The Integrated PSOA RuleML for Interoperating SQL Relations and SPARQL Graphs

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Introduction: Two Orthogonal Dimensions

Generally, relational vs. graph distinction based on two orthogonal dimensions, creating system of four quadrants

Object-relational integration achieved by permitting atom to be

- **predicate-centered** (without OID) or **object-centered** (with OID) – every OID being typed by predicate as its class – and, orthogonally,
  - predicate’s arguments to be **positional** (sequence), **slotted** (bag of pairs), or **both** (positional-plus-slotted combination)
Atoms resulting from orthogonal system are **positional-slotted, object-applicative (psoa)**

Can be used in six ways, as shown in *psoa table* (quadrants 1. to 4. expanded by combined options 5., 6.):

<table>
<thead>
<tr>
<th>positional</th>
<th>predicate-centered</th>
<th>object-centered</th>
</tr>
</thead>
<tbody>
<tr>
<td>positional</td>
<td>1. relationships</td>
<td>2. shelves</td>
</tr>
<tr>
<td>slotted</td>
<td>3. pairships</td>
<td>4. frames</td>
</tr>
<tr>
<td>positional+slotted</td>
<td>5. relpairships</td>
<td>6. shelframes</td>
</tr>
</tbody>
</table>

Of six options, positional data widely used under names like ‘tuples’, ‘vectors’, ‘lists’, and (1D) ‘arrays’ (mostly 1.)

Likewise, slotted data include ‘objects’, ‘records’, ‘maps’, and ‘property lists’ (usually 4.)
**Relationships** represent n-ary positional information \((n \geq 0)\)

In Grailog, relationship becomes **directed hyperarc**, depicted as: arrow shaft starting at labelnode for relation name or at branch line, cutting through labelnodes for n-1 initial arguments in order they occur, ending with arrow head at labelnode for n\(^{th}\) argument

Sample Grailog figures visualize 3-ary relational betweenness with hyperarcs for two relationships applying relation name `betweenRel` to three argument individuals
Grailog-style visualization syntax (without branch lines):

Grailog-style visualization syntax (with branch lines):
POSL-like presentation syntax:
  betweenRel(pacific, canada, atlantic).
  betweenRel(canada, usa, mexico).

RIF-like presentation syntax:
  betweenRel(pacific, canada, atlantic)
  betweenRel(canada, usa, mexico)
Data Model: Shelves
– Object-Centered, Positional Atoms

- **Shelves** describe an OID with *n* positional arguments (n≥0)
- A shelf thus endows *n*-tuple with OID, typed by relation/class, keeping positional representation of *n*-ary relationships
- Sample Grailog figure visualizes two OIDs, \(a_1\) and \(a_2\), typed by relation/class name \(betweenObjRel\), and two 3-tuples with three individuals as arguments
Grailog-style visualization syntax:

betweenObjRel

POSIL-like presentation syntax:

betweenObjRel(a1^pacific, canada, atlantic).
betweenObjRel(a2^canada, usa, mexico).

RIF-like presentation syntax:

a1#betweenObjRel(pacific canada atlantic)
a2#betweenObjRel(canada usa mexico)
Pairships apply a relation/class to n slots: non-positional attribute-value pairs (n \geq 0)

In Grailog, pairship is depicted as relation/class node pointing, with unary hyperarc, to branch line having n outgoing circle-shaft slot arrows, using: label for attribute, target node for value

Sample Grailog figure visualizes 3-slot betweenness of two pairships that apply relation name betweenObj to branch line for three slots, with labels outer1, inner, and outer2, targeting three individuals as values.
Grailog-style visualization syntax:

betweenObj

POSSL-like presentation syntax:

betweenObj(outer1->pacific; inner->canada; outer2->atlantic).
betweenObj(outer1->canada; inner->usa; outer2->mexico).

RIF-like presentation syntax:

betweenObj(outer1->pacific inner->canada outer2->atlantic)
betweenObj(outer1->canada inner->usa outer2->mexico)
Data Model: Frames
– Object-Centered, Slotted Atoms

- **Frames** describe OID using n non-positional attribute-value pairs or **slots** \((n \geq 0)\), with kind of object becoming OID-typing class name.
- In Grailog, frame is depicted as **typing** relation/class node pointing, with unary hyperarc, to central OID node having n outgoing bullet-shaft slot arrows, using: label for attribute, target node for value.
- Sample Grailog figure visualizes object-centered 3-slot betweenness with central nodes, \(b1\) and \(b2\), for OIDs of two frames typed by relation name **betweenObj**, and three slots, with labels **outer1**, **inner**, and **outer2**, targeting three individuals as values.
Grailog-style visualization syntax:

```
betweenObj
```

POSL-like presentation syntax:

```
betweenObj(b1^outer1->pacific; inner->canada; outer2->atlantic).
betweenObj(b2^outer1->canada; inner->usa; outer2->mexico).
```

RIF-like presentation syntax:

```
b1#betweenObj(outer1->pacific inner->canada outer2->atlantic)
b2#betweenObj(outer1->canada inner->usa outer2->mexico)
```
Suppose you are working on project using **SQL queries over relational data** and then proceeding to **SPARQL queries over graph data** to be used as metadata repository.

