Social Choice Theory for Logicians

Lecture 1

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Context of Decision Making

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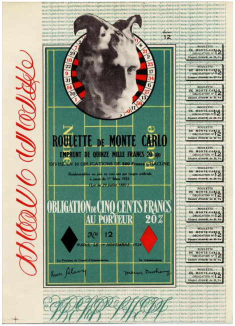
- Individual decision making and individual action against nature.
  - Example: gambling.



Context of Decision Making

- Individual decision making and individual action against nature.

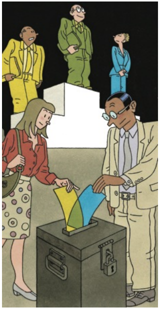
- Individual decision making in interaction.
  - Example: playing chess.

Context of Decision Making

- Individual decision making and individual action against nature.

- Individual decision making in interaction.

- Collective decision making.
  - Example: carrying a piano, voting



Main Question

Given a group of people faced with some decision, how should a central authority combine the individual opinions so as to best reflect the "will of the group"?

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Typical Examples:

- Electing government officials
- Department meetings
- Deciding where to go to dinner with friends
- ....

Which candidate *should* be chosen?

# voters	3	5	7	6
best	A	A	B	C
	B	C	D	B
	C	B	C	D
worst	D	D	A	A

Brams and Fishburn. *Voting Procedures*. Handbook of Social Choice and Welfare (2002).

Which candidate *should* be chosen?

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best	**A**	**A**	B	C
	B	C	D	B
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A few observations:

- More people rank A first than any other candidate

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best	A	A	B	C
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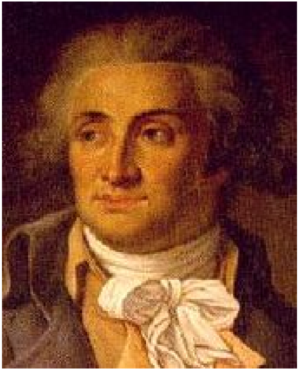
worst	D	D	**A**	**A**

A few observations:

- More people rank A first than any other candidate
- But, a stronger majority ranks A last

Which candidate *should* be chosen?



vs.

Marquis de Condorcet (1743 - 1794) Jean-Charles de Borda (1733 -1799)

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↑	B	C	D	B
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A few observations:

- More people rank A first than any other candidate
- In pairwise elections, C beats every other candidate (C is the Condorcet winner)

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worst	D	D	A	A

A few observations:

- More people rank A first than any other candidate
- In pairwise elections, C beats every other candidate (C is the Condorcet winner)
- B and C are the only candidates not ranked last by anyone

Which candidate *should* be chosen?

# voters	3	5	7	6
best	A	A	B	C
↑	B	C	D	B
	C	B	C	D
worst	D	D	A	A

A few observations:

- More people rank A first (last) than any other candidate
- In pairwise elections, C beats every other candidate (C is the Condorcet winner)
- Taking into account the *entire* ordering, B has the most "support" (B is the Borda winner)

Which candidate *should* be chosen?

# voters	3	5	7	6
3	A	A	B	C
2	B	C	D	B
1	C	B	C	D
0	D	D	A	A

A few observations:

- More people rank A first (last) than any other candidate
- In pairwise elections, C beats every other candidate (C is the Condorcet winner)
- B gets 13 (vs. A) $+$ 10 (vs. C) $+$ 21 (vs. D) $=$ 44 points

Which candidate *should* be chosen?

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3	A	A	B	C
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A few observations:

- More people rank A first (last) than any other candidate
- In pairwise elections, C beats every other candidate (C is the Condorcet winner)
- B gets 13 (vs. A) $+$ 10 (vs. C) $+$ 21 (vs. D) $=$ 44 points
  C gets 13 (vs. A) $+$ 11 (vs. B) $+$ 14 (vs. D) $=$ 38 points

Which candidate *should* be chosen?

# voters	3	5	7	6
best	A	A	B	C
	B	C	D	B
	C	B	C	D
worst	D	D	A	A

A few observations:

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Conclusion: *many ways to answer the above question!*

Choosing How to Choose

Choosing How to Choose

Plurality, Borda Count, Antiplurality/Veto, and k-approval; Plurality with Runoff; Single Transferable Vote (STV)/Hare; Approval Voting; Condorcet-consistent methods based on the simple majority graph (e.g., Cup Rule/Voting Trees, Copeland, Banks, Slater, Schwartz, and the basic Condorcet rule itself), rules based on the weighted majority graph (e.g., Maximin/Simpson, Kemeny, and Ranked Pairs/Tideman), rules requiring full preference information (e.g., Bucklin, Dodgson, and Young); Majoritarian Judgment; Cumulative Voting; Range Voting

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Choosing How to Choose

Plurality Vote: Each voter selects one candidate (or none if voters can abstain) and the candidate(s) with the most votes win.

