Publishing geospatial information as RDF graphs

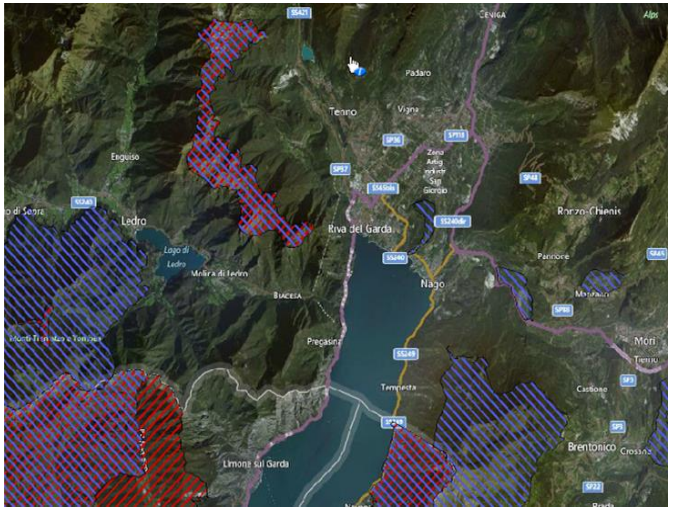
Kostis Kyzirakos, Dimitrianos Savva

HELLENIC REPUBLIC
National and Kapodistrian University of Athens

Outline

- Mapping relational data to RDF graphs
- Mapping non-relational data to RDF graphs
- Geospatial Extensions for mapping geospatial data to RDF graphs
- Implemented Systems
- Demonstration

Mapping relational data to RDF graphs

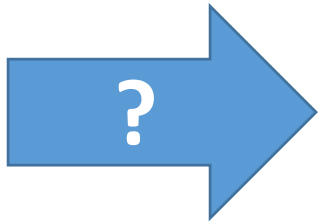


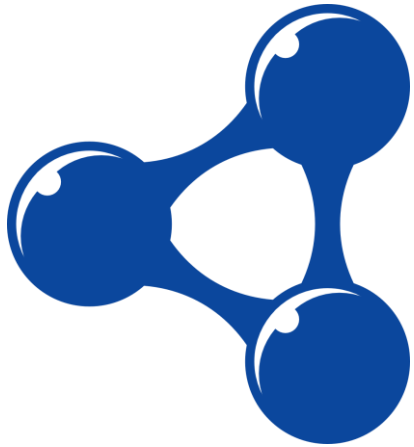
Natura 2000 is an ecological network designated under the Birds Directive and the Habitats Directive which form the cornerstone of the nature conservation policy of the European Union.

http://ec.europa.eu/environment/nature/natura2000/index_en.htm
http://www.eea.europa.eu/data-and-maps/data/natura-6

ProtectedArea

Sitecode	Sitename	ReleaseDate	..
DE0916391	NTP S-H W	2011-01-27	
DE1003301	DOGGERB ANK	2011-01-27	





Direct Mapping

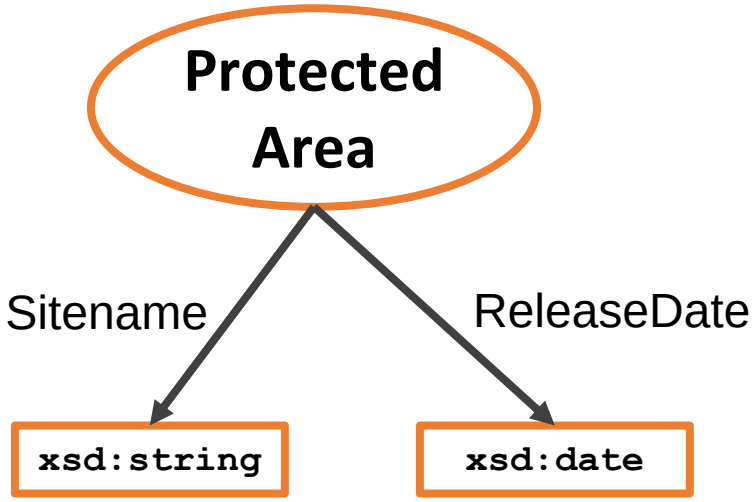
W3C Recommendation from 2012
http://www.w3.org/TR/rdb-direct-mapping/

- Relational **tables** are mapped to **classes** defined by an RDF vocabulary.
- **Attributes** of each table are mapped to RDF **properties** that represent the relation between subject and object resources.
- **Identifiers**, class **names**, **properties** and **instances** are **generated automatically** following the labels of the input data.

Direct Mapping - Example

ProtectedArea

Sitecode	Sitename	ReleaseDate	..
DE0916391	NTP S-H W	2011-01-27	
DE1003301	DOGGERBANK	2011-01-27	

