FAKULTÄT FÜR !NFORMATIK

Faculty of Informatics

dbai

Database and Artificial Intelligence Group

Implementation of Argumentation

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Material

- Final version of slides:

  `http://www.dbai.tuwien.ac.at/research/slides/acai.pdf`

- Survey on implementation of abstract argumentation:

  `http://www.dbai.tuwien.ac.at/research/report/dbai-tr-2013-82.pdf`

Aim of this Talk

- Overview of (our) systems
- Focus on approaches based on Answer-Set Programming
- In (some) detail:
  - ASPARTIX
  - VISPARTIX
  - dynPARTIX
- After the talk: Demo-Session

Argumentation — The Big Picture

Steps

Starting point: knowledge-base

1) Form arguments
2) Identify conflicts
3) Abstract from internal structure
4) Resolve conflicts
5) Obtain conclusions

Argumentation — The Big Picture

Steps

Starting point: knowledge-base

1) Form arguments
2) Identify conflicts
3) Abstract from internal structure
4) Resolve conflicts
5) Obtain conclusions

- Input: A knowledge-base $\mathcal{K}$ and set $\mathcal{C}$ of claims

Example

$$\mathcal{K} = \{a, a \rightarrow b, \neg b\}$$
$$\mathcal{C} = \mathcal{K} \cup \{\neg a, b, a \wedge \neg b\}$$

Argumentation — The Big Picture

Steps

Starting point: knowledge-base

1) **Form arguments**
2) Identify conflicts
3) Abstract from internal structure
4) Resolve conflicts
5) Obtain conclusions

- Form arguments $A = (S, C)$ consisting of support $S \subseteq \mathcal{K}$ and claim $C \in \mathcal{C}$

Example

$$\mathcal{K} = \{a, a \rightarrow b, \neg b\}$$
$$\mathcal{C} = \mathcal{K} \cup \{\neg a, b, a \wedge \neg b\}$$

$(\{a\}, a)$

$(\{\neg b, a \rightarrow b\}, \neg a)$

$(\{a, a \rightarrow b\}, b)$ $(\{a, \neg b\}, a \wedge \neg b)$

$(\{\neg b\}, \neg b)$ $(\{a \rightarrow b\}, a \rightarrow b)$

Argumentation — The Big Picture

Steps

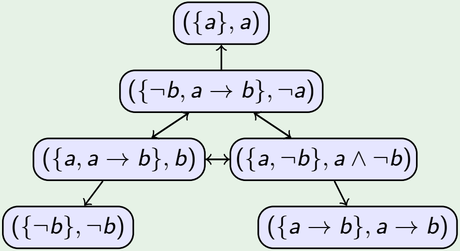
Starting point: knowledge-base

1) Form arguments
2) **Identify conflicts**
3) Abstract from internal structure
4) Resolve conflicts
5) Obtain conclusions

- Identify conflicts between arguments $A = (S, C)$ and $A' = (S', C')$

Example

$$\mathcal{K} = \{a, a \to b, \neg b\}$$
$$\mathcal{C} = \mathcal{K} \cup \{\neg a, b, a \wedge \neg b\}$$



Argumentation — The Big Picture

Steps

Starting point: knowledge-base

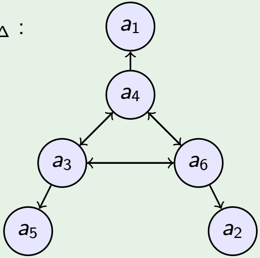
1) Form arguments
2) Identify conflicts
3) **Abstract from internal structure**
4) Resolve conflicts
5) Obtain conclusions

- Obtain an Abstract Argumentation Framework F_Δ

Example

$$\mathcal{K} = \{a, a \to b, \neg b\}$$
$$\mathcal{C} = \mathcal{K} \cup \{\neg a, b, a \wedge \neg b\}$$

F_Δ :



Argumentation — The Big Picture

Steps

Starting point: knowledge-base

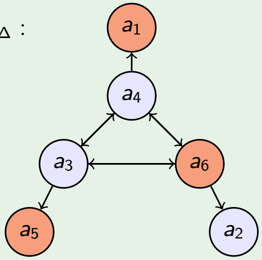
1) Form arguments
2) Identify conflicts
3) Abstract from internal structure
4) **Resolve conflicts**
5) Obtain conclusions

- Based on a semantics, select arguments that 'can stand together'

Example

$$\mathcal{K} = \{a, a \to b, \neg b\}$$
$$\mathcal{C} = \mathcal{K} \cup \{\neg a, b, a \wedge \neg b\}$$

F_Δ :



$$stb(F_\Delta) = \{\{a_1, a_5, a_6\}, \{a_1, a_2, a_3\}, \{a_2, a_4, a_5\}\}$$

Argumentation — The Big Picture

Steps

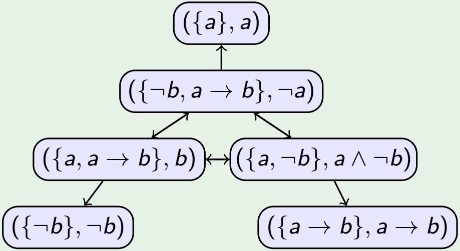
Starting point: knowledge-base

1) Form arguments
2) Identify conflicts
3) Abstract from internal structure
4) Resolve conflicts
5) **Obtain conclusions**