Plurality with Runoff: If there is a candidate with an absolute majority then that candidate wins, otherwise the top two candidates move on to round two. The candidate with the most votes in the second round wins.

Choosing How to Choose

Approval Voting: Each voter selects a *subset* of the candidates (empty set means the voter abstains) and the candidate(s) with the most votes win.

Borda Count: Each voter provides a linear ordering of the candidates. The candidate(s) with the most total **points** wins, where points are calculated as follows: if there are n candidates, $n-1$ points are given to the highest ranked candidates, $n-2$ to the second highest, etc..

How should we judge different social decision methods?

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- **Pragmatic concerns**: Is the procedure easy to use? Is it legal? The importance of ease of use should not be underestimated: Despite its many flaws, plurality rule is, by far, the most commonly used method.

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- **Information required from the voters**: What type of information do the ballots convey? Eg., Choosing a single alternative, linearly rank all the alternatives, report something about the "intensity" of preference.

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- **Behavioral considerations**: Do the different procedures *really* lead to different outcomes in practice?
- **Information required from the voters**: What type of information do the ballots convey? Eg., Choosing a single alternative, linearly rank all the alternatives, report something about the "intensity" of preference.
- **Axiomatics**: Characterize the different social decision methods in terms of normative principles of group decision making.

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- The outcome of a vote should not be "surprising" given the data

Condorcet Paradox

Voter 1	Voter 2	Voter 3
A	C	B
B	A	C
C	B	A

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- Does the group prefer A over B?

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A	C	B
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- Does the group prefer A over B? Yes

Condorcet Paradox

Voter 1	Voter 2	Voter 3
A	C	B
B	A	C
C	B	A

- Does the group prefer A over B? Yes
- Does the group prefer B over C? Yes

Condorcet Paradox

Voter 1	Voter 2	Voter 3
A	C	B
B	A	C
C	B	A

- Does the group prefer A over B? Yes
- Does the group prefer B over C? Yes
- Does the group prefer A over C? No

Condorcet Paradox

Voter 1	Voter 2	Voter 3
A	C	B
B	A	C
C	B	A

- Does the group prefer A over B? Yes
- Does the group prefer B over C? Yes
- Does the group prefer A over C? No
  (this conflicts with transitivity)

W. Gehrlein. *Condorcet's Paradox*. Springer, 2006.

Failure of monotonicity: plurality with runoff

# voters	6	5	4	2
	A	C	B	B
	B	A	C	A
	C	B	A	C

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Winner: A

# voters	6	5	4	2
	A	C	B	A
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Winner: A

# voters	6	5	4	2
	A	C	B	A
	B	A	C	B
	C	B	A	C

Winner: C

Failure of monotonicity: plurality with runoff

# voters	6	5	4	2
	A	C	B	**B**
	B	A	C	**A**
	C	B	A	**C**

Winner: A

# voters	6	5	4	2
	A	C	B	**A**
	B	A	C	**B**
	C	B	A	**C**

Winner: C

No-show paradox

Totals	Rankings	H over W	W over H
417	B H W	417	0
82	B W H	0	82
143	H B W	143	0
357	H W B	357	0
285	W B H	0	285
324	W H B	0	324
1608		**917**	**691**

Fishburn and Brams. *Paradoxes of Preferential Voting*. Mathematics Magazine (1983).

No-show paradox

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1608		**917**	**691**

B: $417 + 82 = 499$
H: $143 + 357 = 500$
W: $285 + 324 = 609$

No-show paradox

Totals	Rankings	H over W	W over H
417	X H W	417	0
82	X W H	0	82
143	H X W	143	0
357	H W X	357	0
285	W X H	0	285
324	W H X	0	324
1608		**917**	**691**

H Wins

No-show paradox

Totals	Rankings	H over W	W over H
419	B H W	417	0
82	B W H	0	82
143	H B W	143	0
357	H W B	357	0
285	W B H	0	285
324	W H B	0	324
1610		**917**	**691**

Suppose two more people show up with the ranking B H W

No-show paradox

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143	H B W	143	0
357	H W B	357	0
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1610		**644**	**966**

B: $419 + 82 = 501$

H: $143 + 357 = 500$

W: $285 + 324 = 609$

No-show paradox

Totals	Rankings	B over W	W over B
419	B X W	419	0
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143	X B W	143	0
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W Wins!

