

Information Visualization

Spatial, NecklaceMaps, Myriahedral

Ex: Ballotmaps

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Week 8, 23 Oct 2025
<https://www.cs.ubc.ca/~tmm/courses/547-25>

Geographic Map

poly marks with 2D shared boundaries, encode:

- position / order channels, using given spatial data

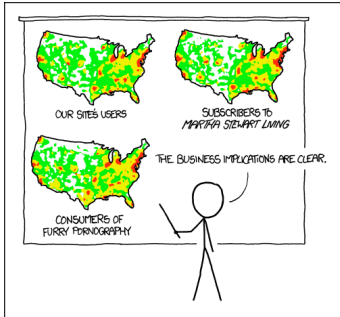
cannot use other channels to show other attributes, locked down as unavailable:

- size
- orientation
- symbol/shape



Beware: Population maps trickiness!

- spurious correlations: most attributes just show where people live



PET PEEVE #208:
GEOGRAPHIC PROFILE MAPS WHICH ARE
BASICALLY JUST POPULATION MAPS
[<https://xkcd.com/1138>]

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 channel (position) used "just" for geographic location
 - reasonable if understanding spatial distribution / patterns is a central task
 - visual salience of color coding 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

Plan for today

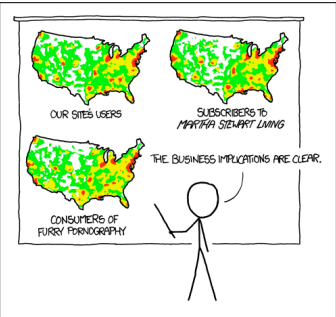
- mini-lecture / Q&A
 - geographic maps
 - paper: Necklace Maps [type: **algorithm**]
 - paper: Myriahedral [type: **algorithm**]
- small group exercises
 - Ballotmaps

Thematic maps

- show spatial variability of attribute ("theme")
 - combine geographic / reference map with (simple, flat) tabular data
 - join together
 - region: shared-boundary poly 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 maps

Beware: Population maps trickiness!

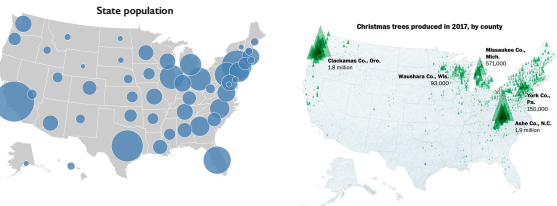
- spurious correlations: most attributes just show where people live
- consider when to normalize by population density
 - encode raw data values
 - tied to underlying population
 - but should use normalized values
 - unemployed people per 100 citizens, mean family income



PET PEEVE #208:
GEOGRAPHIC PROFILE MAPS WHICH ARE
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Idiom: Symbol maps

- family of idioms where symbol is used to represent aggregated data for region: point mark or glyph
 - add second mark type: two different kinds of marks at same level, base polys & new symbols
 - keep original spatial geometry in the background
 - one symbol per region on base map
 - encode quant attribute with size (1D or 2D)
 - free channels: symbol/shape, color, orientation (for asymmetric glyphs)
 - aka *proportional symbol maps*, *graduated symbol maps*
- often a good alternative to choropleth maps

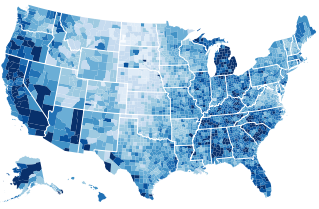


Next time

- week 9 reading
 - chap: Networks.
 - paper: Abyss-Explorer [type: **design study**]
 - paper: Genealogy [type: **technique**]
- week 10 reading
 - paper: Polaris/Tableau [type: **system**]
 - paper: D3 [type: **system**]
 - paper: Vega-Lite [type: **system**]
 - reminder: **NO CLASS Nov 6**

