Lecture 9

Extensions of Abstract Argumentation Frameworks

INST0074

Lecture Outline

- Extensions of Abstract Argumentation Frameworks
  - Extending the notion of attack
  - Preferences in abstract argumentation
  - Incorporating the notion of support
  - Introducing weights on arguments or attacks
- Abstract Dialectical Frameworks

Joint attacks

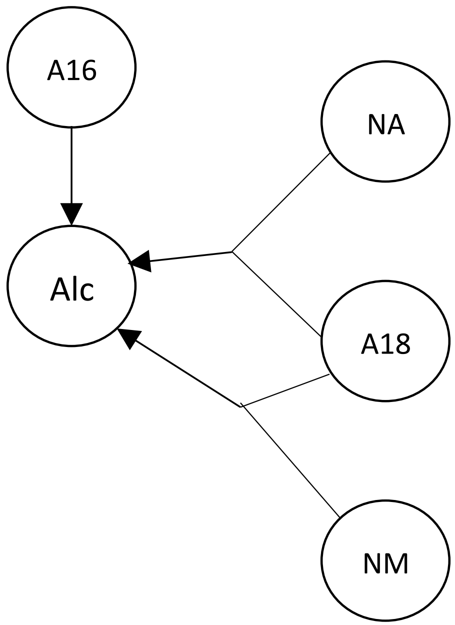
- In AAF, attacks are binary, i.e. from a single argument to another single argument.
- SETAF (Framework with Sets of Attacking Arguments)*
  - An extension of AAF supporting joint attacks.
  - **Joint attack**: Two or more arguments jointly attack another argument.
  - The joint attack is effective only if all the arguments in the set of attacking arguments are accepted.

* Søren Holbech Nielsen and Simon Parsons (2007). A generalization of Dung's abstract framework for argumentation: Arguing with sets of attacking arguments. In Proceedings of the 3rd International Workshop on Argumentation in Multi-Agent Systems, pages 54–73, 2007.

Joint attacks: A motivating example

In the UK, one is allowed to consume alcohol in public,
unless one is under 16,
or one is under 18 and not accompanied by an adult,
or one is under 18 and not having a meal.

Modelling
the example
In SETAF



Alc: Allowed to consume alcohol in public
A16: Aged under 16
A18: Aged under 18
NA: Not accompanied by an adult
NM: Not having meal

A18 and NA **jointly attack** Alc
A18 and NM **jointly attack** Alc
A16 attacks Alc

SETAF: Definitions

- A Framework with Sets of Attacking Arguments (SETAF) is a pair $(\mathbf{A}, \mathbf{R})$ where $\mathbf{A}$ is a set of arguments and $\mathbf{R} \subseteq (2^{\mathbf{A}}\backslash\{\}) \times \mathbf{A}$ an attack relation
- An attack $\triangleright$ relates a set of arguments (attacking arguments) with a single argument. For example, $\{\mathbf{A18},\mathbf{NM}\} \triangleright \mathbf{Alc}$
- Acceptability Semantics
  - Admissible, Complete, Grounded, Preferred, Stable, etc.
  - Defined in terms of extensions and labellings
  - Definitions available in Chapter 3 of Vol.2 of the Handbook of Formal Argumentation (Bikakis et al.: Joint Attacks and Accrual in Arg. Frameworks)
- Relation with AAF: Given a SETAF, it is possible to generate an equivalent (but exponentially bigger) AAF.

Second-order attacks

- In AAF, attacks are directed to arguments.
- EAF (Extended Argumentation Framework)*
  - An extension of AAF supporting second-order attacks.
  - A **simple attack** is an attack directed from an argument to another argument.
  - A **second-order attack** is an attack directed from an argument to a simple attack.
  - Second-order attacks provide a way to represent preferences over arguments.

* Sanjay Modgil (2009). Reasoning about preferences in argumentation frameworks. Artificial Intelligence, 173:901-934.

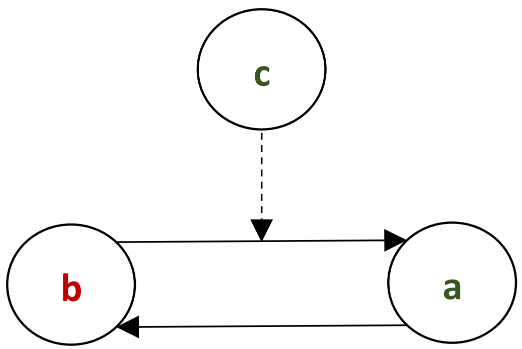
Second-order attacks: A motivating example

P: Today will be dry in London since the BBC forecast sunshine. (**a**)

Q: Today will be wet in London since CNN forecast rain. (**b**)

P: But the BBC are more trustworthy than CNN. (**c**)

Modelling the example In EAF



(a, b), (b, a): Simple attacks

(c, (a, b)): Second-order attack. It expresses a preference of **a** over **b**.

b does not successfully attack **a**, because of the attack from **c**, so **a** becomes justified

