TECHNISCHE UNIVERSITÄT DRESDEN

Artificial Intelligence, Computational Logic

ABSTRACT ARGUMENTATION

Introduction to Formal Argumentation

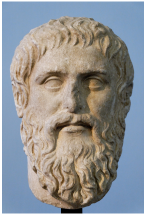
*slides adapted from Stefan Woltran's lecture on Abstract Argumentation

Sarah Gaggl

ICCL Summer School 2017

Outline

Argumentation in History



Plato's Dialectic

The dialectical method is discourse between two or more people holding different points of view about a subject, who wish to establish the truth of the matter guided by reasoned arguments.

The Republic (Plato), 348b

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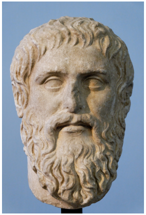

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Leibniz' Dream

"The only way to rectify our reasonings is to make them as tangible as those of the Mathematicians, so that we can find our error at a glance, and when there are disputes among persons, we can simply say: Let us calculate [calculemus], without further ado, to see who is right."

Leibniz, Gottfried Wilhelm, The Art of Discovery 1685, Wiener 51

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Argumentation Nowadays

Abstract Argumentation [Dung, 1995]

- In abstract argumentation frameworks (AFs) statements (called arguments) are formulated together with a relation (attack) between them.
- Abstraction from the internal structure of the arguments.
- The conflicts between the arguments are resolved on the semantical level.

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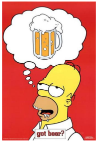

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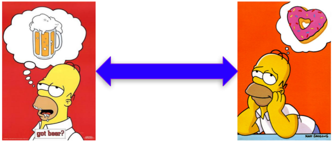

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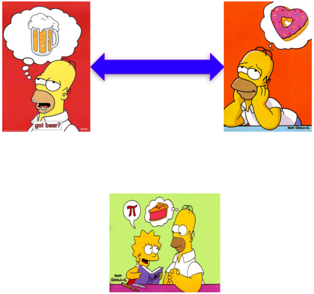

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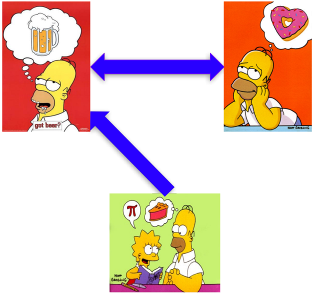

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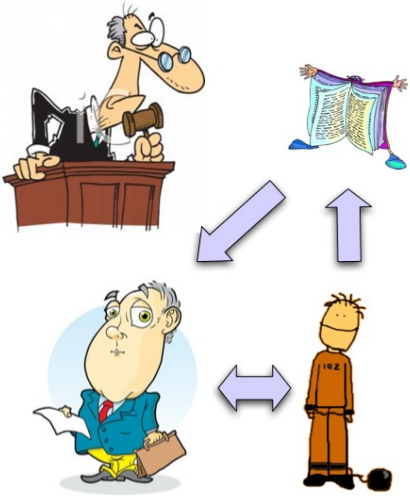
Legal Reasoning



Decision Support

Social Networks

Roadmap for the Lecture

Tuesday
- Introduction
- Abstract Argumentation Frameworks
- Semantics

Thursday
- Decision Problems, Computational Complexity
- Generalizations (ADFs)

Friday
- Implementations
- Argumentation and Answer-Set Programming (ASP)
- Systems and Competition

Outline

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 (`http://comma.csc.liv.ac.uk`), TAFA workshop; and several more workshops
- International Competition on Computational Models or Argumentation (ICCMA `http://argumentationcompetition.org/`)
- Summer School on Argumentation (SSA) - co-located with COMMA
- specialized journal: Argument and Computation (IOS Press)
- two text books:
  - Besnard, Hunter: Elements of Argumentation. MIT Press, 2008
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Handbook of Formal Argumentation HOFA

- `http://formalargumentation.org`
- Volume 1 to appear in 2017

Outline

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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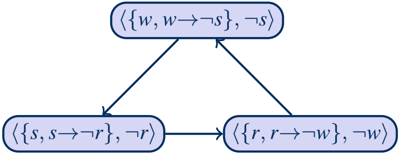

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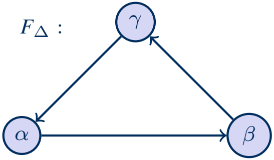

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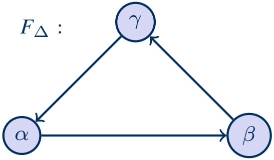

$$pref(F_\Delta) = \{\emptyset\}$$
$$stage(F_\Delta) = \{\{\alpha\}, \{\beta\}, \{\gamma\}\}$$

The Overall Process

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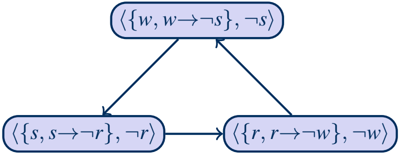

$$Cn_{pref}(F_\Delta) = Cn(\top)$$
$$Cn_{stage}(F_\Delta) = Cn(\neg r \vee \neg w \vee \neg s)$$

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)

