

Evolution Strategies for Optimizing Rectangular Cartograms

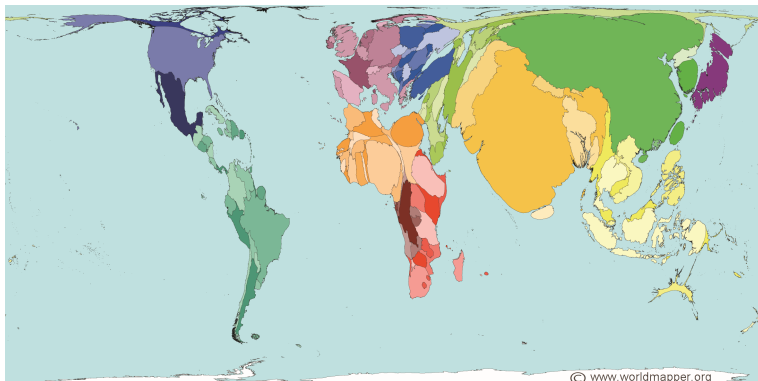
Kevin Buchin¹, Bettina Speckmann¹, and Sander Verdonschot²

¹ TU Eindhoven, ² Carleton University

September 20, 2012

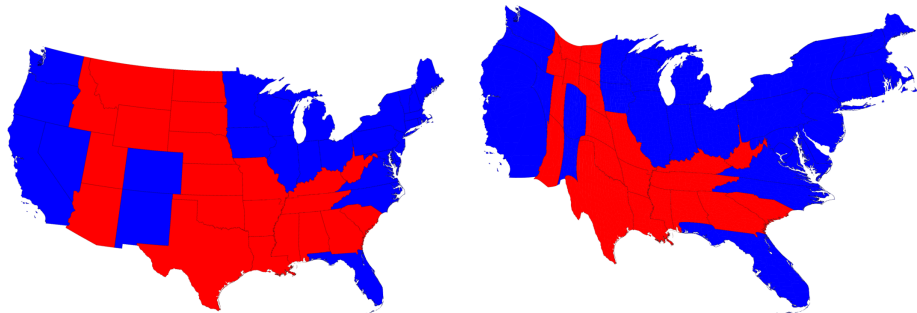
Cartograms

- Map with administrative boundaries
- Visualizes a quantitative value per region (e.g. population, GDP)
- Regions are deformed to make their area proportional to this variable



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Cartograms

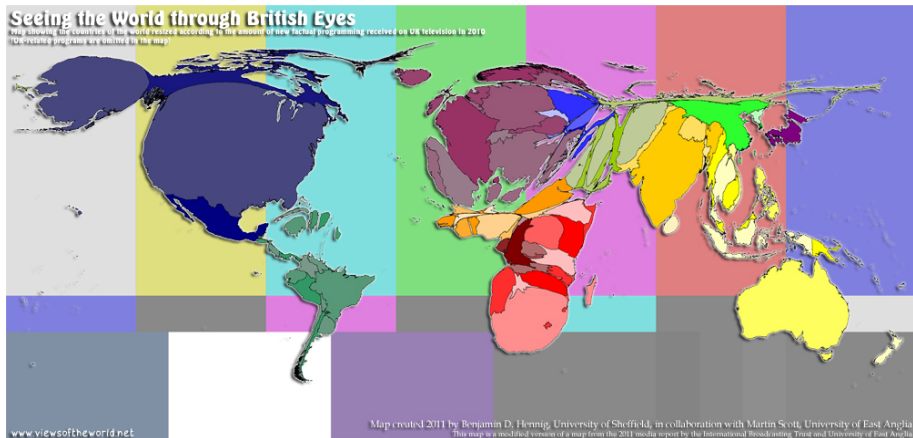


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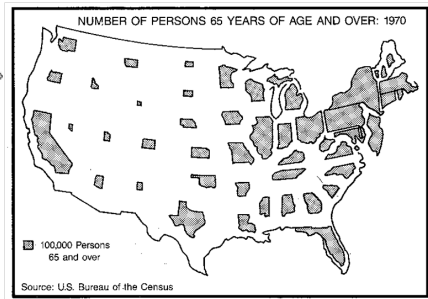
Types of Cartograms

- Contiguous area cartogram
- Non-contiguous area cartogram
- Dorling / Demers cartogram
- Rectangular cartogram

