Recent Trends in Computational Social Choice

Palash Dey
Indian Institute of Technology, Kharagpur

Recent Trends in Algorithms

Date: 9 February 2019

Typical Voting Setting

- A set $\mathcal{A}$ of m candidates
- A set $\mathcal{V}$ of n votes
- Vote - a complete order over $\mathcal{A}$
- Voting rule - $r : \mathcal{L}(\mathcal{A})^n \longrightarrow \mathcal{A}$

Typical Voting Setting

- A set $\mathcal{A}$ of m candidates
- A set $\mathcal{V}$ of n votes
- Vote - a complete order over $\mathcal{A}$
- Voting rule - $r : \mathcal{L}(\mathcal{A})^n \longrightarrow \mathcal{A}$

Example

- $\mathcal{A} = \{a, b, c\}$
- Votes
  - ✓ Vote 1: $a > b > c$
  - ✓ Vote 2: $c > b > a$
  - ✓ Vote 3: $a > c > b$

Plurality rule: winner is candidate with most top positions

Plurality winner: a

Preference Elicitation

Domain: $\mathcal{D} \subseteq 2^{\mathcal{L}(\mathcal{A})}$

Preference Elicitation

Domain: $\mathcal{D} \subseteq 2^{\mathcal{L}(\mathcal{A})}$

For a domain (known) $\mathcal{D}$, we are given black box access to a tuple of rankings $(R_1, R_2, \ldots, R_n) \in D^n$ for some (unknown) $D \in \mathcal{D}$. A query $(i, a, b) \in [n] \times \mathcal{A} \times \mathcal{A}$ to an oracle reveals whether $a > b$ in R_i.

Output: $R_1, R_2, \ldots, R_n$.

Goal: Minimize number of queries asked.

Preference Elicitation

Domain: $\mathcal{D} \subseteq 2^{\mathcal{L}(\mathcal{A})}$

For a domain (known) $\mathcal{D}$, we are given black box access to a tuple of rankings $(R_1, R_2, \ldots, R_n) \in D^n$ for some (unknown) $D \in \mathcal{D}$. A query $(i, a, b) \in [n] \times \mathcal{A} \times \mathcal{A}$ to an oracle reveals whether $a > b$ in R_i.

Output: $R_1, R_2, \ldots, R_n$.

Goal: Minimize number of queries asked.

- For $\mathcal{D} = \{\mathcal{L}(\mathcal{A})\}$: query complexity $\Theta(nm \log m)$

Preference Elicitation cont.

Single peaked domain: $\mathcal{O}(mn) + \mathcal{O}(m \log m)$[1]

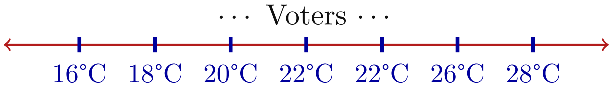
[1] V. Conitzer. “Eliciting Single-Peaked Preferences Using Comparison Queries”, JAIR 2009.

[2] D., N. Misra, “Preference Elicitation for Single Crossing Domain”, IJCAI 2016.

Preference Elicitation cont.

Single peaked domain: $\mathcal{O}(mn) + \mathcal{O}(m \log m)$[1]

Single crossing domain:



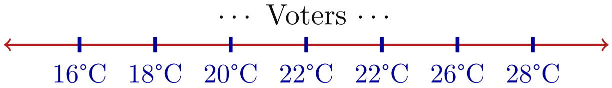
[1] V. Conitzer. “Eliciting Single-Peaked Preferences Using Comparison Queries”, JAIR 2009.

[2] D., N. Misra, “Preference Elicitation for Single Crossing Domain”, IJCAI 2016.

Preference Elicitation cont.

Single peaked domain: $\mathcal{O}(mn) + \mathcal{O}(m \log m)$[1]

Single crossing domain:



$$\boxed{\forall (a, b) \in \mathcal{A} \times \mathcal{A} \Rightarrow \text{voters with } a \succ b \text{ are contiguous}}$$

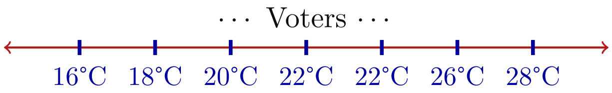
[1] V. Conitzer. "Eliciting Single-Peaked Preferences Using Comparison Queries", JAIR 2009.

