

STCS Vigyan Vidushi 2025

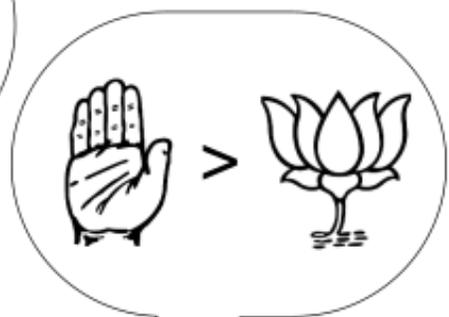
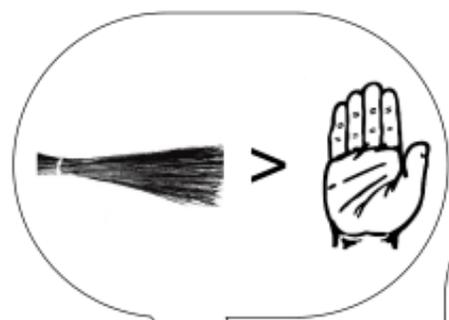
Voting Rules

Rohit Vaish

Computational Social Choice

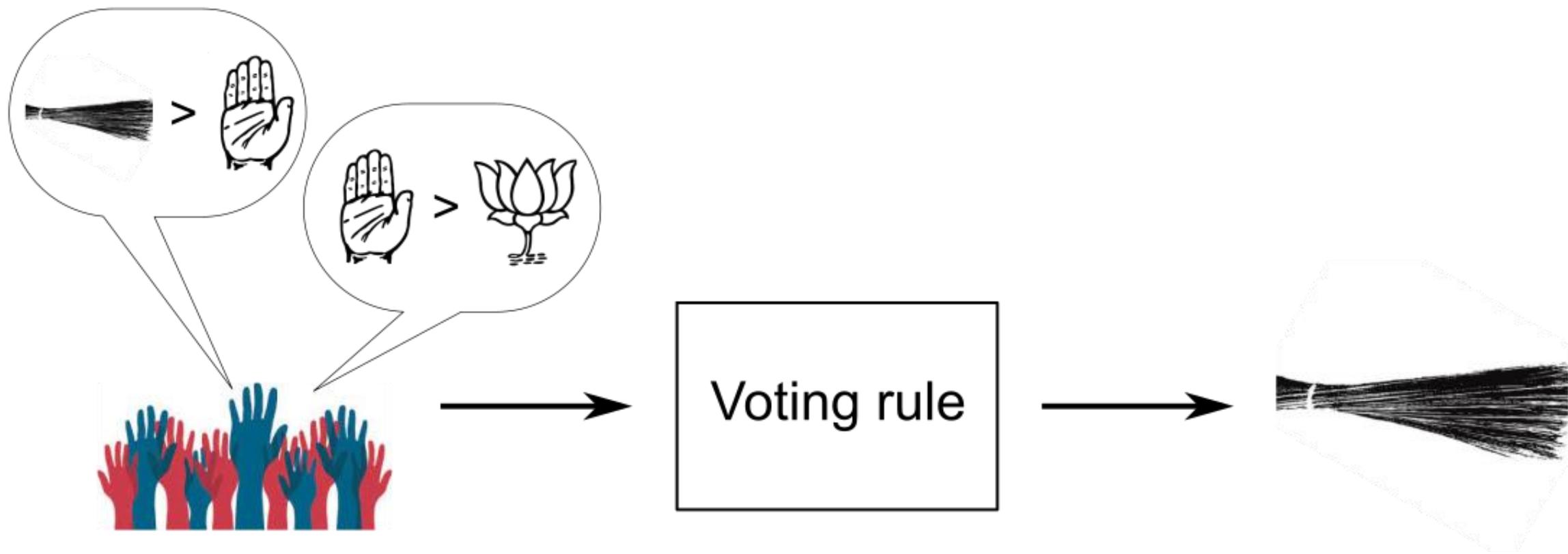


Understanding the role of **computation**
in **collective decision-making** problems

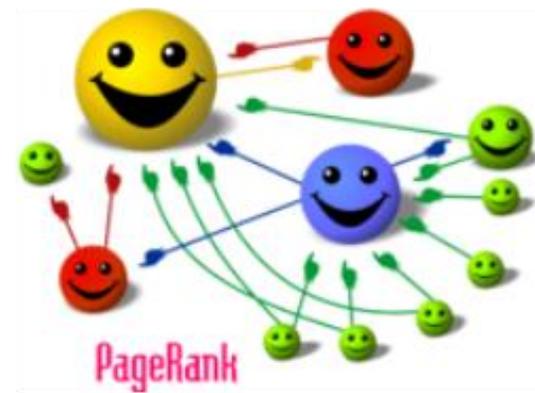


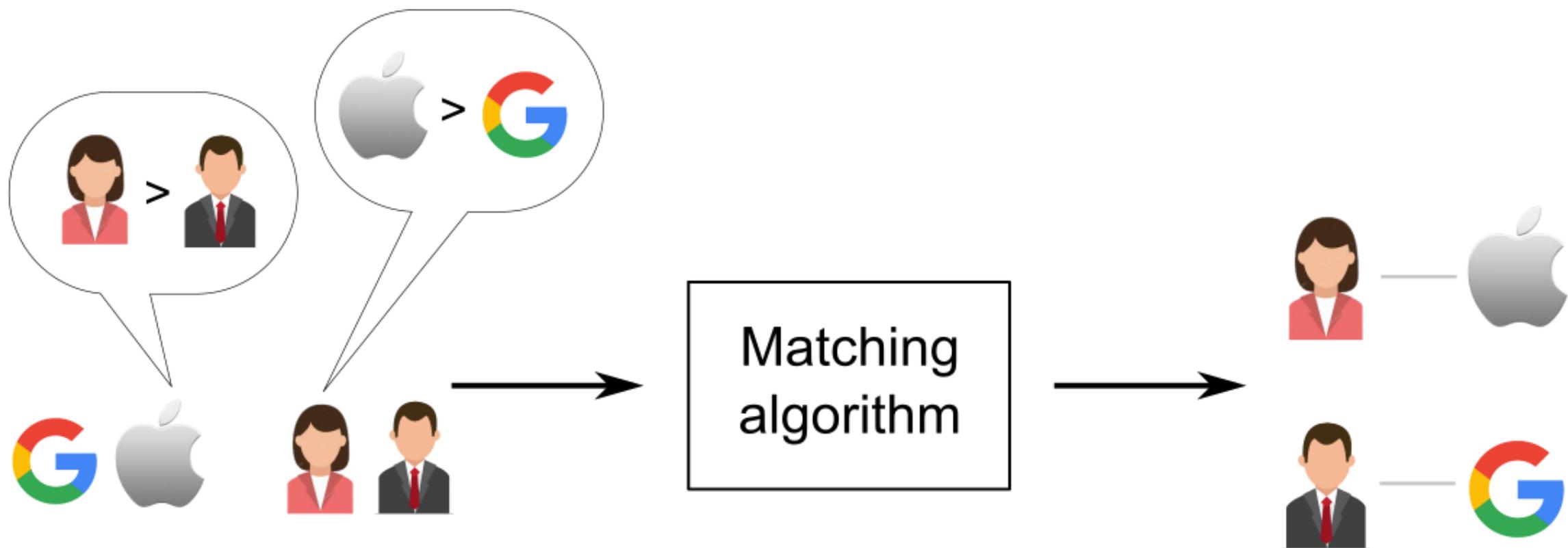
Voting rule

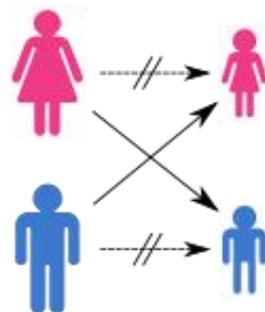
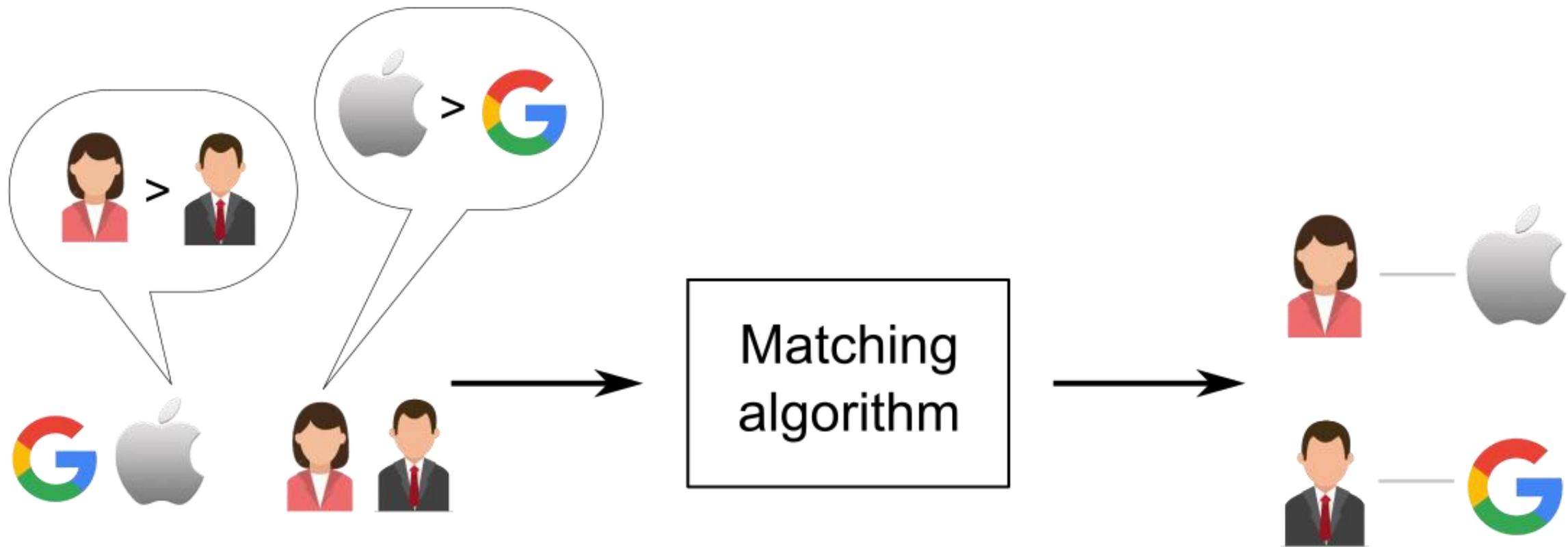




amazon









Allocation
mechanism





Allocation
mechanism

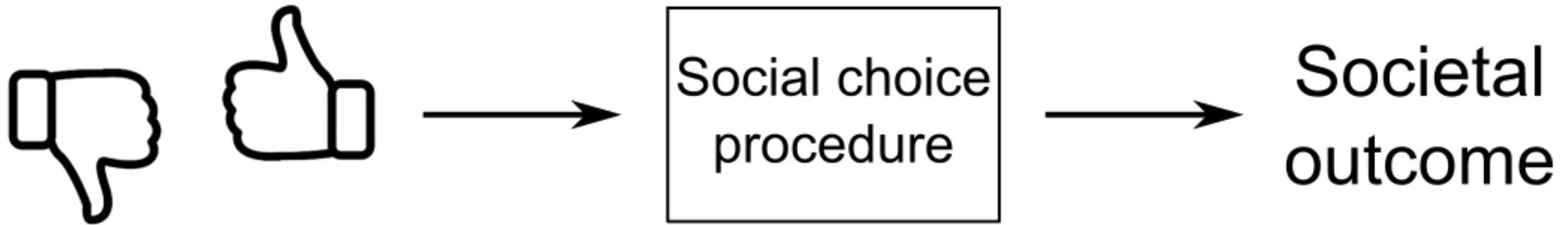


Social Choice

Making a **collective** decision from **individual** preferences

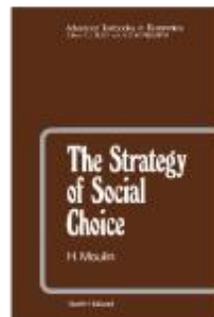
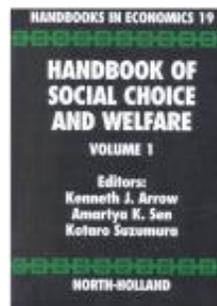
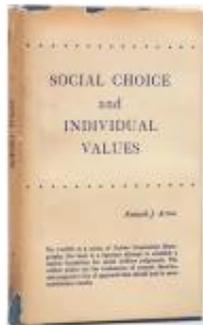
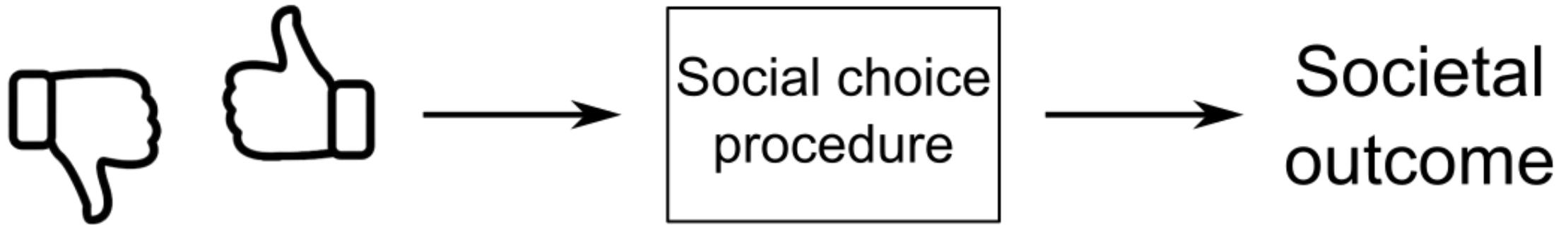
Social Choice

Making a **collective** decision from **individual** preferences



Social Choice

Making a **collective** decision from **individual** preferences



Arrow



Sen



Maskin



Roth



Shapley

Classical Social Choice

Does there exist a social choice procedure
with the desired economic properties?

Classical Social Choice

Does there exist a social choice procedure with the desired economic properties?



Does there exist a "truthful" voting rule?

Classical Social Choice

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Is there a matching procedure that is "stable"?



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Is there an allocation procedure that is "fair" and "economically efficient"?

Classical Social Choice

Does there **exist** a social choice procedure with the desired economic properties?



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Classical Social Choice

Does there **exist** a social choice procedure with the desired economic properties?

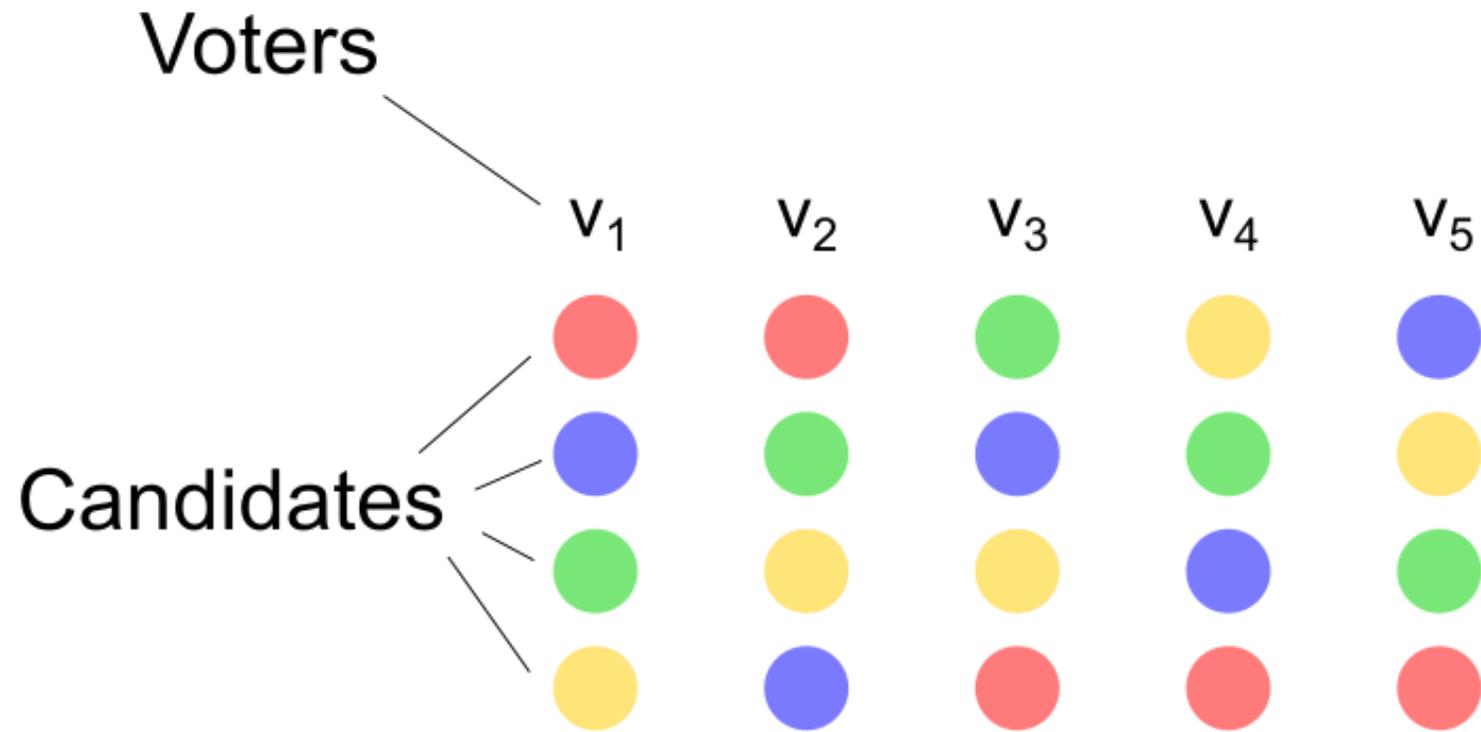
Computational Social Choice

(This course)

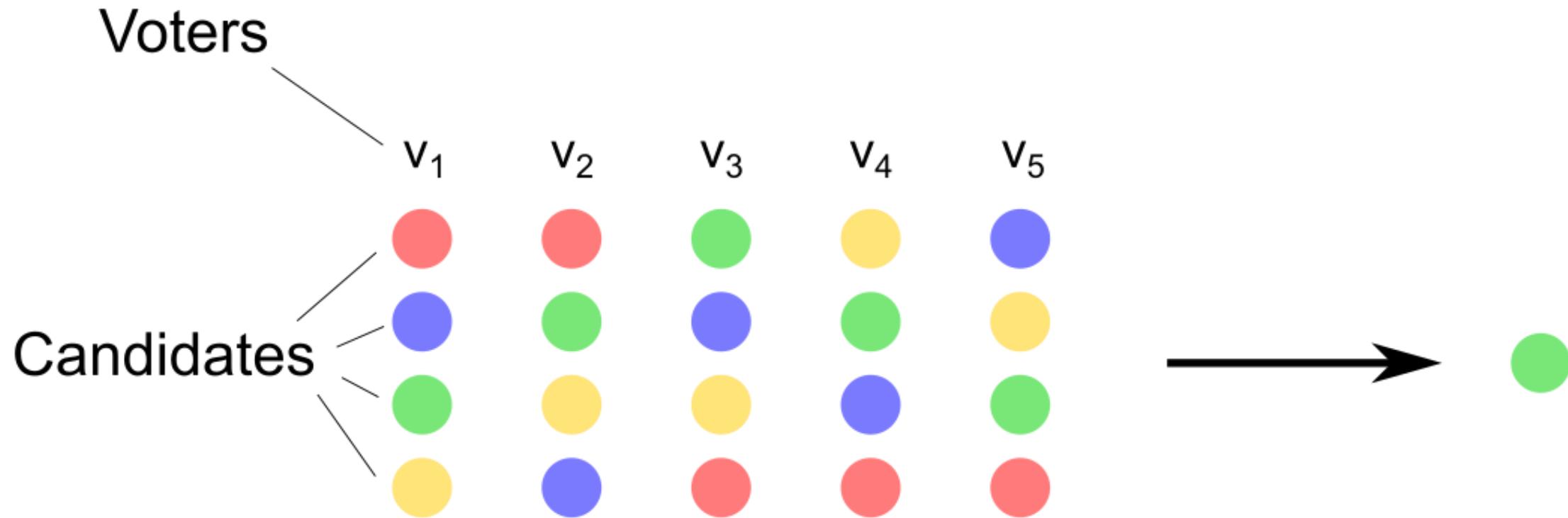
How does **computation** influence the economic properties of social choice procedures?

Voting Setup

Voting Setup



Voting Setup



Goal: Pick exactly one winning candidate.

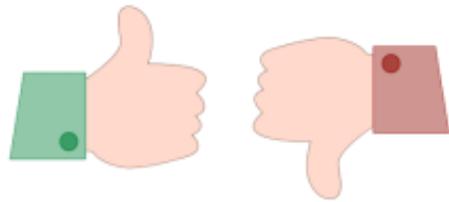
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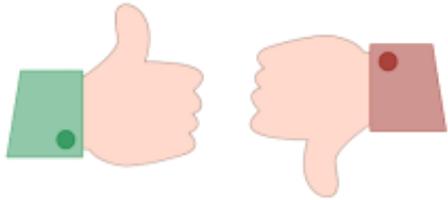


Voting Rule





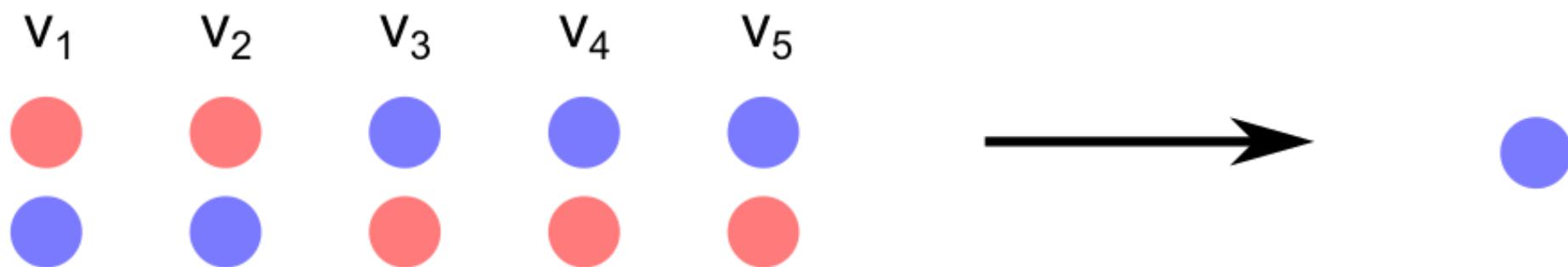
Voting Rule



Voting with Two Candidates

Voting with Two Candidates

Majority!



Voting with More Than Two Candidates

Voting with More Than Two Candidates

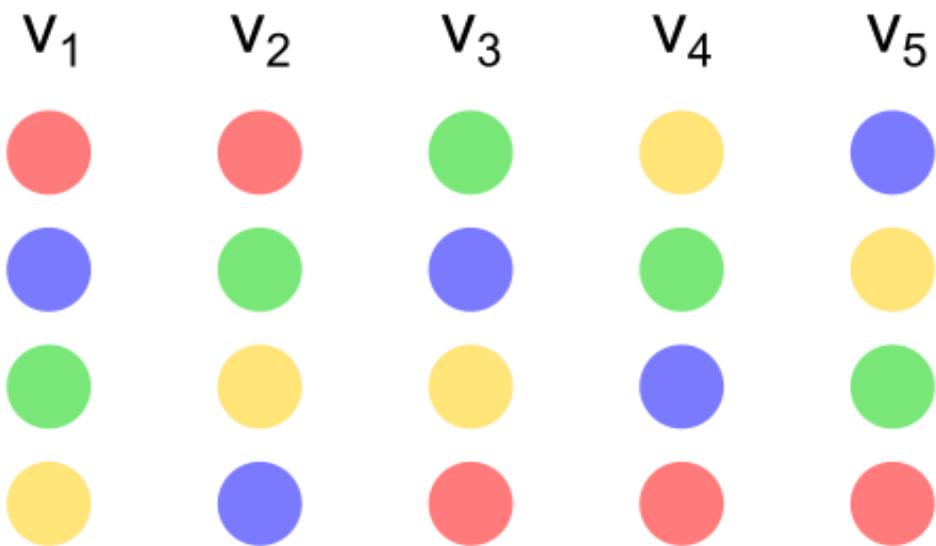
No candidate may have a majority...

