Unit 3 – Languages and Systems

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Reasoning Web Summer School 2008

Unit Outline

1. Introduction
2. RDF Stores with Rules Support
3. SWRL – OWL Reasoners with Rules Support
4. LP Engines with RDF Support
5. Systems for Hybrid Combinations
6. Overview
7. Conclusion

Introduction

- Current state of systems with ontology and rules support
- Presentation will do some kind of assessment, and will build the bridge to the theoretical part
- aim at implemented systems with rule support (only a small selection)
- how we distinguish the systems, classification (RDF/OWL)
  - RDF Frameworks + Rules
  - DL Reasoners + Rules
  - Prolog(-like) Systems + RDF
  - Hybrid Combinations
- systems and languages show case

RDF Stores – what are those?

- sophisticated frameworks for accessing RDF data
- database backends
- query interface, data management interface
- rules support adds additional query expressivity

Jena Rules

Conflicting reviewer in RIF:

```
Forall ?P ?A ?P1 ?N
 ( ?P#ex:ConflictingReviewer :-  And(
      <http://dblp.l3s.de/d2r/page/publications/conf/rweb/EiterIKP08>
         [dc:creator -> ?A]
      ?A[foaf:knows -> ?P1]
      ?P1[foaf:name -> ?N]
      ?P[foaf:name -> ?N]
      ?P#foaf:Person
     )
 )
```

and in Jena rules:

```
[ conflict1:
  (http://dblp.l3s.de/d2r/page/publications/conf/rweb/EiterIKP08 dc:creator ?A),
  (?A foaf:knows ?P1), (?P1 foaf:name ?N), (?P foaf:name ?N),
  (?P rdf:type foaf:Person)
  ->
  (?P rdf:type ex:ConflictingReviewer) ]
```

http://jena.sourceforge.net/inference/

Sesame/OWLIM

Conflicting Reviewers in RIF:

```
Forall ?P ?A ?Pub ?P1 ?N
 ( ?P#ex:ConflictingReviewer :- And(
     <http://dblp.l3s.de/d2r/page/publications/conf/rweb/EiterIKP08>
         [dc:creator -> ?A]
     ?Pub[dc:creator -> ?A]  ?Pub[dc:creator -> ?P1]   ?P1[ foaf:name -> ?N]
     ?P[ foaf:name -> ?N]    ?P#foaf:Person
    )
 )
```

and in OWLIM:

```
Id: conflict2
<http://dblp.l3s.de/d2r/page/publications/conf/rweb/EiterIKP08> <dc:creator> A
Pub <dc:creator> A
Pub <dc:creator> P1
P1 <foaf:name> N
P <foaf:name> N
P <rdf:type> <foaf:Person>
--------------------------
?P#ex:ConflictingReviewer
```

[Kiryakov *et al.*, 2005] `http://www.ontotext.com/owlim/`

Oracle $11g$

- extension of a Oracle database with a rule engine
- extension to SQL for accessing RDF data (SPARQL-like graph queries, SPARQL support planned)
- Native inferencing in the database for
  - RDF, RDFS, OWL-Prime (OWL subset)
  - User-defined rules
- New relationships/triples are inferred and stored ahead of query time
  - Minimizes on-the-fly computation and results in fast query times

[Wu *et al.*, 2008]

`http://www.oracle.com/technology/tech/semantic_technologies/`

Oracle $11g$ (ctd.)

Editing in RIF:

