CIS 4930/6930-002
DATA VISUALIZATION

TREES & GRAPHS

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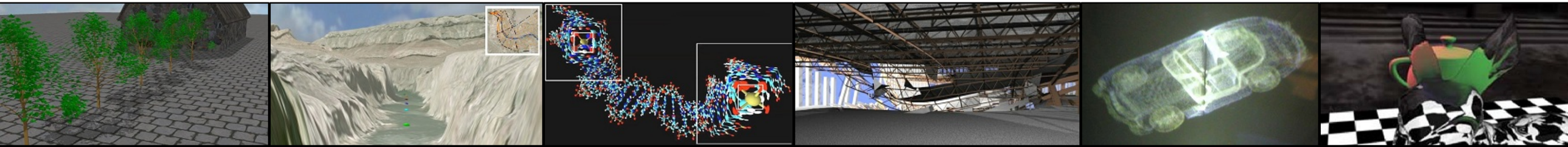
University of South Florida

slides credits Alex Bigelow (U of Utah), Miriah Meyer (U of Utah), Hanspeter Pfister (Harvard), Jeff Heer (Stanford)



REMINDERS

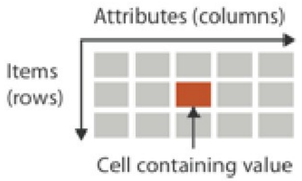
3/2/2018 – Project 5 Due

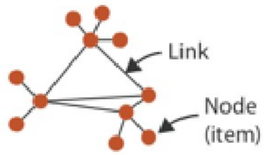
3/7/2018 – Project 5 Peer Reviews Due

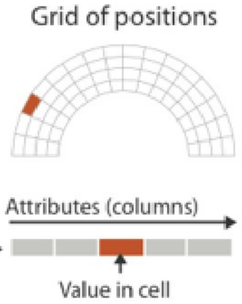
3/19/2018 – Paper Review Presentations Begin

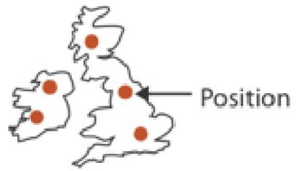
dataset types

Tables	Networks & Trees	Fields	Geometry	Clusters, Sets, Lists
Items	Items (nodes)	Grids	Items	Items
Attributes	Links	Positions	Positions	
	Attributes	Attributes		

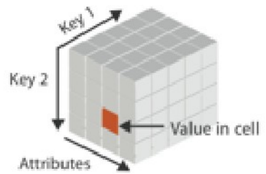




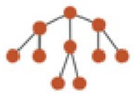


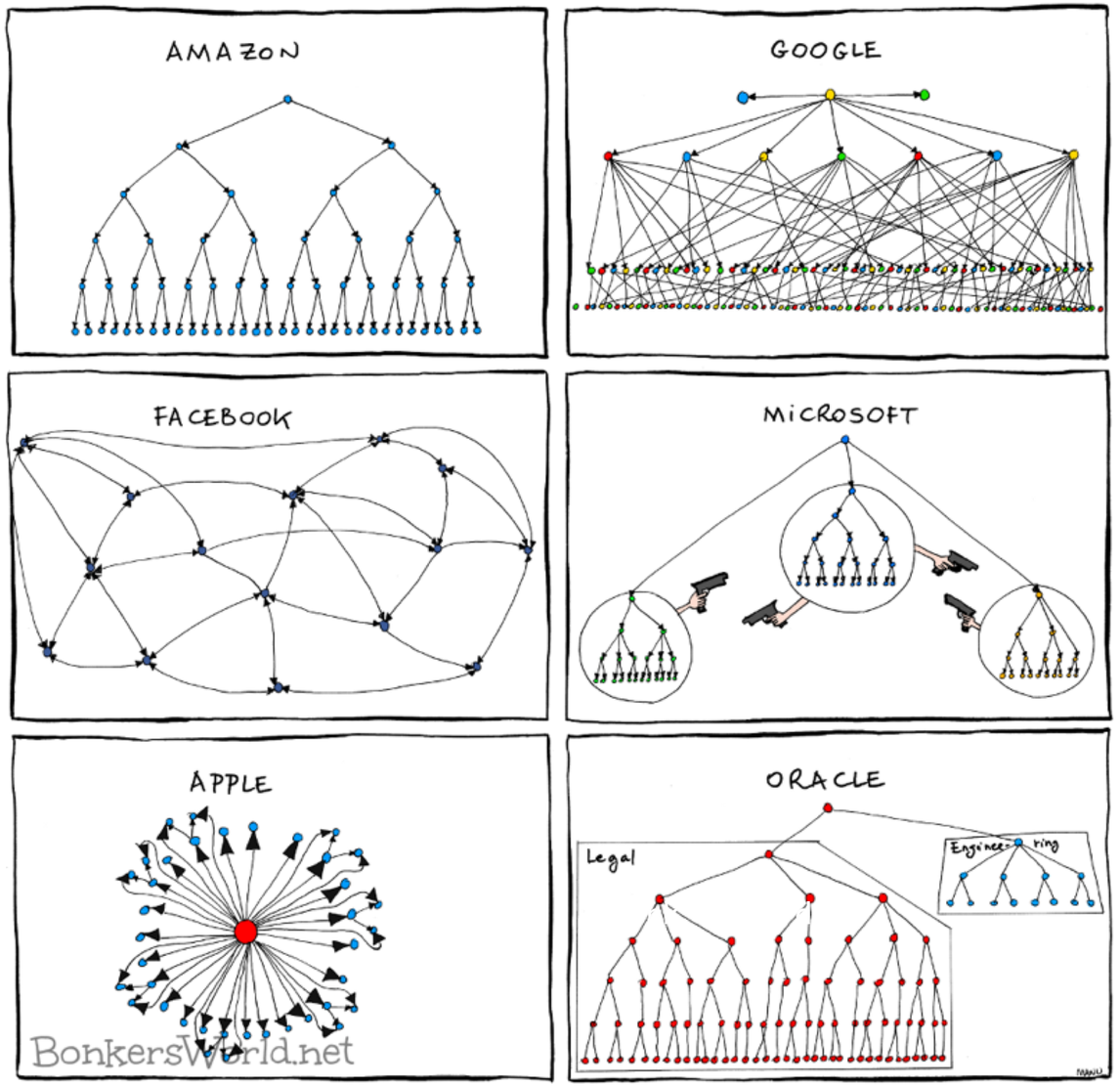


→ *Multidimensional Table*



→ *Trees*

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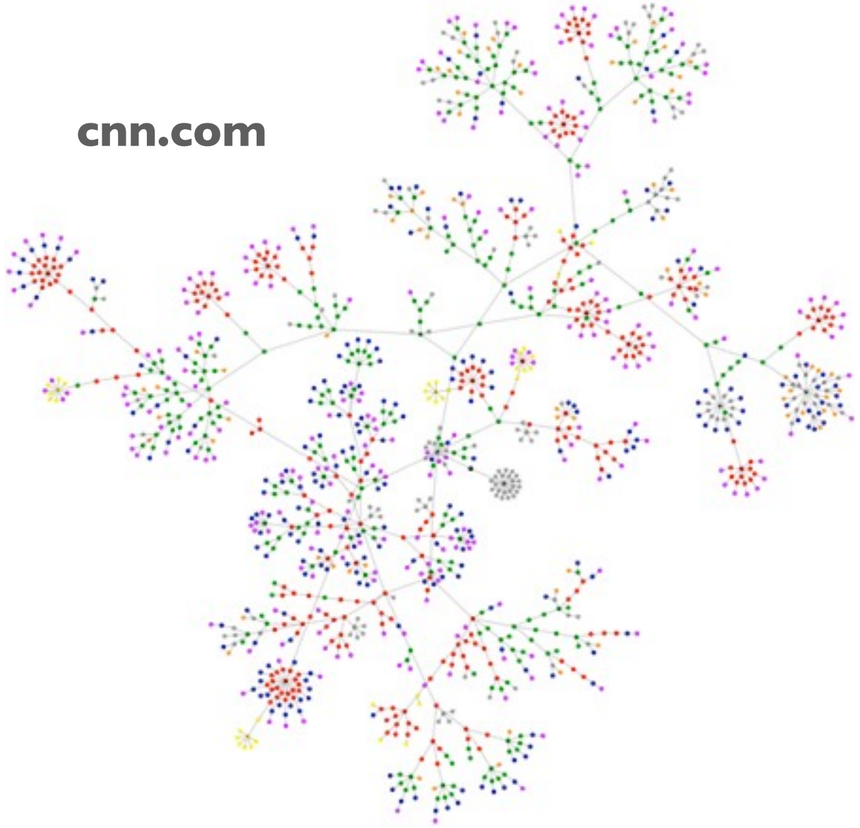

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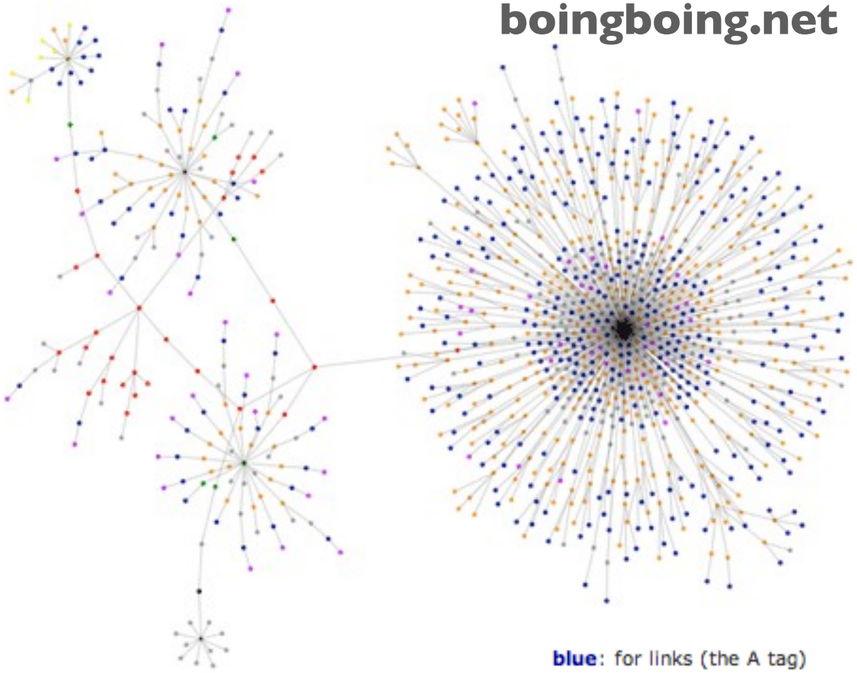
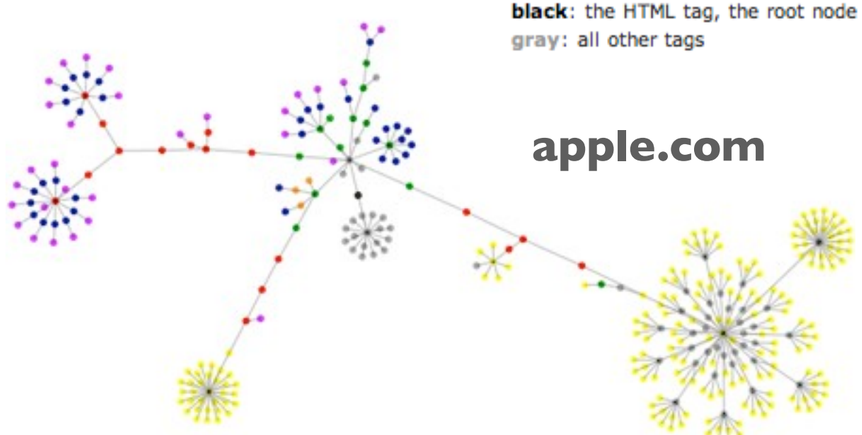


blue: for links (the A tag)
red: for tables (TABLE, TR and TD tags)
green: for the DIV tag
violet: for images (the IMG tag)
yellow: for forms (FORM, INPUT, TEXTAREA, SELECT and OPTION tags)
orange: for linebreaks and blockquotes (BR, P, and BLOCKQUOTE tags)
black: the HTML tag, the root node
gray: all other tags

wired.com



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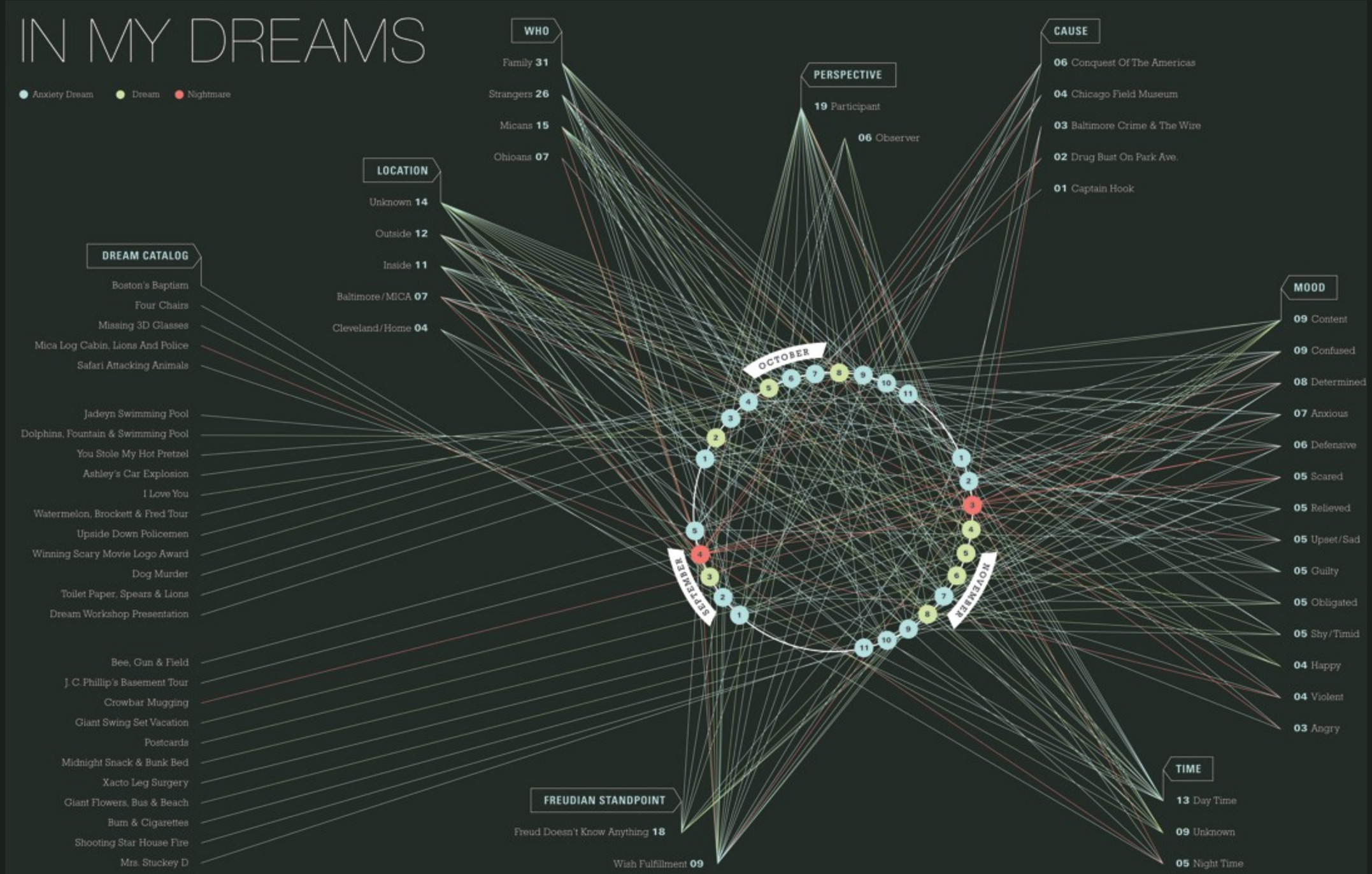


