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Using Linked Data Concepts to Blend and Analyze Geospatial Data

Do you speak GeoSPARQL?

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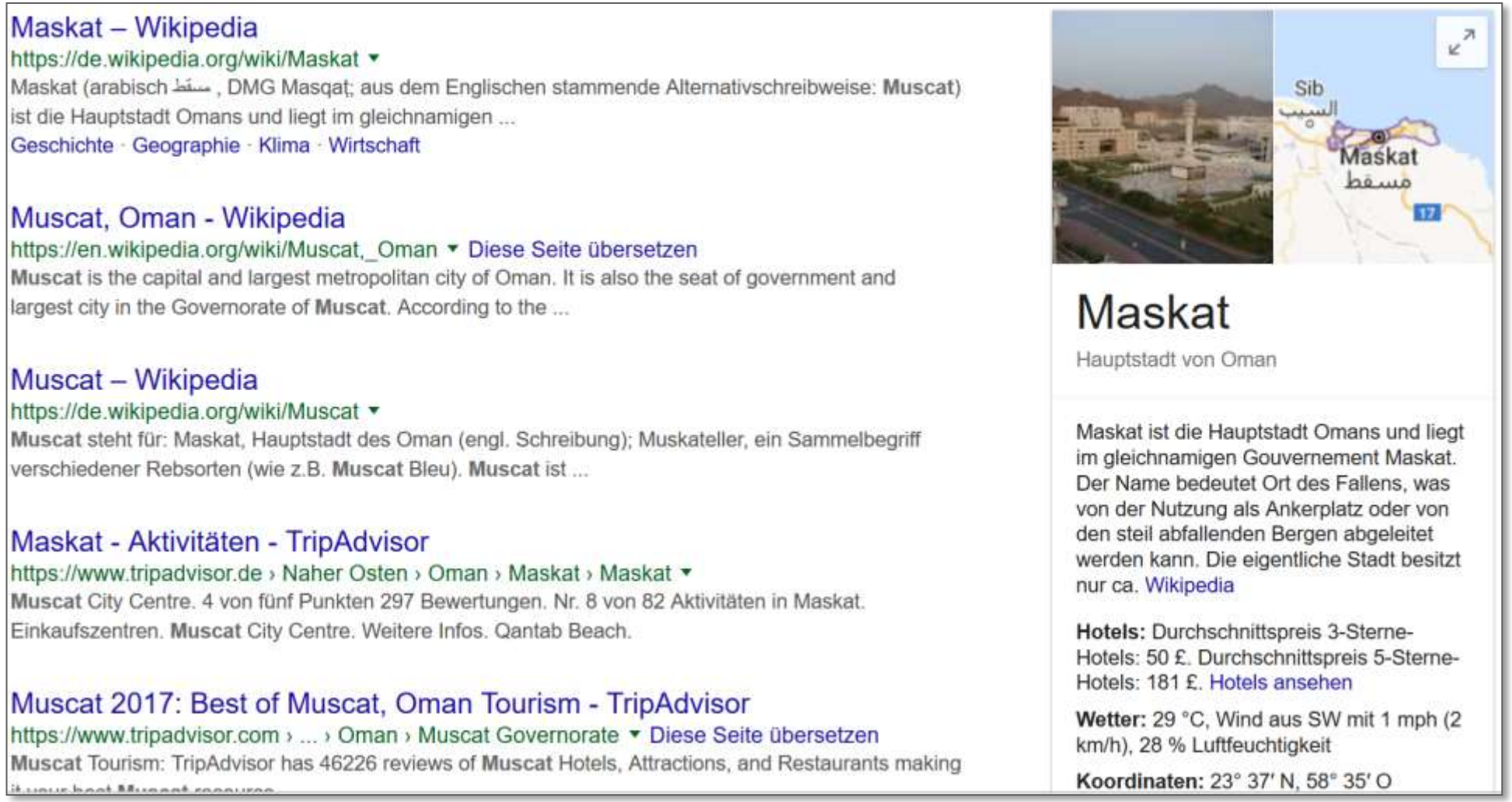
Please use your imagination for a moment ...

Have you ever wondered where the Google text box comes from?



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 Spatial Data Infrastructures?

