

PA-7



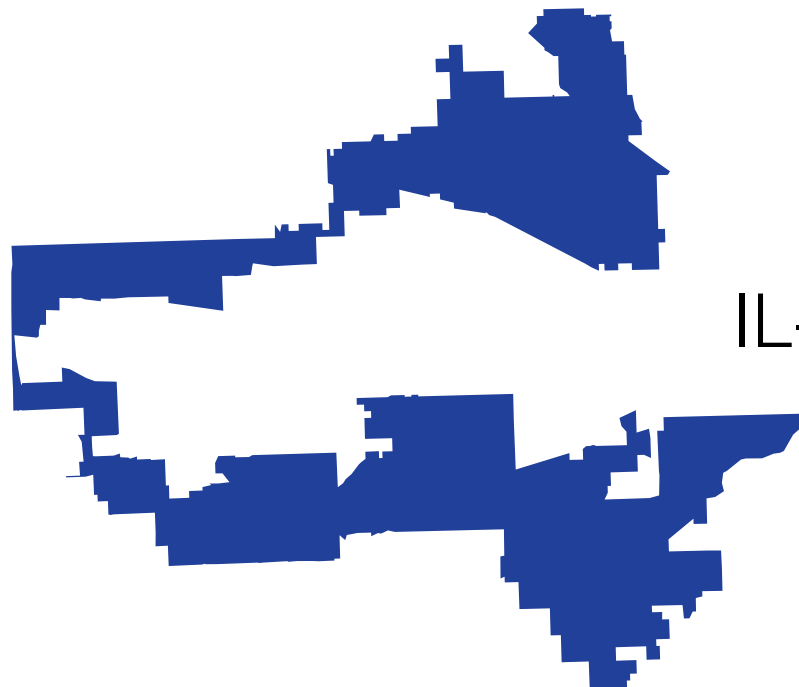
NC-12



MD-3

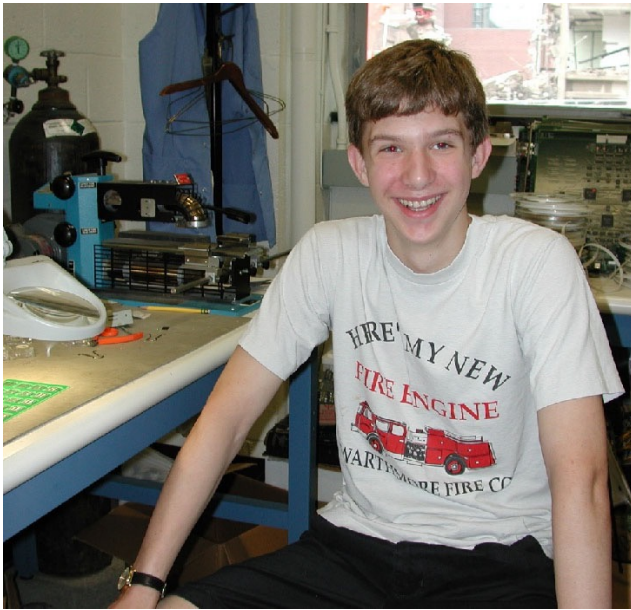


IL-4



13 Years on ATLAS: 2003-2016

Active in Higgs physics and instrumentation.
Came to Chicago as a Fermi Fellow in 2014.



Prototype Electronics
(2003)



Detector Barbecues
(2009)



Defending
(2014)

Life After Particle Physics

Most of my friends have ended up happy —



NavHealth



I was delighted to get a postdoc in economics at:



Gerrymandering and Automated Districting

Jamie Saxon
Harris School of Public Policy
University of Chicago



PA-7



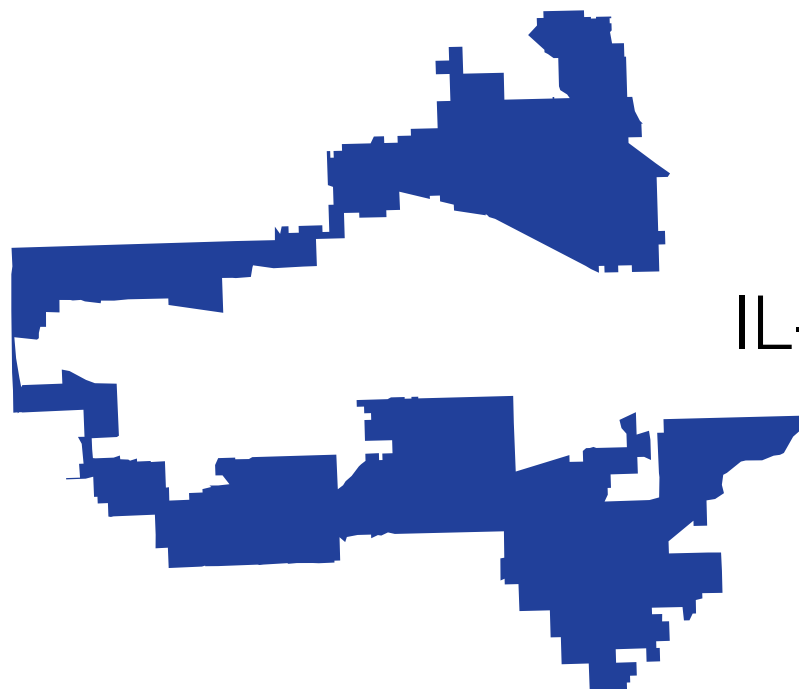
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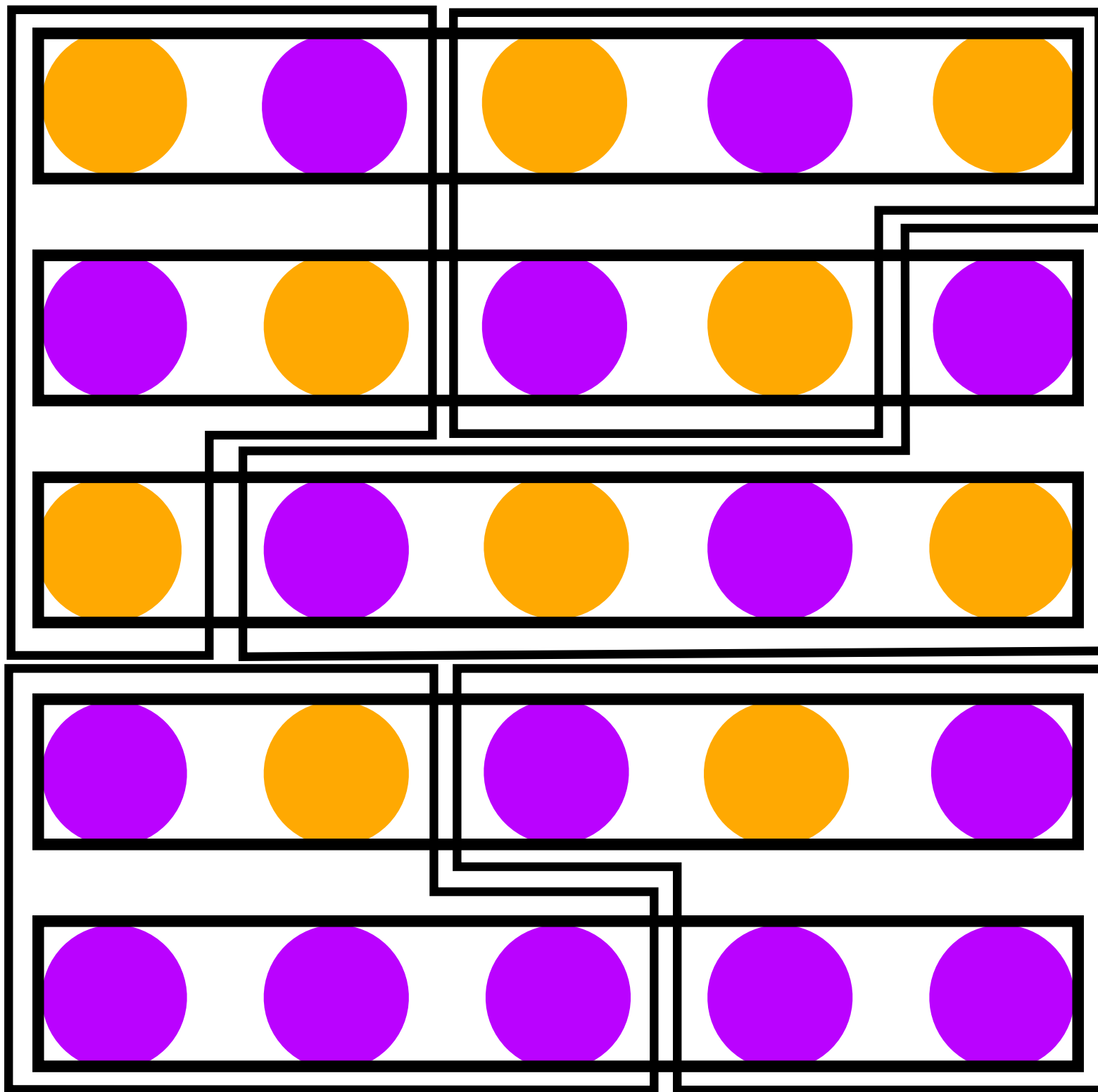


MD-3



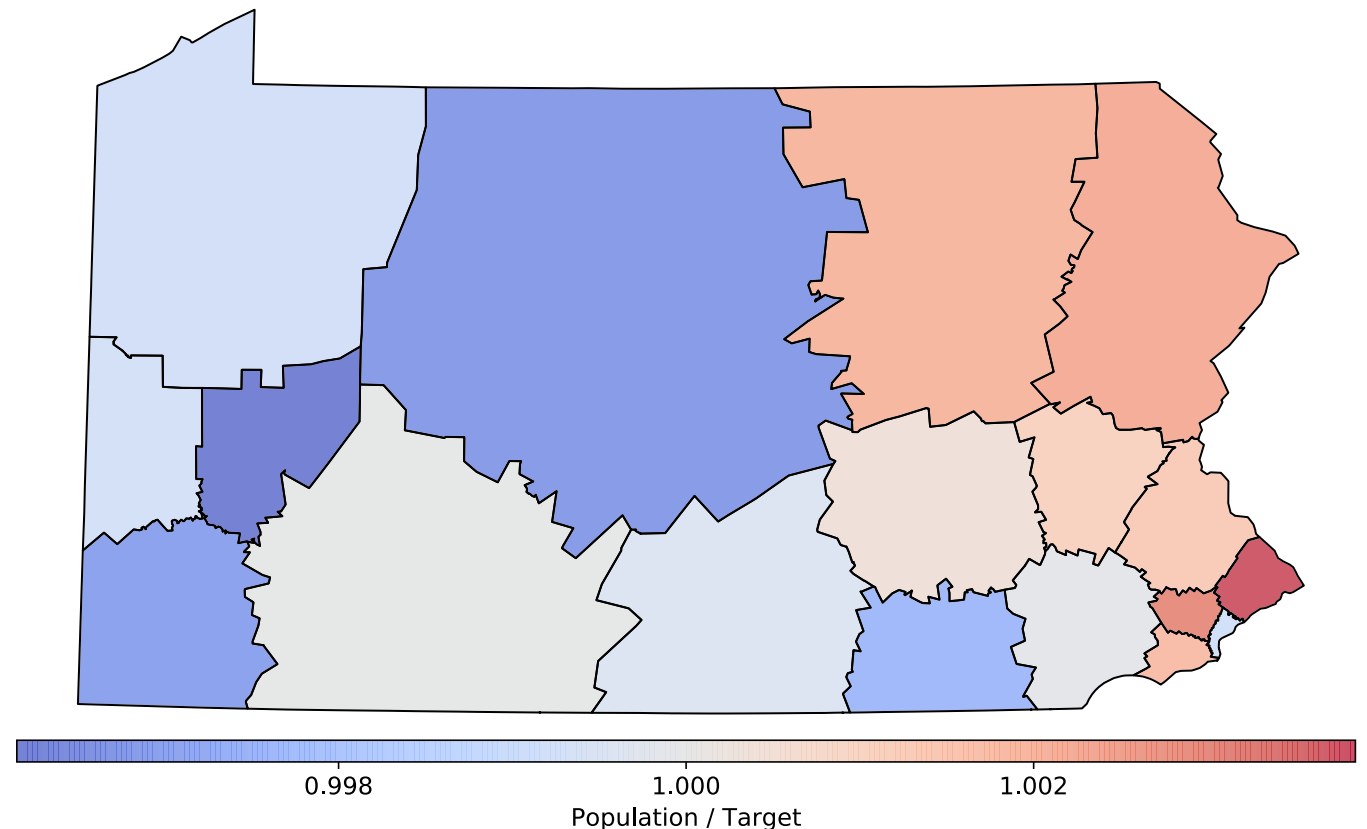
IL-4





It *must* be possible to do this fairly...