KAILIE PARRISH

DEFINITIONS

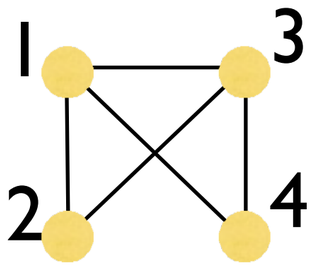
GRAPH

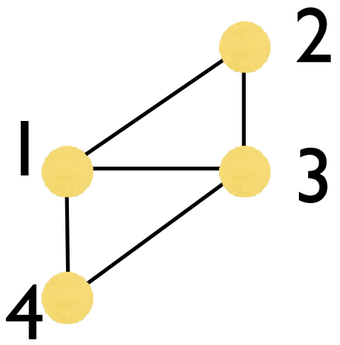
A graph **G** consists of

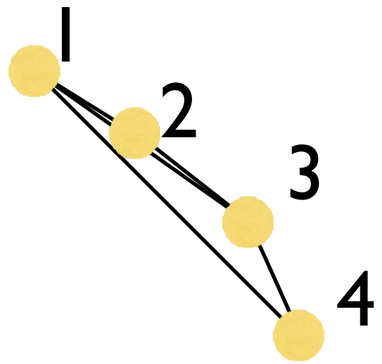
V - a collection of vertices (or nodes)

E - a set of edges consisting of vertex pairs

An edge e_{xy} = (x,y) connects two vertices x and y







Example

V={1,2,3,4}

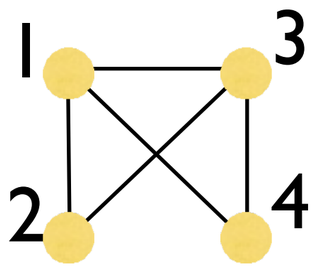
E={(1,2),(1,3),(2,3),(3,4),(4,1)}

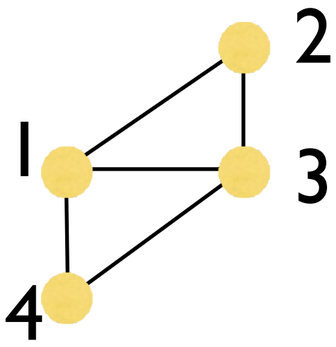
Nodes

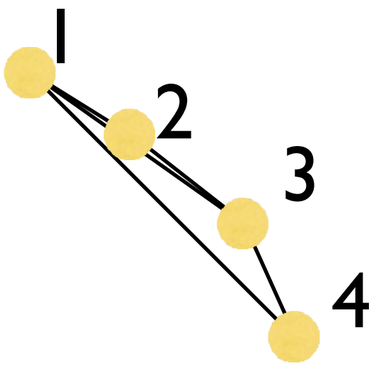
ID	Attribute 1	Attribute 2
1	3.4	Good
2	5.8	Bad
3	1.1	Ugly
4	-3.5	Really Ugly

Edges

Source	Target	Attribute 3
1	2	100
1	3	200
1	4	50
2	3	150
3	4	250

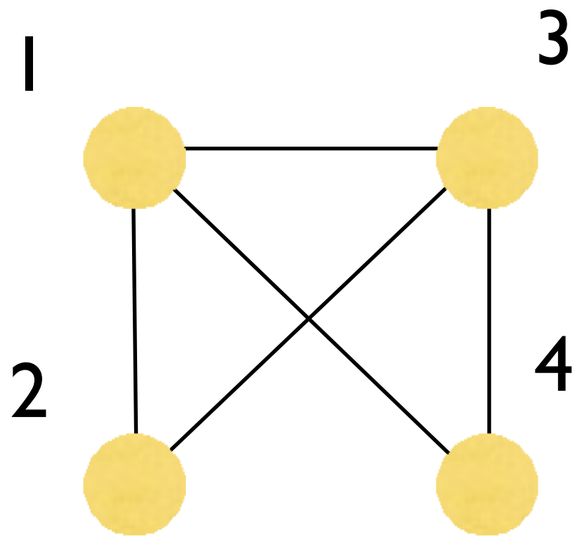






Adjacency Matrix

A matrix that where each row/column represents a node and non-zero values represent edges



Example

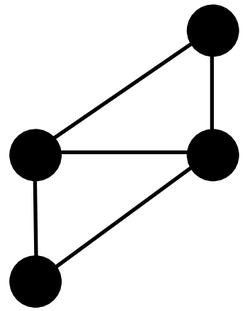
$$\begin{bmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \end{bmatrix}$$

GRAPHS & TREES

graphs

model relationships about data

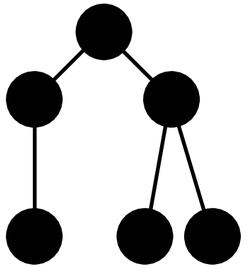
nodes and edges



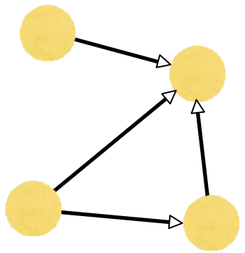
trees

graphs with hierarchical structure

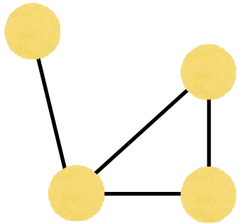
nodes as parents and children



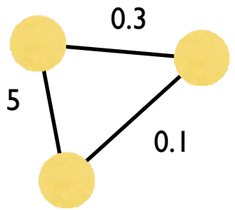
A BUNCH OF DEFINITIONS



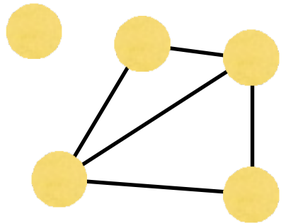
A directed graph



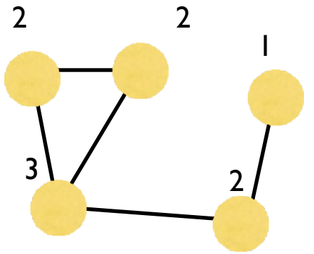
An undirected graph



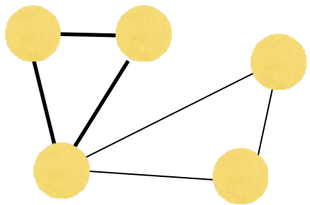
Weighted



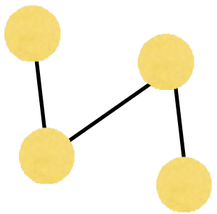
Unconnected



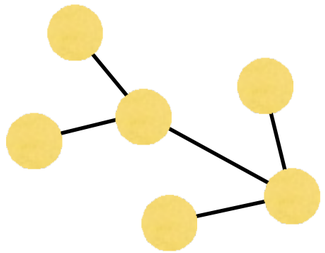
Node degrees



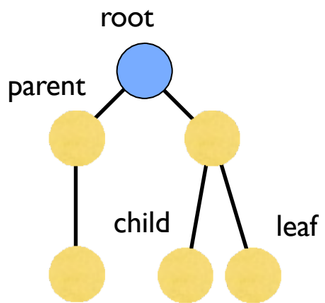
A cycle



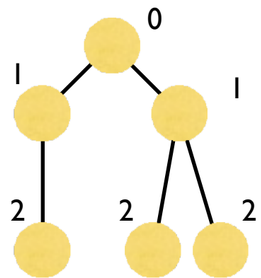
An acyclic graph



A connected acyclic graph,
a.k.a.a **tree**



A rooted tree
or hierarchy



Node depths

VISUALIZING TREES

HTTP://VCG.INFORMATIK.UNI-ROSTOCK.DE/~HS162/TREEPOSTER/POSTER.HTML

ROOTED TREES

recursion makes it elegant and fast to draw trees

approaches:

node link

layered

indentation

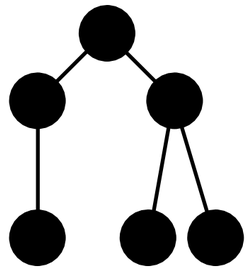
enclosure

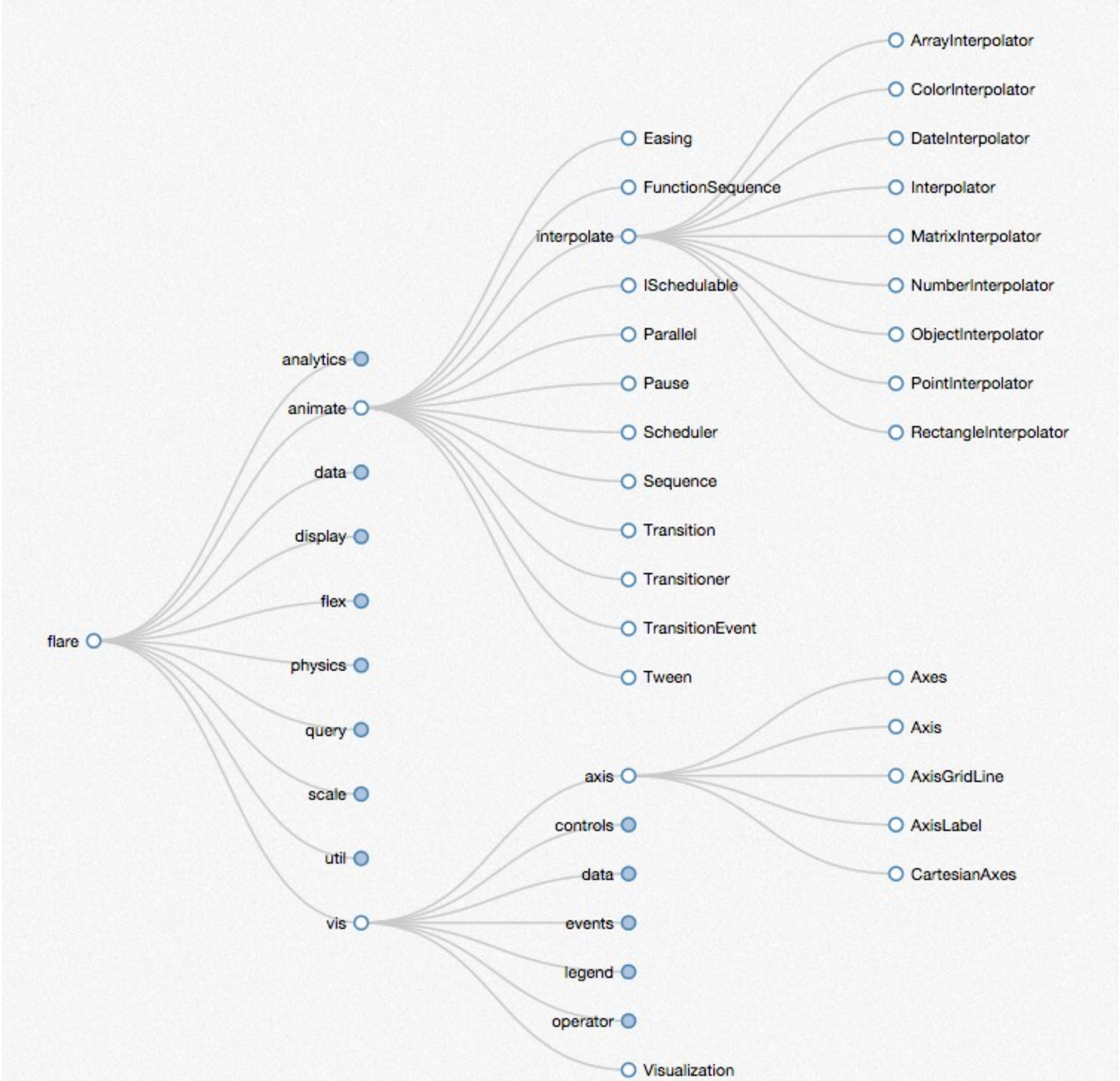
NODE-LINK DIAGRAMS

nodes are distributed in space, connected by straight or curved lines

typical approach is to use 2D space to break apart breadth and depth

often space is used to communicate hierarchical orientation





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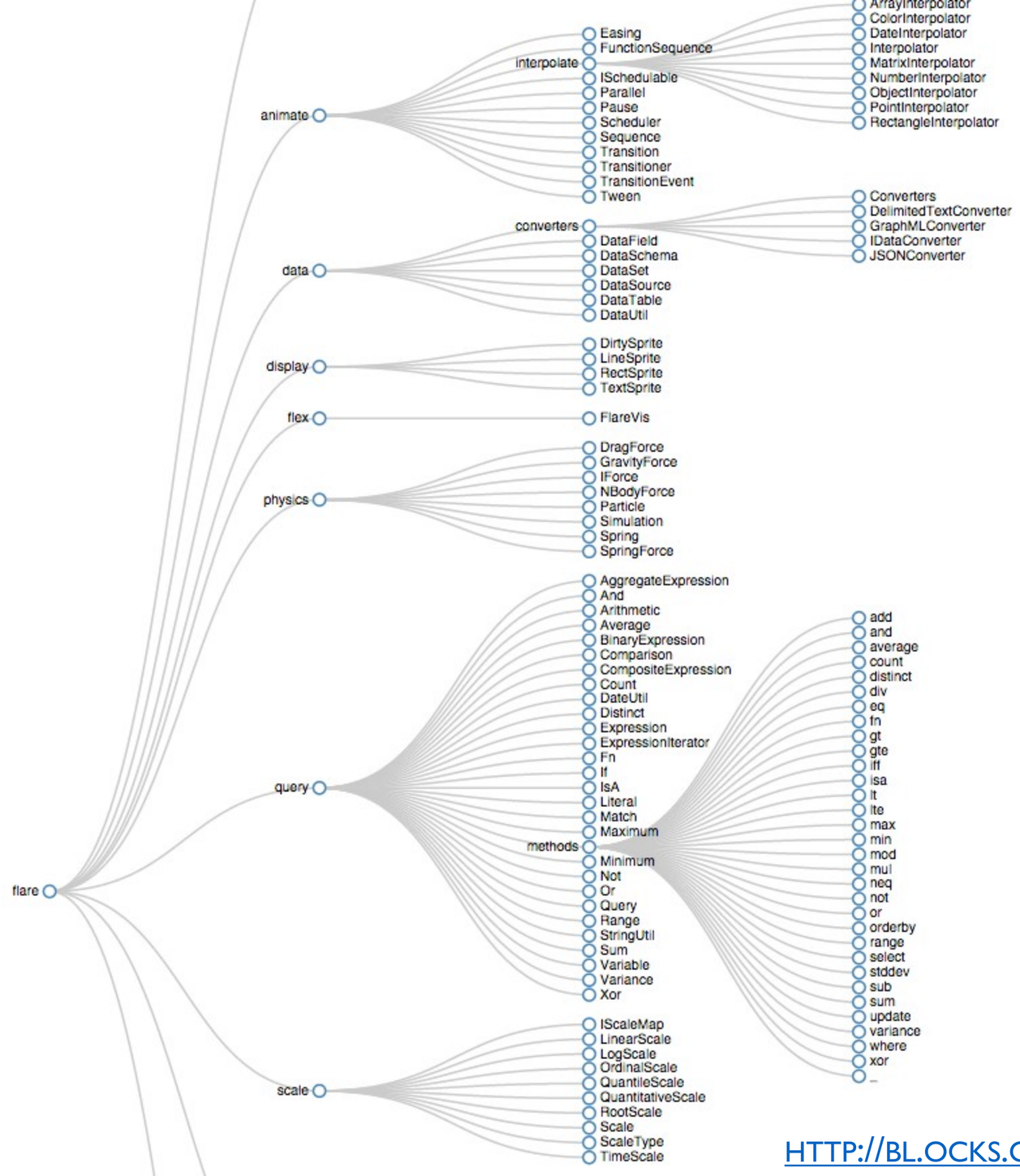