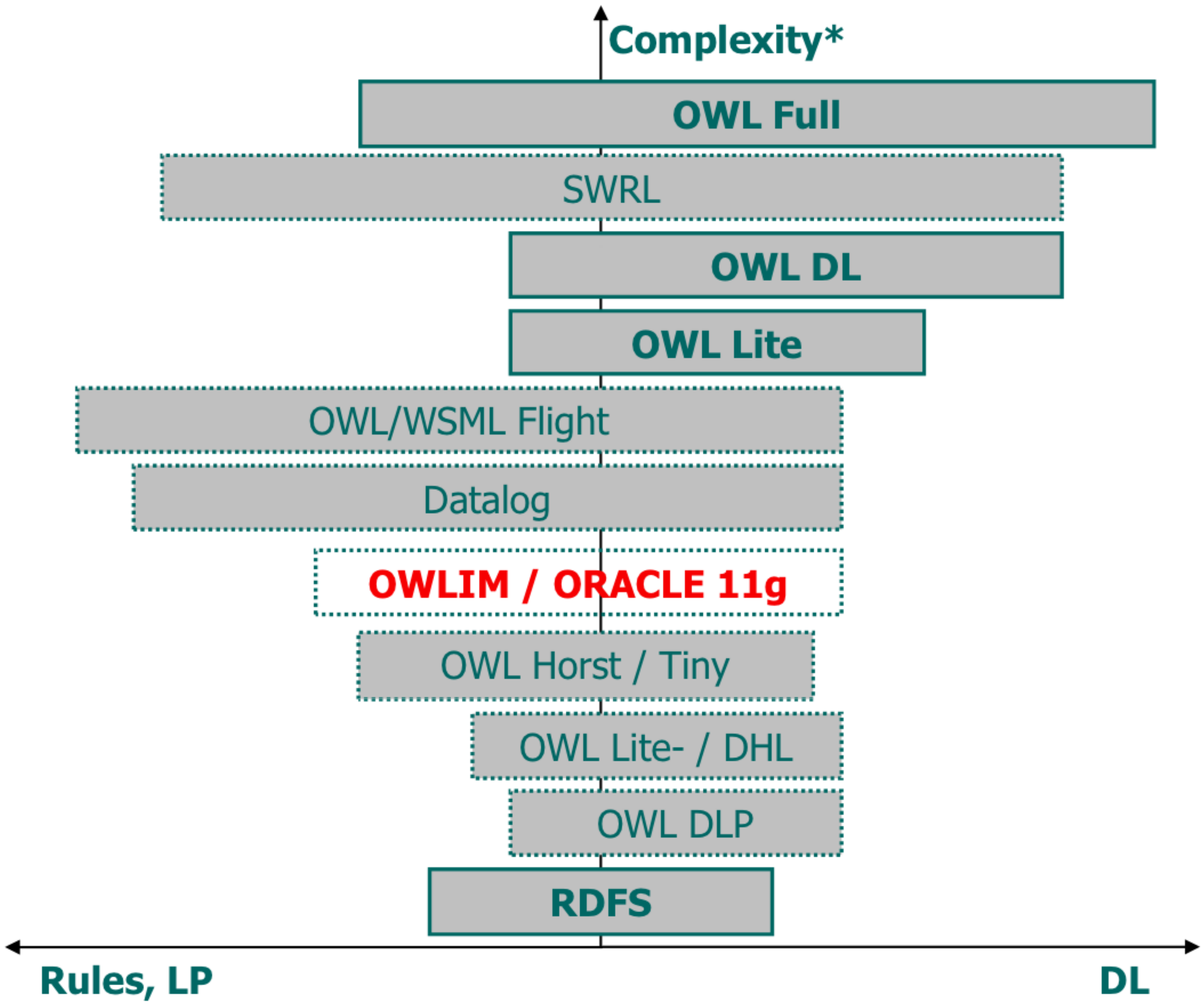
```
Forall ?A ?E ( ?A[ex:editedBy -> ?E] :- Exists ?C ( And (
                     ?A[dc:partOf -> ?C]
                     ?C[swrc:editor -> ?E] )
                 )
              )
```

and in Oracle:

```
INSERT INTO mdsys.semr_user_rulebase VALUES ('editedby_rule',
'(?a <http://purl.org/dc/elements/1.1/partOf> ?c)
 (?c <http://swrc.ontoware.org/ontology#editor> ?e)',
NULL, '(?a <http://www.example.org/editedBy> ?e)', null);

SELECT s,o FROM table(SEM_MATCH('(?s <http://www.example.org/editedBy> ?o)',
           SEM_MODELS('OWLTST'),
           SEM_RULEBASES('OWLPRIME','USER_RULEBASE'),  null, null ));
```

Comparison



(C) Ontotext Lab

SWRL – Semantic Web Rules Language

Observation: OWL DL has limited expressiveness

Example: Expressing editors?

Given the DL roles $partOf$, $editor$, and $editedBy$, one cannot express that

"an article, which is part of a collection with an editor, is edited by the editor of the collection"

by OWL DL *alone*.

but rules can easily express this "triangle:"

$$editedBy(A, E) \leftarrow partOf(A, C) \wedge editor(C, E)$$

Add rules to ontologies: Semantic Web Rules Language (SWRL)
W3C member submission [Horrocks *et al.*, 2004;
Horrocks *et al.*, 2005]

DL-safe Rules

- Well-known: reasoning in a formalism with unrestricted rules over a description logic is *undecidable* [Levy and Rousset, 1998]
- Adding a safety condition to the rules preserves decidability [Motik *et al.*, 2005]:

DL-safe SWRL

A rule r is called *DL-safe* if each variable in r occurs in a non-DL-atom in the rule body.