1

Plurality

1

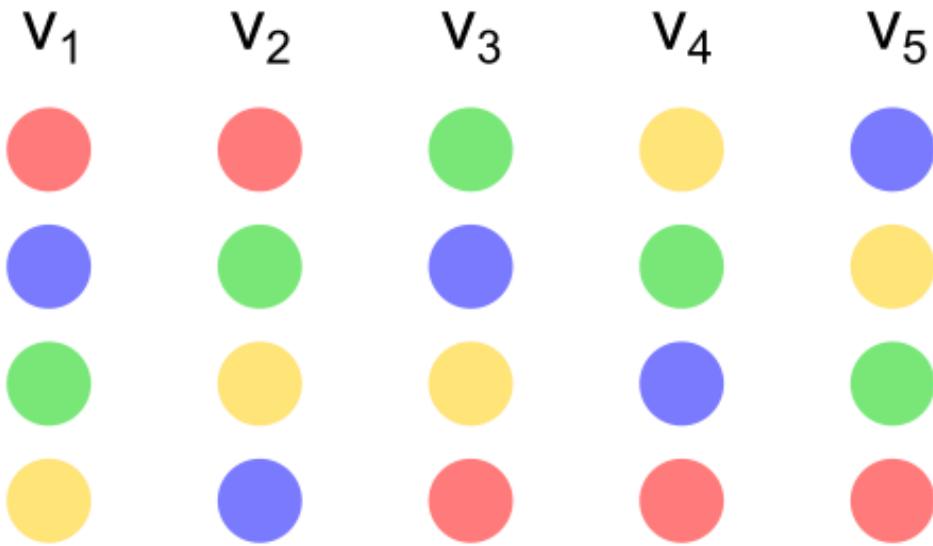
Plurality



1

Candidate with the most first-place votes wins

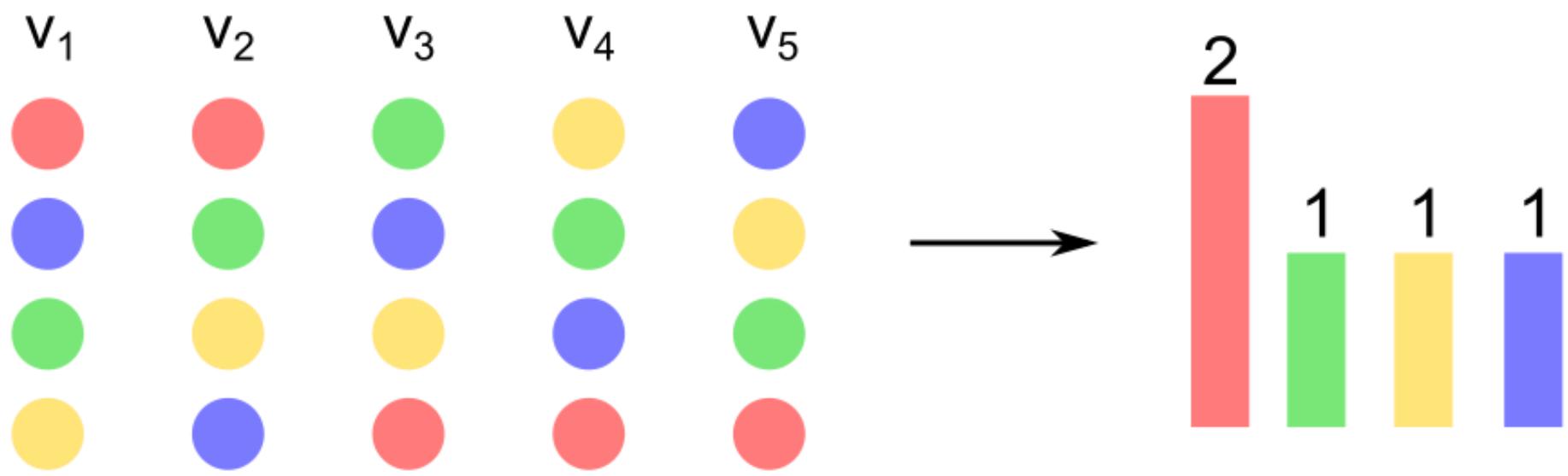
Plurality



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Candidate with the most first-place votes wins

Plurality



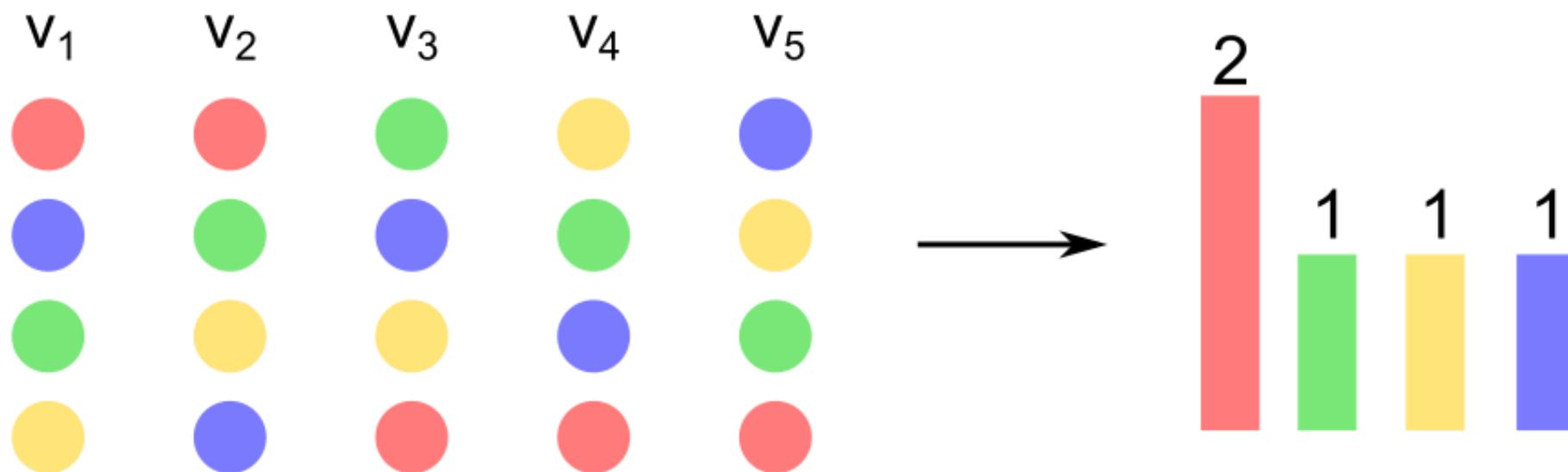
Plurality winner: ●

1

Plurality

Candidate with the most first-place votes wins*

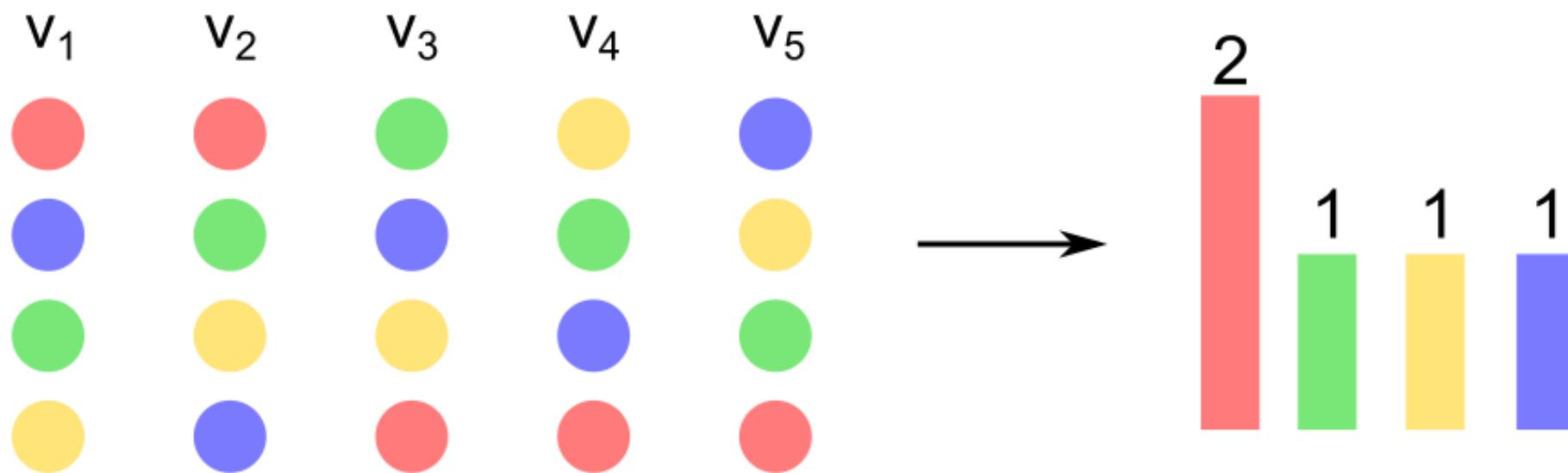
*subject to tie-breaking: lexicographic, random, ...



Plurality winner: ●

1

Problem: A majority prefers ● over the Plurality winner.



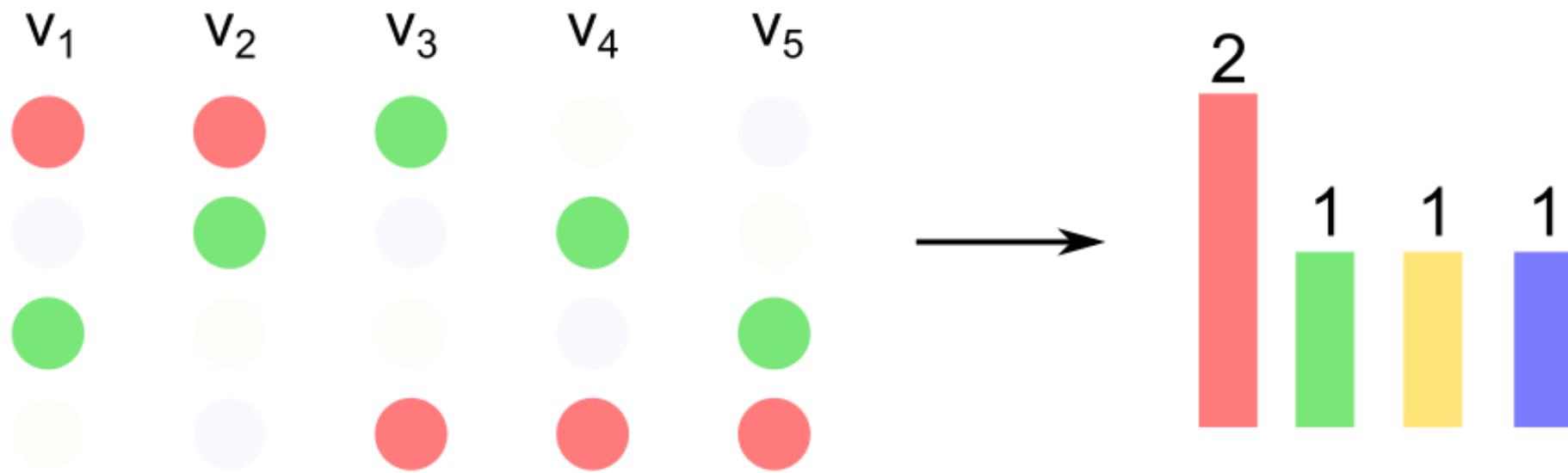
Plurality winner: ●

Plurality

1

Problem: A majority prefers ● over the Plurality winner.

Plurality



Plurality winner: ●

1

Plurality

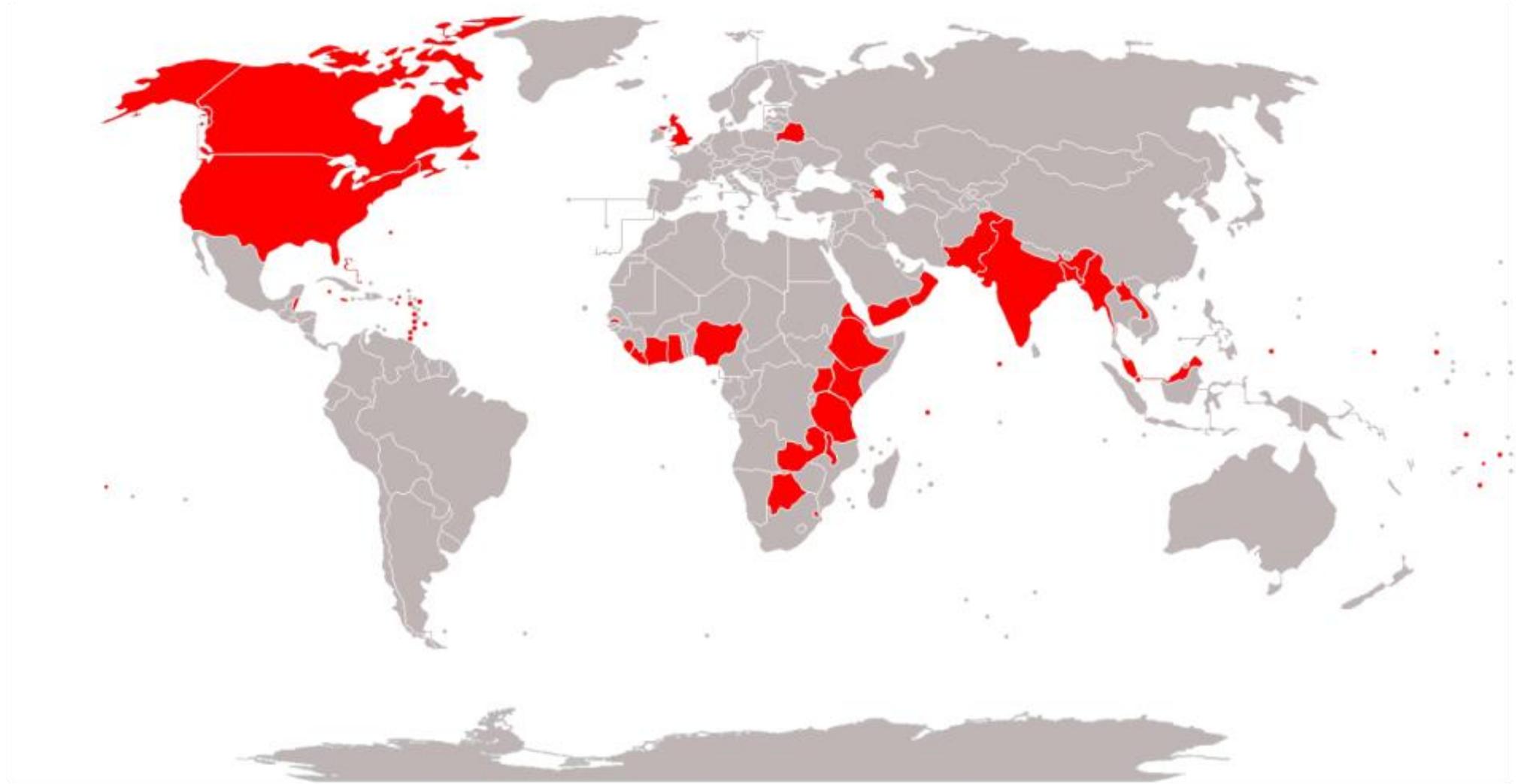


Image Source: Wikipedia article on "Electoral system" (Jan 2022)

2

Borda
Count

2

Borda
Count



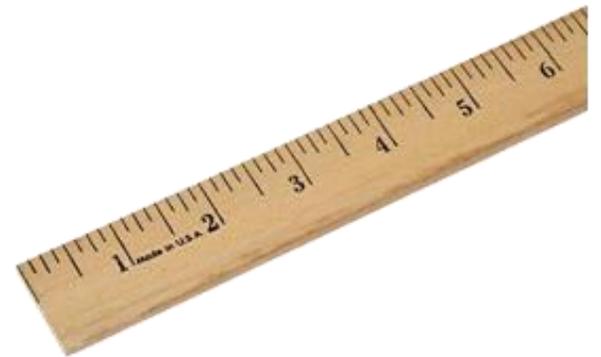
Jean-Charles de Borda
(1733-1799)

2

Borda Count



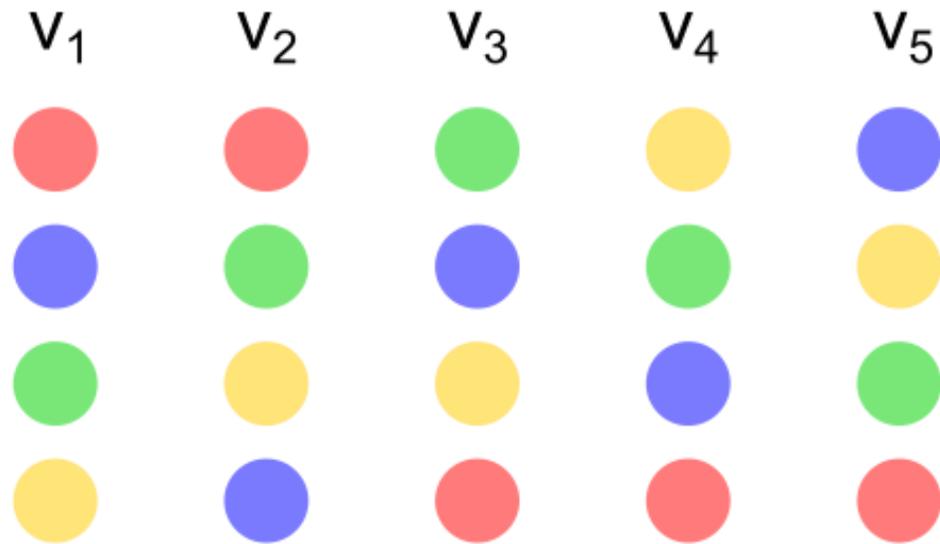
Jean-Charles de Borda
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2

Each voter gives its k^{th} ranked candidate $m-k$ points, where m is the number of candidates.

