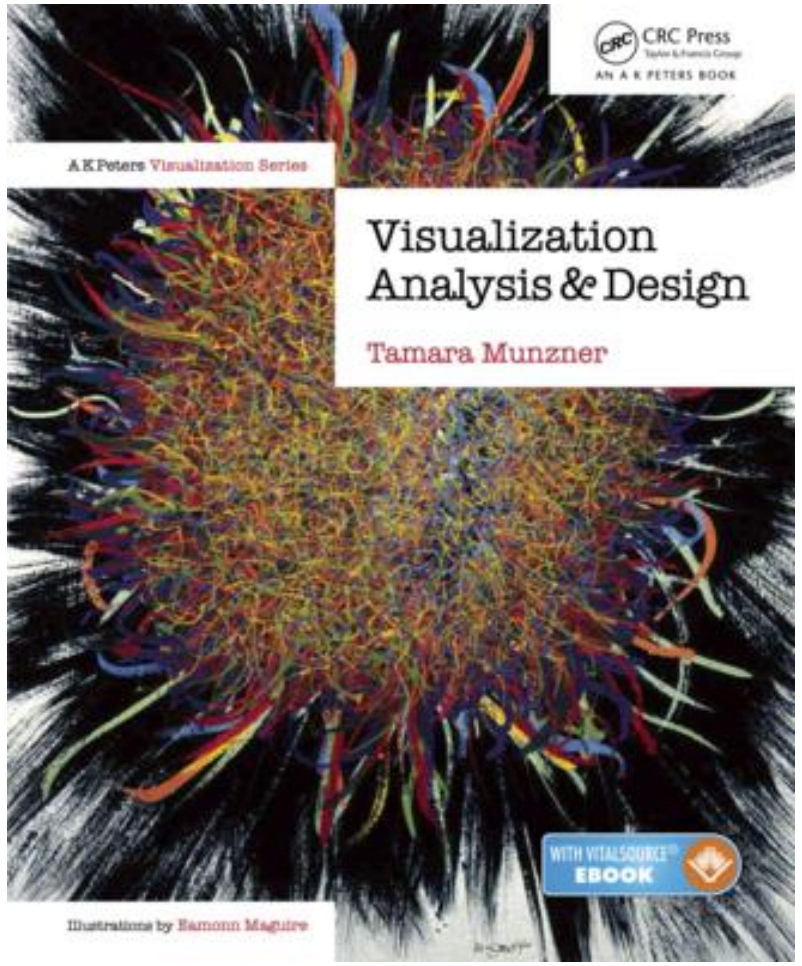
Spatial Layout

Yu-Shuen Wang, CS, NCTU

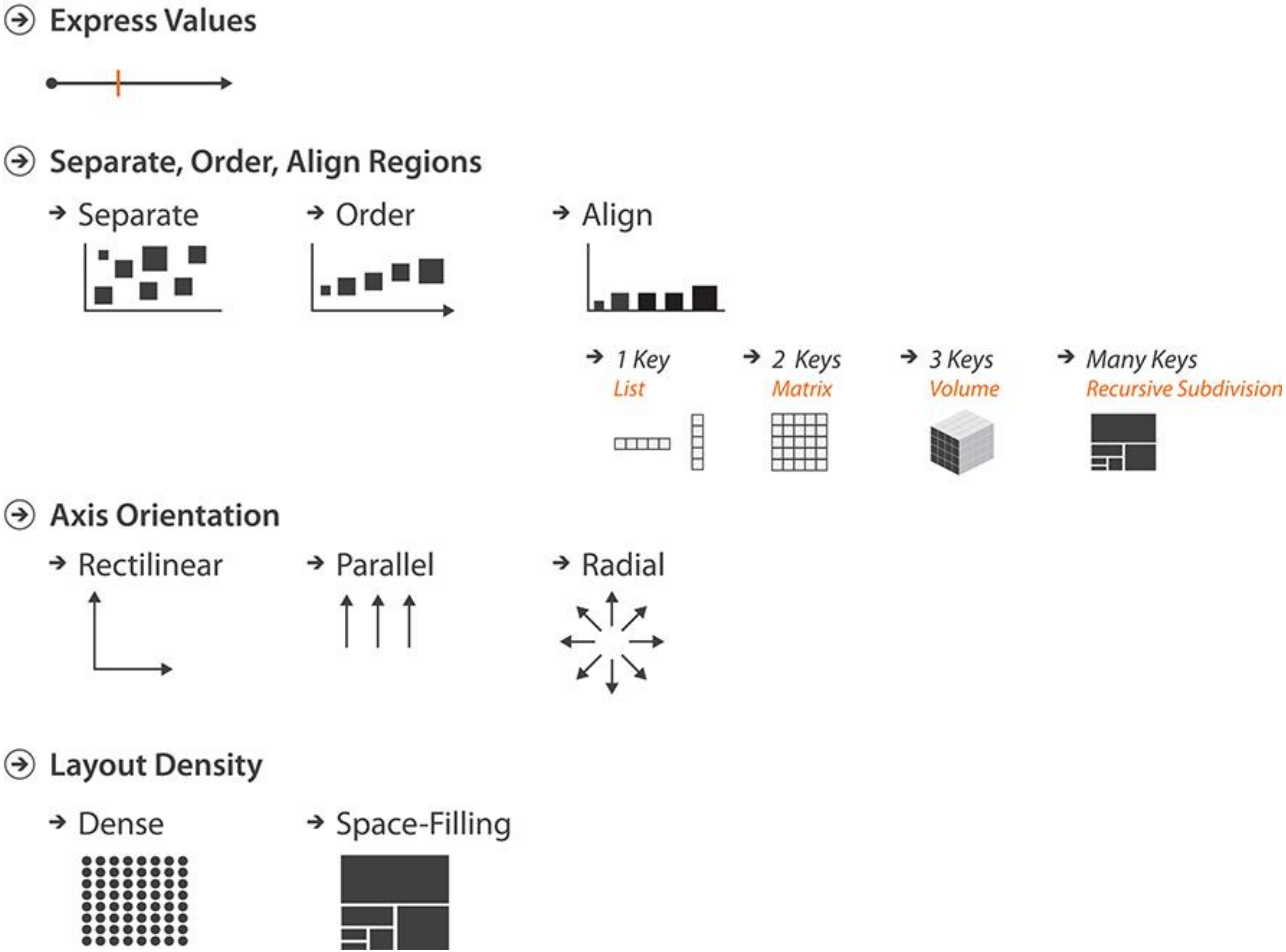


- Slides refer to https://www.cs.ubc.ca/~tmm/

Spatial Layout

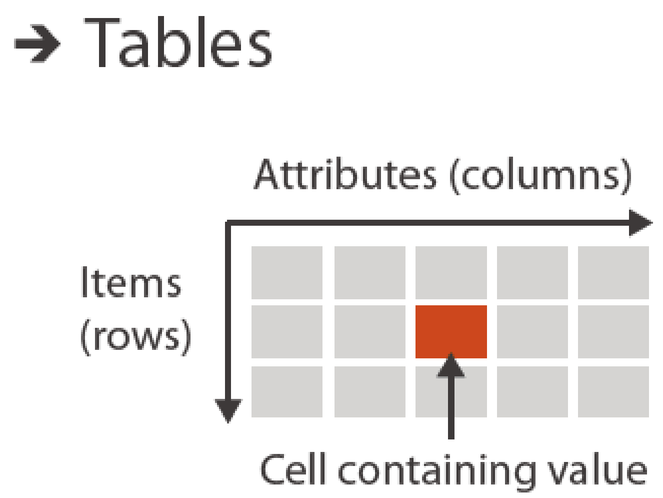
- Arrange Tables (ch. 7)
- Arrange Spatial Data (ch. 8)
- Arrange Networks and Trees (ch. 9)

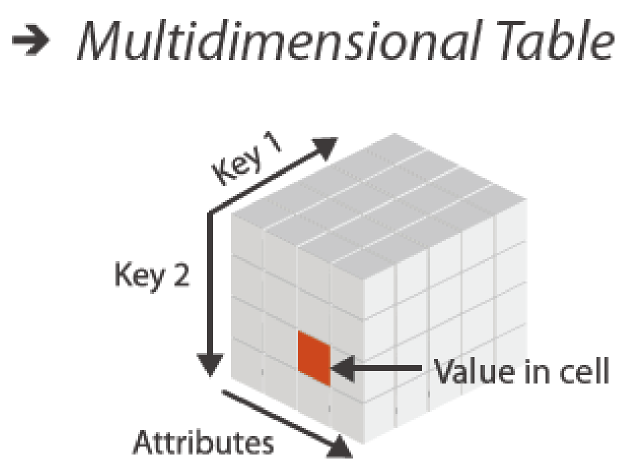
Arrange Tables



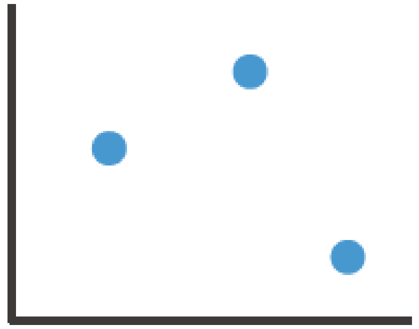
Keys and Values

- **key**
  - –independent attribute
  - –used as unique index to look up items
  - –simple tables: 1 key
  - –multidimensional tables: multiple keys
- **value**
  - –dependent attribute, value of cell
- classify arrangements by key count
  - –0, 1, 2, many...

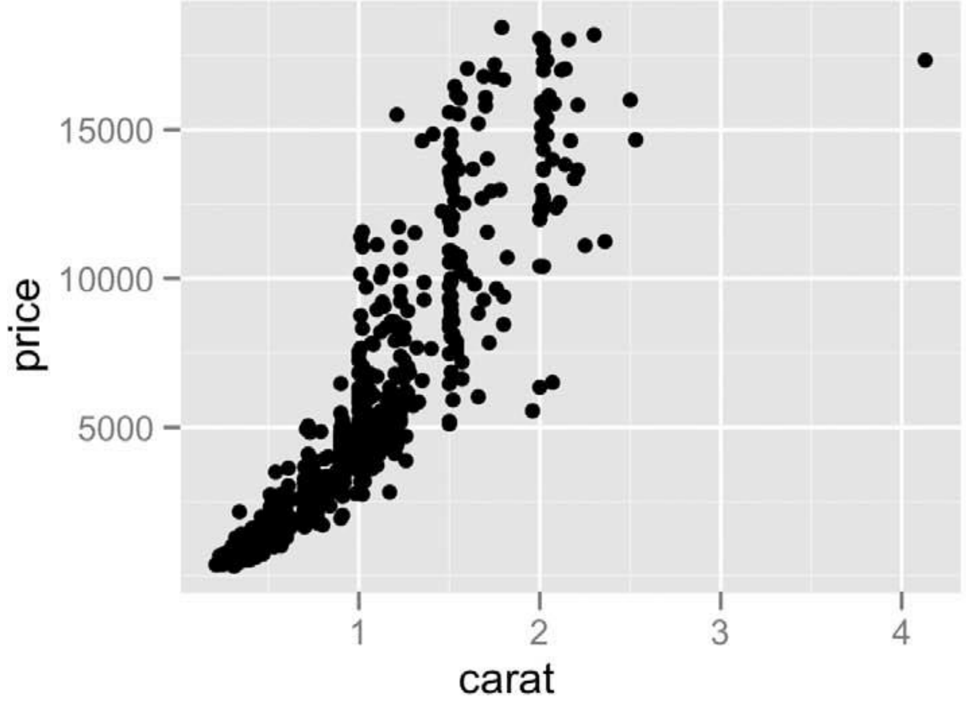


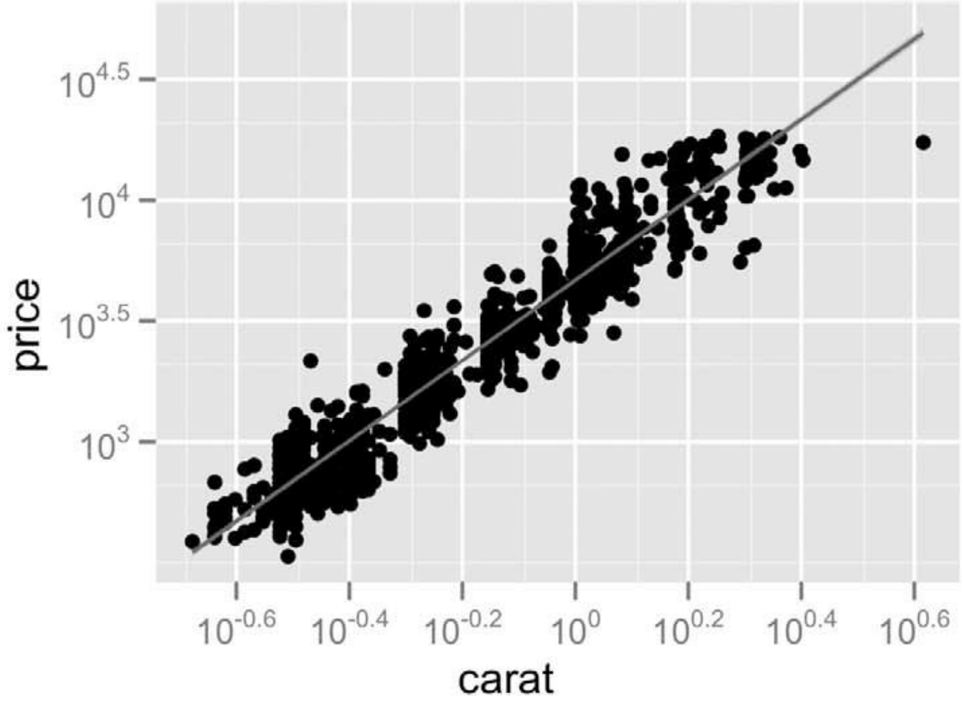


Idiom: **scatterplot**

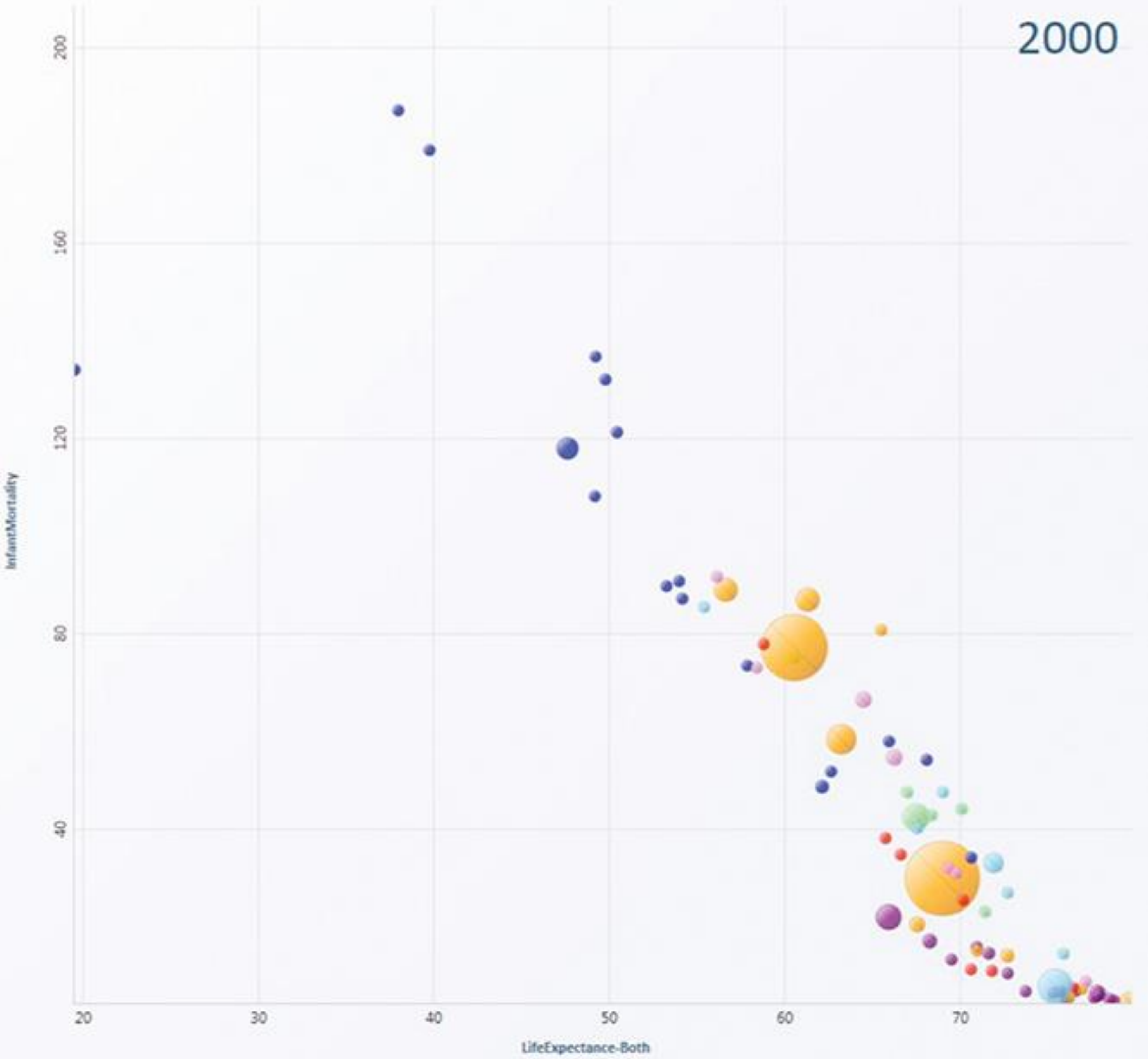


- *express* values
  - –quantitative attributes
- no keys, only values
  - –data
    - 2 quant attribs
  - –mark: points
  - –channels
    - horiz + vert position
  - –tasks
    - find trends, outliers, distribution, correlation, clusters
  - –scalability
    - hundreds of items





[A layered grammar of graphics. Wickham. Journ. Computational and Graphical Statistics 19:1 (2010), 3–28.]



Additional attributes might also be encoded on the same mark with other nonspatial channels such as color and size.

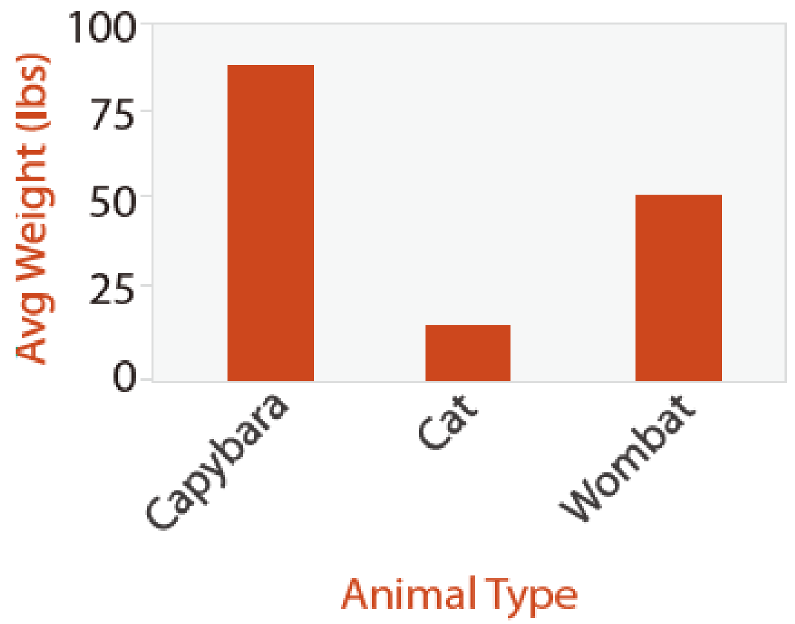
In this scatter plot, each point mark represents a country, with horizontal and vertical spatial position encoding the primary quantitative attributes of life expectancy and infant mortality. The color channel is used for the categorical country attribute and the size channel for quantitative population attribute.

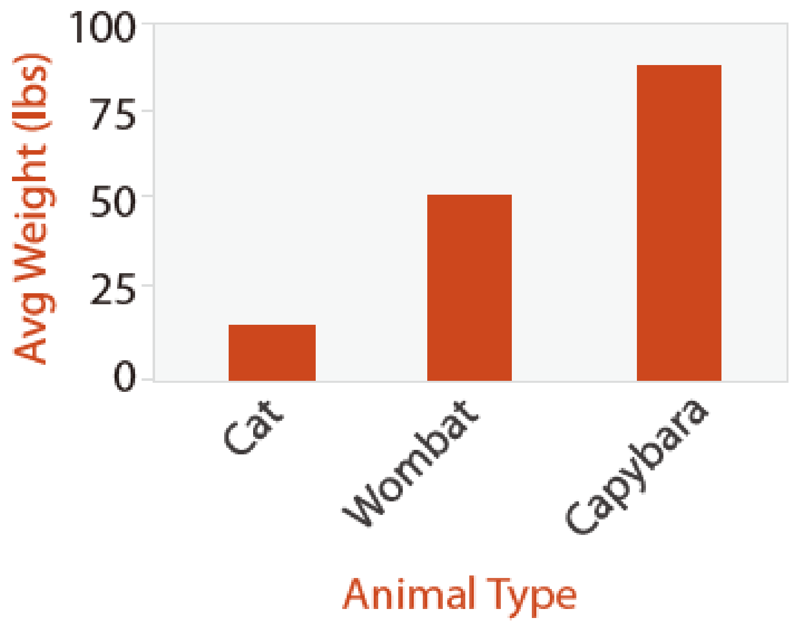
[Robertson et al. 08, Figure 1c].

Some keys: Categorical regions

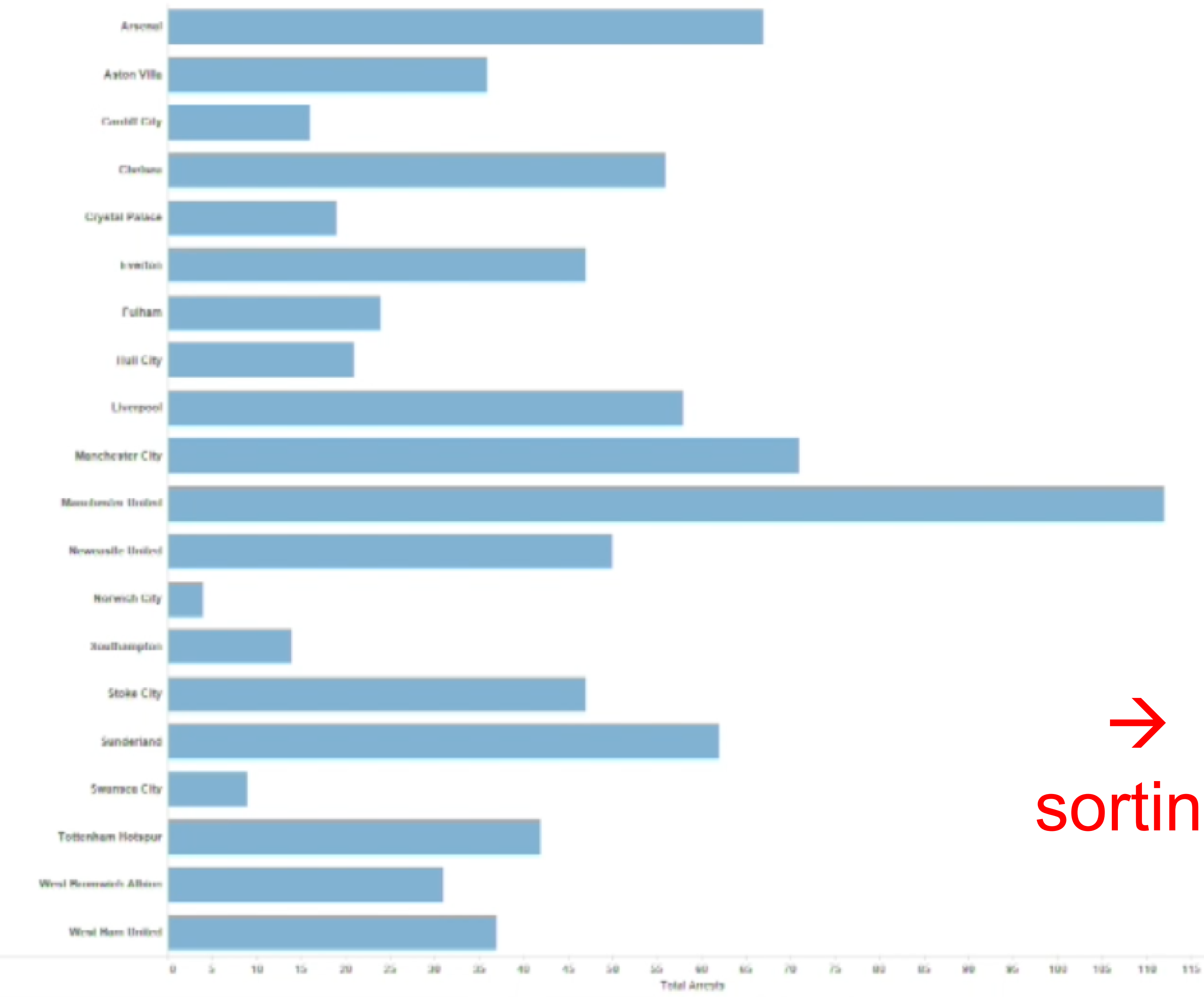
- regions: contiguous bounded areas distinct from each other
  - –using space to *separate* (proximity)
  - –following expressiveness principle for categorical attributes
- use ordered attribute to *order* and *align* regions