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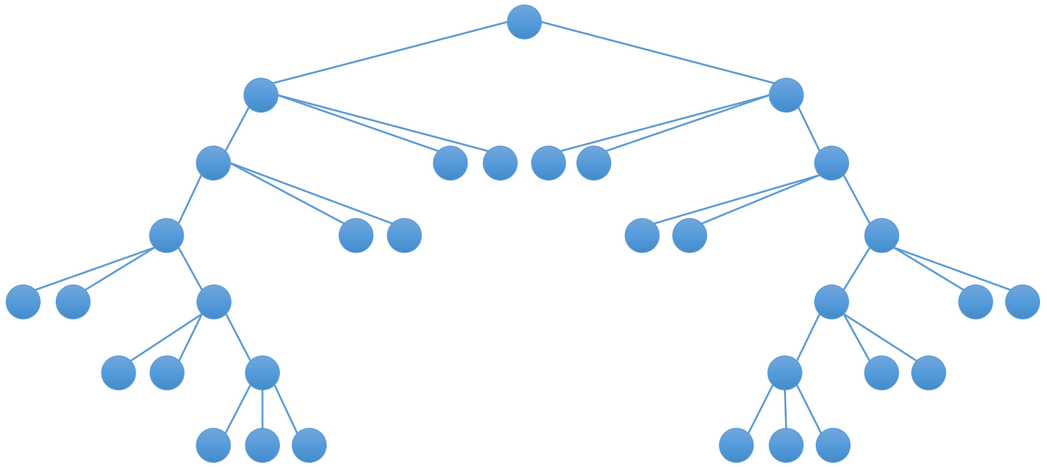
REINGOLD-TILFORD

REPEATEDLY DIVIDE SPACE FOR SUBTREES BY LEAF COUNT

breadth of tree along one dimension

depth along the other dimension

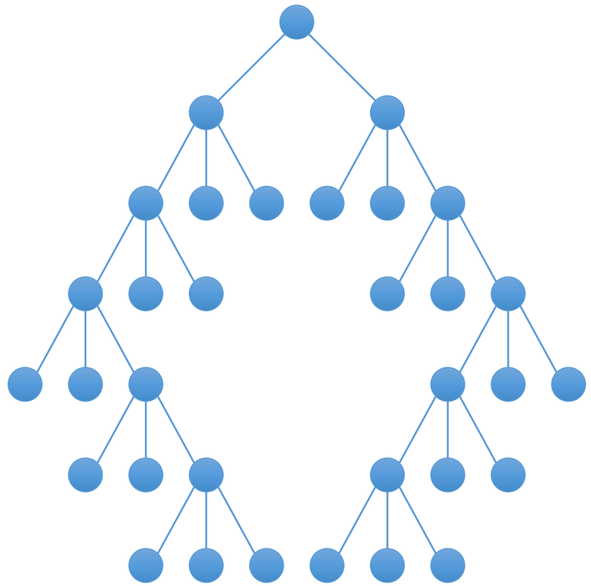


REINGOLD-TILFORD

goal

make smarter use of space

maximize density and symmetry



REINGOLD-TILFORD

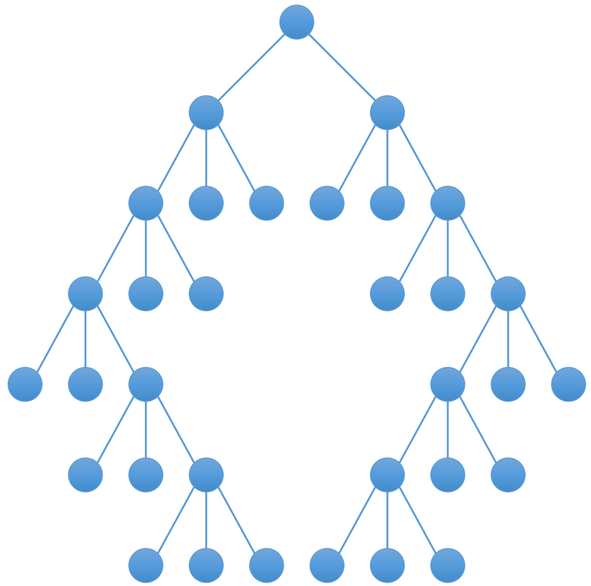
design concerns

clearly encode depth level

no edge crossings

isomorphic subtrees drawn identically

compact



REINGOLD-TILFORD

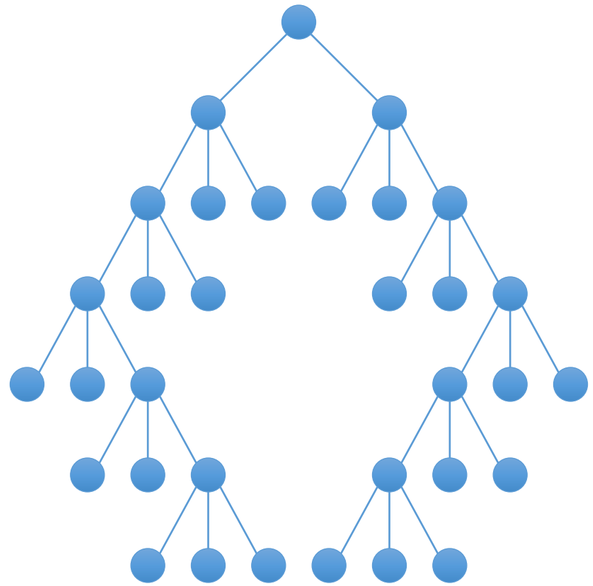
approach

bottom up recursive approach

for each parent make sure every subtree is drawn

pack subtrees as closely as possible

center parent over subtrees



LAYERED DIAGRAMS

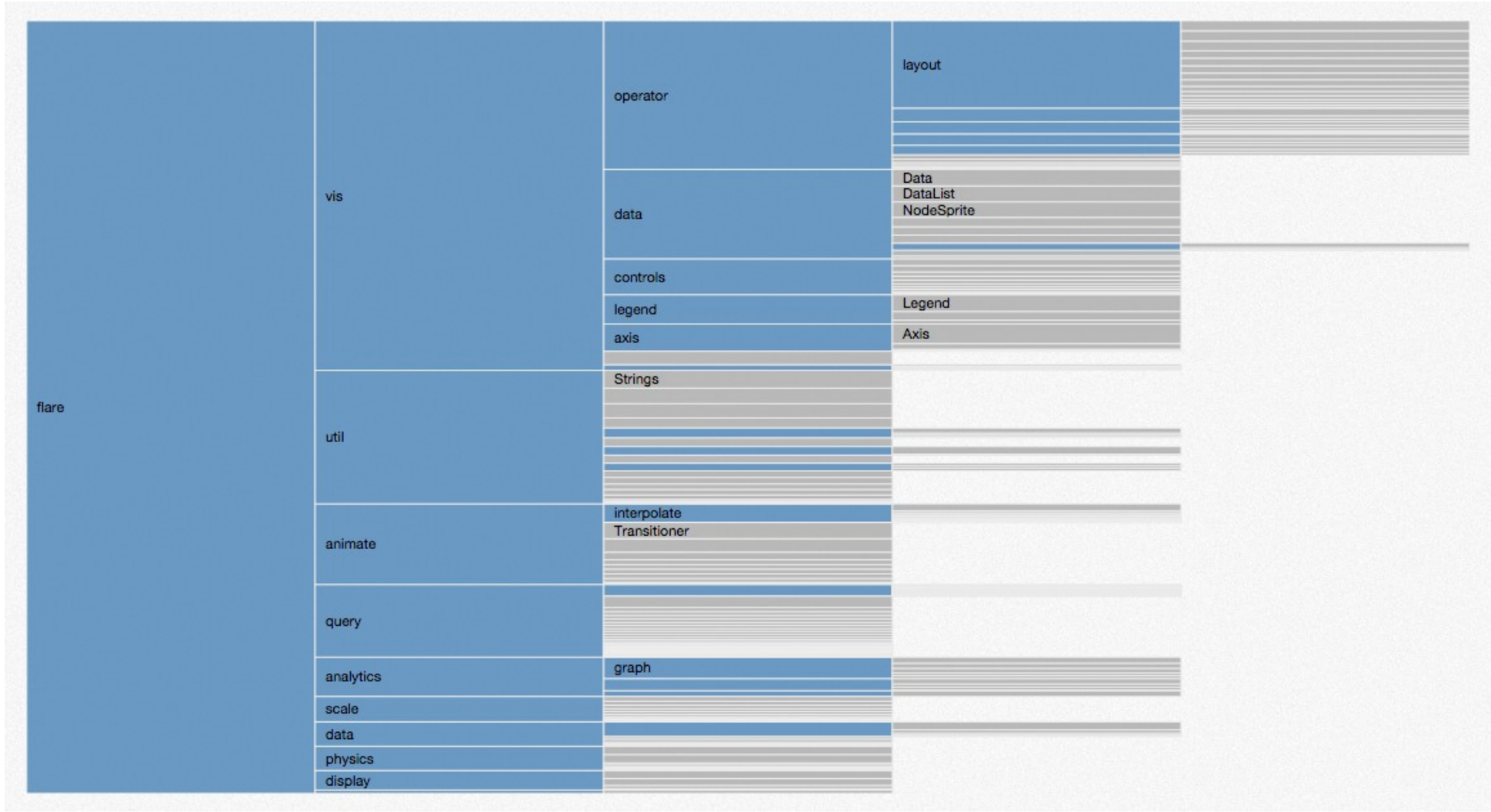
recursive subdivision of space

structure encoded using:

layering

adjacency

alignment



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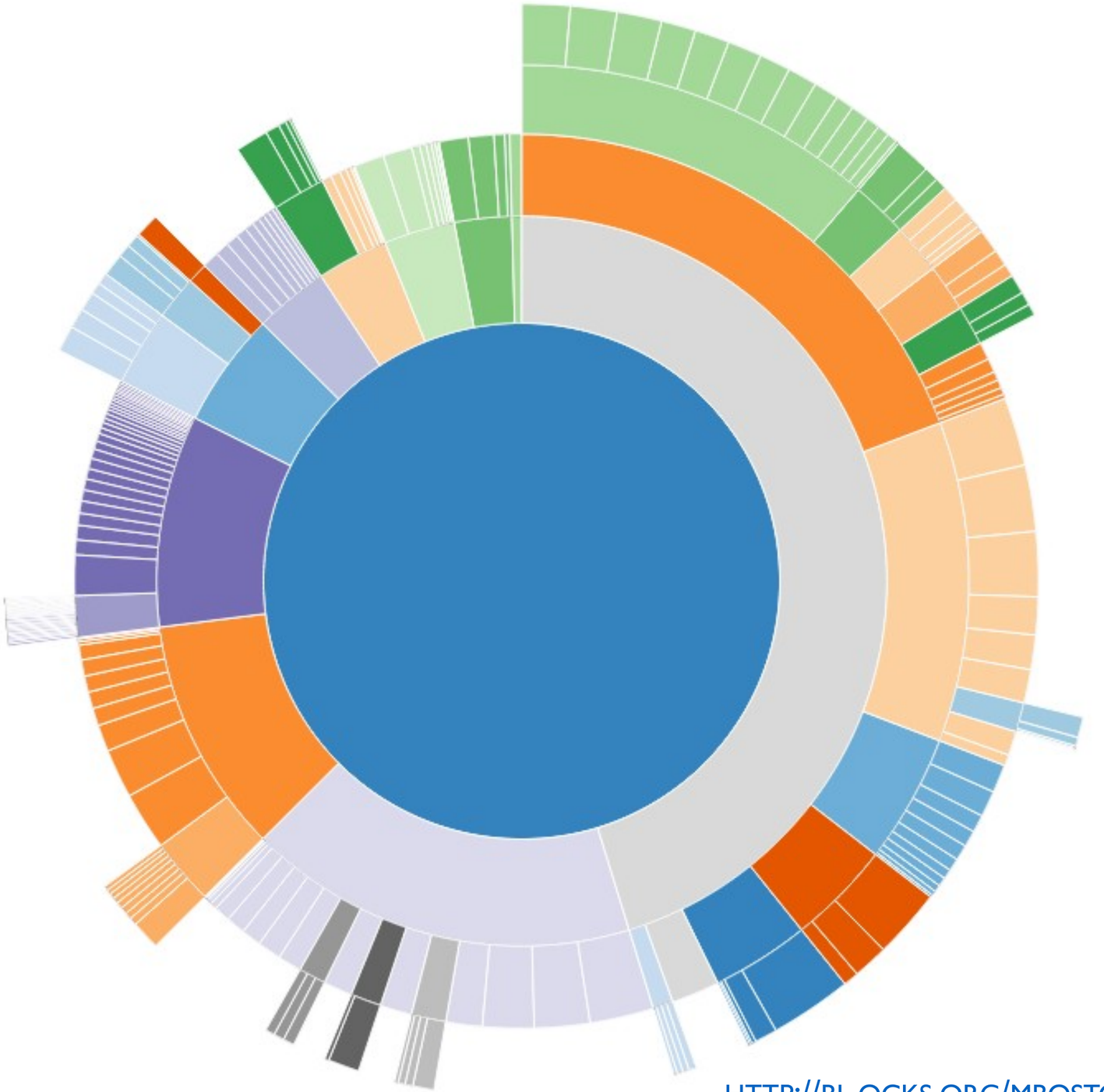

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SCALE PROBLEM

tree breadth often grows exponentially—quickly run out of space!

