

Information Visualization

Spatial, NecklaceMaps, Myriahedral

Ex: Ballotmaps

Tamara Munzner
 Department of Computer Science
 University of British Columbia

Week 7, 20 Oct 2021
<https://www.cs.ubc.ca/~tmm/courses/547-21>

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?

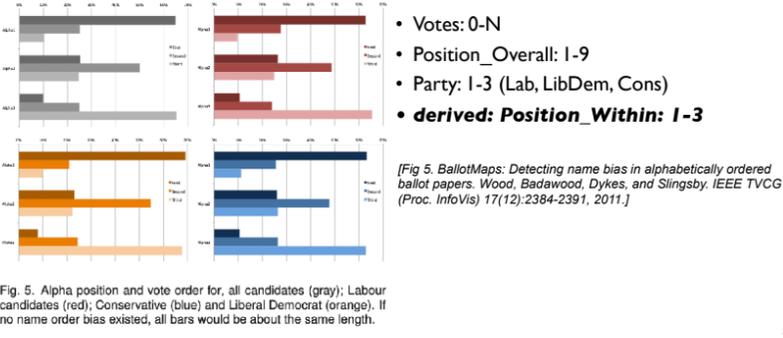


Fig. 5. Alpha position and vote order for, all candidates (gray); Labour candidates (red); Conservative (blue) and Liberal Democrat (orange). If no name order bias existed, all bars would be about the same length.

Plan for today

- last week reading Q&A
 - chap: Networks. papers: Abyss-Explorer, Genealogy
- small group exercises
 - Ballotmaps
- this week reading Q&A
 - chap: Spatial. papers: NecklaceMaps, Myriahedral

AcrossDistrib

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

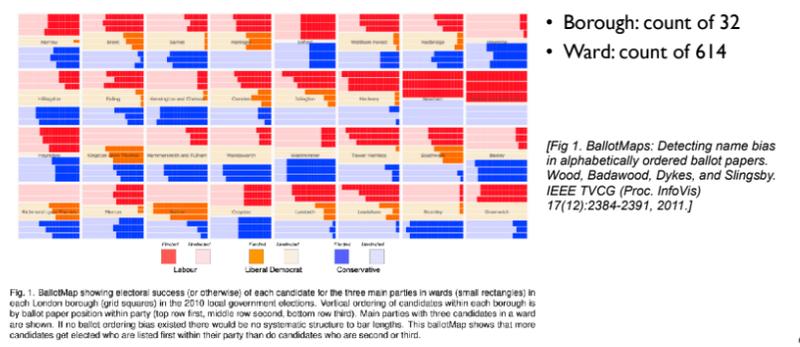


Fig. 1. BallotMap showing electoral success (or otherwise) of each candidate for the three main parties in wards (small rectangles) in each London borough (grid squares) in the 2010 local government elections. Vertical ordering of candidates within each borough is by ballot paper position within party (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.

Next time

- reminder: proposals due tomorrow (Thu Oct 21) noon
- next week is unusual!
 - only one reading: Polaris [system] (now known as Tableau!)
 - **no class session:** instead, attend 2 sessions (90 min each) from IEEE VIS conf
 - <http://ieevis.org/>
 - free registration for students <http://ieevis.org/year/2021/info/registration/conference-registration>
 - interactive full program at <https://virtual.ieevis.org/> (6am-1:30pm Sun, 6-11:30am Mon-Fri)
 - serendipitous paper browser is cool!
 - only exclusion: my full-day tutorial Sunday
- async discussion
 - usual comment for Polaris paper, due by 1pm Mon Oct 25
 - also comment on what you saw at each VIS session, **due by 5pm Fri Oct 29**
 - response to either Polaris or VIS comment, **due by 5pm Sun Oct 31**

Ballotmaps: The 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

AcrossDistrib, Take 2

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

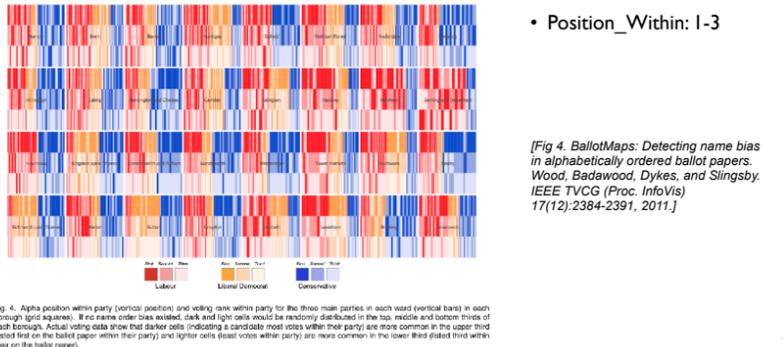


Fig. 4. Alpha position within party (vertical position) and voting row within party for the three main parties in each ward (vertical bars) in each borough (grid squares). If no name order bias existed, dark and light cells would be randomly distributed in the top, middle and bottom thirds of each borough.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

PosWithin

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

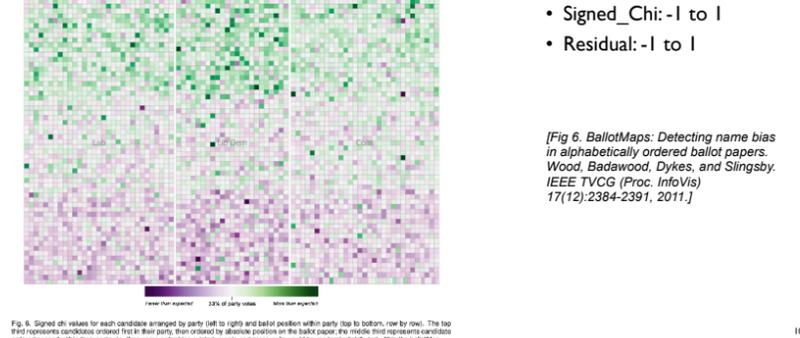


Fig. 6. Signed chi values for each candidate arranged by party (left to right) and ballot position within party (top to bottom, row by row). The top third represents candidates ordered first in their party, then ordered by absolute position on the ballot paper, the middle third represents candidates ordered second within their party etc. Name order bias (preference 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.

