Lecture 8

Principle-based Analysis of Acceptability Semantics

INST0074

Lecture Outline

- Acceptability Semantics
  - Semantics proposed by Dung
  - Other proposed semantics
- Principle-based analysis of semantics
  - Definitions of principles
  - Analysis: Which semantics satisfy each of the principles

Formalizations of acceptability semantics

- Acceptability semantics formally define which arguments are accepted and which are rejected.
- Extension-based semantics
  - An **extension** of an argumentation framework $\mathbf{AF} = \{\mathbf{A}, \mathbf{R}\}$ is a set of arguments $\mathbf{E} \subseteq \mathbf{A}$ that we can reasonably accept.
- Labelling-based semantics
  - Each argument in the framework is assigned a **label**:
    - $\mathbf{Lab(a)} = \mathbf{in}$: the argument is accepted
    - $\mathbf{Lab(a)} = \mathbf{out}$: the argument is rejected
    - $\mathbf{Lab(a)} = \mathbf{undec}$: the argument is neither accepted nor rejected

Semantics proposed by Dung

- Defence and admissibility
  - A set of arguments $\mathbf{S} \subseteq \mathbf{A}$ **defends an argument** $\mathbf{a} \in \mathbf{A}$ iff it attacks any argument $\mathbf{b} \in \mathbf{A}$ that attacks $\mathbf{a}$
  - A set of arguments $\mathbf{E} \subseteq \mathbf{A}$ is **admissible** iff it is conflict-free and defends all its elements.
- Complete semantics
  - A set of arguments $\mathbf{E} \subseteq \mathbf{A}$ is **a complete extension** of $\mathbf{AF} = \{\mathbf{A}, \mathbf{R}\}$ iff it is admissible and contains all the arguments it defends

Semantics proposed by Dung

- Grounded semantics
  - A set of arguments $\mathbf{E} \subseteq \mathbf{A}$ is **a grounded extension** of $\mathbf{AF} = \{\mathbf{A}, \mathbf{R}\}$ iff it is the minimal (w.r.t. set inclusion) complete extension of AF
  - The grounded extension is the intersection of all complete extensions and is unique.
- Preferred semantics
  - A set of arguments $\mathbf{E} \subseteq \mathbf{A}$ is **a preferred extension** of $\mathbf{AF} = \{\mathbf{A}, \mathbf{R}\}$ iff it is a maximal (w.r.t. set inclusion) complete extension of AF
- Stable semantics
  - A set of arguments $\mathbf{E} \subseteq \mathbf{A}$ is **a stable extension** of $\mathbf{AF} = \{\mathbf{A}, \mathbf{R}\}$ iff it is conflict-free and attacks all arguments in $\mathbf{A} / \mathbf{E}$
  - There are argumentation frameworks that have no stable extensions.
  - Every stable extension is also a preferred extension.

