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Publishing Statistical Data and Geospatial Data as Linked Data

Creating a Semantic Data Platform

Hans Viehmann
Product Manager EMEA
ORACLE Corporation
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@SpatialHannes

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Safe Harbor Statement

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What is Linked Data

- Concept of publishing and interlinking structured data on the web
  - Moving from documents to useable data
- Based on W3C standards
  - Resource Description Framework (RDF), OWL, SPARQL ...
- Originally developed by Tim Berners-Lee
- Design principles
  - Use Uniform Resource Identifiers (URIs) to uniquely identify things (data entities)
  - Use HTTP URLs, corresponding to these URIs, so that information can be retrieved
  - Provide metadata using open standards such as RDF
  - Include links to related URIs, so that people can discover more things

Why Linked Data for Statistics Agencies?

- Data dissemination is key to the work of NSIs
  - Production of accurate data is not everything
- Need to broaden reach
  - Simplifying access
- Various models to represent data in the past
  - eg. SDMX (Statistical Data and Metadata Exchange)
- Linked Data allow to
  - Associate data with metadata (or meaning) – major step towards AI
  - Use a common vocabulary
  - Refer to data owner/authoritative datasource or other 3rd party datasets

Two example projects

Based on Oracle Spatial and Graph as Linked Data Platform

- CensLOD project, ISTAT, Italy
  - Publishing 2015 census data as linked (open) data
  - Infrastructure development to publish Linked Open Data
  - Project details kindly provided by Monica Scannapieco
- Ordnance Survey Ireland publishing boundary data
  - Used by Central Statistics Office (CSO) initially for 2011 census data
  - Modelling boundary data at different resolutions, modelling provenance
  - Focus on using GeoSPARQL
  - Collaboration between OSi, CSO and ADAPTcentre (TCD)
  - Material kindly provided by Dr. Christophe Debruyne (TCD)

General project flow

- Domain analysis and ontology definition
  - Using Protégé or Topbraid Composer as ontology editor
- Creation of subject-predicate-object triples
  - Mapping of source data
  - Inferencing
- Publishing
  - Setup of SPARQL endpoint
  - Development of UI

