FAKULTÄT FÜR !NFORMATIK
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Knowledge-Based Systems Group

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Inline Evaluation of Hybrid Knowledge Bases PhD Description

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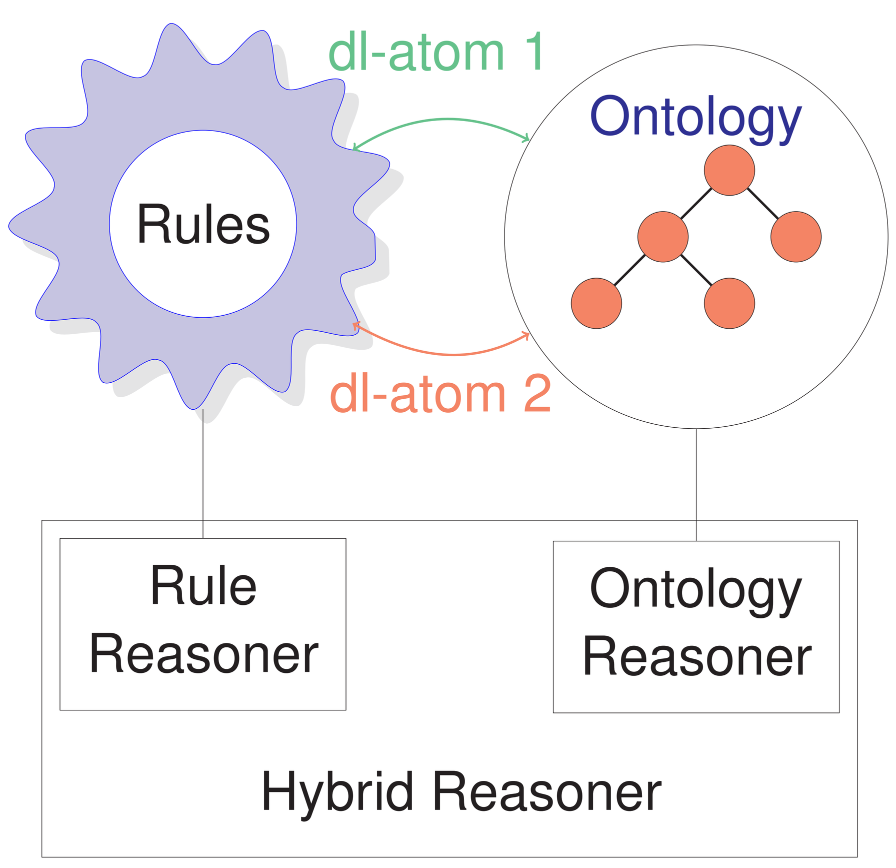
Motivation

- Hybrid Knowledge Bases: combining KBs in different formalisms
- Ontologies + Rules
- Ontology $Father \equiv Man \sqcap \exists hasChild.Human$
- Rule $fly(X) \leftarrow bird(X), not\ penguin(X).$
- Combination Approaches:
  - Loose Coupling Approaches: DL-Programs, F-Logic# KBs
  - Tight Coupling Approaches: SWRL, r-Hybrid KBs, ELP
  - Embedding Approaches: MKNF KBs, Open ASP, g-Hybrid KBs
- Aim of this work: improve the efficiency of reasoning over DL-Programs

DL-Programs

- Loose coupling of Answer Set Programing (with dl-atoms) + OWL DL Ontology
- Semantics: based on the exchange of the entailment between the two components
- DL-atoms
  - normal rule atom: $student(X)$
  - dl-atom – query from DL part: $DL[Person](X)$
  - dl-atom – with DL input: $DL[Student \uplus student; Person](X)$
    extend DL predicate $Student$ with LP predicate $student$; then query $Person$

Previous Evaluation Method



DL-Program $KB = (\Sigma, P)$

$$\Sigma = \{ C \sqsubseteq D \}$$
$$P = \{ p(a).\ \ s(a).\ \ s(b).\ \ q \leftarrow DL[C \uplus s; D](a),\ not\ DL[C \uplus p; D](b).\ \}$$

$KB \models q$?

- Take an arbitrary model I of KB
- $\{p(a), s(a), s(b)\} \subseteq I$
- $I \models DL[C \uplus s; D](a)$? ✓
  - input $C \uplus s$: $\{s(a), s(b)\} \Rightarrow \{C(a), C(b)\}$
  - $\{C \sqsubseteq D\} \cup \{C(a), C(b)\} \models D(a)$ $\rightsquigarrow$ One call to DL reasoner
- $I \models DL[C \uplus p; D](b)$? ✗
  - input $C \uplus p$: $\{p(a)\} \Rightarrow \{C(a)\}$
  - $\{C \sqsubseteq D\} \cup \{C(a)\} \not\models D(b)$ $\rightsquigarrow$ Another call to DL reasoner
- $I \models q$

