Abstract Dialectical Frameworks
Properties, Complexity, and Implementation

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Outline

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Motivation - Argumentation

- Situated in the intersection between
  - Philosophy,
  - Artificial Intelligence, and
  - several application domains.
- Formal approach to nonmonotonic reasoning with potentially inconsistent knowledge

Concerns of Argumentation Models

- representation of arguments
- representation of relations between arguments
- finding “acceptable” sets of arguments with semantics
  - acceptable set is an extension
  - arguments are defeasible during resolving of extensions

Motivation - ADFs

- Dung’s Argumentation Framework
  - introduced by [Dung, 1995]
  - simple
  - powerful
- Dung’s AF can only model attack relations natively
- More complex relations need auxiliary constructs

- Abstract Dialectical Frameworks
  - introduced by [Brewka and Woltran, 2010]
  - generalization of Dung’s AF
  - total functions specify relation types (acceptance conditions)
  - bipolar Abstract Dialectical Frameworks (BADFs) restrict relation types to be attacking or supporting
  - some semantics are only defined for BADFs
**Main contributions**

- **Alternative representations** for ADFs with useful properties
- **Generalized** and unrestricted stable model semantics for ADFs
- **Implementation** of a software system to compute the extensions under several semantics

**Propositional Formula ADF**

**Definition (pForm-ADF)**
A pForm-ADF is a pair $D = (S, AC)$, where
- $S$ is a set of statements
- $AC = \{AC_s\}_{s \in S}$ is the set of acceptance conditions, where each statement has exactly one associated condition.

An acceptance condition $AC_s$ is a propositional formula $\psi$.

**Definition (model semantics)**
Let $D = (S, AC)$ be a pForm-ADF. $M \subseteq S$ is a model of $D$ if for each $s \in S$, $M \in mod_p(AC_s)$ iff $s \in M$, holds. $model_{pADF}(D)$ is the set of models for the pForm-ADF $D$.

**Example (pForm-ADF)**

$S = \{A, B, C\}$
$AC = \{AC_A, AC_B, AC_C\}$
$AC_A = B$
$AC_B = A$
$AC_C = \neg B$

models = $\{\{A, B\}, \{C\}\}$

**Example (pForm-ADF)**

$S = \{A, B, C, D\}$
$AC = \{AC_A, AC_B, AC_C, AC_D\}$
$AC_A = \top$
$AC_B = \neg A$
$AC_C = A$
$AC_D = (\neg B \land C) \lor (B \land \neg A)$

models = $\{\{A, C, D\}\}$
Stable model semantics

It is based on the transformation from an ADF to a BADF:

- splits acceptance conditions with dependent links
- one AC with supporting character
- one AC with attacking character
- done by additional criteria in the ACs

Example

\[ AC_s = (a \land b) \lor (\neg a \land c) \rightarrow s' \lor s'' \]
\[ AC'_s = ((a \land b) \lor (\neg a \land c)) \land a \]
\[ AC''_s = ((a \land b) \lor (\neg a \land c)) \land \neg a \]

ASP encoding

- Encoding for all semantics [Ellmauthaler and Wallner, 2012]
- Based on pForm-ADF representation
- Utilize different logic programming techniques
  - Guess & Check
  - Saturation
  - Optimization
  - Subset-maximality
  - Iterations
- Implementation uses the Potassco Answer Set Solving Collection [Gebser et al., 2011]

Stable model semantics

- stable semantics for bipolar pForm-ADFs
- generalization lifts the restriction of bipolar ADFs

Definition ((generalized) stable model for pForm-ADFs)

Let \( D = (S, AC) \) be a (bipolar) pForm-ADF. A model \( M \) of \( D \) is a stable model if \( M \) is the least model of the reduced pForm-ADF \( D^M = (S^M, AC^M) \) obtained from \( D \) by

