CS49000-VIZ - Fall 2020

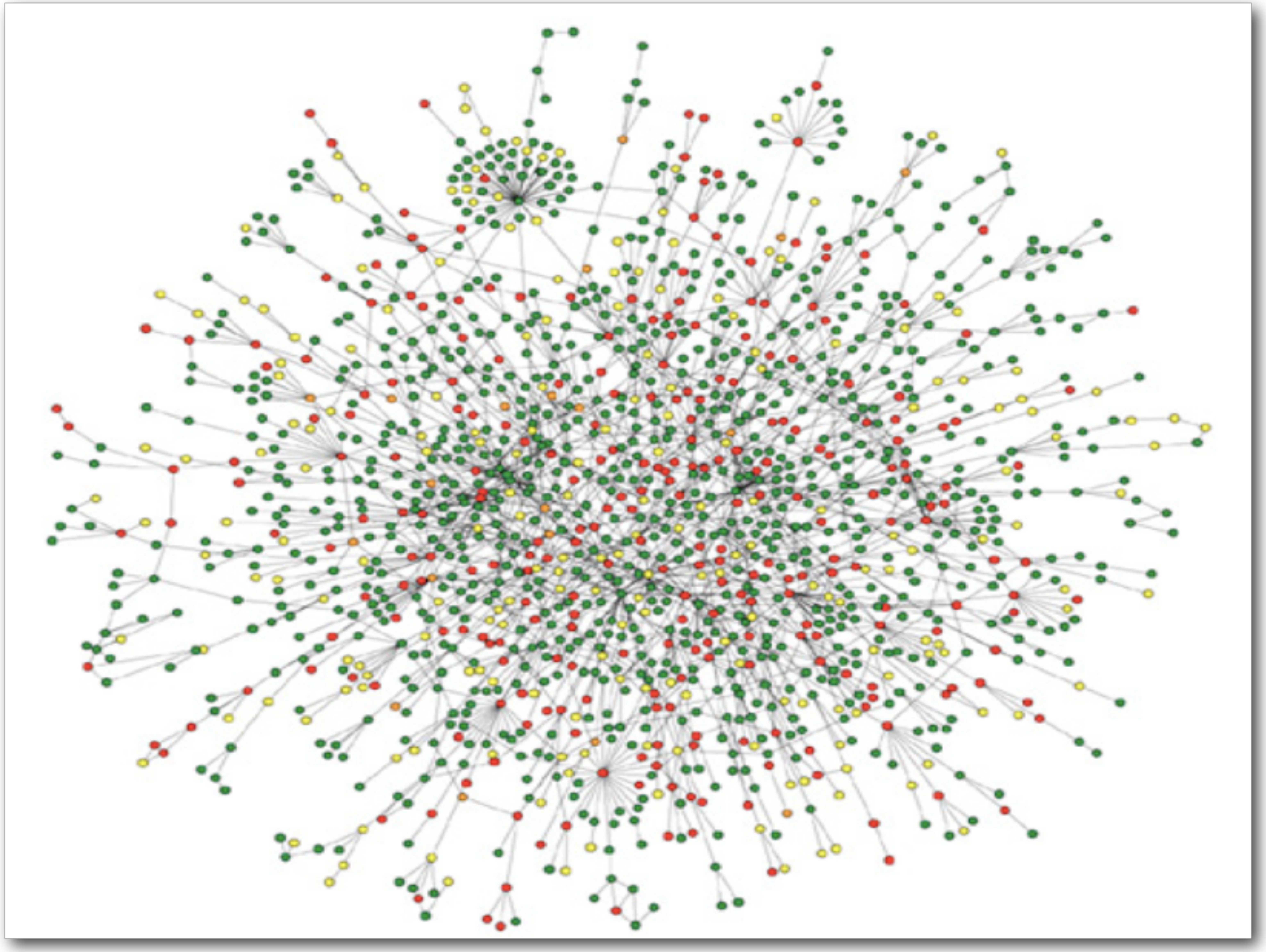
Introduction to Data Visualization

Graphs

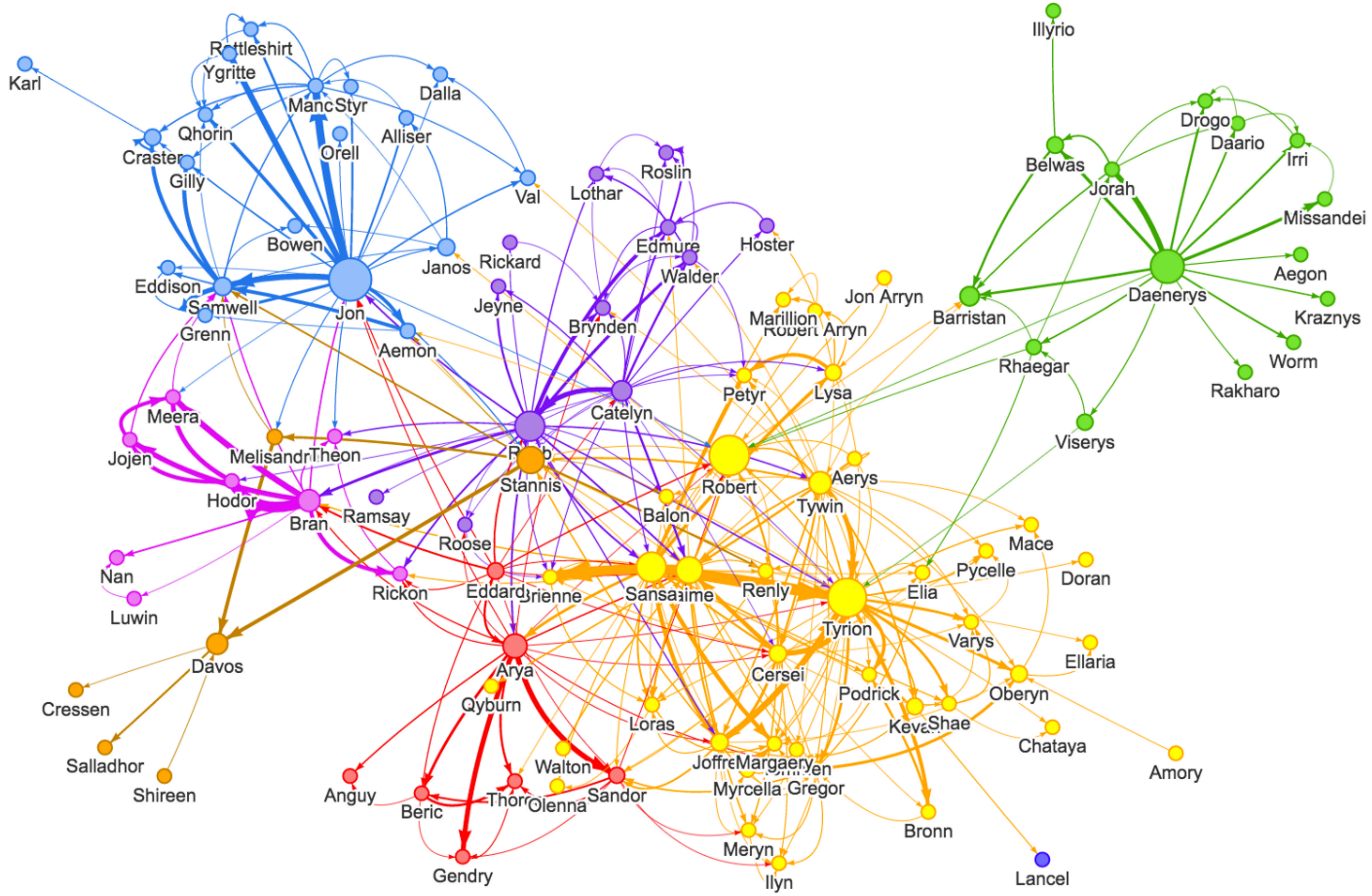
Lecture 10

Slides Credit: A. Lex, U of Utah

September 28, 2020



Reference: Jeong et al, Nature Review | Genetics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Belwas
Drogo
Daario
Irri
Jorah
Missandei
Bowen
Janos
Rickard
Edmure
Hoster
Walder
Eddison
Samwell
Jon
Jeyne
Brynden
Marillion
Jon Arryn
Arryn
Barristan
Daenerys
Aegon
Kraznys
Grenn
Aemon
Rhaegar
Worm
Rakharo
Catelyn
Petyr
Lysa
Meera
Viserys
Jojen
Melisandr
Theon
Robb
Stannis
Robert
Aerys
Tywin
Hodor
Bran
Ramsay
Balon
Roose
Mace
Pycelle
Doran
Nan
Rickon
Eddard