solutions

scrolling or panning

filtering or zooming

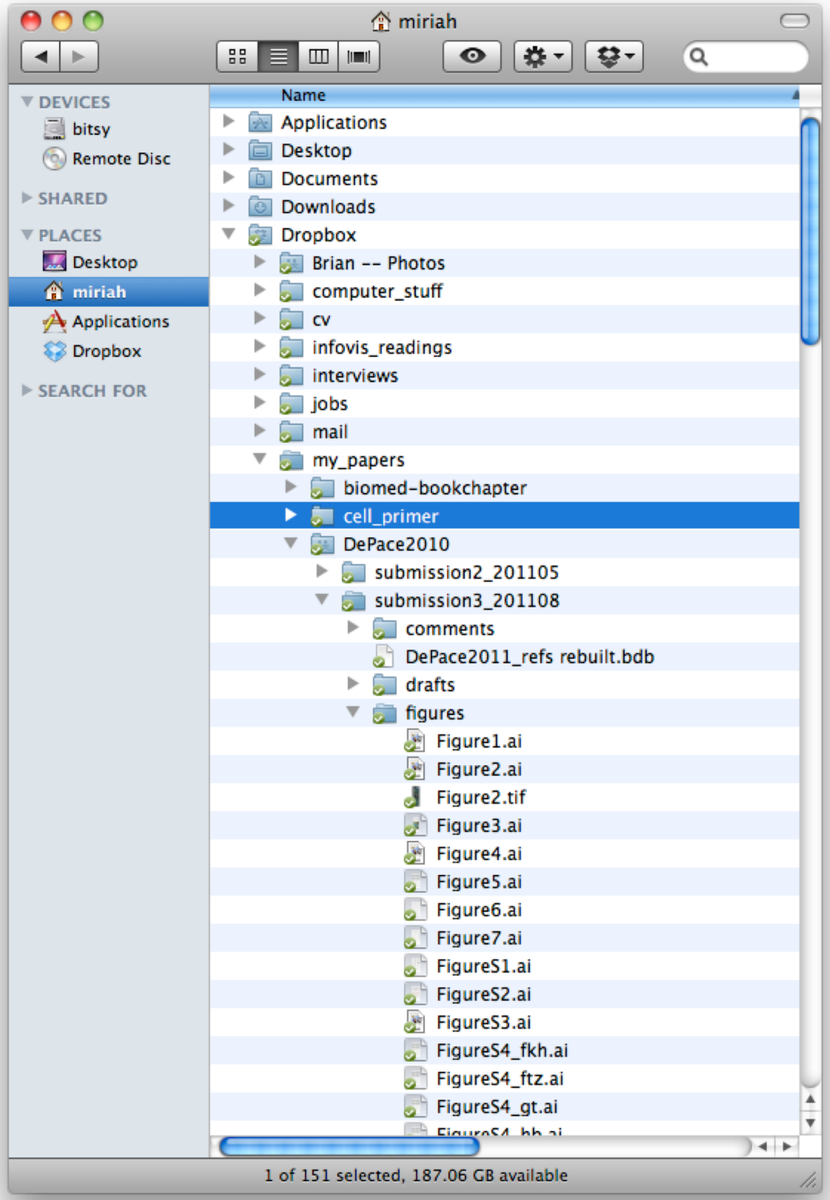
hyperbolic layout

INDENTATION

indentation used to show parent/child relationships

breadth and depth contend for space

problem: often requires a great deal of scrolling



ENCLOSURE DIAGRAMS

encode structure using spatial enclosure

often referred to as treemaps

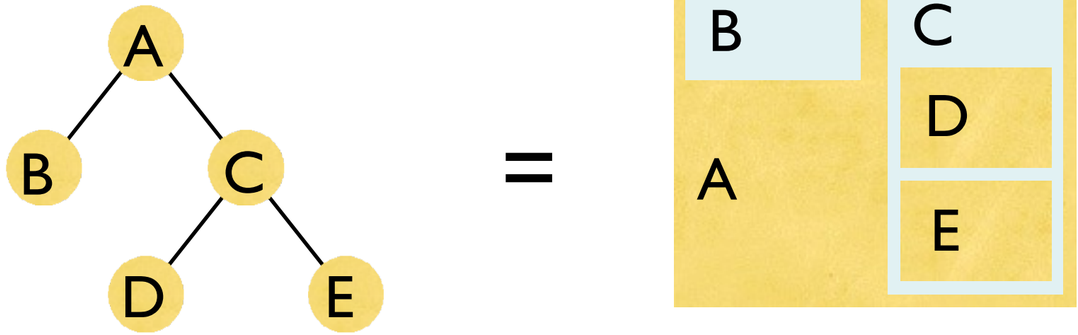
benefits

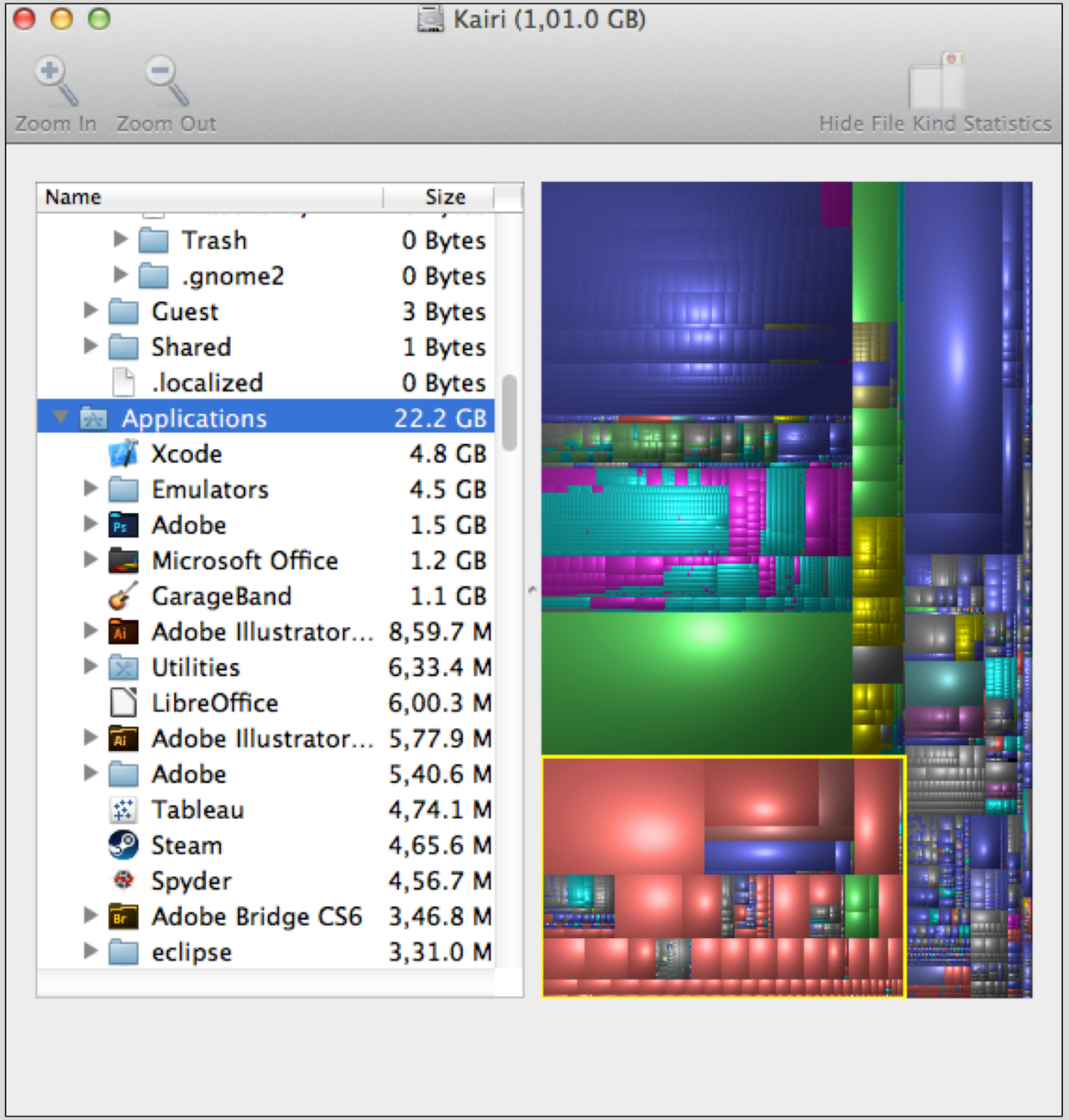
provides single view of entire tree

easier to spot small / large nodes

problems

difficult to accurately read depth





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TREEMAPS

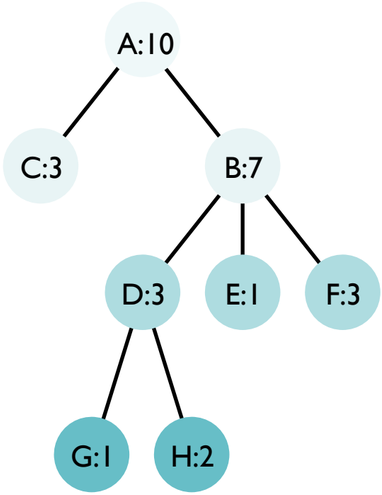
recursively fill space based on a size metric for nodes

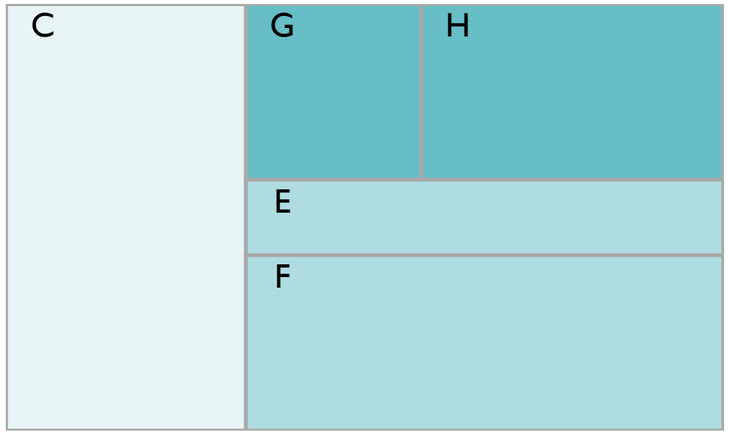
enclosure indicates hierarchy

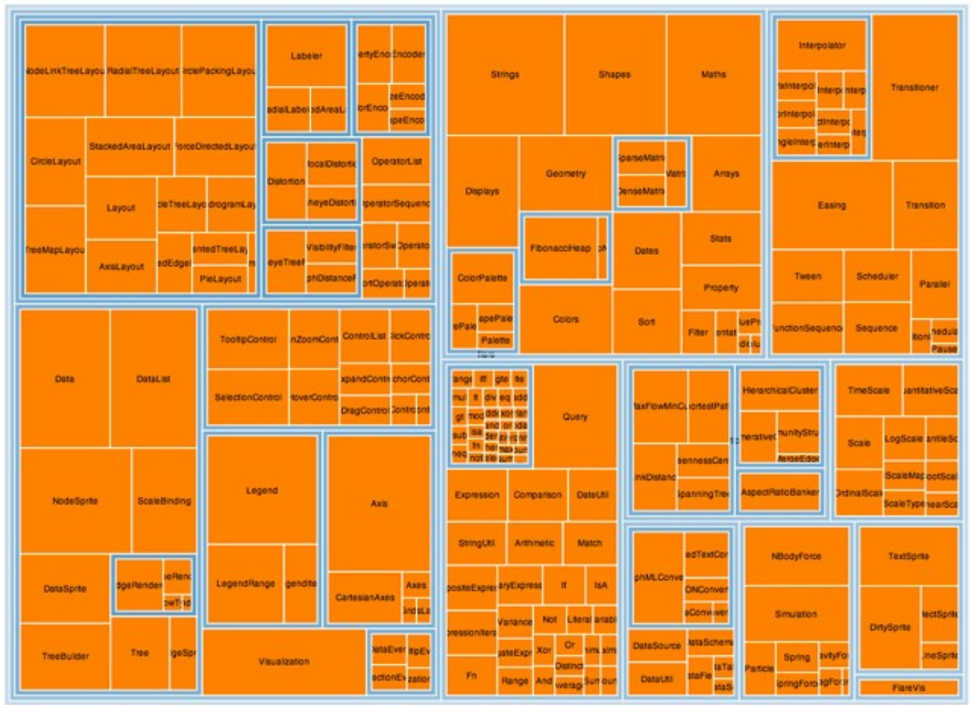
additional measures can control aspect ratio of cells

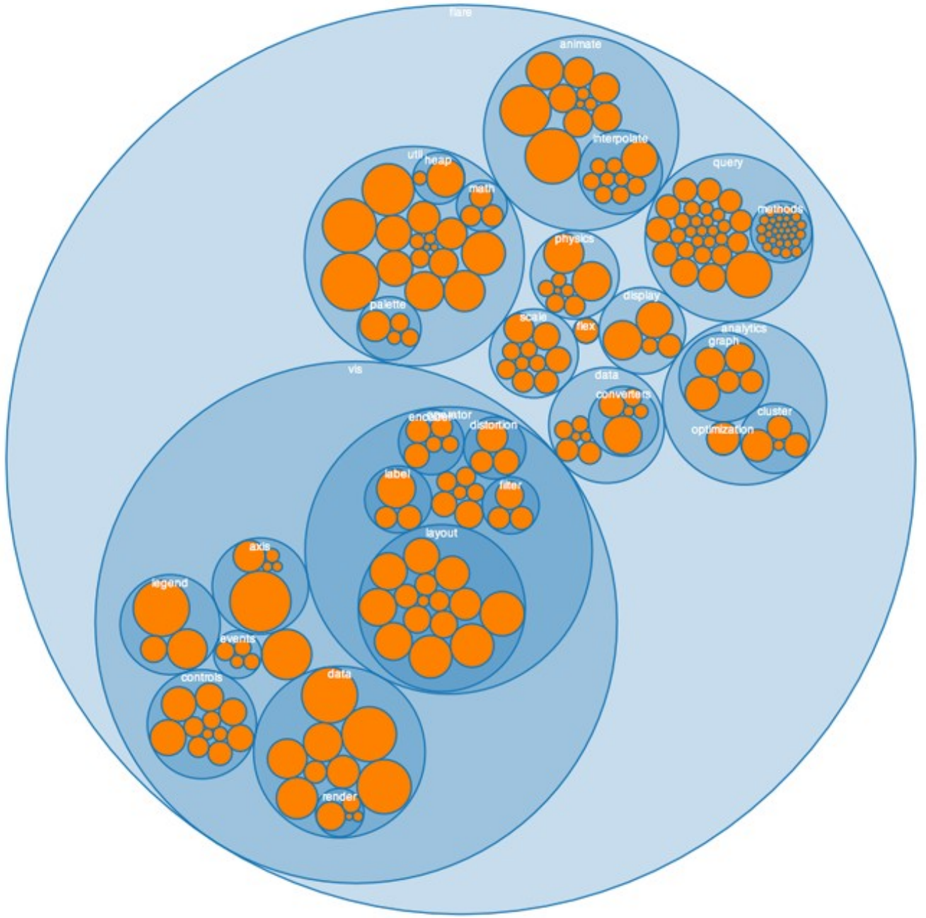
most often use rectangles, but other shapes possible

square, circle, voronoi tessellation









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‘What Do You Think Is the Most Important Problem Facing This Country Today?’