NameEthnicity

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

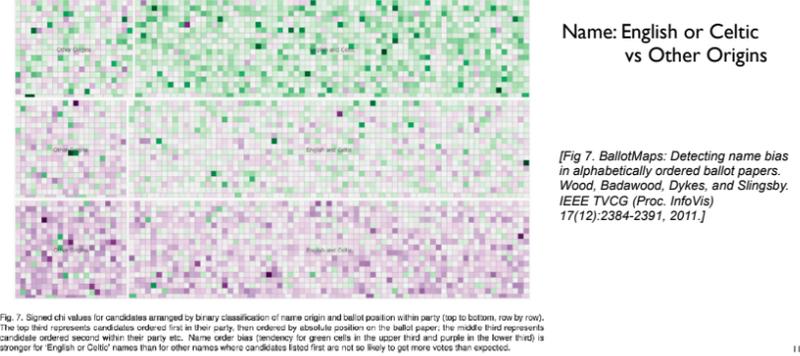


Fig. 7. Signed chi values for candidates arranged by binary classification of name origin and ballot position within party (top to bottom, row by row). The top third represents candidates ordered first in their party, then ordered by absolute position on the ballot paper, the middle third represents candidates ordered second within their party etc. Name order bias (preference 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.

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.

Q&A / Backup Slides

Visualization Analysis & Design

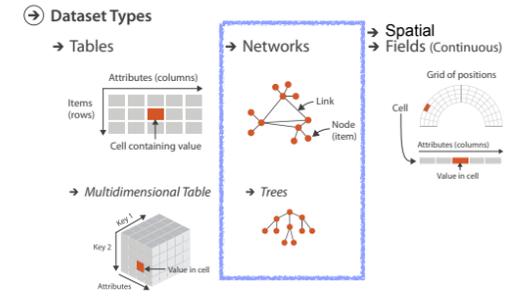
Network Data (Ch 9)

Tamara Munzner
 Department of Computer Science
 University of British Columbia
 @tamaramunzner



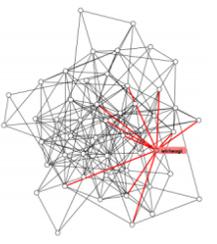
Network data

- 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



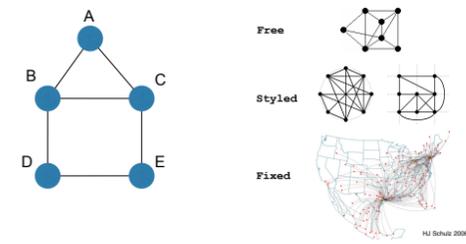
Network tasks: topology-based and attribute-based

- 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

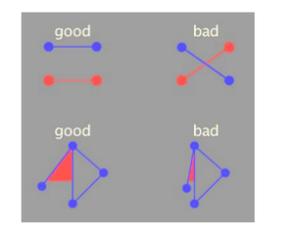


Node-Link Diagrams
Connection Marks

✓ NETWORKS ✓ TREES

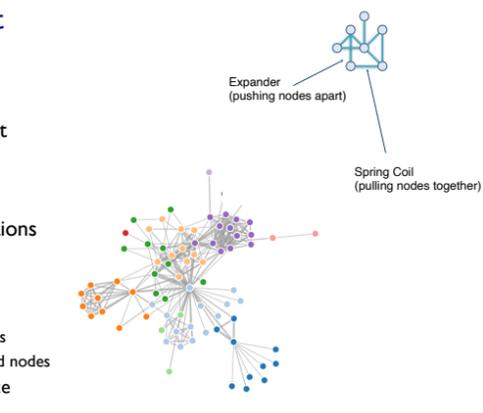
Criteria for good node-link layouts

- 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



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 $c * \text{vertex_force}$



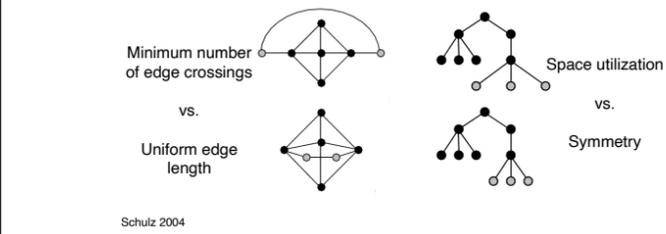
Force-directed placement properties

- 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 $\sim n$ cycles to reach equilibrium
 - naive FD doesn't scale well beyond 1K nodes
 - iterative progress: engaging but distracting



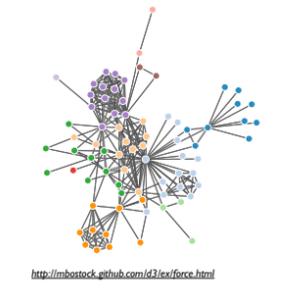
Criteria conflict

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



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 $E < 4N$

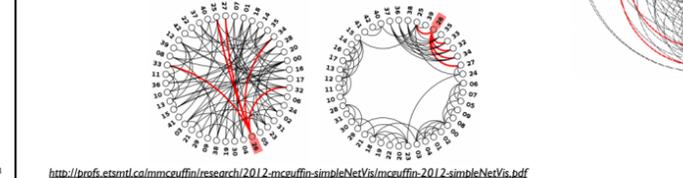


Optimization-based layouts

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

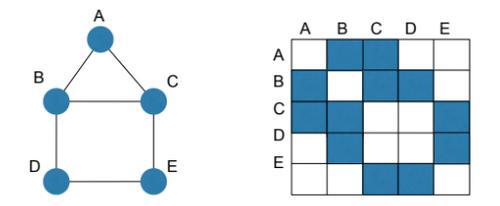
Idiom: circular layouts / arc diagrams (node-link)