- Success of SDIs is dependent on being able to find datasets
  - Production of accurate data is not everything
- Need to broaden reach to generate more added value
  - Simplifying access
- Data and metadata must be understandable across domains
  - Need to cope with different terminologies
- 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)

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General project flow to publish data as Linked Data

- 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

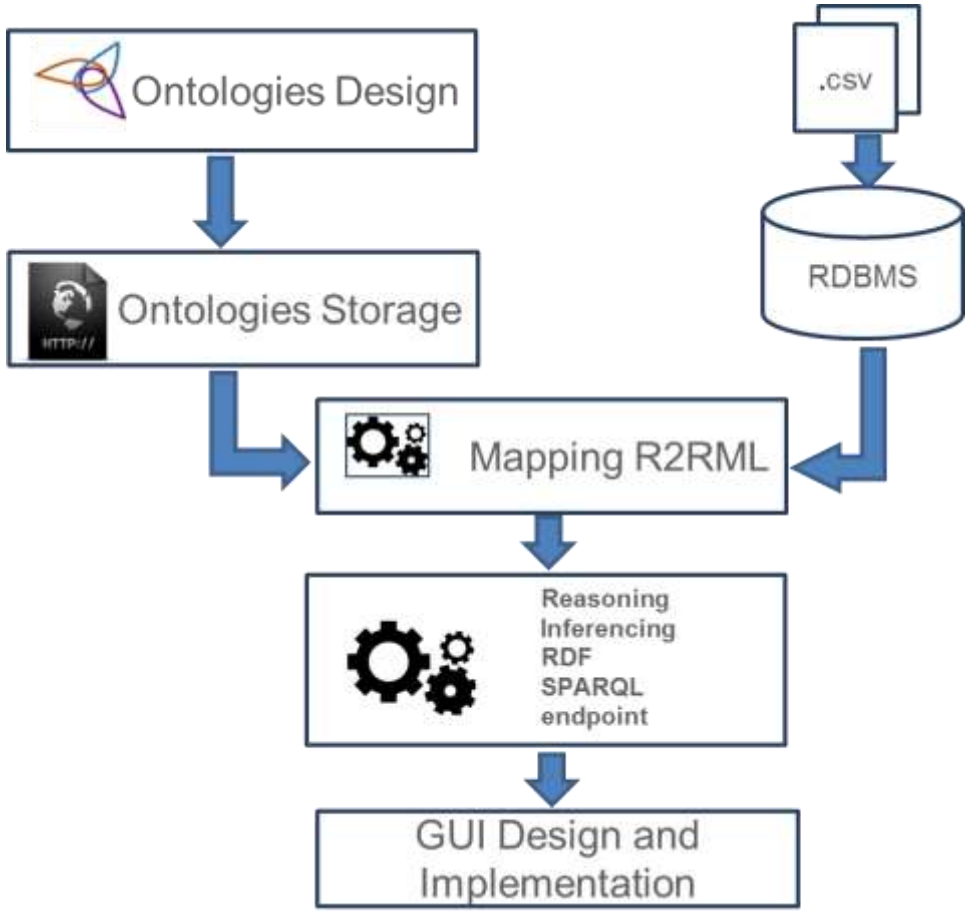
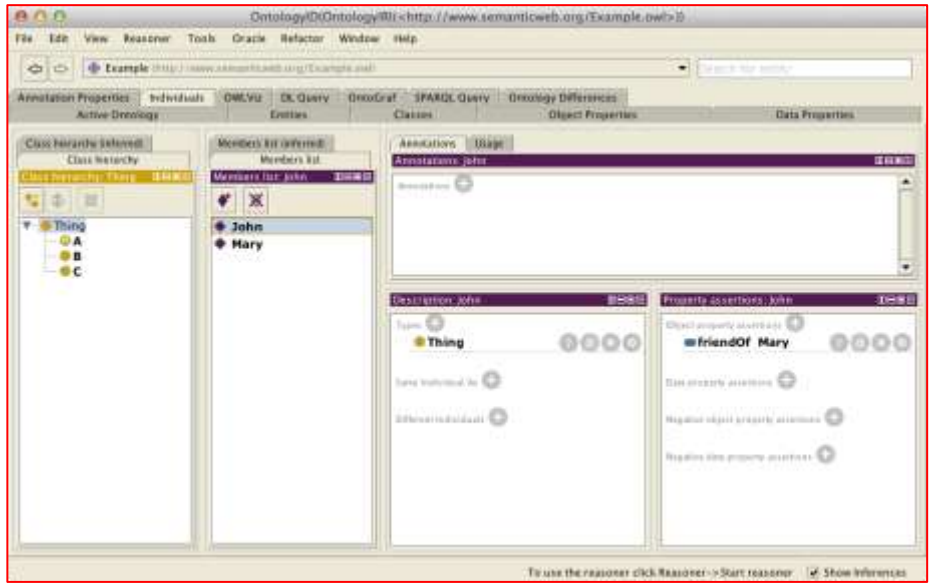