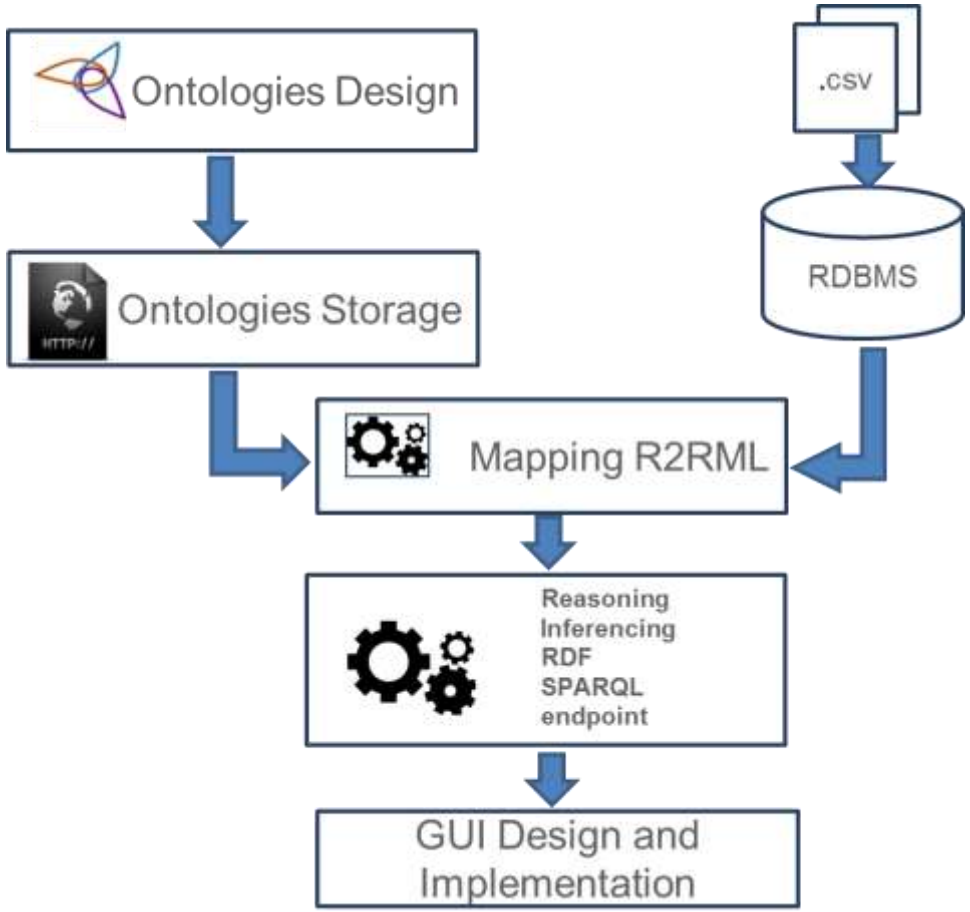
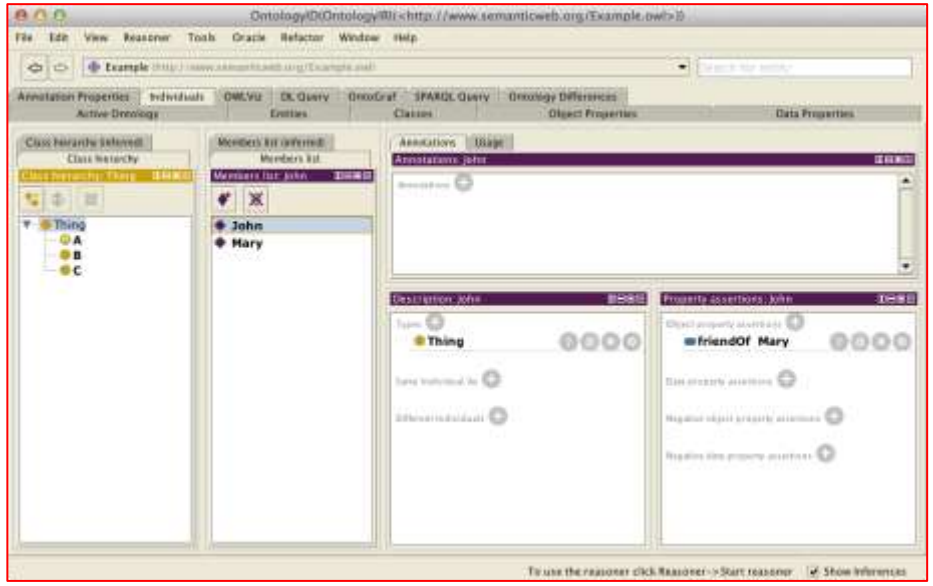


Image courtesy of: Istat, Italy

Ontology definition

ISTAT CensLOD



- Territorial data ontology, census data ontology
- Modeled in OWL using Protégé
- Based on existing meta-ontologies
  - SKOS and XKOS: skos:Concept, …
  - ADMS: adms:AssetRepository, …
  - Data Cube Vocabulary: qb:DataSet, qb:Observation, …
  - PROV: prov:wasGeneratedBy, …
  - GeoNames: gn:name, gn:countryCode, gn:parentCountry, …
- Territorial data resulting in 95 entities and 200 rules, eg. using *EquivalentTo* to link entities to respective Geonames entity

Generating triples

- Describing mapping rules using R2RML standard
  - eg. associating column names with entities
- Choosing rulebase and possible optimizations
  - Using inferencing engine to materialize additional triples for performance
- Creating RDF Views on relational data (optional)
  - No duplication of data and storage

