Compromise and elicitation in social choice

A study of egalitarianism and incomplete information in voting

Beatrice Napolitano

Ph.D. Thesis Defense, 09 December 2022

Classical setting

Agents = {  }, Altern. = {  }, Chair =  $\Rightarrow$ Voting Rule

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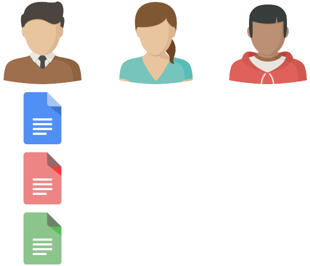

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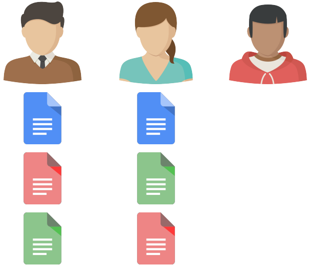

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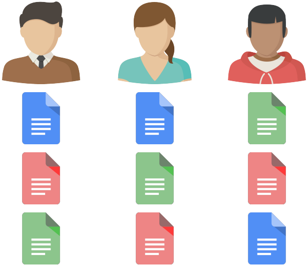

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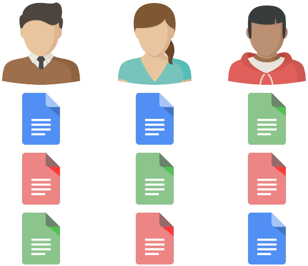

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Borda

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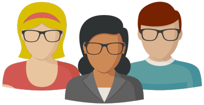

Borda

winner: 

Incomplete knowledge about profile

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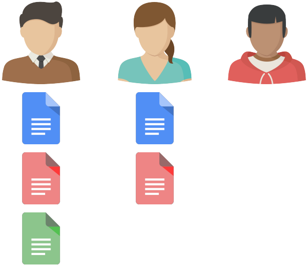
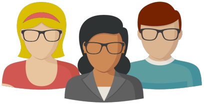


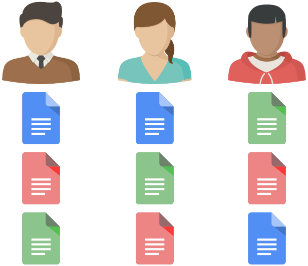


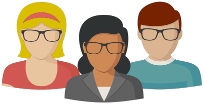
Borda

winner: ?

Incomplete knowledge about voting rule

Agents = { , , }, Altern. = { , , }, Chair = $\Rightarrow$ Voting Rule





?

winner: ?

Research Question I:
Incomplete knowledge about profile and voting rule

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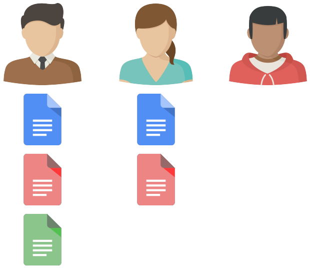


?

winner: ?

Research Question II:
Incomplete knowledge under Majority Judgment

Agents = { , , }, Altern. = { , , }, Chair = $\Rightarrow$ Voting Rule

, Good , Excell.

, Aver. , To rej.

, Med.

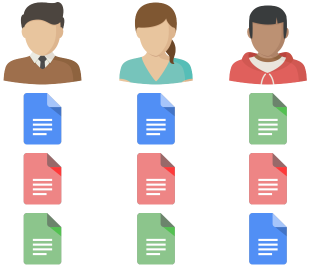
Majority Judgment

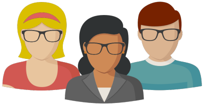
winner: ?

Research Question III:

Compromise from an equal-loss perspective

Agents = { , , }, Altern. = { , , }, Chair = $\Rightarrow$ Voting Rule





What is a compromise?

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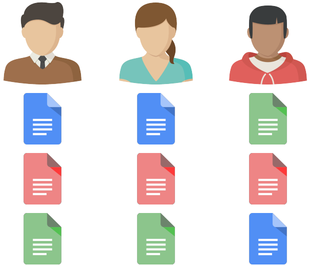

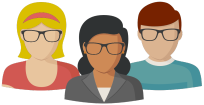

What is a compromise?

maybe  ?

