Metric Geometry and Gerrymandering

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Many slides from M. Duchin & M. Bernstein

MGGG

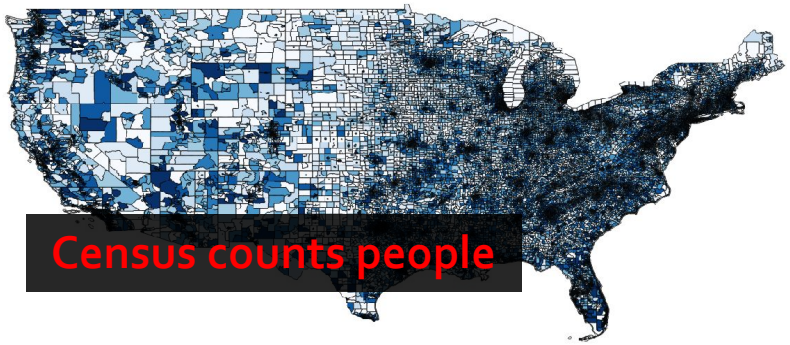
Metric Geometry & Gerrymandering Group

Small team studying applications of math and computing to redistricting

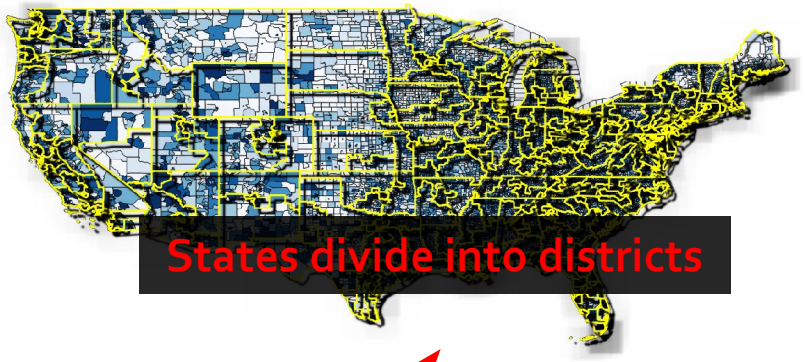
- Research & publication
- Interdisciplinary collaboration
- Outreach & education

sites.tufts.edu/gerrymandr/

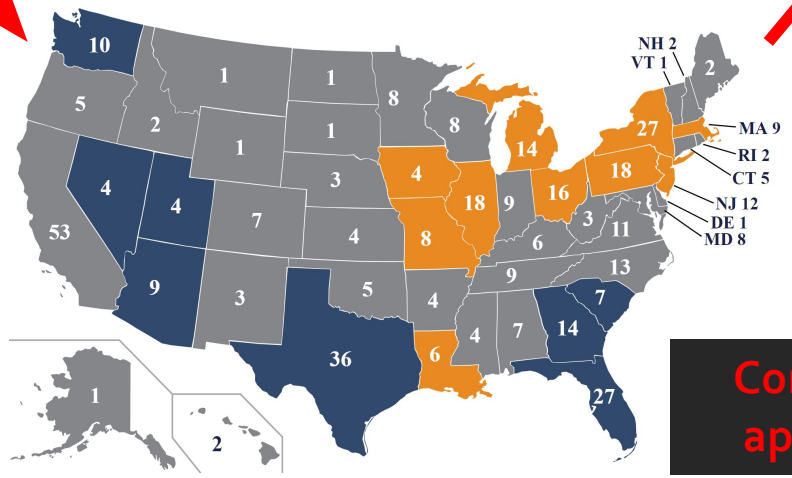
Congressional Representation



Census counts people

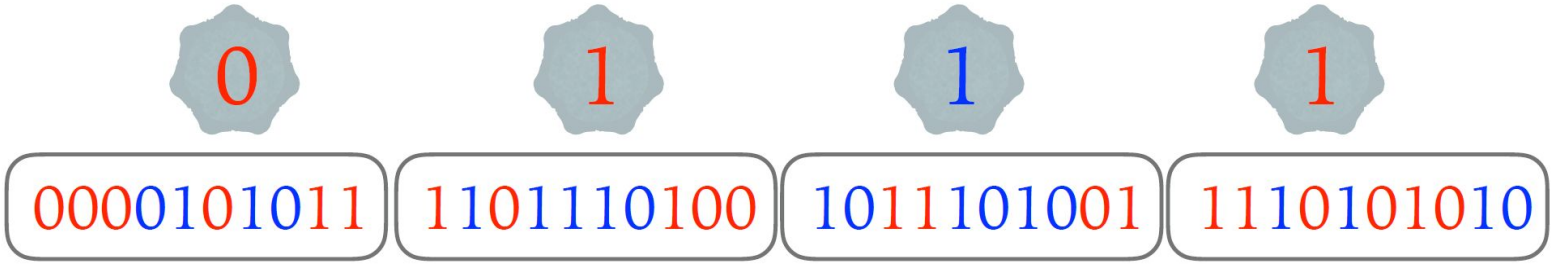


States divide into districts



Congressional reps are apportioned to states

Redistricting as a Math Problem



o has 45% of the population but 25% of the districts
Red has 52.5% of the population by 75% of the districts

… tens of thousands of census blocks per district!