- Derive deductive closure of contents from accepted arguments

Example

$$\mathcal{K} = \{a, a \to b, \neg b\}$$
$$\mathcal{C} = \mathcal{K} \cup \{\neg a, b, a \wedge \neg b\}$$



$$Cn_{stb}(F_\Delta) = Cn((a \wedge \neg b) \vee (a \wedge b \wedge a \to b) \vee (a \to b \wedge \neg a \wedge \neg b))$$

Important Observations

- Each of the steps computationally involved
  - design of systems from scratch vs. reduction-based method
  - in both cases: complexity adequacy important
- Two approaches for the whole process:
  - modular solutions
  - full systems

Landscape of Systems

	direct	reduction
abstract arg.	COMPARG, dynPARTIX	CONARG, **ASPARTIX**
full	TOAST, CARNEADES	**VISPARTIX**+ASPARTIX

Some other approaches follow a "mixed" approach:

- CEGARTIX
- **D-FLAT/dynPARTIX**

Answer-Set Programming

ASP Syntax

A rule r is an expression of the form

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

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;
- $B(r) = \{b_1, \ldots, b_k, \ \mathit{not}\, b_{k+1}, \ldots, \ \mathit{not}\, b_m\}$ 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.

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 π, if each $r \in \pi$ is satisfied by I.
- A non-ground rule r (resp., a program π) is satisfied by an interpretation I iff I satisfies all groundings of r (resp., $Gr(\pi)$).

Gelfond-Lifschitz reduct

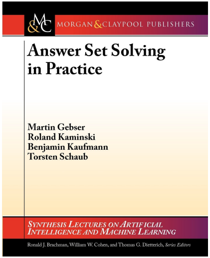
An interpretation I is an answer set of π iff it is a subset-minimal set satisfying

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

ASP - Some Remarks

- Rich rule-based language
- Well suited for combinatorial problems in NP – Guess & Check approach:
  - guess a candidate solution non-deterministically
  - check if the candidate is indeed a solution
- Even problems with high complexity (2nd level in polynomial hierarchy) can be expressed
- Advanced systems available

ASP Information + Systems



- Potassco: `http://potassco.sourceforge.net/`
- DLV: `http://www.dlvsystem.com/`

ASPARTIX Overview

Input

AF

arg(a). att(a,b).
arg(b). att(c,b).
arg(c). att(c,d).
...

Semantics

Preferred
Semi-Stable
Stage
...

ASP-Solver

gringo/clasp(D)
DLV

Answer Sets

$\{\text{in}(a), \text{in}(c), \ldots\}$,
$\{\text{in}(a), \text{in}(d), \ldots\}$

ASPARTIX Overview

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gringo/clasp(D)
DLV

Answer Sets

$\{\mathrm{in}(a), \mathrm{in}(c), \ldots\}$,
$\{\mathrm{in}(a), \mathrm{in}(d), \ldots\}$

ASP Encodings

Argumentation Framework Data Base

$$\mathrm{arg(a).\ arg(b).\ arg(c).\ att(a,c).\ att(b,c).}$$

Conflict-Free Sets

$$\begin{aligned} \mathrm{in(X)} &\leftarrow \mathrm{arg(X)}, \textit{not}\ \mathrm{out(X)}. \\ \mathrm{out(X)} &\leftarrow \mathrm{arg(X)}, \textit{not}\ \mathrm{in(X)}. \\ &\leftarrow \mathrm{in(X), in(Y), att(X,Y)}. \end{aligned}$$

Stable Extensions

$$\begin{aligned} \mathrm{defeated(X)} &\leftarrow \mathrm{in(Y), att(Y,X)}. \\ &\leftarrow \mathrm{out(X)}, \textit{not}\ \mathrm{defeated(X)}. \end{aligned}$$

ASP Encodings

Argumentation Framework Data Base

$$\mathrm{arg}(\mathrm{a}).\ \mathrm{arg}(\mathrm{b}).\ \mathrm{arg}(\mathrm{c}).\ \mathrm{att}(\mathrm{a},\mathrm{c}).\ \mathrm{att}(\mathrm{b},\mathrm{c}).$$

Conflict-Free Sets

$$\begin{array}{rcl} \mathrm{in}(X) & \leftarrow & \mathrm{arg}(X), \textit{not}\ \mathrm{out}(X). \\ \mathrm{out}(X) & \leftarrow & \mathrm{arg}(X), \textit{not}\ \mathrm{in}(X). \\ & \leftarrow & \mathrm{in}(X), \mathrm{in}(Y), \mathrm{att}(X,Y). \end{array}$$

Stable Extensions

$$\begin{array}{rcl} \mathrm{defeated}(X) & \leftarrow & \mathrm{in}(Y), \mathrm{att}(Y,X). \\ & \leftarrow & \mathrm{out}(X), \textit{not}\ \mathrm{defeated}(X). \end{array}$$

ASP Encodings

Argumentation Framework Data Base

$$\mathrm{arg}(\mathrm{a}).\ \mathrm{arg}(\mathrm{b}).\ \mathrm{arg}(\mathrm{c}).\ \mathrm{att}(\mathrm{a},\mathrm{c}).\ \mathrm{att}(\mathrm{b},\mathrm{c}).$$

Conflict-Free Sets

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\mathrm{in}(\mathrm{X}) & \leftarrow & \mathrm{arg}(\mathrm{X}), \textit{not}\ \mathrm{out}(\mathrm{X}). \\
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 & \leftarrow & \mathrm{in}(\mathrm{X}), \mathrm{in}(\mathrm{Y}), \mathrm{att}(\mathrm{X},\mathrm{Y}).
\end{array}$$

