

VISUALIZING TREES AND GRAPHS

Petra Isenberg

RECAP

you have learned about

- simple plots
- multi-attribute data visualization

DATA AND ITS STRUCTURE

STRUCTURED DATA



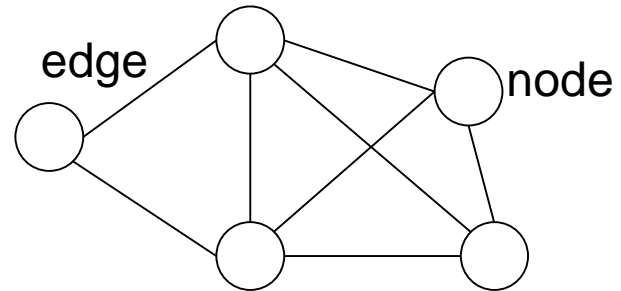
0.103	0.176	0.387	0.300	0.379
0.333	0.384	0.564	0.587	0.857
0.421	0.309	0.654	0.729	0.228
0.266	0.750	1.056	0.936	0.911
0.225	0.326	0.643	0.337	0.721
0.187	0.586	0.529	0.340	0.829
0.153	0.485	0.560	0.428	0.628

UNSTRUCTURED DATA



STRUCTURED DATA

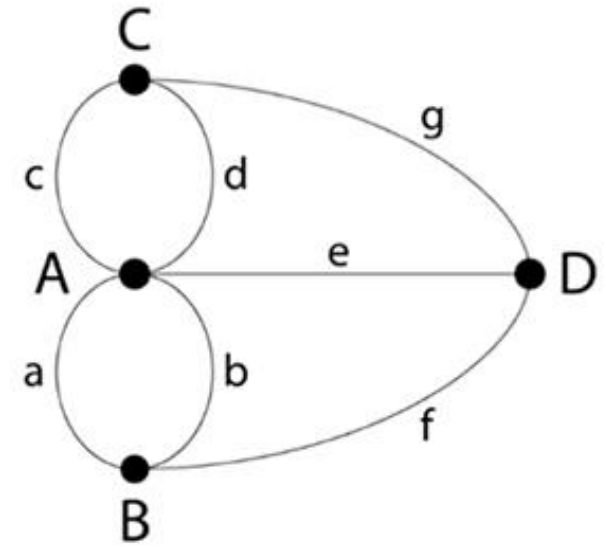
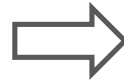
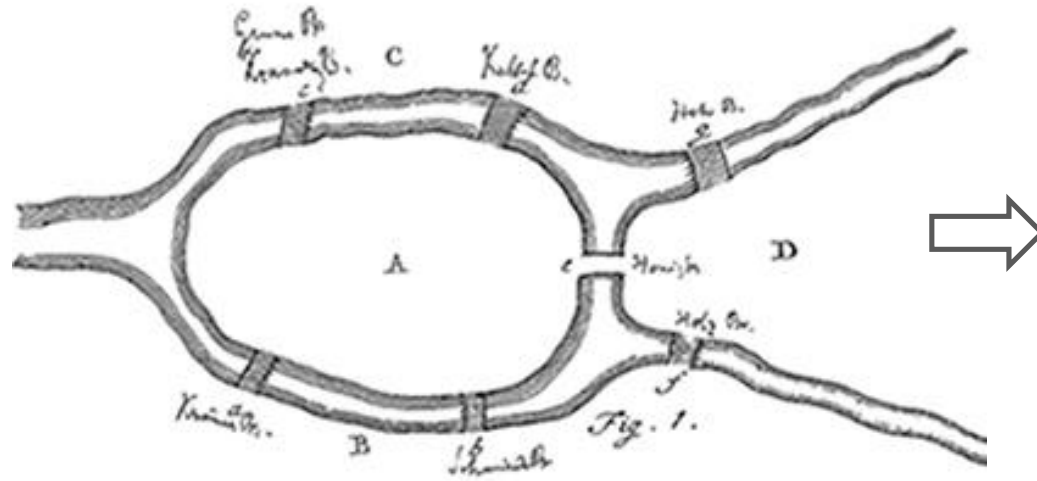
- there are relationships between the data items
- you can use a graph representation



Almost anything can be a graph

0.103	0.176	0.387	0.300	0.379
0.333	0.384	0.564	0.587	0.857
0.421	0.309	0.654	0.729	0.228
0.266	0.750	1.056	0.936	0.911
0.225	0.326	0.643	0.337	0.721
0.187	0.586	0.529	0.340	0.829
0.153	0.485	0.560	0.428	0.628

The 7 bridges of Königsberg



How can you cross all 7 bridges without crossing the same one twice?

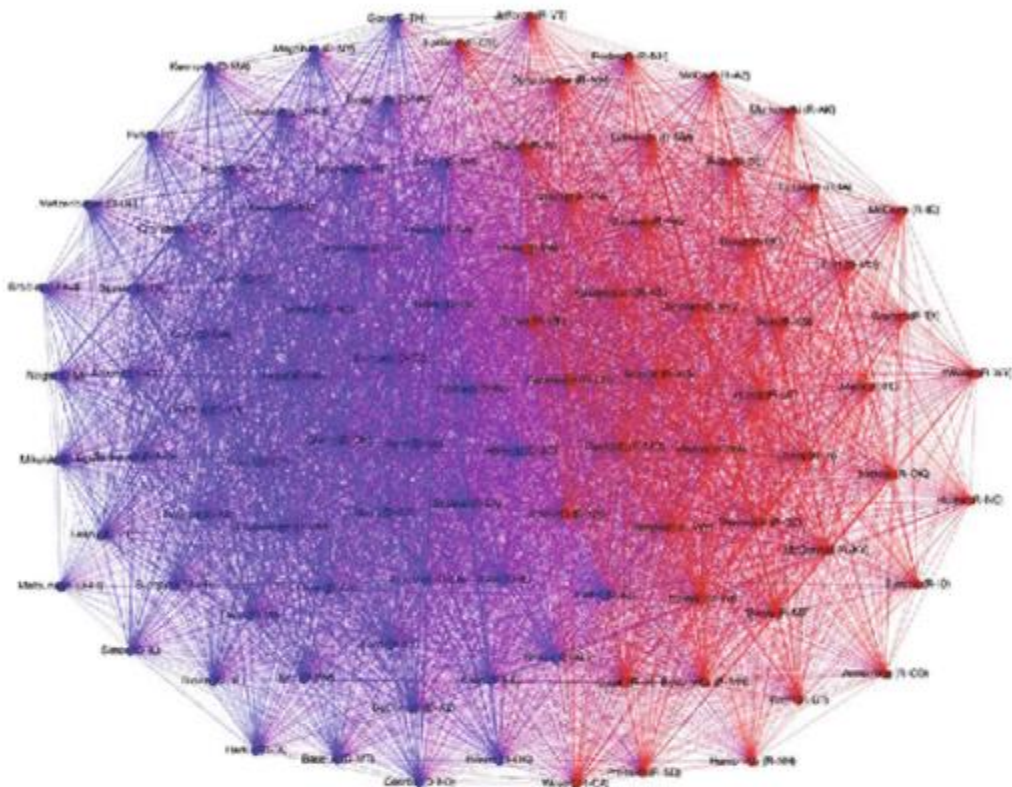
Euler's conceptualization of the same problem

Senators casting the same votes

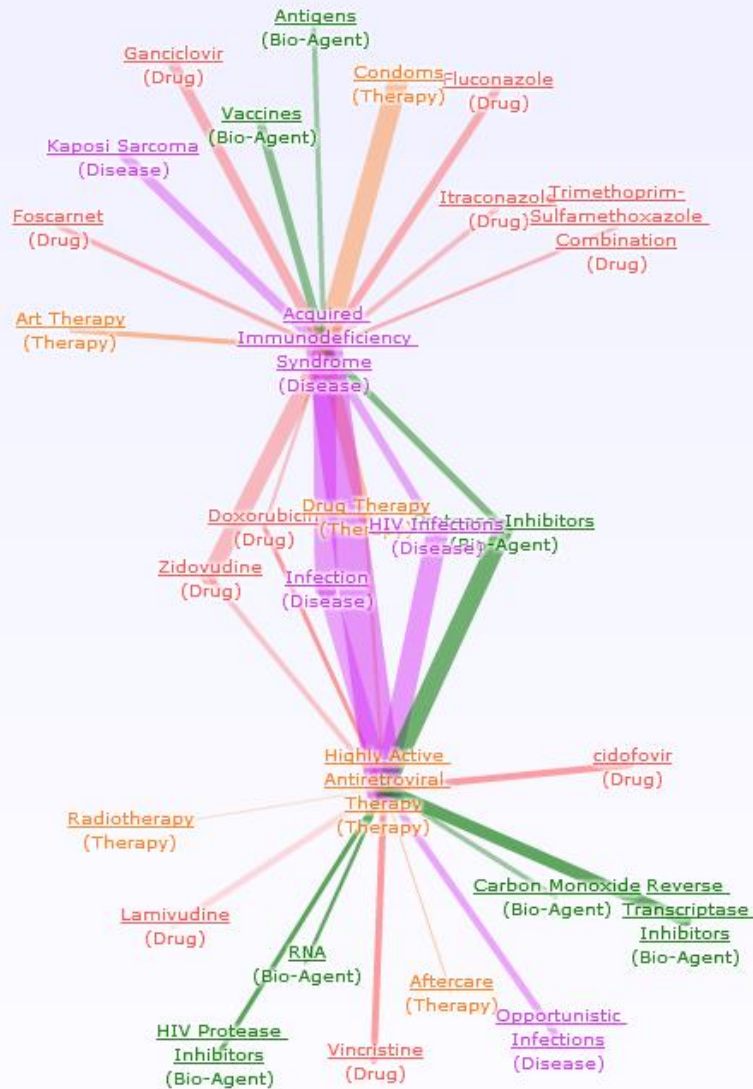
Democrat

Republican

101st Congress, 1989 session



107th Congress, 2002 session



<http://www.curehunter.com>

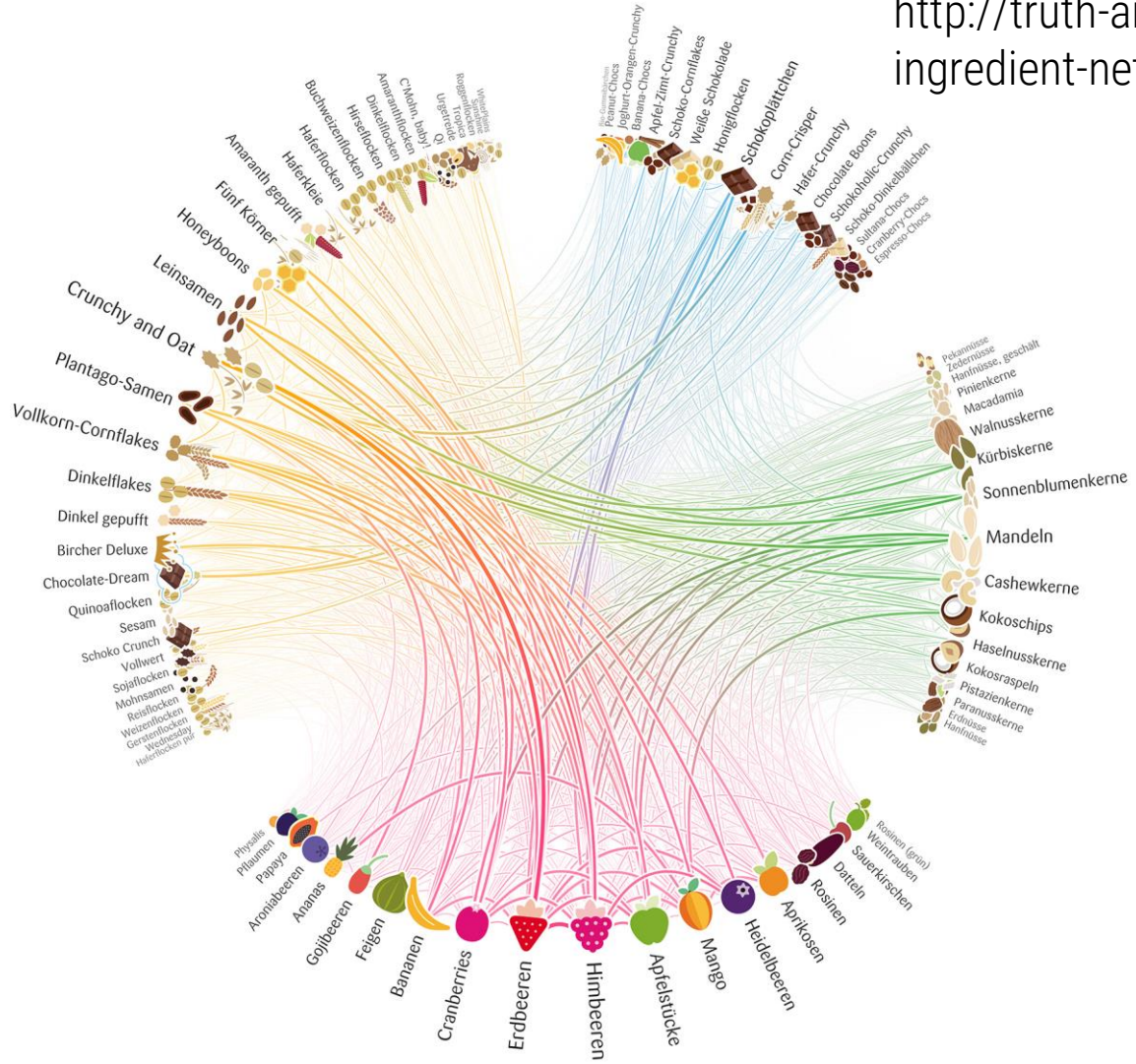
visual dictionary of drugs, diseases and therapies

<https://dhs.stanford.edu/spatial-humanities/visualizing-databases/>



Top Contributors to the Catalogue of Life and their associated species, references and databases

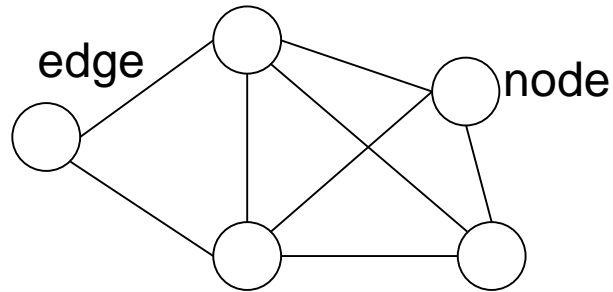
<http://truth-and-beauty.net/projects/muesli-ingredient-network>



GRAPHS

Graphs

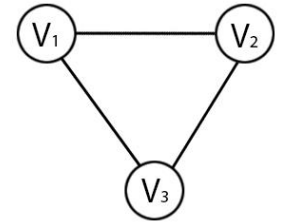
- Describe relations among data items
- Using **nodes** and **edges**



DEFINITIONS

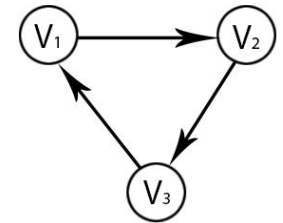
undirected graph: edges have no orientation

Undirected Graph



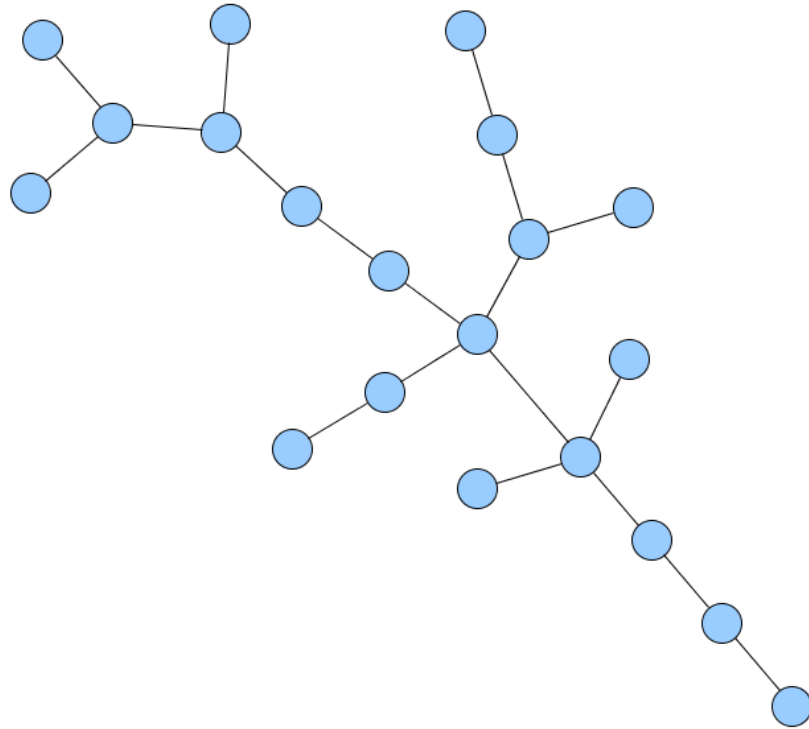
directed graph (digraph): edges have orientation

Directed Graph



DEFINITIONS

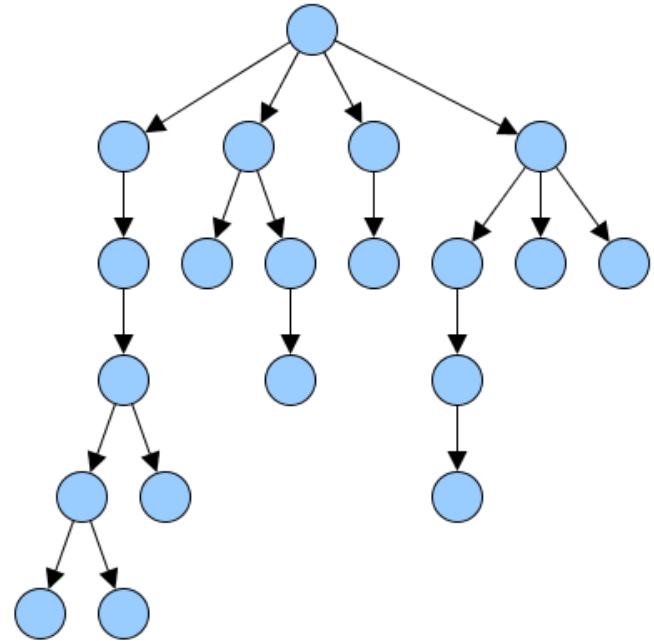
a tree is a **connected graph with no cycles**



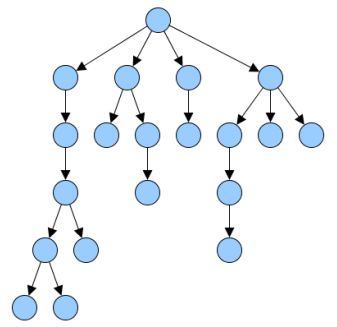
DEFINITIONS

a directed tree is a digraph (directed graph) whose underlying graph is a tree

- a directed tree consists of a number of **nodes** and **parent-child relationships**
- every node has just one **parent** and any number of **children**
- *directed trees are the most common form in computer science*



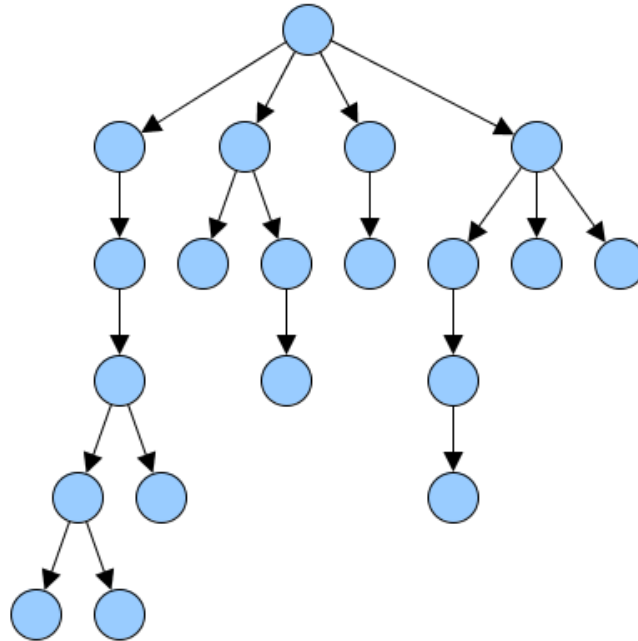
DEFINITIONS



- a **rooted tree** is a directed tree with a distinguished vertex r , called the **root**, such that for every other vertex v there is directed path from r to v
- the root node is the only node with no parent
- any node may act as a root in undirected trees

