Evaluation of arguments: Current methods and challenges

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Introduction

What is an argument?

Premise 1 ⋮ Premise n	All humans have DNA Pat is human
Conclusion	Therefore, Pat has DNA

- The premises are intended to **support** the conclusion
- The aim is **persuading** others that an idea is right or wrong

Introduction

Different *types* of conclusions

- Evaluation arguments (*Is X true or not?, is X good or bad?*)
- Categorical arguments (*Is X a Y?*)
- Causal arguments (*Does X cause Y?*)
- Resemblance arguments (*Is X like Y?*)
- Proposal arguments (*Should we do X?*)
- ...

Introduction

Two basic types of arguments

Deductive argument is s.t.

the truth of its premises ***guarantees*** *the truth of its conclusion* ***(validity)***

Inductive argument is s.t.

the truth of its premises makes the truth of its conclusion ***more or less likely***

Deductive		Inductive	
All humans have DNA	T	52% of the voters sampled said they will vote for Pat	T
Pat is human	T		
Therefore, Pat has DNA	T	Therefore, Pat will win	T/F

The two types differ in {
- structure
- strength of the conclusion

Two sources of uncertainty: Premises and link

All humans have DNA
Probably Toto is human

Therefore, Toto has DNA

52% of the voters sampled said they will vote for Pat

Therefore, Pat will win

Probably 52% of the voters sampled said they will vote for Pat

Therefore, Pat will win

Introduction

What is a good deductive argument?

- Validity
- Truth of the premises
- Relevance of the premises to the conclusion

All philosophers have a brain	T
Pat has a brain	T
Then, Pat is a philosopher	T/F

All actors are robots	F
Pat is an actor	T
Therefore, Pat is a robot	F

Grass is green	T
Therefore, $1 + 1 = 2$	T

What is a good inductive argument?

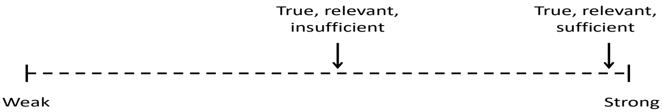
- Strength of its link
- Truth (or acceptability) of the premises
- Relevance of the premises to the conclusion
- Truth of the conclusion

52% of the voters sampled said they will vote for Pat

Therefore, Pat will win

Toulouse is the best place to live

Therefore, we should live there



Introduction

Arguments should be *evaluated*

Deductive argument

- *Validity*
- *Truth of premises*
- *Relevance of the premises to the conclusion*

Inductive argument

- *Strength of its link*
- *Truth/Accept. of premises*
- *Relevance of the premises to the conclusion*
- *Truth of the conclusion*

$\rightsquigarrow$ Provide **attackers** and/or **supporters**

Introduction

A good/strong argument supports its conclusion to a geater degree
but
it is not necessarily *persuasive*

Lying is wrong	Smoking is bad for health
Therefore, one shouldn't lie	Then, one shouldn't smoke

Aim of talk

- Present principles behind evaluation of arguments
- Overview the main methods
- Highlight problematic points
  - Quality of evaluation
  - Suitability for solving AI problems

Outline

1. Axiomatic foundations of evaluation methods (Semantics)
2. Extension-based evaluation methods
   - Recall three methods (naive, stable, preferred)
   - Formal analysis of the methods
   - Application to AI problems
3. Weighted evaluation methods
   - Recall three methods (weighted h-Categorizer, Aggregation-based, DF-QuAD)
   - Formal analysis of the methods
   - Application to AI problems
4. Challenges

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Axiomatic foundations of evaluation methods (Semantics)

- Argumentation structure $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$ such that:
  - $\mathcal{A}$ is a finite set of **arguments**
  - $w : \mathcal{A} \to [0, 1]$ assigns a **basic strength** to each argument
  - $\mathcal{R} \subseteq \mathcal{A} \times \mathcal{A}$ is an **attack** relation
  - $\mathcal{S} \subseteq \mathcal{A} \times \mathcal{A}$ is a **support** relation

- A semantics is a function $\mathbf{S}$ transforming any $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$ into
  - a **weighting** on $\mathcal{A}$ (i.e., a function assigning a value in $[0, 1]$ to each argument) (*Gradual semantics*) [1]
  - a **ranking** on $\mathcal{A}$ (i.e., a total preordering on $\mathcal{A}$) (*Ranking semantics*) [2]

- Notation: $\mathtt{Deg}(a)$ denotes the overall strength of argument a

[1] (Cayrol, Lagasquie, JAIR-05)
[2] (Amgoud, Ben-Naim, SUM-13)

Axiomatic foundations of evaluation methods[3]

- Rationality properties
- **Roles** of attackers/supporters
- Importance of the **quantity** and **quality** of attackers/supporters
- **Intensity** of attack/support
- **Aggregation** of attackers and supporters

[3](Amgoud, Ben-Naim, KR-16, IJCAI-16, ECSQARU-17; Amgoud, Ben-Naim, Doder, Vesic, IJCAI-17)

Axiomatic foundations of evaluation methods

Rationality properties

- Anonymity: $\texttt{Deg}(a)$ is independent from a's identity.
- Independence: $\texttt{Deg}(a)$ is independent from any argument b not connected to a.
- Directionality: $\texttt{Deg}(a)$ doesn't depend on a's **outgoing** arrows.
- Equivalence: $\texttt{Deg}(a)$ depends only on its basic strength and the overall strengths of its attackers and supporters.

Axiomatic foundations of evaluation methods

Role of attackers/supporters

- Stability: $\texttt{Deg}(a) = w(a)$ if a is **not attacked and not supported**.
- Neutrality: **worthless** attackers/supporters have no effect.

Axiomatic foundations of evaluation methods

Grass is green

Tweety is not a bird

$\rightsquigarrow$

Most birds fly

Tweety is a bird

Tweety flies

Axiomatic foundations of evaluation methods

Role of attackers/supporters

- Stability: $\texttt{Deg}(a) = w(a)$ if a is **not attacked and not supported**.
- Neutrality: **worthless** attackers/supporters have no effect.
- Weakening: attacks **weaken** their targets ($\texttt{Deg}(a) < w(a)$).
- Strengthening: supports **strengthen** their targets ($\texttt{Deg}(a) > w(a)$).

