CIS 4930/6930-902
SCIENTIFIC VISUALIZATION

TREES & GRAPHS

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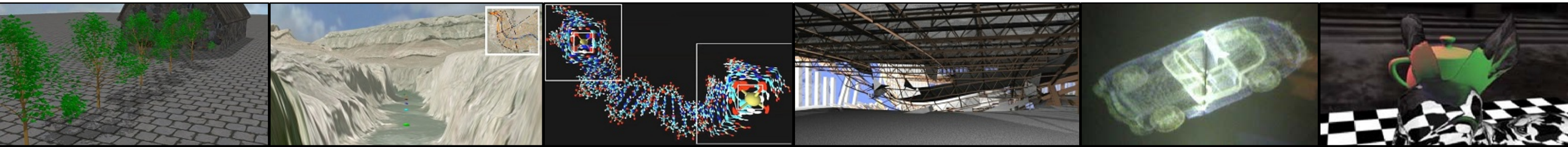
Assistant Professor
University of South Florida

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



ADMINISTRATIVE

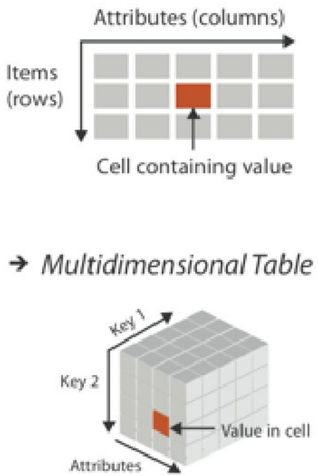
project 3 due on Tuesday

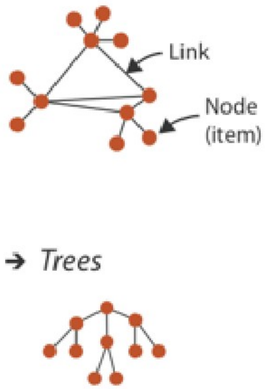
project 4 handed out by Tuesday

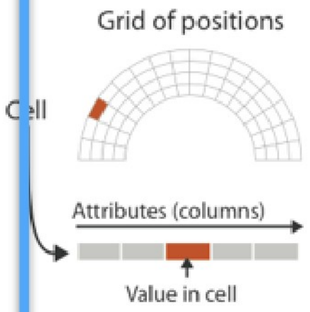
Read: Elzen and van Wijk, Multivariate Network Exploration and Presentation: From Detail to Overview via Selections and Aggregations (video)

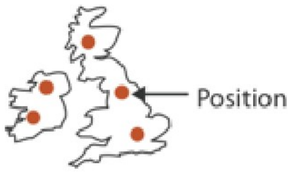
dataset types

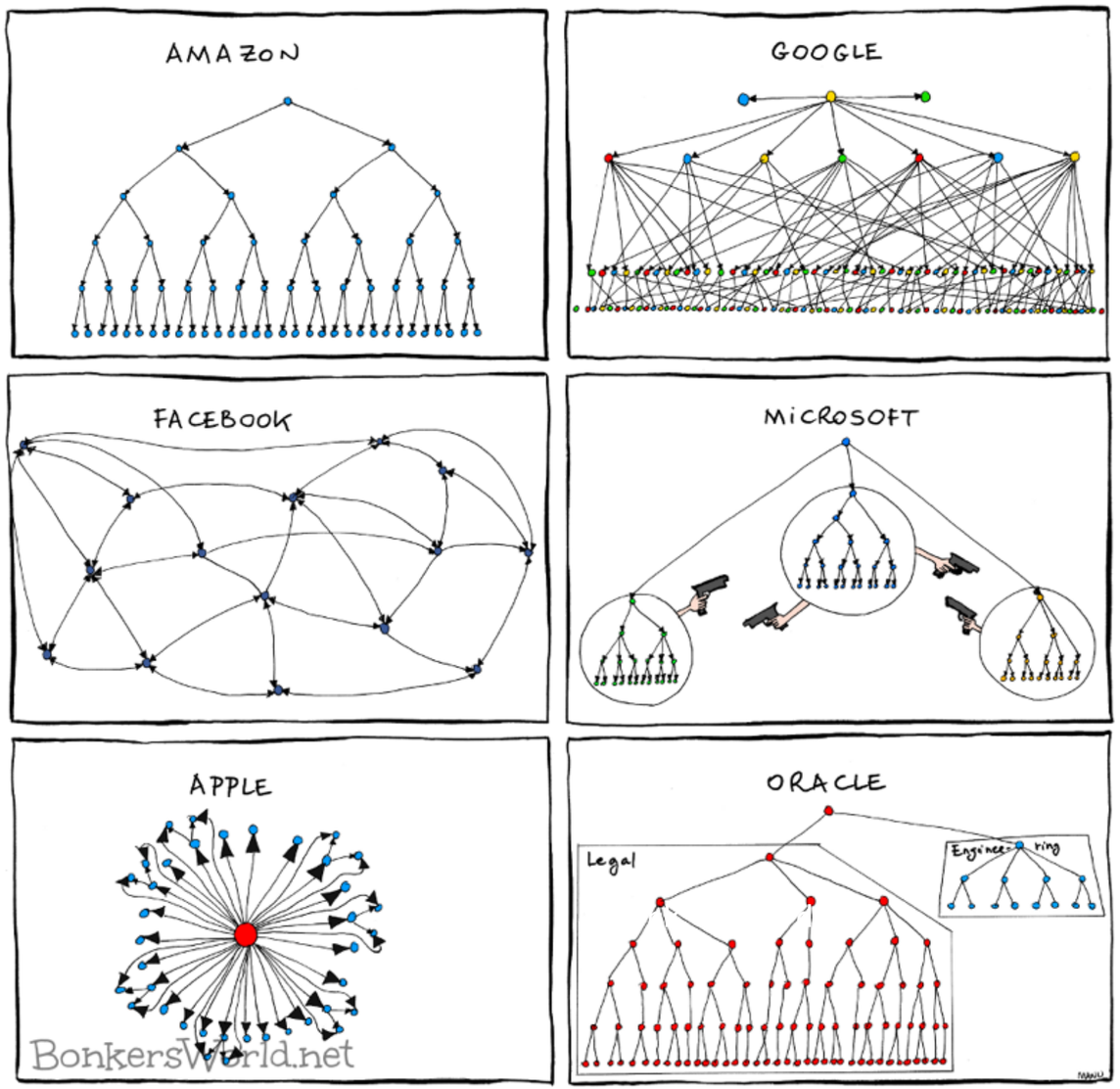
Tables	Networks & Trees	Fields	Geometry	Clusters, Sets, Lists
Items	Items (nodes)	Grids	Items	Items
Attributes	Links	Positions	Positions	
	Attributes	Attributes		







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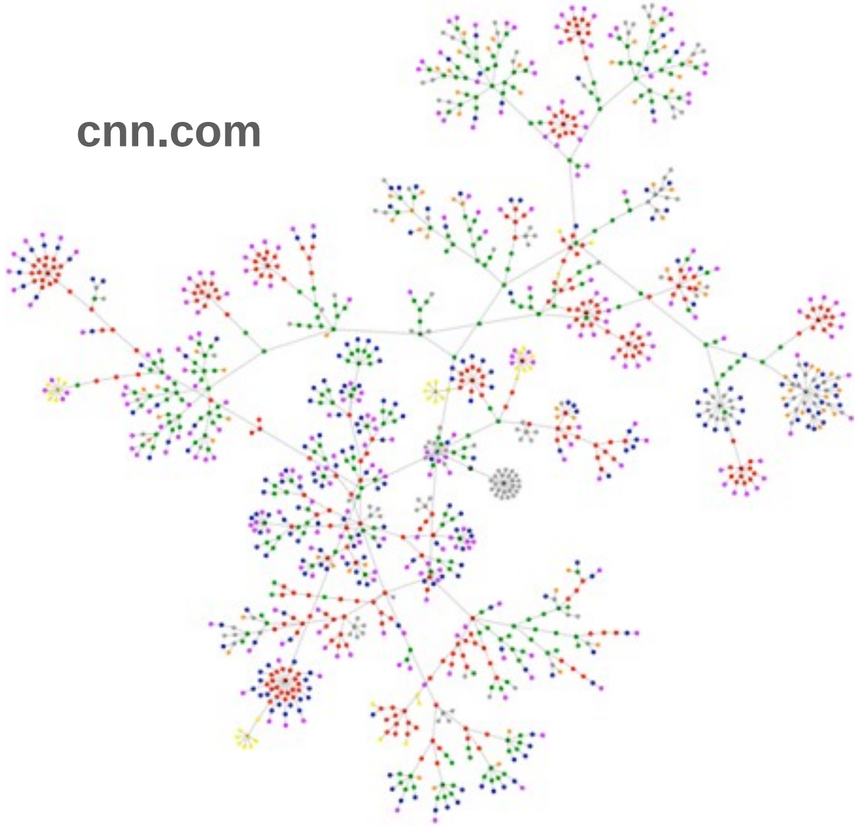

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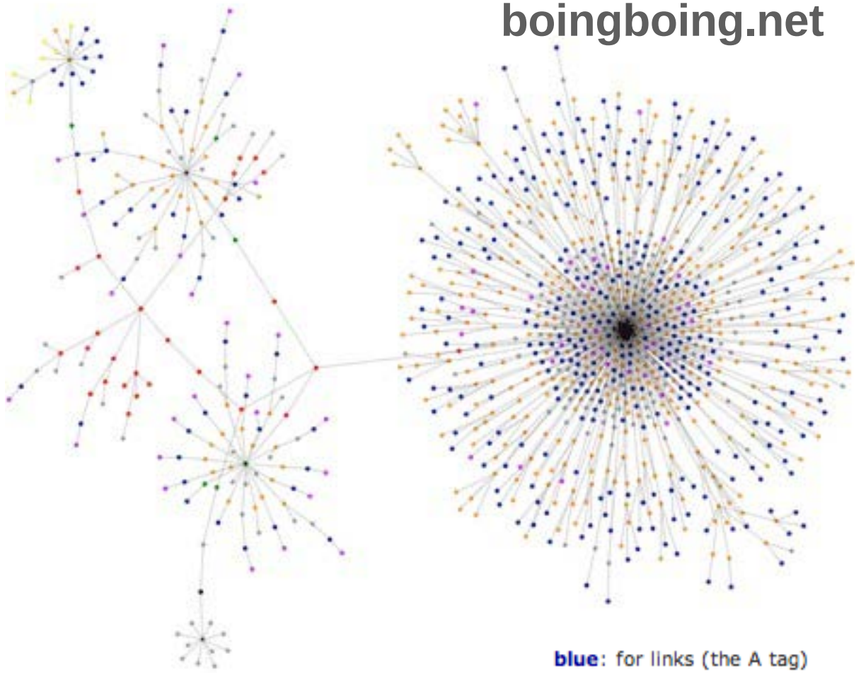

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green: for the DIV tag
violet: for images (the IMG tag)
yellow: for forms (FORM, INPUT, TEXTAREA, SELECT and OPTION tags)
orange: for linebreaks and blockquotes (BR, P, and BLOCKQUOTE tags)
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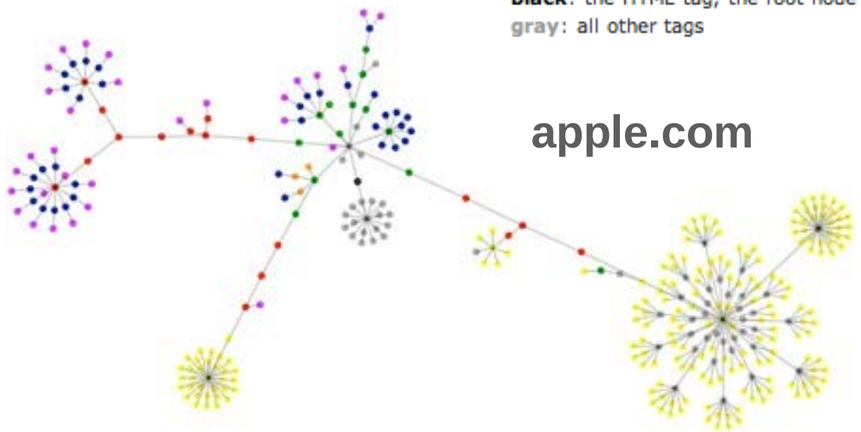
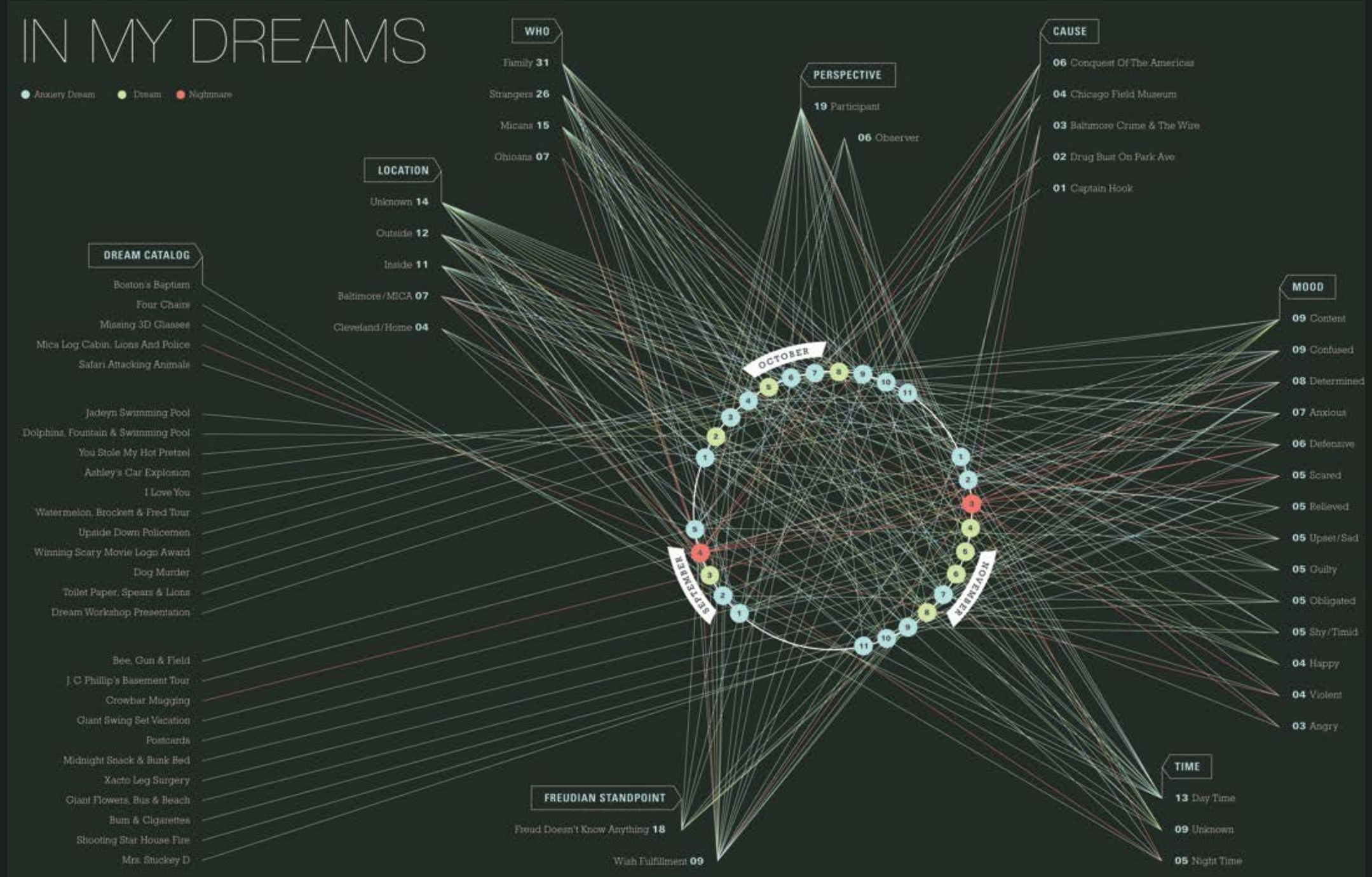


PAUL BUTLER



KAILIE PARRISH

DEFINITIONS

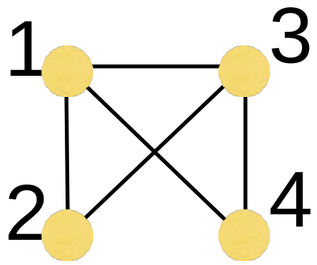
GRAPH

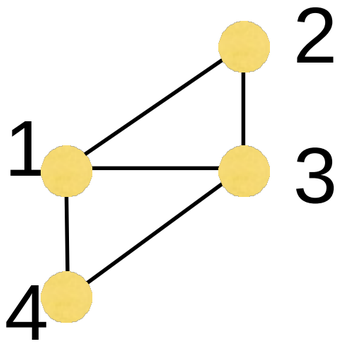
A graph **G** consists of

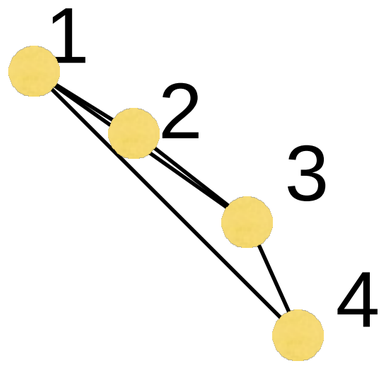
V - a collection of vertices (or nodes)

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}

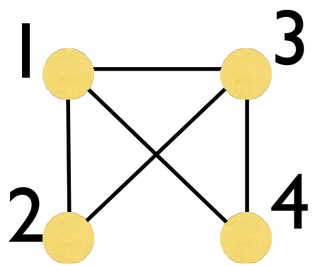
E={(1,2),(1,3),(2,3),(3,4),(4,1)}

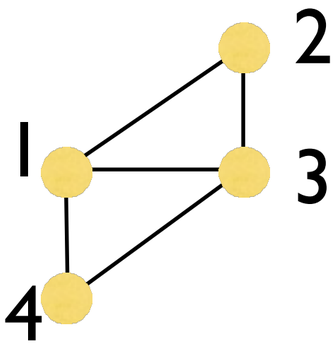
Nodes

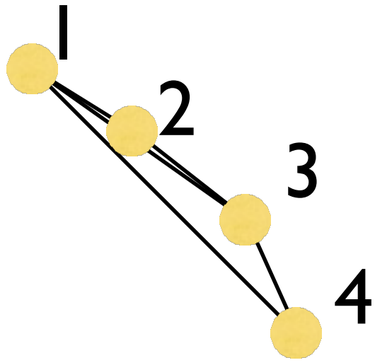
ID	Attribute 1	Attribute 2
1	3.4	Good
2	5.8	Bad
3	1.1	Ugly
4	-3.5	Really Ugly

Edges

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





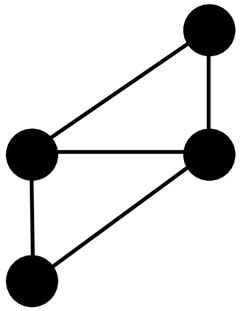


GRAPHS & TREES

graphs

model relationships about data

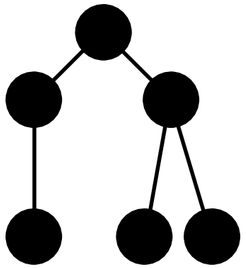
nodes and edges



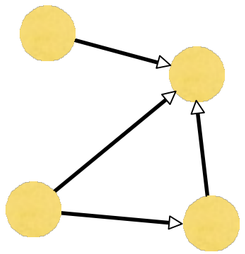
trees

graphs with hierarchical structure

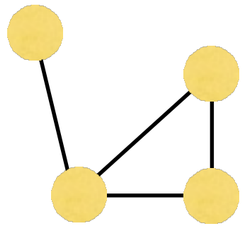
nodes as parents and children



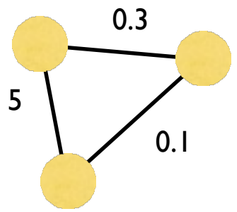
A BUNCH OF DEFINITIONS



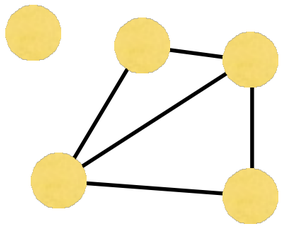
A directed graph



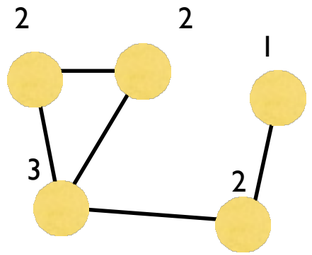
An undirected graph



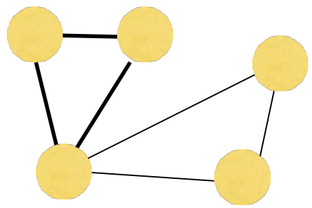
Weighted



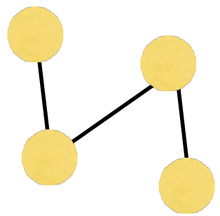
Unconnected



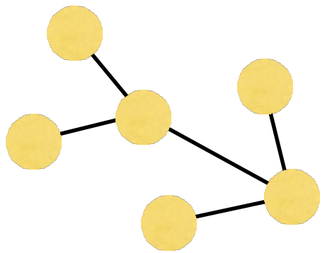
Node degrees



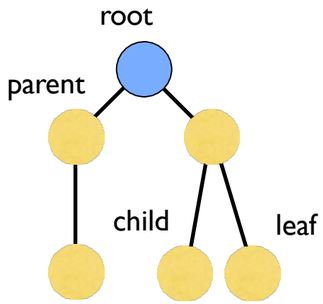
A cycle



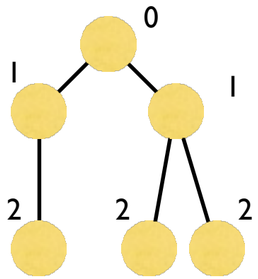
An acyclic graph



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

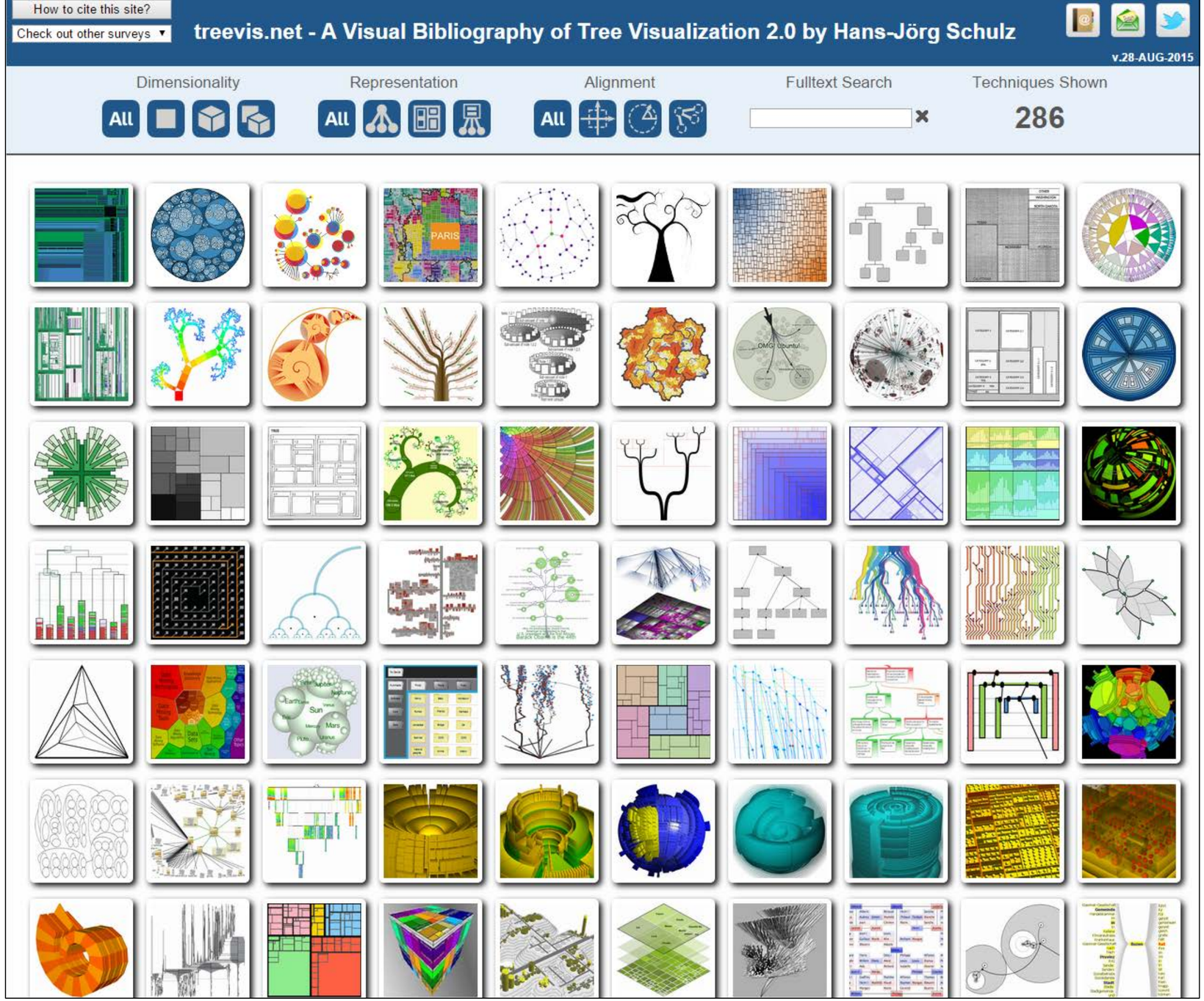


A rooted tree
or hierarchy



Node depths

VISUALIZING TREES



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ROOTED TREES

recursion makes it elegant
and fast to draw trees

approaches:

node link

layered

indentation

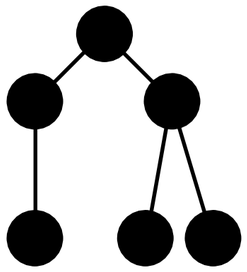
enclosure

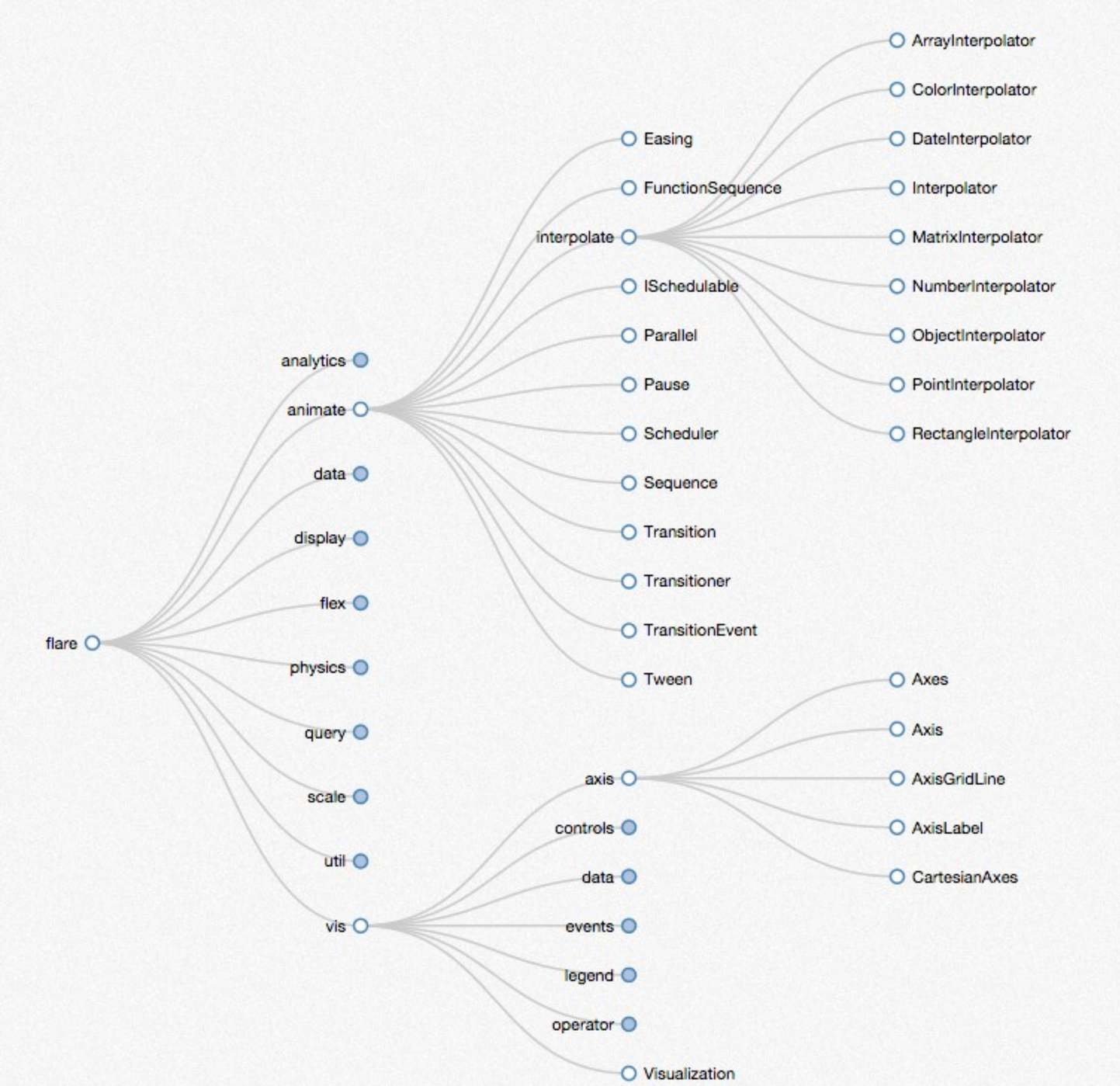
NODE-LINK DIAGRAMS

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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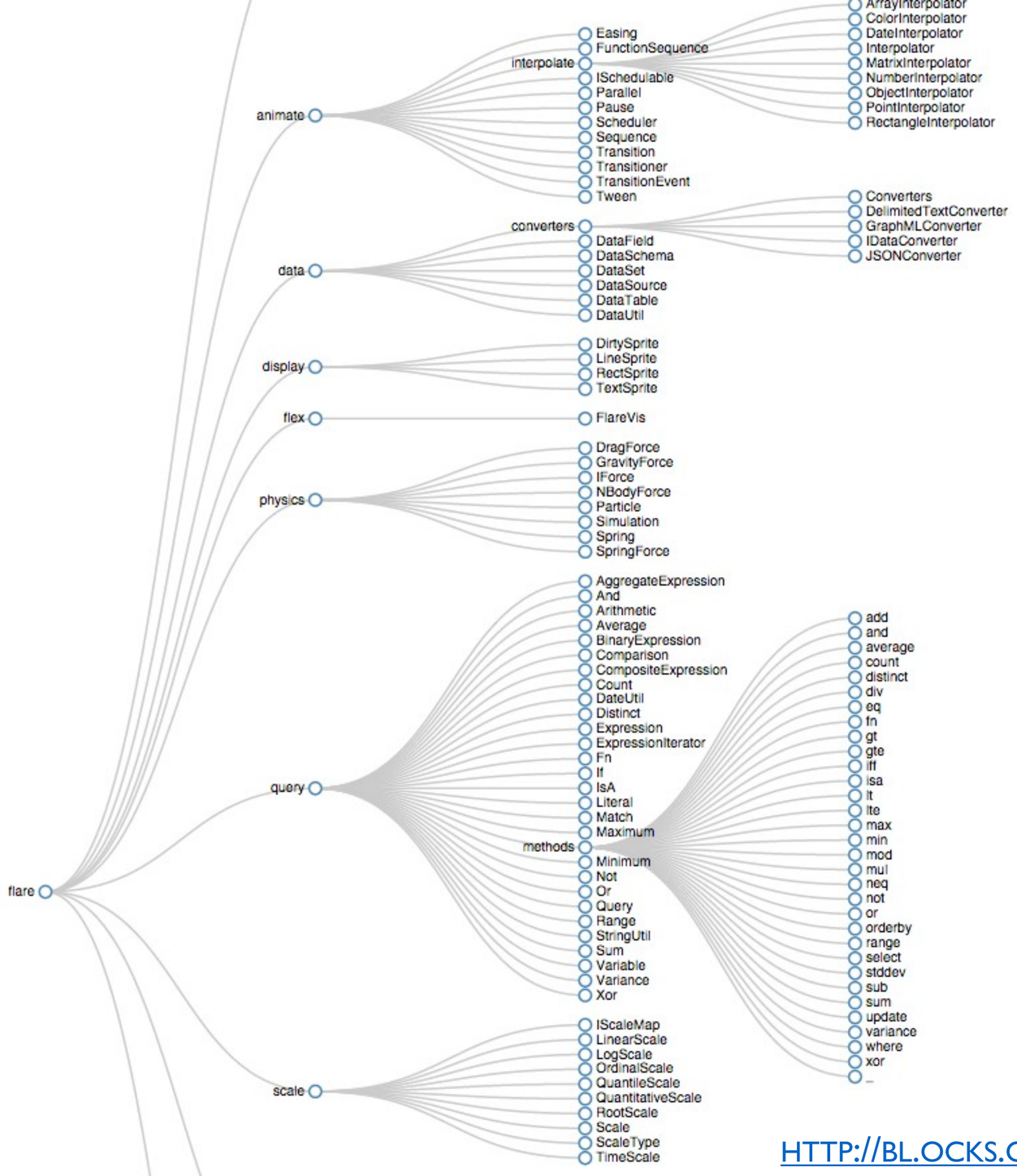

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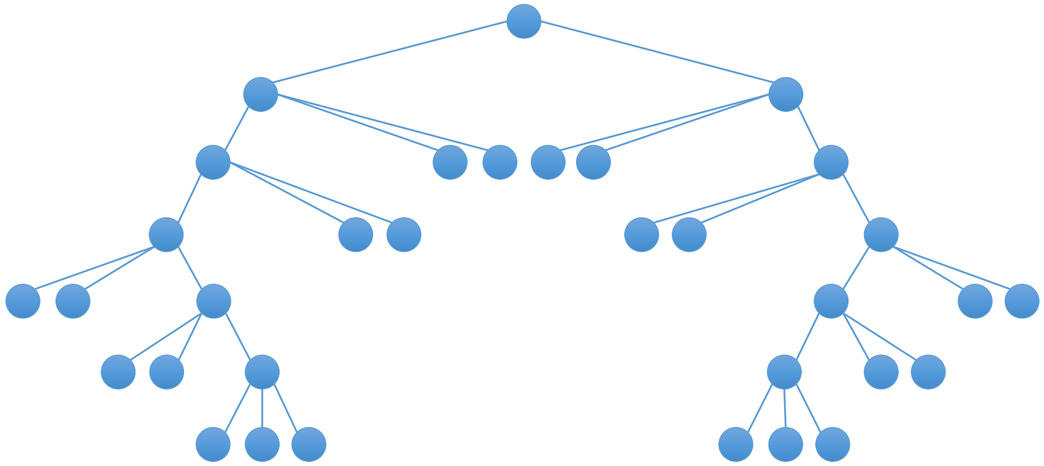
REINGOLD-TILFORD

REPEATEDLY DIVIDE SPACE FOR SUBTREES BY LEAF COUNT

breadth of tree along one dimension

depth along the other dimension

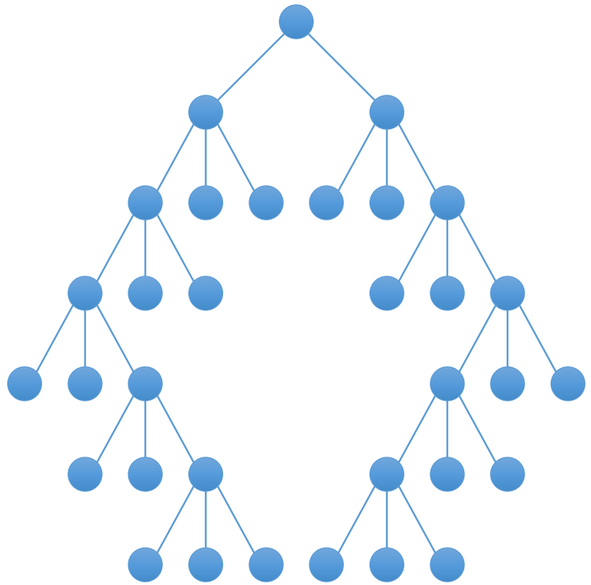


REINGOLD-TILFORD

goal

make smarter use of space

maximize density and symmetry



REINGOLD-TILFORD

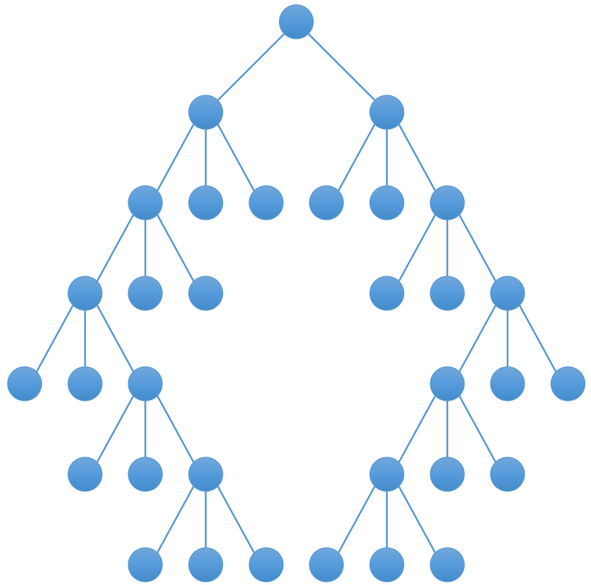
design concerns

clearly encode depth level

no edge crossings

isomorphic subtrees drawn identically

compact



REINGOLD-TILFORD

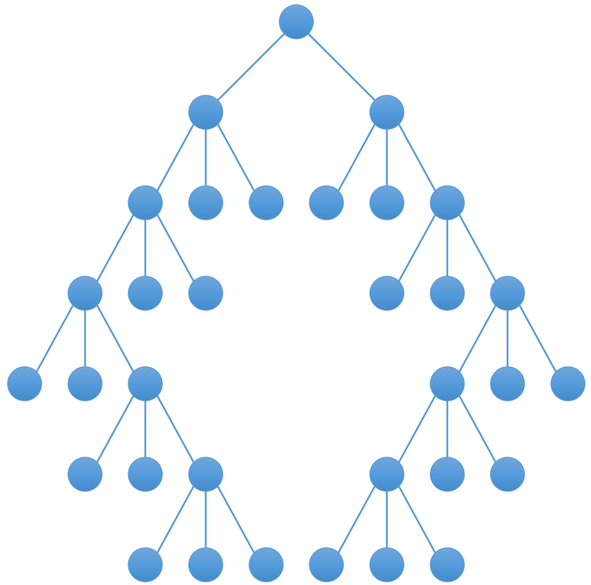
approach

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

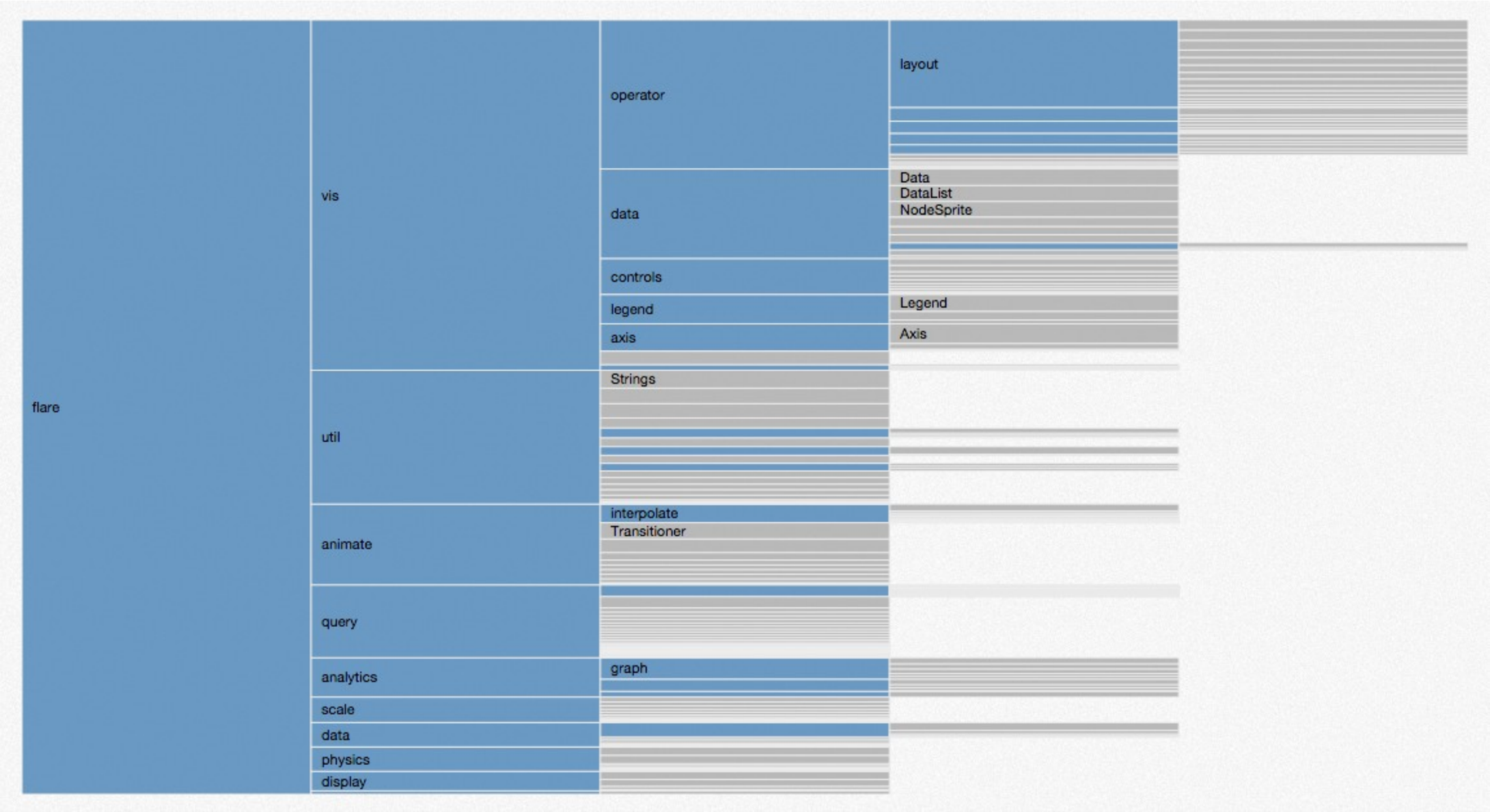
recursive subdivision of space

structure encoded using:

layering

adjacency

alignment



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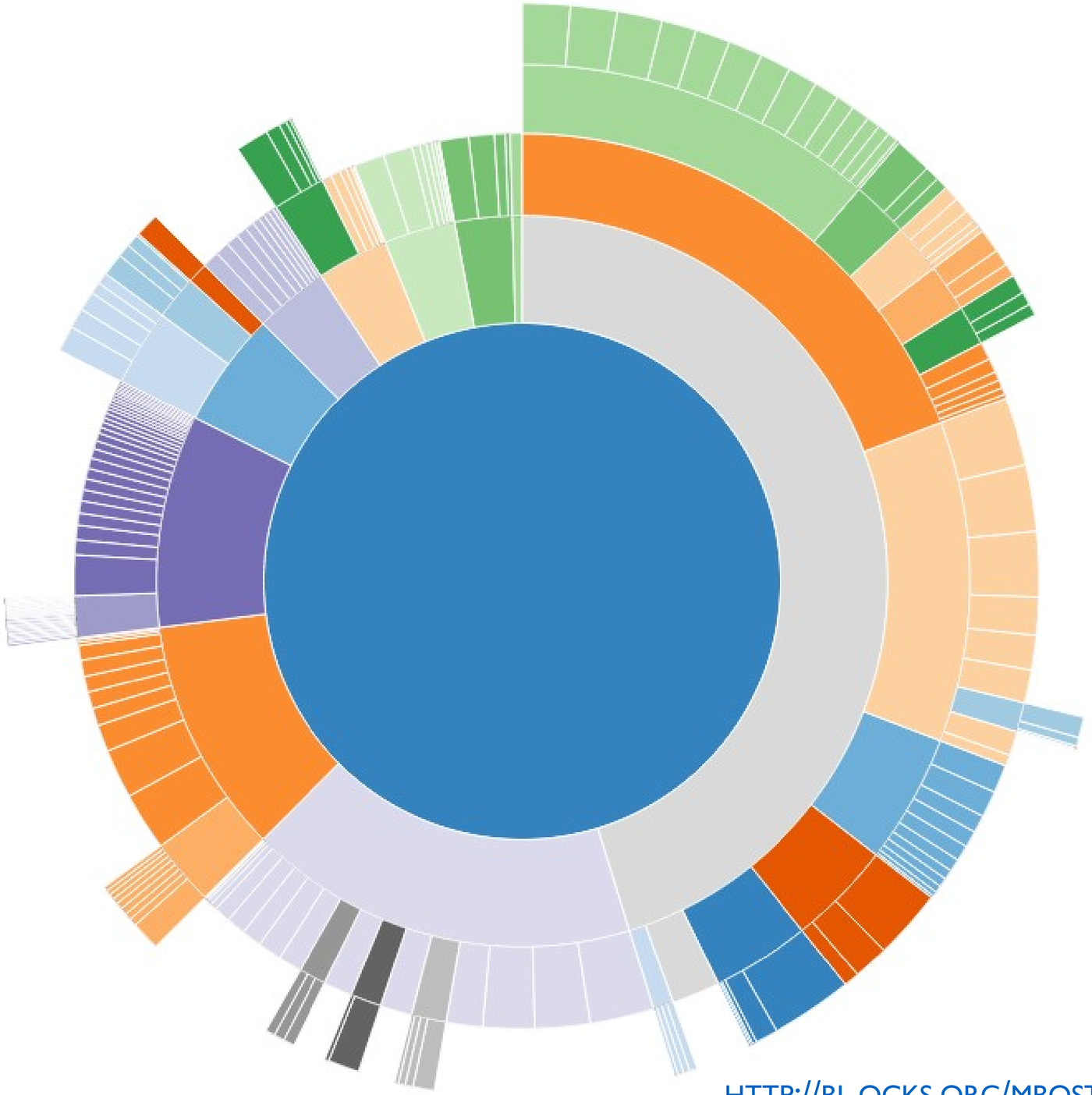