DEFINITIONS

the connection between parent and child nodes
is called an **edge**



EXAMPLES OF TREES

HIERARCHIES

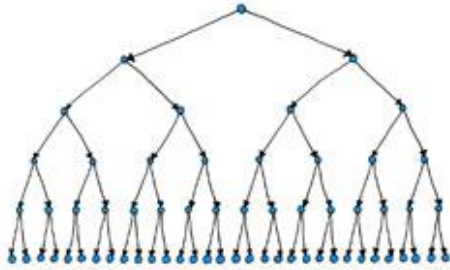
	Name	Date modified	Type	Size
> Videos				
> Public (\\192.168.212.40) (B:)				
▼ Local Disk (C:)				
> Anaconda3				
> Android				
> Dell				
> Intel				
MSOCache				
> NVIDIA				
> OneDriveTemp				
PerfLogs				
> Program Files				
> Program Files (x86)				
> ProgramData				
> Python27				
> Python33				
TEMP				
> totalcmd				
> Users				
> Windows				
	DLLs	23-Mar-16 13:39	File folder	
	Doc	23-Mar-16 13:39	File folder	
	include	23-Mar-16 13:39	File folder	
	Lib	23-Mar-16 13:39	File folder	
	libs	23-Mar-16 13:39	File folder	
	Scripts	23-Mar-16 15:20	File folder	
	tcl	23-Mar-16 13:39	File folder	
	Tools	23-Mar-16 13:39	File folder	
	ez_setup.py	23-Mar-16 13:42	Python File	12 KB
	LICENSE.txt	09-Mar-14 10:37	TXT File	31 KB
	NEWS.txt	09-Mar-14 10:27	TXT File	258 KB
	python.exe	09-Mar-14 10:35	Application	40 KB
	pythonw.exe	09-Mar-14 10:35	Application	40 KB
	README.txt	09-Mar-14 10:27	TXT File	7 KB
	setuptools-20.3.1.zip	23-Mar-16 13:43	Compressed (zipp...	706 KB

HIERARCHIES

OrgOrgChart

Autodesk Research

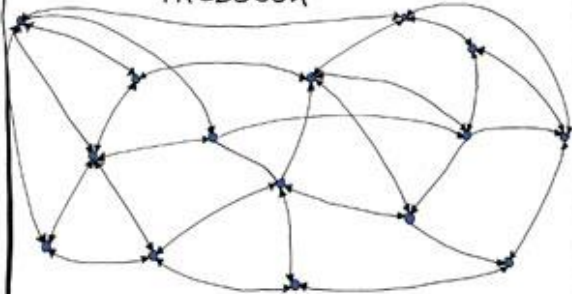
AMAZON



GOOGLE



FACEBOOK



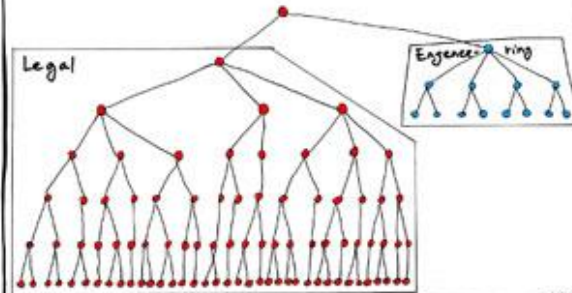
MICROSOFT



APPLE



ORACLE



org charts aren't always trees, though

<http://www.bonkersworld.net/organizational-charts/>

DECISION PROCESS

NADAL

Indian Wells >

Monte-Carlo >

Madrid >

Rome >

Roland Garros >

Brands 4-6, 7-6(4), 6-4, 6-3

Klizan 4-6, 6-3, 6-3, 6-3

Fognini 7-6(5), 6-4, 6-4

Nishikori 6-4, 6-1, 6-3

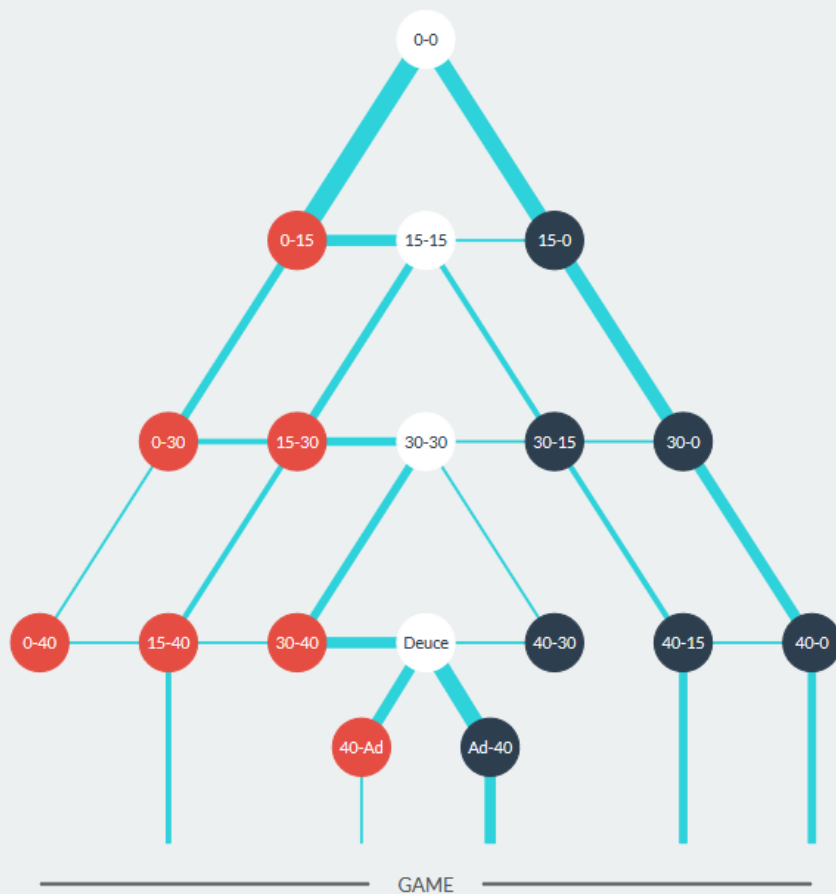
Wawrinka 6-2, 6-3, 6-1

Djokovic 6-4, 3-6, 6-1, 6-7(3), 9-7

Ferrer 6-3, 6-2, 6-3

Wimbledon >

Rogers Cup >



BRANCHING PROCESSES

Think about it: is a family tree really a tree?

GeneaQuilts

A System for Exploring
Large Genealogies

A.Bezerianos P.Dragicevic J.-D.Fekete J.Bae B.Watson

<https://www.youtube.com/watch?v=gncBzql7R-Q>

TREE REPRESENTATION

TECHNIQUES

Dimensionality



Representation



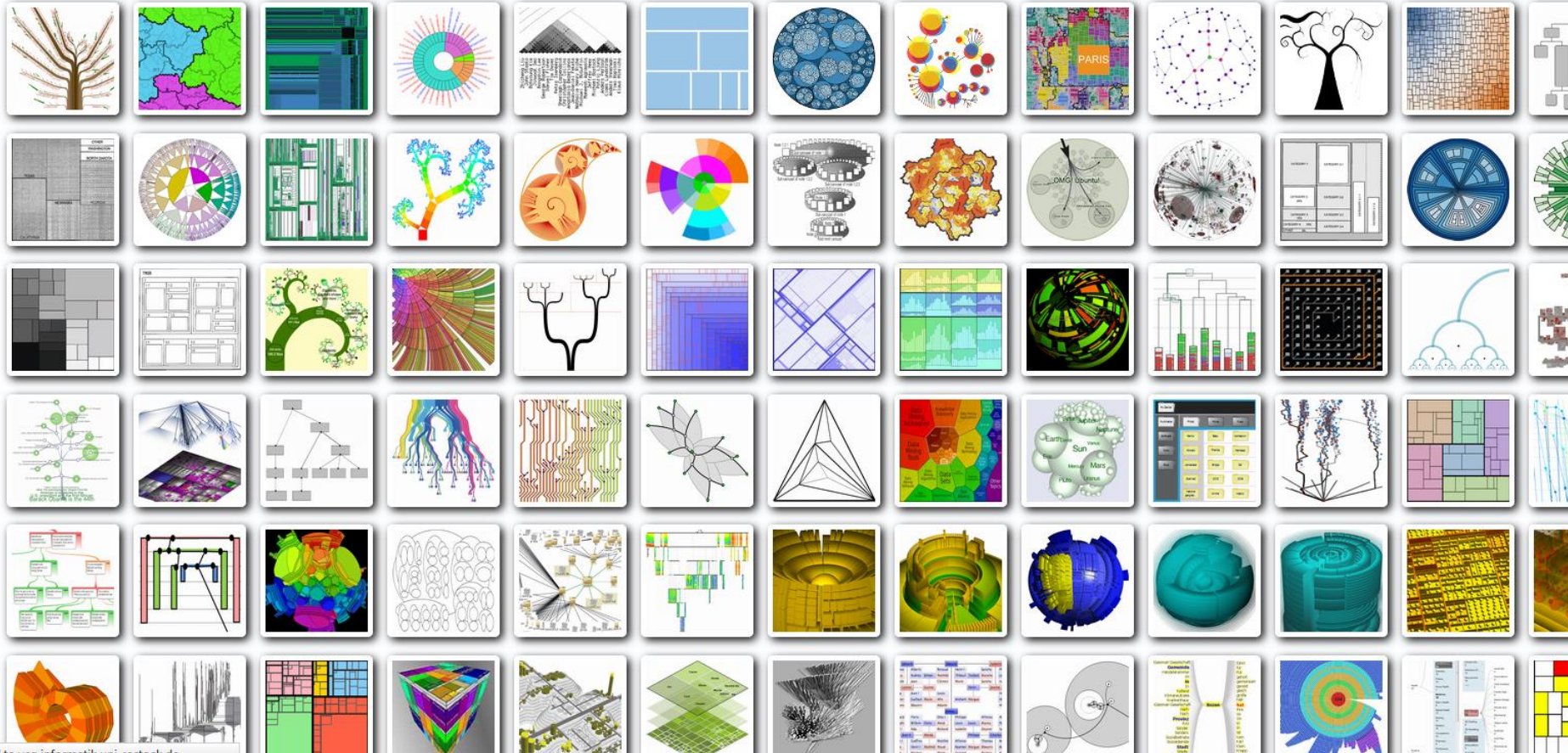
Alignment



Fulltext Search

Techniques Shown

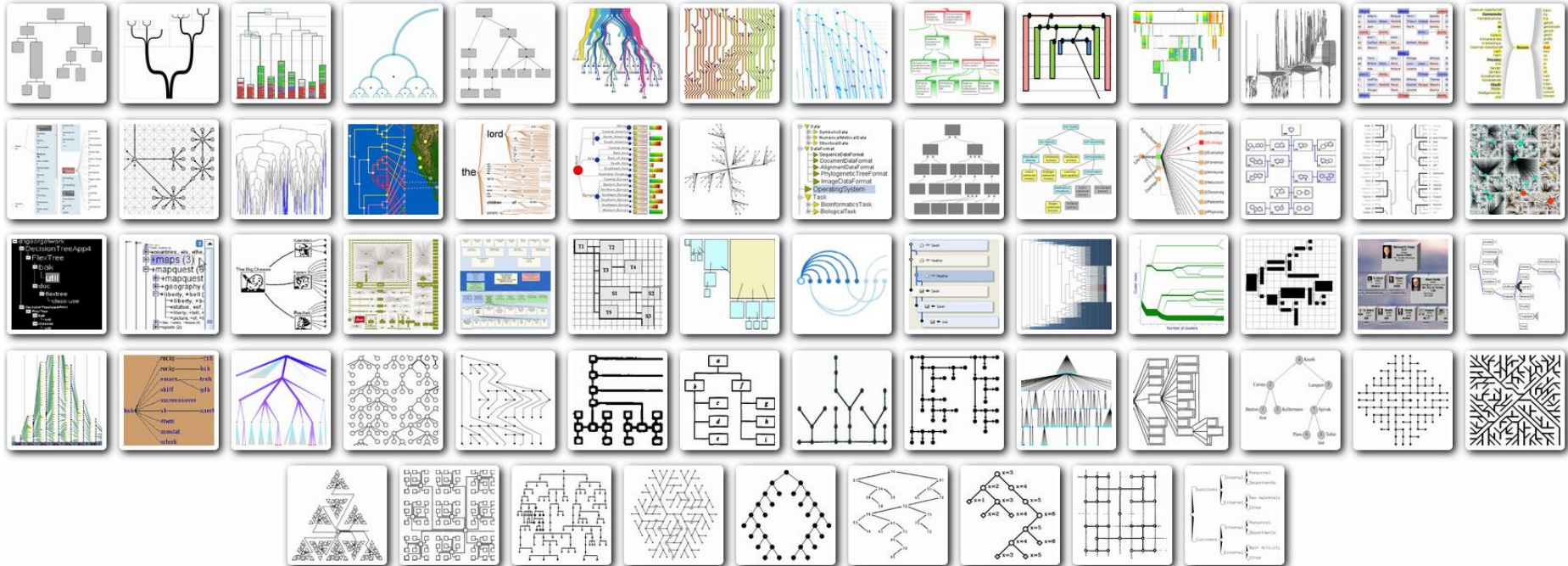
292



CATEGORIZATIONS OF LAYOUTS

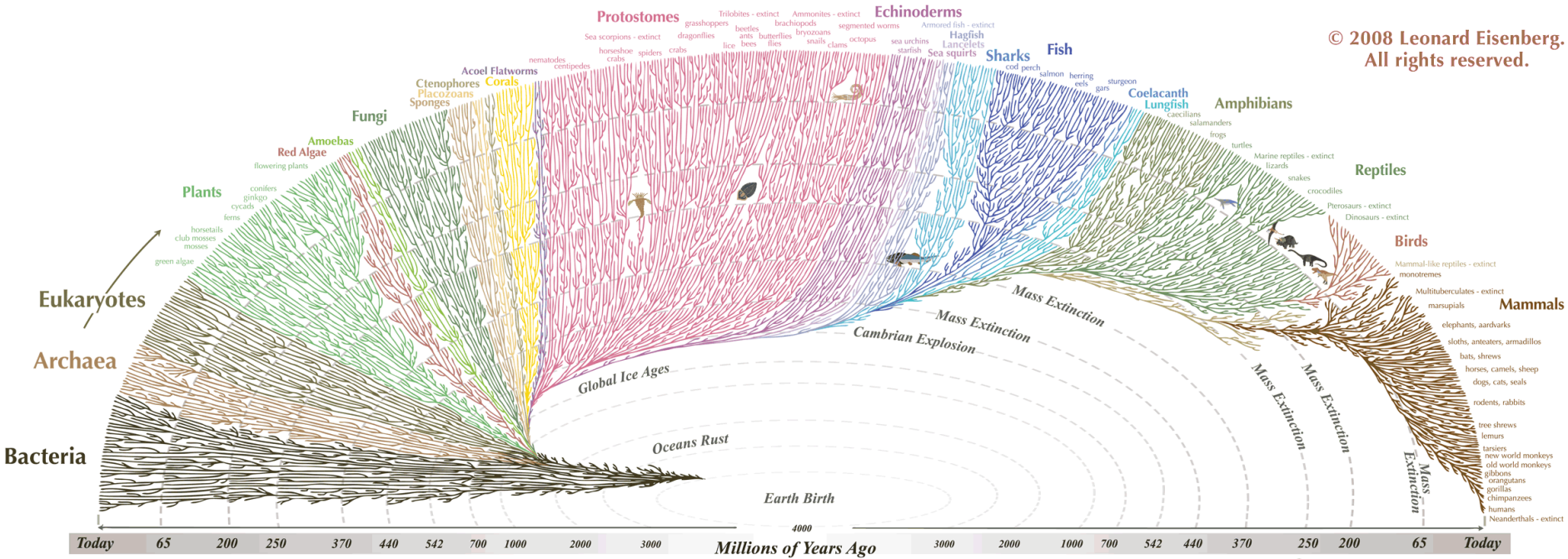
- many possible
- here we follow the categorization on treevis.net:
 - Dimensionality of the layout
 - Representation type
 - Alignment of nodes in space


2D, AXIS-PARALLEL, EXPLICIT EDGES



NODE-LINK

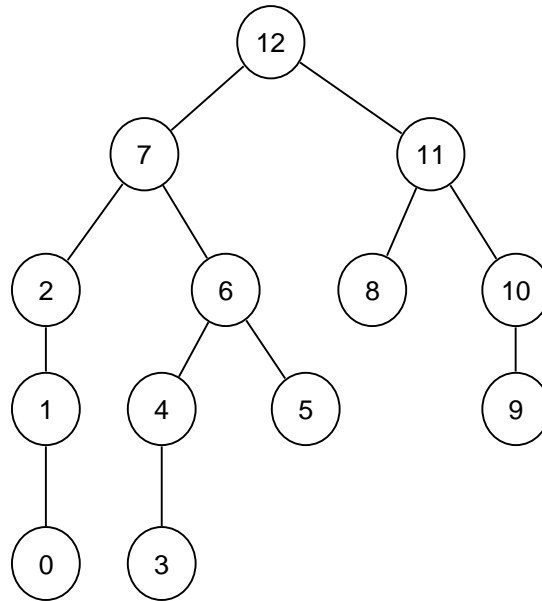
© 2008 Leonard Eisenberg.
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All the major and many of the minor living branches of life are shown on this diagram, but only a few of those that have gone extinct are shown. Example: Dinosaurs - extinct 

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evogeneao.com

NODE-LINK ALGORITHM

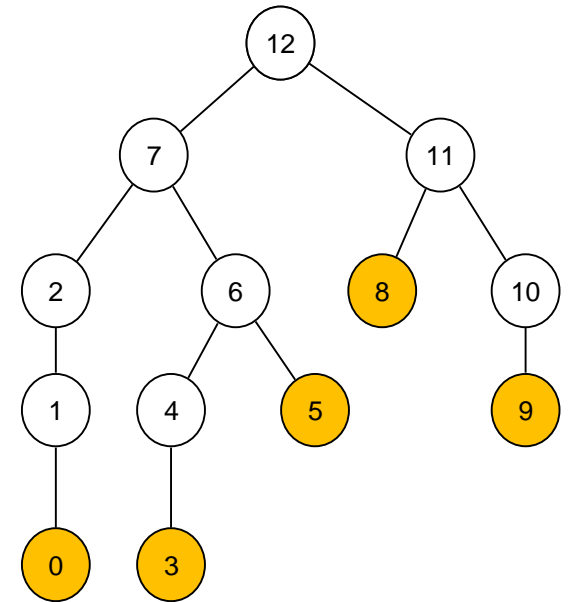
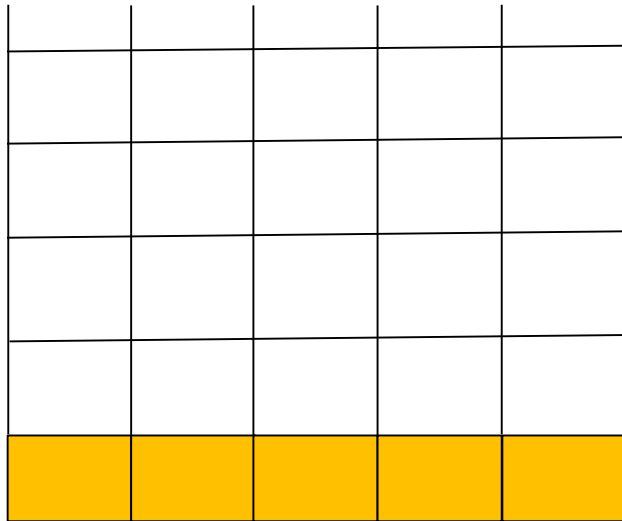


THE LAYOUT WE WANT – HOW DO WE GET THERE?