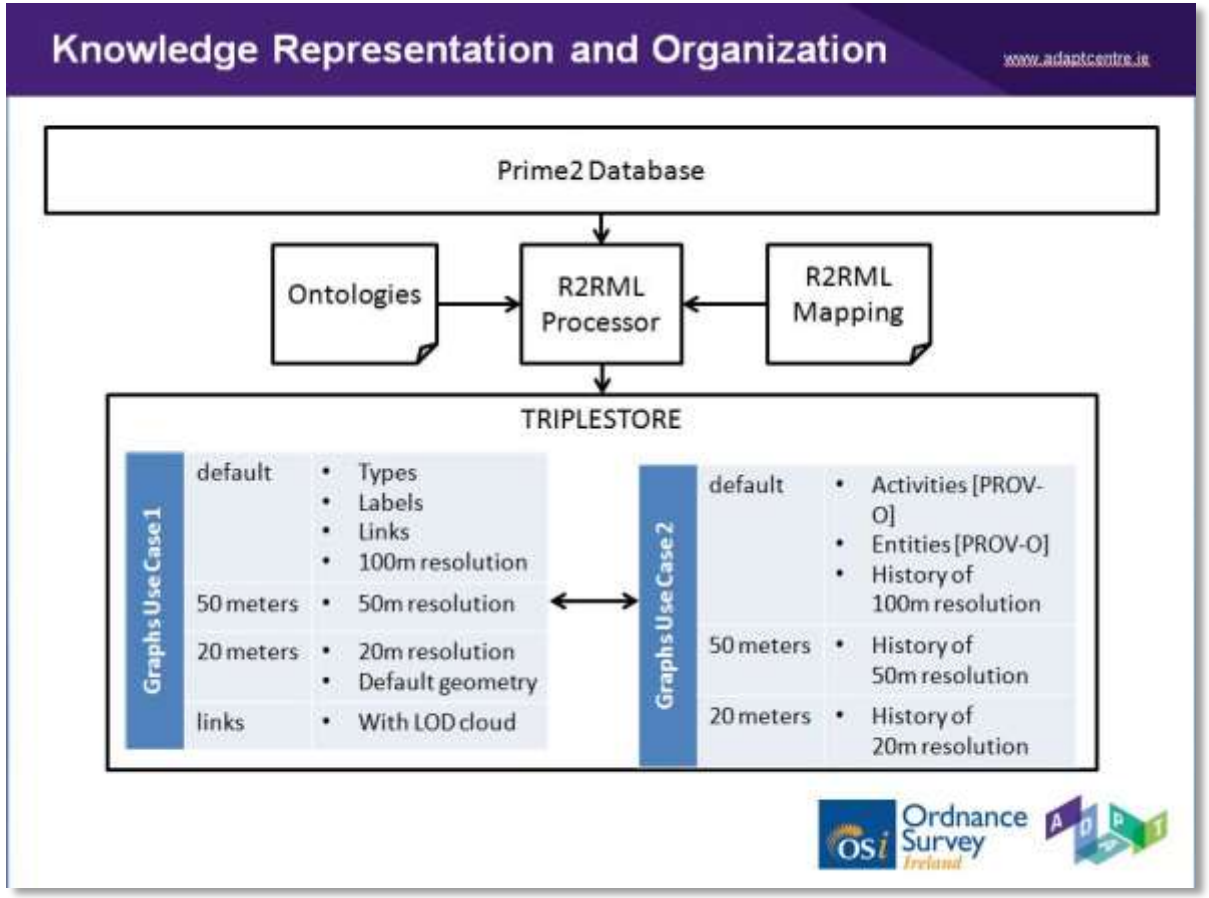


Image courtesy of: ADAPTcentre, Ireland

Publishing

- Creating a SPARQL endpoint
  - For machine-to-machine access
  - For advanced users
- Linked Data interface
  - Faceted search/graph browser
  - For basic users
- GUI to download datasets
  - For basic users
  - For advanced users

