ABSTRACT ARGUMENTATION

Answer Set Programming Encodings for Argumentation Frameworks

Sarah Gaggl

Dresden, 17th September 2015
Motivation

- **Argumentation Frameworks** provide a formalism for a compact representation and evaluation of such scenarios.
- More complex semantics, especially in combination with an increasing amount of data, requires an automated computation of such solutions.
- Most of these problems are intractable, so implementing dedicated systems from the scratch is not the best idea.
- Distinction between direct implementation and reduction-based approach.
- We focus on reductions to propositional logic and Answer-Set Programming (ASP).
Outline

1. Direct- vs. Reduction-based Approach
2. Answer-Set Programming
3. ASP Approach to Abstract Argumentation
4. Evaluation
Laziness and Implementations

Alternative 1: The eastern way

- Implement a separate algorithm for each reasoning task
- Implementation is complicated because most reasoning tasks are inherently intricate (the complexity results given before)
- Implementation, testing, etc. require much effort and time
Laziness and Implementations

Alternative 1: The eastern way

- Implement a separate algorithm for each reasoning task
- Implementation is complicated because most reasoning tasks are inherently intricate (the complexity results given before)
- Implementation, testing, etc. require much effort and time

Alternative: The southern way

- Life is short; try to keep your effort as small as possible
- Let others work for you and use their results and software
- Be smart; apply what you have learned
The rapid implementation approach (RIA)

We know:
- Any complete problem can be translated into any other complete problem of the same complexity class
- Moreover, there exists poly-time translations (reductions)
- Complexity results (incl. completeness) for many reasoning tasks

We used already:
- e.g., the PTIME reduction from a CNF $\varphi$ to an AF $F(\varphi)$ such that $\varphi$ is satisfiable iff $F(\varphi)$ has an admissible set containing $\varphi$
- Can we “reverse” the reduction, i.e., from AFs to formulas?
- YES! Reduce to formalisms for which “good” solvers are available
  - But we have to find the PTIME reduction!
The rapid implementation approach (2)

- Reduce reasoning tasks for AF, e.g., to SAT problems of (Q)BFs
- Reductions are “cheap” (wrt. runtime and implementation effort!)
- Good SAT and QSAT solvers are available; simply use them

Benefits:

- Reductions are much easier to implement than full-fledged algorithms especially for “hard” reasoning tasks
- Basic reductions can be combined and reused
- Different formalisms can be reduced to same target formalism → beneficial for comparative studies
The rapid implementation approach (3)

Target formalisms are:

- The SAT problem for propositional formulas
- The SAT problem for quantified Boolean formulas
- Answer-set programs

Tools are available to solve all these three formalisms

Many developers are happy to give away their tool

They work hard to improve the tool’s performance (for you!)
Required properties of reductions: Faithfulness

- Let $\Pi$ be a decision problem
- $F_\Pi(\cdot)$ a reduction to a target formalism
- $F_\Pi(\cdot)$ has to satisfy the following three conditions:
  1. $F_\Pi(\cdot)$ is **faithful**, i.e., $F_\Pi(K)$ is true iff $K$ is a yes-instance of $\Pi$
  2. For each instance $K$, $F_\Pi(K)$ is poly-time computable wrt size of $K$
  3. Determining the truth of $F_\Pi(K)$ is computationally not harder than deciding $\Pi$

Faithfulness guarantees a correct “simulation” of $K$
Outline

1. Direct- vs. Reduction-based Approach
2. Answer-Set Programming
3. ASP Approach to Abstract Argumentation
4. Evaluation
General Idea of Answer-Set Programming

Fundamental concept:
- **Models** = set of atoms
- **Models**, not proofs, represent solutions!
- Need techniques to compute models (not to compute proofs)
  ➤ Methodology to solve **search problems**

Solving search problems with ASP
- Given a problem $\Pi$ and an instance $K$, reduce it to the problem of computing intended models of a logic program:
  1. Encode $(\Pi, K)$ as a logic program $P$ such that the solutions of $\Pi$ for the instance $K$ are represented by the intended models of $P$
  2. Compute one intended model $M$ (an "answer set") of $P$
  3. Reconstruct a solution for $K$ from $M$
- Variant: Compute all intended models to obtain all solutions
### Efficient solvers available