- 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



Adjacency matrix representations

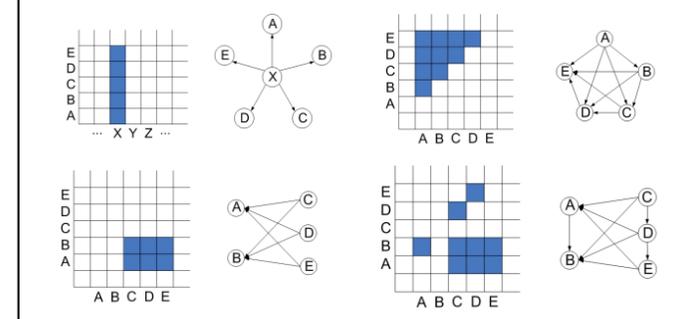
- derive adjacency matrix from network



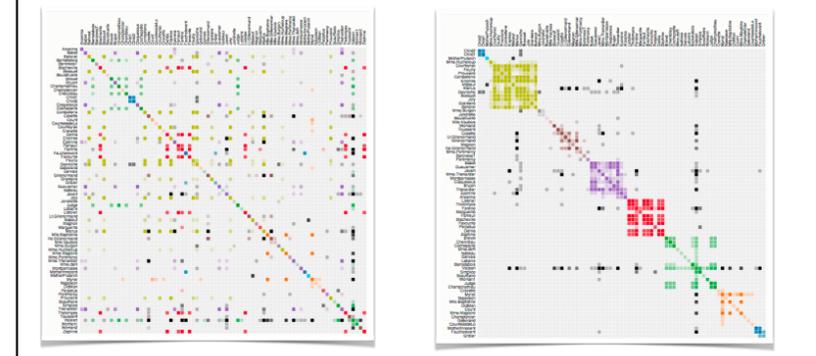
Adjacency Matrix
Derived Table

✓ NETWORKS ✓ TREES

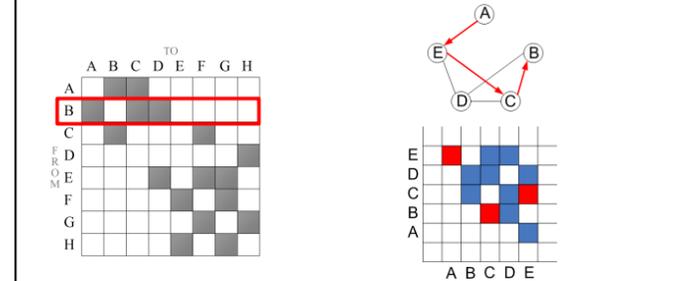
Adjacency matrix examples



Node order is crucial: Reordering



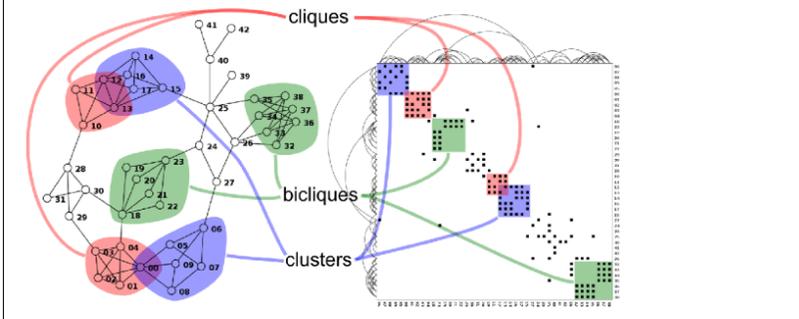
Adjacency matrix



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

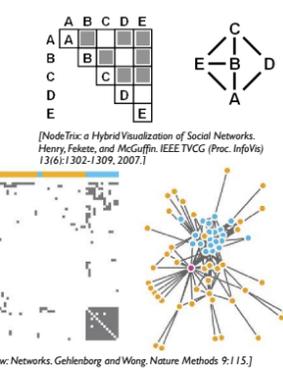
bad for topology tasks related to paths

Structures visible in both



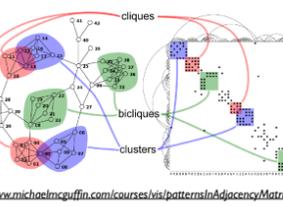
Idiom: adjacency matrix view

- 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



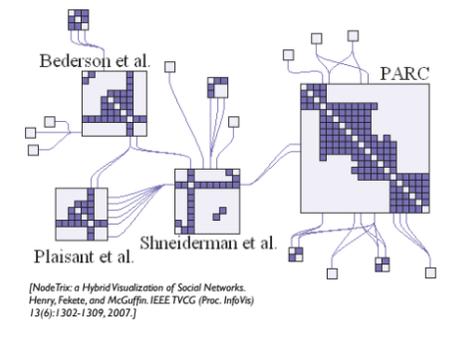
Node-link vs. matrix comparison

- 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!