rienne
Sansa
Renly
Elia
Tyrion
Luwin
Varys
Ellaria
Davos
Arya
Cersei
Cressen
Qyburn
Podrick
Oberyn
Loras
Keva
Shae
Chataya
Salladhor
Walton
Joffre
Margaery
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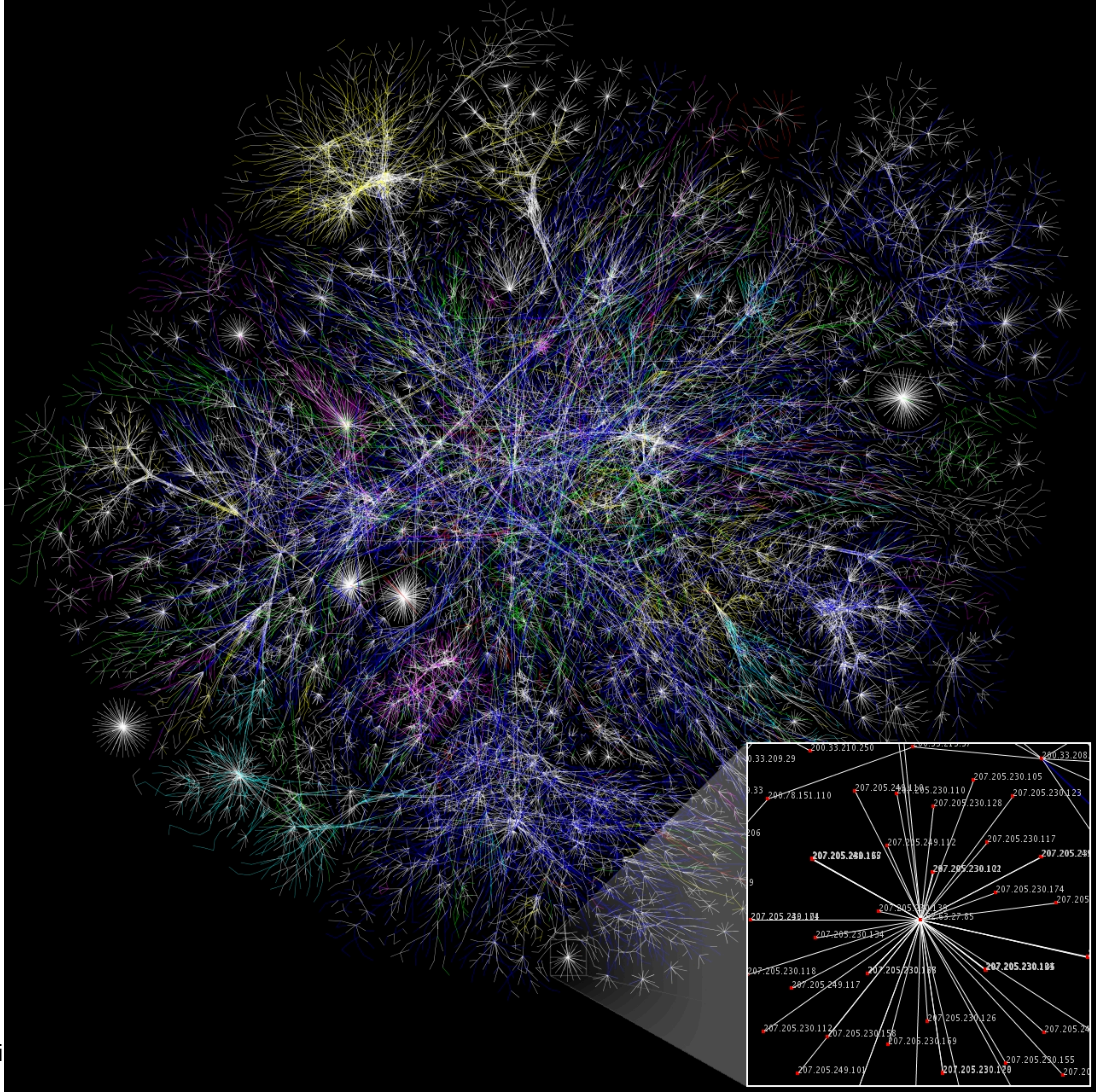
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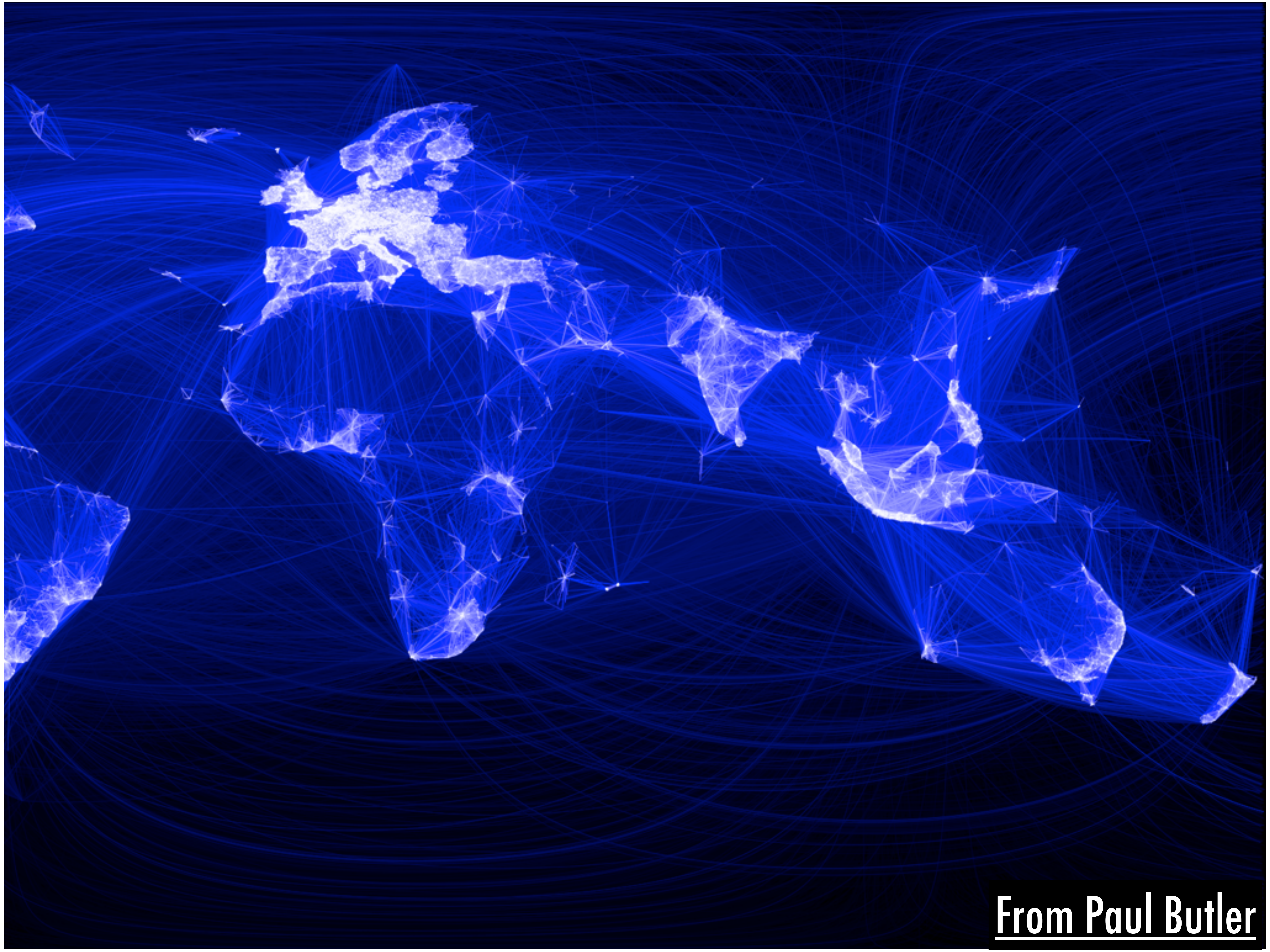
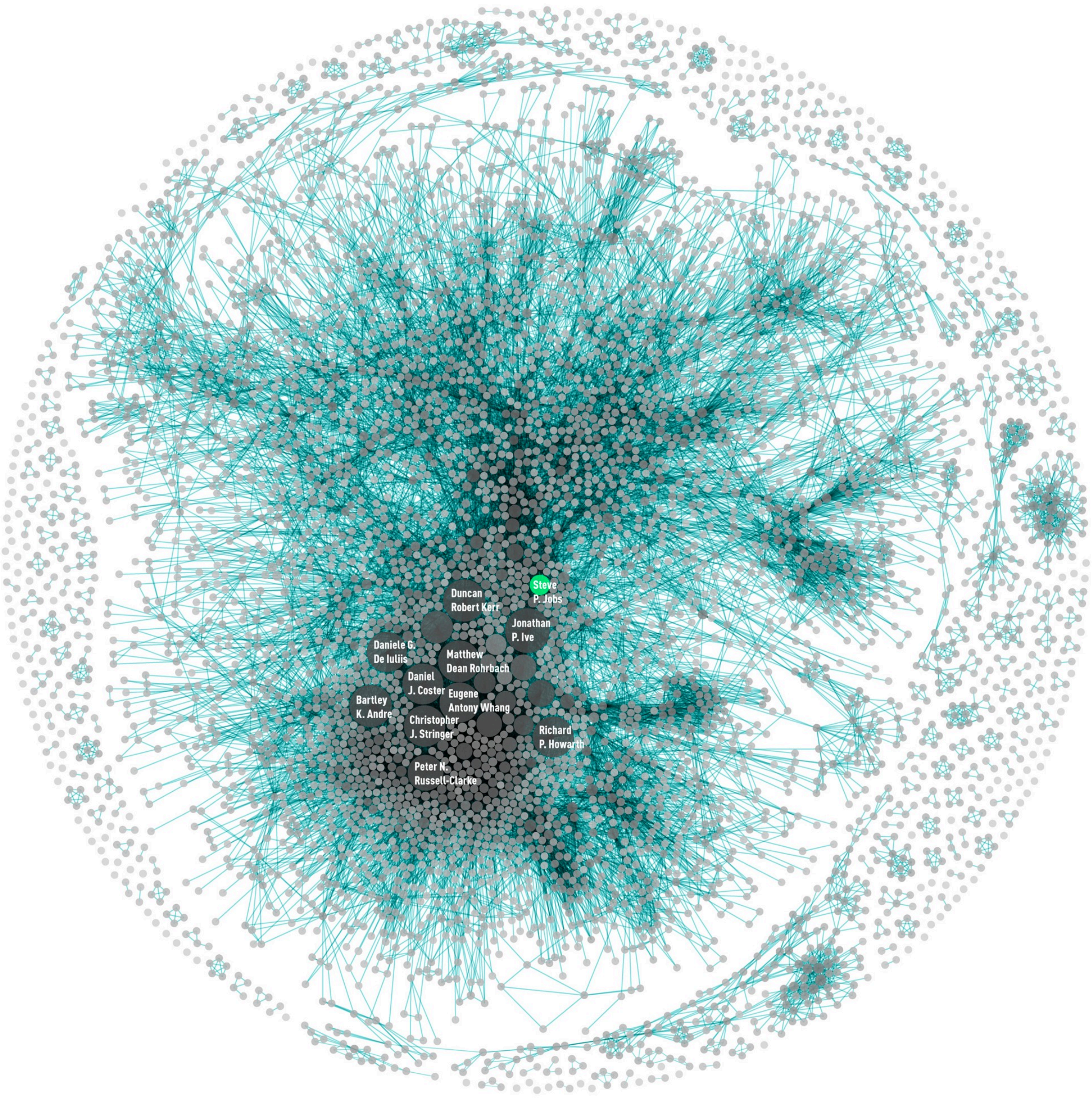
facebook
From Paul Butler


From Paul Butler


Steve P. Jobs
Duncan Robert Kerr
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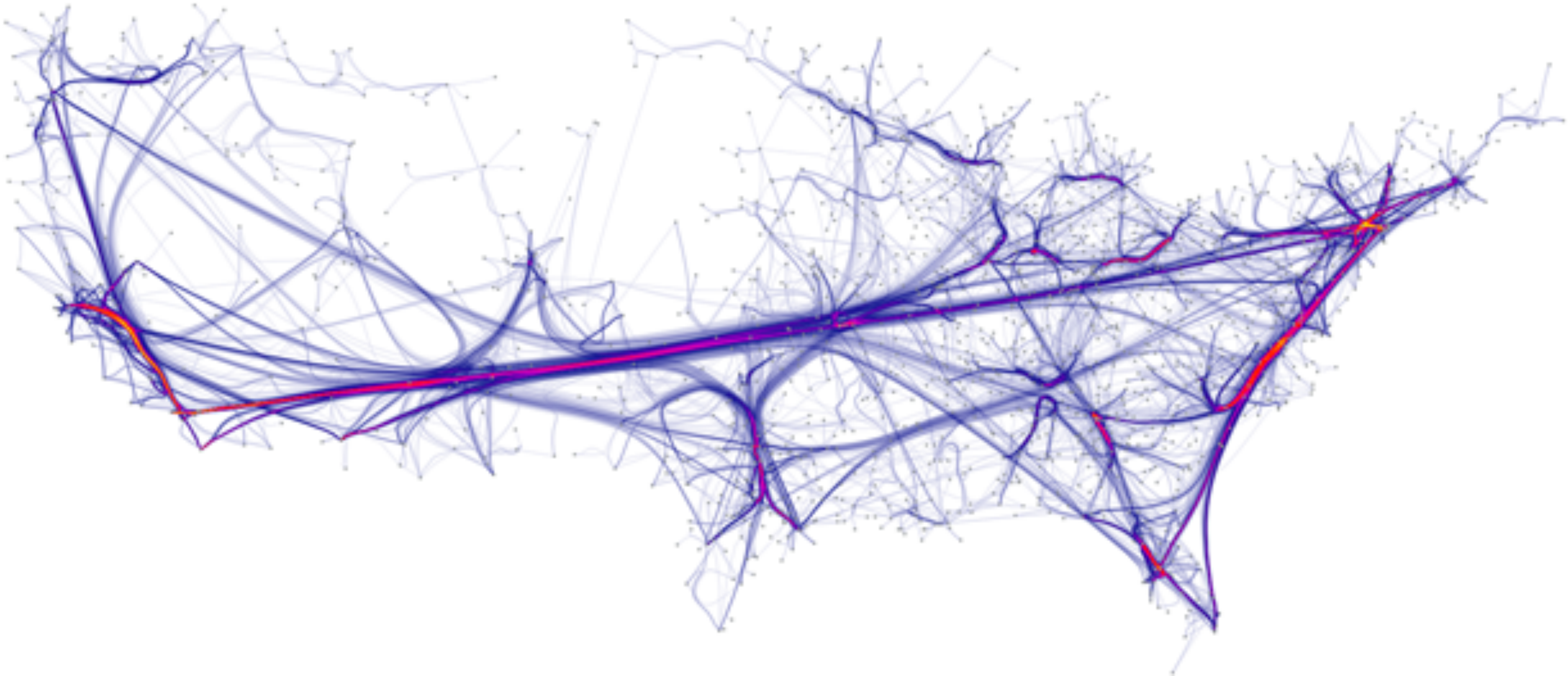
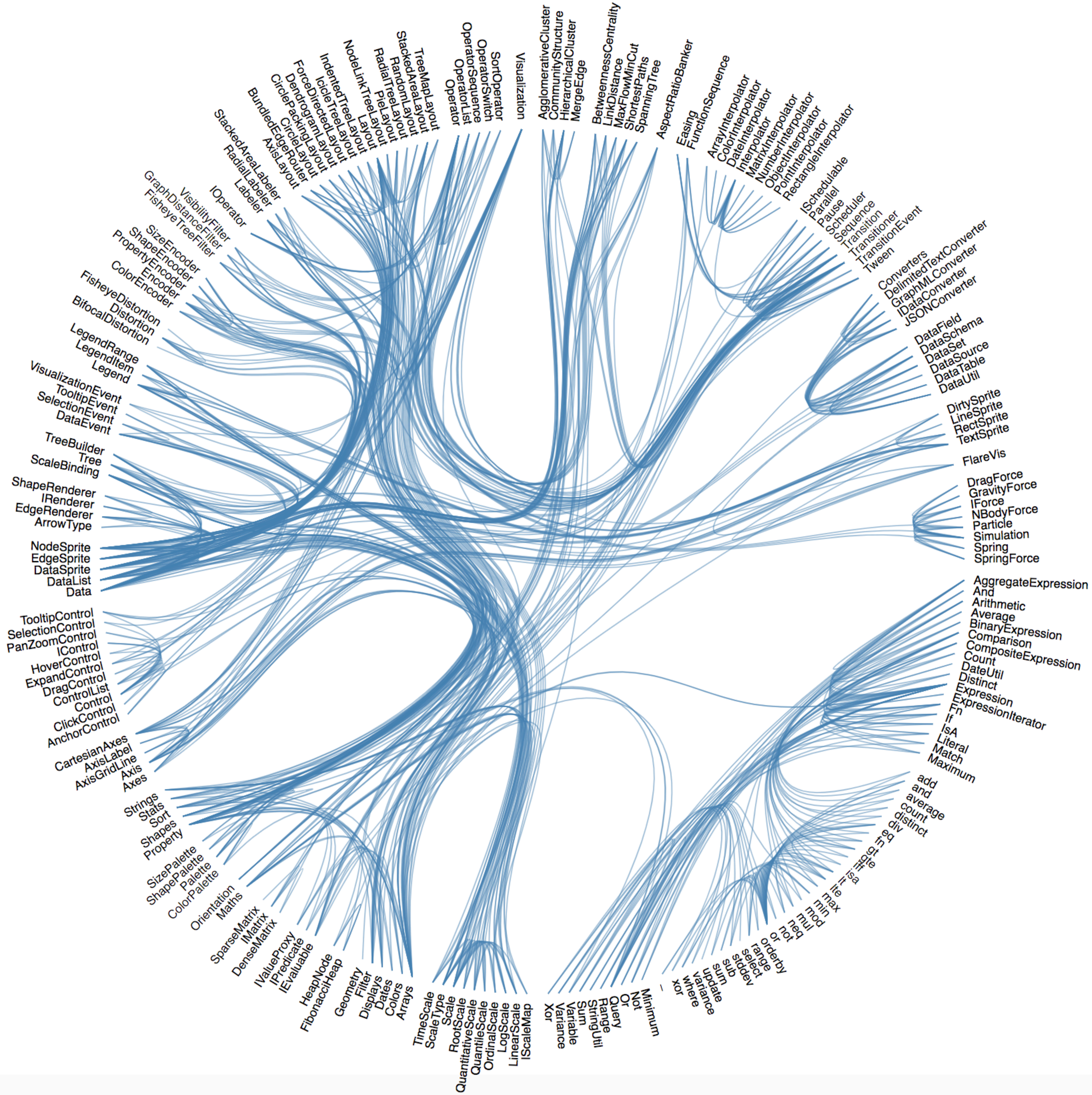
Bartley K. Andre
Christopher J. Stringer
Richard P. Howarth
Peter N. Russell-Clarke




