Timing:
9:00-10:30
11:00-12:30

Experiments in Computational Social Choice

(Using Maps of Elections)

Niclas Boehmer

Piotr Faliszewski

Stanisław Szufa

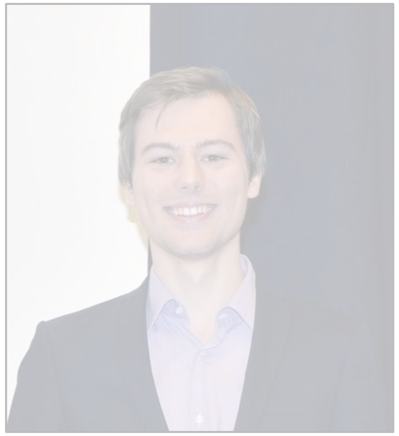
Tomasz Wąs

Timing:
9:00-10:30
11:00-12:30

Using Maps of Elections

Experiments in Computational Social Choice

Niclas Boehmer

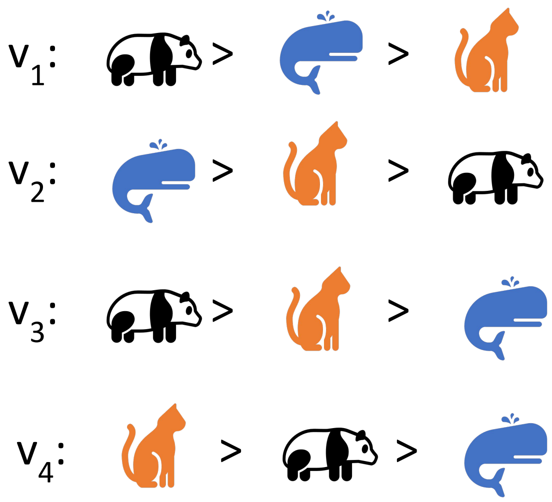


Piotr Faliszewski

Stanisław Szufa

Tomasz Wąs

An Election

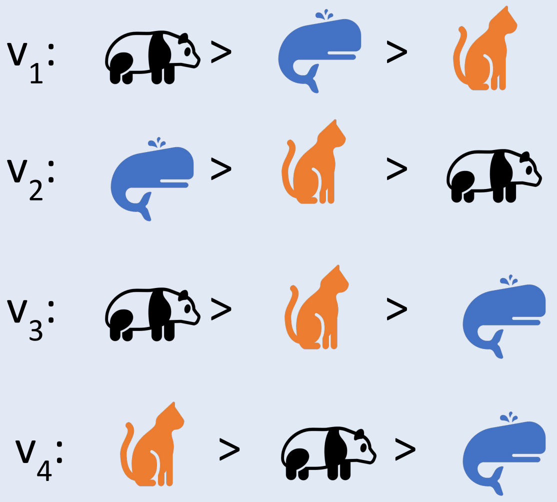


$$E = (C,V)$$

$C = \{$  $\}$

$$V = (v_1, v_2, v_3, v_4)$$

An Election

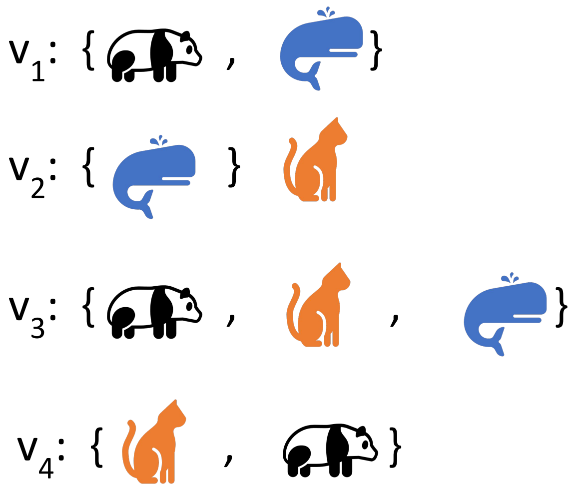


$$E = (C,V)$$

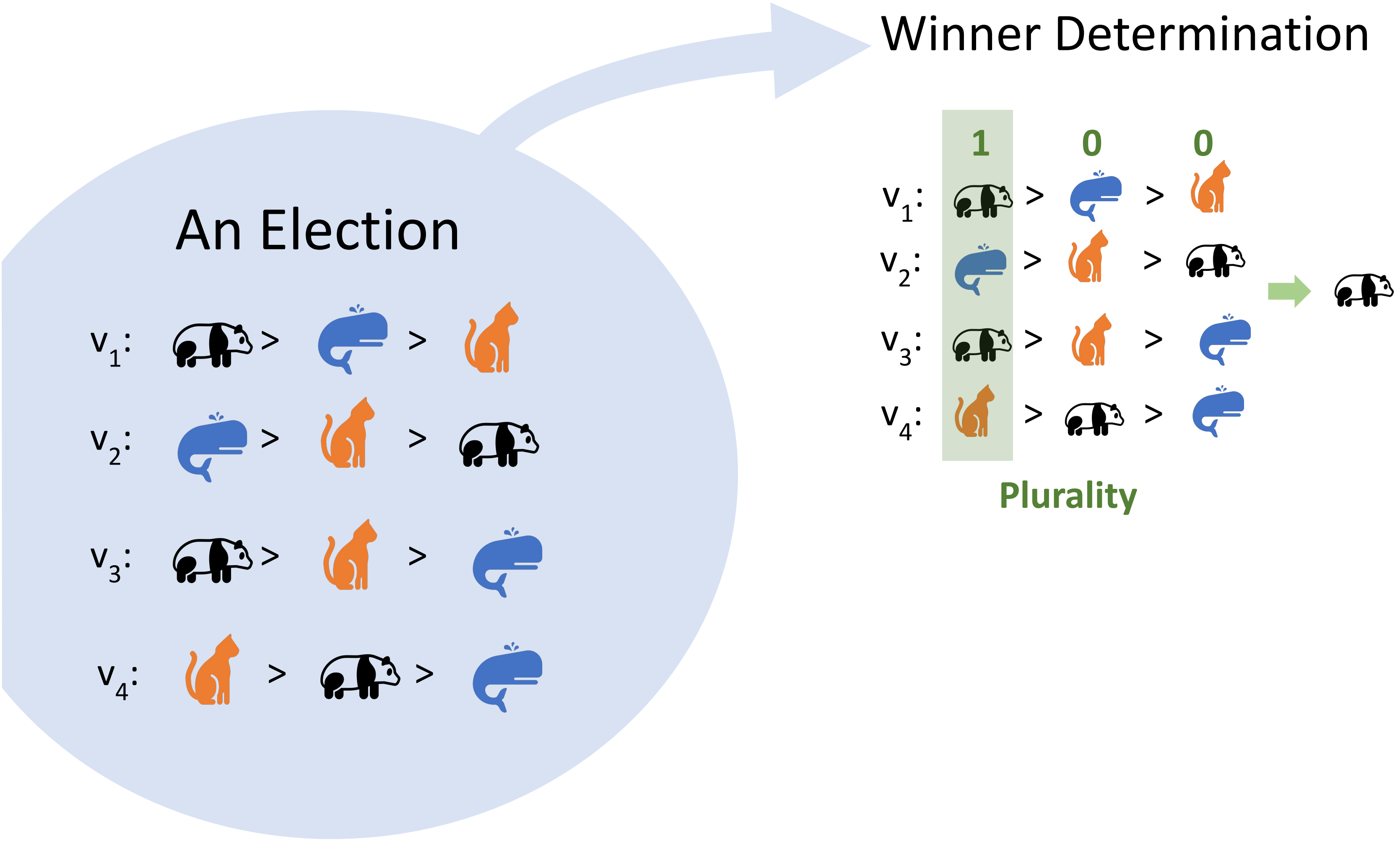
$C = \{$  $\}$

$$V = (v_1, v_2, v_3, v_4)$$

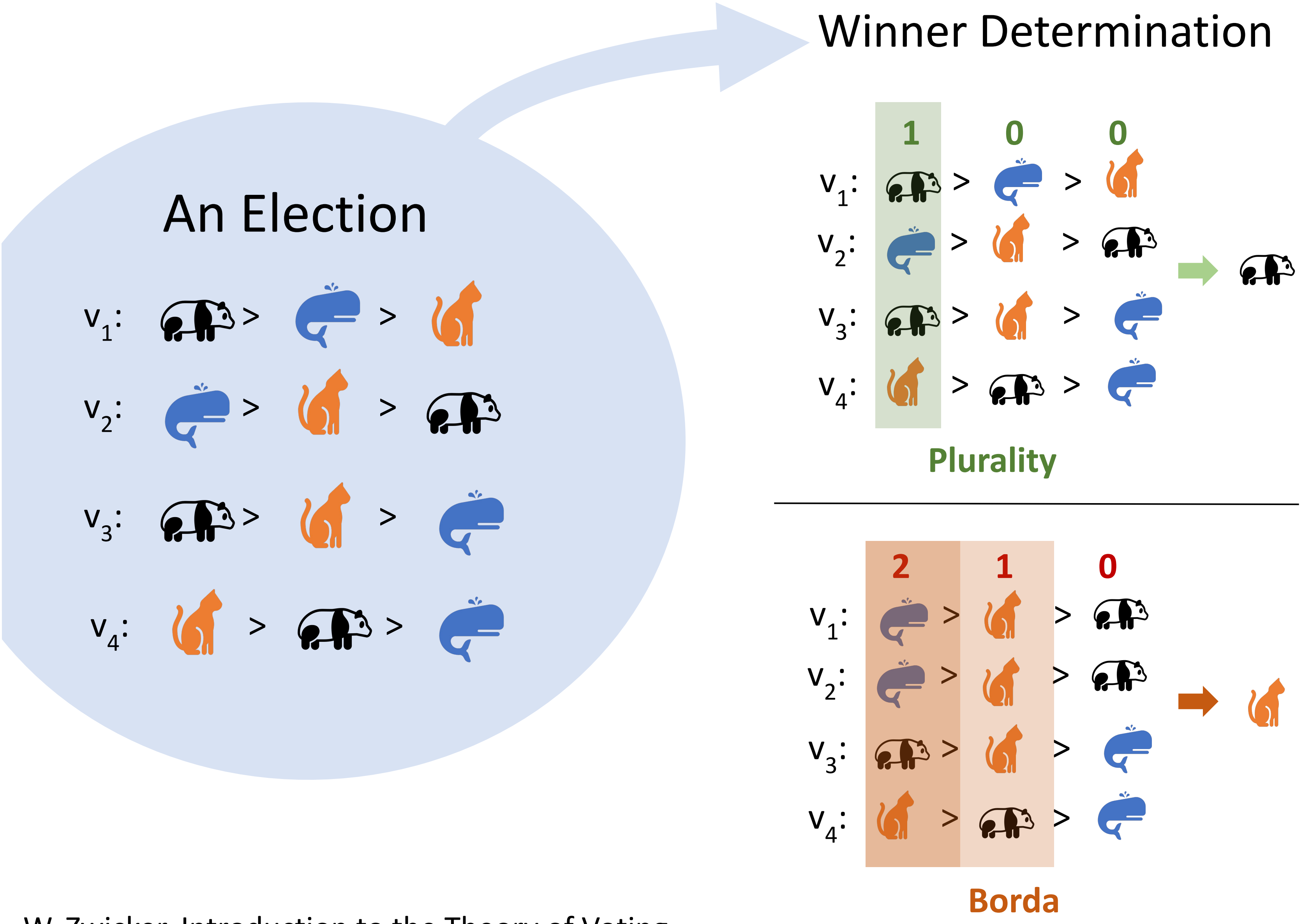
Also an election



We mostly focus on the ordinal setting, but approvals will come!



W. Zwicker, Introduction to the Theory of Voting.
Handbook of Computational Social Choice 2016



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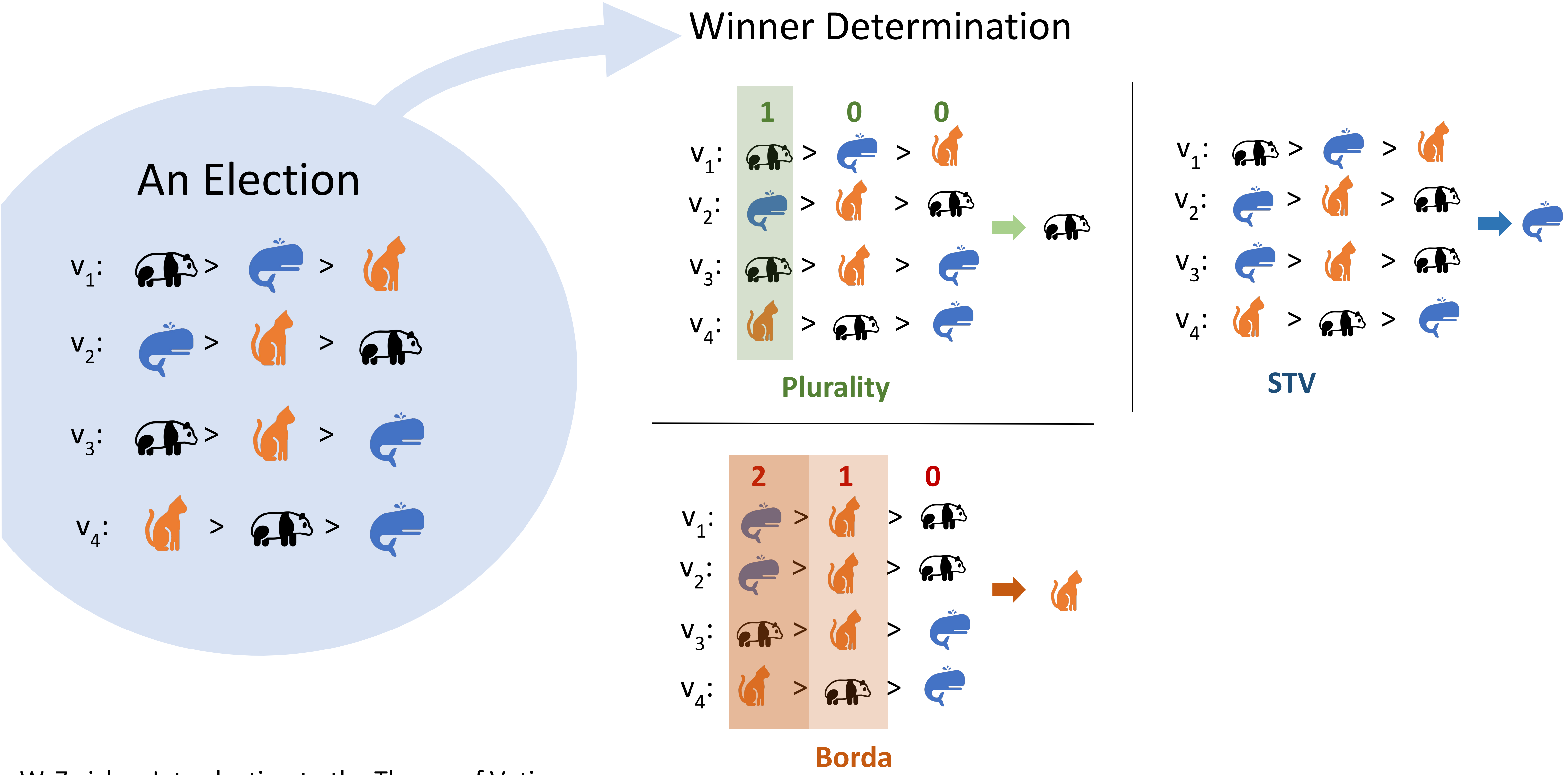

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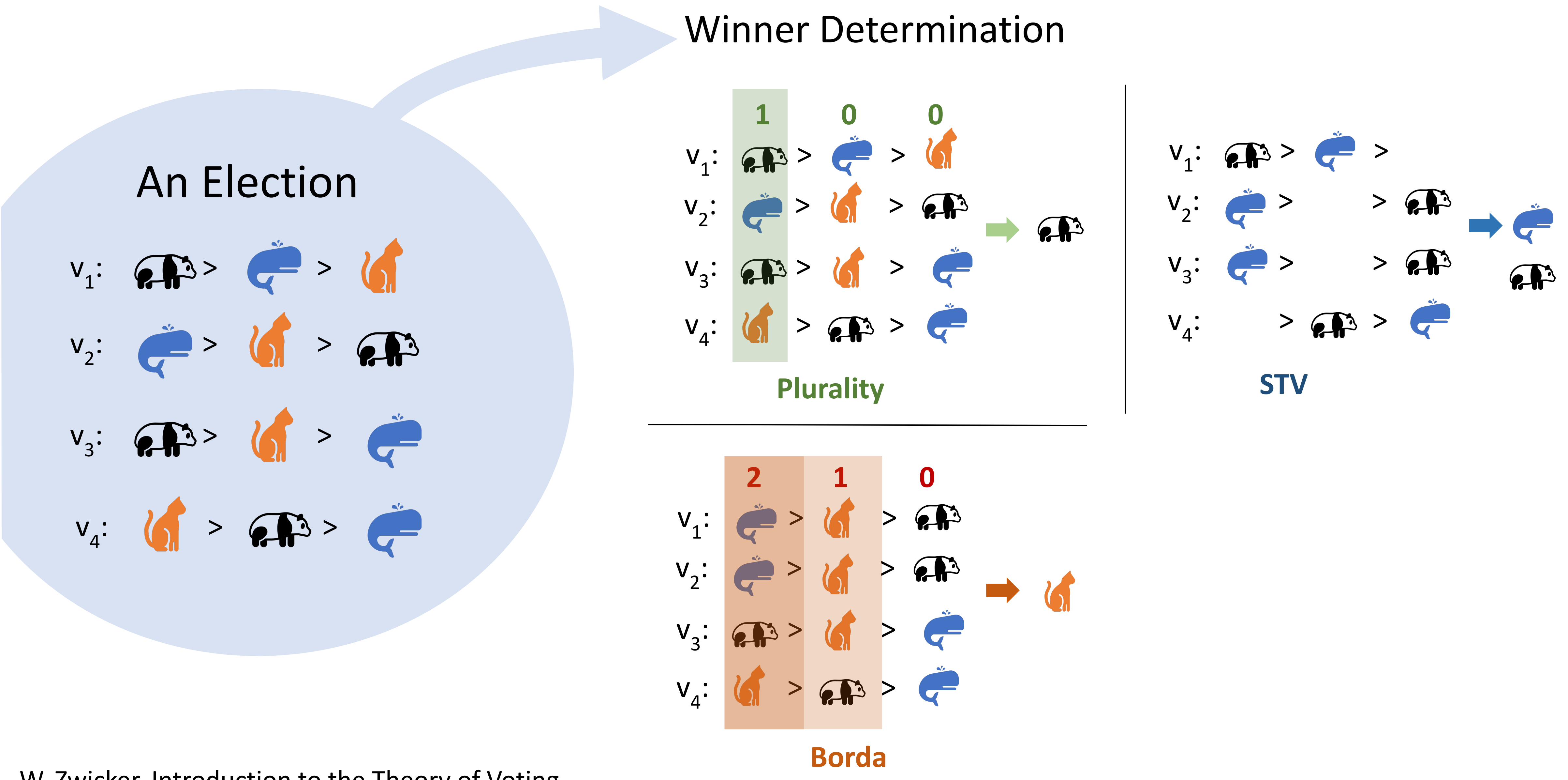

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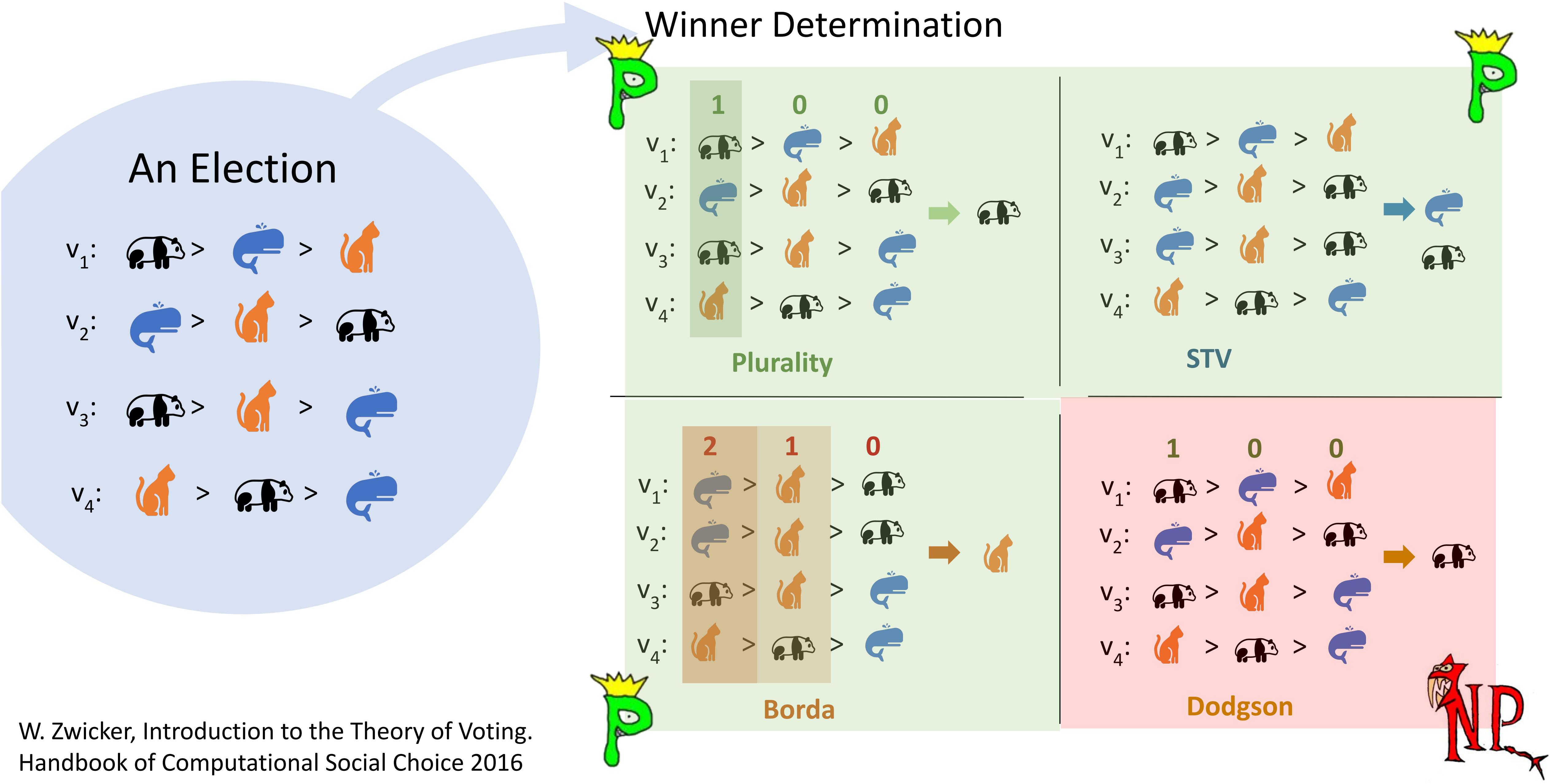
Winner Determination



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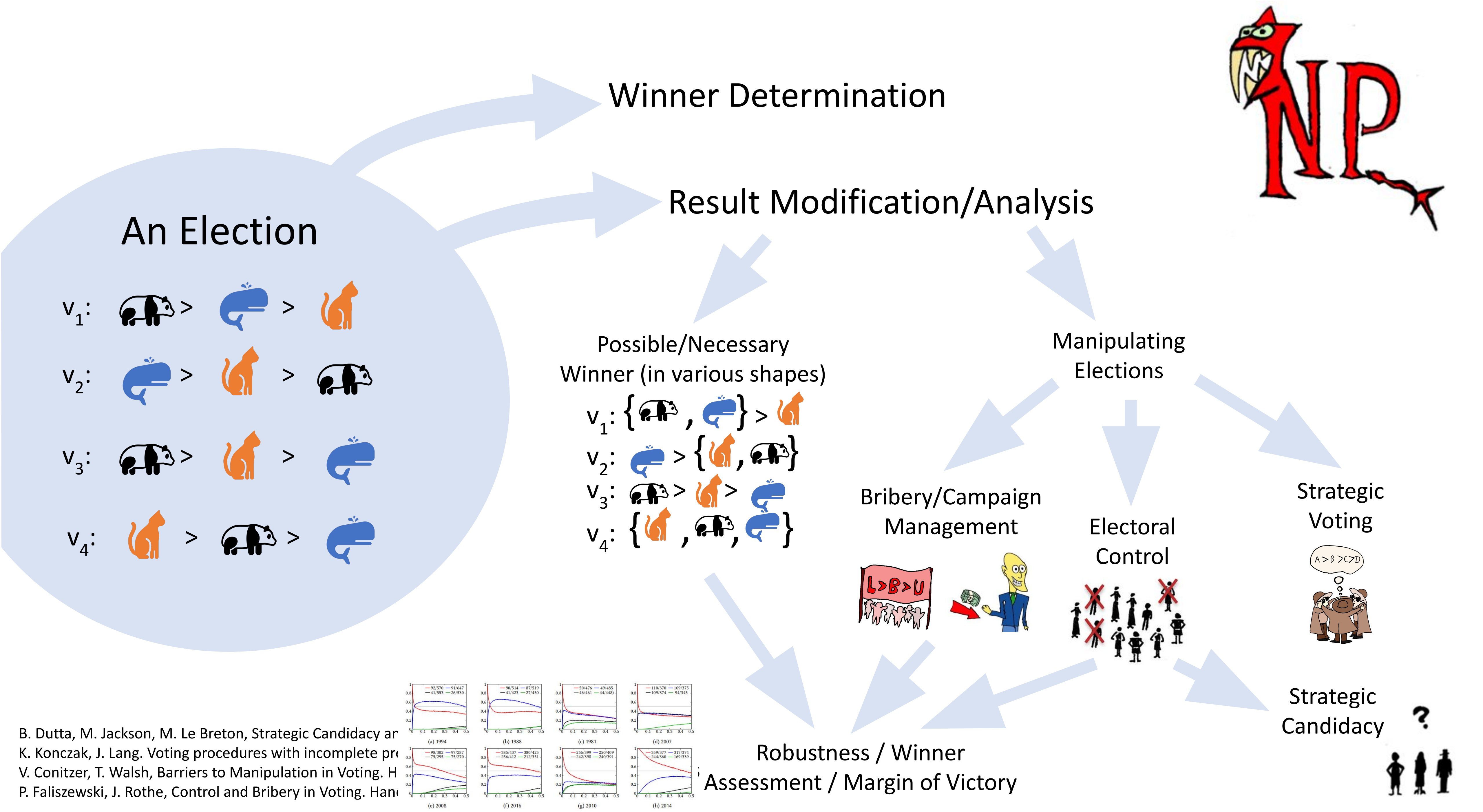
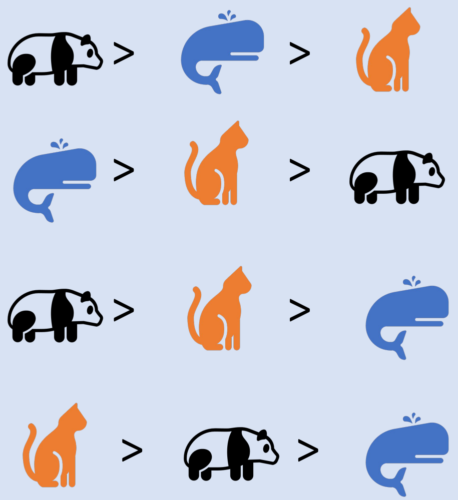


B. Dutta, M. Jackson, M. Le Breton, Strategic Candidacy ar
K. Konczak, J. Lang. Voting procedures with incomplete pr
V. Conitzer, T. Walsh, Barriers to Manipulation in Voting. H
P. Faliszewski, J. Rothe, Control and Bribery in Voting. Han

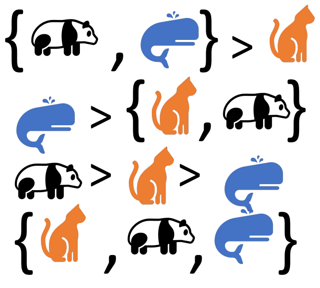
Winner Determination

Result Modification/Analysis

An Election

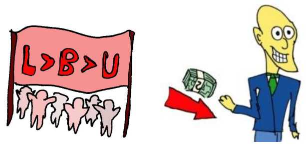


Possible/Necessary Winner (in various shapes)



Manipulating Elections

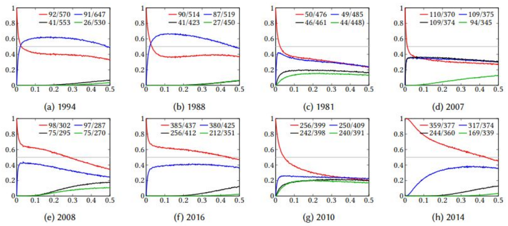
Bribery/Campaign Management



Electoral Control

Strategic Voting

Strategic Candidacy



Robustness / Winner Assessment / Margin of Victory

B. Dutta, M. Jackson, M. Le Breton, Strategic Candidacy ar
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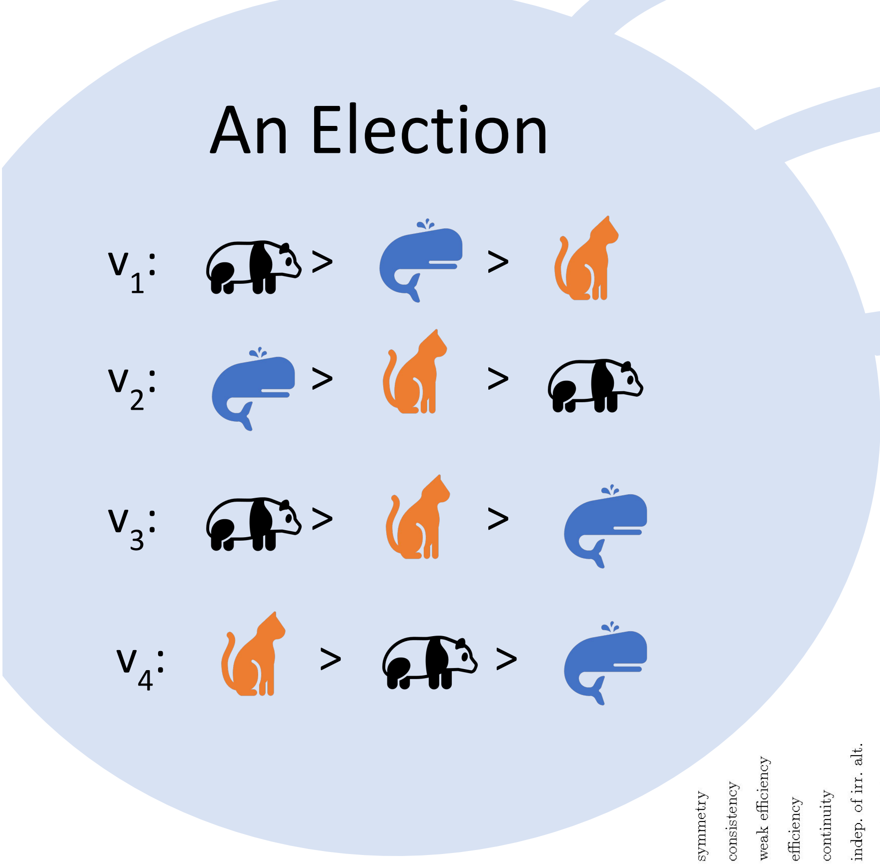


Winner Determination

Rule	Complexity	JR/PJR/EJR	PR	SMWPI	SMWOPI	Com. Mon.
AV	P [a]	No [d]	No [k]	Str. [Thm. 3.4]	Str. [Thm. 3.6]	Yes
SAV	P [a]	No [d]	No [k]	Str. [Thm. 3.4]	Str. [Thm. 3.6]	Yes
CC	NP-comp. [b]	JR [d]	Yes [g, k]	Str. [Thm. 3.4]	Wk. [Thm. 3.5]	No [Ex. 4.2]
Monroe	NP-comp. [b]	JR [d,e]	Yes [k]	No [Ex. 3.10]	Wk. [Thm. 3.9]	No [Ex. 4.2]
PAV	NP-comp. [a]	EJR [d]	No [h]	Str. [Thm. 3.4]	Wk. [Thm. 3.5]	No [j]
max-Phragmén	NP-comp. [c]	PJR [c,f]	Yes [c]	Wk. [i, Thm. 3.12]	Wk. [i, Thm. 3.12]	No [i]

[a] Results by Aziz et al. [4] and Skowron et al. [31].
[b] Results by Procaccia et al. [28].
[c] Results by Brill et al. [7].
[d] Results by Aziz et al. [2].
[e] Monroe satisfies PJR if k divides n [29].
[f] max-Phragmén satisfies PJR when combined with certain tie-breaking rule [7].
[g] CC satisfies PR if ties are broken always in favour of the candidates subsets that provide PR.
[h] Results by Sánchez-Fernández et al. [29].
[i] Results by Janson [15], Mora and Oliver [21], and Phragmén [26].
[j] Results by Thiele [35].
[k] Results by Sánchez-Fernández and Fisteus [30].

Table 1: Properties of approval-based multi-winner voting rules

Result Modification/Analysis

Comparison of preferential electoral systems [hide]

System	Monotonic	Condorcet winner	Majority	Condorcet loser	Majority loser	Mutual majority	Smith	ISDA	LIIA	Independence of clones	Reversal symmetry	Participation, consistency	Later-no-harm	Later-no-help	Polynomial time	Resolvability
Schulze	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	Yes	Yes
Ranked pairs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes
Tideman's Alternative	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	Yes	Yes
Kemeny–Young	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	Yes
Copeland	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes	No
Nanson	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	No	No	No	Yes	Yes
Black	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	No	No	No	Yes	Yes
Instant-runoff voting	No	No	Yes	Yes	Yes	Yes	No	No	No	Yes	No	No	Yes	Yes	Yes	Yes
Smith/IRV	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	Yes	Yes
Borda	Yes	No	No	Yes	Yes	No	No	No	No	No	Yes	Yes	No	Yes	Yes	Yes
Baldwin	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes	Yes
Bucklin	Yes	No	Yes	No	Yes	Yes	No	No	No	No	No	No	No	Yes	Yes	Yes
Plurality	Yes	No	Yes	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
Contingent voting	No	No	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes
Coombs[32]	No	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	Yes	Yes
Mini-Max[specify]	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes
Anti-plurality[32]	Yes	No	No	No	Yes	No	No	No	No	No	No	Yes	No	No	Yes	Yes
Sri Lankan contingent voting	No	No	Yes	No	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes
Supplementary voting	No	No	Yes	No	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes
Dodgson[32]	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	Yes

Normative Properties

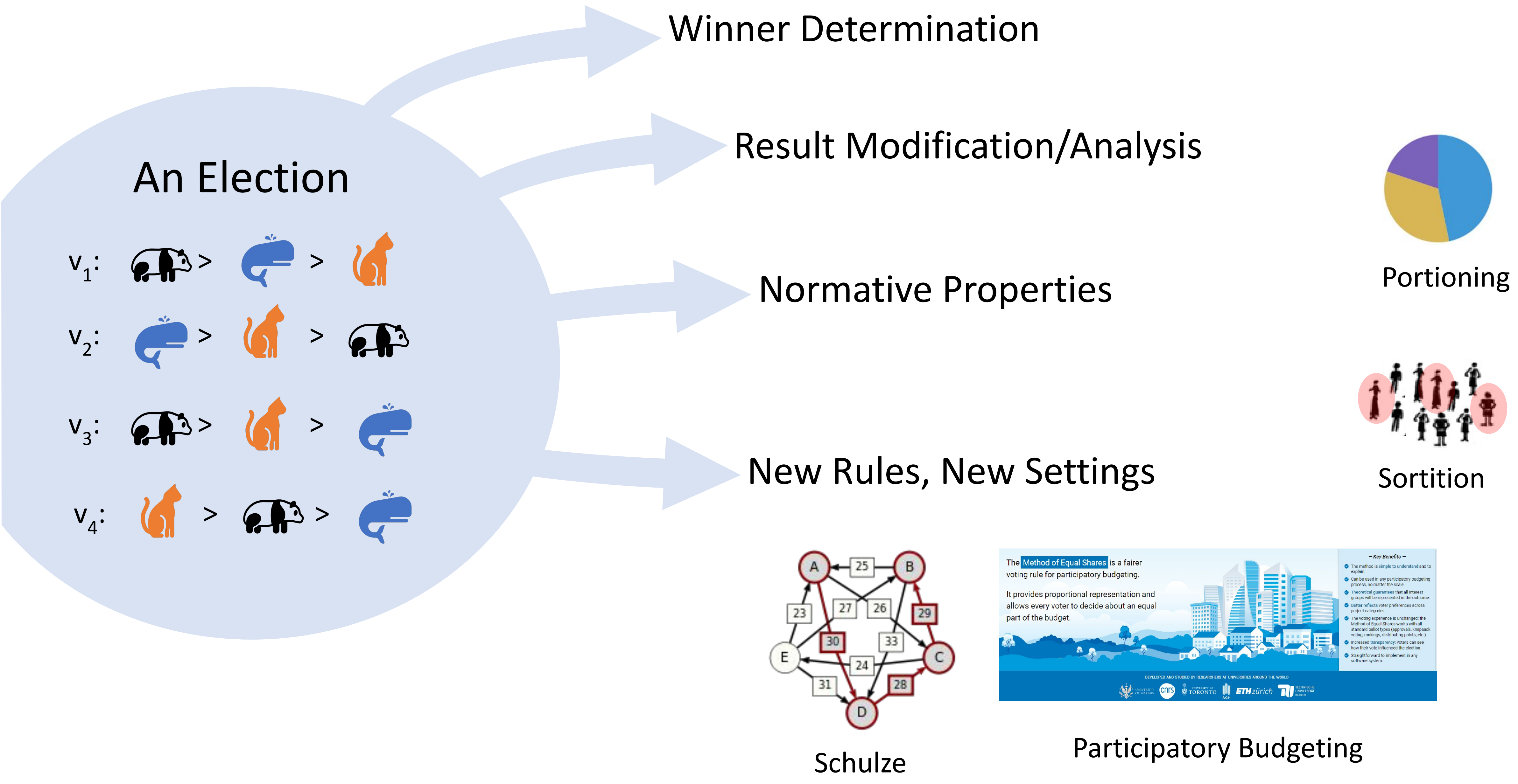
- Monotonicity
- Homogeneity
- Consistency
- Condorecet Consistency
- (Something) Justified Representation
- Core
- Priceability

	symmetry	consistency	weak efficiency	efficiency	continuity	indep. of irr. alt.	monotonicity	D'Hondt prop.	disjoint equality	disjoint diversity
ABC counting rules	+	+	+	+	+					
Thiele Methods	+	+	+	+	+	+				
Dissatisfaction counting rules	+	+	+	+	+		+			
Multi-winner Approval Voting (AV)	+	+	+	+	+	+	+		+	
Proportional Approval Voting (PAV)	+	+	+	+	+	+		+		
Approval Chamberlin–Courant (CC)	+	+	+	+	+	+				+
Constant Threshold Methods	+	+	+	+	+	+				
Satisfaction Approval Voting	+	+	+	+	+					
Sequential Thiele Methods	+		+	+	+	+				
Reverse-sequential Thiele Methods	+		+	+	+					
Sequential PAV	+		+	+	+	+		+		
Reverse-Sequential PAV	+		+	+	+			+		

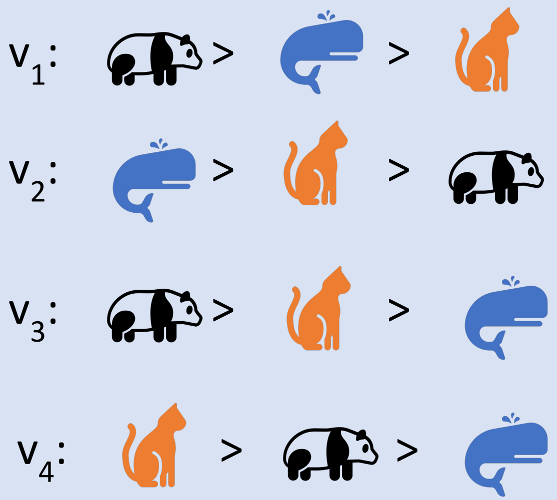
	M	PO	IAWP	CC	IALP	ICLP
Lexicographic rule	✓	✓	✓			
Condorcet's practical method	✓	✓($m=3$)	✓		✓($m \leq 4$)	
Fallback Bargaining	✓	✓				
Majoritarian Compromise	✓	✓	✓		✓	
Obata and Ishii's method	✓	✓	✓			
Contreras, Hinojosa and Mármol's method	✓	✓	✓			
Geometric rule	✓	✓				

M: Monotonicity, PO: Pareto-optimality, IAWP: Immunity to the absolute winner paradox, CC: Condorcet consistency, IALP: Immunity to the absolute loser paradox, ICLP: Immunity to the Condorcet loser paradox.

	Pareto efficiency	committee monoton.	support monot. with / without add. voters	consist.	inclusion-strategypr.	comput. complexity
AV	strong	✓	✓ / ✓	✓	✓	P
CC	weak	×	✓ / cand	✓	?	NP-hard
PAV	strong	×	✓ / cand	✓	×	NP-hard
seq-PAV	×	✓	≥cand / cand	×	×	P
seq-CC	×	✓	? / ?	×	×	P
rev-seq-PAV	×	✓	≥cand / cand	×	×	P
Monroe	×	×	× / cand	×	×	NP-hard
Greedy Monroe	×	×	× / ?	×	×	P
seq-Phragmén	×	✓	cand / cand	×	×	P
lexmin-Phragmén	×	×	cand / cand	×	?	NP-hard
Rule X	?	×	× / ?	×	×	P
MAV	weak	×	? / ?	×	×	NP-hard
SAV	strong	✓	✓ / ✓	✓	×	P


An Election
v1: > >
v2: > >
v3: > >
v4: > >
Winner Determination
Result Modification/Analysis
Normative Properties
New Rules, New Settings
Portioning
Sortition
The Method of Equal Shares is a fairer voting rule for participatory budgeting.
It provides proportional representation and allows every voter to decide about an equal part of the budget.
– Key Benefits –
Schulze
Participatory Budgeting

An Election

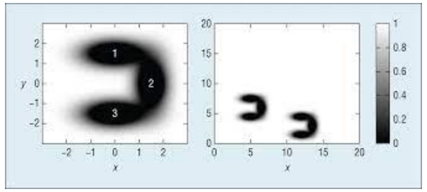


Winner Determination

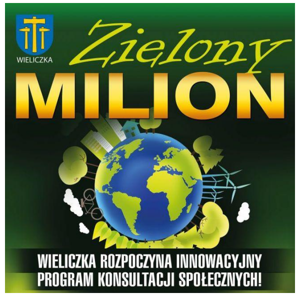
Result Modification/Analysis

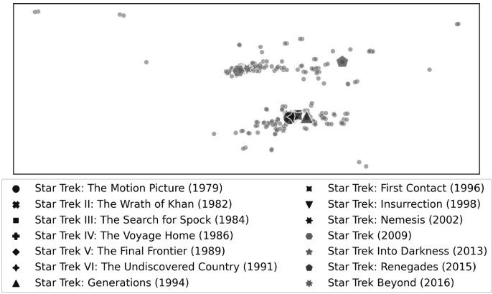
Normative Properties

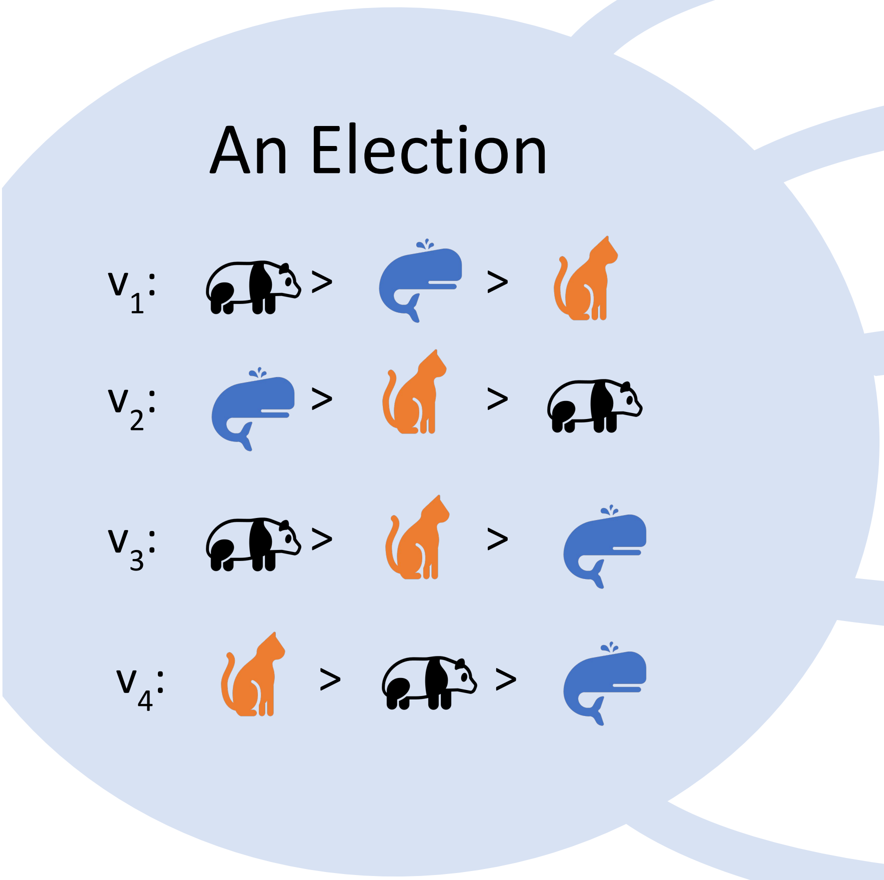
New Rules, New Settings



Applications







Largely studied theoretically

We want more experiments!

N. Mattei, T. Walsh, PrefLib: A Library For Preferences, ADT 2013

Benefits of Experiments

- More complex settings
- More precise results
  - Exact running time vs asymptotic running time
- Observe actual phenomena instead of merely predicting their possibility
  - Condorcet winners often exist
  - No-show paradox is/is-not a problem
  - Voting rules do/do-not give very different results

Problems with Experiments

- They don't generalize
- May be misleading
- Some insights are impossible to get experimentally
- You never really know…

We want more experiments!

Data!

Real-Life Data

- Preflib
- Pabulib
- Others…

Synthetic Data

- Impartial Culture
- Urn, Mallows
- Euclidean, and more

N. Mattei, T. Walsh, PrefLib: A Library For Preferences, ADT 2013

We want more experiments!

Real-Life Data

- Preflib
- Pabulib
- Others…

Real data is real

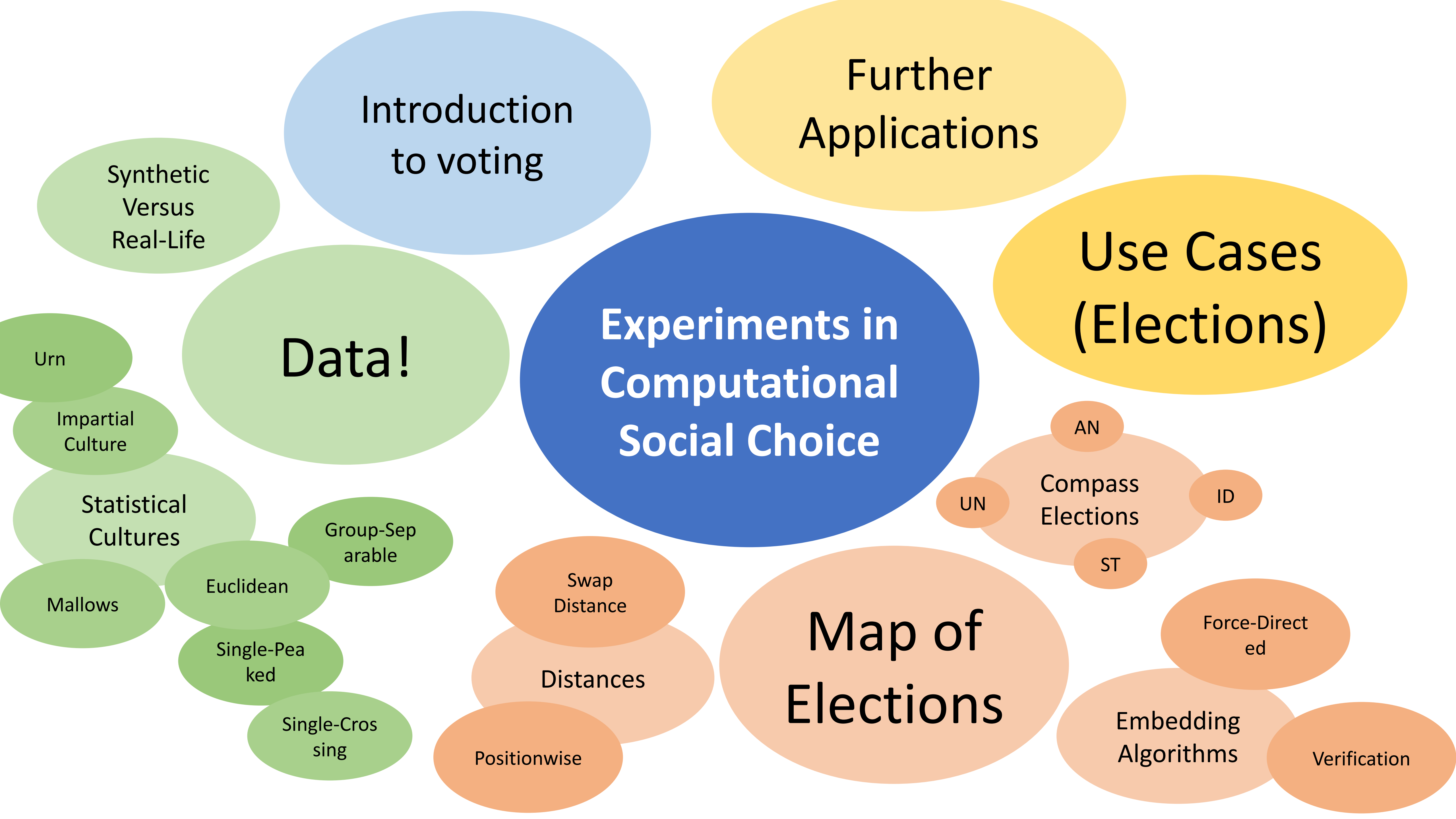
- Fixed, hard to control number of candidates/voters
- Collected under specific circumstances
- Often incomplete
- But it's real!

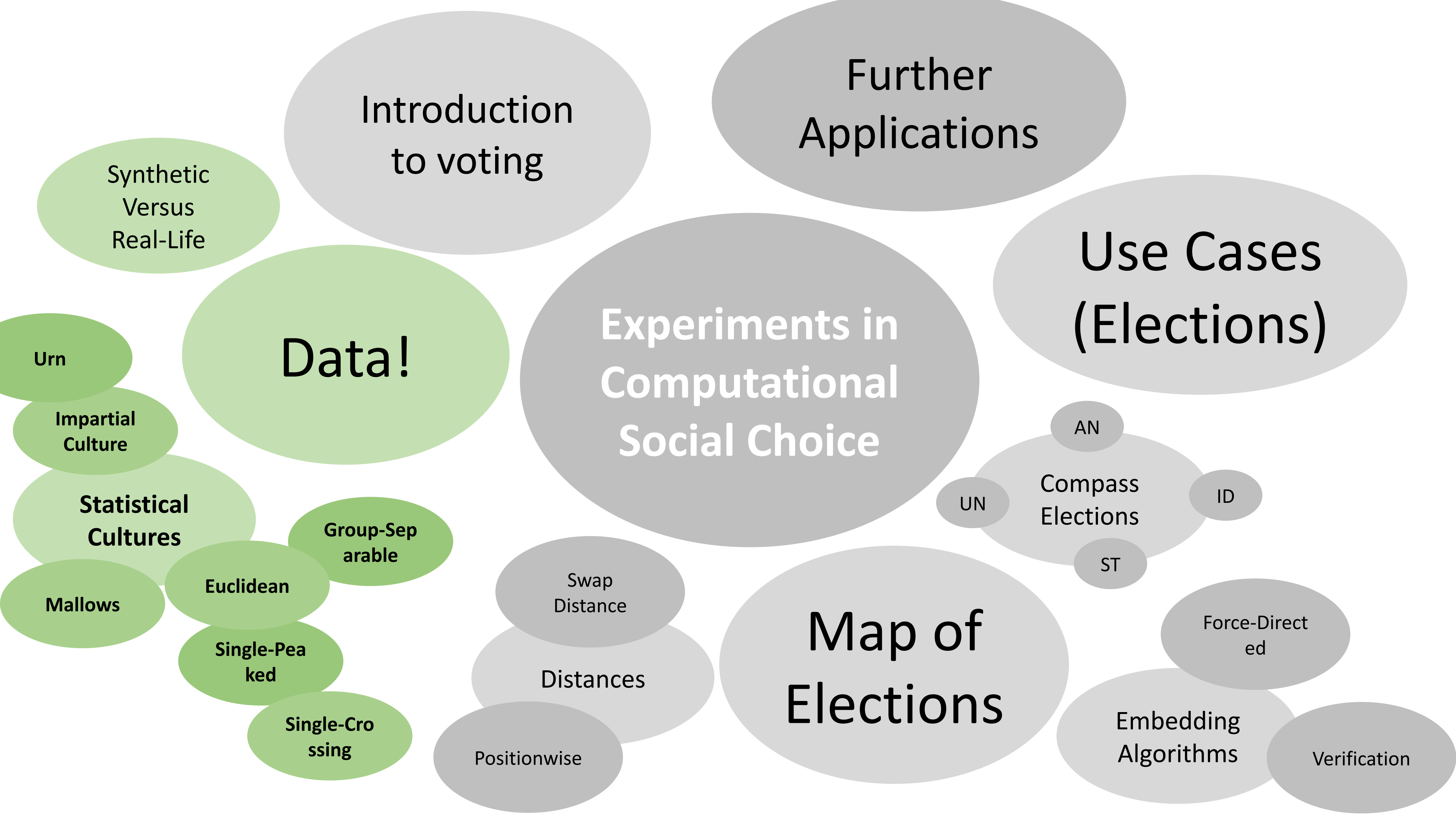
Synthetic Data

- Impartial Culture
- Urn, Mallows
- Euclidean, and more

Easy to control!

- Arbitrary size
- Perfect information
- Unrealistic…
  - All models are wrong but some are wronger than others ;)
- Hard to choose a model


Introduction to voting
Further Applications
Synthetic Versus Real-Life
Use Cases (Elections)
Data!
Experiments in Computational Social Choice
Urn
Impartial Culture
AN
Compass Elections
UN
ID
ST
Statistical Cultures
Group-Separable
Euclidean
Mallows
Swap Distance
Single-Peaked
Distances
Map of Elections
Force-Directed
Single-Crossing
Embedding Algorithms
Positionwise
Verification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Map of Elections
AN
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ID
ST
Force-Directed
Embedding Algorithms
Verification

5 minutes

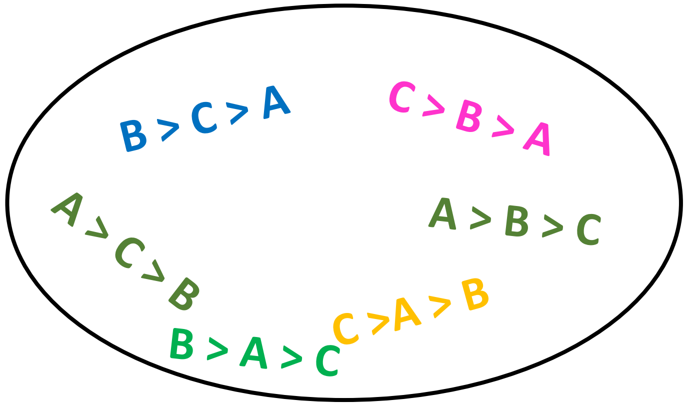
Basic Statistical Cultures

Statistical Cultures

Impartial Culture (IC): Every preference order comes with the same proba-bility (a.k.a. **uniform distribution**)

Polya-Eggenberger Urn Model:
Form an urn of **all possible m! votes**. To generate a vote:

1) Choose a vote from the urn and add it to your election
2) **Return** the vote to the urn, together with **α·m! copies**.



S. Berg. Paradox of voting under an urn model: The effect of homogeneity. Public Choice, 1985.
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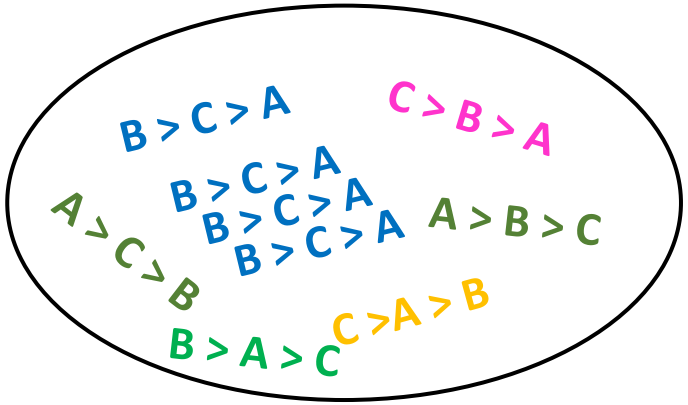

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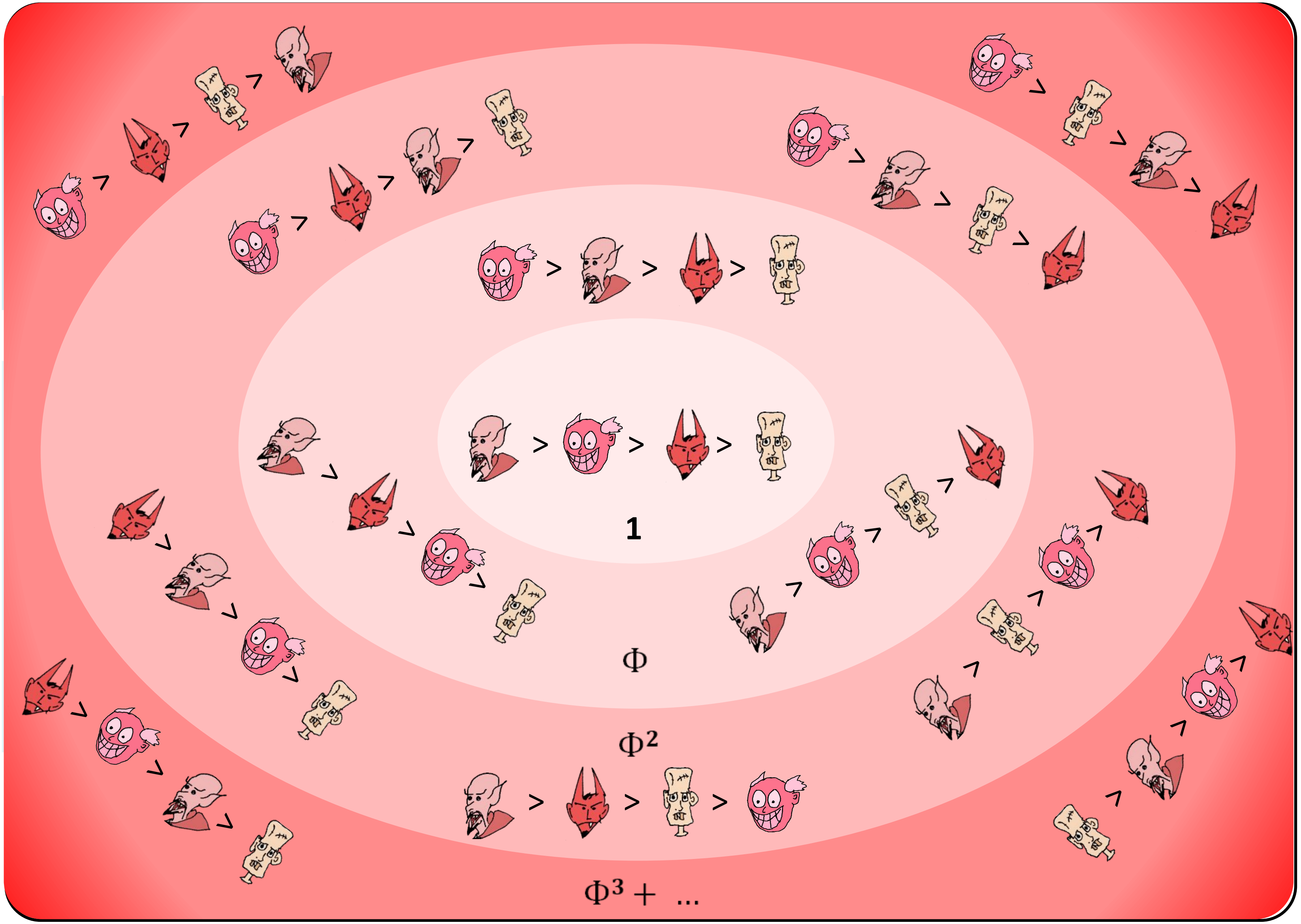
Mallows Model: Choose a center vote u. The probability of generating vote v is:

$$\frac{1}{Z}\Phi^{swap(u,v)}$$

(There are some algorithms that generate votes from this distribution… effectively.)



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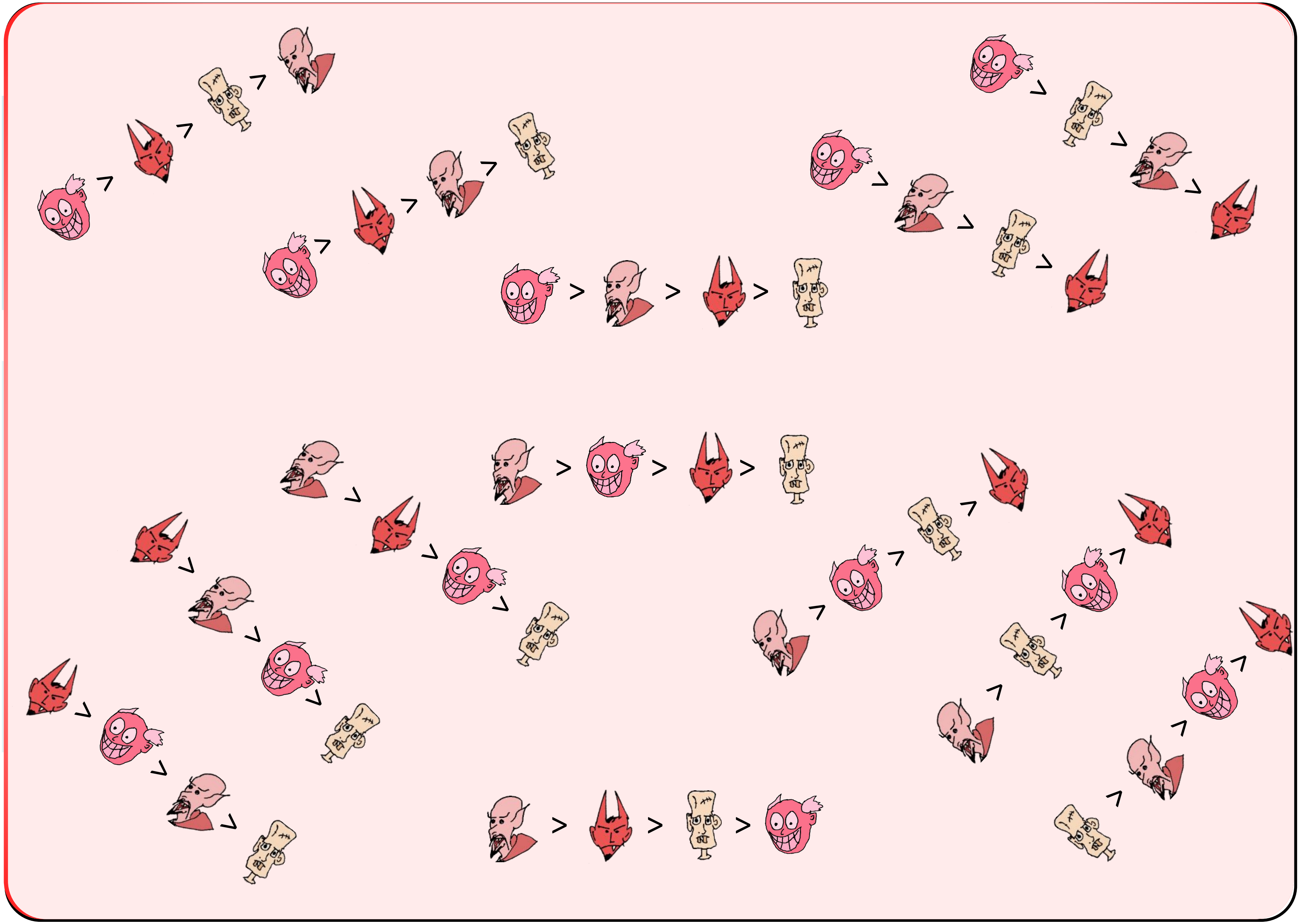
$$\frac{1}{Z}\Phi^{swap(u,v)}$$

There are fast sampling algorithms.