- **gringo/clasp, clingo** *(University of Potsdam)*
- **dlv** *(TU Wien, University of Calabria)*
- **smodels, GnT** *(Aalto University, Finland)*
- **ASSAT** *(Hong Kong University of Science and Technology)*
Answer-Set Programming Syntax

- We assume a first-order vocabulary $\Sigma$ comprised of nonempty finite sets of constants, variables, and predicate symbols, but no function symbols.
- A term is either a variable or a constant.
- An atom is an expression of form $p(t_1, \ldots, t_n)$, where
  - $p$ is a predicate symbol of arity $n \geq 0$ from $\Sigma$, and
  - $t_1, \ldots, t_n$ are terms.
- A literal is an atom $p$ or a negated atom $\neg p$.
  - $\neg$ is called strong negation, or classical negation.
- A literal is ground if it contains no variable.
Answer-Set Programming Syntax ctd.

ASP Syntax

A rule $r$ is an expression of the form

$$a_1 \lor \cdots \lor a_n \leftarrow b_1, \ldots, b_k, \text{not } b_{k+1}, \ldots, \text{not } b_m,$$

with $n \geq 0$, $m \geq k \geq 0$, $n + m > 0$, where $a_1, \ldots, a_n, b_1, \ldots, b_m$ are atoms, and “not” stands for default negation.

We call

- $H(r) = \{a_1, \ldots, a_n\}$ the head of $r$;
- $B(r) = \{b_1, \ldots, b_k, \text{not } b_{k+1}, \ldots, \text{not } b_m\}$ the body of $r$;
- $B^+(r) = \{b_1, \ldots, b_k\}$ the positive body of $r$;
- $B^-(r) = \{b_{k+1}, \ldots, b_m\}$ the negative body of $r$.
- Intuitive meaning of $r$: if $b_1, \ldots, b_k$ are derivable, but $b_{k+1}, \ldots, b_m$ are not derivable, then one of $a_1, \ldots, a_n$ is asserted.
- A program is a finite set of rules.
A rule $a_1 \lor \cdots \lor a_n \leftarrow b_1, \ldots, b_k, \text{not } b_{k+1}, \ldots, \text{not } b_m$ is

- **a fact** if $m = 0$ and $n \geq 1$
- **a constraint** if $n = 0$ (i.e., the head is empty)
- **basic** if $m = k$ and $n \geq 1$
- **non-disjunctive** if $n = 1$
- **normal** if it is non-disjunctive and contains no strong negation $\neg$
- **Horn** if it is normal and basic
- **ground** if all its literals are ground

A program is basic, normal, etc., if all of its rules are
ASP Semantics

- An interpretation $I$ satisfies a ground rule $r$ iff $H(r) \cap I \neq \emptyset$ whenever
  - $B^+(r) \subseteq I$,
  - $B^-(r) \cap I = \emptyset$.
- $I$ satisfies a ground program $\pi$, if each $r \in \pi$ is satisfied by $I$.
- A non-ground rule $r$ (resp., a program $\pi$) is satisfied by an interpretation $I$ iff $I$ satisfies all groundings of $r$ (resp., $Gr(\pi)$).

Gelfond-Lifschitz reduct

An interpretation $I$ is an answer set of $\pi$ iff it is a subset-minimal set satisfying

$$\pi^I = \{H(r) \leftarrow B^+(r) \mid I \cap B^-(r) = \emptyset, r \in Gr(\pi)\}.$$
Outline

1 Direct- vs. Reduction-based Approach

2 Answer-Set Programming
   Guess and Check Methodology

3 ASP Approach to Abstract Argumentation
   ASP Encodings for Argumentation Semantics
   Saturation Encodings for Preferred
   Optimized Encodings for Preferred
   Metasp Encodings for Preferred

4 Evaluation
Simplest technique: Guess and check

- **Guess**: Generate candidates for answer sets in the first step
- **Check**: Filter the answer sets and delete undesirable ones

