



HELLENIC REPUBLIC
National and Kapodistrian
University of Athens

Representation, Querying and Visualisation of Linked Geospatial Data

Konstantina Bereta and George Stamoulis

RoD Tutorial

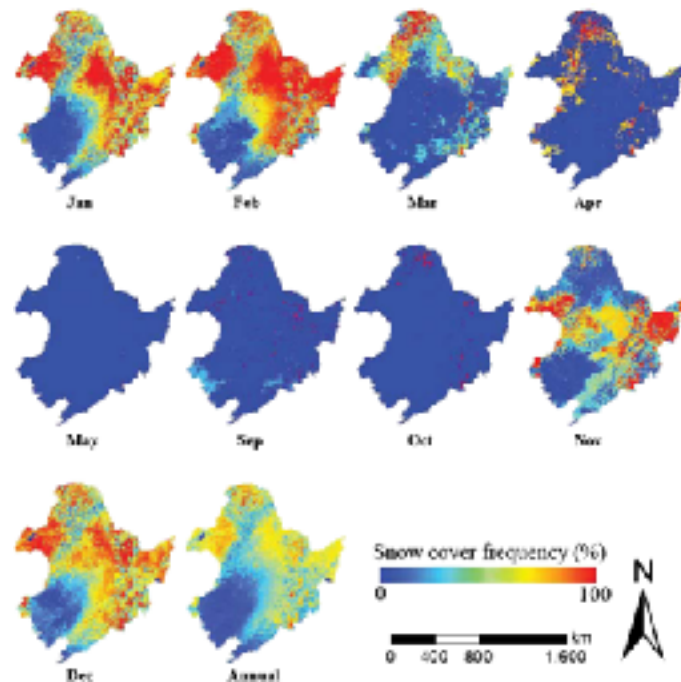
October 4, 2018

Outline

- Introduction
- Previous related research in other areas
- Motivation
- Extensions of RDF and SPARQL for the representation and querying of geospatial data
- Geospatial description logics and geospatial ontology-based data access systems
- Implemented systems, evaluation and comparison
- Visualisation of linked geospatial data
- Open issues

Why Spatial (and Temporal) Data?

- Spatial and temporal data are very important in reality: Everything that happens, happens sometime, somewhere.
- Decision making can be substantially improved if we know when and where things take place.
- This tutorial is for the “where”.



Previous Research

Geographic Information Systems (GIS) Research

- Lots of interesting theoretical and practical work by GIS researchers.
- Topics covered:
 - Geographic data and their representation
 - Geographic data modelling and geographic databases
 - GIS software
 - Cartography and map production
 - Spatial data analysis and decision making
 - Geospatial data on the Web

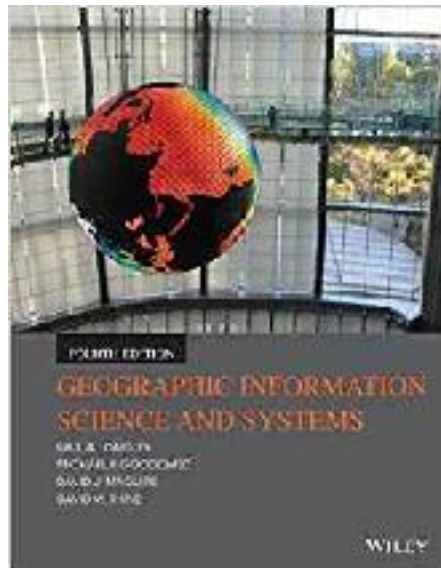
Geographic Information Systems Research (cont'd)

- Industrial impact:
 - Lots of relevant standards by the Open Geospatial Consortium (OGC).
 - State-of-the-art GIS software e.g., ArcGIS or QGIS.



Geographic Information Systems Research (cont'd)

- Educational impact:
 - Relevant ideas have found their way in well-known GIS books.

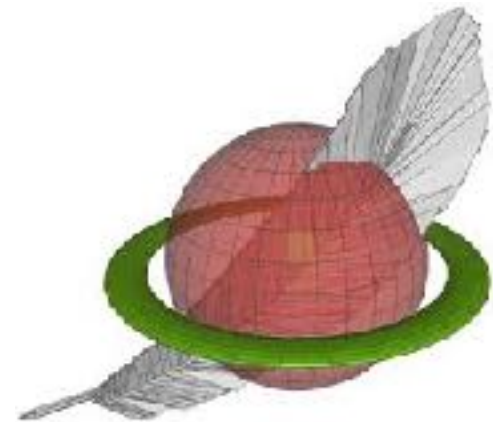


Spatial Database Research

- Lots of interesting theoretical and practical work by database researchers.
- Topics covered:
 - Data models and query languages
 - Storage structures and indexing techniques
 - Query processing
 - User interfaces
 - Implemented systems
 - Applications

Spatial Database Research (cont'd)

- Industrial impact:
 - The OGC standard “OpenGIS Simple Feature Access - Part 2: SQL option” introduced geospatial data in SQL in 2010.
 - Spatially enabled databases (e.g., PostGIS, Oracle Spatial, Spatialite).



Spatial AI Research

- Lots of interesting theoretical and practical work by Artificial Intelligence researchers.
- Topics covered:
 - Spatial logics
 - Spatial constraint networks
 - Implemented systems
 - Applications
 - Contributions to other AI research areas like planning and commonsense reasoning

Motivation

Geospatial Data on the Web

- Very popular and useful map software.



bingTM maps



Open Government Data

The image is a collage of four screenshots from different open government data portals:

- Top Left:** Screenshot of **data.gov.uk** with the slogan "Opening up government". It features a navigation bar with "Data", "Apps", "Consultation", and "Forum". A search box prompts users to "Enter your postcode to find your local area user".
- Top Right:** Screenshot of **DATA.GOV** celebrating its "HAPPY THIRD ANNIVERSARY". It includes a search bar and a "Latest Datasets" section listing various data releases like "FY 10 Multifamily Initial Endorsements" and "FedScope Separations Cube (Fiscal Year 2011)".
- Bottom Left:** Screenshot of **data.gov.de** titled "Das Datenportal für Deutschland". It features a search bar and a map of Germany.
- Bottom Right:** Screenshot of **geoportal.gov.gr** with the title "Δημόσια, Ανοικτά Δεδομένα" (Public, Open Data). It contains text in Greek explaining the portal's purpose and lists categories like "Βασικά στοιχεία", "Περιβάλλον", and "Πολιτική".

Linked Geospatial Data- Ordnance Survey (United Kingdom)

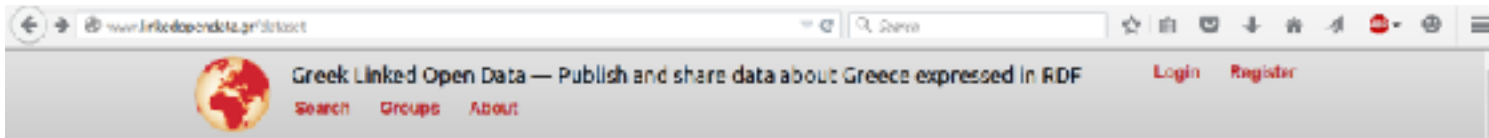


Linked Geospatial Data- Kadaster (The Netherlands)

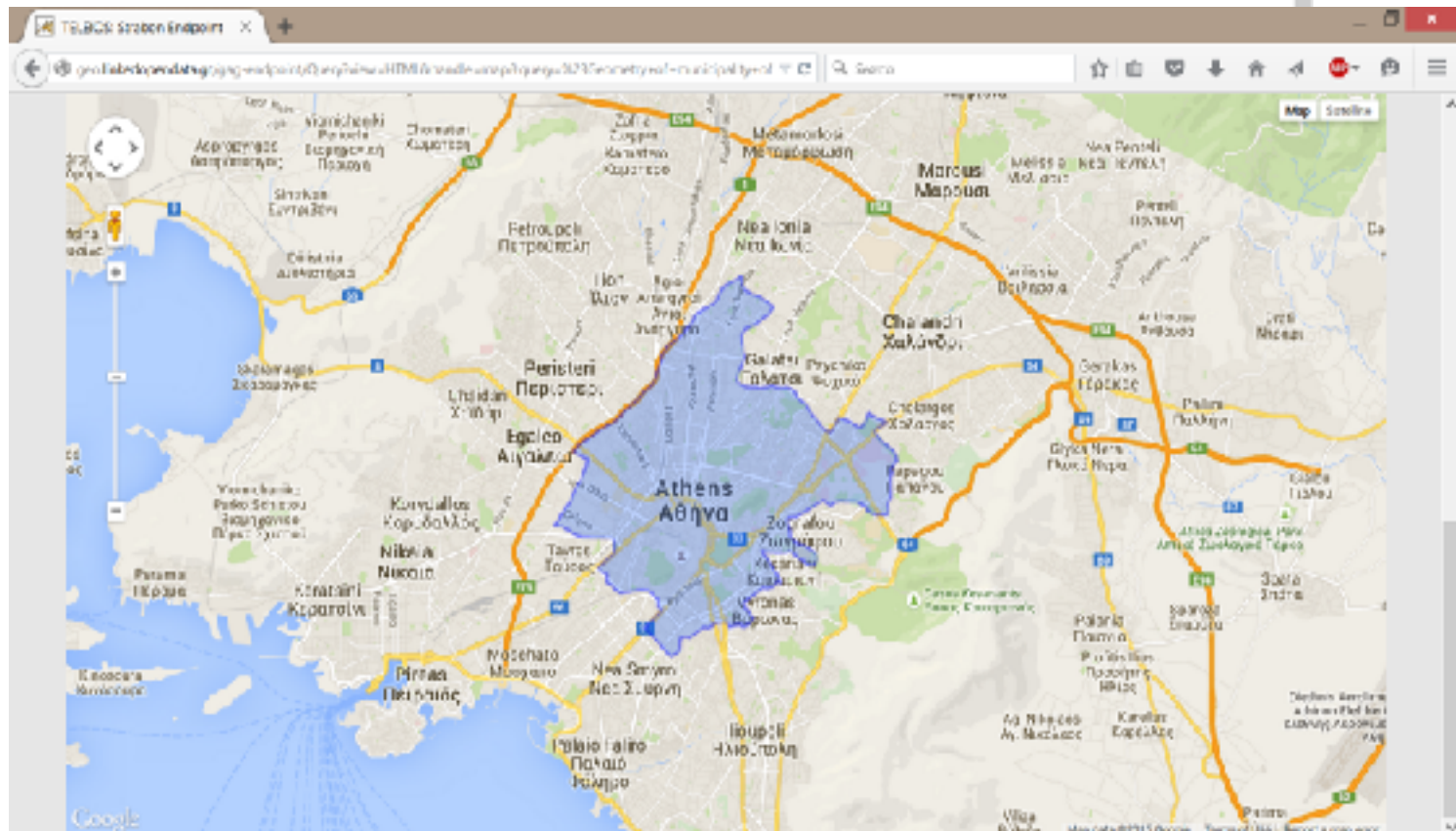
The screenshot displays the PDOK Data Platform website. The header includes the PDOK logo and navigation links for Home, Datasets, SPARQL, and Developers. The main content area features several data service cards:

- Basisregistraties Adresen en Gebouwen (BAG)**: A dark blue card with a list of services including 'Met documentatie', 'Run in Postgres', 'Linked Data', 'Graph browser', and 'Elasticsearch/GeoJSON'. It also lists 'Hoev Kadaster' and 'Tripes: 4/1.2 miljoen' and a 'Meer informatie' button.
- Basisregistratie Kadaster (BKK)**: A white card with a blue header. Text: 'Overzicht van de ligging van de kadastrale percelen in Nederland. Fungeert als schakel tussen tanen en registratie, vervult voor externe gebruikers vaak een rol als de functie, een ondergrond ter oplichte waarvan de gebruiker eigen informatie kan vastleggen en presenteren.'
- Basisregistratie Topografie (BRT) - TOP10NL (feb 2017)**: A white card with a blue header. Text: 'TOP10NL is een digitaal objectgericht kaartbestand wat ten grondslag ligt aan de topografische kaart 1:10000 en wat veelvuldig in diverse GIS- en CAD-systemen wordt gebruikt voor ondergrond analyse, en beheers- en planologische doelen.'
- Natura 2000**: A white card with a blue header. Text: 'Natura 2000 is het samenhangend netwerk van beschermde natuuroebieden in Nederland.'
- Drone no-fly zones**: A white card with a blue header. Text: 'Webservice met de no-fly zones voor drones. Ook de recreatieve dronevlieger meer zich aan deze zones.'
- Vergunningen Eindhoven**: A white card with a blue header. Text: 'Dit betreft een dataset met aanvraagde vergunningen van de gemeente Eindhoven en hun omgeving.'

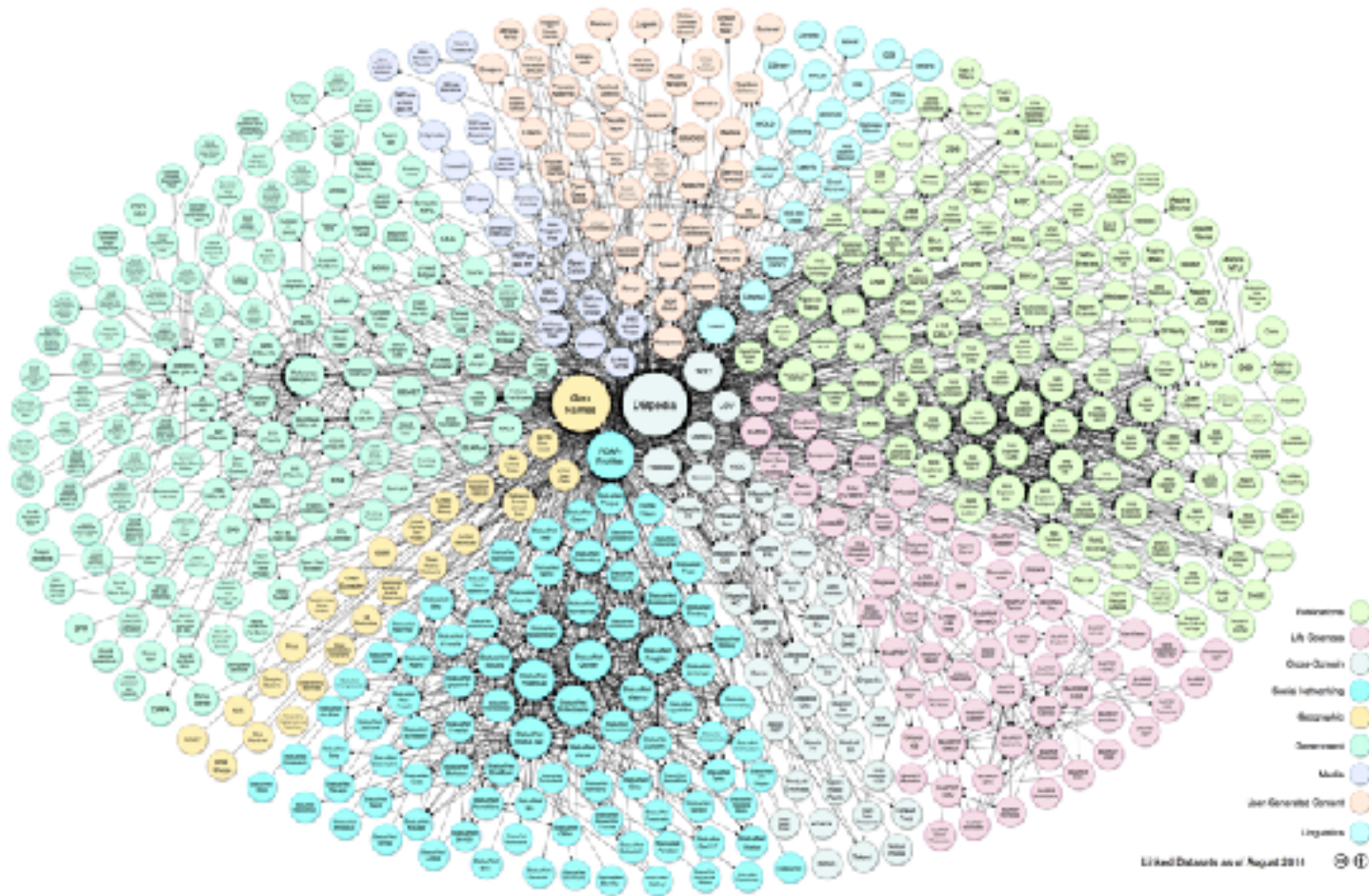
<http://www.linkedopendata.gr>



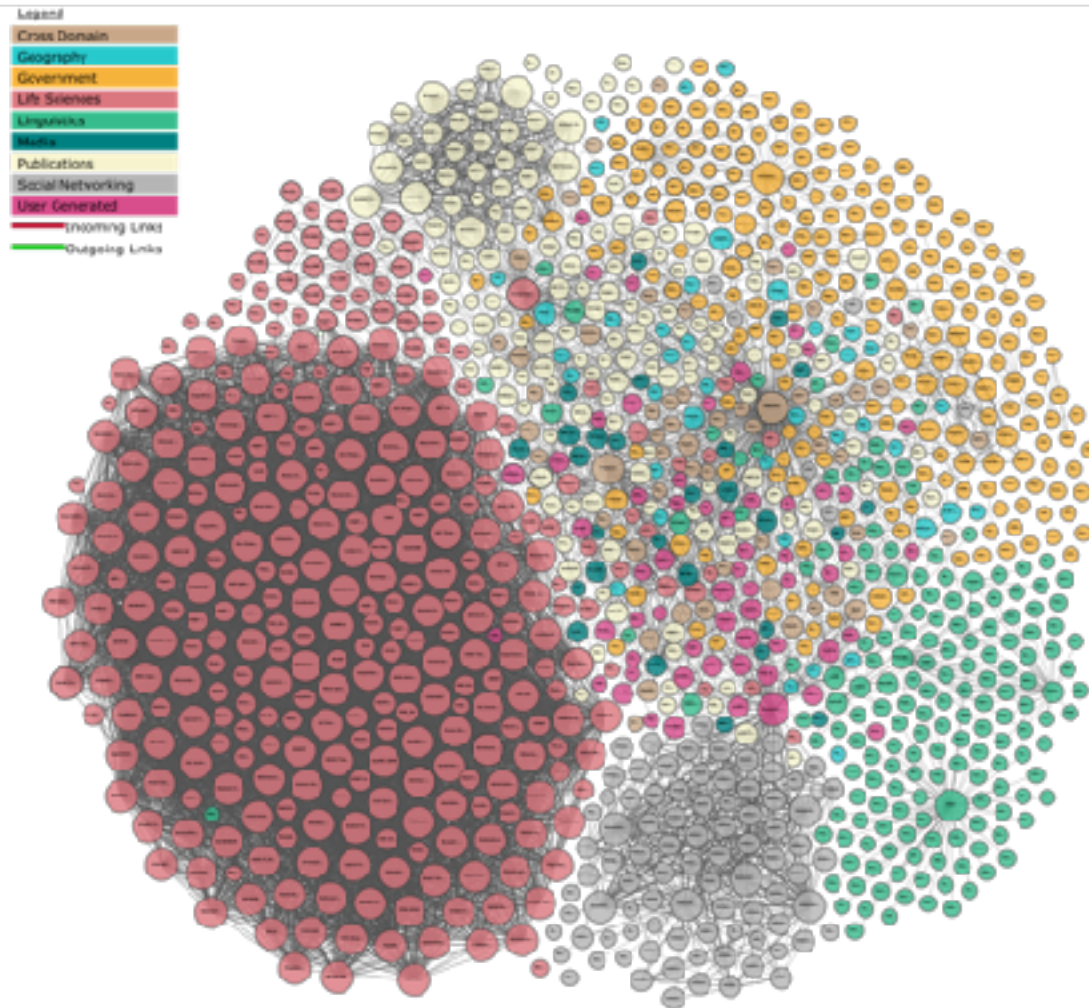
Search - Greek Linked Open Data



LOD Cloud (Aug. 2014): Lots of Geospatial Data



LOD Cloud (Aug. 2017): Lots of Geography Data



Geospatial Extensions of RDF and SPARQL

Overview

- Early papers:
 - Kolas (2007)
 - Perry's PhD dissertation (2008)
 - Koubarakis and Kyzirakos (2010)
- More recent proposals:
 - The OGC standard GeoSPARQL (2012)
 - The data model stRDF/stSPARQL (2012)
 - The framework RDFⁱ (2013)

GeoSPARQL and stRDF/stSPARQL

- The two proposals offer constructs for:
 - Developing **ontologies** for spatial and temporal data
 - Encoding **spatial and temporal data** that use these ontologies in **RDF**
 - **Extending SPARQL** to query spatial and temporal data
- **Temporal data** is covered only by stRDF/stSPARQL

