GeoSPARQL: an introduction

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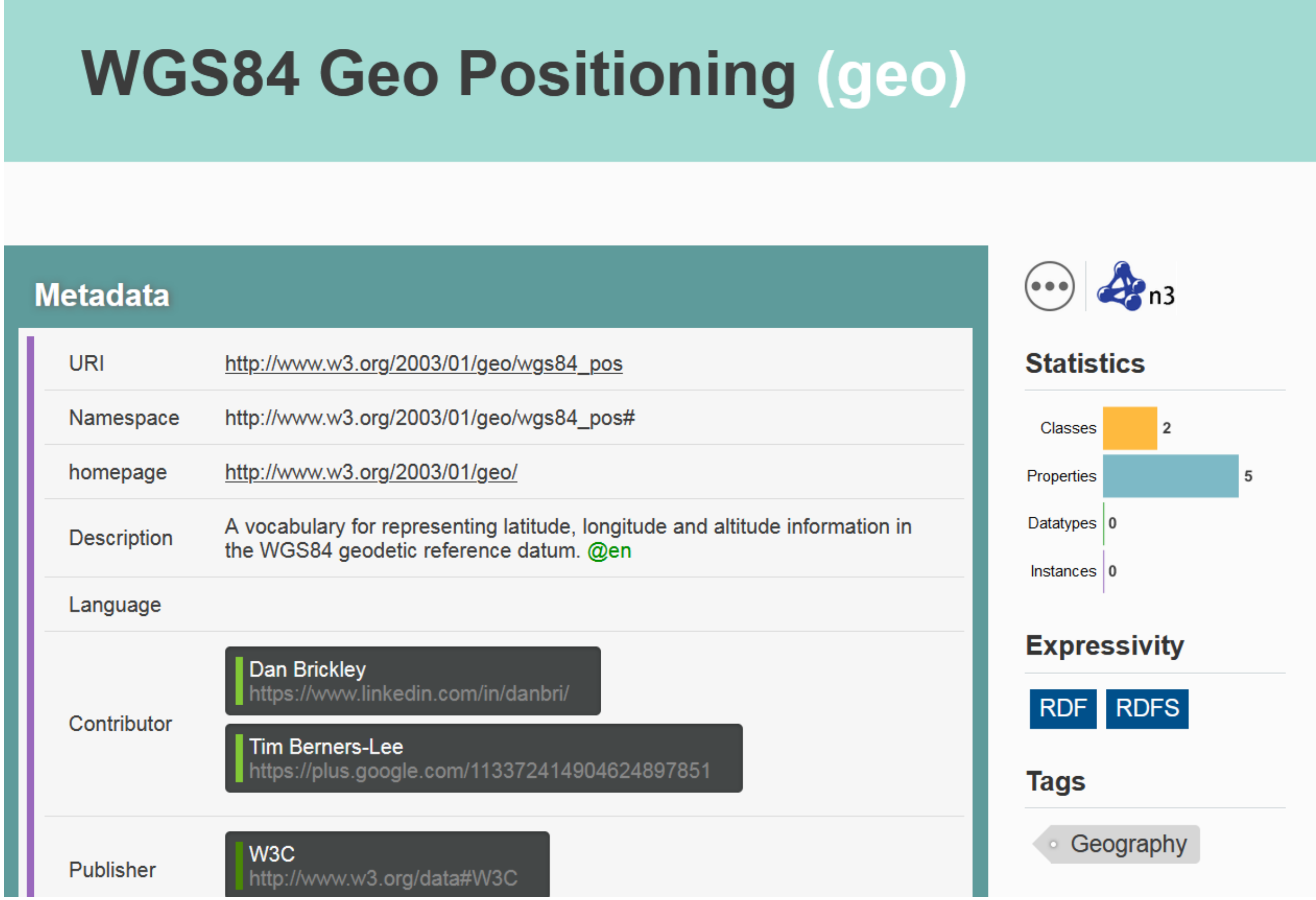
Semantic Web Technologies

Representing Spatial Data

Available vocabulary, such as:



WGS84 Geo Positioning (geo)

Metadata

URI	http://www.w3.org/2003/01/geo/wgs84_pos
Namespace	http://www.w3.org/2003/01/geo/wgs84_pos#
homepage	http://www.w3.org/2003/01/geo/
Description	A vocabulary for representing latitude, longitude and altitude information in the WGS84 geodetic reference datum. @en
Language	
Contributor	Dan Brickley https://www.linkedin.com/in/danbri/ Tim Berners-Lee https://plus.google.com/113372414904624897851
Publisher	W3C http://www.w3.org/data#W3C

Statistics

Classes	2
Properties	5
Datatypes	0
Instances	0

Expressivity

RDF RDFS

Tags

Geography

Handling Spatial Data

Need for **spatial reasoning**

Examples

- What are the monuments in parks of Geneva?
- What are the universities within 20 km?
- What are the commercial land parcels that touch some arterial streets?

=> Need **geospatial concepts and properties** if the relationships (between monuments and parks or between parcels and streets) are not explicit

Handling Spatial Data with semantics

Examples

- What are the monuments in parks of Geneva **that have been made by Paul Landowski**?
- What are the universities within 20 km **that propose courses on RDF**?

=> Need RDF(S) + geospatial concepts and properties for representing such resources

Simple Features Model

Definition

- It is a specification of the Open Geospatial Consortium, which defines a general architecture for geographic data and for their geometries
- More precisely
  - It describes a way to **represent geospatial data** using a hierarchy of classes
  - It defines **functions** for accessing, operating and constructing these data

Features and Geometries

Feature

- Any entity in the real world with some spatial location
- Examples: a university, a parcel, a street…

Geometry

- Any geometric shape, such as a point, a line, a polygon, that is used as a representation of a feature's spatial location
- Examples: a point for a university, a polygon for a parcel…