AgglomerativeCluster
CommunityStructure
HierarchicalCluster
MergeEdge
BetweennessCentrality
LinkDistance
MaxFlowMinCut
ShortestPaths
SpanningTree
AspectRatioBanker
Easing
FunctionSequence
ArrayInterpolator
ColorInterpolator
DateInterpolator
Interpolator
MatrixInterpolator
NumberInterpolator
ObjectInterpolator
PointInterpolator
RectangleInterpolator
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Tween
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JSONConverter
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RectSprite
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IMatrix
SparseMatrix
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ShapePalette
SizePalette
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Stats
Strings
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AxisLabel
CartesianAxes
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ClickControl
Control
ControlList
DragControl
ExpandControl
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IControl
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EdgeSprite
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ArrowType
EdgeRenderer
IRenderer
ShapeRenderer
ScaleBinding
Tree
TreeBuilder
DataEvent
SelectionEvent
TooltipEvent
VisualizationEvent
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LegendItem
LegendRange
BifocalDistortion
Distortion
FisheyeDistortion
ColorEncoder
Encoder
PropertyEncoder
ShapeEncoder
SizeEncoder
FisheyeTreeFilter
GraphDistanceFilter
VisibilityFilter
IOperator
Labeler
RadialLabeler
StackedAreaLabeler
AxisLayout
BundledEdgeRouter
CircleLayout
CirclePackingLayout
DendrogramLayout
ForceDirectedLayout
IcicleTreeLayout
IndentedTreeLayout
Layout
NodeLinkTreeLayout
PieLayout
RadialTreeLayout
RandomLayout
StackedAreaLayout
TreeMapLayout
Operator
OperatorList
OperatorSequence
OperatorSwitch
SortOperator
Visualization

Today

Graph layout

Matrix representations

Graph visualization tools

Graph Drawing

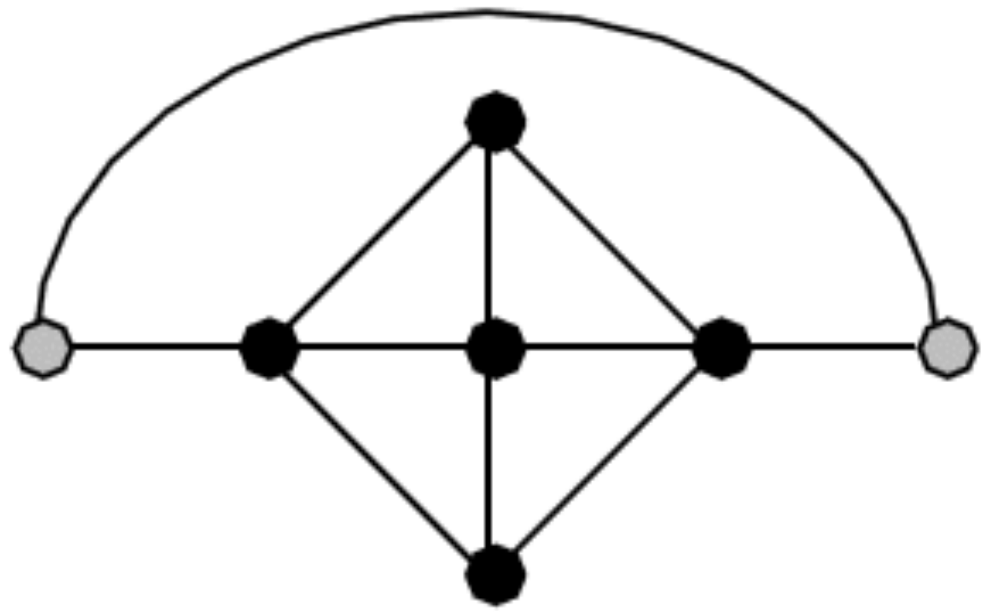
- Node-link representation (cf. trees)
  - Vertex: point
  - Edge: line or curve
- How to lay out?
  - Often: no physical / spatial guidance

Layout Quality Criteria

- Minimize **edge crossings**
- Minimize **distance** of neighboring nodes
- Minimize **drawing area** (compactness)
- Uniform edge **length**
- Minimized edge **bends**
- Maximized **angular distance** between different edges
- Aspect ratio about 1
- **Symmetry**: similar graph structures should look similar

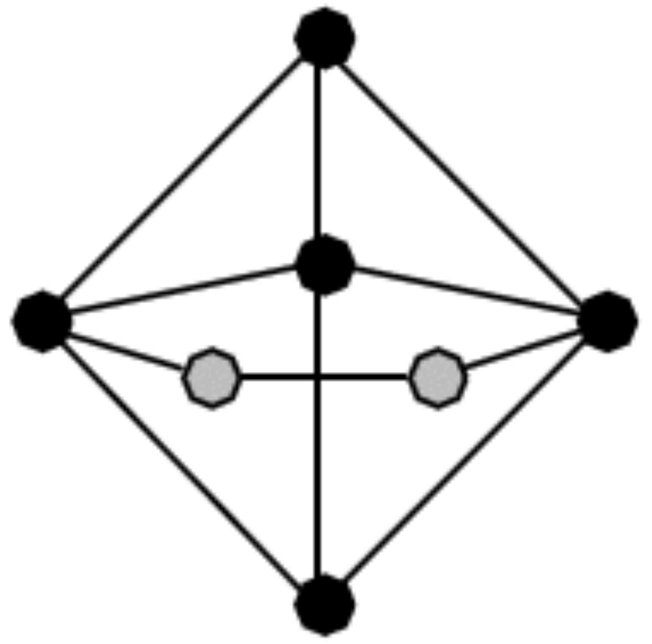
Tension between criteria

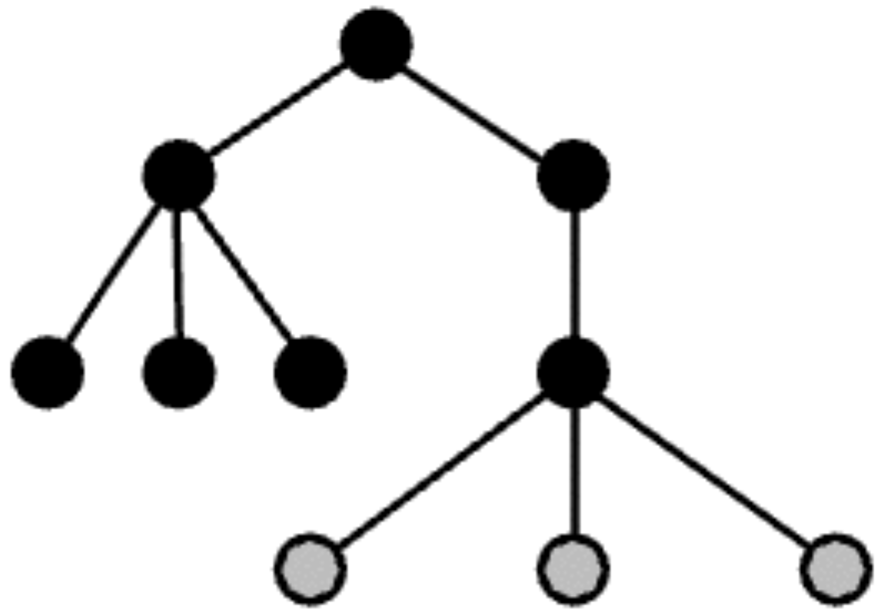
Minimum number of edge crossings



vs.

Uniform edge length

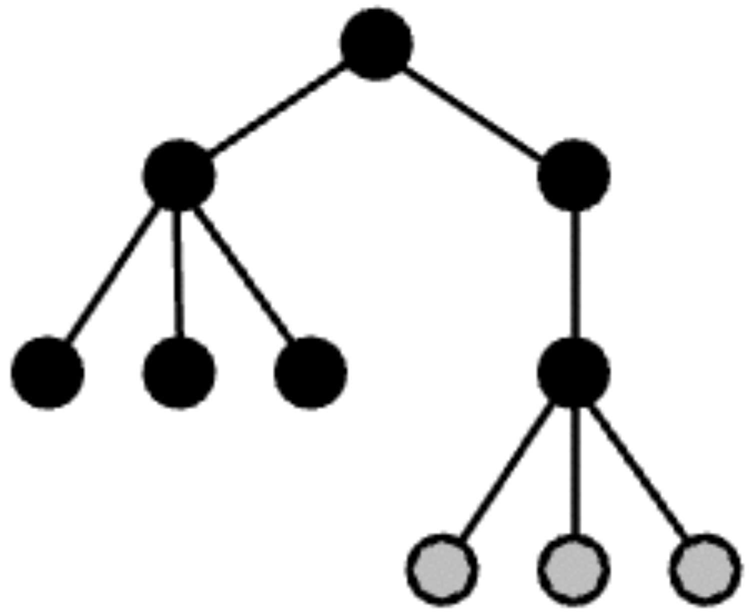




Space utilization

vs.