Partitioning with attributes

Goals and Constraints

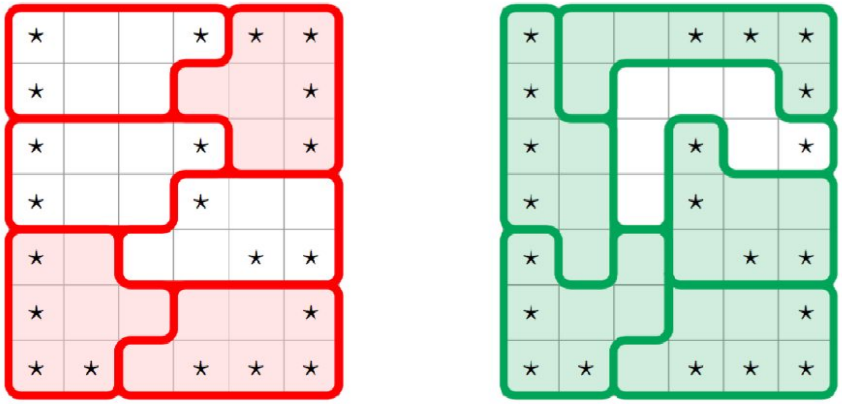
- **Goals**
  - **Proportionality:** Districts are representative
  - **Gerrymandering:** Partition to extremize an attribute
- **Constraints**
  - Equal population
  - No holes
  - Not too "eccentrically shaped"

Other Values or Principles

- Proportionality
- Competitiveness
- Governability
- Partisan Fairness
- …?

Relatively few legal parameters

How to Gerrymander



Intuition:

Any agenda will cause eccentric shapes.

Image from:
A Formula Goes to Court: Partisan Gerrymandering and the Efficiency Gap
Bernstein & Duchin, *Notices of the AMS* (to appear)

Packing & cracking

Compactness

COMPACTNESS

- Many metrics exist:
  - Isoperimetry

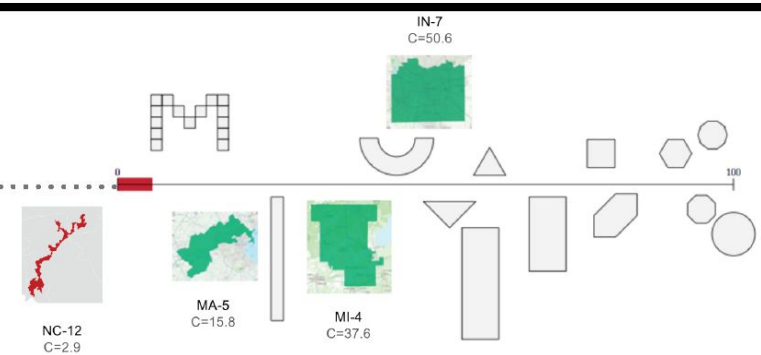
$0 \leq 400\pi A/P^2 \leq 100$

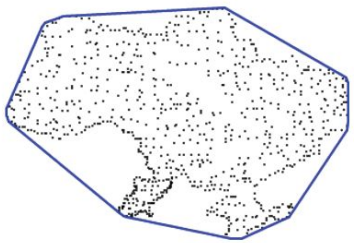
  - Convexity

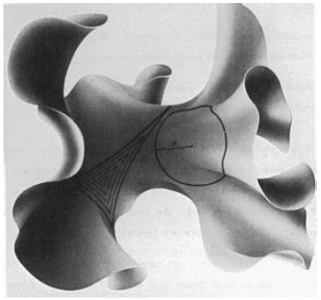
How indented?

  - Dispersion

How spread out?