Idiom: choropleth map

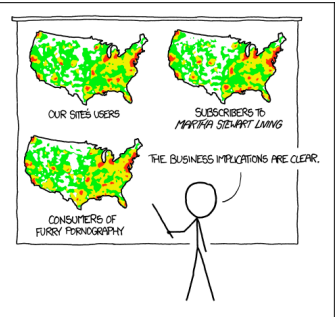
- use given spatial data
 - when central task is understanding spatial relationships
- data
 - geographic geometry
 - table with 1 quant attribute per region
- encoding
 - poly marks use given geometry for each region
 - with 2D shared boundaries
 - encode: quant attribute with color
 - this example: sequential segmented colormap
 - encode: position/order using given spatial data
 - unavailable: size, orientation, shape/symbol
 - only one mark type (polys)



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

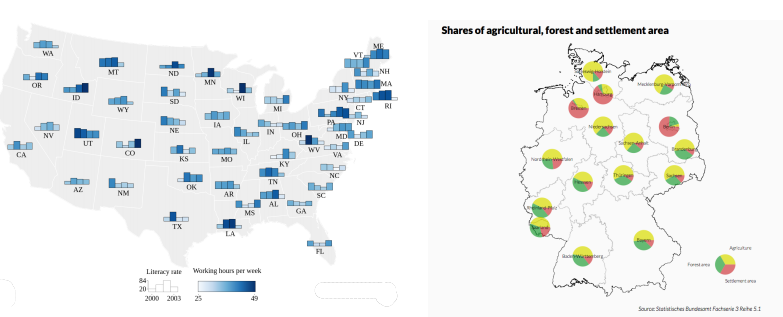
Beware: Population maps trickiness!

- 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

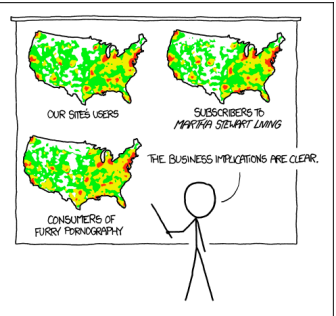


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Symbol maps with glyphs



Beware: Population maps trickiness!



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

Choropleth maps: Recommendations

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

Symbol map: Pros & cons

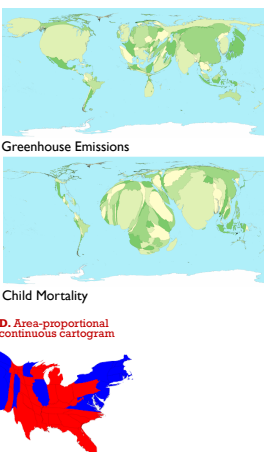
- pros
 - somewhat intuitive to read and understand
 - mitigate problems with region size vs data salience
 - marks: symbol size follows attribute value
 - glyphs: overall symbol size can be uniform (within-glyph marks follow attribute values)
- cons
 - possible occlusion / overlap
 - symbols could overlap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

Idiom: **Cartograms**

- family of idioms where change all poly marks on map simultaneously
 - only one mark type: replace old polys with new marks
 - with shared boundaries cannot change just one mark -- but can change all at once!
 - original map polys have shared boundaries
 - compute new set of interlocking polys, also with shared boundaries
 - preserve relative position as much as possible from old to new
- many variants exist, different constraints
 - preserve shapes as much as possible
 - encode quant attribute with 2D size
 - regularize to uniform shape for every region
 - encode quant attribute with color
 - regularize to uniform size and shape

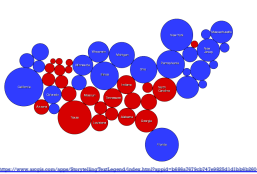
Idiom: **Contiguous cartogram**

- poly marks with 2D shared boundaries
 - aka *area-proportional continuous cartogram*
- derive new interlocking polys
 - based on combination of original interlocking marks and new quantitative attribute
 - encode: area (2D size) for new quant attribute
 - encode: **order, maintaining relative position of polys**
 - unavailable: position, orientation, shape/symbol
- algorithm to create new marks
 - input: target size (quant attribute)
 - goal: keep shape, position, orientation as close as possible to given spatial data for original polys
 - requirement: maintain constraints
 - order (relative position)
 - contiguous shared boundaries with neighbours