Stable Extensions

$$\begin{array}{rcl}
\mathrm{defeated}(\mathrm{X}) & \leftarrow & \mathrm{in}(\mathrm{Y}), \mathrm{att}(\mathrm{Y},\mathrm{X}). \\
 & \leftarrow & \mathrm{out}(\mathrm{X}), \textit{not}\ \mathrm{defeated}(\mathrm{X}).
\end{array}$$

ASP Encodings

Argumentation Framework Data Base

$$\mathrm{arg}(a).\ \mathrm{arg}(b).\ \mathrm{arg}(c).\ \mathrm{att}(a,c).\ \mathrm{att}(b,c).$$

Admissible Sets

$$\begin{aligned}
\mathrm{in}(X) &\leftarrow \mathrm{arg}(X), \textit{not}\ \mathrm{out}(X).\\
\mathrm{out}(X) &\leftarrow \mathrm{arg}(X), \textit{not}\ \mathrm{in}(X).\\
&\leftarrow \mathrm{in}(X), \mathrm{in}(Y), \mathrm{att}(X,Y).\\
\mathrm{defeated}(X) &\leftarrow \mathrm{in}(Y), \mathrm{att}(Y,X).\\
\mathrm{undefended}(X) &\leftarrow \mathrm{att}(Y,X), \textit{not}\ \mathrm{defeated}(Y).\\
&\leftarrow \mathrm{in}(X), \mathrm{undefended}(X).
\end{aligned}$$

Complete Sets

$$\leftarrow \mathrm{out}(X), \textit{not}\ \mathrm{undefended}(X).$$

ASP Encodings

Argumentation Framework Data Base

$$\mathrm{arg(a).\ arg(b).\ arg(c).\ att(a,c).\ att(b,c).}$$

Admissible Sets

$$
\begin{array}{rcl}
\mathrm{in(X)} & \leftarrow & \mathrm{arg(X)}, \textit{not}\ \mathrm{out(X)}. \\
\mathrm{out(X)} & \leftarrow & \mathrm{arg(X)}, \textit{not}\ \mathrm{in(X)}. \\
 & \leftarrow & \mathrm{in(X), in(Y), att(X,Y)}. \\
\mathrm{defeated(X)} & \leftarrow & \mathrm{in(Y), att(Y,X)}. \\
\mathrm{undefended(X)} & \leftarrow & \mathrm{att(Y,X)}, \textit{not}\ \mathrm{defeated(Y)}. \\
 & \leftarrow & \mathrm{in(X), undefended(X)}.
\end{array}
$$

Complete Sets

$$\leftarrow \quad \mathrm{out(X)}, \textit{not}\ \mathrm{undefended(X)}.$$

ASP Encodings

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

Involved Encodings

Preferred Extensions (partial) module

$$
\begin{array}{rcl}
\mathrm{inN}(X) \vee \mathrm{outN}(X) & \leftarrow & \mathrm{out}(X). \\
\mathrm{inN}(X) & \leftarrow & \mathrm{in}(X). \\
\mathrm{undefeated\_upto}(X, Y) & \leftarrow & \mathrm{inf}(Y), \mathrm{outN}(X), \mathrm{outN}(Y). \\
\mathrm{undefeated\_upto}(X, Y) & \leftarrow & \mathrm{inf}(Y), \mathrm{outN}(X), \mathit{not}\ \mathrm{att}(Y, X). \\
\mathrm{undefeated\_upto}(X, Y) & \leftarrow & \mathrm{succ}(Z, Y), \mathrm{undefeated\_upto}(X, Z), \mathrm{outN}(Y). \\
\mathrm{undefeated\_upto}(X, Y) & \leftarrow & \mathrm{succ}(Z, Y), \mathrm{undefeated\_upto}(X, Z), \mathit{not}\ \mathrm{att}(Y, X). \\
\mathrm{undefeated}(X) & \leftarrow & \mathrm{sup}(Y), \mathrm{undefeated\_upto}(X, Y). \\
\mathrm{eq\_upto}(X) & \leftarrow & \mathrm{inf}(X), \mathrm{in}(X), \mathrm{inN}(X). \\
\mathrm{eq\_upto}(X) & \leftarrow & \mathrm{inf}(X), \mathrm{out}(X), \mathrm{outN}(X). \\
\mathrm{eq\_upto}(X) & \leftarrow & \mathrm{succ}(Y, X), \mathrm{in}(X), \mathrm{inN}(X), \mathrm{eq\_upto}(Y). \\
\mathrm{eq\_upto}(X) & \leftarrow & \mathrm{succ}(Y, X), \mathrm{out}(X), \mathrm{outN}(X), \mathrm{eq\_upto}(Y). \\
\mathrm{eq} & \leftarrow & \mathrm{sup}(X), \mathrm{eq\_upto}(X). \\
\mathrm{fail} & \leftarrow & \mathrm{eq}. \\
\mathrm{fail} & \leftarrow & \mathrm{inN}(X), \mathrm{inN}(Y), \mathrm{att}(X, Y). \\
\mathrm{fail} & \leftarrow & \mathrm{inN}(X), \mathrm{outN}(Y), \mathrm{att}(Y, X), \mathrm{undefeated}(Y). \\
\mathrm{inN}(X) & \leftarrow & \mathrm{fail}, \mathrm{arg}(X). \\
\mathrm{outN}(X) & \leftarrow & \mathrm{fail}, \mathrm{arg}(X). \\
 & \leftarrow & \mathit{not}\ \mathrm{fail}.
\end{array}
$$

Metasp

- Recently proposed `metasp` offers meta-programming 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, but may implement different behavior

- Meta encodings also implement subset minimization for the #minimize-statement.