Coordinate Reference System/Spatial Reference System

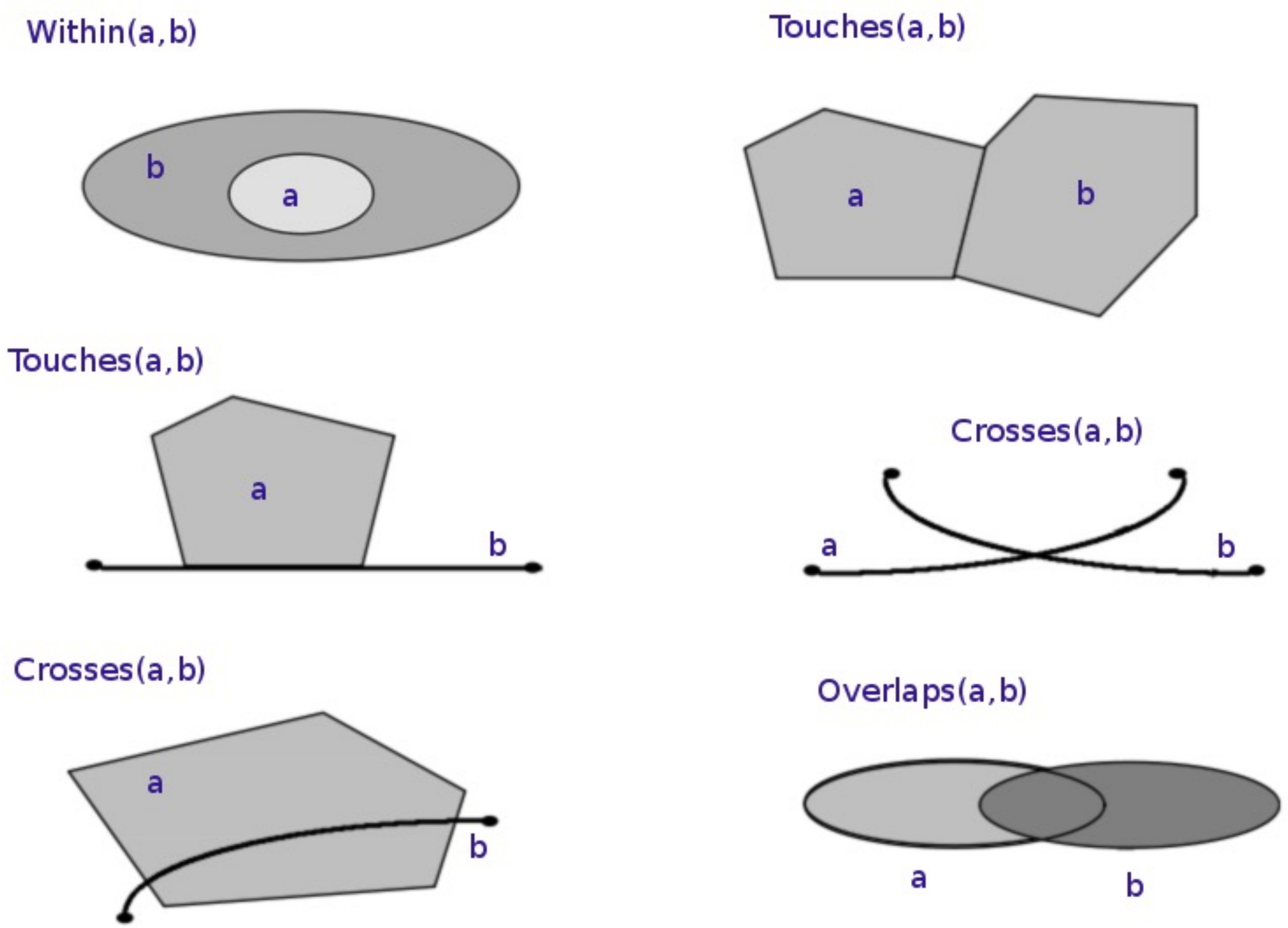
- Part of the metadata associated with a geometry
- Examples: (X,Y) coordinates, longitude and latitude…

Topological relationships

Each spatial entity is inherently related to some other spatial entities
-> **8 geospatial topological relations to describe relationships between entities in space**

equals	
disjoint	
intersects	*at least one point in common (not disjoint)*
touches	*at least one boundary point in common, but no interior points*
within	
contains	*inverse of within*
overlaps	
crosses	

Examples of topological spatial relations



From http://en.wikipedia.org/wiki/Spatial_relation

Handling and Querying Spatial Data

Examples

- What are the universities within 20 km that propose courses on RDF?
- What are the monuments in parks of Geneva that have been made by Paul Landowski?

=> Need of **spatial reasoning with semantic reasoning**

=> Need **geospatial queries**

GeoSPARQL

Definition

A **spatial extension to** the **SPARQL** query language for geospatial information

Built on existing standards

- World Wide Web Consortium W3C
  Semantic Web: RDF, RDFS, SPARQL...
- Open Geospatial Consortium OGC
  Simple Features model, geometry models...
- ISO/TC 211
- ...

GeoSPARQL

Provides the following features

- An RDF/OWL vocabulary for representing spatial information consistent with the Simple Features Model
- A set of SPARQL extension functions for spatial computations
- A set of RIF (Rule Interchange Format) rules for query transformation

From [1]

SPARQL query

What are the universities that propose courses on RDF?

```
…
@prefix cui: <http://cui.unige.ch/> .

SELECT ?i
WHERE {
    ?i a cui:University .
    ?i cui:course ?c .
    ?c cui:keyword ?k .
   FILTER ( ?k = "RDF" )
}
```

GeoSPARQL query

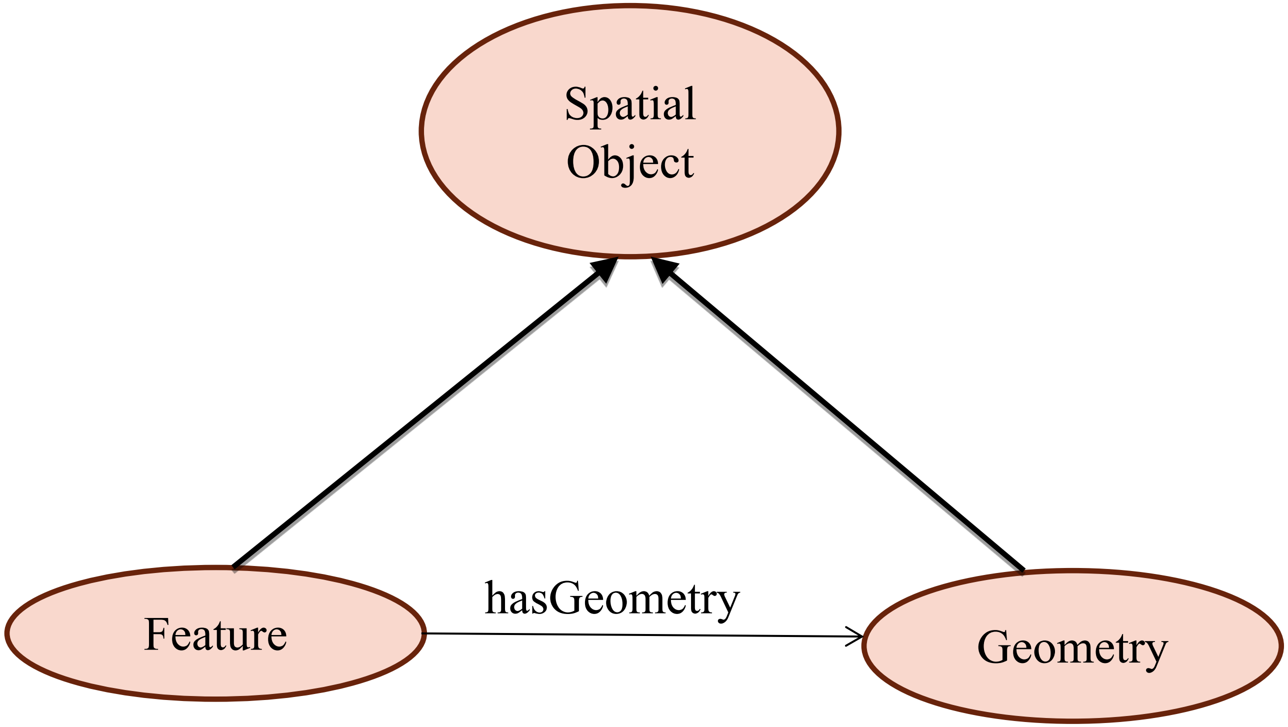
What are the universities **within 20 km** (from a reference point with lat=46.202 and lon=6.146) that propose courses on RDF?

