Modeling with Ontologies and Rules

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Part I
Ontologies and Rules
Textbook

Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph

Foundations of Semantic Web Technologies

Chapman & Hall/CRC, 2010

Choice Magazine Outstanding Academic Title 2010 (one out of seven in Information & Computer Science)

http://www.semantic-web-book.org
Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph

语义 Web 技术基础
Tsinghua University Press (清华大学出版社), 2013.

Translators:
Yong Yu, Haofeng Wang, Guilin Qi (俞勇，王昊奋，漆桂林)

http://www.semantic-web-book.org
Semantic Web journal

• EiCs: Pascal Hitzler
  Krzysztof Janowicz

• New journal with significant initial uptake.

• We very much welcome contributions at
  the “rim” of traditional Semantic Web
  research – e.g., work which is strongly
  inspired by a different field.

• Non-standard (open & transparent)
  review process.

• http://www.semantic-web-journal.net/
Currently

8 PhD students
2 Master students
3 undergrads
The Semantic Web Stack

- User Interface & applications
- Trust
  - Proof
  - Unifying Logic
    - Query: SPARQL
    - ontology: OWL
    - Rules: RIF
    - RDF-S
    - Data interchange: RDF
    - XML
    - URI
    - Unicode
  - Crypto
Contents

1. Description Logics and OWL
2. Rules expressible in description logics
3. Extending description logics with rules through nominal schemas
4. Algorithmizations for nominal schemas
5. Adding non-monotonicity
6. Conclusions
Web Ontology Language (OWL)

- W3C Recommendation since 2004
- OWL 2 since 2009

- based on description logics
- essentially, a decidable fragment of first-order predicate logic
Description Logics (DLs)

classes/concepts
  A, B, C

unary predicates
  A(x), B(X), C(x)

roles/properties
  R, S

binary predicates
  R(x,y), S(x,y)

individuals
  a, b, c

constants
  a, b, c
Some DL constructors

class conjunction

\[ C \sqcap D \rightarrow C(x) \land D(x) \]

existential restriction

\[ \exists R.C \rightarrow \exists y (R(x,y) \land C(y)) \]

class inclusion/subsumption

\[ C \subseteq D \rightarrow C(x) \rightarrow D(x) \]
\[ C \equiv D \leftrightarrow C(x) \leftrightarrow D(x) \]

role chains

\[ R_1 \circ \ldots \circ R_n \subseteq R \rightarrow R_1 (x,x_1) \land \ldots \land R(x_n,x_{n+1}) \rightarrow R(x,x_{n+1}) \]
Some DL constructors

\[
\begin{align*}
\text{ThaiDish} & \sqsubseteq \exists \text{contains.Nut} \\
\text{Nutallergic} & \sqcap \exists \text{eats.Nut} \sqsubseteq \text{Unhappy} \\
\text{eats} & \circ \text{contains} \sqsubseteq \text{eats}
\end{align*}
\]

inverse roles

\[
R \equiv S^{-} \quad R(x,y) \leftrightarrow S(y,x)
\]

This logic is already undecidable! (see e.g. [ISWC 2007])

Name of the logic: ELRI
Decidability is a central characteristic of description logics.
Retaining Decidability

1. Disallow $\exists$:  
   Essentially leads to OWL RL.  
   Fragment of Datalog.  
   Tractable (i.e., polynomial complexity).

2. Disallow inverse roles:  
   Essentially leads to OWL EL.  
   Akin “in spirit” to existential rules/Datalog+-.  
   Tractable.

3. Restrict recursion in role chains (a.k.a. *regularity* restriction):  
   With further constructors, leads to OWL DL, a.k.a. SROIQ.  
   Decidable, but not tractable.
The following can be used in OWL EL (logic remains tractable).

**Self**

\[ C \sqsubseteq \exists R. \text{Self} \quad C(x) \rightarrow R(x,x) \]

Can be used e.g. for typecasting.