- ▶ A brief history of districting
 - ▶ Measuring compactness
 - ▶ Automating districting
 - ▶ Measuring gerrymandering



This has been in the news of late —
but let's start with the history.

The New York Times

Eric Holder to Lead Democrats' Attack on Republican Gerrymandering

By ALEXANDER BURNS and JONATHAN MARTIN JAN. 11, 2017



Eric H. Holder Jr. said that he and President Obama believed Republicans had undermined the political system by creating a patchwork of legislative maps designed to stifle the will of voters.
Jared Soares for The New York Times



How to Quantify (and Fight) Gerrymandering

Powerful new quantitative tools are now available to combat partisan bias in the drawing of voting districts.



The Constitution

§2 The House of Representatives shall be composed of Members **chosen every second Year by the People** of the several States, and the Electors in each State shall have the Qualifications requisite for Electors of the most numerous Branch of the State Legislature. [...]

§4 Representatives and direct Taxes shall be apportioned among the several States which may be included within this Union, according to their respective Numbers, which shall be determined by adding to the whole Number of free Persons, including those bound to Service for a Term of Years, and excluding Indians not taxed, **three fifths of all other Persons...**

The **Times, Places and Manner** of holding Elections for Senators and Representatives, shall be prescribed in each State by the Legislature thereof; but the **Congress may at any time by Law make or alter such Regulations...**

§5 Each House shall be the Judge of the **Elections, Returns and Qualifications of its own Members...**

The Federalist Papers and the Ratifying Conventions

The moderating effect of representation: "...passing them through the medium of a chosen body of citizens" (Madison, Fed. 10)

The city of **Philadelphia** is supposed to contain between fifty and sixty thousand souls. It **will therefore form nearly two districts** for the choice of Federal Representatives. It forms however but one county, in which every elector votes for each of its representatives in the State Legislature.
(Madison, Fed. 57)

Some states might regulate the elections on the principles of equality, and others might regulate them otherwise. This diversity would be obviously unjust. **Elections are regulated now unequally in some states, particularly South Carolina, with respect to Charleston, which is represented by thirty members.** Should the people of any state by any means be deprived of the right of suffrage, it was judged proper that it **should be remedied by the general government.**
(Madison, Virginia Ratifying Convention, 14 June 1788)

Apportionment by Congress

A *very* slow accumulation of district requirements washed away in a twinkling, after a botched census.

The 1911 Apportionment Act

three, as provided in section one of this Act, and all laws and parts of laws in conflict with this section are to that extent hereby repealed.

SEC. 3. That in each State entitled under this apportionment to more than one Representative, the Representatives to the Sixty-third and each subsequent Congress shall be elected by districts composed of a contiguous and compact territory, and containing as nearly as practicable an equal number of inhabitants. The said districts shall be equal to the number of Representatives to which such State may be entitled in Congress, no district electing more than one Representative.

SEC. 4. That in case of an increase in the number of Representatives in any State under this apportionment such additional Representative

Ralph Lozier (MO),
with Mr Graham
concurring, rejects
Congress's authority
over the manner of
elections.

The Tenor of the 1929 Debate

the bringing out and the passage of this bill.

I announced on this floor in 1921 that I was opposed to the reapportionment of the House of Representatives under the census of 1920. I gave as my reasons that that was not a just census. It was taken at a time when our population was very much disturbed, when America was just emerging from the World War, and when a great many of our soldiers were away from home, in the fields, and in camps. It was taken also at a time when great masses of our people were crowded into the industrial centers, working in the various enterprises that had grown up or expanded as a result of the Great War. It was taken in the wintertime, for the first time in the history of this

Apropos the suggestion of the distinguished gentleman from Pennsylvania [Mr. GRAHAM], I have heretofore called the attention of the House, and the committee that reported the bill, to the provisions of sections 3, 4, and 5. No man familiar with the Constitution, no man that has even a speaking acquaintance with our organic law, will contend for one moment that sections 3, 4, and 5 have any binding force or effect whatever. The gentleman from Pennsylvania, one of the ablest lawyers in this body, nods his head in approval. Every lawyer, every man that knows anything about the Constitution, knows that these three provisions are violative of the letter and spirit of constitutional mandate. The only power that Congress is given by the Constitution with reference to apportionment of Representatives is to apportion the representation among the several States in proportion to the numbers or population. That duty done, the power of Congress ends, and

The 1st and 14th Amendments

- A1** Congress shall make no law [. . .] **abridging the freedom of speech**, or of the press; or the right of the people **peaceably to assemble**, and to petition the Government for a redress of grievances.
- A14** §1. [. . .] No State shall make or enforce any law which shall abridge the privileges or immunities of citizens of the United States; nor shall any State deprive any person of life, liberty, or property, without due process of law; nor deny to any person within its jurisdiction the **equal protection of the laws**.
- A14** §2. [...] when the right to vote [...] is denied to any [...] the basis of representation therein shall be reduced in [equal] proportion [...]

The Reapportionment Revolution

Baker v. Carr	1962	TN	Apportionment Justiciable by Federal Courts
Gray v. Sanders	1963	GA	One Person, One Vote (County Unit System)
Wesberry v. Sanders	1964	GA	US Congressional Seats
Reynolds v. Sims	1964	AL	Both Houses of State Legislatures

Political Gerrymandering

Davis v. Bandemer	1986	IN	Political Gerrymandering Justiciable
Vieth v. Jubelirer	2004	PA	Majority hopes against hope...

Traditional Districting Principles

- Contiguity
 - Compactness
 - Respect of existing political boundaries
 - Sometimes: consideration of incumbents
- } In practice, these are linked

Proposed Solutions

Measures

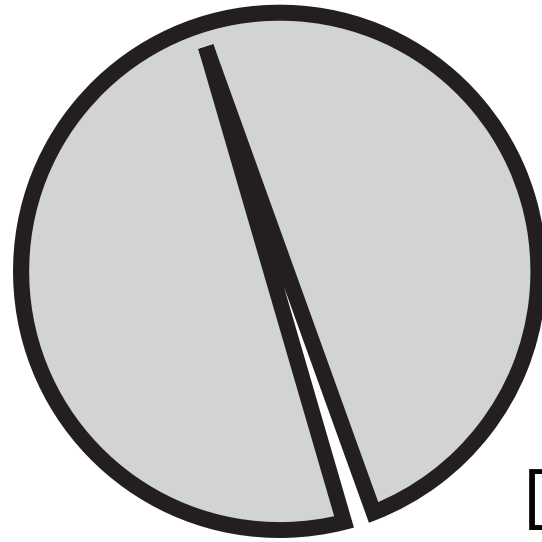
- Partisan bias — seat share at 50% votes
- Efficiency gap — votes wasted by each party
 - Stephanopoulos's strategy for Wisc. case
- Competitiveness — distance from 50%
- Simulated maps, or “random draws” of districts.

Judgment

- Apply similar judgment to VRA cases
- Independent Commissions —
 - Arkansas, Oklahoma, Colorado, Arizona ...
 - And other developed nations.

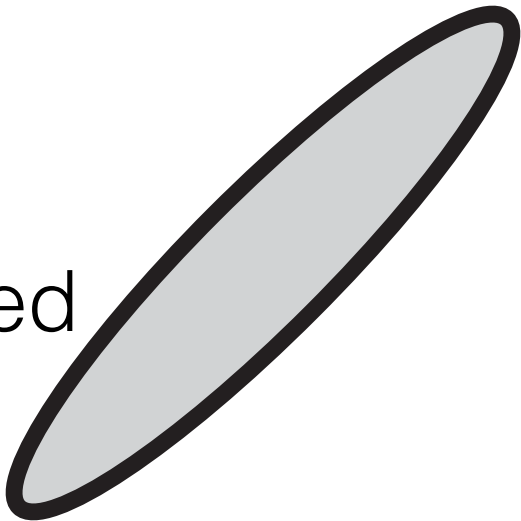
Ultimately, you *always* have to draw a map.

What is *meant* by “compact!?”

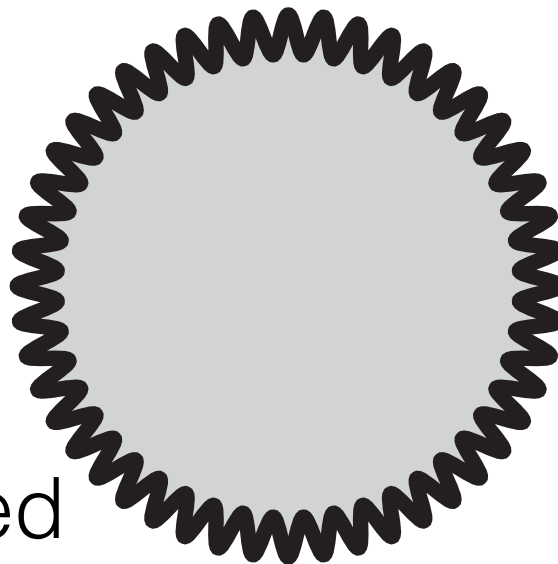


Dissected

Elongated



Indented



Metric	Formula	Sources	Status
Intraocular Test	\odot	[26]	✓
Power Law (Minimum Distance)	$\sum_{i \in S} \sum_{j \in S} w_i w_j d_{ij}^2$	[23]	● ●
Isoperimeter Quotient (IPQ)	$4\pi A / \ell^2$	[36, 22, 40]	●
Detour Index	$2\sqrt{\pi A} / \ell_{CH}$	[37]	●
District to SCC Area Ratio	A / A_{SCC}	[16]	●
District to LIC Area Ratio	A_{LIC} / A	[36]	●
Moment of Inertia	$\sum_{i \in S} w_i (x_i^2 + y_i^2)$	[11]	●
“Bizarreness”			
Traversal			
Exchange			
Width to			
Width to			
Width to			
Convex H			
Convex H			
Populatio			
Mean Rac			
Dynamic			
Harmonic			
Rohrbach			
Split-Line			
Reflexive			

...it is difficult to understand what a “transgression” of “compactness” would even entail. Compactness, like temperature, falls along a range, and there is no professional consensus about what degree of departure (from any of more than twenty measures) is enough to say a district is “not compact.”

(Bethune-Hill v. Virginia Board of Elections, 2015)

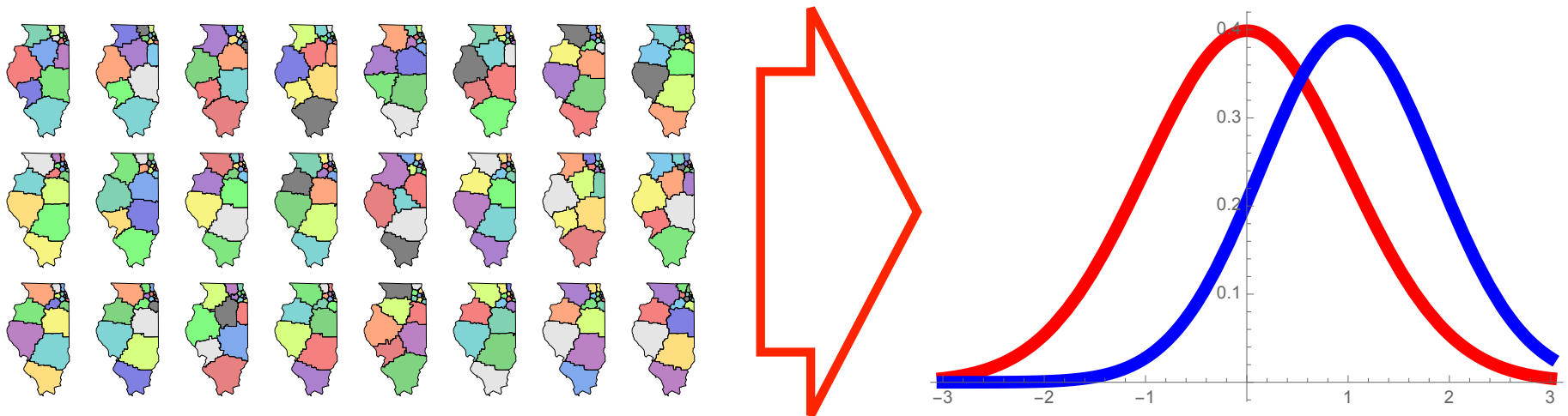
Removing the Mapmaker:

Automation for Election Counterfactuals and Non-Partisan Districting

The promise: an unbiased tool for generating districts and evaluating proposed maps.