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SCALE PROBLEM

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

solutions

scrolling or panning

filtering or zooming

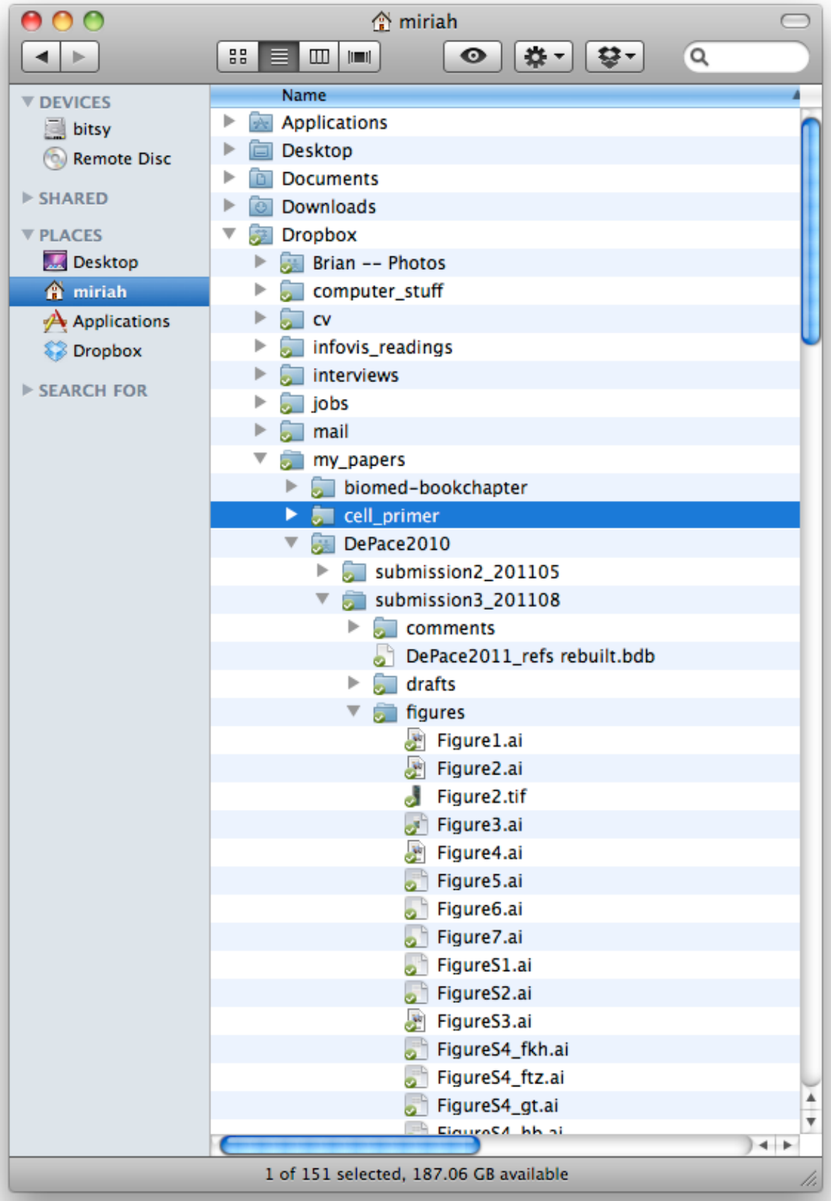
hyperbolic layout

INDENTATION

indentation used to show parent/child relationships

breadth and depth contend for space

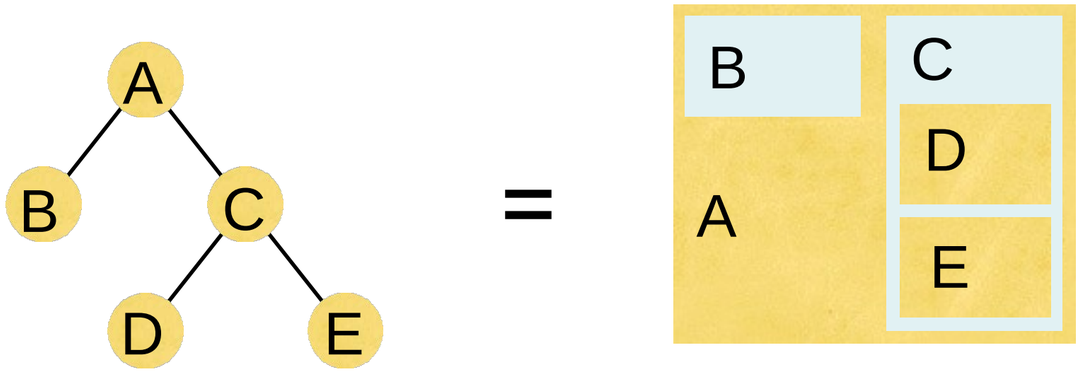
problem: often requires a great deal of scrolling

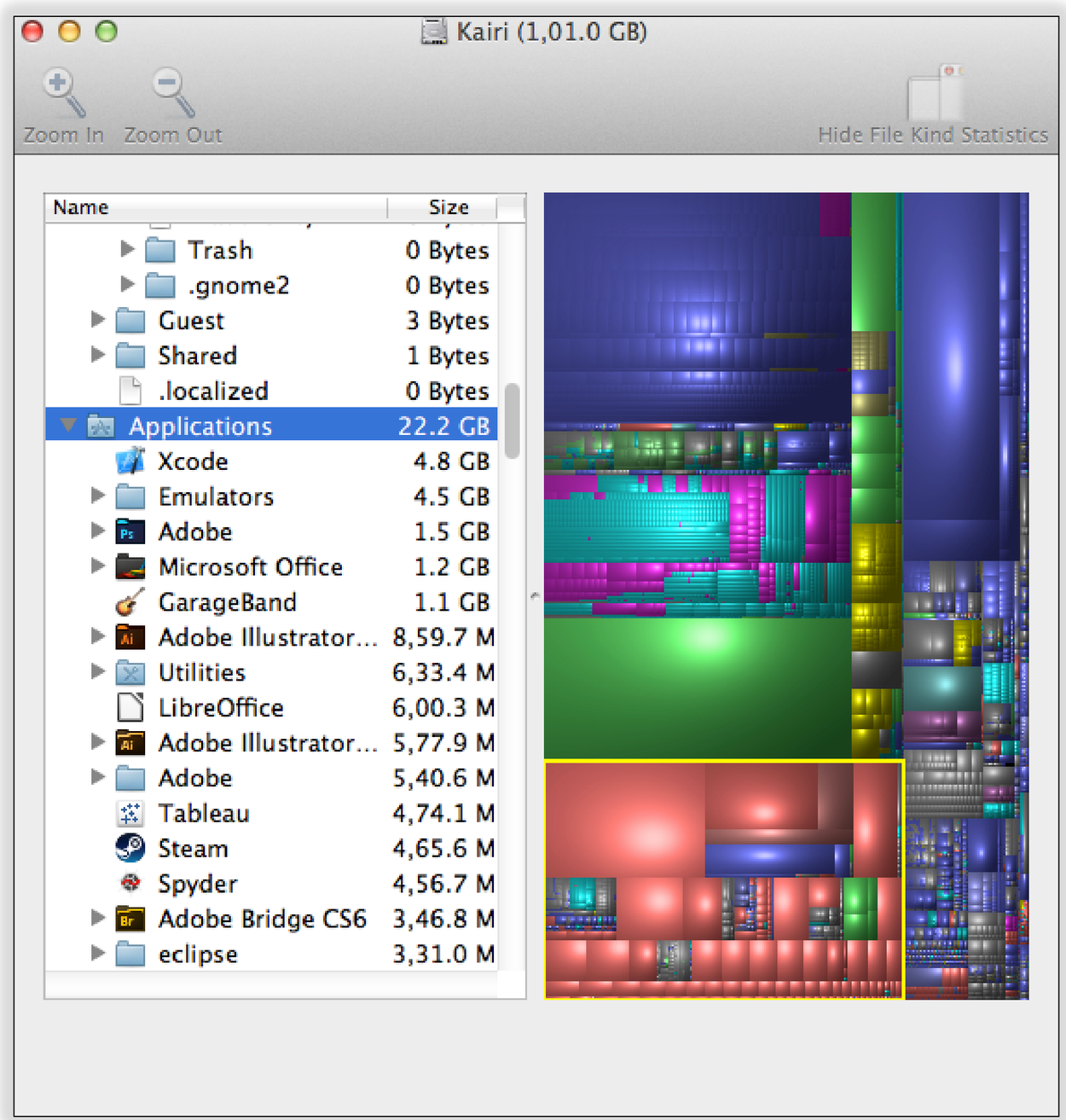


ENCLOSURE DIAGRAMS

encode structure using spatial enclosure

often referred to as treemaps





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TREEMAPS

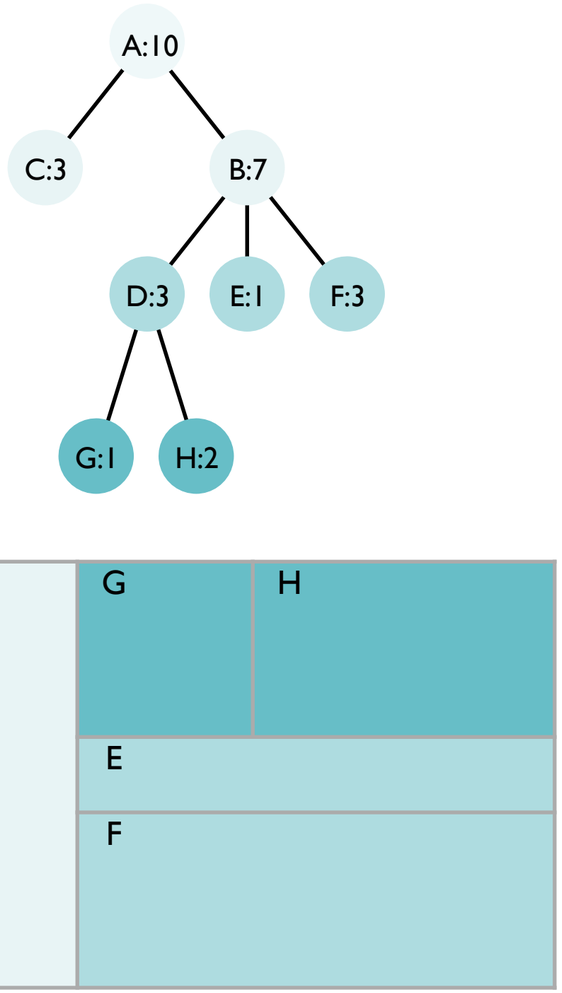
recursively fill space based on a size metric for nodes

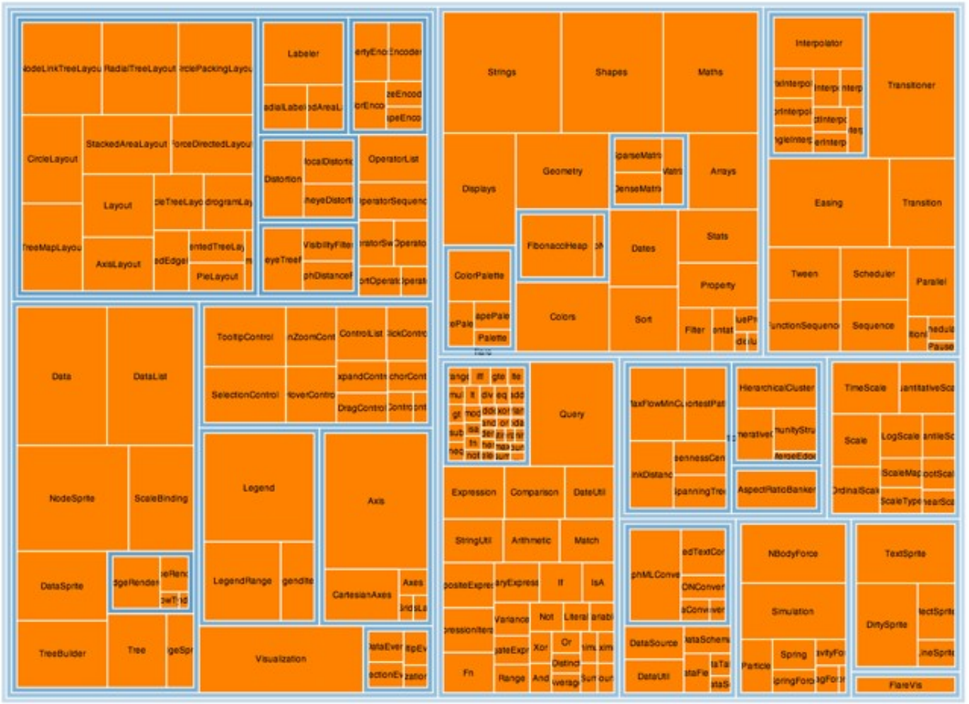
enclosure indicates hierarchy

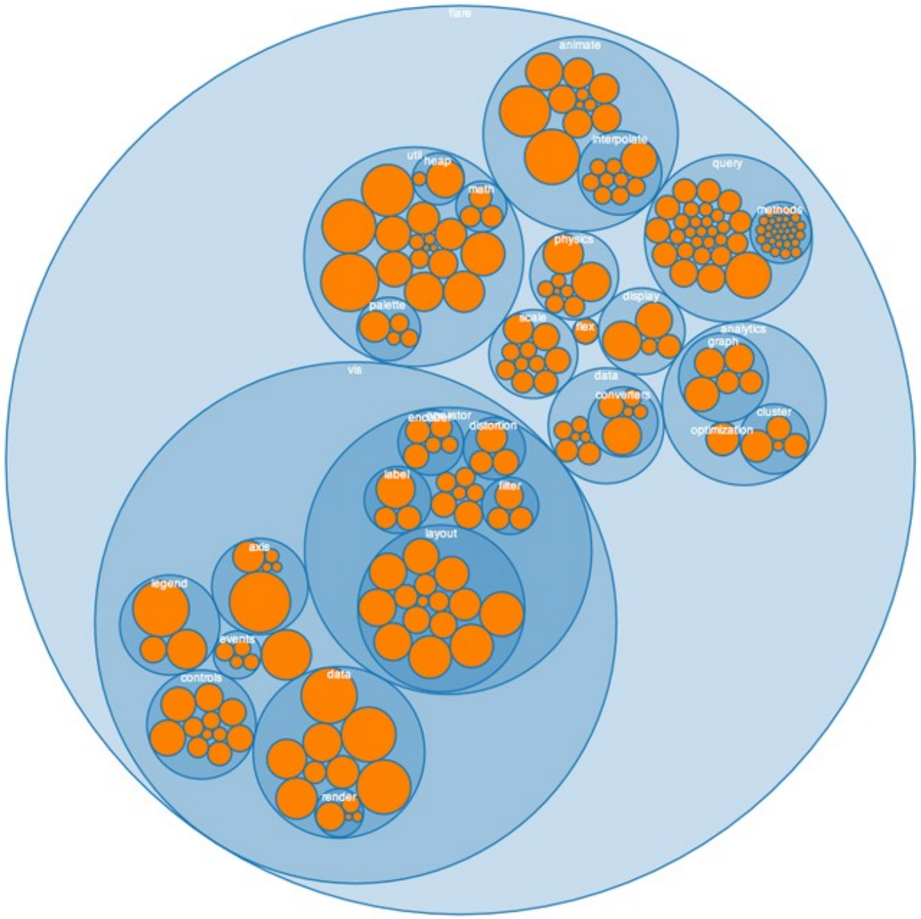
additional measures can control aspect ratio of cells

most often use rectangles, but other shapes possible

square, circle, voronoi tessellation







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VISUALIZING GRAPHS

ADMINISTRATIVE

project 4 questions?

project 3 presentations

visualcomplexity.com | A visual exploration on mapping complex networks

http://www.visualcomplexity.com/vc/

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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

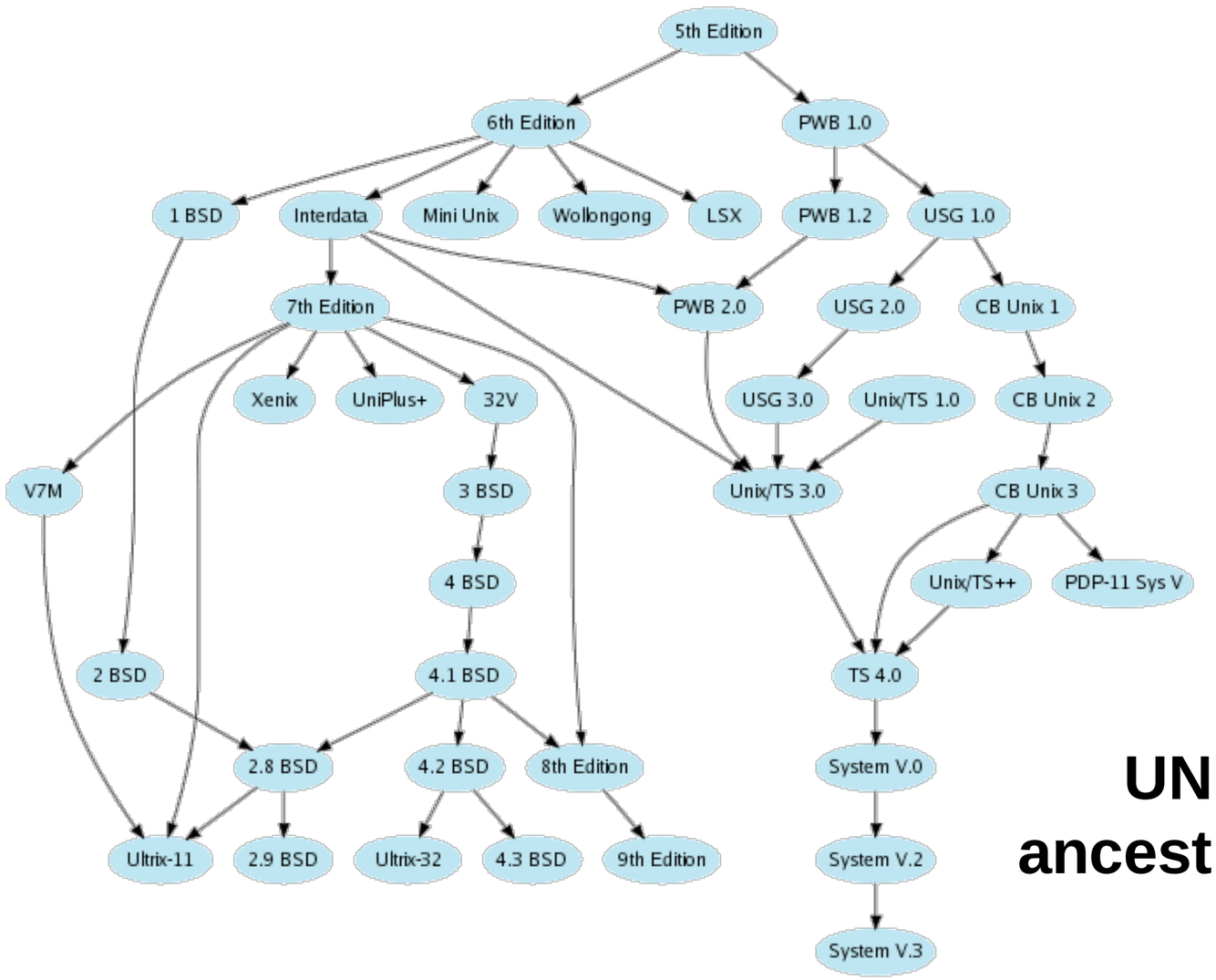
ordering (e.g., hierarchy level)

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 instead: http://www.graphviz.org

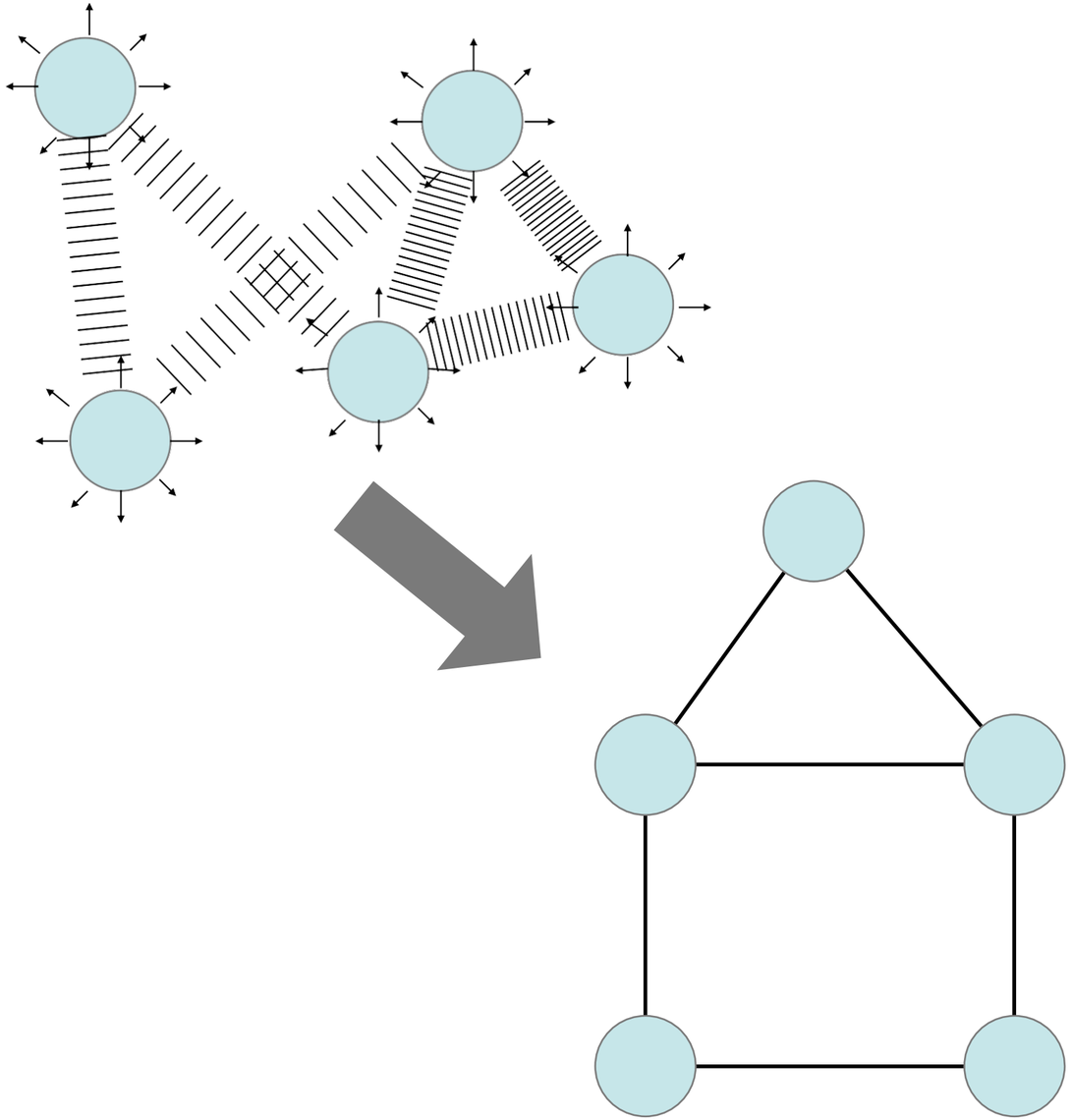
FORCE-DIRECTED

no intrinsic layering, now what?

