Geospatial data in RDF – stSPARQL

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Outline

- Main idea
- Early works
- The data model stRDF
- Examples of publicly available linked geospatial data
- The query language stSPARQL
Main idea

How do we represent and query geospatial information in the Semantic Web?

Extend RDF to take into account the geospatial dimension.

Extend SPARQL to query the new kinds of data.
Early works

SPAUK

- Geometric attributes of a resource are represented by:
  - introducing a **blank node** for the geometry
  - specifying the geometry using **GML vocabulary**
  - associating the blank node with the resource using **GeoRSS vocabulary**

- Queries are expressed in SPARQL utilizing appropriate geometric vocabularies and ontologies (e.g., the topological relationships of RCC-8).

- Introduces a new **PREMISE** clause in SPARQL to specify spatial geometries to be used in a query

- Use some form of the **DESCRIBE** query form of SPARQL for asking queries about geometries
Early works

SPARQL-ST

- Assumes a particular upper ontology expressed in RDFS for modeling theme, space and valid time.

- Spatial geometries in SPARQL-ST are specified by sets of RDF triples that give various details of the geometry.

- SPARQL-ST provides a set of built-in spatial conditions that can be used in SPATIAL FILTER clauses to constrain the geometries that are returned as answers to queries.

[Reference: Perry, 2008]
**stRDF and stSPARQL**

- Similar approach to SPARQL-ST *(theme, space and valid time can be represented)*

- **Linear constraints** are used to represent geometries

- Constraints are represented using literals of an appropriate datatype

- Formal approach

- New version to be presented today uses OGC *standards* to represent and query geometries

[Koubarakis and Kyzirakos, 2010]
Example
Example with simplified geometries
Example in stRDF

```sparql
geonames:Olympia
    geonames:name "Ancient Olympia";
    owl:sameAs dbpedia:Olympia_Greece;
    rdf:type dbpedia:Community .

geonames:Olympia strdf:hasGeometry
    "POLYGON((21.5 18.5, 23.5 18.5, 23.5 21, 21.5 21, 21.5 18.5));
    <http://www.opengis.net/def/crs/EPSG/0/4326>"^^
    strdf:WKT
```
The stRDF Data Model

```
strdf:geometry rdf:type rdfs:Datatype;
    rdfs:subClassOf rdfs:Literal.

strdf:WKT  rdf:type rdfs:Datatype;
    rdfs:subClassOf  rdfs:Literal;
    rdfs:subClassOf  strdf:geometry.

strdf:GML   rdf:type rdfs:Datatype;
    rdfs:subClassOf  rdfs:Literal;
    rdfs:subClassOf  strdf:geometry.
```
The stRDF Data Model

We define the datatypes \texttt{strdf:WKT} and \texttt{strdf:GML} that can be used to represent spatial objects using the WKT and GML serializations.

- **Lexical space:** the finite length sequences of characters that can be produced from the WKT and GML specifications.
  
  - Literals of type \texttt{strdf:WKT} consist of an optional URI identifying the coordinate reference system used.

  e.g., "POINT(21 18);
  
  <http://www.opengis.net/def/crs/EPSG/0/4326>"
  
  ^^\texttt{strdf:WKT}
The stRDF Data Model

- **Value space**: the set of geometry values defined in the WKT and GML standard that is a subset of the powerset of $\mathbb{R}^2$ and $\mathbb{R}^3$.

- **Lexical-to-value mapping**: takes into account that the vector-based model is used for representing geometries.

- The datatype `strdf:geometry` is the union of the datatypes `strdf:WKT` and `strdf:GML`. 
Examples of publicly available linked geospatial data

- Geonames
- Greek Administrative Geography
- Corine Land Use / Land Cover
- Burnt Area Products
Geonames
Geonames

[Map of Vienna with markers indicating various locations like city, village, mountain, stream, country, state, region, park, road, spot, building, farm, forest, heath, undersea.]

