Measures

CSE416

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Session Objectives

- Understand filtering of districtings
- Understand objective function measures
- Know the reference that describes the details of each measure
- Begin to understand the data needed to support the measures
- Start to design you GUI

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Reading

- https://redistricting.lls.edu/redistricting-101/why-should-we-care/ - Interesting brief read
- https://en.wikipedia.org/wiki/Gerrymandering
- Quantifying Gerrymandering in North Carolina, Mattingly, et al – Reference 8 in CSE416 References page
- https://ballotpedia.org/Majority-minority_districts
- Polsby-Popper score - https://en.wikipedia.org/wiki/Polsby%E2%80%93Popper_test
- Fatness - https://en.wikipedia.org/wiki/Fat_object_(geometry)

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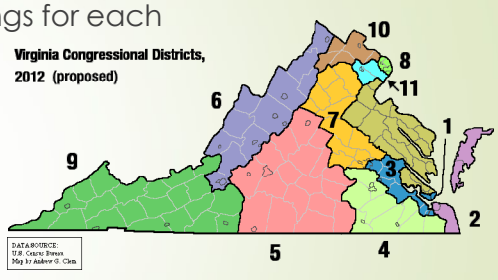
What are the General Goals of the Project?

- Calculate a set of random districtings for each assigned state
- Store the districtings in a server database
- Allow the user to choose a sub-set of the random districtings (e.g., by limiting compactness)
- Allow the user to set the weights of objective function terms (sliders)
- Calculate the objective function of each districting
- Analyze results
- Display requested results to the user



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Subset of Random Districtings

- SeaWulf sub-system will generate a large number of districtings (maybe 100,000)
- User will request that this set be reduced so that selected districtings are feasible (maybe 1,000)
  - Incumbent protection
  - Equal population (e.g., < 1.5%)
  - Majority-minority districts (>= some user provided number)
  - Compactness (e.g., > .3)

During your testing you will determine reasonable values for population and compactness)

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Incumbent Protection

- Some redistricting organizations prefer that a new districting plan not include 2 incumbents in one district.
- Requires
  - Association of every incumbent with a precinct
  - GUI display of incumbents
  - Checkbox for each incumbent to allow the user to provide incumbent protection

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Equal Population

- Districts must be equal in population
- Calculation is usually the percentage difference between the most populous and the least populous
- MCMC algorithm does not run fast if the requested difference is too low – you run MCMC with a very high threshold (e.g., 75%), and then select those districting lower than a more realistic threshold (e.g., 1.5%)

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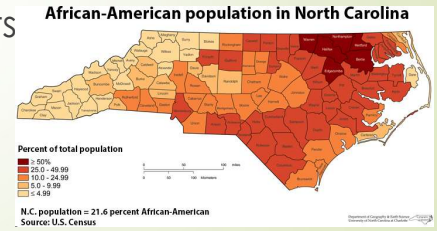
Race/Language Population Groups

- 1965 Voting Rights Act (VRA) mandates (for some states) the establishment of districts in which an ethnic minority has the ability to elect a representative of their choice
- Majority-minority requirement has been used to pack districts



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1965 Voting Rights Act

- VRA
  - Forced selected states to obtain pre-clearance for any election change that might affect the right to vote
  - Was very effective in restoring voting rights
- 2013 decision of Supreme Court struck down parts (e.g., preclearance) of the VRA
- Majority-minority provisions remain, which has been used to enable district packing of congressional districts

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Voting Rights Act

- Mandates that no "standard, practice, or procedure shall be imposed or applied by any State or political subdivision to deny or abridge the right of any citizen of the United States to vote on account of race or color."
- Mandates that electoral district lines cannot be drawn in such a manner as to "improperly dilute minorities' voting power.
- Majority-minority districts are created to prevent the dilution of minorities voting strength

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Majority-Minority District Considerations

- Lack of a precise definition
- Usually a goal in redistricting to set some number of MM districts
- Enacted districtings can be evaluated with a MCMC approach
- MM is not a term in the objective function
- The user selects the desired number of majority-minority districts

Possible change in VRA enforcement to race-blind districting

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Majority-Minority Districts

- Language of the Voting Rights Act is vague in terms of majority minority districts
- User will set:
  - the minimum number of majority-minority (MM) districts (usually the percentage of African-Americans in the state multiplied by the number of districts)
  - the minimum threshold for the minority population in a MM district (e.g., 37%)