Symmetry

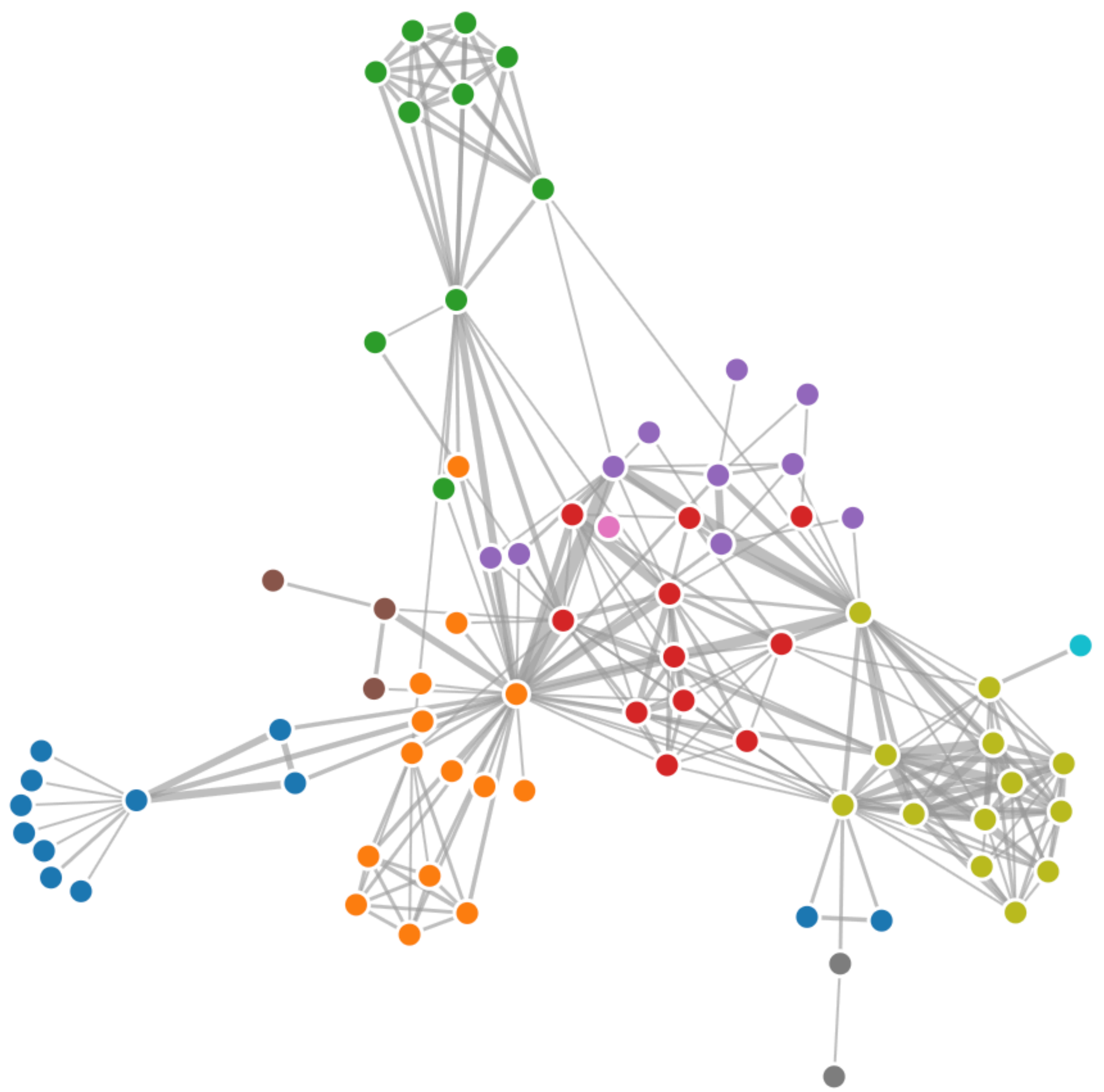


Schulz 2004

Force-directed Layout

- Commonly used strategy
- Basic idea: simple physical metaphor:
  - Nodes: mutually repelling magnets
  - Edges: springs that keep neighbors close

Force-directed Layout



https://beta.observablehq.com/@mbostock/d3-force-directed-graph

Force-directed Layout

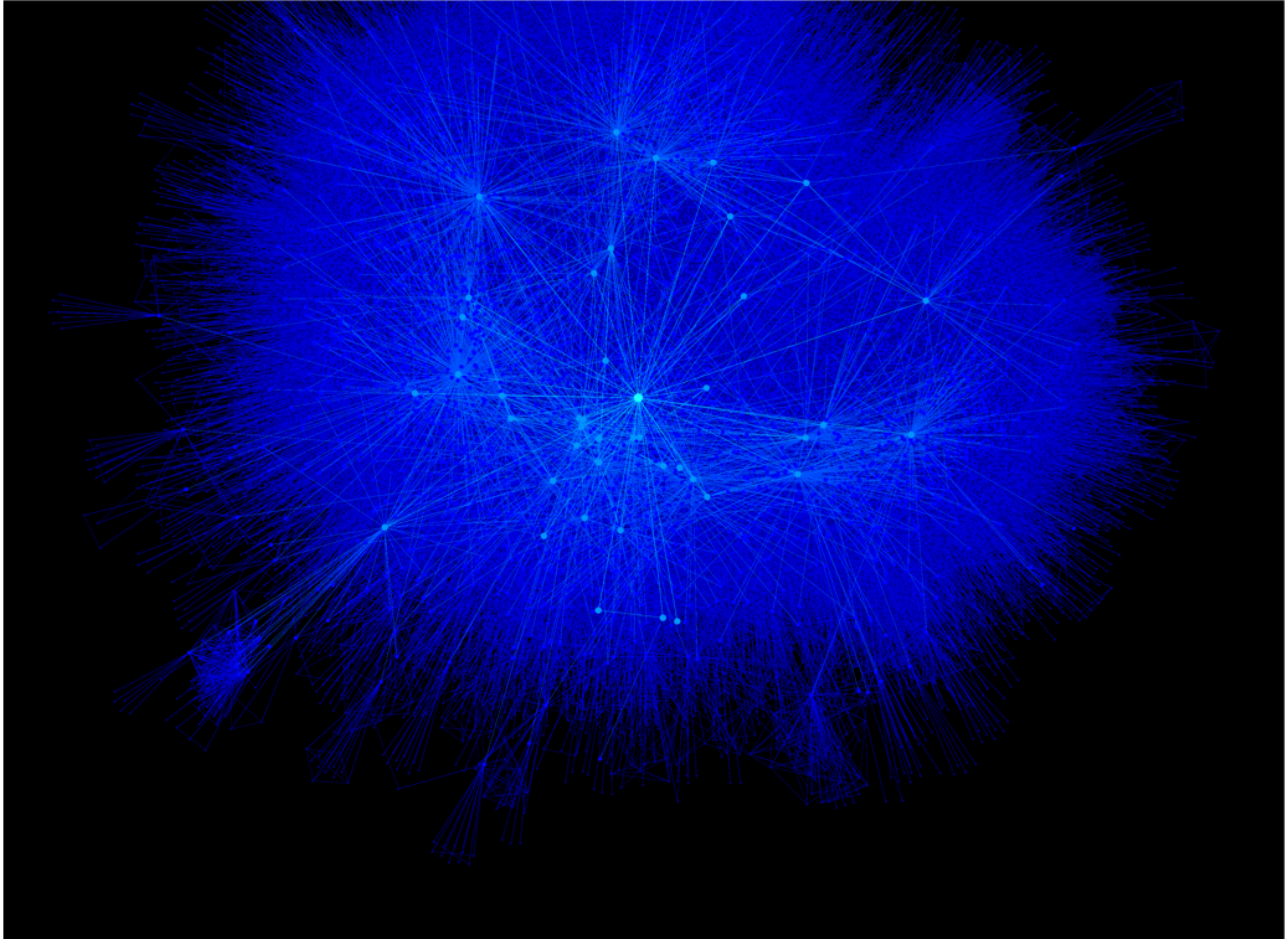
- Model:
  - Repelling forces: $f_r(d) = \frac{C_r m_1 m_2}{d^2}$
  - Attracting forces (springs): $f_a(d) = C_a(d - L)$
  - Force acting upon node at position **x** by its neighbors **y:** $\sum_{\mathbf{y} \in N_1(\mathbf{x})} f_r(||\mathbf{x} - \mathbf{y}||)\vec{u}_{\mathbf{yx}} + f_a(||\mathbf{x} - \mathbf{y}||)\vec{u}_{\mathbf{xy}})$

Algorithm

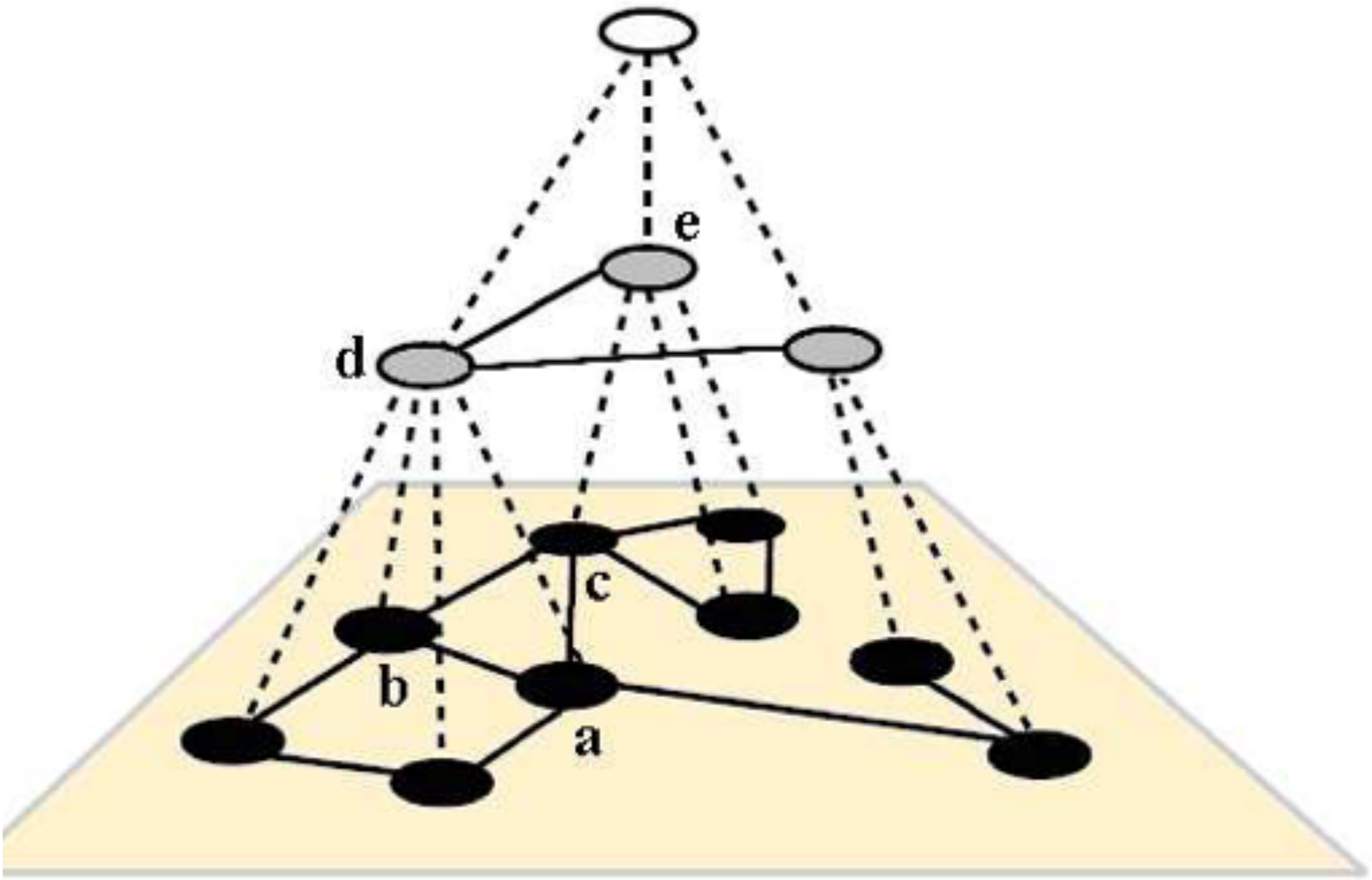
- Start from random layout
- (global) loop:
  - for **every node pair** compute repulsive force
  - for every edge compute attractive force
- Accumulate forces per node
- Update each node position in direction of accumulated force
- Stop when layout is ‘good enough’

