TECHNISCHE UNIVERSITÄT DRESDEN

Artificial Intelligence, Computational Logic

SEMINAR ABSTRACT ARGUMENTATION

Introduction to Formal Argumentation

*slides adapted from Stefan Woltran's lecture on Abstract Argumentation

Sarah Gaggl

Dresden, 1st November 2013

Roadmap for the Lecture

- Introduction
- Abstract Argumentation Frameworks
- Complexity
- Implementation Techniques
- Extensions of Abstract Argumentation Frameworks
- Students' Topics

Introduction

Argumentation:

. . . the study of processes “concerned with how assertions are proposed, discussed, and resolved in the context of issues upon which several diverging opinions may be held”.

[Bench-Capon and Dunne, Argumentation in AI, AIJ 171:619-641, 2007]

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Formal Models of Argumentation are concerned with

- representation of an argument
- representation of the relationship between arguments
- solving conflicts between the arguments (“acceptability”)

Introduction (ctd.)

Increasingly important area

- "Argumentation" as keyword at all major AI conferences
- dedicated conference: COMMA; several workshops
- specialized journal: Argument and Computation (Taylor & Francis)
- two text books:
  - Besnard, Hunter: Elements of Argumentation. MIT Press, 2008
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Applications

- PARMENIDES-system for E-Democracy: facilitates structured arguments over a proposed course of action [Atkinson et al.; 2006]
- IMPACT project: argumentation toolbox for supporting open, inclusive and transparent deliberations about public policy
- Decision support systems, etc.

The Overall Process

Steps

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

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

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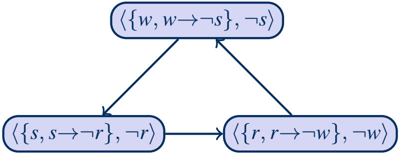

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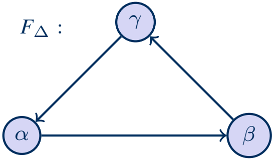
F_Δ :



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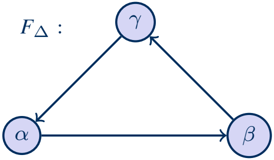

$$pref(F_\Delta) = \{\emptyset\}$$
$$stage(F_\Delta) = \{\{\alpha\}, \{\beta\}, \{\gamma\}\}$$

The Overall Process

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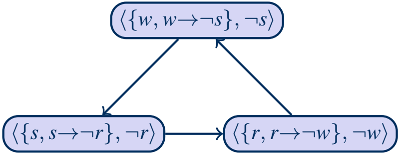

$$Cn_{pref}(F_\Delta) = Cn(\top)$$
$$Cn_{stage}(F_\Delta) = Cn(\neg r \vee \neg w \vee \neg s)$$

The Overall Process (ctd.)

Some Remarks

- Main idea dates back to Dung [1995]; has then been refined by several authors (Prakken, Gordon, Caminada, etc.)
- Separation between logical (forming arguments) and nonmonotonic reasoning (“abstract argumentation frameworks”)
- Abstraction allows to compare several KR formalisms on a conceptual level (“calculus of conflict”)

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Main Challenge

- All Steps in the argumentation process are, in general, intractable.
- This calls for:
  - careful complexity analysis (identification of tractable fragments)
  - re-use of established tools for implementations (reduction method)

Approaches to Form Arguments

Classical Arguments [Besnard & Hunter, 2001]

- Given is a KB (a set of propositions) Δ
- argument is a pair (Φ, α), such that $\Phi \subseteq \Delta$ is consistent, $\Phi \models \alpha$ and for no $\Psi \subset \Phi$, $\Psi \models \alpha$
- conflicts between arguments (Φ, α) and (Φ', α') arise if Φ and α' are contradicting.

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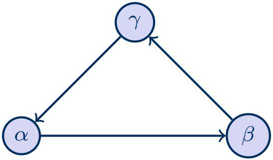
Example

Other Approaches

- Arguments are trees of statements
- claims are obtained via strict and defeasible rules
- different notions of conflict: rebuttal, undercut, etc.

