How to Measure Legislative District Compactness
If You Only Know it When You See it\textsuperscript{1}

Gary King\textsuperscript{2}

Institute for Quantitative Social Science
Harvard University

Hubert M. Blalock Memorial Lecture, University of Michigan, 7/12/2017

\textsuperscript{1}Based on joint work with Aaron Kaufman and Mayya Komisarchik
\textsuperscript{2}GaryKing.org
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

⇝

Get the ball, move the goalposts

Blamed for:

unfair elections,

excessive partisanship,

policy gridlock,

partisan bias,

lack of electoral responsiveness,

racial bias,

...

How to fix this?

Constrain redistricters via:

Population equality,

partisan fairness,

racial fairness,

respect for municipal boundaries . . .

compactness
Fundamental to Democracy
Redistricting Defines Democracy — & Needs Fixing

- Fundamental to Democracy
  - Control redistricting \(\rightsquigarrow\) Define basic units of representation

\[\text{Fundamental to Democracy}
\]
\[\text{Control redistricting } \rightsquigarrow \text{Define basic units of representation}\]
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
Redistricting Defines Democracy — & Needs Fixing

- Fundamental to Democracy
  - Control redistricting \(\implies\) Define basic units of representation
  - $100s$ of millions spent trying to influence the rules of the game
  - Litigation in almost every jurisdiction, every time
Redistricting Defines Democracy — & Needs Fixing

Fundamental to Democracy

- Control redistricting \(\leadsto\) Define basic units of representation
- \$100s of millions spent trying to influence the rules of the game
- Litigation in almost every jurisdiction, every time
- \(\leadsto\) Get the ball, move the goalposts

Blamed for:
- unfair elections,
- excessive partisanship,
- policy gridlock,
- partisan bias,
- lack of electoral responsiveness,
- racial bias,

How to fix this?

Constrain redistricters via:
- Population equality,
- partisan fairness,
- racial fairness,
- respect for municipal boundaries,
- compactness
Redistricting Defines Democracy — & Needs Fixing

**Fundamental to Democracy**
- Control redistricting $\implies$ Define basic units of representation
- $\$100s$ of millions spent trying to influence the rules of the game
- Litigation in almost every jurisdiction, every time
- $\implies$ Get the ball, move the goalposts

**Blamed for:**
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
  - ⟹ Get the ball, move the goalposts

- **Blamed for:**
  - unfair elections,
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
  - ⇔ Get the ball, move the goalposts
- **Blamed for:**
  - unfair elections, excessive partisanship,
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
  - Get the ball, move the goalposts

- Blamed for:
  - unfair elections, excessive partisanship, policy gridlock,
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
  - → Get the ball, move the goalposts

- **Blamed for:**
  - unfair elections, excessive partisanship, policy gridlock, partisan bias,
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
  - ⟷ Get the ball, move the goalposts

- **Blamed for:**
  - unfair elections, excessive partisanship, policy gridlock, partisan bias, lack of electoral responsiveness,
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
  - ⟷ Get the ball, move the goalposts

- **Blamed for:**
  - unfair elections, excessive partisanship, policy gridlock, partisan bias, lack of electoral responsiveness, racial bias,
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
  - ⇝ Get the ball, move the goalposts

- **Blamed for:**
  - unfair elections, excessive partisanship, policy gridlock, partisan bias,
  - lack of electoral responsiveness, racial bias, . . .
Fundamental to Democracy

- Control redistricting $\leadsto$ Define basic units of representation
- $100s$ of millions spent trying to influence the rules of the game
- Litigation in almost every jurisdiction, every time
- $\leadsto$ Get the ball, move the goalposts

Blamed for:

- unfair elections, excessive partisanship, policy gridlock, partisan bias, lack of electoral responsiveness, racial bias, ...

How to fix this?
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
  - ⇔ Get the ball, move the goalposts

- **Blamed for:**
  - unfair elections, excessive partisanship, policy gridlock, partisan bias,
    lack of electoral responsiveness, racial bias, …

- **How to fix this?**
  - Constrain redistricters via:
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
- ⟷ Get the ball, move the goalposts

Blamed for:
- unfair elections, excessive partisanship, policy gridlock, partisan bias,
  lack of electoral responsiveness, racial bias, . . .

