An Introduction to Abstract Argumentation

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Prologue

"Some people believe football is a matter of life and death, I am very disappointed with that attitude. I can assure you it is much, much more important than that."
(Bill Shankly)

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Argumentation is 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".
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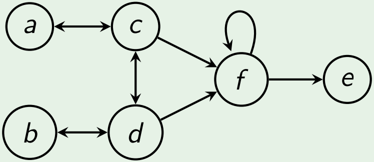
- "The idea of argumentational reasoning is that a statement is believable if it can be argued successfully against attacking arguments."
- "[...] a formal, abstract but simple theory of argumentation is developed to capture the notion of acceptability of arguments."

Prologue

Argumentation Frameworks

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

Example



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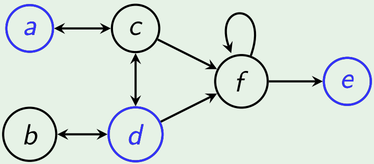

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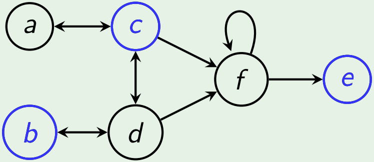

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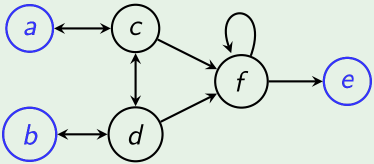

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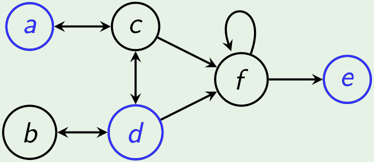

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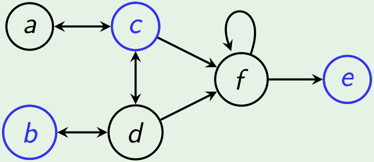

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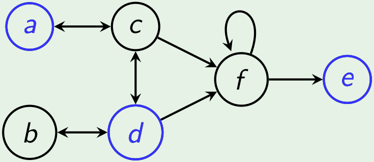

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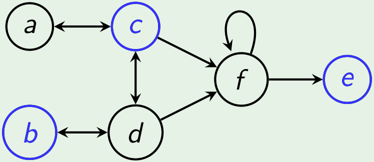

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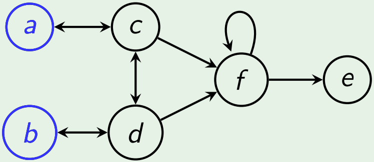

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How to obtain such frameworks?
. . . identify conflicting information

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... identify conflicting information
(it is everywhere!)

Domain	Argument	Attack	Aim
People	person	"dislike"	coalition formation
DSupport	statement	"conflict"	conflict resolution
BBS	message	reply	identify opinion leaders
KB	(Φ, α)	$\neg\alpha \in Cn(\Phi')$	inconsistency handling
LP	derivation	viol. assumption	comparison LP semantics
DL	support chain	viol. justification	nonmonotonic logics

Outline

- Fundamentals of Argumentation Frameworks
- State of the Art: Semantics, Add-Ons, Systems
- Dynamics of Argumentation (and an open question)
- What Argu can learn from Provenance (and vice versa)
- Conclusion

Definition

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

- $A \subseteq \mathcal{A}$ is a finite set of arguments and
- $R \subseteq A \times A$ is the attack relation representing conflicts.

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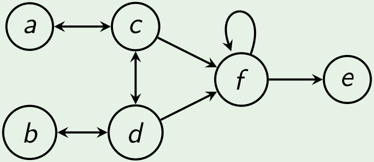

$F = (\{a, b, c, d, e, f\},$
$\{(a, c), (c, a), (c, d), (d, c), (d, b), (b, d), (c, f), (d, f), (f, f), (f, e)\})$

Conflict-free Sets

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

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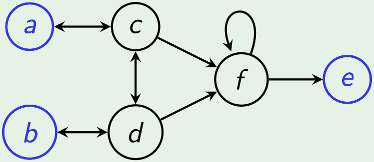

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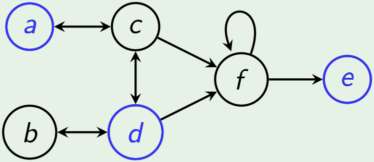

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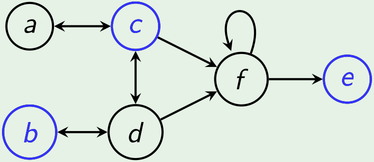