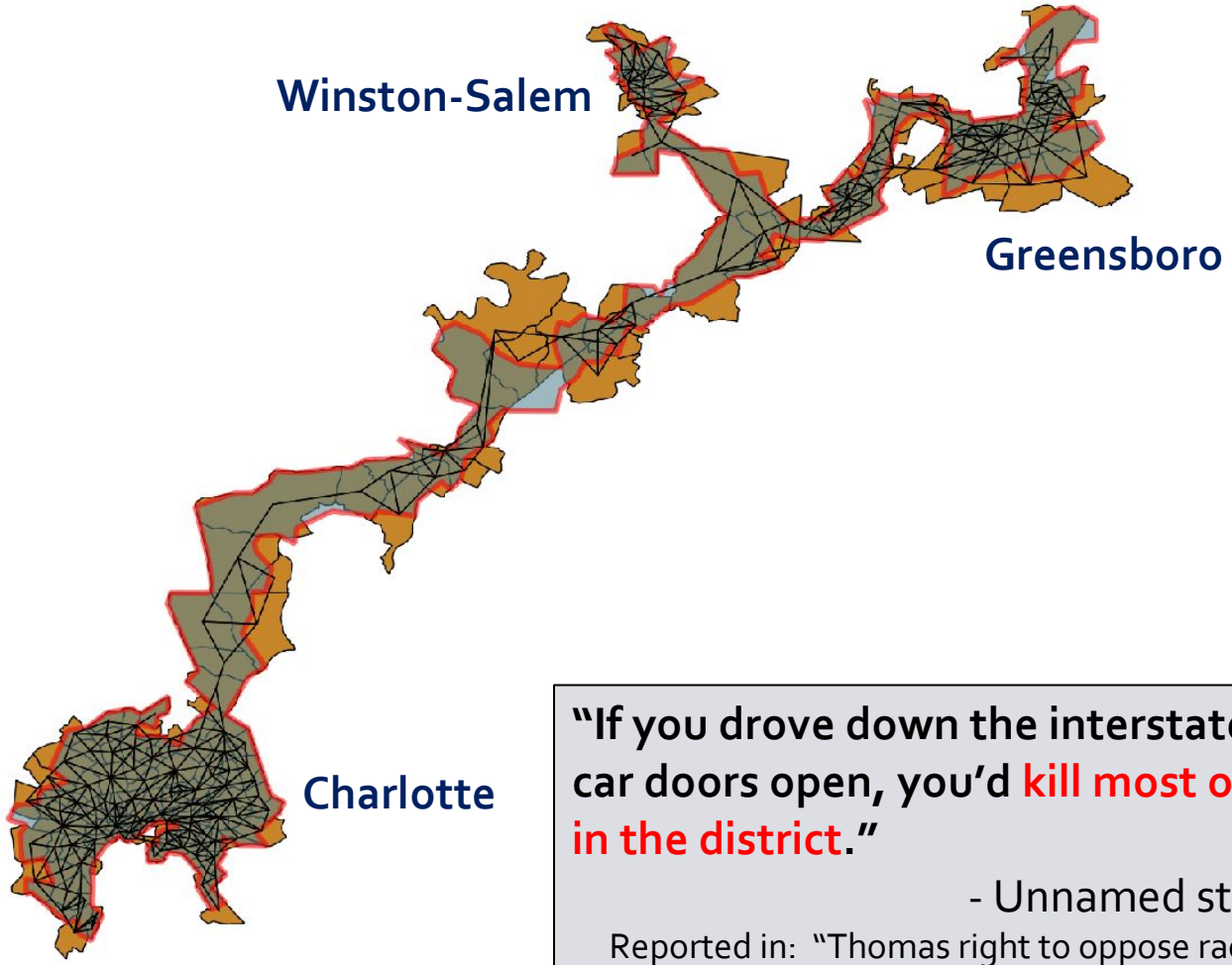
but perimeter is problematic

there are many legitimate reasons for non-convexity

and all of this is 19th century mathematics!

NC-12 at the Census Tract Level

Until 2013



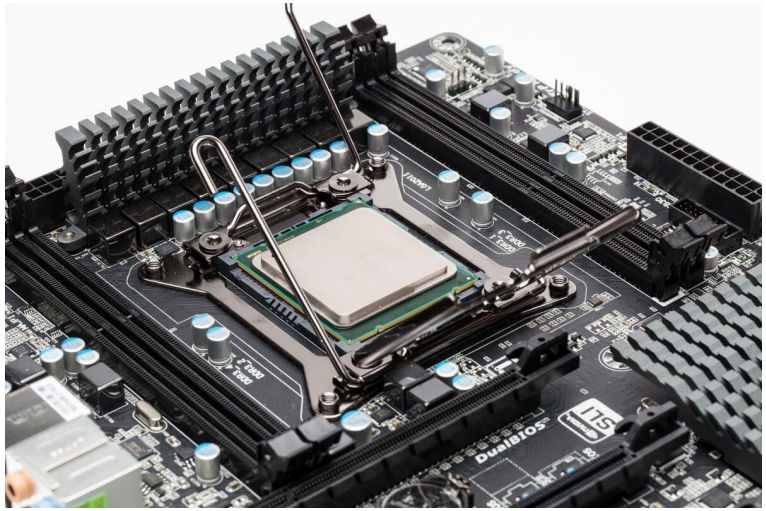
"If you drove down the interstate with both car doors open, you'd kill most of the people in the district."

- Unnamed state legislator

Reported in: "Thomas right to oppose racial 'homelands'" (*The Item*, August 17, 1994)

What can we do as programmers and computer scientists?

Partners in Redistricting



10^9 computations/second
No legal understanding
No sympathy

?? computations/second
Strong legal understanding
Potentially sympathetic

Spectrum

Clearly easy:

- Visualizing districting plans
- Data collection

Clearly difficult:

- Extracting optimal plans

Huge gray area:

- Improving plans
- Evaluating compactness
- Sampling possible plans

Let's be clear:

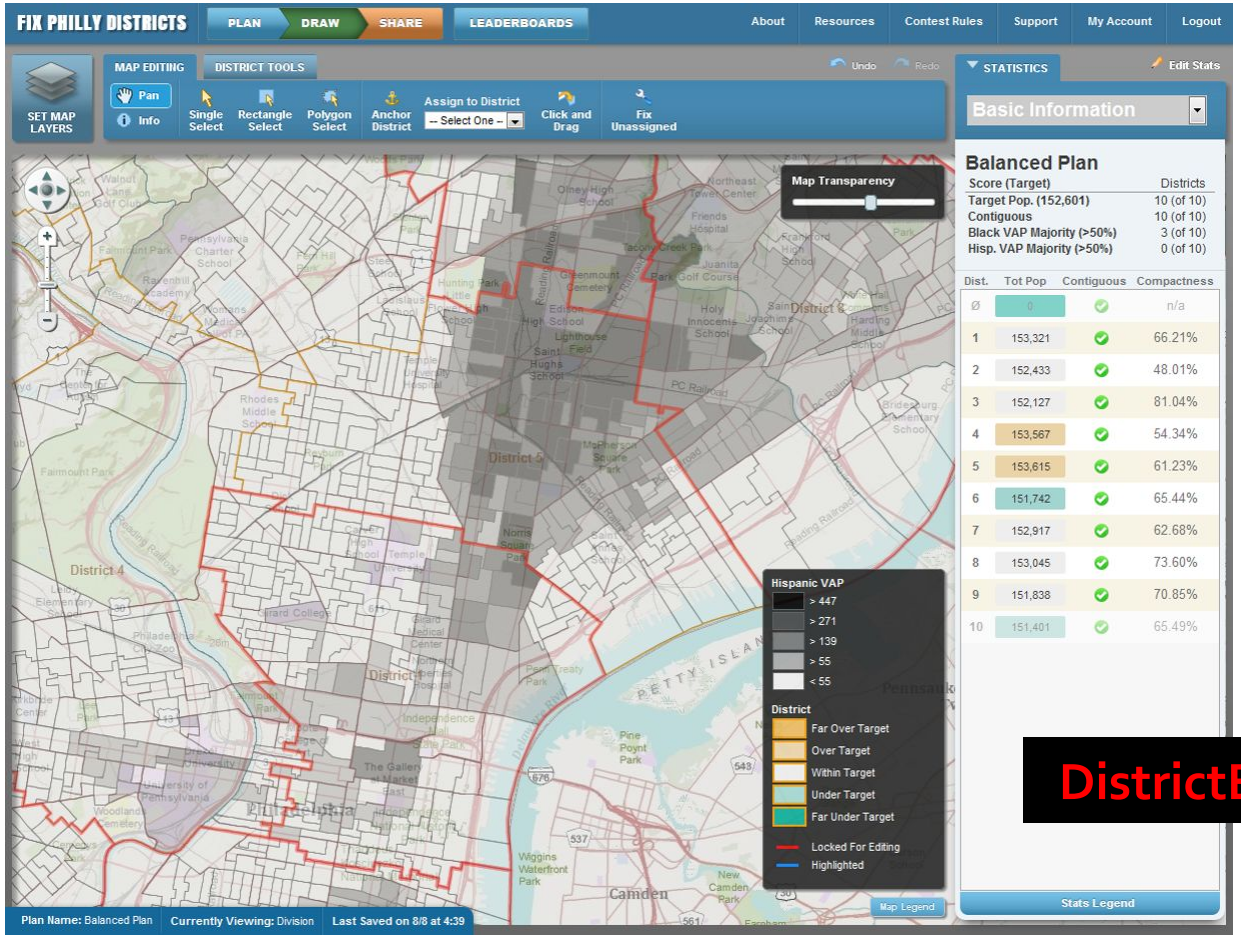
Any software extracting the "best possible" districting plan* also resolves the most famous open problem in computer science.**

