An Introduction to Voting Mechanisms

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Outline

1. Popular Voting Methods
   1.1 Plurality Voting
   1.2 Instant-runoff Voting
   1.3 Borda Count

2. The Gibbard–Satterthwaite Theorem

3. More Voting Methods
   3.1 Random Ballot
   3.2 Approval Voting
   3.3 Range Voting

4. Conclusion
A single-winner voting method has the following ingredients:

- A society of individuals (or voters)
- A collection of feasible alternatives or candidates that affect society; exactly one must be chosen
- A ballot: how a voter expresses preferences over the alternatives
- A social choice function that aggregates the voters’ ballots and chooses a winning alternative, the social choice
Plurality Voting

Also called “first-past-the-post” (UK, Canada).
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How it works

▶ Each voter chooses **one** alternative
▶ The most-chosen alternative wins
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Some current uses

▶ Almost all US elections
▶ Dozens of countries around the world
▶ Among all Western democracies, only the US, UK, and Canada use it to elect their legislatures
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Plurality is often combined with a possible runoff, creating a method called two-round majority (most common worldwide).
Plurality Voting

Advantages

▶ Simplicity
Plurality Voting

Advantages

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Disadvantages

▶ Vote splitting
  ▶ “Spoiler effect”
▶ “Lesser of two evils” dilemma and “favorite betrayal”
  ▶ Otherwise: wasted vote
▶ Uses the least possible amount of preference info from each voter (”just pick one”)
▶ Duverger’s law: may favor a two-party system regardless of voters’ political diversity or desired number of parties
  ▶ E.g. United States, which now consists of 42% independents (no party identification) according to a 2016 Gallup poll
Instant-runoff Voting

Also called the “alternative vote” (UK and Canada), “preferential voting” (Australia), and “ranked choice voting.”
Instant-runoff Voting

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How it works

▶ Each voter ranks the alternatives from “first choice” to “last choice.” No ties allowed
▶ Count all the top-ranked choices
▶ WHILE no alternative has a majority of top-ranked choices
   ▶ Eliminate the alternative with the fewest top-rankings
   ▶ Count all the new top-ranked choices
   ▶ Exhausted ballots (all their ranked alternatives eliminated) are discarded
▶ Alternative with the majority of top-ranked choices wins
Instant-runoff Voting

Example: 57 voters and 3 alternatives A, B, C.

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What if B drops out?
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What if 10 “B>C>A” voters decide not to vote at all? Then C wins. Failure of **rational participation.**

What if B drops out? Then C wins. **Irrelevant alternative.**
Instant-runoff Voting

Advantages

▶ Fairly expressive for voters
▶ Mitigates (eliminates?) the spoiler effect
▶ Complexity makes strategy difficult

Disadvantages

▶ Algorithm confuses voters; results hard to understand
▶ Non-monotonic
▶ Strategic non-participation (although difficult in practice)
▶ May favor a two-party system (e.g. Australia)
▶ “Reversal failure”: inverting preferences may preserve outcome
▶ Logically flawed? Why does fewest 1st-place votes ⇒ worst alternative?
Instant-runoff Voting

Some current uses

- Elections for the Australian House of Representatives
- Election for the President of India
- In the US: San Francisco (mayor), Berkeley CA, Hugo Awards for science fiction, Oscar for Best Picture

Instant-runoff is advocated in the US by the nonprofit organization (fairvote.org). They are currently very active lobbying for instant-runoff in Maine (rcvmaine.com):
Instant-runoff Voting

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After the 2009 election...
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After the 2009 election...

It was repealed in 2010 by referendum, 52% to 48%, in favor of two-round majority.
Borda Count

Named after the 18th-century French mathematician Jean-Charles de Borda.
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How it works

- Assume there are \( n \geq 1 \) alternatives
- Each voter ranks the alternatives from “first choice” to “last choice.” No ties allowed
- For each ballot, an alternative ranked in \( k \)-th place receives \( n - k \) points
- Add up the points from all the ballots
- Most points wins

Some current uses
- National Assembly of Slovenia, Heisman trophy, MLB MVP
- Some universities and private organizations; the Galois Group
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Borda Count: Example

Three friends (Alice, Bob, Carl) want to watch a movie. Choices: Star Wars: Ep. V (SW5) or The Terminator (TT).