**Example (Graph coloring)**

\[
\begin{align*}
\text{node}(a) & . \text{node}(b) . \text{node}(c) . \text{edge}(a, b) . \text{edge}(b, c). \quad \{\text{facts}\} \\
\text{col}(\text{red}, X) \lor \text{col}(\text{green}, X) \lor \text{col}(\text{blue}, X) & \leftarrow \text{node}(X). \quad \{\text{guess}\} \\
\leftarrow & \text{edge}(X, Y), \text{col}(C, X), \text{col}(C, Y). \quad \{\text{check}\}
\end{align*}
\]

**G**: Generate all possible coloring candidates

**C**: Delete all candidates where adjacent nodes have same color
### Corresponding Complexity Results

#### Complexity of Argumentation

<table>
<thead>
<tr>
<th></th>
<th>adm</th>
<th>pref</th>
<th>semi</th>
<th>stage</th>
<th>grd*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cred</td>
<td>NP-c</td>
<td>NP-c</td>
<td>$\Sigma^p_2$-c</td>
<td>$\Sigma^p_2$-c</td>
<td>NP-c</td>
</tr>
<tr>
<td>Skept (trivial)</td>
<td>$\Pi^p_2$-c</td>
<td>$\Pi^p_2$-c</td>
<td>$\Pi^p_2$-c</td>
<td>co-NP-c</td>
<td></td>
</tr>
</tbody>
</table>

[Baroni et al. 11; Dimopoulos & Torres 96; Dunne & Bench-Capon 02; Dvořák & Woltran 10]

#### Recall: Data-Complexity of Datalog

<table>
<thead>
<tr>
<th></th>
<th>normal programs</th>
<th>disjunctive program</th>
<th>optimization programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\models_c$</td>
<td>NP</td>
<td>$\Sigma^p_2$</td>
<td>$\Sigma^p_2$</td>
</tr>
<tr>
<td>$\models_s$</td>
<td>co-NP</td>
<td>$\Pi^p_2$</td>
<td>$\Pi^p_2$</td>
</tr>
</tbody>
</table>

[Dantsin, Eiter, Gottlob, Voronkov 01]
Outline

1. Direct- vs. Reduction-based Approach
2. Answer-Set Programming
3. ASP Approach to Abstract Argumentation
4. Evaluation
Conflict-free Set

Given an AF \((A, R)\).
A set \(S \subseteq A\) is conflict-free in \(F\), if, for each \(a, b \in S\), \((a, b) \notin R\).

Encoding for \(F = (A, R)\)

\[
\hat{F} = \{\text{arg}(a) \mid a \in A\} \cup \{\text{att}(a, b) \mid (a, b) \in R\}
\]

\[
\pi_{cf} = \left\{ \begin{array}{c}
\text{in}(X) \leftarrow \text{not} \text{ out}(X), \text{arg}(X) \\
\text{out}(X) \leftarrow \text{not} \text{ in}(X), \text{arg}(X) \\
\quad \quad \quad \leftarrow \text{in}(X), \text{in}(Y), \text{att}(X, Y) 
\end{array} \right\}
\]

Result: For each AF \(F\), \(cf(F) \equiv \mathcal{AS}(\pi_{cf}(\hat{F}))\)
Outline

1. Direct- vs. Reduction-based Approach

2. Answer-Set Programming
   Guess and Check Methodology

3. ASP Approach to Abstract Argumentation
   ASP Encodings for Argumentation Semantics
   Saturation Encodings for Preferred
   Optimized Encodings for Preferred
   Metasp Encodings for Preferred

4. Evaluation
Admissible Sets

Given an AF \( F = (A, R) \). A set \( S \subseteq A \) is admissible in \( F \), if

- \( S \) is conflict-free in \( F \)
- each \( a \in S \) is defended by \( S \) in \( F \)
- \( a \in A \) is defended by \( S \) in \( F \), if for each \( b \in A \) with \( (b, a) \in R \), there exists a \( c \in S \), such that \( (c, b) \in R \).