…

```
SELECT ?i
WHERE {
    ?i a cui:University .
    ?i spatial:nearby(46.202 6.146 20 'km') .
    ?i cui:course ?c .
    ?c cui:keyword ?k .
   FILTER ( ?k = "RDF" )
}
```

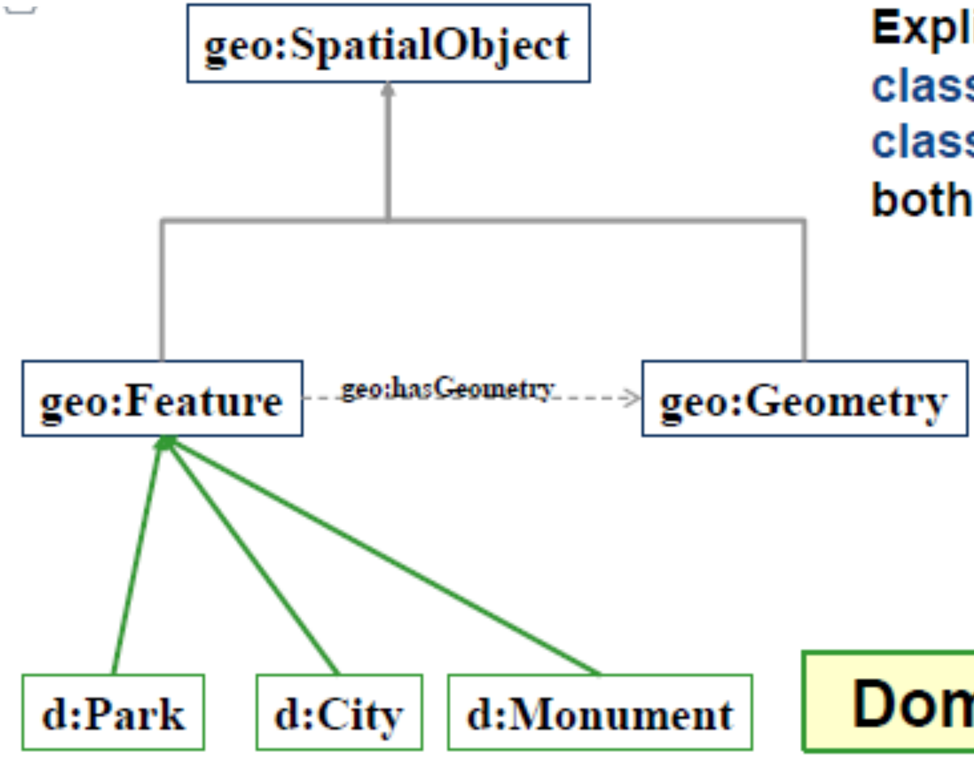
Spatial RDFS

Main geospatial classes and property



From [2]

Geospatial and domain classes



Explicitly typed as OWL classes and RDFS classes to accommodate both types of systems

Domain Classes

From [3]

Main geospatial classes and property

geo:Feature class
A thing with a spatial location (a city, a monument…)

geo:Geometry class
A representation of a spatial location (a set of coordinates)

geo:SpatialObject class
A superclass of both Feature and Geometry classes

geo:hasGeometry property
To link a feature to its geometry that represents its spatial extent
A given feature may have many associated geometries for varying purposes
Example: a city can be represented either by a point or a polygon according to the scale or to the size of the city

See http://www.opengis.net/ont/geosparql

Definition of *geo:SpatialObject* class

```
geo:SpatialObject a rdfs:Class,
                    owl:Class;
rdfs:label "Spatial Object"@en;
rdfs:comment "The class Spatial Object represents
   everything that can have a spatial representation. It is
   superclass of feature and geometry"@en .
```

From [1]

Definition of *geo:Feature* class

```
geo:Feature a rdfs:Class,
                          owl:Class;
rdfs:label "Feature"@en;
rdfs:subClassOf geo:SpatialObject;
owl:disjointWith geo:Geometry;
rdfs:comment "This class represents the top-level feature
    type. This class is equivalent to GFI_ Feature defined in
    ISO 19156, and it is superclass of all feature types"@en .
```

From [1]

Definition of *geo:Geometry* class

```
geo:Geometry a rdfs:Class,
                     owl:Class;
rdfs:label "Geometry"@en;
rdfs:subClassOf geo:SpatialObject;
owl:disjointWith geo:Feature;
rdfs:comment "The class represents the top-level geometry
   type. This class is equivalent to the UML class
   GM_ Object defined in ISO 19107, and it is superclass of
   all geometry types"@en .
```

From [1]

Definition of *geo:hasGeometry* property

```
geo:hasGeometry a rdf:Property,
                              owl:ObjectProperty;
rdfs:label "has Geometry"@en;
rdfs:comment "A spatial representation for a given
   feature."@en;
rdfs:domain geo:Feature;
rdfs:range geo:Geometry .
```

From [1]

Main geometry representations

WKT (Well-known text)

Text markup language for representing vector geometry objects
Defined by the Open Geospatial Consortium (OGC)

Example: the point with 2D coordinates (x=10, y=23) defined by the string "*POINT (10,23)*"

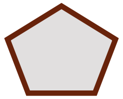
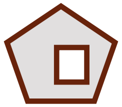
GML (Geography Markup Language)

XML-based language
Defined by the OGC

Example: definition of the point (10,23)

```
<gml:Point srsDimension="2" >
    <gml:pos>10 23</gml:pos>
</gml:Point>
```