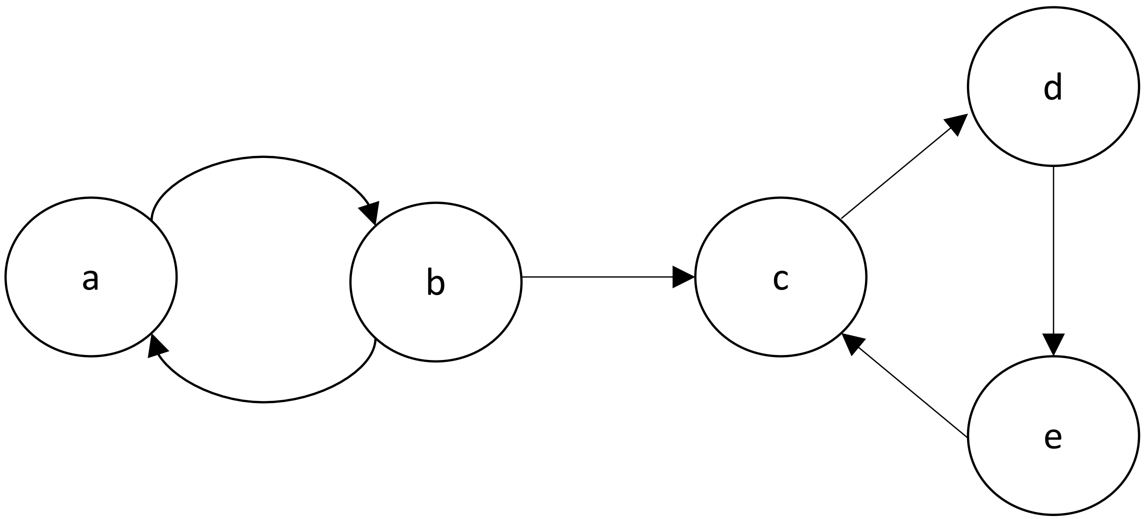
Other proposed semantics

- Semi-stable semantics
  - Guarantees that every argumentation framework has an extension.
  - Coincides with stable semantics when there is at least one stable extension.
  - A set of arguments $\mathbf{E} \subseteq \mathbf{A}$ is **a semi-stable extension** of $\mathbf{AF} = \{\mathbf{A}, \mathbf{R}\}$ iff it is a complete extension and $\mathbf{E} \cup \mathbf{E}^{+}$ is maximal among the complete extensions.
  - $\mathbf{E}^{+}$ denotes the set of arguments attacked by $\mathbf{E}$
  - Every semi-stable extension is also a preferred extension.
- Ideal semantics
  - Similar to but less sceptical (it accepts more arguments) than grounded semantics
  - A set of arguments $\mathbf{E} \subseteq \mathbf{A}$ is **an ideal extension** iff it is a maximal admissible subset of every preferred extension.
  - Unique extension, superset of the grounded extension.

Other proposed semantics

- Eager semantics
  - Similar to but less sceptical than ideal semantics
  - A set of arguments $\mathbf{E} \subseteq \mathbf{A}$ is **an eager extension** iff it is a maximal admissible subset of every semi-stable extension.
  - Unique extension, superset of the ideal extension.
- Stage semantics
  - Similar to semi-stable semantics
  - A set of arguments $\mathbf{E} \subseteq \mathbf{A}$ is **a stage extension** of $\mathbf{AF} = \{\mathbf{A}, \mathbf{R}\}$ iff it is conflict-free and $\mathbf{E} \cup \mathbf{E}^{+}$ is maximal among the conflict free subsets of A.
  - A stage extension is not necessarily an admissible set.
- Naive semantics
  - A set of arguments $\mathbf{E} \subseteq \mathbf{A}$ is **naive extension** iff it is a maximal conflict-free set.