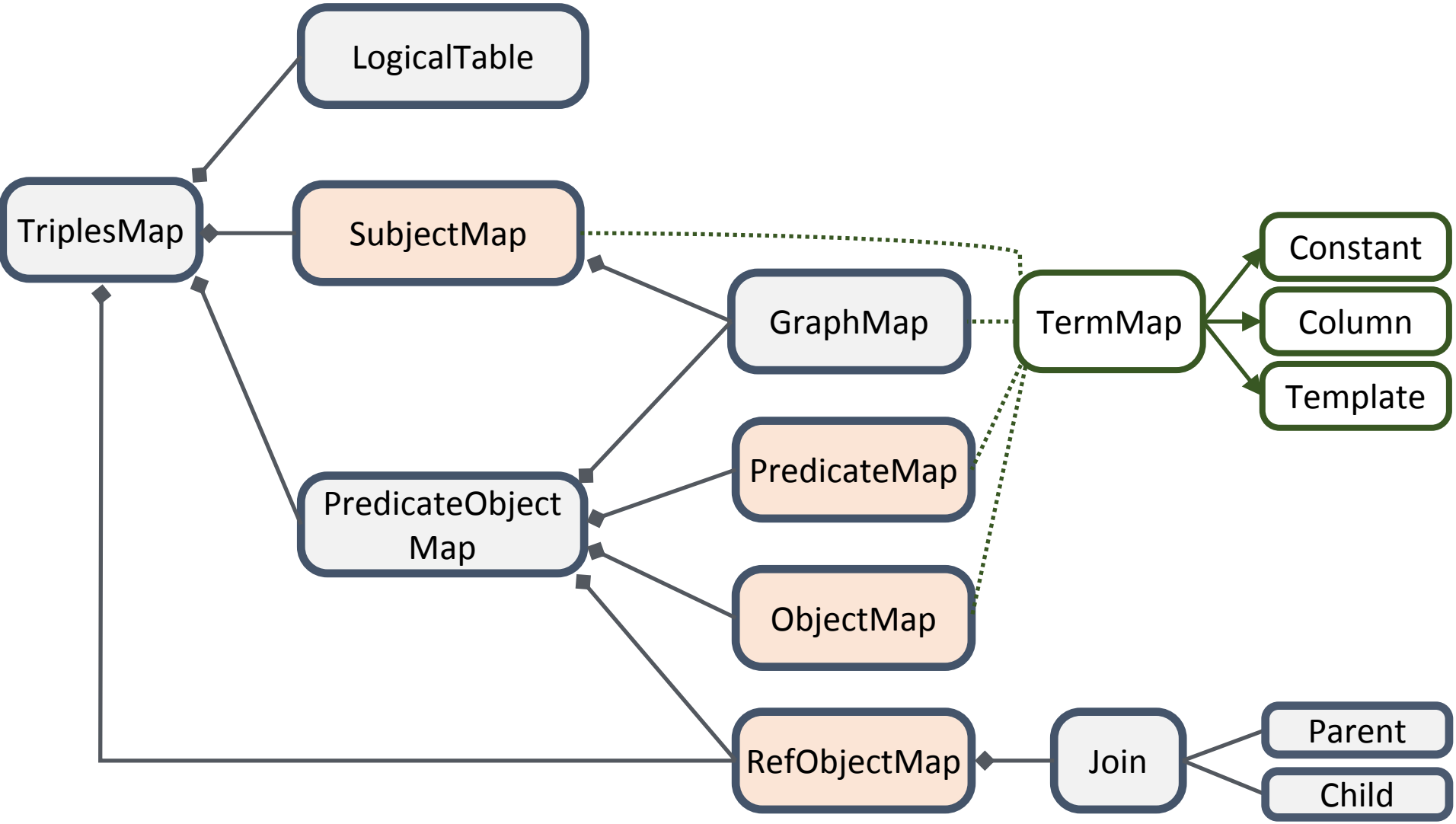



```
@base <http://foo.example/DB/> .
@prefix rdf: <http://www.w3.org/1999/02-22-rdf-syntax-ns#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

<ProtectedArea/Sitecode=DE0916391> rdf:type <ProtectedArea> .
<ProtectedArea/Sitecode=DE0916391> <ProtectedArea#Sitename> "NTP S-H W" .
<ProtectedArea/Sitecode=DE0916391> <ProtectedArea#ReleaseDate>
                                        "2011-01-27"^^xsd:date .

<ProtectedArea/Sitecode=DE1003301> rdf:type <ProtectedArea> .
<ProtectedArea/Sitecode=DE1003301> <ProtectedArea#Sitename> "DOGGERBANK" .
<ProtectedArea/Sitecode=DE1003301> <ProtectedArea#ReleaseDate>
                                        "2011-01-27"^^xsd:date .
```

The language R2RML

- R2RML is a language for expressing **customized mappings** from relational databases to RDF graphs
- R2RML is a W3C Recommendation from 2012 http://www.w3.org/TR/r2rml/
- R2RML mappings provide the user with the ability to **express the desired transformation** of existing relational data into the RDF data model, following a **structure** and a **target vocabulary** that is chosen by the **user**.

The language R2RML (cont'd)



The language R2RML (cont'd)

- A **logical table** can be
  - a **relational table** that is explicitly stored in the database
  - an **SQL view**
  - an **SQL select query**
- A **triples map** is a rule that defines how each tuple of the logical table will be mapped to a set of RDF triples. It consists of
  - a subject map
  - zero or more predicate-object maps.

The language R2RML (cont'd)

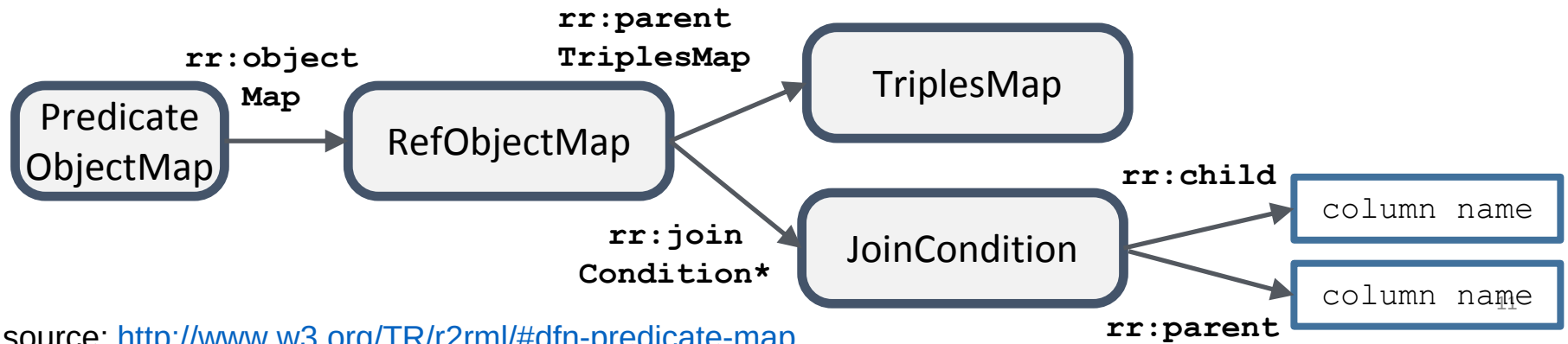
- A **subject map** is a rule that defines how to generate the URI that will be the subject of each generated RDF triple.
- A **predicate-object map** consists of predicate maps and object maps.
- A **predicate map** defines the **RDF property** to be used to relate the subject and the object of the generated triple.
- An **object map** defines how to generate the **object** of the triple which originates from the current row of the logical table.