Outline

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 $\Psi \subset \Phi$, $\Psi \models \alpha$
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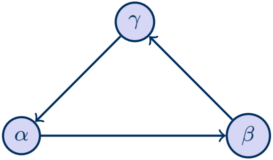
Other Approaches

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

Outline

Dung's Abstract Argumentation Frameworks

Example



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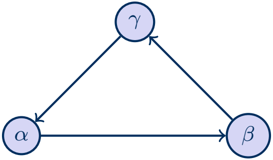

Main Properties

- 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"

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Dung's Abstract Argumentation Frameworks

Definition

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

- A is a set of arguments
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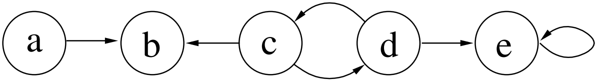
Example

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



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Basic Properties

Conflict-Free Sets

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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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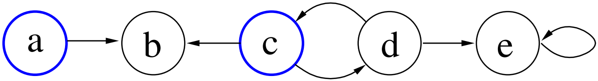

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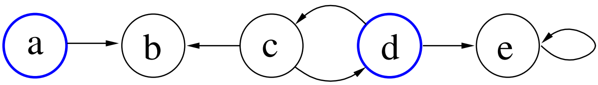

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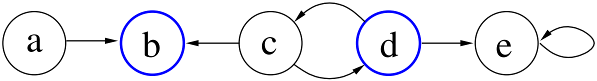

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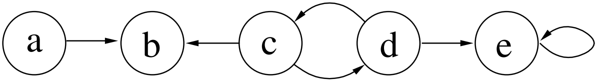

$cf(F) = \{\{a, c\}, \{a, d\}, \{b, d\}, \{a\}, \{b\}, \{c\}, \{d\}, \emptyset\}$

Basic Properties (ctd.)

Admissible Sets [Dung, 1995]

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

- S is conflict-free in F
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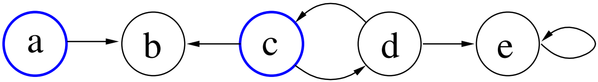

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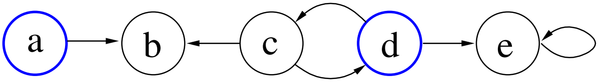

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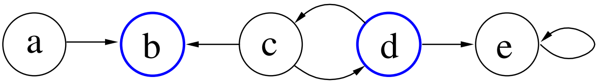

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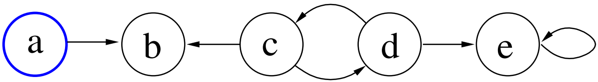

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Dung's Fundamental Lemma

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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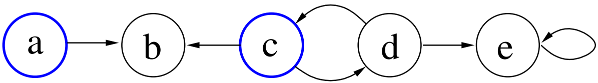

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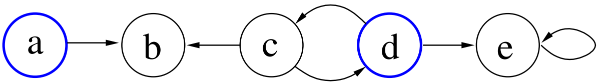

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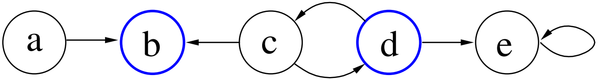

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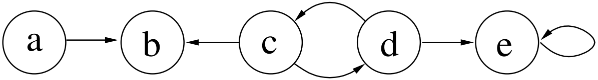

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Semantics (ctd.)

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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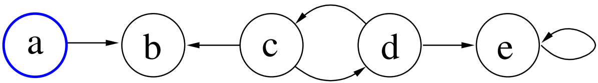


$ground(F) = \{\{a\}\}$

Semantics (ctd.)

Complete Extension [Dung, 1995]

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

- S is admissible in F
- 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 $(c, b) \in R$.

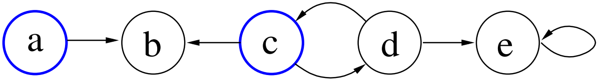
Semantics (ctd.)

Complete Extension [Dung, 1995]

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

- S is admissible in F
- 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 $(c, b) \in R$.

Example



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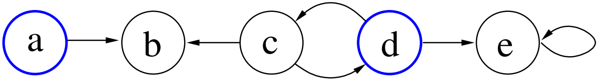

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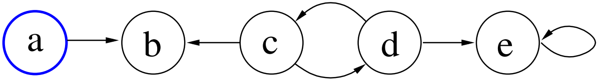

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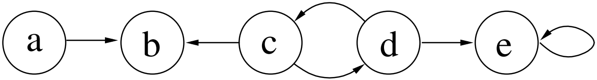

$comp(F) = \{\{a, c\}, \{a, d\}, \{a\}, \cancel{\{c\}, \{d\}, \emptyset}\}$

Semantics (ctd.)

Properties of the Grounded Extension

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

Semantics (ctd.)

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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 $ground(F) = S$ instead of $ground(F) = \{S\}$.

Semantics (ctd.)

Preferred Extensions [Dung, 1995]

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

- S is admissible in F
- for each $T \subseteq A$ admissible in F, $S \not\subset T$

Semantics (ctd.)