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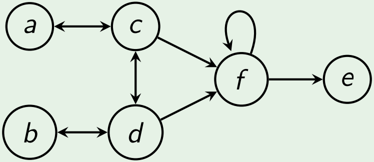

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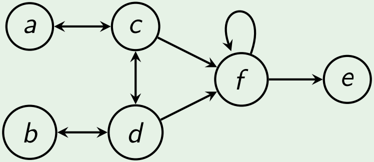

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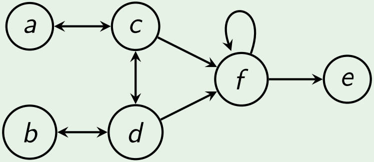

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Given an AF $F = (A, R)$, a set $E \subseteq A$ is a naive extension in F, if

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$\Rightarrow$ Maximal conflict-free sets (w.r.t. set-inclusion).

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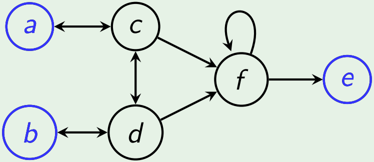

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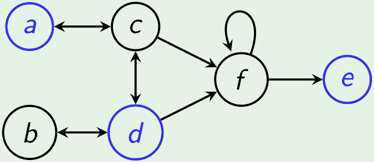

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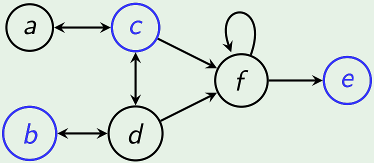

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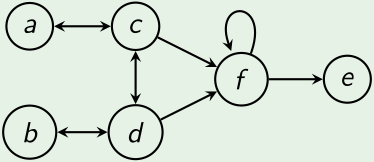

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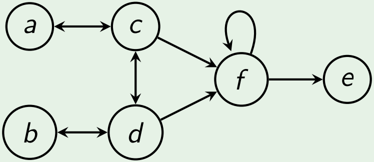

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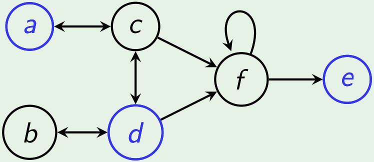

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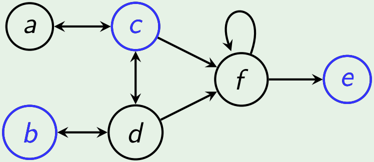

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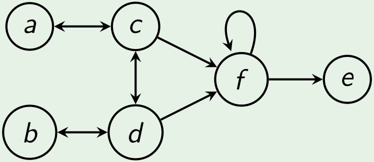

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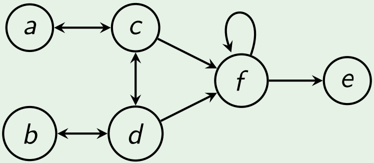

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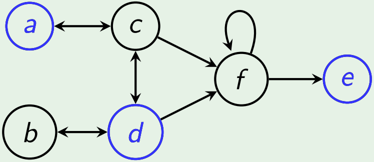

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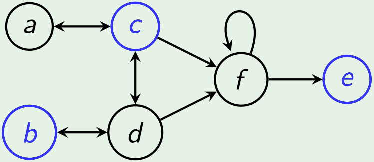

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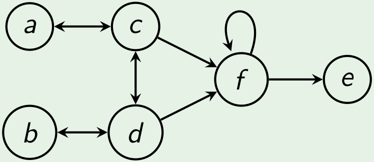

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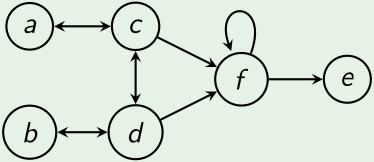

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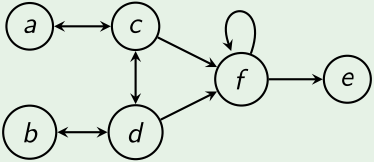

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Preferred Extensions

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- E is admissible in F and
- there is no admissible $T \subseteq A$ with $T \supset E$.

$\Rightarrow$ Maximal admissible sets (w.r.t. set-inclusion).