Axiomatic foundations of evaluation methods (Semantics)

Considering the **quality/quantity** of attackers/supporters

- Reinforcement: an argument becomes stronger if the **quality** of its attackers is reduced and the quality of its supporters is increased (or inversely).
- Monotony: the **more** an argument is attacked, the weaker it is. The more an argument is supported, the stronger it is.
  - **To be used carefully** (Independence, Non-Redundancy)
  - **Suitable** for inductive arguments but may be not for deductive ones

Axiomatic foundations of evaluation methods

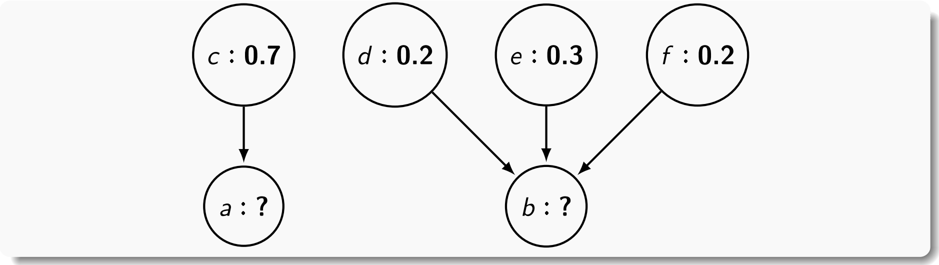
Intensity of attack/support

- Resilience: for any argument a, if $0 < w(a) < 1$, then $0 < \texttt{Deg}(a) < 1$.

Food is quite expensive there	$\rightsquigarrow$	Sẽnor Taco has the best Mexican food
Let's choose another restaurant		Let's go there
Tweety is a penguin Penguins don't fly	$\rightsquigarrow$	Most birds fly Tweety is a bird
Tweety doesn't fly		Tweety flies

Axiomatic foundations of evaluation methods

Quantity vs. Quality of attackers



Cardinality

$\text{Deg}(a) > \text{Deg}(b)$

Quality

$\text{Deg}(a) < \text{Deg}(b)$

Compensation

$\text{Deg}(a) = \text{Deg}(b)$

Some properties: $\mathcal{R} = \emptyset$

Incompatibility results

- *Cardinality Prec., Quality Prec. and Compensation are incompatible.*
- *Independence, Directionality, Equivalence, Resilience, Reinforcement, Stability and Quality Prec. are incompatible.*

Properties

- *Directionality, Independence, Stability and Neutrality imply Weakening soundness.*
- *If a semantics satisfies Independence, Directionality, Neutrality, Proportionality, Weakening and Stability, then for every argument a, $\mathtt{Deg}(a) \in [0, w(a)]$.*

Outline

1. Axiomatic foundations of evaluation methods (Semantics)
2. Extension-based evaluation methods
   - Recall three methods (naive, stable, preferred)
   - Formal analysis of the methods
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Extension-based evaluation methods

- Argumentation structure $\mathbf{A} = \langle \mathcal{A}, \succeq, \mathcal{R}, \mathcal{S} \rangle$ such that:
  - $\mathcal{A}$ is a finite set of **arguments**
  - $\succeq \subseteq \mathcal{A} \times \mathcal{A}$ is a **preference** relation
  - $\mathcal{R} \subseteq \mathcal{A} \times \mathcal{A}$ is an **attack** relation
  - $\mathcal{S} \subseteq \mathcal{A} \times \mathcal{A}$ is a **support** relation
- Evaluation $\rightsquigarrow$ identification of good sets of arguments[4]
  - A **semantics** is a function **S** assigning to each argumentation structure $\mathbf{A} = \langle \mathcal{A}, \succeq, \mathcal{R}, \mathcal{S} \rangle$ some elements of $\mathcal{P}(\mathcal{A})$, called **extensions**
  - An extension represents a **coherent point of view** (or a **coalition**)
  - An argument is **good/accepted** if it is in all extensions, it is **rejected** otherwise

[4] (Dung, IJCAI-93, AIJ-95)

Several extension-based evaluation methods

$\mathbf{A} = \langle \mathcal{A}, \approx, \mathcal{R}, \mathcal{S} = \emptyset \rangle$

- *Naive* — *(Dung, IJCAI-93)*
- *Stable* — *(Dung, IJCAI-93)*
- *Preferred* — *(Dung, IJCAI-93)*
- *Complete* — *(Dung, IJCAI-93)*
- *Grounded* — *(Dung, IJCAI-93)*
- *Stage* — *(Verheij, NAIC-96)*
- *CF2* — *(Baroni and Giacomin, AIJ-05)*
- *Semi-stable* — *(Caminada, COMMA-06)*
- *Ideal* — *(Toni et al., AIJ-07)*
- ...

$\approx$ means all arguments are equally preferred

Several extension-based evaluation methods

$\mathbf{A} = \langle \mathcal{A}, \succeq, \mathcal{R}, \mathcal{S} = \varnothing \rangle$

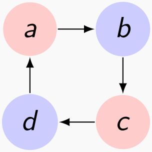
- *Amgoud, Cayrol, AMAI-02*
- *Bench-Capon, JoLC-03*
- *Modgil, AIJ-09*
- *Amgoud, Vesic, AMAI-11*
- *Amgoud, Vesic, IJAR-14*

$\mathbf{A} = \langle \mathcal{A}, \approx, \mathcal{R}, \mathcal{S} \rangle$

- *Cayrol, Lagasquie, ECSQARU-05*
- *Oren, Norman, COMMA-08*
- *Boella et al., COMMA-10*
- *Nouioua, SUM-2013*
- *Polberg, Oren, COMMA-14*
- ...