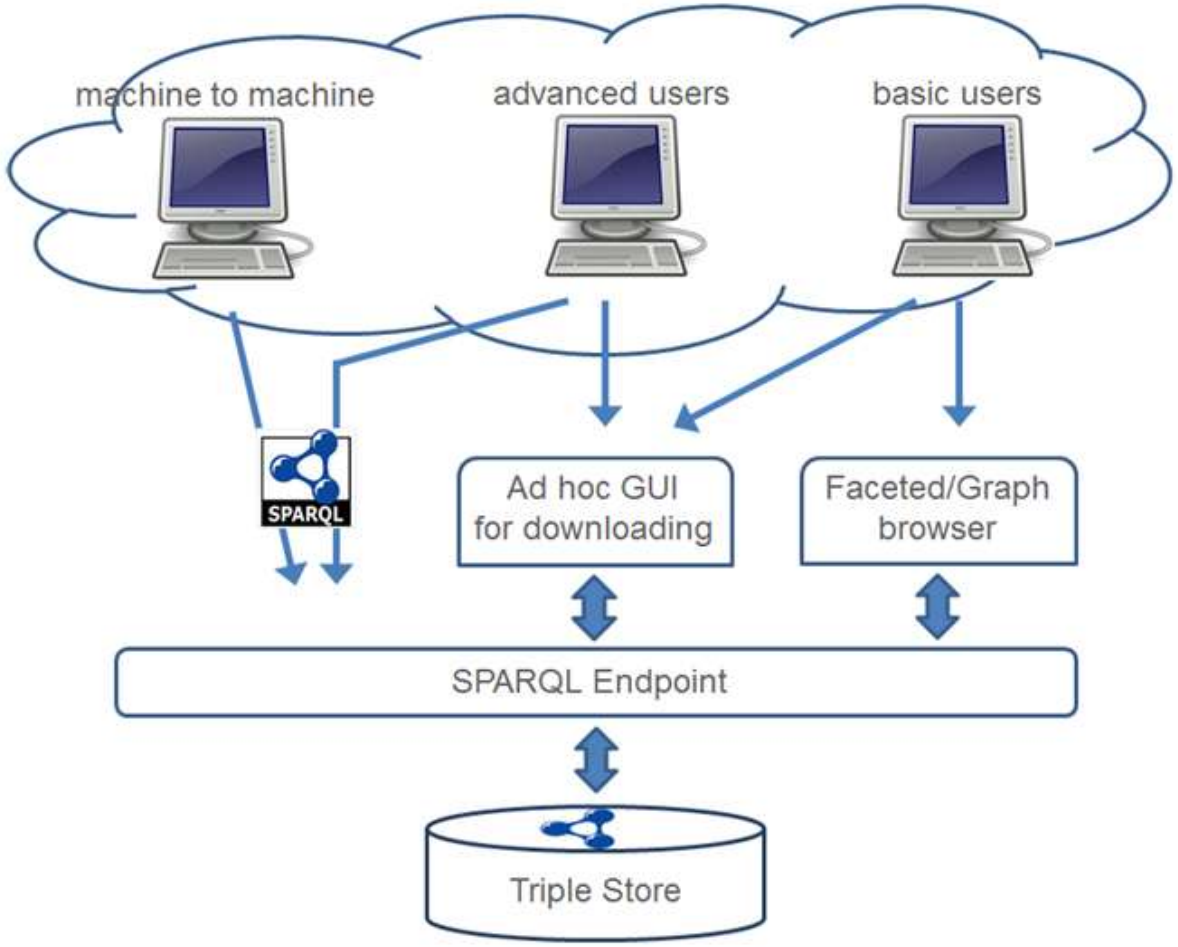


Image courtesy of: Istat, Italy

Linked Geodata and Semantic GIS

- GIS applications with semantically complex thematic aspects
  - Logical reasoning to classify features, eg. land cover type, suitable farm land, etc., combined with spatial queries
  - Linking to available datasources (geonames.org, dbpedia, ...)
- Requirements
  - Consistent modeling of geospatial data, both simple and complex
  - Gemetric functions and topological queries based on Spatial indexing
- Conceptual solution provided by OGC standards
  - Simple Features as WKT literals, eg. `"Point(-83.4 34.3)"^^ogc:wktLiteral`
  - Queries in GeoSPARQL

Single platform for geospatial and linked data

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Transformation and Modeling Tools

- Relational2RDF
- Plug-in for Protégé
- Topbraid Composer integration
- Support for Apache Jena
- Natural Language Processing Extraction (partners)

Load, Query and Inferencing

- RDF/OWL Data Management
- SQL & SPARQL Query
- OWL Inferencing
- Semantic Rules
- Semantic Indexing
- Scalability & Security
- SQL Developer integration

Solution Development and Analytic Tools

- Java, HTTP access
- JSON, XML output
- Graph visualization (Cytoscape)
- Oracle Advanced Analytics (R, Mining)
- Oracle Business Intelligence (OBIEE)
- Map (GIS) Visualization

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Geospatial Linked Data Platform for NSIs

