FAKULTÄT FÜR !NFORMATIK

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Utilizing ASP for Generating and Visualizing Argumentation Frameworks

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ASPOCP'12 - September 4, 2012

Outline

Argumentation - Argumentation Frameworks

Steps

Starting point: knowledge-base

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

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

Example

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

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

Example

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

$(\{a\}, a)$

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

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

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

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

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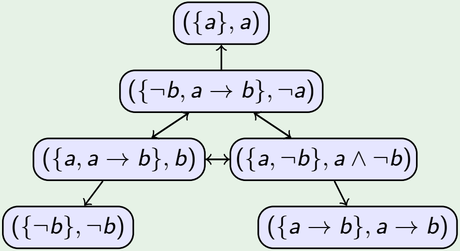

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- Obtain an Abstract Argumentation Framework F_Δ (Dung [1995])

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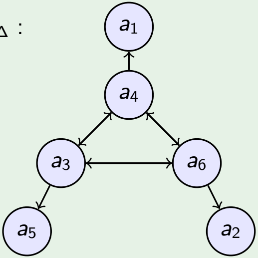
F_Δ :



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

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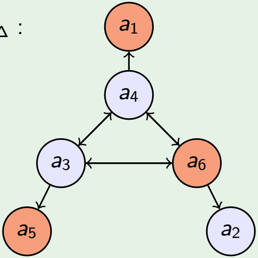
F_Δ :



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

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- Derive deductive closure of contents from accepted arguments

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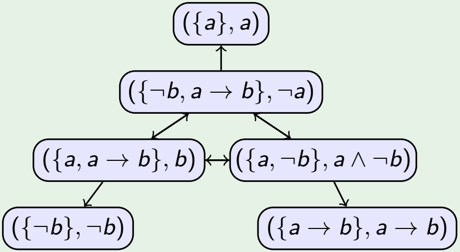

$$Cn_{stb}(F_\Delta) = Cn((a \wedge \neg b) \vee (a \wedge b \wedge a \rightarrow b) \vee (a \rightarrow b \wedge \neg a \wedge \neg b))$$

Argumentation - Our Motivation

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Current Status

- Not many systems for instantiation of AFs: e.g. CARNEADES, TOAST (for ASPIC+)
- Many different systems for evaluating AFs: e.g. ASPARTIX, Dungine, CASAPI, ArguMed, ConArg, reasoner by Visser (2008)
- Few tools for combining Computation and Visualization: e.g. CARNEADES, ASPARTIX (Web)

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Our Goals

→ Instantiation of AFs via ASP encodings

→ Tool for handling instantiation process and visualization of obtained Argumentation Frameworks

ASP Encodings

Overall Approach (Besnard and Hunter [2001]):

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: $C \equiv \neg C'$
   - ...

$\rightarrow$ Model checking via ASP basis for construction of AFs

$\rightarrow$ Two-step approach: One encoding for arguments, another for attacks

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:

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

(2) Consistency: S consistent

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

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 the saturation technique (Eiter and Gottlob [1995])

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

- 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 (see e.g. Eiter et al. [2009])
- 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:

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

Example

Input:

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

Output:

$$a_1 : \quad \{\text{fs}(a).\ \text{claim}(a).\}$$
$$a_2 : \quad \{\text{fs}(\text{imp}(a,b)).\ \text{claim}(\text{imp}(a,b)).\}$$
$$a_3 : \quad \{\text{fs}(a).\ \text{fs}(\text{imp}(a,b)).\ \text{claim}(b).\}$$
$$a_4 : \quad \{\text{fs}(\text{neg}(b)).\ \text{fs}(\text{imp}(a,b)).\ \text{claim}(\text{neg}(a)).\}$$
$$a_5 : \quad \{\text{fs}(\text{neg}(b)).\ \text{claim}(\text{neg}(b)).\}$$
$$a_6 : \quad \{\text{fs}(a).\ \text{fs}(\text{neg}(b)).\ \text{claim}(and(a,\text{neg}(b))).\}$$