**nominals**

\[ \{a\} \sqsubseteq C \quad C(a) \quad a \text{ is a constant} \]
\[ C \sqsubseteq \{a\} \quad C(x) \rightarrow x=a \]
\[ \{a\} \equiv \{b\} \quad \rightarrow a=b \]

\[ A \sqcap \exists R.\{b\} \sqsubseteq C \text{ becomes } A(x) \land R(x, b) \rightarrow C(x) \]
Further essential DL constructors

The following are used in expressive (intractable) DLs

class negation
\(-C\)
\(-C(x)\)

class disjunction
\(C \sqcup D\)
\(C(x) \lor D(x)\)

universal restriction
\(\forall R.C\)
\(\forall y (R(x,y) \rightarrow C(y))\)

There are some more of course.
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Rules in OWL

Which rules can be encoded in OWL?

\[
\begin{align*}
A \sqsubseteq B & \text{ becomes } A(x) \rightarrow B(x) \\
R \sqsubseteq S & \text{ becomes } R(x, y) \rightarrow S(x, y) \\
A \sqcap \exists R. \exists S. B \sqsubseteq C & \text{ becomes } A(x) \land R(x, y) \land S(y, z) \land B(z) \rightarrow C(x) \\
\{a\} & \equiv \{b\} \text{ becomes } \rightarrow a = b. \\
A \sqcap B \sqsubseteq \bot & \text{ becomes } A(x) \land B(x) \rightarrow f \\
R \circ S \sqsubseteq T & \text{ becomes } R(x, y) \land S(y, z) \rightarrow T(x, z) \\
A \sqcap \exists R.\{b\} \sqsubseteq C & \text{ becomes } A(x) \land R(x, b) \rightarrow C(x)
\end{align*}
\]
Rules in OWL

Which rules can be encoded in OWL?

\[ A \sqsubseteq \neg B \sqcup C \text{ becomes } A(x) \land B(x) \rightarrow C(x) \]

\[ A \sqsubseteq \forall R.B \text{ becomes } A(x) \land R(x, y) \rightarrow B(y) \]

\[ A \sqsubseteq B \land C \text{ becomes } A(x) \rightarrow B(x) \text{ and } A(x) \rightarrow C(x) \]

\[ A \sqcup B \rightarrow C \text{ becomes } A(x) \rightarrow C(x) \text{ and } B(x) \rightarrow C(x) \]
Rolification

Elephant\( (x) \land \text{Mouse}(y) \rightarrow \text{biggerThan}(x, y) \)

• Rolification of a concept \( A \): \( A \equiv \exists R_A . \text{Self} \)

\[
\begin{align*}
\text{Elephant} & \equiv \exists R_{\text{Elephant}} . \text{Self} \\
\text{Mouse} & \equiv \exists R_{\text{Mouse}} . \text{Self} \\
R_{\text{Elephant}} \circ U \circ R_{\text{Mouse}} & \subseteq \text{biggerThan}
\end{align*}
\]
Rolification

\[
A(x) \land R(x, y) \rightarrow S(x, y) \text{ becomes } R_A \circ R \sqsubseteq S
\]
\[
A(y) \land R(x, y) \rightarrow S(x, y) \text{ becomes } R \circ R_A \sqsubseteq S
\]
\[
A(x) \land B(y) \land R(x, y) \rightarrow S(x, y) \text{ becomes } R_A \circ R \circ R_B \sqsubseteq S
\]

\[
\text{Woman}(x) \land \text{marriedTo}(x, y) \land \text{Man}(y) \rightarrow \text{hasHusband}(x, y)
\]
\[
R_{\text{Woman}} \circ \text{marriedTo} \circ R_{\text{Man}} \sqsubseteq \text{hasHusband}
\]

careful – regularity of RBox needs to be retained:

\[
\text{hasHusband} \sqsubseteq \text{marriedTo}
\]
worksAt\((x, y) \land University(y) \land \text{supervises}(x, z) \land \text{PhDStudent}(z)\) 
\rightarrow \text{professorOf}(x, z)

\(R_{\exists\text{worksAt.University} \circ \text{supervises} \circ \text{PhDStudent}} \subseteq \text{professorOf.}\)
Tree-shaped rules

$$R_1(x, y) \land C_1(y) \land R_2(y, w) \land R_3(y, z) \land C_2(z) \land R_4(x, x) \rightarrow C_3(x)$$

$$\exists R_1. (C_1 \land \exists R_2. T \land \exists R_3. C_2) \land \exists R_4. Self \subseteq C_3$$
Acyclic Rules

\[ R_1(y, x) \land C_1(y) \land R_2(w, y) \land R_3(y, z) \land C_2(z) \land R_4(x, x) \rightarrow C_3(x) \]

\[ \exists R^-_1. (C_1 \sqcap \exists R^-_2. T \sqcap \exists R^-_3. C_2) \sqcap \exists R^-_4. \text{Self} \sqsubseteq C_3 \]
So how can we pinpoint this?

