Evaluation of arguments in weighted bipolar graphs

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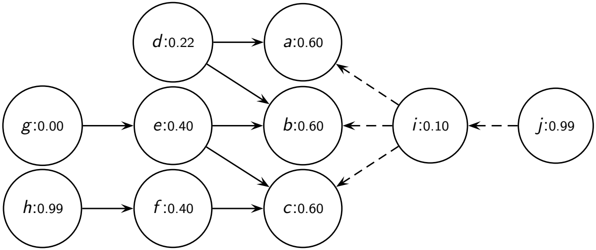
Introduction

Given a **problem** to solve (making decision, reasoning with defeasible information, classifying an object, ...)

- Constructing **arguments**
- Identifying their **basic strengths** + their **interactions**
- Evaluating their **overall strengths** ⇒ Semantics
- Concluding

Weighted bipolar argumentation graphs

- A weighted bipolar argumentation graph is a tuple $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$
  - $\mathcal{A}$: a finite set of arguments
  - w: $\mathcal{A} \to [0, 1]$ basic strengths of arguments
  - $\mathcal{R} \subseteq \mathcal{A} \times \mathcal{A}$: an attack relation
  - $\mathcal{S} \subseteq \mathcal{A} \times \mathcal{A}$: a support relation



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- A semantics is a function **S** assigning to each argument in a graph $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$ a value in $[0, 1]$

- Notations: Let $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$ be a graph and $a \in \mathcal{A}$.
  - $\texttt{Deg}(a)$ the **overall strength** of a in **A** according to semantics **S**
  - $\texttt{Att}(a)$ $\{b \in \mathcal{A} \mid b\mathcal{R}a\}$ (**attackers** of a)
  - $\texttt{Sup}(a)$ $\{b \in \mathcal{A} \mid b\mathcal{S}a\}$ (**supporters** of a)

Existing semantics

Collective vs. *individual* evaluation

Extension semantics	Gradual semantics
Cayrol and Lagasquie-Schiex, 2005	QuAD (Baroni et al. 2015)
Oren and Norman, 2008	DF-QuAD (Rago et al. 2016)
Boella et al., 2010	
Nouioua and Risch, 2010-2011	
Brewka and Woltran, 2010	
Polberg and Oren, 2014	

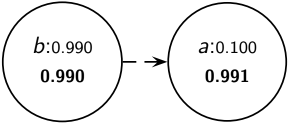
Existing semantics (Cont.)

Extension semantics

- × Arguments have the **same** intrinsic strength
- × When $\mathcal{R} = \emptyset$, supporters are **ignored**
- ✓ Graphs may have **any** structure

Gradual semantics

- ✓ Arguments may have different intrinsic strengths
- ✓ When $\mathcal{R} = \emptyset$, supporters are taken into account
- × Graphs are assumed to be **acyclic**
- × **Big jump** problem



Existing semantics (Cont.)

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Gradual semantics

- ✓ Arguments may have different intrinsic strengths
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Common drawbacks

- × The **principles** behind the semantics are not investigated
- × The semantics (of the two families) are not compared

Our contributions

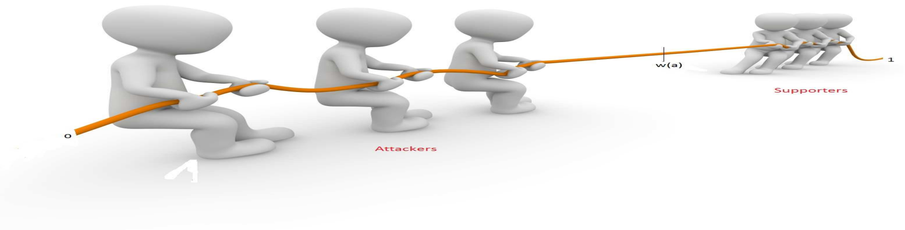
- Axiomatics foundations of semantics for weighted bipolar graphs
- Formal analysis of existing semantics
- New semantics satisfying the axioms + avoiding the big jump problem

Axiomatic foundations of semantics

Let $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$, $a \in \mathcal{A}$.