Metasp Encoding

- Together with the modules for conflict-free sets and admissibility, the remaining encoding for subset maximization reduces to

Preferred Extensions

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

ASPARTIX

aspartix wwtf project on argumentation system page

aspartix > load >

contact help print

Specification of Input:

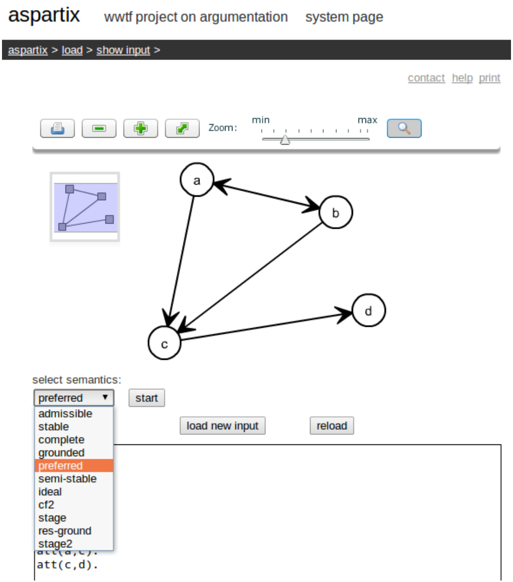
each argument "a" is defined via **arg(a).** ,
and each attack from argument "a" to argument "b" is defined via **att(a,b).**.

```
arg(a).
arg(b).
arg(c).
arg(d).
att(a,b).
att(b,a).
att(b,d).
att(c,d).
```

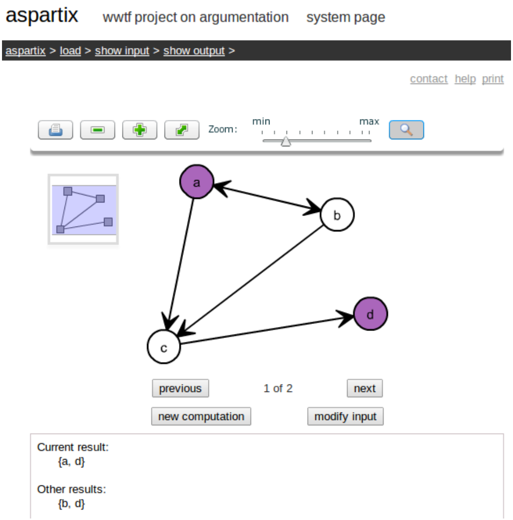
load

Problems with specifications? Look for some examples!

ASPARTIX


aspartix
wwtf project on argumentation
system page
aspartix > load > show input >
contact help print
Zoom:
min
max
a
b
c
d
select semantics:
preferred
start
admissible
stable
complete
grounded
preferred
semi-stable
ideal
cf2
stage
res-ground
stage2
load new input
reload
att(c,d).

ASPARTIX


aspartix
wwtf project on argumentation
system page
aspartix > load > show input > show output >
contact help print
Zoom:
min
max
a
b
c
d
previous
1 of 2
next
new computation
modify input
Current result:
{a, d}
Other results:
{b, d}

VISPARTIX – ASP used for generating abstract AFs

- Tool for handling instantiation process
  - forming arguments from a knowledge base
  - identifying the conflicts
- Visualization of obtained argumentation frameworks
- Based on a two-step evaluation of answer-set programs

Overall Approach

Given knowledge base $\mathcal{K}$; possible claims $\mathcal{C}$:

1. Form arguments $A = (S, C)$ such that for each argument:
   1. Input: $S \subseteq \mathcal{K}$ and $C \in \mathcal{C}$
   2. Consistency: S consistent
   3. Entailment: $S \models C$
   4. Subset Minimality: $\nexists S' \subset S$ s.t. $S' \models C$
2. Identify conflicts between arguments $A = (S, C)$ and $A' = (S', C')$:
   - Variety of different attack types, expressed by satisfiability of formulae, e.g.:
   - Defeat: $C \models \neg S'$
   - Direct Defeat: $C \models \neg\phi'_i$ for a $\phi'_i \in S'$
   - Rebuttal: $C \equiv \neg C'$
   - ...

Model Checking

- Basis for construction of arguments and attack relations
- Any propositional logic formula allowed (e.g. $\mathrm{imp}(a, \mathrm{neg}(b))$)

Model Checking Encoding ($\pi_{\mathrm{modelcheck}}$):

1) Input: Formula, specified by $\mathrm{formula}(F)$
2) Splitting of formula in subformulae and contained atoms
3) Guess interpretations, e.g. $\mathrm{true}(k, A) \vee \mathrm{false}(k, A) \leftarrow \mathrm{atom}(A).$
4) Obtain either $\mathrm{ismodel}(k, F)$ or $\mathrm{nomodel}(k, F)$ for formula F

Example

Input: $\mathrm{formula}(\mathrm{imp}(a, \mathrm{neg}(b)))$

Output (amongst others): $\{\mathrm{false}(k, a).\ \mathrm{true}(k, b).\ \mathrm{ismodel}(k, \mathrm{imp}(a, \mathrm{neg}(b))).\}$

