Expressibility of Argumentation Frameworks and its Relation to the Dynamics of Argumentation

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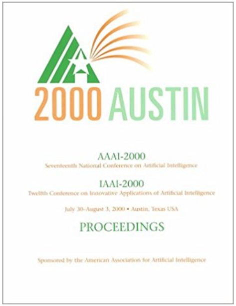
Joint work with

Martin Diller, Paul Dunne, Wolfgang Dvořák, Adrian Haret, Thomas Linsbichler, Stefan Rümmele.


2000 AUSTIN
AAAI-2000
Seventeenth National Conference on Artificial Intelligence
IAAI-2000
Twelfth Conference on Innovative Applications of Artificial Intelligence
July 30–August 3, 2000 • Austin, Texas USA
PROCEEDINGS
Sponsored by the American Association for Artificial Intelligence


IJCAR 2001
International Joint Conference
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June 18–23, 2001, Siena, Italy
CADE + FTP + TABLEAUX
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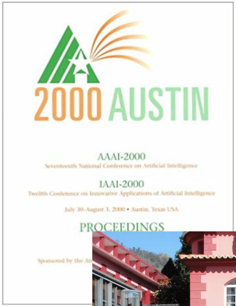
Prologue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MADEIRA WORKSHOPS
BELIEF REVISION & ARGUMENTATION

Prologue

Dynamics of (Abstract) Argumentation

- Change in Argumentation Frameworks:
  - Boella, Kaci, van der Torre; Bisquert, Cayrol, Dupin de Saint-Cyr, Lagasquie-Schiex; Baroni, Giacomin, Liao; Alfano, Greco, Parisi; Coste-Marquis, Devred, Konieczny, Lagasquie-Schiex, Marquis; Doutre, Herzig, Perussel.
- Enforcement:
  - Baumann; Coste-Marquis, Konieczny, Mailly, Marquis; Järvisalo, Niskanen, Wallner; Kontarinis, Bonzon, Maudet, Perotti, van der Torre, Villata; Nouioua, Würbel; Booth, Kaci, Rienstra, van der Torre.
- AGM Belief Change applied to Argumentation Frameworks:
  - Baumann and Brewka; Coste-Marquis, Konieczny, Mailly, Marquis.
  - Dupin de Saint-Cyr, Bisquert, Cayrol, Lagasquie-Schiex.
  - Dellobelle, Haret, Konieczny, Mailly, Rossit, W.
  - Moguillansky, Simari.

Outline

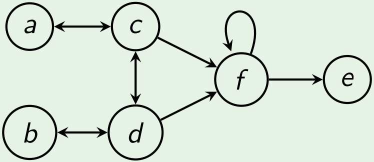
- Expressibility of Argumentation Frameworks
- Revision of Argumentation Frameworks
- Shifting from an Argument-Centric to a Claim-Centric View

Expressibility of AFs

Argumentation Frameworks

. . . abstract away from everything but attacks (calculus of opposition)

Example



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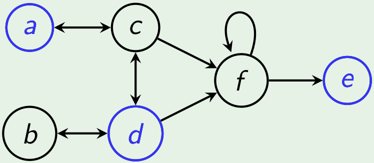

$naive(F) = \{\{a, d, e\},$

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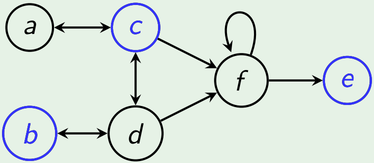

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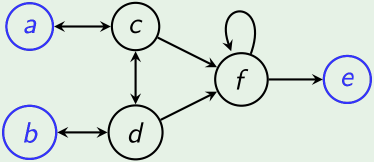

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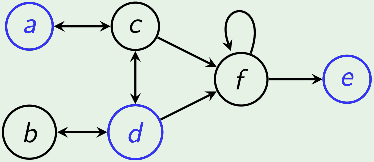

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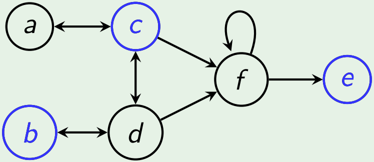