Dung's Abstract Argumentation Frameworks

Example



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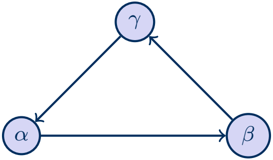

Main Properties

- Abstract from the concrete content of arguments but only consider the relation between them
- Semantics select subsets of arguments respecting certain criteria
- Simple, yet powerful, formalism
- Most active research area in the field of argumentation.
  - "plethora of semantics"

Dung's Abstract Argumentation Frameworks

Definition

An argumentation framework (AF) is a pair (A, R) where

- A is a set of arguments
- $R \subseteq A \times A$ is a relation representing the conflicts ("attacks")

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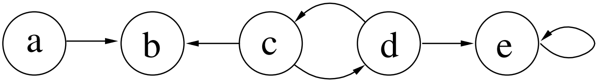
Example

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



Basic Properties

Conflict-Free Sets

Given an AF $F = (A, R)$.
A set $S \subseteq A$ is conflict-free in F, if, for each $a, b \in S$, $(a, b) \notin R$.

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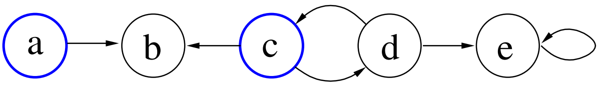

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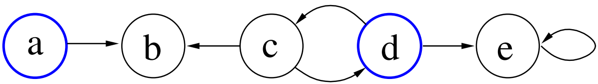

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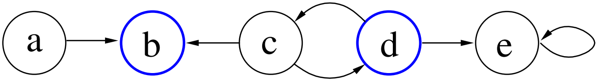

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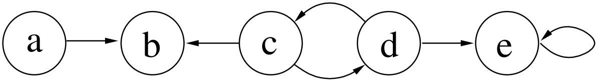

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Basic Properties (ctd.)

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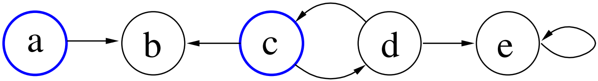

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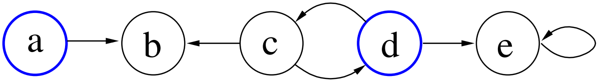

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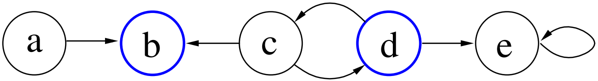

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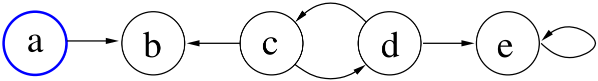

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Basic Properties (ctd.)

Dung's Fundamental Lemma

Let S be admissible in an AF F and a, a' arguments in F defended by S in F. Then,

1. $S' = S \cup \{a\}$ is admissible in F
2. a' is defended by S' in F

Semantics

Naive Extensions

Given an AF $F = (A, R)$. A set $S \subseteq A$ is a naive extension of F, if

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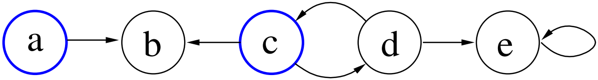

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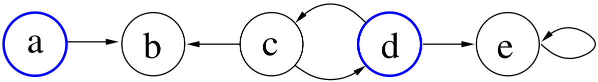

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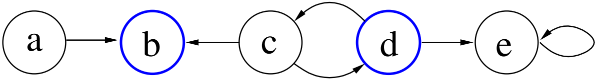

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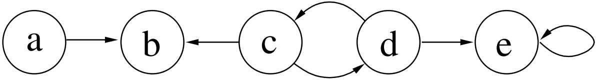

$naive(F) = \{\{a, c\}, \{a, d\}, \{b, d\}, \sout{\{a\}}, \sout{\{b\}}, \sout{\{c\}}, \sout{\{d\}}, \sout{\emptyset}\}$

Semantics (ctd.)

Grounded Extension [Dung, 1995]

Given an AF $F = (A, R)$. The unique grounded extension of F is defined as the outcome S of the following "algorithm":

1. put each argument $a \in A$ which is not attacked in F into S; if no such argument exists, return S;
2. remove from F all (new) arguments in S and all arguments attacked by them (together with all adjacent attacks); and continue with Step 1.