Example

The rule

$$editedBy(A, E) \leftarrow partOf(A, C) \wedge editor(C, E) \wedge o(A) \wedge o(C) \wedge o(E)$$

is DL-safe, if $o(\cdot)$ is a non-DL-atom (o does not appear in the DL-KB).

DL-safe Rules (ctd.)

DL-safe SWRL ontology

Ontology $\mathcal{O}$ describing $editedBy$, $partOf$, $editor$ plus the DL-safe rule

$$editedBy(A, E) \leftarrow partOf(A, C) \wedge editor(C, E) \wedge o(A) \wedge o(C) \wedge o(E)$$

and eventually adding facts $o(a)$ for every known individual a from $\mathcal{O}$.

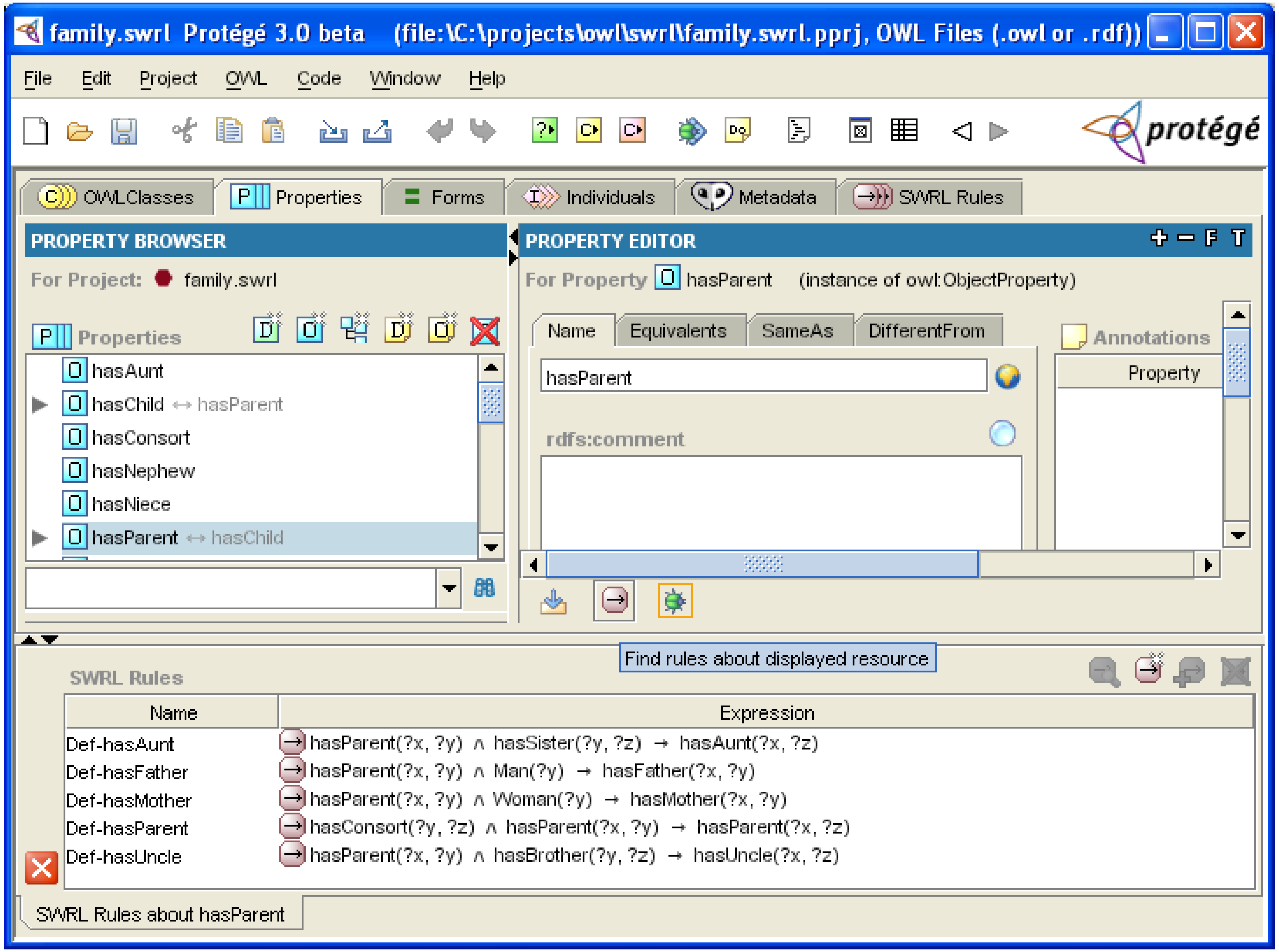
- restricts reasoning with DL-safe rules only to *known* individuals
- more details and other approaches to DL-safety in the next unit

