Argumentation Meets Computational Social Choice

PART I: Preservation of Semantic Properties
Verifying Semantics in Incomplete AFs
PART II: Gradual Acceptance in Argumentation
PART III: Rationalization
Discussion and Outlook

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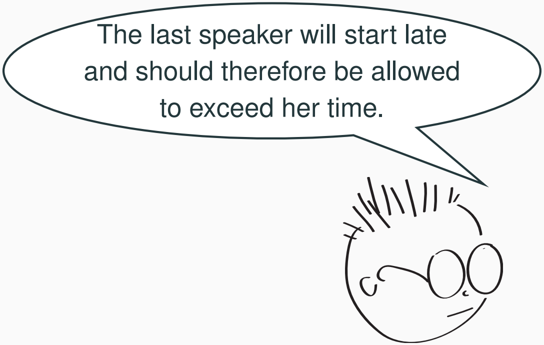
NRW-FORTSCHRITTSKOLLEG ONLINE-PARTIZIPATION

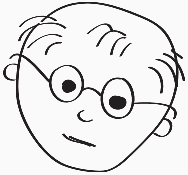
HEINRICH HEINE UNIVERSITÄT DÜSSELDORF

What is Abstract Argumentation?

Abstract Argumentation Frameworks



The last speaker will start late and should therefore be allowed to exceed her time.



It is more important to not miss coffee!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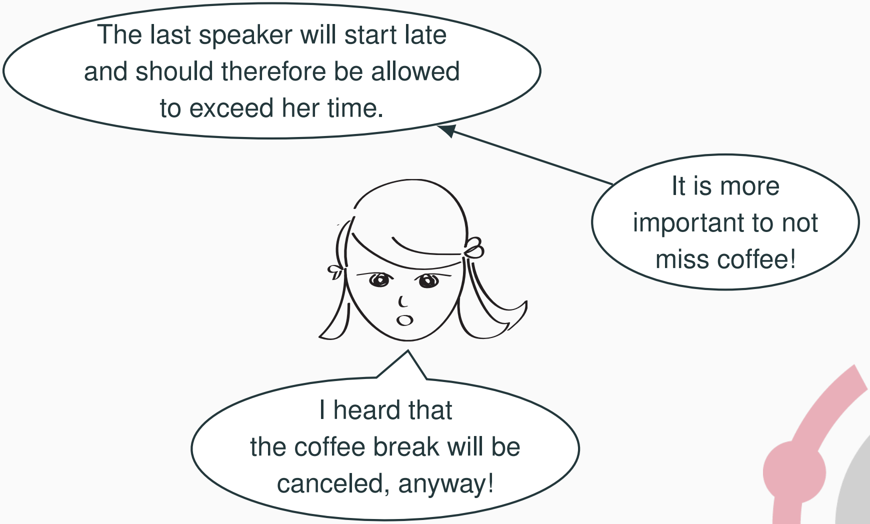
Abstract Argumentation Frameworks



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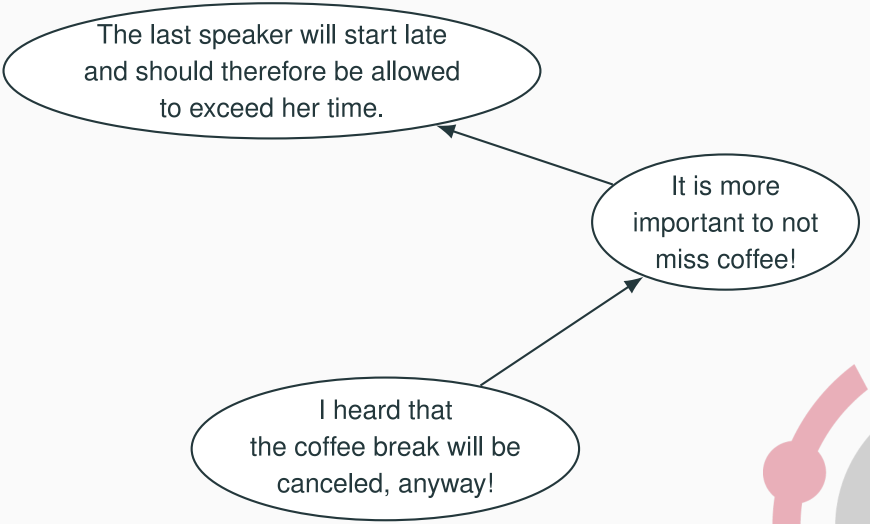