- Tree-shaped bodies
- First argument of the conclusion is the root

\[ C(x) \land R(x,a) \land S(x,y) \land D(y) \land T(y,a) \rightarrow E(x) \]

\[ C \cap \exists R.\{a\} \cap \exists S.\{D \cap \exists T.\{a\}\} \subseteq E \]
Rule bodies as graphs

\[ C(x) \land R(x, a) \land S(x, y) \land D(y) \land T(y, a) \rightarrow P(x, y) \]

\[ a_1 \leftarrow x \rightarrow y \rightarrow a_2 \]

\[ C \cap \exists R.\{a\} \subseteq \exists R1.\text{Self} \]
\[ D \cap \exists T.\{a\} \subseteq \exists R2.\text{Self} \]
\[ R1 \circ S \circ R2 \subseteq P \]
So how can we pinpoint this?

- Tree-shaped bodies
- First argument of the conclusion is the root

\[ C(x) \land R(x,a) \land S(x,y) \land D(y) \land T(y,a) \rightarrow V(x,y) \]

\[
\begin{align*}
C \land \exists R.\{a\} & \subseteq \exists R1.\text{Self} \\
D \land \exists T.\{a\} & \subseteq \exists R2.\text{Self} \\
R1 \circ S \circ R2 & \subseteq V
\end{align*}
\]
Formally

Definition 1. We call a rule with head $H$ tree-shaped (respectively, acyclic), if the following conditions hold.

- Each of the maximally connected components of the corresponding graph is in fact a tree (respectively, an acyclic graph)—or in other words, if it is a forest, i.e., a set of trees (respectively, a set of acyclic graphs).
- If $H$ consists of an atom $A(t)$ or $R(t, u)$, then $t$ is a root in the tree (respectively, in the acyclic graph).

\[ R(x, z) \land S(y, z) \rightarrow T(x, y) \text{ is acyclic but not tree-shaped} \]

Theorem 1. The following hold.

- Every tree-shaped rule can be expressed in $\mathbf{SROEL}$.
- Every acyclic rule can be expressed in $\mathbf{SROIEL}$.
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Rule bodies as graphs

\[
\text{hasReviewAssignment}(v, x) \land \text{hasAuthor}(x, y) \land \text{atVenue}(x, z) \\
\land \text{hasSubmittedPaper}(v, u) \land \text{hasAuthor}(u, y) \land \text{atVenue}(u, z) \\
\quad \rightarrow \text{hasConflictingAssignedPaper}(v, x)
\]

with \(y, z\) constants:

\[
R_{\exists \text{hasSubmittedPaper} \cdot (\exists \text{hasAuthor}.\{y\} \sqcap \exists \text{atVenue}.\{z\})} \circ \text{hasReviewAssignment} \\
\circ R_{\exists \text{hasAuthor}.\{y\} \sqcap \exists \text{atVenue}.\{z\}} \\
\sqsubseteq \text{hasConflictingAssignedPaper}
\]
Non-hybrid syntax: nominal schemas

\[
\begin{align*}
\text{hasReviewAssignment}(v, x) & \land \text{hasAuthor}(x, y) \land \text{atVenue}(x, z) \\
& \land \text{hasSubmittedPaper}(v, u) \land \text{hasAuthor}(u, y) \land \text{atVenue}(u, z) \\
& \rightarrow \text{hasConflictingAssignedPaper}(v, x)
\end{align*}
\]

assume \(y, z\) bind only to named individuals
we introduce a new construct, called
nominal schemas
or nominal variables

\[
R_{\exists \text{hasSubmittedPaper}. (\exists \text{hasAuthor}. \{y\} \land \exists \text{atVenue}. \{z\})} \circ \text{hasReviewAssignment}
\]
\[
\circ R_{\exists \text{hasAuthor}. \{y\} \land \exists \text{atVenue}. \{z\}} \circ \text{hasConflictingAssignedPaper}
\]
Nominal schema example 2

\[
\text{hasChild}(x, y) \land \text{hasChild}(x, z) \land \text{classmate}(y, z) \rightarrow C(x)
\]

\[
\exists \text{hasChild}.\{z\} \sqcap \exists \text{hasChild}.\exists \text{classmate}.\{z\} \sqsubseteq C
\]
Adding nominal schemas to OWL 2 DL

• Decidability is retained.
• Complexity is the same.

• A naïve implementation is straightforward:

Replace every axiom with nominal schemas by a set of OWL 2 axioms, obtained from grounding the nominal schemas.