EAF: Definitions

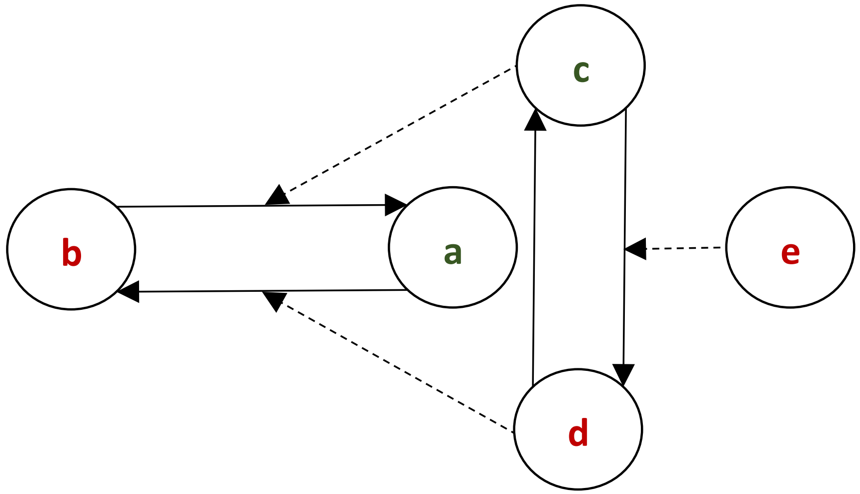
- An Extended Argumentation Framework (EAF) is a tuple $(\mathbf{A}, \mathbf{R}, \mathbf{D})$ where $\mathbf{A}$ is a set of arguments and
  - $\mathbf{R} \subseteq \mathbf{A} \times \mathbf{A}$ is a set of simple (binary) attacks
  - $\mathbf{D} \subseteq \mathbf{A} \times \mathbf{R}$ is a set of second-order attacks
  - If $\mathbf{(a, (x, y)), (b, (y, x))} \in \mathbf{D}$ then $\mathbf{(a, b), (b, a)} \in \mathbf{R}$
- Acceptability semantics are based on the notion of defeat, which takes into account both types of attacks.
- An argument $\mathbf{a}$ **defeats** an argument $\mathbf{b}$ w.r.t. to a set of arguments $\mathbf{S}$ iff $\mathbf{(a, b)} \in \mathbf{R}$ and there exists no argument $\mathbf{c} \in \mathbf{S}$ such that $\mathbf{(c, (a, b))} \in \mathbf{D}$.

Motivating example (extended)

P: Today will be dry in London since the BBC forecast sunshine. (**a**)
Q: Today will be wet in London since CNN forecast rain. (**b**)
P: But the BBC are more trustworthy than CNN. (**c**)

Q: However, statistically CNN are more accurate forecasters than the BBC. (**d**)
Q: And basing a comparison on statistics is more rigorous and rational than basing a comparison on your instincts about their relative trustworthiness. (**e**)

Modelling the example In EAF



{e, d, b} is an admissible, preferred, complete and stable extension of this EAF

Recursive attacks

- AFRA (Argumentation Framework with Recursive Attacks)*
  - An extension of AAF supporting high-order (recursive) attacks.
  - An **attack** is directed from an argument to an argument or attack.
  - Recursive attacks provide a way to represent preferences over arguments or model decision processes.

* Pietro Baroni, Federico Cerutti, Massimiliano Giacomin, and Giovanni Guida (2011). AFRA: Argumentation framework with recursive attacks. International Journal of Approximate Reasoning, 52: 19-37.

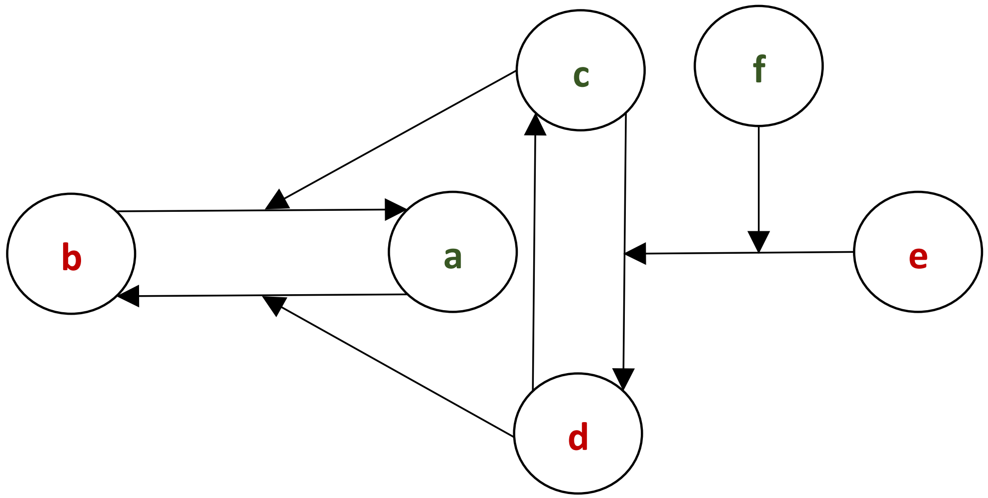
Recursive attacks: A motivating example

…

Q: And basing a comparison on statistics is more rigorous and rational than basing a comparison on your instincts about their relative trustworthiness. (**e**)

