FAKULTÄT FÜR INFORMATIK

Faculty of Informatics

Revision of Abstract Dialectical Frameworks

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Introduction

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- Abstract Argumentation frameworks (AFs) [Dung, 1995]
  - Widely used formalism
  - Various extensions to overcome its limitations

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  - Relation between arguments is modelled via acceptance conditions
  - In use: Preferential reasoning [Brewka et al., 2013], judgment aggregation [Booth, 2015], legal reasoning [Al-Abdulkarim et al., 2016].

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- [Diller et al., 2015]: AGM style revision of AFs
  - Extension-based revision with respect to semantics σ
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$\Rightarrow$ Revision of ADFs under three-valued semantics

Abstract Dialectical Frameworks

Definition

An abstract dialectical framework (ADF) is a triple $F = (S, L, C)$,

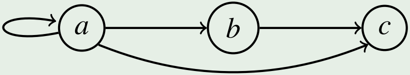
- S ... set of statements (correspond to AF arguments)
- $L \subseteq S \times S$ ... links $(par(s) = L^{-1}(s))$
- $C = \{C_s\}_{s \in S}$ ... acceptance conditions

- links denote some kind of dependency relation
- acceptance condition: Boolean function $C_s : 2^{par(s)} \rightarrow \{\mathbf{t}, \mathbf{f}\}$
- here: C_s specified by propositional formula φ_s
- here: F represented as sets of tuples $\langle s, \varphi_s \rangle$

Abstract Dialectical Frameworks

Example

$$\varphi_a = a \qquad \varphi_b = a \quad \varphi_c = \neg(a \wedge b)$$



$$F = \{\langle a, a\rangle, \langle b, a\rangle, \langle c, \neg(a \wedge b)\rangle\}$$

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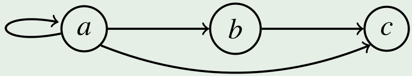

$$F = \{\langle a, a\rangle, \langle b, a\rangle, \langle c, \neg(a \wedge b)\rangle\}$$

- a supports itself
- a supports b
- a and b jointly attack c

Abstract Dialectical Frameworks

Truth values, interpretations

- truth values: true $\mathbf{t}$, false $\mathbf{f}$, unknown $\mathbf{u}$
- interpretation: $v : S \to \{\mathbf{t}, \mathbf{f}, \mathbf{u}\}$

Information ordering

- $\mathbf{u} <_i \mathbf{t}$ and $\mathbf{u} <_i \mathbf{f}$ (as usual $x \leq_i y$ iff $x <_i y$ or $x = y$)
- consensus $\sqcap$ is greatest lower bound w.r.t. $\leq_i$:
  $\mathbf{t} \sqcap \mathbf{t} = \mathbf{t}$ and $\mathbf{f} \sqcap \mathbf{f} = \mathbf{f}$, otherwise $x \sqcap y = \mathbf{u}$
- information ordering generalized to interpretations:
  $v_1 \leq_i v_2$ iff $v_1(s) \leq_i v_2(s)$ for all $s \in S$
- $[v]_2$: two-valued interpretations w with $v \leq_i w$

Abstract Dialectical Frameworks

Characteristic operator

Given ADF F and interpretation v,

$$\Gamma_F(v)(s) = \bigsqcap_{w \in [v]_2} w(\varphi_s).$$

Abstract Dialectical Frameworks

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Semantics

Given ADF F, an interpretation v is

- admissible for F iff $v \leq_i \Gamma_F(v)$,
- complete for F iff $v = \Gamma_F(v)$,
- preferred for F iff v is $\leq_i$-maximal admissible for F
- grounded for F iff v is $\leq_i$-minimal complete for F
- a (supported) model of F iff v is two-valued and $v = \Gamma_F(v)$,
- a stable model of F iff v is a model of F and $v^t = w^t$, where w is the grounded interpretation of $F^v = \{\langle a, \varphi_a[x/\bot : v(x) = \mathbf{f}]\rangle \mid a \in v^{\mathbf{t}}\}$.

