Information Visualization
Spatial, NecklaceMaps, Myriahedral
Ex: Ballotmaps

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Week 8, 26 Oct 2022

https://www.cs.ubc.ca/~tmm/courses/547-22

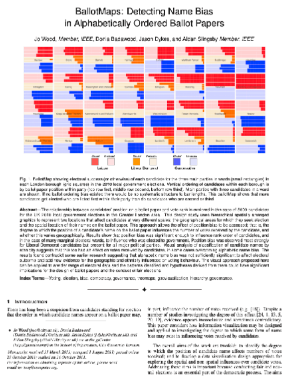
Plan for today

- small group exercises
  - Ballotmaps
- this week reading Q&A
  - chap: Spatial. papers: NecklaceMaps, Myriahedral [type: **algorithm**]
- week 6 reading Q&A
  - chap: Networks.
  - paper: Abyss-Explorer [type: **design study**]
  - paper: Geneaology [type: **technique**]
- week 7 reading Q&A
  - paper: Polaris/Tableau [type: **system**]
  - paper: D3 [type: **system**]
  - paper: Vega-Lite [type: **system**]

Next time

- reading
  - Ch 11, Manipulate View
  - Ch 12, Facet into Multiple Views
  - paper: Pattern-Driven Navigation in 2D Multiscale Visualizations with Scalable Insets [type: **technique**]

Ballotmaps: Design study paper



BallotMaps: Detecting name bias in alphabetically ordered ballot papers. Wood, Badawood, Dykes, and Slingsby. IEEE TVCG (Proc. InfoVis) 17(12):2384-2391, 2011.

http://openaccess.city.ac.uk/436/1/wood_ballotmaps_2011.pdf

PosAcross

- *To what extent does the position in the ballot affect the number of votes received by a candidate, overall? Is there variation across political party?*

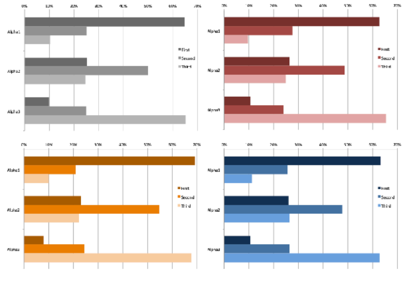


Fig. 5. Alpha position and vote order for, all candidates (gray); Labour candidates (red); Conservative (blue) and Liberal Democrat (orange). If no name order bias existed, all bars would be about the same length.

- Votes: 0-N
- Position_Overall: 1-9
- Party: 1-3 (Lab, LibDem, Cons)
- ***derived: Position_Within: 1-3***

[Fig 5. BallotMaps: Detecting name bias in alphabetically ordered ballot papers. Wood, Badawood, Dykes, and Slingsby. IEEE TVCG (Proc. InfoVis) 17(12):2384-2391, 2011.]

If no name order bias existed, all bars would be same length; but systematic structure visible!

AcrossDistrib

- *Does the ballot-position influence vary geographically in different boroughs?*

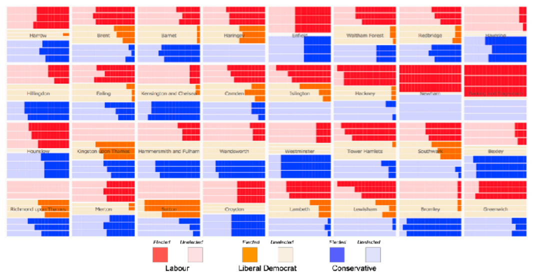


Fig. 1. BallotMap showing electoral success (or otherwise) of each candidate for the three main parties in wards (small rectangles) in each London borough (grid squares) in the 2010 local government elections. Vertical ordering of candidates within each borough is by ballot paper position within party (top row first, middle row second, bottom row third). Main parties with three candidates in a ward are shown. If no ballot ordering bias existed there would be no systematic structure to bar lengths. This ballotMap shows that more candidates get elected who are listed first within their party than do candidates who are second or third.

- Borough: count of 32

[Fig 1. BallotMaps: Detecting name bias in alphabetically ordered ballot papers. Wood, Badawood, Dykes, and Slingsby. IEEE TVCG (Proc. InfoVis) 17(12):2384-2391, 2011.]

If no name order bias existed, all bars would be same length; but systematic structure visible!

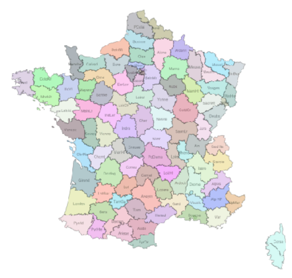
Best of both worlds: quasi-geographic positioning

- choropleth: size issues
- tabular: lose geographic position information

Spatially ordered treemaps

- quasi-geographic positions

Spatially ordered treemaps. Wood and Dykes. IEEE TVCG (Proc. InfoVis) 14(6):1348-1355, 2008.



AcrossDistrib, Take 2

- *Does it vary in different wards? Does it depend on party affiliation?*

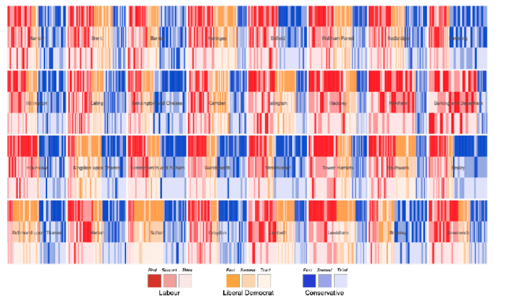


Fig. 4. Alpha position within party (vertical position) and voting rank within party for the three main parties in each ward (vertical bars) in each borough (grid squares). If no name order bias existed, dark and light cells would be randomly distributed in the top, middle and bottom thirds of each borough. Actual voting data show that darker cells (indicating a candidate most votes within their party) are more common in the upper third (listed first on the ballot paper within their party) and lighter cells (least votes within party) are more common in the lower third (listed third within their on the ballot paper).

- Ward: count of 614

[Fig 4. BallotMaps: Detecting name bias in alphabetically ordered ballot papers. Wood, Badawood, Dykes, and Slingsby. IEEE TVCG (Proc. InfoVis) 17(12):2384-2391, 2011.]

If no name order bias existed, dark/light random distribution; but systematic structure visible!

PosWithin

- *To what extent does the position in the ballot influence the number of votes a candidate gets **within** their party?*

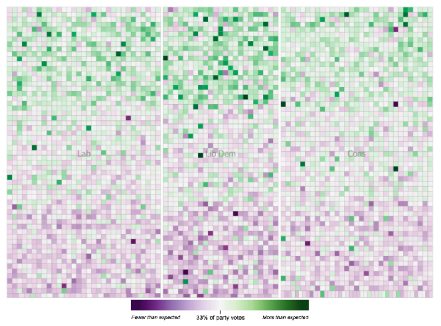


Fig. 6. Signed chi values for each candidate arranged by party (left to right) and ballot position within party (top to bottom, row by row). The top third represents candidates ordered first in their party, then ordered by absolute position on the ballot paper; the middle third represents candidate ordered second within their party etc. If no name order bias existed, purple and green cells would be randomly distributed within the ballotMap.

- Signed_Chi: -1 to 1
- Residual: -1 to 1

[Fig 6. BallotMaps: Detecting name bias in alphabetically ordered ballot papers. Wood, Badawood, Dykes, and Slingsby. IEEE TVCG (Proc. InfoVis) 17(12):2384-2391, 2011.]

If no name order bias existed, green/purple random distribution; but systematic structure visible!

NameEthnicity

- *To what extent does the perceived ethnicity of candidate's name matter?*

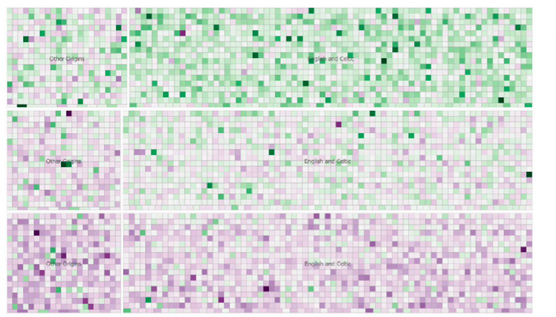


Fig. 7. Signed chi values for candidates arranged by binary classification of name origin and ballot position within party (top to bottom, row by row). The top third represents candidates ordered first in their party, then ordered by absolute position on the ballot paper; the middle third represents candidate ordered second within their party etc. Name order bias (tendency for green cells in the upper third and purple in the lower third) is stronger for 'English or Celtic' names than for other names where candidates listed first are not so likely to get more votes than expected.