Idiom: **bar chart**

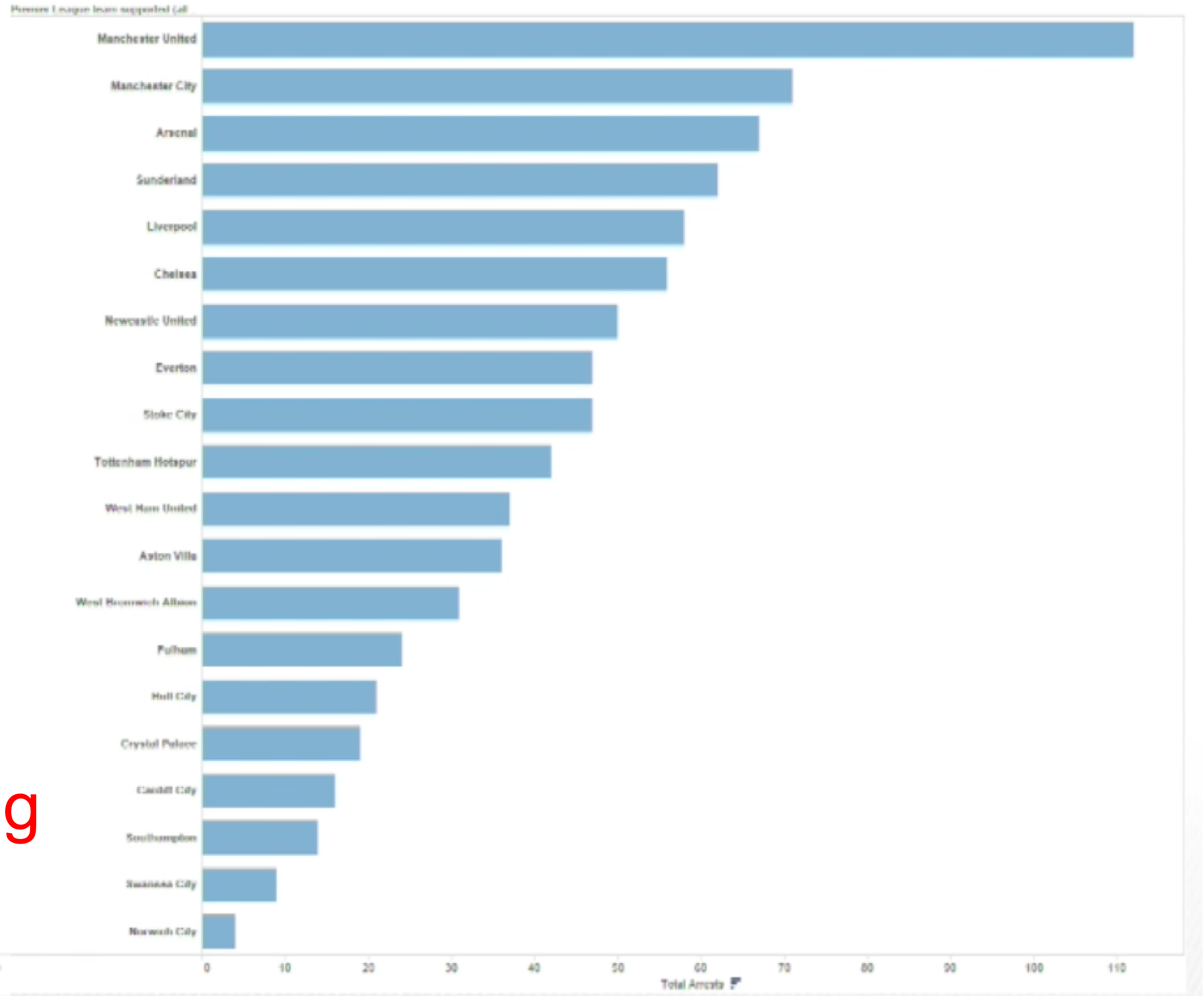




- one key, one value
  - data
    - 1 categ attrib, 1 quant attrib
  - mark: lines
  - channels
    - length to express quant value
    - spatial regions: one per mark
      - separated horizontally, aligned vertically
      - ordered by quant attrib
        - » by label (alphabetical), by length attrib (data-driven)
  - task
    - compare, lookup values
  - scalability
    - dozens to hundreds of levels for key attrib



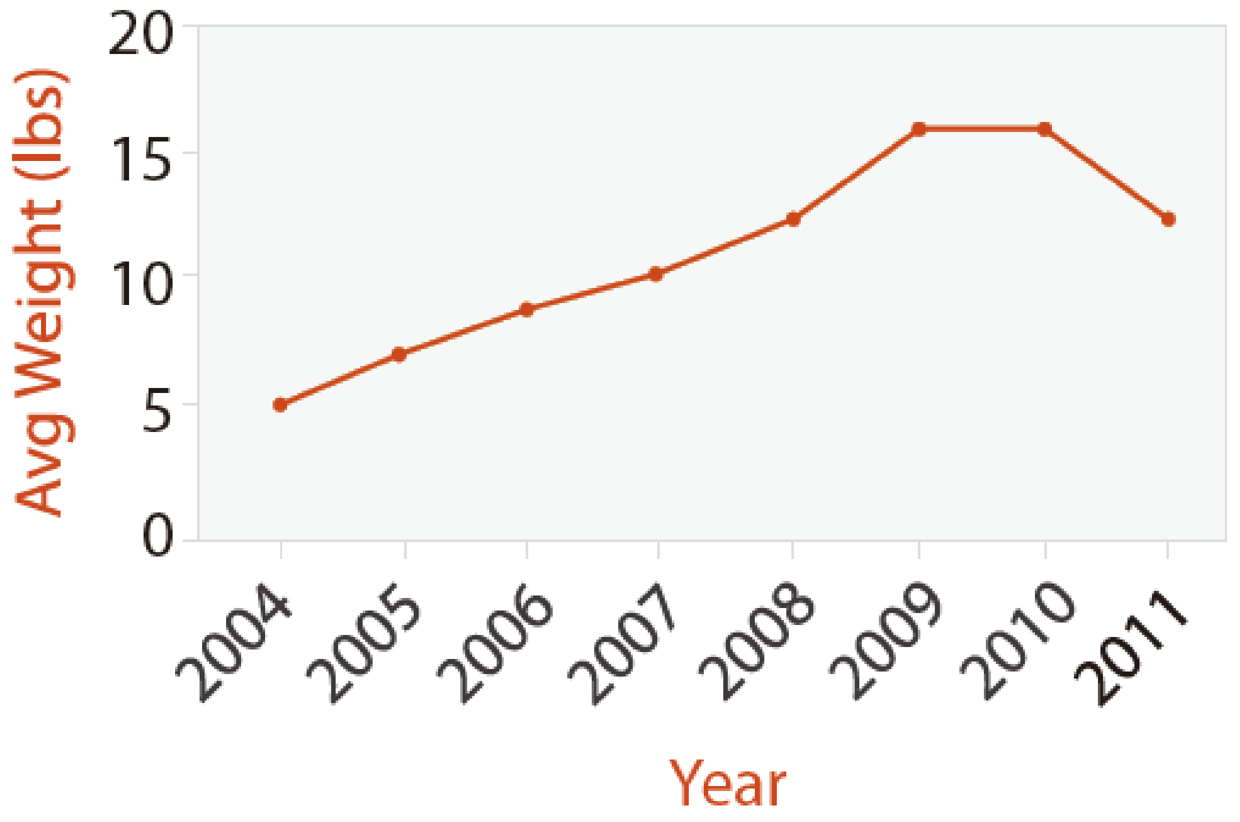
sorting



Which one is the 4th most?

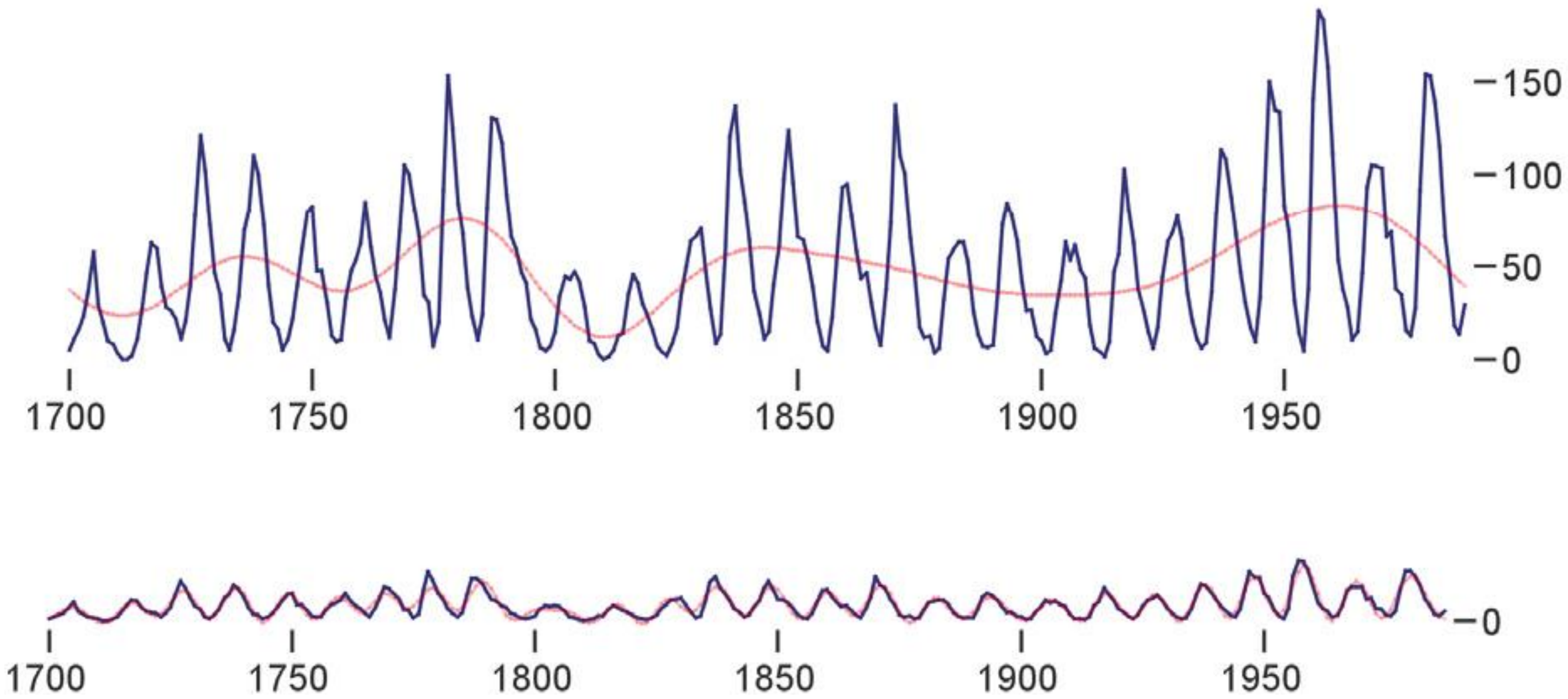
Idiom: **line chart**

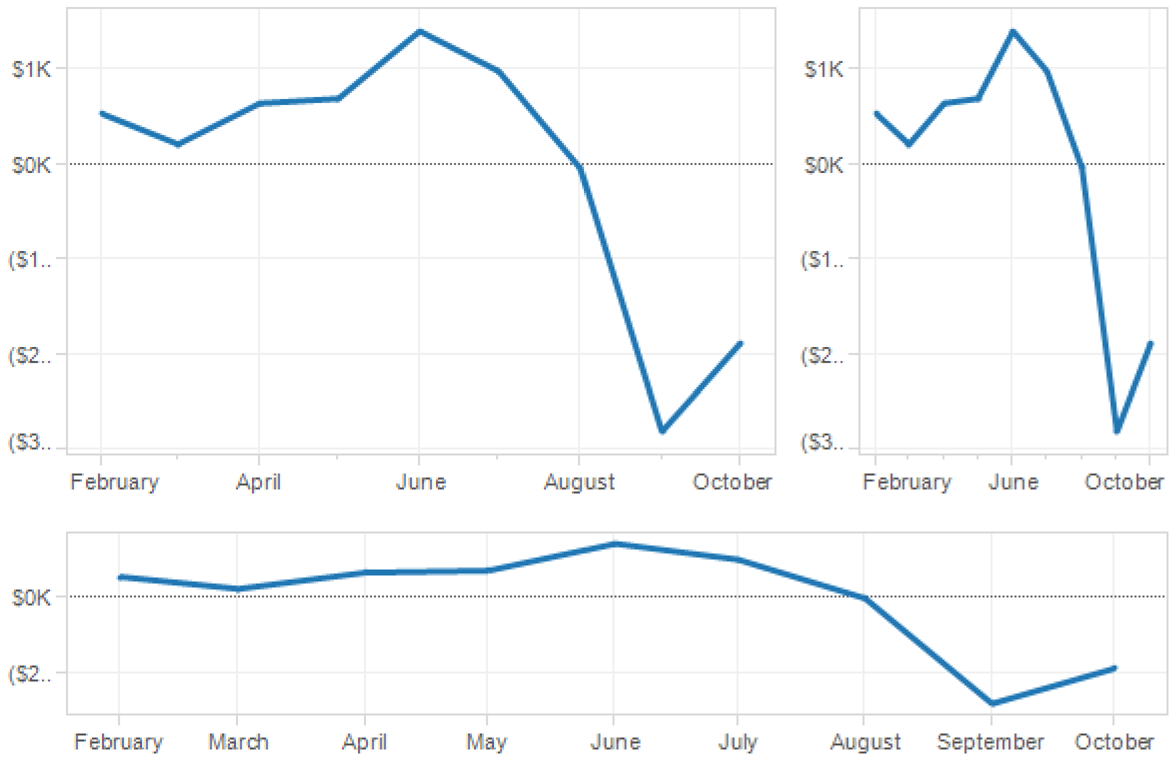
- one key, one value
  - data
    - 2 quant attribs
  - mark: points
    - line connection marks between them
  - channels
    - aligned lengths to express quant value
    - separated and ordered by key attrib into horizontal regions
  - task
    - find trend
      - connection marks emphasize ordering of items along key axis by explicitly showing relationship between one item and the next



Idiom: **line chart**

- Banking to 45 degrees

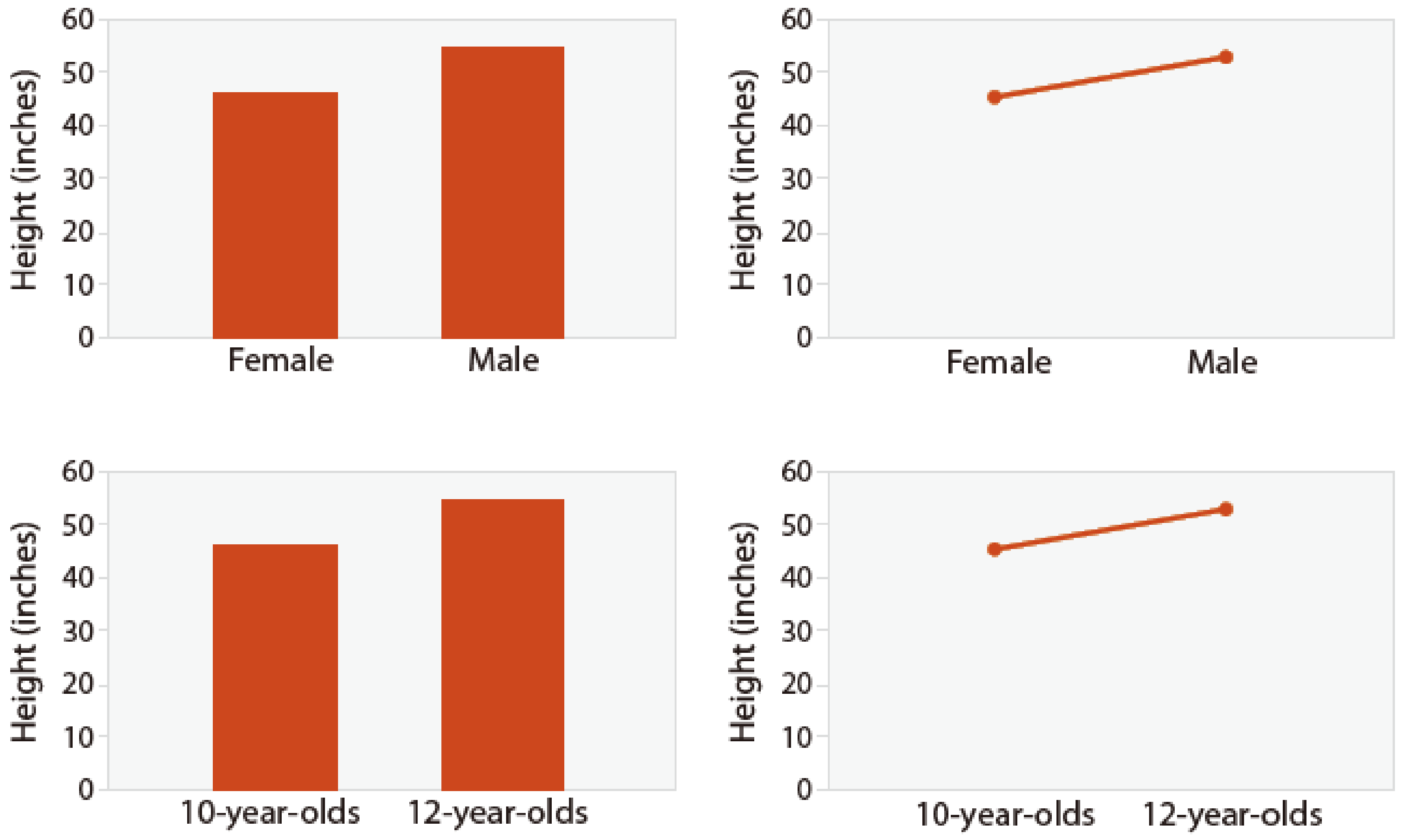




[Heer and Agrawala 06]

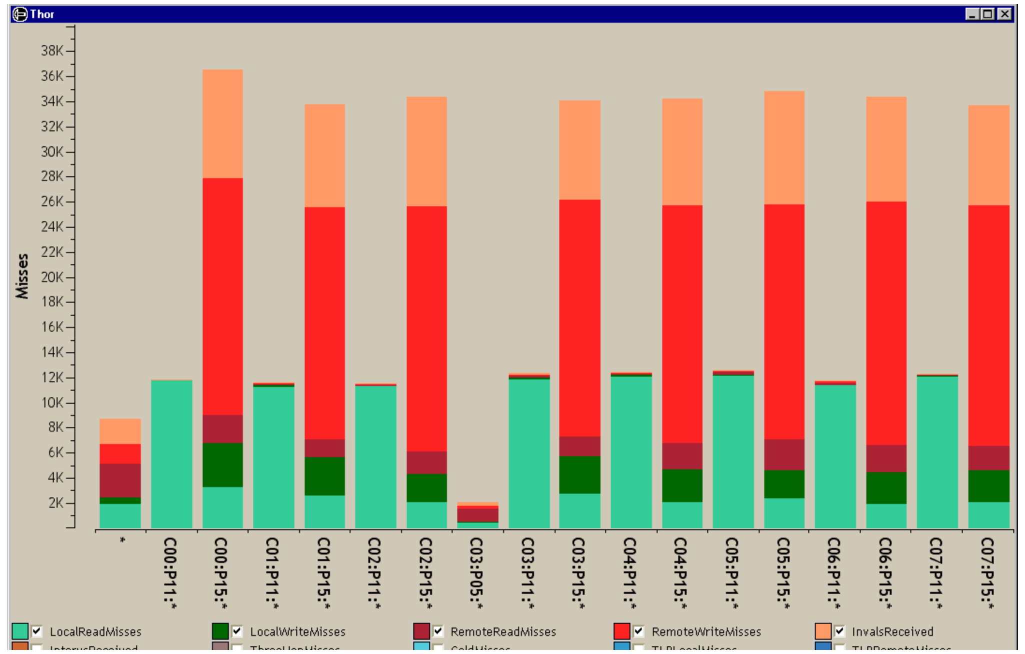
Choosing bar vs line charts

- depends on type of key attrib
  - –bar charts if categorical
  - –line charts if ordered
- do not use line charts for categorical key attribs
  - –violates expressiveness principle
    - implication of trend so strong that it overrides semantics!
      - “The more male a person is, the taller he/she is”



after [Bars and Lines: A Study of Graphic Communication. Zacks and Tversky. Memory and Cognition 27:6 (1999), 1073–1079.]

Idiom: **stacked bar chart**

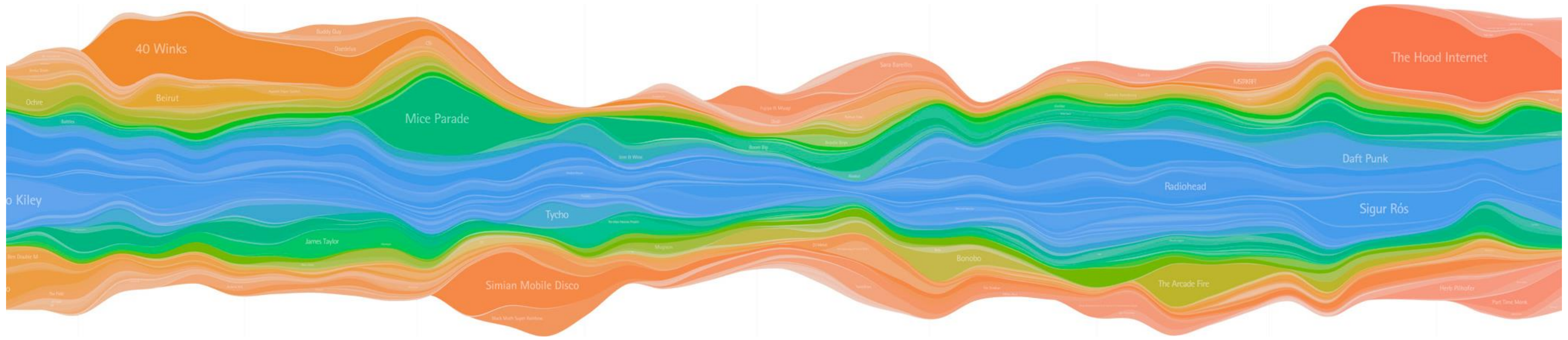


- one more key
  - –data
    - 2 categ attrib, 1 quant attrib
  - –mark: vertical stack of line marks
    - glyph: composite object, internal structure from multiple marks
  - –channels
    - length and color hue
    - spatial regions: one per glyph
      - –aligned: full glyph, lowest bar component
      - –unaligned: other bar components
  - –task
    - part-to-whole relationship
  - –scalability
    - several to one dozen levels for stacked attrib

[Using Visualization to Understand the Behavior of Computer Systems. Bosch. Ph.D. thesis, Stanford Computer Science, 2001.]

Idiom: **streamgraph**

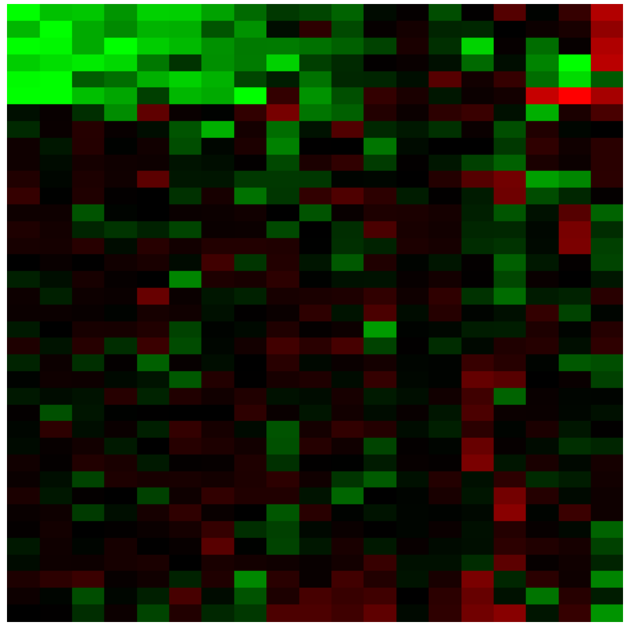
- generalized stacked graph
  - emphasizing horizontal continuity
    - vs vertical items
  - data
    - 1 categ key attrib (artist)
    - 1 ordered key attrib (time)
    - 1 quant value attrib (counts)
  - derived data
    - geometry: layers, where height encodes counts
    - 1 quant attrib (layer ordering)
  - scalability
    - hundreds of time keys
    - dozens to hundreds of artist keys
      - more than stacked bars, since most layers don't extend across whole chart

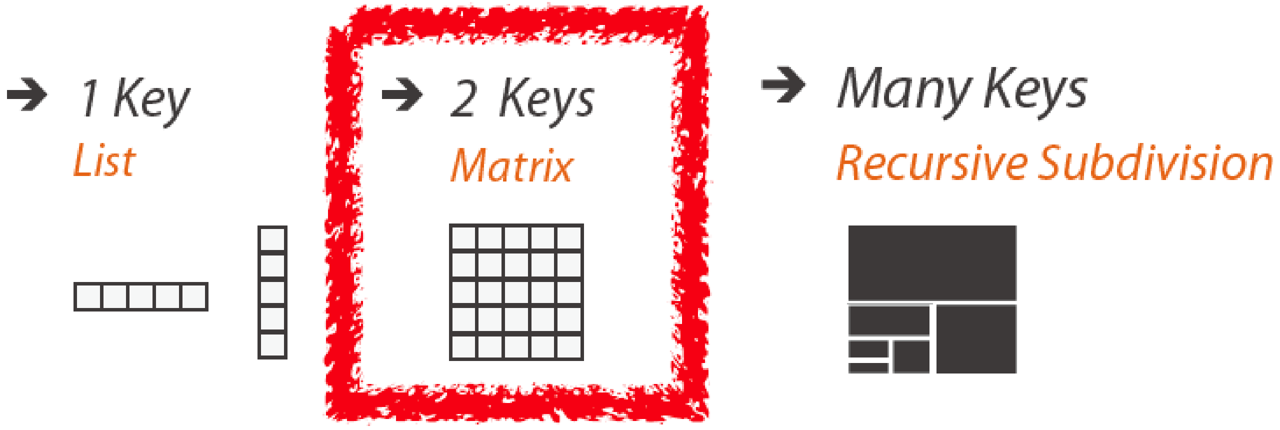


[Stacked Graphs Geometry & Aesthetics. Byron and Wattenberg. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2008) 14(6): 1245–1252, (2008).]

