How to Measure Legislative District Compactness If You Only Know it When You See it

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Society for Political Methodology, University of Wisconsin, 7/14/2017

1Paper available at j.mp/Compactness
Redistricting Defines Democracy — & Needs Fixing

Fundamental to Democracy

Control redistricting ⇝ Define basic units of representation

$100s of millions spent trying to influence the rules of the game

Litigation in almost every jurisdiction, every time

Blamed for: unfair elections, excessive partisanship, policy gridlock, partisan bias, lack of electoral responsiveness, racial bias, ...
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  - E.g., Population equality, partisan fairness, racial fairness, respect for municipal boundaries . . . **compactness**
The Discipline & Redistricting

Political science contributions to the real world:

- Partisan fairness: Invented standard (partisan symmetry) & methods
- Racial fairness: Invented methods of ecological inference (for VRA)
- Forecasting elections in new districts, for all sides
- Public service: as consultants, expert witnesses, special masters
- Measurable impact: in numerous legal cases, state laws

Political science disconnect from the real world: Compactness

Researchers: Assumed so complicated, numerous measures needed

Law: Assumed so simple, no definition needed!

Illinois Constitution: "Legislative Districts shall be compact"

Washington: "Each district shall be as compact as possible"

Iowa: "avoid drawing districts that are oddly shaped"

Supreme Court: "One need not use Justice Stewart's classic definition of obscenity—'I know it when I see it'—. . . to recognize that dramatically irregular shapes may have sufficient probative force to call for an explanation"

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    - Required in many other jurisdictions
Compactness According to the Law

The dimension is intuitive. How to estimate where a new district shape falls on this dimension? Only a consensus measure can constrain advocates.
Compactness According to the Law
A simple single compactness dimension that you know when you see
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More Compact

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- \( \leadsto \) Let’s start with existing measures by social scientists
Measure 1: Length/Width Ratio of Min Bounding Box
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Squarish districts more compact than long thin ones
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Squarish districts more compact than long thin ones

\[
\text{In both districts: } \frac{X}{Y} \approx 1.30
\]

\[
\frac{5}{1}
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Measure 1: Length/Width Ratio of Min Bounding Box
Squarish districts more compact than long thin ones

In both districts: $X/Y \approx 1.30$
Measure 2: Reock, District / Bounding Circle Areas

\[
\frac{X}{Y + X} \approx 0.3761
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Measure 2: Reock, District / Bounding Circle Areas

Circular districts are most compact
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Circular districts are most compact

In both cases, $\frac{X}{Y + X} \approx 0.37$
Measure 3: Boyce-Clark, Variation in Centroid Deviations

$\text{MAD}(r) / \bar{r} \approx 0.317/1$
Measure 3: Boyce-Clark, Variation in Centroid Deviations

All travel distances from center should be similar
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In both cases, $\text{MAD}(r)/\bar{r} \approx 0.31$
A Brief Interlude: Can you Name this Celebrity?
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Human Perception: Not Rotationally Invariant

Existing measures of compactness:
- Nearly 100 proposed
- Almost all are rotationally invariant
- Blind to what humans perceive

Which is more compact?
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- Which is more compact?
New Measure: Y-Symmetry, area of symmetric reflection
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Symmetric figures (circles, squares) are more compact
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New Measure: Y-Symmetry, area of symmetric reflection
Symmetric figures (circles, squares) are more compact

In both cases, Overlap/Original Area \( \approx 0.34 \)
New Measure 2: Number of Visually Significant Corners

Both districts have 21 significant corners.
New Measure 2: Number of Visually Significant Corners
Computer vision algorithm identifies “objects” in photos
New Measure 2: Number of Visually Significant Corners

Computer vision algorithm identifies “objects” in photos

⇒ Fewer corners is more compact
New Measure 2: Number of Visually Significant Corners

Computer vision algorithm identifies “objects” in photos

⇝ Fewer corners is more compact
New Measure 2: Number of Visually Significant Corners

Computer vision algorithm identifies “objects” in photos

 Worse corners is more compact
New Measure 2: Number of Visually Significant Corners

Computer vision algorithm identifies “objects” in photos
⇝ Fewer corners is more compact

Both districts have 21 significant corners
Which is more compact?

- Convex Hull
- Polsby-Popper
- Boyce-Clark

7 measures; 7 unique rankings

Unusual?

From 18,215 Congressional and State Legislative Districts, we found 162 trillion others (about 0.15%).

Many more inconsistencies on individual districts.
Which is more compact? Depends on the standard!