GeoSPARQL

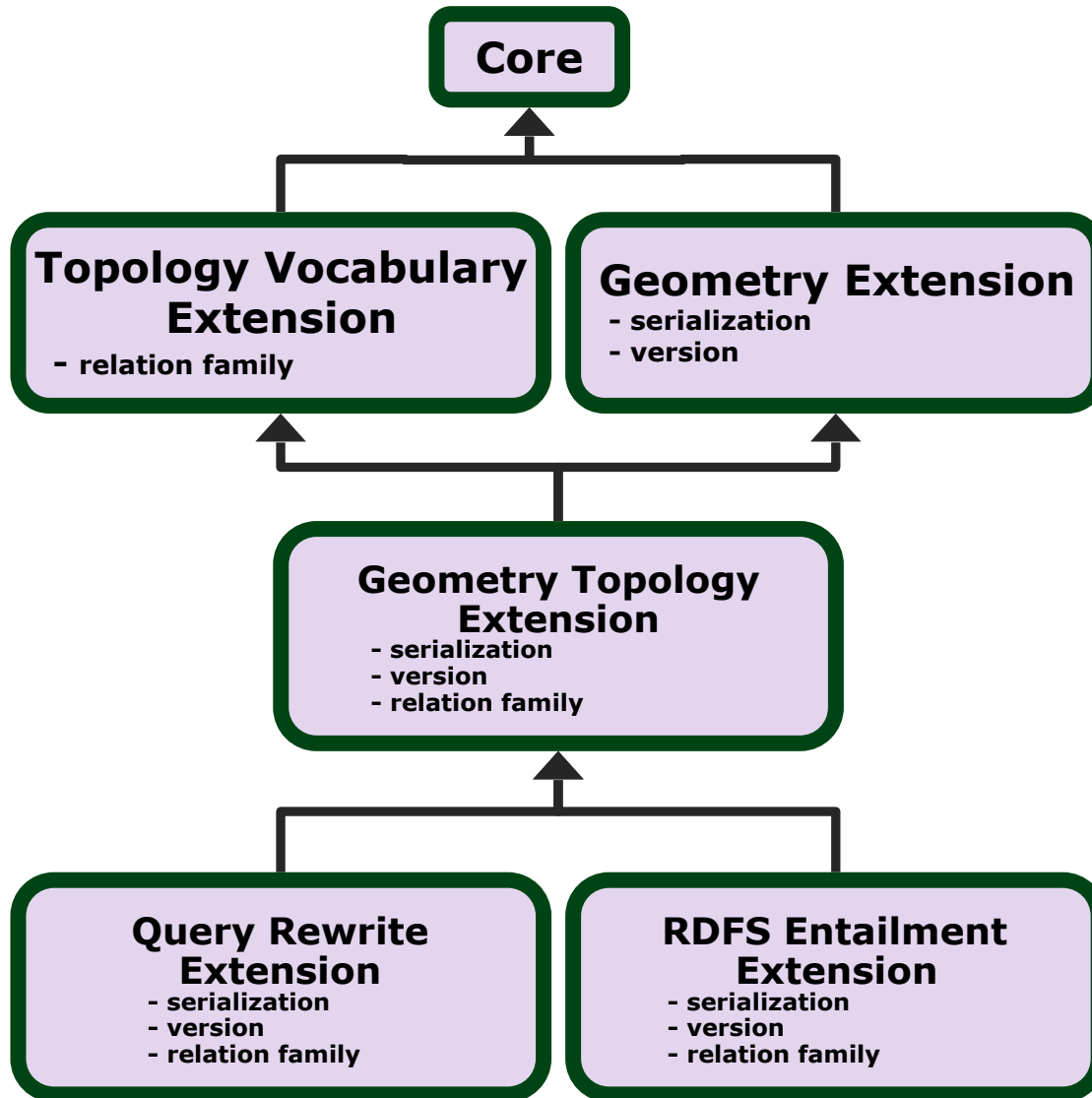
[Perry and Herring, 2012]

GeoSPARQL is an **OGC standard**.

Main functionalities:

- Representing geospatial information is done using **high level ontologies** inspired from GIS terminology
- Geometries are represented using **literals of spatial datatypes**
- Literals are serialized using OGC standards **WKT** and **GML**
- Families of **functions** are offered for querying geometries

GeoSPARQL Components

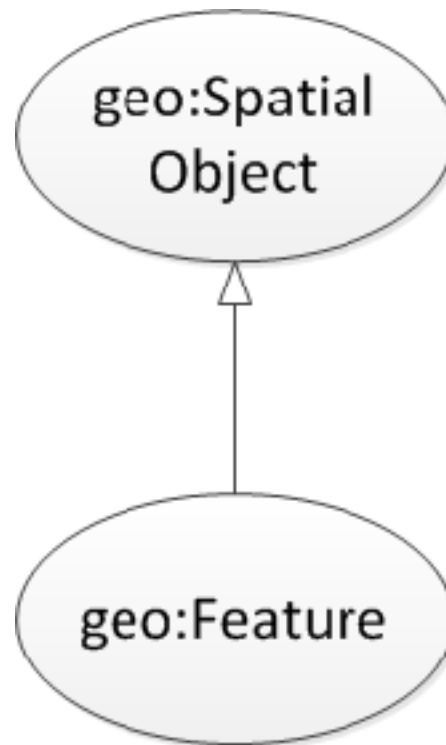


Parameters

- **Serialization**
 - WKT
 - GML
- **Relation Family**
 - Simple Features
 - RCC-8
 - Egenhofer

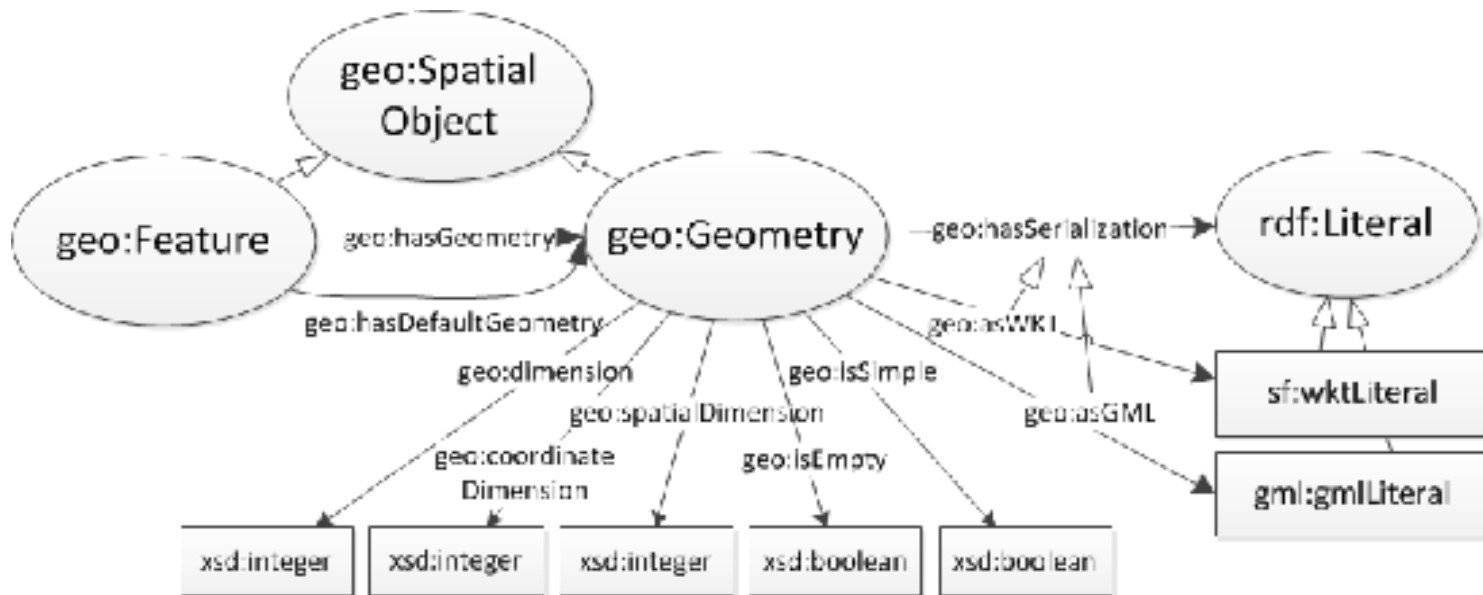
GeoSPARQL Core

- Defines two **top level classes** that can be used to organize geospatial data



GeoSPARQL Geometry Extension

- Provides vocabulary for asserting and querying data about the **geometric attributes** of a feature



Example

```
gag:Olympia
  rdf:type gag:MunicipalCommunity;
  gag:name "Ancient Olympia";
  gag:population "184"^^xsd:int;
  geo:hasGeometry ex:polygon1.
```



Ancient Olympia

```
ex:polygon1
  rdf:type geo:Geometry;
  geo:asWKT "http://www.opengis.net/def/crs/OGC/1.3/CRS84
    POLYGON((21.5 18.5,23.5 18.5,
              23.5 21,21.5 21,21.5 18.5))"
    ^^sf:wktLiteral.
```

GeoSPARQL Geometry Extension (cont'd)

The following **non-topological query functions** from the “OpenGIS Simple Feature Access” standard are also offered:

- `geof:distance`
- `geof:buffer`
- `geof:convexHull`
- `geof:intersection`
- `geof:union`
- `geof:difference`
- `geof:symDifference`
- `geof:envelope`
- `geof:boundary`

Example Query

Find forests near municipal communities.

```
SELECT ?r ?c
WHERE {
  ?r rdf:type clc:Region;
    geo:hasGeometry ?rGeom;
  clc:hasCorineLandCover ?f.
  ?f rdfs:subClassOf clc:Forest.
  ?c rdf:type gag:MunicipalCommunity;
    geo:hasGeometry ?cGeom.

FILTER (geof:distance(?rGeom,?cGeom,uom:metre) < 1000) }
```



GeoSPARQL Geometry Topology Extension (cont'd)

The following **topological query functions** from the “OpenGIS Simple Feature Access” standard are offered:

- `geof:sfEquals`
- `geof:sfDisjoint`
- `geof:sfIntersects`
- `geof:sfTouches`
- `geof:sfCrosses`
- `geof:sfWithin`
- `geof:sfContains`
- `geof:sfOverlaps`

Example Query

Find forests that border municipal communities.

```
SELECT ?r ?c
WHERE {
  ?r rdf:type clc:Region;
     geo:hasGeometry ?rGeom;
  clc:hasCorineLandCover ?f.
  ?f rdfs:subClassOf clc:Forest.
  ?c rdf:type gag:MunicipalCommunity;
     geo:hasGeometry ?cGeom.

FILTER (geof:sfTouches (?rGeom, ?cGeom) ) }
```



GeoSPARQL Geometry Topology Extension (cont'd)

- The previous family of functions are based on the **DE-9IM** model studied by Clementini and Felice.
- Similarly, the family of functions in the **Egenhofer** and **RCC-8** frameworks are offered.

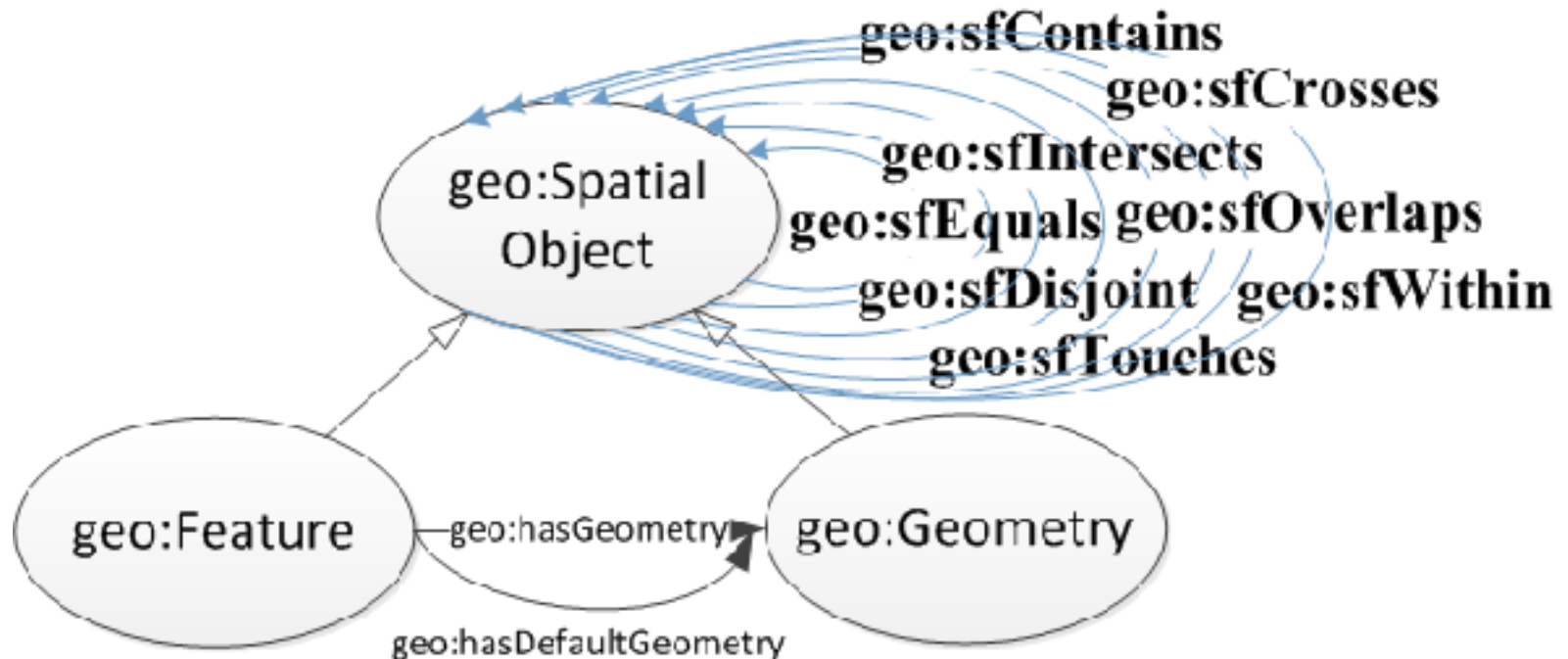
GeoSPARQL Topology Vocabulary Extension

- This extension is used for representing **topological information** about features.
- Topological information is **inherently qualitative** and it is expressed in terms of **topological relations** (e.g., containment, adjacency, overlap etc.).
- Topological information can be **derived from geometric information** or it might be captured by **asserting explicitly the topological relations** between features.



Topological Relations

- The topological relations of the "OpenGIS Simple Feature Access" standard are offered.



Topological Relations (cont'd)

- Similarly, the topological relations of the **Egenhofer** and the **RCC-8** framework.
- GeoSPARQL offers us **vocabulary for expressing these topological relations in the database and the queries.**

Example



```
gag:Olympia rdf:type gag:MunicipalCommunity.
```

```
gag:OlympiaMunicipality rdf:type gag:Municipality.
```

```
gag:WesternGreece rdf:type gag:Region.
```

```
gag:Olympia geo:sfWithin gag:OlympiaMunicipality.
```

```
gag:OlympiaMunicipality geo:sfWithin gag:WesternGreece.
```


Query I

Find the **municipality** that contains the community of Ancient Olympia.

```
SELECT      ?m
WHERE {
    ?m rdf:type gag:Municipality.
    ?m geo:sfContains gag:Olympia.
}
```

Answer

gag:OlympiaMunicipality

Query II

Find the **region of Greece** that contains the community of Ancient Olympia.

```
SELECT      ?m
WHERE {
    ?m rdf:type gag:Region.
    ?m geo:sfContains gag:Olympia.
}
```

Answer

gag:WesternGreece

Query II (cont'd)

- The answer to Query II can be computed by **reasoning about the transitivity** of relation `geo:sfContains`.
- The GeoSPARQL standard **does not cover such entailed topological relations** between spatial objects. Is this a problem?

Administrative Geography of Great Britain

SO16 0AS



SO16 0AS is a Postcode Unit.

Objects related to "SO16 0AS"

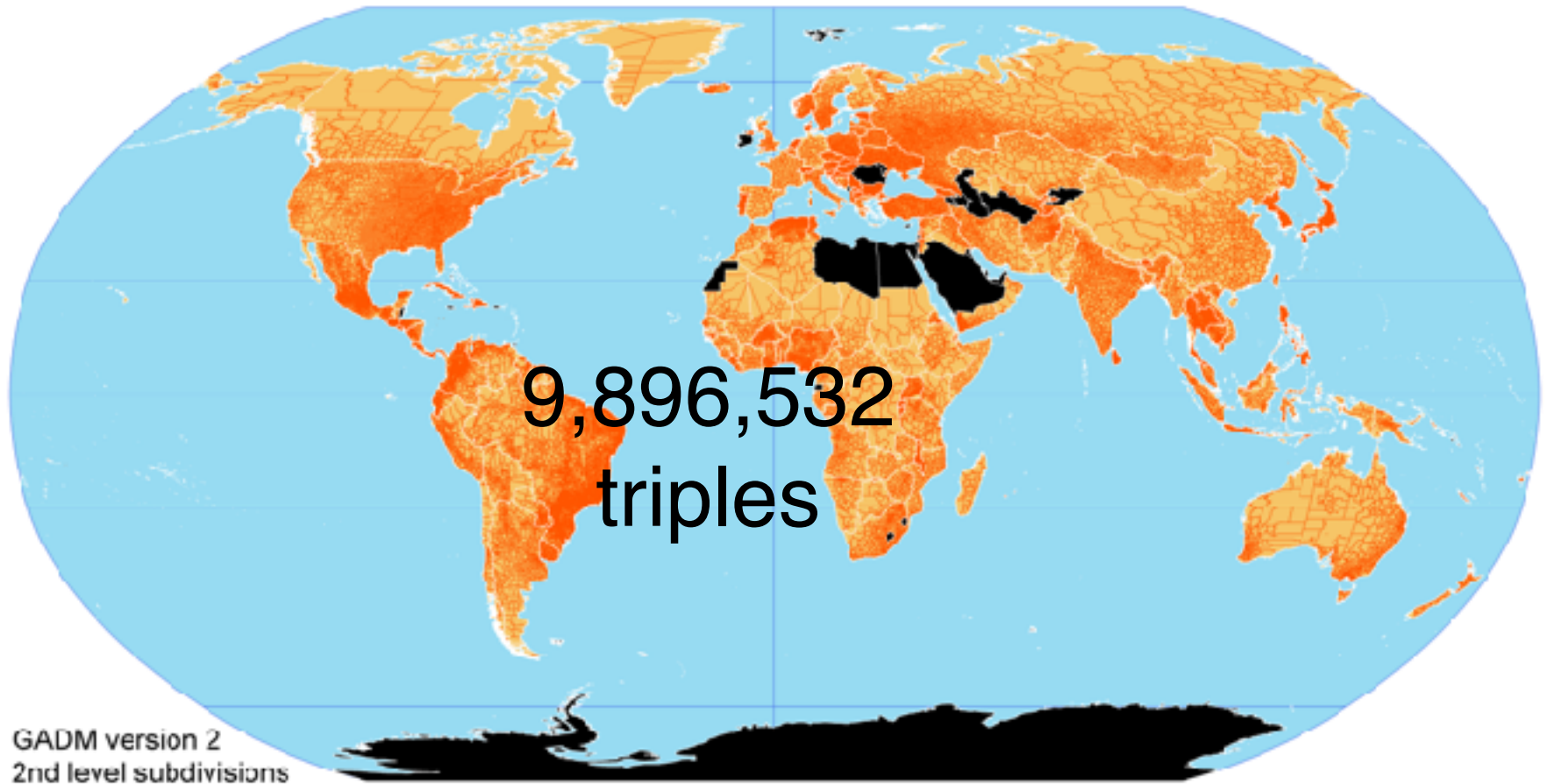
County	Hampshire
Within	SO16 0 SO SO16
NhsHA	E1800009
Nhs Regional HA	E1000002
Positional Quality Indicator	10

73,546,231
triples

Core facts about "SO16 0AS"

Type	Postcode Unit
Label	SO16 0AS
Northing	115515.00
Easting	432901.00
Lat	50.937372
Long	-1.470616
LH	E1800009
Notation	SO16 0AS

Global Administrative Areas (GADM)



Nomenclature of Territorial Units for Statistics (NUTS)

[Home](#)

LV00 - Latvija

This file is a human-readable representation of both the [feature](#) and its [geometry](#).

View the feature as: [Turtle](#), [RDF/XML](#).

View the geometry as: [Turtle](#), [RDF/XML](#), [GML](#), [KML](#).