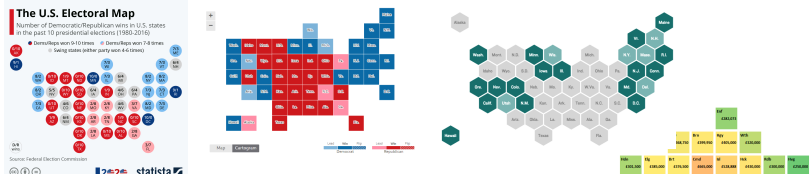
Idiom: **Dorling (circle) cartogram**

- Dorling cartogram
 - throw away shape by regularizing to circles
 - point marks, with shared 2D boundaries
 - encode quant attribute with 2D size
 - encode **relative locations of old polys with order**
 - unavailable:
 - position: algorithm constraint to be as close as possible to original geographic locations (given spatial data)
 - orientation: meaningless since circles are symmetric
 - symbol/shape: must be circle, by definition
 - free: color
 - can treat as special case of circle packing, with quasi-geographic position constraints



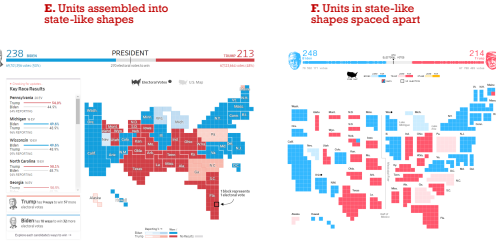
Idiom: **Equal-area (Grid) Cartogram**

- The U.S. Electoral Map (number of Democratic/Republican votes in U.S. states in the past 16 presidential elections (1980-2016))
- regularize shape & size, arranged in grid
 - derive new point marks with 2D shared boundaries
 - unavailable channels: size, shape/symbol, orientation
 - possible shapes: circles, squares, hexagons
 - unavailable: position, algorithm constraint to keep as close as possible to given spatial data
 - encode **relative location/arrangement of original polys with order**
 - encode quant attribute with color, just like with choropleth
- aka: *grid map, mosaic cartogram, pseudo-Demers cartogram, geofacets, geogrid, tile grid map, tile map*



Idiom: **Multi-level unit cartograms**

- two levels
 - top level: poly marks (states)
 - bottom level: square point marks (units)
 - countability for votes
 - shared 2D boundaries at each level
 - F: population density thru "countable" whitespace
 - special case, still consider boundary as shared



Contiguous cartogram: Pros & cons

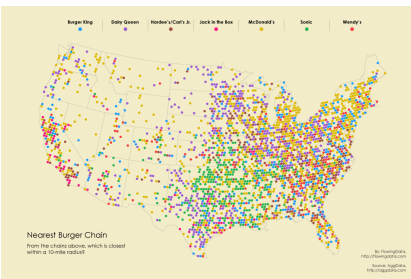
- pros
 - can be intriguing and engaging
 - best case: strong and surprising size disparities
- cons
 - require substantial familiarity with original dataset & use of memory
 - compare distorted marks to memory of original marks
 - mitigation strategies: transitions or side by side views
 - major distortion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

Non-contiguous cartogram: Pros & cons

- pros
 - stylized marks usually easier to understand than distorted contiguous shapes
 - can serve as good base for combining with other approaches
 - especially equal-area versions with uniform shapes
 - equal-area approach can mitigate size disparities problems of cartograms
- cons
 - still requires some familiarity with original dataset
 - quasi-geographic positioning may need some explanation
 - equal-area versions impose substantial distortions if original regions have very disparate size

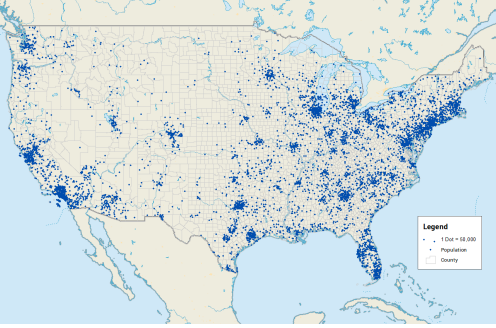
Idiom: **Dot maps, one to one**

- visualize actual location of item / feature / phenomenon by placing dots using 2D position channel
 - aka *dot density maps*
- one point represents a specific item
 - free channels: color, size, symbol/shape
- two mark types at same level
 - dot points and region polys
- task: identify detailed spatial distributions / patterns, clusters, outliers



