# Possible Voter Control in $k$-Approval and $k$-Veto under Partial Information

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# Outline

# Motivation & Related Work I

- voter control under full information [BTT89], [Lin12]
- partial orders, possible/necessary winner [KL05], [XC08]

[BTT89] J. Bartholdi, C. Tovey, and M. Trick: How hard is it to control an election? In *Mathematical and Comp. Modelling 16(8/9)*.
[KL05] K. Konczak and J. Lang: Voting Procedures with Incomplete Preferences. In *MPREF'05*.
[Lin12] A. Lin: The Complexity of manipulating *k*-Approval Elections. In *ICAART(2)'11*.
[XC08] L. Xia and V. Conitzer: Determining Possible and Necessary Winners given Partial Orders. In *JAIR'11*.

# Motivation & Related Work II

- partial information [BER16], [CWX11]
- bribery under partial information [BER16], [ER16]
- (necessary) voter control under partial information [Reg16]

[BER16] D. Briskorn, G. Erdélyi, and C. Reger: Bribery in $k$-Approval and $k$-Veto under Partial Information. In *AAMAS'16*.
[CWX11] V. Conitzer, T. Walsh, and L. Xia: Dominating Manipulations in Voting with Partial Information. In *AAAI'11*.
[ER16] G. Erdélyi and C. Reger: Possible Bribery in $k$-Approval and $k$-Veto under Partial Information. In *AIMSA'16*.
[Reg16] C. Reger: Voter Control in $k$-Approval and $k$-Veto under Partial Information. In *ISAIM'16*.

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  - set of voters $V$
  - every voter has a strict linear order over $C$
- $n$-voter profile $P = (v_1, \ldots, v_n)$
- voting rule $\mathcal{E} : (C, V) \to \mathcal{P}(C)$

# Introduction (Partial Information)

- partial profile $P = (v_1, \ldots, v_n)$
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- information set $I(P)$
  - all complete profiles $P'$ which do not contradict $P$

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- $k$-Approval: $\alpha = (\underbrace{1, \ldots, 1}_{k}, 0, \ldots, 0)$
- Plurality: $\alpha = (1, 0, \ldots, 0)$

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- $k$-Approval: $\alpha = (\underbrace{1, \ldots, 1}_{k}, 0, \ldots, 0)$
- Plurality: $\alpha = (1, 0, \ldots, 0)$
- $k$-Veto: $\alpha = (1, \ldots, 1, \underbrace{0, \ldots, 0}_{k})$
- Veto: $\alpha = (1, 1, \ldots, 1, 0)$

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# Partial Information

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- why partial information?
  - realistic assumption
  - too many candidates
  - indifference
  - incomparability
  - which kind of partial information?

# GAPS, Special Case 1GAP

- in each vote, there may be some *gaps* with no information
- example:
  - $C = \{a, b, c, d, e, f, g, h\}$,
  - voter $v$: $a \succ b \succ c?d?e \succ f \succ g?h$

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# GAPS, Special Case 1GAP

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- 1GAP = special case of GAPS
  - at most one block with no information
  - *doubly-truncated orders* in literature
  - example: $C = \{a, b, c, d\}$, $v$ votes $a \succ b?c \succ d$

[BFLR12] D. Baumeister, P. Faliszewski, J. Lang, and J. Rothe: Campaigns for Lazy Voters: Truncated Ballots. In *IFAAMAS'12*.

# Top-/Bottom-truncated Orders (TTO/BTO)

- TTO = 1GAP with gap "at the bottom"
  - the top set is totally ordered
  - the bottom set contains no information
  - example: $C = \{a, b, c, d, e\}$, $v$ votes $a \succ b \succ c?d?e$

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- TTO = 1GAP with gap "at the bottom"
  - the top set is totally ordered
  - the bottom set contains no information
  - example: $C = \{a, b, c, d, e\}$, $v$ votes $a \succ b \succ c?d?e$
- BTO = 1GAP with gap "at the top"
  - the bottom set is totally ordered
  - the top set contains no information
  - example: $C = \{a, b, c, d\}$, $v$ votes $a?b \succ c \succ d$

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# Complete or Empty Votes (CEV)

- all votes are empty or complete

[KL05] K. Konczak and J. Lang: Voting Procedures with Incomplete Preferences. In *MPREF'05*.