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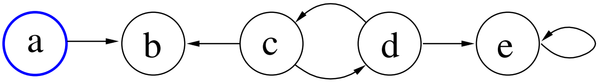

$ground(F) = \{\{a\}\}$

Semantics (ctd.)

Complete Extension [Dung, 1995]

Given an AF (A, R). A set $S \subseteq A$ is complete in F, if

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- each $a \in A$ defended by S in F is contained in S
  - Recall: $a \in A$ is defended by S in F, if for each $b \in A$ with $(b, a) \in R$, there exists a $c \in S$, such that $(c, b) \in R$.

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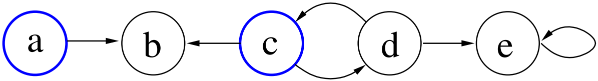

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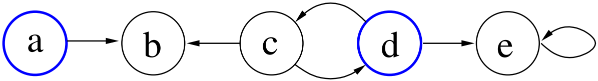

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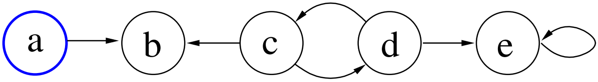

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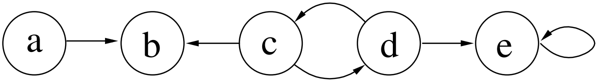

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Properties of the Grounded Extension

For any AF F, the grounded extension of F is the subset-minimal complete extension of F.

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For any AF F, the grounded extension of F is the subset-minimal complete extension of F.

Remark

Since there exists exactly one grounded extension for each AF F, we often write $\mathit{ground}(F) = S$ instead of $\mathit{ground}(F) = \{S\}$.

Semantics (ctd.)

Preferred Extensions [Dung, 1995]

Given an AF $F = (A, R)$. A set $S \subseteq A$ is a preferred extension of F, if

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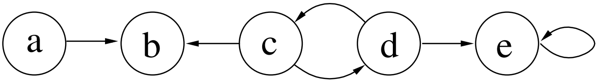

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Semantics (ctd.)

Stable Extensions [Dung, 1995]

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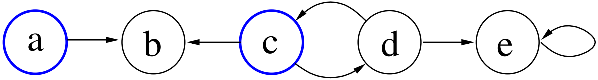

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Semantics (ctd.)

Stable Extensions [Dung, 1995]

Given an AF $F = (A, R)$. A set $S \subseteq A$ is a stable extension of F, if

- S is conflict-free in F
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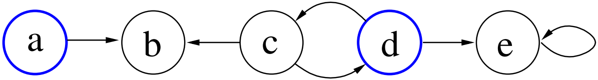
Example



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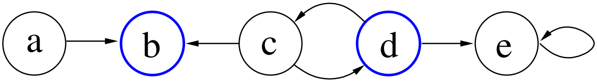

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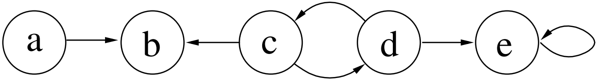

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Semantics (ctd.)

Some Relations

For any AF F the following relations hold:

1. Each stable extension of F is admissible in F
2. Each stable extension of F is also a preferred one
3. Each preferred extension of F is also a complete one

Semantics (ctd.)

Semi-Stable Extensions [Caminada, 2006]

Given an AF $F = (A, R)$. A set $S \subseteq A$ is a semi-stable extension of F, if

- S is admissible in F
- for each $T \subseteq A$ admissible in F, $S^+ \not\subset T^+$
  - for $S \subseteq A$, define $S^+ = S \cup \{a \mid \exists b \in S \text{ with } (b, a) \in R\}$

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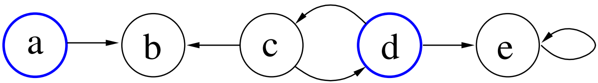

$semi(F) = \{\cancel{\{a, c\}}, \{a, d\}, \cancel{\{a\}}, \cancel{\{c\}}, \cancel{\{d\}}, \cancel{\emptyset}\}$

Semantics (ctd.)