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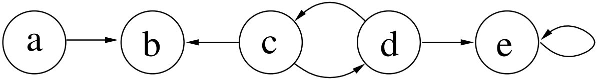

$pref(F) = \{\{a, c\}, \{a, d\}, \cancel{\{a\}, \{c\}, \{d\}, \emptyset}\}$

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
- for each $a \in A \setminus S$, there exists a $b \in S$, such that $(b, a) \in R$

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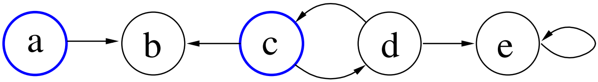

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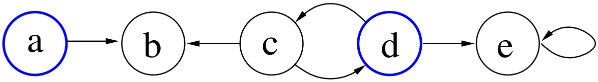

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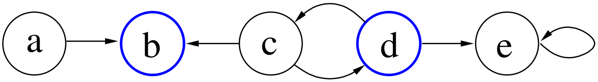

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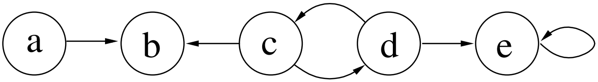

$stable(F) = \{\cancel{\{a, c\}}, \{a, d\}, \cancel{\{b, d\}}, \cancel{\{a\}}, \cancel{\{b\}}, \cancel{\{c\}}, \cancel{\{d\}}, \cancel{\emptyset}, \}$

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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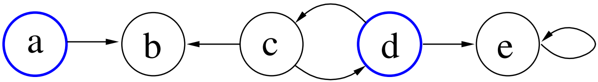

$semi(F) = \{\cancel{\{a, c\}}, \{a, d\}, \cancel{\{a\}}, \cancel{\{c\}}, \cancel{\{d\}}, \cancel{\emptyset}\}$

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
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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 $\mathit{pref}(F)$

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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 $\mathit{semi}(F)$

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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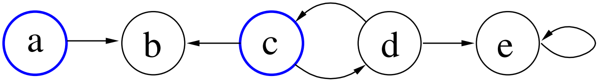

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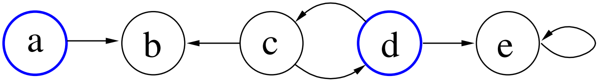


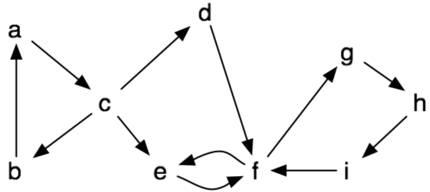
$ground^*(F) = \{\{a, c\}, \{a, d\}\}$

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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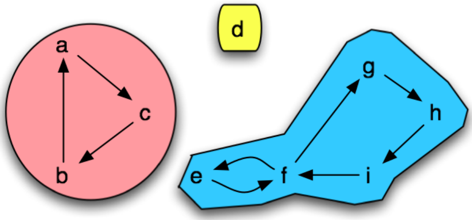

cf2 Semantics (ctd.)

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
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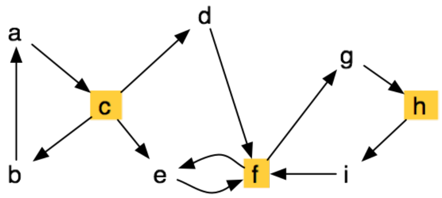
Example

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



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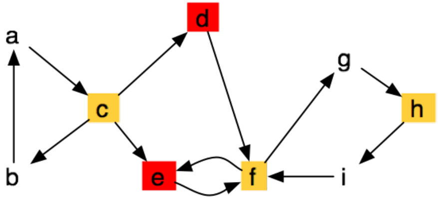
Example

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



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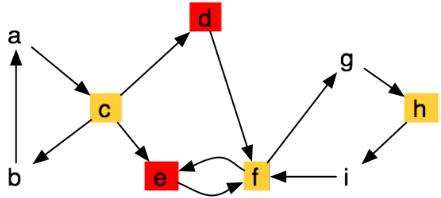

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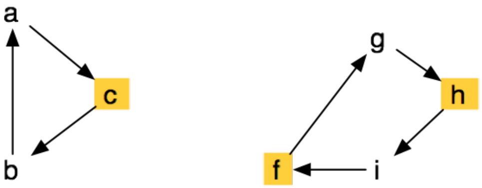

Outline

Relations between Semantics

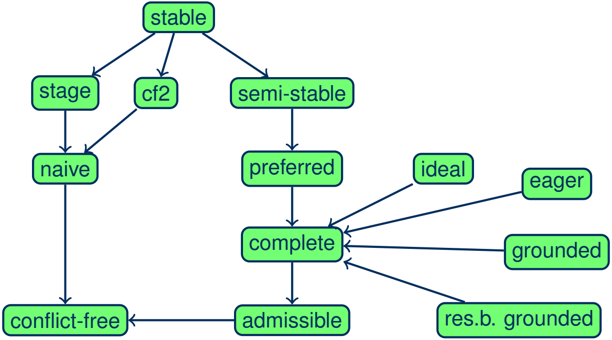

Figure: An arrow from semantics σ to semantics τ encodes that each σ-extension is also a τ-extension.

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