How to fix this?
- Constrain redistricters via: Population equality,
Redistricting Defines Democracy — & Needs Fixing

- **Fundamental to Democracy**
  - Control redistricting $\rightsquigarrow$ Define basic units of representation
  - $100s$ of millions spent trying to influence the rules of the game
  - Litigation in almost every jurisdiction, every time
  - $\rightsquigarrow$ Get the ball, move the goalposts

- **Blamed for:**
  - unfair elections, excessive partisanship, policy gridlock, partisan bias,
    lack of electoral responsiveness, racial bias, . . .

- **How to fix this?**
  - Constrain redistricters via: Population equality, partisan fairness,
Redistricting Defines Democracy — & Needs Fixing

- **Fundamental to Democracy**
  - Control redistricting \(\leadsto\) Define basic units of representation
  - $100s$ of millions spent trying to influence the rules of the game
  - Litigation in almost every jurisdiction, every time
  - \(\leadsto\) Get the ball, move the goalposts

- **Blamed for:**
  - unfair elections, excessive partisanship, policy gridlock, partisan bias, lack of electoral responsiveness, racial bias, . . .

- **How to fix this?**
  - Constrain redistricters via: Population equality, partisan fairness, racial fairness,
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
  - → Get the ball, move the goalposts

- **Blamed for:**
  - unfair elections, excessive partisanship, policy gridlock, partisan bias,
    lack of electoral responsiveness, racial bias, ...

- **How to fix this?**
  - Constrain redistricters via: Population equality, partisan fairness, racial fairness, respect for municipal boundaries ...
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
- ⟷ Get the ball, move the goalposts

Blamed for:
- unfair elections, excessive partisanship, policy gridlock, partisan bias,
  lack of electoral responsiveness, racial bias, …

How to fix this?
- Constrain redistricters via: 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 . . . call for an explanation"
Required in many other jurisdictions
The Discipline & Redistricting

- Political science contributions to the real world
The Discipline & Redistricting

- Political science contributions to the real world
  - Partisan fairness: Invented standard (partisan symmetry) & methods
Political science contributions to the real world

- **Partisan fairness**: Invented standard (partisan symmetry) & methods
- **Racial fairness**: Invented methods of ecological inference (for VRA)
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
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
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
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
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
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!
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:
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”
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:
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”
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:
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”
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:
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 ... call for an explanation”
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** ... call for an explanation”
    - Required in many other jurisdictions
Compactness According to the Law

More

Compact

Less

The dimension is intuitive

How to estimate where a new district shape falls on this dimension?

Only a consensus quantitative measure can constrain advocates

⇝

Let's start with existing measures by social scientists
Compactness According to the Law
A simple single compactness dimension that you know when you see
Compactness According to the Law

A simple single compactness dimension that you know when you see

- More Compact
- Less Compact
Compactness According to the Law

A simple single compactness dimension that you know when you see

More Compact

Less Compact
Compactness According to the Law

A simple single compactness dimension that you know when you see

More Compact  Less Compact
Compactness According to the Law

A simple single compactness dimension that you know when you see

More Compact

Less Compact
Compactness According to the Law

A simple single compactness dimension that you know when you see

More Compact

Less Compact
Compactness According to the Law

A simple single compactness dimension that you know when you see

- More Compact
- Less Compact

- The dimension is intuitive
Compactness According to the Law

A simple single compactness dimension that you know when you see

More Compact

Less Compact

- The dimension is intuitive
- How to estimate where a new district shape falls on this dimension?
Compactness According to the Law
A simple single compactness dimension that you know when you see

The dimension is intuitive
How to estimate where a new district shape falls on this dimension?
Only a consensus quantitative measure can constrain advocates
Compactness According to the Law

A simple single compactness dimension that you know when you see

More Compact

Less Compact

- The dimension is intuitive
- How to estimate where a new district shape falls on this dimension?
- Only a consensus quantitative measure can constrain advocates
- Let’s start with existing measures by social scientists
Measure 1: Length/Width Ratio of Min Bounding Box
Measure 1: Length/Width Ratio of Min Bounding Box