Fundamentals

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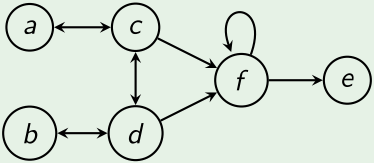
Example



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

Some central properties

For each argumentation framework F:

- $cf(F)$, $naive(F)$, $adm(F)$, $pref(F)$ always non-empty
- $stb(F) \subseteq naive(F) \subseteq cf(F)$
- $stb(F) \subseteq pref(F) \subseteq adm(F) \subseteq cf(F)$

Labeling Semantics

Definition

Given an AF (A, R), a function $\mathcal{L} : A \to \{in, out, undec\}$ is a labeling iff the following conditions hold:

- $\mathcal{L}(a) = in$ iff for each b with $(b, a) \in R$, $\mathcal{L}(b) = out$
- $\mathcal{L}(a) = out$ iff there exists b with $(b, a) \in R$, $\mathcal{L}(b) = in$

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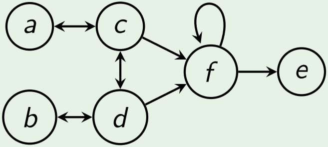
- 1-1 correspondence between preferred labelings and extensions
- Further alternative characterizations exist, in particular for deciding status of a single argument (discussion games).

Labeling Semantics

Example: Preferred Labelings



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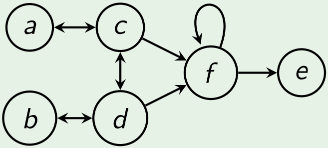

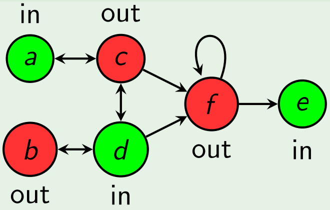

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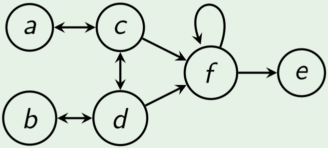

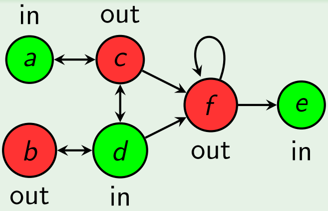

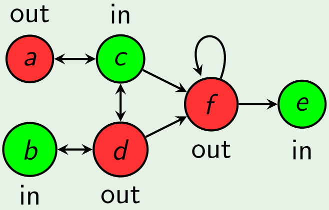

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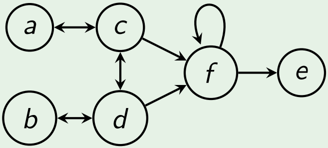
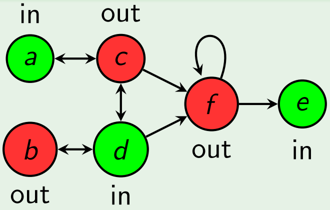
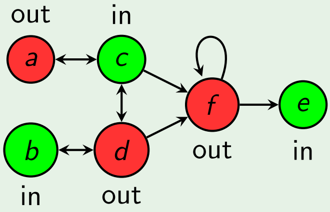
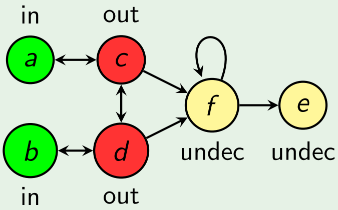
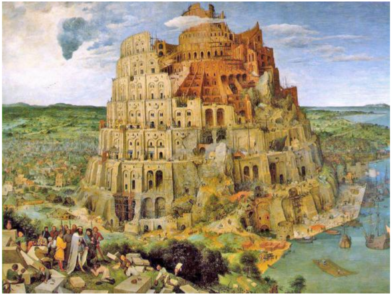




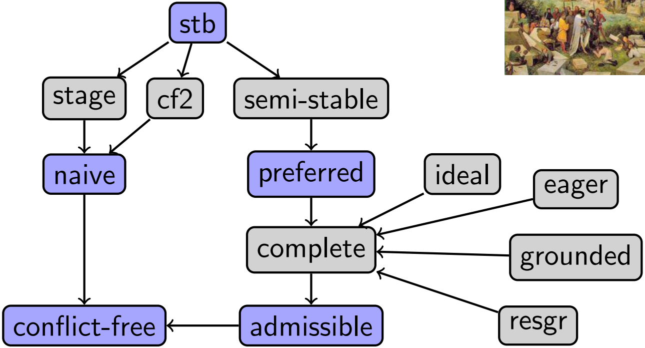




State of the Art



Meanwhile, an invasion of semantics!
Bug or feature?