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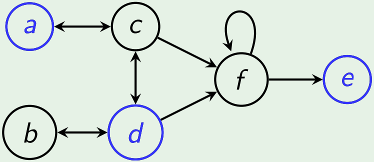

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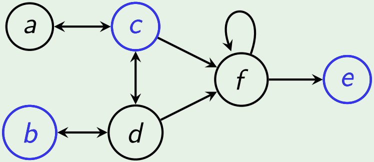

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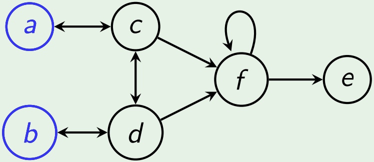

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Expressibility of AFs

Definition

The signature of a semantics σ is defined as

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

Thus signatures capture all what a semantics can express.

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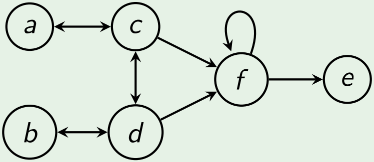

- $\mathcal{S} = \{\{a, d, e\}, \{b, c, e\}, \{a, b\}\} \in \Sigma_{pref}$
- Question: Can we change the AF, such that $\mathcal{S}' = \{\{a, d, e\}, \{b, c, e\}, \{a, b, d\}\}$ become preferred extensions; in other words does $\mathcal{S}' \in \Sigma_{pref}$ hold?
- $\mathcal{S} \in \Sigma_{stb}$?

Expressibility of AFs

Some Notation

Call a set of sets of arguments $\mathcal{S}$ extension-set. Moreover,

- $Args_{\mathcal{S}} = \bigcup_{S \in \mathcal{S}} S$
- $Pairs_{\mathcal{S}} = \{\{a, b\} \mid \exists E \in \mathcal{S} \text{ with } \{a, b\} \subseteq E\}$

Definition

An extension-set $\mathcal{S}$ is called conflict-sensitive if for each $A, B \in \mathcal{S}$ such that $A \cup B \notin \mathcal{S}$ it holds that $\exists a, b \in A \cup B : \{a, b\} \notin Pairs_{\mathcal{S}}$.

Example

Given $\mathcal{S} = \{\{a, d, e\}, \{b, c, e\}, \{a, b\}\}$:
$Args_{\mathcal{S}} = \{a, b, c, d, e\}$
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Given $\mathcal{S} = \{\{a, d, e\}, \{b, c, e\}, \{a, b\}\}$:
$Args_{\mathcal{S}} = \{a, b, c, d, e\}$
$Pairs_{\mathcal{S}} = \{\{a, b\}, \{a, d\}, \{a, e\}, \{b, c\}, \{b, e\}, \{c, e\}, \{d, e\}\}$
Observation: $\mathcal{S}$ is conflict-sensitive; $\{\{a, d, e\}, \{b, c, e\}, \{a, b, d\}\}$ is not!

Expressibility of AFs

Proposition

For any AF F, $\mathit{pref}(F)$ is conflict-sensitive.

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For any AF F, $pref(F)$ is conflict-sensitive.

Recall: $\mathcal{S}$ is conflict-sensitive if for each $A, B \in \mathcal{S}$ such that $A \cup B \notin \mathcal{S}$ it holds that $\exists a, b \in A \cup B : (a, b) \notin Pairs_{\mathcal{S}}$.

Proof:

1. Let F be an AF. $adm(F)$ is conflict-sensitive: Suppose $B, C \in adm(F)$ such that $B \cup C \notin adm(F)$, but for all $b, c \in B \cup C$, $(b, c) \in Pairs_{adm(F)}$. $B \cup C$ defends itself in F. Thus, $(b, c) \in R_F$ for some pair $\{b, c\} \subseteq B \cup C$. But then, for all $D \in adm(F)$, $\{b, c\} \not\subseteq D$. Hence, $\{b, c\} \notin Pairs_{adm(F)}$, a contradiction.
2. For any conflict-sensitive $\mathcal{S}$, its subset-maximal elements form a set $\mathcal{S}'$ that is conflict-sensitive, too (follows from $Pairs_{\mathcal{S}} = Pairs_{\mathcal{S}'}$).

Expressibility of AFs

Proposition

For any non-empty, incomparable conflict-sensitive extension set $\mathcal{S}$, there exists an AF F, such that $\mathit{pref}(F) = \mathcal{S}$.