Squarish districts more compact than long thin ones
Measure 1: Length/Width Ratio of Min Bounding Box

Squarish districts more compact than long thin ones

\[
\frac{X}{Y} \approx 1.30
\]
Measure 1: Length/Width Ratio of Min Bounding Box
Squarish districts more compact than long thin ones
Measure 1: Length/Width Ratio of Min Bounding Box

Squarish districts more compact than long thin ones

\[ \frac{X}{Y} \approx 1.30 \]
Measure 1: Length/Width Ratio of Min Bounding Box
Squarish districts more compact than long thin ones

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

In both cases, \( \frac{X}{Y + X} \approx 0.37 \).
Measure 2: Reock, District / Bounding Circle Areas

Circular districts are most compact
Measure 2: Reock, District / Bounding Circle Areas

Circular districts are most compact
Measure 2: Reock, District / Bounding Circle Areas

Circular districts are most compact
Measure 2: Reock, District / Bounding Circle Areas

Circular districts are most compact

\[
\frac{X}{Y + X} \approx 0.376
\]
Measure 2: Reock, District / Bounding Circle Areas
Circular districts are most compact

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

All travel distances from center should be similar
Measure 3: Boyce-Clark, Variation in Centroid Deviations

All travel distances from center should be similar
Measure 3: Boyce-Clark, Variation in Centroid Deviations

All travel distances from center should be similar

$\text{MAD}(r) \approx 0.317/24$
Measure 3: Boyce-Clark, Variation in Centroid Deviations

All travel distances from center should be similar
Measure 3: Boyce-Clark, Variation in Centroid Deviations

All travel distances from center should be similar
Measure 3: Boyce-Clark, Variation in Centroid Deviations

All travel distances from center should be similar

In both cases, $\text{MAD}(r) \approx 0.31$
A Brief Rotational Invariance Interlude:
A Brief Rotational Invariance Interlude:
Can you Name this Celebrity?
A Brief Rotational Invariance Interlude: Can you Name this Celebrity?
A Brief Rotational Invariance Interlude:
See the Frog?
A Brief Rotational Invariance Interlude:
See the Frog Horse?
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?

Measuring “you know it when you see it”: No rotational invariance
Human Perception: Not Rotationally Invariant

- Existing measures of compactness:
Human Perception: Not Rotationally Invariant

- Existing measures of compactness:
  - Nearly 100 proposed
Human Perception: Not Rotationally Invariant

- Existing measures of compactness:
  - Nearly 100 proposed
  - Almost all are rotationally invariant
Human Perception: Not Rotationally Invariant

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

- ↝ Measuring “you know it when you see it”: No rotational invariance
New Measure: Y-Symmetry, area of symmetric reflection
New Measure: Y-Symmetry, area of symmetric reflection

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

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

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

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

Symmetric figures (circles, squares) are more compact
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

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

Both districts have 21 significant corners
Which is more compact?

Depends on the standard!

Convex Hull 4 3 2 1

Polsby-Popper 4 1 2 3

Boyce-Clark 2 3 1 4

Length/Width 3 2 1 4

X-Axis Symmetry 1 4 3 2

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

13/24
Which is more compact? Depends on the standard!
Which is more compact? Depends on the standard!

Reock

1 2 3 4
Which is more compact? Depends on the standard!

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reock</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Convex Hull</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

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!

<table>
<thead>
<tr>
<th>Method</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reock</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Convex Hull</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Polsby-Popper</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
Which is more compact? Depends on the standard!

<table>
<thead>
<tr>
<th>Method</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reock</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Convex Hull</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Polsby-Popper</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Boyce-Clark</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

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!

<table>
<thead>
<tr>
<th>Method</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reock</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Convex Hull</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Polsby-Popper</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Boyce-Clark</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Length/Width</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
Which is more compact? Depends on the standard!

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reock</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Convex Hull</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Polsby-Popper</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Boyce-Clark</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Length/Width</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>X-Axis Symmetry</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
Which is more compact? Depends on the standard!

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reock</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Convex Hull</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Polsby-Popper</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Boyce-Clark</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Length/Width</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>X-Axis Symmetry</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Significant Corners</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
Which is more compact? Depends on the standard!