Idiom: **heatmap**

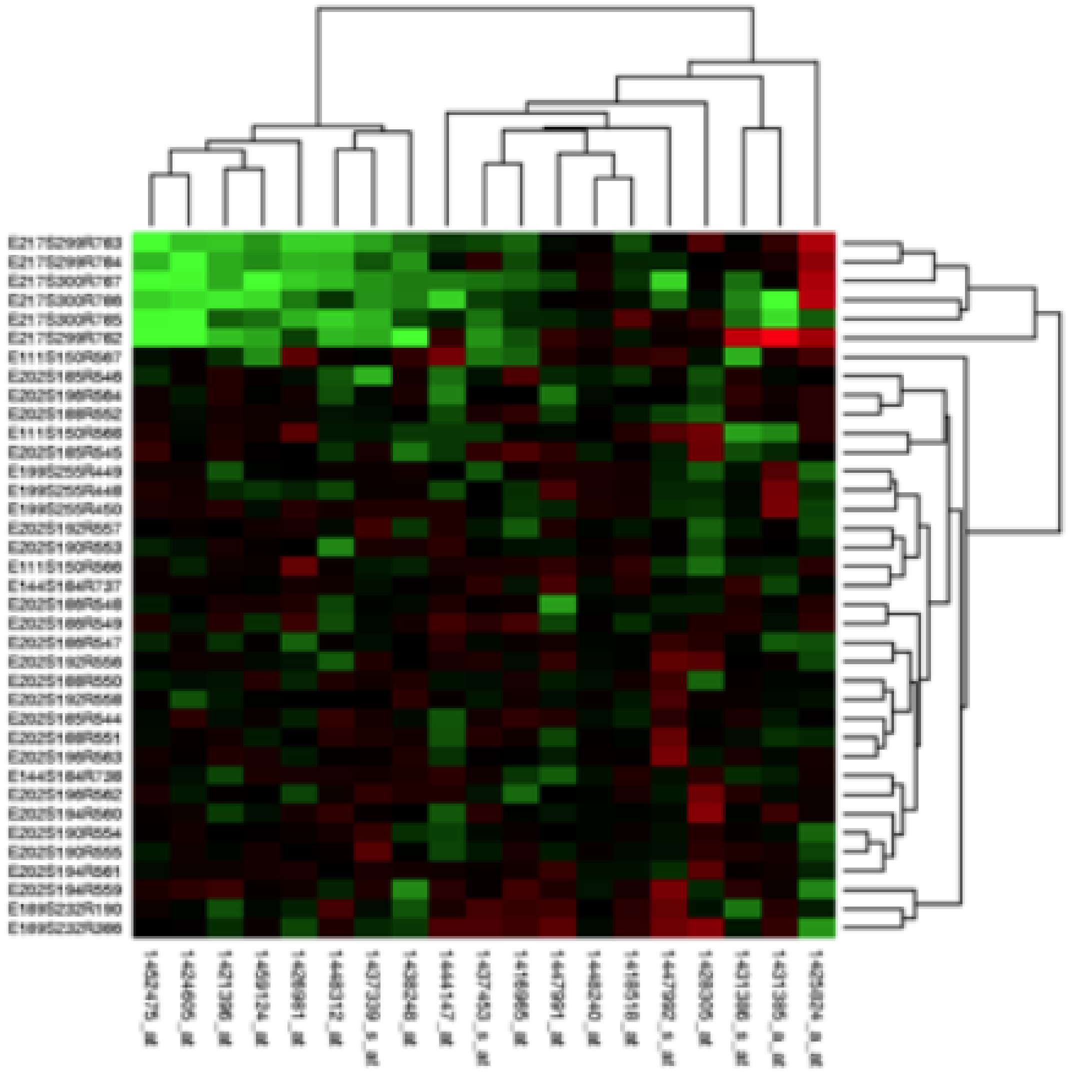
- two keys, one value
  - –data
    - 2 categ attribs (gene, experimental condition)
    - 1 quant attrib (expression levels)
  - –marks: area
    - separate and align in 2D matrix
      - –indexed by 2 categorical attributes
  - –channels
    - color by quant attrib
      - –(ordered diverging colormap)
  - –task
    - find clusters, outliers
  - –scalability
    - 1M items, 100s of categ levels, ~10 quant attrib levels





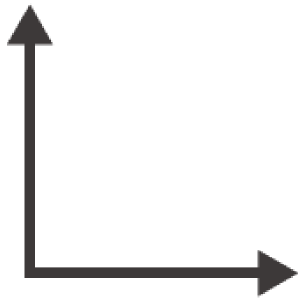
Idiom: **cluster heatmap**

- in addition
  - –derived data
    - 2 cluster hierarchies
  - –dendrogram
    - Parent-child relationships in tree with connection li
    - Leaces aligned so interior branch heights easy to c
  - –heapmap
    - Marks (re-)ordered by cluster hierarchy traversed



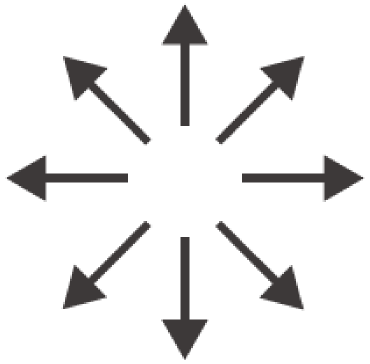
Axis Orientation

- Rectilinear



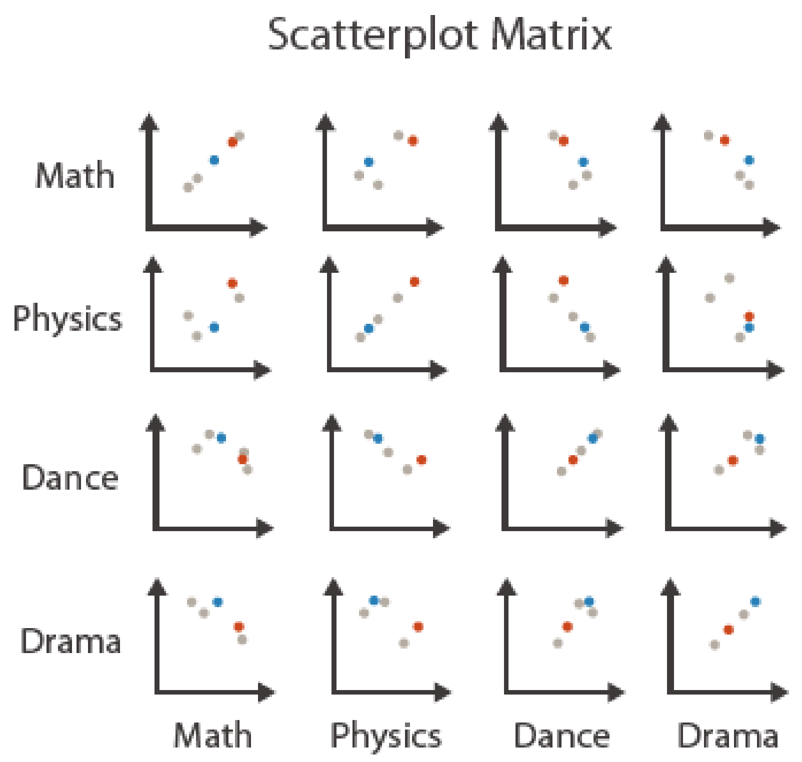
- Parallel

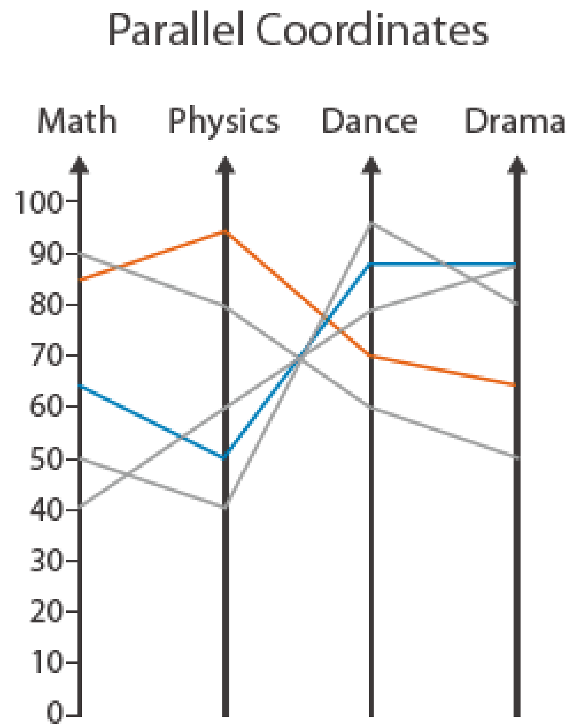
- Radial



Idioms: **scatterplot matrix, parallel coordinates**

- scatterplot matrix (SPLOM)
  - rectilinear axes, point mark
  - all possible pairs of axes
  - scalability
    - one dozen attribs
    - dozens to hundreds of items
- parallel coordinates
  - parallel axes, jagged line representing item
  - rectilinear axes, item as point
    - axis ordering is major challenge
  - scalability
    - dozens of attribs
    - hundreds of items





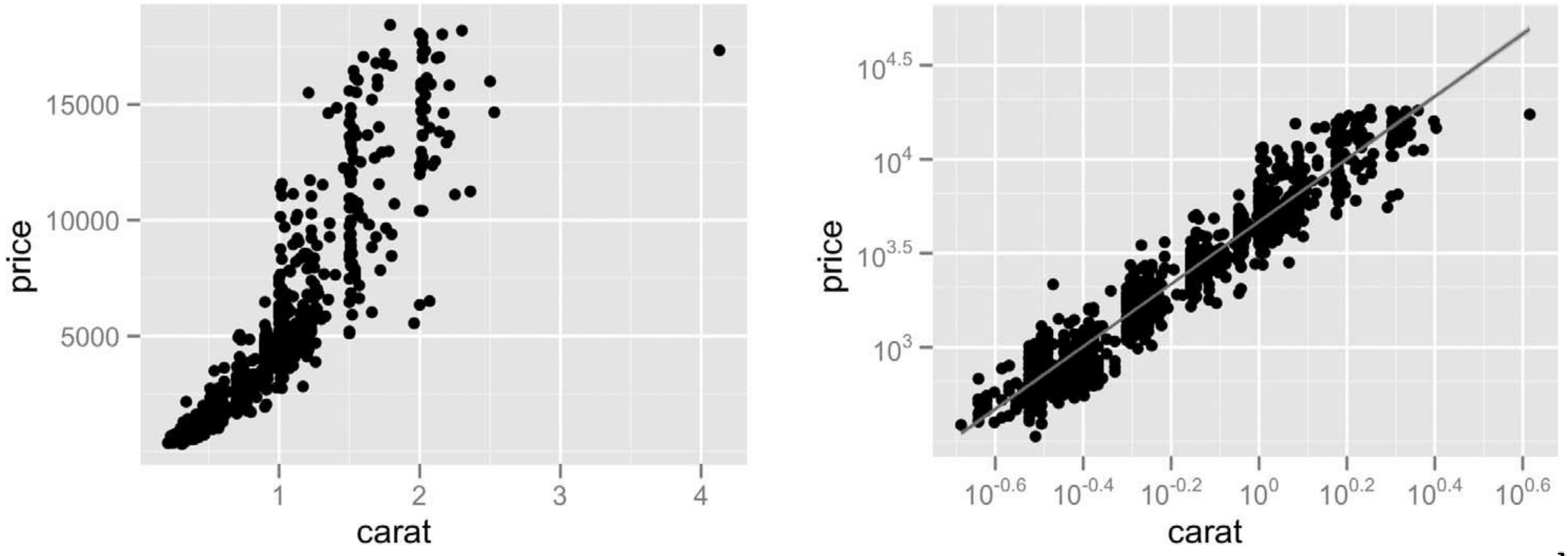
Table

Math	Physics	Dance	Drama
85	95	70	65
90	80	60	50
65	50	90	90
50	40	95	80
40	60	80	90

after [Visualization Course Figures. McGuffin, 2014. http://www.michaelmcguffin.com/courses/vis/]

Task: Correlation

- scatterplot matrix
  - –positive correlation
    - diagonal low-to-high
  - –negative correlation
    - diagonal high-to-low
  - –uncorrelated
- parallel coordinates
  - –positive correlation
    - parallel line segments
  - –negative correlation
    - all segments cross at halfway point
  - –uncorrelated
    - scattered crossings



[A layered grammar of graphics. Wickham. Journ. Computational and Graphical Statistics 19:1 (2010), 3–28.]

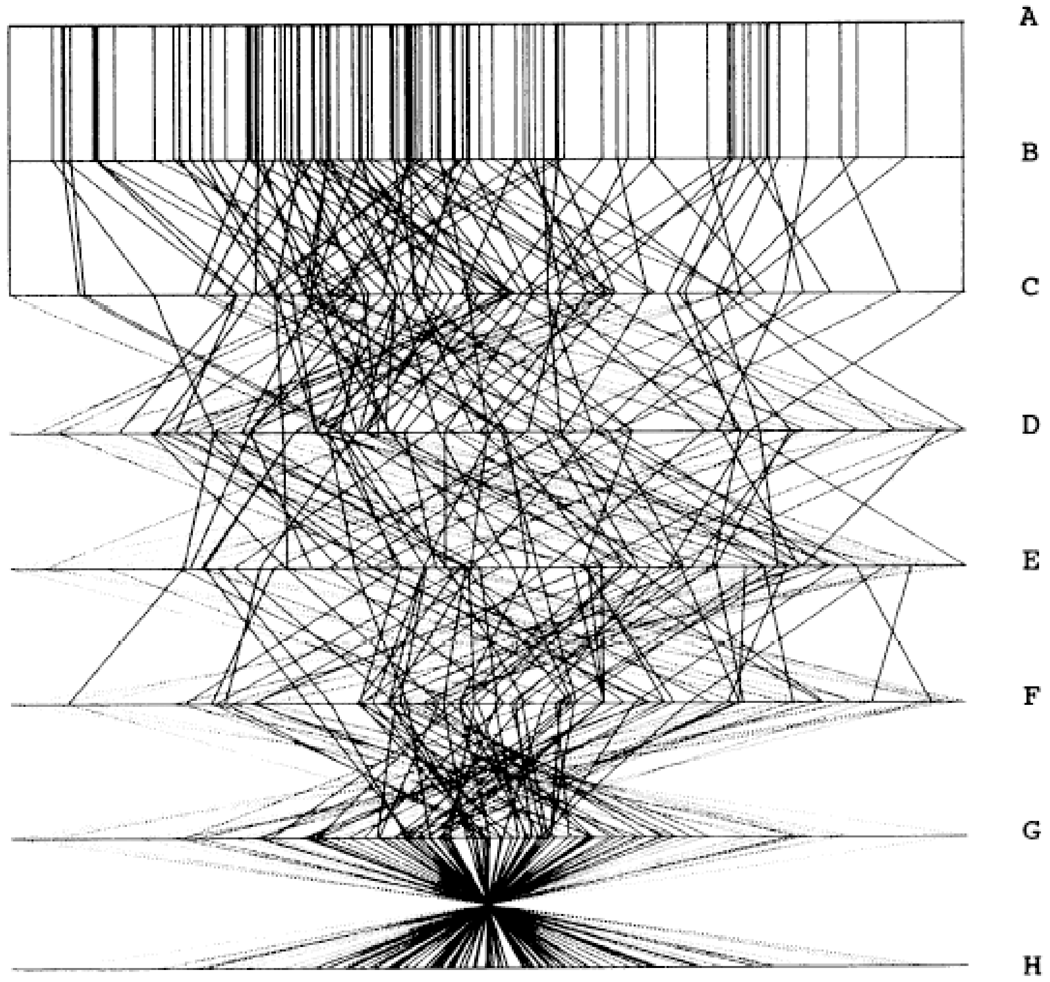
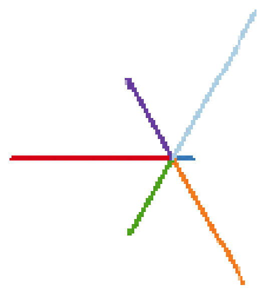


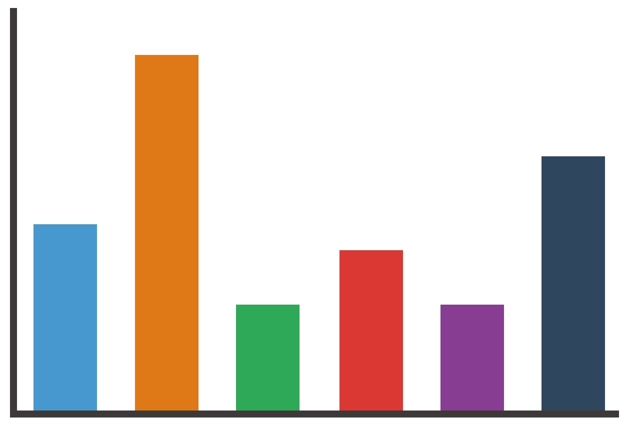
Figure 3. Parallel Coordinate Plot of Six-Dimensional Data Illustrating Correlations of ρ = 1, .8, .2, 0, −.2, −.8, and −1.

[Hyperdimensional Data Analysis Using Parallel Coordinates. Wegman. Journ. American Statistical Association 85:411 (1990), 664–675.]

Idioms: **radial bar chart, star plot**

- radial bar chart
  - –radial axes meet at central ring, line mark
- star plot
  - –radial axes, meet at central point, line mark
- bar chart
  - –rectilinear axes, aligned vertically



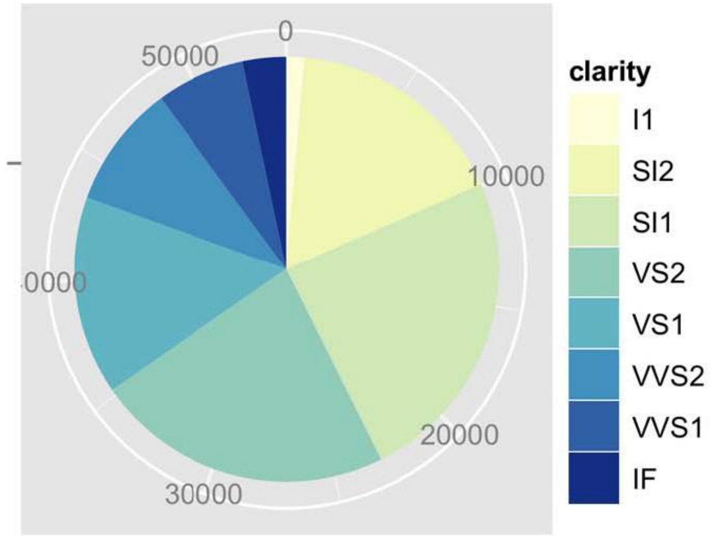


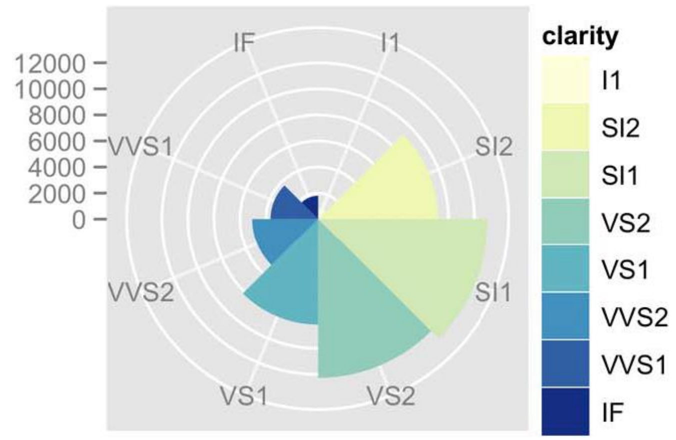
- accuracy
  - –length unaligned with radial
    - less accurate than aligned with rectilinear

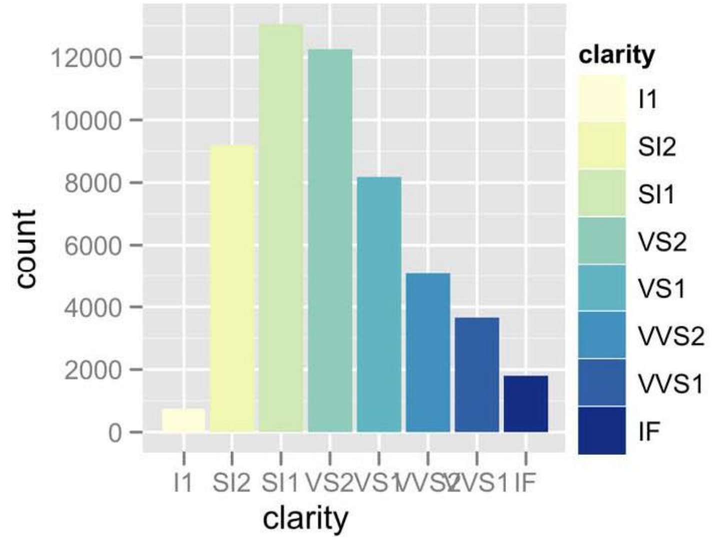
[Vismon: Facilitating Risk Assessment and Decision Making In Fisheries Management. Booshehrian, Möller, Peterman, and Munzner. Technical Report TR 2011-04, Simon Fraser University, School of Computing Science, 2011.]

Idioms: **pie chart, polar area chart**

- pie chart
  - –area marks with angle channel
  - –accuracy: angle/area less accurate than line length
    - arclength also less accurate than line length
- polar area chart
  - –area marks with length channel
  - –more direct analog to bar charts
- data
  - –1 categ key attrib, 1 quant value attrib
- task
  - –part-to-whole judgements



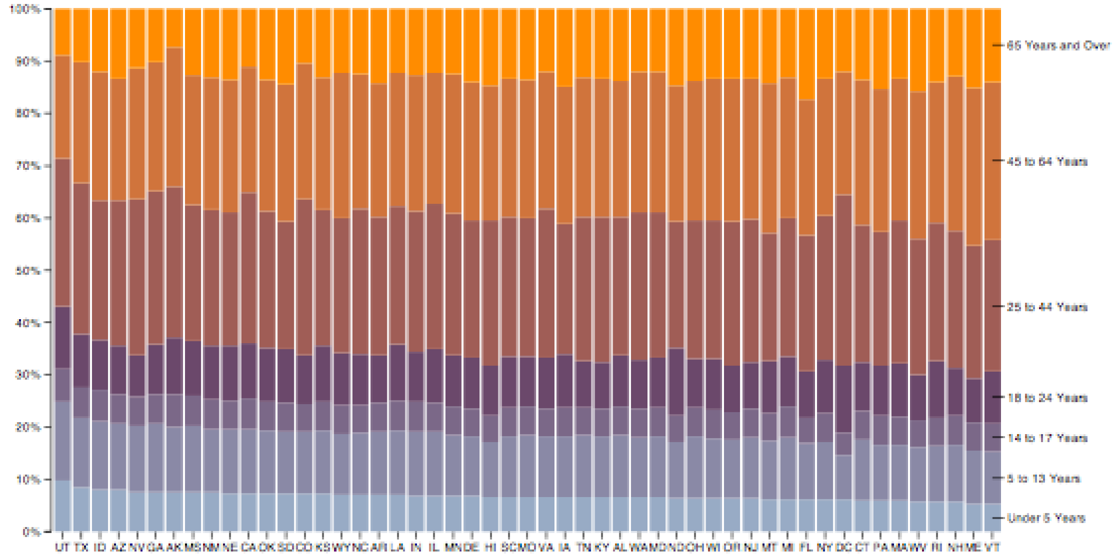


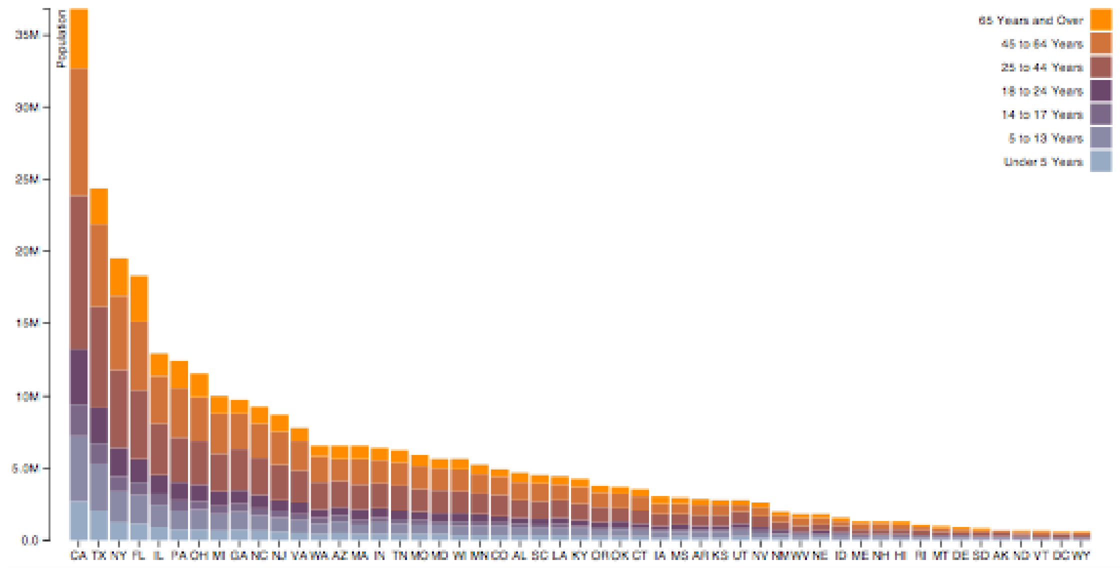


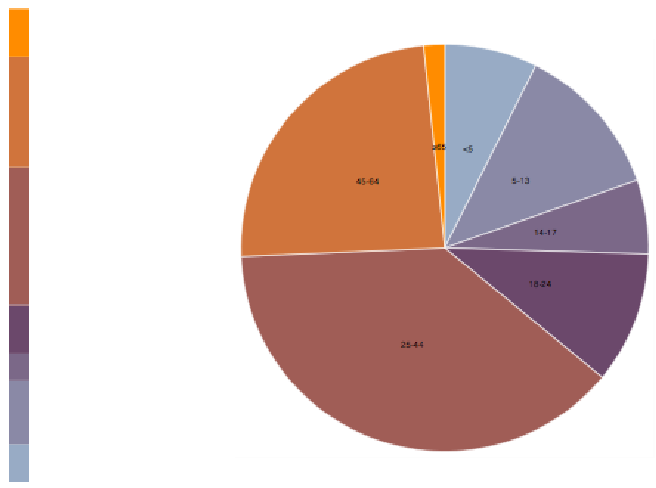
[A layered grammar of graphics. Wickham. Journ. Computational and Graphical Statistics 19:1 (2010), 3–28.]