$\Phi = 1$



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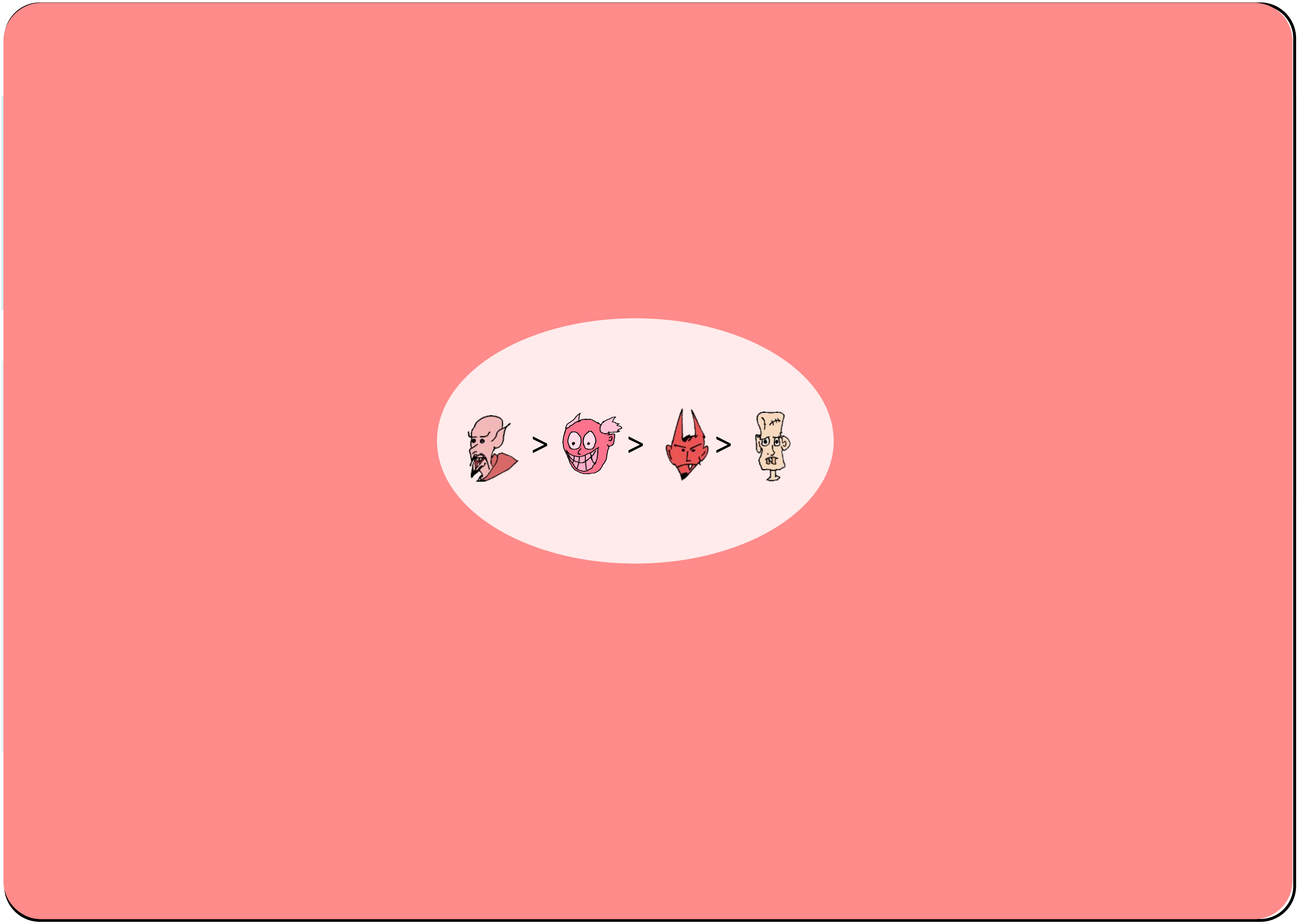
$$\frac{1}{Z}\Phi^{swap(u,v)}$$

There are fast sampling algorithms.

$\Phi = 0$



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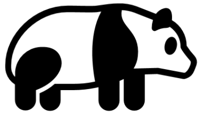
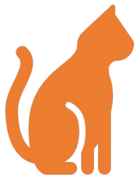
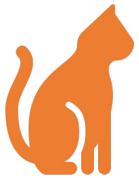
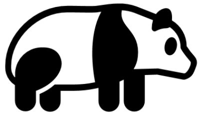
(There are some algorithms that generate votes from this distribution... effectively.)

So… what do these models actually do?

15 minutes

Microscope View of Statistical Cultures

Swap Distance

$d_{swap}($  >  >  ,  >  >  $) = 2$

Number of swaps of adjacent candidates needed to transform one preference order into the other

Swap Distance

Number of swaps of adjacent candidates needed to transform one preference order into the other

Swap Distance

Number of swaps of adjacent candidates needed to transform one preference order into the other

Swap Distance

Number of swaps of adjacent candidates needed to transform one preference order into the other

Election microscope:

1. Generate an election from a statistical culture
2. Compute swap distances between all pairs of votes
3. Represent each vote as a dot in 2D space, so that Euclidean distances are similar to the swap distances **map!**

The Map Idea

We have some objects:

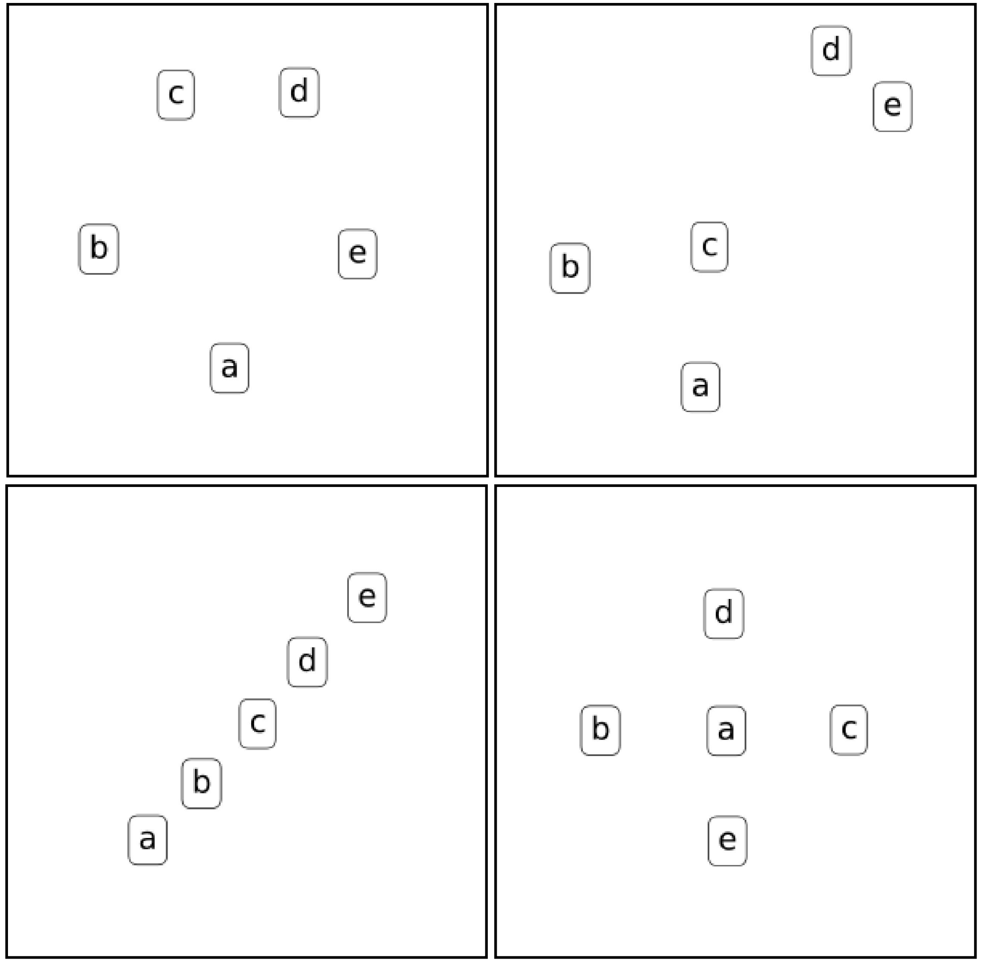
a, b, c, d ,e

We (somehow) know the distances between each pair

–	*a*	*b*	*c*	*d*	*e*
a	–	2	2	4	4
b	2	–	2	4	4
c	2	2	–	3	3
d	4	4	3	–	1
e	4	4	3	1	–

(a) Distance Matrix

Can we arrange them in 2D space?



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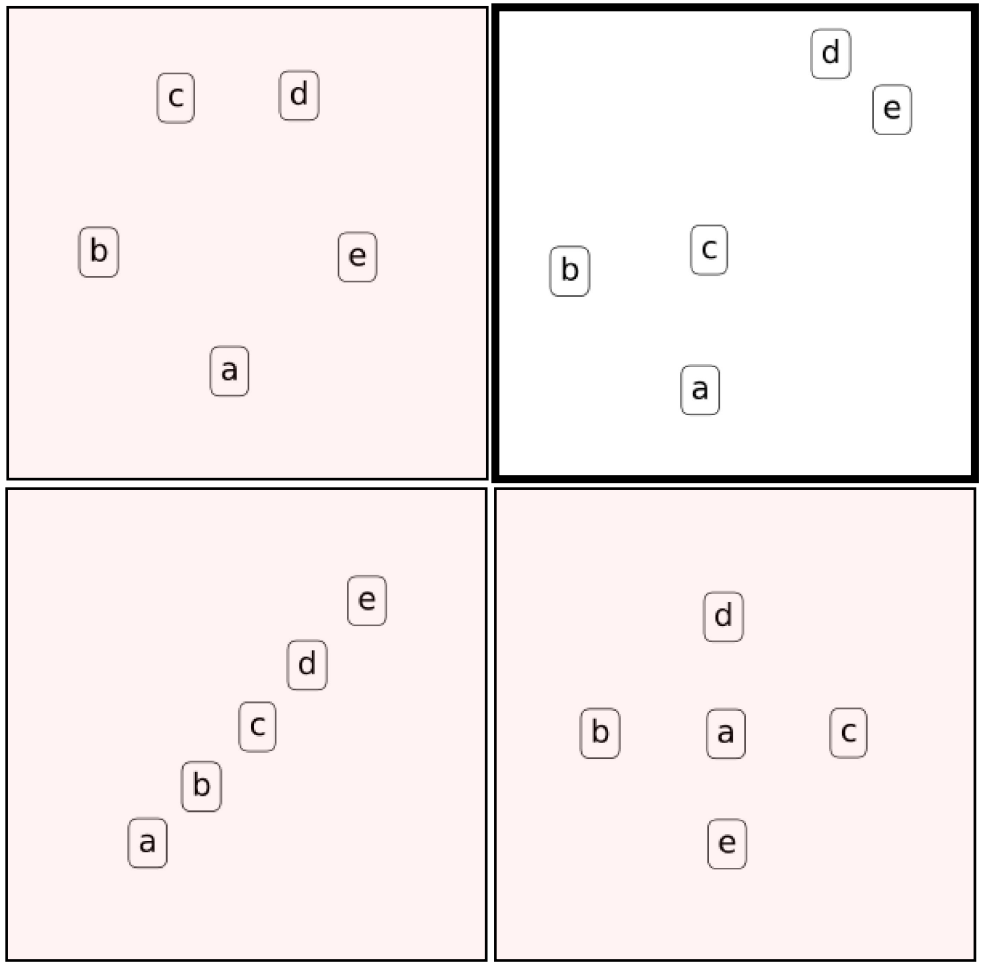


The Map Idea: Sometimes You Fail

Consider objects:

$z_1, z_2, z_3, \ldots, z_{100}$

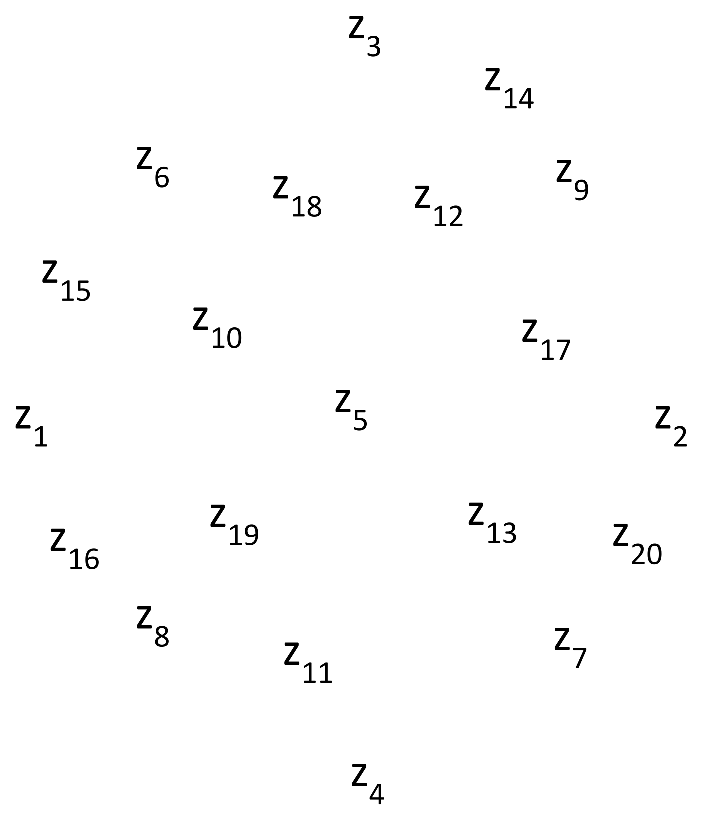
For each $i, j \in [100]$, we have:

$d(z_i, z_j) = 1$

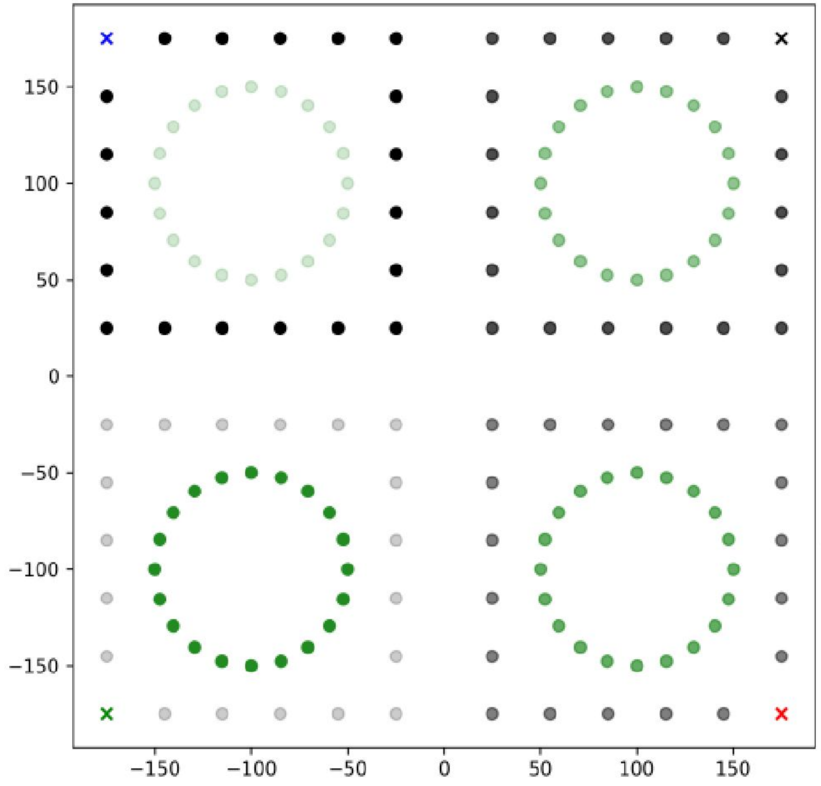
How to arrange these in the 2D space?

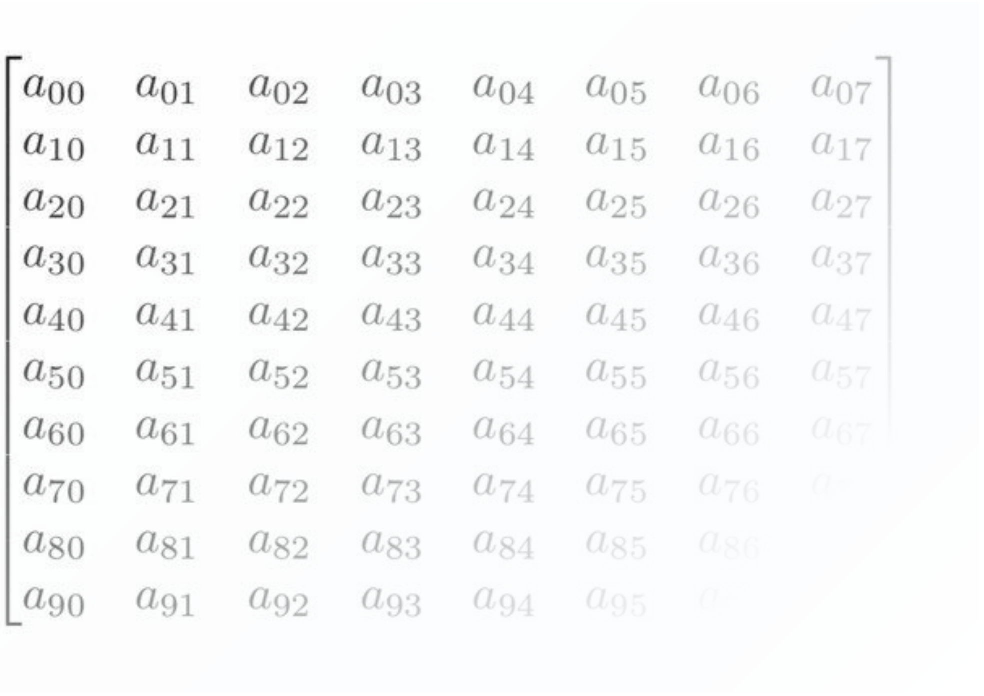
Not much you can do without errors…

But we still do it



The Map Idea: Computing The Embedding





simple geometric dataset
(embedding algorithms only have Euclidean distances of points as inputs)

K. Sapała, Algorithms for Embedding Metrics in Euclidean Spaces, MSc thesis AGH 2022 (specialized implementation of Kamada-Kawai algorithm)

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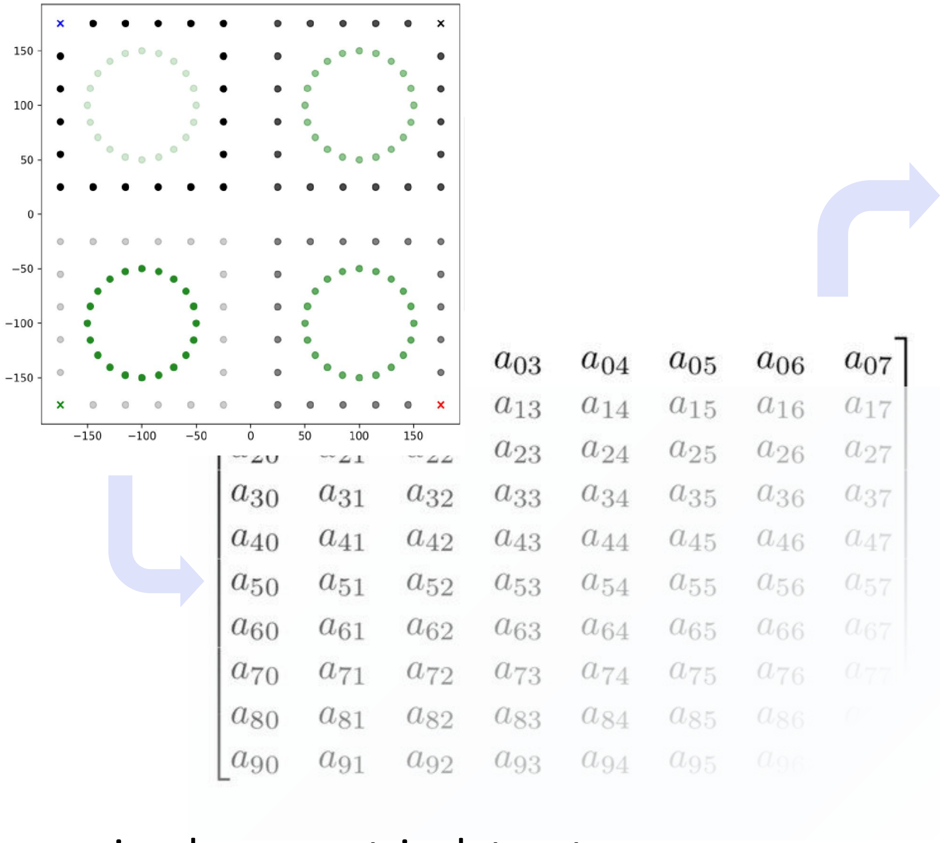

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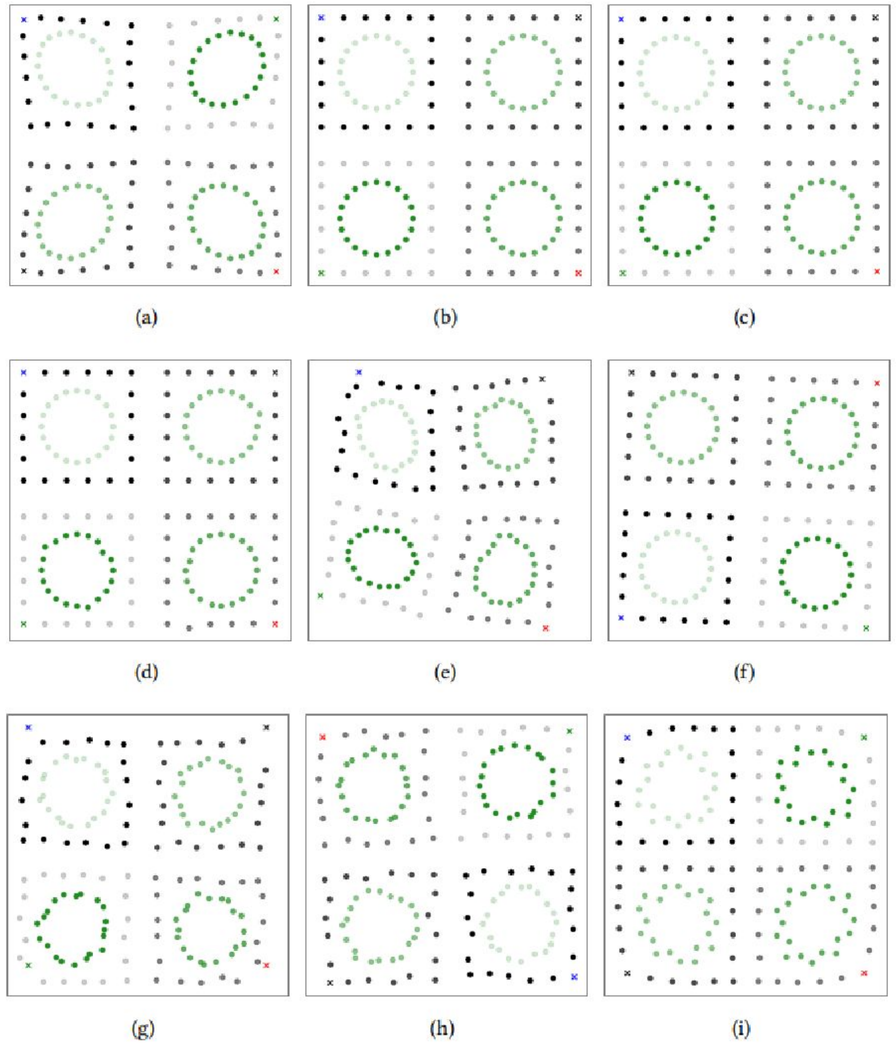

Examples of embeddings

(a) ISOMAP
(b) Kamada-Kawai (KK) with positions of corner points fixed
(c) KK wihtout fixing
(d) KK with Newton-Rhapson + fixing
(e) KK with Newton-Rhapson without fixing
(f) MDS
(g) Simulated annealing with fixing
(h) Simulated annealing without fixing
(i) Fruchterman-Reingold

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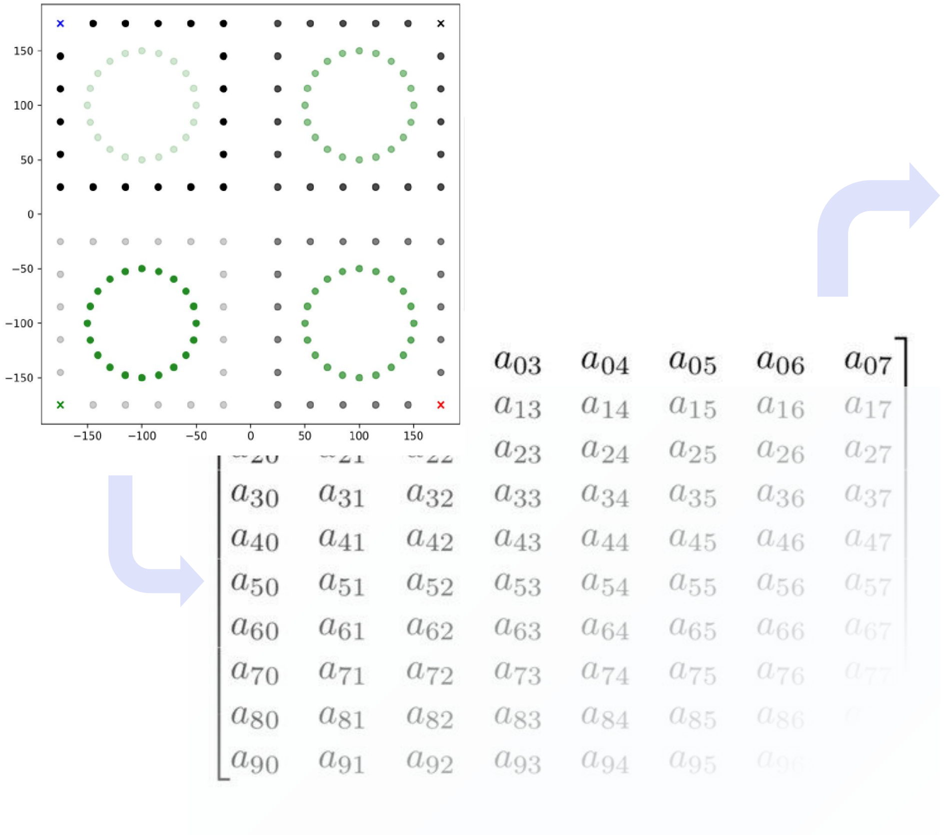

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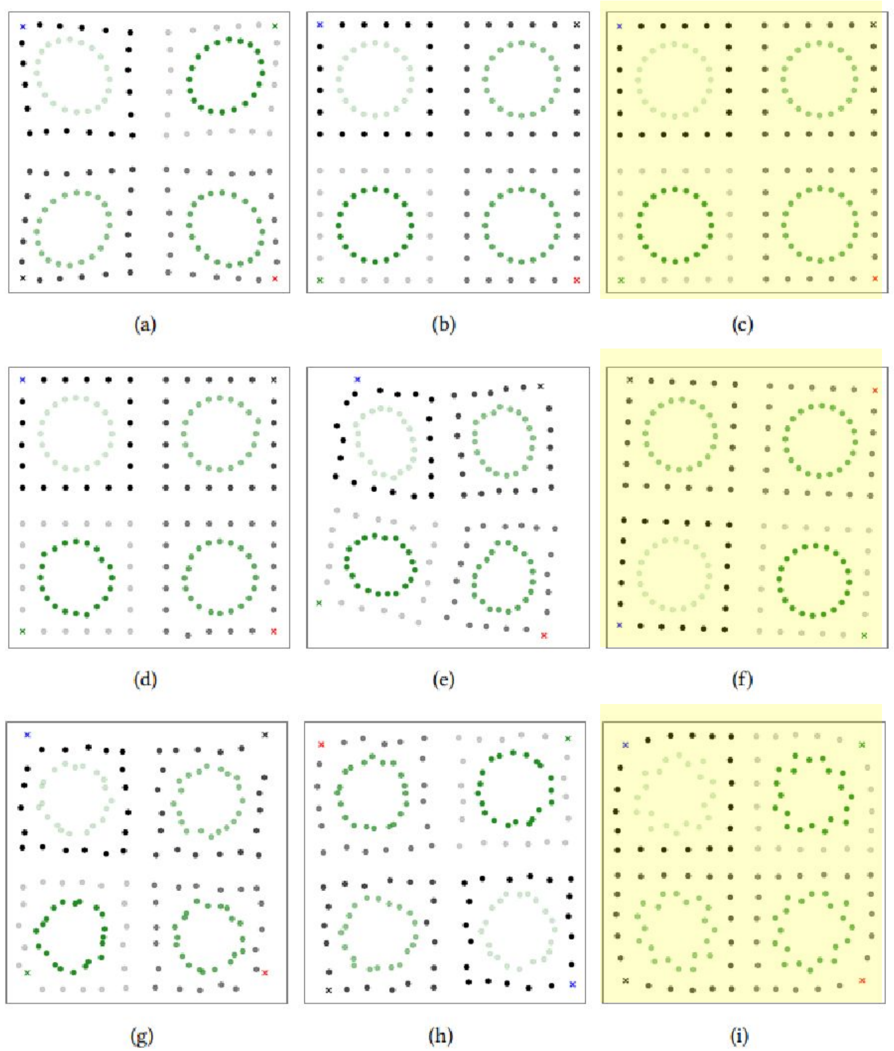

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Swap Distance

Number of swaps of adjacent candidates needed to transform one preference order into the other

Election microscope:

1. Generate an election from a statistical culture
2. Compute swap distances between all pairs of votes
3. Represent each vote as a dot in 2D space, so that Euclidean distances are similar to the swap distances □ **map!**

Impartial Culture (IC): Every preference order comes with the same proba-bility (a.k.a. **uniform distribution**)

Polya-Eggenberger Urn Model: Form an urn of **all possible m! votes**. To generate a vote:

1) Choose a vote from the urn and add it to your election
2) **Return** the vote to the urn, together with **α·m! copies**.

Mallows Model: Choose a center vote u. The probability of generating vote v is:

$$\frac{1}{Z}\Phi^{swap(u,v)}$$

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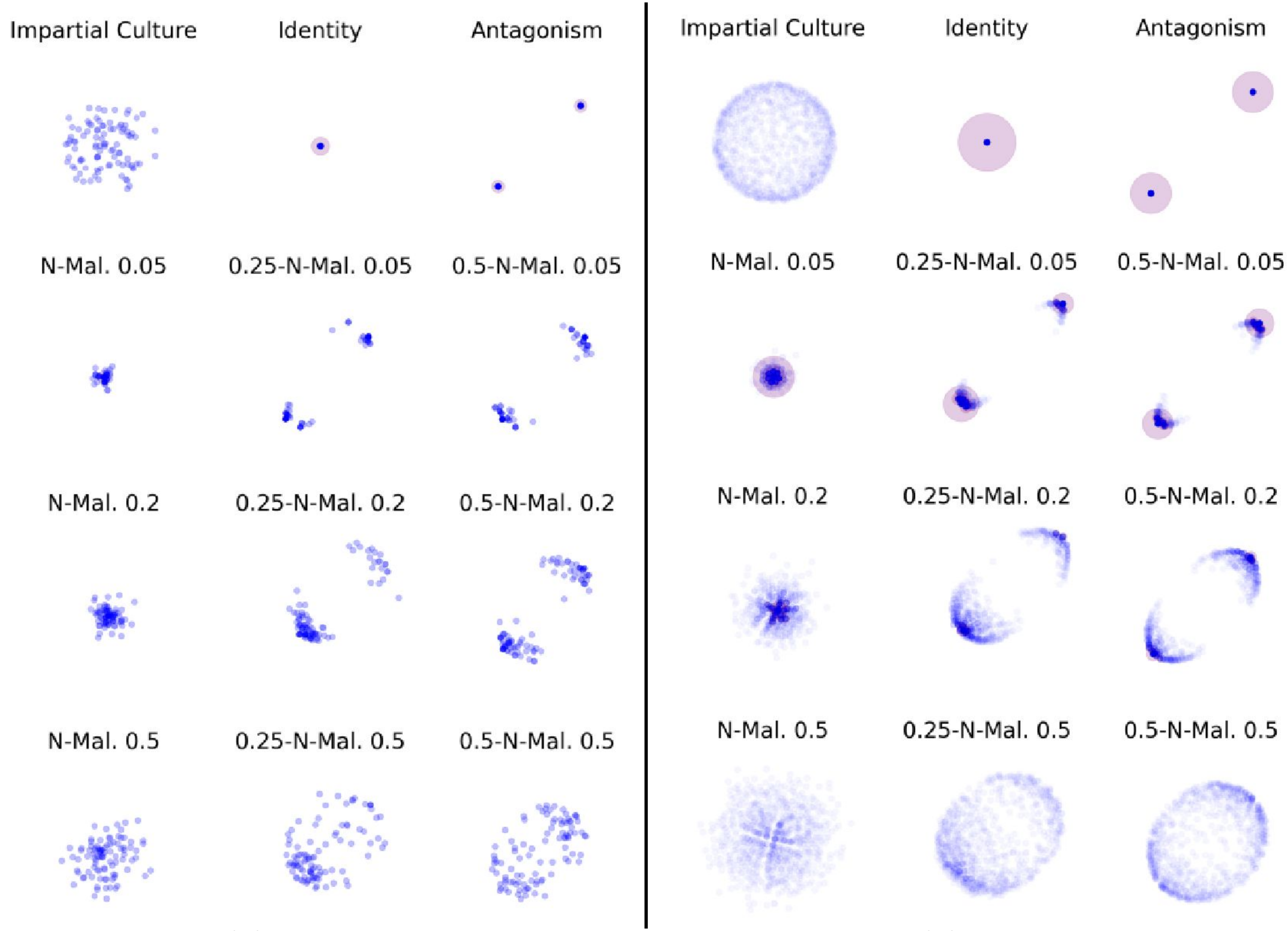
Microscope



8 candidates, 96 voters

8 candidates, 1000 voters

P. Faliszewski, A. Kaczmarczyk, K. Sornat, S. Szufa, T. Wąs, Diversity, Agreement and Polarization in Elections, IJCAI 2023

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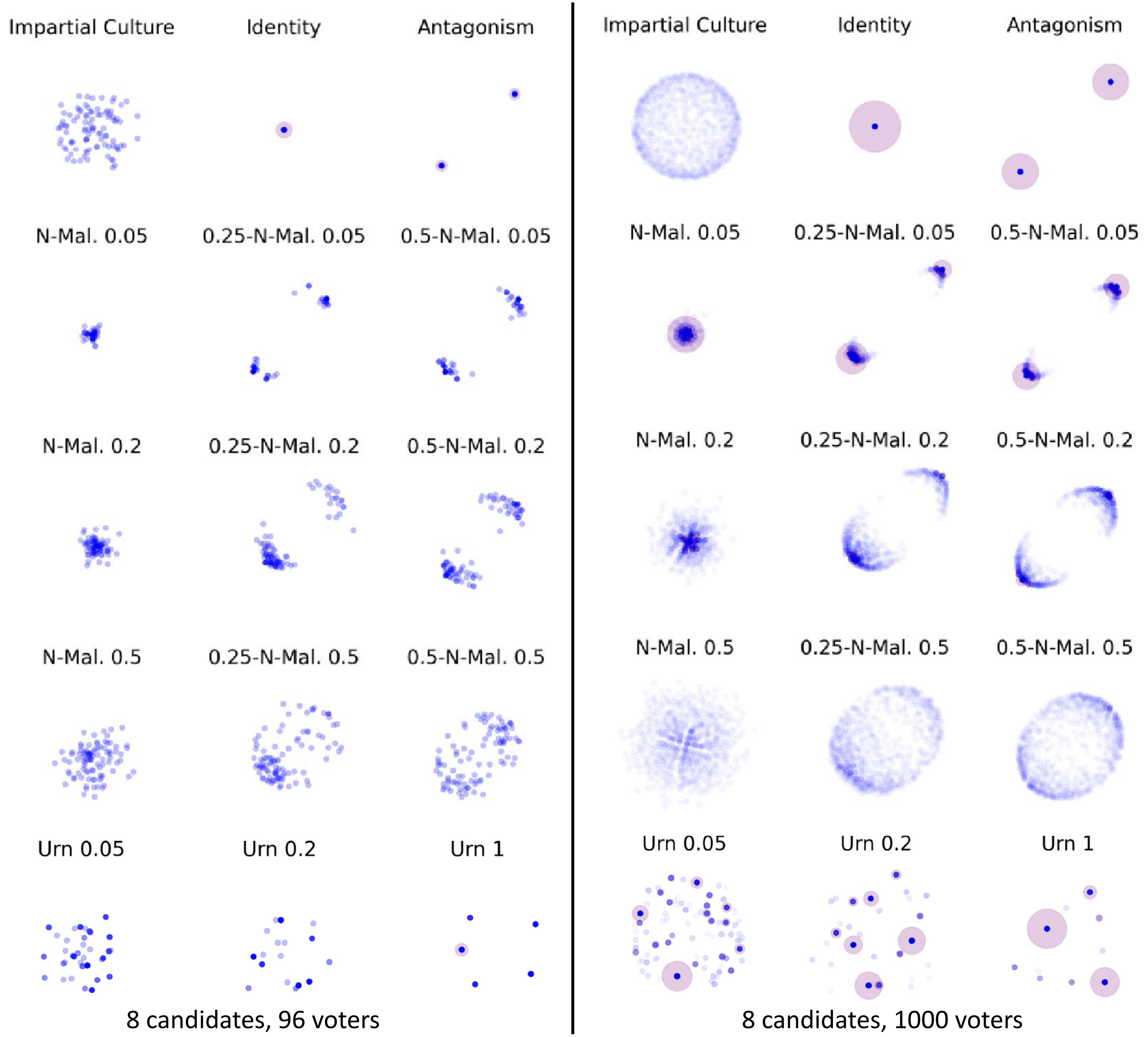

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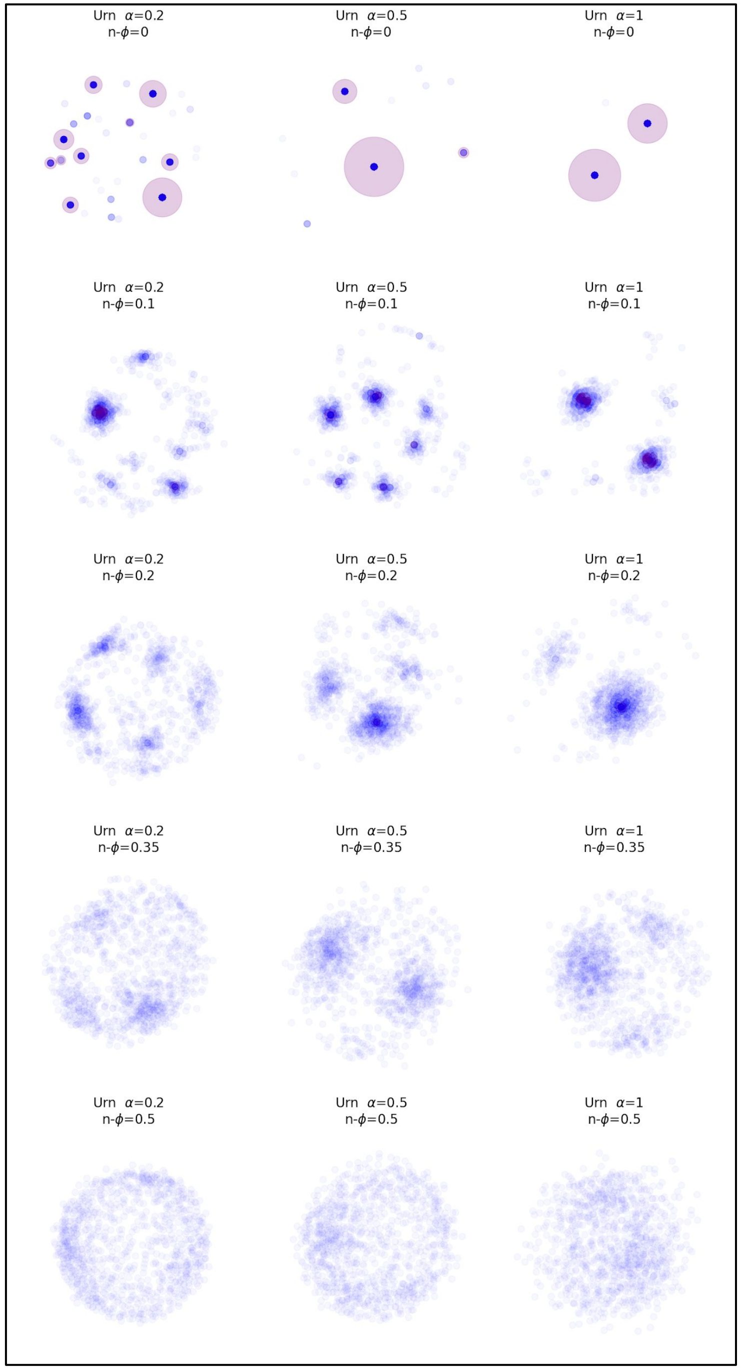


Urn-Mallows Model: First generate an election according to the urn model and then replace each vote *v* with one generated using Mallows model, with *v* as the center vote.

Comparison to real-life elections: Sushi contains preferences about sushi types. Grenoble and Irish are political elections

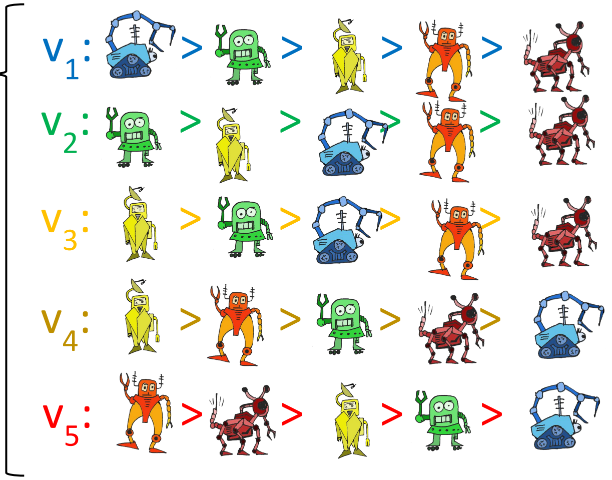
10 minutes

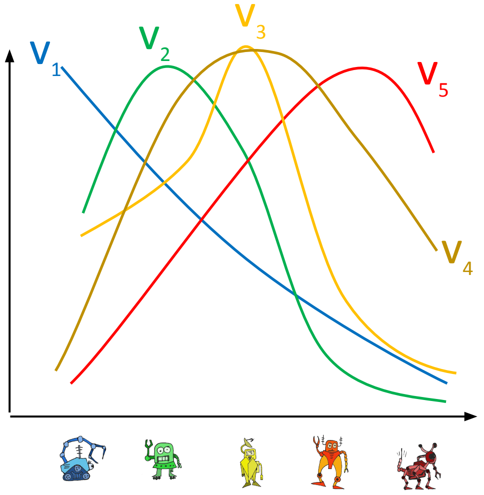
Restricted Domains

Restricted Domains

Single-Peaked (SP): Fix a societal axis, e.g., the following ordering of the candidates. Every single-peaked vote for this axis satisfies the property that „for each t, the top t candidates form an interval on the axis).

single-peakedness





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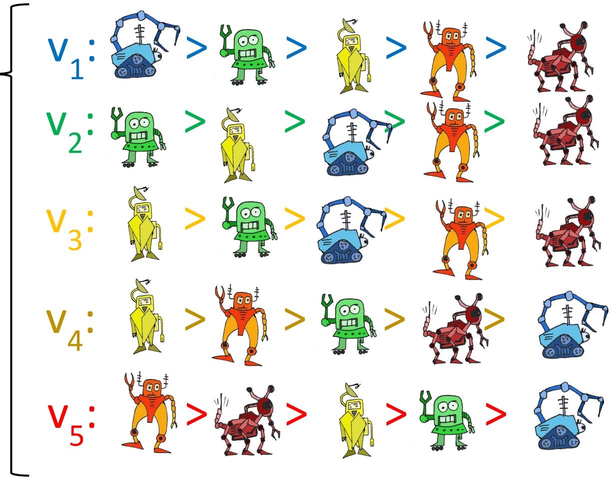
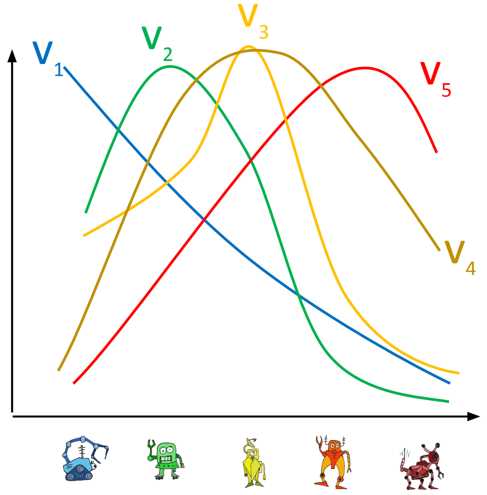
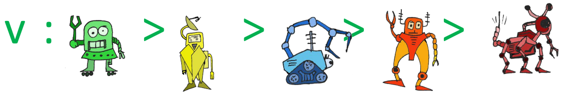




Conitzer model (top-down)

1/n * 1/2 * 1/2 * 1 * 1



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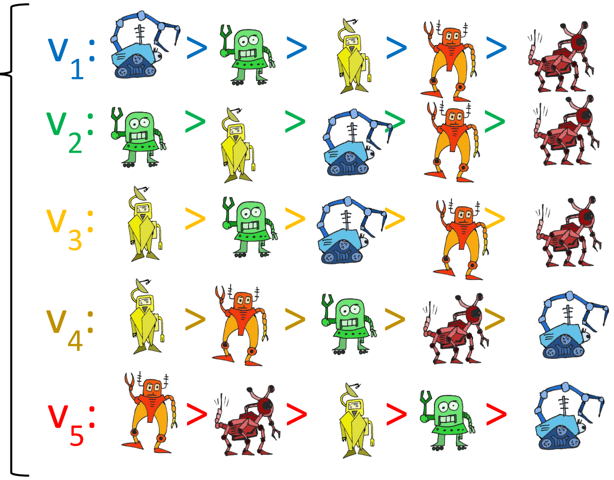
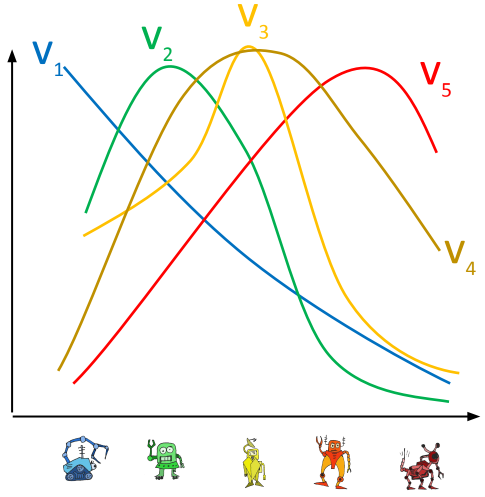
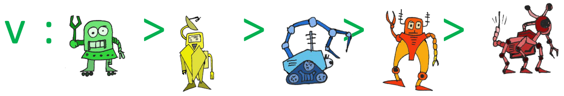




Conitzer model (top-down)

1/5 * 1/2 * 1/2 * 1 * 1



Walsh model (bottom-up)

Uniform distribution

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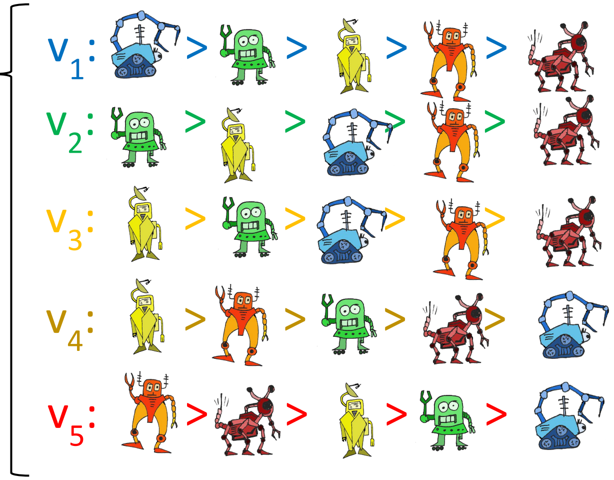
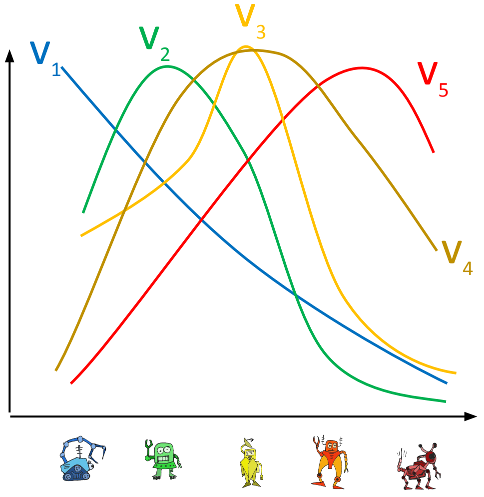
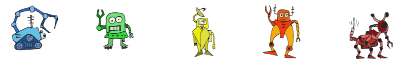
Single-Crossing: Order voters so going from top to bottom, each pair of candidates crosses at most once.

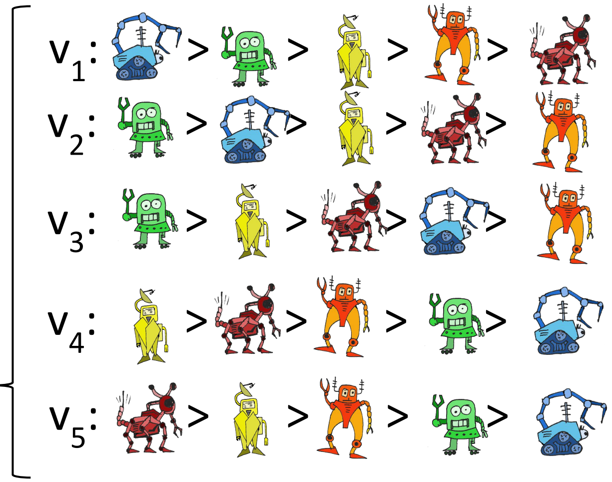
single-peakedness







single-crossingness



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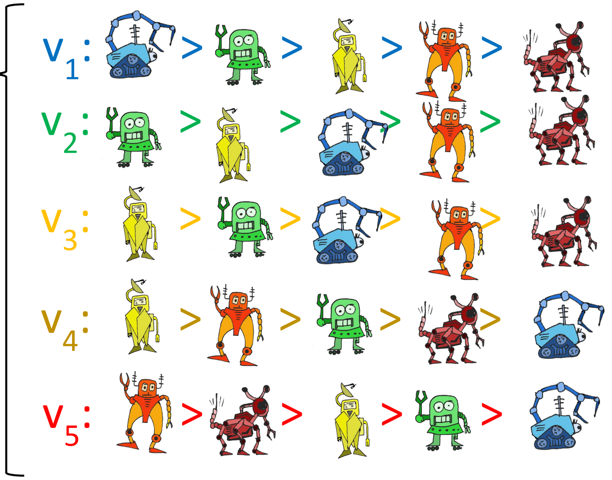

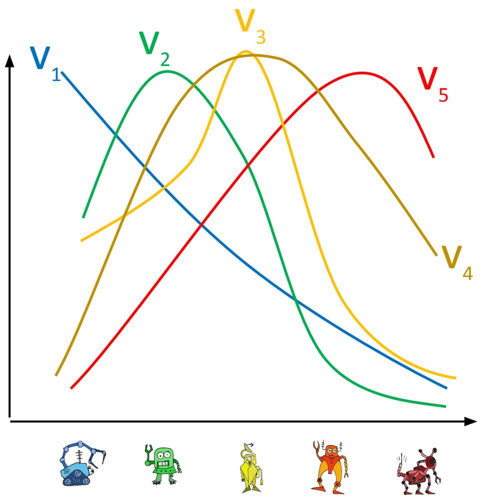

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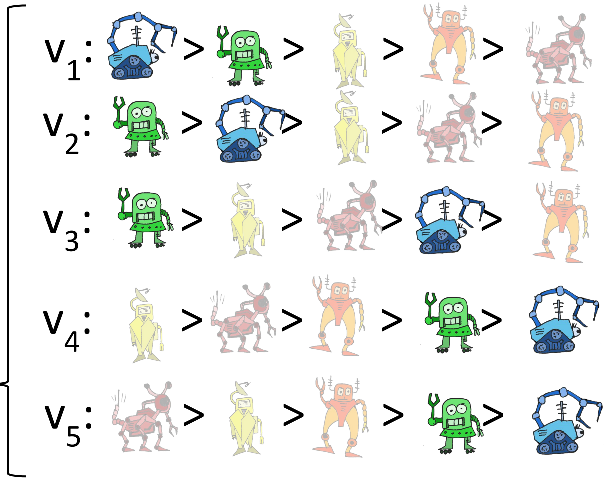

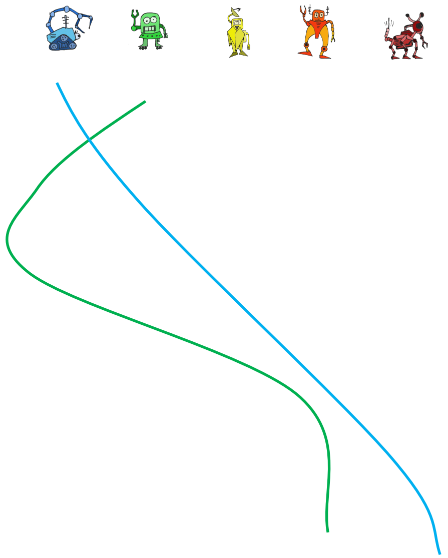

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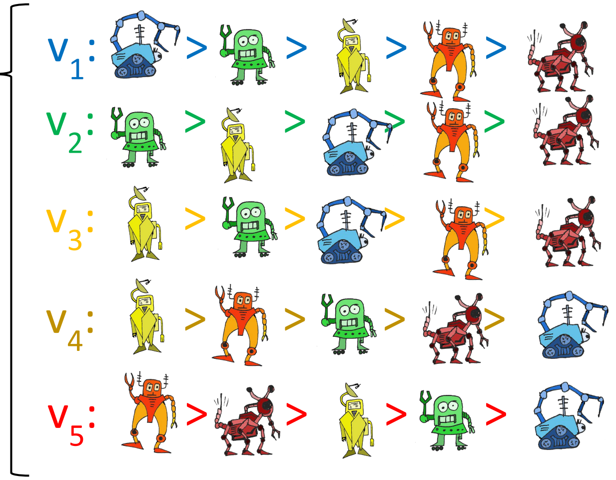

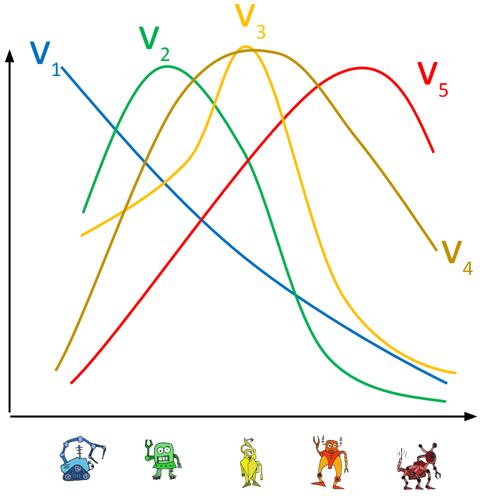

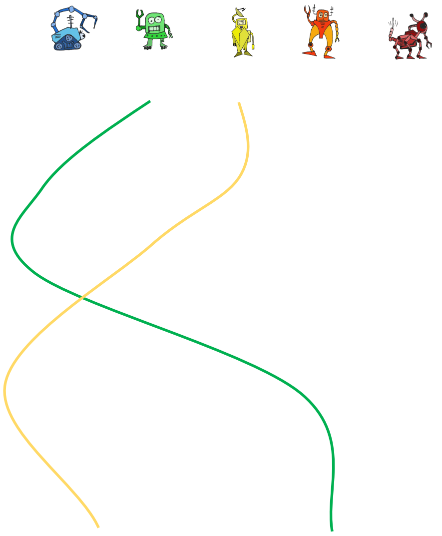

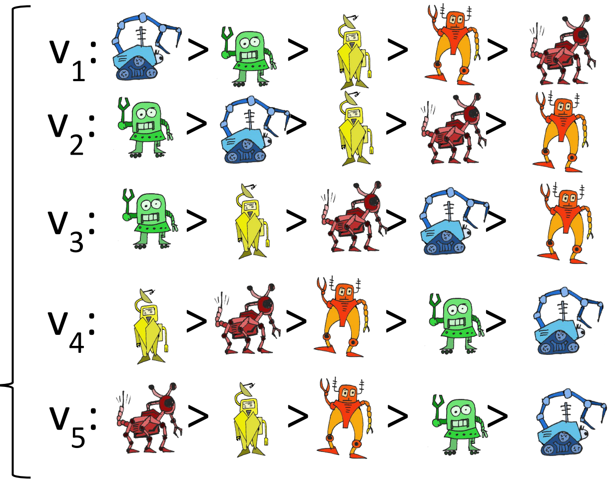

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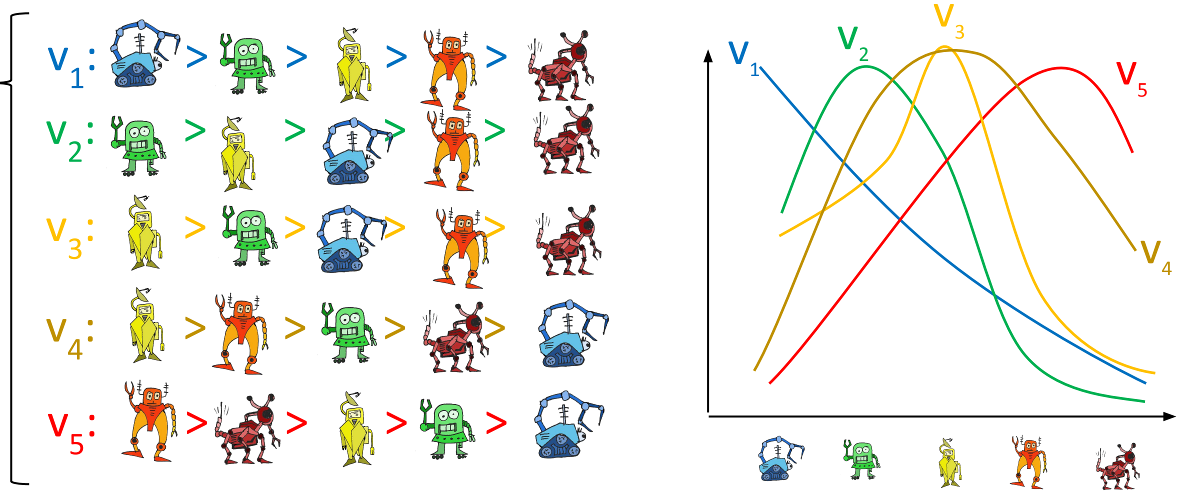

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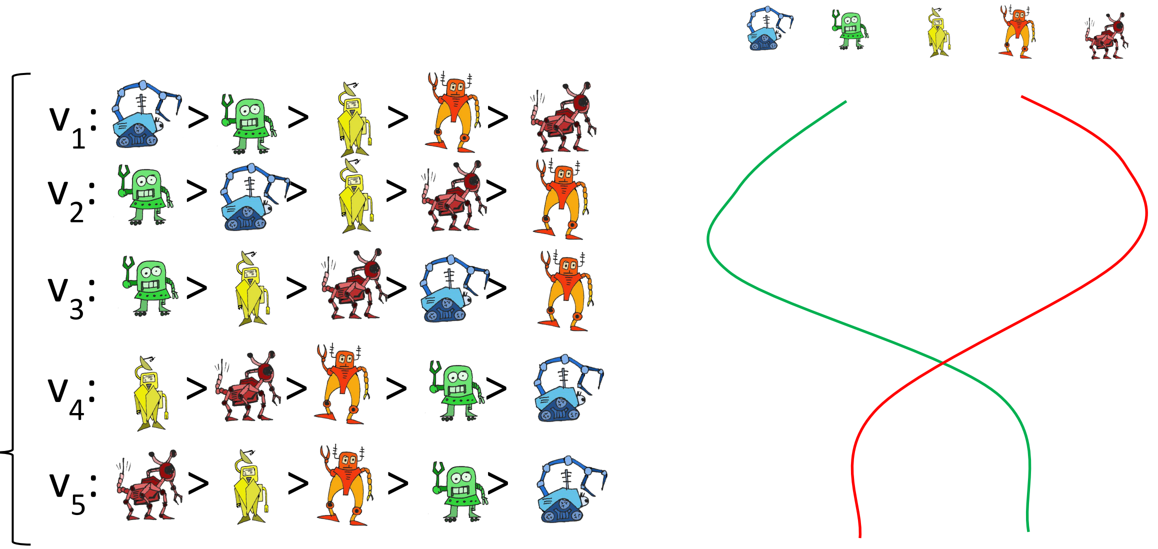

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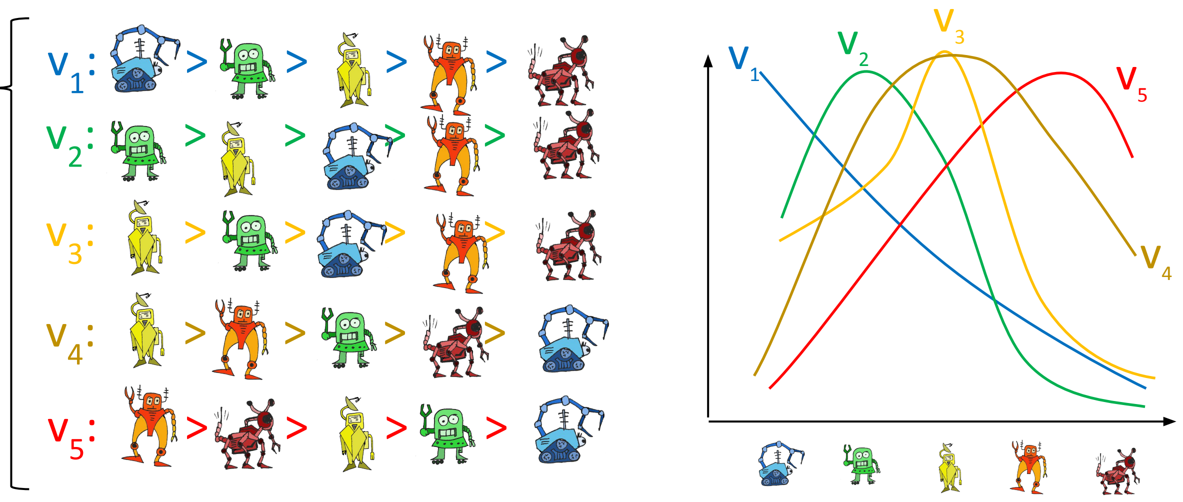

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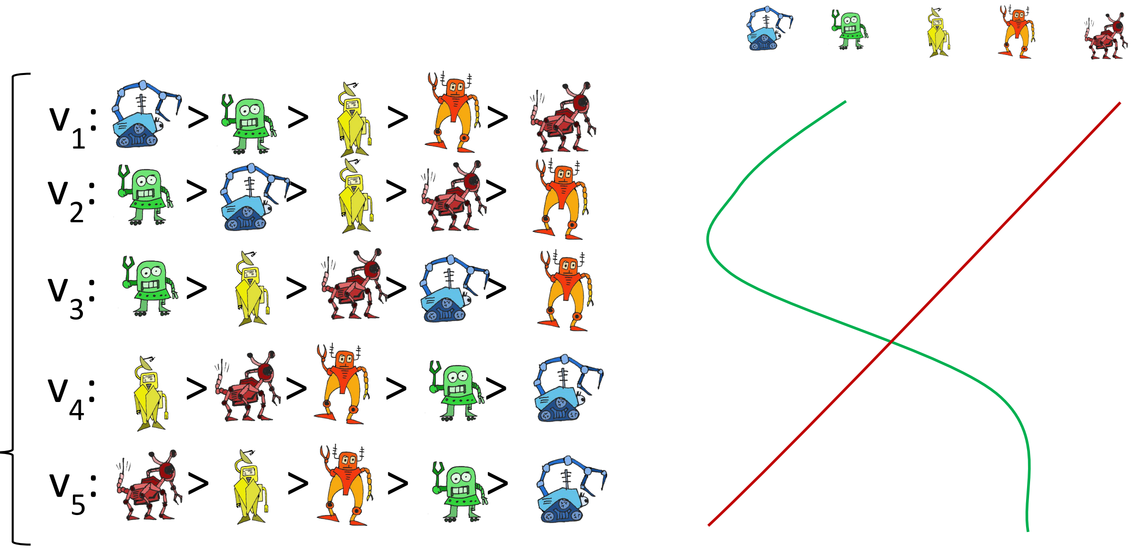
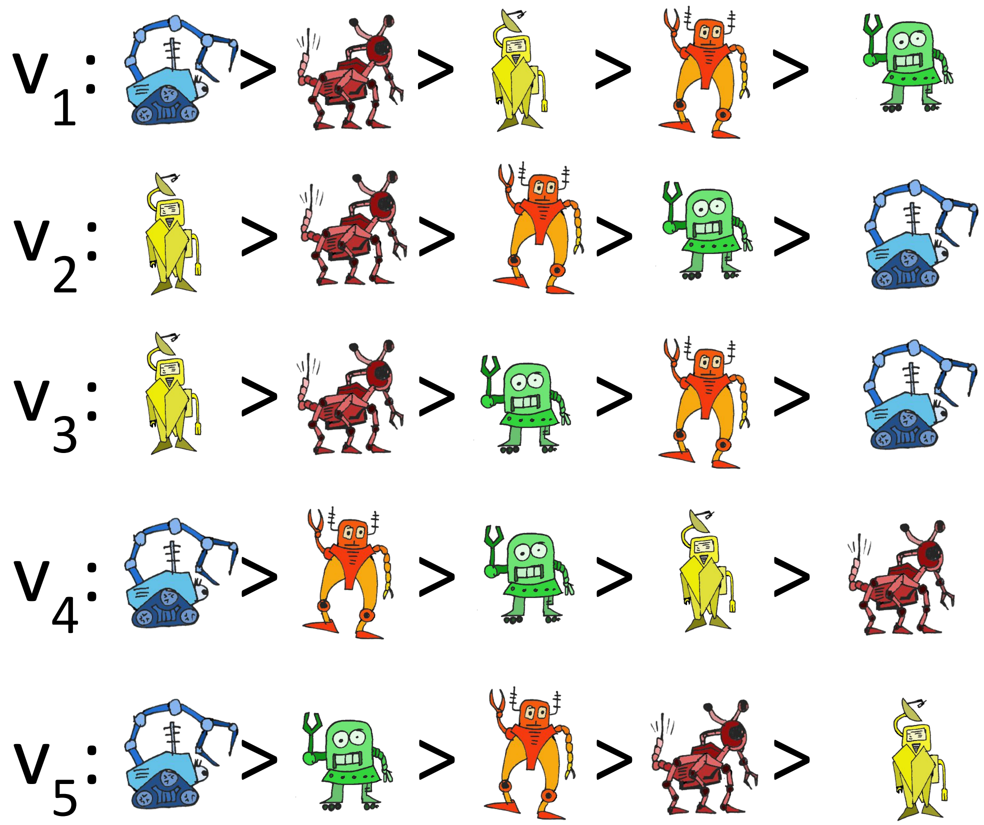
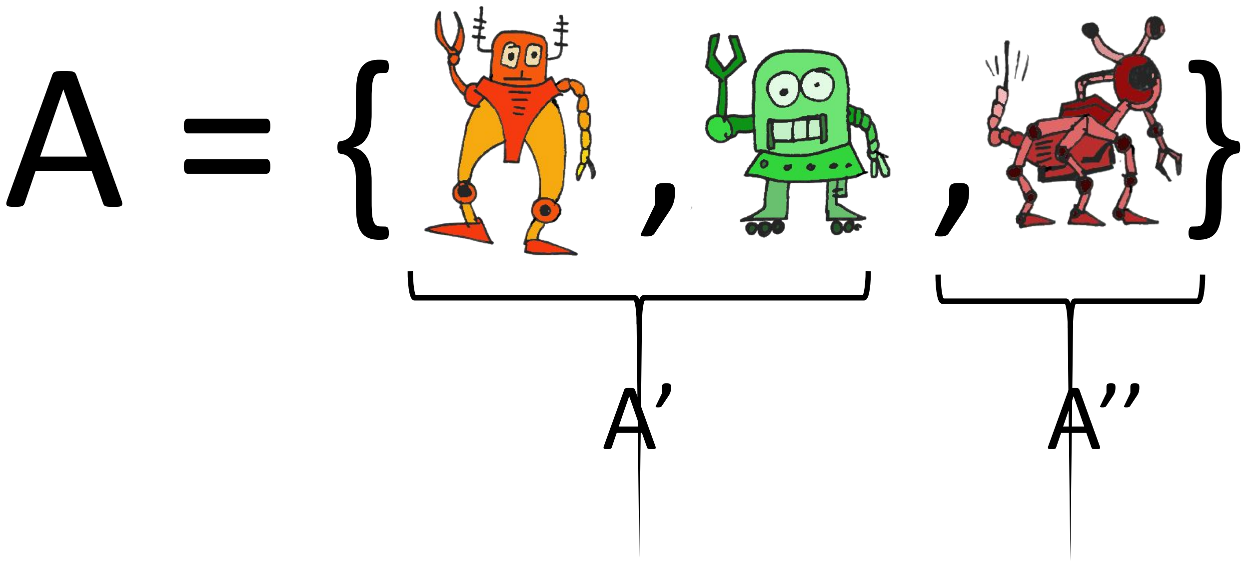


