# Towards Advanced Systems for Abstract Argumentation

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Based on joint work with
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Thomas Linsbichler, Christof Spanring, Hannes Straß

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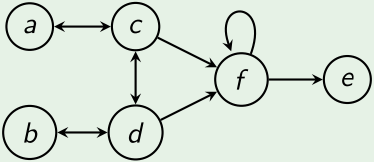
- "The idea of argumentational reasoning is that a statement is believable if it can be argued successfully against attacking arguments."
- "[...] a formal, abstract but simple theory of argumentation is developed to capture the notion of acceptability of arguments."

# Prologue

## Argumentation Frameworks

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

## Example



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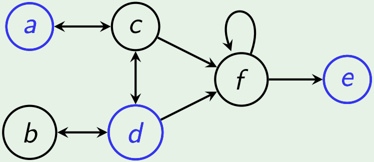


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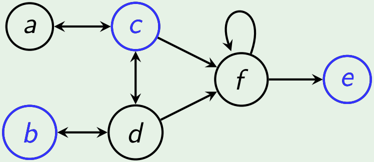


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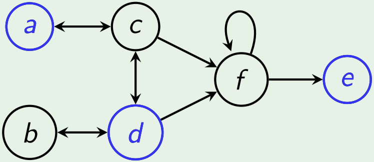


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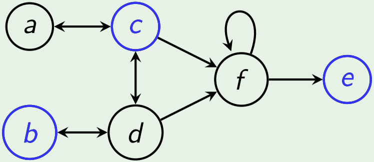


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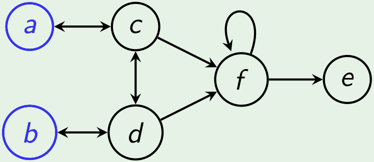


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# Where are We now?

Multitude of semantics

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Faster and better systems

- ICCMA (`http://www.dbai.tuwien.ac.at/iccma17/`)
- so far, best systems reduction-based

# Outline

- The Role of Conflicts Revisited
- Exploiting the Babylonian Confusion
- Conclusions and Open Questions

# Implicit Conflicts

## Definition

Given AF $F = (A, R)$, $a, b \in A$, $\sigma$ a semantics. $\{a, b\}$ is a $\sigma$-implicit conflict if $(a, b) \notin R$, $(b, a) \notin R$, and there is no $E \in \sigma(F)$ s.t. $\{a, b\} \subseteq E$.

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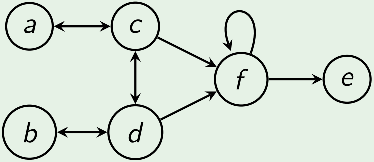
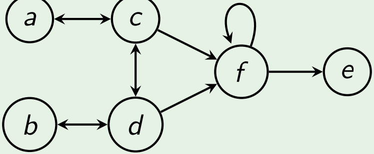



- Recall $pref(F) = \{\{a, d, e\}, \{b, c, e\}, \{a, b\}\}$ and $stb(F) = \{\{a, d, e\}, \{b, c, e\}\}$.
- Implicit conflicts for *pref*: $\{a, f\}$, $\{b, f\}$
- Implicit conflicts for *stb*: $\{a, b\}$, $\{a, f\}$, $\{b, f\}$

# Implicit Conflicts (ctd.)

## Making Implicit Conflicts Explicit



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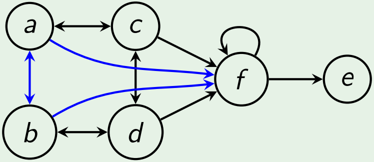


We have $stb(F) = stb(F') = \{\{a, d, e\}, \{b, c, e\}\}$.

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**Conflict-Explicit Conjecture (Stable Case)**

For each AF $F = (A, R)$ there exists an AF $F' = (A', R')$ such that $stb(F) = stb(F')$ and $F'$ is free of *stb*-implicit conflicts.