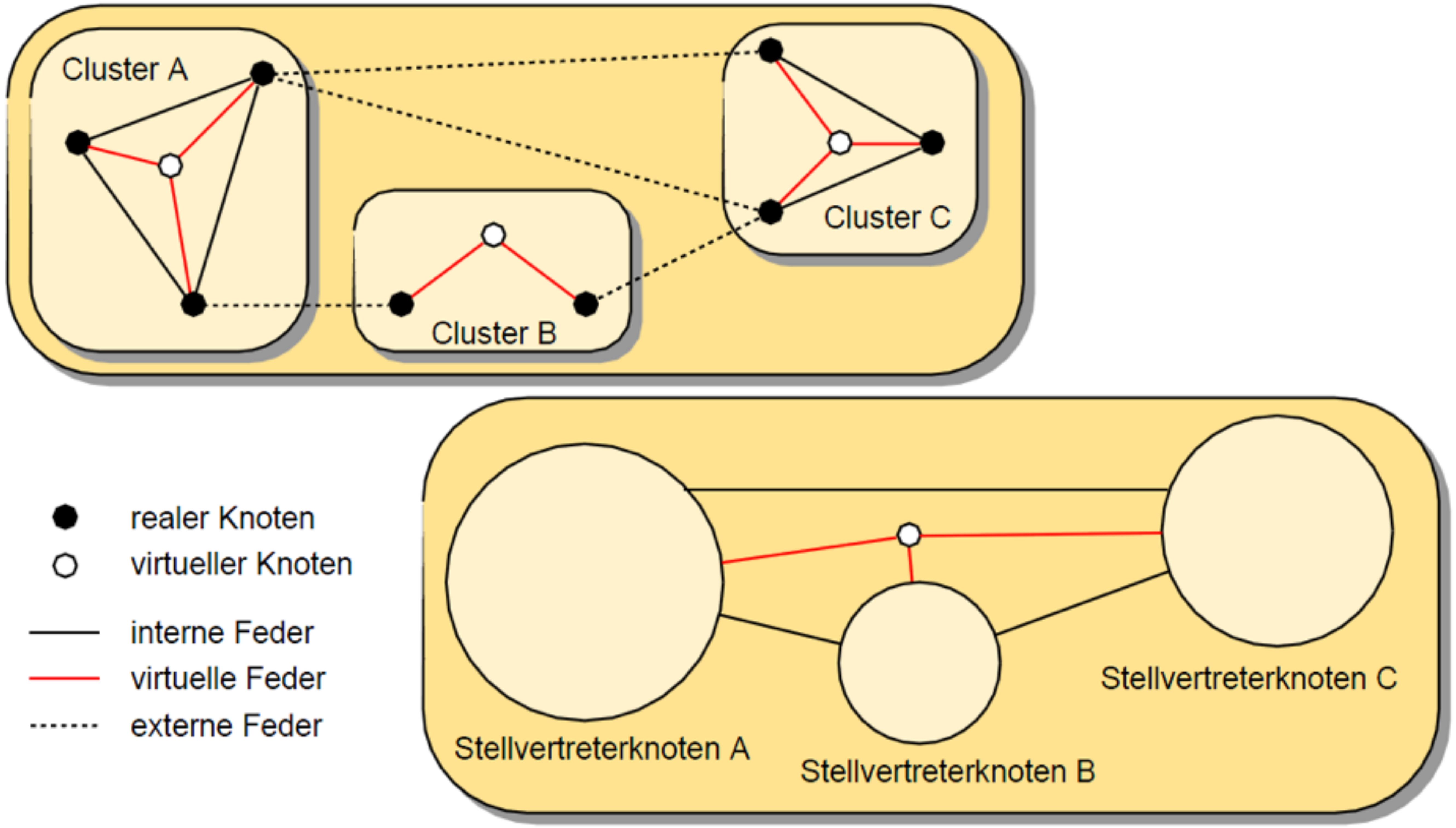
Force-directed Layout

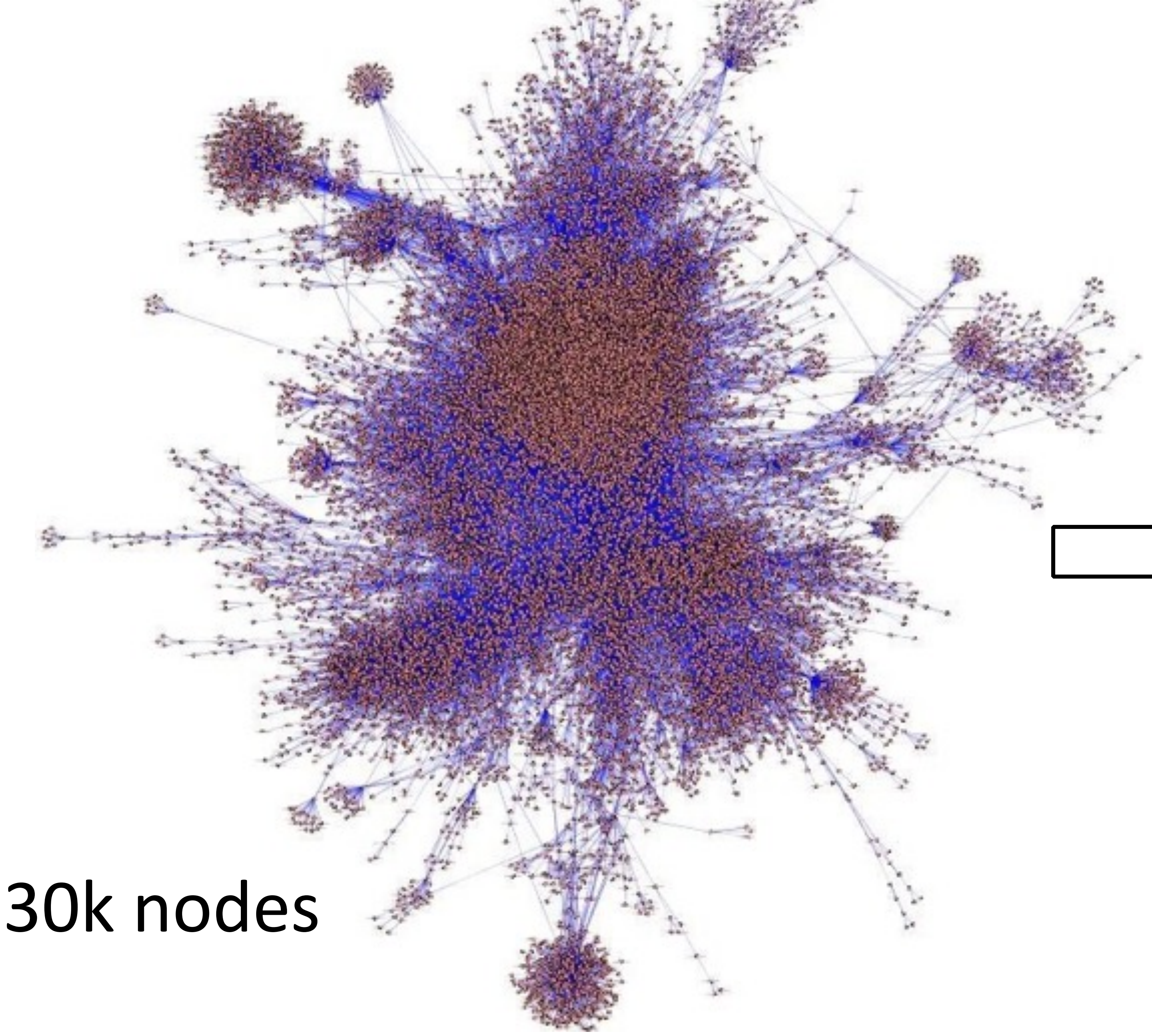
- Simple, flexible
- Overall complexity is $\mathcal{O}(n^3)$
- Issues past a few thousands nodes