Is choosing a metric just a reformulated political choice?

To use compactness, we must better define it.



How do we define it?

What good is **compactness?**

Can we even implement it?

What are its effects?

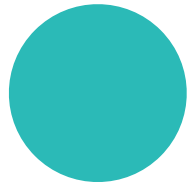
Are the definitions equivalent?

General Principles of Good Measures

Principle

Scale Invariant

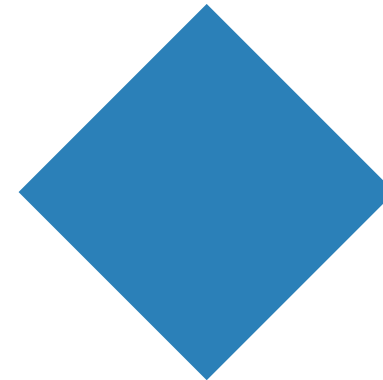
Rotationally Invariant



Example



Wish list: measures
normalized to 1
(easier to combine).



Bad
Measures

Total
Perimeter

North-South/
East-West

Building Compactness

Circles:

Smallest

Circumscribing

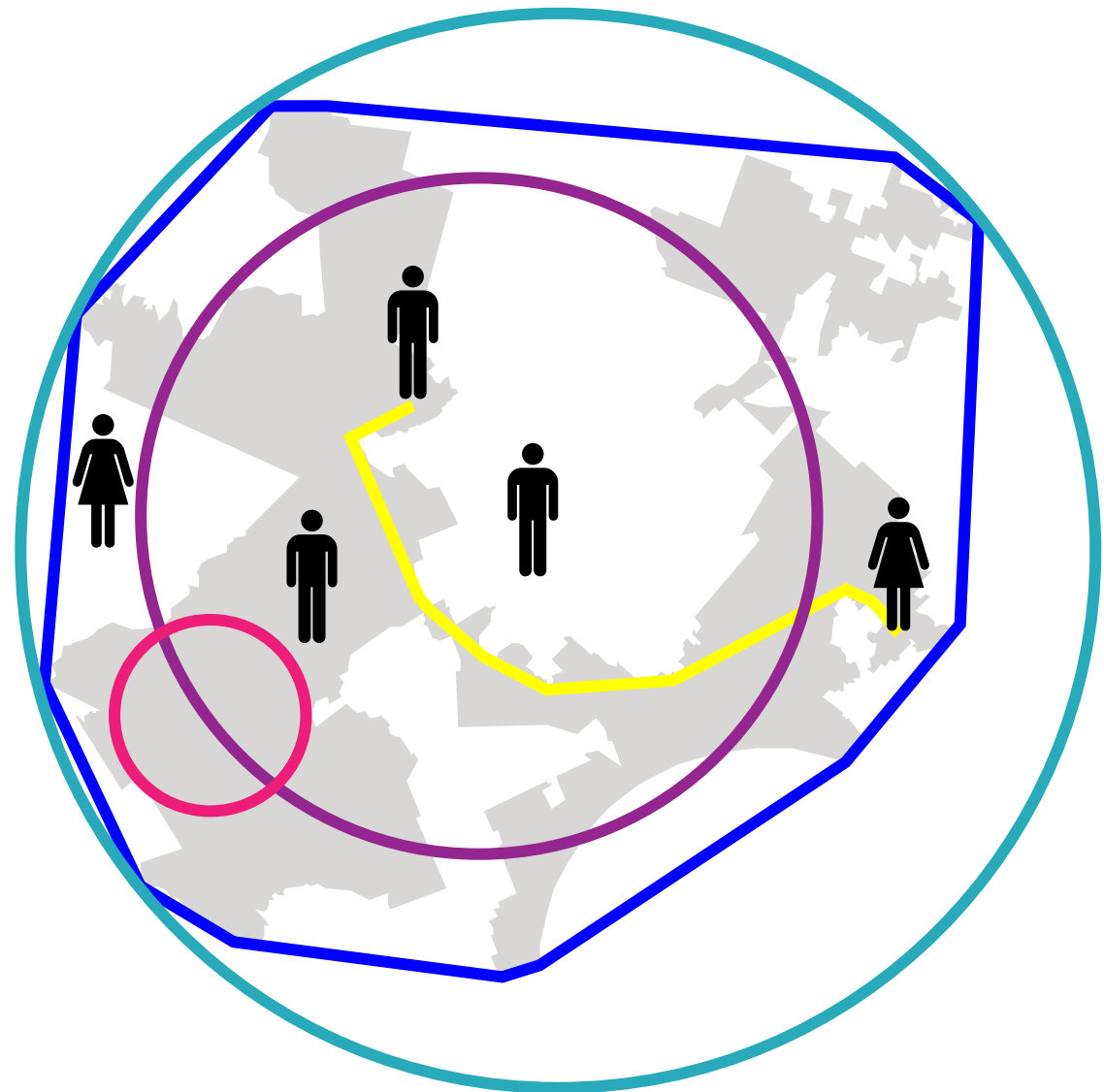
Largest Inscribed

Equal Area

Equal Perimeter

Convex Hull

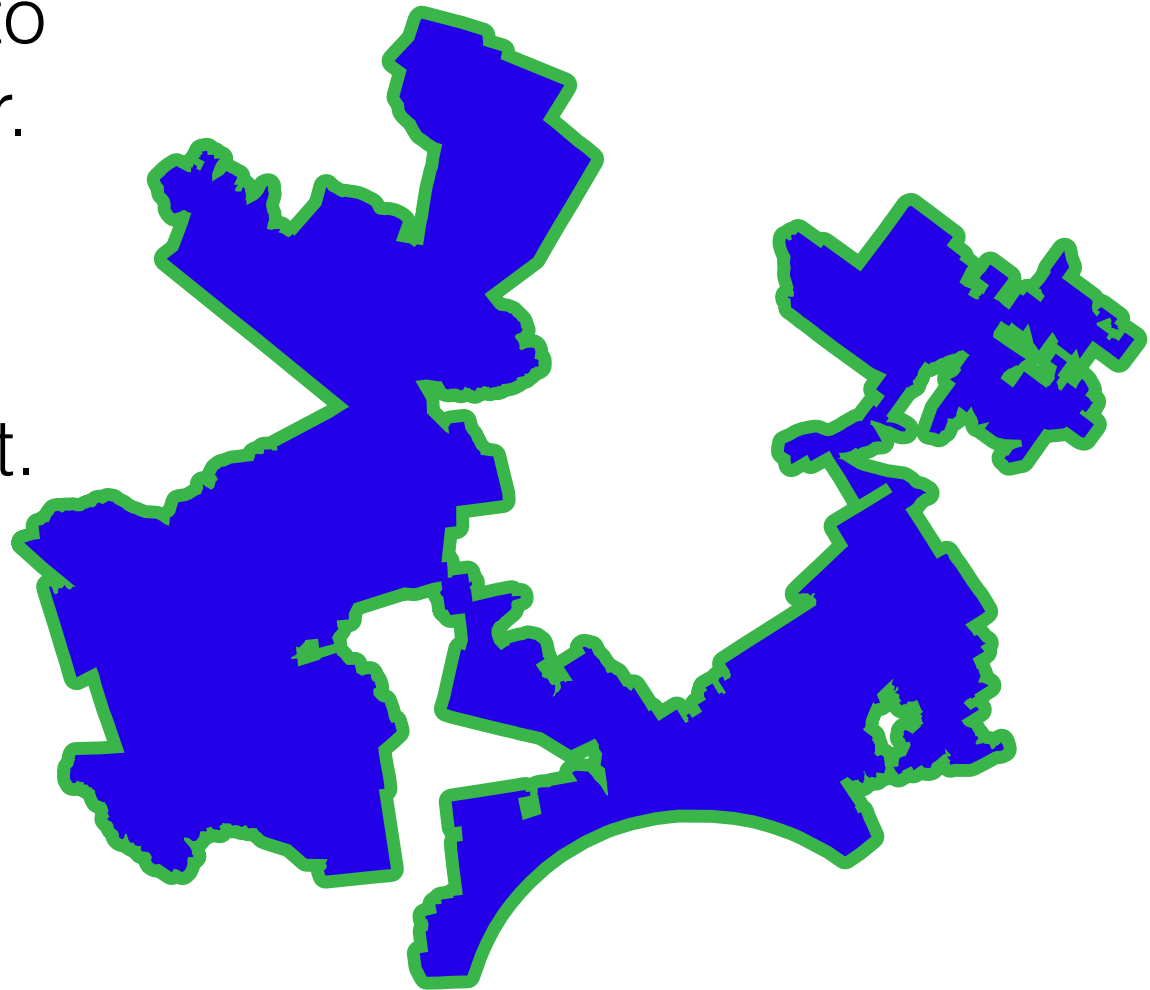
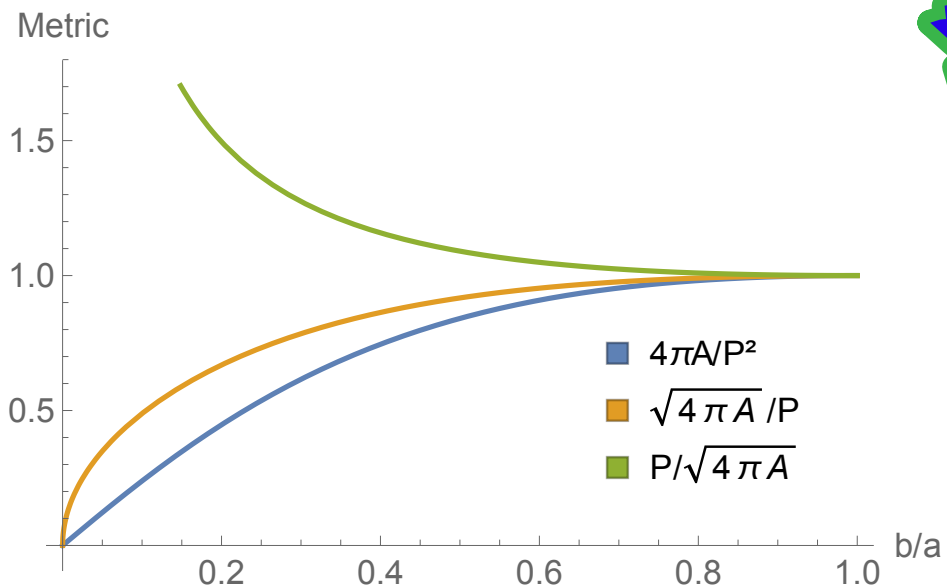
Shortest Path (■)