Idiom: **Dot density maps, many to one**

- visualize distribution of a phenomenon by placing dot point marks where density within region shows quant attribute
 - one symbol represents a constant number of items, all have same size/shape
 - unavailable channels: size & shape & orientation
 - location random within region, **not** meaningful!
 - unavailable channel: position
 - free channel: color
 - aka *dot distribution maps*
- two mark types at same level (point, poly)
- task: show high-level spatial patterns, clusters



Dot density maps: Pros and cons

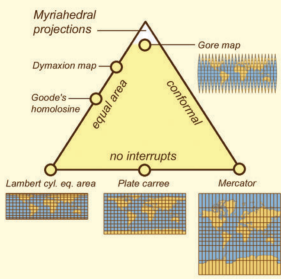
- pros
 - one-to-one is straightforward to understand
 - avoids choropleth non-uniform region size problems
- cons
 - challenge: normalization, just like choropleths
 - show population density (correlated with attribute), not effect of interest
 - perceptual disadvantage: difficult to extract quantities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

Thematic maps combinations

- can mostly mix and match these design elements
 - choropleth can be combined with anything else
 - cartograms can be used together with other approaches
 - can use choropleth color coding
 - can add symbols within those stylized regions
 - can add dots with additional geographic locations for more attributes
 - symbol maps difficult to use together with dot maps
 - ambiguity about whether point mark acting as
 - symbol (aggregate mark representing data for entire region), or
 - one-to-one dot (mark with meaningful position representing specific item of data), or
 - many-to-one dot (mark with random position representing many items of data)

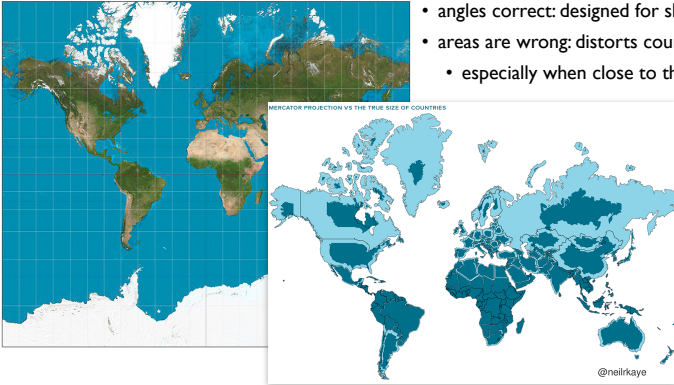
Map projections

- mathematical functions that map curved 3D surface geometry of Earth to flat 2D maps
- all projections of sphere on plane necessarily distort surface in some way
 - imagine flattening orange peel onto table
 - something must give
 - cannot have all 3 correct: area, angles, contiguity



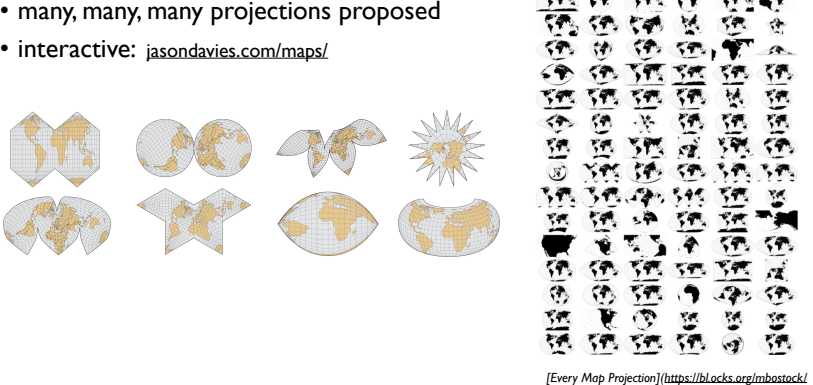
Mercator Projection

- angles correct: designed for ship navigation
- areas are wrong: distorts country sizes
 - especially when close to the poles



