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Incorporating Stage Semantics in the SCC-recursive Schema for Argumentation Semantics

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Motivation

- Distinction between admissible-based and naive-based semantics.
- Naive-based semantics like *cf2* and stage can handle odd-length cycles and as a special case of them self-attacking arguments.
- But, both *cf2* and stage semantics have some drawbacks.
- Our suggestion: combine the concepts of stage and *cf2* semantics.
- *stage2* semantics is defined in the SCC-recursive schema of *cf2* and instantiated in the base case with stage semantics.

Outline

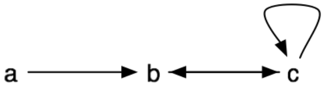
1. Background of abstract argumentation and semantics
   - stable, stage and *cf2* semantics
   - Properties of *cf2* and stage semantics (pros and cons)
2. Combining stage and *cf2* semantics (*stage2*)
   - Comparison of *stage2* with other semantics
   - Extension evaluation criteria [Baroni and Giacomin, 2007]
3. Computational complexity
4. Summary and future work

Abstract Argumentation Framework [Dung, 1995]

An abstract argumentation framework (AF) is a pair $F = (A, R)$, where A is a finite set of arguments and $R \subseteq A \times A$. Then $(a, b) \in R$ if a attacks b.

Example

$F = (A, R), A = \{a, b, c\}, R = \{(a, b), (b, c), (c, b), (c, c)\}$.

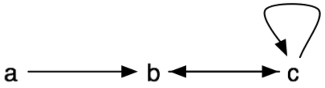


Semantics for AFs

Let $F = (A, R)$ and $S \subseteq A$, we say

- S is conflict-free in F, i.e. $S \in cf(F)$, if there are no $a, b \in S$, s.t. $(a, b) \in R$;
- S is maximal conflict-free or naive, i.e. $S \in naive(F)$, if $S \in cf(F)$ and for each $T \in cf(F)$, $S \not\subset T$.

Example



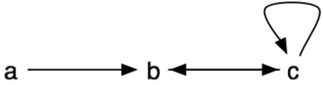
$$cf(F) = \{\emptyset, \{a\}, \{b\}\}, naive(F) = \{\{a\}, \{b\}\}.$$

Semantics for AFs

Let $F = (A, R)$ and $S \subseteq A$. Let $S_R^+ = S \cup \{b \mid \exists a \in S$, s. t. $(a, b) \in R\}$ be the range of S. Then, a set $S \in cf(F)$ is

- a stable extension in F, i.e. $S \in stable(F)$, if $S_R^+ = A$;
- a stage extension, i.e. $S \in stage(F)$, if for each $T \in cf(F)$, $S_R^+ \not\subset T_R^+$.

Example



$$stable(F) = \emptyset,\ stage(F) = \{\{a\}, \{b\}\}.$$

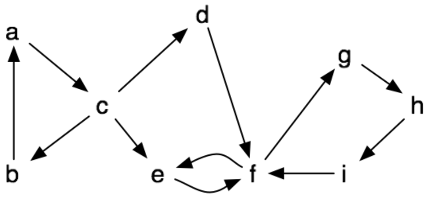
cf2 Semantics

The *cf2* semantics is one of the SCC-recursive semantics introduced in [Baroni et al., 2005]

Separation

An AF $F = (A, R)$ is called separated if for each $(a, b) \in R$, there exists a path from b to a. We define $[[F]] = \bigcup_{C \in SCCs(F)} F|_C$ and call $[[F]]$ the separation of F.

Example



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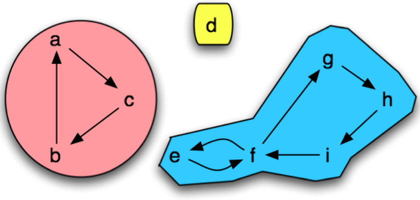

Reachability

Let $F = (A, R)$ be an AF, B a set of arguments, and $a, b \in A$. We say that b is reachable in F from a modulo B, in symbols $a \Rightarrow_F^B b$, if there exists a path from a to b in $F|_B$.

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Definition ($\Delta_{F,S}$)

For an AF $F = (A, R)$, $D \subseteq A$, and a set S of arguments,

$$\Delta_{F,S}(D) = \{a \in A \mid \exists b \in S : b \neq a, (b, a) \in R, a \not\Rightarrow_F^{A \setminus D} b\},$$

and $\Delta_{F,S}$ be the least fixed-point of $\Delta_{F,S}(\emptyset)$.

cf2 Extensions [Gaggl and Woltran, 2010]

Given an AF $F = (A, R)$.

$$cf2(F) = \{S \mid S \in naive(F) \cap naive([[F - \Delta_{F,S}]])\}.$$

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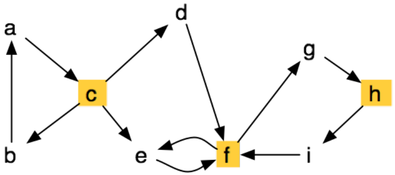
Example

$S = \{c, f, h\}$, $S \in naive(F)$.



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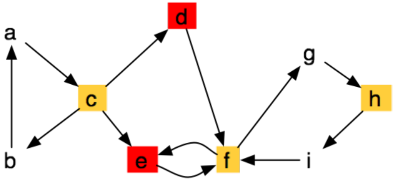

cf2 Semantics ctd.

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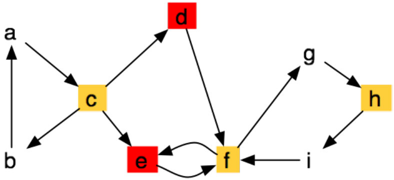
$S = \{c, f, h\}$, $S \in naive(F)$, $\Delta_{F,S}(\{d, e\}) = \{d, e\}$.