Outline

1. Notation
2. Simultaneous Elicitation of Scoring Rule and Agent Preferences for Robust Winner Determination
3. Majority Judgment winner determination under incomplete information
4. Compromising as an equal loss principle
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Notation

$\mathcal{A}$ set of alternatives, $|\mathcal{A}| = m$

N set of voters, $|N| = n$

$\mathcal{L}(\mathcal{A})$ set of all linear orderings given $\mathcal{A}$

$\succ_i \in \mathcal{L}(\mathcal{A})$ preference ranking of voter $i \in N$

$P = (\succ_1, \ldots, \succ_n) \in \mathcal{L}(\mathcal{A})^N$ a profile

$\mathscr{P}^*(\mathcal{A})$ possible winners (non-empty subsets of $\mathcal{A}$)

$f : \mathcal{L}(\mathcal{A})^N \to \mathscr{P}^*(\mathcal{A})$ a Social Choice Rule

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Simultaneous Elicitation of Scoring Rule and Agent Preferences for Robust Winner Determination

Setting: Incompletely specified preferences and social choice rule

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Goal: Reduce uncertainty, inferring (*eliciting*) incrementally and simultaneously the true preferences of agents and chair to quickly converge to an optimal or a near-optimal alternative

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Approach:

Beatrice Napolitano, Olivier Cailloux, and Paolo Viappiani. Simultaneous elicitation of scoring rule and agent preferences for robust winner determination.
In *Proceedings of Algorithmic Decision Theory - 7th International Conference, ADT 2021*, 2021

- Develop query strategies that interleave questions to the chair and to the agents
- Use *Minimax regret* to measure the quality of those strategies

Related Works

Incomplete profile

- and known rule: Minimax regret to produce a robust winner approximation (*Lu and Boutilier 2011*, [5]; *Boutilier et al. 2006*, [2])

Uncertain rule

- and complete profile: dominance relations derived to eliminate alternatives always less preferred than others (*Stein et al. 1994*, [9])
- considering positional scoring rules (*Viappiani 2018*, [10])

Context

$P = (\succ_i,\ i \in N),\ P \in \mathcal{P}$	complete preferences profile unknown to us
$W = (W_r,\ 1 \leq r \leq m),\ W \in \mathcal{W}$	**convex** scoring vector that the chair has in mind

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W defines a **Positional Scoring Rule** $f_W(P) \subseteq A$

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$W = (W_r,\ 1 \leq r \leq m),\ W \in \mathcal{W}$ **convex** scoring vector that the chair has in mind

W defines a **Positional Scoring Rule** $f_W(P) \subseteq A$

P and W exist in the minds of agents and chair but unknown to us

Questions

Two types of questions:

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Questions to the agents

Comparison queries that ask a particular agent i to compare two alternatives $a, b \in \mathcal{A}$

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Two types of questions:

Questions to the agents

Comparison queries that ask a particular agent i to compare two alternatives $a, b \in \mathcal{A}$

Questions to the chair

Queries relating the difference between the importance of consecutive ranks from r to $r+2$

The answers to these questions define $\mathbf{C_P}$ and $\mathbf{C_W}$ that is our knowledge about P and W

Minimax Regret

Given $C_P \subseteq \mathcal{P}$ and $C_W \subseteq \mathcal{W}$:

The *Maximum Regret* MR of an alternative a is the highest possible loss when selecting a as a winner under all possible completions of C_P and C_W

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$$\mathrm{MMR}^{C_P,C_W} = \min_{a \in \mathcal{A}} \mathrm{MR}^{C_P,C_W}(a)$$

Minimax Regret

The alternative that *minimizes* the maximum regret is used:

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- as winner recommendation when the elicitation process stops

Minimax Regret

The alternative that *minimizes* the maximum regret is used:

- as winner recommendation when the elicitation process stops
- to guide elicitation strategies

Elicitation strategies

At each step, the strategy selects a question to ask either to one of the agents about her preferences or to the chair about the voting rule