Feature

rdftype	rmon:NUTSRegion , spatial:Feature
rdfs:label	LV00 - Latvija
ramon:name	Latvija
ramon:level	2
ramon:code	LV00
ngeo:geometry	nuts:LV00_geometry
spatial:PP	LV0
spatial:PFI	http://dbpedia.org/resource/Daugavpils
spatial:EC	http://nuts.geovocab.org/id/EE
spatial:EC	http://nuts.geovocab.org/id/L
spatial:EC	http://nuts.geovocab.org/id/EE0
spatial:EC	http://nuts.geovocab.org/id/L0
spatial:EC	http://nuts.geovocab.org/id/EE00
spatial:EC	http://nuts.geovocab.org/id/L00
spatial:EC	http://nuts.geovocab.org/id/EE004
spatial:EC	http://nuts.geovocab.org/id/L005
spatial:EC	http://nuts.geovocab.org/id/L006
spatial:EC	http://nuts.geovocab.org/id/L003
spatial:EC	http://nuts.geovocab.org/id/L008
spatial:EC	http://nuts.geovocab.org/id/L009
spatial:EC	http://nuts.geovocab.org/id/EE008
owl:sameAs	http://statwrap.ontologycentral.com/dic/geo#LV00
owl:sameAs	http://rdfdata.eu/ont/europa.sw/ramon/nuts2006/LV00
owl:sameAs	http://ec.europa.eu/eurostat/ramon/rdfdata/nuts2008/LV00
owl:sameAs	http://nuts.psi.enacting.org/id/LV00

Geometry

rdftype	ngeo:Polygon
---------	------------------------------

316,246
triples



Pending Extension in schema.org

- Topological relations between places in schema.org

URI	Class/Property or Type	The URI identifies the class.
topologicallyContains	GeoSpatialGeometry or Place	Represents a relationship between two geometries (or the places they represent), relating a containing geometry to a contained geometry. "A contains B iff no points of B lie in the exterior of A, and at least one point of the interior of B lies in the interior of A". As defined in DC-QM .
topologicallyCovers	GeoSpatialGeometry or Place	Represents a relationship between two geometries (or the places they represent), relating a geometry to another that covers it. As defined in DC-QM .
topologicallyCovers	GeoSpatialGeometry or Place	Represents a relationship between two geometries (or the places they represent), relating a covering geometry to a covered geometry. "Every point of B is a point of (the interior or boundary of) A". As defined in DC-QM .
topologicallyCrosses	GeoSpatialGeometry or Place	Represents a relationship between two geometries (or the places they represent), relating a geometry to another that crosses it: "A crosses B: they have some but not all interior points in common, and the dimension of the intersection is less than that of at least one of them". As defined in DC-QM .
topologicallyDisjoint	GeoSpatialGeometry or Place	Represents spatial relations in which two geometries (or the places they represent) are topologically disjoint: they have no point in common. "They form a set of disconnected geometries." (a symmetric relationship, as defined in DC-QM)
topologicallyEqual	GeoSpatialGeometry or Place	Represents spatial relations in which two geometries (or the places they represent) are topologically equal, as defined in DC-QM . "Two geometries are topologically equal if their interiors intersect and no part of the interior or boundary of one geometry intersects the exterior of the other" (a symmetric relationship)
topologicallyIntersects	GeoSpatialGeometry or Place	Represents spatial relations in which two geometries (or the places they represent) have at least one point in common. As defined in DC-QM .
topologicallyOverlaps	GeoSpatialGeometry or Place	Represents a relationship between two geometries (or the places they represent), relating a geometry to another that geospatially overlaps it, i.e. they have some but not all points in common. As defined in DC-QM .
topologicallyTouches	GeoSpatialGeometry or Place	Represents spatial relations in which two geometries (or the places they represent) touch: they share at least one boundary point in common, but no interior points." (a symmetric relationship, as defined in DC-QM)
topologicallyWithin	GeoSpatialGeometry or Place	Represents a relationship between two geometries (or the places they represent), relating a geometry to one that contains it, i.e. it is inside (i.e. within) its interior. As defined in DC-QM .
	Text	The Global Location Number (GLN) sometimes also referred to as International Location

Knowledge Graphs with Geospatial Information

- Current extension of Yago2 with geospatial information including topological relations between geo-entities.



The Query Rewrite Extension

- Enables the **translation of qualitative topological information appearing in a query to quantitative.**
- This is done by rewriting of queries with triple patterns involving topological relations into queries with topological functions on geometries.
- The rewriting is based on a set of **RIF rules** defined in the standard.

The RDFS Extension

- Enables standard RDFS reasoning for GeoSPARQL classes and properties.

The Data Model stRDF

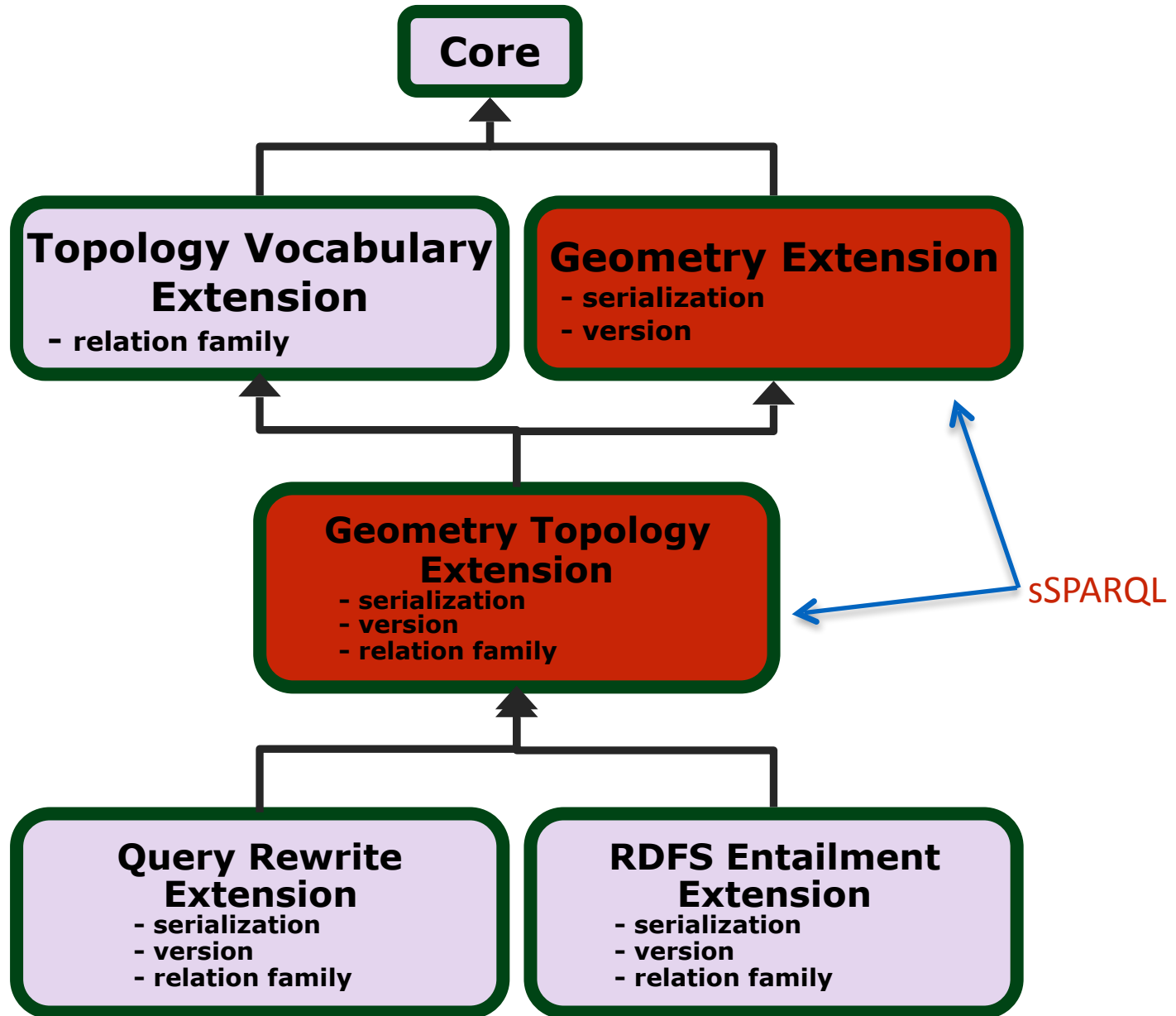
- An extension of RDF for the representation of **geospatial information that changes over time**.
- **Geospatial dimension:**
 - **Spatial data types** are introduced.
 - Geospatial information is represented using **spatial literals** of these datatypes.
 - **OGC standards WKT and GML** are used for the serialization of spatial literals.
- **Temporal dimension**
- Proposed independently and around the same time as GeoSPARQL (starting with an ESWC 2010 paper by Koubarakis and Kyzirakos).

The Query Language stSPARQL

- It is an extension of SPARQL 1.1
- It offers families of functions for querying geometries. The same functions as in the Geometry Extension and Geometry Topology Extension of GeoSPARQL.
- In addition the following **spatial aggregate functions** are offered:

```
strdf:geometry strdf:union(set of strdf:geometry A)
strdf:geometry strdf:intersection(set of strdf:geometry A)
strdf:geometry strdf:extent(set of strdf:geometry A)
```
- **Temporal dimension** (not covered in this tutorial. See the ESWC 2013 by Bereta, Smeros and Koubarakis).

GeoSPARQL vs. stSPARQL



Example of stSPARQL

Compute the parts of burnt areas that lie in coniferous forests.



```
SELECT ?burntArea ( strdf:intersection(?baGeom,  
                                strdf:union(?fGeom) ) AS ?burntForest,  
WHERE { ?burntArea rdf:type noa:BurntArea;  
                                strdf:hasGeometry ?baGeom.  
                                ?forest rdf:type clc:Region;  
                                clc:hasLandCover clc:ConiferousForest;  
                                strdf:hasGeometry ?fGeom.  
FILTER ( strdf:intersects(?baGeom, ?fGeom) ) }  
GROUP BY ?burntArea ?baGeom
```


Geospatial description logics and geospatial ontology-based data access

Motivation

- Publishing data as RDF and correlating them with linked geospatial data is useful
 - Challenges:
 - Domain experts (earth scientists, geologists, etc.) and domain specific applications heavily rely on geospatial databases
 - Original data are stored in them
 - Conversion to RDF is not always practical
 - Frequent updates
 - Large datasets
 - Different tools need to be used
- } Domain experts
☹️

Representing Geospatial Information in Description Logics

- Use OWL-DL [Katz et al. 2005]
- Define a spatial concrete-domain DL
 - $\mathcal{ALC}(\text{RCC8})$ [Lutz and Milisic, 2007]
 - $\text{DL-Lite}_{\mathcal{F}, \mathcal{R}}^{\square}(\text{RCC8})$ [Özçep and Möller, 2012]
- Use OWL and a spatial ABOX
 - RacerPro [Wessel-Möller, 2009]
 - PelletSpatial [Stocker and Sirin, 2009]
 - [Grütter et al., 2008]
- Keyword queries over spatial OBDA sources [Eiter et al. 2013]
- Spatial ontology-mediated query answering over mobility streams [Eiter et al. 2017]

Geospatial Ontology-based Data Access

- Geospatial RDB2RDF systems: GeoTriples, TriplesGeo
- Mapping languages: R2RML (W3C standard), OBDA
- OBDA systems:
 - Ontop [Rodriguez-Muro et al., JWS'15]
 - Ultrawrap [Sequeda et al., JWS'13]
- Geospatial OBDA systems:
 - Ontop-spatial [Bereta & Koubarakis, ISWC'16]
 - Oracle Spatial and Graph 12c release 2

OBDA Mappings

[MappingDeclaration] [[mappingId gag_geometry
target gag:geometry/{gid}/ gag:asWKT {geo}^^geo:wktLiteral .
source select distinct gid,geom from gag
mappingId clc_geometry

Target clc:/{gid}/ clc:hasGeometry clc:/geometry/{id}/ . clc:/{gid}/ clc:asWKT {geom}
^^geo:wktLiteral .
source select distinct gid, geom from clc
mappingId clc_id

target clc:/{gid}/ clc:hasID {gid} . clc:/{gid}/ clc:hasLandUse {code_00} .
source select distinct gid, geom, code_00 from clc
mappingId clc_type

target clc:/{gid}/ clc:type clc:type . clc:/{gid}/ rdf:type clc:Area .
source select distinct gid, geom from clc]]

R2RML example

```
[ a rr:TriplesMap ;
  rr:logicalTable [ a rr:R2RMLView ;
    rr:sqlQuery "select distinct gid,geom from gag" ] ;
  rr:predicateObjectMap [ a rr:PredicateObjectMap ;
    rr:objectMap [ a rr:ObjectMap , rr:TermMap ;
      rr:column "geo" ;
      rr:termType rr:Literal ] ;
    rr:predicate clc:asWKT ] ;
  rr:subjectMap [ a rr:TermMap , rr:SubjectMap ;
    rr:template gag:{gid} ; rr:termType rr:IRI ] ] .
```

Virtual Triples

clc:20440 rdf:type geo:Geometry;

geo:asWKT "POLYGON(...)"^^geo:wktLiteral .

Clc:20512 rdf:type geo:Geometry;

geo:asWKT "POLYGON(...)"^^geo:wktLiteral .

...

	gid integer	code_00 character varying(100)	id character varying(18)	remark character varying(20)	area_ha numeric	shape_leng numeric	shape_area numeric	geom geometry
1	20440	BroadLeavedForest	EU-1900387		9169698	72.0513238	5691.69698	010300002
2	20512	BroadLeavedForest	EU-1900769		13331793	35.0022057	9033.31793	010300002
3	20543	BroadLeavedForest	EU-1900881		19247076	6.17030328	189.247076	010300002
4	20797	BroadLeavedForest	EU-1901587		17822436	3.55011923	107.822436	010300002
5	20904	BroadLeavedForest	EU-1901816		11899830	97.0454395	8618.99830	010300002

Example GeoSPARQL query

Select CORINE areas, their land use and the administrative division they belong to.

PREFIX geo: <<http://www.opengis.net/ont/geosparql#>>

PREFIX gag: <<http://geo.linkedopendata.gr/gag/ontology/>>

PREFIX clc: <<http://geo.linkedopendata.gr/corine/ontology#>>

SELECT DISTINCT ?x1 ?x2 ?lu

WHERE {

?x1 geo:asWKT ?g1 .

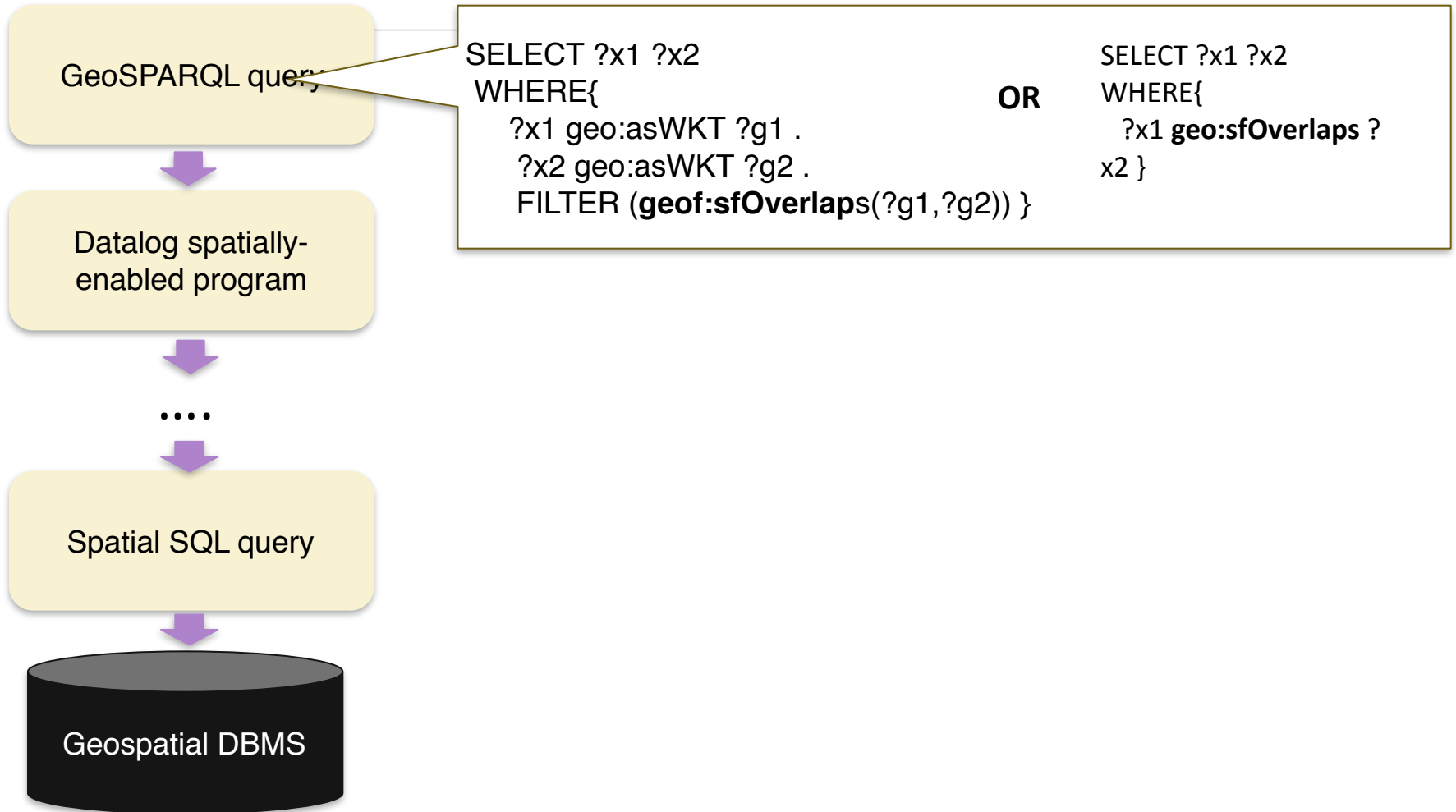
?x2 geo:asWKT ?g2 .

?x2 clc:hasLandUse ?lu .

