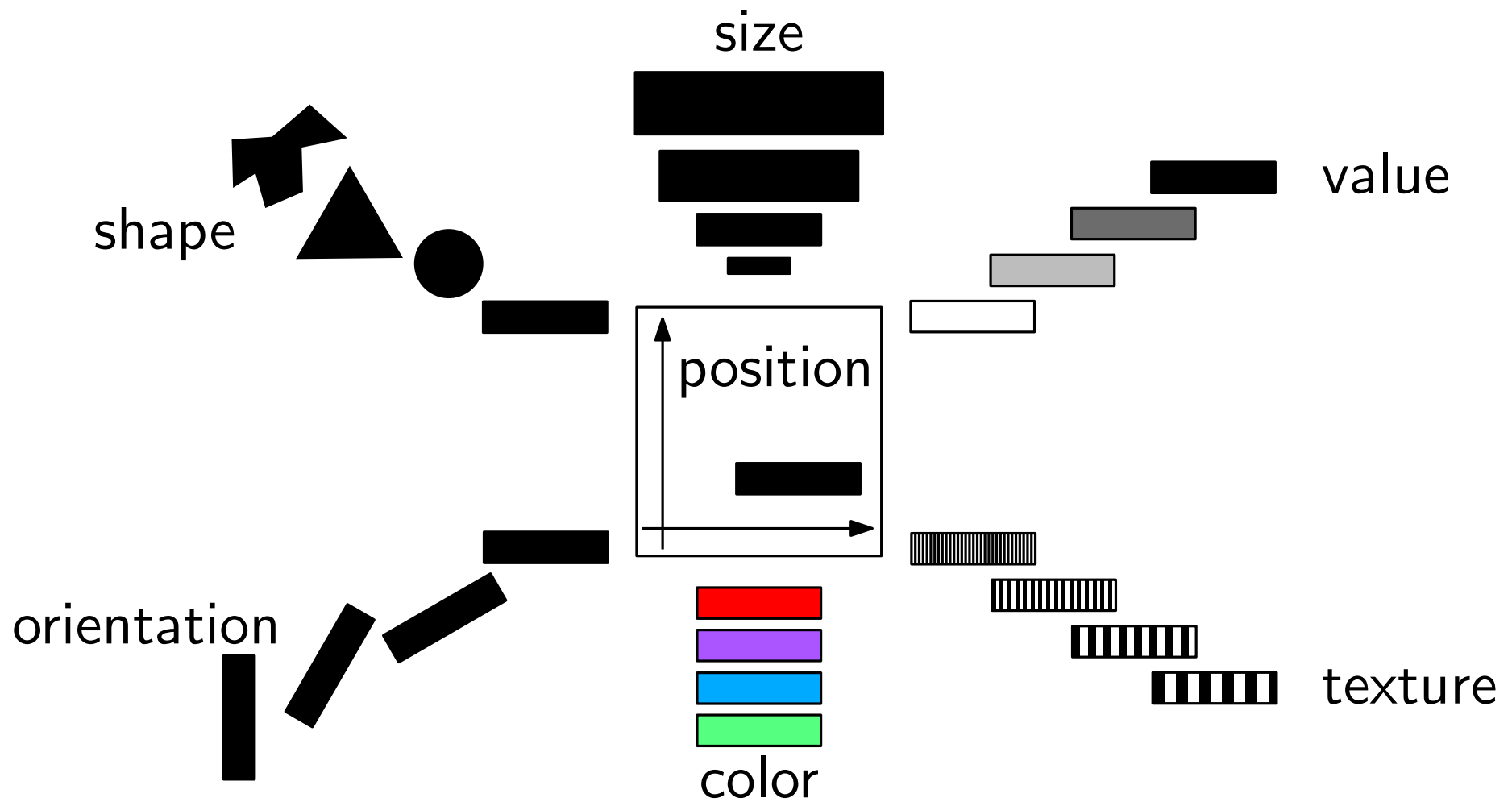
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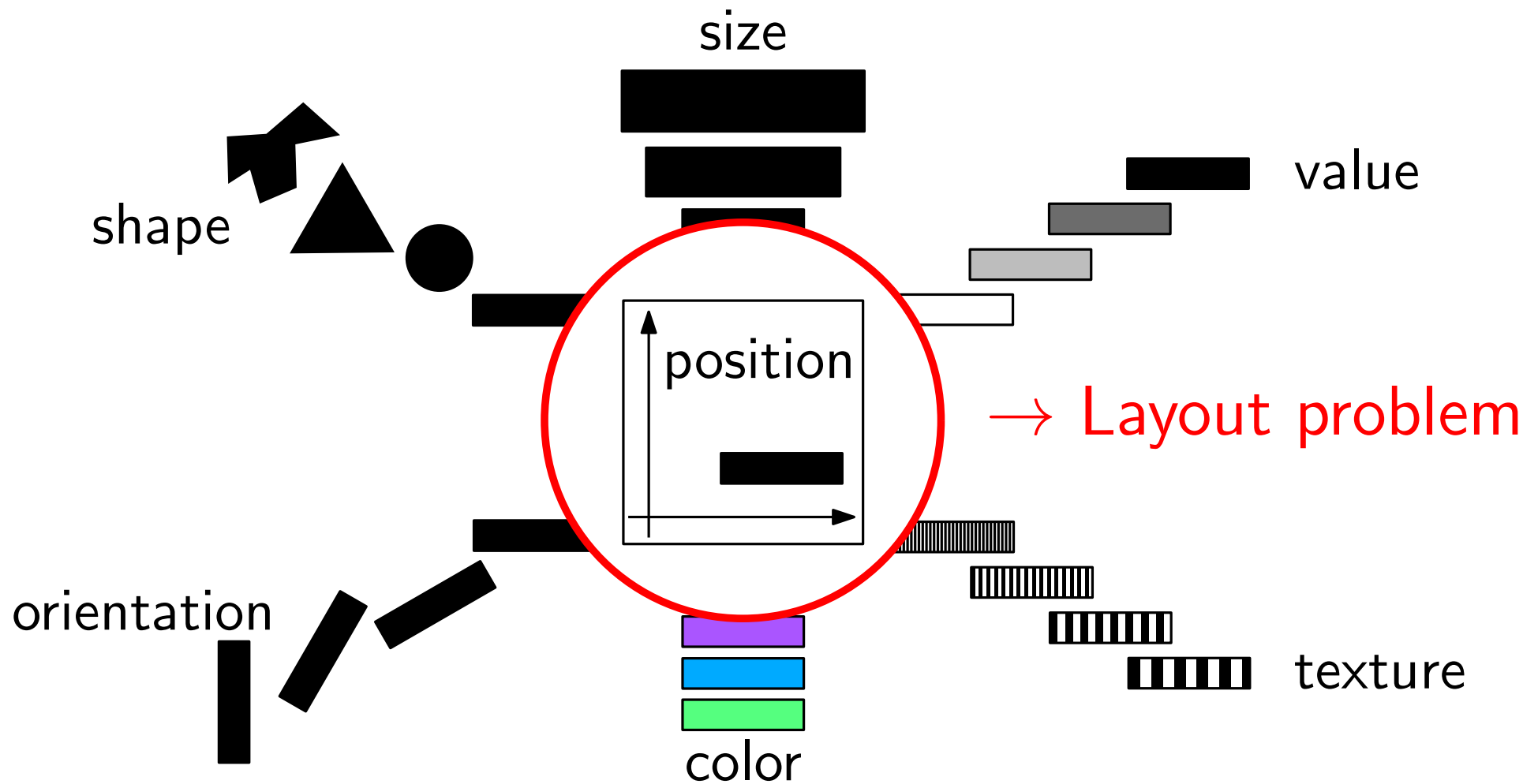
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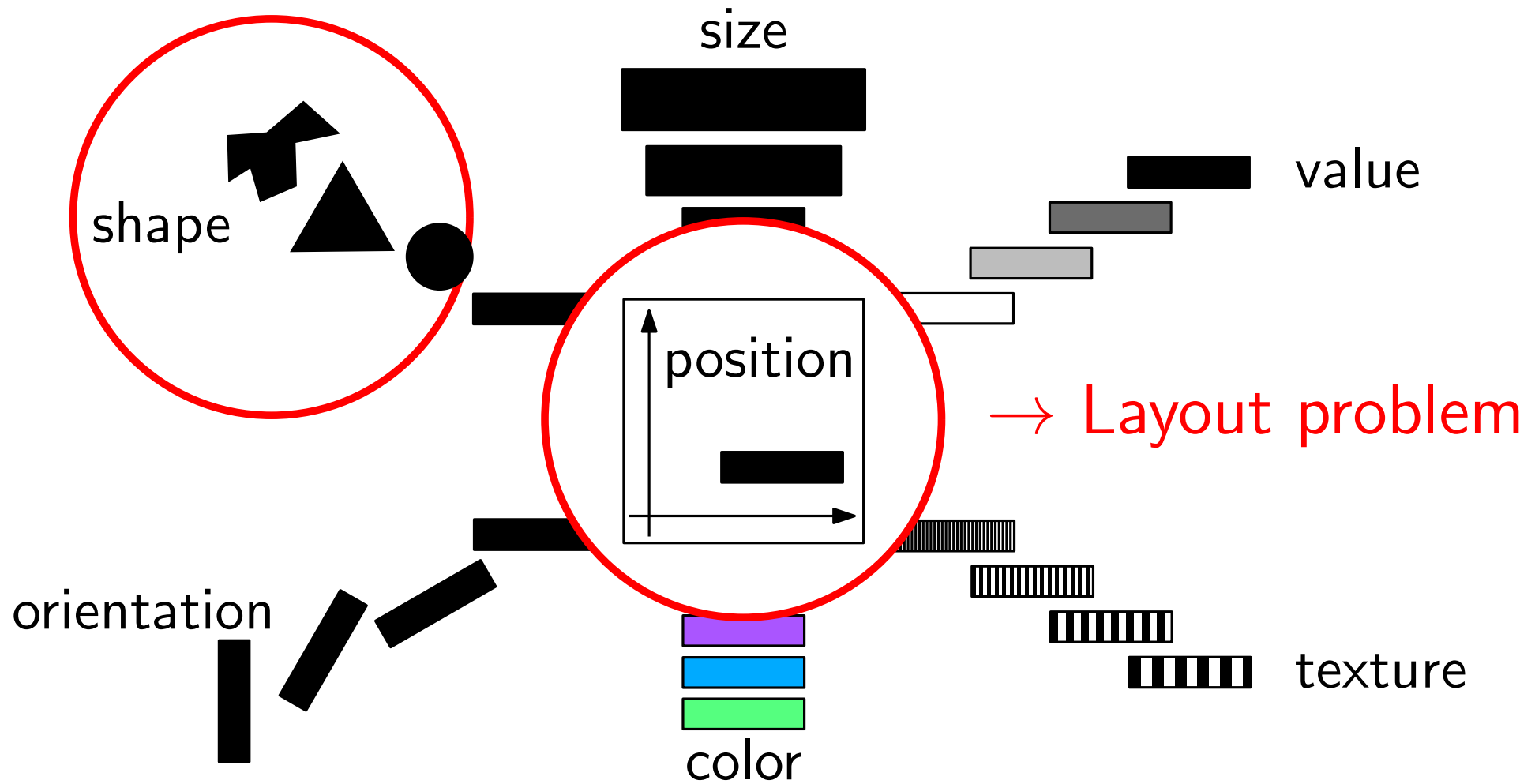
Visual Variables according to Bertin (1967)



Visual Variables according to Bertin (1967)



Visual Variables according to Bertin (1967)



Graph visualization problem

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

find: **good** drawing Γ of G

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

Graph visualization problem

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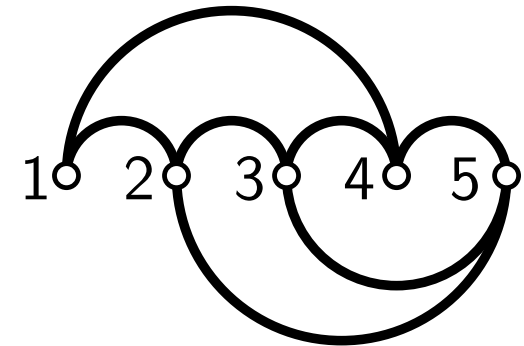
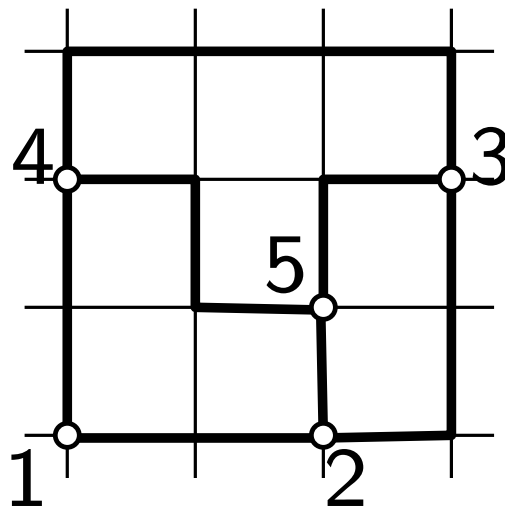
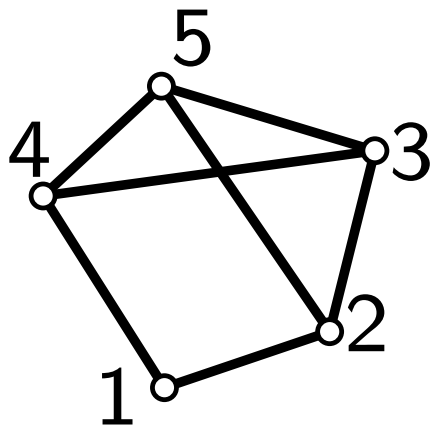
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Layout Problem

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

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

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

→ often lead to NP-hard optimization problems!