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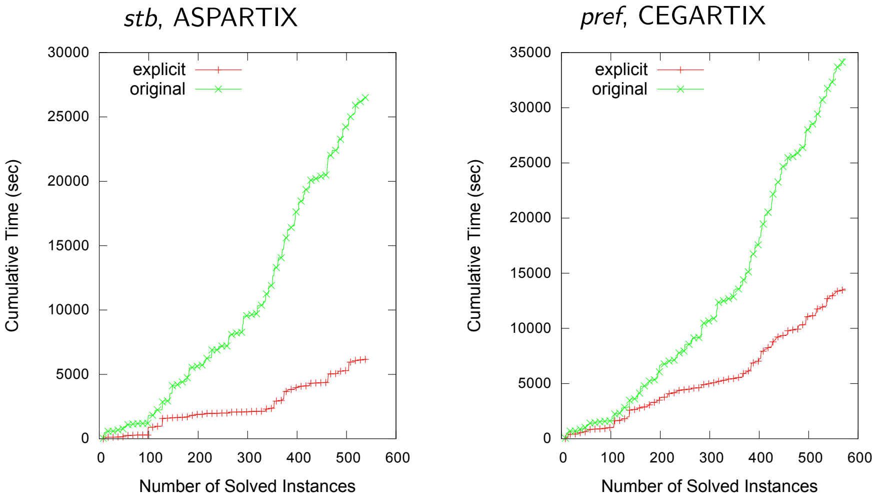
Why important?

- CDCL huge success story in SAT solving
- Experiments indicate that making conflicts explicit is supportive for argumentation systems

# Experiments




Implicit conflicts on instances from the ICCMA 2015 stable generator. Average of 17 implicit conflicts per (non-rejected) argument.

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For preferred and semi-stable semantics, it does not hold in general.

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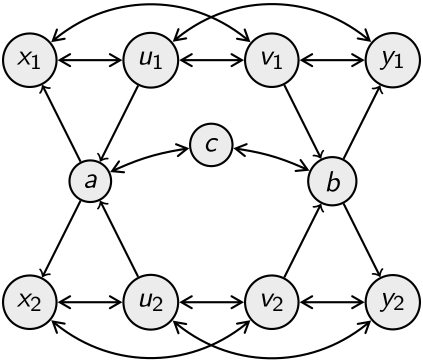

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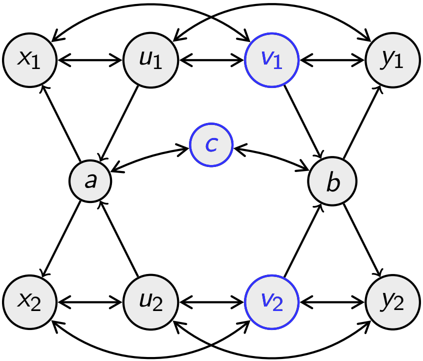


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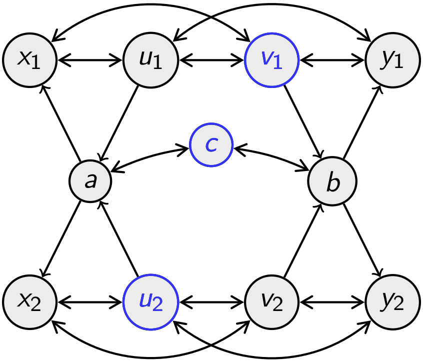


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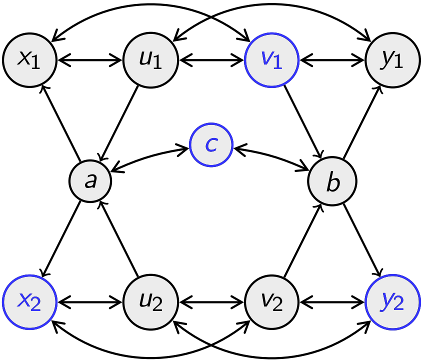


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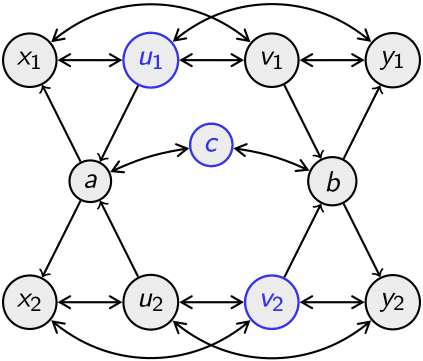


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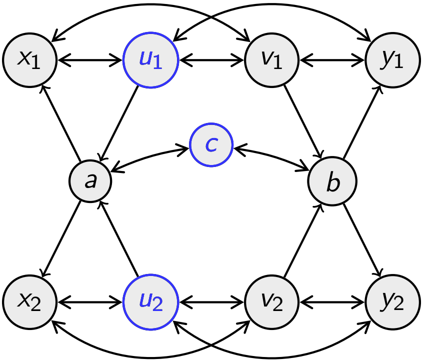