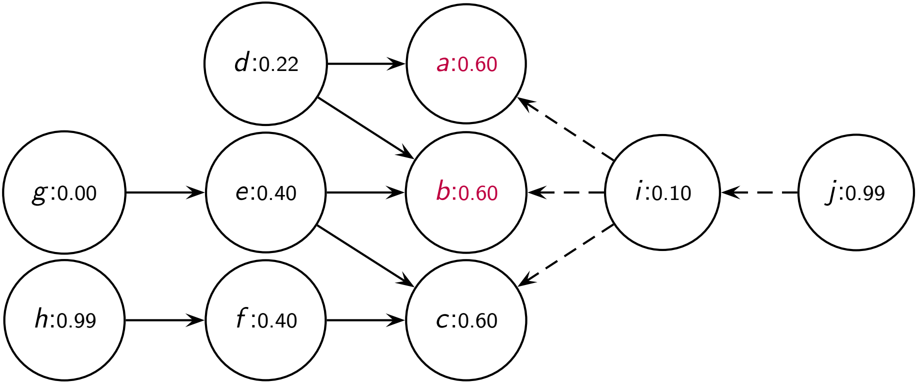
- Anonymity: $\texttt{Deg}(a)$ is independent from a's identity
- Independence: $\texttt{Deg}(a)$ is independent from any argument b not connected to a
- Bi-variate directionality: $\texttt{Deg}(a)$ doesn't depend on a's **outgoing** arrows
- Bi-variate equivalence: $\texttt{Deg}(a)$ depends only on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

Axiomatic foundations of semantics (Cont.)



- Stability: If $\texttt{Att}(a) = \texttt{Supp}(a) = \emptyset$, then $\texttt{Deg}(a) = w(a)$
- Neutrality: **worthless** attackers/supporters have no effect
- Bi-variate monotony: the **more** an argument is attacked, the weaker it is. The more an argument is supported, the stronger it is.
- Bi-variate reinforcement: an argument becomes stronger if the **quality** of its attackers is reduced and the quality of its supporters is increased

Example



- Stability $\Rightarrow$ $\texttt{Deg}(g) = 0$
- Neutrality + Stability $\Rightarrow$ $\texttt{Deg}(e) = 0.4$
- Strict Monotony $\Rightarrow$ $\texttt{Deg}(a) > \texttt{Deg}(b)$

How attackers and supporters are aggregated?

Assumption: Attack $\approx$ Support

Franklin

A semantics $\mathbf{S}$ *satisfies franklin iff, for any graph* $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$*, for all* $a, b, x, y \in \mathcal{A}$*, if*

- $w(b) = w(a)$,
- $\mathtt{Deg}(x) = \mathtt{Deg}(y)$
- $\mathtt{Att}(a) = \mathtt{Att}(b) \cup \{x\}$,
- $\mathtt{Sup}(a) = \mathtt{Sup}(b) \cup \{y\}$,

then $\mathtt{Deg}(a) = \mathtt{Deg}(b)$.

Axiomatic foundations of semantics (Cont.)

Weakening

A semantics **S** *satisfies* *weakening* *iff, for any graph* $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$, *for all* $a \in \mathcal{A}$, *if*

- $w(a) > 0$ *and*
- *there exists an injective function* f *from* $\texttt{Sup}(a)$ *to* $\texttt{Att}(a)$ *s.t.*
  - $\forall x \in \texttt{Sup}(a)$, $\texttt{Deg}(x) \leq \texttt{Deg}(f(x))$; *and*
  - $\texttt{sAtt}(a) \setminus \{f(x) \mid x \in \texttt{Sup}(a)\} \neq \emptyset$ *or* $\exists x \in \texttt{Sup}(a)$ *s.t* $\texttt{Deg}(x) < \texttt{Deg}(f(x))$,

then $\texttt{Deg}(a) < w(a)$.

Axiomatic foundations of semantics (Cont.)

Strengthening

A semantics $\mathbf{S}$ *satisfies strengthening iff, for any graph* $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$, *for all* $a \in \mathcal{A}$, *if:*