The termination condition could be:

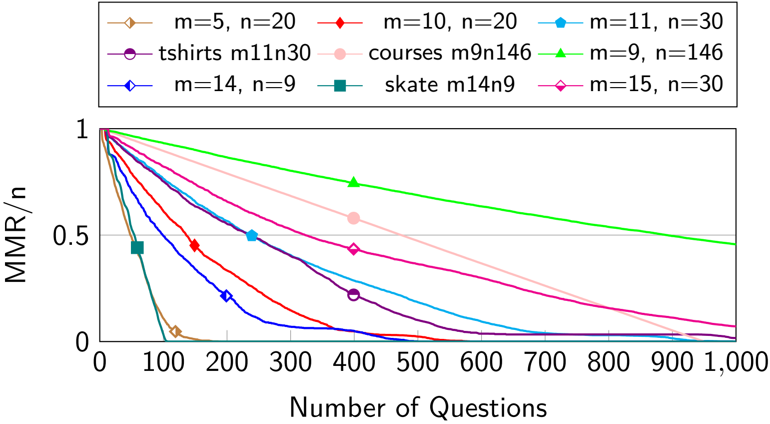
- when the minimax regret is lower than a threshold
- when the minimax regret is zero

- It selects first $n + (m - 2)$ candidate questions: one per each agent and one per each rank (excluding the first and the last one which are known)
- It selects the question that leads to minimal regret in the worst case from the set candidate questions

Empirical Evaluation

Pessimistic for different datasets

Figure: Average MMR (normalized by n) after k questions with Pessimistic strategy for different datasets.



Building concrete questions for the chair

Queries relating the difference between the importance of consecutive ranks

$$W_2 - W_3 \geq 2\,(W_3 - W_4) \quad ?$$

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$$W_2 - W_3 \geq 2\ W_3 - 2\ W_4$$
$$W_2 + 2\ W_4 \geq 3\ W_3$$
$$s(a) \geq s(b)$$

#1	**#2**
–	–
a	–
b	**b**
–	**a**

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$$\begin{aligned} W_2 \ - \ W_3 &\geq 2\ W_3 - 2\ W_4 \\ W_2 + 2\ W_4 &\geq 3\ W_3 \\ s(a) &\geq s(b) \end{aligned}$$

$\#\mathbf{1}$	$\#\mathbf{2}$	$\#\mathbf{3}$	$\#\mathbf{3}$
c	d	a	b
$\mathbf{a}$	c	b	a
$\mathbf{b}$	$\mathbf{b}$	c	d
d	$\mathbf{a}$	d	c

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Incomplete knowledge: profile

Agents = { , , }, Altern. = { , , }, Chair = $\Rightarrow$ Voting Rule

Majority Judgment

Majority Judgment

Voters judges candidates assigning grades from an ordinal scale. The winner is the candidate with the highest median of the grades received. (Balinski and Laraki 2011, [1])

Excellent	Very good	Good	Average	Mediocre	Inadequate	To be Rejected

Majority Judgment

Agents = { , , }, Altern. = { , , }, Chair = $\Rightarrow$ Majority Judgment

Excellent	Average	Mediocre
Good	Mediocre	Good
Inadequate	Excellent	Very good

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Majority Judgment: Incomplete Knowledge

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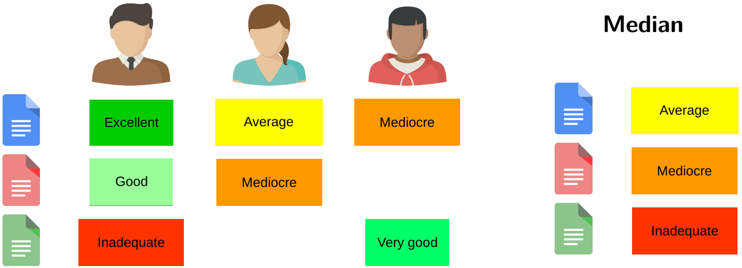