By GREGOR AISCH and ALICIA PARLAPIANO FEB. 27, 2017

Since the presidency of Franklin D. Roosevelt, the Gallup polling organization has asked Americans an open-ended question: “What do you think is the most important problem facing this country today?”

As Donald J. Trump prepares for his first major address to the nation on Tuesday, he has a unique set of issues to tackle. But there is not one singular issue that is dominating the American consciousness.

January 2015

The biggest problems cited by Americans this month:

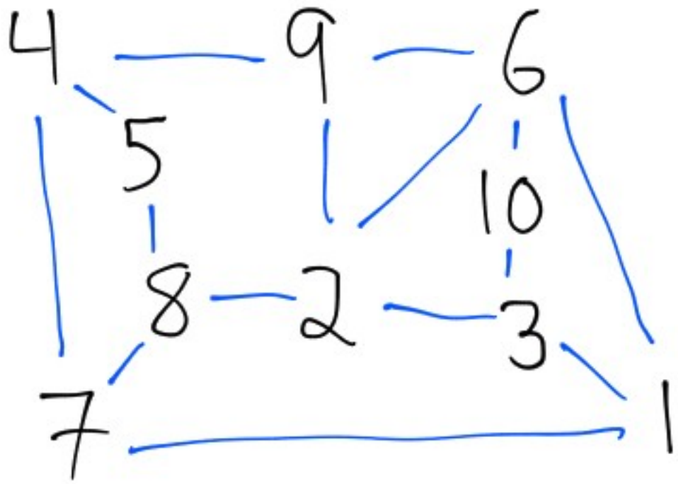
•HTTPS://WWW.NYTIMES.COM/INTERACTIVE/2017/02/27/US/POLITICS/MOST-IMPORTANT-PROBLEM-GALLUP-POLLING-QUESTION.HTML?SMID=PL-SHARE

VISUALIZING GRAPHS

	1	2	3	4	5	6	7	8	9	10
1	0	0	1	0	0	1	1	0	0	0
2	0	0	1	0	0	1	0	1	1	0
3	1	1	0	0	0	0	0	0	0	1
4	0	0	0	0	1	0	1	0	1	0
5	0	0	0	1	0	0	0	1	0	0
6	1	1	0	0	0	0	0	0	1	1
7	1	0	0	1	0	0	0	1	0	0
8	0	1	0	0	1	0	1	0	0	0
9	0	1	0	1	0	1	0	0	0	0
10	0	0	1	0	0	1	0	0	0	0

GRAPH DRAWING EXERCISE

create an aesthetically pleasing **node-link diagram** representation



visualcomplexity.com | A visual exploration on mapping complex networks

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visual complexity

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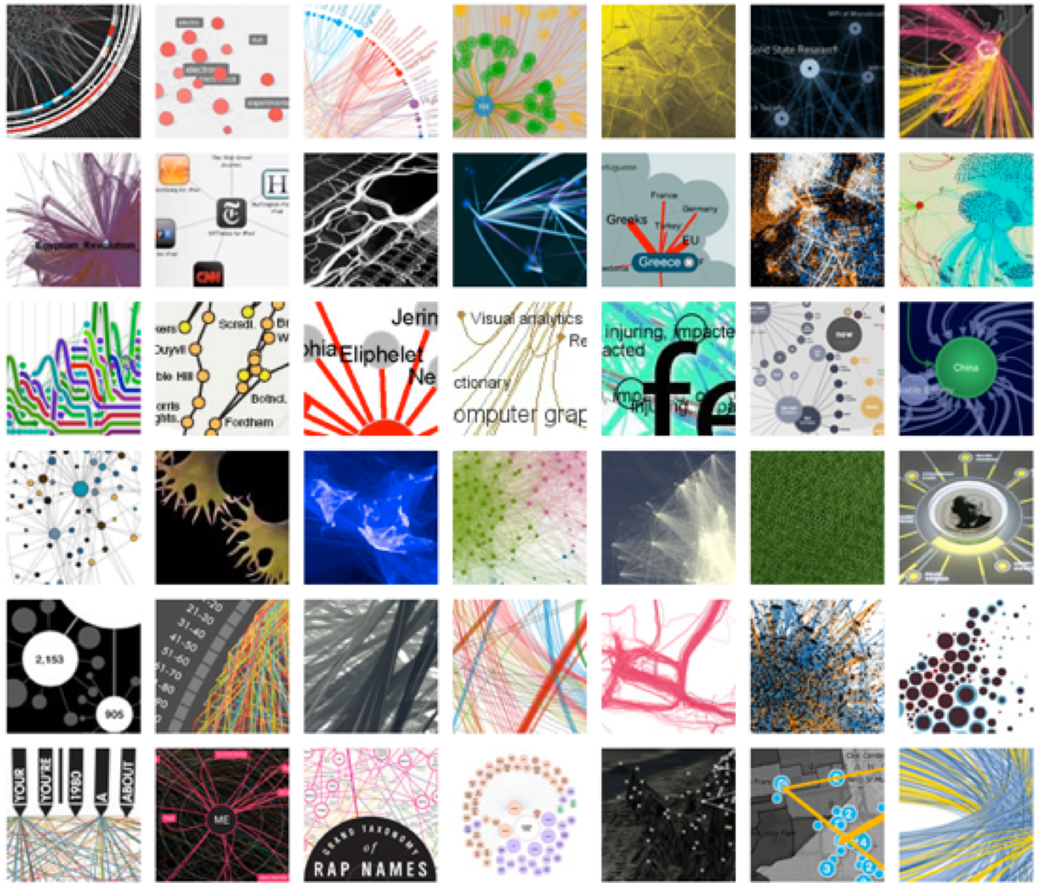

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See All (772)

VISUALIZING GRAPHS

node link layouts

Reingold-Tilford (discussed previously)

Sugiyama (directed acyclic graphs)

Force directed

Attribute-based

adjacency matrices

aggregate views

Motif Glyphs

PivotGraph

SPATIAL LAYOUT

primary concern of graph drawing is the spatial layout of nodes and edges

often (but not always) the goal is to effectively depict the graph structure

connectivity, path-following

network distance

clustering

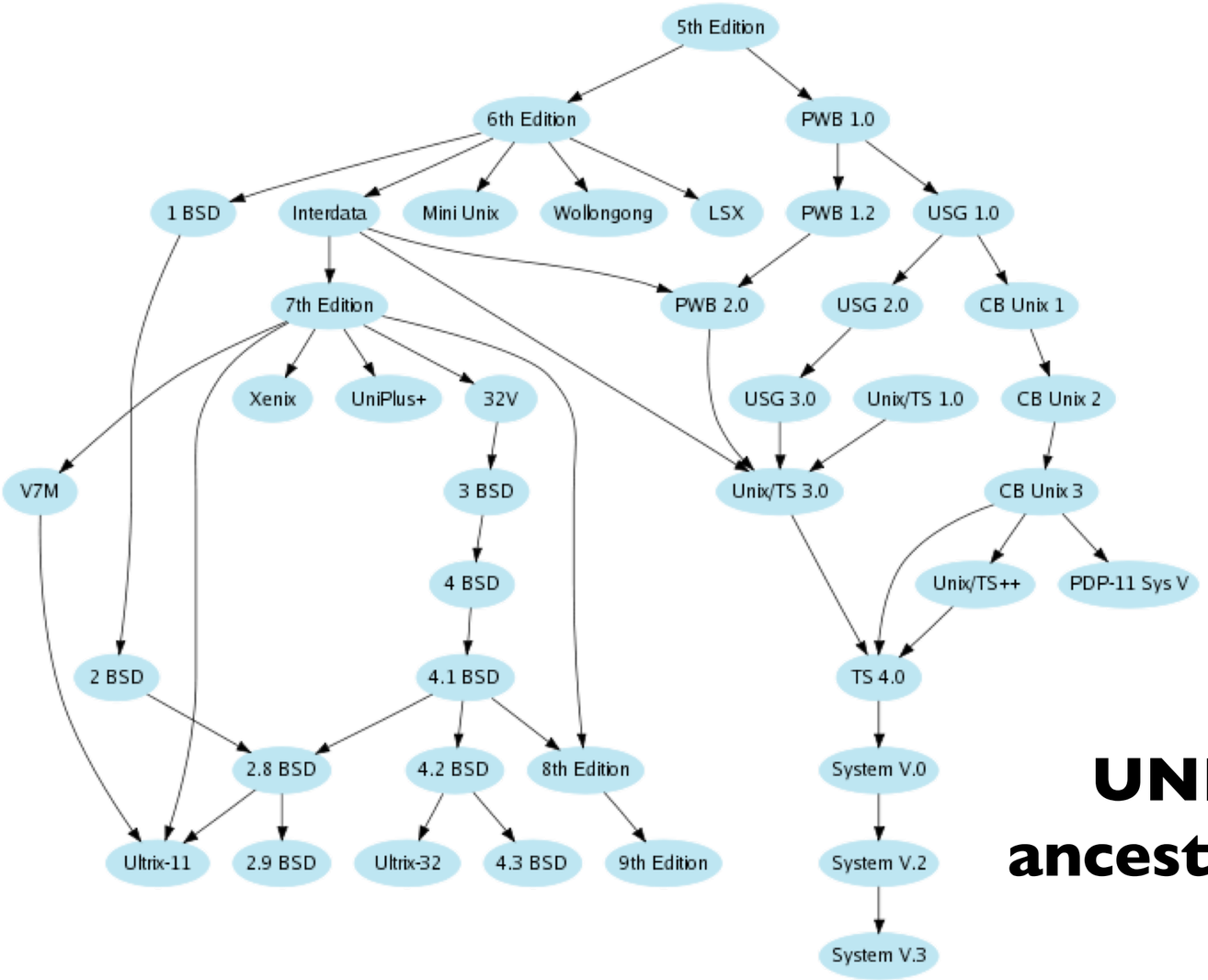
ordering (e.g., hierarchy level)

SUGIYAMA

great for graphs that have an intrinsic ordering

depth not strictly encoded

What is the depth of V7M?



UNIX ancestry

SUGIYAMA

+ nice, readable top down flow

+ relatively fast (depending on heuristic used for crossing minimization)

- not really suitable for graphs that don't have an intrinsic top down structure

- hard to implement

use free graphviz lib: http://www.graphviz.org

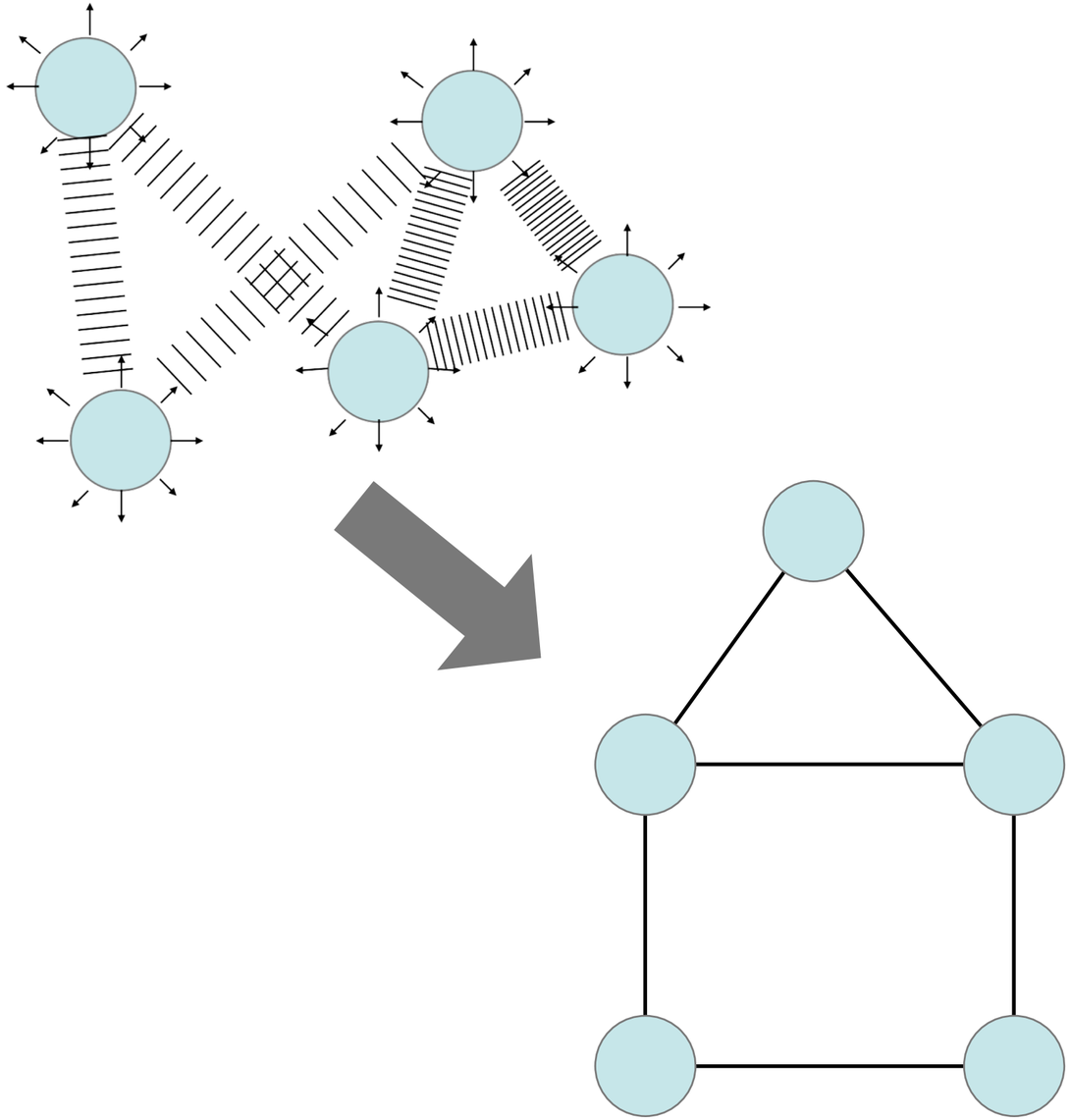
FORCE-DIRECTED

no intrinsic layering, now what?

physically-based model

edges = springs

nodes = repulsive particles



FORCE MODEL

many variations, but usually physical analogy of repulsion and attraction

FORCE MODEL: REPULSIVE FORCES

$$f_R(d) = C_R * m_1 * m_2 / d^2$$

C_R is a strength constant

m_1, m_2 are node masses

d is a distance between nodes

FORCE MODEL: ATTRACTIVE FORCES

$$f_A(d) = C_A * (d - L)$$

C_A is a strength constant
d is a distance between nodes
L is the rest length of the spring (i.e. Hooke's Law)