Idioms: **normalized stacked bar chart**

- task
  - –part-to-whole judgements
- normalized stacked bar chart
  - –stacked bar chart, normalized to full height
  - –single stacked bar equivalent to full pie
    - high information density: requires narrow rectangle
- pie chart
  - –information density: requires large circle



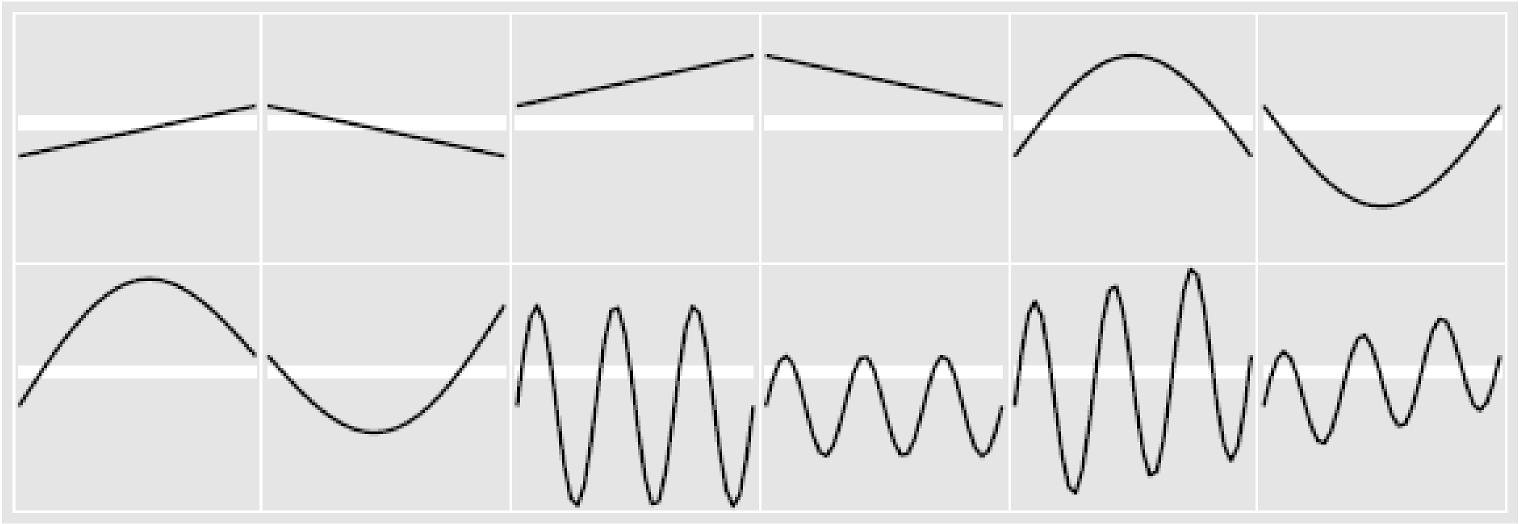




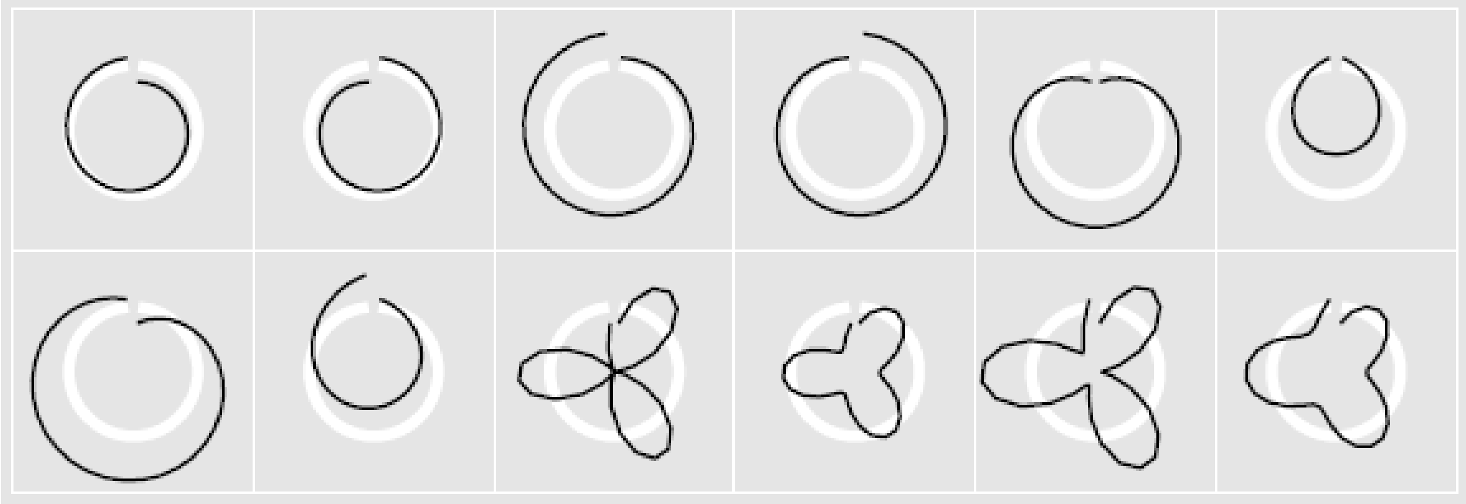
http://bl.ocks.org/mbostock/3887235,
http://bl.ocks.org/mbostock/3886208,
http://bl.ocks.org/mbostock/3886394.

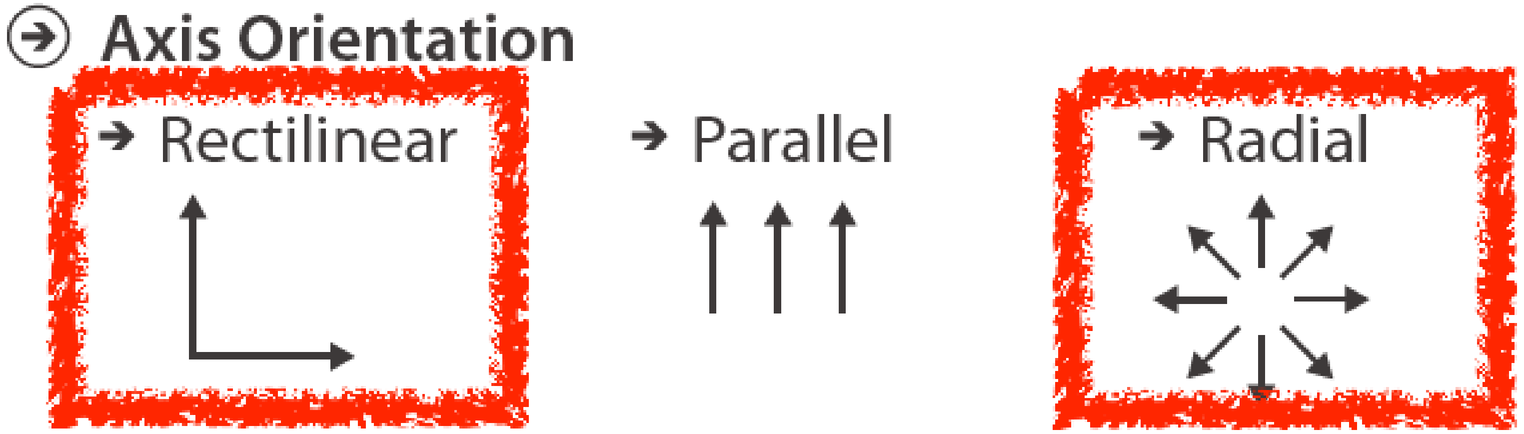
Idiom: **glyphmaps**

- rectilinear good for linear vs nonlinear trends



- radial good for cyclic patterns

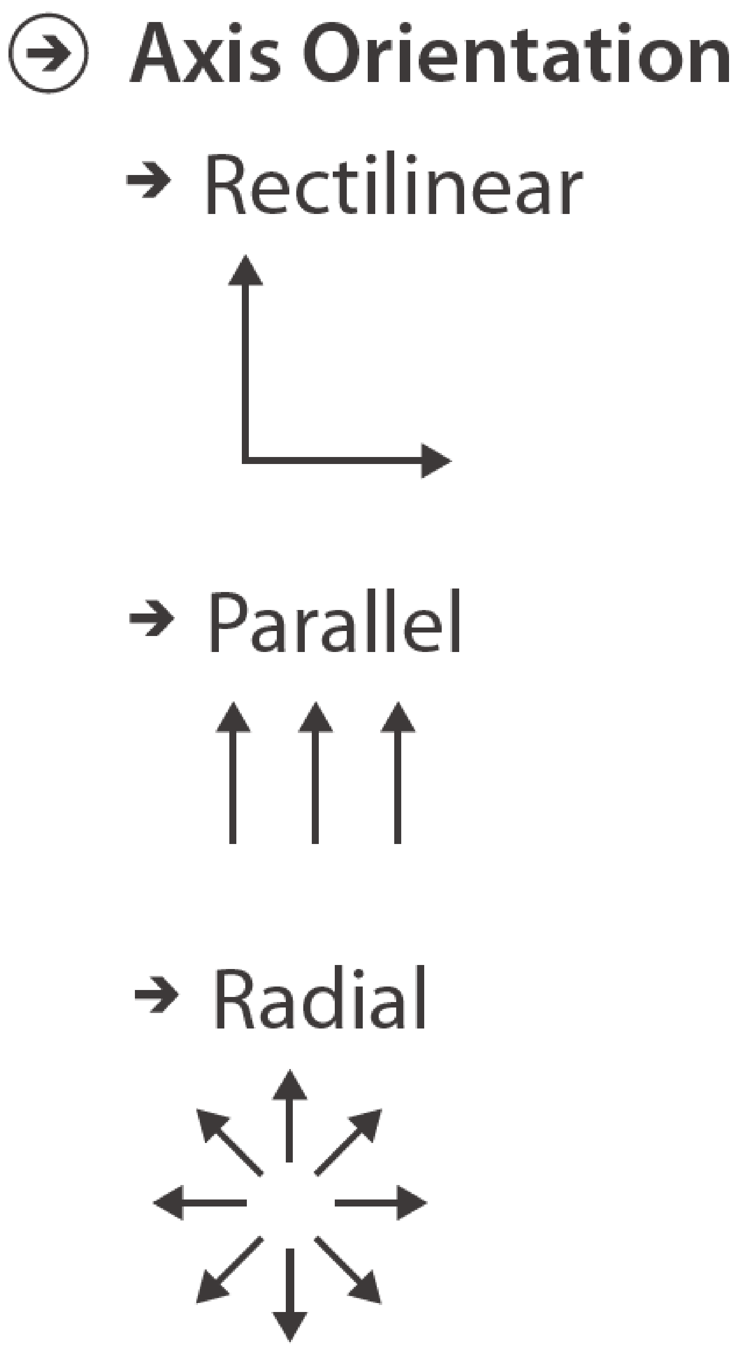




[Glyph-maps for Visually Exploring Temporal Patterns in Climate Data and Models. Wickham, Hofmann, Wickham, and Cook. Environmetrics 23:5 (2012), 382–393.]

Orientation limitations

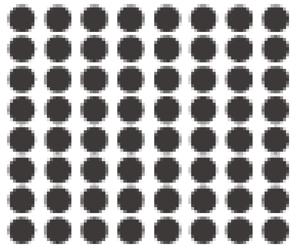
- rectilinear: scalability wrt #axes
    - 2 axes best
    - 3 problematic
    - 4+ impossible
- parallel: unfamiliarity, training time
- radial: perceptual limits
    - –angles lower precision than lengths
    - –asymmetry between angle and length
        - can be exploited!

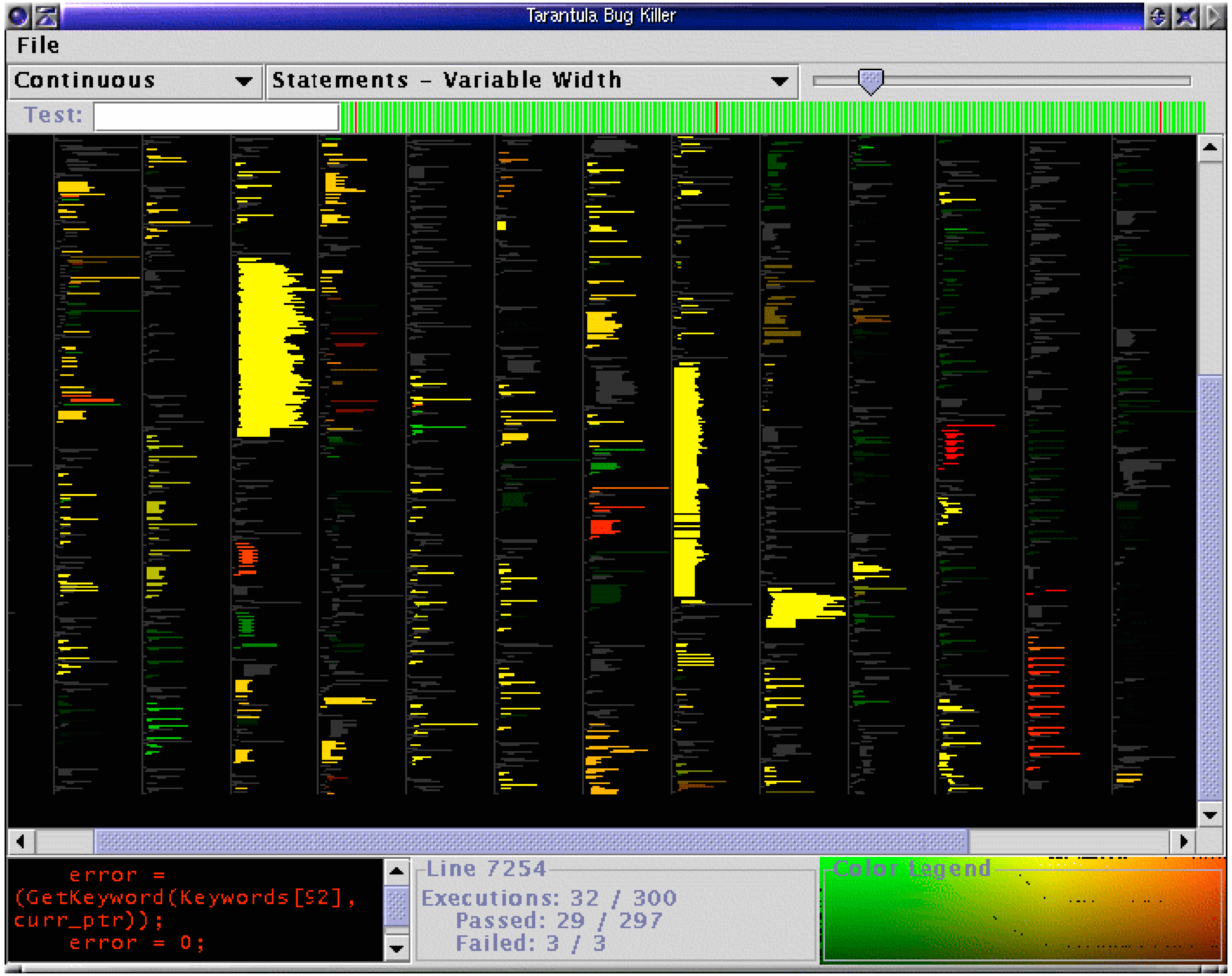


[Uncovering Strengths and Weaknesses of Radial Visualizations - an Empirical Approach. Diehl, Beck and Burch. IEEE TVCG (Proc. InfoVis) 16(6):935--942, 2010.]

dense software overviews

- Layout Density
  - Dense

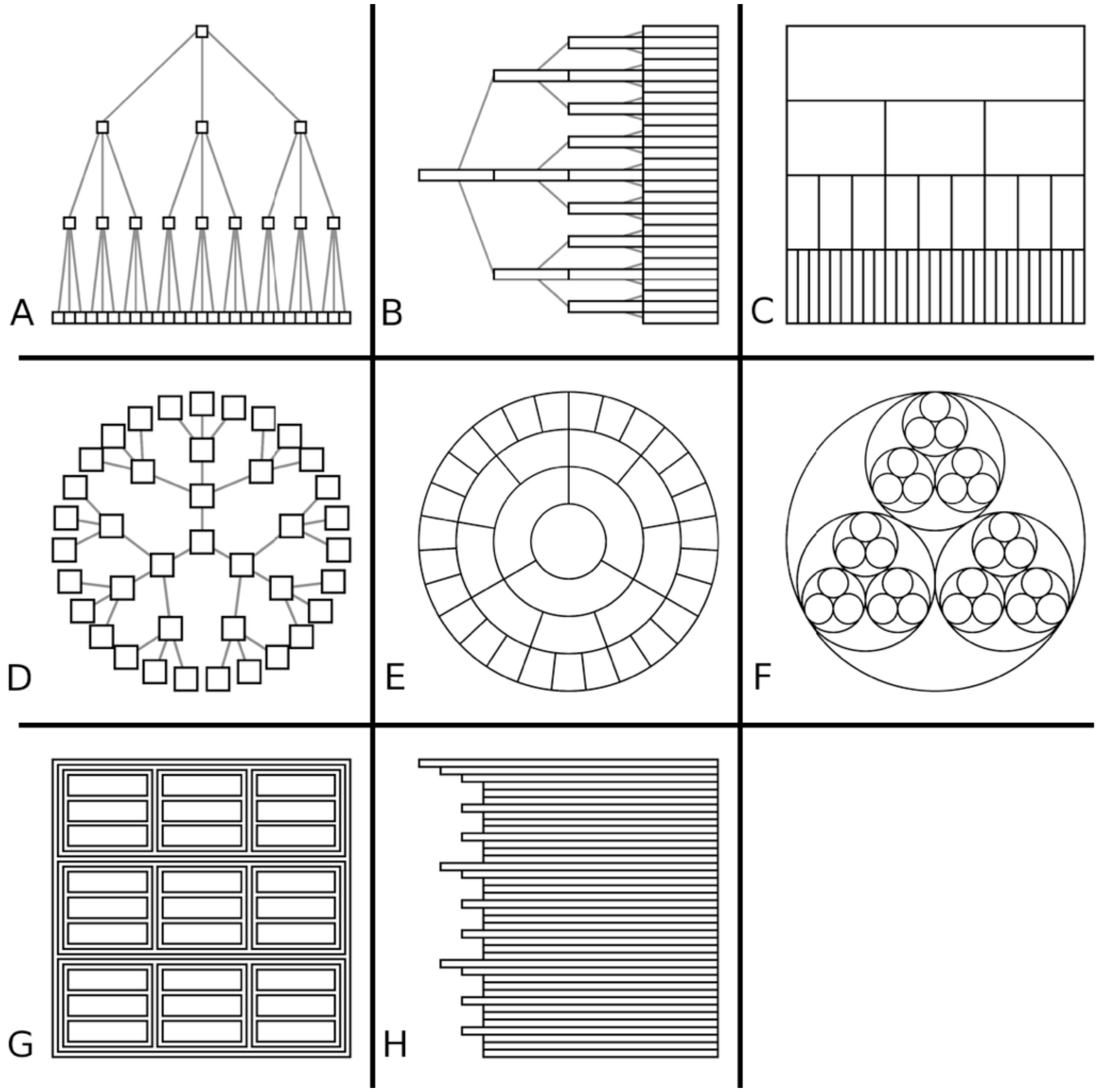




[Visualization of test information to assist fault localization. Jones, Harrold, Stasko. Proc. ICSE 2002, p 467-477.]