Encoding

\[
\pi_{adm} = \pi_{cf} \cup \left\{ \begin{array}{c}
\text{defeated}(X) \leftarrow \text{in}(Y), \text{att}(Y, X) \\
\text{in}(X), \text{att}(Y, X), \text{not defeated}(Y)
\end{array} \right\}
\]

Result: For each AF \( F \), \( adm(F) \equiv AS(\pi_{adm}(\hat{F})) \)
Stable Extensions

Given an AF $F = (A, R)$. A set $S \subseteq A$ is a stable extension of $F$, if

- $S$ is conflict-free in $F$
- for each $a \in A \setminus S$, there exists a $b \in S$, such that $(b, a) \in R$

Encoding

$$\pi_{stable} = \pi_{cf} \cup \left\{ \begin{array}{l} \text{defeated}(X) \leftarrow \text{in}(Y), \text{att}(Y, X) \\ \text{out}(X), \text{not} \text{ defeated}(X) \end{array} \right\}$$

Result: For each AF $F$, $stable(F) \equiv \mathcal{AS}(\pi_{stable}(F))$
Grounded Extension

Given an AF $F = (A, R)$. The characteristic function $\mathcal{F}_F : 2^A \rightarrow 2^A$ of $F$ is defined as

$$\mathcal{F}_F(E) = \{ x \in A \mid x \text{ is defended by } E \}.$$ 

The least fixed point of $\mathcal{F}_F$ is the grounded extension.

Order over domain

$$\pi < = \begin{cases} 
\text{lt}(X, Y) & \leftarrow \text{arg}(X), \text{arg}(Y), X < Y \\
n\text{succ}(X, Z) & \leftarrow \text{lt}(X, Y), \text{lt}(Y, Z) \\
n\text{succ}(X, Y) & \leftarrow \text{lt}(X, Y), \text{not } n\text{succ}(X, Y) \\
n\text{inf}(X) & \leftarrow \text{lt}(Y, X) \\
n\text{sup}(X) & \leftarrow \text{lt}(X, Y) \\
n\text{inf}(X) & \leftarrow \text{not } n\text{inf}(X), \text{arg}(X) \\
n\text{sup}(X) & \leftarrow \text{not } n\text{sup}(X), \text{arg}(X) 
\end{cases}$$
Grounded Extension

Given an AF $F = (A, R)$. The characteristic function $F_F : 2^A \rightarrow 2^A$ of $F$ is defined as

$$F_F(E) = \{x \in A \mid x \text{ is defended by } E\}.$$ 

The least fixed point of $F_F$ is the grounded extension.

Encodings Grounded Extension

$$\pi_{ground} = \begin{cases} 
\text{def}_\text{upto}(X, Y) & \leftarrow \text{inf}(Y), \text{arg}(X), \text{not att}(Y, X) \\
\text{def}_\text{upto}(X, Y) & \leftarrow \text{inf}(Y), \text{in}(Z), \text{att}(Z, Y), \text{att}(Y, X) \\
\text{def}_\text{upto}(X, Y) & \leftarrow \text{succ}(Z, Y), \text{def}_\text{upto}(X, Z), \text{not att}(Y, X) \\
\text{def}_\text{upto}(X, Y) & \leftarrow \text{succ}(Z, Y), \text{def}_\text{upto}(X, Z), \text{in}(V), \text{att}(V, Y), \text{att}(Y, X) \\
\text{defended}(X) & \leftarrow \text{sup}(Y), \text{def}_\text{upto}(X, Y) \\
\text{in}(X) & \leftarrow \text{defended}(X) 
\end{cases}$$

Result: For each AF $F$, $\text{ground}(F) \equiv \mathcal{AS}(\pi_{\text{ground}}(\hat{F}))$
Preferred Extensions

Given an AF \( F = (A, R) \). A set \( S \subseteq A \) is a preferred extension of \( F \), if

- \( S \) is admissible in \( F \)
- for each \( T \subseteq A \) admissible in \( F \), \( S \not\subset T \)

Encoding

- Preferred semantics needs subset maximization task.
- Can be encoded in standard ASP but requires insight and expertise.
Outline

1. Direct- vs. Reduction-based Approach

2. Answer-Set Programming
   - Guess and Check Methodology

3. ASP Approach to Abstract Argumentation
   - ASP Encodings for Argumentation Semantics
   - Saturation Encodings for Preferred
   - Optimized Encodings for Preferred
   - Metasp Encodings for Preferred

4. Evaluation
Saturation Encodings

**Preferred Extension**

Given an AF \((A, R)\). A set \(S \subseteq A\) is preferred in \(F\), if \(S\) is admissible in \(F\) and for each \(T \subseteq A\) admissible in \(T\), \(S \not\subset T\).