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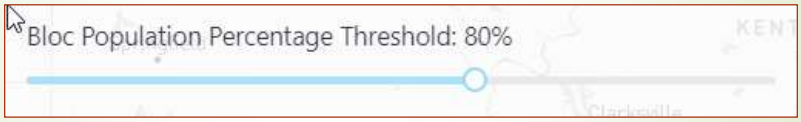
Objective Function

Objective function = W_1*F_1 + W_2*F_2 + W_3*F_3 + …

- Weights (W_1, W_2, …) are set by the user in your GUI, typically using a slider component



- Measures (F_1, F_2, …) return a result in the range [0,1]
- You will calculate the value of the OF for each selected districting

Think about the GUI component to allow user to make request

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Objective Function Categories

- Population equality
- Split counties
- Deviation from average districting
- Deviation from enacted plan
- Compactness
- Political Fairness

Population equality and compactness are both filters and terms in the OF

Each category will have one or more terms in the objective function

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Project Strategy for Equal Population

- Generate random districtings using a wide range of acceptable district population (e.g., 50%)
- Allow user to set a population limit typically larger than that allowed by the courts (user selects a sub-set of districtings in job)
- Assume that subsequent district adjustments will use census blocks to redefine precincts

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Equal Population Measure

- Higher level districts (e.g., congressional districts) should contain approximately equal populations
- No uniform definition of equal population
- Supreme Court usually looks at absolute value percentage variation between most populated district and least populated district
  - .5% is usually OK, .7% or more not OK
- Consider an approach in which you:
  - calculate the ideal population per district (state population / # districts)
  - Calculate the deviation of a district from the ideal population
  - Do a look-up on a curve to calculate the equal population measure in the range [0,1]

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Equal Population Measure

Equal population is both a constraint and an OF measure

- Use Mattingly – Reference 8

The population score function. The population score, which measures how evenly populated the districts are, is defined by

$$J_p(\xi) = \sqrt{\sum_{i=1}^{13} \left(\frac{\text{pop}(D_i(\xi))}{\text{pop}_{\text{Ideal}}} - 1 \right)^2}, \quad \text{pop}_{\text{Ideal}} = \frac{N_{pop}}{13},$$

where N_{pop} is the total population of North Carolina, $\text{pop}(D_i(\xi))$ is the population of the district $D_i(\xi)$ as defined in equation Eq. (2), and $\text{pop}_{\text{Ideal}}$ is the population that each district should have according to the 'one person one vote' standard: $\text{pop}_{\text{Ideal}}$ is equal to one-thirteenth of the total state population.

- Reference refers to North Carolina. You will need to make this more general

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Things to Think About

- What do you need to display?
- What data do you need?

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Split Counties

Counties that contain two or more districts

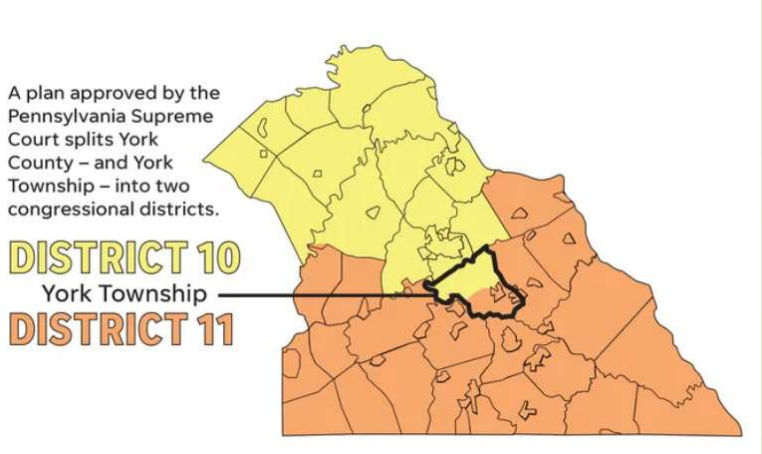

Image: York Daily Record

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Split County Measure

- Use Mattingly formula (Reference 8)

$$J_c(\xi) = \{\#\text{ counties split between 2 districts}\} \cdot W_2(\xi) + M_C \cdot \{\#\text{ counties split between} \geq 3\text{ districts}\} \cdot W_3(\xi),$$

where M_C is a large constant that heavily penalizes three county splits, and W_2 and W_3 are weight factors that smooth abrupt transitions between split/non-split counties and are defined by

$$W_2(\xi) = \sum_{\substack{\text{counties} \\ \text{split between} \\ \text{2 districts}}} \left(\begin{array}{l}\text{Fraction of county VTDs in 2nd largest} \\ \text{intersection of a district with the county}\end{array}\right)^{\frac{1}{2}},$$

$$W_3(\xi) = \sum_{\substack{\text{counties} \\ \text{split between} \\ \geq 3\text{ districts}}} \left(\begin{array}{l}\text{Fraction of county VTDs not in 1st or 2nd} \\ \text{largest intersection of a district with the} \\ \text{county}\end{array}\right)^{\frac{1}{2}}.$$