P: However, BBC has recently changed its whether forecast model, no information on the new model is available; therefore statistics on CNN loses prevalence over personal opinion about BBC (**f**)

Modelling the example In AFRA

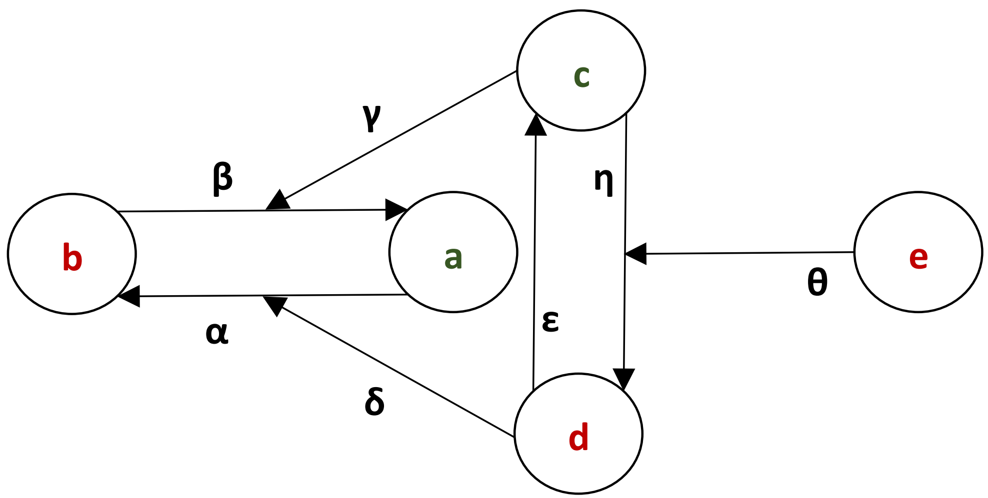


The attack from **f** is a higher order attack, which cannot be expressed in EAF.

AFRA: Definitions

- An Argumentation Framework with Recursive Attacks (AFRA) is a pair $(\mathbf{A}, \mathbf{R})$ where $\mathbf{A}$ is a set of arguments and $\mathbf{R} \subseteq \mathbf{A} \times (\mathbf{A} \cup \mathbf{R})$ is an attack relation.
- An attack $\mathbf{a}$ **defeats** an argument or attack $\mathbf{x}$ if $\mathbf{t(a)=x}$ (direct defeat) or $\mathbf{x} \in \mathbf{R}$ and $\mathbf{t(a)=s(x)}$ (indirect defeat)
  - $\mathbf{s(a), t(a)}$ denote, respectively, the source and the target of an attack $\mathbf{a}$
- Acceptability semantics are based on this notion of defeat and are defined in a very similar way with AAF.
- Attacks are treated as first-class citizens and can themselves be accepted (included in extensions) or rejected.

AFRA: Example



Examples of defeat

θ directly defeats **η**

ε directly defeats **c**

ε indirectly defeats **γ**

…

Complete extension

{e, θ, d, ε, δ, β, b}

Preferences in abstract argumentation

- Preferences are used in abstract argumentation to represent the comparative strength of arguments.
- A Preference-based Argumentation Framework (PAF) is a tuple $(\mathbf{A}, \mathbf{R}, \geq)$ where $\mathbf{A}$ is a set of arguments, $\mathbf{R} \subseteq \mathbf{A} \times \mathbf{A}$ is a binary attack relation and $\geq \subseteq \mathbf{A} \times \mathbf{A}$ is a second binary relation over $\mathbf{A}$, called preference relation.*
- Notation
  - we write $\mathbf{a} \geq \mathbf{b}$ as a shorthand for $(\mathbf{a}, \mathbf{b}) \in \geq$
  - we write $\mathbf{a} > \mathbf{b}$ iff $(\mathbf{a}, \mathbf{b}) \in \geq$ and $(\mathbf{b}, \mathbf{a}) \notin \geq$

* Leila Amgoud and Claudette Cayrol (2002). Inferring from inconsistency in preference-based argumentation frameworks. International Journal of Approximate Reasoning, 29(2):125-169.

Reductions: from PAF to AAF

- To compute the extensions of a PAF $(\mathbf{A}, \mathbf{R}, \geq)$ extensions we can reduce it to an AAF $(\mathbf{A}, \mathbf{R'})$. The extensions of the PAF are the extensions of the corresponding AAF.
- <u>Reduction 1</u>: an attack succeeds only when the attacked argument is not preferred to the attacker
- Formally: for all $\mathbf{a}, \mathbf{b} \in \mathbf{A}$: $(\mathbf{a}, \mathbf{b}) \in \mathbf{R'}$ iff $(\mathbf{a}, \mathbf{b}) \in \mathbf{R}$ and $\mathbf{b} \not> \mathbf{a}$
- Remark: It may lead to non conflict-free extensions
- Example: Consider a PAF with $\mathbf{A}=\{\mathbf{a}, \mathbf{b}\}$, $\mathbf{R}=\{(\mathbf{a}, \mathbf{b})\}$ and $\mathbf{b} > \mathbf{a}$. This is reduced to the AAF with $\mathbf{A}=\{\mathbf{a}, \mathbf{b}\}$ and $\mathbf{R'}=\{\}$. $\{\mathbf{a}, \mathbf{b}\}$ is an extension of the AAF, and, therefore, of the PAF using any of the semantics.