Name: English or Celtic vs Other Origins

[Fig 7. BallotMaps: Detecting name bias in alphabetically ordered ballot papers. Wood, Badawood, Dykes, and Slingsby. IEEE TVCG (Proc. InfoVis) 17(12):2384-2391, 2011.]

Name order bias differs w/ perceived ethnicity: green/purple structure more visible on right than left!

NameEthnicity

- *Does this effect vary with geography?*

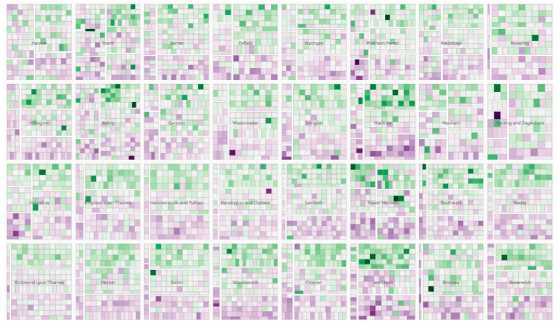
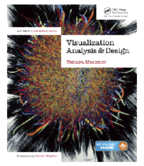


Fig. 8. Signed chi values for each candidate in each borough arranged by binary classification of name origin ('other name origins' left, 'English or Celtic' right) and ballot position within party (top to bottom). The degree of name order bias is indicated by the strength of separation of green (more votes than expected) and purple (fewer votes than expected) cells. This varies by borough and by ethnic origin of candidate names.

[Fig 8. BallotMaps: Detecting name bias in alphabetically ordered ballot papers. Wood, Badawood, Dykes, and Slingsby. IEEE TVCG (Proc. InfoVis) 17(12):2384-2391, 2011.]

Yes. Varies by both borough & perceived ethnicity

Q&A / Backup Slides



Visualization Analysis & Design

Network Data (Ch 9)

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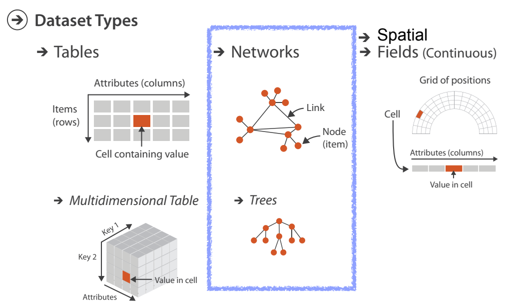
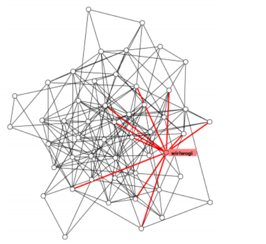
Network data

- networks
  - model relationships between things
    - aka graphs
  - two kinds of items, both can have attributes
    - nodes
    - links
- tree
  - special case
  - no cycles
    - one parent per node



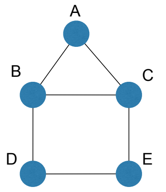
Network tasks: topology-based and attribute-based

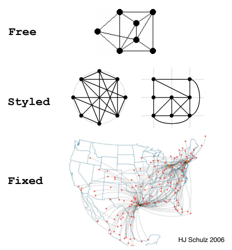
- topology based tasks
  - find paths
  - find (topological) neighbors
  - compare centrality/importance measures
  - identify clusters / communities
- attribute based tasks (similar to table data)
  - find distributions, ...
- combination tasks, incorporating both
  - example: find friends-of-friends who like cats
    - topology: find all adjacent nodes of given node
    - attributes: check if has-pet (node attribute) == cat



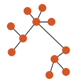
Node-link diagrams

- nodes: point marks
- links: line marks
  - straight lines or arcs
  - connections between nodes
- intuitive & familiar
  - most common
  - many, many variants



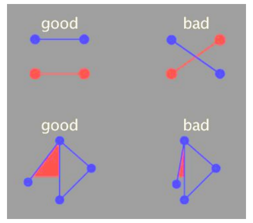


Node–Link Diagrams
Connection Marks
NETWORKS TREES



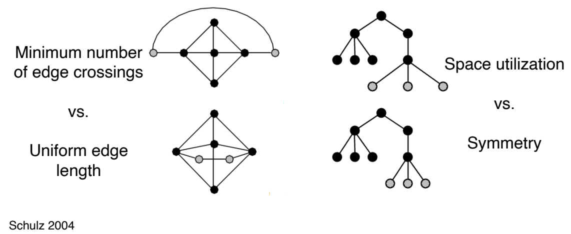
Criteria for good node-link layouts

- minimize
  - edge crossings, node overlaps
  - distances between topological neighbor nodes
  - total drawing area
  - edge bends
- maximize
  - angular distance between different edges
  - aspect ratio disparities
- emphasize symmetry
  - similar graph structures should look similar in layout



Criteria conflict

- most criteria NP-hard individually
- many criteria directly conflict with each other

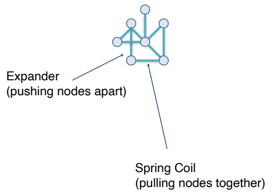


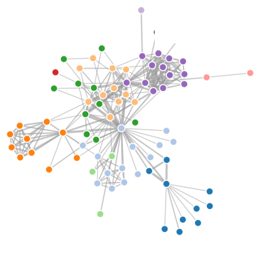
Optimization-based layouts

- formulate layout problem as optimization problem
- convert criteria into weighted cost function
  - F(layout) = a*[crossing counts] + b*[drawing space used]+...
- use known optimization techniques to find layout at minimal cost
  - energy-based physics models
  - force-directed placement
  - spring embedders

Force-directed placement

- physics model
  - links = springs pull together
  - nodes = magnets repulse apart
- algorithm
  - place vertices in random locations
  - while not equilibrium
    - calculate force on vertex
      - sum of
        - pairwise repulsion of all nodes
        - attraction between connected nodes
    - move vertex by c * vertex_force

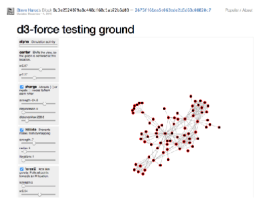




http://mbostock.github.com/d3/ex/force.html

Force-directed placement properties

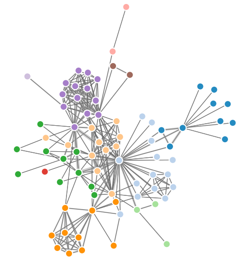
- strengths
  - reasonable layout for small, sparse graphs
  - clusters typically visible
  - edge length uniformity
- weaknesses
  - nondeterministic
  - computationally expensive: O(n^3) for n nodes
    - each step is n^2, takes ~n cycles to reach equilibrium
  - naive FD doesn't scale well beyond 1K nodes
  - iterative progress: engaging but distracting



https://bl.ocks.org/steveharoz/8c3e2524079a8c440df60c1ab72b5d03

Idiom: **force-directed placement**

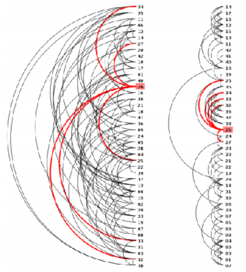
- visual encoding
  - link connection marks, node point marks
- considerations
  - spatial position: no meaning directly encoded
    - left free to minimize crossings
  - proximity semantics?
    - sometimes meaningful
    - sometimes arbitrary, artifact of layout algorithm
    - tension with length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

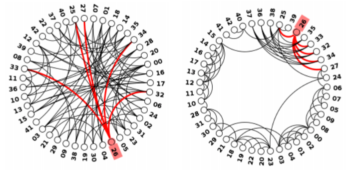


http://mbostock.github.com/d3/ex/force.html

Idiom: **circular layouts / arc diagrams (node-link)**

- restricted node-link layouts: lay out nodes around circle or along line
- data
  - original: network
  - derived: node ordering attribute (global computation)
- considerations: node ordering crucial to avoid excessive clutter from edge crossings
  - examples: before & after barycentric ordering

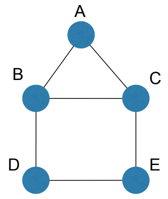


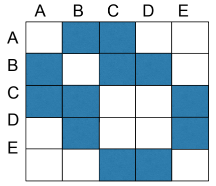


http://profs.etsmtl.ca/mmcguffin/research/2012-mcguffin-simpleNetVis/mcguffin-2012-simpleNetVis.pdf