They will vote with the Borda count to decide. Their preferences:

Alice, Bob: SW5 > TT
Carl: TT > SW5
Borda Count: Example


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Alice, Bob: \(\text{SW5} > \text{TT}\)

Carl: \(\text{TT} > \text{SW5}\)

Carl realizes he will lose, so he nominates *Terminator 2* (T2) and *Terminator 3* (T3). They all agree that TT > T2 > T3.

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- Alice, Bob: SW5 > TT > T2 > T3
- Carl: TT > T2 > T3 > SW5

Then the points are SW5 = 6 and TT = 7. **TT wins!**

This is called **strategic nomination** or **candidate cloning**.
“Begun, the Clone War has”: Alice and Bob nominate all the Star Wars prequels! They all agree that SW3 > SW2 > SW1.

Alice, Bob: SW5 > SW3 > SW2 > SW1 > TT > T2 > T3
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Now **SW5 wins** with 15 to TT’s 10. Any strategic reordering increases the risk of a unanimously worse alternative being chosen.
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The whole situation is absurd. The Borda count values the multiplicities of alternatives over the actual voter preferences.
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The whole situation is absurd. The Borda count values the multiplicities of alternatives over the actual voter preferences.

The general criterion is the independence of clones criterion, proposed by Nicolaus Tideman. It includes immunity to spoilers (e.g. plurality), teams (e.g. Borda), and crowds (the clones neither help nor hinder themselves, but affect the outcome).
Borda Count

Advantages

▶ Fairly expressive for voters
▶ Monotonic
▶ Not too complicated

Disadvantages

▶ Cannot express indifference between alternatives
▶ Strategic nomination (teaming)
▶ “Burying” strategy: rank a not-least-preferred alternative last
▶ “Compromising” strategy: rank a not-most-preferred alternative first
  ▶ Compromising and burying are very tempting when there are 2 clear frontrunners; throws the outcome into disarray

“My scheme is intended for only honest men.” –de Borda
Strategic manipulability is not a property of just a few “bad” voting methods.

In fact, all “rank-based” voting methods can be cheated in at least one way...
The Gibbard–Satterthwaite Theorem

Proven independently by the philosopher Allan Gibbard (1973) and the economist Mark Satterthwaite (1975).
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Let $A$ be a nonempty finite set of alternatives and $V$ a nonempty finite set of voters.

Let $\mathcal{L}(A)$ be the set of all linear orders on $A$. These are binary relations on $A$ that are

(i) Transitive: $x \preceq y$ and $y \preceq z \implies x \preceq z \quad \forall x, y, z \in A$

(ii) Total: $x \preceq y$ or $y \preceq x \quad \forall x, y \in A$

(iii) Antisymmetric: $x \preceq y$ and $y \preceq x \implies x = y \quad \forall x, y \in A$

Let $\mathcal{L}(A)^V = \times_{i \in V} \mathcal{L}(A)$ be the set of all profiles $(\preceq_i)_{i \in V}$ of strict preference relations.
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We call $\preceq \in \mathcal{L}(A)$ a strict preference relation. Let

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A function $F : \mathcal{L}(A)^V \rightarrow A$ is called a social choice function.

Examples: instant-runoff, Borda count, plurality voting.
The Gibbard–Satterthwaite Theorem

A function $F : \mathcal{L}(A)^V \to A$ is called a **social choice function**.

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**Properties**

- $F$ is **onto** if $F(\mathcal{L}(A)^V) = A$
  
  Every alternative has a possibility of winning
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- **$F$ is strategy-proof** if for any $i \in V$, any $(\preceq_j)_{j \in V} \in \mathcal{L}(A)^V$, and any $\preceq'_i \in \mathcal{L}(A)$,

  \[
  \star \quad F(\preceq'_i, \preceq_{-i}) \preceq_i F((\preceq_j)_{j \in V}) \star
  
  \]

  where $\preceq_{-i} = (\preceq_j)_{j \neq i}$
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- **\( F \) is dictatorial** if there is an \( i \in V \) such that for any \( (\succeq_j)_{j \in V} \in \mathcal{L}(A)^V \),

  \[
  F((\succeq_j)_{j \in V}) \in \max(\succeq_i)
  \]
The Gibbard–Satterthwaite Theorem

Theorem (Gibbard–Satterthwaite)

If $|A| \geq 3$ and $F : \mathcal{L}(A)^V \rightarrow A$ is onto and strategy-proof, then $F$ is dictatorial.

