TECHNISCHE UNIVERSITÄT DRESDEN

Artificial Intelligence, Computational Logic

ABSTRACT ARGUMENTATION

Expressiveness of Argumentation Frameworks

*slides adapted from Thomas Linsbichler and Stefan Woltran

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Dresden, 15th September 2015

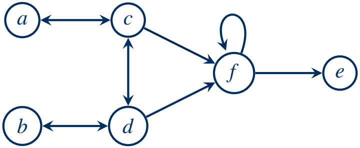
DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

Introduction

- Argumentation has become a major topic in AI research
- Gives answers to "how assertions are proposed, discussed, and resolved in the context of issues upon which several diverging opinions may be held" [Bench-Capon and Dunne, 2007]
- Dung's Abstract Argumentation Frameworks [Dung, 1995] conceal the concrete contents of arguments; only consider the relation between them
- Heavy research on argumentation semantics, i.e. rules for identifying sets of acceptable arguments
- Now we consider a structural analysis of their capabilities [Dunne et al., 2013, Dunne et al., 2014, Dunne et al., 2015]

Motivation

Example



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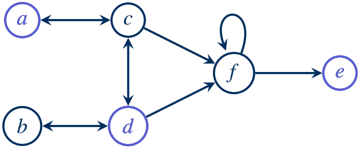

$pref(F) = \{\{a, d, e\},$

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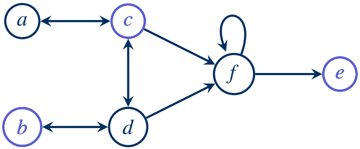

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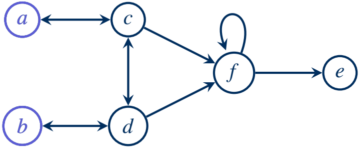

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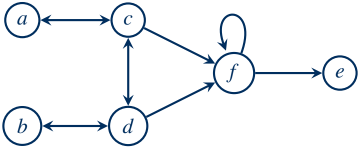

$pref(F) = \{\{a, d, e\}, \{b, c, e\}, \{a, b\}\}$

Natural Questions

- How to adapt the AF to get $\{a, b, e\} \in pref(F)$, but $\{a, b\} \notin pref(F)$?
- How to adapt the AF to get $\{a, b, d\} \in pref(F)$, but $\{a, b\} \notin pref(F)$?

Outline

Main Contributions

We investigate characterizations of the signatures

$$\Sigma_\sigma = \{\sigma(F) \mid F \text{ is an AF}\}$$

for various important semantics σ (conflict-free, naive, stable, admissible, preferred [Dung, 1995], stage [Verheij, 1996], semi-stable [Caminada, 2006]).
We approach signatures via

- necessary properties for extensions $\mathbb{S} \in \Sigma_\sigma$;
- realizability: given a set $\mathbb{S}$ of extensions, is there an AF F with $\sigma(F) = \mathbb{S}$.
    - Constructions of canonical argumentation-frameworks.

Outline

Realizability

Definition

Given a semantics σ, an extension-set $\mathbb{S} \subseteq 2^{\mathfrak{A}}$ is called σ-realizable if there exists an AF F such that $\sigma(F) = \mathbb{S}$. $\mathbb{S}$ is then realized by F under σ.

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Definition

Given an extension-set $\mathbb{S}$,

- $\text{Args}_{\mathbb{S}} = \bigcup_{S \in \mathbb{S}} S$, and
- $\text{Pairs}_{\mathbb{S}} = \{(a, b) \mid \exists S \in \mathbb{S} : \{a, b\} \subseteq S\}$.

Outline

Results on Conflict-free Sets

Theorem

For each AF $F = (A, R)$ it holds that $cf(F)$ is a non-empty, downward-closed and tight extension-set.

An extension-set $\mathbb{S}$ is

- downward-closed, if $\mathbb{S} = \text{dcl}(\mathbb{S}) := \{S' \subseteq S \mid S \in \mathbb{S}\}$ and
- tight, if $\forall S \in \mathbb{S} \, \forall a \in \text{Args}_{\mathbb{S}} \; (S \cup \{a\}) \notin \mathbb{S} \Rightarrow (\exists s \in S : \; (a, s) \notin \text{Pairs}_{\mathbb{S}})$.