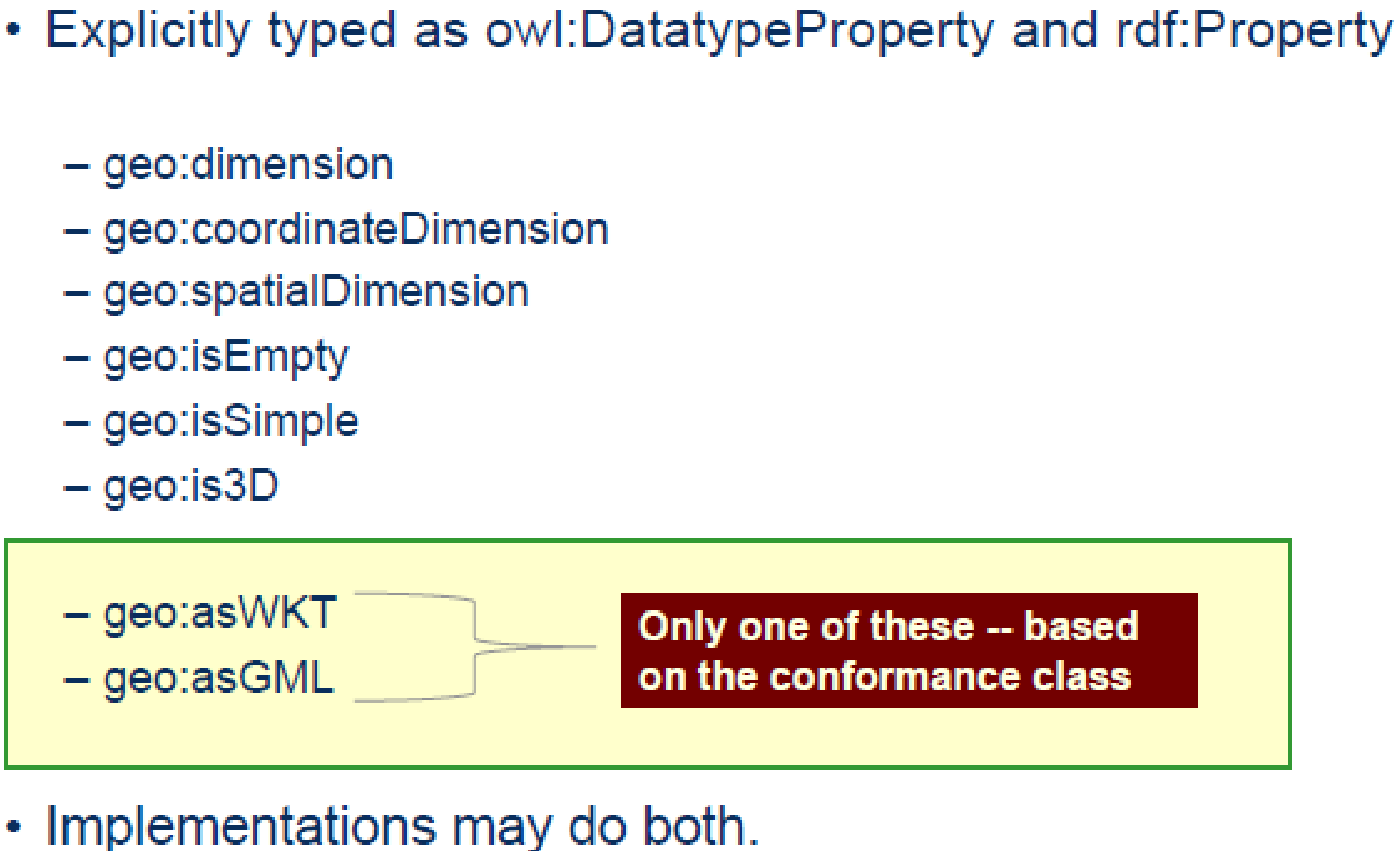
Main geometry types (WKT)

TYPE	SHAPE	Geometry Class	SYNTAX
POINT	●	`sf:Point`	`POINT(longitude latitude)`
LINESTRING		`sf:LineString`	`LINESTRING(long1 lat1, long2 lat2, …)`
POLYGON		`sf:Polygon`	`POLYGON((long1 lat1, long2 lat2, … , long1 lat1))`
POLYGON (WITH HOLE)		`sf:Polygon`	`POLYGON((long1 lat1, long2 lat2, … , long1 lat1), (longA latA, longB latB, …, longA latA))`

To create a WKT geometry, a resource should be declared to be the appropriate type from the table above, and given an **asWKT** property with a literal of the appropriate form.

From [2]
See also http://www.opengis.net/ont/sf

Datatype properties for *geo:Geometry*



- Explicitly typed as owl:DatatypeProperty and rdf:Property
  - geo:dimension
  - geo:coordinateDimension
  - geo:spatialDimension
  - geo:isEmpty
  - geo:isSimple
  - geo:is3D
  - geo:asWKT
  - geo:asGML

Only one of these -- based on the conformance class

- Implementations may do both.

From [3]

Example: representation of a spatial resource

```
ex:Monument1 a geo:Feature;
                                        rdfs:label "Washington Monument";
                                        geo:hasGeometry ex:Point1 .
ex:Point1 a sf:Point;
                    geo:asWKT "POINT(-77.03524
38.889468)"^^geo:wktLiteral.
```

1.The resource is a feature

2.This feature has a label

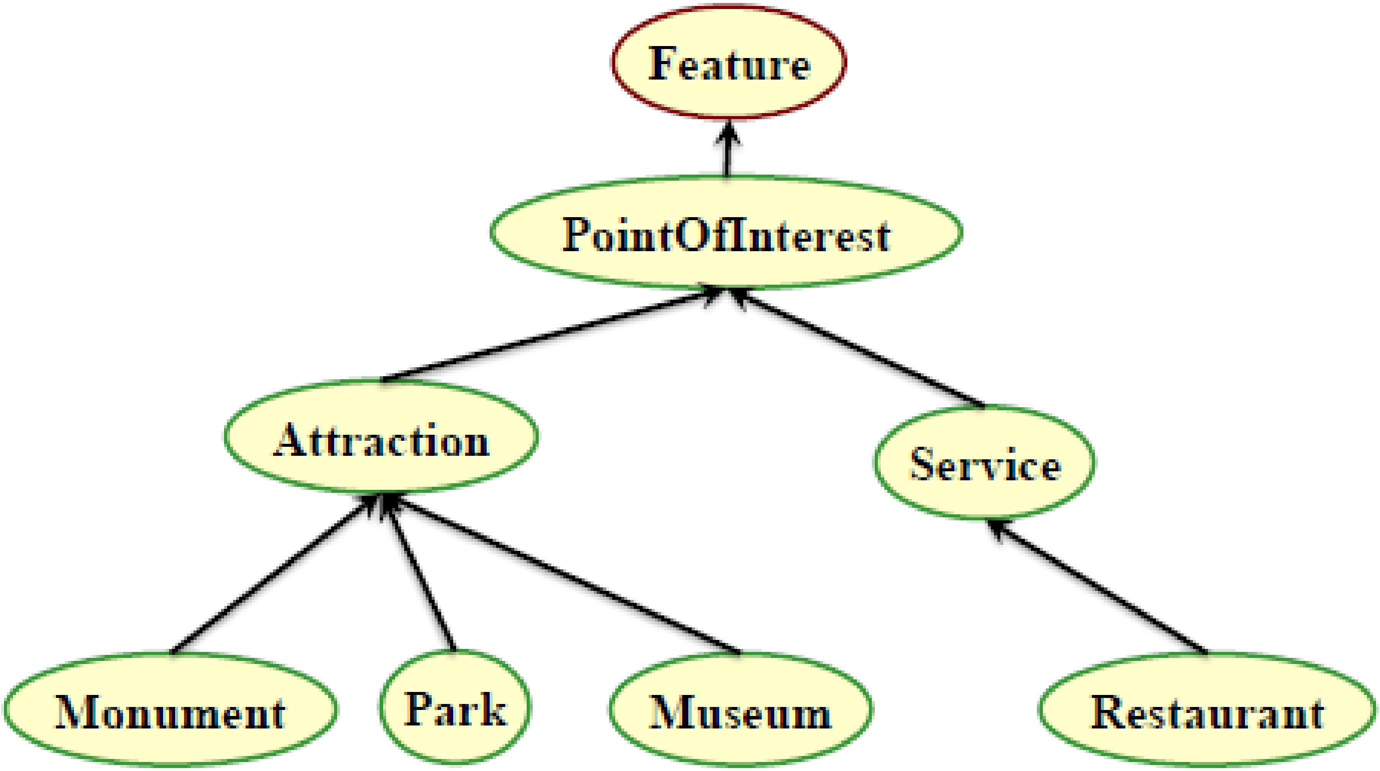
3.This feature has a geometry (geo-location)

4.This geometry is a point

5.This point is defined according the WKT representation by 2 coordinates (longitude latitude)

From [2]

Another example: semantic part



From [3]