Isoperimeter Quotient: $4\pi A / \ell^2$

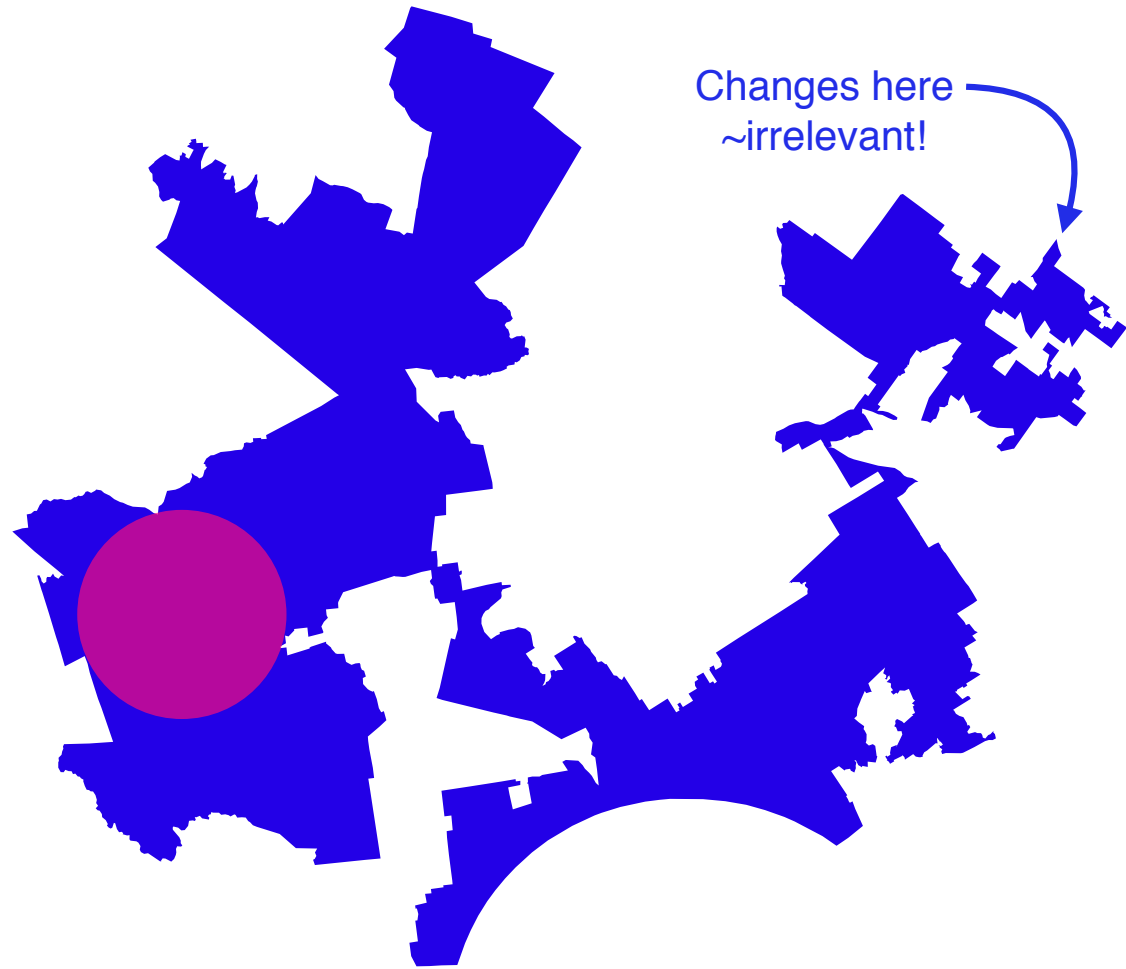
Ratio of the district's area to a circle of equal perimeter.

Poor discrimination,
ambiguity in measurement.



Inscribed Circles: $A(C_{\text{LIC}})/A(S)$

Fraction of the district's area contained in its largest inscribed circle?



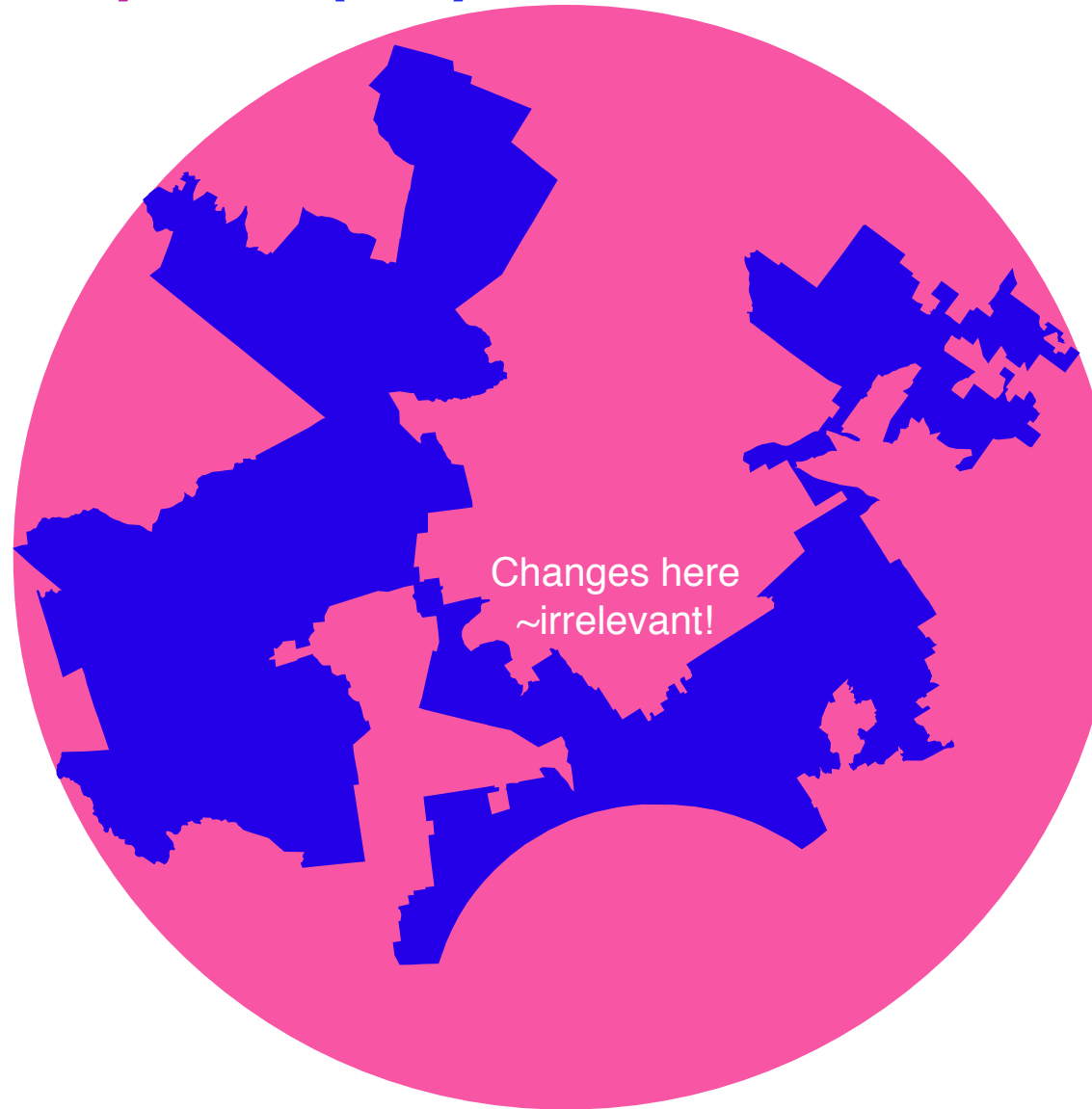
Algorithm: Voronoi

Circumscribing Circles

$$A(C_{\text{scc}})/A(S)$$

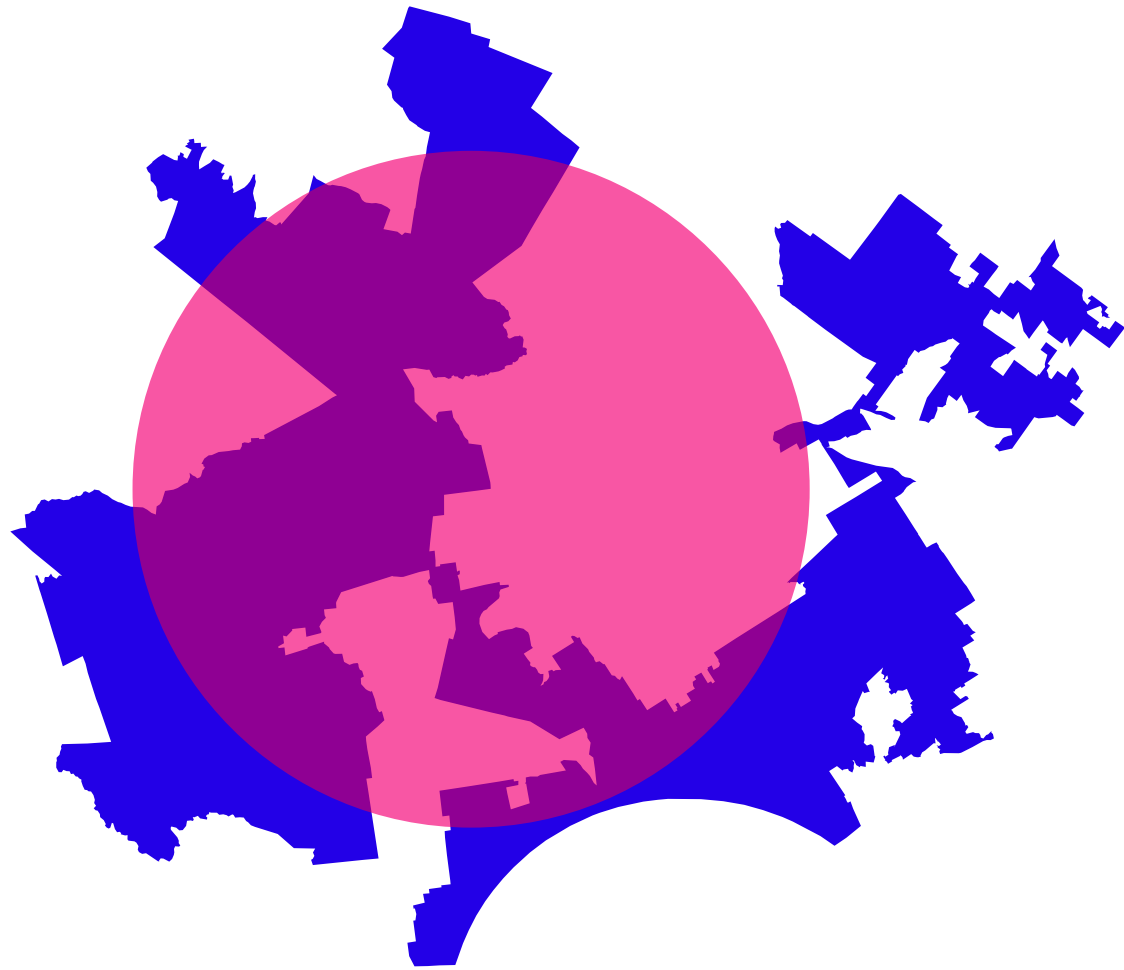
Ratio of the district's area to that of its smallest circumscribing circle?

Algorithm: Miniball



“Exchange”: $A(S \cap C_R) / A(S)$

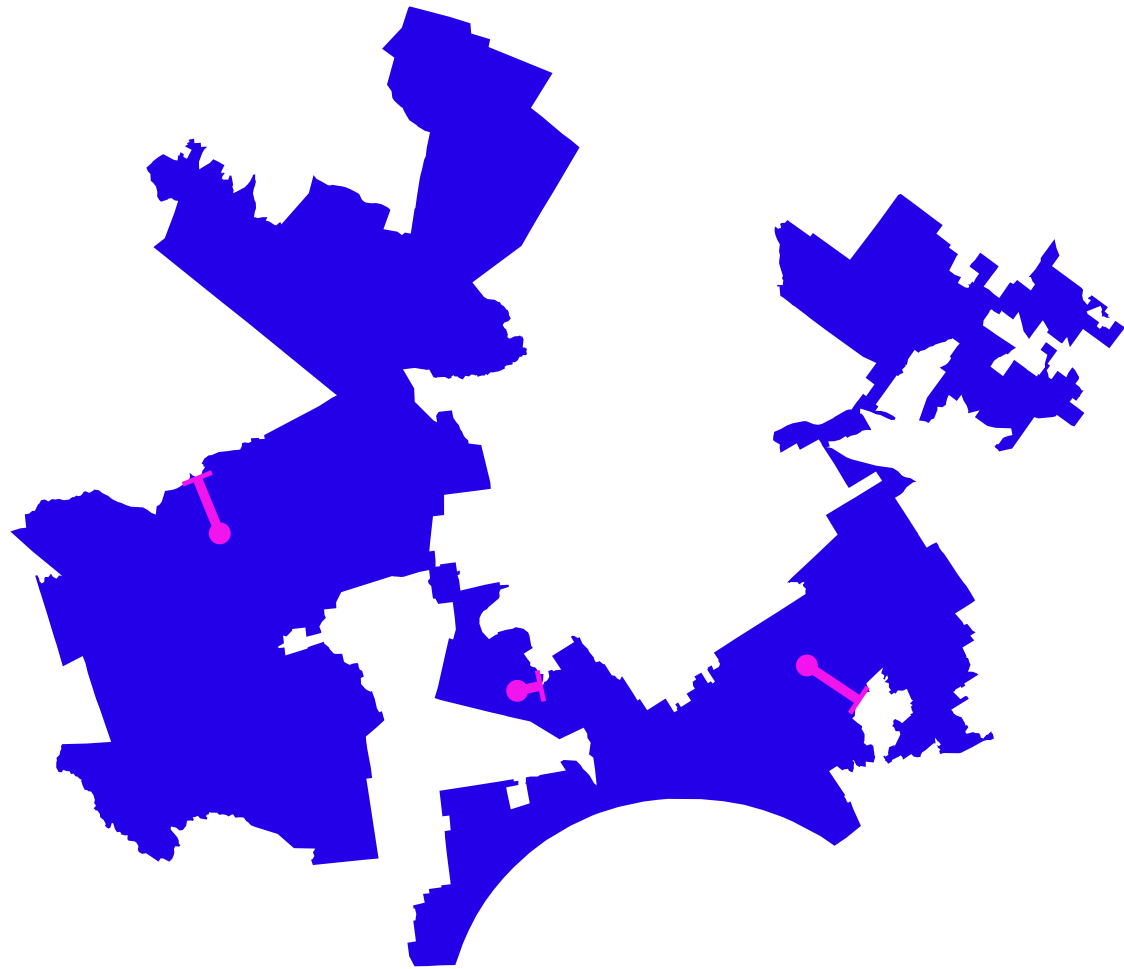
The proportion of a district's surface that intersects a circle of equal area and center.