→ often several competing criteria

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Learning Objectives

At the end of the semester you are able to:

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- List various network visualization styles
- Formally state a network visualization problem
- Describe several algorithms for network visualization in an 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
- Prove correctness of the algorithms
- Use a tool or library to produce a network visualization
- Solve new network visualization problems by selecting and adapting known approaches

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- Recall Level**
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Recall Level

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Analyze, Apply, Generalize Level

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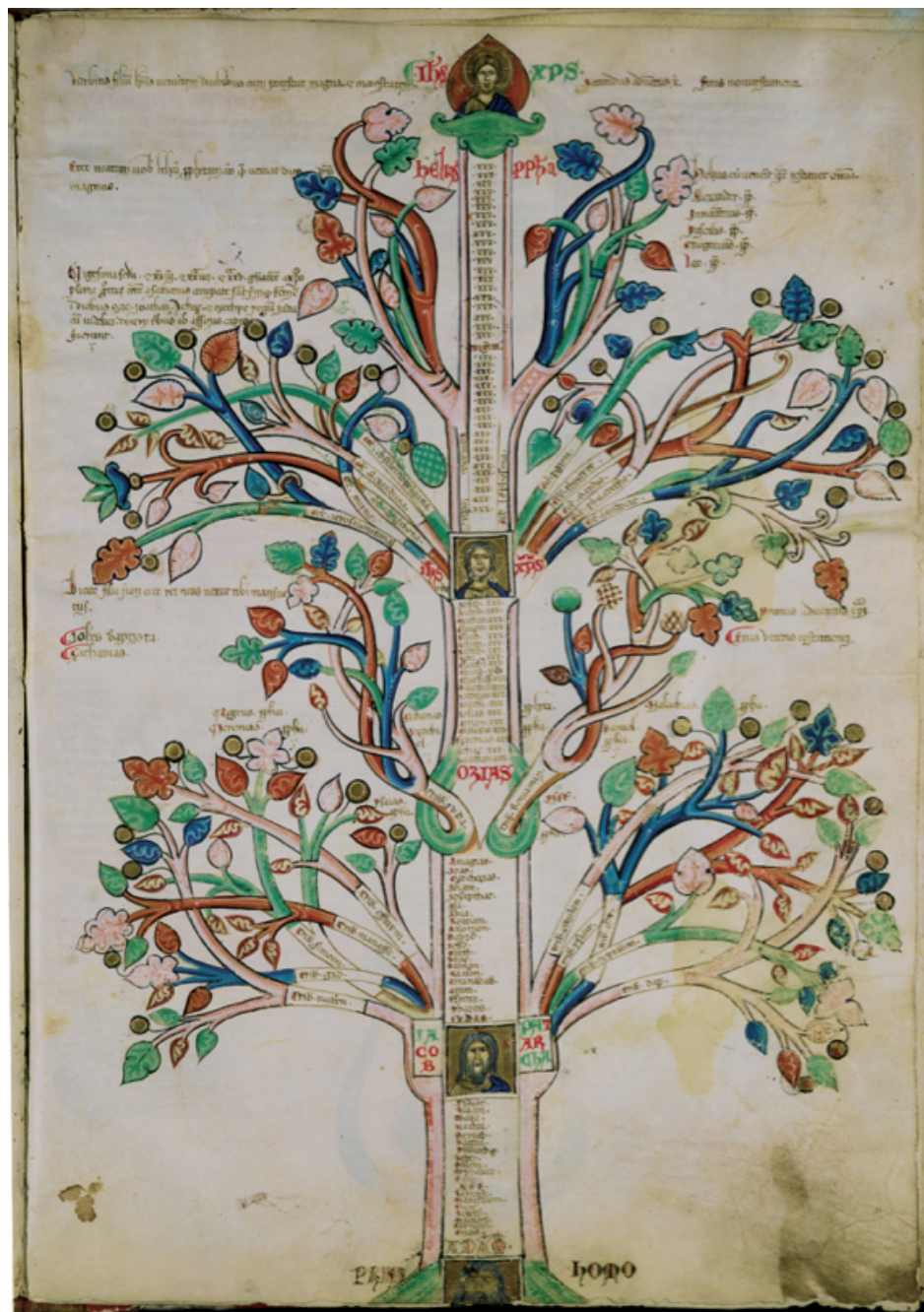
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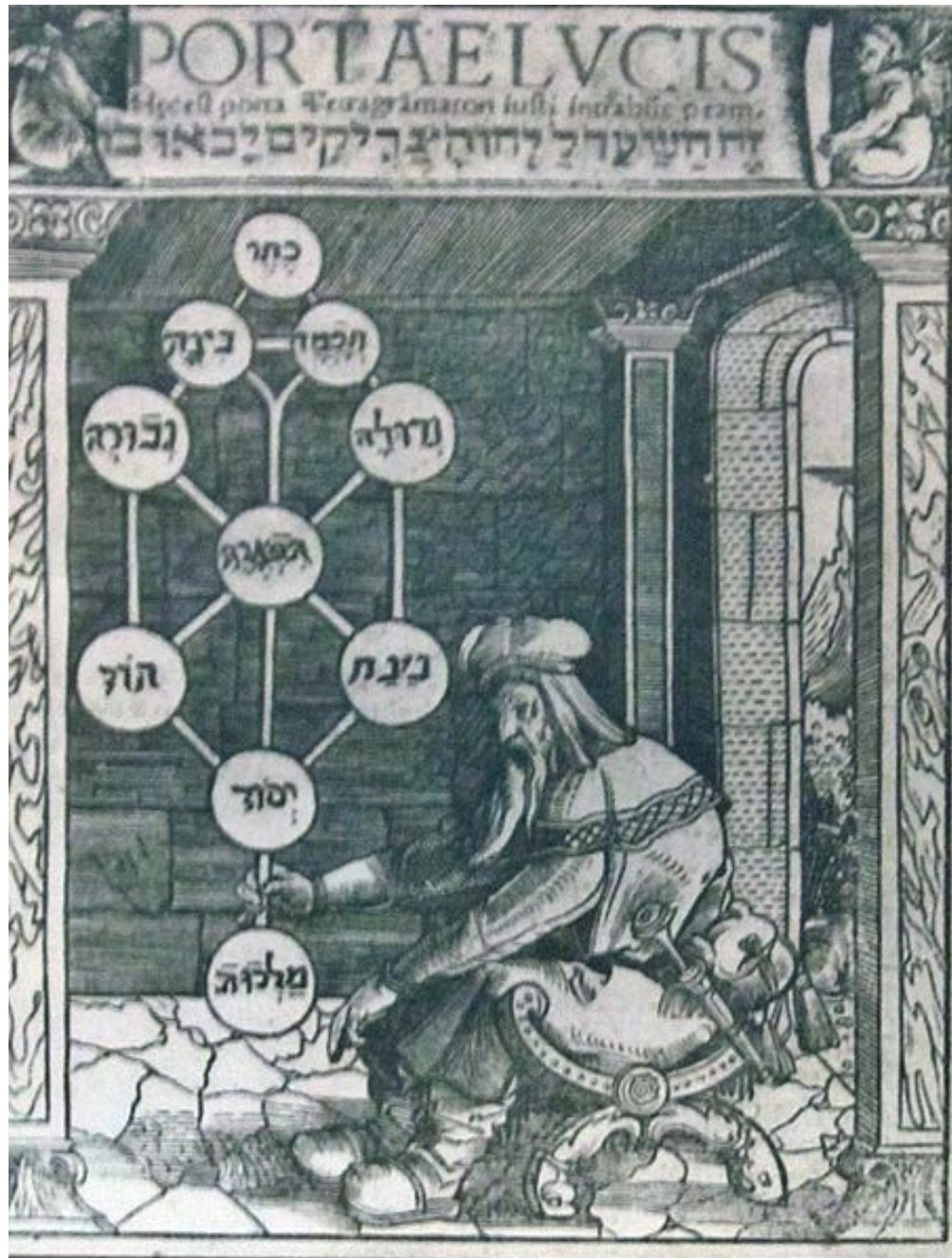
Applications gallery.

Biblical characters and events (1202)



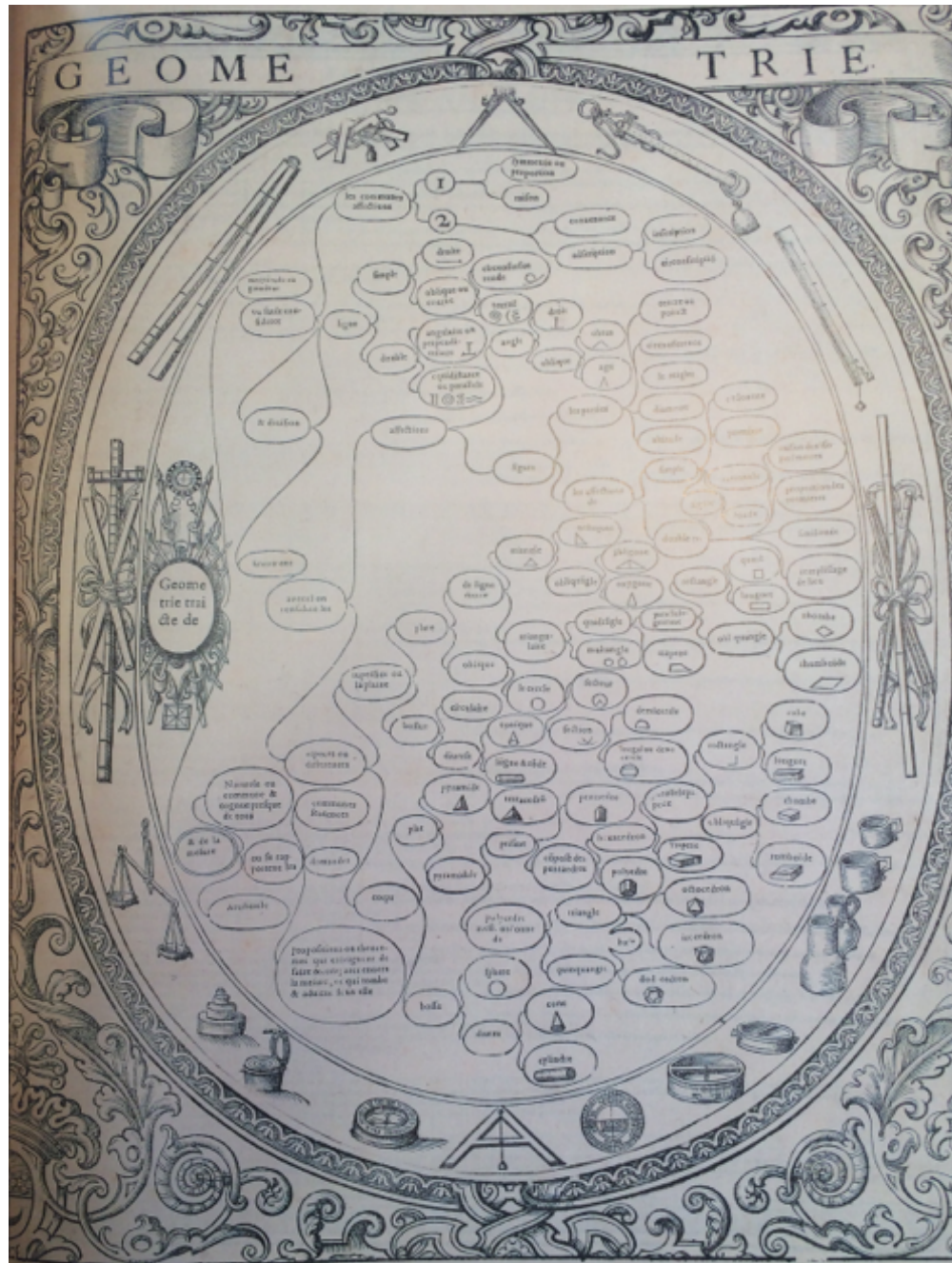
Source: Joachim de Fiore

"Tree of Life" (1516)



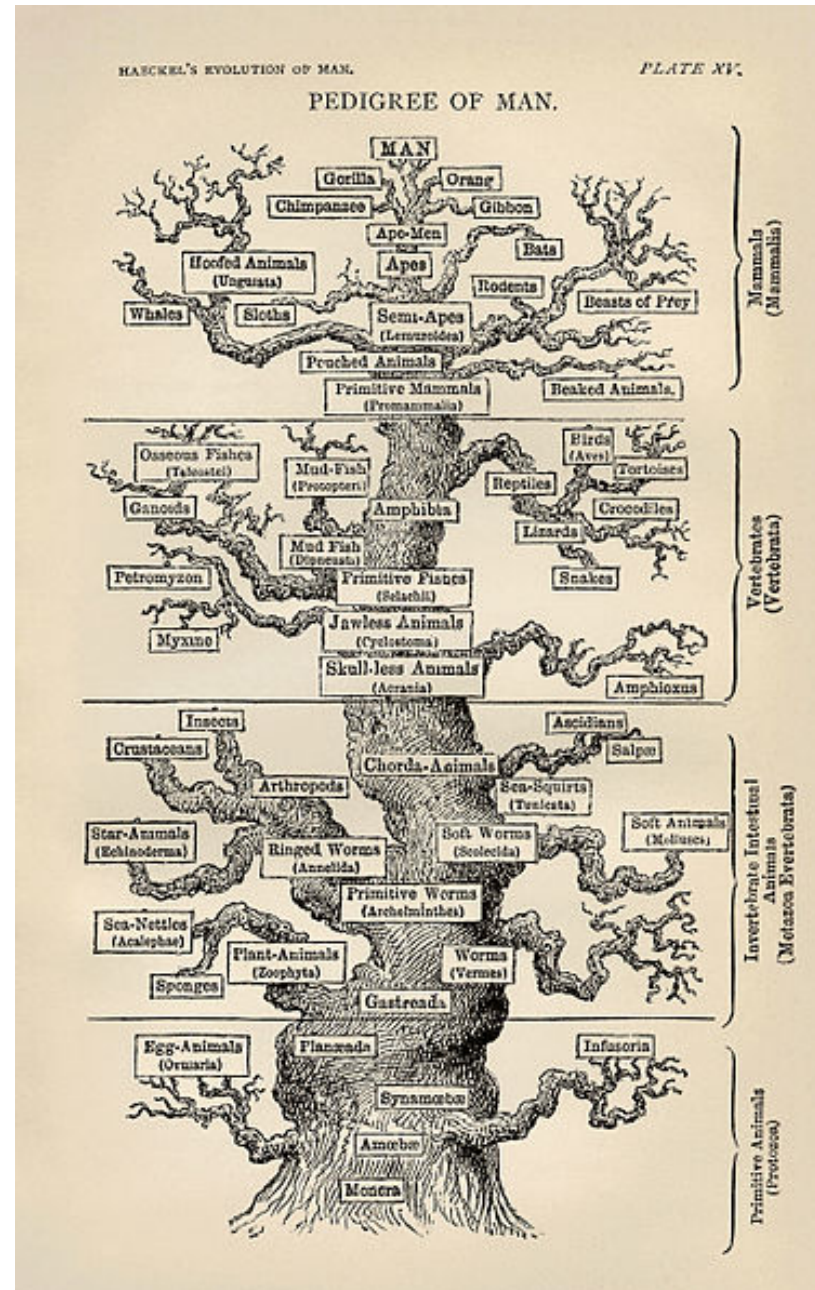
Source: Paul Riccius, Portae Lucis

Geometrical Concepts (1587)



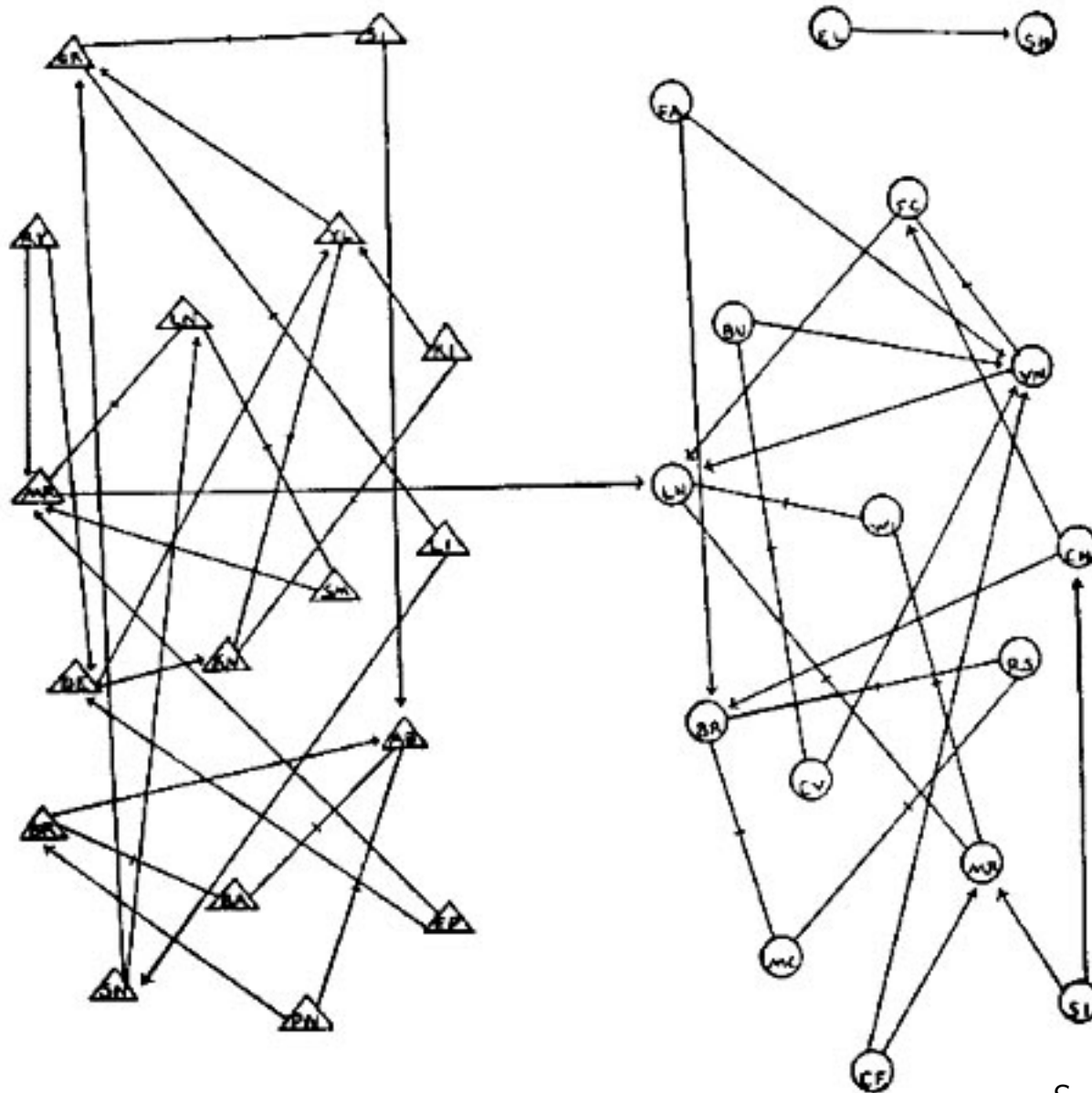
Source: Christophe de Savigny

Genealogical Tree (1879)



