

Object-Oriented RuleML for RDF: Facts, Queries, and Inferences

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www.w3.org/RDF

www.ruleml.org

www.daml.org/committee

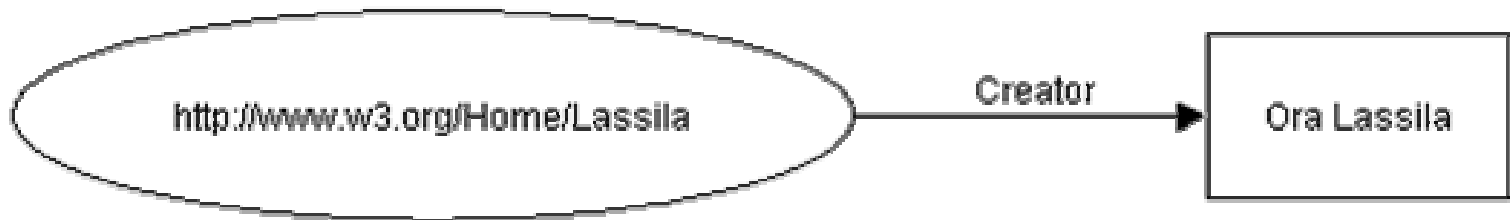
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Introduction

- Increased mutual RuleML-RDF(S) integration:
 - A. RDF(S) needs **rules** for query, inference, transformation
 - B. RuleML rules need alternative **syntactic encodings** in RDF and OWL
 - C. RuleML and OWL overlap as KRs: Description Logic Programs
 - D. RuleML variables need **types**: URIrefs to RDFS/OWL classes
- **re A.** Object-oriented RuleML is useable as an RDF query, inference, and transformation language:
 1. Rules over generic **positional (triple-like)** facts: 2001
 2. Rules over richer generic **object-oriented** facts: 2003
 3. **Queries and inferences** (conjunctive) over OO facts (linked via named – or anonymous/blank – nodes)
 4. Queries and inferences over OO facts with **bNode-embedded descriptions**

The 'First RDF Graph'

How to serialize this RDF graph (from [M&S](#)):



RDF Triples as Positional Facts

- *RDF triples* map to *positional facts*, where
the **Property** maps to a binary **relation**,
the **Subject** to its **first argument**, and
the **Object** to its **second argument**

"<http://www.w3.org/Home/Lassila> has creator Ora Lassila"

```
<fact>
<_head>
  <atom>
    <_opr>
      <rel href="http://dublincore.org/documents/dces/index.shtml.rdf#Creator"/>
    </_opr>
    <ind href="http://www.w3.org/Home/Lassila"/>
    <ind>Ora Lassila</ind>
  </atom>
</_head>
</fact>
```

_head : (system) role

RDF RuleML: Triple Roundtrip

Turn the **has creator** triple, as a RuleML rulebase, again into RDF:

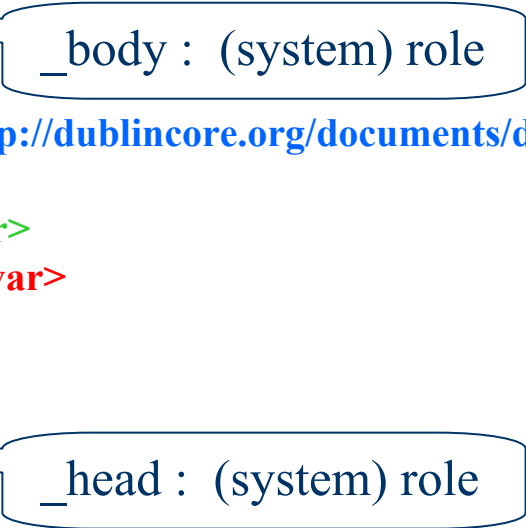
```
<rdf:RDF xmlns:rdf="&rdf;" xmlns:ruleml="&ruleml;" xmlns="&ruleml;">
<rulebase>
  <_clauses>
    <rdf:Seq>
      <rdf:li>
        <fact>
          <_head>
            <atom>
              <_opr> <rel href="http://dublincore.org/documents/dces/index.shtml.rdf#Creator"/> </_opr>
              <_arg>
                <rdf:Seq>
                  <rdf:li> <ind href="http://www.w3.org/Home/Lassila"/> </rdf:li>
                  <rdf:li> <ind ruleml:cdata="Ora Lassila"/> </rdf:li>
                </rdf:Seq>
              </_arg>
            </atom>
          </_head>
        </fact>
      </rdf:li>
    </rdf:Seq>
  </_clauses>
</rulebase>
</rdf:RDF>
```