Distance to Perimeter (Rohrbach)

Compared to a circle of equal area, what is the average distance (d_P) to the perimeter?

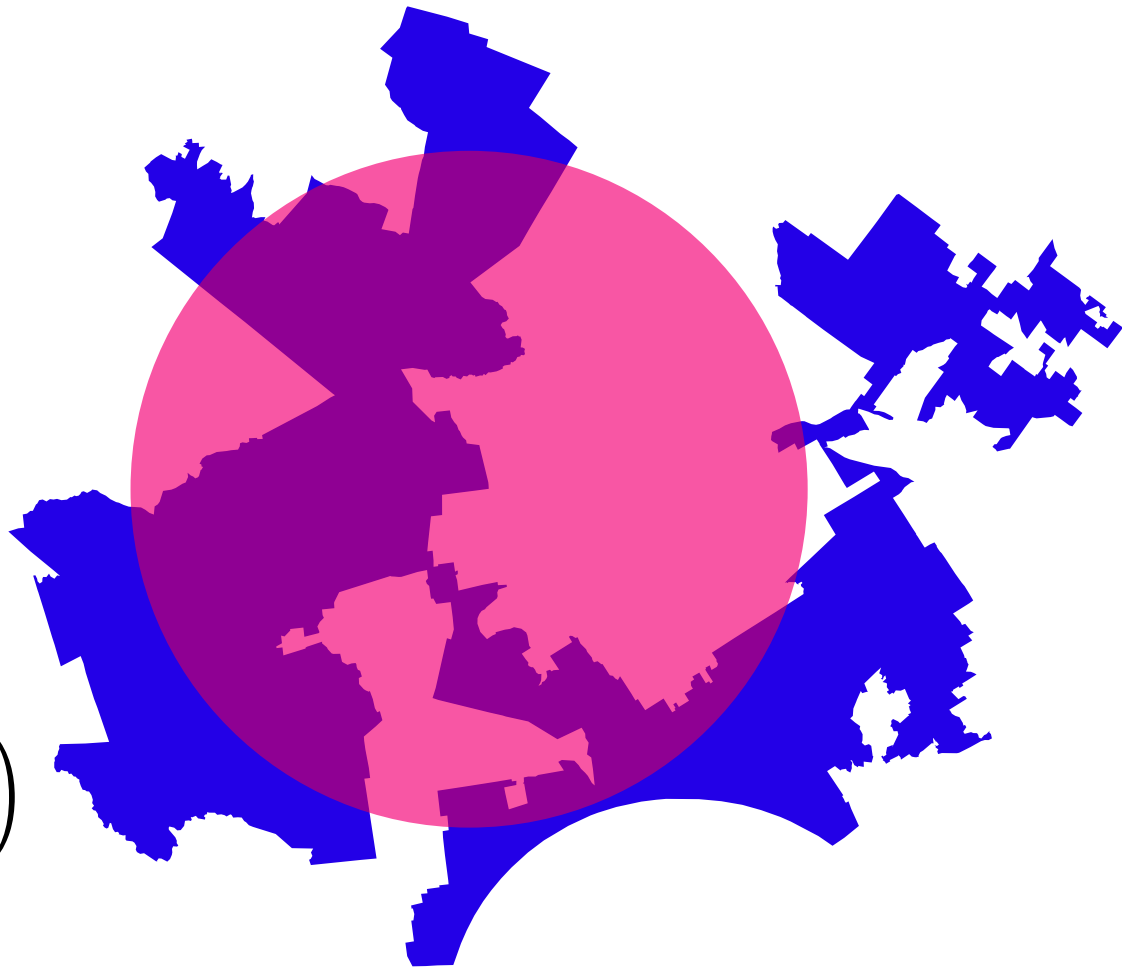
$$\left(\int_S d_P dA \right) / \left(\pi R^3 / 3 \right)$$



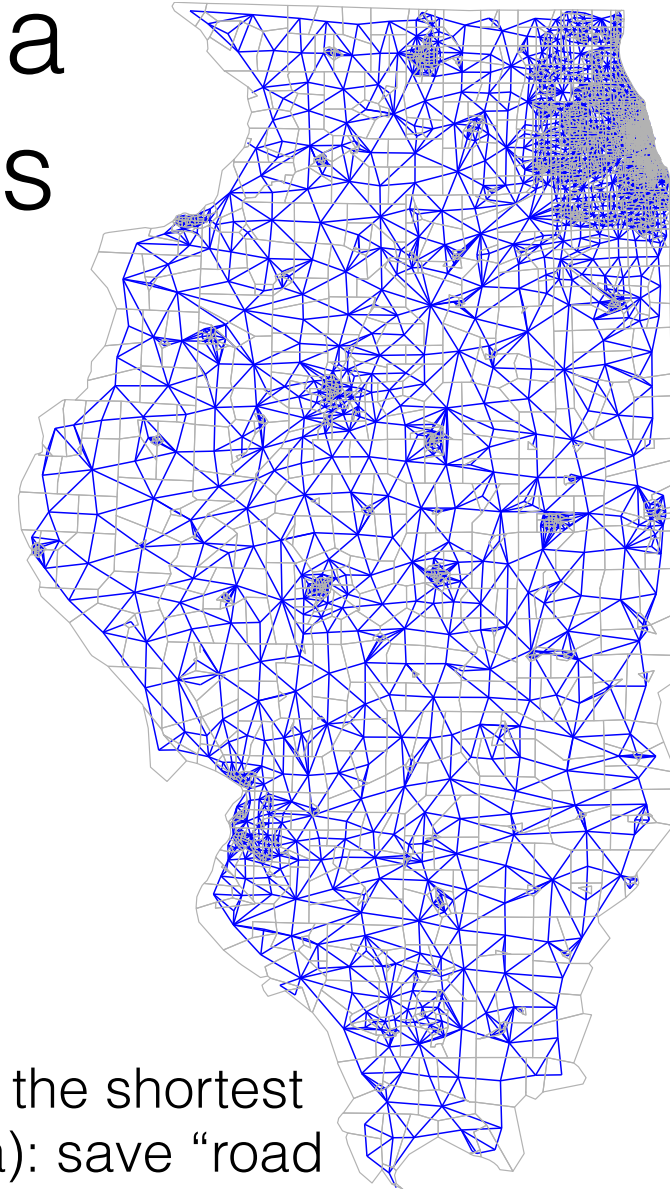
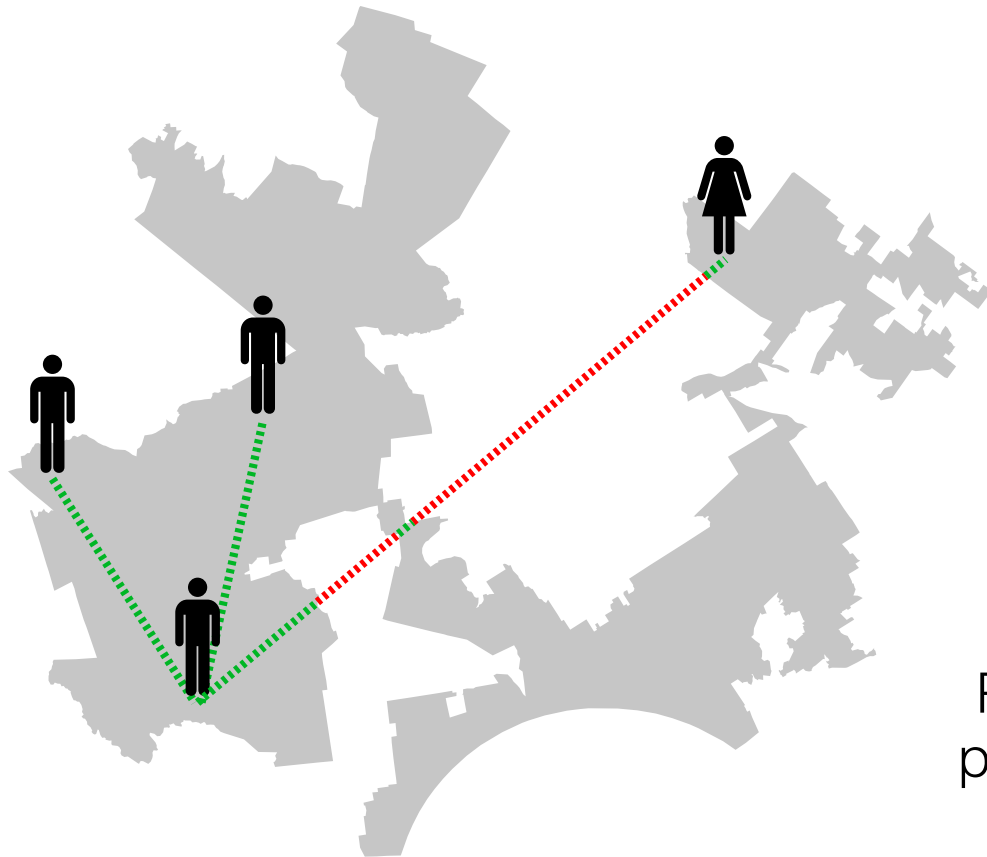
“Dynamic Radius”

Compared to a
circle of equal area,
what is the average
distance squared to
the centroid?

$$(R/\sqrt{2}) / \left(\sqrt{(1/A) \int_S \rho^2 dA} \right)$$



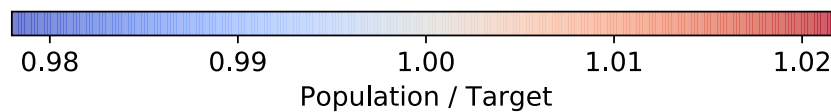
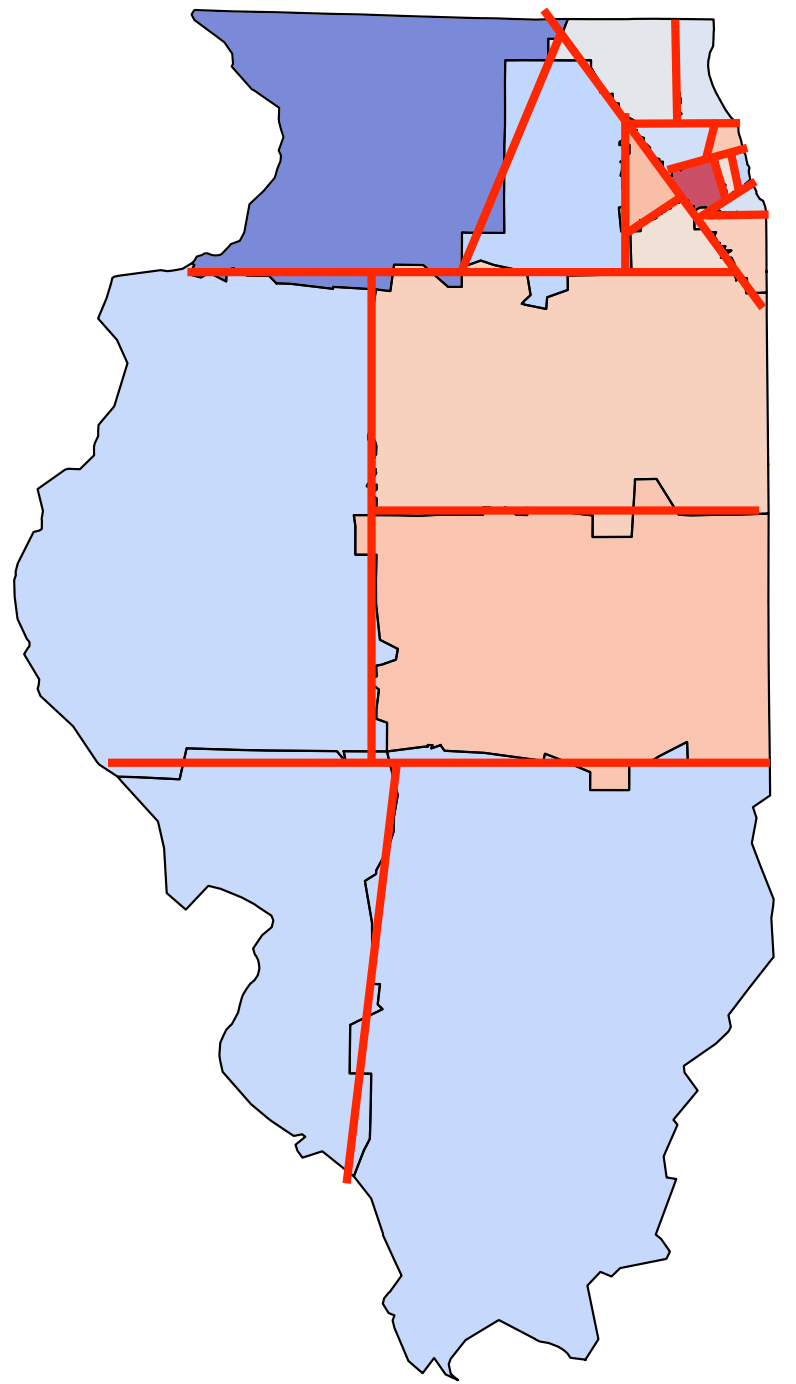
Path Fraction: the fraction of paths between citizens of a district that are themselves contained in the district.