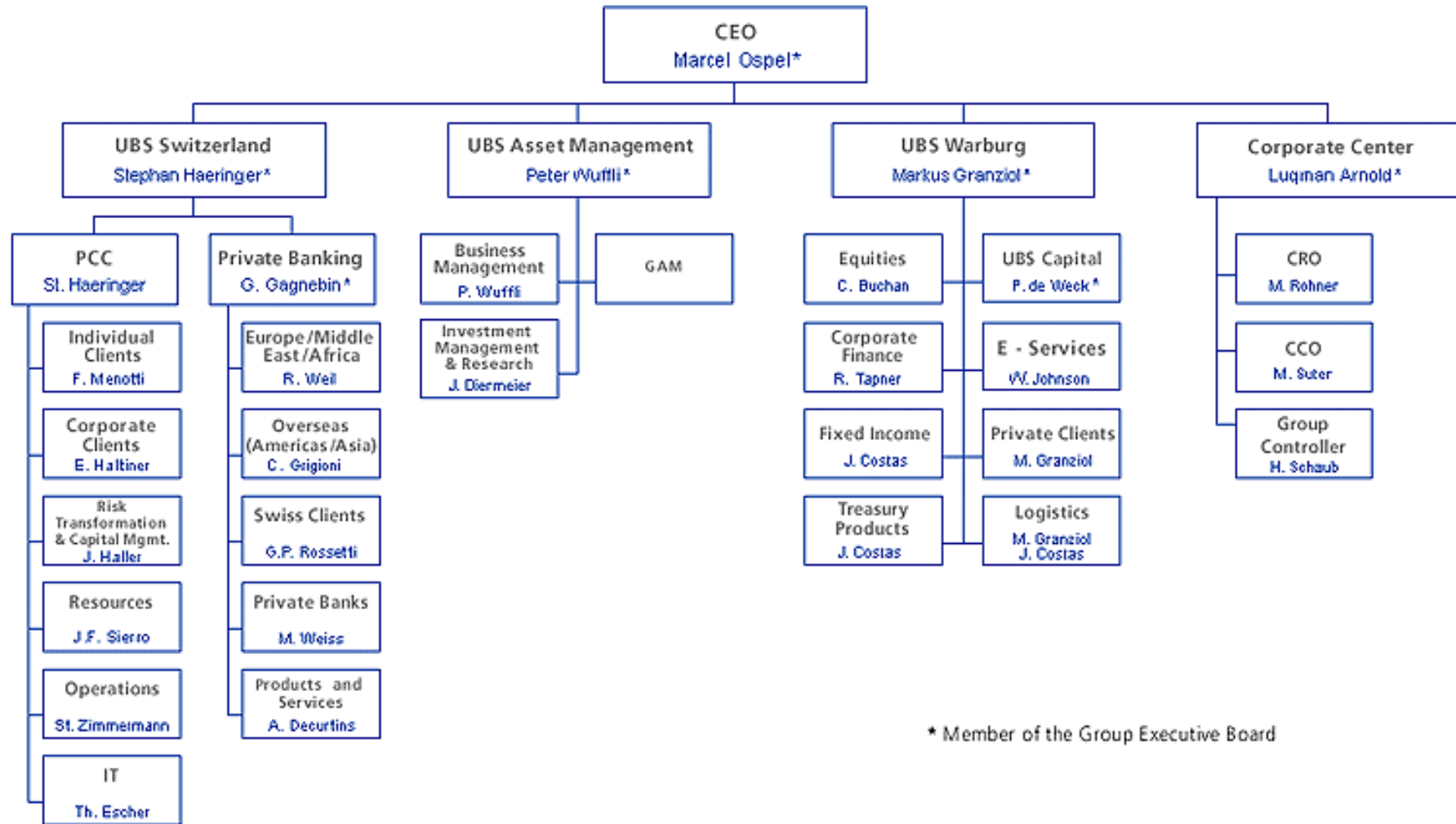
Source: Ernst Haeckel

Sociogram (1933)



Source: Moreno, 1933

Social Network – Organization within UBS



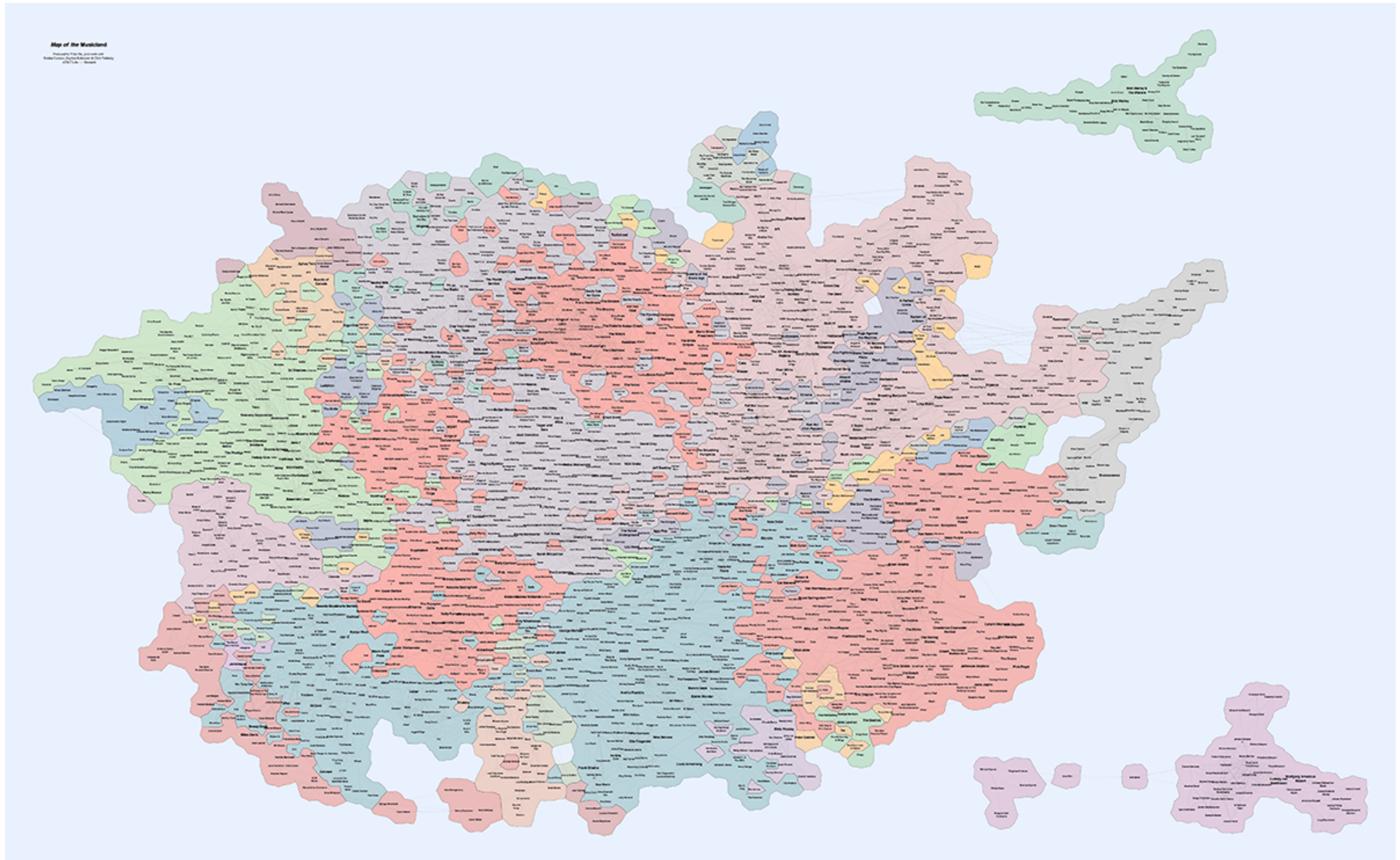
* Member of the Group Executive Board

CPAN Developer-Graph



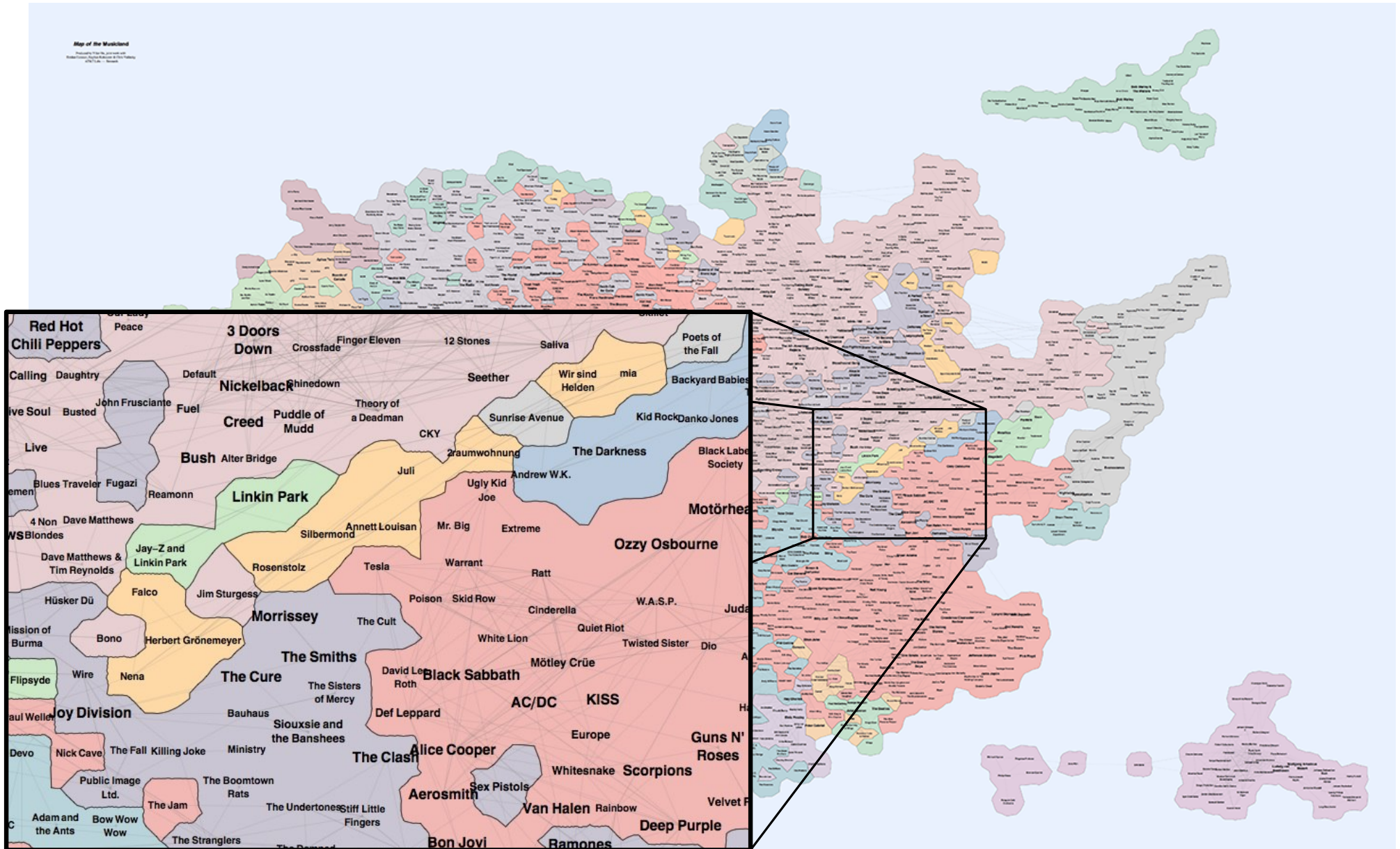
Source: cpan-explorer.org

last.fm Graph of musics as political map



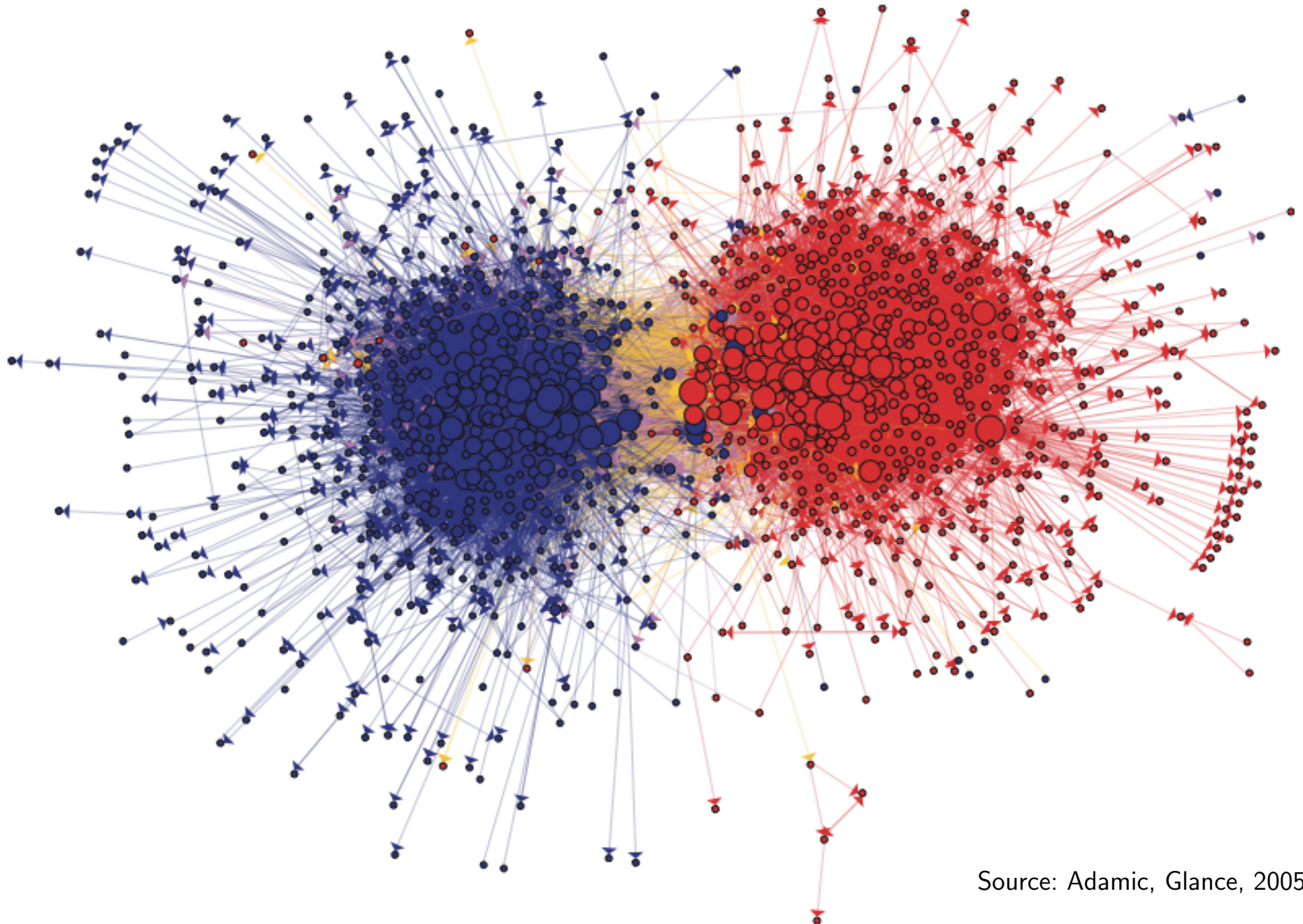
(Gansner, Hu, Kobourov: GMap, 2009)