NODE-LINK ALGORITHM

SIMPLE APPROACH

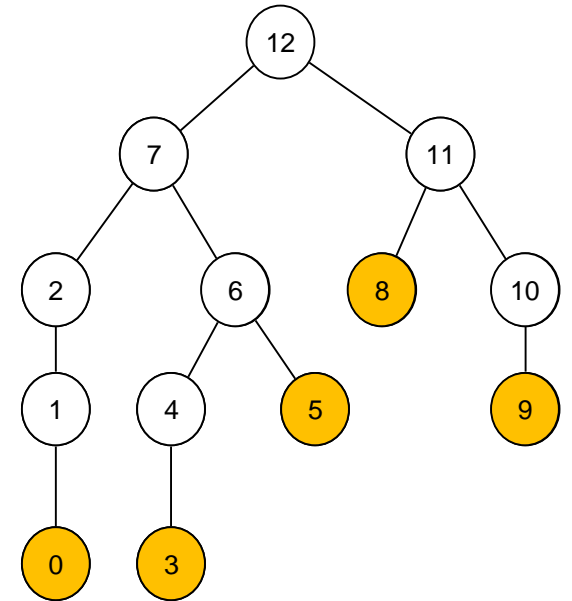
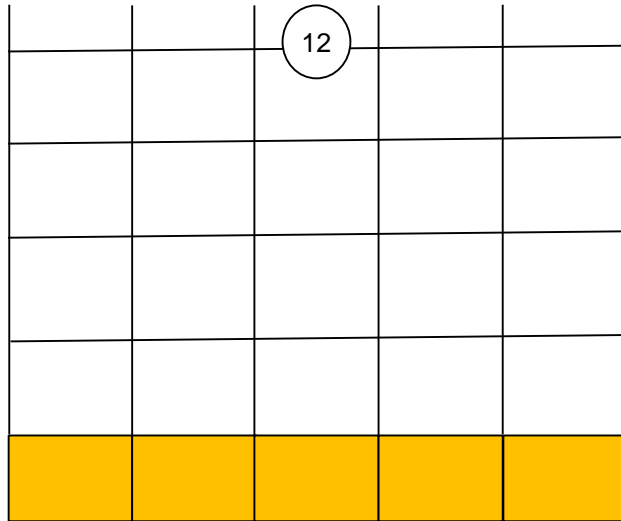
- 1) COUNT THE LEAVES
- 2) PLACE THE ROOT



NODE-LINK ALGORITHM

SIMPLE APPROACH

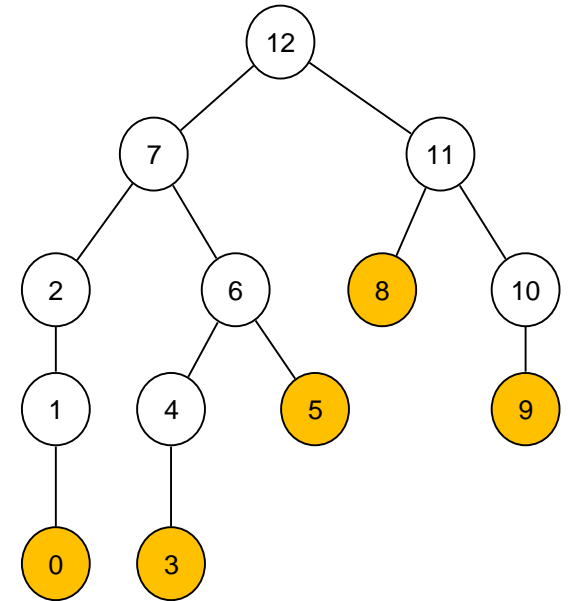
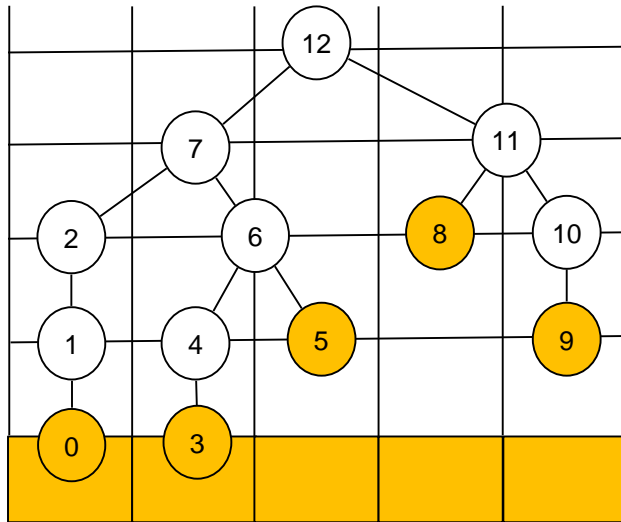
- 1) COUNT THE LEAVES
- 2) PLACE THE ROOT
- 3) RECURSIVELY DIVIDE



NODE-LINK ALGORITHM

SIMPLE APPROACH

- 1) COUNT THE LEAVES
- 2) PLACE THE ROOT
- 3) RECURSIVELY DIVIDE

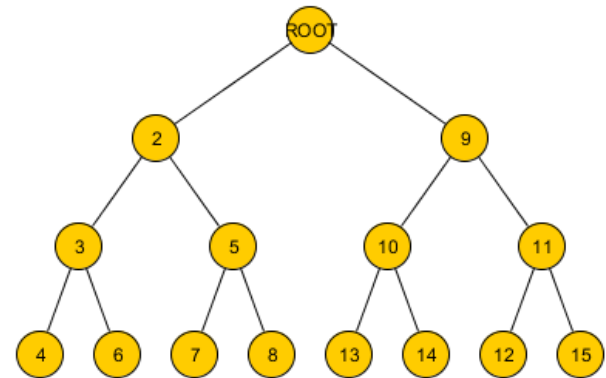


PROS/CONS

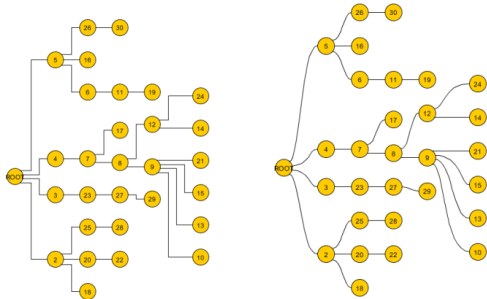
- nodes at the same distance from the root are horizontally aligned
- positive: simple to understand, clear symmetries
- negative: needs large area, often bad aspect ratio (much wider than tall)

what can we vary in this representation?

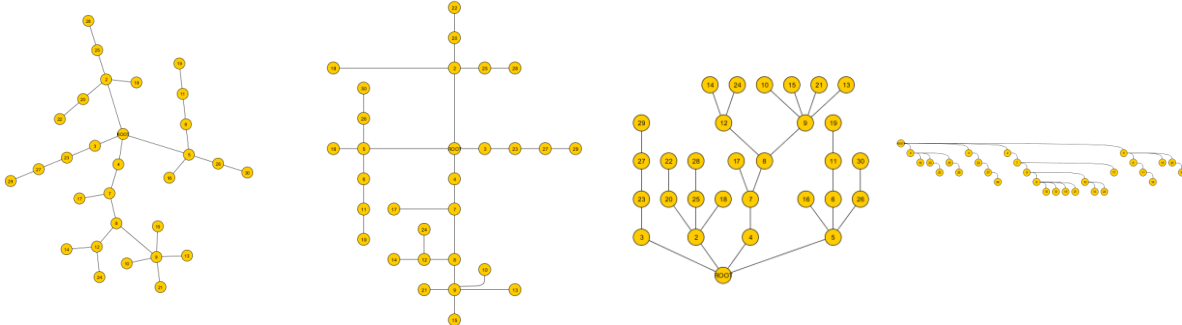
- marks that depict nodes
- visual variables used on marks to depict metadata
- type of links
- visual variables used on marks that depict the links
- placement of nodes



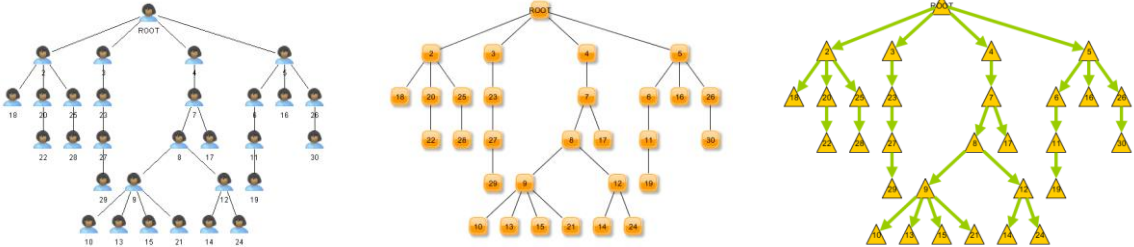
vary edges



node placement



marks



SPECIFIC ALGORITHMS

- usually described recursively
- well known: Reingold-Tilford algorithm
- lots of research in this direction:
 - Wetherell and Shannon 1978, Tidy Drawings of Trees
 - **Reingold and Tilford 1981**, Tidier Drawing of Trees
 - Walker 1990, A Node-positioning Algorithm for General Trees
 - Buchheim et al 2002, Improving Walker's Algorithm to Run in Linear Time

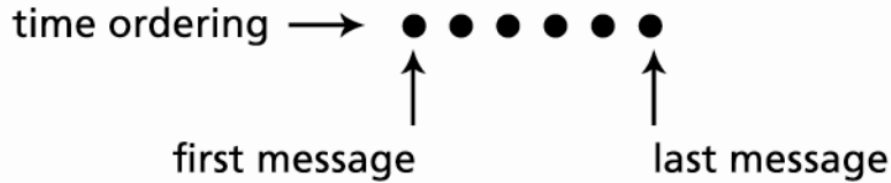
AESTHETICS

aesthetics of node-link tree algorithms describe properties that improve the perception of the data that is being layed out

- **area:** match area of your layout to the size of the display and data
- **aspect ratio:** usually optimal if close to 1
- **subtree separation:** try not to overlap subtrees
- **root-leaf distance:** minimize distance from root to leaves
- **edge lengths:** minimize total, average, maximum, edge lengths & try to make edge lengths uniform
- **angular resolution:** increase angles formed by edges
- **symmetry:** symmetric layouts usually considered pleasing

LAYOUT DIMENSIONALITY: 2D – THREAD ARCS

email visualization



THREADVIS

<http://threadvis.github.io/>

- time-scaling
- coloring people



From [Tobias Isenberg](#)★
Subject **Re: Slides, first draft**
To [Jian Chen](#)★
Cc [Torsten Möller](#)★, [Michael Sedlmair](#)★, Me <petra.isenberg@inria.fr>★

Re: Slides, first draft

- Re: Slides, first draft
- Re: Slides, first draft
- Re: Slides, first draft
- Next steps: QII
- Re: Next steps: QII
- Re: Next steps: QII
- Re: Next steps: QII

From [Tobias Isenberg](#)★
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Cc [Torsten Möller](#)★, [Michael Sedlmair](#)★, Me <petra.isenberg@inria.fr>★

◀ Reply ◀ Reply All ➡ Forward 🗳 Archive

Please note that I said we would meet at 0900. 😊

Cheers,

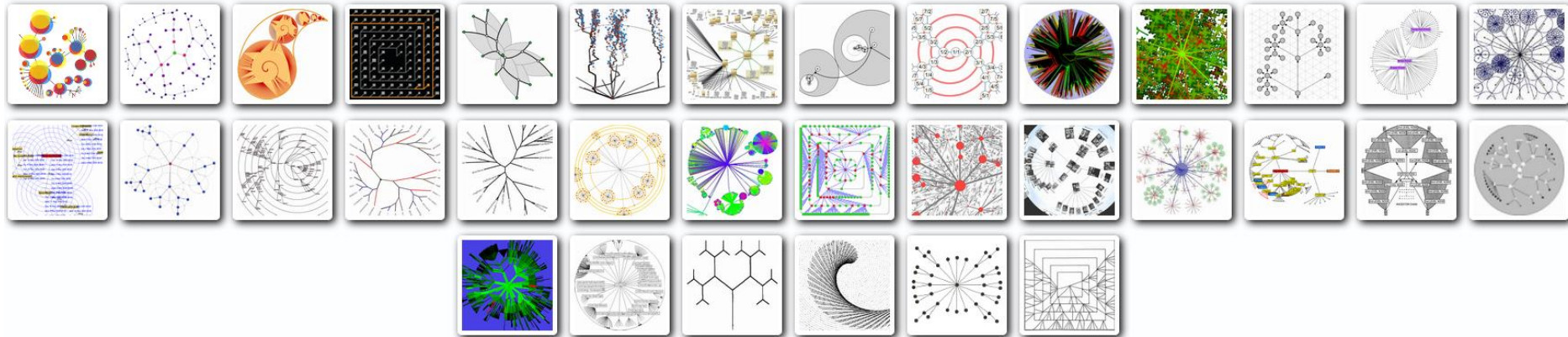
Tobias

TREEJUXTAPOSER

Rectilinear layout and interaction for comparison of very large trees

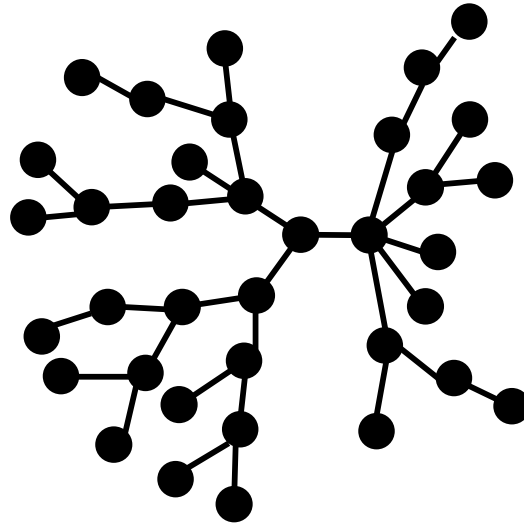
**TreeJuxtaposer:
Scalable Tree Comparison
using
Focus+Context
with
Guaranteed Visibility**

2D, RADIAL, EXPLICIT EDGES



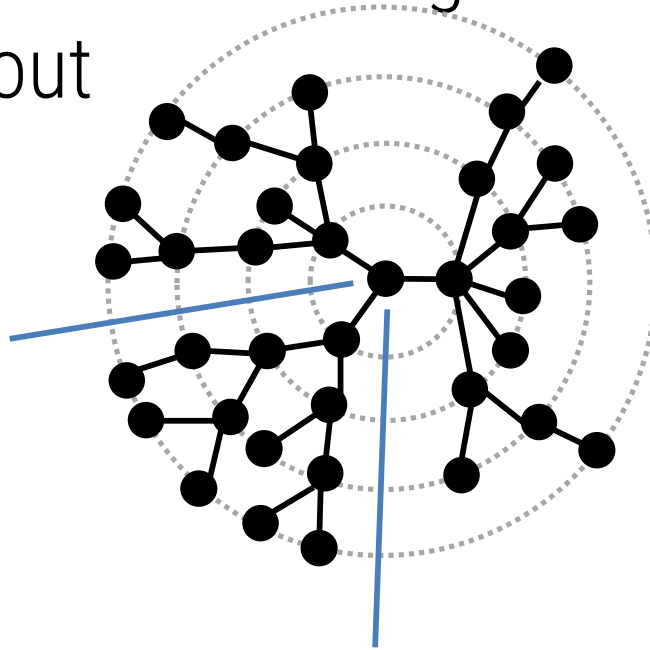
RADIAL NODE-LINK DRAWING

variation of layered drawing from beginning of lecture



RADIAL NODE-LINK DRAWING

- nodes drawn on concentric circles
- nodes drawn within wedges of the circular layout



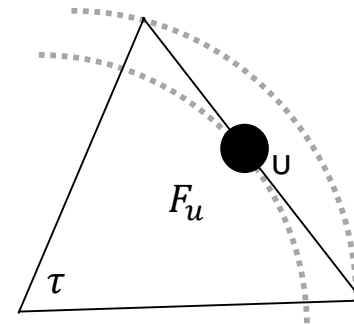
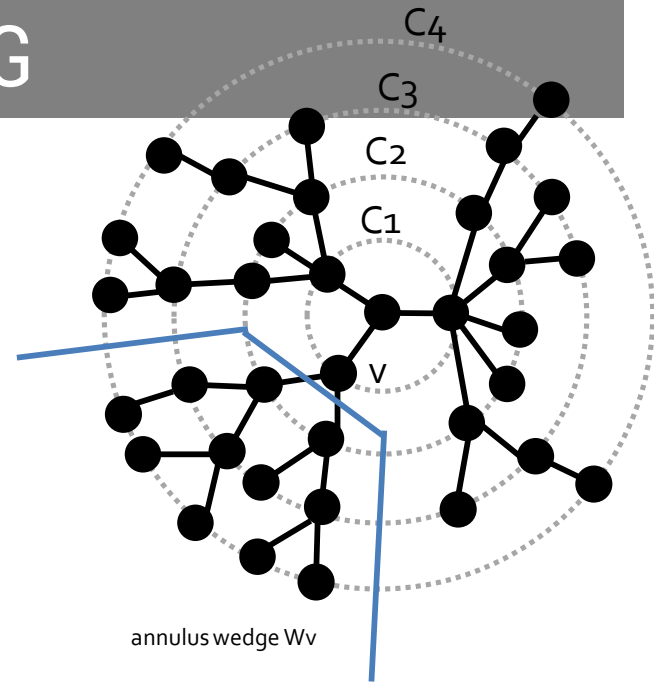
RADIAL NODE-LINK DRAWING

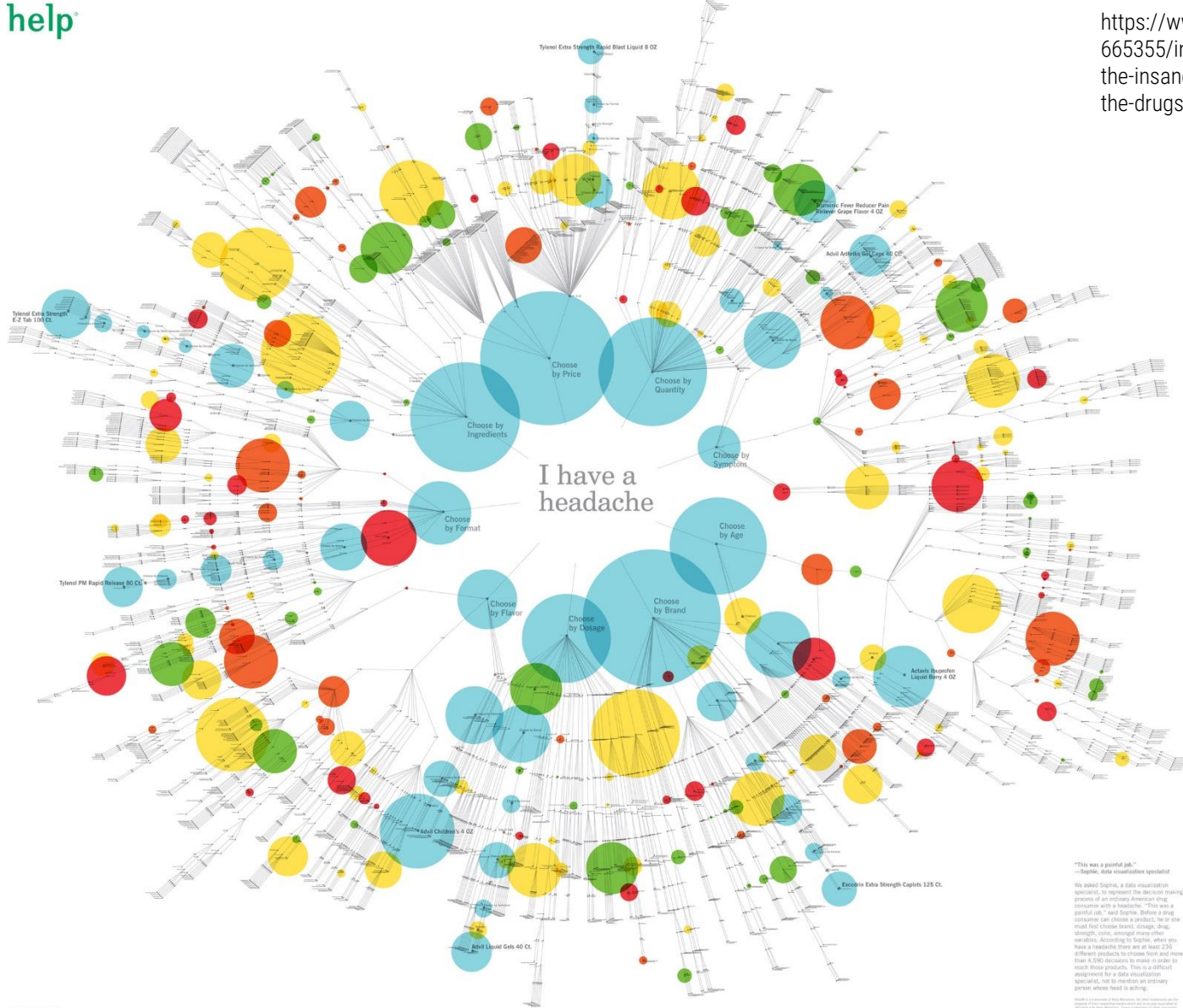
- radius of C_i given by function $p(i)$
- subtree of v drawn within W_v
- to guarantee planarity (no edge crossings), wedge has to be convex
- several algorithms exist for figuring out the correct angles, e.g.

$$\beta_u = \left(\frac{l(u)\beta_v}{l(v)}, \tau \right)$$

For each child u of v :

- β_u is the angle of
- τ is the angle formed by region
- $l(v)$: number of leaves in subtree rooted at v
- place u at center of



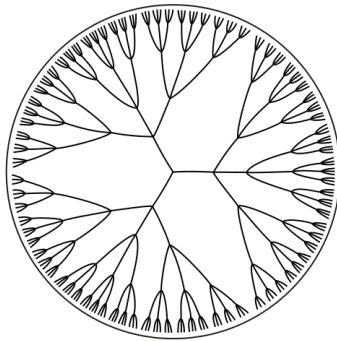


"This was a painful job."
—Sophie, data visualization specialist

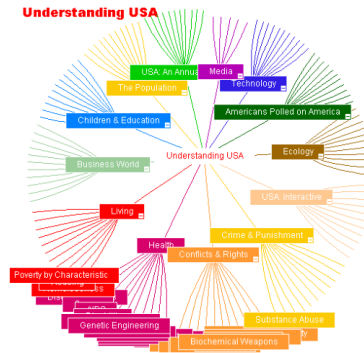
We asked Sophie, a data visualization specialist, to represent the decision-making process of an ordinary American drug consumer with a headache. "This was a painful job," said Sophie. Before a drug consumer can choose a product, he or she must first choose brand, dosage, drug strength, taste, amongst many other variables. According to Sophie, when you have a headache there are at least 235 different products to choose from and more than 4,000 decisions to make in order to match those products. This is a difficult assignment for a data visualization specialist, not to mention an ordinary person whose head is aching.

HYPERBOLIC BROWSER

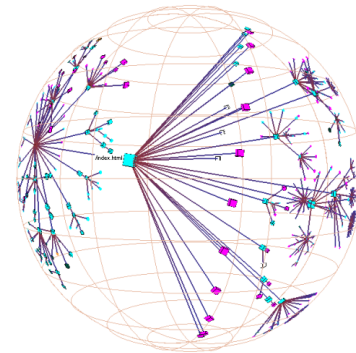
- uses hyperbolic geometry (not euclidean geometry)
- a hyperbolic plane can be displayed using the Poincaré disk model
 - a tree structure of any size fits within a finite area (circle)
 - node is displayed in center
 - all other nodes move away from center and become exponentially smaller



(a) Uniform hyperbolic tree.