Extension-based methods: $\mathbf{A} = \langle \mathcal{A}, \approx, \mathcal{R}, \mathcal{S} = \emptyset \rangle$

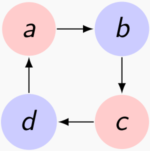
Naive: Maximal non-conflicting sets of arguments



Two naive extensions: $\{a, c\}$ and $\{b, d\}$

Extension-based methods: $\mathbf{A} = \langle \mathcal{A}, \approx, \mathcal{R}, \mathcal{S} = \emptyset \rangle$

Stable: Non-conflicting sets attacking arguments left outside [5]

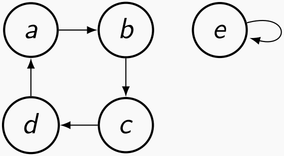


Two stable extensions: $\{a, c\}$ and $\{b, d\}$

[5] (Dung, IJCAI-93)

Extension-based methods: $\mathbf{A} = \langle \mathcal{A}, \approx, \mathcal{R}, \mathcal{S} = \varnothing \rangle$

Stable: Non-conflicting sets attacking arguments left outside

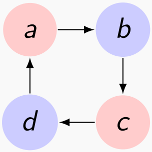


No stable extensions!

Naive extensions are not necessarily stable ones

Extension-based methods: $\mathbf{A} = \langle \mathcal{A}, \approx, \mathcal{R}, \mathcal{S} = \emptyset \rangle$

Preferred: Maximal conflict-free and self-defending sets[6]
(they attack each attacking argument)



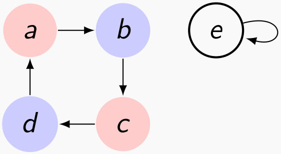
Two preferred extensions: $\{a, c\}$ and $\{b, d\}$

Stable extensions are preferred ones

[6] (Dung, IJCAI-93)

Extension-based methods: $\mathbf{A} = \langle \mathcal{A}, \approx, \mathcal{R}, \mathcal{S} = \emptyset \rangle$

Preferred: Maximal conflict-free and self-defending sets



Two preferred extensions: $\{a, c\}$ and $\{b, d\}$

Preferred extensions are not necessarily stable ones

Formal analysis of the three methods

$$\mathbf{A} = \langle \mathcal{A}, \approx, \mathcal{R}, \mathcal{S} = \varnothing \rangle$$
$$a \in \mathcal{A}$$

- Existence of extensions
  - $\texttt{Deg}(a) = 1$ iff a belongs to all extensions
  - $\texttt{Deg}(a) = 0.5$ iff a belongs to some but not all extensions
  - $\texttt{Deg}(a) = 0.3$ iff a does not belong to and is not attacked by any extension
  - $\texttt{Deg}(a) = 0$ iff a doesn't belong to any extension and is attacked by at least one extension
- Non-existence of extensions
  - $\texttt{Deg}(a) = 0.3$

Formal analysis of the three methods

$$\mathbf{A} = \langle \mathcal{A}, \approx, \mathcal{R}, \mathcal{S} = \varnothing \rangle$$

Axioms - Semantics	Naive	Stable	Preferred
Anonymity	•	•	•
Independence	•	◦	•
Directionality	◦	◦	•
Equivalence	•	◦	◦
Stability	◦	◦	•
Neutrality	◦	•	◦
Monotony	◦	◦	◦
Reinforcement	◦	•	◦
Resilience	◦	◦	◦
Weakening	•	•	•
Strengthening	◦	◦	◦
Cardinality Prec.	◦	◦	◦
Quality Prec.	◦	◦	◦
Compensation	•	•	•

The symbol • (resp. ◦) means the axiom is satisfied (resp. violated).

Formal analysis of the three methods

Consequences of violating independence

No stable extension

$\mathtt{Deg}(a) = 0.3$

But what if *a* is the following argument?

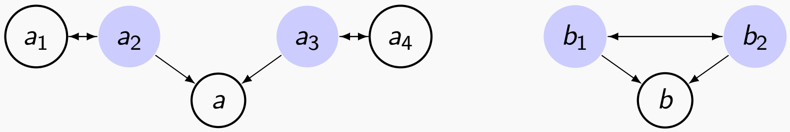
All humans have DNA

Pat is human

Therefore, Pat has DNA

Formal analysis of the three methods

Consequences of violating equivalence

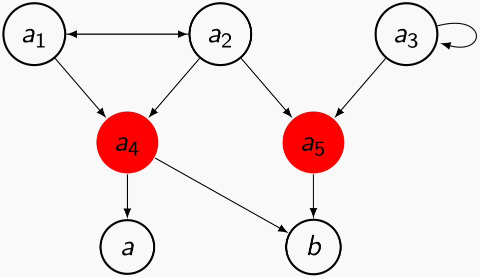


- 8 stable extensions
- Each of $a_1, a_2, a_3, a_4, b_1, b_2$ belongs to 4 extensions
- a belongs to 2 extensions
- b does not belong to any extension

- $\mathtt{Deg}(a_2) = \mathtt{Deg}(a_3) = \mathtt{Deg}(b_1) = \mathtt{Deg}(b_2)$
- while $\mathtt{Deg}(a) > \mathtt{Deg}(b)$

Formal analysis of the three methods

Consequences of violating neutrality



- $w(a_i) = 1,\ i = 1, \dots 5$
- $w(a) = w(b) = 1$

- Two preferred extensions: $\{a_1, a\}$ and $\{a_2, a, b\}$
- $\mathtt{Deg}(a_4) = \mathtt{Deg}(a_5) = 0$
- Still $\mathtt{Deg}(b) = 0.5 < w(b)$
- $\mathtt{Deg}(a) = 1$

Formal analysis of the three methods

$$\mathbf{A} = \langle \mathcal{A}, \geq, \mathcal{R}, \mathcal{S} = \varnothing \rangle$$

30% of European cities are very small
Toulouse is a European city

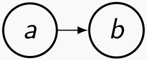
Therefore, Toulouse is very small

- Assume $w(a) = 0.3$
- One stable extension: $\{a\}$
- The argument is declared **good**!