[2] D., N. Misra, "Preference Elicitation for Single Crossing Domain", IJCAI 2016.

Preference Elicitation cont.

Single peaked domain: $\mathcal{O}(mn) + \mathcal{O}(m \log m)$[1]

Single crossing domain:



$$\boxed{\forall (a, b) \in \mathcal{A} \times \mathcal{A} \Rightarrow \text{voters with } a \succ b \text{ are contiguous}}$$

- Random access: $\Theta(m^2 \log n)$[2]
- Sequential access: $\mathcal{O}(mn + m^3 \log m), \Omega(mn + m^2)$

[1] V. Conitzer. "Eliciting Single-Peaked Preferences Using Comparison Queries", JAIR 2009.

[2] D., N. Misra, "Preference Elicitation for Single Crossing Domain", IJCAI 2016.

Preference Elicitation – open problems

2-Dimensional Euclidean domain:

- Alternatives $\mathcal{A}$ are points in $\mathbb{R}^2$ and rankings $R_i, i \in [n]$ correspond to points $p_i \in \mathbb{R}^2, i \in [n]$.
- R_i is the ranking induced by distance of $\mathcal{A}$ from p_i.

Preference Elicitation – open problems

2-Dimensional Euclidean domain:

- Alternatives $\mathcal{A}$ are points in $\mathbb{R}^2$ and rankings $R_i, i \in [n]$ correspond to points $p_i \in \mathbb{R}^2, i \in [n]$.
- R_i is the ranking induced by distance of $\mathcal{A}$ from p_i.

What is query complexity for 2-dimensional Euclidean domain?

Preference Elicitation – open problems

Single Crossing Domain on Median Graphs:

- *median graph:* for any three vertices u, v, w and for any 3 shortest paths between pairs of them $p_{u,v}$ between u and v, $p_{v,w}$ between v and w, and $p_{w,u}$ between w and u, there is exactly one vertex common to 3 paths. Ex: tree, hypercube.

Preference Elicitation – open problems

Single Crossing Domain on Median Graphs:

- *median graph:* for any three vertices u, v, w and for any 3 shortest paths between pairs of them $p_{u,v}$ between u and v, $p_{v,w}$ between v and w, and $p_{w,u}$ between w and u, there is exactly one vertex common to 3 paths. Ex: tree, hypercube.

- *single crossing property:* given a median graph on some multiset $\{R_i \in \mathcal{L}(\mathcal{A}) : i \in [n]\}$ of rankings, for every pair $i \neq j$, the sequence of rankings in the shortest path between R_i and R_j is single crossing.

What is query complexity of single crossing domain on median graphs?

Winner Prediction

r: any voting rule

Given an oracle which gives uniform votes of n voters over m alternatives, predict the winner under voting rule r with error probability at most δ.

Goal: minimize number of samples drawn

Winner Prediction

r: any voting rule

Given an oracle which gives uniform votes of n voters over m alternatives, predict the winner under voting rule r with error probability at most δ.

Goal: minimize number of samples drawn

For $\mathcal{A} = \{a, b\}$, $\lfloor n/2 \rfloor - 1$ votes of type $a > b$, and $\lceil n/2 \rceil + 1$ votes of type $b > a$, sample complexity is $\Omega(n \ln 1/\delta)$.

Winner Prediction

r: any voting rule

Given an oracle which gives uniform votes of n voters over m alternatives, predict the winner under voting rule r with error probability at most δ.

Goal: minimize number of samples drawn

For $\mathcal{A} = \{a, b\}$, $\lfloor n/2 \rfloor - 1$ votes of type $a > b$, and $\lceil n/2 \rceil + 1$ votes of type $b > a$, sample complexity is $\Omega(n \ln 1/\delta)$.

Margin of victory: minimum number of votes need to modify to change the winner.

Assume: margin of victory if εn.

Winner Prediction cont.

Plurality rule: sample complexity is $\Theta\left(\frac{1}{\varepsilon^2}\log\frac{1}{\delta}\right)$ (folklore!)

What about other voting rules?

A. Bhattacharyya, D., "Sample Complexity for Winner Prediction in Elections", AAMAS 2015.

Winner Prediction cont.

Plurality rule: sample complexity is $\Theta\left(\frac{1}{\varepsilon^2}\log\frac{1}{\delta}\right)$ (folklore!)

What about other voting rules?

