The Complexity Landscape of Claim-Augmented Argumentation Frameworks

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A Claim-centric View in Argumentation

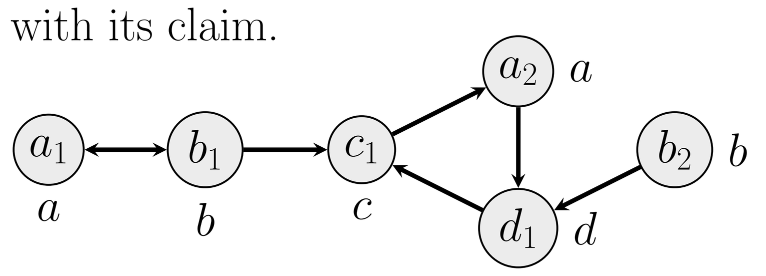
Instantiation-based Argumentation

1. start from a knowledge base (KB), which is potentially inconsistent;
2. construct arguments - arguments consist of *claim* and *support*;
3. relationship between arguments is analysed;
4. abstract away from the contents of the arguments and only consider the remaining abstract argumentation framework (AF);
5. semantics for AFs deliver a collection of sets of arguments ("extensions") which are understood as jointly acceptable;
6. re-interpret extensions in terms of their claims to restate problem in the domain of original setting.

- Re-interpretation can be performed in different steps of evaluation.
  $\hookrightarrow$ Step (6) of instantiation process can be interpreted in different ways

Example

Consider the following AF F where each argument is labelled with its claim.



Goal: Determine *preferred claim-based extensions*, i.e., subset-maximal sets which are *admissible*, i.e., conflict-free and defend themselves

- $adm(F) = \emptyset, \{a_1\}, \{b_1\}, \{b_2\}, \{a_1, b_2\}, \{b_1, b_2\}, \{a_2, b_1\}, \{a_1, b_2, c_1\}, \{a_2, b_1, b_2\}$
  $\hookrightarrow$ Admissible claim-sets: $\emptyset, \{a\}, \{b\}, \{a, b\}, \{a, b, c\}$

Two different variants to determine claim-based preferred extensions:

1. Determine preferred extensions on AF-level: $\{a_1, b_2, c_1\}$ and $\{a_2, b_1, b_2\}$
   $\hookrightarrow$ Outcome in terms of claims: $\{a, b\}$ and $\{a, b, c\}$
2. Maximization over admissible claim-sets yields $\{a, b, c\}$

Argument vs. Claim Acceptance

Skeptical Acceptance: Is a particular argument a / claim c covered by all extensions?

Example (ctd.)

Comparing argument-extensions $\{a_1, b_2, c_1\}, \{a_2, b_1, b_2\}$; claim-sets $\{a, b\}, \{a, b, c\}$ (outcome of variant (1)); and claim-set $\{a, b, c\}$ (cf. variant (2)), we observe that

- argument b_2 is skeptically accepted;
- claims a, b are skeptically accepted wrt. both variants (1) and (2);
- claim c is skeptically accepted wrt. variant (2).

Observation:

- Argument acceptance alone is insufficient to decide the acceptance of claims.
- Claim-acceptance depends on chosen claim-based evaluation method.

Claim-augmented Argumentation

Claim-augmented Argumentation Frameworks

A *claim-augmented argumentation framework (CAF)* is a triple $(A, R, claim)$;

- (A, R) is an AF with arguments A and attacks $R \subseteq A \times A$;
- $claim : A \to \mathcal{C}$ assigns a claim to each argument.

CF is *well-formed* if arguments with the same claim attack the same arguments.

- The concept of well-formedness is satisfied by many (but not all) instantiations.

Semantics for CAFs

Inherited Semantics

Idea: Evaluate underlying AF; interpret outcome in terms of claims (variant (1)).

For $CF = (A, R, claim)$ and AF-semantics σ, we define its *inherited variant* as

$$\sigma_c(CF) = \{claim(E) \mid E \in \sigma((A, R))\}.$$

We consider inherited conflict-free (cf_c), admissible (adm_c), preferred (prf_c), naive ($naive_c$), stable (stb_c), semi-stable (sem_c) and stage (stg_c) semantics.

Claim-level Semantics

Idea: Shift steps in the evaluation from argument- to claim-level (variant (2)):

- *Maximization* of claim-sets (e.g., preferred semantics); and
- *Claim-defeat:* Let $CF = (A, R, claim)$, $E \subseteq A$ and $c \in claim(A)$. E *defeats* c *(in* CF*)* if E attacks every $a \in A$ with $claim(a) = c$.