**Encoding**

\[
\pi_{\text{saturate}} = \begin{cases} 
\text{inN}(X) \lor \text{outN}(X) & \leftarrow \text{out}(X); \\
\text{inN}(X) & \leftarrow \text{in}(X) \\
\text{spoil} & \leftarrow \text{eq} \\
\text{spoil} & \leftarrow \text{inN}(X), \text{inN}(Y), \text{att}(X, Y) \\
\text{spoil} & \leftarrow \text{inN}(X), \text{outN}(Y), \text{att}(Y, X), \text{undefeated}(Y) \\
\text{inN}(X) & \leftarrow \text{spoil}, \text{arg}(X) \\
\text{outN}(X) & \leftarrow \text{spoil}, \text{arg}(X) \\
& \leftarrow \text{not spoil} 
\end{cases}
\]

\[
\pi_{\text{pref}} = \pi_{\text{adm}} \cup \pi_{\text{helpers}} \cup \pi_{\text{saturate}}
\]

**Result:** For each AF \(F\), \(\text{pref}(F) \equiv \text{AS}(\pi_{\text{pref}}(\hat{F}))\)
Check if second guess is equal to the first one.

<table>
<thead>
<tr>
<th>Equation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>equpto(Y)</code></td>
<td><code>inf(Y)</code>, <code>in(Y)</code>, <code>inN(Y)</code></td>
</tr>
<tr>
<td><code>equpto(Y)</code></td>
<td><code>inf(Y)</code>, <code>out(Y)</code>, <code>outN(Y)</code></td>
</tr>
<tr>
<td><code>equpto(Y)</code></td>
<td><code>succ(Z, Y)</code>, <code>in(Y)</code>, <code>inN(Y)</code>, <code>equpto(Z)</code></td>
</tr>
<tr>
<td><code>equpto(Y)</code></td>
<td><code>succ(Z, Y)</code>, <code>out(Y)</code>, <code>outN(Y)</code>, <code>equpto(Z)</code></td>
</tr>
<tr>
<td><code>eq</code></td>
<td><code>sup(Y)</code>, <code>equpto(Y)</code></td>
</tr>
</tbody>
</table>
Outline

1. Direct- vs. Reduction-based Approach

2. Answer-Set Programming
   Guess and Check Methodology

3. ASP Approach to Abstract Argumentation
   ASP Encodings for Argumentation Semantics
   Saturation Encodings for Preferred
   Optimized Encodings for Preferred
   Metasp Encodings for Preferred

4. Evaluation
Proposition 1

Let $F = (A, R)$ be an AF and $S \subseteq A$ be admissible in $F$. Then, $S \in \text{pref}(F)$ iff, for each $E \in \text{adm}(F)$ such that $E \not\subseteq S$, $E \cup S \not\in \text{cf}(F)$.

Example

- $\text{adm}(F) = \{\emptyset, \{a\}, \{c\}, \{a, c\}, \{a, d\}, \{c, f\}, \{a, c, f\}, \{a, d, f\}\}$, and
- $\text{pref}(F) = \{\{a, c, f\}, \{a, d, f\}\}$
Proposition 1

Let $F = (A, R)$ be an AF and $S \subseteq A$ be admissible in $F$. Then, $S \in \text{pref}(F)$ iff, for each $E \in \text{adm}(F)$ such that $E \not\subseteq S$, $E \cup S \not\in \text{cf}(F)$.