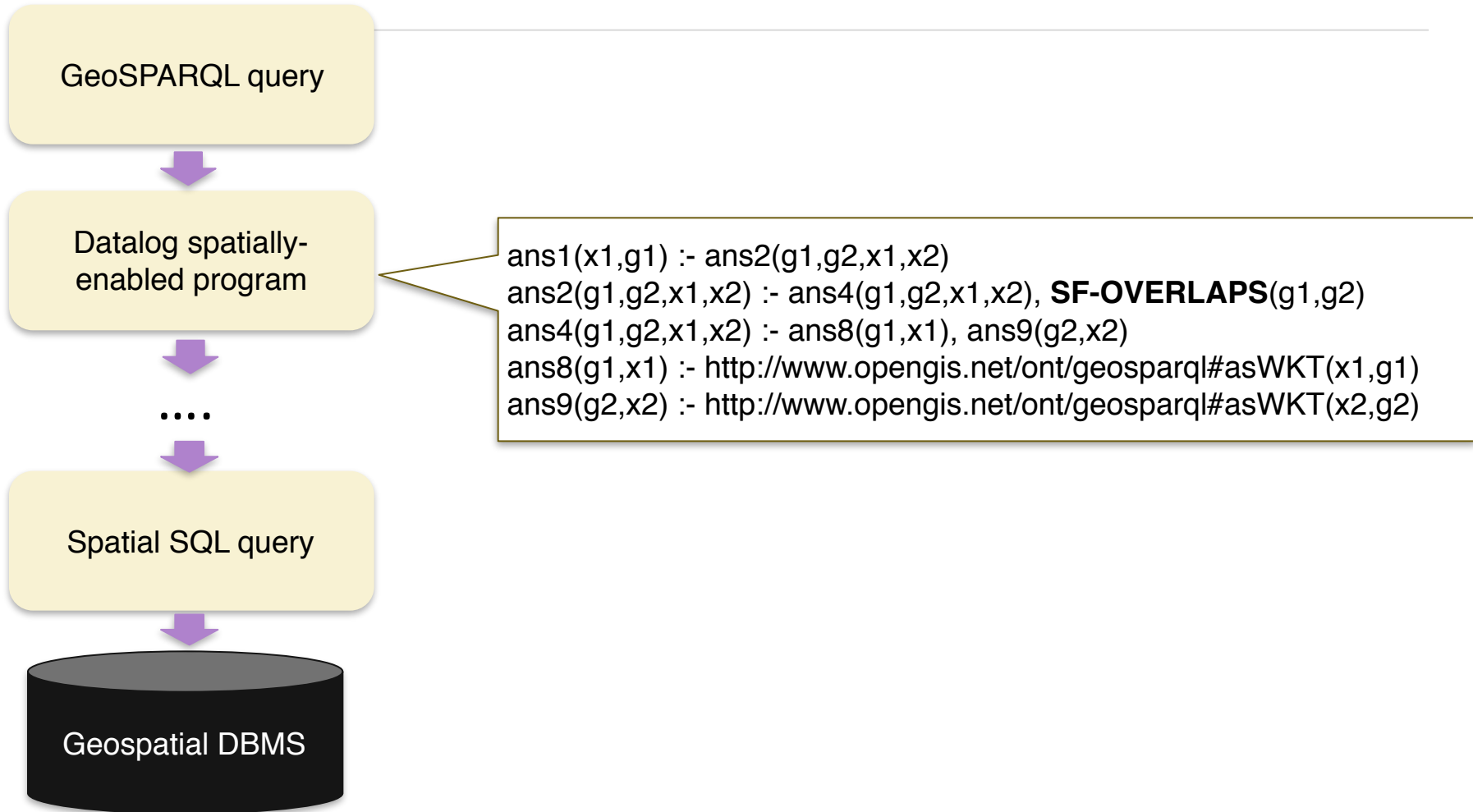
FILTER (geof:sfIntersects(?g1,?g2))

}

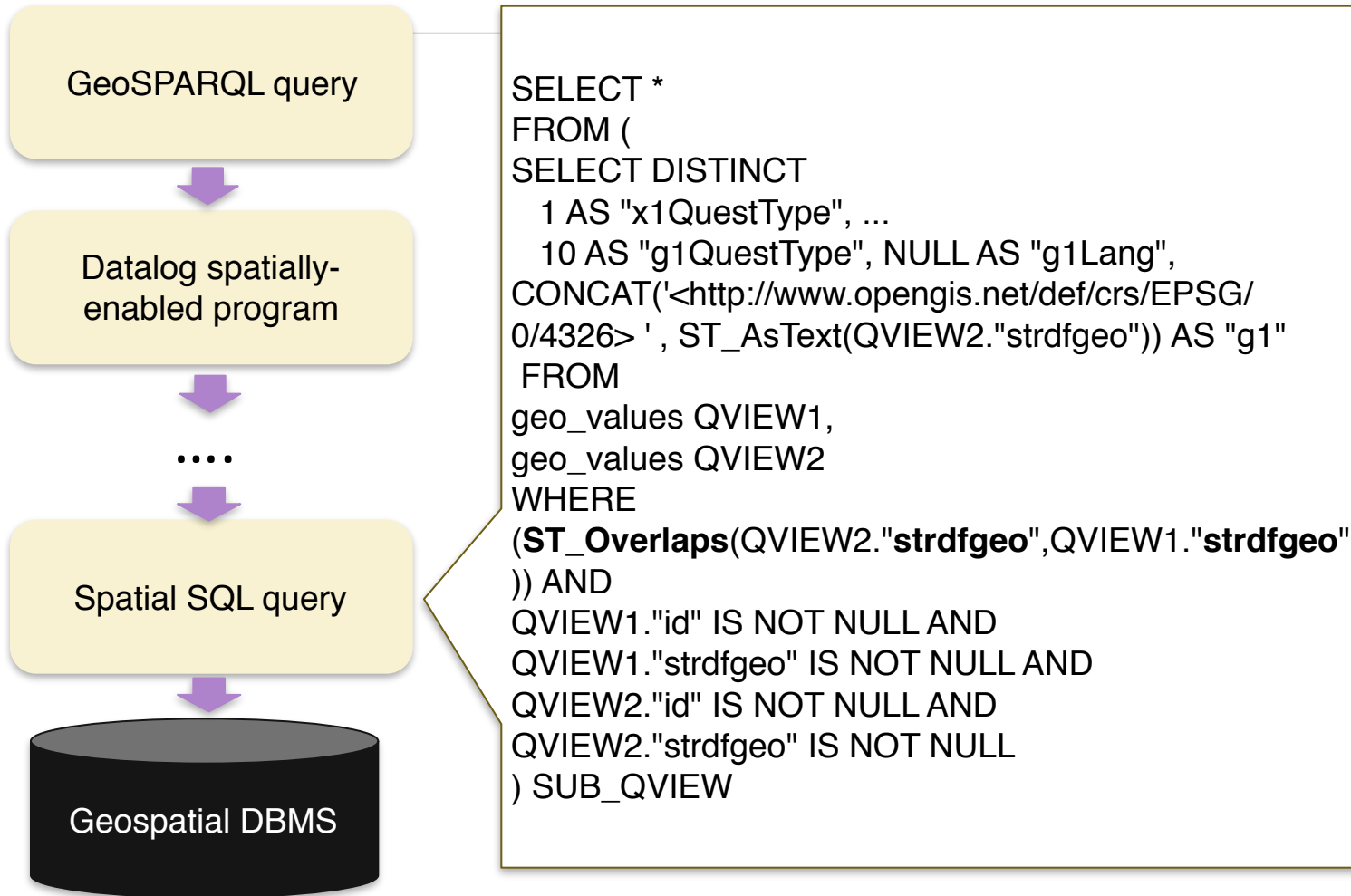
GeoSPARQL-to-SQL translation



GeoSPARQL-to-SQL translation



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Example GeoSPARQL Query

PREFIX gag: <<http://geo.linkedopendata.gr/gag/ontology/>>

PREFIX clc: <<http://geo.linkedopendata.gr/corine/ontology#>>

SELECT distinct ?x1 ?lu

WHERE {

 ?x1 geo:asWKT ?g1 .

 ?x2 geo:asWKT ?g2 .

 ?x2 clc:hasLandUse ?lu .

 FILTER(**geof:sfIntersects**(?g1,?g2)) }

Raster Data Sources

```
[[ mappingId    chicago
   target      :{rid} rdf:type :rasterCell ; :hasGeometry {rast} .
   source      select rid,rast from chicago;
mappingId      gadm
target         : {id_0} rdf:type :AdministrativeDivision; geo:hasGeometry :{gid} .
               :{gid} geo:asWKT {geom}^^geo:WKTLiteral .
source        select * from usa_adm2 ]]
```

Data sources

GeoTIFF image of Chicago imported in PostGIS as table (raster geometries)

CHICAGO[rid | rast]

USA_ADM2[gid | id_0 | iso | name_0 | id_1 | name_1 | id_2 | name_2 | geom]

Shapefile describing USA administrative divisions and boundaries (vector geometries)

Example Query

Retrieve administrative divisions that intersect with raster cells of the GeoTIFF image of Chicago.

```
SELECT ?adm
```

```
WHERE{
```

```
  ?r rdf:type :rasterCell .
```

```
  ?r :hasGeometry ?rast .
```

```
  ?adm rdf:type :AdministrativeDivision .
```

```
  ?adm geo:hasGeometry ?g .
```

```
  ?g geo:asWKT ?geom .
```

```
FILTER(geof:sfIntersects(?geom,rast))
```

Vector geometries will
be bound

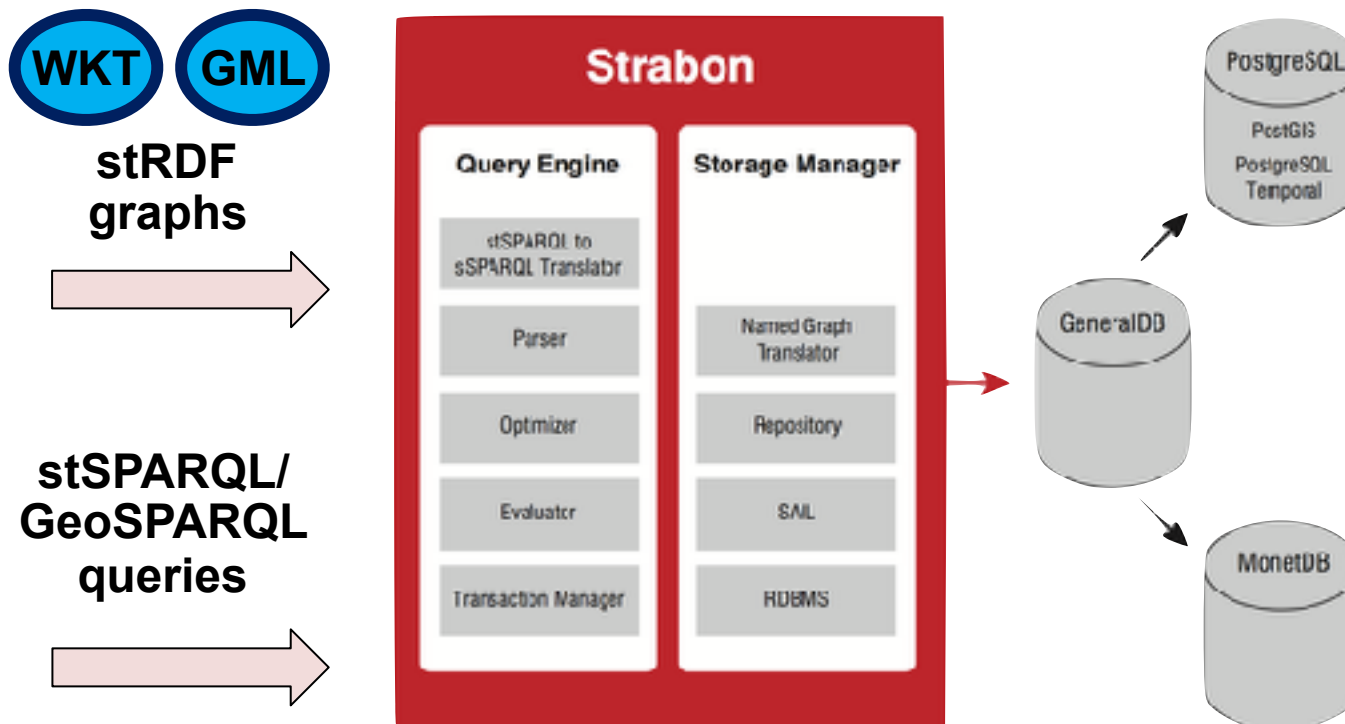
Raster geometries will
be bound

Implemented systems, evaluation and comparison

Strabon (ISWC 2012, ESWC 2013)



Find more at: <http://strabon.di.uoa.gr>



Strabon - Geospatial features



Support for:

- stRDF and stSPARQL
- GeoSPARQL (core, geometry extension, geometry topology extension)
- Multiple Coordinate Reference Systems (CRS)
- Builds on Sesame RDBMS
- Geospatial relational database as back-end (PostGIS, MonetDB)
- R-tree index

Parliament

- Developed by Raytheon BBN Technologies (Dave Kolas). Available at: <http://www.parliament.semwebcentral.org/>
- First GeoSPARQL implementation. Supports:
 - Core
 - Topology vocabulary
 - Geometry
 - Geometry Topology
 - RDF entailment
 - Multiple CRS
 - R-tree index

Spatial plugin for Sesame by OpenSahara. Supports:

- GeoSPARQL
 - Core
 - Topology Vocabulary
 - Geometry
 - Geometry Topology
 - RDFS entailment
- No multiple CRS. Only WGS84
- Open source (Apache v2.0). Available at: <https://dev.opensahara.com/projects/useekm>

GraphDB



-
- Developed by Ontotext. Former OWLIM.
 - GeoSPARQL support
 - Apache Lucene index
 - Closed source. Available at: <https://ontotext.com/products/graphdb/editions/>

Allegrograph



- Quad store developed by Franz Inc
- Closed source. Available at <http://www.franz.com/agraph/allegrograph/>
- No GeoSPARQL support
- Supports only points
- Only a few spatial operations supported (Buffer, Bounding Box, Distance)

OpenLink Virtuoso

- Developed by OpenLink. Available at: <http://virtuoso.openlinksw.com/> Supports:
- No GeoSPARQL
- Points only
 - Serialized as typed literals
- Spatial operations (subset of SQL/MM)
- Multiple CRS
- R-tree

Stardog



- Limited GeoSPARQL support:
 - WKT literals. Native support for points. Use of JTS library for polygons
 - Operators
geof:relate, geof:distance, geof:within, geof:nearby, geof:area
 - Geospatial features only offered in enterprise edition

Brodt et al.

- Built on top of RDF-3X by University of Stuttgart
- No GeoSPARQL support
- Geometries represented as typed WKT literals
- Only WGS84 supported
- OGC-SFA spatial operations as SPARQL filter functions
- R-tree supported (but only used for spatial selections)

Perry PhD thesis

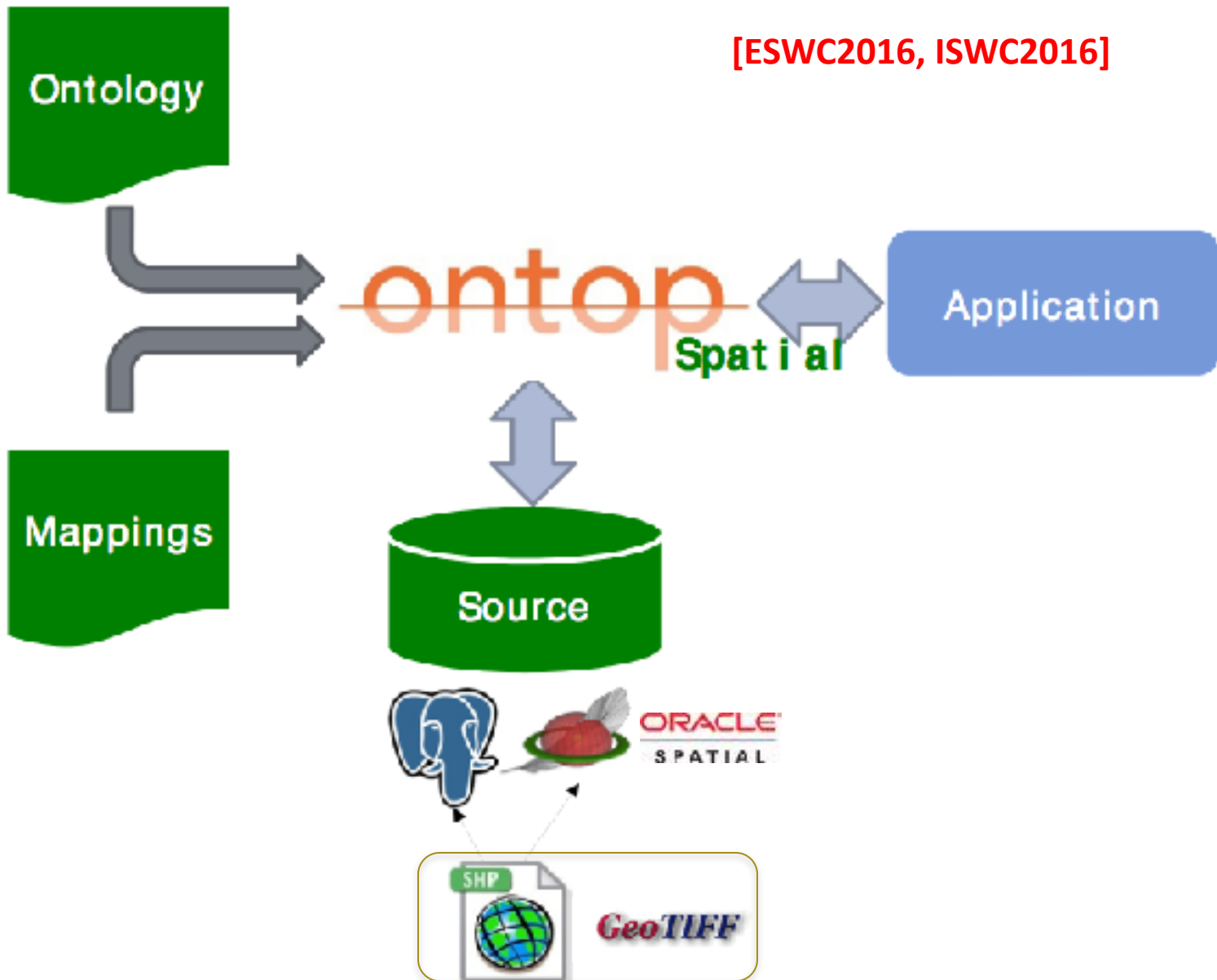
- Implementation on top of Oracle 10g by Wright State University
- Support for SPARQL-ST
- GeoRSS GML serialization of geometries
- Spatial and temporal variables
- Spatial and temporal filters (RCC8, Allen)
- R-tree support

Oracle spatial and Graph

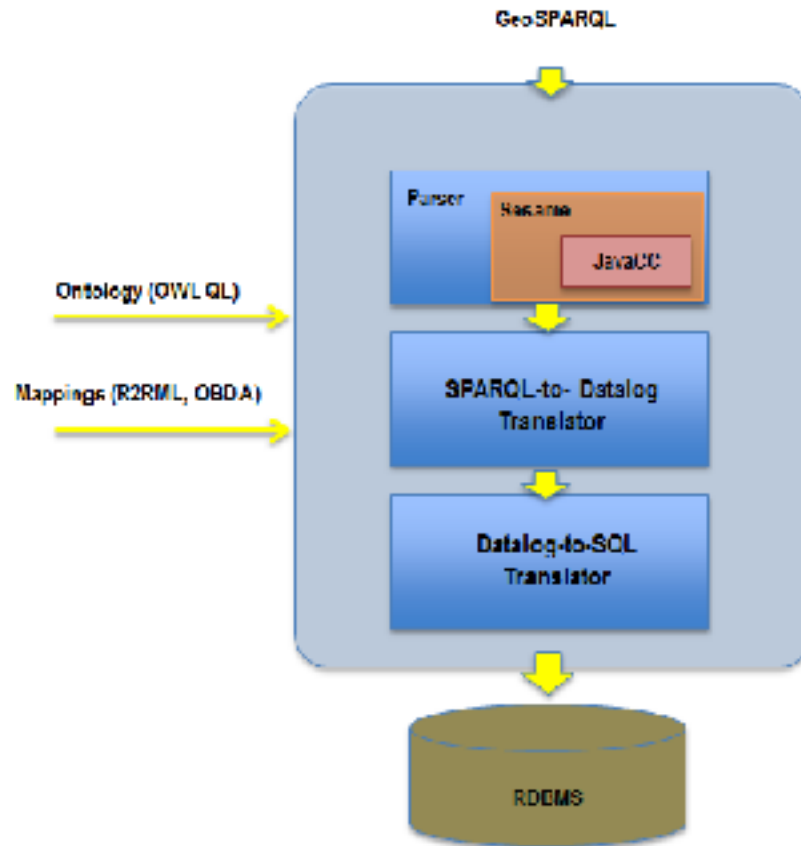


- Developed by Oracle
- GeoSPARQL support
- CRS support
- Recently added support for virtual RDF graphs (as of Oracle Spatial and Graph 12c Release 2)

[ESWC2016, ISWC2016]



Architecture overview (extending Ontop)



Evaluation

Geographica Benchmark

- Evaluation of the state-of-the-art geospatial RDF stores [Garbis et al., ISWC 2013]
 - Real workload
 - Synthetic workload
- Stresses all recent systems in heavily spatial queries and workload.
- Open source Java framework available at <http://geographica.di.uoa.gr>

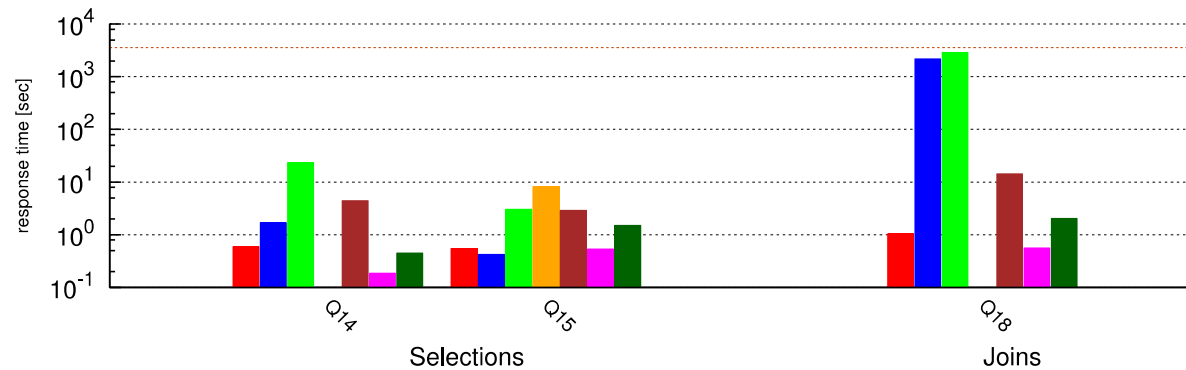
Real workload

Dataset	Size	#triples	#geometries	#points per geometry (avg)
Geonames	45MB	400K	22000	1
DBpedia	89MB	430K	8000	1
LGD	29MB	150K	12000	1
GAG	33MB	4K	325	400
CLC	401MB	630K	45000	140
Hotspots	90MB	450K	37000	4