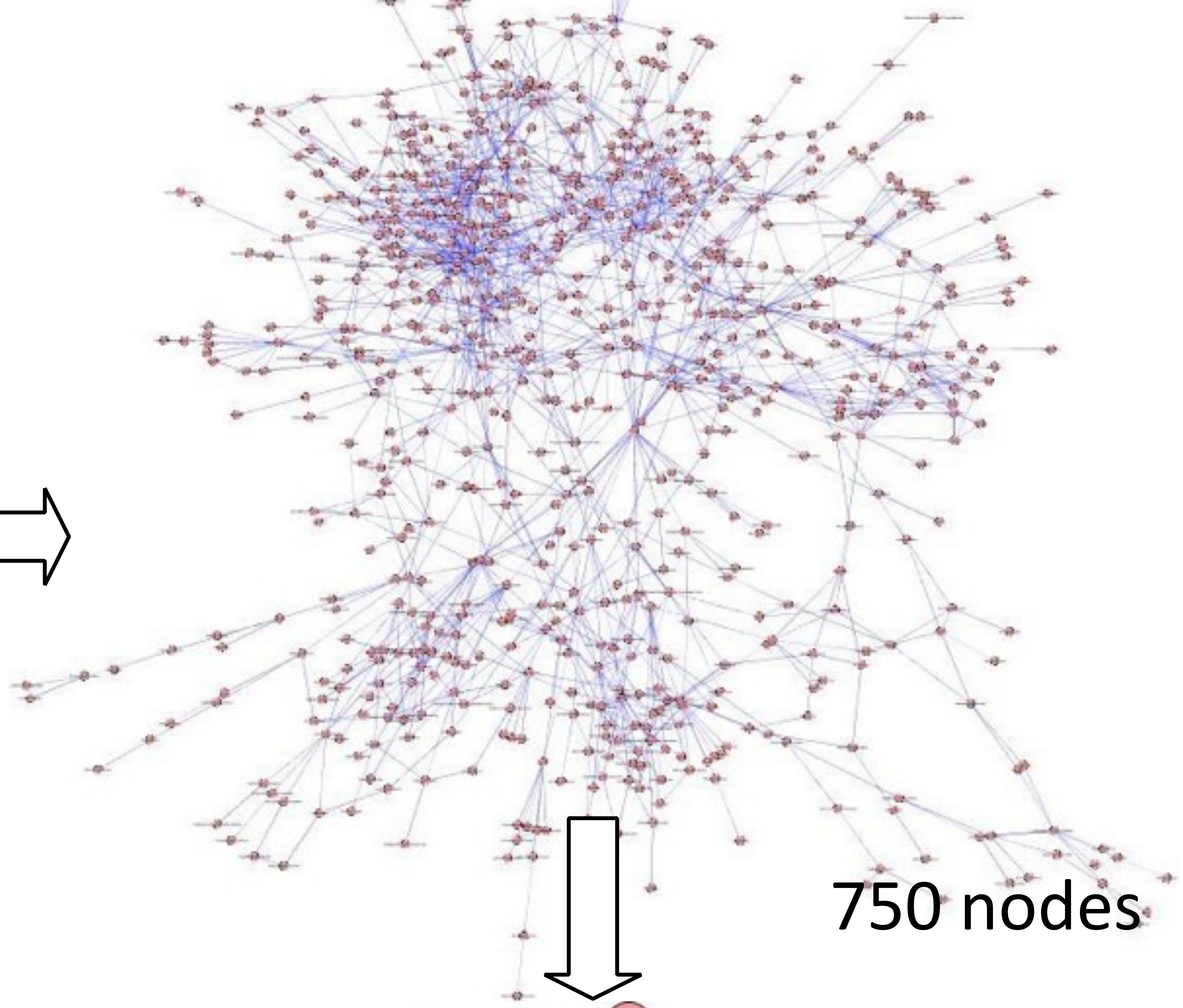
Hierarchical Graph Drawing



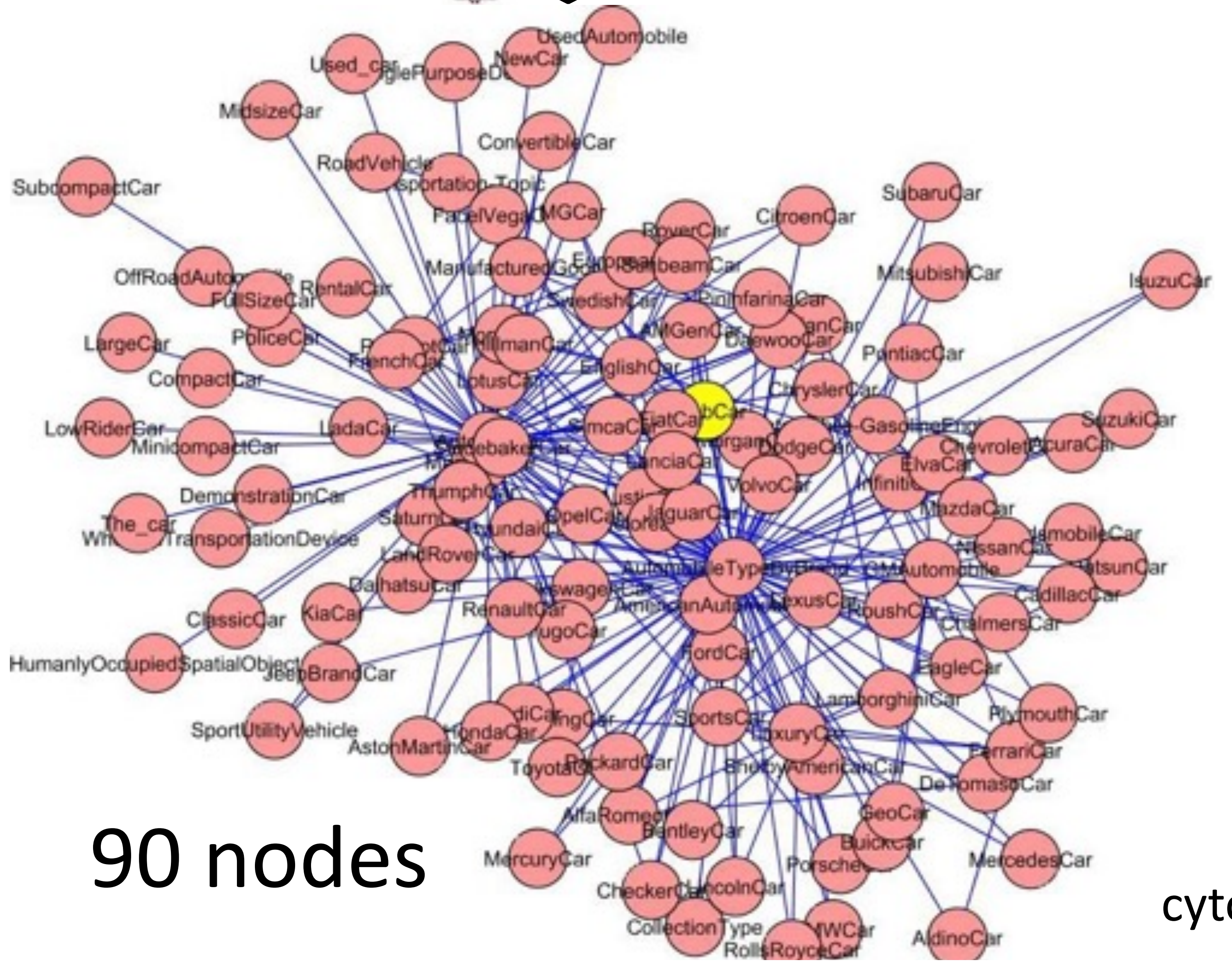




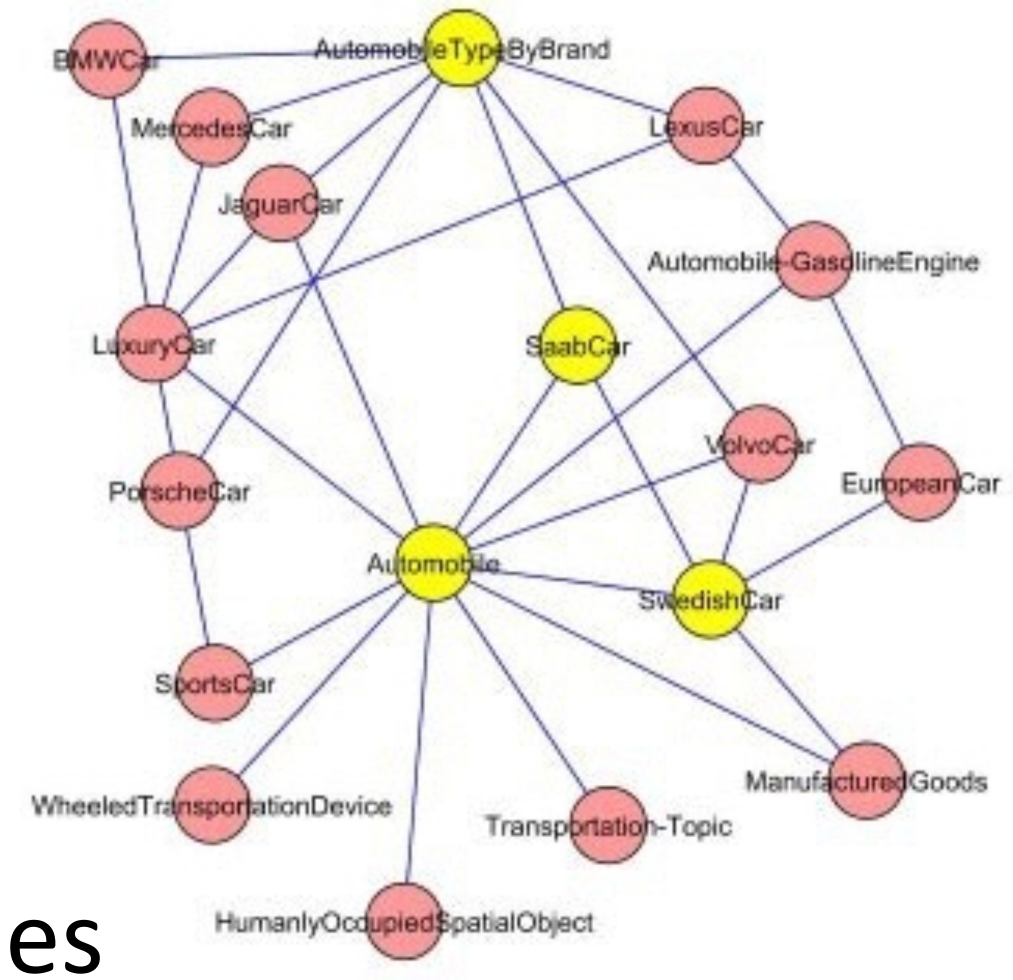
30k nodes



750 nodes



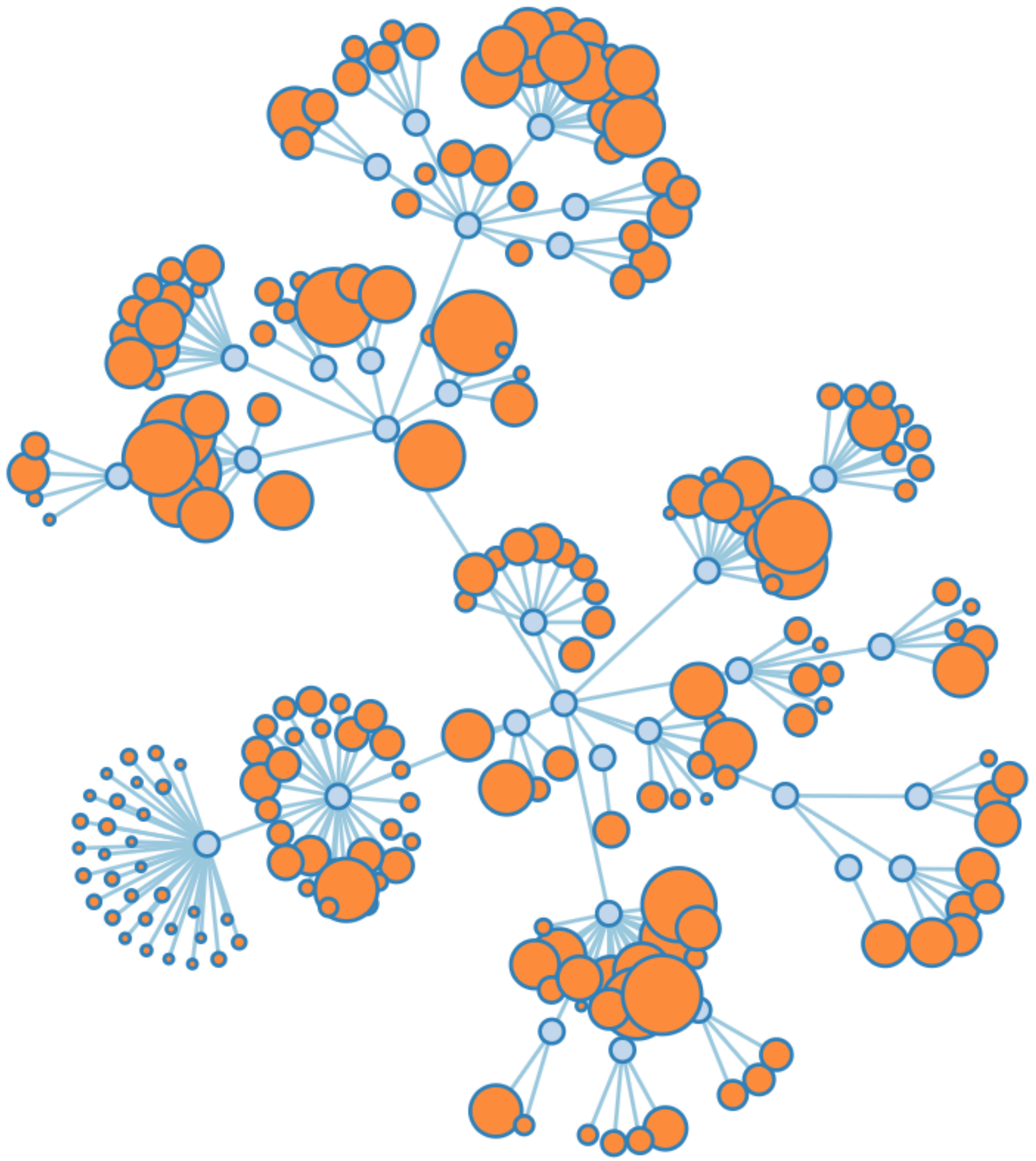
90 nodes



18 nodes

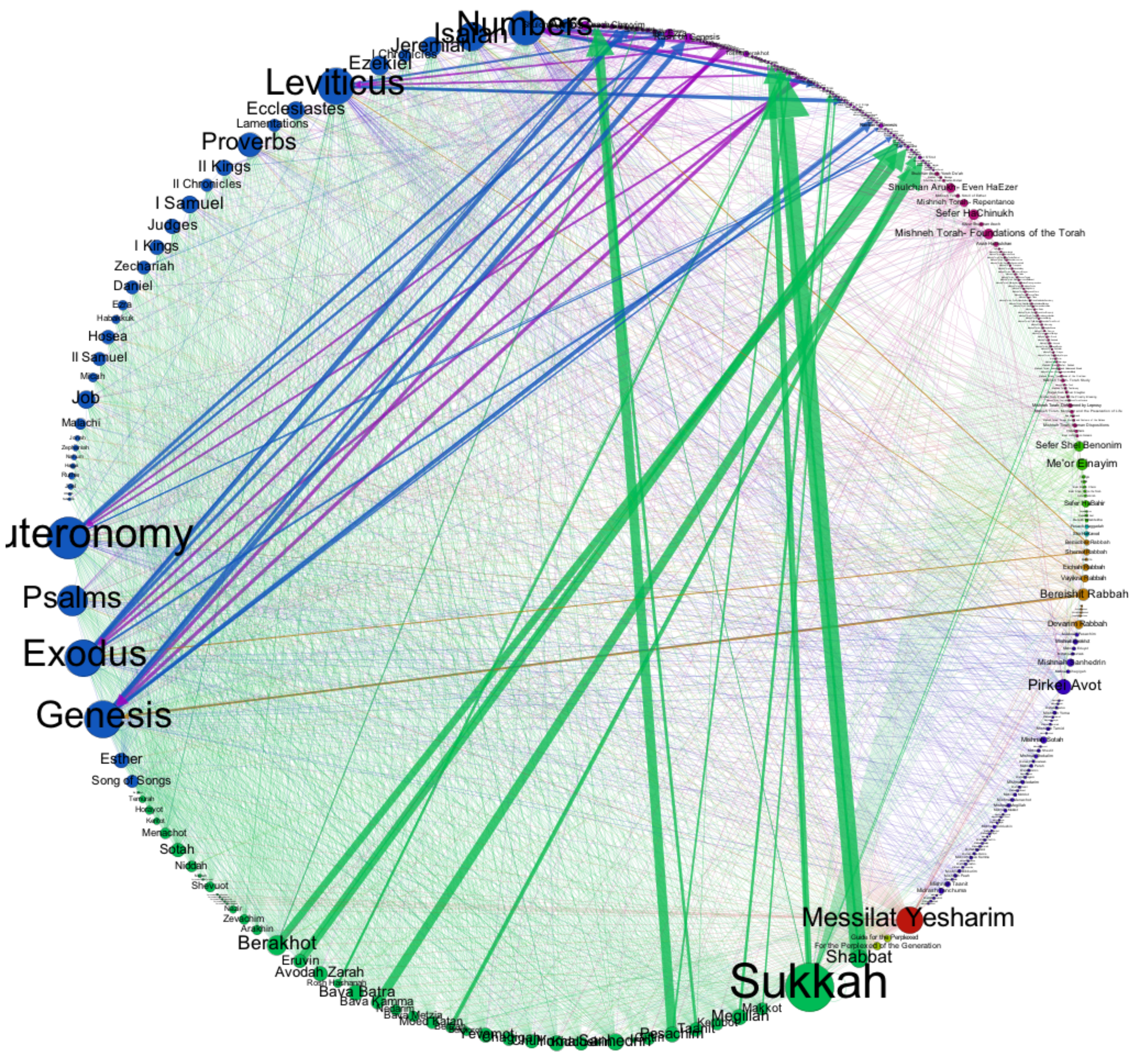
cytoscape.org

Collapsible Force Layout

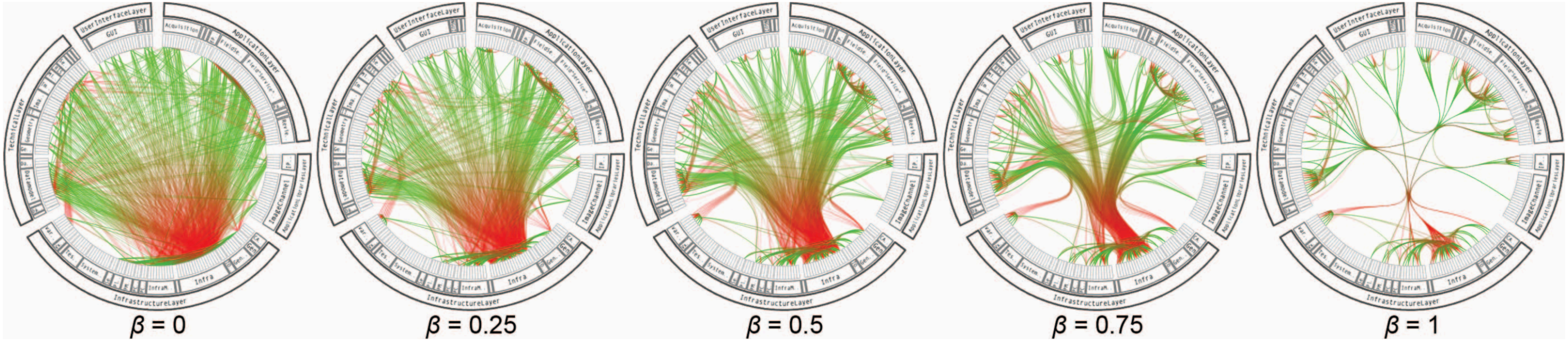


https://bl.ocks.org/mbostock/1062288