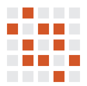
Adjacency matrix representations

- derive adjacency matrix from network

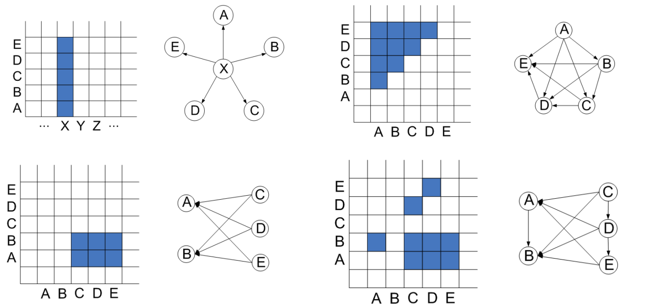




Adjacency Matrix
Derived Table
NETWORKS TREES

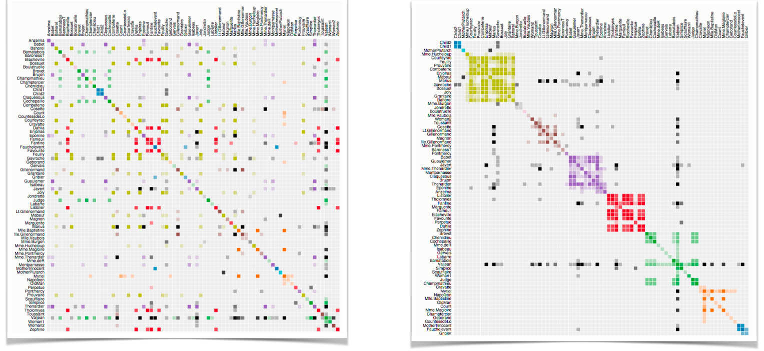


Adjacency matrix examples



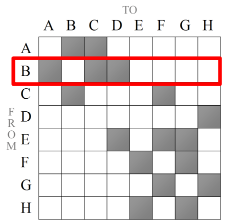
HJ Schulz 2007

Node order is crucial: Reordering

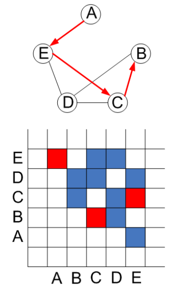


https://bost.ocks.org/mike/miserables/

Adjacency matrix

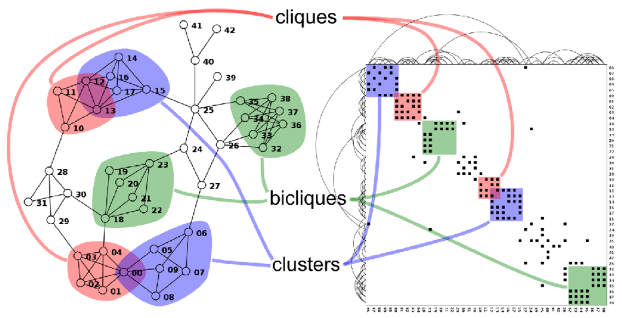


good for topology tasks related to neighborhoods (node 1-hop neighbors)



bad for topology tasks related to paths

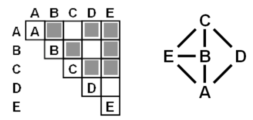
Structures visible in both



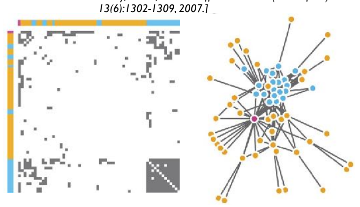
http://www.michaelmcguffin.com/courses/vis/patternsInAdjacencyMatrix.png

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.]

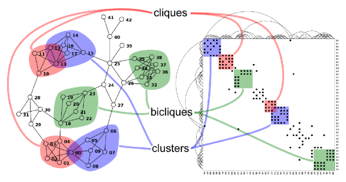


[Points of view: Networks. Gehlenborg and Wong. Nature Methods 9:115.]

Node-link vs. matrix comparison

- node-link diagram strengths
  - topology understanding, path tracing
  - intuitive, flexible, no training needed
- adjacency matrix strengths
  - focus on edges rather than nodes
  - layout straightforward (reordering needed)
  - predictability, scalability
  - some topology tasks trainable
- empirical study
  - node-link best for small networks
  - matrix best for large networks
    - if tasks don't involve path tracing!

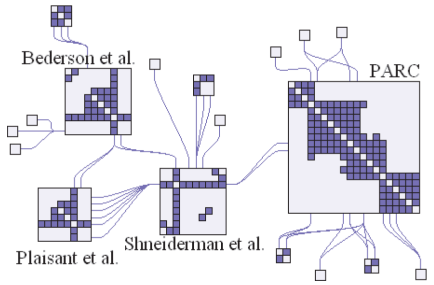
[On the readability of graphs using node-link and matrix-based representations: a controlled experiment and statistical analysis. Ghoniem, Fekete, and Castagliola. Information Visualization 4:2 (2005), 114–135.]



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

Idiom: **NodeTrix**

- hybrid nodelink/matrix
- capture strengths of both



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

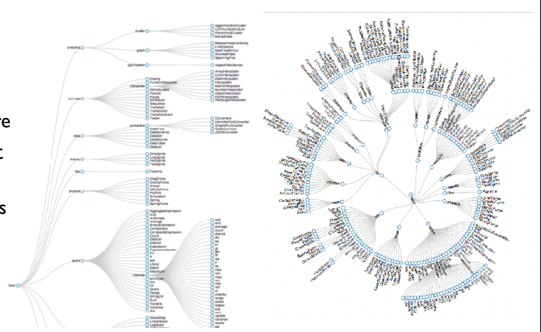
Trees

Node-link trees

- Reingold-Tilford
  - tidy drawings of trees
    - exploit parent/child structure
  - allocate space: compact but without overlap
    - rectilinear and radial variants

[Tidier drawing of trees. Reingold and Tilford. IEEE Trans. Software Eng., SE-7(2):223–228, 1981.]

  - nice algorithm writeup
    - http://billmill.org/pymag-trees/

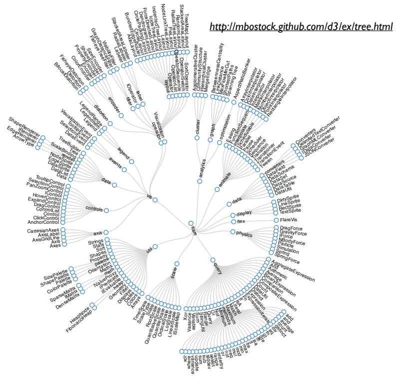


http://bl.ocks.org/mbostock/4339184 http://bl.ocks.org/mbostock/4063550

Idiom: **radial node-link tree**

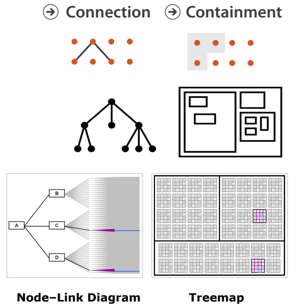
- data
  - tree
- encoding
  - link connection marks
  - point node marks
  - radial axis orientation
    - angular proximity: siblings
    - distance from center: depth in tree
- tasks
  - understanding topology, following paths
- scalability
  - 1K - 10K nodes (with/without labels)

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



Link marks: Connection and containment

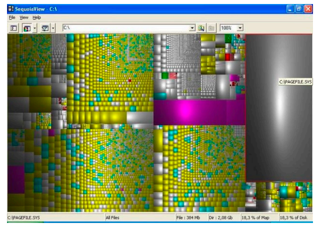
- marks as links (vs. nodes)
  - common case in network drawing
  - 1D case: connection
    - ex: all node-link diagrams
    - emphasizes topology, path tracing
    - networks and trees
  - 2D case: containment
    - ex: all treemap variants
    - emphasizes attribute values at leaves (size coding)
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



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

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
  - ex: disk space usage within filesystem
- scalability
  - 1M leaf nodes



https://www.win.tue.nl/sequoiaview/

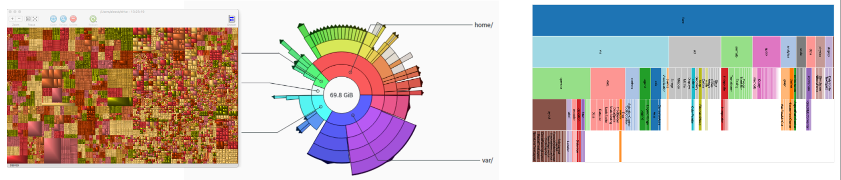
[Cushion Treemaps. van Wijk and van de Wetering. Proc. Symp. InfoVis 1999, 73-78.]