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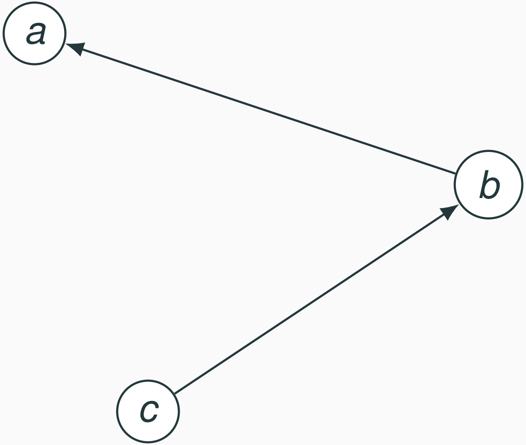

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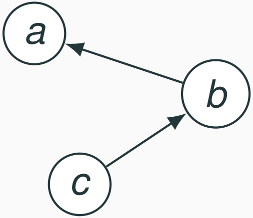
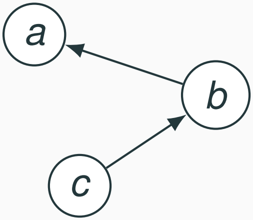


[1] P. Dung. "On the Acceptability of Arguments and its Fundamental Role in Nonmonotonic Reasoning, Logic Programming and *n*-Person Games". In: *Artificial Intelligence* 77.2 (1995), pp. 321–357.

Argumentation Framework[1]



$AF = \langle \mathcal{A}, \mathcal{R} \rangle$ with:

$\mathcal{A} = \{a, b, c\}$	arguments (nodes)
$\mathcal{R} = \{(b, a), (c, b)\}$	attacks (edges)

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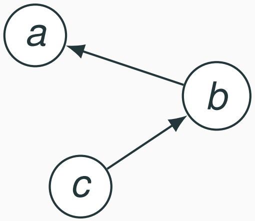
Aim: Identify sets of arguments that are acceptable



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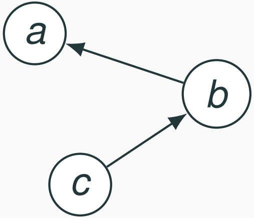

conflict-free (CF) no internal attacks

CF: $\emptyset$, $\{a\}$, $\{b\}$, $\{c\}$, $\{a, c\}$

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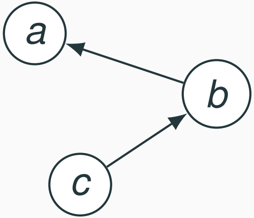
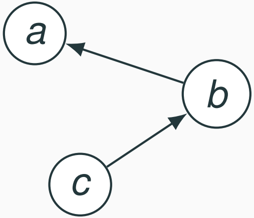


AD: $\emptyset$, $\{c\}$, $\{a, c\}$

conflict-free (CF)	no internal attacks
admissible (AD)	CF & defends all members

Aim: Identify sets of arguments that are acceptable



CP extension: $\{a, c\}$

conflict-free (CF)	no internal attacks
admissible (AD)	CF & defends all members
complete (CP)	AD & does not defend non-members

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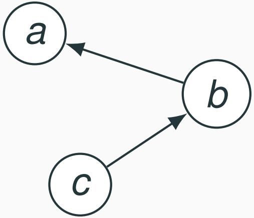
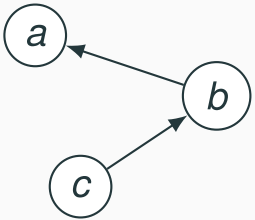


GR extension: $\{a, c\}$

conflict-free (CF)	no internal attacks
admissible (AD)	CF & defends all members
complete (CP)	AD & does not defend non-members
grounded (GR)	minimal CP

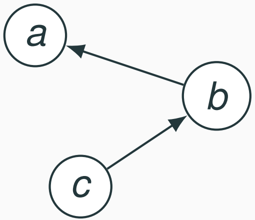
Aim: Identify sets of arguments that are acceptable



PR extension: $\{a, c\}$

conflict-free (CF)	no internal attacks
admissible (AD)	CF & defends all members
complete (CP)	AD & does not defend non-members
grounded (GR)	minimal CP
preferred (PR)	inclusion-maximal AD