Layout density

- Space-Filling
  - It fills all available space in the view
- Marks
  - Area
  - Containment



Further reading

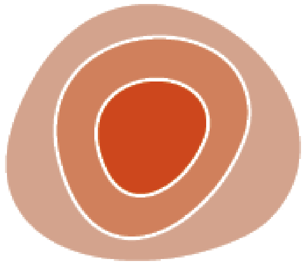
- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - *Chap 7: Arrange Tables*
- Visualizing Data. Cleveland. Hobart Press, 1993.
- *A Brief History of Data Visualization.* Friendly. 2008. http://www.datavis.ca/milestones

Arrange Spatial Data

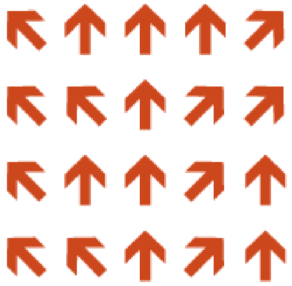
Arrange spatial data

- **Use Given**
  - Geometry
    - *Geographic*
    - *Other Derived*

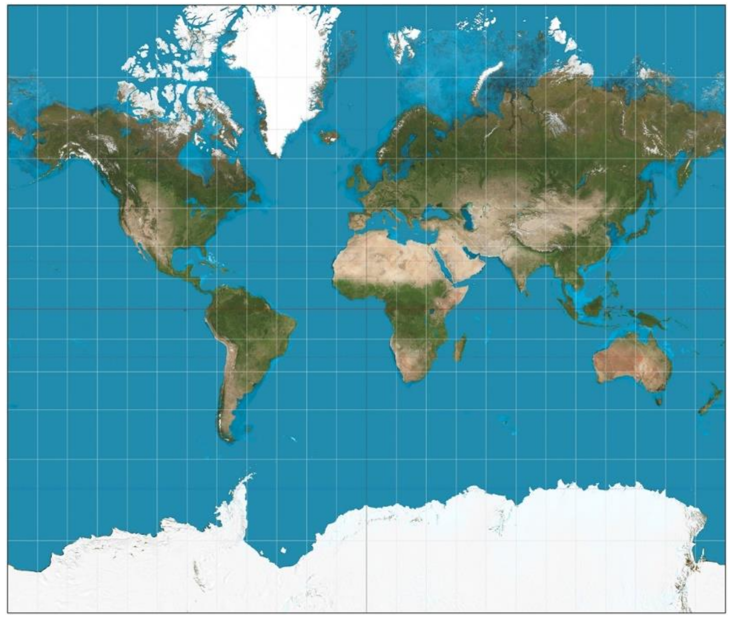
  - Spatial Fields
    - *Scalar Fields (one value per cell)*
      - *Isocontours*
      - *Direct Volume Rendering*



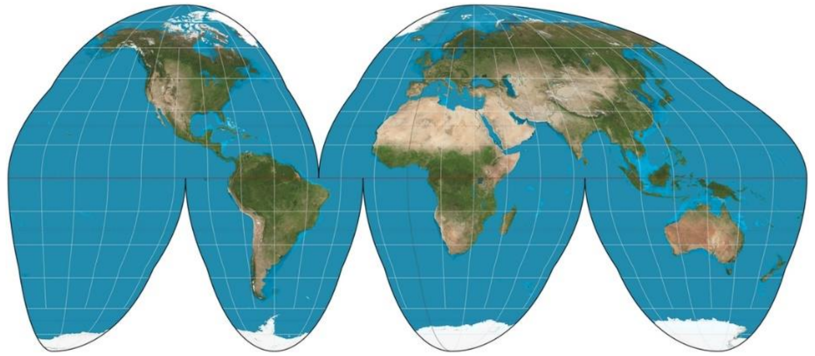
    - *Vector and Tensor Fields (many values per cell)*
      - *Flow Glyphs (local)*
      - *Geometric (sparse seeds)*
      - *Textures (dense seeds)*
      - *Features (globally derived)*



- Projection

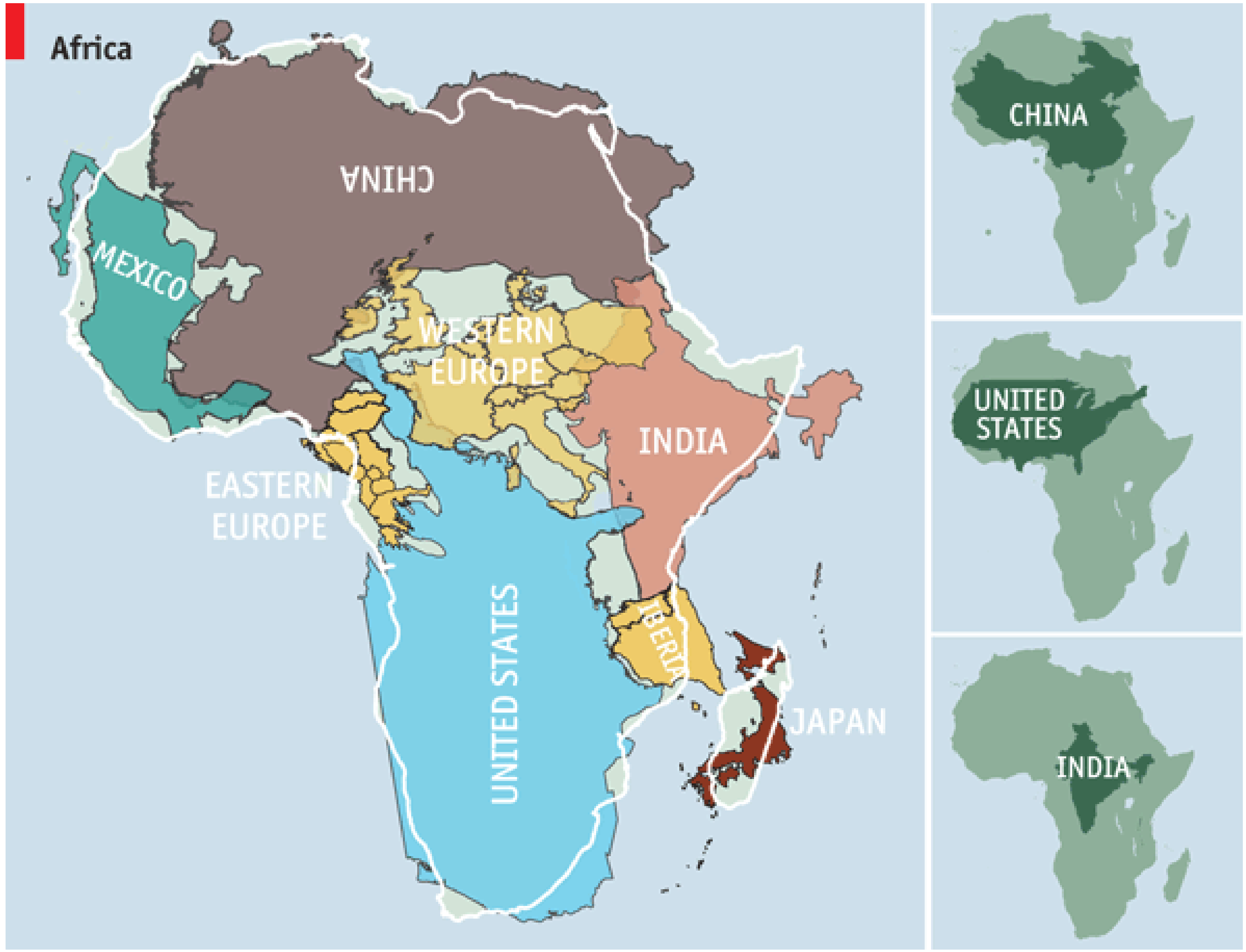


Mercator projection



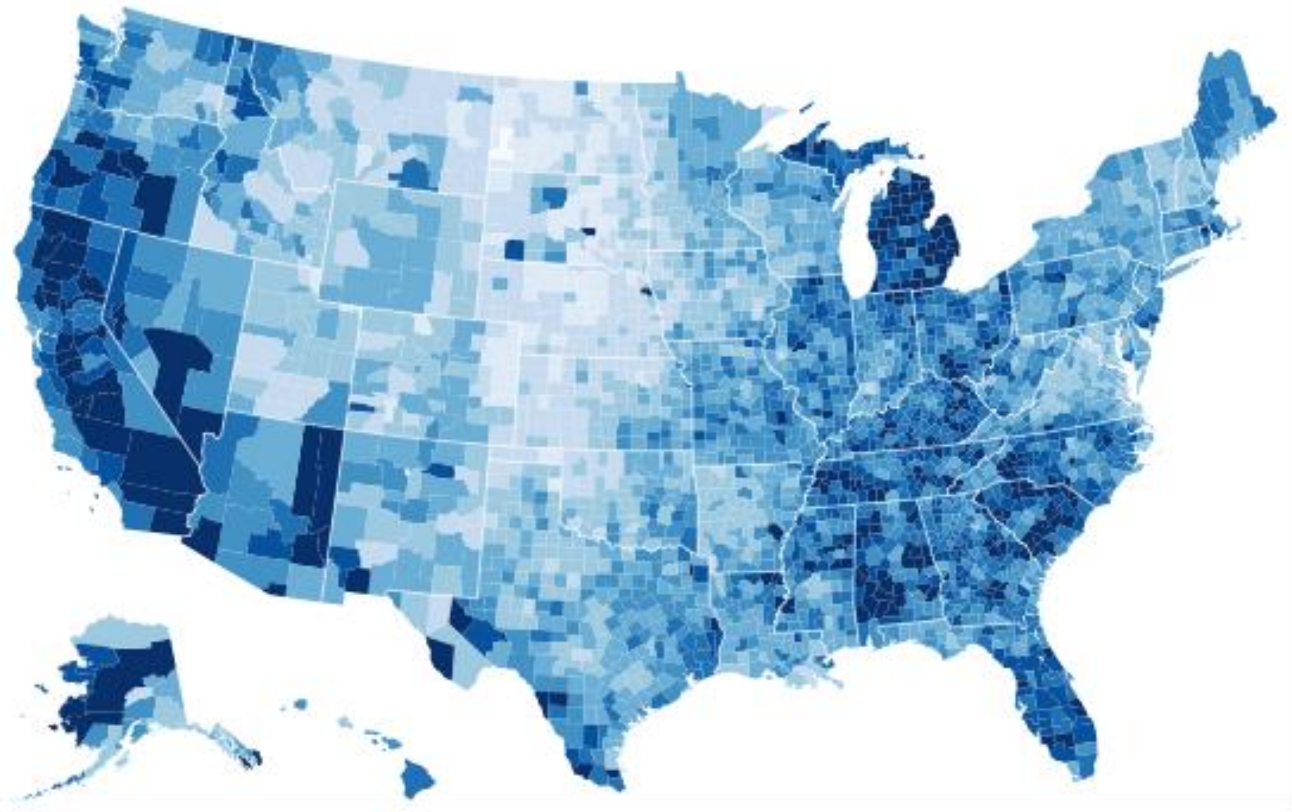
Goode’s projection

Distortion



Idiom: **choropleth map**

- *use* given spatial data
  - –when central task is understanding spatial relationships
- data
  - –geographic geometry
  - –table with 1 quant attribute per region
- encoding
  - –use given geometry for area mark boundaries
  - –sequential segmented colormap *[more later]*

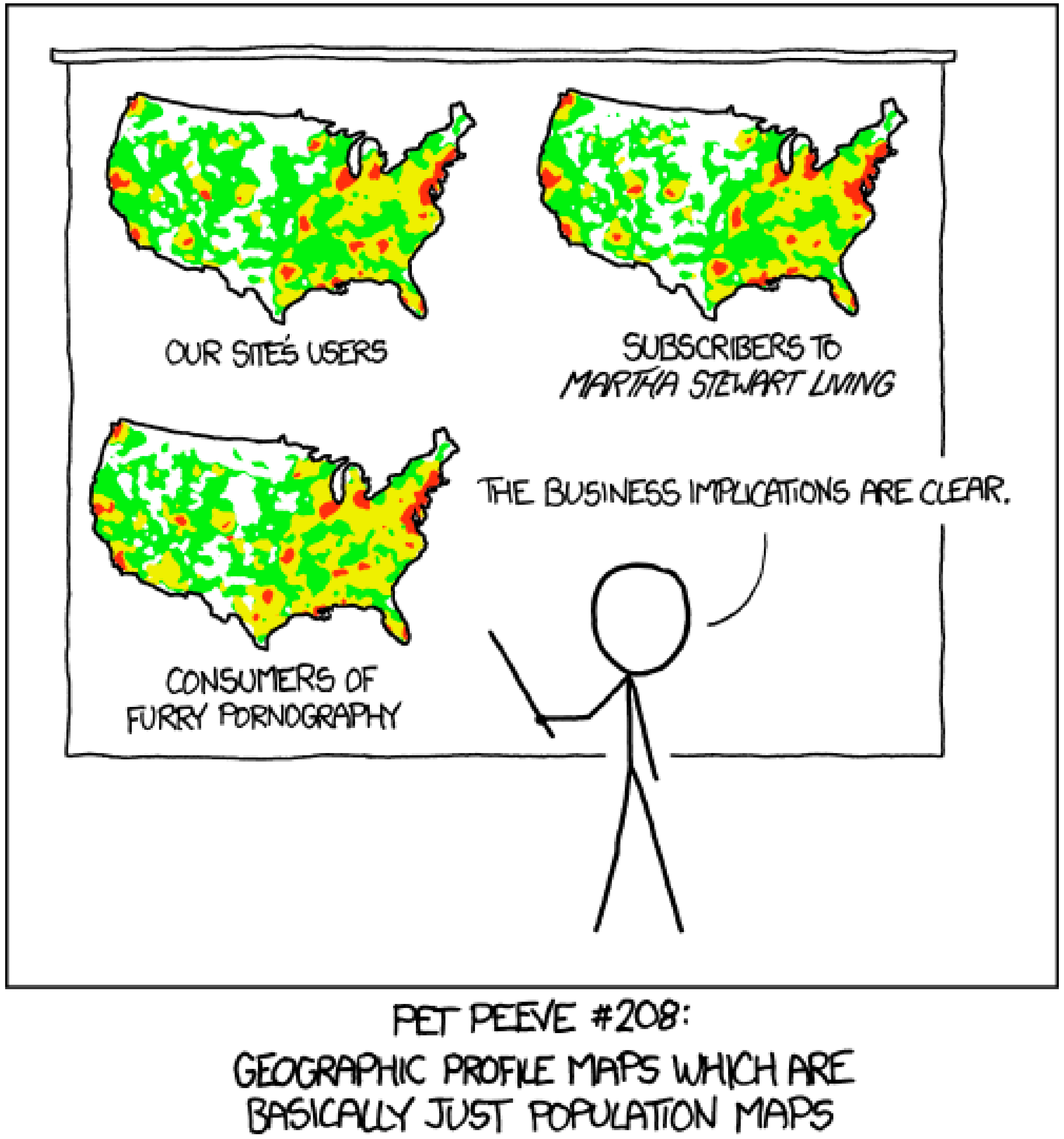


Unemployment rate by county, August 2016

http://bl.ocks.org/mbostock/4060606

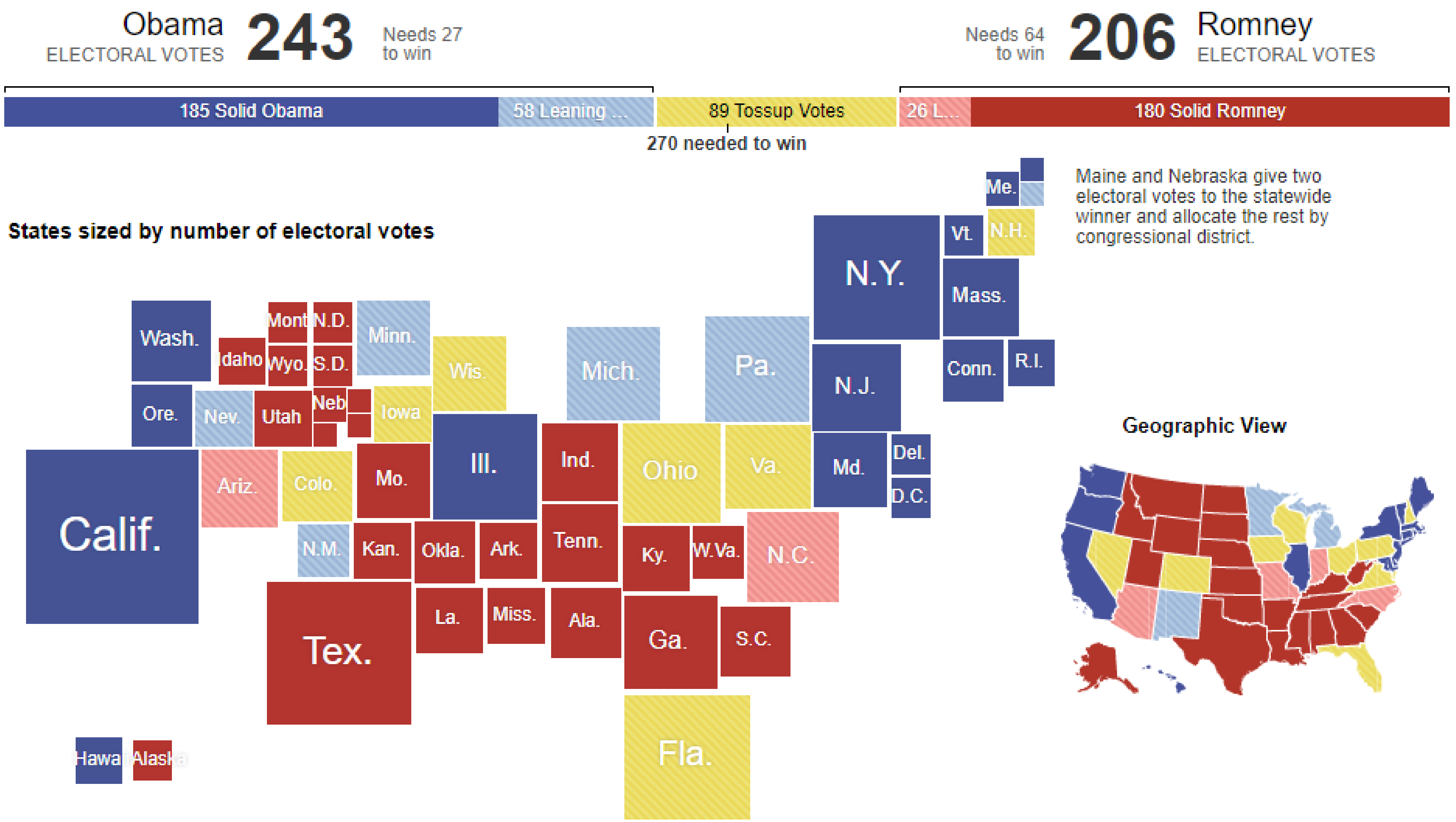
Beware: Population maps trickiness!

- beware!
- absolute vs relative again
  - population density vs per capita
- investigate with Ben Jones Tableau Public demo
  - [Are Maps of Financial Variables just Population Maps?]()
  - yes, unless you look at per capita (relative) numbers



[https://xkcd.com/1138]

Cartograms (示意地圖，又稱比較統計地圖)



[A New York Times assessment of how states may vote in 2012.]()

Spatial Field

- Scalar field
  - Slice
  - Isoline/isosurface
  - Direct volume rendering

- Vector and Tensor field

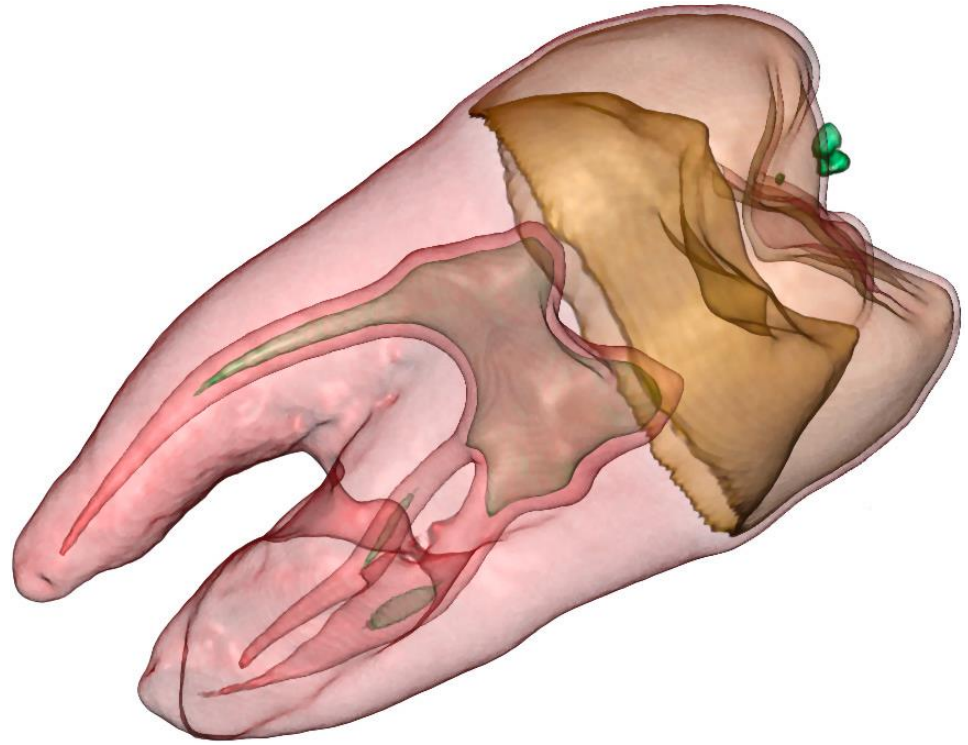
Idiom: **topographic map**

- data
  - –geographic geometry
  - –scalar spatial field
    - 1 quant attribute per grid cell
- derived data
  - –isoline geometry
    - isocontours computed for specific levels of scalar values

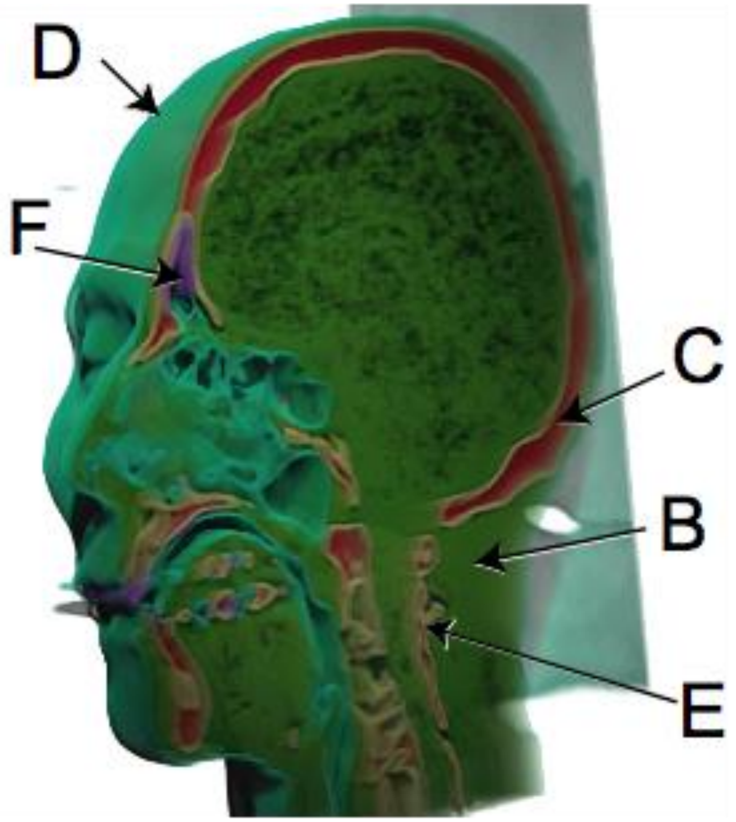
[Land Information New Zealand Data Service]

Idioms: **isosurfaces, direct volume rendering**

- data
  - scalar spatial field
    - 1 quant attribute per grid cell
- task
  - shape understanding, spatial relationships
- isosurface
  - derived data: isocontours computed for specific levels of scalar values
- direct volume rendering
  - transfer function maps scalar values to color, opacity
    - no derived geometry



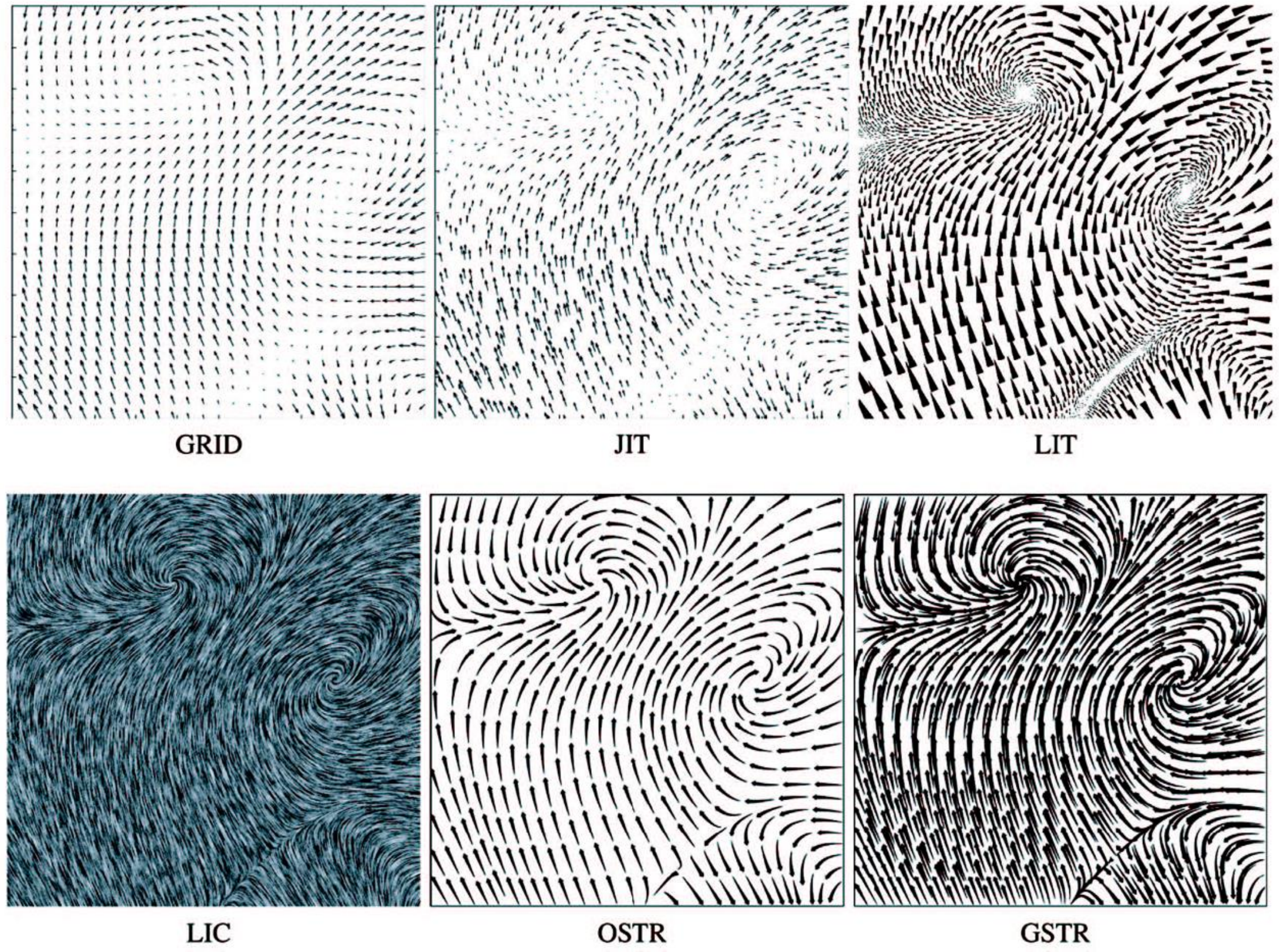
[Interactive Volume Rendering Techniques. Kniss. Master's thesis, University of Utah Computer Science, 2002.]



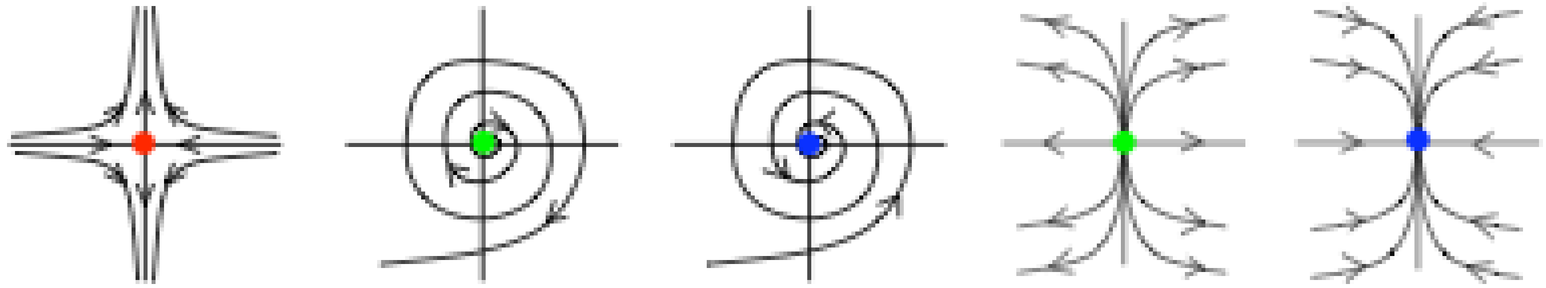
[Multidimensional Transfer Functions for Volume Rendering. Kniss, Kindlmann, and Hansen. In The Visualization Handbook, edited by Charles Hansen and Christopher Johnson, pp. 189–210. Elsevier, 2005.]