Theorem

$\Sigma_{\mathit{pref}} = \{\mathcal{S} \mid \mathcal{S} \neq \emptyset$ is incomparable and conflict-sensitive $\}$.

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Proposition (Limitation)

There exist incomparable sets $\mathcal{S}$, such that $\mathcal{S} \notin \Sigma_{\mathit{pref}}$.

Examples: $\mathcal{S} = \{\{a, b\}, \{a, c\}, \{b, c\}\}$
$\mathcal{S} = \{\{a, d, e\}, \{b, c, e\}, \{a, b, d\}\}$

Expressibility of AFs

Important Consequence

For any semantics σ satisfying, for any AF $F = (A, R)$,

(i) $\sigma(F) \neq \emptyset$;

(ii) $\sigma(F) \subseteq cf(F)$;

(iii) $\sigma(F)$ is incomparable; and

(iv) for all $S_1, S_2 \in \sigma(F)$ $(S_1 \neq S_2)$ there exist $a, b \in S_1 \cup S_2$ with $(a, b) \in R$.

it holds that $\Sigma_\sigma \subseteq \Sigma_{pref}$.

Expressibility of AFs

Definition

Given a collection $\mathcal{S}$ of sets of arguments, define

$$Confs_{\mathcal{S}} = \{\{a,b\} \subseteq Args_{\mathcal{S}} \mid \nexists S \in \mathcal{S} : a, b \in S\}, \text{ and}$$
$$bd(\mathcal{S}) = \{T \subseteq Args_{\mathcal{S}} \mid b \in Args_{\mathcal{S}} \setminus T \textit{ iff } \exists a \in T : \{a,b\} \in Confs_{\mathcal{S}}\}.$$

Theorem

$\Sigma_{stb} = \{\mathcal{S} \mid \mathcal{S} \subseteq bd(\mathcal{S})\}$

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Theorem

$\Sigma_{stb} = \{\mathcal{S} \mid \mathcal{S} \subseteq bd(\mathcal{S})\}$

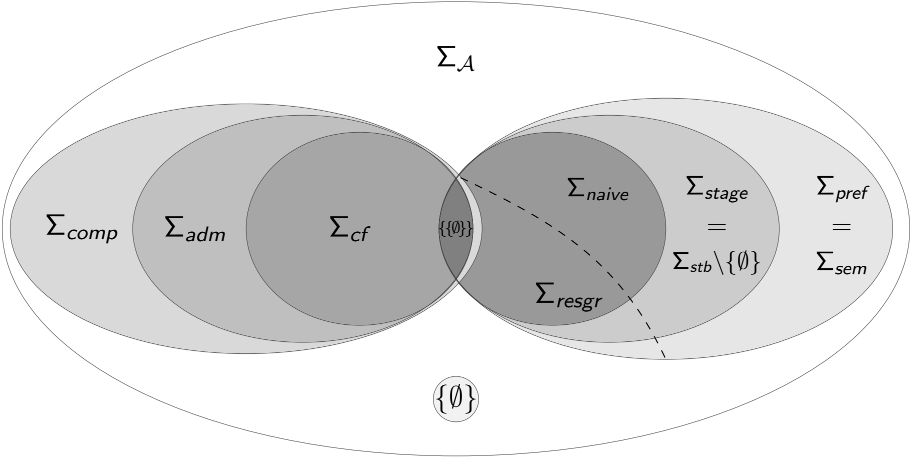
Example

For $\mathcal{S} = \{\{a, b\}, \{a, c, e\}, \{b, d, e\}\} \in \Sigma_{pref}$, we have

$$\begin{aligned} Confs_{\mathcal{S}} &= \{\{a, d\}, \{b, c\}, \{c, d\}\} \\ bd(\mathcal{S}) &= \{\{a, b, e\}, \{a, c, e\}, \{b, d, e\}\} \end{aligned}$$

Hence, $\mathcal{S} \notin \Sigma_{stb}$!

Expressibility of AFs



Expressibility of AFs

Definition ($\cap$-closure)

For any AFs F_1, F_2 such that $\mathcal{S} = \sigma(F_1) \cap \sigma(F_2) \neq \emptyset$ there exists an AF F with $\sigma(F) = \mathcal{S}$.