physically-based model

edges = springs

nodes = repulsive particles



FORCE MODEL

many variations, but usually physical analogy:

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

m_1, m_2 are node masses

d is distance between nodes

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

L is the rest length of the spring

i.e. Hooke's Law

total force on a node x with position x'

$$- \square^{neighbors(x)} : f_A(||x'-y'||) * (x'-y') + -f_R(||x'-y'||) * (x'-y')$$

ALGORITHM

start from random layout

(global) loop:

for every node pair compute repulsive force

for every edge compute attractive force

accumulate forces per node

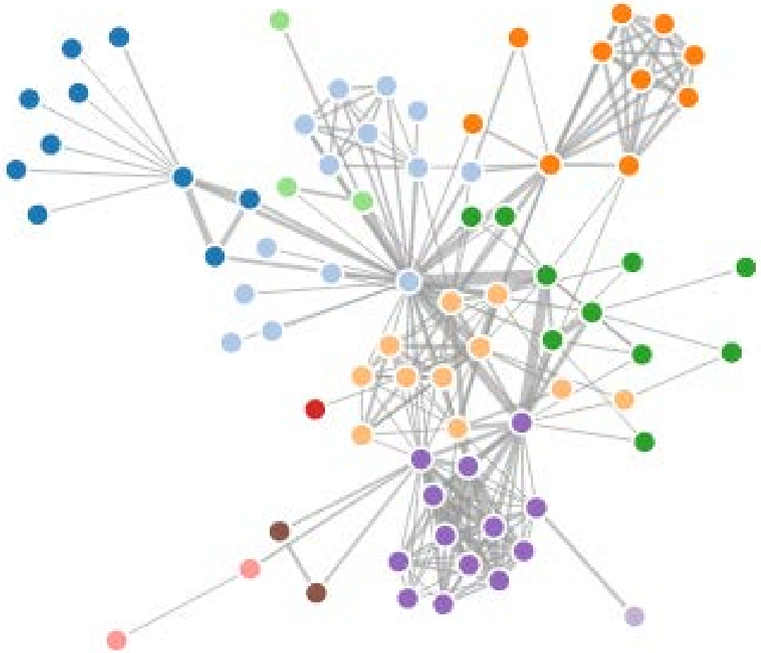
update each node position in direction of accumulated force

stop when layout is ‘good enough’

FORCE DIRECTED

+ very flexible, aesthetic layouts on many types of graphs
+ can add custom forces
+ relatively easy to implement

- 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



HTTP://BL.OCKS.ORG/MBOSTOCK/4062045

OTHER LAYOUTS

orthogonal

great for UML diagrams

algorithmically complex

circular layouts

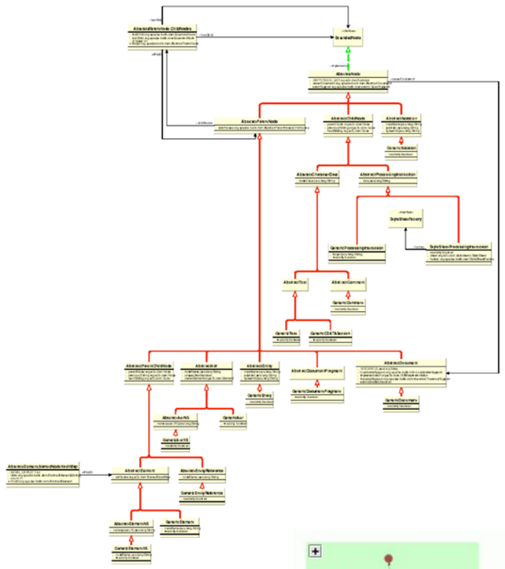
emphasizes ring topologies

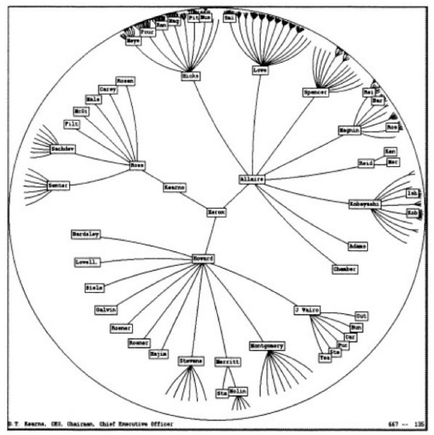
used in social network diagrams

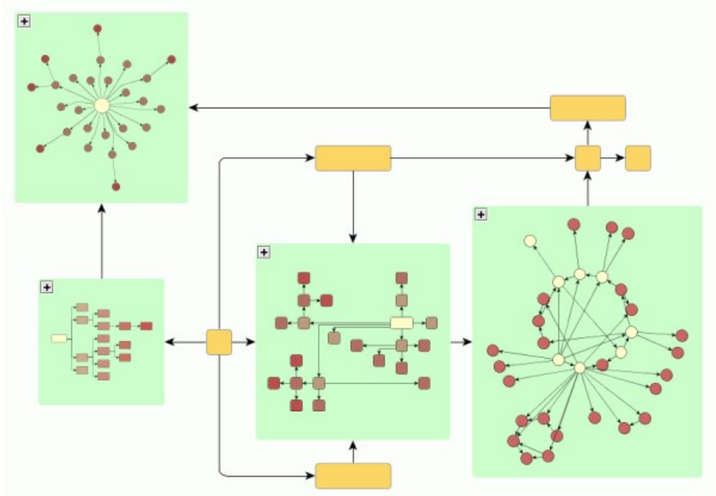
nested layouts

recursively apply layout algorithms

great for graphs with hierarchical structure







Gephi, an open source graph visualization and manipulation software

http://gephi.org/

hookes law

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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.

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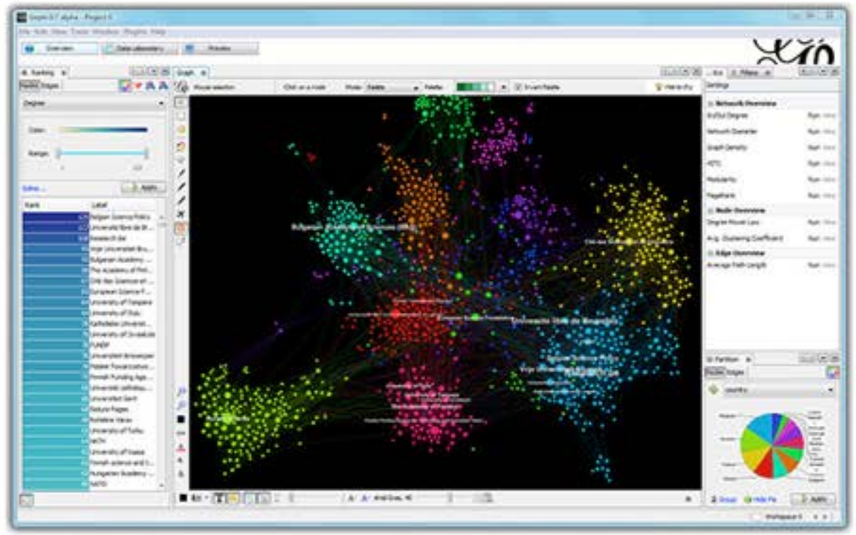
Gephi 0.8 beta

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.

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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!

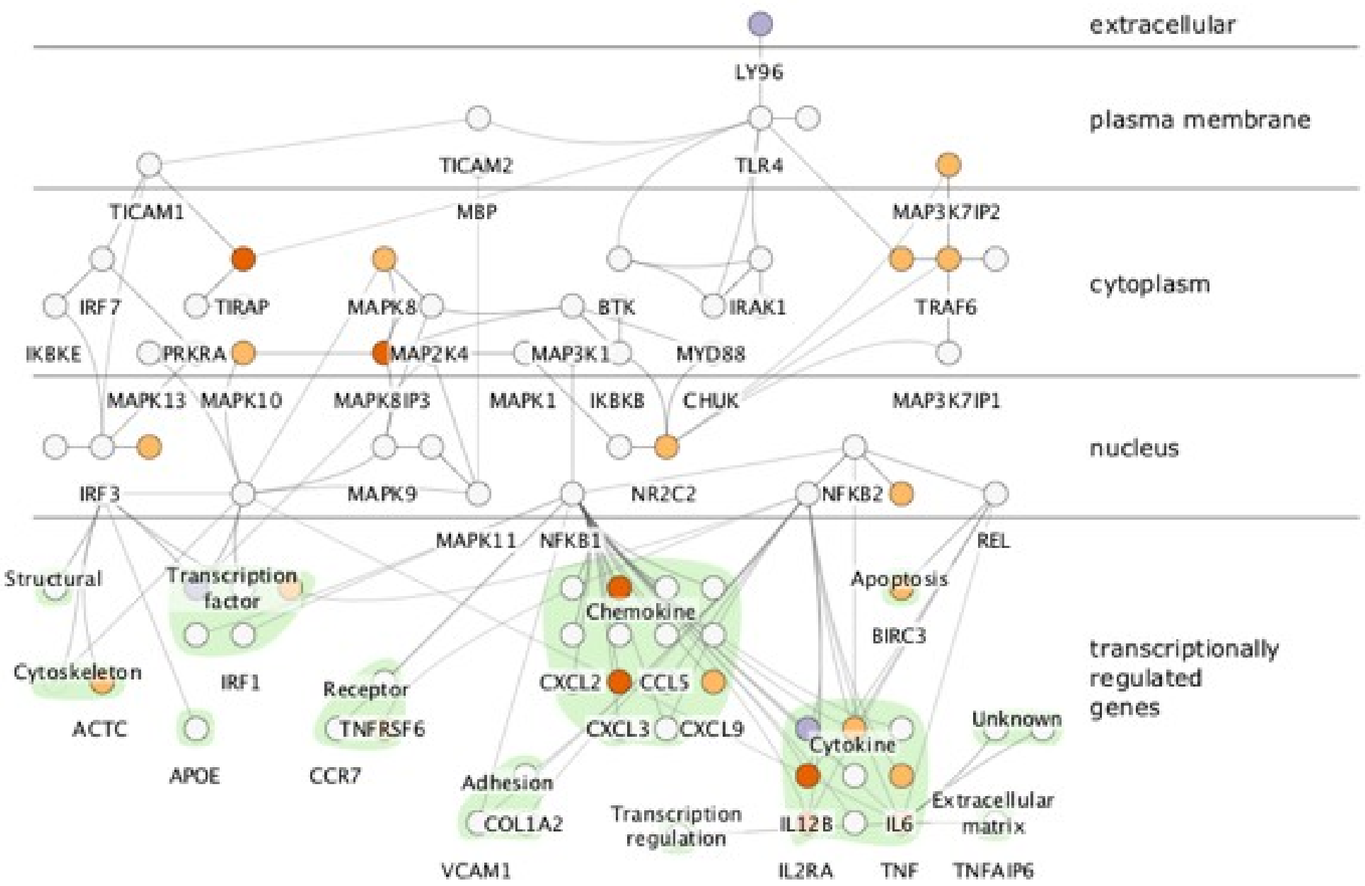
are there additional structures to exploit?

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

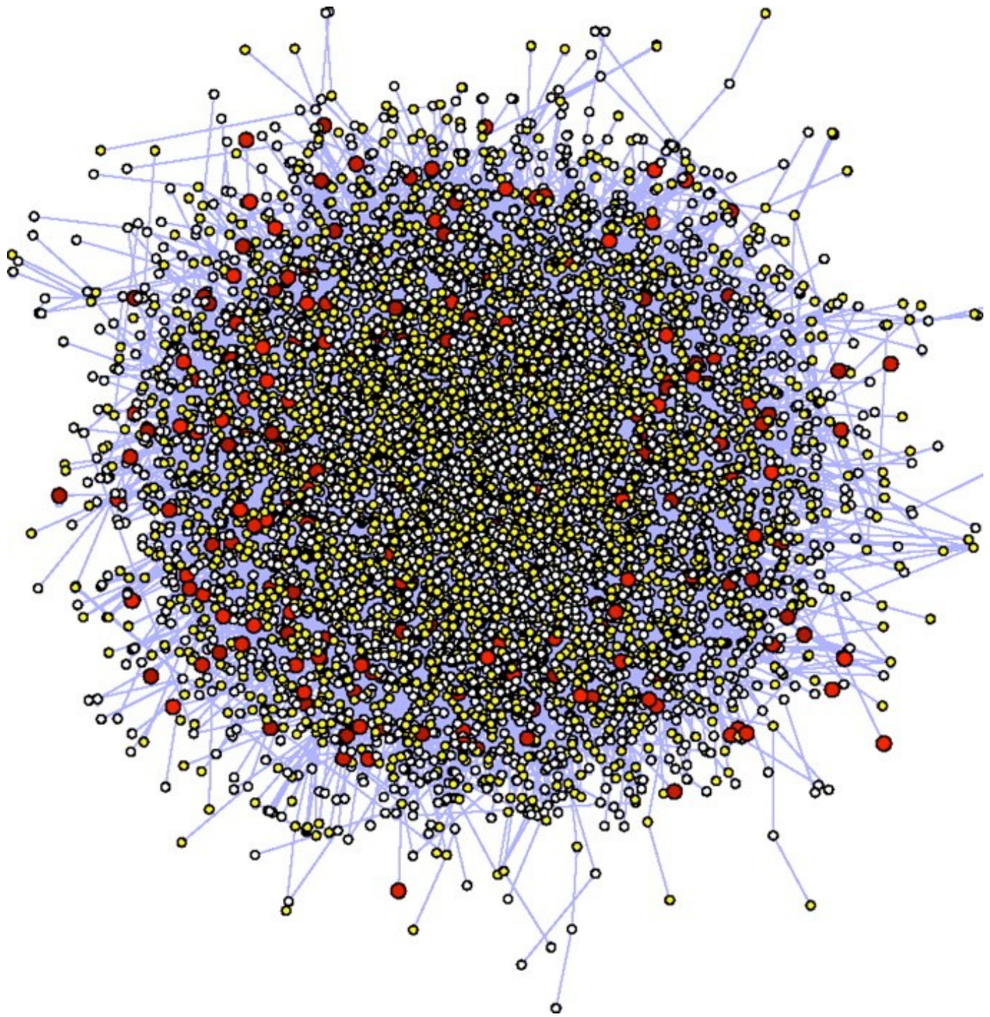


BARSKY 2008

NODE LINK

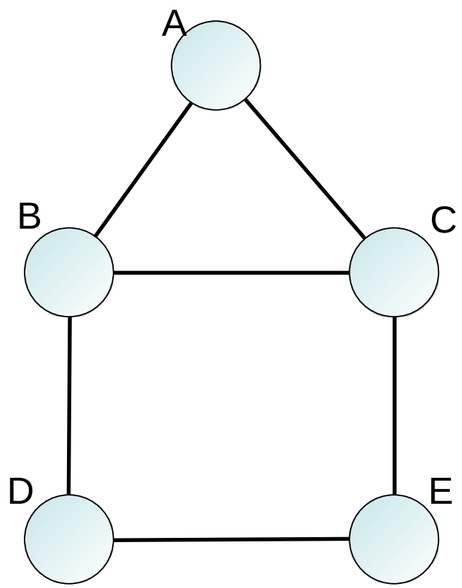
+ understandable visual mapping
+ can show overall structure, clusters, paths
+ flexible, many variations

- all but the most trivial algorithms are > $O(n^2)$
- not good for dense graphs
hairball problem!



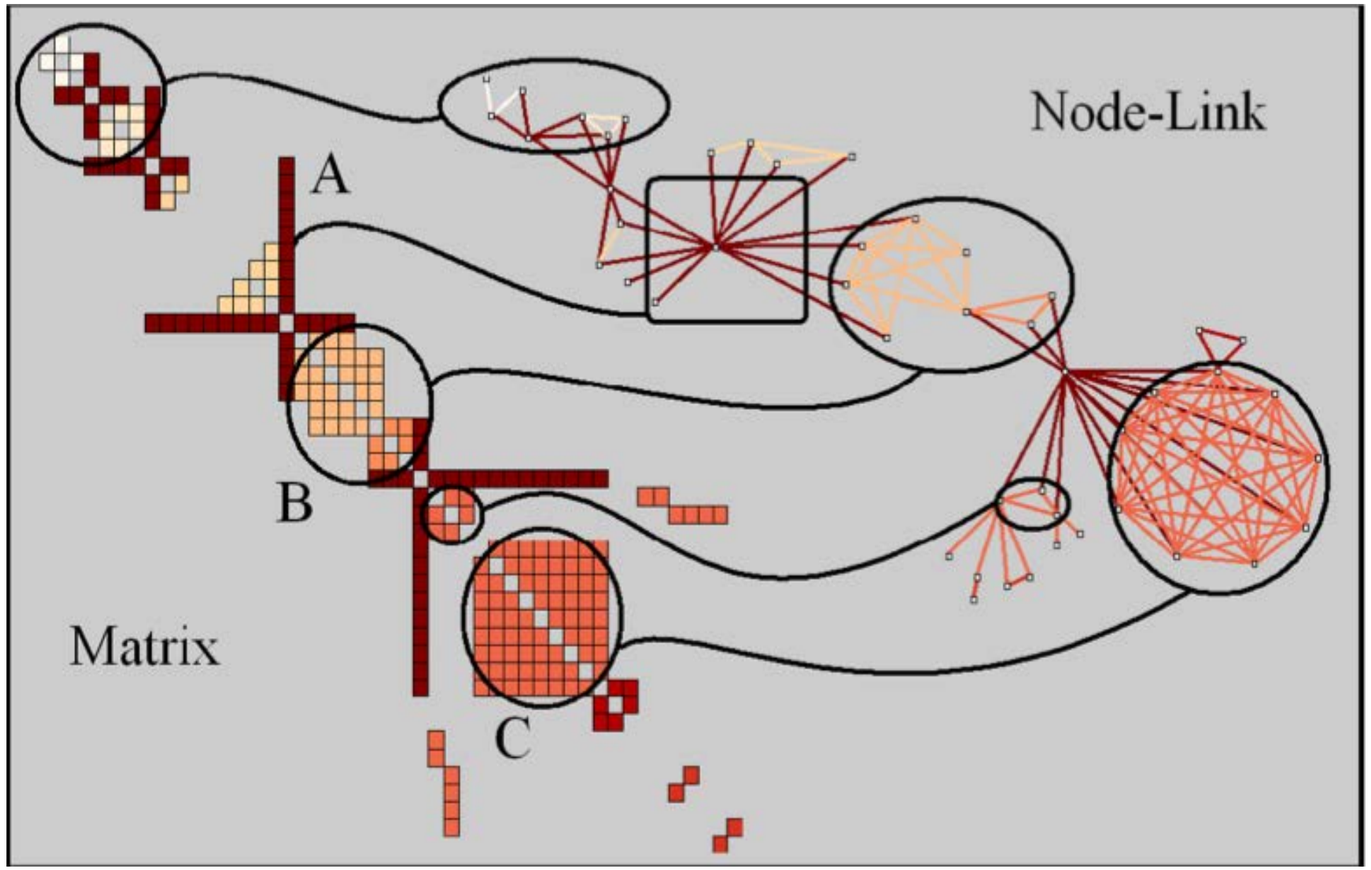
ALTERNATIVE: ADJACENCY MATRIX

instead of node link diagram, use adjacency matrix representation



	A	B	C	D	E
A					
B					
C					
D					
E					

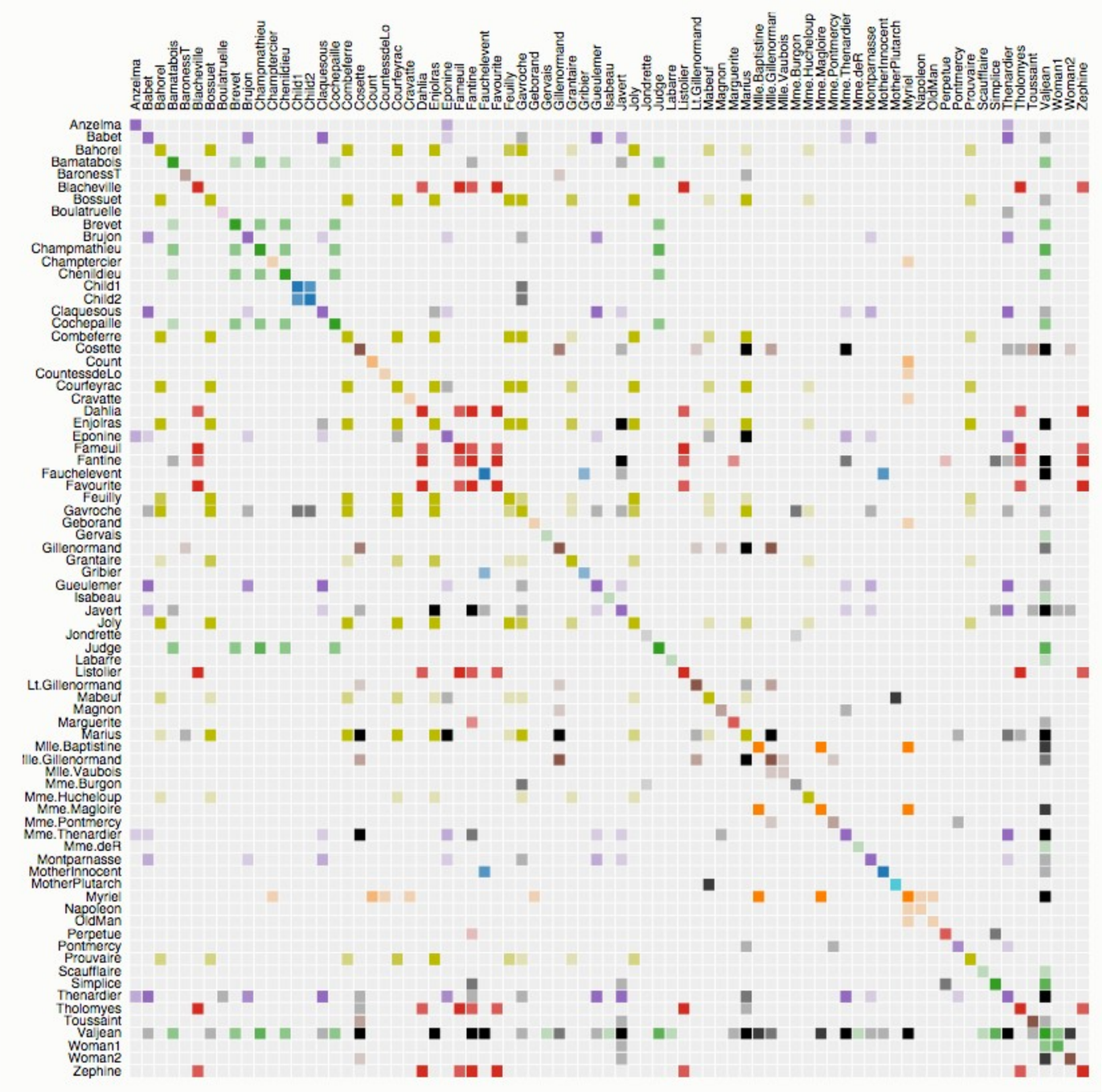
SPOTTING PATTERNS IN MATRICES



HENRY 2006

LES MISÉRABLES

character co-occurrence



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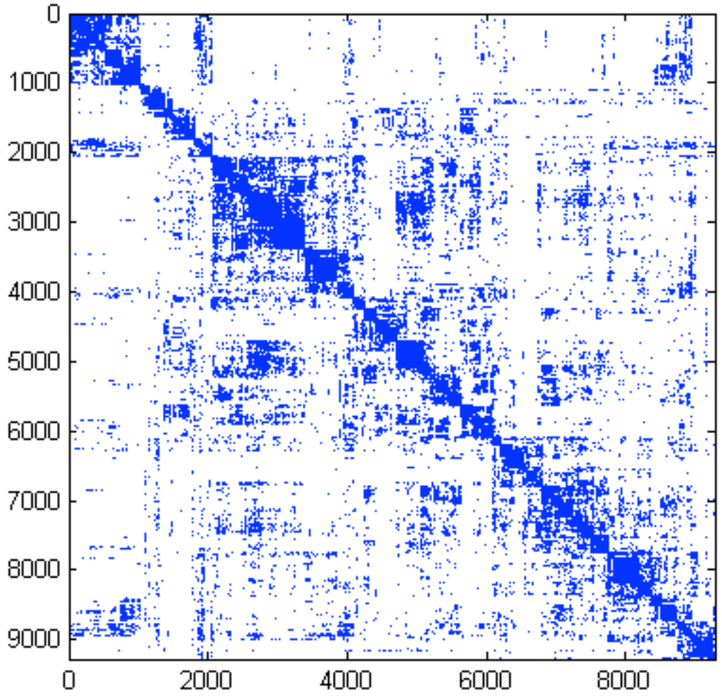
Adjacency Diagram

