Transit Time Compactness

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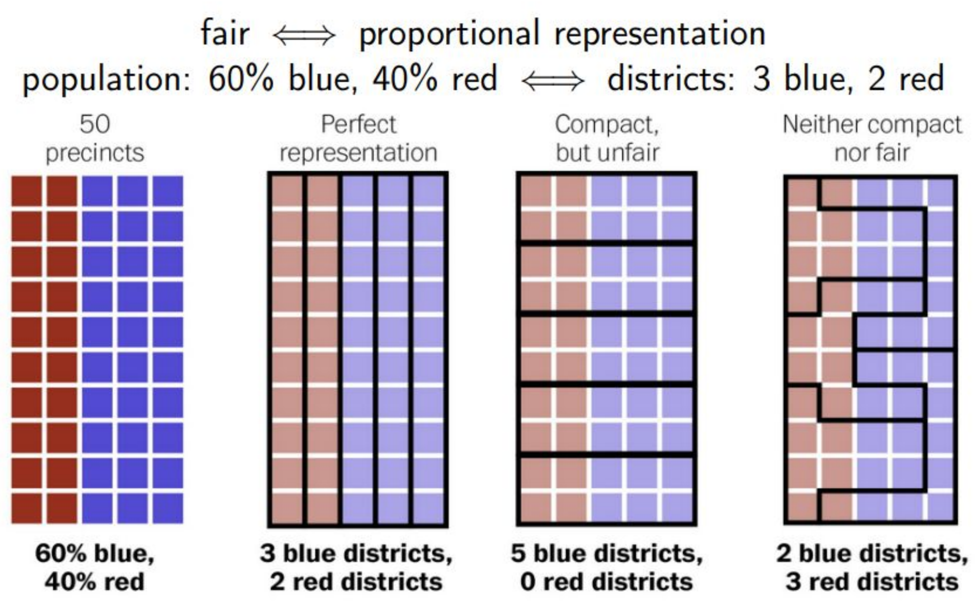
Problem

Political gerrymandering is a complex and pressing threat to our system of government. At the heart of our difficulties to fairly divide ourselves into voting district lies a math problem – how do we measure fairness? Traditionally, it has been thought that districts drawn with "pretty" boundaries are more fair than "ugly" shapes. This lead to several widely-used measures of "compactness" that focus on geographic shape. However, appearance often deceives; pretty shapes can hide gerrymandering and ugly shapes can be fair. So, we present a new measure called "transit-time compactness" that focuses on the cohesiveness of the citizens living inside a district rather the prettiness of its shape.

What is Gerrymandering



Current Compactness

Statutes require districts to be "compact" without defining a measure. Common measures focus on geographic shape:

Polsby-Popper Measure (Isoperimetric):

$$C_{pp}(D) = \frac{4\pi A}{p^2}$$

Reock Measure:

$$C_R(D) = \frac{A_D}{A_{scd}}$$

A_{scd} = area smallest circumscribing circle
A_D = area of district *D*

Geometrically compact, but cities A and B seperated by impassible waterways. As a result, citizens of A rarely interact with citizens of B and may not form a cohesive group. Redrawing boundaries to respect roadways and topolopical features may lead to more cohesive districts.

Proposal: Transit Time Compactness

Transit Time compactness uses the population-weighted average travel time between all pairs of census tracts (centroids) in a district D as a proxy for the "cohesiveness" of the citizens in that district via

$$C_{transit}(D) = \frac{1}{Z}\sum_{ij\in D} P(x_i)P(x_j)T(x_i,x_j)$$

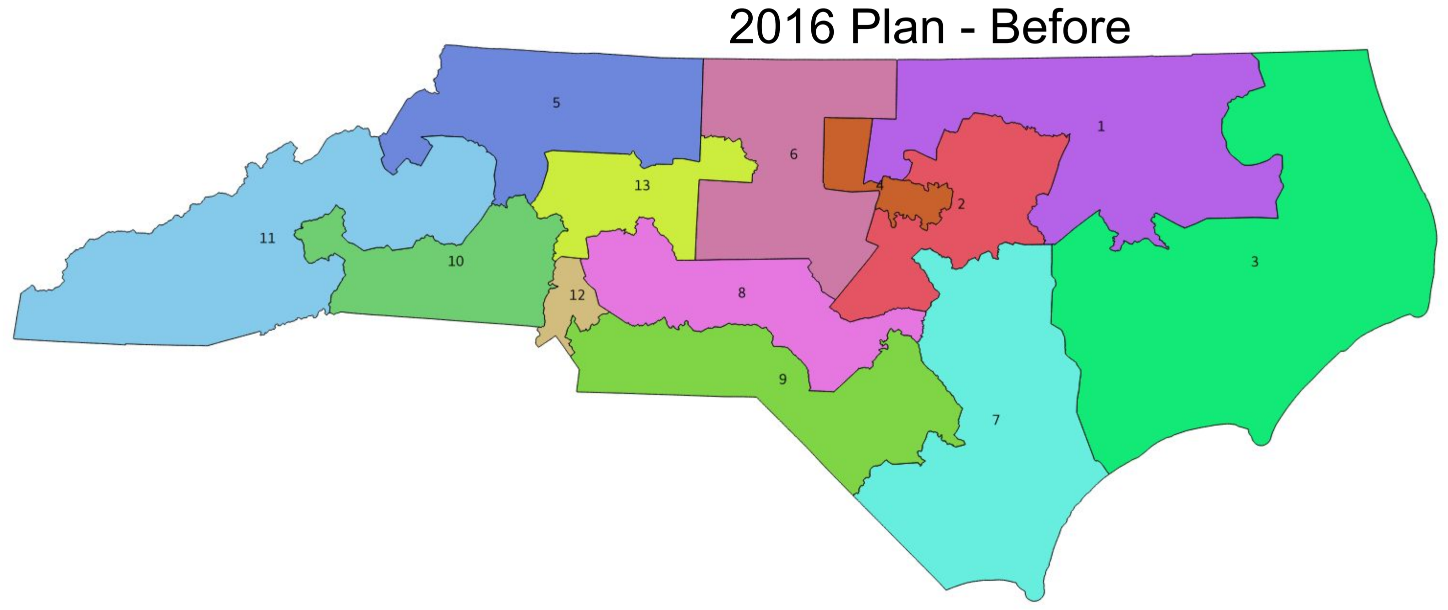
where $P(x_i)$ is the population of tract *i*, $T(x_i,x_j)$ is the transit time between the centroid of tracts *i* and *j*, and *Z* is $C_{transit}$ for all tract pairs in the (undistricted) state.