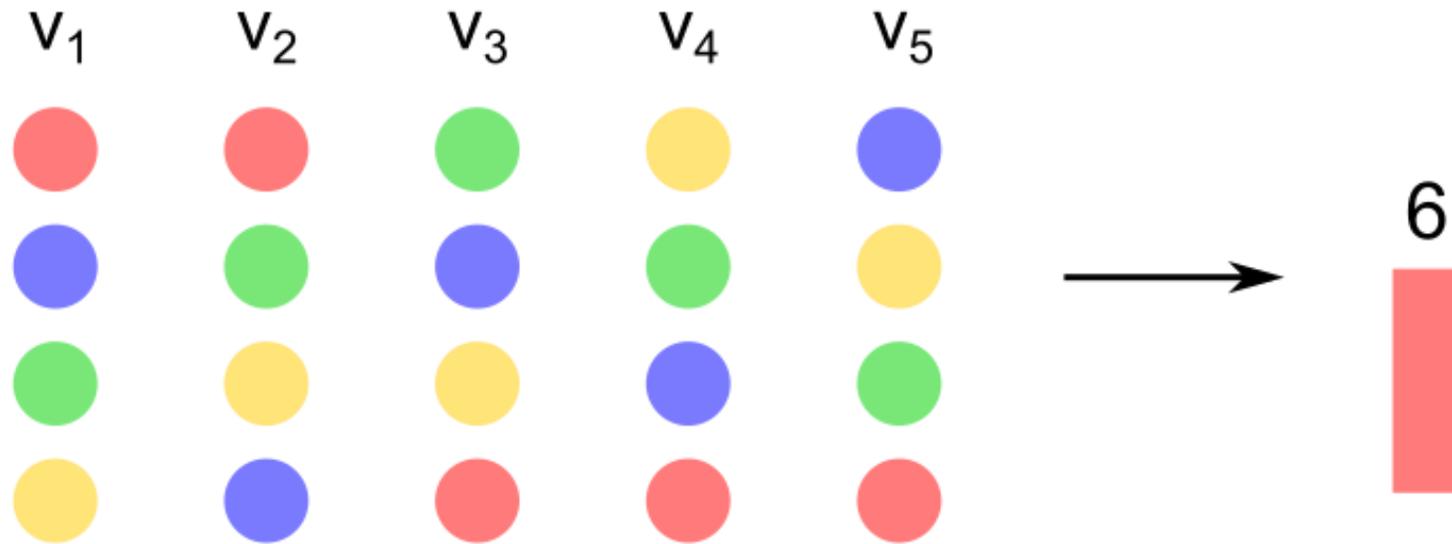
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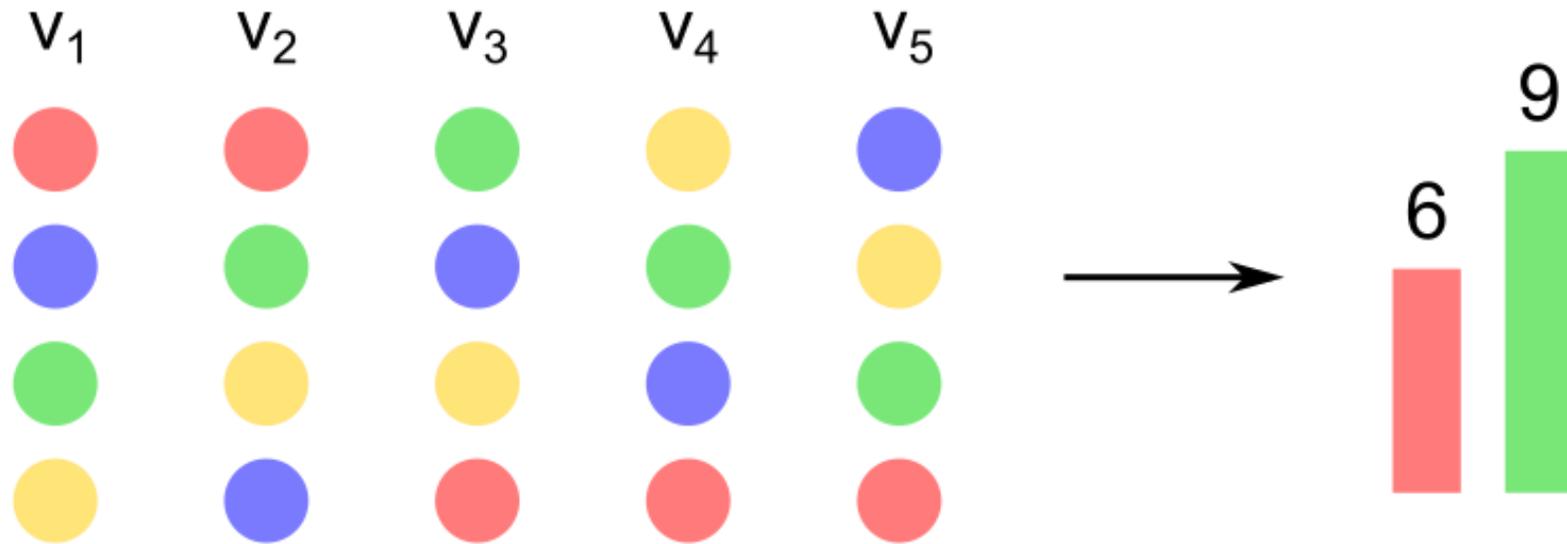
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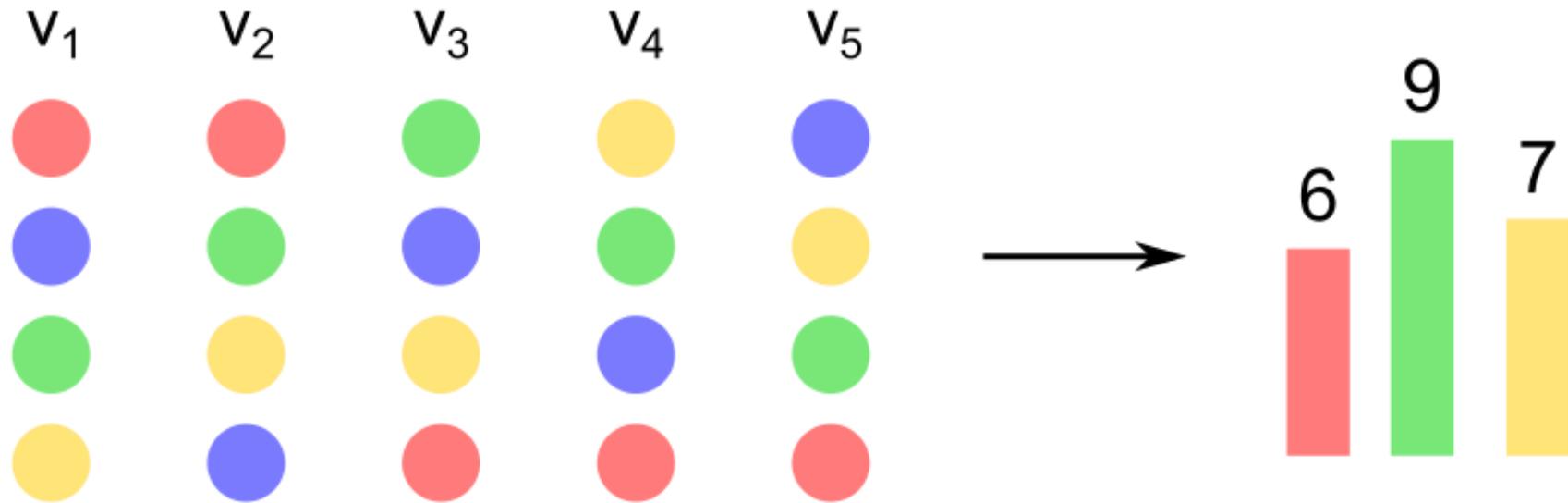
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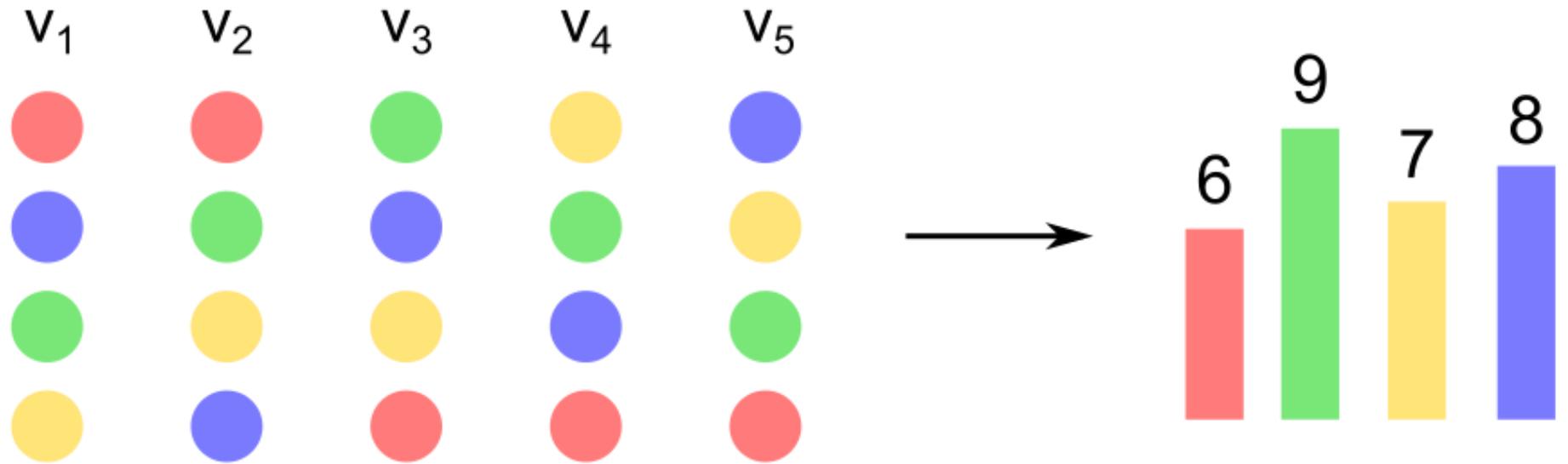
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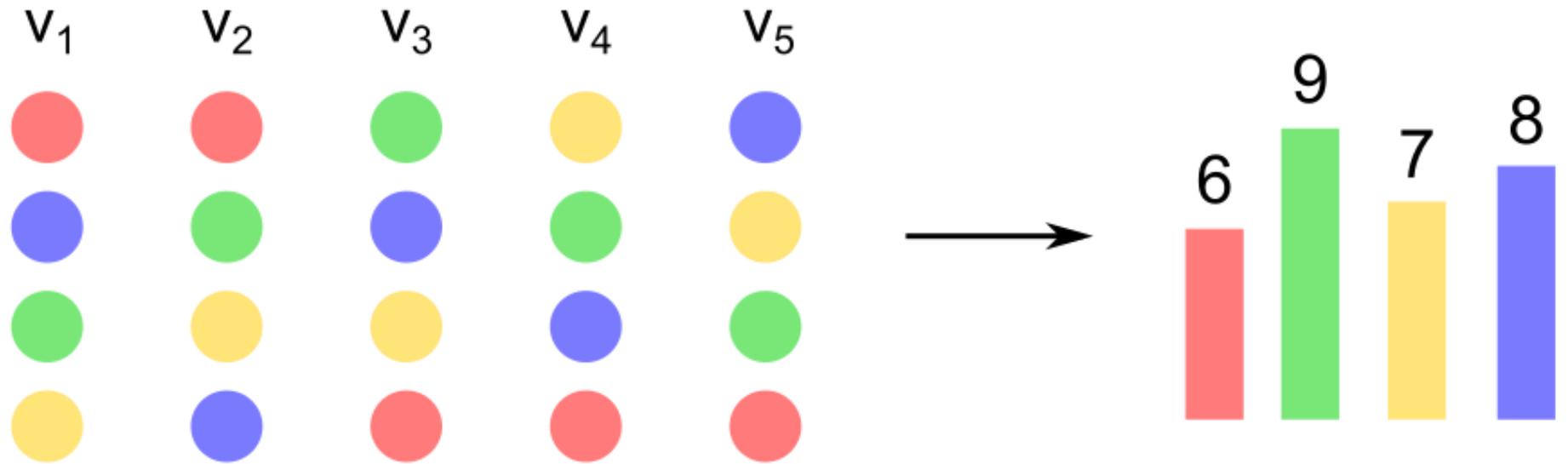
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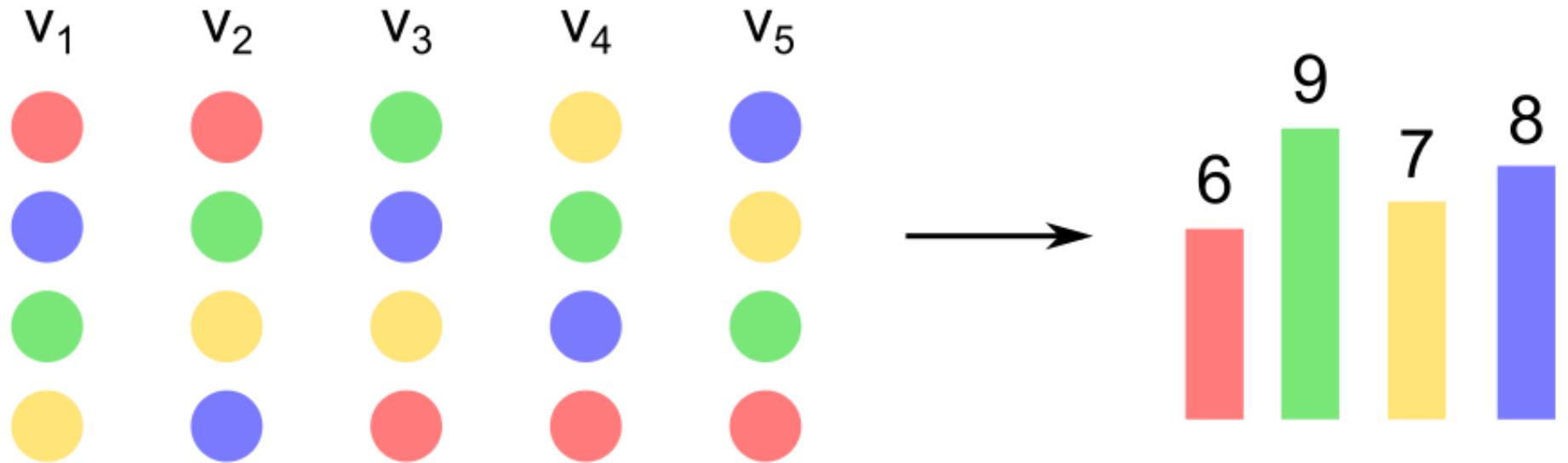


Borda winner: ●

2

Problem: Susceptible to strategic voting (manipulation).

Borda
Count

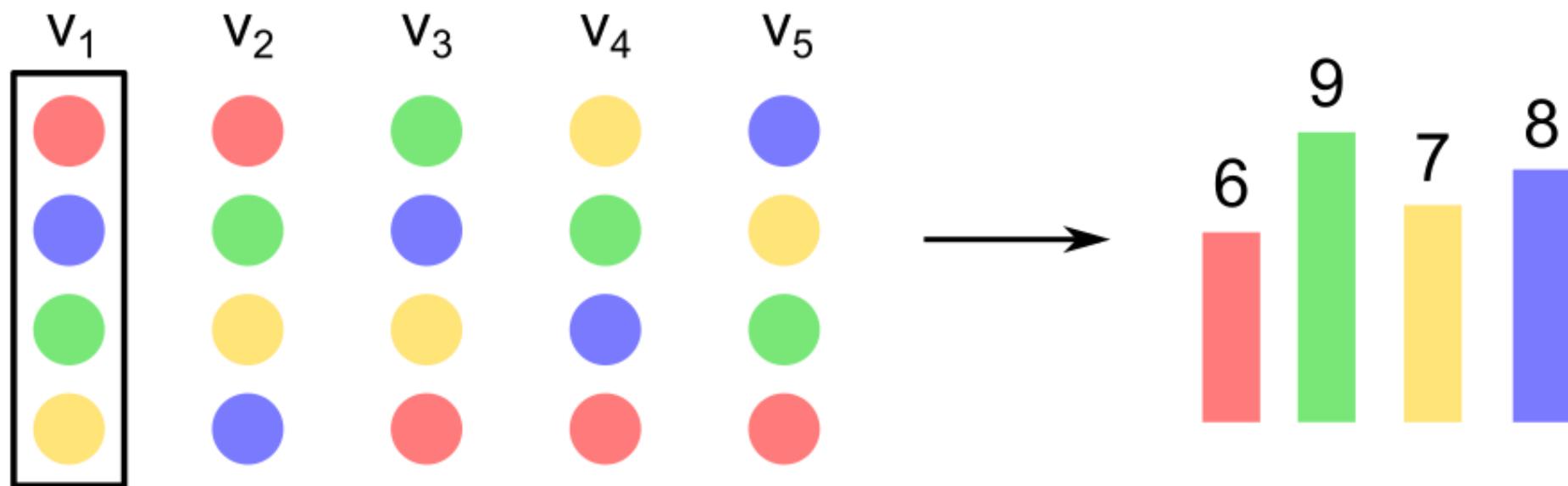


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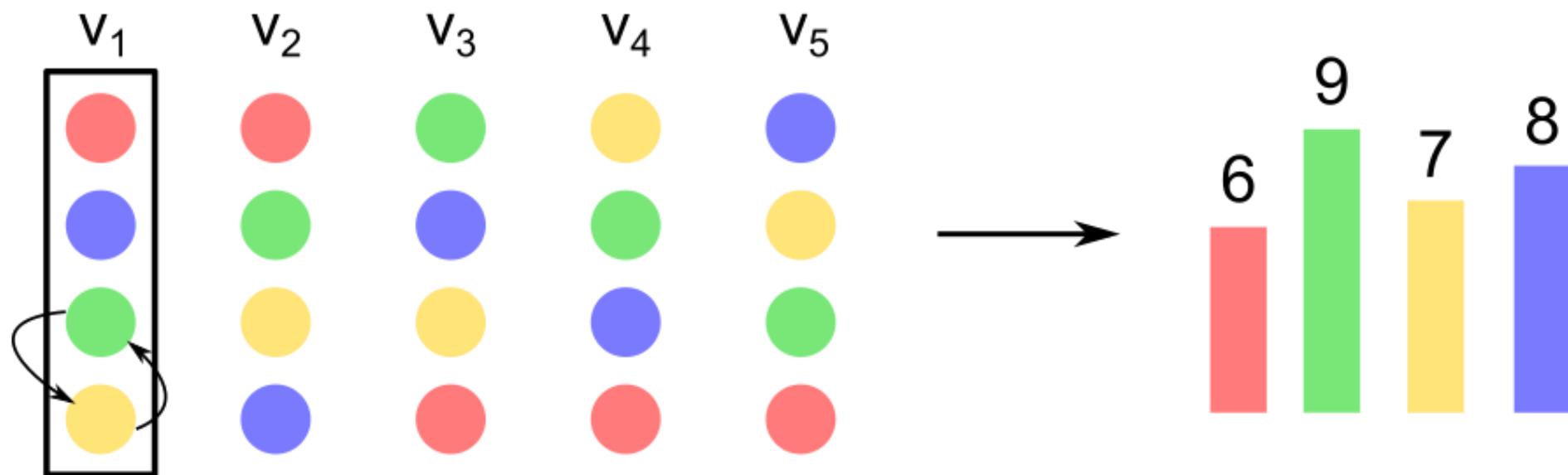


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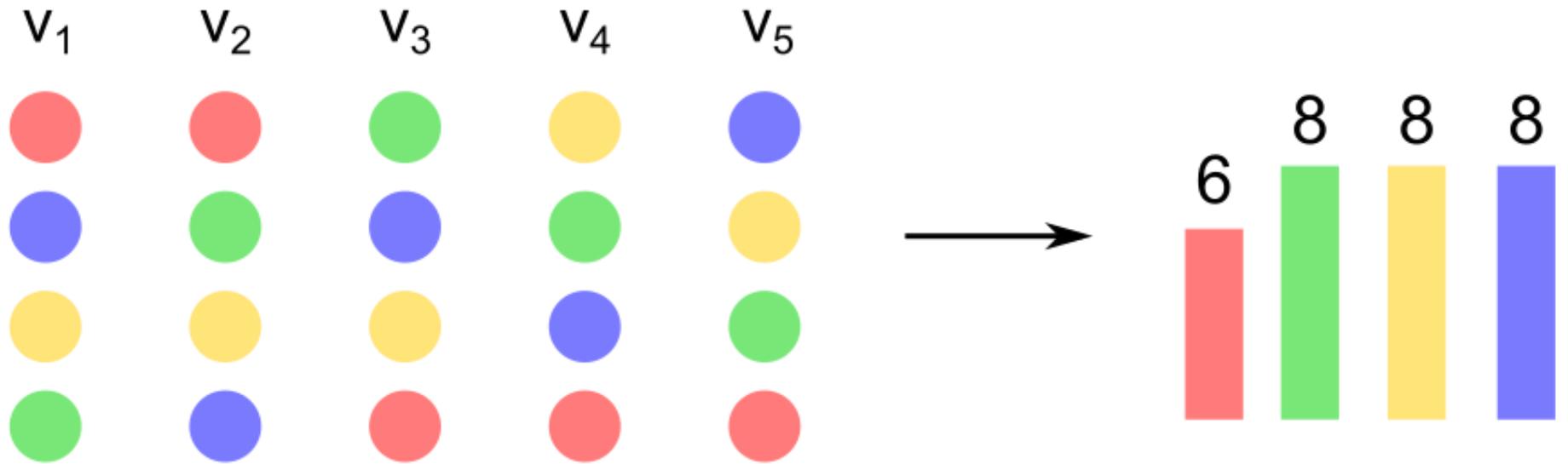


Borda winner: ●

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Borda
Count



Borda winner: ●

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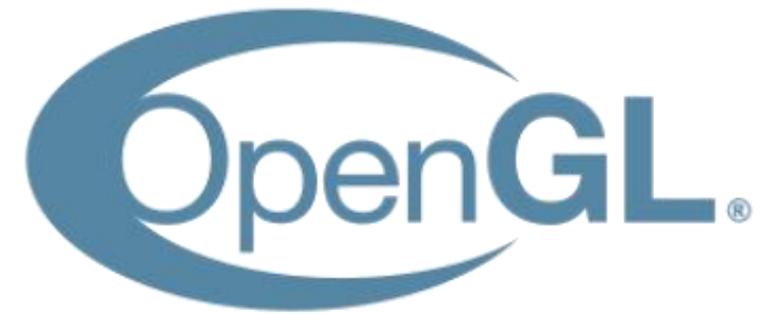
"My scheme is intended for only honest men."



Borda
Count

2

Borda
Count



3

Plurality
With
Runoff

3

Plurality With Runoff



3

Plurality
With
Runoff

3

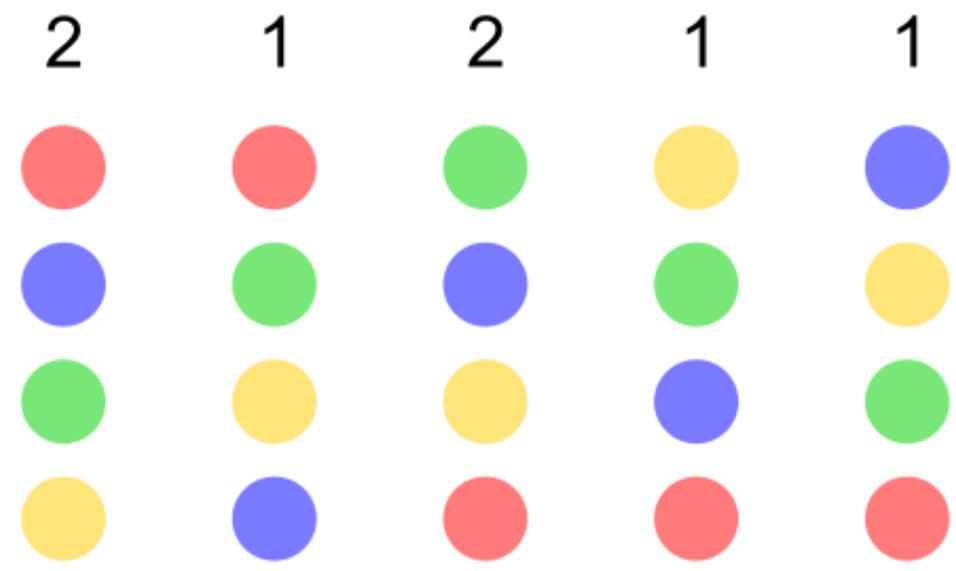
The two candidates with the highest Plurality scores in the first round go head-to-head in the next round

Plurality
With
Runoff

3

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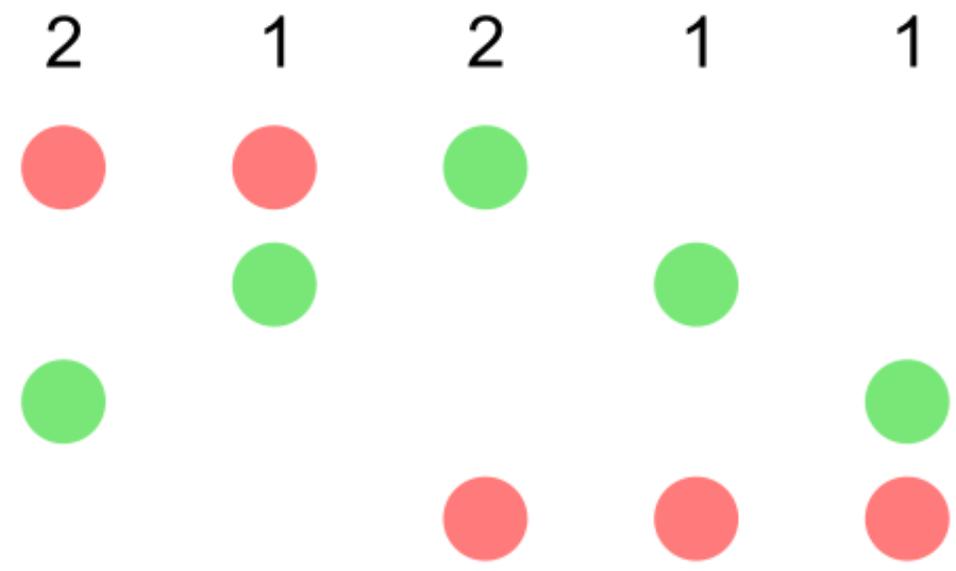
Plurality
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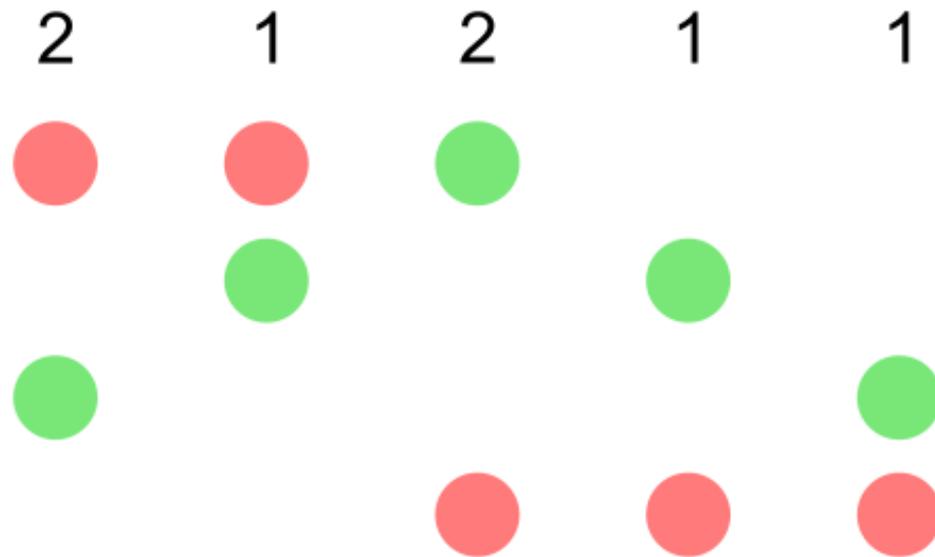
Plurality
With
Runoff



3

The two candidates with the highest Plurality scores in the first round go head-to-head in the next round

Plurality
With
Runoff



Plurality with runoff winner: ●

4

Single
Transferable
Vote

(Instant-Runoff)

4

In each round, eliminate the candidate with the lowest Plurality score, and transfer its supporters' votes