Related links:
- Google Earth
- Tanzania
- MapQuest

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Geonames

gn:2761333
  rdf:type geonames:Feature;
  geonames:officialName "Vienna"@en;
  geonames:name "Politischer Bezirk Wien (Stadt)";
  geonames:countryCode "AT";
  wgs84_pos:lat "48.2066";
  wgs84_pos:long "16.37341".
  geonames:parentCountry gn:2782113;

gn:2782113
  geonames:name "Austria";
  geonames:altName "Republic of Austria"@en,
                "Republik Oesterreich"@de,
                "Αυστρία"@el.
Greek Administrative Geography

Kallikrates ontology
Greek Administrative Geography

Kallikrates ontology
Greek Administrative Geography

gag:Olympia
  rdf:type gag:Community;
  geonames:name "Ancient Olympia";
  gag:population "184"^^xsd:int;
  strdf:hasGeometry "POLYGON (((25.37 35.34,...)))"^^strdf:WKT.

gag:OlympiaBorough
  rdf:type gag:Borough;
  rdfs:label "Borough of Ancient Olympia".

gag:OlympiaMunicipality
  rdf:type gag:Municipality;
  rdfs:label "Municipality of Ancient Olympia".

gag:Olympia gag:isPartOf gag:OlympiaBorough.

gag:OlympiaBorough gag:isPartOf gag:OlympiaMunicipality.
Corine Land Use / Land Cover
Corine Land Use / Land Cover
Corine Land Use / Land Cover

noa:Area_24015134
    rdf:type noa:Area ;
    noa:hasCode "312"^^xsd:decimal;
    noa:hasID "EU-203497"^^xsd:string;
    noa:hasArea_ha "255.5807904"^^xsd:double;
    strdf:hasGeometry "POLYGON((15.53 62.54, ...
    ))"^^strdf:WKT;
    noa:hasLandUse noa:ConiferousForest
Burnt Area Products

![Diagram of Burnt Area Products]

- DataProduct
  - derivedFromSensor
  - isFromProcessingChain
  - hasAcquisitionDateTime
  - derivedFromSatellite

- SWEET

- Data

- NOA
  - subClassOf
  - isProducedBy

- Organization

- BurntArea
  - hasGeometry
  - isDerivedFromFile

- Shapefile
  - containsFlora

- RawData
  - hasFilename
  - isDerivedFrom

- strdf:WKT
- strdf:GML
- xsd:float
- xsd:string
Burnt Area Products
Burnt Area Products

noa:ba_15
  rdf:type noa:BurntArea;
  noa:isProducedByProcessingChain "static thresholds"^^xsd:string;
  noa:hasAcquisitionTime "2010-08-24T13:00:00"^^xsd:dateTime;

strdf:hasGeometry "MULTIPOLYGON(((393801.42 4198827.92, ..., 393008 424131)));<http://www.opengis.net/def/crs/EPSG/0/2100>"^^strdf:WKT.
stSPARQL: Geospatial SPARQL 1.1

We define a SPARQL extension function for each function defined in the OpenGIS Simple Features Access standard

Basic functions

- Get a property of a geometry
  - `xsd:int strdf:Dimension(strdf:geometry A)`
  - `xsd:string strdf:GeometryType(strdf:geometry A)`
  - `xsd:int strdf:SRID(strdf:geometry A)`

- Get the desired representation of a geometry
  - `xsd:string strdf:AsText(strdf:geometry A)`
  - `strdf:wkb strdf:AsBinary(strdf:geometry A)`
  - `xsd:string strdf:AsGML(strdf:geometry A)`

- Test whether a certain condition holds
  - `xsd:boolean strdf:IsEmpty(strdf:geometry A)`
  - `xsd:boolean strdf:IsSimple(strdf:geometry A)`
stSPARQL: Geospatial SPARQL 1.1