Map Projections

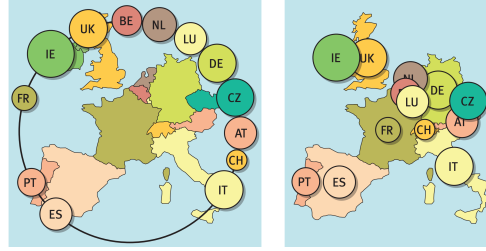
- many, many, many projections proposed
- interactive: jasondavies.com/maps/



Paper: **Necklace Maps**

Idiom: **Necklace maps**

- symbol map variant
 - place symbols algorithmically outside, not inside, region
 - goal: address clutter problem
 - map 2D data to 1D domain
- strengths
 - addresses clutter problem
 - can be hierarchical
- limitations
 - weaker association between symbol and region



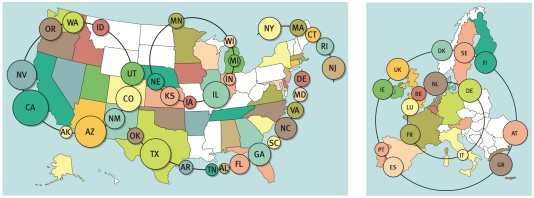
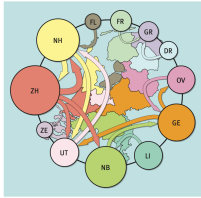
[Fig 3. Necklace Maps. Bettina Speckmann and Kevin Verbeek, TVCG (16):6:881-889, 2010.] <https://speckmann.win.tue.nl/papers/NecklaceMapsFinal.pdf>

Necklace maps

- algorithm: multiple variants provided in many cases
 - compute feasible intervals
 - optimize symbol sizes
 - optimize symbol placements
- quality criteria: some tradeoffs
 - symbol position wrt associated region
 - maximal symbol size
 - disjoint symbols
 - suitable order of symbols along line

Necklace map extensions / variations

- multiple necklaces
 - nested
 - disjoint
- flows



[Fig 9, 10, 11. Necklace Maps. Bettina Speckmann and Kevin Verbeek. TVCG (16)6:881-889, 2010.]

Scope

- contribution: propose technique and propose algorithm
 - some explanation / analysis of what it's good for
- evaluation
 - qualitative analysis/discussion of result images
 - high-level performance discussion

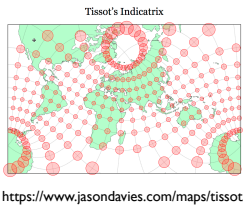
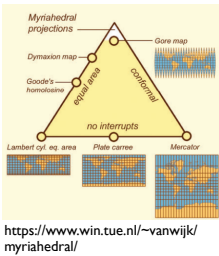
Paper: Myriahedral

Myriahedral projections

- algorithmic framework for many possible projections
 - including unusual ones
- later re-implementation from Belmonte:
<https://philogb.github.io/page/myriahedral/>

Myriahedral projections

- project from 2D sphere surface to 2D plane
 - can only fully preserve 2 out of 3
 - angles: conformal
 - area: equal area
 - contiguity: no interruptions



<https://www.jasondavies.com/maps/tissot/>

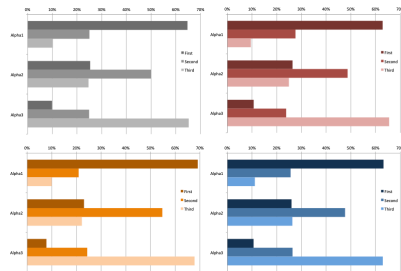
[Unfolding the Earth: Myriahedral Projections. Jarke J. van Wijk. The Cartographic Journal, 45(1):32-42, 2008.]

Break 3-3:10

Breakouts

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?



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

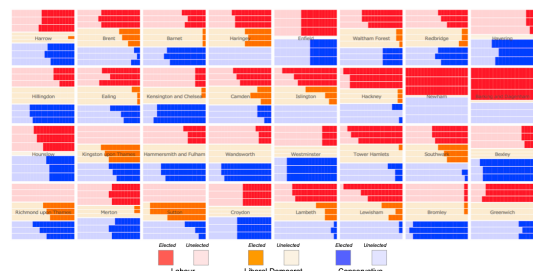
[Fig 5. BallotMaps: Detecting name bias in alphabetically ordered ballot papers. Wood, Badawood, Dykes, and Slingsby. IEEE TVCG (Proc. InfoVis) 17(12):2384-2391, 2011.]