+ great for dense graphs
+ visually scalable
+ can spot clusters

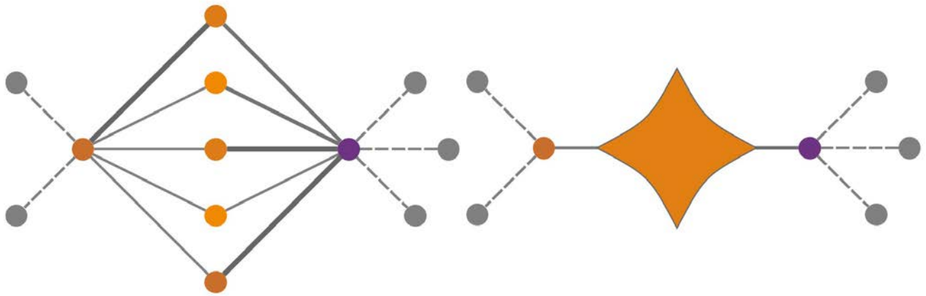
- row order affects what you can see
- abstract visualization
- hard to follow paths



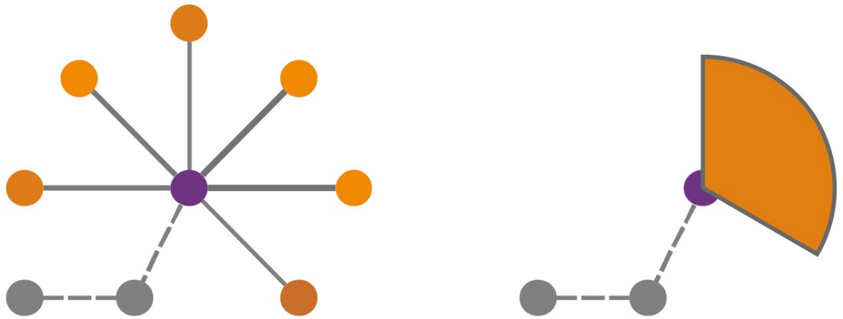
AGGREGATE VIEWS

MOTIF GLYPHS

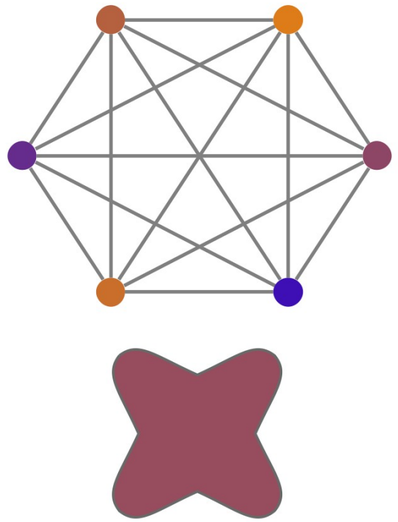
Connector



Fan



Clique



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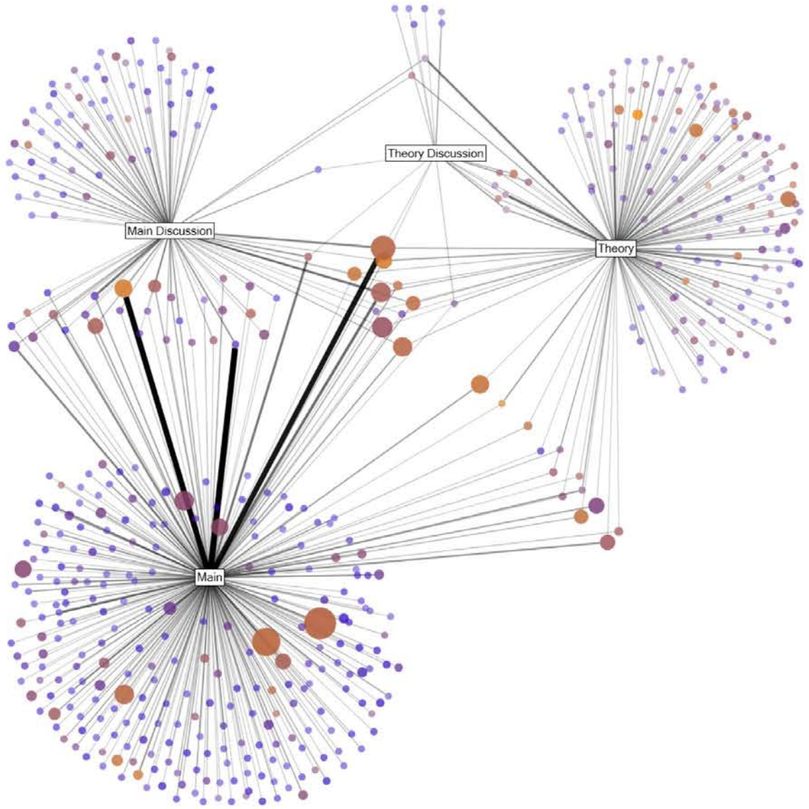

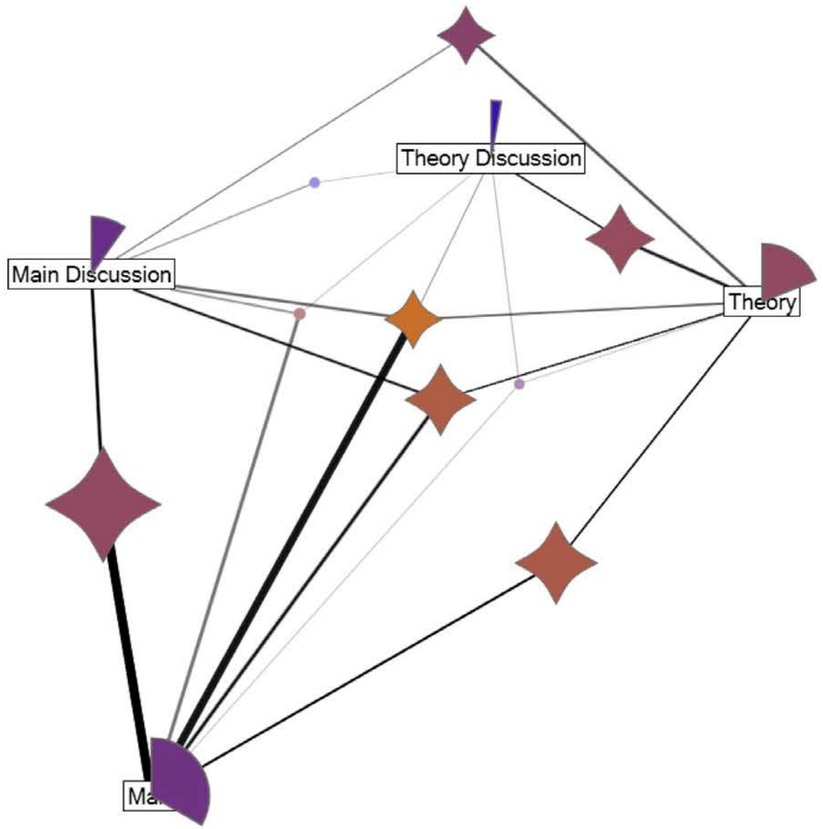

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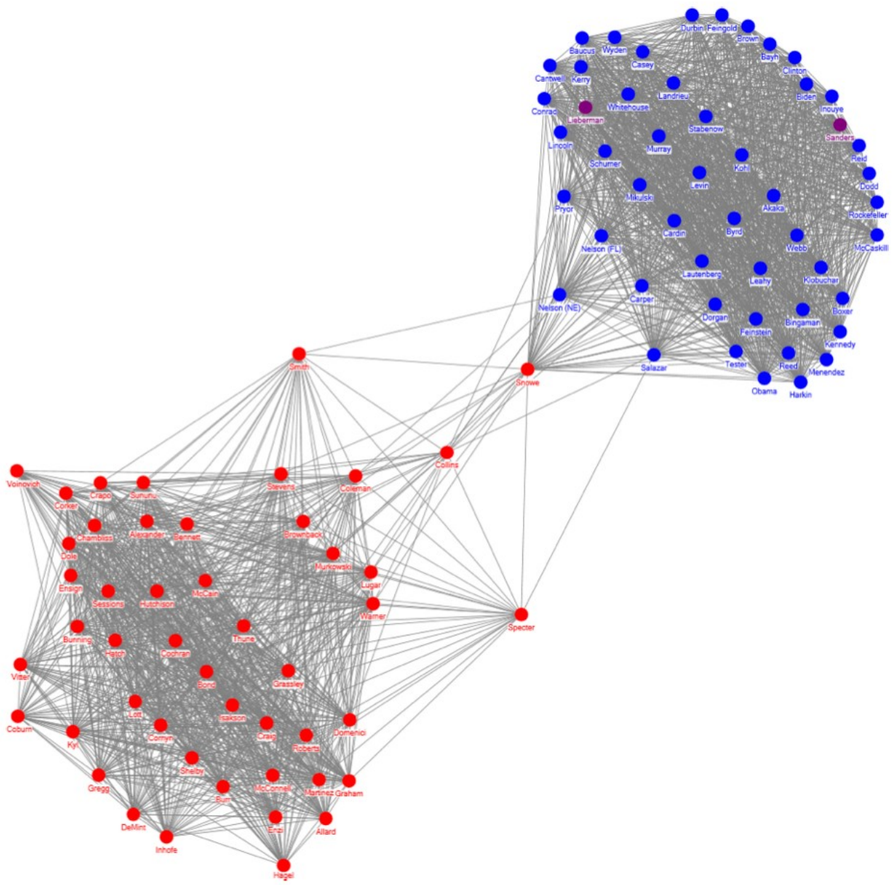
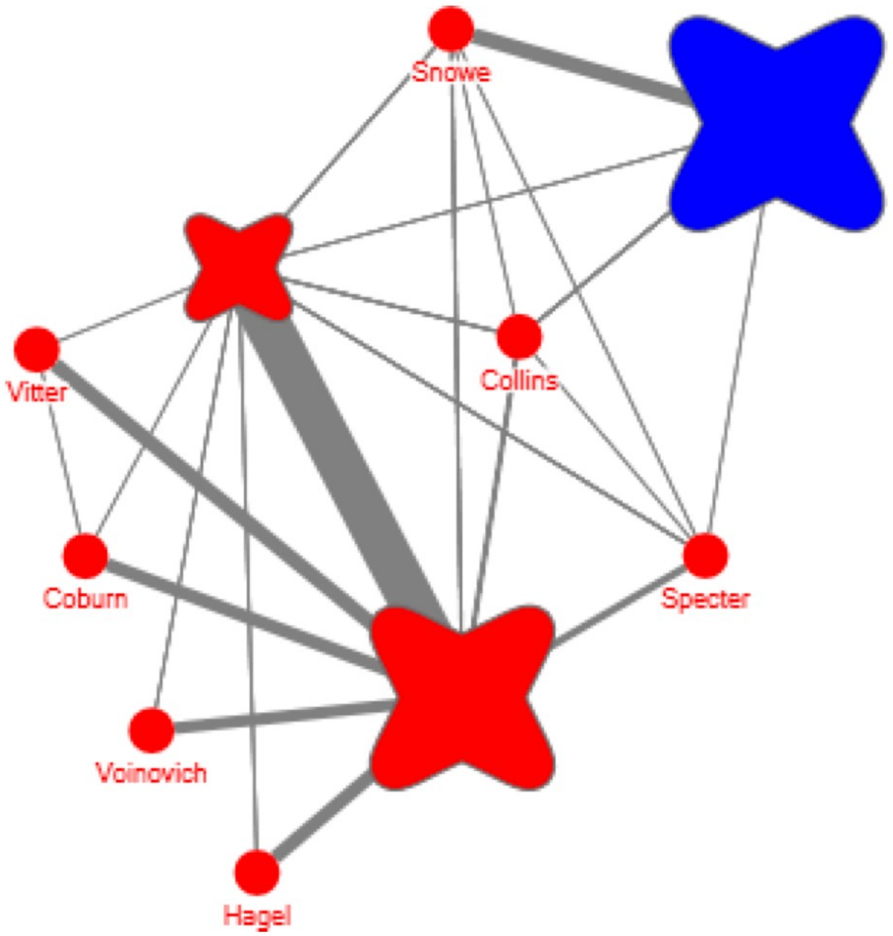




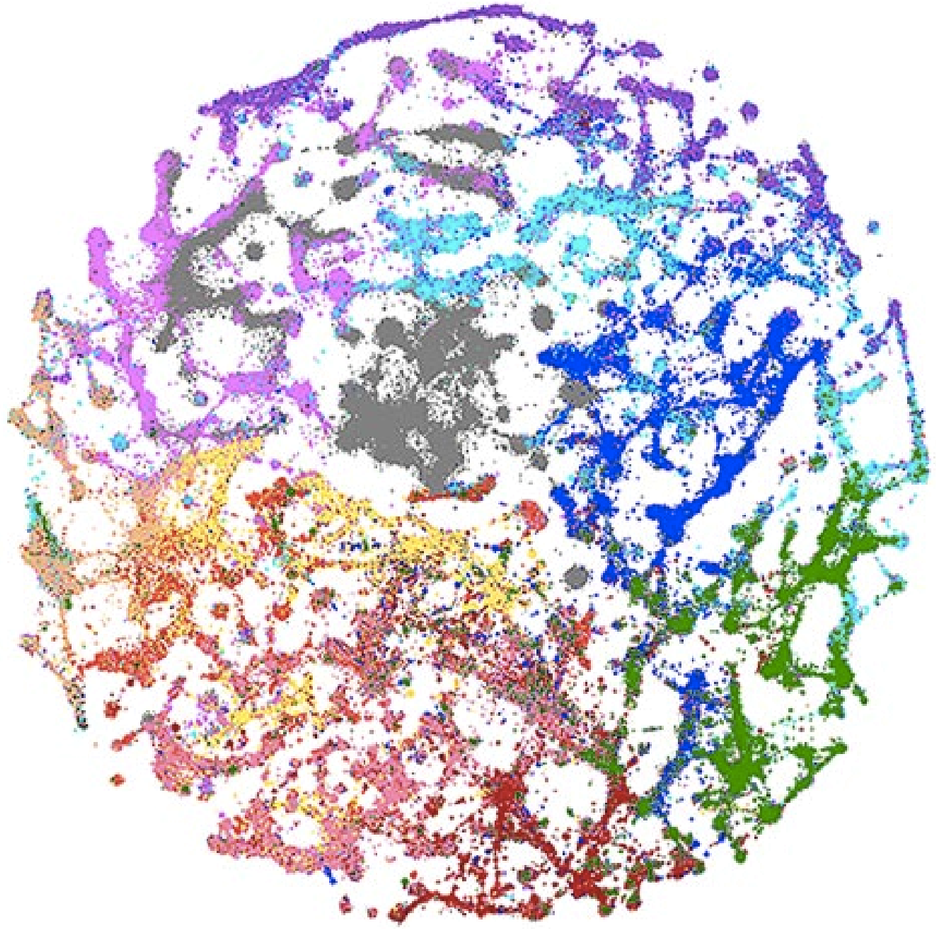
DUNNE 2013

CRITIQUE

When *can* you use this technique?

When *should* you use this technique?

EXTRACTING STRUCTURE



OPEN ACCESS Freely available online PLoS one

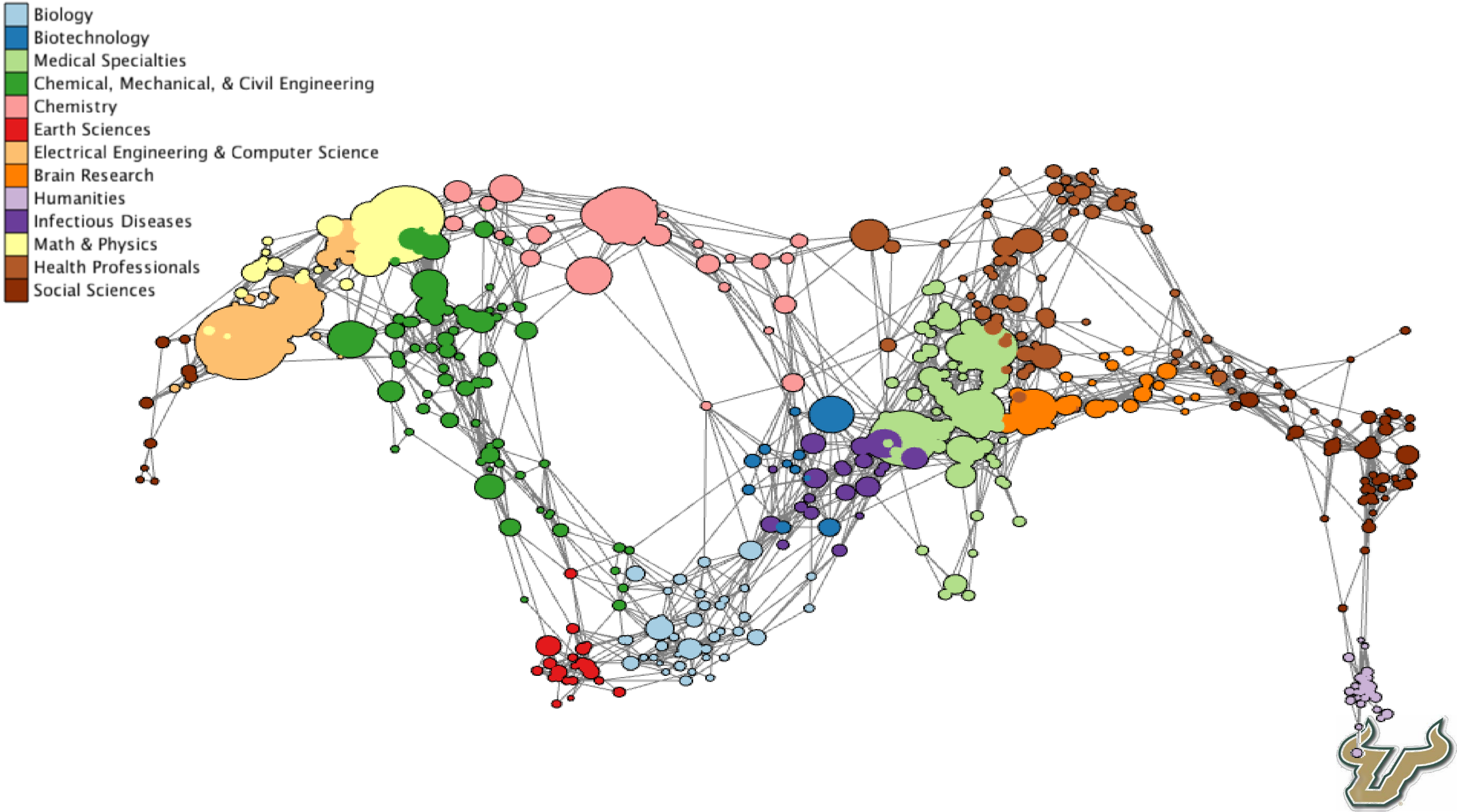
Design and Update of a Classification System: The UCSD Map of Science

Katy Börner[1,2*], Richard Klavans[3], Michael Patek[3], Angela M. Zoss[1], Joseph R. Biberstine[1], Robert P. Light[1], Vincent Larivière[1,4,5], Kevin W. Boyack[6]

1 Cyberinfrastructure for Network Science Center, School of Library and Information Science, Indiana University, Bloomington, Indiana, United States of America, 2 Royal Netherlands Academy of Arts and Sciences (KNAW), Amsterdam, The Netherlands, 3 SciTech Strategies, Inc., Berwyn, Pennsylvania, United States of America, 4 École de Bibliothéconomie et des Sciences de L'information, Université de Montréal, Montréal, Canada, 5 Observatoire des Sciences et des Technologies (OST), Centre Interuniversitaire de Recherche sur la Science et la Technologie (CIRST), Université du Québec à Montréal, Montréal, Canada, 6 SciTech Strategies, Inc., Albuquerque, New Mexico, United States of America

Abstract

Global maps of science can be used as a reference system to chart career trajectories, the location of emerging research frontiers, or the expertise profiles of institutes or nations. This paper details data preparation, analysis, and layout performed when designing and subsequently updating the UCSD map of science and classification system. The original classification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Circular Parameterization

topological analysis tool
that finds circles in
high-dimensional data
and visualizes results