Forming Arguments

(1) Input: $S \subseteq \mathcal{K}$ and $C \in \mathcal{C}$

- Knowledge-base $\mathcal{K}$, represented by the predicate $\mathrm{kb}(\cdot)$
- A set $\mathcal{C}$ of claims, represented by the predicate $\mathrm{cl}(\cdot)$

Guess arguments:

$$\begin{aligned} \pi_{\mathrm{arg}} = \{ \quad & 1\{\ \mathrm{claim}(C) : \mathrm{cl}(C)\ \}1; \\ & 1\{\ \mathrm{fs}(FS) : \mathrm{kb}(FS)\ \}; \\ & \mathrm{formula}(C) \leftarrow \mathrm{claim}(C); \\ & \mathrm{formula}(FS) \leftarrow \mathrm{fs}(FS).\ \} \end{aligned}$$

(2) Consistency: S consistent

$$\begin{aligned} \pi_{\mathrm{consistent}} = \{ \quad & 1\{\ \mathrm{true}(\mathrm{consistent}, A), \mathrm{false}(\mathrm{consistent}, A)\ \}1 \leftarrow \mathrm{atom}(A). \\ & \leftarrow \mathrm{nomodel}(\mathrm{consistent}, FS), \mathrm{fs}(FS).\ \} \end{aligned}$$

Forming Arguments

(3) Entailment: $S \models C$

- Expressible by unsatisfiability of $\neg(S \rightarrow C) \equiv \neg(\neg S \vee C) \equiv S \wedge \neg C$
- We apply saturation technique

$$
\begin{aligned}
\pi_{\text{entailment}} = \{ \quad & \text{true}(\mathit{entail}, A) \vee \text{false}(\mathit{entail}, A) \leftarrow \text{atom}(A); \\
& \text{entails\_claim} \leftarrow \text{nomodel}(\mathit{entail}, \mathit{neg}(C)), \text{claim}(C); \\
& \text{entails\_claim} \leftarrow \text{nomodel}(\mathit{entail}, \mathit{FS}), \text{fs}(\mathit{FS}); \\
& \text{true}(\mathit{entail}, A) \leftarrow \text{entails\_claim}, \text{atom}(A); \\
& \text{false}(\mathit{entail}, A) \leftarrow \text{entails\_claim}, \text{atom}(A) : \\
& \leftarrow \mathit{not}\, \text{entails\_claim}. \}
\end{aligned}
$$

- If S or C not satisfied for interpretation, we obtain entails_claim and saturate
- Otherwise, constraint $\leftarrow \mathit{not}\, \text{entails\_claim}$ removes answer set
- Due to stable model semantics, answer set is only returned in case $S \wedge \neg C$ is unsatisfiable

Forming Arguments

(4) Subset Minimality: $\nexists S' \subset S$ s.t. $S' \models C$

- We apply concept of loop
- All $S' \subset S$ considered where exactly one formula $\alpha \in S$ but $\alpha \notin S'$
- Sufficient due to monotonicity of classical logic

Minimality Encoding (π_{minimize}):

- For each S', check if $S' \models C$ valid
- Only keep answer sets, where guessed interpretation is no model for $S' \models C$
- If $S' \models C$ valid, S is not subset minimal

$\rightarrow$ All answer sets containing S as support are removed

Forming Arguments

Arguments obtained by:

$$\pi_{\text{arguments}} = \pi_{\text{modelcheck}} \cup \pi_{\text{arg}} \cup \pi_{\text{consistent}} \cup \pi_{\text{entailment}} \cup \pi_{\text{minimize}}$$

Example

Input:

$$\{\mathrm{kb}(a).\ \mathrm{kb}(\mathrm{imp}(a,b)).\ \mathrm{kb}(\mathrm{neg}(b)).$$
$$\mathrm{cl}(a).\ \mathrm{cl}(\mathrm{imp}(a,b)).\ \mathrm{cl}(\mathrm{neg}(b)).\ \mathrm{cl}(\mathrm{neg}(a)).\ \mathrm{cl}(b).\ \mathrm{cl}(\mathrm{and}(a,\mathrm{neg}(b))).\}$$

Output:

$$\begin{aligned}
a_1 &: \quad \{\mathrm{fs}(a).\ \mathrm{claim}(a).\}\\
a_2 &: \quad \{\mathrm{fs}(\mathrm{imp}(a,b)).\ \mathrm{claim}(\mathrm{imp}(a,b)).\}\\
a_3 &: \quad \{\mathrm{fs}(a).\ \mathrm{fs}(\mathrm{imp}(a,b)).\ \mathrm{claim}(b).\}\\
a_4 &: \quad \{\mathrm{fs}(\mathrm{neg}(b)).\ \mathrm{fs}(\mathrm{imp}(a,b)).\ \mathrm{claim}(\mathrm{neg}(a)).\}\\
a_5 &: \quad \{\mathrm{fs}(\mathrm{neg}(b)).\ \mathrm{claim}(\mathrm{neg}(b)).\}\\
a_6 &: \quad \{\mathrm{fs}(a).\ \mathrm{fs}(\mathrm{neg}(b)).\ \mathrm{claim}(and(a,\mathrm{neg}(b))).\}
\end{aligned}$$

Identifying Conflicts between Arguments

(1) Input: A set of arguments

- Consists of 'flattened' arguments obtained by $\pi_{\text{arguments}}$
- Each argument specified by a set of predicates $\mathrm{as}(A, fs, \cdot)$ and the predicate $\mathrm{as}(A, claim, \cdot)$