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

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.

AcrossDistrib

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



- Borough: count of 32

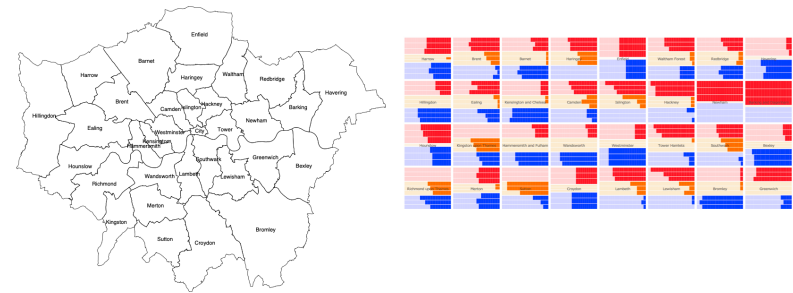
[Fig 1. BallotMaps: Detecting name bias in alphabetically ordered ballot papers. Wood, Badawood, Dykes, and Slingsby. IEEE TVCG (Proc. InfoVis) 17(12):2384-2391, 2011.]

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

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.

Best of both worlds: quasi-geographic positioning

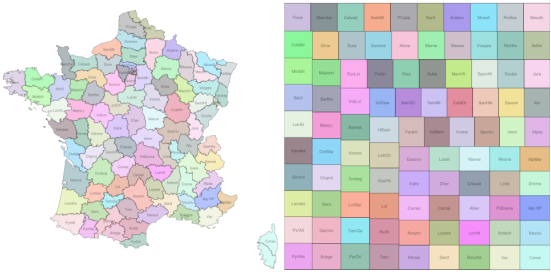
- choropleth: size issues
- tabular: lose geographic position information



Spatially ordered treemaps

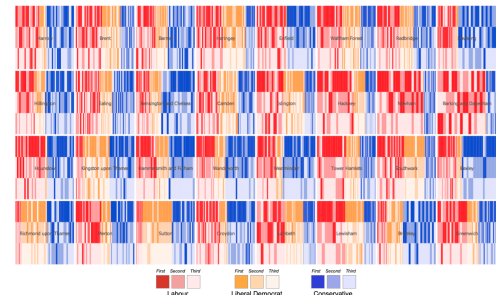
- quasi-geographic positions

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?



- Ward: count of 614

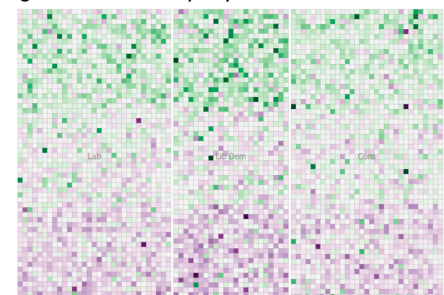
[Fig 4. BallotMaps: Detecting name bias in alphabetically ordered ballot papers. Wood, Badawood, Dykes, and Slingsby. IEEE TVCG (Proc. InfoVis) 17(12):2384-2391, 2011.]

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

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 party on the ballot paper).

PosWithin

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



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

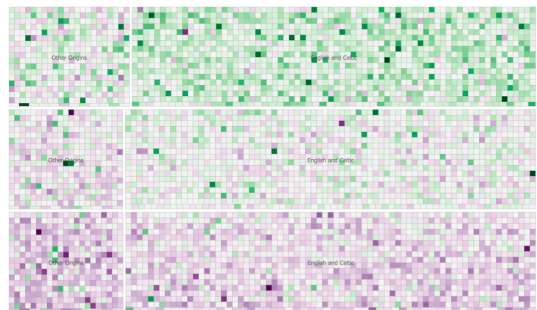
[Fig 6. BallotMaps: Detecting name bias in alphabetically ordered ballot papers. Wood, Badawood, Dykes, and Slingsby. IEEE TVCG (Proc. InfoVis) 17(12):2384-2391, 2011.]

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

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 candidate 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.

NameEthnicity

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



- 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!

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.