(b) StarTree by Inxight Software.



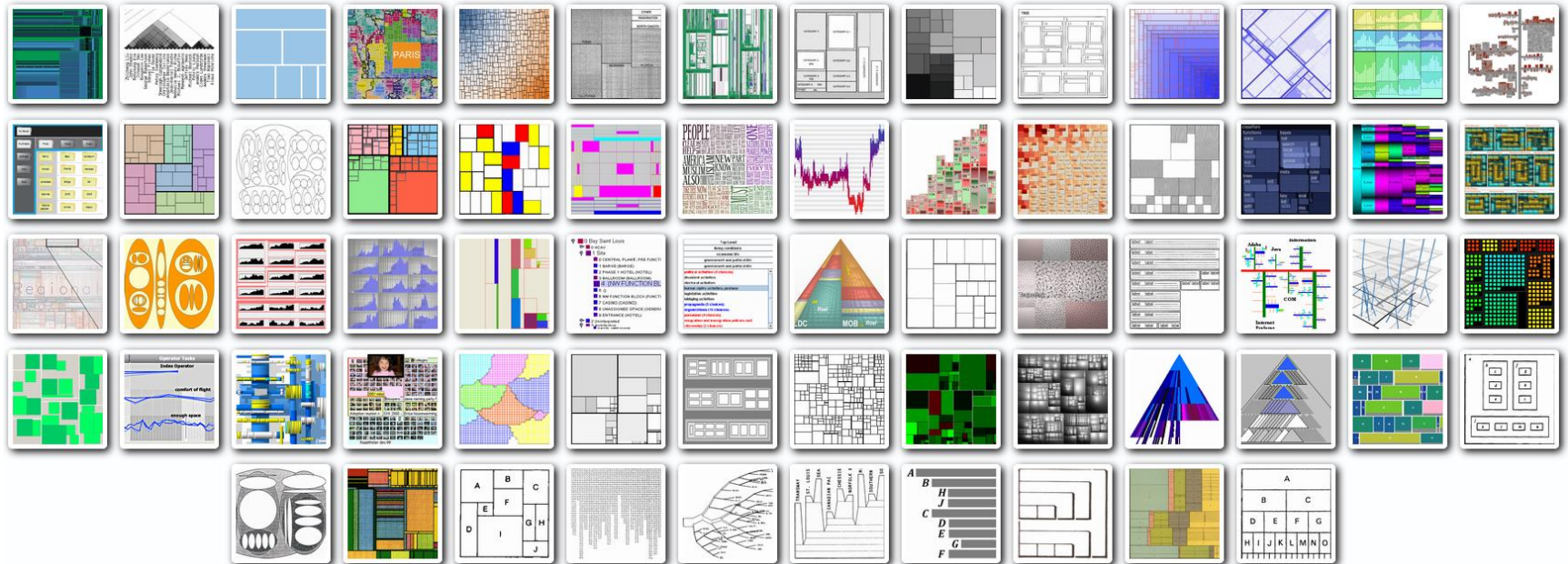
(c) H3 Browser.

CHI 1996 VIDEO OF HYPERBOLIC BROWSER

Special thanks to my colleagues and teachers of the Visible Language Workshop and the MIT Media Lab, to my advisor Bill Mitchell, and to Andrew Eskind of the George Eastman House.

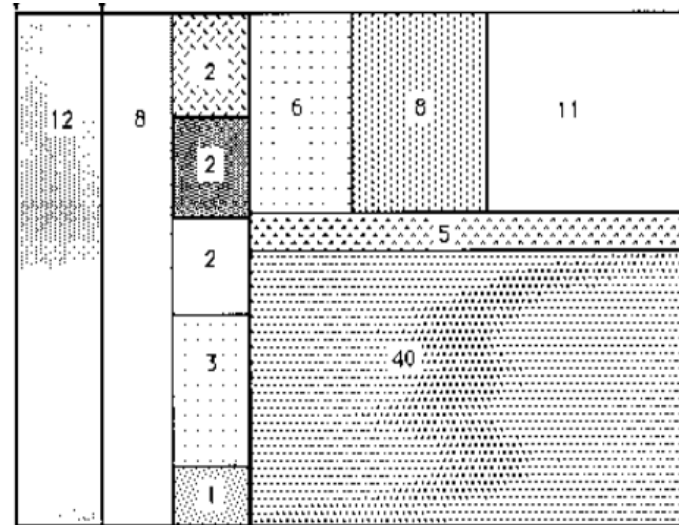
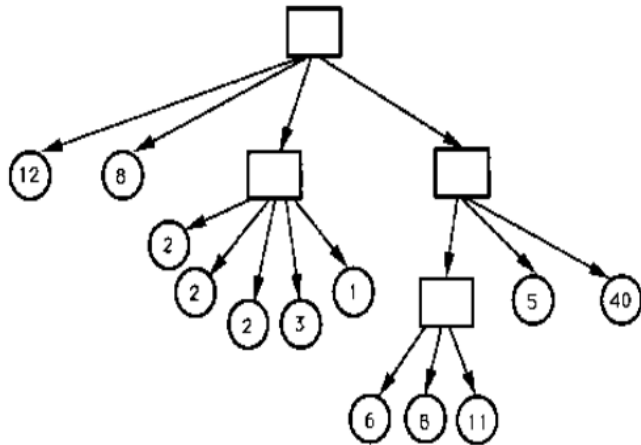
copyright 1995 MIT Media Laboratory

2D, AXIS-PARALLEL, IMPLICIT EDGES



A CLASSIC CONTAINMENT LAYOUT

- example tree to rebuild with treemap algorithm
- size of each node as numbers in leaves



TREEMAP ALGORITHM

- Take a rectangular display area $P1(x1,y1)$, $Q1(x2,y1)$
- This area represents the root of the tree

$P1$

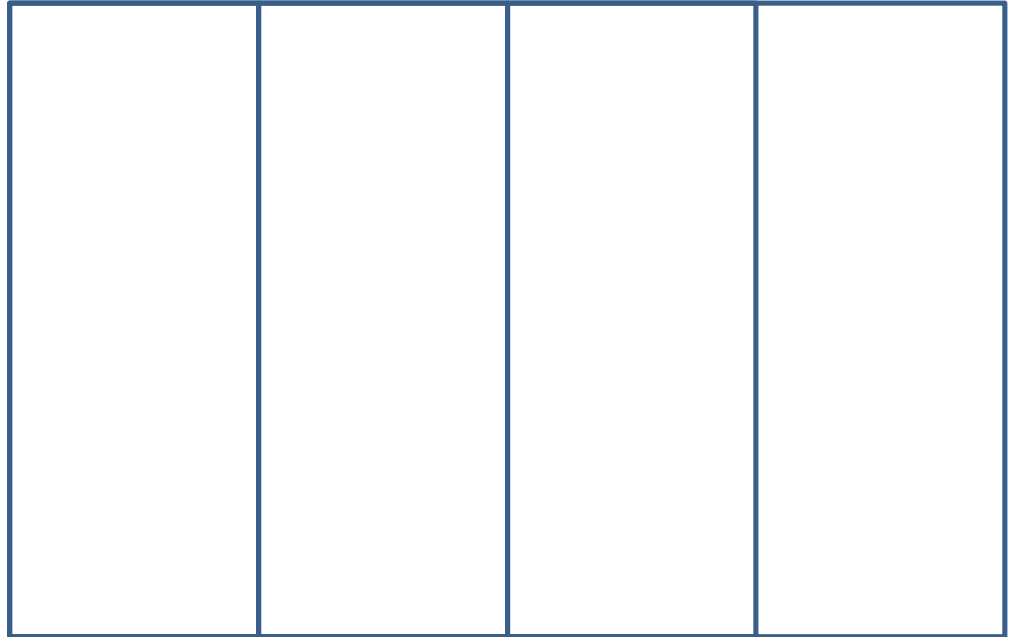
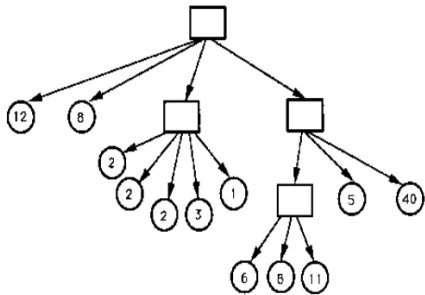


$Q1$

TREEMAP ALGORITHM

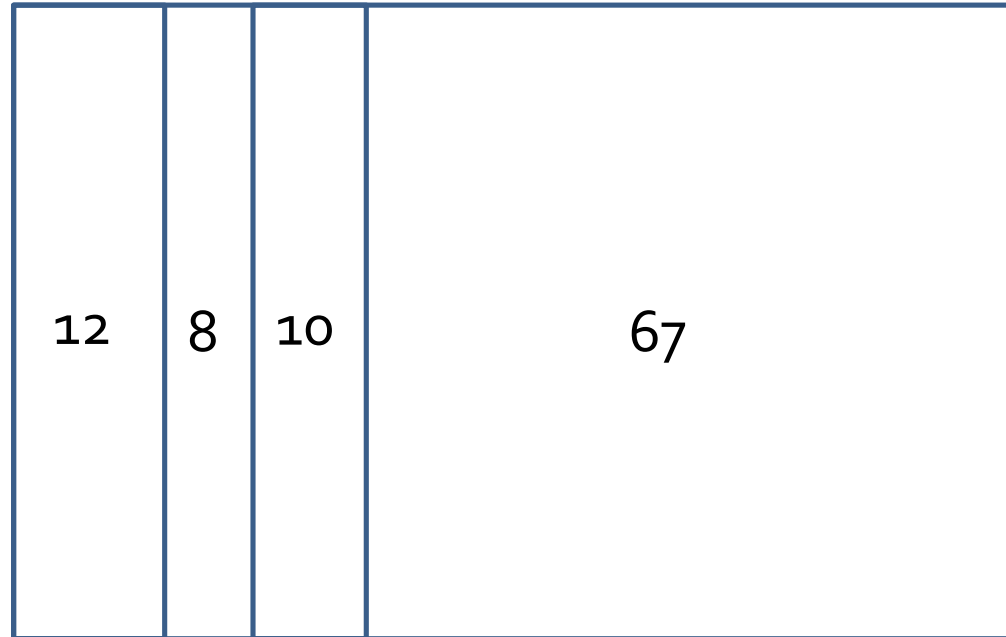
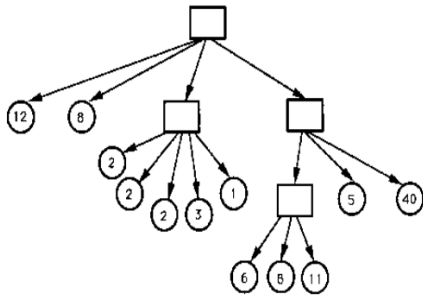
recursive algorithm

- the number of children of the current node define the number of partitions of the current node



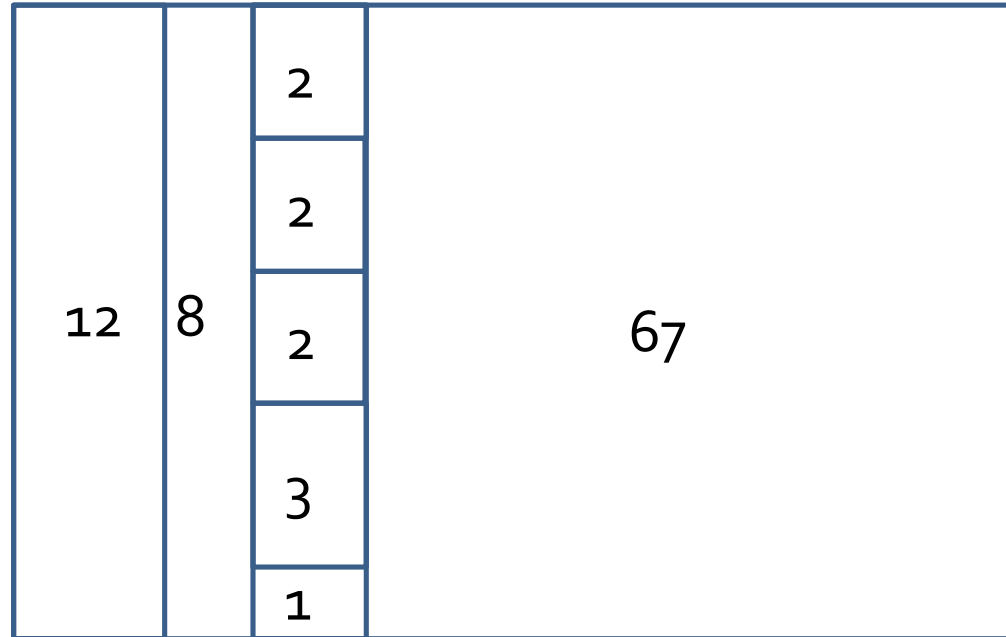
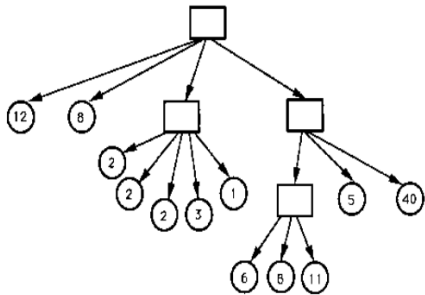
TREEMAP ALGORITHM

the weight of each node determines the size of each partition



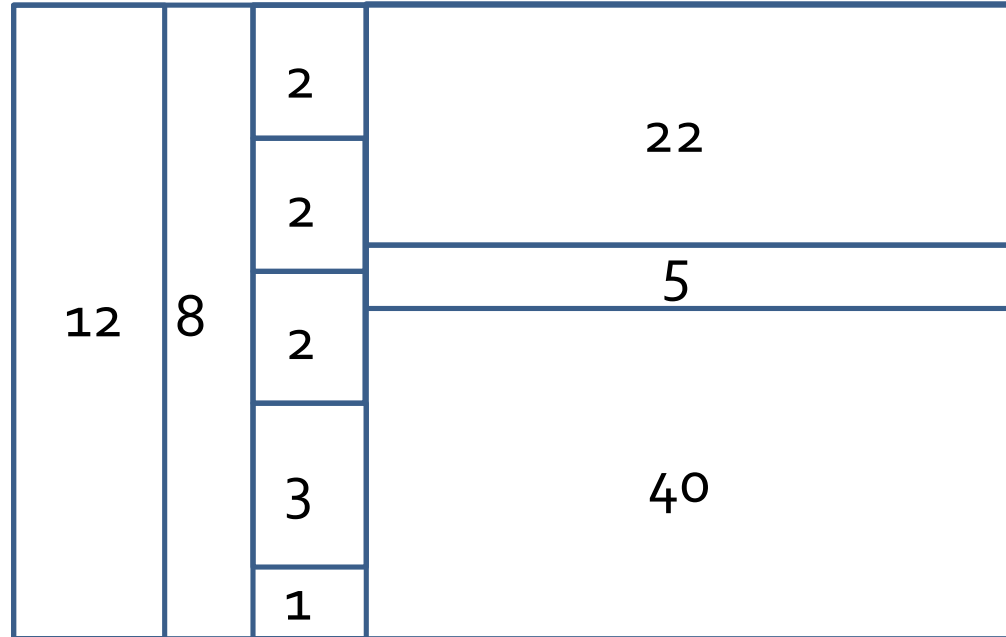
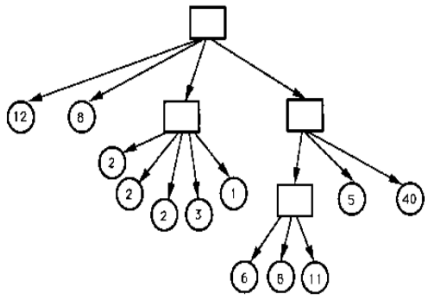
TREEMAP ALGORITHM

at each change of level, rotate orientation of split by 90 degrees



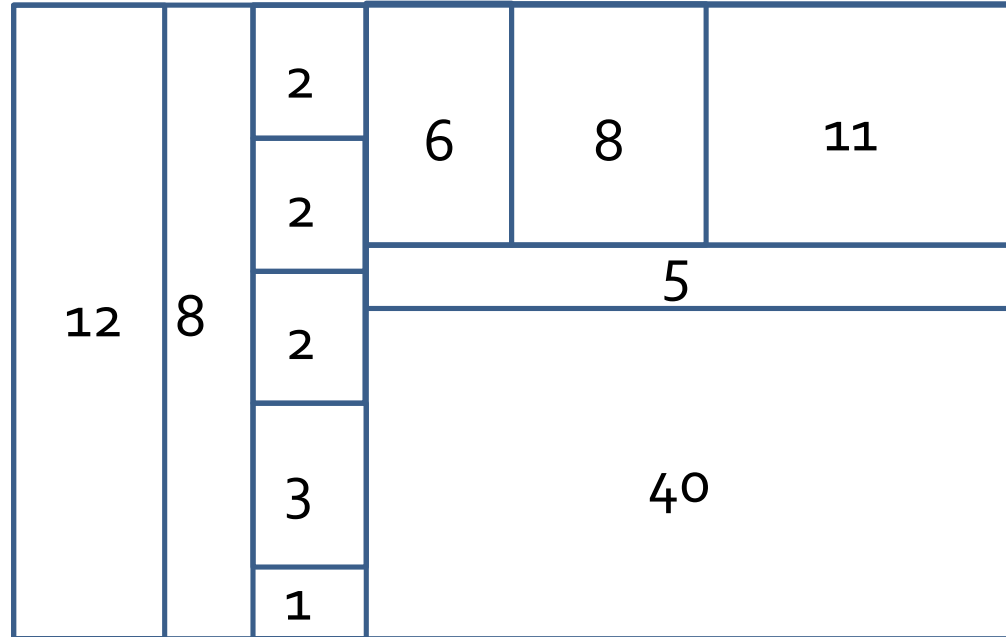
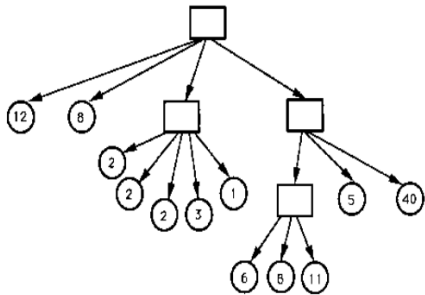
TREEMAP ALGORITHM

at each change of level, rotate orientation of split by 90 degrees



TREEMAP ALGORITHM

at each change of level, rotate orientation of split by 90 degrees

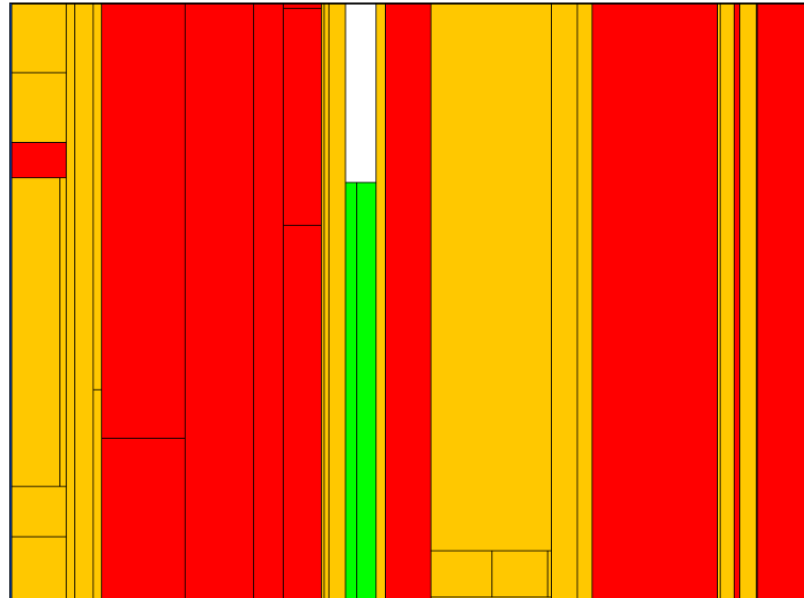


TREEMAP

- a 2-D space-filling layout
- for further references and to try out a treemap in various applications:
<http://www.cs.umd.edu/hcil/treemap-history/>