RDF/RuleML Rules Over Positional Facts

- *RDF/RuleML rules over positional (triple-like) facts* derive new triples, bottom-up, or prove queried triples, top-down

IF "*Page* has creator *Person*" THEN "*Page* was accessed by *Person*"

```
<imp>
  <_body>
    <atom>
      <_opr>
        <rel href="http://dublincore.org/documents/dces/index.shtml.rdf#Creator"/>
      </_opr>
      <var>Page</var>
      <var>Person</var>
    </atom>
  </_body>
  <_head>
    <atom>
      <_opr>
        <rel href="http://logging.org/vocabulary/xyz.rdf#Accessed"/>
      </_opr>
      <var>Page</var>
      <var>Person</var>
    </atom>
  </_head>
</imp>
```



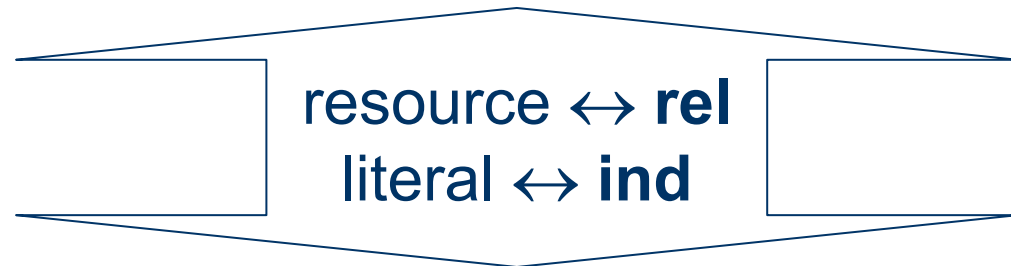
RDF Descriptions as Object-Oriented Facts

- *Object-Oriented RuleML* has been implemented as an extension of, and XSLT translator to, *Positional RuleML*
- *RDF descriptions* map to *object-oriented facts*, where
 - the **Subject** maps to a **relation** (cf. rel.DB tuples),
 - each **Property** maps to a **role**, and
 - each **Object** maps to its **filler**
- The ‘First RDF Triple’ above becomes the RDF/XML **about** description on the following slide
- This maps to an object-oriented RDF/RuleML fact with a **uriref**-attributed empty **rel** shown underneath

```

<rdf:RDF>
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:s="http://dublincore.org/documents/dces/index.shtml.rdf">
  <rdf:Description about="http://www.w3.org/Home/Lassila">
    <s:Creator>Ora Lassila</s:Creator>
  </rdf:Description>
</rdf:RDF>

```



```

<ruleml:rulebase>
  xmlns:ruleml="http://www.ruleml.org/dtd/0.83/ruleml-oodatalog.dtd"
  xmlns:s="http://dublincore.org/documents/dces/index.shtml.rdf">
  <fact>
    <_head>
      <atom>
        <_opr><rel uriref="http://www.w3.org/Home/Lassila"/></_opr>
        <_r n="s:Creator"><ind>Ora Lassila</ind></_r>
      </atom>
    </_head>
  </fact>
</ruleml:rulebase>

```

r : (meta) role
n : (user) name

RDF Types in Object-Oriented RuleML

- The use of a QName in an *attribute value* such as the above **s:Creator** in **n="s:Creator"** has been discussed in [TAG Finding 25 Jul 2002](#)
- This has been extended to a QName in *element content* such as **t:Person** in **<rel ...>t:Person</rel>**, which provides one way to express RDF types in Object-Oriented RuleML
- *Typed RDF descriptions* map to *object-oriented facts*, where the **rdf:type (abbreviation)** maps to a **(non-empty) relation**
 - The earlier RDF/XML description is typed (abbreviated) via a **t:Person** tag in the following slide
 - This maps to an object-oriented RDF/RuleML fact typed via **t:Person** content, shown underneath

```

<rdf:RDF>
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:s="http://dublincore.org/documents/dces/index.shtml.rdf"
  xmlns:t="http://description.org/schema/">
  <t:Person about="http://www.w3.org/Home/Lassila">
    <s:Creator>Ora Lassila</s:Creator>
  </t:Person>
</rdf:RDF>