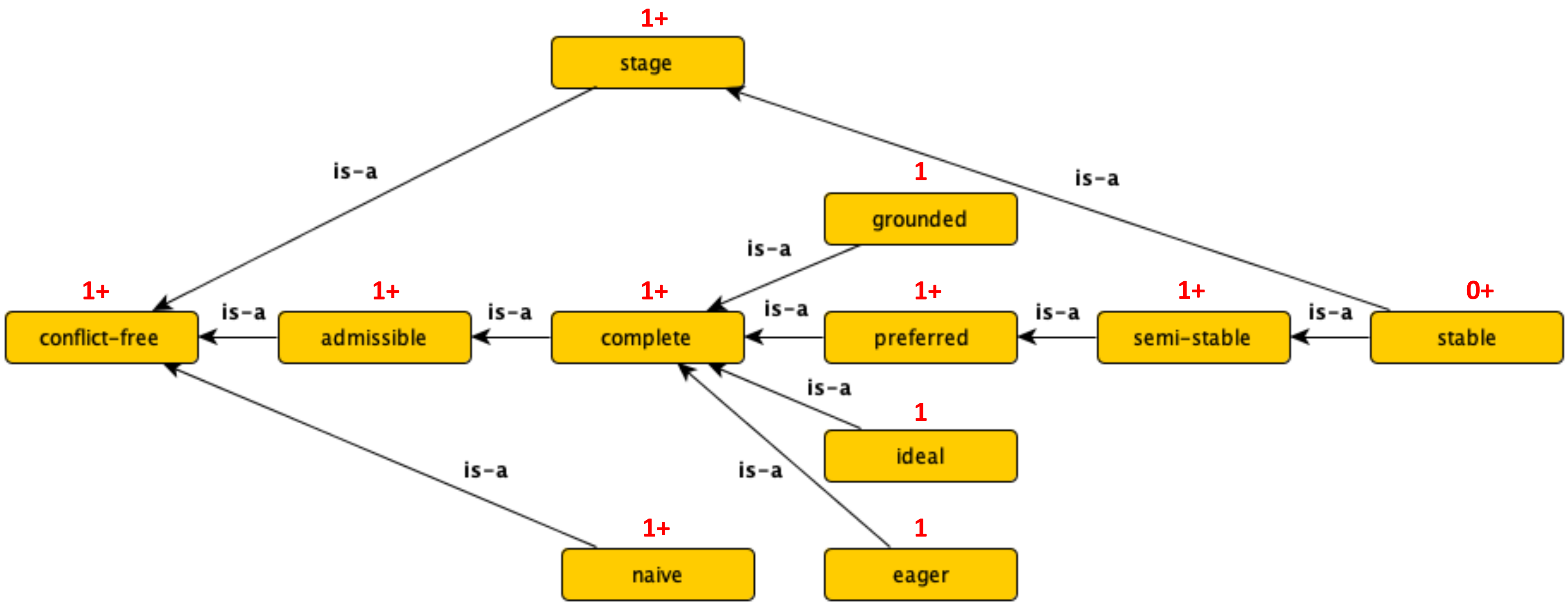
An Example



Extensions

Complete:	{}, {a}, {b,d}
Grounded:	{}
Preferred:	{a}, {b,d}
Stable:	{b,d}
Semi-stable:	{b,d}
Ideal:	{}
Eager:	{b,d}
Stage:	{b,d}
Naive:	{a,c}, {a,d}, {a,e}, {b,d}, {b,e}

Classification and cardinality of semantics



Principle-based analysis of semantics

- Aims to address questions such as:
  - *How do we know that the currently considered set of semantics is sufficient or complete?*
  - *How to choose one semantics from the set of alternatives in a particular application?*
  - *How to guide the search for new and hopefully better argumentation semantics?*

Principle 1: Language independence

- Idea: *The semantics does not take into account the names of arguments*
  - (Baroni and Giacomin, 2007).
- Two argumentation frameworks $\mathbf{F_1} = (\mathbf{A_1}, \mathbf{R_1})$ and $\mathbf{F_2} = (\mathbf{A_2}, \mathbf{R_2})$ are **isomorphic** if and only if there exists a bijective function $\mathbf{m} : \mathbf{A_1} \rightarrow \mathbf{A_2}$, such that $(\mathbf{a}, \mathbf{b}) \in \mathbf{R_1}$ if and only if $(\mathbf{m(a)}, \mathbf{m(b)}) \in \mathbf{R_2}$.
- This is denoted by $\mathbf{F_1} \doteq_{\mathbf{m}} \mathbf{F_2}$.
- A semantics **σ** satisfies the **language independence** principle if and only if for every two argumentation frameworks F_1 and F_2:

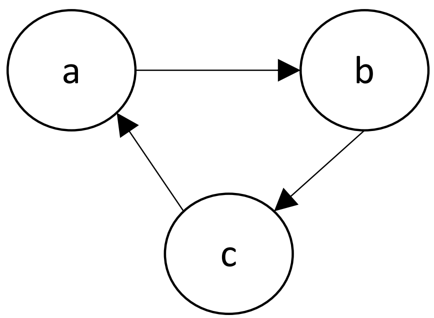
  if $\mathbf{F_1} \doteq_{\mathbf{m}} \mathbf{F_2}$ **then** $\boldsymbol{\sigma}(\mathbf{F_2}) = \{\mathbf{m(E)} \mid \mathbf{E} \in \boldsymbol{\sigma}(\mathbf{F_1})\}$
  - where $\boldsymbol{\sigma}(\mathbf{F})$ is the set of σ-extensions of $\mathbf{F}$
- All semantics satisfy this principle.

Principle 2: Conflict freeness

- Idea: *Accepted arguments should be consistent with each other*.
  - (Dung, 1995), (Baroni and Giacomin, 2007)
- A semantics **σ** satisfies the **conflict freeness** principle if and only if for every argumentation framework $\mathbf{F}$ and for every $\mathbf{E} \in \boldsymbol{\sigma}(\mathbf{F})$, $\mathbf{E}$ is **conflict-free**
- All semantics satisfy this principle.