Enclosure
Containment Marks
✕ NETWORKS ✓ TREES

Idiom: implicit tree layouts (sunburst, icicle plot)

- alternative to connection and containment: position
  - show parent-child relationships only through relative positions

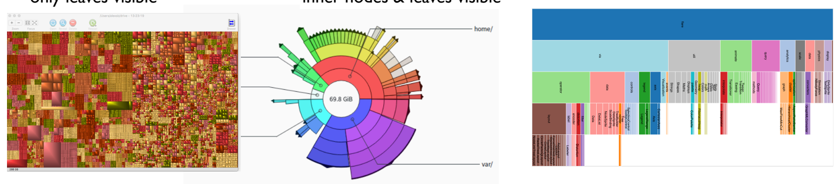
Treemap	Sunburst	Icicle Plot
containment	position (radial)	position (rectilinear)



Idiom: implicit tree layouts (sunburst, icicle plot)

- alternative to connection and containment: position
  - show parent-child relationships only through relative positions

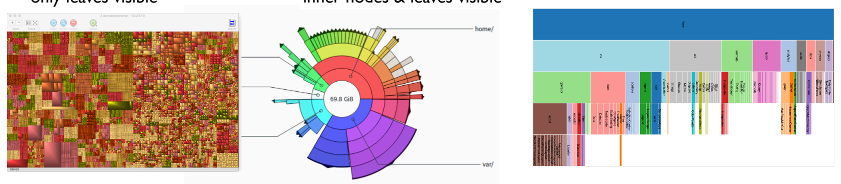
Treemap	Sunburst	Icicle Plot
containment only leaves visible	position (radial) inner nodes & leaves visible	position (rectilinear) inner nodes & leaves visible



Idiom: implicit tree layouts (sunburst, icicle plot)

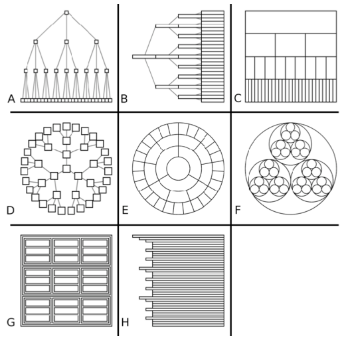
- alternative to connection and containment: position
  - show parent-child relationships only through relative positions

Treemap	Sunburst	Icicle Plot
containment only leaves visible	position (radial) inner nodes & leaves visible	position (rectilinear) inner nodes & leaves visible



Implicit
Spatial Position
✕ NETWORKS ✓ TREES

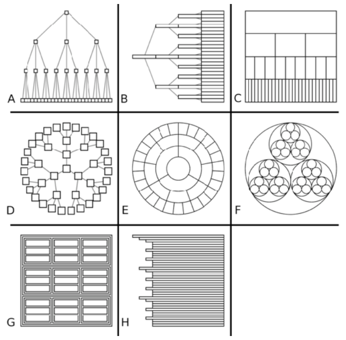
Tree drawing idioms comparison



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

Comparison: tree drawing idioms

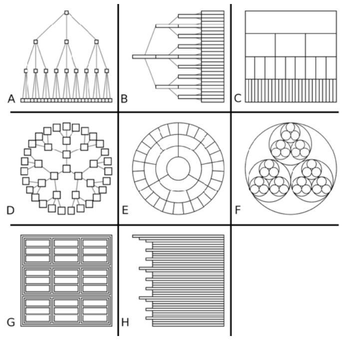
- data shown
  - link relationships
  - tree depth
  - sibling order



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

Comparison: tree drawing idioms

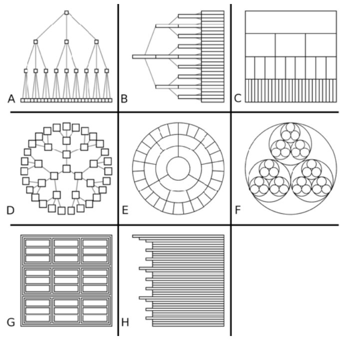
- data shown
  - link relationships
  - tree depth
  - sibling order
- design choices
  - connection vs containment link marks
  - rectilinear vs radial layout
  - spatial position channels



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

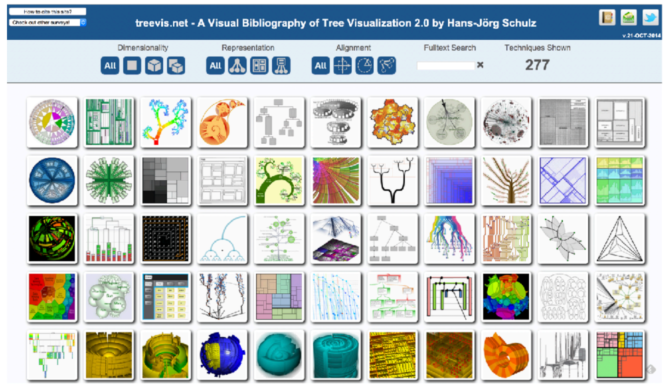
Comparison: tree drawing idioms

- 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
    - consider where to fit labels!



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

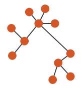
treevis.net: Many, many options!



https://treevis.net/

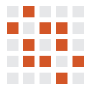
Arrange networks and trees

Node–Link Diagrams
Connection Marks
✓ NETWORKS ✓ TREES



Implicit
Spatial Position
✕ NETWORKS ✓ TREES

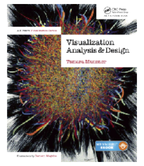
Adjacency Matrix
Derived Table
✓ NETWORKS ✓ TREES



Enclosure
Containment Marks
✕ NETWORKS ✓ TREES

Visualization Analysis & Design

Network Data (Ch 9) II



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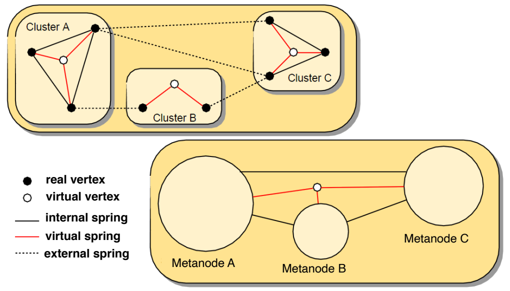
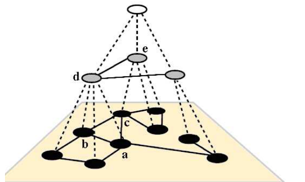
Multilevel networks

- derive cluster hierarchy of metanodes on top of original graph nodes

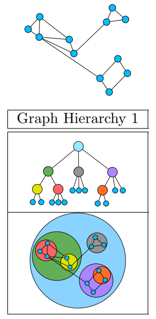




[Schulz 2004]

Idiom: **GrouseFlocks**

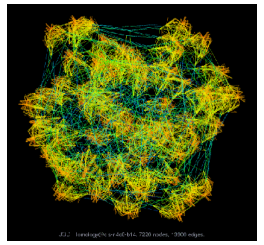
- data: compound network
  - network
  - cluster hierarchy atop it
    - derived or interactively chosen
- visual encoding
  - connection marks for network links
  - containment marks for hierarchy
  - point marks for nodes
- dynamic interaction
  - select individual metanodes in hierarchy to expand/ contract



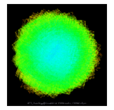
[GrouseFlocks: Steerable Exploration of Graph Hierarchy Space. Archambault, Munzner, and Auber. IEEE TVCG 14(4):900-913, 2008.]

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

- data: compound graph
  - 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



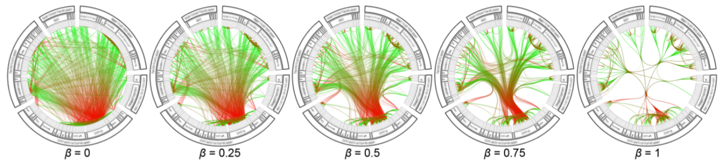
[Efficient and high quality force-directed graph drawing. Hu. The Mathematica Journal 10:37–71, 2005.]