Idiom: NodeTrix

- hybrid nodelink/matrix
- capture strengths of both



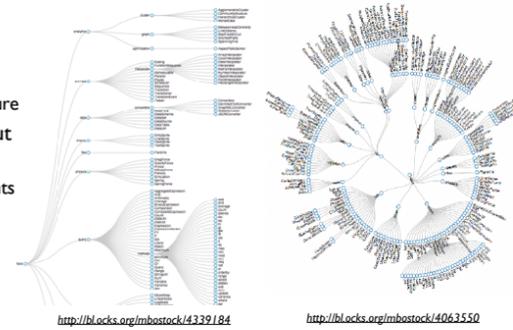
Trees

Node-link trees

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

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

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

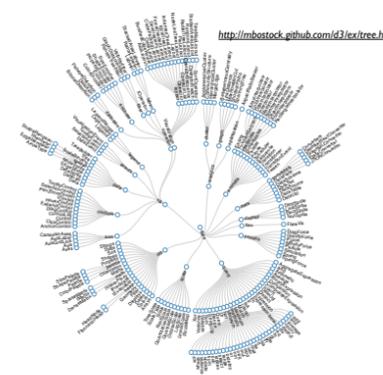


<http://billlocks.org/mbostock/4339184>

<http://billlocks.org/mbostock/4063550>

Idiom: radial node-link tree

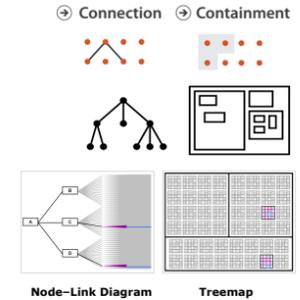
- data
 - tree
- encoding
 - link connection marks
 - point node marks
 - radial axis orientation
 - angular proximity: siblings
 - distance from center: depth in tree
- tasks
 - understanding topology, following paths
- scalability
 - 1K - 10K nodes (with/without labels)



<http://mbostock.github.com/d3.js/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

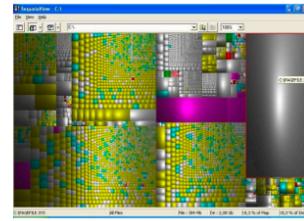


Node-Link Diagram Treemap

[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



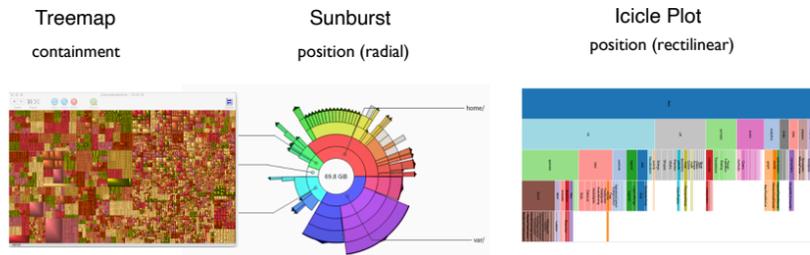
<https://www.win.tue.nl/sequoia/view/>

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



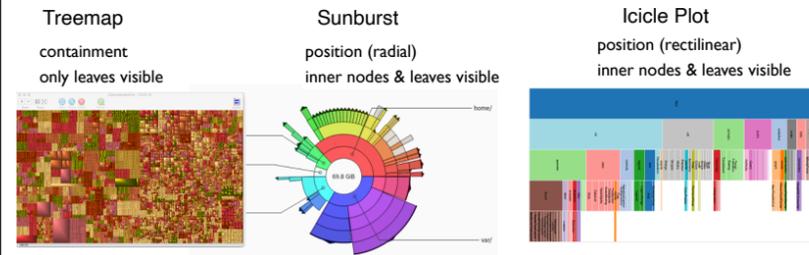
Idiom: implicit tree layouts (sunburst, icicle plot)

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



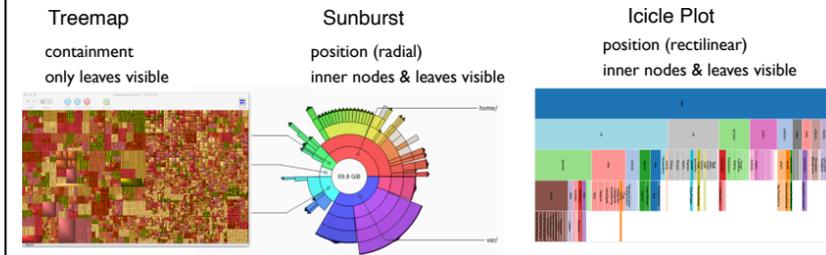
Idiom: implicit tree layouts (sunburst, icicle plot)

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

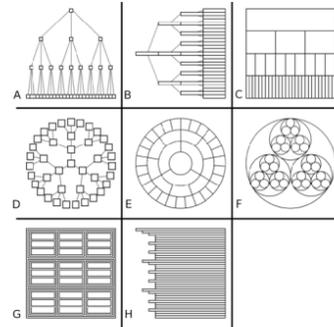


Idiom: implicit tree layouts (sunburst, icicle plot)

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



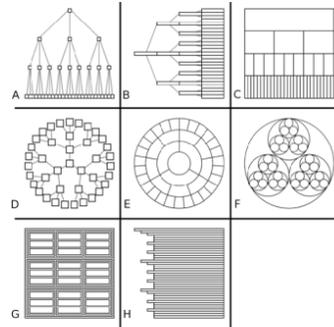
Tree drawing idioms comparison



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

Comparison: tree drawing idioms

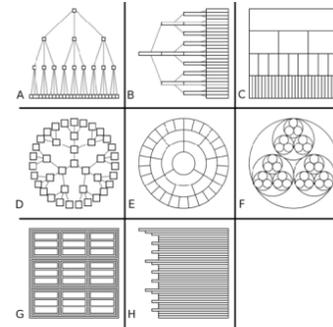
- data shown
 - link relationships
 - tree depth
 - sibling order



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

Comparison: tree drawing idioms

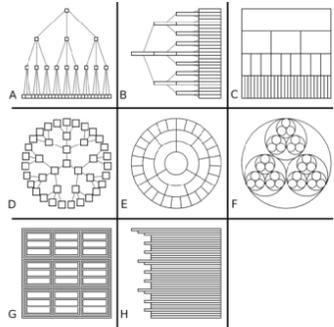
- data shown
 - link relationships
 - tree depth
 - sibling order
- design choices
 - connection vs containment link marks
 - rectilinear vs radial layout
 - spatial position channels



[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!