Execution times in real workload

	Query	Strabon	uSeekM	Parliament	System X - Parallel	System X - Serial
Non topological construct functions	Q1	42.33	38.11	152.71	62.58	293.85
	Q2	22.18	21.47	90.23	41.02	204.65
	Q3	29.48	27.06	98.56	45.86	213.47
	Q4	7.65	3.22	23.16	19.87	309
	Q5	14.80	4.17	21.83	23.6	236.6
	Q6	23.82	19.58	-	39.87	199.25
Spatial selections	Q7	0.36	1.22	2.42	-1	-1
	Q8	0.42	0.57	7.69	-1	-1
	Q9	0.83	1.77	35.03	-1	-1
	Q10	0.73	1.51	76.05	-1	-1
	Q11	2.66	2.96	195.07	-1	-1
	Q12	0.79	0.55	2.39	8.87	6.07
	Q13	0.82	0.89	63.14	-1	-1
	Q14	0.5	2.29	24.31	13.33	11.35
	Q15	0.5	0.99	3.41	10.24	10.27
	Q16	2.79	5.52	63.2	-1	-1
Spatial joins	Q17	3.00	1.6	35.89	-1	-1
	Q18	4.52	2233.73	2680.2	>1h	14.51
	Q19	1272.54	>1h	>1h	>1h	>1h
	Q20	115.93	>1h	>1h	>1h	396.79
	Q21	113.26	>1h	>1h	>1h	409.54
	Q22	26.33	>1h	>1h	-1	-1
	Q23	26.29	>1h	>1h	-1	-1
	Q24	26.66	>1h	>1h	-1	-1
	Q25	342.87	>1h	>1h	>1h	1.879.45
	Q26	343.2	534.81	2040	809.18	>1h
Aggregate functions	Q27	343.72	>1h	>1h	-1	>1h
	Q28	3.56	-	-	-	-
	Q29	258.35	-	-	-	-

Adding systems with limited geospatial functionalities



Geospatial RDF stores vs OBDA

<i>Dataset</i>	<i>Table Size</i>	<i>No. of rows/ geometries</i>	<i>Avg #points/ geometry</i>
Corine Land Cover (CLC)	283MB	44834	187.84
Hotspots	35 MB	37048	5
Global Administrative Geography (GAG)	24 MB	326	3020.14
OSM-Buildings	42 MB	155474	6.5
OSM-Landuse	20 MB	40220	19.4
OSM-places	2.4 MB	13043	1
OSM-points	12 MB	61664	1
OSM-railways	2 MB	4996	13.3
OSM-roads	250 MB	514403	19
OSM-waterways	16 MB	20565	39.84

Queries

No	Query	#BGP's results	
00	Equals GADM P	1	0
01	Contains_GADM_P	1	9
02	Contains GADM P	1	0
03	Equals GADM L	1	1
04	Overlaps GADM L	1	0
05	Contains GADM L	1	0
06	Intersects CLC L	1	5
07	Contains_CLC_L	1	0
08	Equals_CLC_L	1	5
09	Overlaps CLC L	1	0
10	Overlaps CLC P	1	132
11	Intersects CLC P	1	533
12	Contains_CLC_P	1	401
13	Equals_CLC_P	1	0
14	Intersects_LGD_P	2	2749
15	Intersects_LGD_B	2	2749
16	Intersects_LGD_PL	2	2626
17	Intersects LGD P	2	2522
18	Intersects_LGD_LU	2	2722
19	Intersects_LGD_ROA	2	2387
20	Intersects_LGD_bigP	1	729189
21	Intersects_LGD_P2	3	5

Table 1: Spatial selections description

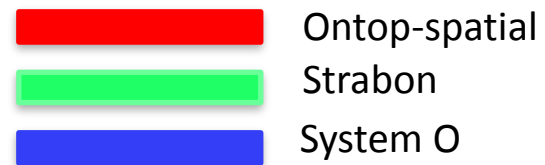
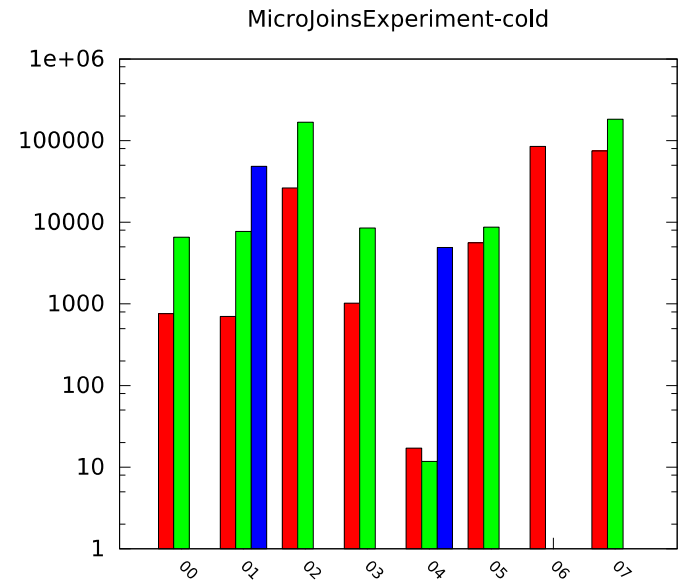
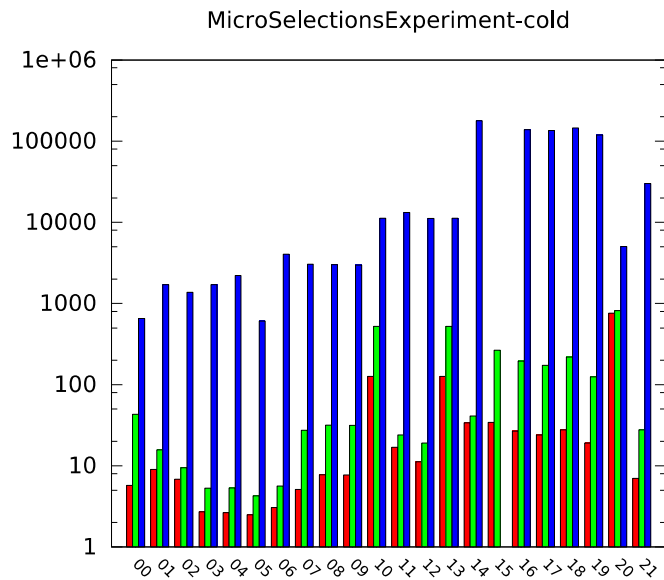
No	Query	#BGP's results	
00	Within CLC GADM	2	34114
01	Intersects GADM GADM	2	1556
02	Overlaps GADM CLC	2	17035
03	Intersects LGD GADM	3	154725
04	Intersects_LGD_LGD_Mus	4	2
05	Intersects_LGD_GADM	2	819319
06	Intersects LGD LGD	1	3686229
07	Crosses LGD LGD Roads	4	178602

Table 2: Spatial joins description

Highly selective query

Poorly selective query

Evaluation



Translated queries

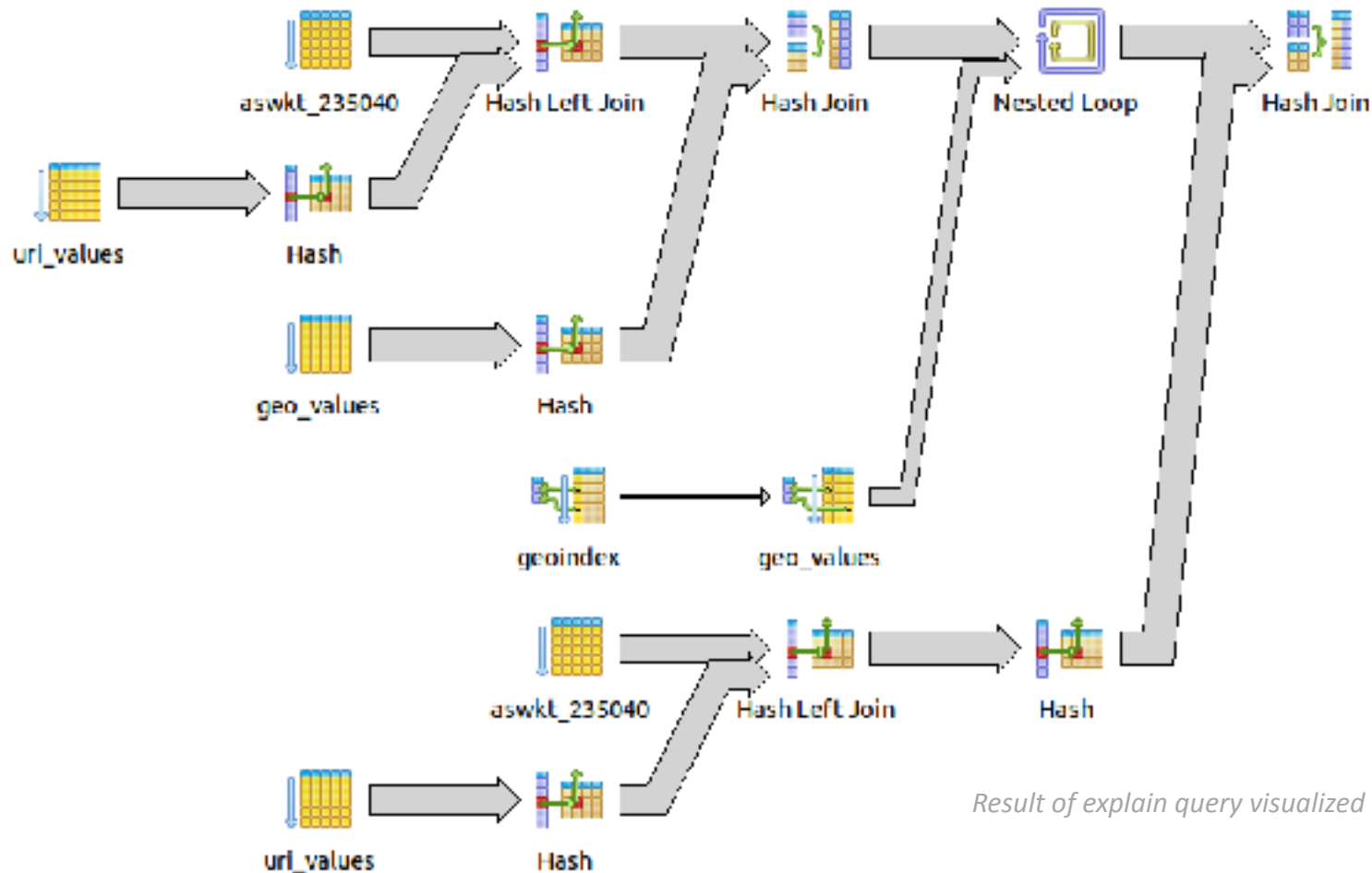
- Strabon query

```
SELECT a0.subj, u_s2.value, a2.subj, u_s1.value
FROM aswkt_855211 a0
INNER JOIN geo_values l_o2 ON (l_o2.id = a0.obj)
INNER JOIN geo_values l_o1 ON
((ST_Within(l_o1.strdfgeo, l_o2.strdfgeo)))
INNER JOIN aswkt_135992 a2 ON (a2.obj = l_o1.id)
LEFT JOIN uri_values u_s2 ON (u_s2.id = a0.subj)
LEFT JOIN uri_values u_s1 ON (u_s1.id = a2.subj)
```

- Ontop-spatial query

```
SELECT 1 AS "s1QuestType", NULL AS "s1Lang", ('http://geo.linkedopendata.gr/clc/'
|| REPLACE(..... || '/') AS "s1",
1 AS "s2QuestType", NULL AS "s2Lang", ('http://geo.linkedopendata.gr/gag/ont/'
|| REPLACE(... '/') AS "s2" FROM clc QVIEW1,
gag QVIEW2 WHERE QVIEW1."gid" IS NOT NULL
AND QVIEW1."geom" IS NOT NULL
AND QVIEW2."gid" IS NOT NULL
AND QVIEW2."geometry" IS NOT NULL
AND(ST_Within(QVIEW1."geom",QVIEW2."geometry"))
```

Spatial join query 6: Strabon query execution



Result of explain query visualized using PgAdmin III

DB statistics for spatial join 6

Strabon db statistics

node type	count	sum of times	% of query
Hash	4	751.907 ms	0.0 %
Hash Join	2	18,036.091 ms	0.0 %
Hash Left Join	2	14,028.716 ms	0.0 %
Index Scan	1	526,737.250 ms	0.3 %
Nested Loop	1	164,863,821.747 ms	99.7 %
Seq Scan	5	1,780.556 ms	0.0 %

Ontop db statistics

node type	count	sum of times	% of query
Append	1	699.975 ms	0.1 %
Index Scan	49	514,878.104 ms	61.0 %
Nested Loop	49	326,798.817 ms	38.7 %
Result	1	958.691 ms	0.1 %
Seq Scan	49	1,348.070 ms	0.2 %

Tables produced using <https://explain.depesz.com/>

Performance Evaluation: Strabon vs. Ontop-spatial on a 30 GB dataset

Operation (geof:intersects)	Selectivity	Geometry types	Strabon	Ontop-spatial	Remarks
Spatial Selection	high	* (irrelevant)	100 msecs	100 msecs	
Spatial Selection	low	Point-Polygon	100 msecs	100 msecs	
Spatial Selection	low	Polygon-Polygon	500 msecs	100-200 msecs	
Spatial Join	high	Point - Polygon	< 1000 msecs	< 1000 msecs	
Spatial Join	high	Polygon-Polygon	100000 msecs	100000 msecs	
Spatial Join	low	Polygon-Polygon	>40 mins	10 mins	Sometimes the difference here is order(s) of magnitude

Performance Evaluation and Scalability of Strabon and Ontop-spatial

- Defined and used the benchmark Geographica (<http://geographica.di.uoa.gr/>).
- Strabon has better performance and functionality than Parliament, uSeekM, System X, Virtuoso, System O, and System Y (longer version of ISWC 2013 paper).
- Ontop-spatial has better performance than Strabon and System O (long version of ISWC 2016 paper).

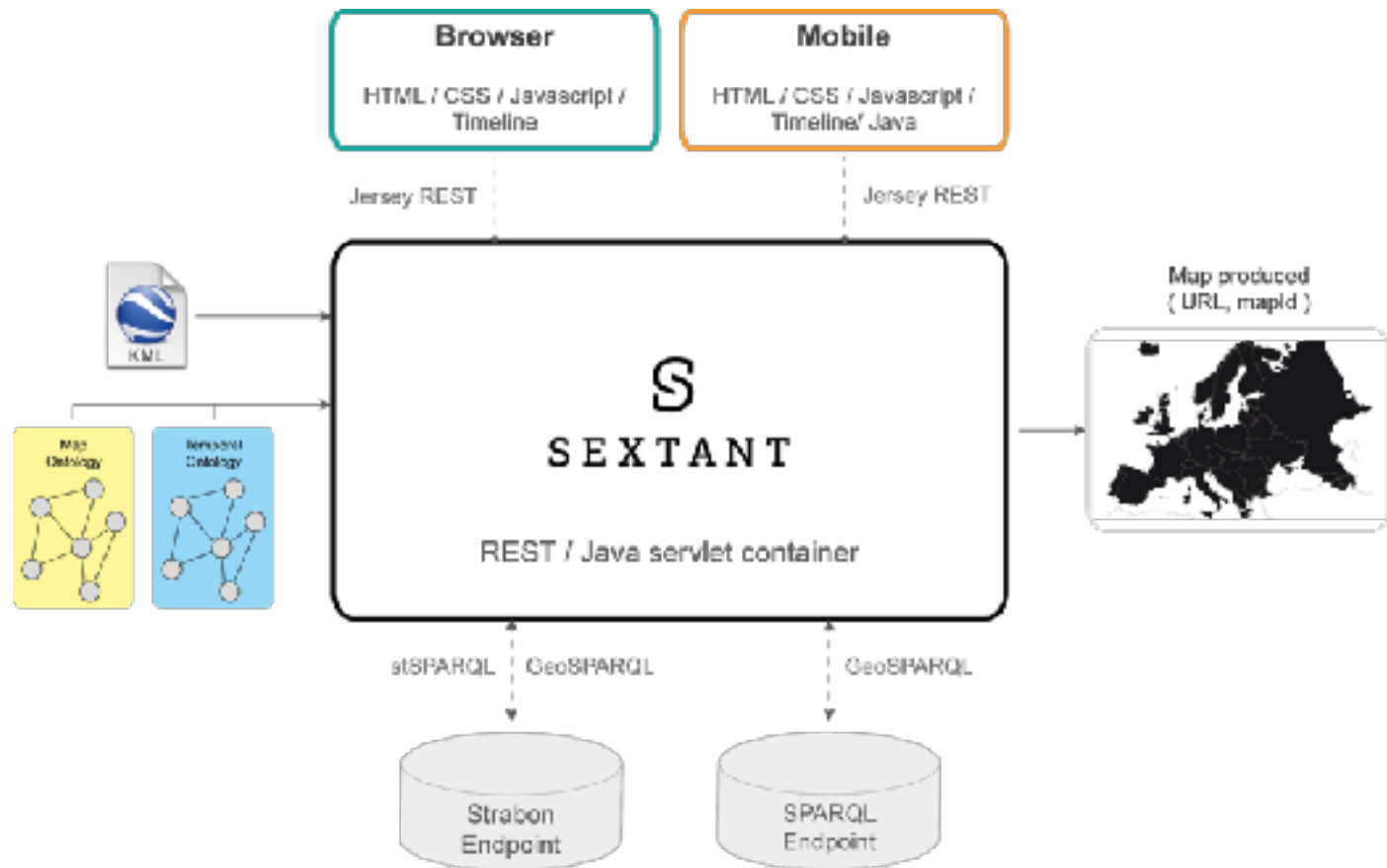
Scalability

- Strabon and Ontop-spatial can scale to **100GB of data and answer queries in milliseconds** if the geometries are points and/or the selectivity of the query is high.
- More complex geometries have an impact on performance.