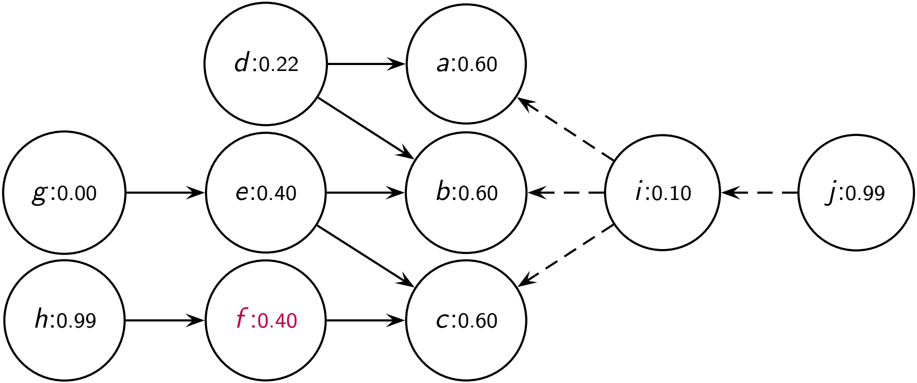
- $w(a) < 1$ *and*
- *there exists an injective function* f *from* $\mathtt{Att}(a)$ *to* $\mathtt{Sup}(a)$ *s.t.*
  - $\forall x \in \mathtt{Att}(a)$, $\mathtt{Deg}(x) \leq \mathtt{Deg}(f(x))$*; and*
  - $\mathtt{sSup}_{\mathbf{A}}(a) \setminus \{f(x) \mid x \in \mathtt{Att}(a)\} \neq \emptyset$ *or* $\exists x \in \mathtt{Att}(a)$ *s.t.* $\mathtt{Deg}(x) < \mathtt{Deg}(f(x))$,

then $\mathtt{Deg}(a) > w(a)$.

Axiomatic foundations of semantics (Cont.)

Resilience

A semantics **S** *satisfies resilience iff, for any graph* $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$*, for all* $a \in \mathcal{A}$*, if* $0 < w(a) < 1$*, then* $0 < \texttt{Deg}(a) < 1$*.*



Euler-based semantics

Euler-based semantics

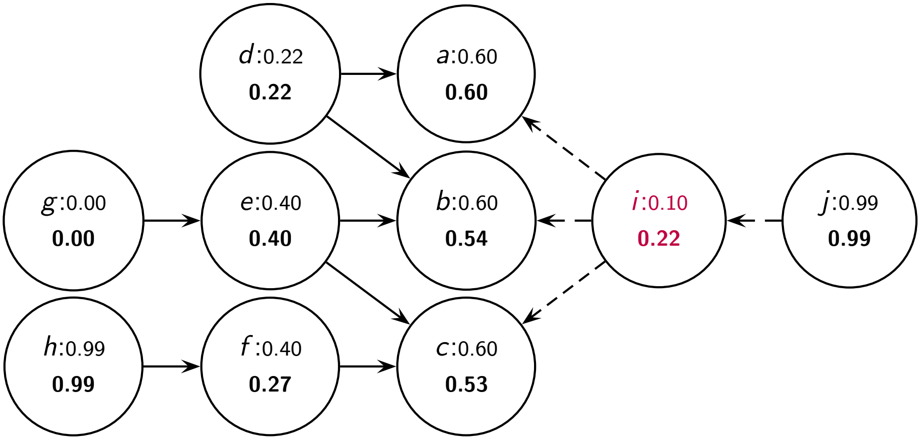
For any ***acyclic*** *non-maximal graph* $\mathbf{A} = \langle \mathcal{A}, w, \mathcal{R}, \mathcal{S} \rangle$ *and* $a \in \mathcal{A}$,

$$\mathtt{Deg}^{\mathtt{Ebs}}_{\mathbf{A}}(a) = 1 - \frac{1 - w(a)^2}{1 + w(a)\mathrm{e}^{E}}$$

where

$$E = \sum_{x \mathcal{S} a} \mathtt{Deg}^{\mathtt{Ebs}}_{\mathbf{A}}(x) - \sum_{x \mathcal{R} a} \mathtt{Deg}^{\mathtt{Ebs}}_{\mathbf{A}}(x).$$

Example (Cont.)



Analysis and comparison of semantics

Axioms - Semantics	Euler-based	QuAD	DF-QuAD	Stable
Anonymity	•	•	•	•
Bi-variate Independence	•	•	•	◦
Bi-variate Directionality	•	•	•	◦
Bi-variate Equivalence	•	•	•	◦
Stability	•	•	•	◦
Neutrality	•	•	•	•
Monotony	•	•	•	◦
Strict Monotony	•	◦	◦	◦
Reinforcement	•	•	•	◦
Strict Reinforcement	•	◦	◦	◦
Resilience	•	◦	◦	◦
Franklin	•	◦	•	◦
Weakening	•	◦	◦	◦
Strengthening	•	◦	◦	◦

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

Perspectives

- Characterize the family of semantics satisfying the axioms
- Apply the semantics to multiple criteria decision making problems
- Consider new axioms where attacks take precedence over supports
- Define new semantics