NameEthnicity

- Does this effect vary with geography?



[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.]

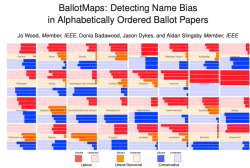
Yes. Varies by both borough & perceived ethnicity

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.

Key principles

- deriving data
- normalization
- information density
- ordering/position

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

Q&A / Backup Slides

Visualization Analysis & Design

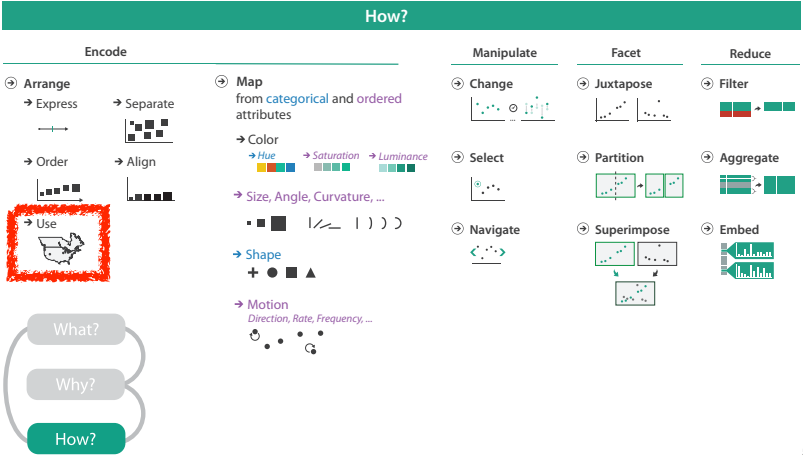
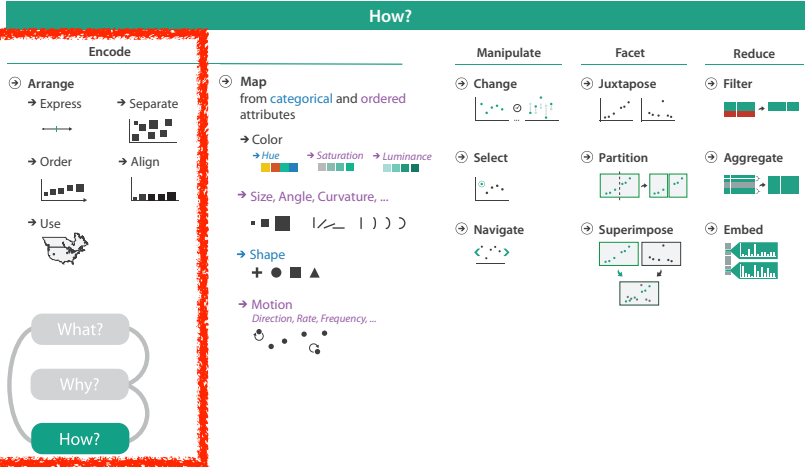
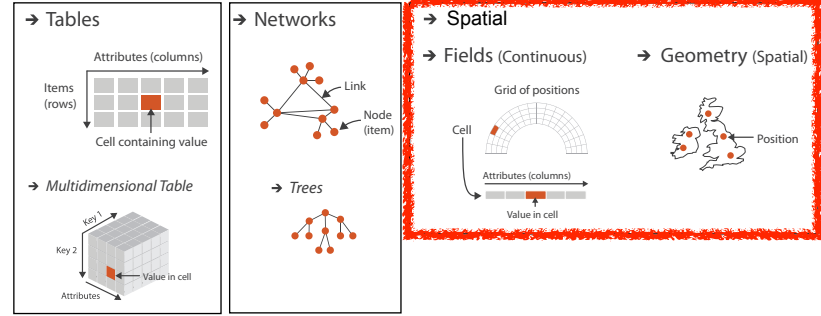
Spatial Data (Ch 9)