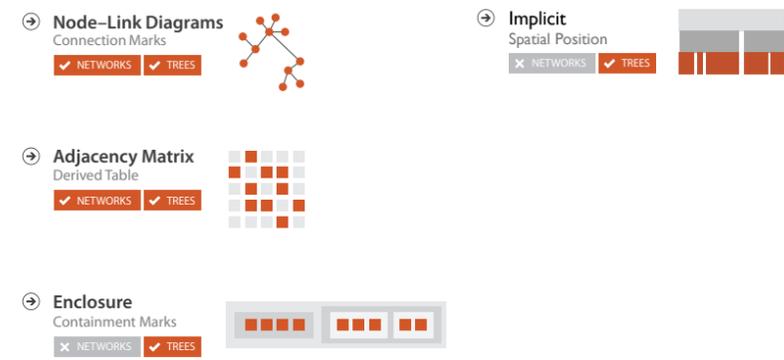


[Quantifying the Space-Efficiency of 2D Graphical Representations of Trees. McGuffin and Robert. Information Visualization 9:2 (2010), 115-140.]

treevis.net: Many, many options!



Arrange networks and trees



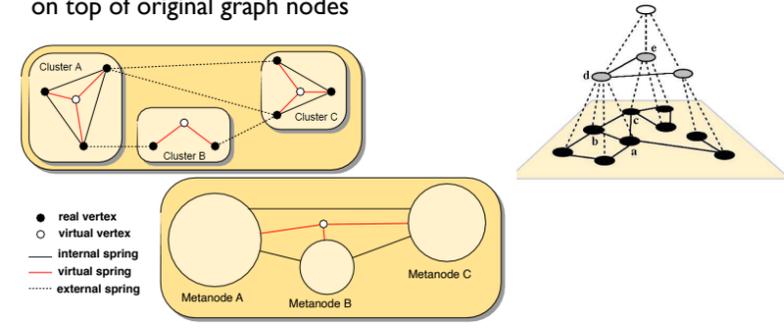
Visualization Analysis & Design

Network Data (Ch 9) II

Tamara Munzner
Department of Computer Science
University of British Columbia
[@tamaramunzner](https://twitter.com/tamaramunzner)

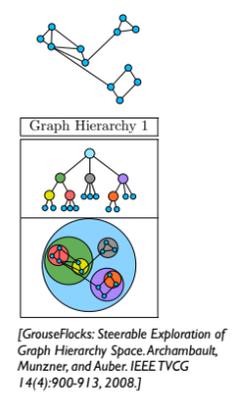
Multilevel networks

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



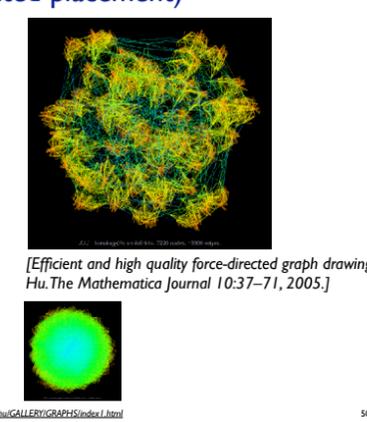
Idiom: GrouseFlocks

- 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



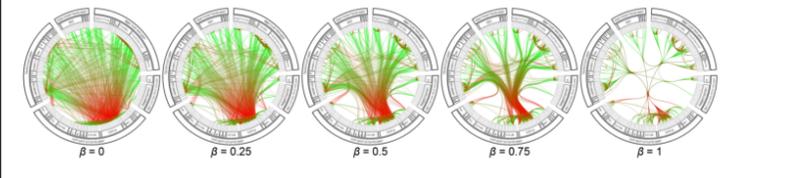
Idiom: sfdp (multi-level force-directed placement)

- 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: 1K-10K
 - hairball problem eventually hits