Reductions: from PAF to AAF

- Reduction 2: extension of Reduction 1 that enforces an attack from an argument to another when the former is preferred but attacked by the latter.
- Formally: for all $\mathbf{a}, \mathbf{b} \in \mathbf{A}$: $(\mathbf{a}, \mathbf{b}) \in \mathbf{R'}$ iff
  - $(\mathbf{a}, \mathbf{b}) \in \mathbf{R}$ and $\mathbf{b} \not> \mathbf{a}$ or
  - $(\mathbf{b}, \mathbf{a}) \in \mathbf{R}, (\mathbf{a}, \mathbf{b}) \notin \mathbf{R}$ and $\mathbf{a} > \mathbf{b}$
- Remark: There is no way to defeat a preferred argument.

Reductions: from PAF to AAF

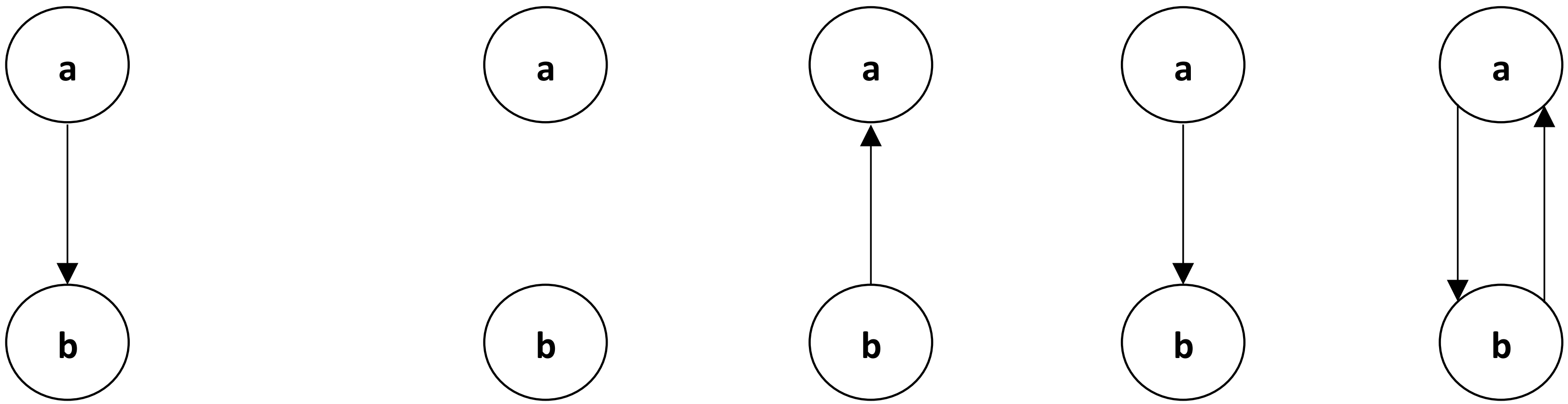
- Reduction 3: extension of Reduction 1 that retains the attacks that cannot be resolved using preferences.
- Formally: for all $\mathbf{a}, \mathbf{b} \in \mathcal{A}$: $(\mathbf{a}, \mathbf{b}) \in \mathbf{R'}$ iff
  - $(\mathbf{a}, \mathbf{b}) \in \mathbf{R}$ and $\mathbf{b} \not> \mathbf{a}$ or
  - $(\mathbf{a}, \mathbf{b}) \in \mathbf{R}$ and $(\mathbf{b}, \mathbf{a}) \notin \mathbf{R}$
- Remark: It makes successful attacks from less preferred arguments.

Reductions: from PAF to AAF

- Reduction 4: Combines the ideas of all other approaches.
- Formally: for all $\mathbf{a}, \mathbf{b} \in \mathcal{A}$: $(\mathbf{a}, \mathbf{b}) \in \mathbf{R'}$ iff
  - $(\mathbf{a}, \mathbf{b}) \in \mathbf{R}$ and $\mathbf{b} \not> \mathbf{a}$ or
  - $(\mathbf{b}, \mathbf{a}) \in \mathbf{R}$, $(\mathbf{a}, \mathbf{b}) \notin \mathbf{R}$ and $\mathbf{a} > \mathbf{b}$ or
  - $(\mathbf{a}, \mathbf{b}) \in \mathbf{R}$ and $(\mathbf{b}, \mathbf{a}) \notin \mathbf{R}$

Differences between the reductions

PAF **AAF**



b > a **Red. 1** **Red.2** **Red.3** **Red.4**

Where are the preferences derived from?