Circular Layout



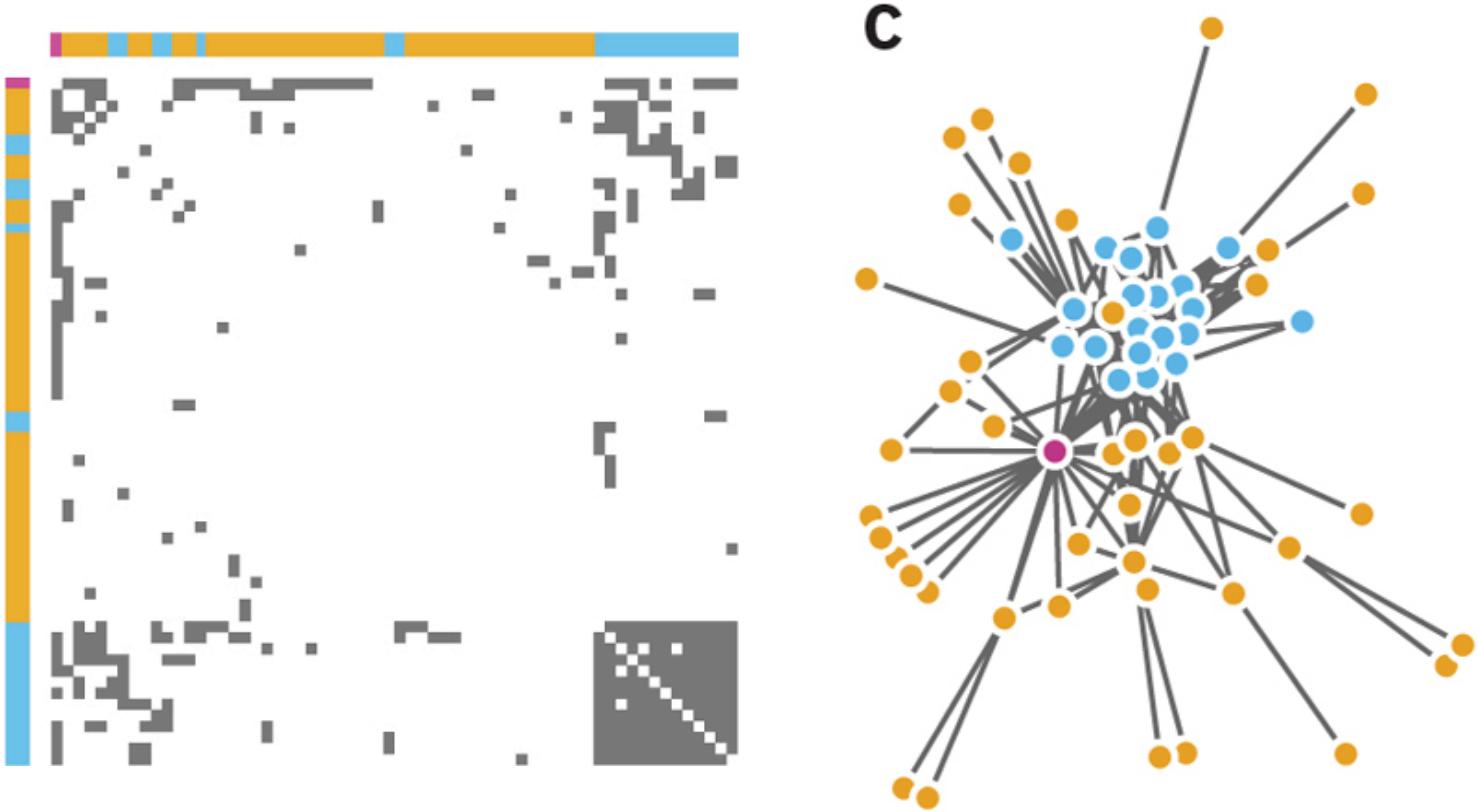
Edge Bundling

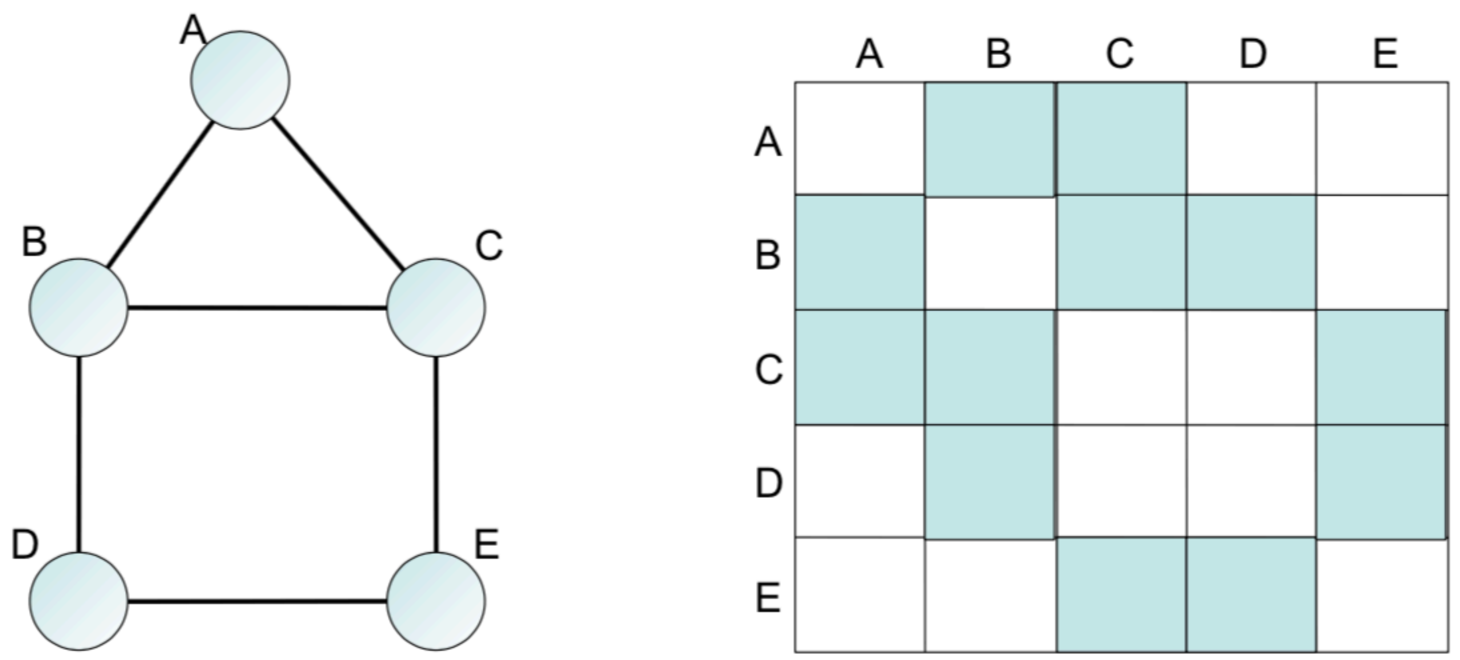


Chord Diagram

https://www.youtube.com/watch?v=9fCq3a2UgsU&feature=youtu.be

Matrix Layout

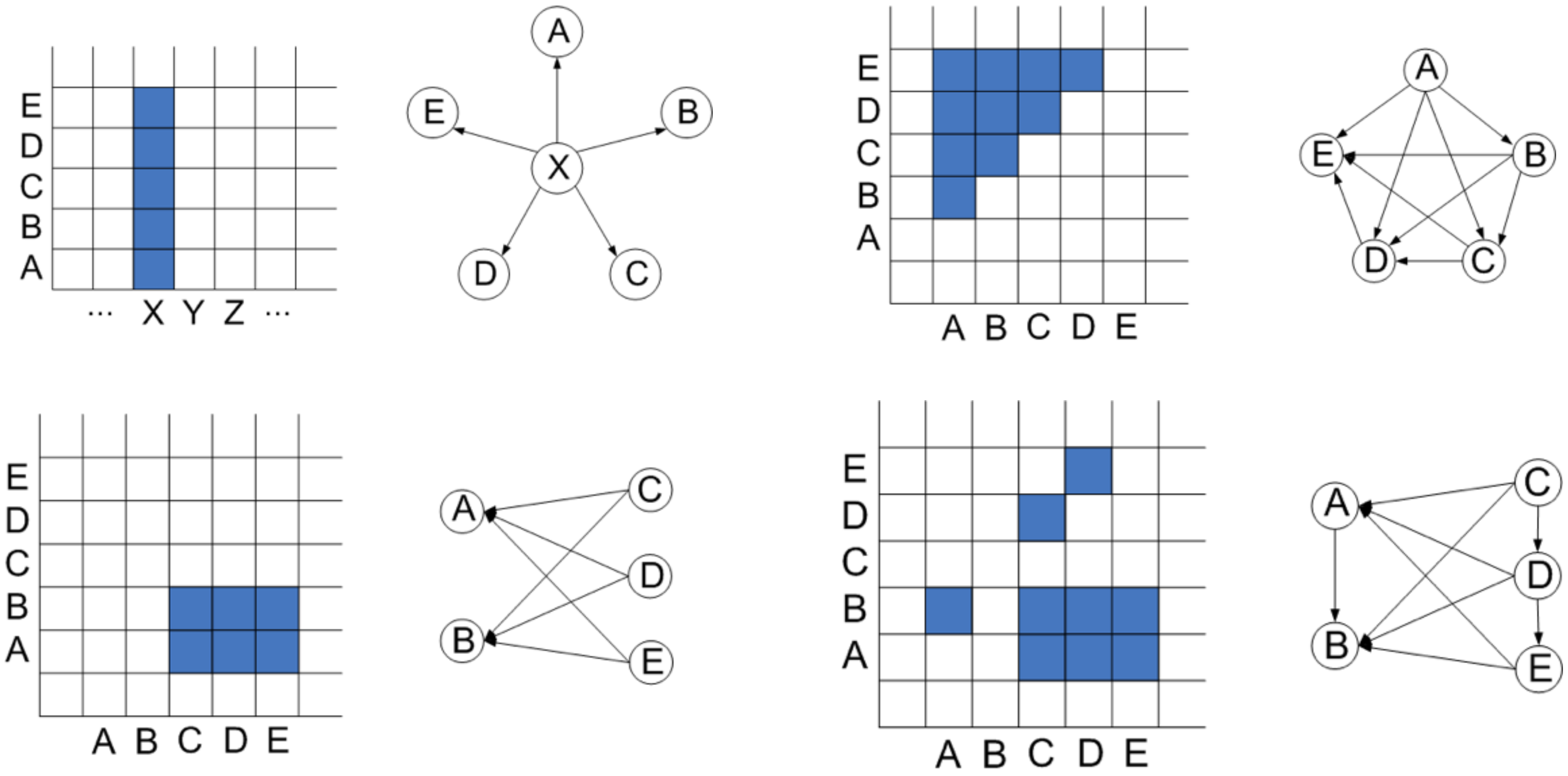




[Points of view: Networks. Gehlenborg and Wong. Nature Methods 9:115.]

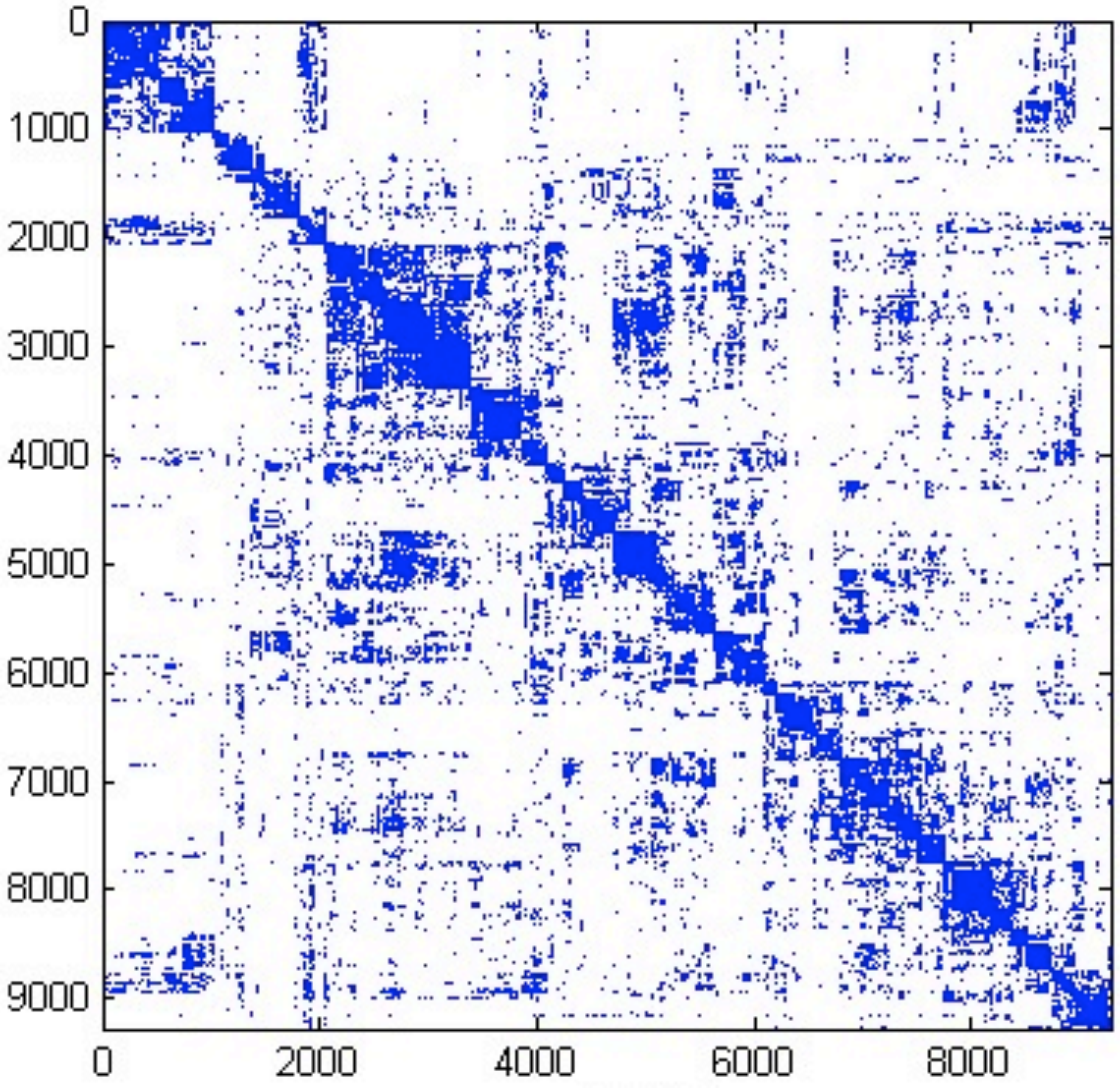
Matrix Layout