# Fixed Positions (FP), Pairwise Comparisons (PC)

- in each vote, some candidates and their positions are known
- example: $C = \{a, b, c, d, e\}$, $v$ votes $? \succ ? \succ a \succ ? \succ b$

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# Fixed Positions (FP), Pairwise Comparisons (PC)

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[BER16] D. Briskorn, G. Erdélyi, and C. Reger: Bribery in $k$-Approval and $k$-Veto under Partial Information. In *AAMAS'16*.

- some pairwise comparisons are known
  - the most general structure of partial information
  - *partial orders* in literature
- example: $C = \{a, b, c, d\}$, $v$ votes $a \succ b$ and $c \succ d$

[KL05] K. Konczak and J. Lang: Voting Procedures with Incomplete Preferences. In *MPREF'05*.

# (Unique) Totally Ordered Subset of Candidates

- for voter $v$, a totally ordered subset of candidates $C^v$ is known
  - example: $C = \{a, b, c, d, e\}$, $v_1 : \ a \succ b \succ c$, $\ v_2 : \ c \succ d$

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- for voter $v$, a totally ordered subset of candidates $C^v$ is known
  - example: $C = \{a, b, c, d, e\}$, $v_1 : \ a \succ b \succ c$, $\ v_2 : \ c \succ d$
- 1TOS: special case of TOS ($C^v =: C' \ \forall v$)
  - every voter ranks the same subset of candidates
  - example: $C = \{a, b, c, d, e\}$, $v_1 : \ a \succ b \succ c$, $v_2 : \ c \succ b \succ a$

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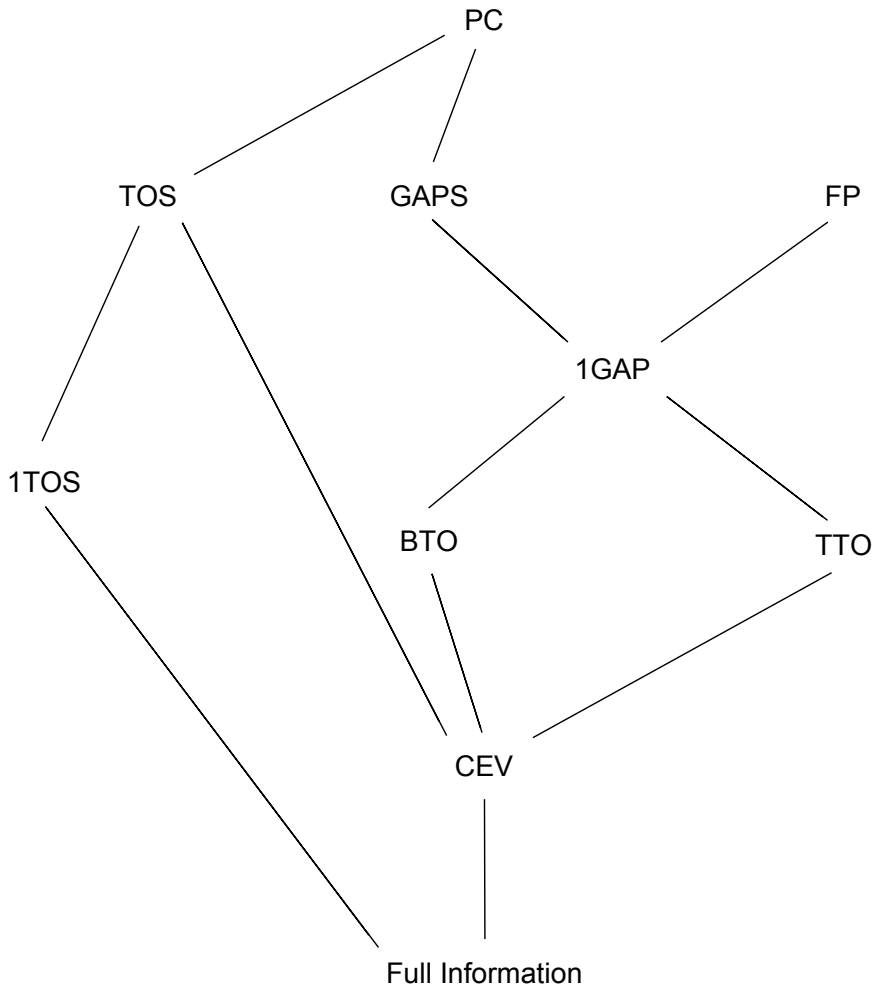
# Interconnections of the Structures