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For any AF F and non-empty set $\mathcal{S} \subseteq \sigma(F)$ there exists an AF G with $\sigma(G) = \mathcal{S}$.

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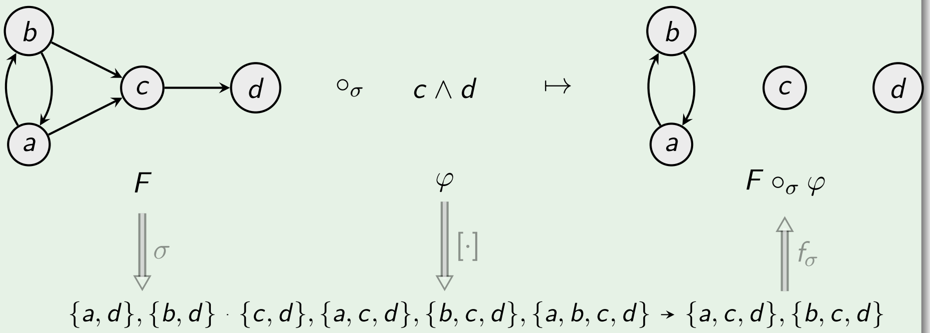
	cf	*adm*	*comp*	*naive*	*pref*	*stb*	*stage*	*sem*
$\subseteq$	✘	✘	✘	✘	✔	✔	✔	✔
$\cap$	✔	✔	✘	✔	✔	✔	✔	✔

Revision of AFs

- In this talk: purely semantic approach of revision
  - AFs play the role of knowledge bases and their extensions express an agent's beliefs
  - a revision formula φ encodes desired changes in the status of some arguments
  - a revision operator yields a result that satisfies φ and preserves as much useful information from the AF as possible.
- Main Goal: Representation Theorems
  - Correspondence between revision operators given by postulates and revision operators captured by rankings.

Revision of AFs

Example



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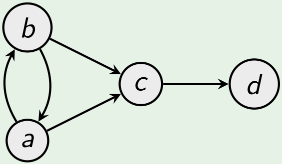

$\circ_\sigma \quad c \wedge d \wedge (a \Leftrightarrow b) \quad \mapsto \quad ?$

$F \;\xrightarrow{\sigma}\; \{a, d\}, \{b, d\}$

$\varphi \;\xrightarrow{[\cdot]}\; \{c, d\}, \{a, b, c, d\}$

$\{a, d\}, \{b, d\} \;\text{———}\; \{c, d\}, \{a, b, c, d\} \longrightarrow \{c, d\}, \{a, b, c, d\} \;\xrightarrow{f_\sigma}\; ?$

Revision of AFs

Variant 1 [Coste-Marquis et al]

$\star_\sigma : AF_{\mathcal{A}} \times \mathcal{P}_{\mathcal{A}} \mapsto 2^{AF_{\mathcal{A}}}$
(For a set S of AFs $\sigma(S) = \bigcup_{F \in S} \sigma(F)$.)

P$\star$1: $\sigma(F \star_\sigma \varphi) \subseteq [\varphi]$.

P$\star$2: If $\sigma(F) \cap [\varphi] \neq \emptyset$ then $\sigma(F \star_\sigma \varphi) = \sigma(F) \cap [\varphi]$.

P$\star$3: If $[\varphi] \neq \emptyset$ then $\sigma(F \star_\sigma \varphi) \neq \emptyset$.

P$\star$4: If $\varphi \equiv \psi$ then $\sigma(F \star_\sigma \varphi) = \sigma(F \star_\sigma \psi)$.

P$\star$5: $\sigma(F \star_\sigma \varphi) \cap [\psi] \subseteq \sigma(F \star_\sigma (\varphi \wedge \psi))$.

P$\star$6: If $\sigma(F \star_\sigma \varphi) \cap [\psi] \neq \emptyset$ then $\sigma(F \star_\sigma (\varphi \wedge \psi)) \subseteq \sigma(F \star_\sigma \varphi) \cap [\psi]$.