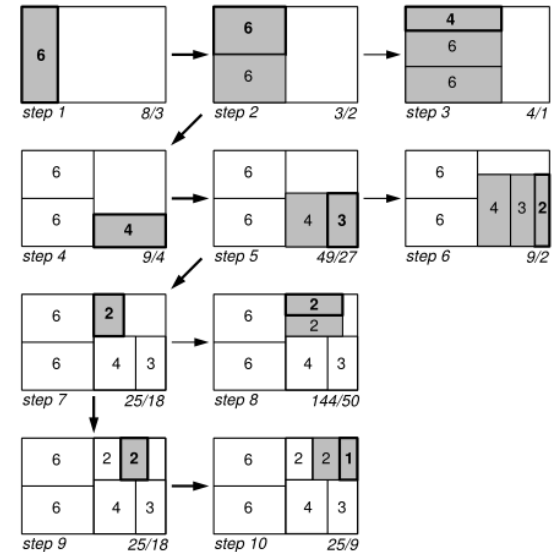
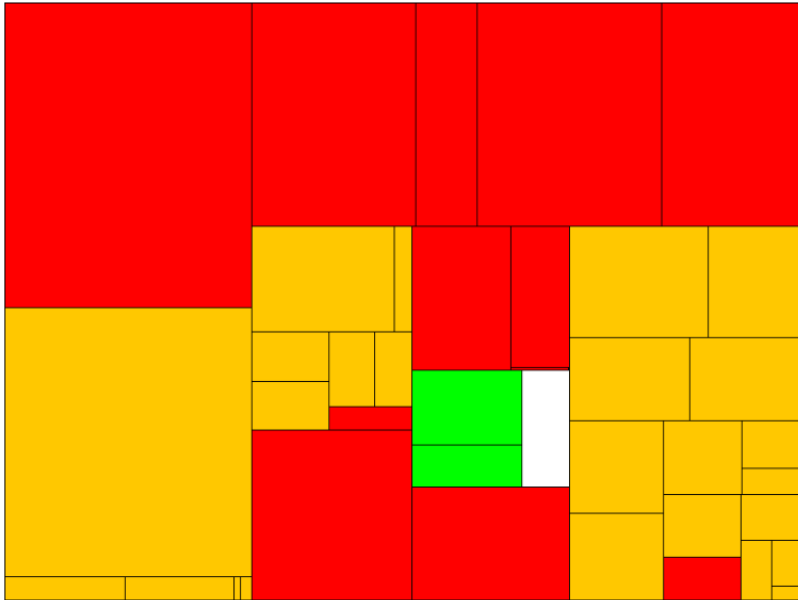
TREEMAP VARIATIONS

- problem with original treemap: lots of long stripes
- for long stripes the areas are difficult to compare

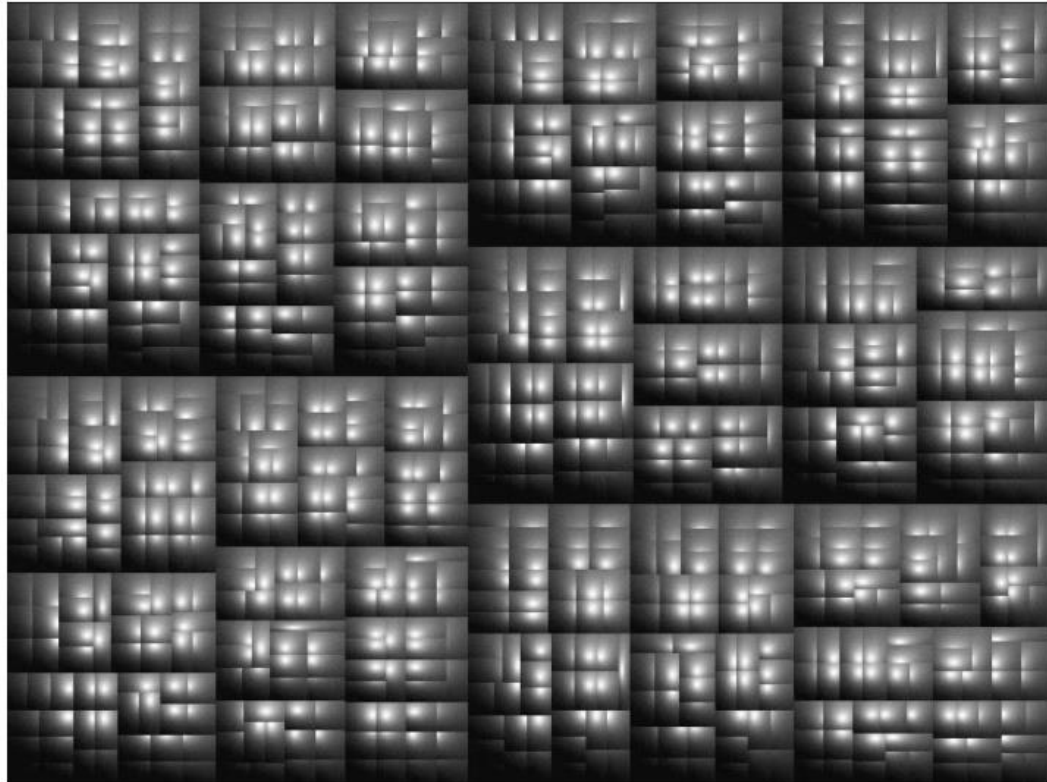


SQUARIFIED TREEMAP

- calculates more squared regions
- problem: order not as easily read, not very stable with dynamically changing data

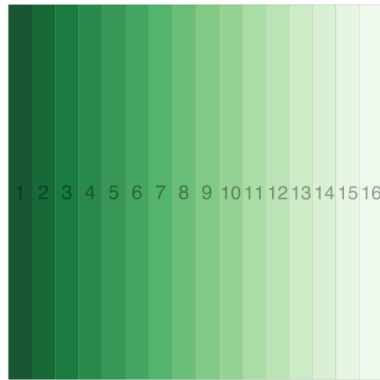


SQUARIFIED TREEMAP



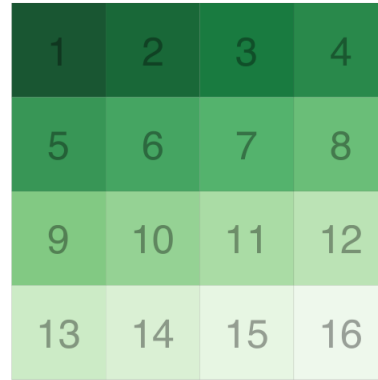
ORDERED TREEMAP

several algorithms in comparison



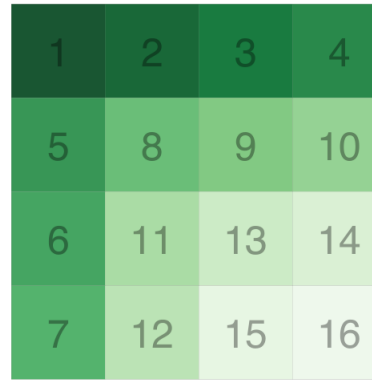
slice and dice

B. Shneiderman. Tree visualization with tree-maps: 2-d space-filling approach. *ACM Transactions on Graphics*, 11:92–99, 1992.



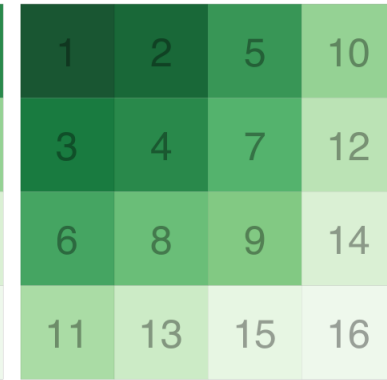
strip

B. B. Bederson, B. Shneiderman, and M. Wattenberg. Ordered and quantum treemaps: Making effective use of 2d space to display hierarchies. *ACM Transactions on Graphics*, 21:833–854, 2002.



squarified

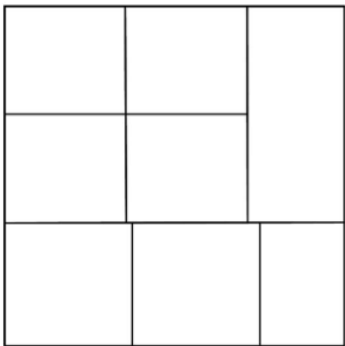
M. Bruls, K. Huizing, and J. van Wijk. Squarified treemaps. *EuroVis*, pages 33–42, 2000.



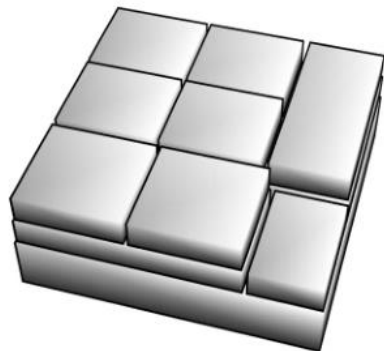
ordered squarified

B. Shneiderman and M. Wattenberg. Ordered treemap layouts. In *Infovis01*, pages 73–78, 2001.

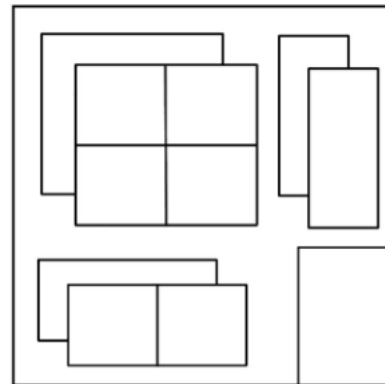
OTHER VARIATIONS OF TREEMAPS



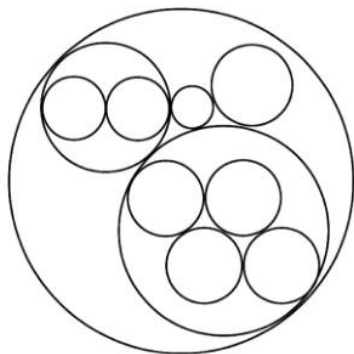
original squarified:
emphasizes leaves and their attributes



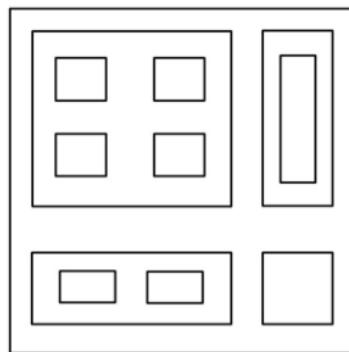
step tree:
emphasizes structure with extrusion



cascaded layout:
emphasizes structure with overlap

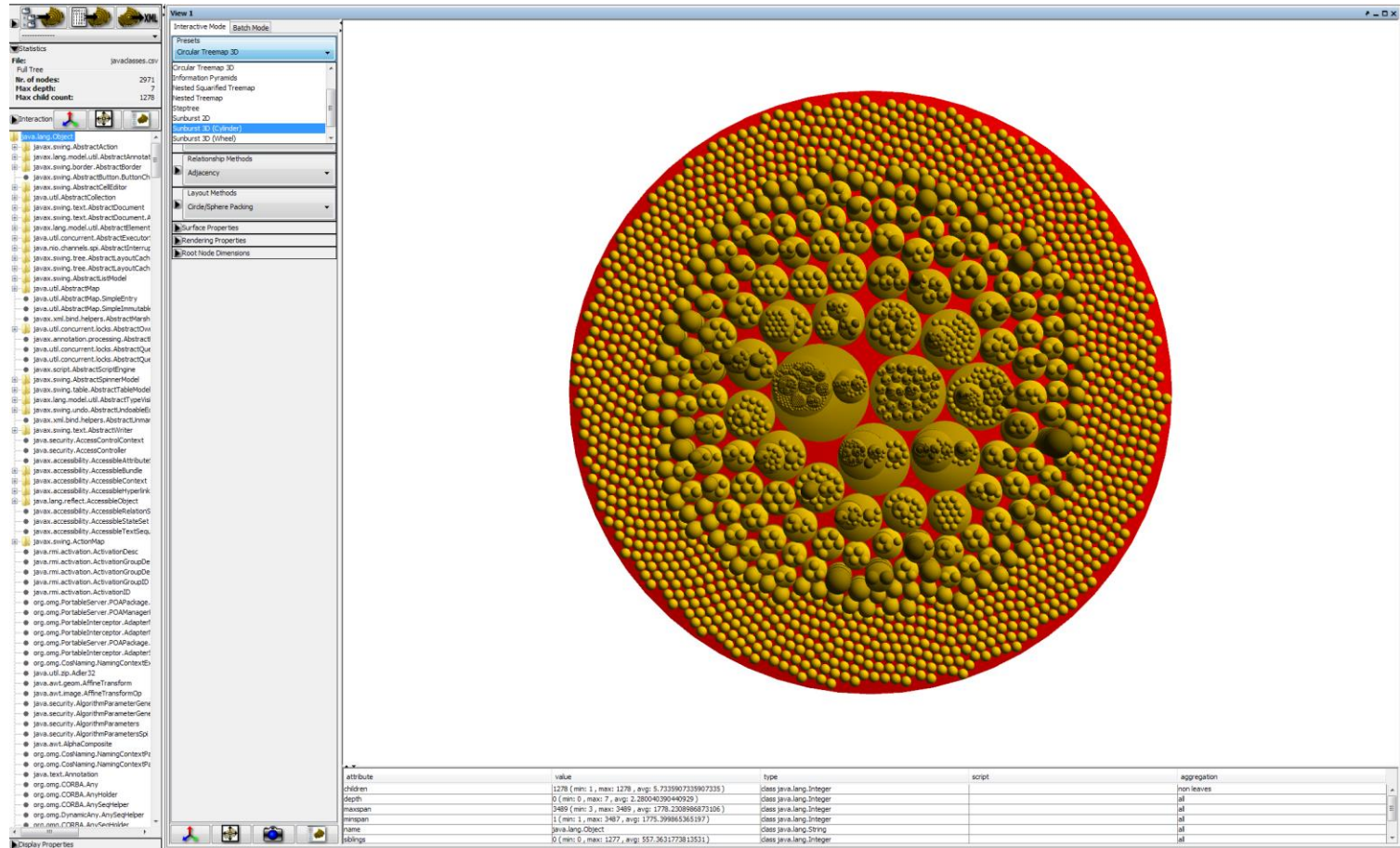


circular treemap:
emphasizes structure with
non-space-filling primitive



nested layout:
emphasizes structure with whitespace

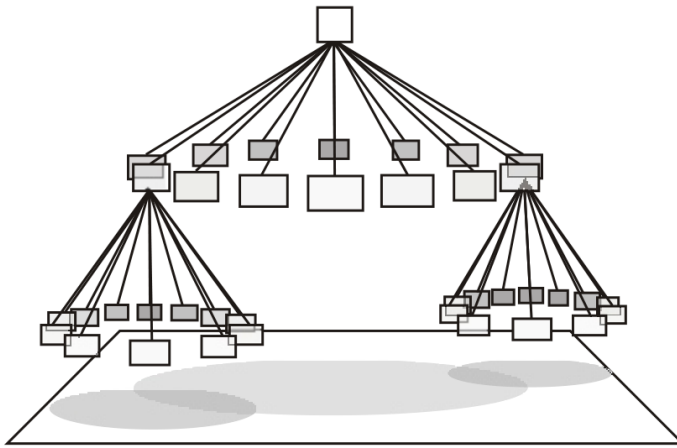
TRY THE IMPLICIT TREE VISUALIZATION TOOLKIT: [HTTP://CG.INFORMATIK.UNI-ROSTOCK.DE/~HS162/ITVTK/START.HTML](http://cg.informatik.uni-rostock.de/~hs162/ITVTK/START.HTML)



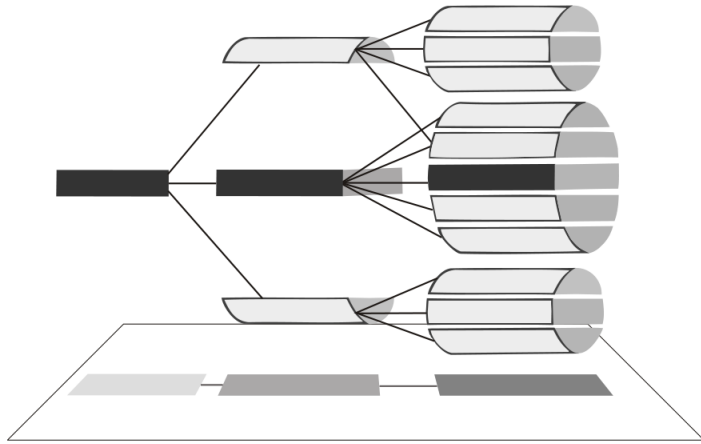
3D LAYOUTS



HISTORIC EXAMPLE: CONETREE / CAMTREE



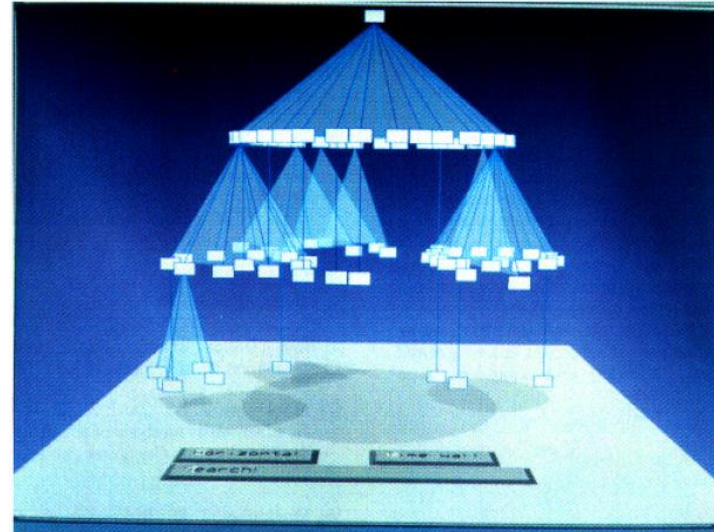
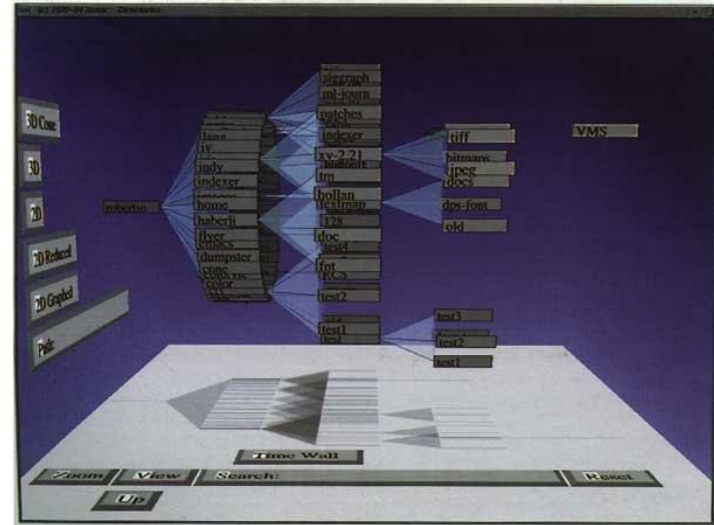
ConeTree



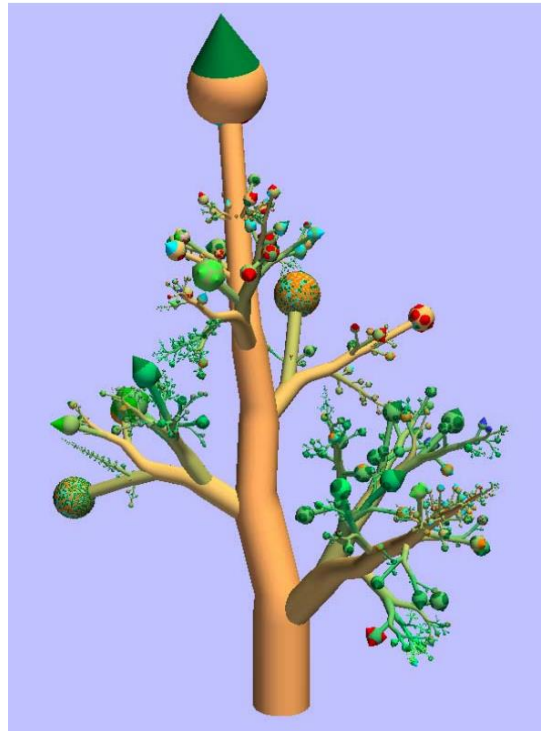
CamTree

CONE/CAMTREE

- children of a node are laid out in a cylinder “below” the parent
- siblings located on the same 2D circle
- use of animation
- shadows to enhance structure



BOTANICAL VISUALIZATION OF HUGE HIERARCHIES



3D LAYOUTS

- advantages
 - fit more data into same aspect ratio
 - aesthetically pleasing
- disadvantages
 - occlusion
 - requires interaction or animation
 - no overviews

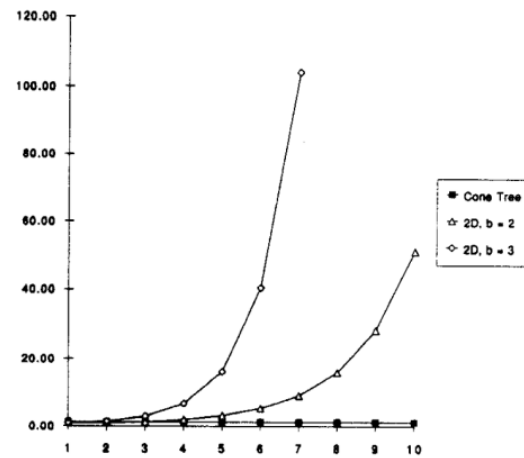


Figure 1: Aspect Ratio of 2D and 3D Trees.