KAON2, Pellet, RacerPro, Protégé

Important: standard DL reasoners support DL-safe SWRL

- KAON2 [Motik, 2006] `http://kaon2.semanticweb.org/`
  supports also F-Logic
- Pellet [Sirin *et al.*, 2007] `http://pellet.owldl.com/`
- RacerPro [Rac, 2007] `http://www.racer-systems.com/`
  also allows some forms of nonmonotonic reasoning
- Protégé support [O'Connor *et al.*, 2005]

SWRL in the Protégé Ontology Editor



(C) `http://protege.cim3.net/`

Logic Programming systems with RDF Support

- Logic Programming systems with additional RDF components
- realized by
  - creating a specialized RDF library to a Prolog engine,
  - compiling to Prolog, or
  - rule engine implemented from scratch with built-in RDF support

SWI-Prolog and $\mathcal{F}$LORA-2

- SWI-Prolog with Semantic Web library [Wielemaker *et al.*, 2008]
  `http://www.swi-prolog.org/`

Implementing RDFS semantics in SWI-Prolog

```
triple(O, rdf:type, C) :- rdf(S,P,O), rdf(P,rdfs:range,C).
```

- $\mathcal{F}$LORA-2 (F-Logic) [Kifer, 2005]
  `http://flora.sourceforge.net/`
  Frame Logic, based on XSB Prolog

Implementing RDFS semantics in $\mathcal{F}$LORA-2

```
?O[rdf:type -> ?C] :- ?S[?P -> ?O], ?P[rdfs:range -> ?C].
```

Combining Rules and Ontologies for the Semantic Web

- systems supporting complex integration of ontologies and rules
- anticipation of next unit
- show a sample combination approach: HEX-programs

HD-Rules and NLP-DL

- Hybrid programs [Drabent *et al.*, 2007]
  `http://www.ida.liu.se/hswrl/`
  HD-Rules: compiling Hybrid rules to prolog program

- dl-programs [Eiter *et al.*, 2008]
  `http://www.kr.tuwien.ac.at/research/systems/semweblp/`
  NLP-DL: implementation for dl-programs
  examples and theoretical details in the next unit

Motivation

- dl-programs: interfacing external source of (DL) knowledge
- Limited flexibility:
  - only one external KB possible
  - only one formalism allowed for KB (OWL)
- Spinning this idea further:
  - Access arbitrary external sources (solvers, services, different knowledge bases, etc.)
  - Standardized interface
  - Entire program: still ASP semantics

$\Rightarrow$ more general formalism needed!

Motivation (ctd.)

Other desirable features for Rules in the Semantic Web:

- Software Interoperability
  - Importing external knowledge
  - Easily extendable reasoning framework
- Higher-Order Reasoning: rules that talk about predicates
  - Stating generic rules
  - Defining ontology semantics in a program

Our extension: *__**H**__igher-order logic programs with __**EX**__ternal atoms* (HEX-programs) [Eiter *et al.*, 2005]

External Atoms

External Atom

$$\&rdf[\text{“http://www.ex.org/kb.rdf”}](S, P, O)$$

consists of

- an identifier: $\&rdf$
- an input list: “http://www.ex.org/kb.rdf”
- an output list: S, P, O

Not only constants, but also predicate extensions can be input:

$\&sum[p](X) \quad \Rightarrow \quad I : \{p(2), p(3), q(4)\} \quad \Rightarrow$ output list: 5

input list: p

$$f_{\&sum}(I, p, n) = 1 \text{ iff } \sum_{p(k) \in I} k = n$$

Higher-Order Atoms

Higher-Order Atoms are expressions of the form

$$(t_0, t_1, \ldots, t_n) \;\; \text{resp.} \;\; t_0(t_1, \ldots, t_n) \;\; ,$$

where $t_0, \ldots, t_n$ are (function-free) terms.