Convex Hull

Reock

Polsby-Popper

Boyce-Clark

Length/Width

X-Axis Symmetry

Significant Corners

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Convex Hull

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- Many more inconsistencies on individual districts
Spanning the Academic–Legal Divide

Recall the concept of compactness. Researchers: so complicated, numerous measures needed. Law: so simple, no definition needed. Our hypothesis: both are right. The theoretical concept: multidimensional. The legal concept: one dimensional. Which dimension? The one we know when we see. How do we know if we find it? Public officials and many other types of people: know it when they see it, see the same dimension. I.e., estimate the one dimension of legal interest; show it has: high intercoder (and intracoder) reliability, high predictive accuracy.
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How to rank districts on the same dimension?

Why Paired Comparisons is supposedly better; example with $n = 20$

Much easier: $(20^2) = 190$ pairs v $20! \approx 2$ quintillion ranks

Everyone does what they are good at:
- Respondents answer simple, concrete questions
- Researchers reconstruct the scale

Why Ranking is actually better (at least in our application)
- Humans use time-saving heuristics.

Would it take you 2 quintillion seconds to rank 20 districts?

190 paired comparisons is tedious and boring; Ranking is more intellectually engaging

Saves time:
- 1 task v 190 comparisons

Paired Comparisons can be answered on different dimensions
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Full Ranking
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- Much easier: \( \binom{20}{2} = 190 \text{ pairs} \) v \( 20! \approx 2 \text{ quintillion ranks} \)
- Everyone does what they are good at:
  - Respondents answer simple, concrete questions
  - Researchers reconstruct the scale

Why Ranking is actually better (at least in our application)

- Humans use time-saving heuristics.
  Would it take you 2 quintillion seconds to rank 20 districts?
- 190 paired comparisons is tedious and boring;
  Ranking is more intellectually engaging
- Saves time: 1 task v 190 comparisons
- Paired Comparisons can be answered on different dimensions
How to rank districts on the same dimension?
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    Ranking: all evaluations on **one dimension** of user’s choice
Intercoder Reliability of Pairs
Intercoder Reliability of Pairs

Paired Comparisons: only slightly better than chance;
Intercoder Reliability of Pairs

Paired Comparisons: only slightly better than chance; Ranking: better
Intracoder Reliability of Pairs
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Intercoder Reliability on Ranks

\[ \rho = 0.77 \]
Intercoder Reliability on Ranks

\[ \rho = 0.77 \]

\[ \rho = 0.81 \]
Intercoder Reliability on Ranks

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\[ \rho = 0.90 \]

\[ \rho = 0.92 \]
Intracoder Reliability on Ranks

\[ T_2 vs. T_1 \]

- \( \rho = 0.90 \)
- \( \rho = 0.84 \)
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Intracoder Reliability on Ranks

\[ \rho = 0.90 \]

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\[ \rho = 0.92 \]
So we can measure it. Can we model it?
So we can measure it. Can we model it?

Goal: Compactness score = \( f(\text{shape}) \)
So we can measure it. Can we model it?

Goal: Compactness score = $f(\text{shape})$

- **Training data:** Outcome variable from human rankings
So we can measure it. Can we model it?

Goal: Compactness score = $f(\text{shape})$

- **Training data:** Outcome variable from human rankings
- **Covariates:** Features of district shape
So we can measure it. Can we model it?

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- **Ensemble of predictive methods**: least squares, AdaBoosted decision trees, SVM, random forests...
Model Validation: 6-Fold Cross-validation
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Predict Test Set from 5 Training Sets
Model Validation: 6-Fold Cross-validation

Predict Test Set from 5 Training Sets

\[ \rho = 0.91 \]
Model Validation: 6-Fold Cross-validation
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ρ = 0.91
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Model Validation: Diverse Respondents
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Respondents ranging from ordinary citizens to those responsible for redistricting
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Concluding Remarks

We address: Disconnect between political science & the real world

The Theoretical Concept: multidimensional and complex
The Legal Concept: one dimensional and simple

A proposed resolution: measure the one dimension everyone sees
Calculated solely from district geometry
Very high intercoder & intracoder reliability
Very high predictive validity
Diverse people see it the same way

⇝
Continue political science tradition of contributing to a fundamental part of representative democracy

Accompanying this paper:
Measures: for 18,215 Congressional & State Legislative districts
Software to calculate compactness from any district shape

Along the way:
New perspective on 150 year consensus of ranking v paired comparisons
New directions for two venerable literatures
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