Example

$$\{\mathrm{as}(1, \mathrm{fs}, a).\ \mathrm{as}(1, \mathrm{claim}, a).\ \mathrm{as}(2, \mathrm{fs}, \mathrm{imp}(a, b)).\ \mathrm{as}(2, \mathrm{claim}, \mathrm{imp}(a, b)).\ \mathrm{as}(3, \mathrm{fs}, a).\ \mathrm{as}(3, \mathrm{fs}, \mathrm{imp}(a, b)).\ \mathrm{as}(3, \mathrm{claim}, b).\}$$

(2) Guess exactly two arguments (π_{att})

(3) Build single support formula (π_{support})

- Define an ordering over support formulae $\mathrm{as}(A, fs, \cdot)$
- 'Iterate' over ordering and combine by conjunction

Identifying Conflicts between Arguments

(4) Define Attack Types (e.g. π_{att})

- Construct formula based on attack type
  e.g. Defeat: $C \models \neg S'$ specified as $\text{imp}(C, \text{neg}(S'))$
- Apply model checking to formula
- Derive predicate entails in case formula is satisfied

(5) Saturate ($\pi_{\text{att\_sat}}$)

- Apply coNP check (similar to entailment for arguments)
- If entails not derived, answer set is removed
- Otherwise, we saturate
- If formula of some attack type valid, we saturate all attack types

Attacks (defeats) obtained by:

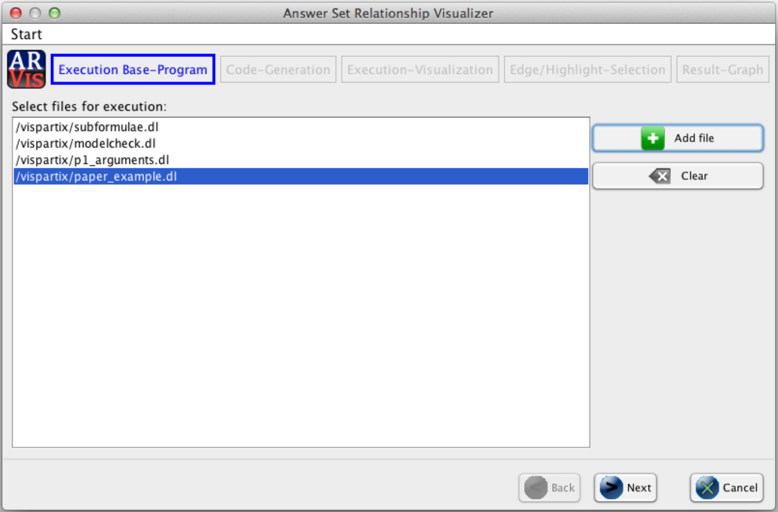
$$\pi_{\text{attacks}} = \pi_{\text{modelcheck}} \cup \pi_{\text{att}} \cup \pi_{\text{support}} \cup \pi_{\text{att}} \cup \pi_{\text{att\_sat}}$$

Visualization of Argumentation Frameworks

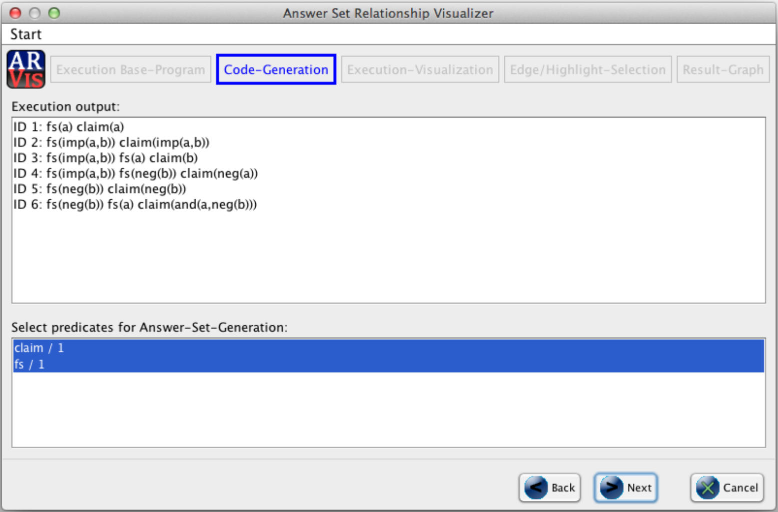
We utilize the purpose built tool ARVis (Answer set Relationship Visualizer):

1. Obtain arguments: Provide $\pi_{\text{arguments}}$ and a problem instance, gringo and claspD compute arguments
2. Flatten arguments: Generate argument facts
3. Obtain attacks: Provide π_{attacks} and any attack type programs, attacks are computed
4. Argumentation Framework: ARVis provides graph visualization consisting of arguments (vertices) and attacks (edges)
5. Export: Graph may be exported for further processing