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 $\text{as}(A, \mathit{fs}, \cdot)$ and the predicate $\text{as}(A, \mathit{claim}, \cdot)$

Example

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

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

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

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

Identifying Conflicts between Arguments

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

- 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:

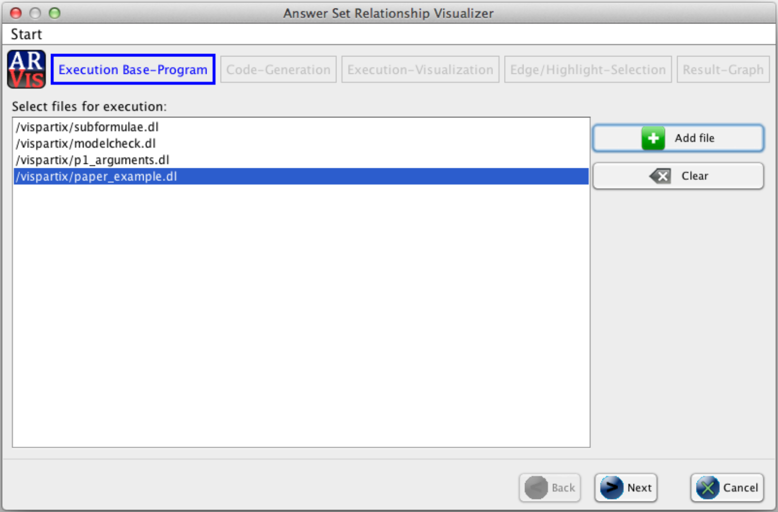
$$\pi_{\text{attacks}} = \pi_{\text{modelcheck}} \cup \pi_{\text{att}} \cup \pi_{\text{support}} \cup \pi_{\text{defeat}} \cup \pi_{\text{att\_sat}}$$

Visualization of Argumentation Frameworks

We utilise 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



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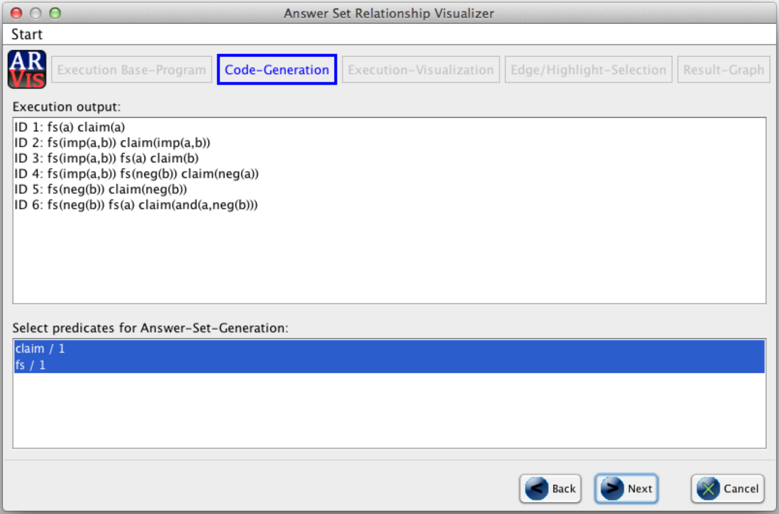