Vector and tensor fields

- data
  - –many attribs per cell
- idiom families
  - –flow glyphs
    - purely local
  - –geometric flow
    - derived data from tracing particle trajectories
    - sparse set of seed points
  - –texture flow
    - derived data, dense seeds
  - –feature flow
    - global computation to detect features
      - –encoded with one of methods above



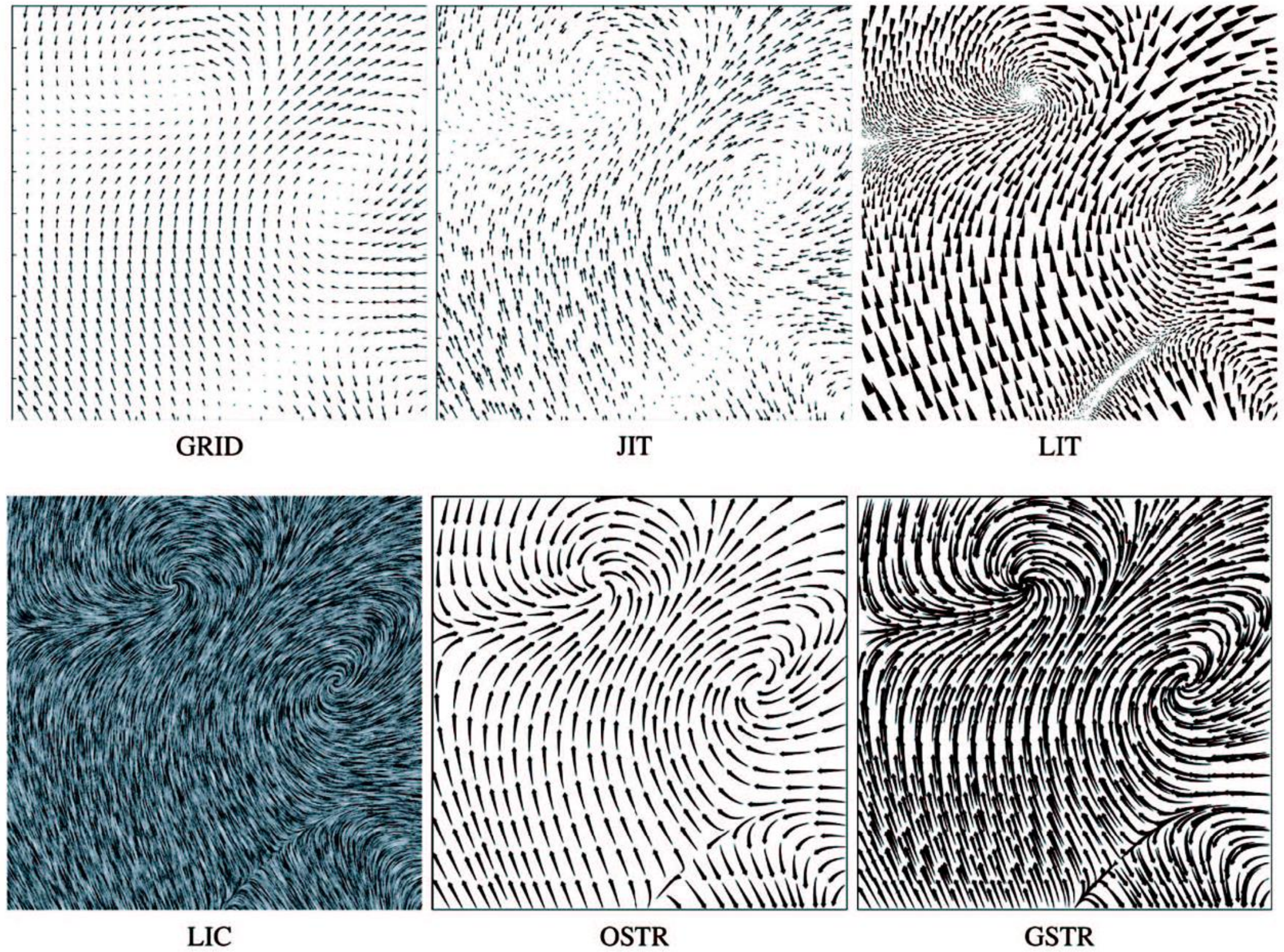
[Comparing 2D vector field visualization methods: A user study. Laidlaw et al. IEEE Trans. Visualization and Computer Graphics (TVCG) 11:1 (2005), 59–70.]



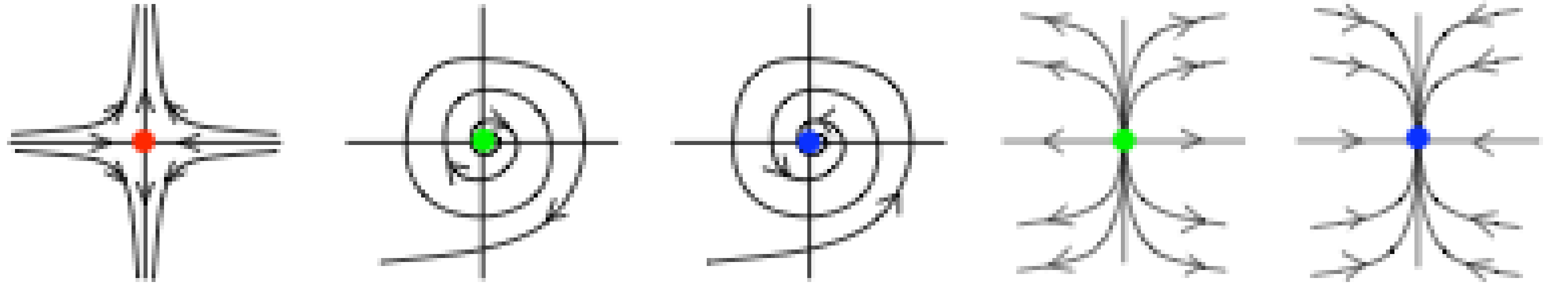
[Topology tracking for the visualization of time-dependent two-dimensional flows. Tricoche, Wischgoll, Scheuermann, and Hagen. Computers & Graphics 26:2 (2002), 249–257.]

Vector fields

- empirical study tasks
  - –finding critical points, identifying their types
  - –identifying what type of critical point is at a specific location
  - –predicting where a particle starting at a specified point will end up (advection)



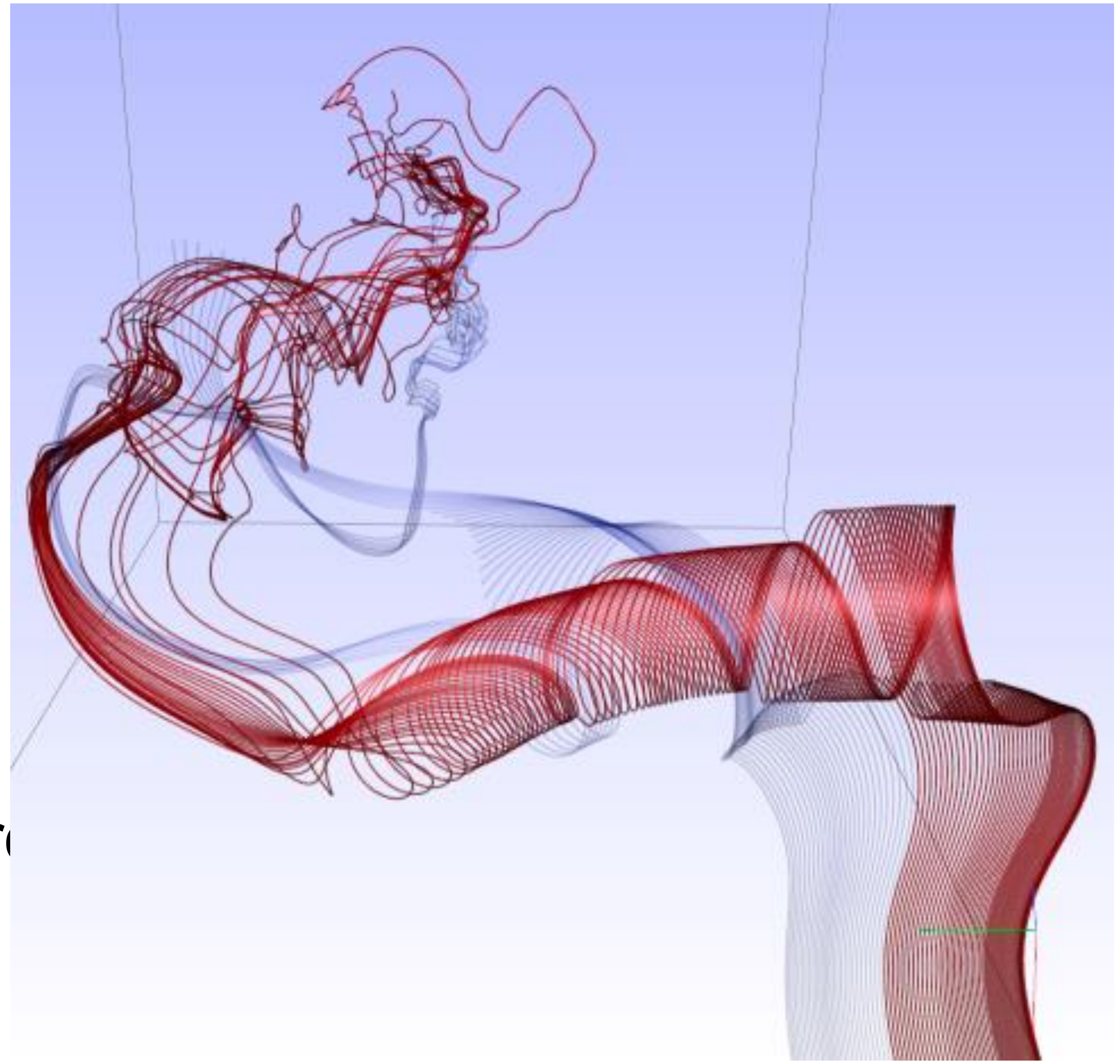
[Comparing 2D vector field visualization methods: A user study. Laidlaw et al. IEEE Trans. Visualization and Computer Graphics (TVCG) 11:1 (2005), 59–70.]



[Topology tracking for the visualization of time-dependent two-dimensional flows. Tricoche, Wischgoll, Scheuermann, and Hagen. Computers & Graphics 26:2 (2002), 249–257.]

Idiom: **similarity-clustered streamlines**

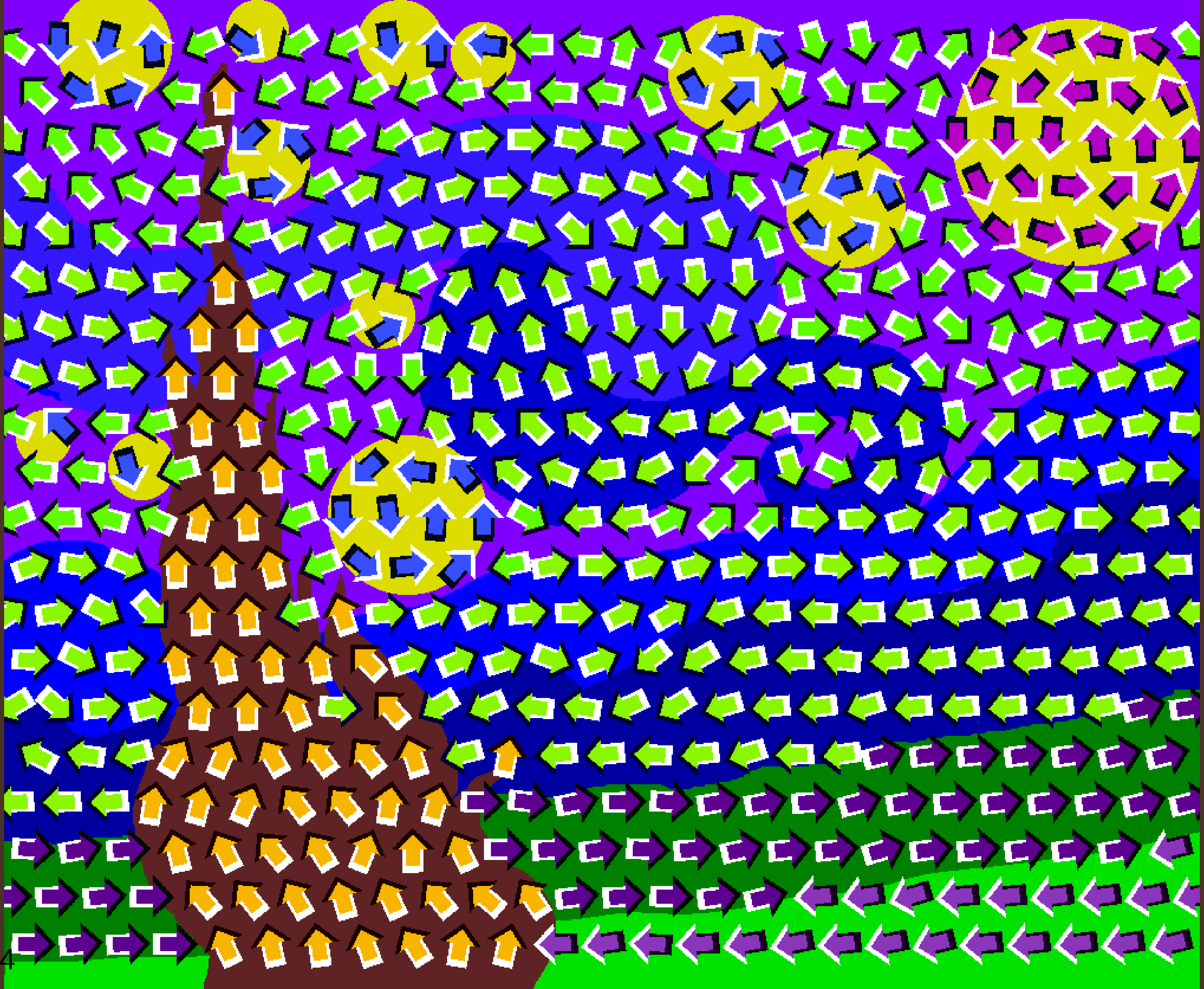
- data
  - –3D vector field
- derived data (from field)
  - –streamlines: trajectory particle will follow
- derived data (per streamline)
  - –curvature, torsion, tortuosity
  - –signature: complex weighted combination
  - –compute cluster hierarchy across all signatur
  - –encode: color and opacity by cluster
- tasks
  - –find features, query shape
- scalability
  - –millions of samples, hundreds of streamlines

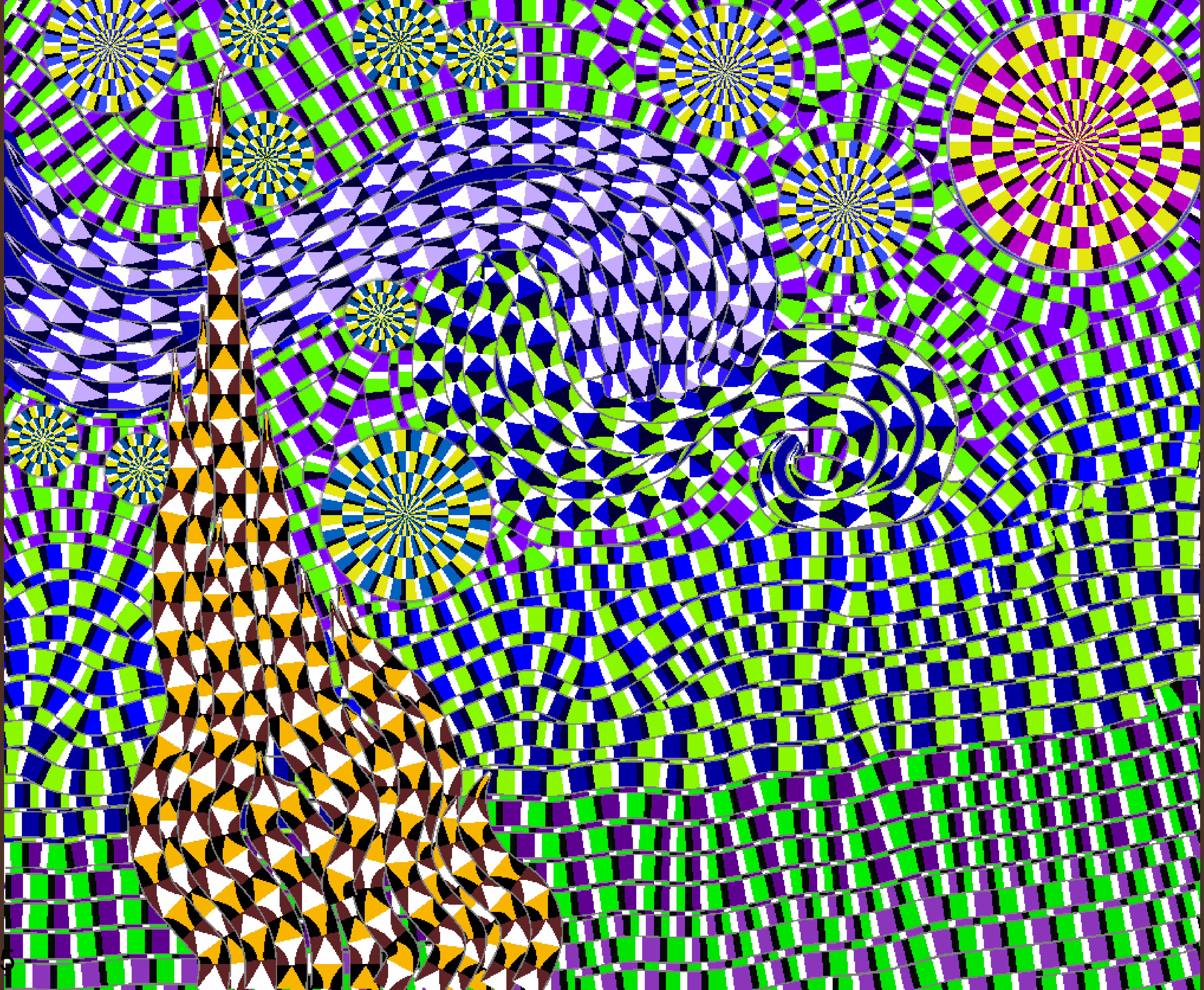


[Similarity Measures for Enhancing Interactive Streamline Seeding. McLoughlin,. Jones, Laramee, Malki, Masters, and. Hansen. IEEE Trans. Visualization and Computer Graphics 19:8 (2013), 1342–1353.]

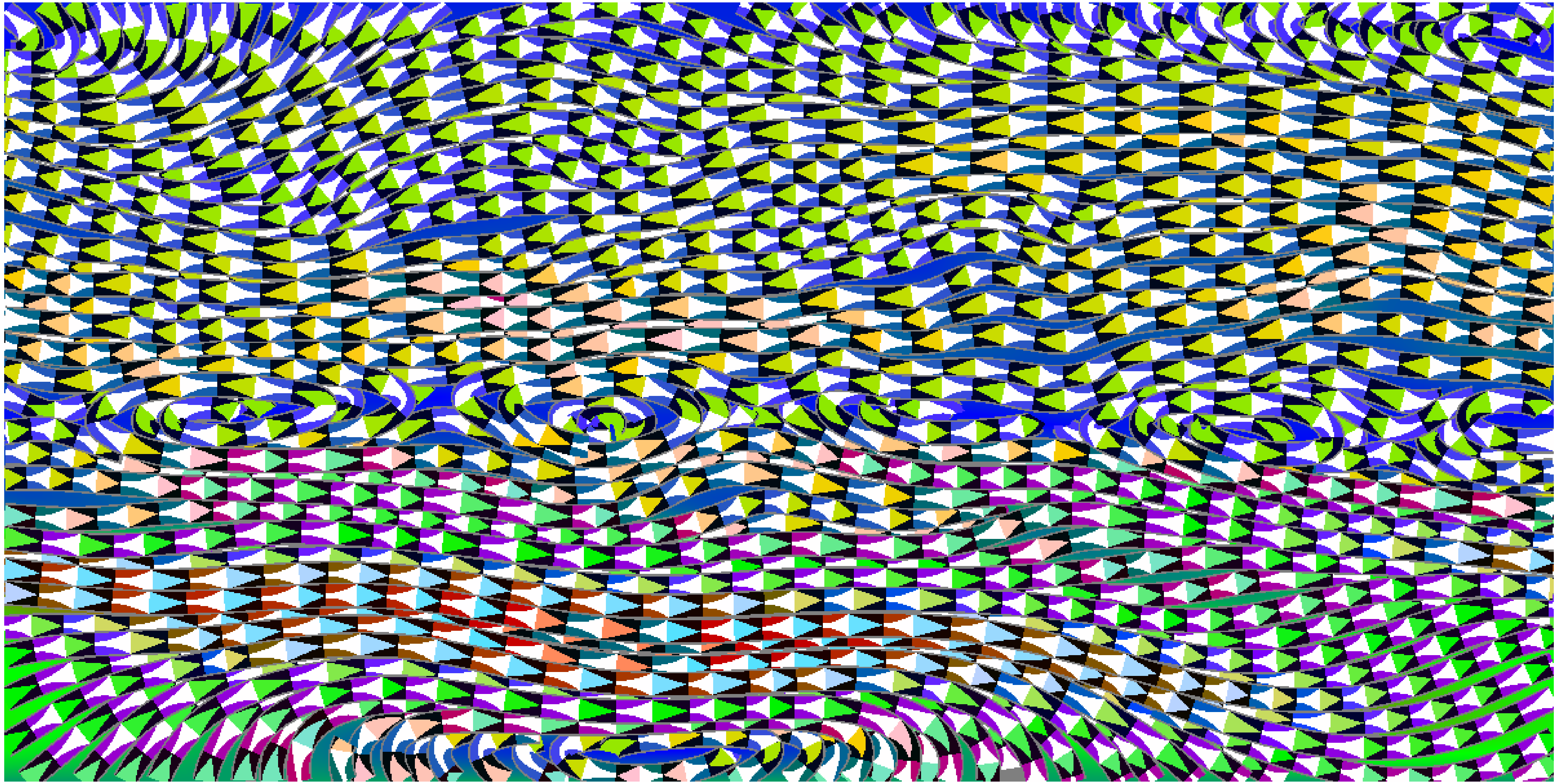
Starry Night with Motion Illusion

Region Map





More RAP Shapes



Further reading

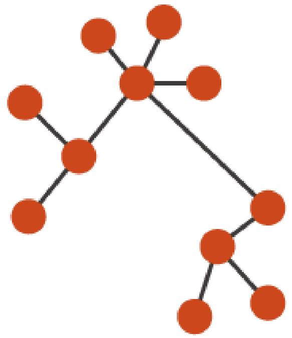
- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - *Chap 8: Arrange Spatial Data*
- How Maps Work: Representation, Visualization, and Design. MacEachren. Guilford Press, 1995.
- Overview of visualization. Schroeder and. Martin. In The Visualization Handbook, edited by Charles Hansen and Christopher Johnson, pp. 3–39. Elsevier, 2005.
- Real-Time Volume Graphics. Engel, Hadwiger, Kniss, Reza-Salama, and Weiskopf. AK Peters, 2006.
- Overview of flow visualization. Weiskopf and Erlebacher. In The Visualization Handbook, edited by Charles Hansen and Christopher Johnson, pp. 261–278. Elsevier, 2005.