FORCE MODEL

Every node feels repulsion to every other node

Only **connected** nodes feel attracted

FORCE MODEL

Repulsive force:

$$F_R(P) = \Sigma_{\text{all neighbors}(Q)} f_R(||Q-P||) * (Q-P)$$

Attractive force:

$$F_A(P) = \Sigma_{\text{connected neighbors }(Q)} f_A(||P-Q||) * (P-Q)$$

FORCE MODEL

New velocity:

$$V(P)' = V(P) + (F_R(P) + F_A(P))*dt$$

New Position:

$$P' = P + V'(P)*dt$$

ALGORITHM

start from random layout

(global) loop:

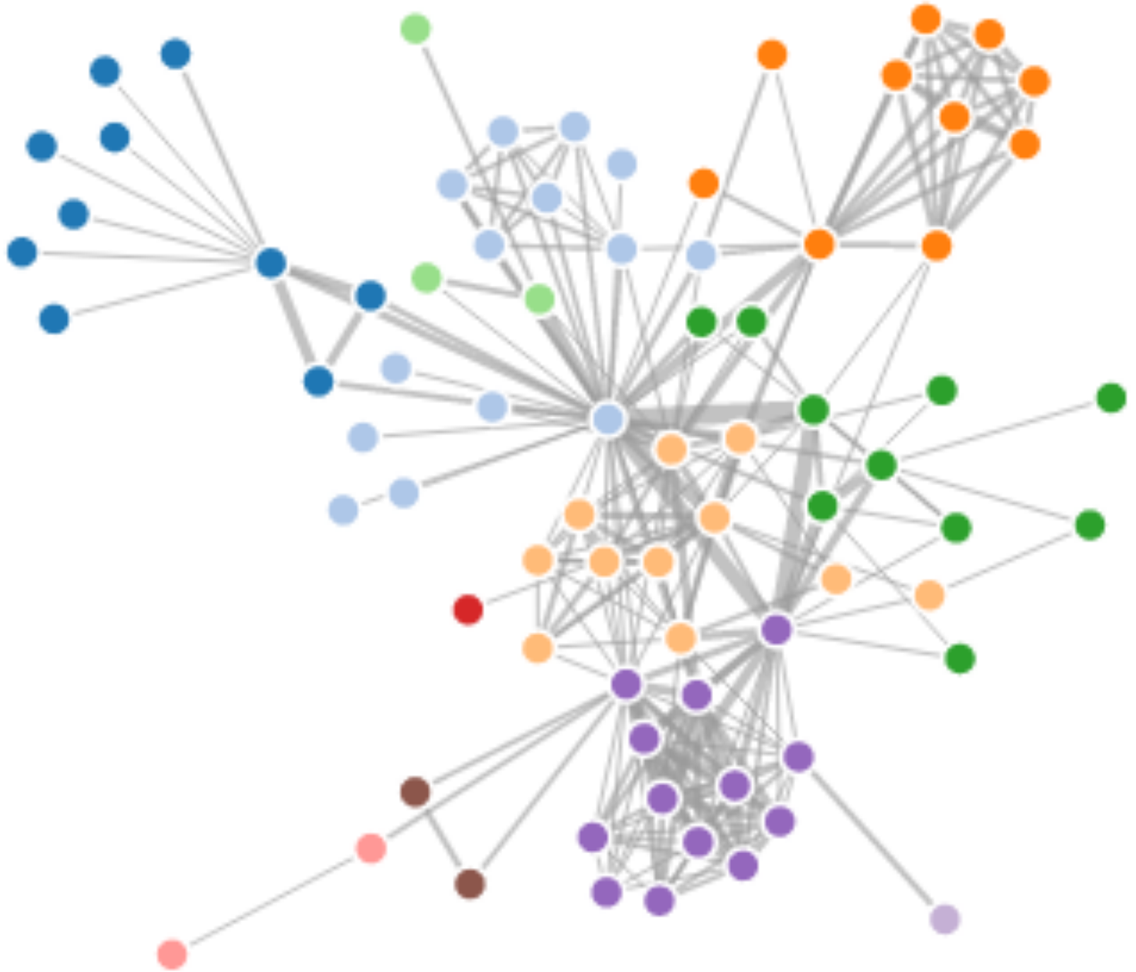
for every node pair compute repulsive force

for every edge compute attractive force

accumulate forces per node and update velocity

update each node position in direction of velocity

stop when layout is ‘good enough’



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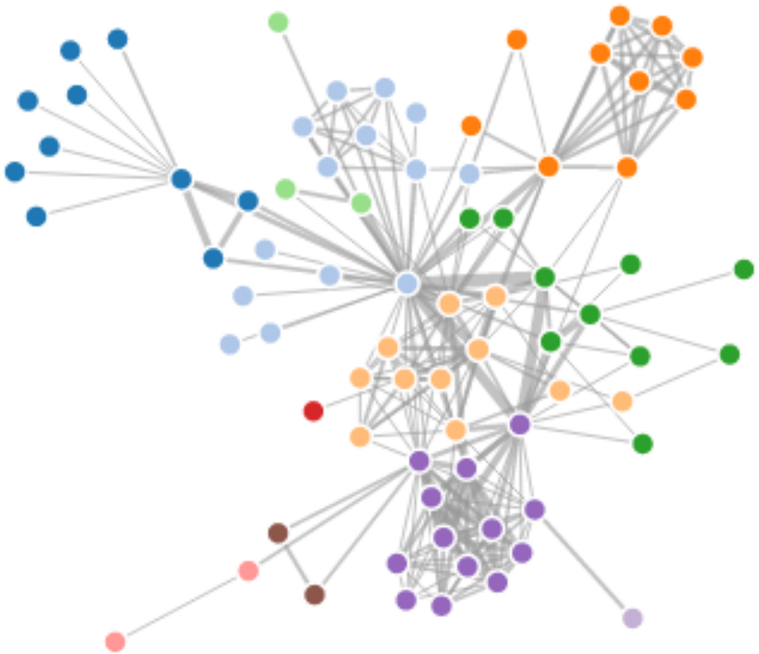
THOUGHTS?

FORCE DIRECTED

+ very flexible, aesthetic layouts on many types of graphs

+ can add custom forces

+ relatively easy to implement



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FORCE DIRECTED

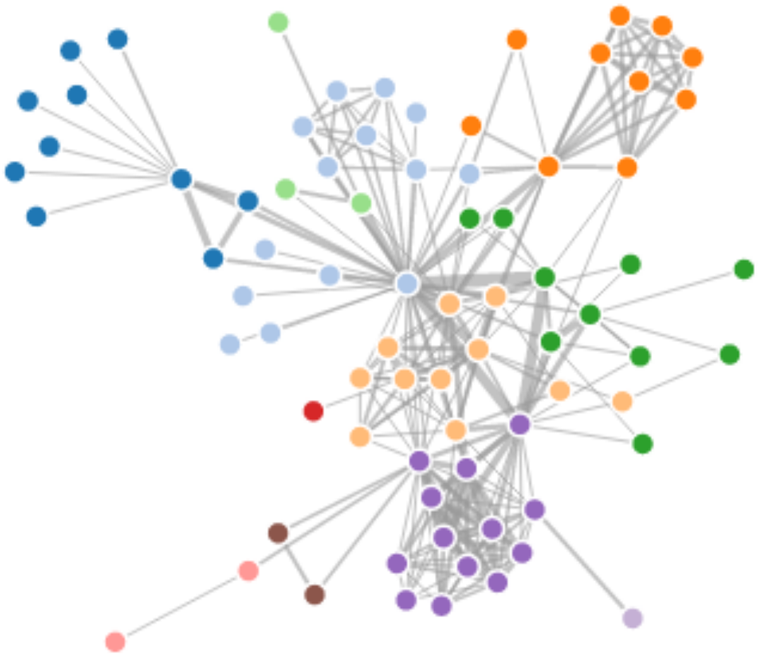
- repulsion loop is $O(n^2)$ per iteration

can speed up to O(n log n) using quadtree or k-d tree

- prone to local minima

can use simulated annealing

- doesn't work well on highly connected (low diameter) graphs



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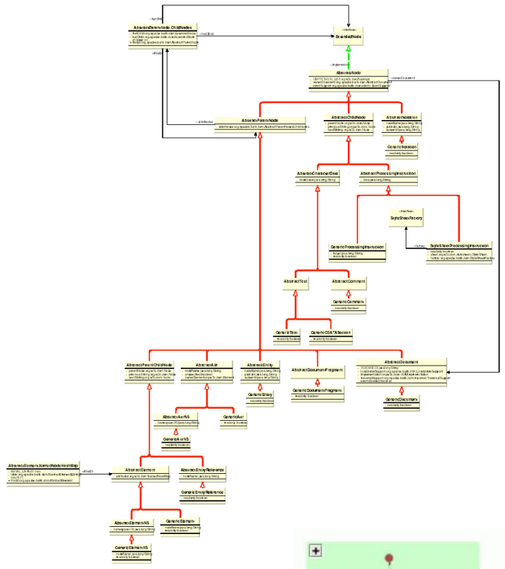
OTHER LAYOUTS

orthogonal

great for UML diagrams

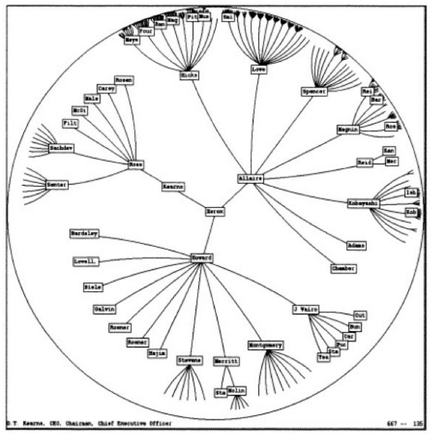
algorithmically complex



circular layouts

emphasizes ring topologies

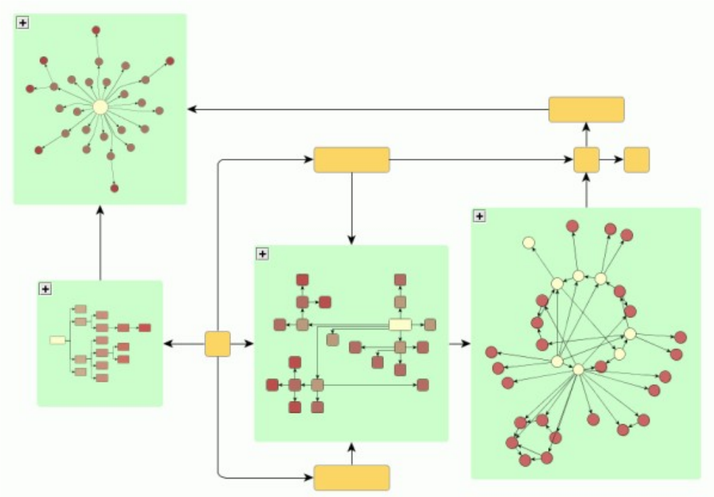
used in social network diagrams



nested layouts

recursively apply layout algorithms

great for graphs with hierarchical structure



Gephi, an open source graph visualization and manipulation software

http://gephi.org/

hookes law

Apple Yahoo! Google Maps YouTube Wikipedia News (1,949) Popular Google Scholar

Gephi
makes graphs handy

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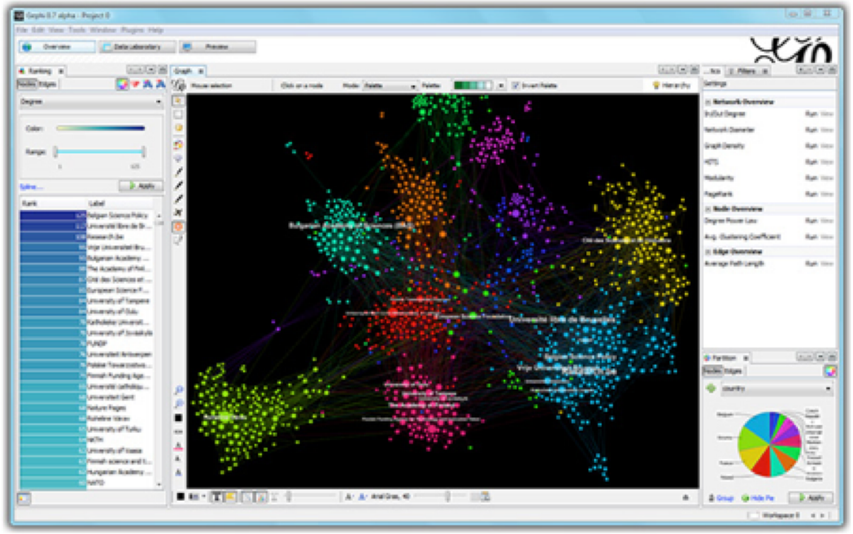
The Open Graph Viz Platform

Gephi is an interactive visualization and exploration platform for all kinds of networks and complex systems, dynamic and hierarchical graphs.

Runs on Windows, Linux and Mac OS X. Gephi is open-source and free.

Learn More on Gephi Platform »



Download FREE
Gephi 0.8 beta

Release Notes | System Requirements

- Features
- Quick start
- Screenshots
- Videos

Gephi 0.8 beta has been released! Discover a new Preview and dynamic features, start building commercial applications with the new open source license.

Learn More »

APPLICATIONS

- **Exploratory Data Analysis**: intuition-oriented analysis by networks manipulations in real time.
- **Link Analysis**: revealing the underlying structures of associations between objects, in particular in scale-free networks.
- **Social Network Analysis**: easy creation of social data connectors to map community organizations and small-world networks.
- **Biological Network analysis**: representing patterns of biological data.
- **Poster creation**: scientific work promotion with hi-quality printable maps.

Learn More »

“Like Photoshop™ for graphs.

— the Community

LATEST NEWS

- Weekly news
  February 27, 2012
- Annual report 2011
  February 25, 2012
- Gephi-Neo4j presentation at FOSDEM
  February 20, 2012
- Gephi meet-up #4 in Berlin
  February 2, 2012
- Introducing the Gephi Plugins Bootcamp
  January 12, 2012

PAPERS

ATTRIBUTE-DRIVEN LAYOUT

large node-link diagrams get messy!