Abstract Dialectical Frameworks

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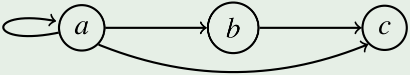

$ad(F) = \{$

Abstract Dialectical Frameworks

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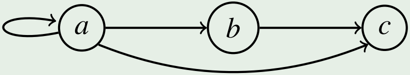

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Abstract Dialectical Frameworks

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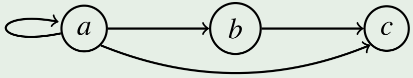

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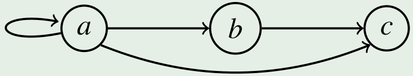

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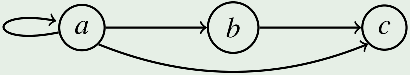

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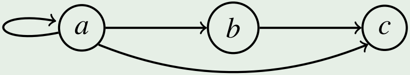

ad$(F) = \{\mathbf{uuu}, \mathbf{tuu}, \mathbf{fuu}, \mathbf{tuf}, \mathbf{ttu}, \mathbf{ffu}, \mathbf{ttf}, \mathbf{fff}\}$

Belief Revision

- Initial beliefs: ψ
- New piece of information (observation,...): μ

$$\begin{array}{ccc} \text{Inputs} & & \text{Outputs} \\ \left.\begin{array}{c} \psi \\ \mu \end{array}\right\} & \Longrightarrow & \psi \circ \mu \end{array}$$

- s.t. $\psi \circ \mu$ implies μ (success principle)
- s.t. $\psi \circ \mu$ is as close as possible to ψ (minimal change principle)
- "good" operators are characterized by postulates + representation theorem

Belief Revision

[Alchourrón et al., 1985, Katsuno and Mendelzon, 1991]:

($R1$) $\psi \circ \mu \models \mu$.

($R2$) If $\psi \wedge \mu$ is satisfiable, then $\psi \circ \mu = \psi \wedge \mu$.

($R3$) If μ is satisfiable, then $\psi \wedge \mu$ is also satisfiable.

($R4$) If $\psi_1 \equiv \psi_2$ and $\mu_1 \equiv \mu_2$, then $\psi_1 \circ \mu_1 \equiv \psi_2 \circ \mu_2$.

($R5$) $(\psi \circ \mu) \wedge \phi \models \psi \circ (\mu \wedge \phi)$.

($R6$) If $(\psi \circ \mu) \wedge \phi$ is satisfiable, then $\psi \circ (\mu \wedge \phi) \models (\psi \circ \mu) \wedge \phi$.

Belief Revision

Definition

Given a formula ψ, a preorder $\preceq_\psi$ is a faithful ranking for ψ if it is total and for all interpretations $v_1, v_2 \in \mathcal{V}$ it holds that

(i) if $v_1, v_2 \in Mod(\psi)$ then $v_1 \approx_\psi v_2$, and

(ii) if $v_1 \in Mod(\psi)$ and $v_2 \notin Mod(\psi)$ then $v_1 \prec_\psi v_2$.

Function mapping each formula to a faithful ranking: faithful assignment.

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Function mapping each formula to a faithful ranking: faithful assignment.

Theorem [Katsuno and Mendelzon, 1991]

A revision operator $\circ$ satisfies $R1 - R6$

iff

there is an assignment mapping each formula ψ to a faithful ranking $\preceq_\psi$ such that $\mathit{Mod}(\psi \circ \mu) = \min(\mathit{Mod}(\mu), \preceq_\psi)$

- $\min(V, \preceq) = \{v_1 \in V \mid \nexists v_2 \in V : v_2 \prec v_1\}$.

Main Contributions

- $* : \mathcal{F}_A \times \mathcal{F}_A \mapsto \mathcal{F}_A$:
- Representation theorems: Correspondence between revision operators captured by rankings and revision operators given by (extended) set of AGM postulates.
- Revision under preferred semantics
- Revision under admissible semantics
- Hybrid approach

Main Contributions

- $* : \mathcal{F}_A \times \mathcal{F}_A \mapsto \mathcal{F}_A$:
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Tool-Kit:

- Realizability results for ADF semantics [Strass, 2015, Pührer, 2015]
  - Exact characterization of realizable interpretation sets
- Horn belief revision [Delgrande and Peppas, 2015]
  - How to modify postulates and rankings in order to stay in the fragment

Revision of ADFs

$* : \mathcal{F}_A \times \mathcal{F}_A \mapsto \mathcal{F}_A$:

($A1_\sigma$) $\sigma(F * G) \subseteq \sigma(G)$.