Aim: Identify sets of arguments that are acceptable



ST extension: $\{a, c\}$

conflict-free (CF)	no internal attacks
admissible (AD)	CF & defends all members
complete (CP)	AD & does not defend non-members
grounded (GR)	minimal CP
preferred (PR)	inclusion-maximal AD
stable (ST)	CF & attacks all non-members

Mr. & Mrs. Smith – Shooting Scene

Stability in Argumentation May Change over Time

Mr. & Mrs. Smith – Attacking Each Other

Relations Among Semantics

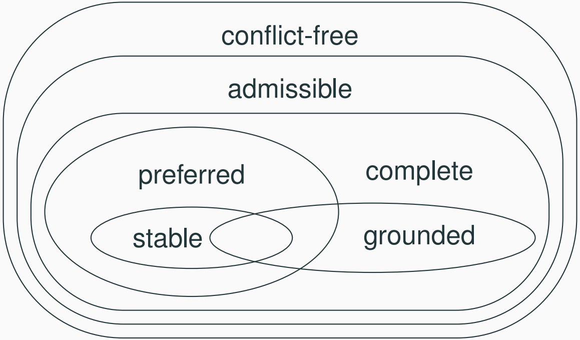


Figure 1: Relations among various semantics for sets of arguments

An Example

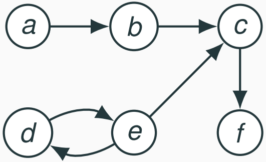
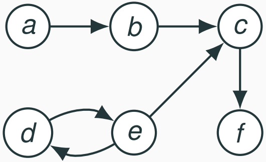


Figure 2: An argumentation framework

- $\{a, c, d\}$, $\{a, d, f\}$, $\{a, e, f\}$, $\{b, d, f\}$, and $\{b, e, f\}$ are each **conflict-free**

An Example



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- $\{a, c, d\}$, $\{a, d, f\}$, $\{a, e, f\}$, $\{b, d, f\}$, and $\{b, e, f\}$ are each **conflict-free**
- none of $\{a, d, f\}$, $\{b, d, f\}$, and $\{b, e, f\}$ is **admissible** ($\{a, d, f\}$ does not defend f against c's attack and the other two sets do not defend b against a's attack)

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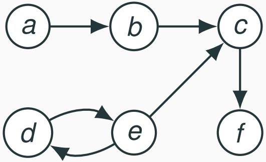

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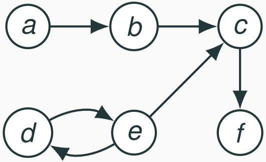
- $\{a, c, d\}$ and $\{a, e, f\}$ are
    - **admissible** (they defend each of their attacked arguments),
    - **complete** (they also contain each argument they defend),
    - **preferred** (adding any other argument to them would violate conflict-freeness), and
    - even **stable** (they attack each outside argument)

An Example



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  - even **stable** (they attack each outside argument)
- $\{a\}$ is the **grounded** extension

Preservation of Semantic Properties

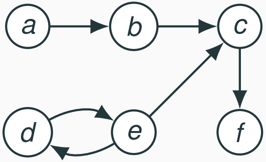
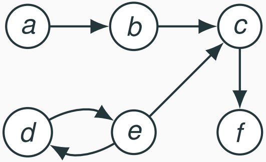


Figure 2:  and  report this AF

Aggregation Rules and Axioms



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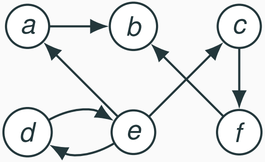

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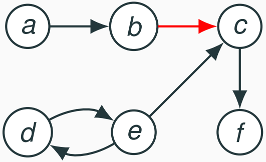

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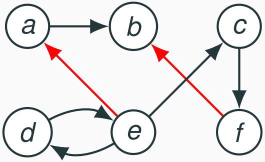

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How can we aggregate their individual views so as to reach—as a consensus—a single AF acceptable to the group as a whole?

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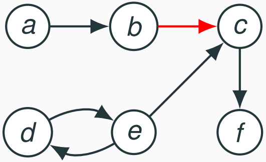

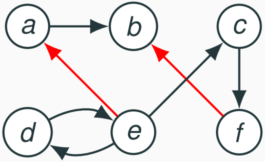

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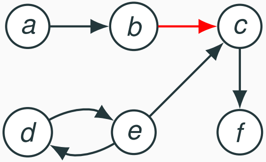

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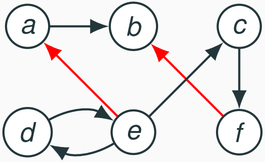

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$\Longrightarrow$ **Use COMSOC methods!**

What is COMSOC?