Voting rule	Sample complexity
Borda: $s(a) = \sum_{b \neq a} N(a > b)$	$\Theta\left(\frac{1}{\varepsilon^2}\log\frac{\log m}{\delta}\right)$
Maximin: $s(a) = \min_{b \neq a} N(a > b)$	$\Theta\left(\frac{1}{\varepsilon^2}\log\frac{\log m}{\delta}\right)$
Copeland: $s(a) = \lvert\{b \neq a : N(a > b) > \frac{n}{2}\}\rvert$	$\mathcal{O}\left(\frac{1}{\varepsilon^2}\log^3\frac{\log m}{\delta}\right)$ $\Omega\left(\frac{1}{\varepsilon^2}\log\frac{\log m}{\delta}\right)$

A. Bhattacharyya, D., "Sample Complexity for Winner Prediction in Elections", AAMAS 2015.

Winner Prediction Future Directions

- What is sample complexity for winner prediction for specific domains, for example, single peaked, single crossing, and single crossing on median graphs?

Winner Prediction Future Directions

- What is sample complexity for winner prediction for specific domains, for example, single peaked, single crossing, and single crossing on median graphs?
- What is the sample complexity for committee selection rules like Chamberlin–Courant or Monroe.

Liquid Democracy

- *If you are not sure whom you should vote, then you can delegate your friend!*[3][4]

[3] J.C. Miller, "A program for direct and proxy voting in the legislative process," Public Choice, 1969.

[4] Kling et al. "Voting behaviour and power in online democracy," ICWSM, 2015.

Liquid Democracy

- *If you are not sure whom you should vote, then you can delegate your friend!*[3][4]

- Delegations are transitive.

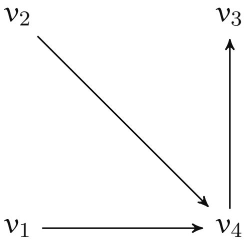


Figure 1: Delegation graph

---

[3] J.C. Miller, "A program for direct and proxy voting in the legislative process," Public Choice, 1969.

[4] Kling et al. "Voting behaviour and power in online democracy," ICWSM, 2015.

Pitfalls of Liquid Democracy: Super voter

Voting power can be concentrated in one super voter which may be undesirable even if he/she is competent.

[5] Gölg et al. “The Fluid Mechanics of Liquid Democracy,” WINE 2018.

Pitfalls of Liquid Democracy: Super voter

Voting power can be concentrated in one super voter which may be undesirable even if he/she is competent.

- Natural solution: put cap on the maximum weight of a voter.

[5] Gölg et al. "The Fluid Mechanics of Liquid Democracy," WINE 2018.

Pitfalls of Liquid Democracy: Super voter

Voting power can be concentrated in one super voter which may be undesirable even if he/she is competent.

- Natural solution: put cap on the maximum weight of a voter.
- Can lead to delegation outside system thereby reducing transparency!

[5] Gölg et al. "The Fluid Mechanics of Liquid Democracy," WINE 2018.

Pitfalls of Liquid Democracy: Super voter

Voting power can be concentrated in one super voter which may be undesirable even if he/she is competent.

- Natural solution: put cap on the maximum weight of a voter.
- Can lead to delegation outside system thereby reducing transparency!
- Ask voters to provide multiple delegations whom they trust and let system decide the rest.[5]

[5] Gölg et al. "The Fluid Mechanics of Liquid Democracy," WINE 2018.