Group-Separable Preferences

A profile is group-separable if each subset A, |A| ≥ 2, of candidates can be partitioned into A’ and A’’ so that each voter prefers all members of one to all members of the other





K. Inada, A Note on the Simple Majority Decision Rule, Econometrica ,1964.
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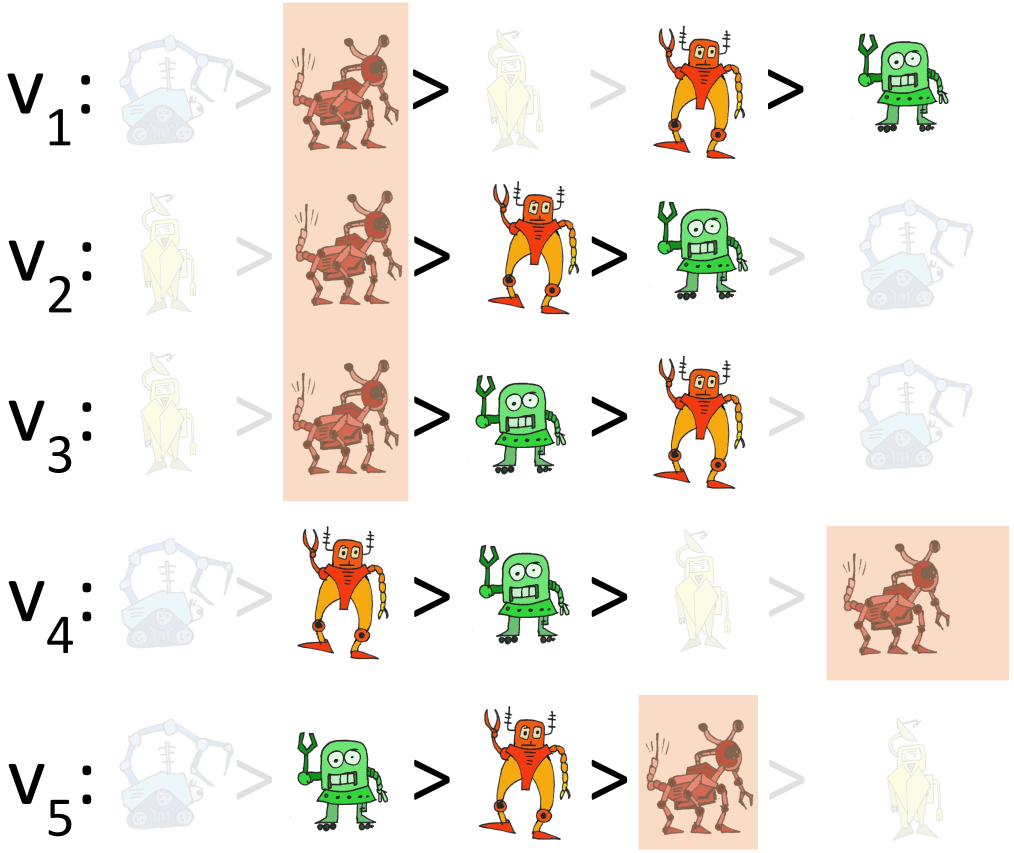

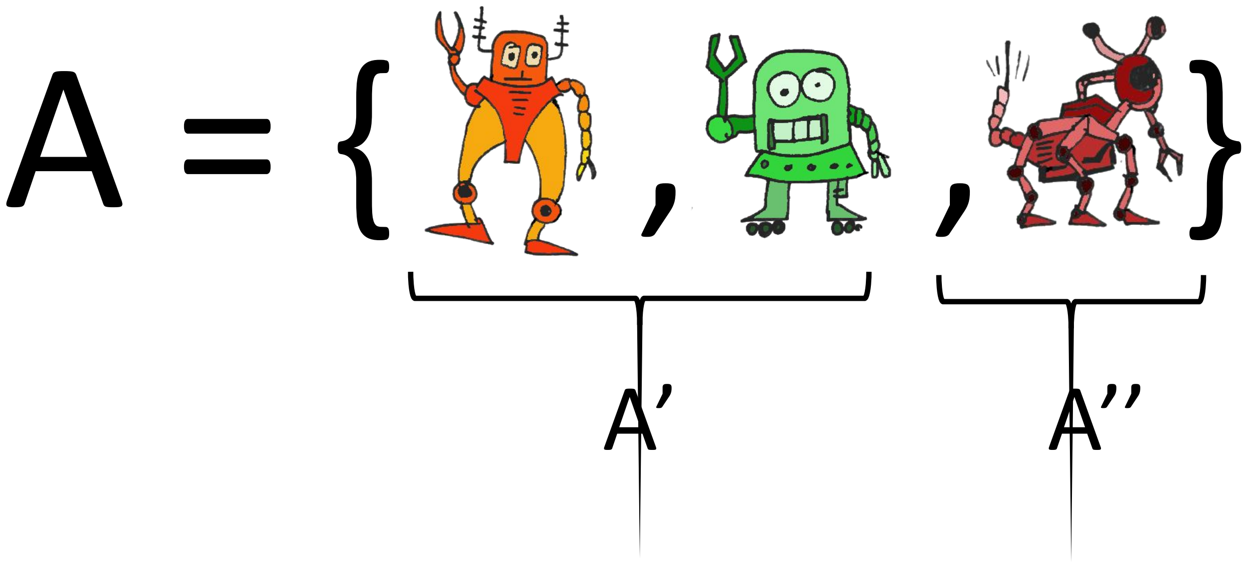

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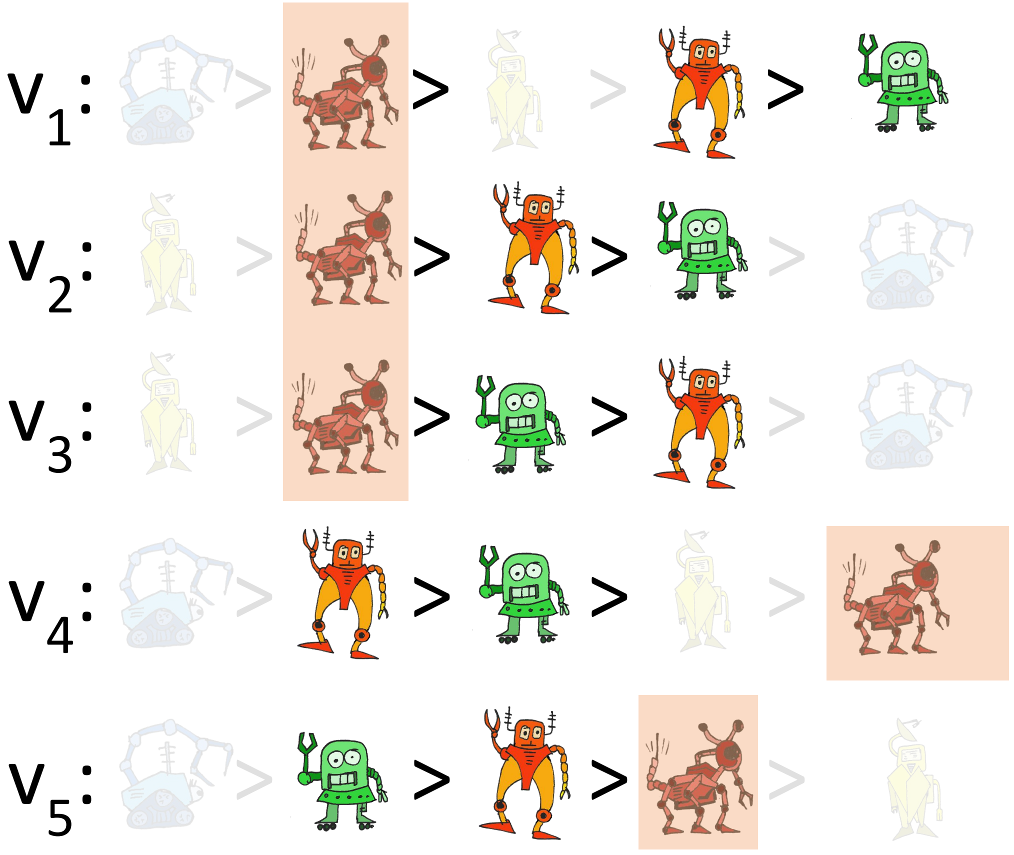

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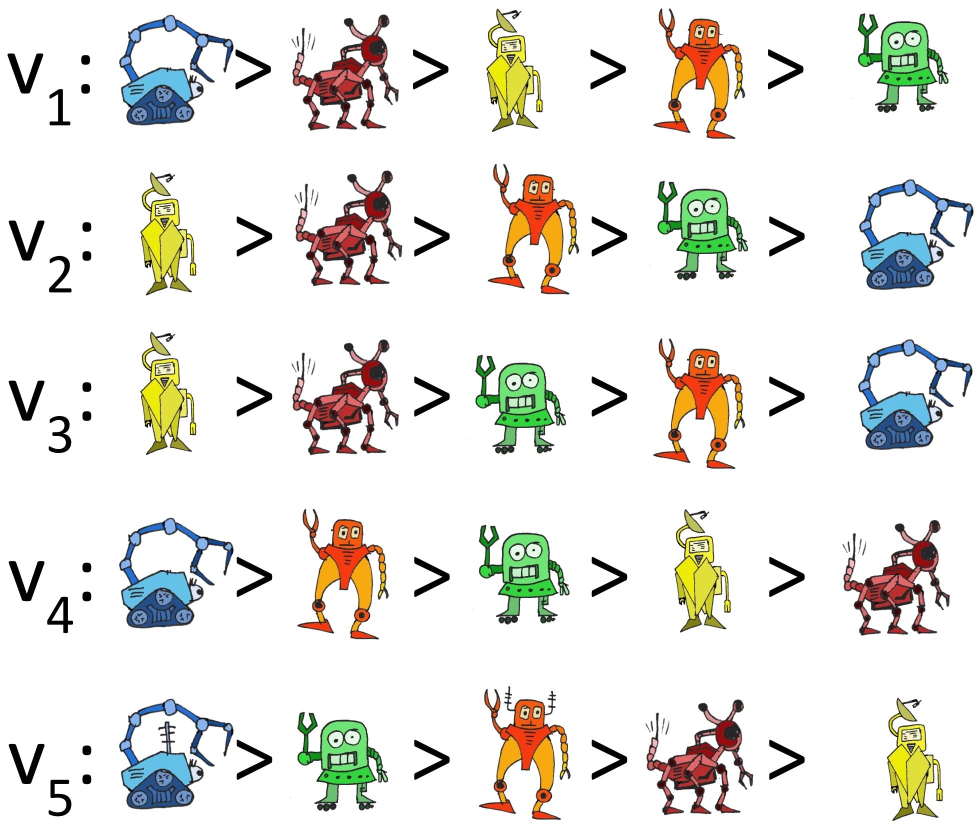
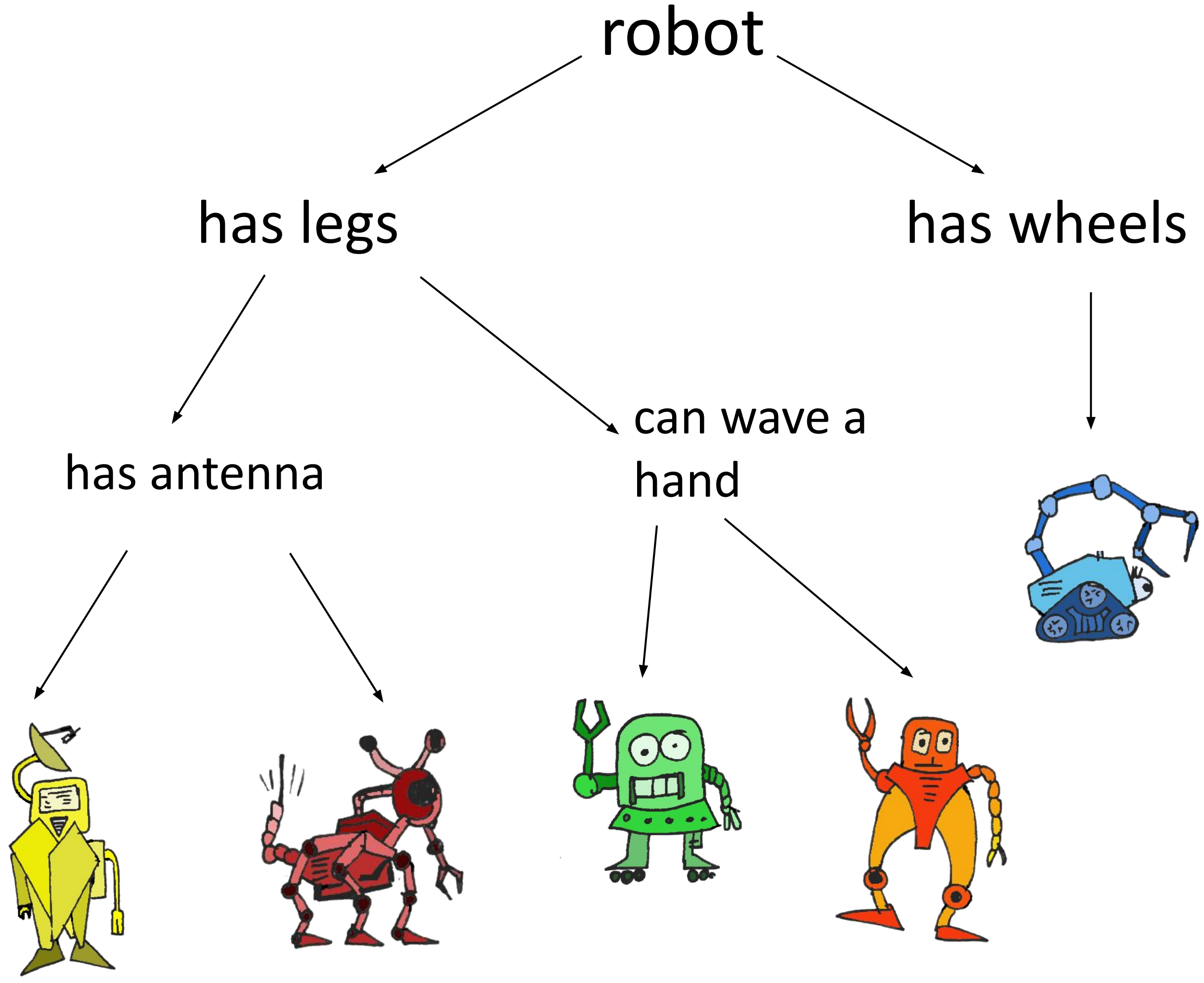
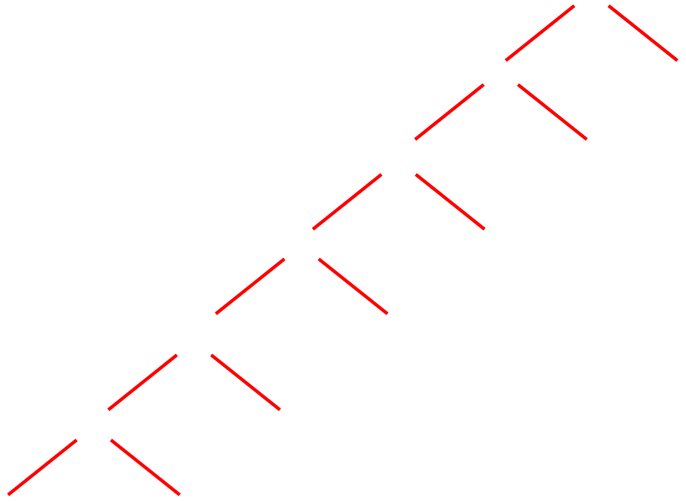




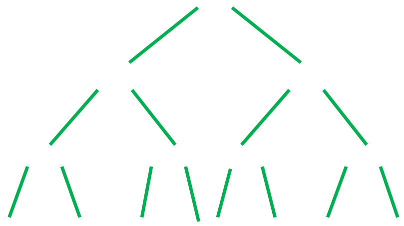
A. Karpov, On the Number of Group-Separable Preference Profiles, Group Decision and Negotiation, 2019

Group-Separable Preferences

Caterpillar Trees



Balanced Trees



Euclidean Preferences

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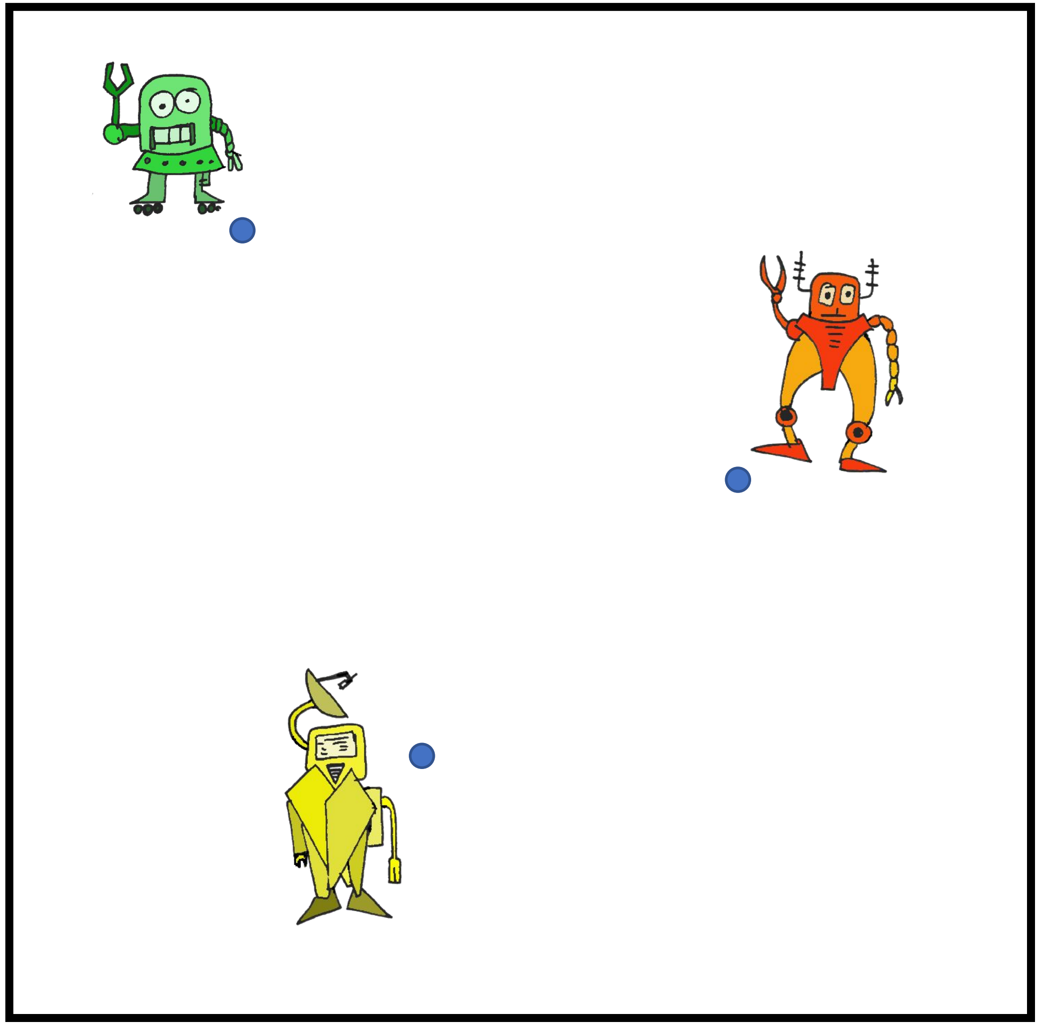

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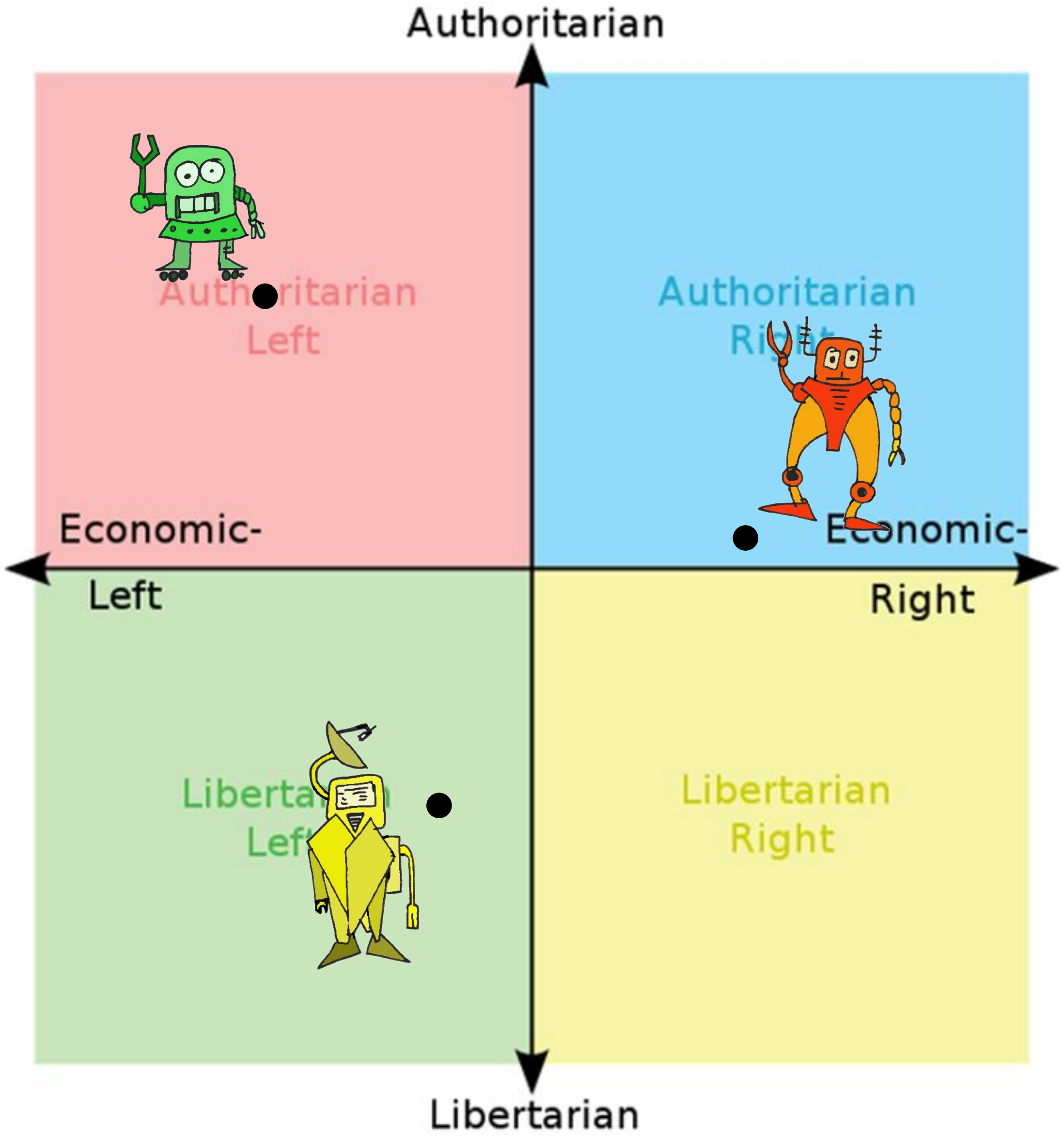

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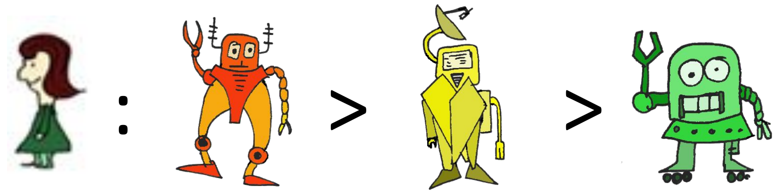

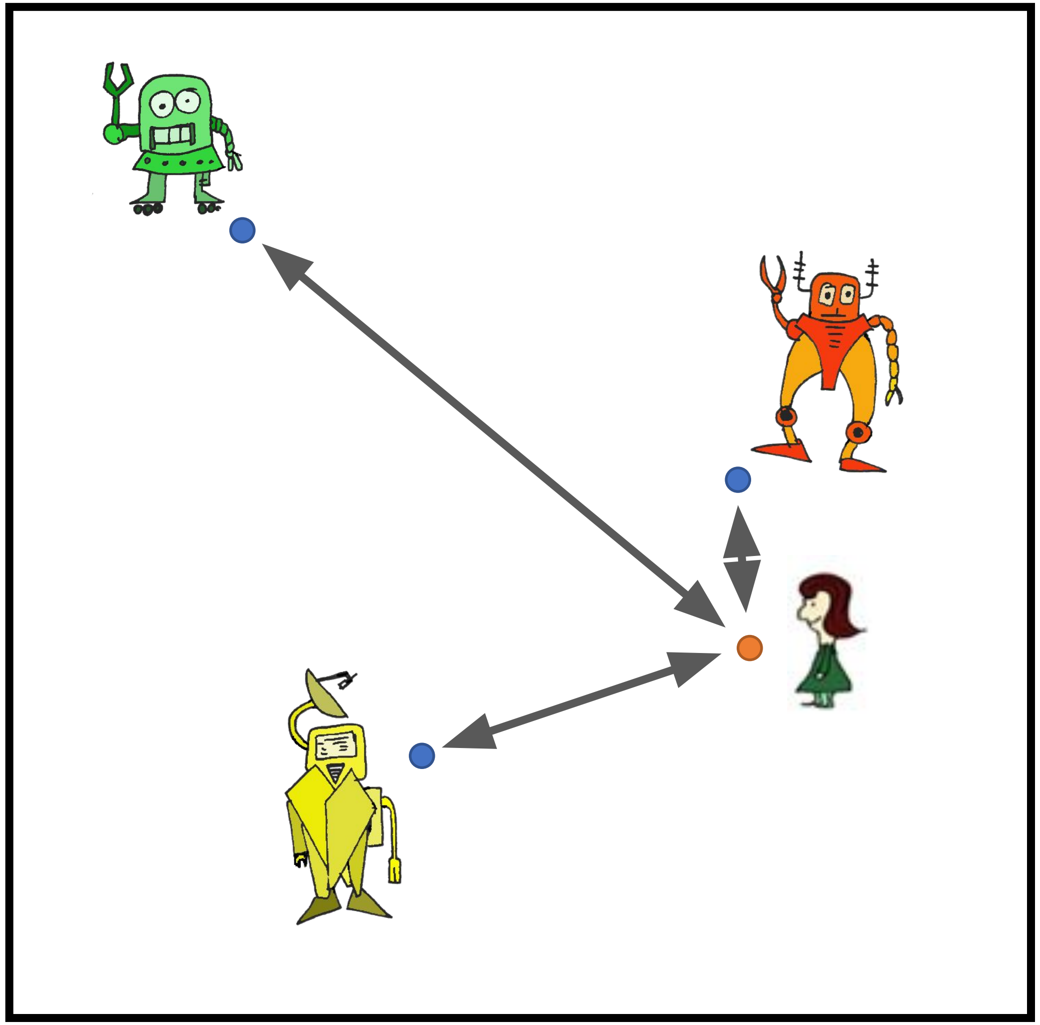

Euclidean Preferences

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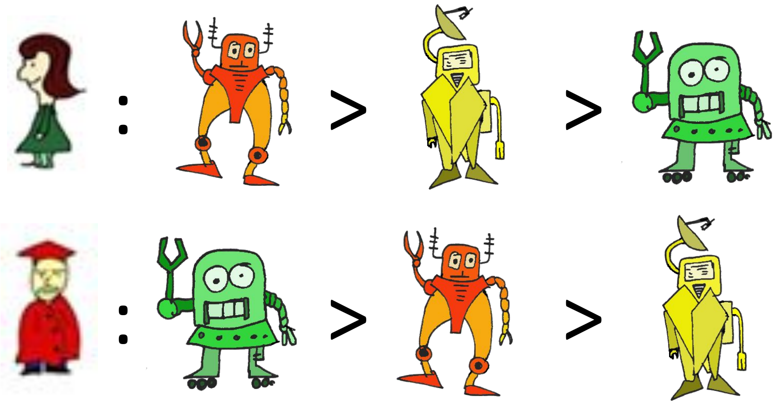
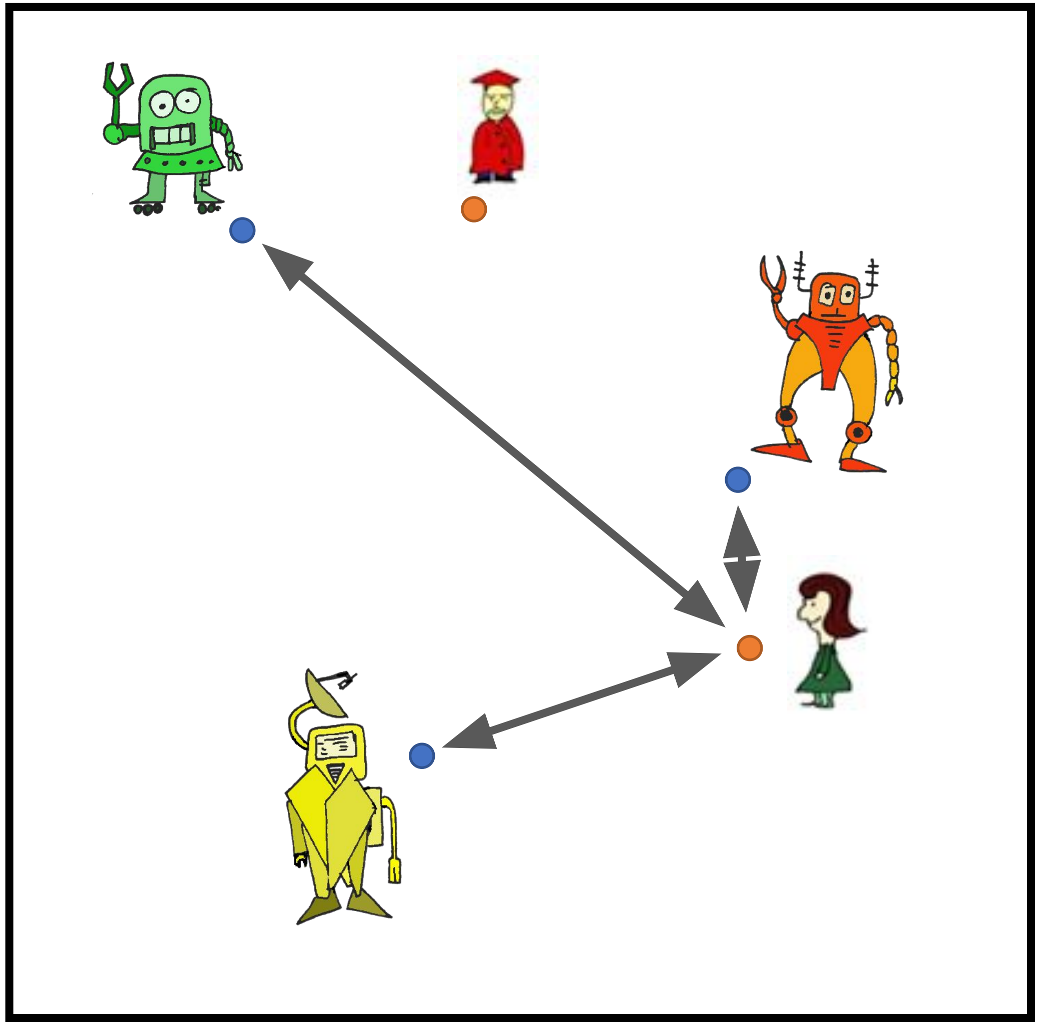




Microscope of Structured Domains

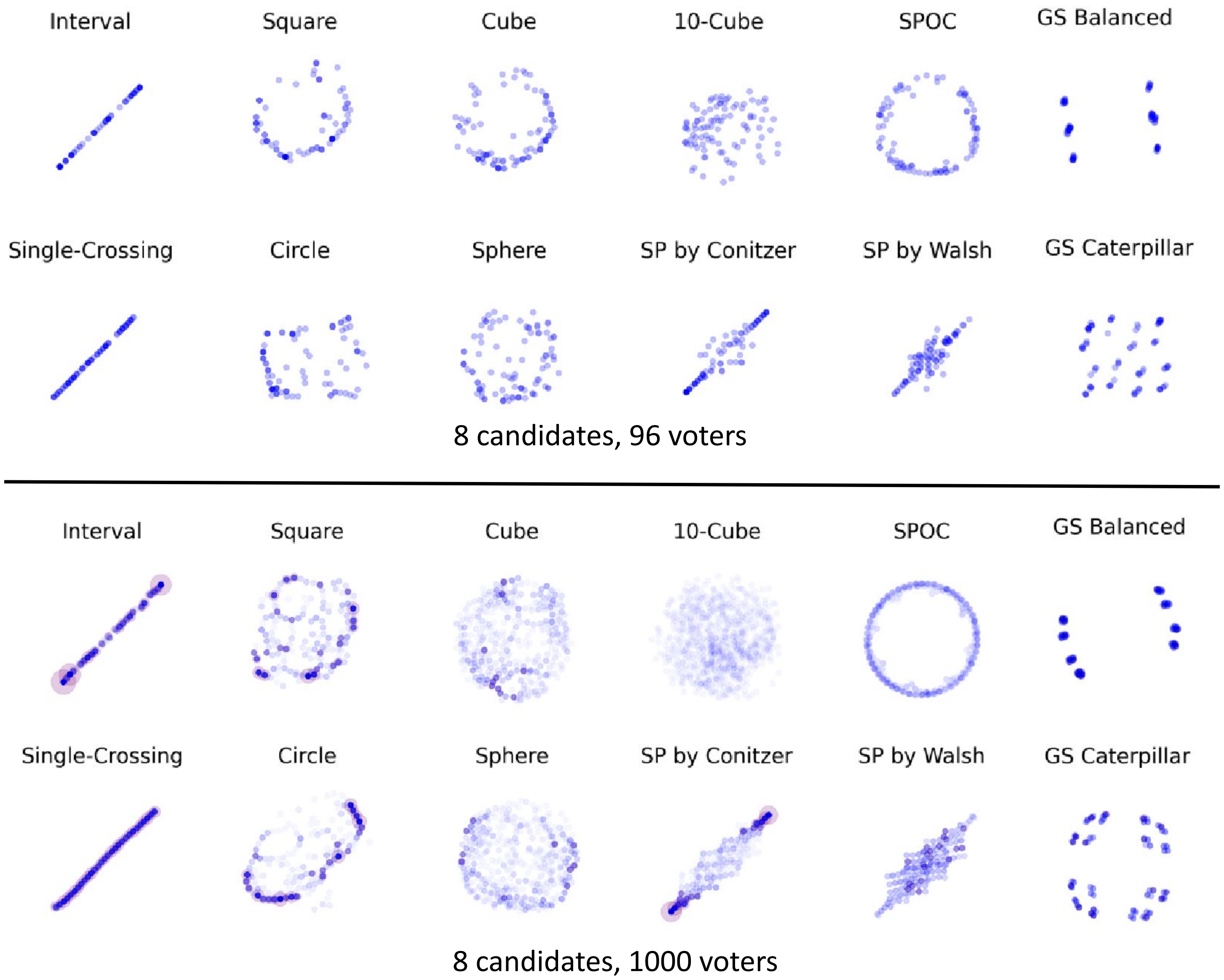
Euclidean Model: Choose points for the voters and candidates from Euclidean space R^t. Voter *v* prefers candidate *x* to *y* if *x*'s point is closer to *v* than *y*'s.

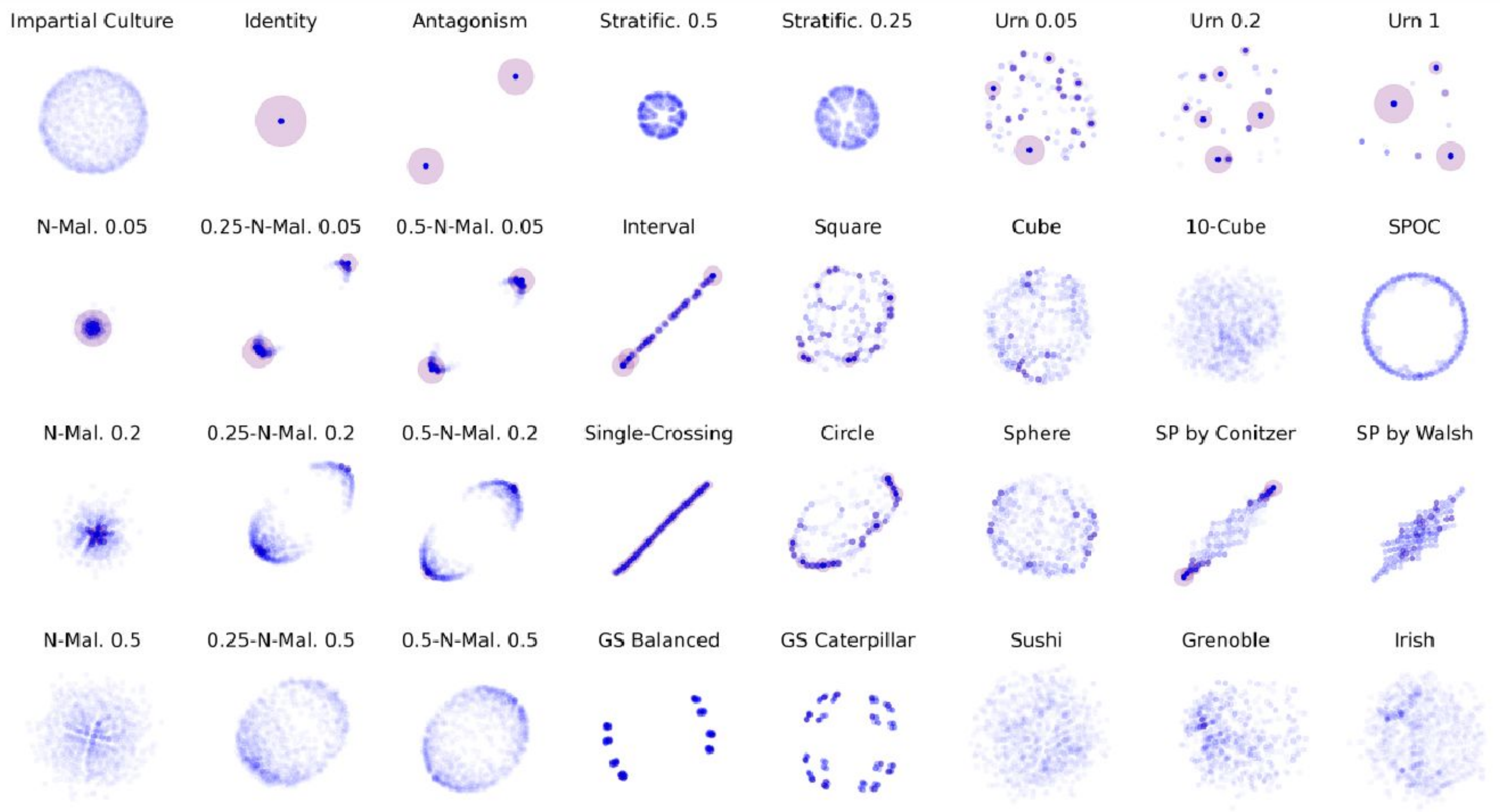
Single-Peaked: There is societal axis (order of the of the candidates). Every single-peaked vote for this axis satisfies the property that „for each t, the top t candidates form an interval on the axis".

SPOC: Like SP, but the axis is cyclic

Single-Crossing: It is possible to order the voters so that as we go along this order, the relative ranking of two candidates changes at most once

Group-Separable: Trees, trees everywhere!



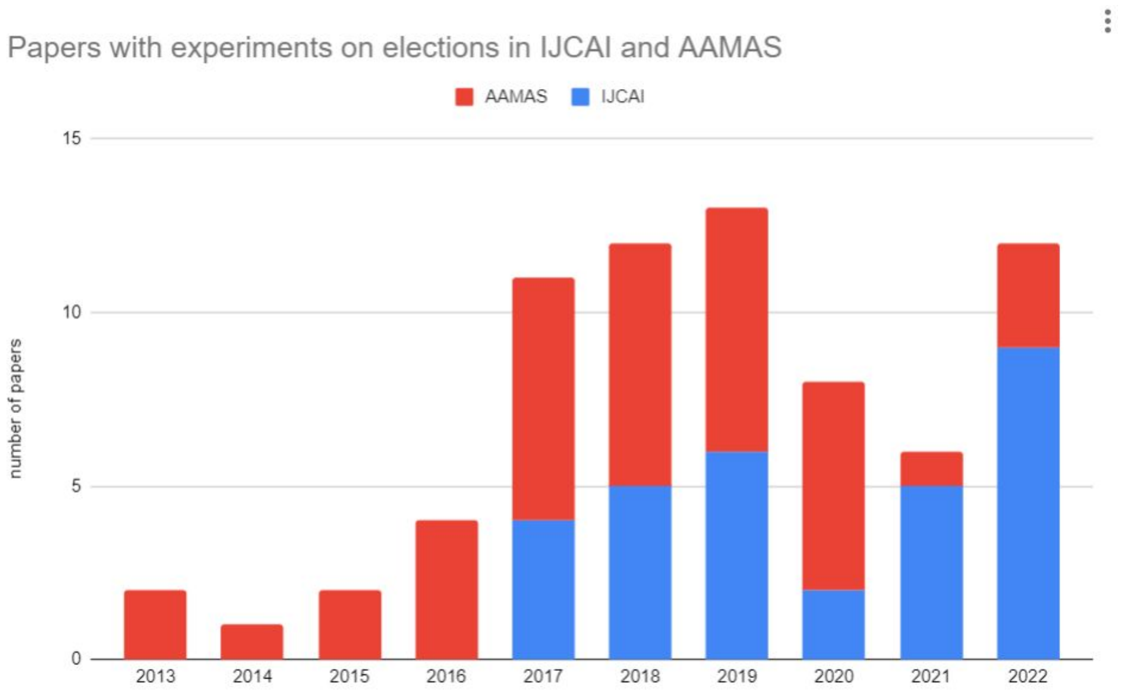


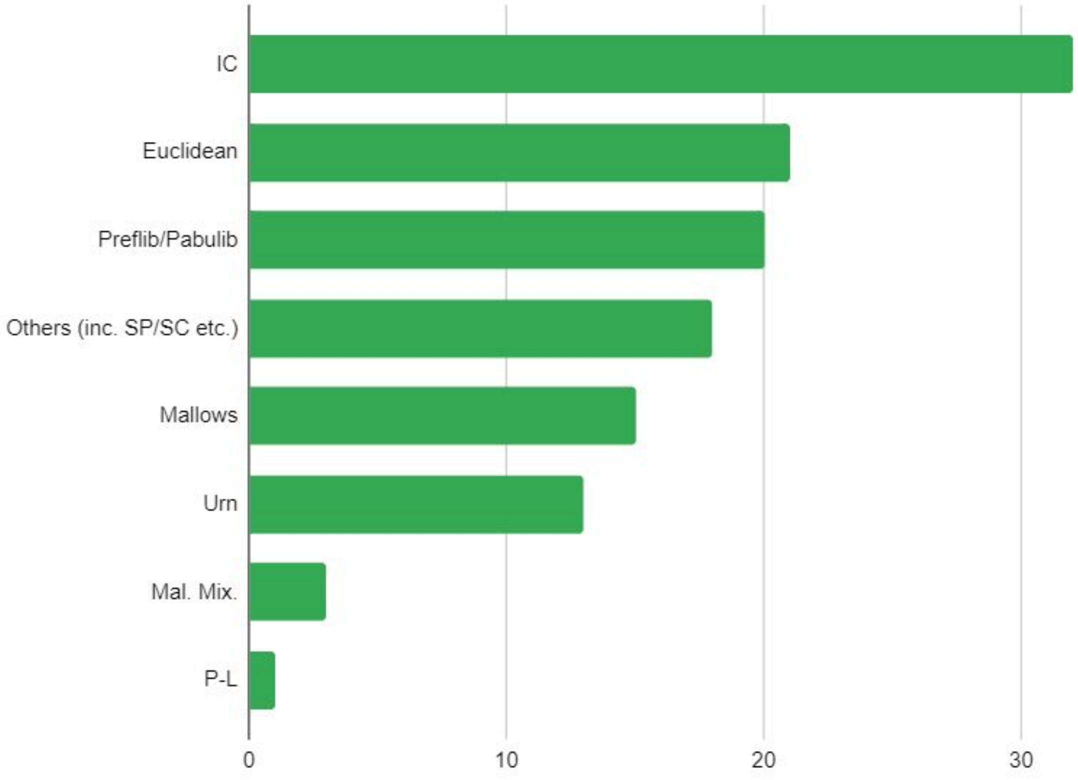
P. Faliszewski, A. Kaczmarczyk, K. Sornat, S. Szufa, T. Wąs, Diversity, Agreement and Polarization in Elections, IJCAI 2023

5
minutes

What’s Used?

Which Cultures Are Used?

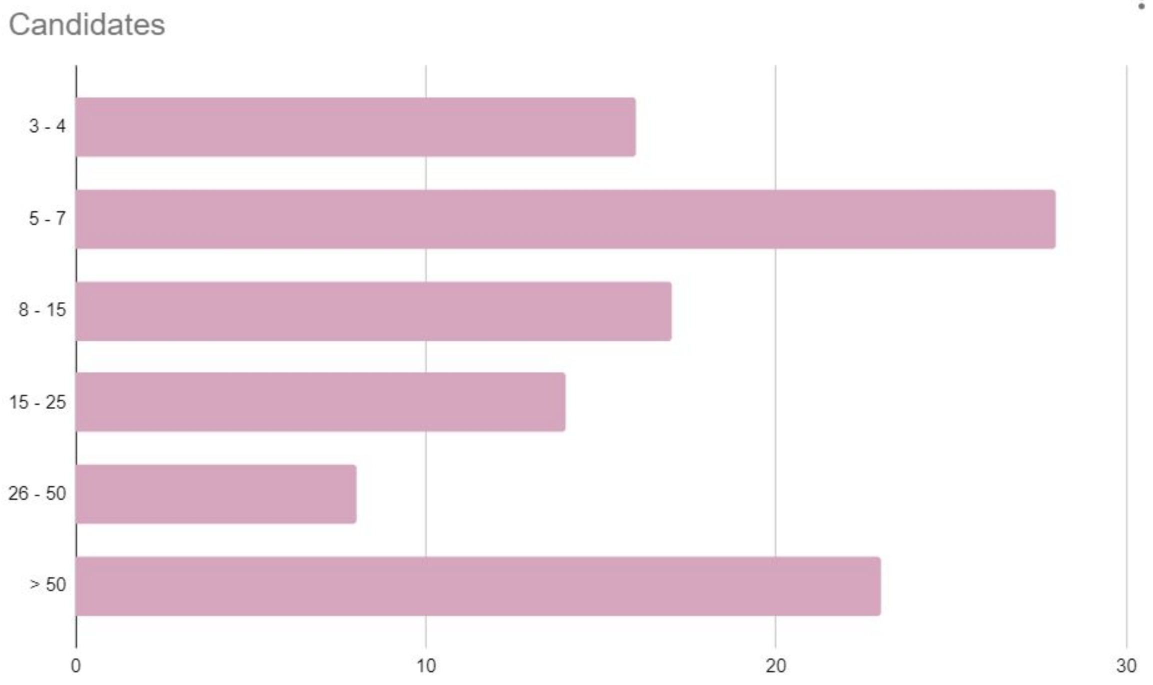


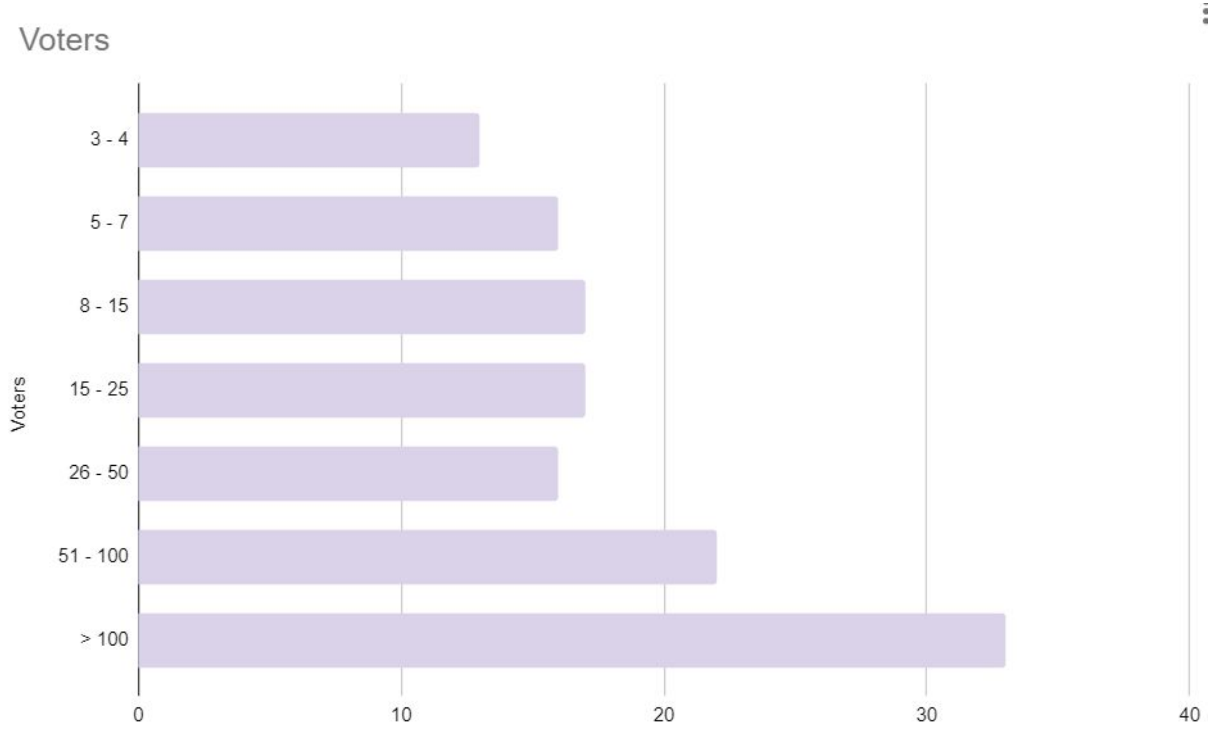


Common statistical cultures in IJCAI/AAMAS research (just a snapshot! Now looking at AAAI and others!)

Grain of salt warning!

What Election Sizes?





Common statistical cultures in IJCAI/AAMAS research (just a snapshot! Now looking at AAAI and others!)

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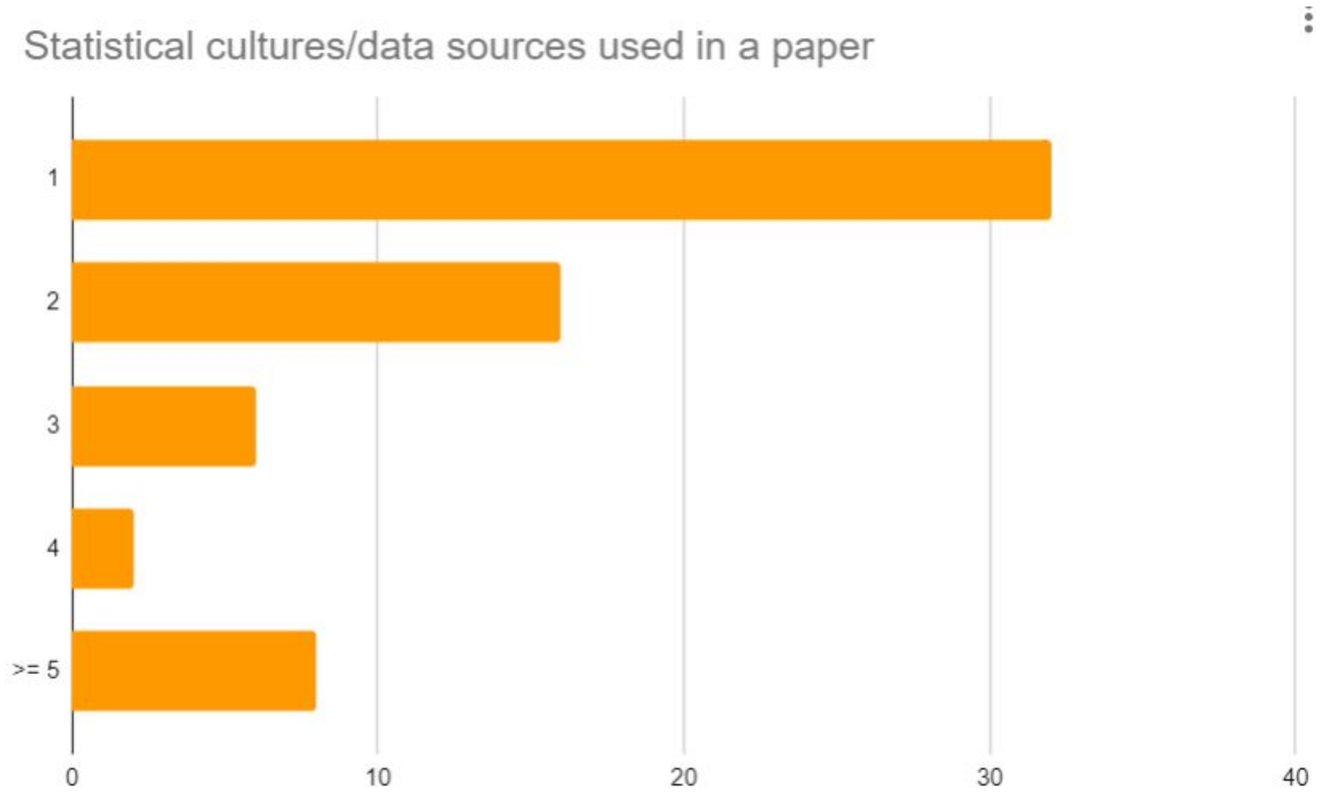
Number of Cultures/Data Sources



Common statistical cultures in IJCAI/AAMAS research (just a snapshot! Now looking at AAAI and others!)

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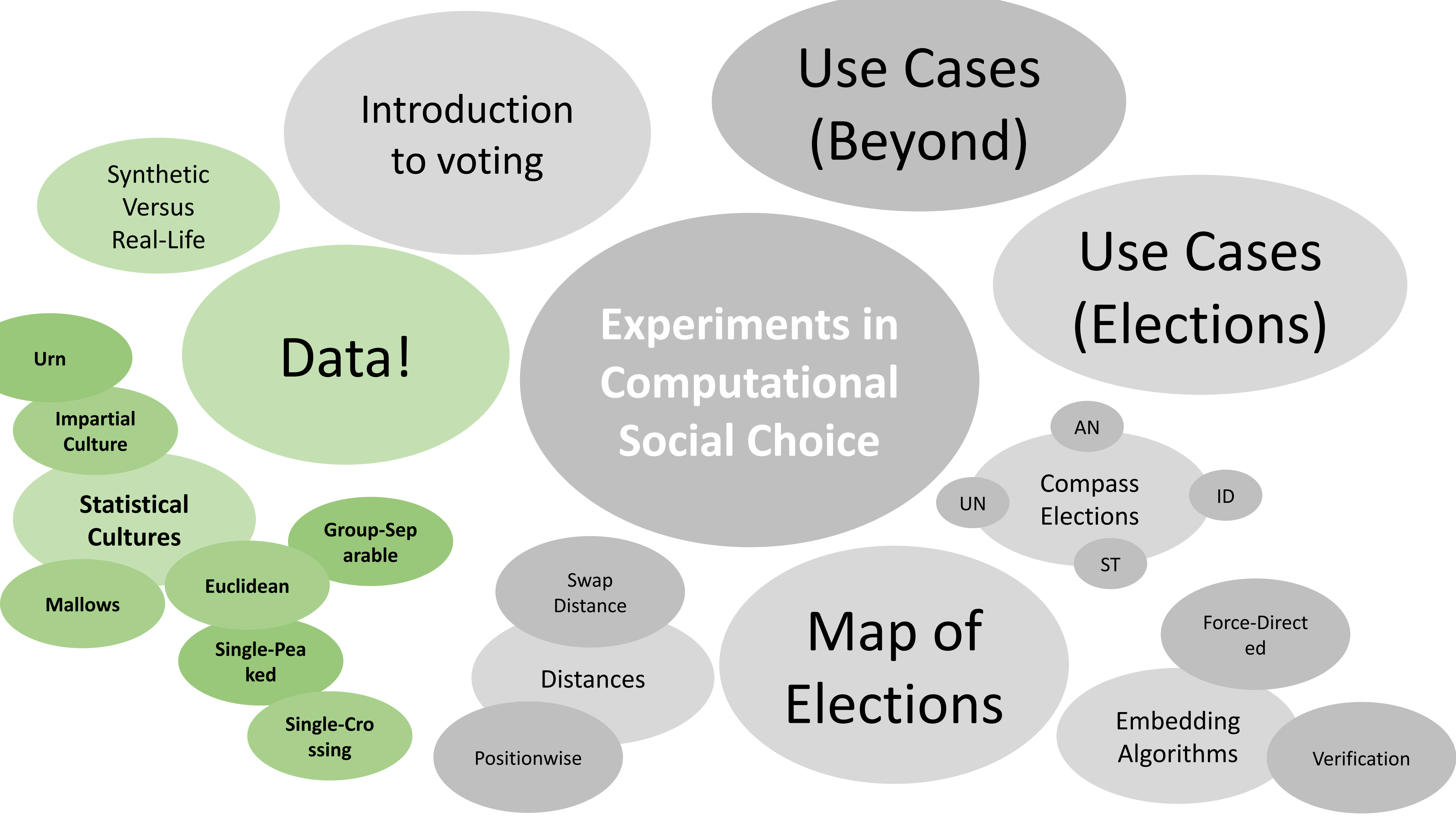
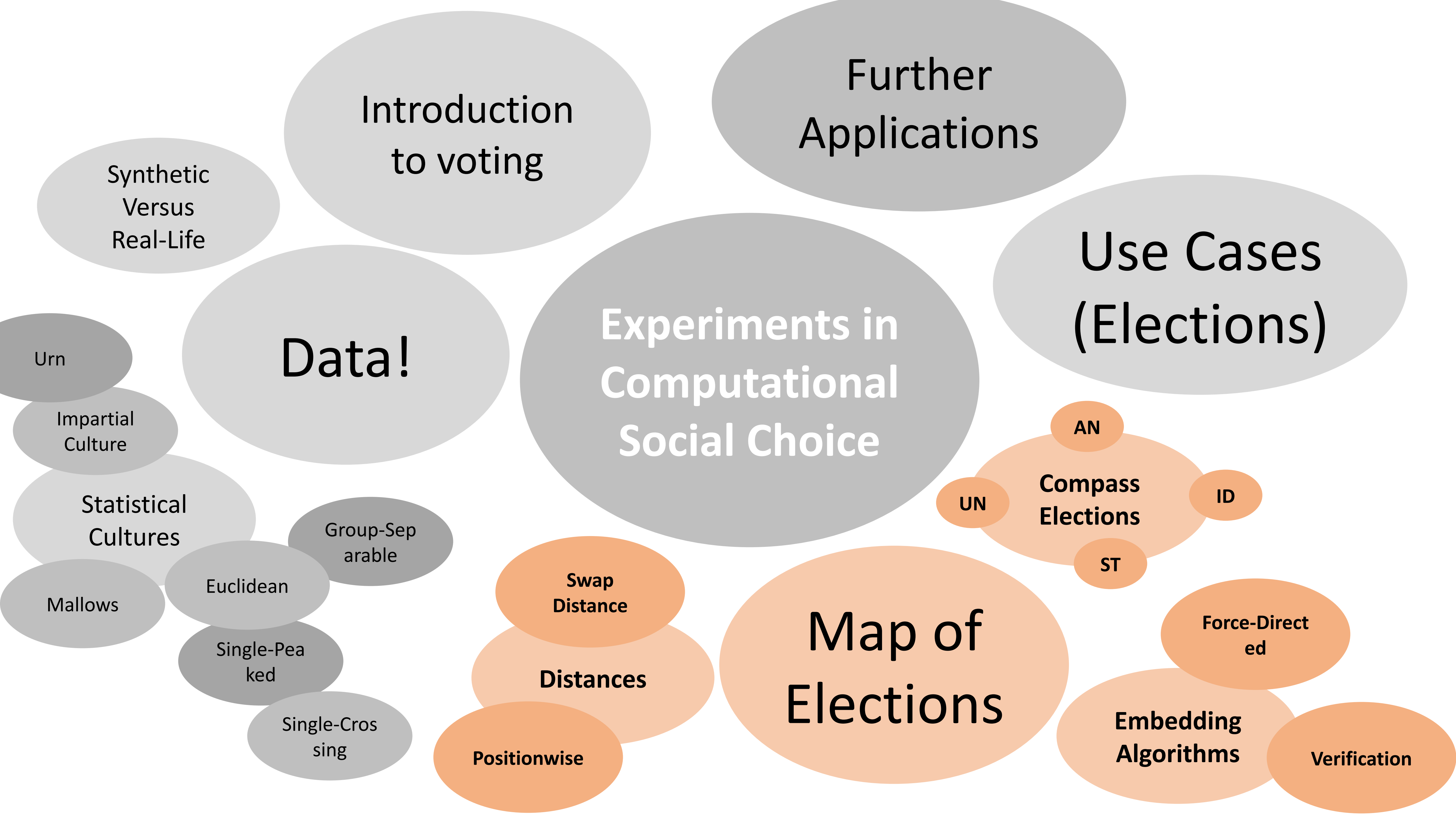

Introduction to voting
Use Cases (Beyond)
Synthetic Versus Real-Life
Use Cases (Elections)
Data!
Experiments in Computational Social Choice
Urn
Impartial Culture
Statistical Cultures
AN
Compass Elections
UN
ID
ST
Group-Separable
Euclidean
Mallows
Swap Distance
Map of Elections
Force-Directed
Single-Peaked
Distances
Single-Crossing
Embedding Algorithms
Positionwise
Verification


Introduction to voting
Further Applications
Synthetic Versus Real-Life
Use Cases (Elections)
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Urn
Impartial Culture
Statistical Cultures
Group-Sep arable
Mallows
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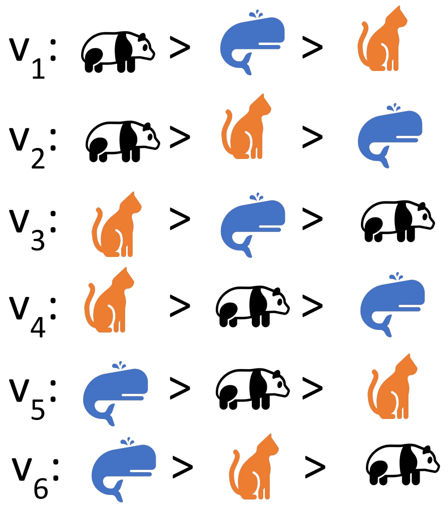
Single-Pea ked
Single-Cros sing
AN
Compass Elections
UN
ID
ST
Swap Distance
Distances
Positionwise
Map of Elections
Force-Direct ed
Embedding Algorithms
Verification

30 minutes

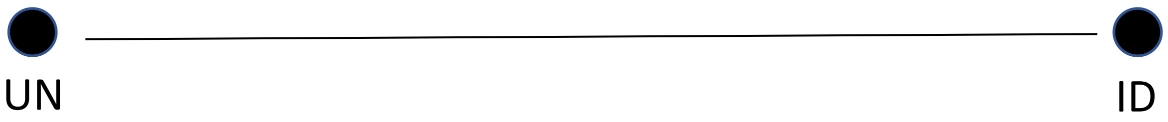
Map of Elections

How different?