- In structured argumentation, preferences over arguments are derived from the internal structure of the arguments, e.g.
  - Preferences may be associated with the specificity of arguments
  - Preferences may be derived from the preferences over the elements that the arguments consist of
- In abstract argumentation
  - Preferences may be associated with the values that the arguments promote (value-based argumentation frameworks)
  - Preferences may be the result of argument-based reasoning (hierarchical extended argumentation frameworks)

Value-based Argumentation Frameworks

- In dialogues, the acceptability of an argument does not only depend on the argument itself and its counter-arguments, but also on the audience to which it is addressed.
- In such cases, we need to take into account the values that the arguments promote and the preference of the audience over these values.
- Example: Consider suppose that two parents discuss whether their son
  - can watch the football game on the TV (**a**) or
  - whether he should prepare for his exam (**b**)
  - Argument **a** promotes their son's **sociability**, while argument **b** promotes his **education**.
  - The preference between the two arguments depends on the relevant importance of the values they promote.

VAF: Definitions*

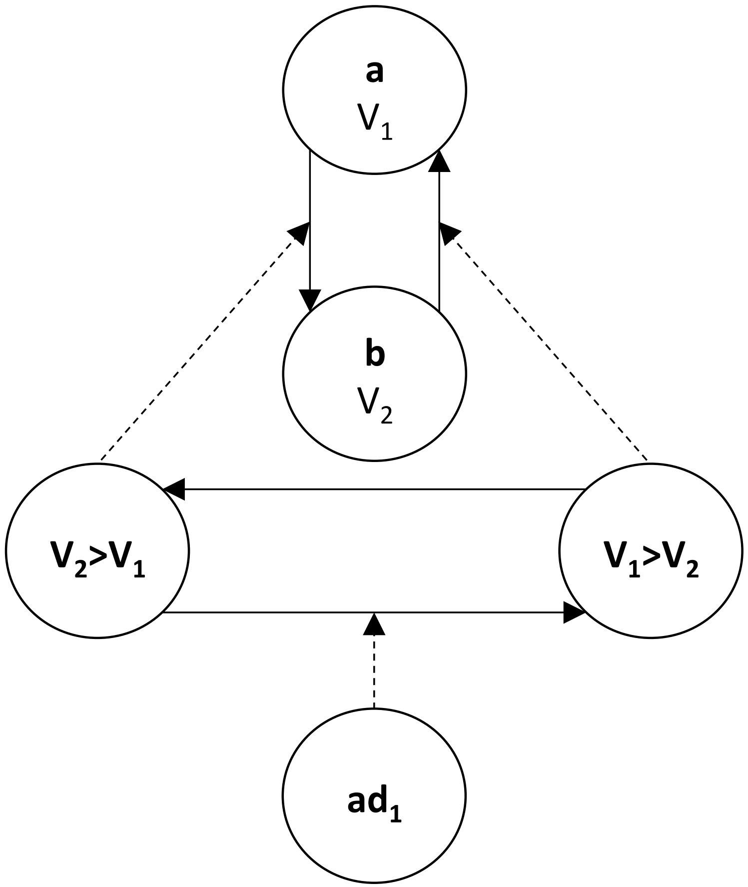
- A Value-based Argumentation Framework is a tuple $(\mathbf{A, R, V, val, D})$ where $\mathbf{A}$ is a set of arguments, $\mathbf{R} \subseteq \mathbf{A} \times \mathbf{A}$ is an attack relation, $\mathbf{V}$ is a set of values, $\mathbf{val: A \rightarrow V}$ a function that assigns a value to each argument and $\mathbf{D}$ the set of possible audiences.
- An Audience-specific VAF is a tuple $(\mathbf{A, R, V, val,} >_{\mathbf{ad}})$ where $\mathbf{ad} \in \mathbf{D}$ is and $>_{\mathbf{ad}}$ is a partial order over $\mathbf{V}$.
- Acceptability semantics are based on the notion of defeat:
- An argument $\mathbf{a}$ defeats an argument $\mathbf{b}$ for audience $\mathbf{ad} \in \mathbf{D}$ if and only if $(\mathbf{a, b}) \in \mathbf{R}$ and the value of $\mathbf{b}$ is not preferred to the value of $\mathbf{a}$.

* Trevor Bench-Capon (2003). Persuasion in practical argument using value-based argumentation frameworks. Journal of Logic and Computation, 13(3):429-448.

Hierarchical EAF

- A special class of Extended Argumentation Frameworks
- In Hierarchical EAF, the argumentation is stratified into levels:
  - Each level is an AAF (with only simple attacks)
  - Simple attacks are attacked by second-order attacks that originate from arguments expressing preferences in the next level.
- Hierarchical EAF can formalise different types of PAF, including VAF
  - Level 1: Arguments and attacks of the VAF
  - Level 2: Partial orders on the set of values, modelled as value preference arguments
  - Level 3: Audience arguments on the choice of value ordering

VAF as an instance of Hierarchical EAF



<u>Level 1</u>

A = {a, b}

R={(a, b),(b, a))

<u>Level 2</u>

A=$\{V_2>V_1,\ V_1>V_2\}$

R=$\{(V_2>V_1,\ V_1>V_2),\ (V_1>V_2,\ V_2>V_1),$
$(V_2>V_1,\ (a, b)),\ (V_1>V_2,\ (b, a))\}$