Functions for testing topological spatial relationships

- **OGC Simple Features Access**

  - `xsd:boolean strdf:Equals(strdf:geometry A, strdf:geometry B)`
  - `xsd:boolean strdf:Disjoint(strdf:geometry A, strdf:geometry B)`
  - `xsd:boolean strdf:Intersects(strdf:geometry A, strdf:geometry B)`
  - `xsd:boolean strdf:Touches(strdf:geometry A, strdf:geometry B)`
  - `xsd:boolean strdf:Crosses(strdf:geometry A, strdf:geometry B)`
  - `xsd:boolean strdf:Within(strdf:geometry A, strdf:geometry B)`
  - `xsd:boolean strdf:Contains(strdf:geometry A, strdf:geometry B)`
  - `xsd:boolean strdf:Overlaps(strdf:geometry A, strdf:geometry B)`

  - `xsd:boolean strdf:Relate(strdf:geometry A, strdf:geometry B, xsd:string intersectionPatternMatrix)`

- **Egenhofer**

- **RCC-8**
stSPARQL: Geospatial SPARQL 1.1

Spatial analysis functions

- Construct new geometric objects from existing geometric objects

```
strdf:geometry strdf:Boundary(strdf:geometry A)
strdf:geometry strdf:Envelope(strdf:geometry A)
strdf:geometry strdf:Intersection(strdf:geometry A, strdf:geometry B)
strdf:geometry strdf:Union(strdf:geometry A, strdf:geometry B)
strdf:geometry strdf:Difference(strdf:geometry A, strdf:geometry B)
strdf:geometry strdf:SymDifference(strdf:geometry A, strdf:geometry B)
strdf:geometry strdf:Buffer(strdf:geometry A, xsd:double distance)
```

- Spatial metric functions

```
xsd:float strdf:distance(strdf:geometry A, strdf:geometry B)
xsd:float strdf:area(strdf:geometry A)
```

- Spatial aggregate functions

```
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)
```
**stSPARQL: Geospatial SPARQL 1.1**

**Select clause**
- Construction of new geometries (e.g., `strdf:buffer(?geo, 0.1)`)
- Spatial aggregate functions (e.g., `strdf:union(?geo)`)
- Metric functions (e.g., `strdf:area(?geo)`)

**Filter clause**
- Functions for testing topological spatial relationships between spatial terms (e.g., `strdf:contains(?G1, strdf:union(?G2, ?G3))`)
- Numeric expressions involving spatial metric functions (e.g., `strdf:area(?G1) \leq 2*strdf:area(?G2)+1`)
- Boolean combinations

**Having clause**
- Boolean expressions involving spatial aggregate functions and spatial metric functions or functions testing for topological relationships between spatial terms (e.g., `strdf:area(strdf:union(?geo)) > 1`)

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Return the names of communities that have been affected by fires

```
SELECT ?name
WHERE {
  ?community rdf:type dbpedia:Community;
  geonames:name ?name;
  strdf:hasGeometry ?comGeom.
  ?ba rdf:type noa:BurntArea;
  strdf:hasGeometry ?baGeom.
  FILTER(strdf:overlap(?comGeom, ?baGeom))
}
```
stSPARQL: An example (2/3)

Find all burnt forests near communities

```
SELECT ?ba ?baGeom
WHERE {
  ?r rdf:type noa:Region;
  strdf:geometry ?rGeom;
  noa:hasCorineLandCoverUse ?f.
  ?c rdf:type dbpedia:Community;
  strdf:geometry ?cGeom.
  ?ba rdf:type noa:BurntArea;
  strdf:geometry ?baGeom.

  FILTER ( strdf:intersects(?rGeom,?baGeom) &&
          strdf:distance(?baGeom,?cGeom) < 0.02 )
}
```

Spatial Functions
Isolate the parts of the burnt areas that lie in coniferous forests.

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

Spatial Aggregate

Spatial Function
Conclusions

- Geospatial data in the Semantic Web - stSPARQL
  - Early works
  - The data model stRDF
  - Examples of publicly available linked geospatial data
  - The query language stSPARQL

- Next topic: Geospatial data in RDF - GeoSPARQL
[Kolas and Self, 2007]

[Perry, 2008]

[Koubarakis and Kyzirakos, 2010]