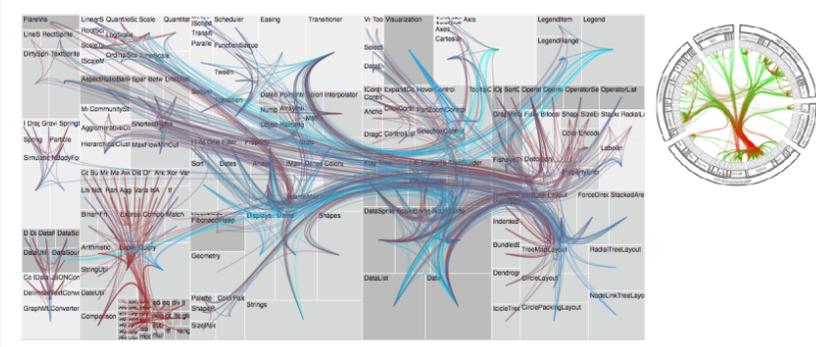
Idiom: hierarchical edge bundling

- 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 bundling

- works for any layout: treemap vs radial

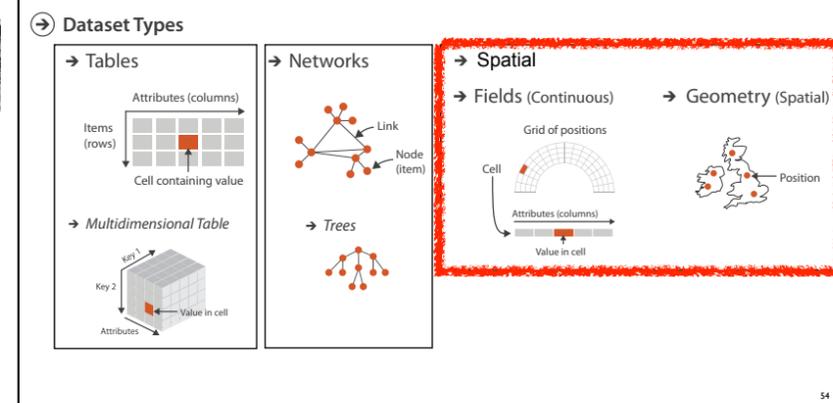


Visualization Analysis & Design

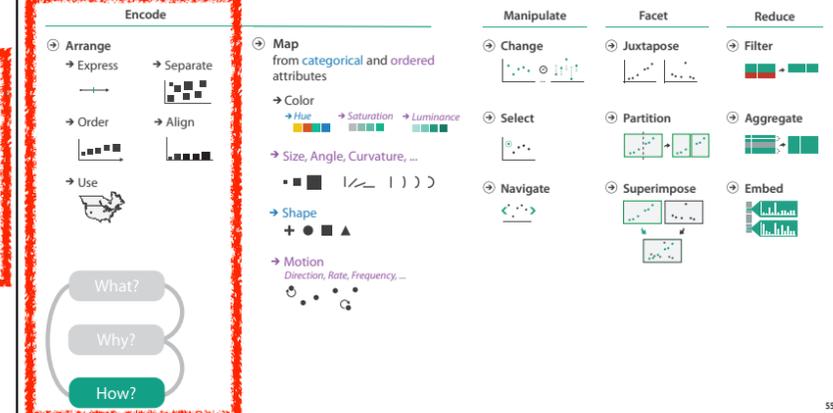
Spatial Data (Ch 9)

Tamara Munzner
 Department of Computer Science
 University of British Columbia
 @tamaramunzner

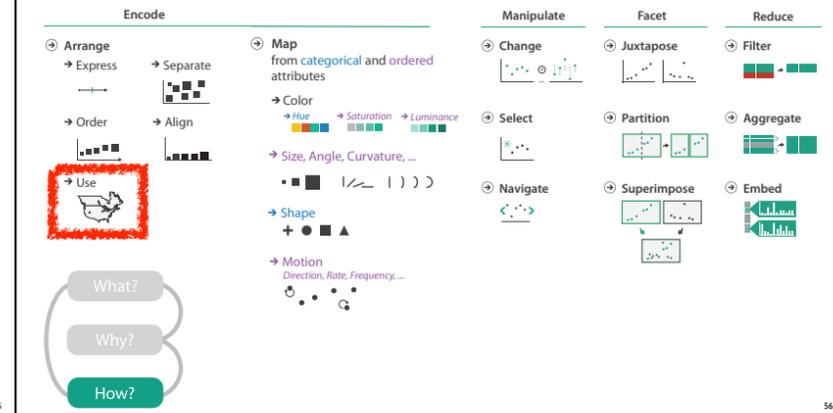
Focus on Spatial



How?



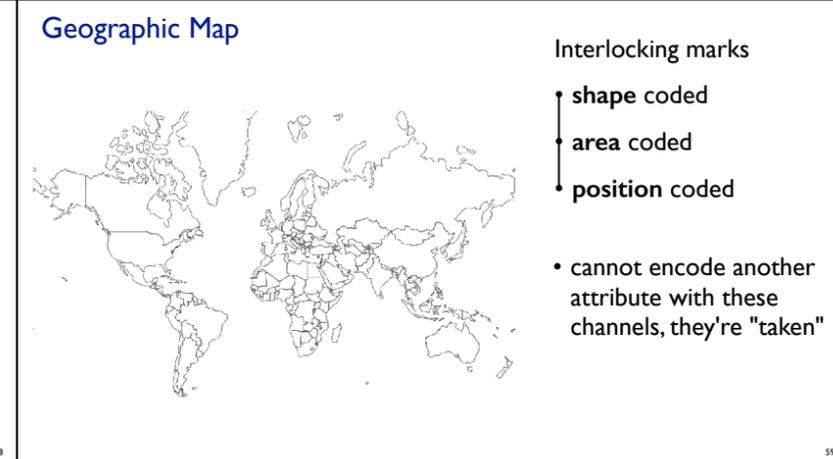
How?



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



Thematic maps

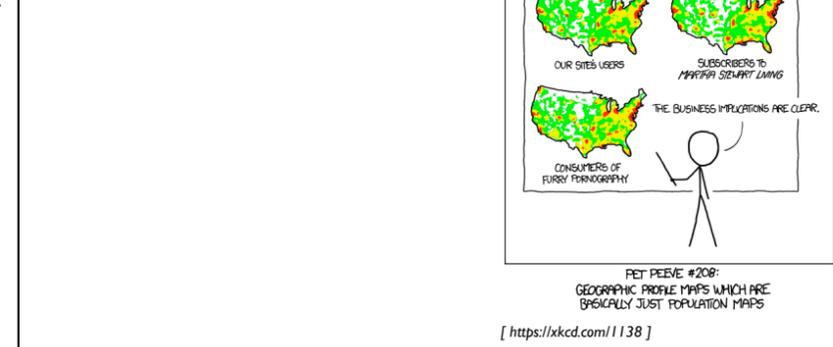
- show spatial variability of attribute ("theme")
 - combine geographic / reference map with (simple, flat) tabular data
 - join together
 - region: interlocking area marks (provinces, countries with outline shapes)
 - also could have point marks (cities, locations with 2D lat/lon coords)
 - region: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