Contiguous area cartogram

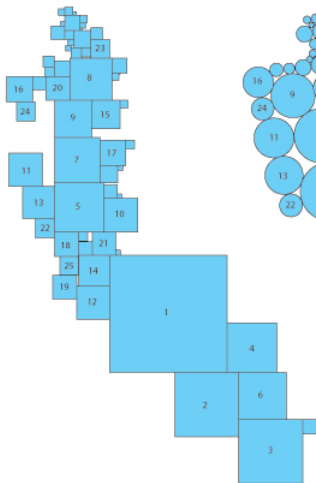


Non-contiguous area cartogram

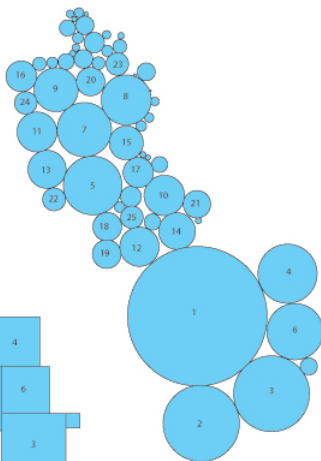


Dorling / Demers cartogram

Demers Cartogram

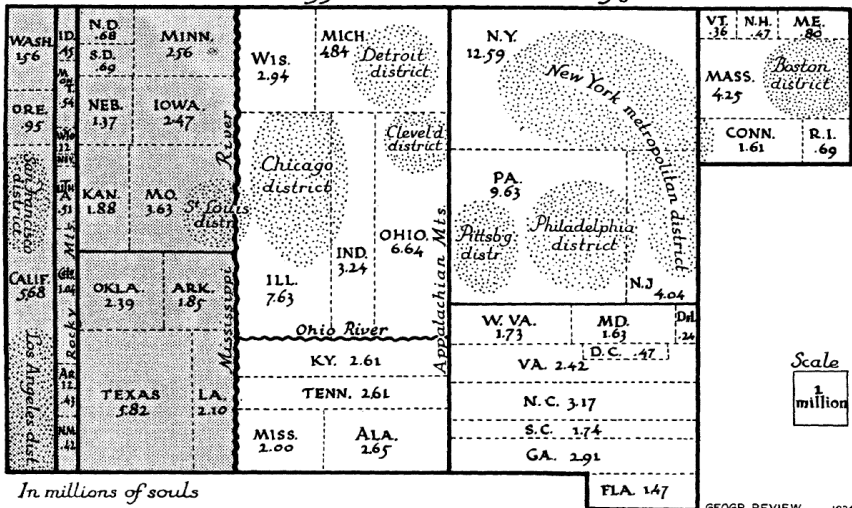


Dorling Cartogram



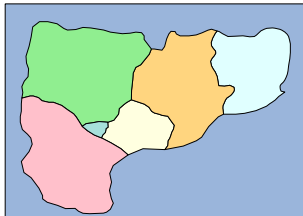
Rectangular Cartogram

POPULATION 1930 census. U.S. total 123.6 million

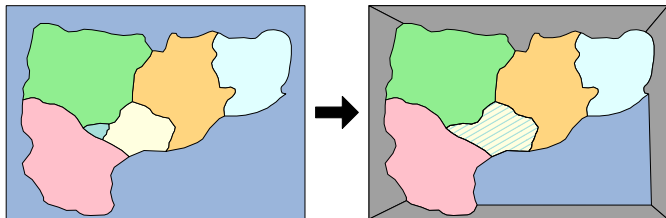


GEOGR. REVIEW, 1934

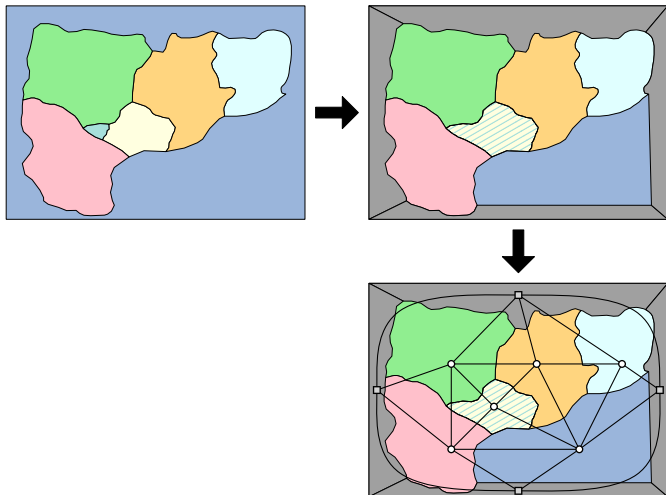
- Given a geometric map and a corresponding variable