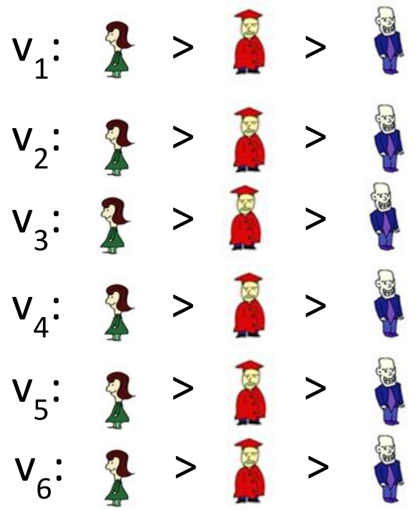


all possible preference orders

uniformity



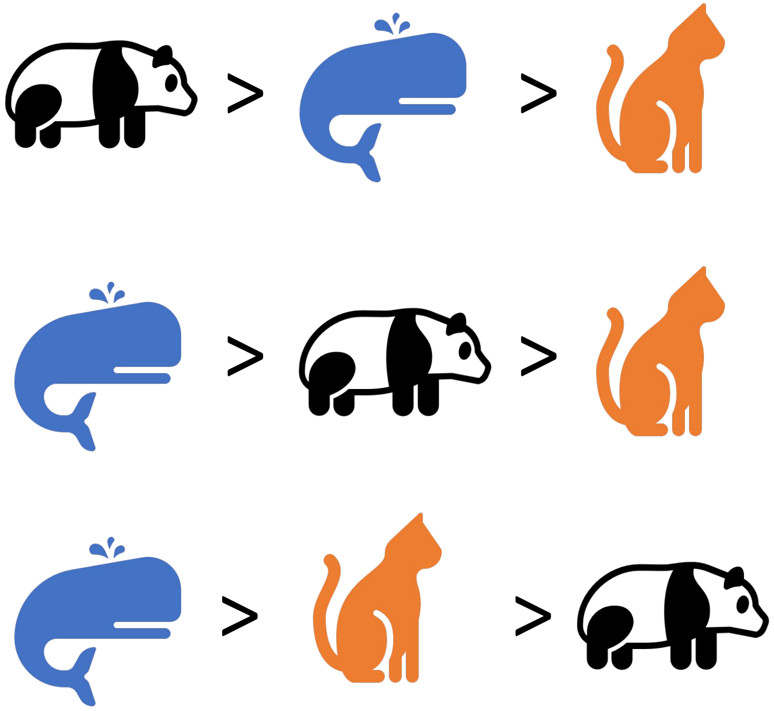
Count the number of swaps that make the elections isomorphic (i.e., identical up to renaming the candidates and reordering the voters)

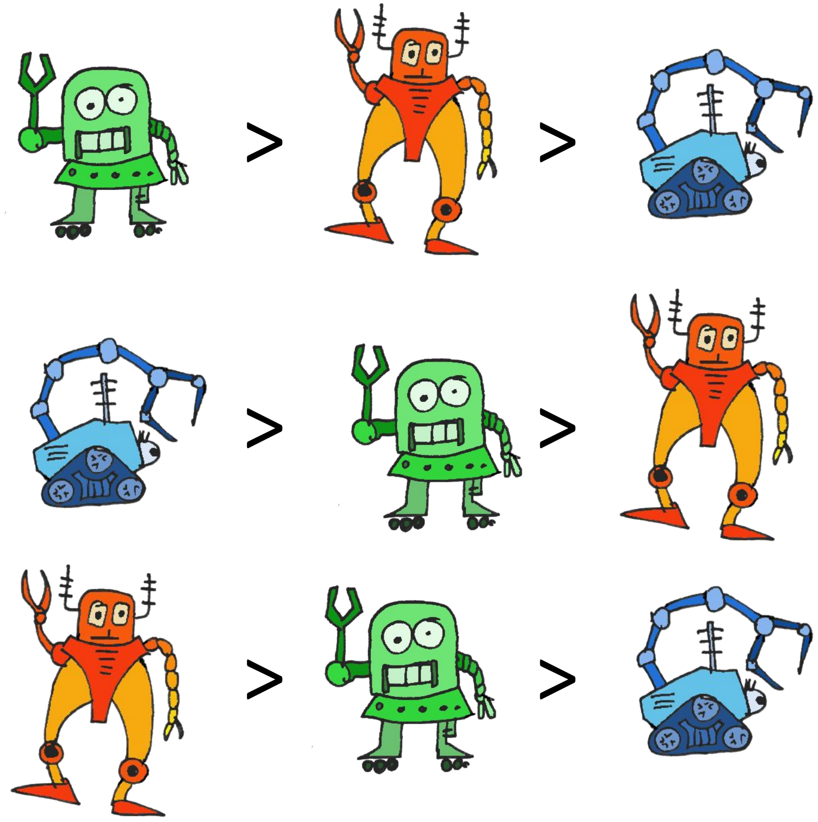


Identical preference orders

identity

Isomorphic Swap Distance

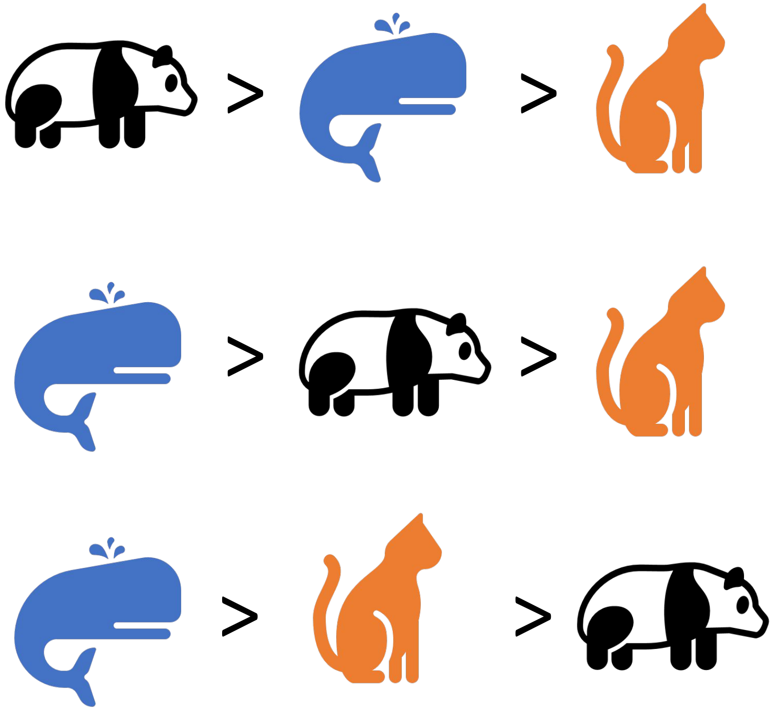


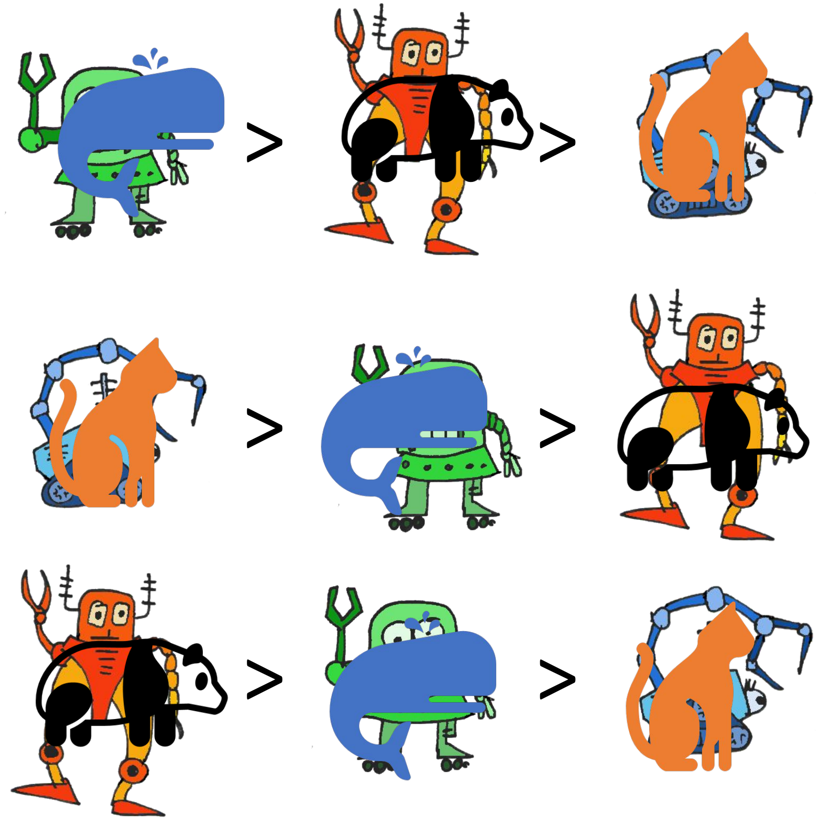


1. Match the candidates
2. Match the voters
3. Count the swaps

P. Faliszewski, P. Skowron, A. Slinko, S. Szufa, N. Talmon: How Similar Are Two Elections? AAAI 2019

Isomorphic Swap Distance





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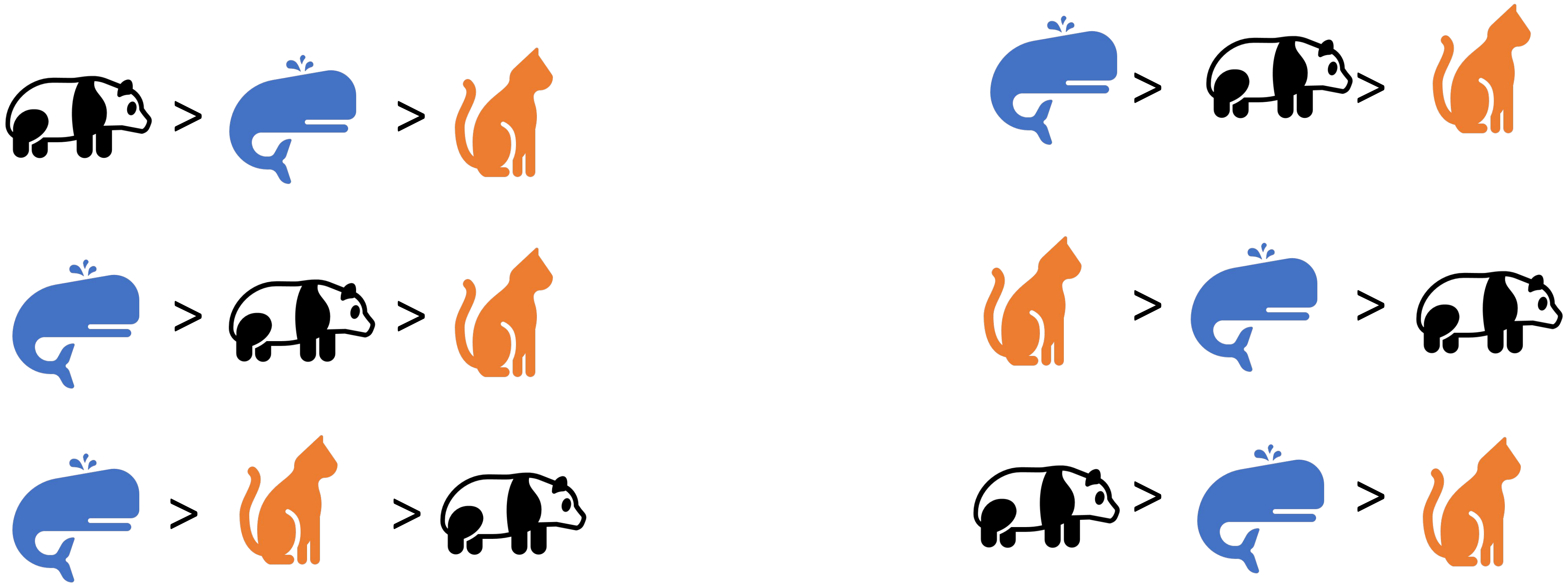

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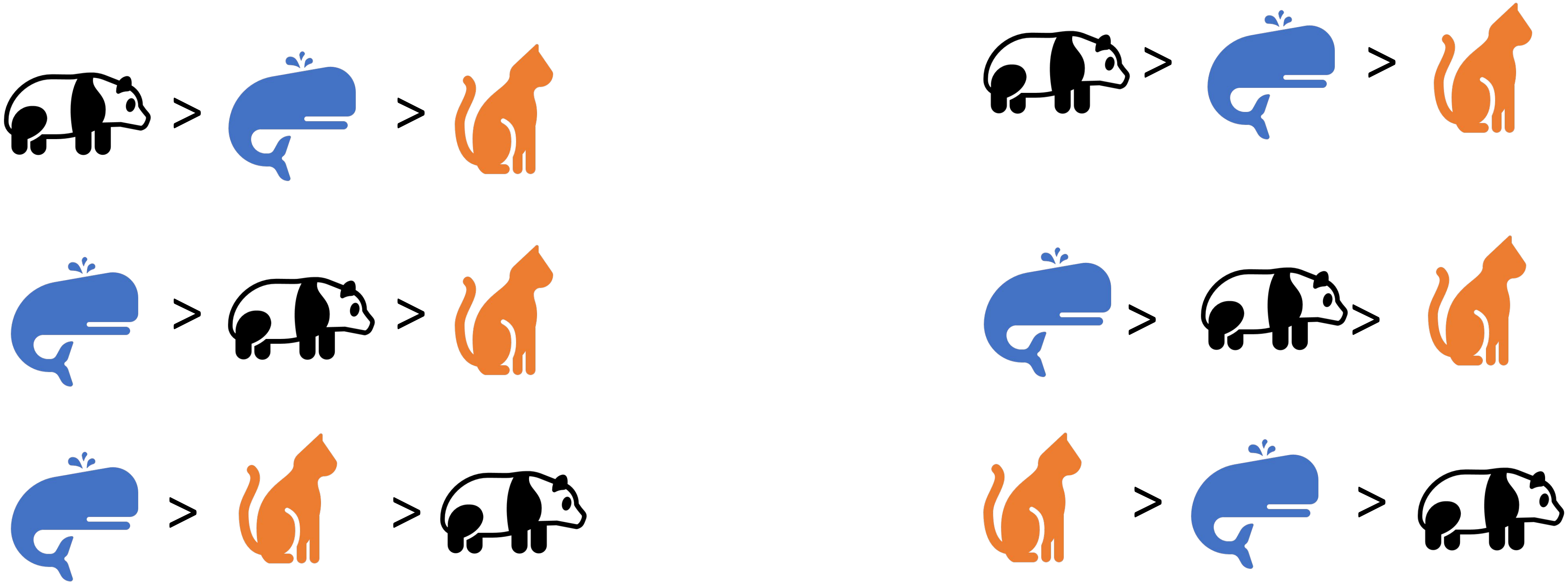

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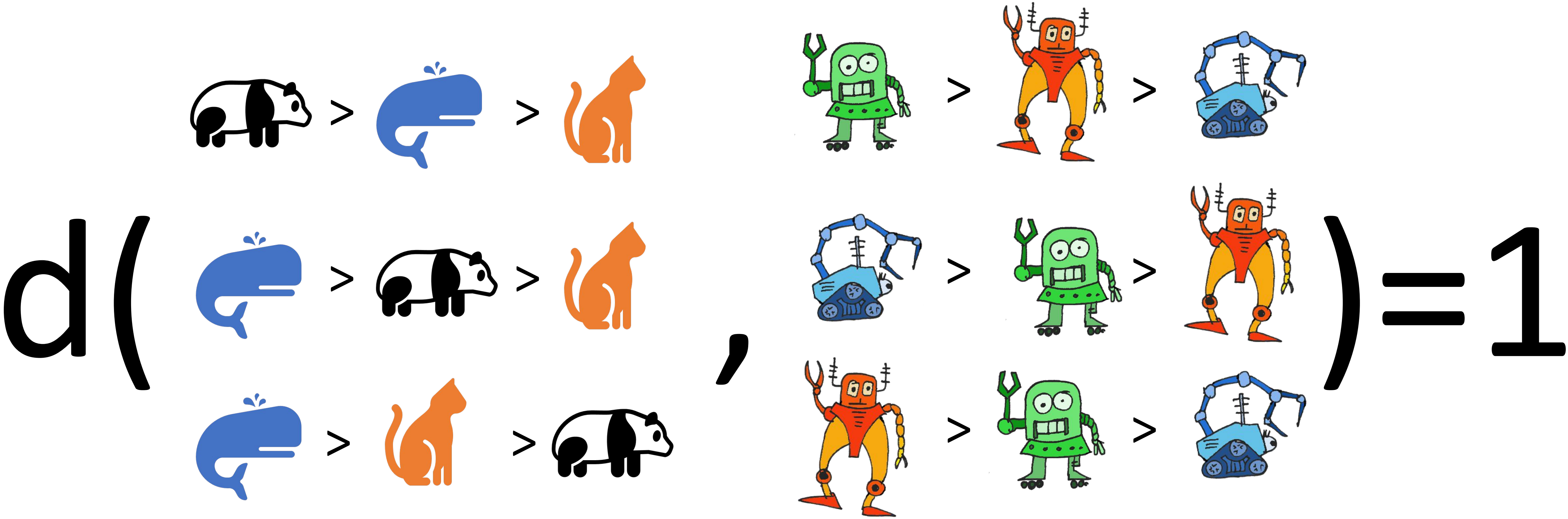

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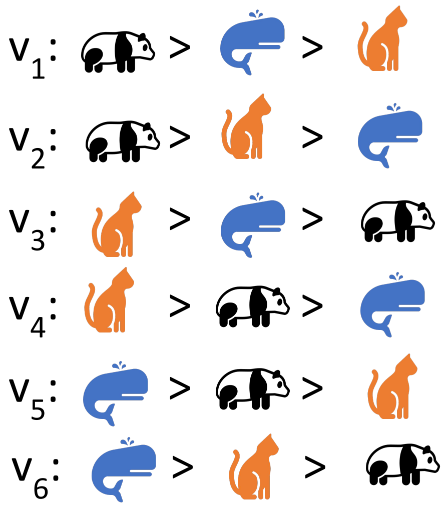
P. Faliszewski, P. Skowron, A. Slinko, S. Szufa, N. Talmon: How Similar Are Two Elections? AAAI 2019

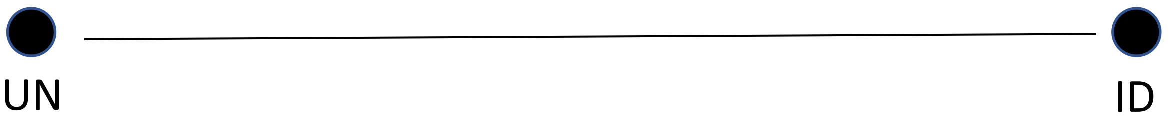
Thm. In an election with m candidates and $n = t*m!$ votes, every two elections are at distance at most $\frac{1}{4} n(m^2-m)$.



all possible preference orders

uniformity

$$\frac{1}{4} n(m^2-m)$$



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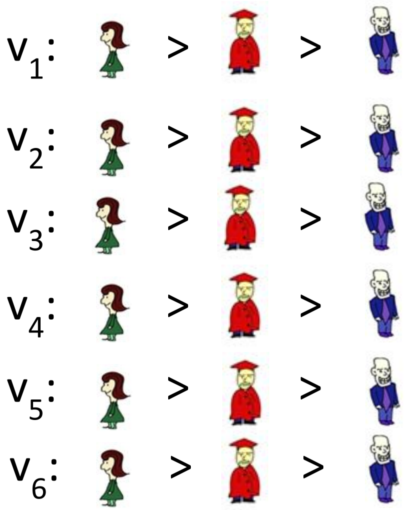
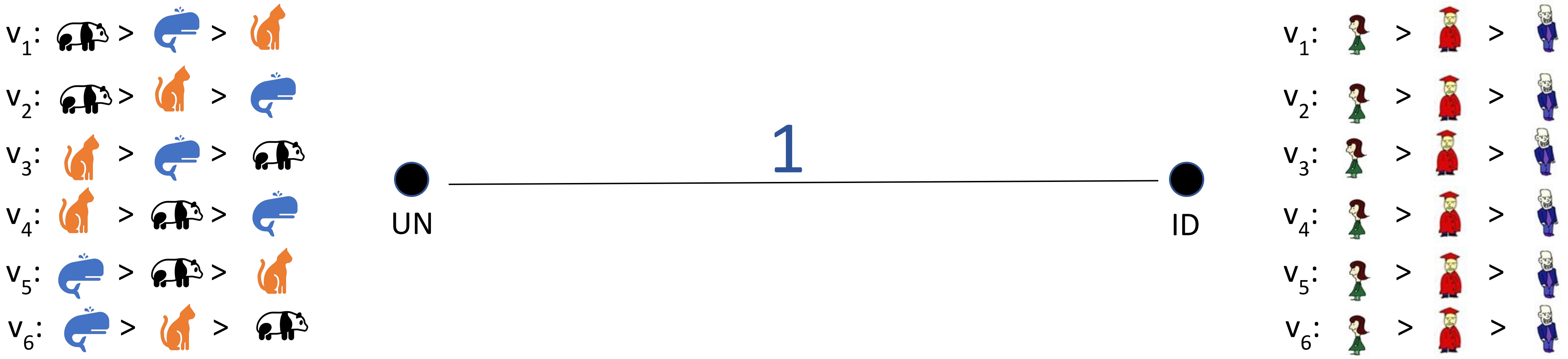


Identical preference orders

identity

N. Boehmer, P. Faliszewski, R. Niedermeier, S. Szufa, T. Wąs, Understanding Distance Measures Among Elections, IJCAI 2022



all possible preference orders

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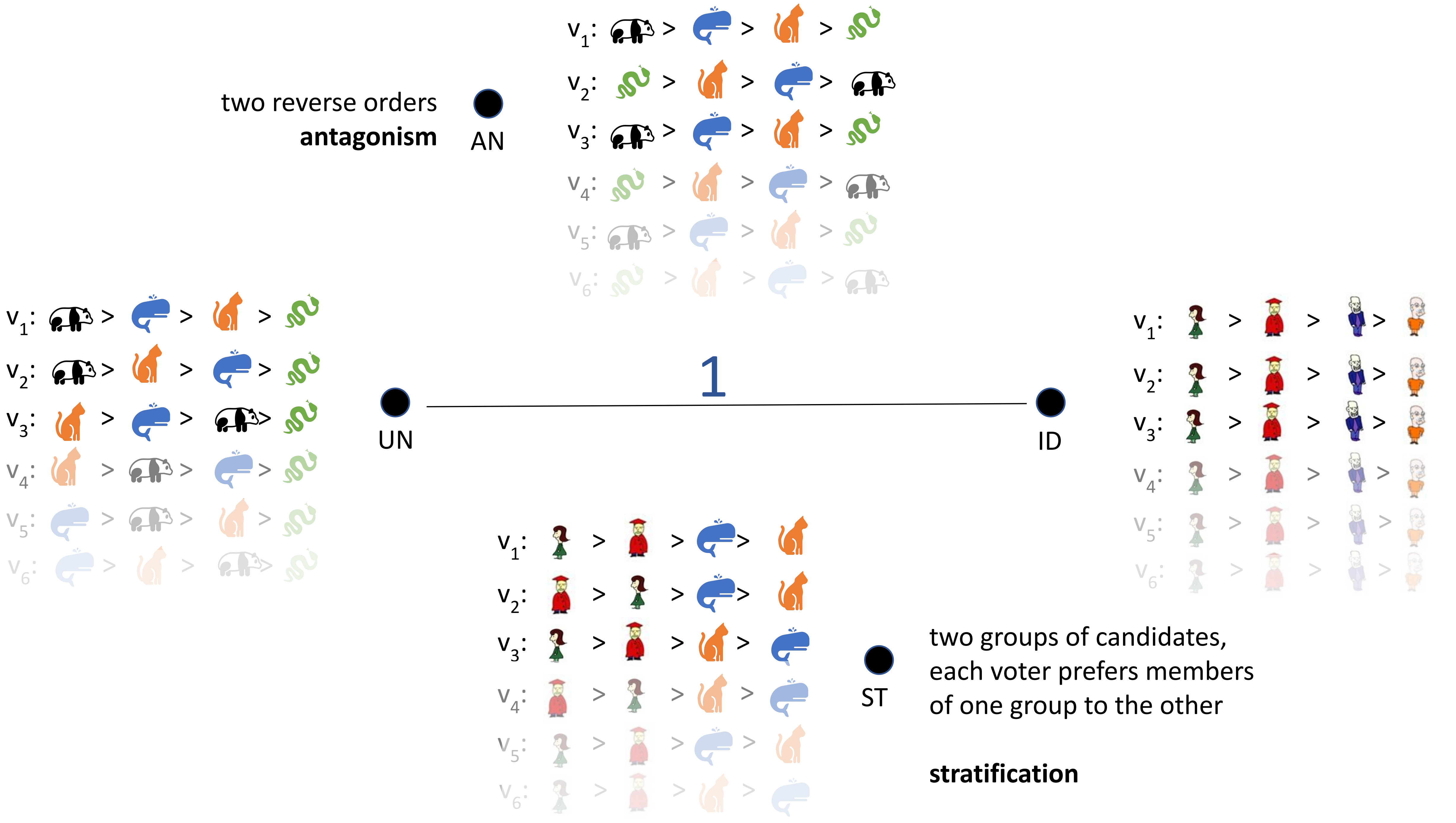
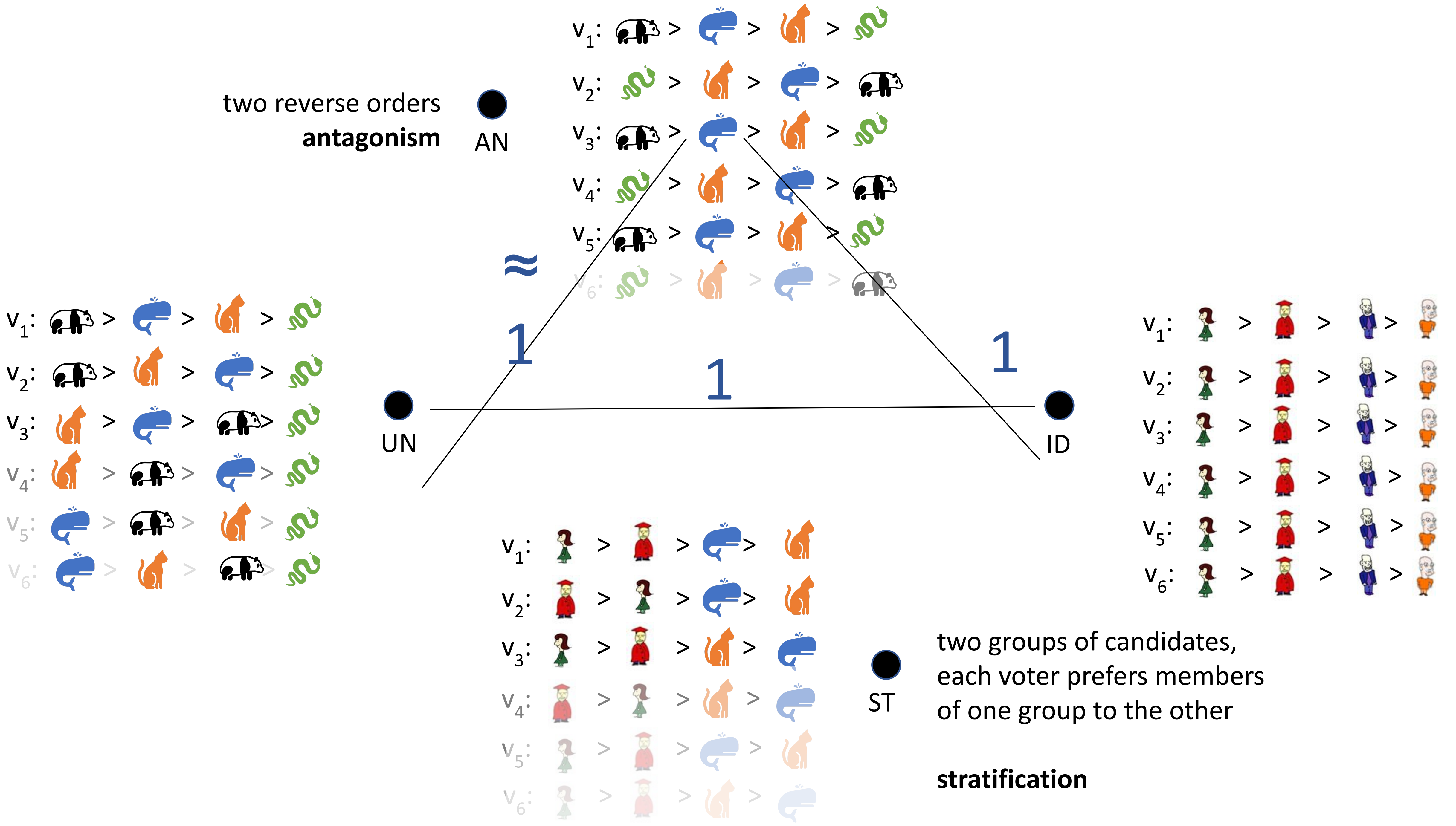
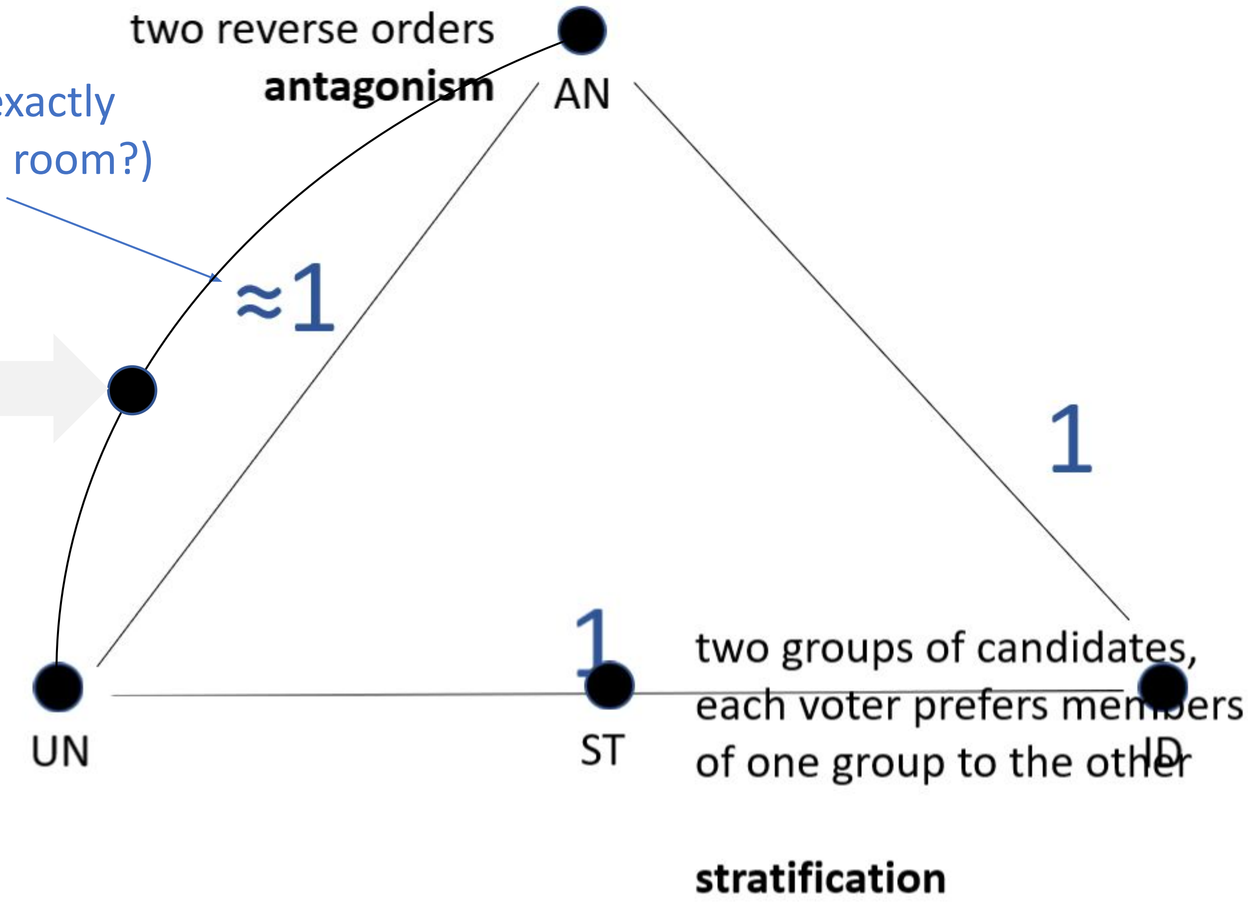

two reverse orders
antagonism
AN
UN
1
ID
ST
two groups of candidates, each voter prefers members of one group to the other
stratification

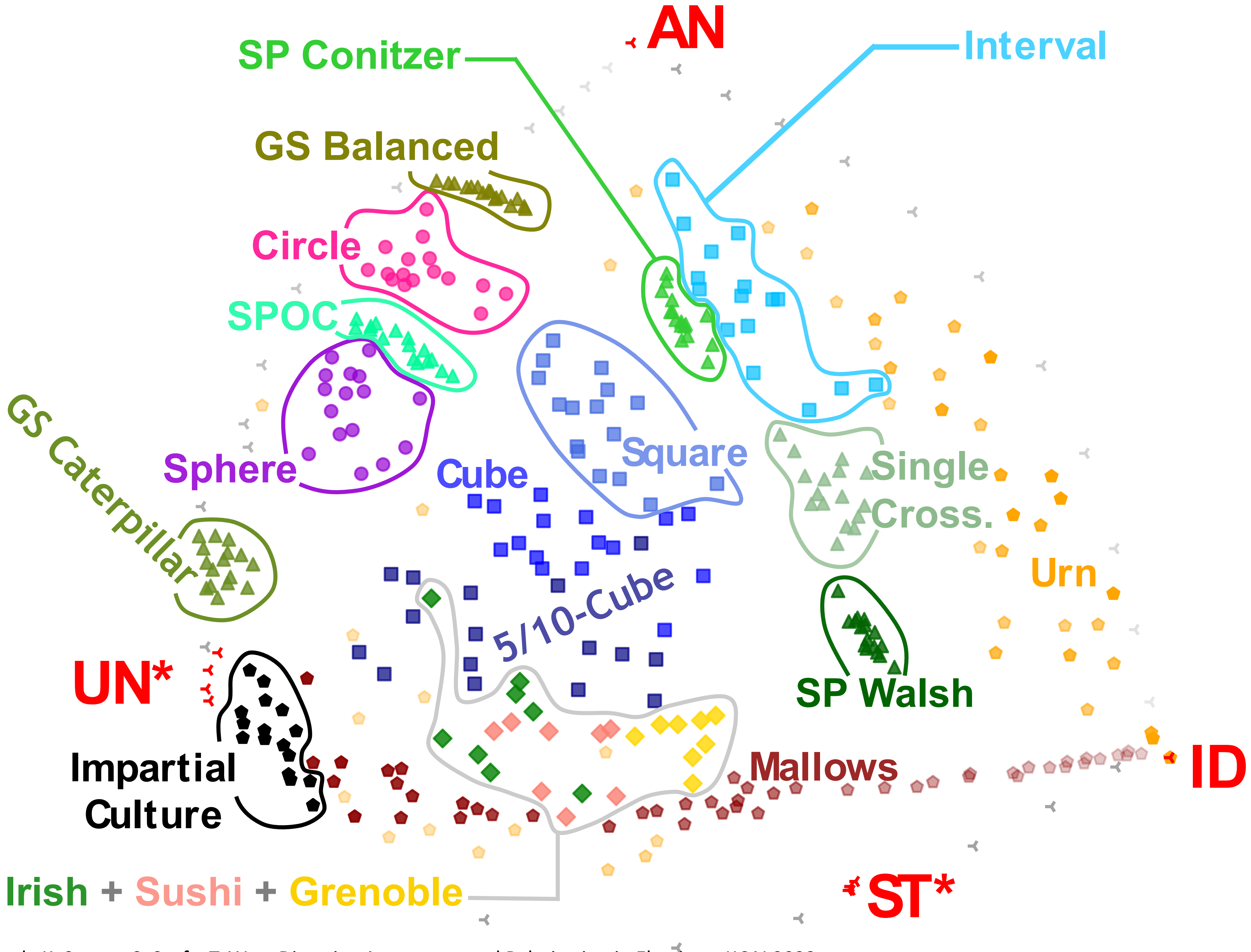

two reverse orders
antagonism
AN
UN
ID
ST
≈
1
1
1
two groups of candidates,
each voter prefers members
of one group to the other
stratification

Somehow difficult to compute exactly
(is there a mathematician in the room?)

Thm. An election is at (normalized) distance 1 from ID if and only if for all pairs of candidates *a* and *b*, half of the voters prefer *a* to *b*, and half of the voters prefer *b* to *a*.



V_6: > > >



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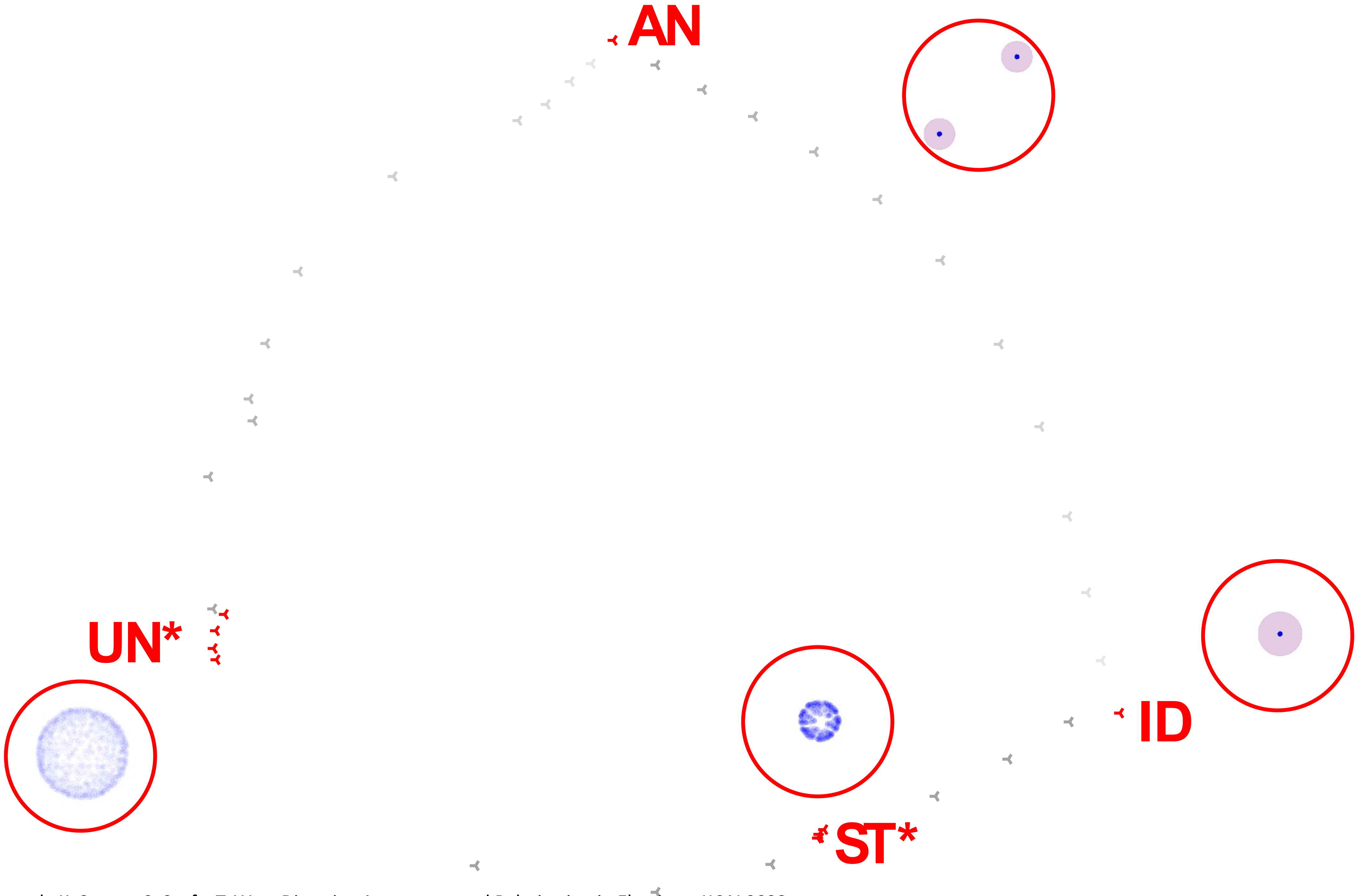

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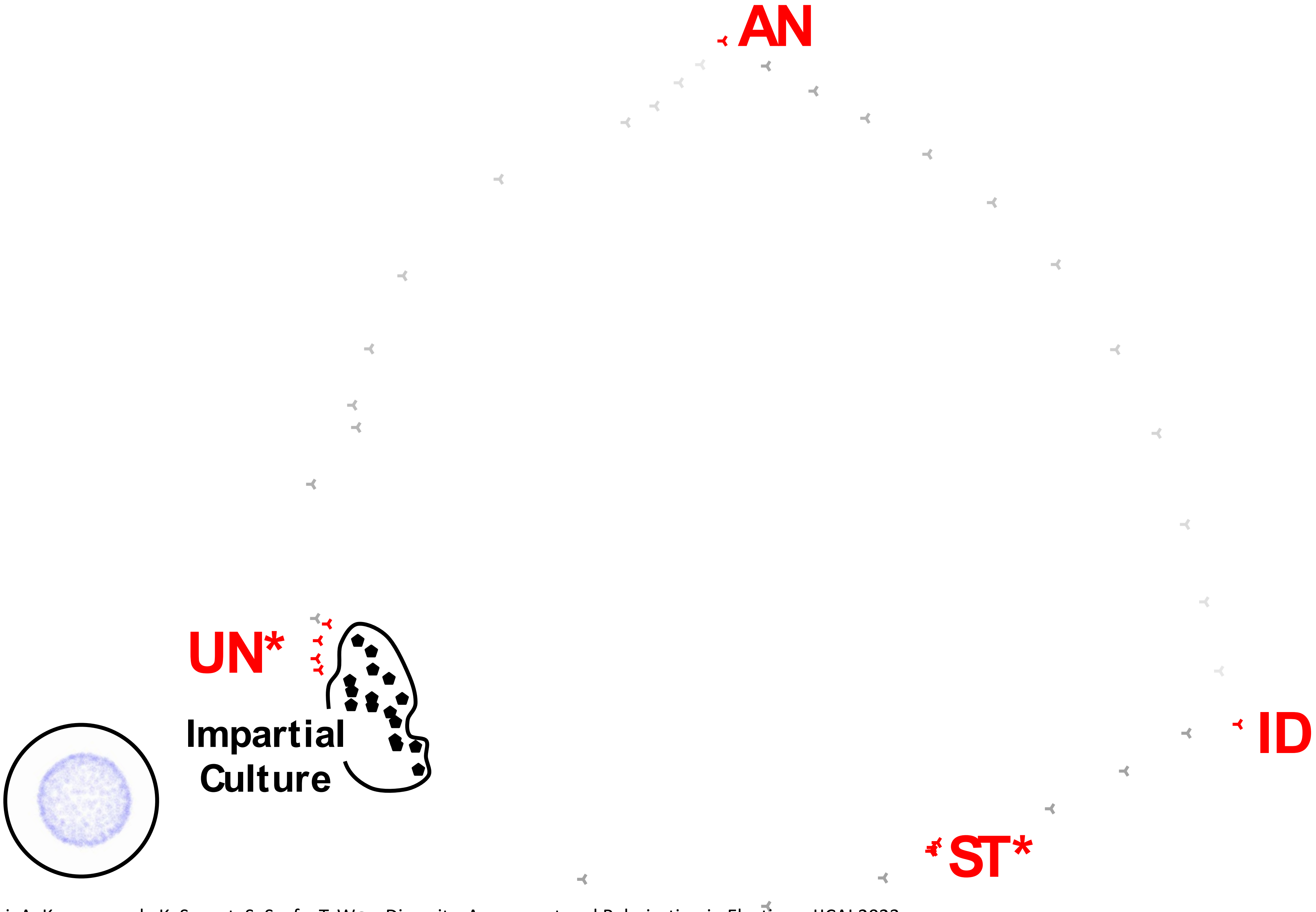

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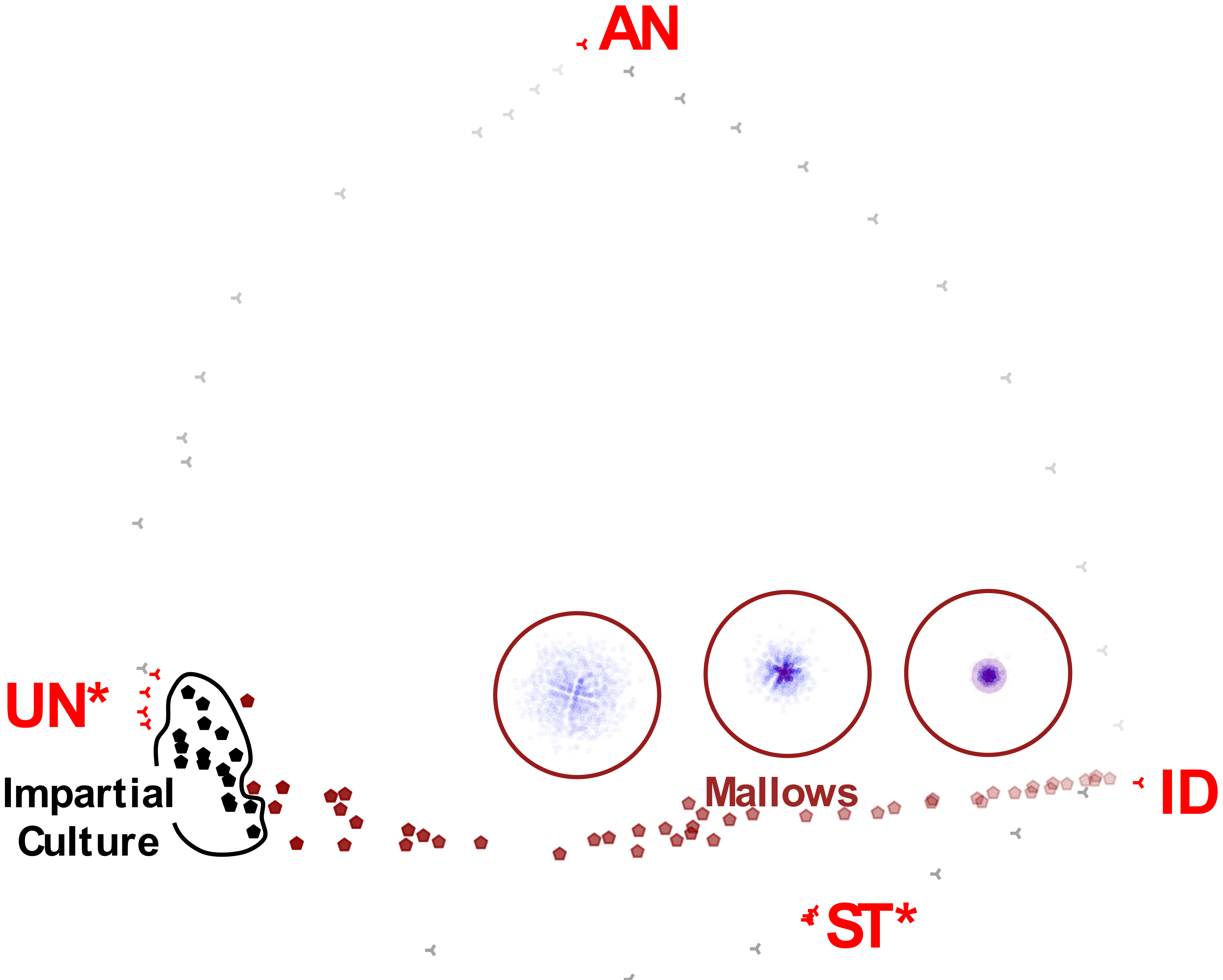

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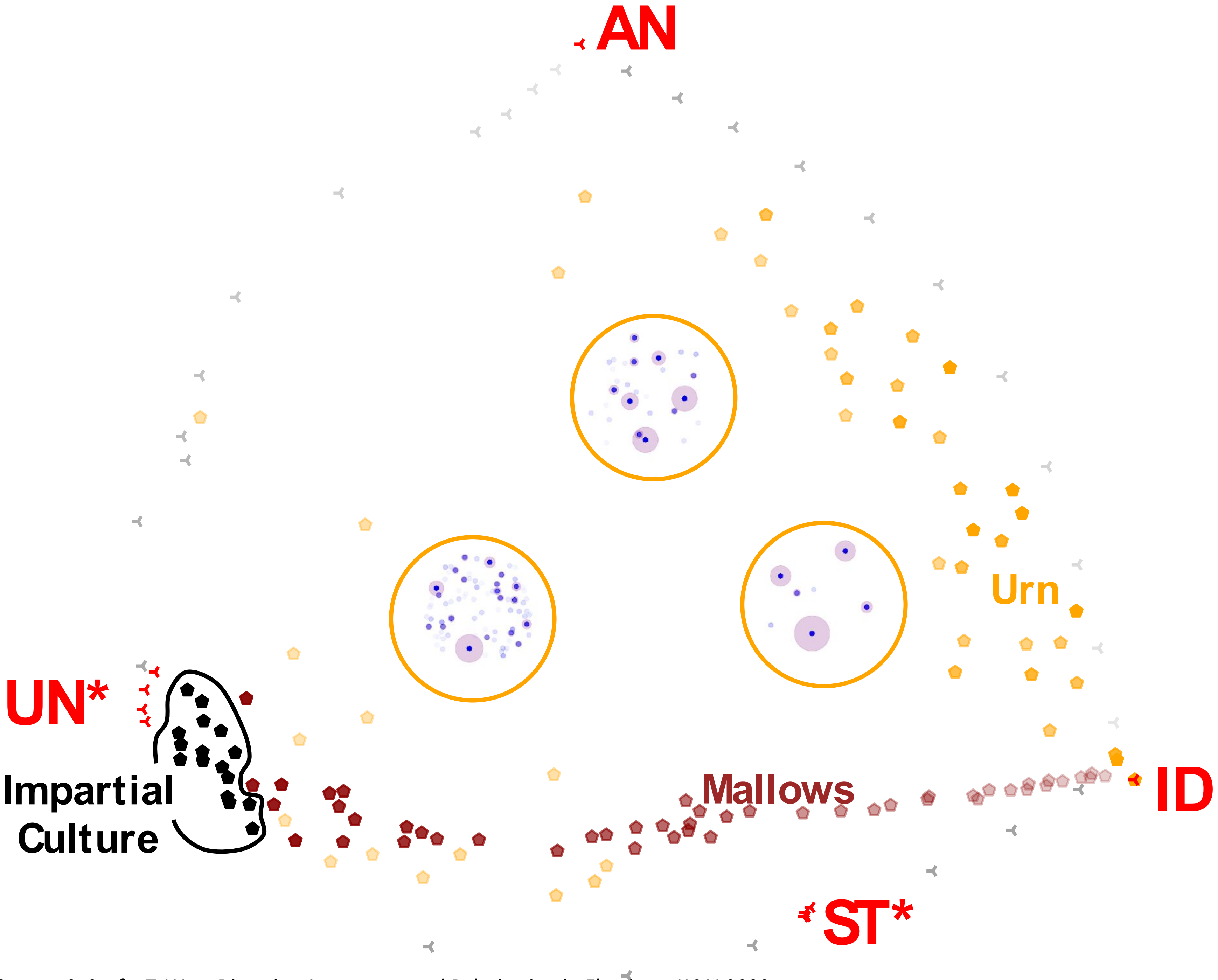

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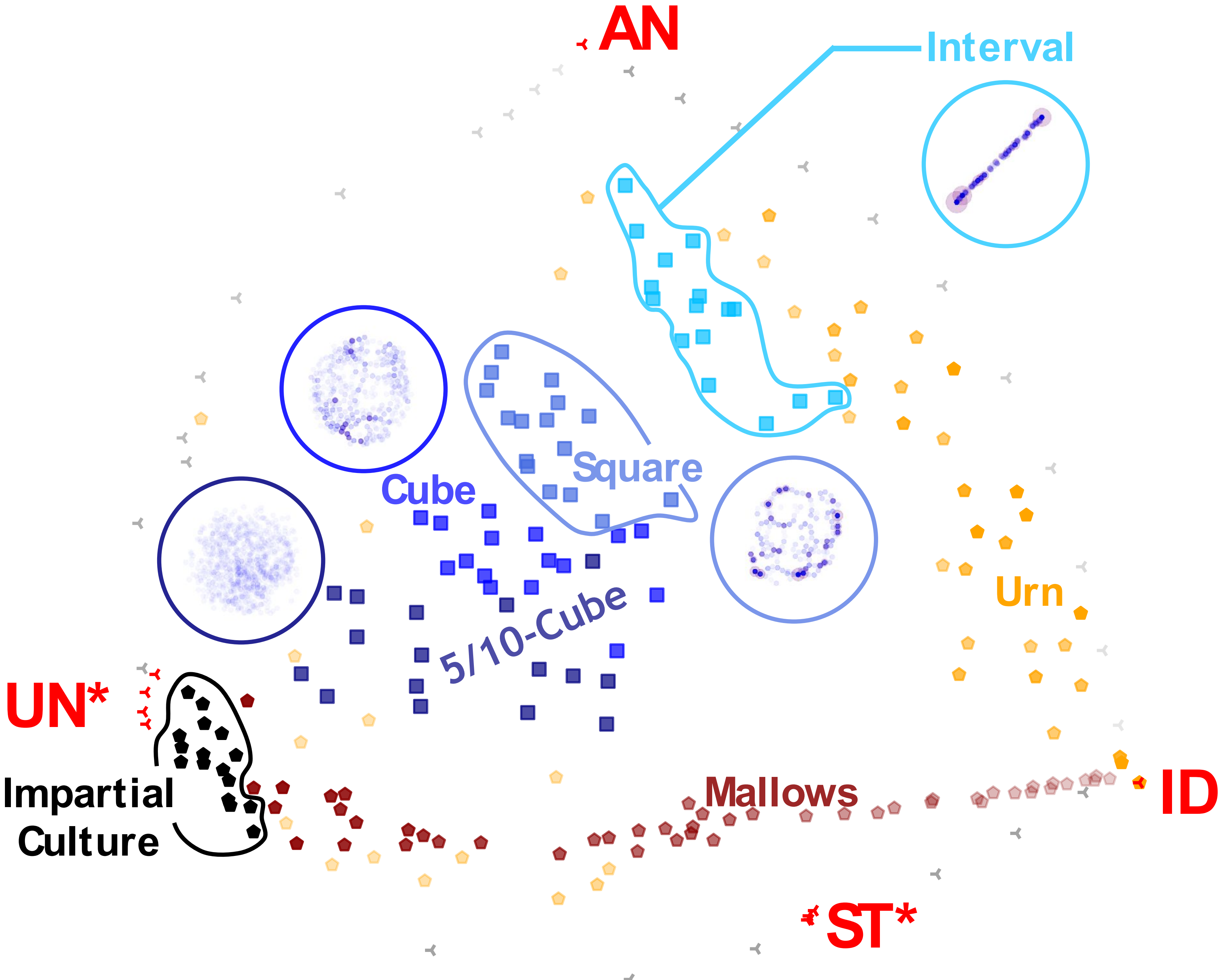

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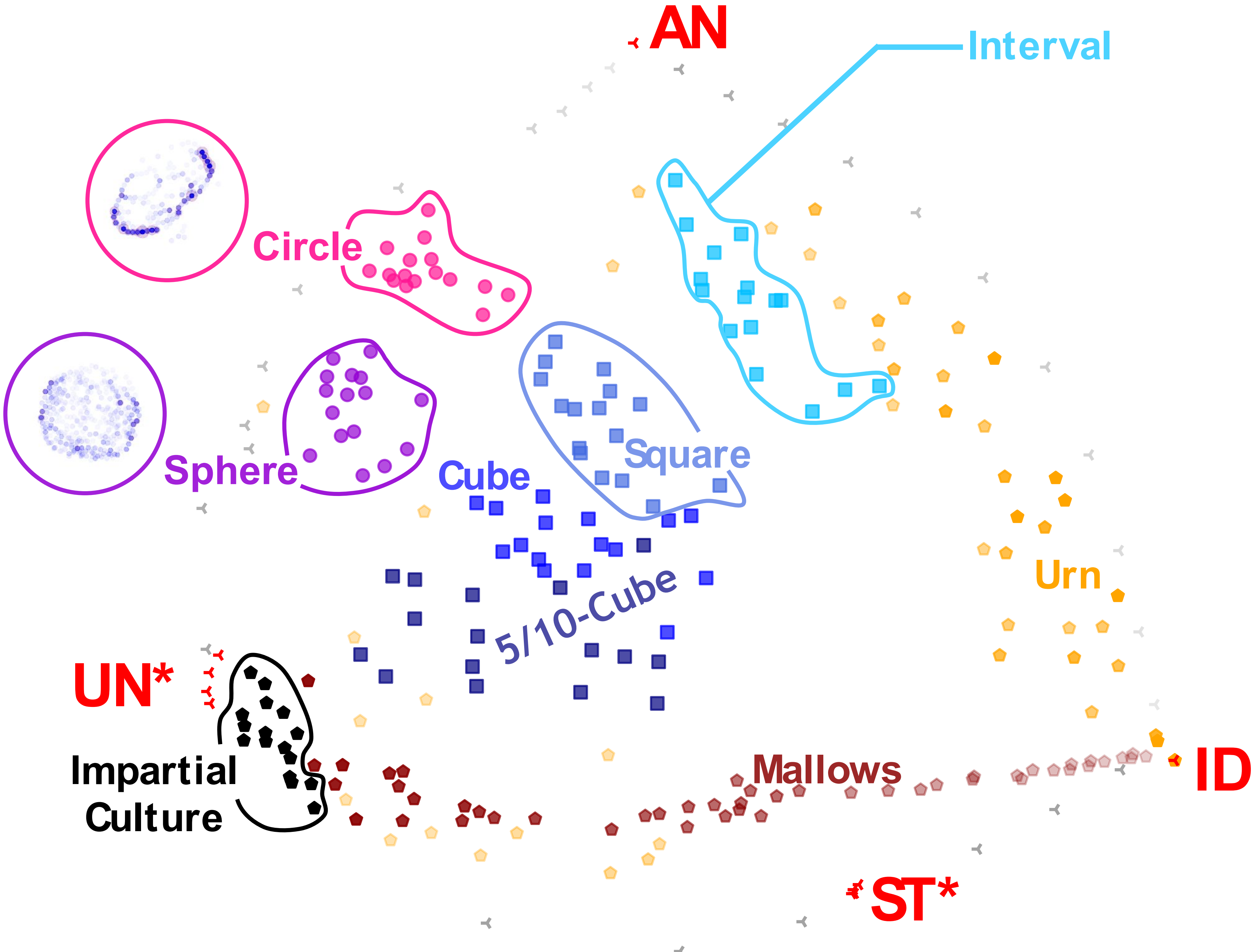

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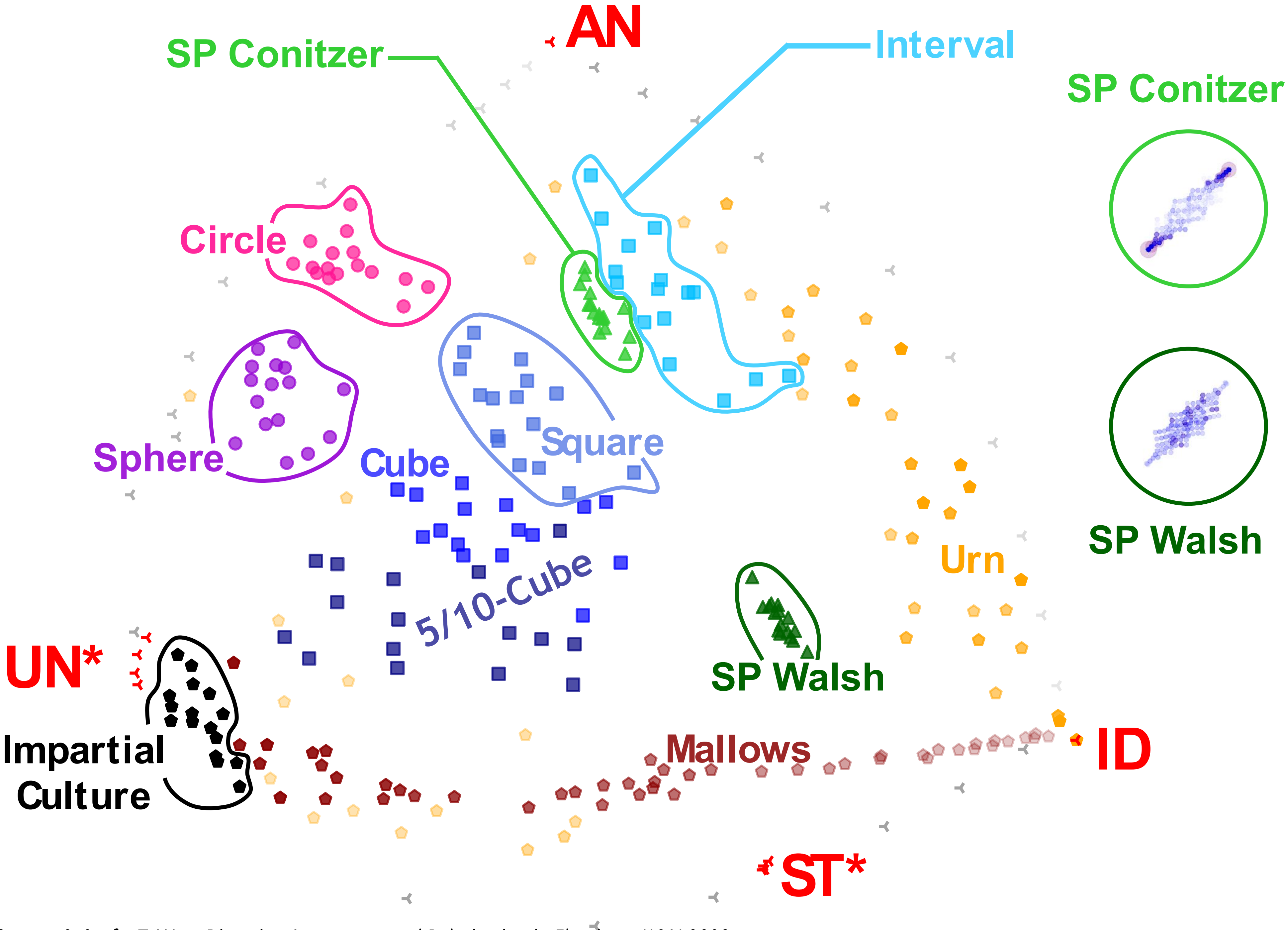

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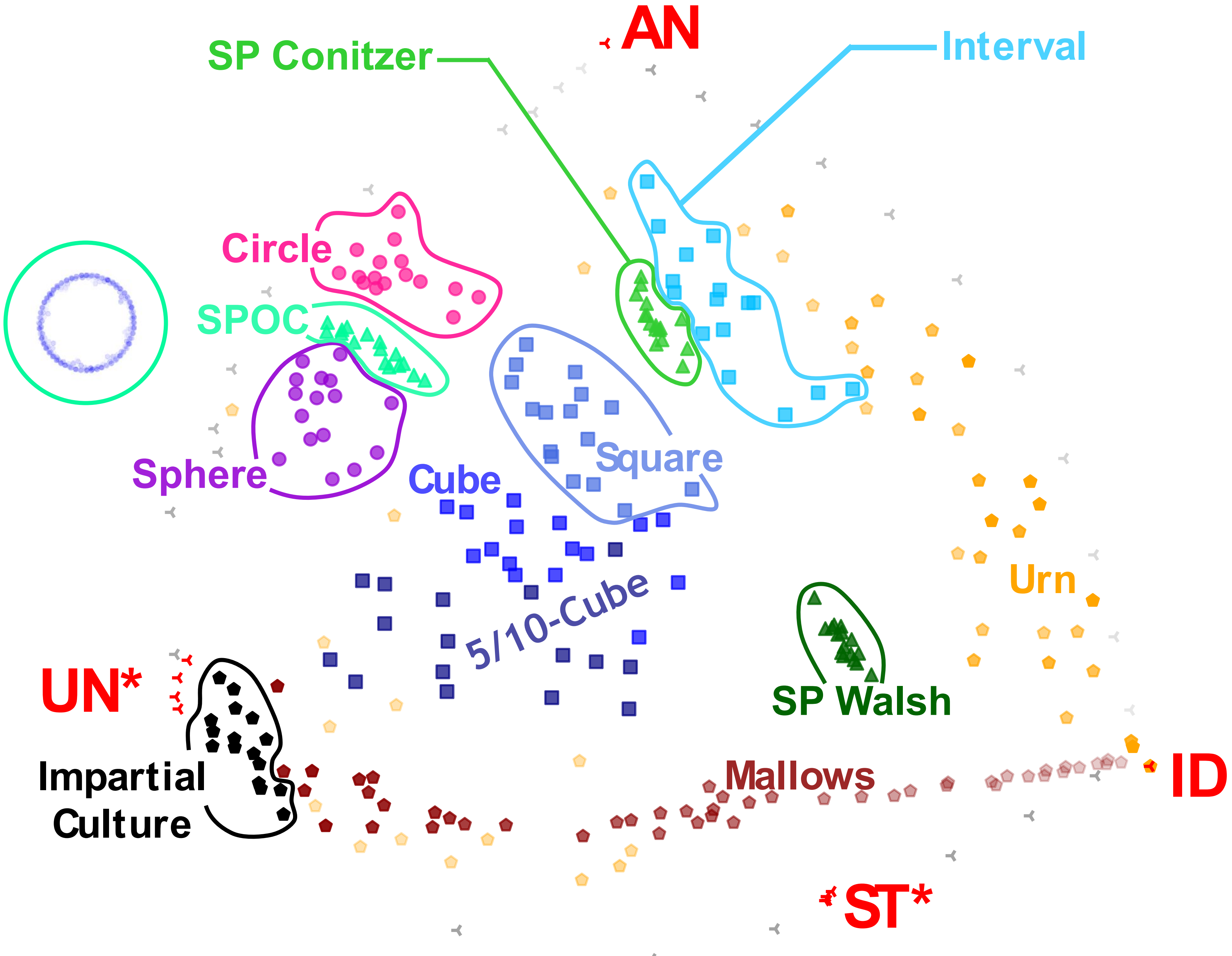