Resolving Delegation Graph

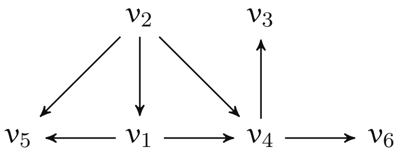


Figure 2: Input graph

Resolving Delegation Graph

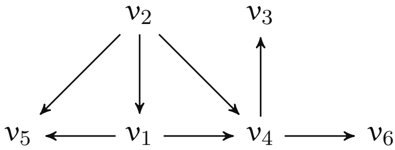


Figure 2: Input graph

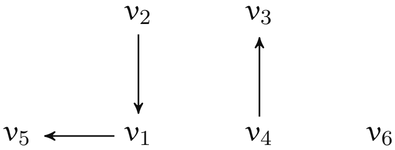


Figure 3: Delegation graph

Resolving Delegation Graph

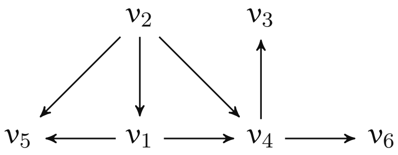


Figure 2: Input graph

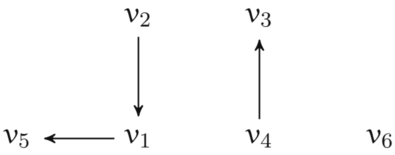


Figure 3: Delegation graph

Given a directed graph $\mathcal{G} = (\mathcal{V}, \mathcal{E})$ with sink nodes $\mathcal{S}[\mathcal{G}]$, find a spanning subgraph $\mathcal{H} \subseteq \mathcal{G}$ such that $\mathcal{S}[\mathcal{H}] \subseteq \mathcal{S}[\mathcal{G}]$ which minimizes the weight (number of nodes that can reach it) of any node.

Resolving Delegation Graph

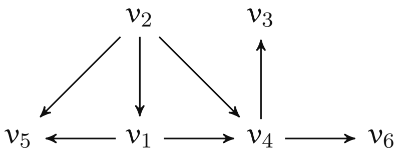


Figure 2: Input graph

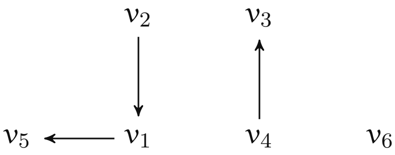


Figure 3: Delegation graph

> Given a directed graph $\mathcal{G} = (\mathcal{V}, \mathcal{E})$ with sink nodes $\mathcal{S}[\mathcal{G}]$, find a spanning subgraph $\mathcal{H} \subseteq \mathcal{G}$ such that $\mathcal{S}[\mathcal{H}] \subseteq \mathcal{S}[\mathcal{G}]$ which minimizes the weight (number of nodes that can reach it) of any node.

Gölg et al. present $1 + \lg n$ approximation and show $\frac{1}{2} \lg n$ inapproximability assuming $\mathsf{P} \neq \mathsf{NP}$ by reducing to the problem of minimizing maximum confluent flow.

Restricting Voter Power is Recommended for Efficiency Reason too

- Assume there are only 2 choices ($\mathcal{A} = \{0, 1\}$) with 0 being ground truth.
- Every voter has a potency $p_i (\geqslant \frac{1}{2})$: the probability that its opinion is 0.

Restricting Voter Power is Recommended for Efficiency Reason too

- Assume there are only 2 choices ($\mathcal{A} = \{0, 1\}$) with 0 being ground truth.
- Every voter has a potency $p_i (\geqslant \frac{1}{2})$: the probability that its opinion is 0.
- Gain: given a delegation mechanism, its gain is the probability that 0 wins minus 0 wins under direct voting.

Restricting Voter Power is Recommended for Efficiency Reason too

- Assume there are only 2 choices ($\mathcal{A} = \{0, 1\}$) with 0 being ground truth.
- Every voter has a potency $p_i (\geqslant \frac{1}{2})$: the probability that its opinion is 0.
- Gain: given a delegation mechanism, its gain is the probability that 0 wins minus 0 wins under direct voting.
- Positive Gain (PG): A mechanism is said to have PG property if its gain is positive for all sufficiently large instances.
- Do Not Harm (DNH): A mechanism is said to have DNH property if its gain is non-negative for all sufficiently large graphs

Restricting Voter Power is Recommended for Efficiency Reason too cont.

- No local delegation mechanism has DNH property![6]

[6] Kahng et al. “Liquid Democracy: An Algorithmic Perspective,” AAAI 2018.

Restricting Voter Power is Recommended for Efficiency Reason too cont.

- No local delegation mechanism has DNH property![6]
- There exists a non-local mechanism which satisfies PG property and the main idea is to provide cap on the weight of any voter.

[6] Kahng et al. "Liquid Democracy: An Algorithmic Perspective," AAAI 2018.

Participatory Budgeting

In participatory budgeting, community collectively decides how public money will be allocated to local projects.

[7] Fain et al. "The Core of the Participatory Budgeting Problem," WINE 2016.

Participatory Budgeting

In participatory budgeting, community collectively decides how public money will be allocated to local projects.

- The problem is different from fair resource allocation of public goods since allocated goods benefit everyone.