Example: definition of the (semantic) structure

```
@prefix…

ex:Monument a owl:Class;
              rdfs:subClassOf ex:Attraction .
ex:Park a owl:Class;
        rdfs:subClassOf ex:Attraction .
ex:Museum a owl:Class;
            rdfs:subClassOf ex:Attraction .
ex:Restaurant a owl:Class;
             rdfs:subClassOf ex:Service .
ex:Attraction a owl:Class;
             rdfs:subClassOf ex:PointOfInterest .
ex:Service a owl:Class;
           rdfs:subClassOf ex:PointOfInterest .
ex:PointOfInterest a owl:Class;
                  rdfs:subClassOf geo:Feature .
```

From [2]

Example: definition of the geospatial data

```
@prefix…

ex:Monument1 a ex:Monument;
                    rdfs:label "Washington Monument";
                    geo:hasGeometry ex:Point1 .

ex:Point1 a sf:Point;
             geo:asWKT "POINT(-77.03524 38.889468)"^^geo:wktLiteral .

ex:Park1 a ex:Park;
              rdfs:label "Example Park";
              geo:hasGeometry ex:Polygon1 .

ex:Polygon1 a sf:Polygon;
                geo:asWKT "POLYGON((-77.05 38.87, -77.02 38.87, -77.02 38.9,
                                -77.05 38.9, -77.05 38.87))"^^geo:wktLiteral .
```

From [2]

Example of a query

Retrieve the geometry information of *ex:Monument1*

```
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX ex: <http://cui.unige.ch/>

SELECT ?wkt
WHERE {
        ex:Monument1 geo:hasGeometry ?g .
        ?g geo:asWKT ?wkt .
}

-> "POINT(-77.03524 38.889468)"
```

From [2]

GeoSPARQL relationships

Topological relationships :

equals

disjoint

intersects

touches

within

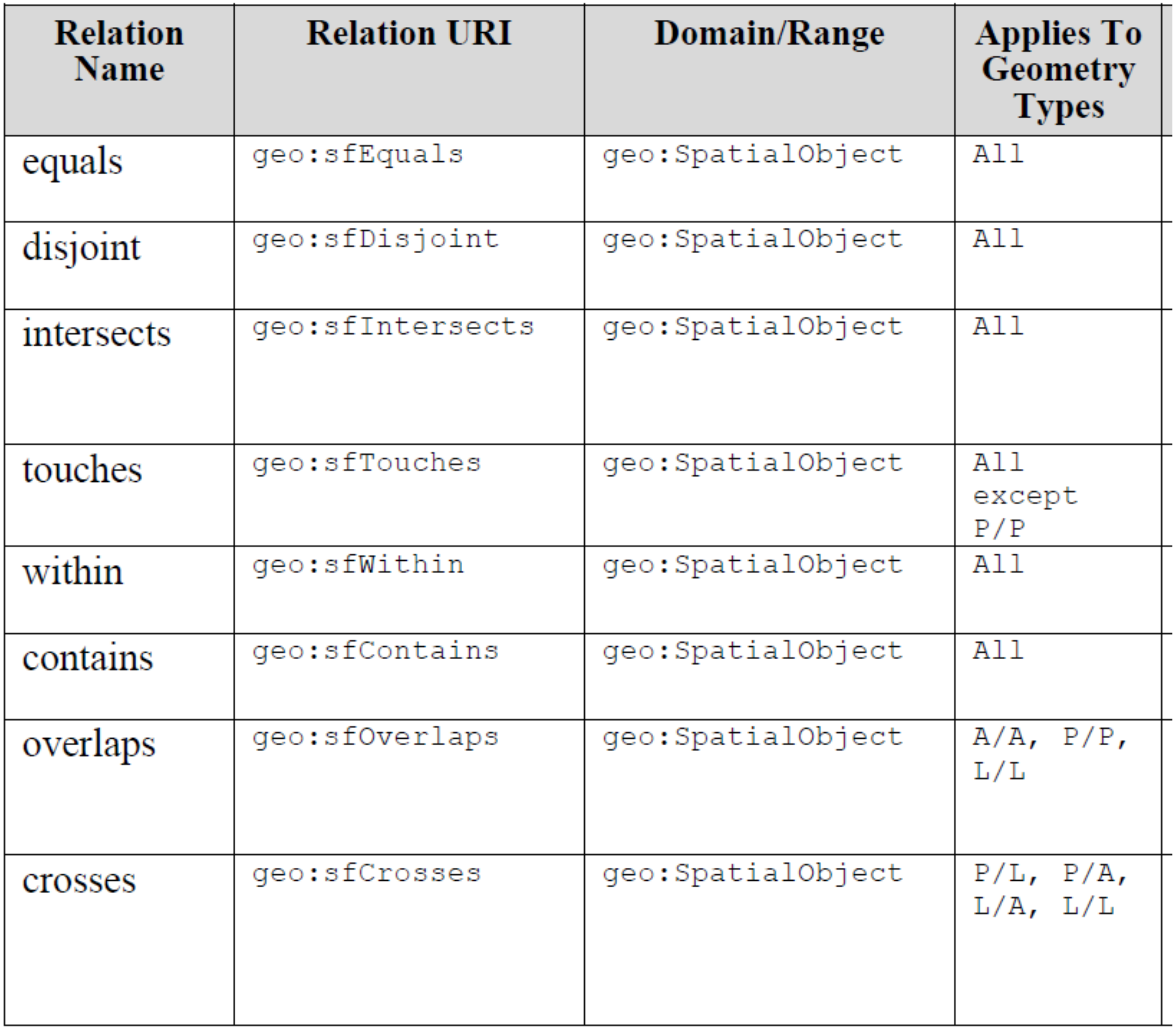
contains

overlaps

crosses

Different syntaxes according to the relations family:
for example, *geo:sfEquals* (Simple Features), *geo:ehEquals* (Egenhofer), *geo:rcc8eq* (RCC8) for the *equals* relation