TREE VISUALIZATION SUMMARY

- there are lots of tree visualizations
 - there is also lots of free software, try it out, (see links earlier in the lecture plus e.g.):
 - <http://www.informatik.uni-rostock.de/~hs162/optreedemo/TestBed.htm#>
 - http://w3.win.tue.nl/nl/onderzoek/onderzoek_informatica/visualization/sequoia/view/
 - there are a few overview articles, e.g.:
 - **A Generative Layout Approach for Rooted Tree Drawings** by Hans-Jörg Schulz, Zabed Akbar, and Frank Maurer - at IEEE PacificVis 2013
 - **The Design Space of Implicit Hierarchy Visualization: A Survey** by Hans-Jörg Schulz, Steffen Hadlak, and Heidrun Schumann - in IEEE TVCG 17(4)

TREE VISUALIZATIONS

- can be categorized by
 - edge representations (implicit, explicit)
 - dimensionality of layout
 - radial vs. axis-parallel
- can be modified by
 - layout parameters
 - which marks are used
 - visual variables on marks (which meta-data is represented?)

GRAPHS / NETWORKS

DEFINITION GRAPH

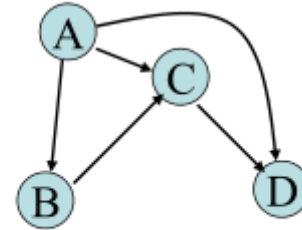
- A set of **vertices** $V = \{v_i\}$
- A set of **edges** $E = \{e_{ij}\}$ with $e_{ij} = \{v_i, v_j\}$
- When the order of vertices of an edge is meaningful, the graph is **directed**

GRAPH MEASURES

- SIZE = #nodes
- DENSITY = edges/vertices (roughly)
- PATH = sequence of edges connecting (different) vertices
- VERTEX DEGREE = #edge connections
- DISTANCE = #hops between vertices

TWO CLASSICAL VISUAL REPRESENTATIONS

Node-Link Diagram

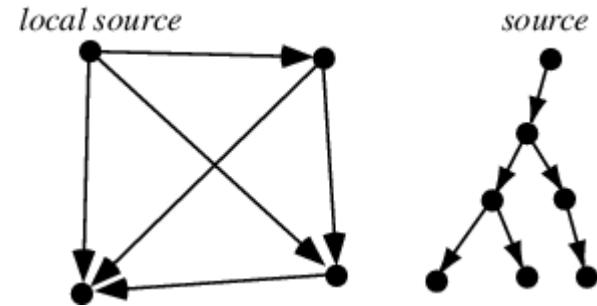
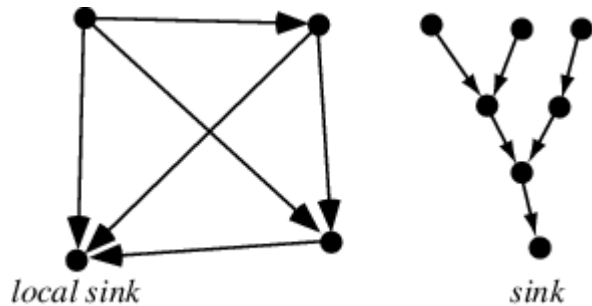


Adjacency Matrix

↗	A	B	C	D
A		X	X	X
B			X	
C				X
D				

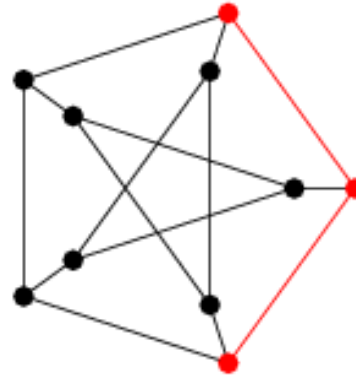
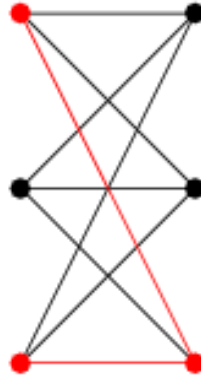
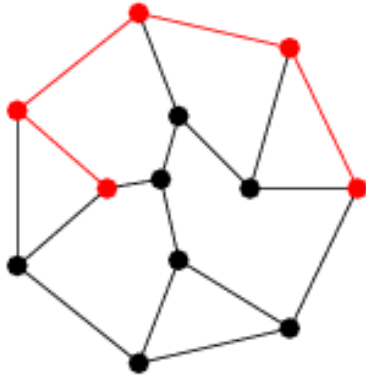
TASKS

Find # of neighbors of a vertex
(e.g. source vs. sink)



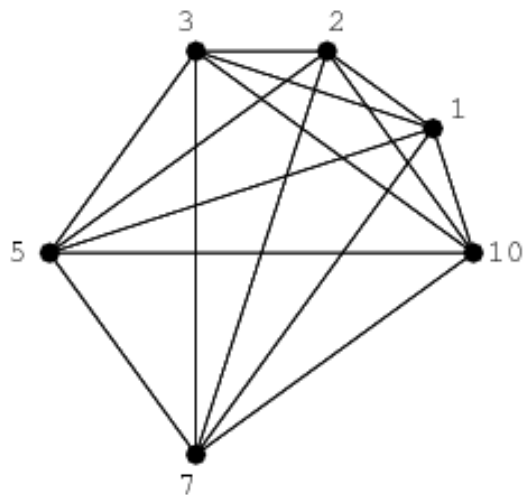
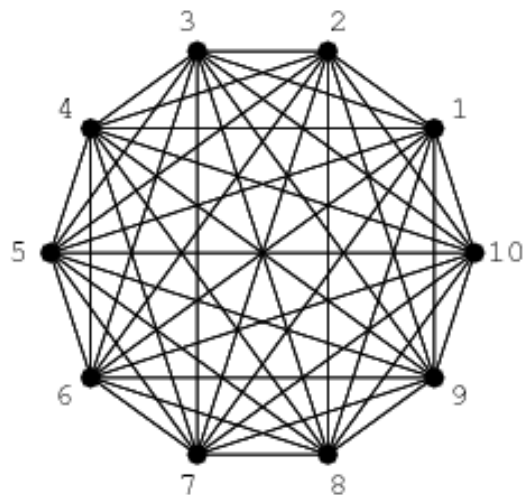
TASKS

See paths (overviews, shortest, cycles)



TASKS

Identify Sub-graphs



TASKS

HIGHER-LEVEL

involves many elements

involves more human judgment

- which nodes are important?
- where are clusters?
- what are attribute and connection correlations?
- how does the network change over time?

TASKS

- Many many more specific tasks
- Each application domain will add more

Task Taxonomy for Graph Visualization

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Jean-Daniel.Fekete@inria.fr, nhenry@lri.fr

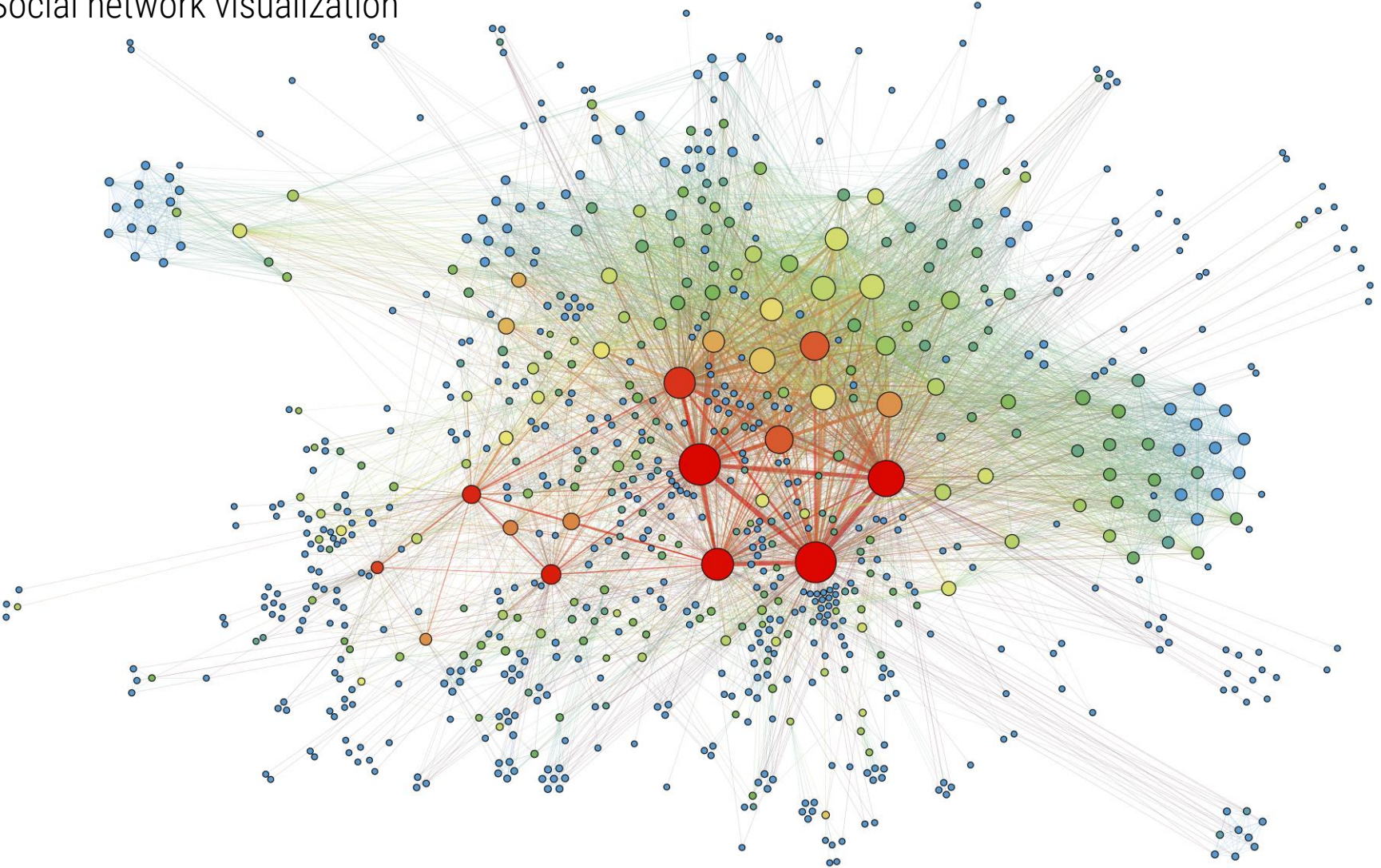
ABSTRACT

Our goal is to define a list of tasks for graph visualization that has enough detail and specificity to be useful to: 1) designers who want to improve their system and 2) to evaluators who want to compare graph visualization systems. In this paper, we suggest a list of tasks we believe are commonly encountered while analyzing graph data. We define graph specific objects and demonstrate how all complex tasks could be seen as a series of low-level tasks performed on those objects. We believe that our

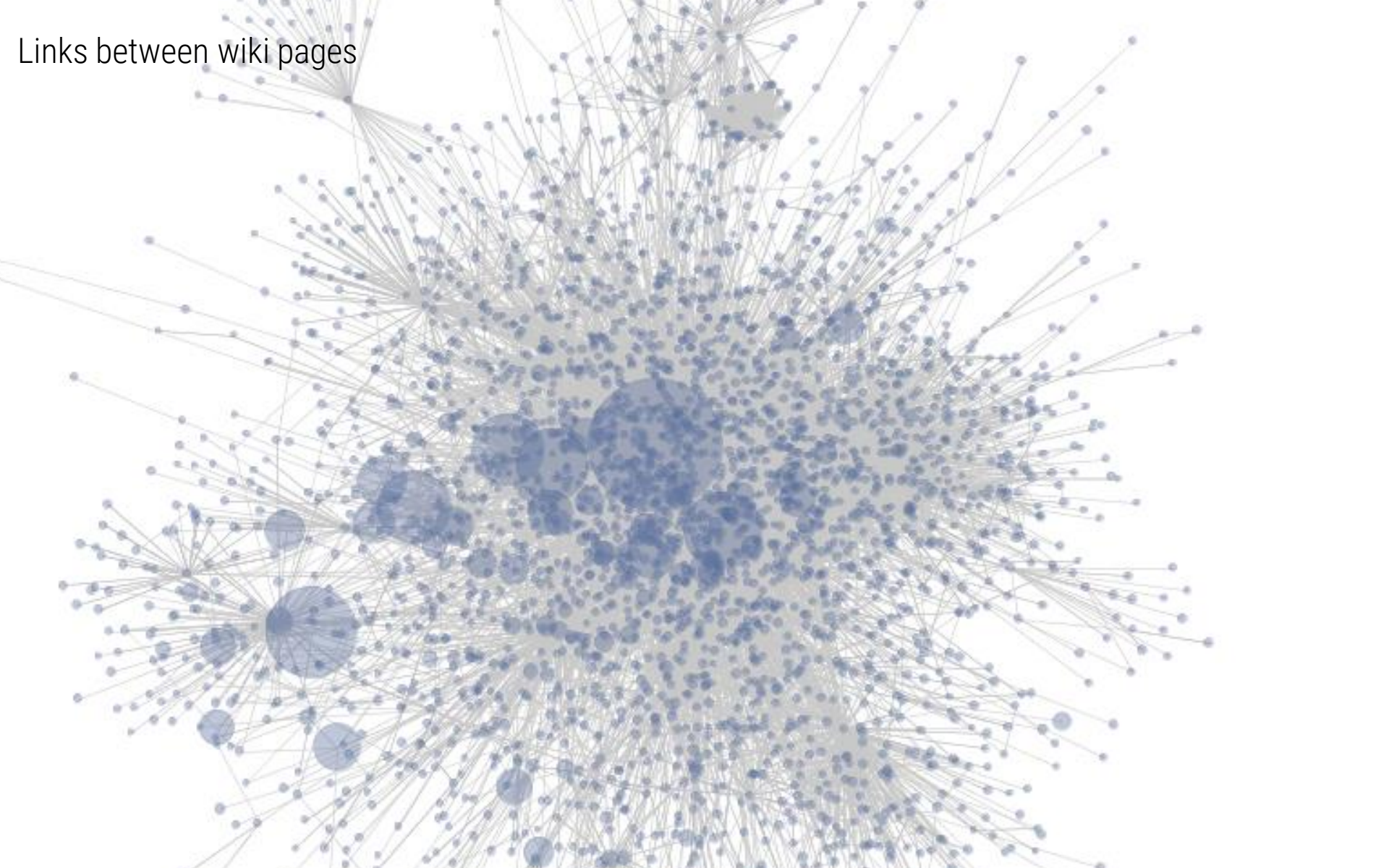
user studies of graph visualization techniques and extracted the tasks used in those studies.

After making those two lists, we considered the set of low-level Visual Analytics tasks proposed by Amar *et al.* [2]. These tasks were extracted from a corpus of questions about tabular data. We realized that our tasks all seem to be compound tasks made up of Amar *et al.*'s primitive tasks applied to the graph objects. When some tasks could not be represented with those tasks and objects, we added either an object or a low-level task. In this paper, we

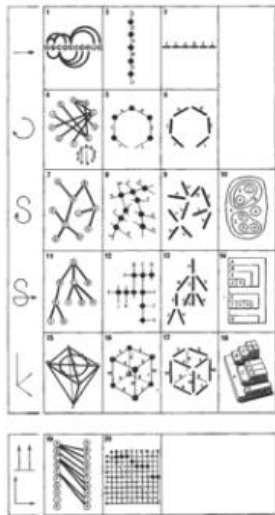
Social network visualization



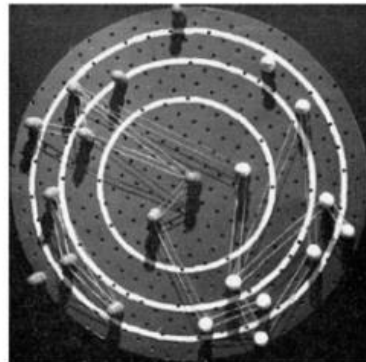
Links between wiki pages



GRAPH VISUALIZATION CHALLENGES



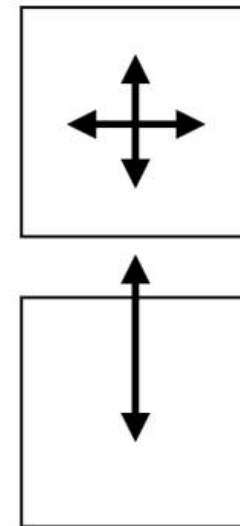
Representation



Layout



Types +
Attributes



Navigation

SOCIAL NETWORK ANALYSIS

<https://datascientistinsights.com/2014/02/18/art-of-resistance-the-social-network-anatomy-of-a-kinetic-activist-group/>

- determine if [Greenpeace](#) was or could become a significant disruptive geopolitical force
- first: identify who/what to concentrate resources on

SOCIAL NETWORK ANALYSIS

<https://datascientistinsights.com/2014/02/18/art-of-resistance-the-social-network-anatomy-of-a-kinetic-activist-group/>

Data Scientist Insights

EXPLORING THE DARKEST PLACES ON EARTH

🏠 DATA SCIENCE FIELD NOTE TOOLS VISUALIZATION BIG DATA R CASE STUDY 🔍

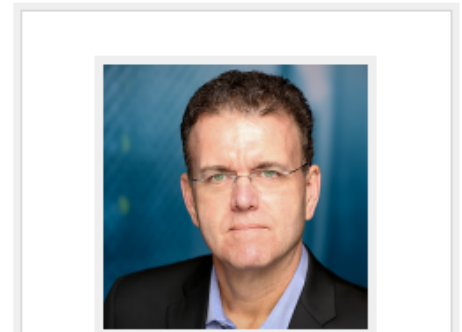
[HOME](#) > [DATA SCIENCE](#) > [ART OF RESISTANCE – THE SOCIAL NETWORK ANATOMY OF A KINETIC ACTIVIST GROUP](#)

Art of Resistance – The Social Network Anatomy of a Kinetic Activist Group

BY DR. J on FEBRUARY 18, 2014 • (0)



As a data scientist that works in the intelligence community, we are often asked to help identify where intelligence gathering and analysis resources should be allocated. Governmental and non-governmental



SOCIAL NETWORK ANALYSIS

1) get Facebook data using Netvizz

Studying Facebook via Data Extraction: The Netvizz Application

Bernhard Rieder

University of Amsterdam

Turfdraagsterpad 9

1012TX Amsterdam

rieder@uva.nl

ABSTRACT

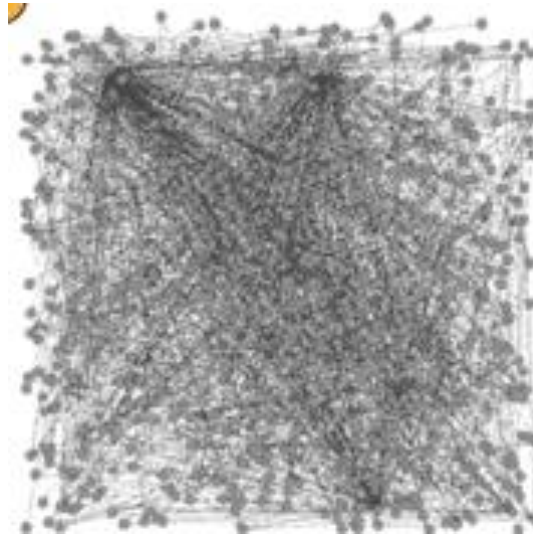
This paper describes Netvizz, a data collection and extraction application that allows researchers to export data in standard file formats from different sections of the Facebook social networking service. Friendship networks, groups, and pages can thus be analyzed quantitatively and qualitatively with regards to demographical, post-demographical, and relational characteristics. The paper

numerous publications employing conceptual and/or critical approaches. While traditional empirical methods such as interviews, experiments, and observations are widely used, a growing number of studies rely on what the authors call “data crawling”, i.e. “gleaning information about users from their profiles without their active participation” [19]. This paper presents a software tool, Netvizz, designed to facilitate this latter approach.

SOCIAL NETWORK ANALYSIS

2) load the data into Gephi

<https://gephi.org/>



585 nodes, interconnected by 1788 edges.

“Somewhere in that spaghetti is a potential bad guy, but where?”

SOCIAL NETWORK ANALYSIS

3) choose a layout algorithm that makes sense for social networks

Force Atlas 2



provides some transparency into the network but still lacks any real clarity around behavioral importance

SOCIAL NETWORK ANALYSIS

4) map an attribute to size of the nodes

betweenness centrality (number of shortest paths from all vertices to all others that pass through that node)



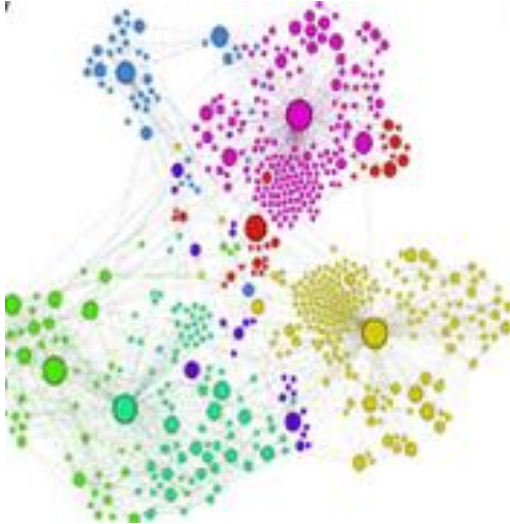
Bigger nodes are more central to behavioral dynamics.

Several nodes become central figures in the overall network.

SOCIAL NETWORK ANALYSIS

5) highlight communities

color nodes by modularity / clusters



We now begin to see a clearer picture of who is doing what with whom.

What becomes really interesting at this stage is understanding some of the more nuanced relationships.

SOCIAL NETWORK ANALYSIS

6) filter, explore, label



Five outlying nodes in the network (blue, maroon, yellow, dark green, and light green).