```

```

<ruleml:rulebase>
  xmlns:ruleml="http://www.ruleml.org/dtd/0.83/ruleml-oodatalog.dtd"
  xmlns:s="http://dublincore.org/documents/dces/index.shtml.rdf"
  xmlns:t="http://description.org/schema/">
  <fact>
    <_head>
      <atom>
        <_opr>
          <rel uriref="http://www.w3.org/Home/Lassila">t:Person</rel>
        </_opr>
        <_r n="s:Creator"><ind>Ora Lassila</ind></_r>
      </atom>
    </_head>
  </fact>
</ruleml:rulebase>

```

RDF/RuleML Rules Over Object-Oriented Facts

- *RDF/RuleML rules over object-oriented facts can prove queried descriptions or derive new description-like facts*

```
<ruleml:rulebase>
  <imp>
    <_body>
      <atom>
        <_opr><var>Page</var></_opr>
        <_r n="s:Creator"><var>Person</var></_r>
      </atom>
    </_body>
    <_head>
      <atom>
        <_opr><var>Page</var></_opr>
        <_r n="t:Accessed"><var>Person</var></_r>
      </atom>
    </_head>
  </imp>
</ruleml:rulebase>
```

IF

*"Page
has creator Person"*

THEN

*"Page
was accessed by Person"*

OO RuleML and RDF

Bottom-Up: RDF/RuleML Derivations of Object-Oriented Facts

- RDF/RuleML rule over above object-oriented fact *derives* a new description in bottom-up / forward manner

```
<ruleml:rulebase>
```

```
<fact>
```

```
<_head>
```

```
<atom>
```

```
<_opr><rel uriref="http://www.w3.org/Home/Lassila"/></_opr>
```

```
<_r n="s:Creator"><ind>Ora Lassila</ind></_r>
```

```
</atom>
```

```
</_head>
```

```
</fact>
```

```
<fact>
```

```
<_head>
```

```
<atom>
```

```
<_opr><rel uriref="http://www.w3.org/Home/Lassila"/></_opr>
```

```
<_r n="s:Accessed"><ind>Ora Lassila</ind></_r>
```

```
</atom>
```

```
</_head>
```

```
</fact>
```

```
</ruleml:rulebase>
```

derives

new

Top-Down: RDF/RuleML Queries Over Object-Oriented Facts

- RDF/RuleML rule over above object-oriented fact *proves a queried description* in top-down / backward manner

<ruleml:query>

WHICH

<_body>

<atom>

<_opr><var>Page</var></_opr>

"Page

<_r n="t:Accessed"><var>Person</var></_r>

was accessed by Person"