$\rightsquigarrow$ Basic weights are ignored

Formal analysis of the three methods

Should weak attackers have effect on stronger arguments?



$$w(a) < w(b)$$

- Removal of attack: Both arguments are accepted
- Reversal of attack: b is accepted and a rejected

(a) 30% of sampled voters said they will abstain

Her chances are lower

(b) According to FiveThirtyEight, H. Clinton has 66% chances to win

H. Clinton will win

Summary

- Attacks are either lethal or without impact
- Good arguments may be rejected due to
  - non-existence of extensions
  - bad manipulation of basic strengths
- Bad arguments may be accepted
- Discrepancies in evaluations
- Poor consideration of basic strengths (**crucial** for an argument)

Extensions allow poor evaluations of arguments

Application to AI problems

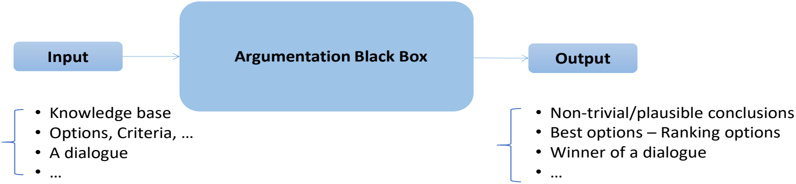
- AI applications

Type of claim		Applications
Evaluation arguments	(*Is X true or not?*)	Inconsistency handling Defeasible reasoning Merging knowledge bases
Evaluation arguments	(*Is X good or bad?*)	(Group) Decision making
Resemblance arguments	(*Is X like Y?*)	Negotiation
Proposal arguments	(*Should we do X?*)	Deliberation
Categorical arguments	(*Is X a Y?)*	Persuasion
...		...

- Argumentation is a reasoning process in which reached conclusions are those supported by **good/strong** arguments

Argumentation systems

Given an application (inconsistency handling, decision making, . . .)



Argumentation systems

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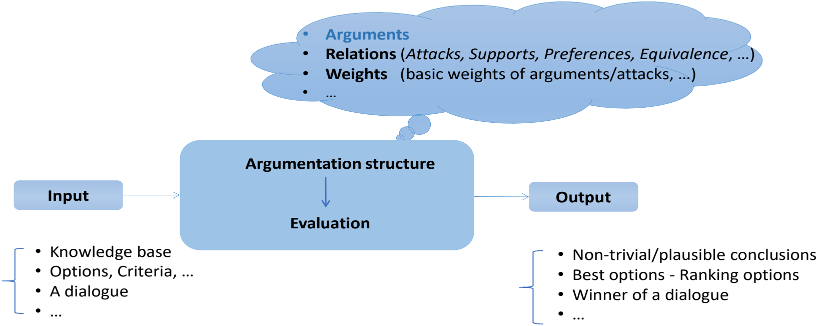
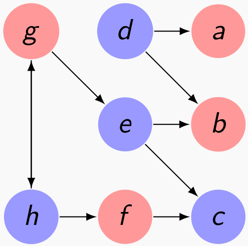


Application 1: Dialogue

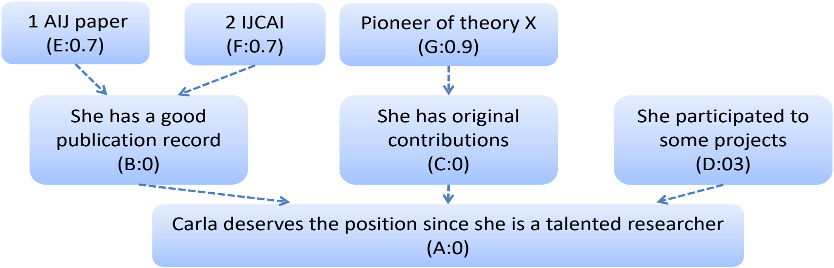
⇝ Look for agreements between Paul & John



- Stable extensions
  - $\{d, g, f\}$
  - $\{d, h, e\}$
- Agreement: $\{d, g, f\}$

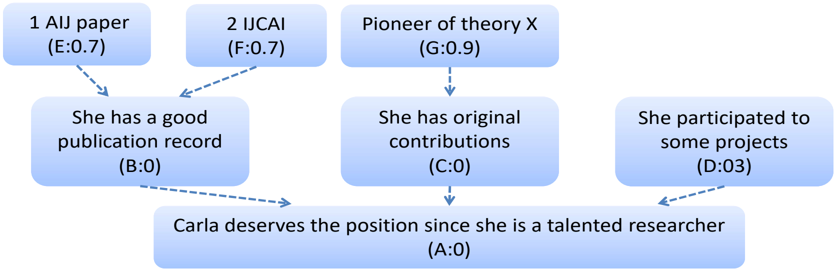
Application 2: Recommendation letter

⇝ Evaluate the overall strength of A



- One stable/preferred extension: $\{A, B, C, D, E, F, G, H\}$
- All the arguments are **good**!

Application 2: Recommendation letter

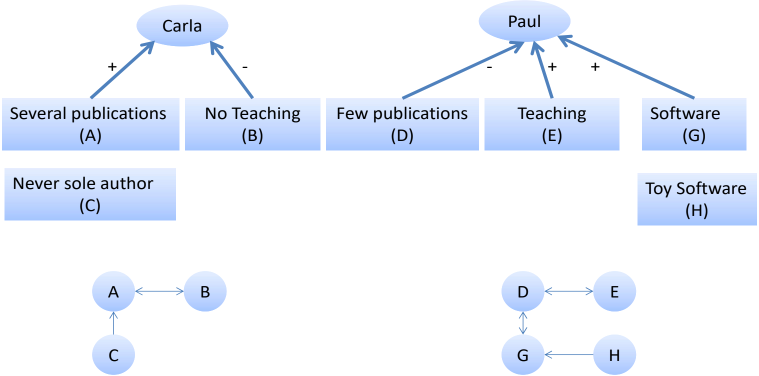


- For any $\mathbf{A} = \langle \mathcal{A}, \succeq, \mathcal{R} = \emptyset, \mathcal{S} \rangle$, all the arguments are good
- Extensions do not tell much about A