($A2_\sigma$) If $\sigma(F) \cap \sigma(G) \neq \emptyset$, then $\sigma(F * G) = \sigma(F) \cap \sigma(G)$.

($A3_\sigma$) If $\sigma(G) \neq \emptyset$, then $\sigma(F * G) \neq \emptyset$.

($A4_\sigma$) If $\sigma(G) = \sigma(H)$, then $\sigma(F * G) = \sigma(F * H)$.

($A5_\sigma$) $\sigma(F * G) \cap \sigma(H) \subseteq \sigma(F * f_\sigma(\sigma(G) \cap \sigma(H)))$.

($A6_\sigma$) If $\sigma(F * G) \cap \sigma(H) \neq \emptyset$, then
$\sigma(F * f_\sigma(\sigma(G) \cap \sigma(H))) \subseteq \sigma(F * G) \cap \sigma(H)$.

Revision of ADFs – Obstacles

- Limited expressiveness: not every set of interpretations has a realizing ADF

Proposition [Pührer, 2015, Strass, 2015]

A set of interpretations V is realizable under

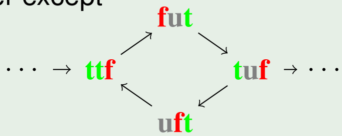
- *ad* iff $V \neq \emptyset$ and $V = \mathit{cl}(V)$;
- *pr* iff $V \neq \emptyset$ and V is incompatible;
- *mo* iff $V \subseteq \mathcal{V}^2$;
- *st* iff $V \subseteq \mathcal{V}^2$ and $v_1^{\mathbf{t}} \not\subseteq v_2^{\mathbf{t}}$, $v_2^{\mathbf{t}} \not\subseteq v_1^{\mathbf{t}}$ for all $v_1, v_2 \in V$.

- Postulates may be satisfied by operators induced by pseudo-preorder
- Three-valued interpretations: alternative distance measures needed

Revision under Preferred Semantics

Example

- $\preceq_F$: Faithful preorder except



- $f_{pr}(\min(pr(G), \preceq_F))$ well defined for any ADF G.
- Operator induced by $\preceq_F$ satisfies $R1 - R6$.
- Any binary relation $\preceq'_F$ inducing the same operator must contain this cycle.

- Revision operators characterizing non-transitive rankings

Revision under Preferred Semantics

- Additional postulate [Delgrande and Peppas, 2015]:

(*Acyc*$_\sigma$) If for $1 \leq i < n$, $\sigma(F * G_{i+1}) \cap \sigma(G_i) \neq \emptyset$ and $\sigma(F * G_1) \cap \sigma(G_n) \neq \emptyset$ then $\sigma(F * G_n) \cap \sigma(G_1) \neq \emptyset$.

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- Faithfulness adapted:

Definition

Given a semantics σ and an ADF F, a preorder $\preceq_F$ is a i-max-faithful ranking for F if it is i-max-total and for all incompatible interpretations $v_1, v_2 \in \mathcal{V}$ it holds that

(i) if $v_1, v_2 \in \sigma(F)$ then $v_1 \approx_F v_2$, and

(ii) if $v_1 \in \sigma(F)$ and $v_2 \notin \sigma(F)$ then $v_1 \prec_F v_2$.

A function mapping each ADF to a i-max-faithful ranking is called i-max-faithful assignment.