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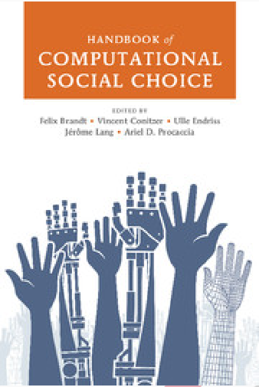
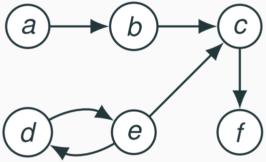


www.cambridge.org/files/5015/1077/0783/9781107060432AR_final3.pdf

Aggregation Rules and Axioms



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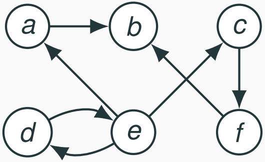
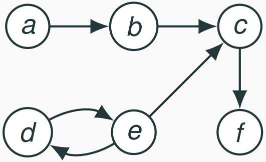


Figure 3:  reports another AF

Definition (Chen & Endriss[a])

Let $\mathcal{A}$ be the set of arguments. An *aggregation rule* R maps any given profile $\mathcal{P} = (\mathcal{R}_1, \ldots, \mathcal{R}_n)$ of n agents' individual attack relations on $\mathcal{A}$ to a single attack relation $R(\mathcal{P}) = \mathcal{R}$ on $\mathcal{A}$.

[a] W. Chen and U. Endriss. "Preservation of Semantic Properties during the Aggregation of Abstract Argumentation Frameworks". In: *Proc. TARK'17*. July 2017, pp. 118–129.



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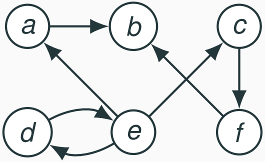

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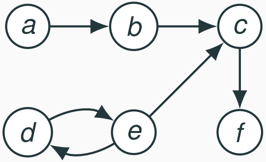
Majority rule:
An attack is in the outcome if and only if a weak majority of agents support it.

Aggregation Rules and Axioms



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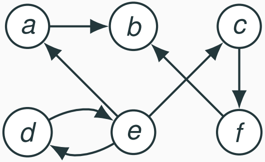

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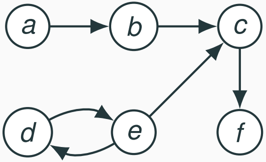

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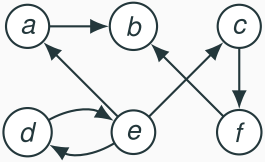

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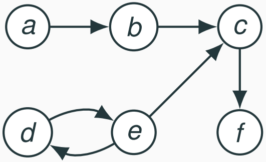
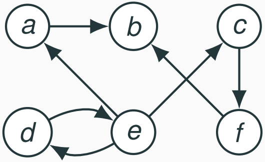
Quota rule with quota q: Accept exactly those attacks that have at least q supporters.





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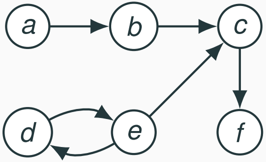

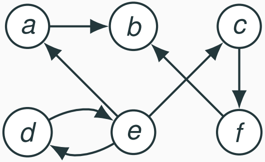

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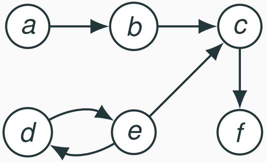

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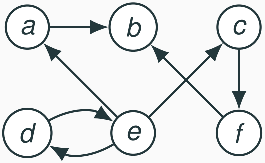

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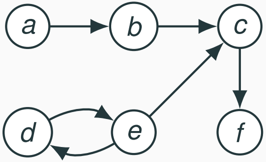

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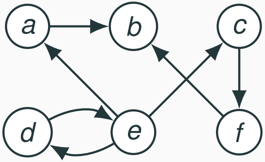

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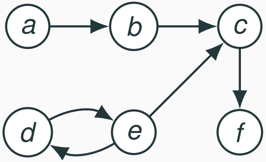
Oligarchic rule: For any coalition $C \neq \emptyset$ of agents, accept exactly those attacks that are supported by all agents in C (neglecting the other agents' opinions).