Visualizing Time-Evolving Linked Geospatial Data

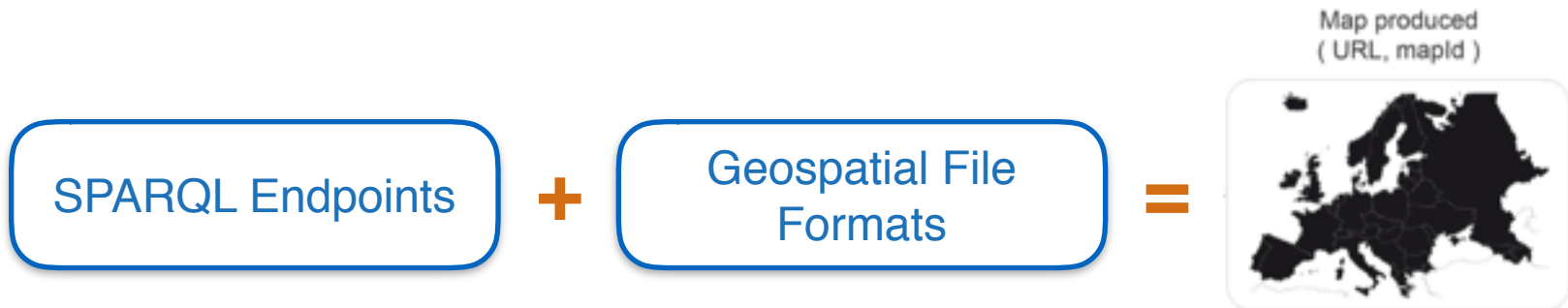
Architecture

Find more at: <http://sextant.di.uoa.gr>

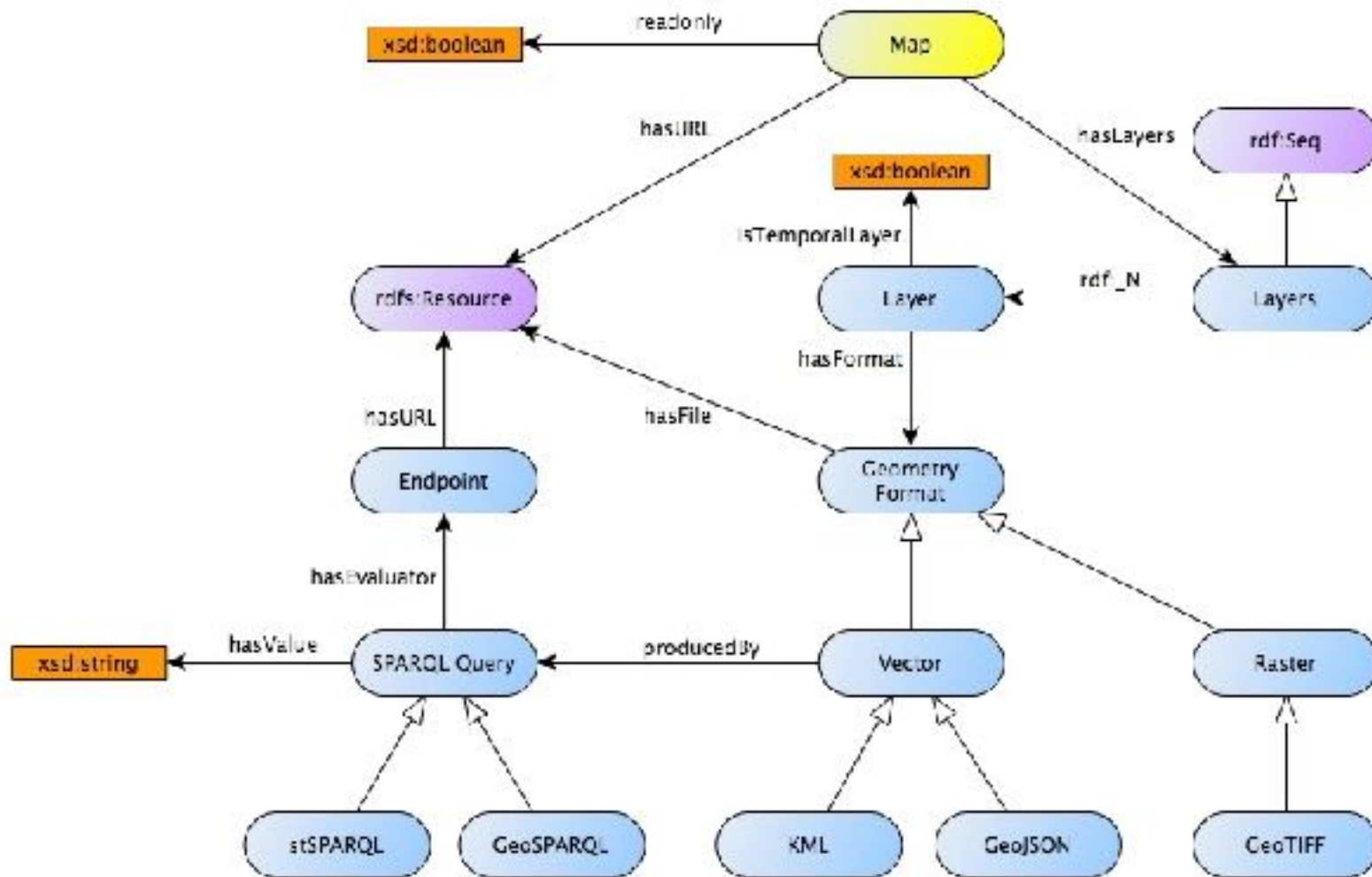


Thematic Maps

Definition: A *thematic map* is a type of map designed to show a particular theme connected with a specific geographic area. These maps can portray physical, social, political, cultural, economic, sociological, agricultural, or any other aspects of a city, state, region, nation, or continent.



Map Ontology



Map Sharing

Share maps using map URI, or the load map modal

Map URI: `http://<domain>/Sextant/?mapid=<mapID>`



Visualize a Map

Load Map from MapID

Map ID

Endpoint Information

(leave empty for Registry:)

URI

Port: 80

OK Cancel

Temporal Dimension

Strabon DBMS and SIMILE Timeline

Implementation of the valid time component of stRDF and stSPARQL in system Strabon allows us to query both the spatial and the temporal dimension. Enriching our results with temporal information allows us to create layers with valid time. Using the SIMILE Timeline widget we can make these layers appear and disappear from the map according to their valid time.

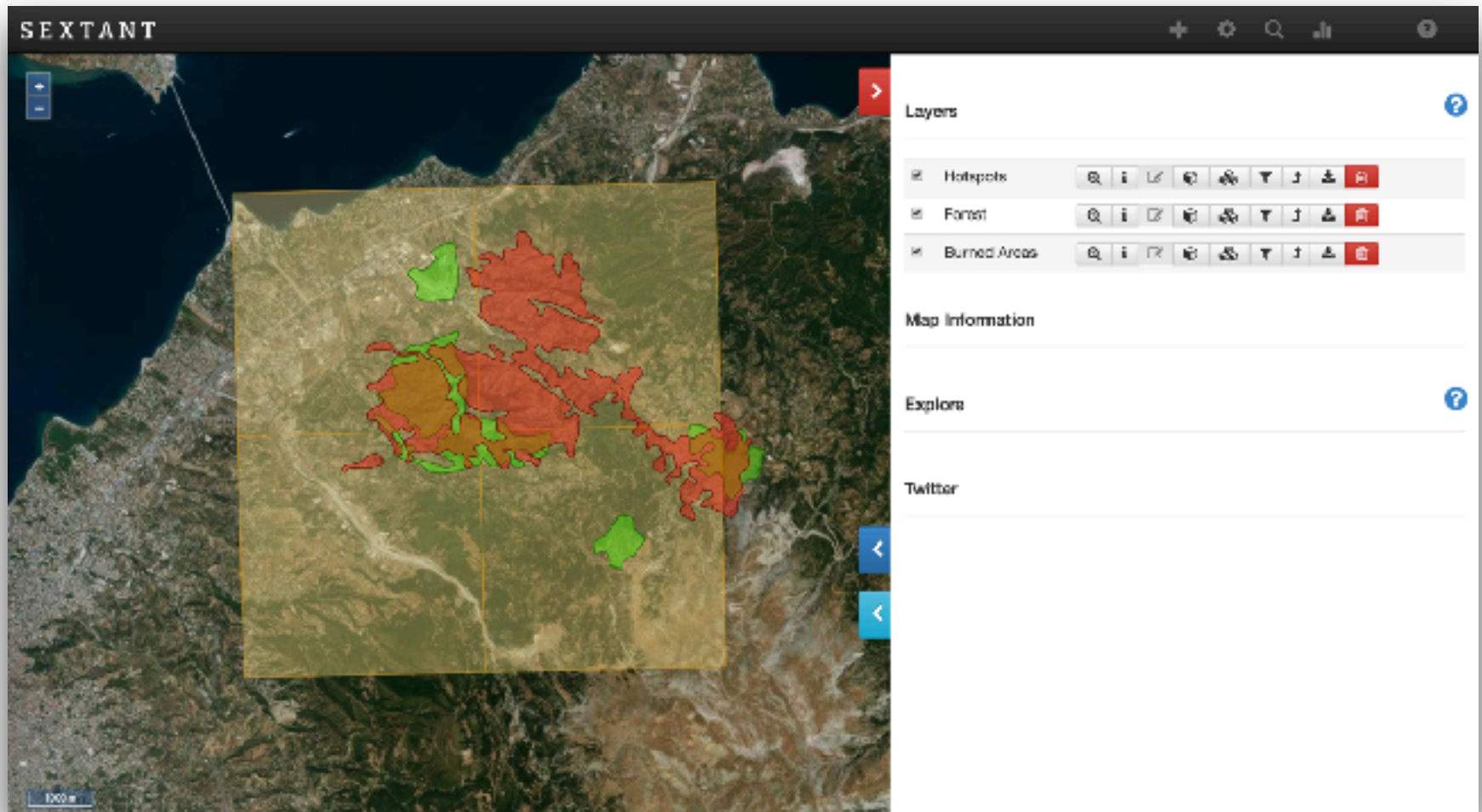
Temporal Dimension

Query example in stSPARQL

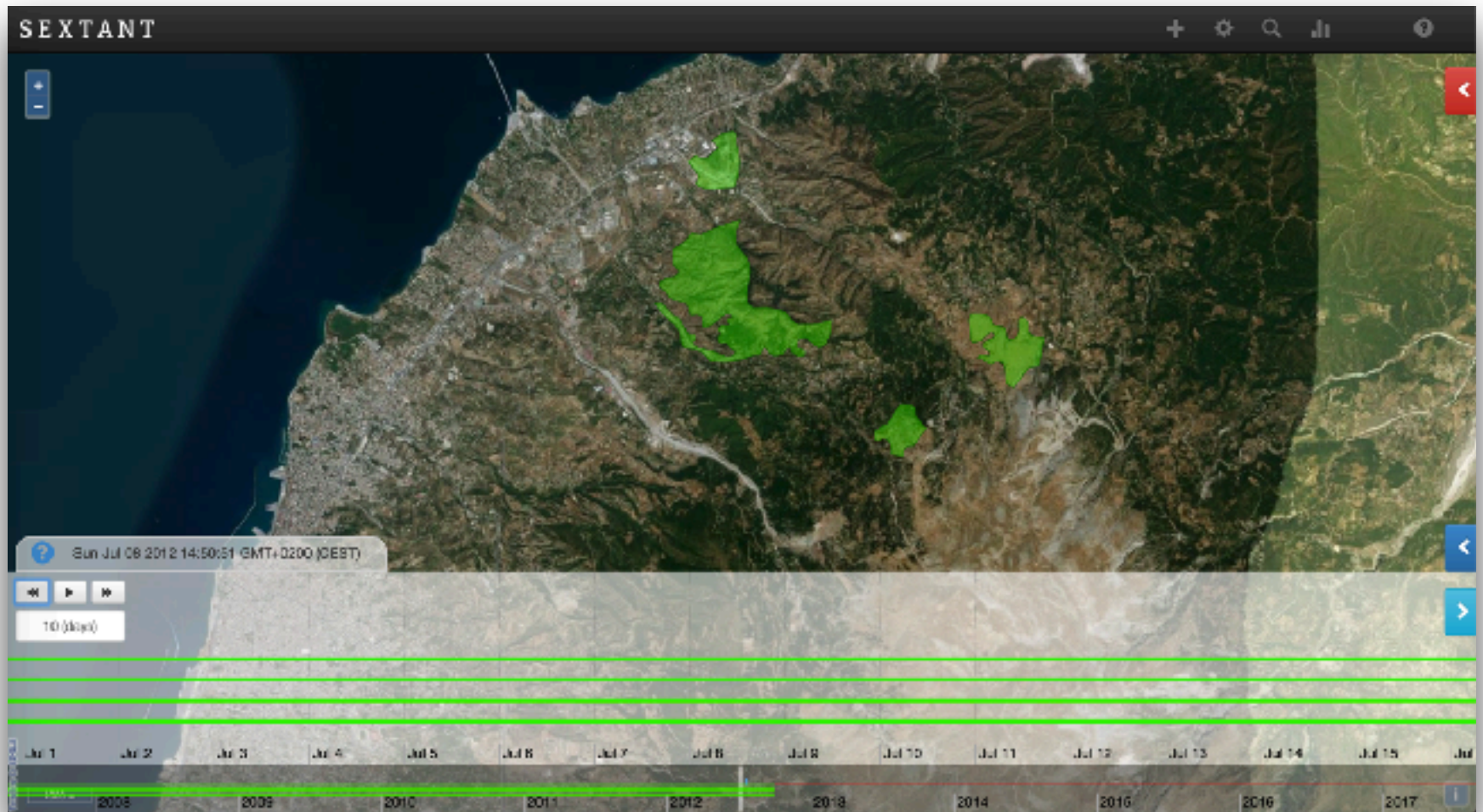
```
PREFIX noa: <http://teleios.di.uoa.gr/ontologies/noaOntology.owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX strdf: <http://strdf.di.uoa.gr/ontology#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>

SELECT DISTINCT (strdf:transform(?hGeo, <http://www.opengis.net/def/crs/EPSSG/0/4326>) as ?
geometry) ?time
WHERE {
    ?h rdf:type noa:Hotspot ;
        noa:hasAcquisitionTime ?time;
        noa:hasGeometry ?hGeo .
    FILTER(?time = "2012-07-18T11:30:00"^^<http://www.w3.org/2001/XMLSchema#dateTime>)
    FILTER (strdf:within(?hGeo, "POLYGON((21.70 38.23, 21.70 38.33, 21.91 38.33, 21.91
38.23, 21.70 38.23));http://www.opengis.net/def/crs/EPSSG/0/4326"^^strdf:WKT))
}
```

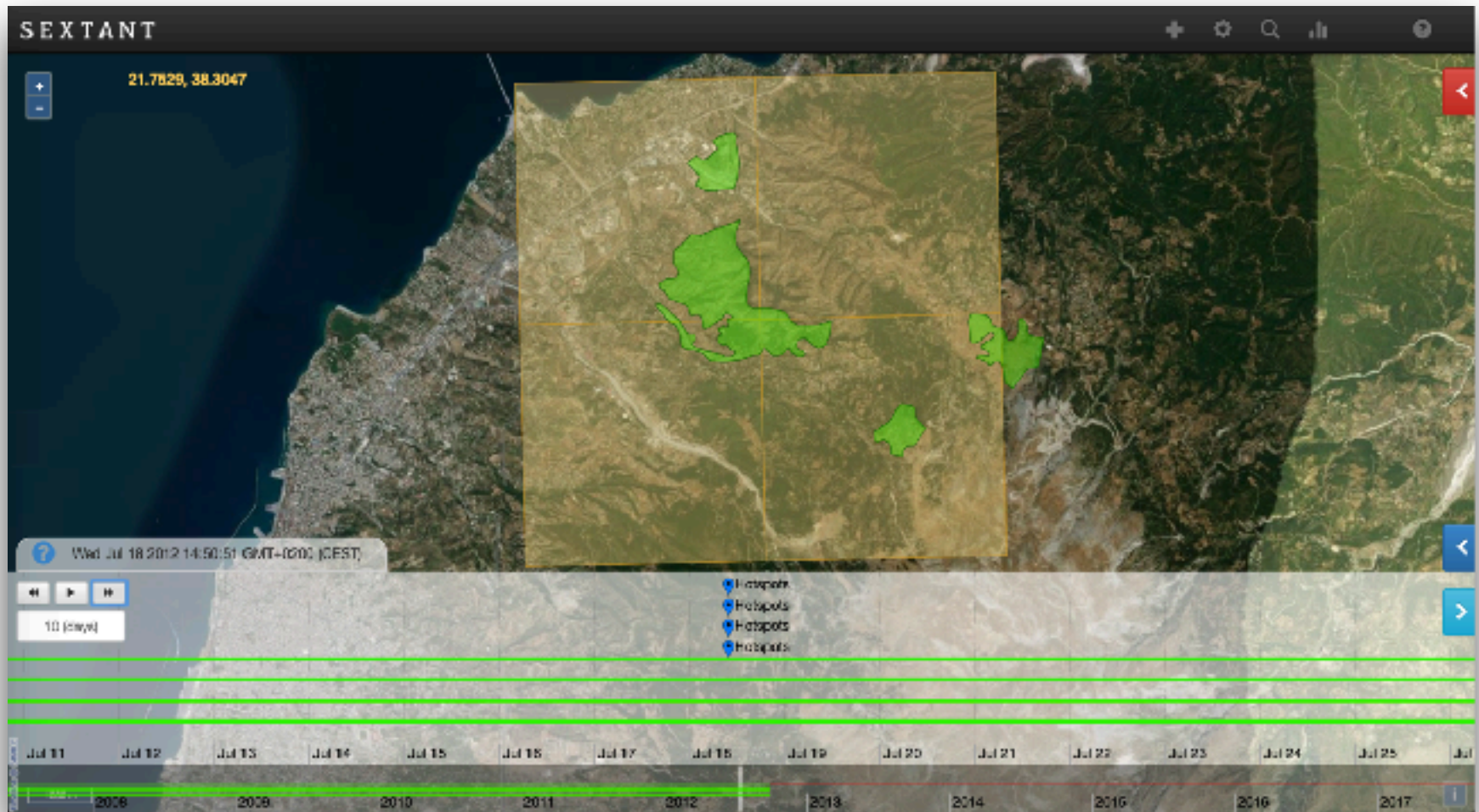
Temporal Dimension



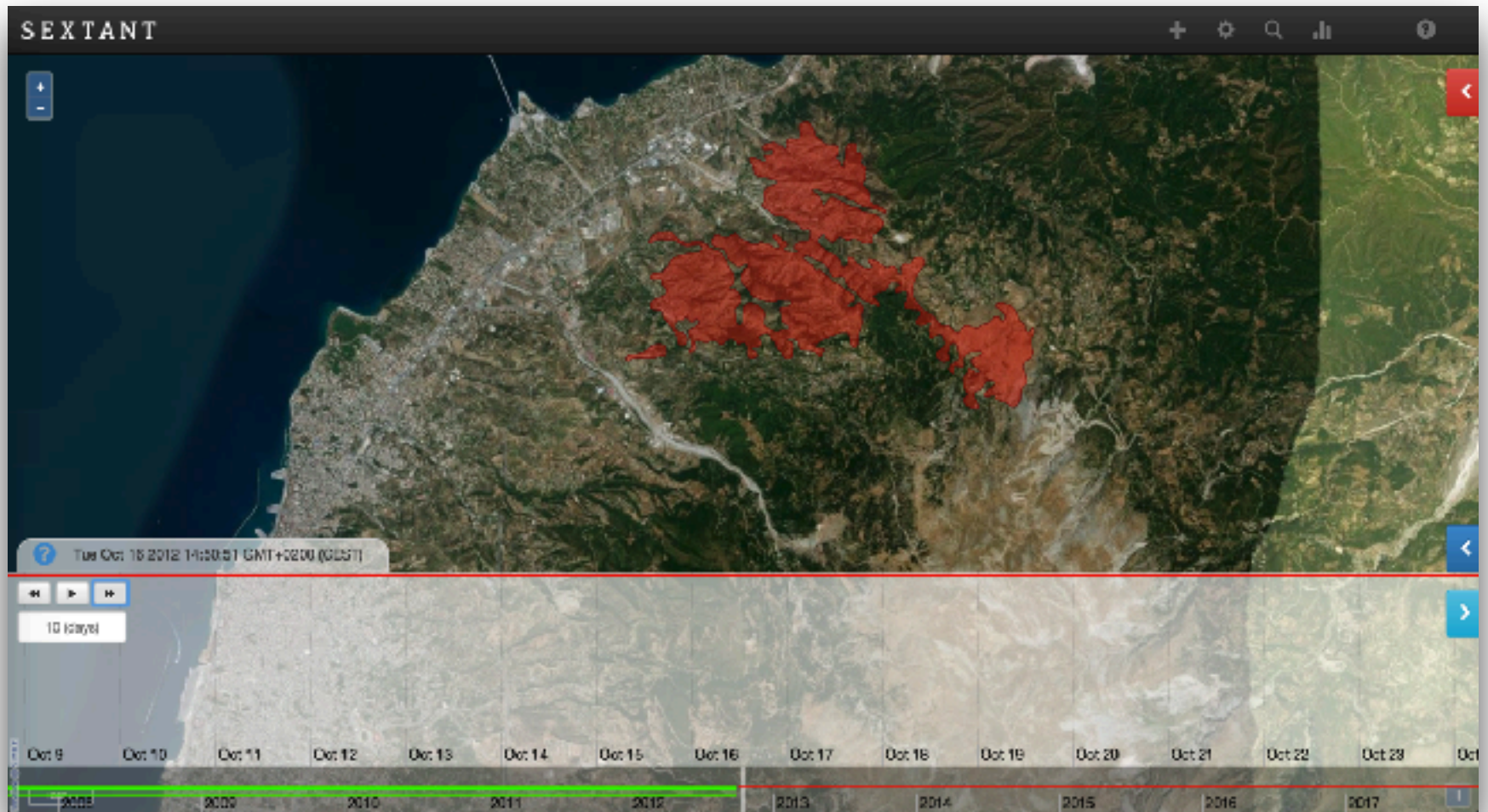
Temporal Dimension



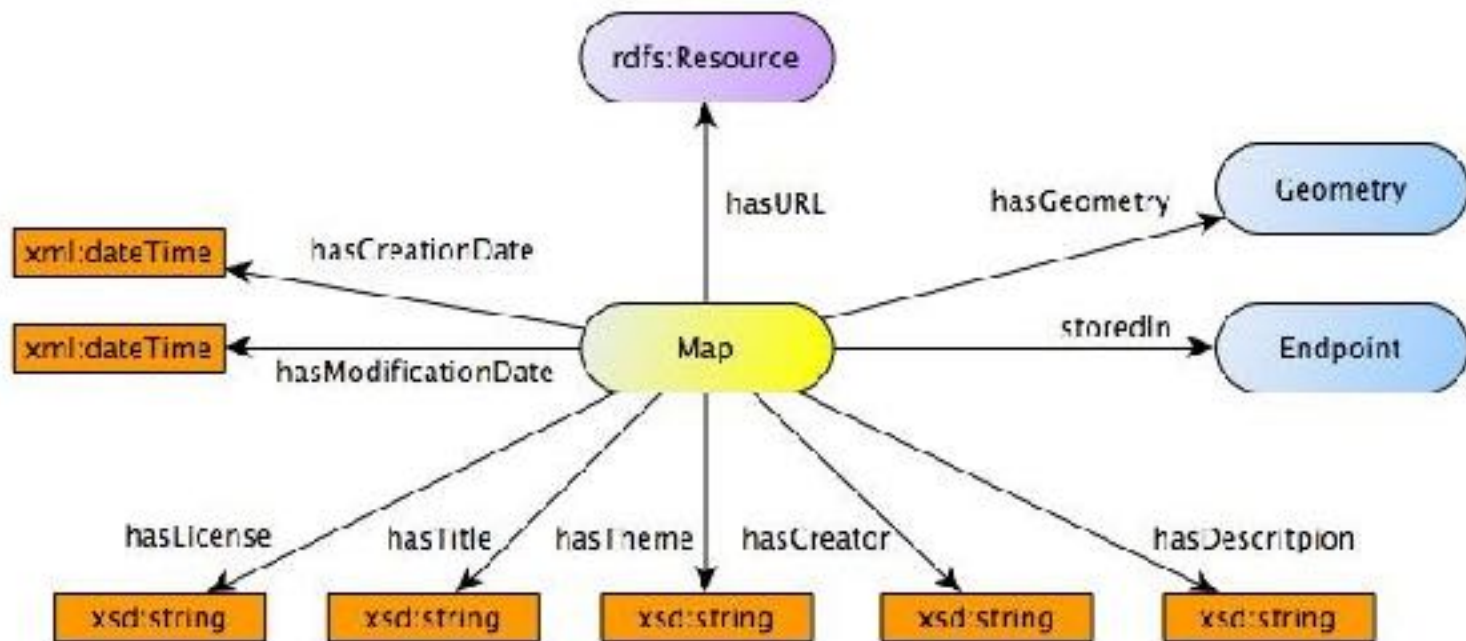
Temporal Dimension



Temporal Dimension



Map Metadata



Map Registry

Definition: *Map registries*, are SPARQL endpoints that hold all the map information and metadata to assist us in saving and retrieving the maps.