Revision of AFs

Definition

Given semantics σ and AF F, a pre-order $\preceq_F$ is a faithful ranking if it is total and for any sets E_1, E_2 and AFs F, F_1, F_2:

(i) if $E_1, E_2 \in \sigma(F)$, then $E_1 \approx_F E_2$,

(ii) if $E_1 \in \sigma(F)$ and $E_2 \notin \sigma(F)$, then $E_1 \prec_F E_2$,

(iii) if $\sigma(F_1) = \sigma(F_2)$, then $\preceq_{F_1} = \preceq_{F_2}$.

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Theorem

Let σ a semantics such that, for each $S \subseteq \mathcal{A}$, $\{S\} \in \Sigma_\sigma$.

An operator $\star_\sigma$ satisfies postulates P$\star$1 – P$\star$6 for σ
iff
there exists an assignment mapping each AF F to a faithful ranking $\preceq_F$ such that $\sigma(F \star_\sigma \varphi) = \min([\varphi], \preceq_F)$.

Revision of AFs

Variant 2 [Diller et al]

$\circ_\sigma : AF_\mathcal{A} \times \mathcal{P}_\mathcal{A} \mapsto AF_\mathcal{A}$

P∘1: $\sigma(F \circ_\sigma \varphi) \subseteq [\varphi]$.

P∘2: If $\sigma(F) \cap [\varphi] \neq \emptyset$ then $\sigma(F \circ_\sigma \varphi) = \sigma(F) \cap [\varphi]$.

P∘3: If $[\varphi] \neq \emptyset$ then $\sigma(F \circ_\sigma \varphi) \neq \emptyset$.

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Theorem

Let σ a semantics which is (i) I-maximal, (ii) $\subseteq$-closed, and (iii) such that for all incomparable $S_1, S_2 \subseteq \mathcal{A}$, $\{S_1, S_2\} \in \Sigma_\sigma$.

An operator $\circ_\sigma$ satisfies postulates $P\circ1$ – $P\circ6$ for σ
iff
there exists an assignment mapping each AF F to a faithful and σ-compliant ranking $\preceq_F$ such that $\sigma(F \circ_\sigma \varphi) = \min([\varphi], \preceq_F)$.

Revision of AFs

Example

- $\sigma(F) = \{\{a, b, c\}\}$.
- $\varphi = \neg(a \wedge b \wedge c)$
- $\{a, b, c\} \prec \{a, b\} \approx \{a, c\} \approx \{b, c\} \prec \{a\} \approx \{b\} \approx \{c\} \prec \emptyset$
  - $\min([\varphi], \preceq) = \{\{a, b\}, \{a, c\}, \{b, c\}\} \notin \Sigma_\sigma$
  - $\preceq$ is not σ-compliant
- $\{a, b, c\} \prec' \{a\} \approx' \{b\} \approx' \{c\} \prec' \{a, b\} \prec' \{a, c\} \prec' \{b, c\} \prec' \emptyset$
  - $\preceq'$ is σ-compliant
  - For instance, $\min([\varphi], \preceq') = \{\{a\}, \{b\}, \{c\}\} \in \Sigma_\sigma$

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- $\sigma(F) = \{\{a, b, c\}\}$.
- $\varphi = \neg(a \wedge b \wedge c)$
- $\{a, b, c\} \prec \{a, b\} \approx \{a, c\} \approx \{b, c\} \prec \{a\} \approx \{b\} \approx \{c\} \prec \emptyset$
  - $\min([\varphi], \preceq) = \{\{a, b\}, \{a, c\}, \{b, c\}\} \notin \Sigma_\sigma$
  - $\preceq$ is not σ-compliant
- $\{a, b, c\} \prec' \{a\} \approx' \{b\} \approx' \{c\} \prec' \{a, b\} \prec' \{a, c\} \prec' \{b, c\} \prec' \emptyset$
  - $\preceq'$ is σ-compliant
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- finding concrete AF revision operators comes down to defining appropriate (i.e. faithful and σ-compliant) rankings on extensions
- compliance leads to quite discriminating choices
- Example operator (indexed preorder) ranks extensions by cardinality plus a form of tie-breaking using lexicographic information

Argumentation Frameworks with Claims

- Abstract argumentation frameworks introduced as part of an argumentation process
- arguments and conflicts are constructed from a given knowledge base
- arguments typically consist of a claim and a support
- hence, in this context claims are the central objects of interest (rather than arguments)

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- hence, in this context claims are the central objects of interest (rather than arguments)
- how does this affect expressibility and dynamic aspects?