The approach is not suitable for the evaluation of arguments

Application 3: Decision making

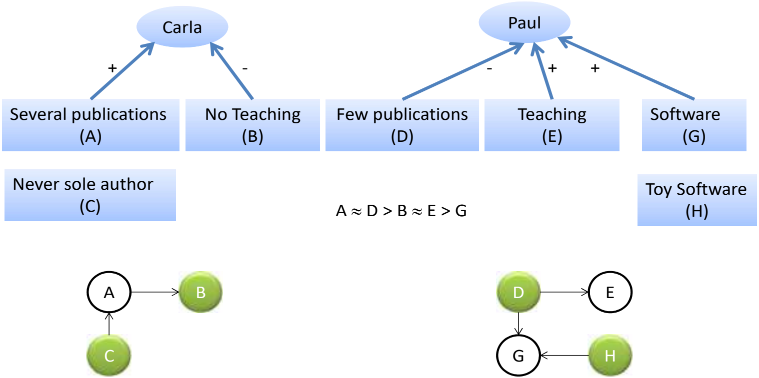
⇝ Compare candidates for a lecturer position



Publication record ≻ Teaching experience ≻ Software development

$$A \approx D \succ B \approx E \succ G$$

Application 3: Decision making



- Conclusions: $\neg$*Carla* and $\neg$*Paul* $\rightsquigarrow$ No ranking
- The effect of attack is lethal $\rightsquigarrow$ A and G are completely rejected
- The number of arguments is neglected

The approach is not suitable for decision making

Application 4: Inconsistency handling

- $\Phi = \{p, \neg p, q, p \rightarrow \neg q\} \mid\!\sim\ ?$
- 16 non-equivalent formulas

$p \wedge \neg p$	$\neg p \wedge \neg q$	$\neg p$	$p \rightarrow \neg q$	$p \vee \neg p$
	$\neg p \wedge q$	$\neg q$	$p \rightarrow q$	
	$p \wedge \neg q$	$p \leftrightarrow q$	$q \rightarrow p$	
	$p \wedge q$	$p \leftrightarrow \neg q$	$\neg p \rightarrow q$	
		q		
		p		

Application 4: Inconsistency handling

- Argument: a pair $\langle \Psi, \psi \rangle$ such that Ψ is a **minimal** (for set inclusion) and **consistent** subset of Φ such that $\Psi \vdash \psi$[7]

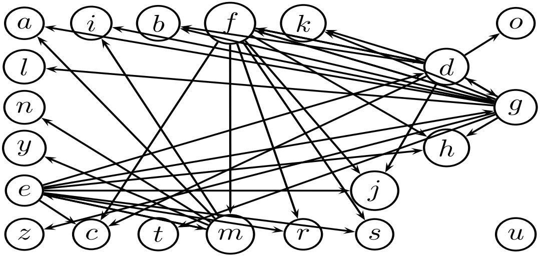
a	$\langle \{\neg p, q\}, \neg p \wedge q \rangle$	k	$\langle \{q, p \rightarrow \neg q\}, p \leftrightarrow \neg q \rangle$
b	$\langle \{q, p \rightarrow \neg q\}, \neg p \wedge q \rangle$	l	$\langle \{q\}, q \rangle$
c	$\langle \{p, p \rightarrow \neg q\}, p \wedge \neg q \rangle$	m	$\langle \{p\}, p \rangle$
d	$\langle \{p, q\}, p \wedge q \rangle$	n	$\langle \{\neg p\}, p \rightarrow \neg q \rangle$
e	$\langle \{\neg p\}, \neg p \rangle$	o	$\langle \{p \rightarrow \neg q\}, p \rightarrow \neg q \rangle$
f	$\langle \{q, p \rightarrow \neg q\}, \neg p \rangle$	y	$\langle \{\neg p\}, p \rightarrow q \rangle$
g	$\langle \{p, p \rightarrow \neg q\}, \neg q \rangle$	z	$\langle \{q\}, p \rightarrow q \rangle$
h	$\langle \{p, q\}, p \leftrightarrow q \rangle$	r	$\langle \{p\}, q \rightarrow p \rangle$
i	$\langle \{\neg p, q\}, p \leftrightarrow \neg q \rangle$	s	$\langle \{p\}, \neg p \rightarrow q \rangle$
j	$\langle \{p, p \rightarrow \neg q\}, p \leftrightarrow \neg q \rangle$	t	$\langle \{q\}, \neg p \rightarrow q \rangle$
		u	$\langle \varnothing, p \vee \neg p \rangle$

[7] (Simari, Loui, AIJ-92)

Application 4: Inconsistency handling

- Argument: a pair $\langle \Psi, \psi \rangle$ such that Ψ is a **minimal** (for set inclusion) and **consistent** subset of Φ such that $\Psi \vdash \psi$
  - Minimality $\rightsquigarrow$ **Relevance**
  - Propositional logic $\rightsquigarrow$ **Validity**

- Attack: an argument $\langle \Psi, \psi \rangle$ attacks $\langle \Psi', \psi' \rangle$ iff $\neg\psi \in \Psi'$[8]
  - $\langle \{p\}, p \rangle$ attacks $\langle \{\neg p, q\}, \neg p \wedge q \rangle$



Application 4: Inconsistency handling

$$\Phi = \{p, \neg p, q, p \rightarrow \neg q\}$$

- Stable extensions
  - $\mathcal{E}_1 = \{d, h, l, m, z, r, s, t, u\}$
  - $\mathcal{E}_2 = \{c, g, j, m, o, r, s, u\}$
  - $\mathcal{E}_3 = \{a, b, e, f, i, k, l, n, o, y, z, t, u\}$
- Non-trivial conclusions of Φ are formulas supported by at least one argument in every extension
  - $\Phi \mid\!\sim p \vee \neg p$

Application 4: Inconsistency handling

- $\Phi = \{p, \neg p, q, p \rightarrow \neg q\}$
- $\mathtt{Max}(\Phi)$ = the set of maximal (for set $\subseteq$) consistent subsets of Φ
- $\mathtt{Arg}(\mathcal{S})$ = the set of arguments built from $\mathcal{S} \subseteq \Phi$

Theorem (Cayrol, IJCAI-95)