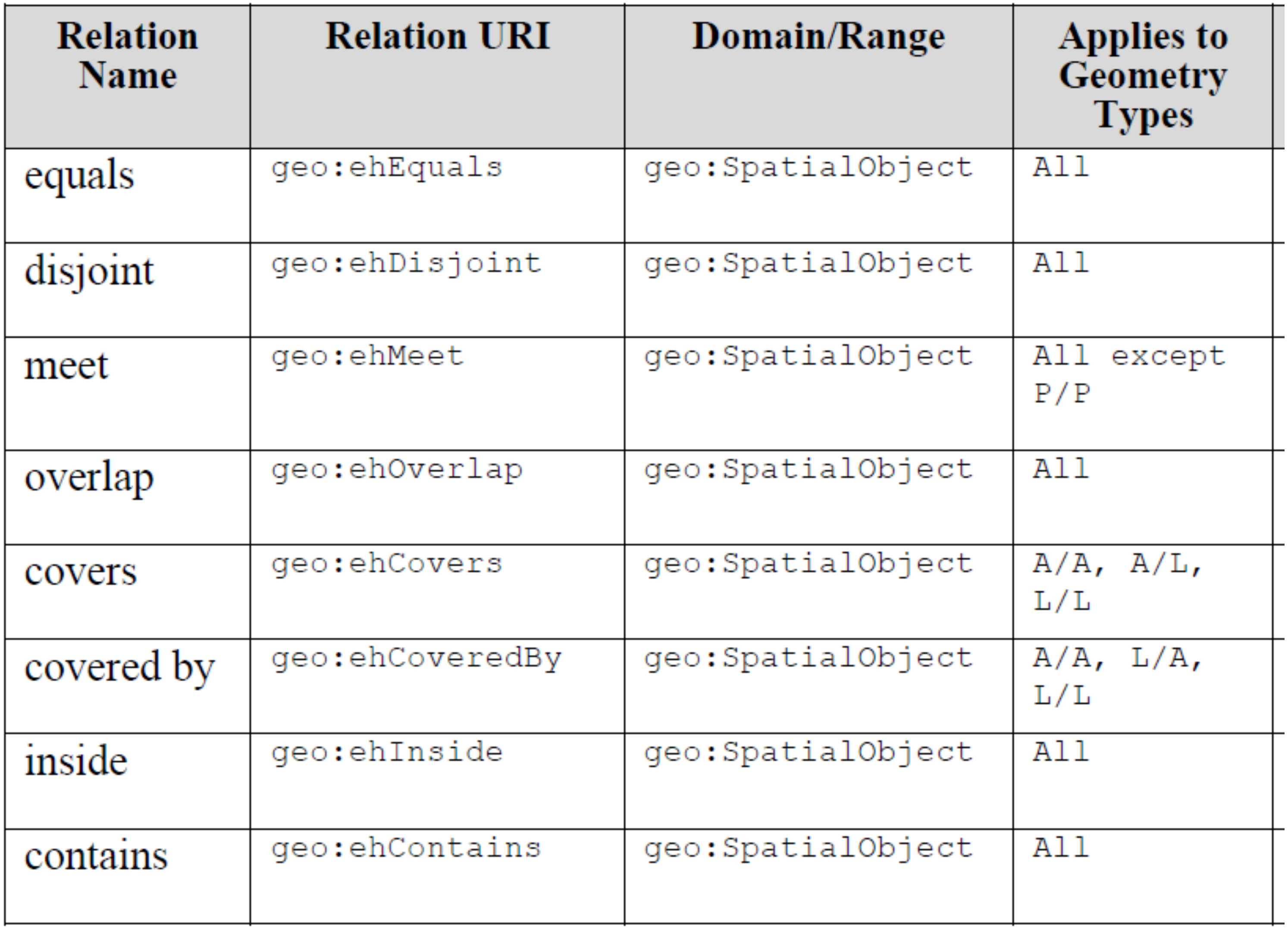
Simple features topological relations



Relation Name	Relation URI	Domain/Range	Applies To Geometry Types
equals	geo:sfEquals	geo:SpatialObject	All
disjoint	geo:sfDisjoint	geo:SpatialObject	All
intersects	geo:sfIntersects	geo:SpatialObject	All
touches	geo:sfTouches	geo:SpatialObject	All except P/P
within	geo:sfWithin	geo:SpatialObject	All
contains	geo:sfContains	geo:SpatialObject	All
overlaps	geo:sfOverlaps	geo:SpatialObject	A/A, P/P, L/L
crosses	geo:sfCrosses	geo:SpatialObject	P/L, P/A, L/A, L/L

From [1]

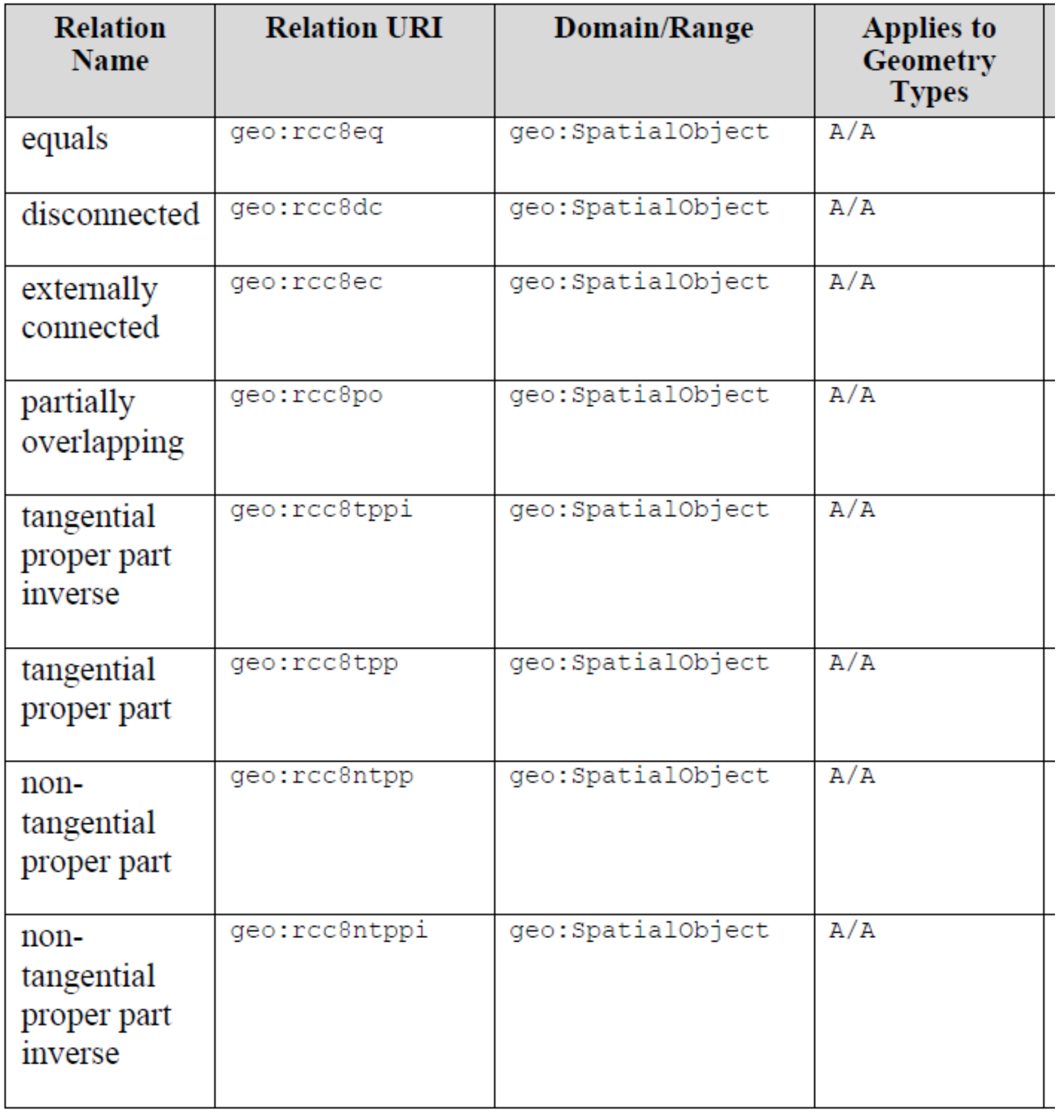
Egenhofer topological relations



Relation Name	Relation URI	Domain/Range	Applies to Geometry Types
equals	geo:ehEquals	geo:SpatialObject	All
disjoint	geo:ehDisjoint	geo:SpatialObject	All
meet	geo:ehMeet	geo:SpatialObject	All except P/P
overlap	geo:ehOverlap	geo:SpatialObject	All
covers	geo:ehCovers	geo:SpatialObject	A/A, A/L, L/L
covered by	geo:ehCoveredBy	geo:SpatialObject	A/A, L/A, L/L
inside	geo:ehInside	geo:SpatialObject	All
contains	geo:ehContains	geo:SpatialObject	All