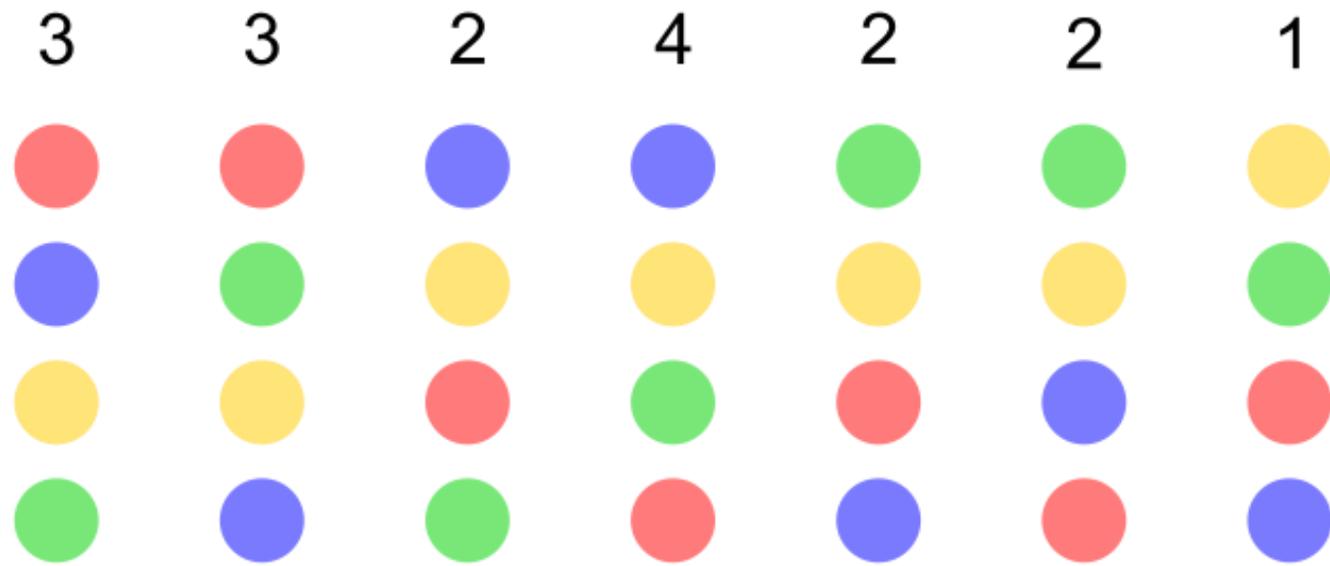
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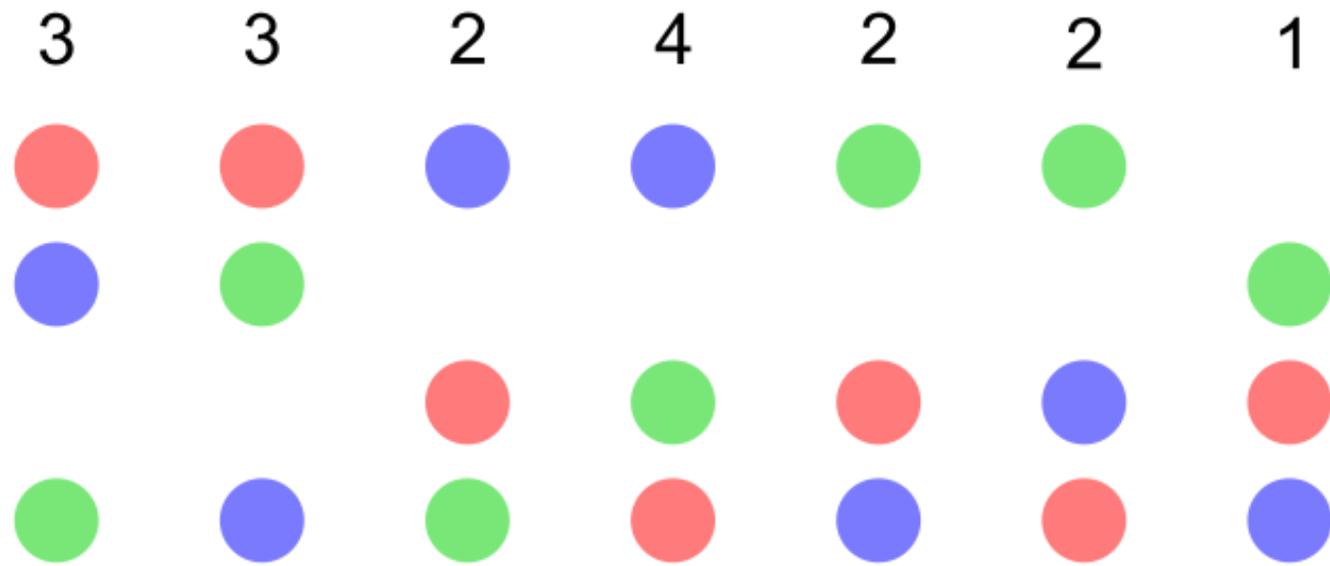
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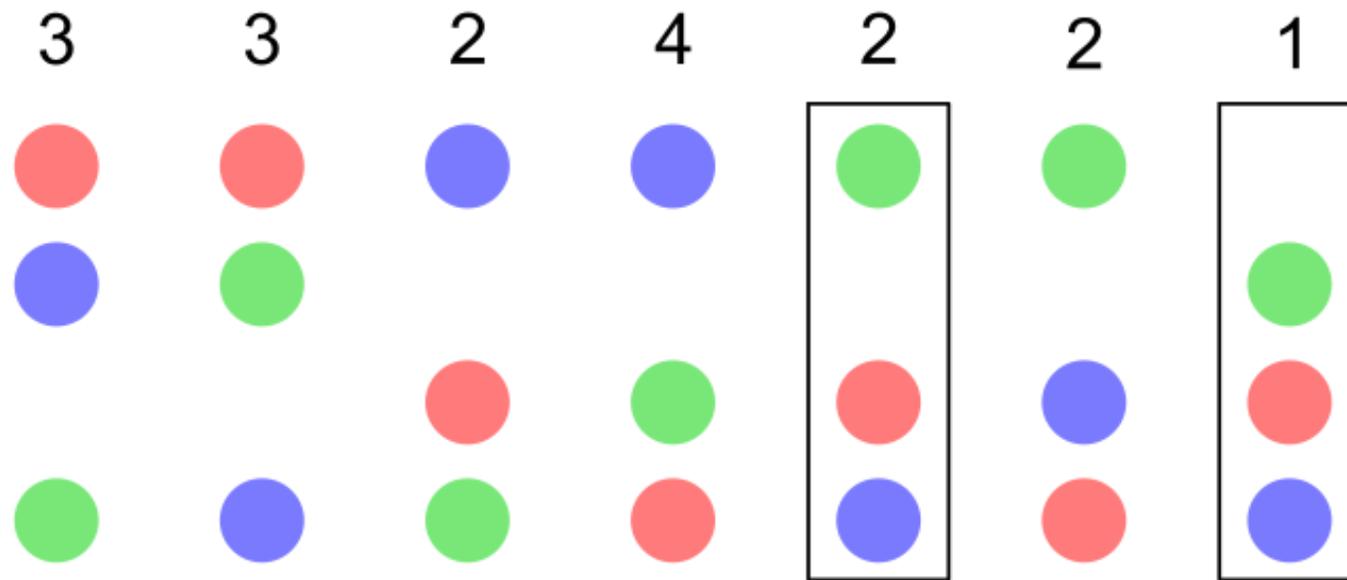
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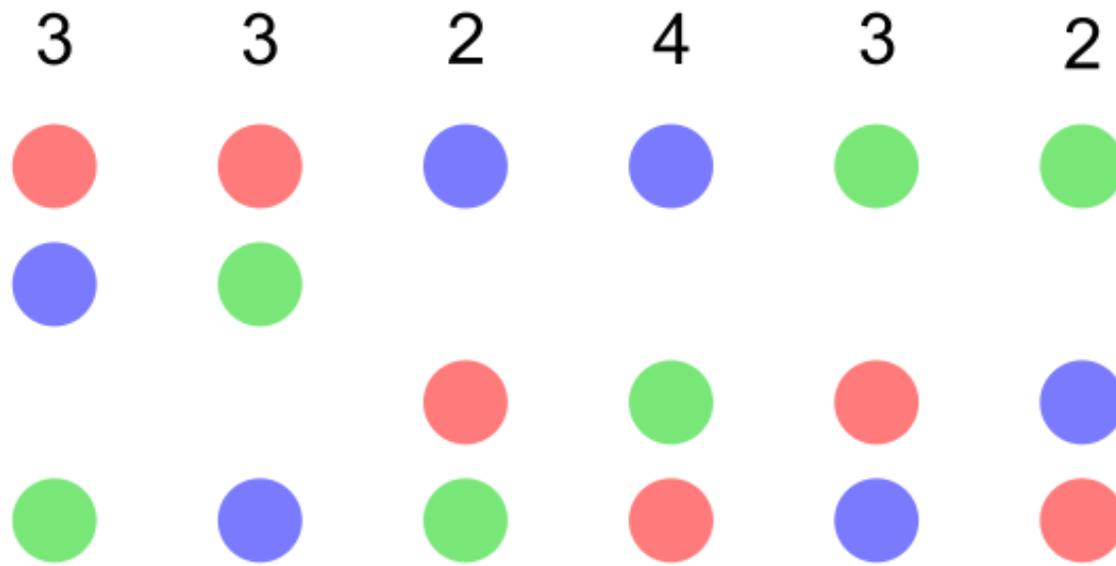
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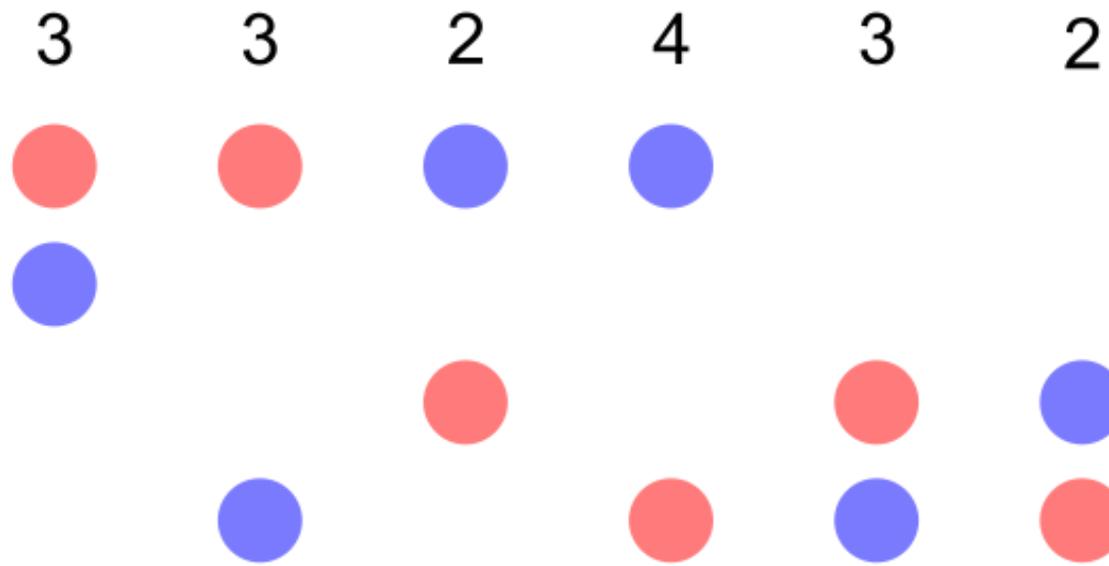
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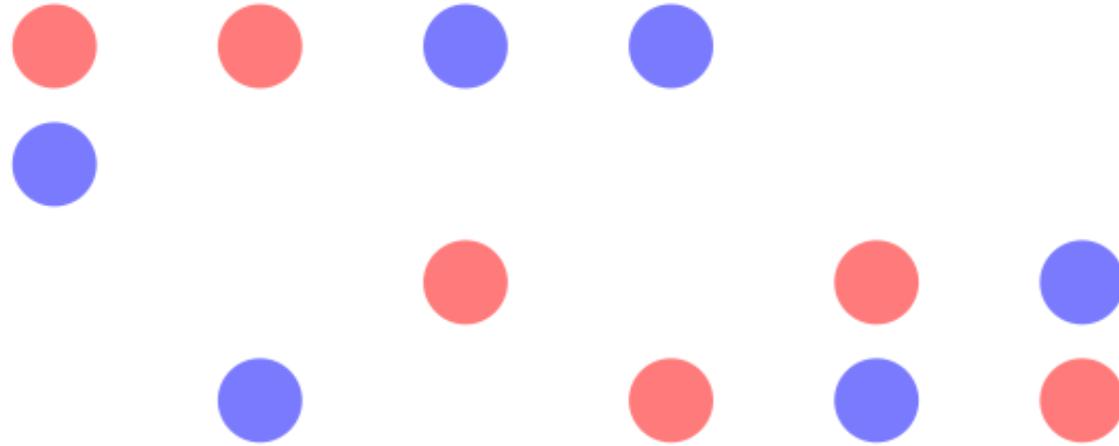
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Single
Transferable
Vote

(Instant-Runoff)

3 3 2 4 3 2



STV winner: ●

4

Single
Transferable
Vote

(Instant-Runoff)



4

Single
Transferable
Vote

(Instant-Runoff)



4

Single
Transferable
Vote

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Single
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Vote

(Instant-Runoff)

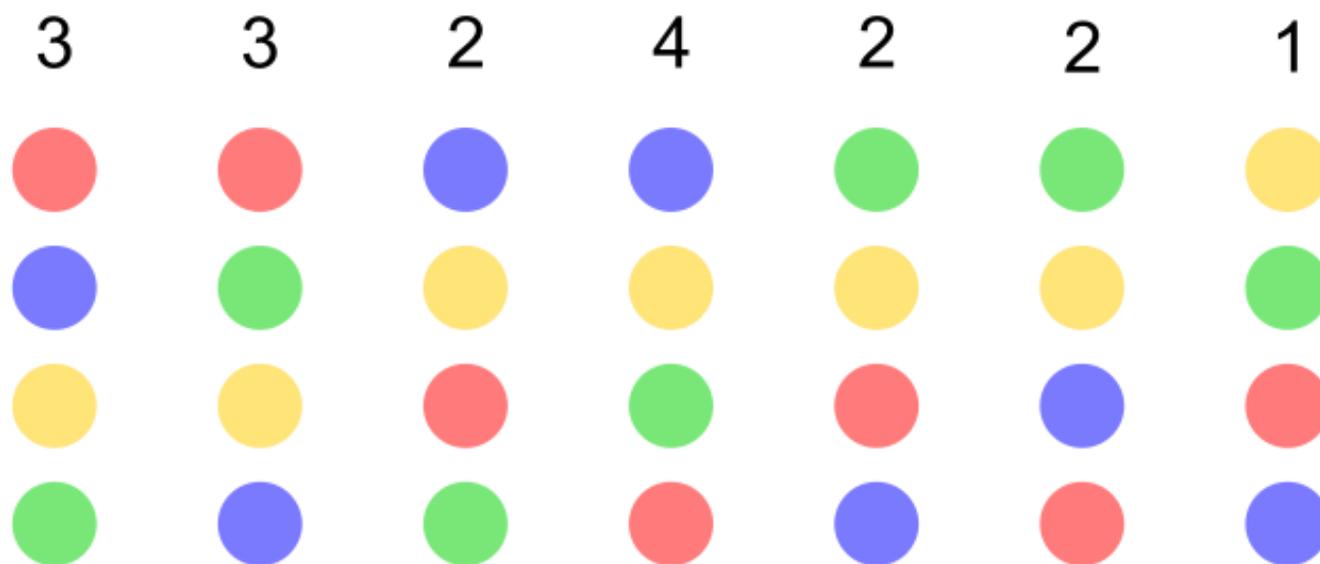
Problem: Failure of *monotonicity*
(improving a candidate's support could make it worse off)

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Single
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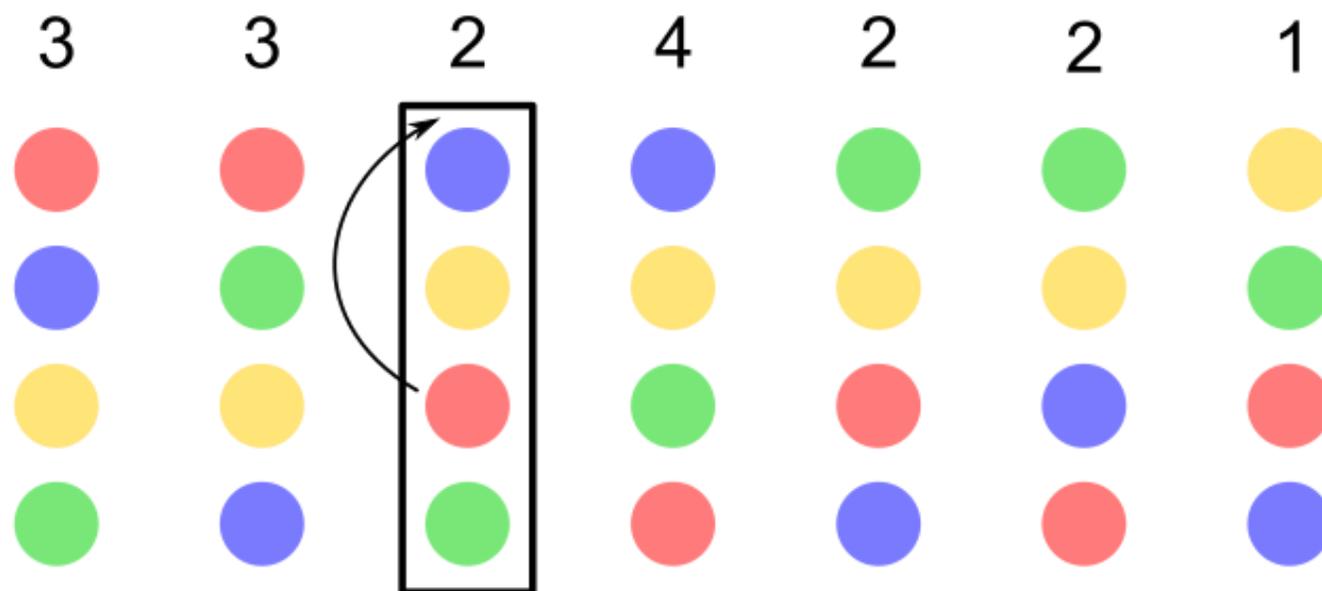
Recall that STV winner was 

4

Problem: Failure of *monotonicity*

(improving a candidate's support could make it worse off)

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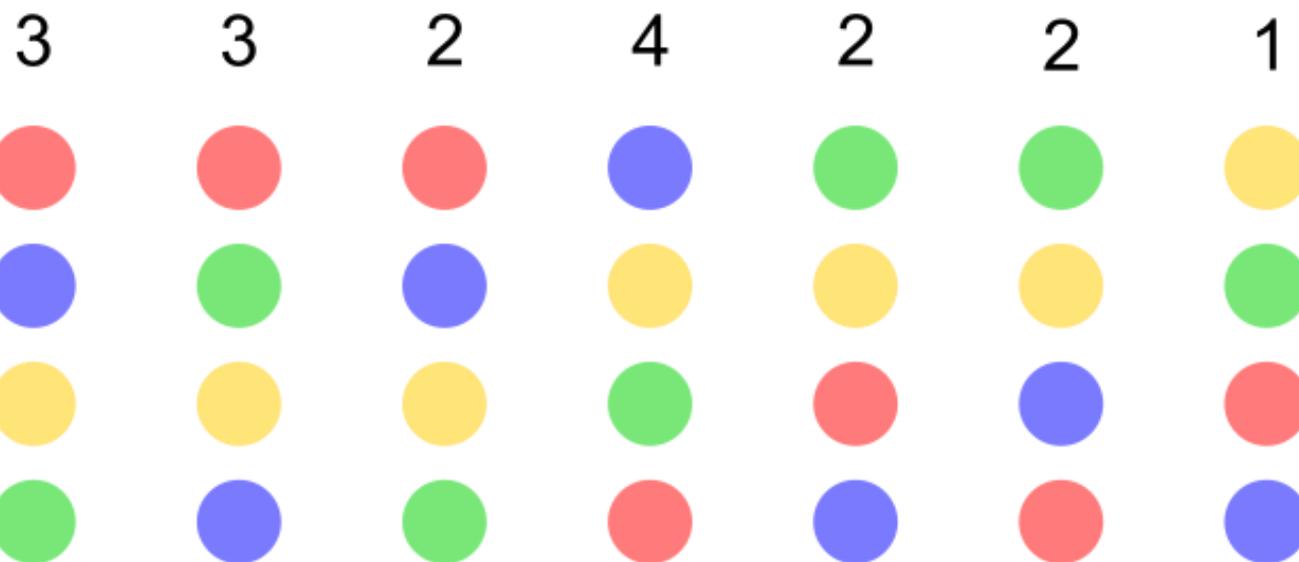


Recall that STV winner was ●

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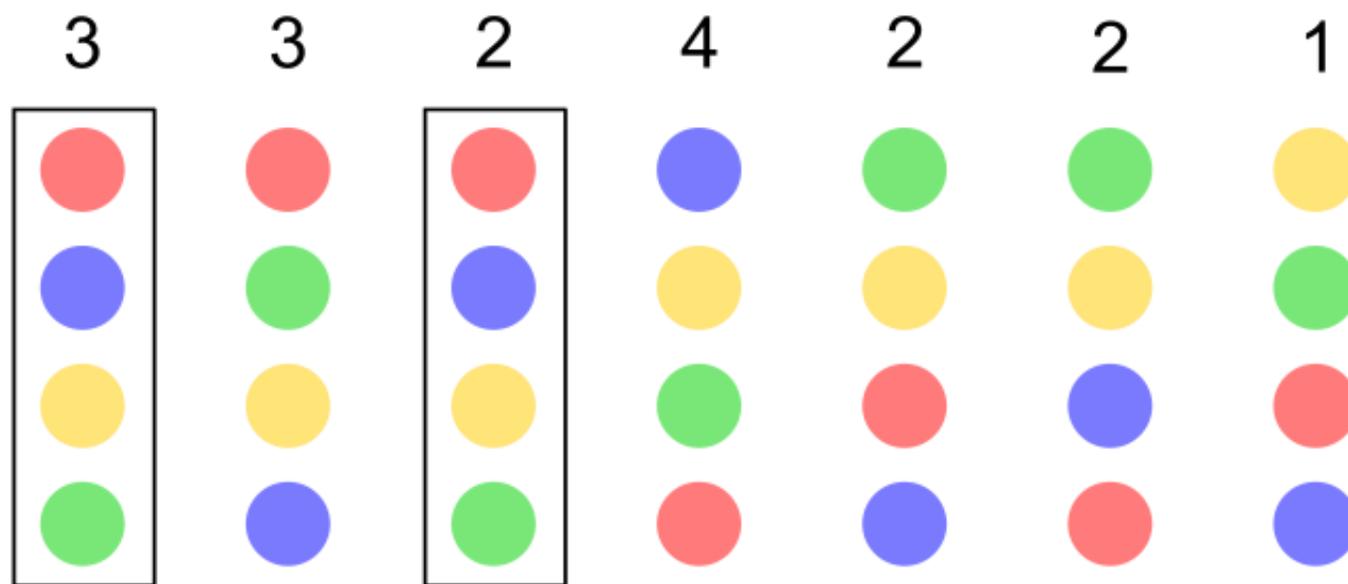
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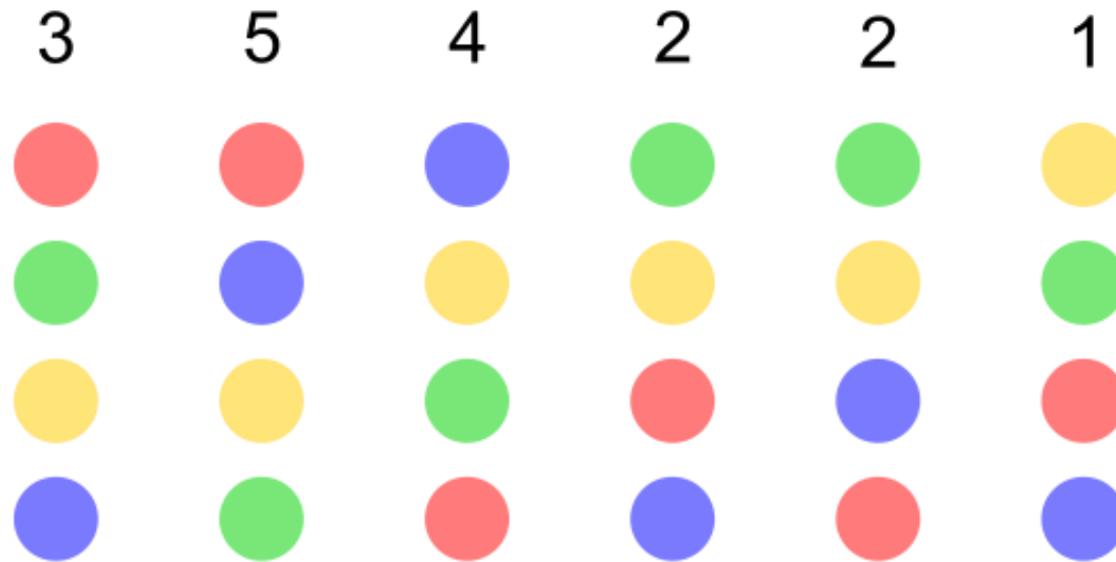
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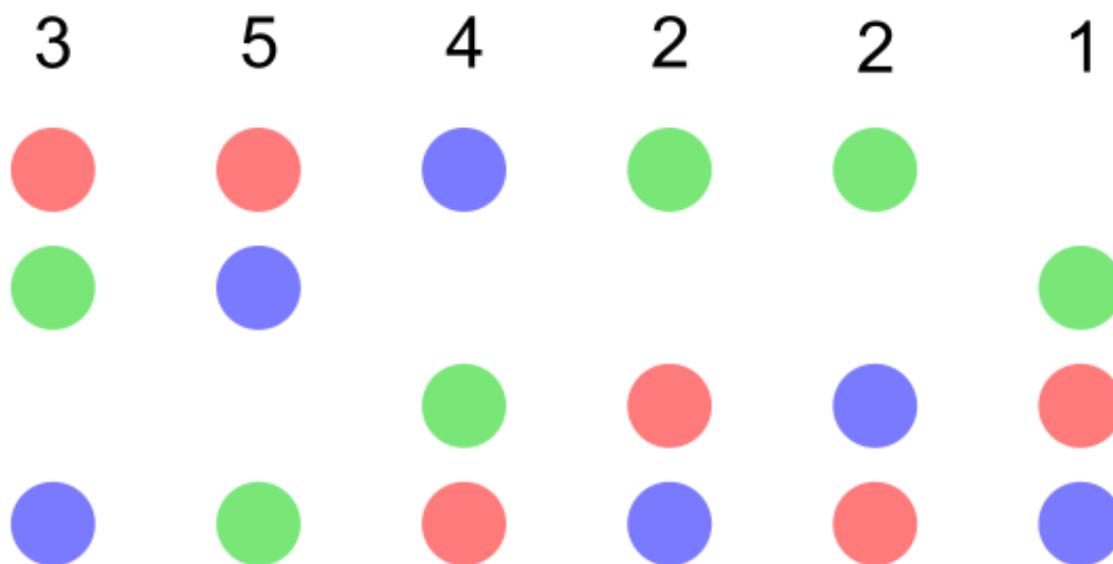