- *If $\mathcal{E}$ is a stable extension, then* $\bigcup_{\langle\Psi,\psi\rangle\in\mathcal{E}} \Psi \in \mathtt{Max}(\Phi)$
- *If $\mathcal{S} \in \mathtt{Max}(\Phi)$, then $\mathtt{Arg}(\mathcal{S})$ is a stable extension*
- *Non-trivial conclusions of Φ = $\bigcap \mathtt{CN}(\mathcal{S})$, where $\mathcal{S} \in \mathtt{Max}(\Phi)$*

$$\mathcal{E}_1 = \{d, h, l, m, z, r, s, t, u\}$$
$$\mathcal{E}_2 = \{c, g, j, m, o, r, s, u\}$$
$$\mathcal{E}_3 = \{a, b, e, f, i, k, l, n, o, y, z, t, u\}$$

$$\mathcal{S}_1 = \{p, q\}$$
$$\mathcal{S}_2 = \{p, p \rightarrow \neg q\}$$
$$\mathcal{S}_3 = \{\neg p, q, p \rightarrow \neg q\}$$

Application 4: Inconsistency handling

- $\texttt{Max}(\Phi)$ = the set of maximal (for set $\subseteq$) consistent subsets of Φ
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Theorem (Cayrol, IJCAI-95)

- *If $\mathcal{E}$ is a stable extension, then $\bigcup_{\langle\Psi,\psi\rangle\in\mathcal{E}} \Psi \in \texttt{Max}(\Phi)$*
- *If $\mathcal{S} \in \texttt{Max}(\Phi)$, then $\texttt{Arg}(\mathcal{S})$ is a stable extension*
- *Non-trivial conclusions of $\Phi = \bigcap \texttt{CN}(\mathcal{S})$, where $\mathcal{S} \in \texttt{Max}(\Phi)$*

Reasons

- *Consistency of the premises of an argument*
- *If an argument is in a stable extension, then all its sub-arguments are in the extension* *(Closure under sub-arguments)*
- *For any extension $\mathcal{E}$, $\{\psi \mid \langle\Psi,\psi\rangle \in \mathcal{E}\}$ is consistent* *(Consistency)*
- *Maximality of stable extensions* *(Maximality)*

Application 4: Inconsistency handling

- Generalization of the previous results to
  - any Tarskian logic
  - any inconsistency-based attack relation

Theorem (Amgoud, SUM-12), (Amgoud, Besnard, JNCL-13)

- *The previous correspondence holds for any system satisfying consistency + closure under sub-arguments*
- *Stable extensions = Preferred extensions = Naive extensions*

Generalization of the syntactic approach[9]

[9] N. Rescher, R. Manor (1970). On Inferences from Inconsistent Premises. In journal of Theory and Decision, pp. 179–217.

Application 4: Inconsistency handling

- Advantages
  - Ensuring "rational" conclusions
  - Generalizing the syntactic approach of Rescher and Manor
  - Generalizing[10] Brewka's preferred sub-theories[11]
- Limits
  - The different semantics coincide
  - Nothing new for inconsistency handling
  - The approach is not based on the evaluation of arguments

[10](Amgoud, Vesic, AMAI-11)
[11](Brewka, AAAI-94)

Application to nonmonotonic reasoning

- Logic Programming: Let $\mathbf{A} = \langle \mathcal{A}, \approx, \mathcal{R}, \mathcal{S} = \emptyset \rangle$ be built over a program P
  - Stable extensions correspond to (Gelfind & Lifschitz) **answer sets** of P
  - Preferred extensions correspond to (Saccà and Zaniolo) **partial stable models** of P
  - Grounded extension corresponds to (Van Gelder et al.) **well-founded model** of P
- Default Logic:
  - Stable extensions correspond to Reiter's **extensions** of (W, D)

Summary

Extension semantics are

- suitable for problems that amount to looking for coalitions
- but not suitable for those where individual arguments need to be evaluated

Outline

1. Axiomatic foundations of evaluation methods (Semantics)
2. Extension-based evaluation methods
   - Recall three methods (naive, stable, preferred)
   - Formal analysis of the methods
   - Application to AI problems
3. Weighted evaluation methods
   - Recall three methods (weighted h-Categorizer, Aggregation-based, DF-QuAD)
   - Formal analysis of the methods
   - Application to four AI problems
4. Challenges

Weighted evaluation methods

- Argumentation structure $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$ such that:
  - $\mathcal{A}$ is a finite set of **arguments**
  - $w : \mathcal{A} \to [0, 1]$ assigns a **basic strength** to each argument
  - $\mathcal{R} \subseteq \mathcal{A} \times \mathcal{A}$ is an **attack** relation
  - $\mathcal{S} \subseteq \mathcal{A} \times \mathcal{A}$ is a **support** relation
- A semantics is a function $\mathbf{S}$ transforming any $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$ into
  - a **weighting** on $\mathcal{A}$ (i.e., a function assigning a value in $[0, 1]$ to each argument) (*Gradual semantics*)[12]
  - a **ranking** on $\mathcal{A}$ (i.e., a total preordering on $\mathcal{A}$) (*Ranking semantics*)[13]

[12] Cayrol, Lagasquie, JAIR-05

[13] Amgoud, Ben-Naim, SUM-13

Weighted evaluation methods

$\mathbf{A} = \langle \mathcal{A}, w = 1, \mathcal{R}, \mathcal{S} = \varnothing \rangle$

- *h-Categorizer* *(Besnard, Hunter, AIJ-01)*
- *Game-theoretic* *(Matt, Toni, JELIA-08)*

$\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} = \varnothing \rangle$

- *Trust-based* *(Boella et al., IJCAI-11)*
- *Iterative Schema* *(Gabbay, Rodriguez, Log-Univ.-15)*
- *Weighted h-Categorizer* *(Amgoud et al., IJCAI-17)*
- *Weighted max-based* *(Amgoud et al., IJCAI-17)*
- *Weighted cardinality-based* *(Amgoud et al., IJCAI-17)*

Weighted evaluation methods

$\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R} = \varnothing, \mathcal{S} \rangle$

- *Top-based* (Amgoud, Ben-Naim, IJCAI-16)
- *Reward-based* (Amgoud, Ben-Naim, IJCAI-16)
- *Aggregation-based* (Amgoud, Ben-Naim, IJCAI-16)

$\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$

- *QuAD* (Baroni et al., AC-15)
- *DF-QuAD* (Rago et al., KR-16)
- *Euler-based* (Amgoud, Ben-Naim, ECSQARU-17)

Weighted h-Categorizer[14]: $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} = \emptyset \rangle$

Let $a \in \mathcal{A}$, $i \in \{0, 1, 2, \dots\}$.