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

Idiom: **hierarchical edge bundling**

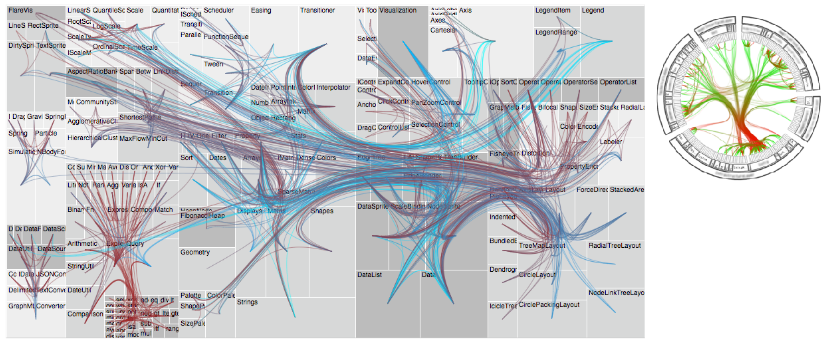
- data
  - any layout of compound network
    - network: software classes (nodes), import/export between classes (links)
    - cluster hierarchy: class package structure
  - derived: bundles of edges with same source/destination (multi-level)
- idiom: curve edge routes according to bundles
- task: edge clutter reduction



[Hierarchical Edge Bundles: Visualization of Adjacency Relations in Hierarchical Data. Danny Holten. TVCG 12(5):741-748 2006]

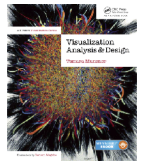
Hierarchical edge bundling

- works for any layout: treemap vs radial



[Hierarchical Edge Bundles: Visualization of Adjacency Relations in Hierarchical Data. Danny Holten. TVCG 12(5):741-748 2006]

Visualization Analysis & Design



Spatial Data (Ch 9)

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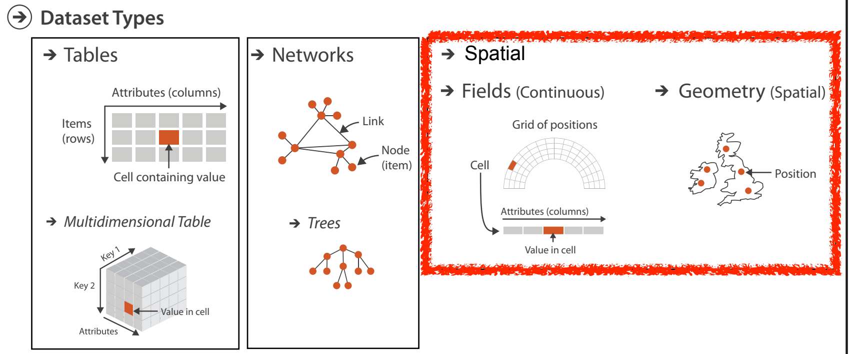
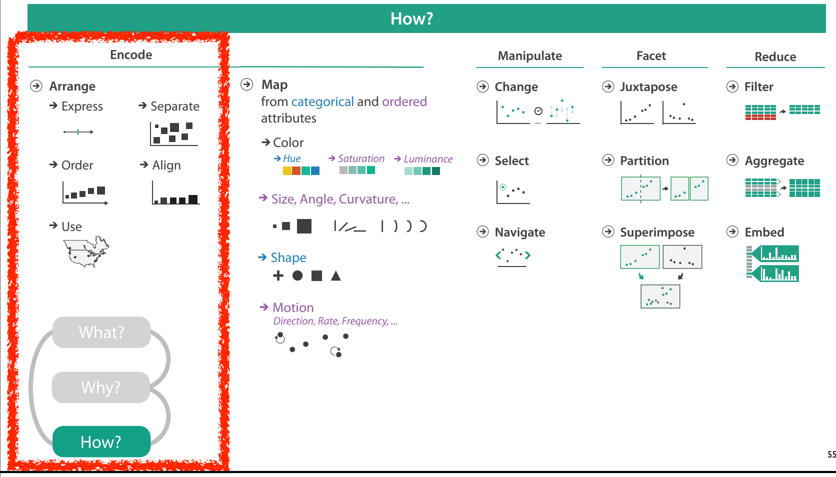
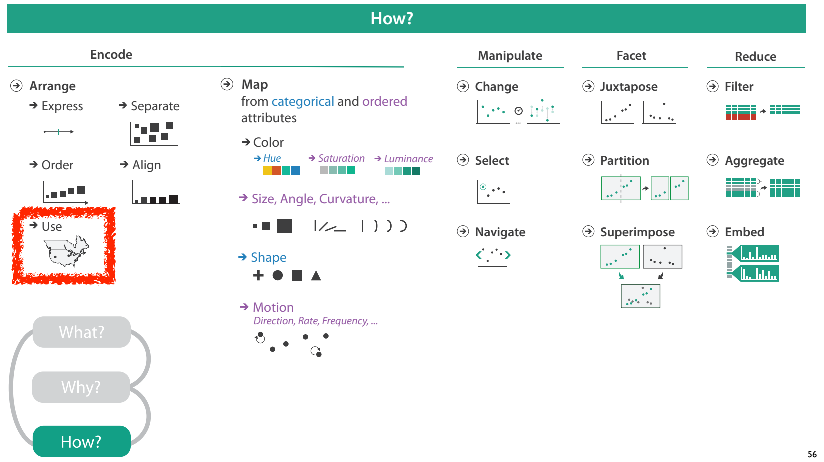
Focus on Spatial







Spatial data

- use given spatial position
- when?
  - dataset contains spatial attributes and they have primary importance
  - central tasks revolve around understanding spatial relationships
- examples
  - geographical/cartographic data
  - sensor/simulation data

Geographic Maps

Geographic Map

Interlocking marks

- **shape** coded
- **area** coded
- **position** coded

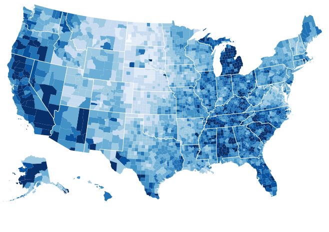
- cannot encode another attribute with these channels, they're "taken"

Thematic maps

- show spatial variability of attribute ("theme")
  - combine geographic / reference map with (simple, flat) tabular data
  - join together
    - region: interlocking area marks (provinces, countries with outline shapes)
      - also could have point marks (cities, locations with 2D lat/lon coords)
    - region: categorical key attribute in table
      - use to look up value attributes
- major idioms
  - choropleth
  - symbol maps
  - cartograms
  - dot density maps

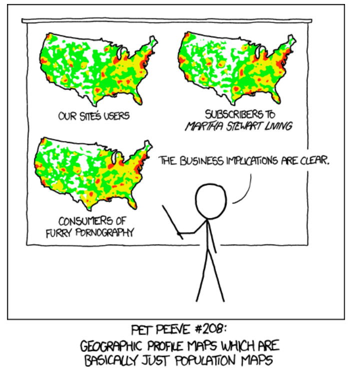
Idiom: **choropleth map**

- use given spatial data
  - when central task is understanding spatial relationships
- data
  - geographic geometry
  - table with 1 quant attribute per region
- encoding
  - position: use given geometry for area mark boundaries
  - color: sequential segmented colormap



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

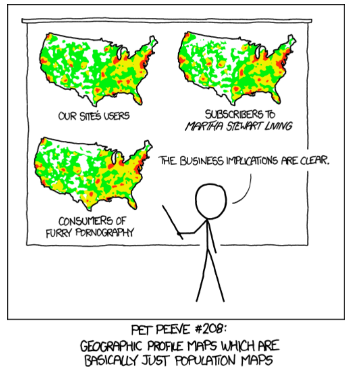
Beware: Population maps trickiness!



[https://xkcd.com/1138]

Beware: Population maps trickiness!

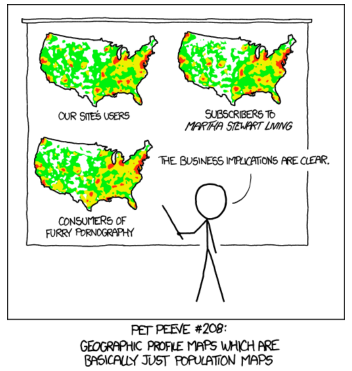
- spurious correlations: most attributes just show where people live



[https://xkcd.com/1138]

Beware: Population maps trickiness!

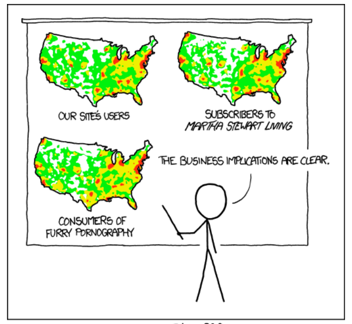
- spurious correlations: most attributes just show where people live
- consider when to normalize by population density
  - encode raw data values
    - tied to underlying population
  - but should use normalized values
    - unemployed people per 100 citizens, mean family income



[https://xkcd.com/1138]

Beware: Population maps trickiness!