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# Necessary Winner

| $\mathcal{E}$-$X$-NECESSARY WINNER | |
|---|---|
| **Given:** | An election $(C, V)$, a designated candidate $c \in C$, and a partial profile $P$ according to model $X$ |
| **Question:** | Is $c$ a winner under $\mathcal{E}$ for every complete profile $P' \in I(P)$? |

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# Possible Winner

| $\mathcal{E}$-$X$-Possible Winner | |
|---|---|
| **Given:** | An election $(C, V)$, a designated candidate $c \in C$, and a partial profile $P$ according to model $X$ |
| **Question:** | Is $c$ a winner under $\mathcal{E}$ for at least one complete profile $P' \in I(P)$? |

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# Constructive (Destructive) Control by Adding Voters

$\mathcal{E}$-CONSTRUCTIVE (DESTRUCTIVE) CONTROL BY ADDING VOTERS

**Given:** An election $(C, V \cup W)$ with registered voters $V$, unregistered voters $W$, a designated candidate $c \in C$, a non-negative integer $\ell \leq |W|$, and a complete profile $P$ over $V \cup W$.

**Question:** Is it possible to choose a subset $W' \subseteq W$, $|W'| \leq \ell$ such that $c$ is (not) a winner of the election $(C, V \cup W')$ under $\mathcal{E}$ for $P$?

[BTT89] J. Bartholdi, C. Tovey, and M. Trick: How hard is it to control an election? In *Mathematical and Comp. Modelling 16(8/9)*.
[HHR07] E. Hemaspaandra, L. Hemaspaandra, and J. Rothe: Anyone but him: the complexity of precluding an alternative. In *Artificial Intelligence 171(5-6)*.

# Possible Constructive Control by Adding Voters

$\mathcal{E}$-$(X, Y)$-Possible Constructive Control by Adding Voters

**Given:** An election $(C, V \cup W)$ with registered voters $V$ according to model $X$, unregistered voters $W$ according to model $Y$, a designated candidate $c \in C$, a non-negative integer $\ell \leq |W|$, and a partial profile $P$ according to $(X, Y)$

**Question:** Is it possible to choose a subset $W' \subseteq W$, $|W'| \leq \ell$ such that $c$ is a winner of the election $(C, V \cup W')$ under $\mathcal{E}$ for at least one complete profile $P' \in I(P)$?

# Possible Destructive Control by Adding Voters

$\mathcal{E}$-$(X, Y)$-POSSIBLE DESTRUCTIVE CONTROL BY ADDING VOTERS

| | |
|---|---|
| **Given:** | An election $(C, V \cup W)$ with registered voters $V$ according to model $X$, unregistered voters $W$ according to model $Y$, a designated candidate $c \in C$, a non-negative integer $\ell \leq \|W\|$, and a partial profile $P$ according to $(X, Y)$ |
| **Question:** | Is it possible to choose a subset $W' \subseteq W$, $\|W'\| \leq \ell$ such that $c$ is not a winner of the election $(C, V \cup W')$ under $\mathcal{E}$ for at least one complete profile $P' \in I(P)$? |

# Constructive (Destructive) Control by Deleting Voters

| $\mathcal{E}$-Constructive Control by Deleting Voters | |
|---|---|
| **Given:** | An election $(C, V)$, a designated candidate $c \in C$, a non-negative integer $\ell$, and a complete profile $P$ over $V$. |
| **Question:** | Is it possible to choose a subset $V' \subseteq V$, $\lvert V \setminus V' \rvert \leq \ell$ such that $c$ is (not) a winner of the election $(C, V')$ under $\mathcal{E}$ for $P$? |

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# Possible Constructive Control by Deleting Voters

$\mathcal{E}$-$X$-Possible Constructive Control by Deleting Voters

**Given:** An election $(C, V)$, a designated candidate $c \in C$, a non-negative integer $\ell$, and a partial profile $P$ according to model $X$.

**Question:** Is it possible to choose a subset $V' \subseteq V$, $|V \setminus V'| \leq \ell$ such that $c$ is a winner of the election $(C, V')$ under $\mathcal{E}$ for at least one complete profile $P' \in I(P)$?

