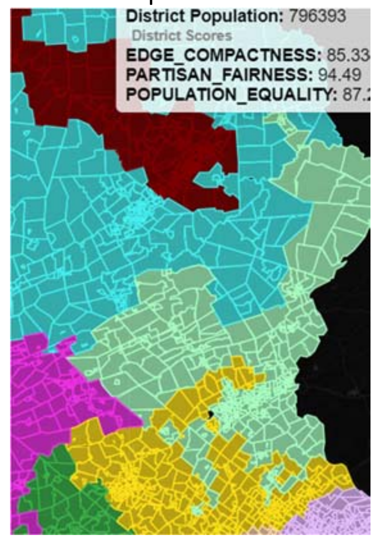
Algorithms and Measures for Political Redistricting

Drawing Congressional district boundaries for the 43 states with multiple congressional representatives is a challenging problem, especially if the goal of such redistricting is to provide fair representation to the people in the state, especially to minority populations. Historically, many states used undue political influence to draw the districts, resulting in underrepresentation of the other political party or underrepresentation of minority groups. The term used to refer to this practice of political redistricting is Gerrymandering, and current estimates of the cost of this practice is 17-18 congressional seats that would normally be held by the other political party. The PoliTech research group is developing systems, methodologies, algorithms, and analysis focused on setting congressional boundaries that are independent of undue political influence. In this talk, I will focus on the algorithms and measures used in this work.



We formulate the redistricting problem as a graph partitioning problem in which election districts (i.e., precincts or wards) are the nodes in the graph while edges are defined by the pairs of adjacent precincts. The problem is to partition the graph into n connected sub-graphs, where n is the number of congressional districts. This partitioning is subject to a variety of constraints set by constitutions, laws, and court precedent. These constraints are different for each state, and typically include requirements for compactness, equal population, keeping together communities of interest, and providing minority representation.

Our approach involves the formulation of an objective function, which when optimized, will produce a "good" district plan. Processing is performed in two phases; a first phase develops a seed districting in which graph edges are iteratively collapsed until there are n sub-graphs, where n is the desired number of districts. The second phase uses a modified simulated annealing approach to incrementally improve the value of the objective function. A critical step in the first phase is generating seed districts that are approximately equal in population. Our combining approach first employed a tree structure to record the combinations so that the final iteration could move branches in the tree to achieve more equal population. The current version uses a spanning tree approach in which neighboring sub-graphs are balanced by first combining the two, then split by cutting a population-favorable edge in the spanning tree.

The objective function uses measures that are some mathematical counterpart to the general definition of requirements typically found in legal documents. Formulation of the measures is important for the correct operation of steps in the edge-collapsing and simulated annealing phases. Relevant measures include those for equal population, minority population goals, county containment and equal population. Measures are also used to assess the lack of political and/or racial gerrymandering.

One algorithmic approach to the measure of political and/or racial gerrymandering involves the generation of large numbers of random districtings. In this approach random districtings are formed using a modified version of the "optimal" districting mentioned earlier, replacing optimal actions with random actions. Districts in each such districting are ordered by either the political or the racial result of a district. Each such district (e.g., 3rd largest African American) contributes to the estimation of the associated probability distribution among all possible districtings. The resulting data can be used to assess whether a redistricting plan under consideration is anomalous through a comparison of its ordered districts with those generated probability distributions.