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 districts 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 than the prettiness of its shape.

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:

\[ C_{\text{transit}}(D) = \frac{1}{Z} \sum_{i,j} P(x_i)P(x_j)T(x_i, x_j) \]

where \( P(x_j) \) 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 the transit cost 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.

Method
We built an enterprise grade server to process osm.pbf files from GEONABRIK 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