Idiom: choropleth map

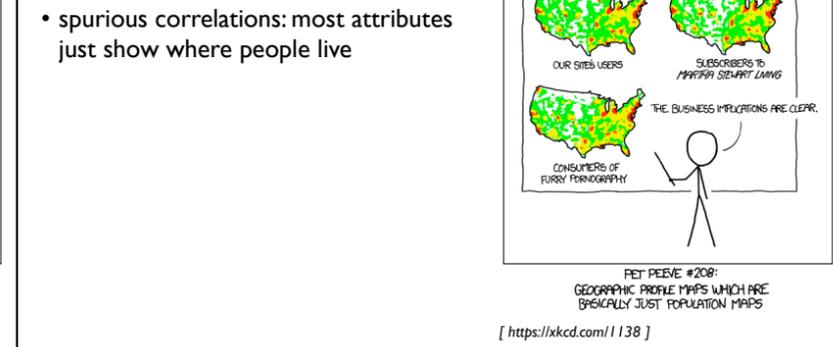
- use given spatial data
 - when central task is understanding spatial relationships
- data
 - geographic geometry
 - table with 1 quant attribute per region
- encoding
 - position: use given geometry for area mark boundaries
 - color: sequential segmented colormap



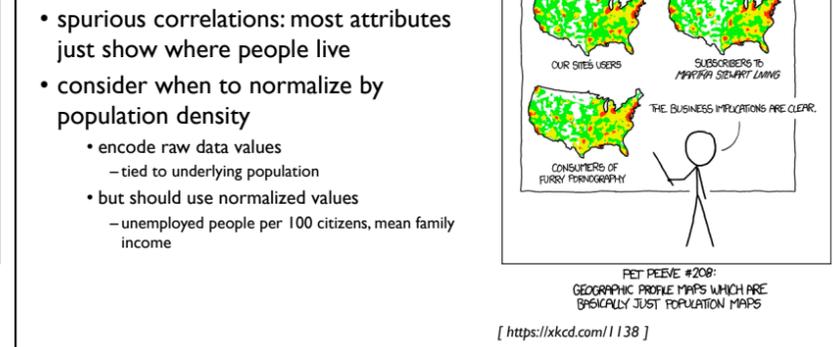
Beware: Population maps trickiness!



Beware: Population maps trickiness!

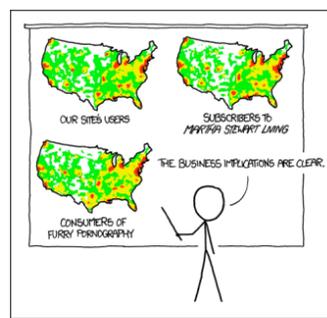


Beware: Population maps trickiness!



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



[<https://xkcd.com/1138/>]