Smooths abrupt transitions

Penalizes 3-district split

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Things to Think About

- How do you display split county results
  - Summary results?
  - Detailed results?
  - Graphic results?
- What data is needed to
  - Calculate measure
  - Display results

You should be designing your GUI now

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Deviation from Average Districting

- Categories
  - Political
  - Racial – e.g., African American
- Rank the districts in the selected districting by either Democratic population or African-American population
- Measure the sum of squares of the difference between the selected districting and the average districting

Each category is a term in the objective function

Think about your box & whisker plot

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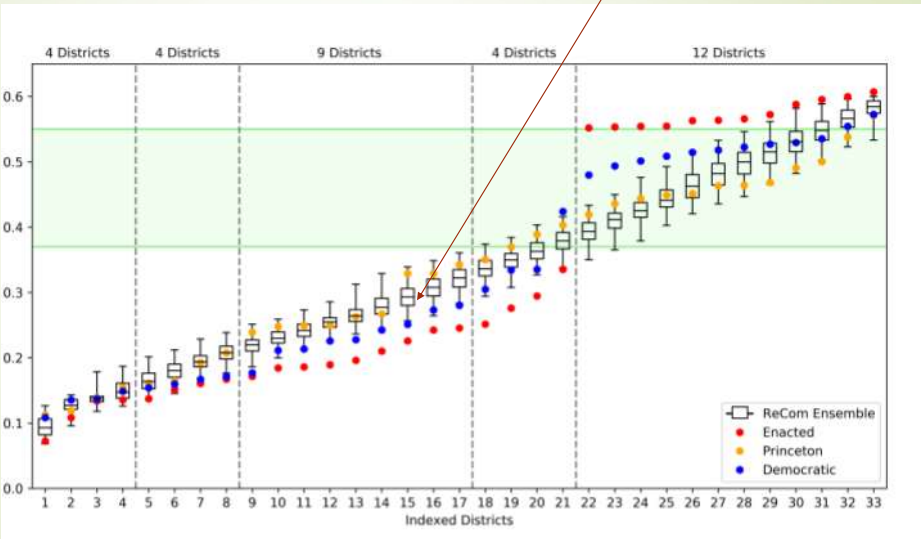
Average Districting

Average for the district

Y-Axis is either % of a minority group or % of votes for a political party



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Things to Think About

- What data do you need?
- How do you show details of the measure to the user?
- How do you visualize a geometric difference to the user?

Comparison of 2 districts can use different measures (e.g., population, geometric

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Deviation from Enacted Districting

- Measures how different a given districting is from the enacted districting
  - Geometric measures
  - Population measures
- Requires you to renumber the given districting so you can do a district by district comparison
- Once renumbered, you compare each generated district to the counterpart enacted district

https://www3.cs.stonybrook.edu/~cse416/Section01/District_Geometric_Similarity-Draft.pdf

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Computation

- For 2 districting plans (D_1 and D_2), reorder the plans in D_2 to determine the maximum value of f

$$f(D_1, D_2) = \frac{1}{A}\sum_{n=0}^{i} I(d_1^i, d_2^i)$$

- Where
  - A is the total area of the state
  - $I(d_a, d_b)$ is the intersection area of district a in D_1 with district b in D_2

A similar computation can be done for a population comparison of 2 districts

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Things to Think About

- What data do you need?
- How do you show details of the measure to the user?
- How do you visualize a geometric difference to the user?