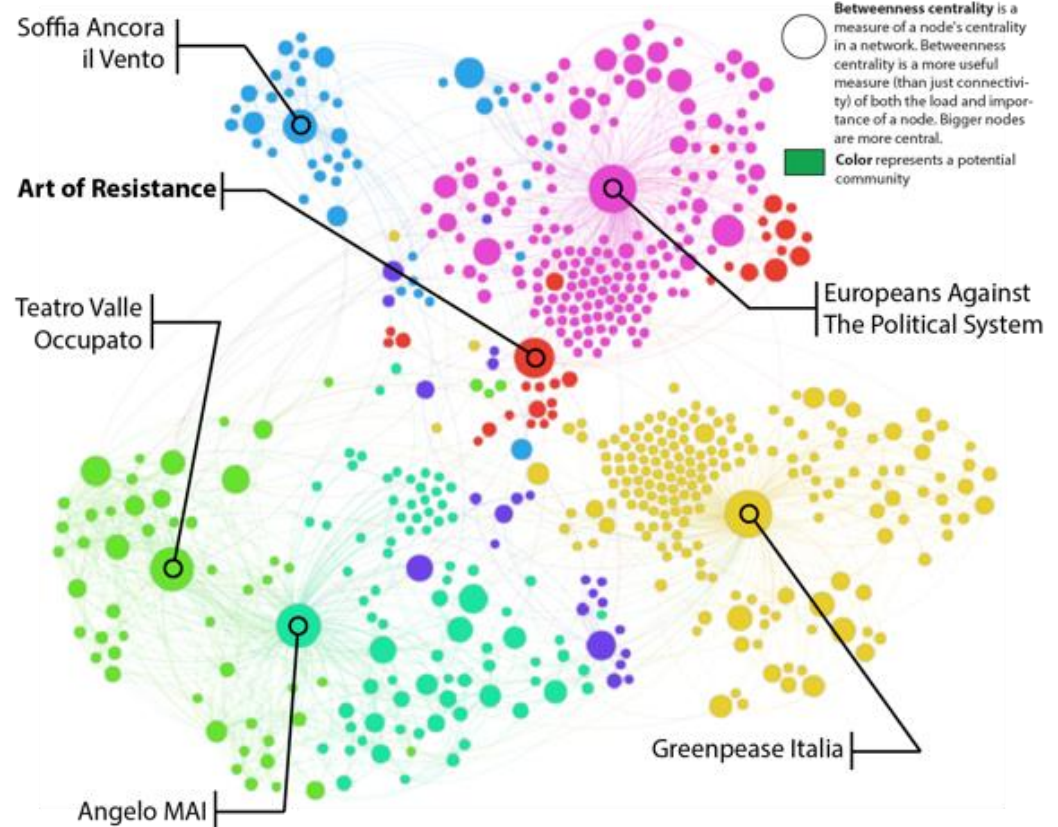
Center: an equally important red node

Emergence of a previously un-recognized activism player: [Art of Resistance](#).



SOCIAL NETWORK ANALYSIS

7) communicate & explain



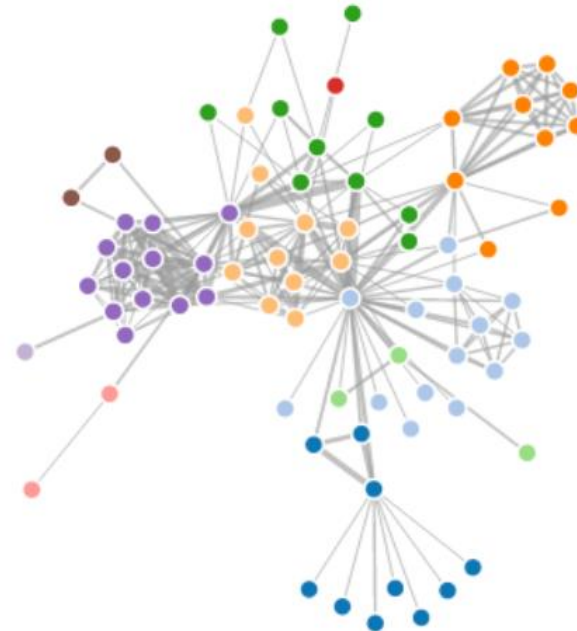
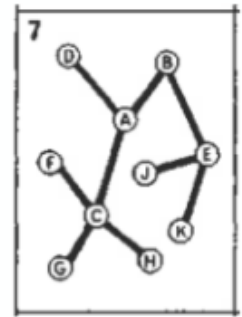
LAYOUTS

Important to the success of your analysis

LAYOUT FREE

- Physical forces
- Proximity based
- Spring Model
- Kamada&Kawai
- Frucherman&Reingold
- Davidson&Harel
- LinLog

Force Directed





LAYOUT FREE

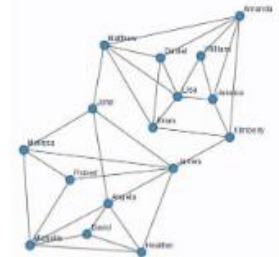
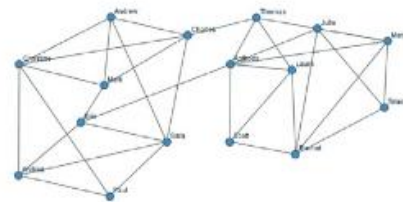
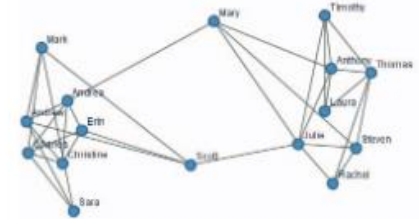
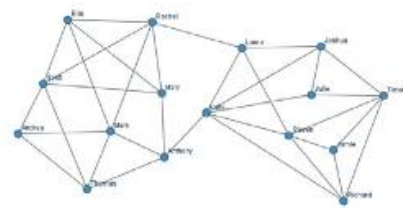
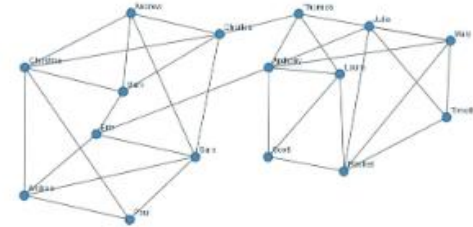
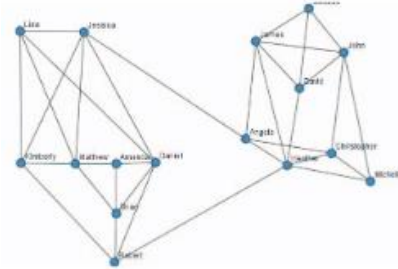
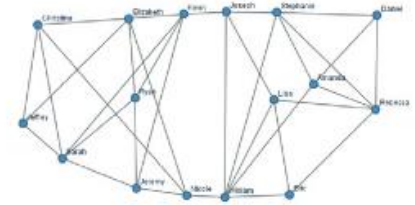
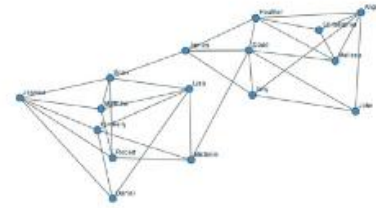
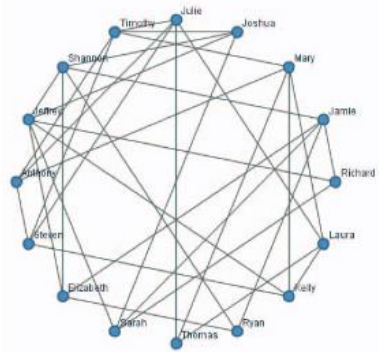
Aesthetic Criteria

- Reduce number of edge crossing
- Foster Symmetry
- Uniform edge length
- Aspect Ratio
- Equal Angles
- ...

GRAPH DRAWING

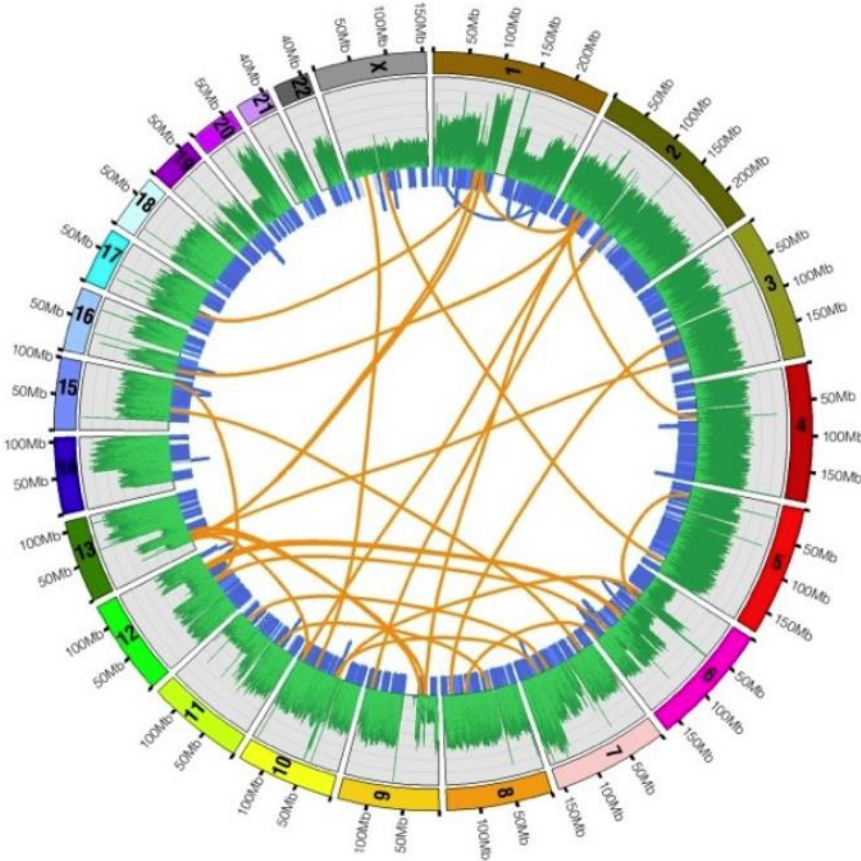
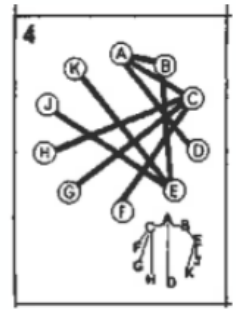
LAYOUT FREE

HAND MADE



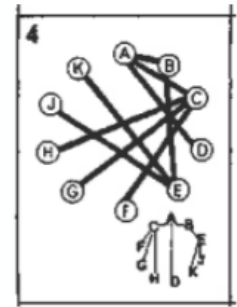
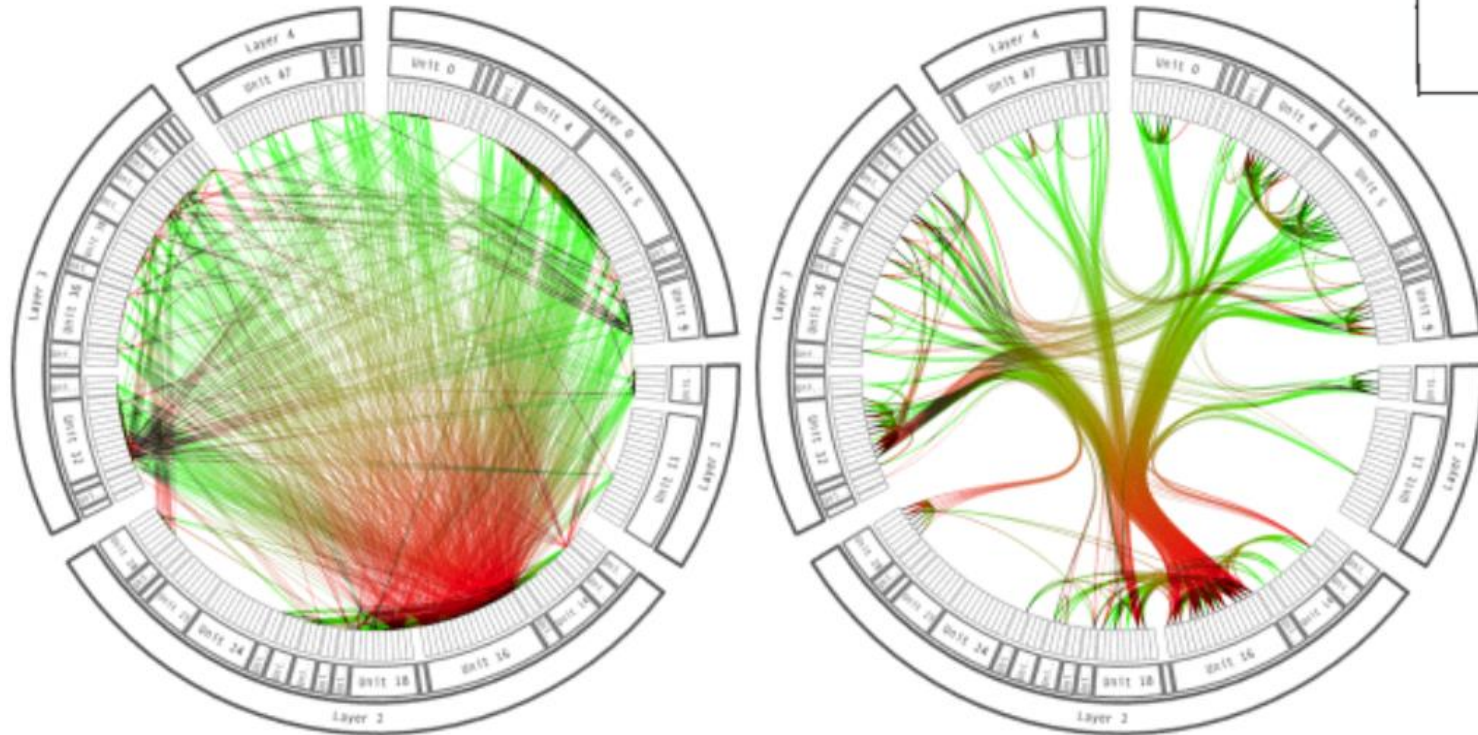
optimal organization in user-generated graph layouts
Tam, F.J.J.; Rogowitz, B.

LAYOUT CIRCULAR



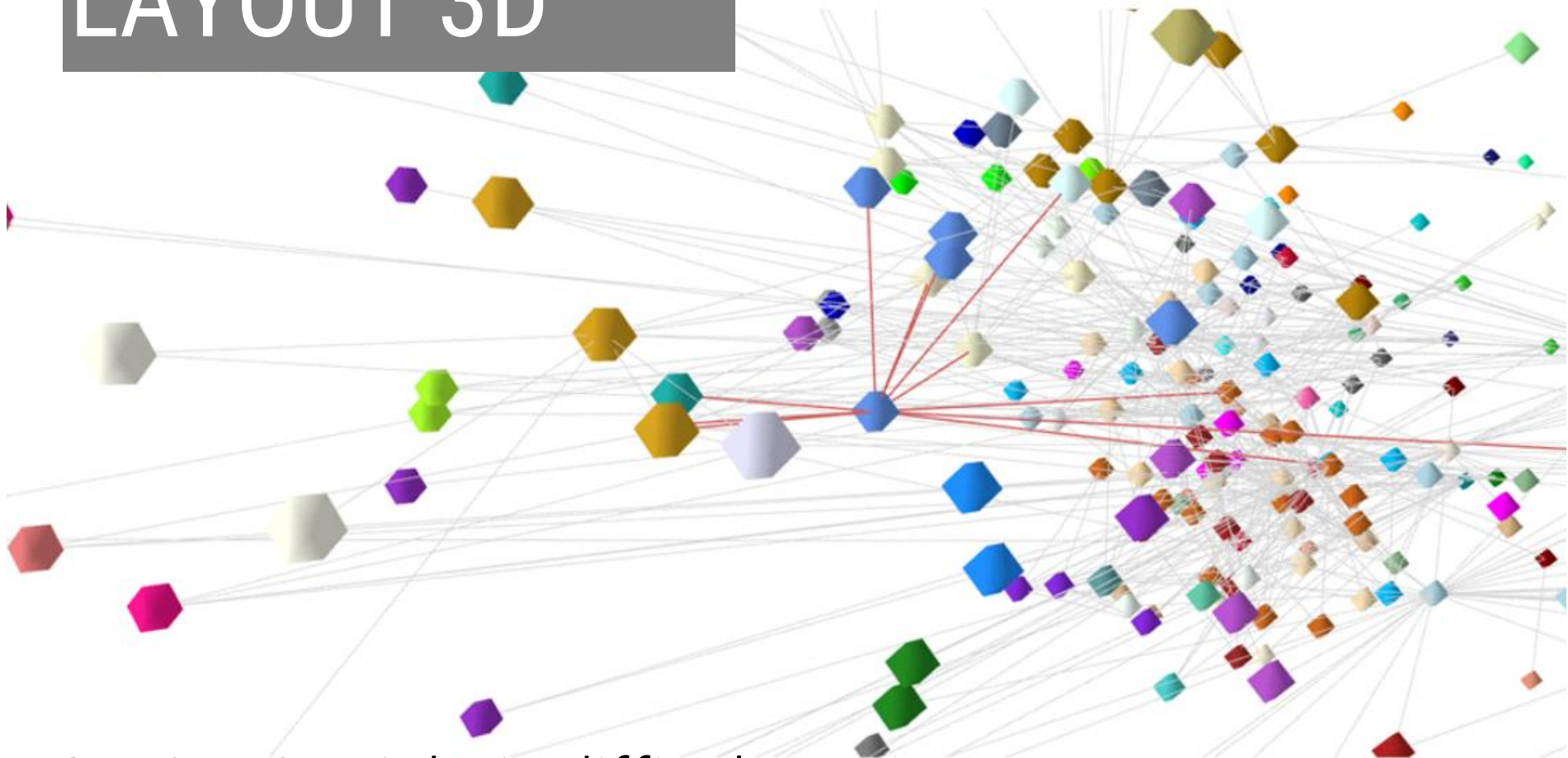
- Edges on the inside
- Vertices & attributes on the outside
- Ordering possible