State of the Art

Meanwhile, an invasion of semantics!
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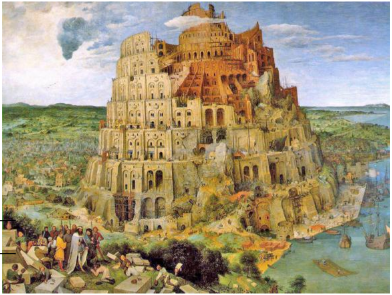
σ	$Cred_\sigma$	$Skept_\sigma$	Ver_σ	NE_σ
cf	in L	trivial	in L	in L
naive	in L	in L	in L	in L
grd	P-c	P-c	P-c	in L
stb	NP-c	coNP-c	in L	NP-c
adm	NP-c	trivial	trivial	NP-c
comp	NP-c	P-c	in L	NP-c
resgr	NP-c	coNP-c	P-c	in P
pref	NP-c	Π_2^P-c	coNP-c	NP-c
sem	Σ_2^P-c	Π_2^P-c	coNP-c	NP-c
stage	Σ_2^P-c	Π_2^P-c	coNP-c	in L
ideal	in Θ_2^P	in Θ_2^P	coNP-c	in Θ_2^P

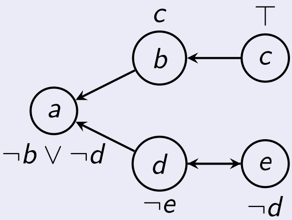


State of the Art

Lots of Add-Ons!

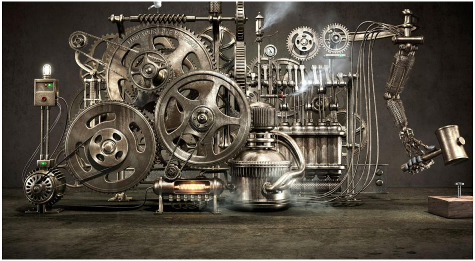
Some Examples:

- preferences (e.g. value-based frameworks)
- support relation (e.g. bipolar frameworks)
- abstract dialectical frameworks



State of the Art

Systems emerge . . .



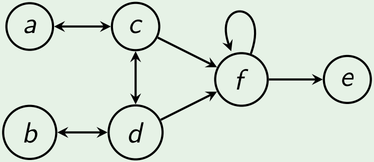
- http://ova.computing.dundee.ac.uk/ova-gen/
- http://rull.dbai.tuwien.ac.at:8080/ASPARTIX/
- https://sites.google.com/site/santinifrancesco/tools
- http://heen.webfactional.com/

Outline

- Fundamentals of Argumentation Frameworks
- State of the Art: Semantics, Add-Ons, Systems
- Dynamics of Argumentation (and an open question)
- What Argu can learn from Provenance (and vice versa)
- Conclusion

Dynamics of Argumentation

Example



$$
\begin{aligned}
stb(F) &= \{\{a, d, e\}, \{b, c, e\}\} \\
pref(F) &= \{\{a, d, e\}, \{b, c, e\}, \{a, b\}\}
\end{aligned}
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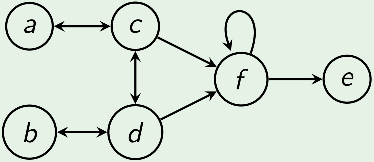

$stb(F) = \{\{a, d, e\}, \{b, c, e\}\}$
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Natural Questions

- How to expand the AF such that $\{a, b\}$ becomes a stable extension?
- When are two frameworks equivalent under any expansion?
- How to adapt the AF to replace $\{a, b\}$ by $\{a, b, d\}$ in $pref(F)$?

Dynamics of Argumentation: Enforcement

Proposition

Let $F = (A, R)$ be an AF. Then for any $S \in \mathit{cf}(F)$, there is an AF $F' = (A', R')$ with $A \subseteq A'$, $R \subseteq R'$ such that $S \in \sigma(F')$ $(\sigma \in \{\mathit{adm}, \mathit{naive}, \mathit{stb}, \mathit{pref}\})$.

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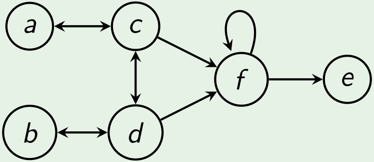

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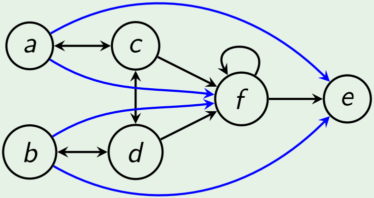

Dynamics of Argumentation: Strong Equivalence

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Two AFs F, G are strongly equivalent wrt. σ (in symbols $F \equiv_s^\sigma G$), if for any H, $\sigma(F \cup H) = \sigma(G \cup H)$

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$(A, R) \equiv_s^{stb} (B, S)$ iff $A = B$ and $R^- = S^-$ where
$R^- = R \setminus \{(a, b) \in R \mid (a, a) \in R\}$.