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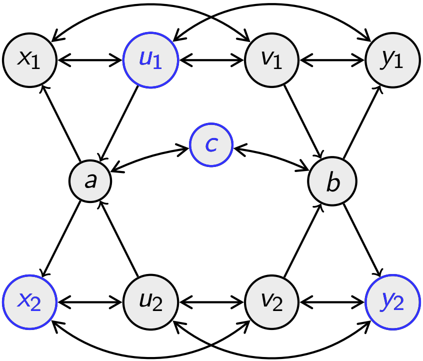


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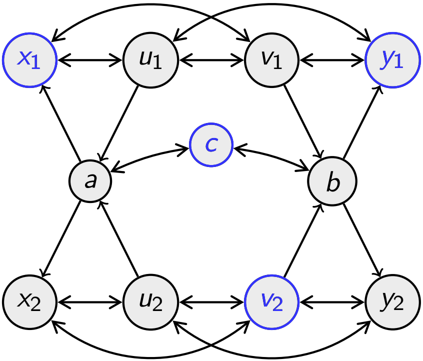


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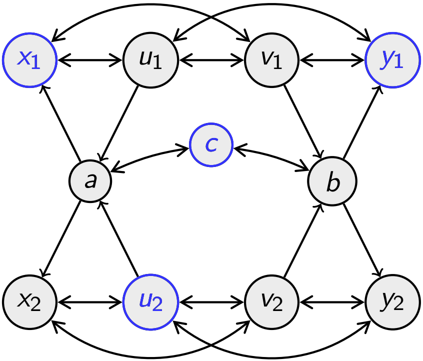


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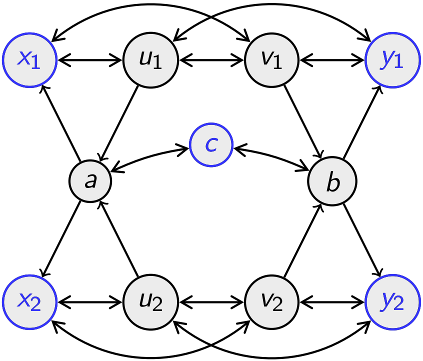


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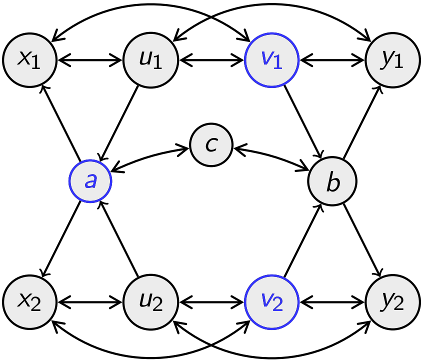


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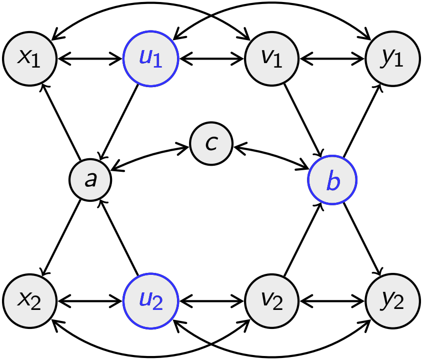


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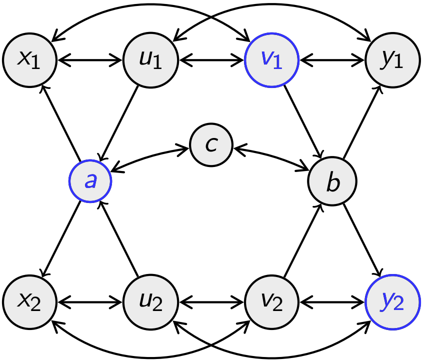


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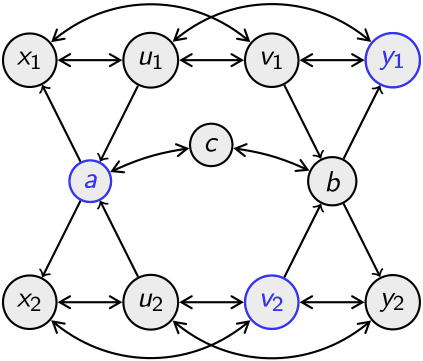