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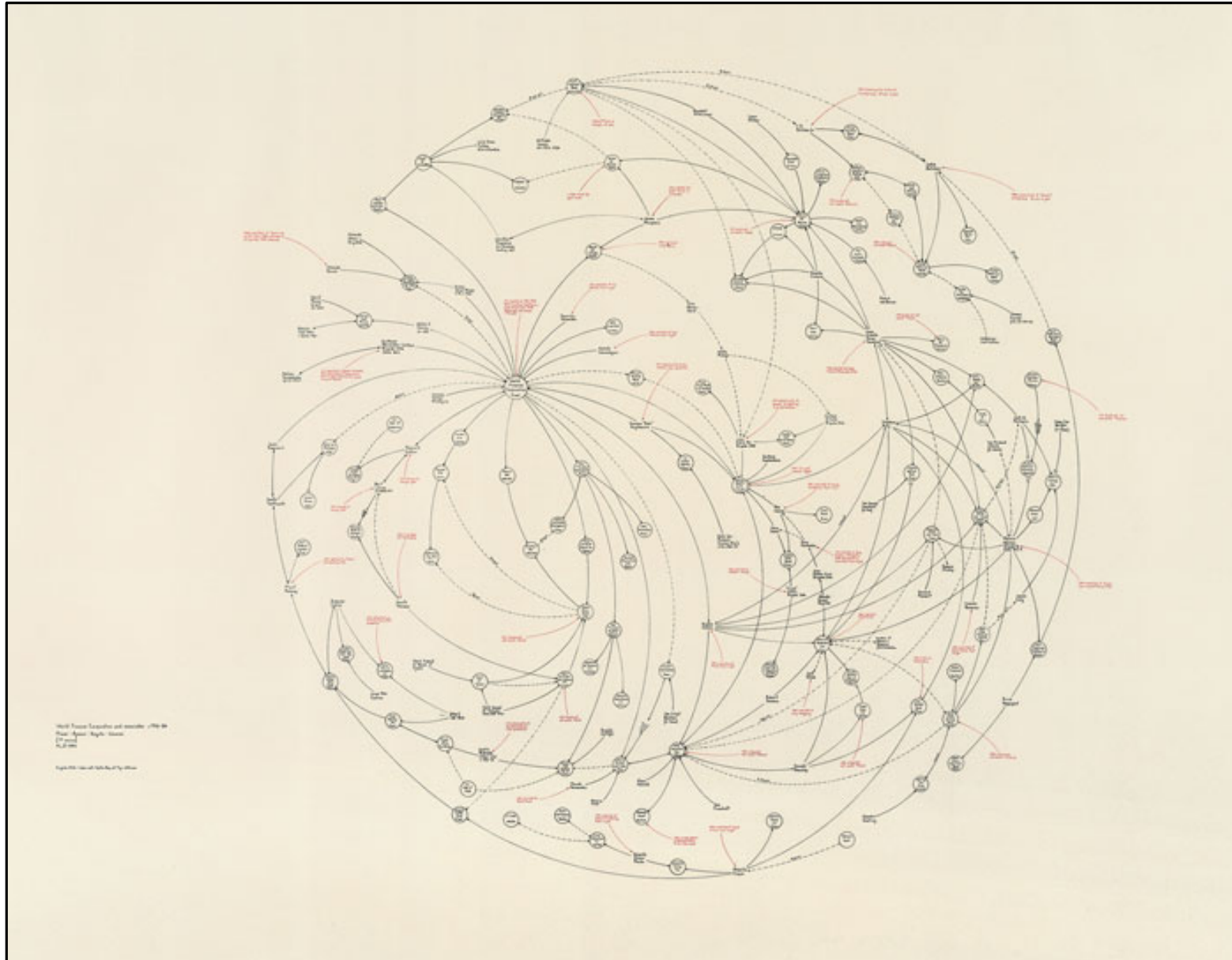
(Gansner, Hu, Kobourov: GMap, 2009)

Blogosphere 2004 Elections USA



Source: Adamic, Glance, 2005

Social Network – World Finance System



World Finance Corporation
© Mark Lombardi

Social Networks – State Funds

FOLLOW THE MONEY

The New Global Wealth Machine

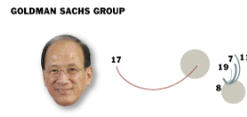
Sovereign wealth funds have emerged in recent months as the world's power brokers. They have used their tremendous wealth to make big cross-border investments and prop up some of Wall Street's best-known firms. The increased activity comes as other kinds of acquirers have been sidelined by the credit crisis. These funds are state-sponsored investment vehicles and have combined assets of \$2 trillion. With that much dry powder, sovereign funds dwarf the formerly booming private equity industry — and in some cases, compete directly with it. The Government of Singapore Investment Corporation has been the most active among the world's sovereign funds, making its deputy chairman, Tony Tan, a major center of gravity. Wall Street veterans always follow the money, so many of the big-name advisers in New York and London have found themselves traveling the globe playing international matchmaker to these funds. But sovereign funds have also learned the downside of deal-making: some of their blockbuster transactions have been big money losers so far. The question is where all that money will go next. **ANDREW ROSS SORKIN**

The Advisers

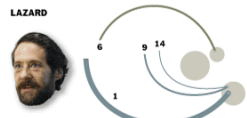
Selected financial advisers who worked on more than one of the top 20 deals.



Michael Klein, Chairman, institutional clients group
One of the firm's highest-profile investment bankers, he advised Cayle in its stake sale to Mohandis, as well as Citigroup in both of its deals with sovereign wealth funds.



Richard Ong, Former managing director
Mr. Ong left Goldman early this year after the Chinese government refused to allow the firm to promote him to run its Beijing office. Mr. Ong's brother, Charles, was the chief investment officer of Temasek Holdings until 2006.

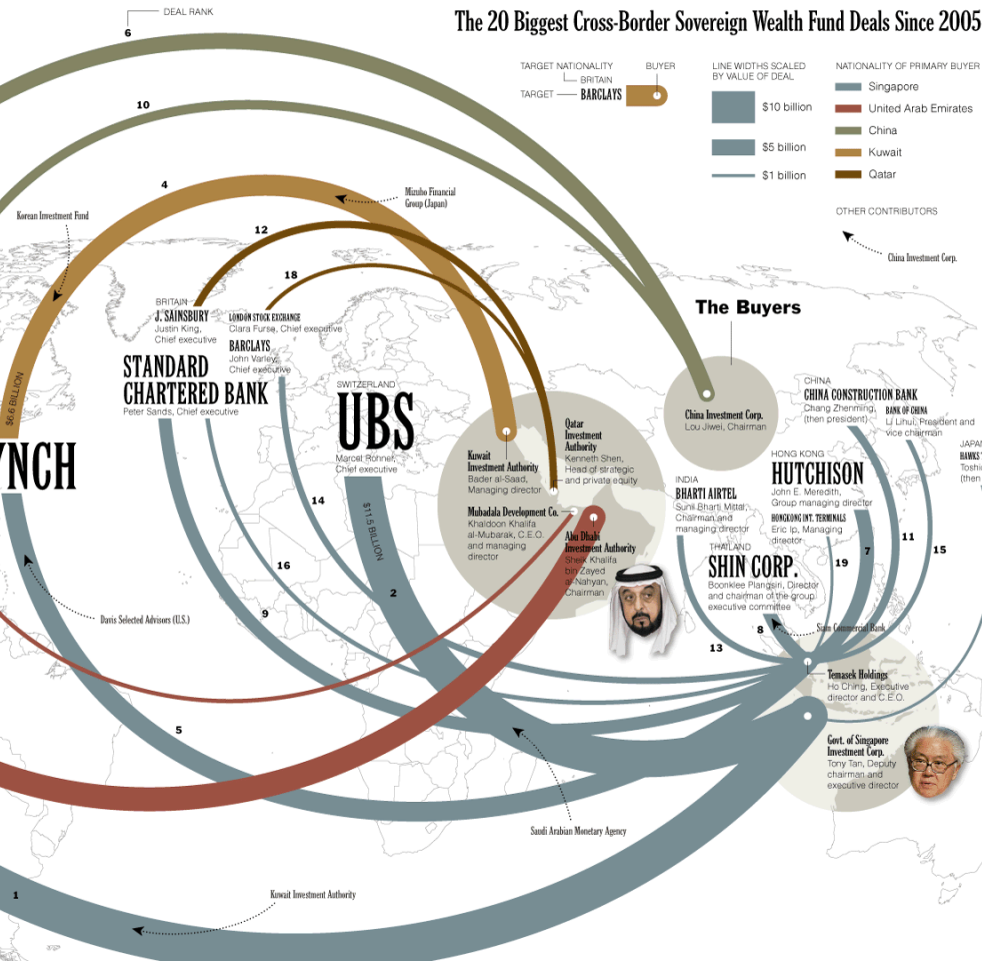
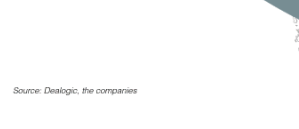


Gary Parr, Deputy chairman
In addition to becoming the key adviser on many of the biggest sovereign wealth deals, Mr. Parr helped advise Bear Stearns on its distressed sale to JP Morgan Chase.



Kate Richdale, Managing director
The head of Morgan Stanley's Asian general industries group, based in Hong Kong. She previously held a senior position in the investment bank's Southeast Asia group.

The Targets



The 20 Biggest Cross-Border Sovereign Wealth Fund Deals Since 2005

TARGET NATIONALITY
— BRITAIN
— BARCLAYS
— TARGET

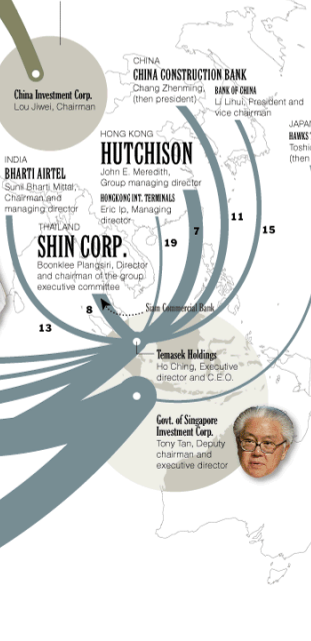
BUYER

LINE WIDTHS SCALED BY VALUE OF DEAL
\$10 billion
\$5 billion
\$1 billion

NATIONALITY OF PRIMARY BUYER
Singapore
United Arab Emirates
China
Kuwait
Qatar

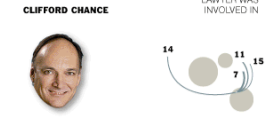
OTHER CONTRIBUTORS
China Investment Corp.

The Buyers

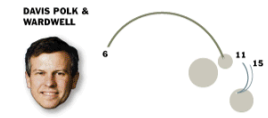


The Lawyers

Selected lawyers who worked on more than one of the top 20 deals.



James Baird, Partner and global head of private equity
Mr. Baird's firm, based in London, was one of the early firms to make a bet on Asia by staffing up there before some of the traditional white-shoe Wall Street firms ventured there.



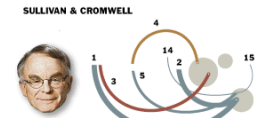
Randall D. Guynn, Partner
As head of the firm's financial institutions group, he has advised on many international deals in Europe and Asia. He also worked on the team that advised Morgan Stanley in its \$5.5 billion stake sale to China's sovereign wealth fund.



Richard Good, Partner
Based in Singapore, Mr. Good is the firm's man-on-the-ground in Asia. He has worked for Linklaters in Asia since 2000.



Stephen M. Besen, Partner
A longtime hand in the Middle East, Mr. Besen's deep relationships have helped his firm carve out one of the strongest niches in the region.

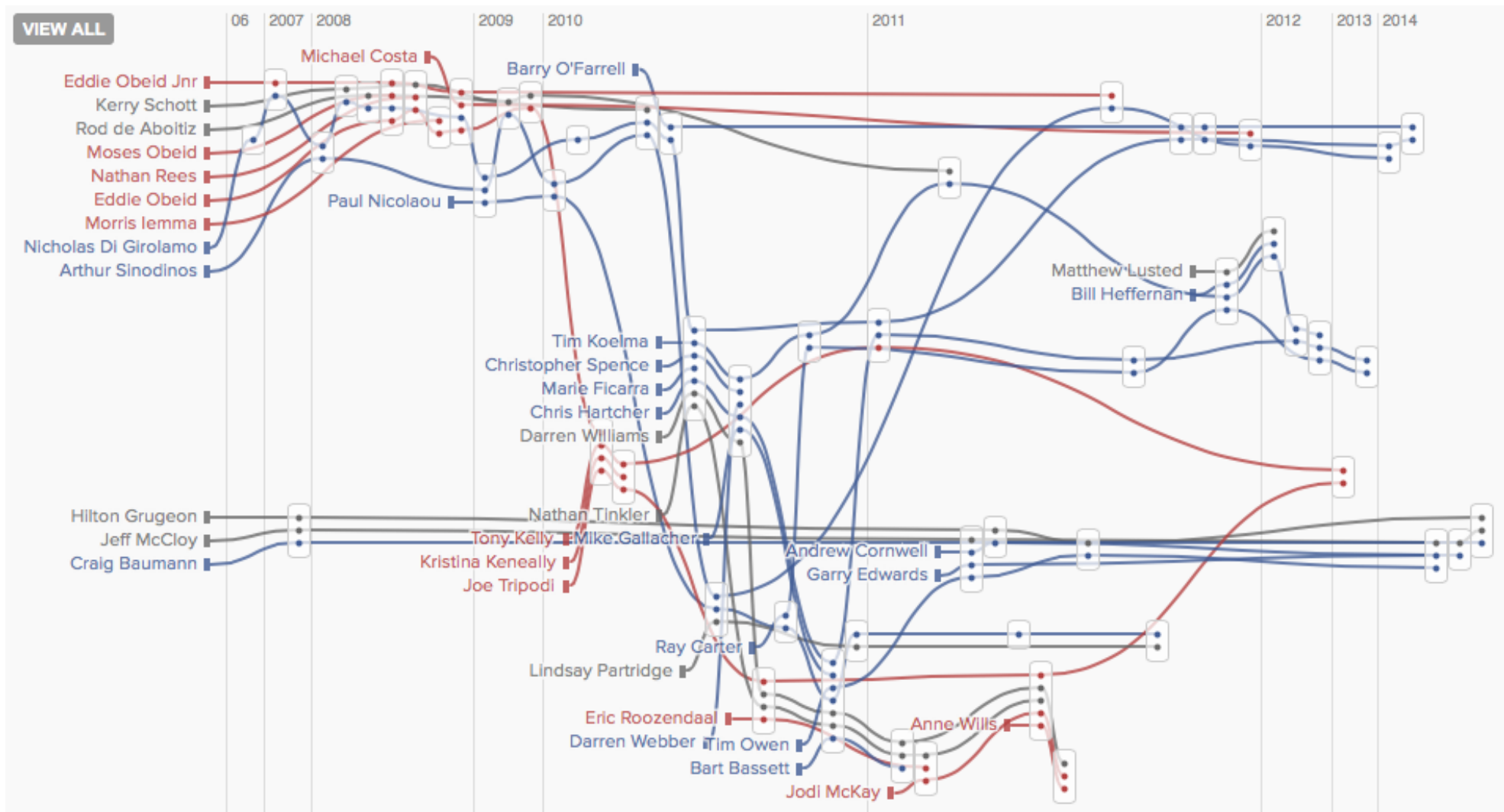


H. Rodgin Cohen, Chairman
The world's go-to lawyer for sovereign wealth investments in financial services firms. He worked on twice as many sovereign wealth related deals than any other individual.