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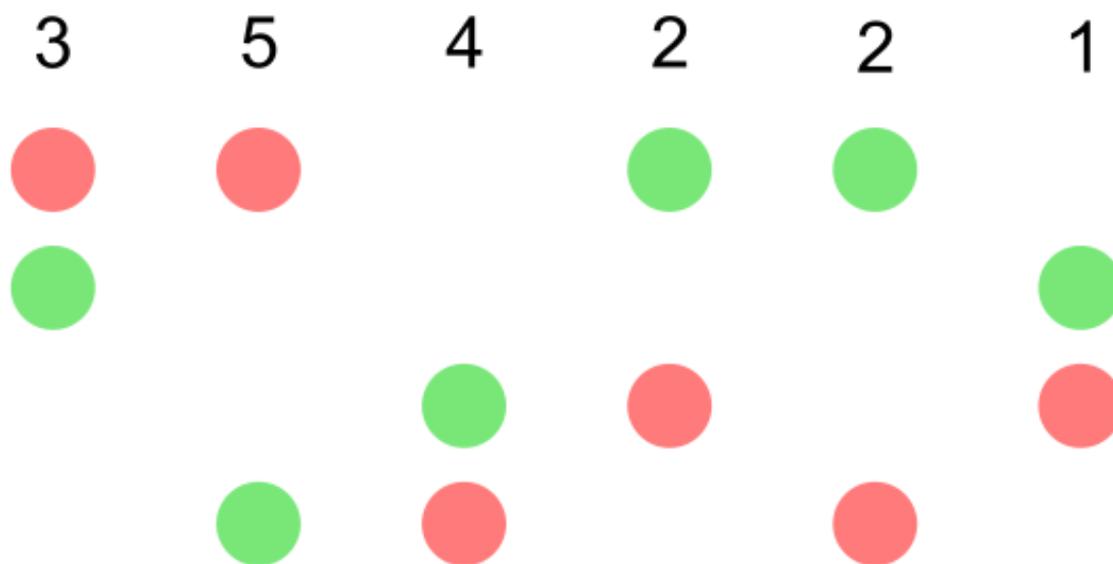
Recall that STV winner was 

Single
Transferable
Vote
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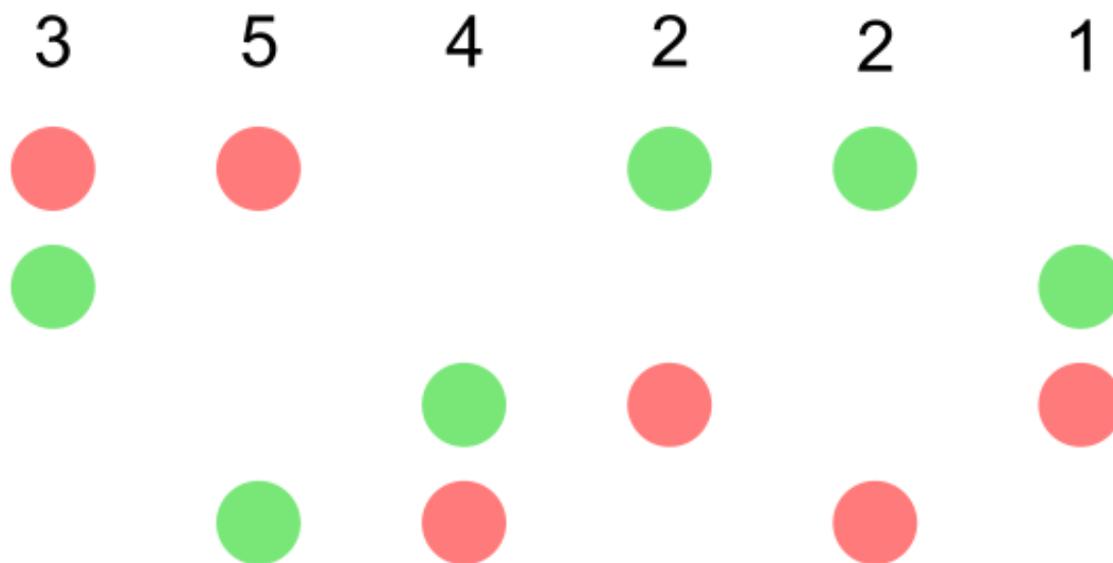
Recall that STV winner was ●

Single
Transferable
Vote
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4

Problem: Failure of *monotonicity*

(improving a candidate's support could make it worse off)



Recall that STV winner was 
but now it's 

Single
Transferable
Vote
(Instant-Runoff)

4

Single
Transferable
Vote
(Instant-Runoff)

2016 host city election ballots results [\[edit \]](#)

City	NOC	Round 1	Round 2	Round 3
Rio de Janeiro	 Brazil (COB)	26	46	66
Madrid	 Spain (COE)	28	29	32
Tokyo	 Japan (JOC)	22	20	—
Chicago	 United States (USOC)	18	—	—

Venue
Bella Center 121st IOC Session October 2, 2009  Copenhagen

Vote details	Round 1	Round 2	Round 3
Eligible members	95	97	99
Participants	94	96	98
Abstentions	0	1	0
Valid ballots	94	95	98

4

2016 host city election ballots results [\[edit \]](#)

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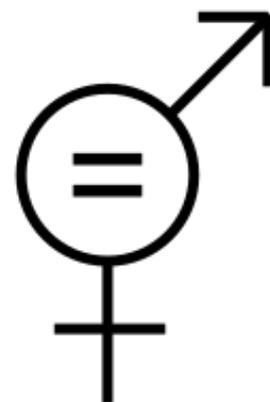
(Instant-Runoff)



Nicolas de Condorcet
(1743-1794)



Nicolas de Condorcet
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If a candidate beats every other candidate
in a head-to-head election, select it!

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3



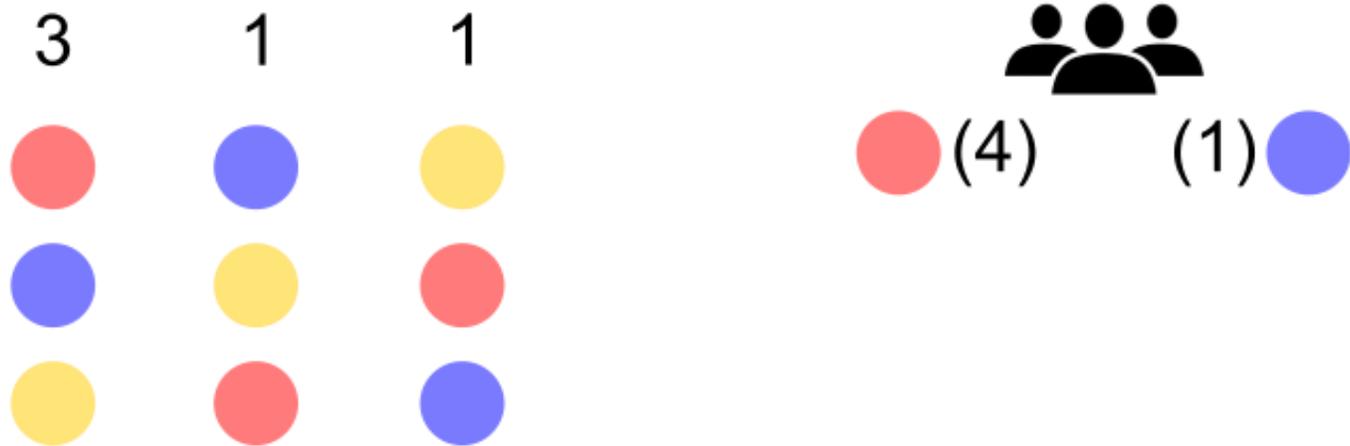
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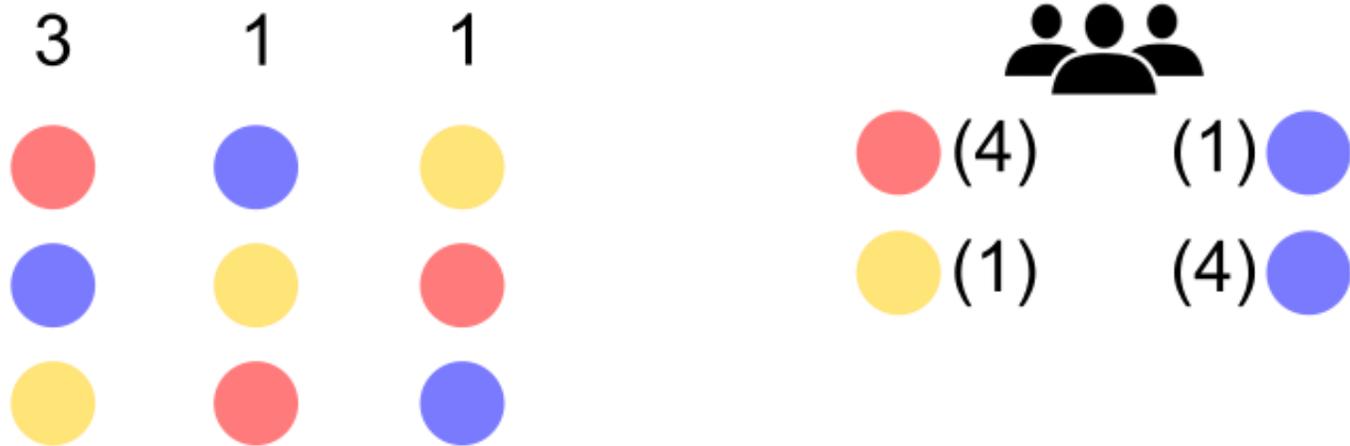
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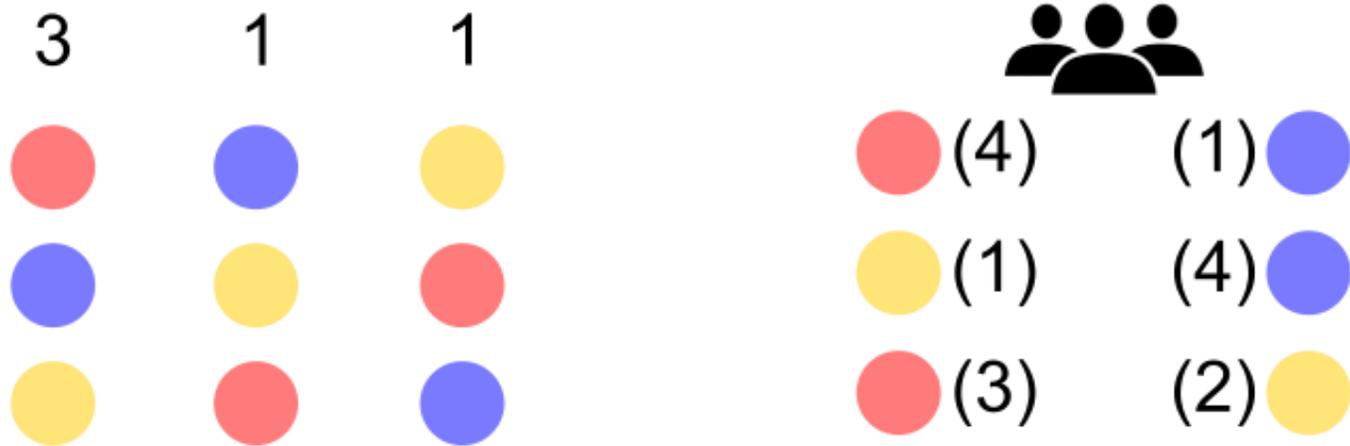
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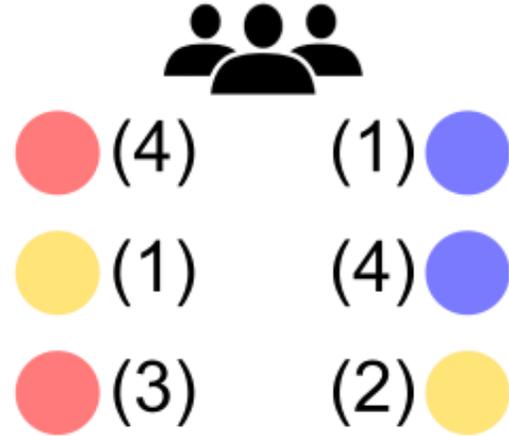
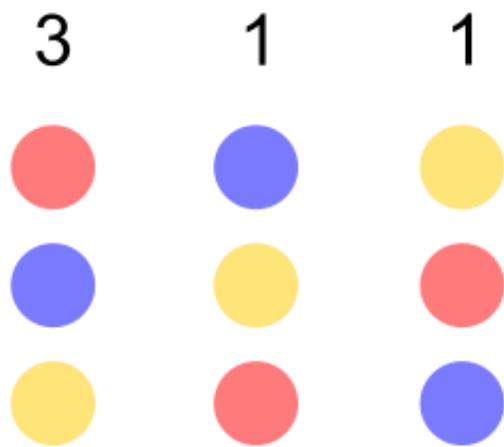
If a candidate beats every other candidate
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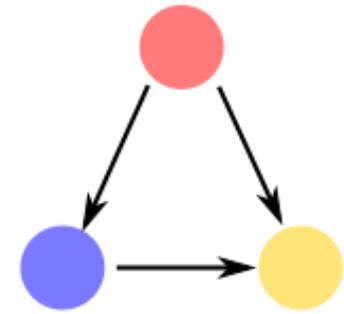
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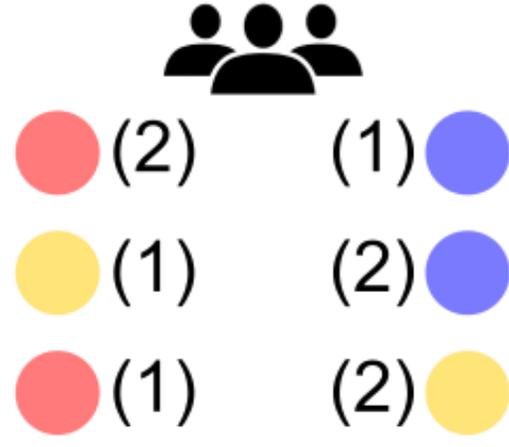
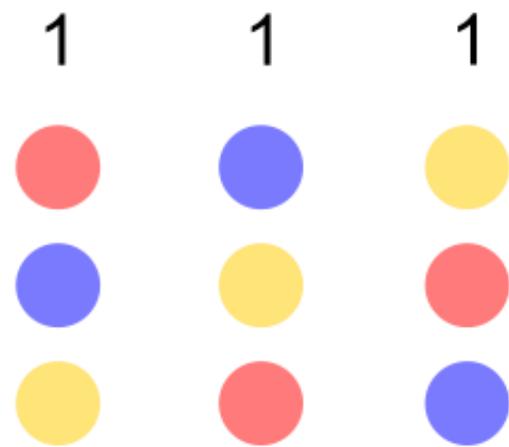
Condorcet winner



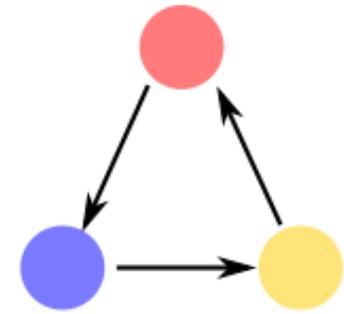
Condorcet Criterion

Problem: A Condorcet winner may not exist

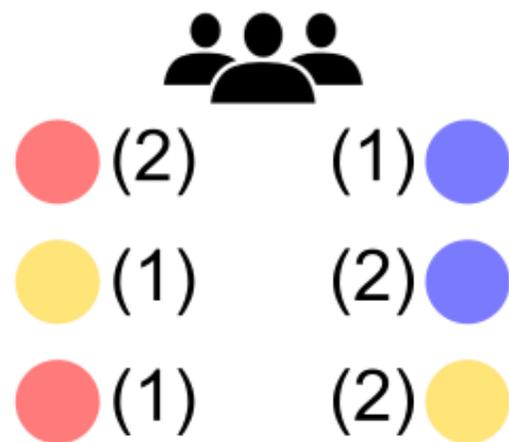
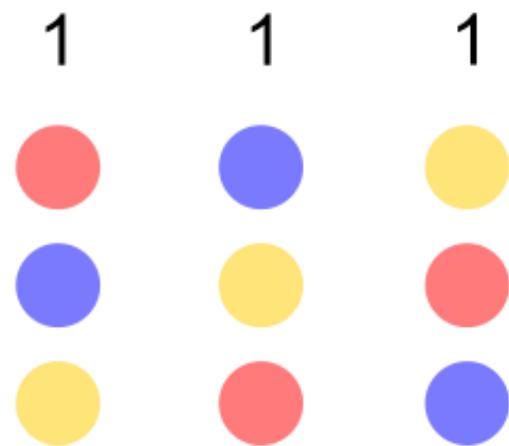
Problem: A Condorcet winner may not exist



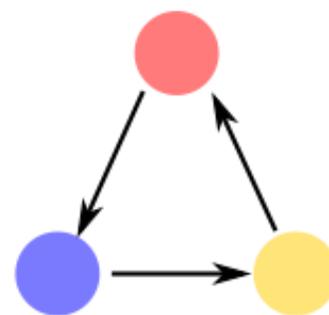
Condorcet cycle



Problem: A Condorcet winner may not exist



Condorcet cycle



Condorcet paradox

Transitivity of individual preferences $\not\Rightarrow$ Transitivity of societal preferences

5

Copeland

5

For each head-to-head election, a candidate gets 1 point for winning, 0 for losing, and 0.5 for a tie

Copeland

5

For each head-to-head election, a candidate gets 1 point for winning, 0 for losing, and 0.5 for a tie

3



1



1



4



4



Copeland

5

For each head-to-head election, a candidate gets 1 point for winning, 0 for losing, and 0.5 for a tie

3



1



1



4



4



Copeland

5

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3



1



1



4



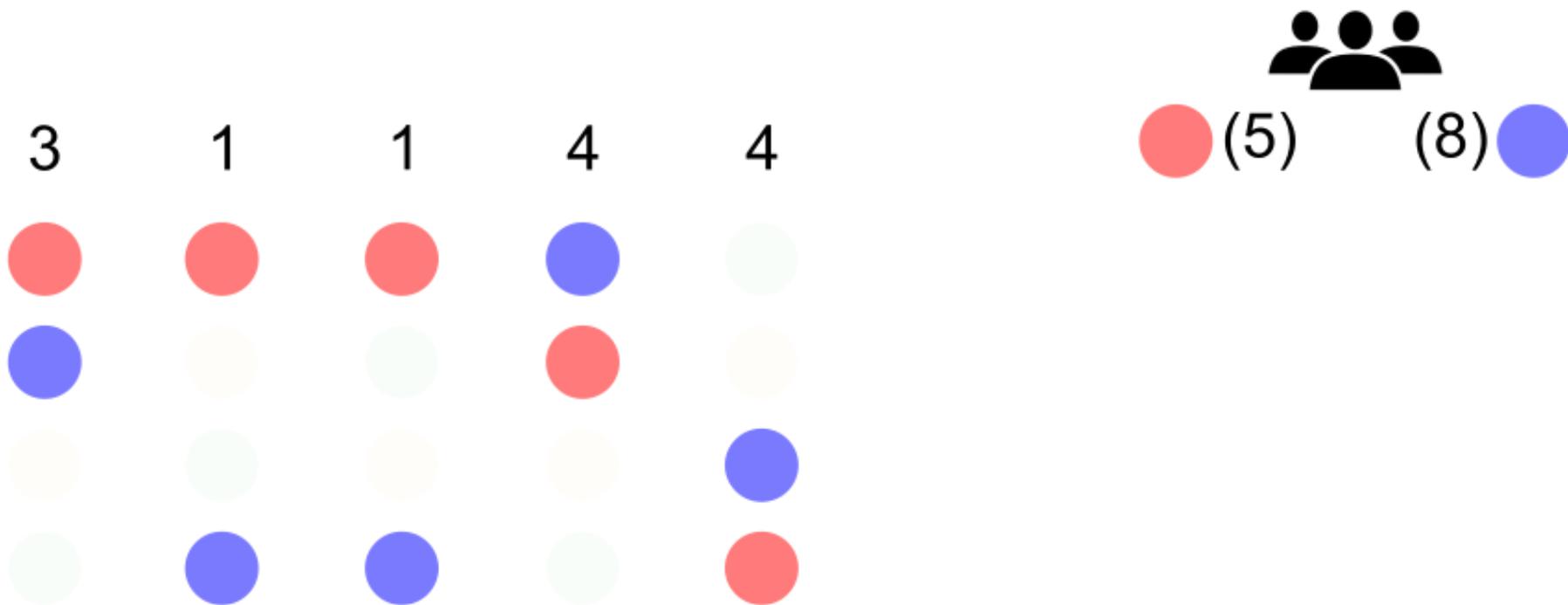
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Copeland

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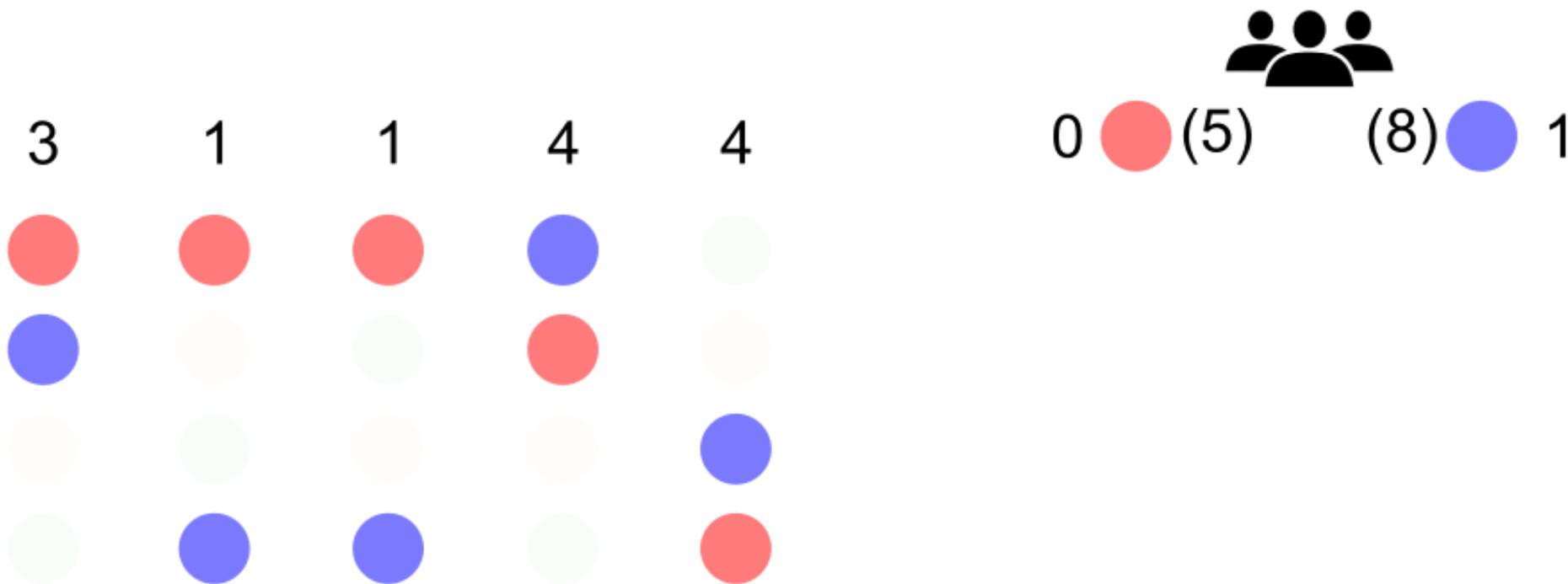
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Copeland