The language R2RML (cont'd)

- Subject, predicate, object and graph maps are term maps. A **term map** is a function that generates an RDF term from a logical table. Three types of term maps are defined:
  - **constant-valued term maps**
  - **column-valued term maps**
  - **template-valued term maps**

The language R2RML (cont'd)

- A **referencing object map** allows using the subjects of another triples map as the objects generated by a predicate-object map.
  - Optionally, it has one or more join condition properties.

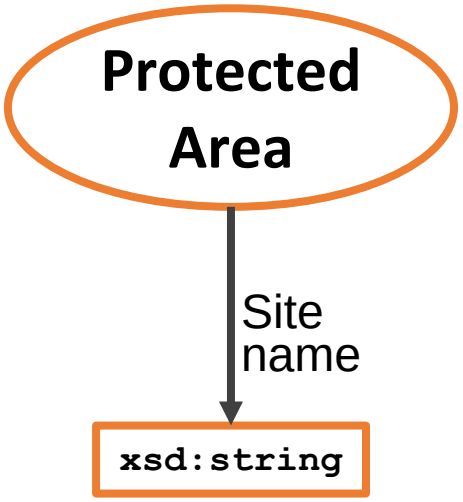


source: http://www.w3.org/TR/r2rml/#dfn-predicate-map

The language R2RML – Example

ProtectedArea

Sitecode	Sitename	ReleaseDate	..
DE0916391	NTP S-H W	2011-01-27	
DE1003301	DOGGERBANK	2011-01-27	



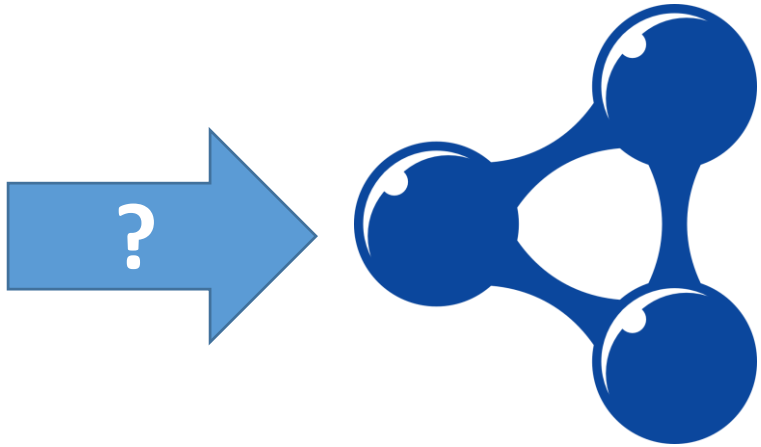

```
@base <http://foo.example/DB/> .
<NaturaMapping>
rr:subjectMap [
  rr:template "ProtectedArea/SiteCode={SiteCode}";
  rr:class <ProtectedArea> ];
rr:predicateObjectMap [
  rr:predicate ProtectedArea:SiteName;
  rr:objectMap [ rr:column "SiteName"; ]; ] .
```

```
<ProtectedArea/Sitecode=DE0916391> rdf:type <ProtectedArea> .
<ProtectedArea/Sitecode=DE0916391> <ProtectedArea#Sitename> "NTP S-H W" .

<ProtectedArea/Sitecode=DE1003301> rdf:type <ProtectedArea> .
<ProtectedArea/Sitecode=DE1003301> <ProtectedArea#Sitename> "DOGGERBANK" .
```

Mapping non-relational data to RDF graphs

OpenStreetMap is a collaborative project for publishing free maps of the world. OSM maintains a community-driven global editable map that gathers map data in a crowdsourcing fashion.
http://www.openstreetmap.org/

```
<ogr:FeatureCollection>
  <gml:featureMember>
    <ogr:waterways fid="waterways.128">
      <ogr:osm_id>8108139</ogr:osm_id>
      <ogr:name>Lech</ogr:name>
      <ogr:type>river</ogr:type>
      <ogr:geometryProperty>
        <gml:LineString>
          <gml:coordinates>
            10.9034096,47.7996669
            10.9037025,47.8003338 …
          </gml:coordinates>
        </gml:LineString>
      </ogr:geometryProperty>
    </ogr:waterways>
  </gml:featureMember>
</ogr:FeatureCollection>
```