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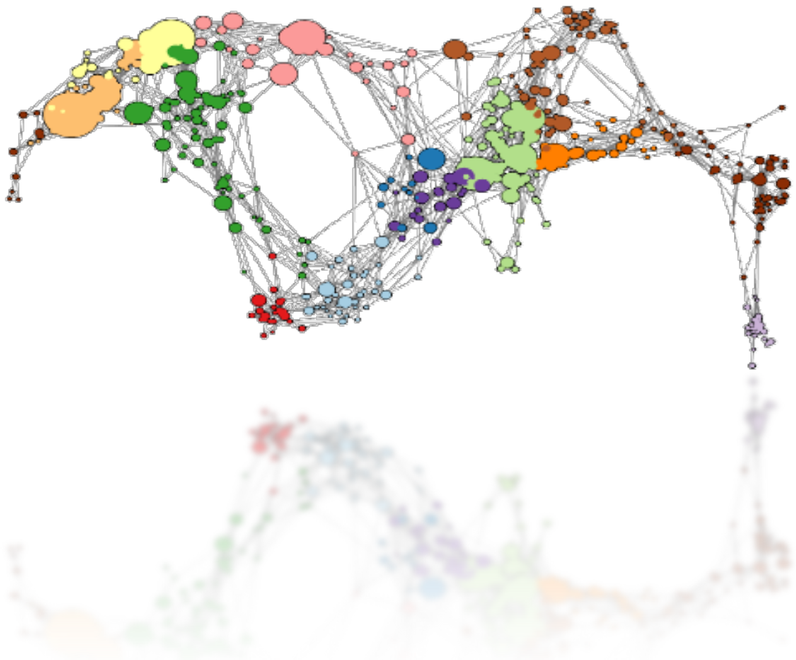

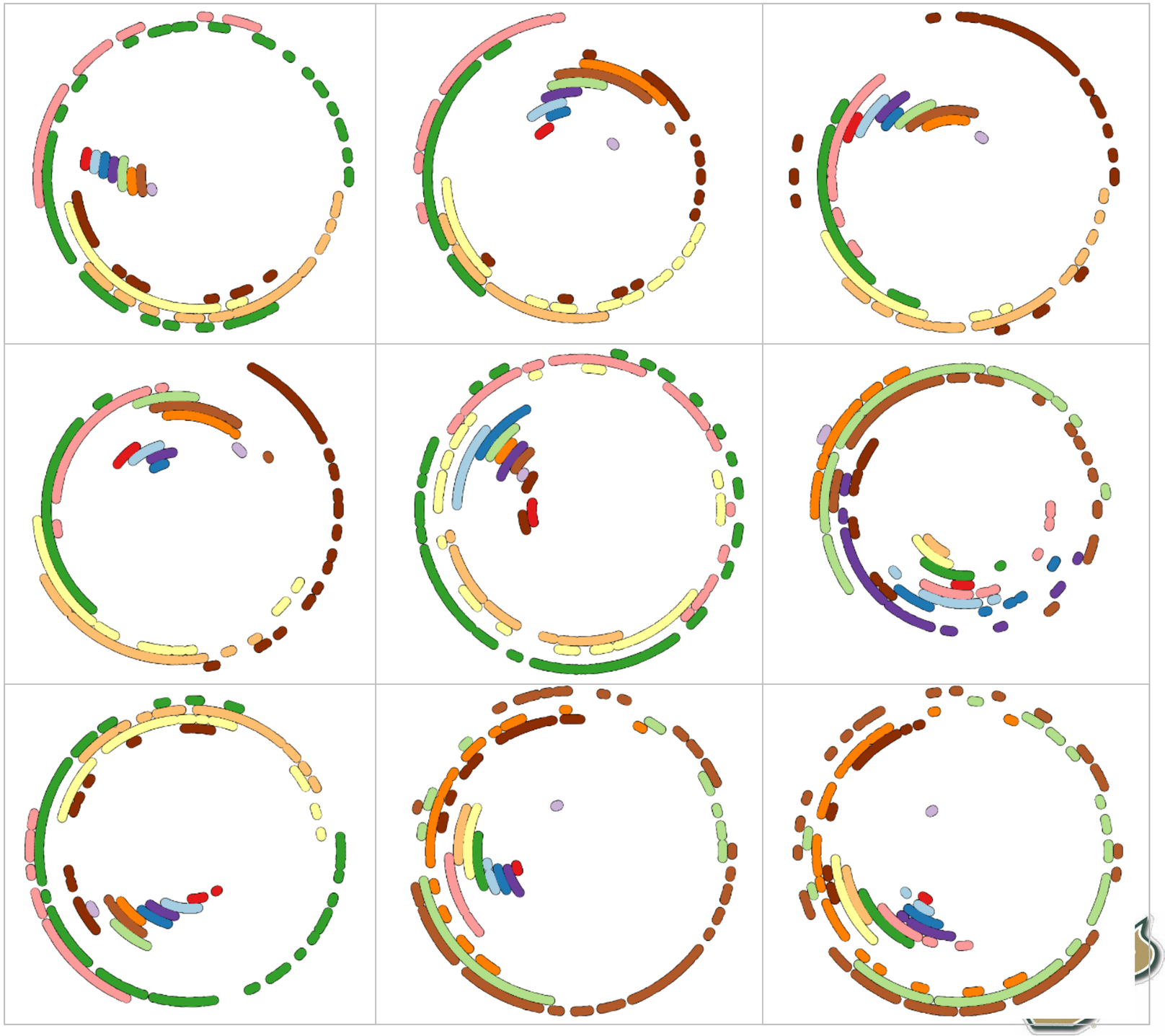

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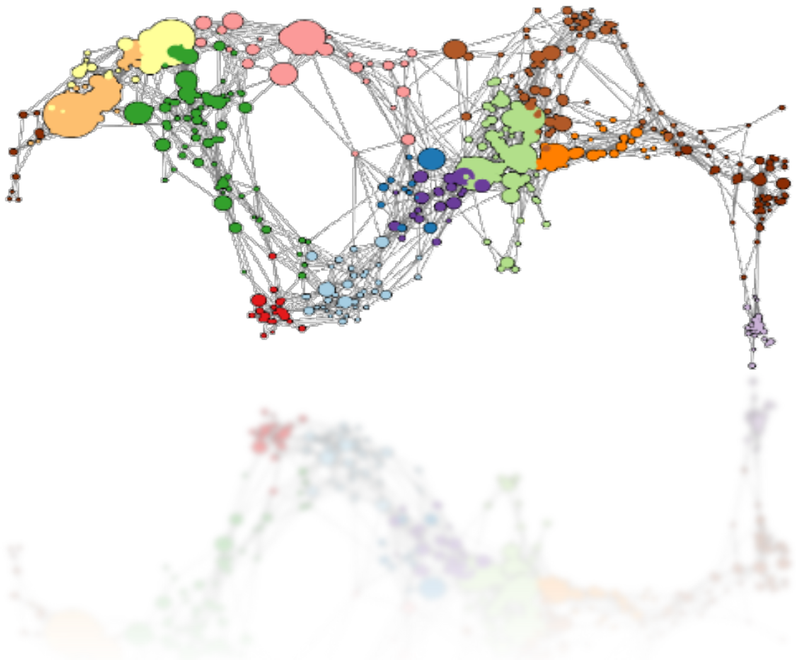

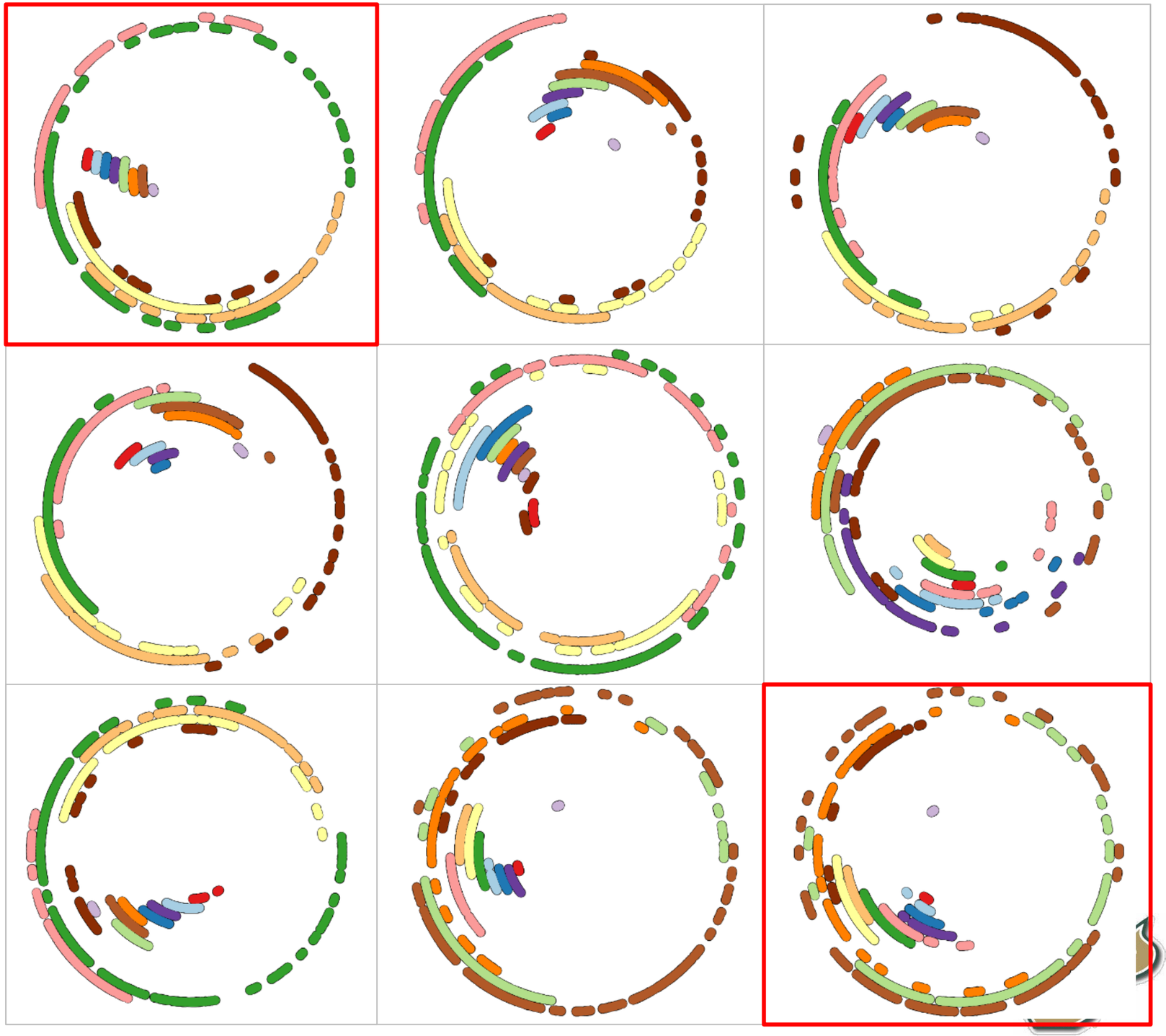

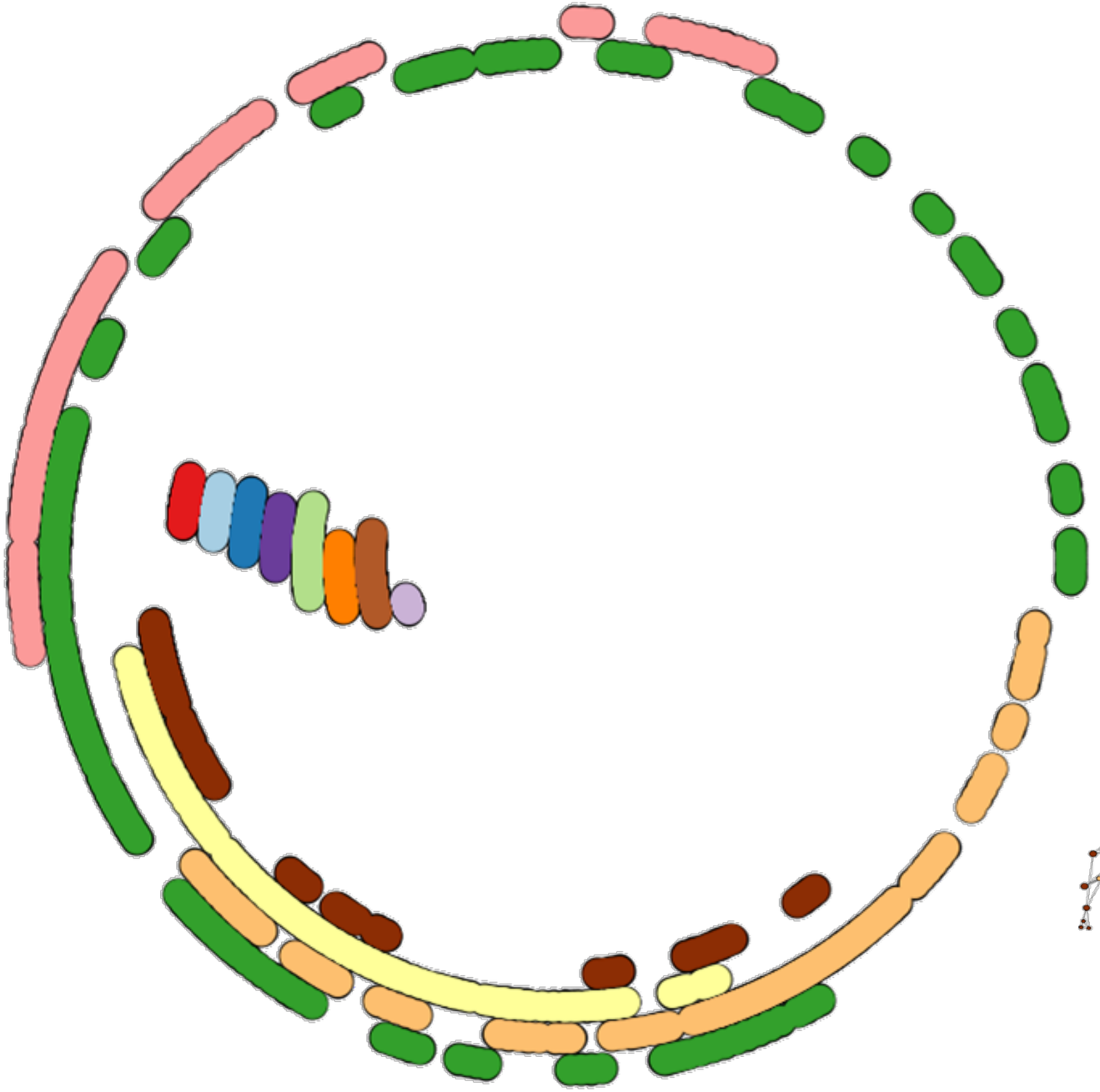

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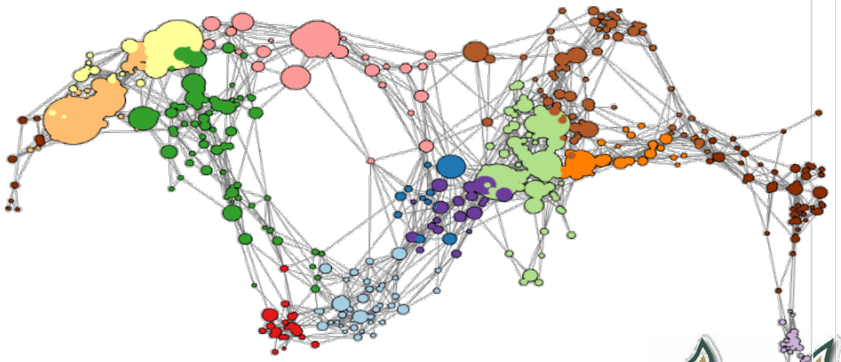

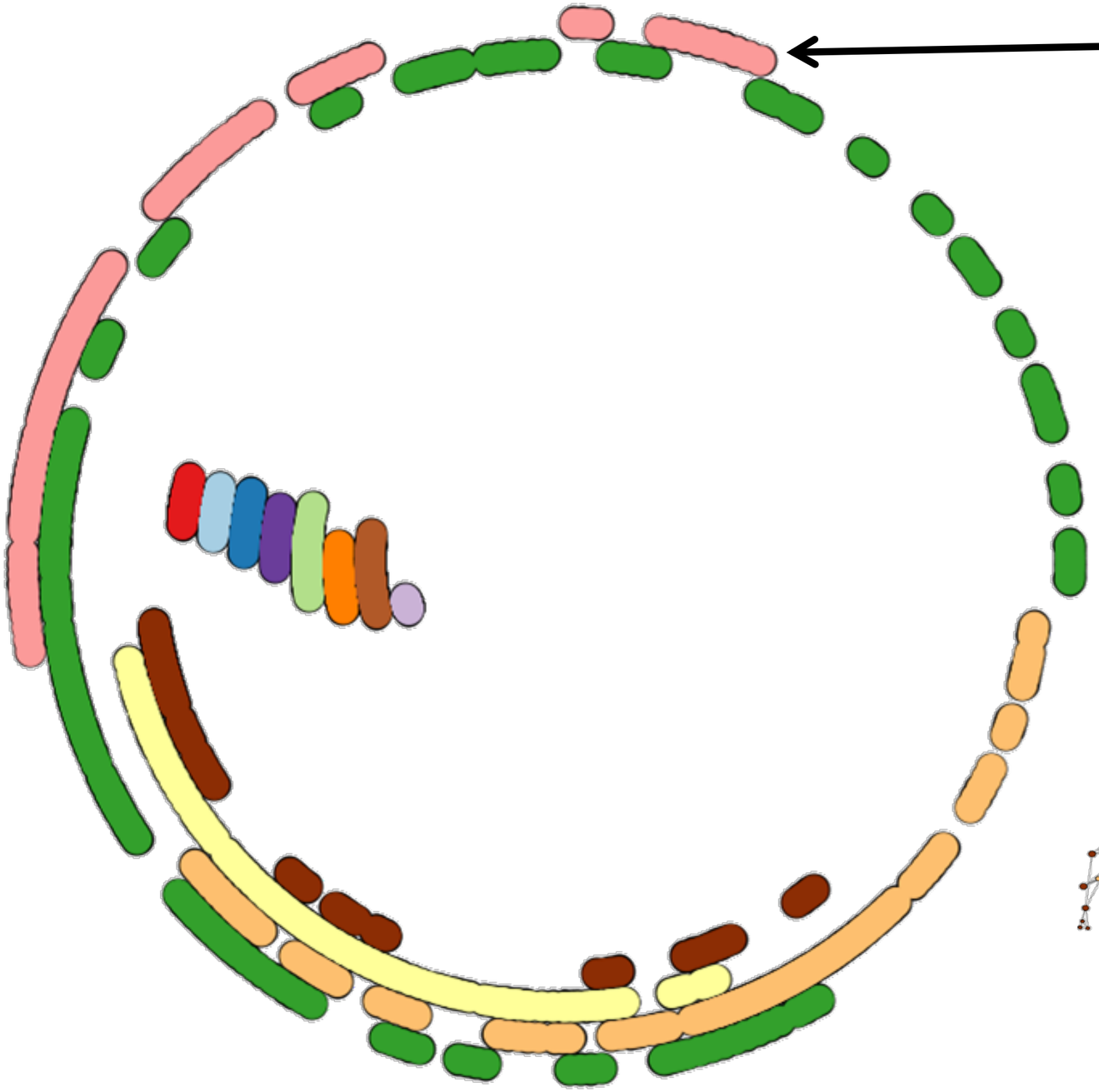

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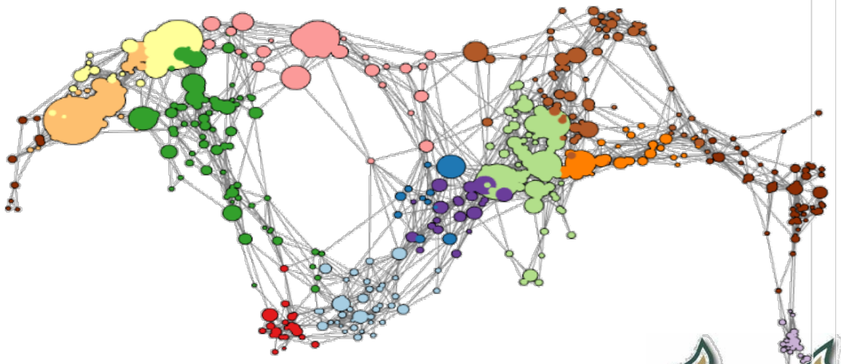

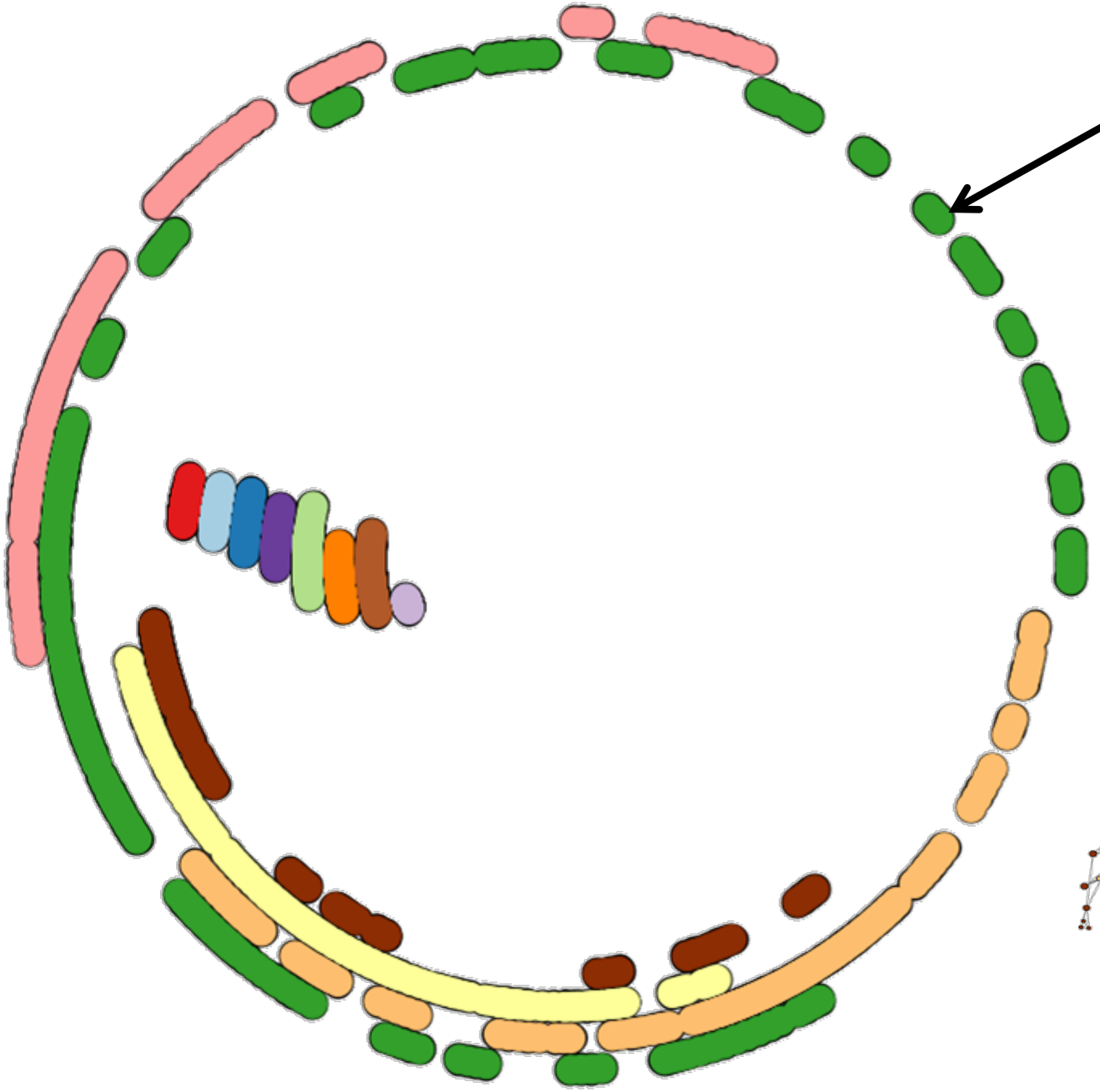

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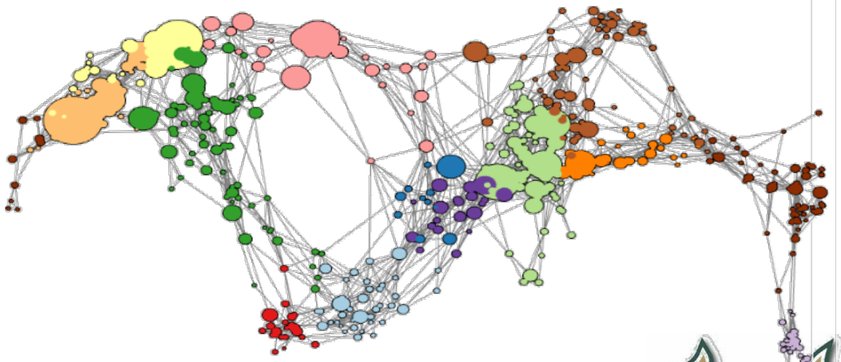