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reock</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Convex Hull</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Polsby-Popper</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Boyce-Clark</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Length/Width</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>X-Axis Symmetry</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Significant Corners</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

7 measures;
Which is more compact? Depends on the standard!

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reock</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Convex Hull</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Polsby-Popper</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Boyce-Clark</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Length/Width</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>X-Axis Symmetry</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Significant Corners</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

- 7 measures; 7 unique rankings

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!

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reock</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Convex Hull</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Polsby-Popper</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Boyce-Clark</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Length/Width</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>X-Axis Symmetry</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Significant Corners</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

- 7 measures; 7 unique rankings
- Unusual?
Which is more compact? Depends on the standard!

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reock</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Convex Hull</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Polsby-Popper</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Boyce-Clark</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Length/Width</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>X-Axis Symmetry</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Significant Corners</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

- 7 measures; 7 unique rankings
- **Unusual?** From 18,215 Congressional and State Legislative Districts,
Which is more compact? Depends on the standard!

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reock</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Convex Hull</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Polsby-Popper</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Boyce-Clark</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Length/Width</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>X-Axis Symmetry</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Significant Corners</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

- 7 measures; 7 unique rankings
- **Unusual?** From 18,215 Congressional and State Legislative Districts, we found 162 trillion others (about 0.15%)
Which is more compact? Depends on the standard!

<table>
<thead>
<tr>
<th>Measure</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reock</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Convex Hull</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Polsby-Popper</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Boyce-Clark</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Length/Width</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>X-Axis Symmetry</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Significant Corners</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

- 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
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: complex and multidimensional.

The Legal Concept: simple and one dimensional.

Which dimension? The one we know when we see.

How do 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
Spanning the Academic–Legal Divide

- (Recall) The concept of compactness
Spanning the Academic–Legal Divide

- (Recall) The concept of compactness
  - Researchers: So complicated, numerous measures needed
Spanning the Academic–Legal Divide

(Recall) The concept of compactness
- Researchers: So complicated, numerous measures needed
- Law: So simple, no definition needed
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
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: complex and multidimensional
(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: complex and multidimensional
- The Legal Concept: simple and one dimensional
(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: complex and multidimensional
- The Legal Concept: simple and one dimensional
- Which dimension? The one we know when we see
(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: complex and multidimensional
- The Legal Concept: simple and one dimensional
- Which dimension? The one we know when we see

How do we find it?
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: complex and multidimensional
  - The Legal Concept: simple and one dimensional
  - Which dimension? The one we know when we see
- How do we find it?
  - Public officials and many other types of people:
(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:** complex and multidimensional
- **The Legal Concept:** simple and one dimensional
- **Which dimension?** The one we know when we see

**How do we find it?**

- Public officials and many other types of people:
  - Know it when they see it,
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: complex and multidimensional
  - The Legal Concept: simple and one dimensional
  - Which dimension? The one we know when we see

- **How do we find it?**
  - Public officials and many other types of people:
    - Know it when they see it,
    - See the same dimension
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: complex and multidimensional
  - The Legal Concept: simple and one dimensional
  - Which dimension? The one we know when we see
- How do 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:
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: complex and multidimensional
  - The Legal Concept: simple and one dimensional
  - Which dimension? The one we know when we see
- How do 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
(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: complex and multidimensional
- The Legal Concept: simple and one dimensional
- Which dimension? The one we know when we see

How do 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
How to rank districts on the same dimension?

Why Paired Comparisons is supposedly better

Everyone does what they are good at:

Respondents answer simple, concrete questions
Researchers reconstruct the scale

Much easier: \( \binom{20}{2} = 190 \) pairs v \( 20! \approx 2 \) quintillion ranks

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
Ranking: users choose one dimension for all evaluations
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

Paired Comparisons

Why Paired Comparisons is supposedly better

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

Much easier:

\[ \binom{20}{2} = 190 \text{ pairs} \approx 2 \text{ quintillion ranks} \]

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
- Ranking: users choose one dimension for all evaluations
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

Paired Comparisons

Utterly fails on inter- and intra-coder reliability
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

Full Ranking
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

Full Ranking — on line
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

Full Ranking — on line

We show: very high reliability
How to rank districts on the same dimension?