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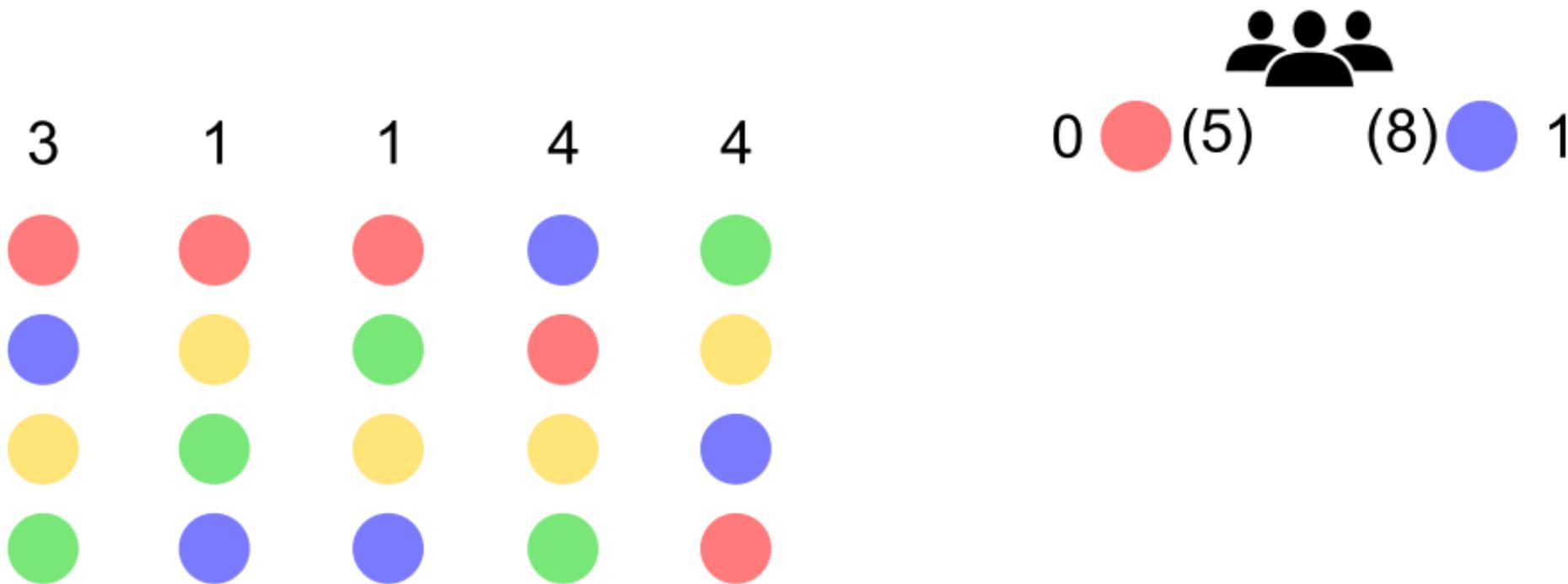
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Copeland

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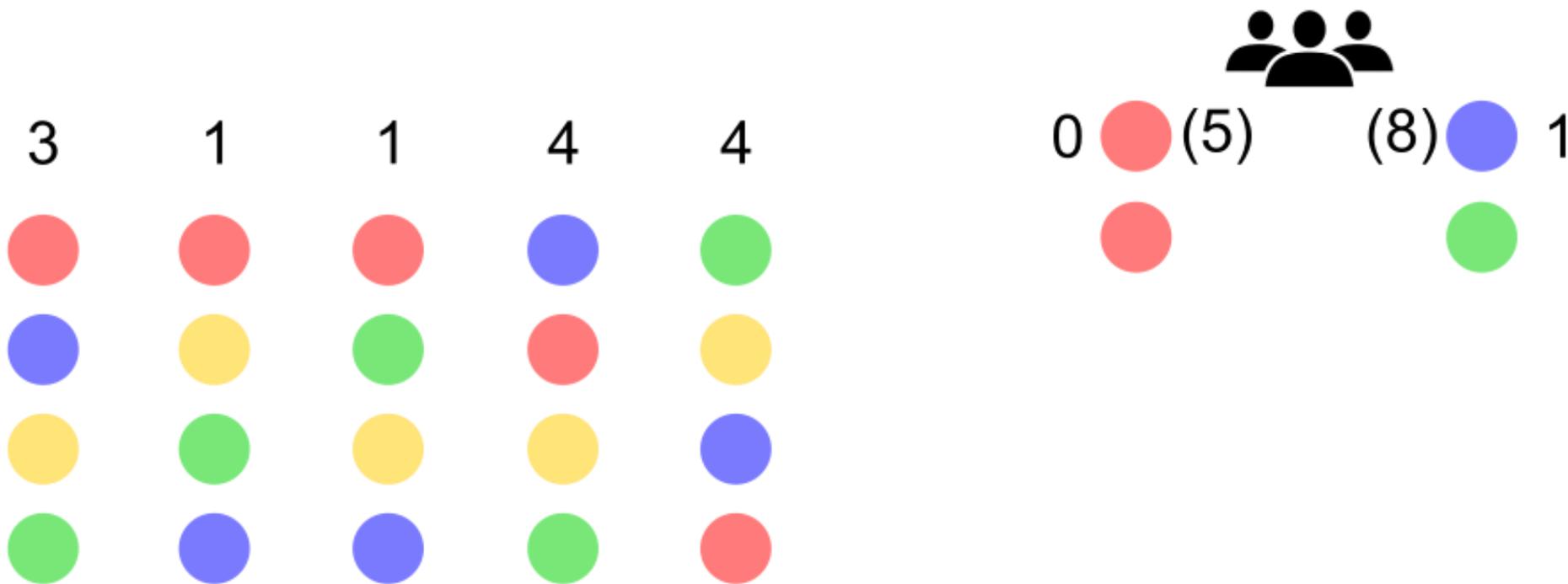
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Copeland

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Copeland

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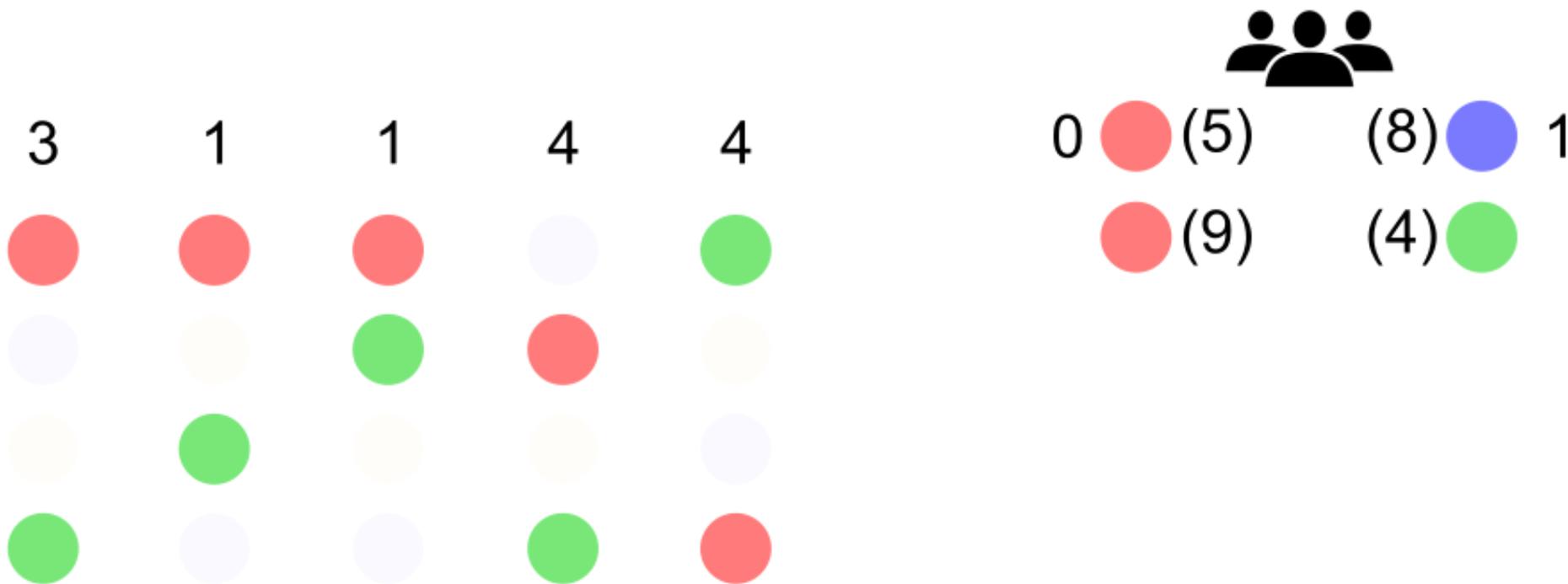
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Copeland

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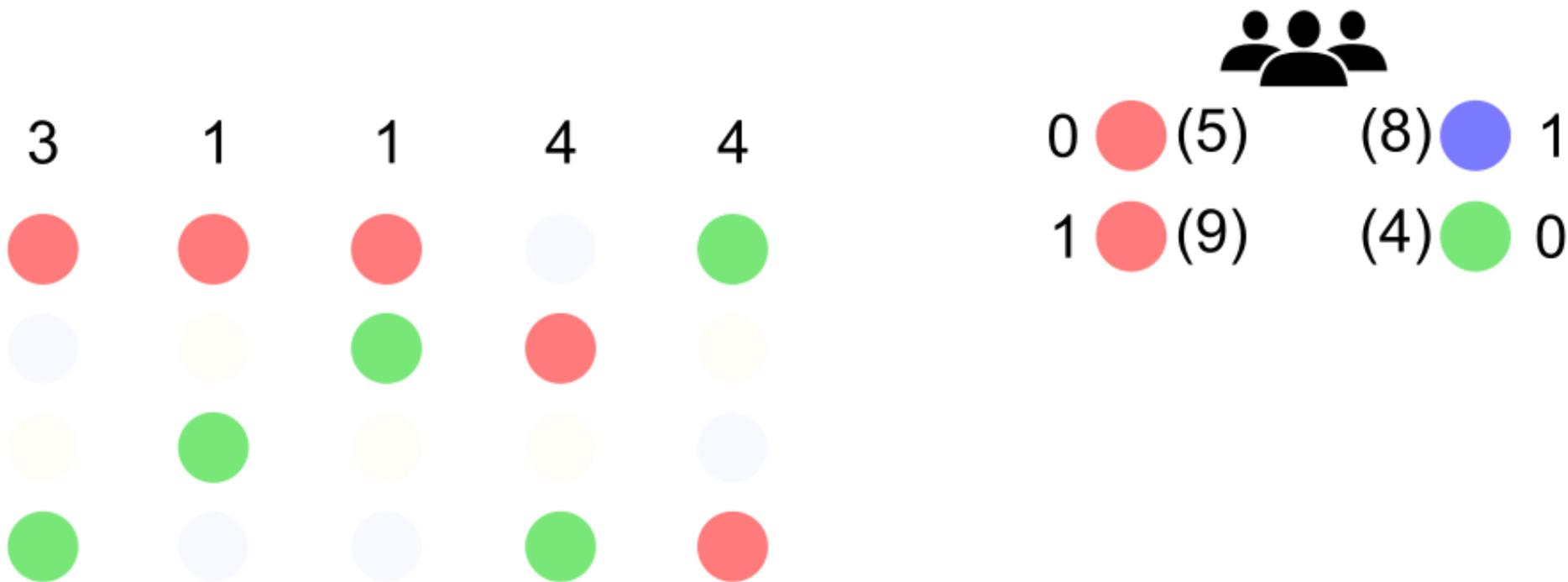
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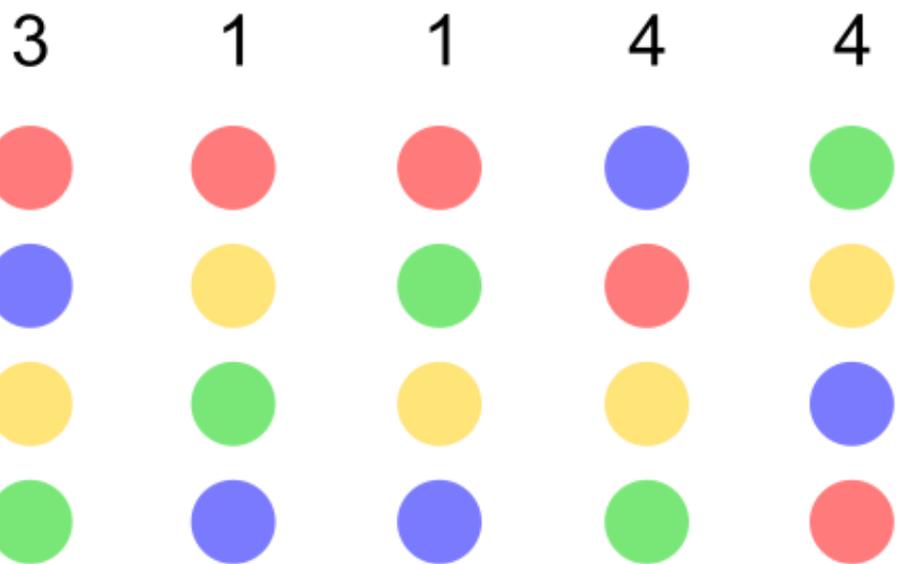
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Copeland

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Copeland

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Copeland winner: 

Copeland

5



BUNDESLIGA



**Premier
League**



**ICC WOMEN'S
CRICKET WORLD CUP
NEW ZEALAND 2022**



**INDIAN
PREMIER
LEAGUE**

Copeland

5

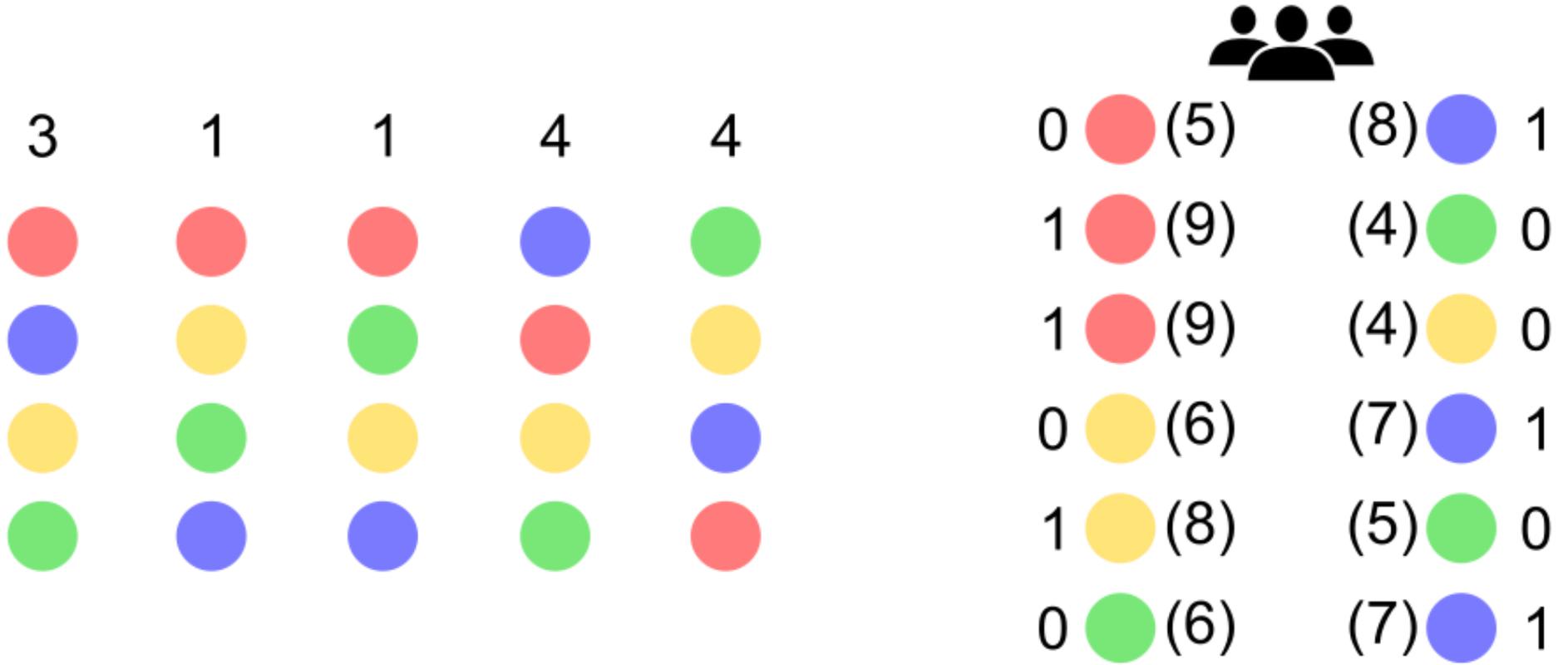
Problem: Voters are sometimes better off not voting

Copeland

5

Problem: Voters are sometimes better off not voting

Copeland



Copeland winner: 

5

Problem: Voters are sometimes better off not voting

Copeland



Copeland winner: ●

5

Problem: Voters are sometimes better off not voting

Copeland



6

Schulze

6

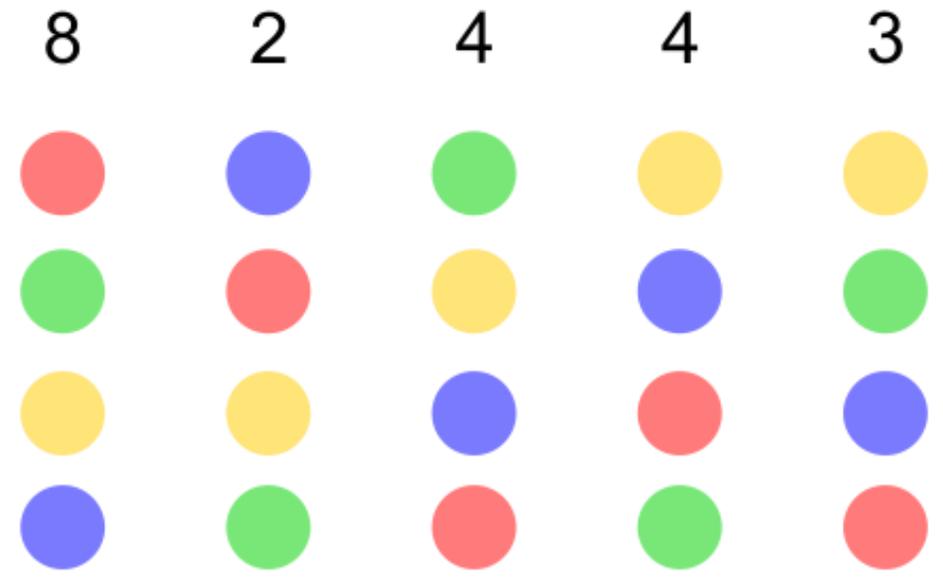
Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph

Schulze

6

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph

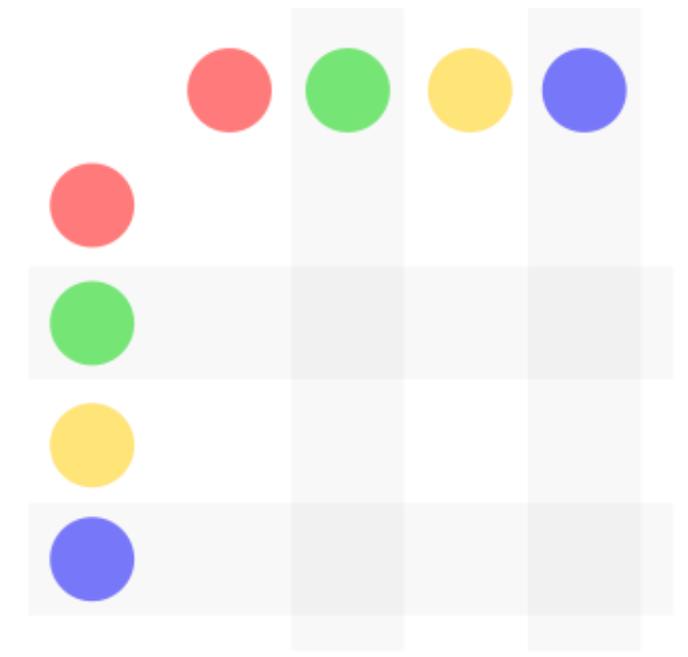
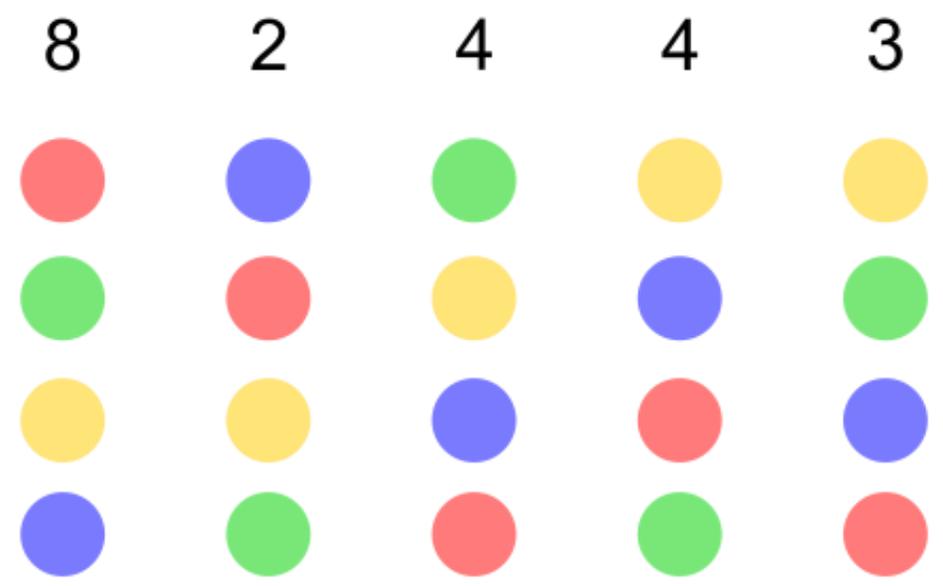
Schulze



6

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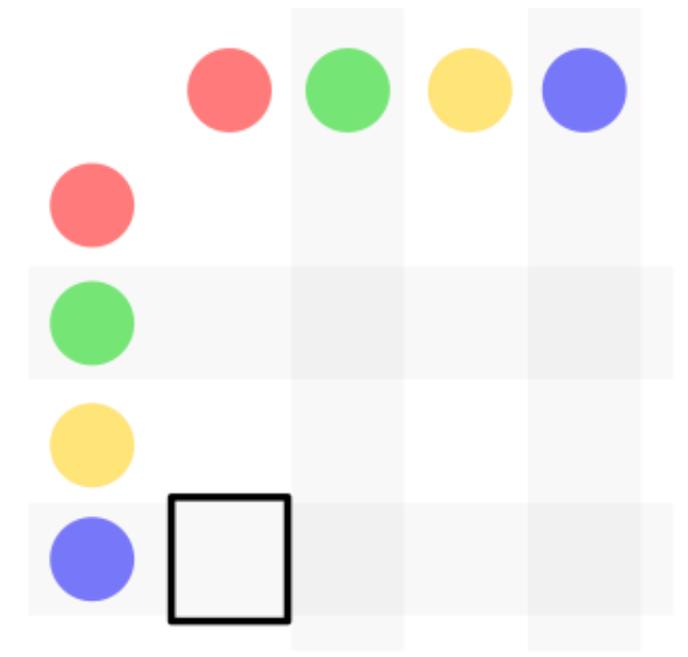
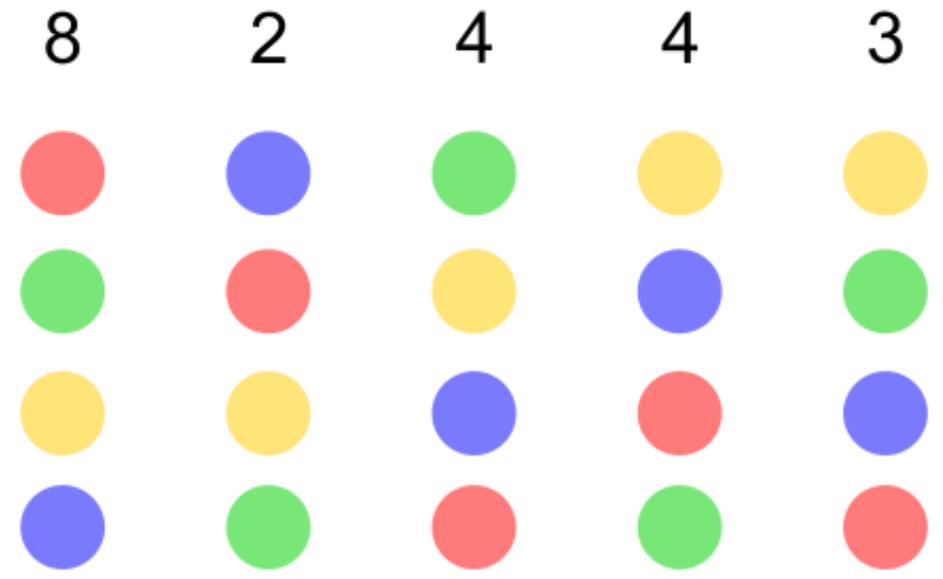
Schulze