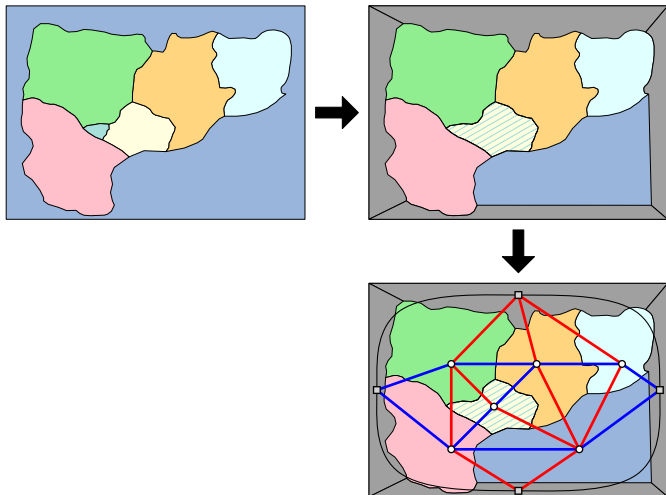
- Convert it to the correct format



- Assign a direction to each adjacency

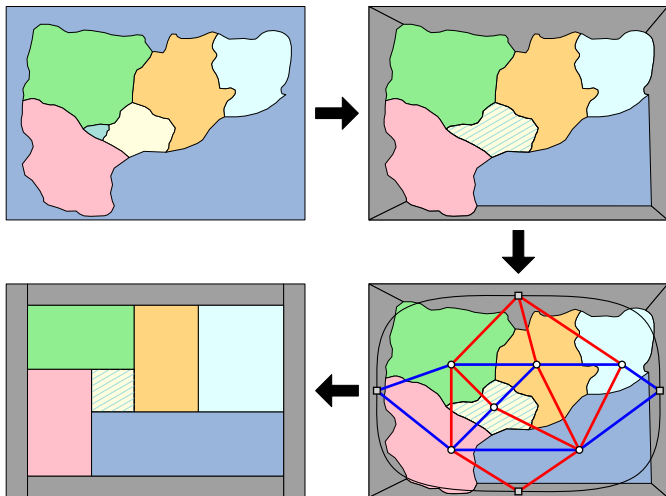


- Assign a direction to each adjacency



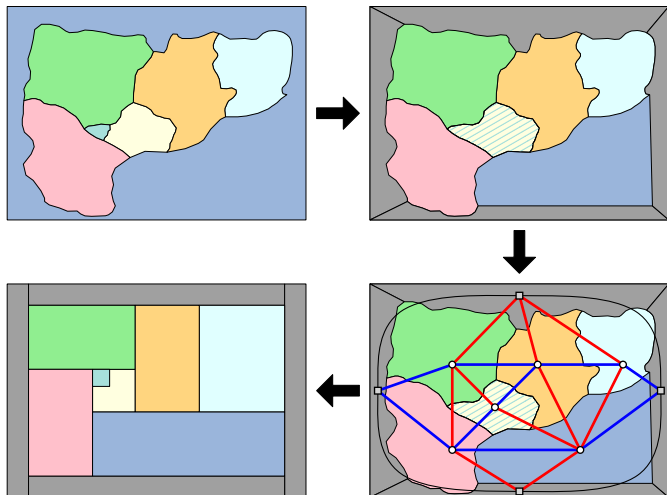
Workflow

- Build the cartogram [Speckmann, van Kreveld, and Florisson, 2006]



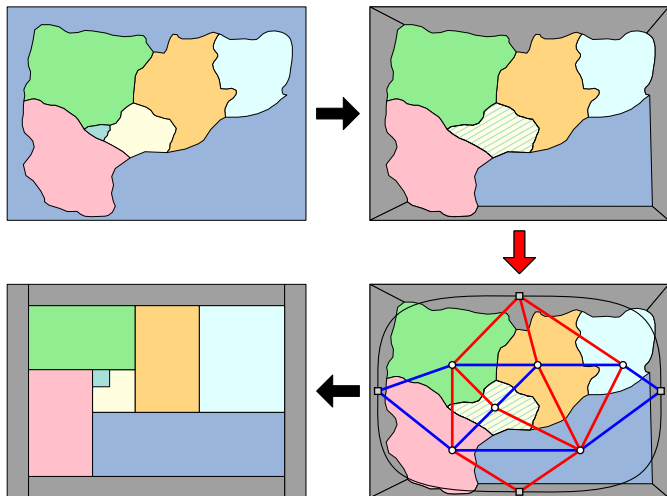
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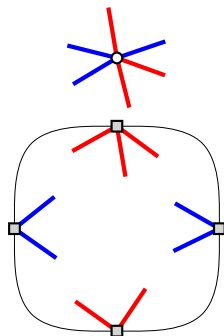
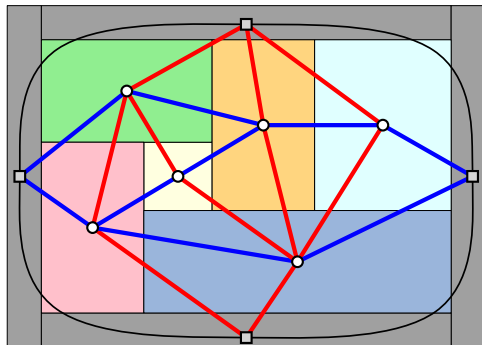
Workflow