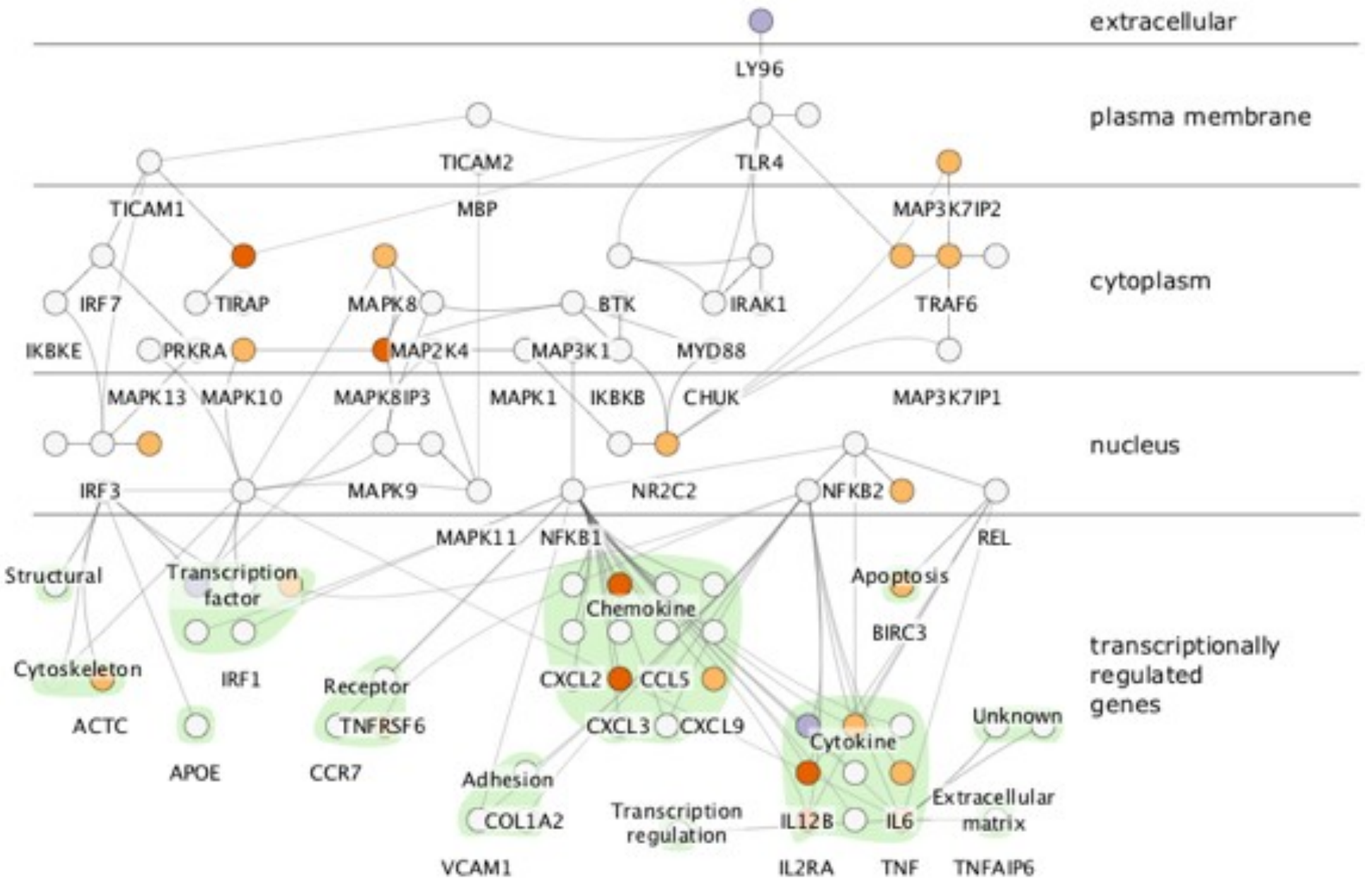
are there additional structures to exploit?

idea: use data attributes to perform layout

e.g., scatterplot based on node values

dynamic queries and/or brushing can be used
to enhance perception of connectivity

CEREBRAL



BARSKY 2008

NODE LINK

+ understandable visual mapping

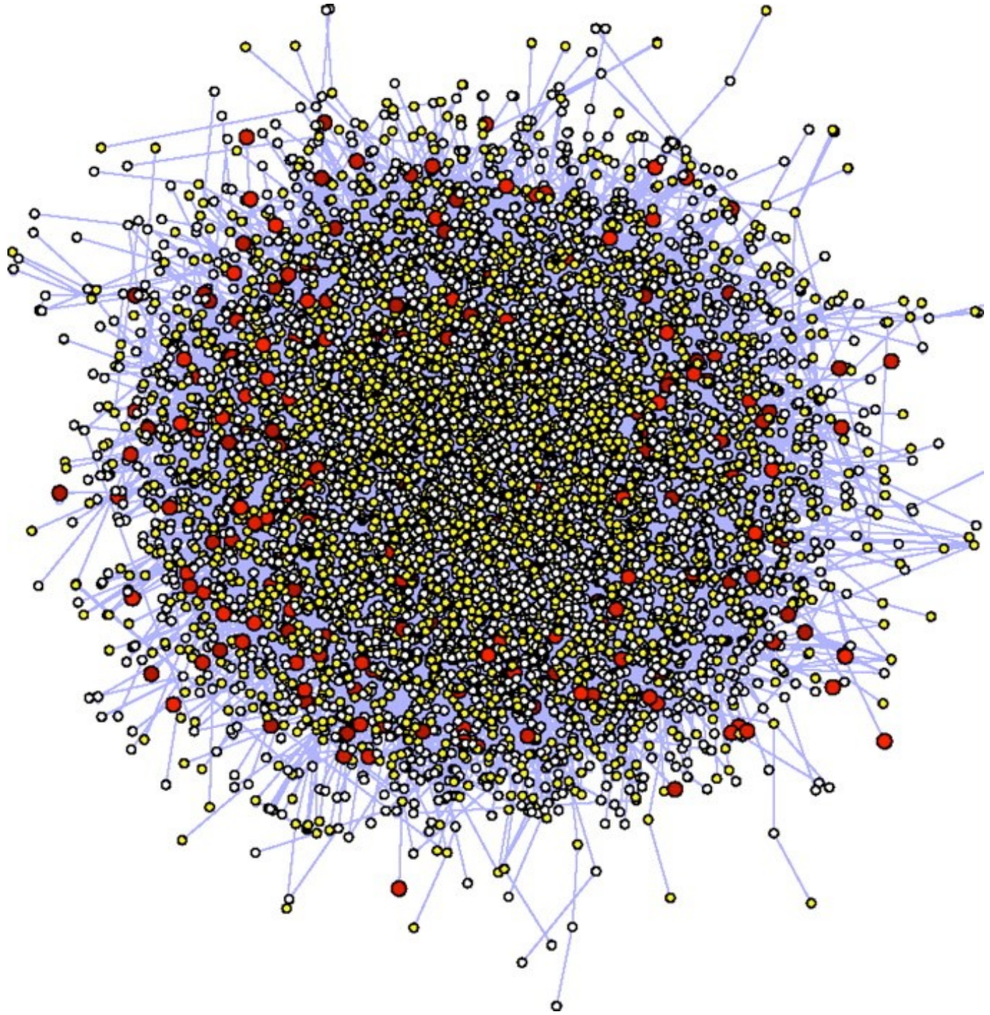
+ can show overall structure, clusters, paths

+ flexible, many variations

- all but the most trivial algorithms are > $O(n^2)$

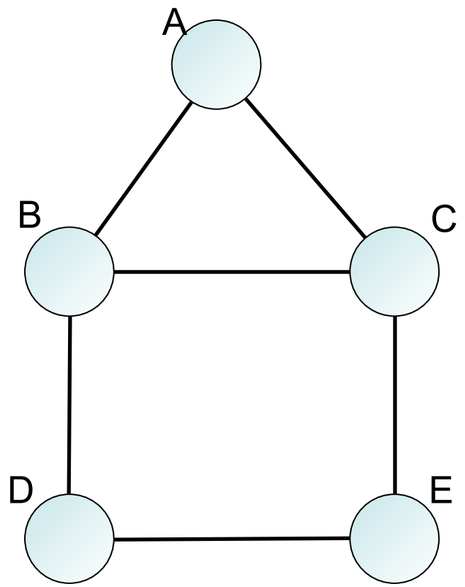
- not good for dense graphs

hairball problem!



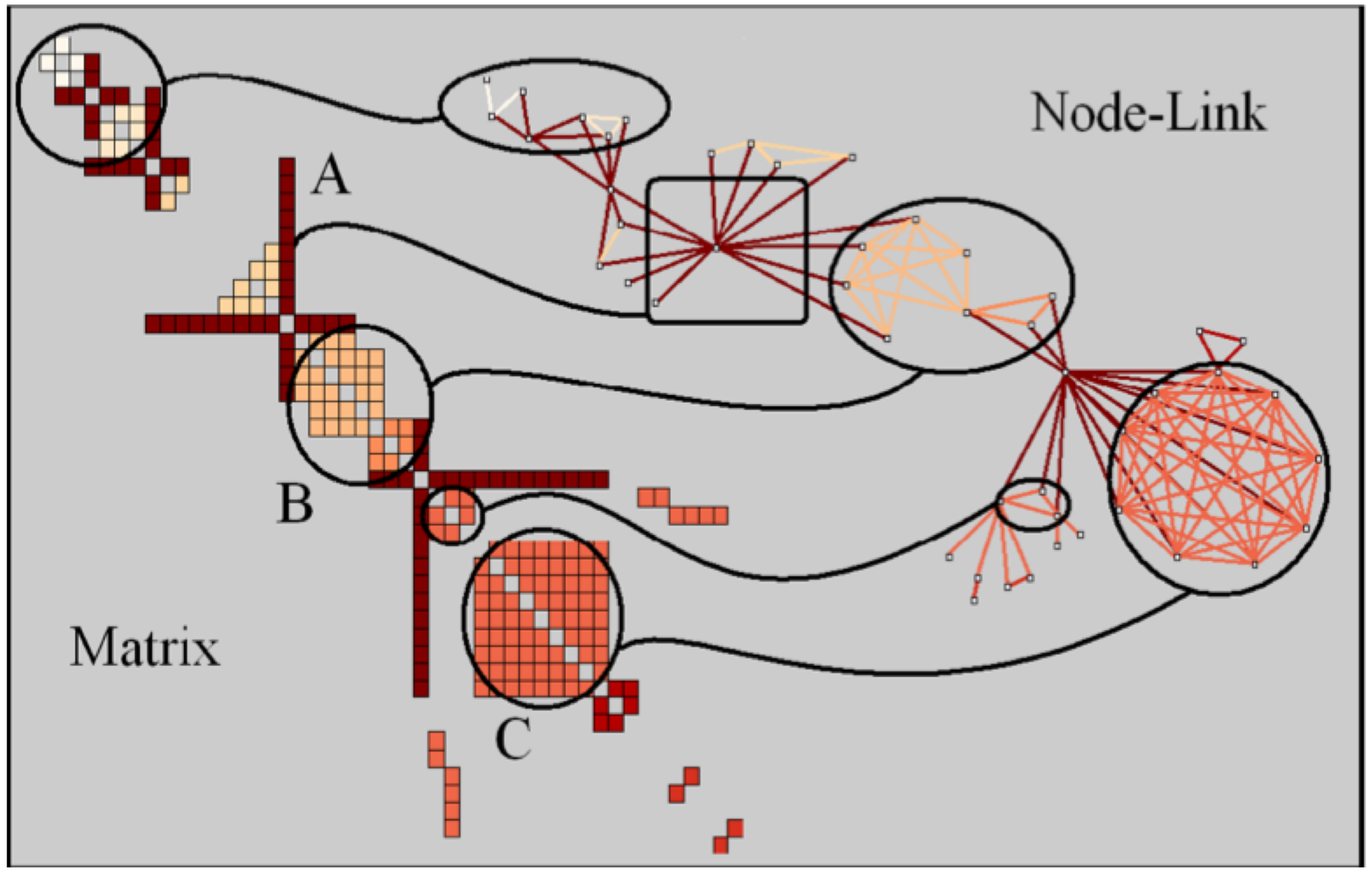
ALTERNATIVE: ADJACENCY MATRIX

instead of node link diagram, use adjacency matrix representation



	A	B	C	D	E
A		■	■		
B	■		■	■	
C	■	■			■
D		■			■
E			■	■	

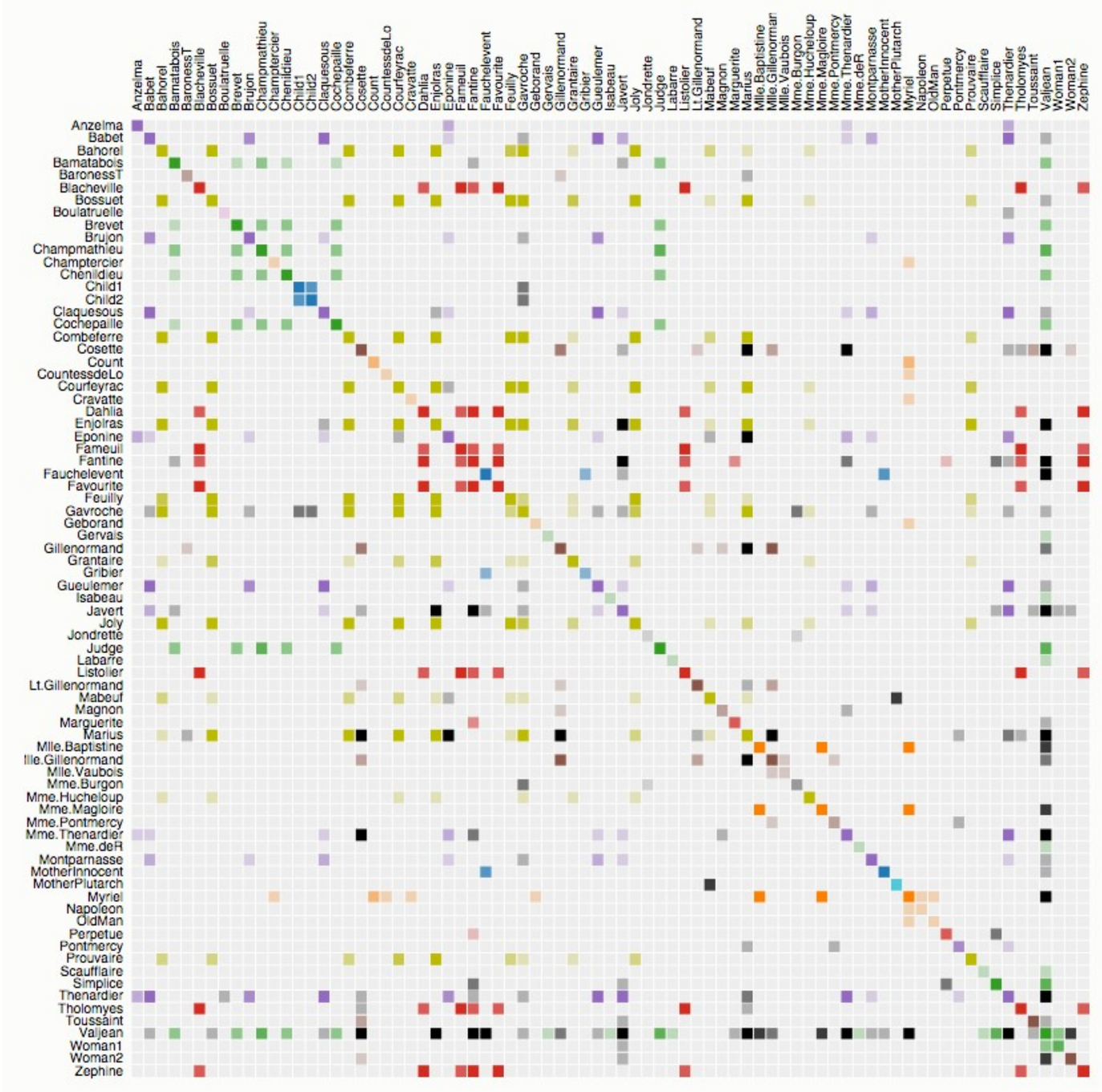
SPOTTING PATTERNS IN MATRICES



HENRY 2006

LES MISÉRABLES

character co-occurrence



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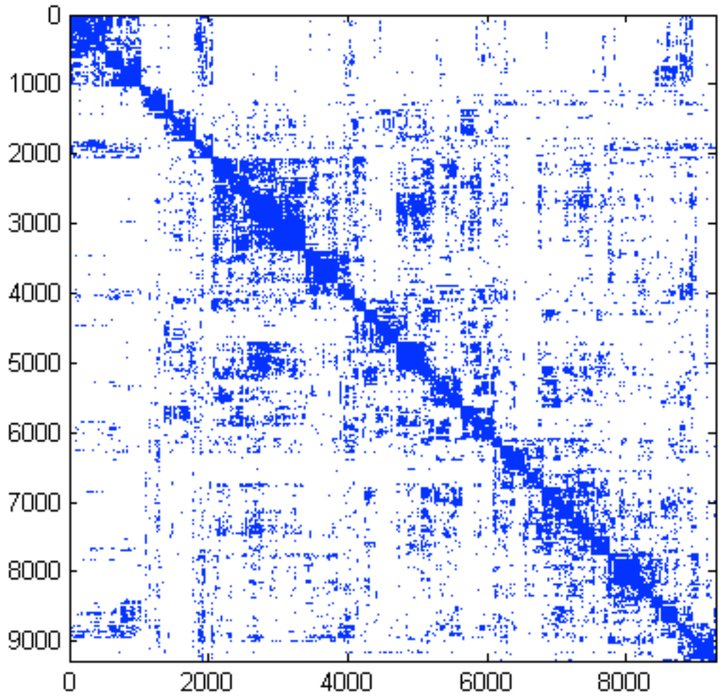
Adjacency Diagram