[7] Fain et al. "The Core of the Participatory Budgeting Problem," WINE 2016.

Participatory Budgeting

In participatory budgeting, community collectively decides how public money will be allocated to local projects.

- The problem is different from fair resource allocation of public goods since allocated goods benefit everyone.

- There are n voters, k projects, and the set of allocations is $\{x \in \mathbb{R}^k : \sum_{i=1}^k x_i \leqslant B\}$. Let $U_i(x)$ be the utility of voter i from allocation x.

[7] Fain et al. "The Core of the Participatory Budgeting Problem," WINE 2016.

Participatory Budgeting

In participatory budgeting, community collectively decides how public money will be allocated to local projects.

- The problem is different from fair resource allocation of public goods since allocated goods benefit everyone.

- There are n voters, k projects, and the set of allocations is $\{x \in \mathbb{R}^k : \sum_{i=1}^{k} x_i \leqslant B\}$. Let $U_i(x)$ be the utility of voter i from allocation x.

- *Core:* An allocation x is called a core if, for every subset $S \subseteq [n]$, there does not exist any allocation y such that $\sum_{i \in S} y_i \leqslant \frac{|S|}{n} B$ and $U_i(y) > U_i(x)$ for every $i \in S$.

[7] Fain et al. "The Core of the Participatory Budgeting Problem," WINE 2016.

Participatory Budgeting

In participatory budgeting, community collectively decides how public money will be allocated to local projects.

- The problem is different from fair resource allocation of public goods since allocated goods benefit everyone.
- There are n voters, k projects, and the set of allocations is $\{x \in \mathbb{R}^k : \sum_{i=1}^{k} x_i \leqslant B\}$. Let $U_i(x)$ be the utility of voter i from allocation x.
- *Core:* An allocation x is called a core if, for every subset $S \subseteq [n]$, there does not exist any allocation y such that $\sum_{i \in S} y_i \leqslant \frac{|S|}{n} B$ and $U_i(y) > U_i(x)$ for every $i \in S$.
- Core captures fairness notion in this context and an allocation in the core can be computed in polynomial time for a class of utility functions. [7]

[7] Fain et al. "The Core of the Participatory Budgeting Problem," WINE 2016.

Participatory Budgeting: Preference Elicitation

How voters can express their utility function?

Benadè et al. "Preference Elicitation For Participatory Budgeting," AAAI 2017.

Participatory Budgeting: Preference Elicitation

How voters can express their utility function?

- Knapsack vote: feasible subset κ_i of projects which gives maximum utility to voter i.

Benadè et al. "Preference Elicitation For Participatory Budgeting," AAAI 2017.

Participatory Budgeting: Preference Elicitation

How voters can express their utility function?

- Knapsack vote: feasible subset κ_i of projects which gives maximum utility to voter i.
- Ranking by value.

Benadè et al. "Preference Elicitation For Participatory Budgeting," AAAI 2017.

Participatory Budgeting: Preference Elicitation

How voters can express their utility function?

- Knapsack vote: feasible subset κ_i of projects which gives maximum utility to voter i.
- Ranking by value.
- Ranking by value for money.

Benadè et al. "Preference Elicitation For Participatory Budgeting," AAAI 2017.

Participatory Budgeting: Preference Elicitation

How voters can express their utility function?

- Knapsack vote: feasible subset κ_i of projects which gives maximum utility to voter i.
- Ranking by value.
- Ranking by value for money.
- For a threshold t, a feasible subset of projects which ensures an utility of at least t.

Benadè et al. "Preference Elicitation For Participatory Budgeting," AAAI 2017.

Participatory Budgeting: Preference Elicitation cont.

How good is an elicitation method? Notion of distortion!

Benadè et al. "Preference Elicitation For Participatory Budgeting," AAAI 2017.

Participatory Budgeting: Preference Elicitation cont.

How good is an elicitation method? Notion of distortion!

Distortion: fraction of welfare (sum of utilities) loss due to lack of information.

Benadè et al. "Preference Elicitation For Participatory Budgeting," AAAI 2017.

Participatory Budgeting: Preference Elicitation cont.

How good is an elicitation method? Notion of distortion!

Distortion: fraction of welfare (sum of utilities) loss due to lack of information.