$$\pi_{\text{satpref}^2} = \left\{ \begin{array}{ll}
\text{nontrivial} & \leftarrow \text{out}(X) \\
\text{witness}(X) : \text{out}(X) & \leftarrow \text{nontrivial} \\
\text{spoil} | \text{witness}(Z) : \text{att}(Z, Y) & \leftarrow \text{witness}(X), \text{att}(Y, X) \\
\text{spoil} & \leftarrow \text{att}(X, Y), \text{witness}(X), \text{witness}(Y) \\
\text{spoil} & \leftarrow \text{in}(X), \text{witness}(Y), \text{att}(X, Y) \\
\text{witness}(X) & \leftarrow \text{spoil}, \text{arg}(X) \\
& \leftarrow \text{not spoil, nontrivial}
\end{array} \right\}$$

$$\pi_{\text{pref}^2} = \pi_{\text{adm}} \cup \pi_{\text{satpref}^2}$$

Result: For each AF $F$, $\text{pref}(F) \equiv \mathcal{AS}(\pi_{\text{pref}^2}(\hat{F}))$
Functionality of New Encodings

Example

nontrivial ← out(X)
witness(X) : out(X) ← nontrivial

\[
\begin{array}{cccc}
    a & b & c & d & e & f \\
    \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \\
    a & b & c & d & e & f \\
\end{array}
\]
Functionality of New Encodings

Example

\[
\begin{align*}
\text{nontrivial} & \quad \leftarrow \quad \text{out}(X) \\
\text{witness}(X) : \text{out}(X) & \quad \leftarrow \quad \text{nontrivial}
\end{align*}
\]
Functionality of New Encodings

nontrivial ← out(X)
witness(X) : out(X) ← nontrivial
spoil|witness(Z) : att(Z, Y) ← witness(X), att(Y, X)

Example
Functionality of New Encodings

nontrivial ← out(X)
witness(X) : out(X) ← nontrivial
spoil | witness(Z) : att(Z, Y) ← witness(X), att(Y, X)
spoil ← att(X, Y), witness(X), witness(Y)

Example
Functionality of New Encodings

nontrivial \rightarrow out(X)

witness(X) : out(X) \rightarrow nontrivial

spoil|witness(Z) : att(Z, Y) \rightarrow witness(X), att(Y, X)

spoil \rightarrow att(X, Y), witness(X), witness(Y)

spoil \rightarrow in(X), witness(Y), att(X, Y)

Example
nontrivial → out(X)

witness(X) : out(X) ← nontrivial

spoil|witness(Z) : att(Z, Y) ← witness(X), att(Y, X)

spoil ← att(X, Y), witness(X), witness(Y)

spoil ← in(X), witness(Y), att(X, Y)

witness(X) ← spoil, arg(X)

← not spoil, nontrivial

Example
Proposition 1

Let $F = (A, R)$ be an AF and $S \subseteq A$ be admissible in $F$. Then, $S \in \text{pref}(F)$ iff, for each $E \in \text{adm}(F)$ such that $E \not\subseteq S$, $E \cup S \not\in \text{cf}(F)$.

Example
Positive Example

Example

\[
\begin{align*}
\text{nontrivial} & \leftarrow \text{out}(X) \\
\text{witness}(X) : \text{out}(X) & \leftarrow \text{nontrivial}
\end{align*}
\]
Positive Example

\[
\text{nontrivial} \quad \leftarrow \quad \text{out}(X) \\
\text{witness}(X) : \text{out}(X) \quad \leftarrow \quad \text{nontrivial}
\]

Example

TU Dresden, 17th September 2015
Abstract Argumentation
Positive Example

\[
\begin{align*}
\text{nontrivial} & \quad \leftarrow \quad \text{out}(X) \\
\text{witness}(X) : \text{out}(X) & \quad \leftarrow \quad \text{nontrivial} \\
\text{spoil} | \text{witness}(Z) : \text{att}(Z, Y) & \quad \leftarrow \quad \text{witness}(X), \text{att}(Y, X)
\end{align*}
\]