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Example

- $\mathbb{S} = \{\emptyset, \{a\}, \{b\}, \{c\}, \{a, b\}, \{b, c\}\}$ is tight.
- $\mathbb{T} = \{\emptyset, \{a\}, \{b\}, \{c\}, \{a, b\}, \{b, c\}, \{a, c\}\}$ is not tight, as $(\{a, b\} \cup \{c\}) \notin \mathbb{T}$, but $(a, c), (b, c) \in \text{Pairs}_{\mathbb{T}}$.

Intuition behind tight: Limitation of the multitude of incomparable extensions.

Results on Conflict-free Sets

Canonical Argumentation Framework

Given an extension-set $\mathbb{S} \subseteq 2^{\mathfrak{A}}$, we define

$$F^{cf}_{\mathbb{S}} = \big(\mathsf{Args}_{\mathbb{S}}, (\mathsf{Args}_{\mathbb{S}} \times \mathsf{Args}_{\mathbb{S}}) \setminus \mathsf{Pairs}_{\mathbb{S}}\big).$$

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Theorem

For each non-empty, downward-closed, and tight extension-set $\mathbb{S}$, it holds that $cf(F^{cf}_{\mathbb{S}}) = \mathbb{S}$.

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Canonical Argumentation Framework

Given an extension-set $\mathbb{S} \subseteq 2^{\mathfrak{A}}$, we define

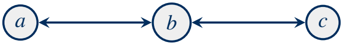
$$F_{\mathbb{S}}^{cf} = (\mathsf{Args}_{\mathbb{S}}, (\mathsf{Args}_{\mathbb{S}} \times \mathsf{Args}_{\mathbb{S}}) \setminus \mathsf{Pairs}_{\mathbb{S}}).$$

Theorem

For each non-empty, downward-closed, and tight extension-set $\mathbb{S}$, it holds that $cf(F_{\mathbb{S}}^{cf}) = \mathbb{S}$.

Example

$F_{\mathbb{S}}^{cf}$ with $\mathbb{S} = \{\emptyset, \{a\}, \{b\}, \{c\}, \{a, c\}\}$:



Outline

Results on Stable Semantics

Theorem

For each AF $F = (A, R)$, $\text{stb}(F)$ is an incomparable and tight extension-set.

An extension-set $\mathbb{S}$ is

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Theorem

For each incomparable and tight extension-set $\mathbb{S}$, there exists an AF F such that $\mathsf{stb}(F) = \mathbb{S}$.

Idea: Adapt the canonical argumentation framework (for $\mathbb{S} \neq \emptyset$) to:

$$F_{\mathbb{S}}^{\mathsf{st}} = \left(\mathsf{Args}_{\mathbb{S}} \cup \{\bar{E} \mid E \in \mathbb{X}\}, R_{\mathbb{S}}^{\mathsf{st}}\right), \quad \text{where}$$

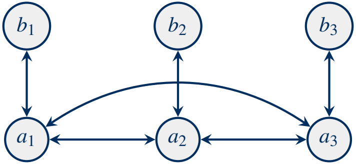
$$\begin{aligned} \mathbb{X} &= \mathsf{stb}(F_{\mathbb{S}}^{cf}) \setminus \mathbb{S} \\ R_{\mathbb{S}}^{\mathsf{st}} &= ((\mathsf{Args}_{\mathbb{S}} \times \mathsf{Args}_{\mathbb{S}}) \setminus \mathsf{Pairs}_{\mathbb{S}}) \cup \\ &\quad \{(\bar{E}, \bar{E}), (a, \bar{E}) \mid E \in \mathbb{X}, a \in \mathsf{Args}_{\mathbb{S}} \setminus E\} \end{aligned}$$

Then $\mathsf{stb}(F_{\mathbb{S}}^{\mathsf{st}}) = \mathbb{S}$.