$$P \stackrel{?}{=} NP$$

* under any reasonable metric.

** (News!) *Perhaps* not open any more.

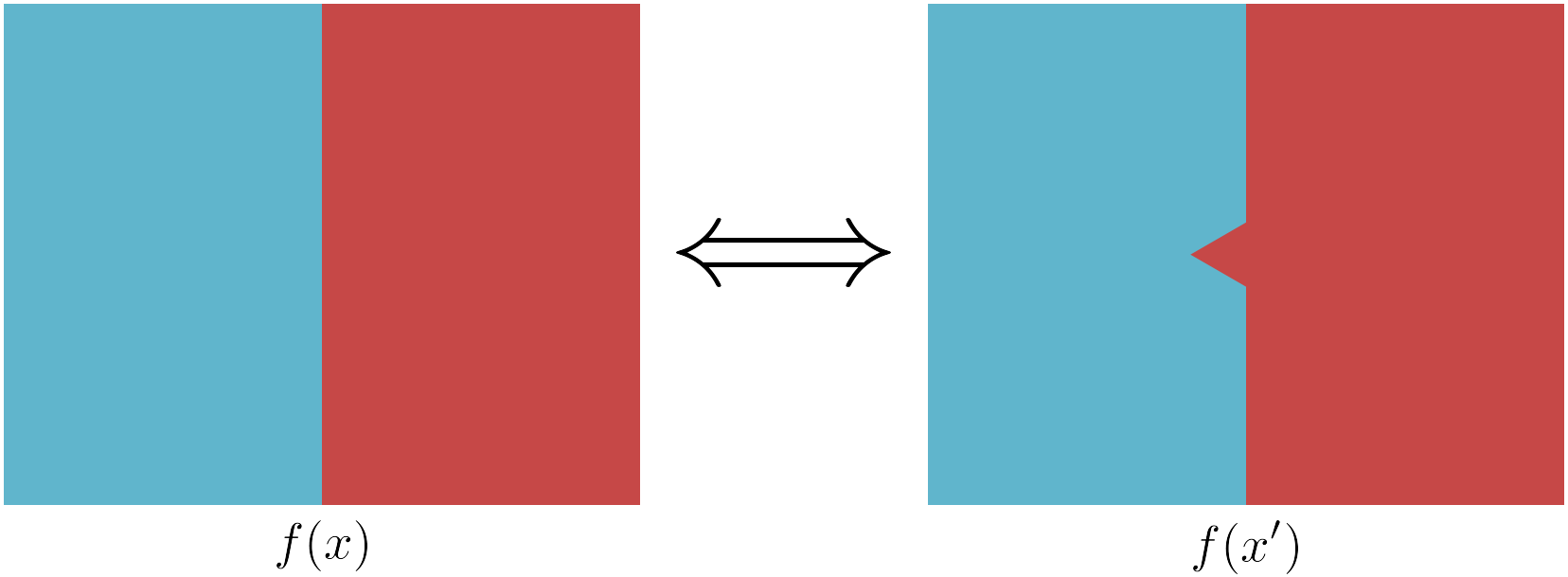
What Can We Do?



DistrictBuilder

Analysis and comparison

What Can We Do?