- Burden numbers: $\texttt{Bur}_i(a) = \begin{cases} w(a) & \text{if } i = 0 \\ \dfrac{w(a)}{1 + \sum_{b \mathcal{R} a} \texttt{Bur}_{i-1}(b)} & \text{otherwise} \end{cases}$

  If $\{b \in \mathcal{A} \mid b \mathrel{\mathcal{R}} a\} = \emptyset$, then $\sum_{b\mathcal{R}a} \texttt{Bur}_{i-1}(b) = 0$.

- For any $a \in \mathcal{A}$, $\texttt{Deg}(a) = \lim_{k \to +\infty} \texttt{Bur}_k(a)$

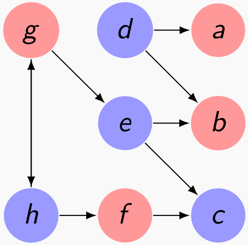
Theorem

For any argumentation graph $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} = \emptyset \rangle$, *any argument* $a \in \mathcal{A}$,

$$\texttt{Deg}(a) = \frac{w(a)}{1 + \sum_{b\mathcal{R}a} \texttt{Deg}(b)}$$

[14] (Amgoud et al., IJCAI-17)

Application 1: Dialogue



- $\mathtt{Deg}(d) = 1$
- $\mathtt{Deg}(e) = \mathtt{Deg}(f) = \mathtt{Deg}(g) = \mathtt{Deg}(h) = 0.61$
- $\mathtt{Deg}(a) = 0.5$
- $\mathtt{Deg}(c) = 0.44$
- $\mathtt{Deg}(b) = 0.38$

$\rightsquigarrow$ Not suitable for detecting coherents points of view

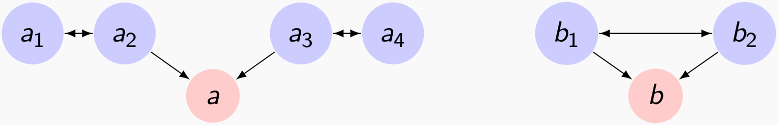
Weighted h-Categorizer

$w(a) = w(b) = 1$

$\mathtt{Deg}(a) = 1$

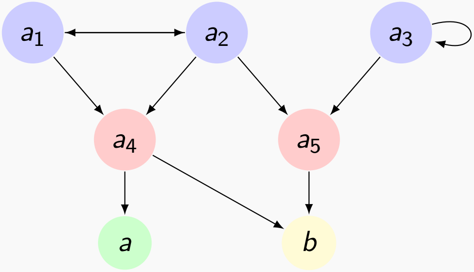
$\mathtt{Deg}(b) = 0.61$

Weighted h-Categorizer



- $w(a_1) = \ldots = w(a_4) = w(b_1) = w(b_2) = w(a) = w(b) = 1$
- $\mathtt{Deg}(a_2) = \mathtt{Deg}(a_3) = \mathtt{Deg}(b_1) = \mathtt{Deg}(b_2) = 0.61$
- $\mathtt{Deg}(a) = \mathtt{Deg}(b) = 0.44$

Weighted h-Categorizer



- $w(a_i) = 1,\ i = 1, \ldots 5$
- $w(a) = w(b) = 1$

- $\mathtt{Deg}(a) = 0.69$
- $\mathtt{Deg}(a_1) = \mathtt{Deg}(a_2) = \mathtt{Deg}(a_3) = 0.61$
- $\mathtt{Deg}(b) = 0.52$
- $\mathtt{Deg}(a_4) = \mathtt{Deg}(a_5) = 0.44$

Weighted h-Categorizer

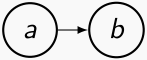
30% of European cities are very small
Toulouse is a European city

Therefore, Toulouse is very small

- Assume $w(a) = 0.3$
- $\mathtt{Deg}(a) = 0.3$

Weighted h-Categorizer

Should weak attackers have effect on stronger arguments?



$w(a) < w(b)$

(a) 30% of sampled voters said they will abstain

Her chances are lower

(b) According to FiveThirtyEight, H. Clinton has 66% chances to win

H. Clinton will win

- $\mathrm{Deg}(a) = w(a)$
- $\mathrm{Deg}(b) < w(b)$

Aggregation-based method[15]: $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R} = \varnothing, \mathcal{S} \rangle$

Let $a \in \mathcal{A}$, $i \in \{0, 1, 2, \ldots\}$.

- Reward numbers:

$$\mathtt{Rew}_i(a) = \begin{cases} w(a) & \text{if } i = 0 \\ w(a) + (1 - w(a)) \frac{\sum_{b \mathcal{S} a} \mathtt{Rew}_{i-1}(b)}{1 + \sum_{b \mathcal{S} a} \mathtt{Rew}_{i-1}(b)} & \text{otherwise} \end{cases}$$

If $\{b \in \mathcal{A} \mid b \; \mathcal{S} \; a\} = \varnothing$, then $\sum_{b \mathcal{S} a} \mathtt{Rew}_{i-1}(b) = 0$.