Principle 3: Defence

- Idea: *An extension should defend its elements from external attacks*.
  - (Dung, 1995)
- A semantics **σ** satisfies the **defence** principle if and only if for every argumentation framework F and for every $\mathbf{E} \in \boldsymbol{\sigma}(\mathbf{F})$, for every $\mathbf{a} \in \mathbf{E}$, $\mathbf{E}$ **defends** $\mathbf{a}$
- This principle is satisfied by complete, grounded, preferred, stable, semi-stable, ideal and eager semantics, but not by naive and stage semantics.
- Example:



Naive extensions: {a}, {b}, {c}
Stage extensions: {a}, {b}, {c}
Neither of these extensions defends the arguments it contains.

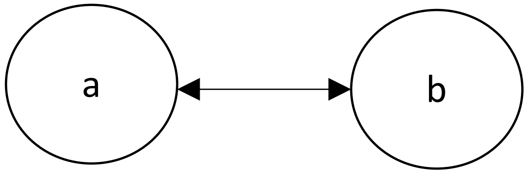
Principle 4: Admissibility

- Combination of conflict-freeness and defence.
  - (Dung, 1995)
- A semantics **σ** satisfies the **admissibility** principle if and only if for every argumentation framework $\mathbf{F}$ and for every $\mathbf{E} \in \boldsymbol{\sigma}(\mathbf{F})$, $\mathbf{E}$ **is admissible**
- If a semantics satisfies admissibility, it also satisfies conflict-freeness and defence.
- This principle is satisfied by complete, grounded, preferred, stable, semi-stable, ideal and eager semantics.
- Not satisfied by naive and stage semantics.

Principle 5: Strong admissibility

- A set of arguments $\mathbf{S} \subseteq \mathbf{A}$ **strongly defends an argument** $\mathbf{a} \in \mathbf{A}$ iff for every argument $\mathbf{b} \in \mathbf{A}$ that attacks $\mathbf{a}$, there exists an argument $\mathbf{c} \in \mathbf{S}/\{\mathbf{a}\}$ such that $\mathbf{c}$ attacks $\mathbf{b}$, and $\mathbf{c}$ is strongly defended by $\mathbf{S}/\{\mathbf{a}\}$
  - (Baroni and Giacomin, 2007)
- A set of arguments $\mathbf{E} \subseteq \mathbf{A}$ is **strongly admissible** iff it is conflict-free and strongly defends all its elements.
- A semantics **σ** satisfies the **strong admissibility** principle if and only if for every argumentation framework $\mathbf{F}$ and for every $\mathbf{E} \in \boldsymbol{\sigma}(\mathbf{F})$, $\mathbf{E}$ **is strongly admissible**
- The principle is satisfied only by the grounded semantics.

Strong admissibility (counter-example)



- Complete: {}, {a}, {b}
- Preferred: {a}, {b}
- Stable: {a}, {b}
- Semi-stable: {a}, {b}

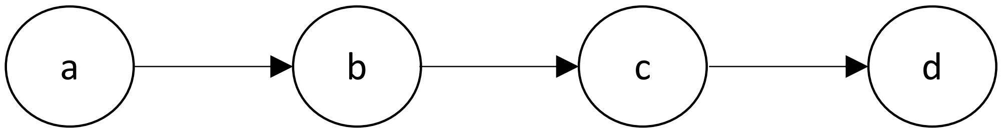
- {a} does not strongly defend a, therefore it’s not strongly admissible
- {b} does not strongly defend a, therefore it’s not strongly admissible

Principle 6: Naivety

- Idea: *Every extension must be maximal among the conflict free sets*.
  - (van der Torre and Vesic, 2018)
- A semantics **σ** satisfies the **naivety** principle if and only if for every argumentation framework $\mathbf{F}$ and for every $\mathbf{E} \in \boldsymbol{\sigma}(\mathbf{F})$, $\mathbf{E}$ **is maximal** (w.r.t. set inclusion) **among the conflict free sets in** $\mathbf{F}$**.**
- The principle is only satisfied by the naive, stable and stage semantics.