**Paired Comparisons** (Fechner 1860; Thurstone 1912) v **Ranking** (very old, rarely used)

- Why Paired Comparisons is **supposedly** better

  - Respondents answer simple, concrete questions
  - Researchers reconstruct the scale

  Much easier: \( 20^2 = 190 \text{ pairs} \approx 2 \text{ quintillion ranks} \)

- 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
  - Ranking: users choose one dimension for all evaluations
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

- Why Paired Comparisons is supposedly better
  - Everyone does what they are good at:
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

- Why Paired Comparisons is supposedly better
  - Everyone does what they are good at:
    - Respondents answer simple, concrete questions
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

- Why Paired Comparisons is supposedly better
  - 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
  - Ranking: users choose one dimension for all evaluations
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

- Why Paired Comparisons is supposedly better
  - Everyone does what they are good at:
    - Respondents answer simple, concrete questions
    - Researchers reconstruct the scale
  - Much easier: \( \binom{20}{2} = 190 \) pairs v 20! \( \approx \) 2 quintillion ranks
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

Why Paired Comparisons is supposedly better

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

- Much easier: \( \binom{20}{2} = 190 \) pairs v \( 20! \approx 2 \text{ quintillion} \) ranks

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
- Ranking: users choose one dimension for all evaluations
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

- Why Paired Comparisons is supposedly better
  - Everyone does what they are good at:
    - Respondents answer simple, concrete questions
    - Researchers reconstruct the scale
  - Much easier: \( \binom{20}{2} = 190 \) pairs v \( 20! \approx 2 \) quintillion ranks

- Why Ranking is actually better (at least in our application)
  - Humans use time-saving heuristics.
How to rank districts on the same dimension?

**Paired Comparisons** (Fechner 1860; Thurstone 1912) v **Ranking** (very old, rarely used)

- **Why Paired Comparisons is supposedly better**
  - Everyone does what they are good at:
    - Respondents answer simple, concrete questions
    - Researchers reconstruct the scale
  - Much easier: \( \binom{20}{2} = 190 \text{ pairs} \) v \( 20! \approx 2 \text{ quintillion ranks} \)

- **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?
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

- Why Paired Comparisons is supposedly better
  - Everyone does what they are good at:
    - Respondents answer simple, concrete questions
    - Researchers reconstruct the scale
  - Much easier: \( \binom{20}{2} = 190 \) pairs v \( 20! \approx 2 \) quintillion ranks

- 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;
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

- Why Paired Comparisons is supposedly better
  - Everyone does what they are good at:
    - Respondents answer simple, concrete questions
    - Researchers reconstruct the scale
  - Much easier: \( \binom{20}{2} = 190 \) pairs v \( 20! \approx 2 \text{ quintillion ranks} \)

- 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
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

- Why Paired Comparisons is supposedly better
  - Everyone does what they are good at:
    - Respondents answer simple, concrete questions
    - Researchers reconstruct the scale
  - Much easier: \( \binom{20}{2} = 190 \) pairs v \( 20! \approx 2 \text{ quintillion} \) ranks

- 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
How to rank districts on the same dimension?

Paired Comparisons (Fechner 1860; Thurstone 1912) v Ranking (very old, rarely used)

- Why Paired Comparisons is *supposedly* better
  - Everyone does what they are good at:
    - Respondents answer simple, concrete questions
    - Researchers reconstruct the scale
  - Much easier: \( \binom{20}{2} = 190 \text{ pairs} \) v \( 20! \approx 2 \text{ quintillion ranks} \)

- 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?