+ great for dense graphs

+ visually scalable

+ can spot clusters



- row order affects what you can see

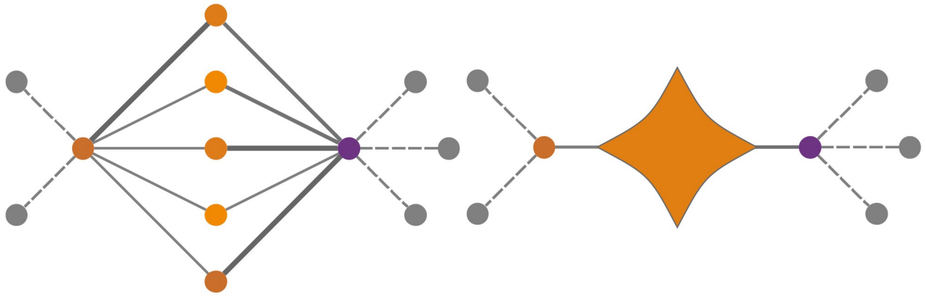
- abstract visualization

- hard to follow paths

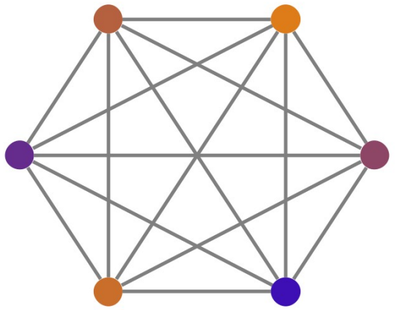
AGGREGATE VIEWS

MOTIF GLYPHS

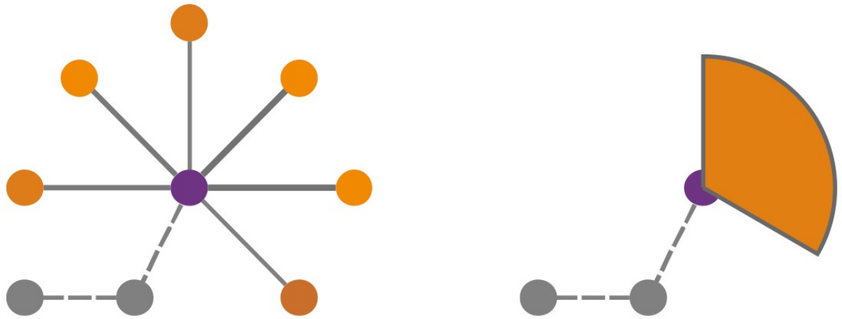
Connector

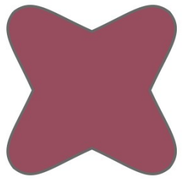


Clique



Fan





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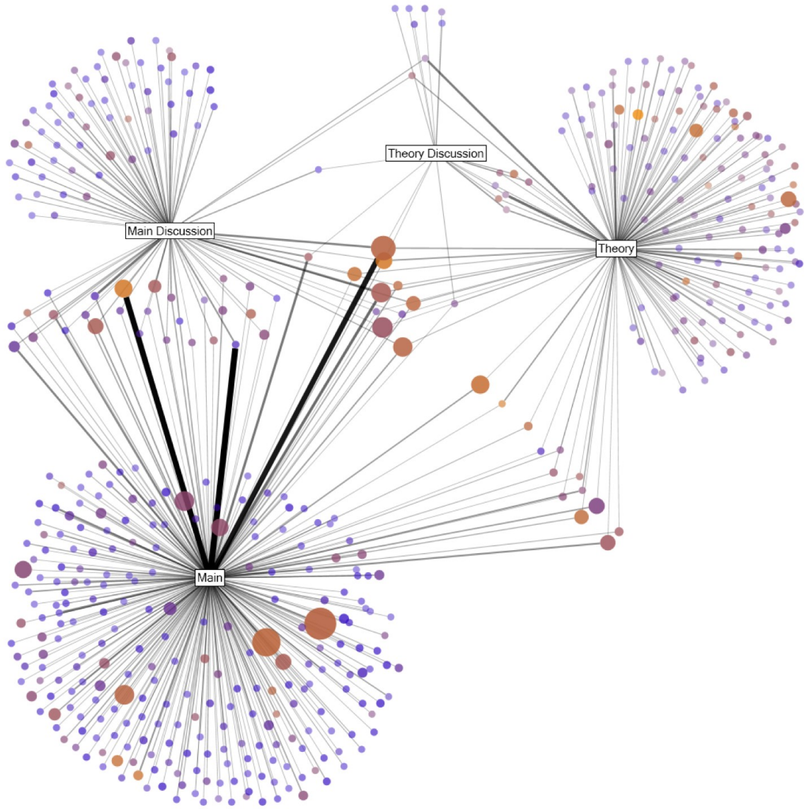
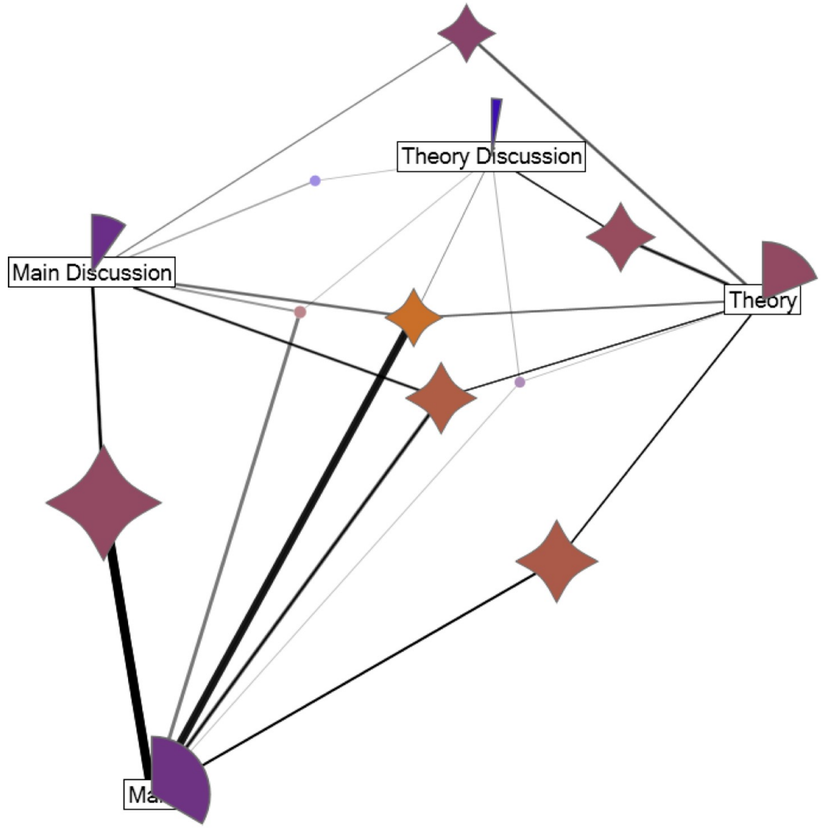
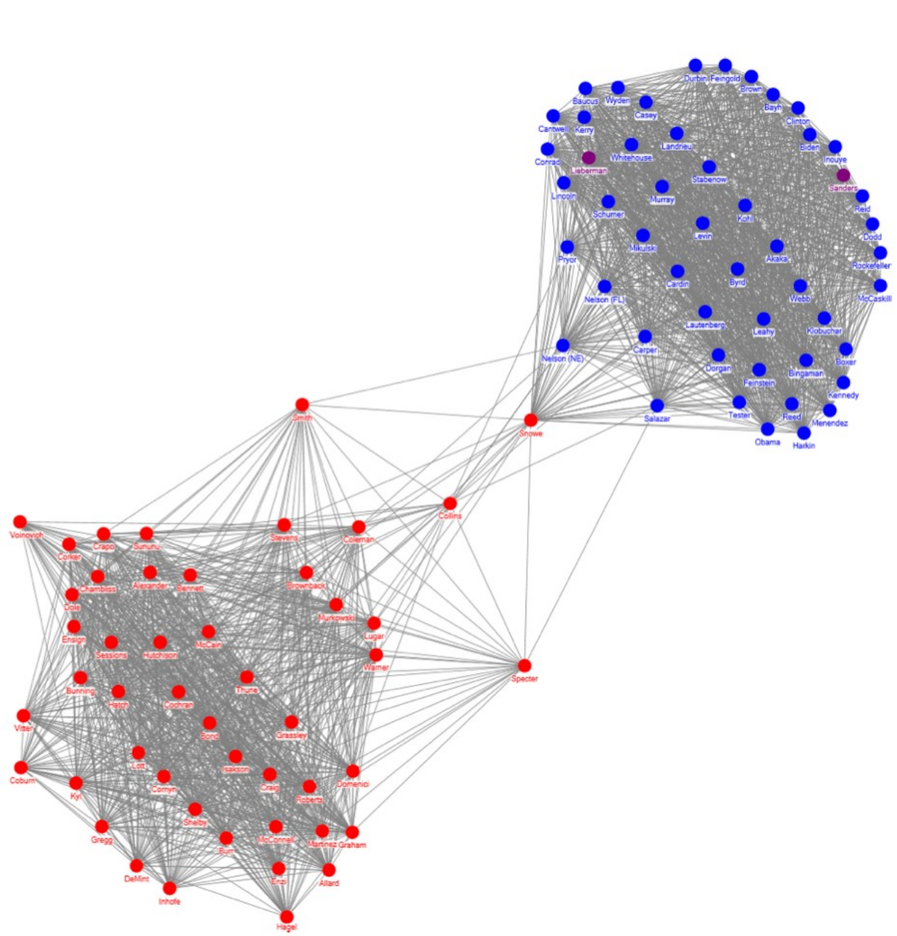
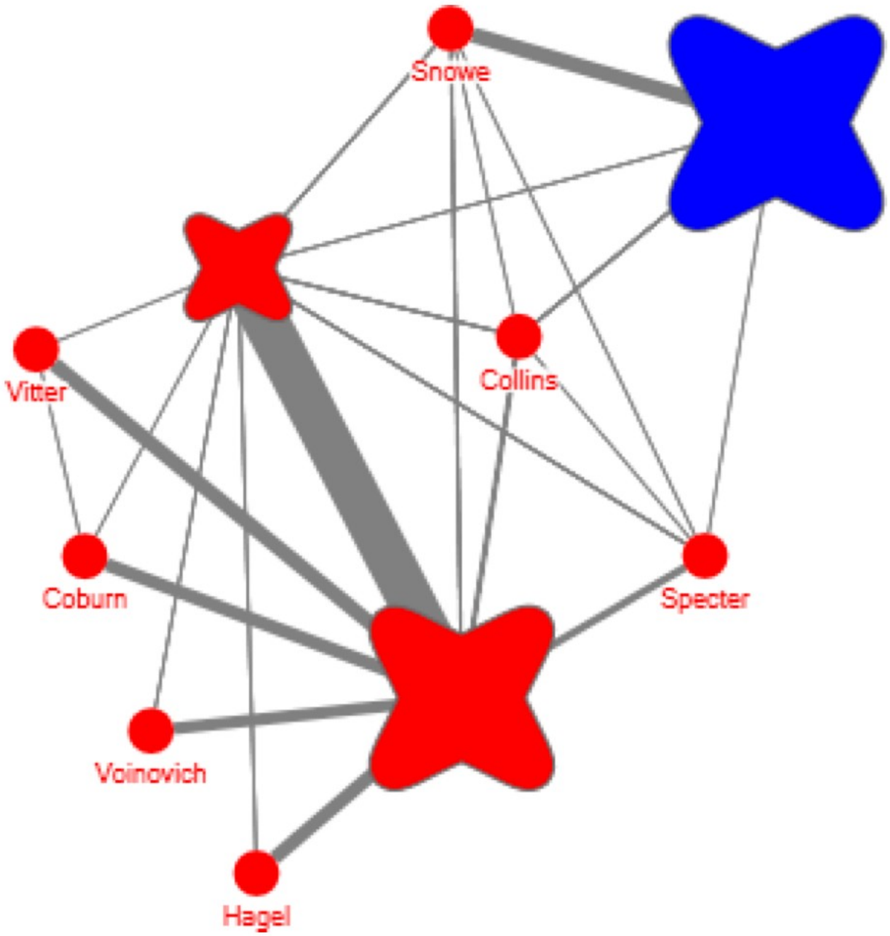




MOTIF GLYPHS





CRITIQUE

When *can* you use this technique?

When *should* you use this technique?

RECAP

TREES

indentation

simple, effective for small trees

node link and layered

looks good but needs exponential space

enclosure (treemaps)

great for size related tasks but suffer in structure related tasks

GRAPHS

node link

familiar, but problematic for large or dense graphs

adjacency matrices

abstract, hard to follow paths

aggregation can help

not always possible, not always appropriate

extracting structure can help

unclear how crosscutting it will be

TAKE HOME MESSAGE: NO BEST SOLUTION

Recommended Reading

Visualization Analysis & Design: Chapter 9 (pp. 200-217)