Argumentation Frameworks with Claims

Steps

- Starting point: knowledge-base
- Form arguments
- Identify conflicts
- Abstract from internal structure
- Resolve conflicts
- Draw conclusions

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Example

$$\Delta = \{s, r, w, s \rightarrow \neg r, r \rightarrow \neg w, w \rightarrow \neg s\}$$

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- Starting point: knowledge-base
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$\langle\{w, w{\rightarrow}\neg s\}, \neg s\rangle$

$\langle\{s, s{\rightarrow}\neg r\}, \neg r\rangle$ $\langle\{r, r{\rightarrow}\neg w\}, \neg w\rangle$

Argumentation Frameworks with Claims

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Example

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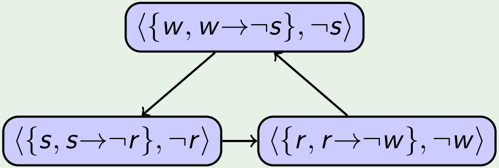

Argumentation Frameworks with Claims

Steps

- Starting point: knowledge-base
- Form arguments
- Identify conflicts
- **Abstract from internal structure**
- Resolve conflicts
- Draw conclusions

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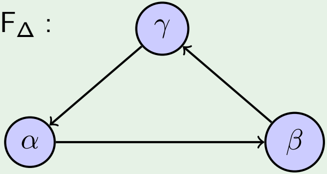
AF_Δ :



Argumentation Frameworks with Claims

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- Starting point: knowledge-base
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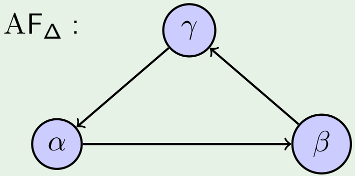
$$\Delta = \{s, r, w, s \to \neg r, r \to \neg w, w \to \neg s\}$$



$$pref(\mathrm{AF}_\Delta) = \{\emptyset\}$$
$$naive(\mathrm{AF}_\Delta) = \{\{\alpha\}, \{\beta\}, \{\gamma\}\}$$

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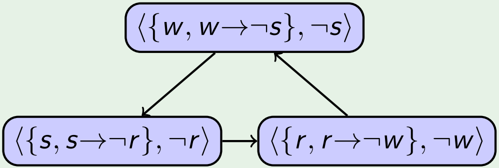
Example

$$\Delta = \{s, r, w, s \rightarrow \neg r, r \rightarrow \neg w, w \rightarrow \neg s\}$$



$$Cn_{pref}(\mathrm{AF}_\Delta) = Cn(\top)$$
$$Cn_{naive}(\mathrm{AF}_\Delta) = Cn(\neg r \vee \neg w \vee \neg s)$$

Argumentation Frameworks with Claims

Definition

A Claim-augmented Argumentation Framework (CAF) is a triple (A, R, γ) where (A, R) is an AF and $\gamma : A \rightarrow C$ maps arguments to claims.
A CAF (A, R, γ) is called well-formed if, for any a, b with $\gamma(a) = \gamma(b)$, $\{c \mid (a, c) \in R\} = \{c \mid (b, c) \in R\}$.

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Given a set A of arguments and $\gamma : A \to C$, let $\gamma(A) = \{\gamma(a) \mid a \in A\}$.

Definition

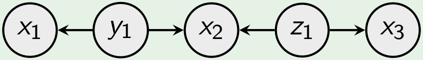
For a semantics σ, we define its claim-based variant as follows:
$\sigma_c((A, R, \gamma)) = \{\gamma(S) \mid S \in \sigma((A, R))\}$.

Immediate Consequence: For each (well-formed) CAF CF,

- $stb_c(CF) \subseteq pref_c(CF)$;
- $stb_c(CF) \subseteq naive_c(CF)$.

Example

Let $CF = (A, R, \gamma)$ with (A, R) given as



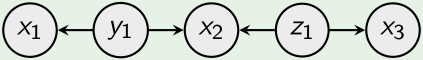
and with $\gamma(x_1) = \gamma(x_2) = \gamma(x_3) = x$, $\gamma(y_1) = y$ and $\gamma(z_1) = z$.