Source: Dealogic, the companies

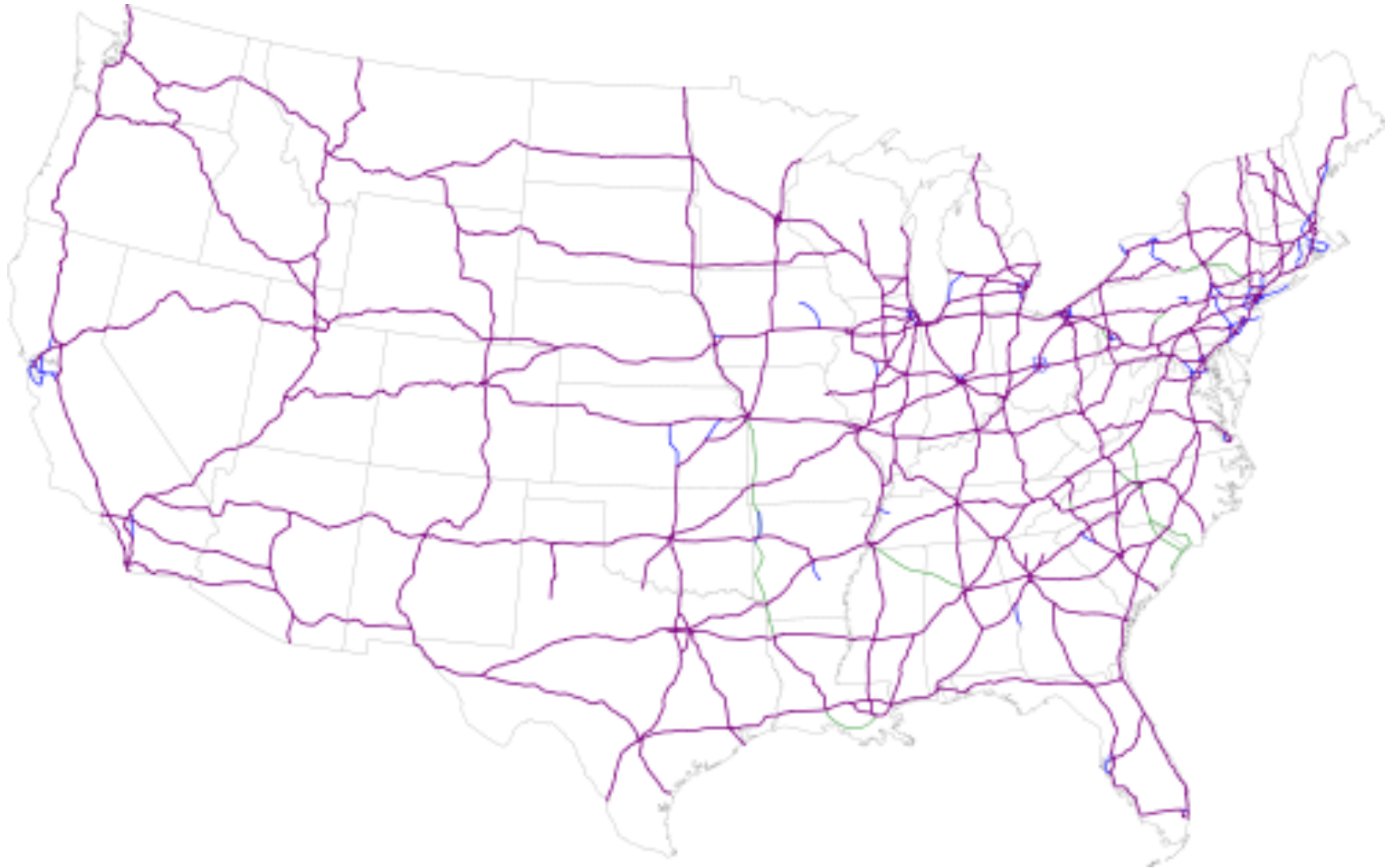
RESEARCH BY MICHAEL DE LA MERCEZ, GRAPHIC BY GILBERT GATES FOR THE NEW YORK TIMES

Temporal Graph Layout: Storylines

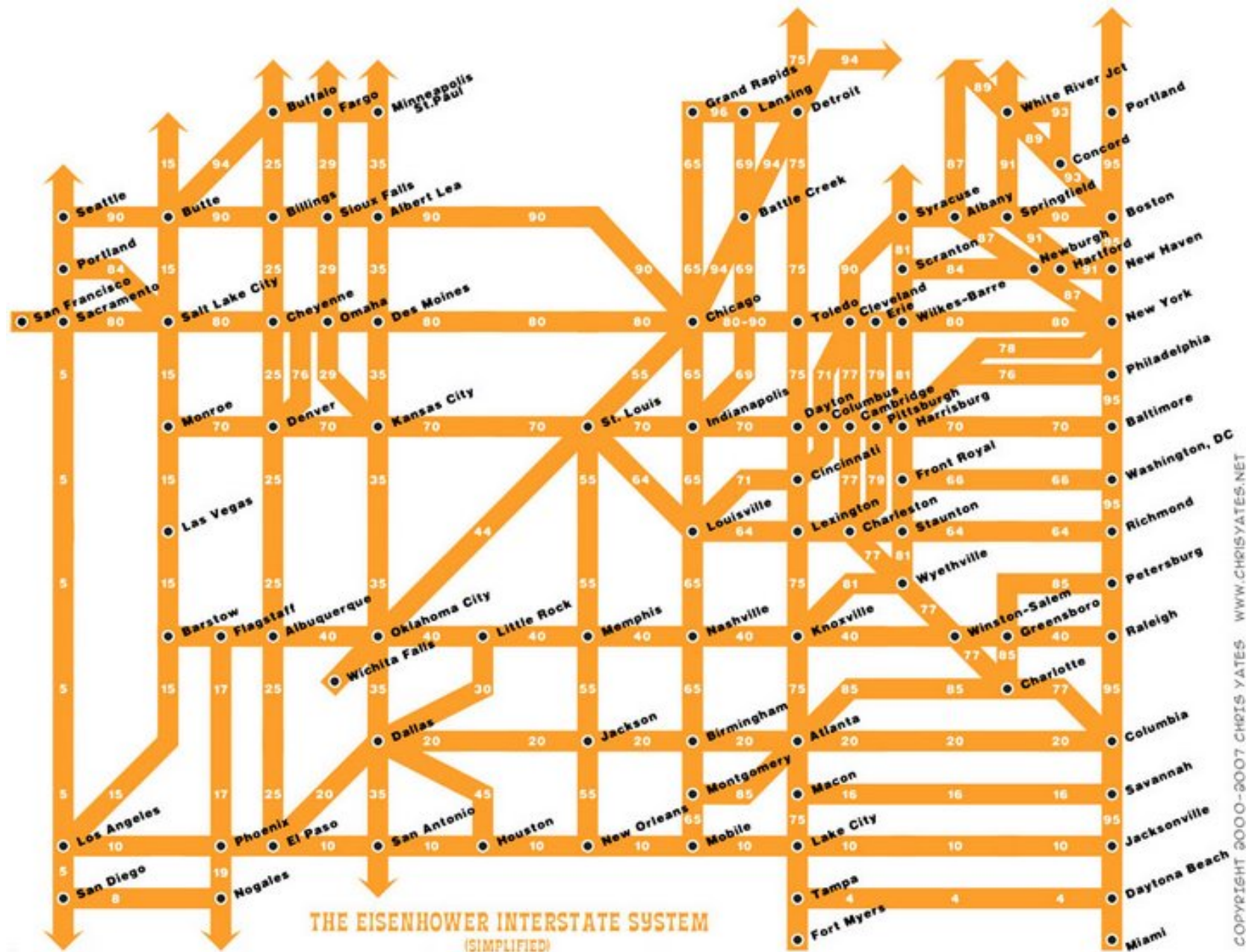


Source: ABC news, Australia

Traffic network – Highways USA



Traffic network – Highways USA

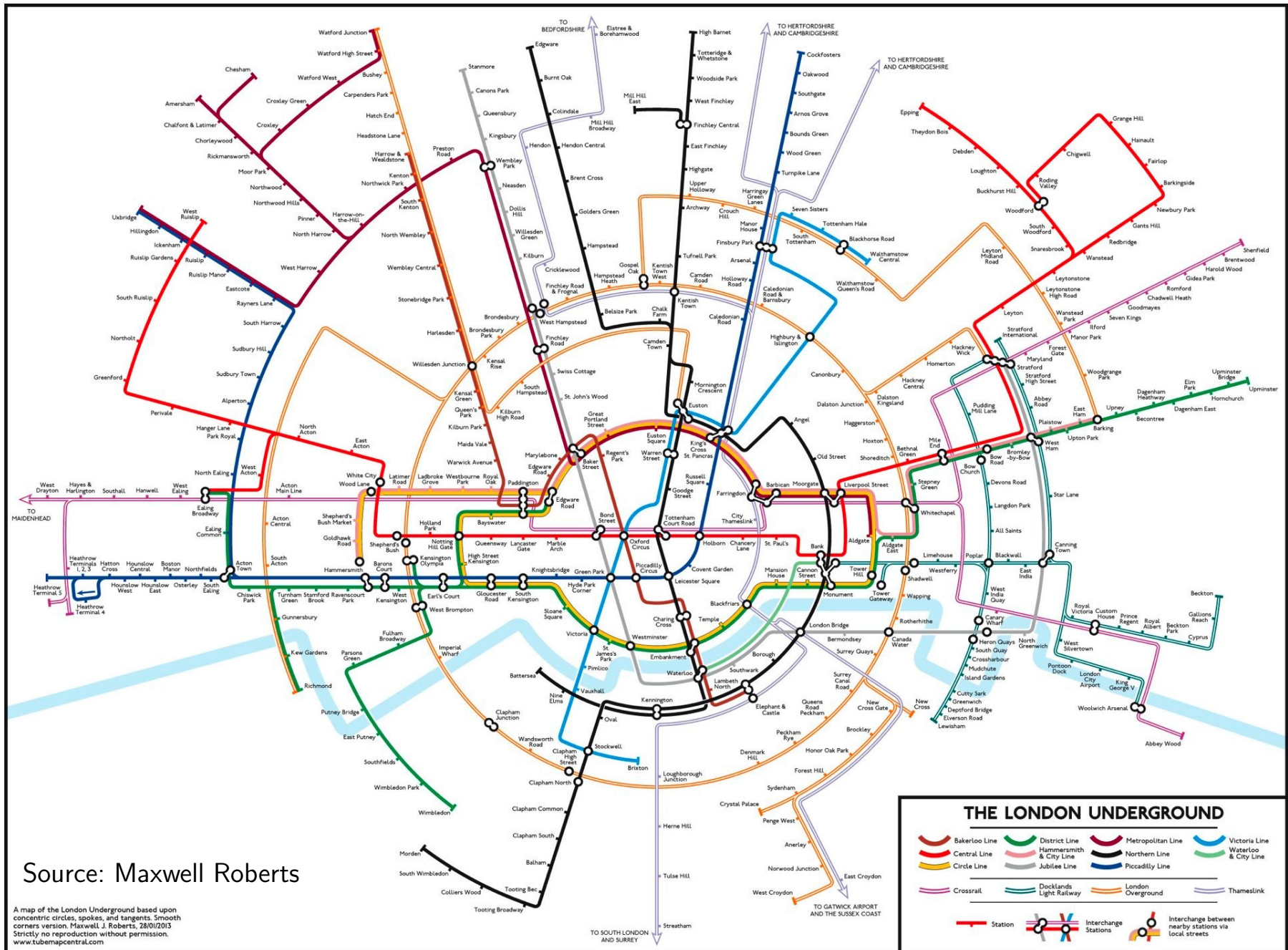


London Tube Map (1933)