Failure of Independence

# voters	3	2	2
	A	B	C
	B	C	A
	C	A	B

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# voters	3	2	2
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- The BC ranking is: A (8) $>$ B (7) $>$ C (6)

Failure of Independence

# voters	3	2	2
	A	B	C
	B	C	X
	C	X	A
	X	A	B

- The BC ranking is: A (8) $>$ B (7) $>$ C (6)
- Add a new (undesirable) candidate X

Failure of Independence

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	X	A	B

- The BC ranking is: A (8) $>$ B (7) $>$ C (6)
- Add a new (undesirable) candidate X
- The new BC ranking is: C (13) $>$ B (12) $>$ A (11) $>$ X (6)

Multiple Elections Paradox

Voters are asked to give their opinion on three yes/no issues:

YYY	YYN	YNY	YNN	NYY	NYN	NNY	NNN
1	1	1	3	1	3	3	0

S. Brams, D. M. Kilgour, and W. Zwicker. *"The paradox of multiple elections"*. Social Choice and Welfare, 15(2): 211 - 236, 1998.

Multiple Elections Paradox

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Outcome by majority vote

Proposition 1: N (7 - 6)

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Proposition 2: N (7 - 6)

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Proposition 3: N (7 - 6)

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Outcome by majority vote

Proposition 1: N (7 - 6)
Proposition 2: N (7 - 6)
Proposition 3: N (7 - 6)

But there is no support for NNN!

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Anscombe's Paradox

	Issue 1	Issue 2	Issue 3
Voter 1	Yes	Yes	No
Voter 2	No	No	No
Voter 3	No	Yes	Yes
Voter 4	Yes	No	No
Voter 5	Yes	No	Yes
Majority	Yes	No	Yes

G. E. M. Anscombe. *On Frustration of the Majority by Fulfillment of the Majority's Will*. Analysis, 36(4): 161-168, 1976.

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Voters 4 & 5 support the outcome on a majority of issues

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Voters 1,2 & 3 do not support the outcome on a majority of issues

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Voter 3	No	Yes	Yes
Voter 4	Yes	No	No
Voter 5	Yes	No	Yes
Majority	Yes	No	Yes

Voters 4 & 5 support the outcome on a majority of issues
Voters 1,2 & 3 do not support the outcome on a majority of issues

A majority of voters do not support the majority outcome on a majority of issues.

G. E. M. Anscombe. *On Frustration of the Majority by Fulfillment of the Majority's Will*. Analysis, 36(4): 161-168, 1976.

What properties do we want?

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- The outcome of a vote should not be "surprising" given the data

Arrow's Theorem

K. Arrow. *Social Choice & Individual Values*. 1951.

Also, see

J. Geanakoplos. *Three Brief Proofs of Arrow's Impossibility Theorem*. Economic Theory, **26**, 2005.

A. Taylor. *Social Choice and The Mathematics of Manipulation*. Cambridge University Press, 2005.

W. Gaertner. *A Primer in Social Choice Theory*. Oxford University Press, 2006.

Sen's Liberal Paradox

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l: Lewd reads the book;
p: Prude reads the book;
$l \to p$: If Lewd reads the book, then so does Prude.

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Lewd desires to read the book, and if he reads it, then so does Prude (Lewd enjoys the thought of Prude's moral outlook being corrupted)

Prude desires to not read the book, and that Lewd not read it either, but in case Lewd does read the book, Prude wants to read the book to be informed about the dangerous material Lewd has read.

Sen's Liberal Paradox

	l	p	$l \rightarrow p$

Sen's Liberal Paradox

	l	p	$l \to p$
Lewd	True	True	True

Sen's Liberal Paradox

	l	p	$l \to p$
Lewd	True	True	True
Prude	False	False	True

Sen's Liberal Paradox

	l	p	$l \to p$
Lewd	True	True	True
Prude	False	False	True

1. Society assigns to each individual the liberal right to determine the collective desire on those propositions that concern only the individual's private sphere
   l is Lewd's case, p is Prude's case

Sen's Liberal Paradox

	l	p	$l \to p$
Lewd	True	True	True
Prude	False	False	True

1. Society assigns to each individual the liberal right to determine the collective desire on those propositions that concern only the individual's private sphere
   l is Lewd's case, p is Prude's case

2. Unanimous desires of all individuals must be respected.

Sen's Liberal Paradox

	l	p	$l \to p$
Lewd	True	True	True
Prude	False	False	True

1. Society assigns to each individual the liberal right to determine the collective desire on those propositions that concern only the individual's private sphere
   l is Lewd's case, p is Prude's case

2. Unanimous desires of all individuals must be respected.

So, society must be inconsistent!

Muller-Satterthwaite Theorem

E. Muller and M. A. Satterthwaite. *The equivalence of strong positive association and strategy-proofness*. Journal of Economic Theory, 14(2):412-418, 1977.

P. Tang and T. Sandholm. *Coalitional Structure of the Muller-Satterthwaite Theorem*. In *Proceedings of the Workshop on Cooperative Games in Multiagent Systems* (CoopMAS) at AAMAS, 2012.