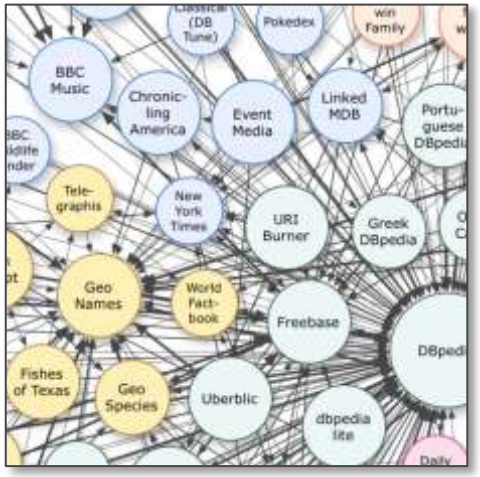
Graph Analysis and Reporting

GeoSPARQL, SQL, Java, …

Linked Data

Graph Data Management
Query Engine
Ontologies
Inferencing Engine

RDF Graph Layer



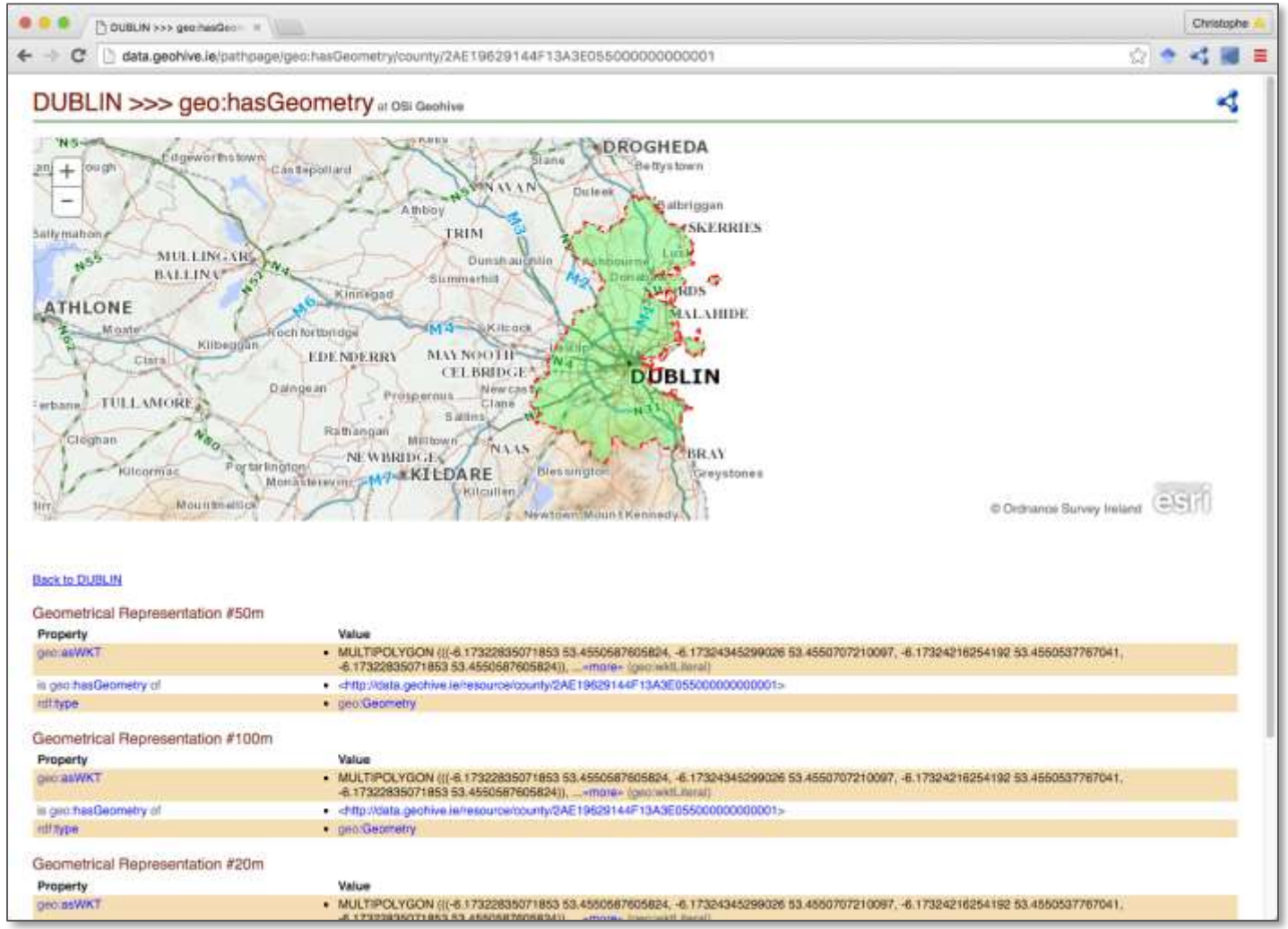
Public LOD endpoints (DBPedia, GeoNames, …)