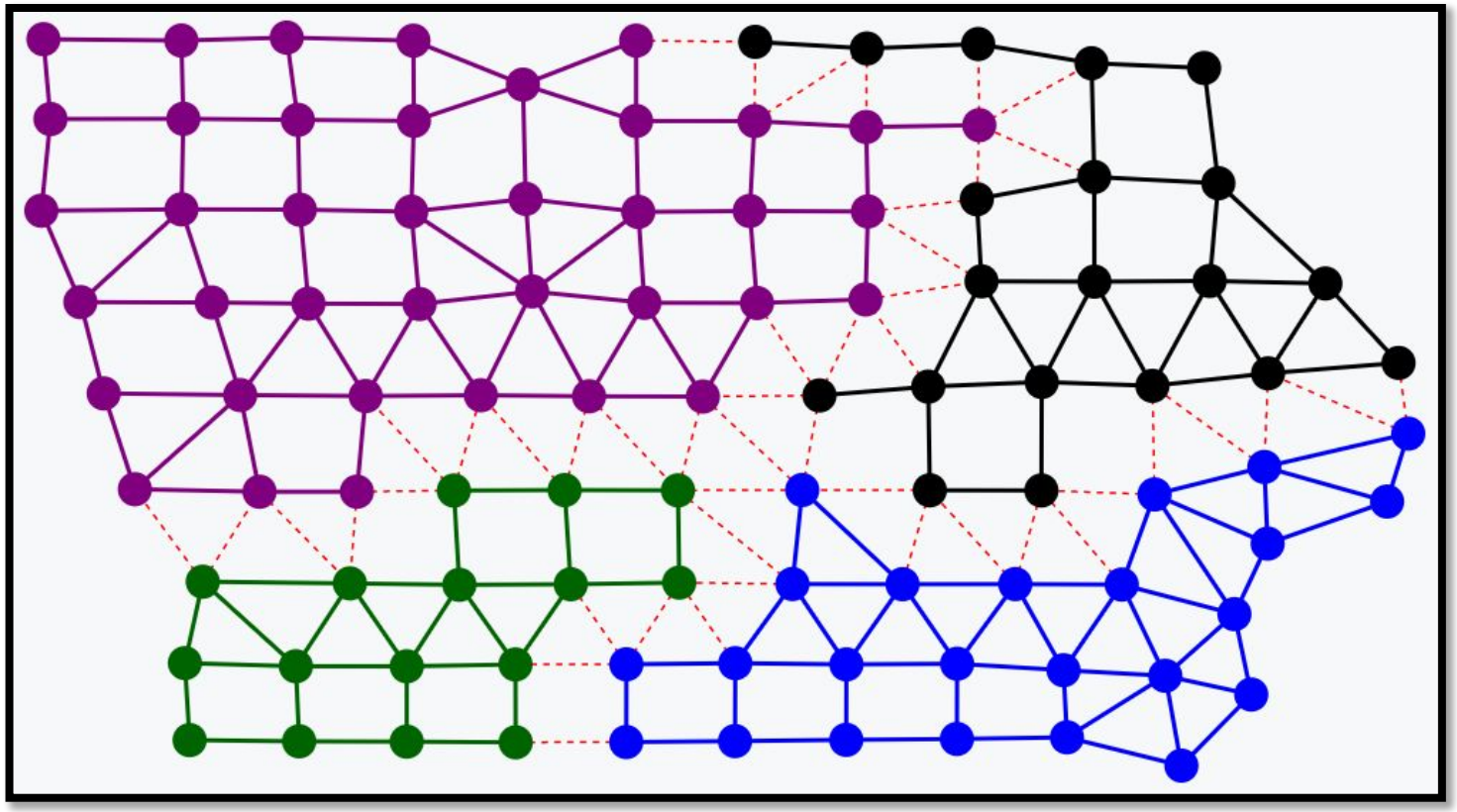
Local optimization

Which Objective Function?

- Isoperimetric ratio?
- Graph curvature?
- Dispersion?
- Equal population?
- Minority representation?
- Efficiency gap?

"Pareto optimality"

What Can We Do?



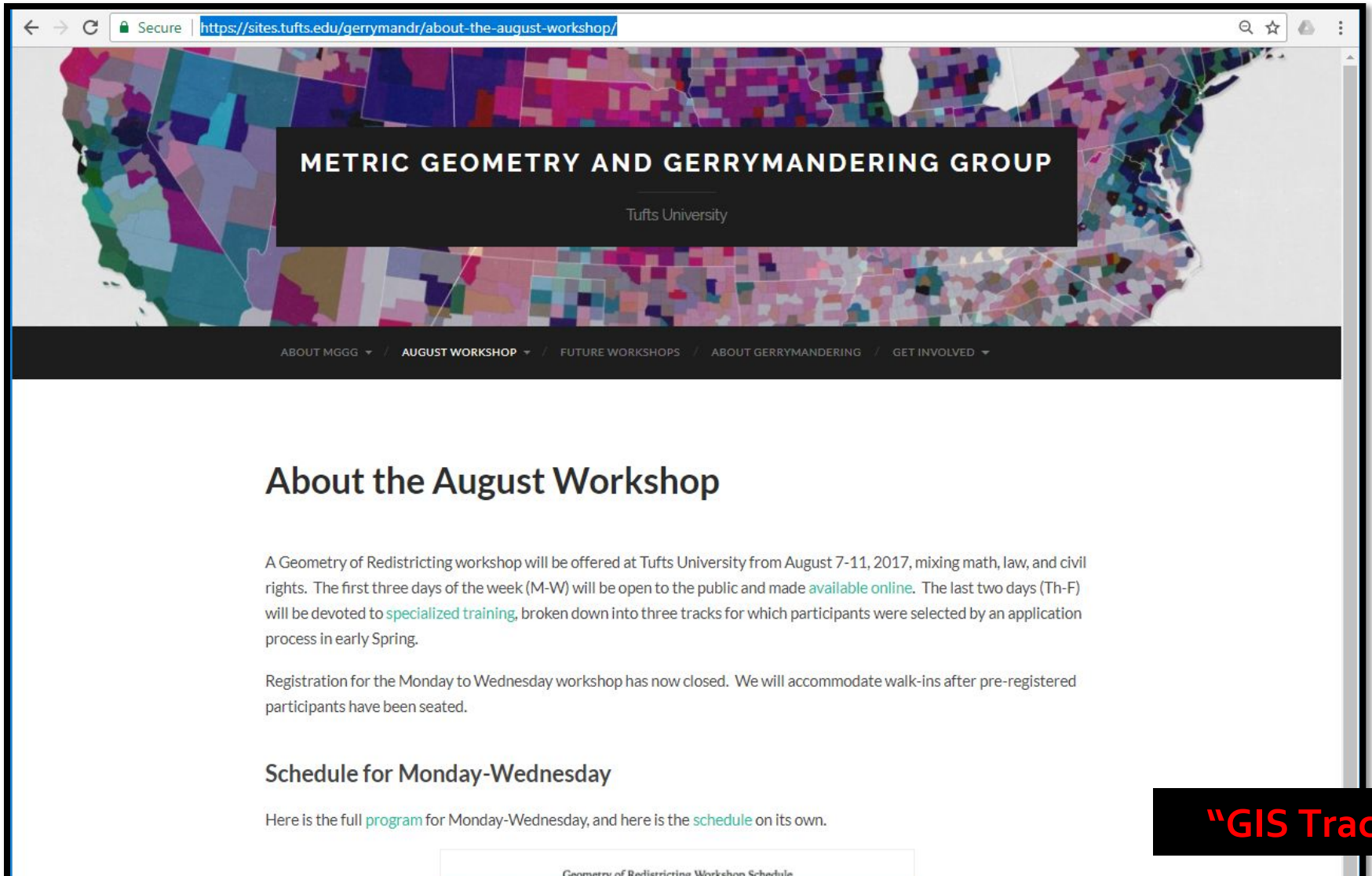
Screenshot from "Quantifying Gerrymandering" (Duke Data+)
https://services.math.duke.edu/projects/gerrymandering/