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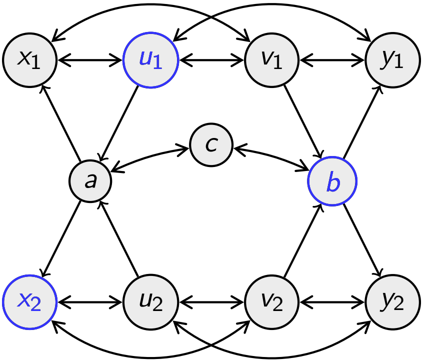


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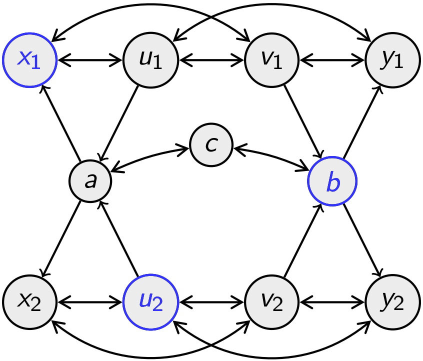


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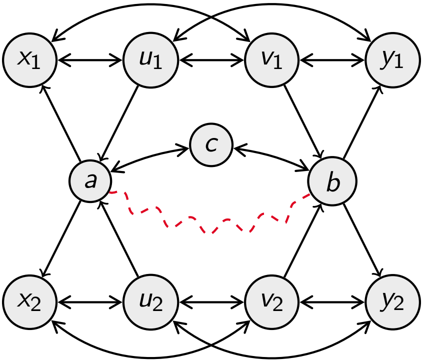


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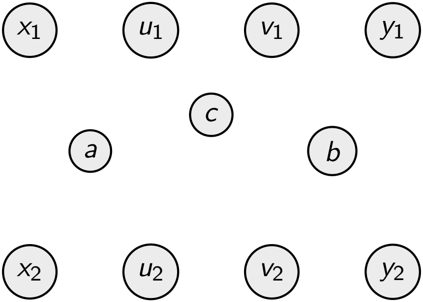


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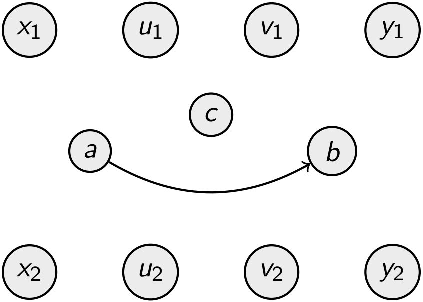


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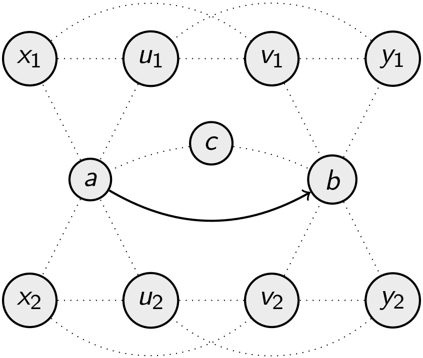


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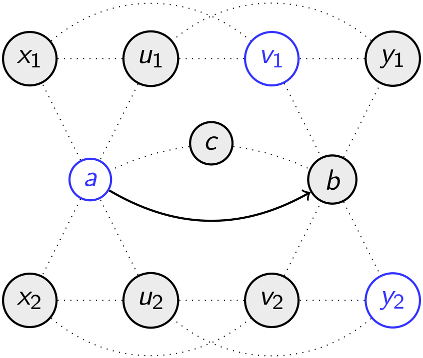


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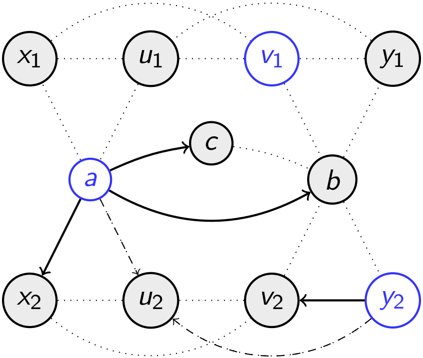


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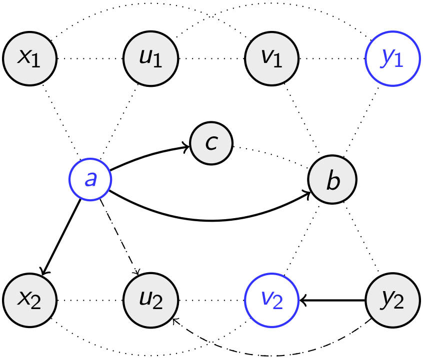