- spurious correlations: most attributes just show where people live
- consider when to normalize by population density
  - encode raw data values
    - tied to underlying population
  - but should use normalized values
    - unemployed people per 100 citizens, mean family income
- general issue
  - absolute counts vs relative/normalized data
  - failure to normalize is common error



PET PEEVE #208: GEOGRAPHIC PROFILE MAPS WHICH ARE BASICALLY JUST POPULATION MAPS

[https://xkcd.com/1138]

Choropleth maps: Recommendations

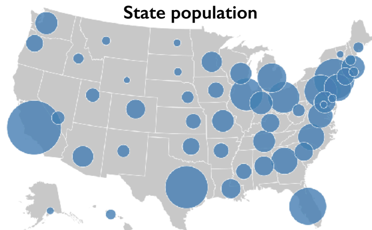
- only use when central task is understanding spatial relationships
- show only one variable at a time
- normalize when appropriate
- be careful when choosing colors & bins
- best case: regions are roughly equal sized

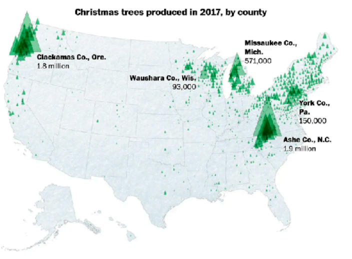
Choropleth map: Pros & cons

- pros
  - easy to read and understand
  - well established visualization (no learning curve)
  - data is often collected and aggregated by geographical regions
- cons
  - most effective visual variable used for geographic location
  - visual salience depends on region size, not true importance wrt attribute value
    - large regions appear more important than small ones
  - color palette choice has a huge influence on the result

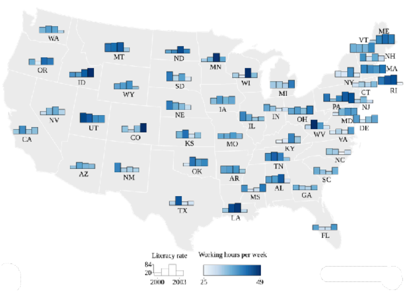
Idiom: **Symbol maps**

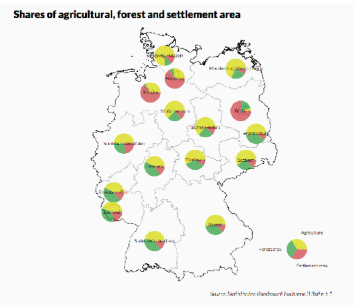
- symbol is used to represent aggregated data (mark or glyph)
  - allows use of size and shape and color channels
    - aka proportional symbol maps, graduated symbol maps
- keep original spatial geometry in the background
- often a good alternative to choropleth maps





Symbol maps with glyphs



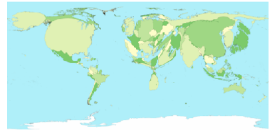


Symbol map: Pros & cons

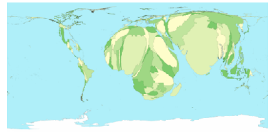
- pros
  - somewhat intuitive to read and understand
  - mitigate problems with region size vs data salience
    - marks: symbol size follows attribute value
    - glyphs: symbol size can be uniform
- cons
  - possible occlusion / overlap
    - symbols could overlap each other
    - symbols could occlude region boundaries
  - complex glyphs may require explanation / training

Idiom: **Contiguous cartogram**

- interlocking marks: shape, area, and position coded
- derive new interlocking marks
  - based on combination of original interlocking marks and new quantitative attribute
- algorithm to create new marks
  - input: target size
  - goal: shape as close to the original as possible
  - requirement: maintain constraints
    - relative position
    - contiguous boundaries with their neighbours



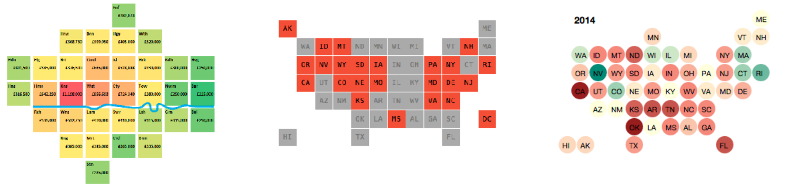
Greenhouse Emissions



Child Mortality

Mark Newman, Univ. Michigan

Idiom: **Grid Cartogram**



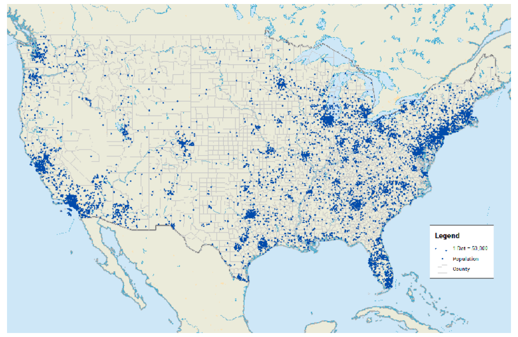
- uniform-sized shapes arranged in rectilinear grid
- maintain approximate spatial position and arrangement

Cartogram: Pros & cons

- pros
  - can be intriguing and engaging
  - best case: strong and surprising size disparities
  - non-contiguous cartograms often easier to understand
- cons
  - require substantial familiarity with original dataset & use of memory
    - compare distorted marks to memory of original marks
    - mitigation strategies: transitions or side by side views
  - major distortion is problematic
    - may be aesthetically displeasing
    - may result in unrecognizable marks
  - difficult to extract exact quantities

Idiom: **Dot density maps**

- visualize distribution of a phenomenon by placing dots
- one symbol represents a constant number of items
  - dots have uniform size & shape
  - allows use of color channel
- task: show spatial patterns, clusters

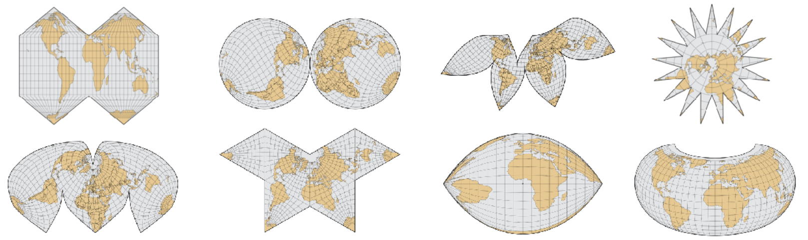


Dot density maps: Pros and cons

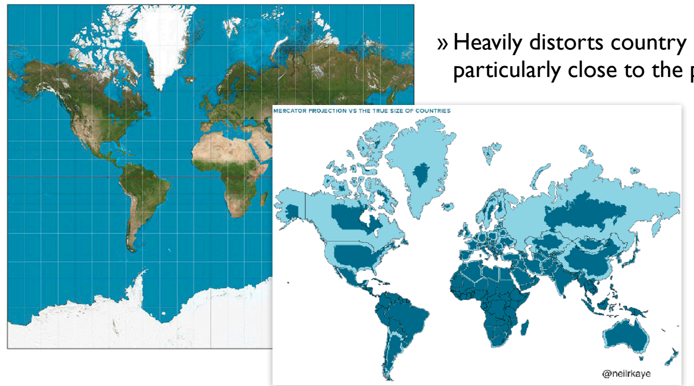
- pros
  - straightforward to understand
  - avoids choropleth non-uniform region size problems
- cons
  - challenge: normalization, just like choropleths
    - show population density (correlated with attribute), not effect of interest
  - perceptual disadvantage: difficult to extract quantities
  - performance disadvantage: rendering many dots can be slow

Map Projections

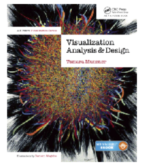
- mathematical functions that map 3D surface geometry of the Earth to 2D maps
- all projections of sphere on plane necessarily distort surface in some way
- interactive: philogb.github.io/page/myriahedral/ and jasondavies.com/maps/



Mercator Projection



» Heavily distorts country sizes; particularly close to the poles.



Visualization Analysis & Design

Spatial Data (Ch 9) II

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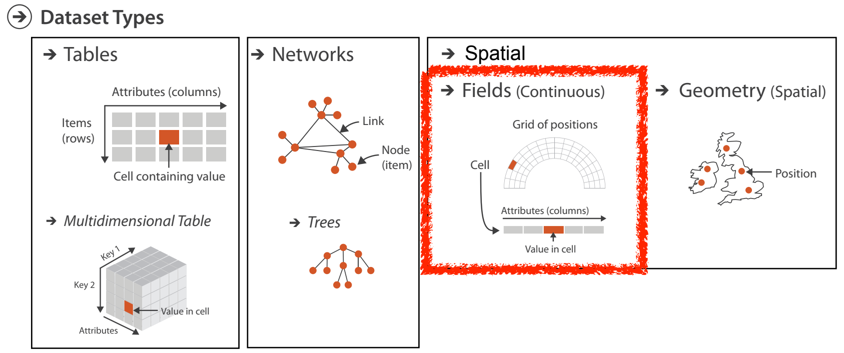
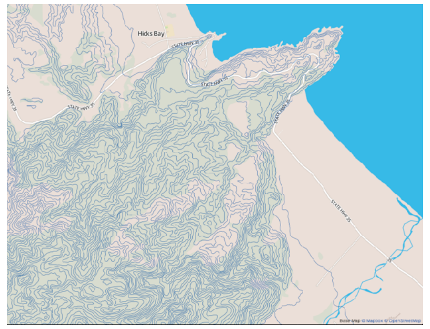
Focus on Spatial



Spatial Fields

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
- task
  - understanding terrain shape
    - densely lined regions = steep
- pros
  - use only 2D position, avoid 3D challenges
  - color channel available for other attributes
- cons
  - significant clutter from additional lines



Land Information New Zealand Data Service

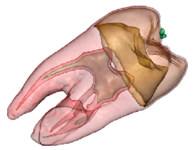
Idioms: **isosurfaces, direct volume rendering**

- data
  - scalar spatial field (3D volume)
    - 1 quant attribute per grid cell
- task
  - shape understanding, spatial relationships

[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.]