# Possible Destructive Control by Deleting Voters

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# (*FI*, *X*)-Possible Constructive Control by Adding Voters

| | FI | GAPS | FP | TOS | PC | CEV | 1TOS | TTO | BTO | 1GAP |
|---|---|---|---|---|---|---|---|---|---|---|
| Plurality | P | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** |
| 2-Approval | P | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** |
| 3-Approval | P | **P** | **P** | | **NPC** | **P** | **P** | **P** | **P** | **P** |
| 4-Approval | NPC | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* |
| Veto | P | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** |
| 2-Veto | P | **P** | **P** | | **NPC** | **P** | **P** | **P** | **P** | **P** |
| 3-Veto | NPC | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* |

- results for full information and hardness results in italic follow from [BTT89] and [Lin11]
- results in boldface are new
- the two hardness results in boldface largely follow from [BD10], [XC08]


[BD10] N. Betzler and B. Dorn: Towards a Dichotomy for the Possible Winner Problem in Elections based on Scoring Rules In *JCSS'10*.
[BTT89] J. Bartholdi, C. Tovey, and M. Trick: How hard is it to control an election? In *Mathematical and Comp. Modelling 16(8/9)*.
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# $(X, FI)$-Possible Constructive Control by Adding Voters

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|---|---|---|---|---|---|---|---|---|---|---|
| Plurality | P | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** |
| 2-Approval | P | **P** | **P** | | *NPC* | **P** | **P** | **P** | **P** | **P** |
| 3-Approval | P | **P** | **P** | *NPC* | *NPC* | **P** | *NPC* | **P** | **P** | **P** |
| 4-Approval | NPC | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* |
| Veto | P | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** |
| 2-Veto | P | **P** | **P** | | *NPC* | **P** | **P** | **P** | **P** | **P** |
| 3-Veto | NPC | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* |

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# $(X, X)$-Possible Constructive Control by Adding Voters

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| Plurality | P | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** |
| 2-Approval | P | **P** | **P** | | *NPC* | **P** | **P** | **P** | **P** | **P** |
| 3-Approval | P | **P** | **P** | *NPC* | *NPC* | **P** | *NPC* | **P** | **P** | **P** |
| 4-Approval | NPC | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* |
| Veto | P | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** |
| 2-Veto | P | **P** | **P** | | *NPC* | **P** | **P** | **P** | **P** | **P** |
| 3-Veto | NPC | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* |

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| 2-Approval | P | **P** | **P** | | *NPC* | **P** | **P** | **P** | **P** | **P** |
| 3-Approval | NPC | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* | *NPC* |
| Veto | P | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** | **P** |
| 2-Veto | P | **P** | **P** | | *NPC* | **P** | **P** | **P** | **P** | **P** |
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# Destructive Possible Control by Adding/Deleting Voters

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  - adding and deleting voters
  - in particular, it is easy for $k$-Approval and $k$-Veto ($k \in \mathbb{N}$)

# Conclusion

- complexity of possible voter control under 9 models of partial information in $k$-Approval and $k$-Veto

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  - predominantly, models ”near” PC do not yield hardness

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- PCCAV is at least as hard for complete unregistered and incomplete registered voters than the other way around
  - compare with necessary control
    - e.g., 2-APPROVAL-$(PC, FI)/(FI, PC)$-PCCAV

# Conclusion

- complexity of possible voter control under 9 models of partial information in $k$-Approval and $k$-Veto
  - destructive and constructive
  - dichotomy results for all scoring rules (destructive variants)
- surprising results
  - for PC (canonical model), possible winner is only in $\mathrm{P}$ for Plurality and Veto (initial expectation: most problems hard)
  - predominantly, models ”near” PC do not yield hardness
- PCCAV is at least as hard for complete unregistered and incomplete registered voters than the other way around
  - compare with necessary control
    - e.g., 2-APPROVAL-$(PC, FI)/(FI, PC)$-PCCAV
- possible winner can be harder than possible control
  - 2-Approval-PC-Possible Winner is hard
  - 2-Approval-(FI,PC)-PCCAV is easy

# Directions for Future Research

- open problems

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- dichotomy result for all scoring rules (for constructive case)

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**Thank you!**