<u>Level 3</u>

A=$\{ad_1\}$

R=$\{(ad_1,\ (V_2>V_1,\ V_1>V_2))\}$

Bipolar Argumentation Frameworks

- They extend AAF with a binary support relation on the set of arguments.
- A Bipolar Argumentation Framework (BAF) is a tuple $(\mathbf{A}, \mathbf{R}, \mathbf{S})$ where $\mathbf{A}$ is a set of arguments, $\mathbf{R} \subseteq \mathbf{A} \times \mathbf{A}$ is a binary attack relation and $\mathbf{S} \subseteq \mathbf{A} \times \mathbf{A}$ is a binary support relation over $\mathbf{A}$.*
- A **supported attack** from $\mathbf{a_1}$ to $\mathbf{a_n}$ exists iff there exists a sequence of arguments $\mathbf{a_1,\ldots,a_n}$ such that $(\mathbf{a_1,a_2}),(\mathbf{a_2,a_3}),\ldots,(\mathbf{a_{n-2},a_{n-1}}) \in \mathbf{S}$ and $(\mathbf{a_{n-1},a_n}) \in \mathbf{R}$
- A **secondary attack** from $\mathbf{a_1}$ to $\mathbf{a_n}$ exists iff there exists a sequence of arguments $\mathbf{a_1,\ldots,a_n}$ such that $(\mathbf{a_1,a_2}) \in \mathbf{R}$ and $(\mathbf{a_2,a_3}), (\mathbf{a_3,a_4}),\ldots, (\mathbf{a_{n-1},a_n}) \in \mathbf{S}$

* Claudette Cayrol and Marie-Christine Lagasquie-Schiex (2005). On the acceptability of arguments in bipolar argumentation frameworks. In Symbolic and Quantitative Approaches to Reasoning with Uncertainty, 8th European Conference, ECSQARU 2005, Proceedings, pages 378-389.

BAF: An example

Consider the following arguments exchanged during the meeting of the editorial board of a newspaper:

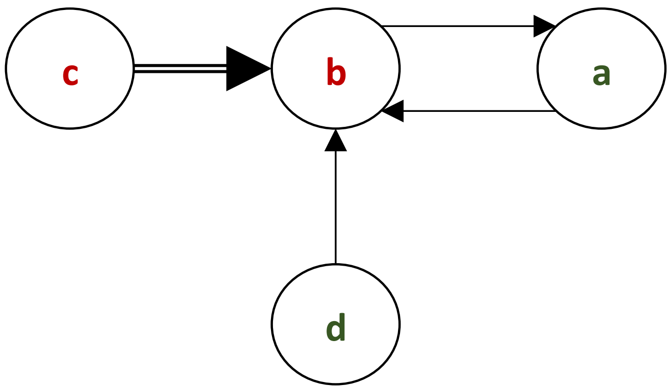
Information I concerning person P should be published. (**a**)

Information I is private, so P denies publication. (**b**)

I is an important information concerning P's son. (**c**)

P is the new prime minister, so everything related to P is public. **(d)**

Modelling the example In BAF



(a, b), (b, a), (d, b): Direct attacks

(c, b): Support

(c, a): Supported attack

Argumentation Framework with Necessities*

- Additionally to the attack relation, AFNs include a binary necessity relation.
- **Necessity** is a special kind of support: if an argument **a** supports another argument **b**, then **a** is necessary to obtain **b**.
  - If **b** is accepted then **a** should also be accepted
  - If **a** is not accepted then **b** cannot be accepted

* Farid Nouioua and Vincent Risch (2011). Argumentation frameworks with necessities. In Scalable Uncertainty Management - 5th International Conference, SUM 2011, Dayton, OH, USA, October 10-13, 2011. Proceedings, pages 163-176.

Evidential Argumentation System*

- Extends AAF with a specialised support relation that captures the notion of **evidential support**.
- It distinguished between prima-facie and standard arguments
- A **prima-facie argument** does not require support from other arguments
- A **standard argument** must be linked to at least one prima-facie argument through a chain of supports.

* Nir Oren and Timothy J. Norman (2008). Semantics for evidence-based argumentation. In Proc. of COMMA, volume 172 of Frontiers in Artificial Intelligence and Applications, pages 276-284. IOS Press.

Weighted argumentation

- In AAF, all arguments and all attacks are equal in strength.
- Some recent extensions of AAF incorporate the notions of weighted arguments or attacks to represent the strength of arguments or attacks.
- This allows for more sophisticated modelling and analysis of conflicting information.
- A common problem that these studies deal with is how to compute the acceptability of an argument in a weighted argumentation framework.

Weighted argumentation graphs

- In weighted argumentation graphs, each argument has a **weight** in the interval [0,1] representing its basic strength.
- A Weighted Argumentation Graph (WAG) is a tuple $(\mathbf{A}, \mathbf{w}, \mathbf{R})$ where $\mathbf{A}$ is a set of arguments, $\mathbf{R} \subseteq \mathbf{A} \times \mathbf{A}$ an attack relation and $\mathbf{w}$ a function from $\mathbf{A}$ to [0.1].
- **Graded Semantics**: An acceptability semantics is a function assigning a numerical value (**acceptability degree**) to every argument in a WAG. This value is derived from the aggregation of the basic strength of the argument and the overall strengths of its attackers.