We consider claim-level variants of preferred ($cl\text{-}prf$), naive ($cl\text{-}naive$), stable ($cl\text{-}stb_{adm}$, $cl\text{-}stb_{cf}$), semi-stable ($cl\text{-}sem$) and stage ($cl\text{-}stg$) semantics.

- A set of claims S is *cl-τ-stable*, $\tau \in \{cf, adm\}$, in $CF = (A, R, claim)$ if there is $E \in \tau((A, R))$, $claim(E) = S$ & E defeats all claims in $claim(A) \setminus S$.
- A set of claims S is *cl-preferred* if it is a subset-maximal i-admissible set.

- For well-formed CAFs, variants of preferred and stable semantics coincide.

Comparing Semantics

Concurrence Problem

Given AF-semantics σ, and a CAF $CF = (A, R, claim)$,

- Con_σ^{CAF}: Does it hold that $\sigma_c(CF) = cl\text{-}\sigma(CF)$?

The concurrence problem restricted to well-formed CAFs is denoted by Con_σ^{wf}.

Complexity of Concurrence

	prf	$naive$	stb_τ	sem	stg
Con_σ^{CAF}	Π_2^P-c	coNP-c	Π_2^P-c	Π_3^P-c	Π_3^P-c
Con_σ^{wf}	trivial	in coNP	trivial	Π_2^P-c	Π_2^P-c

Claim-centric Complexity Analysis

Claim-centric Reasoning Problems

Given semantics σ, CAF $CF = (A, R, claim)$, claim $c \in \mathcal{C}$, and $C \subseteq \mathcal{C}$:

- $Cred_\sigma$: Does $c \in S$ hold for at least one $S \in \sigma(CF)$?
- $Skept_\sigma$: Does $c \in S$ hold for all $S \in \sigma(CF)$?
- Ver_σ: Does $C \in \sigma(CF)$ hold?
- NE_σ^{CAF}: Does $S \neq \emptyset$ hold for some $S \in \sigma(CF)$?

Complexity of CAFs

σ	$Cred_\sigma^{CAF}$	$Skept_\sigma^{CAF}$	Ver_σ^{CAF}	NE_σ^{CAF}
sem_c	Σ_2^P-c	Π_2^P-c	**Σ_2^P-c**	NP-c
stg_c	Σ_2^P-c	Π_2^P-c	**Σ_2^P-c**	in P
$cl\text{-}stb_{adm}$	NP-c	coNP-c	**NP**-c	NP-c
$cl\text{-}stb_{cf}$	NP-c	coNP-c	**NP**-c	NP-c
$cl\text{-}prf$	NP-c	Π_2^P-c	<u>**DP**-c</u>	NP-c
$cl\text{-}naive$	in P	<u>**Π_2^P**-c</u>	<u>**DP**-c</u>	in P
$cl\text{-}sem$	Σ_2^P-c	Π_2^P-c	**Σ_2^P-c**	NP-c
$cl\text{-}stg$	Σ_2^P-c	Π_2^P-c	**Σ_2^P-c**	in P

Results that deviate from the corresponding AF results are **blue**; results that deviate from those wrt. inherited semantics are <u>underlined</u>.

Complexity of well-formed CAFs

σ	$Cred_\sigma^{wf}$	$Skept_\sigma^{wf}$	Ver_σ^{wf}	NE_σ^{wf}
sem_c	Σ_2^P-c	Π_2^P-c	**coNP**-c	NP-c
stg_c	Σ_2^P-c	Π_2^P-c	**coNP**-c	in P
$cl\text{-}stb_{cf}$	NP-c	coNP-c	in **P**	NP-c
$cl\text{-}stb_{adm}$	NP-c	coNP-c	in **P**	NP-c
$cl\text{-}naive$	in P	**coNP**-c	in **P**	in P
$cl\text{-}prf$	NP-c	Π_2^P-c	**coNP**-c	NP-c
$cl\text{-}sem$	Σ_2^P-c	Π_2^P-c	**coNP**-c	NP-c
$cl\text{-}stg$	Σ_2^P-c	Π_2^P-c	**coNP**-c	in P

Coincides with corresp. results for AFs except $Skept_{cl\text{-}naive}^{wf}$.

Results that deviate from corresp. results for general CAFs are **red**.

Main References

[1] Dung, P. M. 1995. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artif. Intell.* 77(2):321–358.

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[3] Dvořák, W.; and Woltran, S. 2020. Complexity of abstract argumentation under a claim-centric view. *Artif. Intell.* 285:103290.