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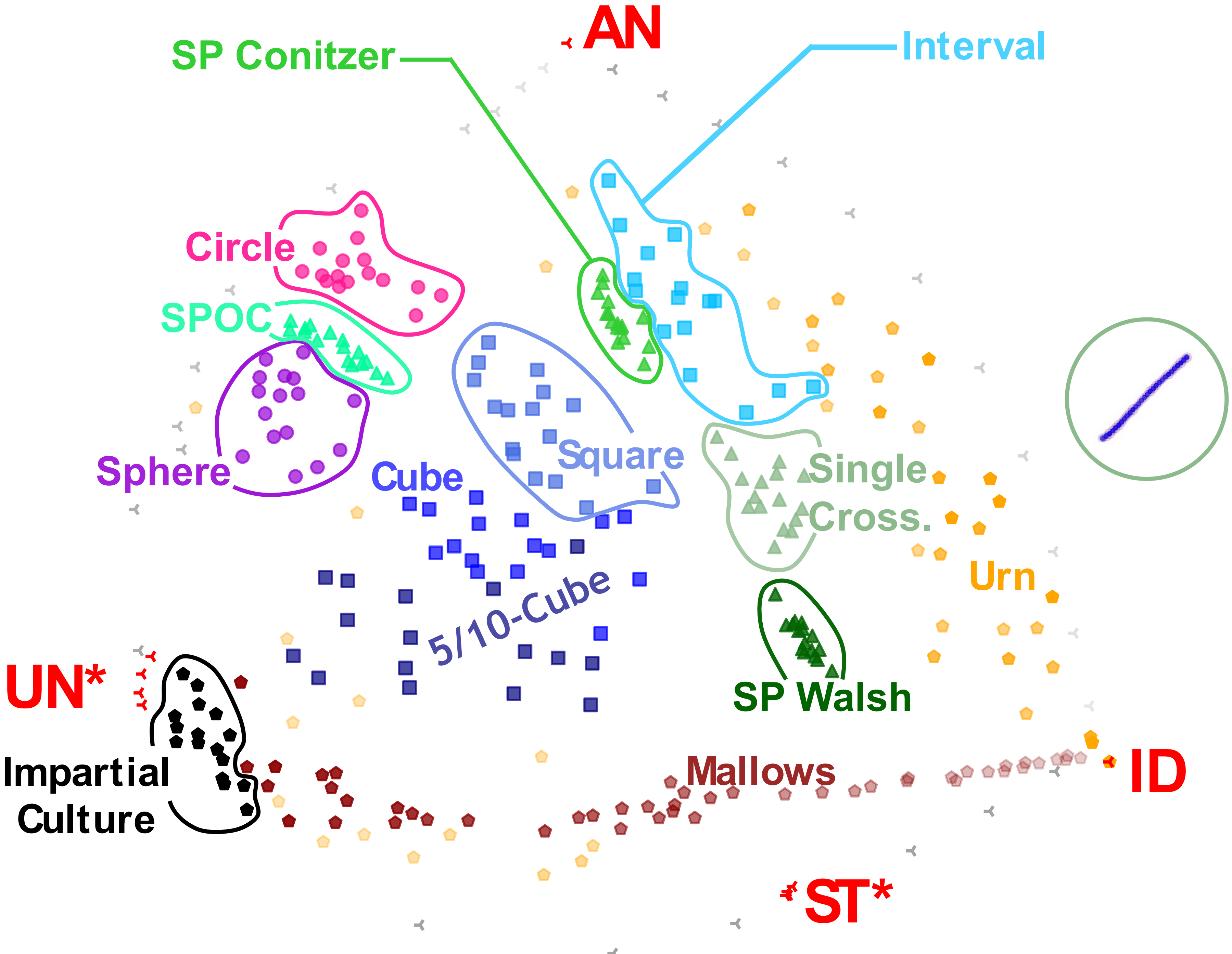

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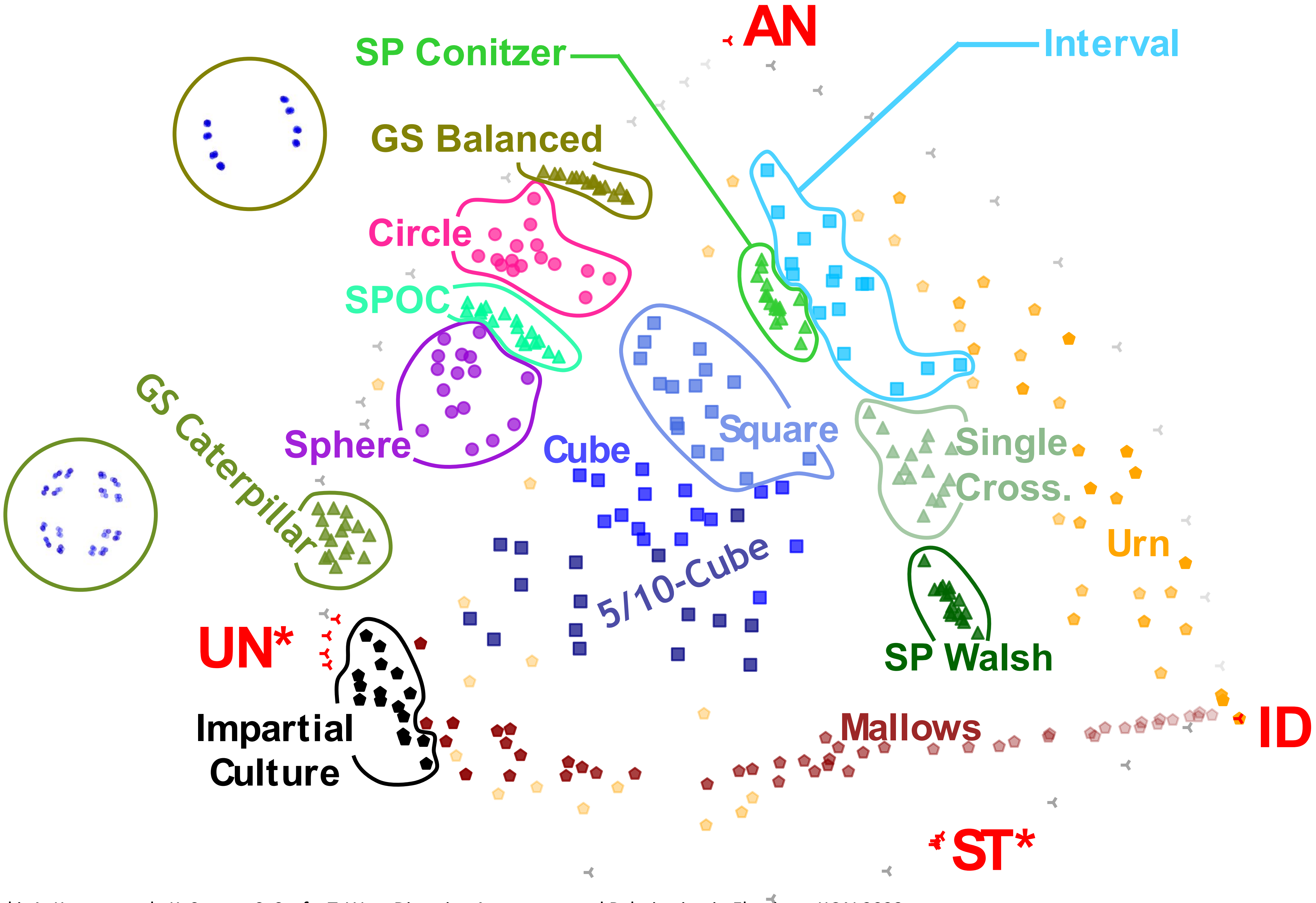

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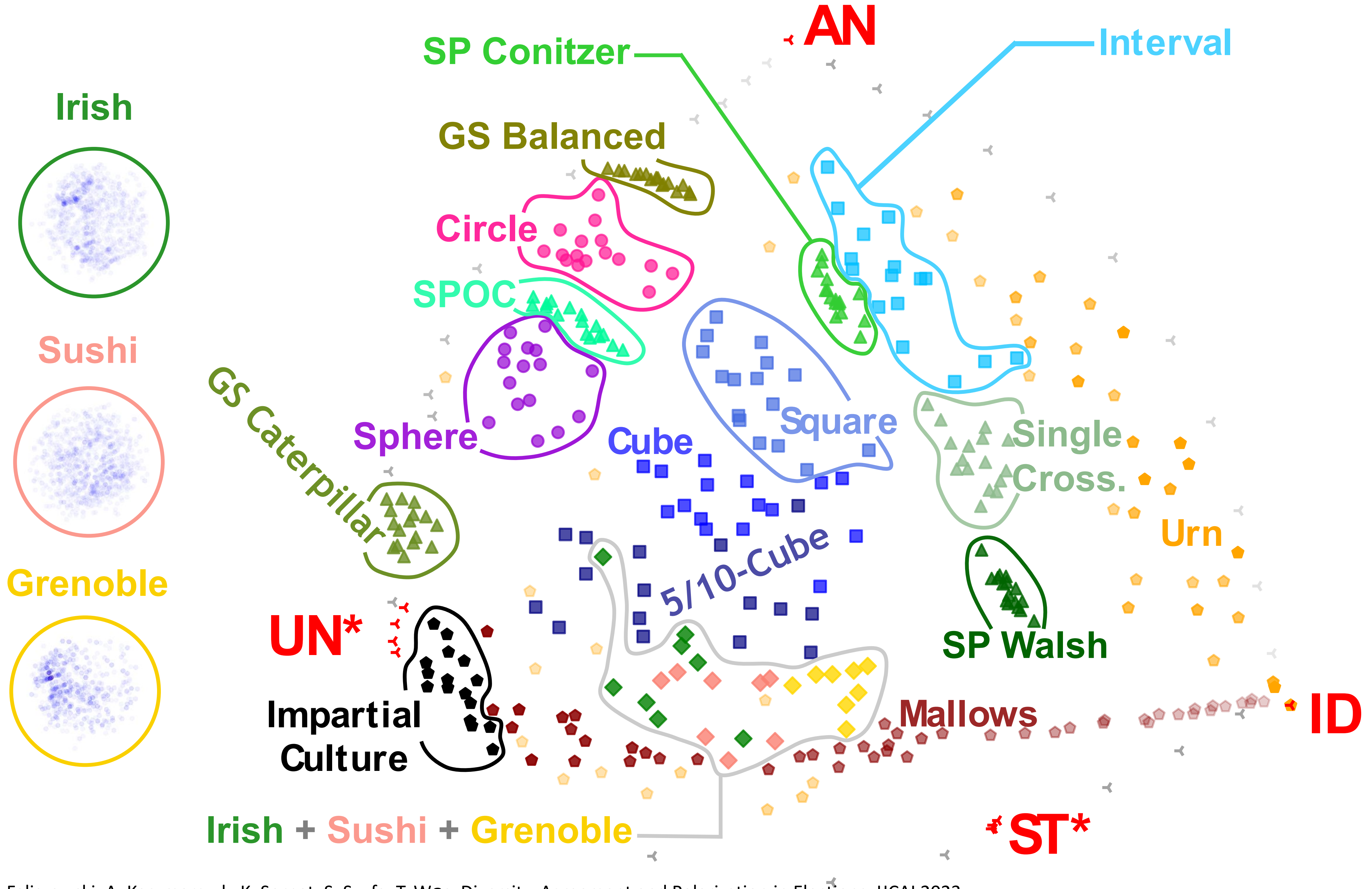

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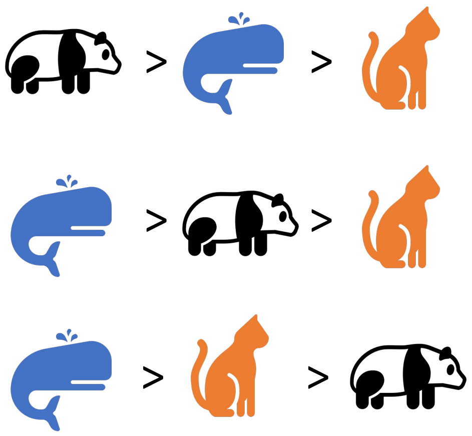
Computing Isomorphic Swap distance is:

- NP-hard
- Hard to approximate
    - O(m)-approx. and no better
- FPT-computable, but impractical
- Infeasible using ILP
- Just plain tough!
- Bruteforce works up to 10x50 elections, if you have hundreds of cores and plenty of time…

P. Faliszewski, P. Skowron, A. Slinko, S. Szufa, N. Talmon: How Similar Are Two Elections? AAAI 2019

How to Go Around Isomorphic Swap Distance?



1. Match the candidates
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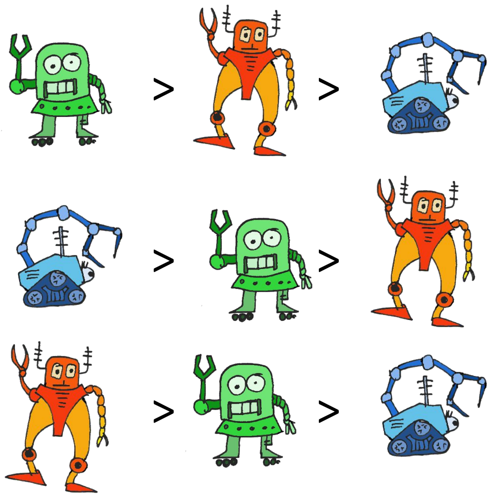
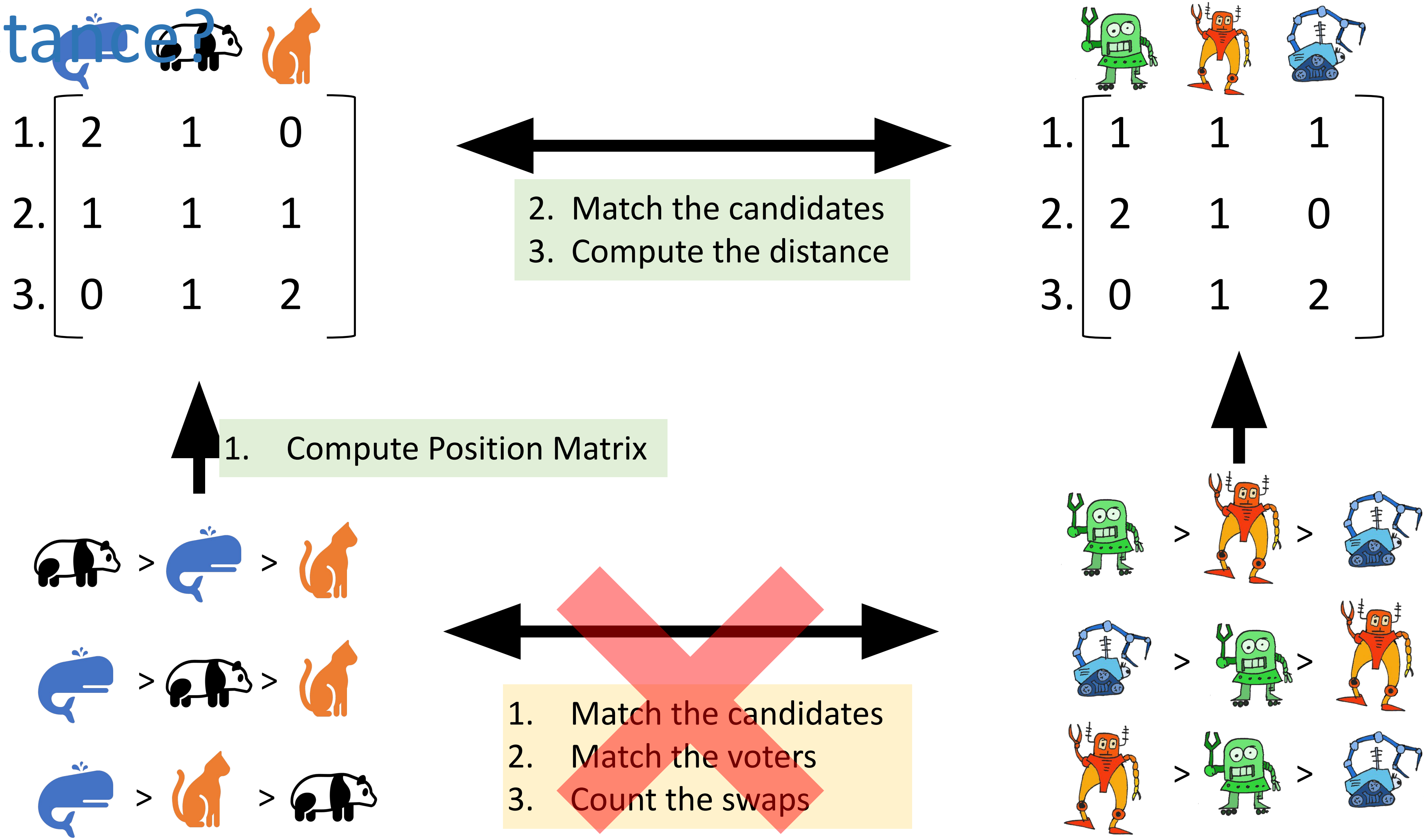
3. Count the swaps



S. Szufa, P. Faliszewski, P. Skowron, A. Slinko, N. Talmon, Drawing a map of elections in the space of statistical cultures, AAMAS 2020

How to Go Around Isomorphic Swap Distance?



S. Szufa, P. Faliszewski, P. Skowron, A. Slinko, N. Talmon, Drawing a map of elections in the space of statistical cultures, AAMAS 2020

Distance Between Vectors

$$\begin{bmatrix} 3 & 1 & 0 & 1 & 1 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 3 & 0 & 1 & 0 & 1 \end{bmatrix}$$

Distance Between Vectors

ℓ_1-distance

$$\begin{bmatrix} 3 & 1 & 0 & 1 & 1 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 3 & 0 & 1 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 2 & 0 & 0 & 1 & 1 \end{bmatrix} \quad 6$$

N. Boehmer, P. Faliszewski, R. Niedermeier, S. Szufa, T. Wąs, Understanding Distance Measures Among Elections, IJCAI 2022

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ℓ_1-distance

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$$\begin{bmatrix} 1 & 1 & 0 & 3 & 0 & 1 \end{bmatrix}$$

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N. Boehmer, P. Faliszewski, R. Niedermeier, S. Szufa, T. Wąs, Understanding Distance Measures Among Elections, IJCAI 2022

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ℓ_1-distance

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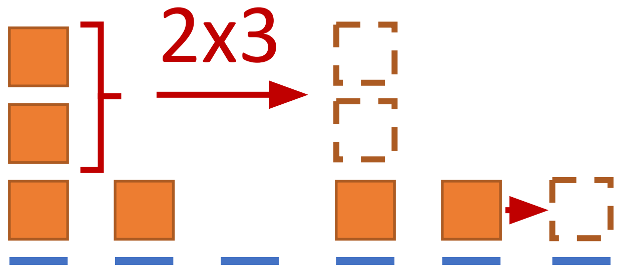
$$\begin{bmatrix} 1 & 1 & 0 & 3 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 0 & 0 & 2 & 1 & 1 \end{bmatrix} \quad 6$$

Earth Mover's Distance (EMD)

$$\begin{bmatrix} 3 & 1 & 0 & 1 & 1 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 1 & 0 & 3 & 0 & 1 \end{bmatrix}$$



7

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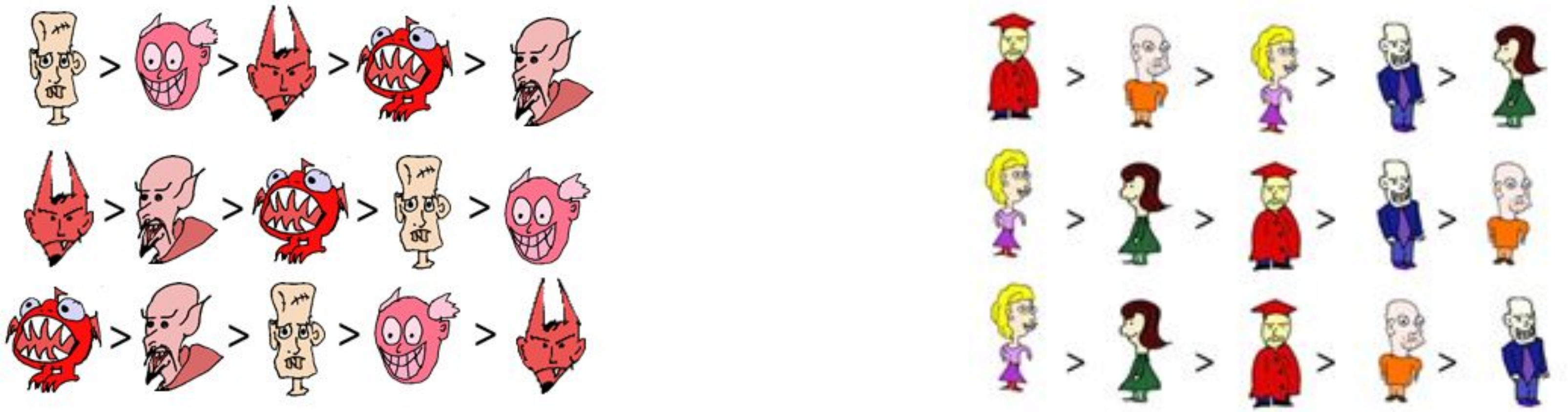
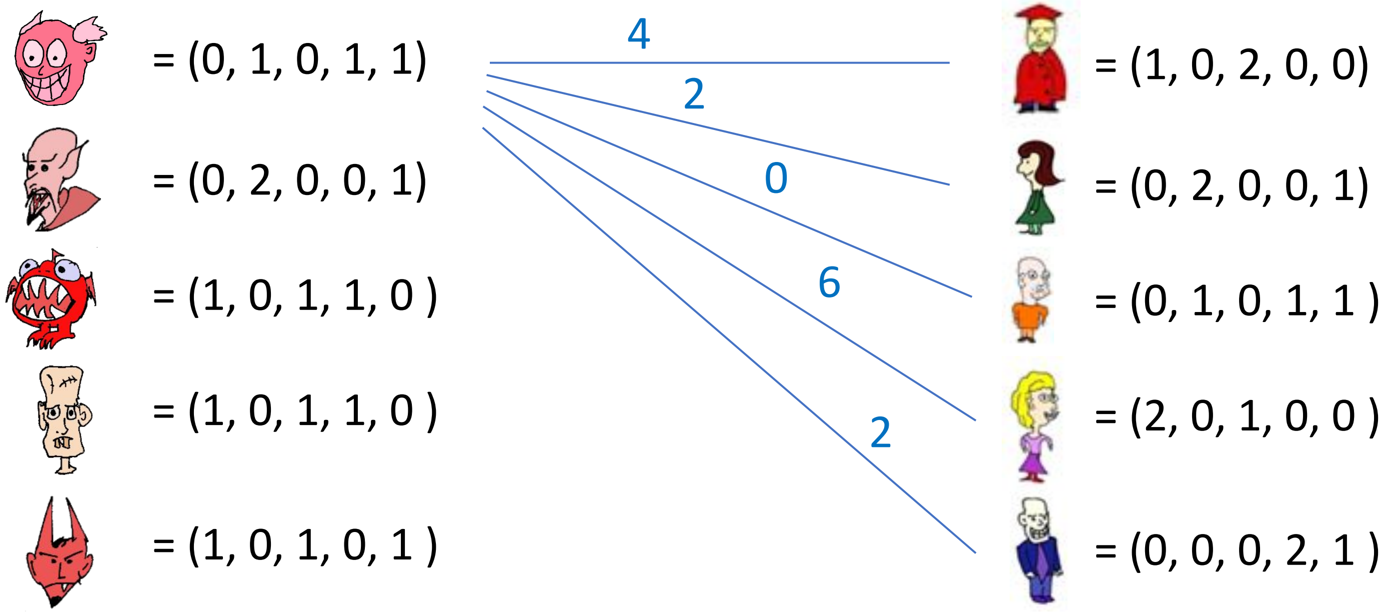
Positionwise Distance





Earth mover distances

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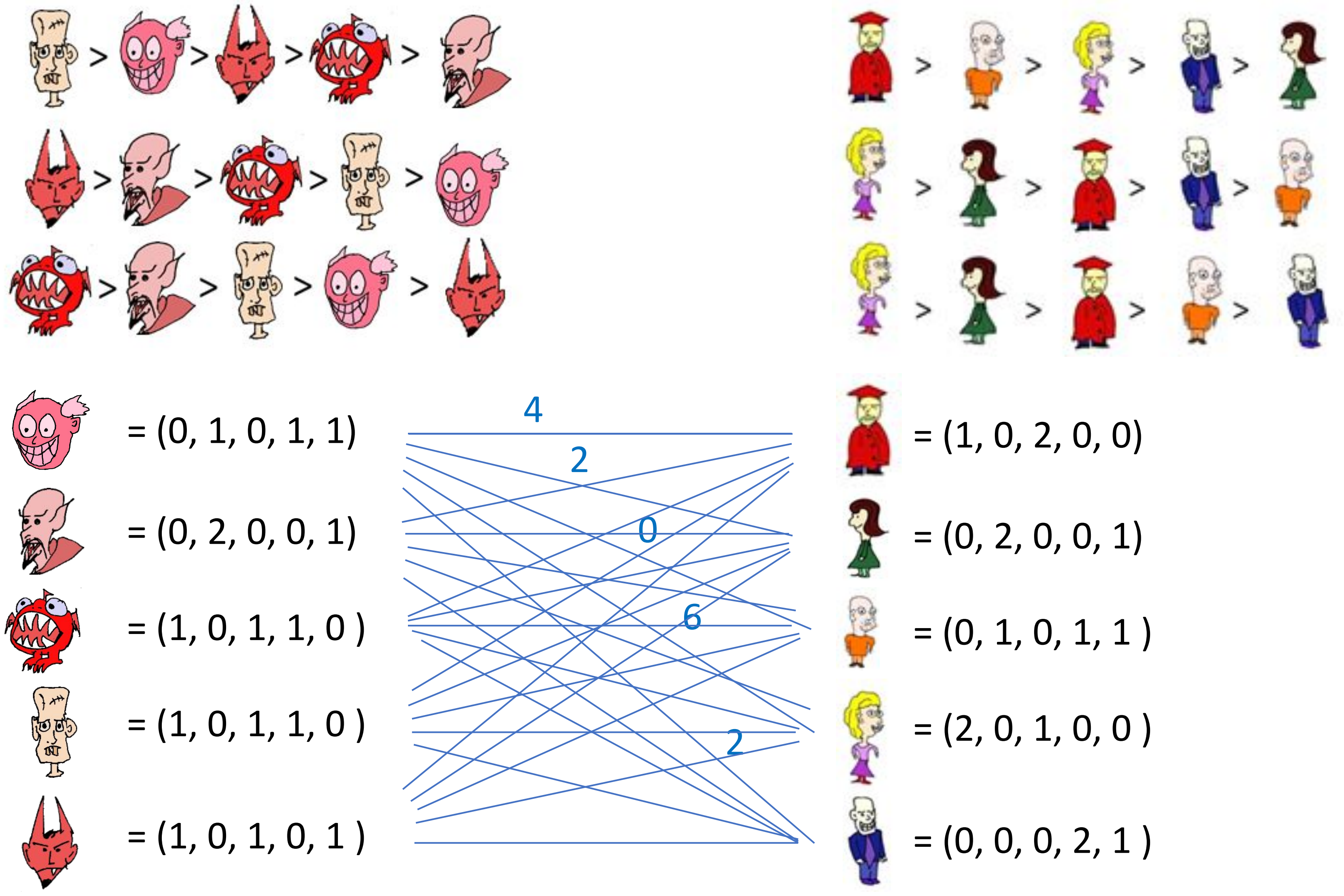

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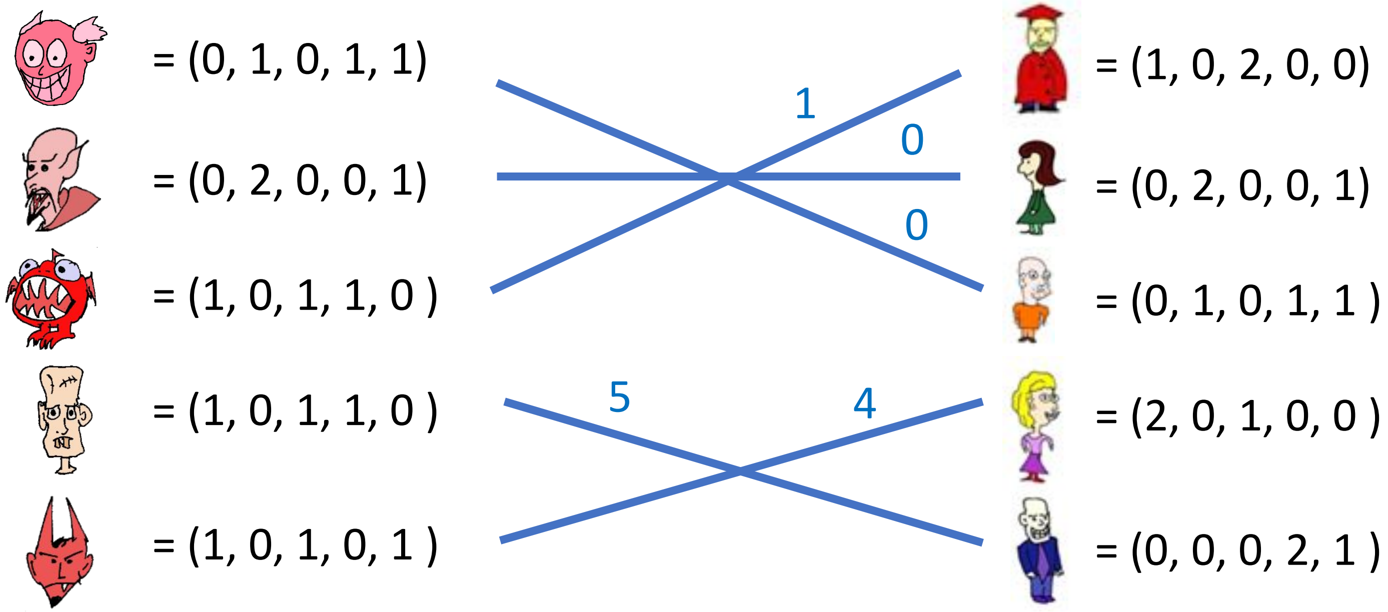
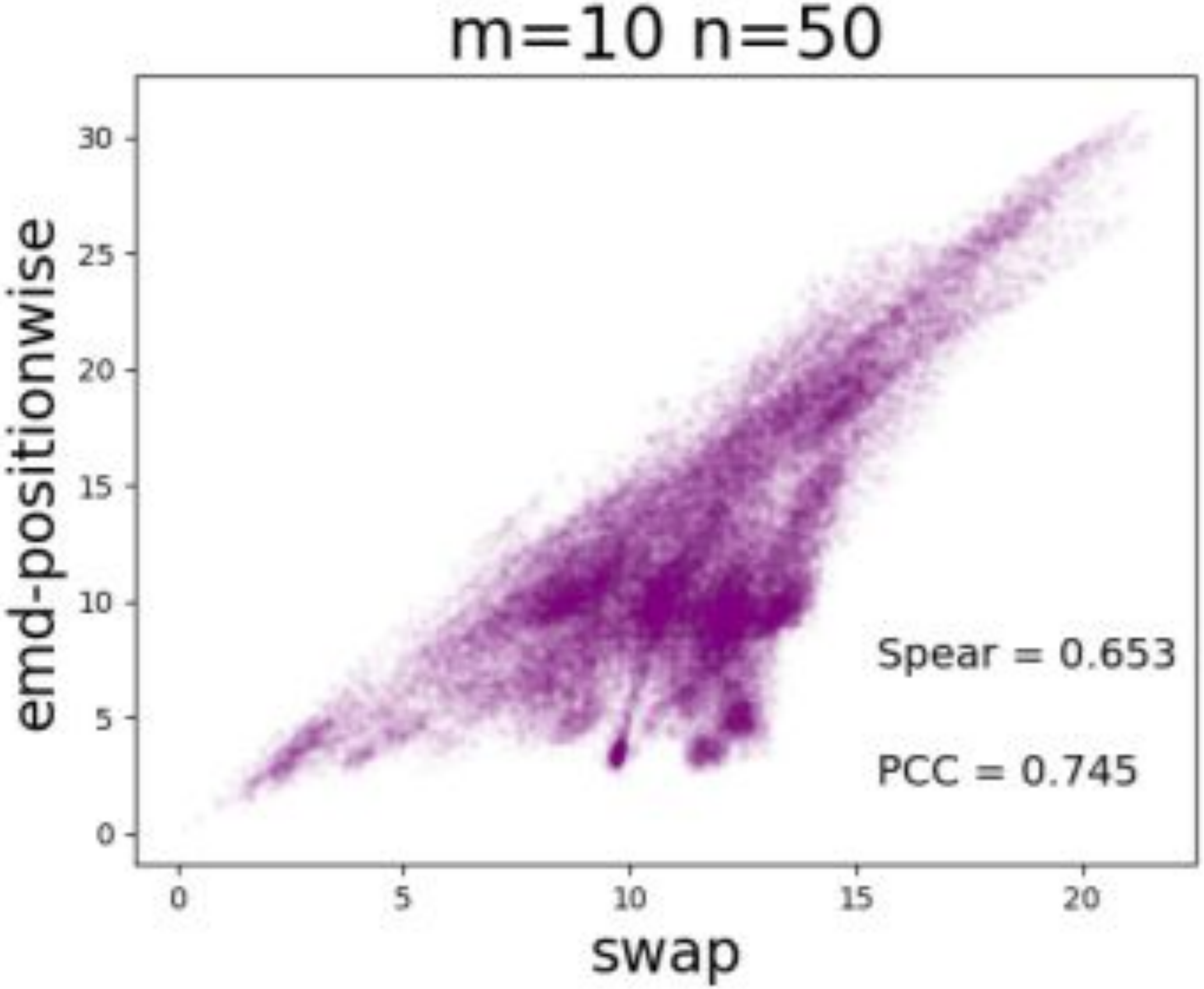
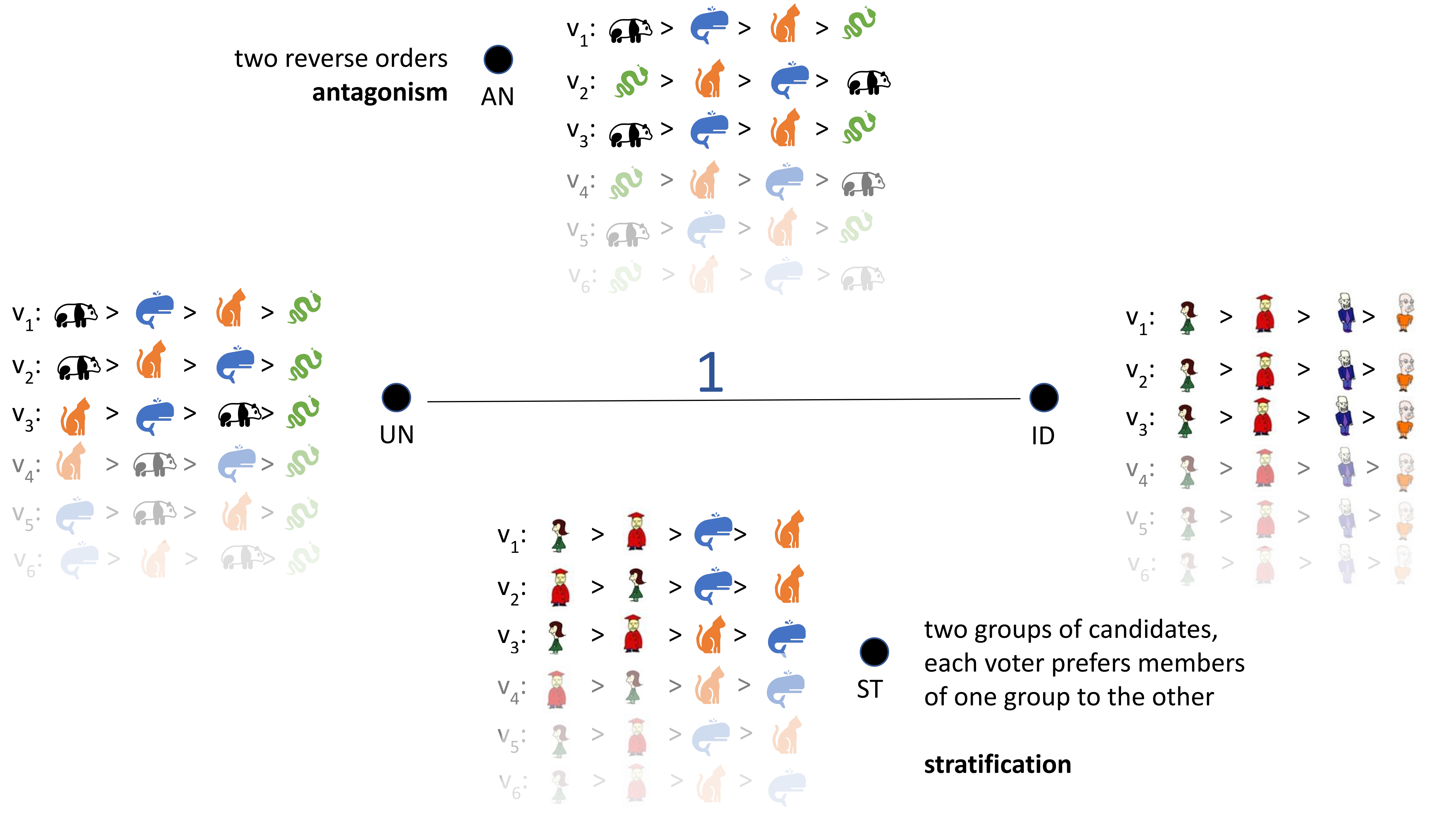
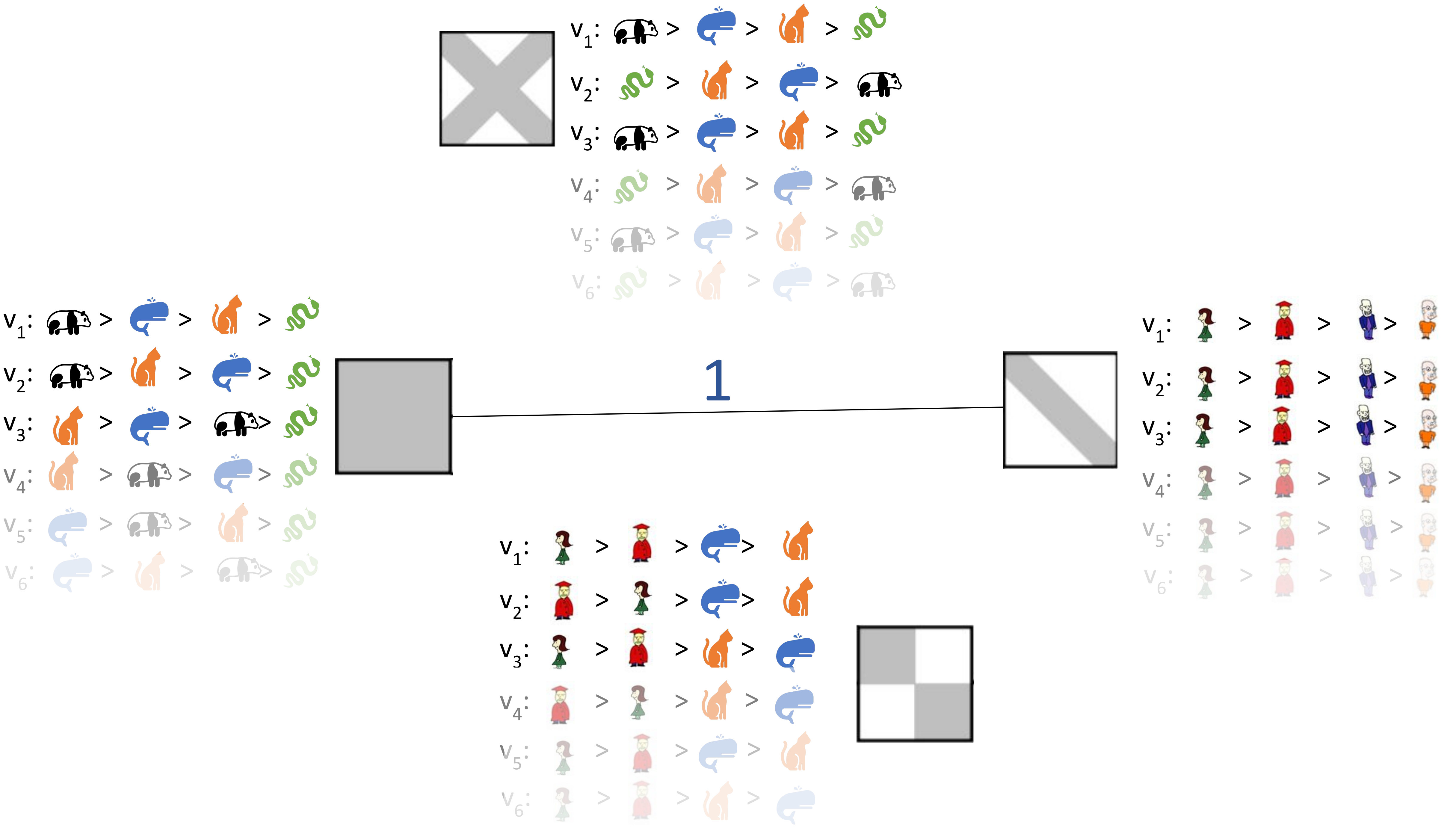


distance = 1+0+0+5+4 = 10

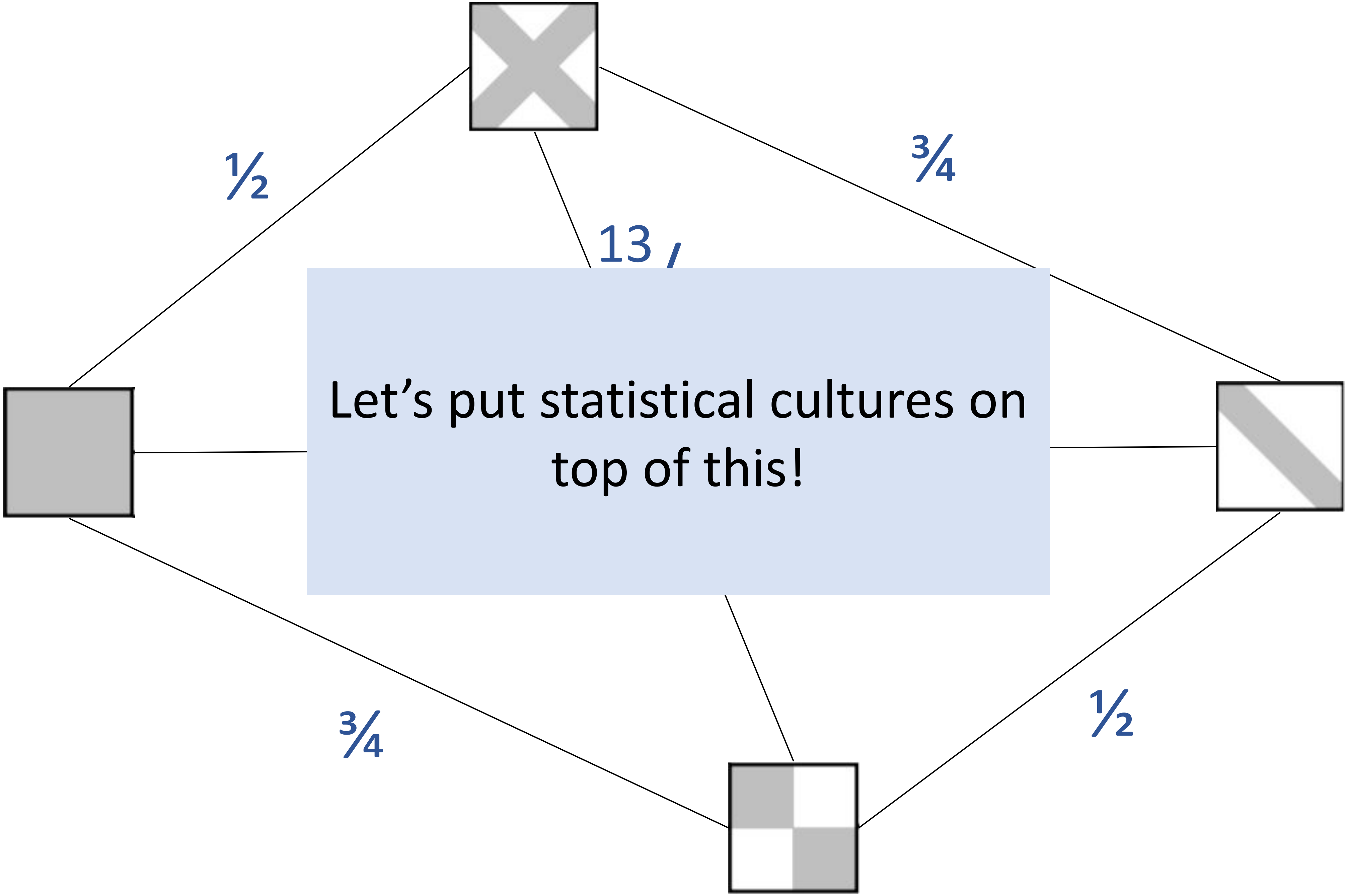


m=10 n=50
emd-positionwise
swap
Spear = 0.653
PCC = 0.745
0
5
10
15
20
25
30
0
5
10
15
20


two reverse orders
antagonism
AN
v1: > > >
v2: > > >
v3: > > >
v4: > > >
v5: > > >
v6: > > >
UN
1
ID
ST
two groups of candidates, each voter prefers members of one group to the other
stratification

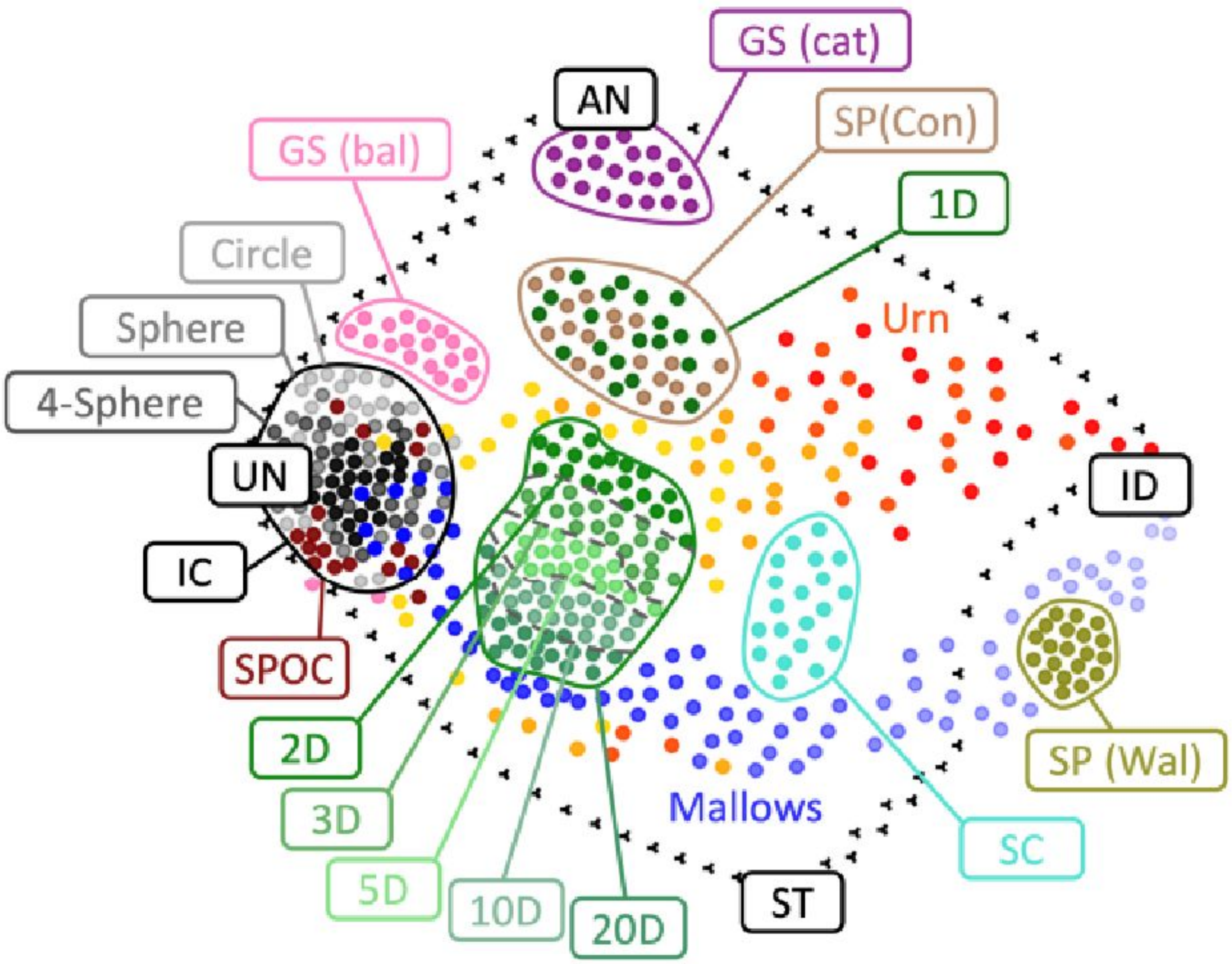


v_1:
v_2:
v_3:
v_4:
v_5:
v_6:
1



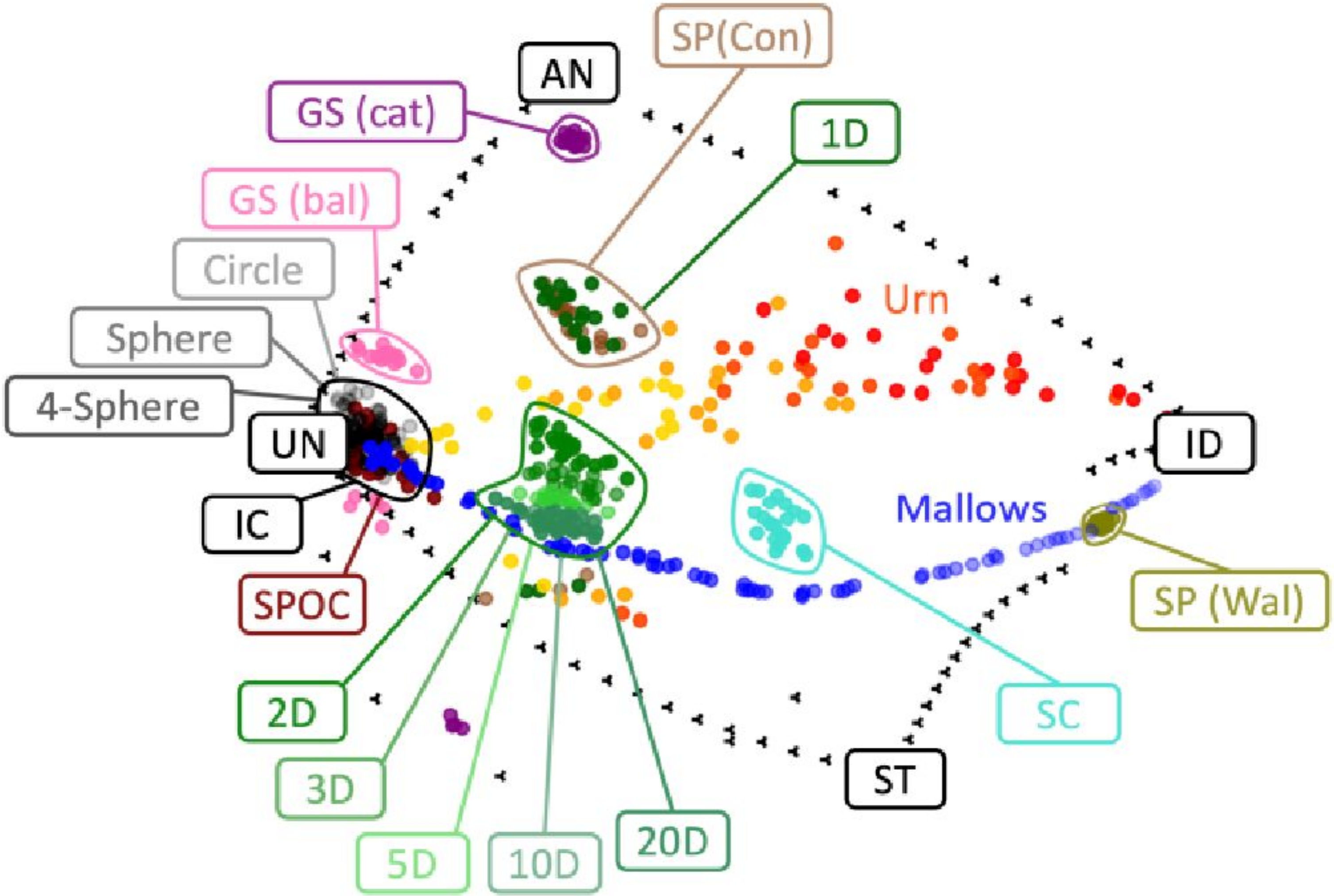
Let’s put statistical cultures on top of this!

N. Boehmer, R. Bredereck, P. Faliszewski, R. Niedermeier, S. Szufa: Putting a Compass on the Map of Elections, IJCAI 2021

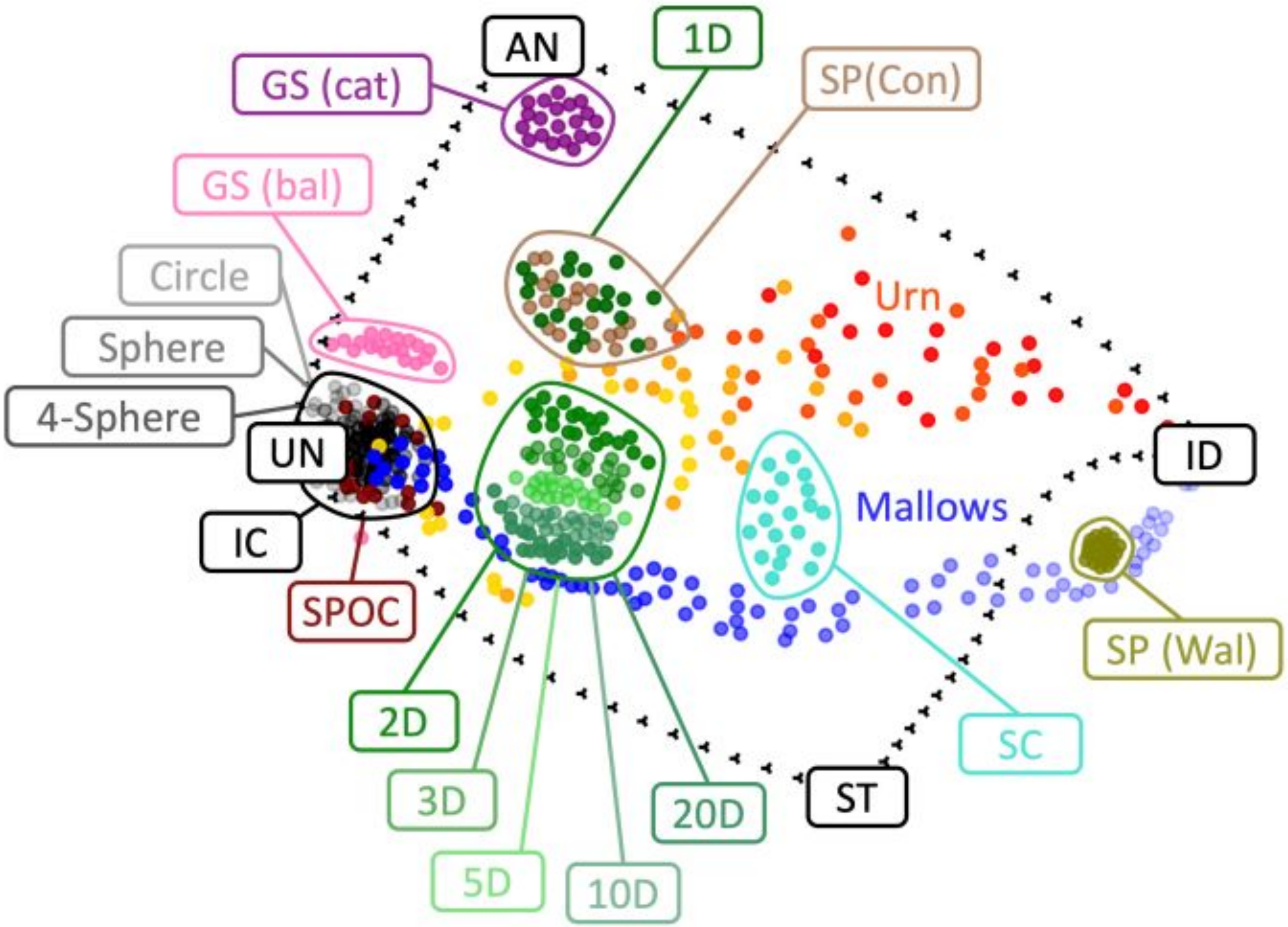


(a) FR

N. Boehmer, R. Bredereck, P. Faliszewski, R. Niedermeier, S. Szufa: Putting a Compass on the Map of Elections, IJCAI 2021


AN
SP(Con)
GS (cat)
1D
GS (bal)
Circle
Urn
Sphere
4-Sphere
UN
ID
Mallows
IC
SPOC
SP (Wal)
2D
SC
3D
ST
5D
10D
20D

(b) MDS


AN
1D
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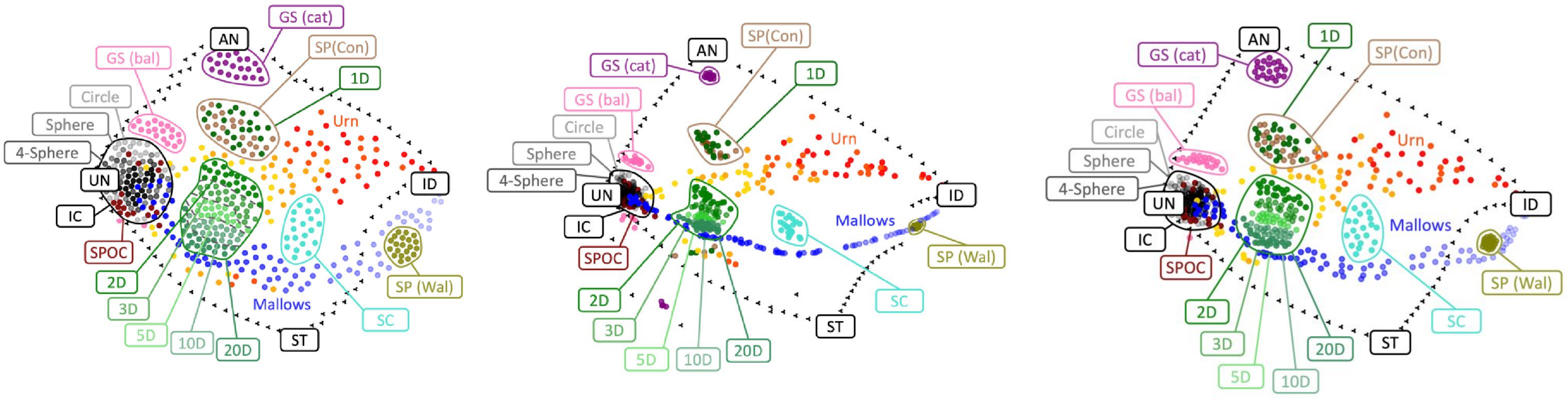
UN
IC
SPOC
Urn
Mallows
ID
SP (Wal)
2D
3D
5D
10D
20D
ST
SC

(c) KK



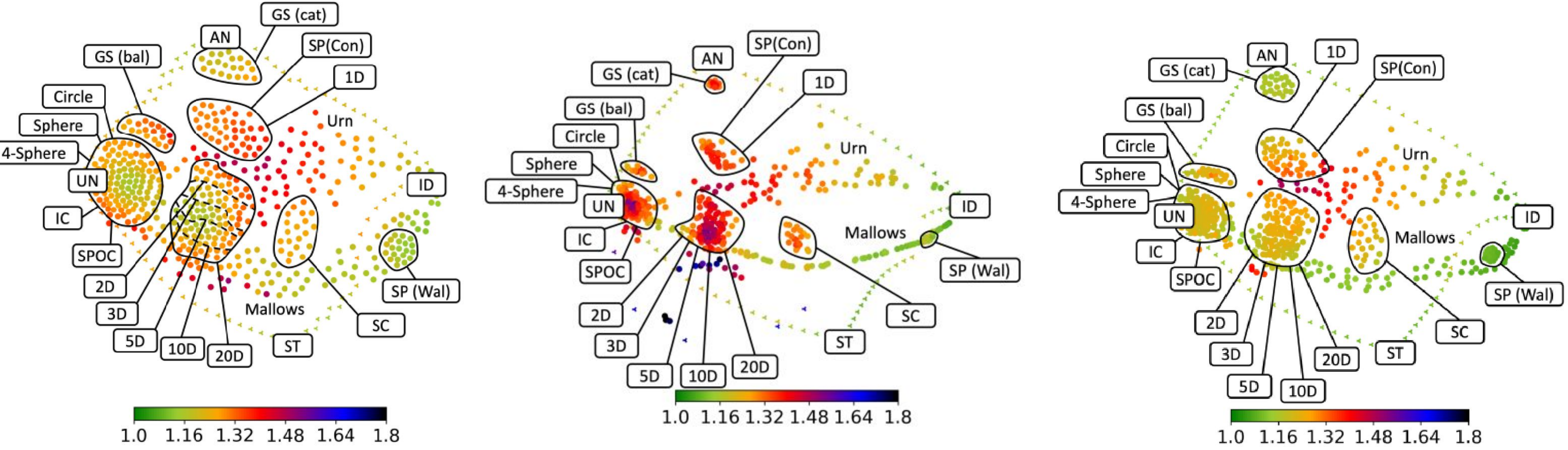
(a) FR

(b) MDS

(c) KK

Which embedding is best?