Principle 7: Indirect conflict freeness

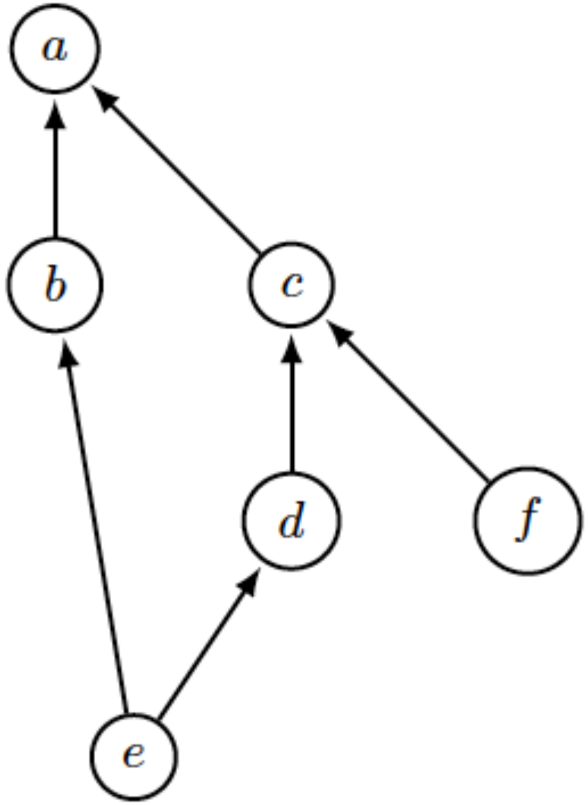
- Idea: *Consistency of arguments should also account for indirect conflicts*.
  - (Coste-Marquis et al., 2005)
- An argument $\mathbf{a}$ **indirectly attacks** an argument $\mathbf{b}$ iff there is an **odd-length path** with respect to the attack relation from $\mathbf{a}$ to $\mathbf{b}$.



a indirectly attacks **b** and **d**

- A semantics **σ** satisfies the **indirect conflict freeness** principle if and only if for every argumentation framework $\mathbf{F}$ and for every $\mathbf{E} \in \boldsymbol{\sigma}(\mathbf{F})$, $\mathbf{E}$ is **without indirect conflicts**
- None of the semantics we have seen so far satisfy this principle.

Indirect conflict-freeness (counter-example)



{e, f, a} is a complete, preferred, grounded, stable, semi-stable, eager, ideal, stage and naive extension

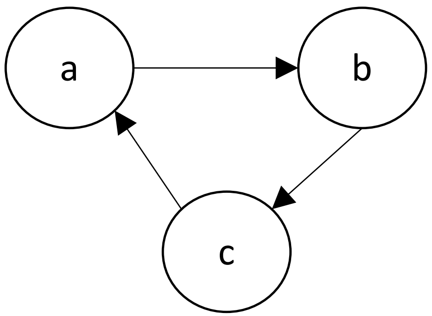
e indirectly attacks a

Prudent semantics

- Idea: *An extension should not contain indirect conflicts*.
  - (Coste-Marquis et al., 2005)
- A set of arguments $\mathbf{E} \subseteq \mathbf{A}$ is **p-admissible** iff it is without indirect conflicts and defends all its elements.
- A set of arguments $\mathbf{E} \subseteq \mathbf{A}$ is **a p-complete extension** of $\mathbf{F} = \{\mathbf{A}, \mathbf{R}\}$ iff it is p-admissible for every argument $\mathbf{a} \in \mathbf{A}$: if $\mathbf{E}$ defends $\mathbf{a}$, and $\mathbf{E} \cup \{\mathbf{a}\}$ is without indirect conflicts, then $\mathbf{a} \in \mathbf{E}$
- Definitions of **p-grounded**, **p-preferred** and **p-stable** semantics are also based on the notion of p-admissibility.
- All prudent semantics satisfy the principle of indirect conflict-freeness.

Principle 8: Reinstatement

- Idea: *An extension must contain all arguments it defends*.
  - (Baroni and Giacomin, 2007)
- A semantics **σ** satisfies the **reinstatement** principle if and only if for every argumentation framework $\mathbf{F}$, for every $\mathbf{E} \in \boldsymbol{\sigma}(\mathbf{F})$, and for every $\mathbf{a} \in \mathbf{A}$, **if** $\mathbf{E}$ **defends** $\mathbf{a}$ **then** $\mathbf{a} \in \mathbf{E}$
- The principle is satisfied by the complete, grounded, preferred, stable, semi-stable, ideal and eager semantics, but not by the naive and stage.
- Example:



- **{a}**, **{b}**, **{c}** are all naive and stage extensions
- All of them defend an argument that they do not contain, e.g. {a} defends c but doesn't contain it