Elicitation method	Distortion
Any method	$\leqslant m$
Knapsack vote	$\Omega(m)$
Ranking by value	$\mathcal{O}(\sqrt{m}\log m)$
Ranking by value for money	$\mathcal{O}(\sqrt{m}\log m)$
Deterministic threshold	$\Omega(\sqrt{m})$
Randomized threshold	$\mathcal{O}(\log^2 m), \Omega\left(\frac{\log m}{\log\log m}\right)$

What is the optimal elicitation method?

Benadè et al. "Preference Elicitation For Participatory Budgeting," AAAI 2017.

Distortion of Voting Rules

Implicit Utilitarian Voting Model

Although votes are rankings over alternatives, every voter i has an underlying utility function $u_i : \mathcal{A} \to [0, 1], \sum_{a \in \mathcal{A}} u_i(a) = 1$.

[8] A. Procaccia and J. S. Rosenschein, "The Distortion of Cardinal Preferences in Voting," CIA 2006.

[9] Boutilier et al. "Optimal Social Choice Functions: A Utilitarian View," EC, 2012.

[10] Benadè et al. "Low-Distortion Social Welfare Functions," AAAI 2019.

Distortion of Voting Rules

Implicit Utilitarian Voting Model

Although votes are rankings over alternatives, every voter i has an underlying utility function $u_i : \mathcal{A} \to [0, 1], \sum_{a \in \mathcal{A}} u_i(a) = 1$.

Distortion of a voting rule: what fraction of welfare ($\sum_{i=1}^{n} u_i(w)$ if w wins) it achieves in the worst case compared to optimal.[8]

[8] A. Procaccia and J. S. Rosenschein, "The Distortion of Cardinal Preferences in Voting," CIA 2006.

[9] Boutilier et al. "Optimal Social Choice Functions: A Utilitarian View," EC, 2012.

[10] Benadè et al. "Low-Distortion Social Welfare Functions," AAAI 2019.

Distortion of Voting Rules

Implicit Utilitarian Voting Model

Although votes are rankings over alternatives, every voter i has an underlying utility function $u_i : \mathcal{A} \to [0, 1], \sum_{a \in \mathcal{A}} u_i(a) = 1$.

Distortion of a voting rule: what fraction of welfare ($\sum_{i=1}^{n} u_i(w)$ if w wins) it achieves in the worst case compared to optimal.[8]

Distortion of any randomized voting rule is $\Omega(\sqrt{m})$. The distortion of harmonic scoring rule (i-th ranked alternatives receives a score of $1/i$) is $\mathcal{O}(\sqrt{m \log m})$.[9]

---

[8] A. Procaccia and J. S. Rosenschein, "The Distortion of Cardinal Preferences in Voting," CIA 2006.

[9] Boutilier et al. "Optimal Social Choice Functions: A Utilitarian View," EC, 2012.

[10] Benadè et al. "Low-Distortion Social Welfare Functions," AAAI 2019.

Distortion of Voting Rules

Implicit Utilitarian Voting Model

Although votes are rankings over alternatives, every voter i has an underlying utility function $u_i : \mathcal{A} \to [0,1], \sum_{a \in \mathcal{A}} u_i(a) = 1$.

Distortion of a voting rule: what fraction of welfare ($\sum_{i=1}^{n} u_i(w)$ if w wins) it achieves in the worst case compared to optimal.[8]

Distortion of any randomized voting rule is $\Omega(\sqrt{m})$. The distortion of harmonic scoring rule (i-th ranked alternatives receives a score of $1/i$) is $\mathcal{O}(\sqrt{m \log m})$.[9]

Distortion of optimal social welfare function is $\tilde{\Theta}(\sqrt{m})$.[10]

---

[8] A. Procaccia and J. S. Rosenschein, “The Distortion of Cardinal Preferences in Voting,” CIA 2006.

[9] Boutilier et al. “Optimal Social Choice Functions: A Utilitarian View,” EC, 2012.

[10] Benadè et al. “Low-Distortion Social Welfare Functions,” AAAI 2019.

Metric Distortion of Voting Rules

Implicit Utilitarian Model. Voters and Alternatives are embedded in a metric space.

[11] E. Anshelevich and J. Postl, "Randomized social choice functions under metric preferences," JAIR 2017.

[12] Goelet al. "Metric distortion of social choice rules: Lower bounds and fairness properties," EC 2017.

Metric Distortion of Voting Rules

Implicit Utilitarian Model. Voters and Alternatives are embedded in a metric space.