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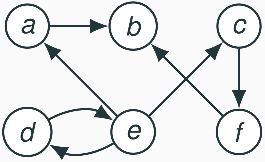

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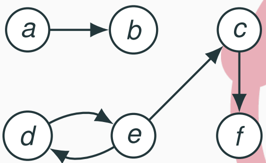
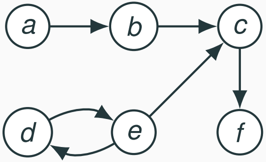
In the example above, if $C = \{$ ,  $\}$, we get:



Each member of C has *veto powers*.

Aggregation Rules and Axioms



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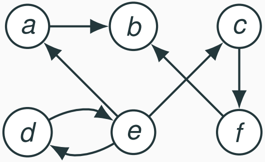

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Special cases:

- **unanimity rule** (if $C =$ all agents)
- **dictatorship** (if $C =$ singleton)

Aggregation Rules and Axioms

Chen & Endriss consider the following semantic properties (or axioms).

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($\mathbb{A}$) *anonymous* if the order of individual attack relations does not matter for R;

($\mathbb{N}$) *neutral* if attacks are treated equally by R whenever they have the same supporters;

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- ($\mathbb{U}$) *unanimous* if R must accept an attack whenever it is supported by all agents;
- ($\mathbb{G}$) *grounded* if R can accept an attack only if it is supported by at least one agent.

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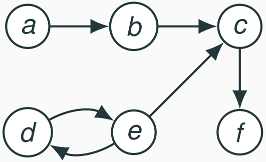
2. *The quota rules are also anonymous.*
   In fact, the quota rules are the only aggregation rules that satisfy all six axioms (adapting a result by Dietrich & List[b] from judgment aggregation).

[a] W. Chen and U. Endriss. “Preservation of Semantic Properties during the Aggregation of Abstract Argumentation Frameworks”. In: *Proc. TARK’17*. July 2017, pp. 118–129.
[b] F. Dietrich and C. List. “Judgment Aggregation by Quota Rules: Majority Voting Generalized”. In: *Journal of Theoretical Politics* 19.4 (2007), pp. 391–424.



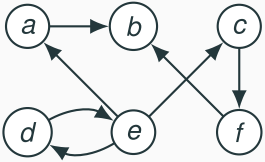


Figure 2:  and  report this AF

Figure 3:  reports another AF

Recall that $\{a, c, d\}$ and $\{a, e, f\}$ are stable extensions for the AF in Figure 2.

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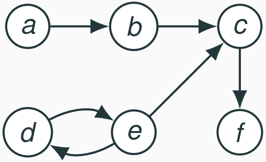

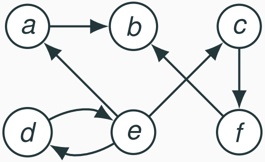

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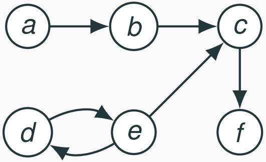

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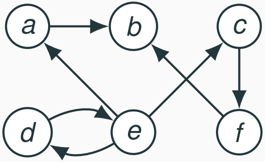

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> **Collective rationality:** A rule aggregating these two argumentation frameworks should output an *AF* in which $\{a, c, d\}$ still is stable, i.e., *the rule should preserve stability*. Similar so for other semantics.

Which Semantic Properties Can Be Preserved?

Definition (Chen & Endriss[a])

For an $AF = \langle \mathcal{A}, \mathcal{R} \rangle$, by *AF-property* (such as stability) we mean the set of all attack relations on $\mathcal{A}$ that satisfy this property.

An aggregation rule R *preserves an AF-property* Π if for each profile $\mathcal{P} = (\mathcal{R}_1, \ldots, \mathcal{R}_n)$, if $\mathcal{R}_i$ is in Π for all i, then so is $R(\mathcal{P})$.

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Theorem (Chen & Endriss[a])

For four agents or more, if Π is the property of accepting arguments under either the complete, preferred, stable, or grounded semantics then any $R \in \mathbb{N} \cap \mathbb{I} \cap \mathbb{U} \cap \mathbb{G}$ preserving Π must be a dictatorship.