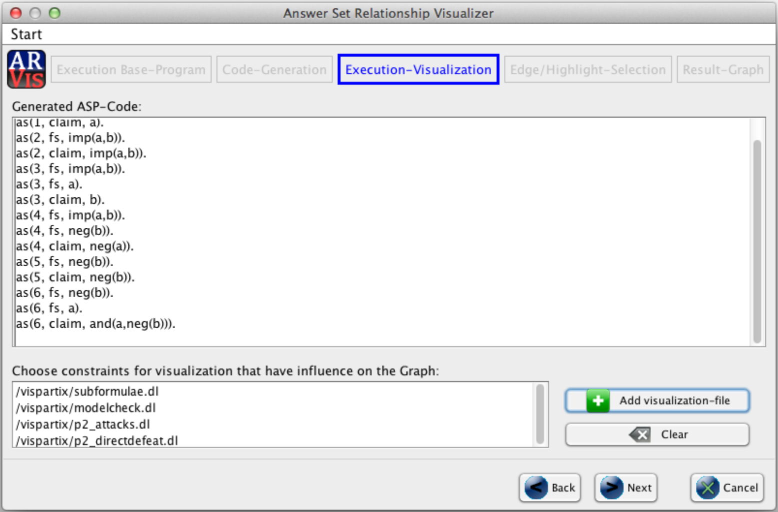
Visualization of Argumentation Frameworks



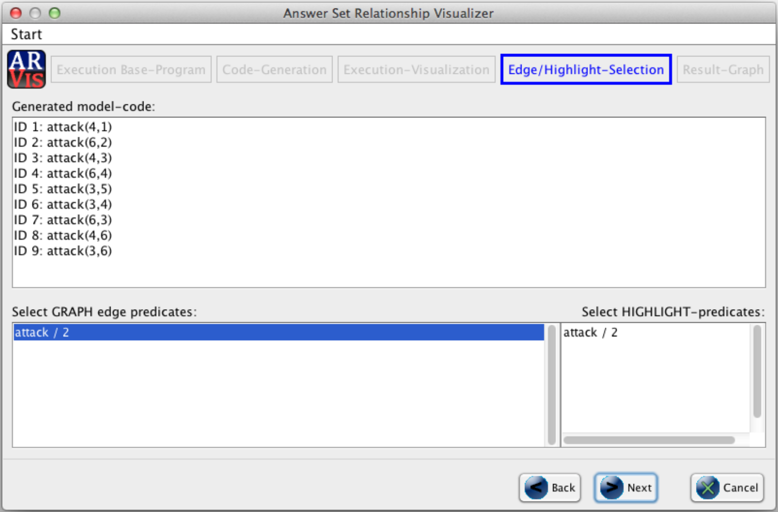
Visualization of Argumentation Frameworks



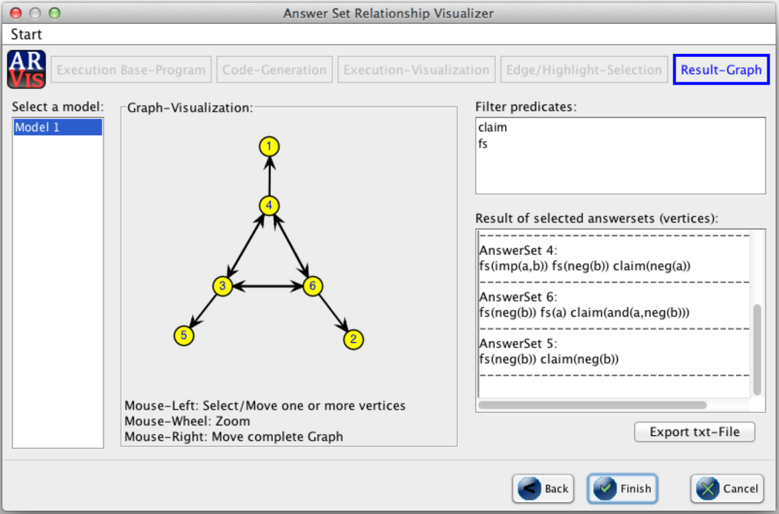
Visualization of Argumentation Frameworks



Visualization of Argumentation Frameworks



Visualization of Argumentation Frameworks



D-FLAT/dynPARTIX

Underlying Idea:

- Exploit structure of instances
- Many problems easy on tree-like graphs
- Apply *dynamic programming* on a *tree decomposition*

Systems:

- dynPARTIX: dedicated C++ system for abstract argumentation
- D-FLAT: Decompose, Guess & Check (ASP on decomposition)

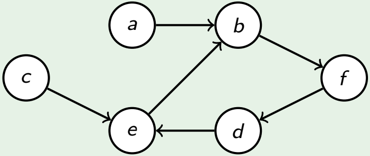
Tree Decompositions (I)

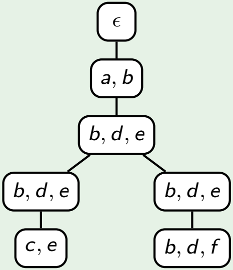
Definition

A *tree decomposition* is a tree obtained from an arbitrary graph s.t.

1. Each vertex must occur in some bag.
2. For each edge, there is a bag containing both endpoints.
3. If vertex v appears in bags of nodes n_0 and n_1, then v is also in the bag of *each node on the path* between n_0 and n_1.