* Leila Amgoud, Jonathan Ben-Naim, Dragan Doder, and Srdjan Vesic (2017). Acceptability semantics for weighted argumentation frameworks. In Proc. of the 26th International Joint Conference on Artificial Intelligence, (IJCAI'17), pages 56–62.

Examples of graded semantics

- Weighted max-based semantics
  - Follows a multiple-steps process
  - Favours the quality of attackers over their cardinality

$$\mathtt{f}^{\mathtt{i}}_{\mathtt{m}}(a) = \begin{cases} w(a) & \textit{if } i = 0 \\ \frac{w(a)}{1+\max_{b \in \mathtt{Att}_{\mathbf{G}}(a)} \mathtt{f}^{\mathtt{i-1}}_{\mathtt{m}}(b)} & \textit{otherwise} \end{cases}$$

$$\mathtt{Deg}^{\mathtt{Mbs}}_{\mathbf{G}}(a) = \lim_{i \to \infty} \mathtt{f}^{\mathtt{i}}_{\mathtt{m}}(a)$$

- Weighted card-based semantics
  - Follows a multiple-steps process
  - Favours the number of attackers over their quality

$$\mathtt{f}^{\mathtt{i}}_{\mathtt{c}}(a) = \begin{cases} w(a) & \textit{if } i = 0 \\ \frac{w(a)}{1+|\mathtt{AttF}_{\mathbf{G}}(a)|+\frac{\sum_{b \in \mathtt{AttF}_{\mathbf{G}}(a)} \mathtt{f}^{\mathtt{i-1}}_{\mathtt{c}}(b)}{|\mathtt{AttF}_{\mathbf{G}}(a)|}} & \textit{otherwise} \end{cases}$$

$$\mathtt{Deg}^{\mathtt{Cbs}}_{\mathbf{G}}(a) = \lim_{i \to \infty} \mathtt{f}^{\mathtt{i}}_{\mathtt{c}}(a)$$

- Weighted h-Categorizer semantics
  - Follows a multiple-steps process
  - Takes into account the strength of all attackers

$$\mathtt{f}^{i}_{h}(a) = \begin{cases} w(a) & \textit{if } i = 0; \\ \frac{w(a)}{1+\sum_{b_i \in \mathtt{Att}_{\mathbf{G}}(a)} \mathtt{f}^{i-1}_{h}(b_i)} & \textit{otherwise.} \end{cases}$$

$$\mathtt{Deg}^{\mathtt{Hbs}}_{\mathbf{G}}(a) = \lim_{i \to +\infty} \mathtt{f}^{i}_{h}(a)$$

Probabilistic argumentation*

- In probabilistic argumentation frameworks, each argument is assigned a probability denoting the degree of belief that the argument is acceptable.
- A probability function $\mathbf{P}$ on a set $\mathbf{X}$ is a function $\mathbf{P}: 2^{\mathbf{X}} \rightarrow [0, 1]$ satisfying:

$$\sum_{Y \in 2^X} P(Y) = 1$$

- Let $\mathbf{AF}=\{\mathbf{A}, \mathbf{R}\}$ be an AAF and $\mathbf{P}$ a probabilistic function on $\mathbf{A}$. The probability of an argument $\mathbf{a} \in \mathbf{A}$ is defined as

$$P(a) = \sum_{a \in Y \subseteq A} P(Y)$$

- A. Hunter and M. Thimm (2017). Probabilistic reasoning with abstract argumentation frameworks. Journal of Artificial Intelligence Research, 59:565–611.

Constraints on the probability function

- Epistemic labelling of arguments

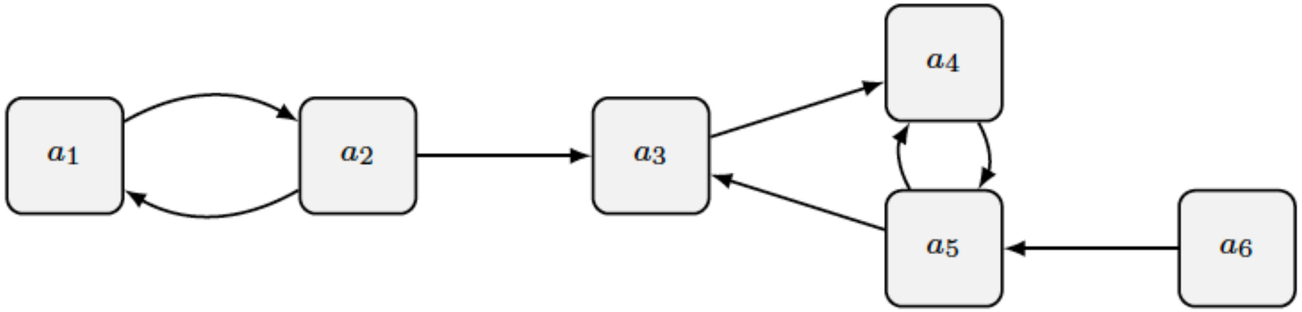
(i) L_P**(a) = in** iff **P(A) > 0.5**

(ii) L_P**(a) = out** iff **P(A) < 0.5**

(iii) L_P**(a) = undec** iff **P(A) = 0.5**

- The probability function is:
  - **Coherent** if for every two arguments **a**, **b** such that **a→b**: **P(a) ≤ 1 - P(B)**
  - **Rational** if for every two arguments **a**, **b** such that **a→b**: **P(a) > 0.5 implies P(B) ≤ 0.5**
  - **Founded** if for every argument **a** that receives no attacks: **P(a) = 1**
  - **Trusting** if for every **a** s.t. for every **b** that attacks **a, P(b) < 0.5, then P(a) > 0.5**
  - **Optimistic** if for every argument **a**: **P(a) ≥ 1 – ∑P(b)** (for all **b** that attack **a**)