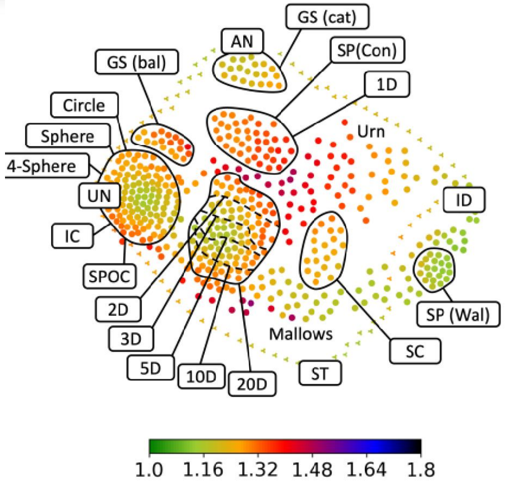
$$\mathrm{MR}(X,Y) = \frac{\max(\bar{d}_{\mathrm{Euc}}(X,Y), \bar{d}_{\mathcal{M}}(X,Y))}{\min(\bar{d}_{\mathrm{Euc}}(X,Y), \bar{d}_{\mathcal{M}}(X,Y))},$$



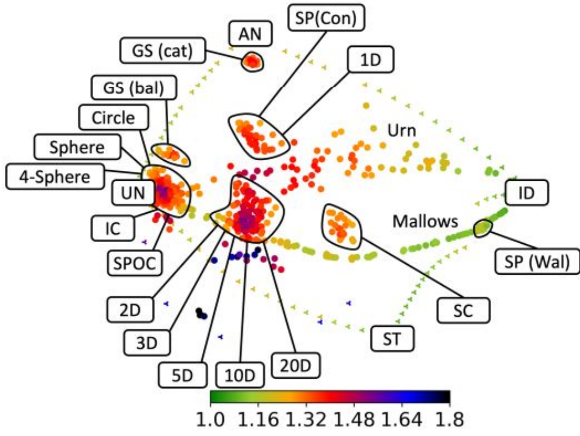
(a) FR (b) MDS (c) KK

dataset	average total distortion values FR	MDS	KK
4×100	1.3213 ± 0.0157	1.3099 ± 0.0076	1.2612 ± 0.0158
10×100	1.3119 ± 0.0194	1.3531 ± 0.0108	1.2625 ± 0.0125
20×100	1.2979 ± 0.0195	1.3545 ± 0.0126	1.2406 ± 0.0060
100×100	1.3006 ± 0.0256	1.3225 ± 0.0194	1.2119 ± 0.0123

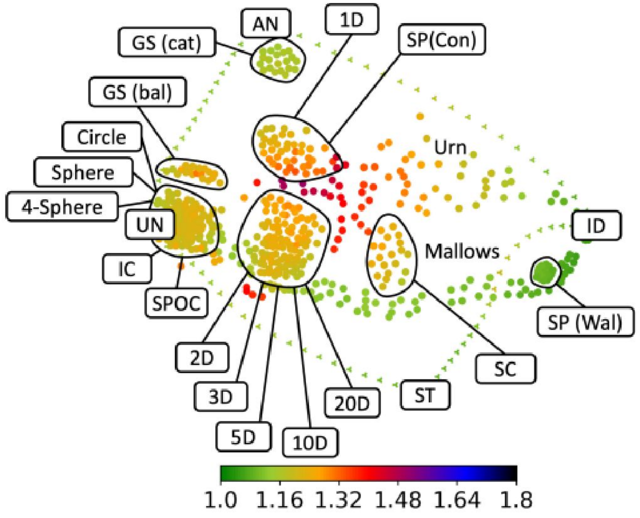
Model	average total distortion values FR	MDS	KK
Impartial Culture	1.145	1.087	1.07
Single-Peaked (Conitzer)	1.313	1.305	1.244
Single-Peaked (Walsh)	1.114	1.067	1.071
SPOC	1.223	1.094	1.081
Single-Crossing	1.256	1.298	1.225
Interval	1.321	1.3	1.233
Square	1.267	1.274	1.203
Cube	1.216	1.217	1.146
5-Cube	1.155	1.177	1.114
10-Cube	1.2	1.162	1.094
20-Cube	1.252	1.162	1.097
Circle	1.222	1.105	1.101
Sphere	1.187	1.09	1.077
4-Sphere	1.174	1.084	1.072
Group-Separable (Balanced)	1.302	1.298	1.204
Group-Separable (Caterpillar)	1.215	1.218	1.14
Urn	1.338	1.298	1.285
Mallows	1.195	1.121	1.094
All	1.241	1.198	1.159



(a) FR



(b) MDS

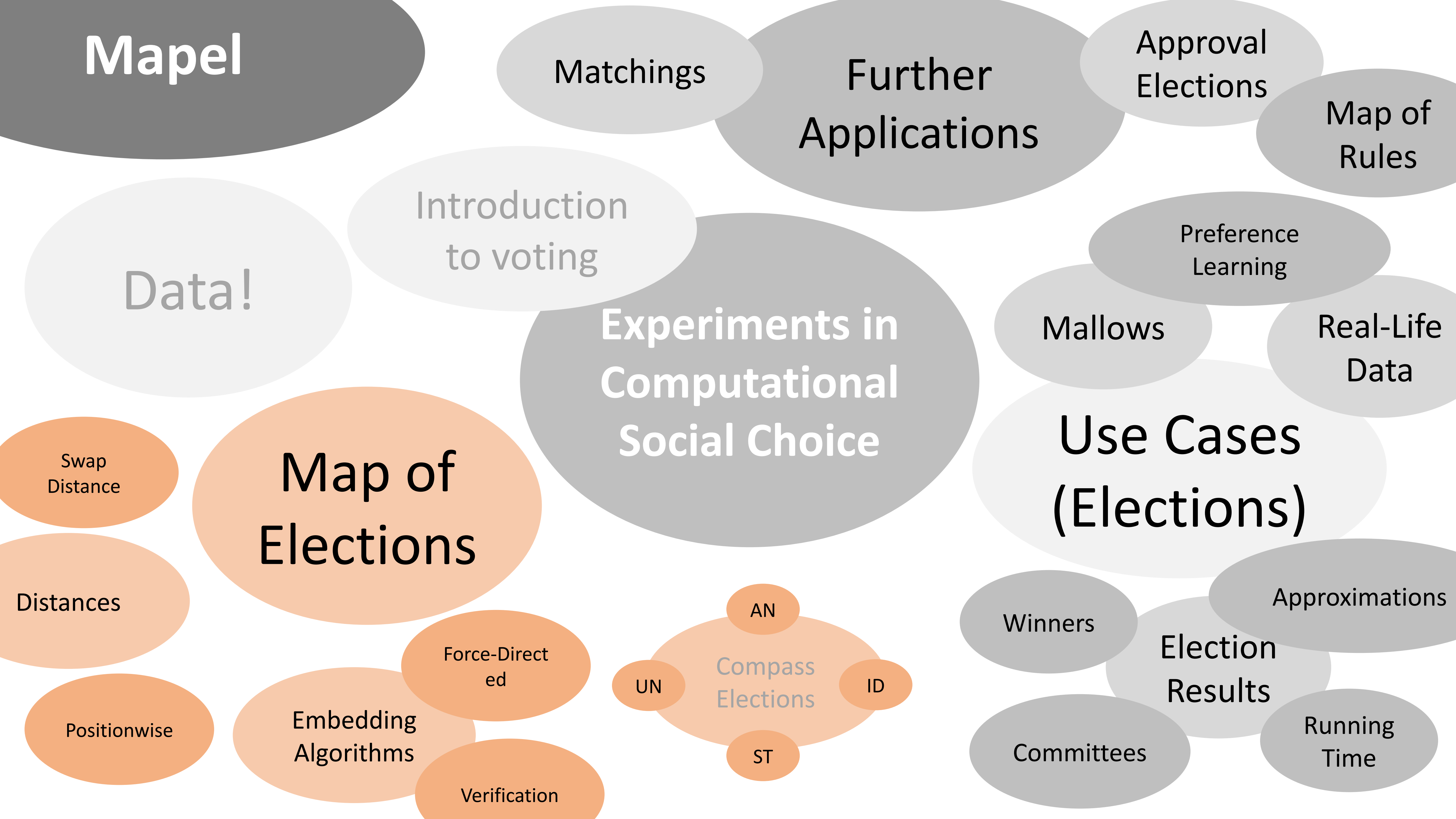


(c) KK

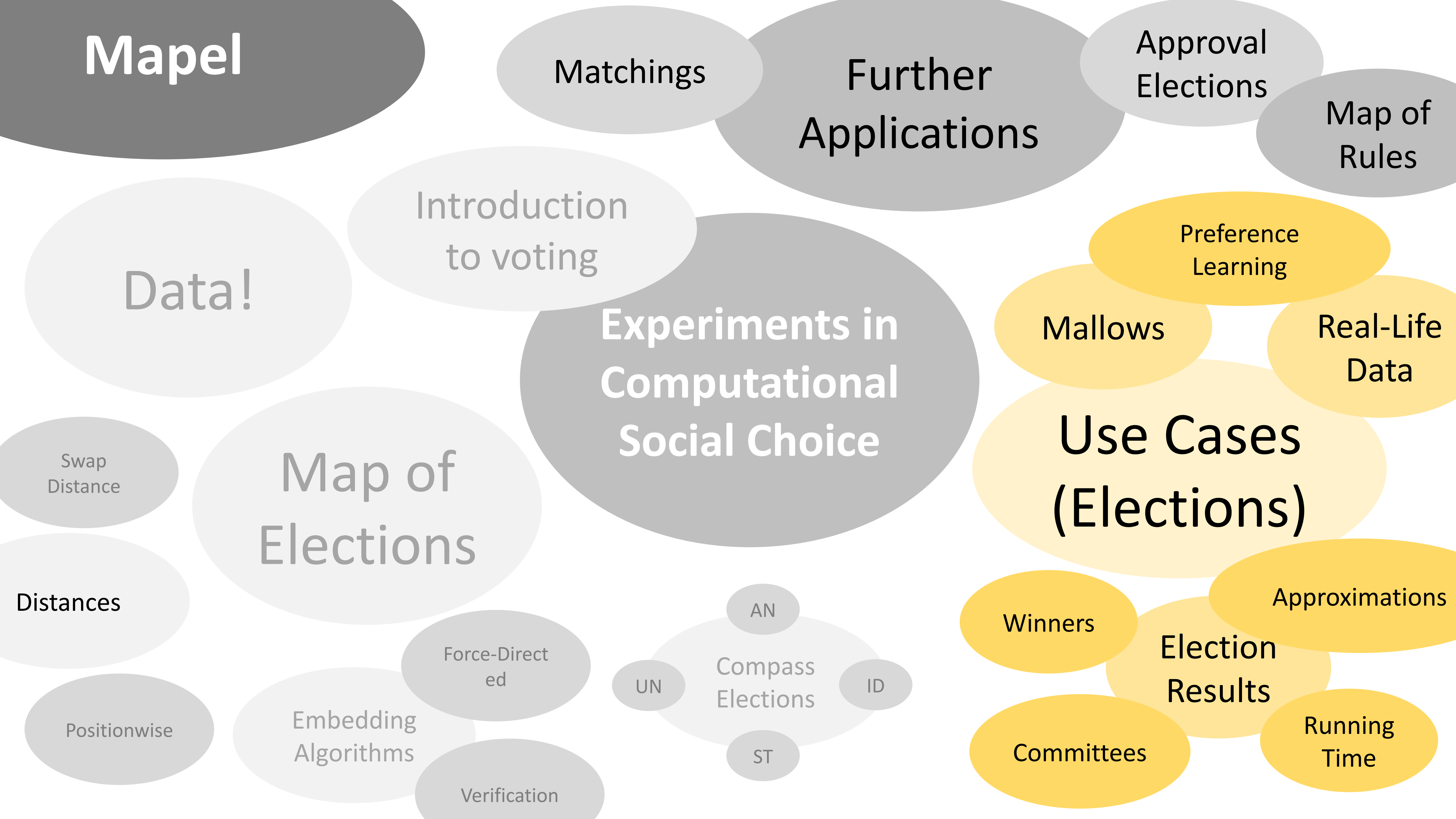
15 minute
s

Create your own map of elections!

Introduction to Mapel Software Package 1/2



Mapel
Matchings
Further Applications
Approval Elections
Map of Rules
Data!
Introduction to voting
Experiments in Computational Social Choice
Preference Learning
Mallows
Real-Life Data
Use Cases (Elections)
Swap Distance
Map of Elections
Distances
Positionwise
Force-Directed
Embedding Algorithms
Verification
AN
UN
Compass Elections
ID
ST
Winners
Approximations
Election Results
Committees
Running Time


Mapel
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Running Time

Drawing a Map of Elections in the Space of Statistical Cultures, Szufa et al., AAMAS-20

Map of Elections, S. Szufa, PhD Thesis

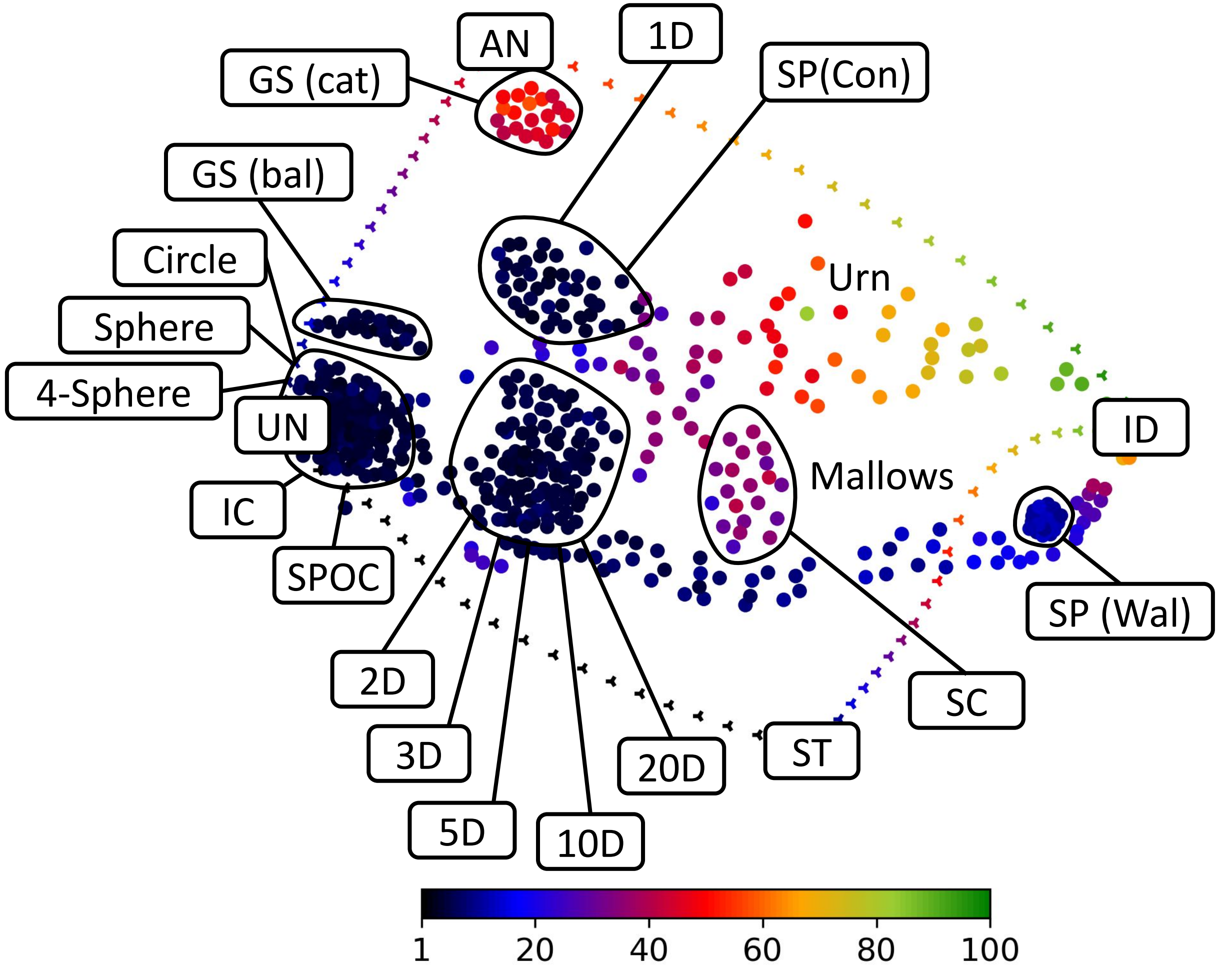
20 minutes

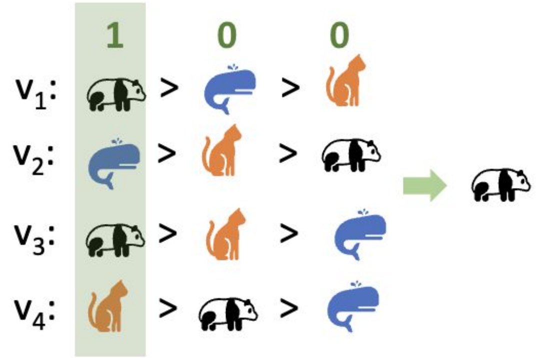
Visualizing Experiment Results

Use Cases

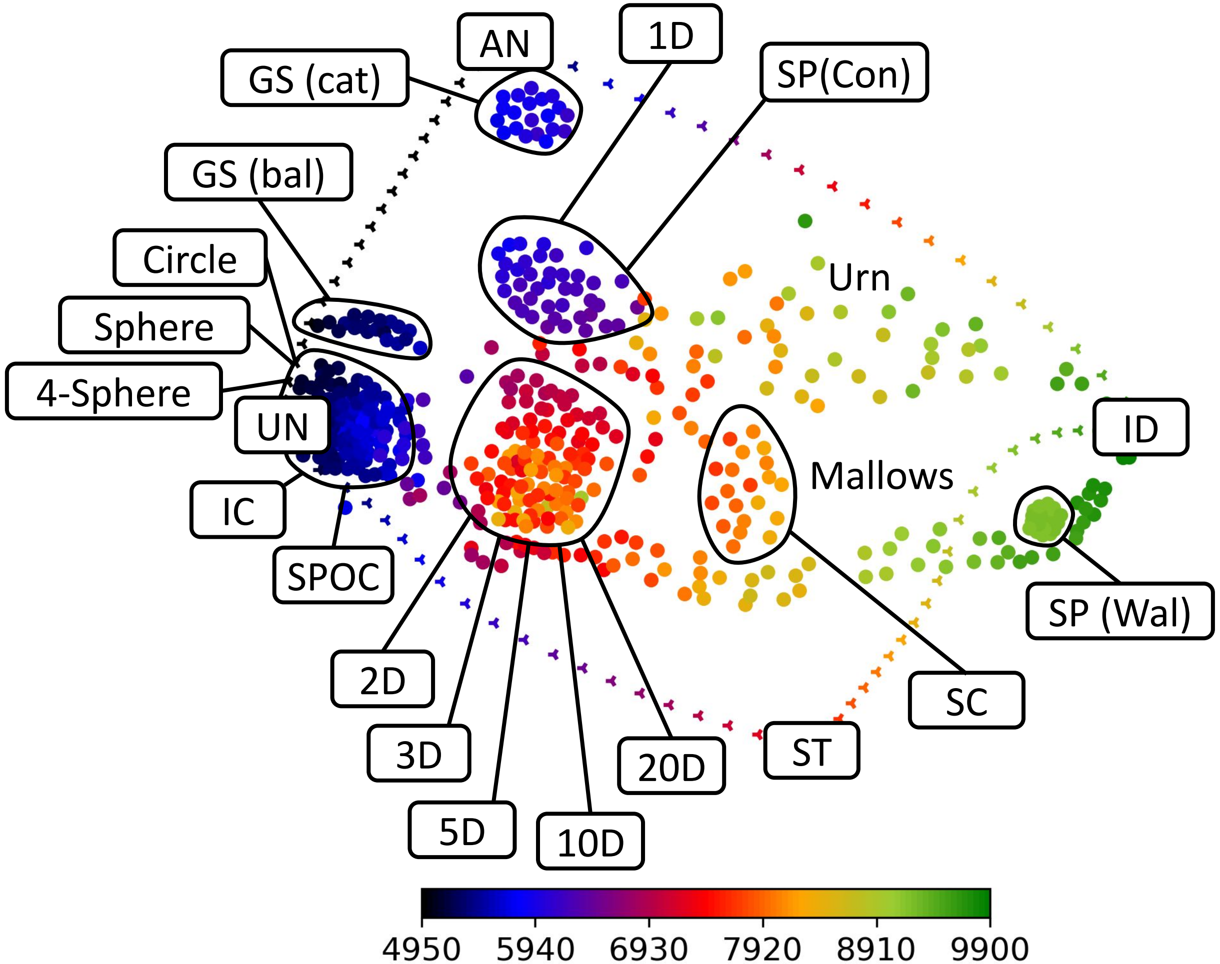
Winner Score

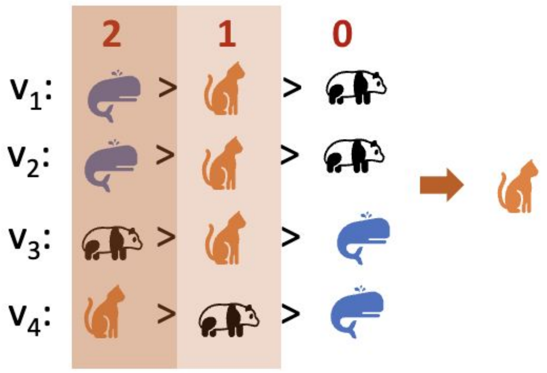
Visualizing Experiment Results





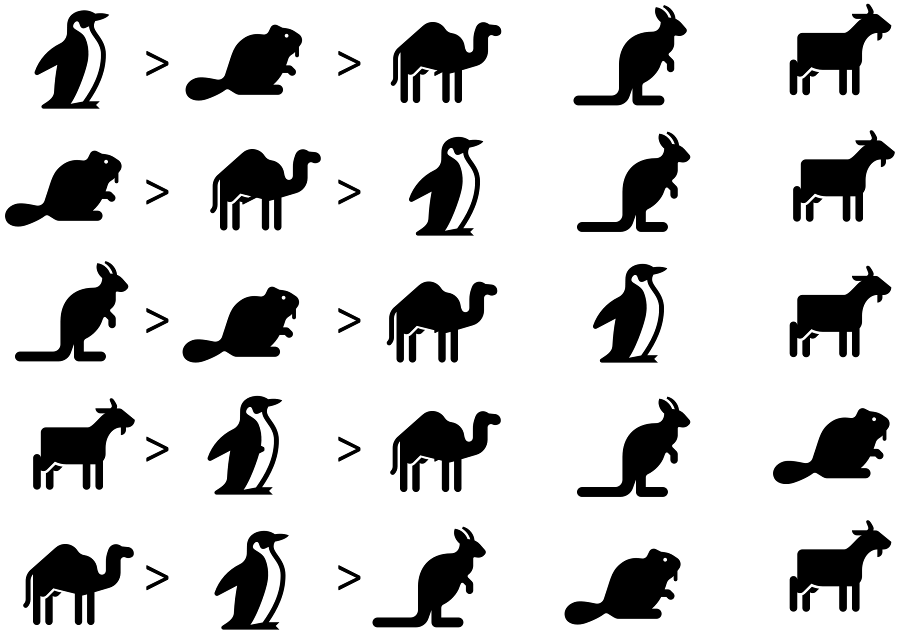
Highest Plurality Score

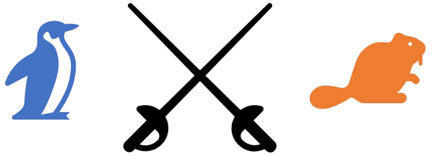




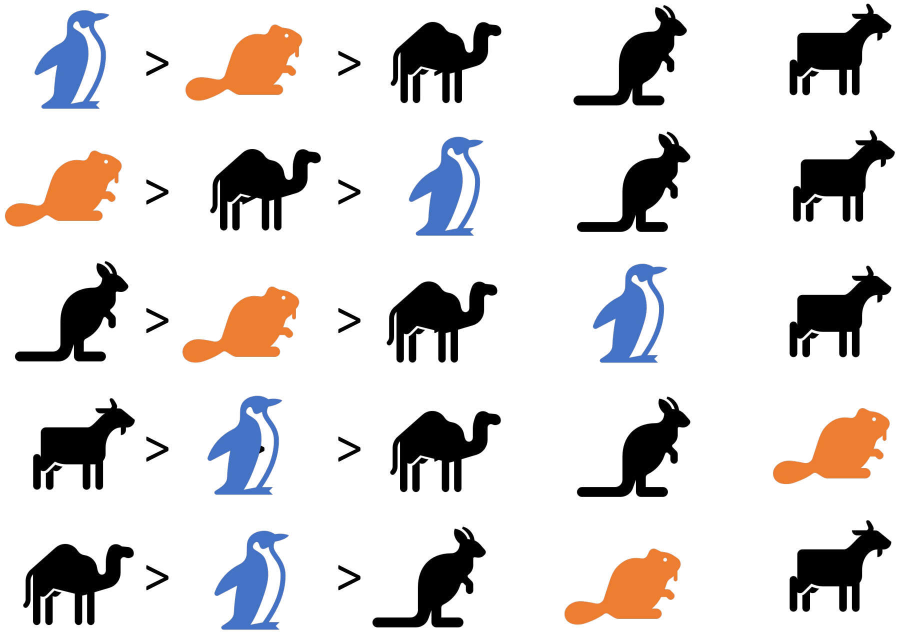
Highest Borda Score

Copeland Rule

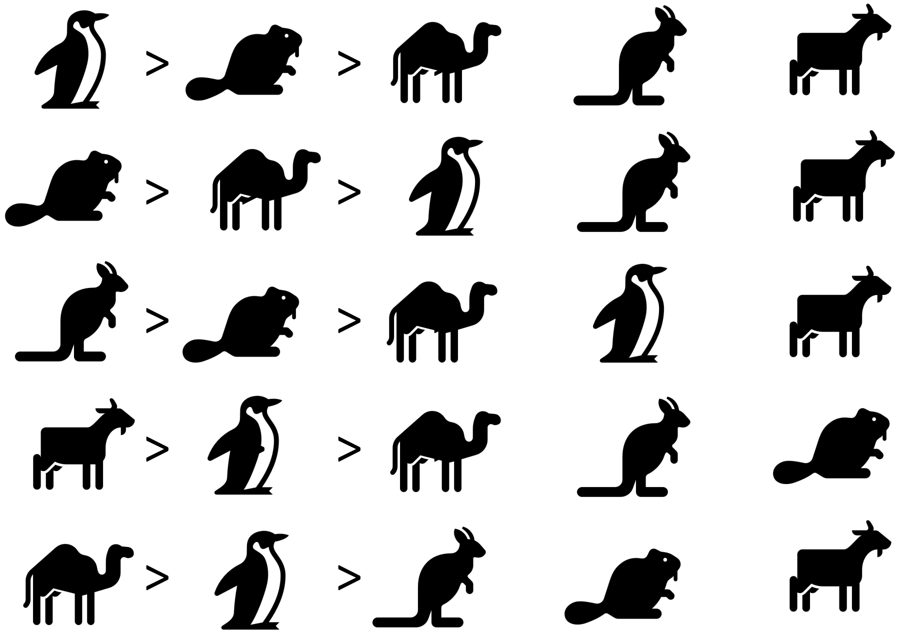




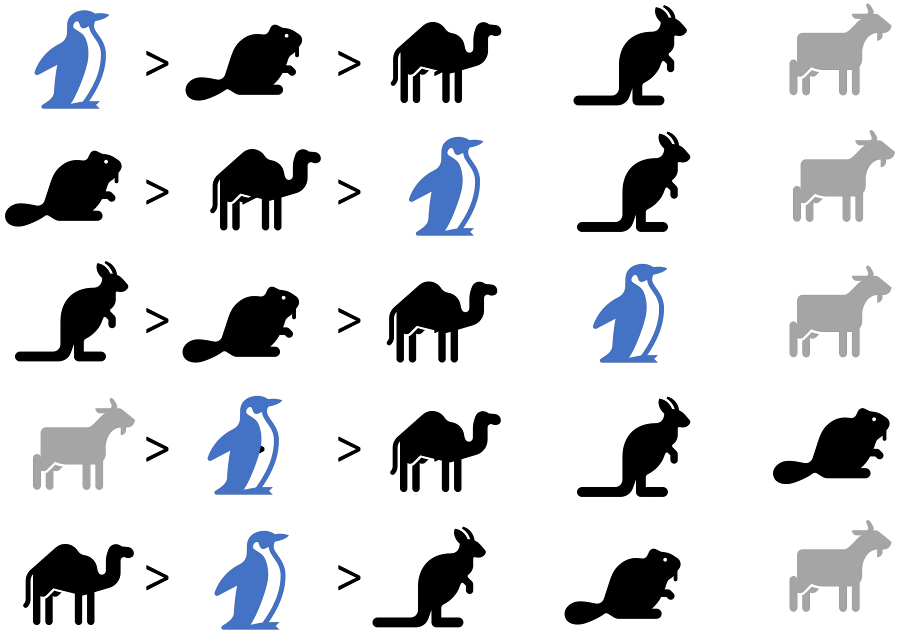
Copeland Rule



Copeland Rule

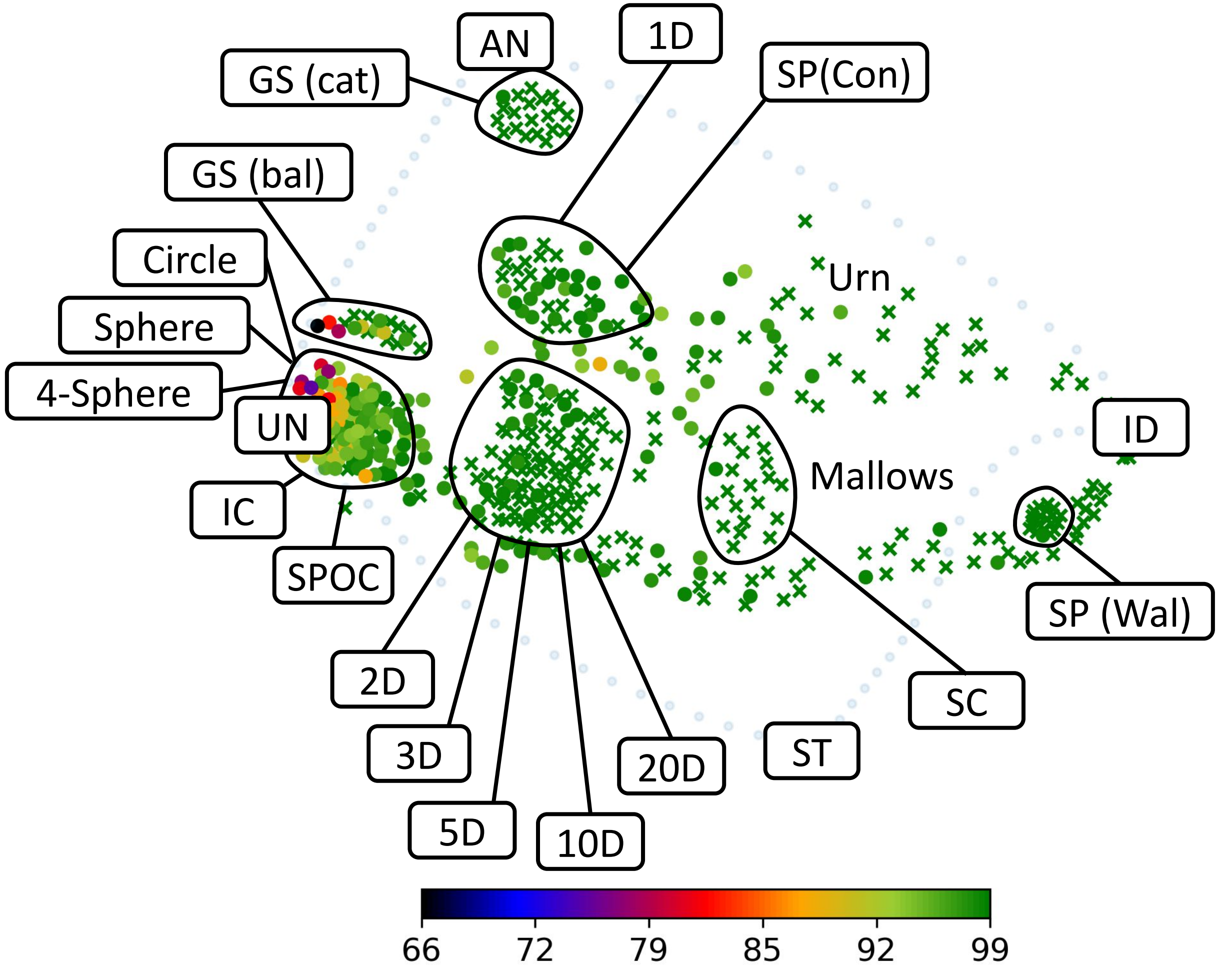


Copeland Rule



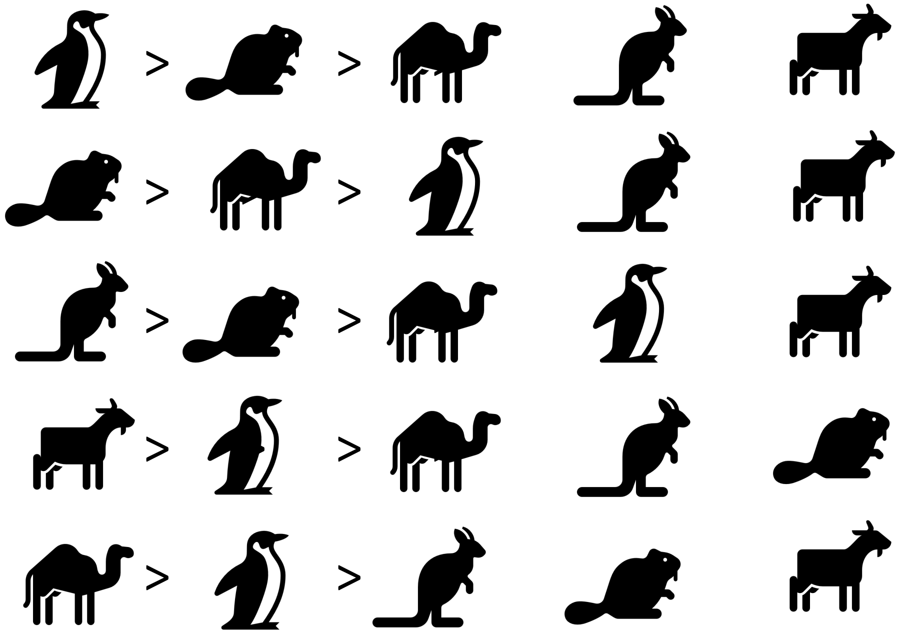
Condorcet winner
A candidate that wins all pairwise comparisons

The candidate with the highest score wins



Highest Copeland Score

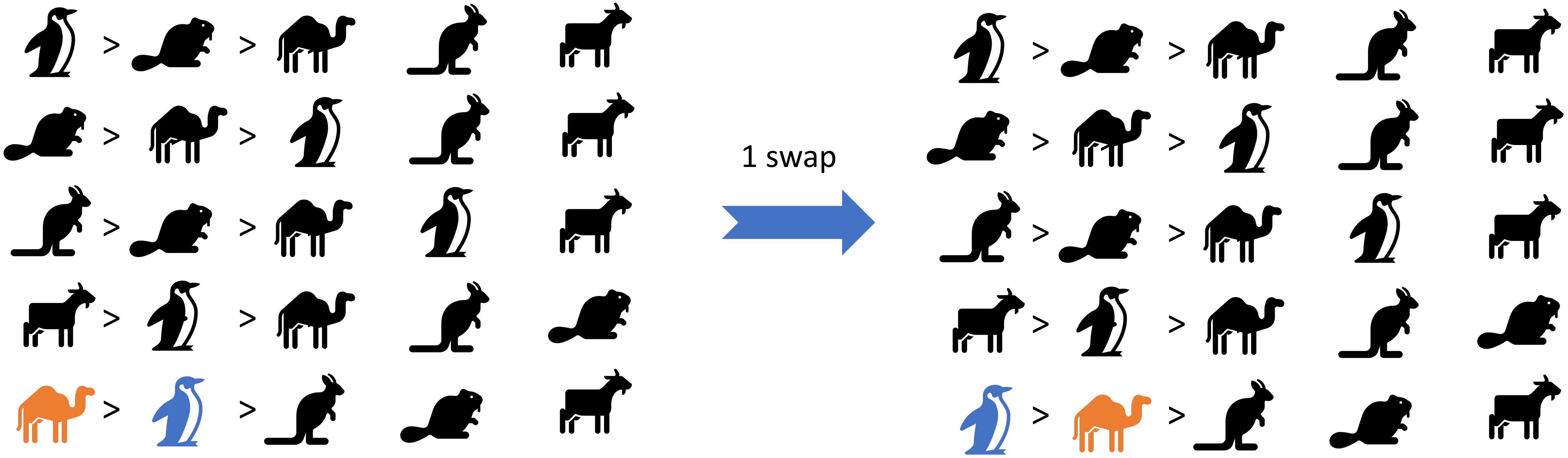
Dodgson Rule



Score of a candidate is the minimal number of swaps needed to make him or her a Condorcet winner

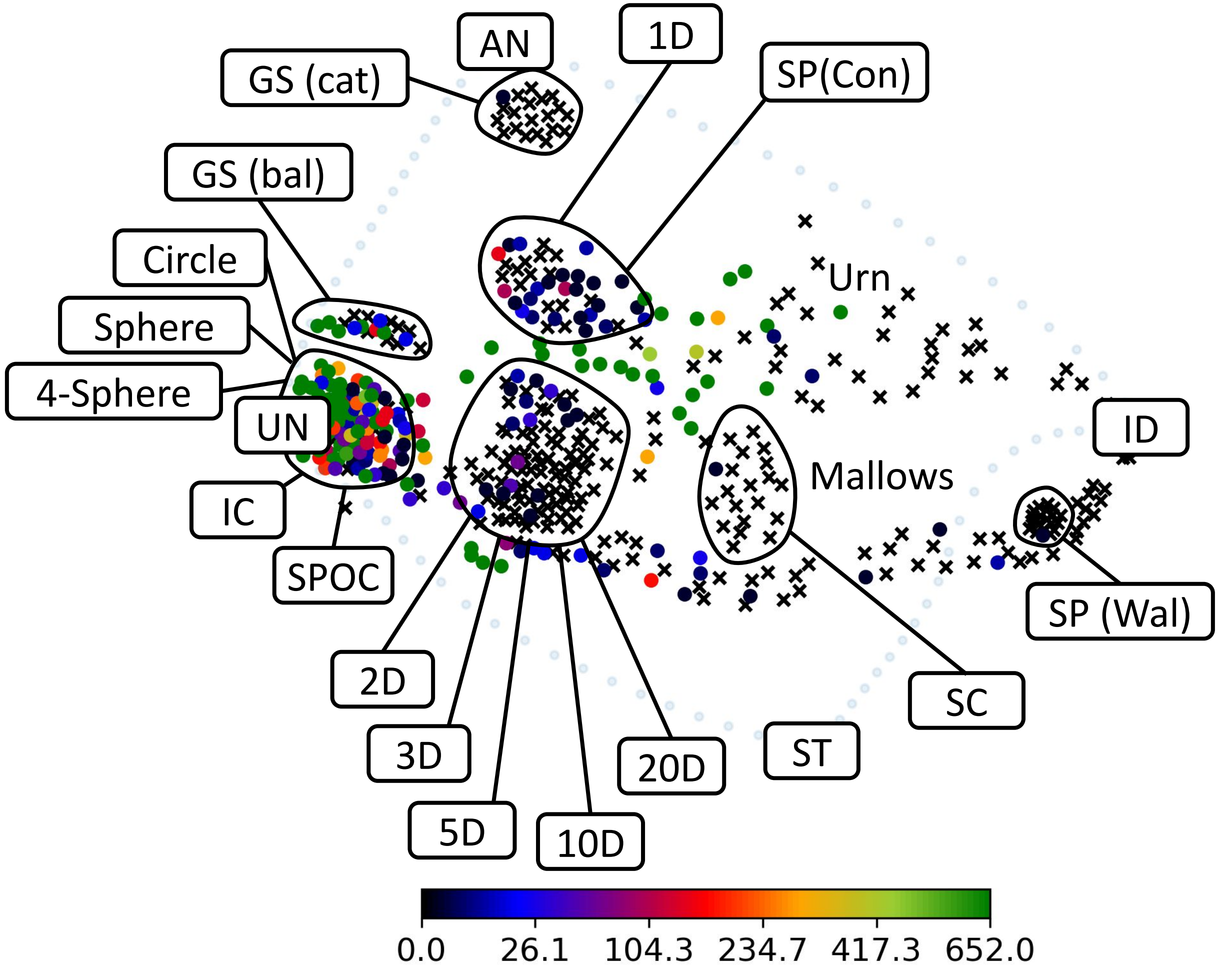
The candidate with the smallest score wins

Dodgson Rule



Score of a candidate is the minimal number of swaps needed to make him or her a Condorcet winner

The candidate with the smallest score wins

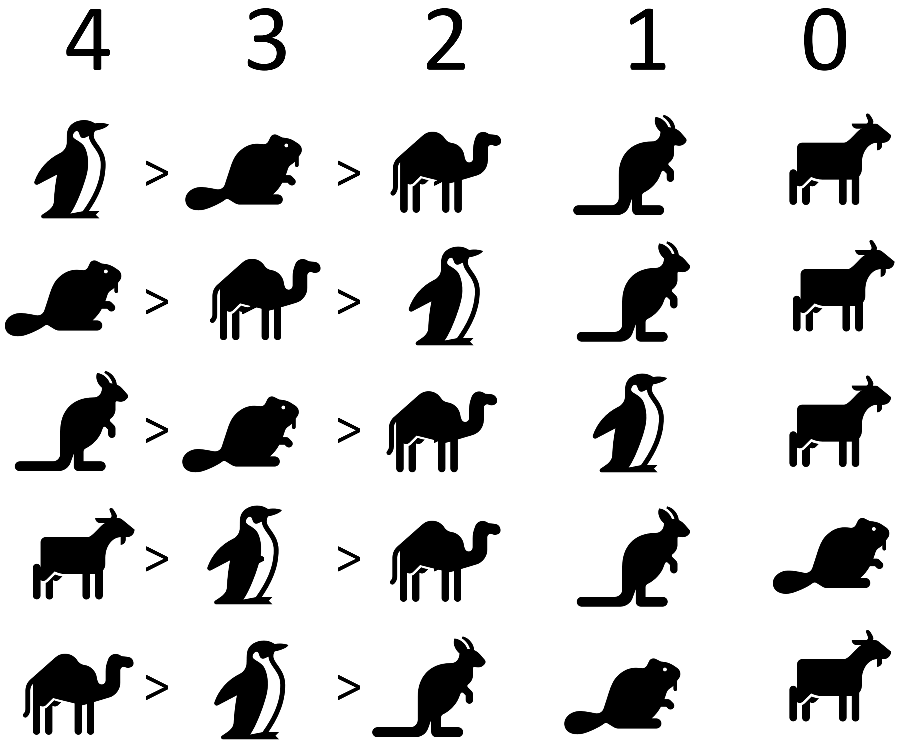


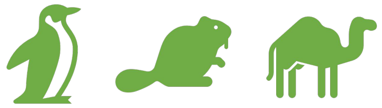
Lowest Dodgson Score

Winning Committee Score

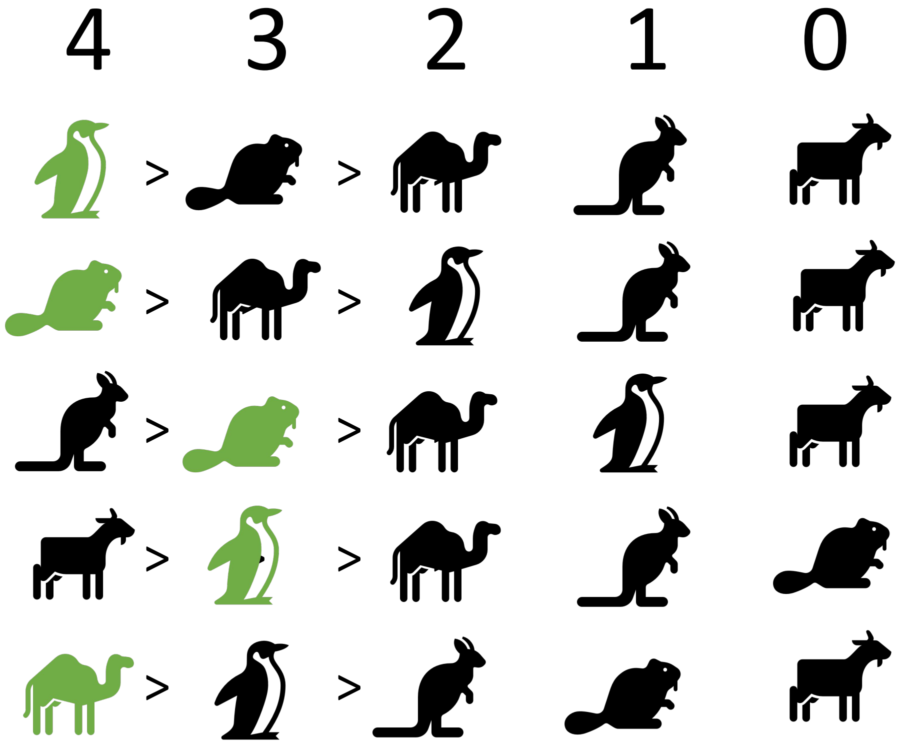
Visualizing Experiment Results

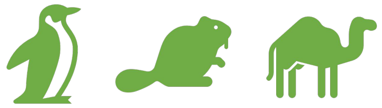
Chamberlin—Courant (CC) Rule





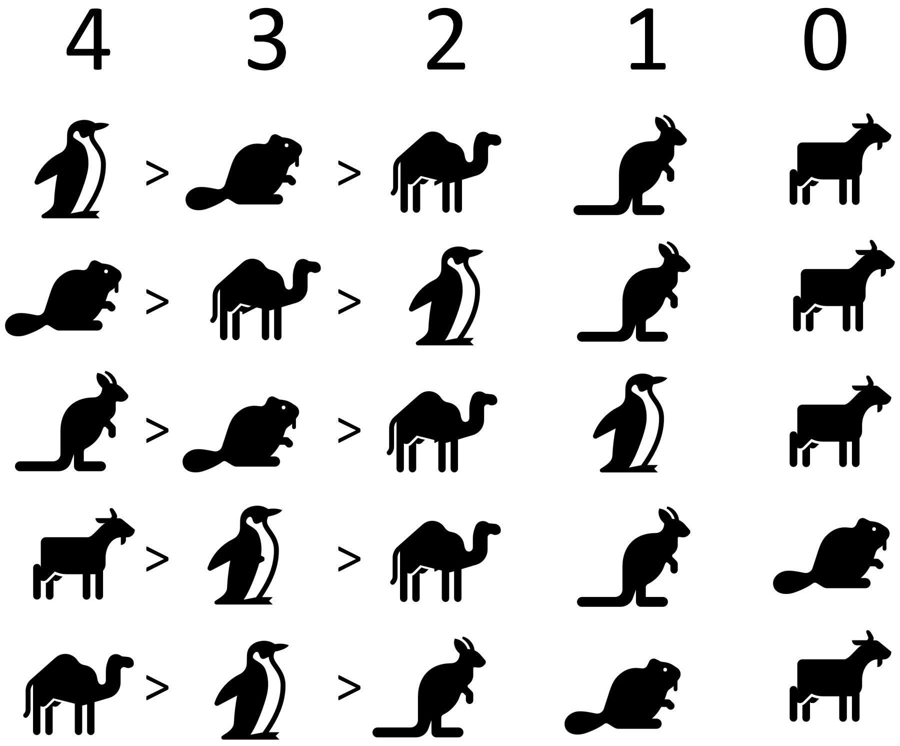
Chamberlin—Courant (CC) Rule

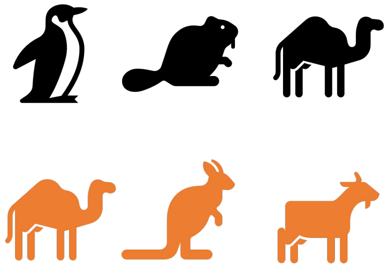




18 = 4+4+3+3+4

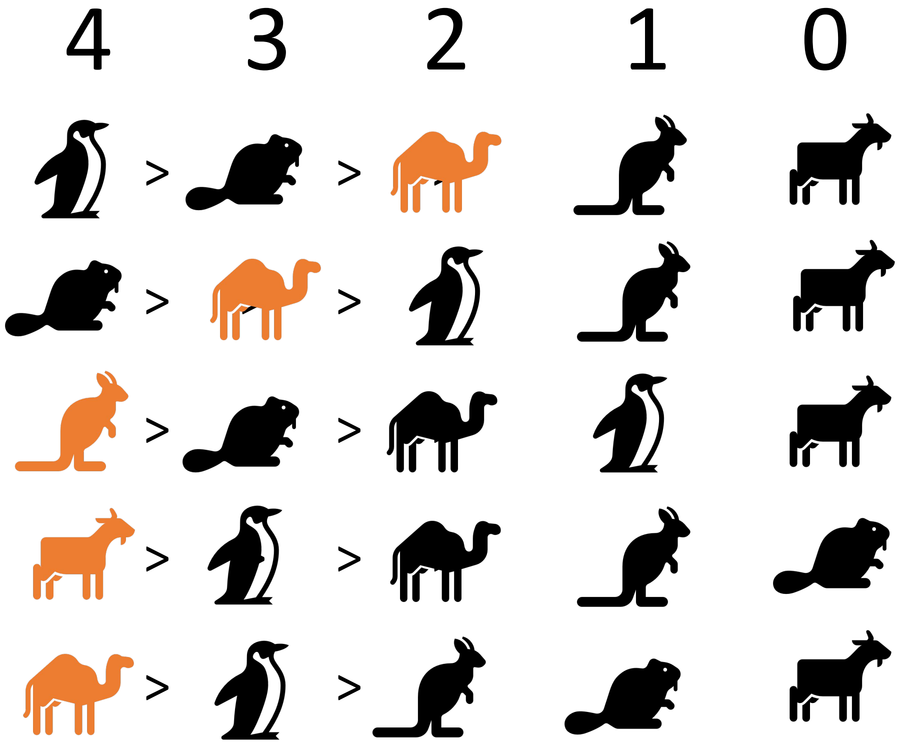
Chamberlin—Courant (CC) Rule

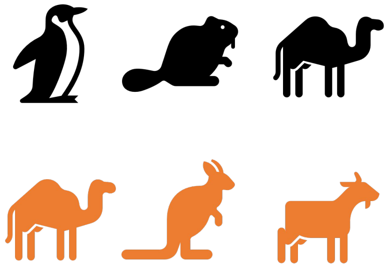




18 = 4+4+3+3+4

Chamberlin—Courant (CC) Rule

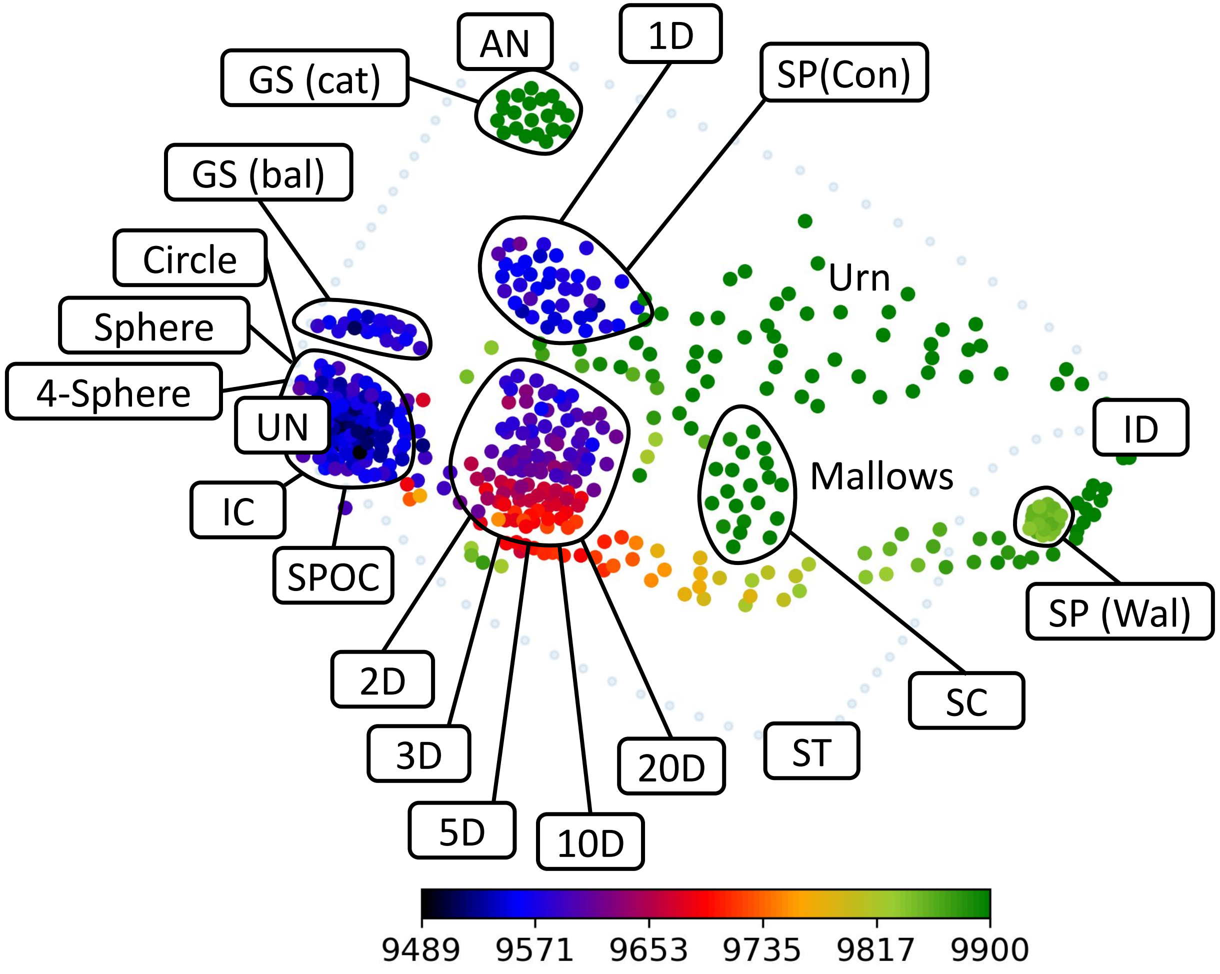




18 = 4+4+3+3+4

17 = 2+3+4+4+4

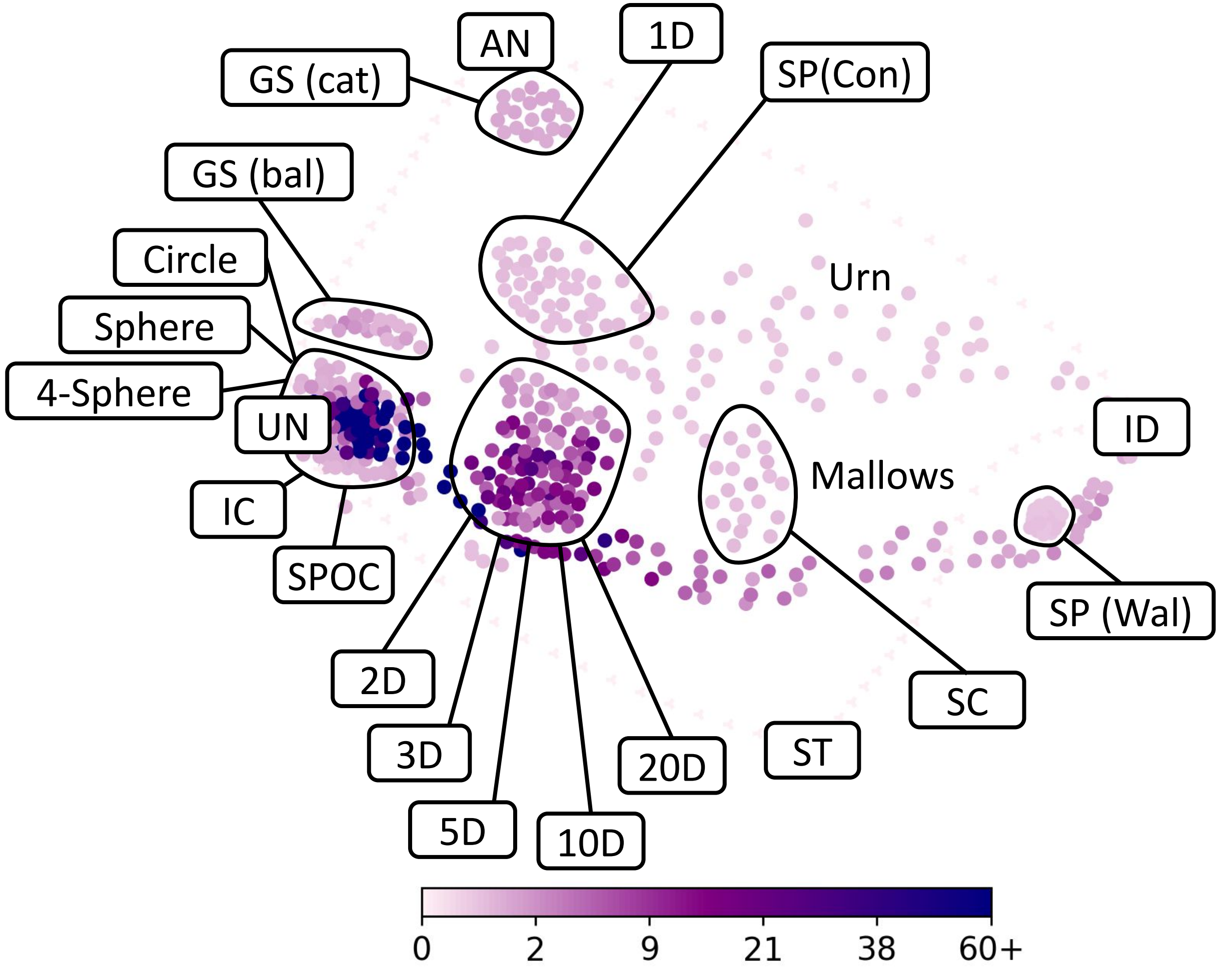
Committee with the highest score wins

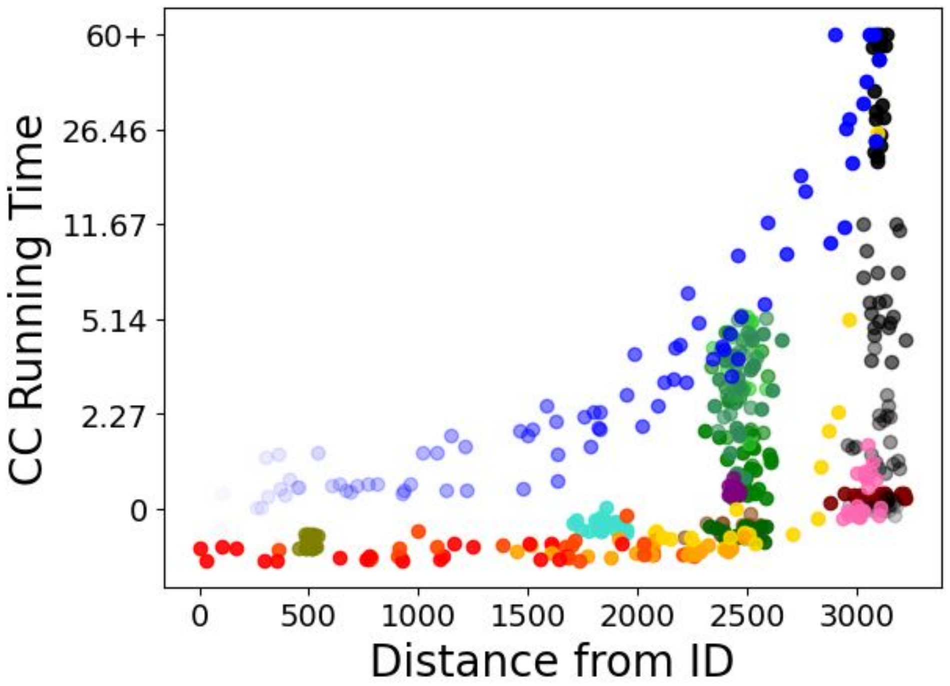


Highest CC Score

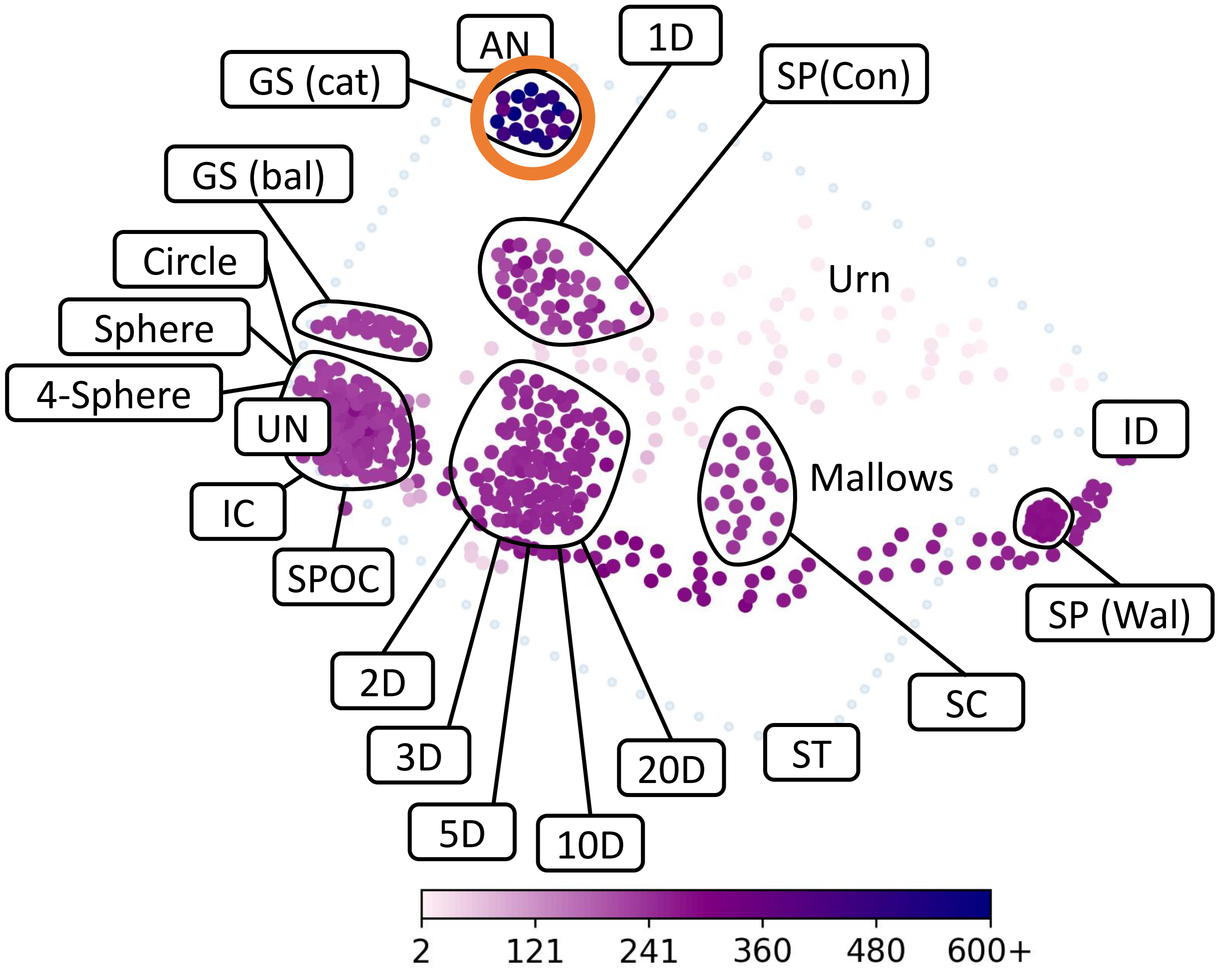
Running Time

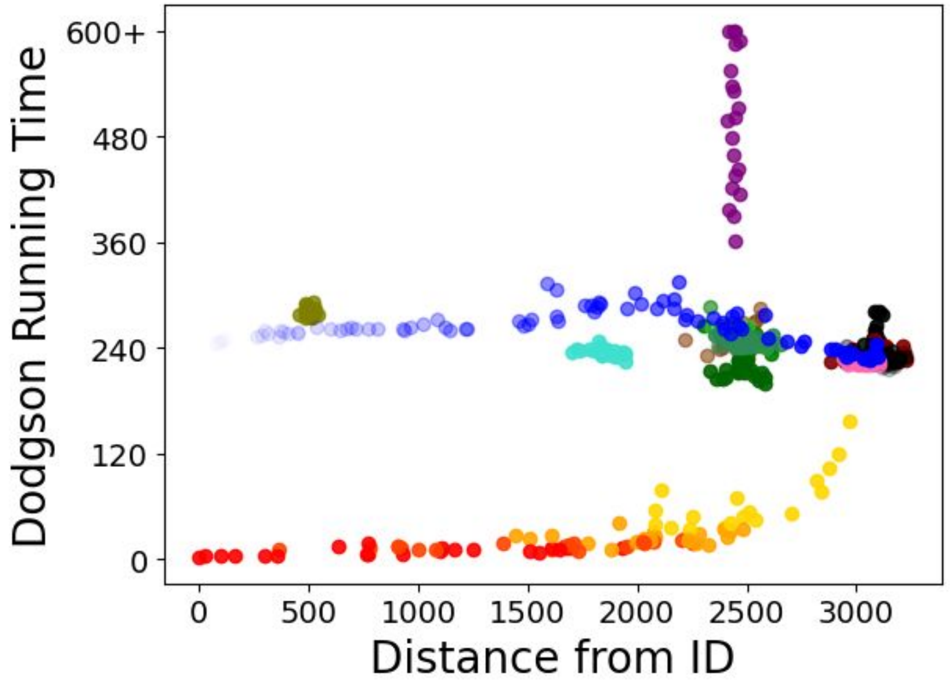
Visualizing Experiment Results





CC - Running Time (in seconds)



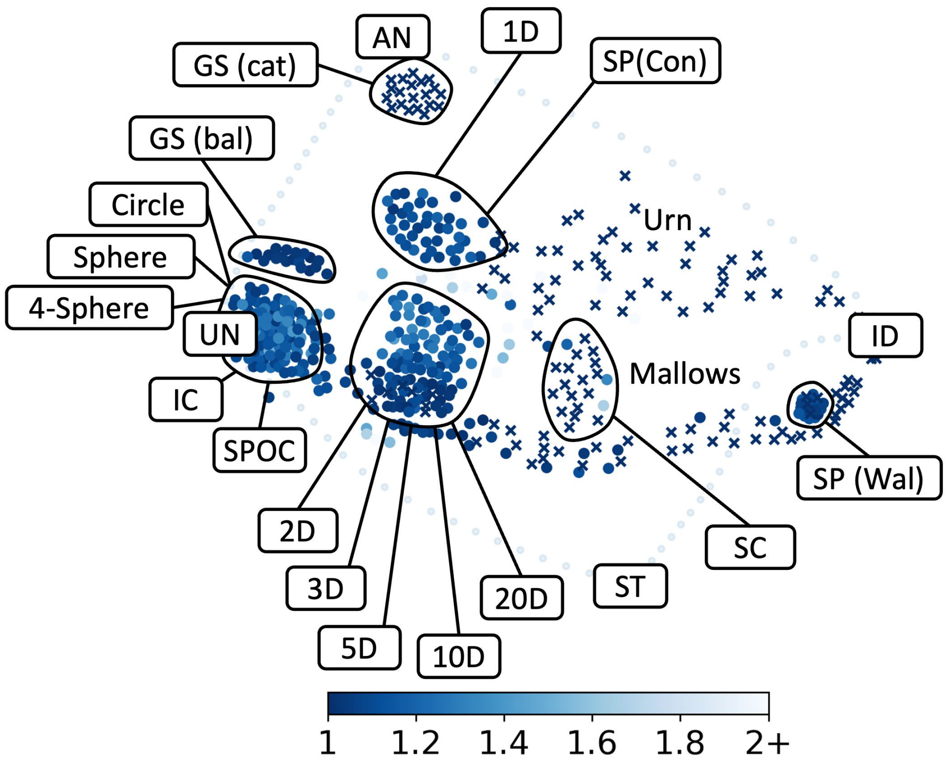


Dodgson - Running Time (in seconds)