Revision under Preferred Semantics

Theorem

An operator $\star_{pr}$ satisfies postulates $A1_{pr} - A6_{pr}$ and Acyc$_{pr}$
iff
there exists an assignment mapping each ADF *F to an i-max-faithful ranking $\preceq_F$ such that pr$(F \star_\sigma G) = \min(pr(G), \preceq_F)$.*

Revision under Preferred Semantics

Symmetric distance function $\triangle$:

- $\mathbf{t} \triangle \mathbf{f} = 1$,
- $\mathbf{t} \triangle \mathbf{u} = \mathbf{f} \triangle \mathbf{u} = \frac{1}{2}$, and
- $\mathbf{x} \triangle \mathbf{x} = 0$ for $\mathbf{x} \in \{\mathbf{t}, \mathbf{f}, \mathbf{u}\}$.

$$v_1 \triangle v_2 = \sum_{a \in A} v_1(a) \triangle v_2(a).$$

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$$v_1 \triangle v_2 = \sum_{a \in A} v_1(a) \triangle v_2(a).$$

$$v_1 \preceq_F^\sigma v_2 \Leftrightarrow \min_{v \in \sigma(F)} (v \triangle v_1) \leq \min_{v \in \sigma(F)} (v \triangle v_2).$$

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$$v_1 \triangle v_2 = \sum_{a \in A} v_1(a) \triangle v_2(a).$$

$$v_1 \preceq_F^{\sigma} v_2 \Leftrightarrow \min_{v \in \sigma(F)} (v \triangle v_1) \leq \min_{v \in \sigma(F)} (v \triangle v_2).$$

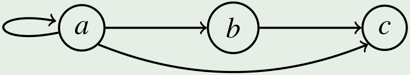
$\Rightarrow$ $\preceq_F^{pr}$ is i-max-faithful.

$\Rightarrow$ $*_{pr}^{D} : F *_{pr}^{D} G = f_{pr}(\min(pr(G), \preceq_F^{pr}))$ satisfies the postulates.

Revision under Preferred Semantics

Example

$\varphi_a = a \qquad \varphi_b = a \qquad \varphi_c = \neg(a \wedge b)$



- $pr(F) = \{\mathbf{ttf}, \mathbf{fff}\}$
- $\mathbf{ttf} \approx_F^{pr} \mathbf{fff} \prec_F^{pr}$ *others*.

Revision under Preferred Semantics

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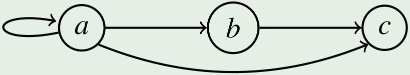

- $pr(F) = \{$**ttf**, **fff**$\}$
- **ttf** $\approx^{pr}_{F}$ **fff** $\prec^{pr}_{F}$ *others.*
- Revision by $G = \{\langle a, \top\rangle, \langle b, \neg a\rangle, \langle c, \neg b\rangle\}$
  - $ad(G) = \{$**tft**, **tfu**, **tuu**, **uuu**$\}$

Revision under Preferred Semantics

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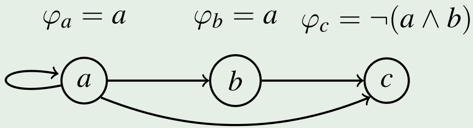

- $pr(F) = \{\mathbf{ttf}, \mathbf{fff}\}$
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- Revision by $G = \{\langle a, \top\rangle, \langle b, \neg a\rangle, \langle c, \neg b\rangle\}$
  - $ad(G) = \{\mathbf{tft}, \mathbf{tfu}, \mathbf{tuu}, \mathbf{uuu}\}$
- $F \star^{D}_{pr} G = f_{pr}(\{\mathbf{tft}\})$.
- $\mathbf{tuu}$ is admissible in both F and G and has less distance.

Revision under Admissible Semantics

Theorem

An operator $\star_{ad}$ *satisfies postulates* $A1_{ad} - A6_{ad}$
iff
it is defined as $F \star_{ad} G = f_{ad}(ad(F) \cap ad(G))$.

Revision under Admissible Semantics

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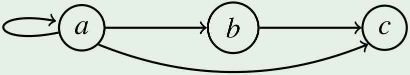

- *pr*$(F) = \{$ttf, fff$\}$; *ad*$(F) = \{$ttf, fff, ttu, tuf, ffu, tuu, fuu, uuu$\}$
- Revision by G'
    - *ad*$(G') = \{$utf, uuu$\}$

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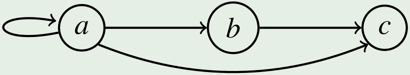