This approach respects non-uniform population distributions, locations of connecting roads, and barriers to transportation like mountains and waterways.

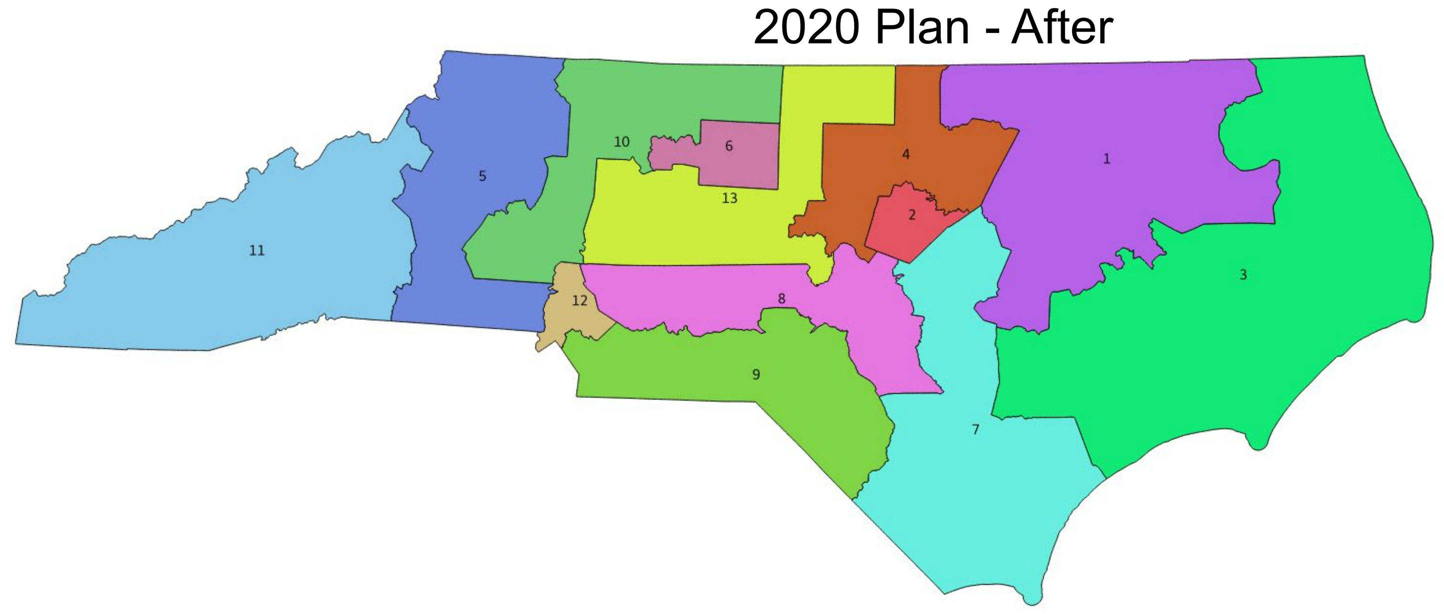
Transit Time Compactness: Results

In 2017, the North Carolina Supreme Court struck down the congressional districting map drawn in 2016 and mandated that a new map be drawn. We compare the compactness scores before and after using the standard, shape-focused Polsby-Popper Compactness (PP) and our novel Transit Time Compactness (TT).

2016 Plan - Before



2020 Plan - After



District	PP_{2020}/PP_{2016}	TT_{2020}/TT_{2016}
1	-25.21%	-70.25%
2	-44.89%	-52.78%
3	11.71%	90.49%
4	-14.49%	129.10%
5	23.37%	-5.26%
6	31.64%	-11.35%
7	6.92%	-16.56%
8	-12.25%	-1.17%
9	-40.36%	-22.83%
10	6.81%	-71.95%
11	-11.43%	16.72%
12	4.89%	184.02%
13	-17.04%	86.30%
State	**-0.14%**	**-13.20%**

Using PP=1-PolsbyPopper so that for both measures
- smaller values → more compact
- negative chage → increased compactness

Method

We built an enterprise grade server to process osm.pbf files from GEOFABRIK to generate the complete graph on census tract centroids with edges weighted by time of fastest route by car. The continental US involves 850 million nodes, 96 gigabytes of ram, and 30 hours of processing.

Conclusions

Transit Time (TT) compactness detects more significant differences between the 2016 & 2020 NC plans than Polsby-Popper (PP). Statewide, TT sees 13.20% improvement while PP sees 0.14% improvement.

At the district level, TT's biggest changes detect the districts explicitly targeted for adjustment by the court case (red) and their adjacent districts impacted by those adjustments (green).

Thus, TT correctly detects details of the court case purely from characteristics of the redrawn map.

References

Luxen, Dennis, and Christian Vetter. "Real-time routing with OpenStreetMap data." *Proceedings of the 19th ACM SIGSPATIAL international conference on advances in geographic information systems.* 2011.