Source: Henry Beck

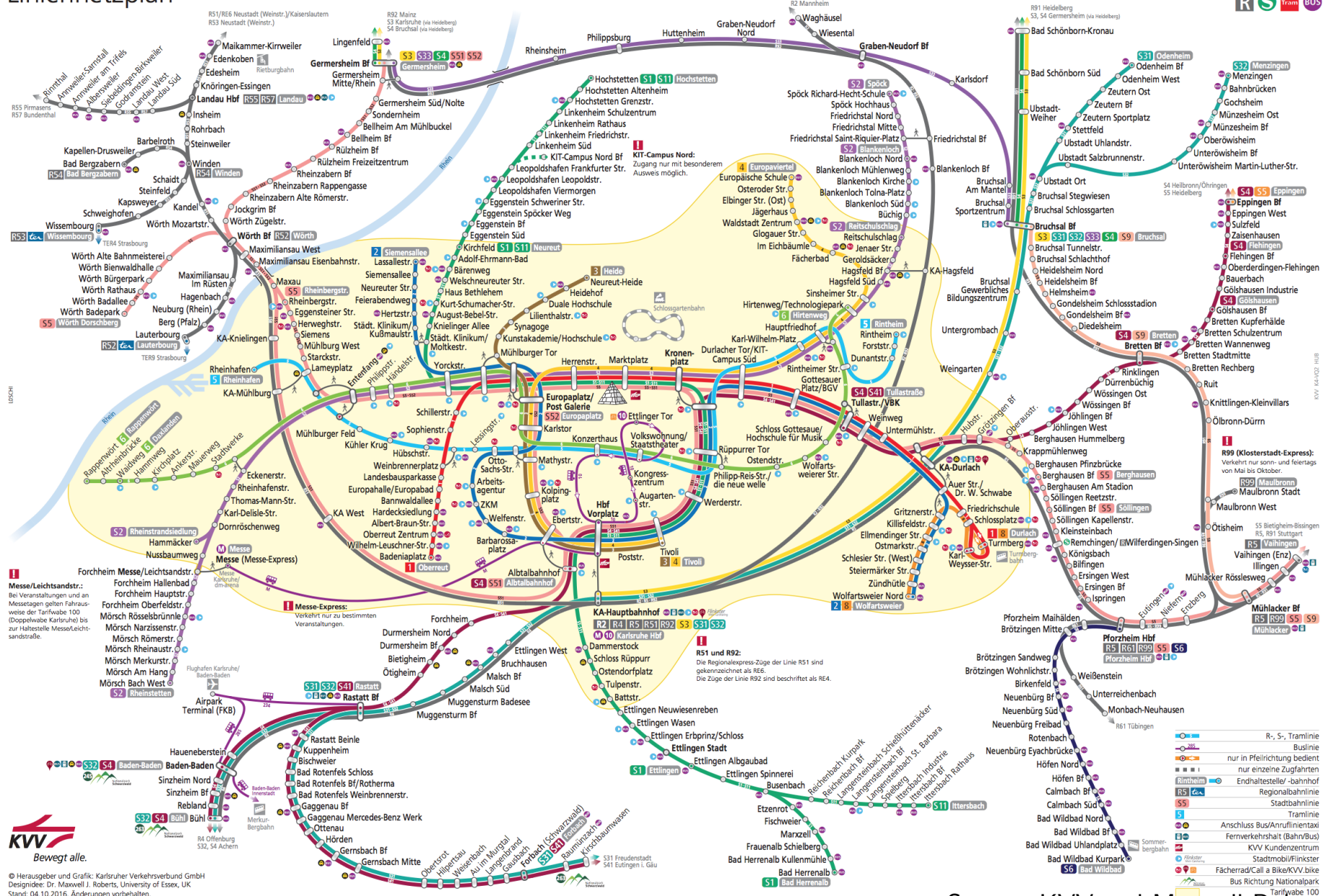
Co-centric Tube Map



Curvilinear S/U-bahn map

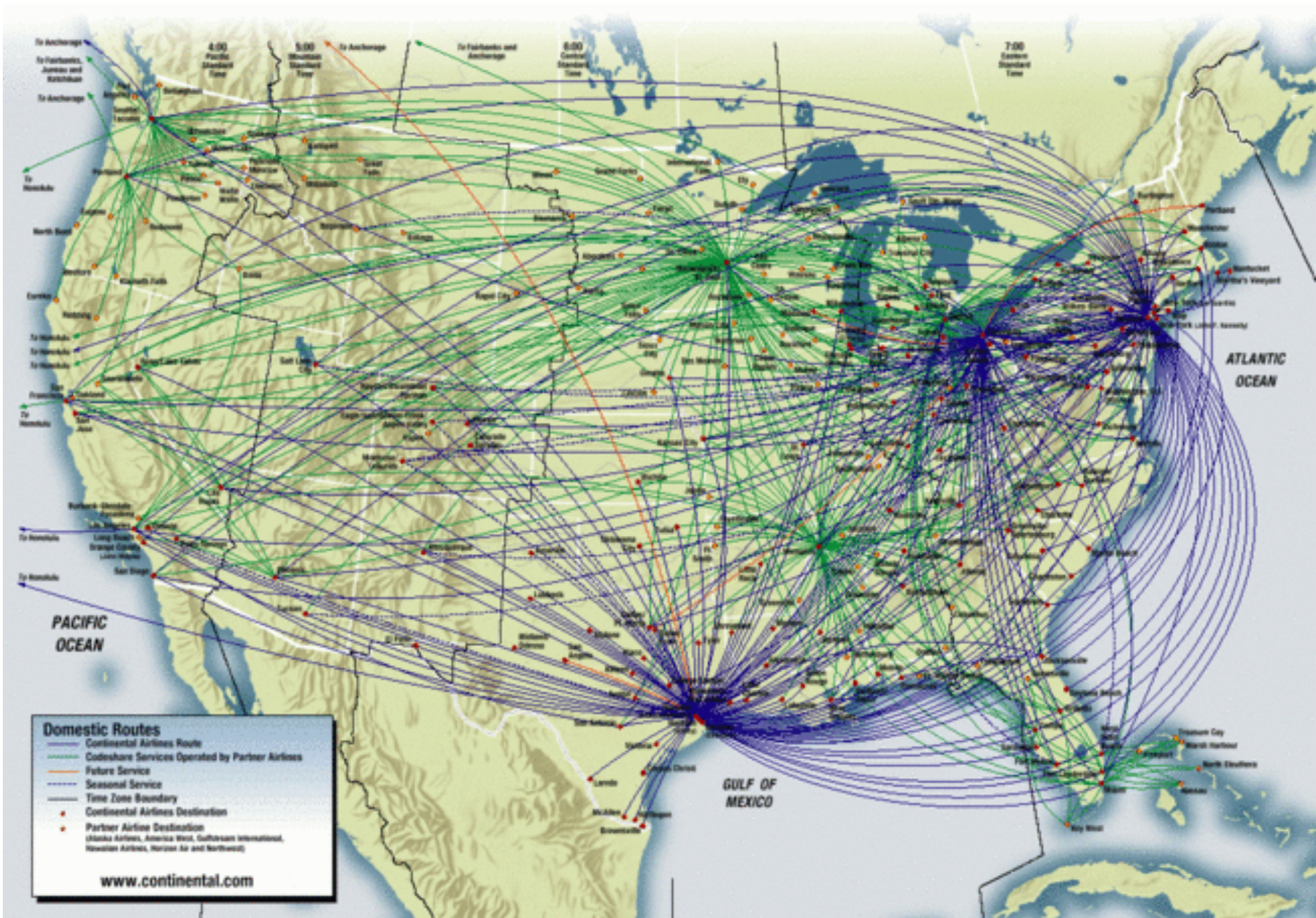
Liniennetzplan

Gültig ab 13. Dezember 2015

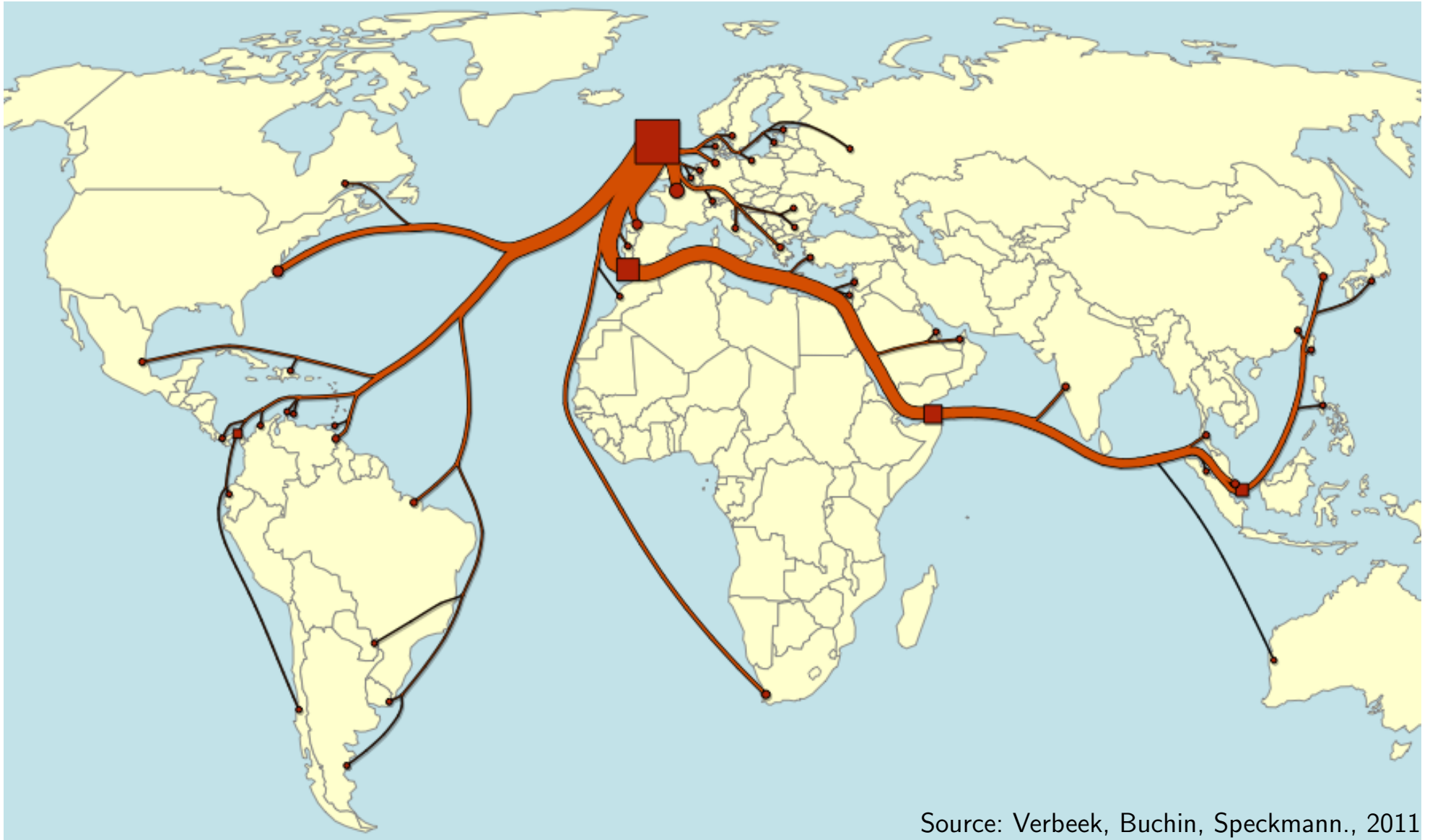


Source: KVV and Maxwell Roberts

Flight Connections

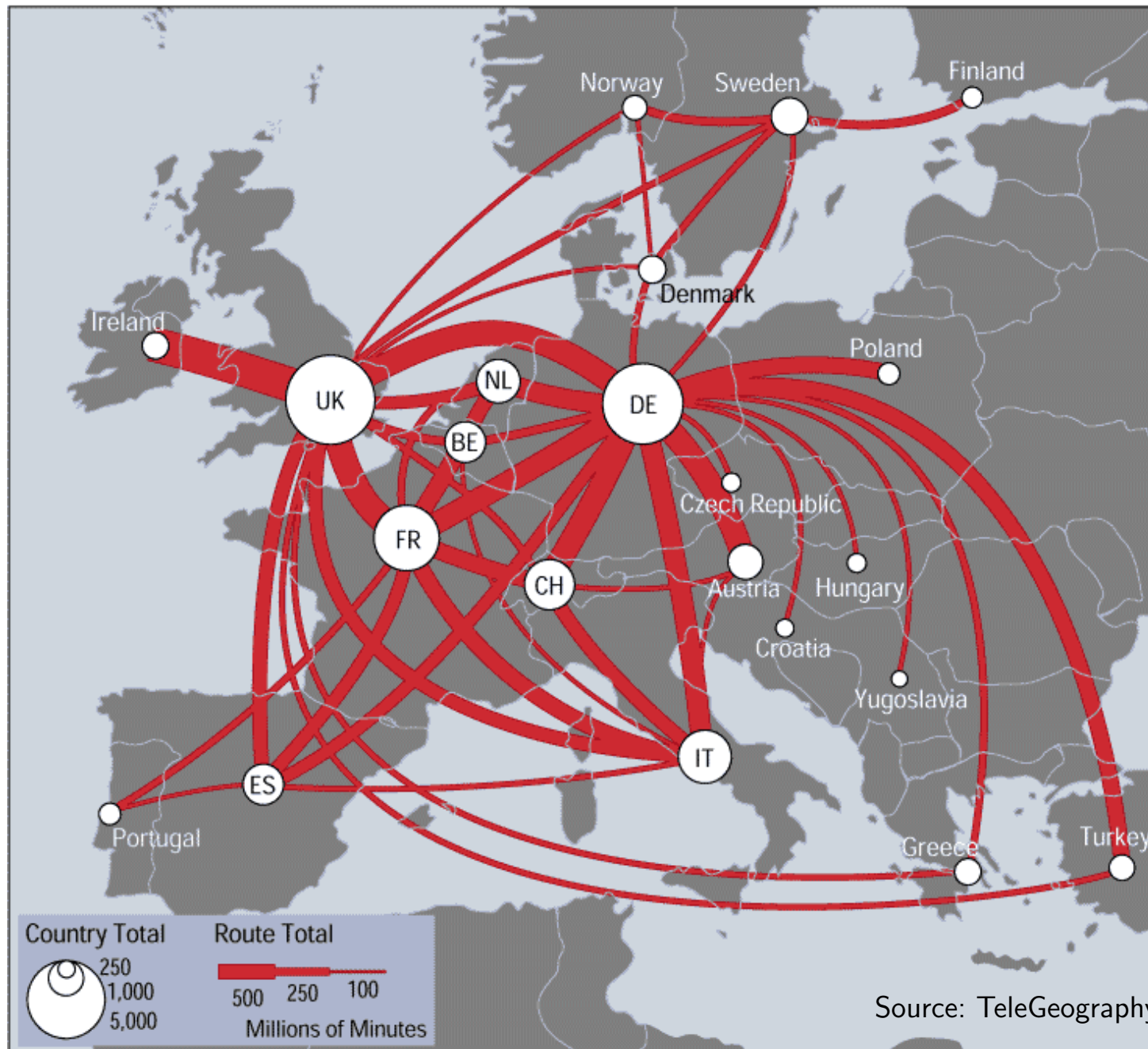


Flow-Map: Whiskey Export



Source: Verbeek, Buchin, Speckmann., 2011

Telephony Map

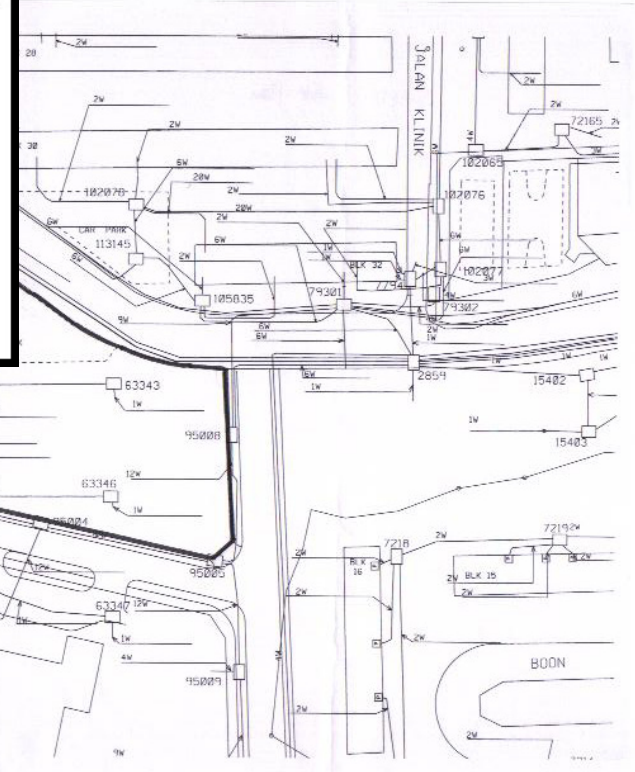
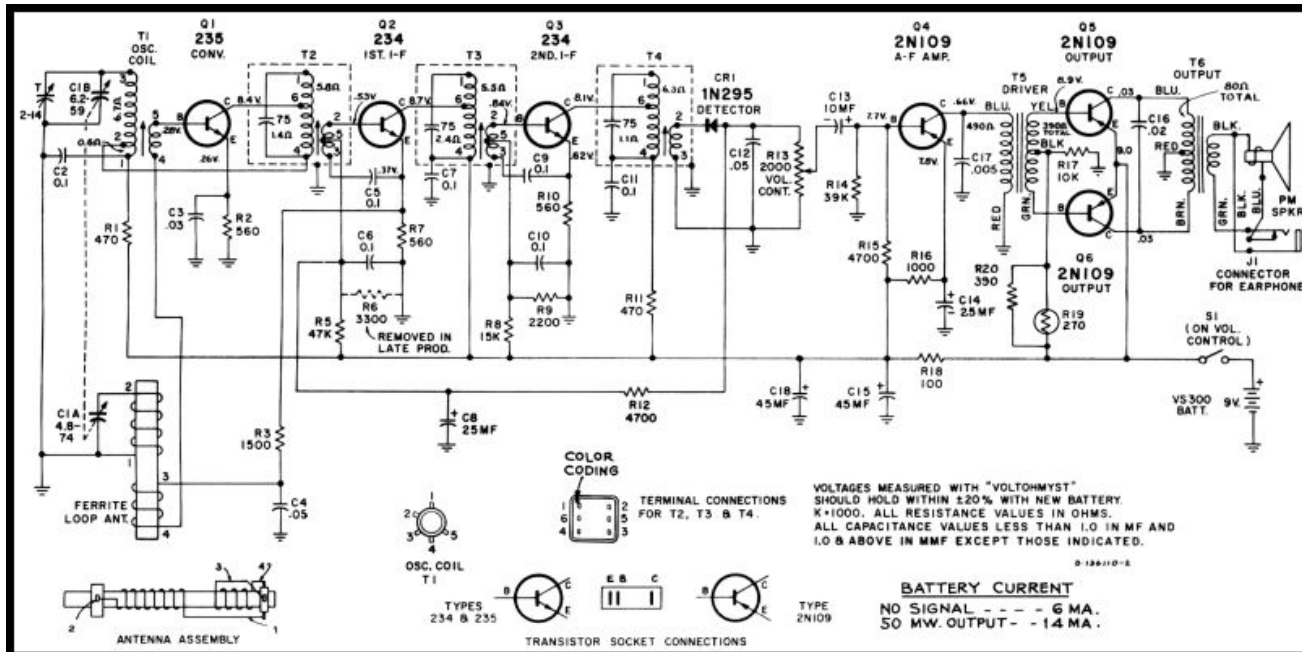