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5. *When there are at least as many arguments as there are agents, under each rule in $\mathbb{N} \cap \mathbb{I}$ that preserves acyclicity or nonemptiness of the grounded extension, at least one agent must have veto powers.*

Verifying Semantics in Complete AFs

Computational complexity of verifying extensions

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s-VERIFICATION	
Given:	An argumentation framework $\langle \mathcal{A}, \mathcal{R} \rangle$ and a subset $S \subseteq \mathcal{A}$.
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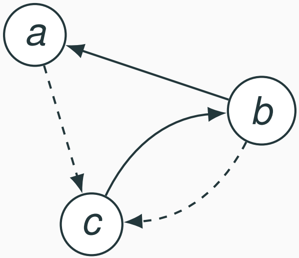
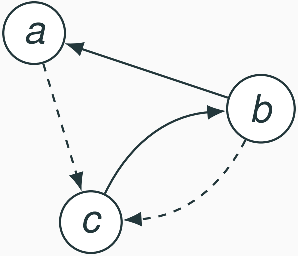
- PR-VERIFICATION is coNP-complete.
- For all other semantics considered here, VERIFICATION is in P.

Incomplete Knowledge in Abstract Argumentation



Dashed edges represent uncertain attacks

Attack-incomplete Argumentation Frameworks



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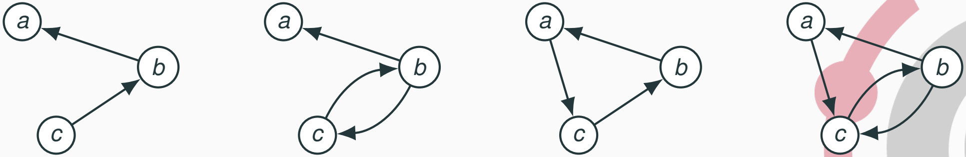
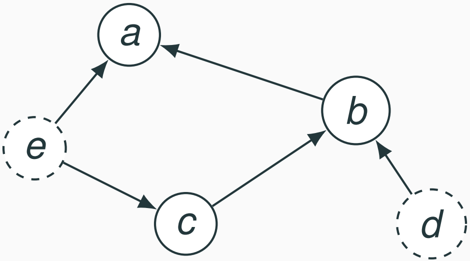


Argument-incomplete Argumentation Frameworks



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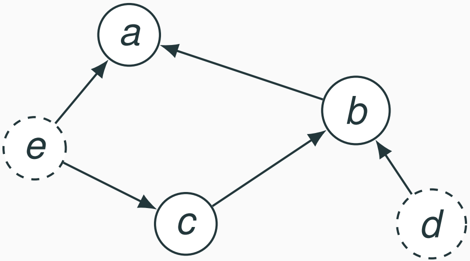

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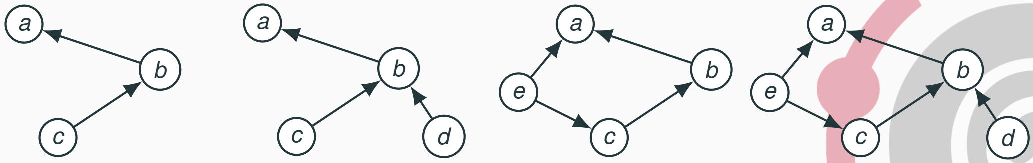

Possible and Necessary Verification

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Possible and Necessary Winner[2]

$\mathcal{E}$-WINNER:
Given an election and a candidate c, is c an $\mathcal{E}$ winner of it?

[2] K. Konczak and J. Lang. "Voting Procedures with Incomplete Preferences". In: *Proceedings of the Multidisciplinary IJCAI-05 Workshop on Advances in Preference Handling*. 2005, pp. 124–129.

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Possible and Necessary Winner – Analogues Have also Been Studied in

- **voting** by, e.g., Xia and Conitzer[3], Chevaleyre et al.[4], and Baumeister et al.[5];
- **fair division** by Bouveret et al.[6] and Baumeister et al.[7];
- **algorithmic game theory** by Lang et al.[8]; and
- **judgment aggregation** by Baumeister et al.[9].

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[3] L. Xia and V. Conitzer. "Determining Possible and Necessary Winners Given Partial Orders". In: *Journal of Artificial Intelligence Research* 41 (2011), pp. 25–67.

[4] Y. Chevaleyre et al. "New Candidates Welcome! Possible Winners with respect to the Addition of New Candidates". In: *Mathematical Social Sciences* 64.1 (2012), pp. 74–88.