Example
Positive Example

\[
\begin{align*}
\text{nontrivial} & \leftarrow \text{out}(X) \\
\text{witness}(X) : \text{out}(X) & \leftarrow \text{nontrivial} \\
\text{spoil} \| \text{witness}(Z) : \text{att}(Z, Y) & \leftarrow \text{witness}(X), \text{att}(Y, X) \\
\text{spoil} & \leftarrow \text{att}(X, Y), \text{witness}(X), \text{witness}(Y)
\end{align*}
\]

Example
Positive Example

nontrivial

witness(X) : out(X) ← nontrivial

spoil|witness(Z) : att(Z, Y) ← witness(X), att(Y, X)

spoil ← att(X, Y), witness(X), witness(Y)

spoil ← in(X), witness(Y), att(X, Y)

Example
Positive Example

nontrivial ← out(X)

witness(X) : out(X) ← nontrivial

spoil|witness(Z) : att(Z, Y) ← witness(X), att(Y, X)

spoil ← att(X, Y), witness(X), witness(Y)

spoil ← in(X), witness(Y), att(X, Y)

witness(X) ← spoil, arg(X)

← not spoil, nontrivial

Example

TU Dresden, 17th September 2015

Abstract Argumentation

slide 47 of 59
Outline

1 Direct- vs. Reduction-based Approach

2 Answer-Set Programming
   Guess and Check Methodology

3 ASP Approach to Abstract Argumentation
   ASP Encodings for Argumentation Semantics
   Saturation Encodings for Preferred
   Optimized Encodings for Preferred
   Metasp Encodings for Preferred

4 Evaluation
Metasp [Gebser et al., 2011]

- Recently proposed metasp front-end for the gringo/claspD package.
- The problem encoding is first grounded with the reify option, which outputs ground program as facts.
- Next the meta encodings mirror answer-set generation.
- Meta encodings also implement subset minimization for the \#minimize-statement.
Metasp Encoding

- Together with the module admissibility, the remaining encoding for subset maximization reduces to

\[ \pi_{adm} \cup \{ \#\text{minimize}[\text{out}(X)] \} \].

- This relocates the optimization encoding to the meta-encodings.
- Enables simple encodings and performs surprisingly well.
Outline

1. Direct- vs. Reduction-based Approach
2. Answer-Set Programming
3. ASP Approach to Abstract Argumentation
4. Evaluation
Evaluation

- New encodings were tested against CSP system ConArg, original encodings, and Metasp encodings
- Collection of 4972 frameworks (structured and random)
- Reasoning task: enumeration of all extensions
- 10 min timeout

**Bull HPC-Cluster (Taurus)**

- Intel Xeon CPU (E5-2670) with 2.60GHz
- 6.5 GB Ram, 600 seconds
- from 16 cores we used every 4th

We thank the Center for Information Services and High Performance Computing (ZIH) at TU Dresden for generous allocations of computer time.

TU Dresden, 17th September 2015  Abstract Argumentation  slide 52 of 59
## Results

<table>
<thead>
<tr>
<th>PR</th>
<th>usc</th>
<th>solved</th>
<th>med</th>
</tr>
</thead>
<tbody>
<tr>
<td>ConArg</td>
<td>60</td>
<td>2814</td>
<td>43.65</td>
</tr>
<tr>
<td>Original</td>
<td>-</td>
<td>3425</td>
<td>180.36</td>
</tr>
<tr>
<td>Meta</td>
<td>1</td>
<td>4626</td>
<td>20.83</td>
</tr>
<tr>
<td>New</td>
<td>101</td>
<td>4765</td>
<td>5.77</td>
</tr>
</tbody>
</table>

Figure: Runtimes for preferred (PR) semantics.
ICCMA 2015 Results

New encodings for preferred semantics reached in two categories of the first International Competition on Computational Models of Argument the 4th rank.