</atom>

</_body>

</ruleml:query>

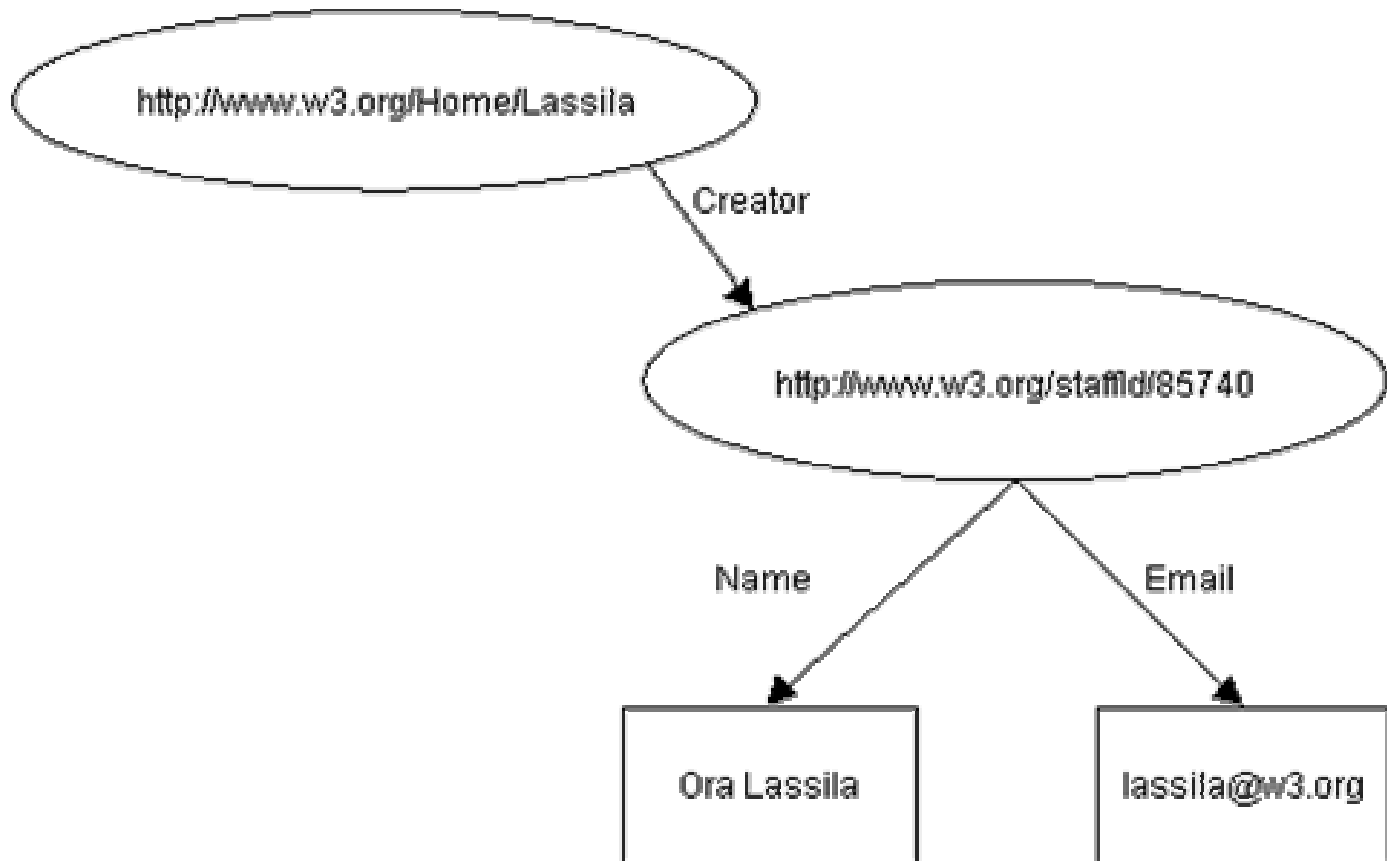
?

binds <var>Page</var> to <rel uriref="http://www.w3.org/Home/Lassila"/>

and <var>Person</var> to <ind>Ora Lassila</ind>

Intermediate Nodes for RDF Descriptions and Object-Oriented Facts

How to serialize this RDF graph (from [M&S](#)):



Intermediate Nodes for RDF Descriptions and Object-Oriented Facts (Cont'd)

- *RDF descriptions* and *object-oriented facts* can employ **named** intermediate nodes (e.g., staff IDs – as from a corporate relational DB – used as URIrefs)
 - The following classical two RDF/XML descriptions link Ora's homepage with his staff ID as a named intermediate node <http://www.w3.org/staffId/85740>, which gives further information via literals
 - These map to two object-oriented RDF/RuleML facts linked in the same fashion, shown interleaved: Both the RDF attributes `about` and `resource` map to the RuleML attribute `uriref` (to allow `rel` unification)

```
<ruleml:rulebase>
  <fact>
    <_head>
      <atom>
        <_opr><rel uriref="http://www.w3.org/Home/Lassila"/></_opr>
        <_r n="s:Creator"><rel uriref="http://www.w3.org/staffId/85740"/></_r>
      </atom>
    </_head>
  </fact>

  <fact>
    <_head>
      <atom>
        <_opr><rel uriref="http://www.w3.org/staffId/85740"/></_opr>
        <_r n="v:Name"><ind>Ora Lassila</ind></_r>
        <_r n="v:Email"><ind>lassila@w3.org</ind></_r>
      </atom>
    </_head>
  </fact>
</ruleml:rulebase>
```

```
<rdf:RDF>
  <rdf:Description about="http://www.w3.org/Home/Lassila">
    <s:Creator rdf:resource="http://www.w3.org/staffId/85740"/>
  </rdf:Description>
```

```
<rdf:Description about="http://www.w3.org/staffId/85740">
  <v:Name>Ora Lassila</v:Name>
  <v:Email>lassila@w3.org</v:Email>
</rdf:Description>
</rdf:RDF>
```

roles 'build in'
commutativity

Conjunctive RDF/RuleML Queries Over Object-Oriented Node-Linked Facts

- *Conjunctive RDF/RuleML query of object-oriented facts allows a (relational-like) join over a link variable*