Or, vice versa, on project complementing SPARQL with SQL for querying evolving mass-data store.

Or, on project using SQL and SPARQL from the beginning.

In all of these projects, **object-relational interoperability issues** may arise.

Hence use case on **bidirectional SQL-PSOA-SPARQL transformation (schema/ontology mapping)** for interoperability.

Core transformation between relational and object-centered paradigms is expressed in language-internal manner within PSOA RuleML itself.
Use case represents **addresses as (flat) relational facts and as – subaddress-containing – (nested) object-centered facts**, as shown for Seminaris address below

- Earlier (flat and nested) positional versions have been used to explain XML-to-XML transformation
- Later, similar use case was employed to demonstrate SPINMap for RDF-to-RDF transformation

**OID-conclusion direction of implication from relational to object-centered (frame) paradigm** is given as first rule below

**OID-condition direction from object-centered (frame) to relational paradigm** is given as second rule
addressRel("Seminaris" "Takustr. 39" "14195 Berlin")
% relational fact

r1#addressObj(name->"Seminaris" % object-centered fact
place->r2#placeObj(street->"Takustr. 39"
town->"14195 Berlin"))

Forall ?Name ?Street ?Town ( % OID-conclusion rule
   Exists ?O1 ?O2 ( ?O1#addressObj(
      name->?Name
      place->?O2#placeObj(street->?Street
town->?Town)) ) :-
      addressRel(?Name ?Street ?Town)
)

Forall ?Name ?Street ?Town ?O1 ?O2 ( % OID-condition rule
   addressRel(?Name ?Street ?Town) :-
   ?O1#addressObj(name->?Name
   place->?O2#placeObj(street->?Street
town->?Town))
)
Besides directly retrieving relational fact, OID-condition rule and object-centered fact can be used for **derivation of relational queries** as follows (corresponding to **RDF-to-RDB data mapping** direction):

\[
\text{addressRel("Seminaris" \ ?S "14195 Berlin")}
\]

\[
?O1\#addressObj(\text{name-"Seminaris"} \ \text{place-}\ ?O2\#placeObj(\text{street-}\ ?S \ \text{town-"14195 Berlin"}))
\]

\[
?S = "Takustr. 39"
\]
Besides directly retrieving object-centered fact, OID-conclusion rule and relational fact can be used for **derivation of object-centered queries** as follows (corresponding to **RDB-to-RDF data mapping** direction):

```
?O1#addressObj(name->"Seminaris"
               place->?O2#placeObj(
               street->?S
town->"14195 Berlin")
addressRel("Seminaris" ?S "14195 Berlin")

?O1 = skolem5("Seminaris" "Takustr. 39" "14195 Berlin")
?O2 = skolem6("Seminaris" "Takustr. 39" "14195 Berlin")
?S = "Takustr. 39"
```
If object-centered PSOA RuleML fact is replaced by corresponding RDF triple facts, OID-condition PSOA RuleML rule can also be used for language-internal transformation of SQL-like queries to SPARQL-like queries as shown shortly.

‘Neutral’ column headings $\text{Col}i$, with $1 \leq i \leq 3$, are used to avoid providing slot-name-like information, thus keeping SQL purely positional.

Paradigm-crossing translation step is done by OID-condition rule completely within PSOA RuleML, starting at SQL queries “lifted” to PSOA and ending at SPARQL queries “dropped” from PSOA.
SELECT * FROM addressRel
WHERE Col1='Seminaris'

addressRel("Seminaris" ?S ?T) % PSOA

?O1#addressObj(name->"Seminaris"
    place->?O2#placeObj(street->?S
town->?T))

SELECT ?S ?T # SPARQL
WHERE {?O1 rdf:type addressObj. ?O1 name "Seminaris".
    ?O2 town ?T.}

?S = "Takustr. 39"
?T = "14195 Berlin"
If relational PSOA RuleML fact is replaced by corresponding SQL table row, OID-conclusion PSOA RuleML rule can be used for language-internal transformation of SPARQL-like queries to SQL-like queries as shown shortly.

Paradigm-crossing translation step is done by OID-conclusion rule completely within PSOA RuleML.
SELECT ?S ?T  
WHERE {?O1 rdf:type addressObj. ?O1 name "Seminaris".  
    ?O2 town ?T.}  

?O1#addressObj(name->"Seminaris" 
    place->?O2#placeObj(street->?S 
    town->?T))  

addressRel("Seminaris" ?S ?T)  

SELECT * FROM addressRel  
WHERE Col1='Seminaris'  

?S = "Takustr. 39"  
?T = "14195 Berlin"