From [1]

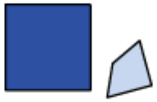
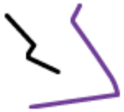
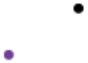
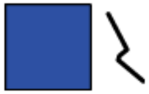
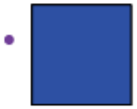
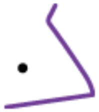
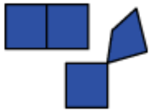
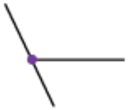
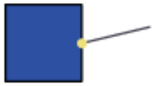
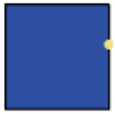
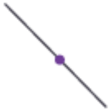
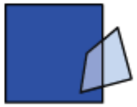
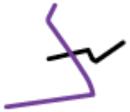
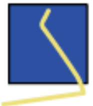
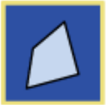
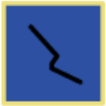
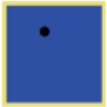
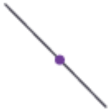
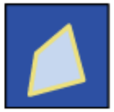
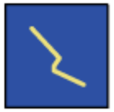
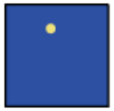
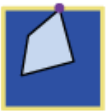
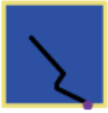
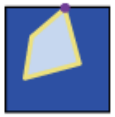
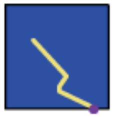
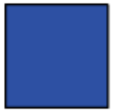
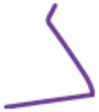
RCC8 topological relations



Relation Name	Relation URI	Domain/Range	Applies to Geometry Types
equals	geo:rcc8eq	geo:SpatialObject	A/A
disconnected	geo:rcc8dc	geo:SpatialObject	A/A
externally connected	geo:rcc8ec	geo:SpatialObject	A/A
partially overlapping	geo:rcc8po	geo:SpatialObject	A/A
tangential proper part inverse	geo:rcc8tppi	geo:SpatialObject	A/A
tangential proper part	geo:rcc8tpp	geo:SpatialObject	A/A
non-tangential proper part	geo:rcc8ntpp	geo:SpatialObject	A/A
non-tangential proper part inverse	geo:rcc8ntppi	geo:SpatialObject	A/A

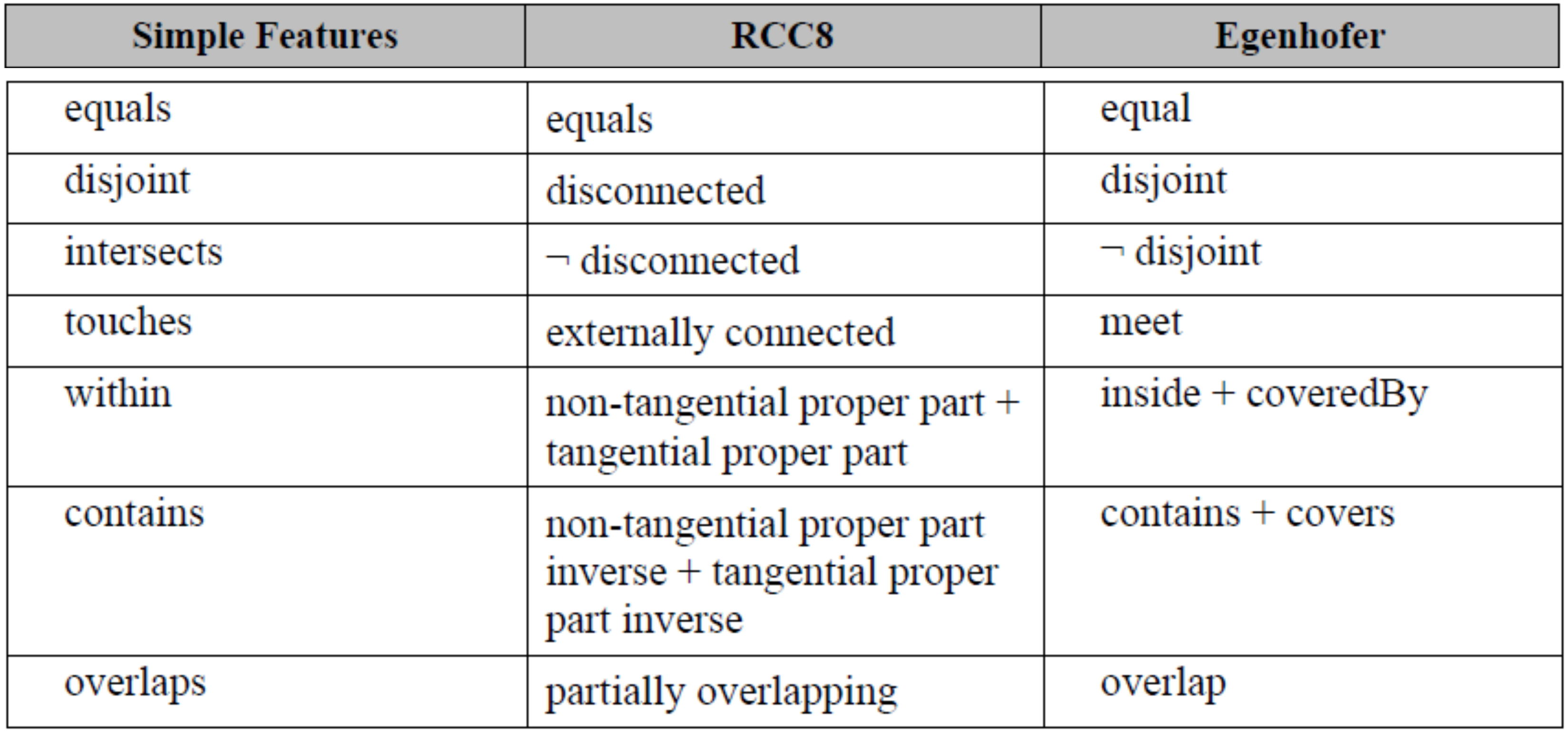
From [1]

RCC8 topological relations

	poly-poly	line-line	point-point	poly-line	poly-point	line-point
Disjoint						
Meet						
Overlap						
Contains						
Inside						
Covers						
Covered by						
Equal						

From
http://www.gitta.info/SpatialQueries/en/html

Equivalent RCC8, Egenhofer and Simple Features Topological Relations



Simple Features	RCC8	Egenhofer
equals	equals	equal
disjoint	disconnected	disjoint
intersects	¬ disconnected	¬ disjoint
touches	externally connected	meet
within	non-tangential proper part + tangential proper part	inside + coveredBy
contains	non-tangential proper part inverse + tangential proper part inverse	contains + covers
overlaps	partially overlapping	overlap

From [1]

Example of a query

Find the monuments that are within *ex:Park1*

```
PREFIX geo: <http://www.opengis.net/def/geosparql/>
PREFIX ex: <http://cui.unige.ch/>

SELECT ?f
WHERE {
            ex:Park1 geo:hasGeometry ?g1 .
            ?f a ex:Monument;
             geo:hasGeometry ?g2 .
            ?g2 geo:sfWithin ?g1 .
}

-> ex:Monument1
```