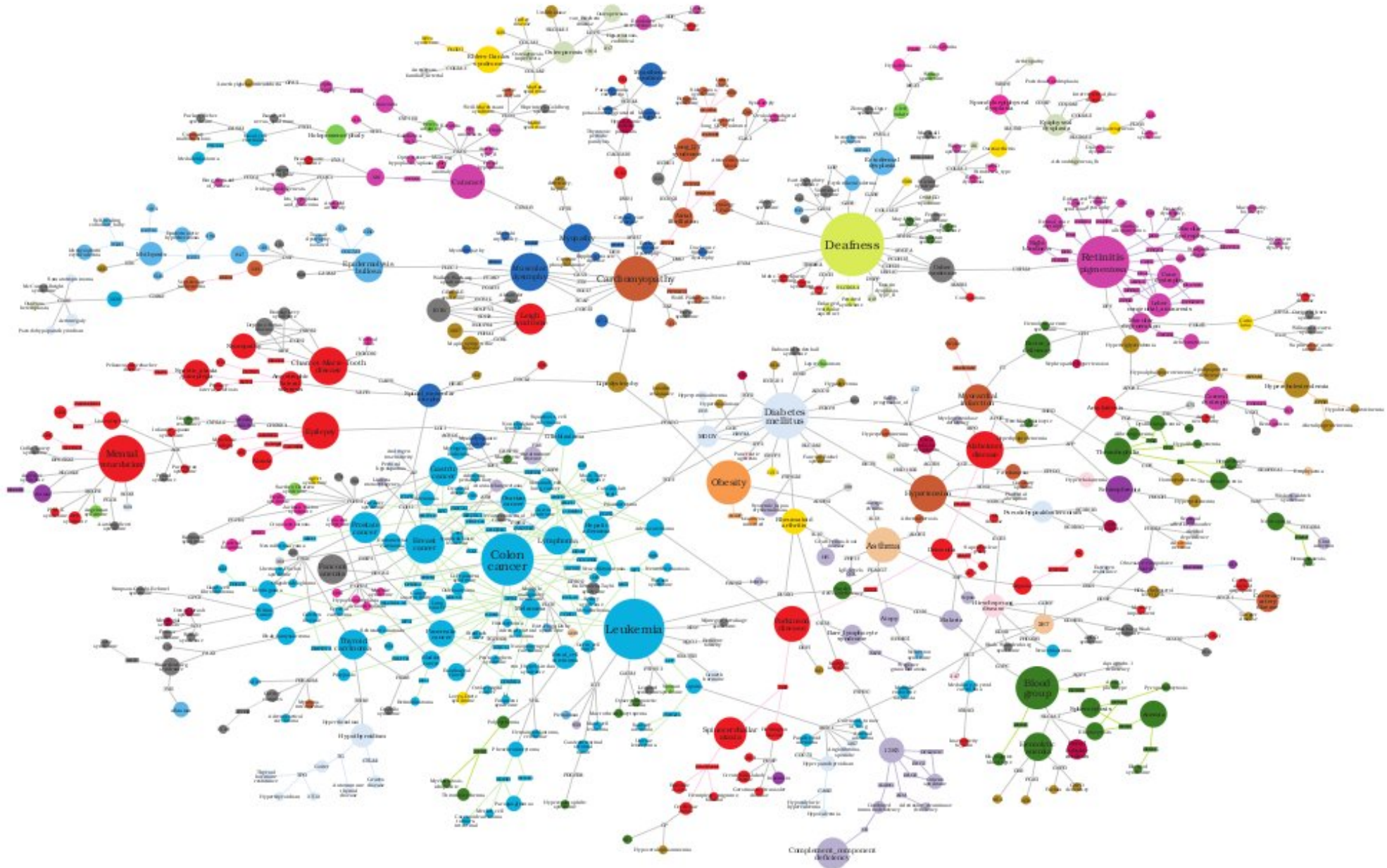
Monitoring of Energy Network



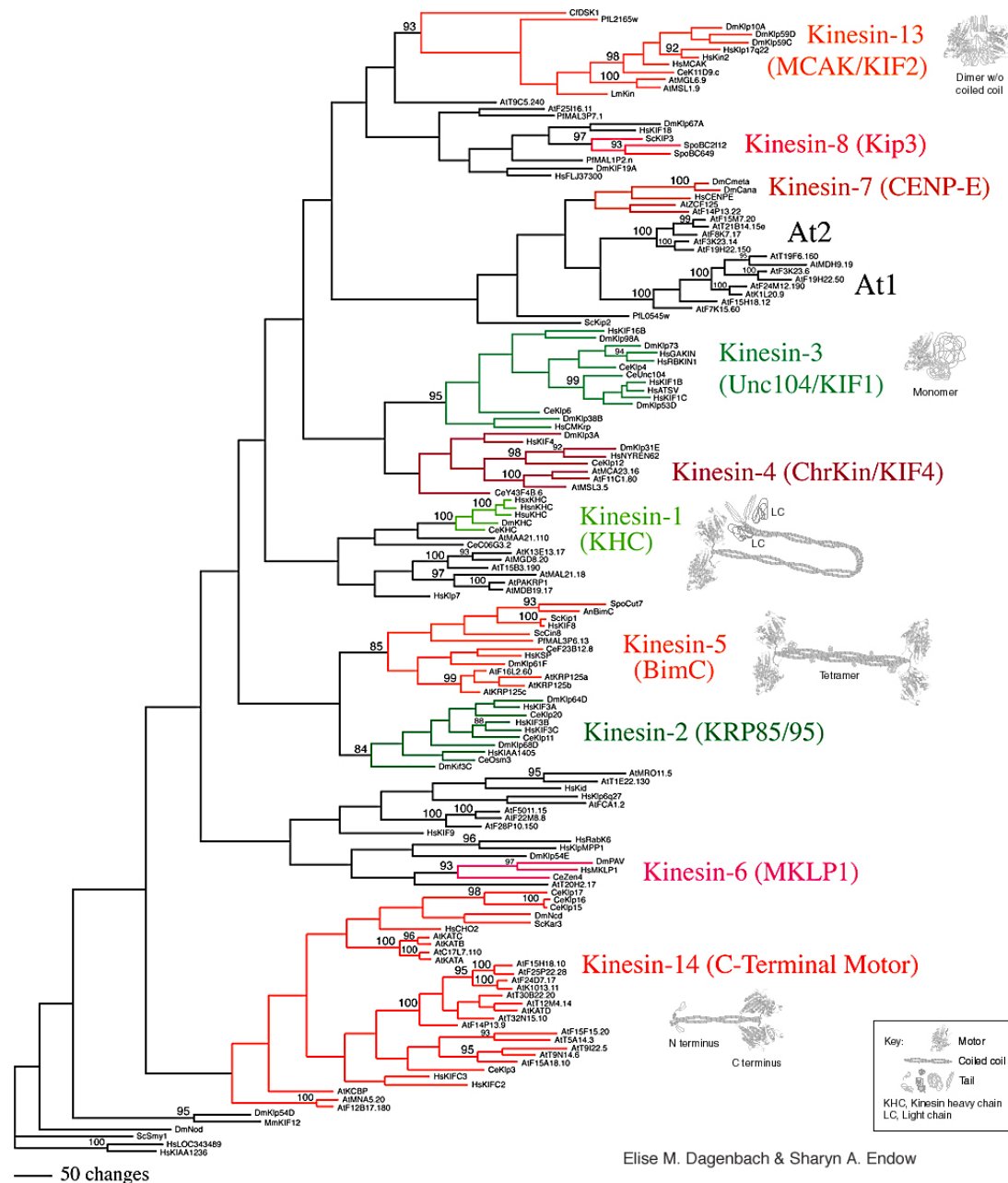
Source: Eir Grid, Ireland

Wiring plan/ Cable plan

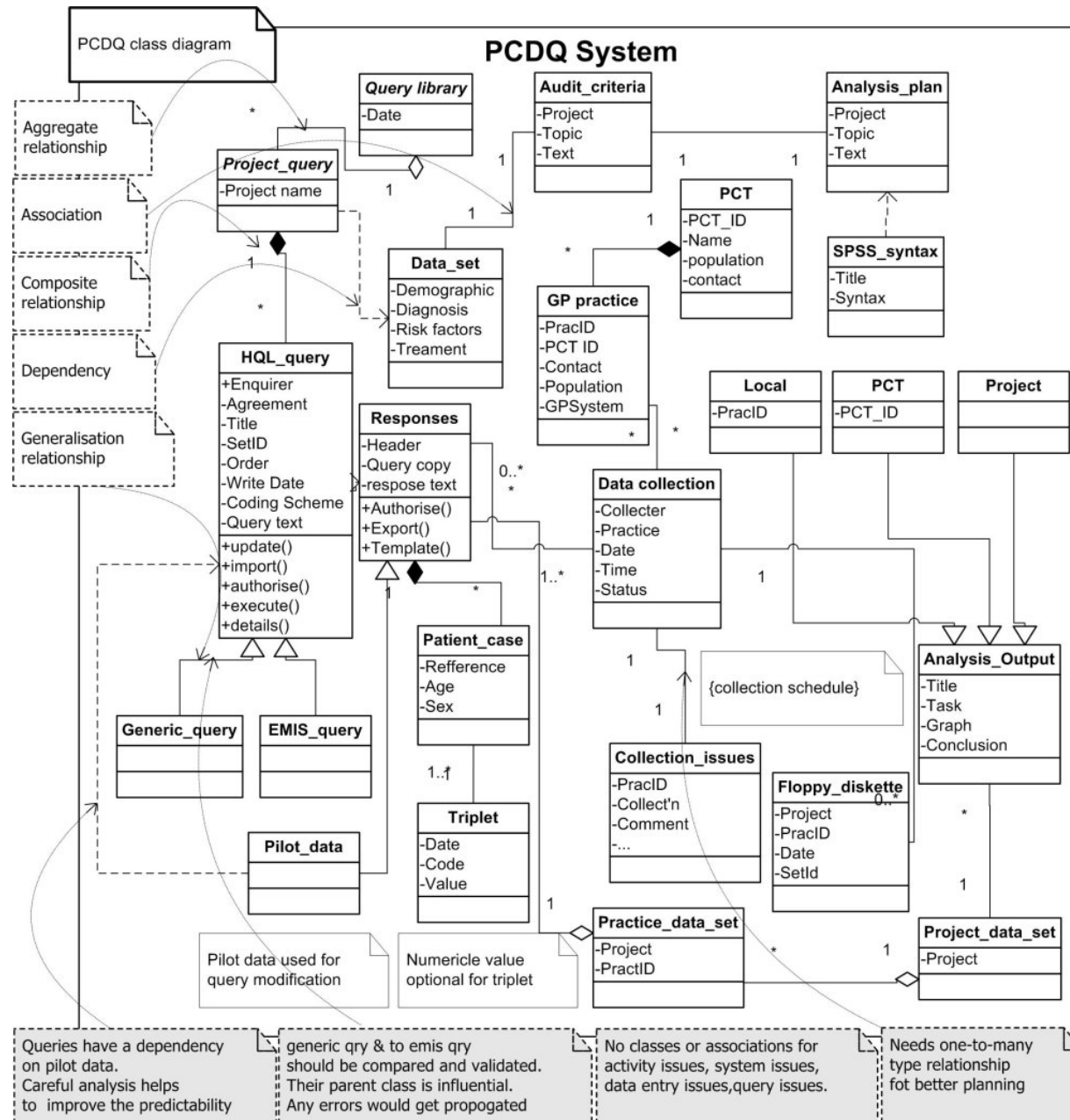




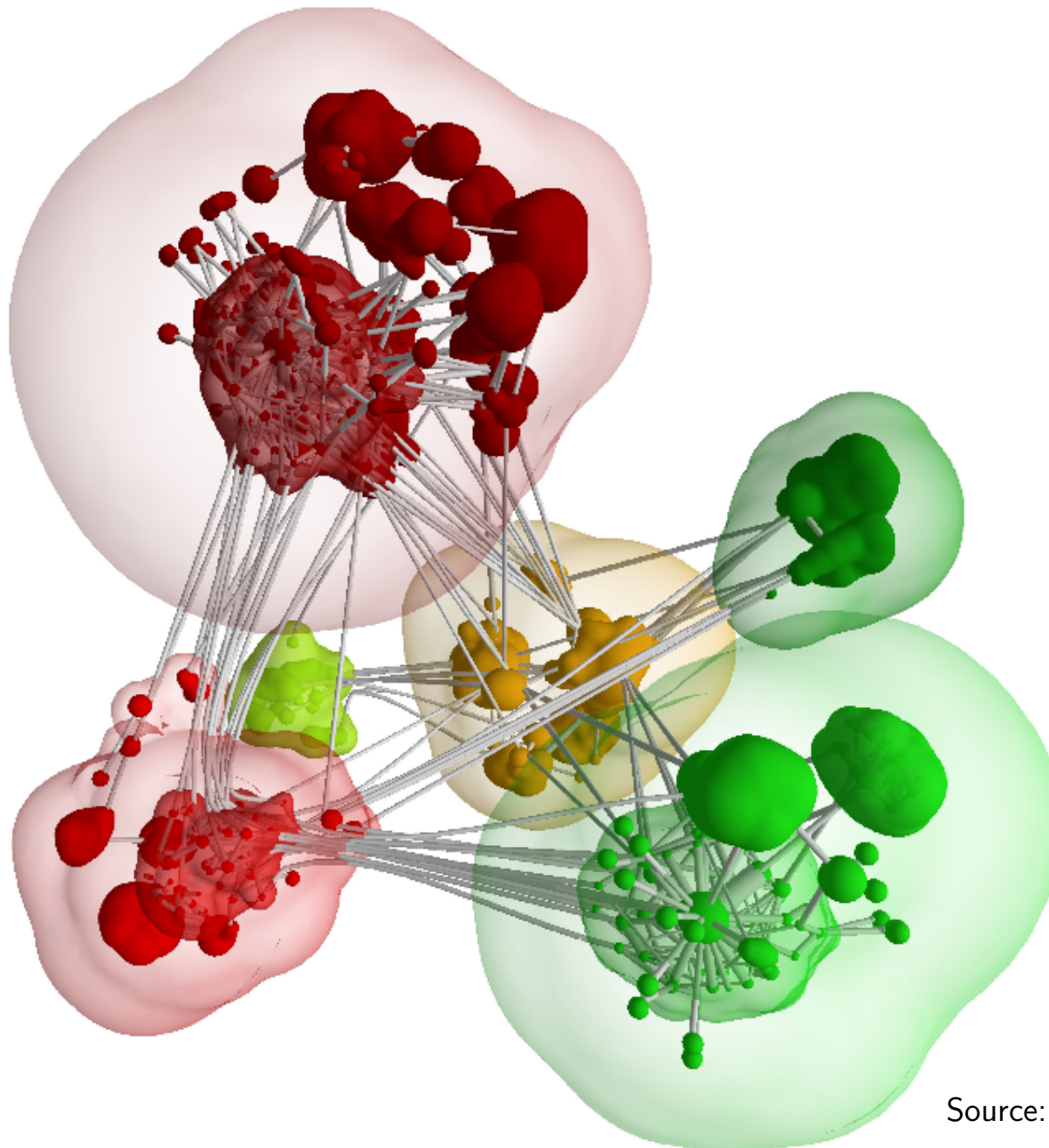
Medicine – phylogenetic Tree



Software-Network – UML Diagram

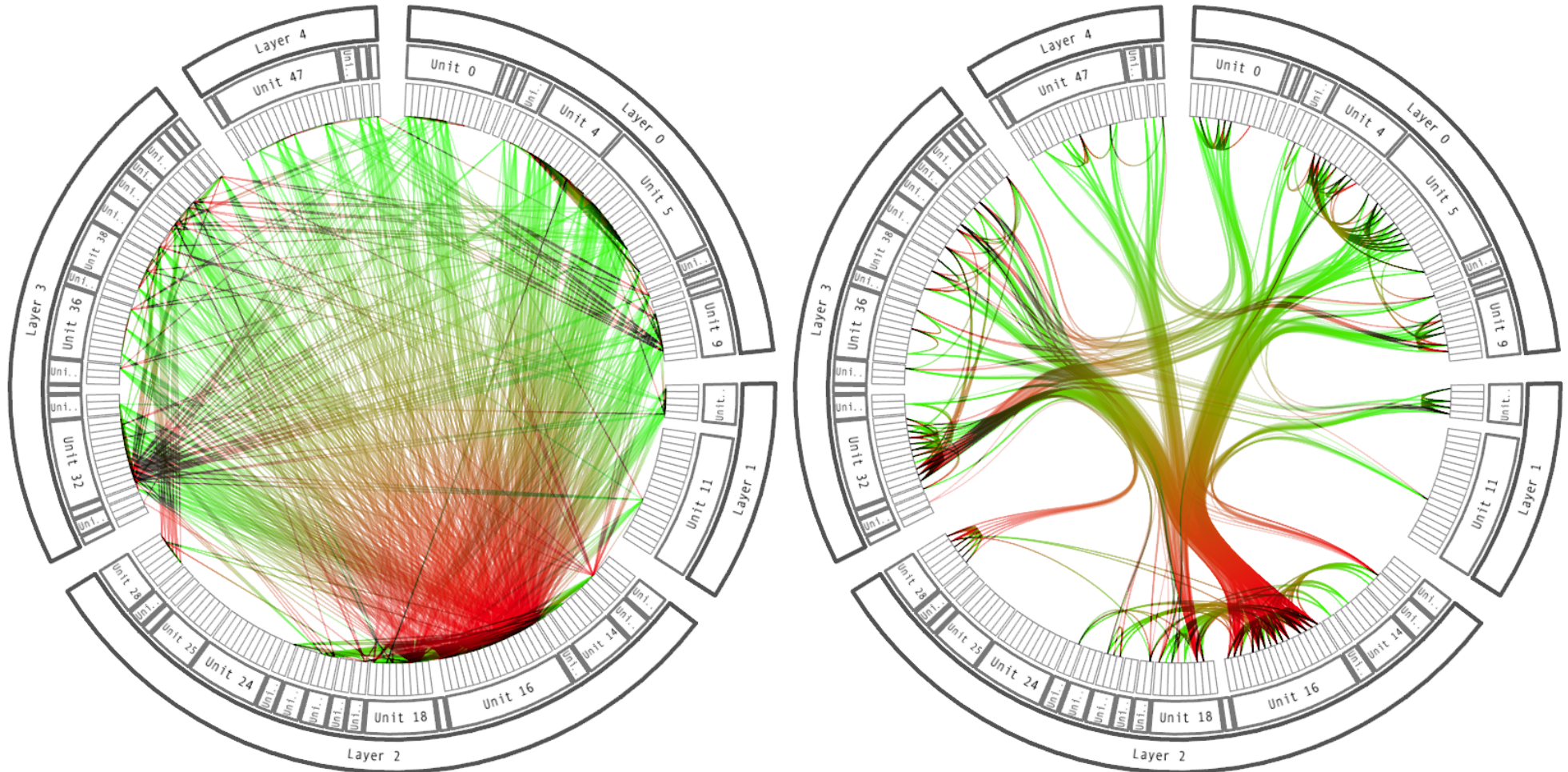


Clustered Software-Graph in 3D



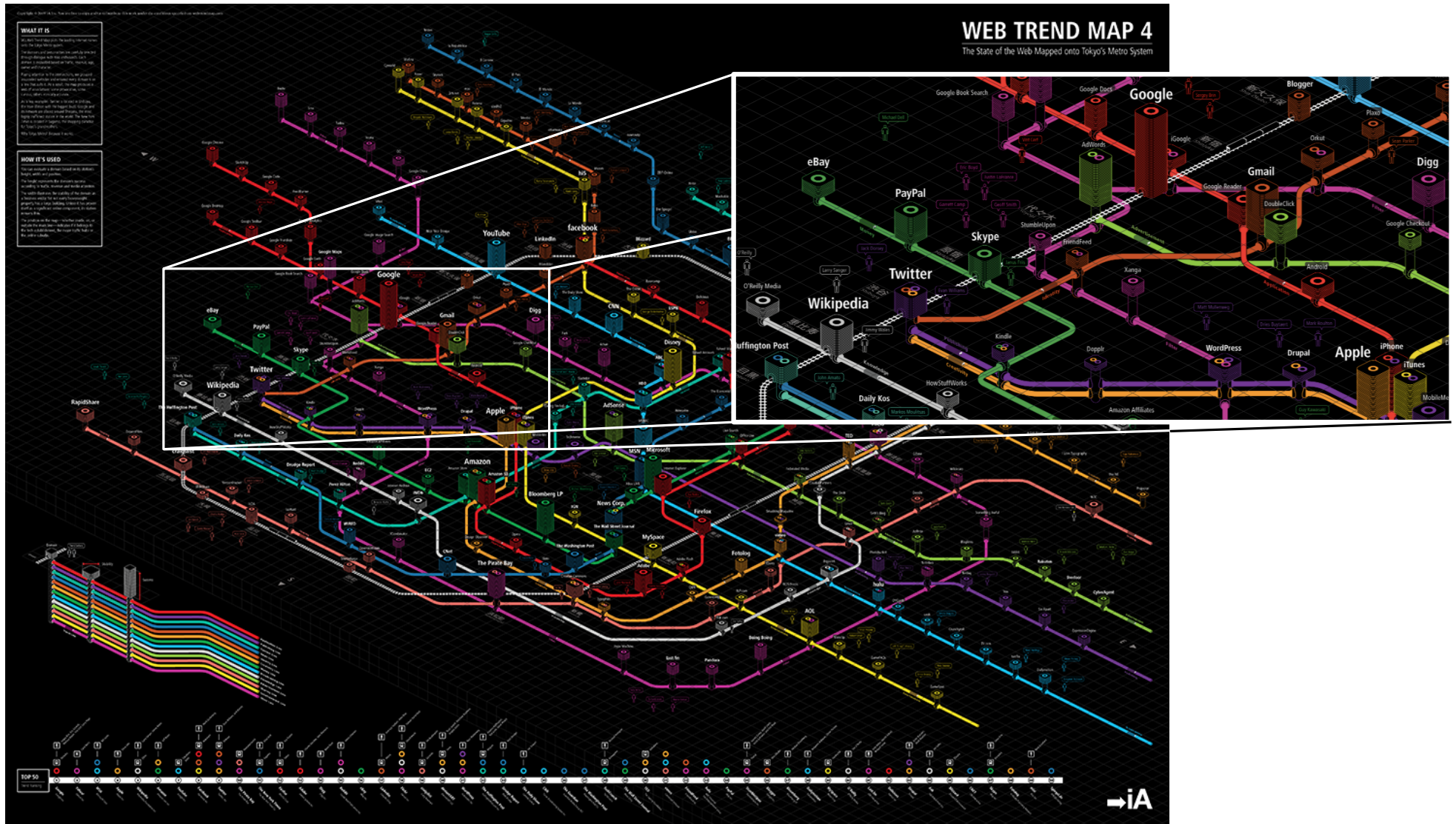
Source: Balzer, Deussen, 2007

Software Call-Graph with edge-bundling