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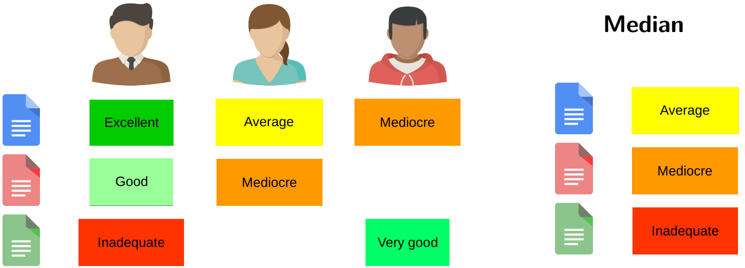

winner: 

In the last few years MJ has being adopted by a progressively larger number of french political parties including: Le Parti Pirate, Génération(s), LaPrimaire.org, France Insoumise and La République en Marche. [6]

LaPrimaire.org is a french political initiative whose goal is to select an independent candidate for the french presidential election using MJ as voting rule.

The procedure consists of two rounds:

1: each voter expresses her judgment on five random candidates. The five ones with the highest medians qualify for the second round

2: each voter expresses her judgment on all the five finalists. The one with the best median is the winner

The procedure consists of two rounds:

1: each voter expresses her judgment on k random candidates. The k ones with the highest medians qualify for the second round

2: each voter expresses her judgment on all the k finalists. The one with the best median is the winner

Incomplete Knowledge

Remark

If a winner of the complete profile is among the k finalists then it will also be a winner of the incomplete profile

Theorem

There exist an incomplete profile and one of its completion that do not share the same sets of winners

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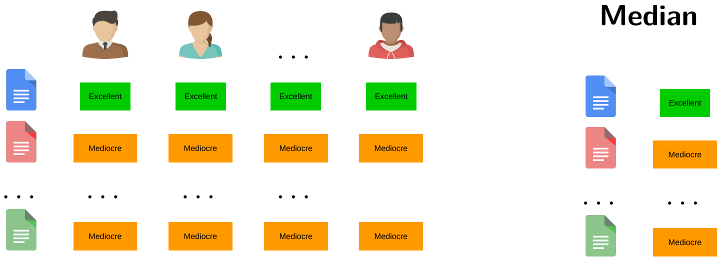

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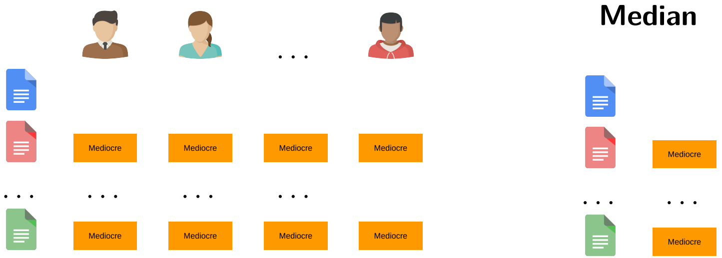

Probability of missing the winner

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By asking each voter to evaluate k equiprobably picked alternatives, the probability that an alternative j is never asked about is $(1 - \frac{k}{m})^n$

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For $k = 3$, $n = m = 10$ this is $0.7^{10} \approx 0.0282\%$

Probability of missing the winner

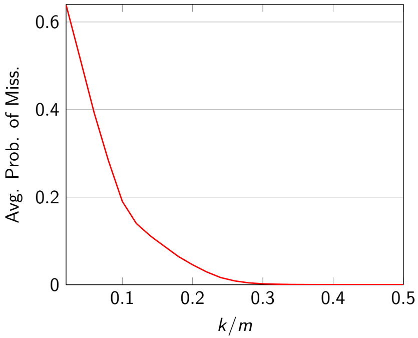
Theorem

By asking each voter to evaluate k equiprobably picked alternatives, the probability that an alternative j is never asked about is $(1 - \frac{k}{m})^n$

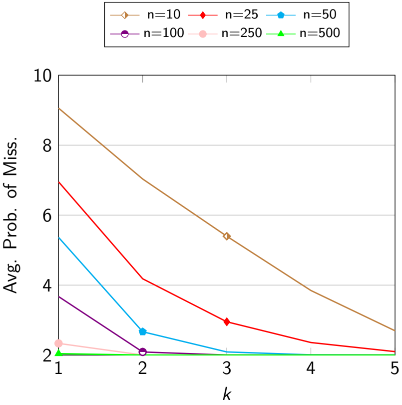
What about real scenarios?