- Our focus is on the direction of the adjacencies



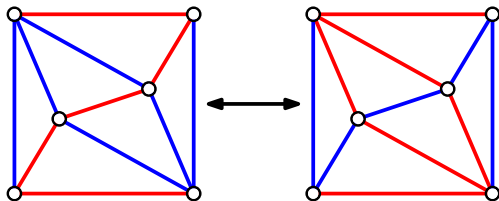
Regular Edge Labelings

- Colouring of interior edges of the dual graph
- Red: vertical adjacency, Blue: horizontal adjacency
- Must satisfy local constraints



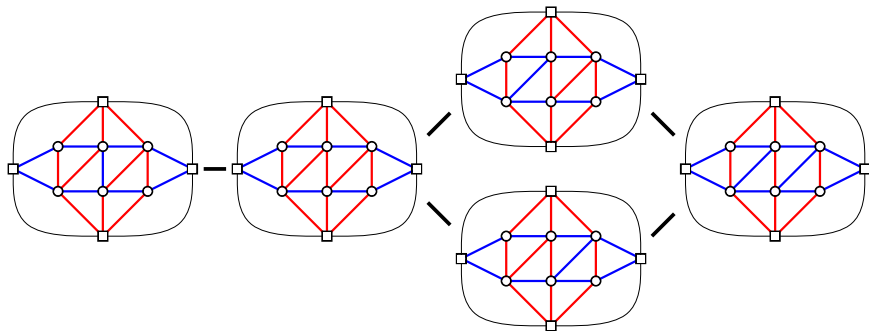
Regular Edge Labelings

- *Flip*: invert colour of all edges inside alternating 4-cycle



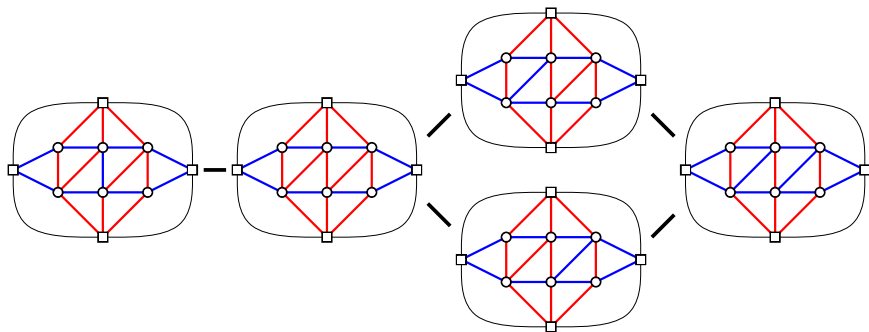
Regular Edge Labelings

- *Flip*: invert colour of all edges inside alternating 4-cycle
- *Flip graph*: Take all labelings, add an edge if two are connected by a flip



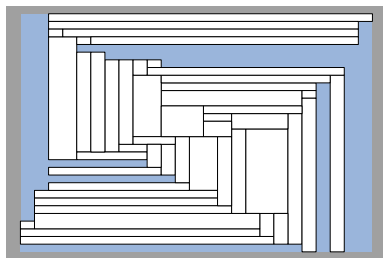
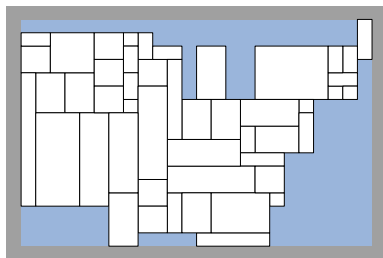
Regular Edge Labelings

- *Flip*: invert colour of all edges inside alternating 4-cycle
- *Flip graph*: Take all labelings, add an edge if two are connected by a flip
- This graph is a distributive lattice [Fusy, 2009]



Challenges

- Maps of EU and US have over 100 million labelings
- The 'best' labeling can vary between data sets
- A local change in the labeling can cause global changes in the cartogram



- 1 Initialize a random population of labelings
 - Start at the minimum labeling
 - Follow a random path towards the maximal labeling
 - Stop at a random height

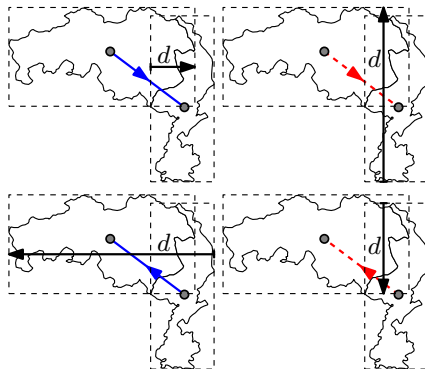
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 - Select a random labeling, favouring higher quality
 - With low probability, take a long random walk in the lattice
 - With high probability, take one random step in the lattice

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- 4 Repeat steps 2 and 3 a fixed number of times, keeping track of the best labeling found