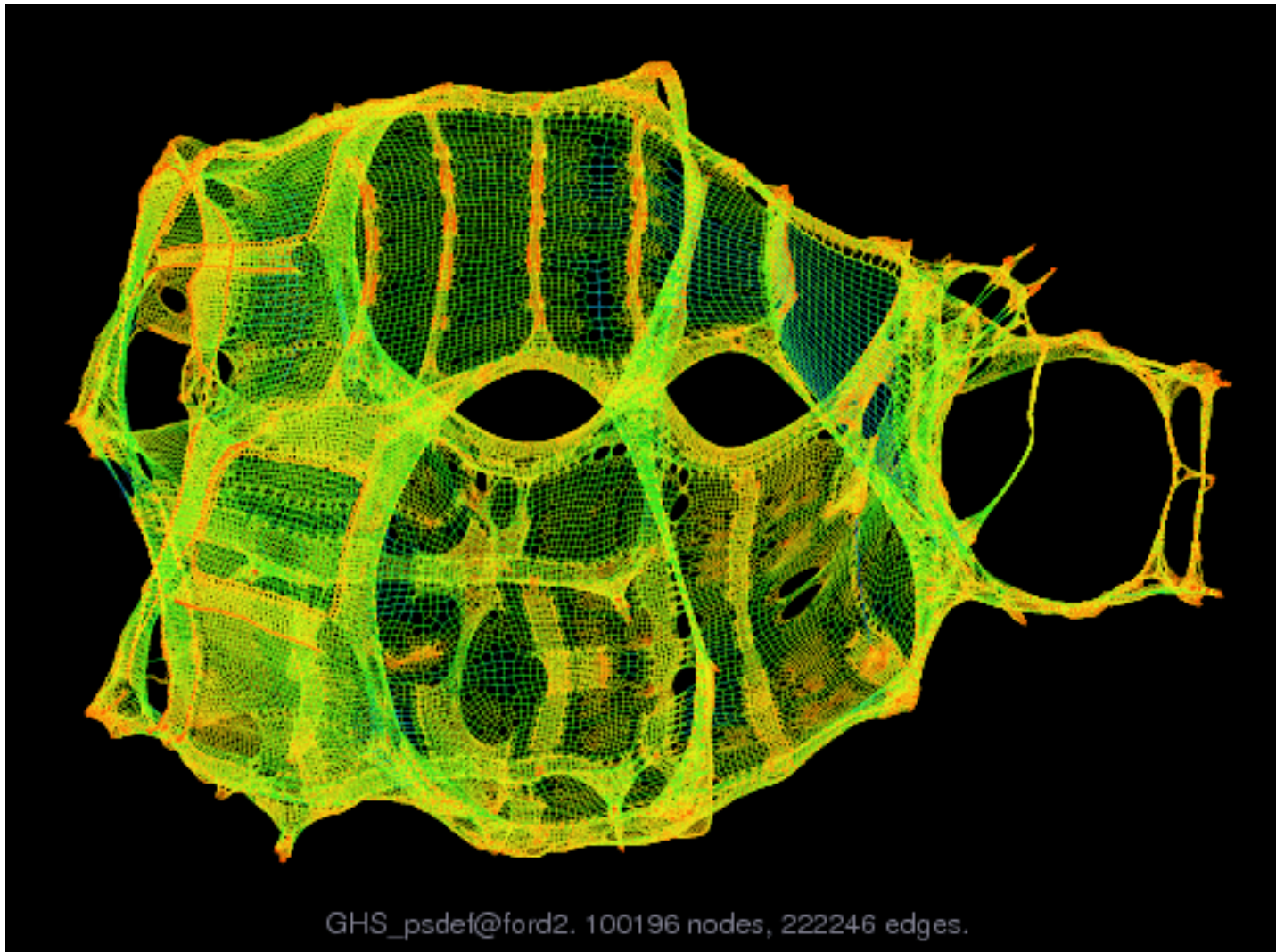
Source: Danny Holten, 2011

Web Trend Map



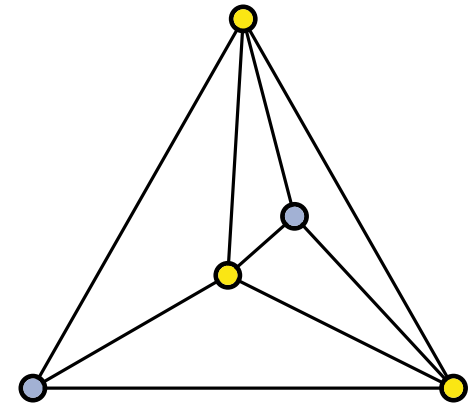
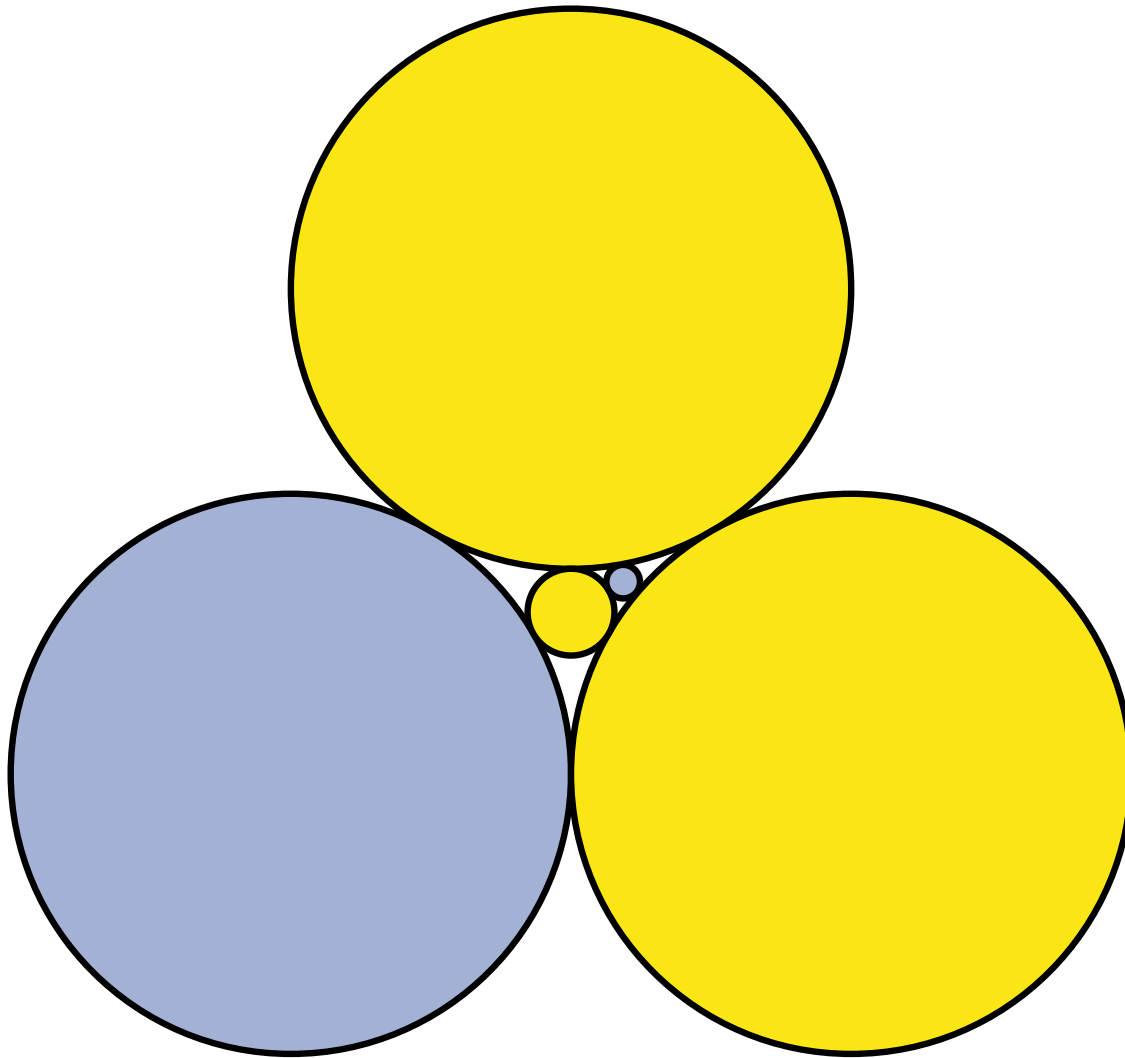
Source: information Architects, 2009

Large Graphs – Object Mesh



Source: Yifan Hu

Alternative Visualizations: Contact map



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 26.10, 2.11 14:00

Exercise on 8.11 14:00

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Topic Tree Layouts

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