However, this may result in a lot of new OWL 2 axioms. The naïve approach will probably only work for ontologies with few nominal schemas.
What do we gain?

- A powerful macro.
- A conceptual bridge to rule formalism:

We can actually also express all DL-safe Datalog rules!

\[ R(x, y) \land A(y) \land S(z, y) \land T(x, z) \rightarrow P(z, x) \]

\[ \exists U. (\{x\} \sqcap \exists R.\{y\}) \]
\[ \sqcap \exists U. (\{y\} \sqcap A) \]
\[ \sqcap \exists U. (\{z\} \sqcap \exists S.\{y\}) \]
\[ \sqcap \exists U. (\{x\} \sqcap \exists T.\{z\}) \]
\[ \sqsubseteq \exists U. (\{z\} \sqcap \exists P.\{x\}) \]
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## Naïve implementation – experiments

<table>
<thead>
<tr>
<th></th>
<th>No axioms added</th>
<th>1 different ns</th>
<th>2 different ns</th>
<th>3 different ns</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fam (5)</strong></td>
<td>0.01&quot;</td>
<td>0.00&quot;</td>
<td>0.01&quot;</td>
<td>0.00&quot;</td>
</tr>
<tr>
<td><strong>Swe (22)</strong></td>
<td>3.58&quot;</td>
<td>0.08&quot;</td>
<td>3.73&quot;</td>
<td>0.07&quot;</td>
</tr>
<tr>
<td><strong>Bui (42)</strong></td>
<td>2.7&quot;</td>
<td>0.16&quot;</td>
<td>2.5&quot;</td>
<td>0.15&quot;</td>
</tr>
<tr>
<td><strong>Wor (80)</strong></td>
<td>0.11”</td>
<td>0.04”</td>
<td>0.12”</td>
<td>0.05”</td>
</tr>
<tr>
<td><strong>Tra (183)</strong></td>
<td>0.05”</td>
<td>0.03”</td>
<td>0.05”</td>
<td>0.02”</td>
</tr>
<tr>
<td><strong>FTr (368)</strong></td>
<td>0.03”</td>
<td>4.28”</td>
<td>0.05</td>
<td>5.32”</td>
</tr>
<tr>
<td><strong>Eco (482)</strong></td>
<td>0.04”</td>
<td>0.24”</td>
<td>0.07”</td>
<td>0.02”</td>
</tr>
</tbody>
</table>

OOM = Out of Memory

---

from the TONES repository:

<table>
<thead>
<tr>
<th>Ontology</th>
<th>Classes</th>
<th>Data P.</th>
<th>Object P.</th>
<th>Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fam</td>
<td>4</td>
<td>1</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Swe</td>
<td>189</td>
<td>6</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>Bui</td>
<td>686</td>
<td>0</td>
<td>24</td>
<td>42</td>
</tr>
<tr>
<td>Wor</td>
<td>1842</td>
<td>0</td>
<td>31</td>
<td>80</td>
</tr>
<tr>
<td>Tra</td>
<td>445</td>
<td>4</td>
<td>89</td>
<td>183</td>
</tr>
<tr>
<td>FTr</td>
<td>22</td>
<td>6</td>
<td>52</td>
<td>368</td>
</tr>
<tr>
<td>Eco</td>
<td>339</td>
<td>8</td>
<td>45</td>
<td>482</td>
</tr>
</tbody>
</table>
Delayed grounding

- Adding nominal schemas to existing tableaux algorithms:

\[
\text{grounding} : \quad \text{if } C \in L(s), \{z\} \text{ is a nominal schema in } C,
\]
\[
C[z/a_i] \notin L(s) \text{ for some } i, 1 \leq i \leq \ell
\]
\[
\text{then } L(s) := L(s) \cup \{C[z/a_i]\}
\]

plus some restrictions on existing tableaux rules, essentially to ensure that (1) no variable binding is broken and (2) nominal schemas are not propagated through the tableau.
Further Tableaux Optimizations

• variant of absorption [Steigmiller, Glimm, Liebig, IJCAI-13]
• essentially, a sort of smart rewriting as pre-processing