Image courtesy of: Istat, Italy

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

Lots of existing databases and ontologies

Eg. crowd sourced content in Geonames.org

```
<rdf:RDF>
 – <gn:Feature rdf:about="http://sws.geonames.org/7631677/">
    <rdfs:isDefinedBy rdf:resource="http://sws.geonames.org/7631677/about.rdf"/>
    <gn:name>As Sultan Qaboos Grand Mosque</gn:name>
    <gn:alternateName xml:lang="en">As Sultan Qaboos Grand Mosque</gn:alternateName>
    <gn:alternateName>As Sultan Qaboos Grand Mosque</gn:alternateName>
    <gn:alternateName>Jāmi‘ as Sulţān Qābūs al Akbar</gn:alternateName>
    <gn:alternateName xml:lang="ar">جامع السلطان قابوس الأكبر</gn:alternateName>
    <gn:featureClass rdf:resource="http://www.geonames.org/ontology#S"/>
    <gn:featureCode rdf:resou
    <gn:countryCode>OM</gn
    <wgs84_pos:lat>23.58635<
    <wgs84_pos:long>58.3831
    <gn:parentFeature rdf:res
    <gn:parentCountry rdf:re
    <gn:parentADM1 rdf:reso
    <gn:nearbyFeatures rdf:r
    <gn:locationMap rdf:resou
    <gn:wikipediaArticle rdf:r
    <rdfs:seeAlso rdf:resource
  </gn:Feature>
```

```
<gn:Code rdf:about="#S.MSQE" skos:notation="S.MSQE">
  <skos:definition xml:lang="en">a building for public Islamic worship</skos:definition>
  <skos:definition xml:lang="ru">у мусульман: молитвенный дом</skos:definition>
  <skos:inScheme rdf:resource="#S"/>
  <skos:prefLabel xml:lang="no">moské</skos:prefLabel>
  <skos:prefLabel xml:lang="sv">moské</skos:prefLabel>
  <skos:prefLabel xml:lang="en">mosque</skos:prefLabel>
  <skos:prefLabel xml:lang="bg">джамия</skos:prefLabel>
  <skos:prefLabel xml:lang="ru">мечеть</skos:prefLabel>
</gn:Code>
```

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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