[5] D. Baumeister et al. "The Possible Winner Problem with Uncertain Weights". In: *Proc. ECAI'12*. IOS Press, 2012, pp. 133–138.

[6] S. Bouveret, U. Endriss, and J. Lang. "Fair Division under Ordinal Preferences: Computing Envy-Free Allocations of Indivisible Goods". In: *Proc. ECAI'10*. IOS Press, 2010, pp. 387–392.

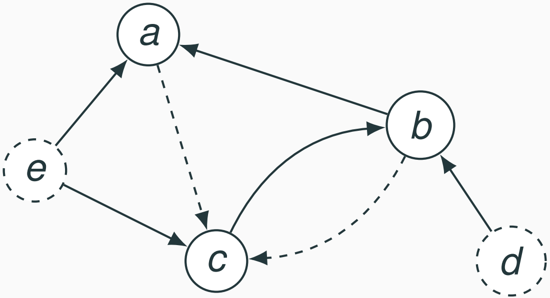
[7] D. Baumeister et al. "Positional Scoring-Based Allocation of Indivisible Goods". In: *Journal of Autonomous Agents and Multi-Agent Systems* 31.3 (2017), pp. 628–655.

[8] J. Lang et al. "Representing and Solving Hedonic Games with Ordinal Preferences and Thresholds". In: *Proc. AAMAS'15*. IFAAMAS, 2015.

[9] D. Baumeister et al. "Complexity of Manipulation and Bribery in Judgment Aggregation for Uniform Premise-Based Quota Rules". In: *Mathematical Social Sciences* 76 (2015), pp. 19–30.

Verifying Semantics in Incomplete AFs

General Model of Incomplete Argumentation Frameworks



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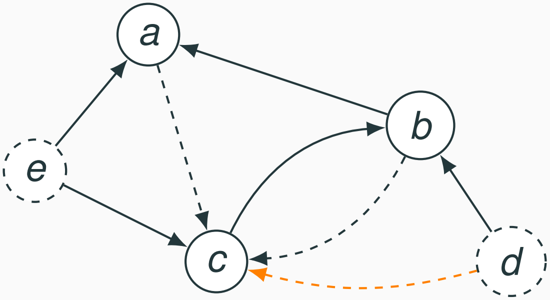

Complexity Results

s	VER	ATTINCPV	ATTINCNV	ARGINCPV	ARGINCNV	INCPV	INCNV
CF	in P♠	in P★	in P★	in P♦	in P♦	in P♡	in P♡
AD	in P♠	in P▲	in P★	NP-c.♦	in P♡	NP-c.♡	in P♡
ST	in P♠	in P▲	in P▲	NP-c.♦	in P♡	NP-c.♡	in P♡
CP	in P♠	in P▲	in P▲	NP-c.♦	in P♡	NP-c.♡	in P♡
GR	in P♠	in P▲	in P▲	NP-c.♦	in P♡	NP-c.♡	in P♡
PR	coNP-c.♣	NP^{NP}-c.♡	coNP-c.▲	NP^{NP}-c.♡	coNP-c.♦	NP^{NP}-c.♡	coNP-c.♡

♠[10], ♣[11], ★[12], ▲[13], ♦[14], ♡[15]

[10] P. Dung. "On the Acceptability of Arguments and its Fundamental Role in Nonmonotonic Reasoning, Logic Programming and *n*-Person Games". In: *Artificial Intelligence* 77.2 (1995), pp. 321–357.

[11] Y. Dimopoulos and A. Torres. "Graph Theoretical Structures In Logic Programs and Default Theories". In: *Theoretical Computer Science* 170.1 (1996), pp. 209–244.

[12] S. Coste-Marquis et al. "On the Merging of Dung's Argumentation Systems". In: *Artificial Intelligence* 171.10 (2007), pp. 730–753.

[13] D. Baumeister, D. Neugebauer, and J. Rothe. "Verification in Attack-Incomplete Argumentation Frameworks". In: *Proc. ADT'15*. Springer-Verlag *LNAI*, 2015, pp. 341–358.

[14] D. Baumeister, J. Rothe, and H. Schadrack. "Verification in Argument-Incomplete Argumentation Frameworks". In: *Proc. ADT'15*. Springer-Verlag *LNAI*, 2015, pp. 359–376.

[15] D. Baumeister et al. "Complexity of Verification in Incomplete Argumentation Frameworks". In: *Proc. AAAI'18*. AAAI Press, 2018, pp. 1753–1760.