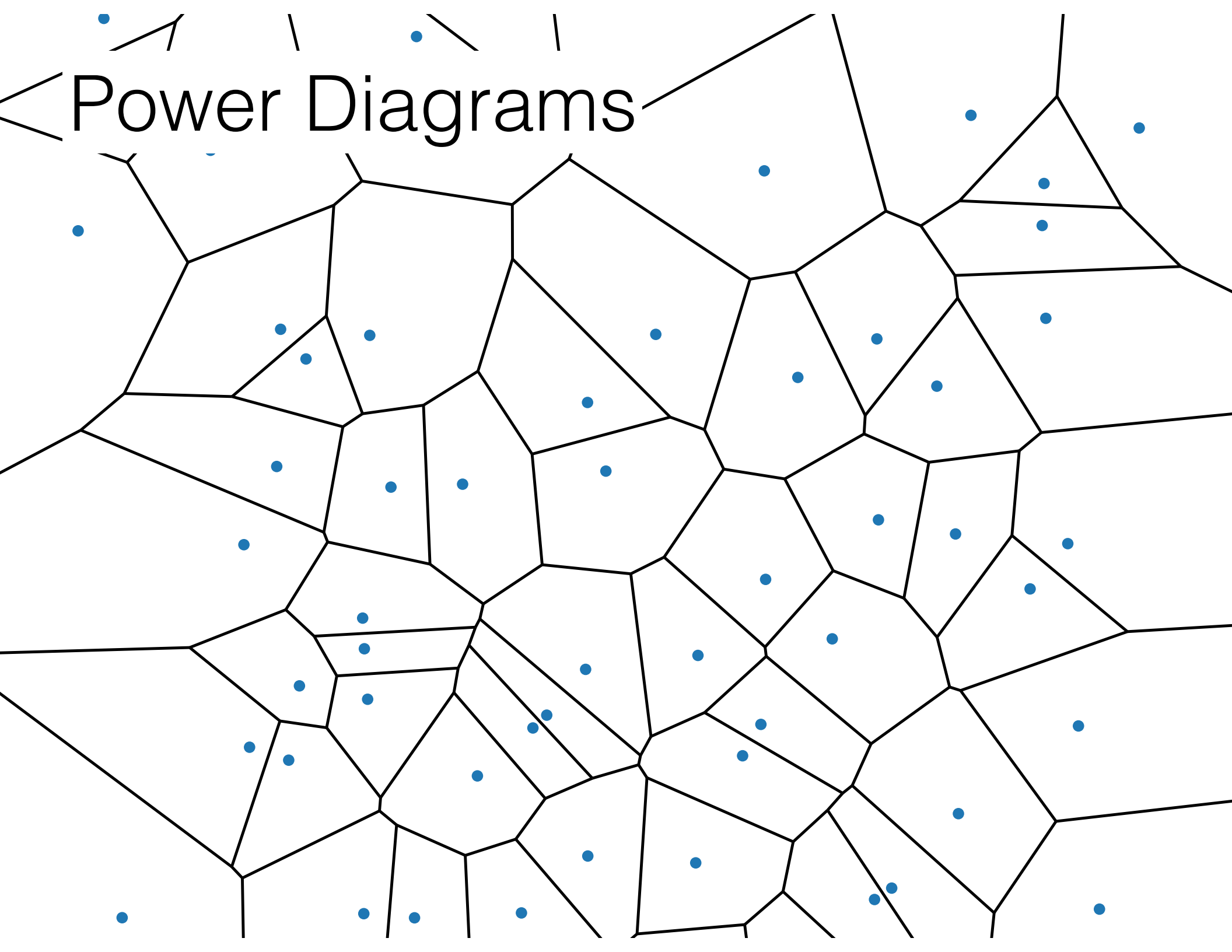
Precompute the shortest path (Dijkstra): save “road signs” for the next step.

The Split-Line Algorithm

Successive
splits with equal
seats per
constituent.