65

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

66

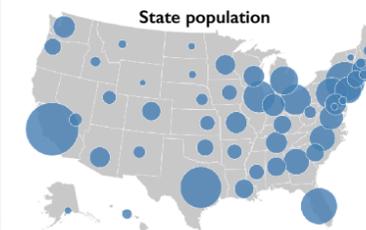
Choropleth map: Pros & cons

- 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

67

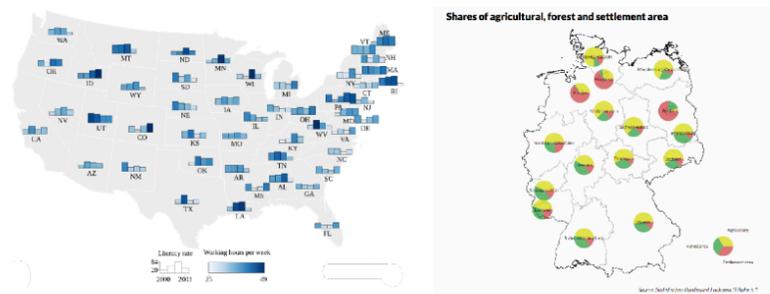
Idiom: Symbol maps

- 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



68

Symbol maps with glyphs



69

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

70

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

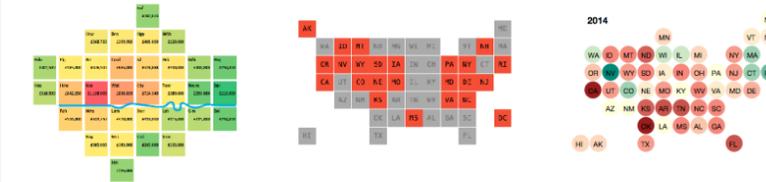


Greenhouse Emissions



Child Mortality

Idiom: Grid Cartogram



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

71

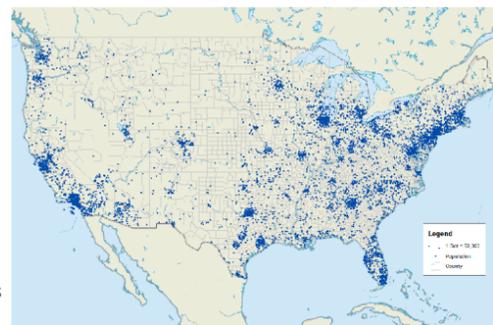
Cartogram: Pros & cons

- 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

73

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



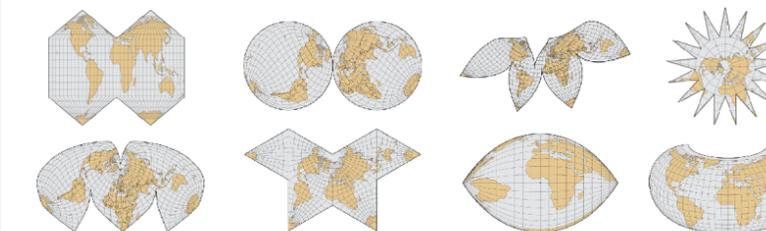
74

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

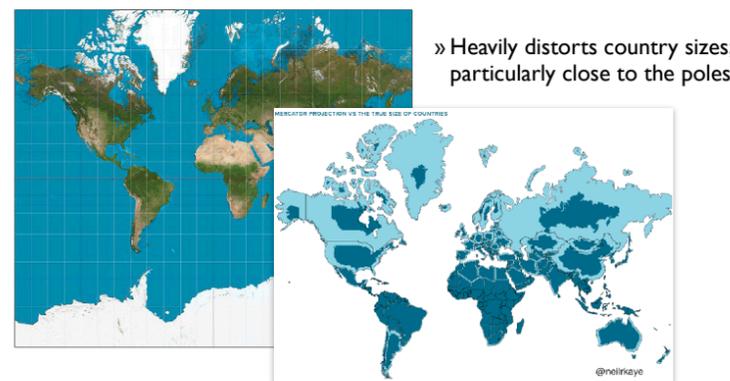
Map Projections

- 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/



75

Mercator Projection



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

77

Visualization Analysis & Design

Spatial Data (Ch 9) II

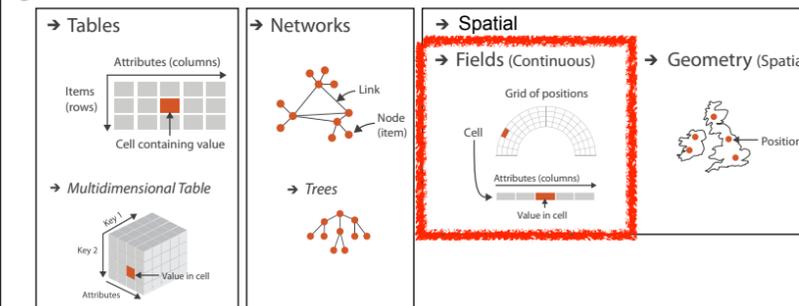
Tamara Munzner
Department of Computer Science
University of British Columbia
[@tamaramunzner](https://twitter.com/tamaramunzner)



79

Focus on Spatial

Dataset Types



79

Spatial Fields

80

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

81

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.]

82

Idioms: isosurfaces, direct volume rendering

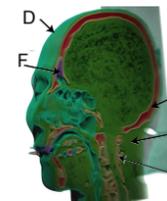
- data
 - scalar spatial field (3D volume)
 - 1 quant attribute per grid cell
- task
 - shape understanding, spatial relationships
- isosurface
 - derived data: isocontours computed for specific levels of scalar values



[Interactive Volume Rendering Techniques. Kniss, Master's thesis, University of Utah Computer Science, 2002.]
 [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
- direct volume rendering
 - transfer function maps scalar values to color, opacity
 - no derived geometry

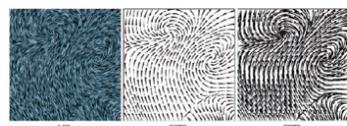
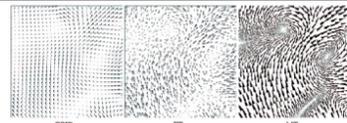


[Interactive Volume Rendering Techniques. Kniss, Master's thesis, University of Utah Computer Science, 2002.]
 [Multidimensional Transfer Functions for Volume Rendering. Kniss, Kindlmann, and Hansen. In The Visualization Handbook, edited by Charles Hansen and Christopher Johnson, pp. 189-210. Elsevier,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

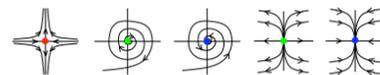
84

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



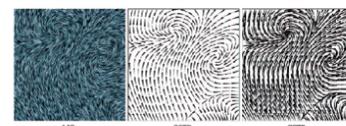
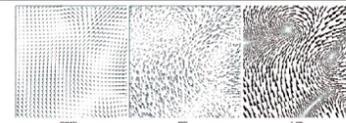
[Comparing 2D vector field visualization methods: A user study. Laidlaw et al. IEEE Trans. Visualization and Computer Graphics (TVCG) 11:1 (2005), 59-70.]



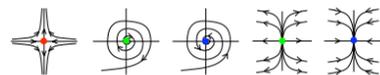
[Topology tracking for the visualization of time-dependent two-dimensional flows. Tricoche, Wischgoll, Scheuermann, and Hagen. Computers & Graphics 26:2 (2002), 249-257.]

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.]

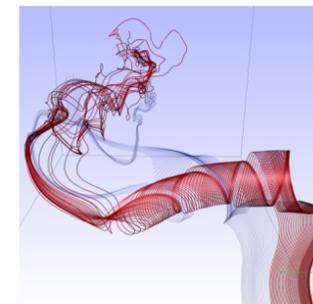


[Topology tracking for the visualization of time-dependent two-dimensional flows. Tricoche, Wischgoll, Scheuermann, and Hagen. Computers & Graphics 26:2 (2002), 249-257.]

86

Idiom: similarity-clustered streamlines

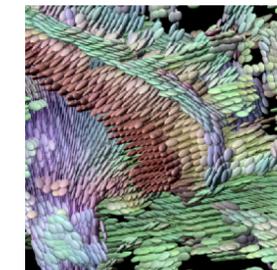
- data
 - 3D vector field
- derived data (from field)
 - streamlines: trajectory particle will follow
- derived data (per streamline)
 - curvature, torsion, tortuosity
 - signature: complex weighted combination
 - compute cluster hierarchy across all signatures
 - encode: color and opacity by cluster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



[Similarity Measures for Enhancing Interactive Streamline Seeding. McLaughlin, James, 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.]

88

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)



89