Stage Extensions [Verheij, 1996]

Given an AF $F = (A, R)$. A set $S \subseteq A$ is a stage extension of F, if

- S is conflict-free in F
- for each $T \subseteq A$ conflict-free in F, $S^+ \not\subset T^+$
  - recall $S^+ = S \cup \{a \mid \exists b \in S \text{ with } (b, a) \in R\}$

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Ideal Extension [Dung, Mancarella & Toni 2007]

Given an AF $F = (A, R)$. A set $S \subseteq A$ is an ideal extension of F, if

- S is admissible in F and contained in each preferred extension of F
- there is no $T \supset S$ admissible in F and contained in each of $\mathit{pref}(F)$

Semantics (ctd.)

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Eager Extension [Caminada, 2007]

Given an AF $F = (A, R)$. A set $S \subseteq A$ is an eager extension of F, if

- S is admissible in F and contained in each semi-stable extension of F
- there is no $T \supset S$ admissible in F and contained in each of $semi(F)$

Semantics (ctd.)

Properties of Ideal Extensions

For any AF F the following observations hold:

1. there exists exactly one ideal extension of F
2. the ideal extension of F is also a complete one

The same results hold for the eager extension and similar variants [Dvořák et al., 2011].

Semantics (ctd.)

Resolution-based grounded Extensions [Baroni,Giacomin 2008]

A resolution β of an AF $F = (A, R)$ contains exactly one of the attacks (a, b), (b, a) for each pair $a, b \in A$ with $\{(a, b), (b, a)\} \subseteq R$.

A set $S \subseteq A$ is a resolution-based grounded extension of F, if

- there exists a resolution β such that $ground((A, R \setminus \beta)) = S$
- and there is no resolution β' such that $ground((A, R \setminus \beta')) \subset S$

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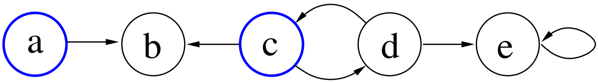

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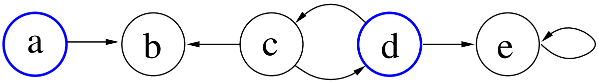


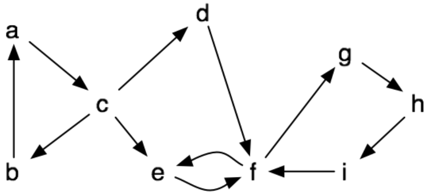
$ground^*(F) = \{\{a, c\}, \{a, d\}\}$

cf2 Semantics [Baroni, Giacomin & Guida 2005]

Definition (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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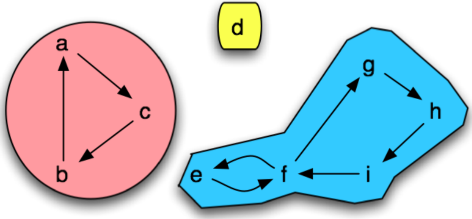

cf2 Semantics (ctd.)

Definition (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,

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

By $\Delta_{F,S}$, we denote the lfp of $\Delta_{F,S}(\emptyset)$.

cf2 Semantics (ctd.)

cf2 Extensions [G & Woltran 2010]

Given an AF $F = (A, R)$. A set $S \subseteq A$ is a cf2-extension of F, if

- S is conflict-free in F
- and $S \in naive([[F - \Delta_{F,S}]])$.

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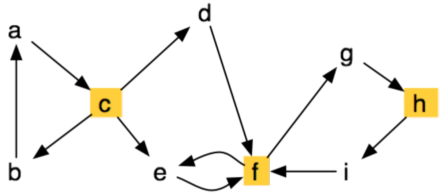
Example

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



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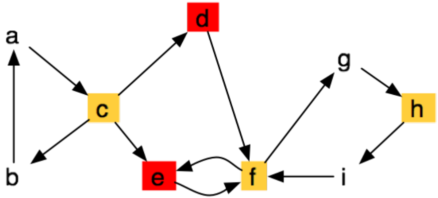
Example

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



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Example

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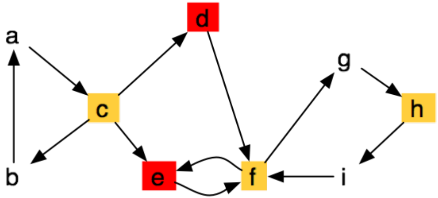

