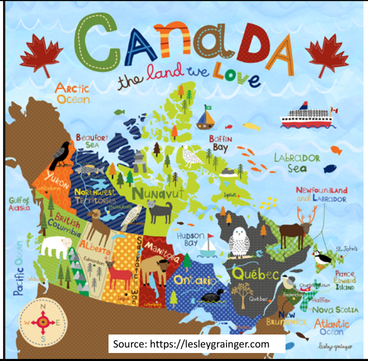
Visual Encoding of Dissimilarity Data via Topology-Preserving Map Deformation*

CPSC 547: Information Visualization

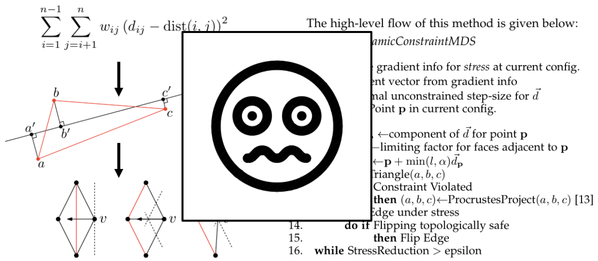
Felix Grund

*Cartography



We love maps!

But when it comes to science…



Let's split the title…

Visual Encoding of Dissimilarity Data via Topology-Preserving Map Deformation

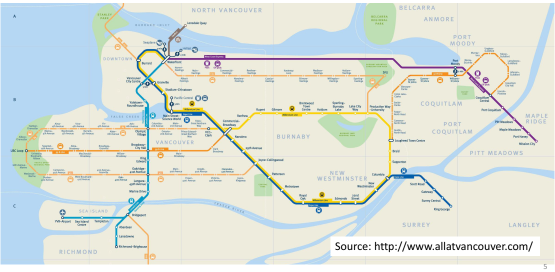
We visualize…

…things that are different…

…by changing a map…

…without losing regional structure.

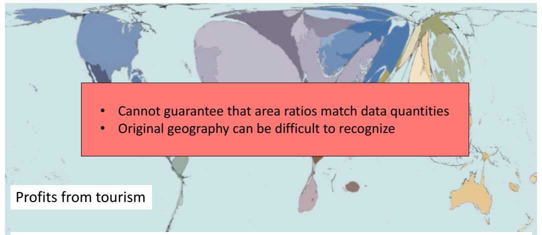
"We visualize things (that are different) by changing a map without losing regional structure."



Background (1) – Cartograms

- Deformation of map such that
  - geographic regions correspond to quantitative value
  - but adjacencies and shapes are preserved
- Have been used to show a variety of attributes
- Create flashy juxtaposition between geography and data

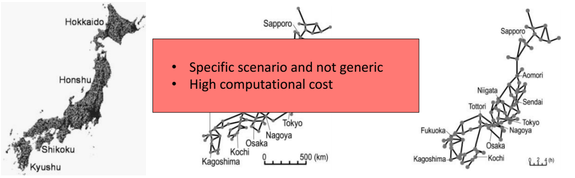
Background (2) – Cartogram Example



From: *Worldmapper: The World as You've Never Seen it Before* (Cited paper [10])
Published in: IEEE Transactions on Visualization and Computer Graphics (Volume: 12, Issue: 5, Sept.-Oct. 2006)

Background (3) – Travel Time Maps

- Focus on special case of transportation network (locations/distances)
- Deform map so travel times become edge lengths



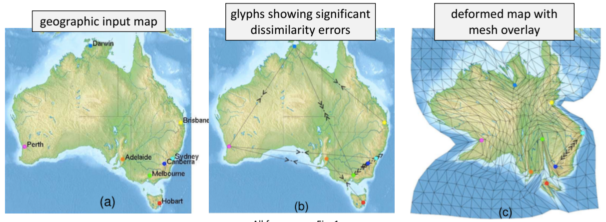
From: *A new algorithm for distance cartogram construction* (Cited paper [35])
Published in: International Journal of Geographical Information Science (ISSN: 1365-8816)

Contribution

- New map deformation technique that
  - preserves topology
  - balances preserving geographic shape with conveying data
- Instead of simple scalar values and regions (cartogram)
  - take a complete weighted graph between locations
  - move the locations such that distance corresponds to weights
  - but only as closely as possible
- Encode dissimilarity between locations as edge weights
  - distance in deformed map then related to data dissimilarity
  - enable to compare distances between locations and attributes
- Overcome limitations of deformation with visual overlays
- Deformation in response to interaction (with good performance)

First impression…

House price increases in Australia 2013



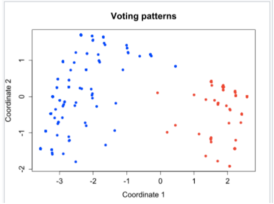
All from paper Fig. 1

Technique:
Topology preserving multidimensional scaling

???