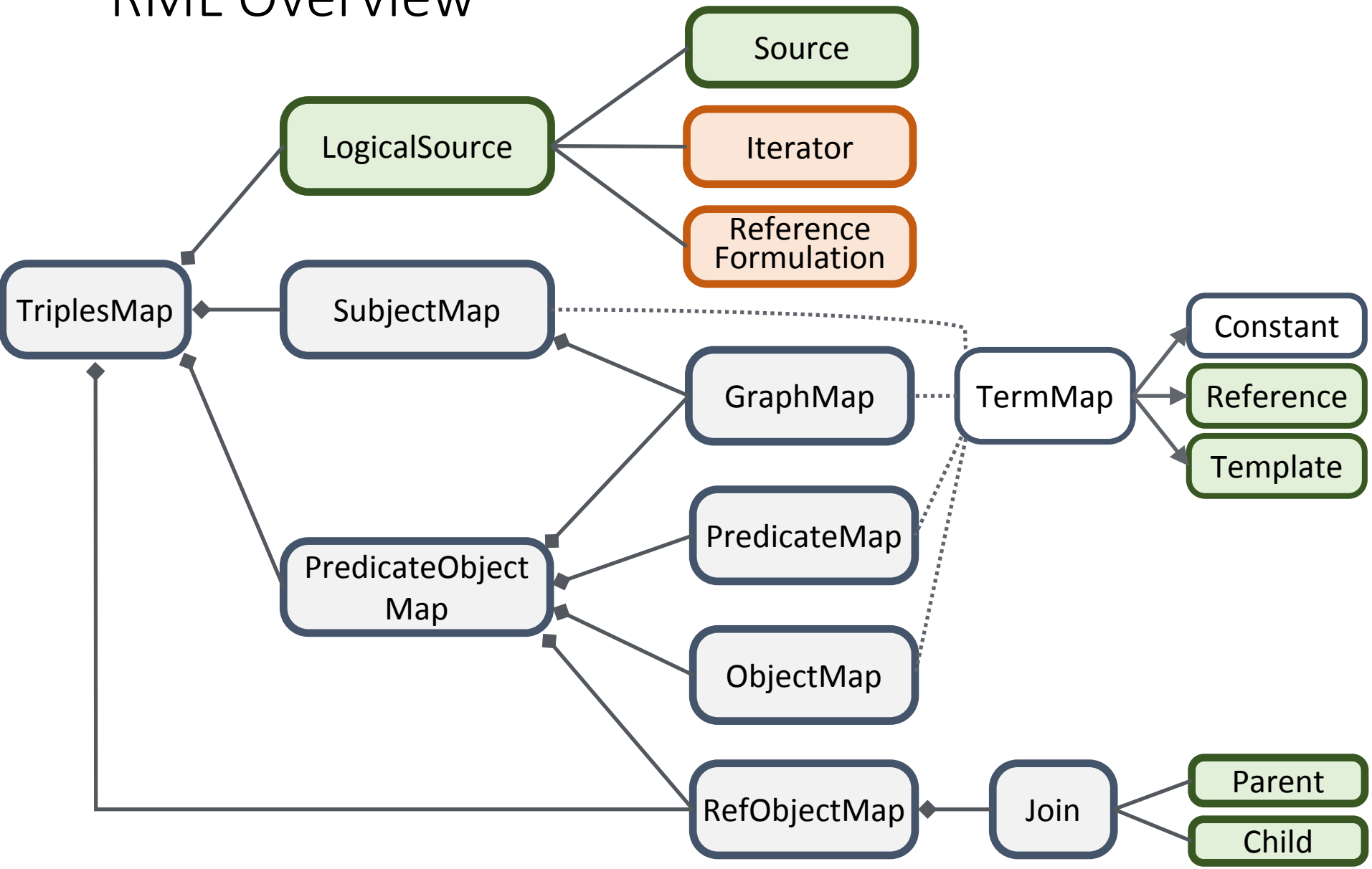
RDF Mapping Language (RML)

- RML is a recently proposed mapping language that defines how to map heterogeneous sources into RDF. http://semweb.mmlab.be/rml/spec.html
- RML is defined as a superset of the W3C-standard R2RML

R2RML		RML	
Logical Table	`rr:logicalTable`	Logical Source	`rml:logicalSource`
Table Name	`rr:tableName`	URI	`rml:source`
column	`rr:column`	reference	`rml:reference`
SQL		Reference Formulation	`rml:referenceFormulation`
per row iteration		defined iterator	`rml:iterator`

source: http://semweb.mmlab.be/rml/RML_R2RML.html

RML Overview



RML extensions

- A **logical source** refers to the input dataset that will be converted to an RDF graph.
- Each logical source has
  - a **source** property pointing to input data
  - a logical **iterator** that defines the iteration pattern over the input data source
  - an optional **reference formulation** property that defines the query language that may be used (e.g., SQL2008, XPath, JSONPath)
- An RML **reference** is a term map that refers to a column name (SQL, CSV), an XML element or attribute, or an JSON object.

RML Example

```
<ogr:FeatureCollection>
  <gml:featureMember>
    <ogr:waterways fid="waterways.128">
      <ogr:osm_id>8108139</ogr:osm_id>
      <ogr:name>Lech</ogr:name>
      <ogr:type>river</ogr:type>
      <ogr:geometryProperty>
        <gml:LineString>
          <gml:coordinates>
            10.9034096,47.7996669
            10.9037025,47.8003338 …
          </gml:coordinates>
        </gml:LineString>
      </ogr:geometryProperty>
    </ogr:waterways>
  </gml:featureMember>
</ogr:FeatureCollection>
```

```
<#waterways>
rml:logicalSource [
  rml:source "/home/leo/osm.gml";
  rml:referenceFormulation ql:XPath;
  rml:iterator "/ogr:FeatureCollection
                /gml:featureMember
                /ogr:waterways";
];
rr:subjectMap [
  rr:template
  "http://www.example.com/id/{@fid}";
  rr:class onto:waterways;
];
rr:predicateObjectMap [
  rr:predicate onto:hasOgr-Name;
  rr:objectMap [
    rr:datatype xsd:string;
    rml:reference "ogr:name";
  ]; ] .
```

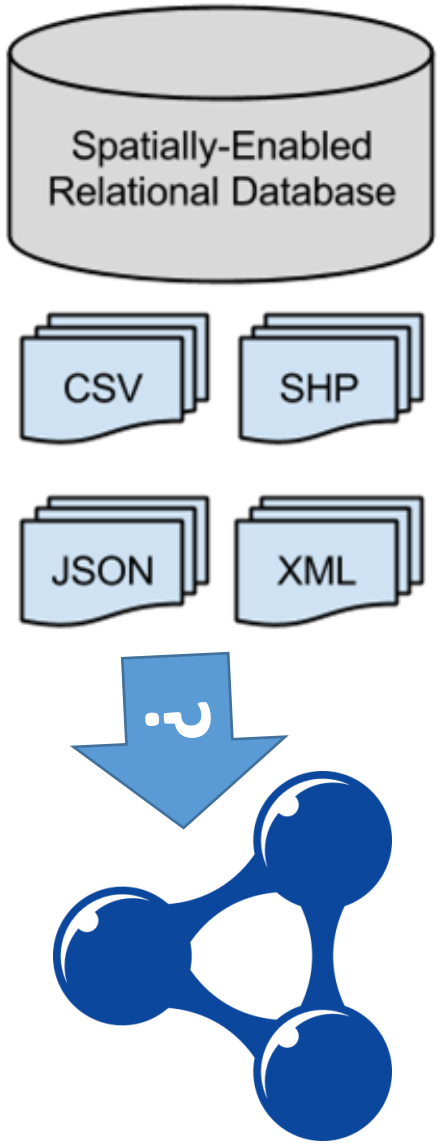
```
ex_id:waterways.128 rdf:type onto:waterways ;
                    onto:hasOgr-Name "Lech" ;
                    onto:hasFid "waterways.128"^^xsd:ID ;
                    onto:hasOgr-Osm_id "8108139" ;
                    onto:hasOgr-Type "river" .
```