<ruleml:query>

WHAT IS

<_body>

<and>

".../ *Home/Lassila*

<atom>

<_opr><rel uriref="http://www.w3.org/Home/Lassila"/></_opr>

<_r n="s:Creator"><var>ID</var></_r>

Creator's ID"

</atom>

<atom>

AND

<_opr><var>ID</var></_opr>

"*that ID's*

<_r n="v:Name"><var>N</var></_r>

Name N

<_r n="v:Email"><var>E</var></_r>

Email E"

</atom>

</and>

</_body>

?

</ruleml:query>

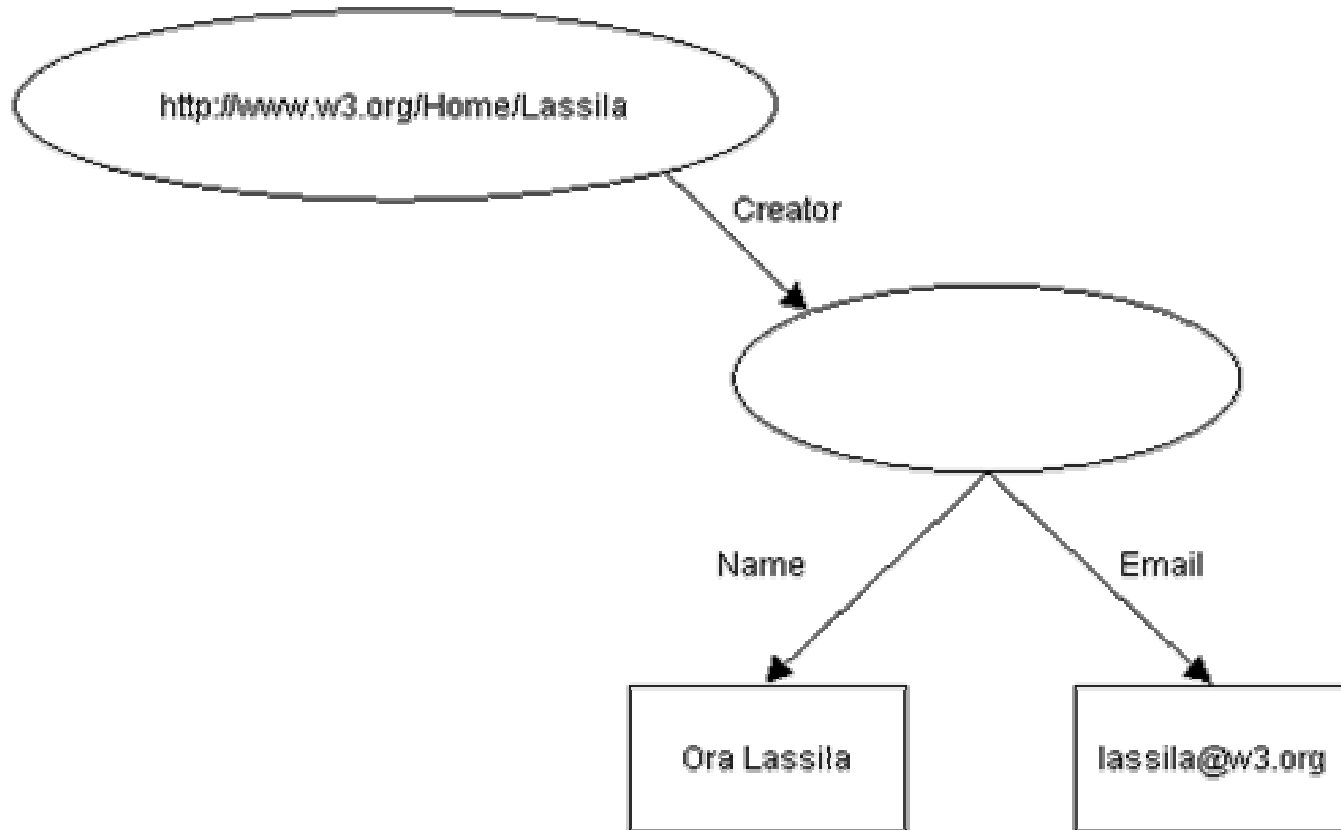
binds <var>ID</var> to <rel uriref="http://www.w3.org/staffId/85740"/>