Arrange Networks and Trees

Arrange networks and trees

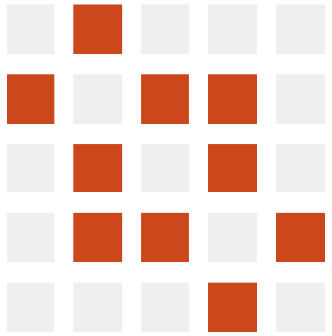
Node–Link Diagrams
Connection Marks

✔ NETWORKS ✔ TREES



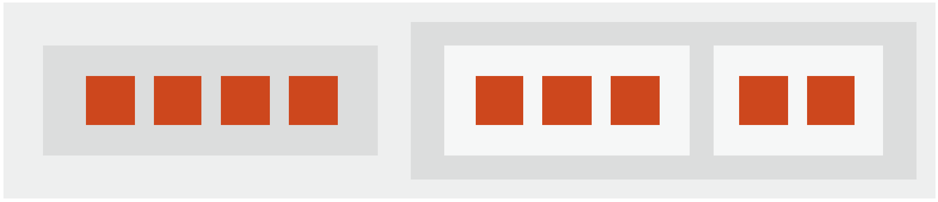
Adjacency Matrix
Derived Table

✔ NETWORKS ✔ TREES

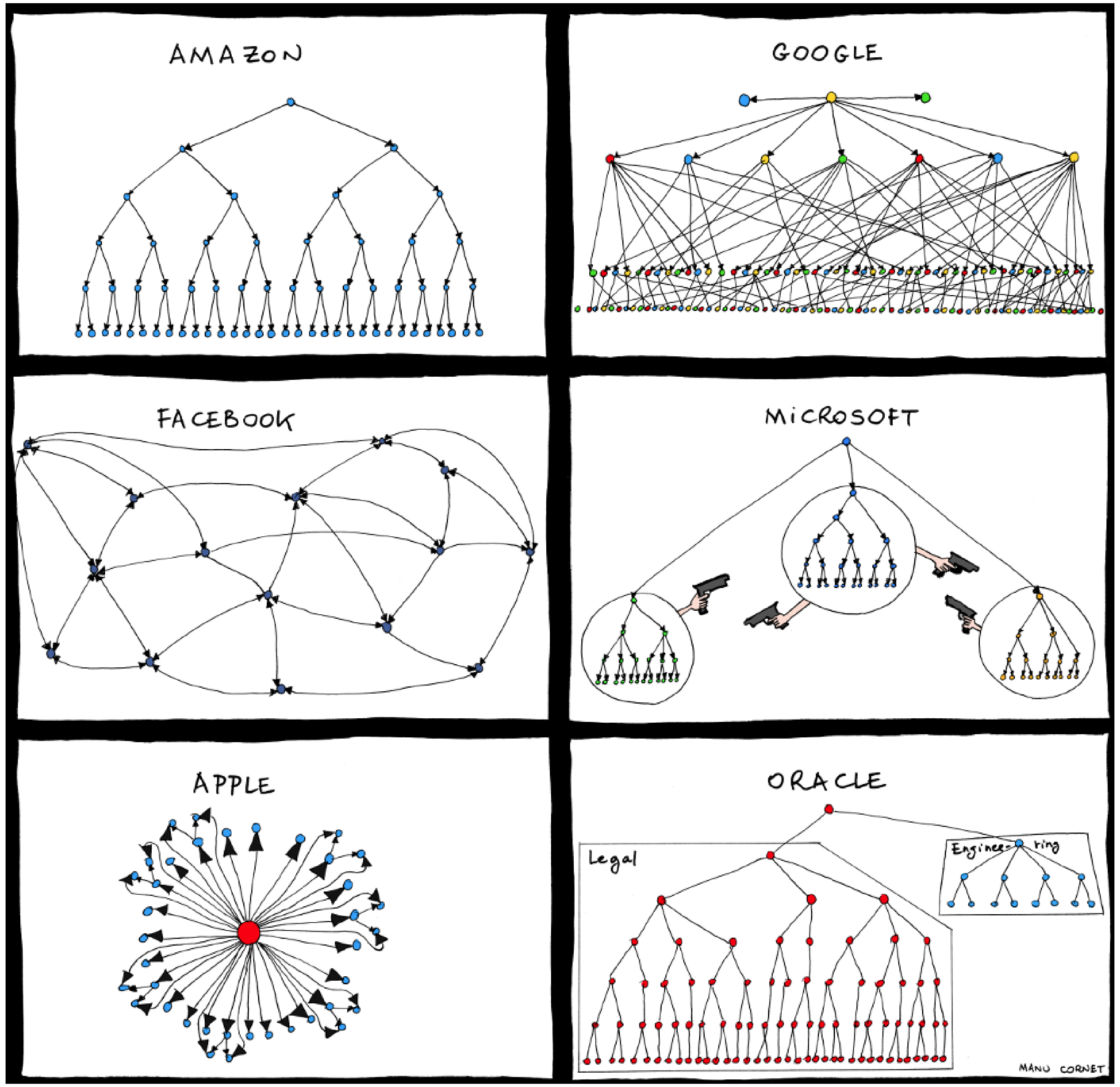


Enclosure
Containment Marks

✖ NETWORKS ✔ TREES



Organization

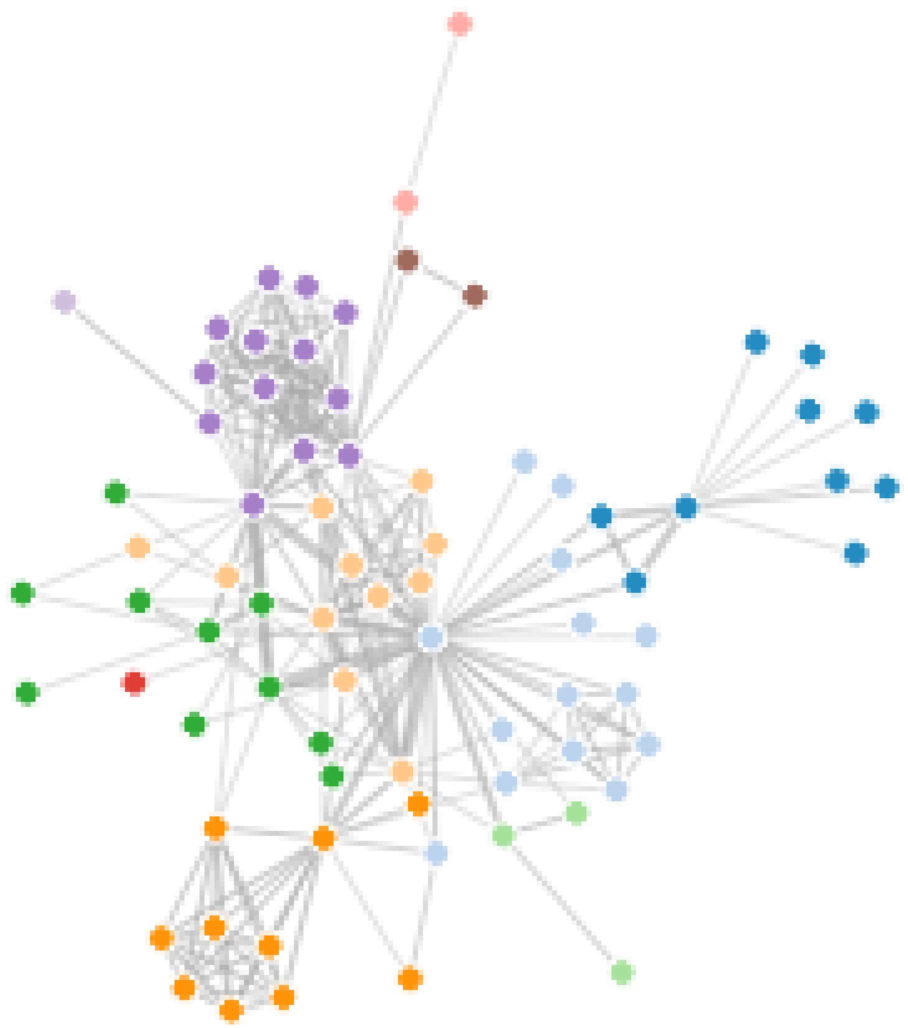


http://www.bonkersworld.net/organizational-charts/

2011 version

Idiom: **force-directed placement**

- visual encoding
  - –link connection marks, node point marks
- considerations
  - –spatial position: no meaning directly encoded
    - left free to minimize crossings
  - –proximity semantics?
    - sometimes meaningful
    - sometimes arbitrary, artifact of layout algorithm
    - tension with length
      - –long edges more visually salient than short
- tasks
  - –explore topology; locate paths, clusters
- scalability
  - –node/edge density E < 4N

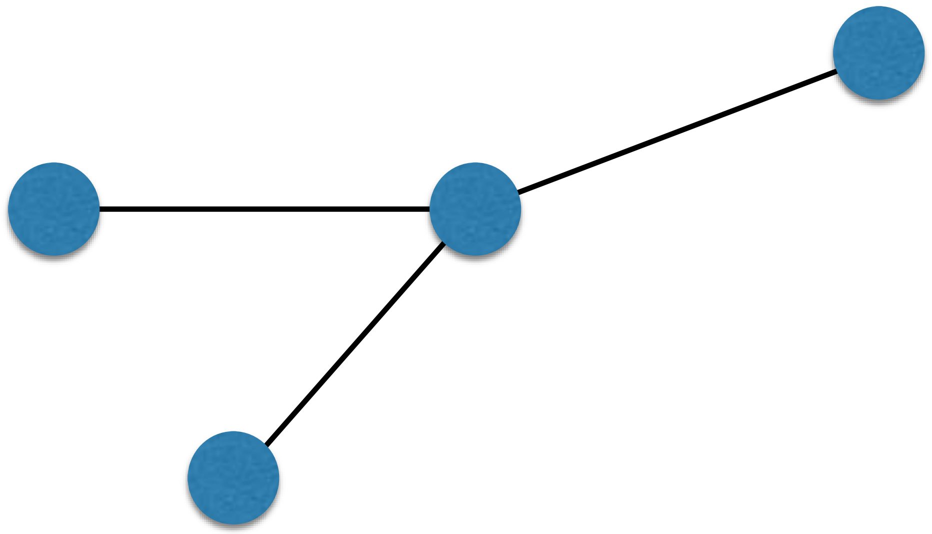


[character co-occurence in *Les Misérables*](http://mbostock.github.com/d3/ex/force.html)

http://mbostock.github.com/d3/ex/force.html

A heuristic for graph drawing [1984]

- *Spring force*
  - $F_{spring} = c_1 \log(\frac{d}{c_2})$
    - *force = 0, when* $d = c_2$
- *Repel force for non-adjacent vertex*
  - $F_{repeling} = c_3/d^2$
- *Move*
  - $c_4 F_{total}$



```
Spring (G: graph)
-------------------------------
Place vertices of G in random locations;

Repeat M times
    calculate the force on each vertex;
    move the vertex;

Draw the graph;
```

Force-Directed Graph

- **Fruchterman and Reingold[1991]**

Even vertex distribution $$\boldsymbol{k} = \sqrt{\frac{\boldsymbol{area}}{\boldsymbol{number\ of\ vertices}}}$$

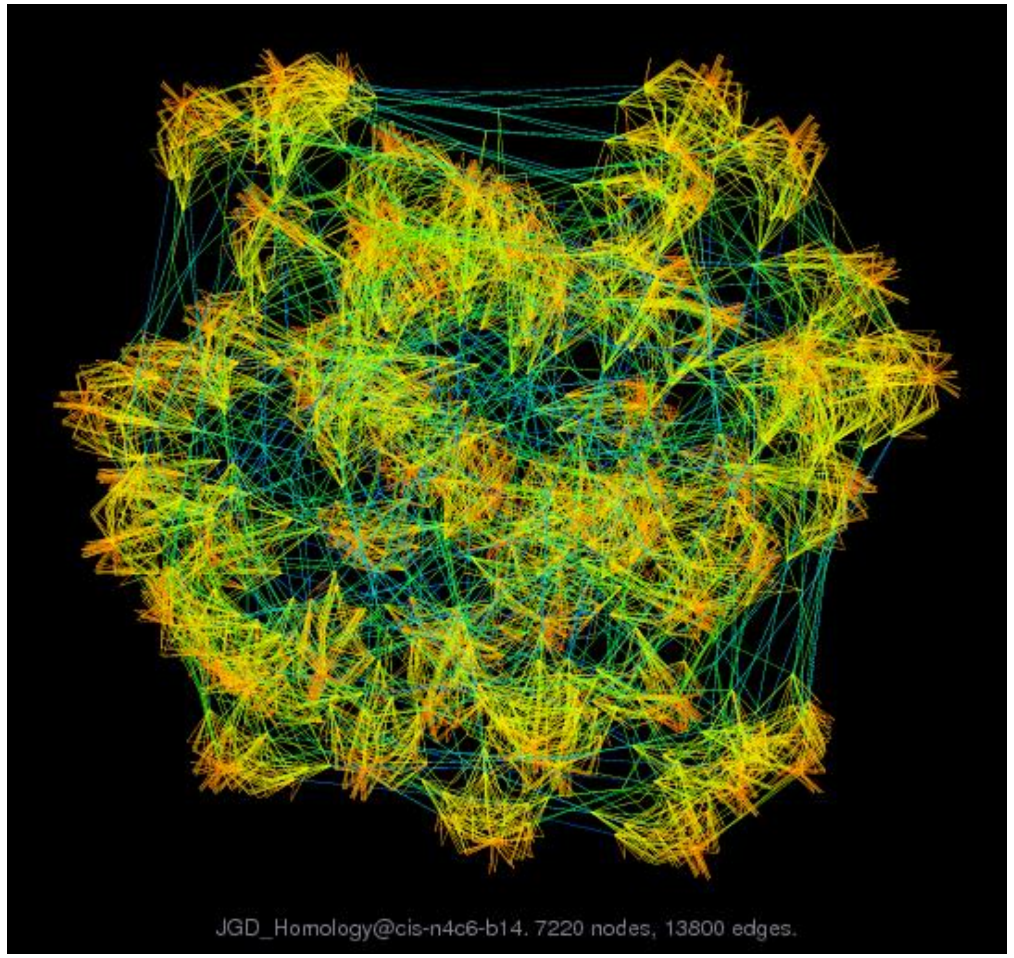
$\Delta = \boldsymbol{v.pos} - \boldsymbol{u.pos},$ ***for each node u, v***

attractive $$\boldsymbol{f_a}(\Delta) = \frac{\Delta^2}{\boldsymbol{k}}$$

repulsive $$\boldsymbol{f_r}(\Delta) = \frac{\boldsymbol{k}^2}{\Delta}$$

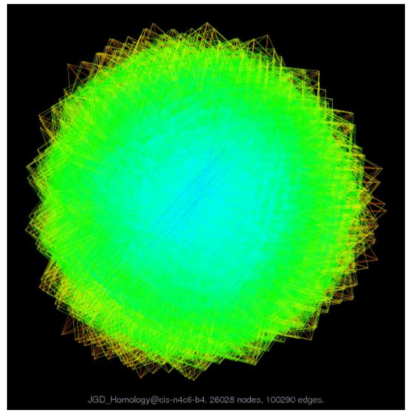
Idiom: **sfdp** (multi-level scalable force-directed placement)

- data
  - original: network
  - derived: cluster hierarchy atop it
- considerations
  - better algorithm for same encoding technique
    - same: fundamental use of space
    - hierarchy used for algorithm speed/quality but not shown explicitly
- scalability
  - nodes, edges: 1K-10K
  - hairball problem eventually hits



7,220 nodes and 13,800 edges

[Efficient and high quality force-directed graph drawing. Hu. The Mathematica Journal 10:37–71, 2005.]

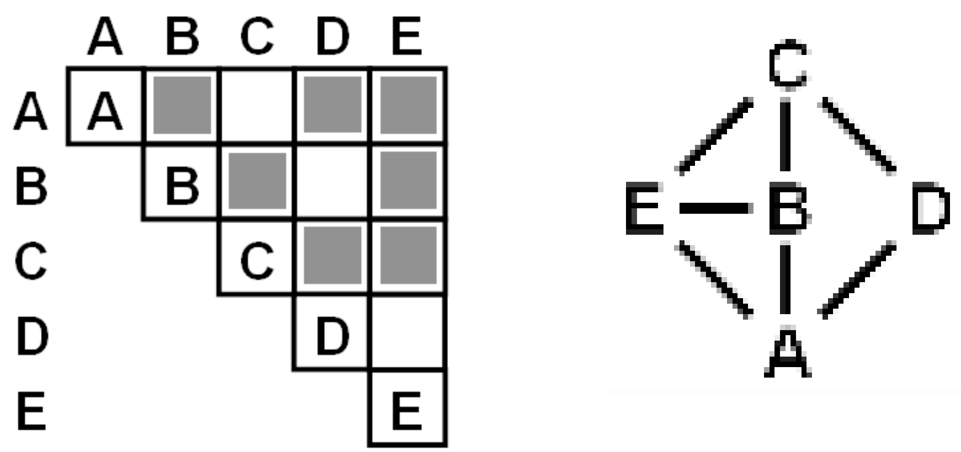


26,020 nodes and 100,290 edges

http://www.research.att.com/yifanhu/GALLERY/GRAPHS/index1.html

Idiom: **adjacency matrix view**

- data: network
  - –transform into same data/encoding as heatmap
- derived data: table from network
  - –1 quant attrib
    - weighted edge between nodes
  - –2 categ attribs: node list x 2
- visual encoding
  - –cell shows presence/absence of edge
- scalability
  - –1K nodes, 1M edges

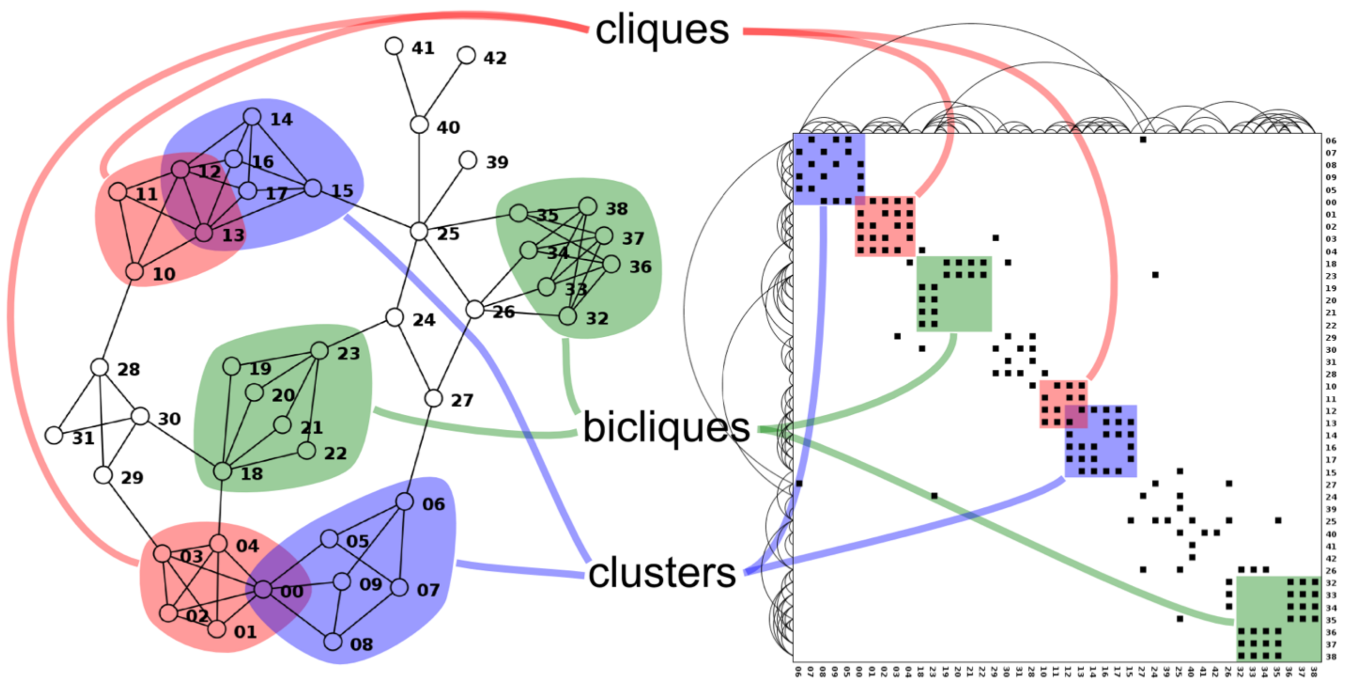


[NodeTrix: a Hybrid Visualization of Social Networks. Henry, Fekete, and McGuffin. IEEE TVCG (Proc. InfoVis) 13(6):1302-1309, 2007.]

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

Connection vs. adjacency comparison

- adjacency matrix strengths
  - –predictability, scalability, supports reorderi
  - –some topology tasks trainable
- node-link diagram strengths
  - –topology understanding, path tracing
  - –intuitive, no training needed
- empirical study
  - –node-link best for small networks
  - –matrix best for large networks
    - if tasks don't involve topological structure!

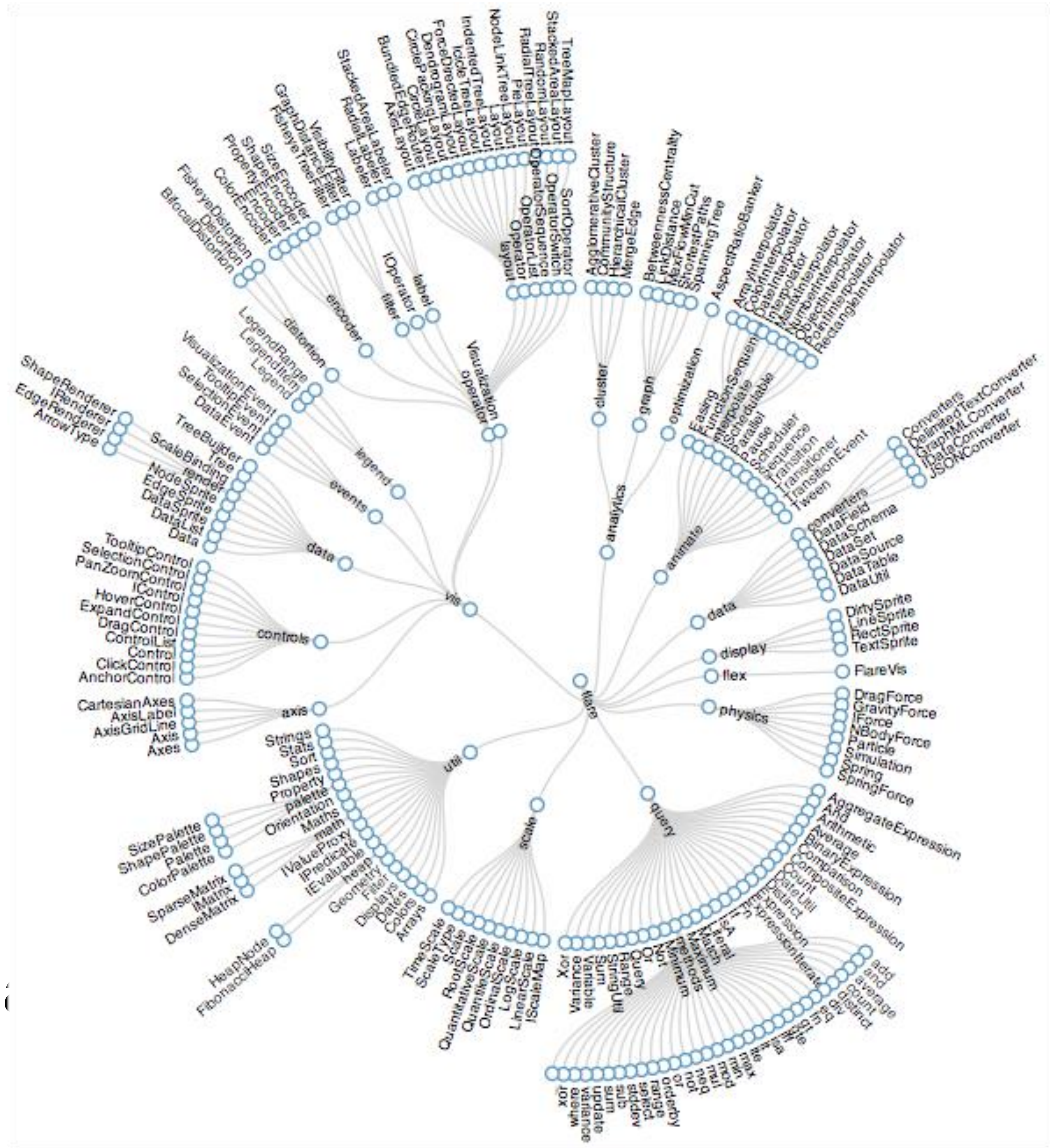


http://www.michaelmcguffin.com/courses/vis/patternsInAdjacencyMatrix.png

[On the readability of graphs using node-link and matrix-based representations: a controlled experiment and statistical analysis. Ghoniem, Fekete, and Castagliola. Information Visualization 4:2 (2005), 114–135.]