Mapping geospatial data to RDF graphs

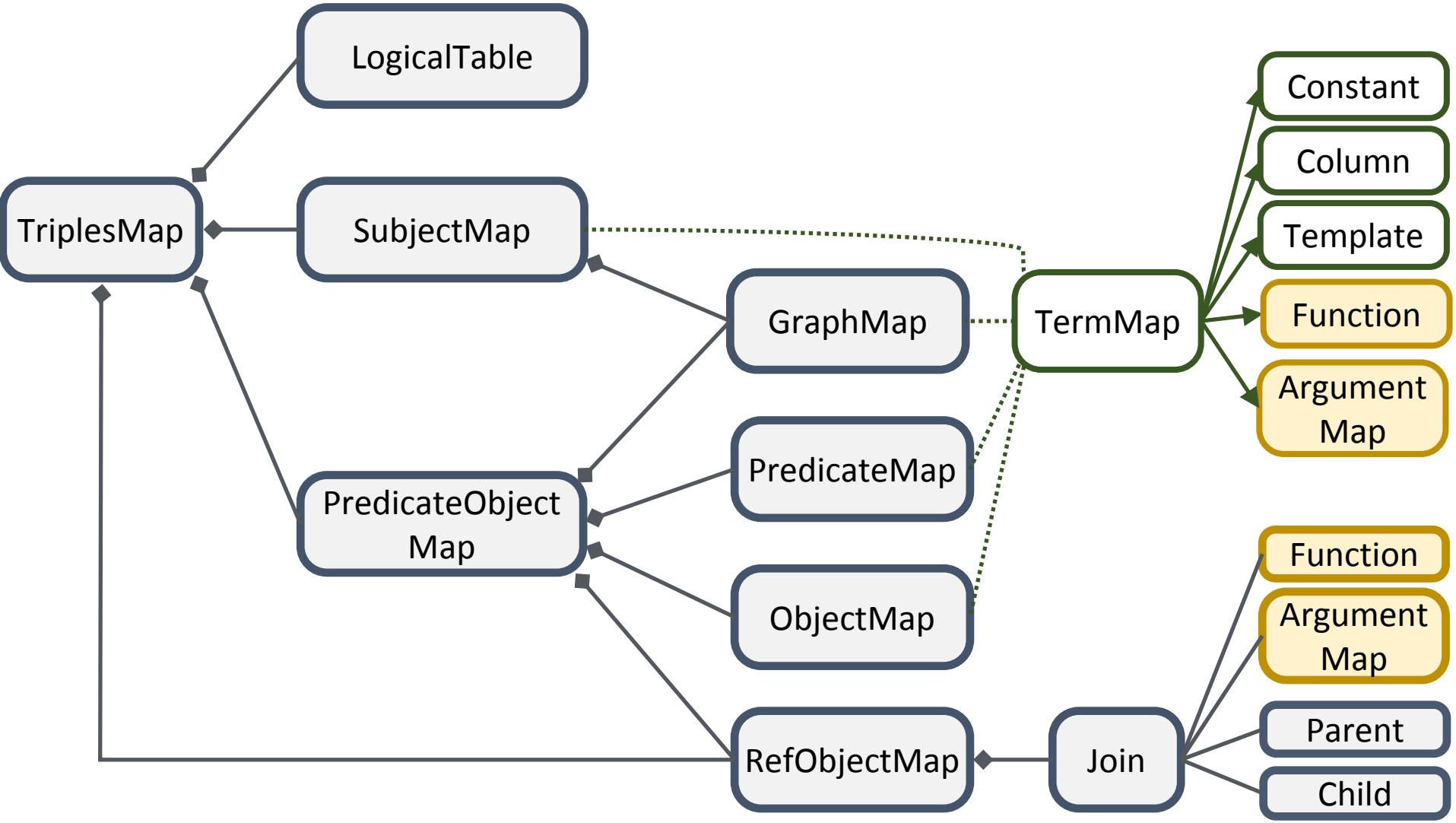
Geospatial data are available in formats such as:

- ESRI shape files
- KML documents
- GeoJSON documents
- XML documents

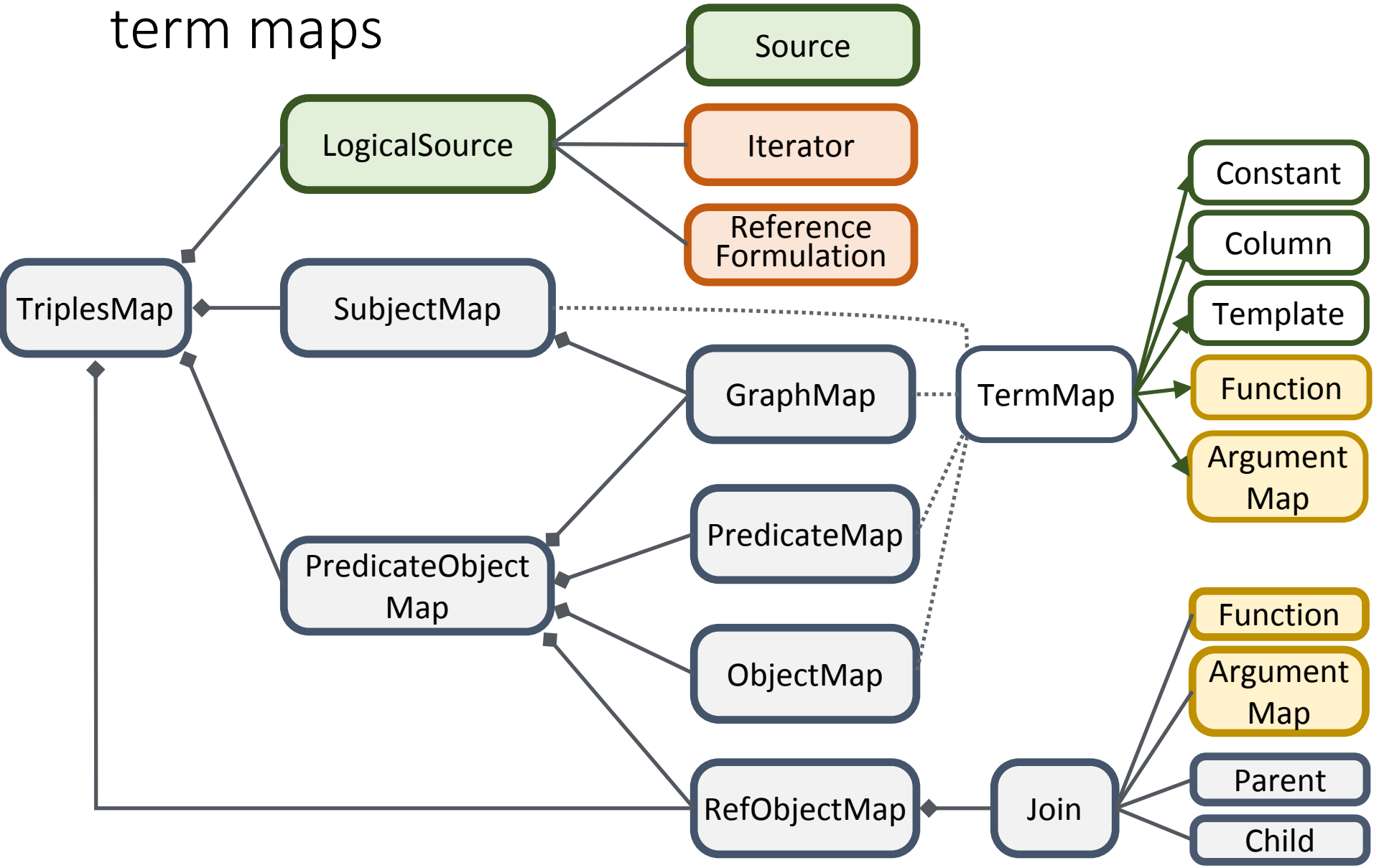
Geospatial data may also be stored in spatially-enabled relational databases.



Extending R2ML with transformation-valued term maps



Extending RML with transformation-valued term maps



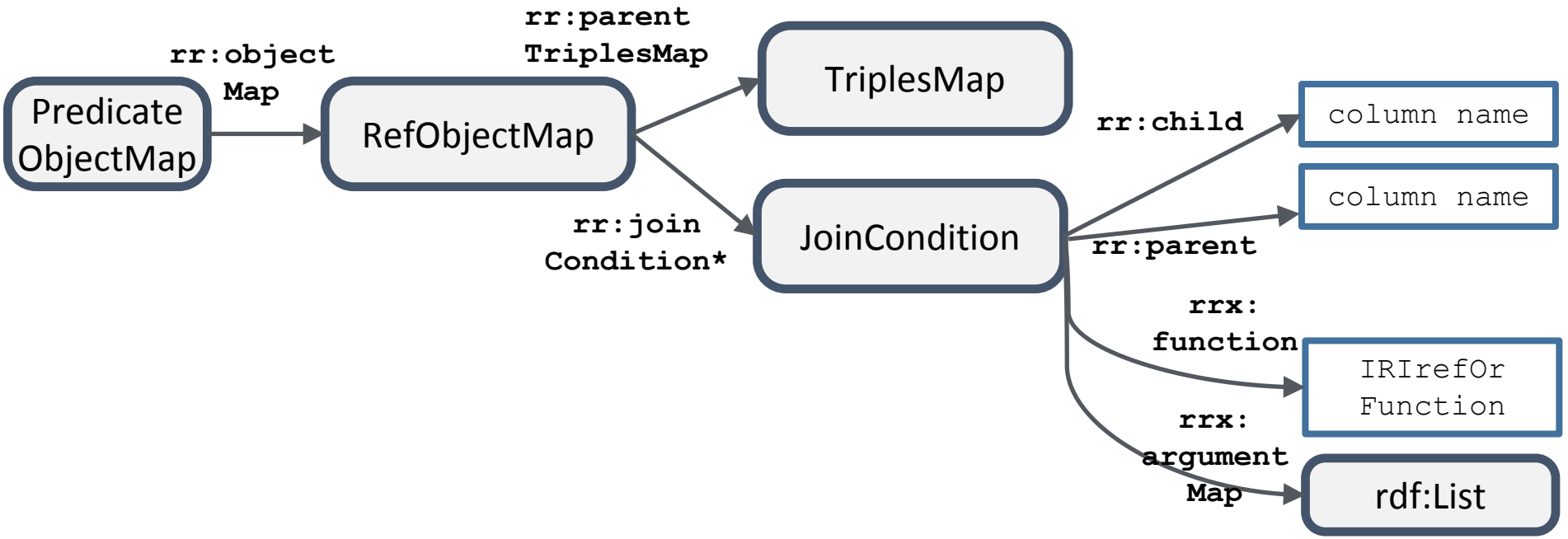
Transformation-valued term maps

- A **transformation-valued term maps** is a term map that generates an RDF term by applying a **SPARQL extension function** on one or more term maps.
- A transformation-valued term map has
  - exactly one **`rrx:function`** property that defines a **SPARQL extension function** that performs the desired transformation
  - one **`rrx:argumentMap`** property that has as range an **`rdf:List`** of term maps that define the **arguments** to be passed to the transformation function

Transformation-valued term maps (cont'd)

Extension Function URI	Corresponding GeoSPARQL property
strdf:dimension	geo:dimension
strdf:spatialDimension	geo:spatialDimension
strdf:coordinateDimension	geo:coordinateDimension
strdf:isEmpty	geo:isEmpty
strdf:isSimple	geo:isSimple
strdf:asText	geo:asWKT geo:hasSerialization
strdf:asGML	geo:asGML