Note that CF is a well-formed CAF.

Argumentation Frameworks with Claims

Example

Let $CF = (A, R, \gamma)$ with (A, R) given as



and with $\gamma(x_1) = \gamma(x_2) = \gamma(x_3) = x$, $\gamma(y_1) = y$ and $\gamma(z_1) = z$.

Note that CF is a well-formed CAF.

We have

- $pref_c(CF) = stb_c(CF) = \{\{y, z\}\}$.
- $naive_c(CF) = \{\{x\}, \{x, y\}, \{x, z\}, \{y, z\}\}$.

Argumentation Frameworks with Claims

We define signatures for well-formed CAFs as follows:

$$\Sigma_\sigma^c = \{\sigma_c(CF) \mid CF \text{ is a well-formed CAF }\}.$$

Lemma

For any well-formed CAF $F = (A, R, \gamma)$, $\mathit{pref}_c(F)$ is incomparable.

Proof: Let $S, T \in \mathit{pref}((A, R))$. Then, there exists an $s \in S$ attacking some $t \in T$. It follows that $\gamma(s) \notin \gamma(T)$ (otherwise the argument $t' \in T$ with $\gamma(t') = \gamma(s)$ also attacks t due to well-formedness; since T is conflict-free, this cannot be the case). By symmetry, the claim follows.

Corollary

For any well-formed CAF $F = (A, R, \gamma)$, $\mathit{stb}_c(F)$ is incomparable.

Argumentation Frameworks with Claims

Theorem

$\Sigma^c_{stb} = \{\mathcal{S} \subseteq 2^C \mid \mathcal{S} \text{ is incomparable}\}; \quad \Sigma^c_{pref} = \Sigma^c_{stb} \setminus \{\emptyset\}.$

Proof Sketch: Given $\mathcal{S} = \{S_1, \ldots, S_n\}$, let $CF = (A, R, \gamma)$ be as follows:

- $A = \{a_i \mid a \in S_i, 1 \leq i \leq n\}$;
- $R = \{(a_i, b_j) \mid 1 \leq i, j \leq n, a \notin S_j\}$;
- $\gamma(a_i) = a$ for all $1 \leq i \leq n$.

Then, $stb((A, R)) = pref((A, R)) = \{\{a_i \mid a \in S_i\} \mid S_i \in \mathcal{S}\}$.

Theorem

$\Sigma^c_{stb} = \{\mathcal{S} \subseteq 2^C \mid \mathcal{S} \textit{ is incomparable}\}$; $\Sigma^c_{pref} = \Sigma^c_{stb} \setminus \{\emptyset\}$.

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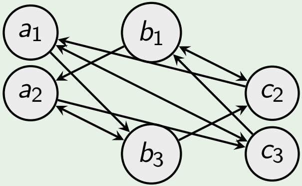
Example

A well-formed CAF with $pref_c(CF) = stb_c(CF) = \{\{a, b\}, \{a, c\}, \{b, c\}\}$:



Towards Claim-based Revision

Revision now shall take place on the level of the knowledge base.

- CAFs represent the status of a knowledge base and their claim-based extensions express an agent's beliefs
- a revision formula φ encodes desired changes in the status of claims
- a revision operator yields a result that satisfies φ and preserves as much useful information from the KB as possible

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Most ingredients already available:

- stb_c and $pref_c$ satisfy the necessary properties to revise CAFs
- even more flexibility for concrete operators (card-based revision)
- open issue: how to obtain revised KB from revised CAF

Conclusion

- Dynamic aspects applied to argumentation frameworks important and vibrant research field
- Understanding expressibility of argumentation formalisms key for extension-based change operations
- Results on the level of abstract frameworks available; less is known for structured argumentation
- Here: first step towards bridging this gap

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- Understanding expressibility of argumentation formalisms key for extension-based change operations
- Results on the level of abstract frameworks available; less is known for structured argumentation
- Here: first step towards bridging this gap
- Open Issues:
  - combination of compliance and principle of minimal change
  - is revision on the level of extension always appropriate?
  - missing pieces for revision in instantiation-based argumentation

References

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