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Given an AF $F = (A, R)$.

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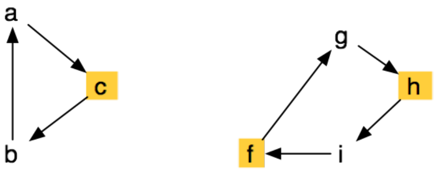
Example

$S = \{c, f, h\}$, $S \in naive(F)$, $\Delta_{F,S} = \{d, e\}$, $S \in naive([[F - \Delta_{F,S}]])$,
thus $S \in cf2(F)$.



Properties of *cf2* and Stage

Advantages of *cf2* and stage:

- Both can accept arguments in odd-length cycle.
- Both can accept arguments attacked by an odd-length cycle (self-attacking arguments).
- The grounded extension is contained in every *cf2* extension (weak reinstatement) [Baroni and Giacomin, 2007].
- *cf2* satisfies the directionality criterion.
- If there is a stable extension then stable and stage coincide, so stage turns to satisfy admissibility.
  - Stage semantics still gives reasonable results on AFs with cycles of length ≥ 6.

Properties of *cf2* and Stage ctd.

Disadvantages of *cf2* and stage:

- The grounded extension is not necessarily contained in every stage extension.
  - Stage semantics does not satisfy directionality.
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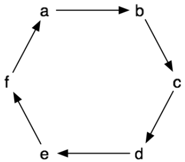

$$cf2(F) = naive(F) = \{\{a,d\},\{b,e\},\{c,f\},\{a,c,e\},\{b,d,f\}\};$$
$$stage(F) = \{\{a,c,e\},\{b,d,f\}\}.$$

Combining stage and *cf2*

We combine stage and *cf2* semantics, by

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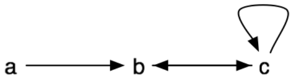

$stage2(F) = cf2(F) = \{\{a\}\}$, where $stage(F) = \{\{a\}, \{b\}\}$.

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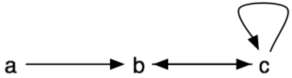

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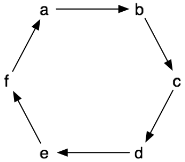
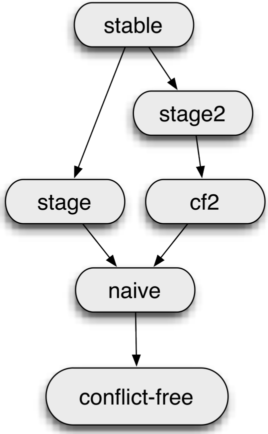


$stage2(G) = stage(G) = \{\{a, c, e\}, \{b, d, f\}\}$, but
$cf2(G) = naive(F) = \{\{a, d\}, \{b, e\}, \{c, f\}, \{a, c, e\}, \{b, d, f\}\}$.

Relations between Semantics



Relations ctd.

Stage and *stage2* semantics are incomparable w.r.t. set inclusion.

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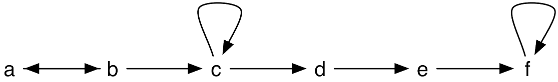

$$stage2(F) = \{\{a, d\}, \{b, d\}\}, \text{ but } stage(F) = \{\{b, d\}, \{b, e\}\}.$$

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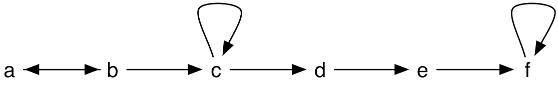

$stage2(F) = \{\{a, d\}, \{b, d\}\}$, but $stage(F) = \{\{b, d\}, \{b, e\}\}$.

- For any coherent AF F, i.e. AFs where stable and preferred semantics coincide, $stable(F) = stage(F) = stage2(F)$.

Evaluation Criteria

	naive	*stable*	*stage*	*cf2*	*stage2*
I-max.	Yes	Yes	Yes	Yes	Yes
Reinst.	No	Yes	No	No	No
Weak reinst.	No	Yes	No	Yes	Yes
$\mathcal{CF}$-reinst.	Yes	Yes	Yes	Yes	Yes
Direct.	No	No	No	Yes	Yes

Table: Evaluation Criteria w.r.t. Naive-based Semantics.

Results for stable, stage and *cf2* semantics are due to [Baroni and Giacomin, 2007].

Computational Complexity

	naive	*stable*	*stage*	*cf2*	*stage2*
$Cred_\sigma$	in P	NP-c	Σ_2^P-c	NP-c	Σ_2^P-c
$Skept_\sigma$	in P	coNP-c	Π_2^P-c	coNP-c	Π_2^P-c
Ver_σ	in P	in P	coNP-c	in P	coNP-c

Table: Computational Complexity of naive-based semantics ($\mathcal{C}$-c denotes completeness for class $\mathcal{C}$).

Conclusion and Future Work

Summary:

- *stage2* semantics combines concepts of *cf2* and stage to overcome their shortcomings.
- For any AF F $stable(F) \subseteq stage2(F) \subseteq cf2(F)$.
- *stage2* satisfies most evaluation criteria.
- *stage2* is located at second level of polynomial hierarchy, thus among hardest and most expressive argumentation semantics.
- *stage2* semantics has been incorporated in ASPARTIX (see `http://rull.dbai.tuwien.ac.at:8080/ASPARTIX/`).

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Future Work:

- Analysis of tractable fragments for *stage2* semantics.
- Algorithms and labelings for *stage2*.
- Real world examples and benchmarks!

- Baroni, P. and Giacomin, M. (2007).
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- Baroni, P., Giacomin, M., and Guida, G. (2005).
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- Gaggl, S. A. and Woltran, S. (2010).
  cf2 semantics revisited.
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