Example 1: Our running example $\exists r. (\{x\} \sqcap \exists a.\{y\} \sqcap \exists v.\{z\} \sqcap \exists s. (\exists a.\{y\} \sqcap \exists v.\{z\}) \sqsubseteq \exists c.\{x\}$ can be almost completely absorbed into the following axioms:

\[
\begin{align*}
O &\sqsubseteq \downarrow x.T_x \\
T_z &\sqsubseteq \forall v^-.T_2 \\
(T_1 \sqcap T_2) &\sqsubseteq T_3 \\
O &\sqsubseteq \downarrow y.T_y \\
T_3 &\sqsubseteq \forall s^-.T_4 \\
(T_3 \sqcap T_x) &\sqsubseteq T_5 \\
O &\sqsubseteq \downarrow z.T_z \\
T_5 &\sqsubseteq \forall r^-.T_6 \\
(T_4 \sqcap T_6) &\sqsubseteq T_7 \\
T_y &\subseteq \forall a^- .T_1 \\
T_7 &\subseteq gr(\exists c.\{x\}) ,
\end{align*}
\]

where $T_x, T_y, T_z, T_1, \ldots, T_7$ are fresh atomic concepts. Only $\exists c.\{x\}$ cannot be absorbed and has to be grounded on demand.
**Further Tableaux Optimizations**

[Steigmiller, Glimm, Liebig, IJCAI-13]

### Table 2: DL-safe Rules for UOBM-Benchmarks

<table>
<thead>
<tr>
<th>Name</th>
<th>DL-safe Rule</th>
<th>Matches</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td><code>isFiredOff(?x, ?y), like(?x, ?z), like(?y, ?z) → hasLink1(?x, ?y)</code></td>
<td>4,037</td>
</tr>
<tr>
<td>R2</td>
<td><code>isFiredOff(?x, ?y), takesCourse(?x, ?z), takesCourse(?y, ?z) → hasLink2(?x, ?y)</code></td>
<td>82</td>
</tr>
<tr>
<td>R3</td>
<td><code>takesCourse(?x, ?z), takesCourse(?y, ?z), hasSameHomeTownWith(?x, ?y) → hasLink3(?x, ?y)</code></td>
<td>940</td>
</tr>
<tr>
<td>R4</td>
<td><code>hasDoctoralDegreeFrom(?x, ?z), hasMasterDegreeFrom(?x, ?w), hasDoctoralDegreeFrom(?y, ?z), hasMasterDegreeFrom(?y, ?w), worksFor(?x, ?v), worksFor(?y, ?v), → hasLink4(?x, ?y)</code></td>
<td>369</td>
</tr>
<tr>
<td>R5</td>
<td><code>isAdvisedBy(?x, ?z), isAdvisedBy(?y, ?z), like(?x, ?w), like(?y, ?w), like(?z, ?w) → hasLink5(?x, ?y)</code></td>
<td>286</td>
</tr>
</tbody>
</table>

### Table 3: Comparison of the increases in reasoning time of the consistency tests for UOBM₁\D extended by rules in seconds

<table>
<thead>
<tr>
<th>Rule</th>
<th>upfront grounding</th>
<th>direct propagation</th>
<th>representative propagation</th>
<th>HermiT</th>
<th>Pellet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mem</td>
<td>without BC</td>
<td>with BC</td>
<td>without BC</td>
<td>with BC</td>
</tr>
<tr>
<td>R1</td>
<td>(10.99)</td>
<td>9.12</td>
<td>7.10</td>
<td>5.06</td>
<td>3.38</td>
</tr>
<tr>
<td>R2</td>
<td>(10.92)</td>
<td>4.05</td>
<td>3.33</td>
<td>2.33</td>
<td>2.11</td>
</tr>
<tr>
<td>R3</td>
<td>(13.33)</td>
<td>3.55</td>
<td>1.98</td>
<td>0.62</td>
<td>2.20</td>
</tr>
<tr>
<td>R4</td>
<td>(16.44)</td>
<td>0.30</td>
<td>1.08</td>
<td>0.09</td>
<td>1.06</td>
</tr>
<tr>
<td>R5</td>
<td>(time)</td>
<td>–</td>
<td>1.87</td>
<td>0.50</td>
<td>1.80</td>
</tr>
</tbody>
</table>

Wright State University

November 2013 – STIDS’13 – Pascal Hitzler
Algorithm for ELROVn

Based on [Krötzsch, JELIA10]