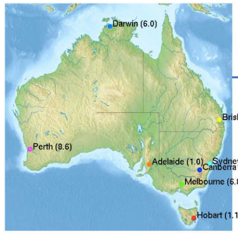
Background: Multidimensional Scaling (MDS)

- Visualizes level of (dis-)similarity of individual cases of a dataset
- Achieved by minimizing *stress function* over data points
- Plot with "minimal stress": distance between points is proportional to dissimilarity

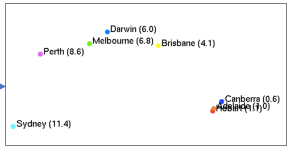


MDS applied to voting patterns in US house of representatives - blue: democrats, red: republicans (Source: Wikipedia)

House price increases in Australia 2013



stress function



Paper Figs. 2a + 2b

- Left: Topology
- Right: MDS => topology is lost!
- This paper: MDS but preserve Topology

Approach

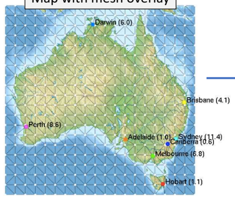
- MDS of data points in deformable mesh
- Original map image is mapped onto mesh incrementally through transformations
- Mesh may be deformed
- Constraint: mesh and data vertices cannot pass through mesh edges
- 3 steps
  1. Deform map to follow points (MDS)
  2. Preserve map topology
  3. Enable interaction by *dynamic mesh modification*

Step 1: deform map to follow points

- Map with triangular mesh overlay
  - Edges of triangles: *Delaunay triangulation* (?)
  - "no point in P is inside the circumcircle of any triangle" (Wikipedia)
- Vertices: geographic locations + "helper points"
  - add bendpoints
  - regularize and preserve topology
- New stress function with helper points to model both:
  - degree of fit of the data points to their ideal separation
  - degree of deformation of the mesh

Step 1: deform map to follow points (cont.)

Map with mesh overlay



Paper Fig. 3a

Minimal stress result

Paper Fig. 3b

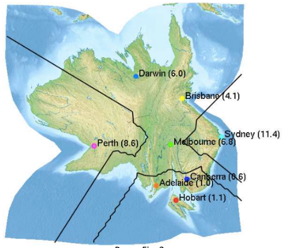
Problem: points are different from topology => map is distorted beyond recognition

Step 2: preserve mesh topology

- Idea: preserve orientation of triangles in the mesh
- Constraint in the deformation:
  - No inverted triangles
  - Minimum height for triangles
- Algorithm for stress reduction by iteratively refining triangles
  - Start with the original deformation and run through all triangles
  - Correct triangle's orientation to meet constraints with minimal change
  - Repeat until satisfying overall configuration is found

Step 2: preserve mesh topology (cont.)

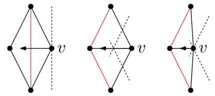
- Result: MDS with topology constraint
- Isolines highlight similar areas



Paper Fig. 3c

Step 3: dynamic mesh modification

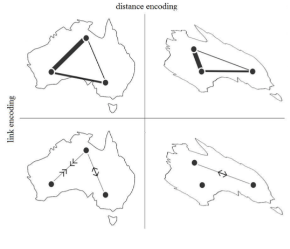
- Challenge: interactive setting
  - Impossible to predict where points will move
- Solution: update mesh while stress reduction algorithm is running
  - Options: adding/removing points vs. changing edges
  - Decision: changing edges is sufficient *(edge flipping)*
  - After edge flip: minimal height constraint not violated and points can move
- Again: preserve topology!
  - by constraints on flips



Paper Fig. 5

Visual Design

- Deformation: <u>incomplete</u> representation of complex dissimilarities
- Solution: combine map deformation with overlays
  - Show dissimilarities with <u>visual links</u>
  - Show errors in map distance <u>using error glyphs</u>



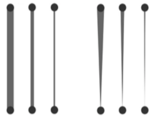
Paper Fig. 7

Visual Design Part 1: Visual Links

- Goal: convey dissimilarity <u>and</u> geographical data
- Solution: visual links
- Challenge: maps are dense representation and links should
  - be distinguishable from background map
  - limit clutter of the background map
  - encode weight
  - encode directionality

Visual Design Part 1: Visual Links (cont.)