Map Information

Title: Review Demo
MapID: m8z4kllcarub1mun_
Endpoint: registry
Number of layers: 6
Number of charts: 0
Date of creation: 2017-07-05T17:15:58
Date of modification: 2018-05-21T11:08:49
Creator: UoA
License: Free
Themes: Copernicus App Lab
Extent:

```
<http://www.opengis.net/def/crs/EPSG/0/4326>  
POLYGON((47.952274999999988 3.5083219999999997,  
47.952274999999988 0.7457479999999999, 49.521535  
0.7467479999999999, 49.521535 3.5083219999999997,  
47.952274999999988 3.5083219999999997))
```

Search for Maps

Search Parameters


Title

Creator

License

Theme

Draw Extent

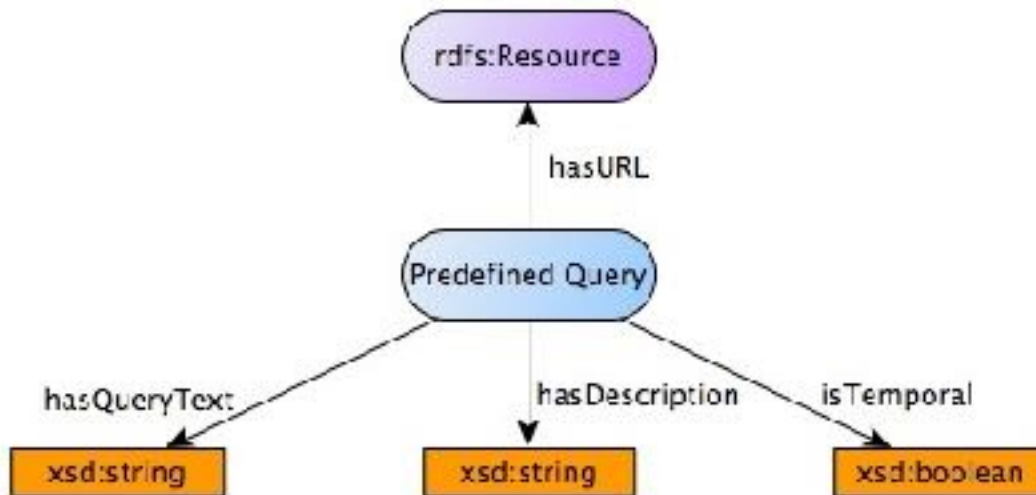


Endpoint Information
(Leave empty for Refresh)

URI

Predefined Queries

Queries that are **created by an expert** and are stored as triples in a SPARQL endpoint. **Non-expert users** can provide the URL of the endpoint and get a list of the **descriptions** of all the predefined queries available, then select one and visualize it on the map.



Predefined Queries

Predefined Query selection

Provide endpoint URL for queries

URL

Port: 80

Connect

Select query

Ok

Cancel

Predefined Query selection

Provide endpoint URL for queries

http://test.strabon.di.uoa.gr/LEO/Query

Port: 80

Connect

Select query

Present the field with id 1088 along with the measurements for CV and fertilization for its raster cells.

Present the fields that belong to the farm with id 002 along with the measurements for CV and fertilization for their raster cells.

Present the field with id 1045 along with the measurements for CV for its raster cells and apply color filtering according to the CV values.

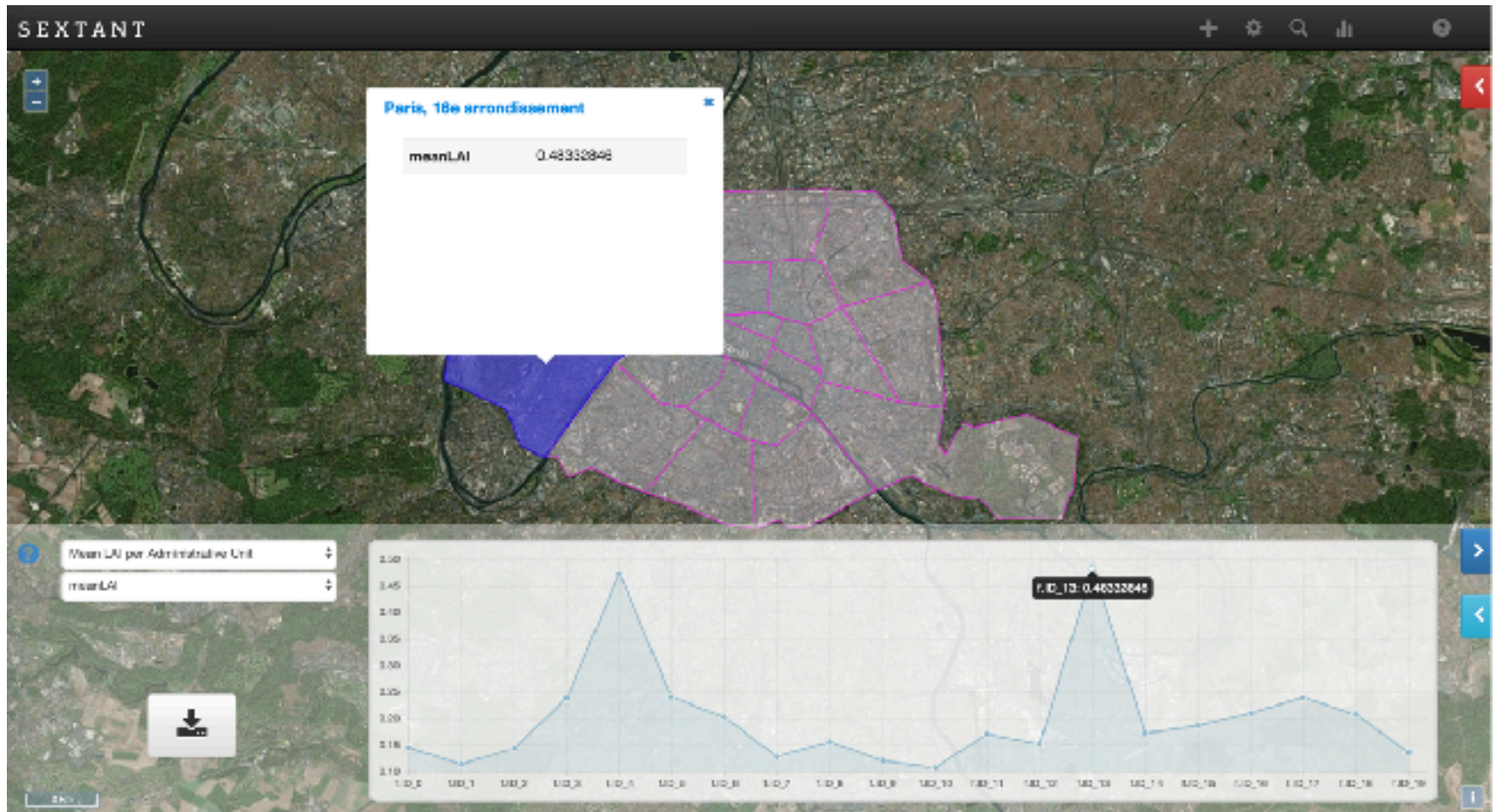
Find all fields that are close to water bodies with a threshold of 50 metres.

Ok

Cancel

Statistical Charts

Automatic creation of charts over a layer's attribute



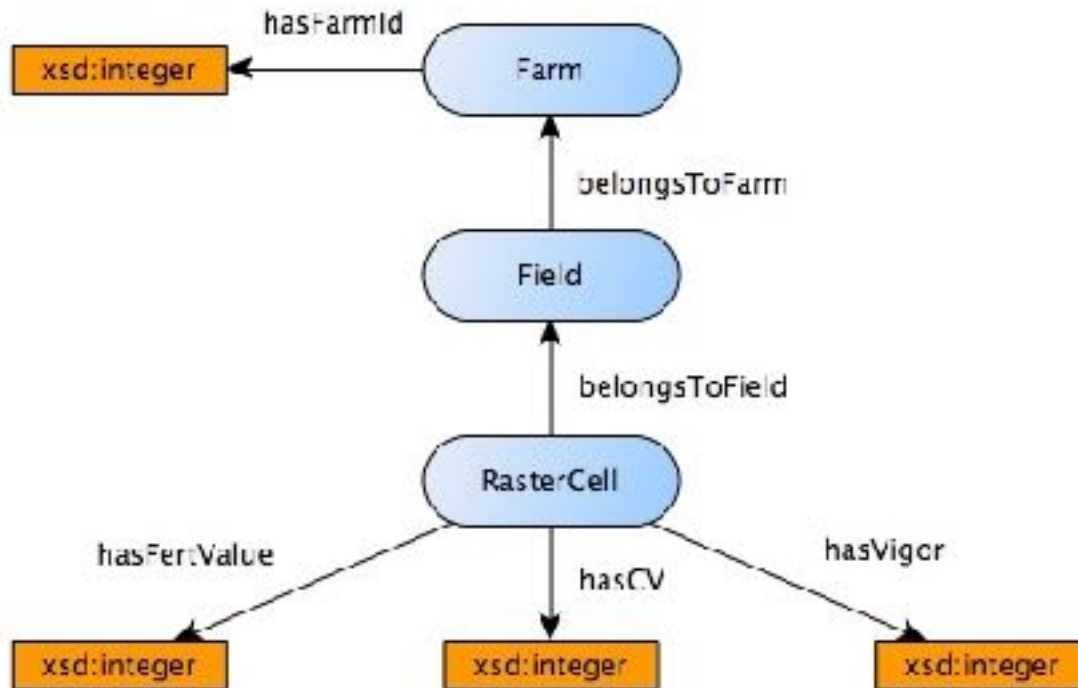
Statistical Charts

Enhancement of Datasets

- The RDF **Data Cube** Vocabulary (W3C recommendation).
- Define the **dimensions** and the **measures** of the dataset.
- Use the classes **qb:DimensionProperty**, **qb:MeasureProperty**, and the property **qb:order** from Data Cube to enhance our schema.
- A **Self-adjusting query** to create all possible charts.

Statistical Charts

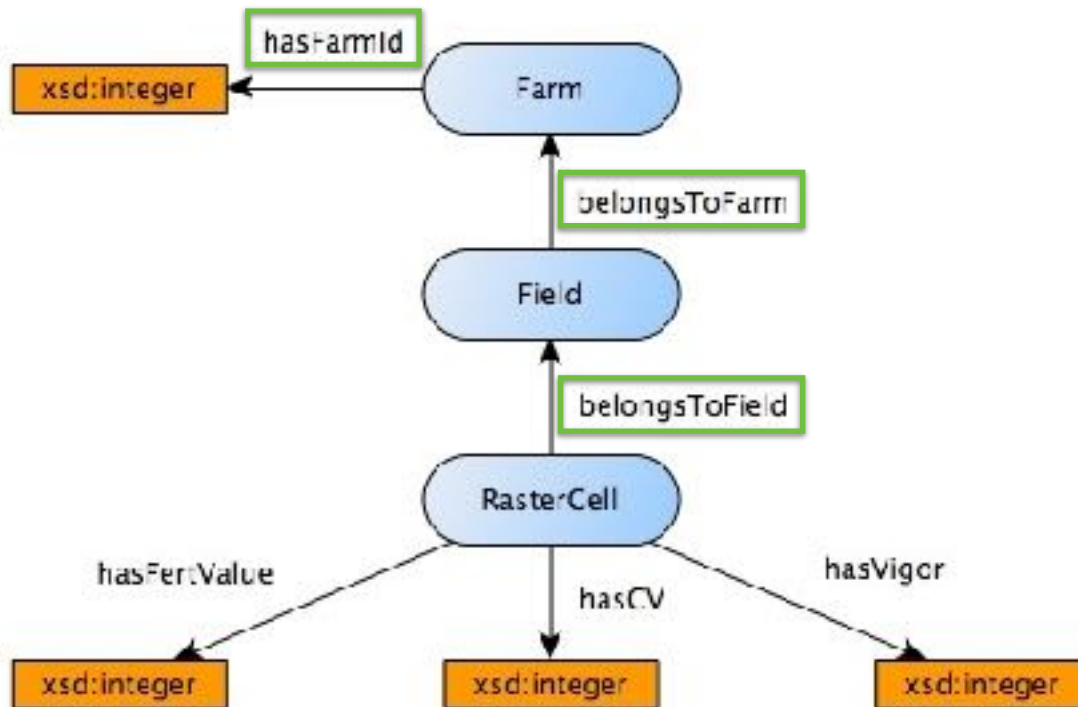
Enhancement of Ontology Schema



Statistical Charts

Enhancement of Ontology Schema

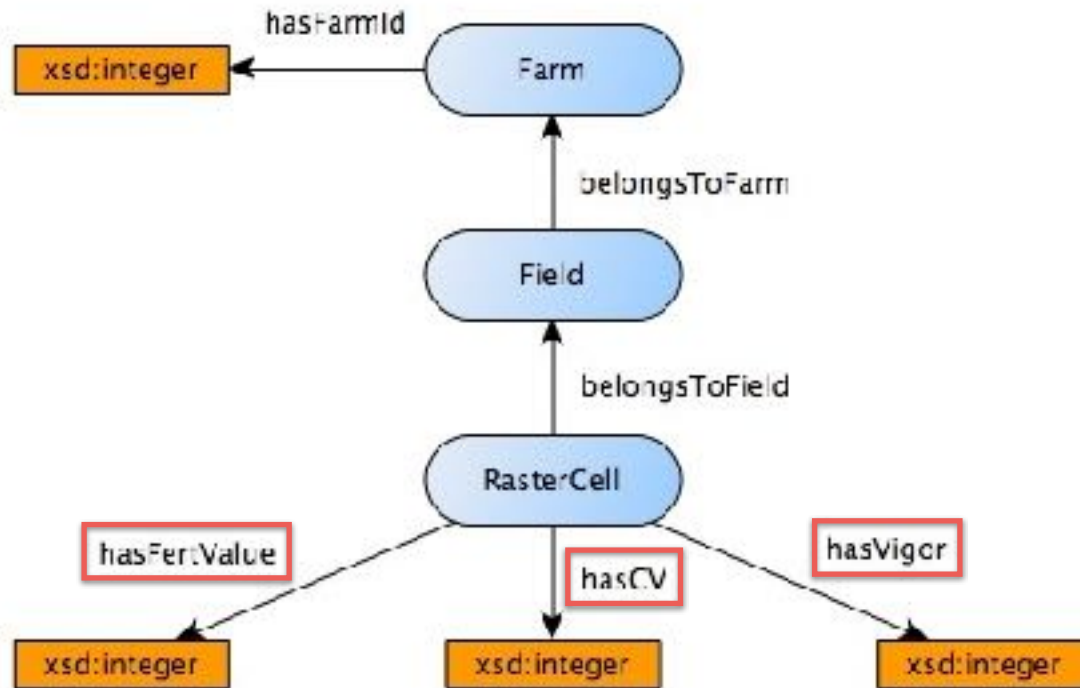
qb:DimensionProperty



Statistical Charts

Enhancement of Ontology Schema

qb:MeasureProperty



Statistical Charts

Self-adjusting Query

The image displays three sequential screenshots of a 'Create a new Chart' dialog box, illustrating the configuration steps for a self-adjusting query.

Step 1: Provide endpoint URL for input data

Endpoint URL: `http://test.stroben.01.uoa.gr/LEC/Query`
Port: `80`
Buttons: `Connect`, `Next`, `Ok`, `Cancel`

Select Dimension(s) to fix

Dimension: `RasterCell`
Field: `Field` (checked)
Field: `Farm` (checked)
Buttons: `Next`, `Ok`, `Cancel`

Step 2: Provide endpoint URL for input data

Endpoint URL: `http://test.stroben.01.uoa.gr/LEC/Query`
Port: `80`
Buttons: `Connect`, `Next`, `Ok`, `Cancel`

Select Instance(s) to fix

Field: `1154`
Buttons: `Next`, `Ok`, `Cancel`

Step 3: Provide endpoint URL for input data

Endpoint URL: `http://test.stroben.01.uoa.gr/LEC/Query`
Port: `80`
Buttons: `Connect`, `Next`, `Ok`, `Cancel`

Select Instance(s) to fix

Field: `1154`
Buttons: `Next`, `Ok`, `Cancel`

Select measure to project in chart

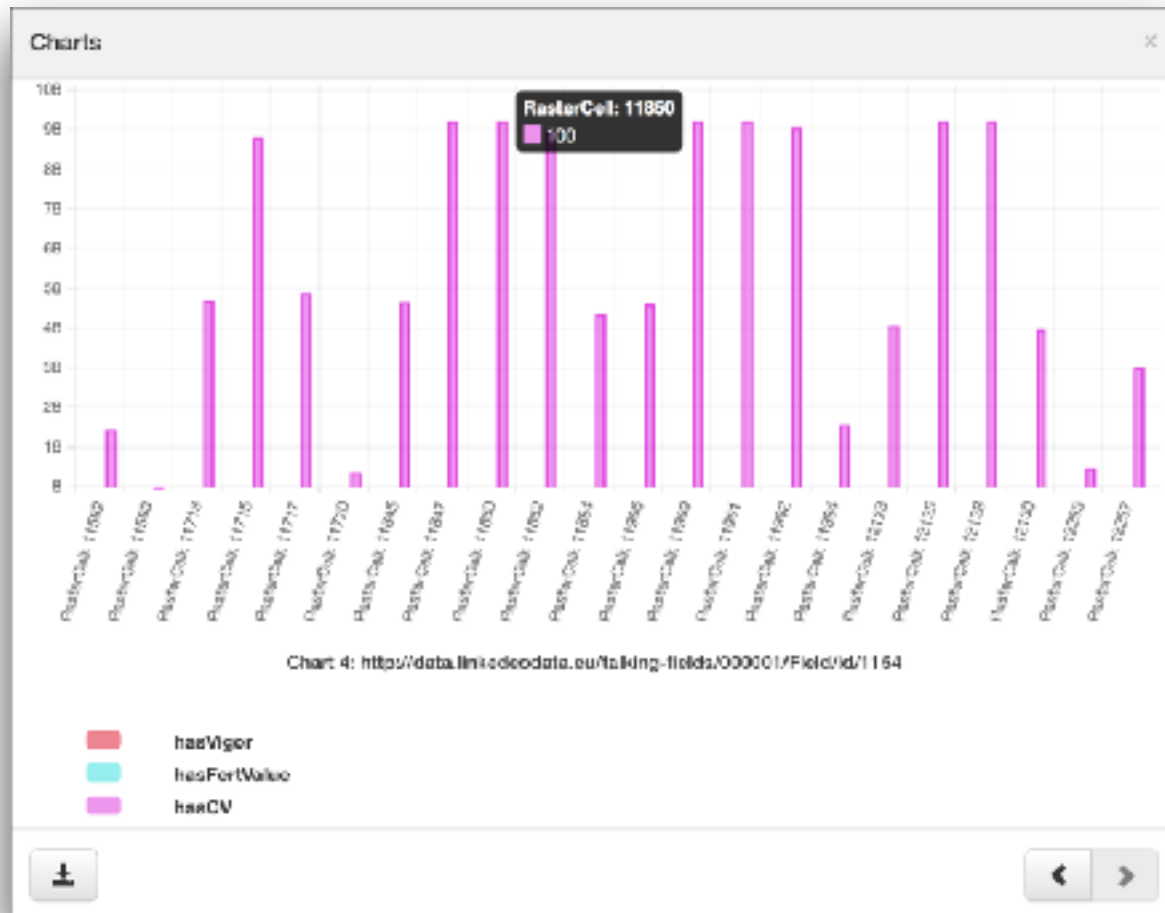
Measure: `%Vqz` (checked)
Measure: `%FerValue` (checked)
Measure: `%CV` (checked)
Buttons: `Next`, `Ok`, `Cancel`

Select chart type

Chart type: `Bar chart`
Buttons: `Ok`, `Cancel`

Statistical Charts

Self-adjusting Query



Statistical Charts

Self-adjusting Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX tf: <http://data.linkedeodata.eu/talking-fields/ontology#>
```

```
SELECT DISTINCT ?RasterCell ?hasVigor ?hasFertValue ?hasCV
WHERE {
  ?Farm rdf:type tf:Farm .
  ?Field rdf:type tf:Field .
  ?RasterCell rdf:type tf:RasterCell .