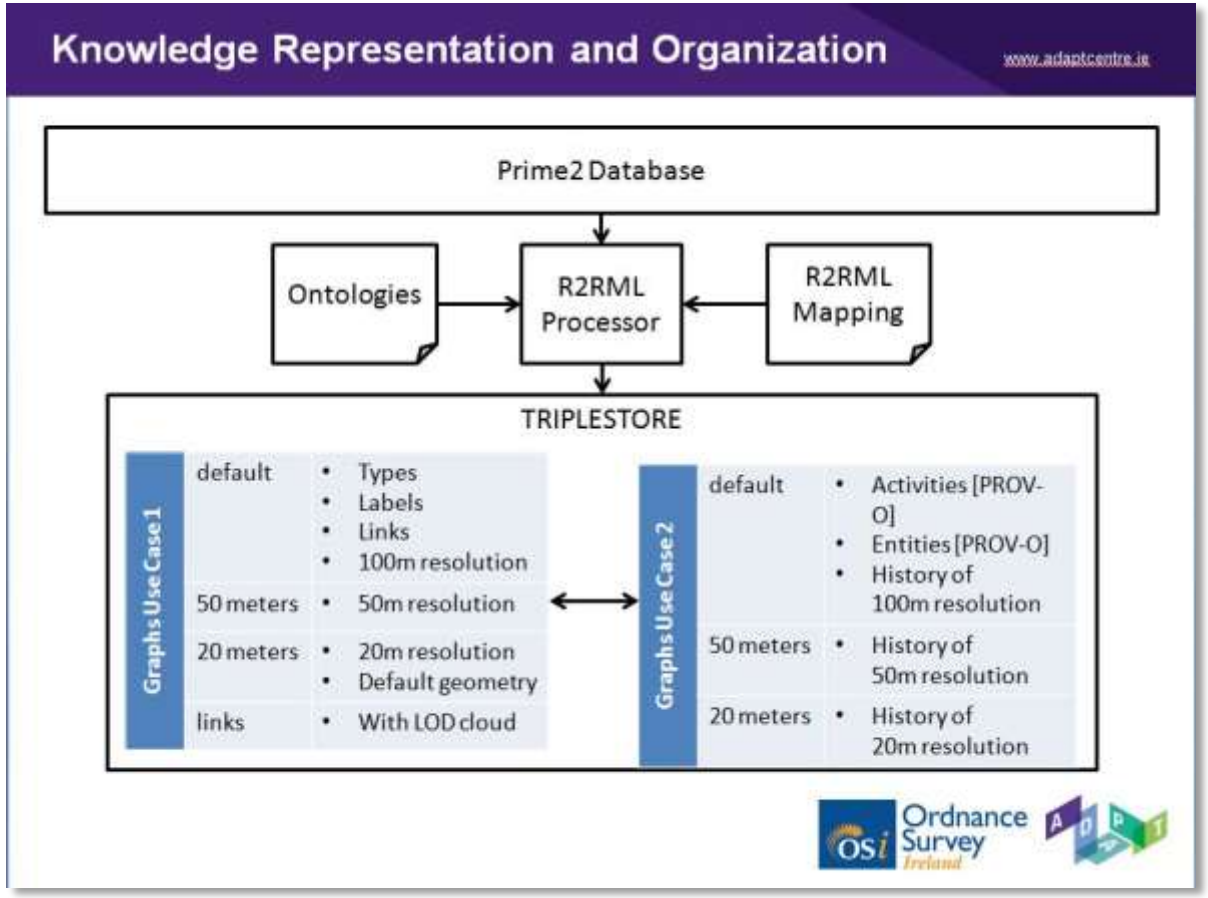

Image courtesy of: ADAPTcentre, Ireland

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

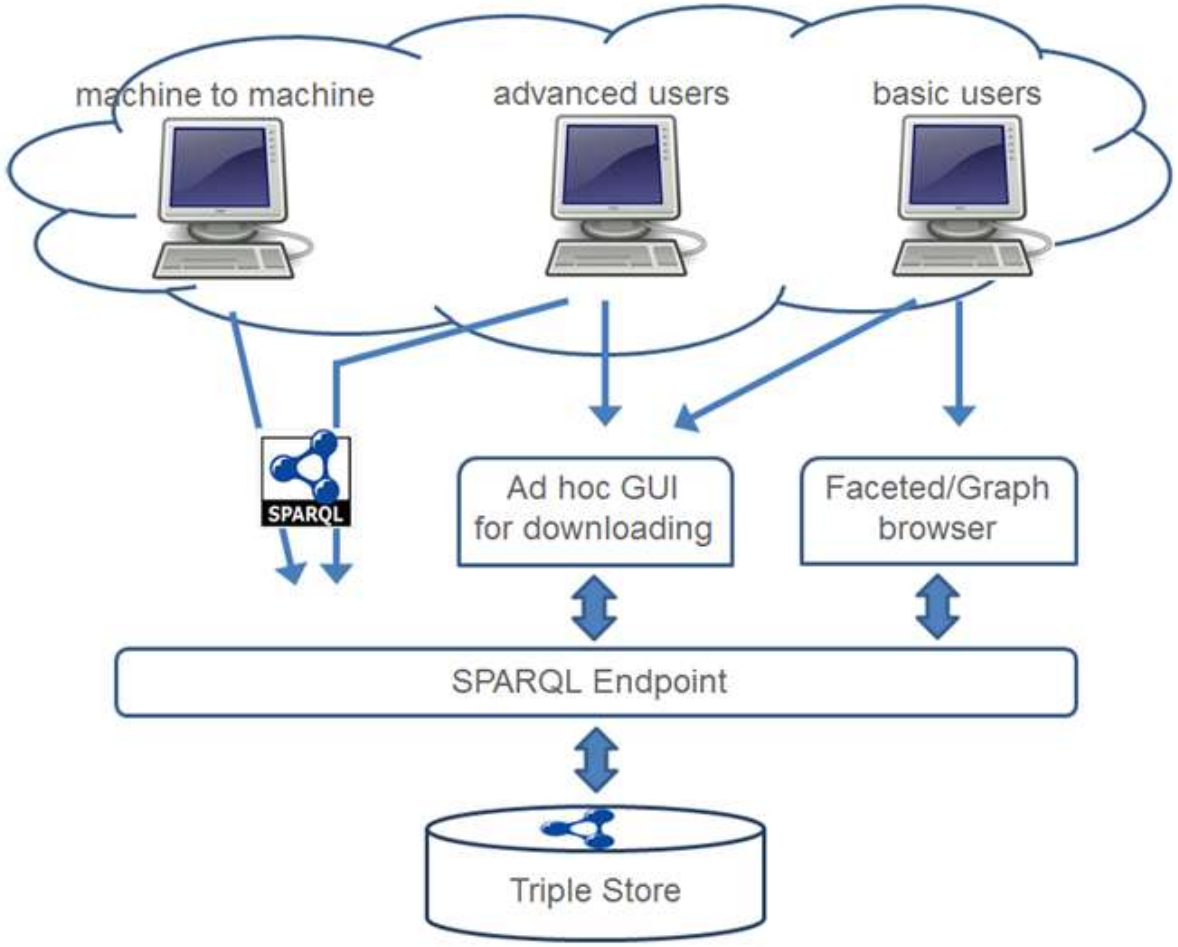

Image courtesy of: Istat, Italy

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	Load, Query and Inferencing	Solution Development and Analytic Tools
• Relational2RDF	• RDF/OWL Data Management	• Java, HTTP access
• Plug-in for Protégé	• SQL & SPARQL Query	• JSON, XML output
• Topbraid Composer integration	• OWL Inferencing	• Graph visualization (Cytoscape)
• Support for Apache Jena	• Semantic Rules	• Oracle Advanced Analytics (R, Mining)
• Natural Language Processing Extraction (partners)	• Semantic Indexing	• Oracle Business Intelligence (OBIEE)
	• Scalability & Security	• Map (GIS) Visualization
	• SQL Developer integration	

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Geospatial Linked Data Platform for NSIs

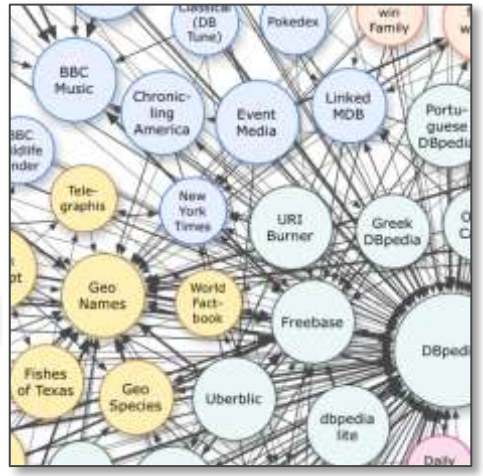
Graph Analysis and Reporting

GeoSPARQL, SQL, Java, …

Linked Data

Graph Data Management
Query Engine
Ontologies
Inferencing Engine

RDF Graph Layer



Public LOD endpoints (DBPedia, GeoNames, …)

Enterprise Data Stores

Attribute Data

Geometry Data

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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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

Australian Government Bureau of Meteorology

Bentley

CSIRO

GeoConnections

Defence Geospatial Information Working Group

USGS science for a changing world

interactive instruments

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Ordnance Survey

Raytheon

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.

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"
```

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)

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

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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