Sampling/MCMC

Call to action:

We need your help.

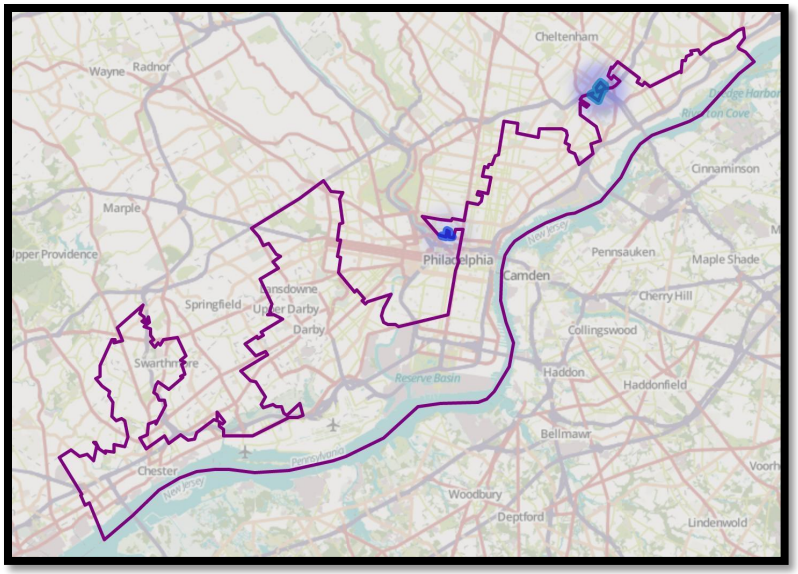
MGGG Effort

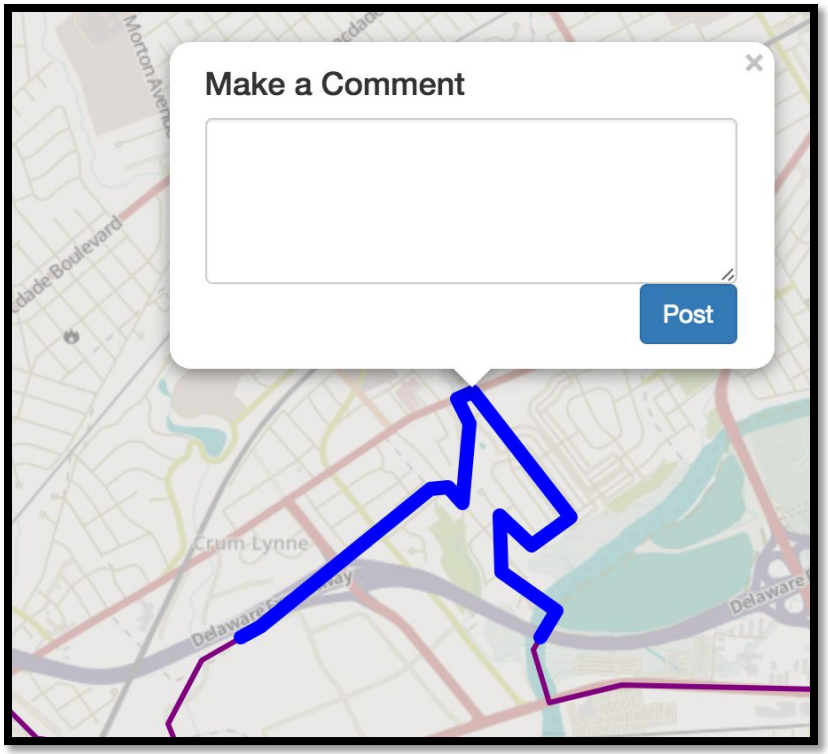


"GIS Track"