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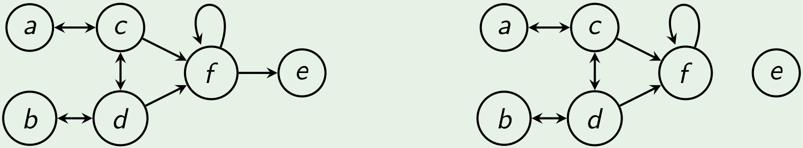
Two AFs strongly equivalent under stable semantics



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.

Dynamics of Argumentation: Signatures

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Some Notation

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

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

Example

Given $\mathcal{S} = \{\{a, d, e\}, \{b, c, e\}, \{a, b\}\}$:
$Args_{\mathcal{S}} = \{a, b, c, d, e\}$,
$Pairs_{\mathcal{S}} = \{\{a, b\}, \{a, d\}, \{a, e\}, \{b, c\}, \{b, e\}, \{c, e\}, \{d, e\}\}$

Dynamics of Argumentation: Signatures

Definition

An extension-set $\mathcal{S}$ is called

- naive-closed if $\mathcal{S}$ is incomparable and closed under ternary majority
- is tight if for all $E \in \mathcal{S}$ and all $a \in Args_{\mathcal{S}} \setminus E$ there exists $e \in E$ such that $\{a, e\} \notin Pairs_{\mathcal{S}}$
- pref-closed if for each $A, B \in \mathcal{S}$ with $A \neq B$, there exist $a, b \in (A \cup B)$ such that $a \neq b$ and $\{a, b\} \notin Pairs_{\mathcal{S}}$

Theorem

- $\Sigma_{naive} = \{\mathcal{S} \neq \emptyset \mid \mathcal{S} \text{ is naived-closed } \}$
- $\Sigma_{stb} = \{\mathcal{S} \mid \mathcal{S} \text{ is tight } \}$
- $\Sigma_{pref} = \{\mathcal{S} \neq \emptyset \mid \mathcal{S} \text{ is pref-closed } \}$

Dynamics of Argumentation: Signatures

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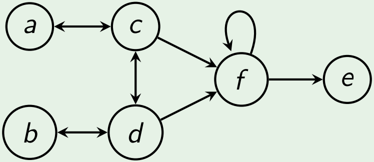

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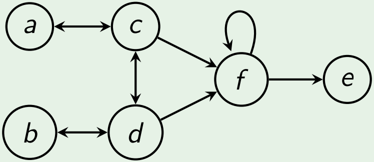

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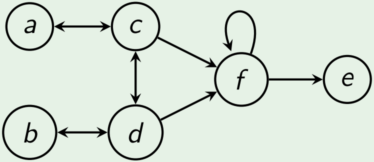

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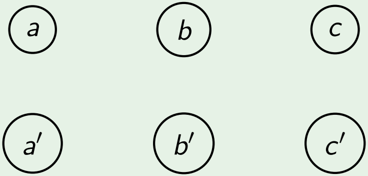
Impossible! $\{\{a, d, e\}, \{b, c, e\}, \{a, b, d\}\}$ is not pref-closed.
(An extension-set $\mathcal{S}$ is pref-closed if for each $A, B \in \mathcal{S}$ with $A \neq B$, there exist $a, b \in (A \cup B)$ such that $\{a, b\} \notin Pairs_{\mathcal{S}}$)

Dynamics of Argumentation: Signatures

Example

Can we realize $\mathcal{S} = \{\{a, b, c\}, \{a', b, c\}, \{a, b', c\}, \{a, b, c'\}, \{a', b', c\}, \{a, b', c'\}, \{a', b, c'\}\}$ with stable semantics?