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$\{\{c\} \cup M_{1i} \cup M_{2j} \mid i, j \in \{1,2,3\}, M_{i1} = \{v_i\}, M_{i2} = \{u_i\}, M_{i3} = \{x_i, y_i\}\} \cup$
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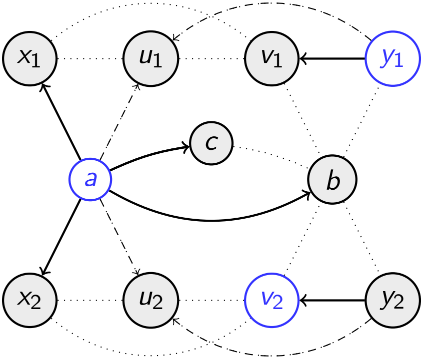


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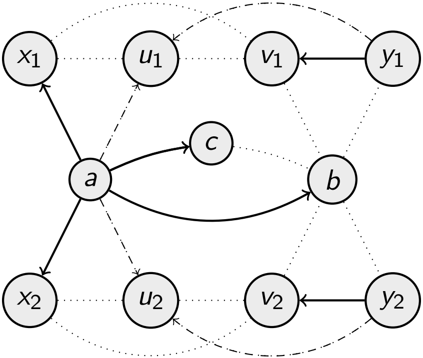


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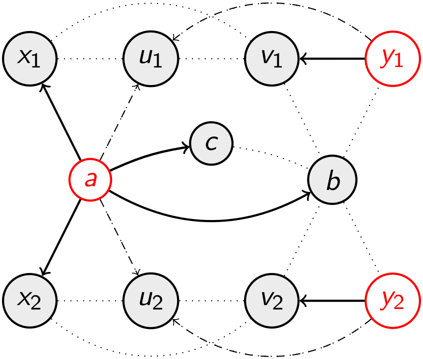


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# A few Remarks

A general way of adding conflicts (as soon as detected) to the AF thus is not possible. Still,

- for stable semantics results show that it can be done by adding arguments
- it might work in certain situations
- relaxation: extensions need not to be fully retained

# Exploiting the Babylonian Confusion

Many things have already been done:

- compute grounded extension first and use reduced AF
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Can we do better?

# Signatures

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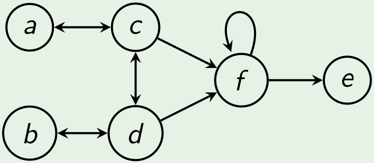


- $\mathcal{S} = \{\{a, d, e\}, \{b, c, e\}, \{a, b\}\} \in \Sigma_{pref}$
- Questions: $\mathcal{S} \in \Sigma_{sem}$? $\mathcal{S} \in \Sigma_{stb}$?

# Signatures (ctd.)

## Definition

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

$$Confs_{\mathcal{S}} = \{(a,b) \in \bigcup \mathcal{S} \times \bigcup \mathcal{S} \mid \nexists S \in \mathcal{S} : a, b \in S\}, \text{ and}$$

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

## Example

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

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

# Signatures (ctd.)

## Theorem

$$\begin{aligned}
\Sigma_{naive} &= \{\mathcal{S} \neq \emptyset \mid \mathcal{S} = bd(\mathcal{S})\} \\
\Sigma_{stb} &= \{\mathcal{S} \mid \mathcal{S} \subseteq bd(\mathcal{S})\} \\
\Sigma_{pref} &= \{\mathcal{S} \neq \emptyset \mid \mathcal{S} \text{ incomparable and conflict-sensitive}\} \\
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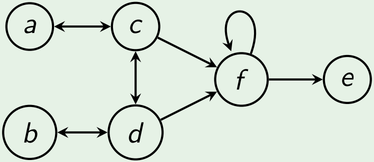


- $\mathcal{S} = \{\{a, d, e\}, \{b, c, e\}, \{a, b\}\} \in \Sigma_{pref}$. $\mathcal{S} \in \Sigma_{sem}$? Yes.
- $\mathcal{S} \in \Sigma_{stb}$? No! $(bd(\mathcal{S}) = \{\{a, b, e\}, \{a, c, e\}, \{b, d, e\}\})$

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$$\Sigma_{naive} \subset \Sigma_{stb} \setminus \{\emptyset\} \subset \Sigma_{pref} = \Sigma_{sem}$$

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**Definition**

Given semantics $\sigma, \tau$, their 2-dimensional signature is defined as

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

- Clearly, $\langle \mathcal{S}, \mathcal{T} \rangle \in \Sigma_{\sigma,\tau}$ only if $\mathcal{S} \in \Sigma_\sigma$ and $\mathcal{T} \in \Sigma_\tau$.

