Novel Algorithms for Abstract Dialectical Frameworks based on Complexity Analysis of Subclasses and SAT Solving

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Motivation: The study of computational aspects of argumentation is an active area of modern AI research. Abstract dialectical frameworks are a powerful generalization of Dung’s argumentation frameworks. Expressive power comes with a price: computational complexity one level higher on the polynomial hierarchy.

Contributions:
- Complexity analysis of ADF subclasses: k-bipolar, (k-)acyclic, and (k-)concise
- Design of algorithms for acceptance problems based on incremental SAT solving
- Implementation and empirical evaluation

ABSTRACT DIACRETICAL FRAMEWORKS: DEFINITIONS

Syntax of ADFs
A tuple $D = (A, L, C)$, where
- $A$ is a finite set of arguments,
- $L \subseteq A \times A$ is a set of links,
- $C = \{\varphi_a\}_{a \in A}$ is a set of acceptance conditions each $\varphi_a$ is a propositional formula over the parents of $a$.

An interpretation $I$ maps each argument to a truth value in $\{t, f, u\}$. Let $I \leq_j I$ if $I(a) \in \{t, f\}$ implies $I(a) = I(a)$ for all $a \in A$.

L is admissible, $I \in adm(D)$, if for all $a \in A$
- $I(a) = t$ implies $\varphi_a[I]$ is a tautology,
- $I(a) = f$ implies $\varphi_a[I]$ is unsatisfiable,
where $\varphi_a[I]$ is the formula obtained from $\varphi_a$ by replacing each argument that $I$ assigns to $t$ or $f$ with $\top$ and $\bot$.

I is preferred, $I \in prf(D)$, if it is $\leq$-maximal admissible.

Figure 1: Example ADF.

COMPUTATIONAL COMPLEXITY OF SUBCLASSES

An ADF is bipolar if every link is attacking or supporting.

An ADF is k-bipolar if for every $a \in A$, there are at most $k$ links $(b, a) \in L$ that are neither attacking nor supporting.

SAT-BASED ALGORITHMS FOR ACCEPTANCE IN ADFs

- Complexity-sensitive algorithms for skeptical and credulous acceptance under preferred semantics
  - Detect whether input ADF is k-bipolar for small enough $k$
  - Utilize SAT solvers as the main search engine
  - System k-ADF implementing the algorithms available at www.cs.helsinki.fi/group/coreo/k++adf

EMPIRICAL EVALUATION

Skeptical acceptance under preferred for k-bipolar ADFs:
- Suitable NP fragment for a SAT solver is $\exists^*_{adm}$
- The resulting admissible interpretation $I$ can be extracted from the truth assignment
- Search for preferred interpretations by iteratively solving $\exists^*_{adm}(D, I)$ and setting $I$ as the corresponding interpretation
- If the query argument is not assigned to true, we can reject it — otherwise, rule out all interpretations $J \leq_i I$ from the search space and continue

REFERENCES