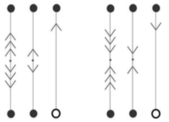
- Decisions:
  - Grayscale: distinguishable from background map
  - Thin lines and pencil-like marks: avoid clutter
  - Weights: thickness
  - Directions: tapered links



Paper Fig. 8a

Visual Design Part 1: Visual Links (cont.)

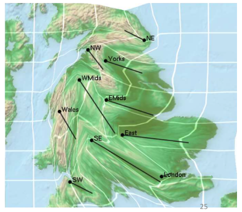
- Problem: not all links can be shown due to clutter
- Solution: Glyphs highlighting difference betw. dissimilarty and spatial separation
- Decisions:
  - Look and feel of error bars
  - Discrete over continuous (three bins)
  - Symbols existent in cartography



Paper Fig. 8d

Visual Design Part 2: Deforming the Map

- Map deformation shows dissimilarities with fewer visual overlays
- Problem: required background knowledge on map
- Solution: modify map design to convey deformation
  - Grid cells are enlarged or shrunk
  - Link current position with previous position



Paper Fig. 10b

Visual Design Part 2: Deforming the Map (cont.)

- Interaction
  - Selection of nodes
  - Filtering of links
  - Switch from general deformed view to centered view with selected points
  - Change stress threshold to show and hide glyphs
  - Config. panel for different encoding combinations => enable comparisons
- Redrawing after each iteration of algorithm

Application Case Studies

- Rail travel-times in the UK
- Socioeconomic data in the UK
- Power grid data in Australia

Demo

Technique Evaluation

- Measure performance: indicate responsiveness for interactive usage
- Datasets: house prices, power grid, socioeconomic data
  - Applied with different grid sizes
- Techniques: unconstrained, constrained, constrained dynamic mesh
- Results:
  - Dynamic mesh is most effective in reducing stress and improve performance (with constraints on grid size)
  - Summary: algorithm is fast enough to compute deformation with interaction
  - Limitation: 30 data points at most

What – Why – How

- What (data):
  - Geographical maps (with arbitrary encoding already present)
  - Arbitrary (dis)similarity data associated with locations
- What (derived):
  - Complete weighted graph
- Why (tasks):
  - Highlight (dis)similarity between locations in terms of underlying attributes
- How (encode):
  - Map deformation
  - Nodes for locations and weighted, directed graph edges (connection marks)
  - Discrete error glyphs on edges
  - Deformed grid
  - Links indicating location before deformation
  - Isolines for areas of high similarity

What – Why – How (cont.)

- How (reduce):
  - Selection of nodes
  - Filtering of nodes
  - Change stress threshold
- How (facet):
  - Switch from general deformed view to centered view with selected points
- How (manipulate):
  - Change encoding combinations
- (some other encoding techniques in case studies)
- Scale: max 30 data points (authors stay vague)

Good

- Novel compromise of both deforming and preserving topology
  - Both are important!
- Novel ability of animation associated with map deformation
  - Algorithm and its performance with animation are impressive
- Good example how one technique can be enriched by another
  - Map deformation + visual overlays
- Visualization techniques are well explained and justified
  - Authors did a lot of research and consulted experts

Bad

- ☹ Hard to read ☹
  - Requires a lot of background knowledge
  - Some terms remain unexplained and unreferenced
- Encoding too many things
  - Even though authors explain how to avoid clutter, we still find it
- Visualization is hard to interpret
  - Also requires background knowledge
  - Even with the demo it's hard to understand what this is about
- Authors remain vague in scalability
  - Evaluation: 30 data points max
  - Theory vs. practical
- Suddenly additional encoding technique (e.g. aggregate data points) explained in case studies

Thank you.