**Paired Comparisons** (Fechner 1860; Thurstone 1912) v **Ranking** (very old, rarely used)

- **Why Paired Comparisons is supposedly better**
  - Everyone does what they are good at:
    - Respondents answer simple, concrete questions
    - Researchers reconstruct the scale
  - Much easier: \( \binom{20}{2} = 190 \text{ pairs v } 20! \approx 2 \text{ quintillion ranks} \)

- **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
    Ranking: users choose one dimension for all evaluations
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
Intracoder Reliability of Pairs

Paired Comparisons: better than chance;
Intracoder Reliability of Pairs

Paired Comparisons: better than chance; Ranking: much better
Intercoder Reliability on Ranks

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

\[ \rho = 0.77 \]

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

\[ \rho = 0.77 \]

\[ \rho = 0.70 \]

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

\[ \rho = 0.77 \]

\[ \rho = 0.70 \]

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

\[ \rho = .90 \]
Intracoder Reliability on Ranks

\[ \rho = 0.90 \]

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

\[ \rho = 0.90 \]

\[ \rho = 0.84 \]

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

\[ \rho = 0.90 \]

\[ \rho = 0.84 \]

\[ \rho = 0.92 \]

Random

Ranking

Intracoder Correlation

-0.5 0.0 0.5 1.0
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(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?

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

- **Training data:** Outcome variable from human rankings
- **Covariates.** Features of district shape
  - **Existing:** Reock, Polsby-Popper, Convex Hull, Length/Width, Boyce-Clark...
So we can measure it. Can we model it?

Goal: Compactness score = f(shape)

- **Training data:** Outcome variable from human rankings
- **Covariates. Features of district shape**
  - **Existing:** Reock, Polsby-Popper, Convex Hull, Length/Width, Boyce-Clark...
  - **Geometric:** Perimeter, area, vertices, polygons, vertex variance, edge length variance...
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**
  - **Existing:** Reock, Polsby-Popper, Convex Hull, Length/Width, Boyce-Clark...
  - **Geometric:** Perimeter, area, vertices, polygons, vertex variance, edge length variance...
  - **New:** X-axis symmetry, Y-axis symmetry, Significant Corners...
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**
  - **Existing:** Reock, Polsby-Popper, Convex Hull, Length/Width, Boyce-Clark...
  - **Geometric:** Perimeter, area, vertices, polygons, vertex variance, edge length variance...
  - **New:** X-axis symmetry, Y-axis symmetry, Significant Corners...
- **Ensemble of predictive methods:** least squares, AdaBoosted decision trees, SVM, random forests...
Model Validation: 6-Fold Cross-validation
Model Validation: 6-Fold Cross-validation

Predict Test Set from 5 Training Sets
Model Validation: 6-Fold Cross-validation
Predict Test Set from 5 Training Sets

ρ = 0.91
Model Validation: 6-Fold Cross-validation

Predict Test Set from 5 Training Sets
Model Validation: Diverse Respondents
Model Validation: Diverse Respondents

Respondents ranging from ordinary citizens to those responsible for redistricting
Model Validation: Diverse Respondents

Respondents ranging from ordinary citizens to those responsible for redistricting
Model Validation: Diverse Respondents

Respondents ranging from ordinary citizens to those responsible for redistricting
Model Validation: Diverse Respondents
Respondents ranging from ordinary citizens to those responsible for redistricting
Model Validation: Diverse Respondents

Respondents ranging from ordinary citizens to those responsible for redistricting
Model Validation: Diverse Respondents

Respondents ranging from ordinary citizens to those responsible for redistricting.
Model Validation: Diverse Respondents
Respondents ranging from ordinary citizens to those responsible for redistricting
Model Validation: Diverse Respondents

Respondents ranging from ordinary citizens to those responsible for redistricting.
Model Validation: Diverse Respondents
Respondents ranging from ordinary citizens to those responsible for redistricting
Model Validation: Diverse Respondents

Respondents ranging from ordinary citizens to those responsible for redistricting
Model Validation: Diverse Respondents

Respondents ranging from ordinary citizens to those responsible for redistricting
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
Concluding Remarks

- We address: Disconnect between political science & the real world
Concluding Remarks

- **We address:** Disconnect between political science & the real world
  - The Theoretical Concept: multidimensional and complex
Concluding Remarks

- **We address:** Disconnect between political science & the real world
  - The Theoretical Concept: multidimensional and complex
  - The Legal Concept: one dimensional and simple

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
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
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 vs paired comparisons
- New directions for two venerable literatures
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

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
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

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
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
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
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
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
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
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:**
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
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
  - \( \rightsquigarrow \) 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
For more information

AaronRKaufman.com

GaryKing.org

j.mp/MayyaKomisarchik

Paper, data, software, slides: j.mp/Compactness