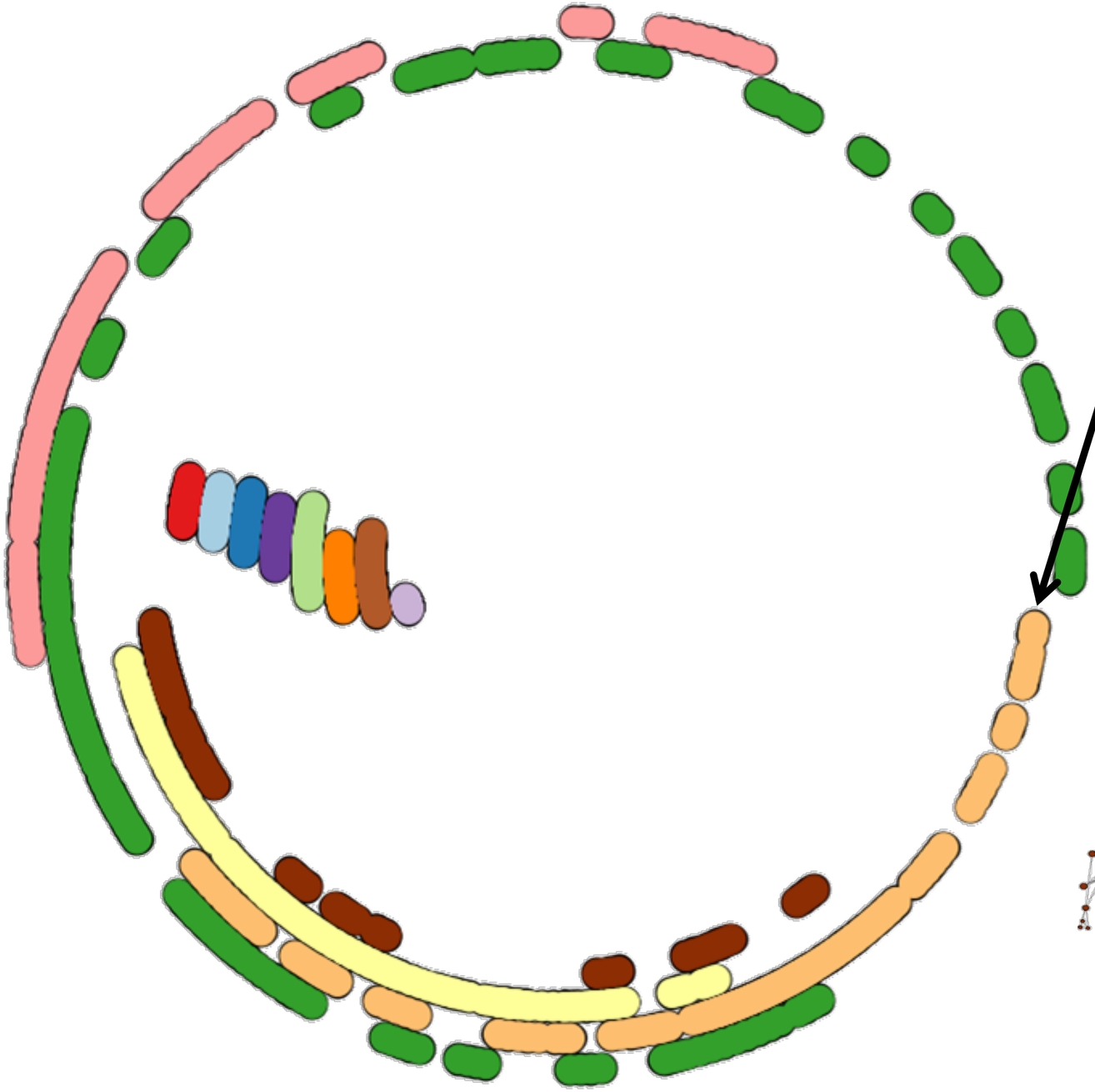

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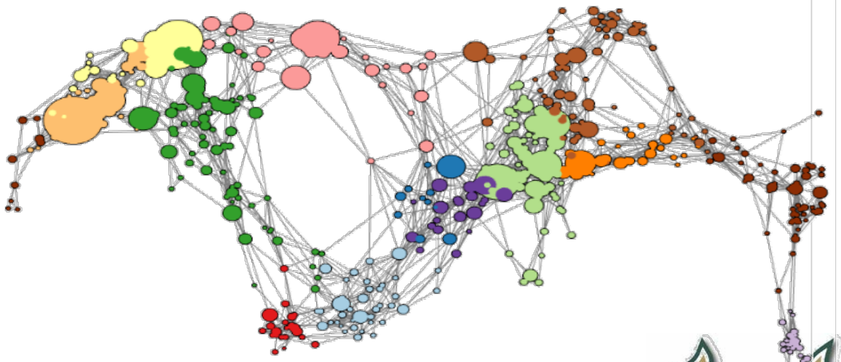

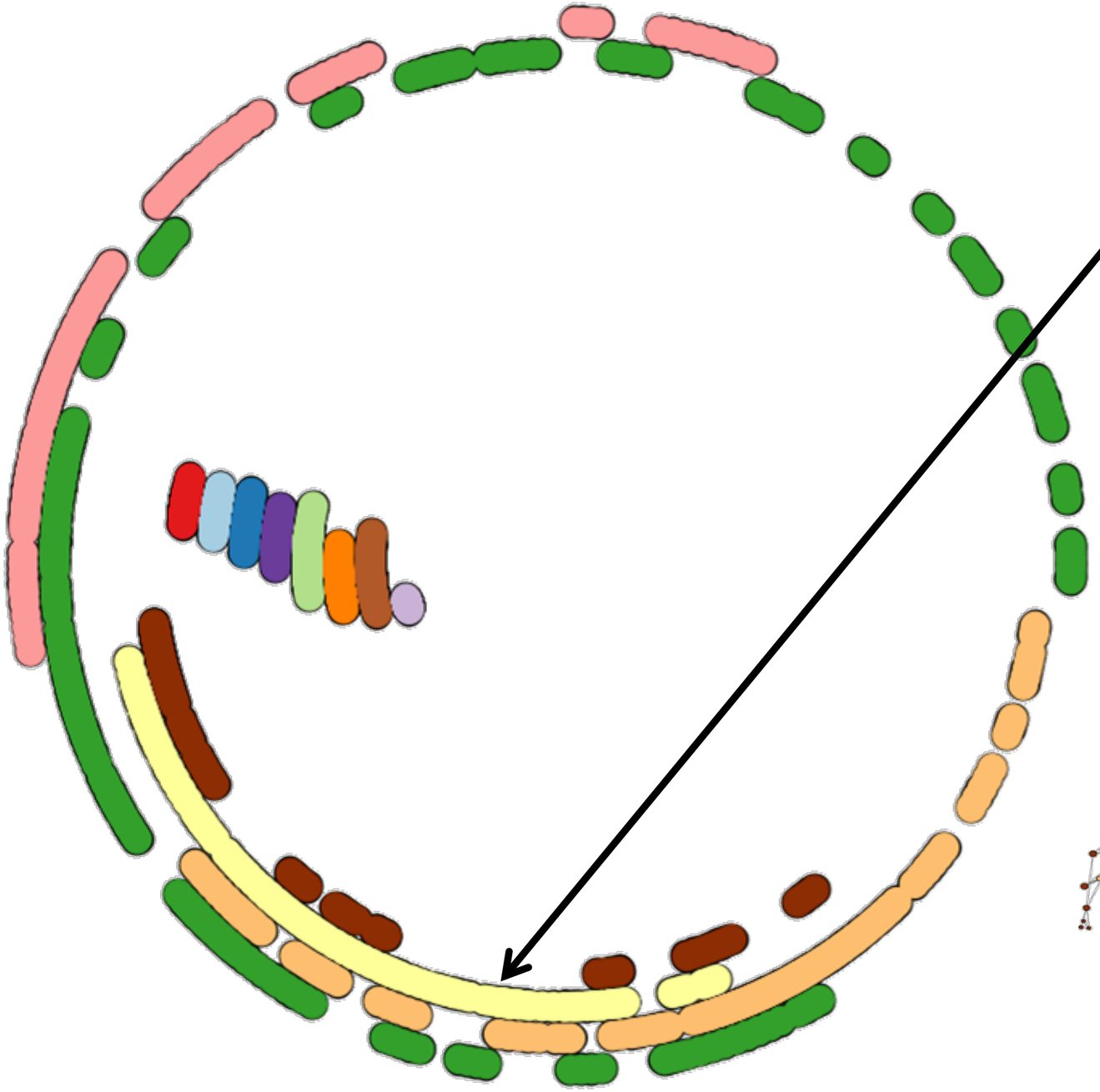

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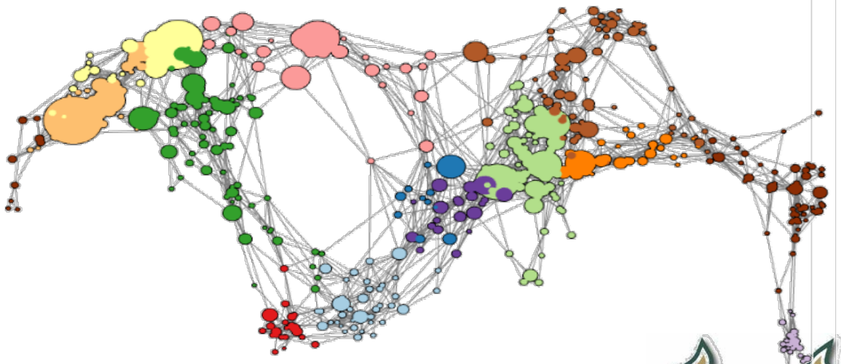

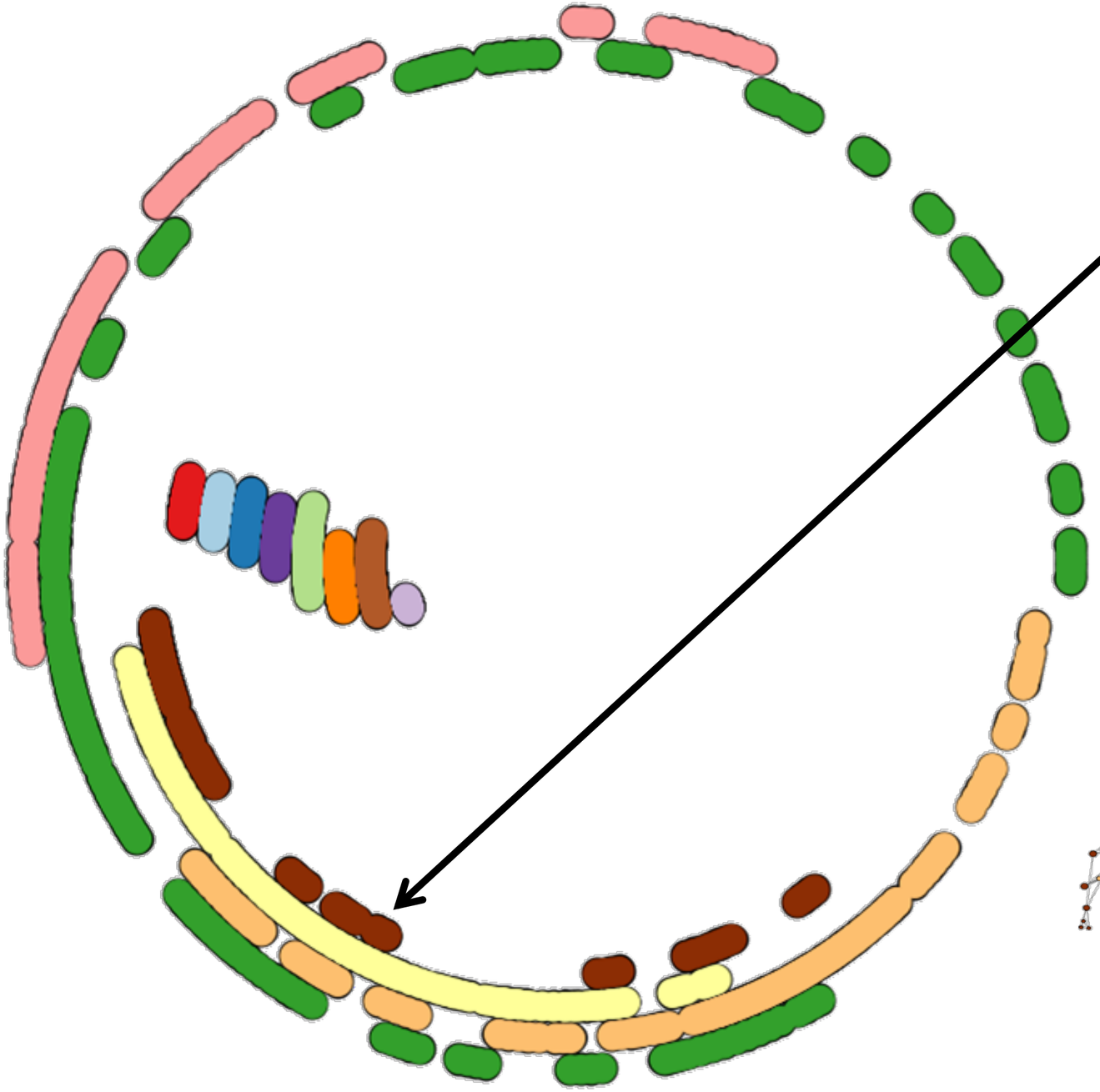

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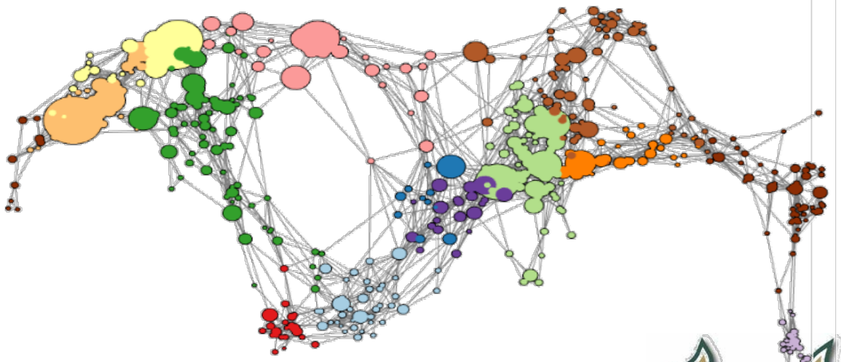

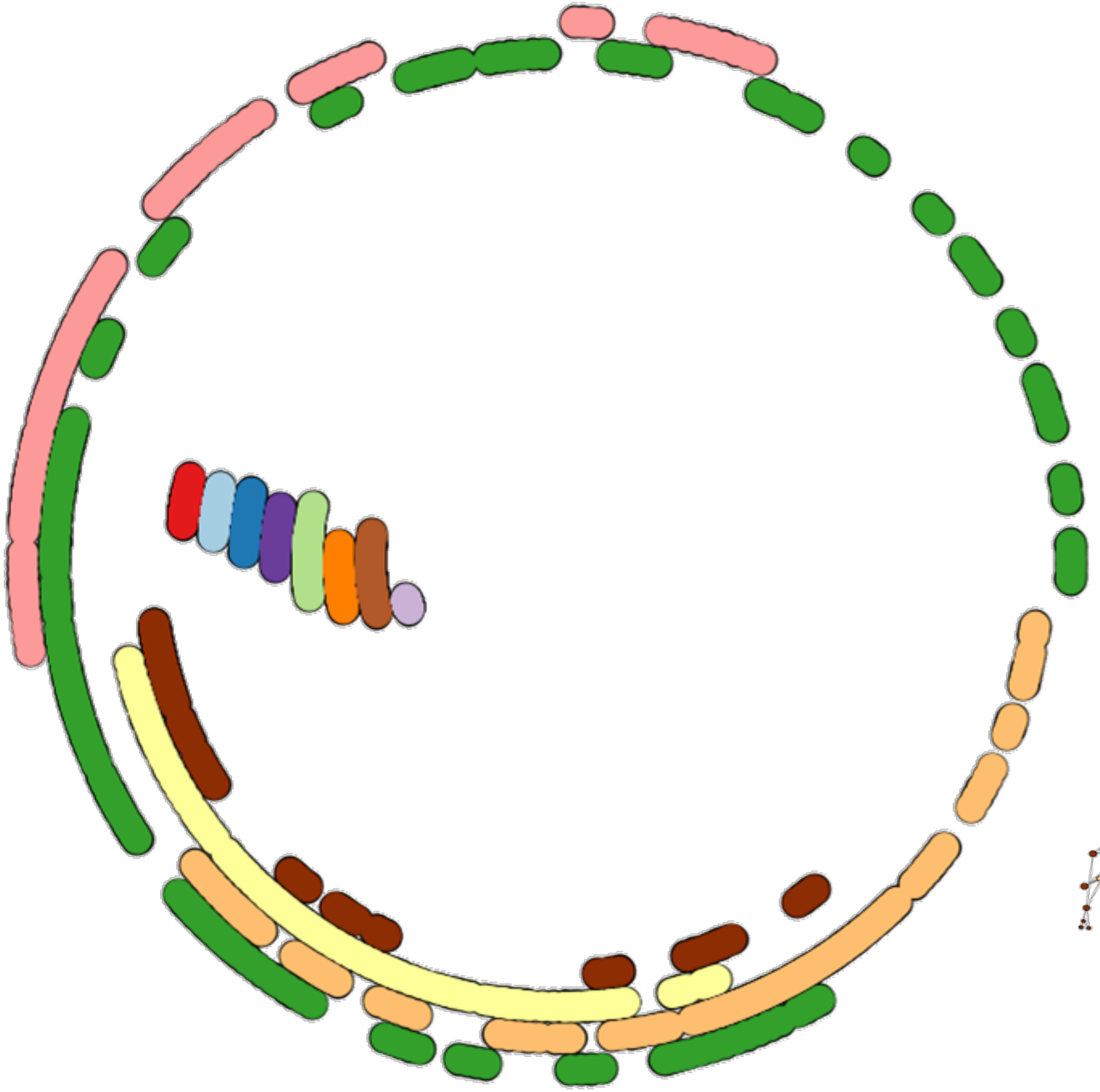

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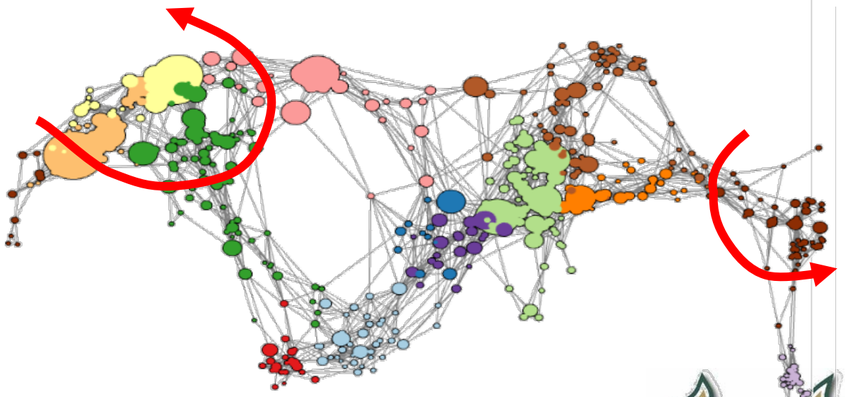