Principle 9: CF-Reinstatement

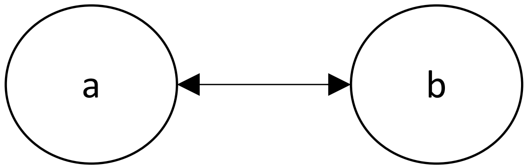
- A weaker form of reinstatement.
  - (Baroni and Giacomin, 2007)
- A semantics **σ** satisfies the **CF-reinstatement** principle if and only if for every argumentation framework $\mathbf{F}$, for every $\mathbf{E} \in \boldsymbol{\sigma}(\mathbf{F})$, and for every $\mathbf{a} \in \mathbf{A}$, **if $\mathbf{E}$ defends $\mathbf{a}$ and $\mathbf{E} \cup \{\mathbf{a}\}$ is conflict-free then $\mathbf{a} \in \mathbf{E}$**
- The principle is satisfied by all semantics (including naive and stage)

Principle 10: I-maximality

- Idea: *An extension cannot contain another extension*.
  - (Baroni and Giacomin, 2007)
- A semantics **σ** satisfies the **I-maximality** principle if and only if for every argumentation framework $\mathbf{F}$, for every $\mathbf{E_1}, \mathbf{E_2} \in \boldsymbol{\sigma}(\mathbf{F})$, **if** $\mathbf{E_1} \subseteq \mathbf{E_2}$ then $\mathbf{E_1} = \mathbf{E_2}$
- The principle is satisfied by all semantics except the complete semantics

Principle 11: Allowing abstention

- A semantics **σ** satisfies the **allowing abstention** principle if and only if for every argumentation framework F**,** for every $\mathrm{a} \in \mathrm{A}$, **if there are two extensions E_1, $\mathrm{E}_2 \in \sigma(\mathrm{F})$, such that $\mathrm{a} \in \mathrm{E}_1$ and $\mathrm{a} \in \mathrm{E}_2^+$ then there exists an extension $\mathrm{E}_3 \in \sigma(\mathrm{F})$ such that $\mathrm{a} \notin (\mathrm{E}_3 \cup \mathrm{E}_3^+)$**
    - (Baroni et al., 2011)
- The principle is satisfied by the complete, grounded, ideal and eager semantics.
- Example:

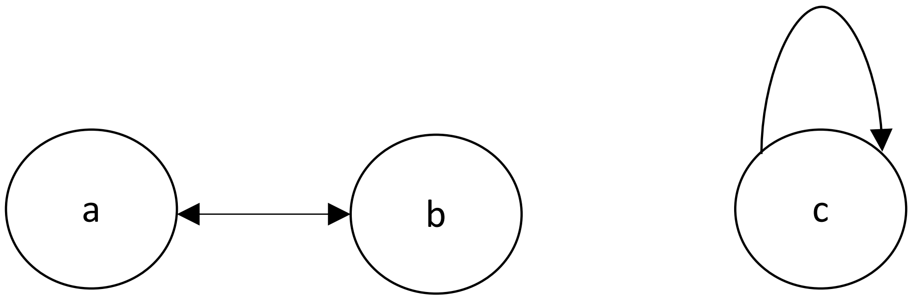


- **{a}**, **{b}** are the preferred extensions
- **a** belongs to **{a}** and is attacked by **{b}**, but there is no other preferred extension

Principle 12: Crash Resistance

- Idea: *There should not exist a framework that causes another disjoint framework to crash*.
  - (Caminada et al., 2012)
- Two argumentation frameworks $\mathbf{F_1} = \{\mathbf{A_1}, \mathbf{R_1}\}$, $\mathbf{F_2} = \{\mathbf{A_2}, \mathbf{R_2}\}$ are **disjoint** if and only if $\mathbf{A_1} \cup \mathbf{A_2} = \emptyset$
- An argumentation framework $\mathbf{F^*}$ is **contaminating** for a semantics **σ** if and only if for every argumentation framework $\mathbf{F}$ disjoint from $\mathbf{F^*}$ it holds that $\boldsymbol{\sigma}(\mathbf{F^*} \cup \mathbf{F}) = \boldsymbol{\sigma}(\mathbf{F^*})$
- A semantics **σ** satisfies the **crash resistance** principle if and only if **there are no contaminating frameworks for σ.**
- The principle is satisfied by all semantics except the stable semantics.