LAYOUT CIRCULAR



Edge Bundling
Holten 2006

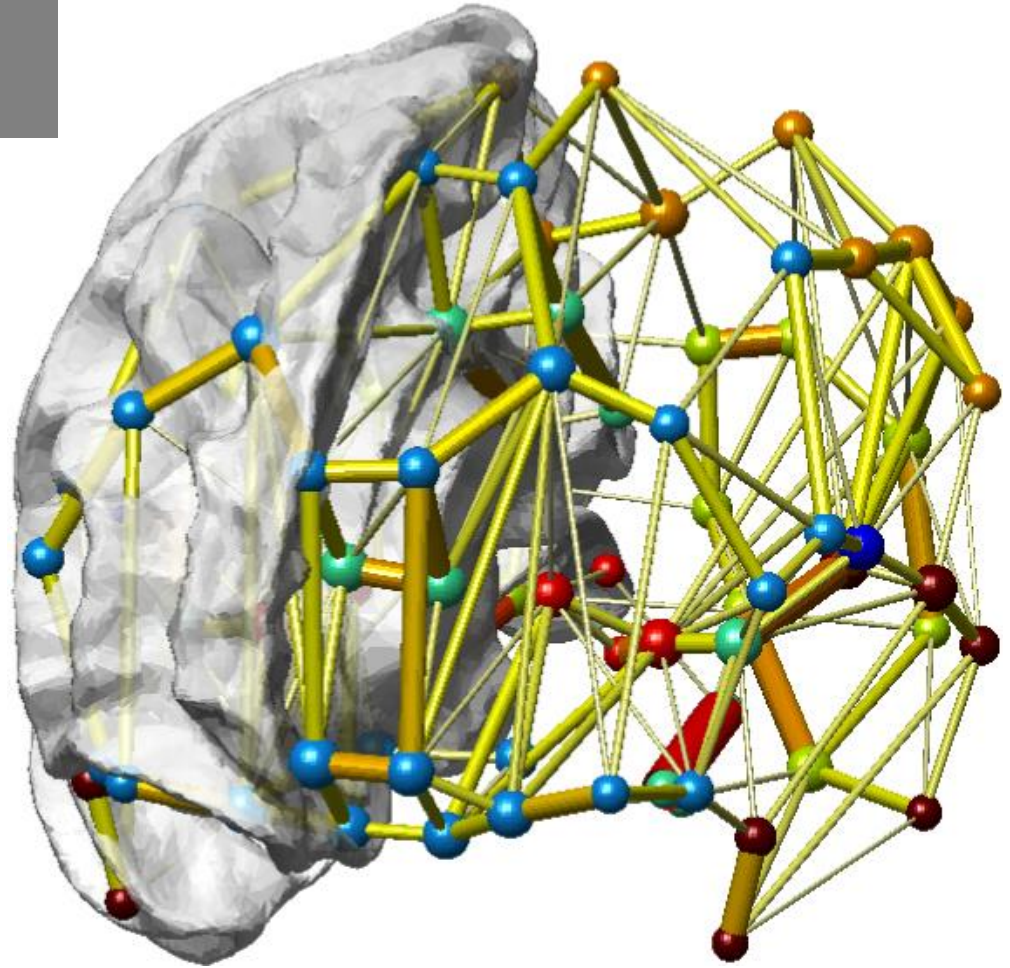
LAYOUT 3D



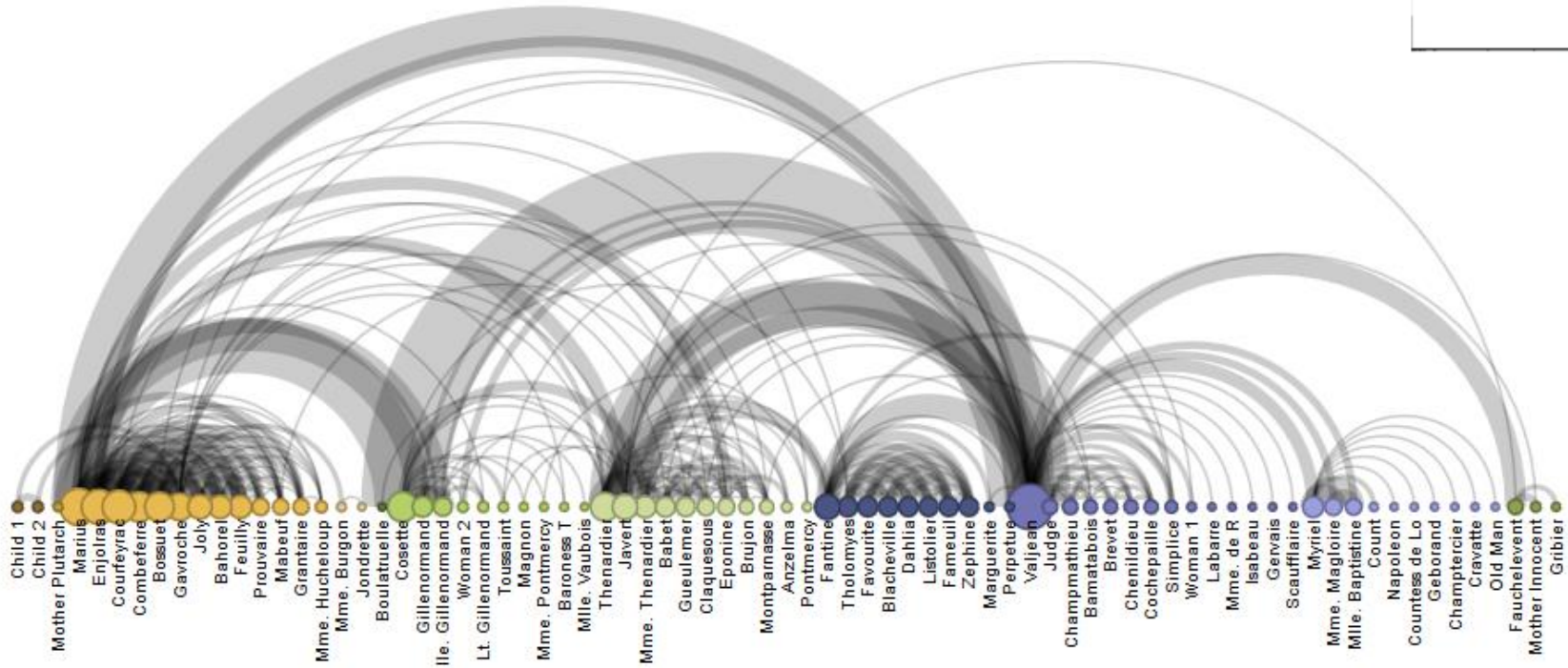
Getting 3D right is difficult

LAYOUT 3D

Sometimes necessary
(!?)



LAYOUT LINEAR



<http://mbostock.github.io/protovis/ex/arc-full.html>

<http://www.bewitched.com/song.html>

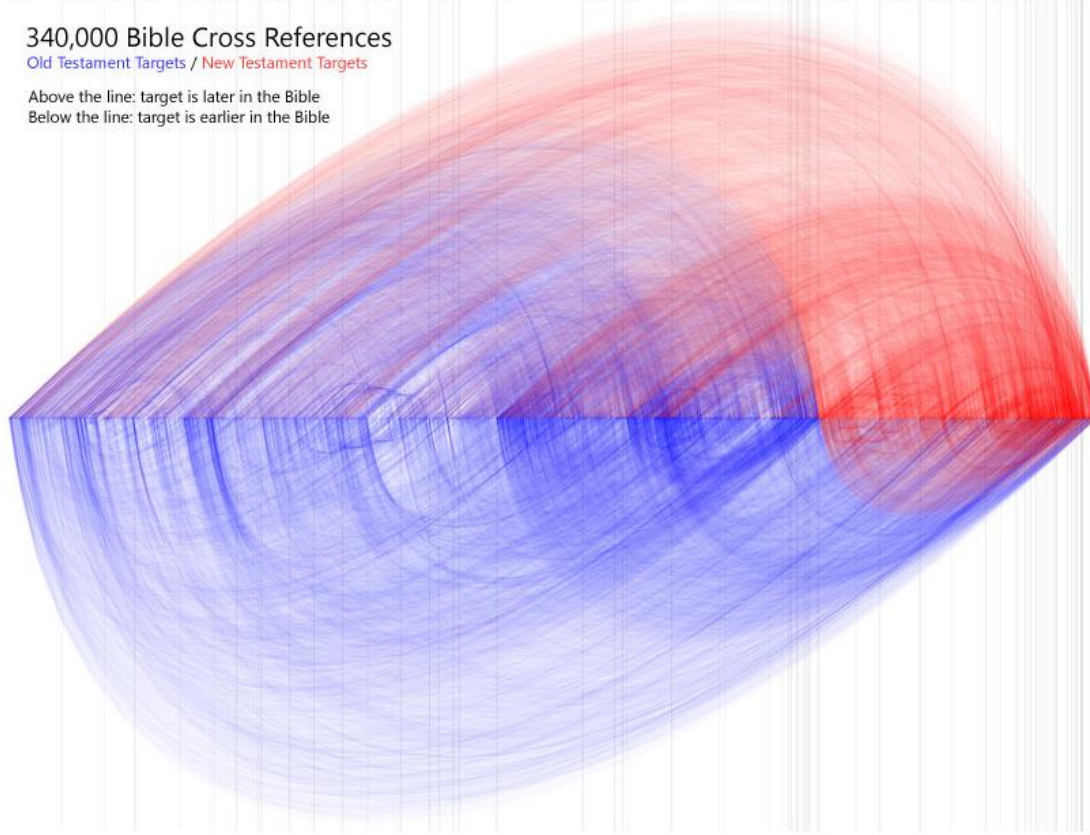
LAYOUT LINEAR

Gen Exod Lev Num Deut Josh 1Sam 1Kgs 1Chr Ezra Ps Prov Isa Jer Ezek Hos Matt Luke JohnActs Rom Gal Hb Re

340,000 Bible Cross References

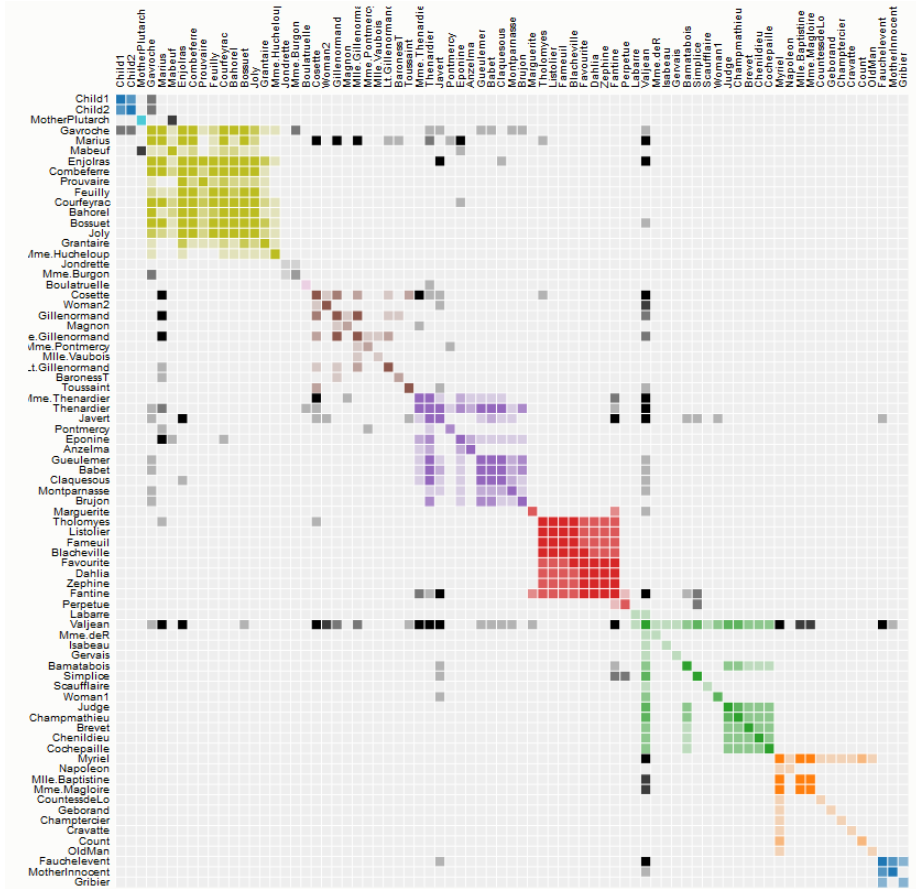
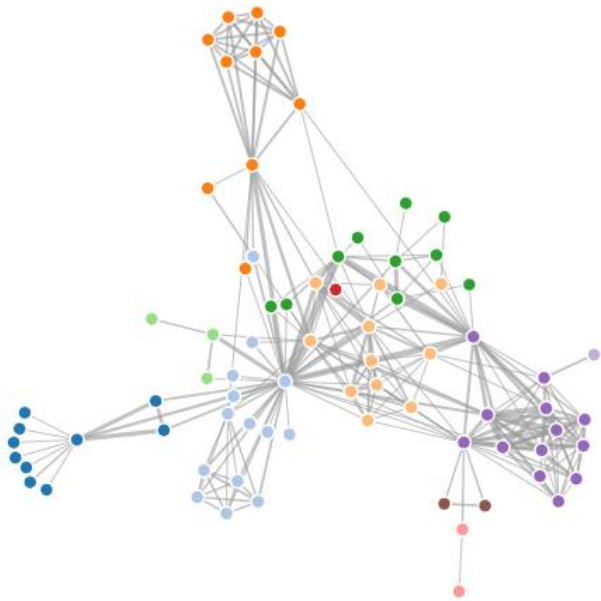
[Old Testament Targets](#) / [New Testament Targets](#)

Above the line: target is later in the Bible
Below the line: target is earlier in the Bible

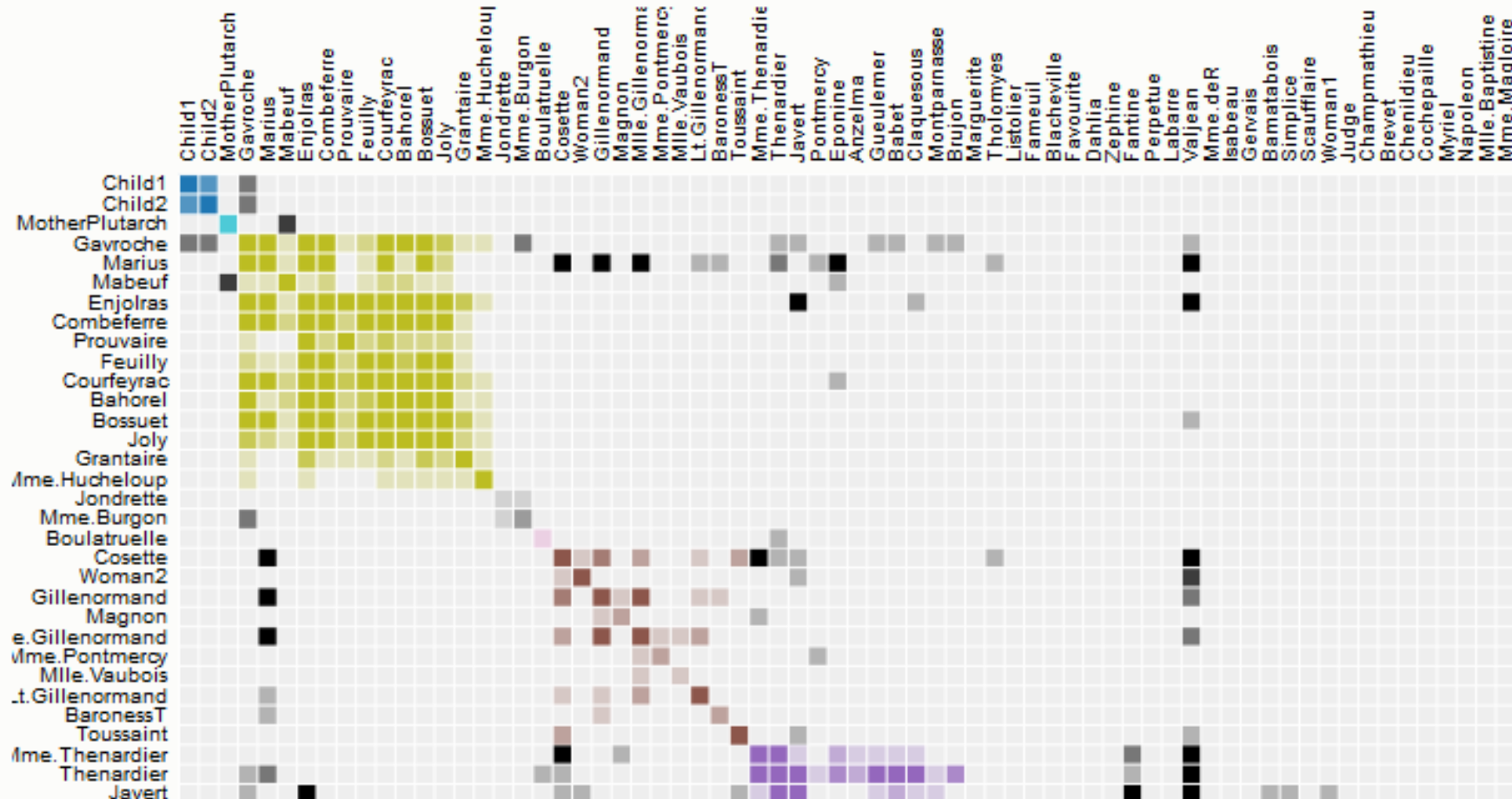
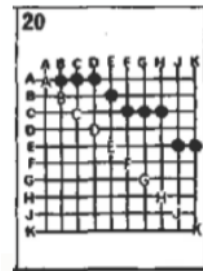


<https://www.openbible.info/labs/cross-references/>

LAYOUT ADJACENCY MATRIX



ADJACENCY MATRIX



PROS/CONS

Matrix

- No vertex/edge overlap or crossings
- Readable for dense graph
- Fast navigation

-
- Less familiar
 - Space intensive
 - Weak for path following tasks

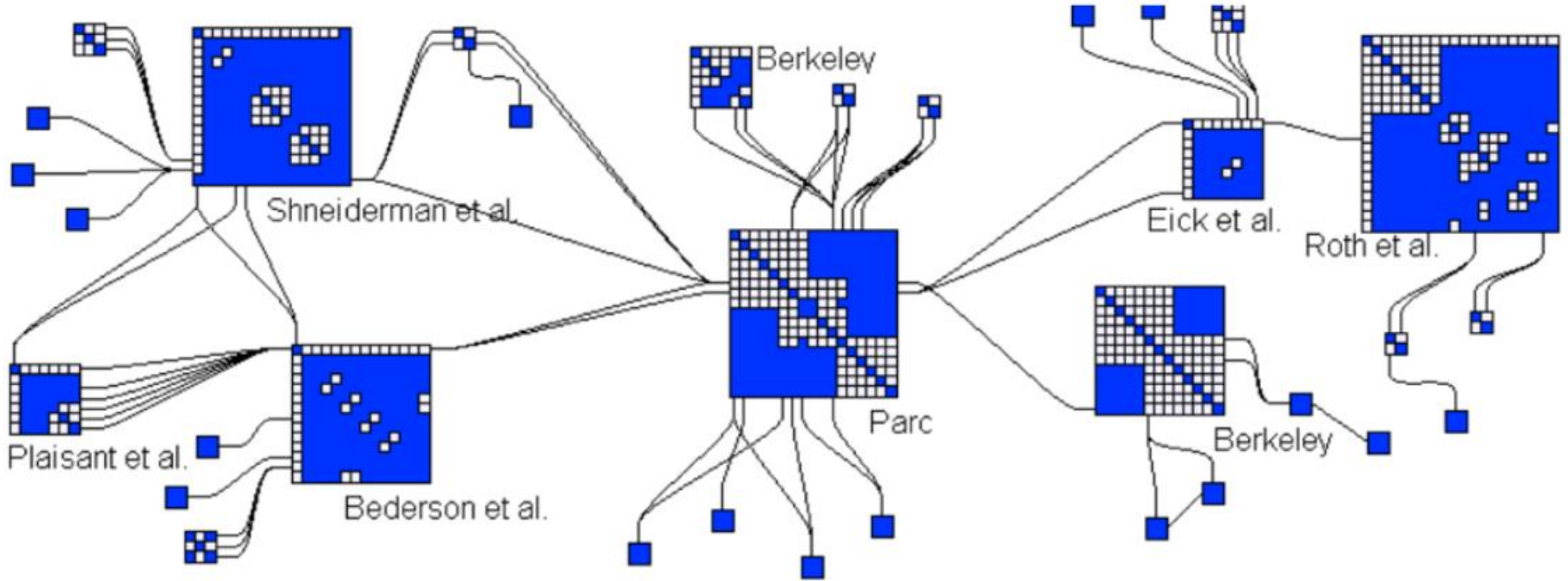
Node-Link

- Familiar
- Compact
- Path following easier
- Effective for small and sparse graphs

-
- Useless without layout
 - Not readable for dense graphs
 - Manipulation requires layout computation

HYBRID

Henry et al., NodeTrix



Infovis Coauthorship (133 actors)

Dense = matrices, sparse = node-link

MULTIVARIATE NETWORKS

Network Visualization by Semantic Substrates

Ben Shneiderman and Aleks Aris
University of Maryland, HCIL

Copyright 2006

<https://www.youtube.com/watch?v=f3hmn7gvocQ>

MULTIVARIATE NETWORKS

Type A

- | Aaron Linus
- | Adam Blackwell
- | **Alameda**
- | Aquatics
- | Arthur Swordane
- | Assan
- | Brandow Tropical Fish
- | Catherine Carnes
- | Cesar Gil
- | Colie Carnes
- | Cr Wharton
- | Don Rabinowitz
- | Donna Ghostley
- | Ed Parker
- | Edward Abbey
- | Eva Berrima
- | **Faron Gardner**
- | Gardner
- | Green
- | Griffin Vulture
- | Jeri Ryan
- | Jessica Alba
- | John Burton Wade
- | John Wharton
- | Kim
- | Kim Basinger
- | Leslie
- | Lily
- | **Luella Vedic**
- | Madhi Kim
- | Marcus James
- | **Melissa Ethridge**
- | Michael Jackson
- | Oogjes
- | Paul McCartney
- | r'Bear
- | Richmond
- | Richmond Shire
- | Singer
- | **songwriter Jimmy Buffett**
- | Spix
- | Terry Mulley
- | Tony Jones

Type B

- | **AJL**
- | **Animal Justice League**
- | Animals Australia Glenys Oogjes
- | **Banfield Hospital**
- | **Broadway Hotel**
- | CDC
- | Centers for Disease Control and Preve...
- | Chiron
- | CITES
- | Department of Health
- | DOA
- | **Earth Liberation Front**
- | **Eighth Annual Society**
- | **ELF**
- | **FBI**
- | Fish and Wildlife Service
- | Florida Department
- | FWS
- | FWS Special Agent
- | Global Ways
- | **Justice League**
- | La Trobe University
- | **Louisiana State University**
- | Mary Washington College
- | Miami Beach Convention Center
- | **PETA**
- | Richmond Shire Council
- | Sanchez
- | Shravaana
- | SPEAC
- | **SPDMA**
- | Tamarack News Service
- | **U.S. Fish and Wildlife Service**
- | University of California Medical Center
- | US Department of Agriculture

Type C

- | Los Angeles
- | **Africa**
- | Connecticut
- | Lily
- | Louisiana State
- | Manchester
- | **New York**
- | Southern California
- | **U.S.**
- | **United States**
- | **US**
- | Alabama
- | Australia
- | California
- | Florida
- | Henrico County
- | Kemp
- | Kenya
- | Melbourne
- | Miami
- | Ms
- | New Guinea
- | Northeast Congo
- | Proa Station
- | San Diego
- | South America
- | **Texas**
- | Toowoomba

Jigsaw,
Stasko et al., 2008

MULTIVARIATE NETWORKS

GraphDice: A System for Exploring Multivariate Social Networks

A. Bezerianos
F. Chevalier
P. Dragicevic
N. Elmqvist
J-D. Fekete

INRIA
École Centrale Paris
Purdue University

ADDITIONAL CHALLENGES

- TIME
- INTERACTION
- EDGE DIRECTION

NETWORK TOOLS

- **Gephi**
- **Cytoscape**
- **Pajek**
- **Java** Jung toolkit
- **D3** + Cola.js

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