In words: “For every reasonable*, deterministic, rank-based voting method over $\geq 3$ alternatives, there are situations in which lying pays.”

*onto, non-dictatorial
The Gibbard–Satterthwaite Theorem

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Notes

- If $|A| = 2$, then majority voting is a counterexample to G–S
- G–S still holds for non-strict preference relations (drop the antisymmetric requirement)
- Possible escape routes
  - Use a stochastic $F$
  - Invent a different class of voting system?
Random Ballot

How it works

▶ Each voter chooses one alternative
▶ Select a voter uniformly at random
▶ Elect that voter’s choice

Current uses: none?
Random Ballot

How it works

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Current uses: none?

Advantages

- Onto, strategy-proof (avoids the G–S theorem!), independent of clones, rational participation

Disadvantages

- Democratic only in mathematical expectation
- Possibility for a terrible winner
Approval Voting

Introduced in 1977–1978, mainly by Steven Brams (political scientist) and Peter Fishburn (mathematician).
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Advocated by a nonprofit, founded in 2011 (electology.org):
Approval Voting

Advantages

▶ Simplicity
▶ Always rational to vote for one’s favorite candidate
  ▶ No wasted votes
▶ Tends to favor compromise candidates
  ▶ Favors moderates in political races
▶ Monotonic
▶ Rational participation
▶ Independent of clones
  ▶ No spoiler effect

Disadvantages

▶ Not very expressive for voters; cannot express all preferences
Range Voting

How it works

- Let $N$ be a positive integer (a parameter)
- Each voter assigns a score from $0, 1, \ldots, N$ to each alternative
- Highest total score wins (or equivalently highest average)

Note: reduces to approval voting when $N = 1$. 

Some current uses

- German Pirate Party; no other political uses?
- Valedictorians, teaching evaluations
- Webby Awards, Mozilla
- Many TV competitions

Advocated by Dr. Warren Smith (rangevoting.org) and The Center for Election Science.
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Range Voting

**Advantages**

- Fairly simple
- Most expressive voting method
- Same advantages as approval voting

**Disadvantages**

- Temptation to exaggerate scores
  - In most situations, “approval style” scoring is optimal (give only max/min scores)
  - Inconsistent strategy levels among societal groups can lead to a skewed outcome
At the 2010 Voting Power in Practice workshop in Normandy, France, 22 professional voting theorists were asked:

“What is the best voting rule for your town to use to elect the mayor?”

They voted on 18 voting methods using approval voting.

Average number of approvals: 3.55.

## Voting Theorists Vote About Voting Methods

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<th>Approvals</th>
<th>Approving percentage</th>
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<td>15</td>
<td>68.18</td>
</tr>
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<td>Alternative vote</td>
<td>10</td>
<td>45.45</td>
</tr>
<tr>
<td>Copeland</td>
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<td>40.91</td>
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<tr>
<td>Kemeny</td>
<td>8</td>
<td>36.36</td>
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<tr>
<td>Two-round majority</td>
<td>6</td>
<td>27.27</td>
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<tr>
<td>Coombs</td>
<td>6</td>
<td>27.27</td>
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<td>Simpson</td>
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<td>22.73</td>
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<td>Majority judgement</td>
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Conclusion

It’s tempting to believe that simply “holding a vote” will magically locate the best alternative for society.

But a poorly designed voting process can lead to chaos.

* cough* Republican primary *cough*

The main concerns are:

1. What information do we ask voters to provide about their preferences?

2. From that information, how do we determine the best option for society as a whole?

3. How do we get voters to vote honestly and not try to cheat the system?

An entire field of study surrounds these questions.