Results on Stable Semantics

Example

$F_{\mathbb{S}}^{\mathsf{st}}$ with $\mathbb{S} = \{\{a_1, b_2, b_3\}, \{a_2, b_1, b_3\}, \{a_3, b_1, b_2\}\}$:



- $\mathbb{X} = \mathsf{stb}(F_{\mathbb{S}}^{cf}) \setminus \mathbb{S} = \{\{b_1, b_2, b_3\}\}$

Results on Stable Semantics

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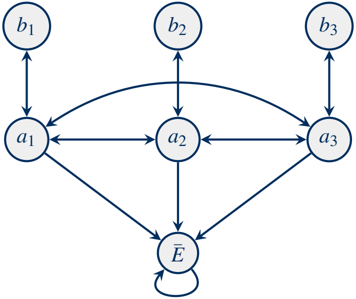

- $\mathbb{X} = \mathsf{stb}(F_{\mathbb{S}}^{cf}) \setminus \mathbb{S} = \{\{b_1, b_2, b_3\}\}$

Outline

Results on Preferred Semantics

Definition

Given an extension-set $\mathbb{S}$, we call $\mathbb{S}$ pref-closed if for each $A, B \in \mathbb{S}$ with $A \neq B$, there exist $a, b \in (A \cup B)$ such that $(a, b) \notin \text{Pairs}_{\mathbb{S}}$.

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- $\mathbb{T} = \{\{a, d, e\}, \{b, c, e\}, \{a, b, d\}\}$ is not pref-closed, since $\forall s_1, s_2 \in (\{a, d, e\} \cup \{a, b, d\})$ it holds that $(s_1, s_2) \in \text{Pairs}_{\mathbb{T}}$.

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Theorem

For each AF $F = (A, R)$, $\mathit{pref}(F)$ is a non-empty and pref-closed extension-set.

Results on Preferred Semantics

Defense Formula

Given extension-set $\mathbb{S}$ and $a \in \mathsf{Args}_{\mathbb{S}}$, the defense-formula $\mathsf{Def}_a^{\mathbb{S}} = \top$ if $\{a\} \in \mathbb{S}$, otherwise

$$\mathsf{Def}_a^{\mathbb{S}} = \bigvee_{S \in \mathbb{S} s.t. a \in S} \quad \bigwedge_{b \in S \setminus \{a\}} b$$

$\mathsf{Def}_a^{\mathbb{S}}$ converted to conjunctive normal form: CNF-defense-formula $\mathsf{CDef}_a^{\mathbb{S}}$

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Let $\mathbb{S} = \{\{b, c\}, \{a, c, d\}\}$.

$$\mathsf{Def}_a^{\mathbb{S}} = c \wedge d \qquad \mathsf{CDef}_a^{\mathbb{S}} = \{\{c\}, \{d\}\}$$

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\text{Def}_d^{\mathbb{S}} &= a \wedge c & \text{CDef}_d^{\mathbb{S}} &= \{\{a\}, \{c\}\}
\end{aligned}$$

Results on Preferred Semantics

Canonical Defense-Argumentation-Framework

Given an extension-set $\mathbb{S}$, we define $F_{\mathbb{S}}^{\mathsf{def}} = (A_{\mathbb{S}}^{\mathsf{def}}, R_{\mathbb{S}}^{\mathsf{def}})$ with

$$A_{\mathbb{S}}^{\mathsf{def}} = A_{\mathbb{S}}^{cf} \cup \bigcup_{a \in \mathsf{Args}_{\mathbb{S}}} \{\alpha_{a,\gamma} \mid \gamma \in \mathsf{CDef}_a^{\mathbb{S}}\}, \text{ and}$$

$$R_{\mathbb{S}}^{\mathsf{def}} = R_{\mathbb{S}}^{cf} \cup \bigcup_{a \in \mathsf{Args}_{\mathbb{S}}} \{(b, \alpha_{a,\gamma}), (\alpha_{a,\gamma}, \alpha_{a,\gamma}), (\alpha_{a,\gamma}, a) \mid \gamma \in \mathsf{CDef}_a^{\mathbb{S}}, b \in \gamma\}.$$

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Example: Let $\mathbb{S} = \{\{b, c\}, \{a, c, d\}\}$.