Experimental results

(a) Avg prob. of missing the winner under uniform distribution of preferences, for $n = 100, m = 50$ and $k \in [\![1, 25]\!]$



(b) Avg prob. of missing the winner using a real case distribution of preferences, given $m = 12$ several n and $k \in [\![1, 5]\!]$



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Goal:Find a procedure determining a collective choice that promotes a notion of compromise

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Approach:

Olivier Cailloux, Beatrice Napolitano, and M. Remzi Sanver. Compromising as an equal loss principle.
Review of Economic Design, May 2022

- Define a compromise from an equal loss perspective
- Propose classes of rules reflecting this concept

Related Works

- **Majoritarian Compromise**: picks the alternatives that receive the support of the majority of voters at the highest possible quality, breaking ties according to the quantity of support (Sertel, 1986 [8])

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Note: q-approval with $q = 1$ corresponds to plurality

Motivation

$n = 100, \mathcal{A} = \{a, b, c\}$

$$\begin{array}{lccccc} \mathbf{51} & a & \succ & b & \succ & c \\ \mathbf{49} & c & \succ & b & \succ & a \end{array}$$

Motivation

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- Plurality: $\{a\}$

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- Plurality: $\{a\}$
- MC: $\{a\}$
- FB_q
  - $q \in \left\{1, \ldots, \frac{n}{2} - 1\right\}$: $\{a, c\}$
  - $q \in \left\{\frac{n}{2}, \frac{n}{2} + 1\right\}$: $\{a\}$
  - $q \in \left\{\frac{n}{2} + 2, \ldots, n\right\}$: $\{b\}$

Motivation

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Observations

- b receives unanimous support when each voter falls back one step from his ideal point
- almost all these SCRs impose a willingness to compromise, but do not ensure a compromise

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Thesis

b is a better compromise when egalitarianism is a major concern

Equal loss

$\lambda_P : \mathcal{A} \to [\![0, m-1]\!]^N$ a loss vector

Equal loss

$\lambda_P : \mathcal{A} \to [\![0, m-1]\!]^N$ a loss vector

$$\begin{array}{lccccc} v_1 : & a & \succ & b & \succ & c \\ v_2 : & c & \succ & b & \succ & a \end{array} \qquad \begin{array}{l} \lambda_P(a) = (0,2) \\ \lambda_P(b) = (1,1) \\ \lambda_P(a) = (2,0) \end{array}$$

Equal loss

$\lambda_P : \mathcal{A} \to [\![0, m-1]\!]^N$ a loss vector
$\sigma : [\![0, m-1]\!]^N \to \mathbb{R}^+$ a spread measure

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$\lambda_P : \mathcal{A} \to [\![0, m-1]\!]^N$ a loss vector
$\sigma : [\![0, m-1]\!]^N \to \mathbb{R}^+$ a spread measure

Σ is the set of spread measures σ such that

$$\sigma(l) = 0 \iff l_i = l_j,\ \forall i, j \in N, \quad \forall l \in [\![0, m-1]\!]^N$$

.

Equal loss

$$\arg\min_{\mathcal{A}}(\sigma \circ \lambda_P) = \{a \in \mathcal{A} \mid \forall b \in \mathcal{A} : \sigma(\lambda_P(a)) \leq \sigma(\lambda_P(b))\}$$

$\arg\min_{\mathcal{A}}(\sigma \circ \lambda_P)$ denotes the alternatives in $\mathcal{A}$ whose loss vectors are the most equally distributed according to σ

Equal loss

$$
\begin{array}{cc}
P & \lambda_P \\
v_1 : a \succ b \succ c & a : (0,2) \\
v_2 : c \succ b \succ a & b : (1,1) \\
 & c : (2,0)
\end{array}
$$

$$\arg\min_{\mathcal{A}}(\sigma \circ \lambda_P) = \{b\} \quad \forall \sigma \in \Sigma$$