Approximation Ratio

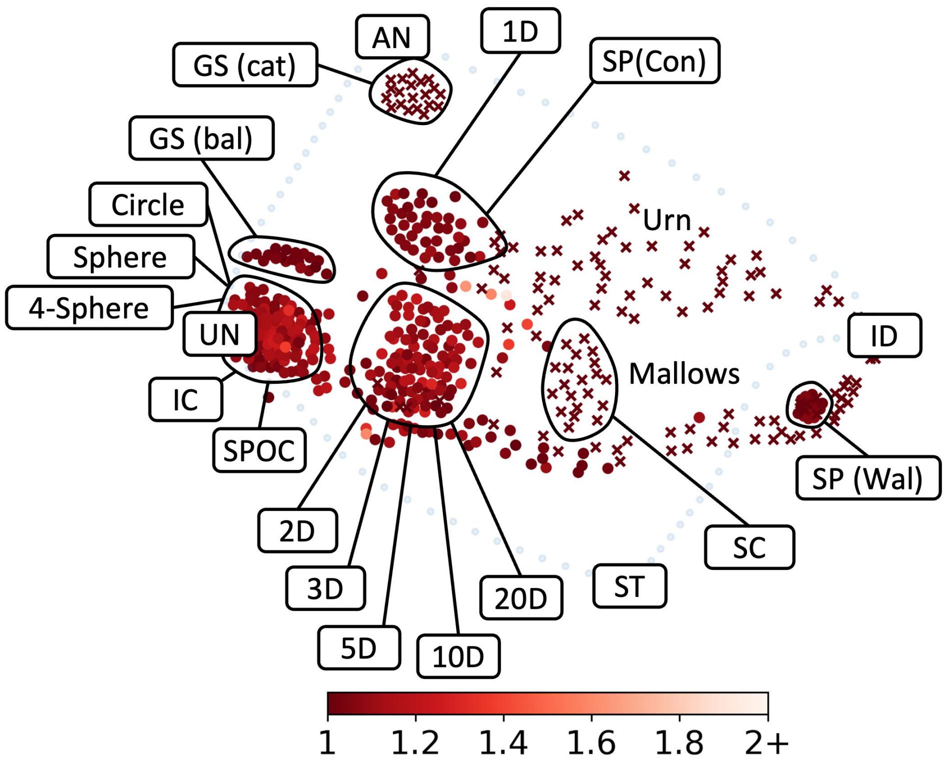
Visualizing Experiment Results

In each step, add the candidate
who increases the committee's score the most

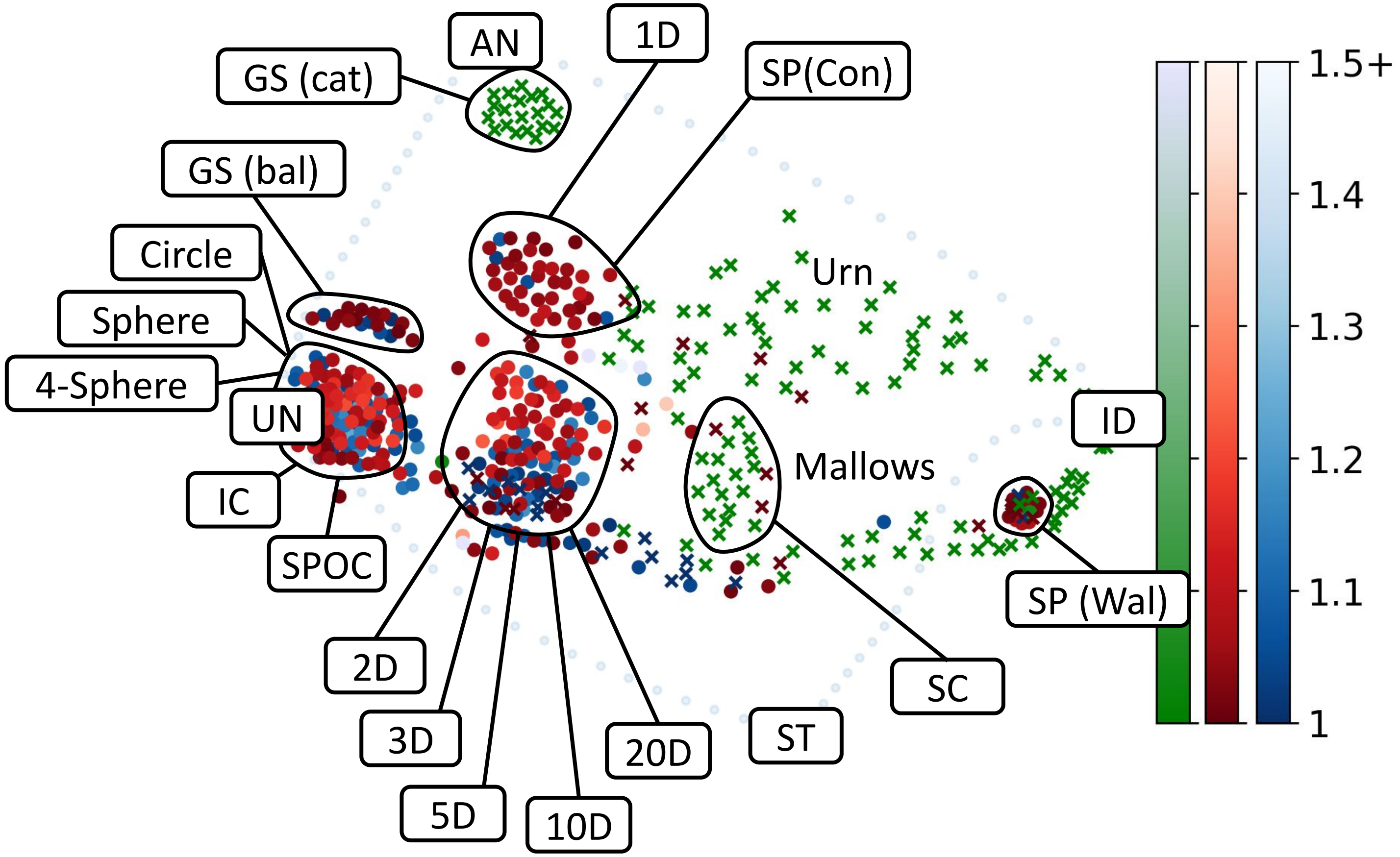


Sequential CC Approx. Ratio

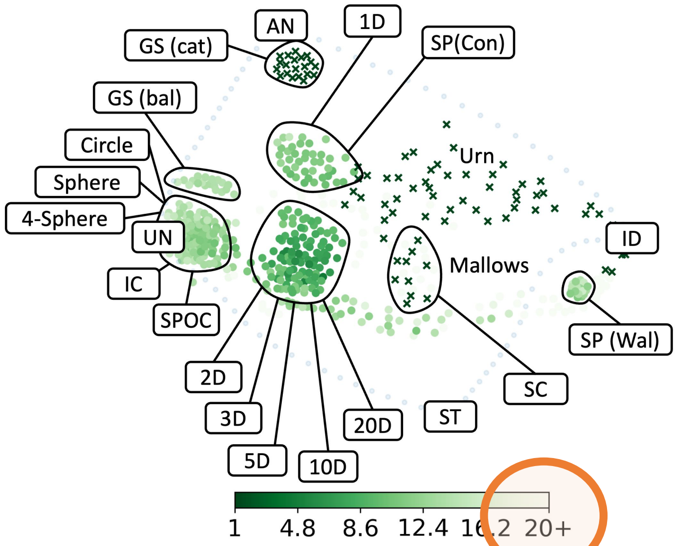
In each step, remove the candidate
who decreases the committee's score the least



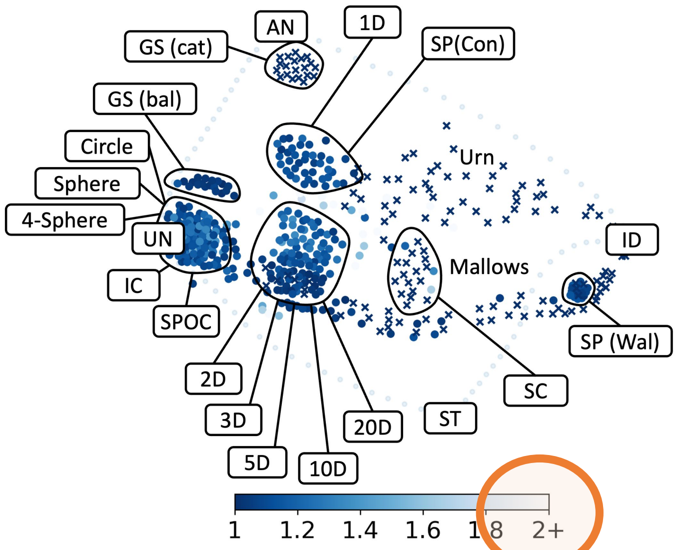
Removal CC Approx. Ratio



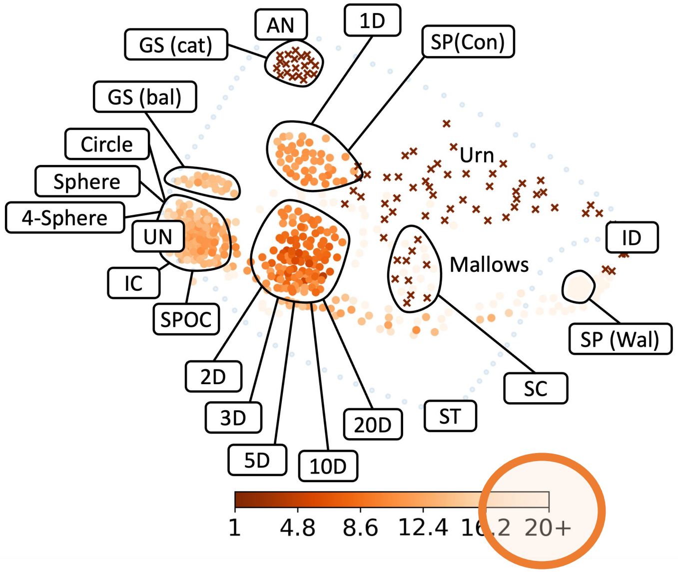
Sequential CC vs Removal CC



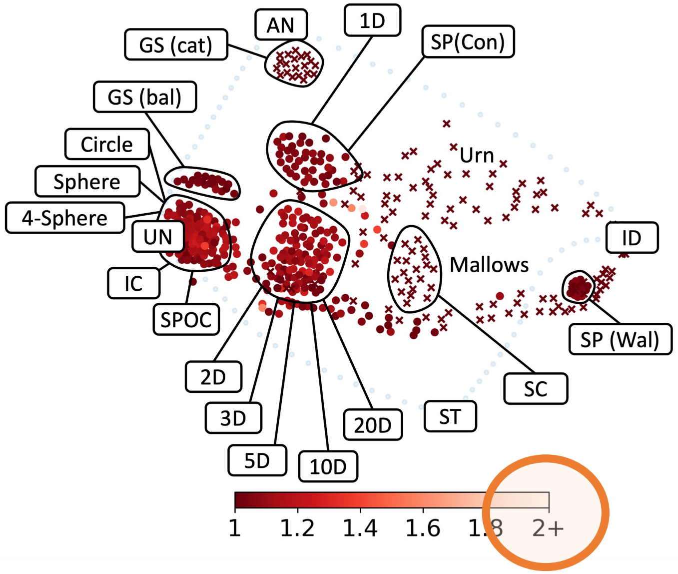
Banzhaf CC Approx. Ratio



Sequential CC Approx. Ratio



Ranging CC Approx. Ratio



Removal CC Approx. Ratio

Collecting, Classifying, Analyzing, and Using Real-World Ranking Data, Boehmer and Schaar, AAMAS-23

Putting a Compass on the Map of Elections, Boehmer et al., IJCAI-21

PrefLib: A Library for Preferences http://www.preflib.org, Mattei and Walsh, ADT-13

10 minutes

Putting Real-World Elections on the Map

Preflib Data

PrefLib ID	Name	Type	#Elections	Avg. m	Avg. n	Avg. Inc
1	Irish	political	3	11.67	46003.67	0.39
2	Debian	survey	8	6.25	419	0.08
3	NASA	survey	1	32	10	0.1
4	Netflix	user ratings	200	3.5	818.79	0.0
5	Burlington	political	2	6	9384	0.27
6	Skate	survey	48	23.31	8.67	0.0
7	ERS	association	87	8.74	409.31	0.25
8	Glasgow	political	21	9.9	8970.29	0.5
9	AGH	survey	2	8	149.5	0.0
10	Ski	sport	2	260.5	4	0.23
11	Web	meta-search	77	1874.74	4.04	0.36
12	T-Shirt	survey	1	11	30	0.0
14	Sushi	survey	1	10	5000	0.0
15	Clean Web	meta-search	79	78.15	4.04	0.0
16	Aspen	political	2	8	2502	0.26
17	Berkley	political	1	4	4173	0.13
18	Minneapolis	political	4	218	34370.5	0.76
19	Oakland	political	7	7	52449.29	0.39
20	Pierce	political	4	5	188627	0.29
21	San Francisco (sf)	political	14	10.43	61635.79	0.51
22	San Leandro (sl)	political	3	5.33	23666	0.27
23	Takoma Park	political	1	4	204	0.13
24	Mechanical Turk dots	human tests	4	4	795.75	0.0
25	Mechanical Turk puzzle	human tests	4	4	795	0.0
26	French Presidental	political	6	16	430.83	0.68
27	Proto French	political	1	15	398	0.7
28	APA	association	12	5	16991.33	0.16
30	UK Labor Leadership	political	1	5	266	0.21
31	Vermont	political	15	3.93	1160.73	0.42
32	Education Survey	survey	7	13.57	21.86	0.39
33	San Sebastian Poster	survey	2	17	61.5	0.59
34	Cities	survey	2	42	392	0.73
35	Breakfast Items	survey	6	15	42	0.0
57	Austrian Parliamentary	political	9	12.22	4792773.11	0.84

637 elections from 35 datasets of different types:

- Humans expressing opinions concerning candidates for a position (political, association)
- Humans expressing preferences over objects (survey, user ratings)
- Humans ranking items as part of a test (human tests)

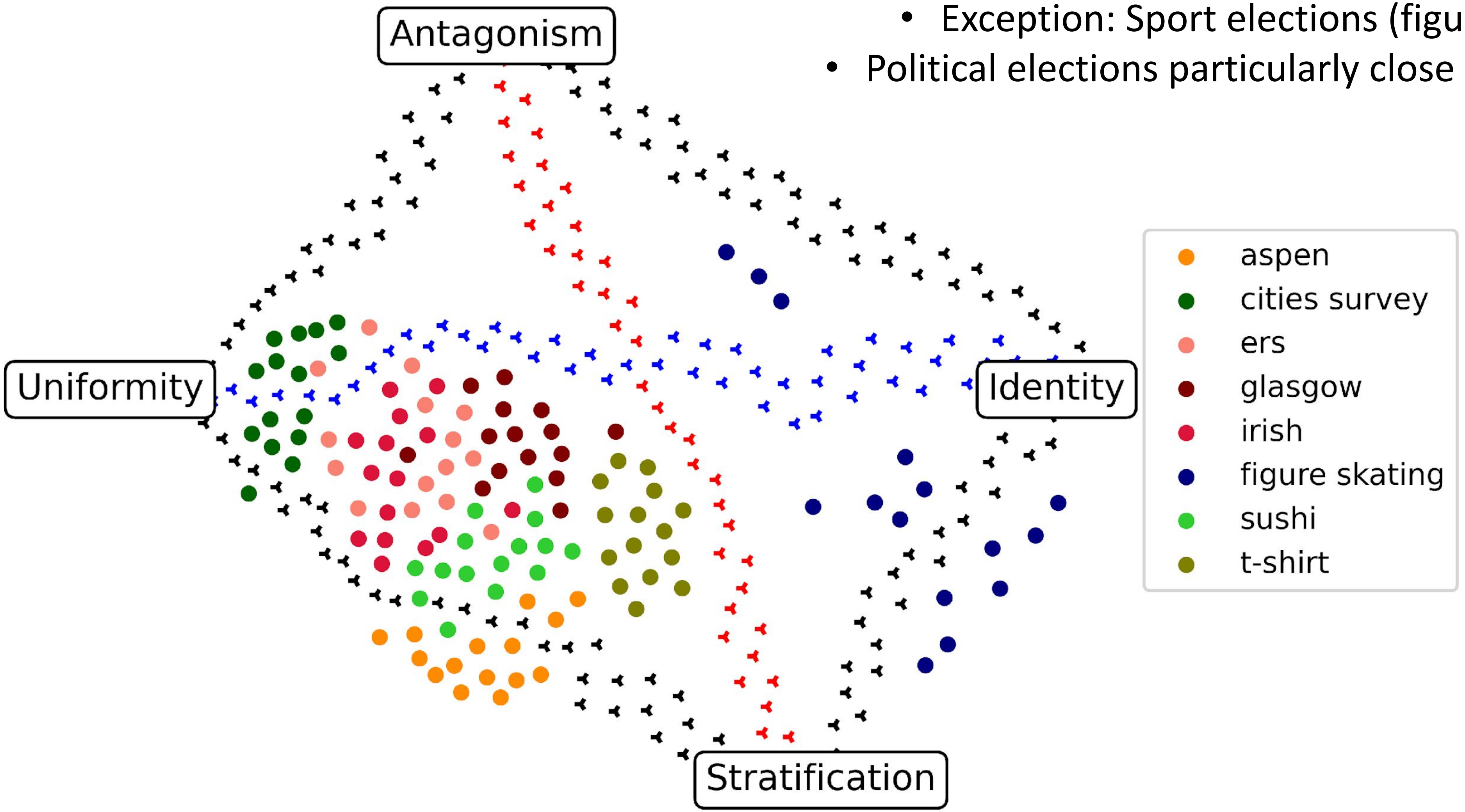
Decisive features:

- Typcially below 10 candidates or below 10 voters.
- Often highly incomplete votes, voters typically rank only small subset of candidates.

Usable for map:

Irish, Skate, ERS, Glasgow, T-Shirt, Sushi, Aspen, and Cities

Map of Preflib Elections



- Most elections fall in bottom left of map
  - Exception: Sport elections (figure skating)
- Political elections particularly close to each other

A Second Datasource

Collecting, Classifying, Analyzing, and Using Real-World Ranking Data, AAMAS 2023.

Time-Based Elections

- Multi-race competitions (Formula 1 season/Tour de France)
- Top-x rankings at different times (Spotify, boxing, tennis top 100, american football)

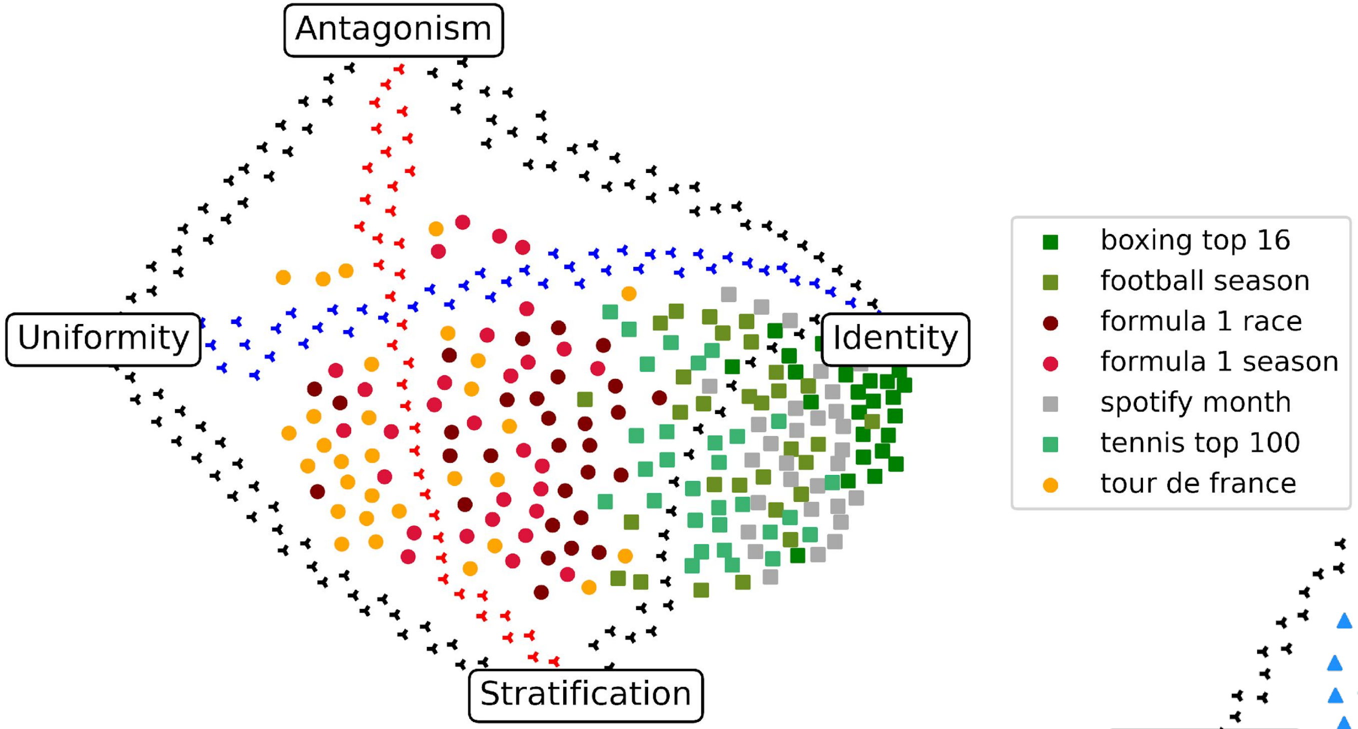
…

Criterion-Based Elections

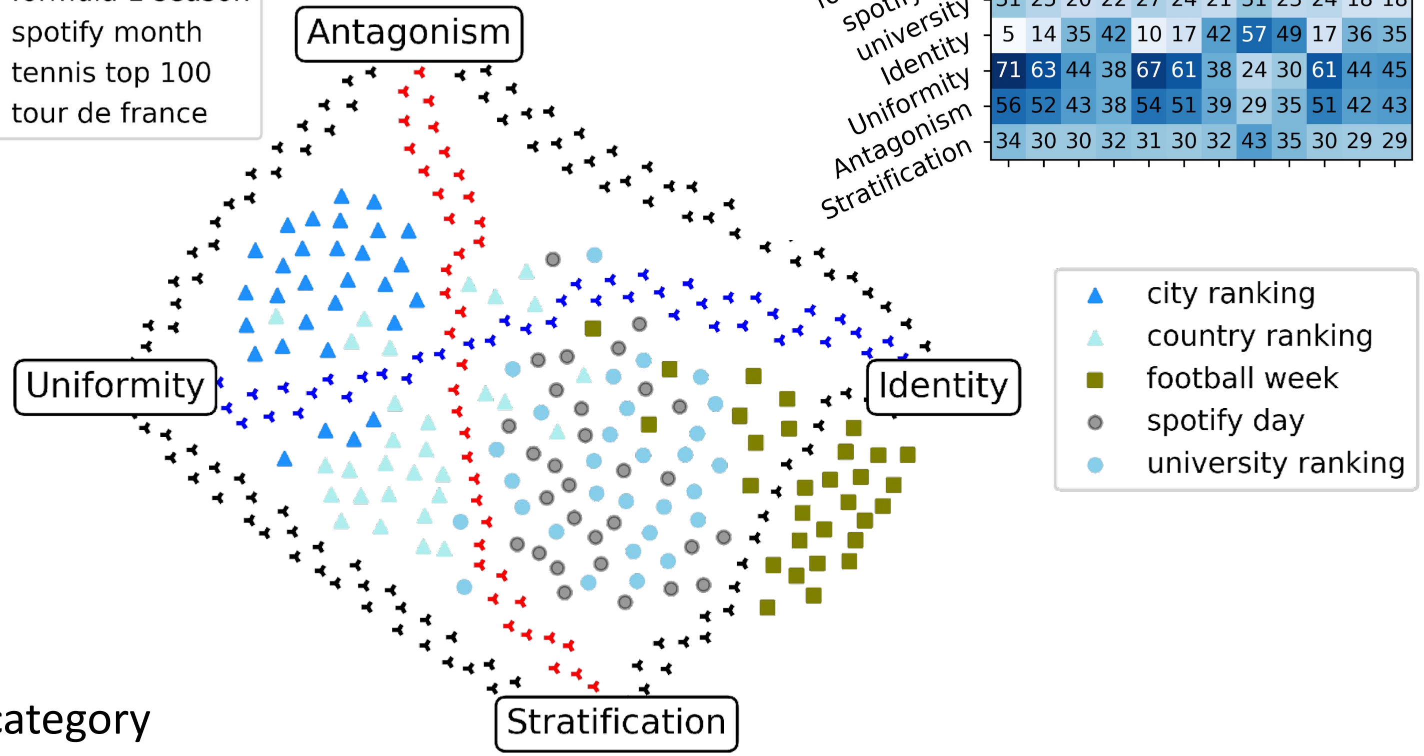
- Indicator-based rankings (cities, countries, universities)
- Top-x rankings from different sources (Spotify, american football)

…

Map of Real-World Elections



	boxing top 16	football season	formula 1 race	formula 1 season	spotify month	tennis top 100	tour de france	city ranking	country ranking	football week	spotify day	university
boxing top 16	7	13	32	38	10	15	38	53	45	15	32	31
football season	13	13	26	31	13	15	31	46	38	14	26	25
formula 1 race	32	26	20	22	28	25	22	31	24	24	20	20
formula 1 season	38	31	22	20	34	30	21	27	21	30	21	22
spotify month	10	13	28	34	10	13	34	50	41	14	28	27
tennis top 100	15	15	25	30	13	15	30	45	36	15	24	24
tour de france	38	31	22	21	34	30	21	26	21	29	20	21
city ranking	53	46	31	27	50	45	26	18	22	44	30	31
country ranking	45	38	24	21	41	36	21	22	18	35	23	23
football week	15	14	24	30	14	15	29	44	35	14	24	24
spotify day	32	26	20	21	28	24	20	30	23	24	18	18
university	31	25	20	22	27	24	21	31	23	24	18	18
Identity	5	14	35	42	10	17	42	57	49	17	36	35
Uniformity	71	63	44	38	67	61	38	24	30	61	44	45
Antagonism	56	52	43	38	54	51	39	29	35	51	42	43
Stratification	34	30	30	32	31	30	32	43	35	30	29	29



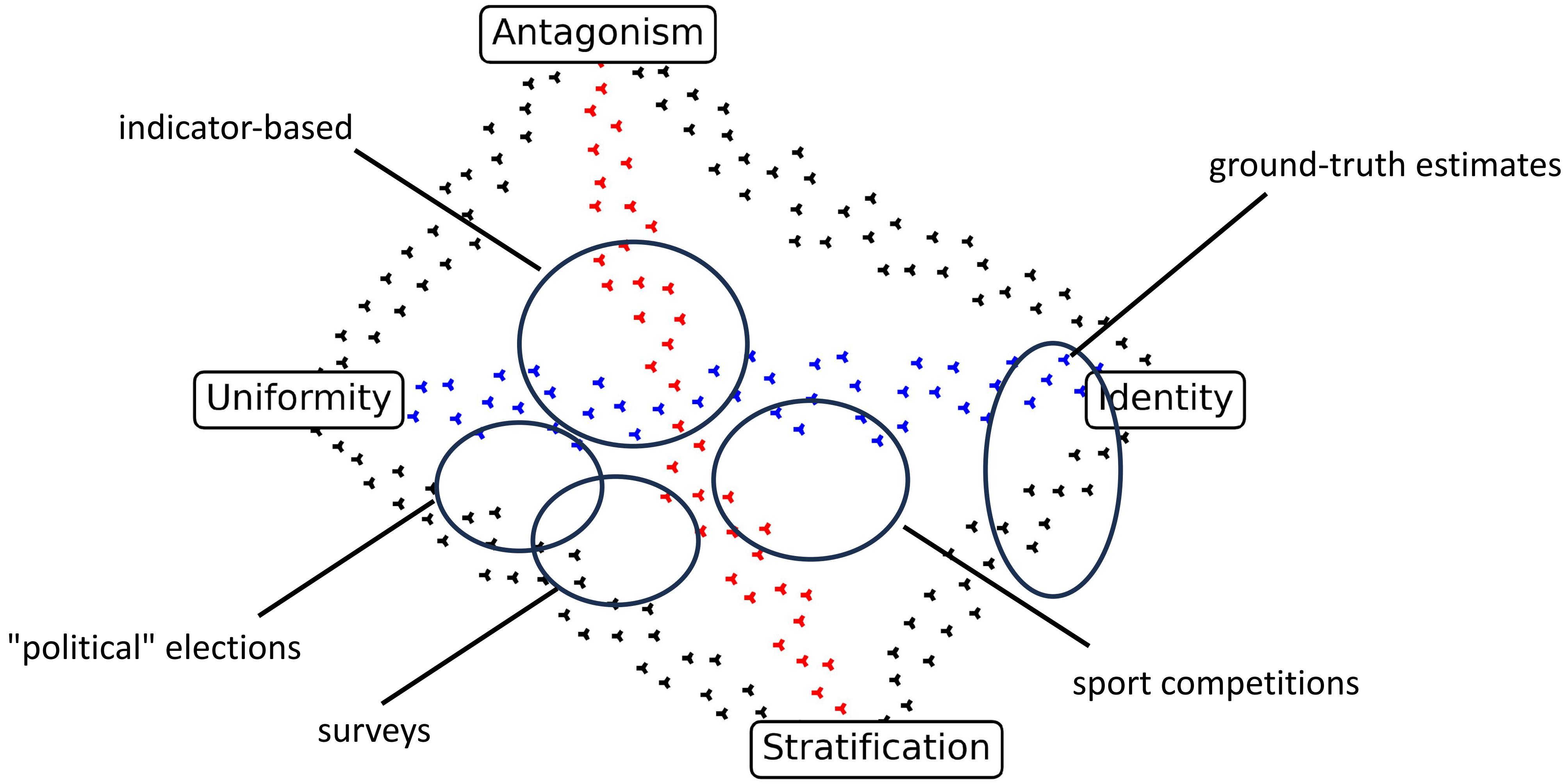
■ Close to Identity elections (mostly time-based)

● Elections from "the middle"

▲ "Outliers" closer to Uniformity

→ very consistent behavior of data sources from one category

Different Types of Real-World Elections

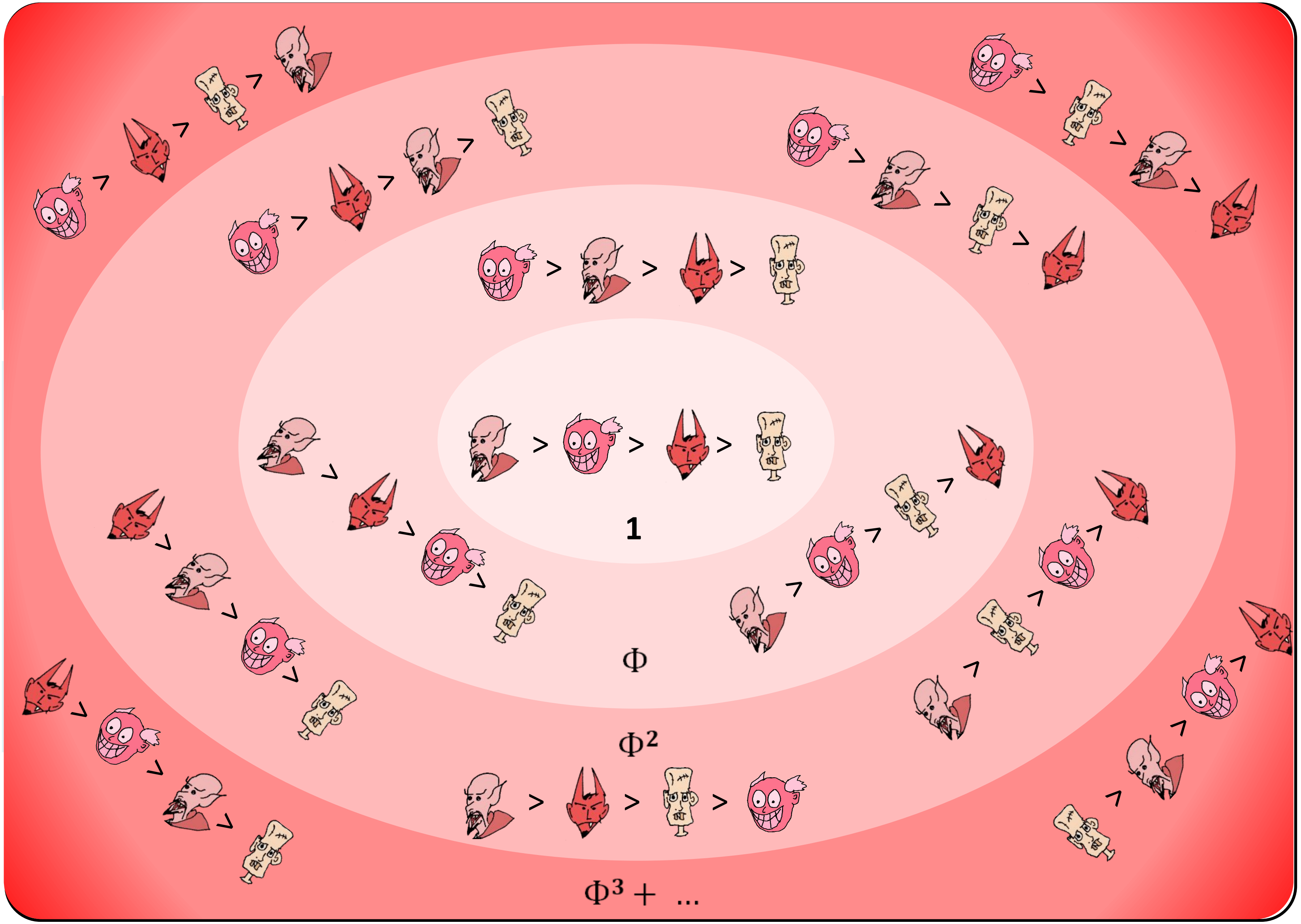


Putting a Compass on the Map of Elections, Boehmer et al., IJCAI-21

Properties of the Mallows Model Depending on the Number of Alternatives: A Warning for an Experimentalist, Boehmer et al., ICMl-23

15 minutes

Using the Map to Generate Realistic Data: (Normalized) Mallows Model



Mallows Model

Input

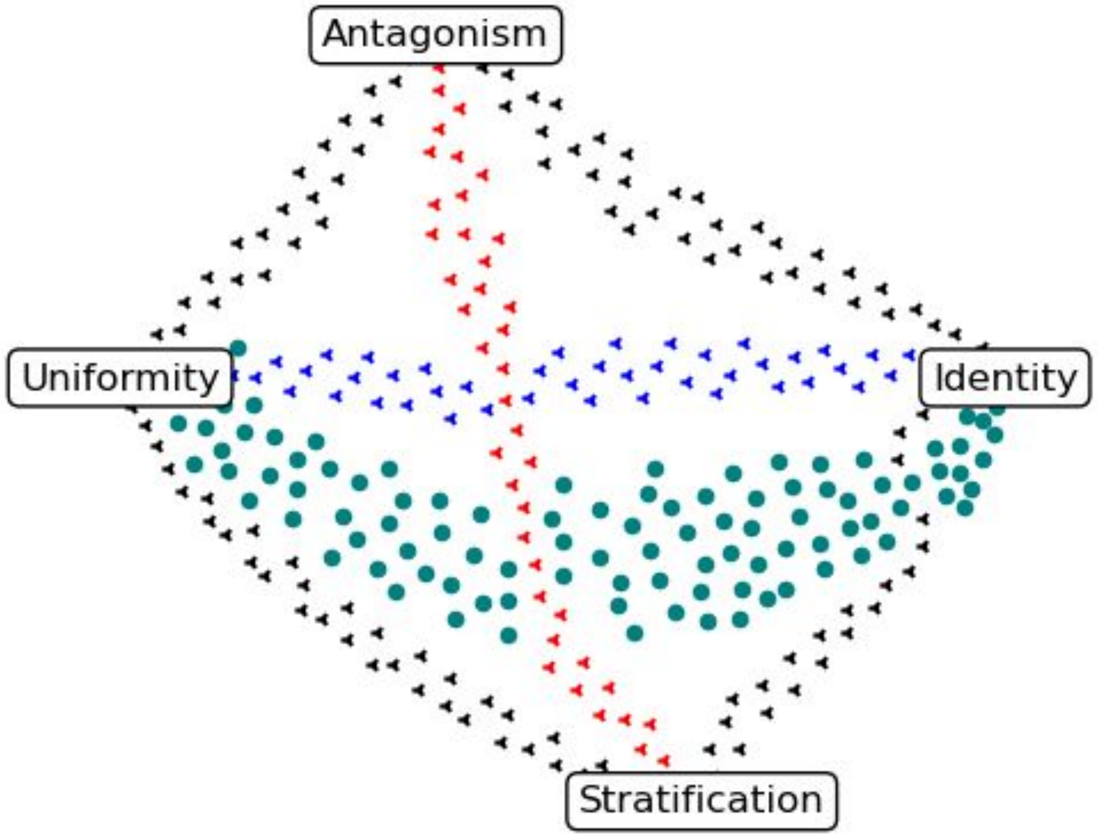
Central vote v* + dispersion paramter ϕ

Sampling

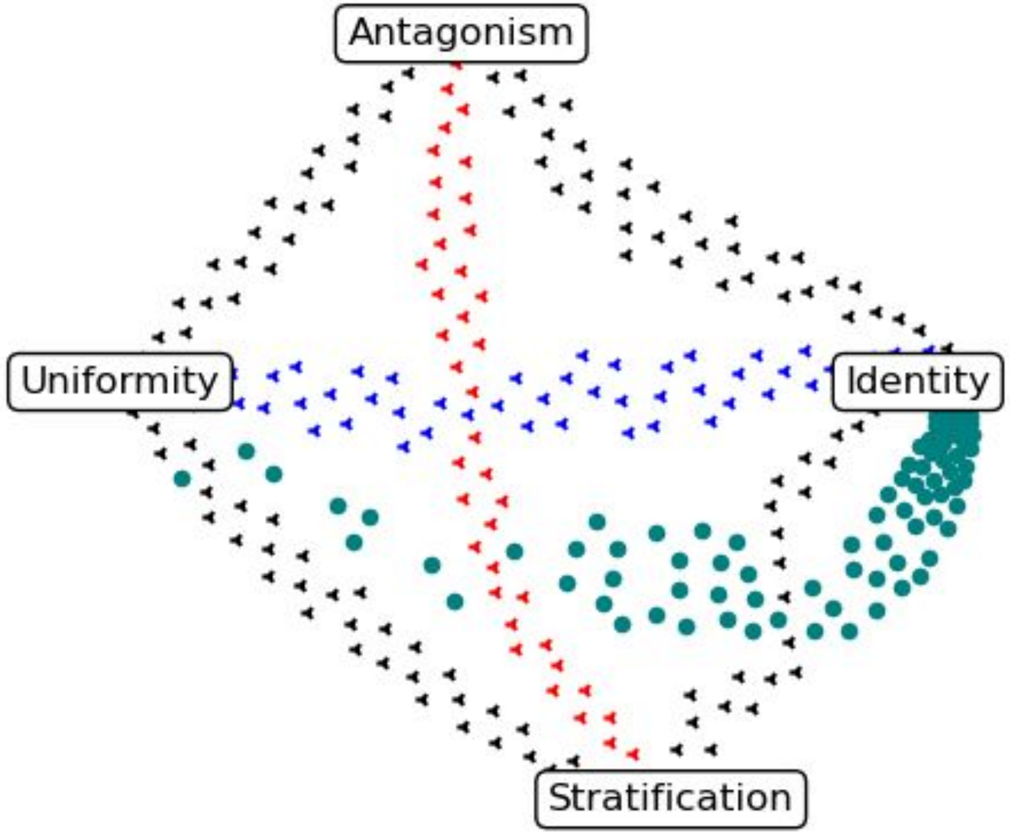
Probability of sampling vote v proportional to:

$$\phi^{swap(v,v^*)}$$

Mallows Model with Uniformly Sampled ϕ

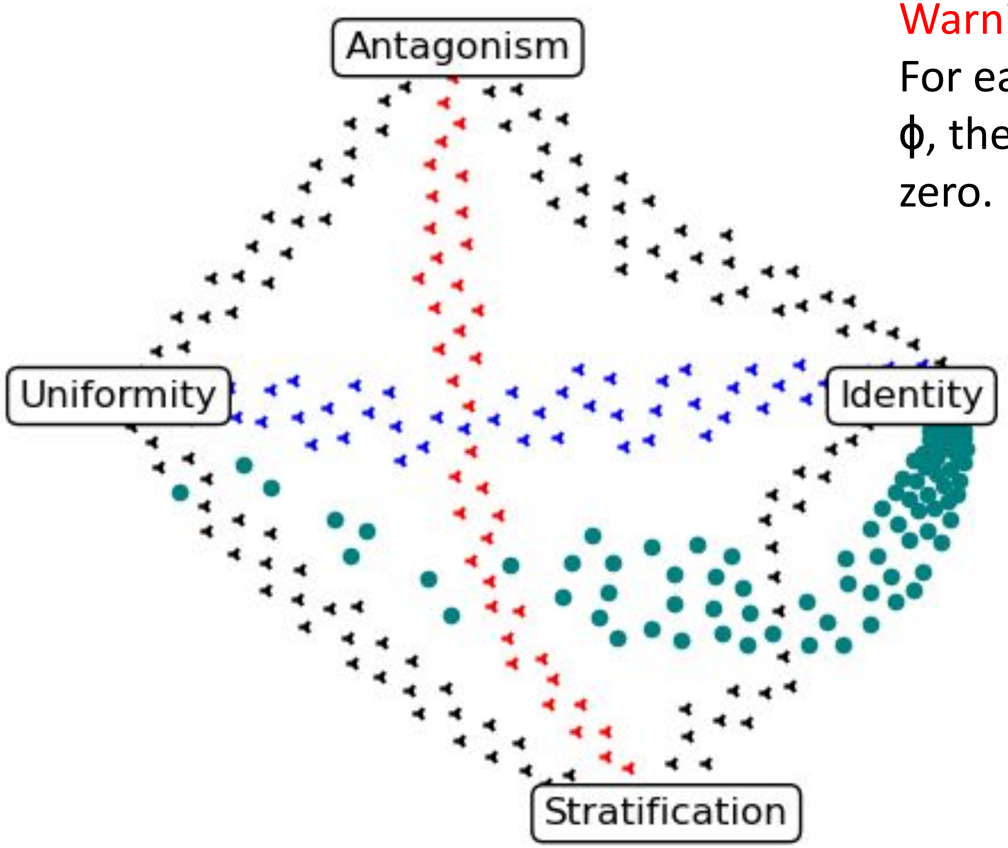


100 voters and 10 candidates



100 voters and 50 candidates

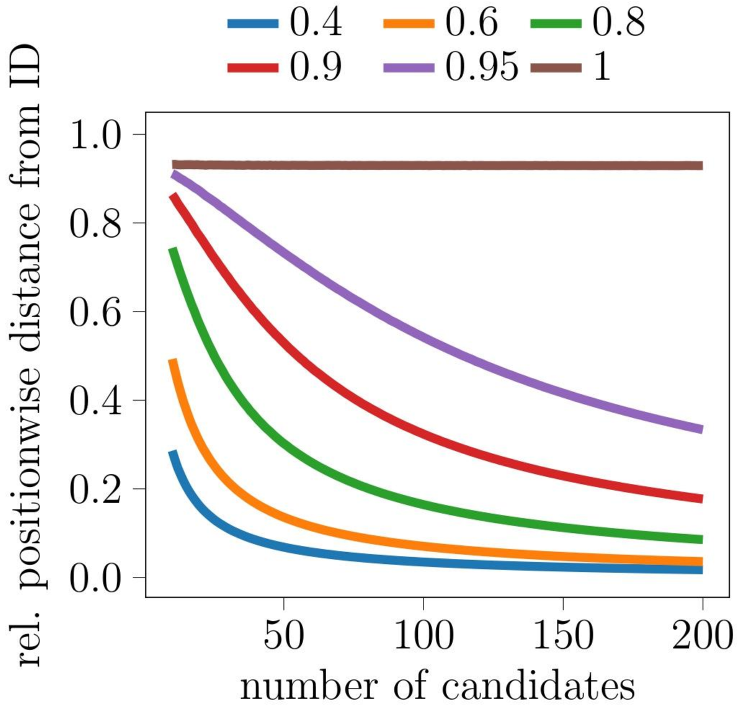
Mallows Model with Uniformly Sampled ϕ

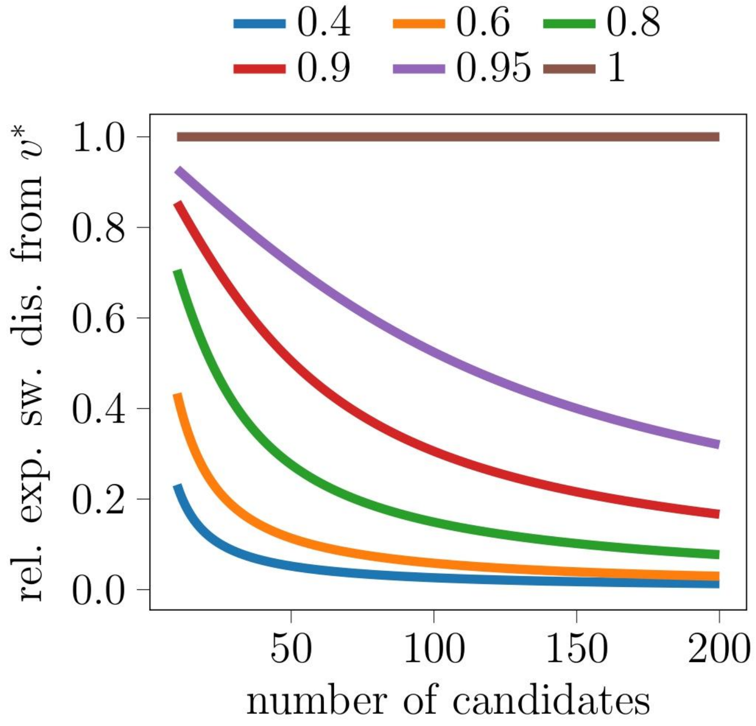


100 voters and 50 candidates

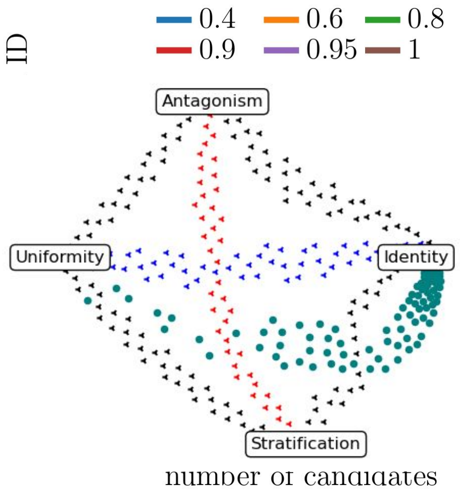
Warning

For each fixed dispersion parameter ϕ, the relative distance to ID goes to zero.





Problems with Mallows Model



Common Implicit Assumptions

Evidence

A fixed dispersion parameter produces "structurally similar" elections for different candidate numbers.

⇨ Fixed dispersion parameter for different candidate numbers in one experiment.

A uniformly at random chosen dispersion parameter "uniformly covers" the space between identity and uniformity elections.

⇨ Don’t know what dispersion to use? Just choose uniformly at random, it’s the *natural* agnostic choice.

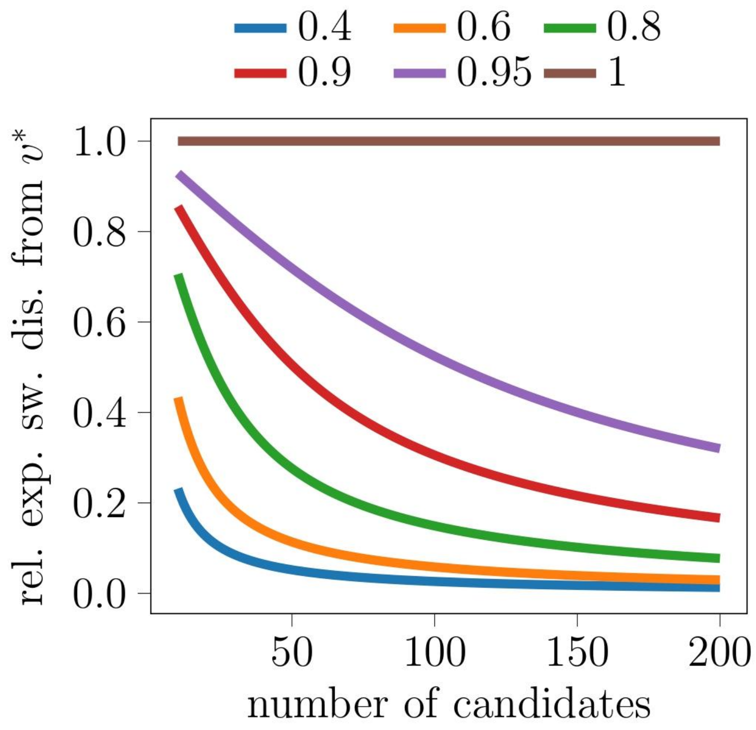
⇩

Possibility for methodological errors!

What Can We Do?

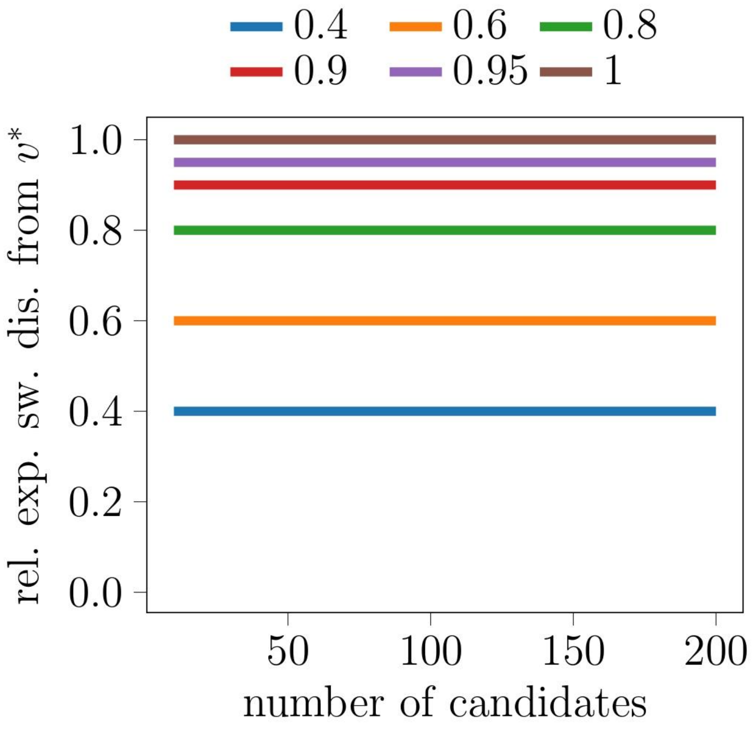
Mallows Model

Sampled votes become more and more similar to central one



Normalized Mallows Model

Keep expected swap distance from central order fixed



Normalized Mallows Model

Idea

- Keep expected swap distance from central order fixed

Advantage

- Uniform parameter values lead to uniform coverage of election space
- "Consistent" behavior for varying number of candidates
- Easy-to-interpret parameter values

Input

Central vote v* with m candidates + "new" paramter norm-ϕ

Conversion

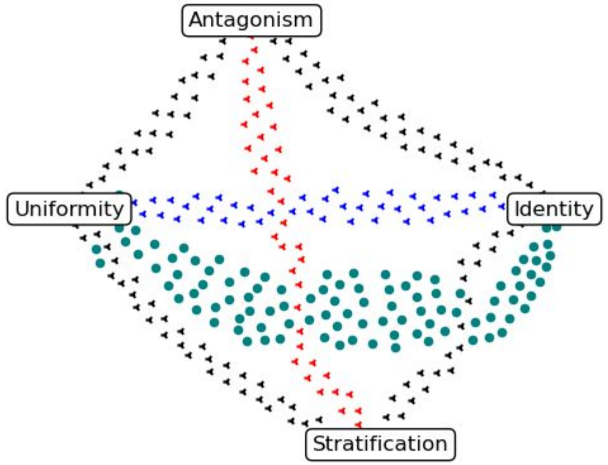
Choose a value ϕ of the dispersion parameter s.t. expected swap distance between central and sampled vote:

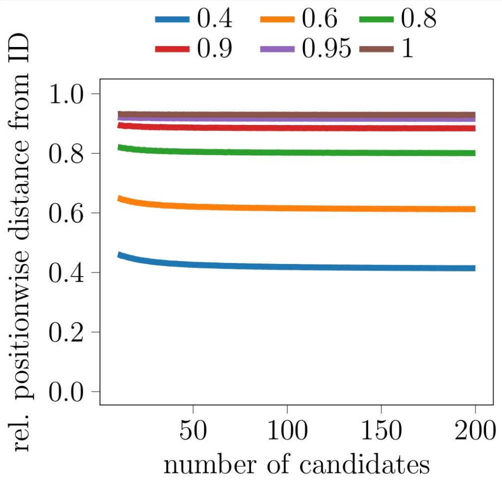
$$\text{norm-}\phi \cdot \tfrac{1}{4}\, m(m-1)$$

Sampling

Probability of sampling vote v proportional to:

$$\phi^{\text{swap}(v,v^*)}$$

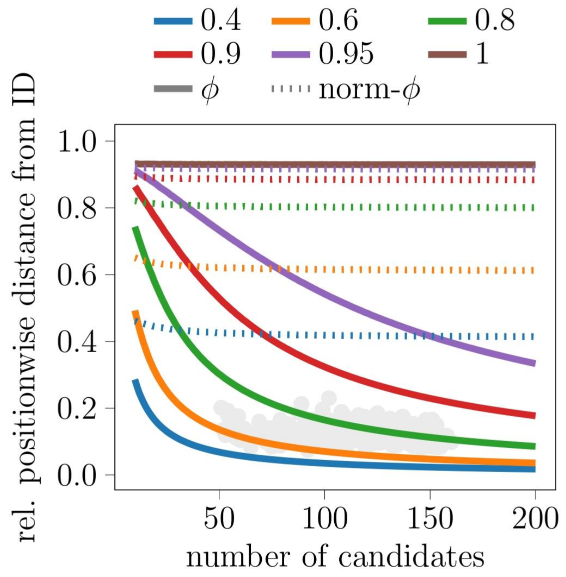


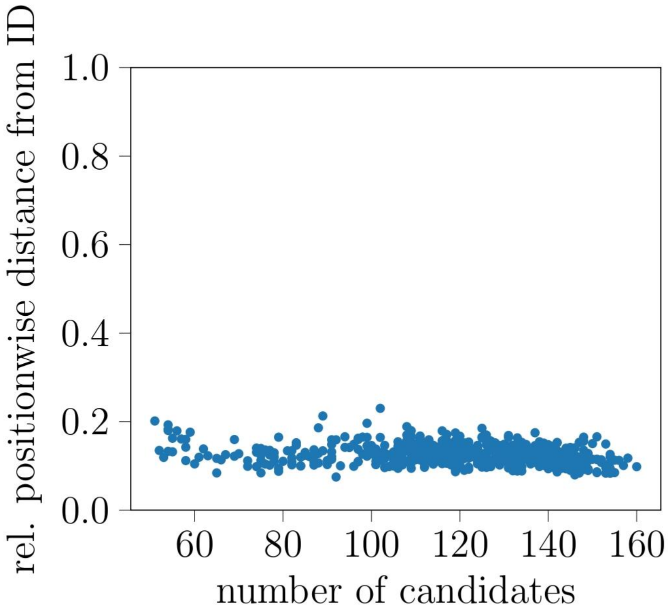


Real-World Evidence

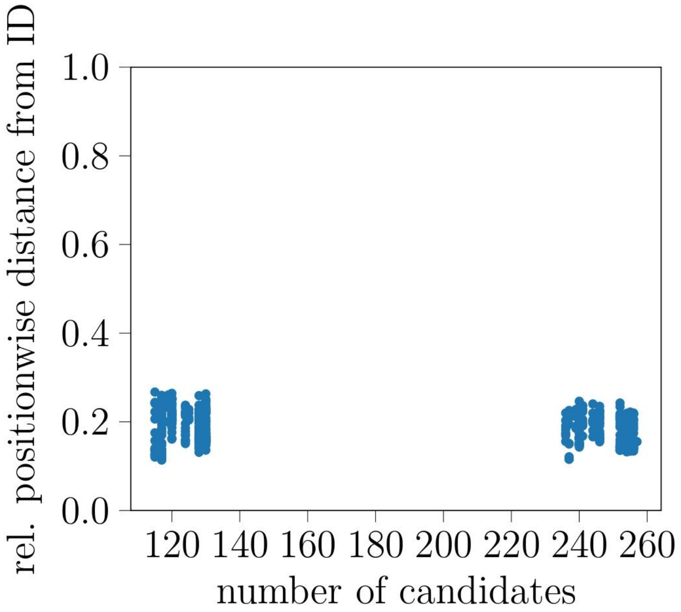
⇩

Behaves as normalized Mallows model

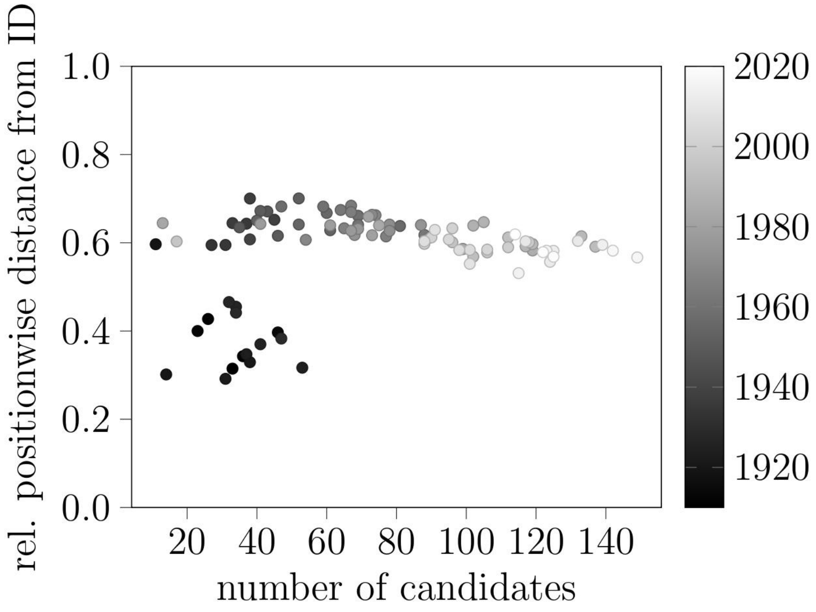




Spotify charts



American football power rankings



Tour de France

Central order: $c_1 > c_2 > \ldots > c_m$

Further Results

Fixing dispersion parameter also "fixes":

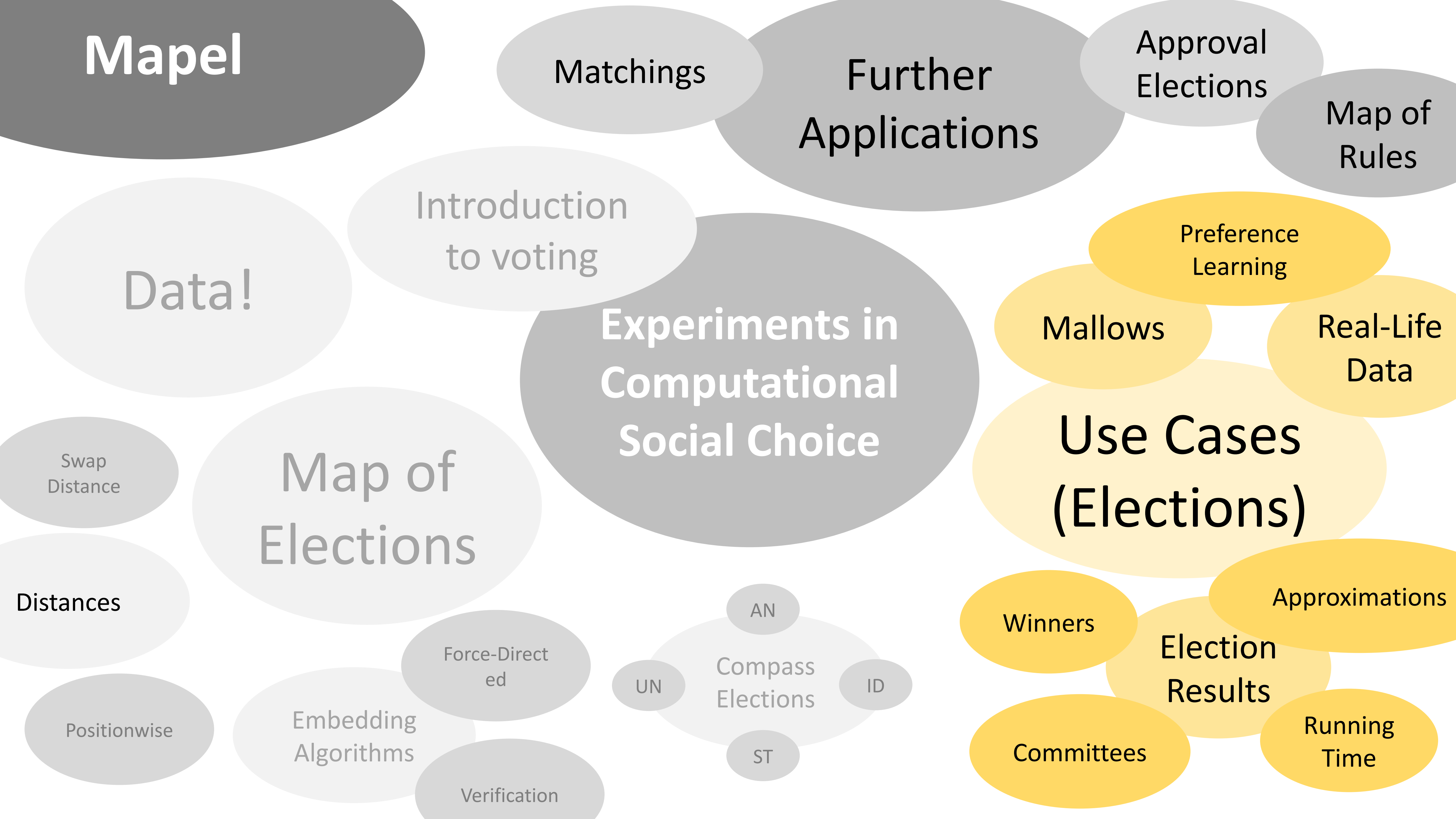
- Probability that c_1 is ranked in the first position
- Probability that c_i is ranked before c_j for fixed i and j
- Probability that c_1 is Plurality winner in 100 voter election

Fixing normalized dispersion parameter also "fixes":

- Relative position of c_1
- Probability that c_1 is ranked before c_m

Mallows Model: Warnings

- Be careful when varying the number of candidates: Trends could be artifact of Mallows model.
- Statements about certain ranges of dispersion parameter unlikely to generalize for other candidate numbers.
- Be careful how to select values of dispersion parameter in experiments to ensure meaningful coverage.
- Problems get intensified for generalizations such as Mallows mixtures.