Quality Criteria

- Correct adjacencies
- Relative positions of the regions



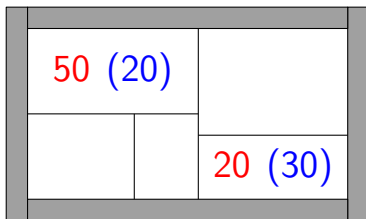
Quality Criteria

- Correct adjacencies
- Relative positions of the regions
- Cartographic error of the regions

$$\frac{|A_c - A_s|}{A_s}$$

A_c : Area in cartogram

A_s : Area specified



Error: 1.5

Error: 0.33

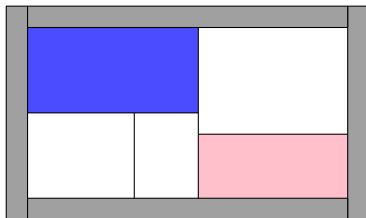
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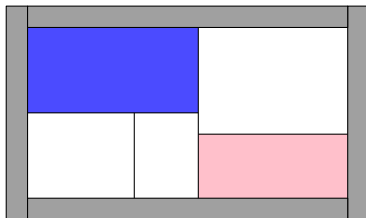
Quality Criteria

- Correct adjacencies
- Relative positions of the regions (30 %)
- Cartographic error of the regions (70 %)

$$\frac{|A_c - A_s|}{A_s}$$

A_c : Area in cartogram

A_s : Area specified



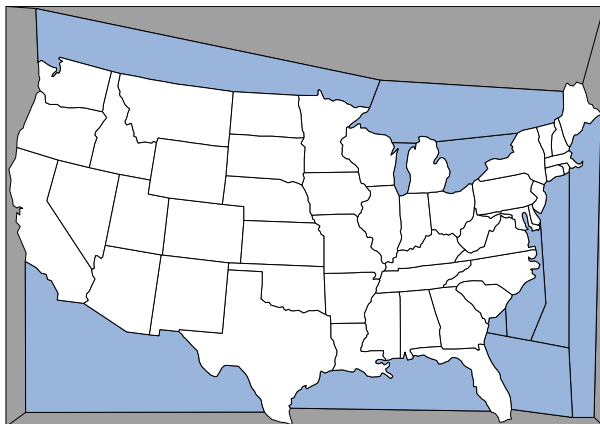
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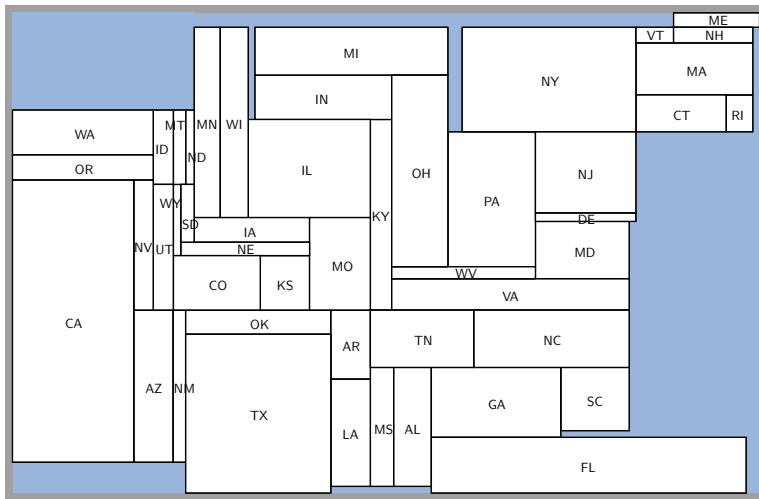
Experimental Results

United States (63 regions)

- Made New Mexico adjacent to Utah to resolve 4-state point
- All US Census data sets with a positive value for each state
- Generating one cartogram took ~8 minutes