(I) eliminating all nodes not contained in \( M \), s.t. \( S^M = S \cap M \),
(II) for all \( s \in S^M \) substitute in \( AC_s \) all \( a \in \text{atoms}(AC_s) \) with \( \bot \) if \( a \notin S^M \),
(III) for all \( s \in S^M \) substitute in \( AC_s \) all \( a \in \text{att}(AC_s) \) with \( \bot \) if \( a \in \text{att}(AC_s) \),
(IV) for all \( s \in S^M \), if \( \{a_1, \ldots, a_n\} \) is the set of all selected dependent variables in \( AC_s \) and \( M \) then \( AC'^M_s = AC_s \land a_1 \land \ldots \land a_n \)

ASP Encoding

Example (Instance format)

\[ \text{statement}(a). \quad \text{ac}(a,b). \quad \text{supp}(b,a). \]
\[ \text{statement}(b). \quad \text{ac}(b,a). \quad \text{supp}(a,b). \]
\[ \text{statement}(c). \quad \text{ac}(c,\neg \text{neg}(b)). \quad \text{att}(b,c). \]

Example

Model semantics

\[ \text{in}(X) :\neg \text{not out}(X), \text{statement}(X). \]
\[ \text{out}(X) :\neg \text{not in}(X), \text{statement}(X). \]
\[ :\neg \text{in}(X), \text{ac}(X,F), \text{nomodel}(F). \]
\[ :\neg \text{out}(X), \text{ac}(X,F), \text{ismodel}(F). \]
Achievements - Implementation

- **Implementation** for the following semantics
  - conflict-free set
  - model
  - linktype distinction
  - stable model
  - admissible set
  - preferred model
  - well-founded model
- Preliminary **benchmark tests** for BADFs with up to 30 statements and up to 8 links per statement

Achievements - Theoretical

- **Alternative Representations** for ADFs
  - Propositional Formula ADFs
  - Hypergraph ADFs
- **Subclass for BADFs** on pForm-ADFs (monotone pForm-ADF)
- ADF $\rightarrow$ BADF **transformation**
- Unrestricted **generalized stable models semantics**
- **Complexity results** for link-type decision problem for ADFs (coNP-complete)
- **Complexity results** for the generalized stable model semantics ($CA^{monotone} = NP$-complete)
- **Counter-examples** where AF based inter-semantics relations for ADFs do not hold

Related Work

- Many **different approaches** based on Dung’s AF, like
  - Constraint Argumentation Frameworks (CAF) [Coste-Marquis et al., 2006],
  - Extended Argumentation Frameworks (EAF) [Modgil, 2009],
  - Argumentation Frameworks with Recursive Attacks (AFRA) [Baroni et al., 2011],
  - Context Based Argumentation [Brewka and Eiter, 2009], and
  - Managed Multi Context Systems (mMCS) [Brewka et al., 2011].
- **Carneades** [Gordon et al., 2007]
  - is used for law interpretation
  - utilizes another approach
  - multiple stages of computation
  - one fixed stage can be simulated with ADFs [Brewka and Gordon, 2010]

Future Work

- **Further investigations** of inter-semantic relations and possibly revamping some semantics
- **Further investigation** of the correspondence between stable model semantics and the Gelfond-Lifschitz reduct for Logic Programming
- **Simulations** of CAF, EAF, AFRA, ... with ADFs
- **Enhance** mMCS with ADFs
- **Optimization** of the implementation
- **Utilization** of other argumentation systems for AFs (e.g. CEGARTIX, DYNPARTIX)
References I

AFRA: Argumentation framework with recursive attacks.

Argumentation context systems: A framework for abstract group argumentation.

References II

Managed multi-context systems.

Carneades and abstract dialectical frameworks: A reconstruction.

References III

Abstract dialectical frameworks.

Constrained argumentation frameworks.

References IV

On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games.

Abstract Dialectical Frameworks: Properties, Complexity, and Implementation.

Evaluating Abstract Dialectical Frameworks with ASP.