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Focus on Spatial

Dataset Types



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

Visualization Analysis & Design

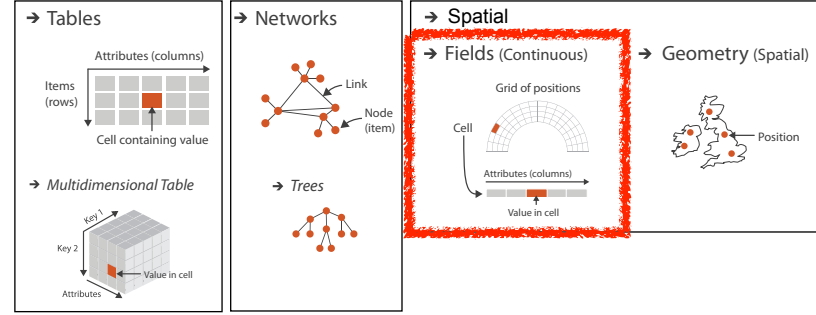
Spatial Data (Ch 9) II

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Focus on Spatial

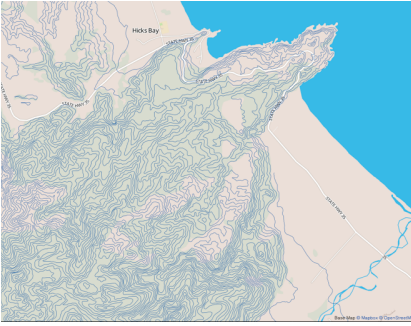
Dataset Types



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



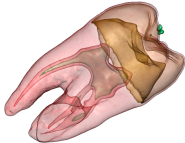
Land Information New Zealand Data Service

Idioms: isosurfaces, direct volume rendering

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

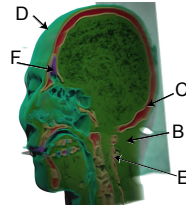
Idioms: isosurfaces, direct volume rendering

- 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



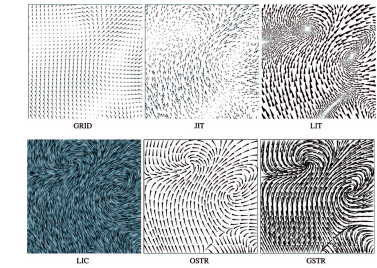
Idioms: isosurfaces, direct volume rendering

- 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

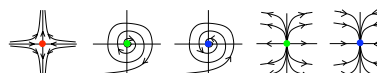


Vector and tensor fields

- 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



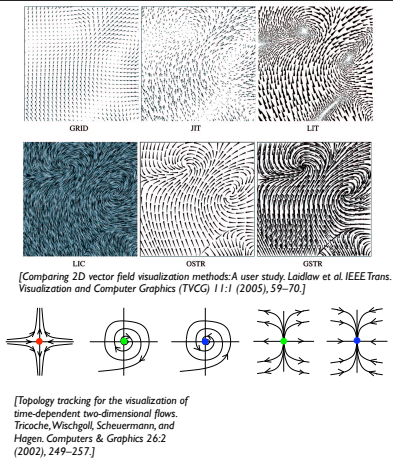
[Comparing 2D vector field visualization methods: A user study. Laidlaw et al. IEEE Trans. Visualization and Computer Graphics (TVCG) 11:1 (2005), 59–70.]



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

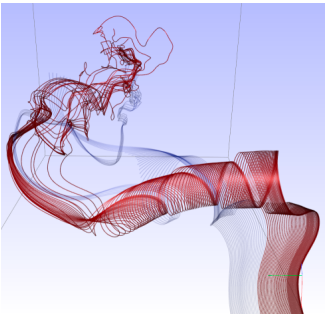
Vector fields

- 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)



Idiom: **similarity-clustered streamlines**

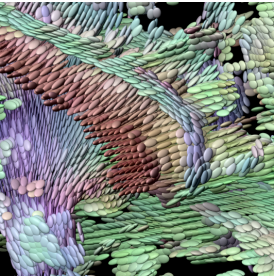
- data
 - 3D vector field
- derived data (from field)
 - streamlines: trajectory particle will follow
- derived data (per streamline)
 - curvature, torsion, tortuosity
 - signature: complex weighted combination
 - compute cluster hierarchy across all signatures
 - encode: color and opacity by cluster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



[Similarity Measures for Enhancing Interactive Streamline Seeding. McLaughlin, Jones, Laramée, Maki, 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)