- Metric distortion of any rule is at least 3.[11]

[11] E. Anshelevich and J. Postl, "Randomized social choice functions under metric preferences," JAIR 2017.

[12] Goelet al. "Metric distortion of social choice rules: Lower bounds and fairness properties," EC 2017.

Metric Distortion of Voting Rules

Implicit Utilitarian Model. Voters and Alternatives are embedded in a metric space.

- Metric distortion of any rule is at least 3.[11]
- Metric distortion of plurality and Borda are at least $2m - 1$, of veto and k-approval are at least $2n - 1$.

[11] E. Anshelevich and J. Postl, "Randomized social choice functions under metric preferences," JAIR 2017.

[12] Goelet al. "Metric distortion of social choice rules: Lower bounds and fairness properties," EC 2017.

Metric Distortion of Voting Rules

Implicit Utilitarian Model. Voters and Alternatives are embedded in a metric space.

- Metric distortion of any rule is at least 3.[11]
- Metric distortion of plurality and Borda are at least $2m - 1$, of veto and k-approval are at least $2n - 1$.
- Metric distortion of Copeland is 3.[12]

---

[11] E. Anshelevich and J. Postl, "Randomized social choice functions under metric preferences," JAIR 2017.

[12] Goelet al. "Metric distortion of social choice rules: Lower bounds and fairness properties," EC 2017.

Very Hard Voting Problems

Some natural problems in voting are Σ_2^p*-complete and* Θ_2^p*-complete.*

[13] Hemaspaandra et al. "The complexity of Kemeny elections," TCS 2005.
[14] Fitzsimmons et al. "Very Hard Electoral Control Problems," AAAI 2019.

Very Hard Voting Problems

Some natural problems in voting are Σ_2^p*-complete and* Θ_2^p*-complete.*

Kemeny rule: Kemeny ranking is a ranking which has smallest sum of Kendall-tau distances from all votes. Kemeny winner is the alternative at the first position of a Kemeny ranking.

[13] Hemaspaandra et al. "The complexity of Kemeny elections," TCS 2005.

[14] Fitzsimmons et al. "Very Hard Electoral Control Problems," AAAI 2019.

Very Hard Voting Problems

Some natural problems in voting are Σ_2^p-complete and Θ_2^p-complete.

Kemeny rule: Kemeny ranking is a ranking which has smallest sum of Kendall-tau distances from all votes. Kemeny winner is the alternative at the first position of a Kemeny ranking.

Deciding if an alternative is a Kemeny winner is Θ_2^p-complete.[13]

[13] Hemaspaandra et al. "The complexity of Kemeny elections," TCS 2005.

[14] Fitzsimmons et al. "Very Hard Electoral Control Problems," AAAI 2019.

Very Hard Voting Problems

Some natural problems in voting are Σ_2^p-complete and Θ_2^p-complete.

Kemeny rule: Kemeny ranking is a ranking which has smallest sum of Kendall-tau distances from all votes. Kemeny winner is the alternative at the first position of a Kemeny ranking.

Deciding if an alternative is a Kemeny winner is Θ_2^p-complete.[13]

Constructive Control by Deleting Alternatives (CCDA): Given a set of votes over a set of alternative and an alternative c, compute if it possible to delete at most k candidates such that c wins in the resulting election.

[13] Hemaspaandra et al. "The complexity of Kemeny elections," TCS 2005.

[14] Fitzsimmons et al. "Very Hard Electoral Control Problems," AAAI 2019.

Very Hard Voting Problems

Some natural problems in voting are Σ_2^p-complete and Θ_2^p-complete.

Kemeny rule: Kemeny ranking is a ranking which has smallest sum of Kendall-tau distances from all votes. Kemeny winner is the alternative at the first position of a Kemeny ranking.

Deciding if an alternative is a Kemeny winner is Θ_2^p-complete.[13]

Constructive Control by Deleting Alternatives (CCDA): Given a set of votes over a set of alternative and an alternative c, compute if it possible to delete at most k candidates such that c wins in the resulting election.

CCDA for Kemeny rule is Σ_2^p-complete.[14]

---

[13] Hemaspaandra et al. "The complexity of Kemeny elections," TCS 2005.

[14] Fitzsimmons et al. "Very Hard Electoral Control Problems," AAAI 2019.

Thank You!

palash.dey@cse.iitkgp.ac.in