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- Other conditions?

$\Rightarrow$ Measure of the independence of semantics.

$\Rightarrow$ Useful for the enumeration of multiple sets of extensions.

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$$\Sigma_{naive,stb} = \{\langle \mathcal{S}, \mathcal{T} \rangle \mid \mathcal{S} \in \Sigma_{naive}, \mathcal{T} \in \Sigma_{stb}, \mathcal{T} \subseteq \mathcal{S}\}$$

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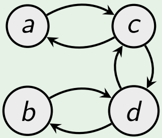
**Example**

$F_{naive,stb}(\{\{a, b\}, \{a, d\}, \{b, c\}\}, \{\{a, d\}\})$:



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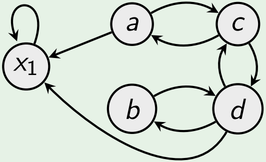

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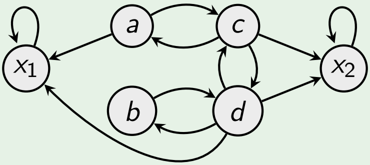

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## Example – Stable vs. Preferred

- $\mathcal{S} = \{\{a, b\}, \{a, d, e\}\}$
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- $\langle \mathcal{S}, \mathcal{T} \rangle \in \Sigma_{stb,pref}$ ?

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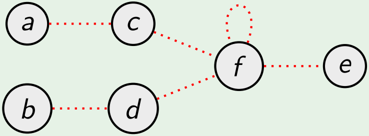

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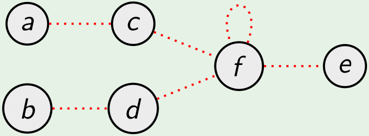


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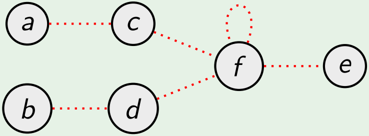


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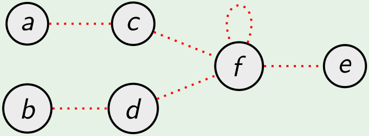


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# Two-dimensional Signatures (ctd.)

## Possible Application in Practice

Consider enumerating preferred extensions:

- start with the less complex stable semantics
- Assume $\{a, b\}$ and some $S \cup \{a\}$ is stable
- By inspecting $\Sigma_{stb,pref}$ we can exclude any $S' \cup \{b\}$ with $S \cap S' \neq \emptyset$ as preferred, even though

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- Explanation: $bd(\mathcal{T}) = \{(S \cap S') \cup \{a, b\}, S \cup \{a\}, S' \cup \{b\}\}$
- Recall:

$$\Sigma_{stb,pref} = \{\langle \mathcal{S}, \mathcal{T} \rangle \mid \mathcal{S} \in \Sigma_{stb}, \mathcal{T} \in \Sigma_{pref}, \mathcal{S} \subseteq \mathcal{T} \cap bd(\mathcal{T})\}$$

# A few Remarks

- Two-dimensional signatures provide a clear picture about the relationship between semantics
- This can be exploited by solvers by first computing extensions of an "easier" semantics and – before searching for the remaining ones – prune the search space accordingly
- Open issues
  - how to incorporate the information about the stable extensions into the AF such that they are not encountered twice?
  - can we find properties for terminating the search for preferred extensions after having found all stable ones?
  - useful in practice?

# Conclusion

- ICCMA has stipulated development of abstract argumentation solvers
- So far, competitive systems rely on reductions to SAT, ASP, CSP, etc.
  - recent analysis shows the picture is not that clear
- In this talk:
  - Review of recent advancements from the theory of abstract argumentation
  - Discussion of potential advanced mechanisms to use genuine argumentation properties in solvers

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  - Discussion of potential advanced mechanisms to use genuine argumentation properties in solvers
- Learn from success stories in other communities:
  - clasp: combination of SAT-techniques and specific ASP features

# Future Work

A ToDo-list for our community

- Continue development of native genuine argumentation systems
  - may outperform reduction-based methods on certain instances
- Enhance reduction-based methods by argumentation-specific "short-cuts"
- Preprocessing
- Better and more benchmarks!
- Understanding the shape of such "meaningful" instances and how do the presented concepts behave on such instances

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"Dung is necessary, but not sufficient"
(H. Prakken)

# Some References


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