Crash Resistance (counter-example)



F $\qquad$ **F***

- **F** and **F*** are disjoint
- **F** has two stable extensions: **{a}**, **{b}**
- **F*** has no stable extensions
- **F*** ∪ **F** has no stable extensions either
- For any **F** that is disjoint with **F***: **F*** ∪ **F** has no stable extensions
- **F*** is contaminating for stable semantics

Principle 13: Non-interference

- Idea: *Arguments that do not interfere with a set of arguments should not have an effect on the acceptability of the arguments in this set*.
  - (Caminada et al., 2012)
- Let $\mathbf{F} = \{\mathbf{A}, \mathbf{R}\}$ be an argumentation framework. A set $\mathbf{S} \subseteq \mathbf{A}$ is **isolated** in $\mathbf{F}$ if and only if **there are no attacks between $\mathbf{S}$ and $\mathbf{A}/\mathbf{S}$**
- A semantics **σ** satisfies the **non-interference** principle if and only if for every isolated set $\mathbf{S}$, the intersections of the extensions with set $\mathbf{S}$ coincide with the extensions of the restriction of the framework on $\mathbf{S}$:

$$\boldsymbol{\sigma}(\mathbf{F}{\downarrow_S}) = \{\ \mathbf{E} \cap \mathbf{S} \mid \mathbf{E} \in \boldsymbol{\sigma}(\mathbf{F})\ \}$$

- $\mathbf{F}{\downarrow_S} = \{\ \mathbf{S}, \mathbf{R} \cap (\mathbf{S} \times \mathbf{S})\ \}$
- The principle is satisfied by all semantics except the stable semantics.

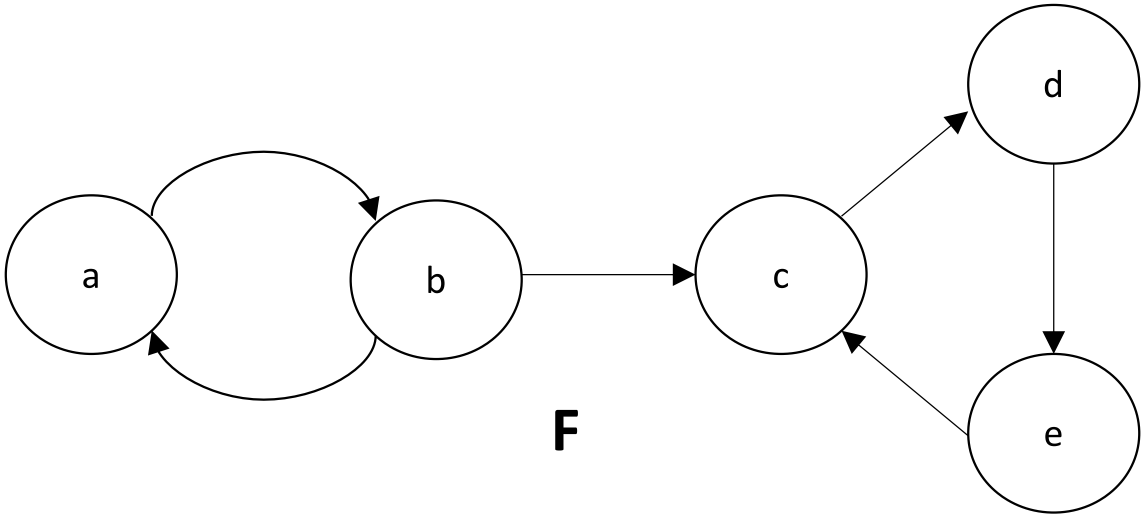
Principle 14: Directionality

- Idea: *Arguments that only receive attacks from a set of arguments should not have any effect on the state of the arguments in this set*.
  - (Baroni and Giacomin, 2007)
- Let $\mathbf{F} = \{\mathbf{A}, \mathbf{R}\}$ be an argumentation framework. A set $\mathbf{U} \subseteq \mathbf{A}$ is **unattacked** in $\mathbf{F}$ if and only if **it is not attacked by** $\mathbf{A/S}$. The set of unattacked sets of arguments in $\mathbf{F}$ is denoted $\mathbf{US(F)}$
- A semantics **σ** satisfies the **directionality** principle if and only if for every unattacked set $\mathbf{U}$, the intersections of the extensions with set $\mathbf{U}$ coincide with the extensions of the restriction of the framework on $\mathbf{U}$:

$$\boldsymbol{\sigma}(\mathbf{F}\downarrow_{\mathbf{U}}) = \{\ \mathbf{E} \cap \mathbf{U} \mid \mathbf{E} \in \boldsymbol{\sigma}(\mathbf{F})\ \}$$