<table>
<thead>
<tr>
<th>SE-PR</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cegartix</td>
</tr>
<tr>
<td>2.</td>
<td>ArgSemSAT</td>
</tr>
<tr>
<td>3.</td>
<td>LabSATSolver</td>
</tr>
<tr>
<td>4.</td>
<td>ASPARTIX-V</td>
</tr>
<tr>
<td>5.</td>
<td>CoQuiAAS</td>
</tr>
<tr>
<td>6.</td>
<td>ASGL</td>
</tr>
<tr>
<td>7.</td>
<td>ConArg</td>
</tr>
<tr>
<td>8.</td>
<td>ASPARTIX-D</td>
</tr>
<tr>
<td>9.</td>
<td>ArgTools</td>
</tr>
<tr>
<td>10.</td>
<td>GRIS</td>
</tr>
<tr>
<td>11.</td>
<td>DIAMOND</td>
</tr>
<tr>
<td>12.</td>
<td>Dungell</td>
</tr>
<tr>
<td>13.</td>
<td>Carneades</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EE-PR</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cegartix</td>
</tr>
<tr>
<td>2.</td>
<td>ArgSemSAT</td>
</tr>
<tr>
<td>3.</td>
<td>CoQuiAAS</td>
</tr>
<tr>
<td>4.</td>
<td>ASPARTIX-V</td>
</tr>
<tr>
<td>5.</td>
<td>LabSATSolver</td>
</tr>
<tr>
<td>6.</td>
<td>prefMaxSAT</td>
</tr>
<tr>
<td>7.</td>
<td>ASGL</td>
</tr>
<tr>
<td>8.</td>
<td>ASPARTIX-D</td>
</tr>
<tr>
<td>9.</td>
<td>ConArg</td>
</tr>
<tr>
<td>10.</td>
<td>ArgTools</td>
</tr>
<tr>
<td>11.</td>
<td>ZJU-ARG</td>
</tr>
<tr>
<td>12.</td>
<td>GRIS</td>
</tr>
<tr>
<td>13.</td>
<td>DIAMOND</td>
</tr>
<tr>
<td>14.</td>
<td>Dungell</td>
</tr>
<tr>
<td>15.</td>
<td>Carneades</td>
</tr>
</tbody>
</table>
ASPARTIX (ASP Argumentation Reasoning Tool)

- Encodings are used together with an ASP-solver, like clasp or dvl
- Implements all prominent argumentation semantics
- Even for extended frameworks like PAFs, VAFs, BAPs, ...
- Easy to use
- Web-interface available:
  http://rull.dbai.tuwien.ac.at:8080/ASPARTIX/

Info and encodings are available under:
http://www.dbai.tuwien.ac.at/research/project/argumentation/
Conclusion and Future Work

- With new characterization we avoided complicated looping techniques
- New encodings clearly outperform original and metasp encodings
- New encodings scored good results at ICCMA 2015
- Same results also for stage and semi-stable semantics (in the paper)
- Encodings and benchmarks are available at http://dbai.tuwien.ac.at/research/project/argumentation/systempage/#conditional

Future Work

Optimize ASP encodings for ideal and eager semantics
Related work

Other encodings

- by [Nieves et al., 2008] and follow-up papers; mostly a new program has to be constructed for each instance
- DIAMOND (DIAlektical MOdels eNcoDing) is a software system to compute different ADF models (see https://isysrv.informatik.uni-leipzig.de/diamond)
- ConArg is a tool, based on Constraint Programming [Bistarelli and Santini, 2012] (see http://www.dmi.unipg.it/conarg/)

Other systems

- Collection: http://wyner.info/LanguageLogicLawSoftware/index.php/software/
- System Demos at COMMA 2014: http://comma2014.arg.dundee.ac.uk/demoprogram
Philippe Besnard and Sylvie Doutre.
Checking the acceptability of a set of arguments.

S. Bistarelli, F. Santini, Conarg: a tool to solve (weighted) abstract argumentation frameworks with (soft) constraints, CoRR abs/1212.2857.

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

Making use of advances in answer-set programming for abstract argumentation systems.

Uwe Egly and Stefan Woltran.
Reasoning in argumentation frameworks using quantified boolean formulas.

Uwe Egly, Sarah Gaggl, and Stefan Woltran.
Answer-set programming encodings for argumentation frameworks.

Sarah Alice Gaggl, Norbert Manthey, Alessandro Ronca, Johannes Peter Wallner, and Stefan Woltran
Improved answer-set programming encodings for abstract argumentation.

Complex optimization in answer set programming.