<table>
<thead>
<tr>
<th>Ontology</th>
<th>Individuals</th>
<th>no ns</th>
<th>1 ns</th>
<th>2 ns</th>
<th>3 ns</th>
<th>4 ns</th>
<th>5 ns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rex (full ground.)</td>
<td>100</td>
<td>263</td>
<td>263 (321)</td>
<td>267 (972)</td>
<td>273</td>
<td>275</td>
<td>259</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>480</td>
<td>518 (1753)</td>
<td>537 (OOM)</td>
<td>538</td>
<td>545</td>
<td>552</td>
</tr>
<tr>
<td></td>
<td>10000</td>
<td>2904</td>
<td>2901 (133179)</td>
<td>3120 (OOM)</td>
<td>3165</td>
<td>3192</td>
<td>3296</td>
</tr>
<tr>
<td>Spatial (full ground.)</td>
<td>100</td>
<td>22</td>
<td>191 (222)</td>
<td>201 (1163)</td>
<td>198</td>
<td>202</td>
<td>207</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>134</td>
<td>417 (1392)</td>
<td>415 (OOM)</td>
<td>421</td>
<td>431</td>
<td>432</td>
</tr>
<tr>
<td></td>
<td>10000</td>
<td>1322</td>
<td>1792 (96437)</td>
<td>1817 (OOM)</td>
<td>1915</td>
<td>1888</td>
<td>1997</td>
</tr>
<tr>
<td>Xenopus (full ground.)</td>
<td>100</td>
<td>62</td>
<td>332 (383)</td>
<td>284 (1629)</td>
<td>311</td>
<td>288</td>
<td>280</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>193</td>
<td>538 (4751)</td>
<td>440 (OOM)</td>
<td>430</td>
<td>456</td>
<td>475</td>
</tr>
<tr>
<td></td>
<td>10000</td>
<td>1771</td>
<td>2119 (319013)</td>
<td>1843 (OOM)</td>
<td>1886</td>
<td>2038</td>
<td>2102</td>
</tr>
</tbody>
</table>
Approximating OWL through ELROVn

- We rewrite mincardinality restrictions into maxcardinality restrictions or approximate using an existential.
- We rewrite universal quantification into existential quantification.
- We approximate maxcardinality restrictions using functionality.
- We approximate inverse roles and functionality using nominal schemas.
- We approximate negation using class disjointness.
- We approximate disjunction using conjunction.

- **inverses:**
  \[ \{x\} \cap \exists R. \{y\} \subseteq \{y\} \cap \exists S. \{x\} \]

- **functionality**
  \[ C \subseteq 1R.D \]
  \[ C \cap \exists R. (\{z1\} \cap D) \cap \exists R. (\{z2\} \cap D) \subseteq \exists U. (\{z1\} \cap \{z2\}) \]
### Approximation results (using IRIS)

<table>
<thead>
<tr>
<th>Ontology</th>
<th>HermiT</th>
<th>Fact++</th>
<th>Pellet</th>
<th>Ours</th>
<th>Ours Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAMS</td>
<td>3</td>
<td>2</td>
<td>10</td>
<td>107</td>
<td>100%</td>
</tr>
<tr>
<td>DOLCE</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>53</td>
<td>100%</td>
</tr>
<tr>
<td>GALEN</td>
<td>4</td>
<td>2</td>
<td>17</td>
<td>7840</td>
<td>90.8%</td>
</tr>
<tr>
<td>GO</td>
<td>36</td>
<td>75</td>
<td>59</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>GardinerCorpus</td>
<td>14</td>
<td>6</td>
<td>17</td>
<td>89</td>
<td>92.3%</td>
</tr>
<tr>
<td>OBO</td>
<td>34</td>
<td>61</td>
<td>139</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Contents

1. Initial examples
2. Rules expressible in description logics
3. Extending description logics with rules through nominal schemas
4. Algorithmizations for nominal schemas
5. Adding non-monotonicity
6. Conclusions
Adding non-monotonicity

- [Knorr, Hitzler, Maier ECAI2012]

- Extension of an autoepistemic description logic approach by nominal schemas.
- Results in a language which incorporates most of the major approaches to non-monotonic extensions of DLs.
- E.g. covers
  - hybrid MKNF [Motik & Rosati], which in turn covers
  - non-disjunctive ASP
  - DL Programs / dlvhex (Eiter et al.)
- Also covers OWL / SROIQ(D) of course.
Conclusions

• Paradigms are converging.

• More work needed e.g. re.
  – algorithmizations
  – relating OWL EL and existential rules research
  – making non-monotonic reasoning fit for semantic web applications
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References

A tutorial:


Background reading:

References


References


References


References


References

- Benjamin N. Grosof, Ian Horrocks, Raphael Volz, Stefan Decker: Description logic programs: combining logic programs with description logic. WWW 2003: 48-57
References