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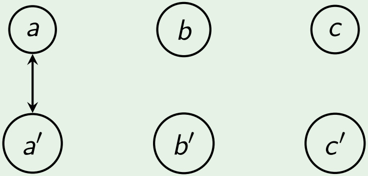

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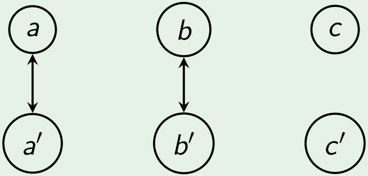

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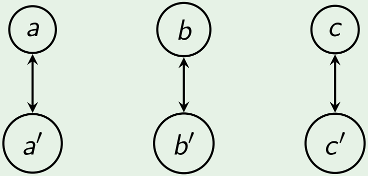

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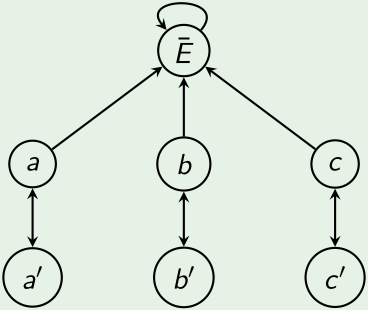

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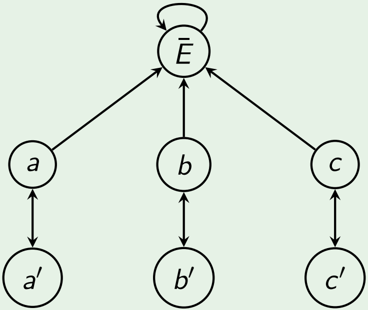

Can we also do it without additional argument E?

Dynamics of Argumentation: Signatures

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An AF $F = (A, R)$ is compact wrt. semantics σ if $Args_{\sigma(F)} = A$
Strict Signature: $\Sigma^s_\sigma = \{\sigma(F) \mid F \text{ is compact wrt. } \sigma\}$

So far, no exact results for strict signatures. However, we have such a result for conflict-explicit AFs

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Definition

We call an AF $F = (A, R)$ conflict-explicit under σ iff for each $a, b \in A$ such that $\{a, b\} \notin Pairs_{\sigma(F)}$, $(a, b) \in R$ or $(b, a) \in R$ (or both)

Conjecture

For each $F = (A, R)$ there exists an $F' = (A, R')$ which is conflict-explicit under the stable semantics such that $stb(F) = stb(F')$

What Argu can learn from Provenance

Provenance interesting on two levels:

1. trace back why an argument is warranted in one/all/none extensions (apply why-provenance, causality, responsibility)
2. use information on the non-abstract level in order to provide additional provenance values for a each single argument before starting the evaluation on the abstract level

$\Rightarrow$ in both scenarios, argumentation can benefit from formal models provenance provides

What Provenance can learn from Argu

- Whenever (potentially asymmetric) conflicts have to be treated, abstract argumentation provides a wide variety of well-understood mechanisms
- in abstract argumentation we deal with inconsistency on a conceptually simple level
- . . . many side-results available which might prove useful (and prevent re-inventing the wheel)
- there is also a huge body of work on visualization issues!

What Argu can learn from Provenance (and vice versa)

A first touch point: (abstraction of) provenance graphs

In argumentation recent work has focussed on similar issues; moreover, results on strong equivalence and signatures might be beneficial here

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A (maybe more concrete) touch point: recursive queries with negation

Provenance games look very close to Dung's idea to capture LP via abstract argumentation.
Exact relation needs to be explored in order to make further use of argumentation

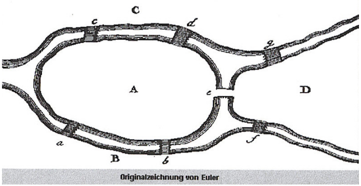
Conclusion

Summary

- Argumentation a highly active area in AI
- Dung's abstract frameworks a gold standard within the community
- AFs provide account of how to select acceptable arguments solely on basis of an attack relation between them
- AFs can be instantiated in many different ways
- Useful analytical tool with a variety of semantics and add-ons
- Systems are available

Conclusion

Isn't that all just graph theory?



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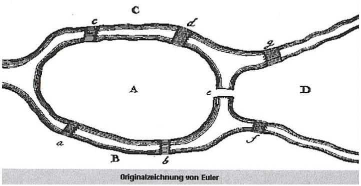

No ...

- Edges have different meaning (reachability vs. attack and defense)
- Different abstraction model
- Still,
  - stable extensions ⇔ independent dominating sets
  - several graph classes also important in Argu (acyclic, bipartite, ...)

Conclusion

Future Perspective: "Web of Arguments"

- Web of Information $\Rightarrow$ Web of Opinions (ratings, comments, ...)
- Conflicting information thus even more present
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... obviously, provenance has to play a major role here!

Thanks & looking forward to seeing you in Vienna ...

Main References

- P. M. Dung, On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games, Artif. Intell. 77 (2) (1995) 321–358.
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