Patterns correspondence

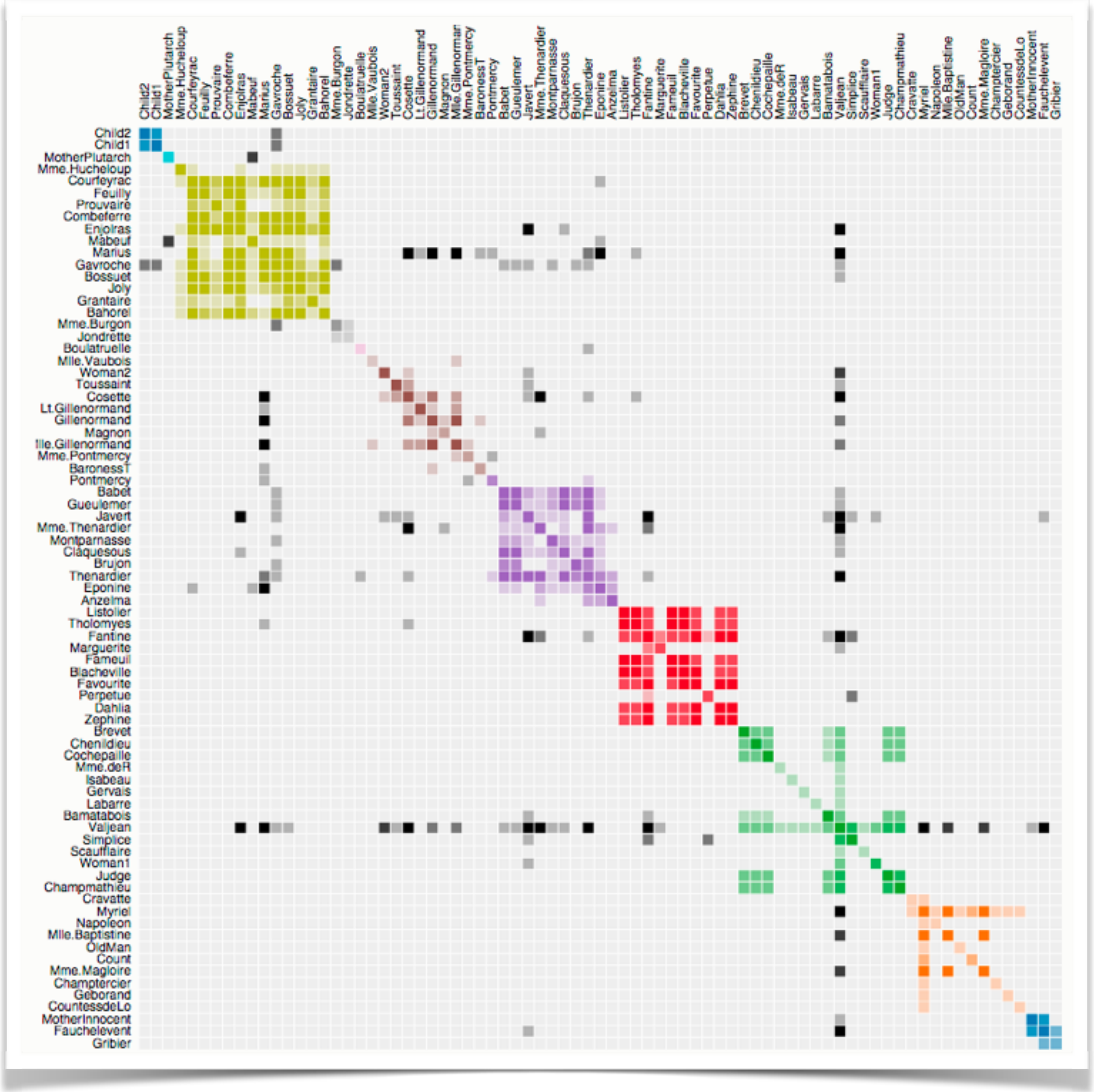


Matrix Layout

- Scalable
- Works with dense graphs
- Requires V^2 storage



Row/Column



Next Lecture: Trees

- Read VAD Chapter 9
- Start thinking about **final project topic** and **dataset**

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- Read VAD Chapter 9
- Start thinking about **final project topic** and **dataset**