and <var>N</var> to <ind>Ora Lassila</ind>

and <var>E</var> to <ind>lassila@w3.org</ind>

Blank Nodes in RDF Descriptions and Object-Oriented Facts

How to serialize this RDF graph (from [M&S](#)):



Blank Nodes in RDF Descriptions and Object-Oriented Facts (Cont'd)

- *RDF descriptions and object-oriented facts* can employ **anonymous (blank)** intermediate nodes (as implicit in RDF's most abbreviated 'purely striped' syntax)
 - The following RDF/XML description embeds
 - in Ora's homepage – a blank intermediate node, which gives two bits of literal information
 - This maps to an object-oriented RDF/RuleML fact embedding an object-oriented cterm in a similar way, shown underneath

```

<ruleml:rulebase>
  <fact>
    <_head>
      <atom>
        <_opr><rel uriref="http://www.w3.org/Home/Lassila"/></_opr>
        <_r n="s:Creator">
          <cterm>
            <_opc><ctor/></_opc>
            <_r n="v:Name"><ind>Ora Lassila</ind></_r>
            <_r n="v:Email"><ind>lassila@w3.org</ind></_r>
          </cterm>
        </_r>
      </atom>
    </_head>
  </fact>
</ruleml:rulebase>

```

```

<rdf:RDF>
  <rdf:Description about="http://www.w3.org/Home/Lassila">
    <s:Creator>
      <rdf:Description>
        <v:Name>Ora Lassila</v:Name>
        <v:Email>lassila@w3.org</v:Email>
      </rdf:Description>
    </s:Creator>
  </rdf:Description>
</rdf:RDF>

```

RDF/RuleML Rules Over Object-Oriented Facts with bNode-Embedded Descriptions

- *RDF/RuleML rules over object-oriented facts can also prove queried descriptions with embedded descriptions*

```
<ruleml:rulebase>
  <imp>
    <_body>
      <atom>
        <_opr><var>Page</var></_opr>
        <_r n="s:Creator"><var>descr</var></_r>
      </atom>
    </_body>
    <_head>
      <atom>
        <_opr><var>Page</var></_opr>
        <_r n="t:Accessed"><var>descr</var></_r>
      </atom>
    </_head>
  </imp>
</ruleml:rulebase>
```

IF

*"Page
has creator descr"*

THEN

*"Page
was accessed by descr"*

RDF/RuleML Queries Over Object-Oriented Facts with bNode-Embedded Descriptions

- RDF/RuleML rule over above object-oriented fact *proves a queried description with an embedded description*

<ruleml:query>

<_body>

<atom>

<_opr><var>Page</var></_opr>

<_r n="t:Accessed"><var>descr</var></_r>

</atom>

</_body>

</ruleml:query>

WHICH

"Page
was accessed by descr"

?

binds <var>Page</var> to <rel uriref="http://www.w3.org/Home/Lassila"/>
and <var>descr</var> to

<cterm>

<_opc><ctor/></_opc>

<_r n="v:Name"><ind>Ora Lassila</ind></_r>

<_r n="v:Email"><ind>lassila@w3.org</ind></_r>

</cterm>

OO RuleML and RDF

Conclusions

- RDF mapped to Object-Oriented RuleML:
resource → **rel** element with a `uriref` attribute
literal → **ind** element (*then mapped to RDF*)
- Object-oriented **queries** can
 - employ **resource-linked variables** in conjunctions
 - invoke object-oriented rules in a **backward** manner
- **Object-oriented rules** can also be invoked in a **forward** manner to derive new OO facts, e.g. using *CommonRules*, *j-DREW*, *Jess*, or *cwm*
- Handle **bNodes** in **RDF trees**: via embedding;
in general **RDF graphs**: via generated URIs
- Model theory can build on RuleML's **RDF-XML-integrating data model**: via F-Logic or TRIPLE

References

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