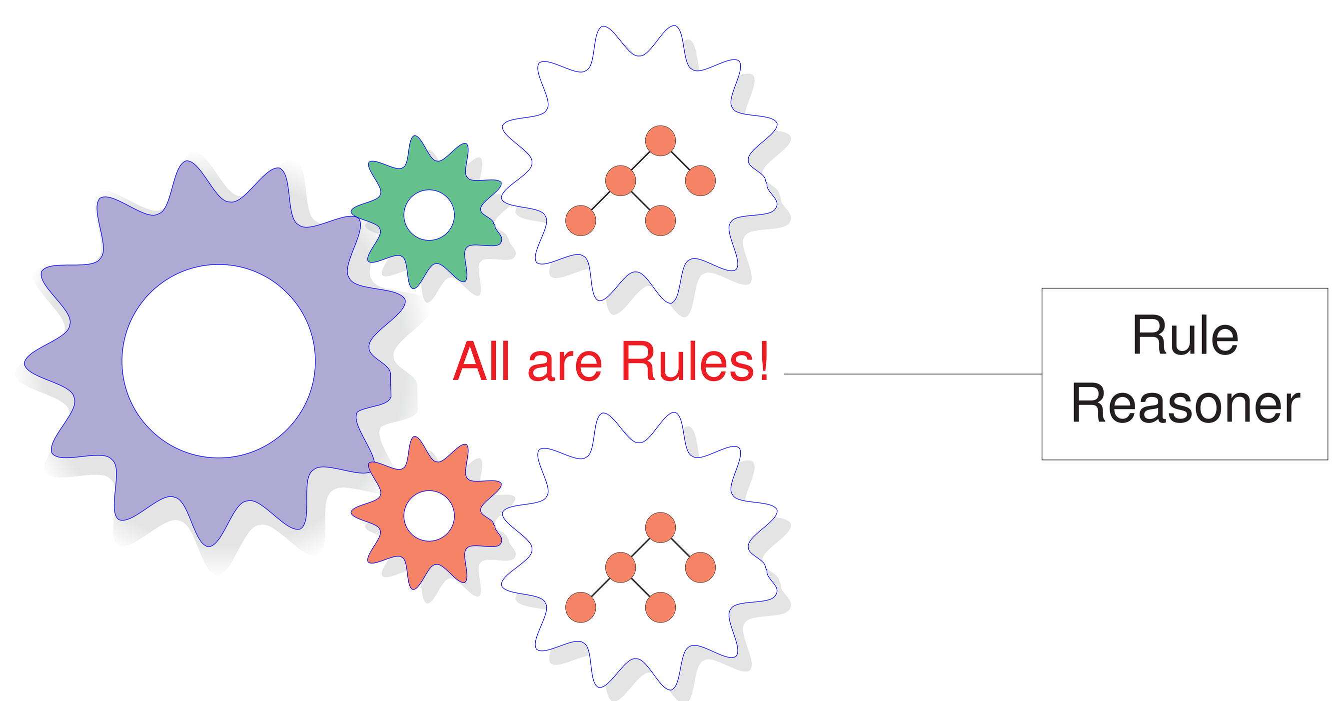
$KB \models q$ ✓

Issues:

- overhead of multi calls to external reasoners
- costly exchange of the entailments

$\equiv$

Inline Evaluation Method



- DL-Program $KB \Rightarrow Datalog^{\neg}$ program $\Phi(KB)$
- different inputs from a dl-atom cause different DL KBs
  - $\Sigma \rightsquigarrow \Sigma_{\lambda_1}, \Sigma_{\lambda_2}$
- Rewrite Σ

$$\Sigma_{\lambda_1} = \{ C_{\lambda_1} \sqsubseteq D_{\lambda_1} \} \qquad D_{\lambda_1}(X) \leftarrow C_{\lambda_1}(X)$$
$$\Sigma_{\lambda_2} = \{ C_{\lambda_2} \sqsubseteq D_{\lambda_2} \} \qquad D_{\lambda_2}(X) \leftarrow C_{\lambda_2}(X)$$

- Rewrite the interaction (dl-atoms)

$$\lambda_1 \triangleq C \uplus s \qquad C_{\lambda_1}(X) \leftarrow s(X)$$
$$\lambda_2 \triangleq C \uplus p \qquad C_{\lambda_2}(X) \leftarrow p(X)$$

- Rewrite the original dl-rules to remove the dl-atoms

$$q \leftarrow DL[\lambda_1; D](a), not\ DL[\lambda_2; D](b) \qquad q \leftarrow D_{\lambda_1}(a), not\ D_{\lambda_2}(b)$$
$$p(a).\ \ s(a).\ \ s(b). \qquad p(a).\ \ s(a).\ \ s(b).$$

- It works!

$$KB \models q \quad \textit{iff} \quad \Phi(KB) \models q$$

Effects

- hybrid KB $\Rightarrow$ single rule formalism
- only rule reasoner is needed — the ontology part is "inlined"
- improved efficiency

Contributions

- Notion of datalog-rewritable DLs
- A general framework for inline evaluation of DL-Programs
- A Datalog rewritable DL: $\mathcal{LDL}^{+}$
- A prototype implementation: DReW
- Promising evaluation results

Future Work

- Inline Evaluation of DL-Programs over OWL 2 Fragments
- ... over Horn DLs
- Optimization of rewriting
- More benchmark tests
- Apply this idea to other hybrid KBs

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