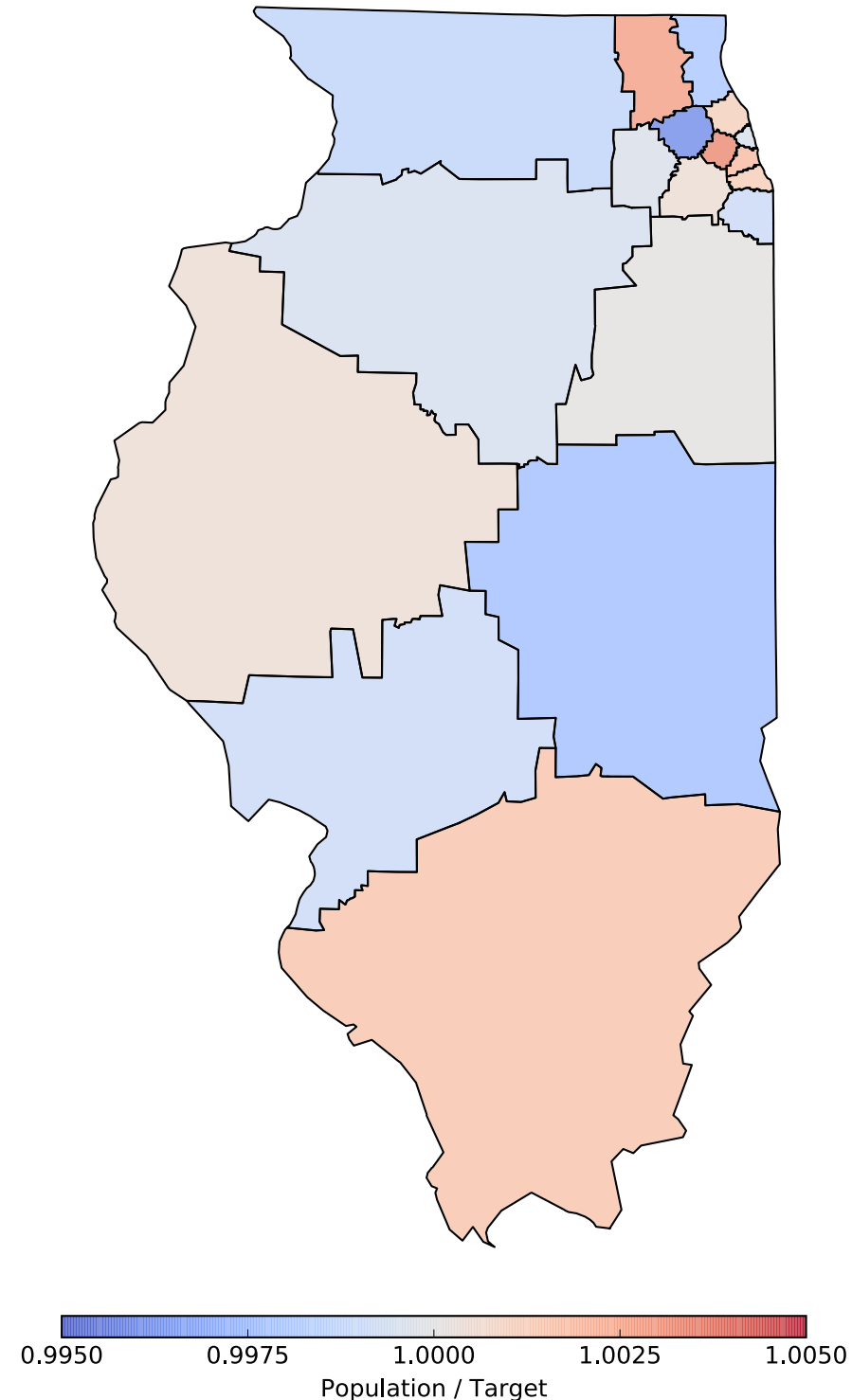


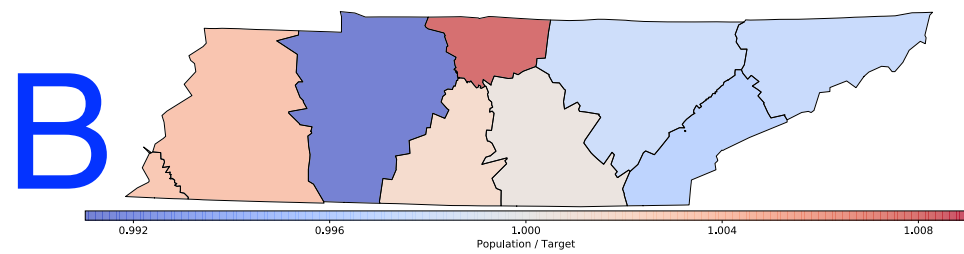
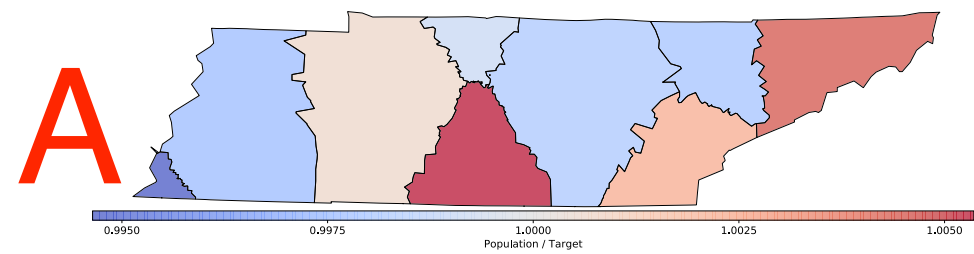
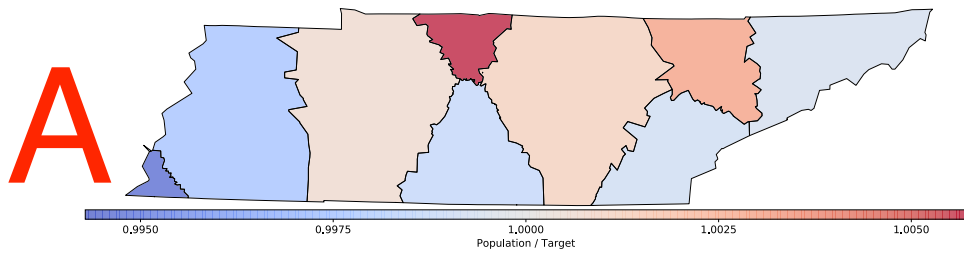
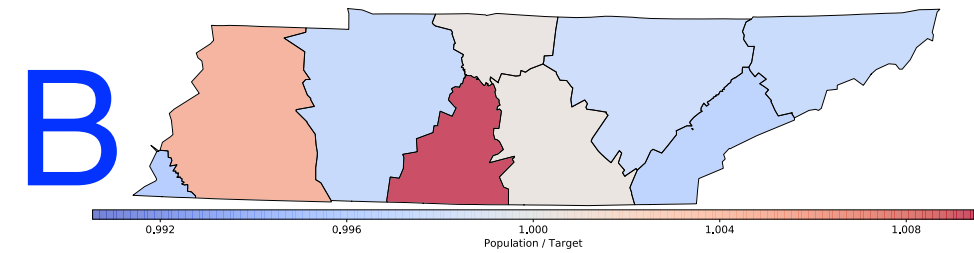
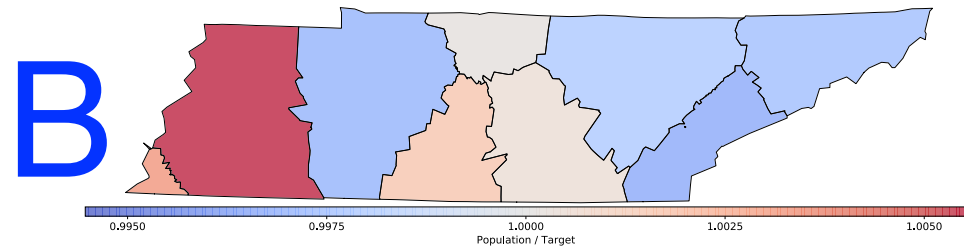
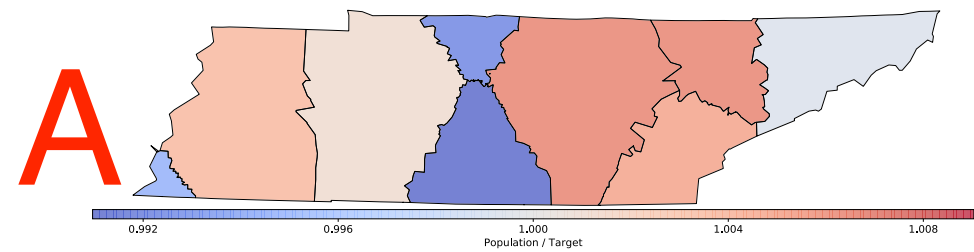
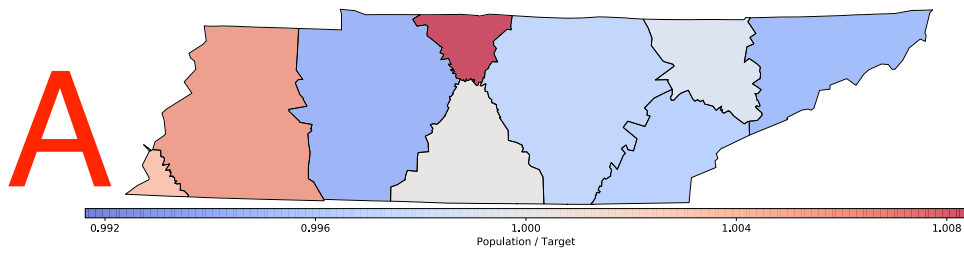
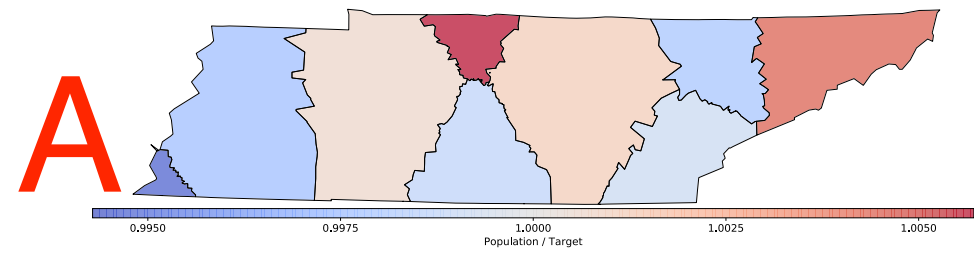
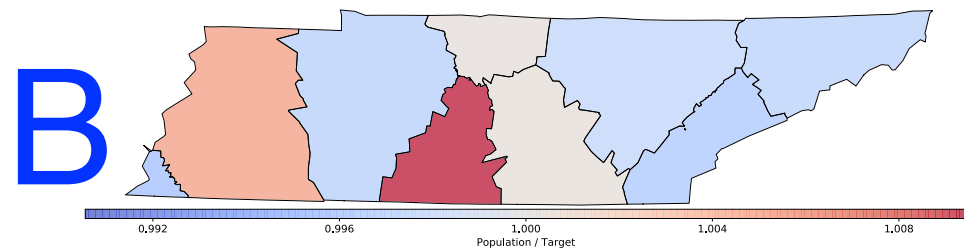
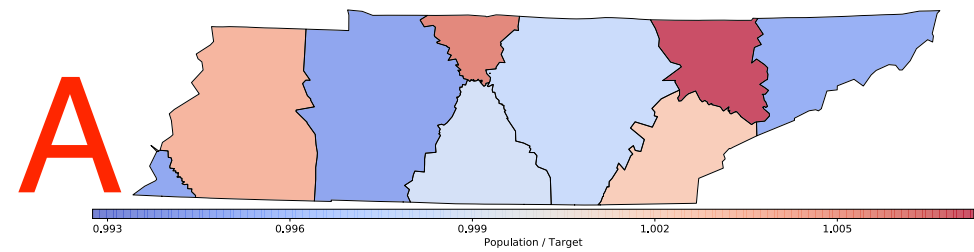
Power Diagrams

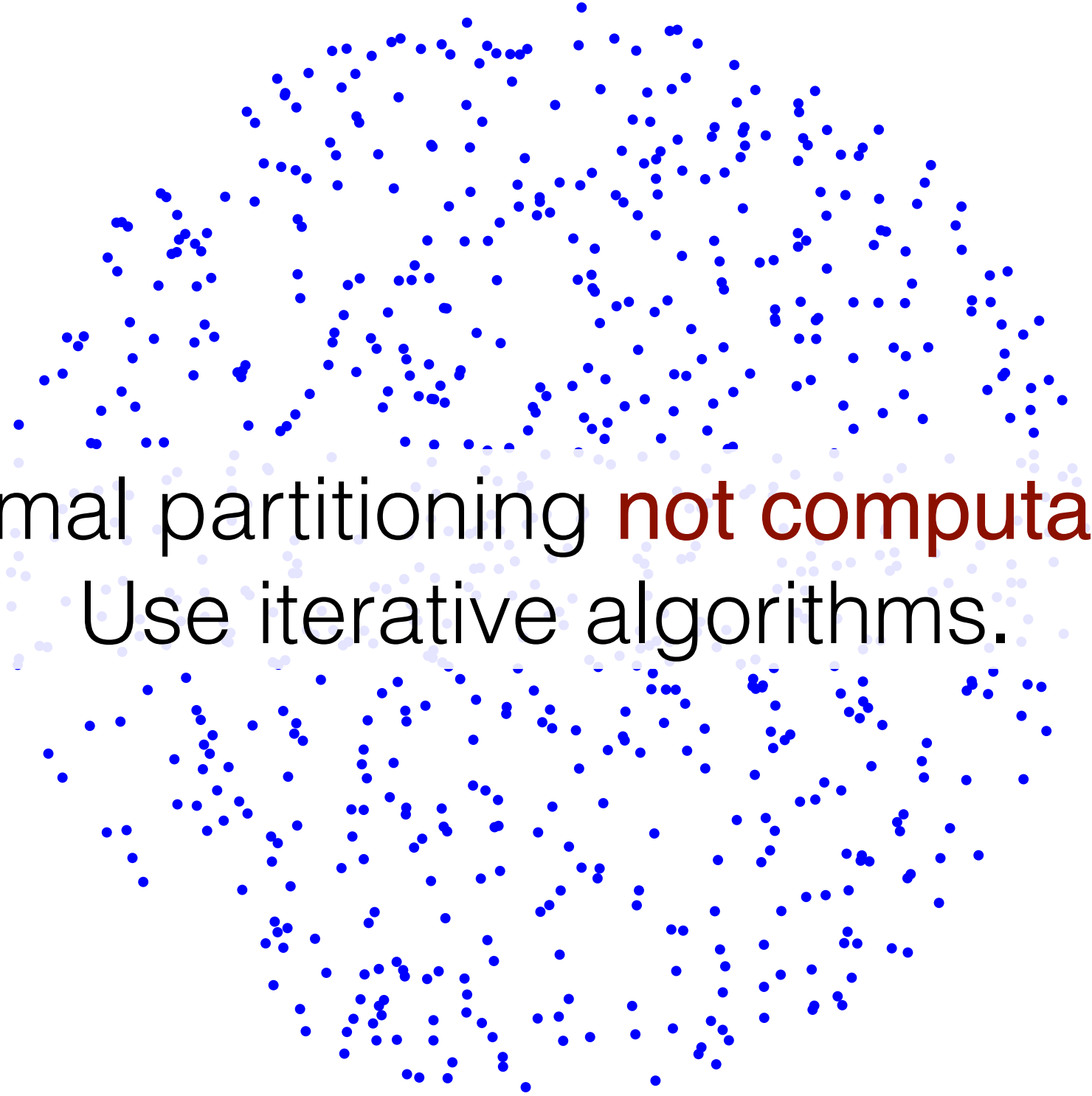


Power Diagrams

1. Regions r_i defined by centers r_i and 'power' λ_i .
 2. Cells c_j assigned to r_i by $\operatorname{argmin}_i (|r_i - c_j|^2 - \lambda_i^2)$.
 3. Iteratively update r_i and λ_i to equalize populations until convergence.
- Axiomatic arguments for 'optimal' definition.
 - Guaranteed convex.
 - Fast; reliable results.







Optimal partitioning **not computable!***
Use iterative algorithms.

*NP complete: ~knapsack or traveling salesman problem.

Building Maps

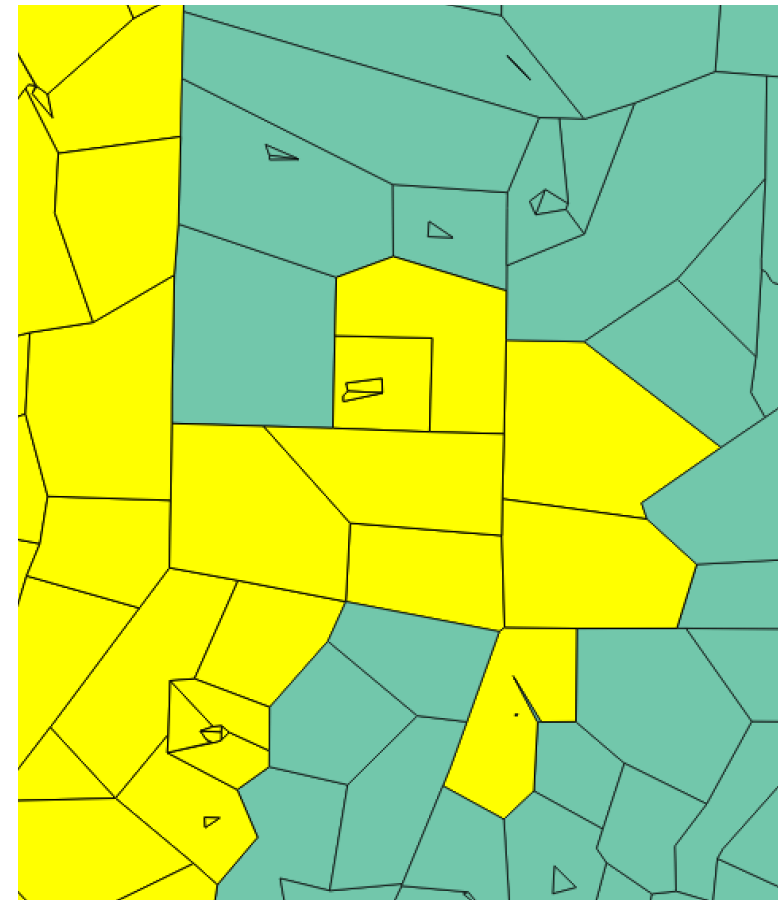
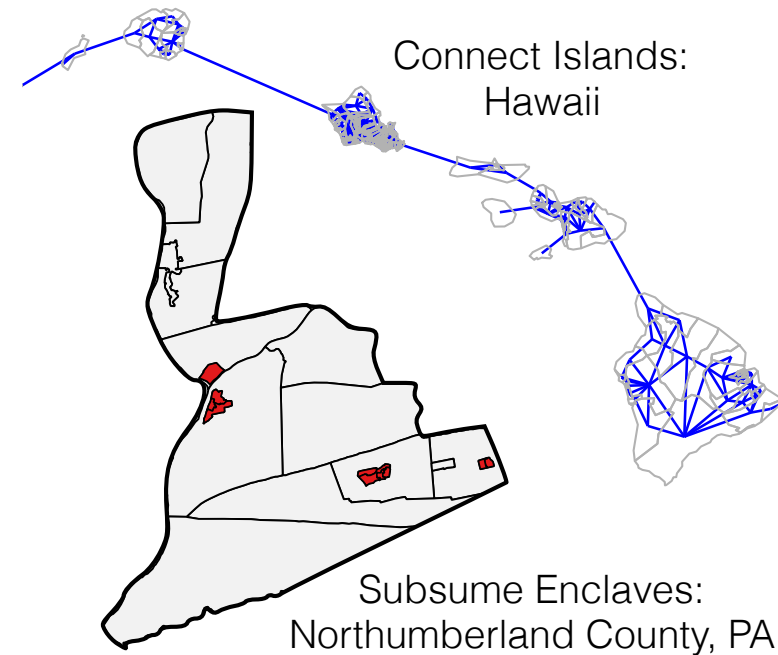
Basic Cell: Census Tracts

3-5k people, variable land area
(geometries from the Census)

Modifications for Contiguity

Connect islands to nearest neighbor

Subsume fully-contained enclaves



The Population Objective Function

Optimize on compactness
and equality of population.