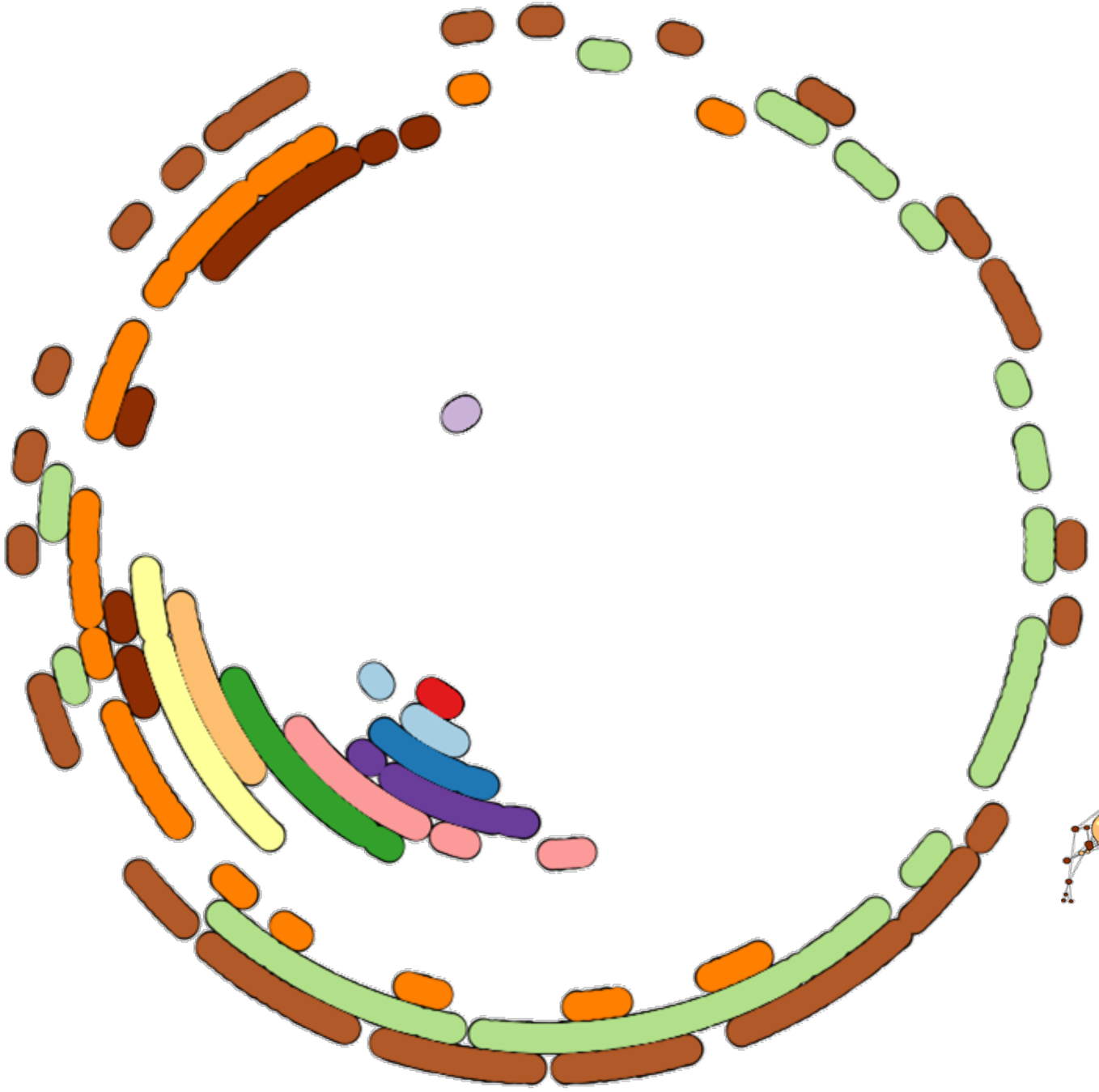

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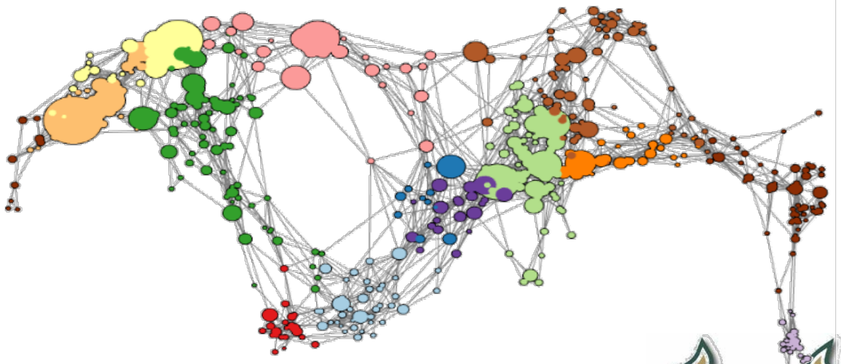

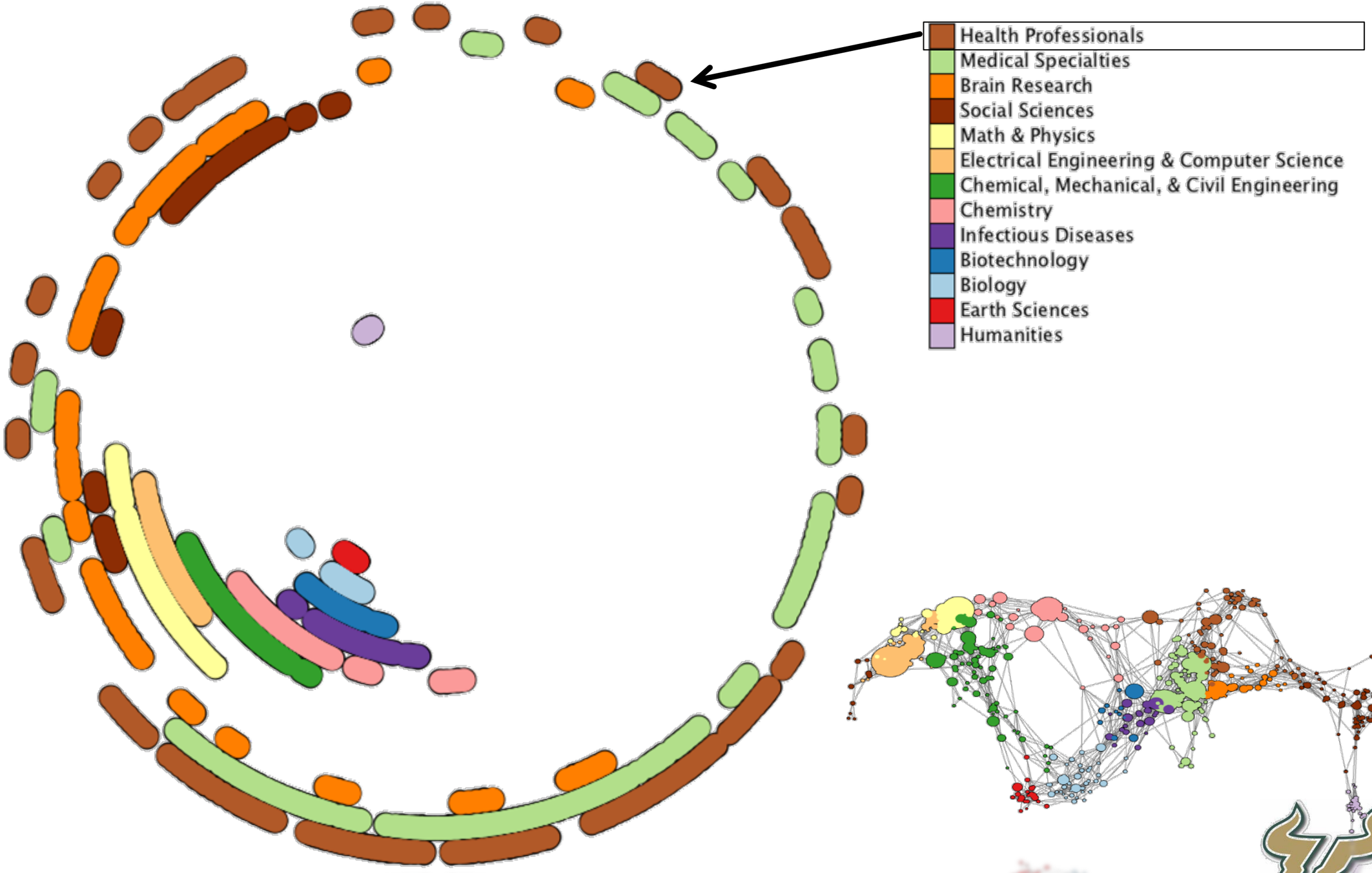
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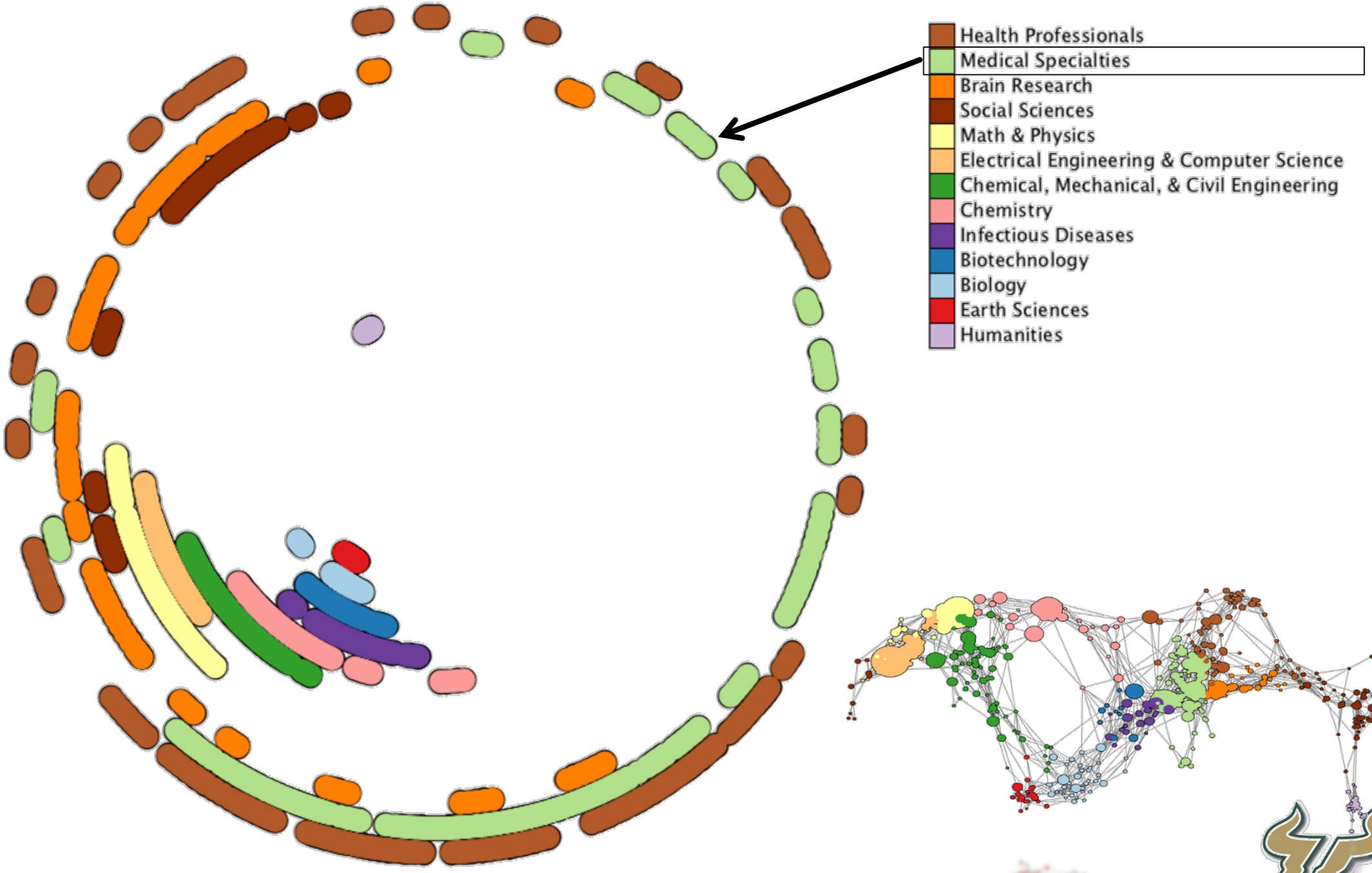
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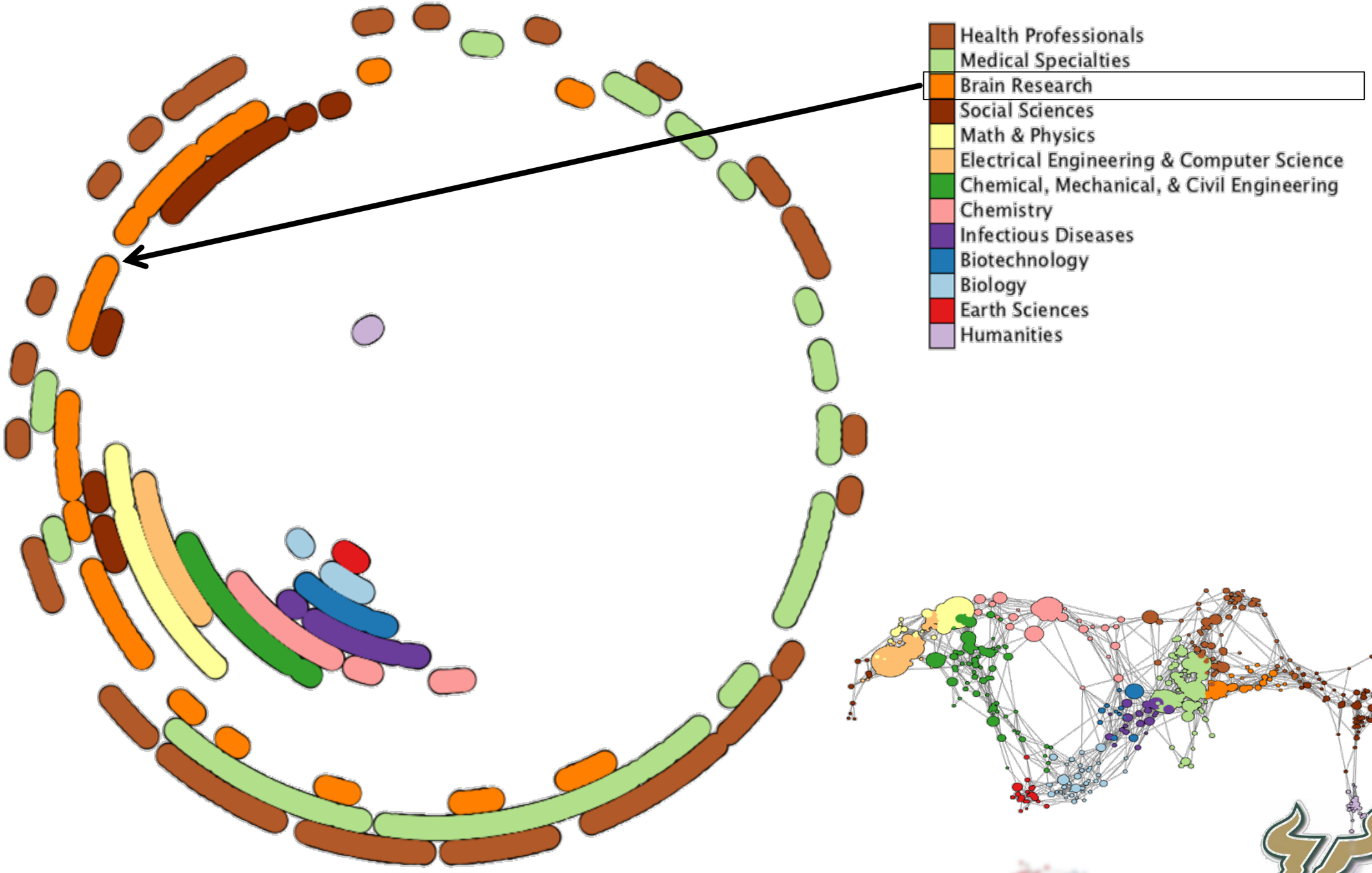
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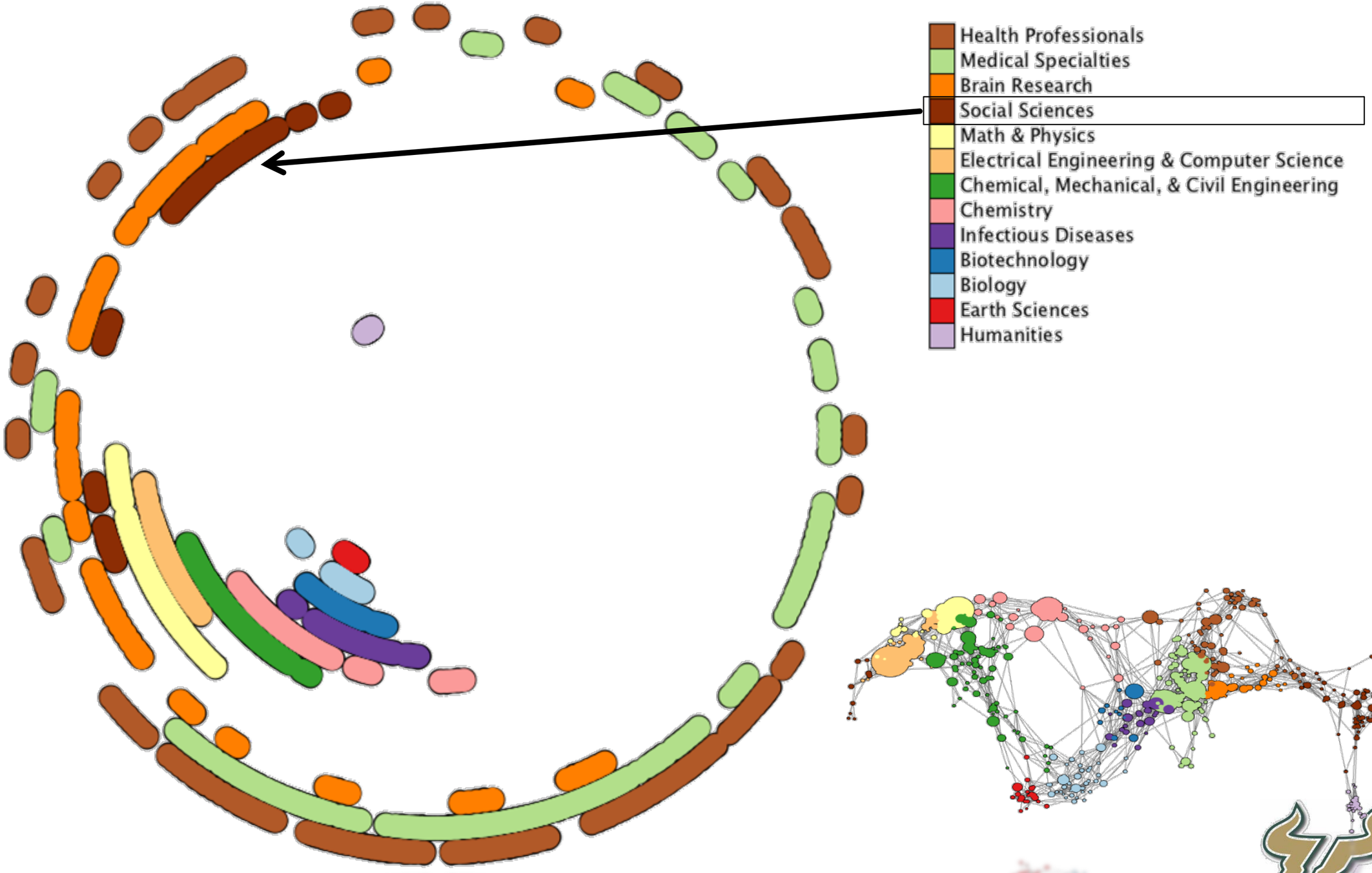
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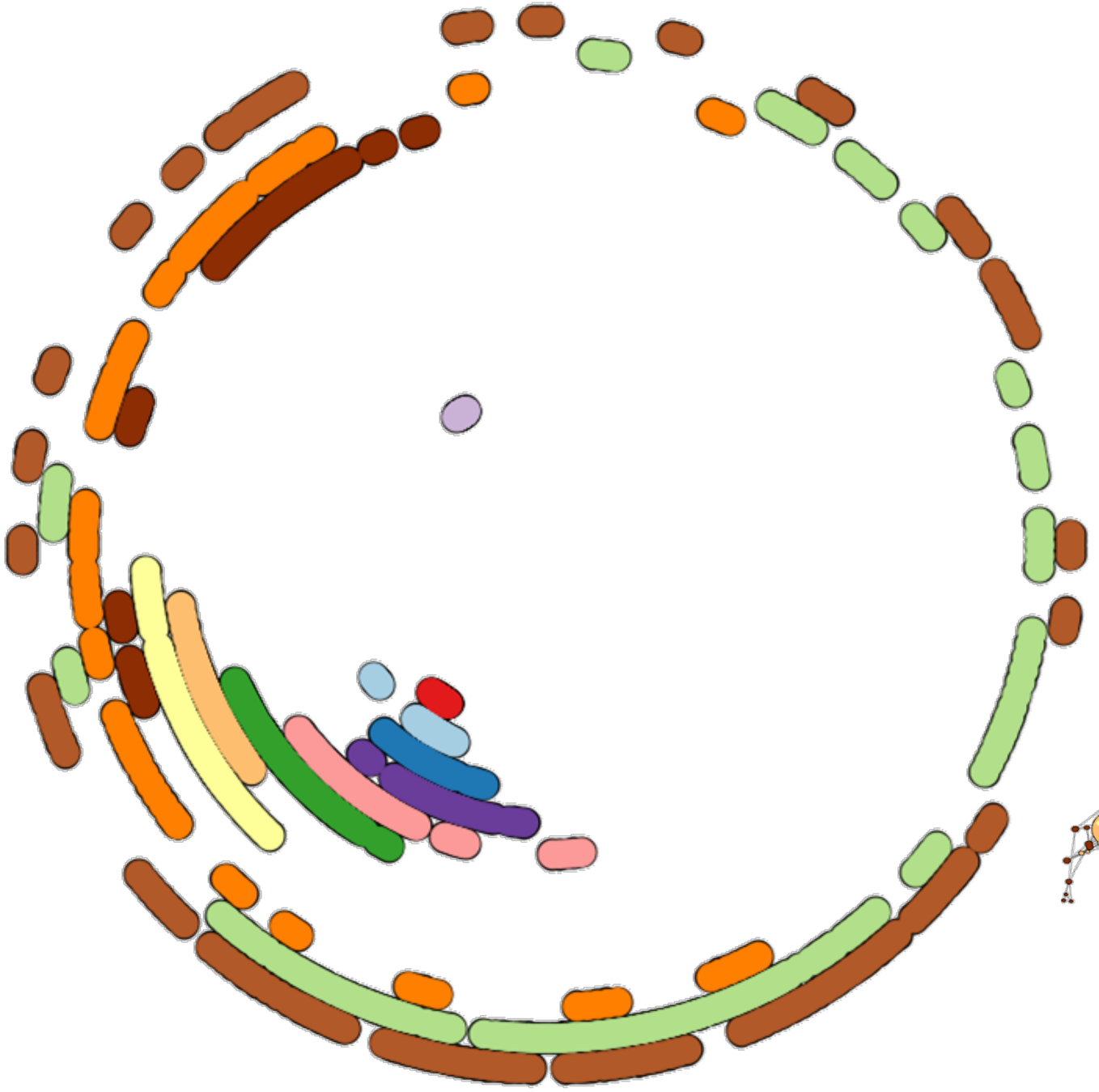

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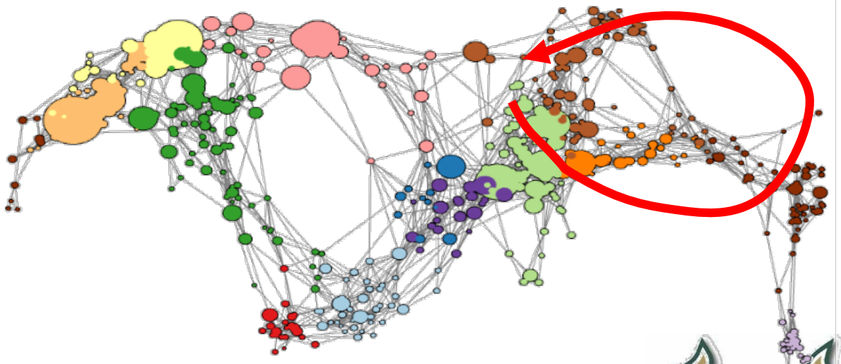
- Chemical, Mechanical, & Civil Engineering
- Chemistry
- Infectious Diseases
- Biotechnology
- Biology
- Earth Sciences
- Humanities



Discussion

Elzen and van Wijk,
Multivariate Network Exploration and Presentation: From Detail to Overview via Selections and Aggregations
(video)

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