Variable predicate symbols, meta-reasoning:

$$C(X) \leftarrow subClassOf(D, C), D(X) \;\; .$$

Further features, inherited from DLV:

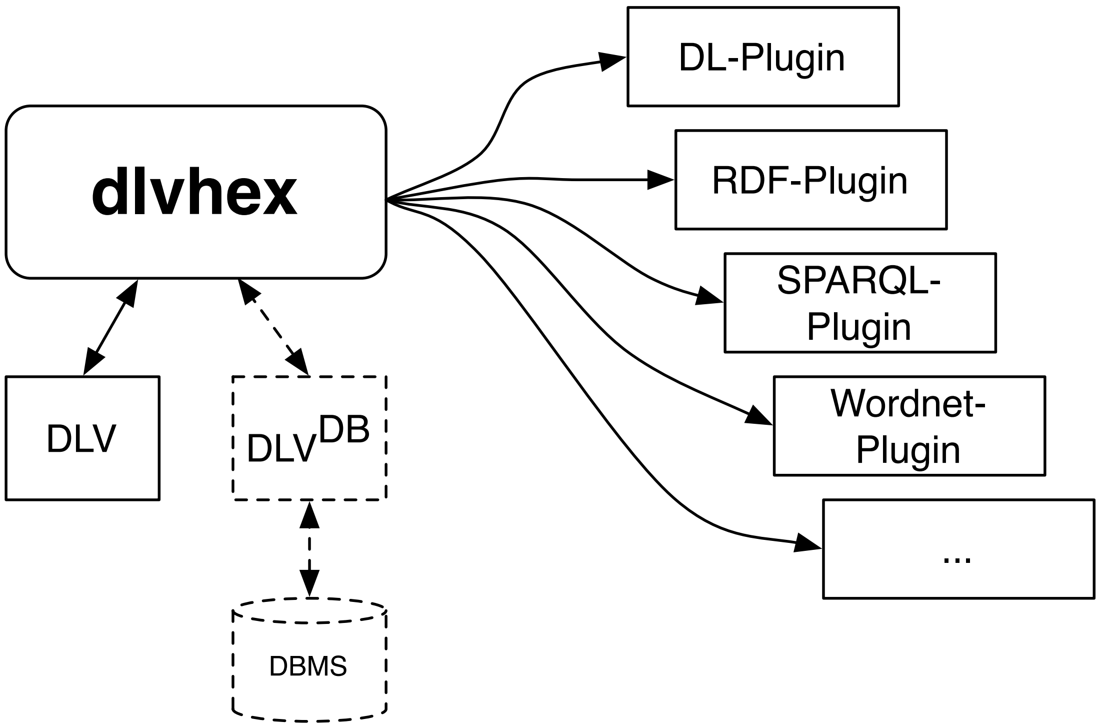
- Constraints, weak constraints
- Aggregates

Architecture

dlvhex [Eiter *et al.*, 2006]: a reasoner for HEX-programs

- Command line application
- interfaces DLV and plugins for external atoms used in a program
- alternatively, it can use DLV^{DB} to interface a database

Design principle:



Demo

see also `http://asptut.gibbi.com/` for a tutorial and demos on

- Answer Set Programming with dlv
- ASP with templates (dlt)
- dl-programs (NLP-DL)
- HEX-programs (dlvhex)

Overview of rule systems features

Features as shown in the previous unit

- Modules
- Function symbols
- Built-Ins
- Higher-order predicates
- Constraints
- Negation As Failure
- Disjunctive Rules

Next slide: current state of the systems

Overview of rule systems features

System (Language)	RDF(S)	OWL	M	F	BI	HO	C	NAF	∨
cwm (N3)	+	−	−	−	+	−	−	+	−
dlvhex (HEX)	+	+	−	−	+	+	+	+	+
$\mathcal{F}$LORA-2 (F-Logic)	+	−	+	+	+	+	−	+	−
HD-rules (Hybrid rules)	−	+	−	+	−	−	−	+	−
Jena (Jena Rules)	+	+	−	−	+	−	−	−	−
KAON2 (SWRL)	+	+	−	−	+	−	−	−	+
NLP-DL (dl-programs)	−	+	−	−	−	−	+	+	−
Oracle $11g$ (OWLPrime)	+	+∼	−	−	+	−	−	−	−
OWLIM (OWL Horst)	+	+∼	−	−	−	−	−	−	−
Pellet (SWRL)	+	+	−	−	−	−	−	−	−
RacerPro (SWRL)	+	+	−	−	+	−	−	−	−
SWI-Prolog (RDF(S))	+	−	+	+	+	−	−	+	−

Legenda: Modules, Functions, Built-Ins, Constraints, Higher Order, Negation As Failure
+ = yes, − = no, +∼ = yes, with some proviso

Conclusion

- current state of systems:
  - diverse syntax and
  - not so formal semantics
- demand for a standardized rule language like RIF (previous unit)
- support for RDF(S), OWL, and Built-ins is standard
- support for “LP-features” is not standard
- different approaches for combining ontologies with rules (next unit)

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