- Satisfied by all semantics except stable, semi-stable, naive, eager and stage

Directionality (counter-example)



- **U = {a,b}** is an unattacked set in **F**
- **{b,d}** is the only stable, semi-stable and stage extension of **F**
- $\{ E \cap U \mid E \in \sigma(F) \} = \{b\}$
- **{a}, {b}** are the stable, semi-stable and stage extensions of $F{\downarrow_U}$
- $\sigma(F{\downarrow_U}) \neq \{ E \cap U \mid E \in \sigma(F) \}$ for stable, semi-stable and stage semantics

Weaker forms of directionality

- A semantics **σ** satisfies the **weak directionality** principle if and only if for every unattacked set U, the intersections of the extensions with set U **are a subset of** the extensions of the restriction of the framework on U:

  $$\boldsymbol{\sigma(F{\downarrow_U}) \supseteq \{ E \cap U \mid E \in \sigma(F) \}}$$

  - (van der Torre and Vesic, 2018)
  - Satisfied by all semantics except semi-stable, eager, naive and stage
- A semantics **σ** satisfies the **semi-directionality** principle if and only if for every unattacked set U, the intersections of the extensions with set U **are a supserset of** the extensions of the restriction of the framework on U:

  $$\boldsymbol{\sigma(F{\downarrow_U}) \subseteq \{ E \cap U \mid E \in \sigma(F) \}}$$

  - (van der Torre and Vesic, 2018)
  - Satisfied by all semantics except stable, semi-stable, eager and stage

Dependencies among the principles

- A semantics **σ** satisfies directionality if and only if it satisfies both weak and semi-directionality.
- Directionality implies non-interference, and non-interferences implies crash resistance.
- If a semantics **σ** satisfies reinstatement then it satisfies CF-reinstatement.
- If a semantics **σ** satisfies indirect conflict-freeness then it satisfies conflict-freeness.
- If a semantics **σ** satisfies strong admissibility then it satisfies admissibility.
- If a semantics **σ** satisfies admissibility then it satisfies conflict-freeness and defence.

An overview of the properties of semantics

	Defence	Admissibility	Strong Adm.	Naivety	Indirect CF	Reinstat.	CF-Reinstat.
complete	✓	✓	✗	✗	✗	✓	✓
grounded	✓	✓	✓	✗	✗	✓	✓
preferred	✓	✓	✗	✗	✗	✓	✓
stable	✓	✓	✗	✓	✗	✓	✓
semi-stable	✓	✓	✗	✗	✗	✓	✓
ideal	✓	✓	✗	✗	✗	✓	✓
eager	✓	✓	✗	✗	✗	✓	✓
naive	✗	✗	✗	✓	✗	✗	✓
stage	✗	✗	✗	✓	✗	✗	✓

An overview of the properties of semantics

	I-maximality	Allowing Abs.	Crash Resist.	Non-interfer.	Directionality	Weak direct.	Semi-direct.
complete	✗	✓	✓	✓	✓	✓	✓
grounded	✓	✓	✓	✓	✓	✓	✓
preferred	✓	✗	✓	✓	✓	✓	✓
stable	✓	✗	✗	✗	✗	✓	✗
semi-stable	✓	✗	✓	✓	✗	✗	✗
ideal	✓	✓	✓	✓	✓	✓	✓
eager	✓	✓	✓	✓	✗	✗	✗
naive	✓	✗	✓	✓	✗	✗	✓
stage	✓	✗	✓	✓	✗	✗	✗

Other proposed principles

- **Skepticism adequacy, Resolution adequacy** (Baroni and Giacomin, 2007)
- **Succinctness** (Gaggl and Woltran, 2013)
- **Tightness** (Dunne et. al, 2015)
- **Conflict-sensitiveness** (Dunne et. al, 2015)
- **Com-closure** (Dunne et. al, 2015)
- **SCC-recursiveness** (Baroni et. al, 2005)

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