6

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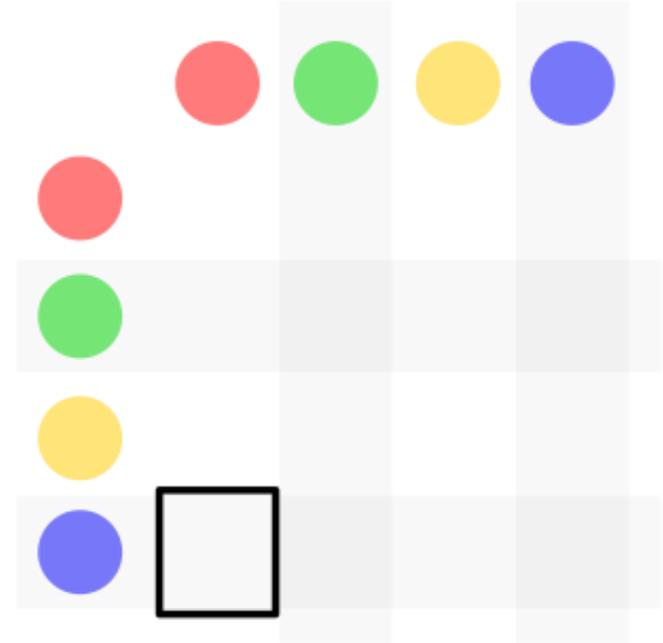
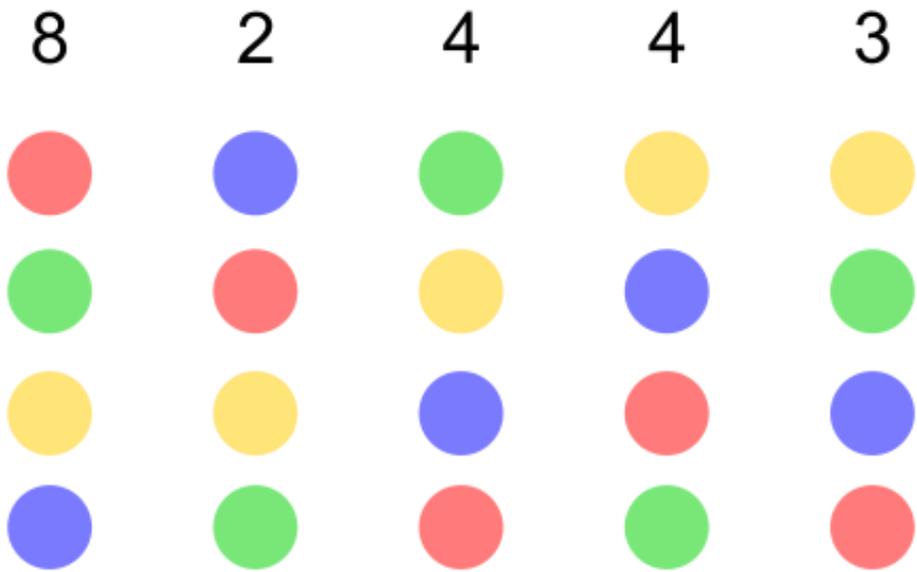
Schulze



6

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Schulze

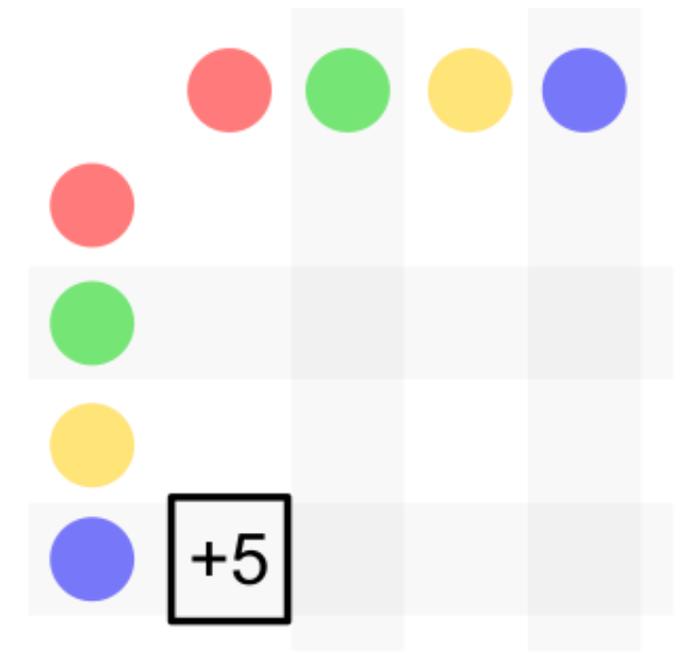
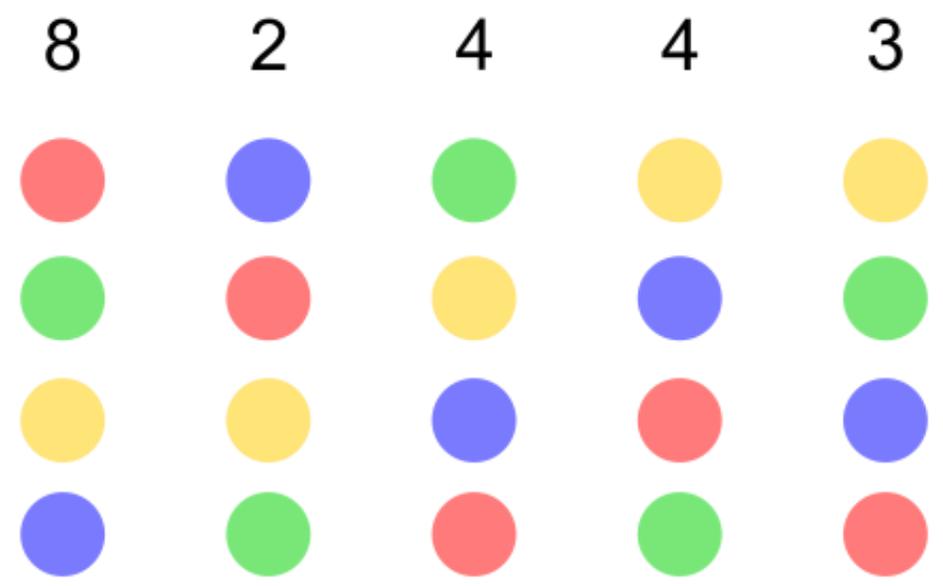


#voters who think > $(2+4+4+3) - 8$ #voters who think >

6

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph

Schulze



#voters who think ● > ●

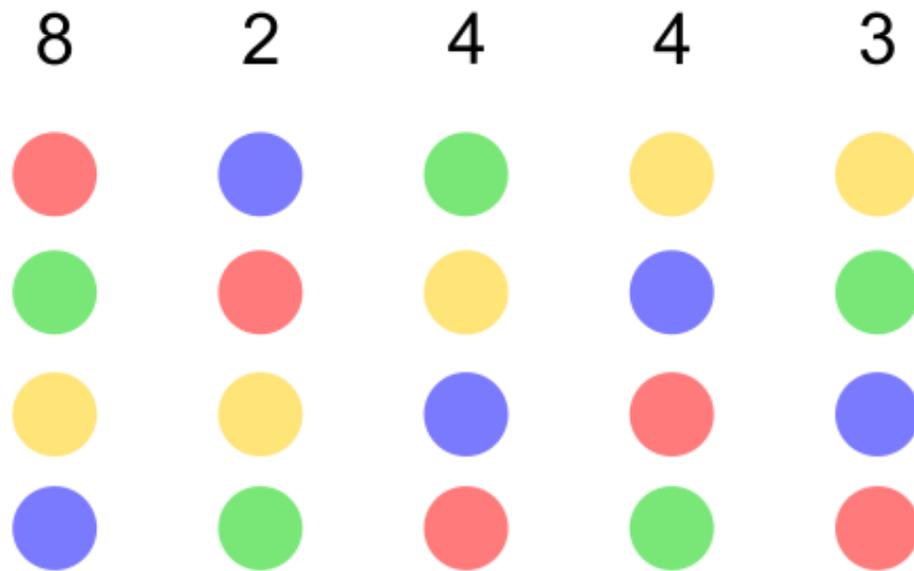
$$(2+4+4+3) - 8$$

#voters who think ● > ●

6

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph

Schulze



	Red	Green	Yellow	Blue
Red	0	+7	-1	-5
Green	-7	0	+3	+9
Yellow	+1	-3	0	+17
Blue	+5	-9	-17	0

#voters who think Blue > Red

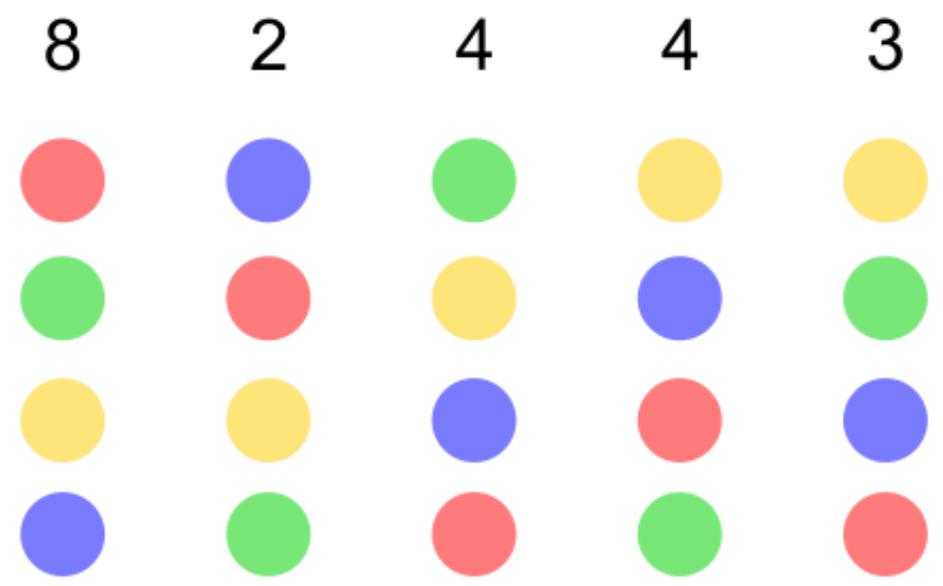
$$(2+4+4+3) - 8$$

#voters who think Red > Blue

6

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Schulze



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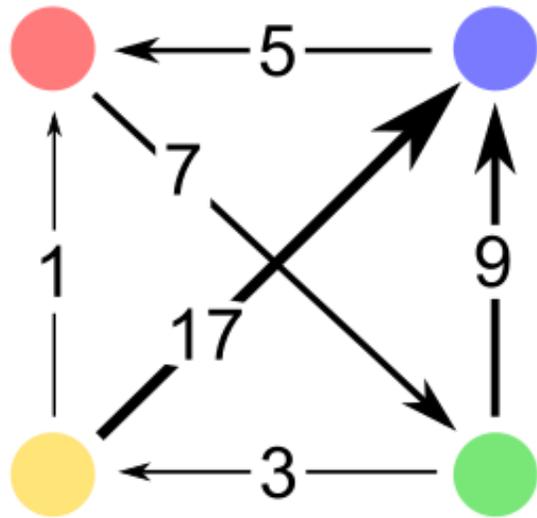
Schulze

				
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6

Schulze

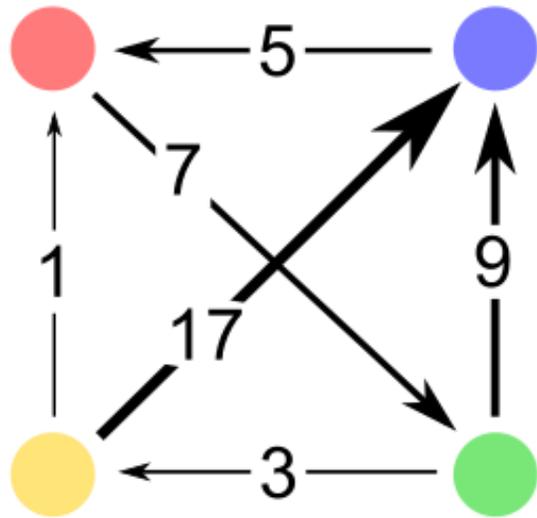
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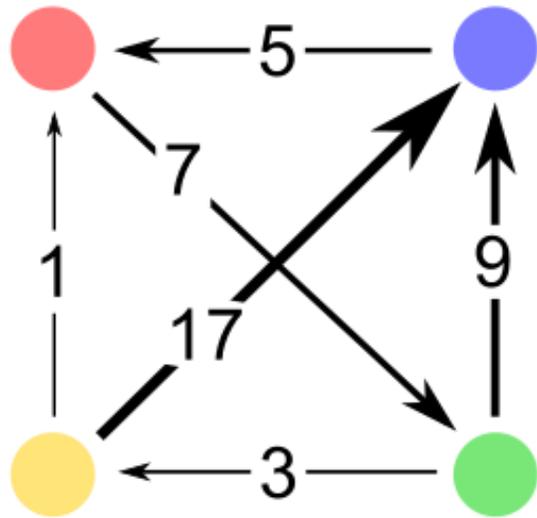


Schulze

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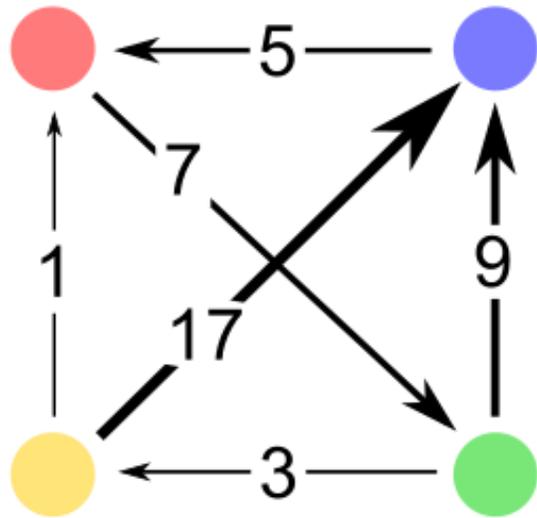
The **strength** of a path/chain is the weight of the **weakest** link in it



Schulze

6

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph



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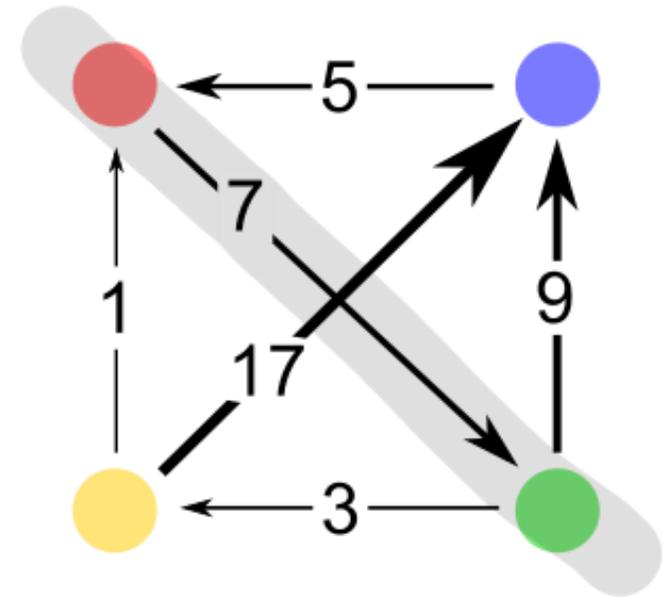
What's the strongest path from ● to ●?

Schulze

6

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph

Schulze



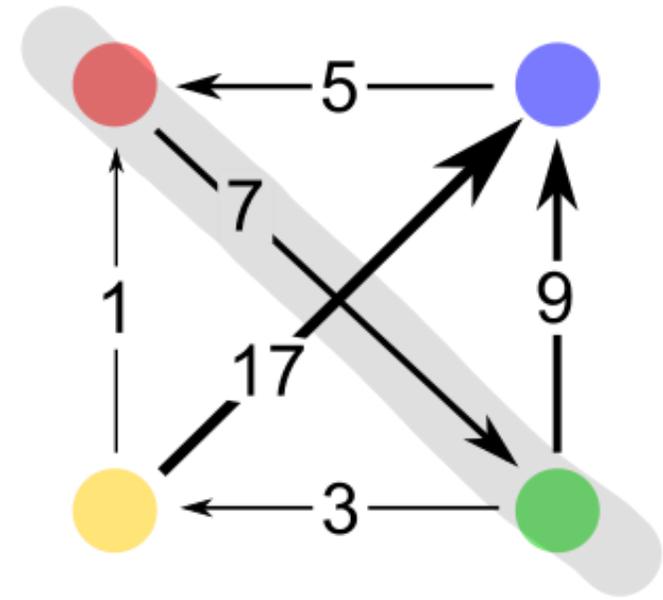
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Schulze



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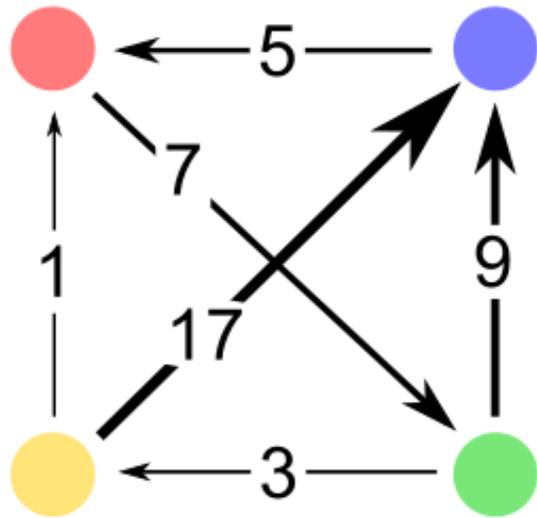
What's the strongest path from red to green?



6

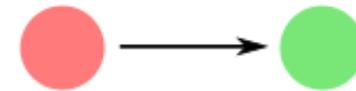
Schulze

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph



The **strength** of a path/chain is the weight of the **weakest** link in it

What's the strongest path from red to green?

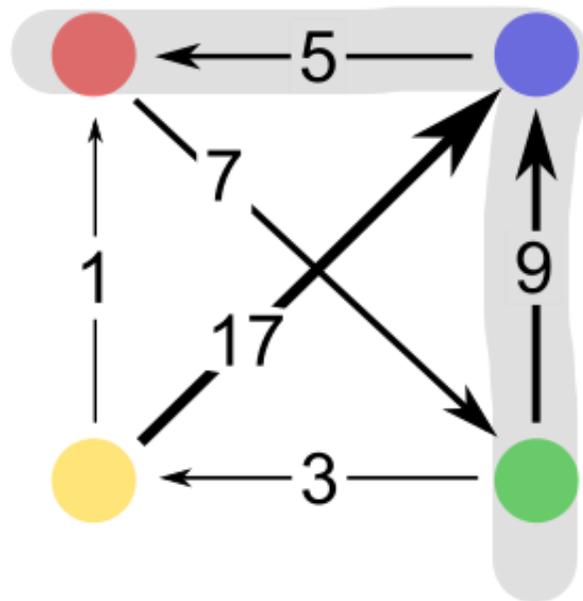


What's the strongest path from green to red?

6

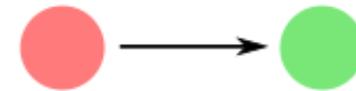
Schulze

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph



The **strength** of a path/chain is the weight of the **weakest** link in it

What's the strongest path from red to green?

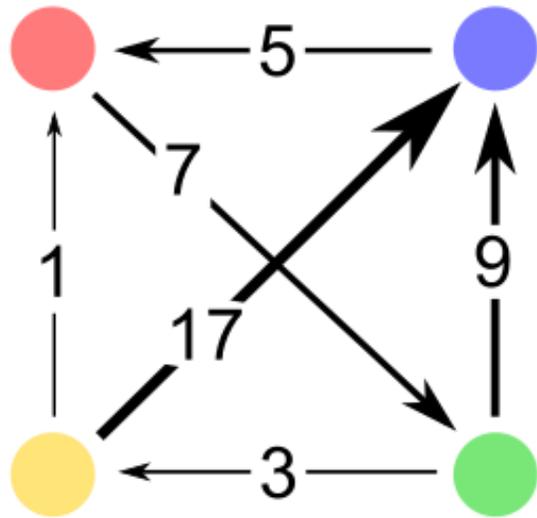


What's the strongest path from green to red?