Idiom: **radial node-link tree**

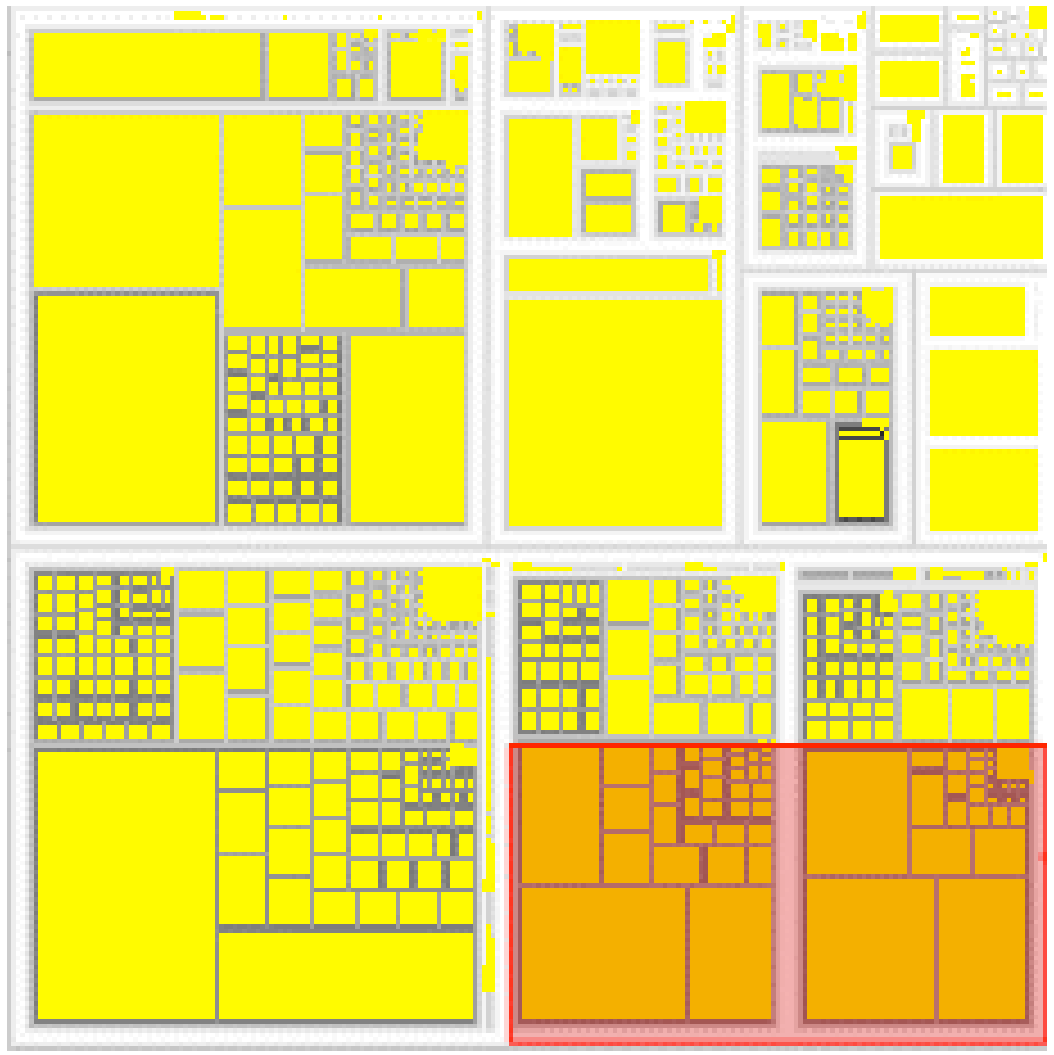
- data
  - –tree
- encoding
  - –link connection marks
  - –point node marks
  - –radial axis orientation
    - angular proximity: siblings
    - distance from center: depth in tree
- tasks
  - –understanding topology, following pa
- scalability
  - –1K - 10K nodes



http://mbostock.github.com/d3/ex/tree.html

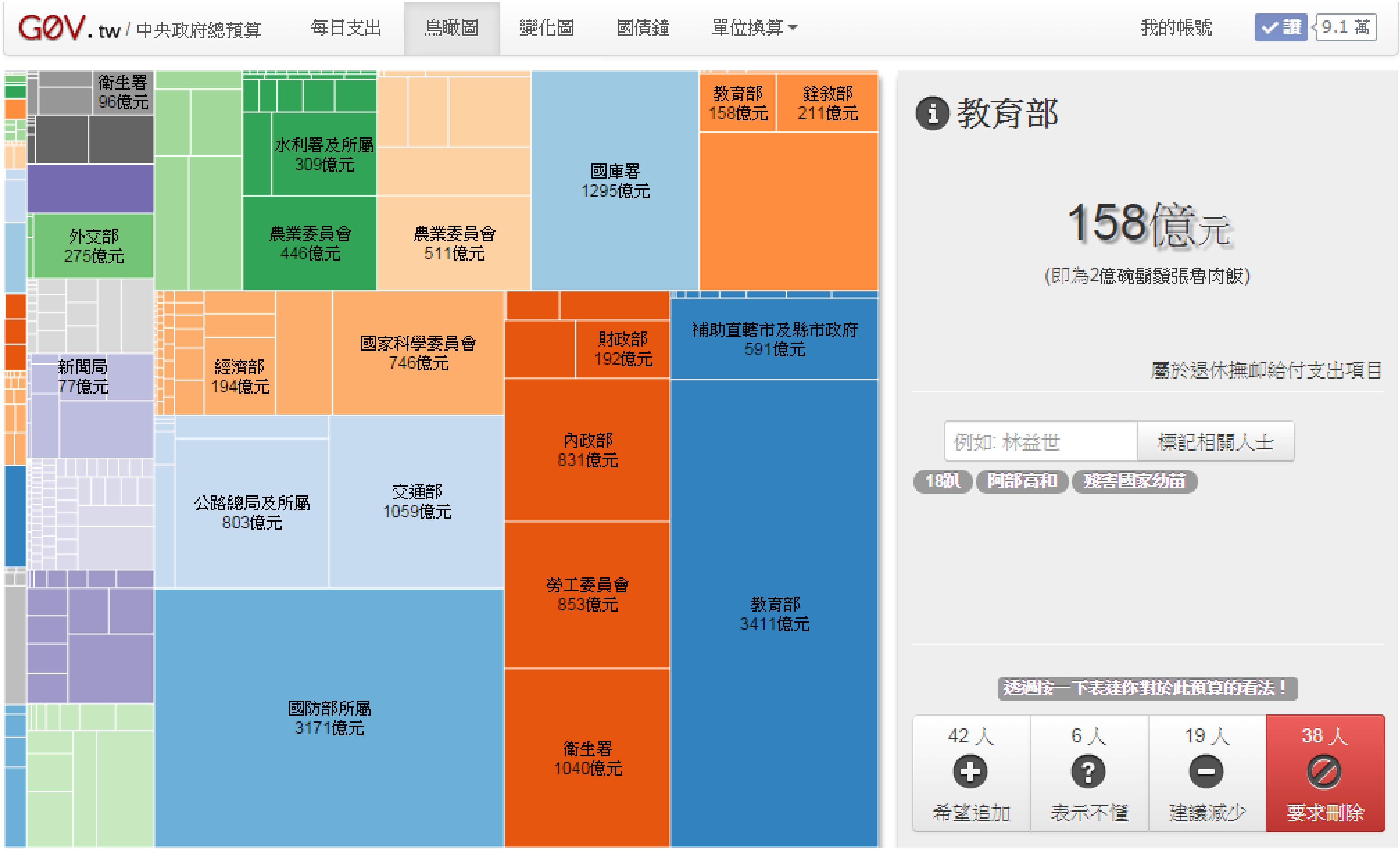
Idiom: **treemap**

- data
  - –tree
  - –1 quant attrib at leaf nodes
- encoding
  - –area containment marks for hierarchical structure
  - –rectilinear orientation
  - –size encodes quant attrib
- tasks
  - –query attribute at leaf nodes
- scalability
  - –1M leaf nodes



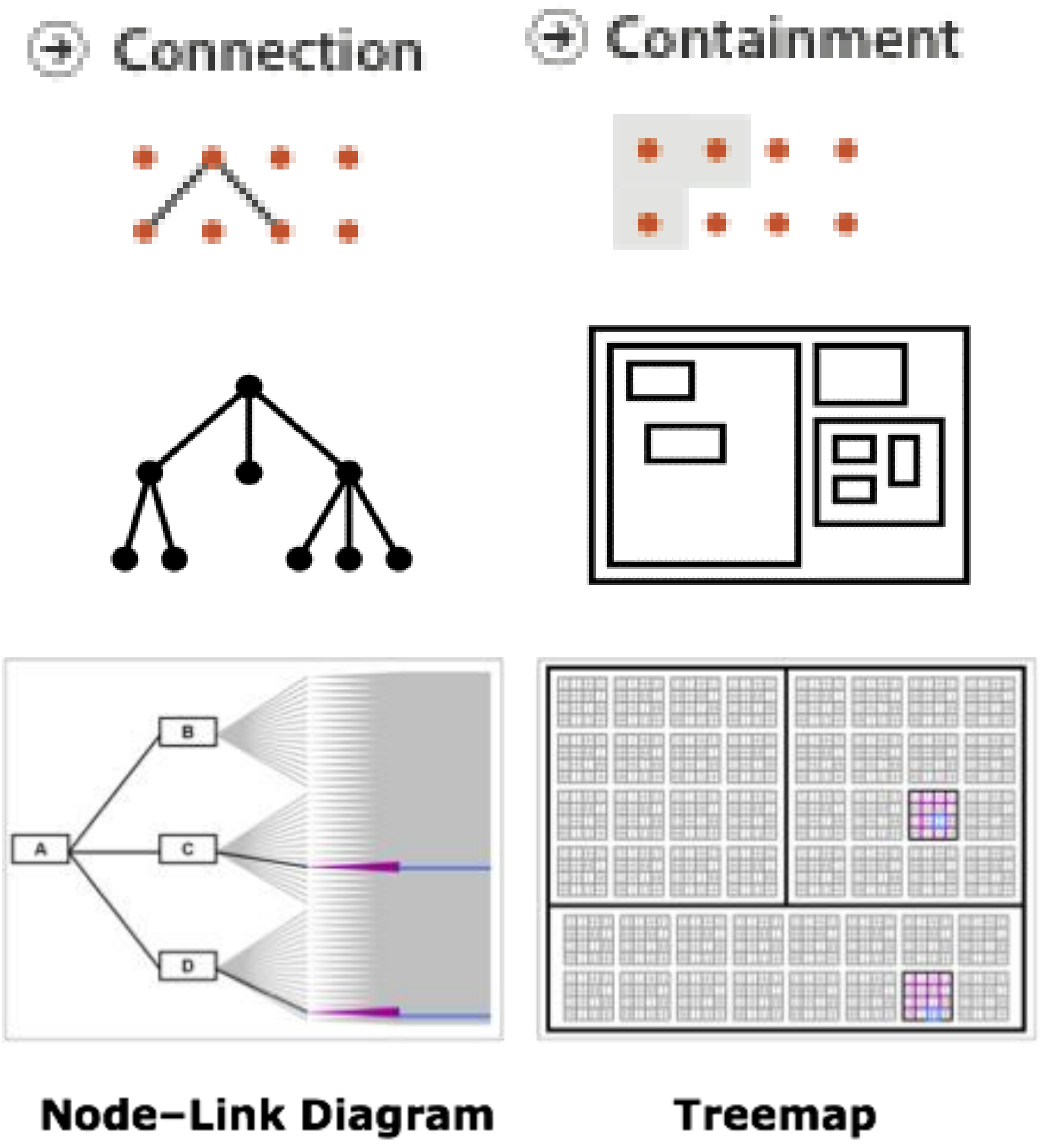
http://tulip.labri.fr/Documentation/3_7/userHandbook/html/ch06.html

g0v 中央政府總預算


G0V.tw / 中央政府總預算
每日支出
鳥瞰圖
變化圖
國債鐘
單位換算
我的帳號
9.1 萬
衛生署 96億元
水利署及所屬 309億元
國庫署 1295億元
教育部 158億元
銓敘部 211億元
外交部 275億元
農業委員會 446億元
農業委員會 511億元
國家科學委員會 746億元
財政部 192億元
補助直轄市及縣市政府 591億元
新聞局 77億元
經濟部 194億元
內政部 831億元
公路總局及所屬 803億元
交通部 1059億元
勞工委員會 853億元
教育部 3411億元
國防部所屬 3171億元
衛生署 1040億元
教育部
158億元
(即為2億碗鬍鬚張魯肉飯)
屬於退休撫卹給付支出項目
例如: 林益世
標記相關人士
42 人
希望追加
6 人
表示不懂
19 人
建議減少
38 人
要求刪除

Link marks: Connection and containment

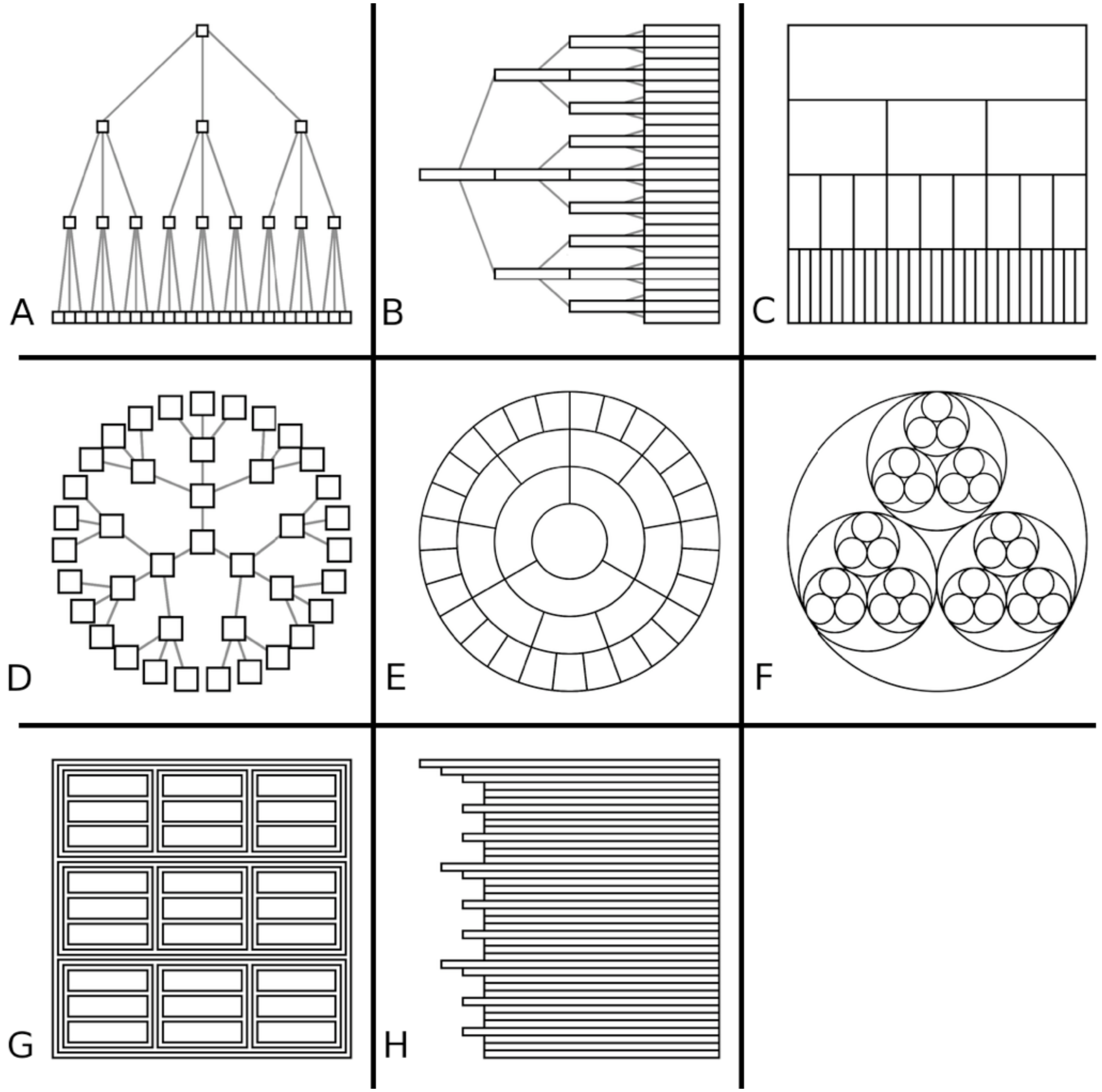
- marks as links (vs. nodes)
  - –common case in network drawing
  - –1D case: connection
    - ex: all node-link diagrams
    - emphasizes topology, path tracing
    - networks and trees
  - –2D case: containment
    - ex: all treemap variants
    - emphasizes attribute values at leaves (size coding)
    - only trees



[Elastic Hierarchies: Combining Treemaps and Node-Link Diagrams. Dong, McGuffin, and Chignell. Proc. InfoVis 2005, p. 57-64.]

Tree drawing idioms comparison

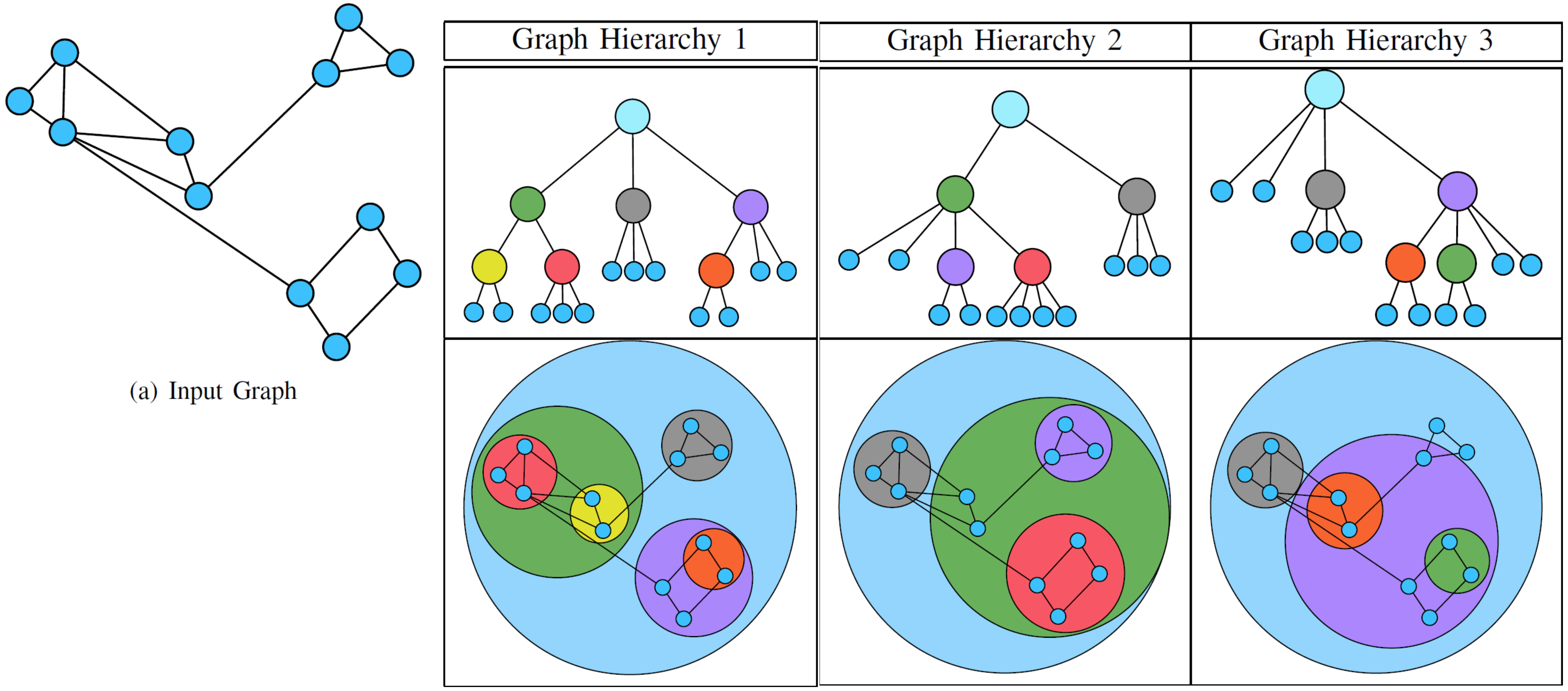
- data shown
  - link relationships
  - tree depth
  - sibling order
- design choices
  - connection vs containment link marks
  - rectilinear vs radial layout
  - spatial position channels
- considerations
  - redundant? arbitrary?
  - information density?
    - avoid wasting space



[Quantifying the Space-Efficiency of 2D Graphical Representations of Trees. McGuffin and Robert. Information Visualization 9:2 (2010), 115–140.]

GrouseFlocks: Steerable Exploration of Graph Hierarchy Space[2008]

- A Network + A tree
- Interactively explore and modify graph hierarchies.



Hierarchies in D3


Treemap

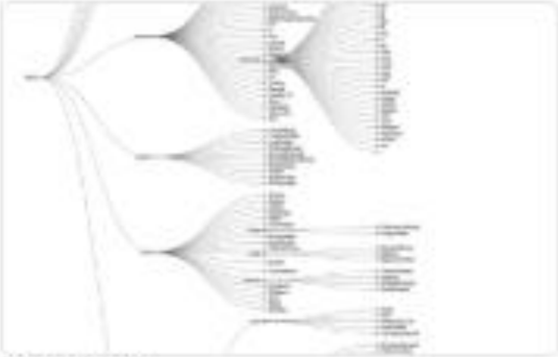

Cascaded treemap


Nested treemap

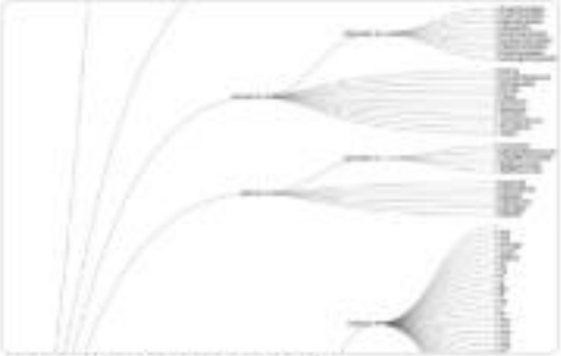

Circle packing


Circle packing (monochrome)


Indented tree


Tidy tree


Radial tidy tree


Cluster dendrogram

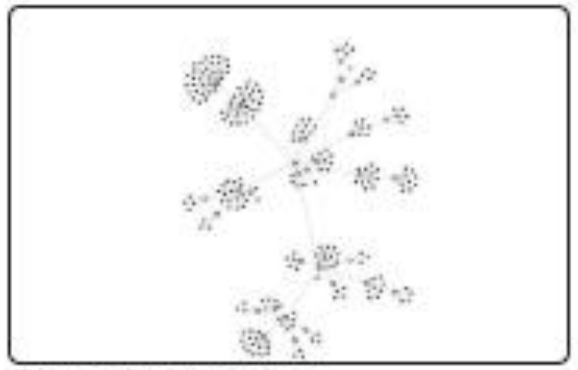

Radial dendrogram


Sunburst


Icicle

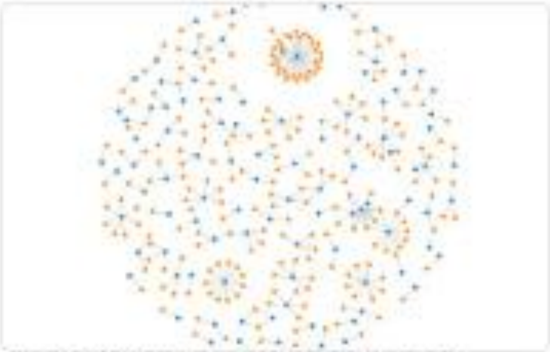

Tangled tree visualization


Phylogenetic tree


Force-directed tree

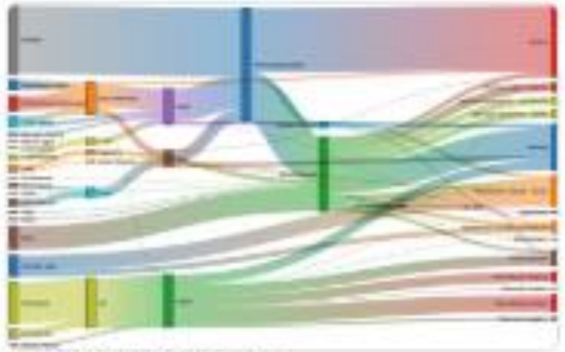
Networks in D3

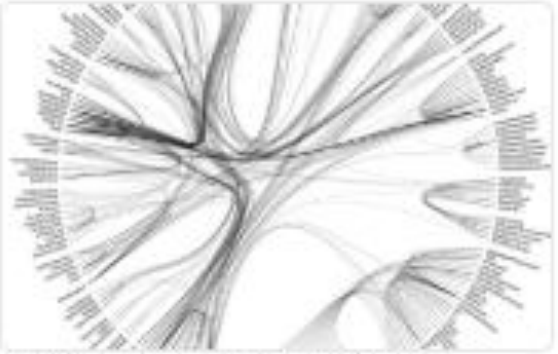

Force-directed graph


Disjoint force-directed graph


Mobile patent suits

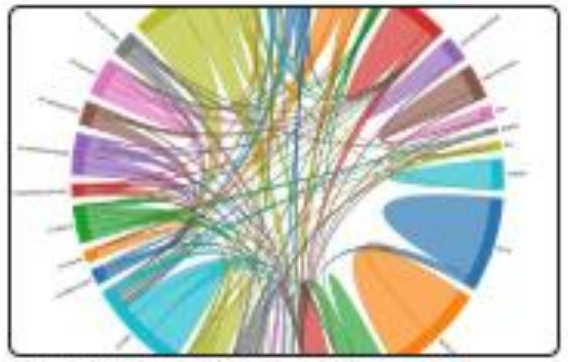

Arc diagram


Sankey diagram


Hierarchical edge bundling


Hierarchical edge bundling


Chord diagram


Chord dependency diagram

Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.
  - *Chap 9: Arrange Networks and Trees*
- Visual Analysis of Large Graphs: State-of-the-Art and Future Research Challenges. von Landesberger et al. Computer Graphics Forum 30:6 (2011), 1719–1749.
- Simple Algorithms for Network Visualization: A Tutorial. McGuffin. Tsinghua Science and Technology (Special Issue on Visualization and Computer Graphics) 17:4 (2012), 383–398.
- Drawing on Physical Analogies. Brandes. In Drawing Graphs: Methods and Models, LNCS Tutorial, 2025, edited by M. Kaufmann and D. Wagner, LNCS Tutorial, 2025, pp. 71–86. Springer-Verlag, 2001.
- http://www.treevis.net Treevis.net: A Tree Visualization Reference. Schulz. IEEE Computer Graphics and Applications 31:6 (2011), 11–15.
- Perceptual Guidelines for Creating Rectangular Treemaps. Kong, Heer, and Agrawala. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis) 16:6 (2010), 990–998.