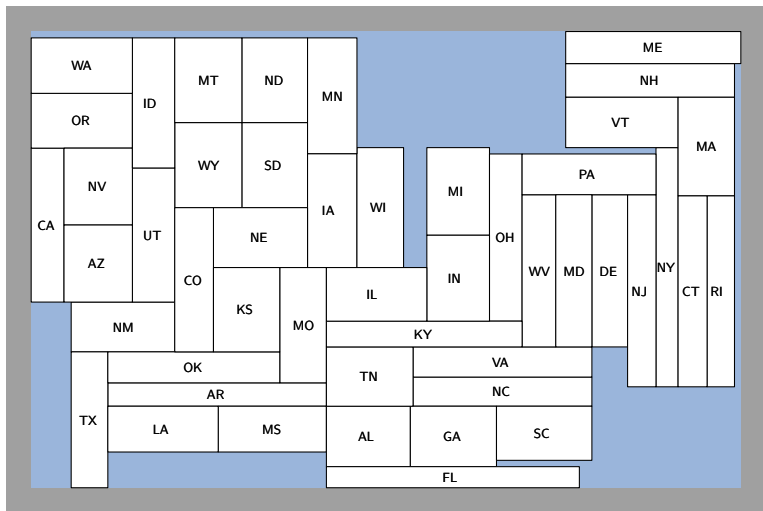
United States - Population



Average error: 0.5 %

Maximum error: 2.2 %

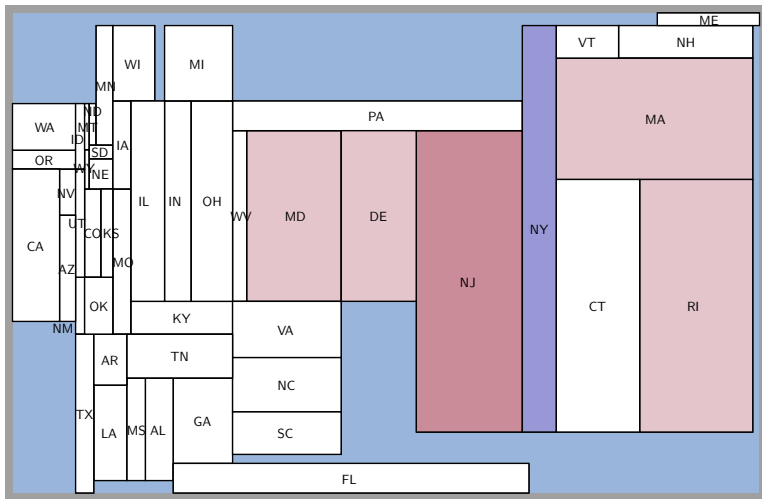
United States - High School Graduates (%)



Average error: 0.0 %

Maximum error: 0.0 %

United States - Population per square mile

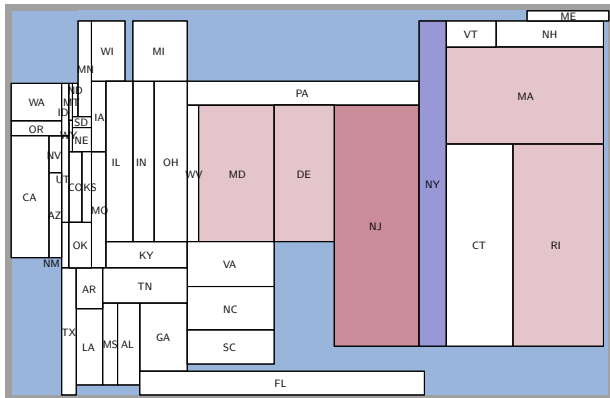


Average error: 2.0 %

Maximum error: 11.3 %

United States - Population per square mile

- Negative correlation with land area
- Large variation

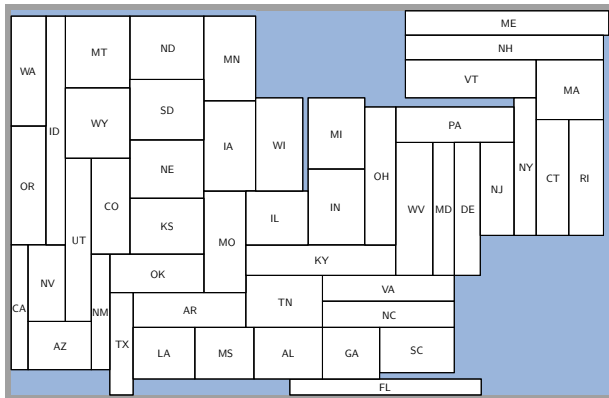


Average error: 2.0 %

Maximum error: 11.3 %

United States - Non-Hispanic White Population (%)