Enterprise Data Stores

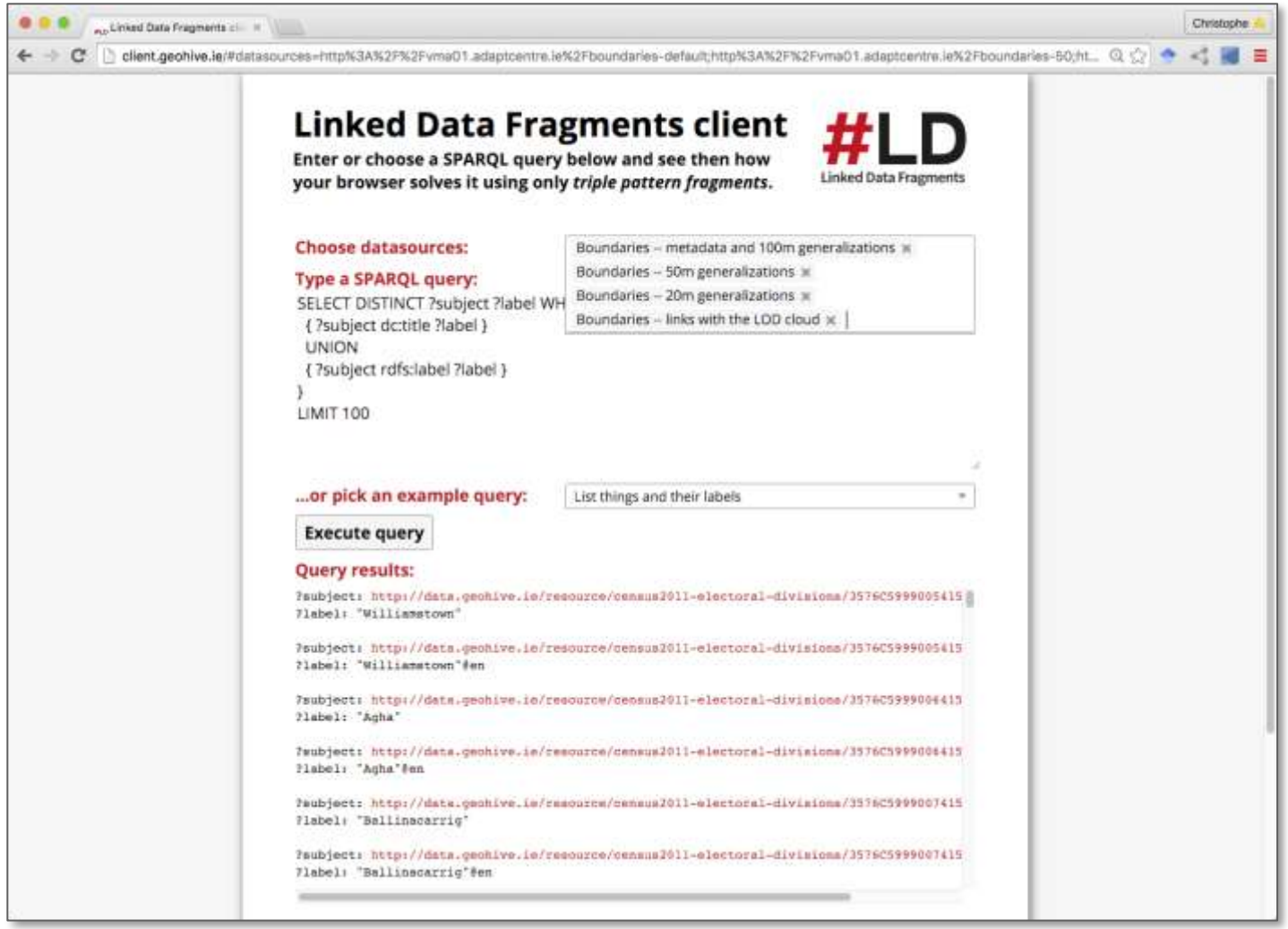
Statistics Data

Geometry Data

Implementation on Geohive.IE



Implementation of Triple Fragments Client



Resources

- Oracle Spatial and Graph OTN product page here
  - White papers, software downloads, documentation and videos
  - Performance White Paper on 1 Trillion Triple Benchmark
- Oracle Big Data Lite Virtual Machine - a free sandbox to get started: www.oracle.com/technetwork/database/bigdata-appliance/oracle-bigdatalite-2104726.html
- Hands On Lab with RDF Graph data included
  - Content also available on GITHub under http://github.com/oracle/BigDataLite/
- Blog – examples, tips & tricks: blogs.oracle.com/oraclespatial
- @OracleBigData, @SpatialHannes, @JeanIhm Oracle Spatial and Graph Group

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Applications & Platform Services

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Appendix

OGC GeoSPARQL Support in Oracle Spatial and Graph 12c

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OGC GeoSPARQL

- GeoSPARQL – A Geographic Query Language for RDF Data
  - OGC Standard (document 11-052r4)
  - Published in June 2012
  - Submitting Organizations

Traverse Technologies, Inc.

Why GeoSPARQL? – Linked Geo Data

- Many Linked Open Data (LOD) datasets have geospatial components
- Barriers to integration
  - Vendor-specific geometry support
  - Different vocabularies
    - W3C Basic Geo, GML XMLLiteral, Vendor-specific
  - Different spatial reference systems
    - WGS84 Lat-Long, British National Grid

Why GeoSPARQL? – Semantic GIS

- GIS applications with semantically complex thematic aspects