Idioms: **isosurfaces, direct volume rendering**

- data
  - scalar spatial field (3D volume)
    - 1 quant attribute per grid cell
- task
  - shape understanding, spatial relationships
- isosurface
  - derived data: isocontours computed for specific levels of scalar values



[Interactive Volume Rendering Techniques. Kniss. Master's thesis, University of Utah Computer Science, 2002.]
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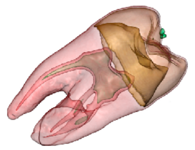
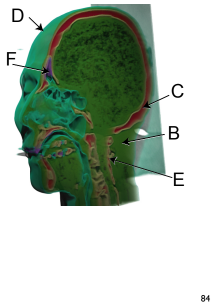
Idioms: **isosurfaces, direct volume rendering**

- data
  - scalar spatial field (3D volume)
    - 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

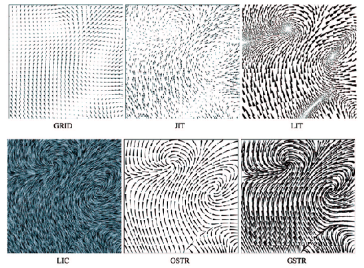




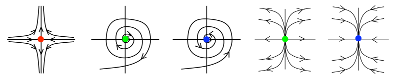
[Interactive Volume Rendering Techniques. Kniss. Master's thesis, University of Utah Computer Science, 2002.]
[Multidimensional Transfer Functions for Volume Rendering. Kniss, Kindlmann, and Hansen. In The Visualization Handbook, edited by Charles Hansen and Christopher Johnson, pp. 189–210. Elsevier, 2005.]

Vector and tensor fields

- data
  - multiple attribs per cell (vector: 2)
- 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



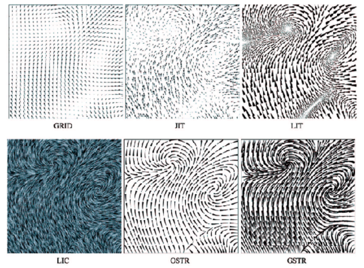
[Comparing 2D vector field visualization methods: A user study. Laidlaw et al. IEEE Trans. Visualization and Computer Graphics (TVCG) 11:1 (2005), 59–70.]



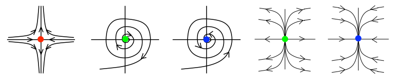
[Topology tracking for the visualization of time-dependent two-dimensional flows. Tricoche, Wischgoll, Scheuermann, and Hagen. Computers & Graphics 26:2 (2002), 249–257.]

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)



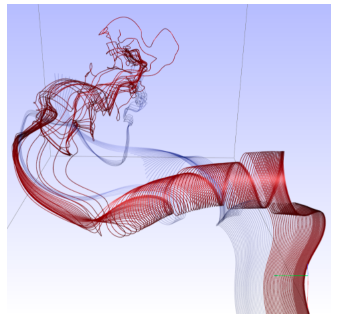
[Comparing 2D vector field visualization methods: A user study. Laidlaw et al. IEEE Trans. Visualization and Computer Graphics (TVCG) 11:1 (2005), 59–70.]



[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**

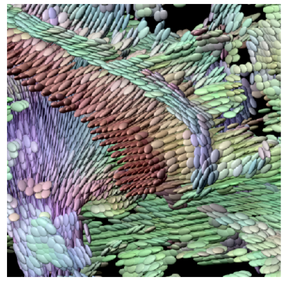
- data
  - 3D vector field
- derived data (from field)
  - streamlines: trajectory particle will follow
- derived data (per streamline)
  - curvature, torsion, tortuosity
  - signature: complex weighted combination
  - compute cluster hierarchy across all signatures
  - encode: color and opacity by cluster
- 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.]

Idiom: Ellipsoid Tensor Glyphs

- data
  - tensor field: multiple attributes at each cell (entire matrix)
    - stress, conductivity, curvature, diffusivity...
  - derived data:
    - shape (eigenvalues)
    - orientation (eigenvectors)
- visual encoding
  - glyph: 3D ellipsoid



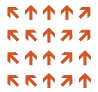
[Superquadric Tensor Glyphs. Kindlmann. Proc. VisSym04, p147-154, 2004.]

Arrange spatial data

- **Use Given**
  - Geometry
    - *Geographic*

  - 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)*



Paper: D3 System

Paper: D3

- paper types
  - design studies
  - technique/algorithm
  - evaluation
  - model/taxonomy
  - **system**

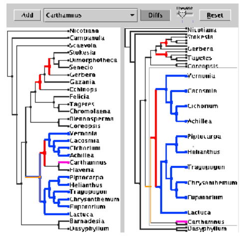
[D3: Data-Driven Documents. Bostock, Ogievetsky, Heer. IEEE Trans. Visualization & Comp. Graphics (Proc. InfoVis), 2011.]

Toolkits

- imperative: how
  - low-level rendering: Processing, OpenGL
  - parametrized visual objects: prefuse
    - also flare: prefuse for Flash
- declarative: what
  - Protoviz, D3, ggplot2
  - separation of specification from execution
- considerations
  - expressiveness
    - can I build it?
  - efficiency
    - how long will it take?
  - accessibility
    - do I know how?

WebGL/OpenGL

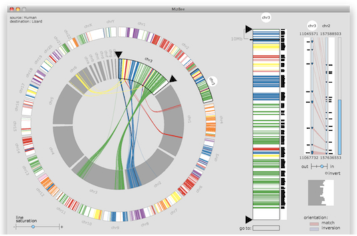
- graphics library
  - pros
    - power and flexibility, complete control for graphics
    - hardware acceleration
    - many language bindings: js, C, C++, Java (w/ JOGL)
  - cons
    - big learning curve if you don't know already
    - no vis support, must roll your own everything
  - example app: TreeJuxtaposer (OpenGL)



[Fig 5. Munzner et al. TreeJuxtaposer: Scalable Tree Comparison using Focus+Context with Guaranteed Visibility. Proc SIGGRAPH 2003, pp 453-462.]

Processing / p5.js

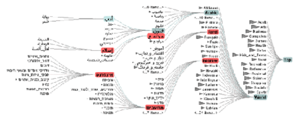
- layer on top of Java/OpenGL, Javascript/WebGL
- visualization esp. for artists/designers
- pros
  - great sandbox for rapid prototyping
  - huge user community, great documentation
- cons
  - poor widget library support
- example app: MizBee



[Fig 1. Meyer et al. MizBee: A Multiscale Synteny Browser. Proc. InfoVis 2009.]

prefuse

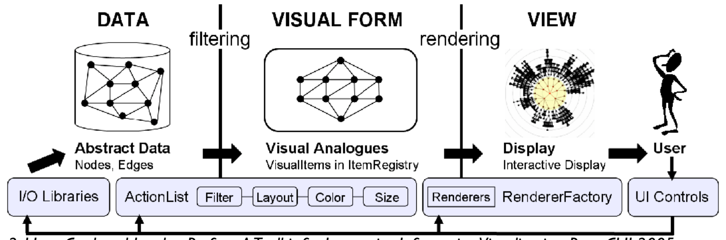
- infovis toolkit, in Java
- fine-grained building blocks for tailored visualizations
- pros
  - heavily used (previously)
  - very powerful abstractions
  - quickly implement most techniques covered so far
- cons
  - no longer active
  - nontrivial learning curve
- example app: DOITrees Revisited



[DOITrees Revisited: Scalable, Space-Constrained Visualization of Hierarchical Data. Heer and Card. Proc. Advanced Visual Interfaces (AVI), pp. 421–424, 2004.]