Egalitarian compromises

An SCR is Egalitarian Compromise Compatible iff at each profile, it selects some "less unequal" alternatives

Egalitarian compromise compatibility

An SCR f is ECC iff

$$\exists \sigma \in \Sigma \mid \forall P \in \mathcal{L}(\mathcal{A})^N : f(P) \cap \underset{\mathcal{A}}{\arg\min}(\sigma \circ \lambda_P) \neq \emptyset$$

Egalitarian compromises and Pareto dominance

ECC rules are *very* egalitarian

P	λ_P
$v_1 : a \succ c \succ b$	$a : (0, 1)$
$v_2 : c \succ a \succ b$	$b : (2, 2)$
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Theorem

ECC $\cap$ *Paretian* $= \emptyset$ *(for $n, m \geq 2$)*

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Theorem

$ECC \cap Paretian = \emptyset$ *(for $n, m \geq 2$)*

$f \in \text{ECC} \Rightarrow b \in f(P)$, $f \in \text{Paretian} \Rightarrow b \notin f(P)$

Paretian compromises

An SCR is Paretian Compromise Compatible iff at each profile, it selects some "less unequal" alternatives *among the Pareto optimal ones*

Paretian compromise compatibility

An SCR f is PCC iff

$$\exists \sigma \in \Sigma \mid \forall P \in \mathcal{L}(\mathcal{A})^N : f(P) \cap \underset{PO(P)}{\arg\min}(\sigma \circ \lambda_P) \neq \emptyset$$

Results

For at least three voters and no restrictions on Σ:

	ECC	PCC
Condorcet procedures	No	No
Scoring rules	No	No
Antiplurality	No	Yes
BK compromises	No	No
Fallback bargaining	No	Yes

Restricting Σ

We consider a restriction $\bar{\Sigma} \subset \Sigma$ such that, for each $\bar{\sigma} \in \bar{\Sigma}$ if

$$
\begin{array}{lcccccc}
v_1 : & & & \mathbf{a} & \mathbf{b} & x_1 \\
v_2 : & & & \mathbf{b} & & \mathbf{a} \\
v_3 : & & \mathbf{b} & & \mathbf{a} & x_2 \\
v_4 : & \mathbf{b} & & & \mathbf{a} & x_3
\end{array}
$$

then: $(\bar{\sigma} \circ \lambda_P)(a) < (\bar{\sigma} \circ \lambda_P)(b)$

Restricting Σ

Theorem

Under $\bar{\Sigma}$, AP and FB are not PCC.

Proof for $m = 5, n = 4$.

$$
\begin{array}{lccccc}
v_1 : & & & a & b & x_1 \\
v_2 : & & & b & & a \\
v_3 : & & b & & a & x_2 \\
v_4 : & b & & & a & x_3
\end{array}
$$

- b is the only alternative never last, thus for both rules: $f(P) = \{b\}$
- $(\bar{\sigma} \circ \lambda_P)(a) < (\bar{\sigma} \circ \lambda_P)(b)$
- and $a \in PO(P)$, thus $b \notin \arg\min_{PO(P)}(\bar{\sigma} \circ \lambda_P)$ $\square$

Results

For at least three voters and **no** restrictions on Σ:

	ECC	PCC
Condorcet procedures	No	No
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Results

For at least three voters **with** restrictions $\bar{\Sigma}$ on Σ:

	ECC	PCC
Condorcet procedures	No	No
Scoring rules	No	No
Antiplurality	No	No
BK compromises	No	No
Fallback bargaining	No	No

Results

For at least three voters **with** restrictions $\bar{\Sigma}$ on Σ:

	ECC	PCC
Condorcet procedures	No	No
Scoring rules	No	No
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Similar results for two voters

Outline

1. Notation
2. Simultaneous Elicitation of Scoring Rule and Agent Preferences for Robust Winner Determination
3. Majority Judgment winner determination under incomplete information
4. Compromising as an equal loss principle
5. Conclusions

Conclusions

Considering a classical setting, we:

- revised the concept of compromise on an equal loss perspective
- proved that almost all SCRs fail to ensure a compromise
- defined new classes of voting rules reflection this notion

Conclusions

Considering a classical setting, we:

- revised the concept of compromise on an equal loss perspective
- proved that almost all SCRs fail to ensure a compromise
- defined new classes of voting rules reflection this notion

Considering incomplete knowledge, we:

- analyzed the elicitation strategy used in a real voting scenario using MJ
- introduced a simultaneous and incremental elicitation approach for agents and chair preferences
- developed several strategies and released our framework for further experiments and improvements

Future work

Considering a classical setting:

- the cardinal setting can be analyzed including intensity of preferences
- new definitions of compromise can be conceived
- the trade-off between equity and efficiency can be explored

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Considering incomplete knowledge using MJ:

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Considering a classical setting:

- the cardinal setting can be analyzed including intensity of preferences
- new definitions of compromise can be conceived
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Considering incomplete knowledge using MJ:

- the manipulability of the elicitation process using MJ can be explored
- steps toward explicability and axiomatization can be taken

Considering incomplete knowledge of agents and chair preferences:

- more strategies with different heuristics can be implemented
- the elicitation of the rule can be expanded to more than scoring rules and the convexity constraint can be relaxed
- the conversion of questions into profiles can be used in other settings

Thank You!

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Empirical Evaluation

Pessimistic reaching "low enough" regret

Table: Questions asked by Pessimistic strategy on several datasets to reach $\frac{n}{10}$ regret, columns 4 and 5, and zero regret, last two columns.

dataset	m	n	$q_c^{MMR \leq n/10}$	$q_a^{MMR \leq n/10}$	$q_c^{MMR=0}$	$q_a^{MMR=0}$
m5n20	5	20	0.0	[4.3 | 5.0 | 5.8]	5.3	[5.4 | 6.2 | 7.2]
m10n20	10	20	0.0	[13.9 | 16.1 | 18.4]	32.0	[19.7 | 21.8 | 24.7]
m11n30	11	30	0.0	[16.6 | 19.0 | 22.3]	45.2	[23.1 | 25.7 | 28.9]
tshirts	11	30	0.0	[13.1 | 16.6 | 19.6]	43.2	[28.2 | 32.0 | 35.6]
courses	9	146	0.0	[6.0 | 7.0 | 7.0]	0.0	[6.8 | 7.0 | 7.0]
m14n9	14	9	5.4	[30.3 | 33.5 | 36.7]	64.1	[37.6 | 40.5 | 44.3]
skate	14	9	0.0	[11.4 | 11.6 | 12.3]	0.0	[11.5 | 11.8 | 12.8]
m15n30	15	30	0.0	[25.0 | 29.5 | 33.7]		

Empirical Evaluation

Pessimistic chair first and then agents (and vice-versa)

Table: Average MMR in problems of size $(10, 20)$ after 500 questions, among which q_c to the chair.

q_c	ca $\pm$ sd	ac $\pm$ sd
0	0.6 ± 0.5	0.6 ± 0.5
15	0.5 ± 0.5	0.5 ± 0.5
30	0.3 ± 0.5	0.3 ± 0.4
50	0.0 ± 0.1	0.0 ± 0.1
100	0.1 ± 0.2	0.1 ± 0.1
200	2.3 ± 1.4	2.1 ± 1.8
300	5.2 ± 2.4	6.8 ± 0.6
400	10.9 ± 0.9	12.2 ± 1.0
500	20.0 ± 0.0	20.0 ± 0.0

FB and AP are PCC

Theorem

FB and Antiplurality are PCC. *(for $n, m \geq 3$)*

Proof sketch.

Define $\sigma^{\text{discrete}}(I) = 1 \iff I$ is not constant.
If some $a \in PO(P)$ has a constant loss vector, e. g.

$a_1 \succ a_2 \succ a_3 \succ a_4$
$a_3 \succ a_2 \succ a_1 \succ a_4$

there is exactly one such alternative, $FB(P) = \{a\}$ and it is never last so $a \in AP(P)$.
Otherwise, σ does not discriminate among $PO(P)$, thus Paretianism suffices. □