  - Logical reasoning to classify features
    - Land cover type, suitable farm land, etc.
  - Complex Geometries
    - Polygons and Multi-Polygons with 1000's of points
  - Complex Spatial Operations
    - Union, Intersection, Buffers, etc.

Find parcels with an area of at least 3 sq. miles that touch a local feeder road and are inside an area of suitable farm land.

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From SPARQL to GeoSPARQL

RDF Data

```
:res1 rdf:type   :House .
:res1 :baths       "2.5"^^xsd:decimal .
:res1 :bedrooms "3"^^xsd:decimal .

:res2 rdf:type     :Condo .
:res2 :baths       "2"^^xsd:decimal .
:res2 :bedrooms "2"^^xsd:decimal .

:res3 rdf:type   :House
:res3 :baths       "1.5"^^xsd:decimal .
:res3 :bedrooms "3"^^xsd:decimal .
```

SPARQL Query

```
SELECT ?r ?ba ?br
WHERE { ?r rdf:type :House .
        ?r :baths ?ba .
        ?r :bedrooms ?br }
```

Result Bindings

```
?r    | ?ba   | ?br
===================
:res1 | "2.5" | "3"
:res3 | "1.5" | "3"
```

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From SPARQL to GeoSPARQL

RDF Data

```
:res1 rdf:type   :House .
:res1 :baths       "2.5"^^xsd:decimal .
:res1 :bedrooms "3"^^xsd:decimal .

:res2 rdf:type     :Condo .
:res2 :baths       "2"^^xsd:decimal .
:res2 :bedrooms "2"^^xsd:decimal .

:res3 rdf:type   :House
:res3 :baths       "1.5"^^xsd:decimal .
:res3 :bedrooms "3"^^xsd:decimal .
```

SPARQL Query

```
SELECT ?r ?ba ?br
WHERE { ?r rdf:type :House .
        ?r :baths ?ba .
        ?r :bedrooms ?br
        FILTER (?ba > 2) }
```

Result Bindings

```
?r    | ?ba   | ?br
===================
:res1 | "2.5" | "3"
```