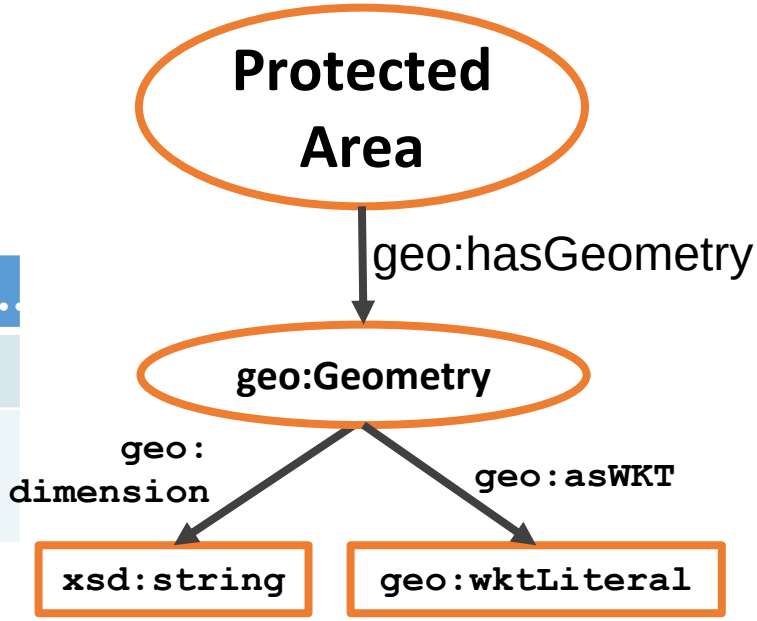
Extending join conditions



Example

ProtectedArea

Sitecode	Sitename	Geometry	…
DE0916391	NTP S-H W	POLYGON((…))	
DE1003301	DOGGERB ANK	POLYGON((…))	




```
<NaturaGeometryMapping>
rr:subjectMap [
  rr:template "ProtectedArea/Geometry/SiteCode={SiteCode}";
  rr:class geo:Geometry ];
rr:predicateObjectMap [
  rr:predicate geo:dimension;
  rr:objectMap [
     rrx:function strdf:dimension;
     rrx:argumentMap ( [rr:column "`Geom`"] ); ]; ] .

<ProtectedArea/Geometry/Sitecode=DE0916391>
   rdf:type <ProtectedArea> ;
   geo:dimension "2"^xsd:integer .
```

Example

ProtectedArea

Sitecode	Sitename	Geom	…
DE0916391	NTP S-H W	POLYGON((…))	
DE1003301	DOGGERBANK	POLYGON((…))	

```
<NaturaGeometryMapping>
rr:subjectMap [
  rr:template
"ProtectedArea/Geometry/SiteCode={SiteCode}";
  rr:class geo:Geometry ];
rr:predicateObjectMap [
  rr:predicate geo:sfIntersects;
  rr:objectMap [
    rr:parentTriplesMap <#waterwaysGeom> ;
    rr:joinCondition [
      rrx:function geof:intersection;
      rrx:argumentMap (
        [rr:column "`Geom`"] ;
        [rml:reference "ogr:geometryProperty";
        rr:parentTriplesMap <#waterwaysGeom>]
); ] ; ]; ] .
```

OSM Waterways

```
<ogr:FeatureCollection>
  <gml:featureMember>
    <ogr:waterways fid="waterways.128">
      <ogr:osm_id>8108139</ogr:osm_id>
      <ogr:geometryProperty>
        <gml:LineString>
          <gml:coordinates>
            10.9034096,47.7996669 …
          </gml:coordinates>
        </gml:LineString>
      </ogr:geometryProperty>
    </ogr:waterways>
  </gml:featureMember>
</ogr:FeatureCollection>
```

```
<#waterwaysGeom>
rml:logicalSource [
  rml:source "/home/leo/osm.gml";
  rml:referenceFormulation ql:XPath;
  rml:iterator "/ogr:FeatureCollection
                /gml:featureMember
                /ogr:waterways";
];
rr:subjectMap [
  rr:template
  "http://www.osm.org/id/{@fid}";
  rr:class onto:waterways;
].
```

natura:DE0916391 geo:sfIntersects osm-id:waterways.128 .

Implemented Systems

- Direct Mapping processors:
  - SquirellRDF
- R2RML processors:
  - D2RQ Platform
  - OpenLink Virtuoso
  - Ultrawrap
  - Morph
  - Ontop
  - Oracle
- RML processor
  - Processor by iMinds Lab, Ghent University
- Other Mapping Language:
  - Triplify
- Geospatial capabilities
- So far:
  - Geometry2RDF
  - Sparqlify
  - TripleGeo
  - GeoTriples

	Custom Mapping Language	Direct Mapping	R2RML	RML	SPARQL query evaluation	Automatic Mapping Generation	Geospatial support
OpenLink Virtuoso	✓	✗	✓*	✗	✓	✗	✗
RDF-RDB2RDF	✗	✓	✓	✗	✗	✗	✗
D2RQ Platform	✓	✗	✓	✗	✓	✓	✗
Db2triples	✗	✓	✓	✗	✗	✗	✗
Morph	✓	✗	✓	✗	✓	?	✗
Sparqlify	✓	✗	✗*	✗	✓	✗	✓
Ontop	✓	✗	✓	✗	✓	✗	✗*
Ultrawrap	✓*	✓	✓	✗	✓	✗	✗
Oracle	✗	✓	✓	✗	✓	✓	✗
Geometry2RDF	✗	✓	✗	✗	✗	✗	✓*
TriplesGeo	✗	✓	✗	✗	✗	✗	✓*
iMinds lab RML processor	✗	✗	✓	✓	✗	✗	✗
GeoTriples	✗	✗	✓	(✓)	✗*	✓	✓