Mapel
Matchings
Further Applications
Approval Elections
Map of Rules
Data!
Introduction to voting
Experiments in Computational Social Choice
Preference Learning
Mallows
Real-Life Data
Use Cases (Elections)
Swap Distance
Map of Elections
Distances
Positionwise
Force-Directed
Embedding Algorithms
Verification
AN
UN
Compass Elections
ID
ST
Winners
Approximations
Election Results
Committees
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UN

ID

ST

Positionwise

Embedding Algorithms

Verification

Winners

Approximations

Election Results

Committees

Running Time

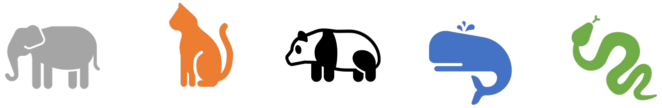
25 minutes

Approval Elections

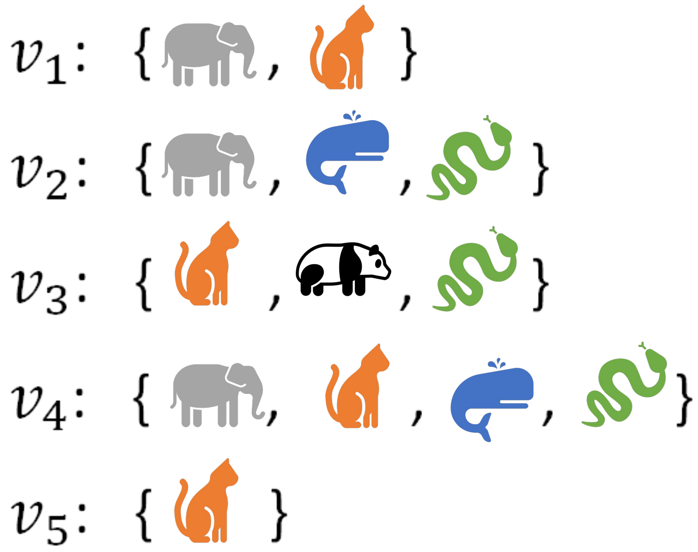
Further Applications

Instance of Approval Election

Candidates:

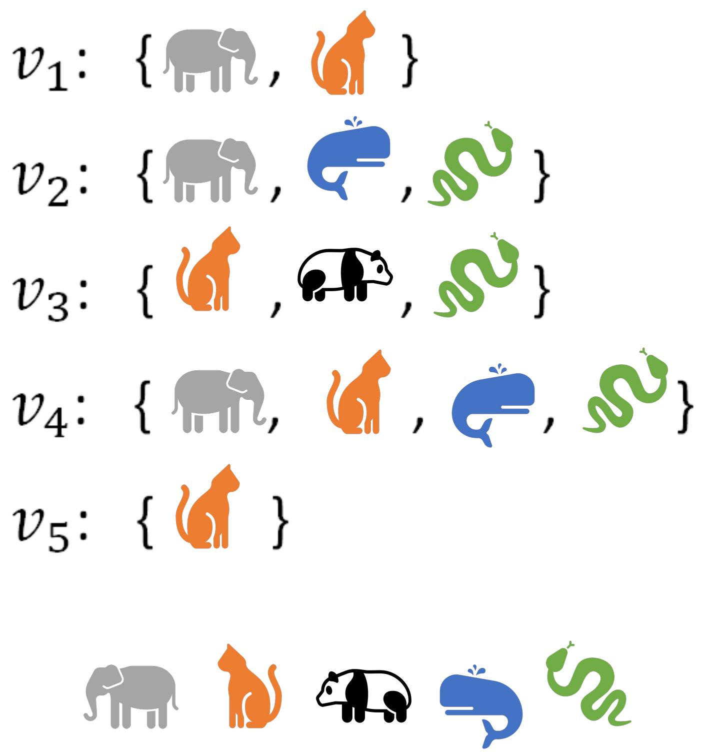


Voters:



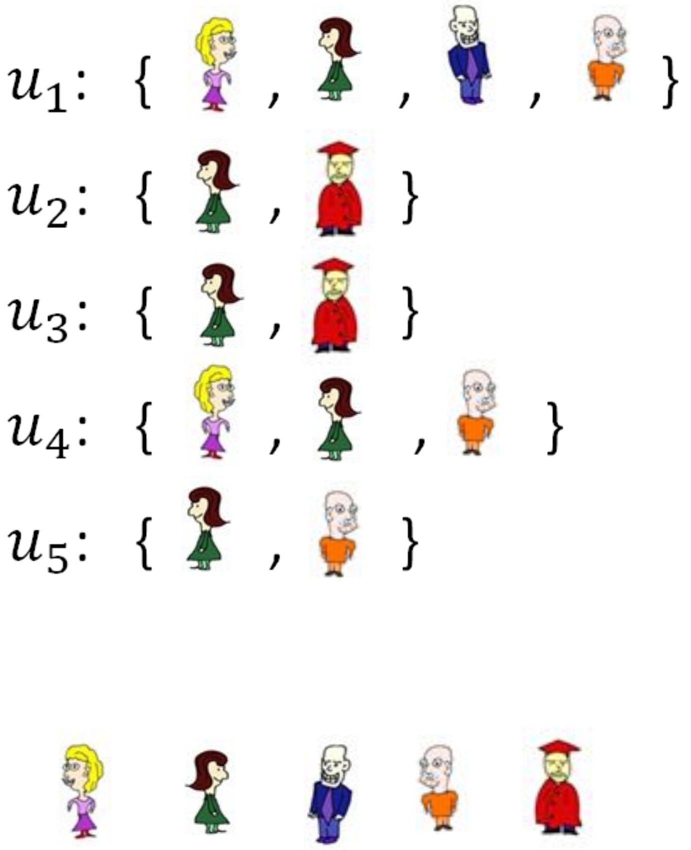
Approvalwise distance

Approvalwise distance



Score: **3** **4** **1** **2** **3**

Sorted vector: [4, 3, 3, 2, 1]



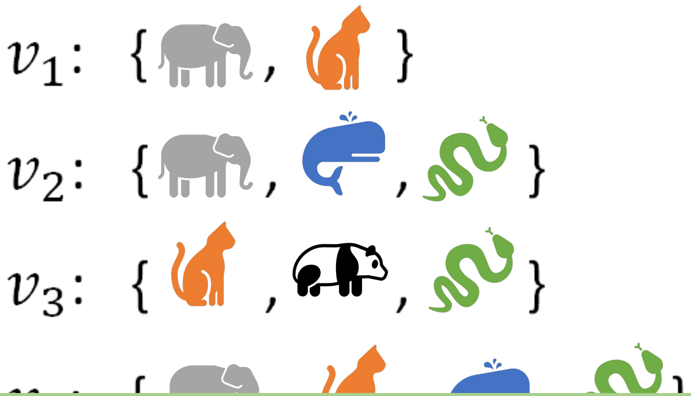
2 **5** **1** **3** **2**

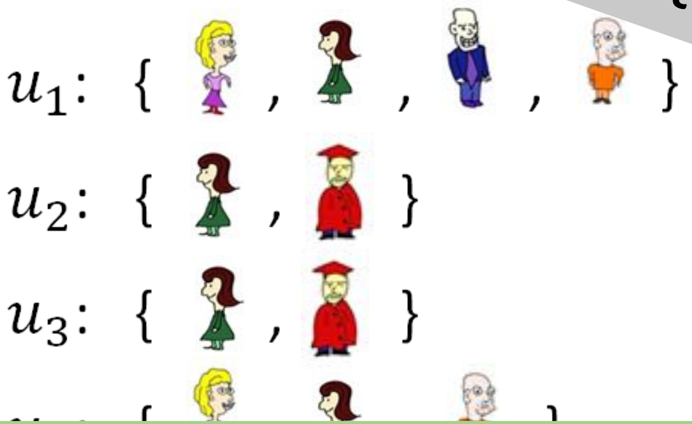
[5, 3, 2, 2, 1]

$$\ell_1([4, 3, 3, 2, 1], [5, 3, 2, 2, 1]) = 2$$

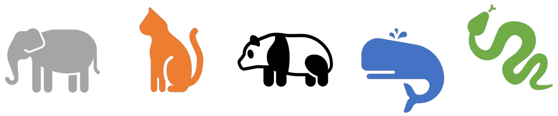
Approvalwise distance

Pseudodistance





Can be computed in polynomial time



Score: **3** **4** **1** **2** **3**

Sorted vector: [4, 3, 3, 2, 1]

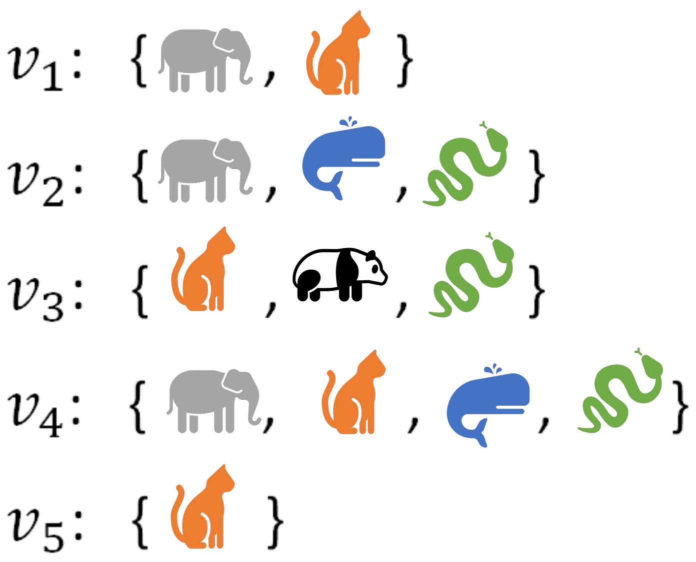
2 **5** **1** **3** **2**

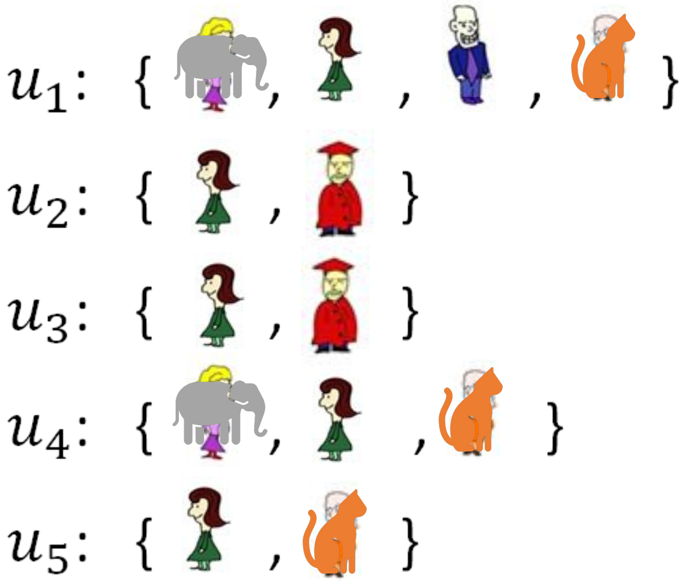
[5, 3, 2, 2, 1]

$$\ell_1([4, 3, 3, 2, 1], [5, 3, 2, 2, 1]) = 2$$

Hamming distance

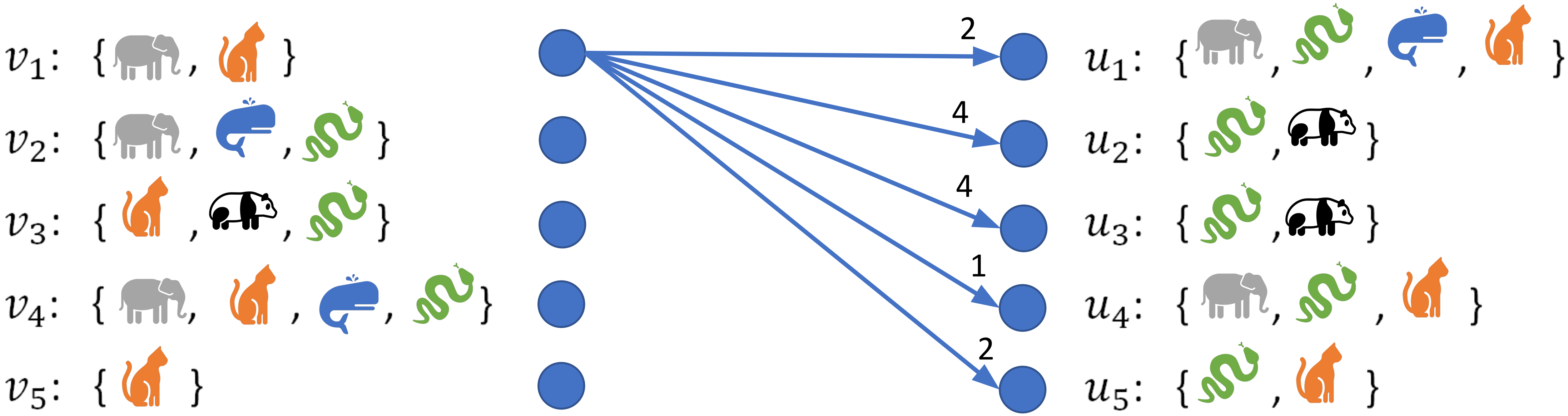
Hamming distance



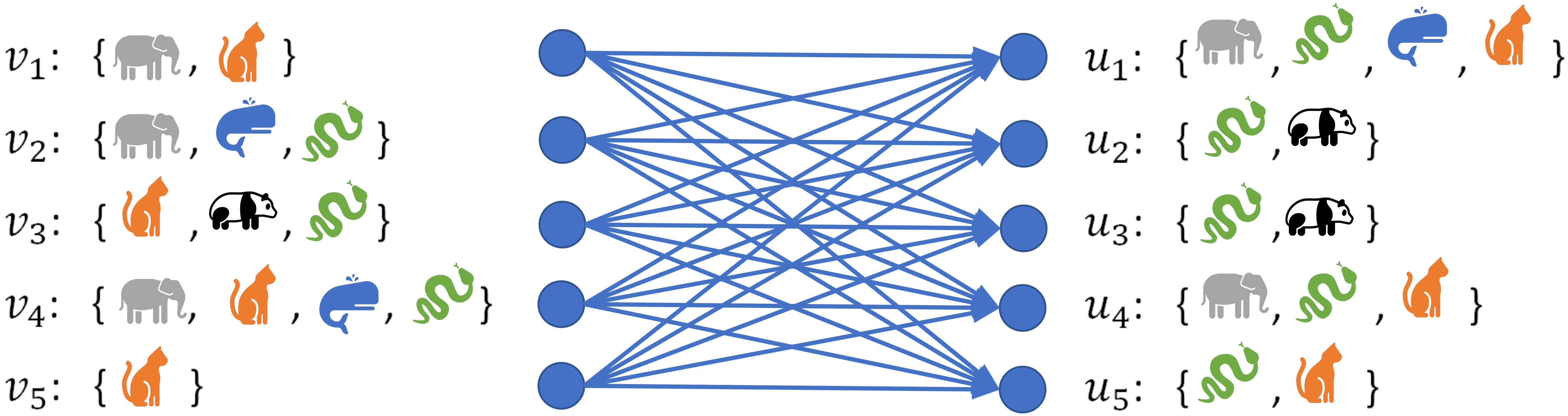


Matching

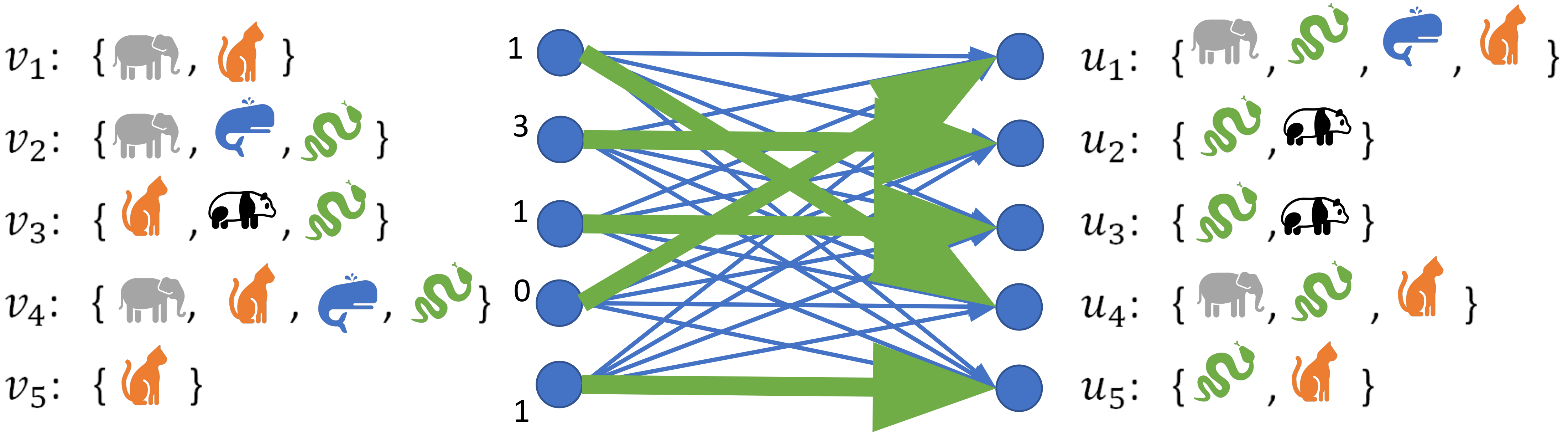
Hamming distance



Hamming distance

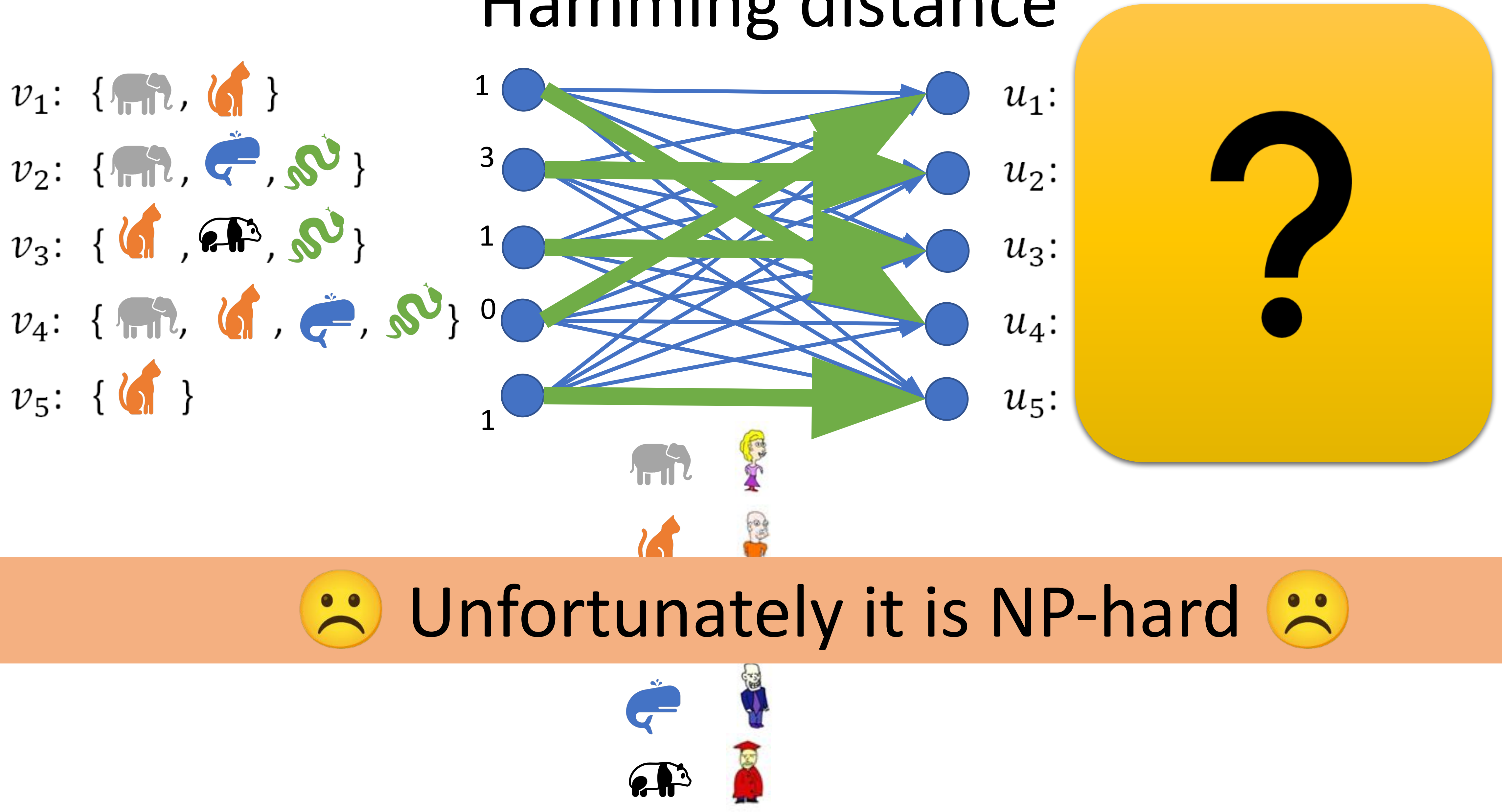


Hamming distance



1 + 3 + 1 + 0 + 1 = 6

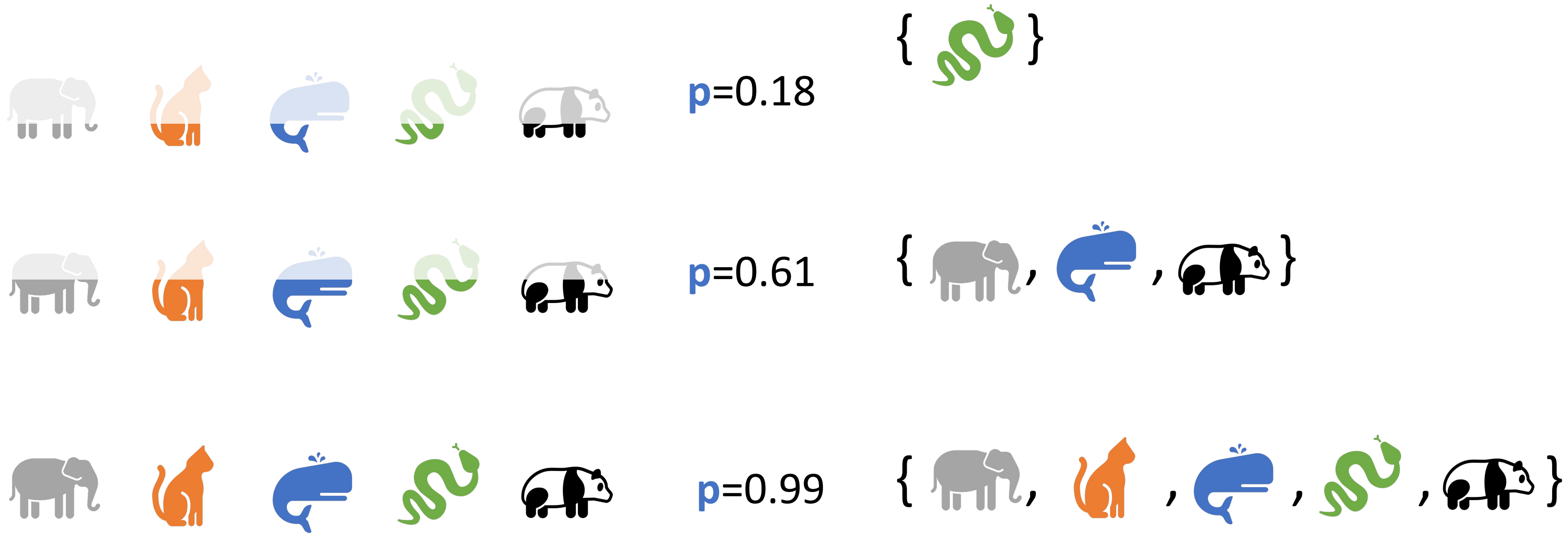
Hamming distance



Unfortunately it is NP-hard

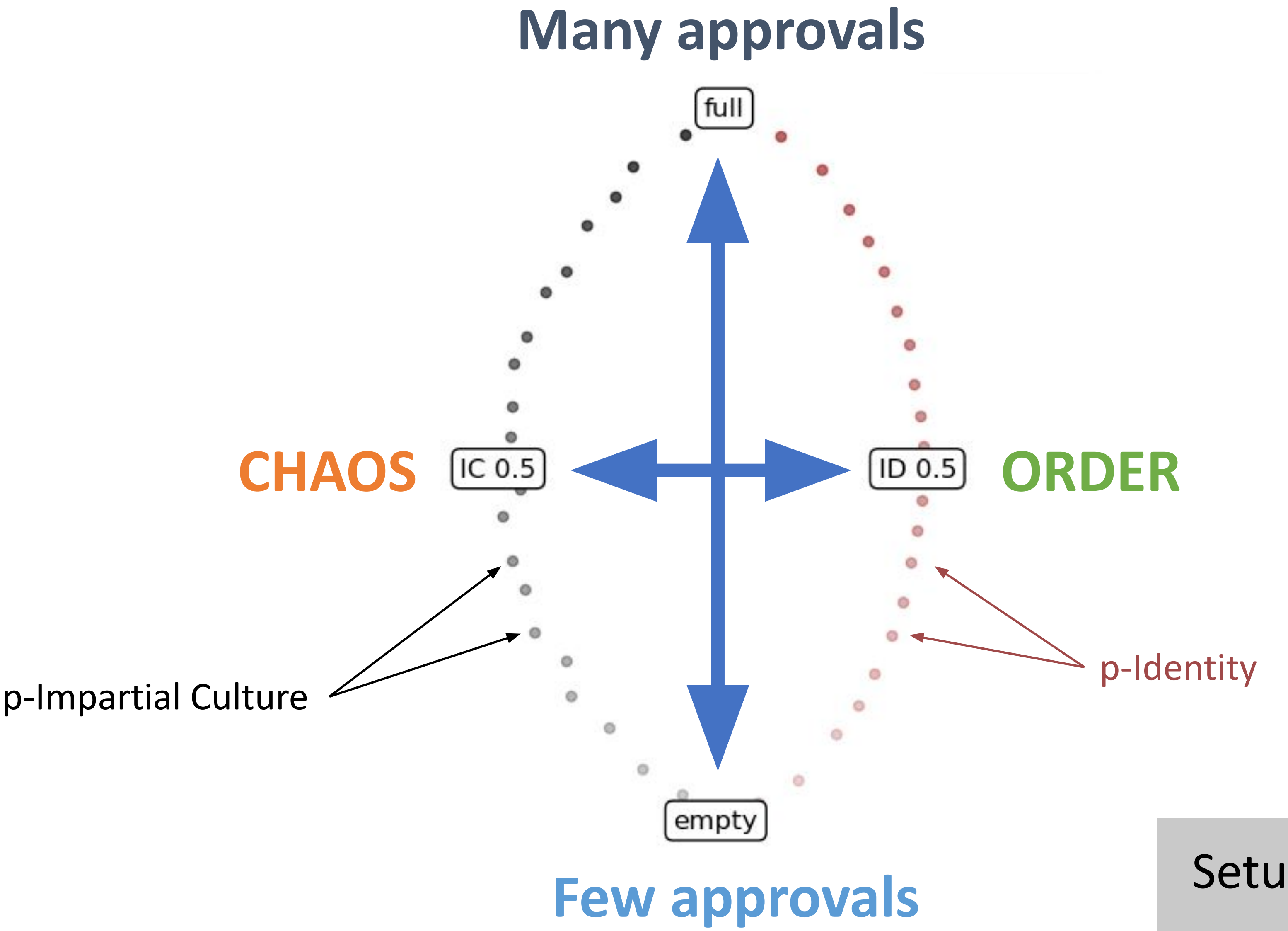
p-Impartial Culture

To generate a vote, for each candidate we flip an assymetric coin, and with probability p we put that candidate in our ballot



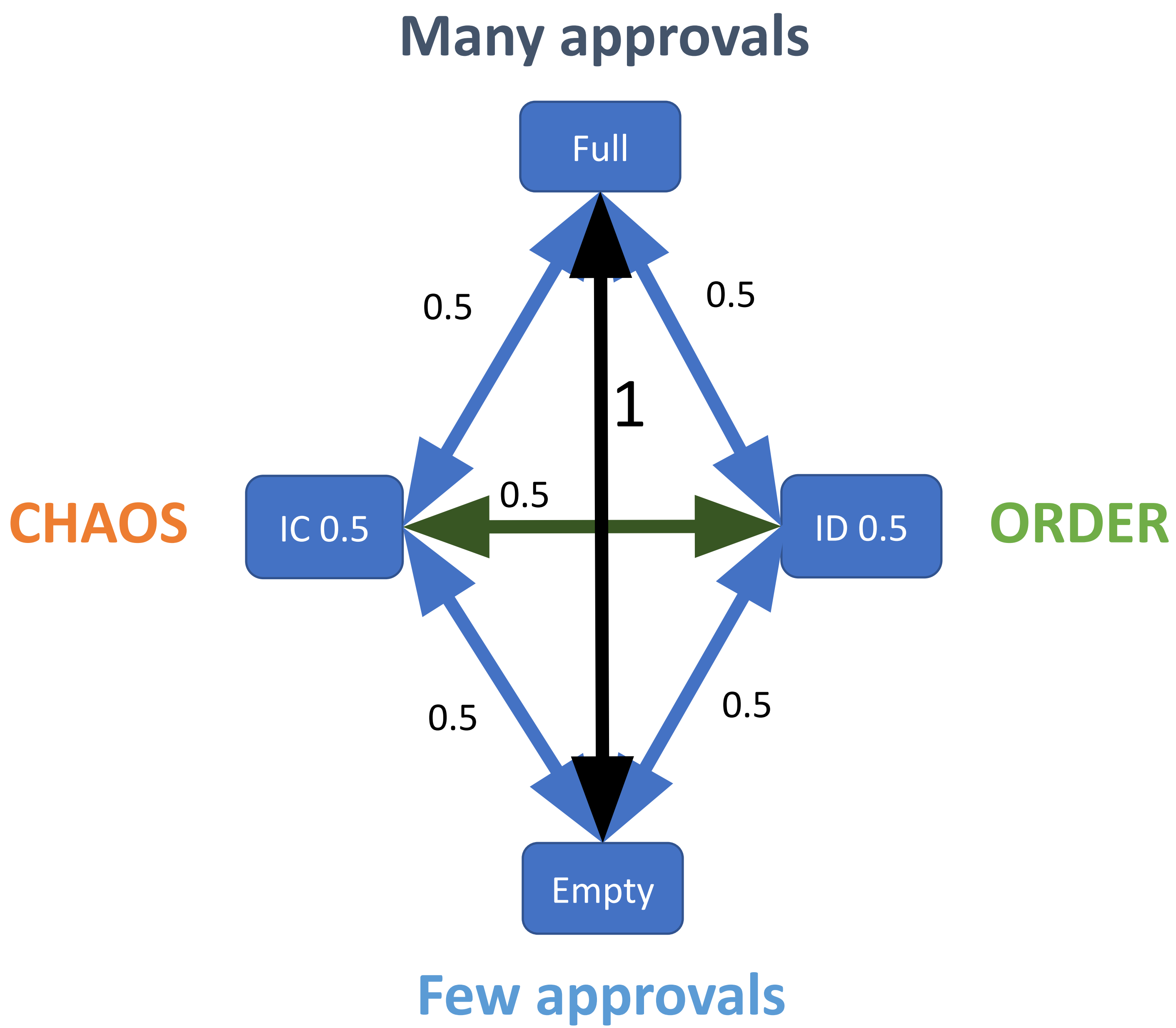
p-Identity

We sample just one vote from p-IC, and all other votes are its copies

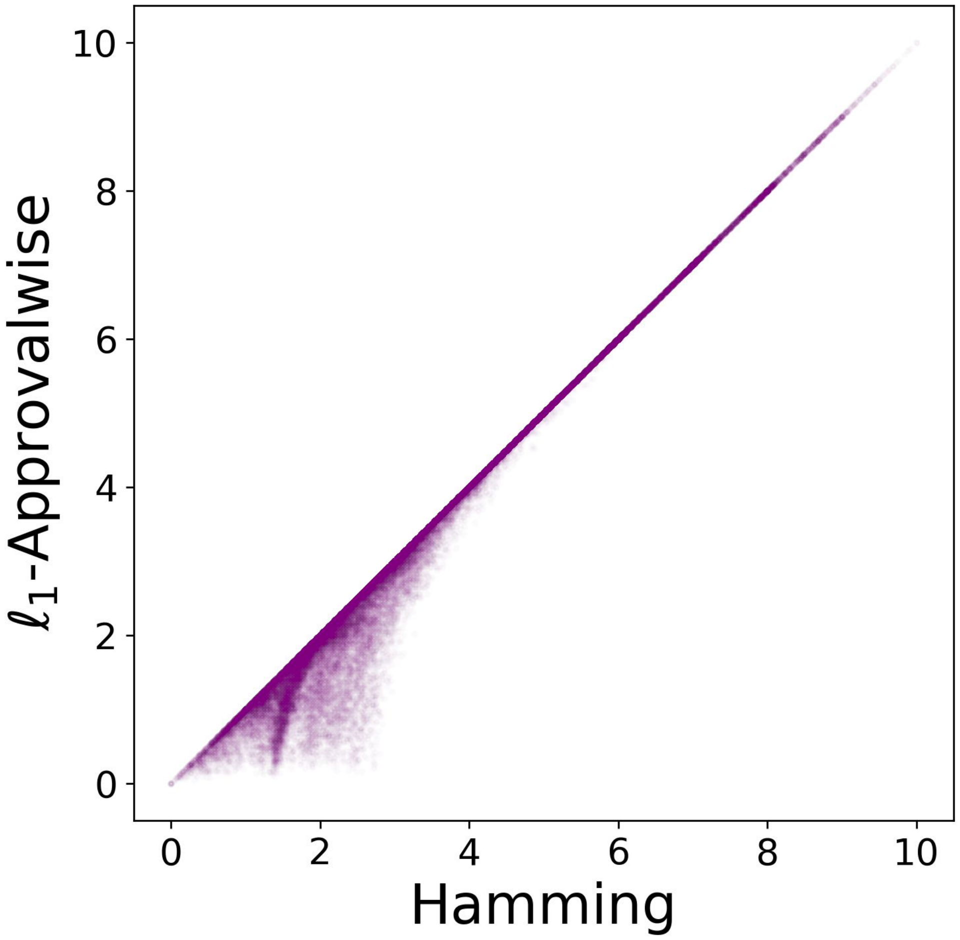


Setup

number of candidates	50
number of voters	100


Many approvals
Full
0.5
0.5
1
CHAOS
IC 0.5
0.5
ID 0.5
ORDER
0.5
0.5
Empty
Few approvals

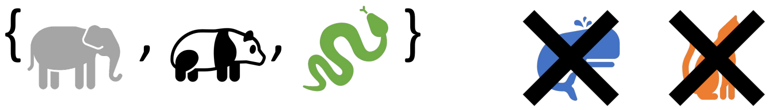
Correlation



Setup

number of candidates	10
number of voters	50

p-Identity with ϕ-resampling

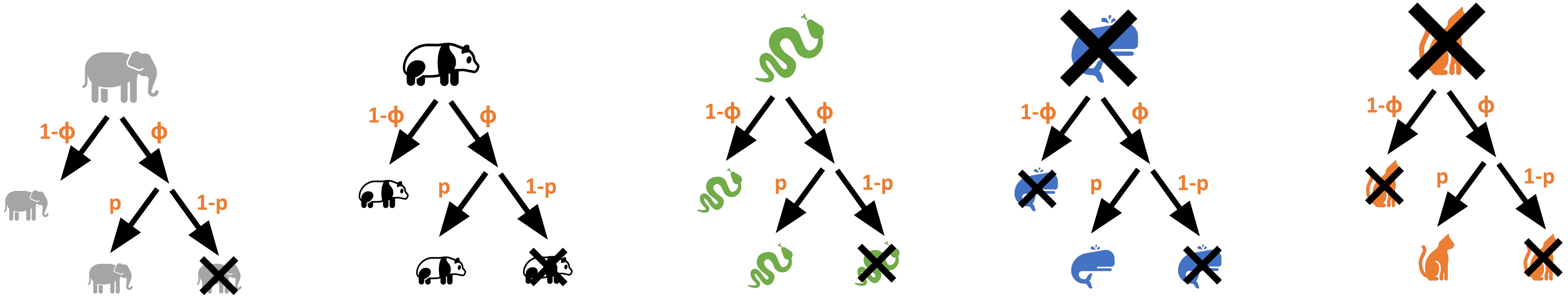
Initial ballot (from p-IC) 

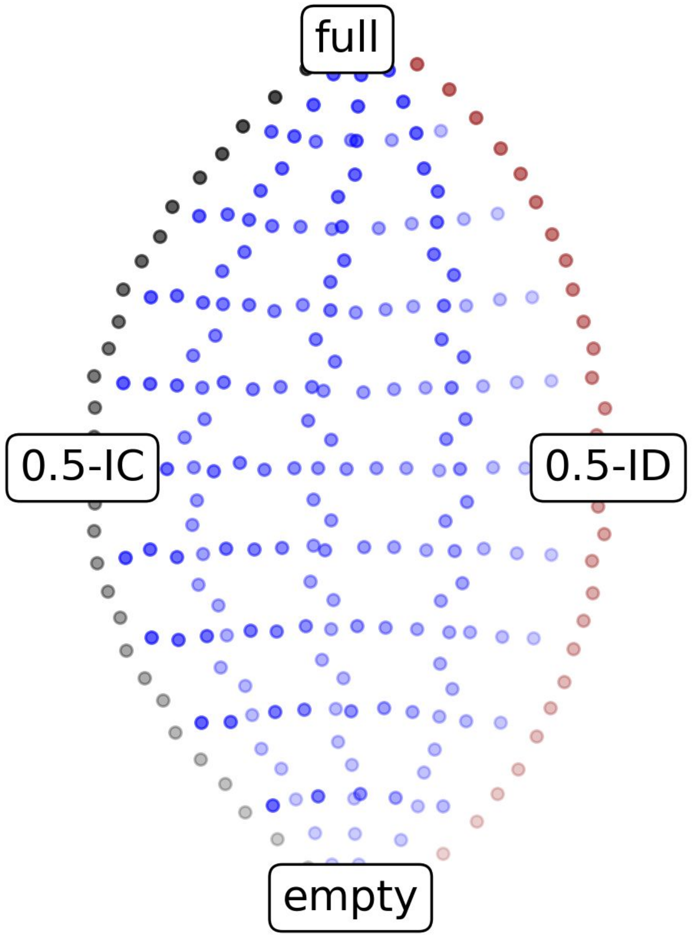
To generate a vote:

Step 0: copy initial ballot
Step 1: for each candidate, **resample** that candidate with probability ϕ

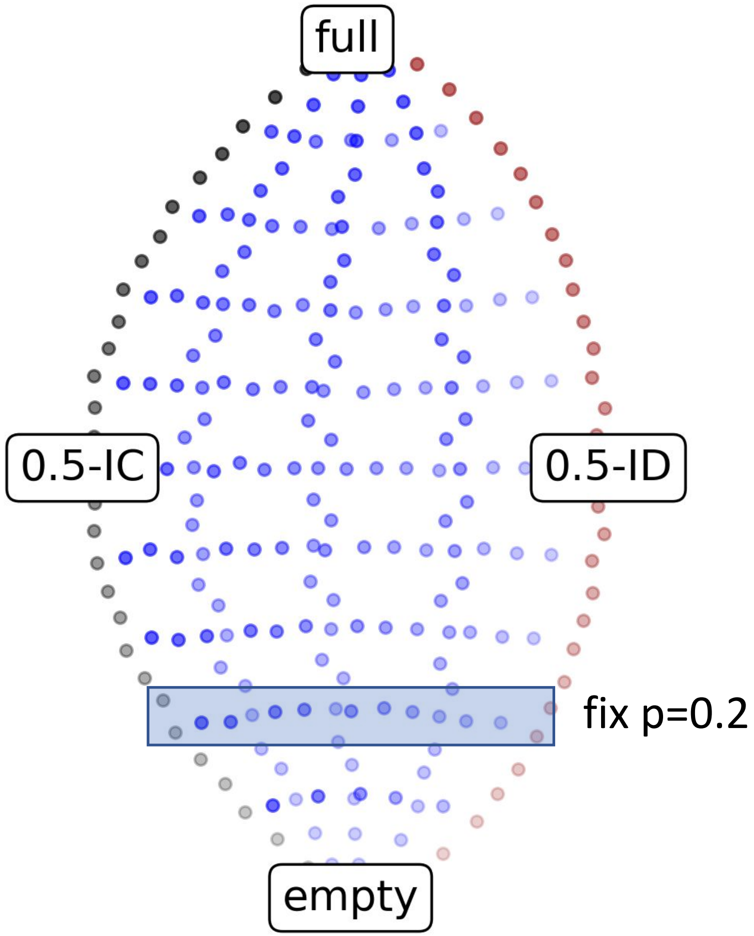
not reverse

(resample = toss an assymetric coin; approve with probability p)

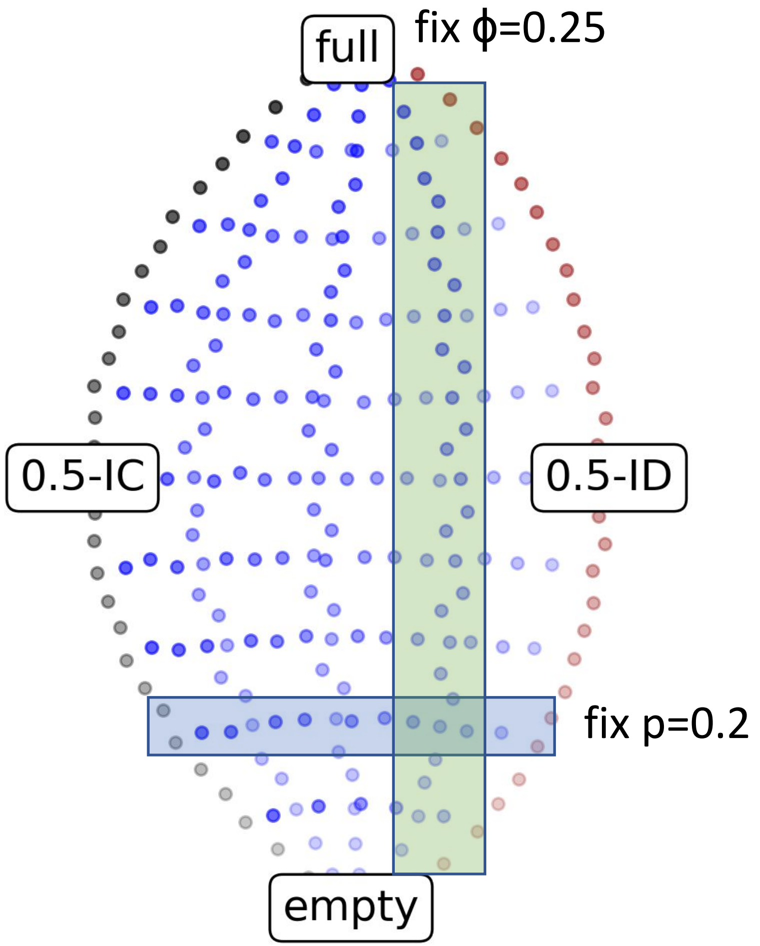




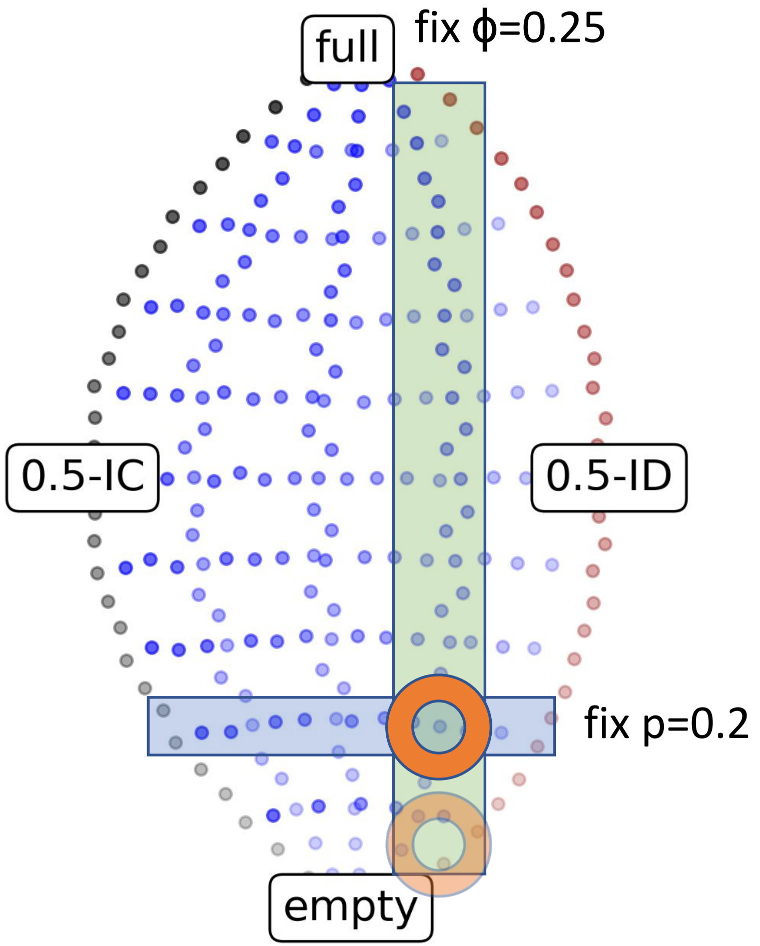
p-Identity with ϕ-resampling



p-Identity with ϕ-resampling



p-Identity with ϕ-resampling

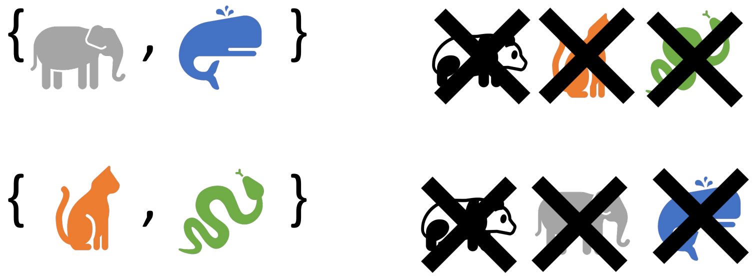


p-Identity with **ϕ**-resampling

Disjoint p-Identity with ϕ-resampling

First initial ballot

Second initial ballot



To generate a vote:

Step 0: copy one of the initial votes

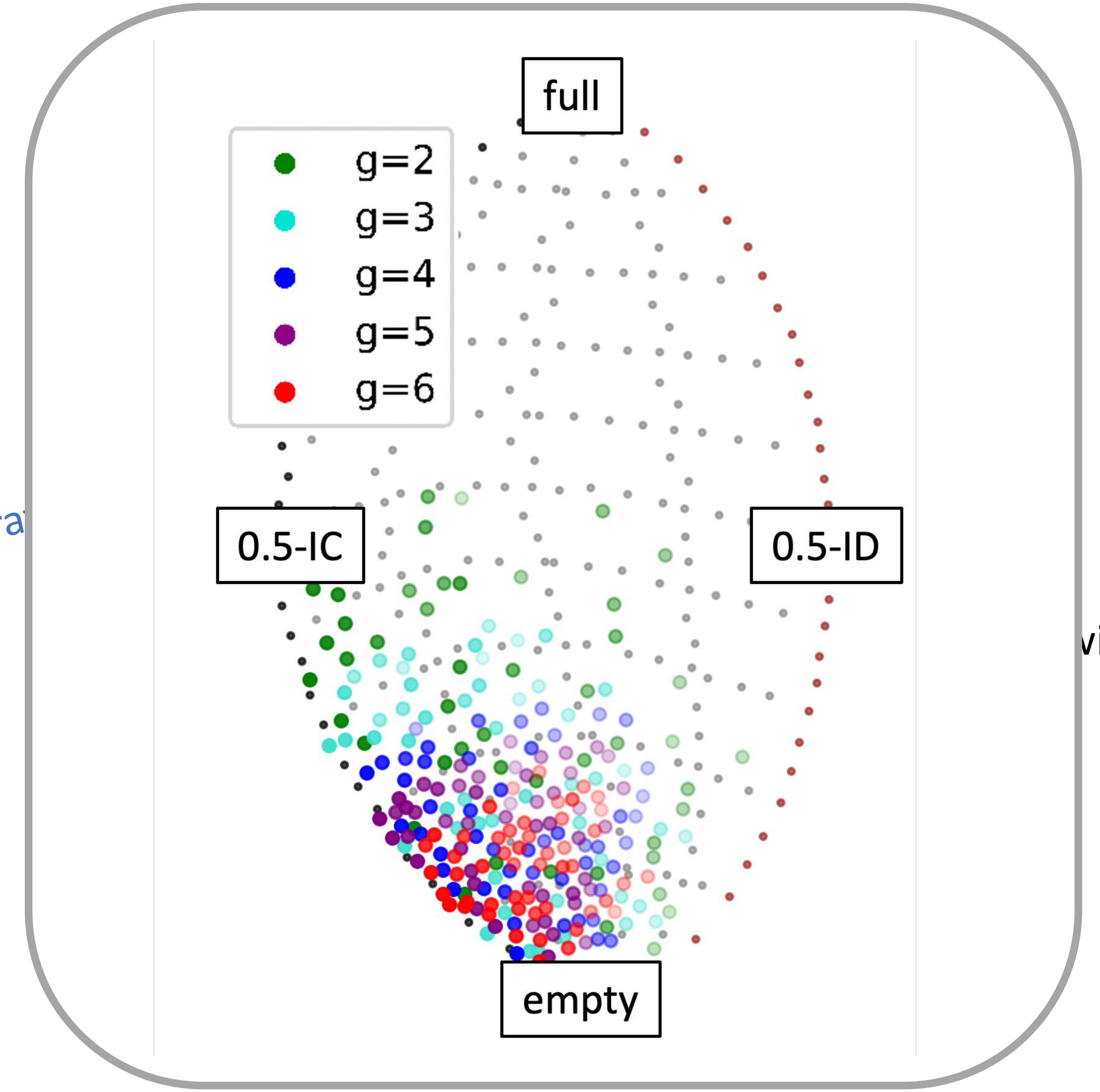
Step 1: for each candidate, **resample** that candidate with probability ϕ

Disjoint p-Identity with ϕ-resampling

First initial ballot

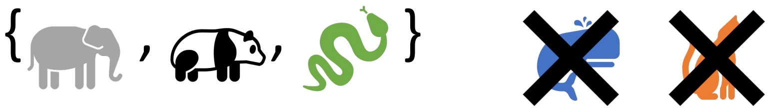
Second initial ballot

To genera



vith probability ϕ

(p, ϕ) Noise Model

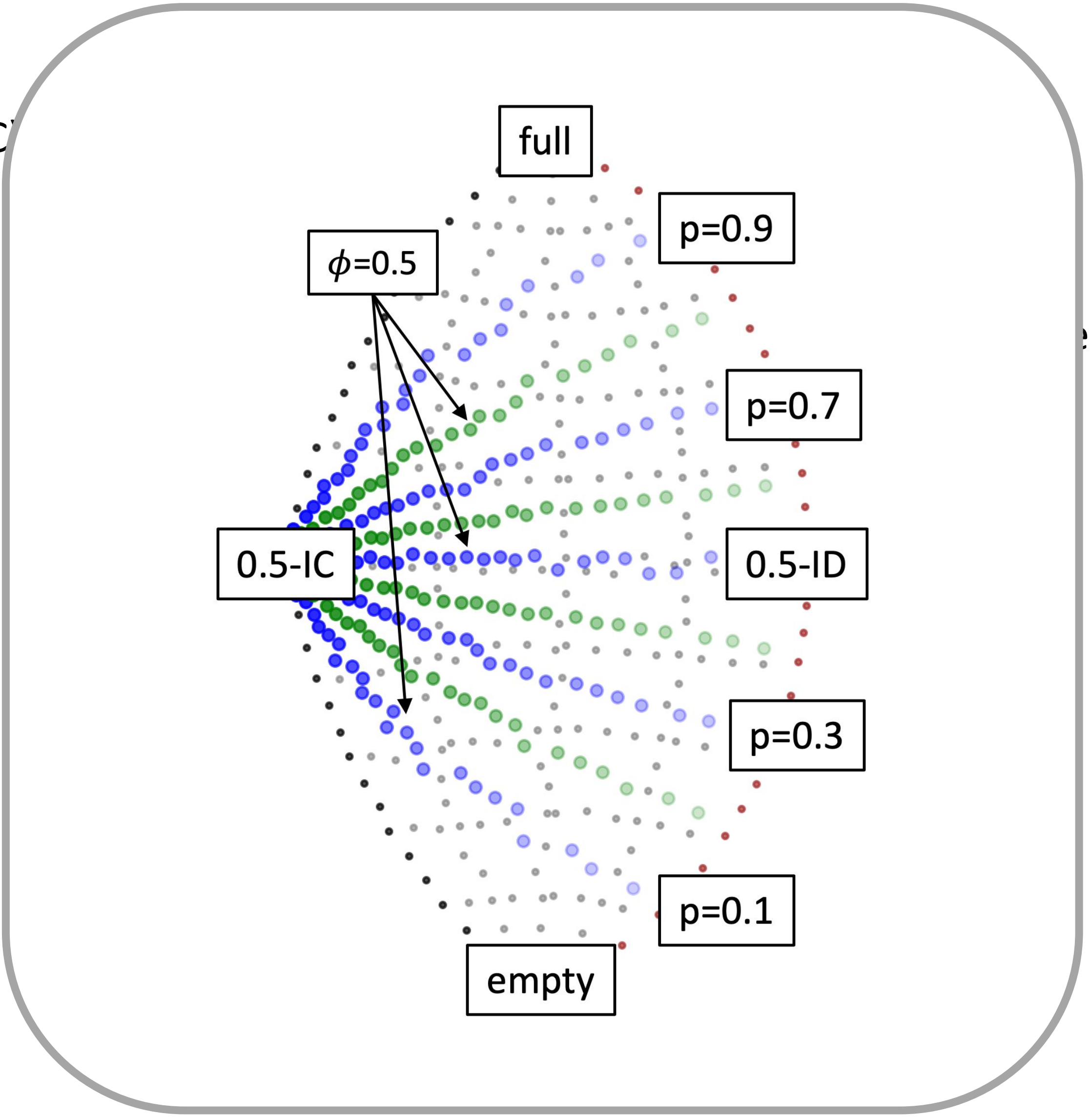
Initial ballot (from **p**-IC) 

The probability of a given vote is proportional to its **Hamming** distance from the initial ballot

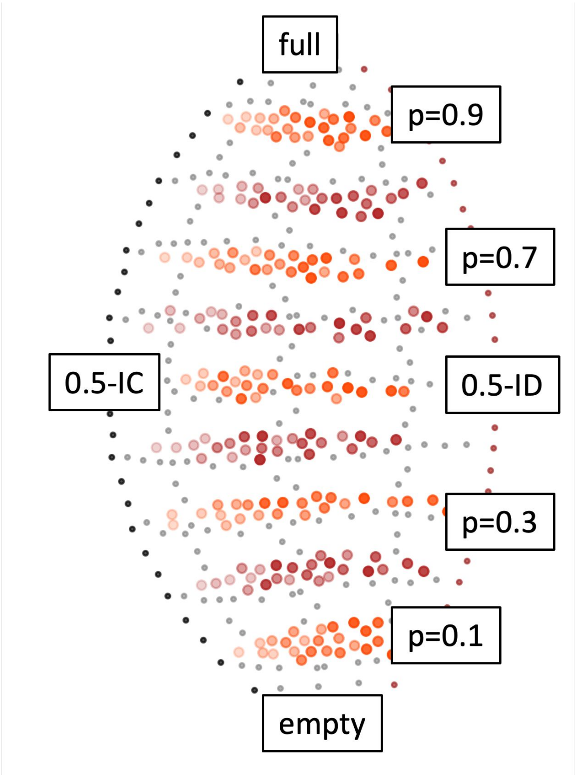
(p, ϕ) Noise Model

Initial ballot (from p-IC)

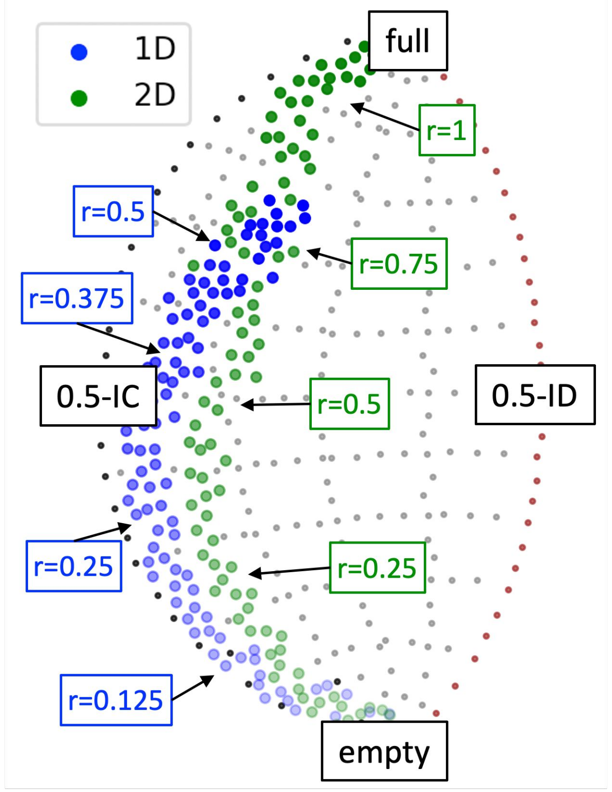
The probability of a g … initial ballot



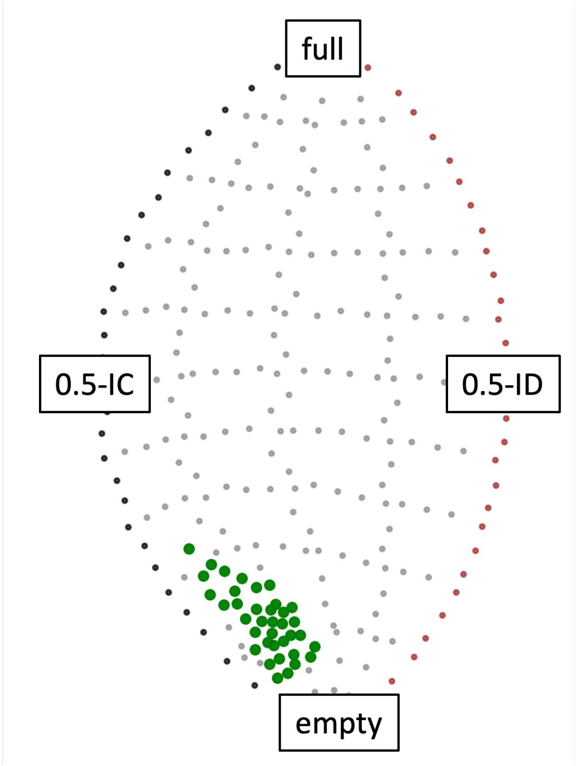
Other Cultures



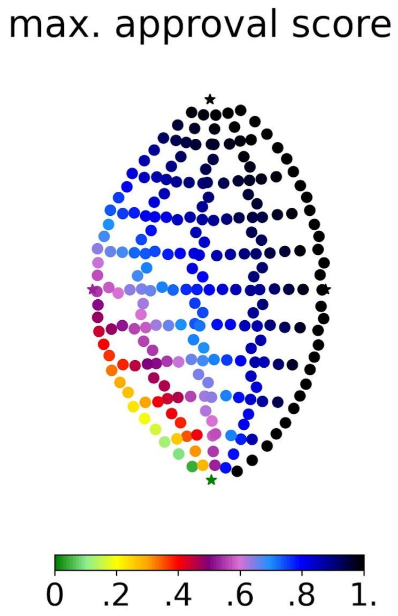
(p, α) Urn Model

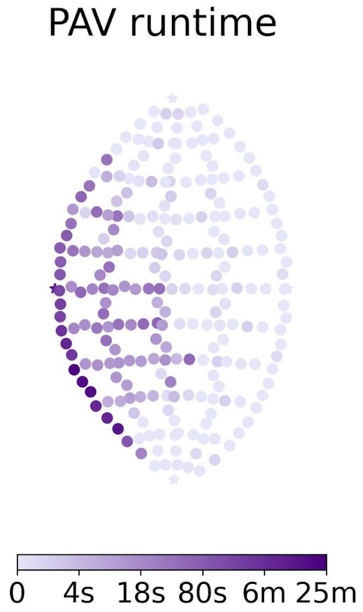


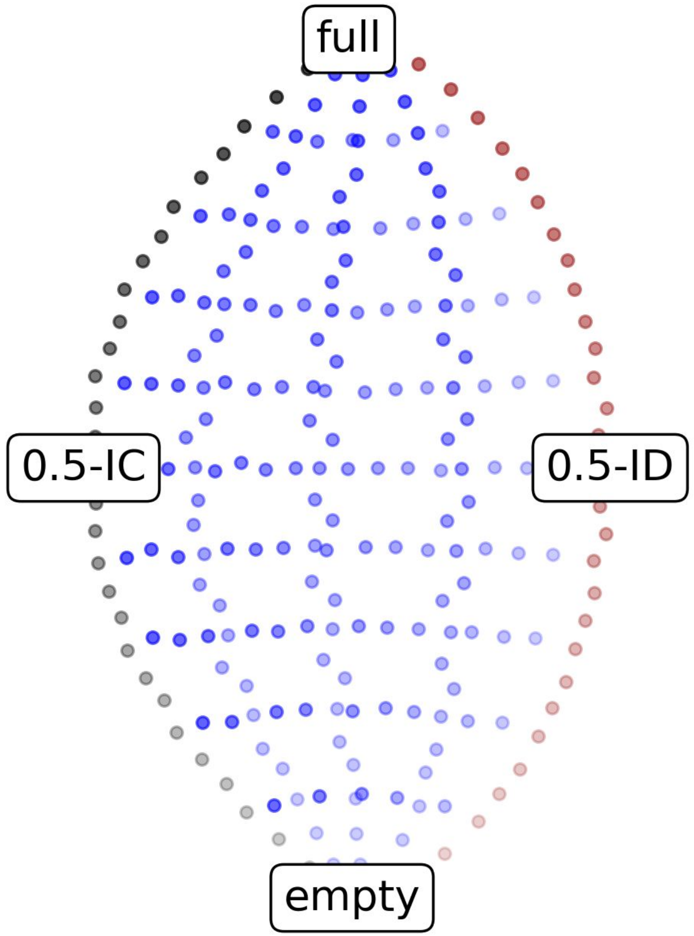
Euclidean

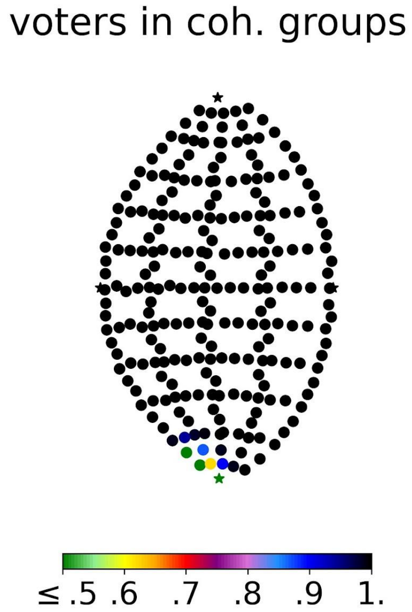


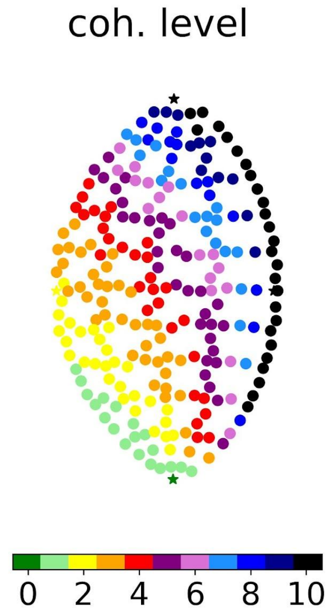
Real life data



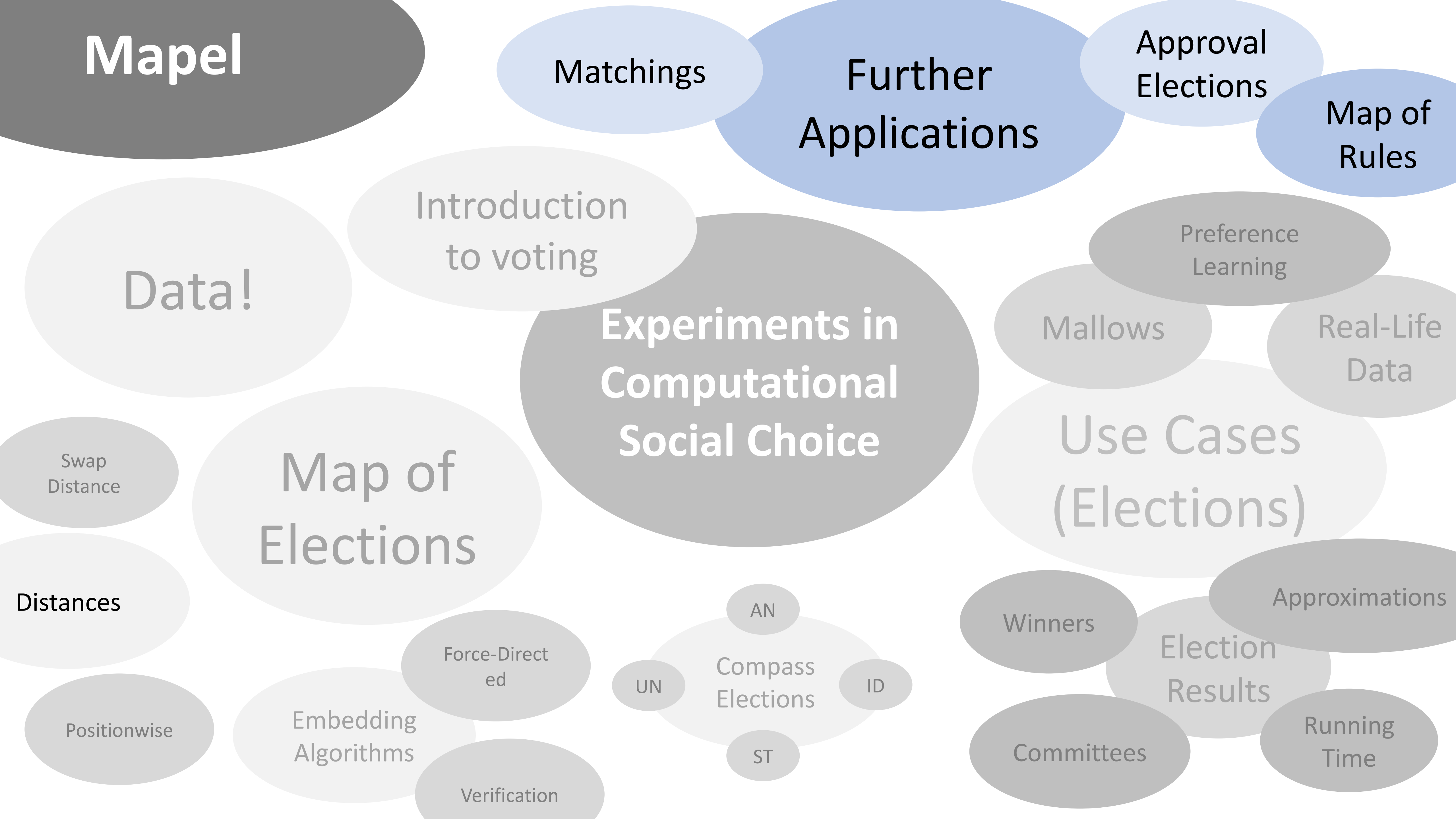








p-Identity with ϕ-resampling


Mapel
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Approval Elections
Map of Rules
Introduction to voting
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Experiments in Computational Social Choice
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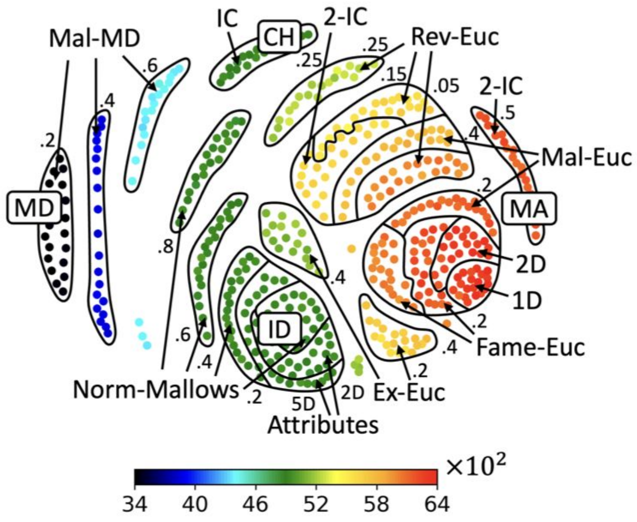
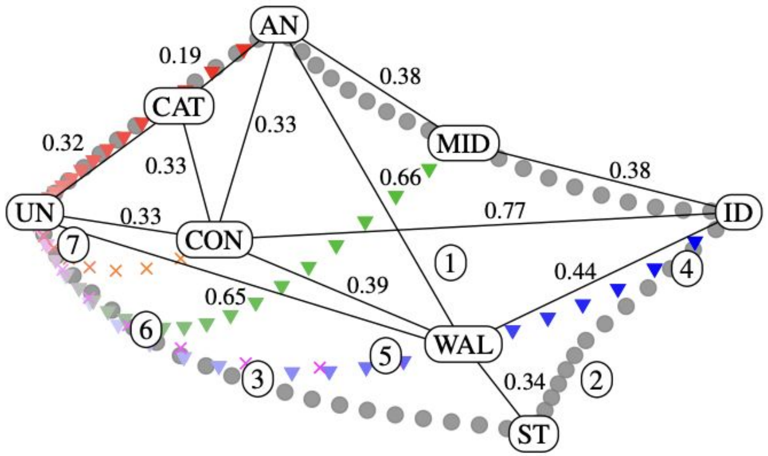
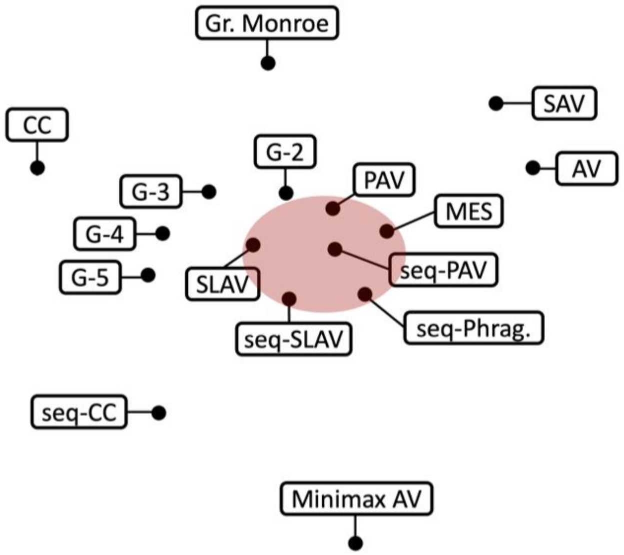
Running Time

Map of Stable Roommates



Map of Distributions





Map of Voting Rules

Mapel

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Approximations

Committees

Running Time

15 minute
s

Create your own map of elections!

Introduction to Mapel Software Package 2/2

Do
More
Experiments!

Please…