- $pr(F) = \{\mathbf{ttf}, \mathbf{fff}\}$; $ad(F) = \{\mathbf{ttf}, \mathbf{fff}, \mathbf{ttu}, \mathbf{tuf}, \mathbf{ffu}, \mathbf{tuu}, \mathbf{fuu}, \mathbf{uuu}\}$
- Revision by G'
  - $ad(G') = \{\mathbf{utf}, \mathbf{uuu}\}$
- $F \star^{D}_{ad} G' = f_{ad}(\{\mathbf{uuu}\})$.
- From *pr*-perspective questionable:
  - $\mathbf{utf} \triangle \mathbf{ttf} = \frac{1}{2}$
  - $\mathbf{uuu} \triangle \mathbf{ttf} = \frac{3}{2}$

Hybrid Approach

$F \star G$:

- Selecting from *ad*(G) .
- Distance based on *pr*(F).

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$(P1)$ *pr*$(F \star G) \subseteq$ *ad*(G).

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$(P3)$ If *ad*$(G) \neq \emptyset$, then *pr*$(F \star G) \neq \emptyset$.

$(P4)$ If *ad*$(G) =$ *ad*(H), then *pr*$(F \star G) =$ *pr*$(F \star H)$.

$(P5)$ *pr*$(F \star G) \cap$ *ad*$(H) \subseteq$ *pr*$(F \star f_{ad}($*ad*$(G) \cap$ *ad*$(H)))$.

$(P6)$ If *pr*$(F \star G) \cap$ *ad*$(H) \neq \emptyset$, then
pr$(F \star f_{ad}($*ad*$(G) \cap$ *ad*$(H))) \subseteq$ *pr*$(F \star G) \cap$ *ad*(H).

(*Acyc*) If for $1 \leq i < n$, *pr*$(F * G_{i+1}) \cap$ *ad*$(G_i) \neq \emptyset$ and
pr$(F * G_1) \cap$ *ad*$(G_n) \neq \emptyset$ then *pr*$(F * G_n) \cap$ *ad*$(G_1) \neq \emptyset$.

Hybrid Approach

Example

- $F = \{\langle a, \bot\rangle, \langle b, \bot\rangle\}$: *pr*$(F) = \{\mathbf{ff}\}$
- $G = \{\langle a, \top\rangle, \langle b, \top\rangle\}$: *ad*$(G) = \{\mathbf{uu}, \mathbf{ut}, \mathbf{tu}, \mathbf{tt}\}$
- $\mathbf{ff} \prec$ *others* $\prec \mathbf{tu} \approx \mathbf{ut} \prec \mathbf{tt} \prec \mathbf{uu}$: faithful ranking for F.
- $F \star G = f_{pr}(\{\mathbf{ut}, \mathbf{tu}\})$, but $\{\mathbf{ut}, \mathbf{tu}\}$ is not realizable under *pr*.

$\Rightarrow$ $\star$ violates $P5$.

Hybrid Approach

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$\Rightarrow$ $\star$ violates $P5$.

Definition

A preorder $\preceq$ is σ-τ-compliant if, for every ADF $F \in \mathcal{F}_A$, $\min(\tau(F), \preceq)$ is realizable under σ.

Hybrid Approach

Theorem

An operator $\star$ satisfies postulates $P1 - P6$ and Acyc
iff
there exists an assignment mapping each ADF F *to a faithful and pr-ad-compliant ranking* $\preceq_F$ *such that pr*$(F \star G) = \min($*ad*$(G), \preceq_F)$.

- Valid operator induced from $\preceq$: *pr*(F) followed by $\prec$-chain.
- Three-valued Dalal operator not applicable: does not yield *pr*-*ad*-compliant rankings in general.
- Refinement need to obtain concrete operator.

Conclusion

Summary:

- Combining recent results in argumentation and belief revision
- Revision of ADFs under preferred and admissible semantics
  - Three-valued version of Dalal's operator
- Hybrid approach
- No AGM revision operators for complete and grounded semantics
- Discussion of revision under stable and supported models

Future work:

- Refinement of ranking for hybrid approach
- Hybrid approach for revision in other formalisms
- Syntactic aspects
- Revision of AFs under three-valued semantics
- Complexity of Dalal's operator under preferred semantics

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