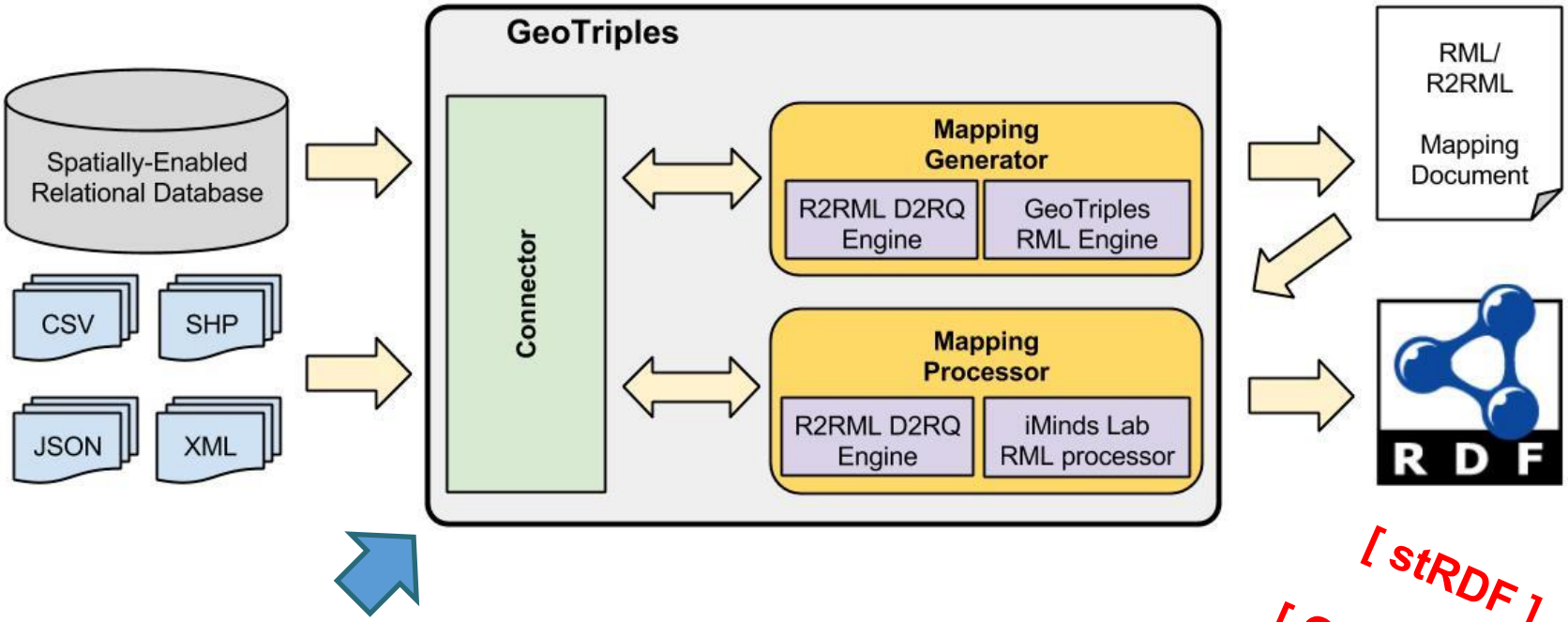
Comparison of Geo2RDF tools

	Direct Mapping	R2RML	RML	Automatic Mapping Generation	GeoSPARQL compliance	RDBMS	ESRI Shape file	GML	Geo JSON
Geometry2RDF	✓	✕	✕	✕	✕	✓	✕	✕	✕
TriplesGeo	✓	✕	✕	✕	(✓)	✓	✓	✕	✕
GeoTriples	✕	✓	✓	✓	✓	✓	✓	✓	✓

GeoTriples

- Open Source software
- Released under Mozilla Public Licence v2.0
- Available at: https://github.com/LinkedEOData/GeoTriples
- Extends the D2RQ Platform
- Extends the iMinds lab RML processor
- Provides both a graphical user interface and a command line interface

Architecture of GeoTriples



Earth Obsevation Acquisitions

[stRDF]

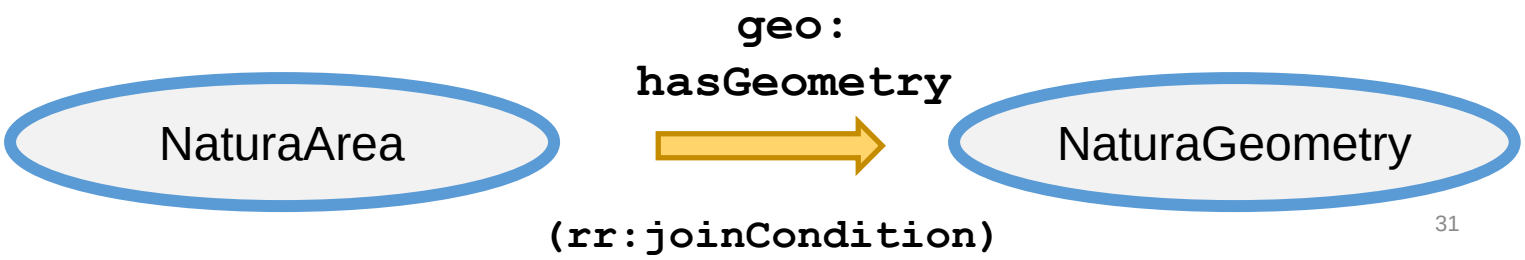
[GeoSPARQL]

Future:
[W3C Spatial Data on the Web]

Automatic generation of R2RML mappings (cont'd)

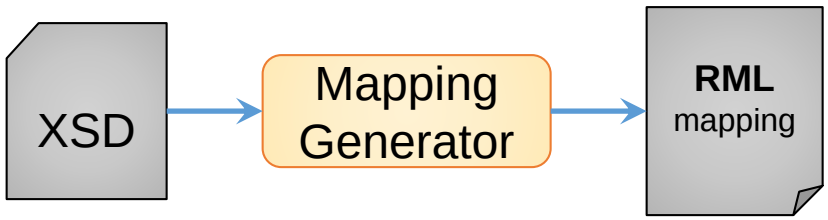
- Generate **two** triples maps for each table that has a `geometry` column.
  - **Thematic** triples map for the non-geometric information
  - **Spatial** triples map for the geometric information

- The spatial triples map contains multiple **transformation functions** over the input geometries in order to generate a **GeoSPARQL** compliant dataset.



Automatic generation of RML mappings for GML documents

- Each geometric object is mapped to a `geo:Geometry` instance
- For each geometric object we generate a **set** of predicate object maps that use the appropriate **transformation functions** for producing a GeoSPARQL compliant dataset
- Each **simple** element is mapped to a predicate object map
- Each **non simple** element is mapped to a triples map
- Appropriate mappings are generated for **linking nested** elements



Demonstration