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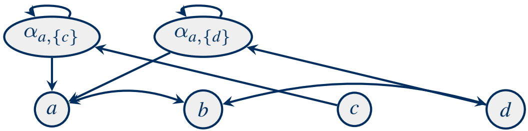

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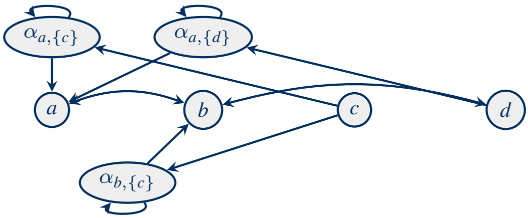

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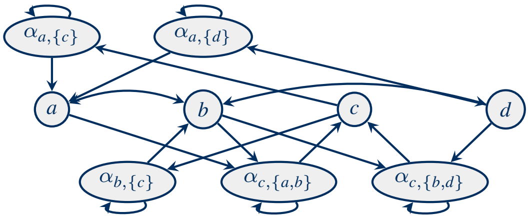

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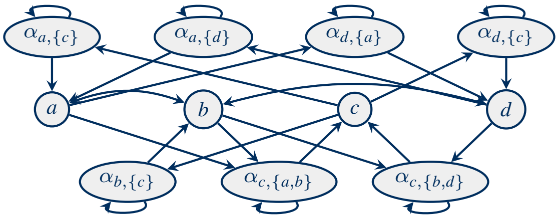
Example: Let $\mathbb{S} = \{\{b, c\}, \{a, c, d\}\}$. $\mathsf{CDef}_d^{\mathbb{S}} = \{\{a\}, \{c\}\}$



Results on Preferred Semantics

Theorem

For each non-empty and pref-closed extension-set $\mathbb{S}$, it holds that $\mathit{pref}(F_{\mathbb{S}}^{\mathsf{def}}) = \mathbb{S}$.

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Example

$\mathbb{S} = \{\{a,d,e\},\{b,c,e\},\{a,b\}\}$ is pref-closed and therefore $\mathit{pref}(F_{\mathbb{S}}^{\text{def}}) = \mathbb{S}$. Since $\mathbb{S}$ is not tight, $\mathbb{S}$ is not realizable under naive and stable semantics.

$\mathbb{T} = \{\{a,d,e\},\{b,c,e\},\{a,b,d\}\}$ is not pref-closed, therefore $\mathbb{T}$ is not realizable under preferred semantics.

Outline

Signatures

Theorem

$$\Sigma_{cf} = \{\mathbb{S} \neq \emptyset \mid \mathbb{S} \text{ is downward-closed and tight}\}$$

$$\Sigma_{naive} = \{\mathbb{S} \neq \emptyset \mid \mathbb{S} \text{ is incomparable and } \mathsf{dcl}(\mathbb{S}) \text{ is tight}\}$$

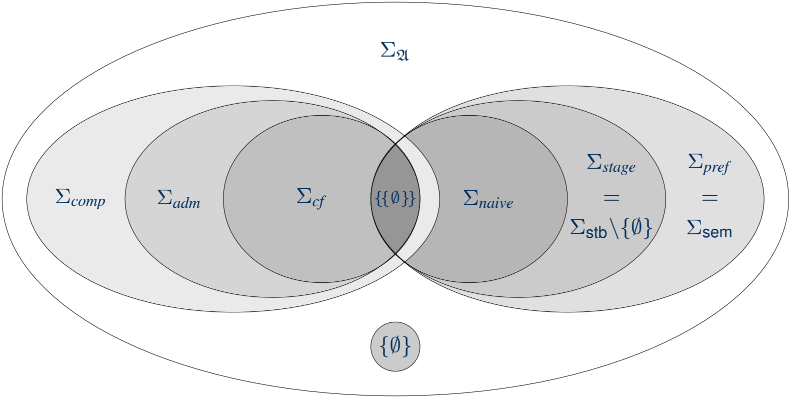
$$\Sigma_{\mathsf{stb}} = \{\mathbb{S} \mid \mathbb{S} \text{ is incomparable and tight}\}$$

$$\Sigma_{stage} = \{\mathbb{S} \neq \emptyset \mid \mathbb{S} \text{ is incomparable and tight}\}$$

$$\Sigma_{pref} = \{\mathbb{S} \neq \emptyset \mid \mathbb{S} \text{ is pref-closed}\}$$

$$\Sigma_{semi} = \{\mathbb{S} \neq \emptyset \mid \mathbb{S} \text{ is pref-closed}\}$$