From [2]

GeoSPARQL query functions

As topological relationships but use the prefix *geof* instead of *geo*:
for example, *geof:sfEquals*
(and not anymore *geo:sfEquals*)

Returns *true* or *false* instead of a geometry as it is with the topological relations

Example of a query

Find whether there are monuments that are within *ex:Park1*

```
PREFIX geo: <http://www.opengis.net/def/geosparql/>
PREFIX geof: <http://www.opengis.net/def/function/geosparql/>
PREFIX ex: <http://cui.unige.ch/>

SELECT ?f
WHERE {
                ex:Park1 geo:hasGeometry ?g1 .
                ?f a ex:Monument;
                 geo:hasGeometry ?g2 .
                ?g2 geof:sfWithin ?g1 .
}

-> true
```

From [2]

Other query functions

Properties	Parameters	Returns
geof:distance	Geom1, Geom2, unitsURI	xsd:double
geof:buffer	Geom1, radius, unitsURI	Geometry literal
geof:convexHull	Geom1	Geometry literal
geof:intersection	Geom1, Geom2	Geometry literal
geof:union	Geom1, Geom2	Geometry literal
geof:difference	Geom1, Geom2	Geometry literal
…		
geof:envelope	Geom1	Geometry literal
geof:boundary	Geom1	Geometry literal
geof:getsrid	Geom1	SRID of literal

From [2]

Query Transformation Rules

- Allow for an additional layer of abstraction in SPARQL queries
- If a feature is used as the subject or object of a topological relation, the query is automatically rewritten to compare the geometry linked, thus removing the abstraction for processing

From [4]

Before:

```
…
SELECT ?f
WHERE {
      ?f a ex:Monument;
      ?f geo:sfWithin ex:Park1.
}
```

Query Transformation Rules

After:

```
…
SELECT ?f
WHERE {
            ex:Park1 geo:hasGeometry ?g1 .
            ?f a ex:Monument;
             geo:hasGeometry ?g2 .
            ?g2 geo:sfWithin ?g1 .
}
```

From [2]

Implementation: some sites

Some triple store implementations that can spatially index information in the vocabulary, and perform spatial reasoning

AllegroGraph

for geospatial and temporal reasoning

https://franz.com/agraph/allegrograph/

Stardog

https://www.stardog.com

https://www.stardog.com/docs/java/snarl/com/complexible/stardog/spatial/geosparql

Strabon

spatiotemporal RDF store with a subset of GeoSPARQL

https://strabon.di.uoa.gr

Implementation: some sites

GraphDB

limited custom geospatial queries possible over WGS84 data (GraphDBfunctions)

GeoSPARQL sites (Online queries)

http://www.geosparql.org/

http://linkedgeodata.org/sparql

On GraphDB

Usage

- Plugin control predicates
- Enable plugin with
  PREFIX : <http://www.ontotext.com/plugins/geosparql#>
  INSERT DATA { _:s :enabled "true" . }
- Disable plugin with
  PREFIX : <http://www.ontotext.com/plugins/geosparql#>
  INSERT DATA { _:s :enabled "false" . }
- Note that
  - When the plugin is disabled, it does not index any data or process updates. It does not handle any of the GeoSPARQL predicates either
  - All GeoSPARQL functions starting with geof: like *geof:sfOverlaps* do not use any indexes and are always enabled

Some references

[1] **OGC GeoSPARQL – A Geographic Query Language for RDF Data**, Open Geospatial Consortium, OGC 11-052r4
http://www.opengis.net/doc/IS/geosparql/1.0

[2] **GeoSPARQL user guide**, Dave Kolas & Robert Battle, 1/19/2012

[3] **Getting started with GeoSPARQL**, Dave Kolas, Matt Perry & John Herring, OGC, Oct 29 2013
http://www.ssec.wisc.edu/meetings/geosp_sem/presentations/GeoSPARQL_Getting_Started%20-%20KolasWorkshop%20Version.pdf

[4] **GeoSPARQL: Enabling a Geospatial Semantic Web**, Robert Battle, Dave Kolas
http://www.semantic-web-journal.net/sites/default/files/swj176_0.pdf

Some references

W3C Geospatial Ontologies
http://www.w3.org/2005/Incubator/geo/XGR-geo-ont/
Geonames interface http://www.geonames.org/
Vocabularies for geospatial modelling http://geovocab.org/

Basic Geo (WGS84 lat/long) Vocabulary
https://www.w3.org/2003/01/geo/

Annex: acronyms

GeoJSON	Geographic JavaScript Object Notation
GFM	General Feature Model (as defined in ISO 19109)
GML	Geography Markup Language
KML	Keyhole Markup Language
OWL	OWL 2 Web Ontology Language
RCC	Region Connection Calculus
RDF	Resource Description Framework
RDFS	RDF Schema
RIF	Rule Interchange Format
SPARQL	SPARQL Protocol and RDF Query Language
WKT	Well Known Text (as defined by Simple Features or ISO 19125)
W3C	World Wide Web Consortium (http://www.w3.org/)
XML	Extensible Markup Language

From [1]

Annex: XML namespaces

geo:	http://www.opengis.net/ont/geosparql#
geof:	http://www.opengis.net/def/function/geosparql/
geor:	http://www.opengis.net/def/rule/geosparql/
gml:	http://www.opengis.net/ont/gml#
owl:	http://www.w3.org/2002/07/owl#
rdf:	http://www.w3.org/1999/02/22-rdf-syntax-ns#
rdfs:	http://www.w3.org/2000/01/rdf-schema#
sf:	http://www.opengis.net/ont/sf#
xsd:	http://www.w3.org/2001/XMLSchema#

From [1]

Annex: Turtle prefixes

```
@prefix rdf:  <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix xsd:  <http://www.w3.org/2001/XMLSchema#> .
@prefix geo: <http://www.opengis.net/ont/geosparql#> .
@prefix geof: < http://www.opengis.net/def/function/geosparql/> .
@prefix geor: < http://www.opengis.net/def/rule/geosparql/> .
@prefix sf:  < http://www.opengis.net/ont/sf# > .
@prefix gml: < http://www.opengis.net/ont/gml# > .
@prefix owl: < http://www.w3.org/2002/07/owl#> .
```

From [1]

Annex: SPARQL prefixes

```
PREFIX rdf:    <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs:   <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd:    <http://www.w3.org/2001/XMLSchema#>
PREFIX geo:  <http://www.opengis.net/ont/geosparql#>
PREFIX geof: <http://www.opengis.net/def/function/geosparql/>
PREFIX geor: <http://www.opengis.net/def/rule/geosparql/>
PREFIX sf:         <http://www.opengis.net/ont/sf#>
PREFIX gml:   <http://www.opengis.net/ont/gml#>
PREFIX owl:  <http://www.w3.org/2002/07/owl#>
```

From [1]

Annex: SPARQL prefixes

PREFIX geo: <http://www.w3.org/2003/01/geo/wgs84_pos#>

PREFIX gn: http://www.geonames.org/ontology#

PREFIX geom: <http://geovocab.org/geometry#>

PREFIX spatial: <http://geovocab.org/spatial#>

PREFIX loticoowl: <http://www.lotico.com/ontology/>

PREFIX my: <http://example.org/ApplicationSchema#>

From [1]