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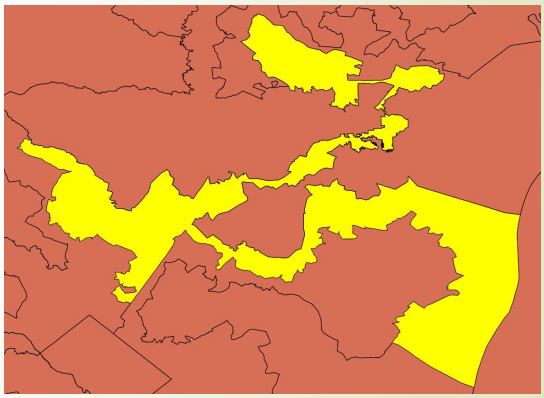
Compactness Measures

- Not a single best measure
- Good description of the measures in Kaufman, King, and Komisarchik
- You will use multiple compactness measures in your OF
- Categories
  - Geometric
  - Graph
  - Compound (e.g., population)



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Geometric Compactness

- Best understood by people engaged in redistricting
- Polsby-Popper
  - Most used/referenced
  - = $4 * \pi * D_A / (D_P)^{2,}$ where D_A is the area of district D and D_P is the perimeter of district D
  - Can be a computationally expensive calculation for congressional districts because the perimeter has many edges

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Graph Theoretical Compactness

- Not well recognized, but possible very effective
- Dube paper – link in class web site references
- Represent precincts as nodes in a graph with edges connecting nodes if the precincts are adjacent
- Demonstrated correlation with Polsby Popper
- Essential for SeaWulf calculations (since you do not need geometry on SeaWulf)

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Population Fatness

- Extends beyond pure geometry to include population
- Consistent with redistricting language that states that districts should not be bypass populations to extend to more distant populations
- Ratio of district population to the population enclosed by the bounding circle of the district

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Things to Think About

- What compactness data do you need to display?
- Is it possible to highlight the possible reasons for a compactness score
- What data do you need?
  - Geometric compactness
  - Graph compactness
  - Population fatness

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Political Fairness

- Results from gerrymandering
- Most measures look at congressional seat shares not consistent with vote shares
- Issues
  - Results might result naturally (e.g., city concentration of Democratic voters)
  - Not justiciable by the Supreme Court
  - No consistent measurement

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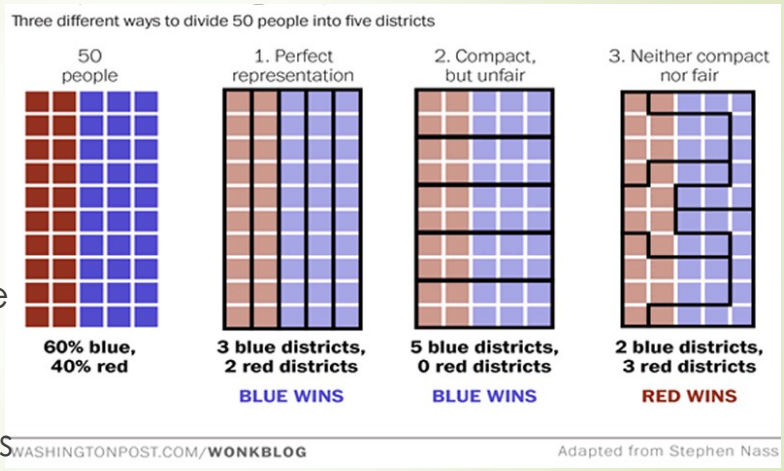
How Gerrymandering Works

- With the same statewide vote share, congressional seat share can vary widely due to districting
- Example – 50 voters, 5 districts



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Packing and Cracking

- Most proposed measures analyze the extent to which districts are
  - Packed (very large vote majority to the underrepresented party) and
  - Cracked (modest vote majority to the overrepresented party)
- Typical results show 70% - 80% in packed districts and 55% in cracked districts
- Measure of vote percentage is usually the 2-party vote, which means you subtract all the third party votes and measure the percentage of votes for the remaining data

When you get to design phase, be sure to consider data for all parties

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Efficiency Gap Measure

- Stephanopoulos & McGhee
- Aggregates packing and cracking measure into a single number
- Defines wasted votes as votes for a party in a losing election or votes for a winning party over 50%
- Measures difference between wasted votes for each party within a statewide election
- Computed as the difference between the two parties' wasted divided by the total votes cast in the election
- 0 is "good" and .5 is "bad"

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Partisan Symmetry Measures

- Measures fairness as a comparison of percentage seats won vs. percentage of statewide votes
- Example – if total congressional votes are 50/50 for Republicans/Democrats, the seats should be 50/50
- There are multiple measures of partisan fairness, but these will be optional in your project
  - Seats – to – votes curve analysis
  - Mean-median difference
  - Others

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What Data is Needed?

- Geospatial boundary data
  - Precincts
  - Existing Congressional districts
  - Incumbent precincts
  - Cities/counties
  - More
- Election results data
- More

You will use one or more data sources to measure the party preference of a precinct