- Negative correlation with land area
- Large variation

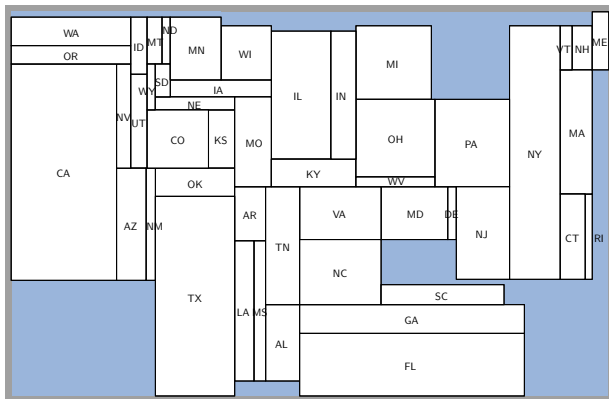


Average error: 0.0 %

Maximum error: 0.0 %

United States - Businesses w/o Paid Employees

- Negative correlation with land area
- Large variation

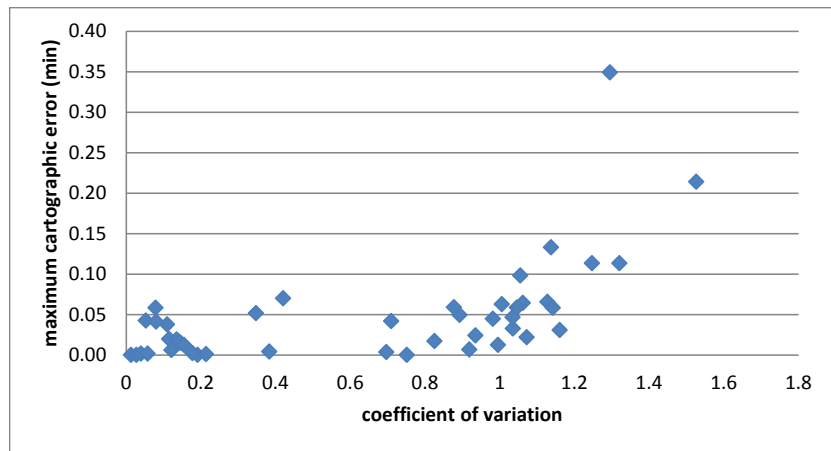


Average error: 0.7 %

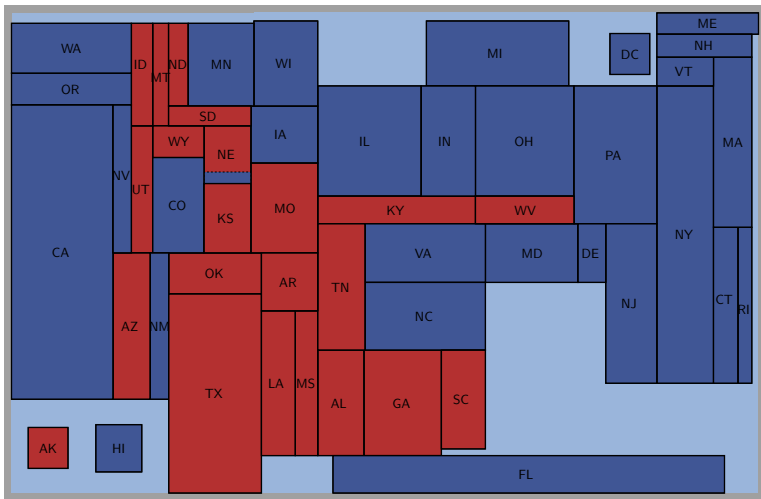
Maximum error: 3.1 %

United States - Variation vs Maximum Error

- Negative correlation with land area
- Large variation



United States - 2008 Presidential Elections

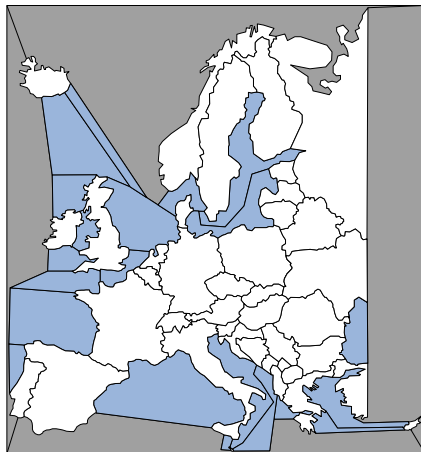


Average error: 0.0 %

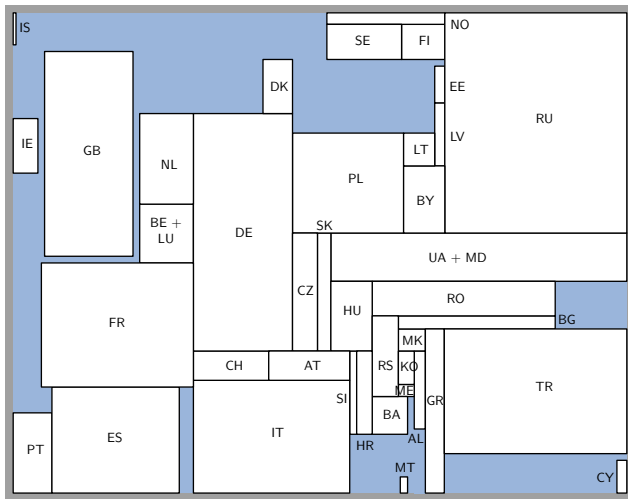
Maximum error: 0.0 %

Europe (65 regions)

- Merged Luxembourg with Belgium, and Moldova with Ukraine
- All CIA World Fact Book ranked data sets with data for each country
- Generating one cartogram took ~6 minutes