prefuse

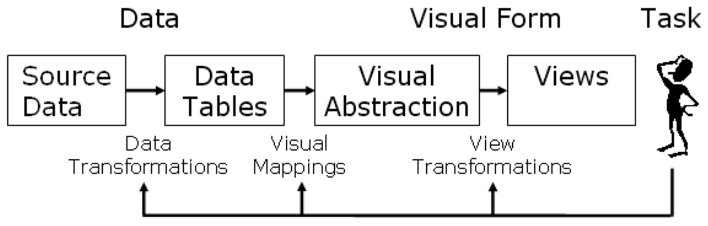
- separation: abstract data, visual form, view
  - data: tables, networks
  - visual form: layout, color, size, ...
  - view: multiple renderers



[Fig 2. Heer, Card, and Landay. Prefuse: A Toolkit for Interactive Information Visualization. Proc. CHI 2005, 421-430]

InfoVis Reference Model

- conceptual model underneath design of prefuse and many other toolkits
- heavily influenced much of infovis (including nested model)
  - aka infovis pipeline, data state model



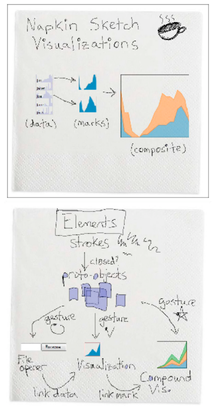
[Redrawn Fig 1.23. Card, Mackinlay, and Shneiderman. Readings in Information Visualization: Using Vision To Think, Chapter 1. Morgan Kaufmann, 1999.]

Declarative toolkits

- imperative tools/libraries
  - say exactly **how** to do it
  - familiar programming model
    - OpenGL, prefuse, ...
- declarative: other possibility
  - just say **what** to do
  - Protovis, D3

Protovis

- declarative infovis toolkit, in Javascript
  - also later Java version
- marks with inherited properties
- pros
  - runs in browser
  - matches mark/channel mental model
  - also much more: interaction, geospatial, trees,...
- cons
  - not all kinds of operations supported
- example app: NapkinVis (2009 course project)



[Fig 1, 3. Chao. NapkinVis. http://www.cs.ubc.ca/~tmm/courses/533-09/projects.html#will]

Protovis Validation

- wide set of old/new app examples
  - expressiveness, effectiveness, scalability
  - accessibility
- analysis with cognitive dimensions of notation
  - closeness of mapping, hidden dependencies
  - role-expressiveness visibility, consistency
  - viscosity, diffuseness, abstraction
  - hard mental operations

[Cognitive dimensions of notations. Green (1989). In A. Sutcliffe and L. Macaulay (Eds.) People and Computers V. Cambridge, UK: Cambridge University Press, pp 443-460.]

D3

- declarative infovis toolkit, in Javascript
- Protovis meets Document Object Model
- pros
  - seamless interoperability with Web
  - explicit transforms of scene with dependency info
  - massive user community, many thirdparty apps/libraries on top of it, lots of docs
- cons
  - even more different from traditional programming model
- example apps: many

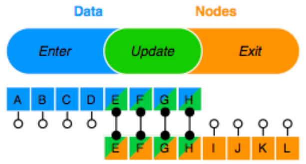
D3

- objectives
  - compatibility
  - debugging
  - performance
- related work typology
  - document transformers
  - graphics libraries
  - infovis systems
    - general note: all related work sections are a mini-taxonomy/typology!

[D3: Data-Driven Documents. Bostock, Ogievetsky, Heer. IEEE Trans. Visualization & Comp. Graphics (Proc. InfoVis), 2011.]

D3 capabilities

- query-driven selection
  - selection: filtered set of elements queries from the current doc
    - also partitioning/grouping!
  - operators act on selections to modify content
    - instantaneous or via animated transitions with attribute/style interpolators
    - event handlers for interaction
- data binding to scenegraph elements
  - data joins bind input data to elements
  - enter, update, exit subselections
  - sticky: available for subsequent re-selection
  - sort, filter

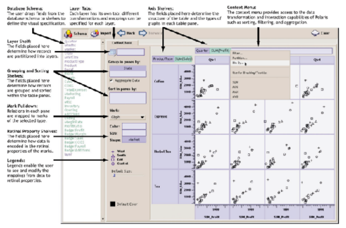


[D3: Data-Driven Documents. Bostock, Ogievetsky, Heer. IEEE Trans. Visualization & Comp. Graphics (Proc. InfoVis), 2011.]

D3 Features

- document transformation as atomic operation
  - scene changes vs representation of scenes themselves
- immediate property evaluation semantics
  - avoid confusing consequences of delayed evaluation
- validation
  - performance benchmarks
    - page loads, frame rate
  - accessibility
  - (adoption)
    - everybody has voted with their feet by now!

Paper: Polaris/Tableau System



Polaris

A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases

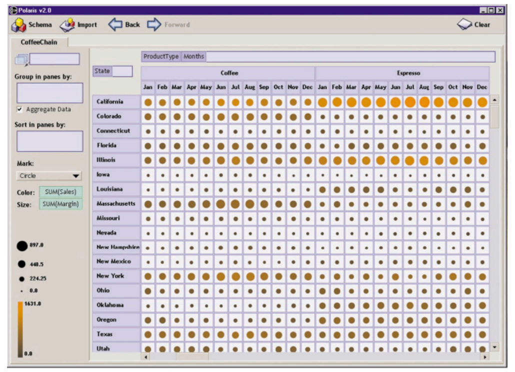
Chris Stolte, Diane Tang, Pat Hanrahan

http://www.graphics.stanford.edu/projects/polaris/

Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases. Stolte, Tang and Hanrahan, IEEE TVCG 8(1):52-65 2002

Polaris: Stolte, Tang, and Hanrahan

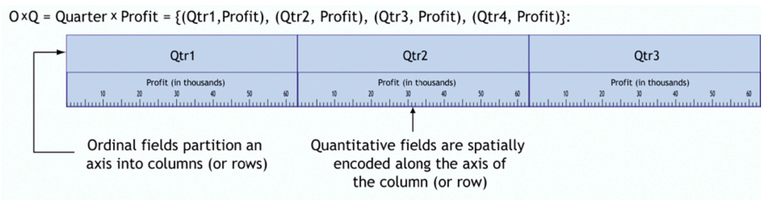
- infovis spreadsheet
  - table cells have graphical elements, not just numbers
  - wide range of channels and marks
- example
  - marks: circles
  - color channel: saturation
  - size channel: area
  - partition: state x product:month
    - ord x ord



[Fig 3a. Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases. Stolte, Tang and Hanrahan, IEEE TVCG 8(1):52-65 2002.]

Table Algebra :: Interactive Interface

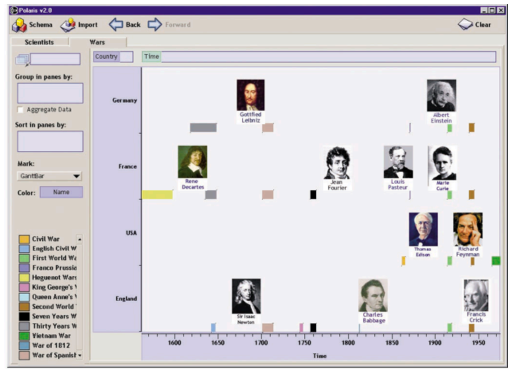
- drag and drop actions map to formal language underneath
  - partitioning using shelves
  - different results for ord vs quant



[Fig 2. Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases. Stolte, Tang and Hanrahan, IEEE TVCG 8(1):52-65 2002.]

Polaris

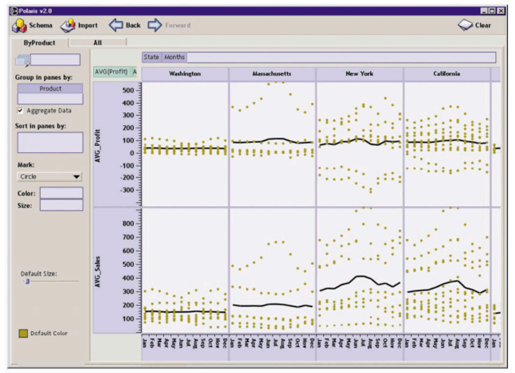
- example
  - marks: Gantt chart bars
  - color channels: nominal / categorical
  - spatial position channels: country x year
    - ord x quant



[Fig 3b. Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases. Stolte, Tang and Hanrahan, IEEE TVCG 8(1):52-65 2002.]

Polaris

- example
  - views: scatterplots
  - marks: points
  - spatial position channels: profit x month
    - quant x (2 ord)



[Fig 3d Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases. Stolte, Tang and Hanrahan, IEEE TVCG 8(1):52-65 2002.]