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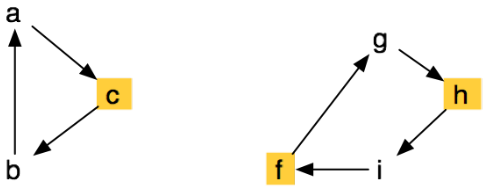


Relations between Semantics

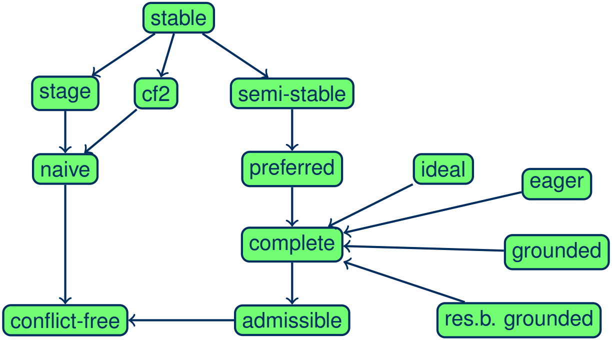
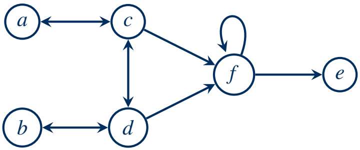


Figure: An arrow from semantics σ to semantics τ encodes that each σ-extension is also a τ-extension.

Characteristics of Argumentation Semantics

Example



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

Natural Questions

- How to change the AF if we want $\{a, b, e\}$ instead of $\{a, b\}$ in $pref(F)$?
- How to change the AF if we want $\{a, b, d\}$ instead of $\{a, b\}$ in $pref(F)$?
- Can we have equivalent AFs without argument f?

Some Properties . . .

Theorem

For any AFs F and G, we have

- $adm(F) = adm(G) \Longrightarrow \sigma(F) = \sigma(G)$, for $\sigma \in \{pref, ideal\}$;
- $comp(F) = comp(G) \Longrightarrow \vartheta(F) = \vartheta(G)$, for $\vartheta \in \{pref, ideal, ground\}$;
- no other such relation between the different semantics (adm, $pref$, $ideal$, $semi$, $eager$, $ground$, $comp$, $stable$) in terms of standard equivalence holds.

Strong Equivalence [Oikarinen & Woltran 2011, G & Woltran 2011]

Definition

Two AFs F and G are strongly equivalent wrt. a semantics $\sigma \in \{stable, adm, pref, ideal, semi, comp, ground, stage\}$, in symbols $F \equiv_s^\sigma G$, iff $\sigma(F \cup H) = \sigma(G \cup H)$, for each AF H.

- Idea: Find "σ-kernels" of AFs, such that the σ-kernels of F and G coincide iff $F \equiv_s^\sigma G$.
  - Verification of strong equivalence then reduces to checking syntactical equivalence

Strong Equivalence for Stable Semantics

Kernel for stable semantics

For AF $F = (A, R)$, we define *stable*-kernel of F as $F^\kappa = (A, R^\kappa)$ with

$$R^\kappa = R \setminus \{(a,b) \mid a \neq b, (a,a) \in R\}.$$

Theorem

For any AFs F and G: $F^\kappa = G^\kappa$ iff $F \equiv_s^{stable} G$ iff $F \equiv_s^{stage} G$.

Exercises

1. Give an AF F such that $stable(F) = \emptyset$ and $semi(F) \neq \{\emptyset\}$.
2. Show that the following statement holds for any AF F.
   If $stable(F) \neq \emptyset$ then $stable(F) = semi(F) = stage(F)$.
3. Select three different semantics $\sigma, \sigma', \sigma''$ out of $\{pref, ideal, semi, eager, ground, stable\}$ of your choice and provide three pairs of AFs such that
   - $\sigma(F_1) = \sigma(G_1)$ but $\sigma'(F_1) \neq \sigma'(G_1)$
   - $\sigma'(F_2) = \sigma'(G_2)$ but $\sigma''(F_2) \neq \sigma''(G_2)$
   - $\sigma''(F_3) = \sigma''(G_3)$ but $\sigma(F_3) \neq \sigma(G_3)$

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