Example





Tree Decompositions (II)

Definition

- *Decomposition width*: size of the largest bag (minus 1)
- Treewidth: minimum width over all possible tree decompositions

- A tree decomposition breaks an instance down into smaller parts
- Dynamic programming: Solve parts and combine partial solutions
  - Algorithms often exponential only in decomposition width
  - ... but *linear* in the input size
  - Bounded treewidth then leads to fixed-parameter tractability (FPT)

Algorithm Execution

1. Decompose instance
   - Construct a “good” tree decomposition
   - Each tree decomposition node is associated with a table
   - Each table row will correspond to partial solutions
2. Solve partial problems
   - Compute the tables in a bottom-up way
   - An ASP program is executed *for each table*
     - The ASP program is provided by the user
     - Child tables are supplied as input
     - Answer sets correspond to new table rows
3. Combine solutions

Example: Computing Stable Extensions

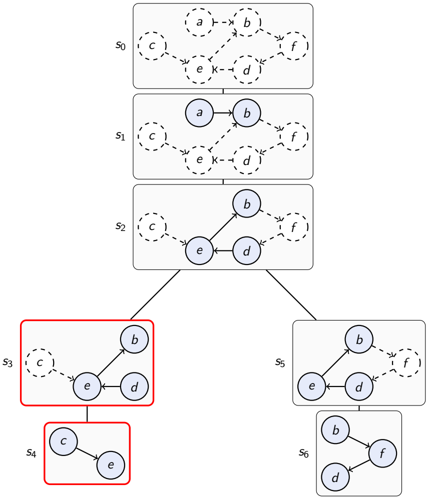


Figure: Nodes with represented AFs

s_3

b	d	e	$e_t(C)$
in	*in*	*def*	$\{\{b, c, d\}\}$
out	*in*	*def*	$\{\{c, d\}\}$
in	*out*	*def*	$\{\{b, c\}\}$
out	*out*	*def*	$\{\{c\}\}$

s_4

c	e	$e_t(C)$
in	*def*	$\{\{c\}\}$
out	*in*	$\{\{e\}\}$
out	*out*	$\{\emptyset\}$

Figure: Tables of s_3 and s_4

Implementation: D-FLAT Framework

Dynamic Programming **F**ramework with **L**ocal Execution of **A**SP on **T**ree Decompositions

1. Parses the input (graph as a set of facts) and stores the graph
2. Constructs a tree decomposition
3. In each node: Executes user-supplied algorithm with ASP solver
4. Extracts table rows from answer sets
5. Materializes the solutions

Properties

- Users only need to write an ASP program
- Communication with the user's program via special predicates

D-FLAT: Stable Extensions

User-supplied program (Stable Extensions)

```
%Exactly extend one child row per child node.
1 { extend(R) : childRow(R, N) } 1 :- childNode(N).

% For every introduced argument guess if it is in xor out/def.
{ item(map(A, in)) } :- introduced(A).

% An argument is defeated if it is not in the set and ..
% ..just introduced and attacked by an in-argument
item(map(A, def)) :- introduced(A), not item(map(A, in)), item(map(A2, in)), att(A2, A).
% ..or has already been introduced and is attacked by an in-argument.
item(map(A, def)) :- current(A), not childItem(I, map(A, in)), item(map(A2, in)), att(A2, A), extend(I).

% Copy already decided in-/def-mappings.
item(map(A, in)) :- current(A), childItem(I, map(A, in)), extend(I).
item(map(A, def)) :- current(A), childItem(I, map(A, def)), extend(I).

% Discard sets if any out-argument is removed.
:- removed(A), not childItem(I, map(A, in)), not childItem(I, map(A, def)), extend(I), childRow(I, N),
   childBag(N, A).

% Discard sets if there is a conflict.
:- item(map(A1, in)), item(map(A2, in)), att(A1, A2).

% Discard sets if the extended child rows exclude a node from the set, but the same node also is in the set.
:- extend(I), item(map(A, in)), not childItem(I, map(A, in)), current(A), childRow(I, N), childBag(N, A).
```

Summary

- Recent years have seen an emergence of argumentation systems
- Focus on systems for abstract argumentation
  - systems should cover the different semantics
  - easy-to-use interfaces important
- but what semantics / graph types are needed in the larger context?

Benchmarking – The Current State

H. Qualtinger; G. Bronner

I hob zwoar ka ohnung wo i hinfoahr
Aber dafir bin i gschwinder duat

Viennese ⇒ German:
Ich habe keine Ahnung wo ich hinfahre
Stattdessen bin ich schneller dort

German ⇒ English:
I have no idea where I am going
But for sure I am faster there

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Links to Systems:

- ASPARTIX http://www.dbai.tuwien.ac.at/research/project/argumentation/systempage/
- ConArg http://www.dmi.unipg.it/francesco.santini/argumentation/conarg.zip
- COMPARG http://www.ai.rug.nl/~verheij/comparg/
- Dung-O-Matic http://www.arg.dundee.ac.uk/?page_id=279
- dynPARTIX http://www.dbai.tuwien.ac.at/proj/argumentation/dynpartix
- D-FLAT http://www.dbai.tuwien.ac.at/proj/dynasp/dflat
- CEGARTIX - http://www.dbai.tuwien.ac.at/research/project/argumentation/cegartix/
- ArgKit (with Dungine) http://www.argkit.org/
- ArguLab http://heen.webfactional.com/

Links (ctd.)

- TOAST http://www.arg.dundee.ac.uk/toast/
- Vispartix http://www.dbai.tuwien.ac.at/proj/argumentation/vispartix/
- CaSAPI http://www.doc.ic.ac.uk/~ft/CaSAPI/
- Visser's Epistemic and Practical Reasoner http://www.wietskevisser.nl/research/epr/
- Carneades http://carneades.github.com/
- OVAgen http://ova.computing.dundee.ac.uk/ova-gen/
- Adam Wyner's web page http://wyner.info/LanguageLogicLawSoftware/index.php/software/

Demo Session

Thank you! And now for the demo session . . .