Relations between Signatures



$\Sigma_{\mathfrak{A}} = \{\mathbb{S} \subseteq 2^{\mathfrak{A}} \mid \mathsf{Args}_{\mathbb{S}} \text{ is finite}\}$

Outline

Intertranslatability of Semantics

Motivation

- Advanced engine for semantics σ' available but we want to evaluate F wrt. semantics σ
- Transform F into F' s.t. evaluating F' wrt. σ' allows for an easy reconstruction of σ-extensions of F
- If Transformation is efficiently computable, this is a more successful approach than implementing a distinguished algorithm for σ

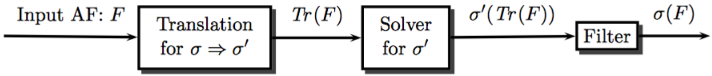
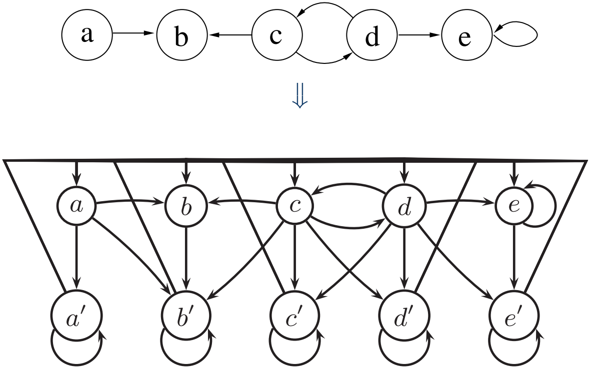


Figure : Solver for a semantic σ, using a translation for $\sigma \Rightarrow \sigma'$

Translating Semantics [Dvořák and Woltran, 2011]

Translation τ for embedding stable into admissible / complete semantics.

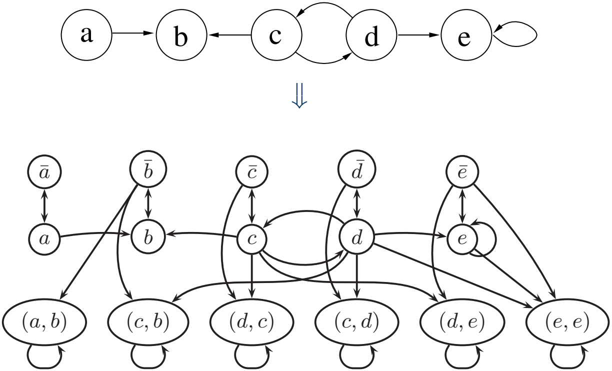


Result:

For each AF F, $stable(F) = \sigma(\tau(F)) \setminus \{\emptyset\}$ with $\sigma \in \{adm, comp\}$.

Translating Semantics

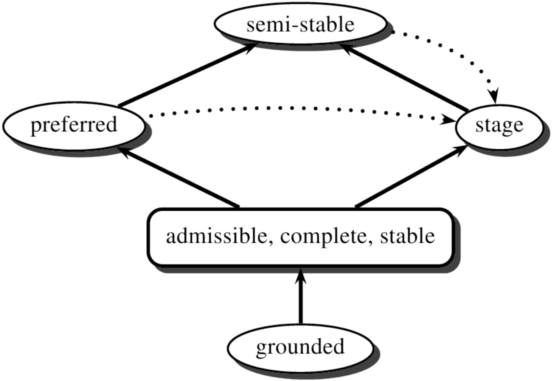
Translating admissible to stable / semi-stable/ stage semantics.



Result:

Tr_α is a faithful translation for $adm \Rightarrow stable$.

Translating Semantics (big picture)



Intertranslatability w.r.t. (weakly) faithful translations

Conclusions

For all main semantics we show properties, which always hold for extension-sets, and conditions for realizability. As they coincide we get exact characterizations of their signatures.

Results on realizability under the various semantics can be used for:

- Checking realizability as first step when considering dynamics.
- Constructions of canonical argumentation frameworks.

Characterizations of signatures of semantics tell us about the expressiveness of semantics.

- Comparison of expressiveness.
- Pruning of search-space possible in implementations of argumentation semantics.

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