An example



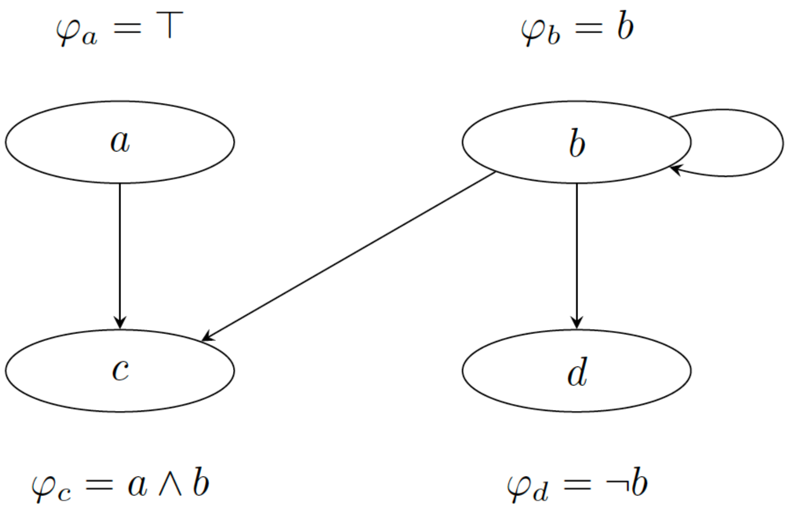
	a_1	a_2	a_3	a_4	a_5	a_6	
P_1	0.2	0.7	0.6	0.3	0.6	1	founded and trusting
P_2	0.7	0.3	0.5	0.5	0.2	0.4	coherent and rational
P_3	0.7	0.3	0.7	0.3	0	1	coherent, rational, founded, trusting and optimistic
P_4	0.7	0.8	0.9	0.8	0.7	1	founded, trusting and optimistic

Abstract Dialectical Frameworks

- A generalization of AAFs allowing the expression of arbitrary relationships among arguments.
- An Abstract Dialectical Framework (ADF) is a tuple $\mathbf{(S, L, C)}$ where $\mathbf{S}$ is a set of statements, $\mathbf{L} \subseteq \mathbf{S} \times \mathbf{S}$ is a set of links between statements and $\mathbf{C}$ = $\{\phi_\mathbf{S}\}_{\mathbf{s}\in\mathbf{S}}$ is a set of acceptance conditions, one for each argument, expressed as propositional formulas.
- **Model:** A mapping from statements to the truth values true and false, $\mathbf{u}$**:** $\mathbf{S} \rightarrow \{\mathbf{t}, \mathbf{f}\}$, that maps to true all statements whose acceptance conditions are satisfied.

* G. Brewka, S. Ellmauthaler, H. Strass, J. P. Wallner, and S. Woltran (2013). Abstract Dialectical Frameworks Revisited. In Proceedings of the 23rd International Joint Conference on Artificial Intelligence (IJCAI), pages 803-809.

ADF: An example



$\boldsymbol{\varphi_a}$: *a* is always true
$\boldsymbol{\varphi_b}$: *b* is true only if b is true (self-support)

$\boldsymbol{\varphi_a}$: *c* is true only if both *a* and *b* are true (necessity support)
$\boldsymbol{\varphi_d}$: *d* is true only if b is false (attack)

Models:

u_1: {*a* → t, *b* → t, *c* → t, *d* → f}
u_2: {*a* → t, *b* → f, *c* → f, *d* → t}

ADFs as an argumentation middleware

- ADFs can represent several types of relationships among arguments that are used in AAFs and their extensions:
  - **Simple attack** (e.g., from *b* to *a*): $\boldsymbol{\varphi_a = \neg b}$
  - **Joint attack** (e.g., from *b*, *c* to *a*): $\boldsymbol{\varphi_a = \neg b \lor \neg c}$
  - **Necessity or evidential support** (e.g. from *b* to *a*): $\boldsymbol{\varphi_a = b}$
- There are also extensions of ADFs that include:
  - **Weight on links** (weighted ADFs)
  - **Preferences on links** (prioritized ADFs)

Summing up

- Extensions of AAFs extend the expressivity of AAFs with
  - Other kinds of attacks (joint attacks, second-order attacks, recursive attacks)
  - Other kinds of relations among arguments (e.g. support)
  - Preferences on arguments
  - Weights on arguments or attacks
  - Arbitrary relationships between arguments (ADFs)
- Trade-off between expressive power and complexity
- Choosing the right frameworks depends on
  - The modelling requirements of the application
  - The expected size of the argumentation graphs
  - The available computational resources