- For any $a \in \mathcal{A}$, $\mathtt{Deg}(a) = \lim_{k \to +\infty} \mathtt{Rew}_k(a)$

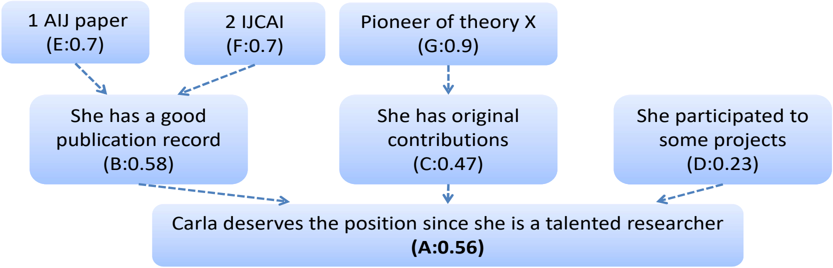
Theorem

For any argumentation graph $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} = \varnothing \rangle$, *any argument* $a \in \mathcal{A}$,

$$\mathtt{Deg}(a) = w(a) + (1 - w(a)) \frac{\sum_{b \mathcal{S} a} \mathtt{Deg}(b)}{1 + \sum_{b \mathcal{S} a} \mathtt{Deg}(b)}$$

[15] (Amgoud, Ben-Naim, IJCAI-16)

Application 2: Recommendation letter



DF-QuAD method[16]: $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$

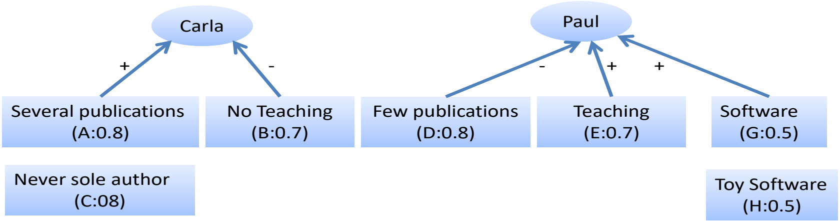
- Let $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$ be **acyclic**
- Let $a \in \mathcal{A}$, $a_1, \ldots a_n$ its **attackers** and $s_1, \ldots, s_m$ its **supporters**

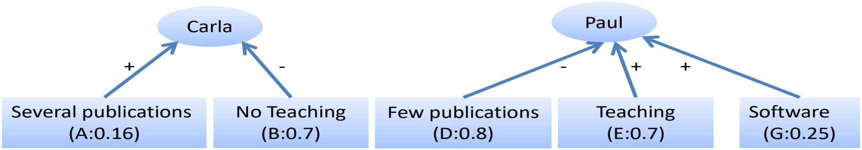
$$\mathtt{Deg}(a) = \begin{cases} w(a) - w(a) \times |\mathcal{F}(\mathtt{Deg}(s_i)) - \mathcal{F}(\mathtt{Deg}(a_j))| \\ \qquad \text{if } \mathcal{F}(\mathtt{Deg}(a_j)) \geq \mathcal{F}(\mathtt{Deg}(s_i)) \\ \\ w(a) + (1 - w(a)) \times |\mathcal{F}(\mathtt{Deg}(s_i)) - \mathcal{F}(\mathtt{Deg}(a_j))| \\ \qquad \text{if } \mathcal{F}(\mathtt{Deg}(a_j)) < \mathcal{F}(\mathtt{Deg}(s_i)) \end{cases}$$

$$\mathcal{F}(v_1, \ldots, v_k) = \begin{cases} 0 & \text{if } k = 0 \\ 1 - \Pi_{i=1}^{k}(1 - v_i) & \text{otherwise} \end{cases}$$

[16] (Rago et al., KR-16)

Application 3: Decision making





Formal analysis of the semantics

Axioms - Semantics	Weighted h-Cat.	Aggregation-based	DF-QuAD
Anonymity	$\bullet$	$\bullet$	$\bullet$
Independence	$\bullet$	$\bullet$	$\bullet$
Directionality	$\bullet$	$\bullet$	$\bullet$
Equivalence	$\bullet$	$\bullet$	$\bullet$
Stability	$\bullet$	$\bullet$	$\bullet$
Neutrality	$\bullet$	$\bullet$	$\bullet$
Monotony	$\bullet$	$\bullet$	$\circ$
Reinforcement	$\bullet$	$\bullet$	$\circ$
Resilience	$\bullet$	$\bullet$	$\circ$
Weakening	$\bullet$	?	$\circ$
Strengthening	?	$\bullet$	$\circ$

The symbol $\bullet$ (resp. $\circ$) means the axiom is satisfied (resp. violated).

Application 4: Inconsistency handling

- Ranking construction: $\phi \succeq \psi$ iff some argument supporting ϕ is at least as strong as any argument supporting ψ
- For $\Phi = \{p, \neg p, q, p \to \neg q\}$,

Arguments
u
o
l, z, t
e, n, y
m, r, s
a, i, b, f, k
c, g, j
d, h

Ranked conclusions
$p \vee \neg p$
$p \to \neg q$
$q,\ p \to q,\ \neg p \to q$
$\neg p$
$p,\ q \to p$
$\neg p \wedge q,\ p \leftrightarrow \neg q$
$p \wedge \neg q,\ \neg q$
$p \wedge q,\ p \leftrightarrow q$

Application 4: Inconsistency handling

- Consistency: when information is consistent, the ranking logic coincides with its base logic
- Flatness: when information is consistent, all formulae are equally plausible
- Non-Trivialization: the ranking logic avoids absurd inferences
- Free Recovering: free formulae are plausible conclusions
- Free Precedence: free formulae are more plausible than any non-free formula
- Dominance: a formula is at most as plausible as its logical consequences

Summary

- Argumentation has for a long time been influenced by works on NMR (using NMR semantics for evaluating arguments)
- Arguments evaluation should be distinguished from **arguments manipulation** for any application purpose
  - DM: Aggregation of arguments ≠ evaluation of arguments
  - Dialogue: Detecting coalitions ≠ evaluation of arguments
  - ...
- Arguments evaluation is the first step towards computing the outcome of any application
- Extension semantics are **one way** of evaluating arguments, but provide poor evaluations
- Weighted semantics focus on the evaluation of arguments

Challenges

- Evaluation methods
  - Measuring the basic strength ($w(.)$) of an argument
    - Two sources of uncertainty (premises, link)
  - Evaluation depends on the type of arguments (analogical, causal, ...)
    - Which properties for each type?
    - But, attackers and supporters may be of different types $\rightsquigarrow$ Hybrid evaluation methods
    - Characterization results
- Applications
  - Investigating ranking logics (characterization, links with existing logics)
  - Towards computational models of persuasion
    - Powerful evaluation methods
    - What is a persuasive argument?