  ?Field tf:belongsToFarm ?Farm .
  ?RasterCell tf:belongsToField ?Field .

  OPTIONAL { ?RasterCell tf:hasVigor ?hasVigor. } .
  OPTIONAL { ?RasterCell tf:hasFertValue ?hasFertValue. } .
  OPTIONAL { ?RasterCell tf:hasCV ?hasCV. } .

  ?Field rdf:type ?typeField .
  FILTER ( ?Field = <http://data.linkedeodata.eu/
            talking-fields/000001/Field/id/1154>
            && ?typeField = tf:Field ) .
}
ORDER BY ?RasterCell
```

SELECT	Select the free dimension(s) and the measurement(s)
WHERE {	Static part of the query. These patterns represent the ontology scheme and in particular the connection of the classes using objectProperties. (we can add here all the attributes)
	The measurements the user selected
	Fixed dimension(s) from the user
	Complete lbound variables with "null" so that we can have fixed size tuples in results

}

Statistical Charts

Self-adjusting Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>  
PREFIX tf: <http://data.linkedeodata.eu/talking-fields/ontology#>
```

```
SELECT DISTINCT ?RasterCell ?hasVigor ?hasFertValue ?hasCV  
WHERE {
```

```
?Farm rdf:type tf:Farm .  
?Field rdf:type tf:Field .  
?RasterCell rdf:type tf:RasterCell .  
  
?Field tf:belongsToFarm ?Farm .  
?RasterCell tf:belongsToField ?Field .
```

```
OPTIONAL { ?RasterCell tf:hasVigor ?hasVigor. } .  
OPTIONAL { ?RasterCell tf:hasFertValue ?hasFertValue. } .  
OPTIONAL { ?RasterCell tf:hasCV ?hasCV. } .
```

```
?Field rdf:type ?typeField .  
FILTER ( ?Field = <http://data.linkedeodata.eu/  
talking-fields/000001/Field/id/1154>  
&& ?typeField = tf:Field ) .
```

```
}  
ORDER BY ?RasterCell
```

SELECT	Select the free dimension(s) and the measurement(s)
WHERE {	
	Static part of the query. These patterns represent the ontology scheme and in particular the connection of the classes using objectProperties. (we can add here all the attributes)
	The measurements the user selected
	Fixed dimension(s) from the user
	Complete lbound variables with "null" so that we can have fixed size tuples in results

}

Statistical Charts

Self-adjusting Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>  
PREFIX tf: <http://data.linkedeodata.eu/talking-fields/ontology#>
```

```
SELECT DISTINCT ?RasterCell ?hasVigor ?hasFertValue ?hasCV
```

```
WHERE {
```

```
  ?Farm rdf:type tf:Farm .  
  ?Field rdf:type tf:Field .  
  ?RasterCell rdf:type tf:RasterCell .  
  
  ?Field tf:belongsToFarm ?Farm .  
  ?RasterCell tf:belongsToField ?Field .
```

```
  OPTIONAL { ?RasterCell tf:hasVigor ?hasVigor. } .  
  OPTIONAL { ?RasterCell tf:hasFertValue ?hasFertValue. } .  
  OPTIONAL { ?RasterCell tf:hasCV ?hasCV. } .
```

```
  ?Field rdf:type ?typeField .  
  FILTER ( ?Field = <http://data.linkedeodata.eu/  
           talking-fields/000001/Field/id/1154>  
           && ?typeField = tf:Field ) .
```

```
}  
ORDER BY ?RasterCell
```

SELECT	Select the free dimension(s) and the measurement(s)
WHERE {	Static part of the query. These patterns represent the ontology scheme and in particular the connection of the classes using objectProperties. (we can add here all the attributes)
	The measurements the user selected
	Fixed dimension(s) from the user
	Complete Ibound variables with "null" so that we can have fixed size tuples in results

}

Statistical Charts

Self-adjusting Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX tf: <http://data.linkeddata.eu/talking-fields/ontology#>
```

```
SELECT DISTINCT ?RasterCell ?hasVigor ?hasFertValue ?hasCV
WHERE {
  ?Farm rdf:type tf:Farm .
  ?Field rdf:type tf:Field .
  ?RasterCell rdf:type tf:RasterCell .

  ?Field tf:belongsToFarm ?Farm .
  ?RasterCell tf:belongsToField ?Field .

  OPTIONAL { ?RasterCell tf:hasVigor ?hasVigor. } .
  OPTIONAL { ?RasterCell tf:hasFertValue ?hasFertValue. } .
  OPTIONAL { ?RasterCell tf:hasCV ?hasCV. } .

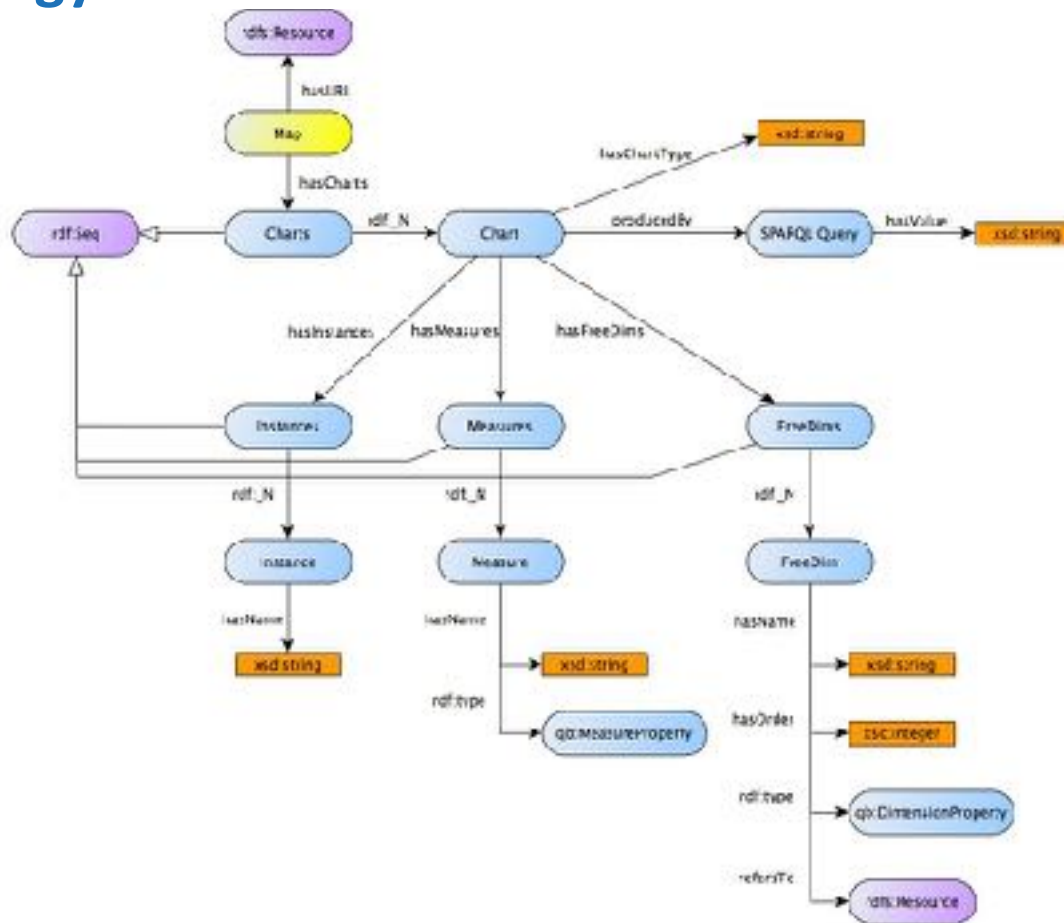
  ?Field rdf:type ?typeField .
  FILTER ( ?Field = <http://data.linkeddata.eu/
           talking-fields/000001/Field/id/1154>
           && ?typeField = tf:Field ) .
}
ORDER BY ?RasterCell
```

SELECT	Select the free dimension(s) and the measurement(s)
WHERE {	Static part of the query. These patterns represent the ontology scheme and in particular the connection of the classes using objectProperties. (we can add here all the attributes)
	The measurements the user selected
	Fixed dimension(s) from the user
	Complete Ibound variables with "null" so that we can have fixed size tuples in results

}

Statistical Charts

Chart Ontology



Explore

Explore ?

Provide endpoint URI

Connect

- Festival **1**
- MusicGroup **2**
- Organization **1**
- Product **2**
- NaturalPerson **1**
- SocialPerson **1**
- Thing **50**

Explore

The screenshot shows the 'Explore' interface with the following elements:

- Header:** 'Explore' title and a help icon (question mark in a blue circle).
- Endpoint:** A text input field containing 'http://dbpedia.org/sparql' and a 'Connect' button below it.
- Category:** A button labeled 'Festival' with a count of 1.
- Item:** A card for 'Festival' with a green plus icon and the URI 'http://schema.org/Festival'.
- Sub-category:** A button labeled 'FilmFestival' with a count of 1, located below the 'Festival' card.
- Sub-item:** A card for 'Festival / FilmFestival' with a green plus icon and the URI 'http://dbpedia.org/ontology/FilmFestival'.
- Other Categories:** Buttons for 'MusicGroup' (count 2) and 'Organization' (count 1) are visible at the bottom.

Explore

Activity **3**

Thing/ Activity

+

URI:

<http://dbpedia.org/ontology/Activity>

Game **2**

Sales

Sport **4**

Properties:

<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>
null

<http://www.w3.org/2000/01/rdf-schema#label>
null

<http://dbpedia.org/ontology/wikiPageID>
<http://www.w3.org/2001/XMLSchema#integer>

<http://dbpedia.org/ontology/wikiPageRevisionID>
<http://www.w3.org/2001/XMLSchema#integer>

Explore

RasterCell

SpatialObject/ Feature / RasterCell

+ [Pencil] i [X]

URI:
<http://data.linkedecdata.eu/talking-fields/ontology/RasterCell>

Properties:

<http://www.w3.org/2000/01/rdf-schema#rdfs:label>
null

<http://data.linkedecdata.eu/talking-fields/ontology/RasterCell>
<http://www.w3.org/2001/XMLSchema#boolean>

<http://www.opengis.net/ont/geosparql#hasGeometry>
<http://www.opengis.net/ont/geosparql#hasGeometry>

<http://data.linkedecdata.eu/talking-fields/ontology/RasterCell>
<http://data.linkedecdata.eu/talking-fields/ontology/RasterCell>

<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>
null

Create Spatial Filter

Class URI: <http://data.linkedecdata.eu/talking-fields/ontology/RasterCell>

Property URI: <http://www.opengis.net/ont/geosparql#hasGeometry>

TYPE	RULE
REGULAR	INTERSECTS

Draw Extent

Add filter(s)

Describe

Describe results

About: <http://schema.org/Organization>

Subject	Predicate	Object
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/7-Eleven	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/Aardman_Animations	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/About.com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/Academy_of_Motion_Picture_Arts_and_Sciences	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/Acom_Computers	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/Activision	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/Ad_Lib_Inc	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/Adnams_Brewery	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/Aermacchi	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/Airco	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/Airspeed_Ltd	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/Albanian_Armed_Forces	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/Alfa_Romeo	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/Algerian_People's_National_Armed_Forces	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization

Describe

Describe results

About: <http://dbpedia.org/resource/3Com>

Subject	Predicate	Object
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.w3.org/2002/07/owl#Thing
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://dbpedia.org/ontology/Company
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.ontologydesignpatterns.org/ont/du/owl#Agent
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.ontologydesignpatterns.org/ont/du/owl#SocialPerson
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.wikidata.org/entity/Q24228398
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.wikidata.org/entity/Q43229
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://dbpedia.org/ontology/Agent
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://dbpedia.org/ontology/Organization
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://schema.org/Organization
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://umbel.org/umbel/rc/Business
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://umbel.org/umbel/rc/Organization
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://dbpedia.org/class/yago/Abstraction10002137
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://dbpedia.org/class/yago/Company108058088
http://dbpedia.org/resource/3Com	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://dbpedia.org/class/yago/ElectronicsCompany108020385

Change Detection Service

The screenshot displays the SEXTANT Change Detection Service interface. The main map area shows a satellite view of a desert region with a large, irregularly shaped area highlighted in light yellow, indicating a detected change. Numerous red dots are scattered across this highlighted area, representing individual change detection points. The interface includes a top navigation bar with the 'SEXTANT' logo and standard map controls (home, settings, refresh, search). A sidebar on the right provides 'Map information' and lists detected events. The first event is titled 'Hygiene, food and health at Zaatari refugee camp - LifeMatters - ABC Radio National (Australian Broadcasting Corporation)' with an event date of 2016-11-25T17:55:00+00:00. The second event is 'In Jordan, a Syrian refugee camp withers | Reuters' with the same event date. Below the events, there is a 'Twitter' section with a search bar containing 'zaatari'. Two tweets are visible: one from 'Rojname News English @ROJNAME_english' dated 1 DEC 2015, and another from 'Rojname News Deutsch @ROJNAME_Deutsch' with the text 'Ein Flüchtlinglager wird zur Großstadt'.

SEXTANT

Map information

Events

Hygiene, food and health at Zaatari refugee camp - LifeMatters - ABC Radio National (Australian Broadcasting Corporation)

Event Date: 2016-11-25T17:55:00+00:00

Event Area

View Sources

In Jordan, a Syrian refugee camp withers | Reuters

Event Date: 2016-11-25T17:55:00+00:00

Event Area

View Sources

Twitter

zaatari

Rojname News English @ROJNAME_english Follow

Jordan: Nobel Peace laureates visit Zaatari Syrian refugee camp | Orient News | rojname.com/2971196

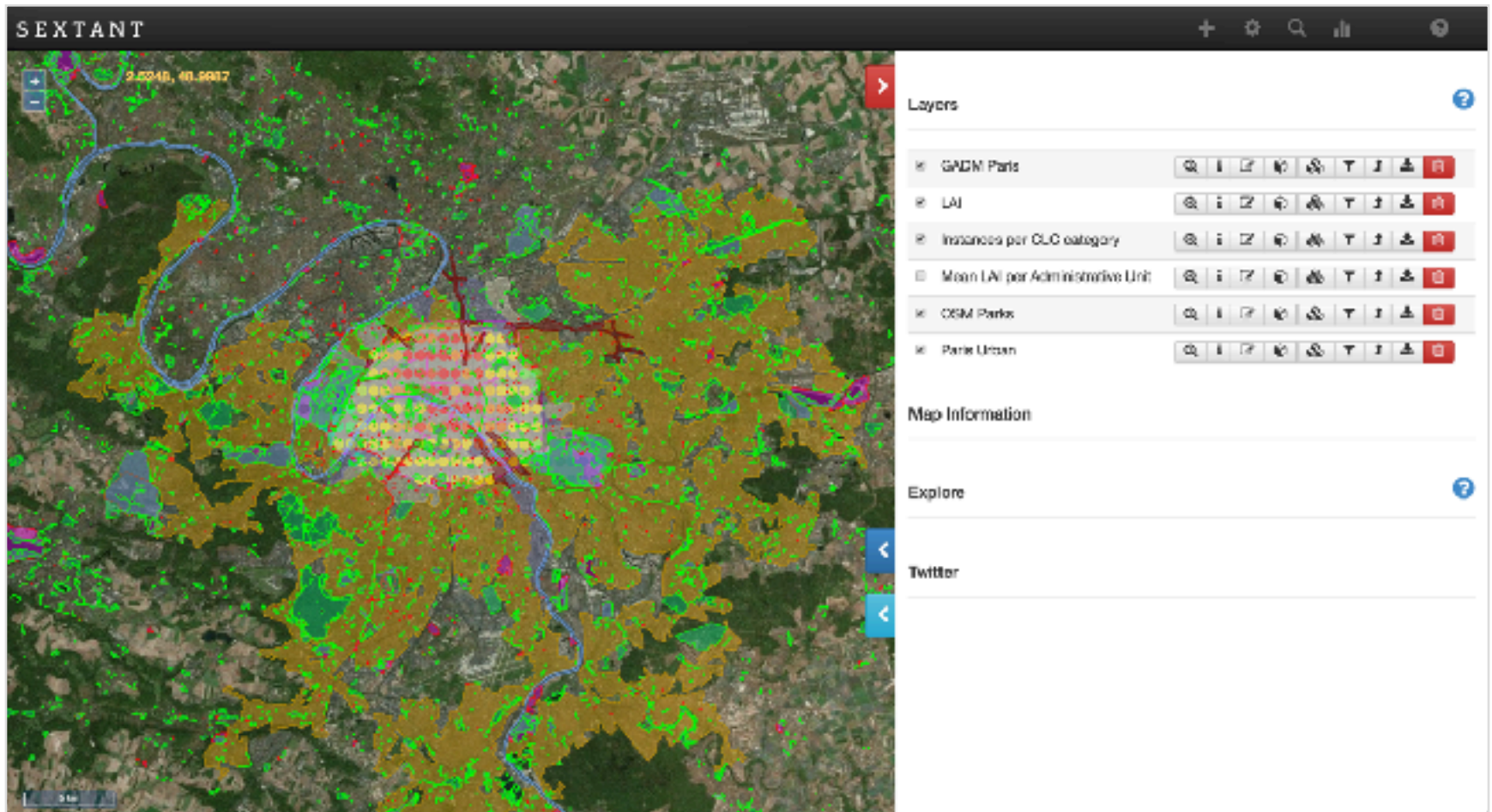
1:34 AM · 1 DEC 2015

Rojname News Deutsch @ROJNAME_Deutsch Follow

Ein Flüchtlinglager wird zur Großstadt | taz.net/1-zaatari-ein...

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Green City



Open Problems

Open Questions (Theory)

- The **data complexity of query processing for stSPARQL and GeoSPARQL** has not been studied so far.
- We have done so only for the original stSPARQL proposal based on constraints (ESWC 2010).
- Similarly for other interesting problems such as **query containment** etc.
- The **foundations of Ontop-spatial** deserve further study (comparison with the theory of spatial description logics).

Open Questions (Practice)

- How can we built an (even more) scalable geospatial RDF store like Strabon on top of Apache big data technologies?
 - Analyzed the pros and cons of using GeoSpark, SIMBA and SpatialSpark.
 - GeoSpark seems to be the most mature and is continuously been improved by its developers.
- How can we handle 10^{12} triples with 10^8 polygons? (the volume of geospatial data owned by a national cartographic agency)

Open Questions (cont'd)

- How do we represent and query raster data on the Semantic Web?
 - Raster extension of Ontop-spatial.
 - Array database extension of Ontop-spatial.
 - Work on “Coverages in Linked Data” by the OGC/W3C Spatial Data on the Web working group.

Other relevant research topics of interest

- Natural language query processing for large geospatial knowledge bases (e.g., Yago2).
- Example queries:
 - Find parks in Bonn close to Fraunhofer IAIS.
 - Find rivers that cross cities of Greece and their length is more than 20km.
- Current work in the context of WDAqua (Answering Questions using Web Data, a Marie Skłodowska-Curie Innovative Training Network, <http://wdaqua.eu/>).

Thanks! Questions?

For more, see the web page of our group <http://kr.di.uoa.gr> .