Acceptance in Incomplete Argumentation Frameworks

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Motivation: The study of **computational models of argumentation** is an active and vibrant area of modern **AI** research. **Incomplete argumentation frameworks (IAFs)** generalize Dung's argumentation frameworks for **reasoning under uncertainty**.

Contributions: **Complexity analysis** of **acceptance problems in IAFs** under various central AF semantics. **Design of algorithms** for solving concrete instances of acceptance problems: direct **SAT encodings** and SAT-based **CEGAR algorithms**. **Strong refinements** for CEGAR algorithms by analyzing redundant atomic changes in IAFs. **System implementation** and **empirical evaluation**: SAT-based approach viable in practice.

INCOMPLETE ARGUMENTATION FRAMEWORKS

Argumentation Framework (AF)

A directed graph $AF = (A, R)$:

- A is the set of **arguments**
- $R \subseteq A \times A$ is the **attack relation**

Semantics σ define σ-**extensions**

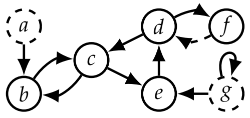
- jointly acceptable sets of arguments
- required to be **conflict-free**
- other desired properties give rise to different semantics: admissible, stable, complete, grounded, preferred

Incomplete Argumentation Framework (IAF)

$IAF = (A, A^?, R, R^?)$, where

- A and R are **definite** arguments and attacks,
- $A^?$ and $R^?$ are **uncertain** arguments and attacks,

$R, R^? \subseteq (A \cup A^?) \times (A \cup A^?)$.



Acceptance Problems in IAFs

Completion: standard AF containing the fixed part and a valid subset of uncertain elements

An argument $a \in A$ is

- **credulously** accepted (CA): a is in **some** extension
- **skeptically** accepted (SA): a is in **all** extensions
  - + existence of an extension (ExSA)

Acceptance of $a \in A$ holds

- **possibly** (P) if it holds for **some** completion
- **necessarily** (N) if it holds for **all** completions

SAT-BASED ALGORITHMS

Input: $IAF = (A, A^?, R, R^?)$, $a \in A$.

Basis: SAT Encodings

Boolean variables:

- y_a for each argument a, $r_{a,b}$ for each attack (a, b)
  - true iff element included in completion
- x_a for each argument a
  - true iff argument included in σ-extension
- z_a for each argument a
  - true iff argument attacked by σ-extension

Propositional formulas:

- $\varphi_?(CAF)$ encodes valid completions
- $\varphi_\sigma(CAF)$ for $\sigma \in \{\text{AD}, \text{ST}, \text{CP}, \text{GR}\}$ encodes the semantics

The encoding for complete semantics is

$$\varphi_{\text{CP}}(IAF) = \varphi_{\text{AD}}(IAF) \wedge \bigwedge_{a \in A \cup A^?} \left(\bigwedge_{(b,a) \in R \cup R^?} \left((y_a \wedge y_b \wedge r_{b,a}) \rightarrow z_b \right) \rightarrow x_a \right).$$

PCA and NSA solved via direct SAT calls.

SAT-based CEGAR Algorithms

Algorithms where a **SAT solver** is **called iteratively** and incrementally using different assumptions.

Task: Possible skeptical acceptance under preferred.

```
φ ← ABSTRACTION(IAF, a)                ▷ Initialize abstraction
while true do
    (sat, τ) ← SAT(φ)                  ▷ Solve abstraction
    if sat = false then return reject
    AF* ← COMPLETION(τ)
    (sat, τ) ← CEGAR(CHECK(IAF, AF*, a))  ▷ Counter-
    if sat = false then return accept     ▷ example?
    φ ← φ∧ REFINE(IAF, AF*)            ▷ Exclude completion
end while
```

Strong refinement: take into account which atomic changes preserve the counterexample extension of the completion: e.g. for preferred semantics adding arguments which are attacked by the extension can be safely ignored.

In journal article: SAT encodings, CEGAR algorithms, and strong refinements for all other variants

COMPUTATIONAL COMPLEXITY

s	s-PCA	s-NCA	s-PSA (s-PExSA)	s-NSA (s-NExSA)
CF	$\in$ P	$\in$ P	trivial	trivial
CF$_{\neq\emptyset}$			$\in$ P	$\in$ P
AD	NP-c.	Π_2^p-c.	trivial	trivial
AD$_{\neq\emptyset}$			Σ_2^p-c.	coNP-c. (Π_2^p-c.)
ST	NP-c.	Π_2^p-c.	Σ_2^p-c.	coNP-c. (Π_2^p-c.)
CP	NP-c.	Π_2^p-c.	NP-c.	coNP-c.
GR	NP-c.	coNP-c.	NP-c.	coNP-c.
PR	NP-c.	Π_2^p-c.	Σ_3^p-c.	Π_2^p-c.

- Lower bounds follow from quantifier representations of the problem
  - Possible: $\exists$ completion
  - Necessary: $\forall$ completions
- Upper bounds via reductions from quantified satisfiability

In journal article: full proofs and illustrations of reductions

EMPIRICAL EVALUATION

Implementation: TAEYDENNAE

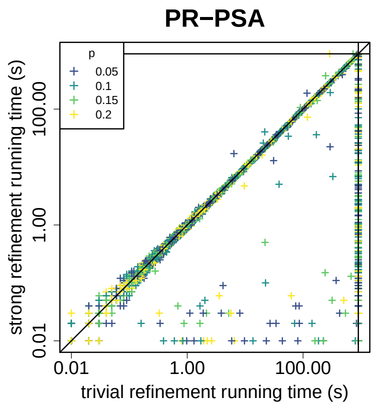
- Solver for acceptance in incomplete AFs
- Direct SAT calls and SAT-based CEGAR algorithms
- Makes use of incremental SAT solving
- Available online in open source:

`bitbucket.org/andreasniskanen/taeydennae`

Benchmark instances

4200 IAFs generated from ICCMA'17 AFs

- Parameter: probability p of element being uncertain



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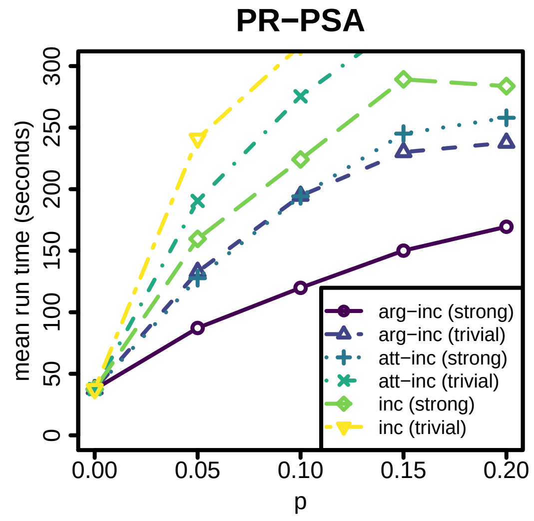

In journal article: Empirical results for other variants, comparison to basic enumeration-based approach