6

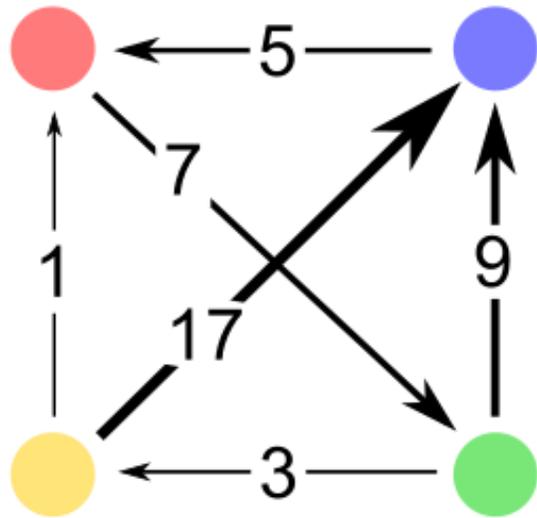
Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph



Schulze

6

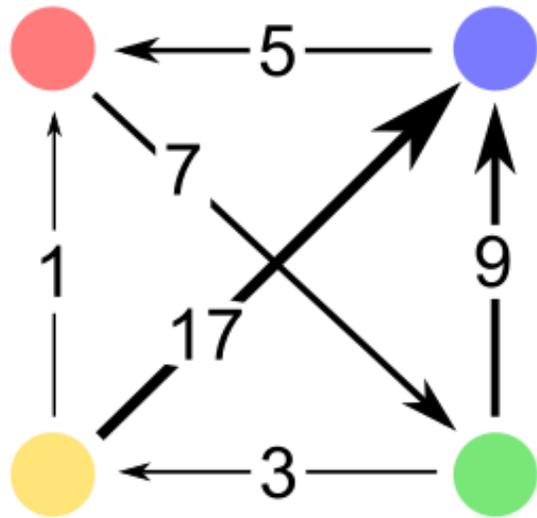
Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph



$\textcircled{a} \gg \textcircled{b}$ (\textcircled{a} "chain beats" \textcircled{b}) if the *strongest* path from \textcircled{a} to \textcircled{b} is *stronger* than the *strongest* path from \textcircled{b} to \textcircled{a}

6

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph

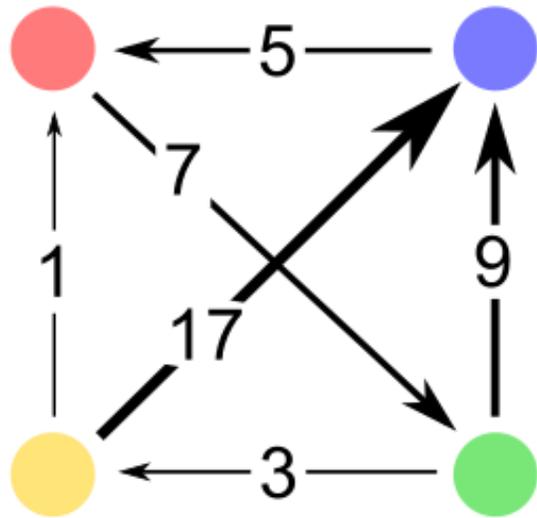


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Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph



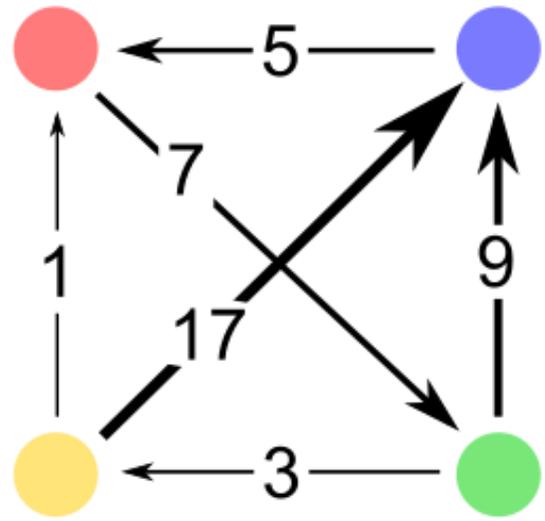
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the strongest path from $\textcircled{\text{red}}$ to $\textcircled{\text{green}}$ has strength 7

6

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph



$\textcircled{a} \gg \textcircled{b}$ (\textcircled{a} "chain beats" \textcircled{b}) if the *strongest* path from \textcircled{a} to \textcircled{b} is *stronger* than the *strongest* path from \textcircled{b} to \textcircled{a}



the strongest path from red to green has strength 7

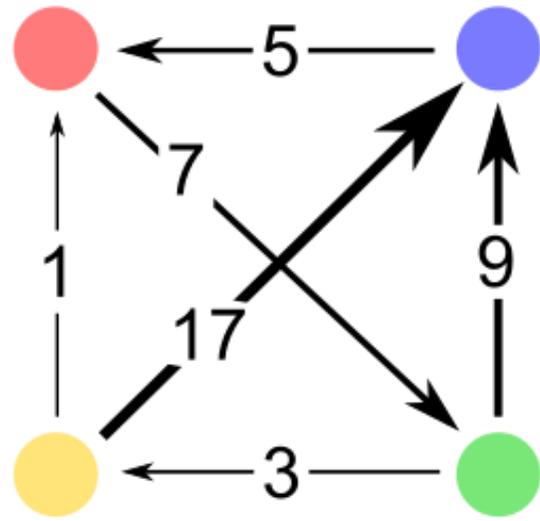
the strongest path from green to red has strength 5

Schulze

6

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph

Schulze

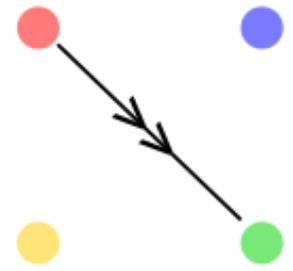


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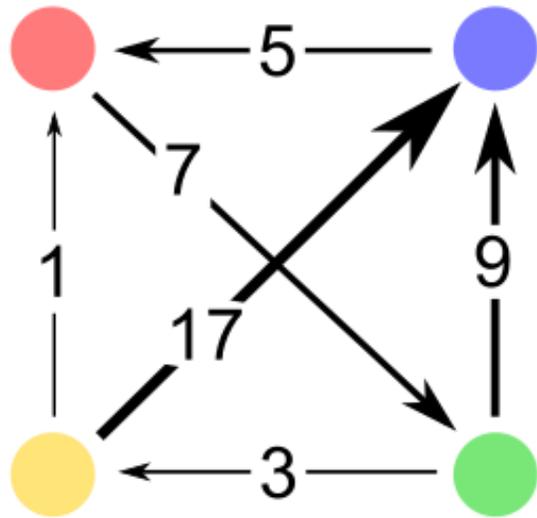
the strongest path from red to green has strength 7

the strongest path from green to red has strength 5



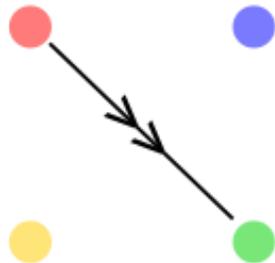
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Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph



$\textcircled{a} \gg \textcircled{b}$ (\textcircled{a} "chain beats" \textcircled{b}) if the *strongest* path from \textcircled{a} to \textcircled{b} is *stronger* than the *strongest* path from \textcircled{b} to \textcircled{a}

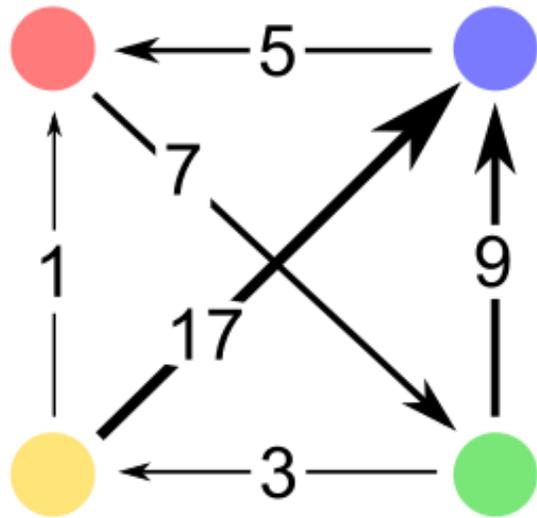
Schulze



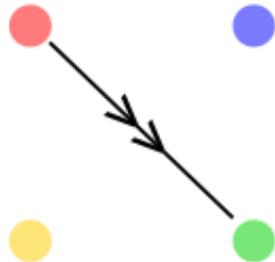
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Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph

Schulze



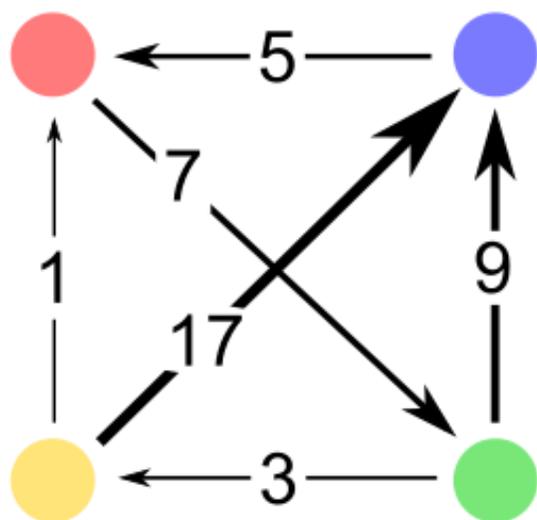
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6

Schulze

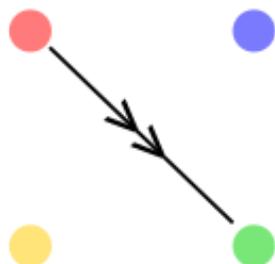
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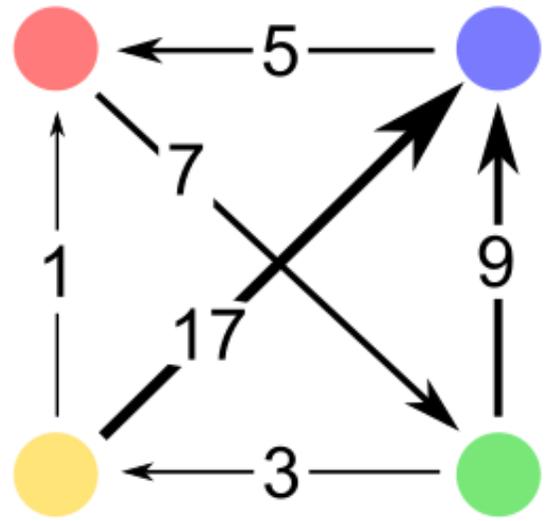
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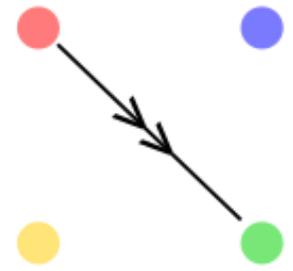
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Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph

Schulze



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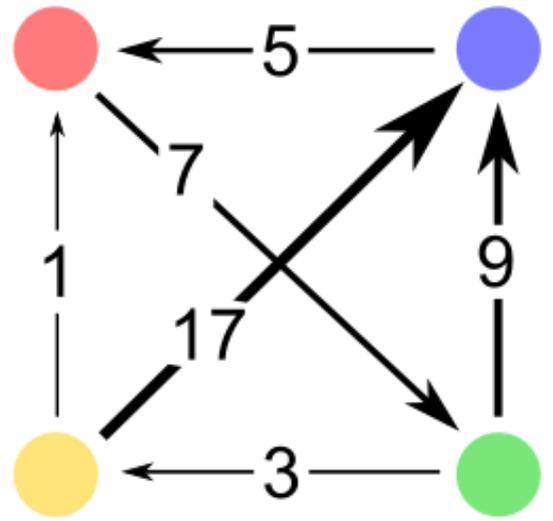
the strongest path from red to blue has strength 7

the strongest path from blue to red has strength 5

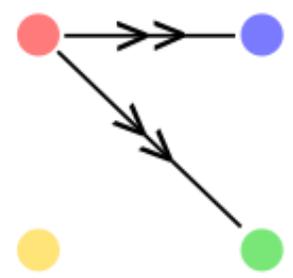
6

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph

Schulze



$\textcircled{a} \gg \textcircled{b}$ (\textcircled{a} "chain beats" \textcircled{b}) if the *strongest* path from \textcircled{a} to \textcircled{b} is *stronger* than the *strongest* path from \textcircled{b} to \textcircled{a}



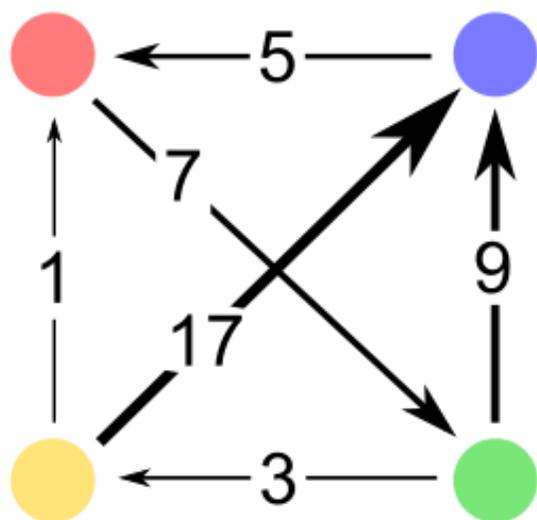
the strongest path from red to blue has strength 7

the strongest path from blue to red has strength 5

6

Schulze

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph

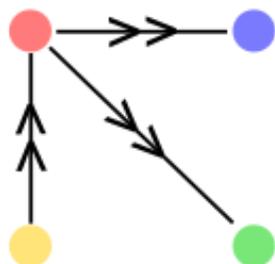


$\textcircled{a} \gg \textcircled{b}$ (\textcircled{a} "chain beats" \textcircled{b}) if the *strongest* path from \textcircled{a} to \textcircled{b} is *stronger* than the *strongest* path from \textcircled{b} to \textcircled{a}



the strongest path from $\textcircled{\text{yellow}}$ to $\textcircled{\text{red}}$ has strength 5

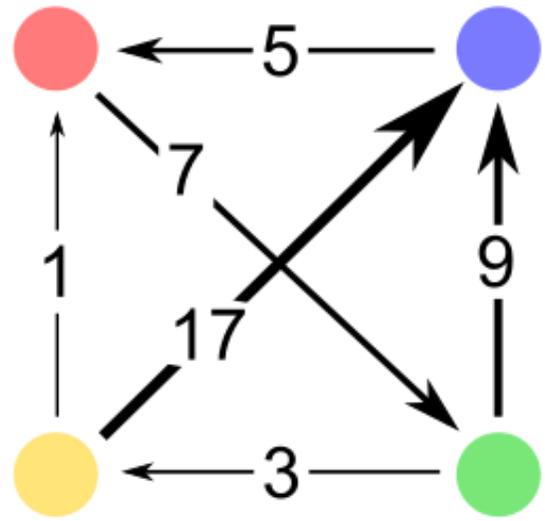
the strongest path from $\textcircled{\text{red}}$ to $\textcircled{\text{yellow}}$ has strength 3



6

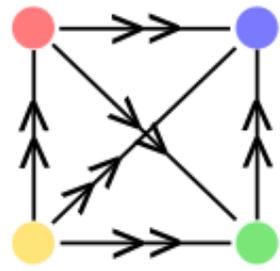
Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph

Schulze



$\textcircled{a} \gg \textcircled{b}$ (\textcircled{a} "chain beats" \textcircled{b}) if the *strongest* path from \textcircled{a} to \textcircled{b} is *stronger* than the *strongest* path from \textcircled{b} to \textcircled{a}

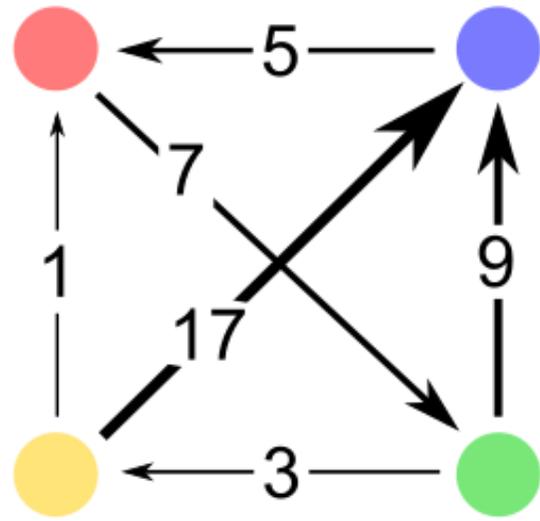
$\textcircled{y} \gg$ all others



6

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph

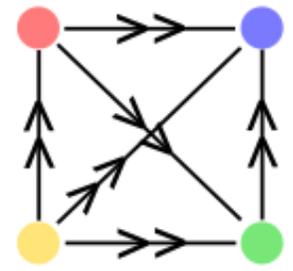
Schulze



$\textcircled{a} \gg \textcircled{b}$ (\textcircled{a} "chain beats" \textcircled{b}) if the *strongest* path from \textcircled{a} to \textcircled{b} is *stronger* than the *strongest* path from \textcircled{b} to \textcircled{a}

● \gg all others

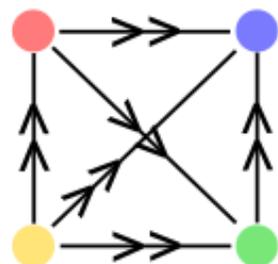
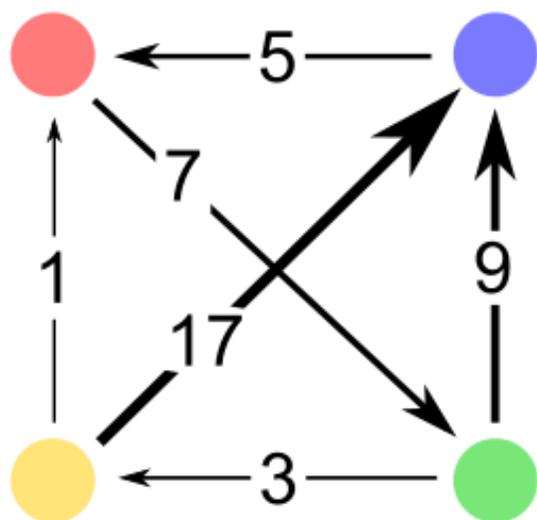
Schulze winner: ●



6

Schulze

Winner is the candidate who "chain beats" every other candidate in the pairwise comparison graph



$\textcircled{a} \gg \textcircled{b}$ (\textcircled{a} "chain beats" \textcircled{b}) if the *strongest* path from \textcircled{a} to \textcircled{b} is *stronger* than the *strongest* path from \textcircled{b} to \textcircled{a}

A Schulze winner always exists!

The "chain beats" relation is transitive

$\textcircled{a} \gg \textcircled{b}$ and $\textcircled{b} \gg \textcircled{c}$, then $\textcircled{a} \gg \textcircled{c}$

6



Schulze

Which Voting Rule is the Best?

Which Voting Rule is the Best?

Voting Power in Practice Summer Workshop

Assessing Alternative Voting Procedures

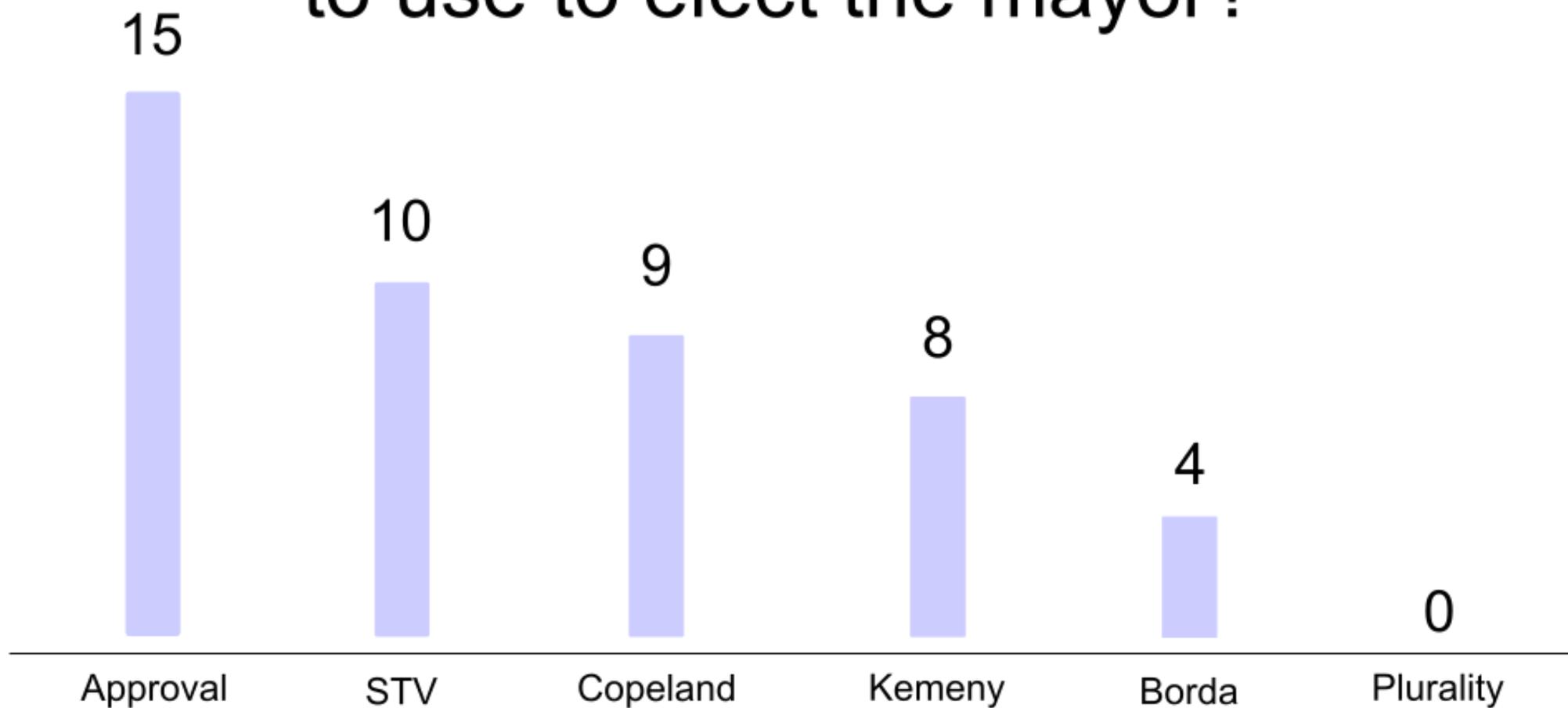
Sponsored by The Leverhulme Trust

Chateau du Baffy, Normandy, France
30 July – 2 August 2010

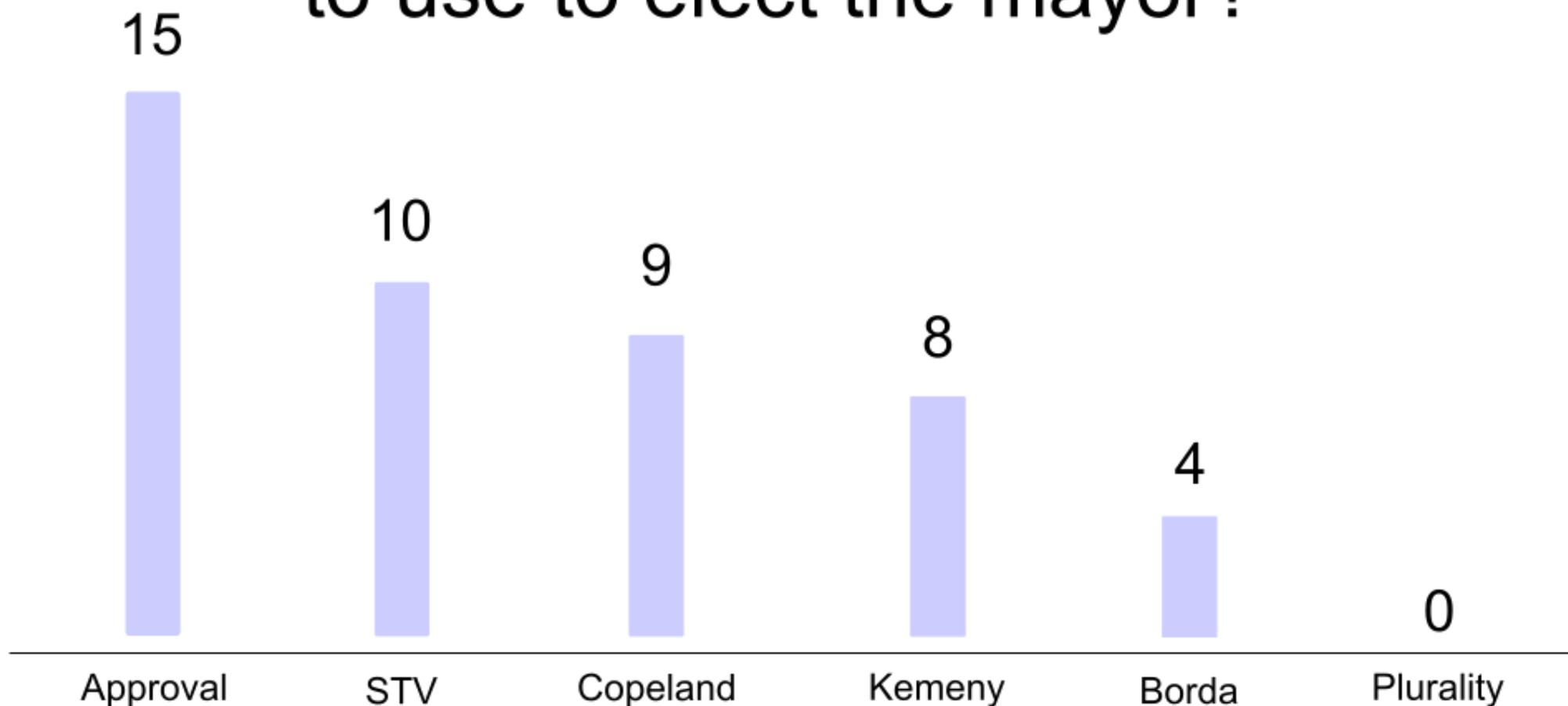
22 voting theorists

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

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



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



Votes were counted via approval voting.

18

12

10

9

4

2

Plurality



Plurality
with runoff



Borda



Condorcet



(Copeland, Schulze)



STV



References

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- The “chain beats” terminology in the description of Schulze rule was borrowed from Hubert Bray’s explanatory video:
<https://www.youtube.com/watch?v=HVeN0GnnuA>
- The Schulze rule example is from the paper “The Schulze Method of Voting” by Markus Schulze:
<https://arxiv.org/abs/1804.02973>
- (Possibly) strategic voting in the selection of Olympics host:
https://www3.nd.edu/~apilking/math10170/Information/Lectures%202015/Topic_2_Plurality_Runoff.pdf

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- “Which voting rule is the best” poll

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