From SPARQL to GeoSPARQL

Spatial RDF Data

```
:res1   rdf:type          :House .
:res1   :baths              "2.5"^^xsd:decimal .
:res1   :bedrooms         "3"^^xsd:decimal .
:res1   ogc:hasGeometry :geom1 .
:geom1 ogc:asWKT          "POINT(-122.25 37.46)"^^ogc:wktLiteral .

:res3   rdf:type          :House
:res3   :baths              "1.5"^^xsd:decimal .
:res3   :bedrooms         "3"^^xsd:decimal .
:res3   ogc:hasGeometry :geom3 .
:geom3 ogc:asWKT          "POINT(-122.24 37.47)"^^ogc:wktLiteral .
```

This is what GeoSPARQL standardizes

Vocabulary & Datatypes

Find houses within a search polygon

GeoSPARQL Query

```
SELECT ?r ?ba ?br
WHERE { ?r rdf:type :House . ?r :baths ?ba . ?r :bedrooms ?br .
        ?r ogc:hasGeometry ?g . ?g ogc:asWKT ?wkt
        FILTER(ogcf:sfWithin(?wkt, "POLYGON(…)"^^ogc:wktLiteral))
}
```

Extension Functions

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RDB2RDF for viewing Spatial Data as RDF

Relational Data

HOUSE table

id int	baths number	bedrooms number	geom SDO_GEOMETRY
1	2.5	3	POINT(-122.25 37.46)
3	1.5	3	POINT(-122.24 37.47)

RDB2RDF: Direct Mapping

```
sem_apis.CREATE_RDFVIEW_MODEL (
   'House_Model',
   sys.odcivarchar2list('HOUSE'),
   'http://dm/');
```

RDF View (of Relational Data)

```
<http://dm/RDFUSER.HOUSE/ID=1>
 rdf:type
   <http://dm/RDFUSER.HOUSE>;
 :baths
"2.5"^^xsd:decimal;
 :bedrooms "3"^^xsd:decimal;
 :geom
   "POINT(…)"^^ogc:wktLiteral.

<http://dm/RDFUSER.HOUSE/ID=3>
 rdf:type
   <http://dm/RDFUSER.HOUSE>;
 :baths
"1.5"^^xsd:decimal;
 :bedrooms "3"^^xsd:decimal;
 :geom
   "POINT(…)"^^ogc:wktLiteral.
```

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RDB2RDF for viewing Spatial Data as RDF

Relational Data

House table

id int	baths number	bedrooms number	geom SDO_GEOMETRY
1	2.5	3	POINT(-122.25 37.46)
3	1.5	3	POINT(-122.24 37.47)

RDB2RDF: Direct Mapping

```
sem_apis.CREATE_RDFVIEW_MODEL (
   'House_Model',
   sys.odcivarchar2list('HOUSE'),
   'http://dm/');
```

Querying RDF View

```
PREFIX :
 <http://dm/RDFUSER.HOUSE#>.
SELECT ?r ?ba ?br
WHERE {
 ?r rdf:type
  <http://dm/RDFUSER.HOUSE>;
 :baths ?ba;
 :bedrooms ?br;
 :geom ?wkt.
FILTER
(ogcf:sfWithin(?wkt,
"POLYGON(…)"^^ogc:wktLiteral)
)
}
```

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GeoSPARQL Support in Oracle

- Oracle Spatial and Graph supports the following conformance classes for GeoSPARQL
  - Core
  - Topology Vocabulary Extension (Simple Features)
  - Geometry Extension (WKT, 1.2.0)
  - Geometry Topology Extension (Simple Features, WKT, 1.2.0)
  - RDFS Entailment Extension (Simple Features, WKT, 1.2.0)

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Builds on the power of Oracle Spatial

- Efficient Spatial Indexing
- Spatial Reference Systems
  - Built-in support for 1000's of SRS
  - Coordinate system transformations applied transparently during indexing and query
- Geometry Types
  - Support OGC Simple Features geometry types
    - Point, Line, Polygon
    - Multi-Point, Multi-Line, Multi-Polygon
    - Geometry Collection
  - Up to 500,000 vertices per Geometry

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GeoSPARQL – New 12.2 Features

- New utility functions
- Support for EPSG SRID URIs
- Revised Geometry Storage Scheme – big performance gain
- SDO_JOIN
- Spatial Aggregates
- 3D Support

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