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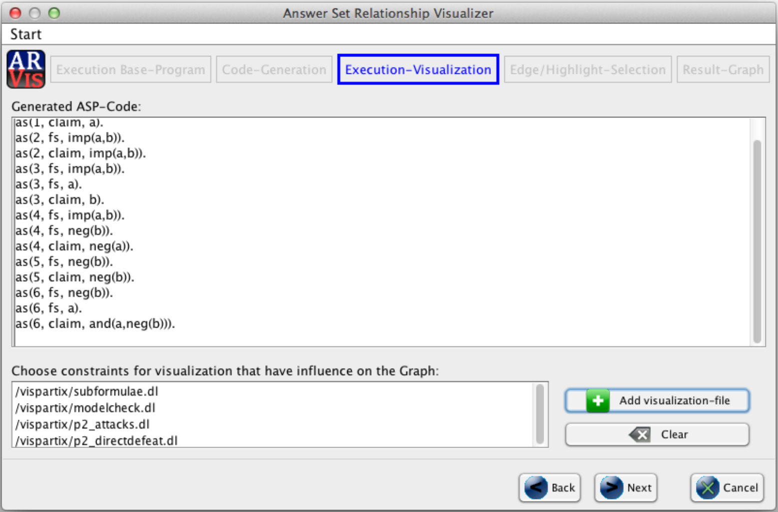

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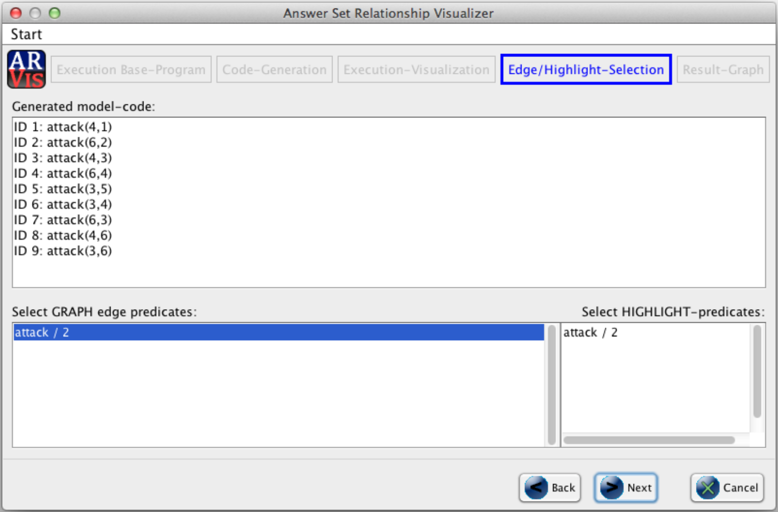

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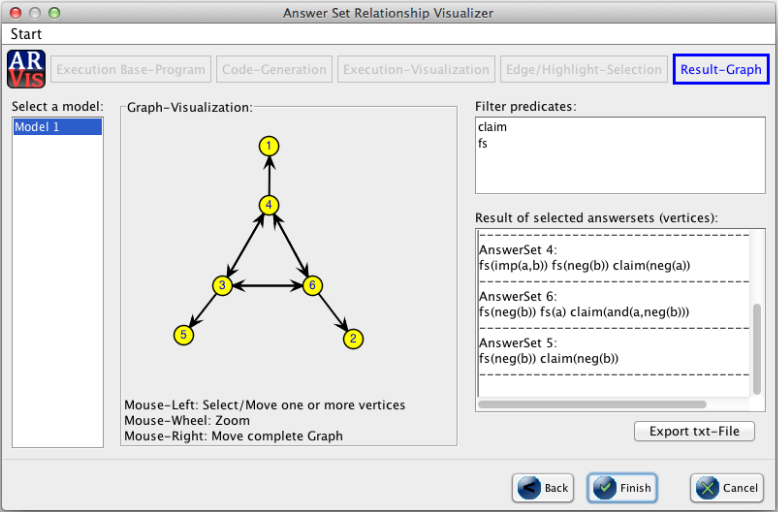

Summary and Future Work

Summary:

- ASP encodings for instantiation of Argumentation Frameworks (two steps)
  - → Declaratively descibed
  - → Easily adaptable to other notions
- New tool for visualising relations between answer sets (ARVis)
  - → Not restricted to Argumentation domain
  - → Versatile, e.g. export of graph for post-processing
- Encodings and tool publicly available:

  `http://dbai.tuwien.ac.at/proj/argumentation/vispartix`

Future Work:

- Implement further instantiation approaches
- Performance evaluation
- Analyze further application areas for answer set relationship visualization

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