N. Doiron:

DistrictGenius

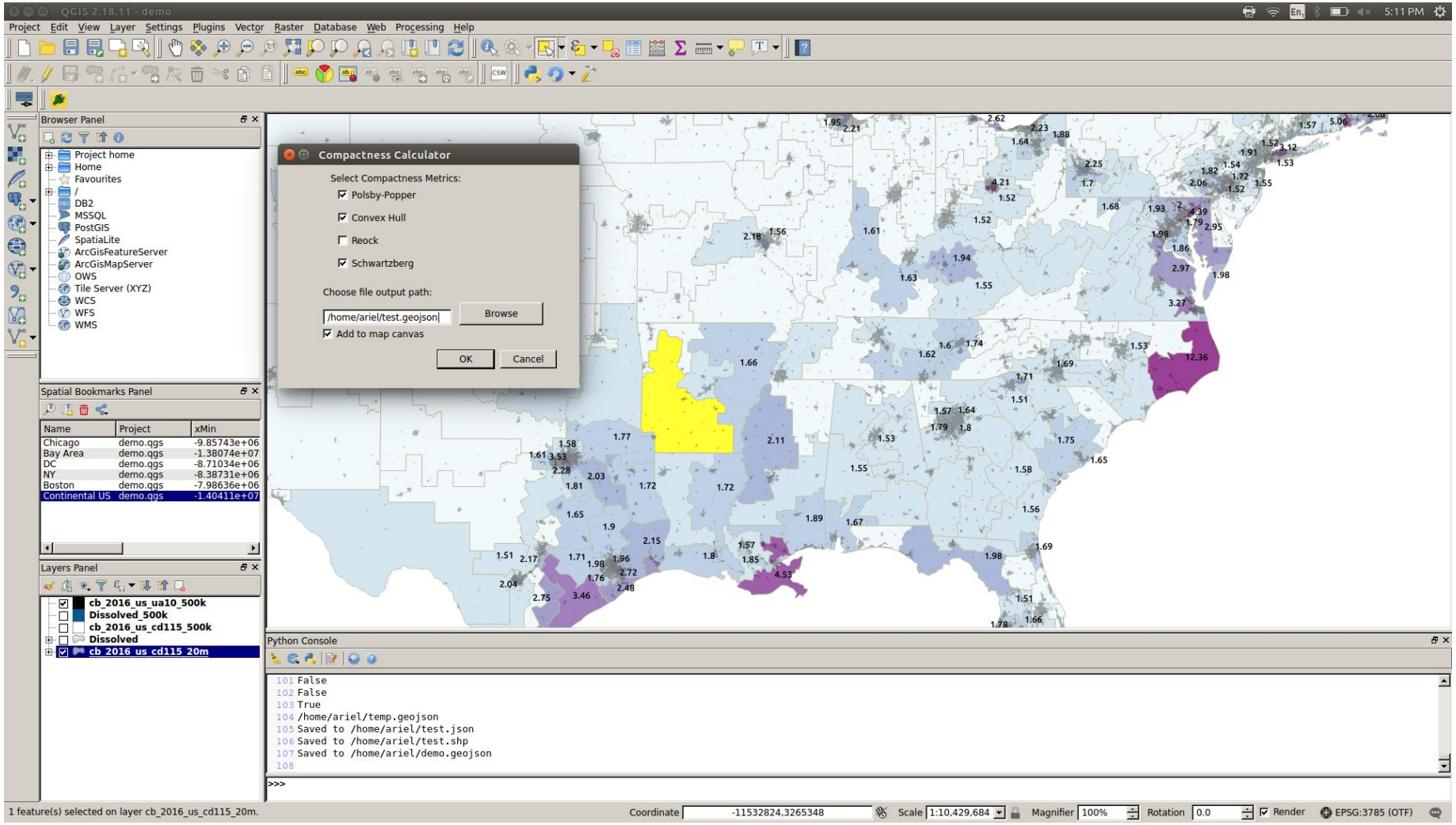




https://github.com/gerrymandr/district-genius

A. M'ndange-Pfupfu
& V. Archambault:

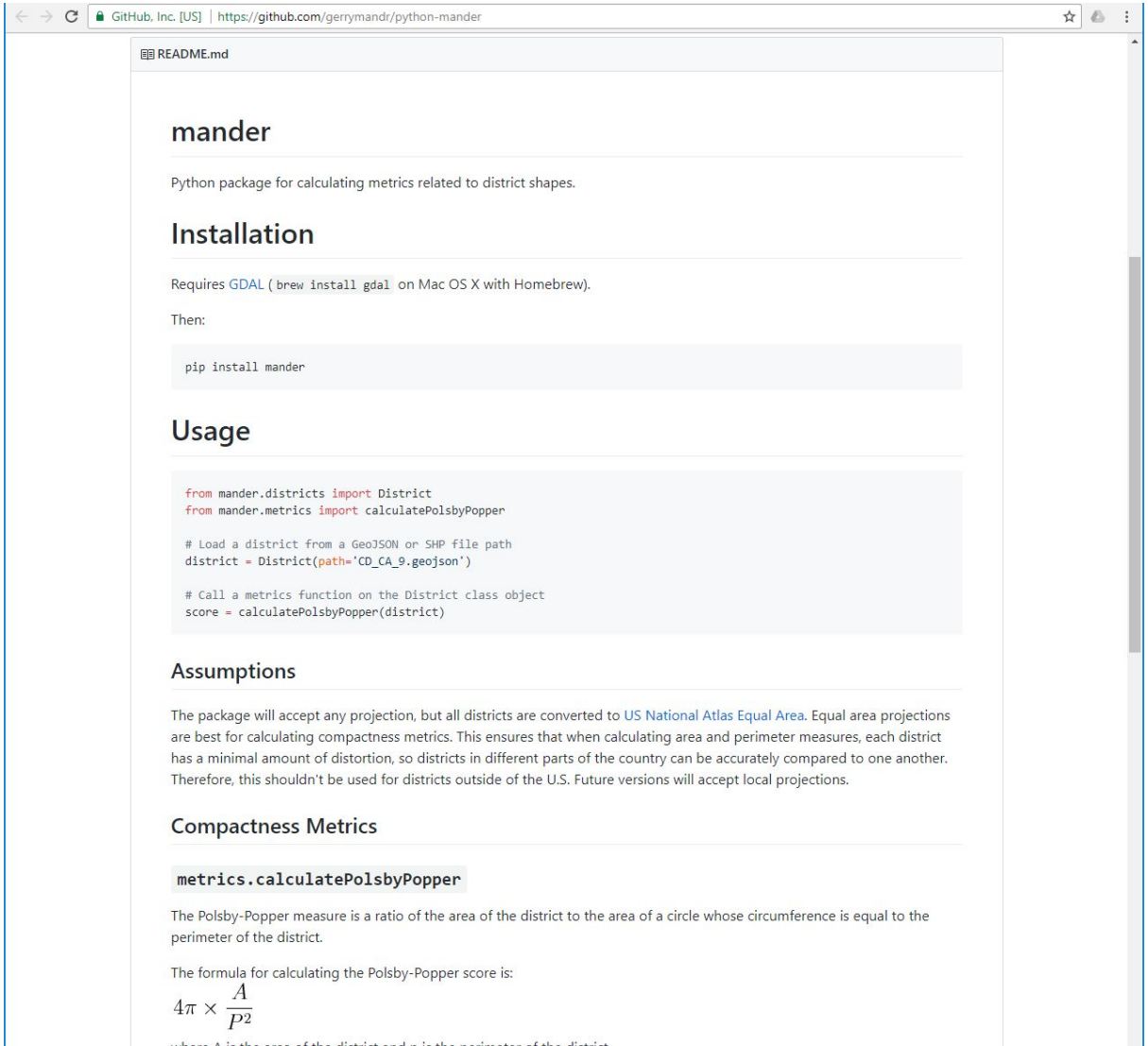
QGIS Compactness Plugin



https://github.com/gerrymandr/qgis-compactness

M. Gardner, R. Barnes, A. Dennis, D. McGlone, J. Connors:

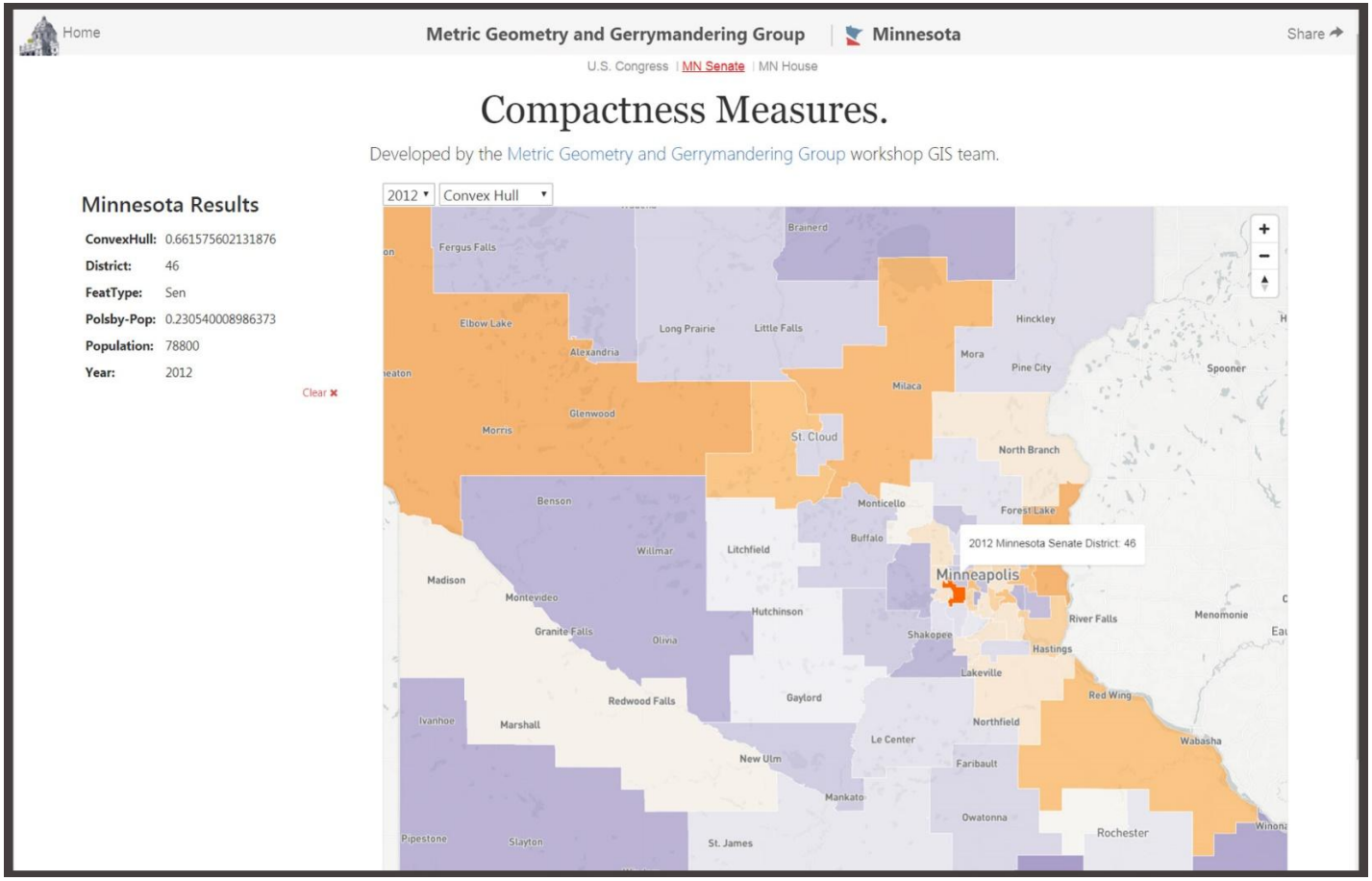
Mander & Compactnesslib



https://github.com/gerrymandr/python-mander

M. Solbrig, C. Cantey:

Metric Visualizer



https://github.com/gerrymandr/metric_visualizer

Future Workshops

- **Wisconsin**

October 12-15, 2017

- **North Carolina**

November 2-5, 2017

- **Texas**

February 1-4, 2018

- **California**

March 15-18, 2018

https://sites.tufts.edu/gerrymandr/project/

Potential Projects

- Unglamorous but necessary data scraping
- Gerrymandr, the app
- Demo and comparison of district sampling algorithms
- Illustrate evolution of districting plans
- Redistricting competitions
- GIS Team request page
- Crowd-sourced redistricting
- Many more!

Open Questions

- What is the role of machine learning in redistricting?
- How complicated is the energy landscape of political redistricting specifically?
- How do we ensure transparency for redistricting software?

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Questions?