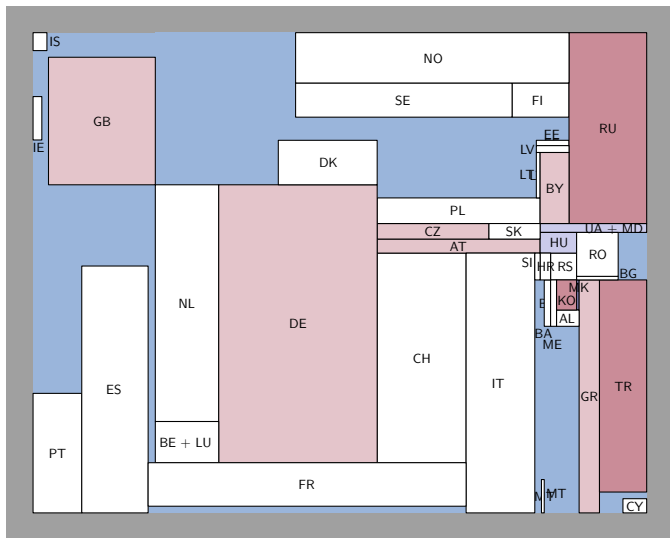
Europe - Population



Average error: 0.0 %

Maximum error: 0.0 %

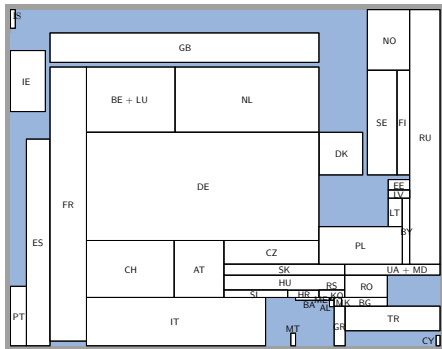
Europe - Account Balance



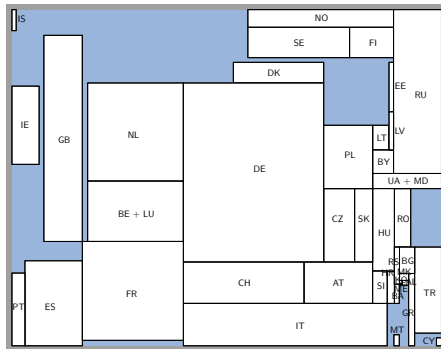
Average error: 4.0 %

Maximum error: 19.7 %

Europe - Exports



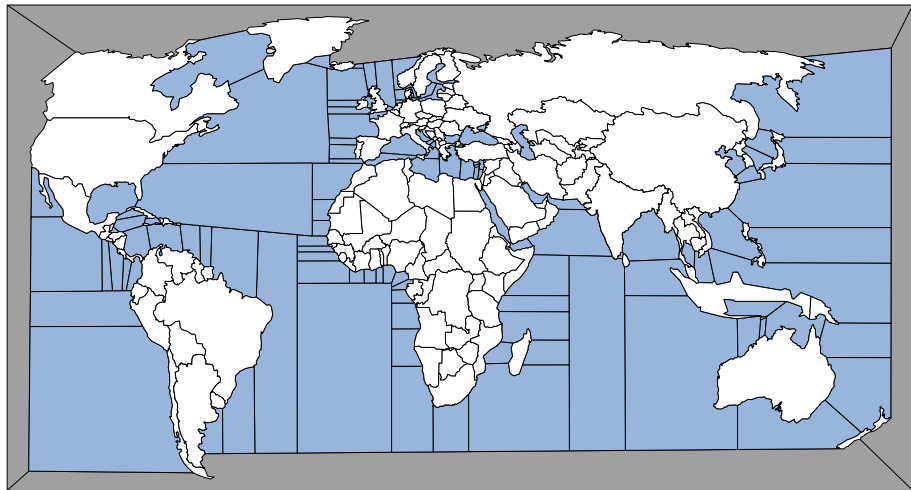
Max error: 0.0 % BBSD: 0.088



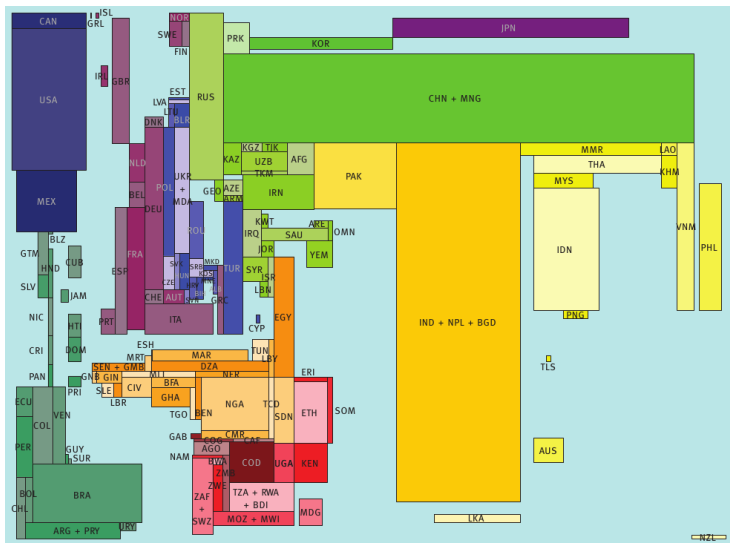
Max error: 1.6 % BBSD: 0.078

World (275 regions)

- All countries with population over 1 million
- Generating one cartogram took ~3.5 hours



World - Population



Average error: 1.17 %

Maximum error: 18.5 %