Abstract Dialectical Frameworks*

Properties, Complexity, and Implementation

Stefan Ellmauthaler

Intelligent Systems
Computer Science Institute
University of Leipzig

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* The presented results are from the same-titled Master's thesis, done at the Vienna University of Technology (Institute of Information Systems, Database and Artificial Intelligence Group)

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

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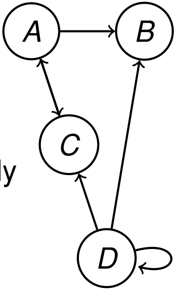
Motivation - ADFs

- **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

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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 ψ.

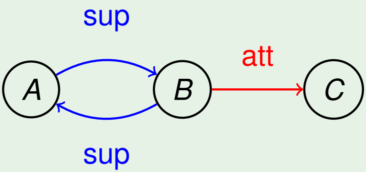
Definition (model semantics)

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.

Propositional Formula ADF

Example (pFormADF)

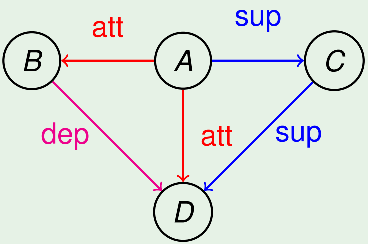
$$S = \{A, B, C\}$$
$$AC = \{AC_A, AC_B, AC_C\}$$
$$AC_A = B$$
$$AC_B = A$$
$$AC_C = \neg B$$
$$\text{models} = \{\{A, B\}, \{C\}\}$$



Propositional Formula ADF

Example (pForm-ADF)

$$S = \{A, B, C, D\}$$
$$AC = \{AC_A, AC_B, AC_C, AC_D\}$$
$$AC_A = \top$$
$$AC_B = \neg A$$
$$AC_C = A$$
$$AC_D = (\neg B \wedge C) \vee (B \wedge \neg A)$$
$$\text{models} = \{\{A, C, D\}\}$$



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

$AC_s = (a \wedge b) \vee (\neg a \wedge c) \mapsto s' \vee s''$
$AC_{s'} = ((a \wedge b) \vee (\neg a \wedge c)) \wedge a$
$AC_{s''} = ((a \wedge b) \vee (\neg a \wedge c)) \wedge \neg a$

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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 $a \in atoms(AC_s)$ with $\bot$ if $a \notin S^M$,

(III) for all $s \in S^M$ substitute in AC_s all $a \in atoms(AC_s)$ with $\bot$ if $a \in att(AC_s)$.

(IV) for all $s \in S^M$, if $\{a_1, ..., a_n\}$ is the set of all selected dependent variables in AC_s and M then $AC_s^M = AC_s \wedge a_1 \wedge ... \wedge a_n$

ASP encoding

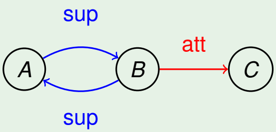
- Encoding for all semantics [Ellmauthaler and Wallner, 2012]
- Based on pForm-ADF representation
- Utilize different logic programming techniques
  - Guess & Check
  - Saturation
  - Optimization
  - Subset-maximality
  - Iterations
- Implementation uses the Potassco Answer Set Solving Collection [Gebser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

ASP Encoding

Example (Instance format)

```
statement(a).    ac(a,b).          supp(b,a).
statement(b).    ac(b,a).          supp(a,b).
statement(c).    ac(c,neg(b)).     att(b,c).
```

Example



Model semantics

```
in(X)  :- not out(X), statement(X).
out(X) :- not in(X), statement(X).

:- in(X), ac(X,F), nomodel(F).
:- out(X), ac(X,F), ismodel(F).
```

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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 ($CA^{monotone} = \text{NP}$-complete)
- **Counter-examples** where AF based inter-semantics relations for ADFs do not hold

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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`)

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