(Contiguity is built in.)

$$\mathcal{P} = \text{sign}(p_a - p_b) \left(\frac{|p_a - p_b|}{p_{\text{target}} \Delta} \right)^\alpha$$

with $\alpha = 4$ and $\Delta \approx 0.01$

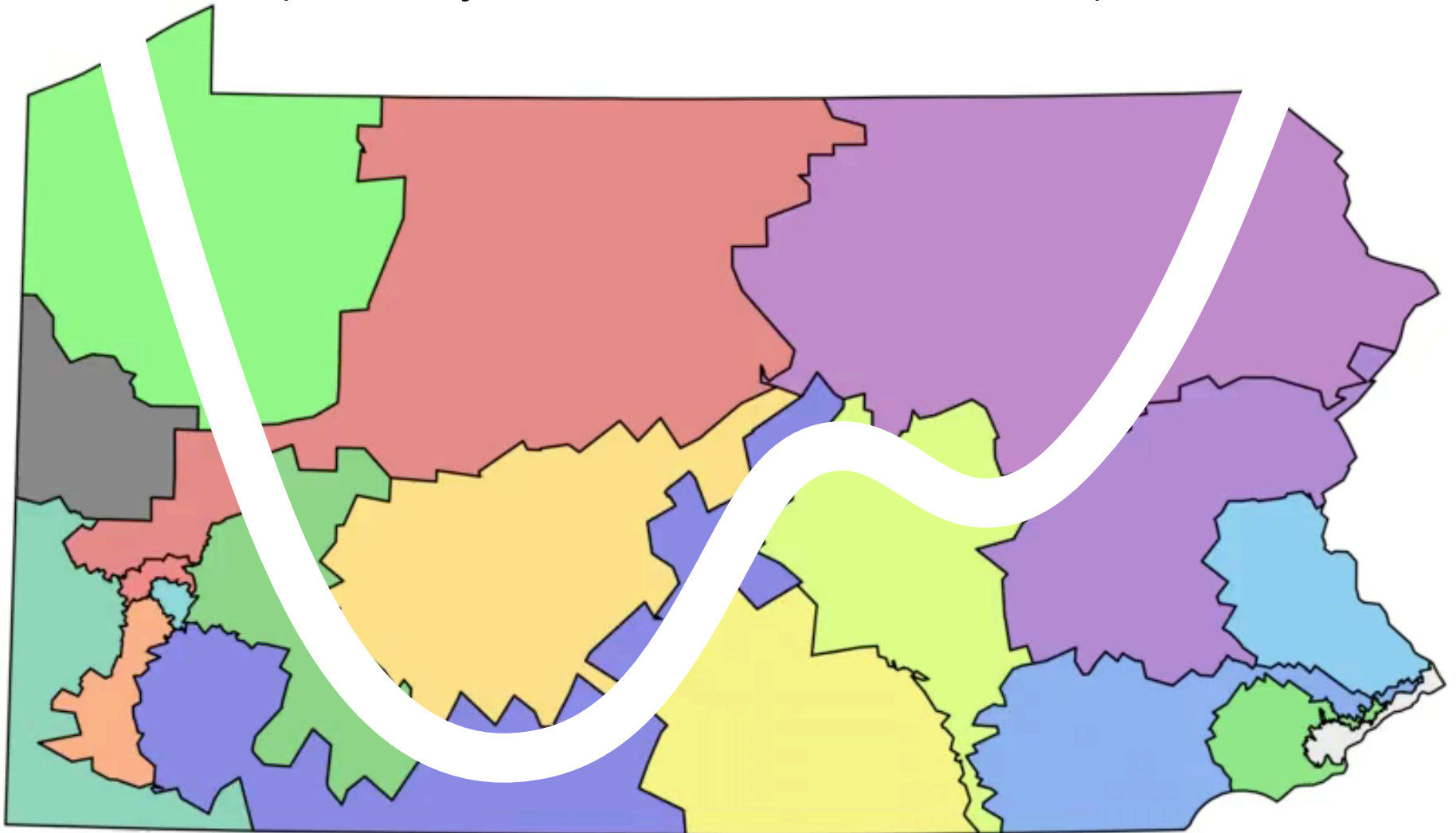
+ any other metric

Iterating with Metaheuristics

Initialize a bad (but legal) solution.

Reallocate census tracts to improve the objective function.

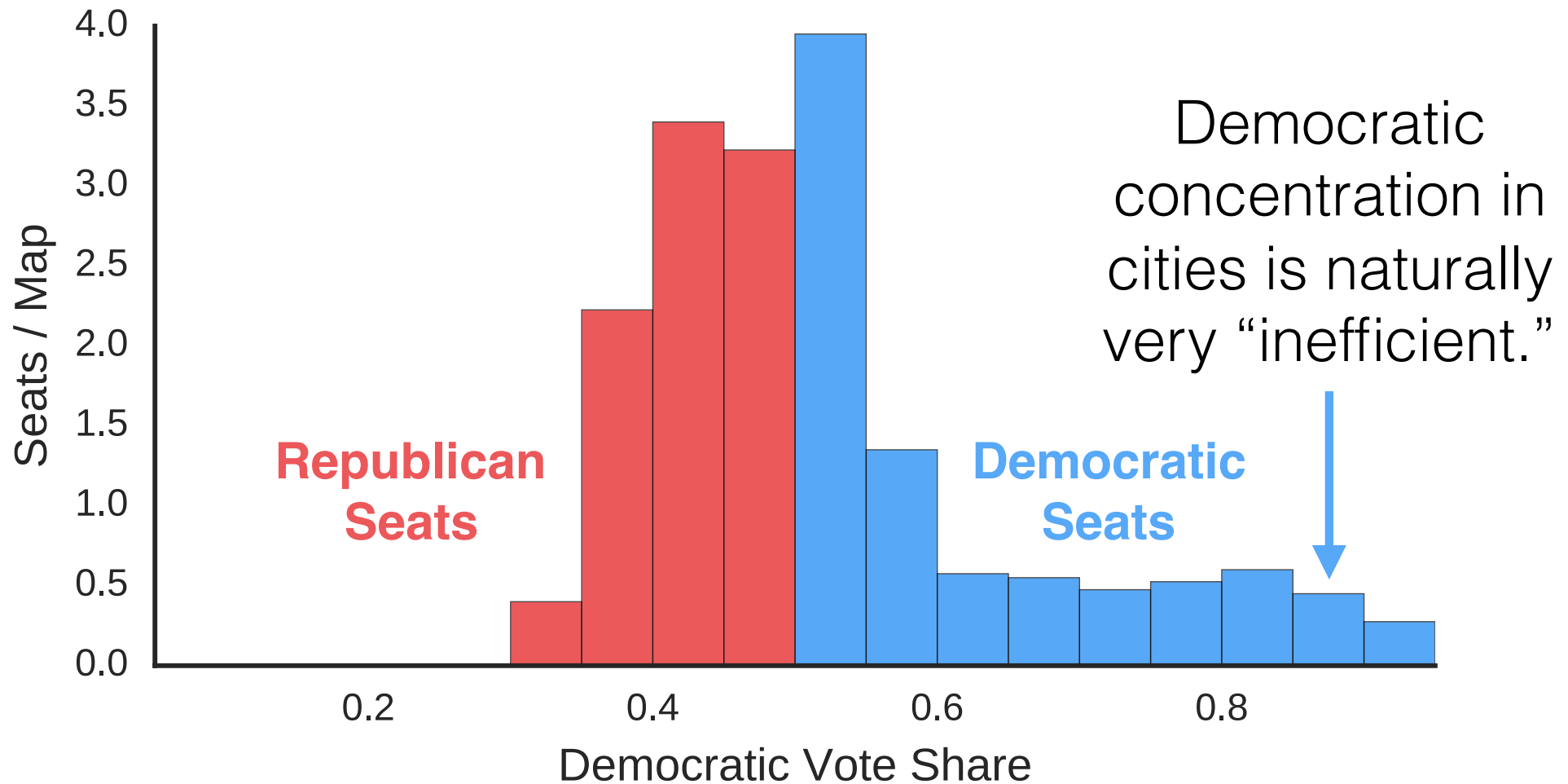
(Greedy/GRASP with tabu lists.)



Exchange Metric: $A(S_n C_R) / A(S)$

Aggregate precinct-level returns from presidential election into (power diagram) districts.

	Rep. Seats	Dem. Seats
Power Diagrams	9.7	8.3
Current Map	12	6



Evaluating Expected Vote Shares

	2000 Pr	2004 Pr	2008 Pr	2012 Pr	Norm
Statewide Votes	0.52	0.51	0.55	0.53	0.54
2000 Map	0.48	0.43	0.67	0.43	0.52
2008 Map	0.53	0.47	0.53	0.47	0.53
2012 Map	0.33	0.33	0.56	0.33	0.33
Power Diagram	0.48	0.42	0.64	0.46	0.56
Split-Line	0.50	0.33	0.61	0.50	0.61
Isoperimeter Quotient	0.45	0.40	0.59	0.47	0.56
Rohrbach	0.45	0.40	0.61	0.47	0.55
Exchange	0.46	0.44	0.61	0.48	0.53
Population Hull	0.46	0.40	0.61	0.49	0.54
Dynamic Radius	0.46	0.42	0.60	0.47	0.55
Inscribed Circles	0.47	0.44	0.59	0.47	0.53
Circumscribing Circles	0.46	0.41	0.61	0.47	0.56
Path Fraction	0.44	0.42	0.64	0.47	0.64

See Also Chen & Rodden, Unintentional Gerrymandering

Some Foreign Perspective

Basically all countries now use independent commissions.

After France moved to to independent commissions, the *Conseil Constitutionnel* declined to intervene, opining that they they lacked the “general power of judgment and decision” of the panel.

New Zealand is the only other country to successfully implement minority representation, with Māori seats.



Painted by John Constable, R.A.

OLD SARUM.

"HERE WE HAVE NO CONTINUING CITY."

S^T. PAUL.

Engraved by David Lucas.

Better Statistics

- More-careful statements about the consistency of measures, and the levels of gerrymandering.

Non-Spatial Adjacency

- How are non-spatially contiguous regions linked?
 - Clustering on intensive variables (income, education, etc.) a developed field.
 - Biclustering people and communities by amenity use.
- Building in more community levels (counties, etc.)

What do citizens have a “right” to?

- Competitive elections (between whom)?
- Unbiased (by what measure)?

Take-aways

- Compactness has a long legal history (both legislative and judicial), and a rich literature, but has remained somewhat nebulous.
 - That said, virtually all measures yield consistent results from a political perspective.
 - A clear directive could help the courts, or spur Congress to reassert its constitutional mandate.
 - Using compact maps, find that voter allocation and legislative prerogative both affect levels of representation.
- ➔ Great variety of projects with training in physics!

Thanks for your time!
Questions / Comments

